Shell Exploration & Production

Shell Exploration & Production Company
3737 Bellaire Boulevard
Houston, Texas 77025, U.S.A.
P.O. Box 481
Houston, Texas 77001-0481, U.S.A.
Internet http://www.shell.com/ep

Mr Steve Shuey
Division of Reclamation, Mining and Safety
101 South 3rd, Ste 301
Grand Junction, CO 81501

December 29, 2010

NOI for Oil Shale RDD Lease COC 69166

Dear Mr Shuey;

Attached is Shell's Notice of Intent to Conduct Prospecting (NOI) on Oil Shale Research, Development and Demonstration (RDD) Lease COC 69166 and Nahcolite Preference Right Sodium Lease C-0120057. The NOI contains no confidential information.

A full copy of this NOI is being submitted to the BLM along with the BLM Plan of Development for this project. We also are submitting permit applications to the Rio Blanco County Development and Planning Department, and to the EPA Underground Injection Control Program.

The reclamation cost estimate covers all reclamation work associated with this project. A separate bond for reclamation of the UIC well will be posted with the EPA, per their regulatory requirements.

We look forward to working through this application with the DRMS. Please contact me if you have any questions or if you need further information.

Sincerely,

Harry H. Posey
Senior Production Geologist
713-245-7385 Office
832-603-7814 Mobile

Cc: Dan Whitney, with attachment
Jon Sellars, with attachment
DRMS – Denver, with attachment
Paul Daggett – BLM Meeker (w/o Attachment)

Attachment:

- NOI - 2 paper copies; 1 CD

STATE OF COLORADO

DIVISION OF RECLAMATION, MINING AND SAFETY
Department of Natural Resources

1313 Sherman St., Room 215
Denver, Colorado 80203
Phone: (303) 866-3567
FAX: (303) 832-8106

COLORADO DIVISION OF RECLAMATION MINING & SAFETY

Form 2 (Public File)
NOTICE OF INTENT TO CONDUCT PROSPECTING OPERATIONS
FOR HARD ROCK/METAL MINES

CHECK ONE:
☐ **There is an NOI Number Already Assigned to this Operation**
P- - (Please reference the file number assigned to this operation)
☑ New NOI
☐ **Modification to** an Existing NOI
NOI# P- - (Provide for **Modifications** to an existing NOI)

GENERAL OPERATION INFORMATION
Type or print clearly, in the space provided, ALL information described below.

I. GENERAL INFORMATION

1. **DATE NOI RECEIVED BY THE DIVISION:** ______ (office use only)
2. **PROJECT NAME:** Multi-Mineral RDD Lease
3. **PROSPECTOR:**
   Name: N/A
   Title:
   Company Name: Shell Frontier Oil and Gas Inc.
   Street: 200 North Dairy Ashford Road
   P.O. Box: P.O. Box 576
   City: Houston
   State: Texas
   Zip Code: 77001
   Telephone Number:
   Fax Number:

   PERSON MLRB SHOULD CONTACT:
   Name: Harry H Posey
   Title: Senior Production Geologist
   Company Name: Shell Exploration and Production Company
   Street: 3737 Bellaire Blvd - 4016 B
   P.O. Box:
   City: Houston
   State: Texas
   Zip Code: 77025
   Telephone Number: 713-245-7385
   Fax Number: 713-245-8299
4. **APPLICATION FEE: $86.** (NOIs require a **$86** fee which must accompany this notice or it cannot be processed by the Division).
5. **LOCATION INFORMATION:**
   County: Rio Blanco
   PRINCIPAL MERIDAN (check one) ☑ 6th (Colorado) ☐ 10th (New Mexico) ☐ (Ute)
   SECTION (write number): S 4

TOWNSHIP (write number and check direction) T 2 North ☐ South ☑
RANGE (write number and check direction) R 98 East ☐ West ☑
QUARTER SECTION (check one): ☐ NE ☑ NW ☐ SE ☐ SW
QUARTER/QUARTER SECTION (check one): ☐ NE ☐ NW ☑ SE ☐ SW
GENERAL DESCRIPTION: (the number of miles and direction to the nearest town and the approximate elevation):
7 mi northwest of Rifle, 25 mi southwest of Meeker at approximately 6,630 ft above mean sea level; lots 9, 10, 15 & 16, Sec 4

NOTE: Supply longitude and latitude or UTM coordinates if lands have not been surveyed or as supplemental information to this NOI. GPS measurements will be acceptable for this purpose:
39°54'27.4" N 108°23'54.3" W

6. **LAND OWNERSHIP**

Private ☐ Public Domain (BLM) ☑ National Forest (USFS) ☐
State ☐ State Sovereign Lands ☐ Other (please describe): ______

If prospecting is located on BLM or USFS land the remaining section must be completed, otherwise go to section II Maps & Drawings

7. **PROSPECTING ON BUREAU OF LAND MANAGEMENT (BLM) LAND AND U.S. FOREST SERVICE (USFS) LAND**

The Division and the BLM/USFS have entered into cooperative agreements that eliminate the need for a prospector to post a financial warranty with each agency and allow them to coordinate the review of the NOI in order to minimize administrative processing time and effort.

A. **LESSEE:**

Name: (See Front Page)
Address: ______
Telephone: ______
Fax Number: ______

B. **SITE/CLAIM INFORMATION:**

List names, serial numbers and provide legal description to nearest quarter-quarter section of all sites or claims (attach additional page, if necessary).

NAME SERIAL NUMBER LEGAL DESCRIPTION

Oil Shale Research, Development and Demonstration (RDD) Lease
Serial# COC 69166; T2S R98W 6th PM, sec 4, lots 9, 10,15 & 16

~~Nahcolite Preference Right Sodium Lease;~~
Serial# C-0120057; T2S R98W 6th PM - ...cont. next page

sec 3, lots 16 to 19, inclusive; sec 4, lots 5 to 20, inclusive; sec. 5, lots 1 to 3, inclusive, S1/2NE1/4, SE1/4NW1/4,NE1/4SW1/4,S1/2SW1/4, and SE1/4; sec 8, all; sec 9, N1/2N1/2, SW1/4NE1/4, and S1/2NW1/4

C. **LOCATION MAP:** Attach a USGS 7.5 minute quad, or similar map of adequate scale, which locates the prospecting site(s).

D. Are prospect sites (e.g., drill holes, trench locations, etc...) staked on the ground? Yes ☐ No ☐

E. Specify the Land Management Agency, Address and Telephone Number:

BLM, White River Field Office, Meeker, CO 970.878.3800

F. The prospector is required to document that the NOI has been sent to the BLM or the USFS. Processing of the NOI will not begin until the prospector has submitted evidence acceptable to the Division that the NOI was sent to the BLM or USFS. Check one:

- ☑ Evidence of notification is attached to this NOI for BLM Land
- ☐ Evidence of notification is attached to this NOI for USFS Land.
- ☐ Other proof of notice is attached to this NOI

II. MAPS & DRAWINGS

Accurate topographic base map showing the location of the proposed project must be submitted with this notice. The prospector may submit a U.S.G.S. 7.5 minute quadrangle, or similar map of adequate scale that:

1. identifies the proposed prospecting site(s) or activity areas involving surface disturbance. Activity areas include all drill holes, mud pits, excavations, trenches, adits, shafts, tunnels, rock dumps, stockpiles, impoundments and prospecting roads, and

2. includes sufficient detail to identify and locate known prospecting features and facilities that may be affected and those that are not anticipated to be affected. This includes the location of all drill holes, mud pits, excavations, trenches, adits, shafts, tunnels, rock dumps, stockpiles, impoundments and prospecting roads. Color photographs, adequately labeled (including date, orientation and location), of the prospecting site may be used to fulfill this requirement if included with the NOI submittal.

III PROJECT DESCRIPTION

1. **Mineral(s) and/or Resource(s) being Investigated:** Oil shale, nahcolite
2. **Estimated dates of commencement and completion:**

   Commencement: 01/01/2012,

   Completion: 12/31/2022,
3. **Amount of material to be extracted, moved or proposed to be moved:** See attached
4. **Identify the type or method of prospecting proposed and quantity (place an "X")**

   ☐ Cuts ☐ Pits ☐ Trenches

   ☐ Shafts ☐ Tunnels ☐ Adits ☐ Declines

   ☐ Air Drilling ☐ Fluid Drilling ☐ Drilling & Blasting

5. Describe proposed surface excavation or other land disturbance, including roads, pits, trenches, waste piles, drill pads and collar areas of underground workings, ponds, etc…

See attached

6. **Proposed Disturbance** (approximate) Describe the proposed drilling to be conducted, including anticipated number of holes, diameter, depth, location, etc… Submit additional pages if necessary:

A. Drill Pads: Quantity See attached Average Width See attached (ft) Average Length See attached (ft)

B. Drill Holes: Quantity See attached Depth See attached (ft) Diameter See attached (in)

C. Mud Pits: Quantity See attached Average Width See attached (ft) Average Length See attached (ft) Average Depth See attached (ft)

Described proposed underground work, including reopening of old workings, advancement of adits or shafts, trenches, pits, cuts, rock dumps, or other types of disturbance, describe type, quantity and general dimensions:

See attached

D. Other Disturbances (please describe):

~~See attached~~

E. Indicate Chemicals and Fuels used or stored on site. List type, quantity and method to store.

See attached

F. New Road(s): Length See attached (ft) Width See attached (ft)

Significantly Upgraded Road(s) Length See attached (ft) Width See attached (ft)

Are culverts or other crossings proposed? If so, please describe:

See attached

G. Total project area to be disturbed 10 +/- (acres)
Access Road previously permitted and constructed.

H. Describe the equipment to be used for the prospecting operations:

See attached

I. Describe and locate any structures to be constructed (i.e. stockpiles, ponds, impoundments):

See attached

J. Describe anticipated relationship to surface water and groundwater (proximity to streams, penetration of ground water aquifers):

See attached

IV. OPERATION AND RECLAMATION MEASURES:

1. The Board suggests that a photographic record of the pre-prospecting and post-prospecting conditions be kept by the prospector. These photos should be taken from the same location and by the same method to clearly show the pre-prospecting condition of the land and the reclamation efforts. Upon completion of reclamation and request for bond or surety release, the Board may consider the photos as evidence of adequate reclamation, and thus, be able to act more quickly on the request for release.

2. Provide a description of the native vegetation of the area to be disturbed, including tree, shrub, and grass communities of the area. Color photographs, sufficient to adequately represent the ecology of the site and adequately labeled (including date, orientation and location), may be used in lieu of a written description. Based on the quality of the photographs, the Division may require additional detail.

See attached

3. Describe the estimated topsoil depth and how topsoil will be salvaged, stockpiled and redistributed for the re-establishment of vegetation. Specify approximate topsoil redistribution depth:

See attached

4. Describe how drill holes will be plugged (refer to Rule 5.4 of the Rules for required abandonment procedures):

See attached

5. Describe how portals, adits, shafts, ponds, excavations, or other disturbances will be reclaimed (refer to Rule 3 and Rule 5 for specific reclamation performance standards). You may wish to contact the Division for closure specifications.

See attached

6. Describe how roads will be reclaimed or returned to their pre-prospecting (or better) condition:

See attached

7. List the seed mixture to be used in the re-establishment of vegetation. See the attached seed mixture calculation to obtain PLS/acre. For assistance with formulating seed mixtures and rates, contact the local NRCS if on private land, BLM/USFS if on public land or State Land Board if on state land.

   A. Provide plant name and seeding rate

Plant Name	Seeding Rate (PLS/acre)
See attached	See attached

   B. Describe the method for seed bed preparation, and application method for grass/forb seeding:

   See attached

V. TERMS AND CONDITIONS FOR PROSPECTING OPERATIONS:

1. Reclamation measures shall be fulfilled in a timely manner and completed within five (5) years of completion of prospecting activities.

2. The prospecting operations described in this Notice will be conducted in such a manner as to minimize surface disturbances. In addition to the measures required in Rule 5, precautions to be taken include:

   A. Confinement of operations to areas near existing roads or trails, where practicable. Existing roads which are to remain as permanent roads after prospecting activities are completed shall be left in a condition equal to or better than the pre-prospecting condition;

   B. Drilling shall be conducted in such a way as to prevent cuttings and fluids from directly entering any dry or flowing stream channel. Drill cuttings must be spread to a depth no greater than one-half (1/2) inch or buried in an approved disposal pit;

C. Proper and timely abandonment of drill holes upon completion of drilling;

D. Reclamation of affected lands upon completion of operations or phases of an operation;,

E. Backfilling and revegetating any pits to blend in with the surrounding land surface;

F. Safeguarding mine entries, trenches and excavations from unauthorized entry at all times;

G. Disposal of any trash, scrap metal, wood, machinery, and buildings;

H. Control of noxious weeds within the area affected by the prospector

3. The prospecting operations shall be conducted in such a manner as to comply with all applicable local, state and federal laws and regulations including applicable state and federal air and water quality laws and regulations.

4. The prospecting operations shall be conducted so as to minimize adverse effects upon wildlife to include covering of open drill holes until properly plugged.

5. During the prospecting operations, the operator will perform the necessary stabilization and reclamation work to ensure those areas affected by prospecting activities are erosionally and geotechnically stable.

6. All prospecting operations shall be in compliance with the Colorado Mined Land Reclamation Act, as amended (34-32-101 et seq. C.R.S.), and all rules and regulations currently in effect or promulgated pursuant thereto. See 2 CCR 407-1, Mined Land Reclamation Board Hardrock /Metal Mining Rules.

VI. ADDITIONAL TERMS AND CONDITIONS FOR PROSPECTING ON BLM/USFS LANDS

1. The prospector will supply a copy of this NOI to the appropriate BLM and/or USFS office.

2. The prospector authorizes the MLRB to discuss the information in this Notice of Intent with the BLM and/or USFS.

3. If on BLM land, the prospector will complete reclamation to the standards described in 43 CFR 3809.1-3 (d) and implement reasonable measures to prevent unnecessary or undue degradation of lands during operations.

VII. FINANCIAL WARRANTY

A financial warranty must be provided for the cost of reclamation of the disturbance described in this Notice. The prospector can either file a "One Site Prospecting Financial Warranty" or a "Statewide Financial Warranty." **The financial warranty must be submitted and approved by the Division prior to entry upon lands for the purpose of prospecting.**

An One-Site Prospecting Financial Warranty is usually filed by individuals or companies where prospecting activities are limited to a single area. It must be filed in the amount of $2,000 per acre for land to be disturbed, or such other amount as determined by the Division, based on the projected costs of reclamation. A Statewide Financial Warranty is usually filed by companies with multiple prospecting sites. It must be filed in an amount equal to the estimated cost of reclamation per acre of affected land for all anticipated sites statewide. (You may increase the Statewide bond at any time in order to cover additional or expanded prospecting activities.)

VIII. SIGNATURE REQUIREMENT

Please place you initials on the line provided:

HHP I hereby verify that the foregoing information is true and accurate and commit to the reclamation of the aforementioned prospecting site as required by the Colorado Mined Reclamation Act and the rules as specified in the Hard Rock/Metal Mining Rules and Regulations and this NOI form.

HHP I have enclosed the required permit fee.

HHP I authorize the Division to contact and copy the BLM and/or USFS on any correspondence related to the prospecting operation, if the prospecting operation is located on federal public land.

HHP I have also enclosed the appropriate reclamation surety amount or will post an amount as determined by the office, based on the projected costs of reclamation.

HHP I understand that I am not authorized to create any surface disturbance until the surety amount is posted and approved in writing from the Division of Reclamation, Mining and Safety.

HHP I accept and agree to comply with the foregoing terms and conditions and with all of the provisions of Rules 3 and 5, and C.R.S. 34-32-101.

This form has been approved by the Mined Land Reclamation Board pursuant to section 34-32-113, C.R.S., of the Mined Land Reclamation Act. Any alteration or modification of this form shall result in voiding any NOI issued on the altered or modified form and subject the operator to cease and desist orders and civil penalties for operating without a NOI pursuant to section 34-32-123, C.R.S.

I, the undersigned, being the NOI holder or the person authorized to sign on behalf of the NOI holder, declare that the information given in this NOI form is true and correct.

SIGNATURES MUST BE IN BLUE INK

Signed and dated this 10th day of December 2010,

Signature of NOI holder or person authorized to sign: [signature]

Name (typed or print) Harry H Posey

Title/Position: Senior Production Geologist

Shell Frontier Oil and Gas Inc.

