EPA REGION 8'S RESPONSE TO PETITION FOR REVIEW

ATTACHMENT T

Powertech, 2013, UIC Class III Permit Application
Permit Application, 7520-6 Form and Report

Administrative Record Document No. 238

OMB No. 2040-0042 Approval Expires 12/31/2011

EPA

United States Environmental Protection Agency

Underground Injection Control
Permit Application

(Collected under the authority of the Safe Drinking Water Act. Sections 1421, 1422, 40 CFR 144)

I. EPA ID Number		T/A	C
U			

Read Attached Instructions Before Starting

For Official Use Only

Application approved (mo day year)	Date received (mo day year)	Permit Number	Well ID	FINDS Number

II. Owner Name and Address			III. Operator Name and Address		
Owner Name: Powertech (USA) Inc.			Owner Name: Powertech (USA) Inc.		
Street Address: 5575 DTC Parkway, Suite 140		Phone Number: (303) 790-7528	Street Address: 5575 DTC Parkway, Suite 140		Phone Number: (303) 790-7528
City: Greenwood Village	State: CO	ZIP CODE: 80111	City: Greenwood Village	State: CO	ZIP CODE: 80111

IV. Commercial Facility	V. Ownership	VI. Legal Contact	VII. SIC Codes
☐ Yes ☒ No	☒ Private ☐ Federal ☐ Other	☒ Owner ☐ Operator	SIC: 1094 NAISC: 212291

VIII. Well Status *(Mark "x")*

☐ A. Operating	Date Started (mo day year)	☐ B. Modification/Conversion	☒ C. Proposed

IX. Type of Permit Requested *(Mark "x" and specify if required)*

☐ A. Individual	☒ B. Area	Number of Existing Wells	Number of Proposed Wells	Name(s) of field(s) or project(s)
		0	Up to 4,000	Dewey-Burdock

X. Class and Type of Well *(see reverse)*

A. Class(es) (enter code(s))	B. Type(s) (enter code(s))	C. If class is "other" or type is code 'x,' explain	D. Number of wells per type (if area permit)
III	U		Up to 4,000

XI. Location of Well(s) or Approximate Center of Field or Project

Latitude Deg	Latitude Min	Latitude Sec	Longitude Deg	Longitude Min	Longitude Sec	Township and Range Sec	Twp	Range	1/4 Sec	Feet From	Line	Feet From	Line
103	59	43	43	28	55	34	6S	1E	SW	93	W	1403	S

XII. Indian Lands (Mark 'x')

☐ Yes
☒ No

XIII. Attachments

(Complete the following questions on a separate sheet(s) and number accordingly; see instructions)

For Classes I, II, III, (and other classes) complete and submit on a separate sheet(s) Attachments A--U (pp 2-6) as appropriate. Attach maps where required. List attachments by letter which are applicable and are included with your application.

XIV. Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibliity of fine and imprisonment. (Ref. 40 CFR 144.32)

A. Name and Title *(Type or Print)*	B. Phone No. *(Area Code and No.)*
Richard Blubaugh, Vice President Environmental Health & Safety Resources	(303) 790-7528
C. Signature: Rchd Blubaugh	D. Date Signed: 8/1/2012

EPA Form 7520-6 (Rev. 12-08)

Well Class and Type Codes

Class I		Wells used to inject waste below the deepest underground source of drinking water.
Type	**"I"**	Nonhazardous industrial disposal well
	"M"	Nonhazardous municipal disposal well
	"W"	Hazardous waste disposal well injecting below USDWs
	"X"	Other Class I wells (not included in Type "I," "M," or "W")
Class II		Oil and gas production and storage related injection wells.
Type	**"D"**	Produced fluid disposal well
	"R"	Enhanced recovery well
	"H"	Hydrocarbon storage well (excluding natural gas)
	"X"	Other Class II wells (not included in Type "D," "R," or "H")
Class III		Special process injection wells.
Type	**"G"**	Solution mining well
	"S"	Sulfur mining well by Frasch process
	"U"	Uranium mining well (excluding solution mining of conventional mines)
	"X"	Other Class III wells (not included in Type "G," "S," or "U")

Other Classes Wells not included in classes above.
Class V wells which may be permitted under §144.12.
Wells not currently classified as Class I, II, III, or V.

Attachments to Permit Application

Class	Attachments
I new well	A, B, C, D, F, H – S, U
existing	A, B, C, D, F, H – U
II new well	A, B, C, E, G, H, M, Q, R; optional – I, J, K, O, P, U
existing	A, E, G, H, M, Q, R, – U; optional – J, K, O, P, Q
III new well	A, B, C, D, F, H, I, J, K, M – S, U
existing	A, B, C, D, F, H, J, K, M – U
Other Classes	To be specified by the permitting authority

INSTRUCTIONS - Underground Injection Control (UIC) Permit Application

Paperwork Reduction Act: The public reporting and record keeping burden for this collection of information is estimated to average 224 hours for a Class I hazardous well application, 110 hours for a Class I non-hazardous well application, 67 hours for a Class II well application, and 132 hours for a Class III well application. Burden means the total time, effort, or financial resource expended by persons to generate, maintain, retain, or disclose or provide information to or for a Federal Agency. This includes the time needed to review instructions; develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating, and verifying information, processing and maintaining information, and disclosing and providing information; adjust the existing ways to comply with any previously applicable instructions and requirements; train personnel to be able to respond to the collection of information; search data sources; complete and review the collection of information; and, transmit or otherwise disclose the information. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. Send comments on the Agency's need for this information, the accuracy of the provided burden estimates, and any suggested methods for minimizing respondent burden, including the use of automated collection techniques to Director, Collection Strategies Division, U.S. Environmental Protection Agency (2822), 1200 Pennsylvania Ave., NW, Washington, DC 20460. Include the OMB control number in any correspondence. Do not send the completed forms to this address.

This form must be completed by all owners or operators of Class I, II, and III injection wells and others who may be directed to apply for permit by the Director.

I. **EPA I.D. NUMBER** - Fill in your EPA Identification Number. If you do not have a number, leave blank.

II. **OWNER NAME AND ADDRESS** - Name of well, well field or company and address.

III. **OPERATOR NAME AND ADDRESS** - Name and address of operator of well or well field.

IV. **COMMERCIAL FACILITY** - Mark the appropriate box to indicate the type of facility.

V. **OWNERSHIP** - Mark the appropriate box to indicate the type of ownership.

VI. **LEGAL CONTACT** - Mark the appropriate box.

VII. **SIC CODES** - List at least one and no more than four Standard Industrial Classification (SIC) Codes that best describe the nature of the business in order of priority.

VIII. **WELL STATUS** - Mark Box A if the well(s) were operating as injection wells on the effective date of the UIC Program for the State. Mark Box B if wells(s) existed on the effective date of the UIC Program for the State but were not utilized for injection. Box C should be marked if the application is for an underground injection project not constructed or not completed by the effective date of the UIC Program for the State.

IX. **TYPE OF PERMIT** - Mark "Individual" or "Area" to indicate the type of permit desired. Note that area permits are at the discretion of the Director and that wells covered by an area permit must be at one site, under the control of one person and do not inject hazardous waste. If an area permit is requested the number of wells to be included in the permit must be specified and the wells described and identified by location. If the area has a commonly used name, such as the "Jay Field," submit the name in the space provided. In the case of a project or field which crosses State lines, it may be possible to consider an area permit if EPA has jurisdiction in both States. Each such case will be considered individually, if the owner/operator elects to seek an area permit.

X. **CLASS AND TYPE OF WELL** - Enter in these two positions the Class and type of injection well for which a permit is requested. Use the most pertinent code selected from the list on the reverse side of the application. When selecting type X please explain in the space provided.

XI. **LOCATION OF WELL** - Enter the latitude and longitude of the existing or proposed well expressed in degrees, minutes, and seconds or the location by township, and range, and section, as required by 40 CFR Part 146. If an area permit is being requested, give the latitude and longitude of the approximate center of the area.

XII. **INDIAN LANDS** - Place an "X" in the box if any part of the facility is located on Indian lands.

XIII. **ATTACHMENTS** - Note that information requirements vary depending on the injection well class and status. Attachments for Class I, II, III are described on pages 4 and 5 of this document and listed by Class on page 2. Place EPA ID number in the upper right hand corner of each page of the Attachments.

XIV. **CERTIFICATION** - All permit applications (except Class II) must be signed by a responsible corporate officer for a corporation, by a general partner for a partnership, by the proprietor of a sole proprietorship, and by a principal executive or ranking elected official for a public agency. For Class II, the person described above should sign, or a representative duly authorized in writing.

INSTRUCTIONS - Attachments

Attachments to be submitted with permit application for Class I, II, III and other wells.

A. **AREA OF REVIEW METHODS** - Give the methods and, if appropriate, the calculations used to determine the size of the area of review (fixed radius or equation). The area of review shall be a fixed radius of 1/4 mile from the well bore unless the use of an equation is approved in advance by the Director.

