



OAKWOOD HOMES

A Berkshire Hathaway Company

May 26, 2020

City of Commerce City
Attn: Mr. Jason Rogers
Community Development Director
7887 East 60th Avenue
Commerce City, CO 80022

Jason,

I am writing to submit formal comments on the amendments to the Municipal Code regarding oil and gas regulations in advance of the May 29, 2020 deadline. These comments are being provided on behalf of Clayton Properties Group II, Inc. dba Oakwood Homes, which is the master developer of Reunion in the City of Commerce City. We appreciate the time you and your staff have spent discussing the new ordinance with us and L.C. Fulenwider, Inc., the landowner in Reunion.

I am reiterating some of the comments during the recent virtual meetings and from my e-mail in mid-May, 2020. We believe we understand the intent of the setback provisions, but in current form we strongly recommend edits in several key sections of the document.

Proposed Amendments

21-5266: Reverse setbacks of 1,000 feet during production phase. We believe the standards in 21-5266 to be changed to match the language in 21-6280. In Reunion Ridge, this would allow us to plat lots within 400 feet once all wells enter Completions. The two sections are inconsistent.

21-5266 (6):

(a) No Oil and Gas Production Site may be located within 1000' of the following:

(i) Any existing residential or platted residential property.

21-6280:

(1) For permitted Well Sites where all permitted wells have not entered Completions, no new residential lots may be platted within 1,000' of such site.

21-6280: The rest of the section clarifies when wells have entered Completions the setback is reduced per the table. We do not have a problem with the table showing the final setback for Reunion Ridge will be 400 feet based on up to 24 well heads. The challenge is how the City proposes to measure the setback referenced in the new code. We believe the City is attempting to define the edge of the Production Site as the fence rather than the nearest tank, equipment, well pad, etc. This is a new standard and a change from the prior versions. We have raised this concern before and the City have been assured us the new code would not conflict with the Extraction Agreement. It clearly does with this latest draft.

21-6280 simply references the definition in 21-5266:

“21-5266 (6c): Measurements shall be taken from the edge of the proposed Production Site to the parcel boundary. For agricultural properties over 10 acres in size with residential uses, the measurement shall be taken from the nearest edge of any occupied dwelling unit.”

But, under the definition of Production Site is where the City added the “enclosed area” language.

Land Development Code Definitions have been revised since the last version:

~~(352)~~(351) **Production Site** shall mean, as it relates to Oil and Gas Operations, the surface area immediately surrounding proposed or existing production equipment, or other accessory equipment necessary for oil and gas production activities, including the fenced, walled, or enclosed area of the facility during the production phase, exclusive of transmission and gathering pipelines.

We believe the City either needs to delete this language or clarify the measurements in 21-5266 (6c) are taken from the nearest well pad, equipment, tank, etc. not the enclosed area.

The attached site plan shows the concept layout for a future filing of Reunion Ridge with the interim and final setback. The measurement for the 400-foot setback was always intended to be measured from the well pad and not the fence/property line. The site plan includes two sets of lines representing the different measurement standards. The dashed yellow line on the plan reflects a 400-foot setback from the well heads not the fence. During the approval of Reunion Ridge Filing No. 1, the City required Oakwood to plat Potomac Parkway from 104th Avenue to 96th Avenue. The alignment and edge of right-of-way was specifically designed around the oil and gas site to ensure a 400-foot setback to the nearest structure and in most cases, platted lots. The red line on the site plan illustrates the setback

measured from the enclosed area. A total of 30 lots would be ineligible for platting under the setback measurement standard noted in the draft code. On both the north and east sides of the oil and gas site, changes to the subdivision design would be necessary to avoid a single-loaded street. However, the Potomac Parkway edge is already set by prior City approvals.

21-6280

The proposed ordinance also includes a setback measurement between well operations and residential lots. It is important to note this is more restrictive than the current COGCC measurement standards which permit measurement to the wall of the building rather than the lot line. In addition, a Surface Use Agreement in Reunion has this standard for measuring setbacks as noted below:

V. Operator agrees to fully develop the OGOA and drill to completion all Wells in the OGOA as may be permitted by the COGCC and applicable local governments within four (4) years from the date of this Agreement. During such 4-year period, Owner and Optionee agree to maintain a one thousand (1000) ft. buffer zone, as depicted on Exhibit B-1 attached hereto, from the well pad within the OGOA to the nearest existing or planned Residential Building Unit (as defined in the COGCC Rules). Notwithstanding the foregoing, Optionee shall be entitled to construct at any time those improvements within such 1,000 ft. buffer zone as further described upon Exhibit "D".

Prior to adoption, we encourage the City Council to consider revisions to the proposed regulations to match COGCC standards and a private Surface Use Agreement in the City as follows:

Section 6 d: Clarification to match the State of Colorado measurement standards from production site to wall of an occupied building.

21-6280

Section 1 and 2: Add that measurement of the setback would be to the nearest Residential Building Unit consistent with COGCC rules. Restatement of the methodology for measuring the setback consistent with COGCC.

In summary, we believe the recommended revisions:

- Maintain the setback requirements of the original draft
- Consistent with the intent of original draft
- Reliable and transparent for landowners and operators
- Consistent with private agreements already executed

In conclusion, please consider all of these proposed revisions before the study session on June 8 and any future scheduled action for adoption.

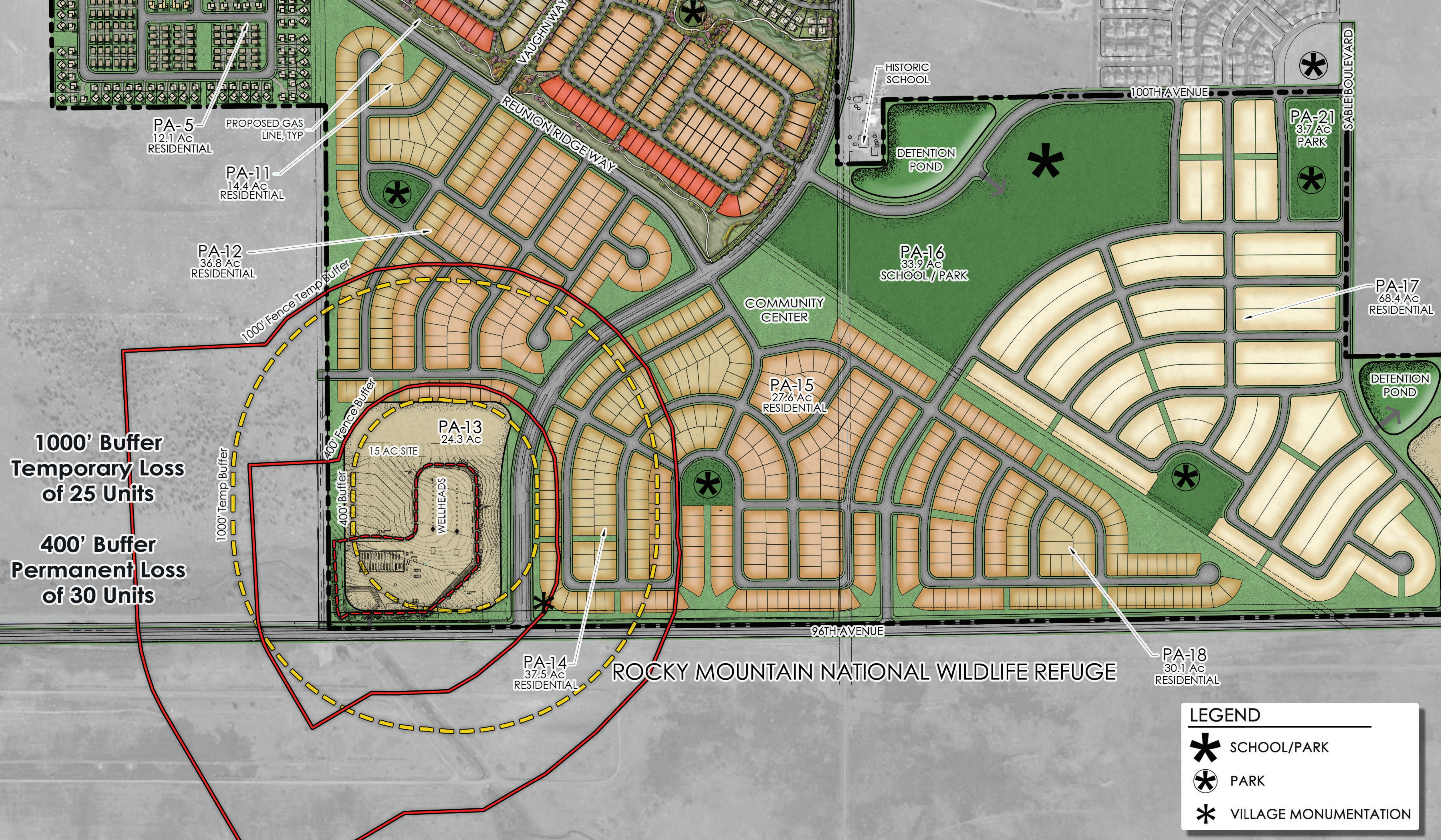
Please keep us informed and we may be in attendance at virtual meetings to provide verbal testimony as appropriate.

Thank you for your time and consideration on this matter.

Sincerely,

James A. Hayes, AICP
Director of Land Acquisition and Development
Clayton Properties Group II, Inc. dba Oakwood Homes
4908 Tower Road
Denver, CO 80249

Cc: Brian McBroom, City Manager
Roger Tinklenberg, Deputy City Manager
Domenic Martinelli, City Planner
Bruce Rau, Oakwood Land Company President
Cherie Talbert, Metro Denver HBA
Blake Fulenwider, L.C. Fulenwider, Inc.





May 28, 2020

City of Commerce City
Attn: Mr. Jason Rogers
Community Development Director
7887 East 60th Avenue
Commerce City, CO 80022

Jason,

I am writing to submit formal comments on the amendments to the Municipal Code regarding oil and gas regulations in advance of the May 29, 2020 deadline. These comments are being provided on behalf of L.C. Fulenwider, Inc. (Fulenwider), which is the landowner of Reunion in the City of Commerce City. We appreciate the time you and your staff have spent discussing the new ordinance with us and Oakwood Homes, the master developer of Reunion.

As landowner, Fulenwider has expended considerable time, effort, resources, and capital to strike a deal with Extraction Oil & Gas as the operator for the Reunion area which we believe allows for reasonable extraction of our mineral assets that underlie Reunion with minimal impact on current and future homeowners by consolidating drilling and operations to a single pad near 96th and Potomac Street. As part of the series of agreements, Fulenwider secured a surface waiver from Extraction for all the remaining land owned by Fulenwider in Reunion in exchange for the single drill site in the SW corner of Reunion Ridge. Further, Fulenwider paid to plug and abandon four existing shut-in wells and remove all flowlines and surface equipment on our land near existing Reunion homes. As a part of the package we negotiated pipeline rights of way, incorporated landscaping requirements, and have setback language all to mitigate the impact of oil and gas operations on future homeowners in Reunion. The configuration of the wellsite, the location, the size, and the platting of adjacent roads were all agreed to between the parties including Commerce City staff. After more than a year of effort by all parties to arrive at a reasonable compromise, we believe we have struck the right balance for all parties and should be allowed, no matter what the final ordinance language, to complete the production site at 96th and Potomac as envisioned in this expansive set of agreements. If you have to add exclusion or amendment language to the ordinance to achieve this result, we strongly encourage you to do so.

In addition to any language that would allow potential exclusion or amendment language in the ordinance to allow drilling operations to move forward at mutually struck 96th and Potomac pad site, in current form, we strongly recommend edits in several key sections of the document outlined below.

Proposed Amendments

21-5266: Reverse setbacks of 1,000 feet during production phase. We believe the standards in 21-5266 to be changed to match the language in 21-6280. In Reunion Ridge, this would allow us to plat lots within 400 feet once all wells enter Completions. The two sections are inconsistent.

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21-6280: The rest of the section clarifies when wells have entered Completions the setback is reduced per the table. We do not have a problem with the table showing the final setback for Reunion Ridge will be 400 feet based on up to 24 well heads. The challenge is how the City proposes to measure the setback referenced in the new code. We believe the City is attempting to define the edge of the Production Site as the fence rather than the nearest tank, equipment, well pad, etc. This is a new standard and a change from the prior versions. We have raised this concern before and the City have been assured us the new code would not conflict with the Extraction Agreement. It clearly does with this latest draft.

21-6280 simply references the definition in 21-5266:

"21-5266 (6c): Measurements shall be taken from the edge of the proposed Production Site to the parcel boundary. For agricultural properties over 10 acres in size with residential uses, the measurement shall be taken from the nearest edge of any occupied dwelling unit."

But, under the definition of Production Site is where the City added the "enclosed area" language.

Land Development Code Definitions have been revised since the last version:

~~(352)~~**(351)** Production Site shall mean, as it relates to Oil and Gas Operations, the surface area immediately surrounding proposed or existing production equipment, or other accessory equipment necessary for oil and gas production activities, including the fenced, walled, or enclosed area of the facility during the production phase, exclusive of transmission and gathering pipelines.

We believe the City either needs to delete this language or clarify the measurements in 21-5266 (6c) are taken from the nearest well pad, equipment, tank, etc. not the enclosed area.

The attached site plan shows the concept layout for a future filing of Reunion Ridge with the interim and final setback. The measurement for the 400-foot setback was always intended to be measured from the well pad and not the fence/property line. The site plan includes two sets of lines representing the different measurement standards. The dashed yellow line on the plan reflects a 400-foot setback from the well heads not the fence. During the approval of Reunion Ridge Filing No. 1, the City required Oakwood to plat Potomac Parkway from 104th Avenue to 96th Avenue. The alignment and edge of right-of-way was specifically designed around the oil and gas site to ensure a 400-foot setback to the nearest structure and in most cases, platted lots. The red line on the site plan illustrates the setback measured from the enclosed area. A total of 30 lots would be ineligible for platting under the setback measurement standard noted in the draft code. On both the north and east sides of the oil and gas site, changes to the subdivision design would be necessary to avoid a single-loaded street. However, the Potomac Parkway edge is already set by prior City approvals.

21-6280

The proposed ordinance also includes a setback measurement between well operations and residential lots. It is important to note this is more restrictive than the current COGCC measurement standards which permit measurement to the wall of the building rather than the lot line. In addition, a Surface Use Agreement in Reunion has this standard for measuring setbacks as noted below:

V. Operator agrees to fully develop the OGOA and drill to completion all Wells in the OGOA as may be permitted by the COGCC and applicable local governments within four (4) years from the date of this Agreement. During such 4-year period, Owner and Optionee agree to maintain a one thousand (1000) ft. buffer zone, as depicted on Exhibit B-1 attached hereto, from the well pad within the OGOA to the nearest existing or planned Residential Building Unit (as defined in the COGCC Rules). Notwithstanding the foregoing, Optionee shall be entitled to construct at any time those improvements within such 1,000 ft. buffer zone as further described upon Exhibit "D".

Prior to adoption, we encourage the City Council to consider revisions to the proposed regulations to match COGCC standards and a private Surface Use Agreement in the City as follows:

Section 6 d: Clarification to match the State of Colorado measurement standards from production site to wall of an occupied building.

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Section 1 and 2: Add that measurement of the setback would be to the nearest Residential Building Unit consistent with COGCC rules. Restatement of the methodology for measuring the setback consistent with COGCC.

In summary, we believe the recommended revisions:

- Maintain the setback requirements of the original draft
- Consistent with the intent of original draft
- Reliable and transparent for landowners and operators
- Consistent with private agreements already executed

In conclusion, please consider all of these proposed revisions before the study session on June 8 and any future scheduled action for adoption.

Please keep us informed and we may be in attendance at virtual meetings to provide verbal testimony as appropriate.

Thank you for your time and consideration on this matter.

Sincerely,



James Blake Fulenwider
Vice President
L.C. Fulenwider, Inc.
1125 17th Street, Suite 2500
Denver, CO 80202

Cc: Brian McBroom, City Manager
Roger Tinklenberg, Deputy City Manager
Domenic Martinelli, City Planner
Bruce Rau, Oakwood Land Company President
Kelly Leid, Oakwood Home Executive VP of Community Operations
Jim Hayes, Oakwood Home Director of Land Acquisition and Development
Cherie Talbert, Metro Denver HBA
Rick Wells, L.C. Fulenwider, Inc. Senior Vice President



May 29, 2020

City of Commerce City
Attn: Mr. Jason Rogers
Community Development Director
7887 East 60th Avenue
Commerce City, CO 80022

Jason,

I am writing to submit formal comments on the amendments to the Municipal Code regarding oil and gas regulations in advance of the May 29, 2020 deadline. These comments are being provided on behalf of Shea Homes Limited Partnership (Shea Homes), which is the owner of portions of the Reunion community in the City of Commerce City, and formerly the master developer of the community.

Shea expended considerable time, effort, resources and capital to strike a deal with Extraction Oil & Gas as the operator for the Reunion area which we believe allows for reasonable extraction of our mineral assets that underlie Reunion with minimal impact on current and future homeowners by consolidating drilling and operations to a single pad site. As part of the series of agreements, Shea secured a surface waiver from Extraction for all its remaining land in Reunion. Further, Shea negotiated to plug and abandon existing shut-in wells and remove flowlines and surface equipment on land near existing Reunion homes. As a part of the package we negotiated pipeline rights of way, incorporated landscaping requirements, and have setback language all to mitigate the impact of oil and gas operations on future homeowners in Reunion. The configuration of the wellsite, the location, the size, and the platting of adjacent roads were all agreed to between the parties including Commerce City staff. After more than a year of effort by all parties to arrive at a reasonable compromise, we believe the parties have struck the right balance for all parties and should be allowed, no matter what the final ordinance language, to complete the production site as envisioned in this expansive set of agreements. If you must add exclusion or amendment language to the ordinance to achieve this result, we strongly encourage you to do so.

In addition to any language that would allow potential exclusion or amendment language in the ordinance to allow drilling operations to move forward at the designated pad site, in current form, we strongly recommend edits in several key sections of the document outlined below.

Proposed Amendments

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Prior to adoption, we encourage the City Council to consider revisions to the proposed regulations to match COGCC standards and a private Surface Use Agreement in the City as follows:

Section 6 d: Clarification to match the State of Colorado measurement standards from production site to wall of an occupied building.

21-6280

Section 1 and 2: Add that measurement of the setback would be to the nearest Residential Building Unit consistent with COGCC rules. Restatement of the methodology for measuring the setback consistent with COGCC.

In summary, we believe the recommended revisions will:

- Maintain the setback requirements of the original draft
- Be consistent with the intent of original draft
- Be reliable and transparent for landowners and operators
- Be consistent with private agreements already executed

In conclusion, please consider all these proposed revisions before the study session on June 8 and any future scheduled action for adoption.

Please keep us informed and we may attend virtual meetings to provide verbal testimony as appropriate.

Thank you for your time and consideration on this matter.

Sincerely,



Chetter Latcham
Colorado Division President

Cc: Brian McBroom, City Manager
Roger Tinklenberg, Deputy City Manager
Domenic Martinelli, City Planner
James Blake Fulenwider, Vice President, L.C. Fulenwider, Inc.
Rick Wells, L.C. Fulenwider, Inc. Senior Vice President
Bruce Rau, Oakwood Land Company President
Kelly Leid, Oakwood Home Executive VP of Community Operations
Jim Hayes, Oakwood Home Director of Land Acquisition and Development
Cherie Talbert, Metro Denver HBA



WESTSIDE INVESTMENT PARTNERS, INC.

4100 East Mississippi Avenue, Suite 500 Denver, CO 80246 p 303.984.9800 f 303.984.9874

May 29, 2020

City of Commerce City
Attn: Mr. Jason Rogers
Community Development Director
7887 East 60th Avenue
Commerce City, CO 80022

Jason,

I am writing to submit formal comments on the amendments to the Municipal Code regarding oil and gas regulations in advance of the May 29, 2020 deadline. These comments are being provided on behalf of Westside Property Investment Company Inc. (Westside), which is a landowner in the City of Commerce City.

As a landowner, Westside has concerns about the negative impact these amendments will potentially have on future development within the City. We respectfully request the modification of the proposed amendments, as outlined below.

Proposed Amendments

21-6280: This section is a wholesale revision to the code. Recent legislation (e.g. S.B. 181) has, purposefully and appropriately, directed regulation of oil and gas operations at oil and gas operators, **NOT** at the activities of property owners not engaged in oil or gas operations. We believe the attempt to restrict the property rights of landowners who are not involved in any oil or gas activities in this manner is unconstitutional and actionable. As an aside, we further would like to point out that the results of such actions are less developable land and less certainty in the entitlement and development process, which ultimately translates into fewer development projects (including less City revenue through fees and taxes) and less attainable housing. Accordingly, we respectfully request that this section be stricken from the code revision, and that the City's regulation of oil and gas activities be limited to oil and gas operators.

In conclusion, we believe the intent of the enabling legislation was to regulate the activities of oil and gas operators, rather than affect the property rights of those not engaged in oil or gas operations. We respectfully ask that you consider our requested modification of the municipal code amendments before the study session on June 8 and any future scheduled action for adoption.

Please keep us informed as to the City's actions, so that we may be in attendance at City meetings and otherwise consider how to best protect our property rights.

Thank you for your time and consideration on this matter.

Sincerely,

Andrew R. Klein
President
Westside Property Investment Company Inc.
4100 East Mississippi Avenue, Suite 500
Denver, CO 80246



1800 GLENARM PLACE

SUITE 1100

DENVER, CO 80202

Phone 303.861.0362

WWW.COGA.ORG

May 22, 2020

VIA EMAIL – NO ORIGINAL TO FOLLOW

ATTN:

Commerce City Mayor & Councilmembers
Domenic Martinelli, Local Government Designee, City Planner
Jason Rogers, Community Development Director
Robert Sheesley, City Attorney
Matt Hader, Deputy City Attorney
Matt Sura, Special Counsel to Commerce City

RE: Colorado Oil & Gas Association – Redlines and Comments to Commerce City
Draft Oil and Gas Regulations

Dear Commerce City Mayor, Council, Staff, and Counsel:

The Colorado Oil and Gas Association ("COGA") appreciates the opportunity to comment on Commerce City's draft oil and gas regulations. We recognize the time and effort the City has put into drafting these regulations, especially considering the challenges the COVID-19 pandemic has presented. This letter serves as part of COGA's preliminary comments on the draft regulations and will be supplemented with a redline of the proposed regulations. Another comment letter will follow, and will also be accompanied with redlines.

Please note that the concerns discussed here and in COGA's future letter are not presented in any particular order. Please do not interpret the order of listed concerns to indicate COGA's estimation of their significance or the degree to which they are, or aren't, potentially problematic.

As drafted, Commerce City's regulations pose significant challenges for future oil and gas operations in Commerce City. In fact, because certain provisions are so unworkable, the regulatory scheme may risk amounting to a de-facto ban on oil and gas development. Bans on oil and gas development remain illegal in Colorado, and COGA does not believe it is Commerce City's intent to ban future responsible and safe energy

development. Fortunately, regulations that protect health, safety, welfare, wildlife, and the environment and regulations that allow for responsible oil and gas development are not mutually exclusive. COGA is committed to working further with the City on creating safe and thorough regulations that are operationally possible and that are necessary and reasonable, as required by state law.

Definitions

For consistency and clarity, COGA recommends the City update the first two below drafted terms to match with the Colorado Oil and Gas Commission's ("COGCC") definitions. COGA also requests a definition for "Nature Area." Please also see attached redline for further definition clarifications in Sec. 21-11200.

- "Well Site" to "Oil and Gas Location" or "Working Pad Surface," depending on context
- "Production Site(s)" & "Well Site(s)" – "Production Site(s)" is undefined, and COGA recommends using the COGCC's definition of Oil and Gas Location (which encompasses both well pads with or without facilities, as well as facility only pads) and the COGCC's draft definition of "Working Pad Surface," again depending on context
- Sec. 21.5266(3)(k) – "Nature Area", please define

Site Eligibility – Sec. 21-3216(5)(b)(i)(1-4)

As currently drafted, COGA questions whether any parcel of land in Commerce City would meet the criteria outlined in this section. If there are no parcels of land that meet these criteria, COGA urges Commerce City to re-draft these provisions to allow for the reasonable extraction and development of minerals.

Alternative Site Location Analysis – Sec. 21-3216(5)(b)(ii)(2-3)

It is unreasonable and unnecessary to require operators to provide a list of all features listed in section 21-3216(5)(b)(i)(1-3) within 1-mile of all drilling and spacing units proposed. Drilling and spacing units (DSUs) may extend several miles outside of the City's jurisdiction depending on the DSU shape, location, and size. What is the City's purpose for knowing these features outside its jurisdiction?

Operators take great care to identify sites that allow for safe development and provide city and community benefit. Given the constraints listed in the proposed code, there is a high probability that an operator may not be able to provide a minimum of three alternative sites for the City to review. COGA suggests the City revisit these requirements to make compliance achievable.

Review Criteria – Sec. 21-3216(5)(b)(iii)(8)

The ability to negotiate and acquire a surface use agreement (SUA) is a key factor in finding a location for oil and gas development. The City should take SUAs into consideration when reviewing site eligibility. This is important because an operator may not be able to secure an SUA for a location that Commerce City deems more appropriate for an oil and gas operation.

Approval Criteria – Sec. 21-3216(8)

COGA firmly believes that when an oil and gas permit application meets the criteria of the Code, it should be approved with no opportunity for denial. If all Code criteria are met and a permit application is denied, the application was necessarily denied for some reason not within the Code. This evades transparency and shatters expectations.

General Terms of Approval – Sec. 21-3216(9)(e)

As drafted, language in this provision suggests that an operator must comply with any amendments made to the code after an Oil and gas Permit is granted. COGA comments that this provision could lead to the illegal impairment of a vested right, and that the language, “...and any subsequent amendments thereto as set forth therein” is struck from the drafted code. There are also practical reasons why this draft provision is misguided. For example, a new amendment might purport to require a retrofit of some kind that extends the surface foot print of the Oil and Gas Location beyond what was negotiated in the SUA.

Best Management Practices Document – Sec. 21.3216(12)(a)

The sentence, “All Oil and Gas Permit holders shall at all times comply with the BMP Document, as it may be amended” should be struck from the draft code for the same reasons set forth in the paragraph above. As interpreted by COGA, this language would effectively allow Commerce City to shut down operations if the City enacts a new BMP that makes compliance impossible or impracticable. As stated previously, retrospectively applying new regulations can lead to the illegal impairment of a vested property right. If this is not the City’s intention behind the language, please clarify.

Application Requirements – Sec. 21-5266(3)(t)

Commerce City makes several references to traffic impacts throughout the draft code, and COGA suggests that this specific provision refer to the traffic impact study and fee passed by the City in 2019. This fee was designed, and passed by Council, to address the impact of oil and gas operations on City roads and apply financial requirements to operators. If desired, an operator should have the ability to perform its own study, but not be required to do so as currently drafted.

Third Party Technical Review – Sec. 21-5266(4)

Given the number of plans (~21) and other items that Commerce City is now requiring operators to submit, it appears highly likely that the City will rely on outside consultants to help staff review future oil and gas permit applications. However, as currently drafted, the language provides little protections for operators against financial abuse by the City’s contractors and outside consultants. COGA suggests that the following provisions be added to this section:

- Allow operators to review the scope of work and estimated costs from a third-party consultant before the contractor is hired
- Commerce City will provide regular updates and accountings of the expended fees for third-party consultant to operators

- If funds are deposited to the City prior to any work, they shall be placed into an interest-bearing account. Unused funds, along with interest, shall be refunded to operators

Traffic Standards – Sec. 21-5266(10)(a-b)

Per C.R.S. 29-20-105.5(2)(a), “A local government shall quantify the reasonable impacts of proposed development on existing capital facilities and establish the impact fee or development charge at a level **no greater than necessary** to defray such impacts directly related to proposed development.” Because Commerce City already has a traffic impact fee in place, COGA suggests the following language is added to this section: “*In accordance with the Traffic Impact Study, the Operator shall not pay ongoing repair or maintenance costs that exceeds the costs reasonably necessary to defray the impacts of the Operations.*” Additionally, what financial assurances shall be mandatory when an Operation will require the construction or reconstruction of a public or private road?

COGA thanks Commerce City in advance for its close attention to the issues addressed in this memo and attached redline. Please consider COGA and our membership as a resource when having discussions related to the oil and natural gas industry and during this and any potential future regulatory changes.

Sincerely,



Ryan Seastrom, Community Outreach Coordinator, Colorado Oil & Gas Association

cc (via email):

Mark Mathews-Brownstein Hyatt Farber Schreck, LLP

Julia Rhine-Brownstein Hyatt Farber Schreck, LLP

Dan Haley-Colorado Oil & Gas Association

Christy Woodward-Colorado Oil & Gas Association

Rich Coolidge-Colorado Oil & Gas Association



1800 GLENARM PLACE

SUITE 1100

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Phone 303.861.0362

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May 28, 2020

VIA EMAIL – NO ORIGINAL TO FOLLOW

ATTN:

Commerce City Mayor & Councilmembers
Domenic Martinelli, Local Government Designee, City Planner
Jason Rogers, Community Development Director
Robert Sheesley, City Attorney
Matt Hader, Deputy City Attorney
Matt Sura, Special Counsel to Commerce City

RE: Colorado Oil & Gas Association – Further Comment to Commerce City Draft Oil and Gas Regulations

Dear Commerce City Mayor, Council, Staff, and Counsel:

The Colorado Oil & Gas Association ("COGA") appreciates the opportunity to comment further on Commerce City's draft oil and gas regulations. This letter provides comment additional to that submitted by COGA on May 22, 2020, and will be the final submission from COGA on this set of draft regulations. Attached for reference are the same redlines attached to our previous comment letter.

As stated in COGA's previous letter, please note that these concerns are not presented in any particular order. Please do not interpret the order of listed concerns to indicate COGA's estimation of their significance or the degree to which they are potentially problematic.

Air Quality Standards and Monitoring – Draft Section 21-5266(12)(a)(d-i)

As currently drafted, COGA submits that this entire section is not technically practicable, nor reasonable and necessary. The Colorado Department of Public Health and Environment ("CDPHE") is undergoing several rulemakings to address air quality and air quality monitoring from oil and gas operations in Colorado, which will again lead to nationally standard-setting regulations. Further, the Air Pollution Control Division

("APCD") has the required funding and staff expertise needed to analyze and interpret the data in an accurate and consistent manner.

Real-time reporting is also problematic, as the data must be adjusted for background concentrations and environmental interferences such as temperature, humidity, and others. Additionally, real-time monitoring data, if made public, would only serve to raise more questions than it answers. Commerce City can look at other municipalities for guidance in this area. For example, Broomfield has invested \$2.6 million in contractors monitoring for air quality that resulted in what the city's Director of Strategic Initiatives called a "flood of questions" to these contractors.

A spike or elevated level of a particular constituent on a graph does not constitute health impacts. If Commerce City plans to analyze and publish air data, it must do its due diligence to itself and to the general public and be able to explain the toxicological impacts of such data. Air studies, both public and private, throughout Colorado have shown that emissions from oil and gas development do not pose any long-term health impacts.

Below are several, specific points related to this section that are problematic.

- Sections of this provision counter one another. Section (g) requires monitoring for the lifetime of each wellsite while section (h)(ii) requires continuous monitoring only under specific circumstances. If the entire provision is not struck, COGA requests that the City clarify which regulation to follow.
- Currently available sensors are not capable of monitoring for all the constituents listed in the code. The reliability and quality of currently available sensors also varies widely and needs further development.
- Continuous monitoring for the lifetime of each wellsite is technically impractical and not reasonable or necessary. Commerce City only needs to review the latest study from CDPHE modeling emissions from oil and gas development. Additionally, as wells begin to decline, they may operate on a very limited basis and may be shut-in for long periods of time. This would give very little potential for fugitive emissions.
- A 10-day turnaround on canister samples is outside of an operator's control. An operator is dependent on the lab for turnaround time.
- The provision requiring continuous monitoring if, "...any use defined is 21-5266(6a) is within 1,000' of the edge of the well site." is simply prejudicial. If the City is concerned with development near oil and gas facilities, it should not approve the development in the first place. To do so otherwise, and place further financial burden upon an operator, is irresponsible.

Enforcements and Penalties – Draft Sec. 21-5266(d)(i-iii)

These provisions are inconsistent with a local government's authority to regulate oil and gas, due process rights, and state statute.

Draft Sec. 21-5266 (d)(i) would require an operator to provide a copy of *any* Colorado Oil and Gas Conservation Commission (“COGCC”) enforcement order to the City, regardless of whether that enforcement order pertains to downhole enforcement issues outside of the City’s jurisdiction. COGA posits it is more appropriate for the City to limit requests of copies of COGCC enforcement orders to those relating to areas where the City also has jurisdiction and further noting that this submittal is for information purposes only. As well, the provision should make clear that it applies only to enforcement orders related to Oil and Gas Locations within Commerce City.

Draft Sec. 21-5266 (d)(ii) would require an operator to pay to the City a fine equal to what was assessed by the COGCC in a COGCC enforcement order. This is flawed in several respects. First, as just mentioned, the fine might relate to a downhole issue over which the City has no authority to regulate. Second, this provision raises due process concerns because the City would be assessing a fine for conduct that may or may not have occurred and which the City did not determine to have occurred. The most common type of “enforcement order” from the COGCC is an Administrative Order on Consent (AOC). This is a type of settlement agreement in which the operator agrees to the order only for purposes of resolving the issue expeditiously without need for an adversarial hearing. Oftentimes an operator will dispute a violation but decide for a variety of practical reasons not to take the alleged violation to hearing and will negotiate an AOC. It is inappropriate for Commerce City to assess fines agreed to for settlement purposes, and even were the COGCC enforcement order to be issued following a hearing and affirmative factual finding that an operator did in fact violate a rule, it is inappropriate for Commerce City to assess a penalty for a violation that it personally did not find and a duplicative fine offends fundamental fairness.

Finally, Commerce City lacks authority to assess fines for violations that are not violations of the Commerce City Code, § 31-16-101, C.R.S, and the COGCC fine may be in excess of what the City is permitted to assess pursuant to the same. The City is statutorily limited assessing fines **no greater** than \$2,650. *Id.* Further, there is no reason or justification provided for an operator to pay a duplicative sum of money to the local government for a violation, real or alleged, assessed at the state level for a violation of a *state* regulation. COGA does not interpret § 31-16-101, C.R.S. to authorize a municipality to assess penalties of regulations adopted by the state. Rather, Commerce City is limited by that statute to assessing penalties no greater than \$2,650 for violations of Commerce City’s regulations, not the state’s regulations.

If an operator’s violation did impact Commerce City in some manner (e.g. use of emergency services), the operator is already required, as outlined in Sec. 21-5266(21)(a)(b), to reimburse the City for any expenses incurred. Specifically, “An operator shall be strictly liable to the City and any emergency service provider for all costs of an emergency response to any Well Sites,” and, “An operator shall be strictly liable to the City...for all damages to any and all City owned or operated property and infrastructure...”

COGA is concerned the intent of this provision is to add revenue to the City rather than to actually address any potential, real impacts from operations.

Initial Assessment Process & Site Eligibility Determination – Draft Sec. 21-3216(d)(e)

Regarding draft Sec. 21-3216(d), COGA submits that if an operator applicant marks information as confidential, and the City discloses or handles it improperly, Commerce City should take financial responsibility for their mistake. It does not make sense for the proposed regulation to provide that the applicant “shall be solely responsible” for the confidentiality of its information when the applicant is not the only custodian of the information. The applicant cannot be held responsible for disclosure it did not make.

Draft Sec. 21-3216(e) is problematic because it proposes that “Materials submitted for review as part of the Initial Assessment Process and site eligibility determination shall not constitute an application for development for purposes of C.R.S. § 24-68-101, et. seq.” But the Initial Assessment Process and site eligibility determination undeniably constitute the first stage of the City’s process of authorizing oil and gas operations. As such, this provision is in direct conflict with §24-68-102, C. R.S., which explicitly states, “For local governments that have provided specific development plans in multiple stages, “application” means the original application at the first stage in any process that may culminate in the ultimate approval [of a site specific development plan.]”

Assignment of Permits – Draft Sec. 21-3216(14)

COGA finds this provision problematic because it gives the City control over a private property transfer. It makes sense to COGA that if one operator intends to transfer its assets to another entity, the City would like to know that this new entity can fulfill the obligations of the previous operator. However, the Director should not have discretion to deny the transfer when the elements of the Code are satisfied, so the use of the permissive “may” is misguided. Also, the new operator’s financial assurance requirements should not necessarily be the same as the prior operator’s. If a to-be transferred well already has been drilled and completed, that well arguably presents less risk, and certainly presents less impacts, than an undrilled and uncompleted well. Section (c) of this provision is also problematic because it conflicts with the responsible party determinations found in the Oil and Gas Conservation Act, §34-60-124, C.R.S. A prior operator may be responsible for reclamation or other remedial activities after transfer pursuant to that statute. So long as there is an operator held responsible, the City should not mandate that the current operator is the responsible party.

Permit Period; Lapse Forfeiture – Draft Sec. 21-3216(10)(d)

As drafted, this provision is unworkable. The COGCC’s permit may not be, and in fact is very unlikely to be, granted within 180-days of the City’s approval. COGA suggests that the City consult with the COGCC on permit processing times if the City wishes to establish a set timeframe. The last sentence of this provision is also ambiguous. It states, “...an Oil and Gas Permit shall automatically lapse and have no further effect if the use is discontinued for 180 consecutive days[,]” which could be interpreted that a temporarily shut-in well would trigger the lapse of a permit. COGA asks that this provision be

revised to avoid that interpretation, which would necessarily implicate downhole concerns and be outside of the City's jurisdiction.

BMP Document – Exhibit I

COGA understands that many provisions in the draft regulations and draft BMP document are taken from an existing operator's Regional Operator Agreement. Creating rules and regulations specific to the abilities and locations of one company poses challenges for future development. As such, COGA requests that, *at a minimum*, a variance process be established and defined in the draft code to allow for other alternative solutions to meet the intent of the City's requirements. Other items of concern in the BMP document include, but are not limited to:

Introduction, A

Regrading paragraph A.(1), and as stated in COGA's previous letter to the City, requiring an operator to comply with BMPs adopted after the fact is extremely problematic. Retrospective application of BMPs to an oil and gas permit may not be technically practical, and retrospective application lends itself challenges with respect to illegal impairment of vested property rights. If this is not the City's intention, COGA suggested this language be clarified or removed.

Regarding paragraph A.(3), COGA is concerned with defining "practicable" to mean "in the Director's opinion that: (a) there is no technology reasonably available to conduct..." What may be deemed "practicable" by the Director may not be possible for a specific oil and gas operation and the Director may not have the oil and gas knowledge and experience necessary to make an informed "opinion". The Director's "opinion" must be objective and based in fact. Second, COGA suggests that the phrase, "and commercially" be added to "reasonably *and commercially* available." Certain requirements outlined in the BMP document, such as Tier 4 hydraulic fracturing fleets, may not be readily available for use.

Air Quality: Ambient Air Monitoring, C.3.

As drafted, this BMP states, "Operator shall provide access to the Well Sites to the City's designated personnel or agent to allow air sampling to occur, without condition." But conditions may be necessary for the safety of the designated personnel or agent and to ensure that the air sampling is conducted properly. COGA recommends that the "without condition" language be stricken and substituted with language explaining that non-operator personnel should be escorted on site and the operator should have the opportunity to observe the air sampling.

Reduced Emission Completions, C.9.

Because the COGCC does not regulate gas gathering lines, this provision needs modification.

Water Quality Protection – Chemical Disclosure, D.1.

COGA has concerns about sharing proprietary information with the City. Where specific information regarding hydraulic fracturing chemicals is confidential, the information should not be made available to the public. The information may be confidentially provided on a “need to know basis” to medical professionals or emergency responders.

Safety – Flowlines, E.6.c & f

COGA has serious confidentiality and safety concerns with this provision, and recommends it be struck from the draft regulations. As the City is aware, the COGCC recently completed a flowline rulemaking pursuant to SB19-181 that will “allow the public disclosure of flowline information.” As such, the COGCC has created a mapping system that shows the locations of existing flowlines without compromising safety. COGA suggests that Commerce City contact the COGCC for specific files related to flowlines.

Safety – Plugged and Decommissioned Well Testing, E.8.

COGA recommends this provision be struck in its entirety because local governments cannot regulate downhole aspects of oil and gas operations, such as plugging and decommissioning oil and gas wells.

Visual & Noise Mitigation – Lighting, F.3

COGA believes the draft lighting provisions in the BMP document are too prescriptive. COGA recommends instead a flexible approach (or at minimum the ability to obtain a variance, as discussed above), as safety concerns and OSHA requirements may dictate lighting specifics different from those drafted.

Community Outreach, Notification, Reporting & Oversight; Hazards & Emergencies – Complaint Response, G.3

COGA suggests that Commerce City add language to this section that would relieve an operator of the obligation of responding to a complaint lacking credibility, such as when repeat complaints by the same individual are determined to be unfounded or when the complaint relates to an activity that is not ongoing. For example, if a complainant purports to complain about drilling noise at a time when there is no drilling, that complaint does not warrant a response.

Community Outreach, Notification, Reporting & Oversight; Hazards & Emergencies – Emergency Response Plan, G.7.c.viii

COGA comments that this provision be struck from the draft code. Downhole matters are outside of Commerce City’s jurisdiction.

COGA thanks Commerce City in advance for its close attention to the issues addressed in this letter and attached redline. Please consider COGA and our membership as a resource when having discussions related to the oil and natural gas industry and during this and any potential future regulatory changes.

Sincerely,

A handwritten signature in dark ink, appearing to read 'R. Seastrom', with a stylized, cursive script.

Ryan Seastrom, Community Outreach Coordinator, Colorado Oil & Gas Association

cc (via email):

Mark Mathews-Brownstein Hyatt Farber Schreck, LLP

Julia Rhine-Brownstein Hyatt Farber Schreck, LLP

Dan Haley-Colorado Oil & Gas Association

Christy Woodward-Colorado Oil & Gas Association

Rich Coolidge-Colorado Oil & Gas Association

EXHIBIT D TO ORDINANCE ~~2235~~2266

(Underlined text indicates new material;
strikethrough text indicates deletions.)

Sec. 21-3216. Oil and Gas Permits

1. **Description.** An Oil and Gas Permit allows the permit holder to undertake construction of an Oil and Gas Facility and to conduct Oil and Gas Operations~~oil and gas project~~. The review of such permit is intended to ensure compliance with this land development code. Oil and Gas Permits shall encompass, as part of its authorization, the right of the Operator, its agents, employees, subcontractors, independent contractors, or any other person to perform that work reasonably necessary to conduct the activities authorized by the Oil and Gas Permit, subject to all other applicable City permits, regulations requirements, and state and federal laws and regulations.
2. **Requirement.** No building permit shall be issued, and no development, excavation, site preparation, or construction activity, including tree/vegetation removal or grading, shall occur on any property in connection with an Oil and Gas Facility~~Well Site~~ until an Oil and Gas Permit has been approved in accordance with this section.
3. **Public Notification Process.** The City shall follow the public notification procedures outlined in Article III and all reasonable costs of property owner notification shall be borne by the Operator.
4. **Public Comment Procedures.** During the Public Notification process, members of the public will have the opportunity to file written comments with the City. The deadline for providing these comments shall be contained in the public notification of the process as outlined in the public notification section. The comments received ~~can~~may be used by the Director to inform the decision based on the relevance to the Approval Criteria and accuracy of the comments. Any written objection or request must be directly related to the proposed Oil and Gas Permit.
5. **Initial Assessment Process & Site Eligibility Determination.**
 - a. **Mandatory meeting.** Prior to submittal of any individual Oil and Gas Permit application, all potential Operators shall conduct a

Commented [BHFS1]: An "oil and gas project" is not defined.

Commented [BHFS2]: An Oil and Gas Facility may not have wells. It could, for example, exclusively house production equipment and environmental control devices. COGA proposes global changes throughout this document to change "Well Site" to "Oil and Gas Location" or "Working Pad Surface," depending on context.

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minimum of one meeting with City staff. The Operator shall provide to the City sufficient information and facts, in writing and prior to the meeting, to allow the City to make a determination as to the process for determining the eligibility of a site and the application process (i.e., whether an alternative site analysis will be required; whether an administrative or City Council review process will be required). If the City is unable to determine if an alternative site analysis will be required, the Operator shall be required to attend additional meetings and provide supplemental information. Full participation and cooperation in the Initial Assessment Process and site eligibility determination, followed by the issuance of an Eligibility Letter, shall be a prerequisite to the submission of an application for an Oil and Gas Permit.

Commented [BHFS3]: Under what circumstances would the City be unable to determine if an alternative site analysis is required? The criteria are objective and clear.

- b. Site Eligibility. Before submitting any application for an Oil and Gas Permit, the Operator shall obtain a determination on the eligibility of all ~~proposed locations~~location(s) proposed for their Oil and Gas Permit. Locations not deemed eligible pursuant to this subsection shall not be included in any application or permitted as Well Sites.

- i. Limited exemption. Proposed locations shall automatically be deemed eligible for the submission of an application and exempt from the requirement of an alternative location analysis if the ~~site-working pad surface of the proposed site~~ meets all of the following criteria:

Commented [BHFS4]: The draft regulations refer variously to "Well Sites" and "Production Sites." Clarity regarding this term is needed. COGA recommends adopting the COGCC's draft definition of "Working Pad Surface, which the COGCC has proposed to mean "the portions of an Oil and Gas Location that has an improved surface upon which Oil and Gas Operations take place." Importantly, the COGCC's definition of "working pad surface"—which is the operative point of measurement for key COGCC setbacks and measurements, such as distance to building units—does not include off-location flowlines, crude oil transfer lines, produced water transfer systems, cut and fill slopes, access roads, stockpiles, landscaped areas, and stormwater controls that are on located on the improved surface where oil and gas operations take place.

1. Is located more than ~~2,000'~~1,500' from the following:

- a. ~~Ten or more existing or platted residential building units. Any existing residential, platted residential, or property currently entitled for residential use, not including properties zoned Agricultural over 10 acres in size;~~

Commented [BHFS5]: COGA questions whether any parcel of land in Commerce City meets this criteria. If there are no parcels of land from which minerals may be extracted that meet this criteria, Commerce City should delete this section entirely.

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- b. Any facility currently classified as a High Occupancy Building Unit, as defined by the COGCC;
 - c. Any Public Park or Public Recreation facility, not including trails or City designated open space;
 - d. Outdoor venues, playgrounds, permanent sports fields, amphitheaters, or other similar places of outdoor public assembly; and
 - e. Senior living or assisted living facilities;
2. Is located more than 500' from the following:
 - a. The centerline of all USGS perennial streams;
 - b. Public Water Supply Wells;
 - c. Reservoirs; and
 - d. Areas defined as land unsuitable for development in Section 21-7100.
3. Is outside of FEMA 100 Year Floodplain boundary and any surface water features; and
4. Meets at least **one** of the following criteria
 - a. Is currently zoned or may be zoned I-1, I-1S, I-2, I-3, or AGI-2, I-3, or PUD with a use category of "general industrial"; or identifies Oil and Gas resource extraction (i.e. subsurface extraction) as an allowed use; or
 - b. Has a future land use designation of Industrial / Distribution or General Industrial.

Measurements shall be taken from the edge of the proposed Production Site/Working Pad Surface to the

Commented [BHFS6]: Does the City have up to date maps available of these facilities to aid operators (and others) in planning development?

Commented [BHFS7]: Counsel for COGA could not identify a Section 21-700 in Commerce City's code. Please provide.

Commented [BHFS8]: Does not match uses allowed in Exhibit E. Exhibit E specifies allowed use in zones: I-1, I-1S, I-2, I-3, and AG.

Commented [BHFS9]: This should be a defined term. As noted above, COGA recommends using the COGCC's draft definition of "Working Pad Surface."

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parcel boundary. The edge of the proposed ~~Production Site-Working Pad Surface~~ shall be defined as the maximum extent of the ~~location's footprint facility~~ during the production phase.

- ii. Alternative Site Location Analysis. If the site is not automatically deemed eligible pursuant to the limited exception, the applicant shall prepare and submit an alternative site location analysis including, at a minimum, the following information:

1. ~~If applicable, a~~All drilling and spacing units proposed by the applicant within the City and within 1 mile of the City's municipal boundaries;
2. The location of all features listed in section 21-3216(5)(b)(i)(1-3) within 1 mile of all drilling and spacing units proposed by the applicant;
3. A minimum of three potential sites that can reasonably access the mineral resources within the proposed drilling and spacing unit(s), including the following information for each site:
 - a. General narrative description of ~~the~~ each site;
 - b. The applicant's basis for proposing each site;
 - c. A summary of the off-site impacts that may be associated with each site;
 - d. Any factors listed in section 21-3216(5)(b)(i) that the particular site does not meet;
 - e. Proposed truck traffic routes and access roads for each site; and
 - f. Any information pertinent to the applicable review criteria that will assist the City in evaluating the sites.

Commented [BHFS10]: The operator may wish to develop within an existing drilling and spacing unit ("DSU").

Commented [BHFS11]: COGA does not understand this section. As drafted, this could require operators to identify features several miles away from the City's municipal boundaries because of DSU shape, location and size.

Commented [BHFS12]: What if there are not three sites? There may not even be two sites that can reasonably access the mineral resources due to a multitude of factors, including existing development, wildlife habitat and traffic access.

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- iii. Review Criteria. The Director may determine that a site identified in the alternative site location analysis is eligible to submit an application, based on the following:
1. A proposed site's conformance with the City's adopted Comprehensive Plan, and any other applicable adopted plans;
 2. The absence of or ability to minimize and/or mitigate any significant impacts the proposed site location may have on adjacent properties;
 3. Adequate surface acreage and suitable topography for safe and efficient operations;
 4. The ability to access targeted minerals with technology available at the time of development;
 5. The ability to reasonably implement the protections contained in the BMP Document from the proposed location;
 6. The ability to consolidate facilities with other planned drilling and spacing units proposed within the City's municipal boundaries;
 7. The ability to reconfigure proposed drilling and spacing unit applications to provide more suitable surface use locations;
 8. ~~The existence of a surface use agreement between any landowner and a potential operator shall not be a factor of consideration in the city's review of an alternative location analysis;~~ and
 9. Any other relevant considerations impacting public health, welfare, safety, and the environment.

- iv. Disposition. Within thirty (30) days of receiving materials either for an exempt proposed location or for location(s) proposed with the Alternative Site Location Analysis.

Commented [BHFS13]: As discussed below, COGA has several issues with the BMP Document, both procedurally and substantively. COGA previews its comments to follow below by noting that the BMP Document as drafted is impossible to implement. Without modification, COGA is concerned that Commerce City's draft regulations will be a de facto ban on oil and gas development.

Commented [BHFS14]: What does this mean? A modern DSU often only allows for one well-pad.

Commented [BHFS15]: This is important because an operator may not be able to secure an SUA for a location that in Commerce City's estimation, is better suited for oil and gas operations.

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The Director or designee shall provide the applicant a written assessment ("Eligibility Letter") indicating which, if any, of the proposed locations qualify as eligible sites or whether the proposed location is automatically deemed eligible. If a proposed location is denied as ineligible, the Eligibility Letter will explain why. The Eligibility Letter shall not be construed as an Oil and Gas Permit or an authorization to conduct any Oil and Gas Operations.

Commented [BHFS16]: COGA urges Commerce City to add due process protections allowing an operator recourse to appeal an Eligibility Letter's denial of one or more proposed locations.

- c. Notwithstanding the eligibility of a site, an application for an Oil and Gas Permit shall not be accepted if the proposed location is not currently zoned for Oil and Gas Operations unless a complete zoning application is concurrently submitted, or is currently pending, that would allow Oil and Gas Operations at the proposed location if approved.

Commented [BHFS17]: What is the City's intent behind having the area where the oil and gas operation will be zoned for oil and gas?

- d. Confidentiality. To the extent permitted by law, information submitted to the City by an applicant in support of the Initial Assessment Process and site eligibility determination may be deemed confidential by the applicant provided that the public release of such information has the potential to negatively impact the applicant's business activities, including the applicant's negotiating position with surface use owners. If the applicant designates any information as confidential, the information may not be released by the City unless required by law. The applicant shall be solely responsible for the protection of its information and shall indemnify the City for any attorneys' fees and costs, and any award thereof, incurred in the defense of the applicant's assertion of confidentiality.

Commented [BHFS18]: If the Operator marks information and confidential and the City discloses it improperly, the City should take financial responsibility for the City' mistake.

- e. Materials submitted for review as part of the Initial Assessment Process and site eligibility determination shall not constitute an application for development for purposes of C.R.S. § 24-68-101, et. seq. Any opinions expressed during the Initial Assessment Process and site eligibility determination are informational only and do not represent a commitment on behalf of the city regarding the acceptability or approval of the development proposal, except the eligibility of a site for application. Any opinions expressed during the Initial

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Commented [BHFS19]: Section 24-68-102, C.R.S. explicitly provides, "For local governments that have provided for the review and approval of site specific development plans in multiple stages, "application" means the original application at the first stage in any process that may culminate in the ultimate approval [of a site specific development plan.]" Commerce City cannot just declare statute does not apply. The City is making the initial assessment process and site eligibility determination the original application in the first stage of the process that might lead to an oil and gas permit approval.

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Assessment Process and site eligibility determination will be part of the administrative record for the permit application.

- 6. Extraction Agreement.** No Extraction Agreement shall be approved by the City before the closure of the public comment period on any pending, related Oil and Gas Permit ~~Application~~ application to put forward site-specific conditions necessary to protect health, safety, and general welfare. The Extraction Agreement will not be finalized until after the public comment period has closed.
- 7. Review.**
- a. Except where public hearings are required pursuant to this section, the Director and Development Review Team (DRT) review applications for Oil and Gas Permits and the Director is authorized to approve, approve with conditions, or deny such applications based upon the approval criteria outlined below (for purposes of this section, this process shall be referred to as an administrative approval). In the event the Director denies the application, the applicant may request that the permit be reviewed through the public hearing process.
 - b. Public hearings before the Planning Commission and the City Council shall be required if: the proposed site location would require an alternative site location analysis under section 21-3216(5)(b), above; a public hearing process is requested by the Operator after the denial of an application by the director; or is otherwise required by this code.
 - c. When public hearings are required by this section, the review process shall be as follows:
 - i. The Director and DRT will review the application and the Director will provide a report to the Planning Commission.
 - ii. The Planning Commission will hold a public hearing on the application and make a recommendation to the City Council based on the approval criteria below.
 - iii. The City Council will consider the application, the director's report, the Planning Commission's

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recommendation, and any other testimony at a public hearing and after the hearing, shall approve, approve with conditions, or deny the ~~proposed plat~~ application, based on the approval criteria below.

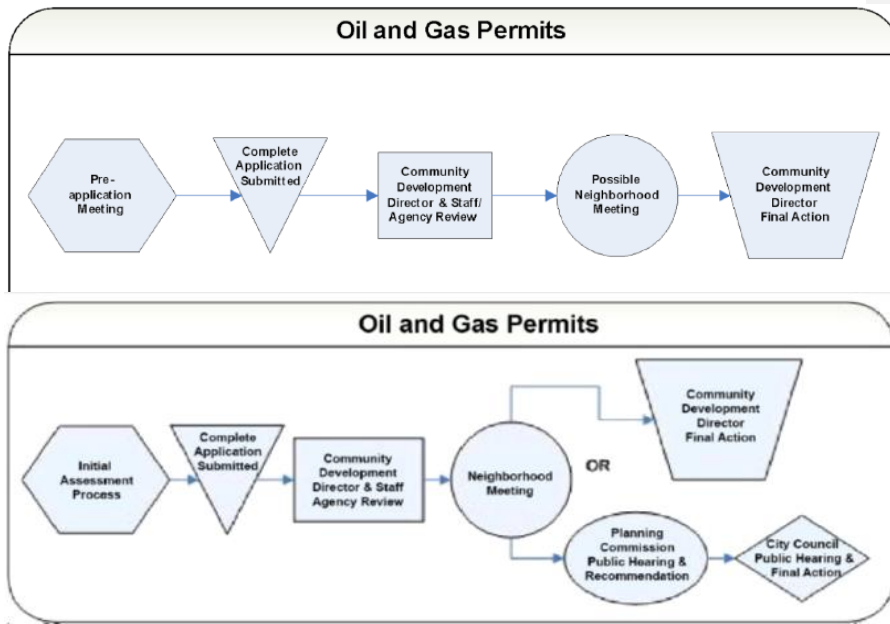


Figure III-6. Oil and Gas Permits

8. **Approval Criteria.** An Oil and Gas Permit ~~may~~ shall be approved if all of the following criteria are ~~met~~:
- The Operator has submitted the appropriate and complete application form and submitted the required fees (except those payable upon the issuance of a permit) to the City;
 - The proposed location has been deemed eligible pursuant to section 21-3216(5) or any granted variance;
 - The proposed operation conforms with any Regional Operator Agreement and any site-specific Extraction Agreement between the operator and the city;

Commented [BHFS20]: If the criteria are satisfied, there should be no reason to deny an Oil and Gas Permit.

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- d. The characteristics of the site are suitable for the proposed facility considering size, shape, location, topography, existence of improvements and natural features;
- e. The proposed operations and facility will not result in ~~substantial or~~ undue adverse impacts or effects (during any phase of operation or during any potential operational, environmental, or meteorological condition) on public health, safety, welfare, or the environment; adjacent property; occupied structures within 2,500' of the proposed facility; the character of the neighborhood; and traffic conditions;
- f. The proposed facility will be adequately served by and will not impose an undue burden on existing public and private improvements, facilities, and services of the Ceity or its residents, either as such improvements, facilities, and services presently exist or as they may exist in the future as a result of the implementation of provisions and policies of the comprehensive plan, this land development code, or any other plan, program or ordinance adopted by the City. Where any improvements, facilities, utilities or services are not available or are not adequate to service the proposed use in the proposed location, the applicant shall, as a ~~part of the application and as~~ a condition of approval, be required to provide such improvements, facilities, utilities and services in sufficient time to serve the proposed use;
- g. Any adverse impacts, effects, and burdens have been or will be mitigated to the maximum extent feasible, necessary and reasonable;
- h. The Operator has entered into a site-specific Extraction Agreement, approved by the Director, if required by the City to establish site-specific protections and public improvements not addressed in the BMP Document, this code, or state law or regulation but necessitated by the proposed operation to address matters of public health, welfare, ~~and~~ safety, and the environment;

Commented [BHFS21]: Please explain what this means.

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- i. The proposed facility is consistent with any applicable zoning ordinance, subdivision plat, and other plans or land use approvals applicable to the site;
- j. The proposed facility complies with all regulations and standards of the BMP Document ~~adopted by the City Council, as such may be amended;~~ in effect at the time of the application's submittal and subject to any variances that might be granted;
- k. The City has approved all plans required by Section 21-5266 ~~or granted a variance therefrom;~~ and
- l. The proposed operation will meet the requirements for Subsurface Extraction as set forth in Section 21-5266 ~~or as relevant due to a variaance; and~~ and will not violate any other applicable City, state, or federal standards or laws.
 - ~~h. The proposed Oil and Gas Operation will not violate any standards or conditions for Subsurface Extraction, and will comply with all plans approved by the City, as set forth in Section 21-5266 and any other applicable City, state, or federal standards or laws.~~

Commented [BHFS22]: COGA again suggests zoning/rezoning specifically for oil and gas operations isn't necessary.

9. General Terms of Approval. The following General Terms and Conditions shall apply to any Oil and Gas Permit.

- a. The granting of an Oil and Gas Permit shall not relieve the Operator from complying with all applicable regulatory requirements of the City, the state of Colorado, or the United States.
- b. The Oil and Gas Permit and existing use site plan required by this Code is in addition to any permit that may be required by any other provision of this Code, or by any other governmental agency.
- c. The Operator shall obtain and maintain a general business license from the City prior to commencing operations and conform to applicable provisions of the Commerce City Revised Municipal Code related to licensing. Such license will be expediently approved by the City upon receipt of application.

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- d. The Operator shall obtain building permits prior to the construction of any above-ground structures to the extent required by the City building and fire codes. Such building permits shall be expediently approved by the City upon receipt of applications.
- e. By accepting an Oil and Gas Permit, the Operator expressly stipulates and agrees to be bound by and comply with the provisions of this Code ~~and any subsequent amendments thereto as set forth therein.~~

Commented [BHFS23]: Changing the law offends due process and could lead to the illegal impairment of a vested right.

10. Permit Period; Lapse; Forfeiture.

- a. The term of the Oil and Gas Permit shall be for ~~three-four (3)~~ four (4) years except as otherwise stated herein. Upon issuance of ~~any state permit issued by final approval from the COGCC allowing State permitting the commencement of~~ Operations on the Site that is the subject of the City's permit, the term of the Oil and Gas Permit shall automatically become coterminous with the COGCC issued permit approving an oil and gas location assessment (Form 2A) unless the Oil and Gas Permit has otherwise expired, lapsed, revoked, forfeited, abandoned, or otherwise ~~terminated.~~
- b. The Oil and Gas Permit shall expire upon permanent abandonment and final reclamation of the permitted Operation, unless otherwise expired, lapsed, revoked, forfeited, abandoned, or otherwise terminated.
- c. Time for Drilling and Forfeiture.
 - 1. Upon issuance of an Oil and Gas Permit, and notwithstanding any other provision in this Code, the total number of wells approved in the Oil & Gas Permit must be drilled and completed within ~~three-four (43)~~ years of permit approval. Failure to do so shall constitute the forfeiture of the authorization and right to drill any undrilled wells. Authority to drill forfeited wells can only be obtained upon the ~~amendment the existing Oil & Gas Permit or~~ issuance of a new Oil & Gas Permit.

Commented [BHFS24]: Because of the lengthy state permitting process, COGA suggests a period of 4 years.

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2. At least ~~three~~ six months prior to forfeiture, an Operator may seek ~~one time~~ relief from forfeiture if, upon formal application to the Director, the Director finds by clear and convincing evidence that ~~drilling (1) no additional undue adverse health, safety, general welfare, or environmental impacts would occur and/or that any such impacts can be reasonably mitigated, and completions were delayed due only~~ (2) the surface use conditions and surrounding land uses that are either existing or planned and will be executed within three years have not changed to ~~state or local permitting requirements, such a degree that current approval criteria could no longer be met.~~ In such case, the ~~Director may authorize a one time~~ Director's authority to grant such an extension of the drilling and completion deadline ~~by up to~~ shall be limited to (1) one extension, and (2) no longer than one year. Any other extensions to avoid forfeiture beyond the extension described above shall require the approval of City Council and shall be based on these same criteria. All application extensions shall require the written consent of the surface owner.

- d. ~~If construction of a structure is required, an Oil and Gas Permit shall lapse unless a City building permit has been issued and construction diligently pursued within two (2) years of approval or at such alternative time specified in the approval. In the event no new structure is required for the operation, the Oil and Gas Permit shall lapse if the Operation is not commenced within 180 days of the approval. In addition, an Oil and Gas Permit shall automatically lapse and have no further effect if the use is discontinued for 180 consecutive days.~~

11. Permit Exceptions.

- a. Operations not in conformance with this Code as of July 7, 2012, or that are in existence and are located within territory that is thereafter annexed to the City, may continue without the issuance of an Oil and Gas Permit until the Operation is expanded, new wells are drilled, or a permit is issued by the COGCC that allows further or additional Operations or modifications to existing Operations. The right to operate any

Commented [BHFS25]: This provision is unworkable. The state permit might not be granted within 180 days of the City approval. Also, the last sentence is ambiguous and could be interpreted to mean that a site whose wells have been shut-in for 180 consecutive days no longer has a valid permit. That is unreasonable and unnecessary. An operator might chose to temporarily shut-in its wells for 180 consecutive days for a variety of reasons, including because of a lack of midstream takeaway capacity or to upgrade emission control devices.

non-conforming Operations terminates if the use thereof is discontinued for six (6) months or more.

- b. Any renovation, replacement or repair of nonconforming Oil and Gas Facilities shall be allowed without an Oil and Gas Permit, provided such work does not increase the degree of nonconformity. The replacement or addition of individual conforming tanks, treaters, or separators shall not require the remaining equipment or systems at an Oil and Gas Facility to conform to the development standards in this Section.

12. Best Management Practices Document.

- a. The City Council may adopt additional standards, protections, and specifications through a series of Best Management Practices ("BMP Document"), adopted by the City Council by ordinance, that shall apply to all applications for new Oil and Gas Operations within the City. ~~All Oil and Gas Permit holders shall at all times comply with the BMP Document, as it may be amended.~~
- b. The City Manager or designee shall be responsible for the administration and enforcement of the BMP Document. The BMP Document shall be enforceable in the same manner as the provisions of this code.
- c. On an annual basis, or as may be otherwise necessary from time to time, and in response to, without limitation, new federal and state laws and regulations, scientific studies, or emerging technologies or changes in industry standards or practices, the City Manager or designee shall recommend modifications to the BMP Document to be reviewed by City Council and amended in a manner consistent with the City Charter for the adoption of ordinances and shall be effective as provided by the City Charter.

Commented [BHFS26]: This effectively would allow Commerce City to shut down operations because the City enacts a new BMP that is impossible or impracticable with which to comply. Changing the rules after the fact invites impairment of vested property rights litigation.

13. Regional Operator Agreement.

- a. The Director may negotiate and execute, consistent with the provisions of the Commerce City Charter and the Commerce City Revised Municipal Code, a Regional Operator Agreement

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to establish terms and conditions for the protection of the public health, safety, and welfare and the environment with any Operator who has submitted an application for an Oil and Gas permit under this Code or an application for a permit issued under the authority of the Colorado Oil and Gas Conservation Commission regarding oil and gas operations in the city.

- b. A Regional Operator Agreement may include, among other things, best management practices applicable to all current and proposed Operations of the Operator within the City.
- c. A Regional Operator Agreement shall not waive or exempt the Operator from any applicable law, regulation, or standard, including any requirement of the Commerce City Revised Municipal Code, unless such variance is specifically authorized by law, regulation, or standard in question.
- d. No Regional Operator Agreement shall grant or be deemed to grant vested rights to any Operator or authorize any activity regulated by the Ccity except pursuant to applicable permitting requirements.
- e. A Regional Operator Agreement shall be in addition to, and shall not replace, the requirement of a site-specific Extraction Agreement required for each Oil and Gas Permit.
- f. The Director may seek input from the City Council regarding the negotiation and terms of any Regional Operator Agreement.
- g. No Regional Operator Agreement may be finalized and executed before the draft agreement has been made available to the public for inspection and written comment for a period of no less than twenty-one (21) days. Following such period of public comment, the Director may incorporate modifications to such draft without the requirement of further public comment unless requested by the Operator, the Director, or the City Council.

14. **Assignment of Permits.** An Oil and Gas Permit may be assigned to another Operator only with the written consent of the City upon the

Commented [BHFS27]: COGA takes issue with this draft provision interfering with private property transfers.

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~~Director's reasonable determination that the~~ Director. The Director
may consent to an assignment of a permit only if:

- ~~14. a. The~~ new Operator can and will comply with all requirements, terms and conditions of the Code, the Oil and Gas Permit and any Regional Operator Agreement and all applicable state, local and federal laws, rules and ~~regulations~~.
- b. ~~Permit not to run~~ The new Operator demonstrates adequate insurance and posts financial assurances required of the previous Operator;
- c. The new Operator will remedy any on-site noncompliance with ~~the land. An~~ any applicable local or state regulations and permits, as a condition of the assignment;
- ~~15. d. The Oil and Gas Permit is not attached to and does not run with the land. An~~ any applicable local or state regulations and permits, as a condition of the assignment;

Commented [BHFS28]: How will the Director determine this? The Director's discretion should not be unreasonably withheld.

Commented [BHFS29]: This goes against responsible party determinations in the Oil and Gas Conservation Act, § 34-60-124.

Section added by Ord. 1891, August 2012
Section amended by Ord. 2183, November 2018

EXHIBIT F TO ORDINANCE ~~2235~~ 2266

*(Underlined text indicates new material;
strikethrough text indicates deletions.)*

Sec. 21-5266. Subsurface Extraction

- (1) Purpose.** This Section is enacted pursuant to the home rule authority, land use authority, and the police powers of the City and to protect and promote health, safety, welfare, and the environment.
- (2) Applicability.**

 - (a) Subject to the provisions of this section, no Oil or Gas Operations (“Operations”) shall be initiated in any manner within the City prior to issuance of an Oil and Gas Permit.
 - (b) All Operations are subject to the requirements of this section, Section 21-3216, and other parts of this code directly addressing Operations. If such provisions directly conflict with any other generally applicable provisions of the Code, sections of this code directly addressing Operations shall supersede but such conflict shall not alleviate an Operator from obtaining any required permits or approvals.
- (3) Application Requirements.** An application for an Oil and Gas Permit shall include the following:

 - (a) City application form and applicable, non-refundable application fee and all other applicable fees, excluding those payable at the time of permit issuance, unless not otherwise due at the time of application;
 - (b) An Eligibility Letter from the City confirming the site proposed in the application is a qualified as eligible;
 - (c) Information sufficient to determine compliance with the BMP Document;
 - (d) A legal description of the property to be used for the Operation;
 - (e) Evidence of legal authority to use the proposed location for the proposed Operations;

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- (f) List of all permits or approvals obtained or to be obtained from local, state, or federal agencies, including any exceptions or variances that are required;
- (g) Operator~~r~~ and applicant name(s), telephone number(s), address(es), and if possible, email address(es); if the Operator is a corporation, the state of incorporation, and if the Operator is a partnership, the names and addresses of the general partners;
- (h) Name of representative with supervisory authority over the proposed Operation and a twenty-four-hour phone number;
- (i) Location and description of all recorded and/or visible improvements, including water wells, and habitable structures, all utility easements and rights of way of record, and all existing irrigation and drainage ditches within 1500' of the proposed Operation;
- (j) Owner and address of each parcel of property within 2500' of the proposed Operation;
- (k) The location of existing sensitive wildlife habitats, nature areas, or open space within 1500' of the well site or Production Site, if any;
- (l) A Site Plan for the proposed Operation showing the location of all improvements and drilling equipment, including, but not limited to, the location of the proposed well(s) and other facilities, tanks, pipelines, compressors, separators, and storage tanks, including the number of the potential maximum number of wells to be drilled and associated drilling equipment;
- (m) A Water Plan describing the water sources to be used for the Operations and the proposed method of delivery;
- (n) Evidence of insurance and security requirements under this section;
- (o) A notarized statement, under oath, signed by the Operator, or designated representative, that the information submitted with

Commented [BHFS30]: What is a "nature area" ?

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the application is, to the best knowledge and belief of the Operator or designated representative, true and correct;

- (p) A Schedule of Operations showing estimated project schedule that may vary for all phases, including “construction phase” (including pipeline construction, if applicable), “drilling phase,” “completion phase” (~~broken-down into~~ detailing activity-based components including flowback), and “production phase” (including estimated timelines for interim reclamation and landscaping);
- (q) An Electrification Plan identifying all sources of electricity that will be brought to or used at the Well Site during all phases, including drilling completion and production;
- (r) A Noise Management Plan to manage noise at or below the levels indicated in the BMP ~~document~~ Document. The plan must include a baseline noise study as well as noise modeling of equipment proposed for the site for drilling and completions;
- (s) A Traffic Control Plan showing public and private roads that traverse or provide access to the proposed operation and a plan showing the estimated number of vehicle trips per day for each type of vehicle, proposed haul routes to and from the site, and measures to mitigate adverse impacts to traffic patterns and safety caused by the proposed operation. The traffic control plan shall provide this information for each phase of Operations;
- (t) If the Operator does not rely on the City’s existing Traffic Impact Study, a Traffic Impact Study, prepared by a vendor selected by Operator from a City-approved list of vendors, which shall clearly identify and distinguish impacts to City roads and bridges related to Facility construction, Operations and ongoing new traffic generation. Traffic impact studies shall be prepared in accordance with City standards and requirements. The study shall include a traffic mitigation plan addressing transportation impacts that will typically include, but not be limited to, a plan for traffic control, the receipt of all necessary permits, ongoing roadway maintenance and improving or

Commented [BHFS31]: COGA understands that Commerce City has recently passed a traffic impact fee for such purposes. COGA suggests that this provision may refer to that study and require a traffic plan pursuant to that document as an alternative path to expending City and operator resources to generate and then review a new study.

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reconstructing City roads, including providing financial assurance;

- (u) An Air Quality Mitigation Plan showing a modeling assessment of air quality impacts and a plan and schedule to maintain air quality, including a plan to minimize VOC emissions in compliance with the BMP Document;
- (v) A Dust Mitigation Plan to control dust and minimize visible dust emissions from roadways or from ~~completion~~ Operations;
- (w) An Emergency Response Plan as detailed in the BMP Document. In preparation of the Emergency Response Plan, Operator shall engage with emergency responders and prepare a plan that includes, without limitation, documentation of the communications and coordination with the City and nearby schools related to evacuation of the nearby schools and all persons residing within a one-half (1/2) mile radius from the edge of disturbance. The Emergency Response Plan must detail all criteria for persons to be notified in the event of an emergency and training for first responders;
- (x) A Will-Serve Letter from the applicable fire district(s), stating that the Operator has agreed to provide adequate emergency response equipment, any necessary training, or fee-in-lieu satisfactory to the district, to adequately respond to potential events that may result from Operations;
- (y) A Resource ~~Mobilization~~ Mobilization/Cache Plan to ensure emergency responders have available the equipment necessary to respond to any emergency identified in the emergency response plan and such plan shall provide that the equipment be stationed in locations as to be readily available for any oil and gas emergency within Commerce City;
- (z) A Waste Management Plan that identifies the projected waste from the site and plans for disposal of such waste;
- (aa) A Hazardous Materials Management Plan that identifies all hazardous materials that will be brought on site, how they will be transported and used, and measures to prevent any release of those materials;

Commented [BHFS32]: What qualifies as a "nearby" school

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- (bb) A Temporary Sanitary Facilities Plan describing the sanitary facilities that will be provided for persons present at the Well Site;
 - (cc) A Water Quality Monitoring Plan describing water quality monitoring practices as required by the BMP Document;
 - (dd) A Spill Prevention, Control, and Countermeasure Plan describing spill prevention and mitigation practices as required by the BMP ~~document~~ [Document](#);
 - (ee) A Stormwater Pollution Prevention and Erosion Control Plan to minimize impacts to surface waters from erosion, sediment, and other sources of non-point pollution. The stormwater control plan required by COGCC Rule 1002(f) may be provided to establish compliance with this provision;
 - (ff) A Wetlands Protection Plan, if any part of a proposed Operation abuts or is adjacent to or may affect or impact a wetland, demonstrating that the Operations shall not cause degradation to wetlands within the City;
 - (gg) A Visual Mitigation Plan demonstrating how the proposed Operation will blend into the surrounding landscape, including consideration of fencing materials, berming, and use of existing vegetation, and natural contours to the maximum extent practicable. The Visual Mitigation Plan shall require photographic simulations of the Oil and Gas Well Site that include proposed ~~impact~~ mitigation measures ~~as indicated in "Visual Mitigation Measures," below~~;
 - (hh) A Landscaping Plan to supplement the Visual Mitigation Plan with the use of drought tolerant species that are native and less desirable to wildlife and suitable for the climate and soil conditions of the area. An irrigation plan may be required where buffering is accomplished with vegetation. Depending on access to water, the Landscaping Plan may be staged to accommodate surface development;
 - (ii) An Interim Reclamation Plan, including a written description of the species, character and density of existing vegetation on the Well Site, a summary of the potential impacts to vegetation as a

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result of the proposed Operations, and proposed replanting and mitigation to address these impacts. The plan shall be consistent with the BMP Document. The plan shall include any COGCC-required interim reclamation procedures and shall include the means by which vegetation will be watered and maintained;

- (jj) An Existing Vegetation Analysis of the existing vegetation at the Well Site to establish a baseline for re-vegetation upon abandonment of the Facility or upon final reclamation of the Well Site;
- (kk) A Weed Control Plan to comply with City requirements for the control of noxious and other weeds. Well Sites shall be considered developed property for the purposes of the control of weeds;
- (ll) A Lighting Plan consistent with the requirements of this code and the BMP Document if there is to be lighting onsite during Operations;
- (mm) A Site Security Plan for each Well Site, including a requirement to review the plan annually and when requested by the City and to update the plan as needed or required by the City;
- (nn) A Risk Management Plan consistent with the BMP Document;
- (oo) A Wildlife Mitigation Plan for surface Operations that will be located within ~~or adjacent to~~ 1/2 mile of a sensitive wildlife habitat or open space;

~~(pp)~~Any variance request necessary for approval;

~~(qq)~~Any other information that the City deems necessary for consideration of an Oil and Gas Permit application, which information may be requested after an application is submitted and before the completeness review concludes.

- (4) Third Party Technical Review.** The City may require third-party consultants to participate on behalf of the City in the Initial Assessment Process, to review any submittals or applications to the City, attend meetings, and to advise on other processes deemed by

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the City to be appropriate and necessary. Reasonable costs associated with such reviews, including third-party consultant fees, shall be paid by the Operator. The scope of work and estimated costs will be previewed with the Operator before the City engages the third-party consultant. The Director may require the Operator to deposit funds with the City prior to the execution of such services based on ~~a reasonable estimate provided to the Director from the independent expert or consultant until a final cost is determined~~the scope of work and reasonable estimates. Fees shall be paid from the Operator's deposited funds, with the City providing to the Operator regular accounting of the fee expenditure and third-party consultant progress. Funds not expended shall be refunded to the Operator at the conclusion of the review ~~with interests.~~ew

(5) General Standards. All Operators and their agents, employees, licensees, and contractors shall:

- (a) Comply with all local, state, and federal laws and regulations;
- (b) Comply with the BMP Document, as such may be modified for a specific Oil and Gas Location, and any Regional Operator Agreement or Extraction Agreement with the City.
- (c) Comply with all required plans submitted and approved by the City as part of the Oil and Gas Permit application and any conditions of approval placed on the permit by the City.

(6) Setbacks and Floodplain Restriction.

- (a) No Oil and Gas Production Site may be located ~~less than~~ within 1000' ~~from~~ of the following:
 - (i) Any existing residential building or platted residential property,
 - (ii) Any building classified as a High Occupancy Building Unit, as defined by the COGCC;
 - (iii) Any Public Park or public recreation facility, not including trails or city designated open space;

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- (iv) Outdoor venues, playgrounds, permanent sports fields, amphitheaters, or other similar place of outdoor public assembly; ~~or~~
- (v) Senior living or assisted living facilities;
- (b) No Oil and Gas Production Site may be located less than 500' from the following:
 - ~~(vi)~~ Public Water Supply Wells; and
 - ~~(vii)~~ Reservoirs.

~~(b)~~ No Oil and Gas Facilities may be located in the Floodplain.

~~(c)~~ Measurements shall be taken from the edge of the proposed Production Site to the parcel boundary or residential building unit corner or High Occupancy Building corner. For agricultural properties over 10 acres in size with residential uses, the measurement shall be taken from the nearest edge of any occupied dwelling unit.

(7) Site Development Standards. The following standards shall apply to all ~~Well Sites~~Oil and Gas Locations, in addition to any requirements of the BMP Document and other generally applicable provisions of this code except to the extent of any direct conflict.

- (a) Visual Mitigation. Visual mitigation will be site specific. The Director may approve a Visual Mitigation Plan that is consistent with the BMP Document that allows the location to blend into the landscape ~~or~~, appear compatible with adjacent existing and reasonably anticipated land uses, or obfuscate the site. Staff ~~may will~~ consider surface owner preferences to the maximum extent practicable. Oil and gas development near planned residential or commercial development may require a staged Visual Mitigation Plan.
- (b) Fencing. Above-ground Operations shall be fenced and gated as part of the Visual Mitigation Plan and Security Plan. Fencing shall be eight-foot (8') high, wrought iron fencing, Ameristar

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Impasse, Stronghold fencing, or an equivalent, or better, as approved in the Visual Mitigation Plan. ~~The fencing color shall be black unless the Director approves an alternative fencing color~~ Eight-foot (8') high masonry may be used as an alternate.

(c) Landscaping.

(i) Landscaping will be site specific. The Director may approve a Landscaping Plan that achieves one or more of the following objectives: to obfuscate the Oil and Gas LocationWell Site from public view; to blend the Well Site into the surrounding landscape; to reinforce or extend any existing pattern of natural vegetation; to improve Oil and Gas LocationsWell Site security; or to create visual enhancement. The Landscaping Plan shall be coordinated with the City, depending on access to water, may be staged to accommodate surface development.

(ii) All plant materials shall be maintained in a healthy growing condition at all times. The Operator is responsible for the regular weeding, mowing, fertilizing, pruning and other maintenance of all plant materials as needed. Adequate irrigation of plant materials (excluding existing vegetation) shall be provided by the Operator.

(d) Lighting. To the maximum extent practicable, exterior lighting shall be downcast to reduce spill-over to adjacent properties and directed away from residential and ~~other~~ sensitive wildlife areas or shielded from said areas to eliminate glare. All permanent lighting fixtures installed at the Operations shall comply with the lighting standards of this Code and the BMP Document.

(e) Signs and Markers. The Operator shall mark each and every Oil and Gas Well as required in the BMP Document.

(8) Environmental Standards.

(a) Wildlife Mitigation.

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- (i) General. When Operations will be located within or adjacent to a sensitive wildlife area or city designated open space, the Operator shall consult with the Colorado Parks and Wildlife to obtain recommendations for appropriate site-specific and cumulative impact mitigation procedures. The Operator shall implement such mitigation procedures as are recommended by the Colorado Parks and Wildlife after consultation with the City. When Operations are adjacent to or within a federal wildlife or natural area, the Operator shall consult with the relevant federal authority to satisfy any applicable federal rules or regulations relevant to Operations. In all such instances, the Operator shall file a mitigation plan with the City.
- (ii) Endangered Species. The Operator shall not engage in activities that, in the opinion of the Colorado Parks and Wildlife, or other relevant federal authority, threaten endangered species.
- (b) General Waste Management.
 - (i) The Operator shall at all times keep all aspects of an Operation, including roads and rights-of-way, safe and in good order and to the extent practicable free and clear of noxious weeds, litter and debris.
 - (ii) Disposal of any water or any equipment, litter, sewage, waste, trash, chemicals or debris shall be at an approved disposal site.
- (c) Sanitary Regulations.
 - (i) The Operator shall provide proper health and sanitation facilities for its employees and subcontractors.
 - (ii) The Operator shall fully comply with all applicable rules and regulations of the county and state health departments or other similar body.
 - (iii) The Operator ~~shall at all times provide at the Oil and Gas Well Site a sufficient supply of safe drinking water~~

Commented [BHFS33]: This language was added because the issue, seemingly simple, can be complex. For example, trash from a neighboring property might blow onto the Operation. For another example, depending on the type of weed involved, an operator may wish to apply a treatment to kill the weeds instead of mowing them (which can spread them) and it may be that weather conditions need to be of a certain kind to apply the treatment.

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~~for its employees and~~ shall give orders against the use of water known or believed to be unsafe.

- (iv) During extended construction and maintenance Operations, the Operator shall, at convenient places within the Oil and Gas ~~Well Site~~Location, provide fly-proof outside toilets, which shall be maintained in a sanitary condition. Toilets shall not be permitted in any water reservoir area and shall not be permitted where they may pollute a water supply.

(d) Drainage and Stormwater Management.

- (i) Drainage. Operations shall comply with all applicable state and local drainage requirements and standards.
- (ii) Stormwater Management. All stormwater management shall comply with state and local requirements and standards.

(9) Nuisance Standards.

- (a) Odor/Dust Containment. Operations shall be conducted in such a manner that odors and dust do not constitute a nuisance or hazard to public health, safety, welfare ~~and/or~~ the environment. All Operations shall use the best available technologies that are technically and economically practicable to control odor and dust. If deemed necessary and reasonable, the City may require additional mitigation efforts at any point during Operations.
- (b) Noise Impacts.
 - (iii) Operations shall be conducted in such a manner that noise does not constitute a nuisance or hazard to public health, safety, welfare ~~and/or~~ the environment. All Operations shall use the best available technologies that are technically and economically practicable to control noise. If deemed necessary and reasonable, the City may require additional mitigation efforts at any point during Operations.

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- (iv) The Operator shall comply with all provisions of COGCC Rules ~~802~~ ~~on~~ ~~regarding~~ Noise Abatement, as may be amended from time to time. The maximum permissible noise levels to be applied under ~~Rule 802~~ COGCC Rules shall be, other than during pad construction ~~at the Well Sites~~ Oil and Gas Locations, the greater of: (i) the levels set forth for the land use type of “Residential/Agricultural/Rural” under Rule 802 if measurements are taken at 1,000 ft. from the sound walls at the Well Site; or (ii) 4 dB(A) higher than baseline ambient sound measured at 1,000 ft. from the sound walls at the Well Site. During pad construction at the Well Sites, noise levels shall not exceed those produced by the construction of a typical residential or commercial development.
- (v) Operators may be required to provide for additional noise mitigation as described in the BMP Document.

Commented [BHFS34]: COGCC Rule numbers are likely due to change during the pending Mission Change Rulemaking.

(10) Traffic Standards.

- (a) If public road improvements are necessary to accommodate an Operation, and before work will be permitted within any City right-of-way, the Operator shall ~~draft~~ ~~engineered~~ submit construction drawings ~~to be~~ prepared by a Colorado licensed civil engineer, in conformance with City standards, for review and approval by the City Engineer. Financial assurances shall be required when any Operation requires the construction or reconstruction of public or private roads.
- (b) Maintenance. If Operations or ~~other~~ related activities cause any City roadway to become substandard, the City may require the Operator to provide ongoing repair and maintenance of the roadway at the Operator’s cost. Such maintenance may include dust control measures and roadway improvements ~~such as~~ (e.g. graveling, shouldering, ~~and/or~~ paving) as determined in the Traffic Impact Study. In accordance with the Traffic Impact Study, the Operator shall not pay ongoing repair or maintenance costs that exceeds the costs reasonably necessary to defray the impacts of the Operations.

Commented [BHFS35]: What would a related operation be?

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- (c) Oil and Gas ~~Well-Site Location~~ Access. Access to any property from a City street requires a City-issued ~~access~~ Right-of-way permit. ~~Access~~ Right-of-way Permits are revocable upon issuance of a stop work order ~~, or if other Oil and Gas Permit violations occur.~~ The permitting and construction of accesses shall comply with the City's Engineering Construction Standards and Specifications and design standards.
- (d) Private Access Roads. All private roads used to access or conduct Operations shall be constructed in compliance with the ~~BMP Document~~ approved Stormwater Management Plan. The Operator shall comply with City standards regarding vehicle tracking and dust mitigation.
- (e) State Highway Access. Where a Site's access is directly to a state highway, the Operator must procure and maintain an approved State Highway Access Permit.
- (f) Access Roads.
 - (i) Tank Battery Access Roads. Access roads to tank batteries shall be, at a minimum, a graded gravel roadway at least twenty feet (20') wide with a minimum unobstructed overhead clearance of ~~thirteen~~ seventeen feet ~~six inches (13' 6")~~ (17') and a minimum thickness to be approved by the City Engineer.
 - (ii) Wellhead Access Roads. Access roads to wellheads shall be, at a minimum, a graded gravel roadway at least twenty feet (20') wide with a minimum unobstructed overhead clearance of ~~thirteen~~ seventeen feet ~~six inches (13' 6")~~ (17'), and a minimum thickness to be approved by the City Engineer.
 - (iii) Pavement Standards. To protect public streets, sidewalks, and curbs and gutters, all tank battery and wellhead access roads that intersect a paved City street or alley shall be paved to standards determined by the City Engineer. The access location shall comply with all City requirements.

Commented [BHFS36]: Because many violations would require the Operator to remediate on location, COGA submits this provision should be struck.

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- (g) Haul Routes. Operators shall only use roadways for haul routes that are identified on a City-approved traffic control plan.
 - (h) Oversize/Overweight Vehicles. Any oversize or overweight vehicle making use of any City street shall obtain an Oversized, Overweight and Longer Vehicle Combination Permit from the City's Department of Public Works prior to any such use.
 - (i) Indemnification. No public improvements, such as curbs, gutters, pavement or sewer lines, etc., shall be damaged by vehicles entering or leaving the location. In the event of damage, the Operator shall indemnify the City for any repair costs.

(11) Prohibition. The following facilities are prohibited within the City:

- (a) Injection Wells for disposal of oil and gas Exploration and Production Wastes;
- (b) Gas Storage Wells;
- (c) Disposal pits;
- (d) Commercial disposal facilities;
- (e) Centralized Exploration and Production Waste management facilities; and
- (f) Subsurface disposal facilities.

(12) Air Quality Standards and Monitoring.

- (a) Operator must eliminate, capture, or minimize all potentially harmful emissions, including Volatile Organic Compounds (VOC's) and BTEX through compliance with these provisions and the BMP Document.
- (b) Operator shall minimize dust associated with onsite activities and traffic on access roads pursuant to the terms as identified herein.

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- (c) Operator shall comply with all applicable state and federal regulations including regulations promulgated by CDPHE, COGCC and US EPA.
- (d) ~~The Ambient Air Monitoring. Operator, at a minimum, shall~~ may create and submit an air monitoring plan describing how the Operator will conduct ~~on-site air quality~~ baseline monitoring prior to construction of the well site. ~~If Ambient Air Monitoring is required,~~ Operator shall conduct continuous monitoring and collect periodic canister samples (or equivalent method) during the drilling, completion and production phases of development. Monitored air pollutants shall include, but are not limited to, methane, VOCs, Hazardous Air Pollutants (HAPs), Oxides of Nitrogen (NOx), Particulate Matter (PM), and Fine Particulate Matter (PM 2.5). ~~At Operator's cost, a~~ third-party consultant approved by the City ~~shall~~ may conduct baseline and ongoing air sampling and monitoring ~~of emissions at each well site that may be reasonably associated with oil and gas production or related Operations, including any volatile organic compounds, Hazardous Air Pollutants as defined by the EPA, and other greenhouse gas emissions.~~ Such sampling and monitoring shall ~~be compliant~~ comply with the following requirements:
- (e) Baseline sampling shall be conducted within 500 feet of a proposed facility over a 90-day period ~~to commence no sooner than within 6 (six) months prior to well site construction;~~
- (f) i. ~~Continuous.~~ Baseline sampling ~~during the drilling and completions phase;~~ shall track levels and changes in monitored air pollutant concentrations. Baseline sampling data shall be provided as part of the Oil and Gas permit submittal.
- (g) Continuous monitoring for the lifetime of each wellsite; and
- (h) Real time reporting of air quality data to the City.
- ii. The Operator shall reimburse the City for all additional air quality sampling or monitoring as deemed reasonably necessary by the City in Continuous monitoring for hydrocarbons shall occur during the drilling and completions phase of oil and gas development. Each

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hydrocarbon monitor shall include a sampling device to automatically collect an air sample when the monitor levels reach a trigger level defined below in (iii). Monitors shall also include meteorological monitoring capabilities. Continuous monitoring may not cease until three years have passed from the date the last well drilled on the site has entered the production phase, unless any use defined in 21-5266(6a) is within 1,000' of the edge of the well site. In such instance, continuous monitoring shall be required until all wells are plugged and abandoned.

- iii. An increase in the detection of hydrocarbon greater than the ambient levels determined during baseline sampling plus the anticipated change based on Operator-provided impacts of modeled operations shall require the Operator to collect a further sample utilizing an 8-hour canister sample immediately after detection.
- iv. In the event a canister sample is triggered, the analysis of such sample shall be provided to the city no less than ten (10) business days after the occurrence of such event.

⊕ In response to a reportable safety event, as defined by COGCC Rule 602(c), a spill, release, or a reported and substantiated nuisance that occurs outside of drilling and completion Operations, the City may require additional air quality sampling or monitoring as deemed reasonably necessary by City. The Operator shall reimburse the City for all costs incurred by the City as a result. Such costs will be payable within one month of invoicing.

(13) Abandonment and Plugging.

- (a) The Operator shall comply with all COGCC rules in relation to abandonment and plugging.
- (b) For new Oil and Gas Facilities, the Operator shall be required to plug and abandon all existing vertical wells owned or controlled by the Operator within a proposed drilling and

Commented [BHFS37]: COGA has concerns with this section as a whole. These provisions are in large part unnecessary and unreasonable and will be costly not just for Operators but also for the City to monitor. COGA suggests a more tempered approach whereby Commerce City requires operators to comply with CDPHE and COGCC regulations regarding air—already some of the most stringent in the nation, if not the most stringent—and not to regulate air emissions and monitoring differently than the state.

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spacing unit (DSU) that target the same formation as any proposed horizontal wells.

- (c) Operators of wells that are to be plugged and abandoned shall notify both the City's Local Government Designee (LGD) and the applicable fire district not less than one week prior to commencing plugging operations.
- (d) Operators shall remove all Flowlines ~~and unused Gathering Lines~~ associated with a plugged and abandoned well. The city may grant an exception to allow a Flowline to be abandoned in place, where the removal of such Flowline would constitute a significant hazard to public health, welfare, safety, and the environment.
- (e) Operators shall provide copies of all COGCC plugging and abandonment reports to the City concurrent with filing the reports with the COGCC.
- (f) It shall be unlawful for any Operator or other person to reactivate a plugged or abandoned Oil and Gas Well unless a new Oil and Gas Permit has first been issued by the City. The recompleting or reworking of an Oil and Gas Well and relocation of accessory equipment or gathering and transmission lines will be permitted if all applicable State applications are obtained.

(14) Fees. These fees identified in this subsection shall apply in addition to any other applicable fees. All fees shall be paid at the time an Oil and Gas Permit is issued.

- (a) Oil and Gas Transportation Impact Fee. The Operator shall pay an Oil and Gas Transportation Impact Fee, pursuant to Section 21-9260.
- (b) Inspection fees. The applicant shall provide reimbursement to the city for the full cost necessary to inspect any Well Site. Upon completion of an inspection, the applicant shall receive an invoice for the cost of such inspection.

(15) Financial Assurances and Insurance.

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- (a) Operator shall provide all necessary insurance as set forth in the BMP document.
- (b) Surety for Financial Setback.
- (i) Prior to the commencement of any work, including Well Pad construction at any permitted Well Site, the Operator shall provide the City with ~~a single~~ surety in the form of a letter of credit or bond in the amount of ~~five hundred~~ eighty six thousand dollars (\$~~500~~86,000.00) ~~per~~), adjusted annually for inflation commencing in 2021, multiplied by the number of approved wells on any planned well site to insure the immediate availability of finances for any costs incurred by the City following a Financial Setback of the Operator. Financial Setback shall be defined as the Operator filing for protection under the bankruptcy laws, making an assignment for the benefit of creditors, appointing or suffering appointment of a receiver or trustee over its property, filing a petition under any bankruptcy or insolvency act or having any such petition filed against it which is not discharged within ninety (90) days of the filing thereof.
- (ii) Operator shall notify the City of the existence of a Financial Setback ~~with~~ within five (5) business days of the Financial Setback. Upon the occurrence of a Financial Setback, the City may call upon the surety effective immediately upon written notice to the Operator for purposes associated with the need to secure the well sites, associated well site lands and infrastructure, or ~~in response to a demonstrated need~~ to protect ~~the~~ public health, welfare ~~and~~, safety, or the environment. The City shall not be liable to the Operator or any surety, guarantor, or financial institution for consequential damages arising from the City's exercise of its rights under this section, including without limitation a claim for impairment of bonding capacity.
- (iii) The letter of credit or bond shall remain in effect until all drilling operations have been completed and the entire well site is in the production phase, without exception.

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The bond or letter of credit shall be released within ten (10) business days of the City's verification of completion in response to Operator's written request for such release following completion whereby all wells at the well site have been turned to production.

- (iv) This financial assurance ~~provision~~, which shall be provided in a form ~~accepted~~ acceptable by the City, is not a substitute for any bonding required by the state regulatory agencies for plugging and abandoning wells. The Operator shall comply with all state regulatory ~~agencies~~ agencies' bonding requirements.
- (v) The bond or letter of credit shall be released within ten (10) business days of the City's verification of completion in response of Operator's written request for such release following completion whereby all wells at the well site have been turned to production.
- (c) Performance Security. To ensure compliance with mitigation and other requirements set forth in this section, the BMP ~~document~~ Document, and any permit conditions, the Operator may be required to provide reasonable performance security to the City in a form acceptable to the City.
- (d) Cost Reimbursement—~~Agreement~~. The Operator shall reimburse the City, the applicable fire district, and any other emergency service provider for any emergency response costs incurred by any of them in connection with the Operations.

(16) Inspection by the City.

- (a) The City has the right to inspect all Well Sites, Operations, and Oil and Gas Facilities. No person shall refuse entry to, impede, obstruct, delay, or in any manner interfere with the inspection of Oil and Gas Facilities subject to an Oil and Gas Permit or the regulations of this section or section 21-3216 by any federal, state, county, or local inspector who is either permitted or required to inspect the premises. Entry and inspection shall be permitted to all areas of the Oil and Gas Facility as defined by

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this code. No inspector shall be required to be escorted or accompanied during an inspection.

- (b) Any attempt to refuse entry to, impede, obstruct, delay, or in any manner interfere with a lawful inspection, or to require that an inspector be escorted or accompanied during an inspection, shall constitute grounds for revocation of an Oil and Gas Permit in addition to any other penalties permitted by the code.
- (c) The Operator shall provide the telephone number of a contact person who may be reached 24 hours a day for purposes of being notified of any proposed city inspection under this section or in case of emergency.

(17) ~~**Variances.** No variances are permitted concerning Oil and Gas Permits or to otherwise facilitate the approval of an Oil and Gas Permit. All requests for non-compliance shall be addressed via the processes identified by the Code.~~

Commented [BHFS38]: There do not appear to be any identified processes in the code for "non-compliance."

(18) Enforcement and Penalties.

- (a) Failure to Obtain Permits. Any Operator that fails to obtain an Oil and Gas Permit, or that fails to comply with requirements of this code, the Oil and Gas Permit, the BMP Document or any applicable [Regional Operator Agreement or](#) Extraction Agreement, may be enjoined by the City from engaging in Operations and may be subject to such other criminal or civil liability as may be prescribed by law.
- (b) Suspension of Oil and Gas Permit. If the City determines that the Operator has violated any term or condition of this Code, the Oil and Gas Permit, the BMP Document or any applicable Regional Operator Agreement or Extraction Agreement, or that one or more material changes to the Operations or Oil and Gas Facilities have been made without the express, written consent of the City, the Director may temporarily suspend the Oil and Gas Permit and order all Operations permitted by the City under the Oil and Gas Permit shall to cease upon written notification to the Operator. In such event, the Operations shall be safely ceased as soon as possible. This suspension shall

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be in addition to any other enforcement mechanism available to the City.

- (c) Revocation of Oil and Gas Permit. In the manner consistent with this code, revocation of an Oil and Gas Permit may be premised upon a violation of any term or condition of this Code, any term or condition of the Oil and Gas Permit, the BMP Document, or any applicable Regional Operator Agreement or Extraction Agreement, or if one or more material changes to the Operations or Oil and Gas Facilities have been made without the consent of the City.

- (d) COGCC Enforcement Orders.

- (i) Within five (5) business days of the receipt of a COGCC Enforcement Order for a violation occurring in the City, the Operator shall provide the Enforcement Order to the City.

- (ii) With submission of the Enforcement Order to the City, the Operator shall pay to the City a fine equal to that mandated by the Enforcement Order unless the Enforcement Order is subject to a pending appeal.

- (iii) Where subject to an appeal, the Operator is excused from payment of the fine pending final disposition of the appeal. If the Enforcement Order, or any part thereof, is upheld on appeal or remand, the Operator shall pay a fine to the City equal to that mandated upon disposition of the appeal and within five (5) days of disposition. If the appeal is disposed of by means other than a final disposition by the reviewing tribunal, and unless remanded, then the Operator shall pay the fine to the City as mandated in the original Enforcement Order within five (5) days of disposal.

- (19) No Permit Approval Pending Enforcement Action.** No Oil and Gas Permit application or any proposed amendment to an Oil and Gas Permit application, shall be processed or approved with regard to a Well Site that is subject to an ongoing enforcement action under ~~the code-~~federal, state, or local law unless expressly required by law.

Commented [BHFS39]: The most common type of "enforcement order" from the COGCC is an Administrative Order on Consent (AOC). This is a type of settlement agreement in which the operator agrees to the order only for purposes of resolving the issue expeditiously without need for an adversarial hearing. Oftentimes an operator will dispute a violation but decide for a variety of practical reasons not to take the alleged violation to hearing and will negotiate an AOC. It is inappropriate for Commerce City to assess fines agreed to for settlement purposes, and even were the COGCC enforcement order to be issued following a hearing and affirmative factual finding that an operator did in fact violate a rule, it is inappropriate for Commerce City to assess a penalty for a violation that it personally did not find and a duplicative fine offends fundamental fairness.

But the problems with this Rule are not limited to the fundamental unfairness and due process problems. The relevant COGCC rule might be related to downhole operations, which Commerce City has no jurisdiction to regulate. Commerce City has no authority to assess fines for downhole issues whatsoever. Additionally, this regulation does not acknowledge the statutory limitation in CRS section 31-16-101 that prohibits a municipality from assessing fines greater than two thousand six hundred fifty dollars; it may be that the COGCC's order is for a fine greater than the amount Commerce City is allowed to assess.

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(20) Other Oil and Gas Operations – Seismic Operations. An Oil and Gas Permit shall not be required for seismic surveys unless the drilling of a seismic (shot hole,) core or other exploratory hole is involved or unless the seismic survey is located on City property. This section shall not operate to relieve any party from the obligation to obtain a Right-of-Way Permit. The Operator may be required to provide the City with resulting data the City determines to be reasonably related to City projects or municipal water supplies and collected within 1,000' of the surface.

(21) Strict Liability.

- (a) An Operator shall be strictly liable to the City and any emergency service provider for all costs of emergency response to any ~~Well Sites~~Oil and Gas Locations. ~~Absent the Operator's negligence, the Operator shall not be liable for such costs caused by a third party lacking privity with the Operator.~~ Such costs shall include, but not be limited to, those born by fire, police, and other first responders, regardless of jurisdiction, including any hazmat response and cleanup costs of any nature whatsoever. Absent the Operator's negligence, the Operator shall not be liable for such costs caused by a third party lacking privity with the Operator. ~~Notwithstanding the foregoing, an Operator also shall not be responsible for costs that arise out of any negligent conduct by the City and any emergency responders.~~
- (b) An Operator shall be strictly liable to the City ~~and any emergency service provider~~ for all damages to any and all City owned or operated property and infrastructure, incurred as a result of the Operator's Operations. Nothing in this subsection shall be construed to require Operator to pay an additional amount where such damages are anticipated and accounted for through the payment of generally applicable fees or impact fees.

Section amended by Ord. 1891, August 2012

Section 21-5266 amended by Ord. 2183, November 2018

Section 21-5268, entitled Telecommunications Facilities, repealed by Ord. 2068, January 2016.

EXHIBIT G TO ORDINANCE ~~2266~~2235
(Underlined text indicates new material;
strikethrough text indicates deletions.)

Sec. 21-6280. Additional Subdivision Standards Relating to Oil & Gas Sites

Oil & Gas Site Setbacks.

- (1) For permitted ~~Well Sites~~Oil and Gas Locations, ~~where the maximum number of wells issued under an Oil and Gas Permit have not yet been drilled, or~~ where all permitted wells have not entered ~~the production phase~~ Completions, no new residential lots may be platted within 1,000' ~~of such site~~Location.
- (2) For permitted Well Sites where all permitted wells have entered ~~the production phase~~ Completions, or the permit has otherwise lapsed, been revoked, or forfeited, and is not subject to renewal or reissuance, then no new residential lots may be platted within the minimum setbacks set forth in Table VI-1:

Table VI-1. Setback from new residential lots to ~~Well~~ Production Sites

Well Count	Setback
1-10	300'
11-24	400'
25 or more	500'

(3) Measurements shall be taken in the same manner as defined in 21-5266(6)

~~(1)~~(4) Plat requirements. The following information shall be denoted on all final plats:

- a. The location of any oil and gas wells, flowlines, and gathering lines, and any associated easements;
- b. The location of all recorded surface use agreements; and

**Article VI – Required Public Improvements,
Subdivision Standards, and Design Requirements
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Relating to Oil & Gas Sites**

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- c. The location of any plugged and abandoned oil and gas wells, flowlines and gathering lines, including a plat designation surrounding such wells and expressly prohibiting any habitable building or structure within 50 feet.

~~(2) Required Notice. The final plat shall include a note stating the location of the oil and gas well(s) and associated easements.~~

~~(2) Vacation of Existing Easements. No easement may be vacated for a previous or existing well ~~or~~, flowline, or gathering line, unless documentation is provided to the city demonstrating such well or, flowline, or gathering line has been vacated in compliance with all applicable ~~COGCC~~ State regulations.~~

(5)

Commented [BHFS40]: The COGCC does not regulate gathering lines. COGA recommends the word "State" be substituted for "COGCC" to capture a scenario where the pipeline at issue is a gathering line, which types of lines are regulated by the Colorado Public Utilities Commission and not by COGCC.

EXHIBIT H TO ORDINANCE ~~2235~~ 2266

*(Underlined text indicates new material;
strikethrough text indicates deletions.)*

DIVISION 2: DEFINITIONS

Sec. 21-11200. Definitions

When used in this land development code, the following terms shall have the meanings ascribed to them herein, except where the context clearly indicates that a different meaning is intended or where the code contains a specific provision to the contrary:

- (1) Access Easement** shall mean an interest in land which allows one or more persons to travel across another person's land.
- (2) Accessory Building or Structure** shall mean a subordinate structure located on the same lot with the principal building, occupied by or devoted to an accessory use. Accessory structures include, but are not limited to, storage sheds, garages, covered porches, large satellite dishes, and telecommunication antennas.
- (3) Accessory Parking Structure** shall mean a permanent one-story structure that is open on one or more sides and is used for the temporary parking or storage of operable vehicles in conjunction with the primary use of the property.
- (4) Accessory Use** shall mean a use, located on the same lot, naturally and normally incidental to, subordinate to, and devoted exclusively to the principal use of the premises.
- (5) Active Rights-of-Way** shall mean rights-of-way currently being utilized or improved.
- (6) Addition** shall mean any activity that expands the enclosed footprint or increases the square footage of an existing structure.
- (7) Adjacent** shall mean to physically touch or border upon, or to share a common property line or border. Adjacent shall include properties or uses that are separated by a street, sidewalk, or other publicly-dedicated right-of-way, canal, or railroad right-of-way.

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(8) Administrative Appeal is an appeal alleging an error in a final order, requirement, decision, or determination made by the director in the administration or enforcement of this land development code.

(9) Adult shall mean a person 18 years of age or older.

(10) Adverse Impact shall mean a negative consequence affecting the physical, social, or economic environment resulting from an action or project.

(11) Agriculture or Farm shall mean the use of land for agricultural purposes, including farming, dairying, floriculture, horticulture, pasturage, viticulture, grazing, animal and poultry husbandry, and the necessary accessory uses for packing, treating, storing, and shipping of farm products.

(12) Alley shall mean a service roadway that provides a means of access abutting properties and that is not intended for general traffic circulation.

(13) Alter or Alteration shall mean any change or rearrangement in the supporting members of an existing building, such as bearing walls, columns, beams, girders, or interior partitions, as well as any change in doors, windows, means of ingress or egress, or any enlargement to or diminution of a building or structure, whether horizontally or vertically, or the moving of a building or structure from one location to another.

(14) Annexation shall mean the incorporation of a land area into the city with a resulting change in the city boundaries.

(15) Antenna shall mean any structure or device used to retransmit or receive electromagnetic waves for the provision of services including, but not limited to, cellular, paging, personal communication services, and microwave communications. Such structures and devices include, but are not limited to, directional antennas, such as panels, microwave and satellite dishes, and omnidirectional antennas, such as whips. Except where the context clearly indicates otherwise, this term shall not include broadcast antennas, antennas designed for amateur radio use, or satellite dishes designed for residential or household purposes.

(16) Antenna, Dish shall mean dish (parabolic or cylindrical) antennas used for microwave and satellite transmission and reception for

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commercial purposes. This definition shall not apply to wireless cable satellite dish antennas or dish antennas less than one meter in diameter or measured diagonally.

(17) Antenna, Panel shall mean an array of antennas, rectangular in shape, used to transmit and receive telecommunication signals.

(18) Antenna, Whip shall mean a single antenna that is cylindrical in shape and omnidirectional.

(19) Apartment shall mean a dwelling unit, located in a building containing three or more such dwelling units, used exclusively for lease or rent as a residence.

(20) Applicant shall mean any person who has filed an application pursuant to the provisions of this land development code.

(21) Approved Plant List and Landscaping Specifications Document shall mean that document containing certain information and requirements pertaining to landscaping in the city.

(22) Appurtenances shall mean transformers, switching boxes, gas regulator stations, terminal boxes, meter cabinets, pedestals, ducts, substations, system amplifiers, power supplies, optical nodes, pump stations, valves and valve housings, and other devices necessary to the function of underground electric, communications, cable television wiring, coaxial, fiber optic, water, sewer, natural gas, other utility lines, and street lighting circuits.

(23) Architectural Appendage shall mean appendages such as fireplaces, roof overhangs, balconies, cornices, and bay or box windows that are attached to principal or accessory structures.

(24) Area of Shallow Flooding shall mean a designated AO, AH, or VO zone on a community's Flood Insurance Rate Map (FIRM) with a one percent or greater annual chance of flooding to an average depth of one to three feet where a clearly defined channel does not exist, where the path of flooding is unpredictable and where velocity flow may be evident. Such flooding is characterized by ponding or sheet flow.

(25) Area of State Interest shall mean an area within which a county or municipality can designate, as enabled by C.R.S. § 24-65.1-101, certain

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activities and establish certain standards for the regulation thereof. Said activities may be regulated by permit and include natural hazard areas, key facilities (e.g., airports, highway interchanges, etc.), and mineral resource areas.

(26) Arterial Street shall mean a public right-of-way used to carry high traffic volume typically for travel between areas within and outside the city. A right-of-way typically is 120 feet to 150 feet in width.

(27) Artificial Turf shall mean a partial or entirely synthetic material designed and manufactured to simulate living turf grass as provided in the city's Approved Plant List and Landscaping Specifications.

(28) Arts and/or Cultural Center shall mean a space providing for creation, display, performance, or enjoyment of heritage, history, or the arts. This use includes but is not limited to: museums, performance space, artist's studios, galleries, interpretive sites, independent theaters.

(29) Artisan/Handcrafted Manufacturing shall mean the shared or individual use of hand-tools, mechanical tools and electronic tools for the manufacture of finished products or parts including design, processing, fabrication, assembly, treatment, and packaging of products; as well as the incidental storage, sales and distribution of such products. Typical artisan manufacturing uses include, but are not limited to: electronic goods, food and bakery products; non-alcoholic beverages; printmaking; household appliances; leather products; jewelry and clothing/apparel; metal work; furniture; glass or ceramic production; paper manufacturing.

(30) Asphalt Mixing Plants shall mean an industrial establishment or plant where gravel or sand are combined with a mixture or bitumens to create a substance for paving, roofing, and waterproofing.

(31) Assisted Living Facility shall mean a state-licensed group living facility regulated as a personal care boarding home, as defined in C.R.S §25-27-101. Such facilities do not offer diagnosed medical or psychological treatment under professional medical supervision, but may offer (1) physical therapy; (2) occasional medical or nursing care to address non-chronic and non-recurring conditions such as colds, flu, or household injuries; and (3) assistance with routine living activities not aimed at recovery from a specific diagnosed condition.

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(32) Auction shall mean a place where objects of art, furniture, or other goods are offered for sale to persons who bid on an object in competition with each other. For an auction to be classified as an indoor auction, all auction activities shall occur within an enclosed building, including storage and processing of items to be auctioned.

(33) Auditorium or Stadium shall mean an open, partially enclosed, or fully enclosed facility used or intended to be used primarily for spectator sports, entertainment events, expositions and other public gatherings. Typical uses include convention and exhibition halls, sports arenas, and amphitheaters.

(34) Automobile Sales and Rental shall mean a specific type of vehicle and equipment use or an establishment arranged, designed, or used for the display, sale, leasing, or rental of any new or used motor vehicle in operable condition.

(35) Awning shall mean a shelter projecting from and supported by the exterior wall of a building constructed of non-rigid materials on a supporting framework. An awning is distinguished from a marquee in that a marquee is covered with rigid material. An awning is distinguished from a canopy in that an awning is cantilevered, whereas a canopy is supported by posts or other devices beyond the building wall.

(36) Bail Bonds Business shall mean a business whose primary purpose is to act as a surety to secure the presence of an accused person at a court proceeding in a criminal manner.

(37) Bakery, Retail shall mean a structure, room, or place used for making, preparing, or baking, bread, biscuits, pastry, cakes, doughnuts, crullers, noodles, macaroni, spaghetti, or tortillas to be sold on-premises at retail and consumed on or off premises.

(38) Bakery, Wholesale shall mean a structure, room, or place used for making, preparing, or baking, bread, biscuits, pastry, cakes, doughnuts, crullers, noodles, macaroni, spaghetti, or tortillas to be sold on or off-premises at wholesale and consumed off premises.

(39) Banner shall mean a sign made of fabric or other non-rigid material with no enclosing framework.

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(40) Bar/Tavern shall mean an eating/drinking establishment providing or dispensing by the drink, for on-site consumption, fermented malt beverages, and/or malt, special malt, vinous or spirituous liquors, and in which the sale of food products such as sandwiches and light snacks is secondary (also known as a tavern). A bar/tavern may include provision of live entertainment and/or dancing; however, a bar/tavern shall not include any adult business use.

(41) Base Flood shall mean a flood having a one percent chance of being equaled or exceeded in any given year (also known as the 100-year flood).

(42) Basement shall mean an area below the first floor, having part, but no more than 1/2 of its height above-grade, and with a floor to ceiling height of not less than seven feet. This term shall not include garden level.

(43) Bed and Breakfast Establishment shall mean an owner-occupied single-family dwelling where up to a maximum of five rooms may be rented for overnight lodging. The five lodging rooms may be in addition to bedrooms used by the resident family.

(44) Berm shall mean in the context of landscaping or buffering requirements, a mound of earth typically used to shield, screen, and buffer undesirable views and to separate potentially incompatible land uses.

(45) Best Management Practices (BMPs) shall mean physical, structural or managerial practices that, when used individually or in combination, prevent or reduce pollution or stormwater runoff. As they relate to Oil and Gas Operations, BMPs are technologies and practices listed in the City's adopted Best Management Practices for Oil and Gas Facilities, *also known as the BMP Document*. BMPs are designed to prevent or reduce impacts caused by Oil and Gas Operations to air, water, soil, or biological resources, and to minimize adverse impacts to public health, safety and welfare, including the environment and wildlife resources.

(46) Block shall mean a tract of land bounded by streets, or by a combination of streets and railroad rights-of-way, shorelines, or boundary lines of municipalities.

(47) Boarding, Lodging, or Rooming House shall mean a group living facility where meals, lodging, or both, are provided for compensation for

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five or more persons, but not more than eight persons, not including members of the owner's or proprietor's immediate family who might be residing in the same building. The word compensation shall include compensation in money, services, or anything of value. A boarding, lodging, or rooming house shall not include more than one person required to register as a sex offender pursuant to C.R.S. § 18-3-412.5, as amended.

(48) Borrow Pit shall mean any place or premises where dirt, soil, sand, gravel, or other material is removed below the grade of surrounding land, for any purpose other than that necessary and incidental to site grading or building construction.

(49) Boundary Line shall mean every separation, natural or artificial, which marks the confines or line of division of two contiguous parcels of land.

(50) Brewery shall mean an establishment where malt liquors are manufactured and production exceeds 60,000 barrels of malt liquor per year, but shall not mean a "brewpub" or "microbrewery."

(51) Brewpub shall mean an establishment that, as an accessory use to on-site food sales, produces no more than 5,000 barrels of handcrafted beer per year for on-site consumption. Such accessory use may occupy up to 30% of the gross floor area of the establishment.

(52) Buffering shall mean methods such as extra deep lots, increased setbacks, landscaping, fencing, or berming to separate properties or uses that may have potential adverse impacts upon one another.

(53) Building shall mean any structure used or intended for supporting or sheltering any use or occupancy including persons, animals, chattels or property of any kind, and not including advertising sign boards or fences.

(54) Building Elevation shall mean a projection of a building plane, including the roof, wall, and all architectural appendages.

(55) Building Height see section 21-11140.

(56) Building Official shall mean the official designated by the city as the official responsible for accepting, reviewing, approving, or rejecting plans and applications for building and occupancy permits, and for the

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interpretation and enforcement of codes and regulations related to such applications and permits.

(57) Building Permit shall mean a written permit issued by the city that allows the permit holder to undertake construction of a project.

(58) Building, Principal shall mean the building(s) housing the principal (primary or most important) uses permitted on the property upon which it is located.

(59) Building Separation shall mean the horizontal distance from one building to another building located on the same or adjacent building site or lot, excluding architectural appendages.

(60) Bulk Grain Transfer shall mean the direct transfer of grain from one truck or container to another via conveyor belt. No on-site storage of grain, either in piles or containers, shall occur.

(61) Canopy shall mean a roof-like shelter projecting from a building wall and supported by posts or other devices beyond the building wall, typically constructed of non-rigid materials on a supporting framework. A canopy is distinguished from an awning in that an awning is cantilevered and supported by the building wall, whereas a canopy is supported away from the building wall.

(62) Carnival or Circus shall mean a temporary amusement center, bazaar, or fair, either involving use of special purpose equipment or conducted by professional operators, or both, and where activities include such things as rides, exhibitions, food services, sales, or small-scale games.

(63) Carport shall mean a one-story structure that is attached to a dwelling unit and entirely open on one or more sides that is used by the legal occupant of the dwelling unit for parking or storing operable vehicles.

(64) Car Wash means an establishment engaged in cleaning or detailing motor vehicles, whether self-service or automated.

(65) Catering Service/Facility shall mean an establishment providing the processing, assembly and packaging of food into servings typically designed for consumption off-premises. These facilities may include commercial or on-site kitchens and may be used in an accessory manner

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for teaching, instructing, or other related indoor activities that utilize the onsite catering service

(66) Cemetery shall mean land used or intended to be used for the burial of the dead and dedicated for cemetery purposes. A cemetery may include a funeral home, mortuary, or a columbarium, but shall not include a crematory.

(67) Centerline shall mean a line painted or marked upon a roadway for the purpose of separating opposing traffic or, where not painted or marked, an imaginary line an equal distance between the opposite curb lines or lateral lines of a roadway.

(68) Centralized Exploration and Production (E&P) Waste Management Facility shall mean a facility, other than a commercial disposal facility regulated by the Colorado Department of Public Health and Environment, that is either used exclusively by one owner or operator or is jointly used by more than one operator under an operating agreement for collection, treatment, temporary storage, and/or disposal produced water, drilling fluids, completion fluids, and any other E&P wastes as defined by the COGCC Rules. This definition includes oil-field naturally occurring radioactive materials (NORM) related storage, decontamination, treatment, or disposal. This definition excludes a facility that is permitted in accordance with COGCC Rules.

(69) Certificate of Occupancy shall mean a certificate issued by the city after final inspection, when it is found that the building, structure, and/or development complies with all requirements and all provisions of the applicable city building code and approved plans.

(70) Chain Link Fence shall mean a fence composed of wire mesh, typically forming woven squares approximately two inches in width.

(71) Charter shall mean the city's home rule charter.

(72) Child shall mean a person less than 18 years of age.

(73) Child Care Center shall mean a facility, by whatever name known, which is maintained for the whole or part of a day for the care of 7 or more children under the age of 18 years who are not related to the owner, operator, or manager thereof, whether such facility is operated with or without compensation for such care, and shall include facilities commonly

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known as day nurseries, nursery schools, preschools, play groups, day camps, summer camps, centers for developmentally disabled, and those facilities which give 24-hour care for dependent and neglected children; and shall include those facilities for children under the age of 6 years with stated educational purposes operated in conjunction with a public, private, parochial college or a private or parochial school, except that the term shall not apply to any kindergarten maintained in connection with a public, private, or parochial elementary school system of at least 6 grades.

(74) Child Care Facility shall mean child care centers and day care homes, as defined herein.

(75) Church (See Religious Institution).

(76) Clean Water Act shall mean the Federal Water Pollution Control Act (33 U.S.C. § 1251, *et seq.*) and any subsequent amendments thereto.

(77) Clearing shall mean any activity that removes vegetative surface cover.

(78) Clock Tower shall mean a free-standing structure displaying the time on one or more sides of the structure.

(79) COGCC shall mean the Colorado Oil and Gas Conservation Commission.

(80) Collector Street shall mean a street which has the primary function of providing for the distribution of traffic within neighborhoods and which carries through traffic and provides access to abutting property. A collector street is also a through street.

(81) Column/Pillar shall mean an architectural support of definite proportions, usually cylindrical in shape, with shaft, capital, and sometimes a base. May be free-standing or attached to a wall or fence.

(82) Co-location shall mean the placement of two or more commercial mobile radio service facilities by different cellular service providers on the same monopole or existing building or other structure of the same parcel of property.

(83) Colorado Discharge Permit System (CDPS) shall mean a permit issued by the state of Colorado that authorizes the discharge of pollutants

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to water of the state or United States, whether the permit is applicable on an individual, group, or general area-wide basis.

(84) Combustible Liquid shall mean any liquid having a flash point at or above 140° F., and below 200° F., and shall be known as Class III liquids.

(85) Commercial Disposal Well Facility shall mean a facility whose primary objective is disposal of Class II waste from a third party for financial profit.

(86) Commercial Indoor Self-Storage Facility shall mean a nonresidential building, portion of building, or group of buildings with defined storage space or units rented to and accessible to the public for the storage of household and personal property. These facilities shall have all units contained within that building(s) and all units having an access door from an interior hallway. For purposes of this code, commercial indoor self-storage facility shall not mean the same use as mini-storage and warehouse.

(87) Commercial Mobile Radio Service Facility or CMRS shall mean a low-power, micro-cell, microwave, or repeater transmission facility, including, but not limited to, freestanding towers, panels, or whip antennas, and accessory buildings and equipment, which are capable of protecting and enabling the operation of the telecommunication facility to receive, switch, or transmit wireless telecommunications.

(88) Commercial Mobile Radio Service Facility, Building Wall shall mean a commercial mobile radio service facility that is supported entirely on the wall of a legally existing building or structure, as defined, which may include a cabinet or structure accessory to a commercial mobile radio service facility, which may be on the ground.

(89) Commercial Mobile Radio Service Facility, Free-standing shall mean a commercial mobile radio service facility that consists of a stand-alone support structure, antennas, and accessory equipment.

(90) Commercial Mobile Radio Service Facility, Roof Mounted shall mean a facility that is supported entirely on the roof of a legally existing building or structure, as defined, which may include a cabinet or structure accessory to a commercial mobile radio service facility, which may be located on the ground or on the roof.

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(91) Commercial Use shall mean an activity involving the sale of goods or services carried out for profit, including office, retail, service business, and other similar development.

(92) Commodity shall mean goods, wares and merchandise of any kind, movables, and articles of trade or commerce. Commodity shall also mean things that are bought and sold.

(93) Communication Long Distance Trunk (Feeder) Line shall mean a low-voltage wiring, cable conduit, coaxial conduit, or fiber optic line carrying voice communications and/or data and shall be classified by definition as a distribution line.

(94) Community Garden shall mean a use in which land is managed by a public or nonprofit organization or group of individuals used to grow plants and harvest food or ornamental crops for donation or for use by those cultivating the land. Community gardens may be organized by the operating agency or group into individual areas for cultivation by one or more persons or may be farmed collectively by members of the group and may include common areas maintained and used by group members.

(95) Compatible or Compatibility shall mean that the characteristics of different uses, activities, or designs allow them to be located near or adjacent to each other in harmony. Some elements affecting compatibility include height, scale, mass, and bulk of structures. Other characteristics include pedestrian or vehicular traffic, circulation, access and parking impacts. Other important characteristics that affect compatibility are color and texture of exterior finishes, landscaping, lighting, noise, odor, building materials, and building architecture. Compatibility does not mean the same as. Rather, compatibility refers to the sensitivity of development proposals in maintaining the character of existing development.

(96) ~~Completion~~ Completions shall mean, as it relates to Oil and Gas Operations, an oil well shall be considered completed when the first new oil is produced through well head equipment into lease tanks from the ultimate producing interval after the production string has been run. A Gas well shall be considered completed when the well is capable of producing gas through wellhead equipment from the ultimate producing zone after the production string has been run. A dry hole shall be considered completed when all provisions of plugging and abandonment are complied with as set out in the COGCC rules. Any well not previously defined as an Oil or Gas

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Well, shall be considered completed ninety (90) days after reaching total depth. If approved by the COGCC Director, a well that requires extensive testing shall be considered completed when the drilling rig is released or six months after reaching total depth, whichever is later.

(97) Comprehensive Plan shall mean the master plan for the city, as adopted and amended by the city council, to provide long-range development policies for the city.

(98) Comprehensive Plan Amendment, Minor shall mean minor text changes and corrections that do not impact the substantive portions of the Land Use Plan's mixture or balance and involve properties that are less than 8 acres in size. Any change mandated by initiatives or state law shall utilize the minor amendment process.

(99) Compressed Gas shall mean any mixture of material having in the container either an absolute pressure exceeding 40 pounds per square inch at 70° F., or an absolute pressure exceeding 104 pounds per square inch at 130° F., or any liquid flammable material having a vapor pressure as defined in the city's fire code exceeding 40 pounds per square inch at 100° F.

(100) Concealed Lighting shall mean an artificial light source intended to illuminate the face of a sign, which may be internally lighted or which is shielded from public view and surrounding properties from which the sign is visible.

(101) Concrete Batching Plant shall mean an industrial establishment or plant where a material made from sand, pebbles, and/or crushed stone is held together by a mass of cement or mortar.

(102) Conditional Use shall mean a use not otherwise provided for, but which may be permitted upon showing that such use fits with the city's comprehensive plan, is essential or desirable to the community, and will not have a significant adverse impact on surrounding uses or on the community at-large. Conditional uses are authorized by the city council after review by the planning commission.

(103) Condominium shall mean a building, or group of buildings, in which dwelling units, offices, or floor area are designated for separate ownership, and the remainder of the structure, land area, and facilities are commonly owned by all the unit owners on a proportional, undivided basis.

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(104) Construction Office or Trailer shall mean a mobile trailer or any temporary structure used by a construction contractor as its office or headquarters during construction of a development or structure.

(105) Contractor's Shop shall mean an establishment that provides a trade service including, but not limited to, plumbing, carpentry, glass/glazing, welding, sheet metal, electrical, and roofing services.

(106) Convenience Store shall mean a general retail store that sells goods and services and that may include the sale of ready-to-eat food products (not generally intended for on-premises consumption), gasoline, groceries, sundries, and 3.2 beer.

(107) Correctional Facility shall mean a facility providing housing and care for individuals confined for violations of law. Typical uses include jails, prisons, work release facilities, and juvenile detention centers.

(108) Courier Services shall mean an establishment primarily engaged in the delivery of individually addressed letters, parcels, and packages that generally weigh less than 100 pounds.

(109) Crematory shall mean a service establishment containing properly installed, certified apparatus intended for, or used for, the act of cremation.

(110) Critical Facility shall mean a structure or related infrastructure, but not the land on which it is situated, as specified in Rule 6 of the State of Colorado, Department of Natural Resources, Colorado Water Conservation Board document entitled "Rules and Regulations for Regulatory Floodplains in Colorado," dated November 17, 2010 and as may be amended from time to time, that if flooded may result in significant hazards to public health and safety or interrupt essential services and operations for the community at any time before, during and after a flood. Generally, critical facilities are those that shelter essential services, hazardous materials, and at-risk populations. If it is unclear whether or not a facility falls within the context of Rule 6, the Floodplain Administrator shall have the sole authority to make such determination.

(111) Crosswalk shall mean that portion of a roadway included within the prolongation or connection of the lateral lines of sidewalks at intersections or any portion of a roadway distinctly indicated for pedestrian crossing by lines or other marking on the surface.

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(112) C.R.S. shall mean the Colorado Revised Statutes, as may be amended from time to time.

(113) Cul-de-sac shall mean a street having one end open to traffic and being terminated at the other end by a vehicular turnaround.

(114) Curb Cut shall mean a street curb depression intended to provide vehicular ingress and egress to a property.

(115) Day Care Center, Adult shall mean a facility, whether non-profit or for-profit, that provides care, protection, and supervision for 6 or more adults on a regular basis away from their primary residence for less than 24 hours per day.

(116) Day Labor Facility shall mean any facility at which job seekers wait on site to be hired by the day or by short-term job by third parties. Job seekers generally must be present to obtain work, are often immediately transported to a job site, and typically return to the facility for payment. Related support services may be offered to job seekers while they wait on site.

(117) Dead-End Street shall mean a street having no exit or turn-around within a right of way.

(118) Decision-Making Body shall refer generally to the body or person with final approval authority for the application or permit in question.

(119) Department shall mean the department of the city charged with the responsibility of interpreting and applying this land development code.

(120)

(121) Designated Agent shall mean the designated representative of any oil and gas well operator.

(122) Developer shall mean any person who participates as owner, promoter, developer, or sales agent in the planning, platting, development, promotion, or sale of a subdivision or development.

(123) Development shall mean any manmade change to improved or unimproved real estate including, but not limited to the construction, reconstruction, conversion, or enlargement of any structure; any change in

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use or platting of a property, building or structure; and any mining, dredging, filling, grading, paving, excavation, or drilling operation or storage of equipment or materials.