Notice of Intent to Conduct Prospecting
on
Oil Shale Research, Development and Demonstration (RDD) Lease COC 69166
and
Nahcolite Preference Right Sodium Lease C-0120057

"Multi-Mineral RDD"

Submitted to:

Division of Reclamation, Mining and Safety
1313 Sherman Street
Room 315
Denver Colorado 80215
and
Division of Reclamation, Mining and Safety
101 South 3rd, Suite 301,
Grand Junction, CO 81501

December 29, 2010

ABBREVIATIONS

AMSL	above mean sea level
APCD	Air Pollution Control Division (CDPHE)
API	American Petroleum Institute. API gravity = specific gravity of liquid hydrocarbons
bbl	barrels
BLM	Bureau of Land Management
BMP	best management practices
boe	barrels of oil equivalent
bopd	barrels of oil per day
BTEX	benzene, toluene, elthybenzene, xylenes
bwpd	barrels of water per day
CDPHE	Colorado Dept of Public Health and Environment
CH_4	methane
CO_2	carbon dioxide
CSU	Colorado State University
DHT	Deep Heater Test: a Shell research project near Cathedral Bluffs
DRMS	(Colorado) Division of Reclamation, Mining and Safety
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMT	Emergency Medical Technician
FA	Fischer assay
H_2S	technically hydrogen sulfide, but used generally for all sulfur gases
HSE	health, safety and environment
ICP	in situ conversion process
LEL	lower explosive limit
MDPo	MDP Original: a Shell research project near Cathedral Bluffs
MDPs	MDP South: a Shell research project near Cathedral Bluffs
MI	mineral insulated (heater)
MIT:	Mahogany Isolation Test: a Shell research project near Cathedral Bluffs
MLRB	(Colorado) Mined Land Reclamation Board
MRP	(Shell) Mahogany Research Project
MTE	Mahogany Test Experiment
Na_2CO_3	soda ash; trona; sodium carbonate
NIA	Notice of Intent to Abandon (permit)
O&G	oil and gas
POD	(BLM) Plan of Development
POO	(BLM) Plan of Operations

PRL	Preference Right Lease (or Preference Right Lease Area)
psi	pounds per square inch
RDD	Research, Development and Demonstration (Lease). Same as R, D &D and RD&D.
ROW	right of way
RPP	Recreation or Public Purposes
SFOGI	Shell Frontier Oil and Gas Inc.
SIA	Subsequent Report to Plug and Abandon (permit)
SIFT	Steam Injection Field Test: a Shell research project near Piceance Creek
SPCC	Spill Prevention, Control and Countermeasures Plan
SWMP	Storm Water Management Plan
TD	total depth
TDS	total dissolved solids
TI	TI bed; (tee-eye bed); a rich nahcolite unit in lower part of Saline Zone
TLQ	temporary living quarters
TVS	table value standards (see WQCC Basic Standards for Groundwater – Regulation 41)
UAA	Use Attainability Assessment
VFD	volunteer fire department
WBI	water bearing interval
WQCC	(Colorado) Water Quality Control Commission

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1. INTRODUCTION

Shell Frontier Oil and Gas Inc. (Shell) has leased approximately 149 acres of oil shale-bearing land to develop a Research, Development and Demonstration (RDD) project in a nahcolite-rich zone of the Eocene Green River Formation in the Piceance Basin, NW Colorado. The RDD project lies on federal land managed by U.S. Bureau of Land Management (BLM) (Figure 1). The target resources include oil shale and nahcolite ($NaHCO_3$). In essence, the plan is to leach nahcolite with hot water to create permeability and recover the leachate, then heat the formation to convert kerogen and recover the oil and gas products.

Shell's Project plans are described in the "Plan of Operations for 2nd Generation ICP Project" (POO) (February 15, 2006 [15]), the "Addendum to Plan of Operation for the 2nd Generation ICP Project" (July 17, 2008 [17]), and the "Addition of No Freeze Wall Option" (November 26, 2008 [18]) (POO Addenda).

The BLM approved the "Environmental Assessment CO-110-2006-117-EA and Finding of No Significant Impact/Decision Record Site 2 COC-69166 Nahcolite Test Site (EA)" (November 9, 2006 [3]). Subsequently, Shell and BLM signed a Research Development and Demonstration Lease (RDD) for approximately 149 acres (December 10, 2008 [4]). The POO Addendum and Addition of no Freeze Wall Option were incorporated into the RDD Lease by BLM letter dated December 10, 2008.

Leases covering the RDD Project include the "Oil Shale Research, Development and Demonstration (R,D&D) Lease" number COC 69166 (December 2006 [2]), "Addendum Number 1 to the Oil Shale Research, Development and Demonstration Lease Number COC-69166, COC-69167, and COC-69194", and the "Preference Right Sodium Lease" number C-0120057 (Sodium PRL) (1992 [1]). The RDD lease term is 10 years with the option to extend 5 years upon a showing of diligence, and is convertible to a 20-year term for commercial development. It is expected that the Sodium PRL will be renewed within the working life of the RDD Project.

It is estimated that leaching, pyrolysis, product recovery, and subsurface reclamation of the RDD Pilot Project will require 6½ to 10 years, more or less depending on the time needed to leach, pyrolyze, and reclaim the subsurface (Figure 2). This time includes ~ 7 months to drill and construct the wells, 6 to 18 months of nahcolite leaching, 5 to 12 months of construction including leach well work-overs transitioning to the heating phase, 2 to 3 years of heating, and 2½ or more years of subsurface reclamation that includes cooling and reservoir filling. Surface reclamation (not shown in Figure 2) will begin once surface facilities can be removed and will continue until the surface is returned to a beneficial post-mining land use. Ground water monitoring sufficient to demonstrate compliance with ground water numeric protection levels will close out the project. Numeric protection levels listed in this Notice of Intent (NOI) will be established by DRMS, the ground water implementing agency for mines in Colorado.

MLRB and BLM approvals are expected to be contingent on release of CSU's Recreation and Public Purposes lease (RPP), and renewal of Shell's Sodium PRL per BLM direction. Included in the NOI is a list of all associated permits, notices, licenses, etc that have been or will be submitted to fulfill local, state, and other federal requirements. All supporting documents to this Plan of Development are contained in Appendix A through G.

2. CONTACT INFORMATION

Lessee:

Shell Frontier Oil and Gas Inc.
P.O. Box 576
200 North Dairy Ashford Road
Houston, Texas 77001

Permit Contact:

Harry H. Posey
Shell Exploration and Production Company
Bellaire Technology Center
3737 Bellaire Blvd – 4016-B
Houston, TX 77025
713-245-7385 Office
832-603-7814 Mobile
713-245-8299 Fax

Operations Contact:

Dan Whitney
Shell Exploration and Production Company
Bellaire Technology Center
3737 Bellaire Blvd – 4066
Houston, TX 77025
713-245- 8346 Office
713-245-7801 Fax

Inspection Contact:

John Woods
Shell Exploration and Production Company
600 CR 83; P.O. Box 478
Meeker, CO 81641
970-675-5272 Office
970-675-6364 Fax

3. LOCATION

3.1. Location, Elevation, Acreage

The East RDD Project site is ~ 37 miles northwest of Rifle and 25 miles west-southwest of Meeker, Colorado (Figure 1) The RDD Lease encompasses the following 149.39 acres more or less, in Rio Blanco County:

Sec. 4; Lots 9, 10, 15, and 16; T2 S, R98 W; 6th P.M.

Elevation at the RDD Lease center is ~ 6,630 ft above mean sea level. The permit boundary for all permits coincides with the RDD Lease boundary; the affected area inscribes a portion of the Permit boundary plus the access road.

The affected area inside the lease covers approximately 12.2 acres. This includes ±9.7 acres of active operations, topsoil storage, and potential fire break, plus the access road outside the permit boundary covering ±2.5 acres.

A pipeline right of way (ROW) traverses the RDD lease on the south side (Figure 3). An unimproved BLM road ("BLM Pipeline Road") along the north side of the pipeline ROW, which will be marked for emergency access only, will not be upgraded or improved. Approximately 5 acres of the RDD Lease that lie south of the Pipeline Road will remain unfenced.

Colorado State University (CSU) holds a Recreation or Public Purposes (RPP) lease with BLM covering 50 acres, more or less, for re-vegetation studies. The study plots cover parts of the RDD, most notably a series of plots inside an 8-ft tall wildlife exclusion fence. A N-S road immediately east of the exclusion fence, which links to the Pipeline ROW, will serve as emergency access for the RDD Pilot. NOI and POD approvals are contingent on a Shell and CSU Agreement to terminate the RPP Lease. Shell's intent is to fence the RDD operating area with an 8 ft high game fence, tied in to the 8 ft exclusion fence in order to maintain the existing (CSU) fence.

The RDD lease area north of the BLM Pipeline Road will be fenced per BLM Gold Book Standards, to preclude livestock. An emergency access gate will be installed in this south fence at the existing N-S dirt road, which lies east of the existing CSU fenced area. Operating areas inside that fenced area will be cleared of vegetation and graveled. Topsoil will be preserved.

3.2. Shell Lands, Projects, Facilities

Shell maintains an office, parking facilities, and helipad on private land approximately ½ mile east of the East RDD. These facilities will help support the RDD project.

Shell maintains temporary living quarters (TLQ) on Corral Gulch, approximately 6 miles WNW of the East RDD. The Corral Gulch TLQ and associated structures, which presently are not occupied, will be reopened to support the East RDD Pilot and other Shell projects on private lands. The TLQ facilities include sleeping quarters, office buildings, cafeteria, warehouse, and storage yard on Shell-owned property.

The Shell Freeze Wall Test (FWT) on Corral Gulch is located on private land approximately 5 miles WNW of the East RDD. Activities at the FWT are ongoing.

Shell's Mahogany Research Project (MRP) sites on private lands near Cathedral Bluffs in the western part of the Piceance basin, approximately 7 miles WNW of the Corral Gulch Facilities, are presently undergoing reclamation. Some of the MRP facilities will be transported to the East RDD for re-use. The MRP will not be used otherwise to support the East RDD Pilot.

3.3. Ownerships, Leases in RDD Lease Area

The East RDD Lease acreage is wholly within federal BLM boundaries. The RDD lease, primary access road, and emergency access road overlap leases and rights of way of other parties (Figure 3). Following is a list of the Shell leases and the ownerships and other leases on or adjacent to the East RDD Lease.

Surface Owner / Mineral Owner / Lessor

United States of America, through the Bureau of Land Management
Meeker, Colorado

Oil Shale Research Development and Demonstration R, D&D) Lease Serial no. COC 69166
Sodium Minerals "Preference Right Sodium Lease" number C-0120057
2009-10 East Lease Appraisal Right of Way Grant COC 73947

Shell Frontier Oil and Gas Inc.
Houston, Texas 77002

Oil and Gas Lease Holder

Williams Production RMT Co.
1 Williams Center
Tulsa, OK 74172 Ph. 970-285-9377
Federal Lease Serial No. COC 60737

Recreation or Public Purposes Lease Holder – (To be cancelled upon POD and NOI approval)

Colorado State University
William H. Farland, VP for Research
2001 Campus Delivery
Fort Collins, CO 80532-2001
Attn: Mark Paschke
Federal Lease Serial No. COC - 34329

Grazing Leases
A grazing lease overlaps the East RDD, and a separate grazing lease overlaps the access road.

Dean Mantle – Reagle Allotment CO-06026

Mantle Ranches – Square S Allotment CO-06027

3.4. Explanation of Ownerships, Leases, Easements, Rights of Way

Leases that affect unimpeded 100% access to the East RDD lease and the lease access road are described in this section along with a description of Shell facilities and projects in the vicinity.

BLM ownership and mineral rights: The East RDD Project area, access road, and proposed activities are on BLM land. Surface and subsurface mineral, oil and gas, and other natural resources are federally owned, and managed by the BLM White River Field Office in Meeker, Colorado.

Shell Leases: Shell has two mineral leases and a Right of Way Access agreement with BLM for the East RDD. The oil shale RDD lease of ±149.39 acres includes the East RDD Permit area. Shell's Preference Right Sodium Lease covers ±2186.76 acres. The ROW Access Agreement covers ±4 acres, approximately 2 of which are outside the RDD Lease area. The leases and agreements include:

- "Oil Shale Research, Development and Demonstration (R,D&D) Lease" number COC 69166
- "Preference Right Sodium Lease" number C-0120057 (Sodium PRL)
- Right of Way Access Agreement number COC 73947

The RDD lease term is 10 years with the option to extend no more than 5 years upon a showing of diligence. The RDD lease is convertible to commercial preference right lease. The Sodium PRL lease term is for 20 years, renewable upon approval by BLM. It is expected that the Sodium PRL will be renewed within the working life of the RDD Project.

Oil and gas lease: Oil and Gas rights beneath the RDD Lease and access road are leased to Williams Production RMT Co. A gas well pad on that lease is located approximately 300 ft east of the eastern RDD Lease boundary and approximately 150 ft south of the RDD access road. This oil and gas lease overlaps the entire East RDD property and is part of a significant tight gas play in the region. The O&G target formations are several thousand feet beneath the oil shale units and are accessible to O&G production via offset drilling. Shell's RDD lease and access road are not available for O&G operations or staging.

Pipeline Easements: The two pipeline rights of way cross the project area; one crosses the southern part of the RDD and includes pipelines constructed by several companies; the other is crossed by the access road east of the RDD lease.

The site access road crosses a north-south gas flow line west of CR 24. This flow line is owned by Williams Production RMT Co. A Shell agreement to cross the Williams flow line is included in the 2009-10 East Lease Appraisal Right of Way Grant, COC 73947. That agreement required a minimal buildup of roadbed thickness to provide access across the line for heavy equipment. This access has been already constructed.

The pipeline right of way crossing the southern part of the RDD lease includes pipelines belonging to Enterprise Products Partners L.P, Colorado Gas Company (CGC), Xcel Energy, and Questar Pipeline Company. No part of this pipeline ROW will be employed for surface operations. An unimproved BLM access road parallels the pipeline ROW on the north side, and will be used by site personnel for emergency use only.

CSU RPP Lease. Colorado State University (CSU) has a ±50 acre Recreation or Public Purposes Lease (RPP) with BLM to conduct disturbed land reclamation. Much of the RPP lease overlaps the RDD lease. An agreement between Shell and CSU provides for termination of the RPP lease in consideration of research and endowment funding to CSU Foundation. Termination by the BLM of the RPP lease is a condition of the POD and NOI.

3.5. Man-made Structures within 200 ft

The lease permit boundary and adjacent man-manmade structures (Figure 3) includes several structures within 200 ft of the permit boundary. Man-made Structures within 200 ft of the Permit Boundary include:

- Shell Hydrology Cluster well pad 22-4-298[1]

- Shell hydrology wells 138-4-298
  Includes Uinta, A-groove, B-groove, L5, and L4 wells (5 wells total)

- Williams Gas Well
  Williams gas well Fed RGU 41-8-298
  NE NE Sec 8, T2S, R98W. Federal Lease Serial No. COC 60737
  This is a producing well.

- CSU fences
  CSU exclusion fences surrounding several areas within the east RDD permit boundary will be removed as necessary to enable access to the RDD disturbed area. Otherwise the CSU fences will be maintained to preclude large game access. POD and other approvals are contingent on an agreement with CSU to terminate the CSU RPP Lease.

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[1] Shell recognizes the distinctions between the terms "well" and "hole" as defined in CRS 33-44-101, CRS 34-32-101, and CRS 37-91-101, regarding permitting and use. This Notice of Intent uses the terms less explicitly: "hole" applies generally to the drilled, unimproved feature; "well" applies generally to a hole that contains casing, equipment, or other additions or improvements.

- Grazing lease fence

  A N-S cattle fence with cattle guard crosses the Access road near CR 24. This cattle guard, erected by Shell to enable access to the appraisal and hydrology wells in 2009 was selected to withstand very heavy equipment specifically for the East RDD project.

- Gas pipelines

  Buried, natural gas pipelines of Enterprise Gas, CGC, Excel, and Questar lie in a single ~E-W pipeline corridor crossing the southern part of the East RDD Permit area.

- Natural Gas flow line

  The RDD Access Road crosses a single natural gas flow line from various Williams gas wells ~N-S along the west side of CR 24. A letter agreement from Williams Pipeline Company gives Shell and others rights to cross gas flow lines provided sufficient crossing surfaces are constructed.

- BLM unimproved dirt road

  Unimproved dirt road along northern boundary of above-mentioned gas pipeline corridor is to be used for emergency use only. The road will not be improved or upgraded, but will be maintained as necessary.

4. GEOLOGY

4.1. Background

The East RDD Pilot site lies in the northern part of the Piceance Basin in northwestern Colorado (Hail and Smith, 1994 [9]) (Figure 4). The Piceance Basin contains the world's richest deposits of oil shale and one of the most significant occurrences of the saline mineral nahcolite, which is $NaHCO_3$ (sodium bicarbonate or baking soda). An estimated one trillion barrels of oil shale resource occurs within the Green River Formation. The resource area covers 1,600 square-miles and is bounded by the Colorado River on the south, the White River on the north, the Douglas Creek Arch on the west, and the White River Uplift on the east. The in-place oil shale resource lying beneath the 149-acre East RDD tract is estimated to be approximately 274 million barrels, based on Fischer Assay (FA) recovery rates.

Nahcolitic oil shale development is planned for the Saline Zone, an oil-shale bearing unit that is rich in nahcolite, has very low permeability, and no producible ground water. The first stage of development is to leach nahcolite from the Saline Zone in order to establish permeability for the subsequent production of oil. Nahcolite is also to be removed to lower the cost of pyrolysis; nahcolite is endothermic so absorbs heat of pyrolysis and thereby increases the cost of heating. The second stage of development is to pyrolyze oil shale in order to produce hydrocarbon liquids and gases.

Portions of the following section are excerpted, abridged and adapted from Dyni, "Stratigraphy and Nahcolite Resources of the Saline Facies of the Green River Formation, Rio Blanco County, Colorado", 1974, pp. 3-16, 21 [7].

4.2. Structural Setting

The East RDD Pilot site is near the depocenter of the Piceance Basin, an intermontane asymmetric basin formed during the Laramide Orogeny (~ 60 ma). Older rocks are exposed in the surrounding uplifts -- Uinta Uplift to the north, Uncompahgre Uplift to the south, Grand Hogback Monocline and White River Uplift (Rocky Mountains) to the east, and the Douglas Creek Arch to the west. The Piceance Basin is one of several basins that are part of the Greater Green River Basin, which includes northeastern Utah and southwestern Wyoming. The Douglas Creek Arch divides the Piceance from the Uinta basin in Utah, and the Uinta Uplift divides it from the Sand Wash and Washakie Basins to the north. Together these basins comprise the Greater Green River Basin. The Colorado River runs along the southern boundary of the Piceance Basin, cutting off the southernmost part of the Piceance Basin, and the White River bounds the basin to the north.