B. **MAPS OF WELL/AREA AND AREA OF REVIEW** - Submit a topographic map, extending one mile beyond the property boundaries, showing the injection well(s) or project area for which a permit is sought and the applicable area of review. The map must show all intake and discharge structures and all hazardous waste treatment, storage, or disposal facilities. If the application is for an area permit, the map should show the distribution manifold (if applicable) applying injection fluid to all wells in the area, including all system monitoring points. Within the area of review, the map must show the following:

Class I

The number, or name, and location of all producing wells, injection wells, abandoned wells, dry holes, surface bodies of water, springs, mines (surface and subsurface), quarries, and other pertinent surface features, including residences and roads, and faults, if known or suspected. In addition, the map must identify those wells, springs, other surface water bodies, and drinking water wells located within one quarter mile of the facility property boundary. Only information of public record is required to be included in this map;

Class II

In addition to requirements for Class I, include pertinent information known to the applicant. This requirement does not apply to existing Class II wells;

Class III

In addition to requirements for Class I, include public water systems and pertinent information known to the applicant.

C. **CORRECTIVE ACTION PLAN AND WELL DATA** - Submit a tabulation of data reasonably available from public records or otherwise known to the applicant on all wells within the area of review, including those on the map required in B, which penetrate the proposed injection zone. Such data shall include the following:

Class I

A description of each well's types, construction, date drilled, location, depth, record of plugging and/or completion, and any additional information the Director may require. In the case of new injection wells, include the corrective action proposed to be taken by the applicant under 40 CFR 144.55.

Class II

In addition to requirement for Class I, in the case of Class II wells operating over the fracture pressure of the injection formation, all known wells within the area of review which penetrate formations affected by the increase in pressure. This requirement does not apply to existing Class II wells.

Class III

In addition to requirements for Class I, the corrective action proposed under 40 CFR 144.55 for all Class III wells.

D. **MAPS AND CROSS SECTION OF USDWs** - Submit maps and cross sections indicating the vertical limits of all underground sources of drinking water within the area of review (both vertical and lateral limits for Class I), their position relative to the injection formation and the direction of water movement, where known, in every underground source of drinking water which may be affected by the proposed injection. (Does not apply to Class II wells.)

E. **NAME AND DEPTH OF USDWs (CLASS II)** - For Class II wells, submit geologic name, and depth to bottom of all underground sources of drinking water which may be affected by the injection.

F. **MAPS AND CROSS SECTIONS OF GEOLOGIC STRUCTURE OF AREA** - Submit maps and cross sections detailing the geologic structure of the local area (including the lithology of injection and confining intervals) and generalized maps and cross sections illustrating the regional geologic setting. (Does not apply to Class II wells.)

G. **GEOLOGICAL DATA ON INJECTION AND CONFINING ZONES (Class II)** - For Class II wells, submit appropriate geological data on the injection zone and confining zones including lithologic description, geological name, thickness, depth and fracture pressure.

H. **OPERATING DATA** - Submit the following proposed operating data for each well (including all those to be covered by area permits): (1) average and maximum daily rate and volume of the fluids to be injected; (2) average and maximum injection pressure; (3) nature of annulus fluid; (4) for Class I wells, source and analysis of the chemical, physical, radiological and biological characteristics, including density and corrosiveness, of injection fluids; (5) for Class II wells, source and analysis of the physical and chemical characteristics of the injection fluid; (6) for Class III wells, a qualitative analysis and ranges in concentrations of all constituents of injected fluids. If the information is proprietary, maximum concentrations only may be submitted, but all records must be retained.

I. **FORMATION TESTING PROGRAM** - Describe the proposed formation testing program. For Class I wells the program must be designed to obtain data on fluid pressure, temperature, fracture pressure, other physical, chemical, and radiological characteristics of the injection matrix and physical and chemical characteristics of the formation fluids.

For Class II wells the testing program must be designed to obtain data on fluid pressure, estimated fracture pressure, physical and chemical characteristics of the injection zone. (Does not apply to existing Class II wells or projects.)

For Class III wells the testing must be designed to obtain data on fluid pressure, fracture pressure, and physical and chemical characteristics of the formation fluids if the formation is naturally water bearing. Only fracture pressure is required if the program formation is not water bearing. (Does not apply to existing Class III wells or projects.)

J. **STIMULATION PROGRAM** - Outline any proposed stimulation program.

K. **INJECTION PROCEDURES** - Describe the proposed injection procedures including pump, surge, tank, etc.

L. **CONSTRUCTION PROCEDURES** - Discuss the construction procedures (according to §146.12 for Class I, §146.22 for Class II, and §146.32 for Class III) to be utilized. This should include details of the casing and cementing program, logging procedures, deviation checks, and the drilling, testing and coring program, and proposed annulus fluid. (Request and submission of justifying data must be made to use an alternative to packer for Class I.)

M. **CONSTRUCTION DETAILS** - Submit schematic or other appropriate drawings of the surface and subsurface construction details of the well.

N. **CHANGES IN INJECTED FLUID** - Discuss expected changes in pressure, native fluid displacement, and direction of movement of injection fluid. (Class III wells only.)

O. **PLANS FOR WELL FAILURES** - Outline contingency plans (proposed plans, if any, for Class II) to cope with all shut-ins or wells failures, so as to prevent migration of fluids into any USDW.

P. **MONITORING PROGRAM** - Discuss the planned monitoring program. This should be thorough, including maps showing the number and location of monitoring wells as appropriate and discussion of monitoring devices, sampling frequency, and parameters measured. If a manifold monitoring program is utilized, pursuant to §146.23(b)(5), describe the program and compare it to individual well monitoring.

Q. **PLUGGING AND ABANDONMENT PLAN** - Submit a plan for plugging and abandonment of the well including: (1) describe the type, number, and placement (including the elevation of the top and bottom) of plugs to be used; (2) describe the type, grade, and quantity of cement to be used; and (3) describe the method to be used to place plugs, including the method used to place the well in a state of static equilibrium prior to placement of the plugs. Also for a Class III well that underlies or is in an exempted aquifer, demonstrate adequate protection of USDWs. Submit this information on EPA Form 7520-14, Plugging and Abandonment Plan.

R. **NECESSARY RESOURCES** - Submit evidence such as a surety bond or financial statement to verify that the resources necessary to close, plug or abandon the well are available.

S. **AQUIFER EXEMPTIONS** - If an aquifer exemption is requested, submit data necessary to demonstrate that the aquifer meets the following criteria: (1) does not serve as a source of drinking water; (2) cannot now and will not in the future serve as a source of drinking water; and (3) the TDS content of the ground water is more than 3,000 and less than 10,000 mg/l and is not reasonably expected to supply a public water system. Data to demonstrate that the aquifer is expected to be mineral or hydrocarbon production, such as general description of the mining zone, analysis of the amenability of the mining zone to the proposed method, and time table for proposed development must also be included. For additional information on aquifer exemptions, see 40 CFR Sections 144.7 and 146.04.

T. **EXISTING EPA PERMITS** - List program and permit number of any existing EPA permits, for example, NPDES, PSD, RCRA, etc.

U. **DESCRIPTION OF BUSINESS** - Give a brief description of the nature of the business.

Powertech (USA) Inc.
Dewey-Burdock Project
Class III Underground Injection Control Permit Application

December 2008
Revised July 2012
Updated January 2013

Prepared for

U.S. EPA Region 8
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POWERTECH (USA) INC.

Powertech (USA) Inc.
Dewey-Burdock Project
Class III Underground Injection Control
Permit Application

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List of Abbreviations and Acronyms

AEB	aquifer exemption boundary
ALARA	as low as reasonably achievable
AOR	Area of Review
ARSD	Administrative Rules of South Dakota
ASTM	ASTM International, formerly American Society for Testing and Materials
BLM	U.S. Department of the Interior, Bureau of Land Management
CFR	Code of Federal Regulations
CPP	central processing plant
DENR	South Dakota Department of Environment and Natural Resources
DES	Draft Environmental Statement
EFN	Energy Fuels Nuclear
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
ISR	*in-situ* recovery
IX	ion exchange
MCL	maximum contaminant level
mgd	million gallons per day
MIT	mechanical integrity testing
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
psi	pounds per square inch
psig	pounds per square inch gauge
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RL	reporting limit
RO	reverse osmosis
SDCL	South Dakota Codified Laws
SDGF&P	South Dakota Department of Game, Fish and Parks
SDWA	Safe Drinking Water Act
SERP	Safety and Environmental Review Panel

List of Abbreviations and Acronyms (Continued)

TDS	total dissolved solids
TVA	Tennessee Valley Authority
UCL	upper control limit
UIC	Underground Injection Control
USDW	underground source of drinking water
USGS	U.S. Geological Survey

Glossary

Aquifer Exemption: The process by which an aquifer, or portion of an aquifer, that meets some of the criteria for an underground source of drinking water, for which protection under the Safe Drinking Water Act has been exempted under the criteria in 40 CFR § 146.4. Injection of fluids through a Class I, II, or III injection well into any aquifer that meets the classification as a USDW requires a demonstration that the aquifer is not currently serving a drinking water system and is not expected to do so in the future.

Bleed: Excess production or restoration solution withdrawn to maintain a cone of depression so native groundwater continually flows toward the center of the production zone.

Brine Solution: A concentrated solution containing dissolved minerals (usually greater than 100,000 mg/l), especially chloride salts.

Central Processing Plant: The main processing facility that includes an ion exchange system, elution and precipitation circuits, and filtering, washing, drying and packaging systems to produce yellowcake.

Confining Bed (layer): A geologic formation, group of formations, or a part of a formation of low permeability above or below an aquifer that confines groundwater flow within the aquifer.