(124) Development Agreement shall mean any contract(s) between a developer and the city in connection with any development approval, including without limitation rezoning, subdivision, or PUD approval. Development Agreements may include provisions clarifying the phasing of construction, the timing, location, and financing of infrastructure, reimbursement for oversized infrastructure, assurances that adequate public facilities (including roads, water, sewer, fire protection, and emergency medical services) will be available as they are needed to serve the development, and mitigation of anticipated impacts of the development on the general public.

(125) Development Plan shall mean a plan, together with written materials, showing the character and layout of the lot or lots including the exact location, square footage, and dimensions of buildings, yards, courts, parking, fences, common open space and other features; the use of each building and area; the architectural elevations of buildings indicating height, materials, and color; detailed landscape plan; streets, curb cuts, and alleys; utilities, drainage, and other easements.

(126) Development Review Team (DRT) shall mean representatives from the city and other officials, consultants, or agencies that review and make recommendations on land use applications.

(127) Director shall mean the head of the department which is charged with the responsibility of interpreting and applying the terms of this land development code.

(128) Distillery shall mean a facility that manufactures alcoholic beverages by the distillation of fermented agricultural products, and including but not limited to whiskey, rum, brandy, and gin, including all dilutions and mixtures thereof.

(129) Distribution Center shall mean a facility for the receipt, transfer, storage, and dispatching of goods transported by truck. Unlike Transportation Terminals, these establishments commonly utilize a warehouse, sometimes specialized with refrigeration or air conditioning, and may include the accessory uses of order processing, package

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handling, cross-dock, storage or parking of trucks awaiting cargo, as well as facilities for the light servicing of trucks.

(130) Distribution Line shall mean the communications, cable television wiring, coaxial, fiber optic, water, sewer, natural gas or other utility line connections, excepting electrical systems, between the provider's generation facility and the service lateral.

(131) Dog Track shall mean an establishment where live dogs are raced or live broadcasts of dog races are televised. Typically, bets are placed and paid out within the establishment.

(132) Doggie Day Care Center shall mean an establishment in which one or more persons regularly provide supervised care during daytime hours for periods of less than 24 hours a day for one or more dogs which they do not own.

(133) Drilling and Spacing Unit ~~as defined by Colorado Revised Statutes §34-60-116(2), shall mean a "common source the section(s) acreage of supply" land encompassing a particular area for the subsurface extraction~~ of oil and gas resources that may be targeted by one or more oil and gas wells ~~or~~, as ~~amended~~ approved by COGCC ~~rule~~ order or statute.

Commented [BHFS41]: This should refer to "acreage" to avoid the legal sense of the term "section" as it relates to legal descriptions of property, i.e. section, township, range.

(134) Drainage Way shall mean any channel that conveys surface water runoff throughout the site.

(135) Drive-Up Facility (also known as Drive-In or Drive-Through Facilities) shall mean an establishment that by design, physical facilities, service, or packaging procedures encourages or permits customers to receive services, obtain goods, or be entertained while remaining in their motor vehicles.

(136) Driveway shall mean a paved or unpaved area used for the ingress and/or egress of vehicles, and allowing access from a street to a building or other structure or facility.

(137) Driveway, Shared shall mean a single driveway serving two or more adjoining lots or uses.

(138) DRT see Development Review Team.

(139) Dry Cleaning Plant shall mean an industrial establishment for the purpose of cleaning garments and fabrics with any of a variety of non-aqueous agents.

(140) Dwelling shall mean any building or portion thereof which is used exclusively for residential occupancy of one or more persons, but not including lodging establishments, clubs, hospitals, recreational vehicles, trailers, or other structures designed or used primarily for temporary occupancy. In no event shall any campground or vehicle be considered a dwelling for purposes of this land development code.

(141) Dwelling, Accessory shall mean a second dwelling unit either within or added to an existing single-family detached dwelling, or in a separate accessory structure on the same lot as the main dwelling, for use as a complete, independent living facility with provision within the accessory dwelling for cooking, eating, sanitation, and sleeping.

(142) Dwelling, Two-Story shall mean a home with two levels where the first floor is no lower than five feet below grade for not more than 50 percent of the perimeter of the home and the second level covers a minimum of 50 percent of the first floor.

(143) Dwelling Unit shall mean one or more rooms connected together but structurally divided from all other rooms in the same structure and constituting a separate, independent housekeeping unit for permanent residential occupancy.

(144) Easement shall mean an interest in land owned by another person, consisting in the right to use or control the land, or an area above or below it, for a specific limited purpose.

(145) Eaves shall mean the projecting lower edges of a roof overhanging the wall of a building.

(146) ECSS shall mean the Engineering Construction Standards and Specifications of the city.

(147) Electrical Distribution Line shall mean an electrical line generally having a rated voltage of less than 26 kilovolts used to distribute electricity from the substation to the service lateral.

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(148) Electrical Transmission Line shall mean an electrical transmission line generally having a rated voltage of 26 kilovolts or greater and used to distribute electricity to utility provider substations.

(149) Elevation shall mean a fully dimensioned drawing of the front, rear, and sides of a building showing features such as windows, doors, and relationship of grade to floor level.

(150) Erosion and Sediment Control Plan shall mean a set of plans prepared by or under the direction of a licensed professional engineer indicating the specific measures and sequencing to be used to control sediment and erosion on a development site during and after construction.

(151) Erosion Control shall mean any measure that prevents soil from wearing away.

(152) Establishment shall mean a place of business, industry, retail, or professional office with its furnishings and staff.

(153) Events Center shall mean a publicly or privately owned building devoted to assembly of people for social, professional, or recreational activities such as meetings, weddings, or conferences.

(154) Existing Building or Improvement shall mean a building or improvement that exists or is under construction at the time the underlying property is initially zoned or rezoned.

(155) Exploration and Production Waste (E&P Waste) shall mean those wastes associated with operations to locate or remove oil, gas or its byproducts from the ground or to remove impurities from such substances and which are uniquely associated with and intrinsic to oil and gas exploration, development, or production operations. For natural gas, primary field operations include those production-related activities at or near the well head and at the gas plant (regardless of whether or not the gas plant is at or near the wellhead) but prior to transport of the natural gas from the gas plant to market. In addition, uniquely associated wastes derived from the production stream along the gas plant feeder pipelines are considered E&P wastes, even if a change of custody in the natural gas has occurred between the wellhead and the gas plant. In addition, wastes uniquely associated with the operations to recover natural gas from underground storage fields are considered to be E&P Wastes.

(156) Explosives shall mean:

- (a) Substances determined to be Class A and Class B explosives as classified by the U.S. Department of Transportation;
- (b) Nitrocarbonitrate substances (blasting agent) as classified by the U.S. Department of Transportation;
- (c) Any material designated as an explosive by the state fire marshal; or
- (d) Certain Class C explosives as designated by the U.S. Department of Transportation.

(157) Extraction Agreement shall mean the agreement between the Operator and the City that is required by this Code.

(158) Façade shall mean the exterior walls of a building.

(159) Factory-Built Home shall mean any structure, designed for permanent residential use, which is wholly or in substantial part, made, fabricated, formed, or assembled in manufacturing facilities for installation or assembly and installation, on a building site. For the purposes of this Land Development Code, factory built home shall include mobile homes, manufactured homes, factory-built (modular) homes, and panelized (pre-fabricated) homes.

(160) Family shall mean:

- (a) An individual or two or more persons related by blood, marriage, adoption, or legal custody, including those persons defined by the Internal Revenue Code who qualify as dependents of the occupants of the subject premises, living together in a dwelling unit; or
- (b) A group of not more than three persons, not related by blood, marriage, or adoption, living together in a dwelling unit.
- (c) Except that a family shall not include more than one individual who is required to register as a sex offender under the provisions of the C.R.S. Sec. 18-3-412.5, as amended, except if the members of the family are related by blood or marriage, or if such

individuals have been placed by order of a state agency with jurisdiction.

(161) Family Child Care Home shall mean a residence which is used by its owner or legal occupant for the purpose of providing care or training to 12 or fewer children who are under the age of 18 years and unrelated to the care provider. For the purposes of this land development code, operation of a day care home is considered to be an accessory use to a principal residential use.

(162) Farmers' Market shall mean the seasonal offering for sale of fresh agricultural products directly to the consumer at an open-air market.

(163) Fast Food Restaurant shall mean an eating/drinking establishment that may be either: (1) a free-standing operation; or (2) a non-free-standing operation incorporated into a building within which one or more other compatible and complimentary uses exist, and whose principal business is the sale of pre-prepared or rapidly prepared food to the customer in a ready-to-consume state for consumption either within the restaurant building or for carry-out with consumption off the premises, and whose design or principal method of operation includes two or more of the following characteristics:

- (a) The elimination, in whole or in part, of table service, thus requiring customers to place orders at a counter where the orders are filled;
- (b) The food is usually served in edible containers or in paper, plastic, or other disposable containers;
- (c) The facilities for on premises consumption of food are insufficient for the volume of food sold by the restaurant; or
- (d) The restaurant provides a drive-up facility for placing and receiving food orders.

(164) FCC shall mean the Federal Communications Commission.

(165) Fence shall mean a free standing structure resting on or partially buried in the ground and rising above ground level used for confinement, screening, or partition purposes.

(166) Final Plat shall mean a map and supporting materials of certain described land prepared in accordance with subdivision regulations as an instrument for recording real estate interests with the county clerk and recorder.

(167) Financial Institutions shall mean establishments that provide retail banking services, mortgage lending, and similar financial services to individuals and businesses. This classification includes those institutions engaged in the on-site circulation of cash money and check-cashing facilities, but shall not include bail bond brokers. This classification also includes automated teller machines (ATM) located within a fully-enclosed space or building, or along an exterior building wall intended to serve walk-up customers only.

(168) Firewood Sales and Storage shall mean a commercial establishment or area for the purpose of firewood sales, splitting, and storage.

(169) Flag shall mean any fabric containing distinctive colors, patterns, or symbols used as a symbol of a government, political subdivision, or other entity.

(170) Flammable Liquid shall mean any liquid having a flash point below 140° F., and having a vapor pressure not exceeding 40 pounds per square inch (absolute) at 100° F. The provisions in this land development code shall also be applied to high flash point liquids that otherwise would be outside of its scope when they are so heated. Flammable liquid shall be divided into two classes of liquids as follows:

- (a) Class I liquids shall include those having flash points below 100° F., and may be subdivided as follows:
 - (i) Class I A: Flash points below 73° F., and having a boiling point below 100° F.;
 - (ii) Class I B: Flash points below 73° F., and having a boiling point at or above 100° F.; or
 - (iii) Class I C: Flash points at or above 73° F., and below 140° F.

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(b) Class II: Flash points at or above 100° F. When artificially heated to temperatures equal to or higher than their flash points, Class II shall be subject to the applicable requirements for Class I.

(171) Flammable Material shall mean any material that will readily ignite from common sources of heat or material that will ignite at a temperature of 600° F. or less.

(172) Flammable Solid shall mean a solid substance other than one classified as an explosive, which is liable to cause fires through friction, through absorption of moisture, through spontaneous chemical changes or as a result of retained heat from the manufacturing or processing.

(173) Flea Market shall mean an occasional or periodic market held in an open area or structure where groups of individual sellers offer goods for sale to the public.

(174) Flood or Flooding shall mean a general and temporary condition of partial or complete inundation of normally dry land areas from:

- (a) The overflow of inland or tidal waters; or
- (b) The unusual and rapid accumulation or runoff of surface waters from any source.

(175) Flood Insurance Rate Map (FIRM) shall mean the official map on which the Federal Emergency Management Agency has delineated both the areas of special flood hazards and the risk premium zones applicable to the city.

(176) Flood Insurance Study shall mean the official report provided by the Federal Emergency Management Agency. The report contains flood profiles, water surface elevation of the base flood, as well as the Flood Boundary-Floodway Map

(177) Floodplain or Flood-Prone Area shall mean any land area susceptible to being inundated by water from any source (see Flooding).

(178) Floodplain Administrator shall mean the local administrative official who is responsible for administering and implementing the city's Flood Overlay District.

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(179) Floodplain Management shall mean the operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to emergency preparedness plans, flood control works and floodplain management regulations.

(180) Floodplain Management Regulations shall mean zoning ordinances, subdivision regulations, building codes, health regulations, special purpose ordinances (such as a floodplain ordinance, grading ordinance and erosion control ordinance) and other applications of police power that provide standards for the purpose of flood damage prevention and reduction.

(181) Floodplain Permit shall mean a permit issued by the city to allow any change in improved and unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials located on property within a designated floodplain.

(182) Flood Proofing shall mean any combination of structural and nonstructural additions, changes, or adjustments to structures that reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, and structures and their contents.

(183) Flood Profile shall mean a graph or longitudinal profile showing the relationship of the water surface elevation of a flood event to location along a stream or river.

(184) Flood Protection Elevation shall mean an elevation 1 foot above the elevation of flood profile of the 100-year flood under existing channel and floodplain conditions.

(185) Floodway (Regulatory Floodway) shall mean the channel of a river or other watercourse and the adjacent land areas that must be preserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot.

(186) Floodway Fringe shall mean the area of the floodplain that lies outside of the floodway and could be completely obstructed without increasing the water surface elevation of the 100-year flood more than 1 foot at any point.

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(187) Flowlines shall mean, as it relates to Oil and Gas Operations, those segments of pipe from the wellhead downstream through the production facilities ending at: in the case of gas lines, the gas metering equipment; or in the case of oil lines the oil loading point or LACT unit; or in the case of water lines, the water loading point, the point of discharge to a pit, the injection wellhead, or the permitted surface water discharge point.

(188) Footcandle shall mean a unit of measurement referring to an illumination incident to a single point. One footcandle is equal to one lumen uniformly distributed over an area of one-square foot.

(189) Footprint shall mean the total area that is covered by a building's perimeter at ground level.

(190) Foster Care Home shall mean a facility, as defined by C.R.S. § 26-6-102(4.3), as amended, that is properly licensed by the state of Colorado, Adams County, or any of its designees as a foster care home. The age of a child placed in a foster care home may not exceed 18 years, or in the case of a child placed in foster care by court order prior to his or her 18th birthday, 21 years.

(191) Frontage shall mean the side(s) of a lot adjacent to a street.

(192) Frontage Road shall mean a roadway located between a controlled access street or highway and adjacent property and that provides access to the street or highway. For purposes of these regulations, all frontage roads shall bear the classification of collector streets. All regulations pertaining to collector streets shall apply to frontage roads. Under these regulations, frontage roads are not considered to be a part of the cross-section or right-of-way of major arterial streets or expressways.

(193) Garage shall mean a building or the portion of a building designed and intended for the parking or temporary storage of motorized vehicles.

(194) Gas Storage Well shall mean any well drilled for the injection, withdrawal, production, observation, or monitoring of natural gas stored in underground formations. The fact that any such well is used incidentally for the production of native gas or the enhanced recovery of native hydrocarbons shall not affect its status as a gas storage well.

(195) Gathering Line shall mean a pipeline and equipment described below that transports gas from a production facility (ordinarily commencing

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downstream of the final production separator at the inlet flange of the custody transfer meter) to a natural gas processing plant or transmission line or main. The term “gathering line” includes valves, metering equipment, communication equipment cathodic protection facilities, and pig launchers and receivers, but does not include dehydrators, treaters, tanks separators, or compressors located downstream of the final production facilities and upstream of the natural gas processing plants, transmission lines, or main lines.

(196) Grade (adjacent ground elevation) shall mean the lowest point of elevation of the finished surface of the ground, paving or sidewalk within the area between the building and the property line or when the property line is more than five feet from the building, between the building and a line five feet from the building.

(197) Grading shall mean excavation or fill of earth material, or any combination thereof, or any land disturbance.

(198) Grading Permit shall mean a permit issued by the city for grading.

(199) Green Completion shall mean those practices intended to reduce emissions from oil and gas production or completion operations, and from condensate vapors during cleanout and flowback operations prior to the well being placed on production and thereafter on any recompletions or reentries.

(200) Greenhouse shall mean a structure whose roof and sides are made largely of glass or other transparent or translucent material and in which the temperature and humidity can be regulated for the cultivation of delicate or out-of-season plants.

(201) Gross Floor Area shall mean the total area in square feet of all floors of a building measured from exterior walls.

(202) Groundcover shall mean low-growing perennial and/or evergreen plants, other than turf-grass, which grow and spread in such a manner as to provide continuous plant coverage. Such plants are typically shorter than 18 inches, and may include herbs, ivies, ornamental grasses, perennials, spreading evergreens, succulents, vines, and wildflowers. Annuals, mulches, and stone are not considered groundcovers, nor are tree canopies.

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(203) Groundwater shall mean, as it relates to Oil and Gas Operations, subsurface waters in a zone of saturation.

(204) Group Home shall mean a residence operated as a single use, licensed or operated by a governmental entity, where authorized supervisory personnel are present on the premises for the purpose of providing physical assistance and/or other supportive services to individuals needing special care or rehabilitation.

(205) Group Home, Type A shall mean a group home serving no more than eight handicapped individuals. Type A group homes shall include, but are not limited to:

(a) *Group Home for Developmentally Disabled Persons* shall mean a state-licensed group home exclusively for the care of person with developmental disabilities, as defined and regulated by the Colorado Department of Human Services, Division for Developmental Disabilities Services, and the Colorado Department of Public Health and Environment;

(b) *Group Home for Elderly Persons* shall mean a group home of persons 60 years of age or older who do not require medical attention associated with a residential health care facility. Group Homes for Elderly Persons shall be either: (1) licensed as a personal care boarding home or alternative care facility by the Colorado Department of Public Health and Environment; or (2) certified as an adult foster care facility by the Adams County Department of Social Services; or

(c) *Group Home for Mentally Ill Persons* shall mean a state-licensed group home exclusively for the care of persons with mental illness, as defined and regulated by the Colorado Department of Public Health and Environment.

(206) Group Home, Type B shall mean a group home whose residents are not handicapped or protected under federal or state fair housing legislation. In addition, a Type B group home includes a Type A group home which houses more than eight residents, subject to the provision for reasonable accommodation set forth in section 21-5238.

(207) Guard House shall mean a structure, located on a private road or on private property for the purpose of manually or electronically regulating

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and monitoring pedestrian and/or vehicular traffic into a development or neighborhood and promoting security within the development or neighborhood; provided however, a guardhouse shall include only those structures that are not designed or used for sleeping or living purposes.

(208) Guest House shall mean an accessory dwelling attached or unattached to a principal dwelling, used to house guests of the occupants of the principal dwelling, and which shall not be rented or leased, or held in ownership by other than the owner of the principal dwelling.

(209) Gun Club shall mean an establishment designed to provide target practice in the use of firearms under controlled conditions whether or not the use is conducted within an entirely enclosed soundproof building or outside of a building so that the public health and safety are protected. These establishments may also include the accessory sale of firearms, the sale of ammunition, the sale of associated equipment or supplies, and the sale of food to the patrons of the establishment.

(210) Halfway House shall mean a building used as a detention or receiving facility for persons who are on probation or parole, or who are placed in the facility by reason of court order resulting from an offense committed or allegedly committed by the person.

(211) Hazardous Materials shall mean those chemicals or substances, which are physical or health hazards as defined and classified in the fire and building codes adopted by the city. Hazardous materials categories include explosives and blasting agents, compressed gases, flammable and combustible liquids, flammable solids, organic peroxides, oxidizers, pyrophoric materials, unstable materials, water-reactive solids and liquids, cryogenic fluids, highly toxic and toxic materials, radioactive materials, corrosives, carcinogens, irritants, sensitizers and other health hazards.

(212) Hazardous Waste Disposal Site shall mean such site for disposal of hazardous waste as defined by the C.R.S. § 25-15-~~201 et seq~~ [200.3](#).

(213) Highest Adjacent Grade shall mean the highest natural elevation of the ground surface prior to construction next to the proposed walls of a structure.

(214) Historic Structure shall mean any structure that is:

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- (a) Listed individually in the National Register of Historic Places (a listing maintained by the Department of Interior) or preliminarily determined by the Secretary of the Interior as meeting the requirements for individual listing on the National Register;
- (b) Certified or preliminarily determined by the Secretary of the Interior as contributing to the historical significance of a registered historic district or a district preliminarily determined by the Secretary to qualify as a registered historic district;
- (c) Individually listed on a state inventory of historic places in states with historic preservation programs which have been approved by the Secretary of Interior; or
- (d) Individually listed on a local inventory of historic places in communities with historic preservation programs that have been certified either:
 - (i) By an approved state program as determined by the Secretary of the Interior; or
 - (ii) Directly by the Secretary of the Interior in states without approved programs.

(215) Home Occupation shall mean a business, profession, occupation, or trade that is conducted for gain as an accessory use within a dwelling unit by a resident of the dwelling.

(216) Hoop House shall mean an unheated greenhouse, most commonly constructed with arches of plastic or metal.

(217) Hospital shall mean any building or portion thereof used for the accommodation and medical care of sick, injured or infirm persons including related facilities such as laboratories, out-patient facilities, training facilities, central service facilities and staff offices.

(218) Illegal Use shall mean any use, whether of a building or other structure, or of a tract of land, in which a violation of any provision of this land development code has been committed or shall exist.

(219) Impervious Surfaces shall mean those portions of a lot or parcel that are covered by principal and accessory buildings or structures, and by

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surfaces that prevent the passage or absorption of stormwater, such as paving and driveways.

(220) Impound yard shall mean use of any property for the temporary outdoor storage of towed vehicles by a towing service operator that are to be claimed by the titleholder or their age.

(221) Improvements shall mean streets, curbs, gutters, drainage facilities, sidewalks, pedestrian walks, water mains, sanitary and storm sewers, underground gas lines, underground and overhead utility lines, telecommunication lines and facilities, street trees, ornamental street lights, and such other items as may be designated by the city.

(222)

(223) Incinerator, Solid Waste shall mean a specific type of waste/salvage use in which an engineered apparatus is used to burn waste substances and in which all the combustion factors, temperature, retention time, turbulence and combustion air, can be controlled.

(224) Industrial Activity shall mean an activity subject to Industrial Permits as defined in 40 CFR, Section 122.26(b)(14).

(225) Infill or Redevelopment shall mean an area of platted or unplatted land that, together with all adjacent vacant land in private ownership, includes no more than 20 acres of land, and where the land along at least 75 percent of the boundaries of the proposed development (ignoring intervening streets) has been developed.

(226) Inert Material Disposal Site shall mean any placement in an excavation or on top of the ground of dirt, gravel, rock, asphalt, slag, brick, concrete, cinders and any other type of noncombustible materials in accordance with the regulations set forth in this land development code except for any such placement of materials approved by the department of community development for use in conjunction with a change in elevation for development of the site. Inert Material is defined in C.R.S. § 25-15-101(14).

(227) Injection Well shall mean any Class II wells used for the exclusive purpose of injecting fluids or gas from the surface for enhanced oil recovery or the disposal of E&P ~~wastes~~ Wastes.

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(228) Inoperable Vehicle shall mean a vehicle which is not awaiting disposition instructions as a result of a collision and: does not display current license plates from any state registered to the vehicle; is visibly damaged, wrecked, dismantled, in serious disrepair, deteriorating (rusting/rotting), or missing major components; or is being salvaged, parted out, prepared for crushing, shredding or scraping. Notwithstanding the foregoing, neither special interest vehicles nor vehicles undergoing reasonably active restoration shall be considered an inoperable vehicle

(229) Junk shall mean any discarded or scrap lumber, metals, materials, furniture, fixtures, appliances, motor vehicle parts or tires; wrecked, abandoned, demolished, dismantled or non-operable machinery and trailers; goods that are so worn or deteriorated as to make them unusable in their existing condition for the purpose intended when first made or assembled; and goods that are extracted, disassembled or removed in parts and left in a condition not capable of use for the purpose intended when first made or assembled.

(230) Junk Yard shall mean a building, structure or parcel of land or portion thereof, used for the collecting, dismantling, storage, salvaging, demolition or sale of junk as defined in this land development code.

(231) Kennel shall mean any establishment or parcel of property upon which a person engages in the business of boarding, housing, breeding, training, trading, buying or selling dogs, cats, or any other domesticated animal. The term kennel shall not include pet stores, doggie day care centers, or any boarding facility operated by a veterinarian as part of a veterinary practice.

(232) Kindergarten shall mean any facility providing an educational program for children only for the year preceding their entrance to the first grade, whether such facility is called a kindergarten, nursery school, preschool, or is called by any other name. The term shall not include any facility licensed as a foster family home under the provisions of this land development code.

(233) Kiosk shall mean a freestanding structure upon which temporary information and/or posters, notices and announcements are posted.

(234) Landfill shall mean a disposal site or facility employing an engineered method of disposing of solid waste, including demolition and

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construction debris. For purposes of this code, the term landfill shall also apply to any solid waste disposal site and facility or any type of hazardous waste disposal site and facility.

(235) Landfill, Demolition and Construction Debris shall mean a disposal site for metal, plastic, glass, concrete, asphalt, brick, wood, dirt, and limited amounts of paper products if such paper is an integral part of materials uses for construction purposes.

(236) Landscaping shall mean aesthetic improvements using natural and manmade materials. Landscaping areas may also include, by way of example but not by way of limitation, the following: Basketball courts, pools, tennis courts, playgrounds or similar recreational areas or uses.

(237) Landscaping Materials shall mean, but not be limited to trees, shrubs, vines and plants of all descriptions (excluding weeds and other unkempt vegetation) and other materials and treatments such as stone, mulches, and other non-living landscape materials.

(238) Letter of Map Revision Based on Fill (LOMR-F) shall mean FEMA's modification of the Special Flood Hazard Area (SFHA) shown on the Flood Insurance Rate Map (FIRM) based on the placement of fill outside the existing regulatory floodway.

(239) Light Trade and Technical Uses shall mean the fabrication, assembly, packaging, or repair, rental, or servicing of any commodity, the sale of which is permitted within the subject zoning district.

(240) Liquor Store shall mean a state-licensed, retail establishment selling packaged alcoholic liquors (including beer, wine, and spirituous liquors) for consumption off-site. Liquor store does not include restaurants, taverns, or bars.

(241) Limited Equipment Rentals shall mean the rental of equipment primarily intended for individual use and minor residential gardening and construction projects. This use category does not include the rental, storage, or maintenance of large construction equipment. Such vehicles are restricted to the broader use category of vehicle/equipment sales and rentals.

(242) Livestock shall mean animals commonly regarded as farm animals, including but not limited to, cattle, horses, goats, llamas, ostriches, and

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sheep, but excluding pet animals such as rabbits, poultry, and domestic fowl.

(243) Living Plant Material Coverage shall mean the covering of raw ground or bare dirt with living landscape materials at a growth size of 2/3 maturity, such as shrubs, groundcovers, perennials, vines and all plants of all descriptions (excluding weeds or other unkempt vegetation).

(244) Local Government Designee (LGD) shall mean the office or person designated to receive, on behalf of the local government, copies of all documents required to be filed with the local government designee pursuant to these rules.

(245) Local Street shall mean a street which has the primary function of providing access to abutting property and which does not normally carry through traffic.

(246) Lodging Establishment shall mean an establishment, building, or premises with more than 20 sleeping rooms where lodging is offered for compensation.

(247) Lodging, Extended Stay shall mean a lodging establishment offering suites with living, kitchen, and sleeping areas.

(248) Lot shall mean a unit of subdivided land occupied or designed to be occupied by a primary use or building or a group of such buildings and accessory buildings.

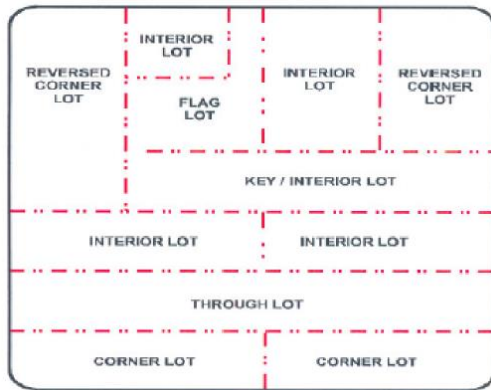


Figure XI-4. Lot Types

(249) **Lot Area** shall mean the total horizontal, square footage area within the lot lines of a lot.

(250) **Lot, Corner** shall mean a lot abutting upon two or more streets at their intersection or upon two parts of the same street and where, in either case, the interior angle formed by the intersection of street lines does not exceed 135 degrees.

(251) **Lot, Double Frontage** shall mean a lot that runs through a block from street to street and which has two non-intersecting sides abutting on two or more streets. The required setbacks from each street shall comply with the zoning requirements of the respective district.

(252) **Lot, Flag** shall mean a lot not meeting minimum frontage requirements and where the access to the public or private road is by a narrow private right-of-way or driveway, also known as a flagpole.

(253) **Lot Frontage** see sections 21-11110 and 21-11115.

(254) **Lot, Interior** shall mean a lot which is not a corner lot and has only one street frontage.

(255) **Lot Line** see Property Line.

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(256) Lot Line Adjustment shall mean a change in lot or parcel boundaries that does not create additional lots or parcels.

(257) Lot Pin shall mean a solid steel pin established to provide for the accurate location of platted property lines.

(258) Lot of Record shall mean a lot that is part of an approved plat, the map of which has been recorded in the office of the Adams County Clerk and Recorder.

(259) Lot, Reversed Corner shall mean a corner lot the side street of which is substantially a continuation of the front lot line of the first lot to its rear.

(260) Lowest Floor shall mean the floor of the lowest enclosed area (including basement) in a structure. An unfinished or flood resistant enclosure, usable solely for parking or vehicles, building access or storage in an area other than a basement area is not considered a building's lowest floor; provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirement of Section 60.3 of the National Flood insurance Program regulations.

(261) Machinery shall mean an assemblage of parts that transmit forces, motion, and energy one to another in a predetermined manner. This term shall also include a mechanically, or electronically operated device for performing a task.

(262) Maintenance shall mean the routine recurring work required to keep a building, equipment, or commodity in such a condition that it may be continuously utilized at its original or designed capacity and efficiency for its intended purpose.

(263) Mansard Roof shall mean a roof with at least two slopes on any side with the tower slope steeper than the upper one(s). The deck line is the top edge of the lower slope.

(264) Manufacturing shall mean the process, assembly, fabrication, production, construction or other preparation of a raw material product or component part of a product to make, create or process towards or into a finished product. Products may be finished or semi-finished and are generally made for the wholesale market, for transfer to other plants, or to

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order for firms or consumers. Good are generally not displayed or sold on site, but if so, they are a subordinate part of sales.

(265) Marijuana Business means any medical marijuana center, optional premises cultivation operation, medical marijuana-infused products manufacturer, retail marijuana store, retail marijuana cultivation facility, retail marijuana products manufacturer and retail marijuana testing facility.

(266) Marijuana Membership Club shall mean an organization and its premises operating on a membership basis for the promotion of interests of the members including the smoking or other consumption of medical or retail marijuana or marijuana products.

(267) Marquee shall mean a shelter projecting from and supported by the exterior wall of a building constructed of rigid materials on a supporting framework. A marquee is distinguished from an awning in that an awning is covered with nonrigid material. A marquee is distinguished from a canopy in that a marquee is cantilevered, whereas a canopy is supported by posts or other devices beyond the building wall.

(268) Massage Therapy Facility shall mean a facility that is operated for the purpose of providing massages. This does not include any type of adult business.

(269) Material Piles shall mean outdoor storage of loose materials in piles, e.g. construction aggregate piles (sand, gravel, crushed stone, recycled concrete or asphalt, etc.) and landscape material piles (topsoil, compost, mulch, etc.), in heights that exceed the limit allowed for regular outdoor storage. This definition specifically excludes scrap metal, salvage, garbage, debris, refuse, as well as any landfill approved by the city and the state of Colorado.

(270) Material Recovery Resource Facility (MRRF) shall mean a facility used to collect, sort, and consolidate recyclable materials including computers, paper, paperboard, glass, plastic, and aluminum, for use as raw material to produce new items at other locations, including interim facilities. This activity may include incidental storage, office, and maintenance facilities.

(271) Maximum Extent Feasible shall mean that no feasible and prudent alternative exists, and that all possible efforts to comply with the regulation or minimize potential harm or adverse impacts have been undertaken.

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Economic considerations may be taken into account but shall not be the overriding factor in determining maximum extent feasible.

(272) Mean Sea Level shall mean for purposes of the National Flood Insurance Program, the North American Vertical Datum (NAVD) of 1988 or other datum, to which base flood elevations shown on a community's Flood Insurance Rate Map are referenced.

(273) Median shall mean that portion of a divided street or highway separating the traveled ways for traffic in opposite directions.

(274) Medical Marijuana Business shall mean a medical marijuana center, optional premises cultivation operation, or medical marijuana-infused products manufacturer as defined in the Colorado Medical Marijuana Code.

(275) Medical Marijuana Center shall have the meaning ascribed to it in state law.

(276) Medical Marijuana Infused Product Manufacturer shall have the meaning ascribed to it by state law.

(277) Microbrewery shall mean an establishment where malt liquors are manufactured and packaged on or off premises, manufacturing more than 5,000 but less than 60,000 barrels of malt liquor on its licensed premises each calendar year.

(278) Micro cell shall include "micro wireless facility" and shall be defined by C.R.S. 29-27-402(3.5) as currently exists and as may be amended from time to time.

(279) Micro-winery shall mean a business that manufactures 5,000 to 10,000 cases of vinous liquors per year.

(280) Mineral Estate Owner shall mean the owner or lessee of minerals located under a surface estate that are subject to an application for development.

(281) Mining shall mean the development or extraction of a mineral from its natural occurrences on affected land. The term includes, but is not limited to: open mining and surface operation and the disposal of refuse from underground and in-situ mining. The term includes the following

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operations on affected lands: transportation concentration; milling; evaporation; and other processing. The term does not include: the exploration and extraction of natural petroleum in a liquid or gaseous state by means of wells or pipe or the extraction of geothermal resources.

(282) Mini-Storage and Warehouse shall mean an establishment primarily offering individualized enclosed storage spaces for rent or lease to the general public, including self-storage and mini-storage facilities. This term excludes establishments where the primary use is outdoor vehicle storage.

(283) Mixed-Use Development shall mean a single building containing more than one principal permitted land use or a single development of more than one building containing more than one principal permitted land use. In a mixed-use development, the different types of land uses are in close proximity, planned as a unified complementary whole, and functionally integrated to the use of vehicular and pedestrian access and parking areas.

(284) Mobile Home shall mean any wheeled vehicle, exceeding 8 feet in width or 32 feet in length, including towing gear and bumpers, with or without motor power, built on a permanent chassis designed for residential occupancy, and containing complete electrical, plumbing, and sanitary facilities designed for installation in a permanent or semi-permanent manner without a permanent foundation that is capable of being drawn over public highways by a motor vehicle. Modular homes shall not be considered mobile homes. For the purpose of interpretation of this land development code, mobile home shall not include travel trailers, camping trailers, truck campers, and motor homes, as licensed and/or defined by the state of Colorado when used or designed to be used as a dwelling as provided in this definition.

(285) Mobile Home Park shall mean a parcel of land which has been planned and approved for the placement of more than one mobile home, occupied for dwelling, sleeping, or storage purposes for transient and/or non-transient use and sometimes termed a trailer court, trailer camp, or trailer park.

(286) Mobile Home Zoning District shall mean land within the corporate limits of the city that has been zoned for the use and operation of mobile homes and mobile home parks.

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(287) Model Home shall mean a dwelling representative of other dwellings offered for sale or lease, or to be built in an area of residential development within the city. A model home is used for the sole purpose of selling similar units within the same development and used for this purpose only until all developments are sold.

(288) Modular Home shall mean a factory built home, other than a mobile home, which meets all of the following requirements: is designed only for erection or installation on a site-built permanent foundation; is not designed to be moved once so erected or installed; is designed and manufactured to comply with a nationally recognized model building code or an equivalent local code, or with a state or local modular building code recognized as generally equivalent to building codes for site-built housing. Such units shall provide all of the accommodations necessary to be a dwelling unit and shall be connected to all utilities in conformance with applicable regulations. The term modular home does not include a recreational vehicle.

(289) Modular Non-Residential Unit shall mean a factory-built structure not built on-site, which is not designed for residential use or human habitation.

(290) Monopole Tower shall mean a structure designed and constructed to support antenna or antennas for the purpose of providing telecommunications services and which consists solely of a stand-alone ground mounted support pole, pipe, or other solid structure. A monopole tower shall not include any tower supported or attached to guy or support wires. A monopole tower is not a lattice tower.

(291) MS4 shall mean the municipal separate storm sewer system.

(292) Mulch shall mean non-living matter, such as bark chips, chipped wood products, pole shavings, stone and any approved like-materials customarily used in landscape for the purpose of retaining soil-moisture, retarding weed growth, and stabilizing soils.

(293) Multi-Well Site shall mean, as it relates to Oil and Gas Operations, a common well pad from which multiple wells may be drilled to various bottomhole locations.

(294) Museum shall mean a profit or non-profit, commercial or non-commercial establishment operated as a repository for a collection of

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nature, scientific, or literary curiosities, objects of interest, or works of art, not including the regular sale or distribution of the objects collected.

(295) MUTCD shall mean the Manual of Uniform Traffic Control Devices.

(296) NAICS shall mean the North American Industry Classification System as published by the U.S. Census Bureau.

(297) Native Seed shall mean any live landscaping, including dryland grasses and vegetation, but not including weeds capable of growing in the local environment without supplementary watering once established.

(298) Non-Combustible shall mean a building construction material which, in the form in which it is used, is either one of the following:

- (a) Material of which no part will ignite and burn when subjected to fire; or
- (b) Material having a structural base of non-combustible material as defined in paragraph (a) above, with a surfacing material not over one-eighth inch thick, and a flame-spread rating of 50 or less.

Non-combustible does not apply to surface finish materials. Material required to be non-combustible for reduced clearances to flues, heating appliances, or other sources of high temperature shall refer to material conforming to paragraph (a) above. No material shall be classified as non-combustible which is subject to increase in combustibility or flame-spread rating beyond the limits herein established, through the effects of age, moisture, or other atmospheric conditions.

(299) Nonconformity shall mean any use, sign, structure, building, or lot that was legally established prior to the effective date of this land development code or any subsequent amendment, but that fails by reason of such adoption, revision, or amendment, to conform to all the current requirements of this land development code.

(300) Non-Stormwater Discharge shall mean any discharge to the storm drain system that is not composed entirely of stormwater.

(301) Nursery shall mean a retail establishment selling plants and garden supplies in which all merchandise other than plants is kept within an enclosed building or a fully screened enclosure, and fertilizer of any type is

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stored and sold in package form only. Stock in trade shall be comprised primarily of live plant material, with hardscape materials such as railroad ties, boulders, landscape gravel, and crushed rock limited to a relatively small percentage of sales.

(302) Nursing Home shall mean a state-licensed group living facility regulated as a skilled nursing facility, as defined in C.R.S. § 26-4-103(11).

(303) Obstruction shall mean any development, stockpile, refuse or matter in, along, across or projecting into any floodplain which might impede, retard or change the direction of a flow of water, either by itself or by catching or collecting debris carried by such floodwater.

(304) Off-Street Loading shall mean a site or portion of a site that is not located in a dedicated public right-of-way devoted to the loading or unloading of motor vehicles or trailers, including loading berths, aisles, access drives, and landscaped areas.

(305) Off-Street Parking shall mean an area, other than a street or alley, designed or used primarily for the temporary parking of vehicles.

(306) Office shall mean establishments providing executive, management, administrative, or professional services, including medical or dental services, but not involving the sale of merchandise, except as incidental to a permitted use. Typical uses include real estate, insurance, property management, investment, employment, travel, advertising, law, doctor, dentist, out-patient medical laboratories, architecture, design, engineering, accounting, and similar offices.

(307) Office Flex shall mean a type of development designed to be versatile, which may be used in combination with office (corporate headquarters), research and development, quasi-retail sales, wholesale operations, and including but not limited to craft manufacturing, warehouse, and distribution uses.

~~(308)~~

~~(309)~~(308) **Oil and Gas** shall mean oil or gas, or both oil and gas.

~~(310)~~(309) **Oil and Gas Facility** shall mean equipment, buildings, structures, or improvements associated with or required for the operation of a well site, pipeline, or compressor facility. Facilities include, but are not

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limited to, well sites, production facilities, production sites, treatment facilities, access roads, well pads, tank batteries, pits, and flowlines.

~~(311)~~(310) **Oil and Gas Permit** shall mean any permit issued by the City that allows an Operator to ~~construct an Oil and Gas Facility~~/Oil and Gas Location and conduct Oil and Gas ~~Operations~~. Well operations.

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~~(312)~~(311) **Oil and Gas Well** shall mean a hole drilled into the earth for the purpose of exploring for or extracting oil, gas, or other hydrocarbon substances.

~~(313)~~

~~(314)~~(312) **Oil and Gas Operation(s) or Operation(s)** shall mean exploration for oil and gas, ~~including the conduct of seismic operations and the drilling of test bores~~; the siting; drilling; deepening, completion recompletion, reworking, or abandonment of an oil and gas well or gas storage well; production operations related to any such well including the installation of flowlines and gathering systems; the generation, transportation, storage and treatment of oil and gas; any construction, site preparation, or reclamation activities associated with such operations; and any Oil and Gas well facility, Oil and Gas well site or location, production site or other facility, site or location upon or within which any of the foregoing are conducted, operated, installed, constructed, generated treated or located.

Commented [BHFS42]: This deletion is necessary for internal consistency. A permit isn't necessary for seismic operations and thus should not be included in the definition of Oil and Gas Operations.

~~(315)~~

~~(316)~~(313) **One-Hundred-Year Flood** See Base Flood.

~~(317)~~

~~(318)~~(314) **Operator** shall mean, as it relates to Oil and Gas Operations, any person who exercises the right to control the conduct of oil and gas operations or applies for an Oil and Gas Permit.

~~(319)~~(315) **Open Space** shall mean any parcel or area of land or water essentially unimproved without any residential, commercial, or industrial uses and set aside, dedicated, or reserved for public or private use and enjoyment including recreational, scenic, or environmental purposes.

Open space may include agricultural uses and natural features located on a site, including but not limited to, meadows, forested areas, steep slopes, flood plains, hazard areas, unique geologic features, ridgelines, unique vegetation, and critical plant communities, stream corridors, wetlands, and riparian areas; wildlife habitat and migration corridors, areas containing threatened or endangered species, and archeological, historical, and cultural resources.

~~(320)~~(316) **Optional Premises Cultivation Operation** shall have the meaning ascribed to it by state law.

~~(321)~~(317) **Ornamental Grass** shall mean those types of grasses that grow in clumps and do not spread to form a continuous mat, as do turf-grasses. Bunch grasses and other, taller, more decorative types, may be considered ornamental grasses when grown as accents, in conjunction with other plants, in larger bed-plantings.

~~(322)~~(318) **Ornamental Tree** shall mean a tree, typically 15- to 20-feet tall at maturity, which is planted for its decorative value, perhaps in screening applications rather than for shading purposes. Ornamental trees are usually deciduous, but may include short-growing conifers such as upright junipers, pinion-and bristle-cone pines.

~~(323)~~(319) **Outdoor Storage** shall mean the placement of materials, merchandise, stock, supplies, shipping containers, mobile storage containers, machines, operable vehicles, equipment, manufacturing materials, or chattels of any nature that are not kept in a structure having at least four walls and a roof, for a continuous period of 24 hours or more. Outdoor storage shall not include:

- (a) Items for the general public such as new and used cars, recreational vehicles, boats, landscape stock or related materials, or rental automobiles where such items are permitted for sale in the district in which they are located;
- (b) Outdoor parking of motor vehicles regularly used in connection with the operation of an establishment or parked for less than 48 hours for maintenance;
- (c) The storage of wrecked or inoperable vehicles.

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~~(324)~~(320) **Overlay Zoning District** shall mean a zoning district superimposed over the underlying zoning district which places further restrictions upon land uses. Developments within the overlay zoning district shall conform to the requirements of both zones.

~~(325)~~(321) **Owner** shall mean any person with fee title to the parcel of land or with a contract to obtain fee title to the parcel of land.

~~(326)~~(322) **Parapet** shall mean an extension of the main walls of a building above the roof level, often used to shield or screen roof top mechanical equipment and vents.

~~(327)~~(323) **Parcel** shall mean a plot of land of any size that may or may not be subdivided or improved.

~~(328)~~(324) **Park, Public** shall mean a public-owned parcel of land, with or without improvements, set apart for the recreation of the public.

~~(329)~~(325) **Park, Private** shall mean land within or related to a development, not individually owned or dedicated for public use but generally owned and maintained by a homeowner's association, that is designed and intended for the common use or enjoyment of the residents of the development and their guests, and may include such complementary structures and improvements as are necessary and appropriate. Private parks may include trail areas, gardens, scenic areas, buffer areas, pools, tennis courts, playgrounds, and clubhouses.

~~(330)~~(326) **Parking Area** shall mean a site or portion of a site devoted to the parking of motor vehicles including parking spaces, aisles, access drives, and landscaped areas.

~~(331)~~(327) **Parking Garage** shall mean a permanent structure that is enclosed on all four sides and consists of one or more levels and is primarily dedicated to providing temporary parking or storage of operable vehicles to the general public, regardless of whether or not there is a fee.

~~(332)~~(328) **Parking Lot** shall mean an area used for the purpose of temporary, daily, or overnight storage of vehicles, which is not located in a dedicated public right-of-way, a travel lane, a service drive, or any easement for public ingress or egress.

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~~(333)~~(329) **Parking, Shared** shall mean joint use of a parking lot or area for more than one principal use.

~~(334)~~(330) **Pawnshop** shall mean a retail sales establishment where a pawnbroker regularly engages in or solicits business.

~~(335)~~(331) **Perimeter Control** shall mean a barrier that prevents sediment from leaving a site by filtering sediment-laden runoff or diverting it to a sediment trap or basin.

~~(336)~~(332) **Permitted Use** shall mean a use allowed in a zoning district either as a Use-by-Right, a Use-by Permit, or as a Conditional Use.

~~(337)~~(333) **Pit** shall mean, as it relates to Oil and Gas Operations, a subsurface earthen excavation (lined or unlined), or open top tank, used for oil or gas exploration or production purposes for retaining or storing substances associated with the drilling or operation of oil and gas wells. Pits may include drilling pits, production pits, reserve pits and special purpose pits as defined in COGCC Rules.

~~(338)~~(334) **Plane** shall mean any vertical surface, or the projection to a vertical plane of an inclined or curved surface, or wall of a structure that when viewed in elevation, incorporates no overhangs, off-sets, projections, decks, ramadas, loggias, or similar architectural features that would produce shadow patterns or otherwise serve to visually blend the structure into its natural background. If a window or door projects or recedes a minimum of 12 inches, either may be considered as providing visual relief.

~~(339)~~(335) **Planned Unit Development (PUD)** shall mean a zone district designation for a tract of land controlled by one or more landowners, which is developed under a plan for either residential, commercial/retail, industrial, public, agricultural, open space or recreational uses, or a combination thereof.

~~(340)~~(336) **Plat** shall mean a map that defines the subdivision of land and commonly shows lots, blocks, streets, and other features relevant to the development of the property.

~~(341)~~(337) **Plaza** shall mean an open space that may be improved and landscaped, usually surrounded by streets or buildings.

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~~(342)~~(338) **Plugging and Abandonment** shall mean, as it relates to Oil and Gas Operations, the cementing of a well, the removal of its associated production facilities, the removal or abandonment in-place of its flowline, and the remediation and reclamation of the well site.

~~(343)~~(339) **Pole**, for the purposes of telecommunications contexts, shall include “pole structure” and “tower” and shall be defined by C.R.S. 29-47-402(6.5) as currently exists and as may be amended from time to time.

~~(344)~~(340) **Pole Construction** shall mean a type of construction for a building that is typically used for the storage of equipment, materials, product, livestock, or crops and is usually constructed of wooden or metal support poles and beams which serve as the primary support for the roof and walls.

~~(345)~~(341) **Pollutant shall mean and include, but not limited to, paints, varnishes,** solvents; oil and other automotive, non-hazardous liquid, solid wastes, and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects; floatables; pesticides, herbicides and fertilizers; hazardous substances or wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from construction of a building or structure; and noxious or offensive matter of any kind.

~~(346)~~(342) **Porch** shall mean a covered or uncovered entrance with vertical supporting members on a foundation, not including walls.

~~(347)~~(343) **Premises** shall mean any building, lot, parcel of land, or portion of land, whether improved or unimproved, including adjacent sidewalks and parking strips.

~~(348)~~(344) **Primary Caregiver** shall have the same meaning as that ascribed to it in C.R.S. § 25-1.5-106(2)(d.5).

~~(349)~~(345) **Primary or Principal Entrance** shall mean the place of ingress and egress used most frequently by the public.

~~(350)~~(346) **Principal or Primary Use** shall mean a use of property or a building that is the predominant or general use. This term shall also mean the use that would regularly encompass, at a minimum, 75 percent of the floor space of a building.

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~~(351)~~(347) **Private Bus Station** shall mean any premise used for the loading and unloading of passengers on non-governmental motor driven buses. The premise may also include ticket purchasing facilities or the storage or parking of buses.

~~(352)~~(348) **Private Road** shall mean every road or driveway not owned by the city.

~~(353)~~(349) **Processing** shall mean subjecting to some special treatment, to prepare for the market, to convert into marketable form, to make usable, marketable, or the like.

~~(354)~~(350) **Production** shall mean the making of goods available for human wants.

~~(355)~~(351) **Production Site** shall mean, as it relates to Oil and Gas Operations, the surface area immediately surrounding proposed or existing production equipment, or other accessory equipment necessary for oil and gas production activities, including the fenced, walled, or enclosed area of the facility during the production phase, exclusive of transmission and gathering pipelines.

~~(356)~~(352) **Property Line** shall mean the legally described boundary line that indicates the limits of a parcel, tract, lot, or block for the purpose of delineating ownership and setback requirements.

~~(357)~~(353) **Property (or Home) Owners' Association** shall mean a private, non-profit corporation or property owners for the purpose of owning, operating, and maintaining various common properties and facilities (except that as this definition relates to a condominium project, the property owners' association does not own the common property/facilities, it operates and maintains them on behalf of the condominium owners).

~~(358)~~(354) **Public** shall mean for the benefit of, or devoted to, the people as a whole or the community at large.

~~(359)~~(355) **Public Building** shall mean any building held, used, or controlled exclusively for public purposes by any governmental entity, without reference to the ownership of the building or of the realty upon which it is situated.

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~~(360)~~(356) **Public Hearing** shall mean a meeting that is noticed in accordance with the terms of this land development code and at which the public is given an opportunity to speak.

~~(361)~~(357) **Public Improvements** shall mean rights-of-way, easements, access rights, and physical improvements that are accepted by the city in writing and that become the responsibility of the city for ownership, maintenance, and repair. Unless otherwise provided by this land development code, public improvements include by are not limited to the following: curb and gutter, asphalt pavement, concrete pavement, streets of all types, alleys, survey monuments, pavement striping, sidewalks, pedestrian/bike paths and trails, landscaping, traffic signals, street lights, highways, greenways, medians, bridges, acceleration and deceleration lanes, culverts, storm drainage facilities including necessary structures, channels, and all other improvements, which upon acceptance by the city, are intended to be for the use of and enjoyment of the public.

~~(362)~~(358) **Public Notice** shall mean the advertisement in a newspaper, posting of the property, and/or the mailing of written notice.

~~(363)~~(359) **Public Sewer and Water Facilities** shall mean those sewer and water facilities of a municipality or special district authorized by Title 32 of the Colorado Revised Statutes.

~~(364)~~(360) **Public Utility** shall mean improvements, which include gas lines, water mains, sanitary storm sewerage, electrical cables and lines, telephone cables and lines, telecommunication facilities and lines, or other facilities of a similar nature.

~~(365)~~(361) **Public Water Supply Well** shall mean a well or system of wells that provide water via piping or other constructed conveyances for human consumption to at least 15 service connections or serves an average of at least 25 people for at least 60 days each year.

~~(366)~~(362) **PUD** - see Planned Unit Development.

~~(367)~~(363) **PUD Concept Schematic** shall mean a generalized land use or site plan for an area proposed to be included within a PUD district.

~~(368)~~(364) **PUD Permit** shall mean the permit which contains a detailed plan for either all or a portion of a planned unit development which authorizes the applicant to apply for a building permit.

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~~(369)~~(365) **PUD Zone Document** shall mean the PUD land use application which establishes entitlements for property including allowable land use and bulk standards.

~~(370)~~(366) **Railroad Right-of-Way** shall mean a strip of land with tracks and auxiliary facilities for track operation, but not including freight depots or stations, loading platforms, train sheds, warehouses, car or locomotive shops, or car yards.

~~(371)~~(367) **Railroad Yard** shall mean an area used for storage by an establishment engaged in rail services.

~~(372)~~(368) **Reclamation** shall mean, as it relates to Oil and Gas Operations, the process of returning or restoring the surface of disturbed land as nearly as practicable to its condition prior to the commencement of oil and gas operations or as required by Operator's approved interim and final reclamation plans.

~~(373)~~(369) **Recreation or Amusement, Private** shall mean any use or development providing amusement, pleasure, or sport, which is not operated or owned by a governmental entity and is operated or carried on primarily for financial gain.

~~(374)~~(370) **Recreation or Amusement, Public** shall mean any use or development providing amusement, pleasure, or sport, which is owned or operated by a governmental entity.

~~(375)~~(371) **Recreational Vehicle** shall mean a vehicle that is:

- (a) Built on a single chassis;
- (b) Four hundred-square feet or less when measured at the largest horizontal projections;
- (c) Designed to be self-propelled or permanently towable by a light duty truck; and
- (d) Not designed primarily for use as a permanent dwelling but as temporary living quarters for recreational, camping, travel, or seasonal use.

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~~(376)~~(372) **Refuse Transfer Facilities** shall mean any facility that accepts garbage, trash, rubbish, debris and other types of discarded or waste materials for the purposes of collection, temporary storage, or transfer to other locations for disposal.

~~(377)~~(373) **Religious Institution** shall mean a use category comprised of structures or places in which worship, ceremonies, rituals, and education pertaining to a particular system of beliefs are held, together with its accessory buildings and uses (including buildings used for educational and recreational activities), operated, maintained, and controlled under the direction of a religious group. Accessory uses include school facilities, parking, caretaker's housing, pastor's housing, and group living facilities such as convents. Examples include churches, temples, synagogues, and mosques.

~~(378)~~

~~(379)~~(374) **Rental Services** shall mean a retail establishment that rents to the general public merchandise, such as furniture, appliances, and similar goods that are housed inside a building.

~~(380)~~(375) **Repair** shall mean the non-routine process of restoring by replacing a part or putting together what is torn or broken. This term shall also mean the non-routine process of restoring to a sound and serviceable state through correction of a specific failure or unserviceable condition.

~~(381)~~(376) **Repair and Normal Maintenance** shall mean with regard to a nonconforming structure or portion or a structure containing a nonconforming use, work done during any 1-year period on ordinary repairs, or on repair and replacement of nonbearing walls, fixtures, wiring or plumbing to an extent not exceeding 10 percent of the current replacement cost of the nonconforming structure, or portion of structure, and provided that the cubic content existing when it became nonconforming is not increased.

~~(382)~~(377) **Replacement Mobile Home** shall mean a mobile home unit entering any mobile home park within the city; and any mobile home that is moved to another space within the mobile home park.

~~(383)~~(378) **Research, Development, Testing Laboratories** shall mean research, development, and testing laboratories that do not involve the mass manufacture, fabrication, processing or sale of products. Such uses

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shall not violate any odor, dust, smoke, gas, noise, radiation, vibration, or similar pollution standards as specified herein.

~~(384)~~(379) **Residential, Multi-Family** shall mean a dwelling or dwellings, or portion thereof, designed for or occupied by three or more families living independently of each other. Multi-family dwelling includes townhouse dwellings, and condominium or apartment buildings in which the individual dwelling units are typically located one over the other.

~~(385)~~(380) **Residential, Single-Family** shall refer to single-family attached and single-family detached dwellings, collectively.

~~(386)~~(381) **Residential, Single-Family Attached** shall mean a dwelling containing two attached dwelling units, located side-by-side and totally separated from each other by an unpierced wall extending from ground to roof designed exclusively for occupancy by two families living independently of each other.

~~(387)~~(382) **Residential, Single-Family Detached** shall mean a detached (freestanding and surrounded on all sides by open areas or yards) dwelling designed exclusively for occupancy by one family.

~~(388)~~(383) **Restaurant** shall mean an establishment where the principal business is the sale of food and beverages in a ready-to-consume state where fermented malt beverages, malt, special malt, and vinous and spirituous liquors may be produced on the premises as an accessory use. See also Fast-Food Restaurant.

~~(389)~~(384) **Retail Establishment** shall mean establishments that sell, lease, or rent consumer, home, and business goods, but excluding merchandise/retail uses classified or defined more specifically in this land development code (e.g., convenience stores and restaurants). Typical uses include department stores, furniture stores, clothing stores, and establishments providing the following products or services: antiques, art, art supplies, bicycles, clothing, dry goods, electronic equipment, fabric, furniture, garden supplies, gifts, hardware, home improvements, household products, jewelry, pet food, pharmaceuticals, printed material, sporting goods, stationary, and videos; and new automotive parts and accessories (excluding service and installation).

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~~(390)~~(385) **Retail Marijuana Code** means title 12, article 43.4 of the Colorado Revised Statutes, as amended from time to time, and any rules or regulations promulgated thereunder.

~~(391)~~(386) **Retail Marijuana Cultivation Facility** shall have the meaning ascribed to it by state law.

~~(392)~~(387) **Retail Marijuana Product Manufacturer** shall have the meaning ascribed to it by state law.

~~(393)~~(388) **Retail Marijuana Store** shall have the meaning ascribed to it by state law.

~~(394)~~(389) **Retail Marijuana Testing Facility** shall have the meaning ascribed to it by state law.

~~(395)~~(390) **Retaining Wall** shall mean a structure designed to resist the lateral displacement of soil or other materials in order to protect property and/or prevent erosion.

~~(396)~~(391) **Right-of-Way** shall mean land devoted to or over which people and goods have the right to pass or travel (e.g., roads, streets, pedestrian walkways, bicycle paths and alleys).

~~(397)~~(392) **Road Impact Fee Study** shall mean a study prepared for and on behalf of the city to determine road impacts generated by new development.

~~(398)~~(393) **Roadside Stand** shall mean a temporary structure used primarily to sell products produced on the property.

~~(399)~~(394) **Roadway** shall mean that portion of a street or highway improved, designed, or ordinarily used for vehicular travel, including the shoulder.

~~(400)~~(395) **Salvage Yard** shall mean a building, structure, parcel of land, or portion thereof, where two or more motor vehicles not in running condition, or parts thereof, are stored in the open and are not being restored to operation; or any land, building, or structure used for wrecking or storing of such motor vehicles or farm machinery, or parts thereof, stored in the open and not being restored to operating condition.

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~~(401)~~(396) **School, Commercial** shall mean a structure or group of structures where instruction is given to pupils in arts, religion, crafts, philosophy, or trades, and is operated as a commercial enterprise.

~~(402)~~(397) **Scrap Yard** shall mean an establishment where materials are collected in bulk quantities for use as raw material to produce new items at other locations, or dismantled for wholesale use or direct sale to the public. This classification excludes collection of household recyclable materials and vehicle salvage.

~~(403)~~(398) **Scrap Tire** means a tire that is no longer used for its original purpose.

~~(404)~~(399) **Screening** shall mean a method of visually shielding or obscuring one abutting or nearby structure or use from another by fencing, walls, berms, or densely planted vegetation.

~~(405)~~(400) **Sediment Control** shall mean BMPs that prevent eroded sediment from leaving the site.

~~(406)~~(401) **Seismic Operations** shall mean, ~~as it relates to Oil and Gas Operations,~~ all activities associated with acquisition of seismic data including but not limited to surveying, shothole drilling, recording, shothole plugging and reclamation.

~~(407)~~

~~(408)~~(402) **Semi-Trailers** - see Trailer.

~~(409)~~(403) **Service Lateral** shall mean the electrical, communications, cable television wiring, coaxial, or fiber optic or other utility line connections between the provider's distribution system and system termination at the point of consumer use.

~~(410)~~(404) **Service Station** shall mean any building, land area, or other premises used for the retail dispensing or sales of vehicular fuels; minor towing, servicing, and repair of automobiles and light trucks; and including as an accessory use the sale and installation of lubricants, tires, batteries, and similar vehicle accessories. Body and fender work, transmission work, engine overhaul work, or heavy truck or vehicle repair are excluded from this use. If a use that fits this definition also includes the sale of ready-to-eat food products (not intended for on-premises consumption), groceries

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and sundries, or 3.2 beer, such use shall be classified as a convenience store as provided above.

~~(411)~~(405) **Setback** shall generally mean the distance from a lot line to the closest projection of a building or structure along such line. For Oil and Gas Locations, the term shall mean the distance from the Working Pad Surface to the closest projection of the relevant physical endpoint, such as the corner of a residential building unit or the boundary line of a wetland.

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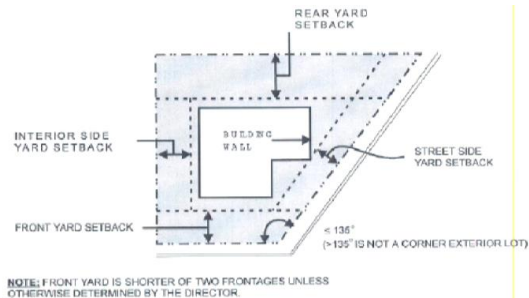


Figure XI-5. Setback Example

~~(412)~~~~(406)~~ **Shade Structure** shall mean gazebos, arbors, or pergolas that are not attached to a principal structure but may be attached to an accessory structure. Shade structure shall not include carports.

~~(413)~~~~(407)~~ **Shade Tree** shall mean a tree, over 15- to 20-feet tall at maturity, that is deciduous and planted for its wider canopy, higher bottom-branch scaffold and shading value, and does not include conifers or evergreens of any kind.

~~(414)~~~~(408)~~ **Shrub** shall mean a long-lived deciduous, evergreen, or coniferous woody plant, typically multi-stemmed and having a mature height of between 3 and 15 feet and does not include perennials.

~~(415)~~~~(409)~~ **Sidewalk** shall mean that portion of a public right-of-way adjacent to lateral property lines intended for the use of pedestrians.

~~(416)~~

~~(417)~~~~(410)~~ **Sight Triangle** shall mean a triangular-shaped portion of land established at street intersections in which nothing is erected, placed, planted, or allowed to grow in such a manner as to limit or obstruct the sight distance of motorists entering or leaving the intersection.

~~(418)~~~~(411)~~ **Sign** shall mean any advertising device, announcement, direction, or communication produced in whole or in part by the construction, erection, affixing or placing of a structure on any land or on any other structure, or produced by painting on or posting or placing any

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painted, lettered, pictured, figured or colored material on any building, structure or surface.

~~(419)~~(412) **Sign, A-Frame or Sandwich Board** shall mean a non-wheeled movable advertising or business ground side constructed in such a manner as to form an “A” or a tent-like shape, hinged or not hinged at the top, with each angular face held at an appropriate distance by a supporting member. These signs shall not be secured or attached to the ground or surface upon which it is located.

~~(420)~~(413) **Sign, Awning** shall mean a sign painted or printed on and attached flat against the surface of an awning.

~~(421)~~(414) **Sign, Digital Display** shall mean a sign with the presentation of pictorials, videos, and graphics displayed in a single or progression of frames which may give the illusion of motion, including but not limited to the illusion of moving objects, moving patterns, bands of light, or expanding or contracting shapes.

~~(422)~~(415) **Sign, Electronic Reader Board** shall mean a sign with a fixed or changing display/message composed of a series of lights that may be changed through electronic means. These signs contain text and/or numbers only. No images, pictures, or videos are allowed.

~~(423)~~(416) **Sign Face** shall mean the surface of a sign upon, against, or through which the advertising message is displayed or illustrated, excluding the necessary supports or uprights on which such sign is placed.

~~(424)~~(417) **Sign, Free-Standing** shall mean any single- or double-faced sign affixed to a free standing supporting pole, or poles, or structure, imbedded in, and extending upward from the ground.

~~(425)~~(418) **Sign, Identification** shall mean a sign indicating the name of an allowed use, the name or address of a building, or the name of the management thereof.

~~(426)~~(419) **Sign, Ideological** shall mean a sign which does not propose a commercial transaction but, instead, involves only the expression of ideas or beliefs.

~~(427)~~(420) **Sign, Illuminated** shall mean a sign designed to give forth any artificial light or reflect such light from an artificial source.

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~~(428)~~(421) **Sign, Informational** shall mean an on-premise sign, which gives direction, instructions, or facility information and does not contain the name or logo of an establishment or contain any advertising copy, e.g. parking, exit, or entrance signs.

~~(429)~~(422) **Sign, Instructional** shall mean a sign conveying instructions with respect to the use of the premises which are reasonably related to, and necessary for, the intended use of the premises, for purposes of informing persons going onto the premises of matters relating to access and use, such as a sign designating the entrance to, or exit from a parking area, a trespassing sign, a danger sign, and/or any similar sign.

~~(430)~~(423) **Sign, Low-Profile** shall mean any single- or double-faced sign affixed to the ground, of which all the structural supporting members must be concealed.

~~(431)~~(424) **Sign, Off-Premise** shall mean a sign advertising goods or services not provided on the property upon which the sign is located.

~~(432)~~(425) **Sign, Real Estate** shall mean a sign advertising the sale, rental, or lease of the premises on which it is maintained.

~~(433)~~(426) **Sign, Temporary** shall mean any sign intended and used for temporary public notification and/or promotion of activities which generally include, but are not limited to: open houses, public benefits, grand openings, special sales/promotions, development projects (project signs), and similar activities of a temporary nature.

~~(434)~~(427) **Site Plan** shall mean the proposed layout of a lot showing all elements of the site development as well as utility and drainage lines, and existing and proposed buildings, structures, trees, and vegetation.

~~(435)~~(428) **Site Specific Development Plan** shall mean any of the following applications, if designated by the applicant as a site specific development plan for the establishment of vested property rights according to C.R.S. § 24-68-103, when approved by the city. The site-specific development plan shall describe with reasonable certainty the type and intensity of use proposed for a specific parcel or parcels of property. Site specific development plans include the following:

- (a) Final plats;

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-
- (b) Development plans; ~~or~~
 - (c) Final PUD development permits; or
 - (d) Approved Oil and Gas Permits.-

~~(436)~~(429) **Small cell** shall include “small cell facility” and shall be defined by C.R.S. 29-27-402(4) as currently exists and as may be amended from time to time.

~~(437)~~(430) **Small Wind Energy Conversion System (Windmill)** shall mean any mechanism, including blades, rotors, or other moving surfaces, designed for the purpose of converting wind energy into mechanical or electrical power. For purposes of this land development code, also included are towers, tower bases, guy wires, and any other structures necessary for installation of a small wind energy conversion system.

~~(438)~~(431) **Solar Energy Collection System** shall mean any mechanical device or structure used to collect, transfer, and/or store solar radiant energy generally including, but not limited to, the following: solar collectors, Trombe walls, greenhouses, or other devices, but not including south facing windows in which solar radiant energy does not reach an acceptable storage medium.

~~(439)~~(432) **Solid Waste** shall mean any garbage, refuse, or sludge from a waste treatment plant, water supply treatment plant, air pollution control facility, or other discarded material; including solid, liquid, semisolid, or contained gaseous material resulting from industrial operations, commercial operations, or community activities. Solid waste does not include any solid or dissolved materials in domestic sewage, or agricultural wastes, or solid or dissolved materials in irrigation return flows, or industrial discharges which are point sources subject to permits under the provisions of the Colorado Water Quality Control Act, Title 25, Article 8, C.R.S. or materials handled at facilities licensed pursuant to the provisions on Radiation Control Act in Title 25, Article 11, C.R.S. Solid Waste does not include: (1) materials handles at facilities licensed pursuant to the provisions on radiation control in Article 11 of Title 25, C.R.S.; (2) excluded scrap metal that is being recycled; or (3) shredded circuit boards that are being recycled.

~~(440)~~(433) **Solid Waste Disposal** shall mean the storage, treatment, utilization, processing, or final disposal of solid wastes.

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~~(441)~~(434) **Solid Waste Disposal Site** shall mean the location at which the deposit and final treatment of solid wastes occur.

~~(442)~~(435) **Special Flood Hazard Area** shall mean that area designated on the flood insurance rate map as subject to a one percent or greater chance of flooding in any given year.

~~(443)~~(436) **Stabilization** shall mean the use of practices that prevent exposed soil from eroding.

~~(444)~~(437) **Standard Zoning Districts** shall mean the following zoning districts, and shall be collectively referred to as standard zoning districts.

- (a) AG
- (b) R-1
- (c) R-2
- (d) R-3
- (e) R-4
- (f) R-U
- (g) C-1
- (h) C-2
- (i) C-3
- (j) MU-1
- (k) I-1
- (l) I-1S
- (m) I-2
- (n) I-3
- (o) PUBLIC

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(p) MHP

~~(445)~~(438) **Stone** shall mean any rock material that may fall under further sub-classification such as river rock, cobble, flagstone, boulders, and others contained in the Approved Plant List and Landscaping Specifications document. Any stone material used in landscape applications must be of at least 3/4-inch diameter or cross-section. Squeegee and road-base are not acceptable materials within the definition of stone.

~~(446)~~(439) **Storm Drainage System** shall mean facilities by which stormwater is collected or conveyed including, but not limited to, any roads with drainage systems, municipal streets, gutters, curbs, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainage channels, reservoirs, or other drainage structures.

~~(447)~~(440) **Stormwater** shall mean any runoff consisting entirely of water from any form of natural precipitation.

~~(448)~~(441) **Stormwater Management Plan (SWMP)** shall mean a document which described the best management practices and activities to be implemented by a person or business to identify sources of discharges to stormwater, stormwater conveyance systems and/or receiving waters to the maximum extent practicable.

~~(449)~~(442) **Street** shall mean a dedicated public or non-dedicated private thoroughfare that affords the principal means of access to abutting property.

~~(450)~~(443) **Structure** shall mean that which is built or constructed, an edifice or building of any kind, or any piece of work artificially built up or composed of parts joined together in some definite manner.

~~(451)~~(444) **Subdivision** shall mean the division by plat of a lot, tract, or parcel of land. The term shall also include and refer to any division of land subdivided or platted prior to the effective date of this land development code.

~~(452)~~(445) **Substance Abuse Treatment Facility, Inpatient Residential** shall mean structures and land used for the treatment of

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alcohol or other drug abuse where one or more patients are provided with care, meals, and lodging.

~~(453)~~(446) **Substance Abuse Treatment Facility, Outpatient Clinic** shall mean structures and land used for the treatment of alcohol or other drug abuse where neither meals nor lodging is provided.

~~(454)~~(447) **Substantial Improvement** shall mean any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the start of construction of the improvement. This term includes structures which have incurred substantial damage, regardless of the actual repair work performed. The term does not, however, include either:

(a) Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications identified by the building official and that are the minimum necessary to assure safe living conditions; or

(b) Any alteration of a historic structure, provide that the alteration will not preclude the structure's continued designation as a historic structure.

~~(455)~~(448) **Substation** shall mean any facility designed to provide switching, voltage transformation, or voltage control required for the transmission of electricity at 115 kilovolts or more, and any addition thereto increasing the existing design capacity.

~~(456)~~(449) **Subsurface Disposal Facility** shall mean a facility or system for disposing of water or other oil field wastes into a subsurface reservoir or reservoirs.

~~(457)~~(450) **Surety** shall mean any form of security including cash deposit, surety bond, property, or instrument of credit in an amount and form satisfactory to the ~~Director~~Director.

(451) Surface Owner shall mean any person owning all or part of the surface of land upon which surface oil and gas operations are conducted, as shown by the tax records of the county in which the tract of land is situated, or any person with such rights under a recorded contract to purchase.

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~~(458)~~(452) **Surface Use Agreement** shall mean an agreement or contract between an Operator and the owner of real property addressing property interests or property use in relation to a specific location for a Well, Multi-Well Site, Production Facility, pipeline or any other Oil and Gas Facility.

~~(459)~~(453) **Survey Monument** shall mean metal pin monuments located in the ground at all points on streets, alleys, or boundary lines where there is a change in direction or curvature.

~~(460)~~(454) **Tank** shall mean, as it relates to Oil and Gas Operations, a stationary vessel that is used to contain fluids, constructed of non-earthen materials (e.g., concrete, steel, plastic) that provide structural support.

~~(461)~~(455) **Tasting Room** shall mean an area devoted to the sampling, and sales thereof, of wine or beer produced on or off premises.

~~(462)~~(456) **Telecommunication Facility** shall mean any facility established for the purpose of providing wireless transmission of voice, data, images or other information including but not limited to cellular telephone service, personal communication service, and paging service for any reason other than communicating with employees of that particular business. A telecommunication facility can consist of one or more antennas and telecommunication accessory equipment.

~~(463)~~(457) **Telecommunication Facility, Accessory Equipment** shall mean equipment, including buildings and cabinets, used to protect and enable operation of radio switching equipment, back-up power and other devices, but not including antennas that are necessary for the operation of a telecommunication facility.

~~(464)~~(458) **Telecommunication Facility, Concealed** shall mean any monopole or building mounted telecommunications facility that blends into the surrounding environment in a visually unobtrusive manner through disguise as a non-telecommunications structure or architectural feature.

~~(465)~~(459) **Temporary** shall mean a period of time under one year, unless otherwise specified in this land development code.

~~(466)~~(460) **Temporary Use** shall mean a use established for a fixed period of time with the intent to discontinue such use upon the expiration of the time period.

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~~(467)~~(461) **Tire Store** shall mean a business where the principal use is the sale or installation of new, used, or retread tires or tubes. Any land or structures with a primary or principal use of tire collection, reduction, or transfer shall not be considered a tire store.

~~(468)~~(462) **Tower** shall mean any structure that is designed and considered primarily for the purpose of supporting one or more antennas, including self-supporting lattice towers, guy towers, or monopole towers. The term includes radio and television transmission towers, microwave towers, common carrier towers, cellular telephone towers, alternative tower structures, and the like.

~~(469)~~(463) **Tower, Lattice** shall mean a tower or structure designed and constructed primarily to support antenna or antennas and comprised of interconnected poles, pipes, bars, beams, strips, wires or cross-members. A lattice tower shall include any type or form of tower that incorporates guy or supporting wires. A lattice tower is not a monopole tower.

~~(470)~~(464) **Towing services** shall mean the business of transporting, towing, or recovering with a wrecker, tow truck, rollback or car carrier any vehicle not owned by the operator of the wrecker, tow truck, rollback or car carrier for which the operator directly or indirectly receives compensation or other personal gain.

~~(471)~~(465) **Townhouse** shall mean a specific type of multi-family dwelling in which individual dwelling units are attached by one or more party walls, with the habitable spaces of different dwelling units arranged on a side-by-side, rather than a stacked, configuration. For the purposes of this land development code, a single-family attached dwelling is not considered a townhouse.

~~(472)~~(466) **Tractor Trailer** shall mean the vehicle formed by combining a trailer and a truck-tractor.

~~(473)~~(467) **Tract** shall mean a unit of subdivided land not occupied or designed to be occupied by a primary building, such as open space or drainage.

~~(474)~~(468) **Trail** shall mean a publicly or privately owned or maintained trail/path system open to the public, intended for non-motorized transportation such as walking, jogging or biking, including trailheads.

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Trailheads may include parking lots, drinking fountains, restrooms, picnic shelters, and related signage and monumentation.

~~(475)~~(469) **Trailer (including semi-trailers)** shall mean a non-motorized vehicle that is pulled by a motorized vehicle for the purpose of transporting equipment, commodities, or for similar purposes.

~~(476)~~(470) **Transfer Facility** shall mean a facility or site at which the exchange or deposit of material is made for ultimate transfer and disposal elsewhere.

~~(477)~~(471) **Transportation Terminals** shall mean a facility for the receipt, transfer, short-term storage, and dispatching of goods transported by truck. Unlike Distribution Centers, these establishments commonly utilize a cross-dock facility and may also include the accessory uses of warehouse, storage or parking or trucks awaiting cargo, as well as facilities for the light servicing of trucks. Included in this definition would be express and other mail and package distribution facilities, including such facilities operated by the U.S. Postal Service, other than a traditional post office.

~~(478)~~(472) **Treatment Facilities** shall mean, as it relates to Oil and Gas Operations, any plant, equipment or other works used for the purposes of treating, separating or stabilizing any substance produced from a well.

~~(479)~~(473) **Tree Lawn** shall mean a landscaped strip of land located between the curb line, or lateral line of the roadway, and the front edge of a sidewalk.

~~(480)~~(474) **Truck** shall mean a motorized vehicle of greater than one-ton carrying capacity with two or more axles, including tractor-trailer combinations and buses; or any vehicle equipped with a body designed to carry property over the public highways and generally and commonly used for such transport of cargo rather than passengers. This term shall also include truck-tractors, trailers, semitrailers when used in combination, but excludes two-axle, four-tired vehicles that may be classified as a truck for registration purposes, but which have operating characteristics similar to those of a passenger car.

~~(481)~~(475) **Truck Repair** shall mean the process or operation of repairing trucks, including major work on engines or transmissions.

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~~(482)~~(476) **Truck Stop** shall mean any property on which a business involving the maintenance, servicing, storage or repair of commercial vehicles of greater than 15,000 gross vehicle weight (GVW) is conducted, including the dispensing of motor fuel or other petroleum products directly into motor vehicles; and the sale of accessories or equipment for such commercial vehicles. A truck stop may also include overnight accommodations and restaurant facilities.

~~(483)~~(477) **Truck, Trailer Sales and Service** shall mean an establishment or area for the purpose of trailer and truck sales, service, and repair.

~~(484)~~(478) **Truck-Tractors** shall mean a motorized vehicle with two or more axles that is used to pull a trailer for purposes of carrying property over the public highways and generally and commonly used for such transport of cargo rather than passengers. Truck-tractors may be operated in combination with, or separate from, a trailer.

~~(485)~~(479) **Turf-Grass** shall mean those types of grasses that do not grow in clumps but, rather, spread naturally to form a continuous sod mat. Such are the grasses customarily used in lawn applications, typically available commercially in sod form, being tolerant of foot traffic, and presenting a finished, maintained appearance with proper care.

~~(486)~~

~~(487)~~(480) **Underlying Zone District** shall mean a base zone district that is affected by an overlay district.

~~(488)~~(481) **Unstable Materials** shall mean materials, other than explosives, which in the pure state or as commercially-produced will vigorously polymerize, decompose, condense, or become self-reactive and undergo other violent chemical changes, including explosion, when exposed to heat, friction or shock, or in the absence of an inhibitor or in the presence of contaminants or in contact with non-compatible materials.

~~(489)~~(482) **Use** shall mean any purpose for which a building or other structure or a tract of land may be designed, arranged, intended, maintained, or occupied; or any activity, occupation, business, or operation carried on or intended to be carried on in a building or other structure or on a tract of land.

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~~(490)~~(483) **Use-By-Permit** shall mean a use that does not qualify as a use-by-right on a particular piece of property but that the board of adjustment, in its discretion, approves or may approve in accordance with the terms of this land development code. Uses-by-permit are typically issued for uses that may have unique or widely varying operating characteristics, may have potential operational or other impacts on adjacent properties, or may have unusual site development demands.

~~(491)~~(484) **Use-By-Right** shall mean a use specifically permitted in a standard zoning district. As long as the use is carried on in the district in which it is characterized as a use-by-right, the use is not subject to discretionary review by the city and may be developed subject only to the conditions shown in the use table (section 21-5200) and a development plan review, if applicable.

~~(492)~~(485) **Use Variance** shall mean a variance authorizing the property to be used for a purpose prohibited by this land development code, as distinguished from a variance in lot area, yard size, building height, or other dimensional bulk requirements. Use variances are prohibited.

~~(493)~~(486) **Utility Lines** shall mean all electrical, communication, cable television wiring, coaxial, fiber optic, water, sewer, natural gas, or other such physical system connections.

~~(494)~~(487) **Vacation** shall mean the termination of or termination of interest in an easement, right-of-way, or public dedication of land.

~~(495)~~(488) **Variance** shall mean a deviation from specific standards contained in this land development code.

~~(496)~~(489) **Vehicle/Equipment Sales and Rentals** shall mean repair of automobiles, trucks, motorcycles, mobile homes, recreational vehicles, or boards, including the sale, installation, and servicing of related equipment and parts. This use includes auto repair shops, body and fender shops, wheel and brake shops, and tire sales and installation. This use excludes junk yards, vehicle dismantling or salvage, and tire retreading or recapping.

~~(497)~~(490) **Vehicle Repair, Major** shall mean the complete repair of automobiles, motorcycles, and light trucks that may include body repair, fender work, or engine repair. In no case shall major vehicle repair include repair of heavy equipment or trucks.

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~~(498)~~[\(491\)](#) **Vehicle Repair, Minor** shall mean the limited repair of automobiles, motorcycles, and light trucks that may include tune-ups, brakes, mufflers, automobile glass replacement, and other minor repair customarily done in service stations, but in no case shall minor vehicle repair include auto/truck body and fender work or repair of heavy equipment or trucks.

~~(499)~~[\(492\)](#) **Vehicle Storage** shall mean the storage of parking tow-aways, impound yards, and storage lots for automobiles, trucks, buses, and recreational vehicles. Vehicle storage includes only the storage of operable vehicles.

~~(500)~~[\(493\)](#) **Vertical Growing Structure** shall mean a permanent structure used to encourage the vertical growing of plants. Traditional examples include arbors and trellis.

~~(501)~~[\(494\)](#) **Vested Property Rights** shall mean the right to undertake and complete the development and use of property under the terms and conditions of a site specific development plan.

~~(502)~~[\(495\)](#) **Veterinarian Clinic or Office** shall mean an establishment that provides medical treatment and care to animals, and which may include temporary or overnight boarding of animals that are recuperating from treatment.

~~(503)~~[\(496\)](#) **Wastewater** shall mean any water or other liquid, other than uncontaminated stormwater, discharged from a facility.

~~(504)~~[\(497\)](#) **Watchman's Quarters, Night** shall mean a dwelling unit located on the same premises as a principal use, which unit is occupied or intended for occupancy by a caretaker employee or owner of said establishment.

~~(505)~~[\(498\)](#) **Water Bodies** shall mean reservoirs, lakes, perennial or seasonally flowing rivers, streams, creeks, springs, irrigation ditches, aquifers, and wetlands.

~~(506)~~[\(499\)](#) **Watercourse** shall mean any body of water, including but not limited to lakes, ponds, rivers, streams, and bodies of water delineated by the city.

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~~(507)~~(500) **Water Surface Elevation** shall mean the height, in relation to the North American Vertical Datum (NAVD) of 1988 (or other datum, where specified), of floods of various magnitudes and frequencies in the floodplains of coastal or riverine areas.

~~(508)~~(501) **Waterway** shall mean a channel that directs surface runoff to a watercourse or to the public storm drain.

~~(509)~~(502) **Weed** shall mean any herbaceous plant which, due to height, smell, appearance, or injurious nature, has a blighting influence.

~~(510)~~(503) **Welding or Machine Shop** shall mean a workshop where machines, machine parts, or other metal products are fabricated. Typical uses include machine shops, welding shops, and sheet metal shops.

~~(511)~~(504) **Well** shall mean, as it relates to Oil and Gas Operations, an Oil or Gas well for purposes of exploration and production.

~~(512)~~(505) **Well Site** shall mean, as it relates to Oil and Gas Operations, a definable area where an Operator has disturbed or intends to disturb the land surface in order to locate an Oil and Gas well facility, and includes a Production Site.

~~(513)~~(506) **Wetlands** shall mean those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

~~(514)~~(507) **Wholesale Establishments** shall mean a use engaged in enclosed wholesale of manufactured products, supplies, and equipment, including accessory offices and showrooms. Products may be picked up on-site or delivered to the customer. Other accessory uses may include product repair, parking, minor fabrication services, and repackaging of goods.

~~(515)~~(508) **Winery** shall mean an establishment that manufactures vinous liquors which may include a restaurant or samples venue that sells the winery's products, including retail sales.

~~(516)~~(509) **Xeriscape** shall mean water conservation through creative landscape design that reduces water consumption, landscape

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maintenance and the use of fertilizers and pesticides. Principles associated with xeriscaping include appropriate planning and design, soil improvements, efficient irrigation, practical turf areas, appropriate plant selection, use of mulches and maintenance.

~~(517)~~(510) **Yard** shall mean a space on the same lot or lots with a principal building, open, unoccupied and unobstructed by buildings or structures from the ground to the sky

~~(518)~~(511) **Yard, Front** shall mean a yard extending across the full width of a lot and between the front lot line and the nearest wall of any principal building on the lot.

~~(519)~~(512) **Yard, Rear** shall mean a yard extending across the full width of a lot and between the rear lot line and nearest wall of any principal building on the lot.

~~(520)~~(513) **Yard, Side** shall mean a yard extending between the front yard and the rear yard and between a side lot line and the nearest main wall of any principal building on the lot.

~~(521)~~(514) **Yard Sale** shall mean an infrequent sale of used goods and material occurring on a residential yard or in a residential garage. This term shall also include that which is known as a garage sale or estate sale.

~~(522)~~(515) **Zoning District** shall mean an area or areas within the limits of the city for which the regulations and requirements governing use, lot, and bulk of building and premises are uniform.

~~(523)~~(516) **6409(a) Facility** shall mean any telecommunication facility associated with an eligible facilities request for a modification of an existing wireless tower or base station that does not substantially change the physical dimensions of such tower or base station pursuant to section 6409(a) of the Spectrum Act, as that section is interpreted, applied, or revised in accordance with federal law.

Section amended by Ord. 1785, June 2010

Section amended by Ord. 1854, April 2011

Section amended by Ord. 1887, July 2012

Section amended by Ord. 1897, July 2012

Section amended by Ord. 1891, August 2012

Section amended by Ord. 1948, April 2013

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Section amended by Ord. 1992, March 2014
Section amended by Ord. 2020, February 2015
Section amended by Ord. 2048, June 2015
Section amended by Ord. 2068, January 2016
Section amended by Ord. 2078, April 2016
Section amended by Ord. 2158, December 2018
Section amended by Ord. 2186, December 2018
Section amended by Ord. 2190, December 2018
Section amended by Ord. 2203, May 2019

EXHIBIT I TO ORDINANCE ~~2235~~2266

(Underlined text indicates new material;
strikethrough text indicates deletions.)

BEST MANAGEMENT PRACTICES FOR
NEW ~~WELL SITES~~Oil and Gas Locations IN COMMERCE CITY
("BMP Document")

A. Introduction.

1. This BMP Document, and each Best Management Practice (each, a "BMP"), are enacted by the City Council of the City of Commerce City ("City") pursuant to the authority established in Section 21-3216 of the City's Land Development Code ("LDC") and any enabling ordinance and amending ordinance and shall be enforced as set forth in the LDC, such ordinances, and the Commerce City Revised Municipal Code ("Code"). This BMP Document and each BMP is reasonable and necessary to achieve the purposes stated herein.
2. This BMP Document, and each BMP, is enacted to protect public health, safety, and welfare and the environment by regulating specific areas of oil and gas operations within the City. These BMPs establish **minimum** standards and may be exceeded voluntarily or as determined by the City in the processing of an Oil and Gas Permit, depending on the nature of the proposed Operations and location. Notwithstanding the foregoing, an Operator may be granted a variance or waiver for individual BMPs pursuant to the processes set forth in this Code.
3. Where used in this BMP Document, the term "practicable" shall mean, ~~in the Director's opinion~~, that: (a) there is no technology reasonably and comomercially available to conduct the proposed Operations in compliance with the BMP and waiver of the provision will not have a significant adverse effect on public health, safety, welfare, or the environment; (b) an alternative approach not contemplated by the BMP is demonstrated to provide a level of protection of public health, safety, welfare, and the environment that would be at least equivalent to the BMP; or (c) application of the BMP would

Commented [BHFS43]: Requiring an operator to comply with BMPs adopted after the fact is extremely problematic and raises impairment of vested rights issues.

Commented [BHFS44]: Basis for this recital? Proclaiming the BMPs necessary and reasonable do not make them necessary and reasonable as a matter of law.

Commented [BHFS45]: This must be an objective determination based in fact.

create an undue hardship because of unique physical circumstances or conditions existing on or near the site of the Oil and Gas Facility, which may include without limitation topographical conditions, shape or dimension of the site, or inadequate public infrastructure, provided adequate protection of public health, safety, welfare, and the environment will be ensured through other means. ~~Except where the term "practicable" is used, modifications of these BMPs shall not be permitted.~~

4. All terms used herein shall have the meaning set forth in the LDC, the Code, unless a different definition is stated in this document; otherwise, terms and abbreviations shall have their generally-accepted meaning as determined by reference to industry and regulatory standards.
5. Each BMP is an integral part of this BMP Document and the City's regulations of oil and gas development. Notwithstanding the foregoing, if any BMP or a part thereof (or any application thereof) is found to be invalid by a court, such invalidity shall not affect the remaining parts of the BMP or this BMP Document which can be given effect without the invalid portion or application, provided such remaining portions or applications are not determining by the court to be inoperable. To this end, BMPs are declared to be severable.

B. Summary of Revisions. [Reserved]

C. Air Quality. Operator shall comply with these air quality standards to: protect human health and safety; prevent injury to plant and animal life; prevent damage to property; prevent unreasonable interference with the public welfare; preserve visibility; and protect scenic, aesthetic, and historic values in the City. These standards are established to prevent or mitigate the degradation of the City's air and visibility resource; prevent odors and other air pollution problems; and to improve the quality of life and the general welfare in the City.

1. Minimization of Emissions.

- a. Operator shall use electric equipment for permanent production equipment, such as electric compressors and pneumatic valves, and use line power as detailed in this BMP Document.

Commented [BHFS46]: Line power may not be available.

- b. Air emissions from the Operations shall be, at a minimum, in compliance with the permit and control provisions of the Colorado Air Quality Control Program, C.R.S. § 25-7-101 et seq. as may be amended.
- c. All fossil-fuel powered engines used for drilling and completions ~~on Well Sites~~ shall employ the latest emission-reduction technologies that are economically practicable. However, if a new technology emerges after drilling and completions have commenced, an Operator shall not be required to retrofit the existed engines.
- d. Operator shall comply with the transportation and circulation section addressing traffic provisions as detailed in this BMP Document.
- e. If required to utilize Pipelines, Operator shall utilize pipelines as detailed in this BMP Document.
- f. Operator shall, through a manufacture-test or other recognized data analysis method, demonstrate hydrocarbon destruction or control efficiency that complies with a design destruction efficiency of 98% or better.
- g. Operator shall use ~~low~~~~no~~-bleed continuous and intermittent pneumatic devices. This requirement can be met by replacing natural gas with electricity or instrument air, or routing the discharge emissions to a closed loop-system or process.
- h. Any flare, auto ignition system, recorder, vapor recovery device or other equipment used to meet the hydrocarbon destruction or control efficiency requirement shall be installed, calibrated, operated, and maintained in accordance with the manufacturer's recommendations, instructions, and operating manuals.
- i. Operators shall not use glycol dehydrators or desiccant gas processing dehydrators.

- j. Compressor engines are prohibited within the City limits except for wellhead, sales, and gas lift compressors, air and/or gas gathering compressors which shall be located on the ~~Well-Sites~~Oil and Gas Locations. Operator shall use enclosures of compressor engines where necessary to provide visual and/or noise mitigation. Any compressors that are used as part of the vapor recovery units (air pollution controls) will be limited to 6-8 small engine drive units. VRU compressors will be installed with sound walls to buffer noise.
- k. Operator shall comply with odor requirements, as established by COGCC and CDPHE regulations, year round.
- l. Operator's ~~Well-Site~~Oil and Gas Location and equipment design shall reduce emissions of associated gas from hybrid gas-oil wells (i.e., gas that is co-produced from a well that primarily produces oil).
- m. Operator shall use current best management practices during liquids unloading (i.e. maintenance activities to remove liquids from existing wells that are inhibiting production), designed to minimize hydrocarbon emissions to the greatest extent practicable. This may require practices and technology beyond those specifically listed in this BMP Document.
- n. Operator shall reduce emissions from oil and gas pipeline maintenance activities such as pigging or blowdowns. Any maintenance activity involving the intentional venting of gas from a well tank, compressor or pipeline, beyond routine pipeline maintenance activity and pigging or during upset conditions, requires forty eight (48) hour advance written notice to the City of such proposed venting. Such notice shall identify the duration and nature of the venting event, a description as to why venting is necessary, a description of what vapors will likely be vented, what steps will be taken to limit the duration of venting, and what steps Operator

proposes to undertake to minimize similar events in the future. If venting is required, or if accidental venting occurs, Operator shall provide such notice to the City of such event as soon as possible, but in no event longer than 24 hours from the beginning of the event, including without limitation the information listed above, an explanation as to the cause, and how the event will be avoided in the future; notices shall be supplemented as additional information becomes available.

- o. Capture of Produced Gas from Wells. Operator shall eliminate ~~or minimize~~ flaring and venting, unless necessary to protect health, safety and general welfare or necessary because of upset conditions or other conditions beyond an Operator's reasonable control. Gas produced during normal production shall be captured, to the maximum extent practicable, and not flared or vented, except in situations where ~~flaring or venting is required to ensure that associated natural gas can be safely disposed of in emergency shutdown situations~~ or other situations beyond an Operator's reasonable control.
- p. Operator shall comply with dust suppression techniques in this BMP Document.
- q. Operator shall comply with odor requirements in this BMP Document.
- ~~r. d.~~ Operator shall consolidate product treatment and storage facilities within an Oil and Gas Location-unless such consolidation expands the footprint of the Oil and Gas Location because it requires other equipment to be reconfigured. Well Site.
- ~~s. f.~~ Operator shall centralize compression facilities within an Oil and Gas Location unless such centralization expands the footprint of the Oil and Gas Location because it requires other equipment to be reconfigured. Well Site.

- ~~t~~s. Operator shall use telemetric control and monitoring systems, including surveillance monitors, to detect when pilot lights on control devices are extinguished.
- ~~u~~t. Operator shall comply with all CDPHE rules and regulations, including air permits, if any, and all OSHA work practice requirements with respect to benzene.
- ~~v~~u. Operator shall participate in Natural Gas STAR program or other equivalent voluntary programs to encourage innovation in pollution control at each Well Site.
- ~~w~~v. Operator shall use pressure-suitable separator and vapor recovery unit (VRU) where applicable.
- ~~x~~w. If applicable, Operator shall make best efforts to construct pipeline infrastructure prior to the Production Phase.
- ~~y~~x. For hydraulic fracturing pumps, Operator shall use ~~Tier 4 or better~~ Tier 4 or better engines.

Commented [BHFS47]: Tier 4 pumps are extremely scarce and not reasonably available.

2. Leak Detection and Repair.

- a. Operator shall develop and maintain an acceptable leak detection and repair ("LDAR") program as required by CDPHE using modern leak detection technologies such as infrared ("IR") cameras for equipment used at a ~~Well Site~~ Oil and Gas Location.
- b. At least once per year, the Operator shall notify the City ten (10) business days prior to an LDAR inspection of its facilities to provide the City the opportunity to observe the inspection.
- c. For a five (5) year period beginning with the start of the Production Phase ~~per well location at the~~ at each Well Site Oil and Gas Location having wells, Operator shall conduct quarterly IR camera monitoring of all equipment ~~at each Well Site.~~

- d. Thereafter, Operator shall conduct IR camera monitoring at least twice annually until all the wells on the ~~Well Site~~Oil and Gas Location are permanently plugged and abandoned.
 - e. Except when a circumstance would necessitate an immediate repair, Operator must repair leaks as soon as possible. If more than 48-hours repair time is needed after a leak is discovered, an explanation of why more time is required must be submitted to the City.
 - f. Operator ~~shall~~may be required to have redundancies in LDAR measures, including conducting continuous pressure monitoring to detect leaks.
3. Ambient Air Modeling. Operator shall provide access to the ~~Well Sites~~Oil and Gas Locations to the City's designated personnel or agent to allow air sampling to occur ~~, without condition,~~. Operator will provide a regionally based air modeling and emissions inventory.

Commented [BHFS48]: Conditions are likely necessary for the safety of the City's designated personnel or agent.

4.3. Ozone Air Quality Action Days.

- a. On Air Quality Action Day advisories posted by the CDPHE for the Front Range Area, the Operator shall implement CDPHE-suggested air emission reduction measures, including the following, for the duration of an Air Quality Action Day advisory:
 - i. Minimize vehicle and engine idling;
 - ii. Reduce truck traffic and worker traffic;
 - iii. Delay vehicle refueling;
 - iv. Suspend or delay use of fossil fuel powered ancillary equipment; and
 - v. Postpone construction activities, if practicable.
- b. Within 30 days following the conclusion of each annual Air Quality Action Day season, Operator must submit a

report to the City that details which measures it implemented during any Action Day advisories.

5.4. Electric Equipment.

- a. All permanent production equipment, such as compressors, motors and artificial lift equipment, shall utilize electric line power to mitigate noise and to reduce emissions.
- b. All drilling rigs capable of drilling to Total Depth (TD) on a well shall be required to utilize electric line power unless the Director waives this BMP in writing for a specific location or for any well ~~not located within 2000' of a Residential Building Unit or not within 2000' of a High Occupancy Structure.~~
- c. At any location where Operator is not required by this BMP to utilize line power for drilling, Operator will utilize line power if available in sufficient quantity from the utility provider.
- d. At any location where line power is not used for drilling, Operator shall provide to City at City's request the source(s) used for power.
- e. Operator shall minimize use of diesel generators for temporary power, including the use of liquified or compressed natural gas for power generation to further reduce emissions and noise.

6.5. Exhaust. The exhaust from all engines, motors, coolers and other mechanized equipment shall be vented up or in a direction away from the nearest occupied building.

7.6. *Flares and Combustion Devices.* To the extent flares, thermal oxidizers, or combustion devices are utilized, all such flares shall be designed and operated as follows:

- a. Flares shall be fired with natural gas and designed to operate with a 98% or higher hydrocarbon destruction efficiency.

- b. Flares shall be designed and operated in a manner that will ensure no visible emissions during normal operation. Visible emissions means observations of smoke for any period or periods of duration greater than or equal to one (1) minute in any fifteen (15) minute period during normal operation, pursuant to EPA Method 22. Visible emissions do not include radiant energy or water vapor.
- c. Flare shall be operated with a flame present at all times when emissions may be vented to it, or shall utilize another mechanism that does not allow uncontrolled emissions.
- d. All combustion devices must be equipped with an operating auto-igniter.

8.7. *Fugitive Dust.* Operator shall comply with the following:

- a. Silica dust must be contained to the maximum extent practicable during the hydraulic fracturing process.
- b. Dust associated with on-site activities and traffic on access roads shall be minimized throughout construction, drilling and operational activities such that there are no visible dust emissions from access roads or any ~~Well-Site~~Oil and Gas Location to the extent practical given wind and weather conditions, as well as conditions on properties neighboring the Oil and Gas Location.
- c. No untreated produced water or other process fluids shall be used for dust suppression.
- d. The Operator will not create dust or conduct dust suppression activities within 300' of the ordinary high water mark of any waterbody, unless the dust suppressant is water.
- e. ~~Material~~ Safety Data Sheets (~~M~~SDS) for any chemical-based dust suppressant, other than magnesium chloride, shall be submitted to the City prior to use.

- f. If a resident of a Residential Building Unit within 2000' of ~~a Well Site~~ an Oil and Gas Location makes a ~~complaint~~ complains of dust regarding dust (either directly to the Operator, ~~to the COGCC~~, or to the ~~City~~). ~~Operator the entity receiving the complaint shall verify the complaint to~~ determine whether the dust is caused by Operator's Operations. ~~If the complaint is verified, Operator shall the entity receiving the complaint shall~~ report its conclusions, including the factual basis for the conclusions, to the ~~complainant and to the City or Operator, whichever was not the recipient of the complaint.~~ ~~City and~~ the complainant. If the dust is caused by Operator's Operations, Operator shall resolve the dust concern to the maximum extent practicable within 24 hours.

Commented [BHFS49]: The City and Operator may not know of a complaint to the COGCC in a timely fashion and the threat may not be credible.

9.8. Odor Containment.

- a. Operator shall control and prevent odors from Operations from affecting adjacent properties and shall proactively address and, to the extent possible, resolve complaints filed by impacted members of the community.
- ~~b. Operator shall use a filtration system or additives to the drilling and fracturing fluids to minimize odors.~~
- ~~c. Operator shall not use fragrance to mask odors.~~
- ~~d. Operator shall implement one or more of the following measures as necessary:~~
- ~~i. Running mud through a cooler to reduce odor;~~
- ~~ii. Wiping down the drill pipe each time that the drilling operation "trips" out of the hole;~~
- ~~iii. Increase additive concentration;~~
- ~~iv. Operator will employ the use of drilling fluid with low to negligible aromatic content during drilling~~

Commented [BHFS50]: As recognized by the COGCC, odor mitigation will necessarily vary on a site-by-site basis. COGA adds that as technology changes, so, too, will the best management practices. Because of the above, COGA believes the City should not create a list of potential BMPs that may not be BMPs in one-year, three years, or five years. Rather, the specific list be removed and replaced with a statement that appropriate BMPs to address odor will be implemented.

~~operations after surface casing is set for the protection of fresh water aquifers;~~

~~v. Operator will haul drill cuttings off on a daily basis; and~~

~~vi. Utilizing an electric drilling rig, where practicable.~~

- e. If a resident of a Residential Building Unit within 2000' of an ~~Oil and Gas Location-Well Site~~ complains of odor ~~.(either directly to the Operator, to the COGCC, or to the City)~~ the entity receiving the Complaint ~~Operator shall verify the Complaint to~~ determine whether the odor is caused by Operator's Operations. ~~Operator~~ If the complaint is verified, the entity receiving the complaint shall report its conclusions, including the factual basis for the conclusions, to ~~the City and~~ the complainant and to the City or Operator, whichever was not the recipient of the complaint. If the odor is caused by Operator's Operations, Operator shall resolve the odor concern to the maximum extent practicable within 24 hours.

10.9. *Reduced Emission Completions (Green Completions).*

- a. Operator shall employ reduced emission completions ("Green Completions") in compliance with federal and state requirements.
- b. Operator shall safely maximize resource recovery and minimize releases to the atmosphere during flowback and subsequent recovery/operation.
- c. Operator shall install ~~gas gathering lines,~~ separators, and sand traps capable of supporting green completions, per the provisions of COGCC ~~Rules 805,~~ as may be amended.
- d. Operator shall comply with 40 CFR 60 (Subpart OOOO), as may be amended, for green completions.

Commented [BHFS51]: COGCC doesn't regulate gas gathering lines and COGC Rule numbers are changing due to the pending Mission Change rulemaking.

- e. Operator shall not conduct or permit uncontrolled venting other than where necessary for safety.
- f. If allowed, temporary flowback flaring and oxidizing equipment shall include the following:
 - i. Adequately sized equipment to handle 1.5 times the largest flowback volume of gas from a vertical/directional and/or horizontally completed well respectively as reported to the COGCC in a ten mile radius;
 - ii. Valves and porting available to divert gas to flaring and oxidizing equipment; pursuant to the above Rules 40 CFR 60 (Subpart OOOO) for green completions & COGCC Rule 805, as each may be amended;
 - iii. Auxiliary fueled with sufficient supply and heat to combust or oxidize non-combustible gases in order to control odors and hazardous gases; and
 - iv. Flowback combustion devices shall be equipped with a reliable continuous ignition source over the duration of flowback, except in conditions that may result in a fire hazard or explosion.

~~11-10~~10. *Annual Report.*

- a. The Operator shall submit annual reports to the Director certifying:
 - i. Compliance with these air quality requirements unless demonstrated to be inapplicable and documenting any periods of material non-compliance, including the date and duration of each such deviation and a compliance plan and schedule to achieve compliance;
 - ii. That the equipment at each ~~Well Site~~Oil and Gas Location continues to operate within its design parameters, and if not, what steps will be taken to

modify the equipment to enable the equipment to operate within its design parameters;

- iii. The accuracy and completeness of the report, signed by a responsible corporate official.
- b. Operator may satisfy this reporting obligation, in whole or in part, by submitting its AQCC Regulations No. 7 annual reports for the prior calendar year to the City, and supplementing them as needed to meet these reporting requirements for covered facilities within the City.
- c. The Operator will also provide the City will a copy of any self-reporting submissions that Operator provides to the CDPHE due to any incidence of non-compliance with any CDPHE air quality rules or regulations at any Well Site.

D. Water Quality Protection. Operator shall comply with these water quality protection standards to: protect human health and safety; prevent injury to plant and animal life; prevent damage to property; prevent unreasonable interference with the public welfare; and to protect water quality. These standards are established to prevent or mitigate the degradation of the City's water resources; prevent odors and other pollution problems; and to improve the quality of life and the general welfare in the City.

1. Chemical Disclosure.

- a. ~~Prior to utilizing~~Before transporting fracturing chemicals ~~onto an Oil and Gas Locatino-Well Site~~, the Operator shall submit to the City, in table format, the name, Chemical Abstracts Service (CAS) number, storage, containment and disposal method for all such chemicals. ~~The identification of such chemicals shall not be considered confidential or proprietary and the City may make the same available to the public as public records.~~
- b. Fracturing chemicals used at any ~~Well Site~~Oil and Gas Location shall be uploaded onto the Frac Focus website

Commented [BHF552]: By its nature, this information can be confidential and proprietary. If knowledge of the specific chemicals is needed due to a significant release or medical reason, the information can be shared with those who have an actual need for the information.

within sixty days of the completion of fracturing operations.

2. Chemical Storage & Prohibitions.
 - a. Operator shall not permanently store fracturing chemicals, flowback from hydraulic fracturing, or produced water in the City limits.
 - b. Operator shall remove all hydraulic fracturing chemicals from a Well Site within thirty (30) days following the completing of hydraulic fracturing at that Well Site.
 - c. In addition to any substances that are not permitted to be used in accordance with state or federal rules or regulations, as may be amended, the chemicals listed in Table 1 shall not be utilized in hydraulic fracturing fluid at any Well Site in the City.

TABLE 1

Ingredient Name	CAS #
Benzene	71-43-2
Lead	7439-92-1
Mercury	7439-97-6
Arsenic	740-38-2
Cadmium	7440-43-9
Chromium	7440-47-3
Ethylbenzene	100-41-4
Xylene-F	1330-20-7
1,3,5-trimethylbenzene	108-67-8
1,4-dioxane	123-91-1
1-butanol	71-36-3
2-butoxyethanol	111-76-2
N,N-dimethylformamide	68-12-2
2-ethylhexanol	104-76-7
2-mercaptoethanol	60-24-2
benzene, 1,1'-oxybis-, tetrapropylene derivatives,	119345-04-9
butyl glycidyl ether	8/6/2426

Ingredient Name	CAS #
polysorbate 80	9005-65-6
quaternary ammonium compounds, dicoco	61789-77-3
tris hexamethylene triamine penta methylene phosphonic	35657-77-3
diethylenetriamine penta (methylene- phosphonic	15827-60-8
FD&C blue no. 1	3844-45-9
Tetrakis(triethanolaminate) zirconium(IV)	101033-44-7

3. *Closed-Loop Pitless Systems for the Containment and/or Recycling of Drilling Fluids.*
 - a. Wells shall be drilled, completed and operated using closed-loop pitless systems for containment and/or recycling of all drilling, completion, flowback and produced fluids.
 - b. Operator shall recycle fluids to the maximum extent practicable, with the understanding that Operator is limited in its ability to recycle all fluids, as doing so would necessitate the use of permanent tanks, which is otherwise prohibited, and result in the potential for additional emissions.
4. *Containment Berms.*
 - a. Operator shall utilize steel-rim berms (or similar material of comparable durability, designed and installed to prevent leakage and resist degradation from erosion or routine operation) around all permanent separation and storage equipment at the Well Sites with sufficient capacity to contain 1.5 times the maximum volume of liquids that such equipment will contain at any given time plus sufficient freeboard to prevent overflow.
 - b. All berms and containment devices shall be inspected quarterly by Operator and maintained in good condition.

- c. Secondary containment, such as duck ponds or lined earthen berms for temporary tanks, shall be used.
 - d. Secondary containment shall be constructed with a synthetic or engineered liner that contains all primary containment vessels and is mechanically connected to the steel ring to prevent leakage.
 - e. No potential ignition sources shall be installed inside the secondary containment area unless the containment area encloses a fired vessel or such sources are rated in accordance with industry codes and standards.
 - f. For locations within 500' and up-gradient of a surface water body, tertiary containment, such as an earthen berm, is required around respective production facilities.
5. *Spill Response Kits.* Operator shall make available at each ~~Well Site~~Oil and Gas Location, or require to be carried by field staff or contractors, Spill Response Kits capable of mitigating small to mid-size spills (e.g., 5 to 50 gallons).
6. *Maintenance of Machinery.*
- a. Operator shall not conduct vehicle maintenance at any ~~Well Site~~Oil and Gas Location.
 - b. Operator shall not conduct routine field maintenance of mobile machinery within 300' of any water body as defined by LDC.
 - c. All fueling must occur over impervious material.
7. *Spills.*
- a. Operator shall notify the City and South Adams County Water and Sanitation District ("SACWSD") of spills at any ~~Well Site~~Oil and Gas Location that has a reportable spill quantity under any law.

- b. Operator shall provide the City with a copy of any self-reporting submissions that Operator provides to the COGCC due to any spills at any Well Site.
8. *Stormwater.* All Operations shall comply and conform to the City's stormwater control regulations.
9. *Water Quality Monitoring Plan.*
- a. Operations shall not cause degradation to surface or ground water within the City or to wetlands within the City.
 - b. Any approved variance to COGCC rules and regulations relating to the same matters shall be reported to the City and shall modify these requirements.
 - c. Using records of the Colorado Division of Water Resources, Operator must implement a water quality monitoring plan that includes the following:
 - i. Operator must obtain initial baseline samples and subsequent monitoring samples from ~~all at least~~ four (4) known, available potable water sources within a one-half (1/2) mile radius of the ~~Well Sites~~ Oil and Gas Locations. The Operator will notify the City of any private landowners who do not consent to such testing. Potable water sources include registered water wells or permitted or adjudicated springs. Where a potable water source is privately owned and the owner refuses to allow Operator access to that source, the Operator shall be exempt from collecting samples from that water source.
 - ii. Operator must collect initial testing of baseline samples from at least four (4) known, ~~all~~-available water sources prior to the commencement of drilling a well, or prior to the re-stimulation of an existing well for which no samples were collected and tested during the previous 6-12 months

Commented [BHF553]: This can likely be an automatic push from the COGCC to the City. In any instance where such automation is possible, COGA recommends the City request notice from the COGCC but does not impose an additional, duplicative burden on the Operator.

except from water sources specifically exempted in this BMP Document.

- iii. Post-stimulation samples of all ~~available~~those same water sources (unless specifically exempted by this BMP Document) shall be collected and tested pursuant to the following time frame:
 - a) One sample approximately one (1) year after commencement of the Production Phase;
 - b) One sample approximately five (5) years after commencement of the Production Phase; and
- iv. Operator shall collect a sample from at least one upgradient and two down-gradient water sources within a one-half (1/2) mile radius of ~~an Oil and Gas Location-Well Site~~. If no such water sources are available, Operator shall collect samples from additional water sources within a radius of up to one (1) mile from the ~~Oil and Gas Well Site~~ until samples from a total of at least one upgradient and two down-gradient water sources are collected. Operator should give priority to the selection of water sources closest to the ~~Oil and Gas Well Site~~.
- v. Operator may rely on existing groundwater sampling data from any water source within the radii described above that was collected in accordance with accepted standards, provided the data was collected within the 12 months preceding the commencement of Drilling Phase for such ~~Oil and Gas Well Site~~, the data includes measurement of all of the constituents measured in Table 2 below and there has been no significant oil and gas activity within a ~~one-half~~ mile radius in the time period between the original

sampling and the commencement of the Drilling Phase for such Well Site.

- vi. Operator shall make reasonable efforts to obtain the consent of the owner of the water source. If the Operator is unable to locate and obtain permission of the water source, the Operator must advise the City that Operator could not obtain access to the water source from the surface owner.
- vii. Testing for the analytes listed in Table 2 below, and subsequent testing as necessary or appropriate.
- viii. Operator shall follow standard industry procedures in collecting samples, consistent with the COGCC model Sampling and Analysis Plan.
- ix. Operator shall report the location of the water source using a GPS with submeter resolution.
- x. Operator shall report results of field observations including reporting on damaged or unsanitary well conditions, adjacent potential pollution sources, odor, water color, sediment, bubbles, and effervescence.
- xi. Operator shall provide copies of all test results to the City, the COGCC, and the water source owners within 30 days after receiving the sample resultss.
- xii. Subsequent sampling. If sampling shows water contamination, additional measures shall be required including:
 - a) If free gas or a dissolved methane concentration level greater than one (1) milligram per liter (mg/l) is detected in a water source, determination of the gas type using gas compositional analysis

- and stable isotope analysis of the methane (carbon and hydrogen).
- b) If the test results indicate thermogenic or a mixture of thermogenic and biogenic gas, an action plan to determine the source of the gas.
 - c) Immediate notification to the City, the COGCC, and the owner of the water well if the methane concentration increases by more than five (5) mg/l between sampling periods, or increases to more than ten (10) mg/l.
 - d) Immediate notification to the City, the COGCC and the owner of the water well if BTEX and/or TPH are detected as a result of testing. Such detections may result in required subsequent sampling for additional analytes.
 - e) Further water well sampling in response to complaints from water source owners.
 - f) Timely production and distribution of test results in electronic deliverable format to the City, the COGCC and the water source owners.
 - g) Qualified Independent Professional Consultant. All subsequent water source testing must be conducted by a qualified independent professional consultant.

TABLE 2

GENERAL WATER QUALITY

Alkalinity, Conductivity & TDS, pH, Dissolved Organic Carbon (or Total Organic Carbon), Bacteria, Perfluorinated Compounds (PFCs), and Hydrogen Sulfide

MAJOR IONS

Bromide, Chloride, Fluoride, Magnesium, Potassium, Sodium, Sulfate, and Nitrate + Nitrite as N

METALS

Arsenic, Barium, Boron, Chromium, Copper, Iron, Lead, Manganese, Selenium, Strontium, Mercury, Uranium, and Radium

DISSOLVED GASES and VOLATILE ORGANIC COMPOUNDS

Methane, Ethane, Propane, BTEX as Benzene, Toluene, Ethylbenzene and Xylenes, Total Petroleum, and Hydrocarbons (TPH)

OTHER

Water Level, Stable isotopes of water (Oxygen, Hydrogen, Carbon), Phosphorus.

10. *Wastewater and Waste Management.*

- a. Operator shall implement a Waste Management Plan to the City that complies with the following:
 - i. All fluids shall be contained and there shall be no unauthorized discharge of fluids.
 - ii. Wastewater shall be stored in tanks, transported by tanker trucks and/or pipelines, and disposed of at licensed disposal or recycling sites in accordance with applicable law.
 - iii. Operator shall not dispose of any wastewater within the City.
 - iv. All other waste shall be disposed of in accordance with state regulations.

- v. The plan shall incorporate secondary containment and stormwater measures consistent with this BMP Document.
 - vi. No land treatment of oil impacted or contaminated drill cuttings are permitted.
 - b. A copy of the Operator's Spill Prevention, Control, and Countermeasure Plan (SPCC) describing spill prevention and mitigation practices will be given to the City.
11. *Well Integrity.*
- a. Operator shall equip the bradenhead access to the annulus between the production and the surface casing, as well as any intermediate casing, with a fitting to allow safe and convenient determinations of pressure and fluid flow.
 - b. Valves used for annular pressure monitoring shall remain exposed and not buried to allow for visual inspection.
 - c. Operator shall take bradenhead pressure readings as required by the COGCC.
12. *Wetlands Protection Plan.* If applicable, Operator shall implement a Wetlands Protection Plan demonstrating the oil and gas operations shall, to the maximum extent practicable, avoid causing degradation to wetlands with Commerce City. Among other methods to achieve compliance with this standard, the proposed oil and gas operation shall not negatively alter historic drainage patterns and/or flow rates or shall include acceptable mitigation measures to compensate for anticipated drainage impacts.
13. *Water Supply.*
- a. Operator shall comply with applicable State of Colorado, Department of Natural Resources and other applicable

State regulations concerning the source(s) of water used in the Drilling Phase and Completions Phase.

- b. Operator shall notify the City, upon its request, of the source(s) of water to be used at ~~Well Sites~~Oil and Gas Locations during the Drilling Phase and Completion Phase and will provide the City with an estimate of the volumes of water to be utilized, with such estimates subject to change.
- c. All water volumes actually used by Operator shall be reported by the Operator to the State of Colorado in accordance with its regulations.
- d. ~~All fresh water for hydraulic fracturing shall be transported to the Well Sites by means other than by truck, unless the Operator provides notice after demonstration of extenuating circumstances which will short amount of time seven days or less. If the transportation of water by means other than truck exceeds seven (7) days the operator will seek any necessary amendments to the Oil and Gas Permit.~~

E. Safety. Operator shall comply with these safety standards to: protect human health and safety; prevent injury to plant and animal life; prevent damage to property; and prevent unreasonable interference with the public welfare.

1. *Use of Pipelines.*

- a. Operator shall use pipelines for the transport of oil, gas, and produced water from ~~Well Sites~~Oil and Gas Locations where feasible, and shall utilize such pipelines at each Well Site before the Production Phase commences.
- b. Operator shall be permitted to utilize temporary tanks during drilling, flowback, workover, completion, hydraulic fracturing and maintenance operations.
- c. Operator shall obtain all permits necessary for the construction and use of pipelines, including a conditional use permit. The City shall expediently

approve all permit applications necessary for the construction and use of pipelines.

2. *Bradenhead Monitoring.* Operator shall conduct bradenhead monitoring on all wells in accordance with COGCC rules and regulations.
3. *Burning.* No open burning shall occur on the site of any oil and gas operation except flaring as allowed in this BMP Document.
4. *Discharge Valves.* Open-ended discharge valves on all storage tanks, pipelines and other containers within any Well Site shall be secured and shall not be accessible to the general public. Open-ended discharge valves within any Well Site shall be placed within the interior of the secondary containment area.
5. *Flammable Material.* All ground within 25' of any tank, or other structure containing flammable or combustible materials, shall be kept free of dry weeds, grass or rubbish, and shall conform to COGCC 600 Series Safety Regulations and the applicable fire code. Landscaping is prohibited within 25' of any tank or other structure containing flammable or combustible materials.
6. *Flowlines.*
 - a. Any newly constructed or substantially modified flowlines on any Well Site Oil and Gas Location shall be constructed and operated under the provisions of the COGCC 1100 Series Flowline Regulations and any future COGCC Flowline Regulations, as either may be amended, and any applicable surface use agreements with the surface owners.
 - b. Operator shall pressure test all flowlines following their construction, including those rated at less than 15 PSI.
 - c. ~~Operator will provide to the City all records required to be submitted to state agencies related to inspections, pressure testing, accidents and other safety incidents related to flowlines at any Well Site and, upon specific request by the City, Operator will provide to the City any~~

~~other records submitted to State agencies related to flowlines at the Well Sites.~~

Commented [BHFS54]: COGCC is creating a system that can push these to the City. It would be inefficient for the operator to submit these records to both the City and the COGCC when the COGCC can automate the process.

d. All new off-location flowlines and pipelines shall have the legal description of the location recorded with the Adams County Clerk and Recorder within thirty (30) days of completion of construction.

e. Abandonment of any recorded flowlines shall be recorded with the Adams County Clerk and Recorder within thirty (30) days after abandonment.

f. ~~Operator will provide the City with GIS files for the location of flowlines.~~

Commented [BHFS55]: COGA has confidentiality concerns about this for safety reasons.

g. Flowlines will be removed when last well utilizing the lines are plugged and abandoned unless ~~this requirement is waived in writing by the Director.~~ abandonment in place is allowed by the COGCC.

7. *General Maintenance.* Operator shall operate and maintain all equipment pursuant to manufacturer specifications consistent with technological limitations and reasonable and customary maintenance practices.

8. *Plugged and Decommissioned Well Testing.*

Commented [BHFS56]: COGCC is creating a system that can push these to the City. It would be inefficient for the operator to submit these records to both the City and the COGCC when the COGCC can automate the process.

a. Before and after the hydraulic fracturing of any new well, Operator shall assess the integrity of all active oil and gas and disposal wells ~~(Active, Dry & Abandoned, Injecting, Plugged & Abandoned, Producing, Shut In, and Temporarily Abandoned)~~ where the surface location of such wells are within the City and within 1500' of the completion interval of the projected track of the borehole of the proposed new well, based upon examination of COGCC and other publicly available records. This shall include assessment of leaking gas, oil, or water to the ground surface or into subsurface water resources, taking into account plugging and cementing procedures described in any recompletion or plugged and

abandoned report filed with the COGCC. The analysis shall be provided to the City.

- b. ~~Based on the results of the assessment, the City may require Operator to plug and abandon, in compliance with all COGCC rules in relation to abandonment and plugging, any of the Operator's existing oil and gas or disposal wells or such wells under the Operator's ownership, control or authority. Additionally, the City may request Operator to attempt to negotiate the plugging and abandonment of other wells of concern, that are not owned by the Operator, but that are within 1500' of the completion interval of the projected track of the borehole of the proposed new well. If wells of concern are not plugged and abandoned, Operator must supply a mitigation plan and a follow-up monitoring plan that will be used to prevent or detect any communication between the well of concern and the proposed wells.~~
- c. Operator shall provide notification to the City and applicable fire district not less than fourteen (14) days prior to commencing plugging operations. Operator shall notify the City and COGCC of the results of plugging and cementing procedures.
- d. ~~For each well abandoned by Operator within the City for which access and permission to test is granted, a soil gas survey to test the soil within a 10' radius of the well shall be completed prior to production from a proposed new well and again one (1) year after production has commenced on the new well. Every well abandoned by Operator shall also be subject to the testing one (1) year after production has commenced on a new well. Operator shall provide the results of the soil gas survey to the City and the COGCC within one (1) month of conducting the survey or advise the City that access to the previously abandoned wells could not be obtained from the surface owner.~~

Commented [BHFS57]: This interferes with downhole considerations. Local governments may not regulate downhole aspects of oil and gas.

Commented [BHFS58]: COGCC is creating a system that can push these to the City. It would be inefficient for the operator to submit these records to both the City and the COGCC when the COGCC can automate the process.

9. *Surface Safety Valve and Automatic Safety Protective Systems.*
 - a. Operator will install an automated safety system, governed by safety devices and a programmable logic computer, at each ~~Well Site~~Oil and Gas Location.
 - b. Each system shall include a Surface Safety Valve (“SSV”) or wellhead master control valve installed for each new well before the commencement of the Production Phase connected to the production tubing at the surface. The SSV or wellhead master control valve shall monitor multiple flowing pressures and rates which have predetermined maximum and/or minimum threshold values programmed and will remotely shut the well in should certain upset conditions be detected. Additionally, the automated safety system shall provide the ability to remotely shut-in wells on demand through operator remote intervention.
 - c. The SSV will have documented, quarterly testing to ensure functionality per manufacturer’s specifications.
10. *Flowback Best Management Practices*
 - a. Before flowback, Operator shall:
 - i. Construct the production facility capable of remote emergency shut down consistent with this BMP Document;
 - ii. Tie flowback equipment into combustors;
 - iii. Notify appropriate fire district at least twenty-four (24) hours before production flowback is scheduled to begin for the first time on a well pad; and
 - iv. Conduct a pre-startup safety review (PSSR), which will review facility and equipment spacing requirements and safety procedures.

- b. During flowback, Operator shall:
 - i. Utilize gas monitors that are capable of detecting Lower Explosive Level and H₂S, which emit an audible tone linked to cell phones to notify people on and off location;
 - ii. Utilize automatic tank gauging to measure tank levels and have 24-hr manned operations;
 - iii. Send flowback gas to sales pipeline, when possible.

- 11. *Safety Management Plans.* Operator shall maintain safety management plans for oil and gas operations including: hazard review, operating procedures, safety training program, maintenance procedures, compliance audits, and design measures.

F. Visual & Noise Mitigation. Operator shall comply with these visual and noise mitigation standards to: protect human health and safety; prevent damage to property; prevent unreasonable interference with the public welfare; preserve visibility; and protect scenic, aesthetic, and historic values in the City. These standards are established to improve and to prevent degradation to the quality of life and the general welfare in the City.

- 1. *Visual Mitigation Methods.* The City may require Operator to implement the following visual mitigation methods may be required on a site-specific basis, taking into consideration surface owner preferences:
 - a. Use of low-profile tanks less than 16 ft. in height;
 - b. Use of equipment with reduced height and profiles;
 - c. Facility painting, vegetative or structural screening, land berming, and landscaping;
 - d. Earthen berms around the perimeter of fencing with turf grass or ground cover generally recognized by landscape architects and horticulturalists for local area use for the purpose of general screening;

- e. Establishment and proper maintenance of ground cover, trees and shrubs for screening and aesthetic purposes;
 - f. Designing an Oil and Gas Facility to utilize natural screens where possible; and
 - g. Construction of fences for use with or instead of landscaping or berming;
2. *Landscaping.* Operator shall comply with the following:
- a. If water for irrigation use is unavailable at the location, the initial phase may utilize natural topography and fencing surrounding the location, as well as any trees already established near the property.
 - b. Initial landscaping, if required by an approved Landscaping Plan, and any fencing will be installed within 6 months of finishing drilling and completion operations.
 - c. Once water for irrigation use is available to the area, the Operator must implement any final landscaping as described in the Landscaping Plan. The Operator must consult with the City as well as meet Land Development Code requirements at the time the final landscaping is installed.
 - d. Existing significant trees (greater than eight inches in caliper) shall be preserved to the maximum extent practicable and may help satisfy the landscaping and visual mitigation requirements. All required landscape plans shall accurately identify the locations, species, size, and condition of all significant trees, each labeled showing Operator's intent to either remove, transplant, or protect. Trees that meet one or more of the following removal criteria shall be exempt from the requirements contained in this subsection:
 - i. Dead, diseased, or naturally fallen trees, or trees found to be a threat to public health, safety or welfare;

- ii. Trees that are determined by the city to substantially obstruct clear visibility at driveways and intersections; or
 - iii. Tree species that constitute a nuisance to the public such as cotton-bearing cottonwood, Siberian or Chinese elm, Russian olive and female box-elder. Native cotton-bearing cottonwood trees and female box-elder trees, when located in a natural area buffer zone, are not nuisance tree species.
3. Lighting. Operators shall comply with the following, unless a different approach is required for operational safety.
- a. Exterior lighting shall be directed away from residential and other sensitive areas or shielded from said areas to eliminate glare. Light spillage beyond the perimeter of a Well Site Oil and Gas Location should be minimized.
 - b. All permanent lighting or lighting higher than a perimeter wall must be downward facing.
 - c. All bulbs must be fully shielded to prevent light emissions above a horizontal plane drawn from the bottom of the fixture.
 - d. Prior to installation of permanent lighting on any Well Site Oil and Gas Location, Operator shall submit to the City a Lighting Plan and the City shall communicate with Operator any modifications to the plan that it deems appropriate. Operator shall make such modifications as reasonably and necessarily required by the City and as required by law.
 - e. The Lighting Plan shall indicate the location of all outdoor lighting on the site and any structures, and include cut sheets (manufacturer's specifications with picture or diagram) of all proposed fixtures.
 - f. During the Drilling and Completion Phases, consistent with applicable law, Operator will construct a minimum

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32 [ft.in](#) height wall around as much of the perimeter of the well pads as operations allow to reduce light escaping from the site, unless taller, shorter, or no walls are mutually agreed to by City and Operator on a site-specific basis.

4. *Artificial Lift.* Artificial lift will not be accomplished through the use of traditional pump jacks. Alternatives such as gas lift, linear rod pumps, or hydraulic pumping unit may be used, and are to be as low profile as practicable with a maximum height of 30 ft. An alternative artificial lift system may be used if it is less visible or auditory impacts and is agreed to by both parties.
5. *Trailers.*
 - a. A construction trailer(s) is permitted as an accessory use during active construction, drilling and well completion or workover operations only.
 - b. Permanent residential trailers are prohibited at ~~Well Sites~~[Oil and Gas Locations](#).
 - c. Until ninety (90) days following the end of the Completion Phase on an ~~Oil and Gas Locaation-Well Site~~[Oil and Gas Location](#), temporary residential and/or security trailers are permitted, as needed for on-site operations, for exclusive use by the Operator's personnel and the personnel of its [contractors and](#) subcontractors on a temporary basis.
6. *Noise.*
 - a. Operator shall use quiet completions technology for all well located within 2000' of a Residential Building Unit or a High Occupancy Structure unless Operator obtains waivers from all affected property owners within that distance.
 - b. Operator shall conduct a Baseline Noise Mitigation Study to ascertain baseline noise levels at each ~~Well Site~~[Oil and Gas Location](#) to demonstrate that noise is

expected to be mitigated to the the [??] extent practicable. A copy will be provided to the City. ~~All baseline measurements considered for compliance with this Section shall be taken by a third party contractor using sound monitoring industry standards and practices.~~

Commented [BHFS59]: This should be a last resort if needed to respond to a verified noise complaint.

- c. The City may require Operator to implement additional noise mitigation if there is a Residential Building Unit, Public Park, or High Occupancy Structure within 2000' of the ~~Well Site~~Oil and Gas Location and based on any of the following additional site-specific characteristics:
 - i. Nature and proximity of adjacent development (design, location, use);
 - ii. Prevailing weather patterns, including wind directions;
 - iii. Type and intensity of the noise emitted; and
 - iv. Vegetative cover on or adjacent to the site or topography.
- d. Additional noise mitigation measures may include:
 - i. Continuous noise monitoring by a third party contractor, at expense of Operator, during construction, drilling, and completions, with instruments placed between the Oil and Gas Location and Residential Building Units within 2000'. Data shall be provided to the City.
 - ii. The Operator shall address C scale noise/vibration through berming, capable sound walls, and other practices.
 - iii. During the drilling and completion, the ~~O~~operator may be required to construct a perimeter wall and/or comparable measures to mitigate noise as appropriate on a case-by-case or modeled basis.