Locally, strata dip gently to the northeast toward basin center (Figure 5). Local strike is approximately N45W, and dip is approximately 2° NE.

The East RDD Pilot area lies on the western side of an ~⅛ mile wide, northerly-trending depression. Strata traversed by wells drilled on the northeastern area of the East RDD (SAW-1 and the 138-4-298 hydrology wells) are ~ 20-25 ft lower than projected by simple layer to layer projections from the nearest wells to the west and east (Figure 5). The length of the structure is approximately 1 mile, as suggested by interpretations from local seismic sections. Several possible interpretations of the depression were considered: a graben; a primary depression on the lake floor; and sag caused by intraformational dissolution of nahcolite. All cores in the vicinity were carefully inspected for signs of fracturing, faulting, brecciation, and dissolution, any of which might indicate a need to locate the leaching and pyrolysis zone elsewhere. As no such indications were observed, it appears that the most reasonable interpretation of the depression is primary local topography on the original lake floor and bed thicknesses controlled by changes in primary water chemistry over broad areas and an absence of detrital input to fill the lake floor depression.

4.3. Stratigraphy and Resources

The Parachute Creek is a Member of the Eocene Green River Formation. Within the Piceance Basin, northwest Colorado, the Parachute Creek Member comprises mostly feldspathic dolomite marlstone, kerogen, the evaporite minerals nahcolite and halite, and minor clay, quartz, and calcite. Siliciclastics occur in some units along the original lake margins and decrease significantly toward basin center, which is a few miles northeast of the East RDD Pilot project site. Most of the Parachute Creek units formed in a deep saline meromictic lake.[2] The absence of overturn of the lake waters allowed concentrated solutions to build up in the deeper lake, eventually leading to precipitation of evaporite minerals. The high salinities, great depth of water, and the anoxic conditions favored kerogen preservation.

Kerogen-rich R zones are laterally continuous through the Saline Zone, and are generally thicker due to their position within the primary depositional basin where they accumulated in or near the basin depocenter. The Saline Zone extends from the base of the R2 to as high as the lower L5 at the thickest point. The lower surface is a depositional surface that marks basin closure during early Parachute Creek time when the basin transitioned from a fresh water lake to hypersaline conditions. The Saline Zone has extremely low permeability and is virtually void of water as noted in underground mine workings in the Horse Draw mine and in drill cores (USGS Project Bronco and others).

The Saline Zone and the Dissolution Surface are important controls on the basin hydrostratigraphy, ground water flow, and geochemistry. Extreme low permeability makes the Saline Zone a regional no-flow boundary for ground water. The extreme salinity of ground water in contact with the salts profoundly affects the water chemistry of waters near the Dissolution Surface.

Strata within the Piceance Basin dip generally toward basin center, with steepest dips on the margins, and near horizontal beds at basin center. In the East RDD Lease area, the units dip 1 to 2 degrees to the northeast. Strata thicken toward basin center primarily due to the increase in

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[2] A meromictic lake is a lake whose water is permanently stratified and therefore does not circulate completely throughout the basin at any time during the year

original depositional thickness in that direction, and secondarily to progressive loss of section, from near the basin margins down dip toward the depocenter, due to dissolution of saline minerals of the Saline Zone.

The Parachute Creek Member is floored by the Garden Gulch Member of the Green River Formation – a fresh water lake unit hospitable to clams and fresh water fishes – and capped by the Eocene Uinta Formation, a predominantly siliciclastic unit. While the Garden Gulch and Uinta each host some measure of organic matter that comprises a part of oil shale, the Parachute Creek is generally richer in those organics that comprise oil shale, and is the unit of principal interest for the East RDD Pilot.

Organic matter that today is kerogen was mostly algae, originally, that formed in the Greater Green River lakes, including the area that now comprises the Piceance Basin. With time, the deposits were compressed and dewatered by the weight of overlying sediments, and the compressed algae and associated organics formed kerogen. Mature hydrocarbons of thermogenic origin are present rarely in the Green River Formation in the Piceance Basin (Day, 2009 [6]), but in the Piceance Basin the Green River has not been heated high enough buried deeply enough to produce hydrocarbons. Today it remains immature as it has not formed crude oil. Methane and CO_2, two gases that appear frequently in wells that transect the Parachute Creek Member in the Piceance Basin, are biogenic gases that represent early diagenesis associated with aging and shallow burial of the kerogen.

The stratigraphy of the Parachute Creek (Figure 6) in the Piceance Basin is divided into kerogen-rich zones and kerogen-lean zones. These are referred to as "R" zones and "L" zones, respectively. The kerogen-rich R zones are numbered, base to top, from R0 through R8, and are separated by kerogen-lean L zones, which are also numbered successively from base to top, L0 through L7. What might be considered the L8 zone marks the lower Uinta. The R zones have extremely low vertical permeability, and form seals that preclude or limit significantly the vertical migration of ground water.

The Uinta Formation has minor low-grade kerogen-bearing interbeds. These beds, like their R zone counterparts in the Parachute Creek, form sealing units that limit vertical transmission of ground water.

Individual marlstone strata, kerogen units, and texturally distinct nahcolitic units in the Parachute Creek are correlative over very large distances, and are actually time synchronous: that is, individual distinct layers in the Parachute Creek Member can be correlated across the basin, and each formed at the same time. Such layers are interpreted to be time correlative because they are conformable with over- and underlying layers of volcanic ash (tuff) in the Parachute Creek that extend over many miles. Because tuff layers represent very short-term events in geological time, they serve as precise time markers. As the tuff layers are conformable with the over- and underlying units, it follows that the R and L zones in the Parachute Creek are time equivalent throughout the basin.

The Green River Formation in the Piceance Basin records a lake sequence that changed with time from a fresh water lake that was hospitable to aquatic life to a hypersaline lake that was generally inhospitable to all species except algae. The early period of fresh water lake deposition, marked by the Garden Gulch Member, was hospitable to fresh water fauna including clams and fresh water fishes. Saline minerals began forming by evaporation of lake waters during early Parachute Creek (R2) time. Although saline minerals appear throughout the Parachute Creek Member in the Piceance Basin, the most significant thicknesses are preserved in the center of the Piceance Basin. There, saline minerals occupy strata from the R2 through the lower L5 zones. This high concentration of saline minerals interlayered with oil shale marks the Saline Zone, and it is the target host for the East RDD Pilot.

The lower section of the Saline Zone contains significant accumulations of nahcolite and dawsonite ($NaAlCO_3(OH)_2$) (Figure 7). Nahcolite is considered a valuable mineral resource as a result of its high concentrations in the Piceance Basin. While high in concentration relative to most rock, dawsonite is considered a mineral of interest, but uneconomic. The upper portion of the Saline Zone includes halite beds farther basinward (northeast) but not in the RDD Pilot area. The high saline mineral content gives the Saline Zone extremely low permeability and no producible water. The Saline Zone behaves as a sealing unit that will provide natural geological containment for the East RDD Pilot.

The Saline Zone originally extended farther than the current limits, both laterally and vertically. Fracturing that accompanied regional uplift allowed the introduction of fresh ground water into the subsurface, displacing the native saline formation water and dissolving part of the original nahcolite and halite. Evaporite dissolution that is evident today occurred slowly over geologic time. The dissolution of saline minerals proceeded from above and from the margins of the basin, and continues today. The areas of evaporite mineral dissolution, which have higher permeability than other units, are most conspicuous in the drill core by nodule-shaped vugs and by breccias that have collapsed into open voids created by the dissolution and removal of saline mineral mass. The breccia-form permeability is prevalent for several miles updip of the Saline Zone, and for a few feet to several tens of feet immediately above the Saline Zone, more or less depending on local rock features their tendency to form breccias. Vugular porosity caused by dissolution of nahcolite nodules is found throughout the Parachute Creek, both updip and above the Saline Zone.

The dissolution of nahcolite increases TDS concentrations in ground water, and yields a Na-HCO_3 type composition. Halite, which occurs always in association with nahcolite, also yields higher TDS content upon dissolution and yields ground water with a Na-Cl-HCO_3 type composition.

The so-called "Dissolution Surface" marks a level in the Saline Zone below evaporite mineral dissolution is not observed. Significant stratal thicknesses of primary saline minerals occasionally do occur above the Dissolution Surface, and such is the case at the East RDD.

The lower half of the East RDD oil shale section consists of low- to high-grade oil shale that contains variable amounts of non-bedded crystalline aggregates and nodules, and bedded disseminated nahcolite. Nodular and aggregate forms of nahcolite comprise about 80% of the saline facies in this area, with the remaining 20% being composed of highly continuous units of nahcolite crystals disseminated in oil shale.

4.4. Nahcolite Forms and Leaching Characteristics

Nahcolite appears in the Parachute Creek Member in several forms (morphologies), in widely varying concentrations (Figure 8) (Dyni, 1974 [7]). Leachability of nahcolite controls the generation of leaching-induced permeability in the natural environment. The development of nahcolite leaching-induced permeability, in the unleached Saline Zone, is necessary for recovery of liquid hydrocarbons generated by ICP. Nahcolite leaching is equally important for nahcolite recovery. Three beds of rich disseminated nahcolite occur within the target section: the Greeno bed near the top of the section, the "lower Greeno" bed, and the TI bed (Figure 7). The intent is to preferentially leach the TI bed, and secondarily to leach the "lower Greeno" and Greeno beds.

Nahcolite leaching varies with the amount of mineral surface exposed to the leach fluid, and with temperature (Waldeck, et al, 1932 [21]; 1934 [22]) and pressure (Nielsen et al, 2004 [11]). An increase in any of these parameters increases the rate of nahcolite leaching; and higher temperature and pressure increase the solubility. Mineral surface area exposed to the leaching fluid (hot water in this case) is considered to have the strongest effect on rate and effectiveness of dissolution. Surface area itself is affected strongly by the nahcolite form and the percent of nahcolite that is exposed to leach fluids in the area of leach fluid circulation.

The amount of nahcolite exposed to the leaching fluid over time depends on the connectivity between individual nahcolite minerals; connectivity in turn is governed by nahcolite morphology. Nahcolite occurs in (1) microcrystalline, (2) aggregate, (3) nodular, and (4) disseminated forms (Figure 9).

Microcrystalline nahcolite tends to occur as small crystals or crystal masses in a matrix of marlstone. Individual crystals or crystal masses tend not to be connected except where nahcolite concentration in a layer is very high.

Nahcolite *aggregates* and nahcolite *nodules* typically comprise crystals visible to the eye, have irregular to round outlines, and range from less than 1 inch to more than 3 feet in diameter. Aggregate and nodular nahcolite units tend to float in a matrix of marlstone or marlstone and kerogen. Although these morphologies are laterally continuous across much of the basin, nonetheless they are not likely to leach much past the immediate area of a leach well because the matrix around the nodules and aggregates is practically insoluble relative to the nahcolite.

Disseminated nahcolite, which Dyni (1974) characterized as sparse, moderate, and densely disseminated based on the nahcolite abundance, tends to produce the richest nahcolite layers. Disseminated nahcolite occurs as a mass of crystals that are physically connected laterally, or they are segregated by relatively minor amounts of kerogen or marlstone. The TI and Greeno nahcolite beds are of the densely disseminated type; they have a high nahcolite concentration, a high crystal surface area that is laterally connected, and thus are projected to be the most leachable nahcolite bearing units.

Nahcolite clusters, nodules, and aggregates that are exposed at the drill hole interface will of course leach once hot water in injected into the open bore hole. However, the lateral progress of leaching is stemmed unless nahcolite at the face of the borehole connects laterally to more nahcolite. Disseminated and microcrystalline nahcolite forms are more laterally connected than other forms and hence are considered most readily leachable. Leaching tendency (Figure 7) favors dissolution of the rich disseminated units, namely the TI, Greeno, and "Sub-Greeno".

Core studies indicate that nahcolite layers with a particular morphology are laterally continuous over many miles. Dyni (1981 [8]) showed that nahcolite morphologies are laterally continuous over more than 9 miles north to south and 6 miles east to west in the northern Piceance Basin.

Nahcolite aggregates and nodules may or may not be in direct or close contact with one another. Such connectivity affects the ability of leach solutions to reach the exposed face of adjacent nahcolite.

Nahcolite crystals within aggregates and nodules are typically bladed, ¼ to 1 in. long forms commonly separated from each other by paper-thin septa of oil shale. Aggregates show crude clustering and are more or less randomly oriented, while nodular crystals are arranged in a radiating rosette-like pattern.

Most of the nahcolite is colored light brown by organic (kerogen) impurities. Many aggregates and nodules are rimmed with pyrite or marcasite that alters to a soft expanded material on exposure to air.

Some units are composed of alternating oil-shale laminae and nahcolite-rich laminae. The contacts between units of disseminated nahcolite may be sharp or gradational. Despite the variations in textures vertically and the gradational nature of contacts, many units of disseminated nahcolite have remarkable lateral continuity.

4.5. Estimated Resources

The RDD Lease (USDOI, 2007 [19]) and the Oil Shale Regulations (USDOI, 2008 [20]) require information on the resource volume and estimated recovery. These include an estimate of the size of the resource to be affected, estimated recovery factors, maximum economic recovery (MER), and ultimate maximum recovery. For this POD, "maximum economic recovery" and "ultimate maximum recovery" are considered the same.

Recoverable resources in the target section include nahcolite ($NaHCO_3$ – sodium bicarbonate) and oil shale. Dawsonite is not of ore grade and is unrecoverable under the conditions planned for the East RDD Pilot, so is not a target of this investigation.

As indicated in consultation with the BLM, "ultimate maximum recovery" may not be required at the East RDD Pilot research because (a) the project is very small in size and (b) is of a research nature, and (c) profitability from the RDD research per se is not intended. Ultimate maximum recovery applies to commercial projects and will be addressed in the plan for conversion to a commercial lease, assuming the RDD Pilot proves successful.

Resource estimates are based on 3-dimensional projections of the nahcolite leaching zone and the target pyrolysis zone – the leach volume and pyrolysis volume, respectively. The progress of leaching and pyrolysis are monitored by remote monitoring devices such as temperature and pressure sensors mounted in the wells. The effectiveness of leaching and pyrolysis and recovery efficiency will be evaluated upon completion of the project.

For estimating purposes, the leaching volume and pyrolysis volume each is projected based on placement of the leach and heater wells and their anticipated performance. The nahcolite leaching design assumes a circular, 40 ft ± diameter zone principally in the most readily leachable TI and Greeno nahcolite beds, with lesser leaching of nahcolite bearing units above the TI bed to the top of the open interval. The open, leaching interval is approximately 153 ft in height, including the TI bed. The TI bed will be preferentially leached while other nahcolite bearing units above the TI to the top of the heater zone will be leached less so, depending on contact with the leach solution.

The pyrolysis target zone is a hexagon of 18.48 ft radius between heater wells in the long dimension by 112 ft in height (Figure 30). The maximum affected area dimensions assume a 36.96 ft hexagonal design diameter plus ~2 ft beyond the outer heaters, for a total of ~40 ft diameter, and a heater length of 112 ft. Heating is not expected to reach optimum temperatures at the top and base of the heater, so the actual height of the heated interval will be less (Figure 35). For instance, at the MDP-South project, a Shell experiment near Cathedral Bluffs, approximately 10 miles west of the East RDD Project area, the area adjacent to the upper 10 feet of the heater reached temperatures that were 150 to more than 500°F lower than the maximum temperatures in the deeper parts of the heater, and the lower 5 feet of area adjacent to the heaters the temperatures was up to 50 °F lower than the maximum. For resource estimating purposes however the shape and dimensions of the pyrolysis zone are considered to be a hexagon 112 ft tall by 40 ft maximum diameter.

The leach volume spans from base of the TI bed to top of the heater (base of the crown). On a layer by layer basis, the grade of nahcolite in the leach volume ranges from less than 1 to about 80 wt %, and average grade is 24 weight %. The shape of the leaching front, while expected to be more or less circular about the leach well, will not be known until leach monitoring is under way. Nahcolite leaching will continue until the leach front traverses an acceptable number of the outer heater wells, for an optimal radius of approximately 20 ft beyond the leach well. When the leach front inscribes an acceptable area in the TI bed, then leaching will be curtailed.

The plan is to pyrolyze the target volume and recover a minimum of 1,500 barrels of liquid hydrocarbons. Volatile hydrocarbons, mainly methane, will be measured at the surface and flared. The amount of recoverable liquid hydrocarbons is affected by many factors including grade of the oil shale, heating efficiency, liquids expulsion from the matrix, production of liquids at the producer wells, matrix permeability, and charring of liquid hydrocarbons near heaters.

Oil shale grade is gauged by the Fischer Assay (FA) method, the standard assay measurement for oil shale. On a layer by layer basis, the FA grade of oil shale in the 112 ft thick target section ranges from zero to ~ 35 gallons per ton (gpt); the average FA grade is 25.3 gpt (Figure 7).

Actual conversion and recovery from lab and field experiments is a fraction of the FA grade, and ranges from about 60 to about 70% of FA, more or less depending on how the volume is pyrolyzed and other physical attributes.