Elution: The process of extracting (or eluting) one material from another by washing with a solvent (eluant) to remove adsorbed material (such as uranium) from an adsorbent such as an ion exchange resin.

Excursion: The exceedance of upper control limits for two or more excursion indicators in a monitor well.

Ion Exchange: A chemical process used to recover uranium from solution by the exchange of dissolved uranium ions between a lixiviant (leach solution) and a solid, either a mineral surface or, more commonly, a synthetic polymer resin.

Injection Well: A well used to inject lixiviant or restoration fluids into the production zone for uranium extraction or aquifer restoration.

***In-situ* Recovery (ISR):** The in-place recovery of a mineral resource without removing overburden or ore. This method of mining is typically accomplished by installing a well and recovering the resource directly from the natural deposit by exposing it to the injection and recovery of the lixiviant that causes dissolution of the mineral.

Lixiviant: A solution composed of native groundwater and chemicals (such as oxygen and carbon dioxide) pumped underground to recover the uranium from the ore body.

Monitor Well: A well used to obtain water quality samples or measure groundwater levels.

Ore Body: The mapped extents of ore mineralization that is expected to be commercially producible. Also referred to as ore zone.

Ore Horizon: The vertical position of the ore mineralization within the host sand unit, formation, aquifer, or between two confining units. There may be more than one ore horizon within a host unit.

Picocurie: One one-trillionth (1/1,000,000,000,000) of a Curie: a measure of radioactivity based on the observed decay rate of approximately one gram of radium. The Curie was named in honor of Pierre and Marie Curie, pioneers in the study of radiation.

Pore Volume (PV): An indirect measurement of a unit volume of aquifer affected by ISR extraction. Pore volume is typically calculated by multiplying the surficial area of a well field by the ore horizon thickness by the porosity.

Production Well: Also known as ‘extraction well’ or ‘recovery well’ for ISR, usually located in the center of a 5- or 7-spot well pattern; used to pump the uranium-bearing solution to the surface for recovery of uranium.

Radionuclide: An unstable form of a nuclide that decays or disintegrates, spontaneously emitting radiation. Nuclide: a general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus as well as by the amount of energy contained within the atom.

Safe Drinking Water Act (SDWA): The main federal law that ensures the quality of Americans' drinking water. The SDWA sets the framework for the UIC Program to control the injection of fluids. EPA and states implement the UIC Program, which sets standards for safe injection practices and bans certain types of injection.

Satellite Facility: A remote plant consisting of an ion exchange system, pumps, groundwater restoration equipment and transportation vehicles (tanker trucks) to transport loaded resins to the central processing plant.

Underground Source of Drinking Water (USDW): An aquifer or portion of an aquifer that supplies any public water system or that contains a sufficient quantity of ground water to supply a public water system, and currently supplies drinking water for human consumption, or that contains fewer than 10,000 mg/l total dissolved solids and is not an exempted aquifer.

Yellowcake: A mixture of uranium oxides that can vary in proportion and in color from yellow to orange to dark green (blackish) depending on the temperature at which the material was dried (level of hydration and impurities). Higher drying temperatures produce a darker, less soluble material. Yellowcake is commonly referred to as U_3O_8. This fine powder is packaged in drums and sent to a conversion plant that produces uranium hexafluoride (UF_6) as the next step in the manufacture of nuclear fuel.

POWERTECH (USA) INC.

Powertech (USA) Inc.
Dewey-Burdock Project
Class III Underground Injection Control
Permit Application

1.0 INTRODUCTION

Powertech (USA) Inc. (Powertech) proposes to produce uranium (U_3O_8 or yellowcake) at the Dewey-Burdock Project using *in-situ* recovery (ISR). This report has been developed to address the permitting requirements for a Class III Underground Injection Control (UIC) permit application in South Dakota. It is being submitted to the United States Environmental Protection Agency (EPA) to demonstrate that the Dewey-Burdock Project will meet the requirements of the UIC Program promulgated under the Safe Drinking Water Act (SDWA).

The SDWA was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supplies. It authorizes EPA to set national health-based standards to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and public water supply wells. EPA, states and water districts work together to ensure protection against naturally-occurring and anthropogenic contaminants. The UIC Program found in 40 CFR Parts 144-147 is one such program designed to implement the SDWA by regulating underground injection practices to protect underground sources of drinking water (USDWs).

To fulfill these informational needs, the following attachments are included with this UIC permit application:

- A - Area of Review Methods (Section 2)
- B - Maps of Area and Area of Review (Section 3)
- C - Corrective Action Plan and Well Data (Section 4)
- D - Maps and Cross Section of USDWs (Section 5)
- F - Maps and Cross Sections of Geologic Structure of Area (Section 6)
- H - Operating Data (Section 7)
- I - Formation Testing Program (Section 8)
- J - Stimulation Program (Section 9)
- K - Injection Procedures (Section 10)
- M - Construction Details (Section 11)
- N - Changes in Injected Fluid (Section 12)
- O - Plans for Well Failures (Section 13)

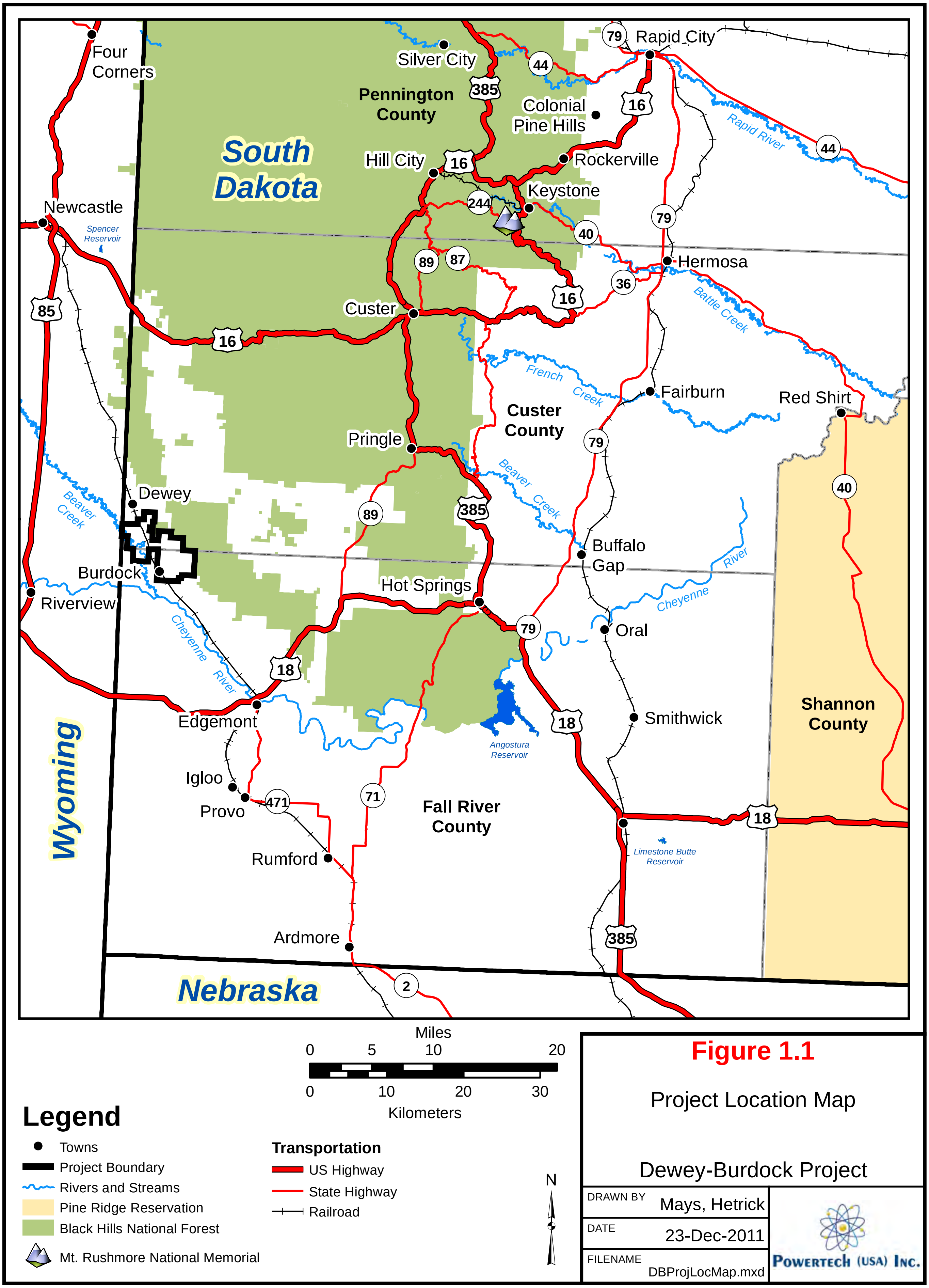
- P - Monitoring Program (Section 14)
- Q - Plugging and Abandonment Plan (Section 15)
- R - Necessary Resources (Section 16)
- S - Aquifer Exemption (Section 17)
- U - Description of Business (Section 18)

1.1 Project Overview

The Dewey-Burdock Project is located approximately 13 miles north-northwest of Edgemont, South Dakota, in an area encompassing portions of Fall River and Custer counties. The Dewey-Burdock Project area (project area) encompasses approximately 10,580 acres of mostly private land on both sides of S. Dewey Road (County Road 6463) and includes portions of Sections 1-5, 10-12, and 14-15, Township 7 South, Range 1 East and Sections 20-21 and 27-35, Township 6 South, Range 1 East, Black Hills Meridian. Approximately 240 acres are under control of the Bureau of Land Management (BLM) in portions of Sections 3 and 10-12. Figure 1.1 shows the project location and permit boundary.