- iv. Additional mitigations must be taken by the Operator if C-scale noise levels are increased the larger of either 5db over ambient or above 65db at 25' from the nearest ~~occupied—building unit~~Residential Building Unit.
- v. Use of electric-powered motors and pumping systems.
- vi. Construction of buildings or other enclosures where Operations create noise and visual impacts that cannot otherwise be mitigated due to proximity, density or intensity of adjacent land use.

G. Community Outreach, Notification, Reporting & Oversight; Hazards & Emergencies. Operator shall comply with these standards to: protect human health and safety; prevent damage to property; and prevent unreasonable interference with the public welfare. These standards are established to improve and to prevent degradation to the quality of life and the general welfare in the City.

1. *Outreach to Affected Residents.*

- a. Operator shall maintain a list, updated ~~annually~~every two years, of the residents and business owners within $\frac{1}{4}$ mile (1320') of an ~~Oil and Gas Location-Well Site~~ ("Affected Residents"). An Operator may rely on public records to create this list and shall not be obligated to conduct additional investigation to learn the identities of such residents and business owners.
- b. Operator shall:
 - i. Provide at least fourteen (14) days advanced written notice to Affected Residents of mobilization in, rig up (~~MIRU~~);
 - ii. Notify Affected Residents in writing within seven (7) days of any reportable events that could have off-site impacts including fires, explosions, blow-outs, venting, or large spills (over 100 barrels);

Commented [BHFS60]: Please clarify that electronic written notice to Affected Residents, wherever required, is permissible.

- iii. Provide these notices to the local fire district and Police Department emergency managers.

Operator may satisfy these notification requirements through direct correspondence, including email, or through direct mail.

2. *Bi-Annual Updates to City.*

- a. Operator biannually shall provide a formal written Progress Report update to the Director, to be shared publicly, as to the progress of Operations, including but not limited to:
 - i. Any reportable spills or reportable accidents at locations;
 - ii. Any notice of alleged violations from the City or COGCC; and
 - iii. A summary of verified complaints to the Operator and COGCC.
- b. Updates shall begin at the beginning of construction and continue throughout drilling and completion operations and cease once the final well approved for an Well Site Oil and Gas Location has been drilled and has been in production for one full year.

3. *Complaint Response.*

- a. Operator shall maintain a dedicated phone line to receive complaints that is open 24 hours per day, 7 days a week. The phone number shall be posted at all Well Sites Oil and Gas Locations and provided to the City's LGD.
- b. Operator shall document and review all complaints and provide the complainant with an initial response within twenty four (24) hours. Responses to complaints shall also be provided to the City's LGD and, if appropriate, state officials.

- c. Any additional responses or corrective actions will be communicated to the complainant, landowner, City's LGD, and, if appropriate, state officials.
 - d. If there are one or more repeat complainants whose complaints are consistently found to be illegitimate, the City and Operator will discuss such complainant(s) and the Operator may be relieved of its obligation to investigate and respond to such complainant(s) in the future.
4. *Risk Management.* Operator shall create and implement a Risk Management Plan for ~~Well Sites and Oil and Gas Facilities~~ Oil and Gas Locations that are part of an Oil and Gas Permit. The plan shall include risk identification, responsibilities, assessment, response, planning mitigation and, methods of risk avoidance and control that implement techniques to prevent the accident/loss and reduce the impact after an accident/loss occurs. Operators shall periodically update and revise the plan, but at least every three years and after any incident.
- a. Operator shall develop a risk identification in a risk table which will identify the particular site by name, describe the risk, identify any health, safety, or environmental impact, identify any impact to Operator's development schedule, provide a description of the risk area and associated factors, and whether it is an unmitigated or mitigated risk.
 - b. Operator shall assign persons or entities under its control or direction to have responsibility for the managing risk identified and plans support the risk mitigation. Such assignment shall not limit the Operator's responsibility.
 - c. Operator shall identify any planned mitigation response (including emergency response, tactical response, and notifications) for certain identified risks.
 - d. Operator will implement a compliance and audit program. The Operator shall determine and document

an appropriate response to each of the findings of the compliance audit, and document that deficiencies have been corrected. If Operator utilizes a self-reporting mechanism to any respective agency, that self-reporting mechanism will be described in the Risk Management Plan. If Operator self-reports, any findings included in the self-reporting to any other respective agency will be provided to the City.

- e. City may retain outside consultants, at Operator's cost, to review Risk Management Plan and may require modifications to Risk Management Plan based on its review.

5. *Incident and accident reporting.*

- a. Within twenty-four (24) of any reportable safety event, as defined by ~~the COGCC in Rule 602(c)~~, COGCC regulation, as may be amended, or any accident or natural event involving a fire, explosion or detonation requiring emergency services or completion of a relevant COGCC Form ~~22~~, Operator shall submit a report to the City that includes the following, to the extent available: fuel source, location, proximity to residences and other occupied buildings, cause, duration, intensity, volume, specifics and degree of damage to properties, if any beyond the Well-Site Oil and Gas Location, injuries to persons, emergency response, and remedial and preventative measures to be taken within a specified amount of time. Additional reporting shall be provided after the conclusion of the event, if the event lasts longer than twenty-four (24) hours.
- b. The City may require Operator to conduct a root cause analysis of any reportable safety events or Grade 1 gas leaks, each as defined by the COGCC.
- c. Any spill or release that is reportable to the COGCC shall be simultaneously reported to the City's LGD and the applicable fire district.

Commented [BHFS61]: References to specific COGCC Rules and Forms are premature because COGCC Rule and Form numbering is likely to change due to the pending Mission Change rulemaking.

Commented [BHFS62]: COGCC is creating a system that can push these to the City. It would be inefficient for the operator to submit these records to both the City and the COGCC when the COGCC can automate the process. (Global comment for all notices and reports, even where a specific comment bubble to this effect has not been added).

6. *Signs and Markers.* Operator shall mark each and every well in a conspicuous place, from the time of initial drilling until final abandonment, as follows:
 - a. General Sign Requirements.
 - i. No sign required under this BMP shall be installed at a height exceeding 6'.
 - ii. Operator shall maintain signs in a legible condition and shall replace damaged or vandalized signs within sixty (60) days.
 - b. Drilling and **Recompletion** Operations.
 - i. Operator shall provide directional signs, no less than three (3) and no more than six (6) sq. ft. in size, during all drilling and recompletion operations.
 - ii. Such signs shall be at locations sufficient to advise emergency crews where drilling or recompletion is taking place.
 - iii. Such sign locations shall include the first point of intersection of a public road and the rig access road and thereafter at each intersection of the rig access route, except where the route to the well is clearly obvious to uninformed third parties in any weather or condition.
 - iv. Such signs not needed to meet other obligations under these rules shall be removed as soon as practical after drilling and recompletion operations are complete.
 - c. Permanent Designations.
 - i. Oil and Gas Wells. Within sixty (60) days after the Completion Phase of an Oil and Gas Well, a permanent sign shall be located at both the wellhead and surface equipment (if not at the

Commented [BHFS63]: Does the City mean to refer to "Completions" operations?

wellhead), which shall identify the Oil and Gas Well, the name and contact information of the Operator and the legal location, including the quarter section.

- ii. Surface Equipment. Within sixty (60) days after the installation of a tank battery, a permanent sign shall be located at the tank battery. At the option of the Operator, or at the request of the City, the sign may be placed at the intersection of the lease access road with a public road nearest the tank battery, if the tank battery is readily apparent from such location. Such sign, which shall be no less than three (3) sq. ft. and no more than six (6) sq. ft., shall provide: the name of the Operator; a phone number at which the Operator may be reached at all times; a phone number for local emergency services; the lease name or Oil and Gas Well name(s) associated with the tank battery; the public road used to access the site; and the legal location, including the quarter section.
 - iii. Tanks and Containers. All tanks with a capacity of ten (10) barrels or greater shall be labeled or posted with the following information:
 - a) Name of Operator;
 - b) Operator's emergency contact telephone number;
 - c) Tank capacity;
 - d) Tank contents; and
 - e) National Fire Protection Association (NFPA) Label.
7. Emergency Response Plan.

- a. Operator shall complete and implement all components of a detailed Emergency Response Plan subject to the approval of the City's emergency manager and the applicable fire district must approve of the Emergency Response Plan ("Plan") before the Drilling Phase commences.
- b. Operator shall review the plan annually and file any updates with the City's Emergency Manager and the applicable fire district. If no updates to the Plan are made then Operator shall provide notice of "No Change."
- c. The Plan shall include:
 - i. Name, address and phone number, including twenty-four-hour numbers for at least two (2) persons responsible for field operations as well as the contact information for any contractor or subcontractor of Operator engaged for well-control emergencies;
 - ii. A process by which the Operator notifies surrounding ~~neighbors~~ Affected Residents to inform them about the on-site operations and emergencies and to provide sufficient contact information for Affected Residents surrounding neighbors to communicate with the Operator;
 - iii. An as-built facilities map in a format suitable for input into the City's GIS system depicting the locations and type of above and below ground facilities, including sizes and depths below grade of all oil and gas flow lines and associated equipment, isolation valves, surface operations and their functions, as well as transportation routes to and from exploration and development sites, for response and management purposes. The information concerning flowlines and isolation valves shall be marked and treated as confidential and shall only be disclosed in the event of an

emergency or to emergency responders or for the training of emergency responders;

- iv. Detailed information addressing each reasonable potential emergency that may be associated with the operation, including without limitation: explosions; fires; gas; oil or water pipeline leaks or ruptures; hydrogen sulfide or other toxic gas emissions; hazardous material vehicle accidents or spills; and natural disasters;
- v. An emergency evacuation plan for the Oil and Gas Location~~Well Site~~ and any person within one-half (1/2) mile of the Oil and Gas Location~~Well Site~~.
- vi. A provision that any spill outside of the containment area, that has the potential to leave the facility or to threaten waters of the state, or as required by the City-approved plan shall be reported to the local dispatch and the COGCC Director in accordance with COGCC regulations;
- vii. Detailed information identifying access, and health care facilities anticipated to be used;
- viii. ~~A project specific plan for any project that involves drilling or penetrating through known zones of hydrogen sulfide gas;~~
- ix. A provision obligating the Operator to reimburse the appropriate agencies for their reasonable expenses resulting from the Operator's operations; and
- x. A statement and detailed information indicating that the Operator has adequate personnel, supplies, and training to implement the plan immediately at all times during construction and operations.

Commented [BHFS64]: "Local dispatch" meaning whom?

Commented [BHFS65]: Downhole concern outside City's jurisdiction.

- d. The Operator shall have current ~~Material~~-Safety Data Sheets (~~M~~SDS) for all chemicals used or stored on a Well Site. The ~~M~~SDS sheets shall be provided immediately upon request to City officials, a public safety officer, or a health professional as required by COGCC Rule 205-regulation.
- e. All training associated with the Plan shall be coordinated with the City and the fire districts within the City.
- f. Operator shall provide the City with its shutdown protocols and promptly notify the City of any shut downs that would have an impact to any area beyond the confines of the Oil and Gas Location~~Well Site~~.

H. Insurance. Operator shall comply with these insurance standards to: protect human health and safety; prevent damage to property; prevent unacceptable losses to public finances; and prevent unreasonable interference with the public welfare. These standards are established to improve and to prevent degradation to the quality of life and the general welfare in the City. The requirements of these BMPs may be reduced by the Director with the consent of the City's designated Risk Manager and Director of Finance based on the Operator's financial condition, the ability to obtain the types and amounts of insurance set forth below, additional protections and guarantees, and the size, scope, location, and nature of the Operations.

- 1. The Operator shall maintain or cause to be maintained, with insurers authorized by the state of Colorado and carrying a financial strength rating from A.M. Best of no less than A- VII (or a similar rating from an equivalent recognized ratings agency), at a minimum, the following types of insurance with limits no less than the amounts indicated:
 - a. Commercial General Liability insurance on an occurrence based form including coverage for bodily injury or property damage for operations and products and completed operations with limits of not less than \$1,000,000 each and every occurrence.
 - b. Automobile Liability insurance with limits of not less than \$1,000,000 each and every occurrence.

- c. Workers' Compensation insurance- Statutory Workers' Compensation Coverage for the employee's normal State of employment/hire. Including Employer's Liability insurance - with limits of not less than \$1,000,000 Each Accident, Disease - Each Employee, Disease - Policy Limit.
 - d. Control of Well/Operators Extra Expense insurance - with limits of not less than \$10,000,000 covering the cost of controlling a well that is out of control or experiences a blowout, re-drilling or restoration expenses, seepage and pollution damage resulting from an out of control well or blowout as first party recovery for the operator and related expenses, including, but not limited to, loss of equipment and evacuation of residents.
 - e. Umbrella/Excess Liability - in excess of General Liability, Employer's Liability, and Automobile Liability with limits no less than \$25,000,000 per occurrence; provided, however, that for so long as the Construction Phase, Drilling Phase or Completions Phase is ongoing at any Well Site under a permit, Operator will maintain such insurance with limits no less than \$100,000,000 per occurrence.
 - f. Environmental Liability/Pollution Legal Liability insurance- with limits of not less than \$5,000,000 per pollution incident, with coverage being required beginning with the date that is eight (8) years from the date of first production from each new well ("Required Date"). Coverage must include gradual pollution events. This insurance may be on a claims-made basis, however the retroactive date must precede the Required Date in order to cover all wells.
2. Operator shall waive and cause its insurers under the above policies to waive for the benefit of the City any right of recovery or subrogation which the insurer may have or acquire against the City or any of its affiliates, or its or their employees, officers or directors for payments made or to be made under such

Commented [BHFS66]: COGA suggests the City consider delaying or removing this provision until after the COGCC conducts its financial assurance rulemaking

policies, unless such right or recovery or subrogation or payments are related to the City's, its affiliates', or its employees', officers' or directors' negligence.

3. Operator shall add the City and its elected and appointed officials and employees as Additional Insureds under general liability (including operations and completed operations), ~~auto liability,~~ and umbrella liability.
4. Operator shall ensure that each of the policies are endorsed to provide that they are primary without right of contribution from the City or any insurance or self-insurance otherwise maintained by the City, and not in excess of any insurance issued to the City, unless the City, its affiliates, or its employees, officers or directors negligence is at issue.-
5. Operator shall ensure that each of the policies above (excluding workers' compensation and OCC/COW) are endorsed to state that the inclusion of more than one insured under such insurance policy shall not operate to impair the rights of one insured against another insured and that the coverage afforded by each insurance policy shall apply as though a separate policy had been issued to each insured.
6. All policies shall be endorsed such that they cannot be canceled or non-renewed without at least 30 days' advanced written notice to Operator and the City, evidenced by return receipt via United States mail, except when such policy is being canceled for nonpayment of premium, in which case ten (10) days advance written notice is required. ~~Language relating to cancellation requirements stating that the insurer's notice obligation is limited to "endeavor to" is not acceptable.~~
7. Operator shall, prior to permit issuance, deliver Certificates of Insurance reasonably acceptable to the City confirming all required minimum insurance ~~will be~~ in full force and effect at the time construction of an Oil and Gas Location commences or Oil and Gas Operations are commenced.
8. Deductibles or retentions shall be the responsibility of Operator. Deductibles or retentions must be listed on the Certificate of

Commented [BHFS67]: COGA does not understand why auto liability would be relevant to the City.

Insurance required herein and are subject to the reasonable approval of the City.

9. Operator shall require any of its contractors or subcontractors to carry the types of coverage and in the minimum amounts in accordance with the requirements set out in Section I.A, 1.B. and 1.C. Operator shall be responsible for any damage or loss suffered by the City as a result of non-compliance by Operator or any contractor or subcontractor with this section.
10. If Operator's coverage lapses, is cancelled or otherwise not in force, the ~~City reserves the right to obtain insurance required herein and charge all costs and associated expenses to Operator, which shall become due and payable immediately~~Operator must immediately obtain new insurance as required herein.
11. If that the coverage required is not widely available to operators in the Denver-Julesburg Basin, in lieu of the coverage required, Operator and the City may establish a joint escrow account that shall be used to satisfy any obligations of Operator that would have otherwise have been covered by the coverage required. Operator shall fund such account with an amount equal to \$5,000.00 per new well then-producing (the "Per Well Amount"). The aggregate amount to be placed into the account shall be revisited on an annual basis based on the then-number of producing new wells. The Per Well Amount shall be adjusted each year by the increase or decrease in the Consumer Price Index issued by the United States Bureau of Labor Statistics for the Denver – Boulder metropolitan area. Any interest accrued in the account shall be credited towards the Operator's required contributions to the account and any excess amounts in the account above and beyond the amount required by this provision shall be promptly returned and released to Operator.

I. Reclamation. Operator shall comply with these reclamation standards to: protect human health and safety; prevent injury to plant and animal life; prevent damage to property; and prevent unreasonable interference with the public welfare. These standards are established to restore the City's resources and to improve the quality of life and the general welfare in the City.

1. *Interim Reclamation Plan.* Operator shall implement an interim reclamation plan including:
 - a. *Removal of Debris.* All construction-related debris shall be removed from the site for proper disposal in a timely manner. The site shall be maintained free of debris and excess materials at all times during operation. Operator shall not burn or bury debris at any time on any ~~Well Site~~Oil and Gas Location.
 - b. *Removal of Equipment.* All equipment used for drilling, ~~re-completion~~ and maintenance of the facility shall be removed from the site within thirty (30) days of completion of the work, weather condition permitting, unless otherwise agreed to by the surface owner. Permanent storage of removable equipment on any ~~Well Site~~Oil and Gas Location is prohibited.
2. *Final Reclamation Plan.* Operator must submit an oil and gas ~~Well Site~~Oil and Gas Location Final Reclamation Plan and reclaim an ~~Oil and Gas Location-Well Site~~ not later than six (6) months after plugging and abandoning the last well at such ~~Well Site~~Oil and Gas Location, weather and planting season permitting, and considering the surface owner's preferences. In addition to any COGCC reclamation requirements, Operator shall:
 - a. Remove all pipelines, ~~gathering lines~~ and flowlines after one (1) year of non-use when last well utilizing lines are plugged and abandoned unless this requirement is waived in writing by the Director or the COGCC authorizes abandonment in place; and
 - b. Reclaim and revegetate, to the original state prior to Operations, all temporary access roads associated with Operations at an ~~Oil and Gas Location-Well Site~~ within a reasonable amount of time, taking into account planting seasons, or as directed by the landowner in a Surface Use Agreement and subject to applicable COGCC variances.

Commented [BHFS68]: Does the City intend to refer to completion?

3. Marking and recording of plugged and abandoned wells.
Operator must comply with the following:

- a. The COGCC well abandonment report must be accurately completed and filed with the ~~City and~~ COGCC.
- b. The well location must be recorded with the Clerk and Recorder of the applicable county.
- c. Operator shall permanently mark the well by a brass plaque set in concrete, similar to a permanent bench mark, to monument the plugged and abandoned well's existence and location. Such plaque shall contain the information required by the COGCC to properly identify the well. Operator may mark the well by an alternative means if pre-approved by the ~~De~~irector.

Commented [BHFS69]: COGCC is creating a system that can push these to the City. It would be inefficient for the operator to submit these records to both the City and the COGCC when the COGCC can automate the process.

J. Transportation and Circulation.

1. *General.*

- a. Operator will comply with all Transportation and Circulation requirements as contained in the LDC and as may be reasonably required by the City's Traffic ~~Engineer~~.
- b. Operator will comply with all applicable hazardous material regulations.
- c. Operator will obtain necessary access permits, which the City will not unreasonably withhold.

Commented [BHFS70]: Need to tie this to Traffic Impact Study.

2. *Traffic Control Plan.* Operator shall establish a Traffic Control Plan including the following:

- a. Estimated weights of vehicles when loaded, a description of the vehicles, including the number of wheels and axles of such vehicles and trips per day;
- b. Detail of access locations for each ~~well site~~Oil and Gas Location including sight distance, turning radius of

- vehicles and a template indicating this is feasible, sight distance, turning volumes in and out of each site for an average day and what to expect during the peak hour;
- c. Truck routing map and truck turning radius templates with a listing of required and determined that certain improvements are necessary at intersections along the route;
 - d. Restriction of non-essential traffic to and from any ~~Well Site~~Oil and Gas Location to periods outside of peak am and pm traffic periods and during school hours (generally 7-8am and 3-6pm) if ~~Well Site~~Oil and Gas Location or access road are within 1000' of school property.
 - e. Identification of need for any additional traffic lanes, which would be subject to the final approval of the City's engineer.
3. *Public Improvements.* If public road improvements are necessary to accommodate an Operation, and before work will be permitted within any City right-of-way, the Operator shall draft engineered drawings to be prepared by a Colorado licensed civil engineer, in conformance with City standards, for review and approval by the City.
4. *Private Access Roads.*
- a. Access points to public roads must be located, improved and maintained to assure adequate capacity for efficient movement of existing and projected traffic volumes and to minimize traffic hazards.
 - b. Permanent access roads must be improved a minimum distance of 200' on the access road from the point of connection to a public road.
 - c. All access roads must be in conformance with the City's standards and specifications. A geotechnical report and pavement design will be submitted to the City for approval.

- d. Access roads must be improved as a hard surface (concrete or asphalt) for the first 100' from the public road, unless public road is not already a hard surface, in which case, Operator shall meet the current standards of the public road.
 - e. Access roads must be improved with a crushed surface (rock, concrete, or asphalt) for the next 100' in the appropriate depth to support the weight load requirements of the vehicles accessing the Well Site.
 - f. If an access road intersects with a pedestrian trail or walk, the Operator shall pave the access road as a hard surface (concrete or asphalt) a distance of 100' either side of the trail or walk, unless the trail or walk is not already a hard surface, in which case, Operator shall meet the current standards of the trail or walk. If necessary, Operator shall replace the trail or walk to address the weight load requirements of the vehicles accessing the well and production facilities.
5. *Mud Tracking.*
- a. Operator shall take all practicable measures to ensure that vehicles do not track mud or debris onto public streets.
 - b. Operator shall immediately, or as soon as practicable, given weather conditions or time of day, clean any mud or debris deposited on public streets that is more than *de minimis*.
 - c. The Director of Public Works or designee may authorize a delay in the cleaning of mud or debris from public streets if Operator submits a plan for removal that is approved.
6. *Chains.* Traction chains from heavy equipment shall be removed before entering a public street.

[END OF BMP DOCUMENT]

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~~20575746.3~~

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EXHIBIT A TO ORDINANCE 2266

(Underlined text indicates new material; strikethrough text indicates deletions.)

Sec. 3-2304. - Penalties.

(a) The following minimum penalties are hereby established for violations prosecuted under this article; provided, however, that the minimum penalties for violations of any provision identified as a civil infraction in chapter 4 of this Code shall be fifty (50) percent of the amounts set forth in this section:

- (1) A minimum penalty of one hundred dollars (\$100.00) shall be imposed against the responsible party for the first violation of a particular code provision within any consecutive twelve-month period.
- (2) For each successive violation of the same code provision within any twelve-month period, minimum penalties shall be imposed against the responsible party as follows:
 - a. Second violation: three hundred dollars (\$300.00).
 - b. Third violation: five hundred dollars (\$500.00).
 - c. Fourth or greater violation: nine hundred ninety-nine dollars (\$999.00).
- (3) Where multiple violations of a single Code provision are found, the applicable minimum penalty shall be imposed for each count.

(b) Notwithstanding the foregoing, the following minimum penalties are hereby established for violations prosecuted under this article relating to oil and gas operations governed by sections 21-3216 and 21-5266 of the Commerce City Land Development Code, the BMP Document (as authorized by the Commerce City Land Development Code):

(1) A minimum penalty of five hundred dollars (\$500.00) shall be imposed against the responsible party for the first violation of a particular provision within any consecutive twelve month period.

(2) For each successive violation of the same provision within any twelve month period, minimum penalties shall be imposed against the responsible party as follows:

a. Second violation: one thousand dollars (\$1,000.00).

b. Third violation: two thousand dollars (\$2,000.00).

Commented [BHFS1]: Why the disparate treatment for oil and gas operations? What are the grounds for treating oil and gas differently from other industries?

Commented [BHFS2]: Please explain how the City calculates penalties where the violation lasts more than one day. For example, if an Operator inadvertently does not submit a report required by the Code, COGA believes that should count as one violation.

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~~c. Fourth or greater violation: two thousand six hundred and fifty dollars (\$2,650.00).~~

~~(3) Where multiple violations of a single provision are found, the applicable penalty shall be imposed for each count.~~

(b~~c~~) Payment of a penalty shall neither excuse the failure to correct a violation nor bar further enforcement action by the city.

(e~~d~~) All penalties imposed and fees assessed shall be payable to the city.

(d~~e~~) The failure of a responsible party to pay the penalties imposed within the time specified in any notice of assessment issued in accordance with this article, or in the enforcement order if a protest hearing was held, may result in the assessment of a late fee in an amount set by city council resolution, and the city manager may refer the matter for collection by whatever means are available to the city.

(e~~f~~) Any action or other process provided by law may be maintained by the city to recover or collect any amounts, including late fees, interest and administrative costs, owing under this article.

(Ord. No. 1848, § 1, 1-10-2011)

EXHIBIT B TO ORDINANCE 2266

(Underlined text indicates new material; strikethrough text indicates deletions.)

Sec. 21-3110. Neighborhood Meetings

- (1) **Purpose.** Neighborhood meetings are intended to inform neighboring property owners of the details of a proposed development, how the developer intends to meet the standards contained in this land development code, and to receive feedback on the proposal early in the review process.
- (2) **Applicability.** The city may require a neighborhood meeting when it appears that an application may have significant neighborhood impacts, including without limitation, impacts related to: traffic; provision of public services such as safety, schools, or parks; compatibility of building design or scale; or operational compatibility such as hours of operation, noise, dust, or glare. Notwithstanding the foregoing, unless exempted by 21-3216(8), significant neighborhood impacts shall be presumed for all oil and gas permit applications and a minimum of one neighborhood meeting shall be required for all oil and gas permit applications.
- (3) **Number of Meetings.** When required, there shall be at least one neighborhood meeting held. Such meeting shall be held prior to submittal of a formal application; prior to any administrative action on the application; or a minimum of 21 days prior to the first public hearing on the application. The director may require additional neighborhood meetings due to the proposed development's mix of uses, density, complexity, potential for impacts, or the need of off-site public improvements created by the development.
- (4) **Attendance Required.** If a neighborhood meeting is required, the applicant or applicant's representative shall attend and conduct the meeting.
- (5) **Scheduling and Location.** The applicant shall be responsible for scheduling the neighborhood meeting at a time when a department staff member can attend, shall coordinate the neighborhood meeting, and shall retain an independent facilitator if needed. All neighborhood meetings shall be convened at a place in the vicinity of the proposed development.

Commented [BHFS1]: Instead of presuming significant impacts, which is a negative assumption treating oil and gas operations disparately from other impactful industries, the City may simply require the neighborhood meeting.

20628730.1



June 3, 2020

Commerce City Public Works
Domenic Martenelli
7887 E. 60th Ave.
Commerce City, CO 80022

VIA EMAIL

SUBJECT: Comments re: Commerce City's Proposed Oil and Gas Ordinance

Dear Mr. Martenelli:

The American Petroleum Institute Colorado ("API") appreciates the opportunity to review and comment on Commerce City's Proposed Oil and Gas Ordinance. We appreciate your belief that a robust stakeholder process is vitally important to identifying and resolving highly technical and complex issues in cases such as this. We sincerely appreciate your outreach thus far.

The American Petroleum Institute (API) represents all facets of the oil and natural gas industry in Colorado. API and its member companies are committed to ensuring a strong, viable oil and natural gas industry capable of meeting the energy needs of Colorado in a safe and environmentally responsible manner. Again, we appreciate your efforts to develop a comprehensive code that meets the needs of operators and residents alike.

A. Proposed Regulations

As an initial matter, we would like to begin by again stating we appreciate the city's stakeholder process throughout the development of this code. However, we would note that we have concerns about two significant provisions.

Sec. 21-3216 Section 14 governs the assignment of permits. We appreciate the city's desire to ensure future compliance with any permitted and operating well in the instance of a sale or transfer. With that in mind, our concerns lie with subsection c which states that "The new Operator will remedy any on-site noncompliance with any applicable local or state regulations and permits, as a condition of the assignment." This provision would require any new owner of the assets to redevelop the already producing wells in a fashion not in accordance with the laws and regulations in place at the time of development. In other words, this code provision would apply new code standards retrospectively.

Retrospective legislation is constitutionally prohibited. Colo. Const. Art. II, § 11 (prohibiting the General Assembly from passing *retrospective* legislation) (emphasis added); *People v. D.K.B.*, 843 P.2d 1326, 1332 (Colo.1993). A statute is retrospective if it "takes away or impairs vested rights acquired under existing laws, or creates a new obligation, imposes a new duty, or attaches a new disability, in respect to transactions or considerations already past." *In re Estate of DeWitt*, 54 P.3d at 854



(quoting *Denver S. Park & Pac. Ry. Co. v. Woodward*, 4 Colo. 162, 167 (1878)). This proscription is intended to prevent the unfairness that would otherwise result from changing the consequences of an act after that act has occurred. *Van Sickle v. Boyes*, 797 P.2d 1267, 1271 (Colo.1990).

We would argue this is the situation under this proposed code language. Essentially the city is requiring that any well that is governed by a private contract or previously issued permit, and has continued to meet those obligations, would be required to be redeveloped under a set of rules and regulations that were not in effect at the time the permit was issued or under contract terms other than those governing the original development. The well, the mineral rights, and the associated permit are all vested personal property rights and requiring a new purchaser to conform to a new set of standards would certainly impact the primary owner's right to sell or transfer those assets.

This issue can be illustrated through your proposed air quality regulations. Sec. 21-5266(12)(a) requires that "Operator must eliminate, capture, or minimize **all** potentially harmful emissions, including Volatile Organic Compounds (VOC's) and BTEX through compliance with these provisions and the BMP Document." As an initial matter, this is a scientific and technical impossibility. Not just with respect to oil and gas, but with any and all business development that is proposed within the city. No industry, business, or otherwise can eliminate and control all emissions. Further, the city has proposed to required a baseline air monitoring plan that is subjective at best, which will then set a "baseline" that essentially requires continuous air monitoring throughout the life of the well. This provision assumes that technology related to continuous emissions monitoring is feasible for various pollutants, proven for a number of different applications, and commercially available. API does not believe that the technology has advanced to this level. Further, the BMP document requires mandatory participation in what are voluntary programs, outlines prohibitions requires the implementation of technology that may either be unnecessary or impracticable, outlines subjective standards that may be amended at any time, and requires other standards that in sum, will essentially prohibit any operator, current of future, from being able to comply. We would suggest one avenue would be for the city to contact the APCD to discuss your proposal. We would also note that APCD will be considering rules for emissions monitoring of its rulemaking docket in 2020 and 2021, which should be helpful to local governments and the public in understanding the potential for application of this technology.

In other words, the regulations taken as a whole will make compliance by any operator nearly impossible, and in effect will prohibit the sale and transfer of any asset.

We also understand you view an oil and gas permit as analogous to a business or franchise license which is not transferrable under city statute and requires a prospective purchaser to reapply. There are several important distinctions with respect to this comparison. First, it is important to note we are not asking to be exempted from the transfer requirements for a permit, rather we seek to be treated as other private property where the purchaser is required to continue compliance with those regulations that



governed its original development. This is similar to personal property such as a house. We can find no regulation that requires the retroactive application of building requirements prior to the sale of a house in Commerce City. We believe this issue can be resolved with the substitution of a provision that provides that any new operator “will continue compliance with all rules, regulations, or governing contracts applicable at the time of development.” This simply means that any prospective buyer will know they will be required to continue compliance in the same manner as the current owner of the assets. Further, this will remedy any issue with impairment of property rights as any owner will be free to sell or transfer their assets upon any new buyer agreeing to the original terms governing development, and the city can feel comfortable that compliance with its rules will be continued.

The final issue is again retrospective in nature. Section 18 governs enforcement and penalties, and the new language seems to seek the ability to apply the new code’s enforcement mechanisms to already in place permits and developments. Thus, we would suggest you insert the word “prospective” in front of the term Regional Operator Agreement to clarify that the code only applies to future agreements, not those that are already in place and governed by their own terms. Any in-place ROA certainly contains its own enforcement mechanisms, and under Colorado law those will control.

Again, we appreciate the opportunity to comment on this proposal. Thank you for your time and we are looking forward to providing any further comments as needed. If you have any questions, please do not hesitate to contact me at (720) 878-7688, or mcgownec@api.org.

Sincerely,

Chris McGowne
Associate Director
Colorado Petroleum Council



May 29th, 2020

Commerce City Council
7887 E. 60th Ave.,
Commerce City, CO 80022

RE: Commerce City Draft Oil and Gas Regulations

LOGIC appreciates the opportunity to engage with Commerce City throughout the process of drafting new oil and gas regulations for the City. LOGIC is a 501.c.3 nonprofit organization that works to bring the voice of impacted communities directly to their decision makers. Our goal is to enact policies that protect public health and safety and our environment. With that in mind, we offer the following comments.

SB19-181, signed into law by Governor Polis in April of 2019, granted local governments the authority to enact local regulations more protective of public health, safety, and welfare, the environment, and wildlife resources than the State. Under this new law, local governments like Commerce City no longer need to fear that the best possible regulations they can enact will be preempted by the State's own, less protective regulations. This shift allows a local government to specifically tailor their regulations to the needs of their community.

SB19-181 also transformed the Colorado Oil and Gas Conservation Commission (COGCC) from an agency that fosters oil and gas development to one that regulates oil and gas development to protect public health, safety, and welfare, the environment, and wildlife resources. This change prioritizes health and safety over the extraction of oil and gas.

We thank Commerce City and recognizing their new authority and the new state priorities, and for recognizing the need for new local oil and gas regulations as the result. These new regulations will have the added benefit of universal application, unlike the outdated operator agreements currently used to regulate oil and gas operations within Commerce City. The draft published by the City in March 2020 included many valuable provisions that will significantly improve the health and safety of the residents of Commerce City. We appreciate the zoning provisions that recognize

that oil and gas development only belongs (if it belongs anywhere) in areas already zoned for industrial activity. We also appreciate that the draft regulations allow for the denial of applications that would adversely impact public health, safety, and welfare, and that increased bonding requirement of \$82,500 per well, not well pad.

However, there are a few areas where the City must go much further. The primary areas for improvement are: setbacks, cumulative impact assessments, and the City's denial authority.

1. Setbacks

Sec. 21-5266(6) Setbacks and Floodplains states that no oil and gas production site may be located within 1,000' of homes, schools, and businesses, among other locations. This standard is likely to be well under the distance the COGCC ends up adopting. As of May 26th, the COGCC is working off a draft that includes a 1,500' setback from ten or more homes. However, LOGIC and numerous other organizations have offered amendments to that proposal to expand the distance to 2,640' from schools, and 2,500' from an individual home, any other dwelling, high occupancy buildings, and outdoor activity areas.

Even if the COGCC goes with its current draft, Commerce City has the authority to enact a more protective setback provision than the state. 1,000' is not far enough to ensure that oil and gas operations will not adversely impact the health and safety of Commerce City residents. Extensive research has demonstrated that the effects of oil and gas development extend far beyond the proposed 1,000' limit. North Range Concerned Citizens (NRCC) has provided an extensive list of health impact studies which thoroughly demonstrate the need for much greater setbacks. The studies included in NRCC's summary include presence of excessive benzene and other Volatile Organic Compounds (VOCs) near in neighborhoods near oil and gas facilities, increased cancer rates, pre- and post-natal health issues, birth defects, increased asthma attacks, headaches, dizziness, nose and throat irritation, eye irritation, shortness of breath, and skin rashes.¹

¹ See Appendix A to comments on Commerce City draft oil and gas regulations submitted by North Range Concerned Citizens on May 29th.

Beyond the studies included in the EarthJustice comments, the Colorado Department of Public Health and the Environment (CDPHE) published a study last year that found adverse health impacts extending to 2,000' from oil and gas locations.²

All of these studies highlight the need for setbacks greater than 1,000' from places where people live, work, and recreate, and they are supported by the real-life experiences of Coloradans living near oil and gas development in other jurisdictions. The residents of Broomfield, Adams County, Battlement Mesa, Erie, and countless other municipalities would tell the tale of what happens when they were forced to deal with inadequate setbacks. Odors and noise along with nosebleeds and headaches were the most common complaints filed by residents in the last ten or so years, and stronger setback regulations in Commerce City could alleviate most of these issues. Other jurisdiction have taken steps to address these issues under the new SB19-181 regime. The Town of Superior has recently enacted a 1,500' setback and zoning restriction, and the City and County of Broomfield raised the bar by enacting a 2,500' setback.

All of this points to the need to increase the setback distance from 1,000' to 2,500' in order to better protect the residents of Commerce City from the adverse health impacts associated with oil and gas development.

2. Reverse Setbacks

In the current draft Sec. 21-6280(1), Commerce City proposes adopting a tiered reverse setback system. The current proposal has different standards for producing wells and wells that have not yet gone into production. For wells that have not gone into production, the current draft proposes a setback of 1,000' between production site and the new home plat. For well that are already producing, the proposal would set back new housing development 300' from 1-10 wells, 400' from 11-24 wells, and 500' from 25 or more wells.

While LOGIC can certainly understand the arguments from housing developers that any increase in reverse setback increase would limit their ability to build new houses, we are more concerned with the health and safety of the residents of Commerce City. We also understand the intent in making the setback distances different for producing wells and wells still being drilled and completed. Oil and gas facilities certainly emit more hazardous chemicals during drilling and completion operations than they do

² Ed Carr, et al. Final Report: Human Health Risk Assessment for Oil & Gas Operations in Colorado, submitted to Colo. Dept. of Public Health and Env., October 17, 2019

during production. However, that does not meet that they emit nothing once they have gone into production.

Even in production, oil and gas production facilities are still major sources of pollution, odors, and noise. The arguments made above in favor of a greater setback between new wells and existing homes apply equally to the setbacks between new homes and existing wells. Furthermore, operators can frack a well more than once. Nothing in the current draft addresses the fact that operators are allowed to re-enter wells to re-complete them. This activity would subject the people living and working within the reverse-setback distance to the same level of emissions as the initial drilling and completion process. The only way to avoid this issue is to either prohibit recompletion operations or expand the reverse setback distance to acknowledge this fact.

For those reasons, we request that Commerce City adopt a uniform 2,500' setback between new homes and existing oil and gas facilities to protect the health and safety of all Commerce City residents.

3. Cumulative Impacts

Commerce City is facing the prospect of a massive amount of new oil and gas development. Though one of the companies proposing to conduct these operations (Extraction Oil & Gas) is on the cusp of bankruptcy, the amount of oil and gas operations proposed within Commerce City remains unchanged. Extraction Oil & Gas alone has submitted applications for a total of 154 oil and gas wells on seven locations.

When paired with the already high emissions originating from industrial facilities like the Suncor refinery within Commerce City's boundaries, the addition of 154 could have potentially extreme consequences. This is especially true when taken in consideration with the emissions from hundreds of additional wells within 20 square miles of the Commerce City.

Given the potential for massive increases in local emissions, it is deeply troubling that the draft regulations have no plan to deal with the cumulative impacts of all the existing and foreseeable development in the area.

We strongly encourage Commerce City to develop a plan to require a cumulative impact assessment prior to the approval of any oil and gas development permit. This could be accomplished by including a definition of Cumulative Impacts in the definition section of the proposed regulation. We propose the following definition:

Cumulative Impact means the total impact to air quality, water quality, traffic, noise levels, odor, soil and visual aesthetics caused by the proposed new or expanded oil and gas facility in combination with all such existing and reasonably foreseeable development of any type within 20 miles, regardless of the jurisdiction in which the activity is taking place. We include soil impacts in this list to address the issues within the Rocky Mountain Arsenal. The background pollution levels must be accounted for in all cumulative impact assessment work. Commerce City must also be able to expand this area if the local topography requires a greater assessment area.

We also request that the City add a cumulative impact assessment plan to the Section 21-3216(8) Review criteria.

4. Consultation with State Agencies

In the current draft regulations, there are several opportunities for the Commerce City to exercise its discretion to require consultation with state agencies, specifically the Colorado Department of Public Health and the Environment (CDPHE) and Colorado Parks and Wildlife (CPW).

We request that these consultations be made mandatory. Any oil and gas permit application should trigger mandatory consultation with both CDPHE and CPW. This consultation must inform both the consideration of the individual application and the cumulative impact analysis discussed above in Section 3 of this comment letter.

5. Assignment of Permits

The current market conditions highlight the need for revisions to Commerce City's regulations on the transferability of oil and gas permits. Sec. 21-3216(14) states that a permit may only be assigned with the consent of the Director, and that the Director may only offer consent to the assignment when certain conditions are met.

We request that an additional condition be added to this section. The new operator must certify that they will comply with all relevant regulations and requirements in the Best Management Practices document, even if these have been updated after the permit was approved. Commerce City must also be able to add any additional conditions to the permit to address any issues that have arisen during the operations on the permitted location.

6. Denial Authority

The draft regulations do recognize the City's authority to deny applications that would adversely impact public health and safety, we want to reaffirm the basis for that authority here.

Oil and gas operators and their supporters love to threaten any jurisdiction contemplating more protective regulations with a regulatory takings lawsuit. Fortunately, these operators rarely follow through on such claims. Perhaps this is because, historically, takings claims are extremely unlikely to succeed.

Fortunately for Commerce City, the passage of SB19-181 has made the oil and gas industry's takings threats even less likely to prevail. In addition to the changes in state priority described above, SB19-181 also changed the definition of waste to specifically exclude any mineral resource left in the ground to protect public health, safety, and welfare, the environment, and wildlife resources. Now, in Colorado, it is no longer considered waste to protect public health and safety.

Furthermore, in order for a regulatory takings claim to prevail, the claimant has to prove that the regulations eliminate virtually the whole value of the property. Colorado courts have allowed regulations that reduced the value of property by up to 93% to survive without a takings finding. Courts have also found that the intent to protect public health and safety weighs in favor of allowing the regulation, even in the result of a total takings. The extensive evidence already provided in the record of this regulatory process is ample support the City's intent to protect public health and safety.

Thus, when alleging a regulatory taking, a plaintiff generally must prove that a government decision eliminated most of a property's value and such a reduction was not justified by other factors like investor expectations, the nature of the government action, or any other relevant reason. A government action justified by appropriate public and safety findings provides considerable protection against a takings claim, even if the action resulted in a significant reduction of value.

Even prior to SB19-181, oil and gas related takings claims were rarely filed in Colorado. Most recently, when the City of Longmont enacted its fracking ban, the plaintiff initially filed a takings claim but later dismissed it to focus on their state preemption argument when lack of standing became an issue. Even in New York, when fracking was banned statewide, very few takings cases were filed, and none were successful.

Post SB19-181, the bar to demonstrate that a local government regulation, designed to protect public health and safety, rises to the level of a regulatory taking is *extremely* high. The commonsense regulations laid out in this draft fall far below that bar.

7. Conclusion

With a few changes, these draft regulations could make a significant improvement to the health and safety of Commerce City residents. We strongly urge you to adopt the changes proposed above. We also urge you to stand strong in the face of the extremely exaggerated claims the oil and gas industry is likely to make. Commerce City needs oil and gas regulations based on science and data, designed to offer maximum protections for its residents' health, safety, and welfare. Thank you for the opportunity to engage in this process, and to provide comments on these draft regulations. We welcome any questions you might have, and would be happy to continue this productive dialogue.

Sincerely,

Sara Loflin, Executive Director
League of Oil and Gas Impacted Coloradans

May 29, 2020

Dear Mayor Huseman, members of City Council, staff, and counsel:

Thank you for the opportunity to comment on Commerce City's latest oil and gas regulations draft released on March 10, 2020. These comments are submitted on behalf of North Range Concerned Citizens (NRCC) after consultation with Earthjustice. The NRCC is a coalition of Commerce City residents and neighborhoods whose goal is to prevent the negative impacts of oil and gas development in residential areas.

As you know, last year the Colorado General Assembly passed Senate Bill 19-181 (SB19-181 or SB 181), which brought about a significant change to oil and gas development in Colorado. Among its main features, SB 181 clarified the power of local governments to treat oil and gas development like any other type of land use and changed the Colorado Oil and Gas Conservation Commission (COGCC) from an agency tasked with simultaneously promoting and regulating the oil and gas industry into exclusively a regulatory body tasked with protecting public health, safety, welfare, the environment and wildlife resources in relation to oil and gas development.

We commend the City Council for recognizing the need to strengthen its regulations to protect Commerce City residents who would be negatively affected by oil and gas operations within city limits. We appreciate the regulatory approach with rules applicable to all operators rather than the *ad hoc* and outdated operator agreement approach previously contemplated by the city. We are encouraged by the recognition shown in the current draft that oil and gas drilling should only occur (if at all) in areas zoned for similarly large industrial operations. We believe the current draft appropriately clarifies oil and gas permits can be denied after an overall analysis that recognizes the primacy of public health, safety, and welfare rather than just an operator's document submission compliance.

We also conclude the latest draft regulations can go further to protect the health, safety, and welfare of Commerce City residents by analyzing cumulative impacts of oil and gas

development and increasing minimum setbacks. As explained further below, neither of these changes would constitute a mineral rights regulatory takings when the regulations are designed to ensure the protection of public health, safety, and welfare.

a. Cumulative impacts

Commerce City is the target for at least ten upcoming large-scale oil and gas development projects, most of which are likely to occur at approximately the same time if the Council and COGCC approve all of the forthcoming permits. Those projects would add to the high emissions activity of several existing industrial facilities, including but not limited to the Suncor refinery, which already contribute to diminished air quality for Commerce City residents.

There is no mention in the latest draft regulations of the cumulative impacts new oil and gas operations would have upon the health, safety, and welfare of Commerce City residents. This is an unfortunate omission because the cumulative impacts of increased oil and gas drilling in a small geographical area would result in a significant degradation of health, safety, and welfare of Commerce City residents.

Publicly available plans and permits currently outline 254 new well sites combined onto 10 new mega-pads within 20 square miles of Commerce City to be drilled within a short time frame of each other.

We urge the Council to account for the cumulative impacts of all of the proposed oil and gas projects in its final regulations and specifically call for a denial of permits if the proposed projects would increase the cumulative impacts above a level detrimental to public health, safety, welfare, the environment, and wildlife resources.

SB19-181 requires the Colorado Oil and Gas Conservation Commission to “evaluate and address the potential cumulative impacts of oil and gas development” in its permitting process. C.R.S. § 34-60-106(11)(c)(II). The COGCC is developing rules to determine its process by which it will evaluate and address cumulative impacts, but those rules are not expected to be finalized until

November of this year at the earliest. In the meantime, it is possible some of those 254 wells slated for Commerce City will be analyzed and approved by the state without regard to the cumulative impacts of those wells.

Commerce City does not need COGCC rules to be finalized before it can utilize a cumulative impacts analysis as part of its own permit review process. *See e.g.* C.R.S. § 29-20-104(1)(i) (local governments have the explicit authority to plan for and regulate the use of land to protect the environment). Indeed, it is crucial that Commerce City incorporate a cumulative impacts analysis into its permitting decisions given the sheer number of proposed new large oil and gas projects set to occur within a very short period of time in a small area.

The provision to evaluate and address cumulative impacts of oil and gas development is a new requirement under Colorado law; however, federal law has required the evaluation of the cumulative effects of many types of proposed developments since the enactment of the National Environmental Policy Act (NEPA) in 1970. 42 U.S.C. § 4321 *et seq.*¹ NEPA requires a cumulative effect analysis as part of an agency's Environmental Impact Statement that must precede approval of a project. *Id.*

For the purposes of NEPA, cumulative impacts are defined as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” 40 CFR 1508.7. “Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.” *Id.* The NEPA cumulative impacts analysis was designed to determine whether “a small amount here, a small amount there, and still more at another point could add up to something with a much greater impact.”²

¹ Colorado law refers to cumulative “impacts” operations while federal law refers to cumulative “effects” and “impacts” interchangeably; this letter refers to cumulative impacts when describing both Colorado and federal law.

² *Wild Earth Guardians v. U.S. Bureau of Land Management*, CV 18-73-GF-BMM, D. Mont. (May 1, 2020 order). Link: http://blogs2.law.columbia.edu/climate-change-litigation/wp-content/uploads/sites/16/case-documents/2020/20200501_docket-418-cv-00073_order.pdf

There are no statutes defining the specific requirements for a cumulative impacts analysis under NEPA, but federal agency guidelines and case law from federal courts emphasize the need to identify the following factors: (1) the geographical area by which a particular impact or range of impacts will occur; (2) the impacts of past, present, and reasonably foreseeable future actions in that geographical area; and (3) the incremental effects of the proposed new action and their contribution to the overall impacts.³

We believe understanding NEPA is useful in outlining a local cumulative effects analysis process but the local government approach need not mirror the federal model. A Commerce City cumulative impacts analysis should ask when a proposed new oil and gas project would be a step too far for residents' health, safety, and welfare given existing or foreseeable future development plans of all types within city limits. A local approach should acknowledge one new oil and gas project in the area may not raise concerns about its overall impact on public health and safety, but a second site may cause unacceptable cumulative impacts, even if that second site follows the same health and safety guidelines as the first one. Such a possibility only increases with the number of additional oil and gas projects that are approved.

Consider, for example, the proposed Falcon, Owl, and Blue Jay wellpad sites. Those three large projects would be located within a two-mile radius in the northeastern corner of Commerce City. The local roads will be profoundly impacted by the truck traffic necessary to construct, drill, complete, fracture, and maintain all 54 wells that will be drilled at these three sites—not just the 18 wells at each pad. There is already a great deal of conflict between wildlife and other land uses in this area, and the cumulative impacts of dozens of new oil and gas wells and the associated construction infrastructure will exacerbate this conflict.

Similarly, the proposed Harlo and Anteater sites on the western side of Commerce City are directly adjacent to one another, which will collectively increase traffic on Highway 2 and Peoria Street, and potentially have cumulative impacts on the First Creek watershed that is nearly

³ See, e.g. Bureau of Land Management, “National Environmental Policy Act Handbook H-1790-1” (2008) at https://www.blm.gov/sites/blm.gov/files/uploads/Media_Library_BLM_Policy_Handbook_h1790-1.pdf.

adjacent to both well pads. The cumulative effect alone of the Harlo and Anteater wellpads may turn those projects into a dangerous health and safety risk for nearby residents.

None of those proposed sites should be analyzed in isolation, but the current draft rules do not require any consideration of the cumulative impacts accompanying two or three sites within close proximity, not to mention the impact of ten large industrial sites constructed during a short time period within city limits.

The cumulative impacts of a proposed new or expanded oil and gas site should be analyzed by Commerce City using information already available to it about existing and reasonably foreseeable future land uses in addition to information provided by the operator-applicant. The analysis should consider the effect of proposed oil and gas facilities on areas of importance to public health, safety, and welfare like air emissions, water quality, traffic, noise, odor, and visual aesthetics. Specific additions to the draft rules to adopt a cumulative impacts analysis are outlined as the following (additions are in red):

Article III, § 21-3216(8) **Review.** An oil and gas permit may be approved if all of the following criteria are met:

...

(m) The cumulative impact of the proposed facility can be addressed to protect and minimize adverse effects on public health, safety, welfare, the environment, and wildlife resources.

Article XI, § 21-11200 **Definitions.**

(113) **Cumulative impact** means the effect on air emissions, water quality, traffic, noise, odor, and visual aesthetics caused by the incremental impact of a new or expanded oil and gas facility when added to other past, present, and reasonably foreseeable future development of any type in the same geographical area.

Article V, § 21-5266, **Subsurface Extraction.**

Application Requirements. An application for an Oil and Gas Permit shall include the following:

...

Section 3(oo): A cumulative impact statement that summarizes the effects of the operator's existing and/or proposed oil and gas facilities within Commerce City and a five mile radius outside of city limits (if any) on air emissions, water quality, traffic, noise, odor, and visual aesthetics.

b. Setbacks and Reverse Setbacks

We appreciate the willingness of the city council to consider setback distances beyond the woefully inadequate state setback requirements. However, we strongly encourage the City to consider going further than its current 1,000-foot proposal. Article V, §21-5266(6). Peer-reviewed scientific studies and anecdotal evidence of the harm caused by oil and gas operations near populated areas continues to expand at a rapid pace. The Town of Superior recently enacted a 1,500-foot setback and the City and County of Broomfield is considering a setback of 2,000 feet. Several other jurisdictions have also noted the latest evidence and asked their staff and counsel to consider setbacks longer than 1,000 feet for their updated oil and gas regulations. We ask Commerce City to do the same, as the evidence of harm to the health and safety of nearby residents from oil and gas facilities is beyond dispute at this point.

We have included a list of recent studies relevant to setback distances recently compiled by Earthjustice in the attached *Appendix A*. Those studies paint a clear picture of the health impacts caused by oil and gas development well beyond 1,000 feet. For example, one study found elevated concentrations of volatile organic compounds, including benzene levels above EPA's cancer risk threshold, at residential properties in Erie and Longmont located up to 1,391 feet

from oil and gas sites. *Thompson et al. (2014)*. Other studies of health impacts in Colorado have found cancer risks above EPA's recommended thresholds at distances of 2,000 and 2,640 feet. *McKenzie et al. (2018)*; *McKenzie et al. (2012)*. These studies are consistent with numerous peer-reviewed studies conducted on the Colorado Front Range finding elevated concentrations of hydrocarbons due to oil and gas section emissions, many of which have direct health effects on people. See e.g. *Oltmans et al. (2019)*; *Bien & Helmig (2018)*; *Evans & Helmig (2017)*; *Kaser et al. (2017)*; *McDuffie et al. (2016)*; *Pétron et al. (2014)*; *Swarthout et al. (2013)*; *Gilman et al. (2013)*; *Pétron et al. (2012)*.

Cancer is far from the only health risk posed by close proximity to oil and gas development. In October 2019 the COGCC and CDPHE released a peer-reviewed health assessment using emissions data and air quality modeling that found acute exposures during flowback and well completion operations to residents 2000 feet from a well at levels that could involve hematological toxicity associated with benzene exposure (which can involve symptoms such as nosebleeds and headaches).⁴ Another study found a statistically significant increase in reported symptoms including headaches, nose bleeds, throat irritation, eye burning, shortness of breath, and skin rashes by residents who lived within 1500 feet of a well compared to those who lived farther away. *Steinzor et al. (2013)*. Other studies, including several in Colorado, have found that mothers living in closer proximity to oil and gas development experience elevated rates of high-risk pregnancies, birth defects, and other pre- and post-natal health issues. See *Casey et al. (2016)*; *Casey et al. (2019)*; *McKenzie et al. (2019)*; *McKenzie et al. (2017)*; *McKenzie et al. (2014)*; *Janitz et al. (2019)*; *Stacy et al. (2015)*. Several studies have found evidence of birth defects and pre-term birth among mothers who live within 2,640 feet (1/2 mile), 3,280 feet (1 km), and even as far as 9,842 feet (3 km) away from oil and gas development. *Whitworth et al. (2017)*; *Curry et al. (2017)*.

Other entities reviewing this literature have determined that setbacks larger than 1,000 feet are warranted to protect public health. A 2014 University of Maryland study concluded that 2,000-

⁴ ICF, *Final Report: Human Health Risk Assessment for Oil and Gas Operations in Colorado* (2019). Link: https://drive.google.com/file/d/1pO41DJMXw9sD1NjR_OKyBJP5NCb-AO0l/view

foot setbacks are justified based on the scientific evidence of impacts.⁵ In 2018, the County of Los Angeles Department of Public Health recommended setbacks of 1,500 feet based on its own literature review.⁶ New York went even further and banned fracking statewide after the state's Department of Public Health issued a report discussing its significant risks and the likelihood of adverse health impacts.⁷

These studies are bolstered by the record of citizen complaints to COGCC. Over the 9 ¾ years from January 2010 through September 2019 (117 months), COGCC recorded 4,772 complaints – more than one per day. Of those, 25 percent involved complaints relevant to CDPHE's 2019 health modeling study of acute impacts. The large majority of those involved odors: COGCC received an average of one odor-related complaint every three days (1,187 complaints). In addition, a substantial number of complaints involved symptoms consistent with the acute exposures modeled by the CDPHE study. These included numerous complaints of headaches (104 complaints), burning/itching/irritation (84 complaints), and nausea (54), as well as periodic complaints about nosebleeds and dizziness.

Other complaint compilations are similar. According to the Colorado state toxicologist in a November 2019 letter to Commerce City staff, “the health effects related to short-term exposures to VOCs modeled in [CDPHE's 2019] study are consistent with concerns from people using the Oil and Gas Health Information Line. These include headaches, dizziness, respiratory problems, and irritation of the eyes and skin. About 60% of health concerns reported to the Oil and Gas Health Information and Response Program since it started in 2015 have been about these kinds of health effects. More than 750 reported health concerns that include these short-term health effects since 2015.”⁸

⁵ Maryland Institute for Applied Environmental Health, *Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland* (2014), <https://phpa.health.maryland.gov/OEHFP/EH/Shared%20Documents/Marcellus%20Shale/MDMarcellusShalePublicHealthFinalReport08.15.2014.pdf>.

⁶ Katherine Butler et al., *Public Health and Safety Risks of Oil and Gas Facilities in Los Angeles County*, Los Angeles County Department of Public Health, Feb. 2018, at 20–22. http://publichealth.lacounty.gov/eh/docs/PH_OilGasFacilitiesPHSafetyRisks.pdf.

⁷ N.Y. State Dept. of Public Health, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development* (2014). Link: https://drive.google.com/file/d/1pO41DJMXw9sD1NjR_OKyBJP5NCb-AO0I/view

⁸ Nov. 1, 2019 letter from K. Boyer, Tri-County Health Dept., to D. Martinelli, City of Commerce City at 5.

Those complaints provide further evidence of the benefit of moving oil and gas operations away from homes, schools, and other occupied structures. Moreover, they are likely just the tip of the iceberg. Most residents experiencing such symptoms were likely unaware of COGCC's complaint process or did not connect their symptoms to the nearby fracking activity. Other residents may have contacted local authorities or other agencies instead of the COGCC.

The increasing weight of authority and experience shows 1,000-foot setbacks are an important starting point for local government discussions but ultimately inadequate to protect public health, safety, and welfare. Many Commerce City residents have rightfully asked for longer setbacks, and those requests are backed by an ever-increasing amount of data.

In the same vein, the currently proposed reverse setback distances are wholly inadequate. Just as the health and safety of residents is not appropriately addressed by a 1,000-foot setback between new oil and gas facilities and existing residential areas, a reverse setback as short as 300 feet (or just one football field) between existing facilities and new residential development is totally deficient. Health and safety concerns about oil and gas facilities do not end once production begins; issues with air emissions and accidents in particular continue throughout the life of the well. Whatever its ultimate decision is on setbacks, the rationale used by Commerce City to justify those setbacks should equally apply to the distances assigned to reverse setbacks as well.

c. Denying a permit is not a regulatory takings if done in a reasonable manner to protect public health, safety, and welfare.

Colorado law does not give oil and gas companies or mineral rights owners an absolute right to drill. We are aware representatives of the oil and gas industry and some public commenters have invoked the spectre of regulatory takings if Commerce City strengthens its regulations. While oil and gas operators and mineral rights owners commonly threaten regulatory takings lawsuits in response to potentially adverse governmental land use decisions, such warnings are merely scare tactics intended to intimidate the local government. Affected parties rarely follow through on those threats because they know winning a regulatory takings claim in Colorado is difficult. The only instance of a regulatory takings claim related to oil and gas development filed

in a Colorado court was related to the 2012 Longmont citywide fracking ban, but the plaintiffs in that case eventually withdrew their takings claim and focused on their state preemption theory.⁹ Notably, even after New York instituted a *statewide* fracking ban in 2014, only one takings lawsuit was filed in its state courts and it was unsuccessful.¹⁰ While often threatened, regulatory takings lawsuits related to oil and gas operations are rarely filed and have yet to succeed.

When alleging a regulatory taking, a property owner must prove a government land use decision eliminated most of that property's value and such a reduction was not justified by other factors like investor expectations, the nature of the government action, or any other relevant reason.¹¹ Colorado courts follow the *Animas Valley*¹² standard, which requires a 'very high level of interference' with property rights before a regulatory takings finding can occur.¹³ *Animas Valley* cited and incorporated several instances where a property value diminution of between 75% and 93% was not considered to be a regulatory takings after a fact-specific analysis. *Id.* at 66.

Changes made to Colorado law by SB 181 further strengthen local governments' defenses against regulatory takings claims. First, SB 181 expressly elevates the importance of public health, safety, and welfare relative to other considerations, including the state's interest in developing minerals. Second, SB 181 changed the definition of resource "waste" to clarify that it "does *not* include the nonproduction of oil or gas from a formation if necessary to protect public health, safety, and welfare, the environment, or wildlife resources." C.R.S. §34-60-103(11)(b),(12)(b),(13)(b). Therefore, if a government entity denies a permit because a proposed location is inconsistent with protecting public health and the environment, temporarily preventing an operator from accessing its mineral rights, it will not constitute "waste" of the resource.

⁹ *City of Longmont v. Colorado Oil and Gas Ass'n.*, 2013CV63 (20th Judicial District Court Order)

¹⁰ See e.g., Jon Campbell, *Expected Lawsuits Don't Follow NY Fracking Ban*, Lohud.com, Apr. 20, 2017.

¹¹ See e.g., *Penn Cent. Transp. Co. v. New York City*, 438 U.S. 104 (1978), *Palazzolo v. Rhode Island*, 533 U.S. 606 (2001).

¹² *Animas Valley Sand & Gravel, Inc. v. Bd. of County Comm'r's*, 38 P.3d 59 (Colo. 2001).

¹³ For context, the specific quote from *Animas Valley* is the following: "Although the *Palazzolo* Court did not address what level of interference a government regulation must have caused to constitute a taking under a fact-specific inquiry, a mere decrease in property value is not enough. This is true because a landowner is not entitled to the highest and best use of his property. Reading *Palazzolo* together with the Court's prior precedent, it is apparent that the level of interference must be very high."

Additionally, a government decision limiting oil and gas drilling in a particular geographic area does not mean those minerals are forever deprived of all economically viable use. They remain in the ground, to be possibly extracted in the future with different technologies or using different safeguards. Many minerals presently coveted were unobtainable and worthless as few as ten years ago. Changes in drilling technology could lead to future extraction consistent with public health and safety. In light of the possibility that a 93% diminution of property value may still not result in a regulatory takings, it is not difficult to imagine that someone might be willing to purchase mineral rights at 7% of their prior value to have the option of producing at a future time when technology and drilling techniques address public health and safety concerns in a satisfactory way.¹⁴

In summary, enacting regulations adequately protective of public health, safety, and welfare as well as denying an oil and gas permit based upon the same criteria provide ample protection against a regulatory takings claim. SB181 allows local governments to treat oil and gas drilling as any other type of land use. A local government would not be liable for a takings if it denied permission to build a large chemical plant on the desired property due to health and safety concerns; the same principle now applies to oil and gas drilling.

d. Conclusion

Thank you again for the opportunity to comment on Commerce City's March 10, 2020 updated regulations draft. We believe the draft takes important new steps to protect the health, safety, and welfare of Commerce City residents. Incorporating a cumulative impacts analysis and increasing setbacks and reverse setbacks are crucial additional steps in that process. As always, we are open to further discussion, participation, and questions.

Sincerely,

The Commerce City residents of North Range Concerned Citizens

¹⁴ Kevin Lynch, *Regulation of Fracking Is Not a Taking of Private Property*, 84 U. Cin. L. Rev. 38, 87 fn 257 (2016).

Comments Pertaining to Ordinance # 2235 (Ordinance Draft)

In recent months, Commerce City's Staff (Staff) members met with various citizens and advocacy groups to discuss oil and gas issues. Discussions included the above referenced Ordinance Draft. Below are comments to address my concerns.

1. In a meeting, Staff explained that Colorado Oil & Gas Conservation Commission (COGCC) would be the ceiling for regulations that govern Commerce City (City). My understanding is that the City has no plans to invoke any rules, regulations, or standards that exceed those brought forth by COGCC. SB19-181 gives local governments' explicit authority to exceed COGCC regulations. Citizens and advocacy groups have repeatedly expressed to the City that this is a unique opportunity to protect the health, safety and welfare of citizens. The City seems to be indicating to citizens, that there is no political will or genuine desire to act accordingly.
2. Further, the City allowed the initial permits for approximately 150 wells to be *deemed complete* even before the new Ordinance Draft is enacted, and therefore, the very weak or minimal standards currently in effect are all that apply. The understanding is that the reason the Ordinance Draft is being written is to enhance and create more substantial regulations to benefit the health, safety and welfare of everyone. This begs the question: Did the City do any type of feasibility/environmental study to determine what potential damage/liability they might be assuming with the approximately 150 wells that are *deemed complete*? This in and of itself demonstrates to the community and State that the City is putting the industry above the health, safety and welfare of the citizens. This is the City's opportunity to protect the citizens and what they are choosing to do is reckless.
3. The setbacks formulated and set forth in the Ordinance Draft of 1,000 feet, is a deplorable health hazard. The Colorado Department of Public Health and Environment (CDPHE) study found adverse impacts on people living/working at least 2,000 feet from a drilling site. Many studies have also documented the adverse impacts on expectant mothers and newborns. Furthermore, studies have substantiated things like congenital heart defects, headaches, allergies, asthma and bloody noses. The reverse setback of 500 feet is simply egregious, and creates an environment where citizens are vulnerable to potential health risks. During a meeting, Staff confirmed they were aware of the health studies and the impacts. Therefore, it appears the City is simply going to ignore this information and "be friendly" to oil and gas. The City would not allow a McDonald's or a Taco Bell within 500 feet of a residence, so the idea of ignoring this information shows your total disregard for the people in your community. The City should explain to the citizens how they arrived at the arbitrary number of 1,000 feet. What study did the City use to demonstrate the adequacy of 1,000 feet?
4. There is no mechanism in the Ordinance Draft to vet or determine the financial solvency of the oil and gas companies that are submitting applications for permits to operate. Here again, this is complete negligence on the part of the City.

Before a problem occurs, the City should demonstrate to the citizens all the mechanisms in place to make the community and individual citizens whole. Oil and gas companies must have the resources in place and demonstrate they are accountable to the community. The new Ordinance Draft is silent on this subject. The City is choosing to partner with companies that have no requirement to demonstrate their solvency. This again is reckless and shows no regard for the health, safety and welfare of citizens. A single incident could destroy a citizen's property and their personal financial well-being, as well as their health.

5. The Colorado Sun newspaper reported on January 29, 2020 that COGCC failed to account for and collect monies owed from the oil and gas industry. An audit found that of the 420 oil and gas operators in Colorado, 316 were out of compliance with their monthly reporting requirements from 2016 to 2018, which left millions of dollars of potential revenues on the table. During a citizen's group discussion with Staff, a recommendation put forth to the City that they should hire a third party to determine or verify what the wells produce. Staff pushed back on the suggestion. Again, if the purpose of allowing heavy industry into the community is to collect large sums of tax revenue, the City should make some attempt to verify the amount of oil and gas being extracted. The City appears to be willing to leave their potential revenues unchecked.
6. An oil and gas company is allowed under the provisions of the Ordinance Draft to sell their permitting rights to another company, without a substantial review by the City. The Ordinance Draft is almost silent on the topic of permit transfers. The Ordinance Draft should have a stringent review process, with clear rules about how the permit is to be passed from one operator to another. There are no additional or new vetting processes and procedures, the next company can just pick up where the old one left off. There is no benefit to the City or citizens to just allow this to happen.

The City says they are concerned with the health, safety and welfare of their citizens, yet they have left such gaping holes in their new proposed Ordinance Draft, and are allowing approximately 150 wells to be permitted under the current requirements with the least possible regulations and requirements and minimal vetting.

As a citizen of Colorado, I am extremely concerned about the cumulative impact Commerce City's oil and gas industry has on our State and environment. As an example, the refinery now operated by Suncor (a Canadian oil company), has been in existence since the 1920s. On December 13, 2019, the Colorado Department of Public Health & Environment issued a Compliance Advisory to Suncor for alleged violations of the Colorado Air Pollution Prevention and Control Act regulations. Suncor agreed to a \$9 million settlement. This is the biggest penalty Colorado Department of Public Health & Environment has ever leveled against a single facility to resolve air pollution violations. The City has never made any attempt to set standards or regulate Suncor's refinery or operations. The City has repeatedly turned a blind eye to the air pollution and hazards emitted from the heavy industry that sits at the core of the City. Commerce City has never independently identified any of the problems brought by Suncor that impact the health, safety and welfare of Commerce City and the State of Colorado.

Rather, the City has completely ignored all the problems and actually encouraged this company to operate in our community. To my knowledge, no attempts were ever made to invoke any type of carbon or eco-tax on Suncor, what a lost opportunity for revenue.

Furthermore, the City should ask, if oil and gas is such a huge revenue boost for Commerce City, annual reports should reflect a more prosperous community. Currently, the school district ranks 178 out of 178 and has moved to a 4-day week, property taxes in the North are so high and continue to rise, and lastly, the Water District has reported highly toxic perfluorinated (also known as PFC) in the water.

The City is at a crossroads, and it is my greatest hope the City will make every effort to prioritize the protection of the health, safety and welfare of the citizens of the City and the State. In closing, I hope the City will choose to, 1). Exceed the COGCC regulations and protect citizens, 2). Conduct feasibility/environmental studies with each proposed well site, 3). Explain the justification for the setback distances, while considering extending them to even greater distances, 4). Prove the financial solvency of each company you permit, 5). Hire a third party to calculate well production, 6). and strengthen the requirements for permit transfers. I hope the lessons learned over the last years with Suncor will serve to guide the City to making better choices about oil and gas hazards in the future.

Public Comments Regarding Proposed Fracking in Commerce City,
Colorado from Sandra Jaquith on May 29, 2020

I grew up in Commerce City. My family still resides in Commerce City and I have remained involved in many ways. As the Denver-metro area has grown, Commerce City has become a close neighborhood of Denver. Commerce City has worked hard to improve its image and the living standards of the community. Fracking will destroy all that Commerce City has worked for and invested in for the past 30+ years. With the cost of housing and property rising drastically in the Denver-metro area, Commerce City is prime for development. The 11-acre arts district off of Colorado Boulevard was a great way to spur new and creative development. Look at the money and development that the arts brought onto Brighton Boulevard - including food, breweries and music. The light rail will eventually come through Commerce City, bringing more people and more need for businesses and services. Fracking will destroy - or at least significantly diminish - this kind of development. Why would Commerce City sabotage its future with fracking?

Commerce City is perched on the edge of The Rocky Mountain Arsenal Wildlife Refuge - one of the premier wildlife refuges in a metropolitan area and which is highlighted on the Commerce City website. Commerce City is benefited by the many visitors who come to see wildlife and enjoy relief from the city. In fact, the city has invested a great deal in getting the Arsenal cleaned up (at one time it was renowned as having the most contaminated square mile on earth). Fracking will negatively affect the health of wildlife as well as the citizens of this community. And the shifting of underground rock and soil caused by fracking is potentially a great risk near the Rocky Mountain Arsenal as so many thousands of acre feet of contaminates were left underground and could be dislodged and/or released by on-going fracking operations. I have been involved with citizen oversight of the clean-up at the Rocky Mountain Arsenal for 35 years and hold an EPA grant to assist in review of the protectiveness of the Rocky Mountain Arsenal. I would be happy to discuss this with you further.

I know that the oil and gas industry claims that there is no air or water pollution from fracking but that is not borne out by evidence. Water is at a premium in Colorado and the industry won't even share information about the multitudes of chemicals that it injects into the ground as a primary part of the fracking process. There is no need to add contaminants to the air and water in the Denver-metro area. At the very least, restrict fracking within half a mile from school, residences, and businesses. Protect people, even if you feel compelled to support fracking as part of the economy. Senate Bill 19-181 is meant to prioritize our health, safety, and welfare of our citizens. Please adhere to the law and put the people first by restricting fracking in Commerce City. We have more than enough industry and industrial pollution in Commerce City already without adding fracking.

As I'm writing this after a 13- hour day during the COVID fight I'm reminded about how the general public is tasked with providing city, county and elected officials a list of the dangers associated with a few oil fracking sites in Adams County. Living in Adams County all of my life and my line of work I cannot look away from the current cases and deaths in Adams County. Colorado cases were at 5655 with 417 in my home county including 14 deaths. The information I'm about to provide can save lives as four sites in the county will have long term effects on people working around and in the oil industry.

Currently the Duck Club site is under production after being approved by the COGCC and Adams county elected officials. The Duck club site had several safety concerns as this site is also near a water treatment facility that provides drinking water for Arapahoe, Centennial and Castle Rock residents. Part of the water treatment and production includes a deep well injection site permitted by EPA to dispose of wastes generated by the Northern Project. (Similar to the one at the Rocky Mountain Arsenal) The Duck club site was approved by the county officials and, also approved was the Pony pipeline to transport the crude oil to the treatment facility out east. Recent findings of an audit and underreporting of production numbers should have raised the following concerns. The Pony Pipeline was pitched to the county as it would eliminate trucking of the crude as it was to service both the DUCK club site and the Warbler (Proposed) site also near the UIC waste injection site. After the Duck club went into production the pipeline was immediately at maximum capacity and would not and could not be used for the proposed Warbler site. Although the general public and with the audit finding the county is also not well informed on the actual production numbers. Is it a possibility the site is removing the waste that was injected for many years as part of the fluids forced out of the ground during the fracking process? Looking at the depths of the UIC and the fracking bores they are dangerously close to each other and evident in the underestimating of the Pony pipeline flows. The Warbler site is also near the deep well injection site below the surface, On top of the surface it's near the Barr Lake state park and bird conservatory with 400 known bird species that reside near it. Recommend not approving the Warbler site as it will also remove hazardous wastes from the UIC. Now the real scary part.

The Rocky Mountain Arsenal started injecting waste in a UIC around 1962. The site was permitted by the Army Corp of engineers, EPA and Adams County with inputs from Commerce City. After the UIC started causing earthquakes based off of the injection rates the arsenal and engineers decided to create holding ponds to treat the waste including evaporation into the air. The dozens of air monitoring sites are still evident along Hwy 2. What was not put in place was water monitoring sites. The holding ponds ended up leaking into the ground water and most residents were notified of the contamination by South Adams County Water. A portion of my immediate family lived near the arsenal and grew up on well water. Six of the eight members died at early ages due to various forms of cancer although not proven it was from the drinking water the two living members from the household both moved out at an early age limiting their exposure. A recent cancerous death of an aunt that worked as a scale operator during the clean up of the dirt surrounding the holding ponds has me suspicious of the toxins that were injected, evaporated and hauled away or even ingested by drinking the well water and treated water from the arsenal. Fast forward to today and the two proposed sites in Commerce City near the Arsenal. If the sites are approved we have no assurance that the removed product surrounding the RMA doesn't contain any of the toxins from the Superfund EPA site. The long-term effects on the oil workers should be considered for all three sites. Lesson learned from the CoVid-19 outbreak shows the importance of PPE when dealing with hazardous/dangerous exposures. Including public messaging. The attached studies include Congressional mandated studies about UIC's and fracking.

Rocky Mountain Arsenal studies are also included as most everyone on the boards and commissioners board may not be aware of the arsenal history. South Adams County water results in past few years are still showing signs of toxins around the area. Movement and seismic activity may be active again as the fracking may cause movement near UIC sites.

Please, please take this information into consideration when reviewing the applications for drilling near three deadly proposed sites. Not all permits need approved and revenue generated by roads and permits should never outweigh the safety of one sole or the public perception of these unpermitted applications.

I have also included a copy of a letter sent to the Adams County Commissioners.

Thank you for your attention.

Lifetime ADCO Resident.

Kualli Tlanezi, Buenos Dias, Good Morning,

My name is Renee Millard-Chacon I am Diné/Mexica Womxn with ancestors from Southern Colorado and New Mexico, and I am an Indigenous Xicana Activist, educator at Spirit of the Sun, and most importantly mother of two sons. I am determined to fight for social justice and climate justice for them and future generations. We live on the land of the Cheyenne, Ute, and Arapahoe people now called Denver Colorado, I ask you to remember this because the health and welfare of land and people where once considered sacred to those that came before and still is to those wanting a renewable future. After eight years in the US Navy with my husband we now reside in Commerce City Colorado that has become known for the insidious pollution of Suncor and other extractive industries choking POC for decades of proven deadly environmental racism. In fact the home we just bought last year now has the full view of the fracking sight they propose to put near me, also by me children school I substitute teach it is with in a mile.

As an Indigenous Womxn and learned from the women before me, we have the resilient perspective of survivorship from fully realizing predatory targeting by industries to exploit resources and people. In fact we are the first victims of that in America, unfortunately going on to this day from the disgraceful epidemic of missing and murdered indigenous children, women, men, and 2 spirits with no accountability or intervention both on the federal or state protection including rural or urban. We have survived this for centuries, we know what predators look like.

Under Trump the EPA has ignored current science on particle pollution that could save thousands of live this year during our generations worst PANDEMIC. Shamefully, EPA's Administrator Andrew Wheeler has refused to strengthen the current national standards of deadly particulate pollution and then has limited public participation of this public health threat not adequately protecting Americans further during a national public health emergency of COVID-19 that has hit polluted BI POC neighborhoods, rural and urban, the hardest.

We already have evidence of low standards in Colorado being so harmful now we have children breathing in the poisonous affect of Benzene at Bella Romero Elementary in Greeley downwind from a fracking well. This isn't a warning to Colorado on what can happen if our leaders continue to be more harmful than heroic, it is already proven what IS happening to our Colorado because current health standards are too weak and not adequately protecting from particle pollution health effects of premature death, heart attacks, strokes, heart disease, congestive heart failure, asthma attacks and long term exposure dramatically increasing the risk of COVID-19 resulting in death. The leaders of Commerce City needs to have independent, uncorrupted monitoring for safe air quality standards, but also a goal towards real enforcement when that is inhumanely violated.

Andrew Wheeler and EPA's cowardly response to decline to strengthen standards is a direct environmental injustice and social welfare injustice to BIPOC Americans first living near and around known fossil fuel industries making this a human rights offense. When science is disregarded and racism can still be perpetuated by a deadly flesh for cash business that has become extractive industries and exploitation, the land and people I love of CO, I warn you, will be the first to fall prey. Add in a pandemic to marginalized communities without protection and enforcement for clean air and water and you are choking future generations before they are even able to grow.

CO has a chance to correct corruption at the expense of our health, by strengthening particle pollution standards. STOP protecting predatory polluters, and START responding to America's environmental human needs during a respiratory pandemic. Dramatically strengthen standards and move towards renewable energy that heals for clean air and water. Our chance to be good ancestors is NOW be being the example future generations WANT to learn from.

Thank you and have a Good day!

Natural Resource Damage Assessment Plan for the Rocky Mountain Arsenal, Commerce City, Colorado



Prepared by:

Natural Resource Trustees for the
State of Colorado

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October 24, 2007

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October 24, 2007

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Acronyms and Abbreviations

ALAD	aminolevulinic acid dehydratase
Army	U.S. Department of Army
BAS	Rocky Mountain Arsenal Biological Advisory Subcommittee
bcy	bank cubic yards
bw	body weight
CAR	Contamination Assessment Report
CBT	Colorado Big Thompson
CCR	Colorado Code of Regulations
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CF&I	Colorado Fuel and Iron
CFR	Code of Federal Regulations
cfs	cubic feet per second
ChE	cholinesterase
CMP	Comprehensive Monitoring Program
CRL	certified reporting limit
CRS	Colorado Revised Statutes
CSRG	containment system remediation goal
CWCB	Colorado Water Conservation Board
DBCP	dibromochloropropane (Nemagon)
DCPD	dicyclopentadiene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenylethane
DDT	dichlorodiphenyltrichloroethane
DIMP	diisopropyl methylphosphonate
DOI	U.S. Department of the Interior
DOW	Colorado Division of Wildlife
DSAY	discounted service-acre year
ECCV	East Cherry Creek Valley
EPA	Environmental Protection Agency

FDA	U.S. Food and Drug Administration
FS	Feasibility Study
GIS	geographic information system
gpm	gallons per minute
HBSF	Hydrazine Blending and Storage Facility
HCBD	hexachlorobutadiene
HEA	habitat equivalency analysis
IEA/RC	Integrated Endangerment Assessment/Risk Characterization
IRA	interim response action
LD ₅₀	50% Lethal Dose
MATC	Maximum Acceptable Tissue Concentration
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/m ³	milligrams per cubic meter
MWDA	Metropolitan Water Development Agreement
NCP	National Contingency Plan
NDMA	nitrosodimethylamine
NPL	National Priorities List
NRD	natural resource damage
NRDA	natural resource damage assessment
O&M	operations and maintenance
OU	Operable Unit
PAH	polynuclear aromatic hydrocarbon
PASD	Preassessment Screen Determination
PCE	perchloroethylene
PEC	probable effects concentrations
ppm	parts per million
RCDP	Restoration and Compensation Determination Plan
RCRA	Resource Conservation and Recovery Act
REA	resource equivalency analysis
RI	Remedial Investigation
ROD	Record of Decision
RP	responsible party

SACWSD	South Adams County Water and Sanitation District
SDWA	Safe Drinking Water Act
SEL	severe effect level
SVOC	semivolatile organic compound
TCE	trichloroethylene
TEC	threshold effects concentration
TRER	Terrestrial Residual Ecological Risk
TRV	Toxicity Reference Value
TSP	total suspended particulates
TVE	total value equivalency
µg/g	micrograms per gram
µg/L	micrograms per liter
µg/m ³	micrograms per cubic meter
UFS	unconfined flow system
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
WD	water district

Executive Summary

The Rocky Mountain Arsenal (the Arsenal) is a federally-owned facility in Adams County, Colorado, just northeast of the Denver metropolitan area and southwest of Denver International Airport (Figure S.1). In 1942, the U.S. Department of Army (Army) purchased this 27 square-mile property for the manufacture of chemical warfare agents and incendiary munitions. Agents and munitions included rockets and projectiles containing blister agents (e.g., mustard gas), lewisite, phosgene bombs, incendiary bombs, napalm, and later, Sarin nerve agent. The Army also used the Arsenal for “demilitarization” of nerve agents and bombs into the 1980s. Manufacturing byproducts, unexploded munitions, and other wastes were stored on-site.

After World War II, the Army leased portions of the site to private industry, primarily Shell Oil Company (Shell). Shell manufactured pesticides, insecticides, herbicides, and other chemicals at the Arsenal from 1952 to 1982. Wastes from both Shell and Army manufacturing were transported through chemical sewers to on-site trenches and waste disposal basins (Figure S.2). Millions of pounds of chemical weapon and pesticide manufacturing wastes were disposed in these waste areas between 1942 and 1982.

The Environmental Protection Agency (EPA) listed the Arsenal on the Superfund National Priorities List (NPL) in the 1980s, thus recognizing the Arsenal as one of the most contaminated sites in the country and making it a priority for cleanup. The final environmental remediation plans were finalized in 1995 and 1996. At that time, the Army anticipated completion of remediation, excluding ongoing treatment of groundwater, by 2011. That estimate has now been revised to 2010.

The Superfund cleanup program addresses threats to human health and the environment. The same federal law that established this cleanup program also included provisions for recovery of natural resource damages (NRDs). Thus, in addition to those cleanup activities, the Colorado Natural Resource Trustees have initiated a natural resource damage assessment (NRDA) at the Arsenal. The goals of NRDs claims are to restore the environment to the state it would have been in had the pollution not occurred, and to compensate the public for the interim losses of public trust natural resources up to the time that such restoration is complete. Restoration can be accomplished by directly restoring the injured resource, or by rehabilitating, replacing, or acquiring equivalent resources.

The Arsenal Records of Decision (RODs) require continued operation of existing groundwater containment, extraction, and treatment systems, as well as installation of additional extraction systems and upgrades to existing systems. Hazardous substances continue to migrate to groundwater from contaminated subsurface soils, and thus groundwater at the Arsenal will not be clean for the foreseeable future.

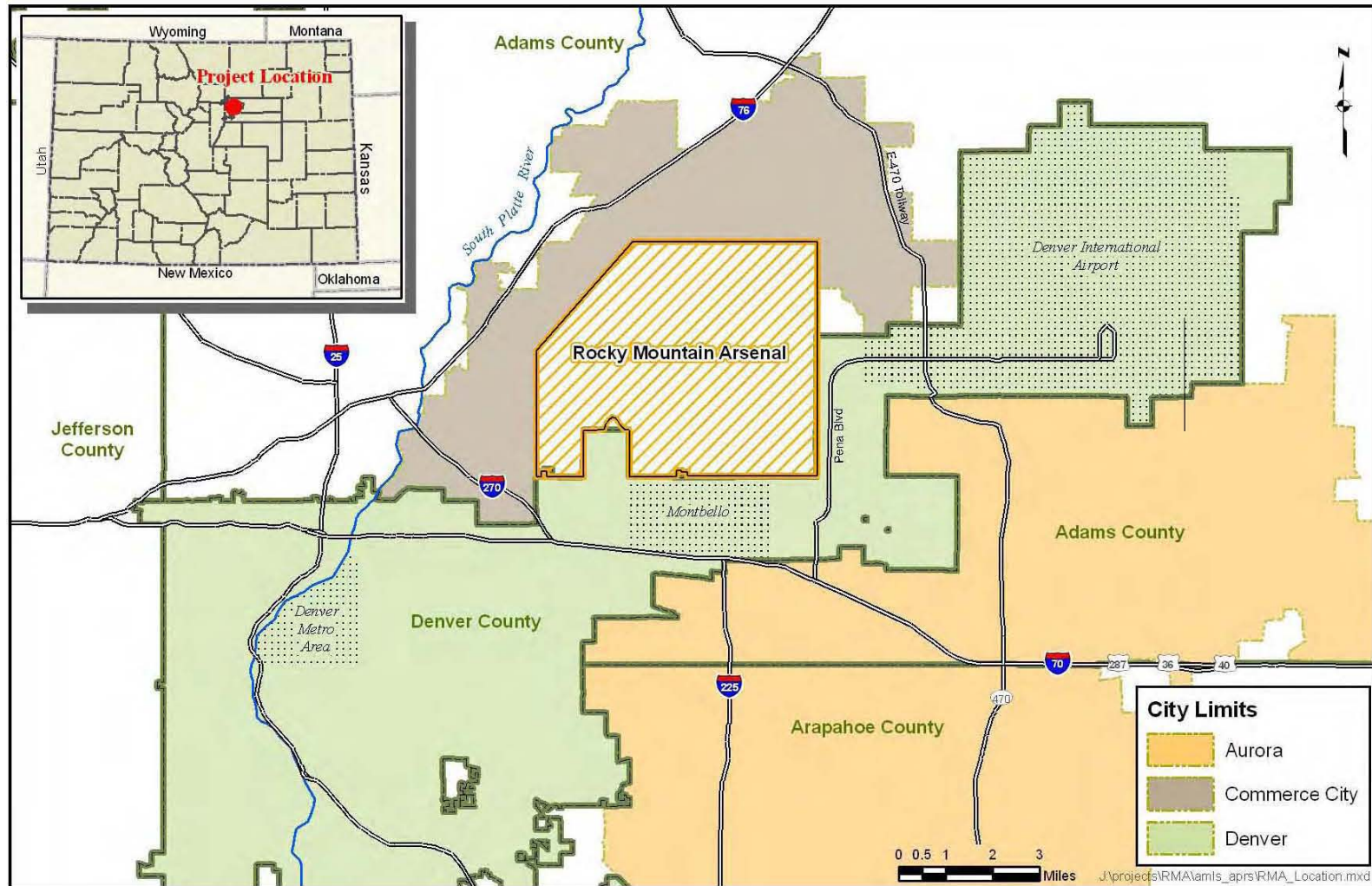


Figure S.1. General location of the Rocky Mountain Arsenal in the Denver area.

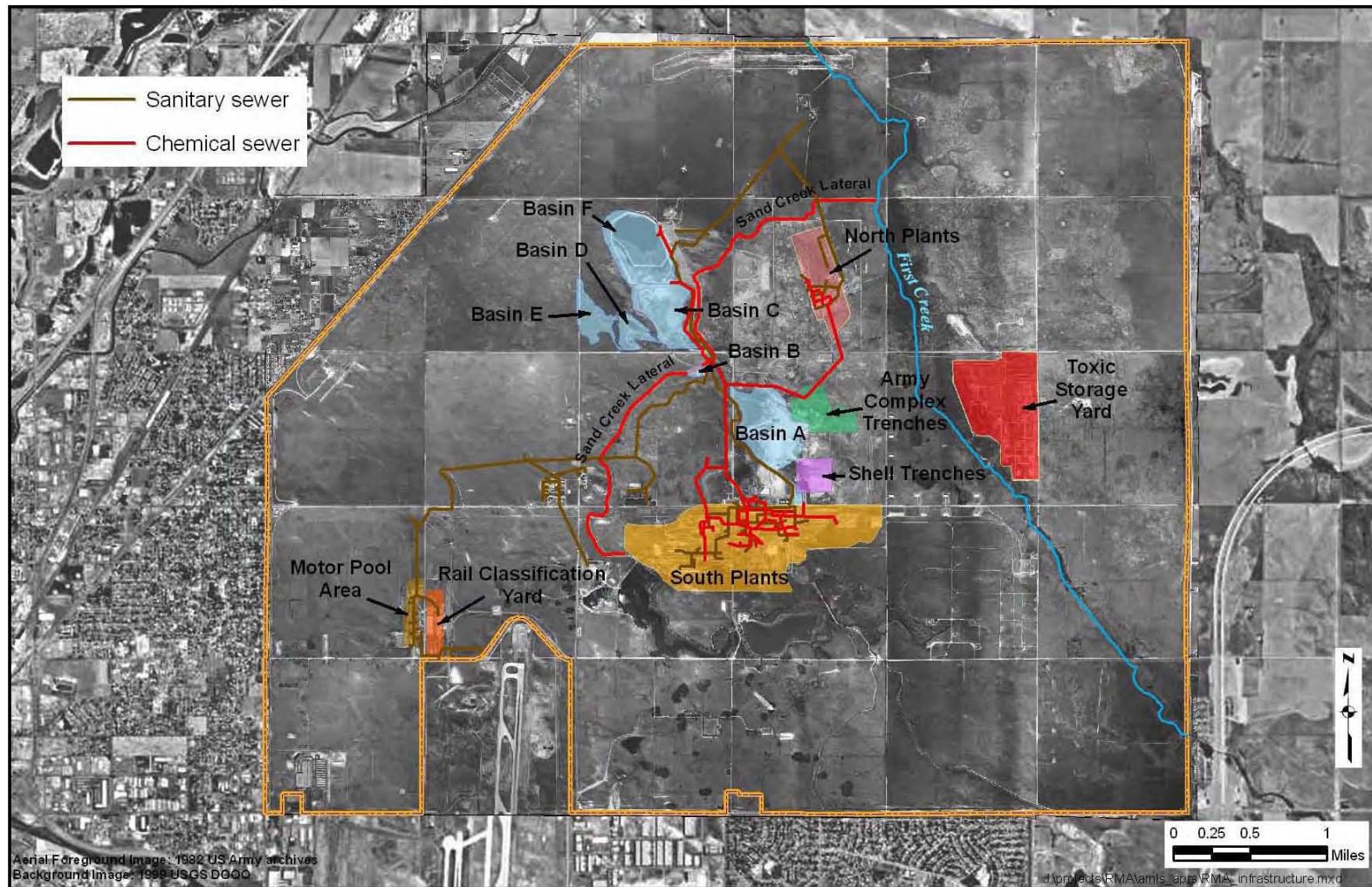


Figure S.2. Manufacturing, storage, waste transit, and waste disposal sites at the Arsenal.

The purpose of this Assessment Plan is to document the State Trustees' basis for conducting a damage assessment, and to set forth the proposed approaches for quantifying harm ("injuries") to natural resources and calculating damages associated with those injuries. The Assessment Plan enables the Trustees to ensure that the NRDA will be completed in a planned and systematic manner and at a reasonable cost. The Plan informs the Army, Shell, and the public of the proposed assessment methods so that stakeholders can participate in the assessment process.

The State Trustees plan to seek recovery for both the costs of restoring injured resources to baseline conditions (i.e., conditions that would have been present absent the releases of hazardous substances), and for compensatory damages to account for lost services in the past, present, and future until the natural resources have been restored to baseline.

The State's NRD calculations will take into account the benefits of the remedial actions at the Arsenal. For resources where the remedial actions will return or have returned resources to baseline conditions, the State's damage calculations will include the period from the onset of injury (or 1981) until baseline conditions are (or were) achieved.

Response actions

The Army and Shell addressed the contamination at the Arsenal through a series of response actions beginning with the installation of groundwater extraction and treatment systems on the boundaries of the facility in the early 1980s. In the mid-1980s, the Army and Shell implemented interim response actions (IRAs) to address known significant sources of contamination and to protect against immediate threats to human health and the environment. The most extensive IRA was the closure of Basin F (Figure S.2), where the Army removed and incinerated nearly 11 million gallons of liquid chemical waste and transferred over 500,000 cubic yards of contaminated soils and sludge to a temporary waste pile. Noxious odors from the excavation and air-drying of the sludges entered nearby neighborhoods. After approximately six months of failing to control the emissions, the Army abandoned the sludge removal and capped the remaining materials in place.

The selected remedies to address human health and the environment put forth in the On-Post and Off-Post RODs included the construction of a lined hazardous waste landfill and re-construction of Basin A (Figure S.2) as a landfill. The hazardous waste landfill received contaminated soils and sludges posing an unacceptable risk to human health, and Basin A received contaminated soils and sludges that did not exceed human health risk thresholds but did pose a risk to biota. Millions of cubic yards of soils have been transported to these repositories; excavation and transport of Basin F soils and sludges are scheduled for completion in 2008. However, in many locations, only the upper five to ten feet of soils were remediated, leaving large quantities of hazardous substances buried in deeper soils.

After excavation of contaminated soils, hundreds of acres at the Arsenal were capped, covered with clean soil, and revegetated, thereby reducing risks to human health and the environment and benefiting injured natural resources. Once appropriate response actions were completed, portions of the Arsenal were deleted from the NPL. Thus far, over 900 acres were removed from the NPL and sold to Commerce City, and over 12,000 acres were removed from the NPL and transferred to the U.S. Fish and Wildlife Service to be part of the National Wildlife Refuge system. Areas such as waste disposal trenches, landfills, and areas with groundwater treatment systems will remain in the Army's possession.

While response actions address threats to human health and the environment, the State Trustees must calculate the cost of restoring injured resources to baseline conditions, and quantify interim losses up to the time that restoration is complete and baseline conditions are achieved. The State Trustees anticipate using existing data to determine and quantify injuries to groundwater, wildlife and its supporting ecosystems, and air resources.

Groundwater injuries and damages

Hazardous substance releases at the Arsenal have resulted in extensive plumes of contaminated groundwater under the Arsenal property and north of the Arsenal towards the South Platte River (Figure S.3). In addition, the Army placed institutional controls preventing the use of the groundwater as a drinking water source on all groundwater under the Arsenal, and preventing any use of shallow groundwater underlying 350 acres of Shell property north of the Arsenal until that groundwater is clean.

To assess lost groundwater services over time, the State Trustees will:

- ▶ Calculate the spatial extent of the groundwater plume containing hazardous substance concentrations in excess of State or federal groundwater standards
- ▶ Determine the extent to which hazardous substances have been released to groundwater in deep aquifers underlying the Arsenal, including the Denver, Upper Arapahoe, Lower Arapahoe, and Laramie – Fox Hills Formations
- ▶ Determine the volume of groundwater in each of the deep aquifers that is inaccessible for use as a drinking water supply because of institutional controls
- ▶ Determine the annual safe yield of shallow alluvial groundwater underlying the Arsenal that is inaccessible as a drinking water supply because of institutional controls, as well as the annual safe yield inaccessible for any purpose because of hazardous substance concentrations.

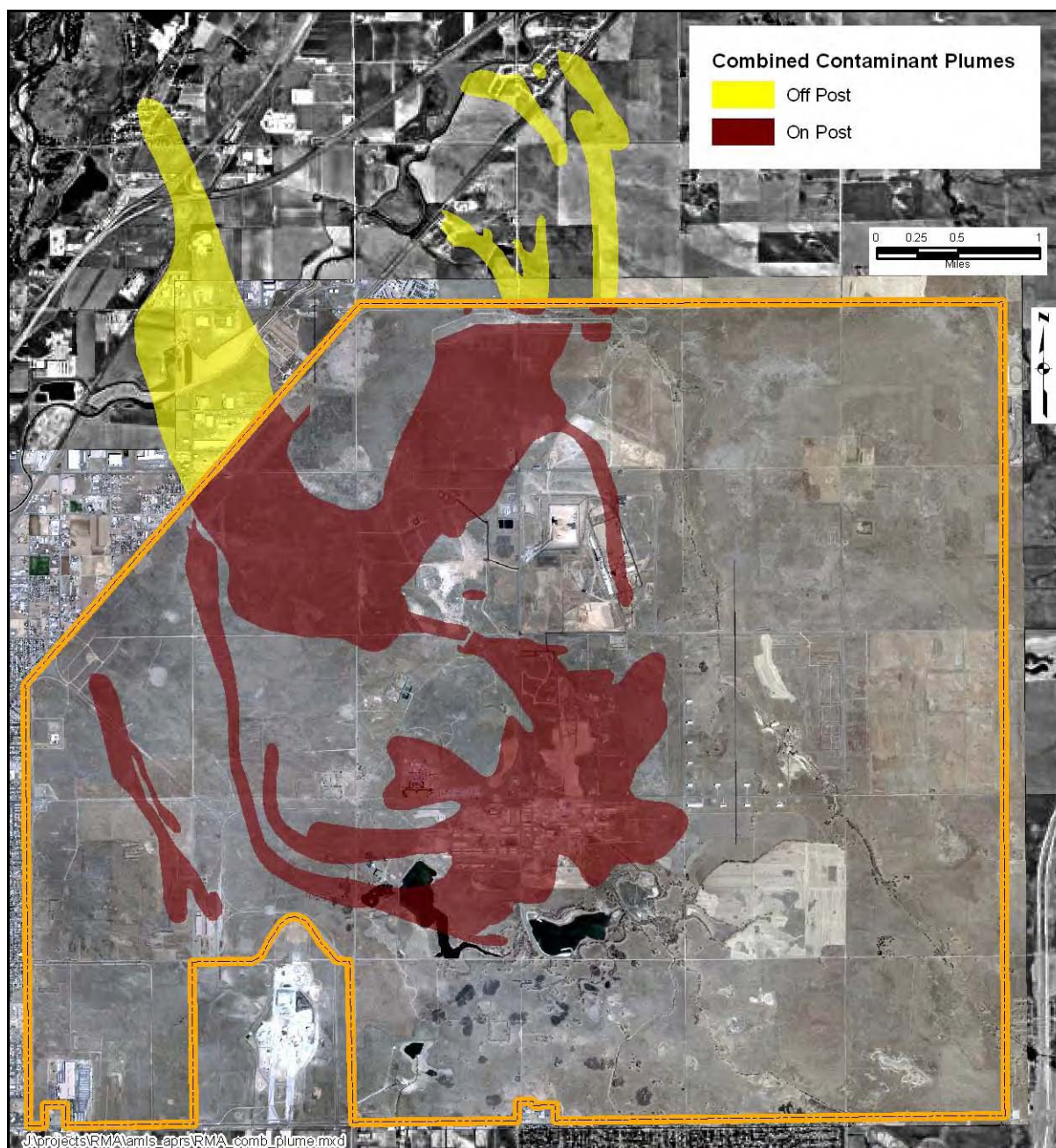


Figure S.3. Estimated extent of a combined contaminant plume (trichloroethylene, benzene, chloroform, dibromochloropropane, and dieldrin) in the shallow alluvial aquifer (1994).

The assessment of groundwater injury will rely primarily on existing data within the Rocky Mountain Arsenal Environmental Database. To determine the spatial extent of groundwater injuries over time, the State Trustees may perform the following additional work as part of the assessment:

- ▶ Develop a flow and transport model using MODFLOW/MT3D or MODFLOW-SURFACT to estimate the spatial extent of groundwater injury in the past, present and future
- ▶ Develop a hazardous substance plume degradation/decay model to estimate the future spatial extent of groundwater injury
- ▶ Evaluate contaminated groundwater in the weathered upper Denver Formation as well as in deeper groundwater formations
- ▶ Further identify past and existing uses of groundwater at and downgradient of the Arsenal.

NRDA regulations specify that the highest-and-best use of an injured resource should be used to calculate damages. In the Denver metropolitan area, municipal water supply qualifies as the highest and best use for groundwater. Thus, the State has incurred lost use damages to groundwater both directly, because of the plume of hazardous substances in groundwater, and indirectly, because the hazardous substances resulted in institutional controls preventing the use of the Arsenal groundwater as a municipal water supply.

Many municipal water suppliers in the Denver metropolitan area use shallow alluvial groundwater tributary to the South Platte River as a water source. When easily accessible water supplies such as the shallow South Platte River groundwater are not available, municipalities spend millions of dollars to transport water tens or even hundreds of miles from distant water sources to the end-user. Preliminary evidence thus suggests that clean alluvial groundwater under the Arsenal would be a practical municipal water source.

Shallow groundwater at the Arsenal is tributary to the South Platte River. To access this water (absent hazardous substances and institutional controls), a user would be required to have an approved augmentation plan demonstrating that senior water rights holders in the South Platte River basin would not be harmed as a result of pumping. Most alluvial groundwater pumped in the Arsenal area is either used in households and then released to the South Platte River via wastewater treatment plant effluent, or is used for irrigation, with a portion percolating back to shallow groundwater. Most municipal suppliers use wastewater effluent as well as rights to more polluted water sources such as ditches to provide augmentation when necessary to offset pumping of clean groundwater. Thus, it is likely that, absent the releases of hazardous substances and subsequent

enactment of institutional controls, the Arsenal groundwater would have been an attractive and usable municipal water source.

The State Trustees will use a combination of approaches to assess damages to injured groundwater at the Arsenal. These approaches will account for both the cost of restoration and the compensable value of the interim loss. Compensable value is the value of lost direct public use of the services, plus lost non-use values such as existence and bequest values. The State Trustees anticipate using the following approaches for estimating damages:

- ▶ Market price methods
- ▶ Resource equivalency methods
- ▶ Total value/restoration scaling methods.

Water resources, including groundwater, are traded in a reasonably competitive market in the Denver metropolitan area. Initial evaluation of data suggests that sufficient information is available to form an accurate representation of the willingness to pay for water for at least the past 15 years in the Front Range area of Colorado. This can provide a basis on which to value contaminated groundwater damages from the Arsenal.

To develop market prices for groundwater in the Arsenal region, the State Trustees will use observed market data, including associated variables, to establish appropriate market prices for which water would sell in the Front Range region at a given date. The sale price of water will then be used to calculate the annual diminished value of injured resources. If necessary, market prices for any dates after those available in the collected transactions will be based on statistical forecasts using projections of variables that help explain changes in water prices, such as urbanization and development in the region.

The State Trustees also intend to use restoration-based equivalency approaches to assess damages. This includes resource equivalency analysis (REA), in which the State Trustees first quantify injuries in terms of lost groundwater services, then scale restoration projects such that they provide the equivalent amount of groundwater service gain. The State expects to use this “service-to-service” scaling method because restoration alternatives are available that provide similar types and quality of services as those lost. Projects that restore groundwater services may include:

- ▶ Water quality protection and improvement programs
- ▶ Water reuse programs
- ▶ Water conservation programs
- ▶ Water recharge programs.

Restoration projects will be scaled to compensate for both interim losses and restoration that is required to return injured resources to baseline conditions. The State will then estimate the cost of the projects based on preliminary project designs – full engineering designs are not feasible or appropriate to develop during the assessment process.

Finally, in addition to service-to-service scaling, the State may use a value-to-value scaling approach to assess the total value equivalency (TVE) of groundwater damages. Using this approach, the State Trustees will conduct a survey with stated-choice questions to determine public preferences for various types of restoration alternatives. This will aid the State Trustees in evaluating the benefits of restoration alternatives and provide additional input into the selection of alternatives. In addition, the study will provide value-based, as opposed to service-based, methods to determine the appropriate scale of potential restoration actions.

Anticipated activities to assess groundwater damages by TVE include:

- ▶ Developing restoration options to offset groundwater injuries at the Arsenal
- ▶ Conducting qualitative survey research such as focus groups and structured individual interviews to aid in the development of the TVE survey
- ▶ Developing the survey instrument, including peer review of the survey and the implementation process
- ▶ Administering the survey to a relevant segment of the population
- ▶ Analyzing and reporting the data.

Using the TVE approach, groundwater damages will be based on both lost active use values and lost passive use values.

Wildlife injuries and damages

Prior to implementation of the cleanup, much of the wildlife habitat at the Arsenal was contaminated with elevated concentrations of hazardous substances, resulting in widespread wildlife mortality. Contaminants found in soils, surface water, and sediments included the toxic pesticides aldrin, dibenzochloropropane, dieldrin, endrin, and isodrin. Prior to remediation, aldrin and dieldrin were detected in surface soils across much of the Arsenal property (Figure S.4). Most soils in the central processing and disposal areas (see Figure S.2) contained pesticide concentrations exceeding ecological risk thresholds. As a result, approximately 1.5 million cubic yards of contaminated soils were excavated and landfilled as part of the implemented remedy at the Arsenal.

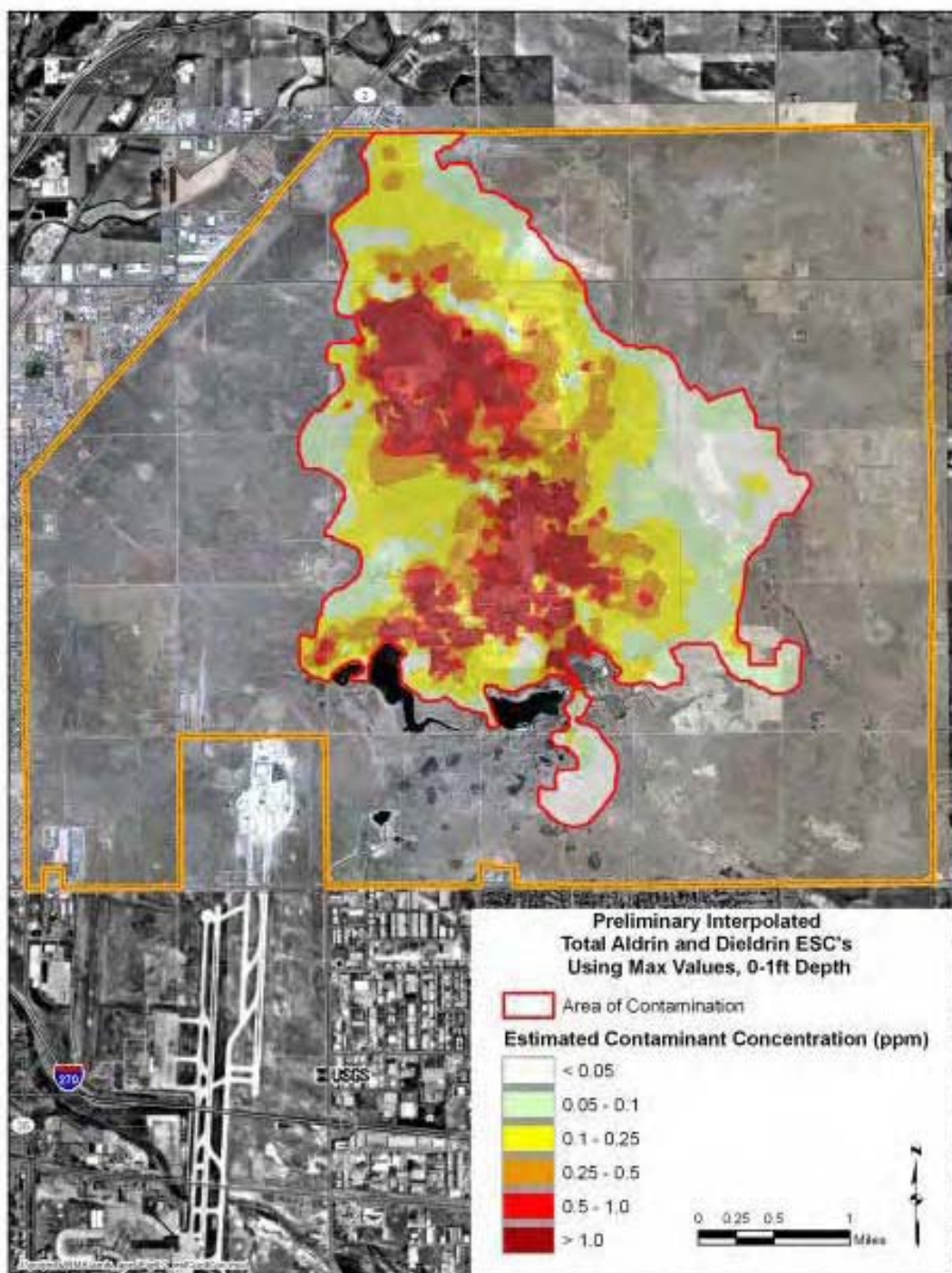


Figure S.4. Organochlorine pesticides such as aldrin and dieldrin were widespread in Arsenal soils before remediation.

To determine and quantify injuries to biota as a result of these hazardous substance releases, the State Trustees will employ multiple methods, including:

- ▶ Identifying Food and Drug Administration (FDA) action level exceedences and/or State and federal consumption advisories. Existing data indicate some exceedences of FDA action levels in Arsenal biota. Consumption of fish caught in Arsenal lakes has been banned since 1984. The 1989 Federal Facility Agreement banned consumption of all Arsenal wildlife.
- ▶ Compiling evidence of wildlife mortality. Existing documents describe thousands of bird and mammal carcasses found at the Arsenal, including over 1,800 waterfowl carcasses in Basin F alone between 1981 and 1988.
- ▶ Developing food web models to estimate injuries to biota. Toxicology studies can be used to determine oral doses of contaminants that cause adverse effects to biota. Food web models will allow estimates of toxic doses of contaminants in wildlife based on contaminant concentrations in soils. Injury thresholds in soils will be developed using these food web models.
- ▶ Estimating injuries that have occurred as a result of response actions. Response actions at the site have resulted in harm to wildlife habitat by heavy machinery, intentional eradication of prairie dogs, and reduction in burrowing animal habitat resulting from constructed biota barriers.

As part of this assessment, the State Trustees will compile existing data from Arsenal documents and from the Rocky Mountain Arsenal Environmental Database. Food web models developed during the Superfund remedial investigation will be updated as appropriate to reflect current scientific understanding. The State Trustees may undertake the following additional work to determine and quantify injuries and damages to biological resources:

- ▶ Revise and update bioaccumulation and dietary toxicity models
- ▶ Address the additive toxicity of organochlorine pesticides such as aldrin and dieldrin
- ▶ Assess injuries to biological resources from exposure to metalloids such as arsenic
- ▶ Assess injuries to biological resources associated with perennial and intermittent surface water and associated sediments
- ▶ Assess injuries to reptiles, amphibians, fish, and bats.

The State Trustees will quantify the spatial and temporal extent of injuries to biological resources and their supporting habitat. Damages will be assessed based on the cost to restore equivalent resources over space and time. The State Trustees will use habitat equivalency analysis or REA to first quantify injuries in terms of lost habitat or lost resource services, then scale restoration projects such that they provide the equivalent amount of habitat or resource service gain.

The State will consider restoration projects from existing regional restoration plans (e.g., from the Northeast Greenway Corridor project) and solicit proposals from State agencies such as the Division of Wildlife, interested nonprofit organizations, and the general public when identifying a list of potential restoration projects. Such projects would benefit the resources that have been injured at the Arsenal. Specific types of restoration projects may include:

- ▶ Preservation of existing habitats at risk to development
- ▶ Restoration and enhancement of existing degraded habitats
- ▶ Preservation of protective buffers for core areas of high wildlife value.

After determining the required size of proposed restoration projects, the State will estimate the cost to implement these projects. Costs will be based on preliminary project designs. Total cost estimates will include project design, implementation, monitoring, continued operation and maintenance, contingencies, Trustee oversight, and adaptive management.

Air injuries and damages

Depending on availability of data, the State Trustees plan to evaluate injuries to air resources incurred during the Basin F IRA in 1988 and 1989. Attempts to excavate and air-dry Basin F sludges released noxious odors to surrounding communities. From the summer of 1988 through the spring of 1989, the Army received 200 odor complaints from nearby citizens. Many people reported adverse effects such as headaches, burning and watering eyes, nausea, and vomiting. Local residents reported that they avoided the outdoors and shut their windows, regardless of the weather. The foul odors and adverse health effects constituted an injury to the State's air resources.

Injuries to air resources will be quantified in terms of lost air services. A REA-type service-to-service scaling approach may be evaluated to quantify damages to air resources. Under this approach, the State would identify air restoration projects that could provide the equivalent of the air resource services lost as a result of the Basin F IRA.

Availability and public comment

The Assessment Plan will be available for public comment for 30 days following publication of a notice of availability in newspapers of statewide circulation. It can be accessed at <http://www.cdphe.state.co.us/hm/rma.htm>. An extension to the public comment period may be granted if requested and found to be reasonable and appropriate. Questions can be directed to vicky.peters@state.co.us or 303-866-5068; or jeff.edson@state.co.us or 303-692-3388. Comments can also be sent to:

Ms. Vicky Peters
Senior Assistant Attorney General
1525 Sherman Street, 7th Floor
Denver, CO 80203

The Assessment Plan may be modified in the future. If a significant modification is made, the revised Plan will be provided to the public for comment.

1. Introduction

1.1 Statement of Purpose

The Colorado Natural Resource Trustees (the Trustees) are assessing natural resource damages (NRDs) caused by releases of hazardous substances at the Rocky Mountain Arsenal (the Arsenal), located in Adams County, Colorado. Under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), also known as the Superfund law, parties responsible for releases of hazardous substances are liable for “damages for injury to, destruction of, or loss of natural resources, including the reasonable costs of assessing such injury, destruction, or loss resulting from such a release” [42 USC § 9607(a)]. While the goal of the Superfund cleanup program is to address any threats to human health and the environment, the goal of the NRD provisions is to restore the environment to the state it would have been in had the pollution not occurred, and to compensate the public for the losses of natural resources up to the time that such restoration is complete. Restoration can be accomplished by directly restoring the injured resource, or by rehabilitating, replacing, or acquiring equivalent resources. Restoration as used in this document refers to all four types of activities.

With the publication of this Assessment Plan, the Trustees’ assessment is being formally initiated pursuant to the U.S. Department of the Interior’s (DOI’s) natural resource damage assessment (NRDA) regulations [43 CFR Part 11]. The purpose of the Assessment Plan is to document the Trustees’ basis for conducting a damage assessment, and to set forth the proposed approaches for quantifying natural resource injuries and calculating damages associated with those injuries. The Assessment Plan enables the Trustees to ensure that the NRDA will be completed at a reasonable cost. The Plan informs responsible parties (RPs) and the public of the proposed assessment methods so that stakeholders can participate in the assessment process productively. The RPs at the Arsenal are Shell Oil Company (Shell) and the U.S. Department of Army (Army).

1.2 The Rocky Mountain Arsenal

The Arsenal is a federally-owned facility in Adams County, Colorado, just northeast of the Denver metropolitan area and southwest of Denver International Airport. In 1942, the Army purchased this 27 square-mile property for the manufacture of chemical warfare agents, nerve agents, and incendiary munitions. Agents and munitions included rockets and projectiles containing blister agents (e.g., mustard gas), Sarin nerve agent, lewisite, phosgene bombs, incendiary bombs, and napalm. The Army used the Arsenal for “demilitarization” of nerve agents and bombs into the 1980s. It also stored and transported raw materials, and disposed of

manufacturing byproducts, unexploded munitions, and other wastes on-site. These activities resulted in the release of hazardous substances to soil, groundwater, surface water, and air.

After World War II, the Army leased portions of the site to private industry, primarily Shell. Shell manufactured pesticides, insecticides, herbicides, and other chemicals at the Arsenal from 1952 to 1982, and disposed of wastes on-site. These activities also resulted in the release of hazardous substances to soil, groundwater, surface water, and air. Later chapters of this Plan discuss the site's history, manufacturing, and cleanup operations in detail.

The Environmental Protection Agency (EPA) listed most of the Arsenal on the Superfund National Priorities List (NPL)¹ on July 11, 1987.² The remainder – the waste disposal impoundment known as Basin F – was included on March 13, 1989.³ Since 1989, the Army's sole mission at the Arsenal has been cleanup. The final environmental remediation plan was contained in two records of decision (RODs) finalized in 1995 and 1996. At the time, the Army anticipated completion of remediation, excluding the continued treatment of groundwater, by 2011. That estimate has now been revised to 2010.

1.3 The Assessment Plan

This Assessment Plan is divided into nine chapters. The remainder of Chapter 1 describes the State Trustees' authority for conducting an NRDA and the process that the Trustees intend to follow. Chapter 2 provides a general description of the site and the assessment area, includes a history of operations at the Arsenal, and identifies both the sources of contamination and the hazardous substances released. Chapter 3 discusses the remediation activities on- and off-post, and the long-term efficacy of the selected response actions. Chapter 4 discusses the exposure pathways from sources of released hazardous substances to the injured natural resources, and presents data confirming exposure of natural resources to hazardous substances. Chapter 5 describes groundwater resources in the assessment area, provides examples of approaches and illustrative calculations for assessing injury to groundwater, and discusses services lost due to contamination. Chapter 6 describes wildlife resources and outlines the anticipated assessment approaches for quantifying injury to wildlife. Chapter 7 describes air injuries in the assessment area, and identifies the anticipated assessment methodology for that resource. Chapter 8 discusses the approaches to be used for damage determination and restoration planning and

1. CERCLA mandated the NPL to identify the worst contaminated sites in the country. These sites were to be the priorities for the federal cleanup program [42 USC § 9605(a)(8)(B)].

2. 52 FR 27619.

3. 54 FR 10512.

costing, and Chapter 9 discusses methods specifically intended for calculating groundwater damages, including both lost use and lost passive or non-use values.

1.4 Trusteeship Authority

1.4.1 State Trustees

The Executive Director of the Colorado Department of Public Health and Environment (CDPHE), the Director of the Division of Reclamation, Mining and Safety within the Colorado Department of Natural Resources, and the Attorney General of Colorado are the three natural resource Trustees for the State. The National Contingency Plan (NCP), which constitutes CERCLA's implementing regulations, provides that "[s]tate trustees shall act on behalf of the public as trustees for natural resources, including their supporting ecosystems, within the boundary of a state or belonging to, managed by, controlled by, or appertaining to such state" [40 CFR §300.605]. Natural resources include land, fish, wildlife, biota, air, water, groundwater, and drinking water supplies belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by a government [42 USC § 9601(16)].

1.4.2 Trusteeship

The DOI regulations require Trustees to provide a statement of authority for asserting trusteeship, or co-trusteeship, for those natural resources considered within the Assessment Plan [43 CFR 11.31(a)(2)]. The basis for the State's assertion of trusteeship over each injured resource is explained below.

Water

Colorado's Constitution states that "[t]he water of every natural stream, not heretofore appropriated, within the State of Colorado, is hereby declared to be the property of the public, and the same is dedicated to the use of the people of the State, subject to appropriation as hereinafter provided" [Colo. Const. Art. XVI, §5; CRS § 37-92-102]. This includes water "hydraulically connected to" tributary groundwater if "it can influence the rate or direction of movement of the water in [the] alluvial aquifer or natural stream" [CRS § 37-92-103(11)]. These provisions confirm the State's trust interest in the waters of the State. In addition, pursuant to its sovereign or trust interest, the State exercises management and control over water – and the use of surface and groundwater – whether tributary or not. For example, CRS § 37-82-101 *et seq.* and CRS § 37-92-102 *et seq.* regulate the appropriation of surface water and tributary groundwater, and CRS § 37-90-102 *et seq.* regulates the appropriation of deep groundwater such as the water in the lower aquifers underlying the Arsenal. Further, among other State water

quality regulatory authorities, the CDPHE has authority pursuant to CRS § 25-8-101 *et seq.* to enforce promulgated water quality standards [5 CCR 1002-41 (Regulation 41), and 5 CCR 1002-31 (Regulation 31)]. A state's natural resource trusteeship over its waters has been recognized in a number of cases, including a recent Tenth Circuit decision.⁴

Wildlife

All wildlife in Colorado that is not privately owned is the property of the State [CRS § 33-1-101 (2)]. The Colorado Division of Wildlife (DOW) and the Wildlife Commission manage and control wildlife for the benefit of the people, including the taking, possession, and the use of wildlife, pursuant to Articles 1 through 6 of Title 33 of the Colorado Revised Statutes, and the rules and regulations promulgated by the Wildlife Commission [2 CCR § 406 (2006)]. This control extends to federal military installations. For example, 10 USC § 2671 requires all hunting and fishing on a military reservation to "be in accordance with the fish and game laws of the State in which it is located." Thus, ownership, trusteeship, and management and control form the basis of the State's trusteeship over wildlife resources.

Air

As far back as 1907, the Supreme Court recognized the unique trust interest of states in the air breathed by their citizens.⁵ Colorado law states that "the prevention, abatement, and control of air pollution in each portion of the state are matters of statewide concern and are affected with a public interest and that the provisions of [Article 25] are enacted in the exercise of the police powers of this state for the purpose of protecting the health, peace, safety, and general welfare of the people of this state" [CRS § 25-7-102 and 5 CCR § 1001-2]. Thus, through its recognized public trust interest, and because of its extensive management and control, the State asserts trusteeship over the air resources adversely affected by Arsenal releases.

Co-trusteeship

The United States claims co-trusteeship for natural resources at the Arsenal through the Army and the U.S. Fish and Wildlife Service (USFWS).

1.5 Restoration and Compensation Determination Plan

The DOI regulations require Trustees to develop a Restoration and Compensation Determination Plan (RCDP). This Plan can be included with the Assessment Plan if existing data are available.

4. *New Mexico v. General Electric*, 467 F.3d 1222, 1243 (10th Cir. 2006).

5. *Georgia v. Tennessee Copper Co.*, 27 S.Ct. 618, 619 (1907).

If sufficient data are not available for the Assessment Plan, the RCDP may be developed at any time before the completion of the Injury Quantification phase, and published separately. The Trustees have determined that separate publication of the RCDP will be necessary at this site.

1.6 Natural Resource Damage Assessment Process

The DOI regulations establish a process for Trustees to follow when assessing NRDs, including pre-assessment, assessment, and post-assessment phases. The use of these regulations is optional, but an NRDA performed in accordance with these regulations has the force and effect of a rebuttable presumption in any administrative or judicial proceeding to recover NRDs [42 USC § 9607(f)(2)(C)]. A rebuttable presumption means that the opposing party has the burden of producing evidence to overcome or rebut the presumption that the Trustees' assessment should form the basis of the damage award.

The assessment process described in the NRDA regulations involves four major components:

1. The Preassessment Screen Determination (PASD)
2. The Assessment Plan
3. The Assessment
4. The Report of Assessment.

1.6.1 Completion of Preassessment Screen Determination

Pursuant to the DOI NRDA regulations, the Trustees conducted a preassessment screen “to provide a rapid review of readily available information” on trust natural resources that may have been injured by releases of hazardous substances [43 CFR § 11.23(b)]. In accordance with the criteria at 43 CFR § 11.23(e), the PASD supported the conclusion that there is a reasonable likelihood that State natural resources have been injured as a result of hazardous substance releases, that sufficient data exist to conduct an assessment, and that response actions will not remedy the injury to natural resources without further actions. Therefore, the Trustees concluded that an NRDA should be undertaken to develop a damage claim under 42 USC § 9607.

1.6.2 The Assessment Plan and Selection of Type B Procedures

The assessment phase begins with the Assessment Plan. This document serves as the work plan for the NRDA. The Assessment Plan is being provided for public review to help the Trustees ensure that the NRDA proceeds efficiently, using data and methodologies appropriate for the site and resources involved. This Assessment Plan was prepared in accordance with the NRDA regulations promulgated by the DOI at 43 CFR § 11.31.

Under DOI's NRDA regulations, the Trustees must elect to perform a Type A or Type B NRDA [43 CFR § 11.33]. Type A assessments use "simplified procedures that require minimal field observation" [43 CFR § 11.33(a)]. Type A procedures are inapplicable in this case because they are designed to address minor releases of short duration resulting from a single event. Further, the DOI has promulgated Type A regulations only for coastal/marine or Great Lakes environments [43 CFR §§ 11.33, 11.34]. Thus, Type A procedures cannot be used at the Arsenal. The Trustees will use the Type B provisions.

1.6.3 Assessment Phase

Under the DOI Type B procedures, three parts comprise the assessment:

1. **Injury Determination Phase.** The first phase of the assessment determines whether injury to the natural resources has occurred and whether the injury has resulted from the release of hazardous substances.
2. **Quantification Phase.** The second phase quantifies the injuries and the reduction of services provided by the natural resources. Services provided by various resources may include such things as habitat for wildlife and drinking water for the public.
3. **Damage Determination Phase.** In the third phase, the monetary compensation for injury is calculated. This phase is based upon the RCDP that, among other things, describes possible alternatives for restoration or replacement of the injured natural resources and their related services. All damages ultimately recovered by RPs must be spent to restore, replace, or acquire equivalent natural resources.

1.6.4 The Report of Assessment

Upon completion of the assessment, the Trustees will prepare a Report of Assessment, which will include the results of analyses performed during assessment. It will also include the Trustees' Restoration Plan. Like this Report, the Assessment Plan will be provided to stakeholders for public comment.

Based on the final Report, the Trustees can make a demand on the RPs for NRDs. If the demand is accepted or some compromise is negotiated, or if the Trustees prevail at trial, any recoveries will be placed in a special account to fund restoration projects, and the Trustees may revise their Restoration Plan to be sure that it can be implemented with the damages recovered. Sometimes RPs choose to conduct appropriate restoration projects themselves instead of paying damages, or a settlement may include both restoration and monetary components. The Trustees can also

recover the reasonable costs of performing an NRDA as part of their NRD claim. Examples of reasonable and necessary costs are set forth in 43 CFR § 11.60(d).

1.7 Coordination

1.7.1 Coordination with response agencies and activities

Coordination with response agencies is desirable to avoid duplication, reduce costs, and achieve dual objectives where practical. The Remedial Investigation (RI) for the Arsenal was completed in 1992. The RODs, setting forth the final remedies for the off-post and on-post areas, were finalized in 1995 and 1996, respectively. The completion of remedial actions, excluding the continued treatment of groundwater, is currently anticipated in 2010.

In preparing the PASD, the Trustees relied on existing data from the remedial process and, based upon preliminary review, intend to rely extensively on those data in conducting the NRDA. Extensive field sampling and studies in addition to those already conducted for the Remedial Investigation/Feasibility Study (RI/FS) and other cleanup purposes are currently not envisioned.

While the Trustees intend to use the existing response agency data from the site, an extensive data set from the RI does not preclude the need for injury assessment, and the implemented remedial actions do not preclude the existence of past and ongoing NRDs. Damages have been incurred since the passage of CERCLA, as provided in the DOI regulations [43 CFR § 11.15(a)(1)]. In addition, because the remediation alone will not achieve full restoration of injured natural resources and the services provided by those resources, damages will continue to be incurred after the implemented remedy is complete in 2010.

1.7.2 Coordination with co-Trustees and responsible parties

The State Trustees formally invited the Army and Shell to participate in the State's NRDA. The Trustees sent a Notice of Intent to perform an NRDA to Shell and the Army with the PASD in February 2007. Shell and the Army have indicated a desire to be involved. The Army also indicated that it will conduct its own PASD. The Trustees and the RPs have shared information in the context of settlement negotiations and in anticipation of a formal assessment. The State Trustees will continue to work with the RPs and federal co-trustees in implementing this Assessment Plan.

1.8 Fundamental Terms and Concepts

Individuals familiar with the cleanup process under Superfund and at the Arsenal may not be as conversant with the NRD process. To aid in the public's review of this Assessment Plan, key terms are defined below. In addition, a list of acronyms is provided at the front of this document, and a glossary of uncommon terms is provided at the end. The terms and concepts defined below will recur in subsequent chapters dealing with injury and damage calculations.

Baseline refers to the conditions that would have existed in the assessment area had the release of hazardous substances not occurred [43 CFR § 11.14 (e)]. This is not the same as "pre-release" conditions because disturbances to the assessment area might have decreased resource services without the release of hazardous substances. For example, if a release were to occur in an area with ongoing development, the Trustees should evaluate the probable condition of the resource assuming development occurred.

Damages is the amount of money needed to satisfy a claim in court. In the context of NRDs, that amount includes the cost to perform an NRDA and to restore injured natural resources to baseline conditions. The amount also includes compensation for interim losses. NRDs continue to accrue until restoration and replacement projects result in the complete recovery of resources or services to baseline conditions. "Residual damages" is a term used to describe any damages that remain after remediation is complete.

Injury is a measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a release of a hazardous substance, or exposure to a product of reactions resulting from the release of a hazardous substance [43 CFR § 11.14(v)]. Definitions of injuries to specific natural resources are provided in the NRDA regulations at 43 CFR § 11.62, and are included in Chapters 5 to 7 as each injured resource is discussed.

Interim losses refer to injuries (and associated service losses) that accrue until injured resources and the services they provide are returned to baseline conditions. The start date for calculating interim losses is either the time of release or December 1980 (following enactment of CERCLA), whichever comes later.