Considering a hexagonal pattern with 18.5 ft outer hexagon diameter by 112 ft, the FA resource is 3,904 bbls in place. Assuming that heating affects an additional 1.5 ft around the outer periphery of the heaters which leads to a total hexagon radius is 20 ft, the FA resource estimate is 4,643 bbls. At 62% recovery, which is on the conservative end of the measured recovery range, the potential recoverable resource for the design heated volume is ~2,829 bbls of oil, for a uniformly heated volume.

5. ENVIRONMENTAL BASELINE

5.1. Background: Basis for Water Quality Protection

Protection of surface and ground water quality is a fundamental design premise for nahcolite leaching, oil shale pyrolysis, and reclamation. Surface water protection considerations are simple compared with ground water because the target zone is over 2,000 ft deep, and surface water is more than one and a half miles from the project. Nonetheless, surface water protection features are included in the RDD Pilot design. Likewise, ground water quality protection is also a design premise because the target zone is overlain by a series of water bearing intervals (WBI) having less than 10,000 mg/L TDS, which the Federal Safe Drinking Water Act defines as Underground Sources of Drinking Water(USDW).

The extreme low permeability of the Saline Zone provides natural geological containment that precludes migration of leach fluids or ICP fluids and gases into the overlying water bearing intervals. The absence of producible water keeps the Saline Zone from being an aquifer or a WBI. Wells and even mines developed in this zone fail to produce any water, even after being left open for several decades. For instance, the Horse Draw Mine, an underground mine located off Piceance Creek approximately 10 miles NE of the East RDD Pilot, at approximately the same depth, presently houses a shaft whose cap is accessible via a small tube. This deepest part of the shaft was investigated by Shell in 2009 and found to have no water after being left open since at least 1983 when it was capped, and for several years prior. The mine shaft consists of a steel collar with annular cement from surface to total depth of approximately 2,300 ft, and seals off WBIs above the saline zone. As discovered in Shell's investigation, the underground workings remain dry even after more than 40 years without any pumping from the subsurface. Hence, the Saline Zone is void of water except perhaps for nahcolite saturated pore water which, as evidenced by the lack of water in the Horse Draw Mine, is not producible. While the reasons for the low permeability and lack of water in the target zone are clear and compelling, (see Geology section) the well penetrations through the WBIs and the ground water zone must completely isolate any overlying aquifers by verifiable cemented casing (see Development Details Section).

The following sections describe the baseline hydrology and water quality of local surface streams, and of the water bearing intervals above the Saline Zone. This section also describes measures that will be taken to monitor water quality in surface and ground waters.

5.2. Surface Water Hydrology

5.2.1. Regional North Piceance Basin

The Piceance Basin is considered a closed basin in that there is no significant ground water underflow into or out of the basin. All water that enters and leaves the basin derives from direct precipitation onto the basin itself. Ground water recharge derives from direct precipitation (mostly as snowmelt) and discharges into surface streams that flow within the basin. Major surface water divides coincide generally with ground water divides. USGS gauges 09306255 and 09306222 indicate that average discharge from Yellow Creek and Piceance Creek at their confluence with the White River are approximately 1.8 and 27.1 cubic feet per second (cfs) respectively.

The primary source of stream flow in Piceance and Yellow Creeks is snowmelt, with lesser contributions from springs and seeps that discharge from shallow portions of the Uinta Formation. Precipitation from November through March is stored in snowpack at higher elevation areas of the basin. Spring snow melt produces a period of high stream flow from about March or April through June or July.

Stream flow in the headwaters of the basin during the spring runoff provides a significant source of ground water recharge to the alluvium and underlying shallow bedrock. Stream flow during the remainder of the year is maintained almost entirely by ground water discharge in the form of alluvial underflow, diffuse seepage, or springs.

Stream flow is intermittent in upland areas. Streams may lose flow due to infiltration into alluvium and may regain flow downstream where the alluvium thins and the saturated zone intersects the channel base. Summer precipitation is largely consumed by evapotranspiration so that only high intensity storms produce significant summer stream flow. Irrigation diversions from mid-March to early November mainly affect Piceance Creek stream flow; irrigation on Yellow Creek is minor.

5.2.2. East RDD Area

The East RDD 149 acre lease lies entirely in the Stake Springs Draw drainage area slightly above the confluence of Stake Springs Draw with Yellow Creek (Figure 10). All potential surface water features are ephemeral on and down topographic gradient from the East RDD Pilot location as evidenced by USGS gauging station Stake Springs Draw 093062300, which had only very sporadic, storm-related discharge for the period of record from March 1974 through September 1977 (Figure 11). Shell established a Stake Springs Draw surface water station up-stream of the USGS station (Figure 12). Quarterly monitoring at the Shell Stake Springs Draw station reported no flow during every attempt from the fourth quarter of 2004 through first quarter of 2008 (19 measurement attempts). Shell's "Use-Attainability Analysis for the Yellow Creek Drainage, Rio Blanco County, Colorado" (April 2008 [16]), presented to the Colorado Water Quality Control Commission as part of a Standards setting hearing in 2008 for Yellow Creek, reported that Stake Springs Draw was dry (Figure 12).

5.3. Ground Water Hydrology

5.3.1. Regional North Piceance Basin

The first encountered ground water in the RDD Lease area is approximately 250 ft below ground surface in the Uinta Formation. Ground water flow is not influenced by topography and the potentiometric down-gradient direction is uniformly to the northeast. Additionally, there is no alluvial ground water as the RDD site is located near the top of the local drainage divide and floored by weathered sandstone bedrock.

The general ground water flow pattern is from the outer perimeter of the basin, where most recharge occurs, toward the center of the basin where there is discharge to the perennial streams, more active evapotranspiration, and a greater frequency of springs (see Figure 13).

A generalized stratigraphic and hydrostratigraphic section (Figure 6) shows the sodium lease monitoring intervals. A conceptual cross-section through the Piceance Basin (Figure 14 and Figure 15) demonstrates the relations between flow and discharge.

With increasing depth, the principal hydrogeologic units are stream alluvium "shoestring" aquifers, the Uinta Formation, upper Green River Formation above the R5 zone, lower Green River Formation below the R5, and the Wasatch Formation. For engineering purposes, Shell has divided the upper and lower Green River into additional hydrostratigraphic units.

Stream alluvium has relatively high hydraulic conductivity, is of limited extent, and exists only below and adjacent to perennial and ephemeral stream channels. The Uinta Formation extends downward generally from ground surface and is moderately transmissive due to its large saturated thickness. At the basin scale, the Uinta is conceptualized as an unconfined aquifer, with stratigraphic heterogeneity that imparts varying degrees of confinement to the deeper strata. "Tongues" of low permeability, kerogen-bearing strata exist in the lower portion of the Uinta and these provide confinement to underlying stratigraphic units and water-bearing intervals (WBIs).

Anisotropic flow conditions, which have been observed from pumping tests performed mostly in the western portion of the Basin, are projected for the East RDD Pilot area based on the strongly correlative nature of the individual beds across the basin. Marlstones of the Parachute Creek Member generally have low primary intergranular porosity. Unfractured oil shale has very low permeability. In the Upper Parachute Creek Group, secondary porosity features are dominated by fractures. In the Lower Parachute Creek Group, secondary porosity is dominated by sodium mineral dissolution features (vugs and collapse breccia). Nearly all ground water in the Green River Formation flows through the secondary porosity fractures and dissolution/collapse features as the fine-grained porous matrix is nearly impermeable. The lean zones tend to be more brittle, contain a higher degree of fracturing, and are thus much more permeable than the rich zones. As a consequence, the Green River Formation is conceptualized as a sequence of relatively transmissive lean zones, which are each confined by overlying and underlying rich zones having very low permeability. Rich zone R5 appears to operate regionally as a highly confining unit and this is reflected in the tendency for a large hydraulic head difference between WBIs above and below the R5 in the region that is northwest of the RDD Lease where the L4 and L3 units exist due to nahcolite dissolution. In addition in the PRL areas, ground water chemistry in lean zones below the R5 differs markedly from the ground water chemistry in WBIs higher in the stratigraphic sequence, with zones below the R5 having much higher TDS and associated trace elements.

PRL = PREFERENCE RIGHT LEASE

5.3.2. East RDD Area

Multiple water level measurements have been obtained from the wells in the area (Figure 16). Figure 17 through Figure 22 show the density and temperature corrected potentiometric ground water contours of the shallowest to deepest WBIs of the Uinta through L3, respectively. The L3, which exists only in the extreme southwest portion of the East PRL, and the L4 WBIs have been corrected to fresh water equivalents using a reference point at the base of the L5 WBI so that the potentiometric surfaces can be compared to the L5 and above WBIs with respect to the potential for up flow or down flow across the regional R5 "seal." The Dissolution Surface affects ground water elevations with the extreme flattening of the contours coincident with where the base of the L4 WBI intersects this surface (Figure 21). Comparing Figures 20 and 21, an approximate 60 ft downward vertical gradient is evident between the L5 and L4 WBIs.

5.4. Ground Water Quality

5.4.1. Regional Ground Water Quality

Shell has been measuring ground water quality in Piceance Basin wells for about 10 years. Several wells were drilled on a single well pad into any or all of the water bearing intervals of the Uinta, L7, L6, L5, L4, and L3 zones. On Shell's Mahogany Fee property in the western Piceance Basin, east of Cathedral Bluffs, wells were drilled starting in 2001. Starting in 2005, Shell drilled wells on more than 30 additional pads in and near the three PRL areas associated with the three RDD sites; these sites comprise a northwesterly trending region between Duck Creek on the north and Black Sulfur Creek on the south. Each well was sampled at least 6 times, usually on a quarterly basis, and some have been sampled quarterly for more than two years.

Ground water wells were sampled for a broad range of analytes, including at least one sample each of the full suite of regulated organics, numerous analyses of all regulated inorganics and major elements, and a single set of isotopic measurements for both stable and radiogenic isotopes including C, O, H, S, B, Sr, and radiogenic Cl. As a result of these studies, Shell has an excellent foundation to interpret the ground water chemistry.

Native ground water composition is affected most significantly by three processes: (1) nahcolite dissolution in most areas of the basin, but most evidently near the Saline Zone boundaries, (2) halite dissolution in areas mostly near basin center and downgradient, and (3) iron sulfide dissolution in shallow Uinta ground water and shallow Parachute Creek Member ground water mostly in the headwaters where the Parachute Creek is exposed. Mineral dissolution has released constituents to ground water in quantities that in some cases cause ambient ground water to exceed standards (TVS).[3] Nahcolite apparently contains trace quantities of arsenic (As), barium (Ba), boron (B), and fluoride (F); halite releases chloride (Cl); and the oxidation of iron sulfides increases sulfate concentrations. The dissolution of nahcolite and halite also has led to TDS concentrations that in some cases exceed 10,000 mg/L, which is the value below which ground water is defined by EPA as an underground source of drinking water (USDW).

The causes for concentrations in excess of ground water use standards are local and native. Industrial or other developments that could affect ground water composition are not present in the immediate area. Hence, the water chemistry as measured is considered to reflect native

[3] Table value standards are taken from Colorado Water Quality Control Commission Regulation 41, Basic Standards for Ground Water, 5 CCR 1002-41. Applicable use standards include domestic and agriculture uses.

ground water quality. Gas drilling is prevalent in the region, and might be considered a potential source for excursions of ground water chemistry. However, based on the following observations, there is no evidence for such effects:

1. Gas wells are cased and cemented to protect water quality of shallow aquifers and to contain and thereby collect the products. Leaks or poor cementing jobs would be reflected routinely in pressure readings at these wells and, presumably, the problems would be addressed appropriately.
2. The composition of ground water in the Green River deposits is explained best by dissolution of minerals within that formation (see next section); there are no measurements that indicate external sources for the water chemistry.
3. Elevated concentrations of organic constituents that could indicate a deeper hydrocarbon source have been observed only rarely in some of the Shell hydrology wells; these are rare, and only a few have been measured in the same well more than one time.
4. Elevated concentrations of the same key regulated constituents that tend to exceed water quality standards have been reported in measurements dating to the 1970s, before gas drilling was as widespread as at present. These observations together, along with the geochemical assessment of Shell and other available water chemistry data for the basin, lead us to conclude that the water chemistry as reported is natural, and unaffected by anthropogenic features.

Oil and gas well drilling impacts on ground water, if any, are not evident. The Ca Tract, an underground oil shale retort that operated in the 1980s, lies well north of the East RDD Pilot location, and across the flow gradient, so could have no effects at the East RDD site, a deduction supported by Shell's ground water sampling.

5.4.2. East RDD Ground Water Quality

Ground water quality downgradient from the East RDD Pilot has been measured at the 138-4-298 Hydrology Pad. This pad lies at the East RDD permit boundary and will be used to demonstrate compliance with numeric protection limits, as established by the DRMS. Per guidance from the DRMS, these limits will be based on the greater of the constituent's mean concentration plus two standard deviations, or the ground water standard. Water quality has been measured in the Uinta, L7, L6, L5, and L4 water bearing units. An L3 water bearing unit is not present at the East RDD Pilot because the Saline Zone at that location is intact.

Ground water chemistry is controlled most significantly by dissolution of nahcolite in the RDD area. Several regulated constituents that tend regularly to exceed CDPHE ground water table value standards for domestic or agriculture uses appear to be derived from the weathering of pyrite in the shallower WBIs and from the dissolution of nahcolite.

Ground water quality baseline is established with at least 5 quarters of water quality measurements, per MLRB Regulations. The downgradient water quality of each WBI above the East RDD Pilot has been established for a number of wells regionally, and will be established locally prior to leaching and pyrolysis activities. There are currently four quarters of monitoring data for the Uinta, L7, L6, and L5 WBIs at the 138-4-298 hydrology pad. Select constituent water quality data for these monitoring events (Table 5.1) include data only for those parameters that exceed applicable water quality standards. In the L4 WBI, only the fourth quarter sample data are available because the L4 well was deepened after the first three quarterly sampling events. Based on these data and the DRMS criteria, preliminary numeric protection limits are proposed by Shell for constituents that tend to exceed ground water standards in the area of the East RDD (Table 5.2). These data as well as the ground water standards are presented in Table 5.3. As additional sample data are collected (minimum of five quarters), these proposed numeric protection standards will be updated and submitted to the DRMS, and may constitute changes in the proposed numeric protection levels.

The hydrology wells are purged, sampled, and analyzed following industry standard protocols using certified analytical laboratories. This includes the 138-4-298 well cluster and will eventually include the 135-4-298 L4 well, which will be drilled and sampled during the period of permit review. The 135-4-298 L4 well is being installed per the EPA UIC Program to establish baseline close to the proposed leach/pyrolysis pattern, and to serve as an "early warning" well to gauge potential impacts from the project prior to their reaching the 138-4-298 well that is located farther down gradient. At least 5 quarters of baseline water quality will be collected from the 135-L4 well prior to initiation of subsurface activities that might affect native ground water quality.

Ground water analyses conducted by Shell at the MDP[o], MDP[s], MTE/DHT, and MIT projects near Cathedral Bluffs, and at numerous hydrology monitoring wells in the Shell PRL areas show that a number of inorganic compounds regularly exceed table value standards (TVS). These same constituents exceed ground water TVS in the East RDD Project Area (Table 5.1). In the RDD area, the average arsenic concentration exceeds TVS in the L6 WBI. Barium, boron, fluoride, and chloride exceed TVS in the L4 well. Fluoride exceeds TVS in all WBIs except the Uinta. All WBIs except the L4 have <10,000 mg/L TDS, which indicates they meet the criteria for underground sources of drinking water (USDW) under the federal Safe Drinking Water Act.

Values that exceed ground water use for the most restrictive (lowest value) standard for "domestic use", "drinking water use", and "agriculture use", as defined by WQCC Regulation 41, were tabulated for each WBI (Table 5.2). Values that exceed applicable standards are highlighted. The trends evident on this table are consistent with observations from other parts of the basin.

Several inorganic parameters have the potential to be affected by pyrolysis, and several organic compounds are generated by pyrolysis. For monitoring purposes, it is proposed that each of the inorganic parameters be measured directly; whereas the organics are estimated from the indicator organic compounds benzene, toluene, ethylbenzene, and xylene (BTEX). For the inorganic parameters that tend to exceed TVS, Shell proposes a set of alternate numeric protection levels (Table 5.3). For all other regulated inorganics, and for all of the regulated organic constituents, the TVS is expected to apply. These constituents will be monitored for potential WBI impacts.

Table 5.1: Water quality sample data for 138-4-298 pad wells. This table will be updated in 2011 as new data become available.