The Dewey-Burdock Project is a proposed uranium ISR project. The uranium will be recovered by injecting groundwater fortified with oxidizing and complexing agents (oxygen and carbon dioxide) into a series of injection wells. The dissolved oxygen will oxidize the solid-phase uranium to a soluble valence state, and the dissolved carbon dioxide will form a complex with the soluble uranium ions so they remain in solution as the recovery solution is transported through the ore body. The recovery solution will be pumped by submersible pumps to the surface, where the uranium will be recovered via ion exchange (IX) and processed into the final product (U_3O_8 or yellowcake). After the uranium is removed, the groundwater will be refortified with oxygen and carbon dioxide and recirculated through the well fields. The uranium mineralization targeted for production is contained within the Inyan Kara Group, specifically within the Fall River Formation and Chilson Member of the Lakota Formation.

The eastern portion of the project area is called the Burdock area. It will include a series of ISR well fields and a central processing plant (CPP), which will be used to recover uranium from the Burdock well fields using IX and to process the uranium-loaded IX resin. The western portion of the project area is called the Dewey area. It will include a series of ISR well fields and a satellite facility, which will be used to recover uranium from the Dewey well fields using IX. The uranium-loaded IX resin will be transported from the satellite facility to the project CPP or to another licensed CPP for processing. Processing will include stripping the uranium from the loaded resin using a saltwater solution (elution), precipitating the dissolved uranium to form an



South Dakota
Wyoming
Nebraska
Pennington County
Custer County
Fall River County
Shannon County
Four Corners
Newcastle
Spencer Reservoir
Silver City
Rapid City
Colonial Pine Hills
Rockerville
Hill City
Keystone
Hermosa
Custer
Fairburn
Red Shirt
Pringle
Dewey
Burdock
Riverview
Buffalo Gap
Hot Springs
Oral
Edgemont
Smithwick
Angostura Reservoir
Igloo
Provo
Rumford
Ardmore
Limestone Butte Reservoir
Rapid River
Battle Creek
French Creek
Beaver Creek
Cheyenne River
79
44
385
16
244
40
87
89
36
85
18
71
471
2
Miles
0 5 10 20
0 10 20 30
Kilometers
Legend
Towns
Project Boundary
Rivers and Streams
Pine Ridge Reservation
Black Hills National Forest
Mt. Rushmore National Memorial
Transportation
US Highway
State Highway
Railroad
N
Figure 1.1
Project Location Map
Dewey-Burdock Project
DRAWN BY Mays, Hetrick
DATE 23-Dec-2011
FILENAME DBProjLocMap.mxd
POWERTECH (USA) INC.

insoluble uranium oxide (precipitation), and filtering, washing, drying, and packaging the dried uranium oxide product (yellowcake) into sealed containers.

Each ISR well field will be operated until uranium recovery is no longer economical. Powertech estimates that individual well field operating lives will be about 2 years, with multiple well fields typically in operation at any given time. Aquifer restoration will be completed following uranium recovery in each well field. During aquifer restoration, the groundwater in the well field will be restored in accordance with NRC requirements.

Liquid waste generated by the Dewey-Burdock Project will be treated and disposed by injection in Class V injection wells or by land application. Figures 1.2 and 1.3 depict the proposed facilities and potential well field areas in the two liquid waste disposal options (refer to Section 10.1 for a description of liquid waste disposal options).

1.2 Applicant Information

The Class III UIC permit application is submitted by Powertech (USA) Inc. or Powertech, which is the U.S.-based wholly owned subsidiary of the Powertech Uranium Corporation, a corporation registered in British Columbia. Powertech Uranium Corporation shares are publicly traded on the Toronto Stock Exchange as PWE and the Frankfurt Stock Exchange as P8A. Powertech Uranium Corporation owns 100 percent of the shares of Powertech. The corporate office of Powertech Uranium Corporation is located in Vancouver, British Columbia. Powertech is a U.S.-based corporation incorporated in the State of South Dakota. The addresses and telephone numbers for the general office (Colorado) and the local office (South Dakota) of the applicant are listed as follows:

Name and address of applicant:

Company:	Powertech (USA) Inc.
Signatory:	Richard Blubaugh
Title:	Vice President, Environmental Health & Safety Resources
Address:	5575 DTC Parkway, Suite #140 Greenwood Village, CO 80111
Telephone:	(303) 790-7528

Local representative or contact person:

Name:	Mark Hollenbeck, P.E.
Title:	Project Manager
Address:	Powertech (USA) Inc. 310 2nd Avenue P.O. Box 812 Edgemont, SD 57735
Telephone:	(605) 662-8308

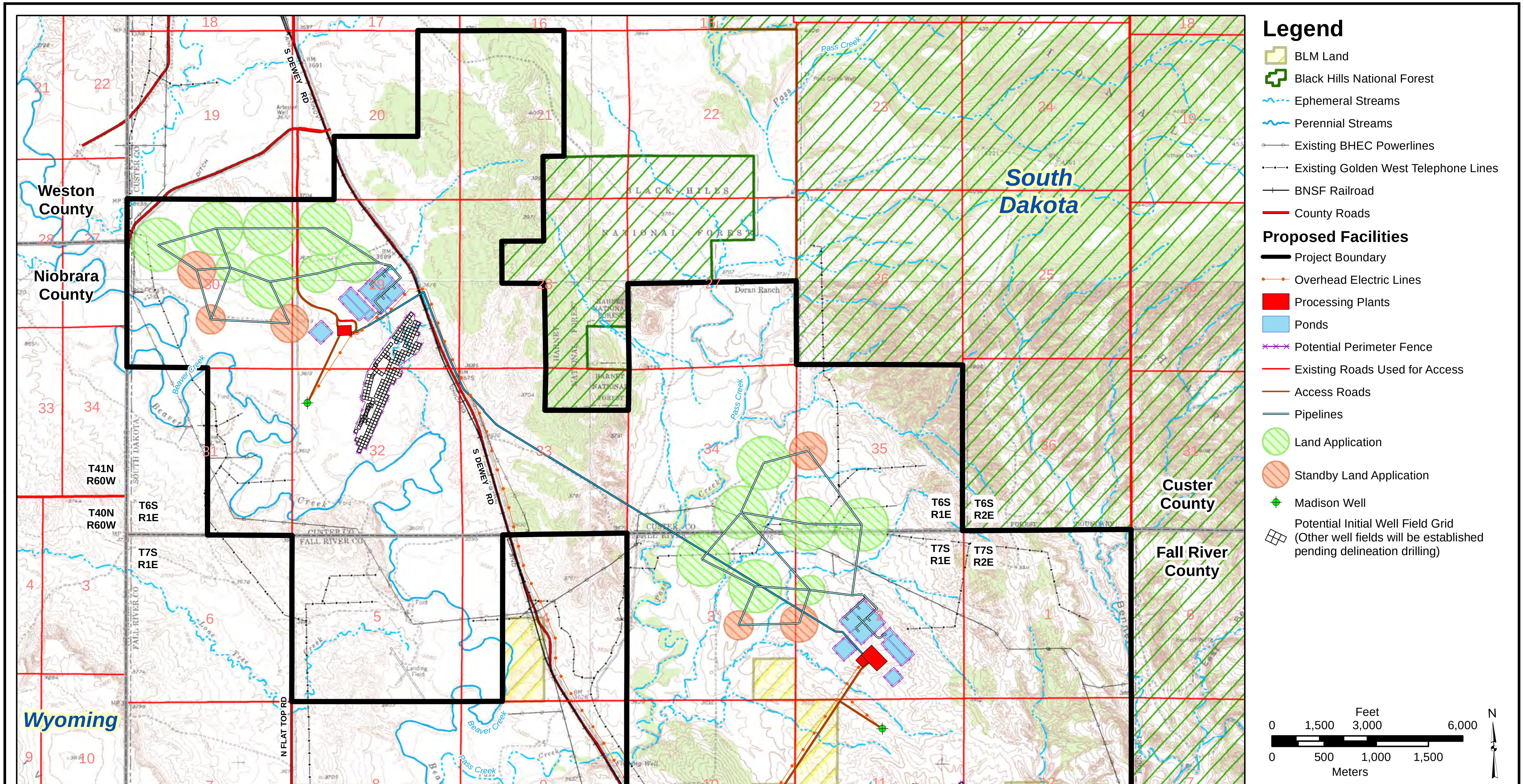


Figure 1.2
Proposed Facilities and Potential Initial Well Field Areas Land Application Option