Response actions refer to activities taken to reduce threats from contaminants to acceptable levels. Short-term actions are generally termed *removals*, and long-term, final response actions are considered *remedial actions* [42 USC § 9601(23) and (24)]. Short-term response actions include initial response actions such as spill containment; long-term actions include permanent treatment or containment of contamination, and revegetation of disturbed areas. Under CERCLA, remedial actions must be protective of human health and the environment.

Restoration refers to actions undertaken to return injured resources and the services they provide to baseline conditions, and additional actions to compensate for interim losses of natural resources and their services. For example, restoration of riparian habitat along a stream might increase the number of birds that use the habitat for food or shelter. Restoration actions can take place off-site, away from the assessment area, or on-site, if the restoration actions improve the condition of the injured resources above levels necessary to satisfy cleanup goals. The term *restoration* may refer to direct restoration of injured resources, replacement of injured resources, or acquisition of the equivalent of such resources.

Service flows refer to the services provided by a resource over time. For example, remediation and restoration activities can increase the service flows provided by a resource.

Services are the “physical and biological functions performed by the resource, including the human uses of those functions” [43 CFR § 11.14 (nn)]. Habitat services include, for example, the provision of food and shelter for all kinds of animals, nutrient cycling, contaminant filtering, and aesthetic and recreational services for humans.

1.9 Public Review and Comment

The Assessment Plan will be available for public comment for 30 days following publication of a notice of availability in newspapers of statewide circulation. It can be accessed at <http://www.cdphe.state.co.us/hm/rma.htm>. An extension to the public comment period may be granted if requested and found to be reasonable and appropriate. Questions can be directed to vicky.peters@state.co.us or 303-866-5068; or jeff.edson@state.co.us or 303-692-3388. Comments can also be sent to:

Ms. Vicky Peters
Senior Assistant Attorney General
1525 Sherman Street, 7th Floor
Denver, CO 80203

The Assessment Plan may be modified in the future. If a significant modification is made, the revised Plan will be provided to the public for comment.

2. Site Description

The Arsenal, a 27 square-mile Army facility located 10 miles northeast of downtown Denver, formerly was used for the production of munitions, chemical warfare agents, nerve agent, industrial and agricultural chemicals, and the blending of rocket fuel. The Arsenal property is adjacent to Commerce City to the north and west, Montbello to the south, and Denver International Airport to the north and east (Figure 2.1) (EPA, 2007a).

Climate

The Arsenal is situated within a temperate grassland region of the High Plains and is part of a broad transition zone between mountain and plains habitats. The land surface slopes from southeast to northwest, with a total change of altitude of 220 ft. Prevailing winds are from the south and southwest. The average annual precipitation is approximately 15 inches, with 50% of that falling between April and July. Snow accounts for about 30% of the average precipitation. Localized summer thunderstorm activity results in large spatial variations in precipitation (Ebasco Services et al., 1989b).

Hydrology

Surface water at the Arsenal follows several small tributaries to the South Platte River, which flows to the northwest approximately 2 miles from the northwest boundary and 3 miles from the north boundary of the Arsenal (Figure 2.2). The drainages within the Arsenal include First Creek in the northeast, and Irondale Gulch in the southwest. A series of ditches, culverts, sewers, retention basins, and constructed lakes have greatly modified surface water flow, particularly in Irondale Gulch.

First Creek is a natural intermittent stream with few diversions. The Creek generally loses water as it crosses the Arsenal. In the mid-1980s, the average flow entering the Arsenal was 1.36 cubic feet per second (cfs), and the average flow leaving was 1.15 cfs (Ebasco Services et al., 1989b). Extended periods with little or no flow are common. First Creek discharges to O'Brian Canal approximately 0.5 miles north of the Arsenal boundary.

Irondale Gulch is a poorly defined topographic feature on the western side of the Arsenal and in the Irondale community northwest of the site (Figure 2.2). Surface water in Irondale Gulch does not follow a defined stream channel. Various lakes, ditches, and retention basins capture the surface water, which subsequently enters shallow groundwater or evaporates. Located in the southern section of the Arsenal, Lower Derby Lake and Lake Ladora were irrigation reservoirs prior to the construction of the Arsenal and were subsequently enlarged by the Army. The Army constructed Upper Derby Lake as an additional water storage area, and constructed Lake Mary for recreational fishing (Ebasco Services et al., 1989b).

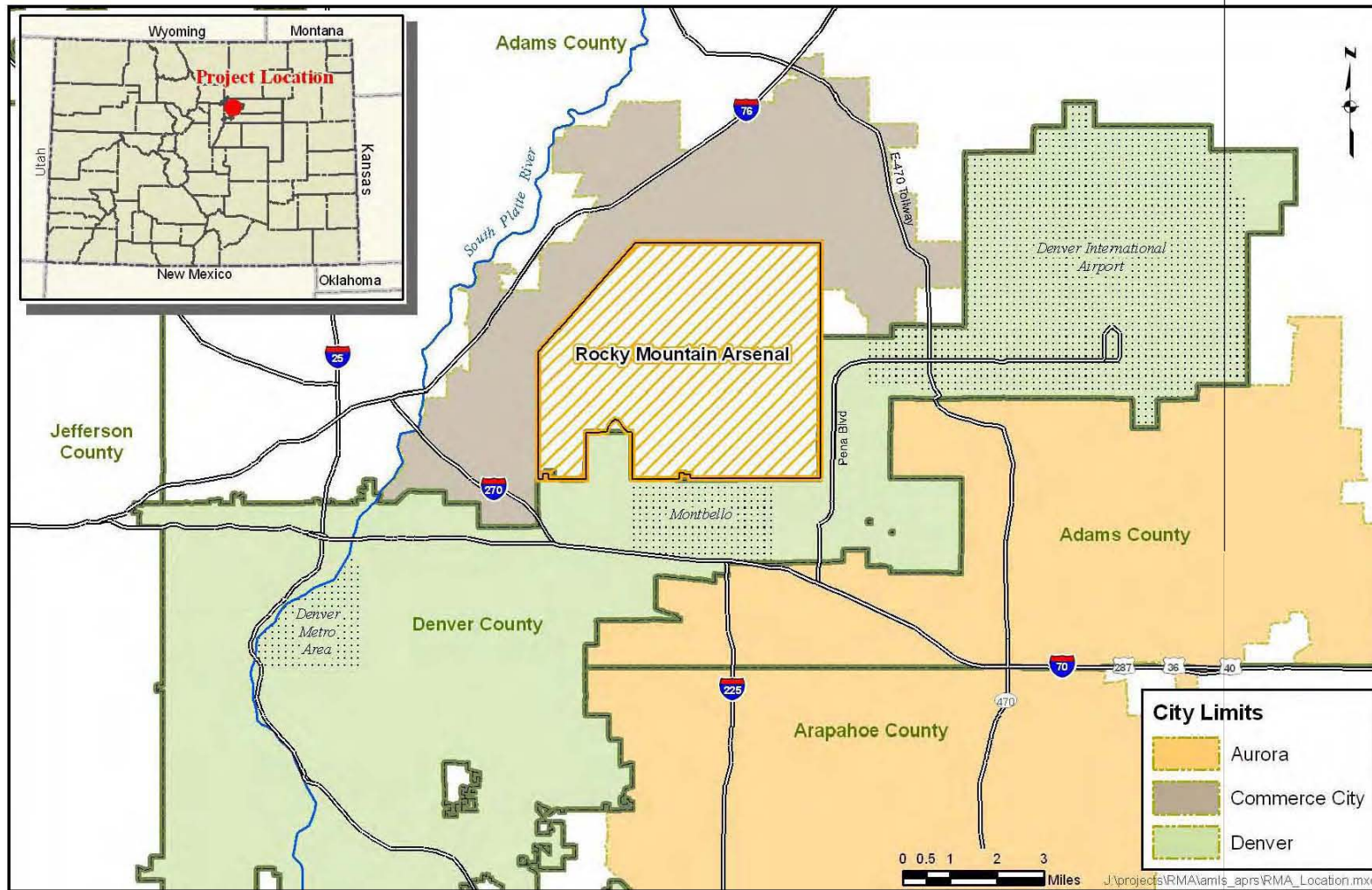


Figure 2.1. General location of the Rocky Mountain Arsenal in the Denver area.

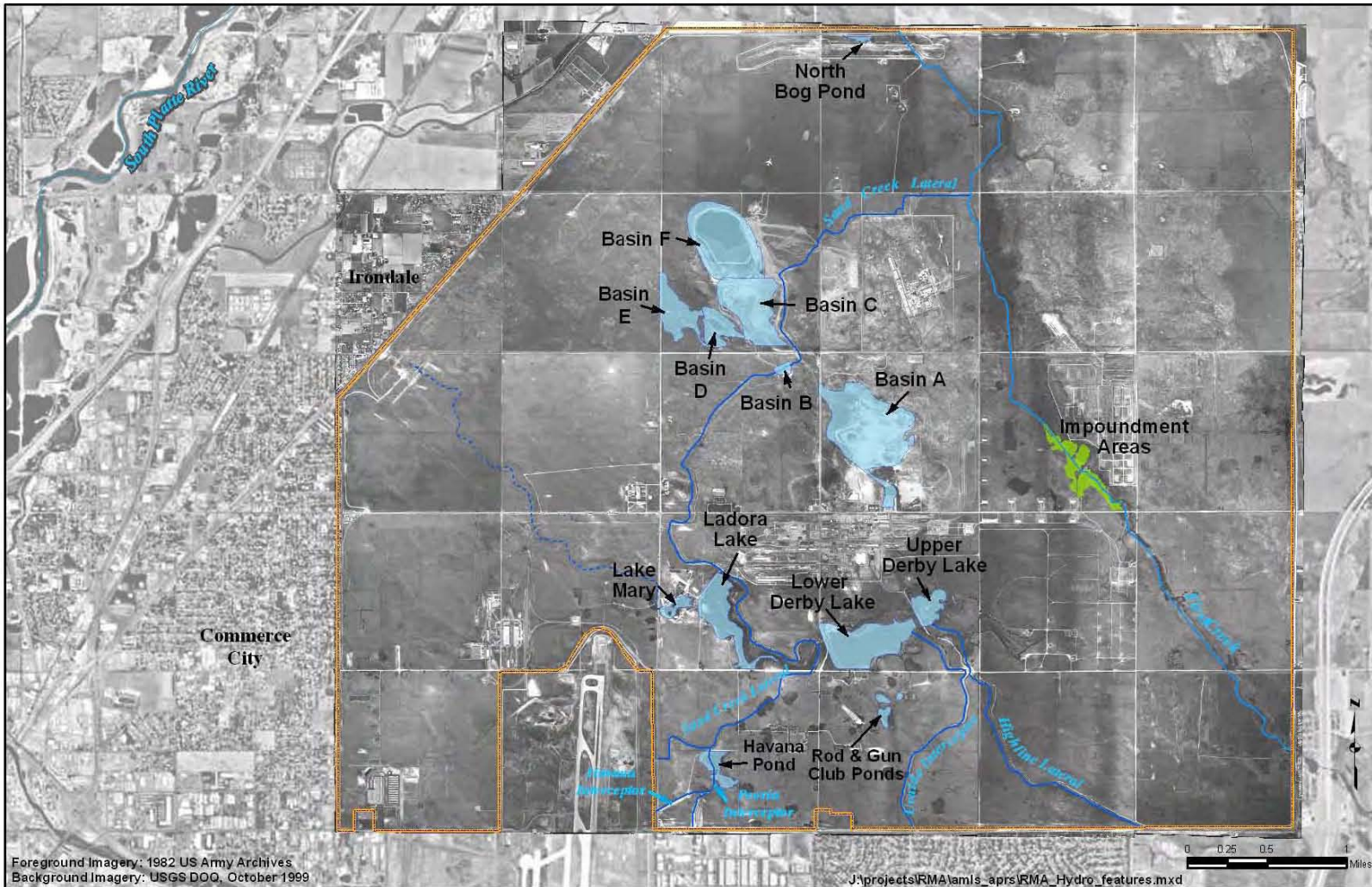


Figure 2.2. Past and present hydrologic features at the Arsenal. Most of the ditches and basins no longer hold surface water.

The Army also maintained six basins, Basin A through Basin F, for retention of stormwater, process water, and process waste (Figure 2.2). Basins A through E were unlined natural depressions, modified with berms and connecting overflow ditches. Basin F was constructed by the Army Corps of Engineers and lined with 3/8-inch thick asphalt (Environmental Science & Engineering and Harding Lawson Associates, 1988d). Liquids in these basins either evaporated or percolated to groundwater. Groundwater was often in direct contact with the bottom of Basin A (Ebasco Services et al., 1989b). The basins are no longer used for water retention and no longer contain surface water.

Groundwater

The groundwater at the Arsenal is part of the regional Denver Basin. Bedrock below the Arsenal is part of the Denver Formation. Sandy deposits known as alluvium overlie the bedrock, with thick deposits ranging from 50 to 130 ft found in ancient channels, and thinner deposits of approximately 20 ft found outside of these channels.

Shallow groundwater tends to follow these ancient alluvial channels, flowing to the north and northwest. The depth to groundwater and the thickness of the alluvial aquifer vary considerably across the site. From the 1950s through the 1980s, the groundwater levels near the manufacturing plants and the Basin A waste disposal basin were close to the surface (Ebasco Services et al., 1989b). Groundwater levels have dropped since manufacturing ended at the site (Foster Wheeler, 2000a).

Chapter 5 discusses the groundwater underlying the Arsenal in more detail.

Biota

Native vegetation at the Arsenal consists primarily of open semiarid grasslands, with some areas of shrubland, patches of yucca, riparian woodlands, cattail marshes and other wetland types, locust and wild plum thickets, upland groves of deciduous trees, and ornamental plantings. Parts of the Arsenal were planted with crested wheatgrass in the 1930s and 1940s to stabilize land susceptible to erosion. Societal changes in the region have altered the landscape to a mosaic of agricultural, developed (industrial and residential), and native habitats (Ebasco Services et al., 1994).

When ecological surveys were conducted in the 1970s and 1980s, 26 species of mammals were found at the Arsenal, including all of the common mammals that inhabit the prairie grasslands of the Colorado Front Range, as well as 176 species of birds and at least 17 species of reptiles and amphibians. The species richness of birds at the Arsenal was found to be high. Ground-nesting songbirds and other birds preferring open habitat are common in the primary Arsenal habitats of open grassland and weedy plains (Ebasco Services et al., 1994).

Ebasco Services et al. (1994) state that the larger lakes at the Arsenal (Figure 2.2) support viable aquatic communities, but benthic invertebrates are largely absent. Fish in the lakes are stocked.

Chapter 6 describes the biota at the Arsenal in more detail.

The remainder of this chapter describes the industrial activities and the waste disposal practices that occurred at the Arsenal. Section 2.1 provides a brief operational history of the Arsenal. Section 2.2 describes some of the manufacturing and disposal sites that became sources of hazardous substance releases to natural resources, followed by references cited in the text. Chapter 3 discusses the investigation and remediation of these releases.

2.1 Site History

Prior to World War II, the land where the Arsenal sits was shortgrass prairie that had been converted to agriculture. In May 1942, the Army purchased over 17,000 acres for manufacturing chemical and incendiary weapons (Army, 2004). After World War II, the Arsenal was placed on standby status, but with the start of the Korean conflict in 1950, the Army resumed operations. Production continued through 1957 as Cold War tensions heightened (Army, 2004). In the late 1950s into the 1960s, Army activities at the Arsenal included the manufacturing of nerve agent and weapons, demilitarization of chemical weapons, and the blending of rocket fuel for the Air Force (Army, 2004). In the 1970s, the Army used the Arsenal primarily for the demilitarization of chemical weapons. These activities ceased in the early 1980s (Army, 2004).

In addition to Army activities, private industries used the Arsenal for manufacturing. Julius Hyman and Company (Hyman) began producing pesticides at the Arsenal in 1946, followed by Colorado Fuel and Iron (CF&I) in 1947. In 1952, Shell acquired Hyman and continued to produce agricultural pesticides on-site until 1982 (EPA, 2007a).

Since the early 1980s, site investigation and remediation have been the primary activities at the Arsenal (Army, 2004; EPA, 2007a). The remainder of this section describes the industrial facilities and the products manufactured at the site. Chapter 3 then discusses cleanup activities in more detail.

2.1.1 Army manufacturing

Chemical agents, nerve agents, and munitions

The majority of the manufacturing at the Arsenal occurred at the South Plants Complex (Figure 2.3), which covered approximately 500 acres with buildings, roads, parking lots, railroad tracks, sewer lines, culverts, steam pipes, manholes, water mains, and some open space (Ebasco Services et al., 1989c). Chemical agents produced within the complex included mustard, lewisite, and phosgene (Table 2.1). Incendiary munitions were mainly napalm, white phosphorous, and a mixture of potassium chlorate, red phosphorous and glass known as “button bombs” and “sandwich button bombs” (DOJ, 1986; Ebasco Services et al., 1988b).

From 1942 to 1943, over 3.5 million tons of mustard were produced. Of this, over 334 tons were determined to be off-specification and ultimately treated and disposed of on-site (DOJ, 1986). In total, the Army produced about 1.6 million nerve gas munitions, including cluster bombs, shells, bomblets, rockets, and warheads at the Arsenal (Goldstein, 2001).

Napalm was produced from 1943 to 1945, with a total output of over 2.6 million bombs (Environmental Science & Engineering et al., 1988d). White phosphorous-filled munitions, including white phosphorous cups, igniters, grenades, and 105 mm shells, followed from 1945 until 1970 (DOJ, 1986). By the end of World War II, the Arsenal had created more than 100,000 tons of incendiary munitions (Army, 2004). By 1968, over 1.7 million button bombs and 7 million sandwich button bombs had been manufactured at the Arsenal (DOJ, 1986). White phosphorous and burned incendiary device casings were disposed of in the Army Section 36 Complex Disposal Trenches (Foster Wheeler, 2001) (Figure 2.3).

The Army constructed the 90-acre North Plants Complex (Figure 2.3) from 1950 to 1952. From 1952 to 1957, the Army used the North Plants Complex to manufacture Sarin nerve agent (Table 2.1), fill munitions with Sarin, and assemble cluster bombs, as well as to store Sarin, feedstock chemicals, and munitions. The facility was later used for the demilitarization of chemical warfare agents. The Army stored Sarin in one-ton containers and in underground tanks (DOJ, 1986; RVO, 2004).

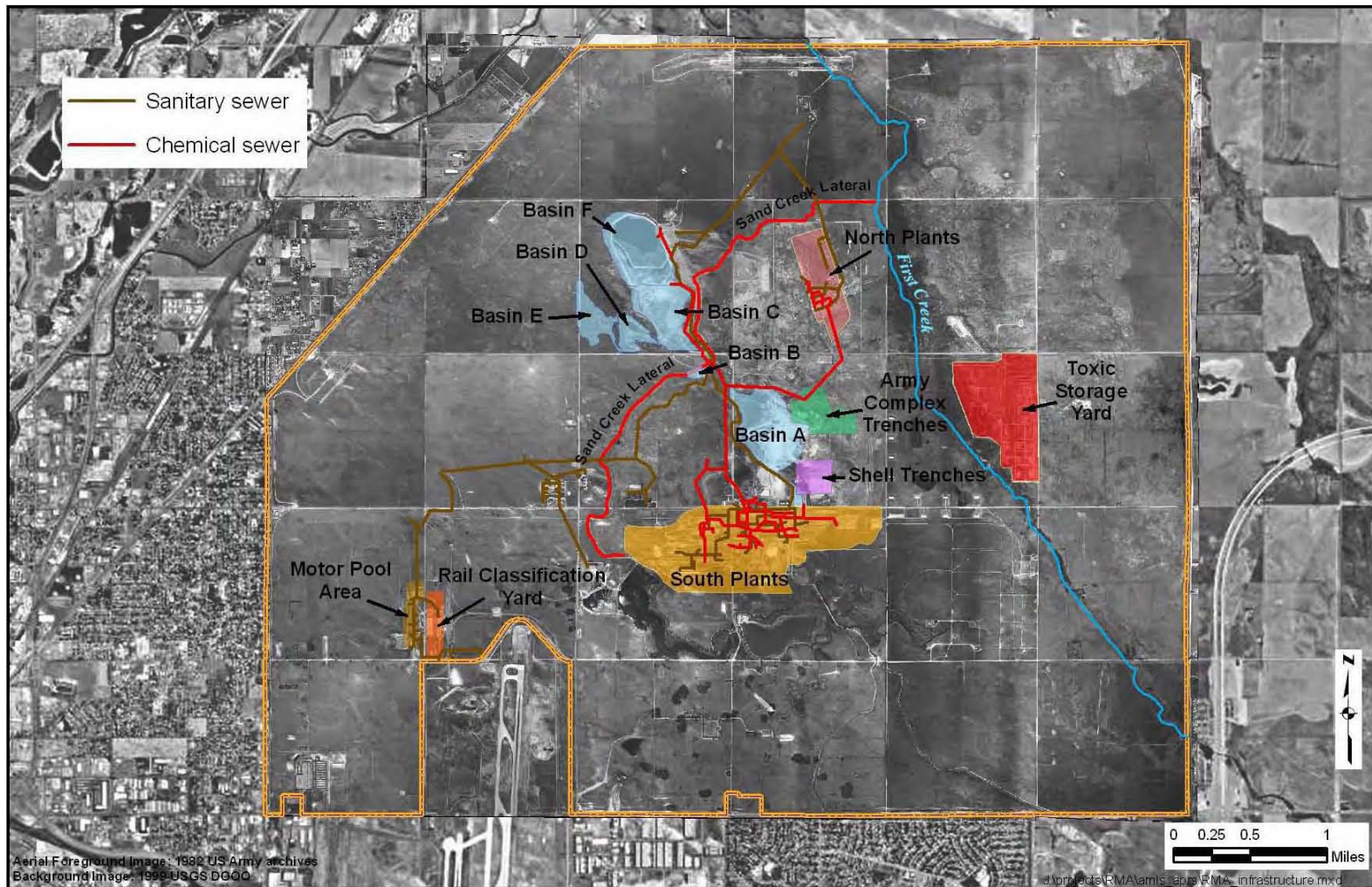


Figure 2.3. Manufacturing, storage, waste transit, and waste disposal sites at the Arsenal. Background image from 1982.

Table 2.1. Chemical agents and munitions manufactured or handled at the Arsenal

Product	Description	Sources
Mustard [bis (2-chloroethyl) sulfide; H; HS; Levinstein mustard]	Mustard is a vesicant, or blistering agent. Raw materials used in the production of mustard were ethyl alcohol, Freon 114, sulfur monochloride, calcium chloride, bleaching powder, coke, kerosene, fuel oil, caustic soda, and hexamine. Mustard and mustard-filled munitions were manufactured at the Arsenal in 1943 and from 1950 to 1957. Between 1945 and 1946, the Army reprocessed mustard into distilled mustard.	Ebasco Services et al., 1988b
Lewisite [2-chlorovinyl dichloro arsine]	Lewisite is a vesicant, sometimes used in combination with mustard. Raw materials associated with lewisite production included acetylene, arsenic trichloride, thionyl chloride, hydrochloric acid and mercuric chloride, many of which were manufactured at the Arsenal. The Army produced lewisite from April through November 1943.	Kuznear and Trautmann, 1980
Phosgene [carbonyl chloride]	Phosgene is a choking agent. The phosgene bomb-filling plant at the Arsenal operated from January 1944 to December 1944.	Kuznear and Trautmann, 1980; Army, 2004
Napalm	Napalm is a powdered thickening agent added to gasoline to produce the incendiary mixture called NP gel. This thickened fuel was used in incendiary bombs and flamethrowers. The incendiary oil plant, which mixed the napalm thickener and gasoline, operated from April 1943 to August 1945.	Ebasco Services et al., 1988b
White and red phosphorus	White phosphorus was used for production of incendiary bombs. Red phosphorus was used as a chemical constituent in button bombs and sandwich button bombs. The phosphorus plant operated in 1944–1945, 1952, 1953, and 1958–1960.	Ebasco Services et al., 1988b
Sarin [GB; isopropyl methylphosphono-fluoridate]	Sarin is an extremely toxic nerve agent. Raw materials included methylphosphonic dichloride, hydrofluoric acid, isopropyl, tributylamine, methanol, carbon tetrachloride, ethyl ether, methylene chloride, and calcium chloride. Sarin was manufactured at the North Plants from July 1952 through March 1957.	Ebasco Services et al., 1988b
VX [O-ethyl-S-(2-diisopropylaminoethyl) methylphosphonothiolate]	VX is an extremely toxic nerve agent. VX was not manufactured at the Arsenal, but VX bombs were decommissioned along with Sarin bombs at the site in the 1960s, and byproducts of the process were disposed of at the site.	Ebasco Services et al., 1988b

Demilitarization of munitions

After manufacturing these chemical agents and munitions, the Army subsequently demilitarized many of the same munitions at the facility (Figure 2.4). Beginning in 1947, obsolete and deteriorating mustard-filled munitions were disassembled at the Arsenal. The mustard was incinerated in a furnace located in the South Plants, and the casings were decontaminated in an acid bath and/or burned (DOJ, 1986). Other mustard demilitarization activities at the site included:

- ▶ 1958 to 1959: 30,000 mustard-filled munitions
- ▶ 1964 to 1969: more than 58,000 mustard-filled munitions
- ▶ 1973 to 1976: 3,407 mustard-filled one-ton containers incinerated (DOJ, 1986).

Demilitarization of Sarin munitions began in the 1950s, primarily on munitions that were off-specification. From 1955 to 1970, over 204,000 Sarin-filled munitions were demilitarized. In 1969, the Army initiated “Project Eagle” to demilitarize excess stocks of toxic agent at the Arsenal. From 1973 to 1976, over 21,000 stored M34 cluster bombs, each containing 76 bomblets filled with 2.6 pounds of Sarin, were demilitarized. The Army drained the bomblets, mixed the Sarin with caustic in a reactor chamber, and spray-dried the brine. Approximately 450,000 gallons of Sarin from over 21,000 munitions were deactivated as part of Project Eagle, resulting in almost 6.25 million pounds of contaminated spray-dried salt. The salt was stored in more than 18,000 steel and fiberboard drums in the Toxic Storage Yard (Army, 1978; DOJ, 1986).

In 1968, the Army began the demilitarization of the nerve agent VX, which was “the deadliest nerve agent ever created” (Council on Foreign Relations, 2006). VX was not produced at the Arsenal, but from 1964 to 1969, 2.3 million pounds were transported to the site and stored in



Figure 2.4. Technician deactivating fuses in cluster bombs at the Arsenal.

Source: Army (2004).

steel containers, spray tanks, rockets, and mines. Approximately 3,600 pounds of VX munitions were neutralized at the Arsenal (DOJ, 1986).

Demilitarization of chemical weapons halted in 1984, essentially ending industrial operations at the site (Ebasco Services et al., 1988g).

Rocket fuel

In 1959, in coordination with the Air Force, the Army constructed the Hydrazine Blending and Storage Facility (HBSF) to blend anhydrous hydrazine with unsymmetrical dimethylhydrazine to produce Aerozine 50 (Ebasco Services et al., 1988c). Aerozine 50 is a hypergolic fuel (ignites spontaneously) when used with nitrogen oxidizers. It was primarily used in the Titan and Delta missile programs (NASA KSC, 2005). Blending of Aerozine 50 began in 1961 and continued through 1982 (Ebasco Services et al., 1988c).

2.1.2 Other chemical manufacturing

CF&I manufactured dichlorodiphenyltrichloroethane (DDT) in the South Plants area in 1947 and 1948 (Ebasco Services et al., 1988d). CF&I also produced monochlorobenzene, a precursor of DDT, at a benzene plant in the South Plants complex in 1947 (Army, 2001). During the 1950s, CF&I manufactured chlorobenzene, DDT, naphthalene, and chlorine (Ebasco Services et al., 1988a).

Hyman developed the pesticides aldrin, dieldrin, and chlordane, and produced those pesticides as well as endrin at the Arsenal between 1947 and 1952 (Army, 2004). In 1950, Hyman took over caustic soda and chlorine production facilities formerly operated by CF&I. In 1948, Shell merged with Hyman, and in 1952, Shell assumed Hyman's leases at the Arsenal.

Shell manufactured a wide variety of pesticides, insecticides, and herbicides at South Plants (Table 2.2), producing aldrin and dieldrin until 1974 and other pesticides until the 1980s (Ebasco Services et al., 1988b; Army, 2001, 2004). Hazardous substance waste streams associated with the production of aldrin/dieldrin included: acetic acid, benzene, cyclopentadiene, dicyclopentadiene (DCPD), hexachlorocyclopentadiene, hydrogen, toluene, and xylene (Ebasco Services et al., 1988b).

Table 2.2. Herbicides and pesticides produced by Shell at the Arsenal

Substance	Years produced	Description
Aldrin/dieldrin	1947–1974	An organochlorine pesticide used on cotton and corn, among others. Use now banned or severely restricted.
Chlordane	1947–1952	A pesticide used on corn and citrus crops and on home lawns and gardens. Use now banned or severely restricted.
Endrin	1952–1965	A chlorinated hydrocarbon pesticide used to control insects, rodents, and birds. Use now banned or severely restricted.
Isodrin	1952–1965	A process intermediate of endrin with insecticidal properties similar to those of aldrin.
Methyl parathion	1957–1967	An insecticide for farm crops, especially cotton. Use now banned or severely restricted.
Ethyl parathion	1964–1966	An organophosphate insecticide used primarily on row crops and fruit.
Vapona	1960–1982	An insecticide used in Shell “No Pest Strips.”
Supona	1963–1969	A pesticide used to kill parasites in sheep and cattle. No longer used in the United States.
Bidrin	1962–1979	A pesticide used to control aphids, mites, thrips, fleahoppers, grasshoppers, boll weevils, and other insects on cotton, ornamental trees, and fruit crops.
Dibrom	1962–1970	An organophosphate pesticide used for, among other things, mosquito control.
Ciodrin	1962–1976	An organophosphate insecticide.
Azodrin	1965–1977	An insecticide used to control a broad spectrum of pests. Use now banned or severely restricted.
Atrazine	1977–1987	An agricultural herbicide.
Gardona	1967–1968	An insecticide used to control flies.
Akton	1952–1974	An organophosphate insecticide.
Landrin	1969–?	An insecticide.
Nudrin	1973–1977	An insecticide included on EPA’s Superfund Extremely Hazardous Substances list.
Nemagon ^a	1955–1977	A soil fumigant used to control soil-inhabiting nematodes. Use now banned or severely restricted.
Bladex	1970–1971, 1974–1975	A restricted use herbicide used to control weeds and invasive grasses.
Planavin	1966–1975	A herbicide used to control weeds and grass.
Nemafere	Unknown	A nemacide used to control nematodes.
Phosdrin	1956–1973	An insecticide used on vegetables, alfalfa, fruits, and nuts. Use now banned or severely restricted.

a. Nemagon is the trade name for dibromochloropropane (DBCP).

Sources: DOJ, 1986; Ebasco Services et al., 1988b; MK-Environmental Services, 1993; ATSDR, 2003; EPA, 2007b; Scorecard.org, 2007.

2.2 Sources of Hazardous Substances

In 1984, the Army developed a map that identified over 100 potentially contaminated sites. These included 15 basins and lagoons; 14 ditches, lakes, and ponds; 13 contaminated sewers; 38 solid waste burial sites; and 8 ordnance testing and disposal sites (Ebasco Services, 1985). Each of these sites may have released hazardous substances into the environment. A detailed assessment of each of the sources of hazardous substances is beyond the scope of this report. The Trustees instead provide a list of contaminants that are known to have been released at the Arsenal (Table 2.3), and then describe some of the primary manufacturing, waste transport, and waste disposal sites that are, or were, sources of hazardous substances and other contaminants (Figure 2.3). Table 2.3 is a partial list of contaminants released at the Arsenal; a complete compendium is beyond the scope of this document.

Table 2.3 lists over 160 contaminants, including over 100 hazardous substances, released at the Arsenal (DOJ, 1986; Ebasco Services et al., 1988b). Shell released an estimated 150,112 tons of contaminants into the environment, and the Army an estimated 26,405 tons (DOJ, 1986).

Table 2.3. Documented contaminants released at the Arsenal

Contaminant	Use	Contaminant	Use
Acetic acid	Used in the production of dieldrin, endrin, and bidrin	Ammonium nitrate	Waste product from Shell manufacturing
Acetone	Used in the production of azodrin and planavin	Ammonium nitrite	Waste product from Shell manufacturing
Acetonitrile	Waste product from Shell manufacturing	Ammonium sulfite	Waste product from Shell manufacturing
Acetophenone	Breakdown product of ciodrin	Antimony	Used in the production of lewisite
Acetylene tetrachloride	Used in laundry and clothing operations	Antimony compounds	Antimony chloride was used in the production of lewisite
Aldrin	Shell product manufactured at the Arsenal	Antimony hydroxide	Used in the production of lewisite
Allyl alcohol	Used in the production of Nemagon	Arsenic	Used in the production of lewisite
Allyl chloride	Used in the production of Nemagon	Arsenic trichloride	Used in the production of lewisite
Aminoisobutyronitrile	Process intermediate in the production of Bladex	Arsenic trioxide	Used in the production of lewisite
Ammonia	Used in the production of azodrin, bladex, and planavin	Asbestos	Insulation of pipes and buildings
Ammonium chloride	Fire retardant	Benzene	Used in the production of aldrin, dieldrin, and endrin

Table 2.3. Documented contaminants released at the Arsenal (cont.)

Contaminant	Use	Contaminant	Use
Bidrin	Shell product manufactured at the Arsenal	Copper	Used in pesticide manufacture
Cacodylic acid	Possibly used in the production of lewisite or as an herbicide	Copper compounds	Used in the production of azodrin and white phosphorous cups
Cadmium	Purpose of use not documented	Cyanide	Purpose of use not documented
Calcium arsenide	Used in the production of lewisite	Cyanogen chloride	Used in the production of phosgene
Calcium arsenite	Used in the production of lewisite	Cyclohexane	Purpose of use not documented
Calcium carbide	Used in the production of aldrin, dieldrin, and acetylene	Cyclohexanone	Purpose of use not documented
Carbon tetrachloride	Used in the production of Dibrom and as a cleaning solvent	Cyclopentadiene	Used in the production of aldrin, dieldrin, and heptachlor
Chlordane	Used in the production of heptachlor	DBCP	Shell product manufactured at the Arsenal
Chlorinated phenols	Use not documented	D-D soil fumigant	Shell product manufactured at the Arsenal
Chlorine	Used in the production of lewisite, azodrin, bidrin, heptachlor, and nudrin	DDT	Product manufactured at the Arsenal
Chloroacetic acid	Purpose of use not documented	Dibromoethane	Purpose of use not documented
Chlorobenzene	Used in the production of lewisite	Dichlorobenzene	Used in the production of akton
Chloroethylbenzene	Shell process intermediate	Dichlorodiphenylethane (DDE)	Decomposition product of DDE
Chloroform	Used in the production of azodrin and bidrin	1,1 dichloroethane	Used in the production of acetylene
Chlorophenylmethyl sulfide	Process intermediate in the production of Planavin	1,2 dichloroethane	Purpose of use not documented
Chlorophenylmethyl sulfone	Process intermediate in the production of Planavin	1,1-dichloroethylene	Purpose of use not documented
Chlorothiophenol	Purpose of use not documented	Dichloromethane	Used in the production of dichlor
Chromic acid	Used in the production of acetylene	Dichloropropane	Used in the production of D-D soil fumigant for nematodes
Chromium	Purpose of use not documented	Dichloropropene	Used in the production of D D soil fumigant for nematodes

Table 2.3. Documented contaminants released at the Arsenal (cont.)

Contaminant	Use	Contaminant	Use
Dichlorotrichlorophenyl urea	Used in laundry and clothing operation	Hexachlorocyclopentadiene	Used in the production of aldrin, dieldrin, and endrin
Dichlorvos	Shell product manufactured at the Arsenal; also used in the production of bidrin	Hexane	Used in the production of ciodrin and nudrin
Dicyclopentadiene	Used in the production of aldrin and endrin	Hydrazine	Used in the production of Aerozine 50
Dieldrin	Shell product manufactured at the Arsenal	Hydrochloric acid	Used in the production of lewisite, phosgene, and landrin
Diketene	Used in the production of azodrin and ciodrin	Hydrofluoric acid	Used in the production of Sarin
Dimethylamine	Used in the production of bidrin	Hydrogen cyanide	Used in the production of Bladex
Dimethylhydrazine	Used in the production of Aerozine 50	Hydrogen peroxide	Used in the production of dieldrin, endrin, and planavin
Dipropylamine	Used in the production of Planavin	Hydrogen sulfide	Decomposition product of akton, parathion, and nudrin
Endrin	Shell product manufactured at the Arsenal	Isodrin	Process intermediate in the production of endrin
Ethylbenzene	Purpose of use not documented	Isopropanol	Used in the production of Sarin, endrin, and planavin
Ferric chloride	Purpose of use not documented	Lead	Purpose of use not documented
Fluoroacetic acid	Purpose of use not documented	Malathion	Used in military training
Freon	Used in the production of button and sandwich button bombs	Mercuric compounds	Mercuric chloride was used in the production of lewisite
Heptachlor	Julius Hyman product manufactured at the Arsenal	Mercury	Purpose of use not documented
Heptachlor epoxide	Degradation product of heptachlor	Methanethiol	Process intermediate associated with the production of nudrin
Heptachlorobicycloheptadiene	Process intermediate in the production of endrin	Methanol	Used in the manufacture of Sarin and akton
Heptane	Purpose of use not documented	Methomyl	Shell product manufactured at the Arsenal
Hexachlorobenzene	Purpose of use not documented	Methyl disulfide	Used in the production of nudrin
Hexachlorobicyclopentadiene	Metabolite of heptachlor	Methyl isobutyl ketone	Used in the production of nudrin

Table 2.3. Documented contaminants released at the Arsenal (cont.)

Contaminant	Use	Contaminant	Use
Methyl isocyanate	Used in the production of landrin and nudrin	Phenol	Purpose of use not documented
Methyl mercaptan	Used in the production of nudrin	Phosdrin	Shell product manufactured at the Arsenal
Methyl parathion	Shell product manufactured at the Arsenal	Phosgene	A choking agent used in bombs at the Arsenal; a decomposition product of dibrom
Methylhydrazine	Used in the production of Aerozine 50	Phosphoric acid	A decomposition product of azodrin, bidrin, ciodrin, and gardona
Methylthioacetaldoxime	Used in the production of nudrin	Phosphorous (red)	Used in the production of button and sandwich button bombs
Mixed oleum and nitric acid	Used in the production of mustard	Phosphorus (white)	Used in the production of white phosphorous cups
Mustard	Army product manufactured at the Arsenal	Potassium chlorate	Used in the production of button and sandwich button bombs
Naled	Shell product manufactured at the Arsenal	Pyrene	Purpose of use not documented
Nitric acid	Used in the production of planavin and mustard demilitarization	Sarin	Army product at the Arsenal
Nitro sodium phenolate	Hydrolysis product of methyl and ethyl parathion	Sodium	Byproduct and decomposition product of Sarin
4-nitrophenol	Product of parathion hydrolysis	Sodium chlorate	Used in the production of Sarin and chlorine
N-nitrosodimethylamine (NDMA)	Impurity of dimethyl hydrazine; used in the production of Aerozine 50	Sodium fluoride	Byproduct of production; filling and demilitarization of Sarin munitions
Octachlorocyclopentadiene	Purpose of use not documented	Sodium hydroxide	Used in the manufacture of caustic, chlorine, Sarin scrubber effluent, akton, and nudrin
Parathion	Shell product manufactured at the Arsenal	Sodium hypochlorite	Used to decontaminate equipment and work areas
Pentachlorobenzene	Purpose of use not documented	Sodium methyllate	Used in the production of akton
Phenanthrene	Purpose of use not documented	Sodium nitrate	Used in M-74 incendiary munitions

Table 2.3. Documented contaminants released at the Arsenal (cont.)

Contaminant	Use	Contaminant	Use
Sodium nitrite	Used in M-74 incendiary munitions and a Shell waste	Trichlorobenzene	Used in the manufacture of gardona
Sulfur monochloride	Used in the production of mustard	1,1,1 trichloroethane	Solvent used by Shell
Sulfuric acid	Used in the production of nudrin and planavin; used in chlorine production and mustard distillation	1,1,2 trichloroethane	Purpose of use not documented
Sulfuryl chloride	Used in the production of ciodrin, heptachlor, and phosdrin	Trichloroethylene (TCE)	Used in laundry and M-74 bomb filling
Tetrachloroethane	Purpose of use not documented	Trimethyl phosphite	Used in the production of azodrin, bidrin, ciodrin, phosdrin, and vapona
Tetrachloroethylene (or perchloroethylene, PCE)	Used in laundry and clothing operations	TX	Army biological agent processed at the Arsenal
Tetrahydrofuran	Solvent used by Shell for unreported purposes	Vinyl chloride	Used in the manufacture of endrin
Thiodiglycol	Used in the production of mustard	Xylene	Used in the production of dieldrin, endrin, and gardona
Toluene	Used in the production of aldrin dieldrin and endrin	Zinc	Purpose of use not documented
Trichloroacetaldehyde	Used in the production of dibrom and dichlorovos	Zinc oxide	Used in laundry and clothing operations

Sources: DOJ, 1986; Ebasco Services et al., 1988b.

2.2.1 South Plants Complex

The South Plants Complex (Figure 2.3) was the site of the first manufacturing operations at the Arsenal and ultimately contained between 165 and 197 structures (Ebasco Services et al., 1988d). The Army initially used South Plants for the production, filling, and storage of bombs containing mustard, lewisite, phosgene, white phosphorus, chlorine, incendiary mixtures, and explosives (Ebasco Services et al., 1988d). Beginning in 1957 and continuing into the 1980s, the Army also demilitarized chemical weapons in the South Plants area. Demilitarization included emptying, burning, neutralizing, and disposing of nerve agents, nerve agent munitions, and nerve agent-contaminated items (Environmental Science & Engineering et al., 1988b). As discussed above, a succession of companies, primarily Shell, manufactured pesticides, insecticides, and herbicides at South Plants beginning in 1946 and continuing until 1982.

The South Plants Complex released hazardous substances to the environment through direct disposal of wastes into, among other locations, Basins A through F, Lime Settling Basins, Army Complex Trenches, Shell Trenches, sewers, ditches, and lakes (Figure 2.3). In addition, numerous spills associated with Army and Shell activities were reported. From the late 1940s to the end of manufacturing activities in the early 1980s, over 87,000 gallons of solvents, pesticides, metals, and other process intermediates leaked or spilled in the South Plants manufacturing area (DOJ, 1986; Ebasco Services et al., 1988b, 1988d).

In 1966, Shell constructed an incinerator in South Plants to decontaminate and dispose of their wastes. The incinerator was shut down in 1970 due to high particulate emission levels (Ebasco Services et al., 1992).

Numerous small waste pits and lagoons were located in and around the South Plants Complex, including the Liquid Storage Pool, Hex Pits, M1 Pits, South Plants Lime Pits, South Plants Lagoon, the Test Site, and the Insecticide/Pesticide Pits. Each of these has been identified as a source of hazardous substances (Ebasco Services et al., 1989c). A description of each is beyond the scope of this document, but all of these sites are within or adjacent to the South Plants and therefore the entire complex should be considered a source of hazardous substances.

South Plants Tank Farm

The South Plants Tank Farm was another source of hazardous substances located within the South Plants Complex. The Army, CF&I, Hyman, and Shell used the tanks for liquid storage (Ebasco Services et al., 1987). The tanks were constructed of dismantled salvage material, and they contained fuel, alcohol, benzene, bicycloheptadiene bottoms, DCPD, water, D-D soil fumigant, DBCP, and sulfuric acid (Ebasco Services et al., 1987). The overall capacity of the tanks was 2.3 million gallons (Ebasco Services et al., 1987). As reported in Ebasco Services et al. (1987), some of the numerous releases to the environment via spills and tank leakage included:

- ▶ 100,000 gallons of benzene in 1947
- ▶ 17,000 gallons of DCPD in 1963
- ▶ 1,548 gallons of DCPD and oil in 1976
- ▶ 58,864 gallons of DCPD in 1978.

In addition, sediments and DCPD bottoms were routinely removed from the tanks during cleaning and buried at unreported locations, possibly in pits adjacent to the tanks (Ebasco Services et al., 1987).

South Plants Chemical Sewers

The South Plants sewer system carried chemical wastewaters from production units to Basin A, the M-1 Pits, the Lime Settling Basins, the Sand Creek Lateral (via the storm sewer), ditches, and Basin F (Ebasco Services et al., 1988a). The sewers were originally constructed to dispose of wastewater generated at the South Plants Complex (Ebasco Services et al., 1988a). These sewers released hazardous substances, including acetic acid, aldrin, caustic soda, dieldrin, endrin, xylene, acids, and tetrachloroethylene, to South Plants groundwater (Ebasco Services et al., 1988a).

Sand Creek Lateral

Farmers originally constructed the Sand Creek Lateral (Figures 2.2 and 2.3) in the early 1900s for flood irrigation (Foster Wheeler, 2000b). As part of Arsenal operations, it served as a chemical sewer conveying wastes from the South Plants. The Sand Creek Lateral originally discharged liquid waste from the chlorine plants and South Plants stormwater runoff directly into First Creek. When sodium chloride concentrations in the waste reached 20,000 parts per million (ppm), flows from the Lateral were redirected to Basins D and E (Tetra Tech EC, 2005).

In 1951, the waste from the White Phosphorus Plant and the M-74 Bomb Filling Operations were redirected from Basin A to the Sand Creek Lateral (Tetra Tech EC, 2005). In 1953, the Sand Creek Lateral was incorporated into the liquid waste disposal system to convey overflow wastes from Basins A and B downstream to Basin C and subsequently into Basins D and E (Tetra Tech EC, 2005). The Sand Creek Lateral was used until the Basin F chemical sewer system was brought online in late 1956 (Tetra Tech FW, 2004; Tetra Tech EC, 2005).

The use of the Sand Creek Lateral for storm water runoff and discharge from the South Plants resulted in releases of hazardous substances, including aldrin, copper, dieldrin, TCE, trichloroethane arsenic, mercury, lead, sulfate, white phosphorous, various salts, caustics, and acids, to groundwater, surface water, and sediments (Tetra Tech FW, 2004; Tetra Tech EC, 2005).

North Plants Complex

The Army constructed the North Plants Complex (Figures 2.3 and 2.5) in the early 1950s to produce Sarin nerve gas, create the Sarin delivery systems (bombs), and subsequently to demilitarize Sarin bombs and other chemical warfare and incendiary munitions (Ebasco Services et al., 1989a; RVO, 2004). The manufacturing process resulted in the release of hazardous substances into, among other locations, Basins A and F, Army Complex Trenches, the Toxic Storage Yard, sewers, trenches, pits, and ditches, as well as directly to the ground from leakage and overflow of underground tanks and sumps within the North Plants (Ebasco Services et al., 1989a).



Figure 2.5. North Plants Complex.

Source: Army archives.

Floor drains from 18 buildings in the North Plants were connected to the Building 1727 Sump, an 80,000-gallon wastewater repository (Ebasco Services et al., 1989a). Wastes in the sump were neutralized with caustic, then pumped into Basin A or Basin F (Ebasco Services et al., 1989a).

Between 1953 and 1982, waste liquids from sump overflow migrated through ditches into First Creek. Leakage from the sump, in addition to spills and leakage from other areas of the North Plants, resulted in the release of benzene, 1,1 dichloroethane, 1,2 dichloroethane, carbon tetrachloride, 1,1,1 trichloroethane, TCE, chloroform, methylisobutyl ketone, arsenic, mercury, cadmium, chromium, copper, lead, zinc, pyrene, chloroacetic acid, aldrin, and dieldrin (Ebasco Services et al., 1989a). Soil samples taken adjacent to the North Plant sewers showed releases of dieldrin, arsenic, cadmium, chromium, and lead (Ebasco Services et al., 1989a).

2.2.2 Basins

Lime Settling Basins

The Lime Settling Basins (Figure 2.3) comprised three, one-acre unlined basins originally used during World War II to precipitate arsenic and metals from lewisite production wastewater (Environmental Science & Engineering et al., 1987e). All South Plants wastewater, including pesticide waste and byproducts, was reportedly channeled through the Lime Settling Basins to Basin A and, later, Basin B (Environmental Science & Engineering et al., 1987e). In addition, over 150 drums of mustard may have been disposed in these basins from 1959 to 1960 (Environmental Science & Engineering et al., 1987e). When their use was discontinued, the Army estimated that 80,000 cubic yards of sludge were contained in the Lime Settling Basins, with an additional 26,000 cubic yards located adjacent to them (Ebasco Services et al., 1990). Discharge of liquids into the Lime Settling Basins resulted in the release of numerous hazardous substances, including aldrin, dieldrin, endrin, isodrin, DDT, DDE, chlorophenylmethyl sulfide, arsenic, mercury, lead, cadmium, and chromium (Ebasco Services et al., 1990).

Basin A

Basin A was an unlined natural depression and the primary disposal area for liquid chemical waste from the South Plants from the time production of mustard was initiated in the early 1940s until the mid-1950s when the construction of Basin F was completed. Liquids were discharged to Basin A primarily through the chemical sewers. At maximum capacity, Basin A covered 125 acres (Environmental Science & Engineering, 1987; Figure 2.6).

In 1943, approximately 10% of the mustard produced was determined to be off-specification (DOJ, 1986). Each batch of off-specification mustard was neutralized with caustic and discharged through a toxic waste sewer into Basin A (Ebasco Services et al., 1988d). The treatment of mustard with caustic was not always successful, and high levels of mustard were often found in the water of Basin A near the sewer outlet (Kuznear and Trautmann, 1980). Mustard neutralization also produced 514,000 pounds of the hazardous substance thioglycol, which was also disposed of in Basin A (DOJ, 1986).

In addition, the Army flushed the mustard storage tanks with a mixture of carbon tetrachloride and fuel oil, and then a 10% solution of caustic and chlorinated water. Other parts of the mustard complex were rinsed using approximately 20,000 gallons of 98% sulfuric acid. All rinsate was discharged through the sewer into Basin A (DOJ, 1986).

During munitions filling operations, approximately 500 gallons of distilled mustard leaked from a corroded storage tank and was discharged untreated into Basin A (DOJ, 1986).



Figure 2.6. Basin A in June 1950.

Source: Army archives.

White phosphorous was shipped to the Arsenal in specialized railroad cars. The phosphorous was covered with water to avoid auto-ignition. The “phossy water,” as it was called, was discharged to Basin A via the chemical sewers until 1951 (DOJ, 1986).

Documented disposal of hazardous substances to Basin A from pesticide and herbicide manufacturing include (Ebasco Services et al., 1988b):

- ▶ > 170,000 pounds of aldrin mixtures
- ▶ 11,000 pounds of endrin manufacturing wastes
- ▶ 17,000 pounds of isodrin manufacturing wastes
- ▶ 406 pounds of nemaferre manufacturing wastes.

Basin B

Basin B was a two-acre, unlined natural depression that was used until 1956 as an intermediate containment reservoir for excess Basin A liquids directed to Basin C (Figure 2.3) (Environmental Science & Engineering et al., 1987d). Disposal of waste liquids into Basin B resulted in the release of numerous hazardous substances, including dieldrin, arsenic, mercury, lead, cadmium, and chromium (Environmental Science & Engineering et al., 1987d; Environmental Science & Engineering and Harding Lawson Associates, 1988e).

Basin C

Basin C was a 77-acre unlined natural depression (Figure 2.3) that the Army reportedly first used in the early 1950s as a repository for an unknown amount of white phosphorous waste considered to be incompatible with Basin A fluid (Environmental Science & Engineering et al., 1987a). The Army constructed dikes in 1953 to create a waste repository with an estimated capacity of 190 million gallons (Environmental Science & Engineering et al., 1987a). All waste liquids flowing into the basin were derived from two sources: (1) overflow from Basins A and B, and (2) surface drainage ditches in the South Plants that led into the Sand Creek Lateral (see Figure 2.2). Basin C was hydraulically connected to groundwater and thus served as a direct source of hazardous substance to groundwater (Environmental Science & Engineering et al., 1987a). Disposal of liquids into Basin C resulted in the release of numerous hazardous substances, including xylene, aldrin, dieldrin, DDE, chlorophenylmethyl sulfide, arsenic, mercury, copper, lead, cadmium, and chromium (Environmental Science & Engineering et al., 1987a; Environmental Science & Engineering and Harding Lawson Associates, 1988a).

Basin D

Basin D was a 21-acre unlined natural depression (Figure 2.3) that originally received Army waste from the chlorine plant and white phosphorous filling operations in the South Plants Complex via the Sand Creek Lateral prior to 1946 (Environmental Science & Engineering et al., 1987b). In 1952, the Army opened a spillway from Basin A, allowing 113 million gallons of Shell and Army waste to flow to Basin D over a three-month period (Environmental Science & Engineering et al., 1987b). From 1953 to 1956, all aqueous wastes entering Basin D were Basin A overflows from Shell manufacturing in the South Plants and the Army's Sarin manufacturing in the North Plants (Environmental Science & Engineering et al., 1987b). Disposal of liquids into Basin D resulted in the release of numerous hazardous substances, including aldrin, dieldrin, chlorophenylmethyl sulfide, arsenic, mercury, copper, lead, cadmium, and chromium (Environmental Science & Engineering et al., 1987b; Environmental Science & Engineering and Harding Lawson Associates, 1988b).

Basin E

Basin E was a 29-acre unlined natural depression (Figure 2.3) that, like Basin D, was a disposal site for wastewater overflow from Basin A (Environmental Science & Engineering et al., 1987c). Basin E began receiving overflow from Basin A and discharge from the chlorine plant in the South Plants in 1953 and continued to be used as additional storage capacity for overflow from Basin A until 1956 (Environmental Science & Engineering et al., 1987c). Disposal of liquids into Basin E resulted in the release of numerous hazardous substances, including aldrin, dieldrin, arsenic, mercury, lead, and chromium (Environmental Science & Engineering et al., 1987c; Environmental Science & Engineering and Harding Lawson Associates, 1988c).

Basin F

Basin F was a 93-acre, asphalt-lined evaporative disposal basin with a capacity of 240,000,000 gallons constructed in 1956 (Figure 2.3). By December 1956, the majority of contaminated liquid waste streams at the Arsenal were discharged into Basin F. On three occasions, Basin F filled to capacity: in 1962, 1965, and between 1975 and 1976. Shell disposed of liquid wastes in Basin F until 1978, and the Army until 1981. In 1981, the Army installed an aeration system that sprayed Basin F liquids into the air. While this accelerated evaporation of Basin F liquids, it also resulted in considerable contamination to surface soils around the exterior of the basin (Tetra Tech EC, 2005).

Repairs and modifications to Basin F's liner and dikes occurred several times during its use. The asphalt liner in Basin F did not prevent the release of hazardous substances to underlying soils and groundwater. Discharge of liquid wastes into Basin F resulted in the release of numerous hazardous substances, including aldrin, dieldrin, endrin, isodrin, toluene, trichloroethane, TCE, DBCP, ethyl benzene, xylene, DDE, arsenic, mercury, lead, and chromium (Environmental Science & Engineering et al., 1988a).

Specific documented disposal of hazardous substances from Shell's pesticide and herbicide manufacturing to Basin F includes (DOJ, 1986; Ebasco Services et al., 1988b):

- ▶ 44,000 pounds of endrin manufacturing wastes
- ▶ 50,000 pounds of isodrin manufacturing wastes
- ▶ 60,000 pounds per year (~10 years) of methyl parathion salts
- ▶ 140,000 pounds of methyl parathion manufacturing wastes
- ▶ 120,000 pounds of ethyl parathion manufacturing wastes
- ▶ 150,000 pounds of bidrim manufacturing wastes
- ▶ 12,000 pounds of dibrom manufacturing wastes
- ▶ 28,000 pounds of ciodrin manufacturing wastes
- ▶ 2,000 pounds of azodrin manufacturing wastes

- ▶ 8,600 pounds of nudrin manufacturing wastes
- ▶ 238,400 pounds of DBCP manufacturing wastes
- ▶ 9,300 pounds of bladex manufacturing wastes
- ▶ 1,360,000 pounds of planavin manufacturing wastes
- ▶ 1,300 pounds of phosdrin manufacturing wastes.

2.2.3 Trenches

Army Complex Trenches

The Army Complex Trenches (Figure 2.3) was a solid waste disposal site covering over 100 acres. The Army used the trenches from the 1940s to the early 1970s to dispose of wastes that included potentially contaminated tools, equipment, unwanted containers, rejected incendiaries, vehicles, empty munitions casings, chemical warfare agent, and chemical agent-filled unexploded ordnance (Foster Wheeler, 2001). Because of the lack of disposal records, and the Army's fear that an intrusive investigation could result in exposure to unexploded ordnance and chemical agent, the nature of waste disposed in discrete portions of the site is undetermined. Hazardous substances identified in some trench contents or trench soils include aldrin, dieldrin, endrin, chlordane, DDT, DBCP, fluoroacetic acid, arsenic, mercury, cadmium, chromium, and lead (Harding Lawson Associates, 1993). Additional hazardous substances identified in groundwater downgradient of the trenches include chlorobenzene, dichloroethane, dichloroethene, tetrachloroethane, TCE, trichloroethane, xylene, and cyanide (Harding Lawson Associates, 1993).

Shell Section 36 Trenches

The Shell Section 36 Trenches (Figure 2.3), also known as the Shell Trenches, covered an eight-acre area that Shell used from 1952 to 1965 for land disposal of liquid and solid hazardous substances from the production of pesticides. Approximately 31 unlined trenches were excavated 10 to 20 ft wide and between 5 and 10 ft below the surface. The trenches were used to dispose of organic and inorganic compounds, process intermediates, and off-specification products. The use of these trenches for disposal resulted in the release of hazardous substances, including aldrin, dieldrin, endrin, isodrin, benzene, chlorobenzene, chloroform, DBCP, dicyclopropane, ethylbenzene, hexane, toluene, xylene, 1,1-dichloroethane, 1,2-dichloroethane, 1,2-dichloroethene, methylene chloride, tetrachloroethylene, and trichloroethene (Environmental Science & Engineering et al., 1987f, 1988c; Environmental Science & Engineering and Harding Lawson Associates, 1988f, 1988g; MK-Environmental Services, 1993).

Whereas the basins were used to dispose of the hazardous byproducts of pesticide and herbicide manufacturing, the Shell Trenches were used to dispose of unused pesticide and herbicide products. Documented products disposed in the Shell Trenches include (DOJ, 1986; Ebasco Services et al., 1988b; MK-Environmental Services, 1993):

- ▶ 842,000 pounds of endrin
- ▶ 5,990,000 pounds of isodrin and isodrin impurities
- ▶ 13,000 pounds of methyl parathion
- ▶ 13,000 pounds of vapona
- ▶ 6,100 pounds of bidrin
- ▶ 10,000 pounds of dibrom
- ▶ 45,000 pounds of azodrin
- ▶ 9,800 pounds of DBCP
- ▶ 70,000 pounds of planavin and planavin impurities
- ▶ 4,000 pounds of phosdrin.

2.2.4 Motor Pool/Rail Classification Yard

The Motor Pool (Figure 2.3) was constructed in the 1940s to service heavy equipment, vehicles, locomotives and rail cars, and for storing fuel, road oil, and flammable liquids (Ebasco Services et al., 1988e). Various wastes may have been discharged into drainage ditches, including solvents, petroleum products, strong caustics, dilute wastes from the motor pool wash bay, and detergents (Ebasco Services et al., 1988e). A 1984 Compliance Order by the Colorado Department of Health halted the use of degreasing solvents at the Motor Pool. The wastes discharged by activities associated with the Motor Pool resulted in releases of hazardous substances, including benzene, chloroform, 1,1-dichloroethane, ethylbenzene, methylene chloride, tetrachloroethylene, toluene, 1,1,1-trichloroethane, TCE, m-, o- and p-xylene, aldrin, DBCP, arsenic, mercury, cadmium, chromium, and lead (Ebasco Services et al., 1988e; Foster Wheeler, 2000a).

The Rail Classification Yard (Figure 2.3), adjacent to the Motor Pool, was built in the late 1940s for the storage of pesticides, solvents, and acids. In addition, the area was used as open storage for tanks, trailers, crates, and for the temporary storage of railcars, including railcars holding DBCP. There were several reported spills in the Rail Classification Yard, resulting in a groundwater plume emanating from the site. DBCP is the only identified hazardous substance released from the Rail Classification Yard (Ebasco Services et al., 1988h, 1989d).

2.2.5 Toxic Storage Yard

The Toxic Storage Yard (Figure 2.3) was originally constructed in 1952 as a 16-acre storage site for lewisite, mustard, phosgene, Sarin, VX, and decontamination agents. The site was later expanded to the south and west to provide additional storage capacity. By April 1953, the Army had constructed four 10,000 square-foot open storage pads as support facilities for Sarin production in the North Plants Complex. In August 1954, 625 one-ton containers, likely containing Sarin, were in the yard. In the early 1960s, the Army discovered that containers and cluster bombs in the Toxic Storage Yard were leaking Sarin. In the early 1970s, the Army stored 76,000 drums of demilitarized Sarin salts in the Toxic Storage Yard as part of Project Eagle (Ebasco Services et al., 1988f, 1988i).

Spills from leaking containers and bombs are the primary source of contaminants in the toxic storage areas (Ebasco Services et al., 1988f). The use of the Toxic Storage Yard to store lewisite, mustard, phosgene, Sarin, VX, and decontamination agents resulted in the release of hazardous substances, including, but not limited to, chloroacetic acid, arsenic, chromium, and lead (Ebasco Services et al., 1988f, 1988h).

2.2.6 Other areas

The Army identified over 178 different contaminant source areas (Ebasco Services et al., 1992). Not all have been discussed in this Plan. The majority of these sources are in the South Plants and in Section 36, where Basin A and the Army and Shell Trenches, among other sites, are located (Figure 2.3). Some sources not discussed above are addressed in the next chapter that summarize cleanup activities at the site.

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3. Response Actions

The Army addressed contamination at the Arsenal through a series of interim response actions (IRAs) in the 1980s, and through the final remedial action that was selected as a result of the RI/FS process discussed below. The first actions were groundwater treatment and containment systems constructed in the early 1980s on the northwest and northern boundaries of the Arsenal to prevent further migration of known groundwater contamination (Harding Lawson Associates, 1995; Foster Wheeler, 1996).

In 1984, the U.S. Army Toxic and Hazardous Materials Agency, under a separate division created specifically to deal with the contamination at the Arsenal, initiated a series of investigations required under CERCLA. These investigations were incorporated into the RI/FS and the Endangerment Assessment (Foster Wheeler, 1996). As the RI proceeded and more was learned about the site, the parties agreed to a number of IRAs to address some of the most obvious and discrete ongoing sources of contamination. The ROD for the Off-Post Operable Unit (OU) was signed in December 1995, and the ROD for the On-Post OU was signed in June 1996. These RODs memorialized the final selected remedy for each OU. Implementation of the on-post remedy is ongoing and is expected to be completed by 2010.

This chapter discusses the response actions that have taken place at the Arsenal. Section 3.1 presents an overview of the RI/FS process, which formed the basis of remedy selection; Section 3.2 discusses actions taken on-post; and Section 3.3 discusses actions taken off-post.

Summary of response actions

The Army constructed several groundwater containment, extraction, and treatment systems to address contaminated groundwater plumes (discussed further in Chapter 5). Pump-and-treat systems included those on the west/northwest boundaries (including the Irondale Containment System and Northwest Boundary Containment System), and north boundary (North Boundary Containment System), as well as the newer Rail Classification Yard system and the Basin A Neck system. Extraction wells were constructed on-post at the Motor Pool, South Plants Complex, Lime Settling Basins, the Army Section 36 Trenches, north of Basin F, the South Channel wells to the east of the original Basin F system, and northeast of Basin A (Bedrock Ridge). Off-post extraction and reinjection wells and a treatment system were also constructed north of the Arsenal boundary (Figure 3.1).

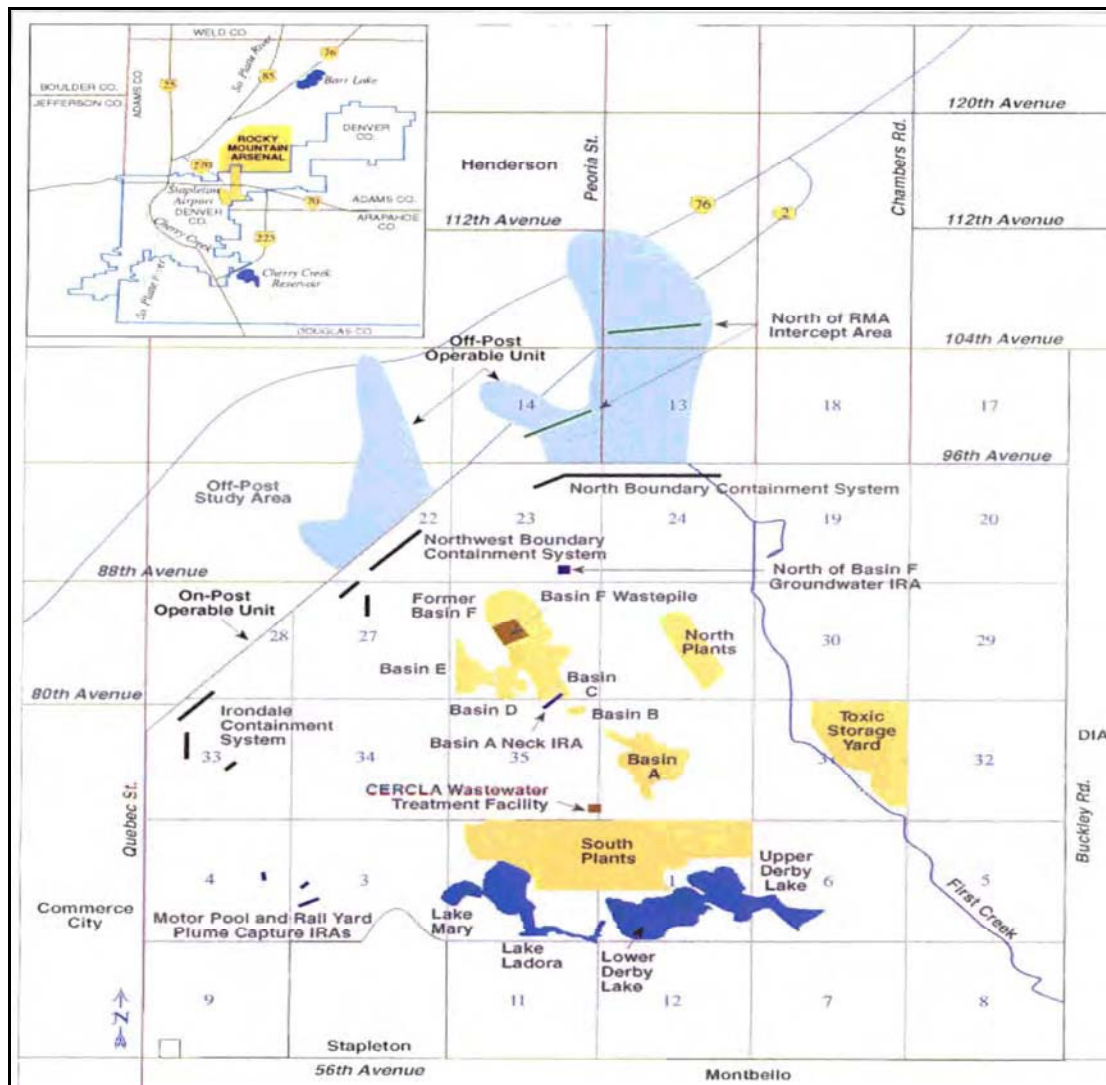


Figure 3.1. Selected areas where some response actions occurred.

Source: Foster Wheeler, 1996, Figure 1.0-1.

In addition, Shell and the Army funded the purchase of water rights and a distribution system for South Adams County Water and Sanitation District (SACWSD) to provide domestic water to residents north of the Arsenal and south of the South Platte River (Figure 3.1). This action prevented these residents from consuming groundwater that would have put them at risk of adverse health effects from diisopropyl methylphosphonate (DIMP), a byproduct of Sarin nerve agent prevalent in shallow groundwater north of the Arsenal (Harding Lawson Associates, 1995).

The response to contaminated soils and sludge included construction of a hazardous waste landfill and an enhanced landfill, with cells triple-lined for particularly contaminated soils, plus reconstruction of Basin A as a soil consolidation area for less contaminated soils. Millions of cubic yards of contaminated soils, sludge, and sediments were excavated and placed in these two landfills and the consolidation area. After excavation, the contaminated areas were covered with a rock biota barrier and soil, and then planted with vegetation. Restoration of the original native prairie grasses on the capped and borrow areas has had mixed success (Foster Wheeler, 1996).

Most of the soil remediation has been completed. Remediation of Basin F is expected to be completed in 2008. Once the final remedy is finished, known residual soil contamination above acceptable levels should be contained in landfills or capped in place (Foster Wheeler, 1996).

3.1 RI/FS Summary

3.1.1 Remedial Investigation

The RI was separated into the On-Post and the Off-Post OUs (Figure 3.2). The formal Off-Post OU was based solely on the spatial extent of off-post groundwater plumes for selected contaminants, while the Off-Post Study Area covered the extent of the areas evaluated for potential risk (Figure 3.2).

On-post

The Army and Shell's releases of hazardous substances extended over a large portion of the 27 square-mile site, and impacted soils, groundwater, surface water, air, and biota. The Army divided the On-Post RI into discrete source areas for study, and carried out the investigation in phases. The results were documented in 124 Phase I Contamination Assessment Reports (CARs), one for each identified or potential waste site and one for areas within each one square-mile section designated by the Army as a "non-source" area. The CARs were subsequently summarized in Study Area Reports for the central, north central, southern, eastern, western, North Plants, and South Plants areas of the Arsenal. In addition, separate RIs were completed for biota, surface water and groundwater, and structures. The Army also instituted Comprehensive Monitoring Programs (CMPs) for water, biota, and air. Ebasco Services et al. (1992) summarized all the foregoing reports in a comprehensive RI summary report. The On-Post RI ultimately covered over 320 locations of suspected contamination and identified 178 contaminated sites at the Arsenal (Ebasco Services et al., 1992).

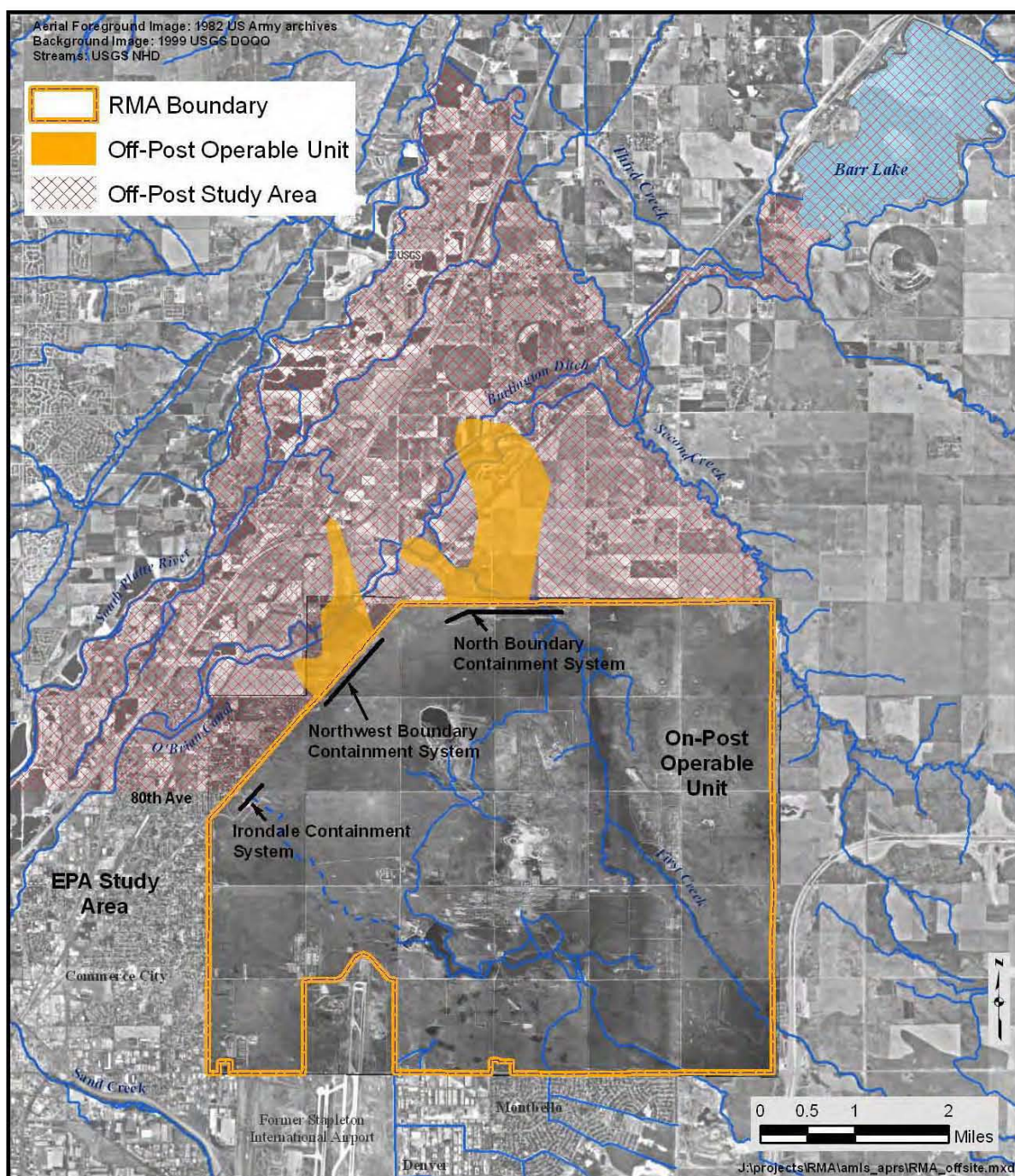


Figure 3.2. On-Post and Off-Post OUs, and the Off-Post Study Area, at the Arsenal. The Off-Post Study Area is the area evaluated for potential risks, while the Off-Post OU covers only the spatial extent of off-post groundwater plumes for selected contaminants.

The Army initiated the CMP in 1987 to collect data for evaluating response actions and to provide continual long-term verification monitoring of environmental conditions, including biota, on- and off-post. Despite the extensive data gathered at the site, the following limitations of the RI and the endangerment assessment should be noted:

- ▶ The RI sampling program may have missed hotspots in non-source areas due to limited sampling density and the Army's compositing of soil samples. If highly contaminated soils were composited with less contaminated soils, hot spots could have been missed because the high concentrations may have been diluted to concentrations below a level of concern.
- ▶ With the exception of 1,1,2,2-tetrachloroethane, none of the dozens of tentatively identified compounds were considered quantitatively in the endangerment assessment and the characterization of risk. These tentatively identified compounds represent a large number of unknown chemicals that were detected in chemical analysis results but were never positively identified by the Army.
- ▶ The extent of contamination at 23 sites identified as areas of potential chemical agent presence may have been underestimated. Detections of chemical agent at these sites were not quantitatively evaluated because the Army considered many of the detections "analytical artifacts" (Ebasco Services et al., 1994).
- ▶ The investigation of areas like the Army Complex Trenches and the Shell Section 36 Trenches, known to be highly contaminated and presenting special safety concerns, were intentionally avoided, providing little contaminant data.
- ▶ Detection levels for some contaminants in some media, most notably dieldrin in surface water, were often higher than the threshold risk concentration. In these cases, a lack of detection provides no assurance that the contaminant concentration is below the level of concern.

Off-post

The Off-Post Study Area was defined as the area southeast of the Platte River, north of 80th Avenue, southwest of Second Creek, and north of the north and northwest boundaries of the Arsenal (Figure 3.2). The Army divided the Off-Post Area into six "zones" based on possible contaminant types, concentrations, and general distribution. The Off-Post Study Area included the surface waters of O'Brian Canal and Burlington Ditch, along with First Creek and Barr Lake (see Figure 3.2) (Foster Wheeler, 1996).

Investigation of groundwater contamination began in 1975 with the 360° Monitoring Program. This investigation was initiated due to lawsuits filed in the 1950s by residents experiencing crop damage to the north of the Arsenal, along with three Cease and Desist Orders issued by the Colorado Department of Health in 1975. The original program investigated water from 42 locations both on and off the Arsenal. It was later revised to include 117 domestic, irrigation, and monitoring wells. After multiple phases and the sampling of nearly 150 wells, the Army identified 33 target chemicals for inclusion in the Off-Post OU groundwater investigation (Harding Lawson Associates, 1995).

The 1987 Groundwater CMP superseded the 360° Monitoring Program and continued both on-post and off-post monitoring well sampling and analyses. The Off-Post RI was also initiated in 1987 to refine the Army's understanding of groundwater flow patterns and the distribution of contaminants (Environmental Science & Engineering and Harding Lawson Associates, 1987).

Groundwater contamination in the Off-Post OU consisted of three groundwater plumes in the unconfined flow system: the northern paleochannel (extending due north from the Arsenal boundary), the First Creek paleochannel (which runs parallel to First Creek, in a northwest direction from the northern boundary of the Arsenal), and the northwest paleochannel (migrating northwest from the northwest boundary of the Arsenal). The Army consolidated the studies of the north and First Creek pathways, referring to them as the "North Plume Group" (see Figure 3.1) (Foster Wheeler, 1996).

According to the Army, soil contamination in the Off-Post Study Area was the result of the disposition of airborne contaminants from on-post and from the use of contaminated groundwater for irrigation purposes (Harding Lawson Associates, 1995). In 1989, soil in residential areas north of the Arsenal on 96th Avenue was targeted for investigation. The results of this sampling program led to additional sampling from several locations off-site. The Army's final sampling event was in 1991, when it investigated off-post areas where previous studies identified high concentrations of chemicals of concern. The majority of the Army's off-post soil investigations were limited to surface soils (0–2 inches) (Harding Lawson Associates, 1995).

Off-post surface soil samples were collected within 30-foot diameter circles and composited prior to analysis. Approximately 100 soil samples were collected from an area of 18 square miles. These composite samples did not show widespread soil contamination above risk thresholds acceptable to the EPA (Harding Lawson Associates, 1995).

3.1.2 Integrated Endangerment Assessment/Risk Characterization

EPA considers risk assessments to be an integral part of an RI. At the Arsenal, the various components of the human health and ecological risk assessments were combined in the

Integrated Endangerment Assessment/Risk Characterization (IEA/RC) report (Ebasco Services et al., 1994).

3.1.2.1 Human health risk

On-post

The IEA/RC evaluated 27 contaminants of concern for the human health risk assessment, which presupposed use restrictions imposed by the Federal Facilities Agreement that Shell and federal agencies signed in 1989. These controls prevent various uses of resources. Specifically:

- ▶ Water on or under the Arsenal cannot be used as a drinking water supply
- ▶ Arsenal property cannot be used for residential or agricultural purposes
- ▶ Hunting and fishing are restricted to nonconsumptive use, subject to appropriate restrictions.

The Federal Facilities Agreement also included the “goal” of establishing a National Wildlife Refuge at the site. Human health risks that were not evaluated as part of the Endangerment Assessment included those associated with exposure to contaminated groundwater and exposures associated with residential development (Ebasco Services et al., 1994).

Based on the RI results and the anticipated land use as open space/wildlife refuge, the human health risk assessment identified biological workers as most at risk. The Army also performed an assessment related to commercial and industrial development, which were not prohibited by the Federal Facilities Agreement. Based on those land use scenarios, the assessment identified industrial workers as most at risk. For the biological worker land use scenario, 149 of the 178 sites investigated in the RI had elevated cancer risks, with 12 of the sites identified as having highly elevated cancer risks. For the industrial worker land use scenario, 70 of the 178 sites studied had elevated cancer risks, and 16 of the sites studied had highly elevated cancer risks (Ebasco Services et al., 1994). Soils at the following areas had elevated cancer risks for both land use scenarios (Ebasco Services et al., 1994):

- ▶ Chemical sewers
- ▶ Sanitary/process water sewers
- ▶ M-1 Pits
- ▶ Section 36 Lime Basins
- ▶ Basins A and F
- ▶ Shell Trenches
- ▶ Five distinct areas within the South Plants.

Isolated soil borings showed elevated cancer risks in Basin C, the Sand Creek Lateral, the North Plants Agent Storage Areas, and the sanitary landfill near the Rail Classification Yard. The contaminants contributing most to potential carcinogenic risks were aldrin, dieldrin, DBCP, and arsenic (Ebasco Services et al., 1994).

Off-post

The Army's endangerment assessment for the Off-Post Study Area included 27 square miles to the north and northwest of the Arsenal. During the early 1990s when the assessment occurred, this area was rural agricultural land and residential neighborhoods, with some industrial use (Harding Lawson Associates, 1995).

For the evaluation of risk to human health, the Off-Post Study Area was divided into six zones. According to the Army, this was done to avoid diluting or averaging contaminant concentrations over the entire Study Area. Based on results of investigations from 1985 to 1991, risks were developed for each of the six zones. The Army recognized a potential cancer risk from benzene, arsenic, and dieldrin, with groundwater being the dominant source contributing to that risk. Non-carcinogenic effects in children exceeded EPA's acceptable level in three of the six zones, primarily due to exposure to dieldrin in groundwater. The Army concluded that no cleanup apart from the existing groundwater intercept systems was necessary because institutional controls would prevent unacceptable exposures to contaminated groundwater (Harding Lawson Associates, 1995).

3.1.2.2 Ecological risk

On-post

The ecological risk assessment went through several iterations due to significant disagreements among the State of Colorado, EPA, Shell, the USFWS, and the Army. Final cleanup levels were agreed upon after the signing of the ROD, based upon additional exposure studies conducted at the Arsenal.

The ecological risk assessment, contained within the IEA/RC (Ebasco Services et al., 1994), focused on three categories of representative species: predators (bald eagle, great horned owl, American kestrel, and great blue heron), species with special feeding niches (including shorebirds such as the mallard, blue-winged teal, and American coot, and small birds such as the mourning dove, vesper sparrow, and western meadowlark), and lastly, prey (deer mouse, thirteen-lined ground squirrel, black-tailed prairie dog, and desert cottontail). Potential ecological risk was evaluated for 14 target compounds, or "chemicals of concern": aldrin, dieldrin, DDT, DDE, endrin, mercury, arsenic, cadmium, copper, chlordane, chlorophenyl methyl sulfide, chlorophenyl methyl sulfone, DCPD, and DBCP (Ebasco Services et al., 1994).

The ecological risk assessment showed that, assuming exposure to all target chemicals combined, most soils at the Arsenal presented a potential risk to at least one representative species, primarily from exposure to aldrin, dieldrin, endrin, DDT/DDE, and mercury (Ebasco Services et al., 1994). Areas where all representative species were at a potential risk include (see Figure 3.1):

- ▶ South Plants and most areas in the vicinity of South Plants and north of Lake Mary, Lake Ladora, and the Derby lakes
- ▶ Basins A, B, C, D, and F
- ▶ Toxic Storage Yard.

Although varying concentrations of pesticides were detected in surface soil samples throughout the Arsenal, exceedences of ecological risk criteria were generally limited to the central processing and disposal areas (Ebasco Services et al., 1994).

3.1.3 Feasibility study

Feasibility studies are conducted to evaluate alternative response actions against regulatory criteria including protectiveness, effectiveness, and cost. Most alternatives for soils remediation involved disposal in an on-post hazardous waste landfill, some covering in place, and some treatment. The selected remedy included a large on-site double-lined landfill with an isolated triple-lined cell to accept the most contaminated waste (Foster Wheeler, 1996). This landfill was designed in accordance with the State's regulatory requirements under the Colorado Hazardous Waste Act. The groundwater remedy was largely reliant on the existing pump and treat systems (Foster Wheeler, 1996). Details of the final remedy are discussed below.

The Army did not evaluate remedial alternatives for soils in the Off-Post Study Area because risks were found to fall within the EPA's acceptable range. The primary component of the off-post groundwater remedy was continued operation of the Arsenal's boundary and off-post groundwater extraction and treatment systems (Harding Lawson Associates, 1995).

3.2 On-Post Actions

3.2.1 Interim response actions

The Army implemented a series of actions in the 1980s to address some of the more urgent contamination problems. With the cooperation of the State, EPA, and Shell, 14 IRAs were identified (13 IRAs on-post and one off-post), with many completed during the RI. The interim

responses were intended to be consistent with the final selected response actions (Foster Wheeler, 1996).

The 13 on-post IRAs (Foster Wheeler, 1996), shown in Figure 3.3, were:

- ▶ **North boundary system improvements:** The Army assessed and implemented operational improvements to groundwater treatment at the north boundary and constructed recharge trenches to improve the reinjection of treated groundwater.
- ▶ **Groundwater interception and treatment north of Basin F:** The Army constructed an extraction system for groundwater contamination migrating north of Basin F. Contaminated groundwater was treated and recharged at the Basin A Neck.
- ▶ **Abandoned well closure:** The Army sampled and subsequently plugged wells on the Arsenal that were not part of the ongoing groundwater monitoring program or that were not suitable for future monitoring programs.
- ▶ **Groundwater interception and treatment at Basin A Neck:** An intercept and treatment system was installed in a constricted alluvial groundwater channel downgradient of Basin A.
- ▶ **Building 1727 sump liquid remediation:** The goal of this project was to treat the contaminated liquid in Sump 1727 in North Plants and control the remaining threat of contaminated liquid that could have been released to the environment.
- ▶ **Hydrazine Blending and Storage Facility remediation:** The Army decommissioned above-ground equipment and treated 300,000 gallons of hydrazine wastewater in the Basin F Incinerator.
- ▶ **Fugitive dust control:** In 1991, due to concerns with wind-blown dispersion of contaminated soils, the Army reapplied a dust suppressant in Basin A.
- ▶ **Sanitary sewer remediation:** In 1992, to eliminate the migration of contaminated groundwater in the sewer system, the Army plugged the sanitary sewer's manholes.
- ▶ **Asbestos removal:** The Army sampled and removed suspected friable asbestos from in and around occupied buildings. This work was completed in 1989.

- ▶ **“Hot Spot” contamination source remediation:**
 - **Shell Trenches:** The Army constructed slurry walls and caps at the Section 36 Shell Trenches to reduce the vertical and horizontal migration of contamination.
 - **Lime Settling Basins:** The Army constructed a soil cover over the Lime Settling Basins area to isolate them from the ground surface and minimize the amount of rainwater seeping into the basins.
 - **Motor Pool:** A groundwater extraction system and soil vapor extraction system were built to address TCE contamination in groundwater and soils.
 - **Rail Classification Yard:** This action included an assessment of groundwater, followed by the construction of a groundwater intercept system.
 - **South Tank Farm plume:** For the South Tank Farm plume, Shell implemented groundwater sampling to monitor the Light Non-Aqueous Phase Liquids portion of the groundwater plume, verify existing data on contaminant migration, and locate the leading edge of the plume over time. Shell determined that the plume was not migrating toward the Lower Lakes, nor posing a significant threat to humans or other biota, prior to the final remedy. Natural biodegradation of the plume was thought to be occurring (EPA and Army, 2000b).
 - **Army Trenches (or Section 36 Trenches):** The Army determined that immediate action was not required and selected groundwater monitoring as the IRA, despite highly elevated contaminant concentrations in surface soils, deep soils, and shallow groundwater (Army, 1998).
- ▶ **Pretreatment of CERCLA liquid wastes:** The Army constructed a treatment system to treat wastewater generated during investigations and remediation activities.
- ▶ **Chemical process-related activities:** This project consisted of the sampling, decontaminating, and dismantling of Army agent- and non-agent-related process equipment in the North and South Plants Complexes.
- ▶ **Remediation of Basin F liquids, sludges, and soil:** This extensive multi-phase project included removal of contaminated sludges and soil, as well as removal and incineration of waste liquids. The Basin F IRA is discussed in more detail below.

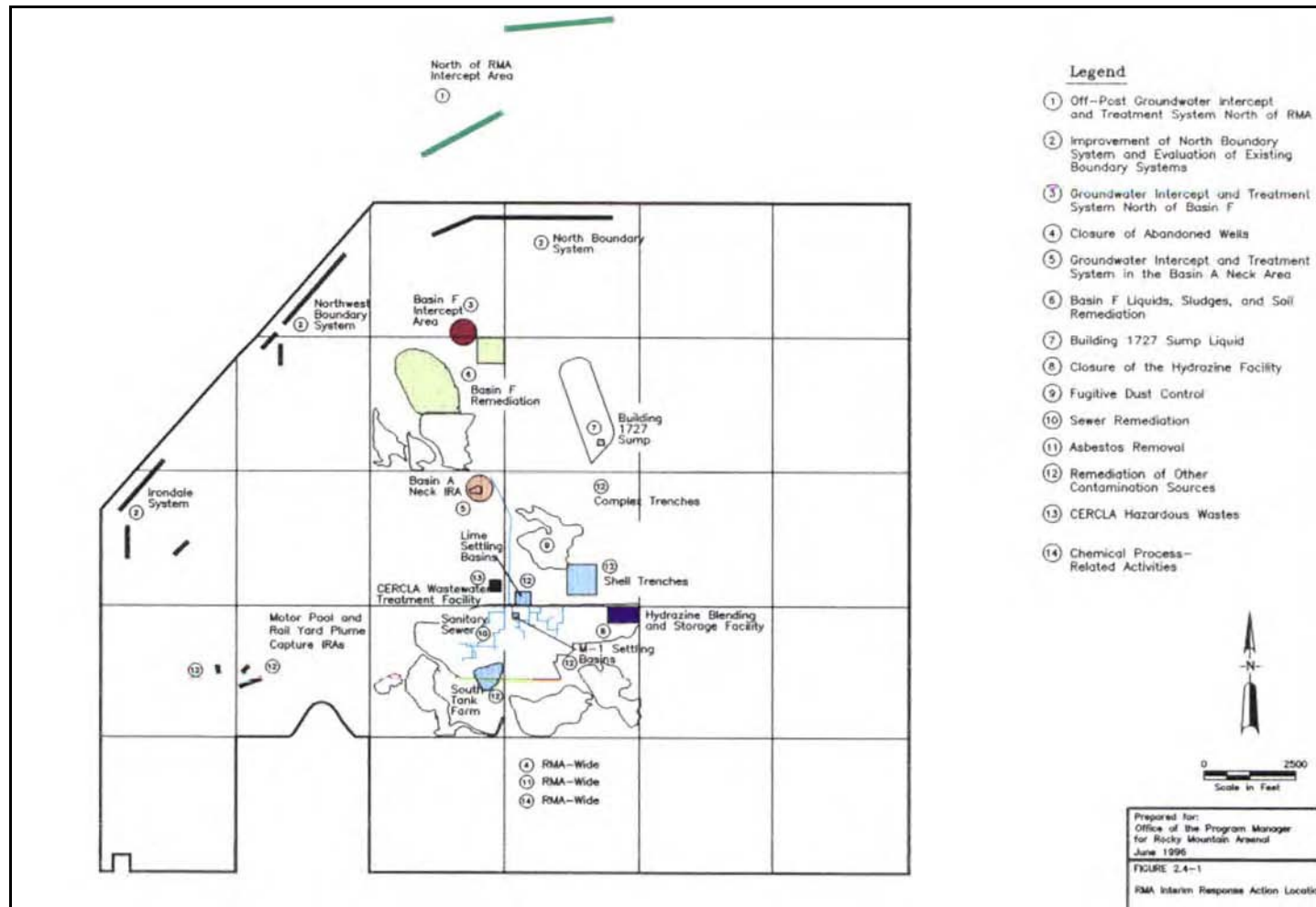


Figure 3.3. Location of interim response actions at the Arsenal.

Source: Foster Wheeler, 1996, Figure 2.4-1.

Basin F IRA

Basin F was by far the most extensive IRA at the Arsenal. The Army implemented this IRA in two phases. The first phase was designed to prevent further infiltration of Basin F waste liquids to the underlying groundwaters; to eliminate adverse effects to wildlife from the contaminated liquids, sludges, and soils in the basin; and to eliminate emissions of volatile chemicals from the basin. The second phase was destruction of the Basin F liquids (Army, 1988).

Phase I of the Basin F IRA (Army, 1988) included:

- ▶ Removal of liquid wastes from the basin to three lined steel storage tanks, each with a capacity of 1.33 million gallons, or approximately 4 million gallons total.
- ▶ Construction of a 16-acre, three-cell, lined waste pile within the southwest corner of the basin's existing footprint, to contain materials excavated from the basin.
- ▶ Excavation, drying, and transport of the basin's bituminous asphalt liner and overburden, along with underlying soils and crystallized or solidified sludges, to the waste pile. Soils and sludges were excavated to a depth of 6 inches to 6 ft below the asphalt liner, based on contamination data or visible discoloration.
- ▶ Recontouring of the remaining 77 acres in the basin's footprint, covering with a clay cap, and revegetating the cap.
- ▶ Construction of a double-lined surface impoundment, ultimately divided into Pond A (3.77 acres) and Pond B (3.2 acres), to contain contaminated runoff, leachate, and decontamination water.

During implementation of the Phase I IRA in Basin F in the summer of 1988, Army contractors discovered a layer of crystallized salts and sludges ranging from two to almost five feet thick. Under this "false bottom" were an additional 3 to 4.5 million gallons of liquid waste, rendering the 4 million gallon holding tanks insufficient (Harding Lawson Associates, 1996). The crystalline layer added over 150,000 cubic yards of sludge to be excavated, on top of the 405,000 cubic yards originally estimated to be in Basin F (Army, 1988; Woodward-Clyde, 1990).

The excavation, air-drying, and transport of Basin F materials during the Phase I IRA created noxious odors that blew into the residential areas of Commerce City adjacent to the Arsenal. Over 200 odor complaints were lodged from July 1988 through March 1989. As a result, the Army abandoned the Phase I IRA plan in December 1988, ordering all remaining waste in the basin to be capped in place (Ebasco Services, 1989).

Basin F was capped in January 1989, after nearly 4 million gallons of liquid waste were pumped into tanks and another 7 million gallons were placed in Pond A. The excavated waste pile, which covered 16 acres with waste up to 58 ft high, was capped and seeded in the spring of 1989 (Harding Lawson Associates, 1996).

Phase II of the Basin F IRA began in May 1990. The Army selected submerged quench incineration to treat millions of gallons of stored Basin F liquid waste and other stored liquid wastes at the Arsenal. The incinerator operated from June 1993 through July 1995, destroying nearly 12 million gallons of Basin F liquids, Basin F waste pile leachate, wastewater from the HBSF, and decontamination liquids from closure activities (EPA and Army, 2000a). Approximately 16,500,000 gallons of metals-laden brine, a waste product of the incineration, were sent to Encycle in Texas for copper recovery and treatment prior to disposal (EPA and Army, 2000a).

3.2.2 Selected remedies

The contaminated areas within the On-Post OU covered approximately 3,000 acres and included 15 groundwater plumes and 798 structures (Foster Wheeler, 1996). On June 13, 1995, the Army, Shell, the USFWS, the EPA, and the State of Colorado signed the "Conceptual Agreement Among the Parties." This agreement outlined the components of the remedies which were ultimately set forth in the RODs. The On-Post ROD (Foster Wheeler, 1996) was signed on June 11, 1996. The selected remedy included 31 cleanup projects for soil and structures and additional treatment of groundwater contamination. Upon completion of the site-wide remedy, much of the Arsenal will have been transferred to the USFWS to become a National Wildlife Refuge. Areas where remedial facilities exist, e.g., the treatment systems, landfills, and covered soils, will remain with the Army. The total estimated cost (in 1995 dollars) for the selected remedy was \$2.2 billion (Foster Wheeler, 1996).

The On-Post remedy, as described by Foster Wheeler (1996), includes the following:

- ▶ Intercept and treat contaminated groundwater
- ▶ Construct a hazardous waste landfill in compliance with State law
- ▶ Construct an additional landfill in Basin A
- ▶ Demolish structures with no designated future use and dispose of the debris in either the on-post hazardous waste landfill or Basin A, depending upon the degree of contamination
- ▶ Contain contaminated soil in the hazardous waste landfill or under caps or covers, or treat, depending upon the type and degree of contamination
- ▶ Continue enforcement of institutional controls from the 1989 Federal Facilities Agreement, and restrict access to capped or covered areas and other remedial facilities.

Groundwater

The selected groundwater remedial alternative included continued operation of all existing groundwater treatment systems, including the North Boundary, Northwest Boundary, and Irondale containment systems, the Motor Pool, Rail Yard, and North of Basin F extraction systems, and the Basin A Neck treatment system (Figure 3.1). It also included construction of the Section 36 Bedrock Ridge extraction and piping system and development of an extended groundwater monitoring program. This program addressed possible upwelling of contaminated groundwater in the lakes and the hydraulic containment of a South Plants groundwater plume. In addition, the program included monitoring of the confined aquifer in South Plants, Basin A, and Basin F; and monitoring and assessing NDMA contamination (Foster Wheeler, 1996). NDMA was discovered in the early 1990s beyond the boundaries of the HBSF, including areas off-post. NDMA was not fully characterized in on and off-post groundwater until after the finalization of both RODs due to unacceptability high Army detection limits.

Other groundwater-related on-post remedial actions include the following:

- ▶ Fifty-one wells were identified as potential conduits from the unconfined flow system to the confined flow system and were sealed with grout plugs to prevent contaminated shallow groundwater from coming in contact with the deeper aquifers (Dames and Moore, 2000).
- ▶ In 1997, the North Boundary Containment System was upgraded with hydrogen peroxide/ultraviolet light treatment to reduce concentrations of NDMA that had been discovered in groundwater crossing the north boundary of the Arsenal (Morrison-Knudsen, 1998).
- ▶ In 1997, the Irondale boundary containment pumping system was shut off when the groundwater quality met the remediation goals. The Motor Pool extraction system was shut down in April 1998. The Irondale treatment plant shut down in July 2001 and was demolished in February 2002. The Rail Classification Yard treatment plant went online when the Irondale treatment system shut down (Washington Group International, 2003).
- ▶ In 2000, the Army shut down the North of Basin F extraction well because it was running dry. The well operated from 1990 to 2000, removing from groundwater 995 pounds of contaminants, primarily chloroform, DCPD, and DIMP (Washington Group International, 2005b).
- ▶ In 2002, the Army constructed two new extraction wells in Section 24 (South Channel Wells) between the former North of Basin F well and the North Boundary Containment System. The new wells used a new in-situ technology using Hydrogen Release

Compound. The project was completed September 2005 (Chadwick Consulting, 2004; RVO, 2005).

- ▶ In 2006, seven extraction wells were placed in the South Plants Tank Farm and four extraction wells were placed in the Lime Settling Basins to extract contaminated groundwater and transport the groundwater to the CERCLA wastewater treatment plant. These wells and the treatment plant are scheduled to be decommissioned in 2010 when the plant will no longer be considered necessary to deal with remedial action-related wastewater (Washington Group International, 2005a).
- ▶ In 2008, the Army will install up to five additional dewatering wells inside the Lime Basins barrier wall. This contaminated groundwater will be treated initially at the CERCLA wastewater plant, followed by treatment at the Basin A Neck plant after the CERCLA plant is decommissioned (Tetra Tech EC, 2007).

Soils

The Army selected the following alternative for soils (Figure 3.4; Foster Wheeler, 1996):

- ▶ Transporting approximately 1.5 million bank cubic yards (bcy) (a measure of in-place soil volume prior to disturbance and compaction) of soil and debris that exceeded acceptable biota risk levels to Basin A and the South Plants Central Processing Area.
- ▶ Engineered caps and covers over 1,100 acres of contaminated soil (including the contaminated soil described above) in the Basins, South Plants, North Plants, and Section 36 sites (including Shell and Army Complex Trenches).¹
- ▶ Treating approximately 207,000 bcy of soil from Basin F, the Hex Pits, and the M1 Pits (all treatment remedies, with the exception of the M1 Pits, were subsequently abandoned as discussed below).
- ▶ Disposing of approximately 1.7 million cubic yards of soil and debris in the on-post hazardous waste landfill (Figure 3.5). One cell of the landfill is triple-lined for the disposal of “principal threat” wastes, or wastes containing contaminant concentrations over 1,000 times higher than acceptable risk levels. Principal threat waste from Basin F is being transported to the landfill. Principal threat waste from the Lime Settling Basins was originally slated for the hazardous waste landfill, but the remedy for the Lime Settling Basin was changed as discussed below.

1. Subsequent modifications to the remedy resulted in fewer acres of covered soils.

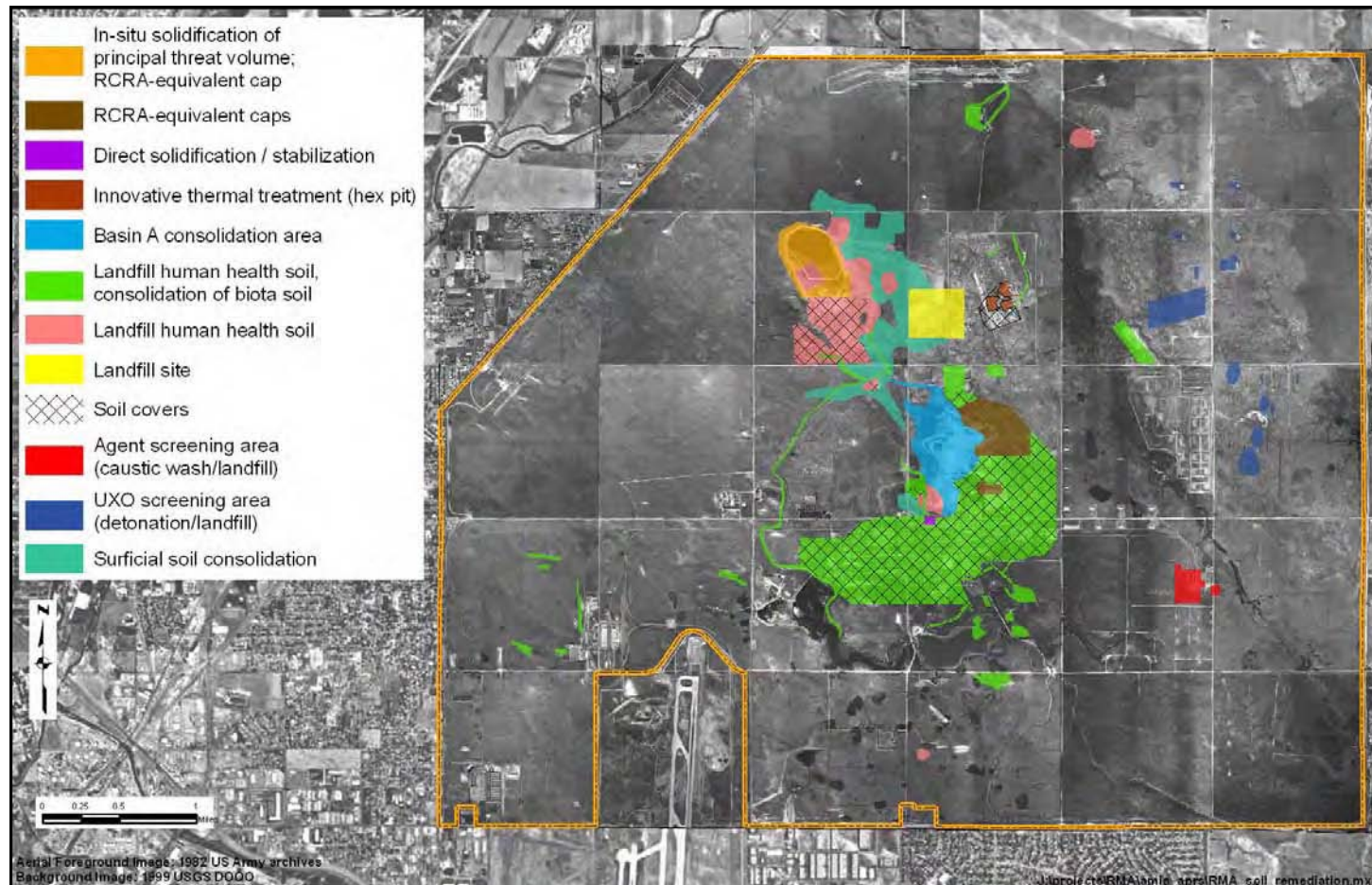


Figure 3.4. Selected soil remedies as depicted in the On-Post ROD. The actual soil remedies were revised as new information became available – see text. Highly contaminated soils were placed in the hazardous waste landfill (yellow) with less contaminated soils consolidated in Basin A (light blue).

Source: Foster Wheeler, 1996, Figure 9.3-1.



Figure 3.5. Construction of the lined on-post hazardous waste landfill for contaminated soils.

Source: Army archives.

Figure 3.4 shows the soil remedies that were selected in the ROD. Some of the soil remedies described in the ROD were later modified as new information became available during remedial design. Below is a brief review of large-scale soil remediation activities that occurred at selected areas of the site (see Figure 2.3 for locations of specific areas).

- ▶ South Plants soil that contained contaminant concentrations exceeding human health risk thresholds was excavated and landfilled. Approximately 330,000 bcy of soil was removed from the Central Processing Area, South Plants ditches, and from other South Plants areas. The Central Processing Area was excavated to a depth of 5 ft, and the remaining areas to a depth of 10 ft. An estimated 590,000 bcy of contaminated soils were left in place. These areas were capped with biota barriers below the surface to eliminate potential cap damage from, and prevent exposure to, burrowing animals. The caps

covered 220,000 square yards in the central processing area, 120,000 square yards above the ditches, and 1.7 million square yards in the rest of the South Plants area (Foster Wheeler, 2002b).

- ▶ Basin A was converted into an unlined landfill primarily for debris and soils containing contaminant concentrations that exceeded risk thresholds for biota but not for human health. A one-foot-thick foundation layer was first placed over the existing contaminated soil in the 100-acre basin. Then, approximately 1.1 million bcy of contaminated soil, and 160,000 bcy of structural debris were placed in the basin. The contaminated soils and debris were capped with a biota barrier and soil, and the cap was revegetated (Foster Wheeler, 1996).
- ▶ North Plants soils were remediated by excavating and disposing in the hazardous waste landfill 43,000 bcy of soils containing contaminant concentrations exceeding human health risk thresholds. An additional 7,234 bcy of soils with contaminant concentrations exceeding risk thresholds for biota but not for human health were excavated and placed in Basin A (Tetra Tech FW, 2004a).
- ▶ From Basins B, C, and D, approximately 50,000 bcy of contaminated soils were removed and placed in the hazardous waste landfill. Approximately 170,000 bcy of soils exceeding thresholds for biota risk were removed and placed in Basin A (Tetra Tech FW, 2004b).
- ▶ For Basin F, the On-Post ROD distinguishes between the Basin F waste pile, a lined landfill of Basin F wastes created as part of the IRA; “Former Basin F,” from which some soils and sediments were removed and placed in the Basin F waste pile; and Basin F Exterior, the soils outside the basin which were contaminated by windblown dust and “enhanced evaporation” spraying. When the Basin F remedy is completed in 2008, approximately 165,000 bcy of soil from the upper 10 ft of Former Basin F, and an additional 600,000 bcy of soil from the Basin F waste pile, will have been removed and placed in the triple-lined cell of the hazardous waste landfill. In addition, over 168,000 bcy of highly contaminated soils from Basin F Exterior have been placed in the hazardous waste landfill, and 73,000 bcy of soils exceeding biota risk thresholds were placed in Basin A. Former Basin F and the former waste pile will be capped with a “Resource Conservation and Recovery Act (RCRA)-equivalent cover” consisting of a concrete biota barrier, 3.5 to 5 ft of soil, and vegetation (Army, 2007).
- ▶ The M1 Pits soil remedy included excavation and solidification/stabilization of approximately 26,000 bcy of contaminated materials exceeding principal threat or human health risk thresholds, with subsequent disposal into the hazardous waste landfill. The Pits were then backfilled with clean borrow soil (Foster Wheeler, 2000, 2002a).

- ▶ The Lime Settling Basin soils were originally slated for excavation and deposition in the hazardous waste landfill. However, because of increased soil volume and concerns about air emissions during excavation and drying, the remedy was changed. A ROD amendment in 2005 called for leaving the contaminated soil in place, with a vertical groundwater barrier surrounding the basin and a RCRA-equivalent cover. Approximately 89,450 bcy of contaminated soils and material were covered in the Lime Settling Basin (Tetra Tech EC, 2007).
- ▶ Groundwater barriers and RCRA-equivalent covers were also implemented at both the Army Complex Trenches and the Shell Section 36 Trenches. Approximately 532,000 bcy of contaminated soils and material were covered in the Army Complex Trenches, and 100,000 bcy of contaminated soils and material were covered in the Shell Section 36 Complex Trenches (Foster Wheeler, 1996).
- ▶ The Army tested thermal destruction of the contamination in the Hex Pits as required by the ROD. The pilot project failed. As a result, approximately 4,200 bcy of contaminated soil and materials were placed in the hazardous waste landfill. The Hex Pit site was then covered along with the rest of the South Plants area (Tetra Tech FW, 2004c).
- ▶ At the Sand Creek Lateral, 15,000 bcy of contaminated sediments were excavated from within 20 ft of its banks and disposed in the hazardous waste landfill. Also, 90,000 bcy of biota exceedence sediment went to Basin A (Foster Wheeler, 1996).

The above descriptions provide examples of some of the soil remediation conducted at the Arsenal. Large volumes of contaminated soils, exceeding both human health and biota risk thresholds, were also remediated from other areas of the Arsenal. The details of those actions are beyond the scope of this report, but the Trustees will take them into consideration when determining residual NRDs.

Deletion from the National Priorities List

All remedial actions required by the On-Post ROD must be completed before areas can be deleted from the NPL. In the past few years, several parcels have been deleted.

In January 2003, 940 acres of land in the western portion of the Arsenal, known as the Western Tier Parcel, were deleted from the NPL in accordance with the Refuge Act (EPA, 2003). A year later, 917 acres of that land were sold to Commerce City. Also in 2004, 5,053 acres of land along the perimeter of the Arsenal were deleted. From this parcel, 4,927 acres were transferred to the USFWS. In addition, 126 acres were transferred to local and state governments for road improvements. Finally, in 2006, 7,399 acres were deleted and transferred to the USFWS to be part of the National Wildlife Refuge (USFWS, 2006). Figure 3.6 shows the most recent map of the Arsenal after the deletions.

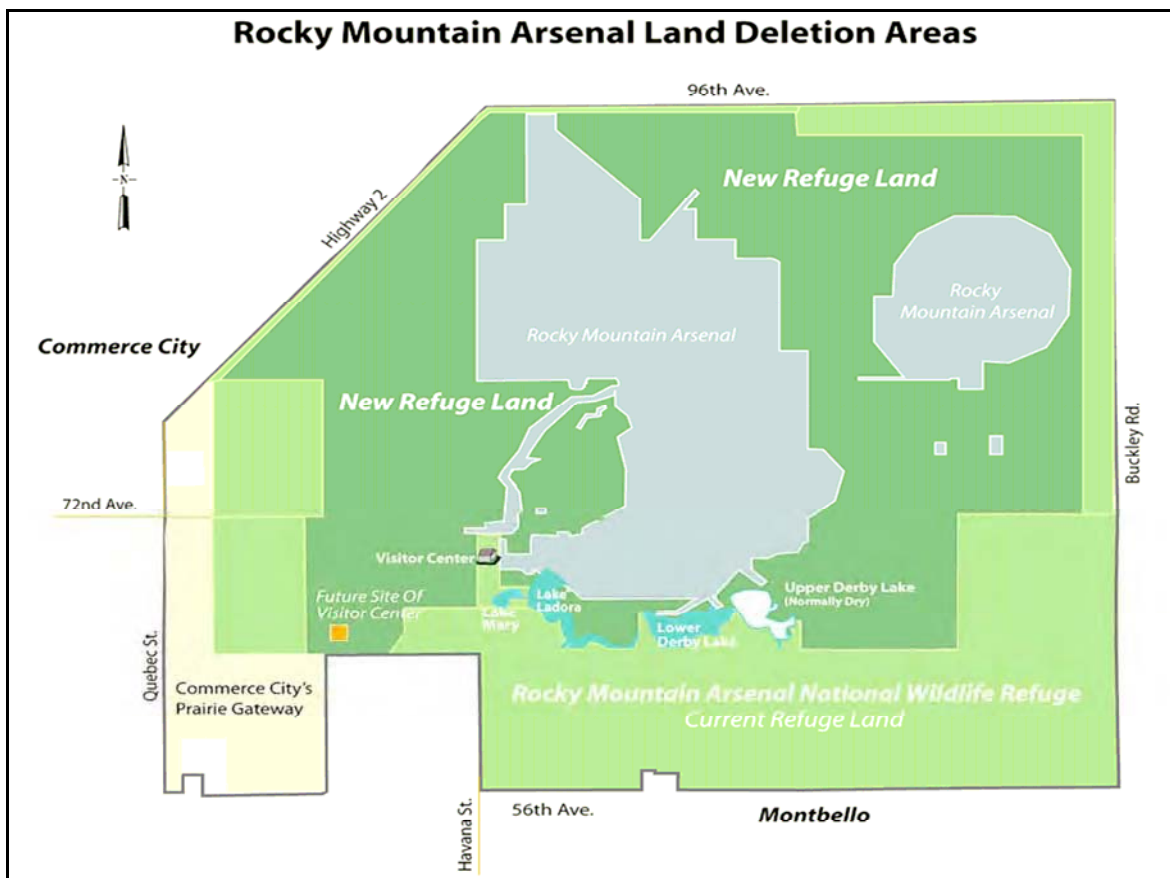


Figure 3.6. Arsenal deletions. The lighter green areas were transferred to USFWS in 2003 and 2004, and the darker green areas in 2006. The Army retains possession of areas in grey, as well as groundwater containment systems and other remedial facilities.

Source: USFWS, 2006.

3.2.3 Anticipated residual contamination following remediation

Soils

The final remedy for the Arsenal did not result in destruction or off-site disposal of contaminated soils. All soils managed as part of the final remedy were either (1) left in place and covered (700 acres), (2) excavated and placed in Basin A and the South Plants Central Processing Area (1.5 million bcy), or (3) disposed of in the on-site hazardous waste landfill (1.7 million bcy) (Foster Wheeler, 1996). Once the remedy is complete these soils will no longer pose a threat to wildlife or individuals visiting or working on the Arsenal because exposure pathways will be eliminated.

Post-remedy soils data do not indicate the presence of widespread areas of surface soil contamination at levels believed to create a risk to human health or biota using the risk thresholds adopted by the Army; however, these concentrations may be compared to different criteria in performing the injury assessment described in Chapter 6.

The highly contaminated soils left under caps and covers continue as sources of contamination to groundwater. These include soils at South Plants, the Army Complex Trenches, the Shell Section 36 Trenches, the Lime Settling Basins, and Basins A and F. The ROD required excavation of contaminated soils only to a depth of 5 ft in the South Plants Central Processing Area and 10 ft in the other South Plants areas and in Former Basin F. Elevated concentrations of volatile and semivolatile organics, pesticides and pesticide-related compounds, organosulfur compounds related to mustard production, arsenic, and mercury have been identified in the South Plants soils at depths greater than 10 ft (Ebasco Services et al., 1994). Many of these chemicals, especially pesticides, are adsorbed onto subsurface soil particles. These chemicals will slowly migrate to underlying groundwater. Although caps and covers at the surface will reduce infiltration of surface precipitation, the deeper soils saturated with liquid chemicals will continue to be a source of hazardous substances to groundwater for hundreds of years.

Groundwater

Because contamination is prevalent in subsurface soils and aquifer materials in the primary source areas at the Arsenal, the major groundwater plumes on the Arsenal property will remain for the foreseeable future. Groundwater treatment systems may reduce the total mass of contamination and the size of some of the chemical plumes, but the plumes will not be entirely eliminated. Some contaminants, particularly dieldrin, are difficult to capture in groundwater because they adsorb to aquifer materials and do not degrade quickly. These plumes in particular are unlikely to diminish significantly despite the ongoing capture and treatment systems on the Arsenal.

Surface water

Most of the contaminants of concern at the Arsenal are hydrophobic (i.e., they sorb to sediments rather than remain dissolved in surface water) and thus are not expected to be dissolved in surface water. Arsenal contaminants were not detected in recent on-post surface water samples from Lake Ladora, Lower Derby, Lake Mary, and First Creek at the North Bog (USGS, 2007).

3.3 Off-Post Actions

3.3.1 Interim response actions

The one off-post IRA was the Off-Post Groundwater Intercept and Treatment Systems (Figure 3.3), where the Army constructed alluvial groundwater intercept systems and a treatment plant north of the Arsenal to mitigate further downgradient migration of contaminated groundwater (Harding Lawson Associates, 1995; Foster Wheeler, 2006).

The types, locations, and configurations of groundwater extraction and recharge facilities were selected in this IRA based on the (1) interpreted location of contaminant plumes; (2) water-table configurations and aquifer parameters; (3) interpretation of paleochannel configuration and lithologies; (4) the location of First Creek and its possible effect on the extraction/recharge system; and (5) access, construction, and logistical considerations. For the First Creek Plume, the groundwater extraction and recharge system consisted of five extraction wells spaced 200 to 500 ft apart, aligned parallel to the plume axis, with one well located off the axis. Six trenches were constructed to recharge treated water. The groundwater extraction and recharge system constructed for the northern plume consisted of 12 extraction wells, placed approximately 200 ft apart and 24 recharge wells, placed approximately 100 ft apart. The extraction wells were placed perpendicular to the direction of groundwater flow. The recharge wells were placed parallel to and approximately 300 ft downgradient of the extraction well (Harding Lawson Associates, 1995).

3.3.2 Selected remedy

The Off-Post ROD was signed in December 1995 (Harding Lawson Associates, 1995).

Soils

Because the Army calculated that the risk from contaminated soils was within EPA's acceptable range (10^{-4} to 10^{-6} excess risk of cancer), it did not evaluate remedial alternatives for off-post soils. Nevertheless, 160 out of the 350 acres previously acquired by Shell were tilled in an effort to dilute surface soil concentrations with uncontaminated subsurface soils. This 160-acre area had the greatest number of detected compounds, and the highest concentrations of Arsenal contaminants in the Off-Post Study Area (Harding Lawson Associates, 1995). At the time of tilling, residents had already been relocated from the area.

Groundwater

The selected alternatives included the continued operation of the Boundary Containment Systems and the Off-Post Intercept and Treatment System, with improvements as necessary to meet Colorado water quality standards and other remediation goals prior to discharge to surface water or reinjection to groundwater. In addition, the Off-Post ROD prescribed long-term groundwater and surface water monitoring, site reviews, and institutional controls to prevent the use of the groundwater as a drinking water supply as long as it failed to meet remediation goals.

In addition, Shell and the Army funded the purchase of water rights and a distribution system for SACWSD to provide domestic water to some residents north of the Arsenal and south of the South Platte River. This action prevented these residents from consuming groundwater that would have put them at risk of adverse health effects from DIMP, a byproduct of Sarin nerve agent prevalent in shallow groundwater north of the Arsenal (Harding Lawson Associates, 1995). Figure 3.7 shows the widespread extent of detectable DIMP in groundwater north of the Arsenal in 1994 (USGS, 1997).

In August 2006, Amber Homes constructed a set of extraction wells within the north plume group, just upgradient of the existing north plume group well field (Chadwick Consulting, 2005). Groundwater extracted from these additional wells is treated at the off-post water treatment plant. This additional extraction and treatment was installed to speed cleanup of the groundwater underlying a large Amber Homes development project that is currently under construction.

3.3.3 Anticipated contaminant levels after remediation

Soils

The total mass of contaminants off-post is unchanged. By tilling the soil, however, the Army may have reduced concentrations in hot spots by mixing the more contaminated soil with less contaminated soil and diluting the concentrations. Adequate data characterizing residual contaminant concentrations on the Shell properties north of the Arsenal are not available.

Groundwater

The off-post groundwater intercept system continues to operate since the groundwater continues to exceed the remediation goals. However, the groundwater immediately upgradient of this system is treated water from the North Boundary Containment System that is reinjected to the aquifer after treatment. Unless contaminated groundwater bypasses the North Boundary Containment System, the off-post plume should continue to contract. It is not known how long the off-post plume will remain. An updated off-post plume map is expected this fall.

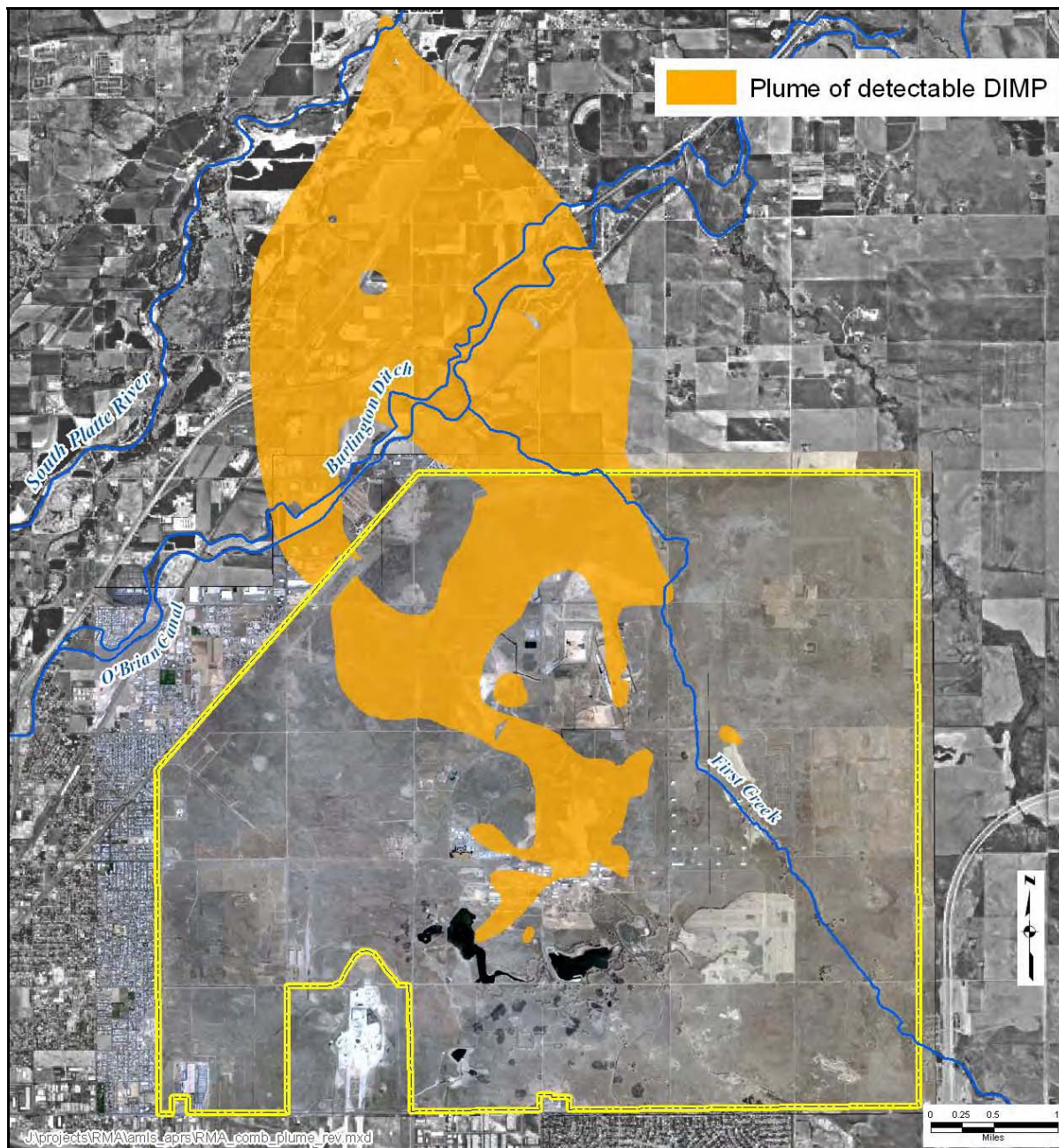


Figure 3.7. Extent of detectable DIMP in shallow groundwater in 1994, according to USGS (1997).

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4. Confirmation of Exposure

DOI regulations require Assessment Plans to confirm that:

at least one of the natural resources identified as potentially injured in the preassessment screen has in fact been exposed to the released substance [43 CFR § 11.37(a)].

A natural resource has been exposed to hazardous substances if “all or part of [it] is, or has been, in physical contact with . . . a hazardous substance, or with media containing the . . . hazardous substance” [43 CFR § 11.14(q)]. The regulations also state that “whenever possible, exposure shall be confirmed using existing data” from previous studies of the assessment area [43 CFR § 11.37(b)(1)].

This chapter first discusses transport pathways, which are the routes or media through which hazardous substances are or were transported from the source of the release to the injured resource [43 CFR § 11.14 (dd)]. At the Arsenal, most of the hazardous substances were deposited on soils or in waste basins. Section 4.2 then confirms that soils, air, sediments, surface and groundwater, as well as aquatic and terrestrial biota and their supporting habitats, have been exposed to hazardous substances. The conclusions in this chapter rely solely on pre-existing data.

4.1 Contaminant Pathways

CERCLA allows Trustees to recover NRDs for injuries that have resulted from releases of hazardous substances. To make the link between release and injury, Trustees examine pathways through which hazardous substances travel. Pathways may be direct, such as a release into surface water causing injury to that water body. Pathways may also be indirect, such as a release to the ground surface that enters the bodies of earthworms, then into small birds that eat the worms, finally causing injury to the eagles that eat the small birds. In the second example, the soils, worms, and small birds are all pathway resources.

Pathways are determined using information about the nature and transport of the hazardous substances, and data documenting the presence of the hazardous substance in the pathway resource. As part of the assessment, the Trustees will use existing data to confirm that resources have been exposed to hazardous substances directly or through contaminant pathways. Specifically, to determine pathways of hazardous substances, the Trustees consider:

- ▶ The chemical and physical characteristics of the released hazardous substance when transported by natural processes or while present in natural media [43 CFR § 11.63(a)(1)(i)]
- ▶ The rate or mechanism of transport by natural processes of the released hazardous substance [43 CFR § 11.63(a)(1)(ii)]
- ▶ Combinations of pathways that, when viewed together, may transport the released hazardous substance to the resource [43 CFR § 11.63(a)(1)(iii)].

The pathway may be determined by either demonstrating the presence of the hazardous substance in sufficient concentrations in the pathway resource or by using a model that demonstrates that the conditions existed in the route and in the hazardous substance such that the route served as the pathway [43 CFR § 11.63(a)(2)]. Data presented in this chapter show sufficient concentrations in pathway resources. Also included is a discussion of a contaminant uptake model that demonstrates how hazardous substances in contaminated soils can injure wildlife resources. Chapter 6 discusses the model in more detail.

Figure 4.1 is a simplified diagram showing pathways by which hazardous substances are transported from hazardous substance sources at the Arsenal to natural resources of the State. In general, hazardous substances were released directly into surface water, sediments, and soil. Plants and invertebrates accumulate the hazardous substances. Biota that ingest these plants and invertebrates accumulate and sometimes “biomagnify” the hazardous substances, such that tissue concentrations (and adverse effects) of the hazardous substances can be greater in higher-level predators. To reach groundwater, hazardous substances in soil, surface water, and sediment either infiltrate the underlying unsaturated zone or are transferred to groundwater via a direct hydrologic connection. The following sections describe these pathways in more detail.

4.1.1 Groundwater pathways

In general, the sources of hazardous substances in groundwater are chemical spills on the ground or disposal into waste trenches, sewers, ditches, lagoons, and basins. Ebasco Services et al. (1989), contractors for the Army, describe the following mechanisms by which contaminants migrate from source areas to groundwater:

- ▶ Direct contact with source areas that are below the water table
- ▶ Percolation from soils downward through the unsaturated zone
- ▶ Hydraulic interchange with contaminated surface water/sediments
- ▶ Downward migration along an improperly constructed well bore.

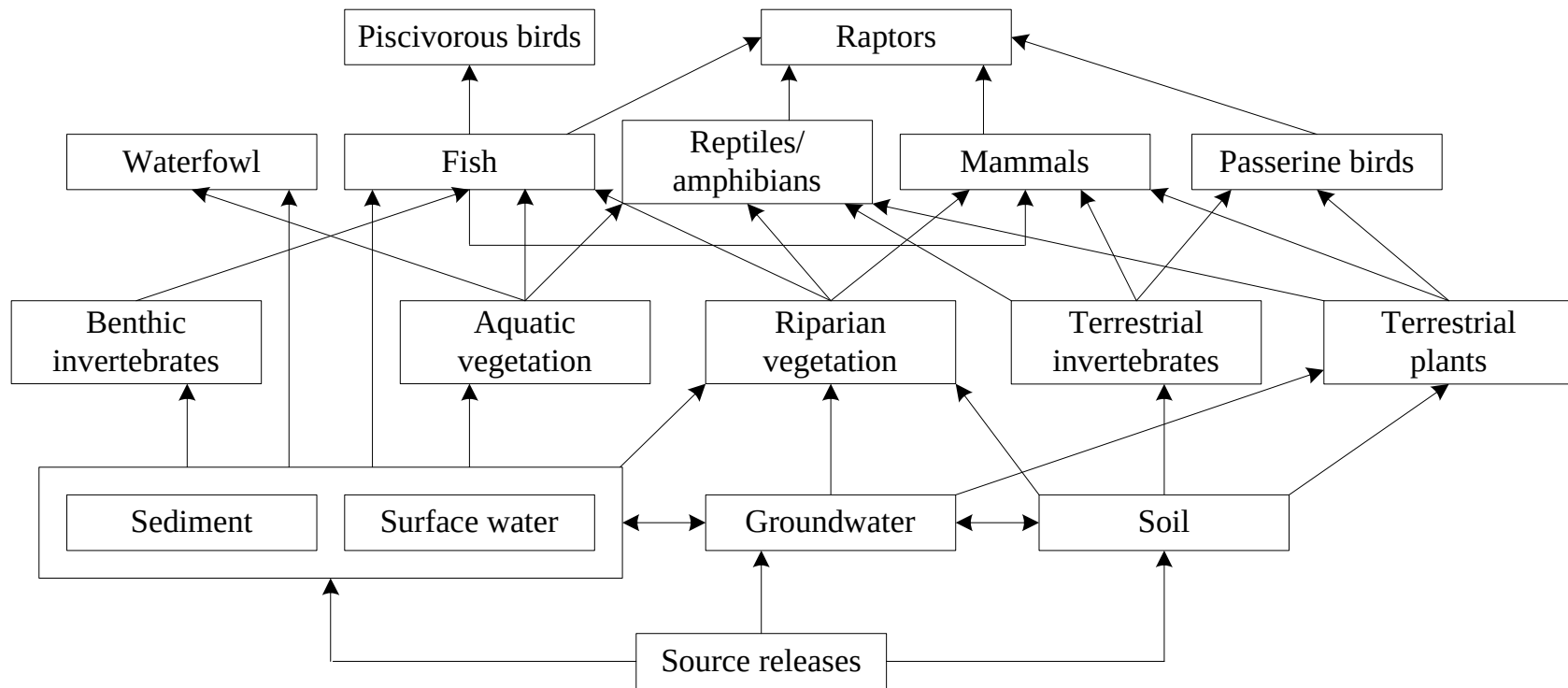


Figure 4.1. Simplified pathways by which hazardous substances are transported from the hazardous substances sources at the Arsenal to natural resources of the State. Pathways to air resources (not shown) include direct releases from source areas and soils.