Measured Concentrations of Select Constituents in 138-4-298 Pad Wells									
WBI	Sample Date	As (mg/L)	Ba (mg/L)	B (mg/L)	Cl (mg/L)	F (mg/L)	SO_4 (mg/L)	TDS (mg/L)	pH[A] (standard units)
Uinta	3/10/2010	0.0065	0.026	0.12	8	0.4*	**310**	950	7.34
Uinta	6/8/2010	0.0034	0.027	0.13	9	0.3*	**320**	980	7.08
Uinta	8/18/2010	0.003	0.023	0.12	9	0.3*	**300**	1000	6.93
Uinta	11/10/2010	0.0017*	0.023	0.12	9	0.3*	**330**	710	7.31
L7	3/10/2010	0.0095	0.028	0.31	10	**8.6**	188	850	7.88
L7	6/8/2010	0.0054	0.029	0.31	11	**9.2**	175	840	7.54
L7	8/18/2010	0.0046	0.041	0.32	10	**9.1**	148	840	7.77
L7	11/9/2010	0.0034	0.027	0.31	12	**9.6**	163	830	7.78
L6	3/10/2010	**0.0493**	0.202	0.36	10	**18.5**	33	770	8.43
L6	6/8/2010	**0.0277**	0.200	0.37	11	**19.5**	20	710	8.14
L6	8/18/2010	**0.0199**	0.215	0.38	11	**19.5**	23	750	8.34
L6	11/9/2010	**0.0167**	0.205	0.38	14	**19.6**	25	760	8.36
L5	3/10/2010	<0.0005	0.228	0.32	9	**15.8**	<1	710	8.50
L5	6/8/2010	<0.0005	0.217	0.32	10	**16.1**	1*	700	8.22
L5	8/17/2010	<0.0005	0.221	0.32	9	**15.9**	1*	700	9.04
L5	11/9/2010	<0.01	0.008*	0.31	9	**16.2**	2	700	8.44
L4	11/10/2010	<0.01	**6.51**	**8.5**	**310**	**55**	<10	45000	7.61
Ground Water Standard		**0.01**	**2.0**	**5.0 [C]**	**250**	**2**	**250**	**1.25 X Background**	**6.5 - 8.5**

Notes:

[A] Field measurement

[B] Specific conductivity not regulated

[C] Non-agriculture standard applicable due to absence of sensitive crops

Bold values exceed agriculture, drinking water, or domestic use ground water standards

* value < Practical Quantitation Limit and > Method Detection Limit

Table 5.2: Baseline ground water quality concentrations for regulated constituents that tend to exceed most restrictive ground water standard for agriculture or domestic water uses. All other regulated constituents meet ground water standards.

Measured Concentrations of Key Inorganic Constituents at NE Lease Boundary

East RDD Point of Compliance Wells - Well Pad 138-4-298

MEAN CONCENTRATIONS (mg/L)

WBI	As	Ba	B	Cl	F	SO_4	TDS
UT	0.0037	0.025	0.123	8.8	0.0	**315**	910
L-7	0.0057	0.031	0.313	10.8	**9.1**	169	840
L-6	**0.0284**	0.21	0.37	11.5	**19.3**	25	748
L-5	0	0.17	0.32	9.3	**16.0**	0.5	703
L-4[A]	0	**6.51**	**8.5**	**310**	**55.0**	0	45000

MEAN + 2 STANDARD DEVIATIONS (mg/L)

WBI	As	Ba	B	Cl	F	SO_4	TDS
UT	0.0085	0.029	0.133	9.8	0.0	**341**	1180
L-7	**0.0110**	0.044	0.323	12.7	**9.9**	203	856
L-6	**0.0578**	0.22	0.39	15.0	**20.3**	36	800
L-5	0	0.39	0.33	10.3	**16.4**	2.5	713
L-4[A]	0	**6.51**	**8.5**	**310**	**55.0**	0	45000
Groundwater Standard	**0.01**	**2.0**	**5.0 [B]**	**250**	**2**	**250**	**1.25 X Background**

Notes

[A] Only one quarter of sample data available for L-4 well

[B] Non-agriculture boron standard applicable due to absence of sensitive crops

Zero values are below laboratory detection limits

Highlighted **bold** values exceed groundwater standards

Table 5.3: Ground water numeric protection limits proposed for East RDD based on baseline ground water quality data.

Proposed Numeric Protection Limits - East RDD Pilot Site							
			CONCENTRATIONS (mg/L)				
WBI	As	Ba	B	Cl	F	SO_4	TDS
UT	**0.01**	**2.0**	**5.0**	**250**	**2**	341	1138
L-7	0.0110	**2.0**	**5.0**	**250**	9.9	**250**	1050
L-6	0.0578	**2.0**	**5.0**	**250**	20.3	**250**	934
L-5	**0.01**	**2.0**	**5.0**	**250**	16.4	**250**	878
L-4	**0.01**	6.51	8.5	310	55.0	**250**	56250

Notes

TDS values based on 138-4-298 mean concentrations X 1.25

Other constituent values equal to the greater of either 1) 138-4-298 mean + 2 standard deviations of measured values (highlighted values) or 2) ground water standard **(bold values)**

5.5. Ground Water Monitoring and Response

As a means to avoid impacts to the WBIs during Pilot leaching, pyrolysis, and reclamation activities, the Pilot will rely on natural geologic containment of the impermeable Saline Zone below the Dissolution Surface and on verified cementing of well casings. All wells within the Pilot leaching and pyrolysis interval will be sealed with cement grout; cement bond logs will assure adequate cement distribution behind the casing. Each well is to be pressure tested to assure proper cementing, and reservoir containment relative to the overlying L4 WBI. The leaching wells, heater wells, and reclamation wells will be monitored for down hole and surface pressure and temperature with data recording. Any incident having the potential to impact the WBIs will be detected with the pressure and temperature monitoring. If monitoring detects unexpected changes, Shell will investigate, develop appropriate monitoring or response plans, and take appropriate actions as approved by the agencies. Response plans may include items such as a risk and impact assessment, ground water WBI assessment, monitoring plans, or remediation plans, as necessary.

Although a breach of containment is unlikely due to the low pressure that is to be maintained in the reservoir during leaching and pyrolysis, a breach if encountered would first affect the L4 WBI, which is the first WBI above the Dissolution Surface. Upward advance to any higher WBI is highly unlikely as the hydraulic gradient is downward from all succeeding aquifers above the L4. For that reason the L4 is targeted for additional monitoring. An L4 monitoring well is to be drilled approximately 60 ft downgradient (northeasterly) of the Pilot in early 2011, and at least 5 quarters of baseline data will be gathered and submitted to the agencies prior to any activities that might affect ground water quality. Owing to the location of this well closer to the leach and heater pattern, any effect on ground water would be detected earlier in this well than the 138-4-298 L4 well.

In addition to the pressure and temperature monitoring in the various Pilot wells, Shell will monitor water quality quarterly at the down-gradient 138-4-298 Pad compliance wells during Pilot activities, quarterly for one year after Pilot activities, and annually for two additional years to assure no ground water impacts.

5.6. General Vegetation

The East RDD Pilot site and surrounding areas were surveyed in July of 2009 for non-native, invasive plant species (noxious weeds) and threatened or endangered, candidate, and BLM sensitive plant species. A copy of the survey report has been provided to BLM in past correspondence. There are no threatened, endangered or candidate or BLM sensitive plant species on the East RDD Pilot properties or nearby.

Three principal vegetation types occur within the East RDD Pilot site: Sagebrush shrubland type, Pinyon-Juniper Woodland type, and a Disturbed Land type. The sagebrush scrubland type consists primarily of Wyoming big sagebrush as the dominant shrub with several variations of cover, understory, and production. The type is a rolling loam ecological site on Bar D Mesa occurring primarily on the Forelle and Yamac loam soils.

The Pinyon-Juniper woodland type consists primarily of a mix of pinyon pine and Utah juniper trees with differences in tree cover and understory composition. The type is a Pinyon/Juniper woodland ecological site occurring primarily on the Rentsac channery loam soil. Areas within this type occur on the Forelle and Yamac loam soils on which pinyon and juniper trees have encroached into the adjoining sagebrush shrublands.

The Disturbed Lands type consists of several large disturbances from a major pipeline right-of-way (ROW) crossing the southern portion of the tract and from a Colorado State University (CSU) research site situated within the tract. The pipeline ROW has been reclaimed with a vegetation cover primarily of native and introduced grasses with scattered occurrences of forbs and shrubs.

The CSU research site has numerous small disturbances that are in various stages of plant succession. Many small plots occur within the research site, which appear to have been seeded with native or introduced reclamation species or both or have been allowed to naturally re-vegetate by species from adjacent areas.

5.6.1. Special Status Plant Species (T&E, Candidate, and BLM sensitive species)

The 2009 vegetation survey included a search for the presence of plants federally listed as Threatened or Endangered, Candidate species for federal listing, and BLM sensitive plant species. Special Status Species (SSS) that occur within or near areas managed by the BLM White River Field Office consist of the following:

Federally listed T&E plant species:

Dudley Bluffs bladderpod (*Lesquerella congesta*)
Dudley Bluffs twinpod (*Physaria obcordata*)
Ute ladies' tresses orchid (*Spiranthes diluvialis*)

Candidate species:

White River penstemon (*Penstemon scariosus var. albifluvis*)

BLM sensitive plant species:

Debris milkvetch (*Astragalus detritalis*)
Dúchense milkvetch (*Astragalus duchesne*)
Park rockcress (*Boechera fernaldiana var. fernaldiana*)
Tufted cryptanth (*Cryptantha caespitosa*)
Rollins cryptanth (*Cryptantha rollinsii*)
Ephedra buckwheat (*Eriogonum ephedroides*)
Utah gentian (*Gentianella tortuosa*)
Narrow-stem gilia (*Gilia stenothyrsa*)
Piceance bladderpod (*Lesquerella parviflora*)

Narrow-leaf evening primrose (*Oenothera acutissima*)
Graham beardtongue (*Penstemon grahamii*)

None of the plant species listed above were observed within or near the East RDD Pilot site during the 2009 plant survey. In addition, no occurrences of any of the listed plant species have been documented on Bar D Mesa, the local geographic landform upon which the East RDD Pilot site is located. The nearest documented occurrence of any special status species are the Dudley Bluffs bladderpod and the Dudley Bluffs twinpod. Both of these species have been observed within the Ryan Gulch ACEC (BLM Area of Critical Environmental Concern) located approximately 4.25 miles east of the lease tract.

5.6.2. Invasive, Non-Native Plant Species (Noxious Weeds)

The 2009 vegetation survey included a field survey for Colorado noxious weed species. No noxious weed species from the Colorado noxious weed "List A" or "List B" were observed within the area surveyed. Common mullein (*Verbascum thapsus*), a "List C" Colorado noxious weed, is scattered within the CSU test plot area on the east side of the lease tract. Cheatgrass (*Bromus tectorum*) occurs within a few of the CSU test plots and within areas of the pipeline ROW situated near the southern boundary of the lease tract. For the most part, cheatgrass is absent from the undisturbed native plant communities on and around the lease tract.

5.7. Project Activities and Vegetation

Disturbances to vegetation during site development work could result in increased soil erosion, and will increase the potential for the growth of undesirable plant species and indirect impacts to wildlife resulting from a temporary reduction in habitat, until successful reclamation of disturbed areas is achieved following project closure. Timely interim reclamation of areas no longer needed for project-related activities, e.g. construction staging and laydown areas, is planned to reduce the impacts of site development. In addition, Shell's area-wide weed control program, which actively identifies then eliminates undesirable plants, will be implemented on the East RDD to help minimize impacts associated with the growth of noxious weeds or otherwise undesirable plants on cleared areas.

Impacts to special status plant species are not expected from project-related activities because no special status species were observed within or near the project site during the 2009 vegetation survey and no potential habitats for special status species were observed. Special status species within the Piceance Basin occur on relatively sparsely vegetated barrens of the Green River Formation; soils within the survey area are for the most part well-developed loams and sandy loams on gentle slopes. Green River Formation shale barrens do not occur within the survey area; Uinta Formation derived soils cover all of the local area, and these are not known to support any of the special status plant species identified within or near areas managed by the BLM White River Field Office.

6. IN SITU DEVELOPMENT PLAN

6.1. Development Sequence

The East RDD Pilot is to be developed in the nahcolitic oil shale section to earn Shell the exclusive right to convert the 149 acre RDD lease to a commercial oil shale lease of ±5,120 contiguous acres upon demonstration of "production in commercial quantities" and payment of a bonus based on Fair Market Value (FMV). "Production in commercial quantities" involves the following:

1. Generate sufficient permeability by hot-water leaching of the Saline Zone oil shale section to enable oil generated in the ICP phase to flow and be produced at (pumped from) the producer wells.
2. Demonstrate that ICP heating can be achieved using electric heaters in the Saline Zone at the depths proposed in this NOI.
3. Produce a minimum of 1,500 barrels cumulative oil at a peak rate of greater than 10 barrels of oil per day (bopd) as defined in the Plan of Operations.

Achievement of the above thresholds requires two key project phases: the first to remove nahcolite via hot water solution mining (Figure 23) and the second deploying electric heaters to pyrolyze the leached oil shale (Figure 24). Overall Pilot development will proceed in the following stages:

1. Drilling
2. Nahcolite leaching
3. Pyrolysis (kerogen heating by ICP to produce hydrocarbons) and Production
4. Subsurface reclamation
5. Surface reclamation

6.2. Development Details

6.2.1. Drilling

The RDD well pattern (Figure 25) comprises 13 heaters, 2 producers, and 6 observer wells. Several wells will be converted for dual use. All wells will be drilled, cased, and cemented prior to leaching and ICP activities. Drilling is expected to require 6 or more months.

Well heads will be converted on several wells to serve more than one purpose. The SAW-1 well, a geology appraisal well drilled in 2009, will be converted to an observer well outside the heater pattern (Figure 25). The leach well will be converted to a heater well. Some of the heater wells may be used for leaching if the leach front proves to be significantly anisotropic. Two or more of the heater wells may be converted for water injection following the ICP phase. The two producer wells and several heater or producer wells may be converted for recovery of steam and volatiles for the subsurface reclamation phase. Well specifications are discussed in Section 6.4.

Five hydrology monitoring wells were installed in 2009 in the northeast quadrant of the RDD Lease. These wells are being currently monitored to assess baseline water quality in the near downgradient area. An additional ground water monitor well will be drilled near the East RDD Pilot pattern, ~ 60 ft NE of the pattern. Elsewhere in the basin, Shell has drilled, tested, and sampled a considerable number of hydrology wells. These are discussed in the sections on hydrology and baseline water chemistry in this NOI.

6.2.2. Nahcolite Leaching

Nahcolite leaching facilities include a fired heater to heat fresh water, a leach well with a single tube to deliver the hot water to the reservoir and a second tube to retrieve the water, and a nitrogen blanket to help retain hot solutions in the reservoir below the casing shoe (Figure 27). Solutions will be routed to an oil/gas/water separator, as a precaution to sequester ambient gases (methane and CO_2) which are present already in the formation at ambient formation pressures.

Leach water is heated because even though nahcolite is leachable in cold water, the rate of dissolution increases significantly in hot water. Nahcolite is mined in the Piceance Basin by injection of hot water into nahcolitic formations, sometimes under pressure, and pumping the leachate to surface facilities. A similar process will be initiated at the East RDD Pilot in order to generate permeable pathways for the subsequent movement and recovery of liquid hydrocarbons from producer wells.

The nahcolite leach well is to be situated in the center of the RDD well pattern (Figure 25). (This central leach well will be converted to a heater well after leaching.) Initially, fresh water imported to the site will be circulated into the leach well to initiate water circulation. Later, water will be heated in the surface facilities and circulated to conduct nahcolite leaching. (Figure 27). This water once heated will be injected into the zone of interest such that leaching is focused primarily on the TI bed. Leaching is expected to take 6 or more months.

Leaching will focus on the TI bed, with much less recovery anticipated from the Greeno bed and other nahcolite bearing units. Nahcolite solution will be recovered at the surface, transferred to holding tanks until sufficient volume is accumulated so that it may be loaded onto trucks for off-site transport. Owing to the small volume, the nahcolite solution will be disposed at an approved facility.

Following the leaching phase, the leaching well will be converted to a heater well. A construction period of approximately 5 or more months is expected to follow the leaching phase prior to initiation of the pyrolysis phase.

6.2.3. Pyrolysis and Production

Pyrolysis facilities will include a set of electric heaters to heat the formation to convert kerogen oil and gas and one to two producing wells (Figure 28). Each heater will be installed inside a thick walled canister. Water will be released from the kerogen during the heating process. Oil and water will be pumped via the producer wells to the separator; the gases will flow in response to pressure generated as they form. At the surface, the gases will be flared, and the oil and water will be recovered from the separator and trucked off site. Diluent and fresh makeup water will be added at the surface to assist in the production of bitumen which will form during the lower temperature phases of pyrolysis.

ICP involves the gradual heating of the formation using electric heaters inserted into heater wells to gradually heat the rock over a period of time. Kerogen in oil shale converts to oil, gas, water, and coke beginning at temperatures of ~550°F. The reaction is strongly temperature dependant, i.e. at 550°F it takes several years for completion but only a few days at 650°F. The produced oil is relatively light in API gravity, and after hydro-treating to remove nitrogen and other heteroatoms, it is easily refined to finished products.

The liquid hydrocarbons will be recovered at surface via two pumping wells. Gases will be separated from the oil and water, measured, and periodically sampled at the surface facilities. All produced gaseous hydrocarbons will be flared on location. Produced CO_2 and other non-combustibles will be included in the stream of gas sent to the flare and will ultimately be vented. The ICP phase of the East RDD Pilot project is expected to require 2 or more years (Figure 2).

6.2.4. Subsurface Reclamation

Full details of subsurface reclamation are described in the Subsurface Reclamation Plan Section of this NOI. A synopsis follows.

Facilities for subsurface reclamation will consist of an injection well, a production well (for gas capture), and the Separator (Figure 29). As with the pyrolysis phase, the gas from the Separator will be flared. An option exists to pump water and residual oil to the surface, via a pumping well, whereupon it will be routed to the separator. Afterwards, and after the reservoir is cooled to an average temperature below boiling point of water at formation pressure, the voids generated by leaching, pyrolysis and production will be filled with water.