Dewey-Burdock Project

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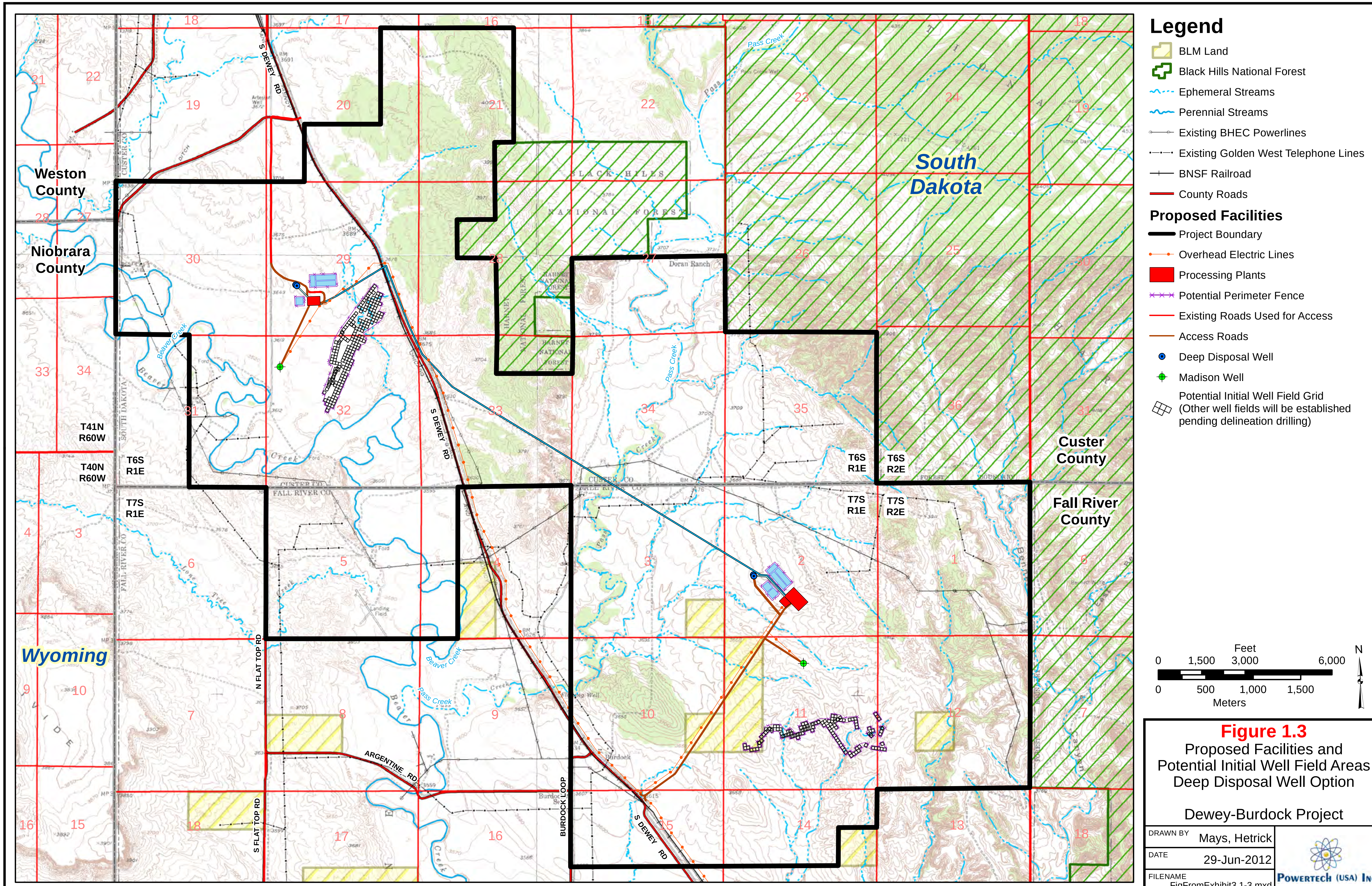

Figure 1.3
Proposed Facilities and
Potential Initial Well Field Areas
Deep Disposal Well Option

Dewey-Burdock Project

1.3 Project History

Uranium was first discovered in the Edgemont District in 1951 by professors from the South Dakota School of Mines and Technology (SDSMT). They mined about 500 pounds of ore and hauled it to the Union Carbide mill at Rifle, Colorado. The Atomic Energy Commission (AEC) announcement of a new district at Edgemont led to a boom of staking, mining, and dealing in the summer of 1952. By 1953 the AEC had built a buying station in Edgemont. In 1956 a 250-ton-per-day mill was built in Edgemont by a subsidiary of Susquehanna Western Inc. and soon expanded to 500 tons per day. In 1960 a vanadium circuit was added. Susquehanna Western Inc. provided mill feed from production from the Edgemont District (open pits and shallow underground operations in the Fall River Formation), some mines in the Powder River Basin and several mines in the northern Black Hills. The Edgemont mill operated through 1968.

In 1974, the Tennessee Valley Authority (TVA) bought the Edgemont mill and took control of Susquehanna Western's mines and exploration properties in the Edgemont District. TVA soon began extensive exploratory drilling in the Burdock portion of the project area. In 1967, Homestake Mining Company began exploration in the Dewey portion of the project area. In 1974, Wyoming Mineral Corporation (WMC) acquired the Dewey properties from Homestake. Besides WMC and TVA, other companies exploring in the district were Union Carbide, Federal Resources, and Kerr McGee. TVA consolidated the project area in 1978 by acquiring the Dewey portion from WMC and continued exploration until 1986. In total, over 4,000 exploration drill holes were completed in the project area.

In 1981 TVA completed a mine feasibility study on the project deposits. A draft environmental statement (DES) was prepared by TVA to address the potential impacts of a proposed underground mine in the project area, but the National Environmental Policy Act (NEPA) process was never completed by TVA. In 1994 Energy Fuels Nuclear (EFN) acquired the mineral interests within the project area. Their intention was to extract the uranium by ISR. EFN did no additional exploration drilling on the project. In 2000 the leases were dropped.

In 2005, Powertech acquired control of the property, which currently consists of approximately 10,580 acres. Since spring 2007, Powertech has drilled approximately 115 exploration holes, including 20 monitor wells on the project. Both the historical and recent drill holes have been used to generate the geologic model and delineate the extent of the mineralized sands.

1.4 Permitting Requirements

Powertech is currently working on obtaining all the necessary permits and licenses for the Dewey-Burdock Project. Table 1.1 presents the permits and licenses being obtained. In addition to the Dewey-Burdock Project, Powertech has one exploration permit in Colorado (Centennial Project) and two exploration permits in Wyoming (Dewey Terrace and Aladdin projects).

Table 1.1: Permits and Licenses for the Dewey-Burdock Project

Issuing Agency	Permit or License	Status
US EPA Region 8 8P-W-GW, UIC 1595 Wynkoop St Denver, CO 80202-1129	Class III UIC Permit	Submitted January 2009, revised this application
	Aquifer Exemption (Class III Wells)	Submitted January 2009, revised this application
	Class V UIC Permit	Submitted March 2010
US Nuclear Regulatory Commission TWFN, Mail stop: 8 F5 Washington, DC 20555-0001	Source and Byproduct Material License	Submitted August 10, 2009, Docket No. 40-9075
BLM Eastern Montana/Dakotas District 310 Roundup St Belle Fourche, SD 57717	Plan of Operations	Submitted October 2009
South Dakota Department of Environment and Natural Resources Joe Foss Building 523 E Capitol Pierre, SD 57501	Large Scale Mine Permit	Application in preparation
	Uranium Exploration Permit	Approved, Permit EXNI-404
	Special, Exceptional, Critical, or Unique Land Determination	Completed February 19, 2009
	Groundwater Discharge Plan (Land Application)	Submitted March 9, 2012
	Water Right (Madison Limestone)	Submitted June 11, 2012
	Water Right (Inyan Kara Group)	Submitted June 11, 2012
	Temporary Water Right for Testing	Approved January 2, 2008
	Temporary NPDES Permit for Testing	Approved December 5, 2007, Permit SDG 070626
	Air Quality Permit	In preparation
	NPDES Construction Stormwater Permit	Pending
	NPDES Industrial Stormwater Permit	Pending
	Public Water Supply System Construction Permit	Pending
	Class V UIC Septic Permit	Pending
Custer County 420 Mount Rushmore Road Custer, SD 57730-1934	Building Permit, Grading Permit, Floodplain Construction Permit (if applicable), Sign Permit and Septic System Permit	Pending
	Conditional Use Permit	Not Required
Fall River County 906 N. River Street Hot Springs, SD 57747	Building Permit, Grading Permit, Floodplain Construction Permit (if applicable), Sign Permit and Septic System Permit	Pending
	Conditional Use Permit	Not Required

1.5 Health, Safety, and Environmental Responsibilities

During operation of the facility, Powertech, via the company's Safety and Environmental Review Panel (SERP), will ensure that the facility will comply with all applicable laws and regulations. Powertech also will maintain the health and safety of the workers, general public, and the environment. This includes maintaining potential occupational and public exposures to ionizing radiation as low as reasonably achievable (ALARA). Additional information on the SERP, personnel responsible for radiation protection such as the radiation safety officer, and the management control program is found in the NRC license application (Powertech, 2009a).

2.0 ATTACHMENT A - AREA OF REVIEW METHODS

This attachment details the methods used to determine the Area of Review (AOR) for the Class III UIC permit application.

2.1 Introduction

The AOR is established to maximize the data to be described before an aquifer exemption is granted in order to prove the integrity of the injection zones and their relationship to surrounding USDWs. The AOR normally specified by the EPA is the area within ¼ mile from the proposed injection wells. However, Powertech chose a more extensive AOR in order to also satisfy the NRC review area guidance for groundwater resources (see Attachment B, Section 3). For the purposes of this report, the AOR will include the area within 2 kilometers or 1.2 miles from the proposed NRC license boundary.