Stormwater and snowmelt can dissolve contaminants in soils, carrying the contaminants downward through the unsaturated zone to the water table. In addition, large spills of liquid contaminants may percolate through the unsaturated zone and enter the groundwater undiluted. Direct percolation of contaminants may also occur from the waste disposal basins, sewers, and ditches that transported and accumulated industrial wastes at the site (Ebasco Services et al., 1989).

The RI Summary Report (Ebasco Services et al., 1992a) contains the following confirmations of the pathways to groundwater:

- ▶ “There are 14 basin and lagoon sites containing approximately 4.3 million bcy of contaminated material. Basins and lagoons formerly used for liquid waste disposal are among the most contaminated sites at the Arsenal . . . contaminant concentrations in soils at several of these sites exceed levels detected elsewhere at the Arsenal, and groundwater contaminant plumes are observed to originate below these sources. The continuous presence of contaminant occurrences throughout the unsaturated soil column below many of these sites supports the conclusion that the more contaminated basins and lagoons are sources of groundwater contamination” (Ebasco Services et al., 1992a, p. 2-12).
- ▶ “Like the disposal basins, burial trenches contain a wide variety of contaminants, most notably Army agent breakdown products, volatile organic compounds, and metals . . . These trenches have been identified as sources of pesticides, agent breakdown products, and volatile organics in groundwater” (Ebasco Services et al., 1992a, p. 2-14).
- ▶ “Leakage from faulty joints and fractures [of chemical sewers] historically allowed infiltration of wastewater into subsurface soils . . . Several portions of the chemical sewer are characterized by a wide variety of contaminants at moderate to high concentrations . . . [The chemical sewers] are significant because of their potential to contribute large volumes of contaminants to soil and groundwater” (Ebasco Services et al., 1992a, p. 2-19).

Pathways by which contaminants reach deeper aquifers are either through direct contact with the contaminated shallow aquifer, or through improper well construction. The Denver aquifer underlies the shallow aquifer; the upper Denver aquifer includes some weathered sandstone and fractures that have a direct hydraulic connection to the upper alluvium. Chapter 5 discusses the aquifers underlying the Arsenal and the extent of any downward migration of contamination in more detail.

For a period between 1962 and 1966, the Arsenal liquid wastes were directly injected into a well that was over 12,000 ft deep, thousands of feet below all usable deep aquifers underlying the Arsenal. This well was sealed in 1985 (Foster Wheeler, 1996). The direct injection of contaminants into this well served only as a pathway to Precambrian basement rock; these deep contaminants are unlikely to affect any of the usable overlying aquifers.

4.1.2 Surface water/sediment pathways

The banks, beds, and suspended sediments of water bodies are considered part of surface water resources, according to the DOI regulations [43 CFR § 11.14 (pp)].

Hazardous substances were released directly into surface water resources through chemical sewers and ditches, as well as indirectly via groundwater. Some example releases of hazardous substances to surface water resources include:

- ▶ Releases directly from the South Plants Complex to Lower Derby Lake and the Sand Creek Lateral (Ebasco Services et al., 1989)
- ▶ Releases from the North Plants Complex to ditches that could transport the hazardous substances to First Creek during storm events (Ebasco Services et al., 1989)
- ▶ Releases from the Arsenal wastewater treatment plant directly to First Creek (Ebasco Services et al., 1989)
- ▶ Releases from contaminated groundwater to First Creek at the northern boundary of the Arsenal (Harding Lawson Associates, 1992).

Hazardous substances may also have been transported to surface water resources from soils through aerial deposition from wind. Most of the contaminants of concern at the Arsenal are hydrophobic and thus are likely to sorb to sediment rather than remain dissolved in surface water.

4.1.3 Soil pathways

Most of the hazardous substances in soils were released directly onto the soils. Some of the waste disposal basins were under water at the time of contaminant disposal; the contaminated sediment in the basins subsequently became contaminated soil when the basins were dewatered.

4.1.4 Biota pathways

Exposure pathways include direct contact of biota with hazardous substances in air, soil, surface water, and sediments, and exposure through aquatic and terrestrial food web pathways (Figure 4.1). Biota comes in direct contact with hazardous substances through dermal contact, inhalation, and ingestion of contaminated soil, sediment, and surface water (Figure 4.1).

Organochlorine pesticides, including dieldrin and aldrin, are primary hazardous substances of concern at the Arsenal. These contaminants are used as an example to discuss the pathways by which these persistent pesticides affect biota. Many of the other hazardous substances released at the Arsenal follow similar pathways. The Trustees' assessment will include an analysis of these pathways for several of the primary contaminants of concern.

Soils and sediments often contain organic matter in which organochlorine pesticides accumulate. Plant roots, and to a lesser extent plant green tissues, also accumulate pesticides (International Programme on Chemical Safety, 1992). Higher trophic-level organisms, such as earthworms, insects, birds, or mammals, ingest contaminated soils, sediments, or lower-order biota (Figure 4.1). The transfer of contamination from media such as soils to animal tissue is called bioaccumulation.

Wildlife that ingest the bioaccumulated hazardous substances in prey may have higher contaminant tissue concentrations through the process of biomagnification, which is an increase in tissue residue concentration in predators compared to the concentration in prey (Schwarzenbach et al., 2003). Organochlorine pesticides become concentrated in fats and lipid membranes of soil-dwelling earthworms or sediment-dwelling aquatic macroinvertebrates (Beyer and Gish, 1980). These organisms can have very high body burdens of toxic compounds because they have direct contact with contaminated soils and are often insensitive to pesticide toxicity. Consumers of these worms accumulate and biomagnify the pesticides in fat and in fatty tissues such as the brain and liver, with organochlorine pesticide concentrations in these tissues increasing by 3–10 times the ingested concentrations (Klaassen, 2001). As a result, predatory birds and mammals at the top of the food web generally have the highest levels of persistent pesticides in their tissues and thus are the most likely species to be injured by releases of organochlorine pesticides and similar hazardous substances.

4.2 Confirmation of Exposure

Hazardous substances released from the Arsenal include organic contaminants and metals (see Chapter 2). The following sections present data confirming exposure of groundwater, surface water and sediment, geologic resources (soil), biota, and air resources to hazardous substances.

Additional natural resources beyond those discussed in this chapter may also be exposed to hazardous substances released from the Arsenal.

4.2.1 Groundwater

According to DOI regulations, groundwater resources are:

water in a saturated zone or stratum beneath the surface of land or water and the rocks or sediments through which ground water moves. It includes ground water resources that meet the definition of drinking water supplies [43 CFR § 11.14 (t)].

Drinking water supplies are defined as:

any raw or finished water sources that may be used by the public or by one or more individuals [43 CFR § 11.14 (o)].

The Arsenal RI confirms that contaminants released at the Arsenal have migrated into the groundwater. According to the RI Summary Report (Ebasco Services et al., 1992b, p. 2-12), the principal contaminants in groundwater are relatively mobile volatile compounds (volatile halogenated organics, volatile hydrocarbon compounds, and volatile aromatic organics) and less mobile contaminants, including organochlorine pesticides and arsenic.

The RI found exposure of both the alluvial aquifer and the Denver formation aquifer below it. Data evaluated in the Water RI were primarily collected during the third quarter of 1987 from a total of 296 alluvial wells and 176 wells screened in the Denver formation (Ebasco Services et al., 1989). Table 4.1 presents a summary of the results of these samples for selected contaminants. These concentrations are elevated above background conditions as described in the RI Summary Report (Ebasco Services et al., 1992b, Table RISR B.2-1). Chloroform and dieldrin were found in over 100 different alluvial wells. Chloroform was also found in over half of the wells in the unconfined Denver formation (Table 4.1).

Table 4.1. Summary of groundwater data from the Arsenal Water RI

Analyte	Detections	Wells sampled	Range (µg/L)	Median (µg/L)
Alluvium				
Dieldrin	102	262	0.062–3.48	0.245
Endrin	35	262	0.064–1.51	0.321
Oxathiane	37	230	1.66–68.6	6.610
Dithiane	47	232	1.25–498	19.300

Table 4.1. Summary of groundwater data from the Arsenal Water RI (cont.)

Analyte	Detections	Wells sampled	Range (µg/L)	Median (µg/L)
Chlorophenylmethyl sulfide	74	231	0.68–748	5.345
Chlorophenylmethyl sulfoxide	44	230	2.16–148	11.750
Chlorophenylmethyl sulfone	61	231	2.83–1,390	11.000
Benzene	31	296	1.49–25,000	3.250
Chlorobenzene	49	297	0.582–31,200	6.910
Chloroform	109	297	0.54–38,800	16.500
Methylene chloride	6	295	6.63–5,780	13.735
1,1,1-Trichloroethane	24	297	0.8–102	8.935
1,1-Dichloroethane	9	297	1.2–9.74	3.270
1,2-Dichloroethene	26	297	0.636–143	5.635
1,1-Dichloroethene	14	297	2.28–35.6	8.210
Trichloroethene	90	297	0.71–2,840	5.285
Tetrachloroethene	57	297	0.82–926	8.760
DBCP	55	264	0.146–278	0.586
DCPD	25	262	10.7–1,200	152.000
DIMP	102	259	11.9–12,100	203.500
Arsenic	66	257	2.56–315	5.270
Fluoride	179	259	1,000–13,400	2,290
Chloride	260 [sic]	259	25,700–6,230,000	187,000
Denver unconfined				
Dieldrin	13	35	0.103–8.92	0.221
Endrin	8	35	0.115–1.22	0.234
Oxathiane	10	35	1.79–1,950	8.100
Dithiane	9	35	3.16–7,760	34.800
Chlorophenylmethyl sulfide	10	35	3.38–94.3	7.845
Chlorophenylmethyl sulfoxide	7	35	8.97–392	47.300
Chlorophenylmethyl sulfone	9	35	3.28–520	16.500
Benzene	5	35	2.15–16,000	7.470
Chlorobenzene	3	35	1.74–1,170	55.900
Chloroform	19	35	1.99–16,500	24.500
Methylene chloride	3	32	11.7–7,340	58.900
1,1,1-Trichloroethane	0	35		
1,1-Dichloroethane	3	35	1.57–3.77	2.110
1,2-Dichloroethene	8	35	2.62–474	34.100

Table 4.1. Summary of groundwater data from the Arsenal Water RI (cont.)

Analyte	Detections	Wells sampled	Range (µg/L)	Median (µg/L)
1,1-Dichloroethene	2	35	1.70–4.41	3.055
Trichloroethene	11	35	1.2–175	4.380
Tetrachloroethene	13	35	2.31–184	15.500
DBCP	8	35	0.609–5.57	1.335
DCPD	6	35	16.6–256	128.700
DIMP	19	35	11.9–5,230	322.000
Arsenic	8	34	4.59–410	17.685
Fluoride	32	35	1,200–223,000	2,410
Chloride	35	35	5,730–28,200,000	246,000
Denver confined				
Dieldrin	10	140	> 0.05–1.23	0.123
Endrin	4	140	< 0.057–0.162	0.060
Oxathiane	5	140	3.09–49.5	12.800
Dithiane	6	140	1.68–263	56.500
Chlorophenylmethyl sulfide	5	140	1.25–4.09	2.50
Chlorophenylmethyl sulfoxide	0	140		
Chlorophenylmethyl sulfone	3	140	3.16–9.58	3.650
Benzene	27	141	1.63–73.8	4.500
Chlorobenzene	24	141	0.79–74.7	16.050
Chloroform	19	141	1.71–194	8.790
Methylene chloride	1	138	6.76	6.760
1,1,1-Trichloroethane	0	141		
1,1-Dichloroethane	2	141	5.21–8.82	7.015
1,2-Dichloroethene	2	141	0.97–2.61	1.759
1,1-Dichloroethene	0	141		
Trichloroethene	11	141	1.24–8.68	2.550
Tetrachloroethene	3	141	1.54–6.67	3.060
DBCP	5	141	0.191–0.779	0.370
DCPD	0	139		
DIMP	11	136	17.0–5,350	127.000
Arsenic	16	138	2.57–26.7	6.460
Fluoride	80	139	913–7,870	1,675
Chloride	132	139	5,520–7,290,000	57,450

µg/L = micrograms per liter.

Source: Ebasco Services et al., 1989, Table 4.2-5.

4.2.2 Surface water/sediment

According to DOI regulations, surface water resources are defined as:

the waters of the United States, including the sediments suspended in water or lying on the bank, bed, or shoreline and sediments in or transported through coastal and marine areas [43 CFR § 11.14 (pp)].

The Arsenal RI confirmed that surface water, when present, was exposed to hazardous substances. Contamination is primarily introduced during precipitation and runoff events, which were not targeted for sampling (Ebasco Services et al., 1992b). Table 4.2 presents a summary of detected contaminants in samples collected from fall 1985 through fall 1987 (Ebasco Services et al., 1989).

Few analytes were detected in samples entering the Arsenal along the south boundary. Contaminants, including DBCP, aldrin, dieldrin, chloroform, and arsenic, were detected sporadically in samples collected along First Creek, the only continuous surface water drainage through the Arsenal (Ebasco Services et al., 1989, 1992b). Sewage treatment plant effluent discharged to First Creek contained detectable levels of the same contaminants. Very few constituents were detected in RI samples from Lower Derby Lake, Lake Ladora, and Lake Mary. However, historically, organochlorine pesticides, including dieldrin, were detected frequently in the lakes (Ebasco Services et al., 1989). When they contained water, Basin A and a pond near the South Plants Water Tower had elevated levels of organic contaminants, arsenic, and chloride (Table 4.2).

Sediment samples from 36 ditch, lake, and pond sites, including the three major lakes on the Arsenal (Upper and Lower Derby Lakes and Lake Ladora), were collected for the Arsenal RI (Ebasco Services et al., 1992b). These samples confirmed that sediment was exposed to hazardous substances. Table 4.3 presents a summary of selected contaminants in samples from these ditch, lake, and pond sites. Sediments contained elevated concentrations of pesticides, arsenic, and mercury. The highest contaminant concentrations were observed in samples collected from depths of less than 5 ft.

4.2.3 Soils

According to DOI regulations, geologic resources are defined as:

those elements of the Earth's crust such as soils, sediments, rocks, and minerals, including petroleum and natural gas, that are not included in the definitions of ground and surface water resources [43 CFR § 11.14 (s)].

Table 4.2. Summary of surface water data from the Arsenal Water RI

Location description	Sample site	Detections	Number of samples	Analyte	Arithmetic mean (µg/L) ^a	Range (µg/L)
South boundary the Arsenal – water entering the Arsenal						
First Creek at East Boundary entering the Arsenal	08-001	1	10	Aldrin	0.200	< 0.070–0.20
Peoria Interceptor entering the Arsenal	11-001	1	5	Aldrin	0.200	< 0.070–0.200
		1	2	Benzothiazole	12.0 ^b	< 1.70–2.93
		2	5	1,1,1-Trichloroethene	2.430	–
Havana Interceptor entering the Arsenal	11-002	1	2	Arsenic	2.56	–
Havana Pond outlet	11-003	1	1	Benzothiazole	2.06	–
South Boundary ditch – surface drainage entering the Arsenal	12-004	1	1	Arsenic	3.79	–
First Creek						
First Creek at 6th Avenue	05-001	1	2	Arsenic	3.79	–
Sewage Treatment Plant effluent to First Creek	24-001	1	5	DBCP	0.15	< 0.13–0.15
		5	5	Aldrin	0.853	0.080–2.98
		4	5	Dieldrin	0.332	< 0.060–0.936
		2	5	Chloroform	8.1	< 1.40–11.4
		2	2	Arsenic	33.7	–
First Creek at North boundary exiting the Arsenal	24-002	1	6	Aldrin	0.200	< 0.070–0.200
Ponds and lakes						
Lake Ladora and Lake Mary overflows	02-004	1	4	Chloroform	18.1	< 1.40–18.1
		1	1	Arsenic	10.5	–

Table 4.2. Summary of surface water data from the Arsenal Water RI (cont.)

Location description	Sample site	Detections	Number of samples	Analyte	Arithmetic mean (µg/L) ^a	Range (µg/L)
Other locations						
Pond south of South Plants Water Tower	01-002	2	4	DBCP	0.708	< 0.130–1.08
		1	4	Aldrin	0.530	< 0.083–0.530
		3	4	Dieldrin	0.571	< 0.055–0.913
		1	1	Benzothiazole	18.4	
		4	4	Chlorophenylmethyl sulfone	198.7	85.8–298
		3	4	Chlorophenylmethyl sulfoxide	89	< 4.20–204
		2	4	Chlorophenylmethyl sulfide	27.5	< 1.30–52.9
		2	4	Toluene	4.94	< 1.21–8.37
		1	4	Benzene	1.98	< 1.34–1.98
		1	1	Arsenic	11.5	–
Basin A – South Plants surface water/groundwater discharges	36-001	4	5	DBCP	3.8	> 2.2–140
		4	5	DCPD	32.8	< 9.31–70.2
		5	5	Methylisobutyl ketone	1,048	> 104–2,800
		2	4	Hexachlorocyclopentadiene	1.85	< 1.40–2.45
		2	5	Aldrin	2.03	< 0.700–3.07
		4	5	Dieldrin	6.7	3.75–> 20.8
		3	5	Endrin	2.70	< 1.04–5.16
		1	5	DIMP	32.0	< 10.5–32.0
		1	5	Dimethylmethyl phosphonate	17.3	< 15.2–17.3
		5	5	Chlorophenylmethyl sulfone	1,389	> 110–1,870
		5	5	Chlorophenylmethyl sulfoxide	58.3	26.0–87.1
		1	5	1,4-Dithiane	1.46 ^b	< 1.10–< 1.59
		4	5	Toluene	25	< 12.1–41.2
		5	5	Benzene	53.8	1.72–176

Table 4.2. Summary of surface water data from the Arsenal Water RI (cont.)

Location description	Sample site	Detections	Number of samples	Analyte	Arithmetic mean (µg/L) ^a	Range (µg/L)
Basin A – South Plants surface water/groundwater discharges (cont.)		4	5	Ethylbenzene	54.0	< 1.28–102
		5	5	o- and p-xylenes	214	18.1–286
		5	5	Chloroform	432	188–641
		5	5	Chlorobenzene	1101	15.8–1,700
		1	5	Methylchloride	7.85	< 5.00–7.85
		5	5	Tetrachloroethylene	83.0	43.1–130
		4	5	Trans 1,2-Dichloroethene	4.38	< 1.10–5.70
		3	5	1,1,1-Trichloroethane	2.87	< 1.70–3.25
		4	5	1,1,2-Trichloroethane	4.01	< 1.00–5.93
		4	5	Trans 1,2-Dichloroethene	8.93	1.20–12.2
		5	5	Trichloroethene	45.5	19.7–62.0
Basin A central pool	36-003	1	2	Aldrin	4.98	4.98–< 8.30
		2	2	Dieldrin	45.6	43.3–47.9
		1	2	DIMP	27.6	< 10.5–27.6
		2	2	Chlorophenylmethyl sulfone	172	125–208
		1	2	1,4-Dithiane	3.57	< 1.10–3.57
		1	2	Chloroform	2.14	< 1.40–2.14
		1	2	Chlorobenzene	3.82	< 0.580–382
		1	2	1,1,2-Trichloroethane	7.85 ^b	< 1.00–6.85
		1	2	1,2-Dichloroethane	6.14	< 0.610–6.14
		1	1	Arsenic	1,240	–
		1	1	Chloride	252,000	–

Note: Organic contaminants from samples collected fall 1985 to fall 1987; arsenic and chloride from samples collected in spring of 1987.

a. Arithmetic means are based solely on values above the certified reporting limit (CRL).

b. As reported in source. Mean outside of range.

Source: Ebasco Services et al., 1989, Table 4.1-3.

**Table 4.3. Summary of ditch, lake, and pond sediment samples from the Arsenal
Summary RI**

Analyte	Detected	Samples	Detected concentration range (µg/g)	Median of detected samples (µg/g)
Volatile halogenated organics				
Methylene chloride	16	321	0.64–170	1.7
Tetrachloroethene	6	327	0.30–1.0	0.40
Volatile aromatic organics				
Toluene	4	322	0.30–4.0	0.70
Organophosphorous compounds – GB-agent related				
DIMP	23	687	0.19–5.0	3.2
DBCP	31	1,236	0.0068–0.65	0.036
Organochlorine pesticides				
Aldrin	164	1,041	0.0022–1,100	0.14
Chlordane	48	995	0.026–800	0.13
DDE	95	1,041	0.0012–6.6	0.014
DDT	67	1,041	0.0025–10.0	0.041
Dieldrin	263	1,041	0.0015–3,000	0.19
Endrin	96	1,041	0.0020–20	0.040
Isodrin	68	1,041	0.0013–500	0.024
Arsenic	139	601	2.5–190	7.5
Mercury	187	833	0.052–18	0.16

µg/g = micrograms per gram.

Source: Ebasco Services et al., 1992b, Table RISR A3.1-2.

The Arsenal RI identified 178 sites of soil contamination on the Arsenal (Ebasco Services et al., 1992b, p. A3-4). Contaminated soils were found in source areas, including basins and lagoons; ditches, lakes, ponds, and pits (discussed in Section 4.2.2); ordnance testing and disposal areas; solid waste burial sites; building, equipment, and storage sites; spill sites; sewer sites; surficial soils; and other isolated areas. Contamination was also found in soils collected from nonsource areas.

Soils collected from 14 disposal basins and lagoons¹ had the highest rate of detection and the greatest number of detected analytes (Table 4.4). Soils from waste trenches, buildings, equipment and storage sites, spill sites, and sewer sites also contained a wide range of analytes [not presented; see Ebasco Services et al. (1992b) for summary]. Soils collected from 12 ordnance-testing sites used for testing, burning, or disposal of incendiary devices and munitions were associated with elevated metals concentrations, but few organic contaminants (Table 4.5). Soils from 18 solid waste burial sites, which received contaminated solid and liquid waste materials, contained a wide range of contaminants at relatively high concentrations (Table 4.6). Contamination in surficial soils is characterized by widespread, low levels of contamination indicative of windblown transport of contaminants from poorly vegetated soils, such as the dewatered basins.

Table 4.4. Summary of soil samples from basin and lagoon sites. Selected analytes only.

Analyte	Detected	Samples	Detected concentration range (µg/g)	Median of detected samples (µg/g)
Volatile halogenated organics				
Chlorobenzene	9	508	0.34–5.0	1.7
Chloroform	22	538	0.12–70	1.8
Methylene chloride	58	422	0.27–6.7	1.0
Tetrachloroethene	19	537	0.20–40	2.8
Trichloroethene	4	538	0.14–1.0	0.51
Volatile hydrocarbons				
2,2-Oxybisethanol	36	36	0.6–8	2
2-Pentanone	9	9	1–20	10
Bicycloheptadiene	16	541	0.95–5,100	9.7
DCPD	58	1,079	0.35–22,000	24
Volatile aromatic organics				
Benzene	17	552	0.24–6.0	1.2
Ethylbenzene	11	552	0.14–9.3	1.6
m-Xylene	15	552	0.14–12	1.0
o- and p-Xylene	9	553	0.15–12	2.0
Toluene	18	550	0.13–1,000	0.95

1. These included Basins A, B, C, D, E, and F, and other smaller basins and lagoons.

Table 4.4. Summary of soil samples from basin and lagoon sites (cont.).
Selected analytes only.

Analyte	Detected	Samples	Detected concentration range (µg/g)	Median of detected samples (µg/g)
Organosulfur compounds – mustard-agent related				
Chloroacetic acid	23	242	43–7,900	140
Dithiane	8	1,065	0.47–370	0.70
Thiodiglycol	11	242	6.0–120	25
Organosulfur compounds – herbicide related				
Chlorophenylmethyl sulfide	18	1,070	0.50–700	5.4
Chlorophenylmethyl sulfone	83	1,070	0.34–300	2.5
Chlorophenylmethyl sulfoxide	25	1,067	0.58–70	2.6
Dimethyldisulfide	3	760	2.0–70	10
Organophosphorous compounds – GB-agent related				
DIMP	119	968	0.12–10	1.3
Dimethylmethyl phosphonate	9	767	3.0–70	6.0
Isopropylmethyl phosphonic acid	34	234	4.6–3,700	39
Methylphosphonic acid	24	122	3.1–400	16
Phosphoric acid, triphenyl ester	33	33	1–20	10
DBCP	14	1,099	0.0061–20	0.019
Fluoroacetic acid	25	124	3.4–200	8.5
Polynuclear aromatic hydrocarbons (PAHs)				
Fluoranthene	4	4	4–8	5
Pyrene	3	3	1–100	4
Semivolatile halogenated organics				
Hexachlorocyclopentadiene	24	1,121	0.0040–2,600	0.018
Organochlorine pesticides				
Aldrin	169	1,249	0.0024–18,000	2.0
Chlordane	56	1,125	0.072–660	0.44
DDE	79	1,256	0.0014–28	0.038
DDT	56	1,251	0.0028–60	0.030
Dieldrin	401	1,247	0.0014–2,100	0.60
Endrin	217	1,246	0.0011–1,100	0.085
Isodrin	108	1,251	0.0014–11,000	1.5

Table 4.4. Summary of soil samples from basin and lagoon sites (cont.).
Selected analytes only.

Analyte	Detected	Samples	Detected concentration range (µg/g)	Median of detected samples (µg/g)
Arsenic	531	1,253	2.4–110,000	12
Mercury	313	1,099	0.050–35,000	0.27
Metals				
Cadmium	163	1,047	0.63–3,900	1.3
Chromium	768	1,047	6.9–110	14
Copper	919	1,047	4.8–2,300	12
Lead	305	1,039	10–1,100	25
Zinc	969	1,047	11–910	44

Source: Ebasco Services et al., 1992b, Table RISR A3.1-1.

Table 4.5. Summary of soil samples from ordnance testing sites. Selected analytes only.

Analyte	Detected	Samples	Detected concentration range (µg/g)	Median of detected samples (µg/g)
Volatile hydrocarbons				
2,2-Oxybisethanol	12	12	0.6–2	0.9
Volatile aromatic organics				
Benzene	4	74	0.31–0.47	0.35
PAHs				
Methyl naphthalene	4	4	0.5–1	0.6
Organochlorine pesticides				
Dieldrin	3	315	0.0029–2.8	0.35
Arsenic	56	303	2.8–32	5.8
Mercury	43	310	0.061–0.32	0.084
Metals				
Cadmium	35	313	0.63–59	2.5
Chromium	261	313	7.8–56	17
Copper	306	314	5.0–340	17
Lead	89	313	11–3,400	28
Zinc	295	313	15–57,000	59

Source: Ebasco Services et al., 1992b, Table RISR A3.1-3.

Table 4.6. Summary of soil samples from solid waste disposal sites. Selected analytes only.

Analyte	Detected	Samples	Detected concentration range (µg/g)	Median of detected samples (µg/g)
Volatile halogenated organics				
1,1,1-Trichloroethane	8	510	0.50–3.0	0.79
Carbon tetrachloride	5	510	1.0–8.7	1.0
Chloroform	20	510	0.15–8.8	1.1
Methylene chloride	55	496	0.17–760	0.80
Tetrachloroethene	29	510	0.19–120	1.0
Trichloroethene	11	510	0.11–25	1.0
Volatile hydrocarbons				
Bicycloheptadiene	6	450	0.91–56	5.9
DCPD	15	1,196	1.0–450	37
Methylcyclohexane	4	4	5–100	40
Methylisobutyl ketone	3	459	8.8–20	14
Volatile aromatic organics				
Benzene	25	437	0.12–26	0.74
Ethylbenzene	11	437	0.43–9.9	0.98
m-Xylene	14	437	0.18–13	2.2
o- and p-Xylene	13	437	0.16–14	3.2
Toluene	24	437	0.12–370	3.9
Organosulfur compounds – mustard-agent related				
Dithiane	9	898	0.46–12	3.20
Organosulfur compounds – herbicide related				
Benzothiazole	3	125	1.9–130	60
Chlorophenylmethyl sulfide	10	899	0.50–100	2.7
Chlorophenylmethyl sulfone	8	899	0.68–20	1.3
Chlorophenylmethyl sulfoxide	6	899	1.0–4.2	3.6
Dimethyldisulfide	8	501	0.39–100	13
Organophosphorous compounds – GB-agent related				
DIMP	38	889	0.16–36	1.7
Dimethylmethyl phosphonate	5	569	0.19–0.65	0.2
Isopropylmethyl phosphonic acid	3	61	3.7–17	8.3
Methylphosphonic acid	5	61	2.8–220	3.9
DBCP	51	1,344	0.0076–670	0.15
Fluoroacetic acid	14	58	2.7–27	7.5

Table 4.6. Summary of soil samples from solid waste disposal sites (cont.).
Selected analytes only.

Analyte	Detected	Samples	Detected concentration range (µg/g)	Median of detected samples (µg/g)
PAHs				
Pyrene	4	4	0.7–10	2
Semivolatile halogenated organics				
Hexachlorocyclopentadiene	33	871	0.0037–53,000	1.1
Organochlorine pesticides				
Aldrin	109	978	0.0033–670	1.0
Chlordane	46	861	0.18–100	2.0
DDE	32	979	0.0026–1.9	0.015
DDT	29	979	0.0033–26	0.022
Dieldrin	212	978	0.0021–360	0.83
Endrin	98	968	0.0018–370	0.38
Isodrin	62	979	0.0026–870	0.11
Arsenic	184	823	2.0–1,200	7.2
Mercury	219	980	0.053–40	0.17
Metals				
Cadmium	75	830	0.64–1,100	1.6
Chromium	590	829	5.9–4,900	13
Copper	699	829	4.8–27,000	11
Lead	224	829	10–7,100	20
Zinc	798	829	11–12,000	41

Source: Ebasco Services et al., 1992b, Table RISR A3.1-4.

4.2.4 Biota

According to DOI regulations, biological resources (biota) are defined as:

those natural resources referred to in section 101(16) of CERCLA as fish and wildlife and other biota. Fish and wildlife include marine and freshwater aquatic and terrestrial species; game, nongame, and commercial species; and threatened, endangered, and State sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms not listed in this definition [43 CFR § 11.14 (f)].

The Arsenal RI confirmed that the contaminants released at the Arsenal followed the pathways described in Section 4.1.4 from sources to predators at the top of the food web. Samples were taken from key terrestrial and aquatic species collected from contaminated sites at the Arsenal and at on- and off-post control areas. Biota were grouped into trophic level categories to develop an analysis of biomagnification of contaminants. Terrestrial trophic levels and representative species were:

- ▶ **Primary producers:** morning glory, sunflower
- ▶ **Herbivores:** grasshopper, black-tailed prairie dog, cottontail, mule deer, mourning dove
- ▶ **Omnivores:** ring-necked pheasant, mallard, blue-winged teal, redhead, American coot
- ▶ **Carnivores:** American kestrel, red-tailed hawk, ferruginous hawk, golden eagle, great horned owl, coyote, badger
- ▶ **Detritivores:** earthworms.

Aquatic trophic levels and representative species were:

- ▶ **Primary producers:** aquatic macrophytes (plants)
- ▶ **Primary consumers:** plankton
- ▶ **Omnivores:** black bullhead
- ▶ **Primary carnivores:** bluegill
- ▶ **Top carnivores:** northern pike, largemouth bass.

The RI Summary Report (Ebasco Services et al., 1992b) found elevated concentrations of organochlorine pesticides in terrestrial primary producers (plants) and in wildlife tissue samples compared to plants and wildlife in control sites. Elevated concentrations generally correlated with locations of higher concentrations of organochlorine pesticides in the Arsenal soils. In addition, a pattern of increasing dieldrin biomagnification up the food web was evident. Table 4.7 presents a summary of contaminant concentrations in terrestrial trophic levels. Regarding terrestrial biota, Ebasco Services et al. (1992b) concluded the following:

- ▶ Dieldrin was detected in all trophic levels, with higher concentrations in higher trophic-level organisms due to biomagnification
- ▶ Aldrin was detected in herbivores
- ▶ Endrin was detected in terrestrial herbivores and omnivores
- ▶ DDE was detected in terrestrial omnivores and carnivores
- ▶ Arsenic was detected most frequently in detritivores and primary producers
- ▶ Mercury showed some tendency to bioaccumulate and was most often detected in omnivores.

**Table 4.7. Summary of terrestrial biota samples from the Arsenal
Summary RI**

Analyte	Trophic level	Detections	Samples	Minimum (µg/g) ^a	Maximum (µg/g)	Mean ^b
Dieldrin	Producers	2	19	< 0.044	0.08	0.028
	Herbivores	39	94	< 0.031	56.3	1.2
	Omnivores	55	78	< 0.031	5.38	0.55
	Carnivores	43	73	< 0.031	27.7	2.3
	Detritivores	2	8	< 0.031	5.3	0.92
Aldrin	Herbivores	6	94	< 0.02	5.8	0.1
Endrin	Producers	1	20	< 0.04	0.19	0.029
	Herbivores	5	94	< 0.04	3.74	0.12
	Omnivores	2	73	< 0.04	0.14	0.022
	Detritivores	1	9	< 0.04	0.91	0.12
DDE	Omnivores	10	71	< 0.094	0.92	0.09
	Carnivores	10	72	< 0.094	5.5	0.59
Arsenic	Producers	5	20	< 0.025	4.5	0.46
	Herbivores	7	94	< 0.025	6.6	0.31
	Omnivores	3	59	< 0.025	1.82	0.17
	Detritivores	8	9	< 0.025	1.53	0.93
Mercury	Herbivores	5	94	< 0.05	0.36	0.034
	Omnivores	34	72	< 0.05	1.77	0.25
	Carnivores	16	78	< 0.05	0.405	0.058
	Detritivores	2	9	< 0.05	0.25	0.072

a. Minimum presented as CRL.

b. Mean calculated using one-half the CRL where analyte not detected. Therefore, in some cases where there are many non-detects, the mean will be lower than the minimum.

Source: Ebasco Services et al., 1992b, Table RISR A3.5-1.

Unlike terrestrial biota, a pattern of biomagnification was not generally observed in aquatic biota from the Arsenal lakes. Table 4.8 presents a summary of contaminant concentrations in aquatic trophic levels. Regarding aquatic biota, Ebasco Services et al. (1992b) concluded the following:

- ▶ Dieldrin was detected in omnivores, primary carnivores, and top carnivores.
- ▶ Aldrin and DDE were detected in top carnivores, in about 20–30% of samples.² DDE concentrations were higher than aldrin concentrations.
- ▶ Arsenic was detected in primary producers.³
- ▶ Mercury was detected in primary carnivores and top carnivores.

Table 4.8. Summary of aquatic biota samples from the Arsenal Summary RI

Analyte	Trophic level	Detections	Samples	Minimum (µg/g) ^a	Maximum (µg/g)	Mean ^b
Dieldrin	Omnivores	3	3	0.0851	0.209	0.14
	Top carnivores	16	21	< 0.031	0.161	0.082
	Primary carnivores	15	27	< 0.031	0.86	0.15
Aldrin	Top carnivores	5	27	< 0.020	0.0527	0.015
DDE	Omnivores	1	3	< 0.094	0.098	0.064
	Top carnivores	9	27	< 0.094	0.839	0.2
Arsenic	Primary consumers	1	9	< 0.025	0.432	0.16
	Producers	2	6	< 0.025	0.782	0.29
Mercury	Omnivores	1	3	< 0.050	0.0516	0.034
	Primary carnivores	11	21	< 0.050	0.137	0.058
	Top carnivores	23	27	< 0.050	0.550	0.22

a. Minimum presented as CRL.

b. Mean calculated using one-half the CRL where analyte not detected. Therefore, in some cases where there are many non-detects, the mean will be lower than the minimum.

Source: Ebasco Services et al., 1992b, Table RISR A3.5-2.

DDT and endrin were not detected in any off-post samples. Arsenic, mercury, and dieldrin were detected more frequently and in significantly higher concentrations in on-post specimens than in off-post specimens. DDE was detected more frequently in off-post samples.

2. DDE was also detected in one omnivore sample.

3. Arsenic was also detected in one primary consumer sample.

4.2.5 Air

According to DOI regulations, air resources are defined as:

those naturally occurring constituents of the atmosphere, including those gasses essential for human, plant, and animal life [43 CFR § 11.14 (b)].

Monitoring data from 1988, the year of the Basin F IRA, indicate that air at the Arsenal has been exposed to hazardous substances and other contaminants (R.L. Stollar & Associates, 1990).

The annual mean concentrations of total suspended particulates (TSP) at 12 air monitoring stations throughout the Arsenal ranged from 40 to 97 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) (R.L. Stollar & Associates, 1990, p. 53). R.L. Stollar & Associates (1990, p. 53) reported that the secondary 24-hour ambient air quality standard for TSP of $150 \mu\text{g}/\text{m}^3$ was violated 9 times and the primary standard of $260 \mu\text{g}/\text{m}^3$ was exceeded twice. Elevated TSP concentrations were most likely influenced by remedial cleanup activity at Basin F because the monitoring stations with the highest TSP levels were immediately adjacent to or downwind of Basin F operations. A peak value of $591 \mu\text{g}/\text{m}^3$ TSP was measured in the vicinity of Basin F during remediation (R.L. Stollar & Associates, 1990, p. 57). R.L. Stollar & Associates (1990) concluded that disturbances at Basin F, the Borrow Pit, and Basin A, and general TSP from the Denver metropolitan area, were contributing sources.

Metals above background conditions were also detected in air samples collected during remedial activities in 1988 (Table 4.9). Copper and zinc concentrations decreased with distance from Basin F. The highest arsenic concentrations were measured at a location between the South Plants and Basin A, suggesting that Basin A may have been a source of arsenic emissions. The highest average lead values were observed at sites along the western boundary of the Arsenal, and may be associated with Denver traffic activity. The highest cadmium concentrations were observed along the southern boundary of the Arsenal, and may either be associated with Basin A and the South Plants or various industrial activities to the south of the Arsenal (R.L. Stollar & Associates, 1990).

Monitoring in 1988 also identified volatile organic compounds (VOCs) in air samples (R.L. Stollar & Associates, 1990) (Table 4.9). Remedial activities at Basin F appeared to release bicycloheptadiene, methylene chloride, dimethyl disulfide, benzene, ethylbenzene, and toluene to air. Concentrations of these VOCs were highest in the vicinity of Basin F and decreased with distance. Chloroform was frequently identified in air samples collected from near the South Plants. The Denver urban area may also contribute to many of the VOCs identified in air samples at the Arsenal.

Table 4.9. Maximum detected concentrations in air samples collected at the Arsenal in 1988 (mg/m³)

Analyte	Maximum long-term average	Maximum 24-hour
Metals		
Arsenic	0.0014	0.0041
Cadmium	0.0015	0.0253
Chromium	0.0175	0.2083
Copper	0.1158	0.5671
Lead	0.0270	0.0576
Zinc	0.0745	0.5054
VOCs		
1,1-Dichloroethane	0.139	0.271
1,2-Dichloroethane	0.135	0.358
Bicycloheptadiene	7.153	25.430
Benzene	10.532	44.293
Carbon tetrachloride	0.858	2.609
Methylene chloride	25.201	185.140
Chloroform	6.010	14.520
Chlorobenzene	0.472	2.527
DBCP	2.902	17.039
DCPD	5.392	29.38
Dimethyl disulfide	12.173	159.3
Ethylbenzene	2.394	13.041
Toluene	25.422	91.379
Methyl isobutyl ketone	0.099	0.326
Dimethylbenzene	0.349	0.755
Tetrachloroethene	5.607	23.500
Trichloroethene	0.497	5.500
Xylene	9.604	50.62
Semivolatile organic compounds (SVOCs)		
Aldrin	0.378	2.829
Chlordane	0.004	0.004
Dieldrin	0.397	2.296
Endrin	0.138	0.902
Isodrin	0.112	0.861
p,p-DDE	0.039	0.039
p,p-DDT	0.035	0.058
Parathion	0.131	0.210

mg/m³ = milligrams per cubic meter.

Source: R.L. Stollar & Associates, 1990, Tables 4.2-15, 4.2-23, and 4.2-34.

SVOCs, including pesticides such as aldrin, endrin, and dieldrin, were also detected in air samples during monitoring at the Arsenal in 1988. The highest levels of pesticides were clustered around Basin F. Pesticide concentrations at locations more distant from Basin F were negligible.

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5. Injury to Groundwater Resources

Chapter 2 described sources of hazardous substances to groundwater; Chapter 3 described some of the remedial actions that have taken place to address groundwater contamination; and Chapter 4 confirmed that groundwater and the pathways to groundwater have been exposed to hazardous substances. This chapter addresses groundwater injury at the Arsenal.

Following a summary of conclusions, Section 5.1 describes the groundwater resources and discusses relevant Denver Basin statutes and regulations related to groundwater use in the Arsenal area. Section 5.2 provides a preliminary determination of groundwater injury, and Section 5.3 provides an example of how the injury would be quantified. Section 5.4 discusses potential lost use of the injured groundwater, and Section 5.5 discusses additional groundwater data analyses that the State anticipates conducting as part of the assessment. References cited in the text are listed at the end of the chapter.

Summary of conclusions

Available data on groundwater contamination indicate that groundwater resources have been injured by releases of hazardous substances from the Arsenal. In 1994, the year for which the most extensive data are available, an estimated 12,800 acre-feet of groundwater contained hazardous substances at concentrations exceeding injury thresholds. An additional volume of groundwater has been rendered unusable because of its proximity to the hazardous substance plume. Calculation of the appropriate size of the buffer surrounding the contaminant plume will be undertaken as part of the injury assessment, but based upon preliminary calculations, this buffer zone could nearly double the volume of water that is unavailable for use.

Institutional controls imposed by the Federal Facilities Agreement because of hazardous substance releases have precluded the use of approximately 52,550 acre-feet of alluvial groundwater as well as 1.89 million acre-feet of deep confined groundwater as a source of drinking water.

If shallow alluvial groundwater at the Arsenal were uncontaminated and available for municipal use, the likely annual yield would be at least equivalent to the calculated annual recharge of the aquifer. Calculation of the annual recharge at the Arsenal will be performed as part of the assessment. Based on estimates of water usage and readily available data, the Trustees calculated an example annual recharge of approximately 6,560 acre-feet over the entire Arsenal. This estimate is generally consistent with the volume of contaminated water captured at boundary systems annually, including approximately 3,200 acre-feet in 1997 and an average of 2,850 acre-feet between 1998 and 2001.

5.1 Description of Groundwater Resources

Groundwater is defined in the DOI's NRDA regulations as water in a saturated zone or stratum beneath the surface of land or water, as well as the rocks or sediments through which groundwater moves [43 CFR § 11.14(t)]. Colorado statutes define groundwater as any water not visible on the surface of the ground under natural conditions [CRS 37-90-103(19)].

There are two distinct groundwater resources in the Arsenal assessment area: shallow, unconfined groundwater in alluvium, and deeper, confined bedrock groundwater in the Denver, Arapahoe, and Laramie-Fox Hills Formations. The cross-section in Figure 5.1 illustrates the location of these deep aquifers. Colorado water law classifies the groundwater in the two systems as *tributary*, *nontributary*, and *not-nontributary* water. The shallow, unconfined aquifer is tributary water. The deeper, confined bedrock aquifers are nontributary water in some locations and not-nontributary water in other locations. The three water categories are described in Section 5.1.1. The shallow and deep aquifers are described in Sections 5.1.2 and 5.1.3, respectively.

5.1.1 Tributary, nontributary, and not-nontributary water

Tributary, nontributary, and not-nontributary are specifically defined in Colorado water law. Tributary groundwater is water that is hydrologically connected to a natural stream and thus is administered in conjunction with waters of a natural stream pursuant to the constitutional doctrine of prior appropriation. All groundwaters of the State are presumed to be tributary unless proven otherwise [*Ready Mix Concrete Co. v. Farmers Reservoir and Irrigation Co.*, 115 P.3d 638, 643 (Colo. 2005)].

Nontributary groundwater is “groundwater, located outside the boundaries of any designated ground water basins . . . the withdrawal of which will not, within one hundred years, deplete the flow of a natural stream . . . at an annual rate greater than one-tenth of one percent of the annual rate of withdrawal” [CRS § 37-90-103(10.5)]. Nontributary groundwater is exempt from the doctrine of prior appropriation [CRS § 37-90-102(2); CRS § 37-92-305(11)]. A landowner has the right to use 1% of the estimated volume of nontributary groundwater beneath his land each year.

Some confined groundwater in the Denver Basin is “not-nontributary,” defined as “ground water located within those portions of the Dawson, Denver, Arapahoe, and Laramie-Fox Hill aquifers that are outside the boundaries of any designated groundwater basin . . . the withdrawal of which will, within one hundred years, deplete the flow of a natural stream . . . at an annual rate of greater than one tenth of one percent of the annual rate of withdrawal” [CRS § 37-90-103(10.7)]. Regulatory requirements applying to each of these groundwater classifications are described in Section 5.4.

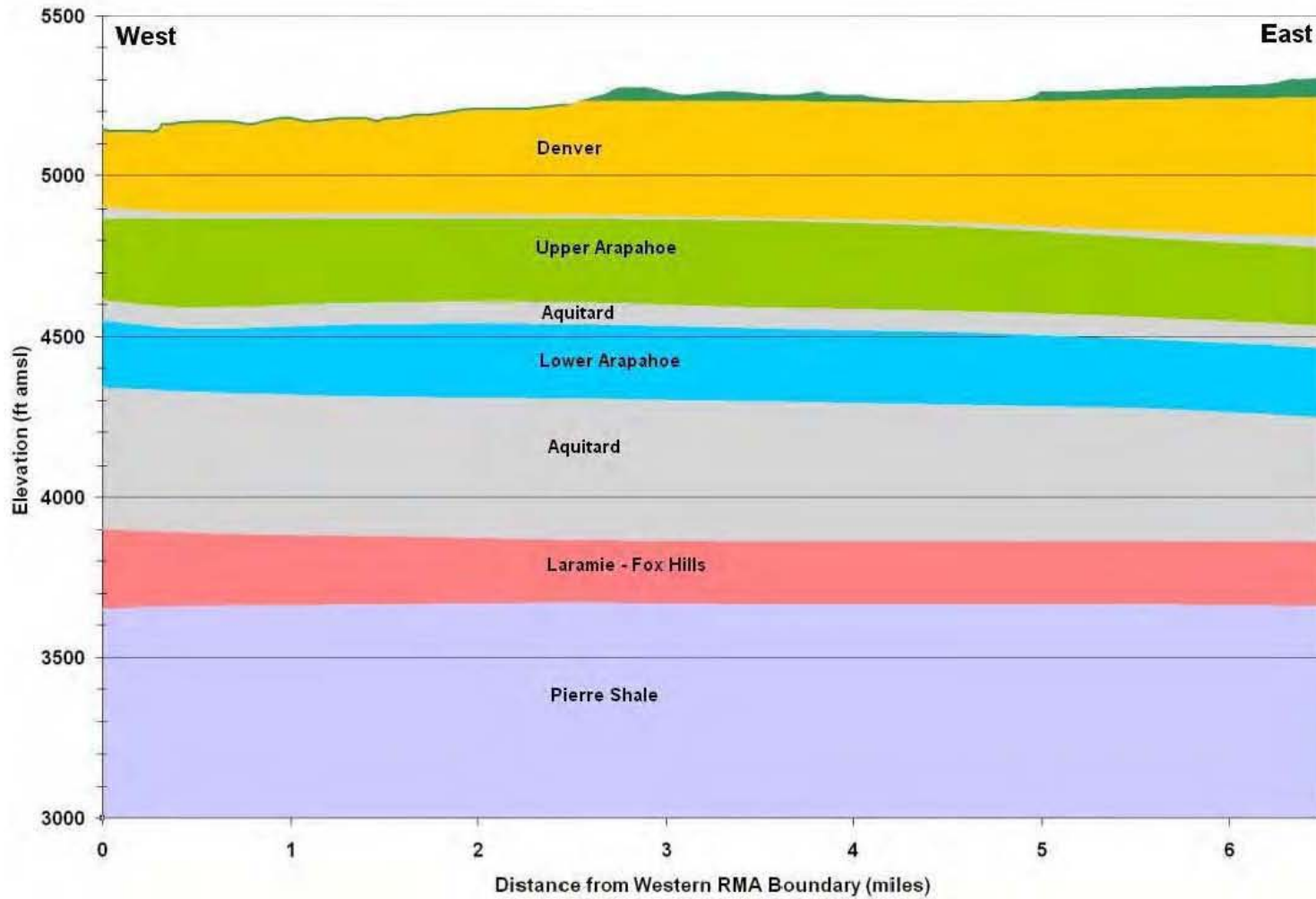


Figure 5.1. Cross-section, from west to east across the center of the site, showing the deep, confined aquifers underlying the Arsenal.

5.1.2 Shallow, unconfined aquifer

Unconsolidated alluvial (water deposited) and aeolian (wind-blown) deposits occupy most of the land surface area at the Arsenal. These unconsolidated deposits sit on the bedrock Denver formation and range in thickness from zero to 130 ft (Ebasco Services et al., 1989). Over much of the area, the unconsolidated deposits are between 20 and 50 ft thick. In some areas, however, unconsolidated materials are absent and rocks of the Denver formation crop out at the ground surface. In addition, several prominent paleochannels (ancient channels associated with a land surface from millions of years ago) have eroded into the rocks of the Denver formation and are filled with unconsolidated deposits between 50 and 130 ft thick.

The water table is typically found from 10 to 50 ft beneath the ground surface at the Arsenal (USGS, 1997b). The unconsolidated materials, together with weathered portions at the top of the Denver formation, comprise the unconfined flow system (UFS). In the preliminary analysis undertaken as part of this Assessment Plan, the shallow alluvial aquifer and the UFS are considered to be synonymous. The saturated thickness of the UFS varies from less than 10 ft to approximately 70 ft, with the greatest thicknesses associated with the buried alluvial paleochannels. The groundwater flow direction is generally to the north and west (Figure 5.2), following the orientation of the paleochannels.

Hydraulic conductivities (the rate at which water moves through the aquifer at a given gradient) for the unconsolidated materials range from less than 1 ft/day (for finer grained deposits) to greater than 1,000 ft/day (for gravels), with typical values on the order of 60 to 300 ft/day (Ebasco Services et al., 1989, Table 2.2). Adjacent weathered bedrock of the Denver formation is somewhat less permeable.

5.1.3 Confined bedrock aquifer

Immediately underlying and transitioning from the unconfined weathered portions of the Denver formation are the unweathered shales and sandstones of the Denver formation. Hydraulic conductivity in the sandstone is generally less than 1 ft/day. An extensive shale unit approximately 30 to 50 ft thick separates the Denver formation from the underlying Arapahoe formation (Black & Veatch et al., 2003). In the study area, a 50- to 100-foot thick shale separates the Arapahoe into an upper and lower zone (Figure 5.1).

Beneath the Arapahoe, approximately 400 ft of shale overlie the extensive permeable sandstone units of the Laramie-Fox Hills aquifer (Figure 5.1). Groundwater within these bedrock units is generally confined.

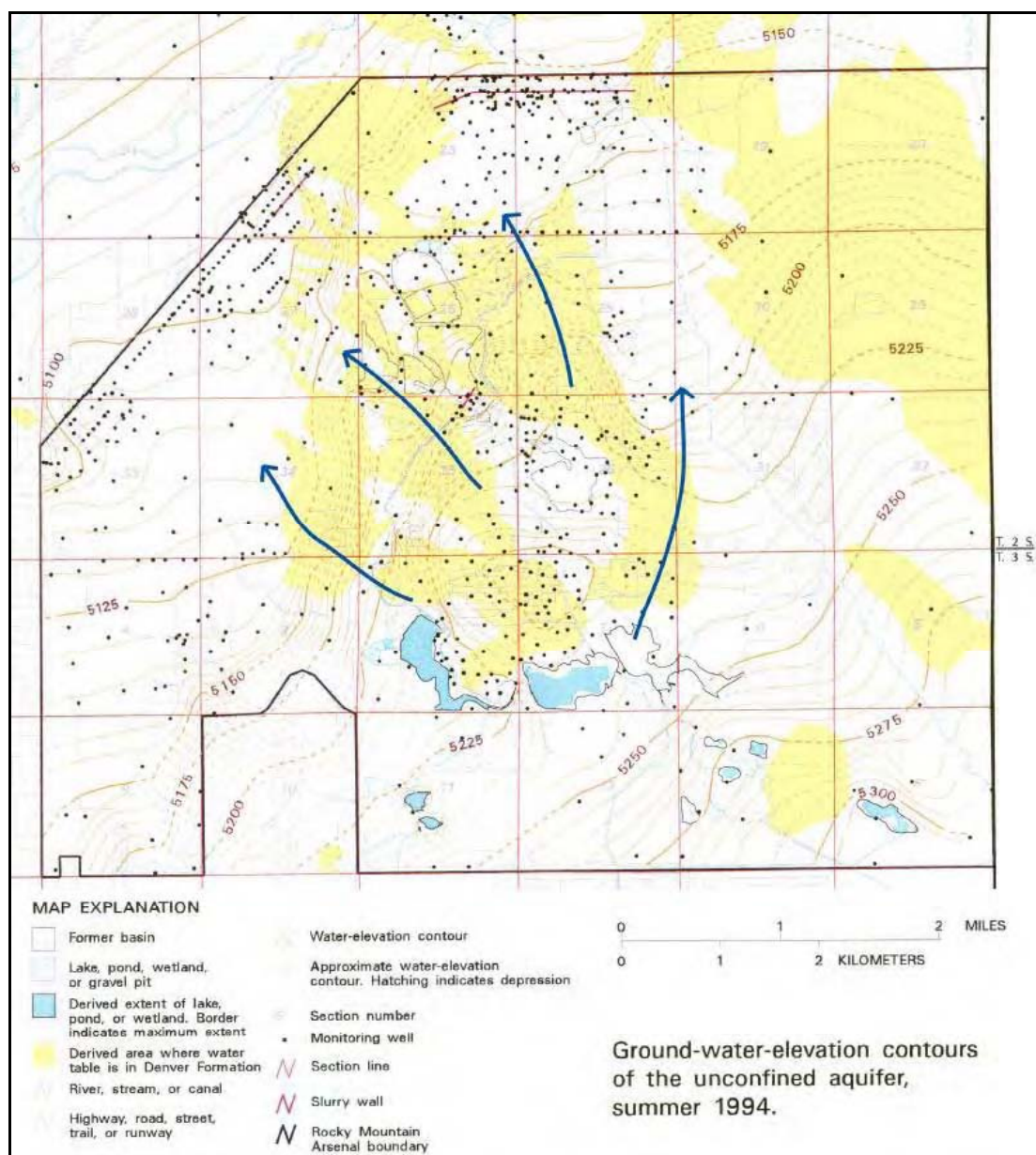


Figure 5.2. Shallow alluvial groundwater contours and flow direction (arrows added) in summer 1994, as depicted in USGS (1997b). Shaded areas indicate the absence of alluvial groundwater (i.e., the water table was in the underlying Denver bedrock formation).

The shale layers between these aquifers form aquitards that prevent vertical mixing of the groundwater. Most of the Denver formation has substantially lower transmissivity than the overlying alluvium. This tends to inhibit the shallow groundwater contamination from reaching water in the deeper formations. Despite their great depth, the extensive permeable layers within these bedrock formations have been tapped in several locations throughout the Denver Basin, particularly in the metropolitan communities south of Denver. Section 5.4 discusses groundwater uses in the vicinity of the Arsenal in more detail.

5.2 Injury Determination

This section presents a preliminary evaluation of groundwater injury, based on a review of groundwater data from 1994, the year in which the most extensive sampling was performed. Section 5.2.1 presents the contaminants of concern in groundwater, Section 5.2.2 contains the regulatory definitions of injury to groundwater, and Section 5.2.3 discusses baseline conditions. Section 5.2.4 shows exceedences of groundwater injury thresholds in 1994, and Section 5.2.5 describes institutional controls preventing the use of Arsenal groundwater as a drinking water source because of the releases of hazardous substances.

5.2.1 Contaminants of concern

Chapter 2 discusses the complete list of contaminants that have been detected at the site. Table 5.1 provides a list of contaminants selected by the Army as chemicals of concern in groundwater. These are chemicals that were targeted in various sampling programs (e.g., Harding Lawson Associates, 1995, Tables 6.1 to 6.4; Foster Wheeler Environmental, 1996, Tables 9.1-1 to 9.1-4).

Table 5.1. Contaminants of concern in the Arsenal groundwater

Contaminant	Hazardous substance^a	Contaminant	Hazardous substance^a
Aldrin	Yes	Carbon tetrachloride	Yes
Allyl chloride	Yes	Chlordane	Yes
Arsenic	Yes	Chloride	No
Atrazine	No	Chlorobenzene	Yes
Benzene	Yes	Chloroform	Yes
Benzothiazole	No	Chlorophenylmethyl sulfide	Yes
Cadmium	Yes	Chlorophenylmethyl sulfone	No

Table 5.1. Contaminants of concern in the Arsenal groundwater (cont.)

Contaminant	Hazardous substance^a	Contaminant	Hazardous substance^a
Chlorophenylmethyl sulfoxide	No	Lead	Yes
Copper	Yes	Malathion	Yes
Cyanazine (Bladex)	No	Manganese	Yes
DBCP	Yes	Mercury	Yes
DCPD	Yes	Methyl parathion	Yes
DDE	Yes	Methylene chloride	Yes
DDT	Yes	Methylphosphonic acid	No
Dichlorobenzene	Yes	Mustard	No
1,3- dichlorobenzene	Yes	Nitrate (as N)	No
1,2, dichloroethane	Yes	n-Nitrosodimethylamine	Yes
1,2- dichloroethylene	Yes	1,4-oxathiane	No
1,1- dichloroethylene	Yes	Oxychlordane	No
Dieldrin	Yes	Parathion	No
Dimethyl methyl phosphonate	No	Polychlorinated biphenyls	Yes
DIMP	No	Selenium	Yes
Dithiane	No	Sulfate	No ^b
Endrin	Yes	TCE	Yes
Ethylbenzene	Yes	Tetrachloroethylene (PCE)	Yes
Fluoride	No	Thiodiglycol	No
Heptachlor	Yes	Toluene	Yes
Heptachlor epoxide	Yes	1,1,1-trichloroethane	Yes
Hexachlorobicycloheptadiene	No	Xylenes (total)	Yes
Isodrin	Yes	Zinc	Yes

a. As listed in Table 302.4 at 40 CFR § 302.4, Ebasco Services et al., 1988, and/or DOJ, 1986.

b. Sulfate that is a degradation product of sulfuric acid is treated as a hazardous substance pursuant to 43 CFR § 11.14 (v).

Sources: Ebasco Services et al., 1988; State of Colorado, 2007.

5.2.2 Definition of injury

“Injury” is defined as “a measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a release of a hazardous substance, or exposure to a product of reactions resulting from the release of a hazardous substance” [43 CFR § 11.14(v)]. The relevant injury definitions for groundwater resources include the following:

- ▶ Concentrations and duration of hazardous substances in excess of drinking water standards as established by Sections 1411-1416 of the Safe Drinking Water Act (SDWA), or by other federal or state laws or regulations that establish such standards for drinking water, in groundwater that was potable before the release [43 CFR § 11.62(c)(1)(i)]
- ▶ Concentrations and duration of hazardous substances sufficient to have caused injury to other resources when exposed to groundwater [43 CFR § 11.62(c)(1)(iv)].

Groundwater may also be injured when the releases of hazardous substances require institutional controls that prevent the future use of the groundwater, constituting an unavoidable injury as a result of a response action [43 CFR § 11.15(a)(1)]. Such institutional controls were imposed on the Arsenal property with the signing of the Federal Facilities Agreement in 1989 and on Shell properties north of the Arsenal as required in the Off-Post ROD (Harding Lawson Associates, 1995).

Groundwater resources include both “water in a saturated zone or stratum beneath the surface of land or water” and “the rocks or sediments through which ground water moves” [43 CFR § 11.14(t)]. There are no promulgated standards that define injury to the aquifer materials. Aquifer materials are likely to be injured if the water moving through the aquifer materials contains contaminant concentrations above groundwater injury thresholds. Most of the contaminants of concern at the Arsenal are hydrophobic and tend to sorb to aquifer materials rather than dissolve into the groundwater. Thus, if the contaminants are in groundwater samples, they are likely sorbed to the aquifer materials as well.

Relevant injury thresholds for groundwater include concentrations in excess of Sections 1411-1416 of the SDWA and Colorado groundwater and drinking water standards [5 CCR 1002-41; 5 CCR 1003-1]. Table 5.2 presents maximum contaminant levels (MCLs) from the SDWA and groundwater standards from 5 CCR 1002-41 for selected contaminants of concern at the Arsenal. Exceedences of these standards indicate injury to groundwater. Table 5.2 also presents containment system remediation goals (CSRGs), which are the target cleanup concentrations for the groundwater containment systems at the Arsenal (see Chapter 3) and in some instances are lower than the relevant standards.

Table 5.2. State and federal groundwater standards for selected contaminants of concern

Contaminant of concern	CSRG ^a (µg/L)	CO standard ^b (µg/L)	MCL ^c (µg/L)
Aldrin	0.002	0.0021	–
Arsenic	2.35	50	10
Benzene	3	5	5
Carbon tetrachloride	0.3	5	5
Chlordane	0.03	2	2
Chloride	250,000	250,000	–
Chloroform	6	6 ^d	–
DBCP	0.2	0.2	0.2
1,2-dichloroethane	0.4	5	5
Dieldrin	0.002	0.002	–
DIMP	8	8	–
Fluoride	2,000	4,000	4,000
Methylene chloride	5	5	–
Sulfate	540,000	250,000	–
Tetrachloroethylene (PCE)	5	5	5
TCE	3	5	5

a. CSRG for the Arsenal containment systems.

b. Colorado groundwater standards at 5 CCR 1002-41.

c. MCLs from the SDWA.

d. The current Colorado chloroform standard of 3.5 µg/L was calculated incorrectly and is expected to change back to 6.0 µg/L (Ed LaRock, CDPHE, personal communication, October 11, 2007).

5.2.3 Baseline conditions

Baseline conditions are the conditions that would have existed had the releases of hazardous substances not occurred [43 CFR § 11.14 (e)]. Groundwater at the Arsenal under baseline conditions is potable, with an exception noted below.

Groundwater at the Arsenal generally moves from southeast to northwest (see Figure 5.2). Groundwater upgradient of the hazardous substance sources at the Arsenal does not exceed groundwater criteria and therefore is potable (Ebasco Services et al., 1989; USGS, 1997a, 1997b). The one exception is groundwater in the UFS in the southwest corner of the Arsenal. A plume of TCE emanates from sources south of the Arsenal and flows north/northwest toward Irondale and the west side of the Arsenal (Figure 5.3). This plume will be excluded from the injury and damage analysis. A narrower plume of TCE and other contaminants originates from the Motor Pool and Rail Classification Yards in this southwest portion of the site (Ebasco Services et al., 1989, p. 4-45); this Arsenal plume is evident on the TCE map (Figure 5.3). The TCE plume downgradient from the Motor Pool and Rail Yards will be included in the injury analysis.

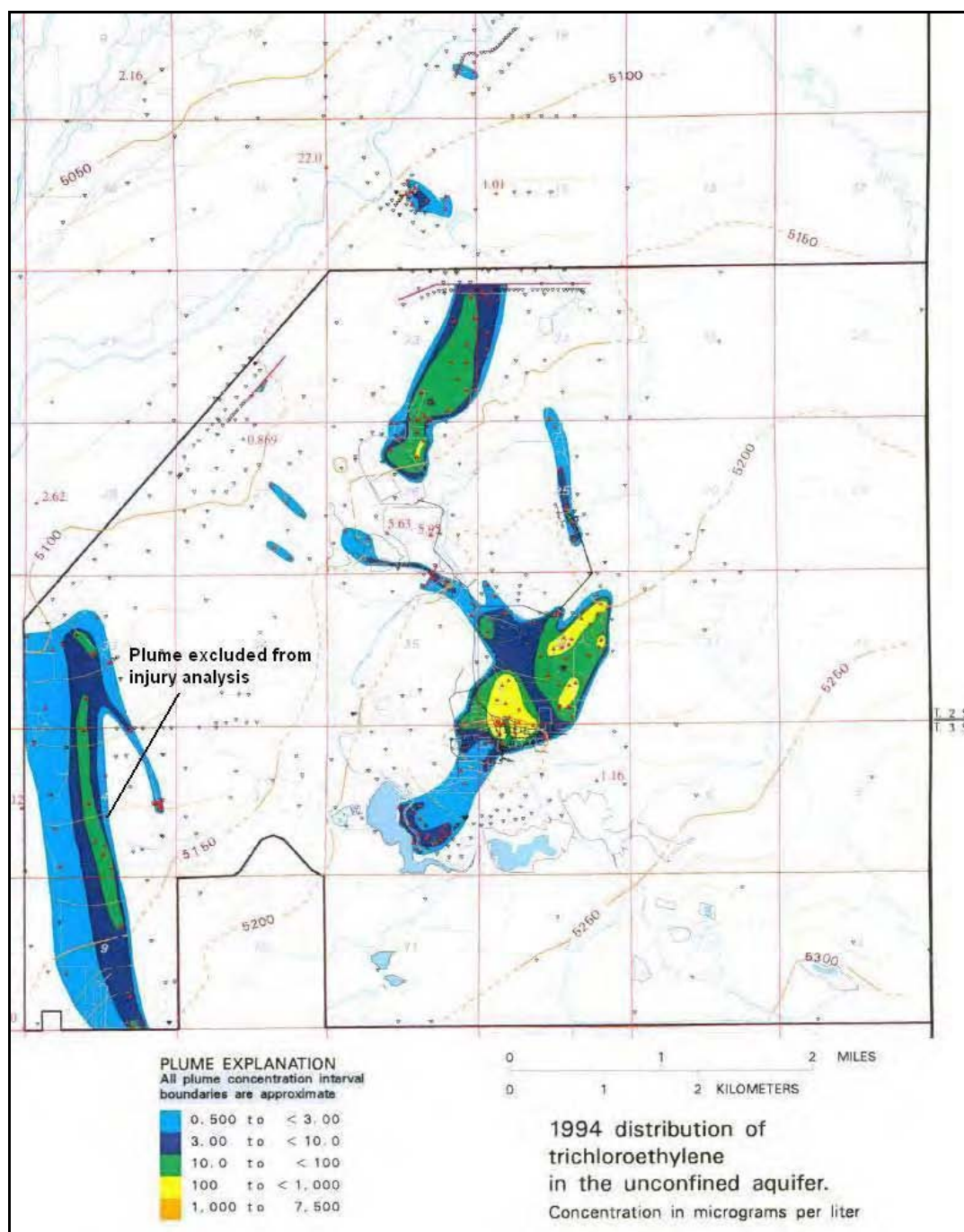


Figure 5.3. TCE plume in water year 1994, as depicted in USGS (1997b). The plume originating south of the Arsenal is excluded in the evaluation of groundwater injuries and damages.

5.2.4 Exceedences of groundwater standards

The U.S. Geological Survey (USGS, 1997a, 1997b) conducted a comprehensive study of groundwater contamination at the Arsenal in water year 1994 (October 1993 through September 1994) and mapped groundwater plumes of various contaminants that exceeded CSRGs (Table 5.2). While CSRGs are not always identical to regulatory injury thresholds, they provide a preliminary indication of contamination. Figures 5.4 through 5.8 present the contaminant plumes that USGS contoured for TCE, benzene, chloroform, DBCP, and dieldrin, respectively. These plumes show the estimated extent of contamination from these five contaminants in water year 1994, and provide an approximation of the extent of injury based on exceedences of Colorado and EPA injury thresholds for these selected hazardous substances (Table 5.2).

Figures 5.4 through 5.8 confirm that groundwater resources have been exposed to hazardous substances at the Arsenal, and that hazardous substances were present at concentrations far exceeding injury thresholds in water year 1994. Other contaminants exceeded injury thresholds as well, but the spatial extent of those plumes was not included in this analysis.

5.2.5 Institutional controls

Institutional controls were placed on the Arsenal and Shell properties to prevent the use of groundwater as a drinking water source. According to the 1989 Federal Facilities Agreement [§ 44.2(c)], “to assure continued protection of human health and the environment . . . the use of groundwater located under, or surface water located on, the Arsenal as a source of potable water shall be prohibited.”

In the Off-Post ROD (Harding Lawson Associates, 1995, Appendix B), to “eliminate the potential exposure to contaminated groundwater under the Shell Oil Company properties,” Shell was required to place covenants on its properties that:

- (i) preclude drilling of all groundwater wells into any alluvial aquifer water under Shell’s property for future use until such groundwater no longer contains contamination in exceedence of groundwater containment system remediation goals established in the ROD, and (ii) preclude any use of any deeper aquifer water (e.g., Denver Basin) containing contamination in exceedence of groundwater containment system remediation goals established in the ROD.

Figure 5.9 shows the area covered by institutional controls. The unrestricted use of this groundwater has been lost to the State due to releases of hazardous substances.

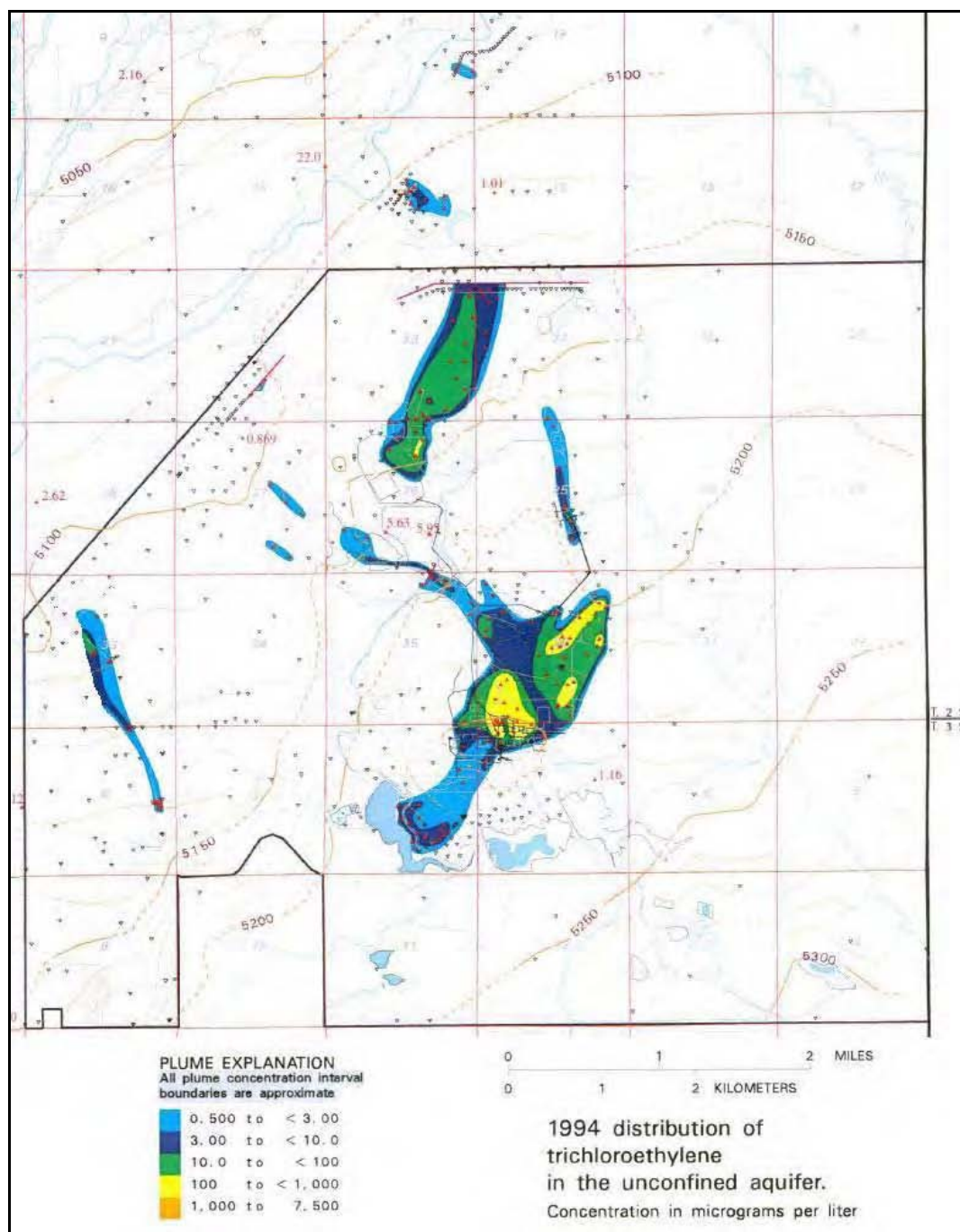


Figure 5.4. TCE plume in the unconfined aquifer in water year 1994, modified from USGS (1997b). The Colorado injury threshold for TCE is 5 µg/L; shaded areas, except light blue, have TCE concentrations exceeding 3 µg/L and are likely to be injured. The part of the TCE plume in the southwest corner that originates offsite (Figure 5.3) is not included in this evaluation of injuries and has thus been removed from this figure.

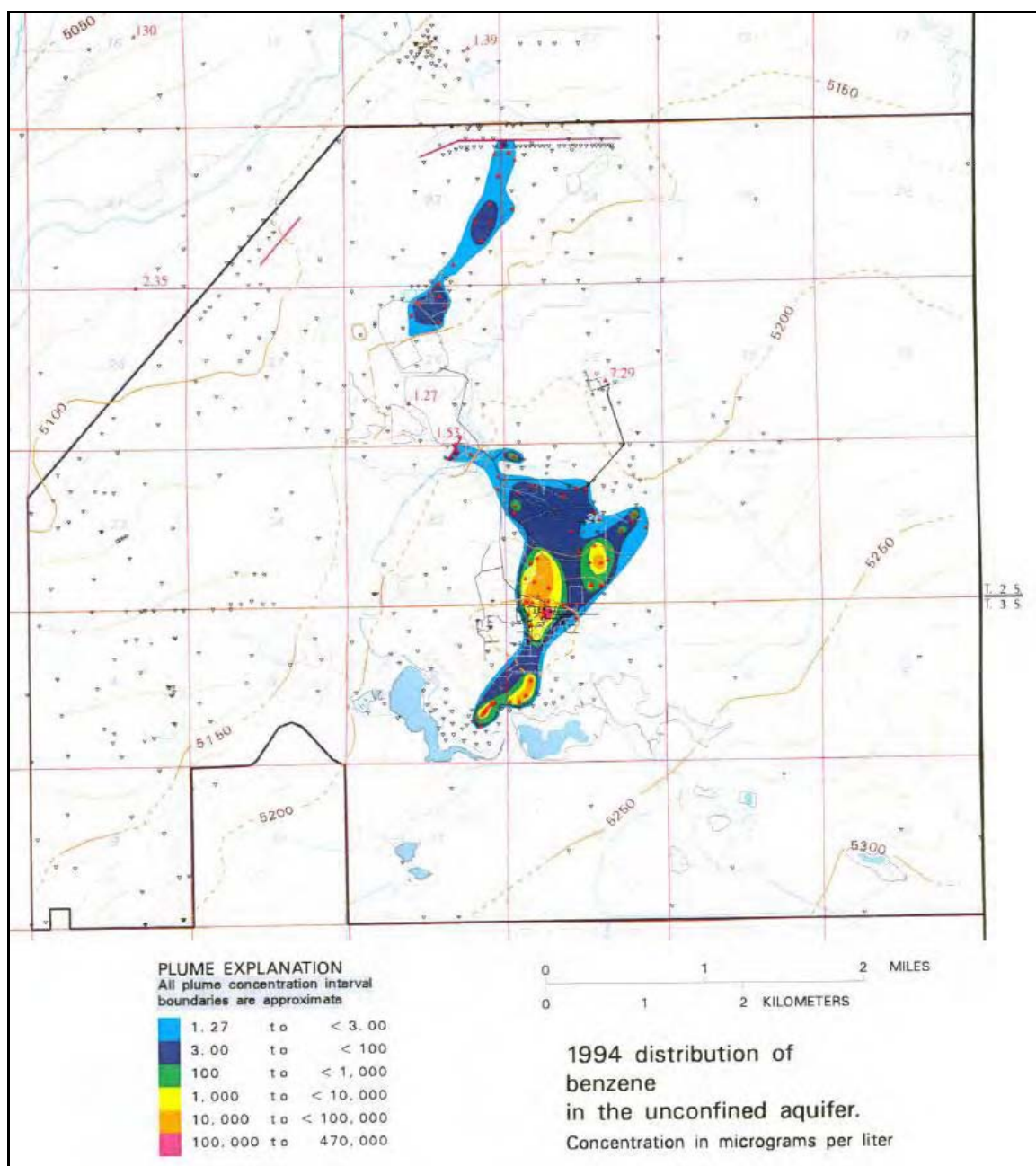


Figure 5.5. Benzene plume in the unconfined aquifer in water year 1994, as depicted in USGS (1997b). The Colorado injury threshold for benzene is 5 µg/L; shaded areas except light blue have benzene concentrations exceeding 3 µg/L and are likely to be injured.

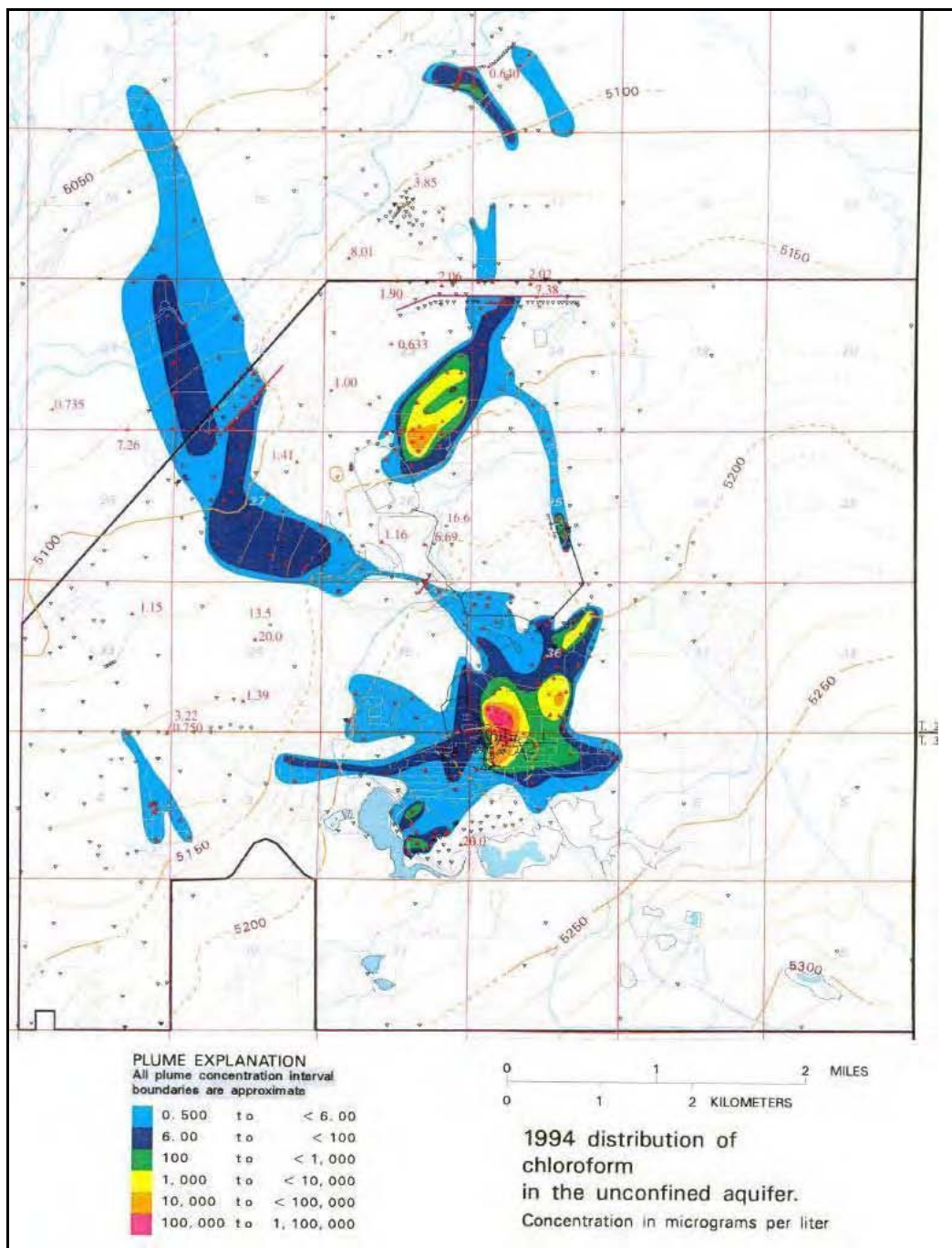


Figure 5.6. Chloroform plume in the unconfined aquifer in water year 1994, as depicted in USGS (1997b). Shaded areas, except light blue, have chloroform concentrations exceeding the injury threshold for Colorado groundwater.

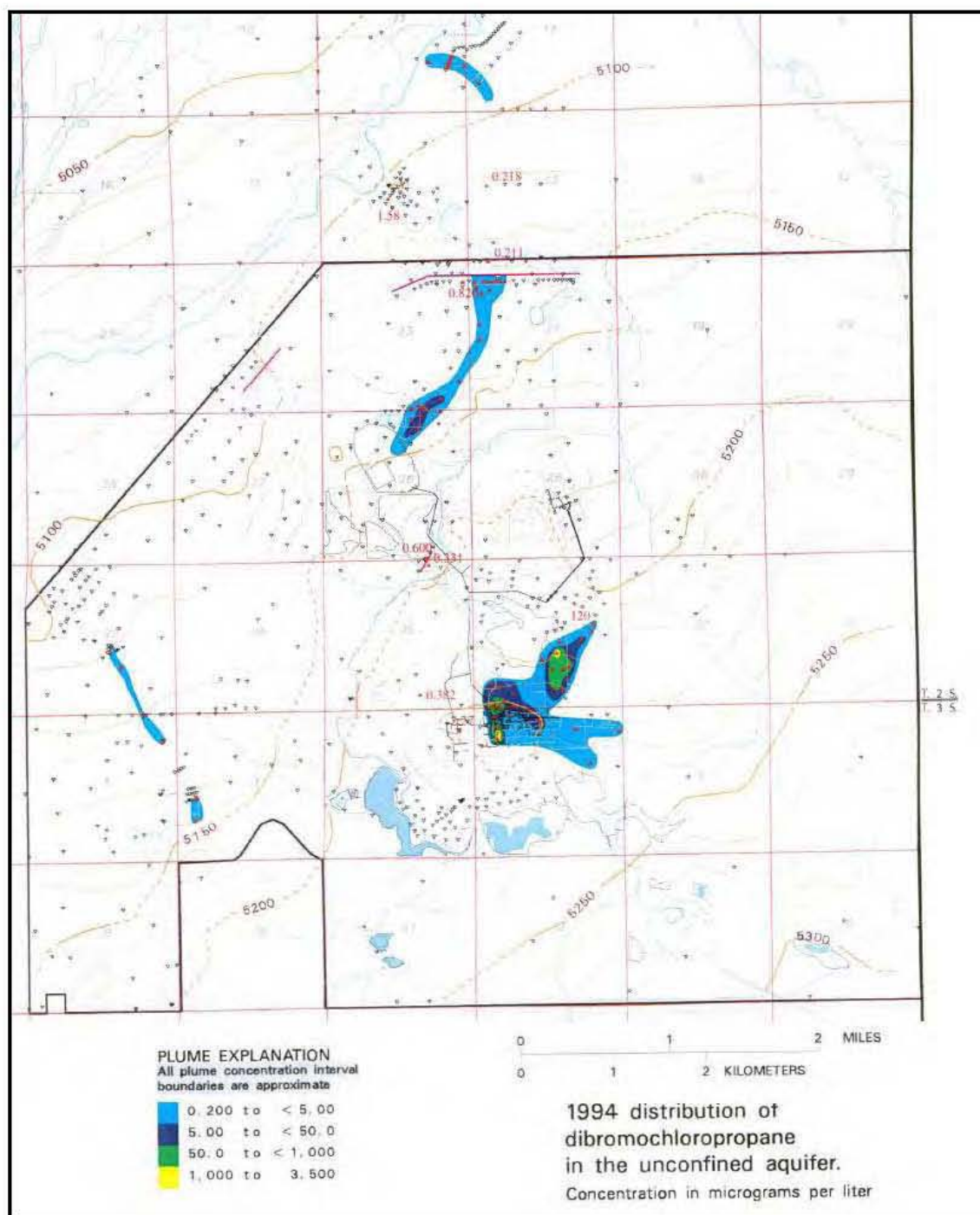


Figure 5.7. DBCP plume in the unconfined aquifer in water year 1994, as depicted in USGS (1997b). All shaded areas contain DBCP concentrations exceeding the 0.2 µg/L injury threshold for Colorado groundwater.

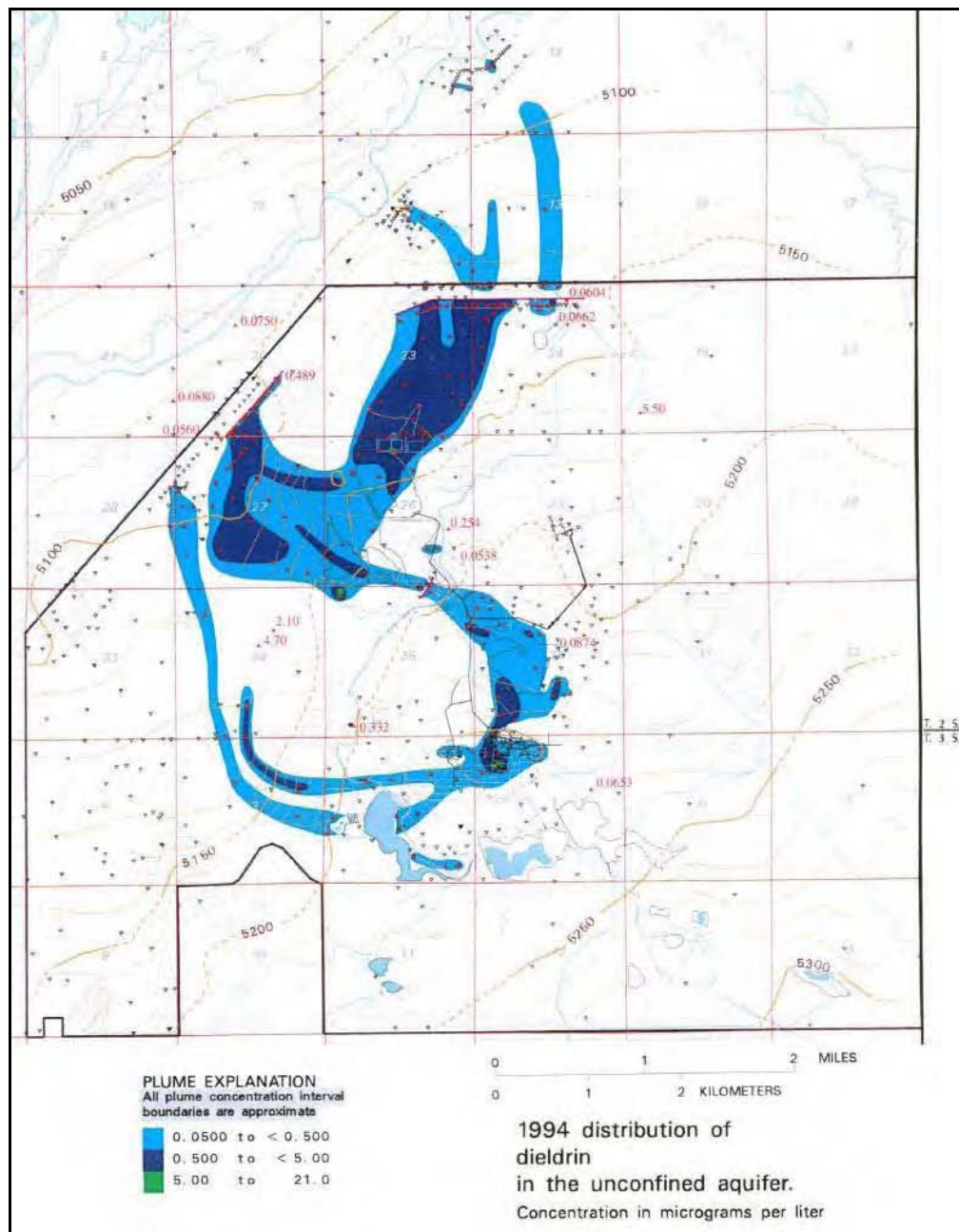


Figure 5.8. Dieldrin plume in the unconfined aquifer in water year 1994, as depicted in USGS (1997b). All shaded areas contain dieldrin concentrations exceeding the 0.002 µg/L injury threshold for Colorado groundwater. The lowest concentration depicted in this figure is 0.05 µg/L; thus, this plume map may underestimate the spatial extent of injury.



Figure 5.9. Geographical area under institutional controls that prevent unrestricted use of groundwater. Off-post institutional controls preclude the use of contaminated groundwater.

5.3 Injury Quantification

This section presents initial estimates of the static volume of groundwater containing hazardous substances exceeding State or federal injury thresholds (Section 5.3.1) in 1994; an example calculation of groundwater adjacent to the plume that is unusable because of proximity to the plume (Section 5.3.2); and the volume of groundwater unusable because of institutional controls (Section 5.3.3). Section 5.3.4 presents an example calculation of the annual recharge and potential “safe yield” of the shallow alluvial aquifer. Thus, this section provides preliminary, conservative estimates of the quantity of groundwater that could have been used had the releases of hazardous substances at the Arsenal not occurred. Section 5.4 discusses how this water might have been used but for the release, and Chapter 9 discusses approaches to estimating damages to compensate for injuries to the public’s water resources.

5.3.1 Plume of hazardous substances

The USGS plume maps shown in Figures 5.3 through 5.8 were scanned and digitized to estimate the area of each contaminant plume. These individual plumes were then combined into one composite plume (Figure 5.10). This combined plume includes the light blue shaded areas from Figure 5.4 (TCE < 3 µg/L), Figure 5.5 (benzene < 3 µg/L), and Figure 5.6 (chloroform < 6 µg/L), where concentrations may not exceed injury thresholds. Thus, this map may overestimate the spatial extent of injury from these contaminants. However, with only five out of dozens of contaminants in the analysis, the extent of injury may in fact be underestimated. For purposes of this preliminary evaluation of injury, the combined plume in Figure 5.10 is a reasonable depiction of the spatial extent of contamination in water year 1994. The shaded areas in Figure 5.10 cover approximately 4,300 acres, or 6.7 square miles, of which 3,255 acres are on-post and 1,045 acres are off-post.

The combined plume in Figure 5.10 does not include the extensive plumes of DIMP and chloride shown in USGS (1997b). Both DIMP and chloride exceed State groundwater standards in areas outside of the combined plume in Figure 5.10 but are not hazardous substances as defined by CERCLA. Figure 5.11 shows the combined plume from Figure 5.10 plus the spatial extent of the combined DIMP and chloride plume from water year 1994 (USGS, 1997b). The spatial extent of the entire contaminant plume including DIMP and chloride is approximately 5,450 acres, or 8.5 square miles.

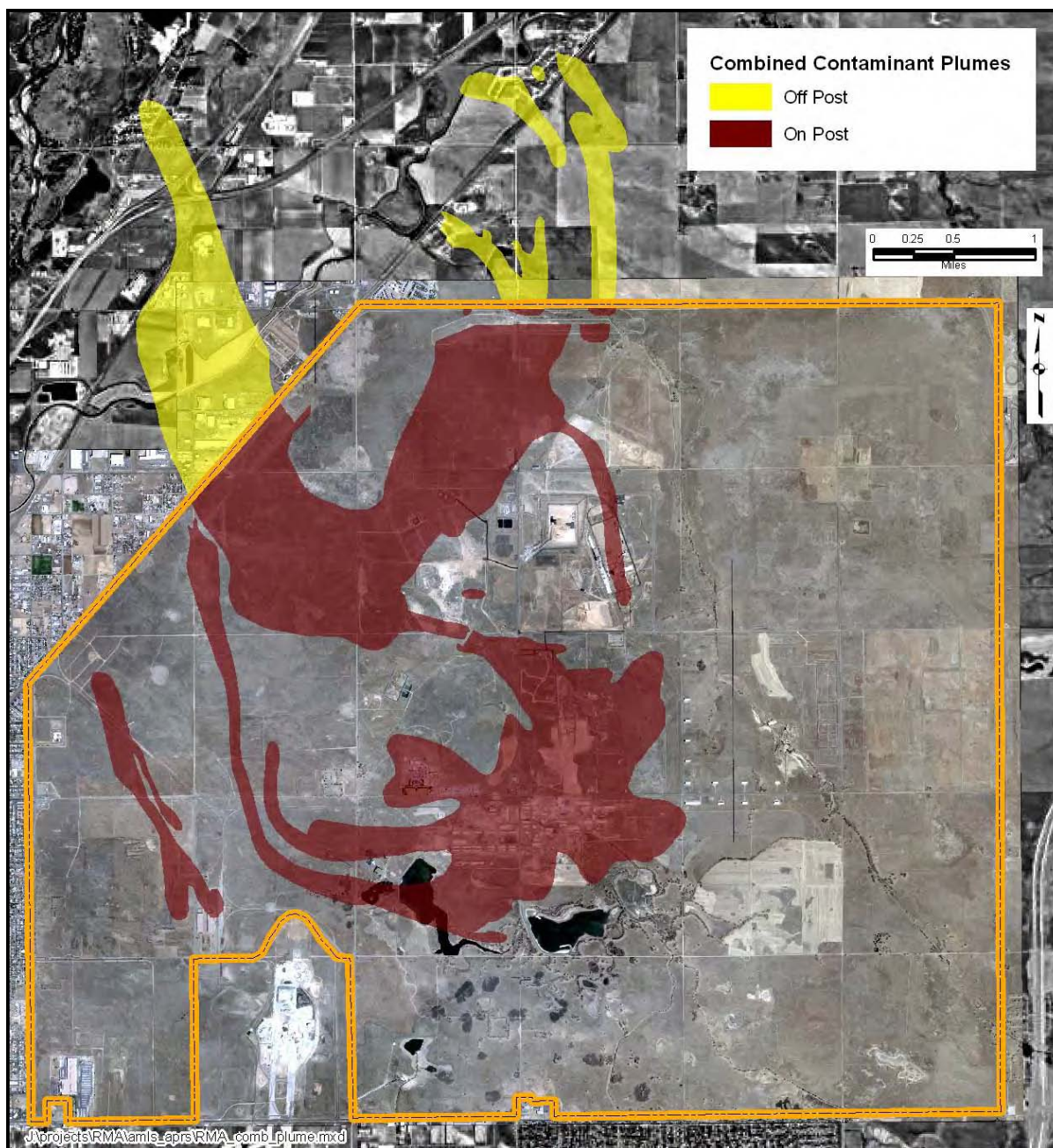


Figure 5.10. Estimated extent of the combined contaminant plume in the unconfined aquifer in water year 1994, based on USGS (1997b). The TCE plume that originates south of the Arsenal is not included in this combined plume.

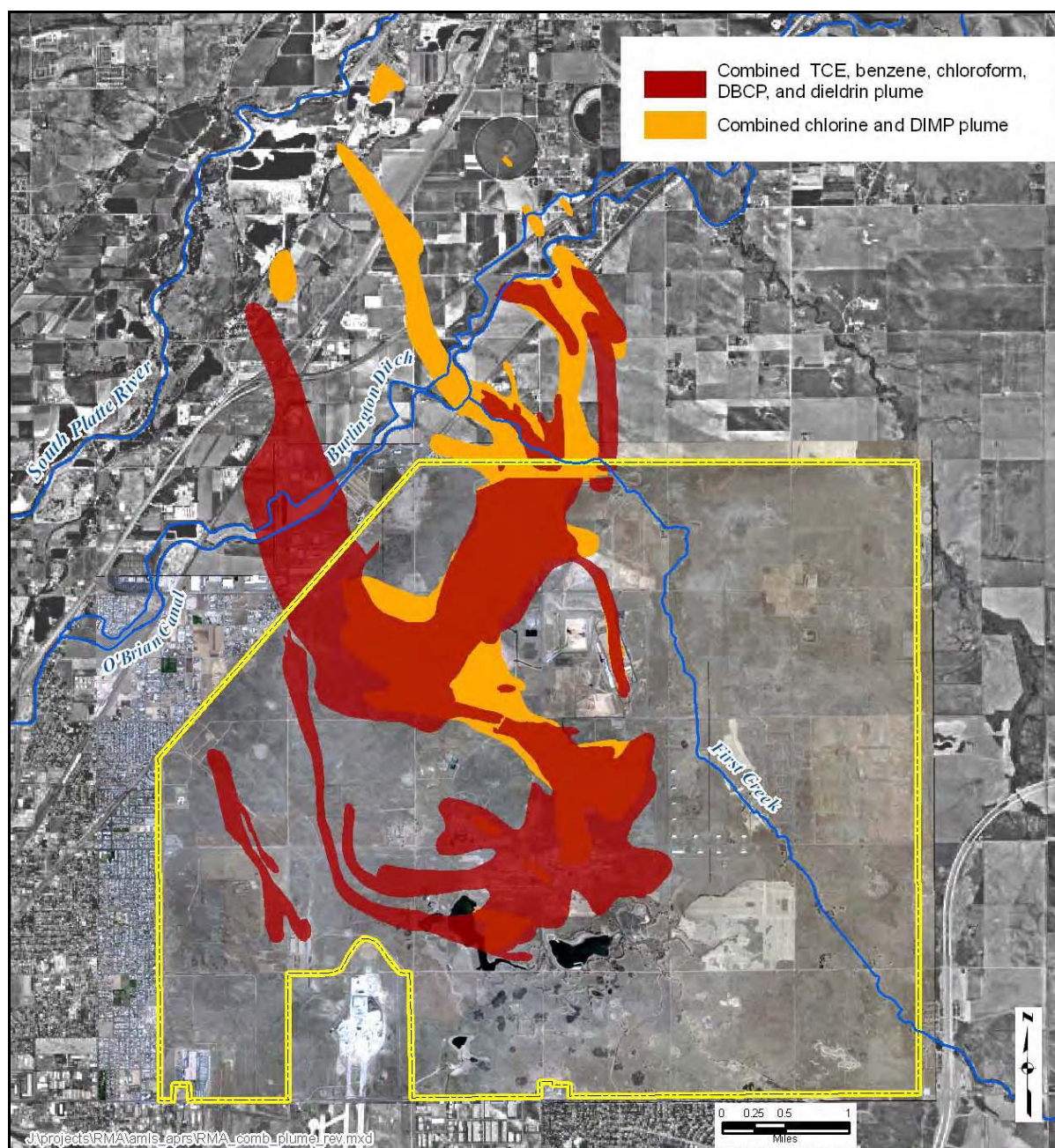


Figure 5.11. Estimated extent of the combined contaminant plume (Figure 5.10) and a combined DIMP and chloride plume in water year 1994, based on USGS (1997b).

Because DIMP and chloride are not hazardous substances as defined by CERCLA, they will not be considered in the injury quantification.

The saturated thickness of the alluvial aquifer was calculated as the difference between the water table elevation and the elevation of the upper bedrock surface. While this provides a reasonable preliminary estimate of contaminated saturated thickness, it is likely an underestimate. As mentioned previously, the UFS includes weathered, permeable bedrock at the top of the Denver formation. Given the direct hydraulic connection to the contaminated alluvium, the weathered bedrock of the upper Denver is likely to be contaminated as well. The contaminated groundwater within the permeable weathered bedrock is not included in this initial estimate of the saturated thickness of the UFS.

The water table elevation from the fall of 1994 was used to estimate the top of the saturated thickness because these water table data were readily available. While water table elevations vary over time, the fall of 1994 is a reasonable representative upper boundary of the UFS, based on seasonal water elevation data presented in USGS (1997b). Figure 5.12 shows the estimated saturated thickness of the UFS in fall 1994.

To estimate the static volume of extractable groundwater containing hazardous substances exceeding injury thresholds in water year 1994, the Trustees used a geographic information system (GIS) grid model to compute the total saturated volume of the shallow aquifer materials underlying the plume footprint in Figure 5.10. This volume was multiplied by the assumed effective porosity or specific yield (i.e., the fractional volume of the aquifer from which water could easily be drained) of 25% (Robson, 1989; Fetter, 1994), yielding a total volume of 12,800 acre-feet of contaminated groundwater, of which approximately 8,275 acre-feet were on-post, and 4,525 acre-feet were off-post.

Based on the data presented in USGS (1997b), the vast majority of the contaminants have remained in the shallow alluvial aquifer. The data showing contamination in deeper aquifers suggest that poorly constructed wells drilled through the contaminated alluvium may have transported some contaminants to the deeper aquifer, but there is little evidence to suggest a defined contaminant plume in the deeper aquifers. Evaluation of deep aquifer contamination will be included in future assessment work.

5.3.2 Halo/buffer

Wells drilled and pumped adjacent to a plume of contaminated groundwater may draw contaminated water laterally into the well. The area from which a well draws water is the “capture zone” for a well. The capture zone width expands as the pumping rate increases. To prevent pumping of contaminated water, a halo or buffer area must be estimated to determine how far outside the edge of a contaminated plume one must go before one could safely drill and pump a well. While the groundwater within a halo may not contain concentrations of hazardous substances exceeding groundwater standards, there is a lost use of that groundwater because of the release of hazardous substances.

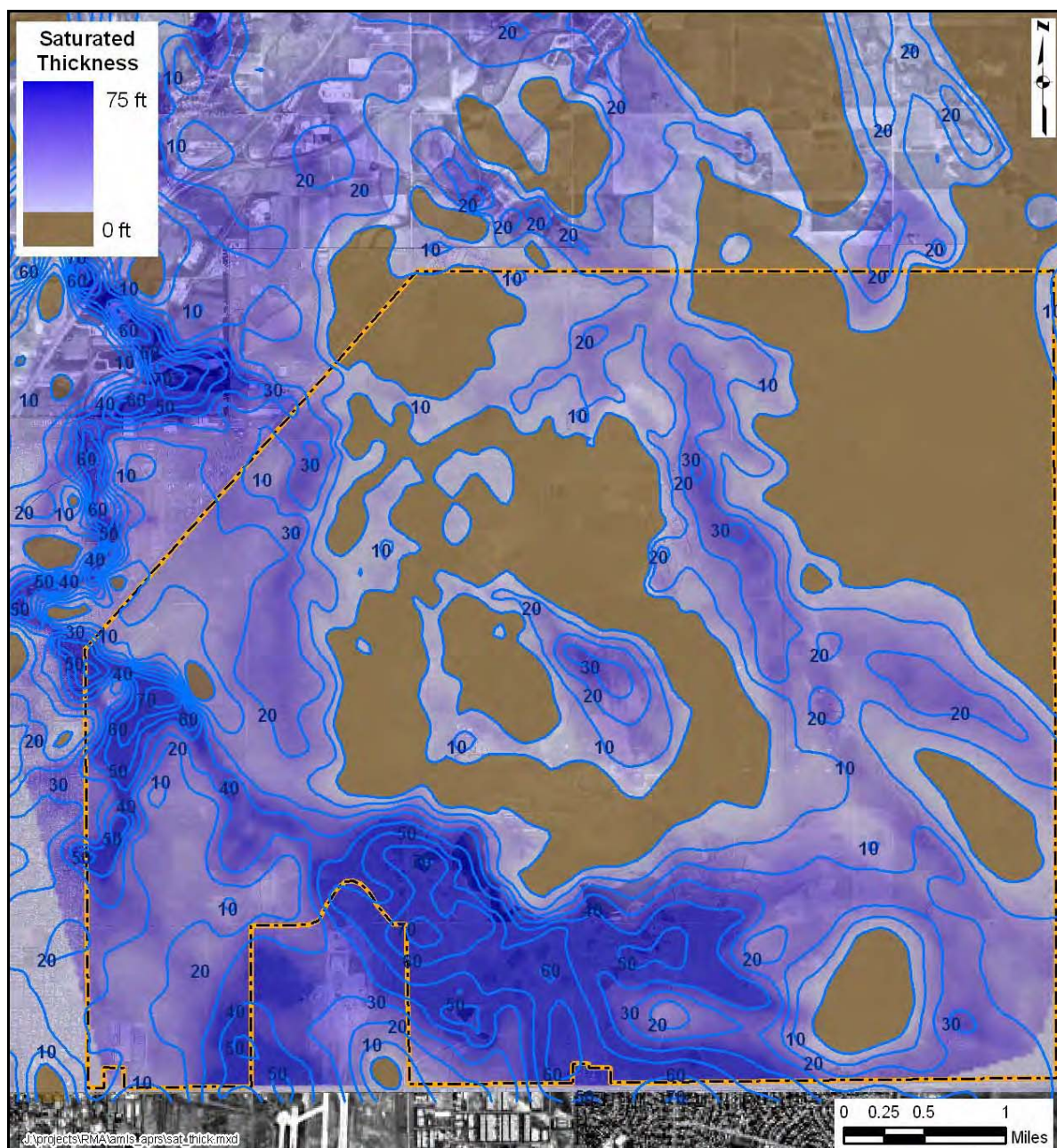


Figure 5.12. Estimated saturated thickness of the UFS in fall 1994. Contour interval = 10 ft. In brown shaded areas, the bedrock elevation is at or above the water table, and the saturated thickness of the UFS is 0.

A reasonable extent of the halo can be calculated using standard capture zone equations (e.g., Javandel and Tsang, 1986; Fetter, 1993; Kraemer et al., 2005). The equation for an asymptotic capture zone half width, $w/2$, is:

$$\frac{w}{2} = \frac{Q}{2KiH} \quad (5.1)$$

where K is a representative hydraulic conductivity, i is the hydraulic gradient, and H is a representative aquifer saturated thickness. This simple equation is for a well pumping in uniform, unbounded aquifer materials. However, most of the flow in the UFS is concentrated within paleochannels bounded by aquifer materials of lower hydraulic conductivity. In some areas, the plume is passing through weathered bedrock of much lower hydraulic conductivity. Because capture zone width increases as hydraulic conductivity decreases (Equation 5.1), this equation may underestimate the appropriate capture zone width for the alluvial contaminant plume under the Arsenal.

To present an example halo calculation, the Trustees assumed an average pumping rate (Q) for wells at the Arsenal of 100 gallons per minute (gpm), a reasonable rate for a community well serving approximately 160 households. Using that assumption plus representative values for other input parameters (Table 5.3), the capture zone width (halo) to prevent pumping of contaminated water would be 461 ft. Figure 5.13 shows the combined contaminant plume from Figure 5.10, with a surrounding 461-foot halo. As part of the assessment, the Trustees will evaluate the effects of other hydrogeologic features and other well pumping scenarios, including a calculation of the capture zone width assuming wells with higher pumping rates that municipalities would be likely to use if the Arsenal groundwater were available.

Table 5.3. Input parameters for calculating the appropriate width of the capture zone adjacent to the contaminant plume at the Arsenal

Parameter	Representative minimum	Representative maximum	Selected value
Well pump rate (Q , gpm)			100
Conductivity (K , ft/day)	60	300	134.2 ^a
Gradient (i , ft/ft)	0.0047	0.0167	0.0074 ^b
Saturated thickness (H , ft)	14.2	34.7	21.1 ^c

a. Geometric mean of minimum and maximum values from Ebasco Services et al. (1989, Table 2.2).

b. Harmonic mean of minimum and maximum values derived from Figure 5.2.

c. Geometric mean of the mean saturated thickness beneath each plume segment, calculated using GIS.

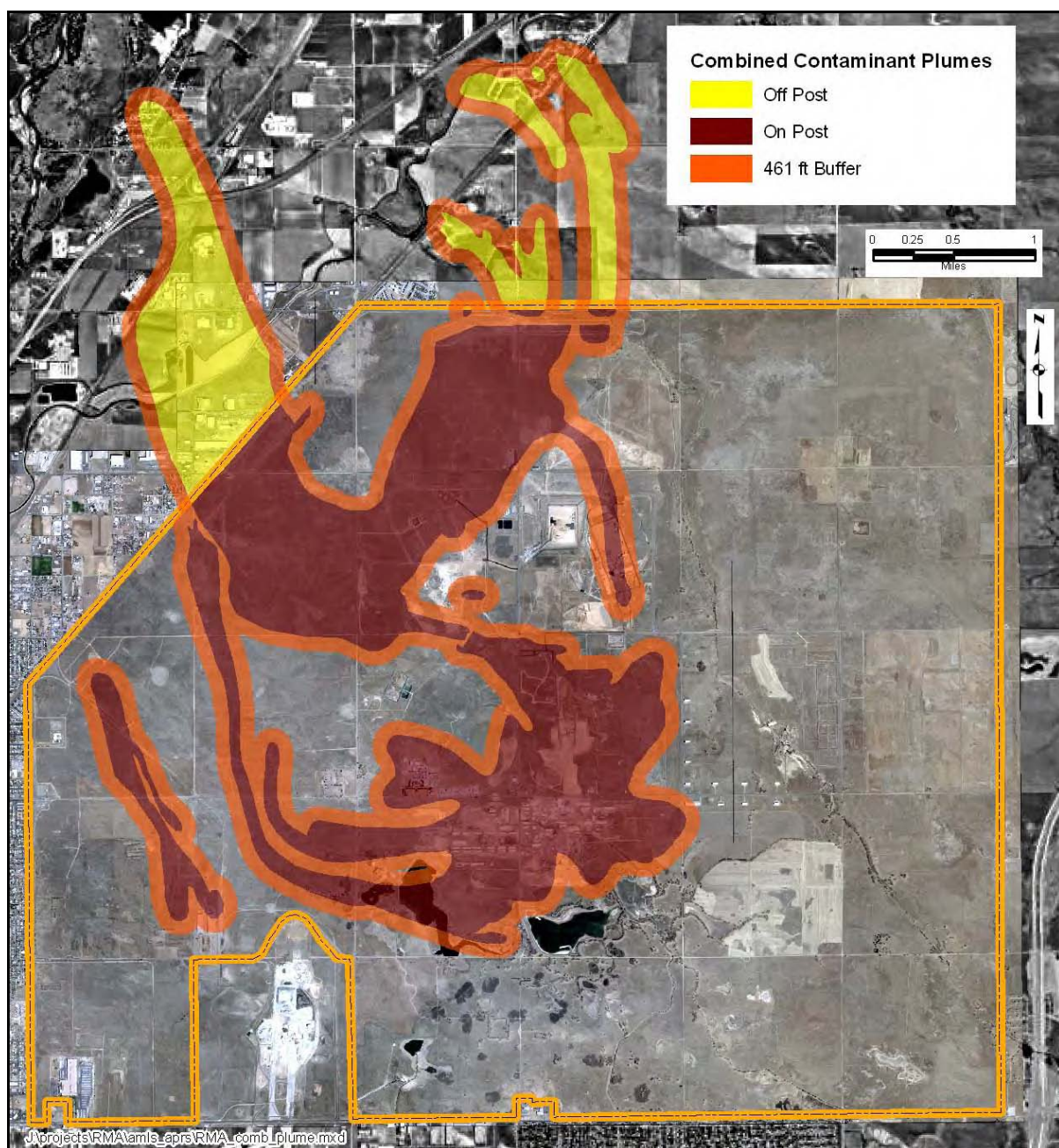


Figure 5.13. Estimated extent of the combined contaminant plume in the unconfined aquifer in 1994 with a surrounding buffer.

The volume in the contaminant plume plus the volume in the calculated halo provide one estimate of the total volume of groundwater that cannot be used because of hazardous substance releases. The GIS grid model was again relied upon to compute the total saturated volume of the aquifer materials underlying the combined plume plus halo described above and shown in Figure 5.13. This volume of impacted alluvial aquifer was then multiplied by the 25% effective porosity, yielding a total volume of 20,835 acre-feet of impacted groundwater, of which approximately 13,670 acre-feet were on-post and 7,165 acre-feet were off-post (Table 5.4).

Table 5.4. Estimated volume (acre-feet) of impacted groundwater, water year 1994

Location	Plume	Halo ^a	Total
On-post	8,275	5,395	13,670
Off-post	4,525	2,640	7,165
Total	12,800	8,035	20,835

a. The halo in this example assumes a 100-gpm extraction rate in a uniform, unbounded alluvial aquifer.

5.3.3 Institutional controls

Figure 5.9 shows the area affected by institutional controls, using the Arsenal boundary when the Federal Facilities Agreement was signed in 1989. The Arsenal covers roughly 26.5 square miles, or 16,940 acres. The Shell properties north of the Arsenal cover approximately 350 acres. As described previously, the grid of saturated alluvial thickness in fall 1994 was overlaid on the surface affected by institutional controls and multiplied by 25% effective porosity. Excluding the TCE plume in the southwest of the site where baseline conditions would have prevented shallow groundwater use, an estimated 52,550 acre-feet of alluvial groundwater are unavailable for drinking water use or storage because of the institutional controls (Table 5.5).

A similar method was used to quantify the volume of groundwater unavailable for unrestricted use in deep aquifers. The on-site institutional controls prevent the drinking water use and storage of both deep and shallow groundwater, and the off-site institutional controls prevent drinking water use or storage of deep groundwater under the Shell properties if contaminants exceed CSRGs (see Section 5.3.5). This preliminary evaluation of data did not reveal consistent CSRG exceedences in off-post deep groundwater, so no estimated quantity of injured off-post deep groundwater is provided. Contamination in deep aquifers will be evaluated more closely as part of the assessment.

Table 5.5. Total volume of groundwater in five aquifers that is unavailable for drinking water use because of institutional controls

Aquifer^a	Effective porosity	Total volume (acre-feet)
Shallow aquifer		
Alluvial ^b	25%	52,550
Deep aquifers		
Denver	15%	863,760
Upper Arapahoe	7%	283,830
Lower Arapahoe	7%	283,260
Laramie-Fox Hills	13%	456,930
Total (deep)		1,887,780
Total		1,940,330

a. The shallow aquifer includes both on-post and off-post institutional controls. The deep aquifers are on-post only.

b. Excludes TCE plume originating south of the Arsenal.

The total volume of restricted on-post groundwater in deep aquifers was calculated by multiplying the surface area by the average saturated thickness for each bedrock aquifer under each one square-mile section using the Colorado State Engineer Office SB-74 MODFLOW model of the Denver Basin (Black & Veatch et al., 2003) and the effective porosity (or specific yield). Total volumes of groundwater unavailable for drinking water use or storage because of institutional controls are shown in Table 5.5.

5.3.4 Shallow aquifer recharge

The State of Colorado assumes that the deep aquifers do not recharge in the timeframe that the aquifer is pumped. The State Engineer's Office allows the aquifer to be pumped at a rate of 1% of the available volume per year [2 CCR § 402-7, Rule 8A (Statewide Nontributary Ground Water Rules)]. The shallow aquifer, on the other hand, is recharged every year by infiltrating rain and snowmelt, infiltrating surface water from lakes, ponds, and ditches, and by upgradient groundwater. While there are no statutory restrictions on pumping rates in the shallow aquifer, for practical purposes, the Trustees have assumed that a user would not pump the alluvial aquifer at a rate greater than the rate at which the aquifer recharges on an average annual basis. In this case, the total recharge can be considered a conservative safe yield for the shallow aquifer.

To demonstrate a method of estimating aquifer recharge and safe yield without developing a complicated groundwater flow model, the Trustees developed a simple groundwater budget. The groundwater budget balances the amount of new water entering the shallow aquifer under the

Arsenal each year with the amount of shallow groundwater leaving the existing stock. This equates the amount of groundwater leaving the existing stock annually to the annual groundwater recharge (and safe yield). In general, the inflows to groundwater comprise:

1. Effective precipitation, i.e., diffuse groundwater recharge, R
2. Seepage from streams, ditches, and lakes, S
3. Lateral groundwater inflows from upgradient areas to the south-southeast, GW_{in} .

Outflows comprise:

1. Evaporation from surface water bodies, E
2. Groundwater outflows, GW_{out} .

This can be expressed in a groundwater budget equation:

$$R + S + GW_{in} = E + GW_{out} \quad (5.2)$$

Solving for GW_{out} provides an estimate of the amount of alluvial groundwater that could be pumped from under the Arsenal without depleting the original stock:

$$GW_{out} = R + S + GW_{in} - E \quad (5.3)$$

Below is an example of a groundwater budget for the alluvial aquifer at the Arsenal. Although it incorporates site data, the input data are from different years, and water use at the Arsenal has changed over time. Should the Trustees elect to use this method of calculating groundwater recharge at the Arsenal (see Section 5.5), additional data will be required to account for changes in groundwater recharge and groundwater use over time, as well as to differentiate between groundwater in the contaminant plume and groundwater under institutional controls. Separate groundwater budgets for different years or for different water use scenarios may be calculated.

For this simple example calculation of groundwater recharge, the input data are:

- **Diffuse groundwater recharge, R :** Diffuse recharge, or effective precipitation, is the areal average amount of precipitation that infiltrates the soil and is not consumed by plants. Diffuse recharge thus accounts for both precipitation and transpiration at the site. The USGS (Wolock, 2003) estimates that 0.5 inches per year is an appropriate average annual value for the Arsenal area. Multiplying this value by the site acreage provides an estimate for the annual volume of diffuse recharge at the Arsenal.

- ▶ **Ditch and lake seepage, S :** Seepage has occurred from several surface water bodies (e.g., Lake Ladora, Upper and Lower Derby Lakes, Lake Mary, Havana Pond, First Creek, and from several ditches and canals (e.g., Uvalda Interceptor, High Line Lateral). Flow data from 2005 were available from several locations along the Uvalda Interceptor and First Creek, and at other ditches that enter the site and discharge into one of the on-site lakes.¹ Ditch seepage was estimated by subtracting the sum of the flow out of the ditch and ditch evaporation from the flow into the ditch. Lake seepage was estimated using lake level gauge records, with seepage estimated to be the total volume of water lost in the lake minus the volume lost to evaporation.
- ▶ **Lateral groundwater inflows, GW_{in} :** Groundwater inflows were computed using Darcy's Law (Fetter, 1994) with observed groundwater gradients, estimated aquifer thickness (from fall 1994 measurements), and an estimated hydraulic conductivity of 134 ft/day (Table 5.3). This calculation was undertaken for each section along the groundwater inflow boundary on the southern border of the Arsenal.
- ▶ **Open-water evaporation, E :** Evaporation was measured in on-post lakes at various periods between 1997 and 2005. The surface area of the ditches was estimated assuming an average width of 5 ft. Because no ditch evaporation data were readily available, the same open-water evaporation rate from the lakes was used to estimate the evaporation from the ditches. This likely overestimates ditch evaporation and underestimates aquifer recharge, since ditch water may be shaded by levees and/or vegetation.
- ▶ **Lateral groundwater outflow, GW_{out} :** Groundwater outflow, an estimate of the annual volume of available alluvial groundwater, is computed from each of the other variables (Equation 5.3).

Table 5.6 provides a summary of this example groundwater budget developed for the Arsenal using 2005 seepage data and 1994 groundwater inflow data. Based on these example data, approximately 7,160 acre-feet per year of alluvial groundwater could be extracted from under the Arsenal without depleting the overall groundwater stock and lowering the water table (Table 5.6).

1. Seepage varies annually based on precipitation and ditch usage. Annual precipitation for water year 2005 at the nearby Brighton weather station was roughly 20% lower than the annual average of 13.9 inches per year. More importantly, the High Line Lateral was no longer in use by 2005, after running dry in 2002 and nearly dry in 2003 (Denver Water, 2003). Prior to the 2002 drought, Denver Water provided the Army with 2,800 acre-feet per year in the High Line Lateral, and they estimated that 60-70% of water delivered in High Line seeped into the ground (Denver Water, 2003). Thus, using only 2005 data, the calculated seepage in this groundwater budget is considerably lower than seepage in earlier years.

Table 5.6. Example groundwater budget for the Arsenal, calculating total groundwater outflow. See text for explanation of the components.

Direction of flow	Component	Volume (acre-feet)
Inflow	Diffuse recharge	700
	Lake/ditch seepage	1,990
	Upgradient groundwater	4,820
	Total	7,510
Outflow	Evaporation	350
	Total	350
Alluvial groundwater outflow		
	Total	7,160

To verify that the estimate of approximately 7,000 acre-feet of groundwater recharge using the simplistic groundwater budget above is reasonable, the Trustees examined pumping data from the on-post groundwater containment systems. LaRock (2004) compiled annual pumping data from the Irondale water treatment plant, the Northwest Boundary Containment System, and the North Boundary Containment System from 1997 through 2001 (Table 5.7).

Table 5.7. Annual volume of water (acre-feet) treated at the Arsenal boundary groundwater treatment and containment systems, 1997 to 2001

Year	Irondale treatment plant ^a	North Boundary Containment System	Northwest Boundary Containment System	Total
1997	1,607	301	1,740	3,648
1998	448	310	1,817	2,575
1999	368	310	3,440	4,118
2000	368	319	3,361	4,048
2001	NA	319	1,556	1,875

a. The 1997 volume includes groundwater from the Irondale Containment System and the Motor Pool and Railyard extraction systems. The 1998 volume includes only the Motor Pool and Railyard extraction systems, and the 1999 and 2000 volumes include only the Railyard system.

Source: LaRock, 2004.

The Irondale water treatment plant treated groundwater from the Irondale Containment System along the western boundary of the Arsenal, as well as groundwater from the Motor Pool and Railyard extraction wells upgradient of the boundary. The Irondale Containment System was decommissioned after 1997, when data indicated that there was no longer a contaminant plume leaving the western boundary of the Arsenal. The Motor Pool extraction system was decommissioned after 1998, and the Irondale Treatment System was demolished in 2001.

For this example analysis, discrete volume data from the Irondale Containment System on the western boundary were not readily available. Thus, to estimate the volume of contaminated groundwater leaving the western boundary in 1997 and prior years, the sum of the Motor Pool and Railyard extraction wells in 1998 (448 acre-feet) was subtracted from the total Irondale treatment plant volume in 1997 (1,607 acre-feet), resulting in an estimated volume of 1,160 acre-feet of contaminated groundwater at the Irondale Containment System along the western boundary. In total, approximately 3,000 acre-feet per year are captured in the boundary systems (Table 5.8). The containment systems are intended to capture only the contaminated alluvial groundwater outflows from the Arsenal. Therefore, the volume of annual captured groundwater should be less than (but within the same order of magnitude as) the calculated groundwater outflow for the Arsenal as a whole. Thus, if the boundary systems capture approximately 3,000 acre-feet per year of contaminated alluvial groundwater, the 7,000 acre-feet per year estimate of total alluvial aquifer recharge is reasonable.

Table 5.8. Estimated annual volume of water (acre-feet) at the Arsenal boundary systems in 1997, and the average annual volume from 1998 to 2001

Year	Irondale treatment plant^a	North Boundary Containment System	Northwest Boundary Containment System	Total (rounded)
1997	1,160	301	1,740	3,200
1998–2001	0	310	2,540	2,850

a. The 1997 volume includes groundwater from the Irondale Containment System and the Motor Pool and Railyard extraction systems. The 1998 volume includes only the Motor Pool and Railyard extraction systems, and the 1999 and 2000 volumes include only the Railyard system.

Source: LaRock, 2004.

5.3.5 Temporal extent of injury

Groundwater subject to institutional controls has been unavailable for drinking water use since the signing of the Federal Facilities Agreement in 1989 and the Off-Post ROD in 1995. Unrestricted use of this groundwater will be lost until the institutional controls are lifted or modified, which is not anticipated.

The spatial extent of the contaminated groundwater plume changes over time. The maximum extent of contamination probably occurred immediately before the installation of groundwater treatment plants at the site in the late 1970s and early 1980s. After some 13 years of pumping and treating, the groundwater plume that USGS identified in 1994 (Figures 5.3 to 5.8) was probably smaller than the groundwater plume that existed in 1981 and larger than the current plume.

The plumes should continue to decrease in size; however, a plume of pesticides probably will remain for hundreds of years. As discussed in Chapter 3, the On-Post ROD did not call for complete removal of all sources of hazardous substances to groundwater. In some areas, the ROD called for removal of the upper 5–10 ft of soil, leaving in place many feet of soils and alluvium saturated with organochlorine pesticides (see Chapter 3) that will continue to enter groundwater. Thus, while the spatial extent of groundwater contamination will decrease with time, these areas of pesticide-laden soils will continue to be a source of hazardous substances to the groundwater for the foreseeable future. For these reasons, the groundwater downgradient of these sources is not expected to recover.

As part of this assessment, the Trustees will model the size of the contaminated groundwater plume over time (see Section 5.5).

5.4 Lost Groundwater Services

The releases of hazardous substances at the Arsenal have made thousands of acre-feet of groundwater unavailable for human uses, including municipal, residential, and agricultural uses. This groundwater contamination under and downgradient of the Arsenal removed a potential source of clean, easily obtained water in the semi-arid Front Range. Municipal water supply is the most important service that groundwater provides in the Denver metropolitan area and qualifies as the “highest-and-best use of the injured resource or services” that the NRDA regulations specify should be used for determining damages [43 CFR § 11.84(b)(3)(i)]. This section first describes conditions that would apply to groundwater use at the Arsenal irrespective of the release of hazardous substances. It then describes the importance of municipal water supply as a groundwater service in the Front Range, and summarizes the lost groundwater services at the Arsenal as a result of hazardous substance releases.

5.4.1 Groundwater use considerations at the Arsenal

In considering whether, absent contamination, the groundwater beneath the Arsenal could have been used as a municipal water supply in the past, or could be so used in the future, the Trustees examined physical and institutional, or legal, considerations, including the adequacy of water

quality for potable use, the quantity of water that would have been available (extractable or “safe” yield), and regulatory requirements.

Water quality

As described previously, except for the TCE plume in the southwest corner of the Arsenal (see Figure 5.3), the groundwater upgradient of the hazardous substance sources at the Arsenal is potable (USGS, 1997a, 1997b; Ebasco Services et al., 1989). Therefore, the alluvial groundwater from the Arsenal, which under baseline conditions would have been free of the pesticides and municipal effluent found in South Platte River surface water and alluvium, would not only have been potable, but would have required less treatment than many of the sources of water upon which area providers currently rely for drinking water (Dennehy et al., 1998).

Annual extractable yield and regulatory requirements

Section 5.3 presents an example calculation of approximately 7,000 acre-feet per year of alluvial groundwater that could have been extracted on a sustainable basis from the Arsenal. An approved augmentation plan and compliance with a 600-foot spacing requirement for alluvial wells [CRS 37-90-137(2)] are the only regulatory restrictions on the amount of water that a user can pump from the alluvial aquifer in the vicinity of the Arsenal. The Trustees will continue to examine this issue, but based on current knowledge, these requirements would not have limited the potable use of Arsenal alluvial water.

Extractable yield for not-nontributary water will be calculated during the assessment. As discussed below, augmentation requirements for not-nontributary groundwater are similar or less than those for alluvial groundwater and are therefore not perceived to create impediments to use.

Fewer regulatory requirements apply to the deep aquifer. The State Engineer’s Office permits a pumping rate of 1% of the total available volume per year in deep aquifers, including the Lower Arapahoe and Laramie-Fox Hills aquifers in the vicinity of the Arsenal [2 CCR 402-7, Rule 8A]. Based on a preliminary review of existing data, these aquifers contain nearly 1.9 million acre-feet of deep groundwater that is inaccessible for potable use due to institutional controls (Table 5.5). Of this total, about 750,000 acre-feet are nontributary and 1.15 million acre-feet are not-nontributary. One percent of the nontributary deep groundwater is roughly 7,500 acre-feet per year that could hypothetically be extracted annually but for the institutional controls.

Replacement requirements for tributary groundwater

By definition, tributary groundwater is groundwater that has a direct hydrological connection to a natural stream. The right to use tributary groundwater and the natural streams of the State is governed by the doctrine of prior appropriation, which is constitutionally mandated and codified

in Colorado statutes [Colo. Const. Art. XVI § 5; CRS § 37-92-102]. The doctrine has its origins in the mining industry, and later agriculture, and was driven by the arid climate of the west:

The climate is dry and the soil, when moistened by the usual rainfall, is arid and unproductive; except in a few favored sections, artificial irrigation for agriculture is an absolute necessity. Water in the various streams thus acquires a value unknown in moister climates. Instead of being a mere incident to the soil, it rises, when appropriated, to the dignity of a usufructuary estate, or right of property. [*Coffin v. Left Hand Ditch Co.*, 6 Colo. 443, 446 (1882)].