Two options are considered for subsurface reclamation: (1) natural cooling and (2) water-assisted cooling. The option selected for permitting is natural cooling over a multi-year period followed by water injection into the permeable zone that will be generated by leaching and pyrolysis. Both options utilize the same equipment and well constructions. The natural cooling option is used for the reclamation cost estimate. If the water cooling option is selected, then prior to well plugging and abandonment, Shell will file a revised reclamation plan under a Notice of Intent to Abandon (NIA) or Subsequent Report Plug and Abandon (SRA), per BLM Gold Book Standards. For either option, Shell will submit a UIC permit application for injection of water, either for cooling and reservoir filling, or for reservoir cooling alone. It is emphasized that the plans for both options rely on the same well construction designs.

Upon completion of pyrolysis and recovery of liquid hydrocarbons, the pyrolyzed zone will be allowed to cool, either naturally or more quickly by slow injection of water (Figure 29). Subsurface reclamation will be considered complete once the average temperature in the reservoir falls below ~200° F (i.e., boiling point of water at reservoir conditions). Once below ~200° F, metal bridge plugs will be placed in each well just above the pyrolyzed reservoir, and wells will be plugged with cement above the bridge plug to approximately 3 ft below the ultimate reclaimed ground surface. Well casings will then be cut 3 or more feet below final ground surface, per BLM Gold Book Standards.

Natural cooling from an average reservoir temperature of 675°F (Figure 26) will require ~1,000 days (~2½ years). Production of liquid hydrocarbons will continue during the initial cooling period, and continue until liquid hydrocarbons are depleted. Cooling rates are affected (increased) by: production of liquid hydrocarbons which removes thermal mass; convection around the reservoir which is assisted by circulation of ambient gases; and absorption of thermal mass by minerals in the surrounding rock, particularly nahcolite and dawsonite which have high heat capacities.

The time required for reservoir cooling can be reduced by adding water to the warm reservoir. At the depths projected for the RDD project, water injected into a reservoir above 200° F will flash to steam if collection is done at a sufficiently low pressure. Hence, a steam collection system consisting of existing piping and surface facilities (separator) will be employed if water is used to cool the reservoir. The reclamation cost estimate anticipates natural cooling over a 2½ year period followed by filling the pyrolyzed and leached volume with water.

6.2.5. Surface Reclamation

Surface reclamation will be completed to return the disturbed site to a beneficial post-mining land use. A synopsis of the surface reclamation plan follows. Details may be found in the Reclamation section of this NOI.

After the reservoir cools, in-well equipment will be removed where feasible, and casings will be cut a minimum of 3 ft below the ground surface level projected after surface grading. Surface equipment not needed for steam recovery and oil water separation may be removed prior to or after decommissioning of the wells. Once all facilities are removed, concrete structures will be crushed on site, rebar will be removed and properly disposed off site, and concrete will be distributed evenly amongst the subsoil. Fill and cuts will be restored to approximate original contours, packed earth will be scarified, topsoil will be re-applied evenly, and the area will be re-seeded with the BLM-approved seed mix of native species.

6.3. Size, Location, Schematics of Structures, Facilities

6.3.1. Surface Facilities Descriptions

Surface facilities (Figure 36) include the buildings, equipment pads, liquids loading and unloading features, electrical infrastructure, tankage, wells, conveyance lines, flare, access infrastructure and other supporting features for the Pilot operation. Additional materials information is provided in the Reclamation Cost Estimate section. All of the operations infrastructure will be inside a security fence (game fence). During operations and reclamation, all access will be controlled by security guards.

For purposes of estimating the reclamation costs, buildings and facilities with concrete foundations are considered permanent structures. These will be constructed on concrete piers with unitized footers and slab-on-grade construction. Buildings subject to product spillage have concrete stem walls for secondary containment and corner sumps for spill collection if necessary. Facilities such as the tank farm that are subject to spillage but not built on concrete floorings will be bermed and covered with artificial liners to house spills. All secondary containment structures will be sized to contain 110% of the holding capacity of the largest holding structure inside that containment structure.

6.3.1.1. Electrical Substation

A high voltage substation, to be installed by Shell, will be placed inside the permit boundary, within the game fence. The substation will power all electric needs. The majority of surface equipment will be used in all phases – leaching, pyrolysis, and cooling – with minor variations in the equipment line-up.

Electrical service lines will be placed above ground on cable trays. Each pipe rack foundation will rest on a concrete footer.

6.3.1.2. Control Building & DCS/MCC

The Distributed Control System (DCS) and the Motor Control Center (MCC) comprise the equipment and controls for the project facilities that occupy ~25 ft x 50 ft space. The DCS generally provides for on-site and remote monitoring and operation by more than one Operator from more than one location.[4] During operations, the DCS will be manned from the Control Room by on-site field operators who will monitor and control the facilities for operational purposes. For research purposes and technical oversight, the facility may be monitored from remote locations by researchers, operators, or others who can be in contact with field operators and other employees and contractors.

6.3.1.3. Heater Shelter

The Heater Shelter will provide a protective shelter for the heater skid for nahcolite leaching. The concrete floor will be tied into stem walls and a corner sump. Shelter foundation is to be 50 ft x 14 ft.

6.3.1.4. Electrical/ Instrument Building (EIB)

The Electrical/ Instrument Building (EIB) will house the transformers and controllers for the downhole electric heaters. Building exterior foundation is to be 40 ft x 20 ft.

6.3.1.5. Separator Building

The Separator Building is to contain two separators discussed above with associated piping and instrumentation. The building will rest on a concrete floor with overflow containment capacity

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[4] Shell has employed a DCS for several years at the Freeze Wall Test (FWT) to monitor activities at that facility.

and a floor collection sump. The dual separators will provide flexibility in operations and testing. The separators will be used during leaching to capture native bitumen from the formation (not from ICP pyrolysis), during pyrolysis to separate the gas, oil and liquid streams, and during reclamation to capture residual gases. The foundation size is 20 ft x 50 ft.

6.3.1.6. Pump Building

The Pump Building will shelter all pumps used in the process. The size is 50 ft x 20 ft.

6.3.1.7. Tank Battery

The Tank Battery is a concrete floored open pad surrounded by a stem wall sized to contain 110% of the largest tank volume. The size is 120 ft x 55 ft.

6.3.1.8. Flare Stack

The Flare Stack will be approximately 50 ft tall x 4 in. diameter with igniters and instruments. The Stack will be set a minimum of 150 ft from facilities, except the flare access road. A negative sloped flare line will run on an elevated line from the separator building to the flare stack.

6.4. Well Construction

6.4.1. General

The RDD Pilot utilizes five types of wells (see well construction diagrams, Figures 31-34):

- Ground water monitoring
- Leach / heater
- Heater
- Producer
- Observer

A set of downgradient ground water monitoring wells (Pad 138-5-298) were drilled in 2009-2010. This pad includes one well each in the Uinta, L7, L6, L5, and L4 hydrostratigraphic units, and monitoring from these wells is ongoing.

Specifications for each well type are discussed in the sections following. Table 6.1 lists the specifications for each well. Specifications listed are intended generally to provide for cement mixes to withstand both the composition (high salinity) and/or sulfate content of the wells plus the temperature fluctuations that will act on the casings and cement. Dimensions provided are for maximum pipe (casing) and drilled well dimensions, and may be decreased if feasible. Annular spaces may vary.

Table 6.1: Well Specifications

	Casing Depths (ft)		Casing Description	Cement Design	Cement Installation Method
HEATER	Surface	60 ft	10¾", 40.5 #, H-40, STC ID:10.05"	Premium Plus + 28.5% SSA-1 11.5ppg	Cement annulus via tremmie pipe
	Intermediate	2,142 ft	7-5/8", 26.4# , J-55, STC ID: 6.969"	Premium Plus + 60% SSA-1 + 5% salt + 0.30% FWCA (11.5ppg Lead, 13.5 ppg Tail)	Mud flush, water flush, cement & displace by one plug system is used to pump cement job. Pump cement to surface.
	Canister	2,257 ft	4½", 11.6#, J-55, LTC. ID:4" + 4½" S-80 + 4", XXH, 347H Canister, Welded	N/A	N/A
LEACH/HEATER	Surface	60 ft	10¾", 40.5 #, H-40, STC	Premium Plus + 28.5% SSA-1 11.5ppg	Cement annulus via tremmie pipe
	Intermediate	2,142 ft	7-5/8", 26.4# , J-55, STC ID: 6.969"	Premium Plus + 60% SSA-1 + 5% salt + 0.30% FWCA (11.5ppg Lead, 13.5 ppg Tail)	Mud flush, water flush, cement and displace by one plug system is used to pump cement job. Pump cement to surface.
	Production	2,257 ft	4½", 11.6#, J-55, LTC. ID:4" + 4½" S-80 + 4", XXH, 347H Canister, Welded	N/A	N/A
PRODUCER	Surface	60 ft	10¾", 40.5 #, H-40, STC	Premium Plus + 28.5% SSA-1 11.5ppg	Cement annulus via tremmie pipe
	Intermediate	2,142 ft	7-5/8", 26.4# , J-55, STC ID: 6.969"	Premium Plus + 60% SSA-1 + 5% salt + 0.30% FWCA (11.5ppg Lead, 13.5 ppg Tail)	Mud flush, water flush, cement & displace by one plug system is used to pump cement job. Pump cement to surface.
	Production	2,320 ft	5½", 23#, L-80, FL4S Liner	N/A	N/A
OBSERVER	Surface	60 ft	7-5/8", 26.4# , J-55, STC ID: 6.969"	Premium Plus + 28.5% SSA-1 11.5ppg	Cement annulus via tremmie pipe
	Intermediate	N/A	N/A	N/A	N/A
	Production	2,280 ft	4½", 11.6#, J-55, LTC ID:4"	Premium Plus + 60% SSA-1 + 5% salt + 0.30% FWCA (11.5ppg Lead, 13.5 ppg Tail)	Mud flush, water flush, cement & displace by one plug system is used to pump cement job. Pump cement to surface.

The project comprises 21 wells for leaching, heating and observation (Figure 24) plus an array of downgradient ground water monitoring wells. Plans call for all wells to be drilled prior to the leaching phase. Wells will be drilled with directional control, with a design deviation from vertical of ~4 ft at 2,000 ft depth (~8 ft diameter). Total depth of the deepest well is projected to be <2,350 ft. The deepest will be the leach well; others will be drilled to ~2,255 ft, and some may be drilled up to 20 ft deeper than their functional depths to accommodate electrical logging tools.

Domestic use water will be transported to the site from outside sources for use in all drilling. This follows Shell's standard drilling methods for drilling in the Piceance Basin. Drilling water typically is supplied from the Meeker public water supply. Cuttings and drilling fluids will be collected in portable tanks (frac tanks[5]) and transported to applicable offsite facilities for permanent disposal. Wells will be drilled with air mist and common water well drilling lubricants.

The leaching and heating zone will include leach, heater, hydrocarbon producer, and observer wells. Some wells will contain pressure or temperature sensors. Each will comprise a conductor casing cemented into shallow bedrock and an intermediate casing set at the top of the leaching and pyrolysis zone and cemented in place.

The heater wells form two hexagonal patterns with maximum diameter of 18.5 ft (Figure 25, Figure 30). Two producer wells flank the central heater (leach) well, and six observation wells will monitor temperature during the heating and pyrolysis phases – three inside the heater pattern and three outside.

Geological conditions at the East RDD are very well informed by the recent drilling of Shell appraisal well 135-4-298 (SAW-1 well) and 5 hydrology wells on the 138-4-298 Pad, which is approximately 500 ft northeast of SAW-1. Ground water is expected at about 250 ft depth, based on the water level in well 135-4-298 (SAW-1 well).

Wells drilled by Shell in the Piceance Basin in the past 10 years generally encountered small amounts of gas, particularly in the deeper formations. The gases contain mostly N_2 and CH_4, with lesser volumes of O_2 and CO_2 (Schatzel et al, 1987 [14]). Hydrogen and ammonia may be present. Samples collected in closed containers for up to 125 days contained up to 0.195 cm^3/g of gas.

A sulfur odor often is detected in drilling of Uinta and some of the shallow Parachute Creek wells. Although LEL (lower explosive limit) measurements are checked at all wells during drilling, and even though methane and sulfur gas occur typically, LELs have never been

[5] Frac tank is the generic term for mobile steel storage tanks used to hold liquids. Their typical use is to hold water or proppant for gas well fracturing – hence the name. Frac tanks typically have 21,000-gallon tank capacity for on-site storage of fluids. Also known as: mobile storage tank, portable tank, Baker Tank, Rhino Tank, Rain-for-Rent Tank, E-Tank, and other names. Double wall tanks can be heated for use in cold climates where regular Frac Tanks freeze.

exceeded. When unusual gas levels are encountered, drilling is shut down and the well is allowed to vent.

6.4.2. Casing Cement Processes

Surface (conductor) casing will be set in cement by placement of cement directly in the annulus of the conductor or by a tremmie pipe. Conductor casing cement will be Type I/II premium plus cement.

Casing in all other wells will be cemented by displacement. With the displacement method, the intermediate casing is installed to TD then lifted a few feet off bottom to create a fluid pathway between the interior and exterior of the casing. Cement is next applied inside the casing and capped with a wiper plug. Water is then added to the column above the plug, providing weight that drives the cement down the casing and up the annulus until cement returns are observed at the surface.

All wells – heater (leaching) and observers – will be cemented with Premium Plus + 60% SSA-1 (with an 11.5 lbs/gallon (ppg) lead, and a 13.5 ppg tail). Once cement returns are observed at the surface, the cement will be allowed to set for the prescribed setting time (usually 8 hours).

A cement bond log will be run in all wells after cementing. The cement bond log is an acoustic geophysical measurement that indicates the presence of cement as a measure of the degree of bonding in the annulus between casing and the drilled hole.

6.4.3. Conductor Casings

Conductor casing will be installed at all wells. Conductors for heater (and leach) holes are 14 in., drilled to 40-60 ft depth (more or less depending on depth to bedrock) and penetrating 3 ft minimum into bedrock.

Conductor casings for the heater (leaching) wells will be 10⅝ in. O.D. (40.5 lbs/ft, H-40 Grade steel, STC). Casing will be cemented from T.D. to surface with type I/II neat cement, placed in the annulus via tremmie pipe.

Conductor casings for the observer wells will be 7⅝ in. O.D. (26.4#, J-55, STC steel casing). These also will be drilled to 40-60 ft depth (more or less depending on depth to bedrock) and will penetrate a minimum of 3 ft into bedrock. Casing will be cemented from TD to surface with type I/II premium plus cement, placed in the annulus via a tremmie pipe.

Conductor casing at the SAW-1 well is installed already under separate permit and separate NOI with the MLRB.

6.4.4. Leach Well

The nahcolite dissolution hole (Figure 31) will be drilled through the TI bed with additional depth to accommodate a sump up to ~50 ft deep. The leach well will later be converted to a heater well and upon conversion will become the center of a hexagon of heater wells. N hcolite leaching will be accomplished by hot water injection via a single tubular and recovery via an adjacent tubular. Depths of the injector and producer tubular will be adjusted periodically to control leaching effectiveness. Potential upward leaching of hot water solutions into the crown will be minimized by a nitrogen blanket, which will be applied at sufficient pressure to inhibit upward movement of the leach fluid.

Drilling will be sequenced as follows. Conductor casing will be installed to ~ 40 - 60 ft depth, as described above, into a 14 in. diameter hole and cemented. A 9⅞ in. hole will be drilled to the top of the leaching and pyrolysis zone; 7⅝ in. casing (26.4#, J-55, LTC) will be placed inside and cemented by displacement to the surface.

The leach well will then be drilled through the base of the TI bed (~2,273 ft), deeper than the heater wells, with additional footage to accommodate logging tools and a cleanout sump. Within this casing, two sets of ~2⅜ in. tubulars will be installed; one set to near the base of the TI bed; the other placed approximately mid-way between the casing shoe and top of TI bed.

Leaching fluids will be injected via the shorter tubular and recovered (pumped) from the longer tubular.

6.4.5. *Heater Wells*

Twelve heater wells will encircle the single leaching / heater well in the center of the heater pattern (Figure 25). The Heater well construction (Figure 32) is similar to the dissolution well, but with the addition of a thick wall sealed canister to contain the heater. (The central leach well will be converted to a heater well after leaching.) A packer will be placed inside the casing, just above the shoe so that the well will remain sealed below the packer and shoe.

6.4.6. *Producer Wells*

Producer wells (Figure 33) include a 9⅞ in. hole drilled inside the surface casing to top of the heater zone with a 6½ in. open well below with a 5½ in. slotted liner for oil production drilled to TD. The 9⅞ in. hole is cased with 7⅝ in. 26.4# K-55 LTC casing and cemented to surface by cement displacement. A slotted liner will be hung from a liner hanger just above the base the shoe. The 2 ⅜ in. production tubing with an insert pump at the base will be placed in the open hole to near the base of slotted liner, ~ 42 ft above TD. Two strands of ⅛ in. capillary pressure tubes and a wired sensor will be attached to the 2⅜ in. tubing. A diluent string will be strapped also to the producer string.

6.4.7. *Observer Wells*

Observer wells (Figure 34) will consist of 4½ in. O.D., 11.6#, J-55, LTC casing, cemented to surface, inside 7⅝ in. 26.4#, J-55 STC conductor casing. The observer well 4½ in. casings will be sealed at the base. Casings may be fit with any of an array of instrumentation to measure temperature, pressure or geomechanical stresses.