The abundance of data from TVA on prior pumping tests in and around the project area yields excellent regional hydrologic information. The historical TVA data and more recent Powertech baseline characterization data presented in this application demonstrate that the ore zone is isolated from USDWs by the presence of major confining units across the entire project area, including the Graneros Group, Fuson Shale, and the Morrison Formation. Geologic confinement, hydrogeologic characterization of each well field, design and operation of monitoring systems specific to each well field, and maintaining well field hydraulic control during production and aquifer restoration will prevent excursions and potential impacts to USDWs.

2.2 Area of Review Methods

The following attachments summarize the activities planned by Powertech and are described for the AOR.

- Chemistry of injected and formation fluids
  - Attachment H - Operating Data (Section 7)
  - Attachment K - Injection Procedures (Section 10)
  - Attachment N - Changes in Injected Fluid (Section 12)
  - Attachment S - Aquifer Exemption (Section 17)
- Hydrogeology
  - Attachment D - Maps and Cross Sections of USDWs (Section 5)
  - Attachment F - Maps and Cross Sections of Geologic Structure of Area (Section 6)

  - Attachment I - Formation Testing Program (Section 8)
  - Attachment S - Aquifer Exemption (Section 17)
- Groundwater use and dependence
  - Attachment B - Maps of Area and Area of Review (Section 3)
  - Attachment C - Corrective Action Plan and Well Data (Section 4)

The population and historical practices in the AOR are described in the following section.

2.3 Population and Land Use

There are five residences within the project area, including seasonal residences. Locations are depicted on Plate 3.1. Approximately 38 people reside within a 6.2-mile (10-km) radius of the center of the project area (Powertech, 2009a).

Land within the project boundary is predominantly privately owned (97.7 percent), with the remaining 2.3 percent managed by the BLM.

The predominant land use within the project area is agricultural production related to grazing (rangeland). Most of the land serves as grazing land for cattle and a few horses. Approximately 390 acres of land are irrigated for hay production along Beaver Creek. Outside of the project area but within the AOR, a small number of pigs are raised and some of the residences have vegetable gardens.

Historically, some of the land within the project area was used for mining. Between 1952 and 1964, approximately 1.5 million lb (680,400 kg) of U_3O_8 were produced from underground and open-pit mines in the Edgemont Uranium District (TVA, 1979). Additional information on historical mine workings is found in Section 3.2.

Recreational use within the project boundary is limited primarily to large game hunting. Within the project area, hunting is open to the public subject to landowner permission on approximately 5,700 acres. Approximately 240 acres are owned by the BLM. In addition, the South Dakota Department of Game, Fish and Parks (SDGF&P) leases around 3,000 acres annually of privately owned land that is designated as walk-in hunting areas. Fishing and other water-based recreational activities on streams within the project vicinity are limited due to low flows and turbid water conditions. Prior to commencement of operations Powertech will work with BLM, SDGF&P and private landowners to limit hunting within the project area to the extent practicable to assure worker safety.

S. Dewey Road, a gravel road leading northwest from Edgemont, serves as the main access to the project area. Other mostly unimproved gravel roads crisscross the project area at irregular intervals. A major line of the Burlington Northern Santa Fe Railroad crosses the center of the project area. This railroad is a primary transportation corridor for Powder River Basin coal. Dakota Minnesota & Eastern has plans to construct a new rail line south of the project area that will not directly affect the project area.

3.0 ATTACHMENT B - MAPS OF AREA AND AREA OF REVIEW

The map of the project area and AOR is provided as Plate 3.1. The proposed aquifer exemption boundary is provided on Figure 17.1 in Section 17. The information provided on Plate 3.1 is described below.

3.1 Area of Review

Plate 3.1 is a topographic map that covers the entire AOR and describes the following information:

- The proposed permit boundary/project area
- AOR boundary (discussed in Attachment A)
- Existing wells
- Surface bodies of water
- Historical mines (surface and subsurface)
- Residences
- Roads
- Faults

Wells depicted on Plate 3.1 are color coded to designate aquifer of completion and depth of completion. Powertech is aware of 17 domestic wells within the AOR (see Section 4.1), not all of which are drinking water wells or associated with currently inhabited or inhabitable residences. No drinking water wells are located within the requested aquifer exemption boundary and completed within the mineralized Inyan Kara Group (see Section 17.3).

No injection wells, intake structures, discharge structures, or hazardous waste treatment, storage, or disposal facilities have been identified in the AOR. Class V injection wells are proposed for the Dewey-Burdock Project as discussed in Section 10.1. There are no natural springs within the project area. There is, however, an isolated area in the southwest portion of the Burdock area, known as the "alkali area," where groundwater is discharging to the surface, presumably through unplugged or improperly plugged exploration boreholes. There are also two springs outside of the project area but within the AOR. These are discussed in Section 4.3. No quarries are located within the AOR; the nearest quarry is located on the GCC Dacotah property north of the project boundary.

Attachment C (Section 4) describes the inventory of existing wells, exploration drill holes, and oil and gas wells and test holes. The following section describes the historical mines in the AOR.

3.2 Historical Mine Workings

The first uranium mines in the Edgemont District were developed in the 1950s by prospectors who followed mineralized Fall River outcrops into the subsurface by driving declines into the mineralized sandstones. Susquehanna Western Inc. consolidated all mining operations in the district in the 1950s and operated underground mines, surface mines, and the Edgemont Mill.

There are historical uranium mine workings, including surface and underground mines, along the eastern portion of the project area. Underground workings are associated with four former, shallow underground uranium mines and two open-pit adits. The locations of historical surface and underground mining operations in the Triangle Mine area and the Darrow Mine area are depicted on Figure 3.1. Susquehanna Western Inc. often drove adits short distances into open-pit walls to recover additional uranium ore that was adjacent to the pit. These types of underground workings were common at historical surface mines and were considered to be extensions of the open-pit mining operations.

All of the underground workings within the project area are associated with open-pit remnants that are clearly visible or, in the case of the Triangle Mine, have been backfilled and partially reclaimed. There are no underground mines within the project area that are not associated with, adjacent to, or extensions of the open pits, all of which are within the upper Fall River Formation. The underground mines consisted of declines (downward sloping ramps) ranging in depth from 0 to 80 feet below land surface. The adits (horizontal tunnels) were driven into the sidewalls of the historical open-pit mines. All underground workings were conducted within sandstones of the Fall River Formation at or above the water table and above the Fuson Shale confining unit such that these workings did not penetrate or otherwise compromise the integrity of this confining unit. Refer to Section 6.2.2 for a description of confining units relevant to ISR. These workings will not be affected by Powertech's proposed ISR operations, since Powertech will not develop well fields within Fall River Formation sandstones in this portion of the project area (refer to Section 10.6) and the Fuson Shale confining unit is intact and undisturbed (refer to Section 6.2.2). The following discussion provides detailed information on the surface and underground workings.

<u>Triangle Mine Area</u>

As shown on Figure 3.1, the Triangle Mine was an open-pit mining operation along the northeastern border of the project area in the NE¼ Section 34, T6S, R1E. Immediately east of this open pit was the Triangle underground mine. Although maps of the Triangle underground workings are not available, Powertech has obtained a description of this operation through