Usufructuary rights are the rights to use, not own, property. This usufructuary water right derives from the dates of the appropriation and water decree. Appropriation generally occurs when water is diverted through a ditch or well and applied to a beneficial use. The senior appropriator has a superior right to use water over any junior-in-time appropriator, or “first in time, first in right,” assuming the appropriator duly adjudicated the right in water court.

In times of scarcity, a senior appropriator can place a “call” on the river and its tributary groundwater, asking the State Engineer to curtail the junior or undecreed diversion of water that might be interfering with the senior water right holder’s use of allocated water. The Colorado Division of Water Resources (State Engineer’s Office) enforces the decrees and otherwise administers the waters of natural streams. Decrees obtained from the court specify the location of the diversion, the amount of water (expressed as flow in cfs) and the type of beneficial use, as well as any replacement water necessary to protect senior rights.

Most Colorado stream systems, including the South Platte River, are over-appropriated. This means that at times there is not enough water in the stream to satisfy all decreed appropriations [*Hall v. Kuiper*, 510 P. 2d 329, 330 (Colo. 1973)]. In an over-appropriated stream system, the uncontrolled drilling of wells in tributary groundwater has the potential to intercept water necessary to satisfy senior decreed water rights. However, new rights can be decreed in an over-appropriated basin, providing there is no harm to senior appropriators. To prevent such harm to senior users, the junior user augments the supply of water to make up for what is consumed, or “depleted.” Such augmentation must be documented in a plan that describes the source of water to be made available to offset any groundwater depletions, and any return flows that would need to be maintained to avoid injury to senior rights [CRS 37-92-305]. The Water Right Determination and Administration Act of 1969 [CRS 37-92-102 *et seq.*] provides the framework for integrating the administration of tributary groundwater and surface water to prevent groundwater use from injuring senior surface water right holders.

Replacement requirements for nontributary groundwater

Water in the Lower Arapahoe and the Laramie-Fox Hill aquifers is nontributary. The withdrawal of this water does not require judicial approval of an augmentation plan, but the landowner must relinquish the right to consume two percent of the amount withdrawn [CRS § 37-90-137(9)(b); 2 CCR § 402.6, Rule 8 (Denver Basin Rules)]. Withdrawals on the basis of an aquifer life of 100 years are allowed by law [CRS § 37-90-137(4)(b)(I)]. The State Engineer thus permits a withdrawal rate of 1% of the total available volume per year [2 CCR § 402-7, Rule 8A].

Replacement requirements for not-nontributary groundwater

In the vicinity of the Arsenal, the waters in the Denver and Upper Arapahoe aquifers are not-nontributary, as specified by the Denver Basin Atlas. Therefore, the use of this groundwater requires the approval of an augmentation plan similar to that for tributary groundwater. The replacement requirement, however, varies with the location of the well [CRS § 37-90-137(9)(c)]. If the well is greater than one mile from the intersection of the stream alluvium and the aquifer's outcrop, the water user must replace 4% of the amount withdrawn on an annual basis. If the well is within one mile of the intersection of the stream alluvium and the aquifer's outcrop, the applicant must replace the actual amount of depletions. Regardless of the location, the applicant may be required to replace the actual amount of depletions after the groundwater pumping stops.² The rights to this type of groundwater are administered under the Groundwater Management Act [CRS § 37-90-102 *et seq.*].

Application of requirements to Arsenal groundwater

The requirements associated with different types of groundwater could be relevant in quantifying services lost due to hazardous substance releases, and potentially in calculating compensable damages. The shallow alluvial aquifer is tributary to the South Platte River. Therefore, alluvial wells need augmentation plans to ensure that senior rights are not injured. Groundwater users need to augment 100% of depletions, or "net pumping," i.e., water that is not returned to the aquifer at the same time and location as that from which it was pumped. Augmentation is not required for that portion of the tributary groundwater that is pumped and returns to the aquifer ("return flow"), for example, through percolation. The most significant consumptive use of water is irrigation and subsequent evapotranspiration during the growing season.

Unlike groundwater used for irrigation, groundwater pumped for household use is subsequently transported to the municipal wastewater treatment system, and then discharged to the river as treated effluent. In such cases, engineers calculate the effects of groundwater pumping on other

2. From July 1, 2009 to July 1, 2012, post-withdrawal replacement will be mandatory [CRS § 37-90-137(9)(c)(II) and (c.5)].

water users, based on the distance of the alluvial wells from the river, aquifer properties, and other factors. This analysis is presented in an augmentation plan, which also includes sources of water to augment, or replace, any depletions. Treated effluent is a common source of augmentation water for municipalities; water released to the river from the wastewater treatment plant can replace tributary groundwater that was pumped several months prior.

In winter, up to 95% of the water used by a municipality is transported to the wastewater treatment plant. Even during the heaviest usage months of July and August, about 40% is returned to the river through wastewater discharge. For example, the SACWSD augmentation plan [CO District Court W-8440-76] states that 95% of non-irrigation water returns to the river via the wastewater treatment plant, and 48% of lawn irrigation water recharges the aquifer. This 48% is considered return flow, but augmentation will be needed for the rest of the pumped water. Such augmentation water might come from effluent or from surface water rights, storage ponds that capture surface water during high flows, or deep groundwater. These sources of augmentation would only be tapped, however, when there is a call on the river.

According to State records, the South Platte River was often a “free river” from 1981 through 2001, meaning there was enough water for everyone and senior rights holders did not make a call for more water. Well augmentation organizations were able to provide adequate replacement water during this period. Drought conditions in 2002 started a period of nearly continuous calls on the South Platte River (Simpson, 2006). These calls on the river, combined with statutory changes to augmentation requirements, made replacement of depletions more difficult. Section 5.4.2 discusses some of the elaborate plans that have been implemented to allow development of South Platte Basin tributary groundwater resources.

Deep aquifer withdrawals from the aquifers below the Arsenal are subject to the Denver Basin Rules. Withdrawals from the Upper Arapahoe and Denver aquifers (not-nontributary) that are not within one mile of the intersection of stream alluvium and an outcrop require an approved augmentation plan for 4% of the amount withdrawn. If within one mile, 100% of actual depletions need to be augmented. For the lower Arapahoe and Laramie-Fox Hills groundwater (nontributary), a user must return 2% of the amount withdrawn to the South Platte River.

Summary

The following legal and practical conditions must be examined when considering the Arsenal as a potential municipal water supply source:

- ▶ For shallow alluvial groundwater (tributary) and for Upper Arapahoe and Denver groundwater (not-nontributary) within one mile of the intersection of stream alluvium and an outcrop, a user must have an approved augmentation plan to offset all depletions.

- ▶ Tributary groundwater that is pumped and then recharges the aquifer via return flow generally does not require augmentation.
- ▶ Alluvial groundwater placed into a municipal system and returned to the South Platte River or its tributaries via a wastewater treatment plant can be used as a source of augmentation for depletions caused by well pumping.
- ▶ Augmentation water need only be supplied when senior rights are not being satisfied and there is a call on the river.
- ▶ Wells drilled into the shallow aquifer are subject to a 600-foot spacing requirement [CRS 37-90-137(2)].
- ▶ Other than an approved augmentation plan and compliance with the 600-ft spacing requirement, there are no other legal restrictions on the amount of water that a user can pump from the shallow aquifer.
- ▶ For Upper Arapahoe and Denver groundwater (not-nontributary) greater than one mile from the intersection of stream alluvium and an outcrop, a user must have an approved augmentation plan to supply the South Platte River system with 4% of the amount withdrawn.
- ▶ For lower Arapahoe and Laramie-Fox Hills groundwater (nontributary) in the vicinity of the Arsenal, Colorado nontributary groundwater rules allow a property owner to pump 1% per year of the volume of nontributary groundwater underlying the property. The user must relinquish to the South Platte River system 2% of the amount withdrawn.

5.4.2 Water demand in the Front Range

Demand for groundwater in the Front Range is high and growing as the population in the region increases. Water supply sources are finite, and drought in the past decade has reduced surface water supplies and shallow aquifer recharge. The major municipal and industrial water providers in the South Platte Basin are essentially meeting the growing urban and suburban demand (with periodic use restrictions), but many will be at or near their build-out capacity within two decades. To access additional water resources in the future, Front Range municipalities will likely have to go far away at great cost to find additional sources of potable water.

Figure 5.14 shows recent historical and projected growth to 2030 in the Denver Metropolitan Area (MetroDenver EDC, 2006). Between 1990 and 2000, the population of the seven-county Denver Metropolitan Area (Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, and Jefferson counties) grew from 1.8 million to 2.4 million, an increase of 30% (MetroDenver EDC, 2006). By 2030, the population of the Denver Metropolitan Area, which will extend over some 750 square miles, is expected to reach almost four million people.

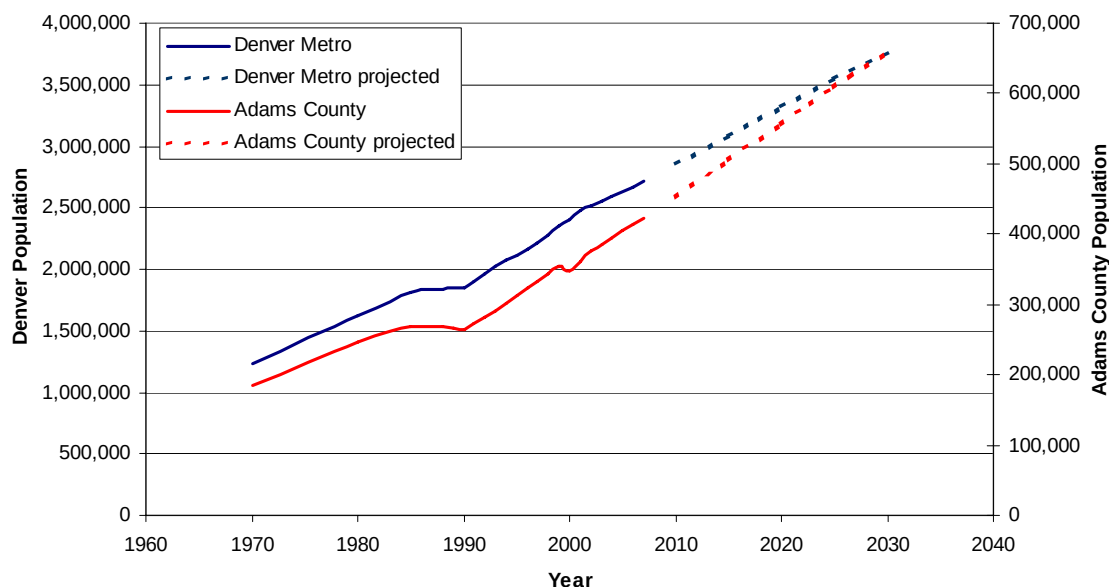


Figure 5.14. Past and projected future population growth for the City of Denver and for Adams County.

Source: MetroDenver EDC, 2006.

The population of Adams County, where the Arsenal is located, is projected to grow even faster (Figure 5.14). The Colorado Demography Section projects growth from an estimated 423,300 people in 2007 to about 660,000 by 2030, a 56% increase (MetroDenver EDC, 2006). Municipalities expected to realize the greatest growth include southern Adams County and the cities of Brighton, Thornton, Aurora, and Denver (DRCOG, 2005).

5.4.3 Efforts to find additional water supply near the Arsenal

Communities in the metropolitan Denver area invest heavily in the acquisition and development of water supplies, the creation of water storage, and distribution of water from the source area to the metro Denver area. Below are examples of projects in which communities near the Arsenal

have participated. Given the effort and expense of these projects, it is clear that clean groundwater under the Arsenal in the past would have been, and in the future would continue to be, attractive to Front Range water suppliers.

- ▶ In 1982, Denver and 47 water providers in Denver, Adams, Arapahoe, Douglas, and Jefferson counties entered into the Metropolitan Water Development Agreement (MWDA) to design and construct water projects to meet increasing water demands. MWDA proposed the Platte and Colorado River Project Participation Agreement, also known as the Two Forks Project, in 1986, at a cost of \$1 billion. The EPA vetoed the project, and the MWDA was forced to seek other alternative water supplies.
- ▶ Aurora is constructing the Prairie Waters Project (Figure 5.15), which will deliver 10,000 to 15,000 acre-feet per year at a capital cost of \$800 million (Russell and Serlet, 2007). The project will be paid for, in part, by increasing user fees and tap fees.
- ▶ Brighton and SACWSD plan to acquire additional surface rights and to drill more alluvial wells to meet anticipated growth in demand. Water providers in both communities plan to meet augmentation requirements using surface water rights, including the Burlington Ditch, Fulton Ditch, and Wellington Reservoir (Leonard Rice Engineers, 2001; BBA, 2004). Brighton and SACWSD are two examples of water providers who use their surface water rights for augmentation in order to use alluvial groundwater in the South Platte River Basin as a drinking water supply.
- ▶ In 2004, Denver Water completed a 30-million gallon per day water recycling plant that treats wastewater for non-potable uses. The initial (Phase I) cost of the project was \$95 million, including the infrastructure to deliver the water from the plant. When completed, the recycling plant will produce almost 19,000 acre-feet per year of reclaimed water for landscape irrigation, fire protection, and industrial and commercial uses (Denver Water, 2007). The Public Service Company plant located just a few miles west of the Arsenal uses about 5,400 acre-feet per year of the reclaimed water.
- ▶ To offset declines in the productivity of the Arapahoe aquifer in the South Metropolitan Denver area, East Cherry Creek Valley (ECCV) and other members of the South Metro Water Supply Authority will spend approximately \$150 million for water rights and initial construction of the Northern Water Project (Figure 5.16; ECCV, 2007). The initial phase of the project, called the H2'06 Project, includes the purchase of rights to 3,000 acre-feet per year of South Platte River water for \$45 million. Water will be stored in Beebe Draw, near Barr Lake (Figure 5.16). The cost to build two pumping stations and a 31-mile pipeline to deliver the water from Beebe Draw to ECCV is \$74 million.

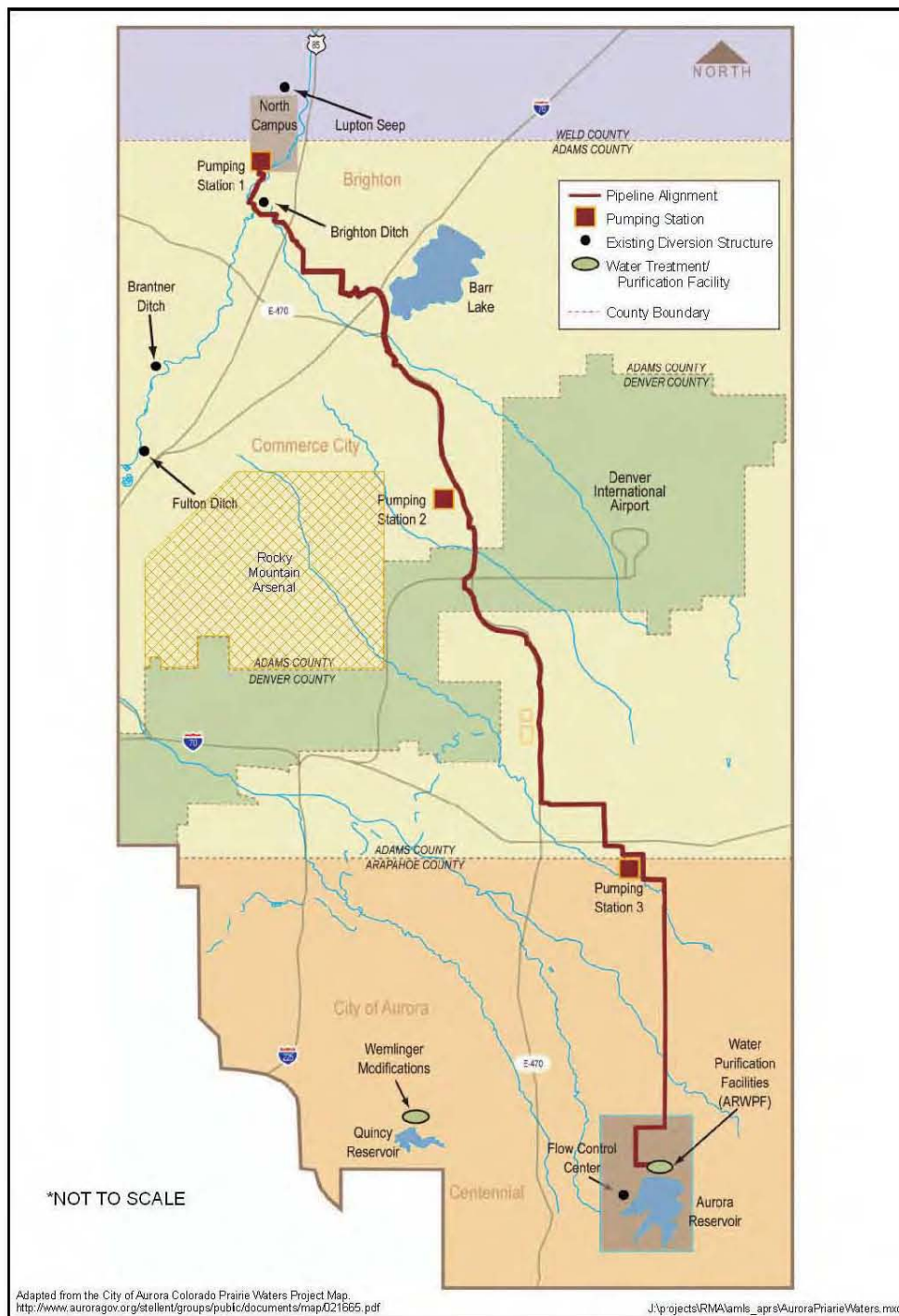


Figure 5.15. Aurora's Prairie Waters Project, currently under construction. South Platte River ditch and tributary groundwater will be pumped 38 miles south to the Aurora Reservoir.

Source: City of Aurora, 2007.

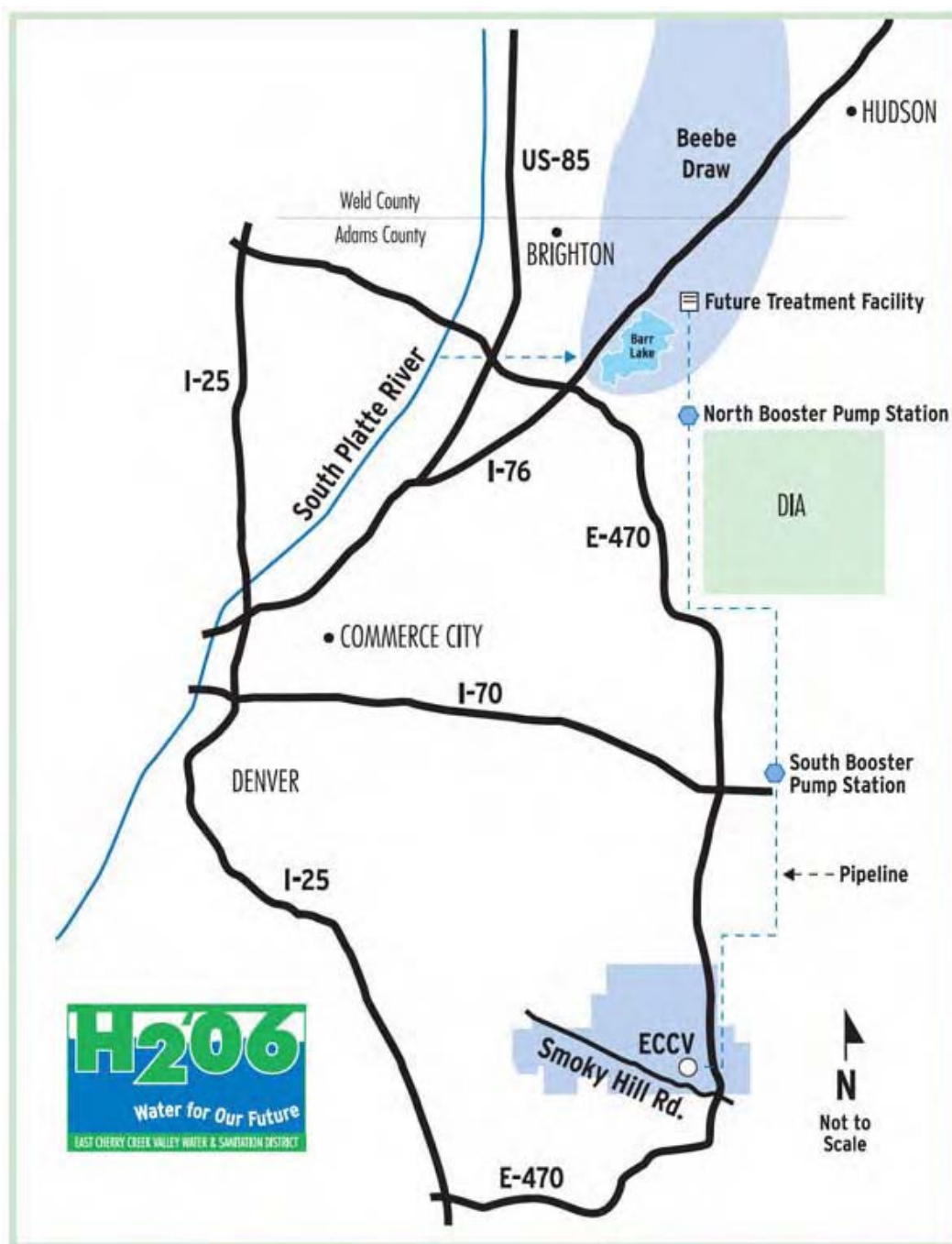


Figure 5.16. ECCV H2'06 project map. ECCV will store water in Beebe Draw and transport it south via a pipeline passing by the east boundary of the Arsenal.

Source: ECCV, 2007.

The scarce water supply in the Front Range requires water providers to encourage or require water conservation. Most water providers in the Denver Metropolitan Area provide their customers with educational materials on voluntary water conservation. In response to the 2002–2003 drought, when water levels in many reservoirs dropped to 50% or less of capacity, many Front Range cities, including Arvada, Aurora, Boulder, Brighton, Broomfield, Castle Rock, Centennial, Colorado Springs, Denver, Englewood, Erie, Ft. Collins, Golden, Greeley, Lafayette, Lakewood, Northglenn, South Adams County (Commerce City), Thornton, and Westminster enacted restrictions on water use (CSU, 2003). Water restrictions, for at least part of the summer, have become common since then (e.g., CSU, 2006).

In 2003, the Colorado Water Conservation Board (CWCB) commissioned the Statewide Water Supply Initiative to examine water supply needs in Colorado through the year 2030. For the South Platte River Basin, the study reported that water acquisition and conservation projects that water providers are implementing or planning to implement will meet approximately 80% of the projected water needs through 2030 (CWCB, 2004). Water providers in the South Platte River Basin plan to meet the increased demand with a combination of solutions, including conservation, water reuse, water transfers, enlargement of storage facilities, purchase of additional rights (including transfers from agricultural use), and new facilities (Table 5.9; CWCB, 2004). Figure 5.17 shows how far water providers reach to bring water to the Front Range. Even after accounting for all these projects, the CWCB concluded that a shortfall of some 90,600 acre-feet per year will remain, and water providers continue to search for solutions to address the projected shortfall.

5.4.4 Lost water supply services

Absent the presence of hazardous substances, groundwater underlying the Arsenal would have been an attractive water supply to surrounding communities, particularly because:

- ▶ Groundwater-derived water supply is more reliable and of higher quality than many other sources (Dennehy et al., 1998)
- ▶ Many water providers near the Arsenal already have surface water rights to use as augmentation to offset withdrawals from the Arsenal (e.g., SACWSD augmentation plan, [CO District Court W-8440-76])
- ▶ The Arsenal is much closer to existing water distribution systems than other sources of water that are currently being acquired and that have been acquired in the past (Figure 5.16).

Table 5.9. Selected plans to meet future water supply needs in the Front Range

Provider	Plans and processes	Source
Aurora	Prairie Waters Project: gravel storage near Brighton using existing rights; collector wells will recover the water from the alluvium; water will be pumped by three new pumping stations 34 miles to Aurora, then treated at a new facility near the Aurora Reservoir.	City of Aurora, 2007
Brighton	Purchasing land for augmentation water storage in Beebe Draw. Seeking additional storage in Chatfield Reservoir. Using lined gravel pits for storage along South Platte River. Applying in Water Court for augmentation plans that will allow pumping from alluvial wells. Well withdrawals will be augmented during times of river calls using municipal wastewater return flows, storage releases, and retired senior agricultural water rights. Constructing non-potable irrigation systems in parks.	City of Brighton, 2007
Denver	Seeking additional storage to maximize use of existing rights from Fraser River (Moffat Firming Project). Using lined gravel pits for storage along South Platte River. Constructed a Recycle Plant to treat wastewater for industrial use and non-potable irrigation water.	Denver Water, 2002, 2007; CWCB, 2004
Northglenn	Seeking additional storage to maximize use of existing rights.	CWCB, 2004
SACWSD	Plans to acquire additional surface rights and to drill more South Platte River alluvial wells. With Denver, using lined gravel pits for storage along South Platte River.	Denver Water, 2002
Thornton	Using gravel pits to develop water by either exchange or pump back. Applying in Water Court for augmentation plans that will allow pumping from alluvial wells. Planning construction of non-potable irrigation systems in parks.	CWCB, 2004; USACE, 2007
Westminster	Using lined gravel pits for storage. Expanding reclaimed water system. Transferring agricultural water rights.	CWCB, 2004
South Metro (providers in Arapahoe, Douglas, and Elbert counties)	Most municipalities and water district reliant on non-renewable deep groundwater. Most seeking renewable water supplies, including surface water and tributary groundwater. Examples: ECCV is purchasing South Platte River water rights and constructing a water treatment facility, pumping facilities, and pipelines (ECCV, 2007). Part of the water will be stored in Beebe Draw until needed, pumped from the ground, treated in the new facility near Barr Lake and Brighton, and pumped 31 miles south to the ECCV. Members of the South Metro Water Supply Authority, which serves adjacent communities, also joined the project. Parker Water and Sanitation District is constructing the Rueter-Hess Reservoir, intended to increase reliability of aquifers by storing surplus water and re-injecting this water into aquifers during non-peak demand. Parker has filed an application in Water Court to divert water from the South Platte River near Sterling and to pipe the water over 80 miles to Parker.	CWCB, 1999, 2004; Parker Water & Sanitation District, 2005; Kaunisto and Mullenix, 2006

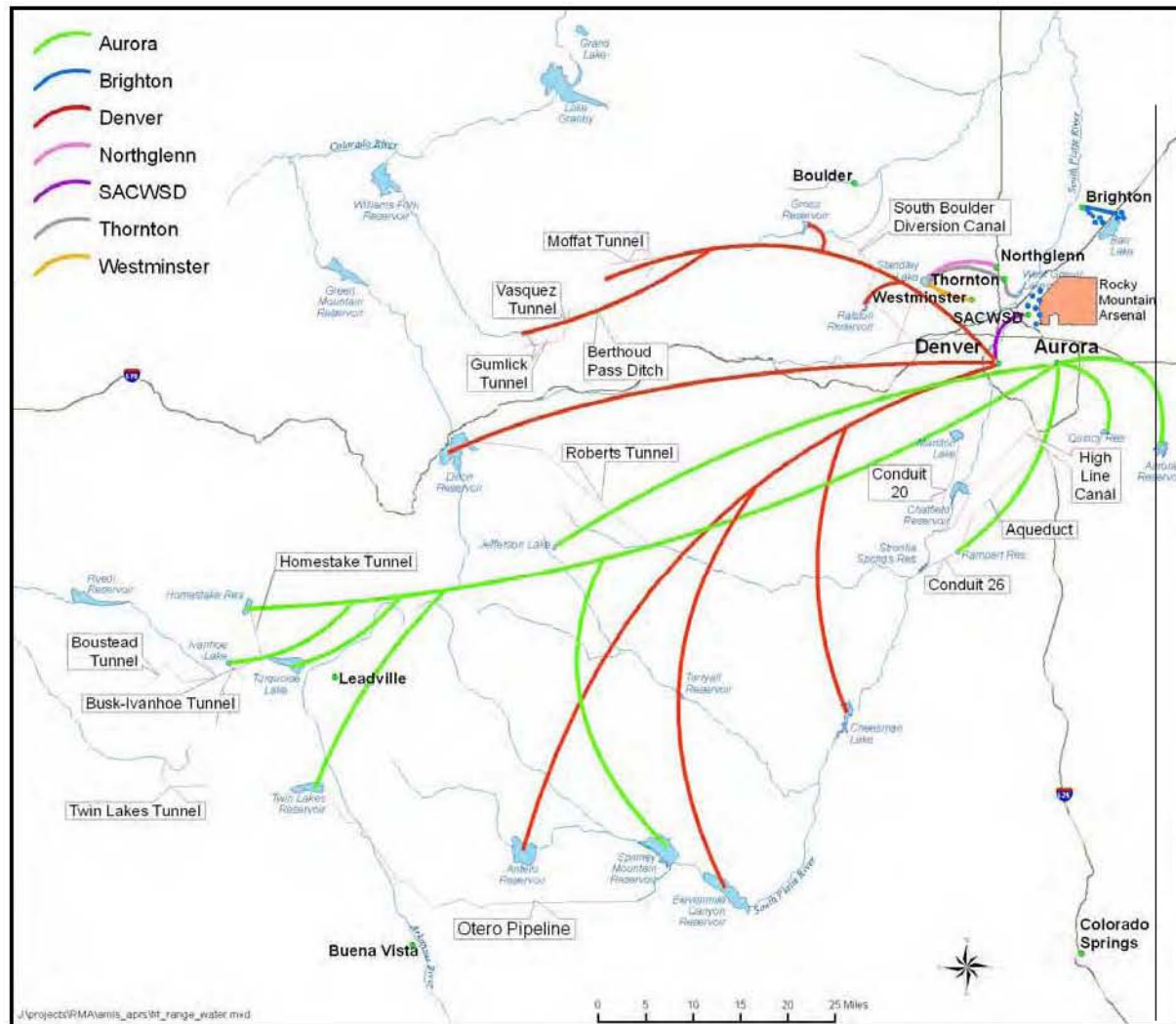


Figure 5.17. Examples of the distance that communities near the Arsenal have gone to obtain reliable water supplies.

When the Denver wastewater treatment plant contaminated Thornton's well field in the 1980s, Thornton's replacement water was surface water of impaired quality, stored in lined gravel ponds where the water could evaporate. Aurora and ECCV are spending tens of millions of dollars to pump alluvial groundwater from well fields near the Arsenal. For these municipalities, clean alluvial groundwater from the Arsenal would likely have been an attractive water source.

Groundwater in the immediate vicinity of the Arsenal (but unaffected by the releases of hazardous substances from the Arsenal) is currently in high demand. Figure 5.18 shows municipal wells near the Arsenal, as listed in the State Engineer's database. Although it is not known how many of the wells shown in Figure 5.18 are actively pumped, the map demonstrates that the groundwater in this area is a popular water source. Verification of the use of the wells shown in Figure 5.18 may be conducted as part of the assessment.

These facts demonstrate that there is and has been great demand for groundwater, particularly shallow alluvial groundwater, in the vicinity of the Arsenal. Despite the fact that surface water in the South Platte River Basin is over-appropriated, water providers in the basin have plans for securing water and for augmentation that will allow them to continue to meet consumer demands by developing additional tributary groundwater.

5.5 Anticipated Assessment Activities

The preliminary evaluation of groundwater injury described in Sections 5.2 and 5.3 is based on a USGS interpretation of the extent of plumes of hazardous substances in water year 1994. To help estimate injuries prior to and after 1994, additional groundwater modeling may be undertaken. Several other tasks may also be undertaken in this assessment to further quantify groundwater injury at the Arsenal. Depending on the modeling approach selected, the following tasks may be performed:

- ▶ Develop a groundwater distributed-parameter flow and transport model to calculate the spatial extent of groundwater injury in the past, present and future. This approach would use a model using the MODFLOW/MT3D or MODFLOW-SURFACT flow and transport codes, parameterized with site-specific hydrologic and chemical data. A MODFLOW-based groundwater model would likely provide the most robust tool for extrapolating the groundwater plume forward and backward in time when observational data are limited or unavailable.
- ▶ Develop a hazardous substance plume degradation/decay model to estimate the future spatial extent of groundwater injury. This empirical approach would rely on observed plume trends over time.

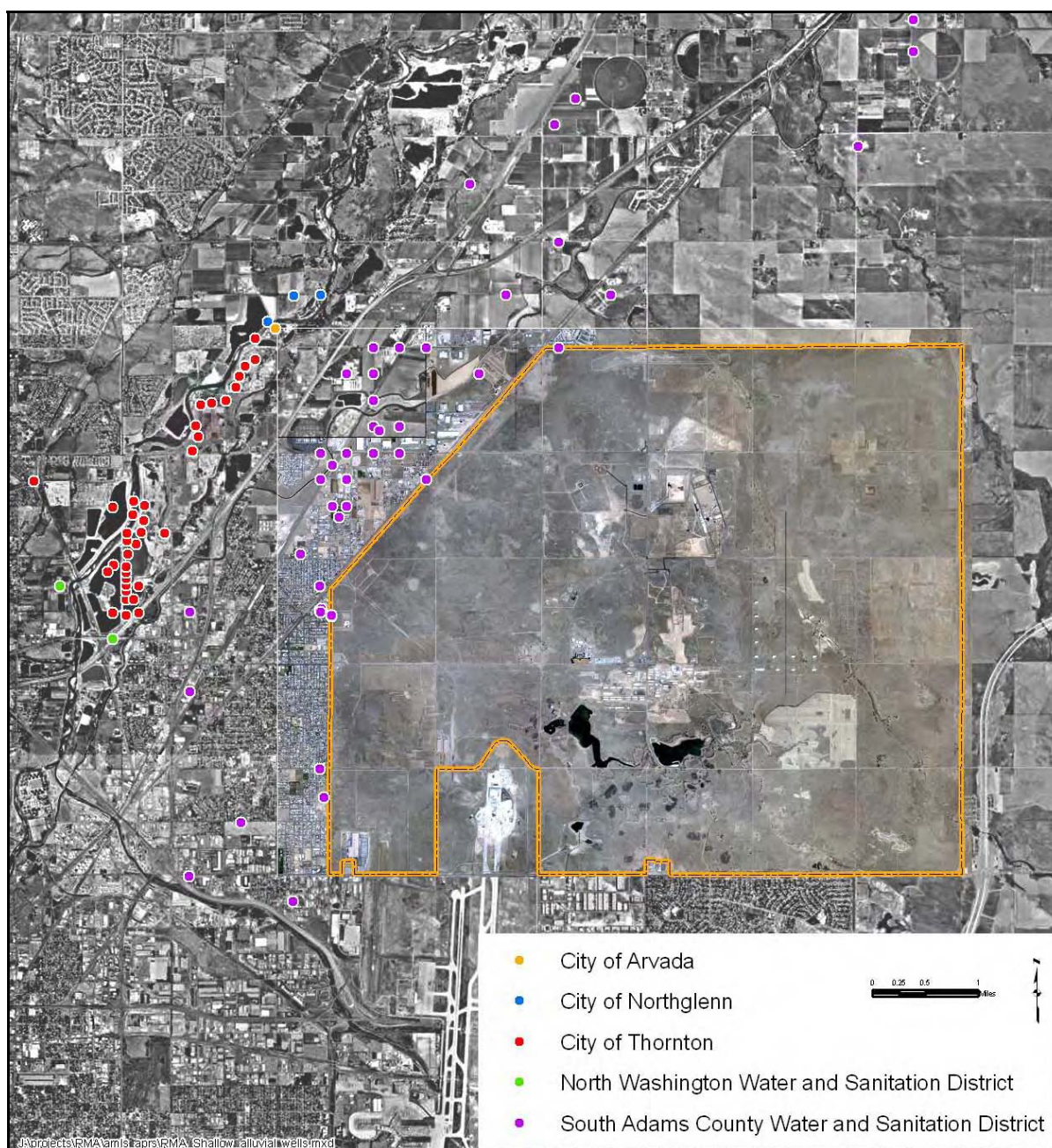


Figure 5.18. Wells near the Arsenal owned by municipal water suppliers. Data from the State Engineer's Office database. It is not known how many of these wells are currently in production. The assessment may include verifying the State Engineer's well data in this area.

- ▶ Evaluate groundwater contamination data collected since 1994 to estimate more recent contaminant plume and to calibrate any models of the plumes.
- ▶ Evaluate contaminated groundwater in the weathered upper Denver formation that is connected to and contaminated by the alluvial aquifer but is not included in preliminary estimates of groundwater contamination.
- ▶ Refine the estimate of alluvial groundwater that would have been available for municipal use absent the releases of hazardous substances and institutional controls:
 - Calculate the appropriate size of a buffer surrounding contaminant plumes
 - Calculate the annual recharge to the alluvial aquifer.
- ▶ Refine the estimates of nontributary and both categories of not-nontributary groundwater that would have been available for municipal use absent the releases of hazardous substances and institutional controls, and determine safe yields for each.
- ▶ Further delineate past, existing, and future uses of groundwater at and downgradient of the Arsenal.
- ▶ Determine whether deep groundwater was exposed to hazardous substances; and if so, quantify the affected volume.

Other activities related to quantification of groundwater injuries may occur as part of this assessment. If the Trustees decide to make substantial changes to this plan, such as conducting new sampling, a revision to this Plan will be made available for comment.

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6. Injuries to Biological Resources

This chapter reflects the State Trustees' current understanding regarding injury to biological resources at the Arsenal, and identifies proposed approaches for completing an injury assessment for these resources.

Biological resources are defined in the DOI regulations as “those natural resources referred to in Section 101(16) of CERCLA as fish and wildlife and other biota. Fish and wildlife include marine and freshwater aquatic and terrestrial species; game, non-game, and commercial species; and threatened, endangered, and State sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms not listed in this definition” [43 CFR § 11.14 (f)].

Outside the central facilities area, the Arsenal consists largely of undeveloped, open grassland. Approximately 20% of the site is currently native grassland, and the rest of the area consists of exotic grasses and forbs, wetlands, riparian woodlands, intermittent streams, and permanent lakes (USFWS, 1997). A wide variety of wildlife use or inhabit the site and has been exposed to contamination. Wildlife at the Arsenal includes fish, reptiles, amphibians, small and large mammals, and more than 200 species of birds (Environmental Science and Engineering, 1989). Injured wildlife includes species that are resident at the site year-round and migrant species that use other habitats outside the Arsenal. Migrants include local migrants such as red fox and coyotes, seasonal migrants such as over-wintering bald eagles, and short-term migrants that use the site during annual migrations.

Section 6.1 of this chapter provides a summary of conclusions. Section 6.2 describes biological resources at the site. Section 6.3 presents relevant injury definitions from the DOI NRDA regulations and their application to the Arsenal. Section 6.4 discusses baseline conditions at the Arsenal. Section 6.5 describes approaches for determining injury for different biological resources. Section 6.6 presents preliminary information relevant for injury quantification. Section 6.7 describes the State Trustees' planned assessment activities, and references are included at the end of this chapter.

6.1 Summary of Conclusions

As described in preceding chapters, much of the habitat at the Arsenal was historically contaminated with elevated concentrations of hazardous substances in soil, surface water, and sediments. In addition, exposure to highly contaminated wastes in disposal basins such as Basin F proved acutely lethal to thousands of waterfowl. Contaminants include the toxic pesticides aldrin, DBCP, dieldrin, endrin, and isodrin. Prior to remediation, the pesticide dieldrin was

detected in surface soils across most of the Arsenal property (Rocky Mountain Arsenal Environmental Database, as described in Potomac Research International, 2006). The highest concentrations of dieldrin were found in the central area (Figure 6.1). Remediation of these areas, in accordance with the 1996 ROD, is anticipated to be complete in 2010.

The PASD and other preliminary observations indicate that injuries at the site include wildlife mortality, sub-lethal adverse effects, gamebird exceedences of U.S. Food and Drug Administration (FDA) safe levels for dieldrin, and exceedences of water quality criteria that are indicative of injuries to aquatic biota. These injuries have been reduced but not eliminated by past and ongoing remediation efforts. When completed, the remediation is expected to prevent any future biota exposures to harmful concentrations of hazardous substances.

In addition to injuries due to contamination exposure, some of the remedial activities themselves have caused injury, such as the construction of “biota barriers” to protect burrowing mammals from exposure to contamination in soils, and the excavation of borrow areas for the construction of landfill caps. Anticipated future assessment activities would expand the injury determination and quantify injuries and ecological service losses at the Arsenal.

Injury quantification will be used as inputs for a habitat equivalency analysis (HEA) or a resource equivalency analysis (REA), as described in Chapter 8. These approaches will allow the Trustees to determine the amount of restoration required to compensate for natural resource injuries at the Arsenal.

6.2 Biological Resources at the Arsenal

The Arsenal is located in the shortgrass prairie “ecoregion” in the Great Plains. The shortgrass prairie extends east from the Rocky Mountains and south from Montana into the high plains of Oklahoma, New Mexico, and Texas (Samson et al., 1998), and is characterized by ankle-high vegetation dominated by the characteristic grasses blue grama and buffalo grass. At a regional level, shortgrass prairie habitat is threatened by land conversion for urban development and agriculture (Neely et al., 2006). The Arsenal contains locally important habitat because of the extensive urban development that surrounds the site.

Within the Arsenal, there are three major habitat categories that each support different types of biological resources: upland prairie, perennial and intermittent surface water, and wetlands and riparian woodlands (Figure 6.2). The vast majority of the site (15,065 acres; 89% of total) is covered by prairie-type habitat, including weedy forbs and grasses, native perennial grasses, and shrubland/succulents. The area of surface water is limited (158 acres, 0.9%), but provides important habitat for waterfowl and other wildlife. Wetlands and riparian woodlands also cover a small area of the site (4%), but provide key habitat for wildlife, including large cottonwoods that are used as winter roosting sites for bald eagles (Table 6.1).

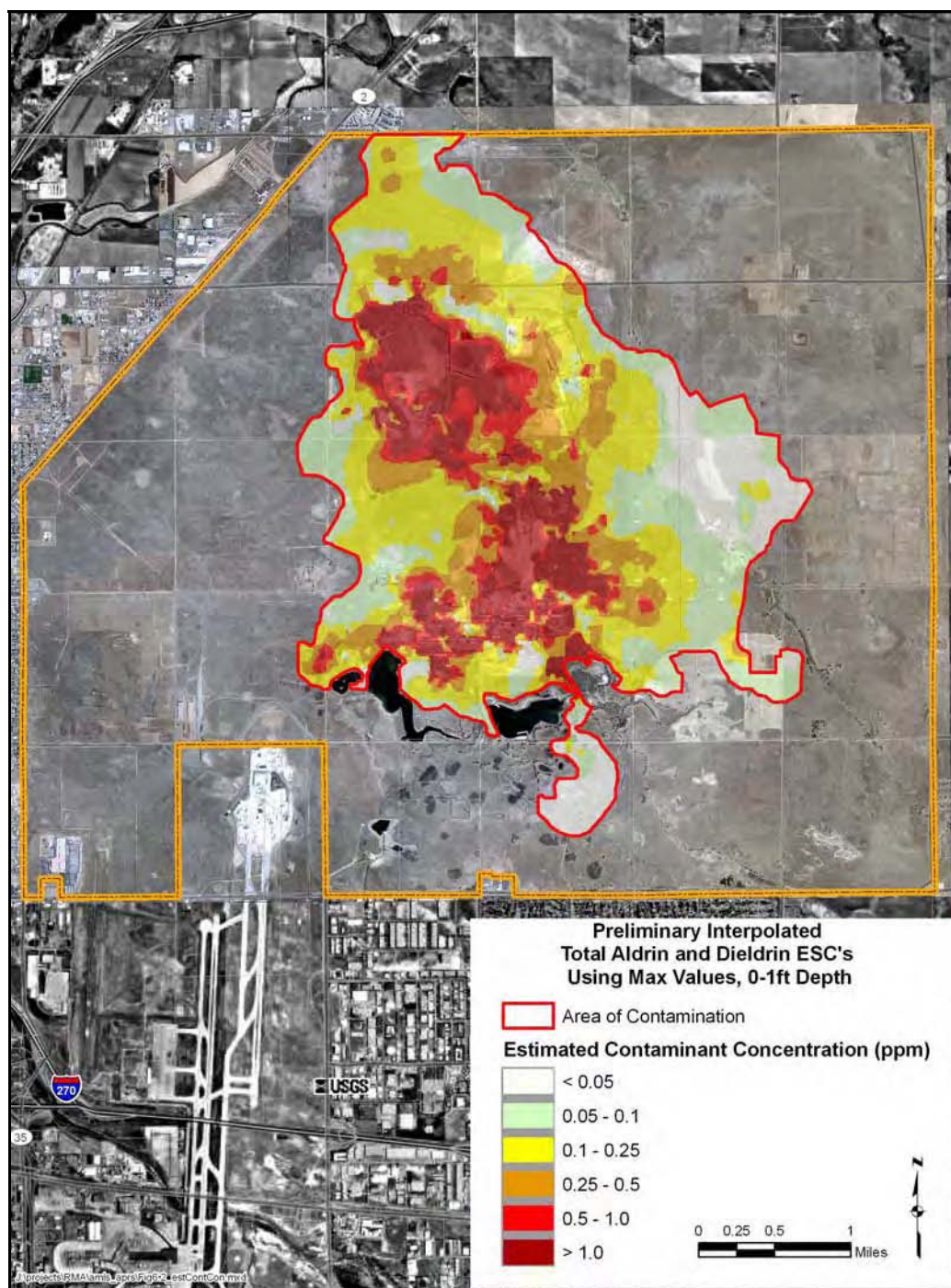


Figure 6.1. Estimated concentrations of aldrin and dieldrin in soils at the Arsenal before remediation.

Source data: BAS, 2002, Figure A1.6-2.

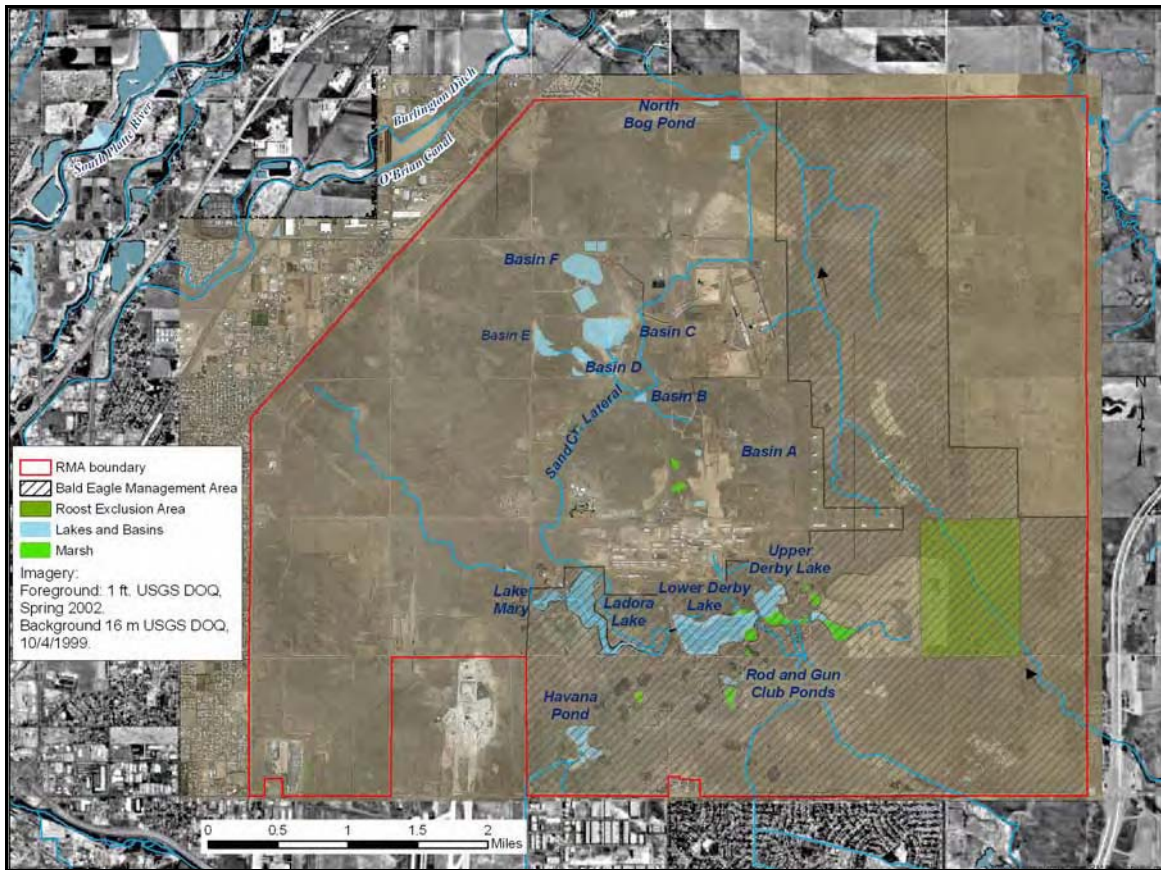


Figure 6.2. Map of the Arsenal showing major habitat features.

Table 6.1. List of habitat types at the Arsenal with associated acreages and percent of total area

Habitat type	Acres	Percent of site
Weedy forbs/grasses	10,002.1	58.9%
Native perennial grasses	4,032.3	23.8%
Shrubland/succulents	1,030.5	6.1%
Disturbed	458.2	2.7%
Wetlands	434.7	2.6%
Unclassified (e.g., Section 9 runway)	356.5	2.1%
Riverine/riparian	258.5	1.5%
Upland trees	240.6	1.4%
Lacustrine	157.9	0.9%
Total	16,971.3	100%

Source: Adapted from USFWS (1999).

6.2.1 Upland prairie

The upland prairie at the Arsenal includes areas classified as weedy forbs and grasses, native perennial grasses, and shrubland/succulents. Resident or migrant species found in upland prairie habitat at the Arsenal include a wide variety of birds, reptiles, and mammals (Table 6.2).

Table 6.2. Examples of species found in prairie habitat at the Arsenal

Wildlife category	Functional group	Species
Birds	Raptors	Bald eagle, sharp-shinned hawk, Cooper's hawk, Swainson's hawk, red-tailed hawk, ferruginous hawk, golden eagle, American kestrel, merlin, prairie falcon
	Breeding songbirds	Western meadowlark, horned lark, grasshopper sparrow, vesper sparrow, lark sparrow, lark bunting
	Game birds	Pheasant, mourning dove
	Migrants	Brewer's sparrow, clay-colored sparrow, Cassin's sparrow, chestnut-collared longspur
Reptiles	Snakes	Bull snake, rattlesnake, hognose snake
Mammals	Rabbits and hares	Eastern cottontail, desert cottontail, black-tailed jackrabbit
	Rodents	Black-tailed prairie dog, Northern pocket gopher, many species of mice and voles
	Carnivores	Coyote, red fox, least shrew, badger
	Ruminants	Mule deer, white-tailed deer
Sources: Morrison-Knudsen Environmental Services, 1989b; Denver Audubon Society, 1994; USFWS, 1994a, 1994b.		

6.2.2 Perennial and intermittent surface water

Both perennial and intermittent bodies of water exist on or flow across the Arsenal (Figure 6.2). The Lower Lakes at the Arsenal (also called the "south lakes") are man-made: they include Lakes Mary, Ladora, Upper Derby, Lower Derby, and Rod and Gun Club Pond(s). Two natural ponds are also found on the Arsenal: North Bog Pond is on the northern edge of the Arsenal, and Havana Pond is on the southern edge. First Creek is the only natural stream at the site, but many man-made canals, including the Highline Lateral, Sand Creek Lateral, Uvalda Interceptor, and Havana Interceptor, also transported water at the site. First Creek is 5.9 miles long and is semi-perennial, with 39 acres of associated wetlands. It flows during the majority of the year in non-drought years (Ebasco Services et al., 1989), and discharges to O'Brian Canal approximately one-half mile north of the site. The creek and its associated wetland area pre-date the Arsenal. The size of the wetland and open water areas fluctuates based on hydrologic conditions and on manipulations by site personnel. Some of the wetland areas are ephemeral, particularly in dry years.

The water bodies on the Arsenal currently support a variety of organisms (Table 6.3). Phytoplankton, micro- and macro-zooplankton communities, and other aquatic plants known as macrophytes, as well as invertebrates, fish, and birds, are found in the Lower Lakes (BAS, 2003). Aquatic plants help provide habitat for aquatic invertebrates, fish, and water birds. Aquatic invertebrates are an important food source for fish, amphibians, reptiles, and birds. Fish populations at the Arsenal are primarily maintained by USFWS stocking from off-site hatcheries, although some species are able to reproduce. Reptiles, amphibians, waterfowl, and wading birds also make use of surface water resources at the Arsenal.

Table 6.3. Examples of species found in perennial and intermittent surface water at the Arsenal

Organism category	Species
Aquatic plants	American pondweed, leafy pondweed, sago pondweed, water-milfoil, watercress, water plantain, arrowhead, sedges, rushes, cattail, coontail
Aquatic invertebrates	Snails, dragonflies, damselflies, midges, crayfish
Fish	Rainbow trout, largemouth bass, smallmouth bass, northern pike, black crappie, bluegill, channel catfish, black bullhead, green sunfish, carp, yellow perch
Reptiles	Bullsnake, western hognose snake, common garter snake, western terrestrial garter snake, yellow-bellied racer, plains garter snake, rattlesnake, lesser earless lizard, short-horned lizards, many-lined skink
Birds – waterfowl	Canada goose, mallard, gadwall, blue-winged and green-winged teal, pintail, wigeon, shoveler, redhead, canvasback, ring-necked duck, lesser scaup, common goldeneye, bufflehead
Birds – wading birds	Great blue herons, black-crowned night herons, white pelican
Amphibians	Tiger salamander, plains spadefoot toad, Woodhouse's toad, striped chorus frog, bullfrog, northern leopard frog
Sources: Morrison-Knudsen Environmental Services, 1989a, 1989b; USFWS, 1994a; BAS, 2003.	

6.2.3 Wetlands, riparian woodland, and upland trees

For the purpose of this Assessment Plan, wetlands and riparian woodland habitat are distinguished from surface water areas. Substantial overlap of wildlife species is expected between the two habitat types because fluctuations in surface water levels can result in areas classified as surface water taking on the characteristics of wetlands. The wetlands and riparian woodland habitats currently support a variety of resident and migrant semi-aquatic and terrestrial organisms (Table 6.4). Migrant diversity through woodlands and upland groves is high: 33 migrant bird species have been noted, with yellow-rumped and yellow warblers, house wrens, and chipping sparrows the most common (Morrison-Knudsen Environmental Services, 1989b). Riparian woodland habitat includes large galleries of cottonwoods along intermittent stream channels and ditches. This habitat is somewhat rare in arid prairie environments and is very valuable for the over-wintering bald eagles that use the trees as roosts (USFWS, 1992).

Table 6.4. Examples of species found in wetlands, riparian woodland, and upland tree habitat at the Arsenal

Wildlife category	Habitat	Species
Birds	Wetlands	White pelican, double-crested cormorant, avocet, killdeer, sandpiper, white-faced ibis, migrant rail, migrant Wilson's phalarope, great blue heron, black-crowned night-heron, bobolink, marsh wren sandpiper, herring gull, ring-billed gull, Franklin's gull
	Marshes and wet meadows	Common yellow throat, red-winged blackbird, yellow-headed blackbird, song sparrow, grebe, American coot, common snipe, Virginia and sora rail, Canada goose, and a variety of ducks
	Riparian woodlands and upland groves	House wren, yellow-rumped and yellow warbler, chipping sparrow, American goldfinch, yellow-billed cuckoo, common nighthawk, downy woodpecker, western wood-peewee, violet-green swallow, blue jay, black-capped chickadee, gray catbird, red-eyed vireo, warbling vireo, black-headed grosbeak, blue grosbeak, indigo bunting, lazuli bunting, rufous-sided towhee
	Upland groves	Northern flicker, western kingbird, eastern kingbird, black-billed magpie, American robin, northern mockingbird, loggerhead shrike, lark sparrow, starling, Brewer's blackbird, common grackle, northern oriole, lesser goldfinch, house finch, house sparrow
Amphibians	Wetlands, floodplains	Northern chorus frog, great plains toad
Mammals	Riparian woodlands	Eastern cottontail, white-tailed deer, red fox, raccoon, fox squirrel, beaver, muskrat, badger, mink, and weasel
Reptiles	Wetlands and moist areas	Common garter snake, western terrestrial garter snake, western box turtle, racer snake, common and plains garter snake
Sources: Morrison-Knudsen Environmental Services, 1989b; USFWS, 1992		

In addition, a small area of upland trees (241 acres; 1.4%) was planted at the Arsenal by settlers. A number of bird species nest in this habitat (Table 6.4).

6.3 Injury Definitions

DOI regulations state that “an injury to a biological resource has resulted from the . . . release of a hazardous substance if the concentration of the substance is sufficient to:

- ▶ Cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)]

- ▶ Exceed action or tolerance levels established under section 402 of the Food, Drug and Cosmetic Act, 21 USC 342, in edible portions of organisms [43 CFR § 11.62(f)(1)(ii)]
- ▶ Exceed levels for which an appropriate State health agency has issued directives to limit or ban consumption of such organism [43 CFR § 11.62(f)(1)(iii)].

The DOI regulations then go on to state that an injury can be demonstrated “if the biological response under consideration can satisfy all of the following acceptance criteria” [43 CFR § 11.62(f)(2)]. These criteria are:

- ▶ The biological response is often the result of exposure to . . . hazardous substances . . . [43 CFR § 11.62(f)(2)(i)]
- ▶ Exposure to . . . hazardous substances is known to cause this biological response in free-ranging organisms . . . [43 CFR § 11.62(f)(2)(ii)]
- ▶ Exposure to . . . hazardous substances is known to cause this biological response in controlled experiments . . . [43 CFR § 11.62(f)(2)(iii)]
- ▶ The biological response measurement is practical to perform and produces scientifically valid results . . . [43 CFR § 11.62(f)(2)(iv)].

In addition, DOI regulations list a number of biological responses that satisfy the criteria stated above. For the injury category of death, “biological responses” that meet the criteria for demonstrating that death resulted from exposure to hazardous substances include [43 CFR § 11.62(f)(4)(i)]:

- ▶ Brain cholinesterase (ChE) enzyme activity that has been inhibited by at least 50% compared to the mean for normal brain ChE activity for the wildlife species
- ▶ Wildlife kill investigations that indicate increased number of dead or dying birds or mammals
- ▶ Laboratory or field toxicity testing that reveals increased mortality.

For the injury category of behavioral abnormalities, the relevant biological response that has been found to meet the criteria is [43 CFR § 11.62(f)(4)(iii)]:

- ▶ Increased clinical behavioral signs of toxicity in the exposed population.

For the injury category of physiological malfunctions, the biological responses that have been found to meet the criteria include [43 CFR § 11.62(f)(4)(v)]:

- ▶ Eggshell thinning resulting from the adult bird having assimilated the hazardous substance
- ▶ Reduced avian reproduction
- ▶ ChE enzyme inhibition
- ▶ Delta-aminolevulinic acid dehydratase (ALAD) inhibition.

For the injury category of physical deformation, the biological responses that have been found to meet the criteria include [43 CFR § 11.62(f)(4)(vi)]:

- ▶ Overt external malformations
- ▶ Skeletal deformities
- ▶ Internal whole organ and soft tissue malformation
- ▶ Histopathological lesions.

In addition, according to DOI regulations, “injuries that are reasonably unavoidable as a result of response actions taken or anticipated” at a site are natural resource injuries for which damages can be recovered [43 CFR § 11.15(2)(1)]. Chapter 3 discussed response actions and remediation activities at the Arsenal. Section 6.5.4 provides a preliminary analysis of how specific response actions and remediation activities at the Arsenal have injured biological resources.

6.4 Baseline

For the purposes of defining injuries to biological resources, the baseline condition for the Arsenal is assumed to be a clean Army facility converted to a Wildlife Refuge. It is assumed the Refuge would have been created regardless of whether hazardous substances were released. Because baseline is assumed to be the Arsenal facility absent the releases of hazardous substances, impacts to wildlife from facilities and infrastructure on-site will not be included as part of the biological resource injury assessments. Only wildlife and habitat injuries resulting from the releases of hazardous substances and responses to those releases will be quantified. This assumption recognizes that the Arsenal was an industrial facility developed in a location with a history of agricultural use. Infrastructure such as buildings and roads reduced or eliminated wildlife habitat regardless of hazardous substance releases, while other infrastructure

such as surface water impoundments may have increased wildlife diversity. Under baseline conditions, it is assumed that this infrastructure would have existed with no releases of hazardous substances.

To evaluate injuries to wildlife from the hazardous substance releases, the Trustees may compare Arsenal data to data from control sites that represent baseline conditions. For example, evaluations of body burdens of contaminants in organisms might take into account background levels of contamination found in organisms at uncontaminated sites. Baseline conditions are discussed in more detail in subsequent sections.

6.5 Approaches for Determining Injury

The State has identified existing data that can be evaluated for each of the main categories of injury: exceedence of federal action levels for contaminants in edible portions of organisms, exceedence of levels that trigger consumption advisories, and exceedence of levels sufficient to cause adverse changes in viability, including wildlife kills. The Trustees included evidence of injury for biological resources in perennial and intermittent surface water. Each category is discussed further below.

6.5.1 Exceedence of FDA action levels in organisms

Injuries to wildlife occur when concentrations of hazardous substances in edible portions of an organism exceed FDA action or tolerance levels for safe consumption. Although the FDA exerts authority over domesticated poultry and not over wild gamebirds, exceedences of action levels for poultry are indicative of injuries to gamebirds.

Concentrations of dieldrin found in four different species of commonly consumed gamebirds at the Arsenal have exceeded the FDA action level of 0.3 milligrams per kilogram (mg/kg) for dieldrin residues in fatty tissue (Food Safety and Inspection Service, 1998) (Table 6.5). Moreover, the data shown in Table 6.5 were from carcasses (whole body) and muscle tissues. These concentrations would likely underestimate the concentrations of dieldrin in fatty tissue, which tends to have the greatest concentration of assimilated pesticide.

In addition, dieldrin concentrations in five largemouth bass samples from Lower Derby Lake in 1988 ranged from 0.067 to 0.644, with a mean concentration of 0.375 mg/kg (Environmental Science and Engineering, 1989, Table 4.3-5). This mean concentration exceeds the FDA action level of 0.3 mg/kg dieldrin for human consumption of fish (FDA, 2000).

Table 6.5. Examples of dieldrin concentrations in gamebirds at the Arsenal in excess of the FDA level of 0.3 mg/kg for poultry

Species	Tissue type	Maximum concentration (mg/kg)
Mallard	Adult carcass	4.53
Mallard	Juvenile carcass	0.52
Ring-necked pheasant	Juvenile carcass	1.33
Ring-necked pheasant	Adult carcass	2.92
Redhead	Muscle	0.32
American coot	Muscle	1.77

Source: Environmental Science and Engineering, 1989, Tables 4.3-1 and 4.3-2.

6.5.2 Exceedence of levels sufficient to trigger consumption advisories

Concentrations of hazardous substances in fish and wildlife at the Arsenal are sufficient to have triggered a ban on consumption. Elevated concentrations of pesticides in fish at the Arsenal led to the imposition of a catch-and-release policy in 1978, and a consumption ban for fish from the Arsenal lakes in 1984 (BAS, 2003). Consumption of all fish and wildlife was prohibited in the 1989 Federal Facilities Agreement, and these prohibitions were subsequently incorporated into the Arsenal National Wildlife Refuge Act of 1992. These bans indicate that fish resources and wildlife resources at the Arsenal have been injured by exposure to hazardous substances released at the site.

6.5.3 Adverse changes in viability

Concentrations of hazardous substances in biological resources have been sufficient to cause adverse changes in the viability of the organisms. In addition, extensive wildlife kills have been documented at the Arsenal. The State Trustees conducted a preliminary evaluation of these biological injuries by (1) collecting evidence related to wildlife kills, and (2) comparing the estimated exposure of wildlife at the Arsenal to toxicity benchmarks and injury thresholds for organochlorine pesticides.

This section is organized as follows: First, background is provided on the toxic effects of organochlorine pesticides. Next, available information on wildlife kills is described. Finally, toxicity benchmarks, injury thresholds, and exposure modeling are discussed and a comparison is made between estimated exposure levels and potential injury thresholds.

6.5.3.1 Toxicity of organochlorine pesticides

Many of the injuries to wildlife at the Arsenal have been caused by exposure to organochlorine pesticides, particularly the class of pesticides known as cyclodienes. Cyclodiene pesticides include aldrin, dieldrin, chlordane, endrin, and isodrin. Other injuries likely have been caused by pesticides from the class known as dichlorodiphenylethanes. This class includes DDT and associated metabolites DDE and dichlorodiphenyldichloroethane (DDD). Both classes of pesticides affect the neurological system of organisms by interfering with ion movements across nerve cell membranes (ATSDR, 1993, 1994, 1996, 2002). In birds and mammals, symptoms of toxicity include rigid paralysis, convulsions, respiratory failure and death. Emaciation is another characteristic symptom of organochlorine poisoning.

Over time, organochlorine pesticides have the potential to accumulate in fat deposits within a living organism and eventually reach toxic levels. These chemicals also tend to “biomagnify” up the food web, meaning that a top carnivore, for example, will accumulate the pesticide present in prey items. Therefore, lower concentrations of pesticides in prey items can become magnified into high concentrations in top predators. In addition, when organisms mobilize their fat stores during times of stress such as migration, they can be poisoned by the pesticides that are released into their circulatory system, even if the actual consumption of the pesticides happened days, weeks, or months previously (e.g., Henriksen et al., 1996).

The organochlorine pesticides discussed here all affect the neurological system in their toxic mode of action; thus the toxicity of multiple compounds may be additive. Additive toxicity means that the toxicity of a mixture of compounds will be approximately equal to the sum of the individual toxicities for each chemical present in the mixture. For example, the literature reports field collections of 425 birds killed by mixtures of dieldrin and chlordane at levels below the demonstrated lethality of either compound (Stansley and Roscoe, 1999). Additive toxicity in bobwhite quail also was reported based on feeding trials with chlordane and endrin (Ludke, 1976). An approach to evaluate the toxicity of compound mixtures is particularly important at the Arsenal, given the presence of multiple organochlorine pesticides that have been produced and identified at the site.

6.5.3.2 Evidence of wildlife kills

Wildlife mortality from chemical poisoning at the Arsenal was reported by the USFWS as early as 1951 (Finley, 1959), and continued at least through 1999 (USFWS, 2000). This mortality is consistent with numerous published accounts that describe poisoning of birds and other wildlife from agricultural use of aldrin and dieldrin. The introduction in 1956 of aldrin and dieldrin in the United Kingdom as seed treatments resulted in immediate poisonings of birds, particularly wood pigeons (*Columba livia*) and pheasants (*Phasianus colchicus*) (Peakall, 1996). Those poisonings

involved hundreds of incidents a year and thousands of individual birds. The deaths continued unabated until use of dieldrin as a wheat seed treatment was discontinued in 1975. At the Arsenal, other chemicals in addition to aldrin and dieldrin would have contributed to mortality.

The following sections give a brief overview of some of the reports of fish and wildlife mortality. This is not a comprehensive review of all mortality data from the site.

1950s–1980

These injuries predate the enactment of CERCLA in 1981 and will not be included in the injury quantification for the site. However, they provide evidence of pesticide poisonings at the Arsenal.

- ▶ An estimated 1,200 ducks died in the spring of 1952 at the Lower Lakes. The USFWS reported that “experiments indicated that the cause of death was a toxic agent or agents carried on the surface of the water and probably entering the lakes through the process-water drain from the chemical plant area” (Finley, 1959, p. 1).
- ▶ In April 1959, 119 dead birds and animals were counted on a single day around the shore of Lake Ladora. An interview with a Shell employee revealed that he had gathered approximately 500 dead ducks for burial during the first three months of 1959 (Finley, 1959, p. 3).
- ▶ The USFWS stated that 2,000 ducks would be a conservative annual estimate of duck mortality in the Lower Lakes area, with 20,000 or more ducks dying over a 10-year period (Finley, 1959). The report noted that high wildlife mortality occurred at the lakes when extensive mud flats were exposed. In addition, the USFWS reported that Upper Derby, Lower Derby, and Ladora Lakes did not support fish, amphibians, or aquatic insects.
- ▶ At the Lower Lakes, more than 100 ducks were found dead on March 28, 1962, and 163 waterfowl deaths were reported between January and May 1966 (Environmental Science and Engineering, 1989, Table 1.3-1).
- ▶ In 1964, the Army removed contaminated sediments from Upper and Lower Derby Lakes and Lake Ladora, and waterfowl mortality declined from previous years. According to the Biota Remedial Investigation, “In subsequent years waterfowl and other wildlife continued to be found dead at the Lower Lakes but in smaller numbers” (Environmental Science and Engineering, 1989, p. 4-7).

- ▶ In a two-week period in early April 1973, approximately 750 dead ducks and grebes were collected from the area of Basin F in three visits, with several hundred additional carcasses observed on June 13 and 14, 1973 (Ward and Gauthier, 1973). The death of 136 ducks occurred in April 1973 at Basin C (Environmental Science and Engineering, 1989, Table 1.3-1).
- ▶ During two days in May 1975, 291 bird carcasses were removed from the shoreline of Basin F, including waterfowl, raptors, pheasants, and songbirds (Environmental Science and Engineering, 1989, Table 1.3-1).
- ▶ In June 1976, a die-off of juvenile starlings was noted at a roosting location on the Arsenal, outside of the contaminated basins area (Olds, 1976).
- ▶ Deaths of a great horned owl, five hawks, a coyote, and starlings were reported between 1976 and 1979 (Environmental Science and Engineering, 1989, Table 1.3-1).
- ▶ On May 7, 1980, the DOW, accompanied by the USFWS, inspected the perimeter of Basin F and found 389 wildlife carcasses, including 344 waterfowl, 40 birds other than waterfowl, and 5 small mammals (Seidel, 1980).
- ▶ An additional 49 waterfowl carcasses were collected at Basin F between October and December 1980 (Environmental Science and Engineering, 1989, Table 1.3-1).

In addition to waterfowl deaths, fish kills and amphibian deaths have been reported at the Lower Lakes:

- ▶ An unpublished USFWS report found an absence of frog choruses, egg masses, and tadpoles at the Lower Lakes in 1960 (USFWS, 1961).
- ▶ Stocking of channel catfish, bluegill, and northern pike in Lake Ladora in 1967 and 1968 was unsuccessful: only a single fish was caught in three 48-hour gill net attempts in 1968 (BAS, 2003).
- ▶ Catfish stocking in Lower Derby Lake in 1968 also was unsuccessful. A fish kill of largemouth bass, bluegill, and catfish was noted on May 16, 1973, following the release of aldrin into lake waters (Environmental Science and Engineering, 1989, Table 1.3-1).
- ▶ Death of rainbow trout in the Lower Lakes was noted on April 18, 1977 (Environmental Science and Engineering, 1989, Table 1.3-1).

Bird hazing devices, including flashing light pontoons, repeating-fire “Zon” guns, and “Avalarms,” were installed around Basin F in 1975 in an attempt to reduce bird mortality (Environmental Science and Engineering, 1989, p. 4-4). In 1980, these devices were found to be inoperable during field inspections by the USFWS. In addition, USFWS personnel observed waterfowl landing and taking off from Basin F even when the devices were operating (Grieb, 1981).

1981–1988

Substantial wildlife mortality at the Arsenal continued in the 1981–1988 time period. Regular quarterly waterfowl mortality counts were conducted at Basin F from 1981 to 1987, and between 139 and 444 dead birds were found each year (Table 6.6). An IRA at Basin F in 1988, which moved contaminated liquids to storage tanks and lined holding basins, and covered the basin site with a clay cap, ended direct waterfowl mortality from exposure to contaminated liquid waste at Basin F.

Table 6.6. Reported waterfowl mortalities at Basin F (1981–1987)

Year	Number found dead
1981	202
1982	222
1983	444
1984	418
1985	140
1986	236
1987	139
Total	1,801
Source: Environmental Science and Engineering, 1989, Table 4.1-1.	

1989–1999

Between 1989 and 1999, wildlife mortality data at the Arsenal were gathered through three programs: the fortuitous specimen program, the Building 111 program, and the avian mortality program. These sampling and collection programs indicate that substantial wildlife mortality continued at the Arsenal through 1999.

- ▶ From 1989 to 1993, 192 bird samples and 52 mammal samples were collected at the Arsenal by the USFWS as “fortuitous specimens” because the animals were either dead or dying (CDPHE, 1994). Bird species collected represented more than 30 different species, including raptors, waterfowl, and passerines.
- ▶ The 1999 USFWS Annual Progress Report for the Rocky Mountain Arsenal (USFWS, 2000) provides a cumulative list of the bird species for which mortalities were attributed to dieldrin or endrin poisoning between 1990 and 1998. A total of 102 bird mortalities in 19 species were attributed to dieldrin or endrin poisoning (USFWS, 2000, Table 1.8). The report also noted that “several birds had pronounced keels and displayed other symptoms of dieldrin poisoning” (USFWS, 2000, p. 28). A pronounced keel indicates emaciation.

These mortality reports are likely to underestimate substantially the total amount of wildlife mortality at the site caused by pesticide poisoning. For example, a bird that died from a collision with a building or power line would not be attributed to pesticide poisoning, even if exposure to pesticides decreased the bird’s ability to avoid the obstacles. Interestingly, the USFWS reported that more birds were found dead at the Arsenal after periods of cold or foul weather, and dead birds were often emaciated (USFWS, 1997). These observations are consistent with the biological mechanisms and toxicokinetics of organochlorine pesticides.

The evidence presented above indicates that organochlorine pesticides have been the causative agent in wildlife mortalities from the mid-1950s through at least 1999.

6.5.3.3 Concentrations of pesticides in animal tissues above mortality thresholds at the Arsenal

In 1994, the USFWS developed guidelines for diagnosing contaminant-related deaths of birds at the Arsenal (USFWS, 1995, 1996, p. 1-35). Under these guidelines, mortality or morbidity of birds with brain levels of dieldrin greater than 9 mg/kg was attributed to dieldrin poisoning, while birds with clinical signs diagnostic of dieldrin poisoning, or with supporting necropsy data and brain dieldrin levels between 5 and 9 mg/kg, were considered evidence of suspected dieldrin poisoning. Levels of brain dieldrin of 1–5 mg/kg indicate a dangerous level of exposure, but it is likely that other factors contributed to or caused the death of the bird. Endrin was considered to be lethal at 0.8 mg/kg in the brain (USFWS, 1998, p. 6). The USFWS also appeared to apply these same diagnostic criteria to other animals collected through the fortuitous specimen program (USFWS, 1998).

As discussed previously, the number of mortalities attributed to dieldrin or endrin poisoning based on the USFWS guidelines is likely to be a substantial underestimate of the total number of mortalities resulting from pesticide exposure because of the additive toxicity of related organochlorine pesticides, among other reasons.

Tissue data available for dead or dying birds collected since 1955 indicate that bird tissue concentrations were high enough to cause or contribute to mortality.

- ▶ Chemical analysis in 1955 of a dead duck from the Lower Lakes revealed 261 mg/kg dieldrin in fat tissue and 32.7 mg/kg dieldrin in the liver (Jensen, 1955, p. 3).
- ▶ Chemical analysis of three ducks in 1959 found dieldrin concentrations between 30 and 64 mg/kg (Finley, 1959, Table 1).
- ▶ In 1982, 1 great blue heron, 1 black-billed magpie, 1 European starling, and 2 Brewer's blackbirds had dieldrin concentrations in brain tissue above 5 mg/kg, with additional specimens having brain concentrations between 1 and 5 mg/kg (McEwen, 1983).
- ▶ Between 1986 and 1988, contaminant analysis was completed for 5 ferruginous hawks, 3 red-tailed hawks, 4 great-horned owls, 2 golden eagles, and 2 mourning doves found dead (Environmental Science and Engineering, 1989, p. 4-37, p. 4-50). Contaminant levels in brain tissues of raptors ranged from < 0.175 to 15.6 mg/kg dieldrin and 0.475 to 10.3 mg/kg DDE. Both golden eagles and one ferruginous hawk had brain tissue dieldrin levels below detection. One additional ferruginous hawk had brain tissue dieldrin of less than 1 mg/kg. Two ferruginous hawks had brain tissue dieldrin levels between 5 and 9 mg/kg, and one ferruginous hawk, two red-tailed hawks, and two great horned owls had brain tissue dieldrin levels of more than 9 mg/kg. Brain tissue dieldrin was not reported individually for the remaining great horned owl and red-tailed hawk, but summary statistics indicate that one of these two samples had brain tissue dieldrin of 15.6 mg/kg.

Because many of the samples of dead wildlife were collected opportunistically, the actual wildlife mortality at the site is likely to have been substantially greater than the number reported. Additionally, the USFWS noted in 1997 that:

...more birds are likely dying than what is found by the Service. Telemetry data in 1994 showed that some poisoned birds die in areas where they are unlikely to be found and not necessarily near contaminated areas. In 1996, a magpie that died from endrin poisoning was found in Section 10 on the abandoned Stapleton runway, a fair distance from contaminated soil areas. Birds that could not be evaluated due to decomposition may also have died from poisoning (USFWS, 1997, p. 53).

In addition to bird kills, evidence exists that pesticide poisoning resulted in the death of mammals at the Arsenal between 1989 and 1999. In 1997, the death of a cottontail rabbit found at Building 111 was attributed to endrin poisoning, based on a brain concentration of 1.05 mg/kg (USFWS, 1998, p. 11). Results of tissue analyses for fortuitous mammal specimens collected in

previous years indicated that mammals accumulate high concentrations of pesticides in their tissues. For example, two coyotes that were hit by a vehicle in 1994 had liver concentrations of dieldrin above 4 mg/kg (USFWS, 1996, Table 1-9). A badger collected in 1992 had a brain concentration of 2.46 mg/kg dieldrin and a liver concentration of 9.65 mg/kg, but the official cause of death reported on the necropsy was “undetermined” (USFWS, 1995, Tables 1-16, 1-17).

All of this information indicates that wildlife deaths have occurred at the Arsenal as a result of exposure to hazardous substances, including, but not limited to, aldrin and dieldrin. The anecdotal nature of the sampling likely substantially underestimates the actual wildlife deaths caused by pesticide poisoning on-site. Additional investigation of wildlife deaths will be undertaken as part of the State Trustees’ assessment activities.

6.5.3.4 Historical benchmarks and potential injury thresholds for pesticide exposure

As discussed above, concentrations of pesticides in animal tissues above injury benchmarks can indicate that mortality of a specimen was caused by exposure to pesticides. It is also possible to develop injury thresholds based on exposure to pesticides in an animal’s diet (or through dermal absorption or inhalation).

Mortality caused by short-term exposure to a hazardous substance is considered “acute toxicity.” An acute oral dose, typically measured as a 50% Lethal Dose (LD_{50}), is the chemical dose sufficient to cause mortality in 50% of test animals in a laboratory study. Chemical doses are measured as mg of chemical per kg of body weight of the animal. When something is highly toxic, it means that ingestion of a small amount of the chemical will cause toxicity. Therefore, chemicals with higher toxicity have lower LD_{50} values – a lower LD_{50} value means that it takes a smaller amount of the chemical to cause mortality.

As shown in Table 6.7 for a variety of bird species, different pesticide compounds have different toxicities. Cyclodiene pesticides such as aldrin and dieldrin are among the most toxic organochlorine pesticides. However, aldrin is rapidly converted to dieldrin in environmental media, such as soil or water, and in the tissues of biological organisms. Therefore, aldrin is rarely detected at high concentrations. Endrin is about 10 times more toxic than dieldrin for common bird test species (Table 6.7). Other cyclodiene pesticides (chlordane, oxychlordane, heptachlor, heptachlor epoxide, and isodrin) are somewhat less toxic than dieldrin to birds (Friend and Trainer, 1974). For each compound, there also is marked variation in toxicity among bird species. For example, mallards are less sensitive to pesticides than California quail, meaning that mallards can ingest a higher dose of pesticide without being killed. The variation in toxicity among species is likely a result of differences in the birds’ ability to metabolize these compounds (Ronis and Walker, 1989).

Table 6.7. Concentrations of different pesticides that cause mortality (“acute toxicity”) in birds

Chemical	Test species	Number of samples	Sex	Age (months)	Acute oral dose (LD ₅₀ mg/kg)
Aldrin	Mallard	16	F	3–4	520
	Bobwhite	12	F	3–4	6.59
	Pheasant	12	F	3–4	16.8
Dieldrin	Mallard	12	F	6–7	381
	California quail	12	M	7	8.8
	Pheasant	9	M	10–23	79
	Rock dove	15	M, F	–	26.6
DDT	Mallard	8	F	3	> 2,240
	California quail	12	M	6	595
	Pheasant	15	F	3–4	1,334
Chlordane	Mallard	12	F	4–5	1,200
	California quail	12	M	12	14.1
	Pheasant	4	F	3	24.0–72.0
Endrin	Mallard	12	F	12	5.6
	California quail	12	F	9–10	1.2
	Pheasant	12	M	3–4	1.8
	Rock dove	16	M, F	–	2.0–5.0

Source: Hudson et al., 1984.

Low-level exposure to organochlorine pesticides (below lethal levels) has the potential to alter wildlife behavior and cause chronic health problems. Chronic low-level dosing results in a steady accumulation of dieldrin in an animal. For example, dogs fed a diet with just 0.01% dieldrin in food by weight (0.1 µg/g dieldrin) showed high concentrations of dieldrin accumulating in fat (Richardson et al., 1967). Similar results have been found in chronic dosing studies with birds. Altered behavior occurring as a result of this low-level dosing includes reduced alertness to predators, altered courtship behavior, and altered aggression (Sharma et al., 1976). Other chronic toxicity effects include increased genetic mutations, higher cancer rates, and endocrine disruption (WHO, 1989). Population effects of pesticide exposure for birds include delayed egg-laying, decreased egg production, reduced egg weights, and reduced eggshell thickness, all of which contribute to reduced hatchability and post-hatching mortality (Dahlgren et al., 1970; Sharma et al., 1976; Busbee, 1977; Newton, 1988; Walker and Newton, 1999).

The EPA (2005a) produced a comprehensive review of literature on dieldrin with the purpose of developing Ecological Soil Screening levels. EPA was particularly interested in papers reporting toxicity responses other than lethality, such as biochemical, behavioral, physiological, pathological, and reproductive impairment. These data were compiled to determine a Toxicity Reference Value (TRV) for birds. EPA defined the TRV as the “Dose above which ecologically relevant effects might occur to wildlife species following chronic dietary exposure and below which it is reasonably expected that such effects will not occur” (EPA, 2005b, p. 4-11). The TRV established by the EPA was 0.0709 mg dieldrin/kg body weight (bw)/day, based on adverse effects on reproduction.

The Rocky Mountain Arsenal Biological Advisory Subcommittee (BAS) established a TRV of 0.028 mg dieldrin/kg bw/day as an “estimated safe level” for small birds at the Arsenal. This number is lower than the TRV established by the EPA (BAS, 2002). The BAS TRV was based on a toxicity benchmark or “critical dose” of 0.28 mg dieldrin/kg bw/day from a study with homing pigeons (Robinson and Crabtree, 1969) and the application of a ten-fold uncertainty factor.

In summary, according to DOI regulations, injuries to wildlife can be evaluated based on the exposure of organisms to pesticides at levels that exceed toxicity thresholds or benchmarks. These thresholds vary by the type of pesticide, by species, and by toxicity endpoints, with sublethal effects occurring at lower exposure levels compared to lethal effects. Thresholds will be compared to Arsenal data to calculate the amount of lost ecological resources and services.

Exposure modeling

Exposure modeling is used to estimate contaminant exposures of different wildlife species, based on concentrations in environmental media such as soil and water. Measurements of pesticide concentrations in soil can be used to predict daily dietary doses of pesticides, based on assumptions about bioaccumulation of pesticides through the food web. Exposure modeling also can be used to predict tissue concentrations of pesticides in animals, based on assumptions about pesticide concentrations in the animal’s diet.

More specifically, in an exposure model, a dose is calculated for each route of exposure: ingestion, inhalation, and dermal absorption. The total dose is compared to a TRV to determine whether it exceeds a safe level. All exposure routes are initially considered, but some may not be included in the exposure model if the route would not be expected to contribute very much to the overall dose. For a simple example of a dietary exposure model, the animal’s average daily food intake is calculated in kilograms of food per day. Then, for each food type in the animal’s diet, the animal’s average daily food intake is multiplied by the fraction of the diet that each type represents. This gives the mass of each food type the animal consumes in an average day. This mass is multiplied by the concentration of pesticide in that type of food, to give a total amount of

the pesticide for that food. Finally, pesticide amounts for all foods are summed, giving a single total daily intake that is divided by the average body weight of the animal. Thus, dose is expressed as mg of pesticide per kilogram body weight per day.

This simple example of exposure modeling relies on single point estimates for average daily food intake, average food type mass, and contaminant concentration in the food source. In more complicated models, ranges and distributions of these variables are used rather than single point estimates. A computer runs multiple simulations, and the resulting dose estimate incorporates information on the uncertainty of variables included in the model.

An extensive risk assessment completed for the site (the IEA/RC; Ebasco Services et al., 1994) developed dietary exposure models for a range of organisms at the Arsenal. A refinement of this approach was subsequently presented in the Terrestrial Residual Ecological Risk (TRER) report (BAS, 2002). The exposure modeling in the TRER predicted that an average soil concentration of 0.065 mg/kg for aldrin/dieldrin across the home range of a small bird would result in a bird exposure dose of 0.028 mg aldrin/dieldrin per kg body weight per day. This exposure modeling was based on dietary intake and did not consider potential exposure through inhalation or dermal pathways, so it likely underestimates total exposure.

This exposure calculation is an example of an exposure calculation for a small bird. Similar exposure calculations can be conducted for other types of birds and wildlife to predict whether soil concentrations could result in wildlife exposure at levels exceeding injury thresholds and benchmarks for either dietary doses or tissue concentrations.

Comparison of estimated exposure to potential injury thresholds

The IEA/RC evaluated the dietary exposure of a variety of species or species groups to different chemicals, and compared exposure estimates to TRVs to quantify ecological risk (Ebasco Services et al., 1994). Comparisons were expressed as “hazard quotients,” where:

$$\text{Hazard quotient} = \text{Exposure estimate} / \text{TRV}.$$

The TRVs were developed by finding the lowest chemical dose associated with adverse effects to a particular class of organisms such as small birds, and then dividing this “critical dose” by a set of uncertainty factors to develop an estimated safe level, below which no adverse effects are expected to occur. For example, as mentioned above, the BAS established 0.028 mg dieldrin/kg bw/day as the TRV for small birds based upon a “critical dose” of 0.28 mg dieldrin/kg bw/day (Ebasco Services et al., 1994). The BAS divided the critical dose by an uncertainty factor of 5 to consider potential interspecies differences in sensitivity, and an additional uncertainty factor of 2 to account for differences between laboratory and field conditions and the potential for variability within a species (Ebasco Services et al., 1994). A calculated hazard quotient of 10 for

small birds would mean that an organism was exposed to a dose 10 times the TRV of 0.028 mg dieldrin/kg bw/day.

Figure 6.3 shows areas at the Arsenal where, prior to remedial activities, the hazard quotient for small birds exceeded 10 based on respective TRVs advocated by the different parties. Regardless of thresholds and exposure models used, the injury will be greatest in the central core of the Arsenal.

6.5.4 Injuries from response actions

Remediation work has occurred extensively across the site (Figure 6.4). Although this work has been necessary to reduce the pervasive contamination, collateral injuries to wildlife have been unavoidable. Soil remediation activities have included physically removing contaminated surficial soils using heavy equipment. Also, some areas with clean soils were excavated to use as soil covers for the landfills and in-place containment of soils. In addition, the Army, Shell, and the USFWS tilled soils for revegetation. These activities disturbed existing habitat on-site. Injuries to biological resources that would have inhabited or utilized this disturbed habitat will occur until the habitat is returned to baseline conditions.

Wildlife also has been injured by the intentional eradication of species at the Arsenal. In 1989, the Army exterminated prairie dogs in Section 36 and the southeast corner of Section 25 because high concentrations of dieldrin present in the prairie dogs were endangering wintering bald eagles that ate the prairie dogs (R.L. Stollar & Associates et al., 1992, p. IV-10).

Permanent remediation injuries to biological resources have also occurred. Specifically, biota intrusion layers are designed as part of the caps on hazardous landfills. For example, an 18-inch-thick layer consisting of crushed concrete is part of the landfill cap design. The crushed concrete layer is specially engineered to prevent burrowing animals such as prairie dogs and badgers from re-exposing buried hazardous substances (CDPHE, 1995; Foster Wheeler, 1996). While this cap is necessary to prevent additional exposure of wildlife to contaminants, the biota intrusion layer will limit habitat available to the Arsenal wildlife and constitutes a permanent injury to biological resources. Biota intrusion layers are also included in the acres of covers over contaminated South Plants soils. As part of the assessment, the State will consider these collateral injuries in addition to the habitat improvements that occur following remediation and revegetation.

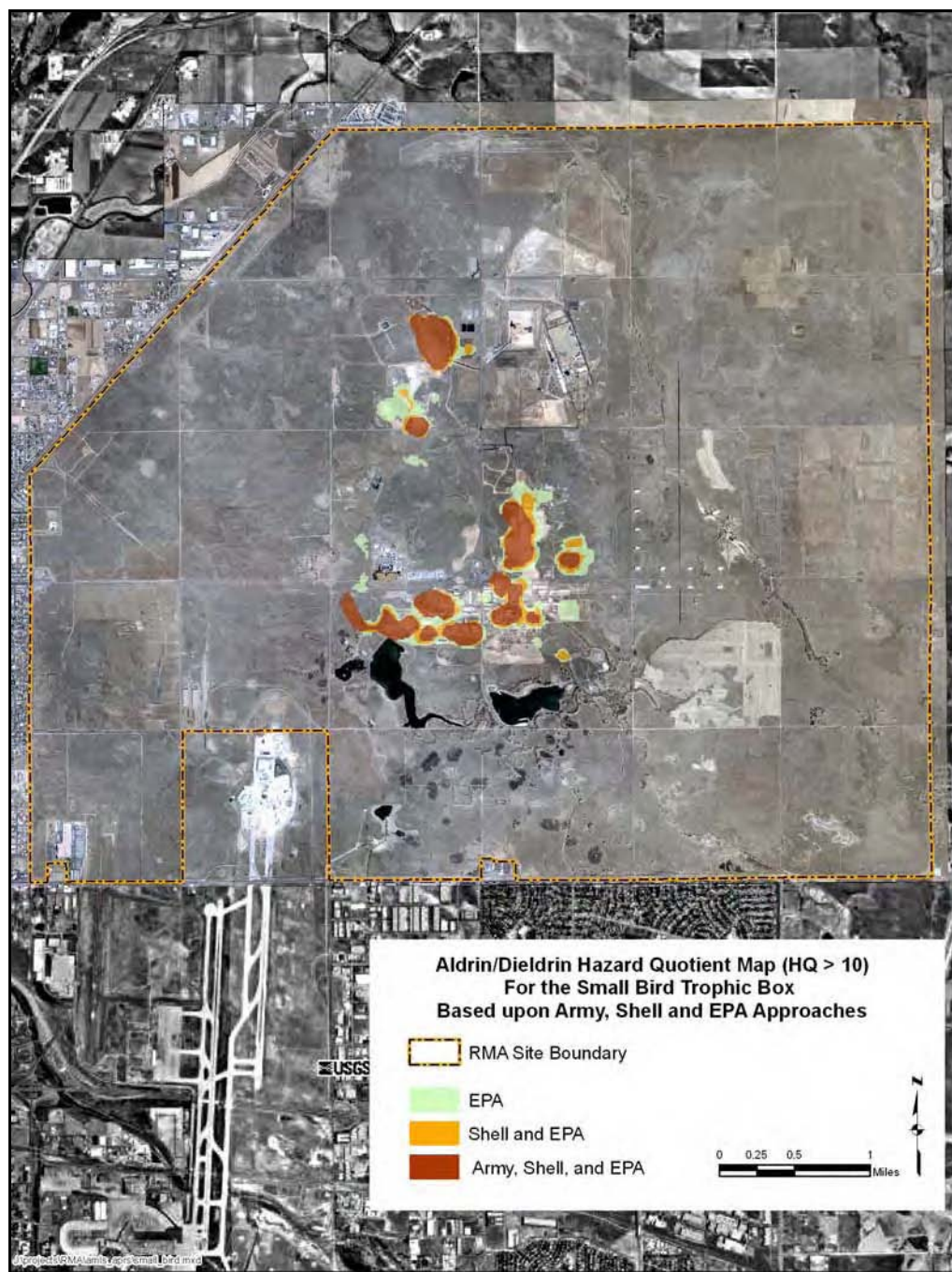


Figure 6.3. Example map of injured areas at the Arsenal for small birds exposed to dieldrin, based on data developed for the Arsenal risk characterization report.

Source: Ebasco Services et al., 1994, Figure C.3-33.

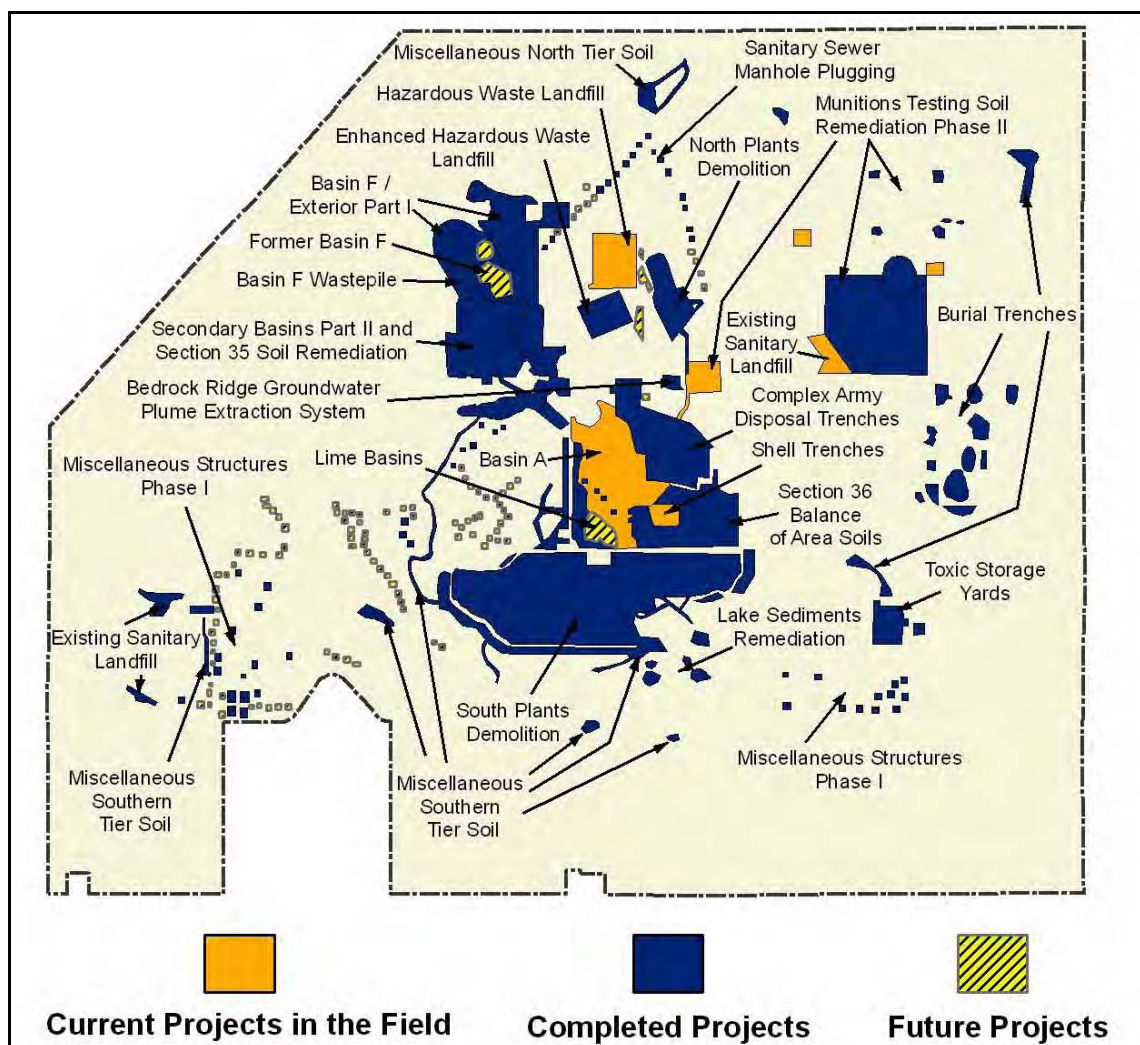


Figure 6.4. Spatial extent of soil remediation activities at the Arsenal as of September 2007.

Source: Rocky Mountain Arsenal, 2007.

6.5.5 Evidence of injury to biological resources associated with surface water

Biological resources at the Arsenal have been exposed to contaminants in surface water and associated sediments. Concentrations of contaminants that exceed established State and federal water quality criteria demonstrate potential injury to biological resources because water quality criteria are derived using exposure effects data from laboratory studies using a diverse assemblage of test organisms (Stephen et al., 1985).

Below is a brief list of water quality exceedences that have occurred in waters of the Arsenal. This is not a complete assessment, but an example using readily available data from the Arsenal reports.

- ▶ Surface water quality data for the Sand Creek Lateral drainage ditch indicated that aldrin and dieldrin were measured above respective water quality criteria between the fall of 1985 and the spring of 1987 (Ebasco Services et al., 1989, pp. 4-9–4-12)
- ▶ Chlordane was measured above the chronic criteria in Lower Derby Lake in April 1989 (Ebasco Services et al., 1994)
- ▶ Endrin was measured above the chronic criteria in Upper Derby Lake in September 1989 (Ebasco Services et al., 1994).

In addition, concentrations of contaminants in sediments have exceeded benchmark levels that indicate the probability of adverse effects on aquatic biota (Table 6.8). The sediment benchmarks that are used for comparison include consensus threshold effects concentrations (TECs), which represent concentrations below which adverse effects to sediment-associated biota would not be expected, and consensus probable effects concentrations (PECs), above which adverse effects to sediment-associated biota are likely (MacDonald et al., 2000). Additional aquatic sediment benchmarks criteria developed by the Ontario Ministry of Environment and Energy include the lowest observed effect levels, below which adverse effects would not be expected, and the severe effect levels (SEL), where “the sediment is considered heavily polluted and likely to affect the health of sediment-dwelling organisms” (Persaud et al., 1993).

6.6 Approaches to Injury Quantification

According to the DOI regulations, quantification of injuries is conducted to “quantify the effects of the discharge or release on the injured natural resources for use in determining the appropriate amount of compensation” [43 CFR § 11.70(c)]. Injuries to natural resources can cause reductions in the services those resources provide relative to baseline conditions, where baseline is defined as conditions that would have existed at the assessment area had the discharge of oil or release of the hazardous substance under investigation not occurred [43 CFR § 11.14(e)]. Services are the “physical and biological functions performed by the resource, including the human uses of those functions” [43 CFR § 11.14 (nn)].

Injury quantification involves determining the spatial extent where injuries have occurred as well as the timing and duration of injuries. Quantification also can involve estimates of the “degree of service loss” in an area – that is, what percentage of services has been lost at a site compared to baseline condition.

Table 6.8. Examples of exceedences of benchmark levels in contaminated sediments at the Arsenal

Water body	Date	Contaminant	Benchmark concentration (ppm)	Maximum sediment concentration (ppm) ^a	Benchmark type ^b
Lake Mary	1998	Arsenic	9.8	11.7	TEC
		Mercury	0.18	0.46	TEC
Lake Ladora	1995	Aldrin	0.08–0.8	0.15	SEL ^c
		Arsenic	9.8	11	TEC
		Dieldrin	0.0019	0.016	TEC
		Mercury	1.1	2.2	PEC
Lower Derby Lake	1985–1994	Aldrin	0.08–0.8	50	SEL ^c
	1995	Aldrin	0.08–0.8	0.56	SEL ^c
		Chlordane	0.018	0.103	PEC
		Dieldrin	0.062	0.063	PEC
		Mercury	1.1	3.2	PEC

ppm = parts per million.

a. All sediment data from the BAS (2003).

b. TEC = “Threshold Effects Concentration;” PEC = “Probable Effects Concentration” (both from MacDonald et al., 2000); SEL = “Severe Effects Level” from Persaud et al. (1993).

c. Severe effects levels based on a benchmark of 8 µg Aldrin/g of organic carbon. The benchmarks given here are calculated for a sediment sample with an assumed total organic carbon concentration between 1% and 10%.

To illustrate such potential quantifications, the Trustees estimated the spatial extent of injuries prior to remediation based on areas where soil concentrations of aldrin and dieldrin would result in small bird exposure that exceeds potential injury thresholds (Table 6.9). Three concentration ranges were defined based on the hazard quotient ranges for small birds in specified areas. All three ranges exceed the EPA (2005a) threshold for birds, while the > 0.65 ppm category also exceeds the critical dose threshold for small birds used in the Arsenal risk evaluation (Ebasco Services et al., 1994). Regardless of selected thresholds, the total spatial extent of injury will have decreased over time at the Arsenal, as remediation activities have cut off exposure pathways to contaminated soils and remediated areas have been revegetated.

Injury quantification also must be conducted for injuries caused by remedial activities. The USFWS estimated that 3,650 acres would be directly disturbed by remedial activities (USFWS, 1999). The duration of injury will depend on the time required to return the habitat to baseline conditions.

During the assessment process, the Trustees will conduct a full injury quantification that takes the timing and benefits of remediation into account more precisely and will also make sure that there is no “double-counting” of the same injured areas, using different injury tests.

Table 6.9. Comparison of injury thresholds for different concentrations of aldrin and dieldrin in soils at the Arsenal

Soil concentration (ppm aldrin/dieldrin)	Acres at the Arsenal (pre-remediation) ^a	Estimated bird exposure dose (mg aldrin-dieldrin/kg bw/day)	Hazard quotient from Ebasco Services et al. (1994)	Exceeds EPA (2005a) threshold (0.0709 mg dieldrin/kg bw/day)	Exceeds the Arsenal threshold for small birds (0.28 mg dieldrin/kg bw/day)
0.130–0.325 (midpoint = 0.2275)	1,114	0.098	2–5	Yes	No
0.325–0.650 (midpoint = 0.4875)	672	0.21	5–10	Yes	No
> 0.65 (midpoint = 0.6500)	1,067	> 0.28	> 10	Yes	Yes
Total	2,853				

a. Acres estimated from a digitized version of Figure B-5 in BAS (2002).

6.7 Anticipated Assessment Activities

During the assessment phase of the NRDA, the Trustees will undertake activities to determine and quantify the full range of injuries to biological resources that have taken place at the Arsenal. Specific activities that the Trustees anticipate undertaking may include the following:

► Injury determination

- **Revise and update bioaccumulation and dietary toxicity models.** The Trustees will review recent scientific literature and potentially expand the number of evaluated species, revise exposure scenarios, and identify additional toxicity references upon which to base injury thresholds. These may include those underlying EPA's Ecological Soil Screening Levels established for avian and mammalian herbivores, ground insectivores, and carnivores (EPA, 2005a), and any recent references regarding tissue concentrations related to adverse effects.
- **Assess injuries to biological resources based on tissue and media concentrations.** The Trustees will assess injuries to biological resources by comparing tissue concentrations and media concentrations for different chemicals reported in the Rocky Mountain Arsenal Environmental Database to injury threshold values.

- **Address the additive toxicity of organochlorine pesticides.** The Trustees will use existing data to evaluate the potential additive toxicity of organochlorine pesticides. For example, wildlife specimens with brain concentrations of dieldrin below injury thresholds may also have had high concentrations of other pesticides that would result in an exceedence of injury thresholds when using additive toxicity models.
- **Assess injuries to reptiles, amphibians, fish, and bats.** The Trustees will assess injuries to reptiles, amphibians, fish, and bats based on a literature review to establish injury thresholds. Previous work at the Arsenal has focused on birds and ground-dwelling mammals, with little known about potential injuries to other types of wildlife.
- **Assess injuries to biological resources from exposure to metalloids.** The Trustees will assess injuries to biological resources from exposure to arsenic and other metalloids, using a literature review to establish injury thresholds. Previous work at the Arsenal has focused on organochlorine pesticides and also has evaluated risk from mercury exposure.
- **Assess injuries to biological resources associated with perennial and intermittent surface water and associated sediments.** The Trustees will assess injuries to biological resources associated with perennial and intermittent surface water and sediments, including the Lower Lakes. Trustees would use existing data on concentrations of contaminants in surface water, sediment, and biota to assess injury.

► **Injury quantification**

- **Quantify spatial extent of injuries over time.** The Trustees will use GIS techniques to quantify the spatial extent of injury and how this injury has changed over time with remediation.
- **Quantify injuries from remediation.** The Trustees will examine information and maps of completed and anticipated remediation activities to determine the spatial extent and duration of injury resulting from loss of wildlife habitat during remediation as well as the degree of habitat improvement associated with the remediation.
- **Quantify resource losses over time.** The State Trustees would develop models to predict injury over time based on existing wildlife kill data, existing data on contaminant concentrations in environmental media, and toxicity thresholds.

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7. Injury to Air Resources

Hazardous substance releases at the Arsenal injured Trustee air resources via windblown dispersion of dried contaminated sediments from disposal basins, vapor emissions from surface impoundments, and emissions resulting from response actions – most notably the 1988 Basin F IRA discussed in Chapters 3 and 4. This chapter contains a qualitative discussion of injury to air resources during the Basin F IRA. A quantitative assessment of injury may be explored as part of the assessment, depending on the availability and reliability of data.

Summary of conclusions

Releases of hazardous substances during the Basin F IRA resulted in a measurable adverse short-term change in the chemical and physical quality or viability of air resources. Technical reports, transcripts of meetings, correspondence, and odor logs confirm that hazardous substances were released into the air from Basin F and migrated off-post. Offensive odors were prevalent to the north and northwest of the Arsenal boundary. Emissions not only created noxious odors but are also believed to have caused significant adverse health effects. Because of these adverse effects, local residents reported that they modified their behavior to avoid exposure to the ambient air. Thus, releases from Basin F during the IRA resulted in the loss of human services provided by the State's air resources.

7.1 Injury Determination

Chapter 4 confirms that air resources were exposed to hazardous substances during the Basin F IRA in 1988. However, inadequate sampling and laboratory techniques at the time complicate the determination and quantification of injury to air resources. Regardless of air monitoring results, parties involved in the Basin F IRA recognized that chemicals at concentrations below selected risk-based levels, and sometimes below detection limits, were sufficient to cause the highly noxious odors that were associated with health problems (Basin F Transcripts, October 26, 1988).

7.1.1 Injury definition

According to the DOI regulations, an injury to the air resource has resulted from the release of a hazardous substance if one or more of the following changes in the physical or chemical quality of the resource is measured:

- ▶ Concentrations of emissions in excess of standards for hazardous air pollutants established by section 112 of the Clean Air Act, 42 USC § 7412, or by other federal or state air standards established for the protection of public welfare or natural resources [43 CFR § 11.62(d)(1)]
- ▶ Concentrations and duration of emissions sufficient to have caused injury as defined in paragraphs (b), (c), (e), or (f) of this section to surface water, groundwater, geologic, or biological resources when exposed to the emissions [43 CFR § 11.62(d)(2)].

Neither EPA nor the State of Colorado has established standards for relevant hazardous air pollutants.

7.1.2 Baseline conditions

The area affected by Basin F emissions is an industrial area, with several other sources of odors and, potentially, airborne hazardous substance emissions. Industries near the Arsenal include Ralston Purina, refineries, and gasoline stations, in addition to urban air releases associated with automobile traffic. Although the air quality near the Arsenal was not pristine in the 1980s, the odors and health effects experienced from the beginning to the end of the Basin F IRA were more extreme and numerous than those reported before or after the response, and most of the odor complaints cited a distinct and familiar odor that was attributable to Basin F (R.L. Stollar & Associates, 1990). Thus, the adverse effects on air resources during the Basin F response exceeded baseline conditions.

7.1.3 Qualitative evidence of injury

The Basin F IRA began on March 22, 1988. Within days, contractors were raising concerns about Basin F emissions, and discussing plans to ascertain the source of the odors (Ebasco Services, 1988). Excavation activities and pumping of Basin F commenced on the last day of April. Prior to commencement, no testing was conducted to characterize the potential emissions, identify target compounds, or design appropriate monitoring and response protocols.

After removal of all free-standing liquid in the northern end of Basin F during the last week of July 1988, the Army and its contractors discovered a false bottom: 26 to 54 inches of stratified, crystallized salts and sludges. Beneath this hard layer were at least 3 million gallons, and possibly as much as 4.5 million gallons, of additional liquid wastes. The capacity of the tanks was inadequate to hold all the liquid waste in Basin F (Campbell, 1988).

In addition to the excess liquids, crystallized salts and material beneath the liner added over 150,000 cubic yards to the estimated 405,000 cubic yards of contaminated sludge expected to be

excavated (Woodward-Clyde, 1990). These saturated soils and sludges had to be dried prior to placement in the Basin F waste pile. To enhance the drying, a piece of equipment called the “Brown Bear” began operations on August 23. The Brown Bear mixed the wet materials with dry soils, exposing more surface area to air in order to dry the materials. This mixing and air-drying of soils and sludges increased the noxious odors released to air. Consequently, the Army discontinued use of the Brown Bear in September (Basin F Transcripts, September 28, 1988).

The first of 200 logged complaints about foul odors came from off-post neighbors during the summer of 1988 (Ebasco Services et al., 1991). In the fall of 1988, with Basin F sludges exposed and the start of Denver’s meteorological inversion season, complaints about noxious odors and adverse health effects from the fumes increased. Multiple complaints per night were recorded. In response, the Army asked Ebasco to commence off-post odor tracking on October 5, 1988. Complaints were registered nearly every day in December 1988 (Ebasco Services et al., 1991).

As a result of the odor complaints, the Army abandoned the Phase I IRA plan in December 1988, ordering all remaining waste in the basin to be capped in place (Ebasco Services, 1989). By January 21, 1989, the “final” cover was placed over the Basin F floor, and by the end of February 1989, the waste pile was closed to contaminated material. The last complaint about odors from off-post neighbors was recorded on March 10, 1989 (Ebasco Services, 1989).

The air monitoring during the Basin F IRA was flawed for several reasons. For example, in early August 1988, Ebasco Services discovered that post calibration of real-time air monitoring instruments was not being performed as required, rendering data “questionable” (Lewis, 1988). More significantly, the analytical methodology used for air sampling of aldrin and dieldrin had a recovery of only 28%, meaning as much as 72% of the compound present was not measured or recorded (EPA, 1984; Sullivan Environmental Consulting and E.H. Pechan & Associates, 1991). Alternative methods may have resulted in 90% recoveries (EPA, 1988, 1989). In addition, hexachlorobutadiene (HCBd), an extremely odorous compound, was not monitored at all during the months of maximum emissions. HCBd was not identified as a target compound until January 1989, when air quality tests indicated that HCBd and ammonia were the most prominent contaminants in gases emanating from Basin F soils and sludges (Ebasco Services, 1989; Ranum, 1989). Thus, much of the Army’s analytical data cannot be considered reliable for determining contaminant concentrations that were released into the air.

Compounds released to the air were associated with noxious odors, and pesticides in particular were linked to the adverse health effects experienced by exposed individuals. Army documents acknowledge that its cleanup activities caused noxious odors that adversely affected downwind individuals during implementation of the Basin F interim action (Basin F Transcripts, September 28, 1988; Ebasco Services, 1989; Ebasco Services et al., 1991). Reported adverse health effects included:

...headaches, nausea, vomiting and anorexia, insomnia, burning and tearing eyes, conjunctivitis, wandering eye and visual disturbances, skin rashes, sore throats, runny noses and nose bleeds, respiratory problems including coughing and shortness of breath, muscle and joint pain, tingling and numbness, ringing in the ears, chronic fatigue and perceived weakness, dizziness, taste perversions, chest pain, abdominal pain, diarrhea, tremors, facial twitches, amnesia, disorientation, irritability, incoordination and depression (Burnett, 1990, pp. 20–22).

Many of these symptoms were also experienced by CDPHE employees and Army contractors (Ebasco Services et al., 1991) and were consistent with the known toxicology of Basin F chemicals (Burnett, 1990).

The Army's Odor Response Program logged 200 complaints between August 1988 and March 1989. The program was terminated in May 1989. The EPA, CDPHE, and Tri-County Health Department received additional complaints (Basin F Transcripts, September 6, 1988). In addition to the symptoms described above, nearby residents suspected the noxious emissions from Basin F of causing or exacerbating cancer, lupus, epileptic seizures, sores in the mouth and the unexpected deaths and illnesses of pets (Basin F Transcripts, October 26, 1988; Ebasco Services et al., 1991).

Because of noxious odors, adverse health effects, and fear of serious long-term illness, residents reported that they avoided the outdoors and shut their doors and windows, even during hot summer months, as much as possible. They employed air purifiers provided by the Army for their homes but concerns and discomfort remained (Basin F Transcripts, October 26, 1988).

The qualitative evidence presented above demonstrates that services provided by the State's air resources were lost as a result of Basin F emissions. A more quantitative analysis of air quality data and lost services is anticipated as part of the assessment.

7.2 Injury Quantification

This section contains a preliminary estimate of the spatial and temporal extent of air resources injury as a result of the Basin F response action. A more detailed analysis may be conducted as part of this assessment.

Spatial extent of injury

Odor complaints were clustered around the Arsenal, with most of the more vocal and persistent complaints coming from residents of 96th Avenue just north of the Arsenal and in the Irondale trailer park, located one mile northwest of Basin F. Sullivan Environmental Consulting and

E.H. Pechan & Associates (1991) included a map of the most persistent complainants (Figure 7.1). Other complainants were located as far away as 46th and York Street, and one complainant resided near the south border of the Arsenal.

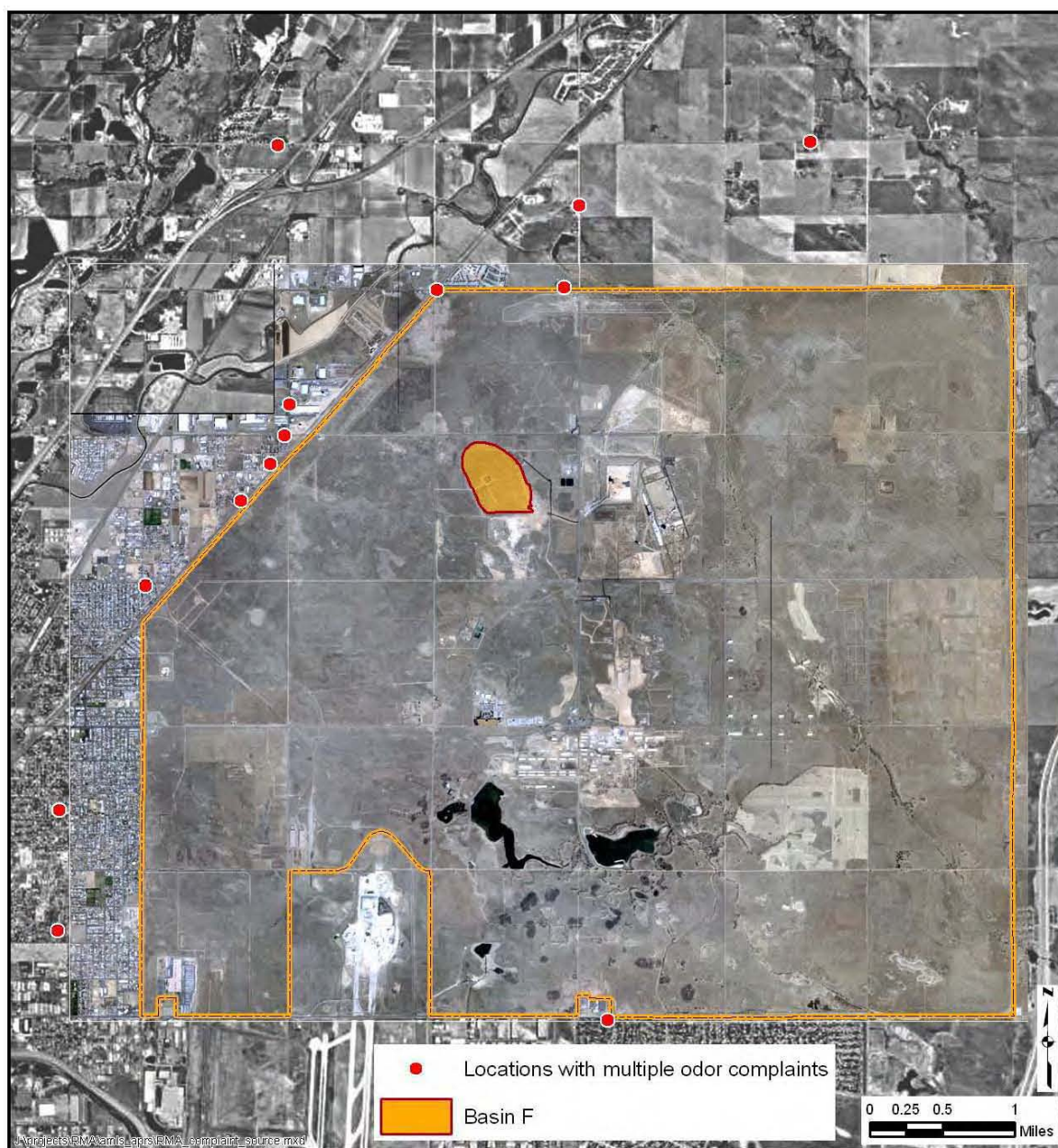


Figure 7.1. Location of complainants noting persistent noxious odors during the Basin F interim response action.

Source: Sullivan Environmental Consulting and E.H. Pechan & Associates, 1991, Figure 7.

Temporal extent of injury

The Basin F response action began on March 22, 1988. By March 28, 1988, contractors were expressing concerns to the Army about the odors (Ebasco Services, 1988). Odor response monitoring for offsite complaints commenced on August 5, 1988 and continued through May 5, 1989. A formal odor response program, which included plume tracking, was initiated in October 1988 and terminated in May 1989 after complaints ceased (Ebasco Services et al., 1991).

7.3 Assessment Activities

As part of the assessment, the Trustees may perform a more quantitative evaluation of injuries to air resources. In particular, the Trustees may:

- ▶ Review quantitative data from air quality monitoring during the Basin F IRA to determine if specific injury thresholds were exceeded, or if injury to air resources may have occurred but was not measured due to inadequate technology and human error
- ▶ Compile odor complaints to assess the likely spatial and temporal extent of injury during the Basin F IRA
- ▶ Review air dispersion models to better quantify hazardous substance releases to air, and the transport of those release through air resources
- ▶ Review on-post fugitive dust emissions data to evaluate other potential injury to air resources.

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8. Damage Determination and Restoration Planning Approaches

Chapters 5, 6, and 7 describe injuries to and anticipated injury assessment activities for groundwater, biological, and air resources, respectively. This chapter briefly introduces general approaches to estimating damages from those injuries, then describes in more detail the restoration-based approach to damage determination. Section 8.1 explains damage determination in general and describes three approaches that the State will use to determine damages at the Arsenal. Section 8.2 presents an introduction to the restoration-based approach. Section 8.3 discusses the most common restoration-based approach: habitat and resource equivalency analyses. Section 8.4 discusses restoration project identification, selection, scaling, and costing. References cited in this chapter follow.

8.1 Damage Determination

A damage determination is intended to “establish the amount of money to be sought in compensation for injuries to natural resources resulting from a . . . release of a hazardous substance.” The DOI regulations identify as the primary measure of damages the cost of “restoration, rehabilitation, replacement, and/or acquisition of the equivalent of the injured natural resources and the services those resources provide” [43 CFR § 11.80(b)]. In addition, the Trustees seek “the compensable value of all or a portion of the services lost to the public for the time period from the release until the attainment of the restoration, rehabilitation, replacement, and/or acquisition of equivalent of the resources and their services to baseline” [43 CFR § 11.80 (b)], also known as interim losses.

The State will quantify damages using three alternative methods for calculating damages:

- ▶ **Cost of restoration:** A restoration-based approach determines damages by quantifying how much restoration is needed to adequately restore, replace, or acquire the equivalent of the injured resources and the lost services provided by such resources. This approach is recognized as an accepted method for quantifying NRDs in the DOI regulations [43 CFR § 11.82; 43 CFR § 11.84(g)]. The State expects to use a restoration-based approach to calculate damages for terrestrial and aquatic resources, groundwater, surface water, and air resources.

- ▶ **Total value equivalency:** The State intends to determine the amount of natural resources and/or services that must be provided to produce the same value as that lost to the public due to hazardous substance releases into groundwater. This approach will determine the restoration required to compensate for losses of both use and non-use values for groundwater.
- ▶ **Use value – market price methodology:** The Front Range has a strong demand for water resources, including groundwater, and these resources are openly traded in a competitive market. The diminution in the market price of injured resources and associated lost services may be used to determine the compensable value of the injured resources [43 CFR § 11.83(c)(2)(i)]. The State will evaluate lost groundwater services and use a market price approach to estimate damages from these lost services.

As these methods measure many of the same values, the results of each analysis will not be additive. Rather, by using three approaches, the Trustees will have more robust information upon which to rely in formulating its ultimate claim for NRDs.

The remainder of this chapter describes generally the restoration-based approach to quantifying all of the State's NRDs. Chapter 9 focuses on the three damage assessment methodologies in the context of groundwater.

8.2 Restoration-Based Damage Determination: Introduction

8.2.1 Conceptual underpinnings of damage determination

Figure 8.1 is a conceptual diagram that depicts what happens to natural resource services over time following the release of a hazardous substance that causes injury. Area A represents the initial loss of services that occurs after the release of a hazardous substance and before remedial actions begin. Area B represents the time when initial recovery of natural resource services takes place as a result of remedial actions at the site. Area C represents the increase in natural resource services that occurs as a result of restoration activities that could be on-site or off-site. The goal of such activities is to restore to baseline conditions resources and services lost due to hazardous substance releases.

In addition to the costs of restoring resources and services to baseline, Trustees may also calculate damages for the interim losses of resources and services from the time of the release (or the enactment of CERCLA, whichever comes later) until full restoration to baseline is achieved. This compensatory restoration would equal the total service loss represented by the sum of the three areas representing less than baseline conditions ($A + B + C$) in Figure 8.1.

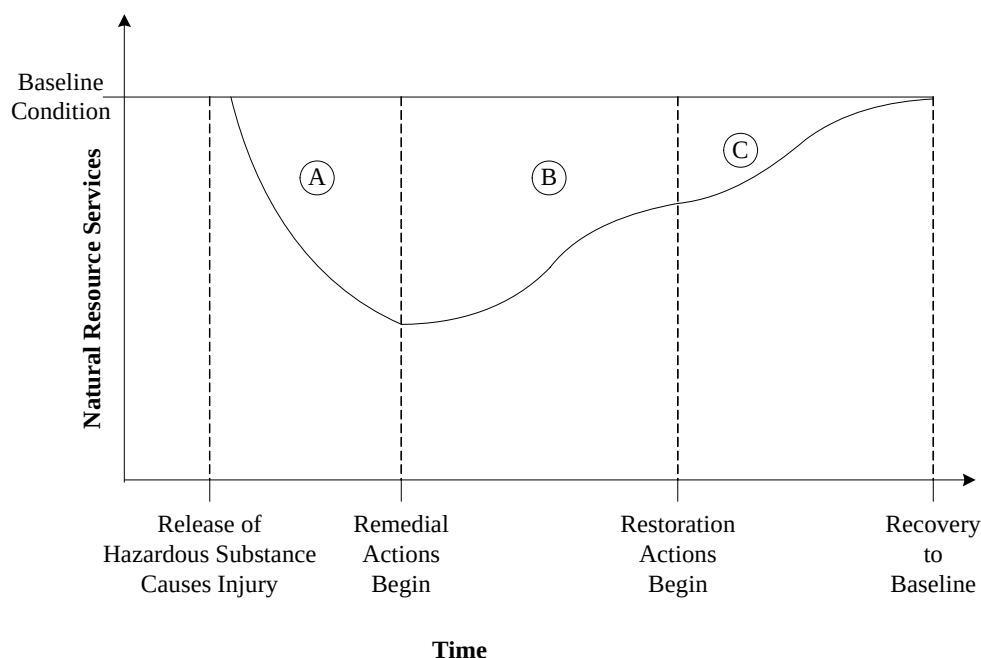


Figure 8.1. Conceptual diagram showing adverse impacts to a natural resource from the time of a release until baseline conditions are restored.

8.2.2 Summary of approach

The State Trustees plan to seek recovery for both components of NRDs: (1) costs of restoring injured resources to baseline conditions, and (2) compensable damages to account for lost services in the past, present, and future until the natural resources have been restored to baseline.

The State's NRD calculations will take into account the remedial actions at the Arsenal. For resources where the remedial actions will return or have returned resources to baseline conditions, the State's damage calculations will include the period from the onset of injury (or 1981) until baseline conditions are (or were) achieved. The State may also account for remedial actions that restore natural resources beyond baseline conditions.

For all injuries, the amount of restoration required for offset will be determined using service-to-service scaling methods such as HEA or REA. These methods are described in Section 8.3.

The State will use input from the public and interested stakeholders to identify potential restoration projects for evaluation using criteria established by the State; select potential restoration projects; scale those projects to offset quantified injuries; and determine the cost of restoration projects at the identified scale of implementation. Section 8.4 describes each of these components of the restoration-based damage determination approach in more detail.

8.3 Overview of HEA and REA

HEA and REA methods have been published in peer-reviewed literature, codified in the National Oceanic and Atmospheric Administration's regulations for NRDA, accepted by Federal Courts [*United States v. Melvin A. Fisher et al.*, Case No. 92-10027-CIVIL-DAVIS; *United States v. Great Lakes Dredge and Dock Co.*, 259 F. 3d 1300 (11th Cir. 2001)], and are routinely performed by Trustees and responsible parties at NRD sites throughout the United States.

Under HEA, service losses are expressed in terms of habitat (e.g., acres of grassland) and are offset by restoration of similar habitat. Under REA, losses are expressed in terms of resource units (such as numbers of fish or birds or acre-feet of groundwater), and are offset by projects that restore equivalent resource units. The HEA method has been described in a number of published technical articles (e.g., Unsworth and Bishop, 1994; Chapman et al., 1998; Peacock, 1999; Strange et al., 2002, 2004; Allen et al., 2005; NOAA, 2006).

HEA/REA is used to quantify the impacts to services resulting from injuries to natural resources (i.e., the debit) as well as the expected benefits from restoration (Figure 8.2). Determining equivalency (scaling) between the debit and credit is conceptually simple:

- ▶ Sum the reductions in services caused by the injury
- ▶ Determine the amount and timing of improvement in services expected per unit of restoration
- ▶ Divide the total losses by the benefit per restored unit to calculate the scale of required restoration.

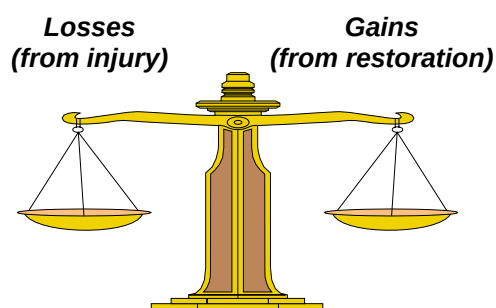


Figure 8.2. HEA and REA are used to determine the type and amount of restoration needed to balance losses from natural resource injuries.

8.3.1 Variables in a HEA/REA model

Necessary input parameters for HEA or REA include:

Start year. A start year must be specified for both the debit and the credit sides of the model. On the debit side, the start year usually is either the year in which injuries began or 1981 (following enactment of CERCLA in December 1980). On the credit side, the start year is the year in which restoration actions are expected to begin generating services.

End year. An end year can be specified, if appropriate. On the debit side, the end year is the year in which injuries stop because resources have returned to baseline conditions, through natural recovery, remedial actions, or projected restoration. On the credit side, the end year is the last year in which the credit from the restoration project is expected. For some restoration projects, benefits are expected to accrue in perpetuity. In that case, one typically specifies an end year at least 100 years after implementation.

Spatial extent. On the debit side, the spatial extent is the area where natural resource services have been degraded as a result of the release of hazardous substances. On the credit side, the spatial extent defines the area where restoration actions will be implemented and where resource service flows will improve.

Service loss. For a HEA, this is the degree of resource or service loss within the spatial extent relative to baseline conditions. Loss can vary from 0% (no loss) to 100% loss (complete loss). The degree of loss can vary over time (as can baseline conditions). The degree of loss will decrease over time if resource conditions improve and will eventually become 0% (no loss) when resource services return to baseline conditions. For a REA, the degree of loss can be expressed in terms of numbers of individuals lost, population reductions, loss of reproductive output or viability (including lost lifespan or reduced number of young), or other measures (“metrics”) of resource impairment. Toxicity data such as soil contaminant concentrations can be an important source of information for determining the degree of loss by translating dose-response models into either a service loss assignment (for HEA) or a measure of resource impairment (for REA). If soil concentrations decrease over time as a result of remedial actions, then service or resource losses decrease as well.

Service gain. This is the amount of benefit expected to derive from implementation of a restoration project. Once a project is implemented, benefits begin to accrue, but full services might not be expected until some time in the future. Service gain could be 100% if entirely new habitat is created that functions at baseline levels, or it could be some percentage of baseline if actions enhance the services of habitat that already exists. As with debit calculations, the amount of service gain is estimated relative to baseline conditions.

Baseline conditions. The conditions that would have existed absent the releases of hazardous substances.

Metric. This is not an input parameter to HEA or REA, but instead is the unit of measure of the service loss and gain.

Damage or recovery trajectory. This also is not an input parameter, but a description of the service losses or gains over time.