6.4.8. Cuttings and Drill Water Disposal

Cuttings and drill fluids will be routed to and captured by a "shale shaker" where fluids and cuttings will be segregated and cuttings transported off-site for proper disposal. Drilling fluid, which consists of domestic water mixed with formation water, will report to an unlined pit, under BLM and DRMS approvals.

6.5. Development Methods, In Situ Methodology

6.5.1. Operational Phases and Timeline

The East RDD Pilot will span ~ 6½ to 10 years, more or less depending on leaching progress, pyrolysis, and cooling time. Projected project initiation date may be extended depending on the time needed for permitting (Figure 2). The minimum assumes all permitting is approved by 2012; the maximum presumes longer.

6.5.1.1. Construction and Leaching Phase

The initial drilling and primary construction phase requires ~ 8-10 months. This phase entails drilling of all wells plus construction of all the fluid heating, pumping, and product recovery units. Grading, drainage, road, and most building construction will take place during this initial construction phase.

Nahcolite leaching is expected to take ~8 - 16 months: longer if the target leach rate is lower than expected or if operational issues arise. During the leaching and recovery phase, construction outside the leach and heating well pattern will commence.

Part of the construction to support the heating phase may commence during the leaching phase. Additional time will be needed after the leaching phase to convert the leach well to a heater well, to mount the heaters, and to convert nahcolite solution collection trains to produced water collection from the separator. This construction period is anticipated to take about 6 months after leaching.

6.5.1.2. Heating Phase

Heating of the 13 heater wells is expected to require ~ 2-years. Heating will be turned off after ~75% of the pyrolysis phase has passed. Heat flow will continue from the high temperature region near the heaters to the lower temperature regions after the heaters are off, enabling pyrolysis effects to reach the entire target resource.

6.5.1.3. Cooling Phase

Two options are discussed for the cooling phase: natural cooling and water assisted cooling. Natural cooling is modeled to require approximately 1,000 days, while water assisted cooling may take 300 to 450 days, more or less depending on when water injection is initiated (Figure 26). The timelines (Figure 2) assume water assisted cooling.

In the initial part of the cooling phase, some time will be required to retrofit several wells, and activate the steam collection facilities. Facilities constructed and used in earlier phases will be reactivated.

6.5.2. Development Methods

In selecting a zone to leach and pyrolyze, Shell evaluated geological features of the leach/heater zone and of the crown above the leach/heater zone. The purpose of the leach/heater zone selection is to assure isolation between the leach/heater zone and water-bearing intervals above the crown. This evaluation considered the following:

a. operating conditions
b. crown composition: i.e. thickness and composition of unleached rock between the leach/pyrolysis zone and overlying water-bearing zone; presence of fractures or faults; leaching potential
c. fracture generation potential during production: i.e. potential for the formation of leaching-induced fractures or heating-induced fractures in the crown and in laterally adjacent rock
d. heat induced changes of minerals in the crown: i.e. possible change in structural strength due to heat-induced breakdown of nahcolite especially in the lower crown above heated zone
e. static geomechanical conditions
f. production-induced changes in geomechanical conditions: geomechanical stresses induced by leaching and mass removal and those induced by heating and potential softening of the formation above the leach/pyrolysis zone.

Fresh water for leaching will be trucked to the site. The water will heated to ~ 350-400°F using surface heating facilities, then injected into the leach well and produced to the surface. Some heat loss will occur in transit; the intent is to attain an average reservoir temperature of ~300°F for leaching.[6] Leach progress will be monitored with temperature sensors in the observer wells and pressure sensors in the outer ring of heater wells.

As nahcolite solution moves up the well during production, there is a potential for clogging due to precipitation of nahcolite because of cooling and the pressure decrease in transit. Nahcolite precipitation will be controlled by maintaining concentrations below 15 wt% $NaHCO_3$ (well below nahcolite saturation, which is approximately 30 wt%). Solution concentrations will be monitored regularly at the surface by collecting solution from a bleed valve, measuring conductivity, and deriving TDS concentration by comparison with a pre-determined relationship between conductivity and TDS.

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[6] The maximum temperature of 300°F, which is listed in the Commercial Nahcolite Lease, is meant to conserve oil shale resources in that lease. However, the RDD Lease for Oil Shale overrides the temperature limit as the RDD Project anticipates higher temperatures for pyrolysis, and the lease requires the recovery of both hydrocarbons and nahcolite.

The operating conditions for leaching are: (a) water injection temperature of 350°F, (b) average reservoir temperature of ~300°F, (c) reservoir pressure of ~1,310 psig, (d) water circulation rate of ~500 bwpd, (e) nahcolite concentration of the injected water not to exceed 3-4 wt%, and (f) nahcolite concentration of the return (produced) water not to exceed 15 wt%. Part of the produced water will be mixed with fresh water, so the overall production and off-site trucking of solution is expected to be approximately 350 bpd.

Hot water injected into the formation will contact nahcolite in the well and is expected to dissolve nahcolite mostly from the TI Bed. As solution circulates in the open hole, nahcolite in other units is expected to dissolve, and the pregnant solution will be produced through the other deeper tubular. The leach well design accommodates vertical movement of the injection in recovery tubes to effect better leaching.

The potential for upward migration of leach fluid through the crown will be controlled to prevent movement of high TDS solutions into overlying water bearing zones. Upward penetration of the leach fluids will be eliminated by a combination of factors including: (a) composition of strata above the proposed leach zone, which is self-limiting because it does not transmit fractures; (b) well installations and testing, which assure proper and verifiable cementing of all casings that pass through the crown; (c) application of a nitrogen blanket inside the leach well casing and upper part of the leach zone, which will hold leach solutions in the zone below the nitrogen blanket; and (d) pressure controls the leach fluid, which will be held to values below the fracture gradient. These features are clarified in the following paragraphs.

Strata above the Greeno Bed are part of the kerogen-rich R4 unit, which contains less nahcolite than the leach target interval of the Saline Zone. As a result, the potential formation of permeable channels by nahcolite leaching is limited by the low percentage of nahcolite in the supra-Greeno units and the absence of nahcolite to nahcolite connections.

Annular cement between the well and the casing further limits upward fluid migration and escape. Once each casing is installed to the top of the eventual leach/pyrolysis zone, and after the casing is cemented, a cement bond log will be run and inspected to assure acceptable placement of the cement. Unacceptable cement jobs will be remedied using standard practices. During operations, a nitrogen blanket will applied to the annular space between the well casing and the solution injection and recovery tubes. Nitrogen pressure will be monitored continuously to assure that the nitrogen pressure exceeds formation pressure, such that the leach fluids will move up the return tubing, rather than into the overlying crown. The nitrogen blanket will preclude contact between the circulating solution and the top of the leach reservoir, further limiting the upward migration of solution and possible penetration along the wellbore.

Nitrogen pressures and formation pressures will be monitored and controlled to remain well below the fracture gradient, which is 0.7 psi/ft. The fracture gradient estimates the pressure at each depth that would need to be applied in order to fracture the rock.

Natural fractures in the crown above the leach zone are limited to brittle units. Marlstone units are brittle, and therefore subject to fracturing, while kerogen-rich R zones are resistant to fracturing. This includes the R4 zone which makes up part of the crown. Unlike the high abundance of brittle minerals in marlstone, kerogen has a high organic content, is malleable, and thus tends not to transmit fractures.

Extensive fracture investigations conducted of cores around the East RDD Pilot show very few natural fractures. Detailed visual logs of the cores plus an array of geophysical logs and down hole video logs all fail to detect fracturing or faulting in the kerogen rich units. Fractures do occur in the marlstone rich layers, which are much more brittle. However, the crown is composed of more kerogen-rich rock than marlstone.

The space produced by nahcolite dissolution is projected to be up to ~120 ft in height, with preferential leaching forming a disc-shaped leach zone in the most readily leachable beds (the TI and Greeno beds, plus other thinner nahcolite rich beds having high leachability characteristics). If the leaching front in the TI and Greeno beds migrates preferentially along some preferred direction, the leaching front will be more elliptical. Units immediately above the TI, Greeno, and other highly leachable beds may sag into the open voids created by leaching, and minor brecciation may occur in these beds. The geometry of leached mass will be affected by the variable rates of nahcolite dissolution, which depends on nahcolite richness, morphology, and connectivity between nahcolite segregations. Nahcolite rich layers that are most susceptible to leaching will have larger leach radii than nahcolite poor layers, and leachable layers that best come into contact with the leach solutions will of course leach fastest and have the largest amount of lateral penetration.

The heating volume likely will be more uniform than the leached volume as heat will move through the area more uniformly than the leach water. The principle heat transfer mechanism is conduction. Thermal conductivities of the various minerals are similar, and laterally the layers are compositionally uniform; alternating nahcolitic and marlstone layers are continuous over several miles within the basin. Heating temperatures will increase uniformly and rapidly inside the heating pattern because of superposition of the many heaters; temperatures will increase relatively slowly outside the pattern because of the lack of superposition. The slight differences in thermal conductivities of the major phases – nahcolite, kerogen and dolomite marlstone – will have a minor effect on the radius of heating: heat transfer in kerogen for instance will be less than in marlstone by ~1 ft.

Residual nahcolite inside the heater pattern will convert above ~350°F to soda ash (Na_2CO_3), and give off water (steam) and CO_2[7]. Initially, kerogen will swell as bitumen is generated during the early, lower temperature phase of pyrolysis. With further heating, kerogen conversion will release water and liquid hydrocarbons. The overall geometry of the mass created by the conversions of nahcolite to soda ash and kerogen to hydrocarbons is projected to be a cylinder of ~20 ft radius and less than the heater height, which is 112 ft.

Conservative geomechanics modeling (Appendix A) was conducted to assess integrity of the crown above the leached and pyrolyzed volume, and to assess the risks to containment integrity. The risks for containment integrity include potential for active failure and for passive failure: (1)

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[7] Steam and CO_2 will report to the gas phase of the separator, at surface where steam will cool to water and CO_2 will be vented.

unacceptably high injection pressure during the leaching phase, which could fracture the formation and lead to *active* failure and (2) materials weakened by heating during the pyrolysis phase, which may induce tensile and shear failure in the cavern roof and wall, thus leading to *passive* failure.

The active failure risk for containment during leaching is alleviated by limiting the operating pressure below the fracture gradient of the formation. Fracture gradients have been determined by in-situ stress measurement from several sources (Bredehoeft et al 1976 [5], Prats et al 1976 [12], Maxwell 1982 [10], and Ramsey et al 2008 [13]). These indicate that the value of 0.7 psi/ft will be adequate as the upper operating pressure limit.

To assess the potential of passive failure of cavern roof and wall in the pyrolysis phase, a systematic approach that included laboratory testing, analytical estimate of material properties, and numerical modeling was adopted. The crown pillar ~20 ft thick is required to sustain the rock load above a void of the assumed shape (see Appendix A – Geomechanics). Rock up to about 10 ft above the "void" will be in tension (i.e., stress greater than zero) while rock up to about 20 ft above will show shear failure (Appendix A, Figures A-2 and A-3). Owing to the thick crown (~100-130 ft) above the pyrolyzed volume, a competent roof will be maintained above the volume generated by leaching and pyrolysis.

Progress of horizontal leaching is monitored by pressure in the heater wells, especially in the outermost heater wells. Water levels in the heater wells initially will be at the level left by drilling. The leach well will be essentially filled with water to the surface, and pressure will be applied to move leach fluids to the surface, so the leaching well pressure will be higher than the heater wells. As leaching progresses laterally and breakthrough occurs – i.e. when the leach well connects horizontally with each heater well – pressures in the wells will increase as each connects with higher pressure water from the leach well. Several heater wells will be monitored and once an adequate array of wells shows connectivity with the leach well, leaching and circulation will be cut off.

Fresh water injection will commence with cold water to assure proper circulation within the leach well, and then will be followed by injection and circulation of hot water (Figure 7). Once the reservoir is fully conditioned, water heated to ~ 350°F at the surface will be injected to attain and maintain an eventual average reservoir water temperature of ~ 300°F. Well instrumentation will include surface temperature and pressure gauges, thermocouples on the casing string, and downhole pressure monitoring gauges in selected wells, and nitrogen pressure will be monitored at the surface in the leach well.

Other wells will be instrumented with pressure and/or temperature gauges, depending on the well functions and monitoring needs. During leaching and before pyrolysis, several of the outermost heater wells in the pattern will be used to monitor pressure, which will gauge breakthrough between the leach well and the monitored heater wells. After leaching to the ±20 ft radius, heater canisters and heaters will be installed in the heater wells and the leach well. Several heaters will be instrumented with a travelling thermocouple tube between the heater canisters and wellbore. Heaters will be activated from the surface with electrical power supplied via the high voltage substation.

The in situ heaters consist of mineral insulated (MI) cables attached to an electric cable and inserted into a thick metal canister traversing the heater zone. The MI cable is similar to an electric stove burner: mineral insulation outside the cable (the burner) does not deliver an electric shock, but does heat upon application of an electric current. Electricity for the heaters will be supplied through electric power purchased commercially.

The leach well will be recompleted as a heater. The two producer wells will be completed with slotted liners. Producers will be instrumented with temperature and pressure gauges on the production string as well as in the annulus. Oil production via conventional insert rod pumps will commence once pyrolysis temperatures indicate adequate pyrolysis. Gases will be recovered at the surface from the oil/gas/water separator, and hydrocarbon gases will be flared.

If water cooling is selected for subsurface reclamation, the cooling phase will involve recompleting several outside observers as injection wells by downhole perforation. These will be instrumented with surface flow meters, temperature gauges and pressure gauges.

One rig is intended to drill the wells sequentially, with ~21 days for the leach well, ~13 days for each heater well, and ~8 days for each observer well. Each rig has a crew of 4 persons / tour. At 2 tours/day and additional directional hands, a supervisor, and well site personnel, the complete crew will total 10 workers/day. The crew will work a 14 days on / 14 days off schedule. The crews for the pyrolysis completion phase will run 7 /tour, 2 tours/day, 14 days on / 14 days off. The project anticipates ~7 days/well for a total of ~133 days to change out the well heads and install heaters. The reclamation crews should run several workers per tour at 2 tours / day on a 14-on / 14-off schedule. These crews will be housed at Shell's Corral Gulch temporary living quarters.

There are no mining features on or near the proposed RDD Pilot. Existing man-made structures including an existing gas well pad within 200 ft of the project are described in Section 3.3.

6.5.3. *Production Monitoring*

Leaching will be conducted at slightly elevated pressures relative to formation pressure, in order to produce nahcolite solution to the surface. Pressure will be continuously monitored and controlled to preclude fracturing that could promote fluid migration out of the formation. Pressure increases that raise the chance for fracturing of the crown, or decreases in pressure that may indicate unexpected open space collapse, will be investigated and assessed immediately upon detection, and leaching will be curtailed if warranted by the assessment. Pressures will be maintained below the fracture gradient, which is interpreted conservatively to be 0.7 psi/ft.

Solution composition (TDS) measured at the well head and down hole temperature measured in the observation wells will be monitored to assess leaching progress. Once the progression of leaching reaches the target radius, leaching will be discontinued, or the "fresh" water injection point will be raised to a shallower rich nahcolite unit in order to best affect leaching progress. A linear to near linear relation between TDS and conductivity will be established for the leach well so that conductivity can be measured simply and frequently.

During pyrolysis, temperature will be monitored periodically and pressure will be monitored continuously. Temperature will be monitored periodically with traveling thermocouples in the observation wells. Pressure will be monitored continuously via the instrumentation in the production wells.

Pressure will be controlled by the gas production rate. Gas buildup in the reservoir would yield high sustained pressure and likely would build up by lack of production during the pyrolysis phase. The design includes a second producer to serve as a backup to provide continuous production during maintenance shutdowns and also for troubleshooting. If uncorrectable production problems develop in both producer wells, which would be an extreme condition, the heaters will be turned off. Such a condition should provide ample warning as the array of pressure and temperature sensors throughout the field provide real-time continuous monitoring of all portions of the heating and production systems.

7. RECLAMATION

7.1. Surface Reclamation Plan

7.1.1. Decommissioning of Facilities

Surface facilities associated with the East Pilot will be removed when no longer needed to support the reclamation efforts. All chemicals will be removed from the site and properly disposed. Any remaining product and wastes will be removed as well; wastes will be disposed off-site and product will be shipped for additional treatment. Storage tanks for waste and product will be triple rinsed prior to removal with the rinse water removed from the site and properly disposed. Facilities equipment will be removed for disposal or reuse, followed by demolition of buildings and other project-related structures. Concrete building foundations will be broken up and buried on-site to a minimum depth of 3 ft. below final surface grade. Rebar and demolished building materials will be hauled to a licensed landfill facility.

7.1.2. Final Regrading

Following completion of demolition of the facilities, land reclamation will begin. Soils around the above ground petroleum product storage tanks will be visually inspected for evidence of petroleum contamination and removed to licensed facilities if necessary. Existing sediment control structures will control erosion and contain runoff and sediment within the project area during reclamation. Using typical earthmoving equipment, the disturbed area will be regraded to blend into surrounding pre-construction contours. Earthmoving should be limited based upon the minimal amount of cut/fill work needed to establish the facilities areas during site development work. Regraded surfaces will be ripped to 18 inches depth to alleviate excess compaction and provide a better bond between regraded overburden and replaced topsoil.

7.1.3. Soil Replacement

Once disturbed areas have been regraded and ripped, soil material salvaged and stockpiled during site development will be evenly redistributed over disturbed areas. Redistributed soil will then be tested to determine if amendments are necessary to ensure successful establishment of planted species. Fertilizer and other appropriate amendments, if needed, will be applied after soil placement.