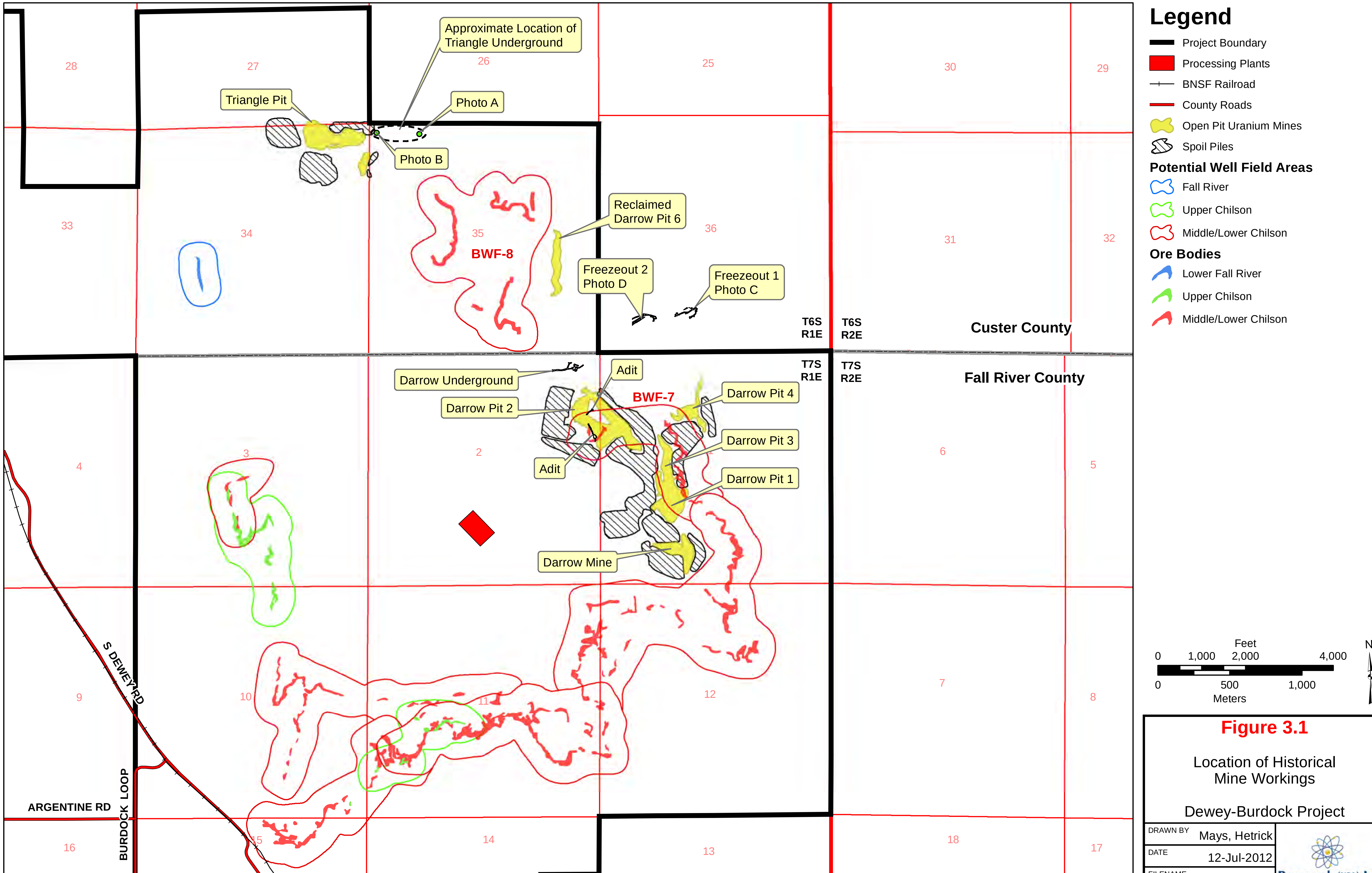

Figure 3.1

Location of Historical Mine Workings

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	12-Jul-2012
FILENAME	Mine-UGWorkings.mxd

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personal communication with Donald Spencer (2011), a local rancher who worked in this underground mine.

Mr. Spencer advised that he worked in the Triangle underground mine in 1957-58. He showed Powertech personnel the location of the decline that was used to access the mine. The decline is located approximately 1,000 feet southeast and updip of the eastern boundary of the Triangle open pit in the NW¼ Section 35, T6S, R1E (see Photo 3-A). Photo locations are depicted on Figure 3.1. As shown in the photo, the haulage road from the decline is still visible, but the entrance to the underground workings has been covered for safety reasons. There were about 1,000 feet of underground workings in the mine. The depth of these workings ranged from outcrop to 70 feet below ground surface. The mineralized sandstone of the Fall River Formation was unsaturated near the ground surface. Approximately 70 feet below the surface, the Fall River sands became saturated, resulting in 2-3 feet of water in the mine, requiring dewatering. Near the end of the underground workings, a vent shaft was installed approximately 400 feet from the eastern highwall of the Triangle open pit to provide air to the underground workings (see Photo 3-B). Powertech measured the depth to the bottom of this vent shaft in April 2011 and found it to be 68 feet below ground surface with approximately 3 feet of groundwater. Mr. Spencer stated that after the Triangle surface mine was completed, an adit was driven into the eastern wall of the pit to recover additional ore. This adit connected the open pit with the abandoned underground workings.

In 1960, Susquehanna Western Inc. began to develop the Triangle surface mine. A description of the mining zone was obtained through personal communication in 2011 with James F. Davis, the Susquehanna Western Inc. geologist who directed the delineation drilling for this mine (Davis, 2011). Mr. Davis stated a single mineralized front progressed from the underground mine area through the surface mine area in an east-west direction. In the western portion of the surface mine area, the trend abruptly turned to the north and the grade of the mineralization quickly diminished. The Triangle surface mine area is down-dip from the underground workings; therefore, the depth to the mining horizon increased steadily. Mr. Spencer recalls the depth of the Triangle open pit to have been approximately 120 feet below ground surface.

Figure 3.2 is an electric log from an historical exploration drill hole located approximately 200 feet north of the mined area. The gamma activity shown in the type log corroborates the portion of the Fall River sand that was mined in the Triangle Mine and its position relative to the Fuson Shale confining unit. The top of the mineralized sand unit in the type log is at a depth of 125 feet below ground surface. The single mineralized front present within this sand unit correlates to Powertech’s F13 interval, which is the upper mineralized zone within the Lower

Photo 3-A: **Former Triangle Underground Mine Decline**

Photo 3-B: Triangle Underground Mine Vent Shaft

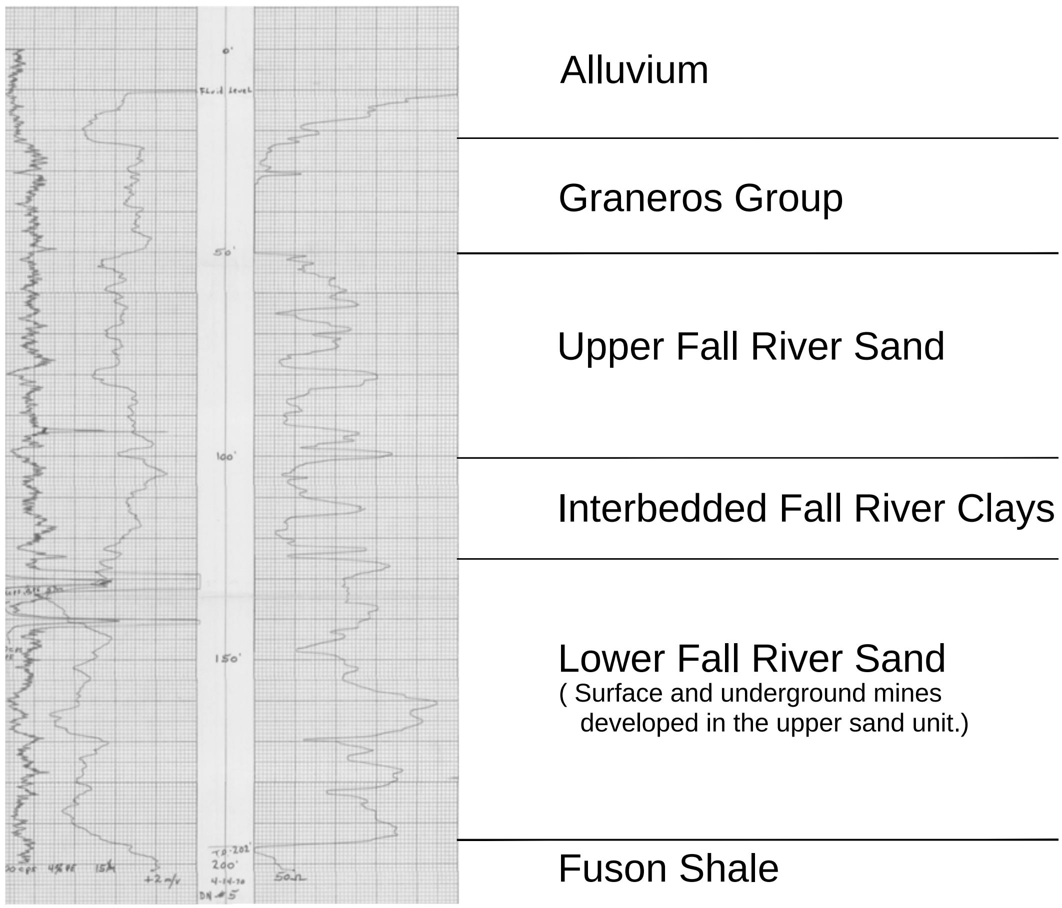

Figure 3.2

Type Log
Triangle Mine Area

Dewey-Burdock Project

DRAWN BY	R. Patton
DATE	24-Jul-2012
FILENAME	Mine-TriangleTypeLog.dwg

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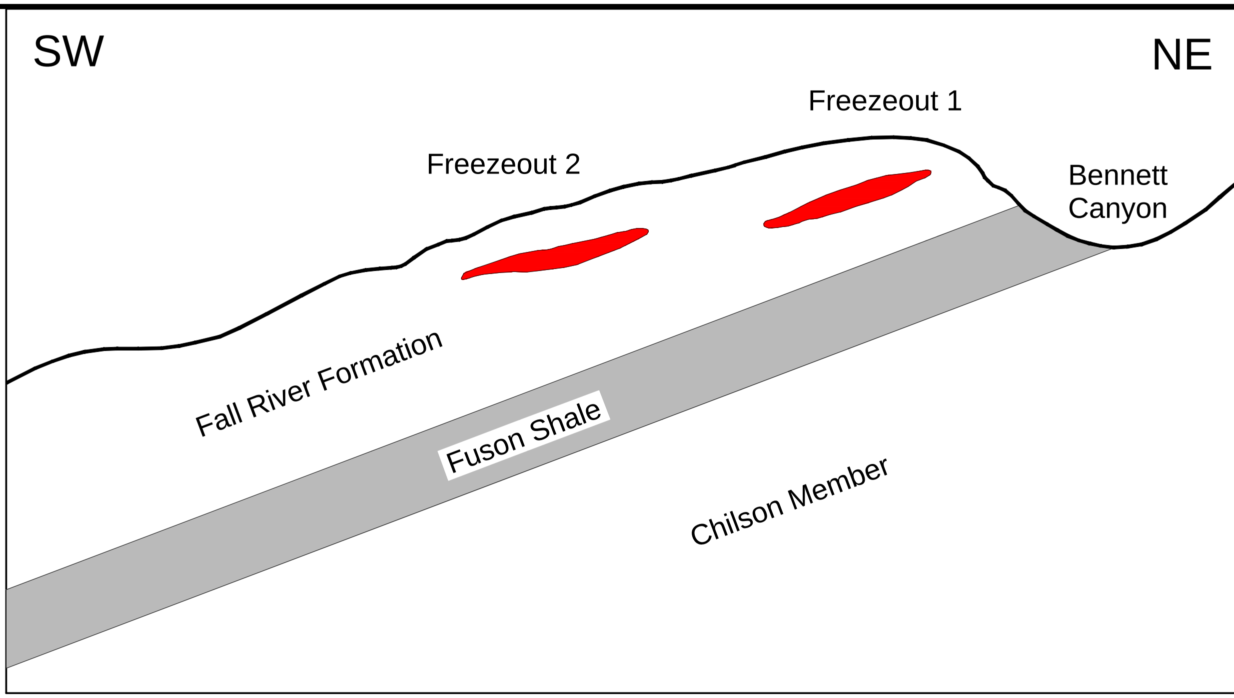
Fall River sand, the bottom of which is approximately 45 feet above the Fuson Shale. All mining took place well above the Fuson Shale, which averages 50 feet thick in this area. Accordingly, these historical mining operations did nothing to compromise the integrity of the Fuson Shale confining unit.