Discount rate. To make past, current, and future losses and gains comparable, while accounting for well established time preferences, (i.e., people are generally willing to pay more for things in the present as opposed to the far future), the changes in service flow levels from past and future years are discounted to present-day terms (i.e., “present value”). An annual “social” discount rate of 3.0% is typically used in HEA and REA present value calculations for service flows (NOAA, 1999).

Base year. The base year is typically the year in which the analysis is conducted. The present value factor is greater than one for years before the base year and less than one for years after the base year.

Present value factor. The present value factor in the base year is one. Because of the discount rate, the value of a service in the past is greater than the value of the service today; thus, the present value factor is greater than one. Similarly, the value of a service in the future is less than the value of that service today; thus, the present value factor is less than one. Present value factors are calculated as follows:

$$\text{Present value factor} = 1 / (1 + \text{discount rate})^{(\text{year} - \text{base year})}.$$

8.3.2 Calculation methods

For a HEA, all of these variables are used to equate injured areas and restored areas in summary units that integrate space and time. For example, a debit of 1 acre-year could reflect 1 acre of land having 100% loss of habitat for one year or 2 acres with 50% loss of services for one year. However, the HEA method incorporates a discount rate into the calculations, so that impacts and benefits that occur in different years are converted to present-value equivalents. Impacts and benefits are therefore generally quantified using units of “discounted service-acre years” (DSAYs), which account for the acreage of habitat impacted or benefited, the duration of impacts or benefits, the level of services provided by the impacted or benefited parcels, and time values, to convert changes in services in different years to a common currency.

Table 8.1 demonstrates how the HEA debit would be calculated for one acre of land with a constant service loss of 50%, from the start of 2000 to the end of 2010. The total HEA debit for one acre during this time period is 5.9 DSAYs.

Table 8.1. Example of HEA debit calculations. This example assumes 1 acre of land with a 50% service loss from the beginning of 2000 to the end of 2010, with a 2007 base year and 3% discount rate.

Year	Percent service loss	Present value factor^a	Debit^b (DSAYs)
2000	50%	1.23	0.62
2001	50%	1.19	0.60
2002	50%	1.16	0.58
2003	50%	1.13	0.56
2004	50%	1.09	0.55
2005	50%	1.06	0.53
2006	50%	1.03	0.52
2007	50%	1.00	0.50
2008	50%	0.97	0.48
2009	50%	0.94	0.47
2010	50%	0.92	0.46
Total			5.9

a. Present value factor = $1 / (1 + \text{discount rate})^{(\text{year} - \text{base year})}$. Values rounded to two decimal places for presentation.

b. Debit is calculated by multiplying percent service loss by present value factor.

HEA credits for service gains associated with restoration are calculated similarly. Table 8.2 demonstrates how HEA credits would be calculated for a restoration project on one acre of land that improves service flows, as a percentage of baseline, by 50% in equal annual increments over the five-year time period from 2010 to 2014, and then maintains the 50% service improvement for the next five years (2015–2019). Again, the base year in this example is 2007 and the discount rate is 3%. The total HEA credit for this acre, for the period 2010–2019, is 3.1 DSAYs.

REA is similar to HEA but uses resource metrics (such as numbers of birds injured) instead of habitat units to quantify changes in services over time. An example of a simple REA might be a single event bird kill. The metric might be lost bird-years, where the loss is the sum of the expected remaining years of life for the killed birds. The data to support expected life spans come from bird population and survival models. Multiplying the estimated number of killed birds by years of life lost gives lost bird-years. This value is discounted to quantify the injury in discounted-lost-bird-years.

Table 8.2. Example of HEA credit calculations. This example assumes 1 acre of land with a service gain increasing from 0% to 50% over baseline service levels from 2010 to 2014 and the 50% improvement maintained from 2015–2019, assuming a 2007 base year and 3% discount rate.

Year	Percent service flow above baseline at end of year	Present value factor ^a	Credit ^b (DSAYs)
2010	10%	0.92	0.09
2011	20%	0.89	0.18
2012	30%	0.86	0.26
2013	40%	0.84	0.34
2014	50%	0.81	0.41
2015	50%	0.79	0.40
2016	50%	0.77	0.38
2017	50%	0.74	0.37
2018	50%	0.72	0.36
2019	50%	0.70	0.35
Total			3.1

a. Present value factor = $1 / (1 + \text{discount rate})^{(\text{year} - \text{base year})}$. Values rounded to two decimal places for presentation.

b. Credit is calculated by multiplying percent service gain by present value factor.

REA approaches can be used for other resources as well. For example, if one quantified air injury in units of volume of air injured, then one could quantify air improvements from restoration projects in units of volume of air restored. The metric for scaling the restoration project would then be discounted-volume-years.

8.3.3 Assessment approach

The State plans to quantify natural resource injuries using HEA and/or REA approaches. The State will choose the appropriate approach (HEA or REA) based on the results of the injury assessment process and the types of information available, including restoration benefit information. Once injury is quantified using appropriate units (DSAYs for HEA; discounted lost-resources or resource years for REA), the State will select potential restoration projects using the project evaluation criteria, and calculate the scale of required restoration to offset the injury.

8.4 Restoration Projects

8.4.1 Identification

Consistent with DOI regulations, the State plans to identify a “reasonable number of possible alternatives for the restoration, rehabilitation, replacement, and/or acquisition of the equivalent of the injured natural resources” [43 CFR § 11.82 (a)]. The State will consider projects from existing regional restoration plans (e.g., from the Northeast Greenway Corridor project) and solicit proposals from State agencies such as the DOW, interested nonprofit organizations, and the general public when identifying a list of potential restoration projects. Such projects would benefit the resources that have been injured at the Arsenal. Examples include:

- ▶ *Projects that provide benefits to terrestrial grassland (e.g., prairie) habitats and species.*
- ▶ *Projects that provide benefits to riparian-wetland habitats and species.*
- ▶ *Projects that provide benefits to groundwater systems, aquifers, groundwater-surface water interactions, or water users.* These potential projects are discussed further in Chapter 9.

Specific types of projects may include:

- ▶ *Preservation of existing habitat at risk for development.* The State may identify parcels of land with high habitat value for wildlife or high rates of groundwater recharge that can be preserved through acquisition or conservation easements. Preservation provides benefits when potential future development would result in the loss of natural resource services.
- ▶ *Restoration and enhancement of existing degraded habitats.* The State may identify degraded grasslands, wetlands or stream corridors that can be restored or enhanced to increase the wildlife services provided.
- ▶ *Preservation of protective buffers for core areas of high wildlife value.* The State may preserve land to protect areas of high wildlife value that would be lost if the surrounding land use changed. Residential development near habitat areas, for example, can result in impacts to birds and wildlife from a variety of factors, including the introduction of non-native predators such as domestic cats and dogs (USDA NRCS, 2007).

8.4.2 Evaluation and selection

Potential restoration projects will be evaluated and ranked using criteria developed by the State. These criteria build on factors identified in the DOI NRDA regulations [43 CFR § 11.82]. The State has grouped criteria into “threshold acceptance criteria” and “project preference criteria” (Table 8.3). Projects will first be evaluated against threshold acceptance criteria. Failure to meet all the threshold criteria would result in elimination of a project from consideration. Projects that meet threshold criteria would then be investigated further to gather information necessary to evaluate the projects using the preference criteria. Projects that best meet the preference criteria will be used for restoration scaling (see Section 8.4.3) and costing (see Section 8.4.4).

Table 8.3. Summary of Trustee criteria for evaluating restoration projects

Threshold acceptance criteria

1. Project must restore, replace, or acquire natural resources, not merely human services.
 2. Project must be subject to a reasonable degree of State management, control, and monitoring.
 3. Project must have a reasonable likelihood of success. The project should be technically feasible and viable.
 4. Project must comply with laws and be protective of health and safety.
 5. Project must be generally acceptable to the public.
-

Project preference criteria

1. Projects that are consistent with existing state, regional, and local resource management and development plans will be strongly preferred.
 2. Projects that provide higher flows of services throughout the project lifetime will be preferred. It is preferable and more cost-effective for projects to provide higher levels of near-term benefits as compared to projects that require protracted periods to realize benefits. Projects that provide long-term sustainable service flows are also preferred.
 3. Projects with less long-term operations and maintenance (O&M) will be preferred unless those costs are assumed by other parties and the State is assured that O&M will be adequately carried out for as long as necessary.
 4. Projects that are likely to benefit more than one resource will be preferred.
 5. Projects that can be reasonably monitored and have benefits that can be measured and verified will be preferred.
 6. Projects that provide actual resource improvements will be preferred over projects that entail only conservation of open space, unless development threats are imminent or the conservation opportunity is of an advantageous scale or timing.
 7. Projects that provide a high ratio of expected benefits compared to expected long-term costs for planning, implementation, operations, and maintenance will be preferred. Cost-effectiveness may be assessed relative to other projects that benefit the same resources.
 8. Projects will be preferred if they are not likely to be funded through other mechanisms, or if implementation of the project would free restoration funding sources to finance other restoration projects.
 9. Projects will be preferred if they leverage damage recoveries to match other funding sources and thereby enable projects to be larger or more comprehensive in scope.
-

8.4.3 Scaling

After quantifying reductions in services from injured resources, Trustees will determine the appropriate scale of restoration projects. For wildlife, service flow reductions may include:

- ▶ Loss of species diversity
- ▶ Loss of threatened and endangered species
- ▶ Loss of common wildlife species
- ▶ Loss of human active-use services (such as hunting or wildlife viewing)
- ▶ Loss of human passive-use services (such as bequest values – valuing the availability of resources for future generations).

Reductions in services provided by surface water may include:

- ▶ Loss of aquatic habitat
- ▶ Loss of species diversity or density
- ▶ Loss of clean water for recharge of alluvial groundwater.

Reductions in services provided by groundwater and aquifers may include:

- ▶ Loss of human active-use services such as drinking water
- ▶ Loss of human passive-use services
- ▶ Loss of clean water for recharge to surface water and wetlands
- ▶ Loss of aquifers for recharge, storage and transportation of groundwater.

Reductions in services provided by air may include:

- ▶ Loss of human active-use services such as unhampered breathing.

For the restoration scaling phase, the State will determine the required size (or “scale”) and timing of implementation for the preferred restoration projects such that increases in services from restoration is equal to the loss of services from injured resources at the Arsenal, with both losses and gains adjusted to present-value equivalents. This scaling would compensate for interim losses and quantify any restoration required to return injured resources to baseline conditions.

As part of the scaling effort, the spatial connectivity, and the timing and magnitude, of anticipated service flow improvements will be considered. For example, acquisition of or habitat restoration on, two adjacent parcels would likely provide greater benefits than identical acquisitions or restoration on parcels separated by miles of developed land. Likewise, projects that yield dramatic improvements in a short period of time would likely provide greater benefits than projects with more subtle improvements that would take longer to accrue. Also, a project

that involves creating riparian habitat around a two-acre gravel pit pond may be fixed in its scope because it involves habitat improvements to an existing site with fixed dimensions. In contrast, a river restoration project often can vary in size depending on the resources available to the project. Projects also can vary in the degree and duration of service improvement depending on the intensity of the restoration work and the commitment to long-term monitoring and maintenance. For example, a project that removes invasive species a single time would generate benefits over a shorter period of time than a project that provides ongoing control of invasive species as necessary.

The State plans to determine the best size and scope for each proposed project to maximize project benefits and overall cost-effectiveness across the suite of selected restoration projects. The State will take advantage of “economies of scale” where possible – sizing projects to get the maximum per-unit benefit, while at the same time being conscious of “diminishing returns” where additional resources spent on a project yield lower per-unit benefits.

The type of scaling described above for HEAs and REAs is called “service to service” scaling, where the services gained from restoration offset the services lost from injury. Projects that involve replacement or acquisition of equivalent resources can be scaled directly using the same metric. However, the State may also consider replacement or acquisition projects that provide services of a different type or quality than those lost if, for example, the replacement or acquisition of equivalent resources is technically infeasible or prohibitively expensive. When a replacement or acquisition project provides services that are not the same as those lost, additional information may be needed to determine when the project has produced “equivalent” resources as measured by the services. Alternative scaling methods such as weighting factors or value-to-value analysis, as opposed to “service-to-service” scaling, may be employed in these situations.

The State expects to use service-to-service scaling for terrestrial and aquatic wildlife injuries because restoration alternatives are available that provide the same or similar types and quality of services as those lost. The State may also use service-to-service scaling for injuries to air and surface and groundwater resources, if appropriate restoration alternatives that provide services of the same or similar type and quality can be quantified.

8.4.4 Costing

After determining the required size of each proposed restoration project, the State will estimate the cost to implement these projects. Costs will be based on preliminary project designs because full engineering designs are not feasible or appropriate to develop during the assessment process. Total cost estimates will include project design, implementation, monitoring, continued operation and maintenance, contingencies, Trustee oversight, and adaptive management. Adaptive management allows project changes to be made if monitoring indicates that goals are

not being achieved. As part of this process, information will be developed that can be used to adjust project cost estimates according to the scale of implementation for projects where the size of the project can vary.

8.4.5 Summary

The determination of damages using the restoration-based cost approach involves the following steps:

- ▶ Quantification of the spatial and temporal extent of natural resource service losses as a result of the release of hazardous substances
- ▶ Identification of projects that can provide restoration, rehabilitation, replacement, and/or acquisition of equivalent of the resources and their services
- ▶ Scaling of the projects such that the service gains that the project provides offset the service losses as a result of the hazardous substance releases
- ▶ Estimation of the total cost to implement the restoration projects that will provide equivalent resources and their services.

The responsible party may either choose to implement the restoration projects directly or provide the Trustees with monetary compensation for the estimated cost of implementing the projects.

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9. Valuing Groundwater

This chapter provides an overview of the NRDA economic valuation approaches to be used to quantify damages to groundwater.

Section 9.1 provides an overview of damage assessment concepts and definitions. Section 9.2 presents a market-based approach to estimating damages resulting from loss of groundwater use services. Section 9.3 describes a restoration-based approach, and Section 9.4 then presents a total value equivalency (TVE)/restoration scaling approach, including a description of the foundations of the approach; the steps and data necessary for implementing this non-market method; and future work that may be conducted as part of this assessment.

9.1 Damage Assessment Concepts and Definitions

As noted in Chapter 8, the purpose of the damage determination phase is to establish the amount of money to be sought in compensation for injuries to natural resources resulting from a release of hazardous substances, including the *cost of restoration* and, at the discretion of the authorized official, the *compensable value* of all or a portion of the interim loss [43 CFR § 11.80(a)(2)(b)]. Compensable values include “the value of lost public use of the services provided by the injured resources, plus lost non-use values such as existence and bequest values” [43 CFR § 11.83(c)(1)].

These terms are defined in the regulations as follows:

- ▶ *Compensable value* is the amount of money required to compensate the public for the loss in services provided by the injured resources between the time of the release and the time the resources and the services those resources provided are fully returned to their baseline conditions [43 CFR 11.83(c)(1)]
- ▶ *Use value* is the value of the resources to the public attributable to the direct use of the resources [43 CFR 11.83(c)(1)(i)]
- ▶ *Direct use values* are generally associated with well-identified, active, and often on-site, uses such as recreational and commercial activities
- ▶ *Non-use value* is the difference between compensable value and use value [43 CFR 11.83(c)(1)(ii)]. Non-use values (or passive use values) arise from the values individuals place on resources apart from their own readily identified and measured direct or active use. Non-use values may include bequest values, which are the values individuals place

on the availability of resources for future generations, existence values, which are those values individuals place on a resource even if they never use it [56 FR 19760], or option values, which are values held by individuals who wish to preserve the resources for their own potential use.

Service flow losses and selection of economic assessment methods

Economic methods are used to identify, characterize, quantify, and value human use service losses. Based on the potential groundwater service losses, the Trustees anticipate using both market price methods and restoration-based approaches for estimating damages. Specifically,

- ▶ **Market price methods.** Market prices can be used to establish the diminished value of the injured groundwater.
- ▶ **Resource equivalency analysis.** REA can be used to develop the cost of restoring, replacing, or acquiring the equivalent groundwater and aquifer resources and services, including interim losses.
- ▶ **Total value/restoration scaling methods.** Methods such as conjoint or stated choice methods can be used to establish the type and amount of restoration actions that provide value to the public equivalent to the value held for the injured resource.

9.2 Market Price Approaches

For water resources, including groundwater, that are traded in reasonably competitive markets, one of the valuation methods available to the Trustees is the market price method [43 CFR §11.83 (c) (2)(i)]. This section describes how market prices for the direct consumption of water in municipal and industrial activities, or for its use as an input to other commodities such as irrigated agriculture, reflect the value of water in the Front Range region of Colorado.

Water that could have been available from the Arsenal absent the contamination can be valued using market data that are readily available, comprehensive, and consistent. Initial evaluation of data indicates that sufficient information is available to form an accurate representation of the willingness to pay for water over the past 15 years in the Front Range area of Colorado. This can provide a basis on which to calculate contaminated groundwater damages from the Arsenal site.

9.2.1 Water market literature overview

Over the past 15 years, natural resource agencies in the western United States have gradually accepted water markets as a way to encourage the efficient allocation of water among competing

uses. In this period, the 14 contiguous western states have enacted legislation that clarify water rights, and in particular the conditions under which water is transferred by a temporary lease or permanent sale. Economists have recognized differences in the value of water depending on the geographic regions and sectors of the economy using the water. They have advocated water markets as a method to allow for the increased benefits that can be realized by allowing water to move between sectors of the economy and across geographic regions. Potential gains in efficiency have been shown by Hartman and Seastone (1970), Vaux and Howitt (1984), and Hearne and Easter (1997). These gains from trade have led to active water markets in many parts of the western United States including Colorado.

The wide range of transferable water rights in western states breaks down into two broad classes commonly termed leases and sales. Leases of water are generally for a single year and for a known quantity of water. Some lease contracts are for longer periods of time and can be contingent on hydrologic conditions. Such contingent leases are a way of sharing the supply risk between the buyer and seller. Sales of water rights, on the other hand, usually entitle the purchaser to a permanent share of a water supply system that may yield varying amounts of water depending on weather and other factors. The seniority of the rights affects their expected yield and their sale price.

Table 9.1. Cumulative volume and volume-weighted prices for reported water transactions in Western states, 1990–2005^a

State	Volume			Lease/sale ratio	Transactions as % of total use
	Lease (thousand acre-feet)	Sale	Total		
AZ	10,869	1,958	12,826		
CA	18,407	2,557	20,965	7.20	3.13
CO	516	2,977	3,494	0.17	1.52
ID	4,338	408	4,746	10.64	1.42
MT	52	9	62	5.56	0.04
NM	837	258	1,095	3.24	1.82
NV	236	960	1,196	0.25	2.38
OR	1,070	2,406	3,476	0.44	2.61
TX	5,351	3,907	9,258	1.37	2.17
UT	262	190	452	1.38	0.55
WA	128	298	427	0.43	0.37
WY	234	207	441	1.13	0.42
Average				2.62	2.35
Total	42,302	16,135	58,437		

a. Water transferred under sale or long-term lease is counted each year for which the transfer occurs.

Source: Data from the *Water Strategist* (1990–2006).

9.2.2 Market value of groundwater: Conceptual approach

Using the market price approach, damages will be estimated based on observed market trades for water in the Front Range region to ascertain a market value (i.e., water users' willingness to pay) for the groundwater that, in the absence of contamination, would have been available.

Many of the Front Range water utilities that purchase surface water supplies also use groundwater that is blended with surface water for consumption, thus creating a single commodity with a shared market price. In addition, the cost of obtaining the rights to use shallow, tributary groundwater is often related to the cost of obtaining sufficient augmentation water. Augmentation water can be other sources of groundwater, including bedrock supplies, but more often is obtained by purchasing and retiring senior surface water rights. Thus, the Trustees will consider both groundwater and surface water transactions in determining appropriate market prices.

As with any market price valuation, the ultimate estimate of appropriate value will depend upon an analysis of variables affecting the price for each transaction. Such variables may include quality, location, reliability of supply, quantity of water transacted, seniority of rights, and consumptive use percentage of the water right. Transactions for sales of permanent rights as well as temporary leases will be analyzed.

To develop market prices for groundwater in the Arsenal region, the Trustees will use observed market data, including associated variables, to establish appropriate prices that water would sell for in the Front Range region at a given date. The sale price of water would then be used to calculate the annual diminished value of injured resources. Market prices for dates after those available in the collected transactions would be based on statistical forecasts using projections of variables that help explain changes in water prices, such as urbanization and development in the region. Values may also be based on differences in water quality and any use restrictions or other constraints not related to the injury.

9.2.3 Illustration of market price approach

To demonstrate the applicability of the market price method, the Trustees identified 1,118 observations of water rights sales in Colorado from 3,696 transactions compiled from the *Water Strategist* (Hansen et al., 2007). The *Water Strategist* reports permanent transfers and leases (including price, quantity, buyer and seller identification, buyer and seller use, and some additional contract terms) in 14 western states on a monthly basis.¹ The details of transactions

1. The implicit assumption is that the *Water Strategist* data are, if not comprehensive, at least representative of trades taking place in western states.

that occurred in Colorado over 16 years allow estimates of the economic, hydrological, and institutional factors that determine the price of water in Colorado, and thus allow direct estimates of water values in monetary terms. Table 9.2 provides information on transactions for the Colorado water market.

Table 9.2. Water purchasers in the Denver area, with number of transactions (1990–2005)

Buyer	Number of permanent transfers	Buyer	Number of permanent transfers
Arkins WA	2	Kersey	6
Arvada	1	LaSalle	20
Ault	6	Left Hand WD	36
Aurora	2	Little Thompson WD	81
Berthoud	4	Longmont	4
Boulder	41	Longs Peak WD	16
Brighton	1	Louisville	25
Broomfield	47	Loveland	3
Central Weld County WD	38	Lower Latham Reservoir Co.	8
Dacono	22	Lyons	5
East Larimer County WD	13	Mead	5
Erie	42	Milliken	19
Estes Park	5	North Weld County WD	28
Evans	29	Northglenn	3
Firestone	44	Nunn	11
Fort Collins-Loveland WD	86	Pierce	10
Fort Lupton	32	Platteville	22
Fort Morgan	17	Severance	1
Frederick	36	St. Vrain and Left Hand WCD	14
Gilcrest	13	Superior Metro District No. 1	5
Golden	1	West Fort Collins WD	1
Greeley	24	Westminster	8
Hudson	6	Windsor	19
Johnstown	6		

WD = water district.

Buyers were included in this list if they made at least one trade through the Colorado Big Thompson (CBT) over the study period or if they are located within the Denver Metropolitan Statistical Area.

Water in Colorado is traded in the form of three different property rights: a short-term lease of a quantity of water (lease), a permanent sale of a water right (sale), and a permanent sale of a share in large water projects (e.g., share in a ditch company or in the CBT project). Shares vary in their yield of water from year to year. In Colorado, like many western states, leases of water are common. However, as shown in Table 9.1, when considering the total volume of water transacted, the ratio of leases to actual sales is relatively low in Colorado. (Colby et al., 1993). On the other hand, Table 9.3 shows the average quantities and prices of transfers by type of water and year. All types of water are traded, but clearly, the number of trades in leases and shares greatly exceeds the number of permanent sales of water rights.

Table 9.3. Water transfers in Colorado by year (1990–2005)

Year	Total quantity (acre-feet)			Average price		
	Lease	Sale	Share	Lease	Sale	Share
1990	14,000		3,626	\$70		\$2,991
1991	10,000	250	12,579	\$93	\$5,851	\$2,890
1992	2,000		4,492	\$27		\$2,734
1993	14,300		2,019	\$25		\$2,334
1994	37,558	200	2,509	\$18	\$5,338	\$2,234
1995	23,312		2,128	\$34		\$2,935
1996	62,534		2,841	\$489		\$3,806
1997	7,000		8,254	\$83		\$3,916
1998	38,857		3,569	\$539		\$4,620
1999	35,256	5,800	7,352	\$8	\$3,666	\$6,839
2000	15,674		4,055	\$10		\$16,800
2001	25,603		2,861	\$73		\$15,850
2002	1,221	450	2,513	\$170	\$9,468	\$20,687
2003	14,946	7,596	2,087	\$159	\$4,845	\$15,862
2004	15,640		3,367	\$347		\$18,365
2005	22,478	873	2,279	\$212	\$948	\$15,797

To demonstrate how water market data are used to estimate a time series of representative prices for the Colorado Front Range water market, a statistical regression analysis was developed to measure those factors that are associated with changes in the price of water rights. The regression results presented here are intended to be illustrative, as the effect of different explanatory variables will be investigated further during the assessment. However, this illustration demonstrates how regression analysis can be used to reveal the factors associated with changes

in prevailing water market prices. The ability to measure these factors enables estimation of a market clearing price. Table 9.4 shows the results of an initial regression applied to 1,118 observations of prices and quantities of water rights sales from 1990 to 2005. In this illustrative example, the data available on annual prices are in constant 2004 dollars, and sale price was related to five variables to explain changes in price through time: the annual quantity of water rights sold in Colorado, a variable that accounts for sales originating from shares in the CBT (see below), a time trend, the number of acre-feet in the particular contract, and an index of the relative level of drought in a given year called the Palmer Drought Index.² Water rights based in the CBT are hypothesized to be more valuable than other sources, as they are for transmountain diversions and have fewer augmentation requirements than many other sources.

Table 9.4. Regression of Colorado water rights sales, 1990–2005

Water price (2004 dollars)	Annual volume traded (1,000 acre-feet)	Transaction volume (acre-feet)	CBT (= 1 if trade occurs within CBT)	Annual Palmer Drought Index (larger numbers = higher precipitation)	Time trend	Constant
	-52.0497	-1.3741	815.7813	-996.6406	1,033.028	738.5783
	(3.02) ^a	(2.08) ^b	(0.38)	(7.26) ^a	(7.77) ^a	(0.53)

Observations: 1,118.

R-squared: 0.24.

Robust t-statistics in parentheses.

a. Significant at 1% level.

b. Significant at 5% level.

The regression equation from Table 9.4 for calculating water price in 2004 dollars is:

$$\text{Water Price} = 738.57 - 52.05 \times (\text{Annual Volume Traded}/1,000) - 1.374 \text{ Transaction Volume} + 815.78 \text{ CBT} - 996.64 \text{ Drought Index} + 1,033.03 \text{ Year Index}.$$

This illustrative regression equation has some explanatory power, with an R^2 of 0.24. Three of the six variables are highly statistically significant in explaining changes in the observed water prices: the total quantity of rights sold, time, and drought severity. The total annual quantity of water rights sold in a year is negatively related to the prevailing market price, as would be

2. The Palmer Index was developed by Wayne Palmer in the 1960s and uses temperature and rainfall information in a formula to determine dryness. The Palmer Index uses 0 as normal, and drought is shown in terms of minus numbers; for example, minus 2 is moderate drought, minus 3 is severe drought, and minus 4 is extreme drought. The Index can also reflect excess rain using a corresponding level reflected by plus figures, e.g., 0 is normal, plus 2 is moderate rainfall.

expected from basic demand theory. The time trend of prices is increasing, as expected given the increased water demand from residential development and economic growth in the Front Range region over the 16-year time period. In addition, water prices increased with the severity of drought conditions, as measured by the Palmer Drought Index. The quantity of the water traded has a moderately significant effect on the price, with smaller quantities requiring a higher unit price.

Using regression results such as those in Table 9.4, the resulting average price of water can be calculated under different conditions and times. Figure 9.1 shows a plot of actual and estimated average prices over the 16 years in the sample. The illustrative regression annual price predictions fit the actual average price quite well, except in the extreme drought years of 2002–2003. Figure 9.1 also shows a pronounced increase in average water prices after 2000, when the current drought cycle began. Average sale prices after 2000 have fluctuated around \$15,000 per acre-foot (in 2004 dollars), providing a reliable estimate of the current value of groundwater rights.

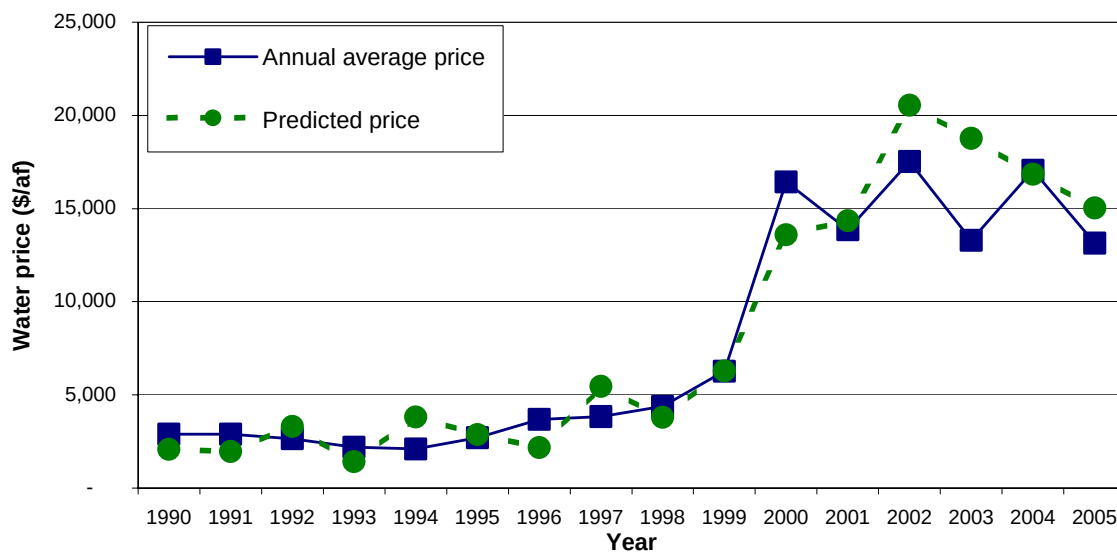


Figure 9.1. Observed and predicted price of permanent water transfers in Colorado over time (2004 dollars).

Water Strategist sales data and other information will be used to measure the actual valuation of water rights in terms of real monetary transactions. Damage recoveries based upon this market price approach would be used for implementing restoration actions. Restoration planning to identify appropriate restoration actions will be undertaken as described in Chapter 8.

9.2.4 Anticipated assessment activities

In the assessment, determination of damages through the market price valuation of groundwater will be pursued. Detailed market price valuation activities will include:

- ▶ Updating and refining a water transactions database to allow for more detailed comparisons to groundwater values in the region
- ▶ Incorporation of regional water demand conditions
- ▶ Refinement of statistical analysis of water market prices
- ▶ Forecasting to future water prices
- ▶ Application of water valuation to estimation of groundwater damages resulting from contamination and institutional controls.

9.3 Restoration-Based Equivalency Approaches

As discussed in Chapter 8, equivalency approaches such as REA can be used to determine the appropriate amount of restoration required to adequately compensate the public for its loss of natural resources and services.

The State will use the selection criteria discussed in Chapter 8 to identify potential restoration projects that would provide compensation for injuries to groundwater. These projects would provide benefits to groundwater systems, aquifers, groundwater-surface water interactions, or water users. Specific types of projects may include:

- ▶ *Water quality protection and improvement programs.* The State may choose to implement projects that protect water quality by reducing urban or agricultural runoff or that improve water quality.
- ▶ *Water reuse programs.* The State may choose to work with municipalities to implement non-potable water reuse programs that would result in measurable savings of potable groundwater. Such a project might involve construction of facilities to transport, store, and apply non-potable irrigation water to public parks, recreational areas, roadway medians, and landscaping around public buildings.
- ▶ *Water conservation programs.* The State may choose to work with municipalities and other appropriate entities to implement water conservation programs that would result in measurable savings of groundwater with no reductions in groundwater services.

- ▶ *Water recharge programs.* The State may choose to create wetlands or detention basins to contain high water flows and allow slower infiltration to groundwater, thereby reducing evaporative losses, increasing the quantity of available groundwater, and restoring groundwater-surface water interaction.
- ▶ *Water salvage programs.* The State may undertake to salvage water lost to invasive species such as tamarisk.

After quantifying reductions in services from injured groundwater resources, the Trustees will determine the appropriate scale of restoration projects. As discussed previously in Chapter 8, reductions in services provided by groundwater may include:

- ▶ Loss of human active-use services such as drinking water
- ▶ Loss of human passive-use services
- ▶ Loss of clean water for recharging surface water
- ▶ Loss of aquifers for recharge, storage and transportation of groundwater.

The Trustees will then determine the required size (“scale”) and timing of implementation for the preferred groundwater restoration projects such that increases in services from restoration would be equal to the loss of services from injured resources at the Arsenal, with both losses and gains adjusted to present-value equivalents. This scaling could compensate for both interim losses and restoration that is required to return injured resources to baseline conditions. Once the required size of each proposed groundwater restoration project is established, the State will estimate the cost to implement these projects. Where the size of the project can vary, unit costs may be developed to enable the Trustees to scale up or down.

9.4 Total Value/Restoration Scaling Method

As discussed previously, when groundwater is injured by releases of hazardous substances, both use and non-use values are lost. Market price approaches, as described in Section 9.2, can measure use values, which make up a portion of total economic value. To estimate total damages for the groundwater injury, however, an alternative to the market price approach is necessary. This alternative approach will identify and quantify the amount and type of restoration that would provide value to the public equivalent to the value of the groundwater that has been injured. These values are ascertained by:

1. Obtaining public preferences for the types and mix of restoration alternatives
2. Providing value-based methods to scale resource restoration projects to provide services of equivalent societal value to the total value of the injured groundwater.

The results of the survey and analysis would determine the restoration plan selected by the Trustees; the cost of the plan would become the amount of damages sought by the Trustees.

A TVE study would support groundwater restoration planning in two ways. First, the study would explicitly obtain the public's input regarding the preferences and values for alternative types of restoration projects. This would aid the Trustees in evaluating the benefits of alternatives [43 CFR § 11.82(d)(2)] and provide additional input into the selection of alternatives [43 CFR § 11.90]. Second, the study provides value-based, as opposed to service-based, methods to determine the appropriate scale of potential restoration actions.

As described in Chapter 8, scaling restoration projects that provide similar services is referred to as *service-to-service* scaling, where the amount of restored services are scaled to be equal to the amount of lost services now and through time. For a large share of the service flow losses in the assessment area, providing restoration with similar groundwater services may not be technically feasible, may be undesirable, or may be too expensive. Thus, it may be preferable to select restoration actions that provide resources and services with similarly held value to those injured in determining the appropriate restoration. *Value-to-value* equivalency analysis ensures that the societal value of the services gained through restoration equals the societal value of losses. Value reflects the benefits or satisfaction that people derive from all active and passive uses of the resources lost due to contamination and gained through restoration.

9.4.1 Conceptual approach

At least since the mid-1960s, environmental economists have argued that people may hold both use (active use) and non-use (passive use) values for environmental resources (Krutilla, 1967). These use and non-use values make up what economists call total value. Passive use values are typically described as values that people hold for goods independent of any direct or active use of the goods. For example, they may gain satisfaction from knowing that an environmental resource will be preserved for others to enjoy, including others alive today and members of future generations. In the case of the Arsenal, even though citizens do not personally use the groundwater from a specific aquifer or area, they might still hold values for it because they would like it to be available to future generations or for other reasons. As the National Research Council (NRC, 1997, p. 2) has stated, "A fundamental step in valuing a ground water resource is recognizing and quantifying the resource's total economic value. Knowing the resource's total economic value is crucial for determining the net benefits of policies and management actions."

Passive values are routinely measured in benefit-cost analysis and have been used in the courts. The D.C. Circuit Court of Appeals confirmed the legitimacy of passive use values in damage assessments in *Ohio v. U.S. Department of the Interior* [880 F.2d 432 (1989)] and these values have been recognized in other cases as well (Freeman, 2003).

Damages for injured groundwater at the Arsenal will be measured using TVE, which considers both active use and passive use values. People's values will be measured by asking them appropriately crafted survey questions. The survey-based approach that is best suited to restoration planning involves stated-choice questions, where members of the public are presented with two or more restoration alternatives with different combinations of environmental resources and services. They are then asked to either choose their preferred alternative or to rank the alternatives. Typically, a cost is also associated with each alternative.

The history of applications of stated-choice questions is presented by Holmes and Adamowicz (2003). Stated-choice questions are now routinely used in nonmarket valuation studies, routinely conducted by state and federal agencies, and the results are accepted in benefit-cost analysis by federal agencies (OMB, 2003). An example of this approach, used on behalf of the USFWS and co-Trustees as part of the Lower Fox River/Green Bay NRDA, is discussed in the Fox River RCDP for the Lower Fox River/Green Bay NRDA (Stratus Consulting, 2000).

9.4.2 Anticipated assessment activities

An approach similar to that undertaken at the Fox River will be applied to determine the types and amount of restoration necessary to compensate for groundwater injuries at the Arsenal. The goal of the TVE approach for the Arsenal assessment will be to develop a variety of restoration projects that provides the public with value equivalent to that lost as a result of groundwater injuries.

Development of restoration options

To identify the potential of restoration options for a TVE study, the Trustees anticipate soliciting projects from a number of sources, including ongoing restoration planning efforts by local resource managers (e.g., Northwest Greenway Corridor); direct solicitation from the public at large through public comment; and focused discussions with identified stakeholder groups and State agencies. Restoration options would then be evaluated for possible inclusion in the TVE survey instrument.

Qualitative survey research

Qualitative survey research such as focus groups and structured individual interviews would be used in the initial stages of TVE survey development. These activities would allow the Trustees to investigate the public's understanding of the injury and its associated value, to identify aspects of greatest concern to the public, to confirm that the exercise is likely to be successful in soliciting the requisite feedback, and to identify types of restoration actions seen as appropriate for compensation.

Development of a survey instrument

Based on findings from the qualitative research phase, and in coordination with the ongoing injury studies, a TVE survey instrument would be designed to measure the public's value for the restoration options in relation to the value of the lost groundwater resources and services due to contamination at the site. Survey development will include peer review of the survey and overall implementation process.

Implementation of survey

The survey would be administered to a representative sample of the relevant population of Colorado. The relevant population would be determined during the qualitative survey research efforts. The survey would be administered in a format (e.g., mail, in-person) determined to obtain reliable results.

Data analysis and reporting

Data collected through the administration of the survey would be evaluated and statistically analyzed to estimate the damages to the public based on a TVE approach.

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Glossary

This section presents definitions of terms in this report.

Baseline. The condition of a natural resource that would have existed but for the release of hazardous substances. Baseline conditions are not necessarily pristine or optimal conditions. See 43 CFR § 11.14(e).

CDPHE. The Colorado Department of Public Health and Environment, the State agency responsible for hazardous waste site compliance and oversight.

CERCLA. The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (42 USC § 9601 to § 9675). This Act, commonly referred to as “Superfund,” is the statutory basis for natural resource damage assessment.

Compensable value. The amount of money required to compensate the public for the loss in services provided by the injured resources between the time of the release and the time the resources and the services those resources provided are fully returned to their baseline conditions. The compensable value includes the value of lost public use of the services provided by the injured resources, plus lost nonuse values such as existence and bequest values. See 43 CFR § 11.83(c).

Damages. The amount of money needed to assess injury and to restore injured natural resources. Damages are sought from the responsible parties. Past damages accrue from the earliest point that injuries from releases can be determined, or authorization of the statute (December 1980 for CERCLA), to the present. Future damages include interim damages, which run from the present until restoration actions return injured resources to baseline conditions. Residual damages, a component of interim damages, accrue after remedial activities have ceased, if the remediation did not fully restore natural resources services to baseline levels.

Discounting. An economic procedure that weights past and future benefits or costs such that they are comparable with present benefits and costs. Discounting converts benefits or costs from different years so that they are mutually comparable.

Discount rate. The rate at which the future is discounted, i.e., the rate at which the future does not count as much as the present. Economists generally agree that the discount rate on social investments such as natural resource services is 3%.

DOI NRDA Regulations. Regulations promulgated by the U.S. Department of the Interior, pursuant to CERCLA, at 43 CFR Part 11.

Exposure. Contact between a hazardous substance or oil and a natural resource. Exposure alone does not constitute an injury, but exposure to a hazardous substance (or byproduct) is necessary to cause an injury. Pursuant to the DOI Regulations, 43 CFR § 11.14(q), exposure occurs when all or part of a natural resource is, or has been, in physical contact with oil or a hazardous substance, or with media containing oil or a hazardous substance.

Groundwater. Groundwater is defined as any water not visible on the surface of the ground under natural conditions; CRS 37-90-103(19).

- ▶ **Tributary groundwater** is hydraulically connected to the surface waters of a stream, and is classified as if it were surface water, subject to the constitutional right of prior appropriation (see below). *Colorado Ground Water Com'n v. North Kiowa-Bijou Groundwater Management Dist.*, 2003, 77 P.3d 62.
- ▶ **Nontributary groundwater** means groundwater having no hydrological connection to surface water; it is administered on the basis of overlying land ownership and is exempt from the doctrine of prior appropriation. See *State Dept. of Natural Resources v. Southwestern Colorado Water Conservation Dist.*, 671 P.2d 1294 (Colo. 1983).
- ▶ **Not-nontributary groundwater** means “. . . ground water located within those portions of the Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers that are outside the boundaries of any designated groundwater basin . . . the withdrawal of which will, within one hundred years, deplete the flow of a natural stream . . . at an annual rate of greater than one tenth of one percent of the annual rate of withdrawal” CRS 37-190-103(10.7).

Habitat. The physical, chemical, and biological attributes that together provide basic needs for plant and animal species and communities of organisms. Habitat includes temperature, moisture, light, structural features such as stream banks and trees, food sources, and nesting, hiding, and thermal cover. The term can be used to define surroundings on almost any scale from very large regions to very small microhabitats.

Habitat equivalency analysis (HEA). An accounting model used to calculate the service losses from past, ongoing, and future injuries (the debit side of the model) and the future service gains from proposed restoration needed to equal the debit (the credit side of the model). HEA is used in cases of habitat injury when the service loss of the injured habitat is comparable to the service gain that will be provided by the replacement habitat.

Harmonic mean. The harmonic mean is calculated by dividing the number of values in a data set by the sum of the reciprocals of those values. It is a more representative central tendency value for skewed data sets than is the geometric mean.

Hazardous substances. Hazardous substances include metals, solvents, pesticides, and other contaminants as specified in Section 101.14 of CERCLA.

Injury. Injury to natural resources is a measurable adverse effect on a physical, biological, or chemical quality of a natural resource. Injuries can occur directly or indirectly. Categories of injury include, but are not limited to, adverse changes in survival, growth, and reproduction; health, physiology and biological conditions; behavior; community composition; ecological processes and functions; physical and chemical habitat quality or structure; and public services. Injury means a measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a discharge of oil or release of a hazardous substance, or exposure to a product of reactions resulting from the discharge of oil or release of a hazardous substance. As used in this part, injury encompasses the phrases “injury,” “destruction,” and “loss.” See 43 CFR § 11.14(v) and 43 CFR § 11.62.

Integrated Endangerment Assessment/Risk Characterization (IEA/RC). The combined human health risk assessment and ecological risk assessment performed as part of the RI/FS at the Arsenal. The report estimated the magnitude of possible exposure and risk to human and ecological receptors. The Army issued the final report in July 1994.

Interim losses. Interim losses accrue from the time of release of the hazardous substance or 1981, whichever is later, until restoration is complete. See 43 CFR § 11.80(b).

Interim Response Action (IRA). A series of 14 response actions at the Arsenal that were identified before the final On-Post FS or Record of Decision. The IRAs were intended to clean up areas of serious contamination before the final remedy was selected or implemented but were intended to be consistent with the final remedy.

Natural resource. Surface water, groundwater, air, geologic resources, and biological resources. See 43 CFR § 11.14(z). Biological resources include those natural resources referred to in section 101(16) of CERCLA as fish and wildlife and other biota. Fish and wildlife include marine and freshwater aquatic and terrestrial species; game, nongame, and commercial species; and threatened, endangered, and State sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms not otherwise listed in this definition. See 43 CFR § 11.14(f).

Natural resource damage assessment (NRDA). The process of collecting, compiling, and analyzing information to determine damages for injuries to natural resources due to the release of hazardous substances. The purpose of NRDA is to determine the amount of damages necessary to compensate the public for loss of resources and services provided by natural resources resulting from releases of hazardous substances. This compensation comes in the form of

restoration or replacement of injured resources, or acquisition of equivalent resources, paid for by the parties who caused the contamination.

NPL (National Priorities List). A list of the hazardous waste sites eligible for long-term remedial action under CERCLA (Superfund). Sites are added to the list through a formal process that evaluates the hazards associated with each site.

Pathway. The route or medium through which a hazardous substance travels from the source of discharge or release to the injured resource. See 43 CFR § 11.14(dd).

Preassessment Screen Determination (PASD). The PASD is a document containing determinations about whether a discharge or release of a hazardous substance warrants conducting a NRDA; it “ensure[s] that there is a reasonable probability of making a successful claim.” 43 CFR § 11.23(a)(b). The PASD is not intended to serve as an actual assessment of natural resource injuries or damages.

Prior appropriation. The doctrine of prior appropriation is constitutionally mandated and codified in Colorado statutes. See COLO. CONST. art. XVI § 5 and CRS § 37-92-102, and simplistically means first in time is first in right. The doctrine has its origins in the mining industry and the arid climate of the west.

Record of Decision (ROD). The document that details the decision-making process and the final selected remedy for an operable unit. The ROD describes the components of the remedy and includes regulatory determinations as required by CERCLA. See 42 USC §§ 121 *et seq.* and, generally, 40 CFR § 300.430.

Release. This term refers specifically to the release into the environment of a hazardous substance. It can mean a leak, a spill, an intentional disposal, the migration of contaminants (e.g., through wind dispersion).

Remedial Investigation/Feasibility Study (RI/FS). The remedial investigation and feasibility study process pursuant to the NCP that forms the basis for selection of a final remedy documented in a ROD. The RI/FS generally occurs before the NRDA process begins.

Remediation/remedy. An action that alleviates contamination or injury; cleanup actions.

Replacement or acquisition of the equivalent. The substitution for injured resources with other resources that provide the same or substantially similar services, when such substitutions are in addition to any substitutions made or anticipated as part of response actions, and when such substitutions exceed the level of response action determined appropriate to the site as described in the ROD. See 43 CFR § 11.82(b)(ii).

Resource equivalency analysis (REA). Similar to HEA but specifically used for scaling losses of resources such as fish, birds, and other wildlife, rather than losses of habitat.

Response actions. Activities taken to reduce threats from contaminants to acceptable levels. Short-term actions are generally termed *removals*, and long-term, final response actions are considered *remedial actions* [42 USC § 9601(23) and (24)]. Short-term response actions include initial response actions such as spill containment. Longer-term actions include permanent treatment or containment of contamination. Under CERCLA, remedial actions must be protective of human health and the environment.

Responsible party. Responsible parties (and potentially responsible parties) mean a person or persons described in or potentially described in one or more of the categories set forth in section 107(a) of CERCLA. 43 CFR § 11.14(kk). Responsible parties may be owners, operators, transporters, or generators of the hazardous substances that cause the contamination at a CERCLA site and that may cause injury to natural resources.

Restoration. Actions that help return injured resources to baseline conditions. Restoration can be accomplished by actual restoration or rehabilitation of resources, or by replacing or acquiring the equivalent of the injured resources and their services. The term “restoration” is shorthand for any such actions. Restoration should be distinguished from “remediation” or “response actions” undertaken pursuant to CERCLA to protect human health and the environment from the threat of hazardous substance releases. See 43 CFR § 11.14(ll).

Restoration and Compensation Determination Plan (RCDP). A document that describes possible alternatives for restoration, rehabilitation, replacement, and/or acquisition of equivalent resources and related services lost to the public. In the RCDP, the Trustees select an alternative, provide justification for the selection of that alternative, and identify the methodologies that will be used to determine the costs and the compensable value of the alternative to the public.

Section. A land section, one square mile, according to the Public Land Survey System for lands in the public domain, which began with the Land Ordinance of 1785 and the systematic survey of public lands, and the Northwest Ordinance of 1787, which established a rectangular survey system designed to facilitate the transfer of Federal lands to private citizens. At its largest extent, the Arsenal comprised sections numbering 1 through 12, 19 through part of 22, 23 through part of 28, and 29 through 36. Section 10 was later ceded to the City and County of Denver for the north-south runway of the old Stapleton International Airport, and since the cleanup, portions of the western tier 9 Section 9, 4, 33, and part of 28 have been sold.

Service flows. The services provided by a resource over time. For example, remediation and restoration activities can increase the service flows provided by a resource.

Services. The physical and biological functions performed by the resource, including any human use of those functions. 43 CFR § 11.14(nn). Natural resources provide ecological and human use and non-use services. Examples of ecological services include nutrient cycling, habitat, water storage and release, and erosion control. Examples of human use services include recreational use such as fishing, hiking, or bird watching, and extractive and consumptive uses, such as mining or grazing. Human non-use services include, for example, the appreciation people feel knowing that habitat is protected for wildlife and for enjoyment by future generations of humans.

Superfund. See CERCLA.

Target analytes. Chemicals or compounds selected for possible monitoring during the Arsenal RI and endangerment assessment. Initially, 666 chemicals and compounds were identified as related to Arsenal activities. Of these, a select subset of 88 compounds served as *target analytes* for the RI.

Trophic level. A group of organisms that occupy the same position in a food chain, or the position of an organism in the food chain. Levels are typically ranged according to how far particular organisms are along the chain from the primary producers (plants) at level 1, to herbivores (level 2), to predators (level 3), to carnivores or top carnivores (level 4 or 5).

Trustee. Any federal agency, state agency, or Indian Tribe that may prosecute a natural resource damage claim.

Water year. October 1 through September 30. October 1, 2007 is the start of water year 2008.

Human-Induced Earthquakes from Deep-Well Injection: A Brief Overview

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Summary

The development of unconventional oil and natural gas resources using horizontal drilling and hydraulic fracturing has created new demand for disposal wells that inject waste fluids into deep geologic formations. Deep-well injection has long been the environmentally preferred method for managing produced brine and other wastewater associated with oil and gas production. However, an increasing concern in the United States is that injection of these fluids may be responsible for increasing rates of seismic activity. The number of earthquakes of magnitude 3.0 or greater in the central and eastern United States, where there are many injection wells, has increased dramatically since about 2009. For example, over 60 earthquakes of magnitudes 4.0 to 4.8 have occurred in central Oklahoma from 2009 to mid-year 2016. Some of these earthquakes may be felt at the surface. The largest earthquake in Oklahoma history (magnitude 5.8) occurred on September 3, 2016, near Pawnee, causing damage to several structures. Central and northern Oklahoma were seismically active regions before the recent increase in the volume of waste fluid injection. However, the sharp uptick in earthquake activity does not seem to be due to typical, random changes in the rate of seismicity, according to several studies.

The relationship between earthquake activity and the timing of injection, the amount and rate of waste fluid injected, and other factors are still uncertain and are current research topics. Despite increasing evidence linking some deep-well disposal activities to human-induced earthquakes, only a small fraction of the more than 30,000 U.S. wastewater disposal wells appears to be associated with damaging earthquakes. However, the U.S. Geological Survey (USGS) deemed the increase in earthquake hazard in the central United States—likely from deep-well injection—sufficient to release a new one-year seismic hazard forecast for 2016 that includes contributions from both induced and natural earthquakes.

The potential for damaging earthquakes caused by hydraulic fracturing, as opposed to deep-well injection of wastewater from oil and gas activities, appears to be much smaller. Hydraulic fracturing intentionally creates fractures in rocks to increase the flow of oil and gas. The technique induces microseismicity, mostly of less than magnitude 1.0—too small to feel or cause damage at the surface. In a few cases, however, hydraulic fracturing has led directly to earthquakes larger than magnitude 2.0, including at sites in Oklahoma, Ohio, and England. In western Canada, earthquakes greater than magnitude 3.0 have been associated with hydraulic fracturing activities, although only from a very small percentage of hydraulic fracturing wells.

The Environmental Protection Agency's (EPA) Underground Injection Control (UIC) program under the Safe Drinking Water Act (SDWA) regulates the subsurface injection of fluids to protect underground drinking water sources. EPA has issued regulations for six classes of injection wells, including Class II wells used for oil and gas wastewater disposal and enhanced recovery. Most oil and gas producing states administer the Class II program. Although the SDWA does not address seismicity, EPA rules for certain well classes require evaluation of seismic risk. Such requirements do not apply to Class II wells; however, EPA has developed a framework for evaluating seismic risk when reviewing Class II permit applications in states where EPA administers this program.

Although only a small fraction of U.S. wastewater disposal wells appears to be problematic for causing damaging earthquakes, the potential for injection-related earthquakes has raised an array of issues and has affected oil and gas wastewater disposal in some areas. In response to induced seismicity concerns, both EPA and state work groups have issued recommendations for best practices to minimize and manage such risks. Several states have increased regulation and oversight of Class II disposal wells. Congress may be interested in oversight of EPA's UIC

program or in federally sponsored research on the relationship between energy development activities and induced seismicity.

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Introduction

Human-induced earthquakes, also known as induced seismicity, are an increasing concern in regions of the United States where the produced fluids and wastewaters from oil and natural gas production are being injected into the subsurface through deep disposal wells. The immediate concern is that injection of these fluids underground may cause damaging earthquakes in regions that typically do not experience much seismic activity. Induced seismicity has garnered increased attention partly as a result of the rapid development of unconventional oil and gas resources using hydraulic fracturing (often referred to as “fracking”). Specifically, the use of high-volume hydraulic fracturing has contributed significantly to the volume of wastewater requiring disposal and has also created demand for disposal wells in new locations. In examining these issues, it is important to distinguish between seismic activity possibly related to hydraulic fracturing itself and the possibility of seismic activity related to injecting fluids down disposal wells, which may not be located near where wells were fracked.

Human activities have long been known to have induced earthquakes in some instances: impoundment of reservoirs, surface and underground mining, withdrawal of fluids such as oil and gas, and injection of fluids into subsurface formations. With the increase in the use of horizontal drilling and hydraulic fracturing to extract oil and gas from shale, and the concomitant increase in the amount of fluids that are injected for high-volume hydraulic fracturing and for disposal, there are several indications of a link between the injected fluids and unusual seismic activity.

The principal seismic hazard that has emerged from increased oil and gas production in the United States appears to be related to disposal of wastewater using deep-well injection in some regions of the country. For example, one study showed the central United States has experienced a sharp increase in seismicity since 2009, increasing from an average of 24 earthquakes per year of magnitude 3.0 (M 3.0) or greater prior to 2009,¹ to an average of 193 earthquakes of M 3.0 or greater through 2014.² The number of M 3.0 or greater earthquakes in the central United States has continued to increase; **Figure 1** shows that the central United States experienced an average of 330 earthquakes of M 3.0 per year or greater from 2009 through January 2016.

Earthquake Magnitude and Intensity³

Earthquake magnitude is a number that characterizes the relative size of an earthquake. It was historically reported using the *Richter* scale. Richter magnitude is calculated from the strongest seismic wave recorded from the earthquake based on a logarithmic (base 10) scale: for each whole number increase in the Richter scale, the ground motion increases by 10 times. The amount of energy released per whole number increase, however, goes up by a factor of 32. The *moment magnitude* (M) scale is another expression of earthquake size, or energy released during an earthquake, that roughly corresponds to the Richter magnitude and is used by most seismologists because it more accurately describes the size of very large earthquakes. Sometimes earthquakes will be reported using qualitative terms, such as Great or Moderate. Generally, these terms refer to magnitudes as follows: Great (M>8); Major (M>7); Strong (M>6); Moderate (M>5); Light (M>4); Minor (M>3); and Micro (M<3). This report uses the moment magnitude scale, which is generally consistent with the Richter scale.

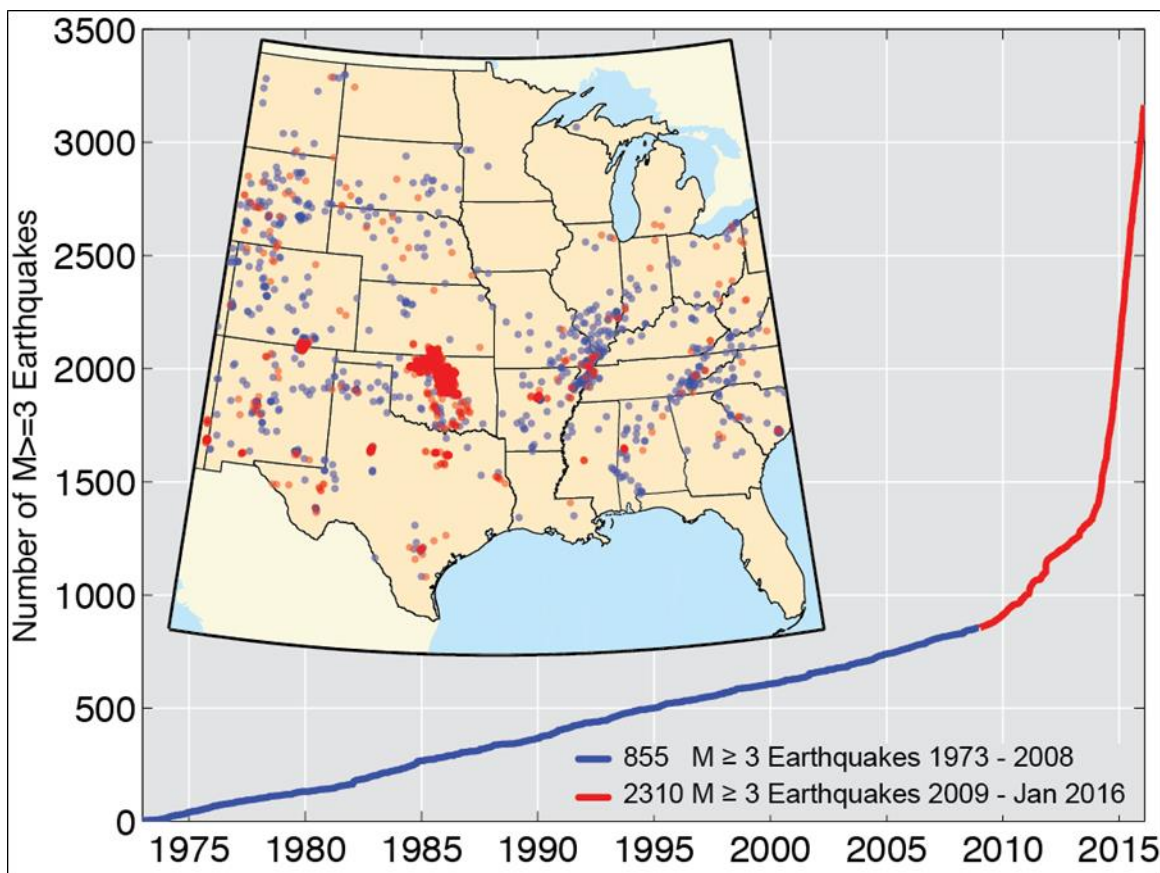
Source: U.S. Geological Survey FAQs, <http://earthquake.usgs.gov/learn/faq/>; and Magnitude/Intensity Comparison, at http://earthquake.usgs.gov/learn/topics/mag_vs_int.php.

¹ Earthquakes of magnitude 3.0 or more can typically be felt at the ground surface. See Box: Earthquake Magnitude and Intensity, above.

² Justin L. Rubinstein and Alireza Babaie Mahani, “Myths and Facts on Wastewater Injection, Hydraulic Fracturing, Enhanced Oil Recovery, and Induced Seismicity,” *Seismological Research Letters*, vol. 86, no. 4 (July/August 2015), p. 1060. Hereinafter Rubinstein and Mahani, 2015.

³ For a more general discussion of earthquakes, see CRS Report RL33861, *Earthquakes: Risk, Detection, Warning, and* (continued...)

Figure 1. Cumulative Number of Magnitude 3.0 or Greater Earthquakes in the Central and Eastern United States, 1973-2016



Source: U.S. Geological Survey, Earthquake Hazards Program, <http://earthquake.usgs.gov/research/induced/>.

Notes: The graph included earthquakes through January 2016. Starting around 2009, the long-term rate of approximately 29 M 3.0 or greater earthquakes per year increased significantly. Between 2009 and January 2016 the region experienced approximately 330 M 3.0 or greater earthquakes per year.

Many studies suggest that the most important contributing factor to this rising trend likely is deep-well injection of oil-and-gas-related wastewater.⁴ However, the precise relationships between earthquake activity and the timing of injection, the amount and rate of fluid injected, and other factors are still not well understood, although a better understanding of these complex relationships appears to be emerging.⁵ Several studies have pointed out that, of the more than 30,000 wastewater disposal wells classified by the Environmental Protection Agency (EPA) as Class II,⁶ only a small fraction appears to be associated with damaging earthquakes.⁷ However,

(...continued)

Research, by Peter Folger.

⁴ See, for example, Rubinstein and Mahani, 2015; A. McGarr et al., "Coping with Earthquakes Induced by Fluid Injection," *Science*, vol. 347, no. 6224 (February 20, 2015), p. 830, hereinafter McGarr et al., 2015; William L. Ellsworth, "Injection-Induced Earthquakes," *Science*, vol. 341, July 12, 2013, <http://www.sciencemag.org/content/341/6142/1225942.full>, hereinafter Ellsworth, 2013.

⁵ See, for example, F. Rall Walsh III and Mark D. Zoback, "Oklahoma's Recent Earthquakes and Saltwater Disposal," *Science Advances*, vol. 1 (June 18, 2015), hereinafter Walsh and Zoback, 2015.

even though it is only a small fraction, the overall number of disposal wells is so large that the total seismic hazard, at least for the central United States, appears to have increased measurably (see “National Issues—Changes to the U.S. Earthquake Hazard Maps”).⁸

The potential for damaging earthquakes caused by injection of fluids for hydraulic fracturing operations, as opposed to deep-well injection of wastewater from fracking and other oil and natural gas production, appears to be much smaller. Multiple studies indicate that the vast majority of fluid injections into production wells for hydraulic fracturing cause microearthquakes—the results of fracturing the rock to extract oil or natural gas—which are typically too small to be felt or cause damage at the surface.⁹ There are some cases where fracking caused detectable earthquakes felt at the surface, but most were too small to cause damage (see “Hydraulic Fracturing” below).

This report reviews the current scientific understanding of induced seismicity, primarily in the context of Class II oil and gas wastewater disposal wells. The report also outlines the regulatory framework for these injection wells and identifies several federal and state initiatives responding to recent events of induced seismicity associated with Class II disposal.

Congressional Interest

How deep-well injection is linked to induced seismicity, and state and federal efforts to address that linkage, are of interest to Congress because of the potential implications for continued development of unconventional oil and gas resources in the United States. If the current boom in onshore oil and gas production continues, then deep-well injection of waste fluids is likely to also continue and may increase in volume. Also, what Congress, the federal government, and the states do to address and mitigate possible human-caused earthquakes from deep-well injection of oil-and-gas-related fluids may provide some guidance for the injection and sequestration of carbon dioxide. Carbon dioxide sequestration—intended to reduce greenhouse gas emissions—would involve ongoing, long-term, high-volume, high-pressure injection via deep wells. Several large-scale injection experiments are currently underway; however, the relationship between long-term and high-volume carbon dioxide injection and induced earthquakes is not known.

The federal Safe Drinking Water Act (SDWA) authorizes EPA to regulate underground injection activities to prevent endangerment of underground sources of drinking water. The SDWA does not address seismicity; however, EPA underground injection control (UIC) program regulations include seismicity-related siting and testing requirements for hazardous waste and carbon sequestration injection wells. Such requirements are not included in regulations governing oil and gas wastewater disposal (Class II) wells, although regulators have discretionary authority to add conditions to individual permits. In February 2015, EPA released a document outlining technical recommendations and best practices for minimizing and managing the impacts of induced seismicity from oil and gas wastewater disposal wells.¹⁰

(...continued)

⁶ EPA has established regulations for six classes of injection wells, including Class II wells used for the injection of fluids for enhanced oil and gas recovery and wastewater disposal. See section on “EPA Regulation of Underground Injection” for more information.

⁷ See, for example, Ellsworth, 2013; McGarr et al., 2015; Rubinstein and Mahani, 2013.

⁸ McGarr et al., 2015, p. 830.

⁹ See, for example, Rubinstein and Mahani, 2015; Ellsworth, 2013; and Walsh and Zoback, 2015.

¹⁰ U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, Underground Injection Control National Technical Workgroup, (continued...)

In the 114th Congress, no legislation has been introduced to address induced seismicity associated with oil and gas wastewater disposal or other injection activities. The Fracturing Responsibility and Awareness of Chemicals (FRAC) Act of 2015 was introduced in the House (H.R. 1482) and the Senate (S. 785). Among other things, the bills would amend the SDWA term “underground injection” to include the injection of fluids and proppants used in hydraulic fracturing operations, thus authorizing EPA to regulate this process under the SDWA. It is unclear whether the legislation would affect EPA regulatory authority regarding the potential for induced seismicity from hydraulic fracturing, unless it could be shown that induced seismicity caused by the hydraulic fracturing process posed a threat to underground sources of drinking water. As discussed, the potential for damaging earthquakes caused by hydraulic fracturing appears to be much smaller than deep-well injection of wastewater from oil and gas production activities.

Current Understanding of Induced Seismicity in the United States

Since about the 1920s, it has been known that pumping fluids in and out of Earth’s subsurface has the potential to cause earthquakes.¹¹ In addition, a wide range of other human activities have been known to cause earthquakes, including the filling of large reservoirs, mining, geothermal energy extraction, and others.¹² The mechanics of how human industrial activities may cause earthquakes are fairly well known: The human perturbation changes the amount of stress in Earth’s crust, and the forces that prevent faults from slipping become unequal. Once those forces are out of equilibrium, the fault ceases to be locked and the fault slips, sending shock waves out from the fault that potentially reach the surface and are strong enough to be felt or cause damage.

Even knowing that human activities can cause earthquakes, and the mechanics of the process, it is currently nearly impossible to discriminate between man-made earthquakes and those caused by natural tectonic forces through the use of modern seismological methods.¹³ Other lines of evidence are required to positively link human activities to earthquakes. That linkage is becoming increasingly well understood in parts of the United States where activities related to oil and gas extraction—deep-well injection of oil and gas wastewater and hydraulic fracturing—have increased significantly in the last few years, particularly in Oklahoma, Texas, Arkansas, Ohio, Colorado, and several other states.¹⁴ Nevertheless, the majority of deep-well injection and hydraulic fracturing activities are not known to cause earthquakes; most are termed “aseismic” (i.e., not causing any appreciable seismic activity, at least for earthquakes greater than M 3.0).¹⁵

Scientists currently have limited capability to predict human-caused earthquakes for a number of reasons, including uncertainty in knowing the state of stress in the earth, rudimentary knowledge of how injected fluids flow underground after injection, poor knowledge of faults that could

(...continued)

November 12, 2014 (released February 6, 2015), <http://www.epa.gov/r5water/uic/ntwg/pdfs/induced-seismicity-201502.pdf>.

¹¹ National Research Council (NRC), “Induced Seismicity Potential in Energy Technologies,” 2013, p. vii.

¹² Ellsworth, 2013.

¹³ Ibid.

¹⁴ According to the NRC report, seismic events likely related to energy development have been documented in Alabama, Arkansas, California, Colorado, Illinois, Louisiana, Mississippi, Nebraska, Nevada, Ohio, Oklahoma, and Texas. NRC, “Induced Seismicity Potential in Energy Technologies,” p. 6.

¹⁵ Ibid.

potentially slip and cause earthquakes, limited networks of seismometers (instruments used to measure seismicity) in regions of the country where most oil-and-gas-related activities are occurring, and difficulty in predicting how large an earthquake will grow once it is triggered.¹⁶

Despite these uncertainties, a simple conceptual model for understanding how deep-well injection may be triggering earthquakes is starting to evolve, particularly for Oklahoma, which has experienced the greatest change in seismicity since about 2009. In the conceptual model, injecting oil and gas wastewater into the sedimentary formation increases its pore pressure.¹⁷ Over time the increase in pore pressure propagates into pre-existing faults in the crystalline basement rocks underlying the sedimentary formation¹⁸ (see **Figure 2**). Some of the faults in the crystalline basement rocks are “critically stressed,” meaning that any change to the pre-existing pressure regime has the potential to initiate “slip” along the fault. Slip along a fault creates an earthquake; the size of the earthquake is generally related to the amount of slip and the length of the fault. Furthermore, studies indicate that even small pressure perturbations have the potential to cause relatively large earthquakes along these critically stressed pre-existing faults in crystalline basement rocks.¹⁹ This may have been the case for the large, M 5.6 and M 5.8 earthquakes in Oklahoma in 2011 and 2016, respectively.²⁰

¹⁶ William Leith, Senior Science Advisor for Earthquakes and Geologic Hazards, U.S. Geological Survey, “USGS Research into the Causes & Consequences of Injection-Induced Seismicity,” presentation at the U.S. Energy Association, October 30, 2014, <http://www.usea.org/sites/default/files/event-/Leith%20induced%20for%20DOE-USEA%20Oct14.pdf>.

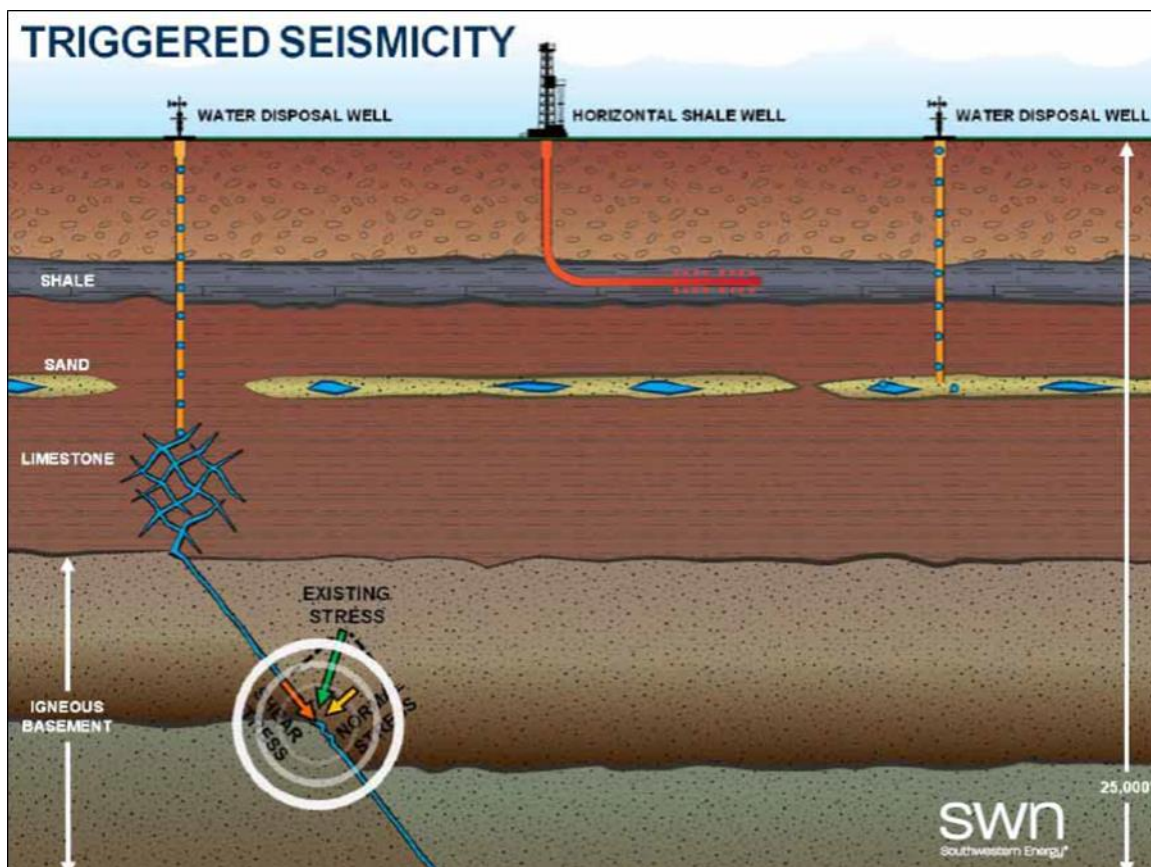
¹⁷ Pore pressure refers to the measure of hydrostatic pressure of the fluid trapped in the pores of a rock. In the case of deep-well injection, the increase in pore pressure caused by the injection of fluids can be transmitted into the basement crystalline rocks if the fluids in pre-existing faults in the basement rocks are hydraulically connected to the sedimentary rocks where the well is located. The injected fluid itself does not necessarily have to travel into the crystalline basement faults to trigger an earthquake; the pressure wave induced by the deep-well injection is potentially sufficient to perturb the stresses on the fault and induce an earthquake.

¹⁸ Simply, crystalline basement rocks refer to older igneous or metamorphic rocks that lie beneath younger sedimentary rocks. Oil and gas wastewaters are typically injected into the overlying sedimentary rocks.

¹⁹ See, for example, Walsh and Zoback, 2015.

²⁰ Ibid.

Figure 2. Illustration of the Possible Relationship Between Deep-Well Injection and Induced Seismicity



Source: North Carolina General Assembly, presentation by the Arkansas Oil and Gas Commission, *Fayetteville Shale Overview, for the North Carolina Delegation*, slide 33, prepared by Southwestern Energy, November 21, 2013, <http://www.ncleg.net/documents/sites/committees/BCCI-6576/2013-2014/5%20-%20Feb.%204.%202014/Presentations%20and%20Handouts/Arkansas%20Site%20Visit%20Attachments/Att.%205%20-%20AOGC%20Presentation%2011-21-13%20%283%29.pdf>.

Notes: The figure is for illustrative purposes only and does not depict any specific location or geological formation. The term “triggered” in the figure is synonymous with the term induced as used in this report.

A Historical Example: The Rocky Mountain Arsenal

Prior to the M 5.6 earthquake that occurred on November 6, 2011, in central Oklahoma, an M 4.8 earthquake that struck northeast Denver, on August 9, 1967 was generally accepted as the largest recorded human-induced earthquake in the United States. The M 4.8 earthquake was part of a series of earthquakes that began within several months of the 1961 start of deep-well injection of hazardous chemicals produced at the Rocky Mountain Arsenal defense plant. The earthquakes continued after injection ceased in February 1966.²¹ The disposal well was drilled through the flat-lying sedimentary rocks into the underlying older crystalline rocks more than 12,000 feet deep, and injection rates varied from 2 million gallons per month to as much as 5.5 million gallons per month.²² Earthquake activity declined after 1967 but continued for the next two

²¹ J. H. Healy et al., “The Denver Earthquakes,” *Science*, vol. 161, no. 3848 (September 27, 1968), pp. 1301-1310.

²² Ibid.

decades. Scientists concluded that the injection triggered the earthquakes. Even after injection ceased, the migration of the underground pressure front continued for years and initiated earthquakes along an ancient fault system many miles away from the injection well.²³ As discussed below, the Rocky Mountain Arsenal earthquakes had many similarities to the recent increased earthquake activity in some deep-well injection activities of the United States, including, for example, injection near or in underlying crystalline bedrock, activation of fault systems miles away from the well, and migration of the pressure front away from the point of injection months or years after injection stopped.

Deep-Well Injection of Oil and Natural Gas Wastewaters

As stated above, the number of earthquakes of M greater than 3.0 in the central and eastern United States has increased dramatically since about 2009 (**Figure 1**). The steep increase in the frequency of M 3.0 or greater earthquakes indicates an increasing likelihood that, in some instances, deep-well injection is linked to earthquakes, some greater than M 5.0. A human-induced M 6.0 or greater earthquake considered to be linked to deep-well injection has not yet been observed, although the September 3, 2016, M 5.8 earthquake northwest of Pawnee, OK, was the largest ever recorded in the state and may be associated with deep-well injection (see Box on p. 11).

Many observers conclude that most wells permitted for deep-well injection are in geologic formations that likely have a low risk of failure that could lead to damaging earthquakes if the injected fluids remain in the intended geologic structure.²⁴ The largest earthquakes apparently triggered by deep-well injection involved faulting that was deeper than the injection interval, suggesting to some that transmitting pressure from the injection point to deeper zones in basement rocks—below the sedimentary layers—increases the potential for triggering earthquakes.²⁵

States experiencing higher levels of seismic activity compared to the pre-2005 average include Arkansas, Colorado, Texas, New Mexico, Ohio, Oklahoma, and Virginia.²⁶ Seismic activity has also increased in south-central Kansas compared to levels in 2013 and before, where there may be a link to deep-well injection of produced waters from unconventional oil and gas development.²⁷ For some of these states, there is an increasing realization of a potential linkage between deep-well injection of oil and gas wastewaters and earthquakes, as the number of wells and volume of disposed wastewater have increased concomitant with increased domestic oil and gas production, particularly since about 2008 and 2009.²⁸ Several instances of suspected human-induced earthquakes that garnered media and national attention include the following:

- October 2008/May 2009: M 2.5-3.3 earthquakes near Dallas-Fort Worth, TX;²⁹
- August 2010/February 2011: earthquake swarm in central Arkansas, with an M 4.7 earthquake on February 27, 2011, near Greenbrier, AR;³⁰

²³ Ellsworth, 2013.

²⁴ Rubinstein and Mahani, 2015.

²⁵ Walsh and Zoback, 2015.

²⁶ Ellsworth, 2013.

²⁷ Rex C. Buchanan et al., Kansas Geological Survey, “Induced Seismicity: The Potential for Triggered Earthquakes in Kansas,” Public Information Circular 36, April 10, 2014, <http://www.kgs.ku.edu/Publications/PIC/pic36.html>.

²⁸ Rubinstein and Mahani, 2015.

²⁹ Cliff Frohlich et al., “Dallas-Fort Worth Earthquakes Coincident with Activity Associated with Natural Gas Production,” *The Leading Edge*, vol. 29, no. 3 (2010), pp. 270-275.

- August 2011: M 5.3 earthquake in the Raton Basin, northern New Mexico/southern Colorado;³¹
- November 2011: M 5.7 earthquake near Prague, OK;³²
- December 2011: M 3.9 earthquake near Youngstown, OH;³³ and
- September 2016: M 5.8 earthquake near Pawnee, OK.³⁴

These examples are summarized below.

Colorado and New Mexico

An investigation of the seismicity in the Raton Basin of northern New Mexico and southern Colorado concluded that increased seismic activity since August 2001 was associated with deep-well injection of wastewater related to the production of natural gas from coal-bed methane fields.³⁵ The study linked the increased seismicity to two high-volume disposal wells that injected more than seven times as much fluid as the Rocky Mountain Arsenal well in the period leading up to an August 2011 M 5.3 earthquake in the Raton Basin.

Arkansas

A study of a 2010-2011 earthquake swarm in central Arkansas noted that the study area experienced an increase in the number of M 2.5 or greater earthquakes since 2009, when the first of eight deep-well injection disposal wells became operational.³⁶ The rate of M greater than 2.5 earthquakes increased from 1 in 2007 to 2 in 2008, 10 in 2009, 54 in 2010, and 157 in 2011, including a M 4.7 earthquake on February 27, 2011.³⁷ Although the area has a history of seismic activity, including earthquake swarms in the early 1980s, the study noted that 98% of the earthquakes during the 2010-2011 swarm occurred within six kilometers of one of the waste disposal wells. In response, the Arkansas Oil and Gas Commission (AOGC) imposed a moratorium on oil and gas wastewater disposal wells in a 1,150-square-mile area of central Arkansas. Four disposal wells were shut down following injection of wastewater from the Fayetteville Shale.

(...continued)

³⁰ U.S. Geological Survey, Earthquake Hazards Program, "Poster of the 2010-2011 Arkansas Earthquake Swarm," <http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2011/20110228.php>.

³¹ J. L. Rubinstein, W. L. Ellsworth, and A. McGarr, "The 2001-Present Triggered Seismicity Sequence in the Raton Basin of Southern Colorado/Northern New Mexico," talk delivered at the Seismological Society of America Annual Meeting, Salt Lake City, UT, April 19, 2013, pp. Abstract #13-206.

³² Danielle F. Sumy et al., "Observations of Static Coulomb Stress Triggering of the November 2011 M 5.7 Oklahoma Earthquake Sequence," *Journal of Geophysical Research—Solid Earth*, vol. 119, no. 3 (March 2014), <http://onlinelibrary.wiley.com/doi/10.1002/2013JB010612/abstract>.

³³ Won-Young Kim, "Induced Seismicity Associated with Fluid Injection into a Deep Well in Youngstown, Ohio," *Journal of Geophysical Research—Solid Earth*, vol. 118, no. 7 (July 19, 2013), pp. 3506-3518.

³⁴ Oklahoma Geological Survey, *Pawnee Earthquake Fact Sheet*, http://www.ou.edu/content/dam/ogs/documents/statements/OGS-Fact_Sheet_Pawnee_Earthquake_2016-09-03.pdf.

³⁵ Rubinstein, Ellsworth, and McGarr, "The 2001-Present Triggered Seismicity Sequence." ...

³⁶ S. Horton, "Disposal of Hydrofracking Waste Fluid by Injection into Subsurface Aquifers Triggers Earthquake Swarm in Central Arkansas with Potential for Damaging Earthquake," *Seismological Research Letters*, vol. 83, no. 2 (2012), pp. 250-260.

³⁷ U.S. Geological Survey, Earthquake Hazards Program, "Poster of the 2010-2011 Arkansas Earthquake Swarm."

Texas

A study of increased seismicity near Dallas-Fort Worth and Cleburne, Texas, identified a possible linkage between high injection rates of oilfield-related wastewater and earthquakes of M 1.5 or greater. The study found that all 24 of the most reliably located earthquake epicenters occurred within about 1.5 miles of one or more injection wells.³⁸ The study examined earthquakes occurring between 2009 and 2011 and noted that it was possible that some of the earthquakes had a natural origin, but that it was implausible that all were naturally occurring. The investigation showed a probable linkage between earthquakes and some high-volume injection wells but also pointed out that in other regions of the study area there exist similar high-volume injection wells but no increased seismic activity. The study hypothesized that injection might trigger earthquakes only if the injected fluids reach suitably oriented nearby faults under regional tectonic stress.

Ohio

A study reported that the Youngstown, Ohio, area, where there were no known past earthquakes, experienced over 100 small earthquakes between January 2011 and February 2012.³⁹ The largest among the six felt earthquakes was an M 3.9 event that occurred on December 31, 2011. The study concluded that the earthquakes, which occurred within the Precambrian crystalline rocks lying beneath sedimentary rocks, were induced by fluid injection from a deep injection well. The study noted that the level of seismicity dropped after periods when the injection volumes and pressures were at their lowest levels, indicating that the earthquakes may have been caused by pressure buildup and then stopped when the pressure dropped.

Oklahoma

Figure 1 shows that the earthquake rate in the central and eastern United States has increased significantly since 2009; more than 50% of those earthquakes since 2009 have occurred in central Oklahoma.⁴⁰ **Figure 3** shows the rate of increase in M 3.0 or greater earthquakes in Oklahoma, in particular the steep increases during 2014 and 2015. As of 2014, the earthquake rate for M 3.0 or greater earthquakes in Oklahoma exceeded the rate for earthquakes of a similar magnitude in California.⁴¹ The rate for M 3.0 earthquakes since 2009 is nearly 300 times higher than for previous decades.⁴²

In the past, Oklahoma has experienced earthquakes large enough to be felt at the surface, including two earthquakes in the range of M 5.0 or greater in 1918 and 1952.⁴³ However, studies indicate that it is highly improbable that the increase in earthquake activity since 2009 is part of a natural fluctuation in earthquake rates.⁴⁴ Studies of the geology of central Oklahoma indicate that the region includes a complex belt of ancient, buried faults that cut through the Arbuckle

³⁸ Cliff Frohlich, "Two-Year Survey Comparing Earthquake Activity and Injection-Well Locations in the Barnett Shale, Texas," *Proceedings of the National Academy of Sciences*, vol. 109, no. 35 (August 28, 2012), pp. 13934-13938.

³⁹ Won-Young Kim, "Induced Seismicity Associated with Fluid Injection into a Deep Well in Youngstown, Ohio," *Journal of Geophysical Research—Solid Earth*, vol. 118, no. 7 (July 19, 2013), pp. 3506-3518.

⁴⁰ D.E. McNamara et al., "Efforts to Monitor and Characterize the Recent Increasing Seismicity in Central Oklahoma," *The Leading Edge*, June 2015, pp. 628-639.

⁴¹ *Ibid.*, p. 629.

⁴² D.E. McNamara et al., "Earthquake Hypocenters and Focal Mechanisms in Central Oklahoma Reveal a Complex System of Reactivated Subsurface Strike-Slip Faulting," *Geophysical Research Letters*, vol. 42, no. 8 (April 28, 2015).

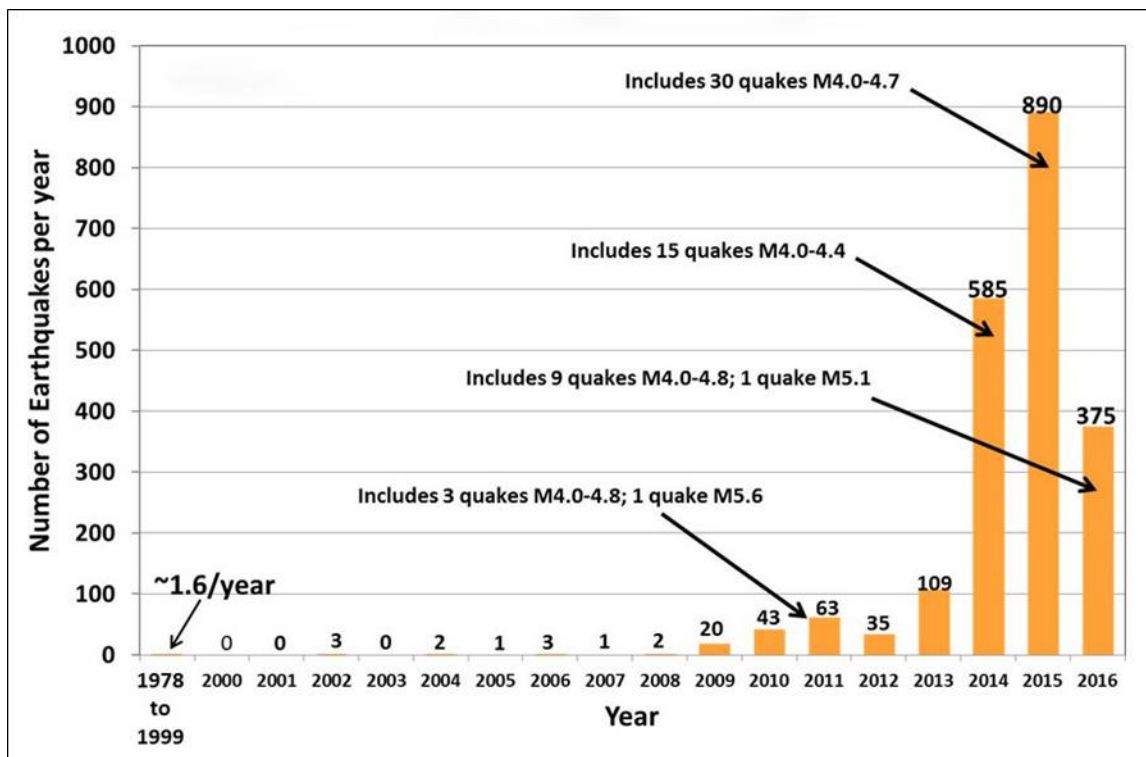
⁴³ *Ibid.*

⁴⁴ *Ibid.*

Formation—the formation into which many of the oil and gas wastewater fluids are injected—and extend deeper into the older crystalline basement rocks.⁴⁵ The disposal of wastewaters into the Arbuckle Formation may be reactivating these faults and causing earthquakes.⁴⁶

In addition to the spike of M 3.0 and greater earthquakes in Oklahoma, the state has also experienced its largest earthquakes ever recorded: a M 5.7 event near Prague on November 5, 2011, and a M 5.8 event near Pawnee on September 3, 2016. The combination of increased frequency of felt earthquakes and relatively large magnitude events has focused attention on Oklahoma and the state and federal response to the new hazard (see text box on p. 11).

Figure 3. Oklahoma Earthquakes of M 3.0 or Greater



Source: U.S. Geological Survey, email communication September 7, 2016. Modified by CRS.

Notes: The bar representing 2016 includes earthquakes through June 22, 2016. The M 5.6 event noted for 2011 has been modified to an M 5.7 earthquake by the USGS. The M 5.8 earthquake of September 3, 2016, is not included.

Kansas

According to the Kansas Geological Survey, several earthquakes were recorded in south-central Kansas in 2013 and 2014 in the vicinity of wastewater injection wells.⁴⁷ One earthquake in Harper County in 2013 had a magnitude of 4.3, and three earthquakes in Sumner County in 2014

⁴⁵ Ibid.

⁴⁶ Ibid.

⁴⁷ Rex C. Buchanan et al., Kansas Geological Survey, "Induced Seismicity: The Potential for Triggered Earthquakes in Kansas," Public Information Circular 36, April 10, 2014, <http://www.kgs.ku.edu/Publications/PIC/pic36.html>, (revised August 2015).

had magnitudes over 3.0.⁴⁸ Although a definitive connection to wastewater injection had not been established, increasing seismicity in Kansas near areas of wastewater injection led the Kansas governor to convene a task force on induced seismicity in January 2014. The task force resulted in an action plan for dealing with earthquakes possibly induced by deep well injection. For example, in March 2015 the Kansas Corporation Commission required operators to reduce the rate of injection in five areas where wells were disposing fluids into the deep Arbuckle Formation (the same formation that occurs in Oklahoma, discussed above).⁴⁹

Magnitude 5.8 Earthquake Near Pawnee, OK, September 3, 2016

On September 3, 2016, a magnitude 5.8 earthquake occurred about 9 miles northwest of Pawnee, OK, and was felt throughout Oklahoma and many other states. Prior to the September 3 event, the largest earthquake to strike Oklahoma was an M 5.7 temblor on November 5, 2011, about 30 miles east of Oklahoma City near the town of Prague. In response to the September 3 earthquake, the Oklahoma Corporation Commission (OCC)—the state entity responsible for regulating oil and gas activity in Oklahoma—ordered a total of 48 injection wells within the OCC jurisdiction to shut down or reduce injection volumes. In addition, 19 wells in the vicinity of the earthquake were located in the Osage Nation Mineral Reserve, where the U.S. Environmental Protection Agency administers the UIC program: operators of these wells agreed to shut down wells consistent with actions in state jurisdiction. The authority for the OCC actions is discussed more fully below in “State Initiatives”.

According to a September 12, 2016 OCC press release announcing the closures, the identification of specific injection wells to shut down or curtail injection volumes resulted from new data resulting from work by the Oklahoma Geological Survey and the U.S. Geological Survey that identified the likely fault systems responsible for the earthquake. The September 12 order amended an order issued by the OCC on the day of the earthquake to shut down and curtail operations of a different set of wells based on a preliminary evaluation of the faults responsible for the September 3 earthquake. (Similarly, EPA contacted operators of 3 additional wells in the Osage Nation Mineral Reserve and requested them to reduce injection volumes; 11 wells were allowed to resume operations at reduced injection levels, and 5 wells remained shut down.) The first order from the OCC was to shut down 37 disposal wells near the epicenter. The orders to immediately shut down or curtail injection wells reflect the OCC’s current understanding of the links between injection activities and earthquakes, as manifest in their emergency authorities for issuing mandatory instructions to wells disposing wastewater into the Arbuckle Formation.

As discussed above in “Deep-Well Injection of Oil and Natural Gas Wastewaters”, the Arbuckle Formation is of great interest to scientists and regulators because of its proximity to crystalline bedrock and the potential for deep-well injection to possibly reactivate existing faults. The difficulties in assigning a specific well’s activities to a specific fault and subsequent earthquake did not preclude the OCC from taking immediate action to shut down or curtail the set of wells that may have a connection to the September 3 earthquake. These recent actions reflect an evolution of understanding of the relationship between deep well injection and earthquakes and the regulatory regime and actions by Oklahoma, and other states, to respond to human-induced earthquakes.

The magnitudes of the September 3, 2016, and the November 5, 2011, earthquakes focuses attention on a scientific and policy challenge: what is the relationship between the sharp increase in frequency of M 3.0 and greater earthquakes in Oklahoma since 2009 and the probability for larger and potentially damaging earthquakes. Despite the rapid uptick in earthquake frequency in Oklahoma (see **Figure 3**), most of the earthquakes have not caused damage. However, both the 2011 and 2016 larger magnitude events damaged buildings and caused injuries. The possibility of perturbing the preexisting faults in the crystalline bedrock below the Arbuckle Formation may be emerging as a mechanism for creating larger earthquakes. Whether the current scientific understanding of the link between deep-well injection and earthquakes in the crystalline basement rocks is sufficient to craft policies that eliminate the chances of large, damaging human-induced earthquakes is not clear.

National Issues—Changes to the U.S. Earthquake Hazard Maps

Until recently, the model for assessing the overall seismic hazard in the United States, which is used to set design provisions in building codes, intentionally excluded the seismic hazard posed

⁴⁸ Ibid.

⁴⁹ Ibid.

by human-induced earthquakes.⁵⁰ This was done, in part, because natural seismicity is assumed to be time-independent in assessing the earthquake hazard,⁵¹ and researchers were not sure how to treat potentially induced earthquakes in their seismic hazard analysis. The natural tectonic processes driving the earthquake hazard are assumed to be nearly constant, which is why portions of California and Alaska, parts of the mid-continent, and other areas of the country are shown on the national seismic hazard maps with only small variations from year to year.⁵² In contrast, human-induced seismicity varies in time—in this case—because of changes in injection rate, location, volume, depth of the injection, and other factors. Those characteristics mean combining natural seismic hazards with human-induced seismic hazards on one map is difficult.⁵³

Despite the difficulty, and because of the sharp uptick in seismic activity in the central and eastern United States since 2009, on March 28, 2016, the USGS released a one-year seismic hazard forecast for 2016 that includes contributions from both induced and natural earthquakes (revised June 16, 2016).⁵⁴ (See **Figure 4**.)

⁵⁰ A. McGarr et al., “Coping with Earthquakes Induced by Fluid Injection,” *Science*, vol. 347, no. 6224 (February 20, 2015), pp. 830-831.

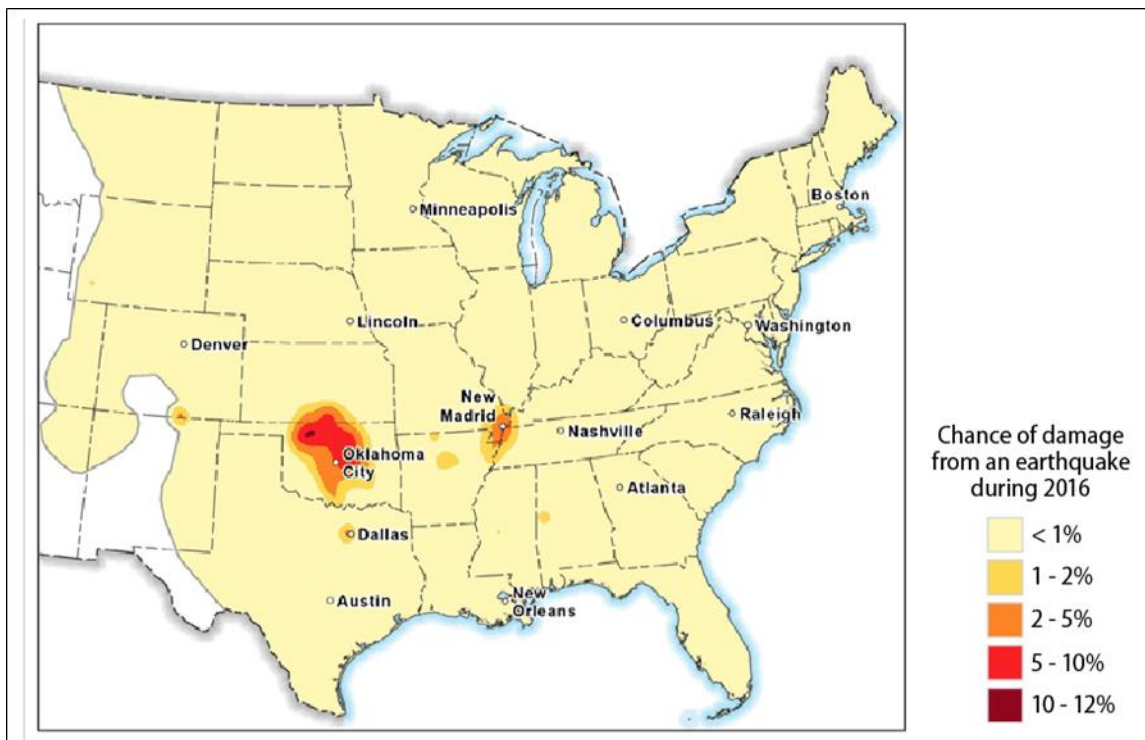
⁵¹ Time-independent in this context means that the tectonic forces that create the earthquake hazard are assumed to be relatively non-changing over a specified time period; in this case, the U.S. Geological Survey designates a 50-year time period. The earthquake hazard caused by deep-well injection can vary on a much shorter time scale, depending on how the wells are operated.

⁵² See, for example, the National Seismic Hazard Maps published by the U.S. Geological Survey, <http://earthquake.usgs.gov/hazards/products/conterminous/>. For more information about earthquakes generally, see CRS Report RL33861, *Earthquakes: Risk, Detection, Warning, and Research*, by Peter Folger.

⁵³ A. McGarr et al., “Coping with Earthquakes Induced by Fluid Injection.”

⁵⁴ Mark D. Petersen et al., *2016 One-Year Seismic Hazard Forecast for the Central and Eastern United States From Induced and Natural Earthquakes*, U.S. Geological Survey, Open-File Report 2016-1035, June 17, 2016, <https://pubs.er.usgs.gov/publication/ofr20161035>.

Figure 4. Chance of Damage from an Earthquake in the Central and Eastern United States in 2016



Source: Mark D. Petersen et al., *2016 One-Year Seismic Hazard Forecast for the Central and Eastern United States From Induced and Natural Earthquakes*, U.S. Geological Survey, Open-File Report 2016-1035, June 17, 2016, <https://pubs.er.usgs.gov/publication/ofr20161035>, p. 39. Modified by CRS.

Notes: Chance of damage refers to all types of structures, including buildings, bridges, and pipelines.

The map in **Figure 4** shows two main areas of earthquake hazard: the zone near New Madrid, Missouri, and the zone extending around Oklahoma City into south-central Kansas. The New Madrid area represents primarily a zone of natural seismic hazard, whereas the zone in Oklahoma is primarily an area of induced seismicity hazard. The induced seismicity hazard from deep-well injection represents what might be considered a short-term hazard, compared with the perennial seismic hazard from natural tectonic forces, because to some degree the chance of an earthquake caused by deep-well injection depends on the injection activity.⁵⁵

Hydraulic Fracturing

Hydraulic fracturing (often referred to as “fracking”) is the process of injecting a slurry of water, chemicals, and sand at high pressure to fracture oil- and gas-bearing rocks in order to provide permeable pathways to extract hydrocarbons.⁵⁶ Fracking has been employed with increasing frequency over the past decade or so to produce oil and natural gas from “unconventional” formations (e.g., shale)—those geologic strata that contained hydrocarbons but because of natural

⁵⁵ For more information about earthquake risk in the United States generally, see CRS Report RL33861, *Earthquakes: Risk, Detection, Warning, and Research*, by Peter Folger.

⁵⁶ This process has also been used for enhanced geothermal energy development, in which rocks are fractured to create permeable pathways to circulate fluids at depth. The fluids are heated by Earth’s natural heat and then recirculated to the surface to drive a turbine and generate electricity.

impermeability were not exploitable by conventional oil and gas producing methods. Fracking intentionally propagates fractures in the rocks to improve permeability. Fracking induces microseismicity, mostly less than M 1.0—too small to feel or cause damage. In some cases, fracking has led to earthquakes larger than M 2.0, including at sites in Oklahoma, Ohio, and England. In western Canada earthquakes larger than M 3.0 have been correlated to fracking.⁵⁷ Hydraulic fracturing is generally thought to present less of a risk than disposal wells for inducing large earthquakes, because the injections are short-term and add smaller amounts of fluid into the subsurface compared to most disposal wells.

Canada

Between April 2009 and July 2011, and over a five-day period in December 2011, nearly 40 seismic events were recorded in the Horn River Basin, northeast British Columbia, ranging from M 2.2 to M 3.8.⁵⁸ A subsequent investigation indicated that the seismic events were linked to fluid injection during hydraulic fracturing activities near pre-existing faults. In contrast to the vast majority of hydraulic fracturing injection activities, which cause earthquakes not felt at the surface (e.g., over 8,000 fracking completions in the Horn River Basin without any associated anomalous seismicity), these anomalous seismic events were felt at the ground surface. A statistical study associated fracking activities at 39 wells in the Western Canadian Sedimentary Basin (WCSB) with seismic events greater than M 3.0, including an earthquake of M 4.6.⁵⁹ The study indicated that most of the seismic activity in the WCSB since 1985 seems to be associated with oil and gas activity, although only a small portion of fracking operations appear to be linked to seismic activity (0.3% of wells used for hydraulic fracturing).⁶⁰ The study warned that hydraulic fracturing may have induced earthquakes in isolated cases even days after injection activities ceased, suggesting that policies that curtail injection (such as “traffic-light” protocols, discussed below in “State Initiatives”) may not have an immediate effect in preventing the occurrence of injection-induced events.⁶¹

England

In Blackpool, England, hydraulic fracturing injection activities led to a series of small earthquakes ranging up to M 2.3, between March 28, 2011, and May 28, 2011.⁶² These seismic events were not large enough to be felt at the surface but were strong enough to deform some of the well casing on the horizontal portion of the production well used for fracking the shale gas-bearing formation.

⁵⁷ Gail M. Atkinson et al., “Hydraulic Fracturing and Seismicity in the Western Canada Sedimentary Basin,” *Seismological Research Letters*, vol. 87, no. 3 (May/June 2016). Hereinafter Atkinson et al., 2016.

⁵⁸ BC Oil and Gas Commission, *Investigation of Observed Seismicity in the Horn River Basin*, August 2012, <http://www.bccgc.ca/node/8046/download>.

⁵⁹ Atkinson et al., 2016. The Western Canadian Sedimentary Basin underlies about 540,000 square miles of western Canada, including portions of Manitoba, Saskatchewan, Alberta, British Columbia, and the Northwest Territories.

⁶⁰ Ibid.

⁶¹ Ibid.

⁶² Christopher A. Green, Peter Styles, and Brian J. Baptie, *Preese Hall Shale Gas Fracturing Review & Recommendations for Induced Seismic Mitigation*, April 2012, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/15745/5075-preese-hall-shale-gas-fracturing-review.pdf.

Oklahoma

In south-central Oklahoma, hydraulic fracturing injections between January 16, 2011, and January 22, 2011, induced a series of 116 earthquakes of M 0.6 to M 2.9, according to one study.⁶³ The study concluded that the lack of similar seismic activity prior to the fracking and after fracking ceased, among other factors, linked the fracking activities to the earthquakes. More recently presented work on the link between hydraulic fracturing and earthquakes in Oklahoma seems to further strengthen the association between fracking and earthquakes that may rarely exceed M 3.0 or even M 4.0 in some cases.⁶⁴ The more recent work in Oklahoma also indicated that the vast majority of fracking operations did not create anomalous seismicity.

Ohio

Research on a series of small earthquakes in Harrison County, Ohio that occurred in 2013, indicated that hydraulic fracturing operations affected a previously unmapped fault in the Precambrian crystalline rocks lying below the sedimentary rocks that were being hydraulically fractured.⁶⁵ None of the Harrison County earthquakes exceeded magnitude 2.2, but various lines of evidence suggested that the fault responsible for the small earthquake was triggered by hydraulic fracturing operations. Some seismic activity possibly related to fracking in the Marcellus Shale and the underlying Utica Shale led to changes in how Ohio permits wells.⁶⁶ The permitting changes include requirements to install seismic monitoring equipment if drilling will take place within three miles of a known fault or in an area with seismic activity greater than M 2.0. Furthermore, if the monitors detect a seismic event greater than M 1.0, activities at the site must cease while the cause is investigated.

Other Hydraulic Fracturing Issues

One of the major shale gas plays in the United States, the Marcellus Shale—which underlies western Pennsylvania and portions of New York, West Virginia, and Ohio—occurs in a region of relatively low levels of natural seismic activity. Despite thousands of hydraulic fracturing operations in the past decade or so, only a handful of M 2.0 or greater earthquakes have been detected within the footprint of the Marcellus Shale, as measured by a regional seismographic network.⁶⁷ The earthquake activity recorded in the Youngstown, OH, region was related to deep-well injection of waste fluids from the development of Marcellus Shale gas but was not associated with hydraulic fracturing of Marcellus Shale in Pennsylvania.⁶⁸

⁶³ Austin Holland, “Earthquakes Triggered by Hydraulic Fracturing in South-Central Oklahoma,” *Bulletin of the Seismological Society of America*, vol. 103, no. 3 (June 2013), pp. 1784-1792.

⁶⁴ Austin Holland, “Induced Seismicity ‘Unknown Knowns’: The Role of Stress and Other Difficult to Measure Parameters of the Subsurface,” presentation at the U.S. Energy Association Symposium: Subsurface Technology and Engineering Challenges and R&D Opportunities, Washington, DC, October 30, 2014, <http://www.usea.org/event/subsurface-technology-engineering-challenges-and-rd-opportunities-stress-state-and-induced>.

⁶⁵ Paul A. Friberg, Glenda M. Besana-Ostman, and Ilya Dricker, “Characterization of an Earthquake Sequence Triggered by Hydraulic Fracturing in Harrison County, Ohio,” *Seismological Research Letters*, vol. 85, no. 6 (November/December 2014), pp. 1-13.

⁶⁶ Ohio Department of Natural Resources, *Ohio Announces Tougher Permit Conditions for Drilling Activities Near Faults and Areas of Seismic Activity*, April 11, 2014, <http://ohiodnr.gov/news/post/ohio-announces-tougher-permit-conditions-for-drilling-activities-near-faults-and-areas-of-seismic-activity>.

⁶⁷ Ellsworth, 2013.

⁶⁸ Ibid.

The linkage between hydraulic fracturing itself and the potential for generating earthquakes large enough to be felt at the ground surface is an area of active research. It appears to be the case that hydraulic fracturing operations mostly create microseismic activity—too small to be felt—associated with fracturing the target formation to release trapped natural gas or oil. However, if the hydraulic fracturing fluid injection affects a nearby fault, there exists the potential for larger earthquakes possibly strong enough to be felt at the surface, as was the case in the Horn River Basin of western Canada and other parts of the Western Canadian Sedimentary Basin.

Overview of the Current Regulatory Structure Regarding Induced Seismicity

The National Research Council (NRC) estimates that conventional oil and gas production and hydraulic fracturing combined generate more than 800 billion gallons of fluid each year. More than one-third of this volume is injected for permanent disposal in Class II injection wells.⁶⁹ Deep-well injection has long been the environmentally preferred option for managing produced brine and other wastewater associated with oil and gas production. However, the development of unconventional formations using high-volume hydraulic fracturing has contributed significantly to a growing volume of wastewater requiring disposal and has created demand for disposal wells in new locations. Recent incidents of seismicity in the vicinity of disposal wells have drawn renewed attention to laws, regulations, and policies governing wastewater management and have generated various responses at the federal and state levels. This section of the report reviews the current regulatory framework for managing underground injection and identifies several federal and state initiatives in response to concerns surrounding Class II disposal and induced seismicity.

EPA Regulation of Underground Injection

As stated earlier, the principal law authorizing federal regulation of underground injection activities is the Safe Drinking Water Act (SDWA) of 1974, as amended.⁷⁰ The law specifically directs EPA to promulgate regulations for state underground injection control (UIC) programs to prevent underground injection that endangers drinking water sources.⁷¹ Historically, EPA has not regulated oil and gas production wells, and as amended in 2005, the SDWA explicitly excludes the regulation of underground injection of fluids or propping agents (other than diesel fuels) associated with hydraulic fracturing operations related to oil, gas, and geothermal production activities.⁷²

The SDWA authorizes states and Indian tribes to assume primary enforcement authority (primacy) for the UIC program for any or all classes of injection wells.⁷³ EPA must delegate this

⁶⁹ National Research Council, Committee on Induced Seismicity Potential in Energy Technologies, *Induced Seismicity Potential in Energy Technologies*, National Academy Press, Washington, DC, 2012, p. 110.

⁷⁰ The Safe Drinking Water Act of 1974 (P.L. 93-523) authorized the UIC program at EPA. UIC provisions are contained in SDWA Part C, §§1421-1426; 42 U.S.C. §§300h-300h-5.

⁷¹ 42 U.S.C. §300h(d). SDWA §1421.

⁷² The Energy Policy Act of 2005 (EPAct 2005; P.L. 109-58, §322) amended the definition of “underground injection,” SDWA §1421(d), to expressly exempt hydraulically fractured oil, gas, or geothermal production wells from the UIC program unless diesel fuels are used in the fracturing fluid.

⁷³ For most SDWA programs, including the UIC provisions, ‘state’ is defined to include the District of Columbia and territories (SDWA §1401; 42 U.S.C. §§300f(14)). Tribes are authorized to receive primacy under SDWA §1451; 42 U.S.C. §300j-11. Navajo Nation and the Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation have (continued...)

authority, provided that the state or tribal program meets certain statutory and EPA requirements.⁷⁴ If a state's UIC program plan is not approved, or if a state chooses not to assume program responsibility, then EPA implements the UIC program in that state. Tribes may also be delegated primacy for the UIC program,

For oil-and-gas-related injection operations (such as produced water disposal through Class II wells), the law allows states to administer the UIC program using state rules rather than meeting EPA regulations, provided a state demonstrates that it has an effective program that prevents underground injection that endangers drinking water sources.⁷⁵ Most oil and gas states and some tribes have assumed primacy for Class II wells under this provision.

Under the UIC program, EPA, states, and tribes regulate more than 800,000 injection wells. To implement the UIC program as mandated by the SDWA, EPA has established six classes of underground injection wells based on categories of materials injected by each class. In addition to the similarity of fluids injected, each class shares similar construction, injection depth, design, and operating techniques. The wells within a class are required to meet a set of appropriate performance criteria for protecting underground sources of drinking water (USDWs).⁷⁶ **Figure 5** provides an illustration of the six well classes established by EPA to implement the UIC program.

(...continued)

attained primacy for Class II wells.

⁷⁴ To receive primacy, a state, territory, or Indian tribe must demonstrate to EPA that its UIC program is at least as stringent as the federal standards. The state, territory, or tribal UIC requirements may be more stringent than the federal requirements. For Class II wells, states or tribes must demonstrate that their programs are effective in preventing endangerment of Underground Sources of Drinking Water.

⁷⁵ SDWA Section 1425 requires a state to demonstrate that its UIC program meets the requirements of Section 1421(b)(1)(A) through (D) and represents an effective program (including adequate record keeping and reporting) to prevent underground injection that endangers underground sources of drinking water. To receive approval under Section 1425's optional demonstration provisions, a state program must include permitting, inspection, monitoring, and record-keeping and reporting requirements.

⁷⁶ EPA regulations define a USDW to mean an aquifer or part of an aquifer that (a) supplies a public water system, or contains a sufficient quantity of groundwater to supply a public water system and currently supplies drinking water for human consumption, or contains fewer than 10,000 milligrams per liter (mg/L or parts per million) total dissolved solids; and (b) is not an "exempted aquifer." 40 C.F.R. 144.3.

Figure 5. Federally Regulated Underground Injection Wells



Source: U.S. Environmental Protection Agency, Underground Injection Control, Typical Injection Wells. For additional details, see http://water.epa.gov/type/groundwater/uic/wells_drawings.cfm.

Class II includes wells used to inject fluids associated with oil and gas production. Class II wells may be used for three broad purposes: (1) to dispose of brines (salt water) and other fluids associated with oil and gas production; (2) to store liquid hydrocarbons; or (3) to inject fluids to enhance recovery of oil and gas from conventional fields. There are more than 172,000 Class II wells across the United States. Based on historical averages, roughly 80% of the Class II wells are enhanced recovery wells,⁷⁷ and 20% are disposal wells (often referred to as Class IId wells).⁷⁸

Table 1 provides descriptions of the injection well classes and subcategories and estimated numbers of wells.

Table 1. UIC Program: Classes of Injection Wells and Nationwide Numbers

Well Class	Purpose and Uses
Class I	Wells inject hazardous wastes, industrial non-hazardous liquids, or municipal wastewater beneath the lowermost underground source of drinking water (USDW). (680 wells, including 117 hazardous waste wells)
Class II	Wells inject brines and other fluids associated with oil and gas production and liquid hydrocarbons for storage. The wells inject fluids beneath the lowermost USDW. (>172,000 wells) Types of Class II wells ^a : • Enhanced recovery wells: Separate from, but often surrounded by, production wells, these wells are used to inject produced water (brine), fresh water, steam, polymers, or carbon dioxide (CO₂) into oil-bearing formations to recover additional oil (and sometimes gas) from production wells. These wells may also be used to maintain reservoir pressure. Approximately 80% of Class II wells are ER wells. • Disposal wells: Produced water and other fluids associated with oil and gas production (including flowback from hydraulic fracturing operations) are injected into these wells for permanent disposal. Approximately 20% of Class II wells are disposal (Class IId) wells. • Hydrocarbon storage wells: More than 100 Class II wells are used to inject liquid hydrocarbons (e.g., petroleum) into underground formations for storage.
Class III	Class III wells inject fluids associated with solution mining of minerals (e.g., salt and uranium) beneath the lowermost USDW. (22,131 wells)
Class IV	Class IV wells inject hazardous or radioactive wastes into or above USDWs. These wells are banned unless authorized under a federal or state groundwater remediation project. (33 wells)
Class V	Class V includes all injection wells not included in Classes I-IV, including experimental wells. Class V wells often inject non-hazardous fluids into or above USDWs, and many are shallow, on-site disposal systems (e.g., cesspools and stormwater drainage wells). Some Class V wells (e.g., geothermal energy and aquifer storage wells) inject below USDWs. (400,000-650,000 wells)
Class VI	Class VI , established in 2010, includes wells used for the geologic sequestration of CO ₂ . (Two permits were approved in 2014.)

Source: U.S. Environmental Protection Agency, *Underground Injection Control Program, Classes of Wells, and Class II Wells—Oil and Gas Related Injection Wells (Class II)*, <http://water.epa.gov/type/groundwater/uic/wells.cfm>, and UIC well surveys.

Notes: Regulations for Class I (hazardous waste) and Class VI (CO₂ sequestration) wells include evaluation of seismic risk among requirements to prevent movement of fluids out of the injection zone to protect USDWs.

⁷⁷ Enhanced recovery wells are separate from, but often surrounded by, production wells, these wells are used to inject produced water (brine), fresh water, steam, polymers, or carbon dioxide (CO₂) into oil-bearing formations to recover additional oil (and sometimes gas) from production wells.

⁷⁸ U.S. Environmental Protection Agency, *Class II Wells—Oil and Gas Related Injection Wells (Class II)*, <http://water.epa.gov/type/groundwater/uic/class2/index.cfm>, May 9, 2012.

- a. Additionally, a Class II permit would be required for an oil, gas, or geothermal production well if diesel fuels were to be used in the hydraulic fracturing fluid.

Consideration of Seismicity in EPA UIC Regulations

The SDWA does not mention seismicity; rather, the law's UIC provisions authorize EPA to regulate underground injection to prevent endangerment of underground sources of drinking water. However, seismicity has the potential to affect drinking water quality through various means (e.g., by damaging the integrity of a well, or creating new fractures and pathways for fluids to reach groundwater). EPA UIC regulations include various requirements aimed at protecting USDWs by ensuring that injected fluids remain in a permitted injection zone. Some of these measures could also reduce the likelihood of triggering seismic events. For example, injection pressures for Class II (and other) wells may not exceed a pressure that would initiate or propagate fractures in the confining zone adjacent to a USDW.⁷⁹ As a secondary benefit, limiting injection pressure can prevent fractures that could act as conduits through which injected fluids could reach an existing fault.

EPA regulations for two categories of injection wells—Class I hazardous waste disposal wells and Class VI wells for geologic sequestration of CO₂—specifically address evaluation of seismicity risks with siting and testing requirements. For Class I wells, EPA regulations include minimum criteria for siting hazardous waste injection wells, requiring that wells must be limited to areas that are geologically suitable. The UIC Director (i.e., the delegated state or EPA) is required to determine geologic suitability based upon an “analysis of the structural and stratigraphic geology, the hydrogeology, and the seismicity of the region.”⁸⁰ Testing and monitoring requirements for Class I wells state that “the Director may require seismicity monitoring when he has reason to believe that the injection activity may have the capacity to cause seismic disturbances.”⁸¹

For Class VI CO₂ sequestration wells, EPA regulations similarly require evaluation of seismicity risks through siting and testing requirements. In determining whether to grant a permit, the UIC Director must consider various factors, including potential for seismic activity.

Prior to the issuance of a permit for the construction of a new Class VI well or the conversion of an existing Class I, Class II, or Class V well to a Class VI well, the owner or operator shall submit ... and the Director shall consider ... information on the seismic history including the presence and depth of seismic sources and a determination that the seismicity would not interfere with containment.⁸²

EPA regulations for oil and gas wastewater disposal wells (or other Class II wells) do not include these provisions or otherwise address seismicity; however, the regulations give discretion to UIC Directors to include in individual permits additional conditions as needed to protect USDWs (including requirements for construction, corrective action, operation, monitoring, or reporting).⁸³ Again, for the purpose of protecting drinking water sources, permits for all Class I, II, and III wells must contain specified operating conditions, including “a maximum operating pressure calculated to avoid initiating and/or propagating fractures that would allow fluid movement into a

⁷⁹ 40 C.F.R. §146.23(a)(1).

⁸⁰ 40 C.F.R. §146.62(b)(1).

⁸¹ 40 C.F.R. §146.68(f).

⁸² 40 C.F.R. §146.82(a)(3)(v).

⁸³ Relevant provisions for Class II wells are published at 40 C.F.R. §144.12(b) and 40 C.F.R. §144.52(a)(9) or (b)(1). See also 40 C.F.R. Part 147.

USDW.”⁸⁴ Regulations for Class I wells further specify that “injection pressure must be limited such that no fracturing of the injection zone occurs during operation.”⁸⁵

Outside of regulations, EPA has recently taken steps to address induced seismicity concerns associated with Class II disposal wells. For example, EPA Region III now evaluates induced seismicity risk factors when considering permit applications for Class II wells. (Region III directly implements the UIC program in Pennsylvania and Virginia.⁸⁶) In responding to public comments on a Class II well permit application in 2013, the regional office noted the following:

Although EPA must consider appropriate geological data on the injection and confining zone when permitting Class II wells, the SDWA regulations for Class II wells do not require specific consideration of seismicity, unlike the SDWA regulations for Class I wells used for the injection of hazardous waste.... Nevertheless, EPA evaluated factors relevant to seismic activity such as the existence of any known faults and/or fractures and any history of, or potential for, seismic events in the areas of the Injection Well as discussed below and addressed more fully in “Region 3 framework for evaluating seismic potential associated with UIC Class II permits, updated September, 2013.”⁸⁷

Federal Initiatives to Address Induced Seismicity

As discussed above, the SDWA does not directly address seismicity; rather, the law authorizes EPA to regulate subsurface injections to prevent endangerment of drinking water sources. In 2011, in response to earthquake events in Arkansas and Texas, EPA asked the Underground Injection Control National Technical Workgroup to “develop technical recommendations to inform and enhance strategies for avoiding significant seismicity events related to Class II disposal wells.” The workgroup was specifically asked to address concerns that induced seismicity associated with Class II disposal wells could cause injected fluids to move outside the containment zone and endanger drinking water sources. EPA requested that the report contain the following specific elements:

- Comparison of parameters identified as most applicable to induced seismicity with the technical parameters collected under current regulations.
- Decisionmaking model/conceptual flow chart to:
 - provide strategies for preventing or addressing significant induced seismicity,
 - identify readily available applicable databases or other information,
 - develop site characterization checklist, and
 - explore applicability of pressure transient testing and/or pressure monitoring techniques.
- Summary of lessons learned from case studies.
- Recommended measurement or monitoring techniques for higher risk areas.

⁸⁴ U.S. Environmental Protection Agency, *Technical Program Overview: Underground Injection Control Regulations*, EPA 816-R-02-005, revised July 2001, p. 65, http://water.epa.gov/type/groundwater/uic/upload/2004_5_3_uicv_techguide_uic_tech_overview_uic_regs.pdf.

⁸⁵ Ibid., p. 66.

⁸⁶ EPA also directly implements the UIC program for other oil and gas producing states, including Kentucky, Michigan, and New York.

⁸⁷ U.S. Environmental Protection Agency Region III, *Response to Comments for the Issuance of an Underground Injection Control (UIC) Permit for Windfall Oil and Gas, Inc.*, 2013, pp. 3-9, http://www.epa.gov/reg3wapd/pdf/public_notices/WindfallResponsivenessSummary.pdf.

- Applicability of conclusions to other well classes.
- Defined specific areas of research as needed.⁸⁸

In February 2015, EPA released the National Technical Workgroup's final report, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, which addressed the above tasks.⁸⁹ The report does not constitute formal agency guidance, nor has EPA initiated any rulemaking regarding this matter. Rather, the document includes practical management tools and best practices to "provide the UIC Director with considerations for addressing induced seismicity on a site-specific basis, using Director discretionary authority."⁹⁰ (The UIC Director is the state program director where the state has program primacy or EPA in states where EPA implements the program directly.)

Among other findings, the report identifies three key components that must be present for injection-induced seismic activity to occur:

- (1) sufficient pressure buildup from disposal activities; (2) a fault of concern; and (3) a pathway allowing the increased pressure to communicate from the disposal well to the fault.⁹¹

As discussed, current Class II regulations give discretion to UIC Directors to include in individual permits additional conditions and requirements as needed to protect USDWs.⁹² The *Practical Approaches* document notes that, while EPA is unaware of any USDW contamination resulting from seismic events related to induced seismicity, potential USDW risks from seismic events could include

- loss of disposal well mechanical integrity,
- impact to various types of existing wells,
- changes in USDW water level or turbidity, or
- USDW contamination from a direct communication with the fault inducing seismicity or contamination from earthquake-damaged surface sources.⁹³

The report includes a decision model to inform regulators on site assessment strategies and recommends monitoring, operational, and management approaches for managing and minimizing suspected injection-induced seismicity. Among the management recommendations, the report suggests that, for wells suspected of causing induced seismicity, managers should take early actions (such as requiring more frequent pressure monitoring or reducing injection rates) rather than requiring definitive proof of causality.⁹⁴

⁸⁸ U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Induced-Seismicity from Class II Disposal Wells: Practical Approaches*, draft report of the Underground Injection Control National Technical Workgroup, November 27, 2012, p. A-1-2.

⁸⁹ U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, Underground Injection Control National Technical Workgroup, November 12, 2014 (released February 2015), <http://www.epa.gov/r5water/uic/techdocs.htm#ntwg>. The report includes case studies of induced seismicity events and responses in four states: Arkansas, Ohio, Texas, and West Virginia.

⁹⁰ Ibid., ES-2.

⁹¹ Ibid., p. 27.

⁹² Relevant provisions for Class II wells are published at 40 C.F.R. §144.12(b) and 40 C.F.R. §144.52(a)(9) or (b)(1). See also 40 C.F.R. Part 147.

⁹³ U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, p. 4.

⁹⁴ Ibid., p. 35.

The authors also identified research needs to better understand potential for injection-related induced seismicity, including research regarding geologic siting criteria for disposal zones in areas with limited or no data. As a general principal, the workgroup recommended that future research be conducted using a holistic and multidisciplinary approach, combining expertise in petroleum engineering, geology, geophysics, and seismicity.⁹⁵

State Initiatives

Several states and state organizations have been assessing the possible relationship between injection wells and seismic activity.⁹⁶ In March 2014, the Interstate Oil and Gas Compact Commission (IOGCC)⁹⁷ and the Ground Water Protection Council (GWPC)⁹⁸ formed an Induced Seismicity Work Group (ISWG) with state regulatory agencies and geological surveys to “proactively discuss the possible association between recent seismic events occurring in multiple states and injection wells.”⁹⁹ In September 2015, the workgroup issued a primer on potential injection-induced seismicity to provide “guidance in mitigating seismic risks associated with waste water disposal wells, not hydraulic fracturing.”¹⁰⁰

Additionally, several states have strengthened oversight and added new operational conditions and requirements for Class II disposal wells in response to recent seismic events that appear to be injection related. Policy and regulatory developments adopted or under consideration by several states are outlined briefly below. Typically, these states have expanded their standard permit application packages to include, for example, requirements for additional existing geologic information and studies and stricter operating requirements. Also, some states have banned the drilling of injection wells in geologic zones of known seismic risk.

⁹⁵ Ibid., pp. 31-32. In another federal initiative, the Department of Energy (DOE) is conducting a research program to promote development of the nation’s geothermal resources, including development of enhanced geothermal systems (EGS). The development of EGS can enable previously uneconomical hydrothermal systems to produce geothermal energy on a large scale. However, the process of injecting fluids to enhance permeability of hydrothermal systems may trigger seismic events. In 2012, DOE released an Induced Seismicity Protocol to mitigate risks associated with the development of these systems. Some of the approaches and mitigation measures included in the DOE protocol may be applicable to issues posed by Class II disposal wells. See Emie Majer, James Nelson, and Ann Roberson-Tait et al., *Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems*, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, DOE/EE-0662, January 2012, 45 pp., https://www1.eere.energy.gov/geothermal/pdfs/geothermal_seismicity_protocol_012012.pdf.

⁹⁶ See, for example, Ground Water Protection Council, *White Paper Summarizing a Special Session on Induced Seismicity*, February 2013, http://www.gwpc.org/sites/default/files/events/white%20paper%20-%20final_0.pdf. See also Association of American State Geologists, “Induced Seismicity,” <http://www.stategeologist.org>.

⁹⁷ The Interstate Oil and Gas Compact Commission is a multi-state agency that “serves as the collective voice of member governors on oil and gas issues and advocates states’ rights to govern petroleum resources within their borders.” The commission works with other stakeholders and is chartered to “efficiently maximize oil and natural gas resources through sound regulatory practices while protecting health, safety and the environment.” <http://iogcc.publishpath.com/>.

⁹⁸ The Ground Water Protection Council represents state groundwater protection and underground injection control agencies, <http://www.gwpc.org/>.

⁹⁹ States First Initiative, *States Team Up to Assess Risk of Induced Seismicity*, April 29, 2014, <http://www.statesfirstinitiative.org>, or <http://www.statesfirstinitiative.org/#!/States-Team-Up-to-Assess-Risk-of-Induced-Seismicity/c8t8/72D0196F-1DAB-4617-B446-B009A1D902FB>.

¹⁰⁰ Ground Water Protection Council and Interstate Oil and Gas Compact Commission, *Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation*, September 2015, <http://www.statesfirstinitiative.org/induced-seismicity-work-group>.

Arkansas

In response to the Guy-Greenbrier earthquake swarm associated with injections of wastewater from shale gas production, the Arkansas Oil and Gas Commission (AOGC) in 2010 imposed a moratorium on new disposal wells in the vicinity of the increased seismic activity and required operators of seven existing wells in the area to report hourly injection rates and pressures bi-weekly through July 2011.¹⁰¹

In 2011, the AOGC revised rules governing Class II wells and established a permanent moratorium zone in the area of a major fault system. The state banned new disposal wells and required plugging of four existing wells within the zone.¹⁰² (Operators voluntarily plugged the other three wells of concern.) The rules also require commission approval and a public hearing before any Class II wells within specified distances from the Moratorium Zone Deep Fault or a regional fault can be drilled, deepened, reentered, or recompleted. Class II wells proposed for disposal above or below the Fayetteville Shale formation are subject to new siting and spacing requirements, and permit applicants are required to provide information on the structural geology of an area proposed for a new disposal well. For existing disposal wells, the state required permit holders to install flow meters and submit injection volume and pressure information at least daily.¹⁰³ State officials continue to monitor disposal well operations and seismic activity. The state purchased additional seismic monitoring equipment, which supports an “early warning” system for detecting and responding to any emerging seismic activity.¹⁰⁴

Colorado

The Colorado Oil and Gas Conservation Commission (COGCC) has identified in existing rules and policies various requirements that aim to reduce the likelihood of induced seismicity.¹⁰⁵ These safeguards, which are imposed through the permitting process, include setting limits on injection volume and rate and requiring that the maximum allowable injection pressure is set below the fracturing pressure for the injection zone.¹⁰⁶ In 2011, the COGCC expanded the UIC permit review process specifically to minimize risk of induced seismicity from oil and gas wastewater disposal. The changes followed a significant earthquake near wells injecting wastewater produced from a coalbed methane field. The COGCC now has the Colorado Geological Survey (CGS) review permit applications to evaluate the area for the proposed well site for seismic activity. The CGS reviews state geologic maps, the USGS earthquake database, and area-specific information. After reviewing the geologic history and maps of the area for faults, the CGS may recommend a more detailed review of subsurface geology or seismic monitoring prior to new drilling. Additionally, the Colorado Division of Water Resources conducts a review of the proposed

¹⁰¹ U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, p. 20.

¹⁰² Specifically, the rules state: “Unless otherwise approved by the Commission after notice and a hearing, no permit to drill, deepen, re-enter, recomplete or operate a Class II Disposal or Class II Commercial Disposal Well may be granted for any Class II or Class II Commercial Disposal wells in any formation within [a prescribed] area (‘Moratorium Zone’).” AOGC Rule H-1, Section (s)(2).

¹⁰³ Arkansas Oil and Gas Commission, General Rule H—Class II Wells, Rule H-1: Class II Disposal and Class II Commercial Disposal Well Permit Application Procedures, Section (s).

¹⁰⁴ U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, p. 20.