7.1.4. Revegetation

Following soil replacement work, disturbed areas will be revegetated with seed mixes recommended in the BLM Resource Management Plan modified based upon site-specific data obtained during the baseline vegetation survey. To ensure the seed mixes are free of noxious weed species, Shell adheres to BLM Instruction Memorandum No. 2006-073 entitled "Weed-Free Seed Use on Lands Administered by the BLM". Seed material will be certified weed-free and purchased from and blended by qualified producers and dealers.

Prior to seeding, areas to be revegetated will be scarified to provide an adequate seedbed. Seed will be drilled or broadcasted. Drill seeding will be used where the machinery can be operated safely and where soil characteristics and slope allow effective operation of a rangeland seed drill. Drill rows will be oriented perpendicular to the slope in areas where such operations can be done with an adequate margin of safety. Drilled seed will be placed at an average depth of 0.5 inch. For broadcast seeding, seed will be applied uniformly over disturbed areas using typical broadcast seeding equipment. Broadcast application rates will be twice that of drill seeding rates, and areas seeded by broadcasting will be uniformly raked, chained, dragged, or cultipacked to incorporate seed to a sufficient seeding depth.

Once the seed has been applied, straw mulch will be spread and crimped over the seed or hydromulch will be spread over seeded areas using a hydromulcher. Seeding will occur in the fall with the early spring serving as an alternative should fall seeding not be completed. Following completion of seeding, woody debris cleared during initial construction will be pulled back over revegetated areas to provide wildlife habitat, protect seedlings, and to serve as flow deflectors and sediment traps for erosion control. Redistribution of woody debris will be limited to no more than 20% of total ground cover in order to meet BLM fire management objectives.

The vegetative habitat occupying the native area that will be disturbed is suited for upland drainage. The mix includes native grasses and shrubs. The two dominant plant communities in the area are sagebrush grassland and pinyon/juniper woodlands. However, pinyon/juniper woodlands are not present in the proposed disturbed area.

Table 7.1: Upland Drainage Community Seed Mix

Species of Plant	Variety	Pure Live Seed (lbs/acre)
Western wheatgrass	Rosanna	2
Needle and thread	na[1]	2
Thickspike wheatgrass	Critana	2
Indian ricegrass	Nespar	2
Sand dropseed	na	1
Slender wheatgrass	Pryor	1
Basin wildrye	Magnar	1
Basin big sagebrush	na	2
Rubber rabbitbrush	na	1
Greasewood	na	1
Prostrate alfalfa	na	2

Note: [1] – na means "not applicable"

Following reclamation, vehicle traffic will be restricted over the area. Some limited travel may be required to conduct post reclamation monitoring of vegetation, potential subsidence, and ground water monitoring wells. The revegetated areas will be monitored for the first two years to evaluate the need for supplemental seeding and noxious weed control. Recontouring, reseeding, or other appropriate measures will address areas of erosion in the revegetated areas. Noxious weed control will occur through the use of BLM recommended procedures based on the amount and type of noxious weed present. Erosion control measures will be maintained until establishment of permanent self-sustaining groundcover of the native species specified in the seed mix (Table 7.1).

7.1.5. Management of Non-Native, Invasive Plant Species

Prior to construction, Shell will conduct a field survey to identify noxious weeds and/or other undesirable plant species within the 149 acre Permit area. Shell recognizes that areas within the 149 acre Permit boundary and the access road have been disturbed significantly by other lessees, notably for construction of pipelines and a flow line, and the CSU revegetation test plots. In addition, part of the 149 acre RDD lease is subject to grazing leases. Based on the results of the plant survey, the overlapping leases and prior disturbance, Shell will develop a treatment strategy in consultation with the BLM and the Rio Blanco County Weed Agent. Shell expects to manage weeds on all lands disturbed by Shell and by the CSU vegetation plots.

Areas disturbed by construction will be monitored for the presence of noxious or undesirable plant species and any identified infestations will be adequately controlled and/or eradicated using materials and methods approved in advance by the BLM Authorized Officer. Vehicles and equipment used for project-related activities will be required to arrive at the site clean and free of soil and vegetative debris capable of transporting weed seeds or other propagules. Interim seeding of disturbed areas will be conducted where practicable in order to prevent introduction/expansion of noxious weed infestations.

7.2. Subsurface Reclamation Plan

Upon completion of pyrolysis and recovery of liquid hydrocarbons, the pyrolyzed zone will be allowed to cool, naturally, or more quickly by injection of water. Subsurface reclamation will be considered complete once the average temperature in the reservoir falls below 200°F, and the reservoir is filled with water. Once cooled and water filled, a metal bridge plug will be placed in each well just above the pyrolyzed reservoir, and the wells will be cemented from the bridge plug to approximately 3 ft below the ultimate reclaimed ground surface. Well casings will then be cut 3 ft or more below final ground surface; monumented with a brass marker placed in the cement at the top, and covered with soil.

7.2.1. Natural Cooling Option

Natural cooling from an average reservoir temperature of 675°F (Figure 35) may require ~1,000 days (~2½ years). At the start of such reclamation, the pyrolyzed reservoir will be dry and permeable. Reservoir surfaces will be coated with chemically immobile, carbonized hydrocarbons (coke or char); boundaries of the reservoir may contain a skin of immobile tar-like bitumen. Because rock encasing the pyrolyzed reservoir is impermeable, bitumen and associated hydrocarbons will be entombed and unable to reach water bearing zones.

After the reservoir is cooled below steam temperatures, water will be injected to fill all the void spaces. Considering the variations in nahcolite and FA grades of the affected volume, it is estimated that 8,000 bbls of water will be necessary to fill the pore spaces generated by the leaching, pyrolysis and hydrocarbon production. Void volumes will vary by layer, depending on the FA and nahcolite grades; the highest porosity could be ~ 38%.

7.2.2. Water Cooling Option

Although the preferred subsurface reclamation plan calls for natural cooling, a water cooling option is described, and models are provided, to demonstrate the means of water-assisted cooling. The time required for reservoir cooling can be reduced by adding water to the warm reservoir. At the depths projected for the RDD project, water injected into a hot reservoir may flash to steam depending on reservoir temperature and pressure. If water is used to cool the reservoir, steam will be collected using the existing equipment – i.e., piping, separator, and tankage. This system also will collect residual volatile organic compounds that travel with the steam. The steam and organics thus collected will be cooled and routed to a separator where organic vapors will be separated from water and liquid hydrocarbons and the gases will be flared.

To exercise the water cooling option, some of the existing wells will be converted to water injection wells, others to steam recovery wells, and the unused wells will be plugged. The cooling rates (Figure 35) assume two water injection wells and five recovery wells. Additional recovery wells could lower the cooling time by adding steam recovery capacity.

The rate of water-assisted cooling is limited by the rate at which steam / hot water can be produced from the hot reservoir. As reservoir pressure is to be maintained below the fracture gradient, the water injection rate will be limited by the number and size of conduits (open wells) between the reservoir and surface. Considering those limits, it is anticipated that water can be injected into the reservoir by two injectors at ~2 gallons per minute, provided steam is recovered through two steam recovery wells.

8. ADDITIONAL TESTING OPTIONS

8.1. Optional Tests

An array of optional tests is proposed for the East RDD property. Some are considered maintenance or operational items that do not require specific permit approval or reclamation bond. The others are options that require more advanced plans to be described in revisions to the Plan of Development. None of these optional tests are included in the Reclamation Cost Estimate, but will be bonded if implemented.

Optional tests that should not require additional NOI or other permit approval or reclamation bond:

1. Post-pyrolysis coring
2. Multiple year operation of a commercial prototype heater, including troubleshooting, repair, and possible replacement
3. Installation of new or replacement surface equipment as required to operate heater well(s), producer wells(s), and/or leaching wells. Such equipment will be installed on existing platforms, unless covered under a NOI amendment.

Optional tests that will require future permitting include

1. Additional nahcolite leaching to be conducted at other locations on the RDD to test perm/porosity development and nahcolite recovery efficiency under a variety of pressure and temperature ranges
2. Horizontal or vertical well drilling within the commercial target interval (for heater deployment, producer deployment, or testing of advance leaching concepts)
3. Deployment of a commercial prototype heater (horizontal or vertical) within commercial target interval
4. Deployment of a commercial prototype production piping and production equipment (horizontal or vertical) within the commercial target interval
5. Multiple year operation of a commercial prototype production well, including troubleshooting, repair, and possible replacement.
6. Deployment of advanced leaching technology inside horizontal or vertical well
7. Continued operation of the surface facilities equipment installed for East RDD for the purpose of handling the production from the above mentioned tests.
8. Injection of other fluids post-leach to test efficacy of alumina production from dawsonite

9. SITE SAFETY AND EMERGENCY RESPONSE

9.1. General Procedures

Shell will operate the existing office, temporary living quarters, warehouse, and storage yard facilities, which are on Shell-owned properties in the vicinity. Access to facilities including the East RDD facilities will be controlled, and access will be limited to personnel with appropriate safety training and equipment.

Shell maintains regular training on personal protection, personal safety, site security, and environmental protections. Shell will staff the operation with medically trained first responders and first aid facilities. Personal protective equipment (PPE) is required according to job and facility needs. Field and operations personnel are required to wear steel-toed shoes/boots, sleeved shirts, long pants, and hard hats, at a minimum, and eye and hearing protection are required in specific areas. Fire retardant clothing (FRC) may be required in hydrocarbon producing facility areas.

9.2. Fire Response Plan

9.2.1. General Fire Response

Shell maintains limited fire response and fire fighting capabilities as explained in the following. Basically, personnel are equipped to only fight incipient stage fires if in their judgment this can be done without injury to themselves or others.

Personnel may use fire extinguishers to try and extinguish small, incipient stage fires if in their judgment this can be done without injury to themselves or others.

- CO_2 extinguishers will be used on electrical fires
- Dry chemical extinguishers will be used on oil fires

In the case of a larger fire, personnel will:

- Notify the local fire department (Dial 911)
- Protect and/or evacuate on-site personnel
- Notify Field Supervisor
- Monitor the fire and secure the area

9.2.2. Forest or Brush Fire

The East RDD Pilot is in a region of mostly native shrubs and grasses with sparse pinyon and juniper located mostly in drainages and on north-facing slopes. Weeds are monitored and controlled at all Shell sites in the Piceance Basin, with at least yearly spraying or removal at all sites when weeds are found. Active weed management program at all sites minimizes the need for fire controls to accommodate dry weeds. Shell's existing weed management program will be expanded to include the East RDD Pilot area.

The potential for brush, range, or forest fires is assessed based on the density and type of local vegetation. Shell maintains the ability to respond to small fires that can be managed with light duty hand held equipment. Shell is not equipped to fight range fires, large operations fires, or building fires that cannot be addressed safely and adequately with hand held equipment.

In the case of larger fires, Shell procedures are to assess the nature of the fire, notify site personnel via 2-way radio, muster at pre-selected muster points, account for all personnel, notify the BLM, activate 911, and monitor or evacuate as appropriate. The following is taken from Shell's Emergency Response Plan regarding range fires.

The main concern is actions to take if wildfire threatens a facility, possibly cutting off normal egress routes. General consensus from forest fire experts is that getting out of the area is the best option as smoke and heat could be very intense. If the emergency occurred at night, the escape route might not be obvious. If a fire approaches from a north to south direction, it might be difficult to drive out on the main road. A color-coded map has been provided to operations personnel to indicate escape routes. If time permits, personnel should contact local authorities to advise of fire and indicate which evacuation route will be taken. This will allow rescuers to follow up in locating persons attempting to evacuate the site. If possible, take cell phones and/or portable radios along in each vehicle so communication can be maintained in the group.

Brush hogging shall be done during fire season months to keep vegetation cut around the complex. Mowing will be maintained around the emergency power generator equipment for a minimum distance of 100 ft. Dead, dry grass should be kept mowed to less than 6 inches.

9.3. Oil Spill Response

A Spill Prevention, Control and Countermeasures (SPCC) Plan as set out by the EPA is on file with BLM and maintained at the MRP site, and is not included here. This plan will be updated for site purposes to cover the East RDD Pilot. Copies of the revised SPCC will be available on request.

9.4. Medical Response, Medical Evacuation Plan

The East RDD Project will have the ability to provide First Aid, First Responder, and Ambulance transport in case of an emergency. A helipad is located at the Shell Administration Building, approximately ½ mile east of the RDD site. The roads between are improved county dirt roads that are maintained year round.

Shell presently has on site three emergency medical technicians (EMT). During operations at the East RDD Project, Shell will have on site at least one EMT per shift and provide coverage during 24 hour operations. In-house HSE (Health, Safety, and Environment) technicians will be on site during all periods or operation.

Shell EMTs at the MRP facilities are members of the Meeker Volunteer Fire Department. EMTs have First Responder status and maintain certifications through the Meeker VFD and Shell training. Most site personnel have first aid training. Shell EMTs and the Meeker VFD maintain 2-way radio contact with O&G operators and other operators in the vicinity including Encana, ExxonMobil, and others. These companies and the Meeker VFD maintain individual facilities, and are on call to share facilities and responsibility for emergency response.

Shell maintains an on-site ambulance, and a first responder truck which has transport capabilities. The ambulance, which is maintained by Shell, is owned by the City of Meeker. Local Meeker VFD affiliates also have ambulance capabilities.

10. OTHER ISSUES

10.1. Temporary Abandonment Procedures

Temporary abandonment is not anticipated. As the project is a research operation, it is not designed to respond to market conditions that might otherwise call for temporary abandonment. Leaching operations can be shut in at any point by, for instance, cessation of hot water circulation during leaching or turning off the heaters during pyrolysis. Oil shale pyrolysis, however, will continue for some time after heaters are turned; heat applied to the formation will continue to break down kerogen to form hydrocarbon gases and liquids, so some amount of production and monitoring will need to remain in place following cessation of heating. The amount of time necessary for such continued monitoring and production will depend on the amount of heat applied up to the point when heaters are turned off, production rates, and other factors that can remove heat from the formations affected by the heaters.

10.2. Treatment

There will be no on-site or off-site treatment of leach solutions, oil or gas, recovered ground water or water injected for leaching.

10.3. Control of Process Solutions and Hydrocarbon Products

Produced liquids, including nahcolite solution and hydrocarbon liquids, will be trucked to appropriate facilities off site. Gases will be flared. Loading of tanker trucks for fluid transport will take place on concrete pads that drain to a collection sump. Spills on these pads, if any, will be removed/recovered from the sumps and trucked off site to appropriate disposal facilities.

10.4. Injection

Fresh water will be trucked to the Project Site and heated for injection to leach nahcolite. Injection will take place under a UIC permit issued by EPA Region VIII.

10.5. Subsidence

Owing to the significant depth and small diameter of the leached and pyrolyzed volume, surface subsidence at the East RDD Pilot is not anticipated.

Conservative geomechanics modeling, which analyzed the stress field above a 40 ft diameter open cavern, indicates that tensional effects will be observed no higher than about 10 ft above the cavern, and total stress induced by a theoretical cavern of 20 ft radius will diminish to nil above about 40 ft above the cavern. (See section Geomechanics, Appendix A).[8] Therefore, surface subsidence monitoring is not planned. Subsidence in the crown will be monitored via radioactive tags.

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[8] Surface subsidence at a similar sized project that was only about 450 ft deep, the MDP[s] on Shell land near Cathedral bluffs, was less than 1 mm.

10.6. Surface Water Pollution Control

The Project site rests atop a local hill, approximately 3 miles from the Stake Springs Draw. Except for rare springs, Stake Springs Draw is dry except during spring snow melt. All surface facilities are designed to contain fluids at the surface for later off site trucking. In the event of a spill or loss of tank containment – the only containment anticipated – the ability for pollutants to reach a stream is not feasible given the overland distance such fluids would have to travel, and the maximum volumes that may be contained on site ready for off-site trucking at any time.

10.7. Natural Resources Protections

Natural resources of the RDD area include ground and surface water, geological resources including sodium minerals and oil shale adjacent to the RDD lease, gas resources beneath the RDD Project target horizons, topsoil, and rangeland vegetation. The operations, geology and resources sections, and reclamation sections describe measures to protect these resources. Subsurface extraction and pyrolysis processes are confined and contained within the target interval. Subsurface reclamation plans provide for closure and containment of the mined (leached and pyrolyzed) interval. Natural gas resources are several thousand feet below the oil shale and sodium mineral resources, sufficiently distant from effects or leaching and pyrolysis. Surface reclamation will replace topsoil, restore drainage, and return the surface to a rangeland habitat, with fencing to remain until reclamation revegetation is self-sustaining.

10.8. Other Permits

Shell will file, or has already received, several permits related to the East RDD Pilot Project. The BLM Access and RBC Driveway Permits are approved. Ground water monitoring well permits also are in place, and monitoring in ongoing.

Several major permit applications and notices are to be filed in late December 2010 to early January 2011. These include the POD, NOI, Air Quality Construction Permit, UIC permit and Rio Blanco County Special Use Permit.

Additional permits covering transport, road use, construction will be submitted as construction and transportation needs are fully known, and after the major permits have been reviewed by the agencies and adjustments are made based on the agency reviews.

An existing occupancy permit for the Corral Gulch Temporary Living Quarters will be reactivated to accommodate construction.

A number of environmental plans, surveys, and studies accompany the BLM Plan of Development. Environmental update studies will be conducted in 2011 as a condition of POD approval.

An entire list of the required permits, plans, notices, and studies associated with the East RDD Pilot are provided in the table following (Table 11.1).

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