¹⁰⁵ The COGCC administers the UIC program in accordance with EPA regulations. 40 C.F.R. §§144-147.

¹⁰⁶ Colorado Oil and Gas Conservation Commission, *COGCC Underground Injection Control and Seismicity in Colorado*, January 19, 2011.

injection zone. If seismicity is identified in the vicinity of the proposed injection well site, the COGCC requires the operator to define the seismic potential and the proximity to faults using the geological and geophysical data prior to approval.¹⁰⁷

In 2014, the COGCC worked with the Colorado Geological Survey, USGS researchers, and state universities to establish an induced seismicity advisory group. Issues for consideration by the advisory group included development of a more comprehensive statewide seismicity monitoring network and improved guidance for managing high-volume injection. COGCC has deployed regional seismic monitoring networks and implemented a traffic light system following seismic events in the vicinity of a disposal well.¹⁰⁸

Kansas

Kansas Governor Sam Brownback convened a State Task Force on Induced Seismicity in response to a significant increase in seismic activity—predominately in three counties—compared to seismic activity in 2013 and years prior. According to the task force report, Kansas has approximately 5,000 disposal wells used to inject waste fluids from oil and gas operations.¹⁰⁹ The action plan called for increased seismic monitoring to improve the state's ability to detect earthquakes greater than magnitude 1.5. The plan also provided a response plan, which would be triggered by earthquakes of magnitude 2.0 or greater. The plan further outlined a set of criteria under which disposal wells located within six miles of an earthquake would be evaluated and a determination made as to whether regulatory remedies under current statutory authorities would be warranted. As recommended, the state has purchased a portable seismic array and established monitor stations.

In 2015, the Kansas Corporation Commission issued an order limiting injection rates for more than 70 wells to monitor the effects of seismic activity. The order limited injection rates for all wells injecting into the Arbuckle Formation in two counties and imposed daily monitoring and monthly reporting requirements for high-volume Arbuckle wells. The order identified five areas of seismic concern based on earthquake clusters that triggered responses under the seismic action plan. Operators of affected wells were required to limit injection volumes at certain times and plug back wells that penetrated the base of the Arbuckle Formation.¹¹⁰

Ohio

Following the Youngstown earthquakes in 2011 associated with Class II disposal wells,¹¹¹ the Ohio Department of Natural Resources (ODNR) prohibited all drilling into the Precambrian basement rock and added new permit requirements for Class II disposal wells to improve site

¹⁰⁷ Ibid.

¹⁰⁸ Ground Water Protection Council and Interstate Oil and Gas Compact Commission, *Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation*, September 2015.

¹⁰⁹ Kansas Department of Health and Environment, Kansas Corporation Commission, Kansas Geological Survey, *Kansas Seismic Action Plan*, September 26, 2014, p. 1, http://kcc.ks.gov/induced_seismicity/state_of_kansas_seismic_action_plan_9_26_14_v2_1_21_15.pdf.

¹¹⁰ Kansas Corporation Commission, Commission Order, Docket No. 15-CONS-770-CMSC (order), http://www.kcc.state.ks.us/induced_seismicity/index.htm.

¹¹¹ Ohio Department of Natural Resources, *Preliminary Report on the Northstar Class II Injection Well and the Seismic Events in the Youngstown, Ohio, Area*, March 2012, http://oilandgas.ohiodnr.gov/portals/oilgas/downloads/northstar/reports/northstar-executive_summary.pdf.

assessment and collection of more comprehensive information. The rules became effective in October 2012 and are implemented on a well-by-well basis through the permitting process. The supplemental permit application requirements could include pressure fall-off testing, geological evaluation of potential faulting, seismic monitoring program (baseline and active injection), minimum geophysical logging suite, radioactive tracer or spinner survey, and any other tests deemed necessary by the Division of Oil and Gas Resources Management.¹¹² Before approving a new Class II disposal well, state officials now review existing geologic data for known faulted areas. ODNr will also require companies to run a complete suite of geophysical logs on newly drilled Class II disposal wells. Companies are required to give ODNr a copy of the log suite and may be required to provide analytical interpretation of the logging. For all new Class II permit applications, ODNr requires installation of monitoring technologies, including a continuous pressure monitoring system and an automatic shutoff system.¹¹³ Additionally, the state has purchased portable seismic units and implemented a proactive approach to seismic monitoring around deep Class II wells.¹¹⁴

Hydraulic Fracturing

In 2014, ODNr drafted new rules and imposed new drilling requirements for construction of horizontal production wells that would be hydraulically fractured (i.e., shale gas and oil wells) in response to seismic activity the state determined had a “probable connection to hydraulic fracturing near a previously unknown microfault.”¹¹⁵ The rules include standards for design, approval, and construction of horizontal well sites and strengthen drilling permit conditions for wells located near faults or areas linked to previous seismic activity.¹¹⁶

New permits for horizontal drilling within 3 miles of a known fault or area of seismic activity greater than a 2.0 magnitude, now include requirements for companies to install seismic monitors. If the monitors detect a seismic event in excess of 1.0 magnitude, the well operator would be required to halt activities while the cause is investigated. If a probable connection to hydraulic fracturing is identified, then the operator would be required to suspend hydraulic fracturing operations.¹¹⁷

Oklahoma

Oklahoma has more than 11,600 Class II wells, including 4,626 Class II disposal wells and 7,037 enhanced oil recovery wells. As discussed above, seismicity events have increased markedly in recent years as Class II disposal wells have been used to manage large volumes of produced water from oil and gas production activities. In 2015, the state reported that most of the wastewater disposed of in the state is the naturally occurring saltwater brine that is brought to the surface

¹¹² Ohio Department of Natural Resources, Division of Oil and Gas Resources, Underground Injection Control (UIC), <http://oilandgas.ohiodnr.gov/industry/underground-injection-control>.

¹¹³ Ohio Department of Natural Resources, Class II Disposal Well Reforms/Youngstown Seismic Activity Questions and Answers, <https://oilandgas.ohiodnr.gov/portals/oilgas/pdf/YoungstownFAQ.pdf>.

¹¹⁴ U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, pp. 24-25.

¹¹⁵ Ohio Department of Natural Resources, “Ohio Announces Tougher Permit Conditions for Drilling Activities near Faults and Areas of Seismic Activity,” press release, April 11, 2014, <http://ohiodnr.gov/news/post/ohio-announces-tougher-permit-conditions-for-drilling-activities-near-faults-and-areas-of-seismic-activity>.

¹¹⁶ Ch. 1501:9-2-02 OAC, <http://codes.ohio.gov/oac/1501%3A9-2>.

¹¹⁷ Ohio Department of Natural Resources, Division of Oil and Gas Resources Management, “Shale Well Drilling and Permitting: Seismic Restrictions,” <http://oilandgas.ohiodnr.gov/shale#SEIS>.

along with the oil and gas, and a relatively small portion is flowback from hydraulically fractured wells.¹¹⁸

In 2013, in response to injection-related induced seismicity concerns, the Oklahoma Corporation Commission (OCC) initiated a “traffic light” permitting system for Class II disposal wells. The system is based on National Academy of Sciences recommendations¹¹⁹ and has continued to evolve to reflect new information. Under the system, all disposal well permit applications must be reviewed for proximity to faults and seismicity in the area of the proposed well. For applications for new wells, regulators must determine whether a location of a proposed well is within three miles of a stress fault, within six miles of a seismic cluster, or within another “area of interest.” If so, the well operator is asked to demonstrate level of risk of induced seismicity and to provide more technical data, and a public hearing must be held on the permit application.¹²⁰ In 2015, the OCC greatly expanded “areas of interest” where injection wells are subject to additional requirements to include seismic clusters.

The “yellow light” permitting requirements apply to proposed wells in areas where some seismicity concerns exist but do not meet prescribed “red light” criteria. Among other conditions that may be imposed, “yellow light” permits are granted for only six months, and permit language may be made more stringent at any time. Additionally, operators may be required to monitor for background seismicity and shut down wells every 60 days for bottom hole pressure readings. A shutdown is mandatory in the event of defined seismic activity.¹²¹

In March 2015, the OCC announced new directives for disposal well operators currently operating in “areas of interest” that inject into the Arbuckle Formation. Under the directives, operators were required to provide to the Oil and Gas Conservation Division (OGCD), by April 18, 2015, information showing that Class II disposal wells in the area of interest were not in contact or communication with the crystalline basement rock. Wells that met the criteria were allowed to resume normal operations. For any wells found to be in contact/communication with basement rock, operators were required to plug back the wells to a shallower depth and meet specified criteria. Operators who did not provide the requested information or did not have an approved plugging schedule were required to reduce injection volumes by 50%.¹²² Since April 2015, the OCC has used the traffic light system multiple times to impose restrictions on well operations in prescribed areas following seismic events.

Following the seismic event on September 3, 2016, the OCC used its emergency authorities to issue mandatory instructions for wells injecting into the Arbuckle Formation. The OGCD required operators to shut in (temporarily shut down) all Arbuckle disposal wells within a 725 square-mile area. Wells within five miles of the location of the earthquake were required to shut in no later than September 10, 2016, and wells located between 5 and 10 miles of the earthquake

¹¹⁸ Oklahoma Geological Survey, “Statement on Oklahoma Seismicity,” summary statement, April 21, 2015, http://earthquakes.ok.gov/wp-content/uploads/2015/04/OGS_Summary_Statement_2015_04_20.pdf.

¹¹⁹ NRC, “Induced Seismicity Potential in Energy Technologies,” ch. 6, “Steps Toward a ‘Best Practices’ Protocol,” pp. 151-164. See also Mark D. Zoback, “Managing the Seismic Risk Posed by Wastewater Disposal,” *Earth Magazine*, April 2012, pp. 38-43.

¹²⁰ Tim Baker, Director, Oil and Gas Conservation Division, Oklahoma Corporation Commission Town Hall Presentation on Seismicity/Updates to the Traffic Light System, http://earthquakes.ok.gov/wp-content/uploads/2015/04/OGCD_Presentation.pdf.

¹²¹ Office of the Oklahoma Secretary of Energy and Environment, “Oklahoma Corporation Commission,” <http://earthquakes.ok.gov/what-we-are-doing/oklahoma-corporation-commission/>.

¹²² Oklahoma Corporation Commission, “Media Advisory—Ongoing OCC Earthquake Response,” press release, March 25, 2015, <http://www.occeweb.com/>. The directives apply to 347 of 900 Arbuckle disposal wells.

were required to shut in by September 13, 2016. The 725 square-mile area included 211 square miles of Osage County, a portion of which is part of the Osage Nation Mineral Reserve. EPA implements the UIC program in Osage County, and the agency requested operators to shut in 17 disposal wells. EPA reports that these operators agreed to do so consistent with the state's directives.

On September 12, 2016, OCC expanded the seismicity impact area of concern to 1,116 square miles based on new data. The total number of wells of interest increased to 67, including 48 wells under OCC jurisdiction and 19 under EPA jurisdiction. Of these, 27 in OCC jurisdiction were required to cease operations with the remainder operating at reduced disposal volumes. EPA requested operators at 14 wells to reduce injection volumes by 25% of recent levels. Five wells in the Osage Nation Mineral Reserve remained shut in.

Texas

In November 2014, the Texas Railroad Commission (RRC) published amendments to the state's oil and gas rules to incorporate requirements related to seismic events in connection with wastewater disposal permits, monitoring, and reporting.¹²³ Several of the new requirements are listed below.¹²⁴

- Applicants for disposal well permits are required to provide information from the USGS regarding the locations of any historical seismic events within 100 square miles of the proposed well site.
- A permit for a Class II disposal well “may be modified, suspended, or terminated if injection is likely to be or determined to be contributing to seismic activity.”¹²⁵
- The RRC may require permit applicants to provide additional information (e.g., logs, geologic cross-sections, and pressure front boundary calculations) if the well is to be located in an area where conditions may increase the risk that fluids will not be confined in the injection interval. (Such conditions may include complex geology, proximity of the basement rock to the injection interval, transmissive faults, and/or a history of seismic events using available USGS information.)
- Operators may be required to conduct more frequent monitoring and reporting of disposal well injection pressures and rates if certain conditions are present that could increase the risk that fluids will not be confined to the injection interval.

Although states have taken various actions in response to recent seismic events and wastewater injection, additional regulatory actions could result as experience is accrued from current approaches. Additional developments might also result from the IOGCC and GWPC Induced Seismicity Work Group initiative, as state regulatory agencies and geological surveys continue to evaluate this issue.

¹²³ *Texas Register*, 39 *TexReg* N8988, November 14, 2014, amending 16 T.A.C. §3.9, §3.46, <http://www.sos.state.tx.us/texreg/pdf/backview/1114/1114adop.pdf>.

¹²⁴ 39 *TexReg* 8996-9005, 16 T.A.C. §3.9.

¹²⁵ 16 T.A.C. §3.9(6)(A)(vi).

Conclusion

The scientific understanding of linkages between deep-well injection of waste fluids from oil and gas production, and from hydraulic fracturing operations, is rapidly evolving. This poses a challenge to state and federal policy makers who are tasked with making policy, regulatory, and permitting decisions in a relatively short time frame, concomitant with the evolving scientific study and understanding, and given public concern over the possibility of damaging earthquakes from some of the deep disposal wells. Some states have already implemented changes to their regulatory and permitting requirements, as discussed above. The vast majority of Class II disposal wells (and hydraulic fracturing wells) do not appear to be associated with significant seismic events; however, due to the growing volumes injected by these wells and increased seismicity in some disposal areas, an increasing concern in the United States is that injection of these fluids may be responsible for increasing rates of seismic activity. Additional geologic studies and reviews adopted by some states should address some potential risks; however, it is likely that states and possibly the federal government will continue to explore ways to understand and mitigate against the possibility of damaging earthquakes caused by a small number of wells.

In February 2015, EPA published a report outlining best practices to minimize and manage seismic events associated with oil and gas wastewater injection. The agency has not issued related guidance or initiated any regulatory actions.

Congress may be interested in oversight of EPA's UIC program or, more broadly, in federally sponsored research on the relationship between energy development activities and induced seismicity. Although only a small fraction of the more than 30,000 U.S. wastewater disposal wells appears to be problematic for causing damaging earthquakes, such incidents may raise questions as to whether other energy-related activity—specifically, underground injection for carbon dioxide sequestration—may present similar risks.

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MEMORANDUM

From: Mike Foote
Mike Freeman

Subject: Senate Bill 19-181

Date: 2/5/2020

CC: Tom Delehanty

Senate Bill 19-181 (“SB 181”) represented a paradigm shift in oil and gas regulation at the state level in Colorado, changing the Colorado Oil and Gas Conservation Commission’s (“COGCC”) mission from “fostering” the oil and gas industry to “regulating” it to protect public health, safety, welfare, the environment, and wildlife. SB 181 directed COGCC to conduct numerous rulemakings to implement these statutory changes. It also directed the Air Quality Control Commission (“AQCC”) to “minimize” emissions of harmful pollutants from the oil and gas sector, and directed it to conduct several rulemakings as well.

In addition to these important changes at the state level, SB 181 clarified the role of local governments in regulating oil and gas development. Prior to SB 181, local government’s ability to set strong health and environmental protections was often limited by the “ceiling” set by COGCC standards under the theory of conflict preemption. Now, state regulations only represent a “floor” for such protections, allowing local governments to require stronger health and environmental protections related to the land use impacts of oil and gas development. SB 181, however, also requires that certain types of local government regulations be “necessary and reasonable,” a term that the statutory language does not define.

This memorandum analyzes how SB 181 may be applied by local governments and interpreted by courts. To illustrate, the analysis below focuses on three areas: (a) traditional local land use and zoning authority, (b) setbacks, and (c) air quality regulations.

In considering these regulations (and others), the statutory text and legislative history provide several key considerations for interpreting SB 181:

- Priority should be given to health, safety and environmental protection, and those efforts are no longer expressly limited by industry claims of “practicability” or cost effectiveness for the operator.
- Local governments have broad authority and can adopt requirements that are more protective than state regulations.
- The term “necessary and reasonable” is intended as a guardrail against regulations that lack a reasonable justification. The term does not prevent governments from adopting

precautionary regulations in the face of incomplete information, or require that all less protective options be exhausted before adopting a particular regulation.

- Local governments adopting new protections should make a clear record of the research and evidence supporting that decision and the factors considered.
- Local government regulations should be given deference and examined on a case-by-case basis. Operators challenging a local government's land use decision in court will face a high bar because those decisions should be evaluated under a deferential standard of review under Colorado Rules of Civil Procedure (C.R.C.P.) 106(a)(4) and 57.

In addition to analyzing local authority over land use, setbacks, and air quality regulations, this memorandum discusses sources of research and information that are available to support stronger oil and gas regulations.

Finally, the memorandum discusses threats of takings claims by companies facing local regulation or denial of permits. Such litigation threats are typically overblown scare tactics: even when New York adopted a statewide fracking ban in 2014, almost no takings claims were actually filed and none were successful. Nevertheless, as with any other type of land use decision, local governments should analyze whether a proposed decision could lead to a takings claim.

BACKGROUND

Before enactment of SB 181, the legislative declaration for the Colorado Oil and Gas Conservation Act (the "Act"), stated that it was in the public interest to "[f]oster the responsible, balanced development, production, and utilization of the natural resources of oil and gas . . . in a manner consistent with protection of public health, safety, and welfare, including protection of the environment and wildlife resources."¹ COGCC was charged with "minimiz[ing] adverse impacts to wildlife,"² and given the "authority" (but not a mandate) to "prevent and mitigate significant adverse environmental impacts . . . to the extent necessary to protect public health, safety, and welfare, . . . the environment and wildlife."³ Those terms, however, were subject to several limitations including that they consider "cost-effectiveness and technical feasibility," and be applied "wherever reasonably practicable."⁴

¹ Colo. Rev. Stat. § 34-60-102 (2018).

² *Id.* § 34-60-128(2) (2018).

³ *Id.* § 34-60-106(1)(d) (2018).

⁴ *Id.* §§ 34-60-106(1)(d) (2018), 34-60-103(5.5) (2018). The earlier Act provided:

"Minimize adverse impacts" means to, wherever reasonably practicable:

- (a) Avoid adverse impacts from oil and gas operations on wildlife resources;
- (b) Minimize the extent and severity of those impacts that cannot be avoided;
- (c) Mitigate the effects of unavoidable remaining impacts; and
- (d) Take into consideration cost-effectiveness and technical feasibility with regard to actions and decisions taken to minimize adverse impacts to wildlife resources.

Id. § 34-60-103(5.5).

SB 181 changed the statutory mission to direct that rather than “foster” oil and gas development, COGCC should “[r]egulate” it in a manner that “protects public health, safety, and welfare . . . [and] the environment.”⁵ The amendments added a new section to the Act reinforcing this new policy by directing that:

In exercising the authority granted by this article 60, the commission shall regulate oil and gas operations in a reasonable manner to protect and minimize adverse impacts to public health, safety, and welfare, the environment, and wildlife resources and shall protect against adverse environmental impacts on any air, water, soil, or biological resource resulting from oil and gas operations.⁶

SB 181 did not expressly define the obligation to “protect” public health, safety, etc., but it did revise the definition of “minimize adverse impacts” to (a) cover not just wildlife, but all types of public health, safety and environmental impacts, and (b) eliminate the direction to consider technical feasibility, cost effectiveness, and reasonable practicability. The definition now states:

“Minimize adverse impacts” means, to the extent necessary and reasonable to protect public health, safety, and welfare, the environment, and wildlife resources, to:

- (a) Avoid adverse impacts from oil and gas operations; and
- (b) Minimize and mitigate the extent and severity of those impacts that cannot be avoided.⁷

Taken together, SB 181’s new language creates two cornerstones for COGCC regulation. First, COGCC must regulate oil and gas to both “protect” public health, safety, and welfare, the environment, and wildlife, and “minimize adverse impacts” to those resources. Second, SB 181 defines “minimize adverse impacts” by reference to what is “necessary and reasonable” to protect public health and safety.

SB 181 also clarified and expanded the role of local governments in regulating oil and gas development. Prior to SB 181, Colorado statutes did not expressly define the scope of local government authority over oil and gas operations, and that authority was heavily contested. Colorado Supreme Court rulings set the outer limits on local authority. For example, the Court held that a drilling ban, a fracking ban, and a five-year fracking moratorium conflicted with and were therefore preempted by state law as it existed prior to SB 181.⁸

However, the exact bounds of what regulatory authority local governments *could* assert remained murky. The Colorado Supreme Court upheld a county’s land use ordinance requiring oil and gas operations to obtain a special use permit that was “designed to harmonize oil and gas

⁵ *Id.* § 34-60-102(1)(a) (2019).

⁶ *Id.* § 34-60-106(2.5) (2019).

⁷ *Id.* § 34-60-103(5.5) (2019).

⁸ *Voss v. Lundvall Bros., Inc.*, 830 P.2d 1061, 1067–69 (Colo. 1992) (overturning drilling ban); *City of Longmont v. Colo. Oil & Gas Ass’n*, 369 P.3d 573, 585 (Colo. 2016) (overturning fracking ban); *City of Fort Collins v. Colo. Oil & Gas Ass’n*, 369 P.3d 586, 593 (Colo. 2016) (overturning fracking moratorium).

development[] . . . with the county’s overall plan for land-use.”⁹ Although the Court identified general categories of local rules that might be preempted by state law—safety regulations, technical conditions, and land restoration requirements—the Court left it as a case-by-case question for courts to consider the propriety of specific local rules.¹⁰ Subsequently, the Colorado Court of Appeals relied on the *Bowen/Edwards* decision to hold that three provisions of Gunnison County oil and gas regulations regarding financial assurances and records inspections operationally conflicted with COGCC rules and were therefore preempted.¹¹ However, the court found that 14 other County regulations—pertaining to water quality, soil erosion, wildlife, vegetation, livestock, cultural and historic resources, geologic hazards, wildfire protection, recreation impacts, and permit duration—did not facially conflict with state regulations and required an evidentiary hearing before the trial court.¹²

From this mixed judicial history, SB 181 clarifies and expands local authority over oil and gas development, and gives local governments authority to “protect” and “minimize” adverse impacts, similar to COGCC regulation. This authority is described below.

DISCUSSION

I. LOCAL GOVERNMENT LAND USE AND ZONING AUTHORITY

Land use and zoning authority is a longstanding, core function of local government, and SB 181 strengthens it. As described above, prior to SB 181 local governments’ exercise of their traditional authority over land use was sometimes preempted if it created an “operational conflict” with state regulation of oil and gas facilities.¹³ In particular, significant questions remained unanswered regarding the extent to which a local government could use its zoning powers to regulate the location and operation of oil and gas facilities.

SB 181 removed this ambiguity, and aims to make the oil and gas industry subject to local regulation like any other industry. The Act makes clear that a local government’s land use authority extends to oil and gas operations, including the siting of those operations. SB 181 also made changes that should prevent local zoning laws aimed at oil and gas “surface impacts” from being preempted when they are more protective than state law.

Specifically, SB 181 amended the Local Government Land Use Control Enabling Act (the “Enabling Act”) to give local governments the express “authority to plan for and regulate the use of land by . . . regulating the surface impacts of oil and gas operations” to address a variety of issues.¹⁴ SB 181 reinforced this point in another statutory section entitled “No land

⁹ *Bd. of Cty. Comm’rs of La Plata Cty. v. Bowen/Edwards Assocs., Inc.*, 830 P.2d 1045, 1060 (Colo. 1992).

¹⁰ *Id.* (holding that a trial court must determine the extent of an operational conflict between local and state law “on an ad hoc basis under a fully developed evidentiary record”).

¹¹ *Bd. of Cty Comm’rs of Gunnison Cty v. BDS Intern., LLC*, 159 P.3d 773, 779–80 (Colo. App. 2006) (citing *Bowen/Edwards*, 830 P.2d at 1060).

¹² *Id.* at 780–82.

¹³ *Id.* at 779–80; *Longmont*, 369 P.3d at 581–83; see also Joel Minor, *Local Government Fracking Regulations: A Colorado Case Study*, 33 Stan. Envtl. L.J. 61, 111–12 (2014).

¹⁴ Colo. Rev. Stat. § 29-20-104(1)(h) (2019).

use preemption,” which states that “[l]ocal governments and state agencies, including the [COGCC] and [other] agencies . . . have regulatory authority over oil and gas development, including as specified in section 34-60-105(1)(b). *A local government’s regulations may be more protective or stricter than state requirements.*”¹⁵ Thus, SB 181 establishes that local governments have broad authority under the Enabling Act to regulate surface impacts from oil and gas operations, including local regulations that are more protective than state law.¹⁶

SB 181 also provides a list of the kinds of matters local governments may address. The relevant section of the Enabling Act now reads in pertinent part:

- (1) Each local government within its respective jurisdiction has the authority to plan for and regulate the use of land by:

- (h) Regulating the surface impacts of oil and gas operations in a reasonable manner to address matters specified in this subsection (1)(h) and to protect and minimize adverse impacts to public health, safety, and welfare and the environment. Nothing in this subsection is intended to alter, expand, or diminish the authority of local governments to regulate air quality under Section 25-7-128. For purposes of this subsection (1)(h), “minimize adverse impacts” means, to the extent necessary and reasonable, to protect public health, safety, and welfare and the environment by avoiding adverse impacts from oil and gas operations and minimizing and mitigating the extent and severity of those impacts that cannot be avoided. The following matters are covered by this subsection (1)(h):

- (I) Land use;
- (II) The location and siting of oil and gas facilities and oil and gas locations . . .
;
- (III) Impacts to public facilities and services;
- (IV) Water quality and source, noise, vibration, odor, light, dust, air emissions and air quality, land disturbance, reclamation procedures, cultural

¹⁵ *Id.* § 34-60-131 (2019) (emphasis added). Similarly, section 34-60-105 states that “nothing in this [Oil and Gas Conservation Act] alters, impairs, or negates the authority of . . . [a] local government to regulate oil and gas operations pursuant to” the Enabling Act. *Id.* § 34-60-105(1)(b)(V) (2019).

¹⁶ Two months after the passage of SB 181, Weld County commissioners attempted to designate their entire county as “an area of state interest” under Colorado’s Areas and Activities of State Interest Act (commonly referred to as “HB1041 powers”) in order to potentially promulgate regulations *less* protective than the COGCC. The County’s claim that SB 181 allows a local government’s less protective regulations to preempt more stringent state regulations has no basis in the Act or land use law; in fact, amendments that would have codified such an intent were offered and rejected by the General Assembly. The COGCC has stated it believes SB 181 only allows local governments to enact more protective regulations, not less. *See, e.g.,* Kyle Davenport, *Letter from COGCC to Weld County RE: Senate Bill 19-181 and Local Government 1041 Regulations*, July 22, 2019, <https://ewscripps.brightspotcdn.com/b0/6a/d2ee971b459484db24455e3c082a/2019-07-22-letter-to-weld-county-signed-final-1.pdf>.

- resources, emergency preparedness and coordination with first responders, security, and traffic and transportation impacts;
 - (V) Financial securities, indemnification, and insurance as appropriate to ensure compliance with the regulations of the local government; and
 - (VI) All other nuisance-type effects of oil and gas development; and
- (i) Otherwise planning for and regulating the use of land so as to provide planned and orderly use of land and protection of the environment in a manner consistent with Constitutional rights.
- (2) To implement the powers and authority granted in Subsection (1)(h) of this section, a local government within its respective jurisdiction has the authority to:
 - (a) Inspect all facilities subject to local government regulation;
 - (b) Impose fines for leaks, spills, and emissions; and
 - (c) Impose fees on operators or owners to cover the reasonably foreseeable direct and indirect costs of permitting and regulation and the costs of any monitoring and inspection program necessary to address the impacts of development and to enforce local governmental requirements.¹⁷

SB 181 thus expressly authorizes local governments to regulate (among many other matters) the “land use” of oil and gas operations, and the “location and siting” of those operations, which should subject them to zoning ordinances.

This list does not expressly address “downhole” (below the surface) operations, but the authority to address water quality, and leaks and spills, may authorize local governments to impose downhole requirements that protect groundwater and domestic water wells.

As the new Enabling Act language indicates, local government regulations (like COGCC regulations) can “protect” resources, and minimize adverse impacts to the extent “necessary and reasonable.” The meaning of these terms is discussed in the section on setbacks, below.

II. SETBACKS AND OTHER PROTECTIVE REGULATIONS

This section discusses setbacks as an illustration of how local governments may be able to exercise their Enabling Act authority under SB 181. The analysis of setbacks could apply to other types of land use regulations as well.

The plain language of subsection 29-20-104(1)(h) appears to include two related but distinct grants of authority, with the “necessary and reasonable” qualifier applicable only to one. First, the subsection states that local governments are authorized to “[r]egulat[e] the surface impacts of oil and gas operations in a reasonable manner to address matters specified in this subsection (1)(h).” Second, the sentence also authorizes local governments “to protect and

¹⁷ Colo. Rev. Stat. § 29-20-104 (2019).

minimize adverse impacts to public health, safety, and welfare and the environment.” The subsection then goes on to define “minimize” in terms of what is necessary and reasonable.¹⁸

Because “minimize” is used only in the second part of the sentence, it does not appear to qualify the grant in the first part allowing local governments to “address” the matters listed in the section. This first clause appears to be limited only by the directive that such regulation be done “in a reasonable manner.” This text suggests that land use measures listed in subsection 29-20-104(1)(h) need only be “reasonable,” not “reasonable and necessary.” That statutory construction aligns with the intent of SB 181 that oil and gas be subject to local regulation like any other industry: courts have long given deference to local governments’ core land use and zoning authority.¹⁹

Establishing a regulatory setback distance is clearly within the scope of SB 181’s amendments allowing local governments to address “land use” and the “location and siting” of oil and gas operations.²⁰ Given that, the “necessary and reasonable” requirement may not apply to regulatory setbacks at all; mere reasonableness may be the only requirement. However, setbacks can also satisfy the direction to “protect” and “minimize adverse impacts to” resources and be “necessary and reasonable.”

The analysis below (1) addresses the meaning of “protect,” “necessary,” and “reasonable” in SB 181; (2) assesses how that language may apply to setbacks; and (3) provides resources that support the use of setbacks and similar regulations. In short, a local government can require greater setbacks than COGCC regulations and should support that decision with clear evidence in the record. Such evidence can include, for example, studies about the health and safety effects of fracking operations, including studies specifically detailing harmful health effects within certain distances. Other regulations could be implemented in a similar manner, when they are rationally supported by facts and science.

A. Meaning of “protect” and “necessary and reasonable” under SB 181

Courts have not yet interpreted SB 181’s “protect” and “necessary and reasonable” language. But the Act’s text, context, purpose, and legislative history provide guidance for local governments. Fundamentally, SB 181 made protection of public health, safety, and welfare and the environment the paramount consideration in matters involving mineral extraction instead of just one factor to balance with the state’s interest in resource development.²¹ The requirement that local government regulation be “necessary and reasonable,” at its core, requires that local

¹⁸ *Id.* § 29-20-104(1)(h).

¹⁹ *See, e.g., Vill. of Euclid, Ohio v. Ambler Realty Co.*, 272 U.S. 365, 395 (1926) (“[I]t must be said before the [local] ordinance can be declared unconstitutional, that such provisions are clearly arbitrary and unreasonable, having no substantial relation to the public health, safety, morals, or general welfare.”); *Mosgrove v. Town of Fed. Heights*, 543 P.2d 715, 717 (Colo. 1975) (upholding a local refuse and litter control ordinance designed to protect “the health, safety and welfare of the community,” and finding the ordinance was “clearly within the framework of that legitimate municipal concern”).

²⁰ *Id.* § 29-20-104(1)(h). This discussion focuses on regulatory setbacks—those adopted by ordinance or rule, rather than limits imposed in the course of approving an application for a particular project.

²¹ *See* pp. 2-4, *supra*.

governments ground their decisions in evidence. Those decisions, moreover, should receive substantial deference from courts.

Colorado courts will likely apply the normal tools of statutory construction to SB 181's meaning, including the text itself, its context in the statute, and the legislative history (including the General Assembly's purpose in adopting the statute).²²

1. Text

SB 181 uses three terms in discussing local government authority: (a) “protect,” (b) “reasonable,” and (c) “necessary.” The dictionary definition of “protect” is to “cover or shield from injury or danger.”²³ The breadth of this language, and the use of “danger” in addition to injury, supports a broad view of local government's authority to address risks and potential impacts from oil and gas development.

Legal dictionaries define “reasonable” as “[f]air, proper, or moderate under the circumstances; sensible”²⁴ and a reasonable action is “what most rational and fair-minded people could be expected to do in a given situation.”²⁵

Industry may argue that “necessary” (or “necessary and reasonable”) substantially restrict the authority of local governments to regulate. The structure of the Act undercuts this argument. The phrase “necessary and reasonable” appears in two sections of the Act: section 4, which addresses local government jurisdiction over oil and gas operations; and section 7, which addresses COGCC regulation of the oil and gas industry.²⁶ The use of the term in both sections indicates that the scope of local regulation, and the deference due local governments, is similar to the authority of COGCC: *i.e.*, broad and given ample discretion.²⁷

2. Legislative History

Moreover, the legislative history of SB 181 also does not support a restrictive reading of “necessary and reasonable.” That history indicates these terms were intended to guard against arbitrary state or local government action, while providing local governments substantially more authority to protect public health, safety, and welfare than the prior statutory language.

²² *State v. Nieto*, 993 P.2d 493, 501 (Colo. 2000) (“A statute must . . . be construed to further the legislative intent represented by the entire statutory scheme.”); *Daniel v. City of Colo. Springs*, 327 P.3d 891, 896 (Colo. 2014) (legislative history and intent can be a helpful tool in the absence of statutory definitions).

²³ *Protect*, Dictionary.com, www.dictionary.com/browse/protect (last visited Nov. 15, 2019).

²⁴ *Reasonable*, Black's Law Dictionary (10th ed. 2014), cited in *Gagne v. Gagne*, 338 P.3d 1152, 1160 (Colo. App. 2014).

²⁵ *Reasonable action*, Wolters Kluwer Bouvier Law Dictionary (1st ed. 2012).

²⁶ Senate Bill 19-181, as adopted, https://leg.colorado.gov/sites/default/files/2019a_181_signed.pdf

²⁷ The Act, both before and after SB 181's enactment, has delegated authority to COGCC using language similar to SB181's “reasonable and necessary” language: “The [COGCC] has . . . the power . . . to do whatever may *reasonably be necessary* to carry out this article . . .” Colo. Rev. Stat. § 34-60-105(1)(a) (2019) (emphasis added). Courts have consistently found that this language “gives the Commission a broad grant of jurisdiction.” *Grant Bros. Ranch, LLC v. Antero Res. Piceance Corp.*, 409 P.3d 637, 641 (Colo. App. 2016); see also, e.g., *Maralex Res., Inc. v. Colo. Oil and Gas Conservation Comm'n*, 428 P.3d 657, 663 (Colo. App. 2018) (noting that “COGCC has promulgated comprehensive rules regulating multitudinous aspects of the oil and gas industry”).

a. Original Bill Expanding Local Government Authority

The original version of SB 181 introduced during the 2019 General Assembly session (often called the ‘Introduced Version’) made three changes to the existing “minimize adverse impacts” definition. First, SB 181 deleted the requirement to consider technical feasibility and cost effectiveness when considering regulations. Second, it deleted the “wherever reasonably practicable” modifier from the existing definition. And third, it broadened the scope of the definition to include all types of impacts rather than those just related to wildlife resources.²⁸

The Introduced Version also added authority for local governments to require the minimization of adverse impacts, similar to what was proposed for COGCC’s authority.

Thus, the Introduced Version of SB 181 provided for both COGCC and local governments to require minimization of adverse impacts. For both COGCC and local governments, the introduced version defined “minimize adverse impacts” as “to (a) Avoid adverse impacts from oil and gas operations, and (b) Minimize and mitigate the extent and severity of those impacts that cannot be avoided.”²⁹

b. Amended Versions of SB 181 Adding “Protect” and “Necessary and Reasonable”

During floor debate in the Senate, legislators amended SB 181 by adding the “necessary and reasonable” language.³⁰ Bill sponsor Senator Fenberg offered the amendments, which modified the “minimize adverse impacts” definition to include the “necessary and reasonable” language both in sections 4 (local government authority) and 7 (COGCC authority) of the bill.³¹ At the same time, the amendments also added language providing for COGCC and local governments to “protect” public health, safety, and welfare and the environment, not just minimize adverse impacts.³² The amendments, however, still excluded language requiring consideration of technical feasibility, cost effectiveness and reasonable practicability.³³ The relevant language from the amended and final version of Sections 4 and 7 are quoted on pp. 3-5, *supra*.

²⁸ SB19-181, 72d Colo. Cong. (as introduced into Senate Mar. 1, 2019), at 11, http://leg.colorado.gov/sites/default/files/documents/2019A/bills/2019a_181_01.pdf (“Introduced Version”).

²⁹ *Id.*

³⁰ SB19-181’s procedural history was as follows: introduction, Senate Transportation and Energy Committee, Senate Finance Committee, Senate Appropriations Committee, Senate Second Reading, Senate Third Reading, House Energy and Environment Committee, House Finance Committee, House Appropriations Committee, House Second Reading, House Third Reading, Senate Concurrence and Repassage, Governor’s approval and signature. See *SB19-181: Protect Public Welfare Oil and Gas Operations*, Colo. Gen. Assembly, <https://leg.colorado.gov/bills/sb19-181> (last visited Nov. 15, 2019).

³¹ SB19-181 Senate Floor Amendments L.074 & L.075 (added Mar. 12, 2019 during Second Reading debate), https://s3-us-west-2.amazonaws.com/leg.colorado.gov/2019A/amendments/SB181_L.074.pdf, https://s3-us-west-2.amazonaws.com/leg.colorado.gov/2019A/amendments/SB181_L.075.pdf.

³² *Id.*

³³ *Id.*

The legislative history shows the amendments were intended to require state and local governments to justify regulations, but not to limit protections based on industry arguments about practicability, cost-effectiveness, and technical feasibility. The amendments also provide COGCC and local governments wide discretion to act in order to protect the environment and communities.³⁴

As bill sponsor Senator Fenberg explained, the local government amendment “adds some guardrails to the local authority that a local government would, if they so choose, take on, and it says that the regulations they will adopt to protect health and safety et cetera will have to be necessary and reasonable for the purposes of protecting health and safety...”³⁵ That amendment was adopted without further legislative debate, as was the amendment adding the same language regarding COGCC regulation.³⁶

Bill sponsor Senator Foote described the intent behind the “necessary and reasonable” language in floor remarks made before the final vote:

[A] question has repeatedly come up about the, quote, “necessary and reasonable” standard language that we added in the Senate. There have been several requests to further define it, but unfortunately that’s proved to be difficult. I will say, though, that it’s the sponsors’ intent to have that phrase interpreted together, and in the context of the bill as a whole, which is (1) a clear desire to prioritize health and safety when it comes to oil and gas operations, permitting, and supervision, without consideration of profitability from the state regulatory authority, the COGCC; and (2) an ability for local governments to do the same, and be more protective than the state if they choose. “Necessary and reasonable” is not intended to mean regulatory authorities can only make a land use decision or enact a regulation once all other options are exhausted. Instead, it is meant to be a guardrail against a regulatory or

³⁴ Cf. *Colorado Oil & Gas Conservation Comm’n v. Martinez*, 433 P.3d 22, 31 (2019). In *Martinez*, the Colorado Supreme Court evaluated the extent of COGCC’s duty, prior to SB 181’s passage, to regulate oil and gas for the protection of human health and the environment. It found this duty was limited due to the very clauses that SB 181 has since removed. The Court reasoned:

Had the legislature intended to preclude any cumulative adverse impacts . . . the statute would not have included the language “and mitigate significant” or “taking into consideration cost-effectiveness and technical feasibility.” Rather, the provision would have required the Commission to regulate oil and gas operations so as to avoid adverse environmental impacts on any air, water, soil, or biological resource, to the extent necessary to protect public health, safety, and welfare, including protection of the environment and wildlife resources.

Id. With SB 181, this is precisely what the legislature has now directed, and this wide grant of authority applies equally to the authorizing language for COGCC and local governments.

³⁵ Second Reading of SB19-181 on Senate Floor, Statement of Sen. Fenberg, Mar. 12, 2019, at 5:10:45, http://coloradoga.granicus.com/MediaPlayer.php?view_id=42&clip_id=13691.

³⁶ SB 181 passed the Senate and was introduced into the House of Representatives shortly thereafter. See *SB19-181: Protect Public Welfare Oil and Gas Operations*, Colo. Gen. Assembly, <https://leg.colorado.gov/bills/sb19-181> (last visited Nov. 15, 2019) (click: “bill history”). While the House approved twenty-six additional amendments to the bill, it did not change the “necessary and reasonable” language. SB 181 passed the House and came back to the Senate for consideration of House amendments. The Senate voted to approve the House amendments and repass the bill.

land use decision without reasonable justification. State and local governments should not be able to impose requirements, limitations, or decisions that defy explanation. However, they should be entitled to deference and allowed to use the precautionary principle to determine if a regulation or a land use decision is necessary and reasonable. Each locality's application of "necessary and reasonable" may be different depending on its circumstances, and should be examined on a case-by-case basis.³⁷

In the House, Bill sponsor Representative Becker similarly explained that local governments and COGCC decisions are reviewed on a deferential "rational basis" or "arbitrary" standard, and that governments have authority under SB 181 to deny proposals for oil and gas development in appropriate circumstances:

This bill requires that local governments or COGCC have a basis, a rational basis at any instance, if it says a particular permit is not protective of health, safety, and welfare. [The government] cannot arbitrarily refuse a permit, and if they are going to, if they have concerns about any oil and gas permit, they first must try to minimize adverse impacts. So this is not a zero impact bill, again, local government or COGCC would still have to work with the industry to minimize any adverse impacts that [they are] really concerned about before turning down any permit.³⁸

Similarly, during debate in the House, Representative Mike Weissman emphasized that local decisions would get deference under the necessary and reasonable standard:

What I think is essential about this legislation and what sets it apart from [a recent ballot measure] is the idea of local control and local judgment . . . that we are giving some discretion to and some deference to. . . . [O]ur local governments need and deserve to be able to assess what is reasonable and necessary. . . . [A local decision may determine that requiring an oil and gas company to] seek the resource somewhere else is reasonable and necessary and I think they need to be given discretion on that matter because local control is at the heart of this bill. . . . Some [] communities . . . may take a very precautionary approach because that may be what their residents are asking them to do and I think that deserves discretion and . . . respect and deference.³⁹

In short, the legislative history and text of SB 181 provide several key lessons for interpreting "necessary and reasonable":

³⁷ Senate Consideration of House Amendments to SB19-181, Statement of Sen. Foote, Apr. 3, 2019, at 1:13:20, http://coloradoga.granicus.com/MediaPlayer.php?view_id=42&clip_id=13895.

³⁸ Hearing on SB19-181 Before the House Energy and Env't Comm., Statement of Rep. Becker, Mar. 18, 2019, at 20:03, http://coloradoga.granicus.com/MediaPlayer.php?view_id=114&clip_id=13741.

³⁹ Second Reading of SB19-181 on House Floor, Statement of Rep. Weissman, Mar. 28, 2019, at 3:33:10, <https://www.coloradochannel.net/sessions/?id=102530>.

- First, priority should be given to health, safety and environmental protection, and those efforts are no longer expressly limited by industry claims of “practicability” or cost effectiveness for the operator.
- Second, local governments have broad authority and can adopt requirements that are more protective than state regulations.
- Third, “necessary and reasonable” is intended simply as a guardrail against regulations that lack a reasonable justification. The term does not prevent governments from adopting precautionary regulations in the face of incomplete information,⁴⁰ or require that all less protective options be exhausted before adopting a particular regulation. However, before denying a permit governments should assess whether the impacts of concern can be avoided or minimized.
- Fourth, local governments adopting new protections should make a clear record of the research and evidence supporting that decision, and the factors considered.
- Fifth, local government regulations should be given deference and examined on a case-by-case basis.

If the local government makes a clear record of the information and factors upon which it based its decision, operators challenging the land use decision in court will face a high bar. Under C.R.C.P. 106(a)(4), local government zoning and other quasi-judicial decisions generally are overturned only for exceeding the government’s jurisdiction or an abuse of discretion.⁴¹ Under this standard, a plaintiff must show the decision is “arbitrary and capricious,” meaning, for example, that there is “no competent evidence” supporting it.⁴² Similarly, courts have held that local ordinances are presumed valid and a declaratory judgment under C.R.C.P. 57 must show an ordinance is invalid “beyond a reasonable doubt.”⁴³

B. Application to Setbacks

The text and legislative history of SB 181 provide ample authority for local governments to adopt setbacks, especially when they have reasonable evidentiary support.⁴⁴ For example,

⁴⁰ The “precautionary principle” (referenced in the legislative history) states that where there is a risk of serious environmental harm, a lack of full scientific certainty should not be used as a reason for postponing reasonable measures to prevent that harm. See *Precautionary Principle Law and Legal Definition*, US Legal, <https://definitions.uslegal.com/p/precautionary-principle/> (last visited Nov. 15, 2019).

⁴¹ C.R.C.P. 106(a)(4); see, e.g., *Whitehall v. Denver City Cncl.*, 405 P.3d 433, 437 (Colo. App. 2017) (upholding zoning decision).

⁴² See *Brd. of Cty Comm’rs v. O’Dell*, 920 P.2d 48, 49 (Colo. 1996); *Ross v. Fire and Police Pension Ass’n*, 713 P.2d 1304, 1309 (Colo. 1986); see generally Daniel E. Kramer, *Springtime for Home Rule over Oil and Gas*, Colorado Lawyer, July 2019, at 36–38.

⁴³ *JJR 1, LLC v. Mt. Crested Butte*, 160 P.3d 365, 372 (Colo. App. 2007).

⁴⁴ As noted previously, local regulations that seek to protect public health and welfare via land use decisions are generally afforded significant deference; evidentiary support further strengthens their position during judicial review. See *Euclid*, 272 U.S. at 395; *Mosgrove*, 543 P.2d at 717.

during consideration in the House, Representative Landgraf (an opponent of SB 181) asked whether “a local municipality could do a 2500-foot setback which [in her view] would be against . . . the will of the people” because Colorado voters voted down a statewide 2500 foot setback proposed by the Proposition 112 ballot initiative in 2018.⁴⁵ In response, bill sponsor Representative Becker suggested that such a local setback would not be foreclosed by SB 181 if it had a rational, non-arbitrary basis and the distance was necessary to minimize adverse impacts:

So the Prop. 112 was mandatory for every place in Colorado, whether you lived in Rifle, whether you lived in Boulder, whether you lived in Fort Morgan. It was a mandatory, no exceptions allowed, 2500-foot setback and local governments couldn’t do anything about it. This bill doesn’t refer to setbacks at all. However if a local government says we want to do a 2500-foot setback, I think that the bill limits their ability to do many things because it says that they may do these things, in a way to minimize- so they first have to work to minimize adverse impacts to public health, safety, welfare, and the environment. Minimize adverse impacts means to the extent reasonable to protect health, safety, welfare, and the environment by avoiding adverse impacts by the oil and gas operations and minimizing and mitigating the extent and severity of those impacts that cannot be avoided. So basically, it also says that they have to have a rational basis for doing this. And they are certainly subject to existing law that says their actions cannot be arbitrary and capricious. So, they can’t just say today we are imposing a new setback because we feel like it. It has to be to protect health, safety, and welfare, they must try to minimize their impacts, and they must have a rational basis for doing it. So I think that the bill and existing law prohibits actions that could be considered arbitrary or capricious.⁴⁶

There are a number of studies and data that provide a “rational basis” for local setbacks substantially larger than current COGCC requirements. Many studies have found that oil and gas development causes health impacts at distances well beyond 1,000 feet. These studies are summarized in Appendix A. For example, one study found elevated concentrations of volatile organic compounds, including benzene levels above EPA’s cancer risk threshold, at residential properties in Erie and Longmont located up to 1391 feet (424 meters) from oil and gas sites. Thompson *et al.* (2014). Other studies of health impacts in Colorado have found cancer risks above EPA’s recommended thresholds at distances of 2000 and 2640 feet. McKenzie *et al.* (2018); McKenzie *et al.* (2012). These studies are consistent with numerous peer-reviewed studies conducted on the Colorado Front Range finding elevated concentrations of hydrocarbons, many of which have direct health effects, due to oil and gas sector emissions. See, e.g. Oltmans *et al.* (2019); Bien & Helmig (2018); Evans & Helmig (2017); Kaser *et al.* (2017); McDuffie *et*

⁴⁵ Hearing on SB19-181 Before the House Energy and Env’t Comm., Statement of Rep. Landgraf, Mar. 18, 2019, at 1:38:44, http://coloradoga.granicus.com/MediaPlayer.php?view_id=114&clip_id=13741.

⁴⁶ Hearing on SB19-181 Before the House Energy and Env’t Comm., Statement of Rep. Becker, Mar. 18, 2019, at 1:39:08 http://coloradoga.granicus.com/MediaPlayer.php?view_id=114&clip_id=13741.

al. (2016); Pétron *et al.* (2014); Swarthout *et al.* (2013); Gilman *et al.* (2013); Pétron *et al.* (2012).

Cancer is far from the only health risk posed by close proximity to oil and gas development. In October 2019 the COGCC and CDPHE released a peer-reviewed health assessment using emissions data and air quality modeling that found acute exposures during flowback and well completion operations to residents 2000 feet from a well at levels that could involve hematological toxicity associated with benzene exposure (which can involve symptoms such as nosebleeds and headaches).⁴⁷ Another study found a statistically significant increase in reported symptoms including headaches, nose bleeds, throat irritation, eye burning, shortness of breath, and skin rashes by residents who lived within 1500 feet of a well compared to those who lived farther away. Steinzor *et al.* (2013). Other studies, including several in Colorado, have found that mothers living in closer proximity to oil and gas development experience elevated rates of high-risk pregnancies, birth defects, and other pre- and post-natal health issues. See Casey *et al.* (2016); Casey *et al.* (2019); McKenzie *et al.* (2019); McKenzie *et al.* (2017); McKenzie *et al.* (2014); Janitz *et al.* (2019); Stacy *et al.* (2015). Several studies have found evidence of birth defects and pre-term birth among mothers who live within 2640 feet (0.5 miles), 3280 feet (1 km), and even as far as 9842 feet (3 km) away from oil and gas development. Whitworth *et al.* (2017); Curry *et al.* (2017).

Other entities reviewing this literature have determined that setbacks larger than 1000 feet are warranted to protect public health. A 2014 University of Maryland study concluded that 2,000-foot setbacks are justified based on the scientific evidence of impacts.⁴⁸ In 2018, the County of Los Angeles Department of Public Health recommended setbacks of 1,500 feet based on its own literature review.⁴⁹ New York went even further and banned high-volume hydraulic fracturing statewide after the state's Department of Public Health issued a report discussing the risks of fracking and the likelihood of adverse health impacts.⁵⁰

These studies are bolstered by the record of citizen complaints to COGCC. Over the 9 3/4 years from Jan. 2010-Sept. 2019 (117 months), COGCC recorded 4,772 complaints – more than one per day. Of those, 25 percent involved complaints relevant to CDPHE's 2019 health study. The large majority of those involved odors: COGCC received an average of one odor-related complaint every three days (1,187 complaints). In addition, a substantial number of complaints involved symptoms consistent with the acute exposures modeled by the CDPHE

⁴⁷ ICF, *Final Report: Human Health Risk Assessment for Oil & Gas Operations in Colorado*, Oct. 17, 2019, https://drive.google.com/file/d/1pO41DJMXw9sD1NjR_OKyBJP5NCb-AO0I/view.

⁴⁸ Maryland Institute for Applied Environmental Health, *Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland*, July 2014, at 94, <https://phpa.health.maryland.gov/OEHFP/EH/Shared%20Documents/Marcellus%20Shale/MDMarcellusShalePublicHealthFinalReport08.15.2014.pdf>.

⁴⁹ Katherine Butler *et al.*, *Public Health and Safety Risks of Oil and Gas Facilities in Los Angeles County*, Los Angeles County Department of Public Health, Feb. 2018, at 20–22, http://publichealth.lacounty.gov/eh/docs/PH_OilGasFacilitiesPHSafetyRisks.pdf.

⁵⁰ See N.Y. State Dept. of Public Health, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development*, Dec. 2014, at 1–12, https://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf.

study. These included numerous complaints of headaches (104 complaints), burning/itching/irritation (84 complaints), and nausea (54), as well as periodic complaints about nosebleeds and dizziness.⁵¹

Other complaint data is similar. According to the State Toxicologist, “the health effects related to short-term exposures to VOCs modeled in [CDPHE’s 2019] study are consistent with concerns from people using the Oil and Gas Health Information Line. These include headaches, dizziness, respiratory problems, and irritation of the eyes and skin. About 60% of health concerns reported to the Oil and Gas Health Information and Response Program since it started in 2015 have been about these kinds of health effects. More than 750 reported health concerns that include these short-term health effects since 2015.”⁵²

These complaints provide further evidence of the benefit of moving oil and gas operations away from homes, schools, and other occupied structures. Moreover, they are likely just the tip of the iceberg. Most residents experiencing such symptoms likely were unaware of COGCC’s complaint process, or did not connect their symptoms to the nearby fracking activity. Other residents may have contacted local authorities or other agencies instead of the COGCC.

Finally, the frequency of fires and explosions at oil and gas sites supports the adoption of setbacks larger than the distances currently required by COGCC. A review of COGCC accident reports found that 116 explosions or fires occurred at Colorado oil and gas sites during the ten years from 2006-2015—an average of one such incident per month.⁵³ Requiring oil and gas locations to be located further than 500 feet from homes provides an obvious benefit when fires or explosions occur.

C. Resources Supporting Other Regulations to Protect Public Health, Safety, and Welfare

Many peer-reviewed scientific studies and other research are also available to support regulations other than setbacks. Much of the peer-reviewed research documenting the harmful impacts of unconventional oil and gas drilling is very recent, with more than half of the available studies published since January 2016.⁵⁴ A large number of studies were conducted in Colorado, making their conclusions especially relevant for Colorado local governments identifying the best available science to support their regulatory and land use decisions.

⁵¹ *Complaints Download*, Colo. Oil and Gas Conservation Comm’n, <https://cogcc.state.co.us/documents/data/downloads/Complaints/ComplaintsDownload.html> (last visited Nov. 15, 2019).

⁵² Nov. 1, 2019 letter from K. Boyer, Tri-County Health Dept., to D. Martinelli, City of Commerce City at 5.

⁵³ Benjamin Blair et al., *Is Reporting “Significant Damage” Transparent? Assessing Fire and Explosion Risk at Oil and Gas Operations in the United States*, 29 *Energy Res. & Soc. Sci.* 36 (2017), <https://www.sciencedirect.com/science/article/pii/S2214629617301081?via%3Dihub>.

⁵⁴ Concerned Health Professionals of New York & Physicians for Social Responsibility, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (6th ed., 2019), at 12, <http://concernedhealthny.org/compendium/> (“PSR Compendium”).

For example, Physicians, Scientists, and Engineers for Healthy Energy (“PSEHE”) has compiled a repository that as of October 2019 includes nearly 1900 peer-reviewed studies on the impacts of oil and gas development, including approximately 200 studies on overall health impacts, 100 on air quality, and 250 on water quality.⁵⁵ In 2016, PSEHE scientists conducted a literature review of 685 peer-reviewed papers on the impacts of unconventional oil and gas development published between 2009 and 2015.⁵⁶ PSEHE calculated that 84% of the health studies it reviewed found public health hazards, elevated risks, or adverse health outcomes; 87% of air quality studies found elevated air pollutant emissions or concentrations; and 69% of water quality studies found potential, positive association, or actual incidence of water contamination.⁵⁷

Physicians for Social Responsibility (PSR) has also developed a comprehensive compendium of health studies, including several studies, reviews, and reports specifically investigating impacts in Colorado. For example:

- In northeastern Colorado, ambient levels of atmospheric hydrocarbons continued to increase even after stricter statewide emission standards were enacted in 2008.⁵⁸
- Increasing oil and gas operations throughout the west have led to elevated ozone levels. Colorado has exceeded federal ozone limits for the prior decade, corresponding with the rapid increase in fracking throughout the state.⁵⁹
- Volatile organic compounds (VOCs) from drilling and fracking operations, together with nitrogen oxides, were responsible for 17 percent of locally produced ozone in the Front Range during the summers of 2012 and 2014, according to data collected from a research facility in Erie, Colorado.⁶⁰

⁵⁵ See Physicians, Scientists, and Engineers for Healthy Energy, *Repository of Oil and Gas Energy Research*, <https://www.psehealthyenergy.org/our-work/shale-gas-research-library/> (last visited Oct 31, 2019).

⁵⁶ Jake Hays & Seth Shonkoff, *Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015*, PLoS ONE, Apr. 20, 2016, <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0154164>.

⁵⁷ *Id.* Additionally, the Endocrine Disruption Exchange (“TEDX”) has compiled a database of 201 peer-reviewed studies on the health impacts of unconventional oil and gas. *FrackHealth Database*, The Endocrine Disruption Exchange, <https://endocrinedisruption.org/audio-and-video/fracking-related-health-research-database/search-the-database#keywords=&action=search> (last visited Oct. 31, 2019).

⁵⁸ PSR *Compendium* at 59 (citing Chelsea Thompson et al., *Influence of Oil and Gas Emissions on Ambient Atmospheric Non-Methane Hydrocarbons in Residential Areas of Northeastern Colorado*, 3 *Elem. Sci. Anth.* 35 (2014), <https://www.elementalscience.org/articles/10.12952/journal.elementa.000035/>).

⁵⁹ *Id.* at 52, fn 158 (citing Anna Boyko-Weyrach, *Ozone, Asthma And The Oil And Gas Connection*, Inside Energy, Oct. 5, 2016, <http://insideenergy.org/2016/10/05/ozone-asthma-and-the-oil-and-gas-connection/>).

⁶⁰ *Id.* at 53, fn 160 (citing Erin McDuffie et al., *Influence of Oil and Gas Emissions on Summertime Ozone in the Colorado Northern Front Range*, 121 *J. Geophys. Research: Atmospheres* 8,153 (2016), <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016JD025265>).

- Air samples recovered near fracking sites in Colorado and four other states revealed the presence of two known carcinogens (benzene and formaldehyde) and exceeded federal safety standards in 38% of the samples taken.⁶¹
- PSR reported that a single well site in Colorado studied in 2012 revealed the presence of 50 airborne chemicals, 44 of which are known to have adverse health effects.⁶²
- A separate 2012 study by the University of Colorado School of Public Health found air pollutants near Colorado fracking sites linked to neurological, respiratory, hematologic, and developmental problems and cancer.⁶³
- In 2014, National Oceanic and Atmospheric Administration (NOAA) scientists reported methane emissions were three times higher than previous estimates and VOC levels seven times previously estimated by government agencies after conducting measurements of Colorado fracking sites by airplane.⁶⁴
- A study published in 2018 by University of Colorado School of Public Health scientists found that air pollution levels along the Front Range increased with proximity to drilling and fracking operations and were sufficiently high to raise cancer risks. For people living within 500 feet of a well, lifetime cancer risks were eight times higher than the EPA's upper threshold.⁶⁵
- Reviewing 48 peer-reviewed studies that sampled air near drilling and fracking operations, researchers identified 106 airborne chemicals associated with oil and gas extraction that were detected in two or more studies, including 21 known endocrine disruptors.⁶⁶
- Wastewater from a Colorado fracking site was examined over a 220 day period and revealed significant toxicity, with its peak toxicity during the first day of flowback.⁶⁷

⁶¹ *Id.* at 59, fn 189 (citing Macey et al., *Air Concentrations of Volatile Compounds near Oil and Gas Production: a Community-Based Exploratory Study*, 13 *Envtl. Health* 82 (2014), <https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-13-82>).

⁶² *Id.* at 65, fn 222 (citing Theo Colborn et al., *An Exploratory Study of Air Quality Near Natural Gas Operations*, 20 *Human and Ecol. Risk Assess.* 86 (2013), <https://www.tandfonline.com/doi/abs/10.1080/10807039.2012.749447>).

⁶³ *Id.* at 66, fn 225 (citing Lisa McKenzie et al., *Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources*, 424 *Sci. Total Env't* 79 (2012), <https://www.sciencedirect.com/science/article/pii/S0048969712001933>).

⁶⁴ *Id.* at 62, fn 200 (citing Bruce Finley, *Scientists Flying over Colorado Oil Boom Find Worse Air Pollution*, *The Denver Post*, May 7, 2014, <https://www.denverpost.com/2014/05/07/scientists-flying-over-colorado-oil-boom-find-worse-air-pollution/>).

⁶⁵ *Id.* at 50, fn 145 (citing McKenzie et al., *Ambient Nonmethane Hydrocarbon Levels Along Colorado's Northern Front Range: Acute and Chronic Health Risks*, 52 *Envtl. Sci. & Tech.* 4,514 (2018), <https://pubs.acs.org/doi/10.1021/acs.est.7b05983>).

⁶⁶ *Id.* at 50, fn 146 (citing Bolden et al., *Exploring the Endocrine Activity of Air Pollutants Associated with Unconventional Oil and Gas Extraction*, *Envtl. Health*, Mar. 21, 2018, <https://www.ncbi.nlm.nih.gov/pubmed/29558955>).

⁶⁷ *Id.* at 75, fn 263 (citing Hull et al., *Succession of Toxicity and Microbiota in Hydraulic Fracturing Flowback and Produced Water in the Denver-Julesburg Basin*, 644 *Sci. Total Env't* 183 (2018), <https://www.ncbi.nlm.nih.gov/pubmed/29981518>).

- Wastewater spills in Colorado have increased since 2009 as the number of fracking sites in the state has grown.⁶⁸
- Using state agency data from 1998-2014, University of Colorado researchers identified the presence of methane with the same chemical composition as nearby drilling operations in 42 water wells located in Colorado's Denver-Julesburg basin. Barrier failure, rather than the fracking process itself, was identified as the likely reason for methane migration into the water supply.⁶⁹
- Denver-based Center for Western Priorities examined COGCC data from 2013 and found Colorado fracking sites averaged over a spill a day during that one-year period. A quarter of those spills impacted ground or surface water; half of those spills occurred within 1500 feet of livestock or buildings.⁷⁰
- Endocrine disruptor chemicals—which can interfere with hormonal activity in the human body and lead to reproductive, metabolic, and neurological disorders—were discovered in groundwater and surface water samples near fracking sites in Garfield County, Colorado and documented in a 2013 study.⁷¹
- A 2014 retrospective cohort study examining nearly 25,000 births between 1996 and 2009 in rural Colorado found an association between low birthweight and birth defects and proximity to natural gas wells.⁷² More recently, a study published in July of 2019 found a link between intense oil and gas development and congenital heart defects among newborns in Colorado.⁷³

⁶⁸ *Id.* at 78, fn 274 (citing S.A. Clancy et al., *The Potential for Spills and Leaks of Contaminated Liquids from Shale Gas Developments*, 626 *Sci. Total Env't* 1,463 (2018), <https://www.sciencedirect.com/science/article/pii/S0048969718302146>). Data on COGCC's website also confirm that wastewater spills are a common occurrence.

⁶⁹ *Id.* at 87, fn 317 (citing Owen Sherwood et al., *Groundwater Methane in Relation to Oil and Gas Development and Shallow Coal Seams in the Denver-Julesburg Basin of Colorado*, 113 *Proc. Nat. Acad. Sci.* 8,391 (2016), <https://www.pnas.org/content/early/2016/07/05/1523267113.full>).

⁷⁰ *Id.* at 108-09, fn 415 (citing John Tomasic, *Colorado Drilling Data: More than a Spill a Day*, *The Colorado Independent*, Jan. 16, 2014, <https://www.coloradoindependent.com/2014/01/16/colorado-drilling-data-more-than-a-spill-a-day/> (in turn citing Center for Western Priorities, *Colorado Toxic Release Tracker 2013 Summary*, <https://westernpriorities.org/colorado-toxic-release-tracker-2013-summary/>)). The Center for Western Priorities tracked these data in subsequent years and found 712 spills in 2014, 615 spills in 2015, 509 spills in 2016, 614 spills in 2017, and 596 spills in 2018. Center for Western Priorities, 2014, 2015, 2016, 2017, and 2018 Colorado Oil and Gas Spill Trackers.

⁷¹ *Id.* at 109, fn 421 (citing Christopher Kassotis et al., *Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region*, 155 *Endocrinology* 897 (2014), <https://www.semanticscholar.org/paper/Estrogen-and-androgen-receptor-activities-of-and-in-Kassotis-Tillitt/867c51e40856b95338c085896fa256f8d54a4bfa>).

⁷² *Id.* at 171, fn 664 (citing Lisa McKenzie et al., *Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado*, 122 *Env'tl. Health Perspectives* 412 (2014), <https://www.ncbi.nlm.nih.gov/pubmed/24474681>).

⁷³ Lisa McKenzie et al., *Congenital Heart Defects and Intensity of Oil and Gas Well Site Activities in Early Pregnancy*, *Env't Int.*, Nov. 2019, <https://www.sciencedirect.com/science/article/pii/S0160412019315429?via%3Dihub>).

- Colorado residents who lived in areas of intense fracking activity examined between 2015 and 2016 showed higher instances of cardiovascular disease. Previous research documented higher rates of cardiology inpatient hospitalization in areas of intense fracking in parts of the country.⁷⁴
- Noise levels from a sampling of four Colorado neighborhood fracking sites over a three month period were found to exceed levels known to cause health impacts over 40 percent of the time during the day and 23 percent of the time at night. Researchers noted that “homes in closer proximity to operations will likely experience noise exposure at levels of concern even with the implementation of sound mitigation best management practices.”⁷⁵
- A 2017 study by researchers at the University of Colorado Boulder positively identified wastewater injection wells at the border of New Mexico and Colorado as sources of earthquakes that occurred from 2008 to 2010.⁷⁶
- Scientists from the United States Geological Survey (USGS) determined that seismicity increases in Colorado’s Raton Basin since 2001—including a magnitude 5.3 earthquake in 2011—was attributable to fracking wastewater disposal.⁷⁷

These research findings focused on the impacts of oil and gas development in Colorado are not unique. Publications ranging from peer-reviewed scientific studies to in-depth media investigations focusing on fracking in states like Texas, North Dakota, Wyoming, Pennsylvania, and Oklahoma parallel the findings from Colorado. Studies compiled in the *PSR Compendium* are authored by thousands of professionals working in *ad hoc* interdisciplinary groups or under the supervision of more than forty universities and government agencies.⁷⁸ Predictably, the oil

⁷⁴ *PSR Compendium* at 156, fn 607 (citing Lisa McKenzie et al., *Relationships Between Indicators of Cardiovascular Disease and Intensity of Oil and Natural Gas Activity in Northeastern Colorado*, 170 *Envtl. Research* 56 (2019), <https://www.sciencedirect.com/science/article/pii/S0013935118306339>).

⁷⁵ *Id.* at 174, fn 675 (citing Benjamin Blair et al., *Residential Noise from Nearby Oil and Gas Well Construction and Drilling*, 28 *J. Expo. Sci. Envtl. Epidemiology* 538 (2018), <https://www.ncbi.nlm.nih.gov/pubmed/29749380>).

⁷⁶ *Id.* at 186, fn 726 (citing Jenny Nakai et al., *A Possible Causative Mechanism of Raton Basin, New Mexico and Colorado Earthquakes Using Recent Seismicity Patterns and Pore Pressure Modeling*, 122 *J. Geophys. Research* 8,051 (2017), <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2017JB014415>).

⁷⁷ *Id.* at 199, fn 797 (citing Justin Rubinstien et al., *The 2001–Present Induced Earthquake Sequence in the Raton Basin of Northern New Mexico and Southern Colorado*, 104 *Bulletin Seismological Soc. Am.* 2,162 (2014), <https://pubs.geoscienceworld.org/ssa/bssa/article-abstract/104/5/2162/351411/the-2001-present-induced-earthquake-sequence-in?redirectedFrom=fulltext>).

⁷⁸ Involved institutions include American University, Appalachian State University, California Council on Science and Technology, Colorado Department of Public Health and Environment, Colorado State University, Cornell University, Columbia University, Drexel University, Duke University, Duquesne University, Johns Hopkins University, Lawrence Berkeley National Laboratory, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, Ohio State University, Oregon State University, Pennsylvania State University, San Francisco State University, Stanford University, Texas A&M University, Texas Commission on Environmental Quality, United States Geological Survey, University of California (Berkeley), University of Central Arkansas, University of Cincinnati, University of Colorado (Anschutz), University of Colorado (Boulder), University of Maryland, University of Michigan, University of Missouri, University of New Hampshire, University of Oklahoma, University of Pennsylvania, University of Pittsburgh, University of Southern California, University of

and gas industry has criticized some of these studies.⁷⁹ However, the sheer number, geographic diversity, variety, authorship, and types of methodology employed in the research makes the final conclusion inescapable. The question is no longer whether oil and gas development negatively affects Colorado’s public health, safety, welfare, wildlife, and the environment, but to what extent local and state governments are willing to allow those risks.

III. AIR QUALITY AUTHORITY

Even before SB 181, the federal and Colorado Clean Air Acts gave local governments broad authority to set stronger air quality standards than the applicable state or federal standard. This authority was not limited by the Colorado Supreme Court’s decisions in *Voss*,⁸⁰ *Longmont*,⁸¹ or *Fort Collins*,⁸² which did not address air quality standards. SB 181 also does not alter local governments’ air quality authority. SB 181 provides that “[n]othing in this [law] is intended to alter, expand, or diminish the authority of local governments to regulate air quality under section 25-7-128.”⁸³ Thus, local governments retain the full extent of their authority to regulate air quality, without federal and state preemption, after the passage of SB 181.

The Federal Clean Air Act (“Federal CAA”) establishes a “cooperative federalism” framework in which the federal government sets broad, health-based standards, but leaves it up to state and local governments to implement the standards. The federal CAA provides that the U.S. Environmental Protection Agency “shall encourage cooperative activities by the States and local governments for the prevention and control of air pollution.”⁸⁴

Rather than preempting local regulations, the Federal CAA generally reserves to state and local governments the right to adopt air quality standards that are more stringent than federal law. The Federal CAA states that (with certain exceptions) “nothing in this chapter shall preclude or deny the right of any State or political subdivision thereof to adopt or enforce (1) any standard or limitation respecting emissions of air pollutants or (2) any requirement respecting control or abatement of air pollution; except that . . . such State or political subdivision may not adopt or enforce any emission standard or limitation which is less stringent than the [federal]

Texas (Arlington), University of Texas (Austin), University of Utah, University of West Virginia, University of Wyoming, Virginia Tech University, and Yale University.

⁷⁹ See, e.g., Rebecca Simons, *Calling out the McKenzie Media Playbook*, Energy In Depth, Apr. 26, 2018, <https://www.energyindepth.org/calling-out-the-mckenzie-media-playbook/>. Energy In Depth is funded by the oil and gas industry. See also Michael Wines, *Oklahoma Acts to Limit Earthquake Risk at Oil and Gas Wells*, The New York Times, Aug. 4, 2015 (touching upon industry’s initial denials of a connection between wastewater disposal and seismic activity), <https://www.nytimes.com/2015/08/05/us/oklahoma-acts-to-limit-earthquake-risk-at-oil-and-gas-wells.html>.

⁸⁰ 830 P.2d 1061.

⁸¹ 369 P.3d 586.

⁸² 369 P.3d 573.

⁸³ Colo. Rev. Stat. § 29-20-104(1)(h).

⁸⁴ 42 U.S.C. § 7402(a).

standard or limitation.”⁸⁵ Local governments are, of course, “political subdivisions” of states. In other words, the federal Clean Air Act does not restrict local governments’ ability to adopt pollution “control or abatement” standards so long as they are at least as protective as the federal standards.⁸⁶

The Colorado Air Pollution Prevention and Control Act (“Colorado CAA”) similarly reserves the rights of local governments to adopt air quality regulations in most situations that are stronger than state (and federal) standards. The statute provides that local government air quality regulations must be “at least the same as, or . . . more restrictive than” state-wide emissions control regulations.⁸⁷ The Colorado CAA also reserves to local governments the right to adopt local ordinances to address air pollutants and air pollution sources that are not addressed by state-level standards.⁸⁸

However, one provision of the Colorado CAA does impose some restrictions on local governments. Section 25-7-128 of the statute prevents a “local air pollution control authority” from adopting an air pollution “system or program” that is “more stringent than a corresponding state provision with respect to hazardous air pollutants.”⁸⁹ However, this provision does not limit local governments’ use of local zoning authority or ordinances enacted under state law other than the Colorado CAA (*e.g.*, the Enabling Act) to address air pollutants.⁹⁰

In short, the Federal and Colorado Clean Air Acts generally allow local governments to adopt air pollution control rules that are stronger than state and federal requirements. Local governments, however, should review the state and federal statutory language carefully to ensure that a proposed local rule would be allowable.

⁸⁵ 42 U.S.C. § 7416. Section 7416 does have certain exceptions, such as regulations on emissions from motor vehicles and nonroad engines (42 U.S.C. § 7543). Governments should review these exceptions carefully when considering specific regulations. Industry, for example, contends that drill rig engines are nonroad engines subject to this exception, thus limiting local authority.

⁸⁶ This statutory provision may not apply if a local government pursues air quality strategies that do not impose standards for pollution “control or abatement” in that locality. *See, e.g., Clean Air Markets Group v. Pataki*, 338 F.3d 82, 87-89 (2d Cir. 2003) (state cap-and-trade program for interstate emissions preempted because it did not represent pollution “control or abatement” standard and interfered with operation of federal Clean Air Act).

⁸⁷ Colo. Rev. Stat. § 25-7-128(1).

⁸⁸ *Id.* Consistent with this recognition of local authority, several provisions of the Colorado CAA contemplate local governments having stronger air quality rules than the state. *See, e.g., id.* § 25-7-105(1)(a)(II) (ensuring that municipal and county air pollution standards are incorporated into the state-level air quality implementation); *id.* § 25-7-103(16) (defining “local air pollution law”); *id.* § 25-7-114.7(2)(a)(I)(C) (discussing who pays for the enforcement costs of a local air pollution regulation “that is more stringent than corresponding state provisions”).

⁸⁹ *Id.* § 25-7-128(7)(c).

⁹⁰ *Id.* That same provision of the Colorado CAA also restricts local government’s ability to adopt air pollution systems or programs regarding certain other specified issues, such as stratospheric ozone, asphalt plants, and air pollution emergency plans. *Id.* § 25-7-128(7).

IV. THREATS OF TAKINGS CLAIMS

As its legislative history indicates, pp. 8-12, *supra*, SB 181 anticipates that local governments can deny oil and gas applications in certain circumstances.⁹¹ Post-SB 181, operators can no longer assume they are entitled to drill if their proposals are found to be insufficiently protective of public health and safety.⁹² Like other types of land use decisions, however, local governments should analyze whether an oil and gas regulation could lead to a mineral rights takings claim. SB 181 does not relieve local governments of that responsibility,⁹³ but it does reduce the legal exposure, as discussed below.

While industry and mineral rights advocacy groups commonly threaten takings claims, such threats are usually scare tactics intended to intimidate the local government. Even prior to SB 181, such cases were rarely filed. The plaintiff in *Longmont*⁹⁴ (the Longmont fracking ban case) filed a takings claim but later agreed to dismiss that claim due to a lack of standing, proceeding instead solely on its state preemption theory.⁹⁵ We are not aware of any other takings claims filed in Colorado related to oil and gas regulation. Notably, even after New York instituted a statewide fracking ban in 2014, news reports state that almost no takings claims were filed there and none were successful.⁹⁶

Federal and Colorado takings law is notoriously complex and inconsistent, with few if any published opinions at this point analyzing alleged takings in the context of hydraulic fracturing regulations.⁹⁷ The United States Supreme Court *Penn Central* (1978) case outlined elements courts should balance in regulatory takings cases.⁹⁸ Its nonexclusive list of factors to consider include: (1) the economic impact of the regulation; (2) the extent to which the

⁹¹ Prior to SB 181's passage, local jurisdictions sometimes entered into contractual operator agreements with oil and gas companies to secure commitments to best management practices beyond what state law required in exchange for various concessions from the local governments. SB 181's passage renders this workaround unnecessary. Because they now have clear statutory authority to require protections stronger than state standards, local governments no longer need to seek agreement from operators for such protections. Moreover, operator agreements limit local governments' ability to update standards over time and adapt to changing circumstances. Such agreements can potentially lock in approval and operating procedures of oil and gas sites that a local government may later realize is not conducive to public health and safety.

⁹²*Cf. City of Colorado Springs v. Bd. of Cty. Comm'rs of Cty. of Eagle*, 895 P.2d 1105, 1110 (Colo. App. 1994) (affirming Eagle County's denial of a special use permit where the city applicants failed to comply with certain mandatory regulatory criteria, and rejecting facial challenges to the regulations).

⁹³ Colo. Rev. Stat. § 29-20-104(1)(i) (authorizing local governments to regulate land use "so as to provide planned and orderly use of land and protection of the environment in a manner consistent with constitutional rights") (emphasis added).

⁹⁴ 369 P.3d 586.

⁹⁵ *Colo. Oil and Gas Ass'n v. City of Longmont*, Case No. 2013cv63 (Boulder Cty. D. Ct. 2013).

⁹⁶ The authors are aware of only one takings lawsuit filed in New York after its fracking ban. It was ultimately unsuccessful in state and federal courts. See, e.g., Jon Campbell, *Expected Lawsuits Don't Follow NY Fracking Ban*, Lohud, Apr. 20, 2017, <https://www.lohud.com/story/news/politics/politics-on-the-hudson/2017/04/20/ny-bans-fracking-but-lawsuits-dont-follow/100706352/>. In adopting its ban, New York relied on an extensive report from its Department of Health analyzing the risks of fracking. N.Y. State Dept. of Public Health, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development*, Dec. 2014, https://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf.

⁹⁷ Kevin Lynch, *Regulation of Fracking Is Not a Taking of Private Property*, 84 U. Cin. L. Rev. 38, 53 (2016).

⁹⁸ *Penn Cent. Transp. Co. v. City of New York*, 438 U.S. 104 (1978).

regulation interfered with distinct investment-backed expectations; and (3) the character of the government action.⁹⁹ The *Palazzolo v. Rhode Island* (2001) case reaffirmed the requirement for courts to apply at least each of the three specifically enumerated *Penn Central* factors when deciding whether a regulatory taking occurred.¹⁰⁰

Other federal cases further developed the *Penn Central* analysis for each factor. The economic impact factor focuses on the diminution of the owner's "parcel as a whole"—meaning subsurface, surface, air, and other property rights in the proverbial bundle of rights making up the property value—as well as, at times, negative effects the proposed use of property has upon public lands and adjacent private properties.¹⁰¹ The second element, investment-backed expectations, involves (among other queries) an examination of the reasonableness of the property owner's assumptions and knowledge when acquiring the property that regulations could potentially limit its use.¹⁰² The third factor, character of government action, focuses on whether the regulation or decision was designed to protect public health and safety. Intentionally avoiding public harm weighs in favor of the regulation even in the instance of a total taking.¹⁰³

Under state law, the Colorado Supreme Court published its seminal *Animas Valley* opinion shortly after the *Palazzolo* decision. *Animas Valley* first clarified that federal case law was relevant when analyzing claims under Colorado's takings clause.¹⁰⁴ It then incorporated *Palazzolo* and other federal cases examining the outer limits of allowable economic diminution of value. Those cases allowed between a 75% and 93% diminution of property value without implicating the takings clause.¹⁰⁵ As stated in the *Animas Valley* opinion:

[T]he Court's current formulation of the fact-specific inquiry seems to contemplate a situation in which the property in question retains more than a de minimis value but, when its diminished economic value is considered in connection with other factors, the property effectively has been taken from its owner. It provides a safety valve to protect the landowner in the *truly unusual case*.¹⁰⁶

Thus, when alleging a regulatory taking, a plaintiff generally must prove a government decision eliminated most of a property's value and such a reduction was not justified by other factors like investor expectations, the nature of the government action, or any other relevant reason. A government action justified by appropriate public and safety findings provides considerable protection against a takings claim.

⁹⁹ *Id.* at 124.

¹⁰⁰ *Palazzolo v. Rhode Island*, 533 U.S. 606, 616 (2001).

¹⁰¹ *Lynch, Regulation of Fracking Is Not a Taking*, at 56 (citing *Lucas v. South Carolina Coastal Council*, 505 U.S. 1003 (1992)).

¹⁰² *Id.* at 56–57.

¹⁰³ *Id.* at 57–58.

¹⁰⁴ *Animas Valley Sand & Gravel, Inc. v. Bd. of County Commr's*, 38 P.3d 59, 65–66 (Colo. 2001) (interpreting Colo. Const. art. II, § 15).

¹⁰⁵ *Id.* at 65–66.

¹⁰⁶ *Id.* at 66 (emphasis added).

Changes made to the Act by SB 181 further strengthen local governments' defenses against takings claims. First, SB 181 expressly elevates the importance of public health, safety, and welfare relative to other considerations, including the state's interest in developing minerals.¹⁰⁷ Second, SB 181 changed the definition of resource "waste" to clarify that it "does not include the nonproduction of oil or gas from a formation if necessary to protect public health, safety, and welfare, the environment, or wildlife resources."¹⁰⁸ Therefore, if a government entity denies a permit because a proposed location is inconsistent with protecting public health and the environment, temporarily preventing an operator from accessing its mineral rights, it should not constitute "waste."

In addition to the *Penn Central* factors, the U.S. Supreme Court has adopted a second takings test that may apply in certain cases. The court has held that where government regulation deprives property of "all economically viable use" it can be a per se taking, without requiring a balancing of the *Penn Central* factors.¹⁰⁹

In cases where an oil and gas company holds only a mineral interest, it may argue that local regulations preventing it from developing those minerals amount to a per se taking.¹¹⁰ However, a government decision limiting or prohibiting hydraulic fracturing in a particular geographic area does not mean those minerals are deprived of all economically viable use. They remain in the ground, to be possibly extracted in the future with different technology or using different health safeguards. Many minerals presently coveted were unobtainable and worthless as few as ten years ago. Changes in technology could lead to future extraction consistent with public health and safety. In light of the *Animas Valley* standard and its incorporated federal precedents allowing up to a 93% diminution of property value, "[i]t is not difficult to imagine that someone might be willing to purchase mineral rights at 7% of their value in order to have the option of producing if the law changes to allow fracking, or the technology allows production without fracking."¹¹¹

Additionally, local governments could insulate their regulations against facial takings challenges by providing for variances where a company has a meritorious takings argument. A variance provision should force companies to bring takings challenges on a permit-specific basis, which is much more difficult than a facial challenge to the regulation itself.

In summary, SB 181 made a difficult takings claim even more challenging for a plaintiff. Specific findings, reliance upon health and safety studies, and the inclusion of a variance provision can all help protect against takings claims just as with other types of challenges to local decisions.

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¹⁰⁷ Colo. Rev. Stat. § 29-20-104(1)(h).

¹⁰⁸ *Id.* § 34-60-103(11)(b), 12(b), 13(b).

¹⁰⁹ *Lucas*, 505 U.S. at 1019; *see also*, *Palazzolo*, 533 U.S. at 630–32.

¹¹⁰ *See Lynch, Regulation of Fracking Is Not a Taking*, at 58–67.

¹¹¹ *Id.* at 86 n.257.

Appendix A

* Full citations for the studies below may be found within the compendium of oil and gas-related health studies curated by Concerned Health Professionals of New York & Physicians for Social Responsibility: *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (6th ed., 2019), available at <http://concernedhealthny.org/compendium/>.

Lead Author	Year	Distance	State	Effect at Distance
Distance-based studies				
McMullin	2018	500 feet (152 meters)	CO	Found hazard index of greater than 1 for combined VOCs; less than 1 for VOCs individually; and cancer rates above EPA threshold.
McKenzie	2018	500 feet (152 meters)	CO	Higher rates of neurological, hematological, and development health effects. Elevated cancer risk 8.3 times above EPA upper threshold.
Macey	2014	885 feet	AR, CO, OH, PA, WY	Elevated benzene concentrations.
Lewis	2018	1320 feet (1/4 mile)	n/a	Expert consensus (Delphi study) that 1/4 mile is insufficient, but no consensus on setbacks between 1/4 and 2 miles.
Thompson	2014	1391 feet (424 meters)	CO	Elevated volatile organic compound concentrations, including benzene levels that exceeded EPA's cancer risk threshold.
Haley	2016	1500 feet	TX, PA, CO	Concluded that catastrophic events, thermal modeling, vapor cloud modeling, and air pollution data indicate that 1500 feet "do[es] not appear sufficient to protect public health and safety."
Los Angeles Department of Public Health	2018	1500 feet	CA	Based on literature review, concludes that 1500 foot setback is necessary to address air pollution, odor, and noise impacts.
Steinzor	2013	1500 feet	PA	Statistically significant increase in reporting symptoms (headaches, etc.).
University of Maryland	2014	2000 feet	MD	Based on review of several studies.
McKenzie	2018	2000 feet (610 meters)	CO	Lifetime excess cumulative cancer risk above EPA threshold.
Macey	2014	2591 feet	AR, CO, OH, PA, WY	Elevated benzene concentrations.
McKenzie	2012	2640 feet (1/2 mile)	CO	Hazard Index: sub-chronic non-cancer of 5; chronic hazard index of 1; cumulative cancer risk = 10/1 million. All at or above EPA thresholds.
Whitworth	2017	2640 feet (1/2 mile)	TX	Higher risk of pre-term birth.

Curry	2017	3280 feet (1 km)	PA	Strongest Evidence of negative health effects, including greater incidence of low-birth weight and significant declines in average birth weight.
Rabinowitz	2015	3280 feet (1 km)	PA	Statistically significant increase in reporting of dermal and respiratory symptoms.
Colborn	2014	3696 feet (0.7 miles)	CO	Measured endocrine-disrupting chemicals in air sampling.
Haley	2016	4224 feet (0.8) miles	TX, PA, CO	Average evacuation zone in safety incidents studied.
Kassotis	2014	5280 feet (1 mile)	CO	Found endocrine disrupting chemicals associated with oil and gas development in surface and groundwater samples.
Curry	2017	9842 feet (3 km)	PA	Some evidence of negative health impacts due to in-utero exposure; no evidence beyond this distance.
Well Density Studies				
Casey	2016		PA	Mothers who lived in the highest exposure quartile (124 wells within 20 km) were 1.4 times more likely to give birth to low-birth-weight children and smaller than gestational age children; compared to lower quartile (8 wells within 20 km). (Inverse Density Weighting (IDW) methodology).
Casey	2019		PA	Higher rates of prenatal anxiety & depression in women living in closer proximity.
McKenzie	2019		CO	Significantly higher rates of congenital heart defects in infants born to women who live in areas with more than 403 wells in a 10-mile radius (IDW methodology).
McKenzie	2017		CO	Higher rates of childhood blood cancers (acute lymphocytic leukemia) based on proximity to oil and gas wells (IDW methodology; uses 16.1 km radius).
McKenzie	2014		CO	Positive association between gas wells within 10 miles of maternal residence (IDW approach), and prevalence of congenital heart defects and neural tube defects in infants.
Janitz	2019		OK	Higher risk of neural tube defects for babies born in closer proximity to natural gas wells. IDW approach.
Rasmussen	2016		PA	Elevated asthma exacerbation (hospitalizations, severity of attacks) due to proximity.

Stacy	2015		PA	Lower birth weight and higher incidence of small for gestational age among babies born to women in areas with greater well density (IDW method).
<u>Studies Finding Elevated Hydrocarbon Levels on the Colorado Front Range Due to Oil and Gas Development</u>				
Oltmans	2019		CO	Wind trajectories show that volatile organic compounds emitted by oil and gas play a "crucial role" in causing the highest ozone levels in Colorado.
Bien	2018		CO	Discussed complicating factor of oil and gas emissions in addressing ozone formation in Colorado front range.
Evans	2017		CO	Finding that 65% of ozone formation on Colorado's Northern Front Range's worst ozone days is due to pollutants transported from oil and gas producing areas, while only 9% is due to transport from the Denver urban corridor.
Kaser	2017		CO	Finding that oil and gas activities were partially responsible for air quality models underestimating ozone formation in the Colorado Front Range.
McDuffie	2016		CO	Finding that oil and gas emissions contribute to approximately 50% of regional VOCs and 20% of regional ozone formation in the Colorado Front Range.
Petron	2014		CO	Finding that oil and gas emissions of benzene and other pollutants was seven times higher than estimated in the Colorado state emissions inventory.
Swarthout	2013		CO	Performing source signature analysis and determining that a high percentage of ozone-forming VOCs at an atmospheric measurement station in the Colorado Northern Front Range originated from the oil and gas sector.
Gilman	2013		CO	Performing source signature analysis Finding that 55% of ozone-forming VOCs measured in the Colorado Northern Front Range were attributable to the oil and gas sector.
Petron	2012		CO	Measuring oil and gas emissions in Colorado's Northern Front Range and concluding that due to oil and gas sector emissions, state emissions inventory may be too low by a factor of two.

Unprecedented 21st century drought risk in the American Southwest and Central Plains

Benjamin I. Cook,^{1,2*} Toby R. Ault,³ Jason E. Smerdon²

In the Southwest and Central Plains of Western North America, climate change is expected to increase drought severity in the coming decades. These regions nevertheless experienced extended Medieval-era droughts that were more persistent than any historical event, providing crucial targets in the paleoclimate record for benchmarking the severity of future drought risks. We use an empirical drought reconstruction and three soil moisture metrics from 17 state-of-the-art general circulation models to show that these models project significantly drier conditions in the later half of the 21st century compared to the 20th century and earlier paleoclimatic intervals. This desiccation is consistent across most of the models and moisture balance variables, indicating a coherent and robust drying response to warming despite the diversity of models and metrics analyzed. Notably, future drought risk will likely exceed even the driest centuries of the Medieval Climate Anomaly (1100–1300 CE) in both moderate (RCP 4.5) and high (RCP 8.5) future emissions scenarios, leading to unprecedented drought conditions during the last millennium.

INTRODUCTION

Millennial-length hydroclimate reconstructions over Western North America (1–4) feature notable periods of extensive and persistent Medieval-era droughts. Such “megadrought” events exceeded the duration of any drought observed during the historical record and had profound impacts on regional societies and ecosystems (2, 5, 6). These past droughts illustrate the relatively narrow view of hydroclimate variability captured by the observational record, even as recent extreme events (7–9) highlighted concerns that global warming may be contributing to contemporary droughts (10, 11) and will amplify drought severity in the future (11–15). A comprehensive understanding of global warming and 21st century drought therefore requires placing projected hydroclimate trends within the context of drought variability over much longer time scales (16, 17). This would also allow us to establish the potential risk (that is, likelihood of occurrence) of future conditions matching or exceeding the severest droughts of the last millennium.

Quantitatively comparing 21st century drought projections from general circulation models (GCMs) to the paleo-record is nevertheless a significant technical challenge. Most GCMs provide soil moisture diagnostics, but their land surface models often vary widely in terms of parameterizations and complexity (for example, soil layering and vegetation). There are few large-scale soil moisture measurements that can be easily compared to modeled soil moisture, and none for intervals longer than the satellite record. Instead, drought is typically monitored in the real world using offline models or indices that can be estimated from more widely measured data, such as temperature and precipitation.

One common metric is the Palmer Drought Severity Index (PDSI) (18), widely used for drought monitoring and as a target variable for proxy-based reconstructions (1, 2). PDSI is a locally normalized index of soil moisture availability, calculated from the balance of moisture supply (precipitation) and demand (evapotranspiration). Because PDSI is normalized on the basis of local average moisture conditions, it can be

used to compare variability and trends in drought across regions. Average moisture conditions (relative to a defined baseline) are denoted by $PDSI = 0$; negative PDSI values indicate drier than average conditions (droughts), and positive PDSI values indicate wetter than normal conditions (pluvials). PDSI is easily calculated from GCMs using variables from the atmosphere portion of the model (for example, precipitation, temperature, and humidity) and can be compared directly to observations. However, whereas recent work has demonstrated that PDSI is able to accurately reflect the surface moisture balance in GCMs (19), other studies have highlighted concerns that PDSI may overestimate 21st century drying because of its relatively simple soil moisture accounting and lack of direct CO₂ effects that are expected to reduce evaporative losses (12, 20, 21). We circumvent these concerns by using a more physically based version of PDSI (13) (based on the Penman-Monteith potential evapotranspiration formulation) in conjunction with soil moisture from the GCMs to demonstrate robust drought responses to climate change in the Central Plains (105°W–92°W, 32°N–46°N) and the Southwest (125°W–105°W, 32°N–41°N) regions of Western North America.

RESULTS

We calculate summer season [June–July–August (JJA)] PDSI and integrated soil moisture from the surface to ~30-cm (SM-30cm) and ~2- to 3-m (SM-2m) depths from 17 GCMs (tables S1 and S2) in phase 5 of the Coupled Model Intercomparison Project (CMIP5) database (22). We focus our analyses and presentation on the RCP 8.5 “business-as-usual” high emissions scenario, designed to yield an approximate top-of-atmosphere radiative imbalance of +8.5 W m⁻² by 2100. We also conduct the same analyses for a more moderate emissions scenario (RCP 4.5).

Over the calibration interval (1931–1990), the PDSI distributions from the models are statistically indistinguishable from the North American Drought Atlas (NADA) (two-sided Kolmogorov-Smirnov test, $p \geq 0.05$), although there are some significant deviations in some models during other historical intervals. North American drought variability during the historical period in both models and observations is driven primarily by ocean-atmosphere teleconnections,

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internal variability in the climate system that is likely to not be either consistent across models or congruent in time between the observations and models, and so such disagreements are unsurprising. In the multimodel mean, all three moisture balance metrics show markedly consistent drying during the later half of the 21st century (2050–2099) (Fig. 1; see figs. S1 to S4 for individual models). Drying in the Southwest is more severe (RCP 8.5: PDSI = -2.31 , SM-30cm = -2.08 , SM-2m = -2.98) than that over the Central Plains (RCP 8.5: PDSI = -1.89 , SM-30cm = -1.20 , SM-2m = -1.17). In both regions, the consistent cross-model drying trends are driven primarily by the forced response to increased greenhouse gas concentrations (13), rather than

by any fundamental shift in ocean-atmosphere dynamics [indeed, there is a wide disparity across models regarding the strength and fidelity of the simulated teleconnections over North America (23)]. In the Southwest, this forcing manifests as both a reduction in cold season precipitation (24) and an increase in potential evapotranspiration (that is, evaporative demand increases in a warmer atmosphere) (13, 25) acting in concert to reduce soil moisture. Even though cold season precipitation is actually expected to increase over parts of California in our Southwest region (24, 26), the increase in evaporative demand is still sufficient to drive a net reduction in soil moisture. Over the Central Plains, precipitation responses during the spring and summer seasons (the main

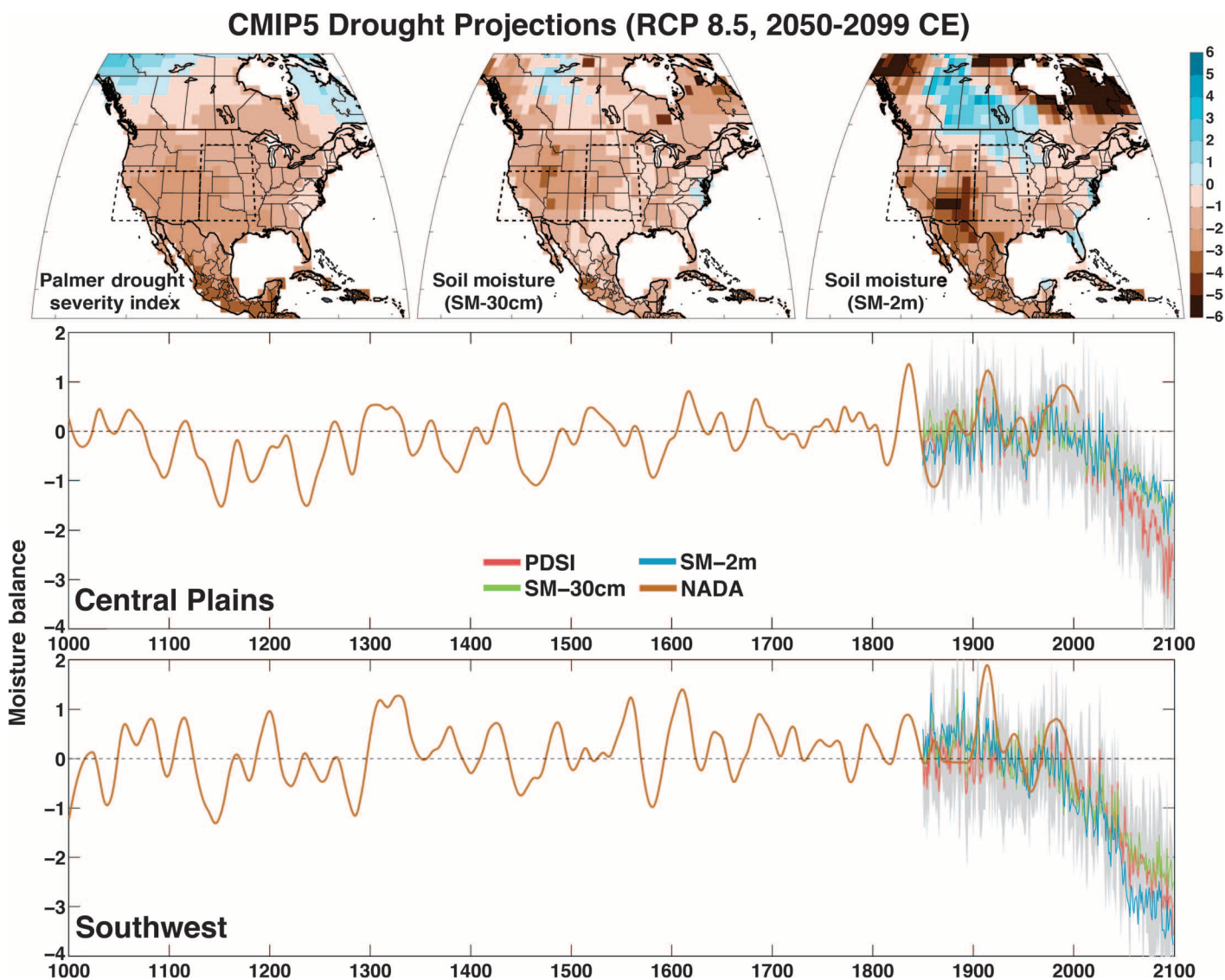


Fig. 1. Top: Multimodel mean summer (JJA) PDSI and standardized soil moisture (SM-30cm and SM-2m) over North America for 2050–2099 from 17 CMIP5 model projections using the RCP 8.5 emissions scenario. SM-30cm and SM-2m are standardized to the same mean and variance as the model PDSI over the calibration interval from the associated historical scenario (1931–1990). Dashed boxes represent the regions of interest: the Central Plains (105°W–92°W, 32°N–46°N) and the Southwest

(125°W–105°W, 32°N–41°N). Bottom: Regional average time series of the summer season moisture balance metrics from the NADA and CMIP5 models. The observational NADA PDSI series (brown) is smoothed using a 50-year loess spline to emphasize the low-frequency variability in the paleo-record. Model time series (PDSI, SM-30cm, and SM-2m) are the multimodel means averaged across the 17 CMIP5 models, and the gray shaded area is the multimodel interquartile range for model PDSI.

seasons of moisture supply) are less consistent across models, and the drying is driven primarily by the increased evaporative demand. Indeed, this increase in potential evapotranspiration is one of the dominant drivers of global drought trends in the late 21st century, and previous work with the CMIP5 archive demonstrated that the increased evaporative demand is likely to be sufficient to overcome precipitation increases in many regions (13). In the more moderate emissions scenario (RCP 4.5), both the Southwest (RCP 4.5: PDSI = -1.49 , SM-30cm = -1.63 , SM-2m = -2.39) and Central Plains (RCP 4.5: PDSI = -1.21 , SM-30cm = -0.89 , SM-2m = -1.17) still experience significant, although more modest, drying into the future, as expected (fig. S5).

In both regions, the model-derived PDSI closely tracks the two soil moisture metrics (figs. S6 and S7), correlating significantly for most models and model intervals (figs. S8 and S9). Over the historical simulation, average model correlations (Pearson's r) between PDSI and SM-30cm are $+0.86$ and $+0.85$ for the Central Plains and Southwest, respectively. Correlations weaken very slightly for PDSI and SM-2m: $+0.84$ (Central Plains) and $+0.83$ (Southwest). The correlations

remain strong into the 21st century, even as PDSI and the soil moisture variables occasionally diverge in terms of long-term trends. There is no evidence, however, for systematic differences between the PDSI and modeled soil moisture across the model ensemble. For example, whereas the PDSI trends are drier than the soil moisture condition over the Southwest in the ACCESS1-0 model, PDSI is actually less dry than the soil moisture in the MIROC-ESM and NorESM1-M simulations over the same region (fig. S7). These outlier observations, showing no consistent bias, in conjunction with the fact that the overall comparison between PDSI and modeled soil moisture is markedly consistent, provide mutually consistent support for the characterization of surface moisture balance by these metrics in the model projections.

For estimates of observed drought variability over the last millennium (1000–2005), we use data from the NADA, a tree-ring based reconstruction of JJA PDSI. Comparisons between the NADA and model moisture are shown in the bottom panels of Fig. 1. In the NADA, both the Central Plains (Fig. 2) and Southwest (Fig. 3) are drier during the Medieval megadrought interval (1100–1300 CE) than either the Little

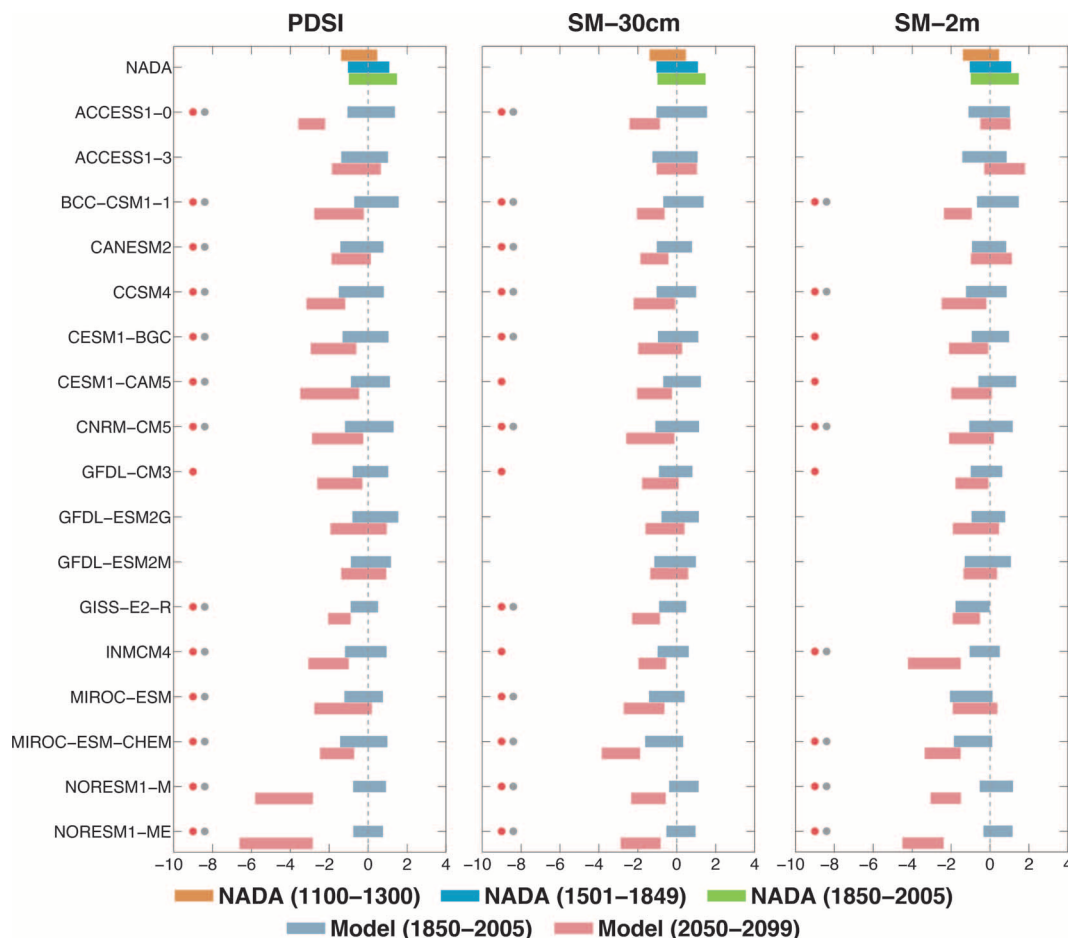


Fig. 2. Interquartile range of PDSI and soil moisture from the NADA and CMIP5 GCMs, calculated over various time intervals for the Central Plains. The groups of three stacked bars at the top of each column are from the NADA PDSI: 1100–1300 (the time of the Medieval-era megadroughts, brown), 1501–1849 (the Little Ice Age, blue), and 1850–2005 (the historical period, green). Purple and red bars are for

the modeled historical period (1850–2005) and late 21st century (2050–2099) period, respectively. Red dots indicate model 21st century drought projections that are significantly drier than the model simulated historical periods. Gray dots indicate model 21st century drought projections that are significantly drier than the Medieval-era megadrought period in the NADA.

Ice Age (1501–1849) or historical periods (1850–2005). For nearly all models, the 21st century projections under the RCP 8.5 scenario reveal dramatic shifts toward drier conditions. Most models (indicated with a red dot) are significantly drier (one-sided Kolmogorov-Smirnov test, $p \leq 0.05$) in the latter part of the 21st century (2050–2099) than during their modeled historical intervals (1850–2005). Strikingly, shifts in projected drying are similarly significant in most models when measured against the driest and most extreme megadrought period of the NADA from 1100 to 1300 CE (gray dots). Results are similar for the more moderate RCP 4.5 emissions scenario (figs. S10 and S11), which still indicates widespread drying, albeit at a reduced magnitude for many models. Although there is some spread across the models and metrics, only two models project wetter conditions in RCP 8.5. In the Central Plains, SM-2m is wetter in ACCESS1-3, with little change in SM-30cm and slightly wetter conditions in PDSI. In the Southwest, CanESM2 projects markedly wetter SM-2m conditions; PDSI in the same model is slightly wetter, whereas SM-30cm is significantly drier.

When the RCP 8.5 multimodel ensemble is pooled together (Fig. 4), projected changes in the Central Plains and Southwest (2050–2099 CE) for all three moisture balance metrics are significantly drier compared to both the modern model interval (1850–2005 CE) and 1100–1300 CE in the NADA (one-sided Kolmogorov-Smirnov test, $p \leq 0.05$). In the case of SM-2m in the Southwest, the density function is somewhat

flattened, with an elongated right (wet) tail. This distortion arises from the disproportionate contribution to the density function from the wetting in the five CanESM2 ensemble members. Even with this contribution, however, the SM-2m drying in the multimodel ensemble is still significant. Results are nearly identical for the pooled RCP 4.5 multimodel ensemble (fig. S12), which still indicates a significantly drier late 21st century compared to either the historical interval or Medieval megadrought period.

With this shift in the full hydroclimate distribution, the risk of decadal or multidecadal drought occurrences increases substantially. We calculated the risk (17) of decadal or multidecadal drought occurrences for two periods in our multimodel ensemble: 1950–2000 and 2050–2099 (Fig. 5). During the historical period, the risk of a multidecadal megadrought is quite small: <12% for both regions and all moisture metrics. Under RCP 8.5, however, there is $\geq 80\%$ chance of a multidecadal drought during 2050–2099 for PDSI and SM-30cm in the Central Plains and for all three moisture metrics in the Southwest. Drought risk is reduced slightly in RCP 4.5 (fig. S13), with largest reductions in multidecadal drought risk over the Central Plains. Ultimately, the consistency of our results suggests an exceptionally high risk of a multidecadal megadrought occurring over the Central Plains and Southwest regions during the late 21st century, a level of aridity exceeding even the persistent megadroughts that characterized the Medieval era.

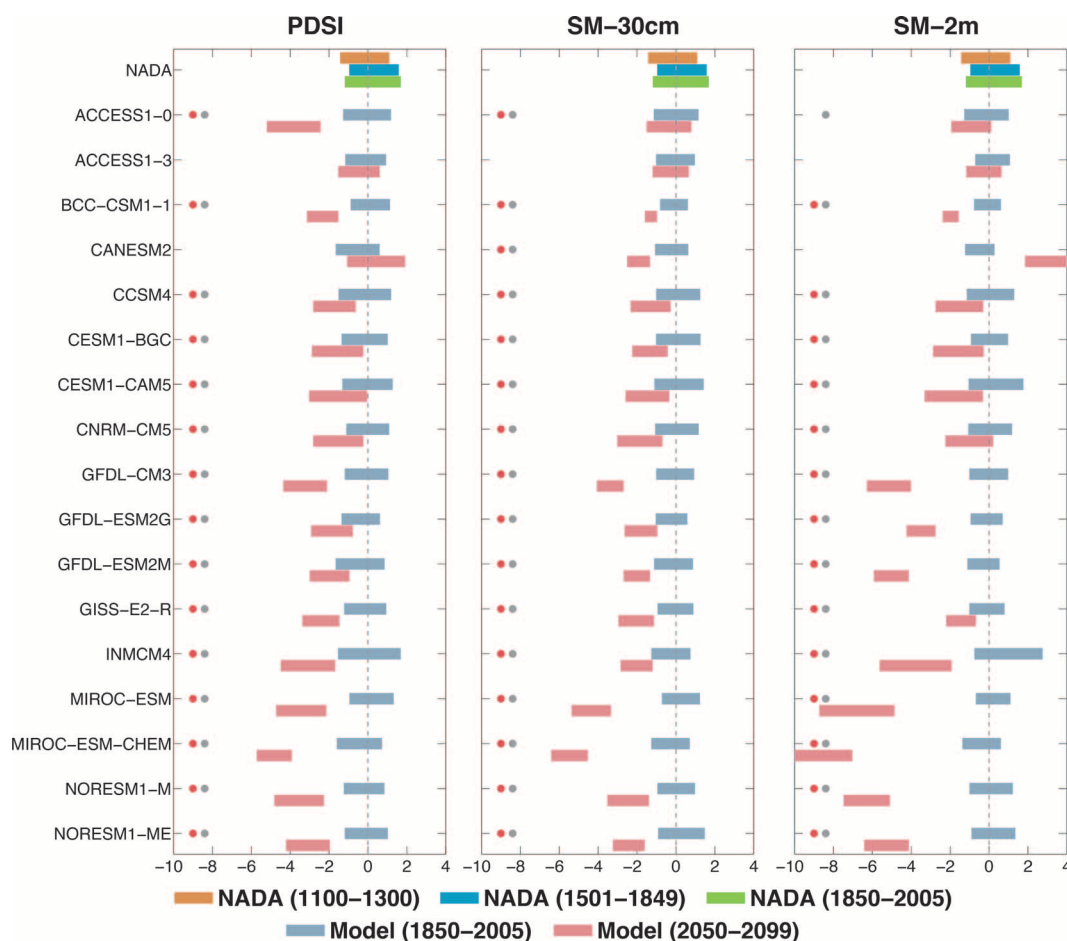


Fig. 3. Same as Fig. 2, but for the Southwest.

DISCUSSION

Within the body of literature investigating North American hydroclimate, analyses of drought variability in the historical and paleoclimate

records are often separate from discussions of global warming-induced changes in future hydroclimate. This disconnection has traditionally made it difficult to place future drought projections within the context of observed and reconstructed natural hydroclimate variability. Here,

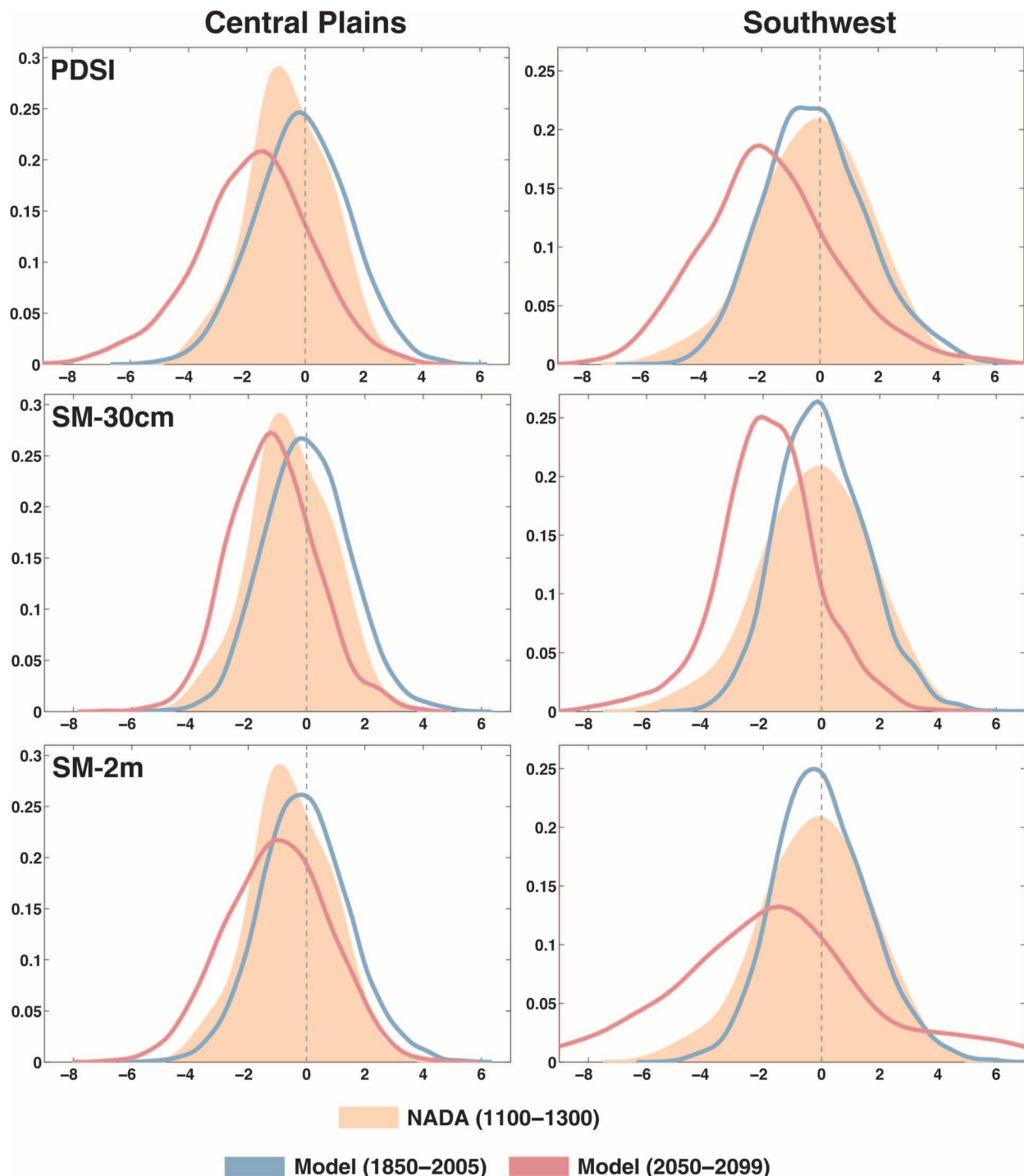


Fig. 4. Kernel density functions of PDSI, SM-30cm, and SM-2m for the Central Plains and Southwest, calculated from the NADA and the GCMs. The NADA distribution (brown shading) is from 1100–1300 CE, the timing of the medieval megadroughts. Blue

lines represent model distributions calculated from all years from all models pooled over the historical scenario (1850–2005 CE). Red lines are for all model years pooled from the RCP 8.5 scenario (2050–2099 CE).

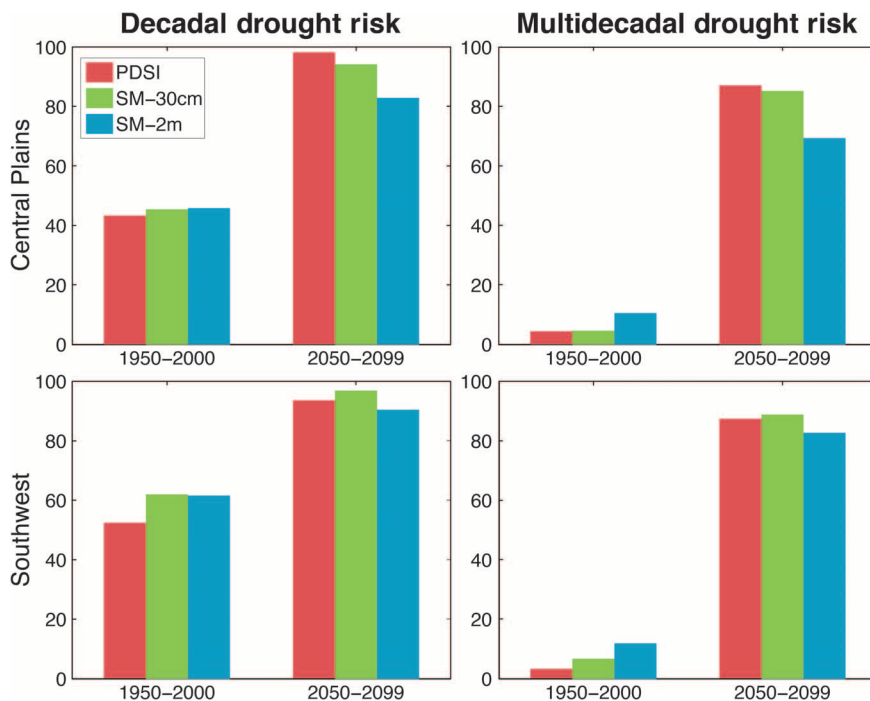


Fig. 5. Risk (percent chance of occurrence) of decadal (11-year) and multidecadal (35-year) drought, calculated from the multimodel ensemble for PDSI, SM-30cm, and SM-2m. Risk calculations are conducted for two separate model intervals: 1950–2000 (historical scenario) and 2050–2099 (RCP 8.5). Results for the Central Plains are in the top row, and those for the Southwest are in the bottom row.

we have demonstrated that the mean state of drought in the late 21st century over the Central Plains and Southwest will likely exceed even the most severe megadrought periods of the Medieval era in both high and moderate future emissions scenarios, representing an unprecedented fundamental climate shift with respect to the last millennium. Notably, the drying in our assessment is robust across models and moisture balance metrics. Our analysis thus contrasts sharply with the recent emphasis on uncertainty about drought projections for these regions (21, 27), including the most recent Intergovernmental Panel on Climate Change assessment report (28).

Our results point to a remarkably drier future that falls far outside the contemporary experience of natural and human systems in Western North America, conditions that may present a substantial challenge to adaptation. Human populations in this region, and their associated water resources demands, have been increasing rapidly in recent decades, and these trends are expected to continue for years to come (29). Future droughts will occur in a significantly warmer world with higher temperatures than recent historical events, conditions that are likely to be a major added stress on both natural ecosystems (30) and agriculture (31). And, perhaps most importantly for adaptation, recent years have witnessed the widespread depletion of nonrenewable groundwater reservoirs (32, 33), resources that have allowed people to mitigate the impacts of naturally occurring droughts. In some cases, these losses have even exceeded the capacity of Lake Mead and Lake Powell, the two major surface reservoirs in the region (34, 35). Combined with the likelihood of a much drier future and increased demand, the loss of groundwater and higher temperatures will likely exacerbate the impacts of future droughts, presenting a major adaptation challenge for managing ecological and anthropogenic water needs in the region.

MATERIALS AND METHODS

Estimates of drought variability over the historical period and the last millennium used the latest version of the NADA (1), a tree ring-based reconstruction of summer season (JJA) PDSI. All statistics were based on regional PDSI averages over the Central Plains (105°W–92°W, 32°N–46°N) and the Southwest (125°W–105°W, 32°N–41°N). We restricted our analysis to 1000–2005 CE; before 1000 CE, the quality of the reconstruction in these regions declines.

The 21st century drought projections used output from GCM simulations in the CMIP5 database (22) (table S1). All models represent one or more continuous ensemble members from the historical (1850–2005 CE) and RCP 4.5 (15 models available) and 8.5 (17 models available) emissions scenarios (2006–2099 CE). We used the same methodology as in (13) to calculate model PDSI for the full interval (1850–2099 CE), using the Penman-Monteith formulation of potential evapotranspiration. The baseline period for calibrating and standardizing the model PDSI anomalies was 1931–1990 CE, the same baseline period as the NADA PDSI. Negative model PDSI values therefore indicate drier conditions than the average for 1931–1990.

To augment the model PDSI calculations and comparisons with observed drought variability in the NADA, we also calculated standardized soil moisture metrics from the GCMs for two depths: ~30 cm (SM-30cm) and ~2 to 3 m (SM-2m) (table S2).

For these soil moisture metrics, the total soil moisture from the surface was integrated to these depths and averaged over JJA. At each grid cell, we then standardized SM-30cm and SM-2m to match the same mean and inter-annual SD for the model PDSI over 1931–1990. This allows for direct comparison of variability and trends between model PDSI and model soil moisture and between the model metrics (PDSI, SM-30cm, and SM-2m) and the NADA (PDSI) while still independently preserving any low-frequency variability or trends in the soil moisture that may be distinct from the PDSI calculation. The soil moisture standardization does not impose any artificial constraints that would force the three metrics to agree in terms of variability or future trends, allowing SM-30cm and SM-2m to be used as indicators of drought largely independent of PDSI.

Risk of decadal and multidecadal megadrought occurrence in the multimodel ensemble is estimated from 1000 Monte Carlo realizations of each moisture balance metric (PDSI, SM-30cm, and SM-2m), as in (17). This method entails estimating the mean and SD of a given drought index (for example, PDSI or soil moisture) over a reference period (1901–2000), then subtracting that mean and SD from the full record (1850–2100) to produce a modified *z* score. The differences between the reference mean and SD are then used to conduct (white noise) Monte Carlo simulations of the future (2050–2100) to emulate the statistics of that era. The fraction of Monte Carlo realizations exhibiting a decadal or multidecadal drought are then calculated from each Monte Carlo simulation of each experiment in both regions considered here. Finally, these risks from each model are averaged together to yield the overall risk estimates reported here. Additional details on the methodology can be found in (17).

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at <http://advances.sciencemag.org>

Fig. S1. For the individual models, ensemble mean soil moisture balance (PDSI, SM-30cm, and SM-2m) for 2050–2099: ACCESS1.0, ACCESS1.3, BCC-CSM1.1, and CanESM2.

Fig. S2. Same as fig. S1, but for CCSM4, CESM1-BGC, CESM-CAM5, and CNRM-CM5.

Fig. S3. Same as fig. S1, but for GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, and GISS-E2-R.

Fig. S4. Same as fig. S1, but for INMCM4.0, MIROC-ESM, MIROC-ESM-CHEM, NorESM1-M, and NorESM1-ME models.

Fig. S5. Same as Fig. 1, but for the RCP 4.5 scenario.

Fig. S6. Regional average moisture balance time series (historical + RCP 8.5) from the first ensemble member of each model over the Central Plains.

Fig. S7. Same as fig. S6, but for the Southwest.

Fig. S8. Pearson's correlation coefficients for three time intervals from the models over the Central Plains: PDSI versus SM-30cm, PDSI versus SM-2m, and SM-30cm versus SM-2m.

Fig. S9. Same as fig. S8, but for the Southwest.

Fig. S10. Same as Fig. 2, but for the RCP 4.5 scenario.

Fig. S11. Same as Fig. 3, but for the RCP 4.5 scenario.

Fig. S12. Same as Fig. 4, but for the RCP 4.5 scenario.

Fig. S13. Same as Fig. 5, but for the RCP 4.5 scenario.

Table S1. Continuous model ensembles from the CMIP5 experiments (1850–2099, historical + RCP8.5 scenario) used in this analysis, including the modeling center or group that supplied the output, the number of ensemble members, and the approximate spatial resolution.

Table S2. The number of soil layers integrated for our CMIP5 soil moisture metrics (SM-30cm and SM-2m), and the approximate depth of the bottom soil layer.

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Unprecedented 21st century drought risk in the American Southwest and Central Plains

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Appendix A



* Full citations for the studies below may be found within the compendium of oil and gas-related health studies curated by Concerned Health Professionals of New York & Physicians for Social Responsibility: *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (6th ed., 2019), available at <http://concernedhealthny.org/compendium/>.

Lead Author	Year	Distance	State	Effect at Distance
Distance-based studies				
McMullin	2018	500 feet (152 meters)	CO	Found hazard index of greater than 1 for combined VOCs; less than 1 for VOCs individually; and cancer rates above EPA threshold.
McKenzie	2018	500 feet (152 meters)	CO	Higher rates of neurological, hematological, and development health effects. Elevated cancer risk 8.3 times above EPA upper threshold.
Macey	2014	885 feet	AR, CO, OH, PA, WY	Elevated benzene concentrations.
Lewis	2018	1320 feet (1/4 mile)	n/a	Expert consensus (Delphi study) that 1/4 mile is insufficient, but no consensus on setbacks between 1/4 and 2 miles.
Thompson	2014	1391 feet (424 meters)	CO	Elevated volatile organic compound concentrations, including benzene levels that exceeded EPA's cancer risk threshold.
Haley	2016	1500 feet	TX, PA, CO	Concluded that catastrophic events, thermal modeling, vapor cloud modeling, and air pollution data indicate that 1500 feet "do[es] not appear sufficient to protect public health and safety."
Los Angeles Department of Public Health	2018	1500 feet	CA	Based on literature review, concludes that 1500 foot setback is necessary to address air pollution, odor, and noise impacts.
Steinzor	2013	1500 feet	PA	Statistically significant increase in reporting symptoms (headaches, etc.).
University of Maryland	2014	2000 feet	MD	Based on review of several studies.
McKenzie	2018	2000 feet (610 meters)	CO	Lifetime excess cumulative cancer risk above EPA threshold.
Macey	2014	2591 feet	AR, CO, OH, PA, WY	Elevated benzene concentrations.

McKenzie	2012	2640 feet (1/2 mile)	CO	Hazard Index: sub-chronic non-cancer of 5; chronic hazard index of 1; cumulative cancer risk = 10/1 million. All at or above EPA thresholds.
Whitworth	2017	2640 feet (1/2 mile)	TX	Higher risk of pre-term birth.
Curry	2017	3280 feet (1 km)	PA	Strongest Evidence of negative health effects, including greater incidence of low-birth weight and significant declines in average birth weight.
Rabinowitz	2015	3280 feet (1 km)	PA	Statistically significant increase in reporting of dermal and respiratory symptoms.
Colborn	2014	3696 feet (0.7 miles)	CO	Measured endocrine-disrupting chemicals in air sampling.
Haley	2016	4224 feet (0.8) miles	TX, PA, CO	Average evacuation zone in safety incidents studied.
Kassotis	2014	5280 feet (1 mile)	CO	Found endocrine disrupting chemicals associated with oil and gas development in surface and groundwater samples.
Curry	2017	9842 feet (3 km)	PA	Some evidence of negative health impacts due to in-utero exposure; no evidence beyond this distance.
<u>Well Density Studies</u>				
Casey	2016		PA	Mothers who lived in the highest exposure quartile (124 wells within 20 km) were 1.4 times more likely to give birth to low-birth-weight children and smaller than gestational age children; compared to lower quartile (8 wells within 20 km). (Inverse Density Weighting (IDW) methodology).
Casey	2019		PA	Higher rates of prenatal anxiety & depression in women living in closer proximity.
McKenzie	2019		CO	Significantly higher rates of congenital heart defects in infants born to women who live in areas with more than 403 wells in a 10-mile radius (IDW methodology).
McKenzie	2017		CO	Higher rates of childhood blood cancers (acute lymphocytic leukemia) based on proximity to oil and gas wells (IDW methodology; uses 16.1 km radius).
McKenzie	2014		CO	Positive association between gas wells within 10 miles of maternal residence (IDW approach), and prevalence of congenital heart defects and neural tube defects in infants.

Janitz	2019		OK	Higher risk of neural tube defects for babies born in closer proximity to natural gas wells. IDW approach.
Rasmussen	2016		PA	Elevated asthma exacerbation (hospitalizations, severity of attacks) due to proximity.
Stacy	2015		PA	Lower birth weight and higher incidence of small for gestational age among babies born to women in areas with greater well density (IDW method).
<u>Studies Finding Elevated Hydrocarbon Levels on the Colorado Front Range Due to Oil and Gas Development</u>				
Oltmans	2019		CO	Wind trajectories show that volatile organic compounds emitted by oil and gas play a "crucial role" in causing the highest ozone levels in Colorado.
Bien	2018		CO	Discussed complicating factor of oil and gas emissions in addressing ozone formation in Colorado front range.
Evans	2017		CO	Finding that 65% of ozone formation on Colorado's Northern Front Range's worst ozone days is due to pollutants transported from oil and gas producing areas, while only 9% is due to transport from the Denver urban corridor.
Kaser	2017		CO	Finding that oil and gas activities were partially responsible for air quality models underestimating ozone formation in the Colorado Front Range.
McDuffie	2016		CO	Finding that oil and gas emissions contribute to approximately 50% of regional VOCs and 20% of regional ozone formation in the Colorado Front Range.
Petron	2014		CO	Finding that oil and gas emissions of benzene and other pollutants was seven times higher than estimated in the Colorado state emissions inventory.
Swarthout	2013		CO	Performing source signature analysis and determining that a high percentage of ozone-forming VOCs at an atmospheric measurement station in the Colorado Northern Front Range originated from the oil and gas sector.

Gilman	2013		CO	Performing source signature analysis Finding that 55% of ozone-forming VOCs measured in the Colorado Northern Front Range were attributable to the oil and gas sector.
Petron	2012		CO	Measuring oil and gas emissions in Colorado's Northern Front Range and concluding that due to oil and gas sector emissions, state emissions inventory may be too low by a factor of two.