Darrow Mines Area

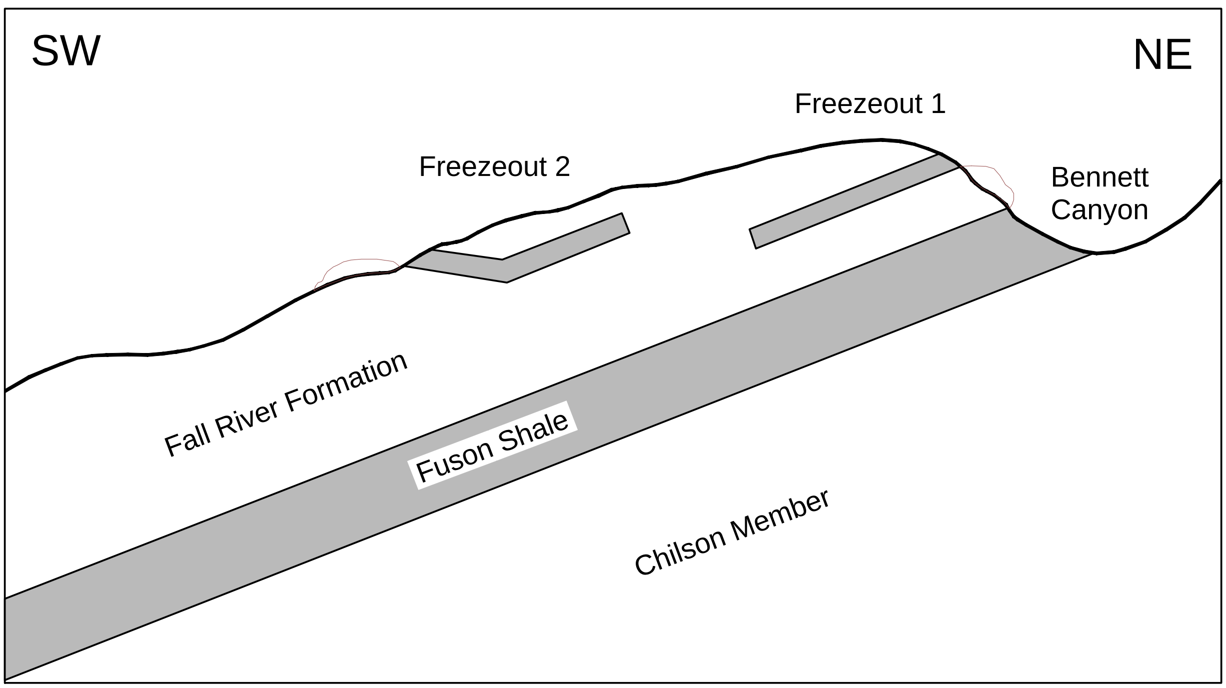
Figure 3.1 depicts the location of the Darrow Mine surface pits in the eastern portion of the project area. These pits were developed within unsaturated sandstones of the Fall River Formation at depths ranging from 50 to 90 feet below ground surface. As illustrated on Figure 3.1, the Freezeout underground mines were located approximately ½ mile north of the Darrow surface mines. These historical underground mines are outside of the project area in the SW¼ Section 36, T6S, R1E. Freezeout No. 1 and Freezeout No. 2 each have approximately 1,000 feet of underground workings. Plan view maps obtained from TVA show the underground workings at Freezeout No. 1 were accessed by two declines, and access to the workings of Freezeout No. 2 was provided by three declines. Photos 3-C and 3-D show the current condition of the declines for the Freezeout mines. The haulage roads are still visible but the access ways or portals to the underground workings have collapsed or have been covered. Figure 3.3 illustrates how these shallow underground mining operations were used to recover ore in this rugged terrain. It is important to note that the workings were above the water table and followed the dip of the mineralized sandstones. Accordingly, these mining operations did not intersect or compromise the integrity of the underlying Fuson Shale confining unit.

Figure 3.1 shows the location of the Darrow underground mine, approximately 500 feet northwest of Darrow Pit No. 2, in the NE¼ of Section 2, T7S, R1E. According to personal communication with Donald Spencer (2011), this underground mine consisted of approximately 1,200 feet of workings within a 250-foot x 700-foot area, which was also accessed by declines. The surface in this area has been reclaimed and all evidence of mining operations has been removed.

Figure 3.4 is a plan view map of the Darrow underground workings taken from a TVA drill hole map. This map shows the locations of many Susquehanna Western Inc. drill holes and air vents for the underground workings. Also shown on this map are five TVA drill holes, one of which is located less than 20 feet from one of the underground drifts. The electric log from this drill hole (DRA-36) is an excellent representation of the mining horizon in these underground workings and is shown in Figure 3.5. The gamma trace on this type log again corroborates that the top of the mining zone for this underground mine was at a depth of 73 feet below ground surface. The base of the mineralized sand lies 23 feet above the top of the Fuson Shale, which is more than 50 feet thick in this area. The Darrow underground mine workings were restricted to the



A. Shallow ore bodies in Fall River



B. Declines developed to access Fall River ore bodies.

Figure 3.3

Schematic - Underground Workings - Freezeout Mines

Dewey-Burdock Project

DRAWN BY	R. Patton
DATE	24-Jul-2012
FILENAME	Mine-FreezeoutUGWork.dwg

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Photo 3-C: Former Freezeout Mine Decline

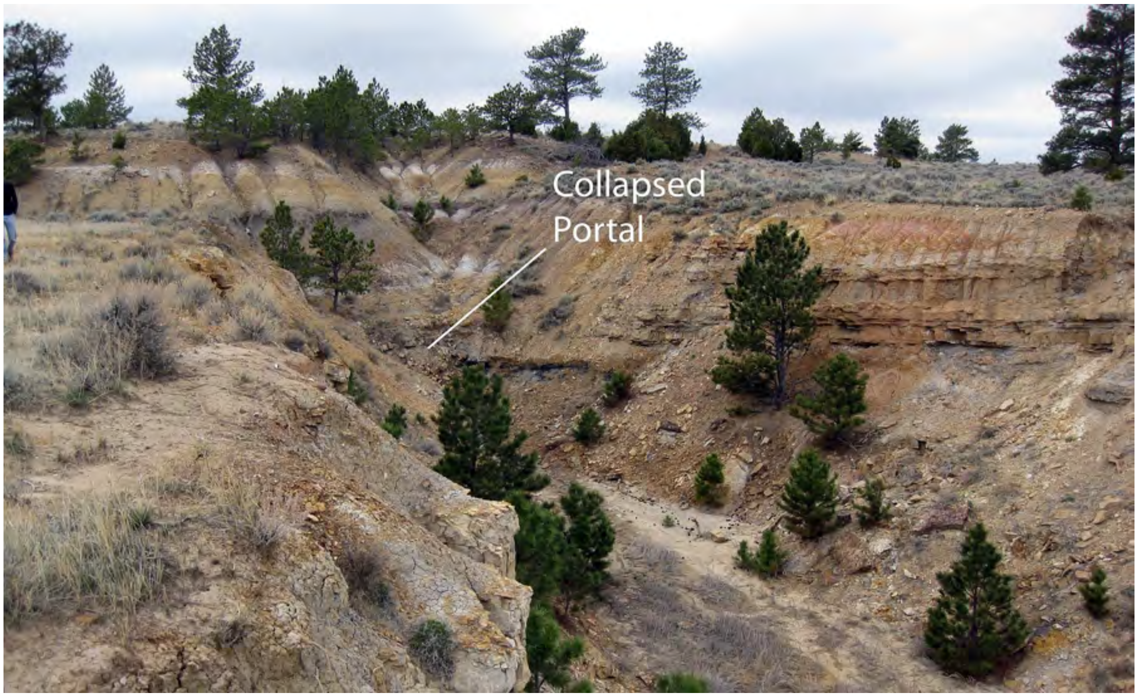
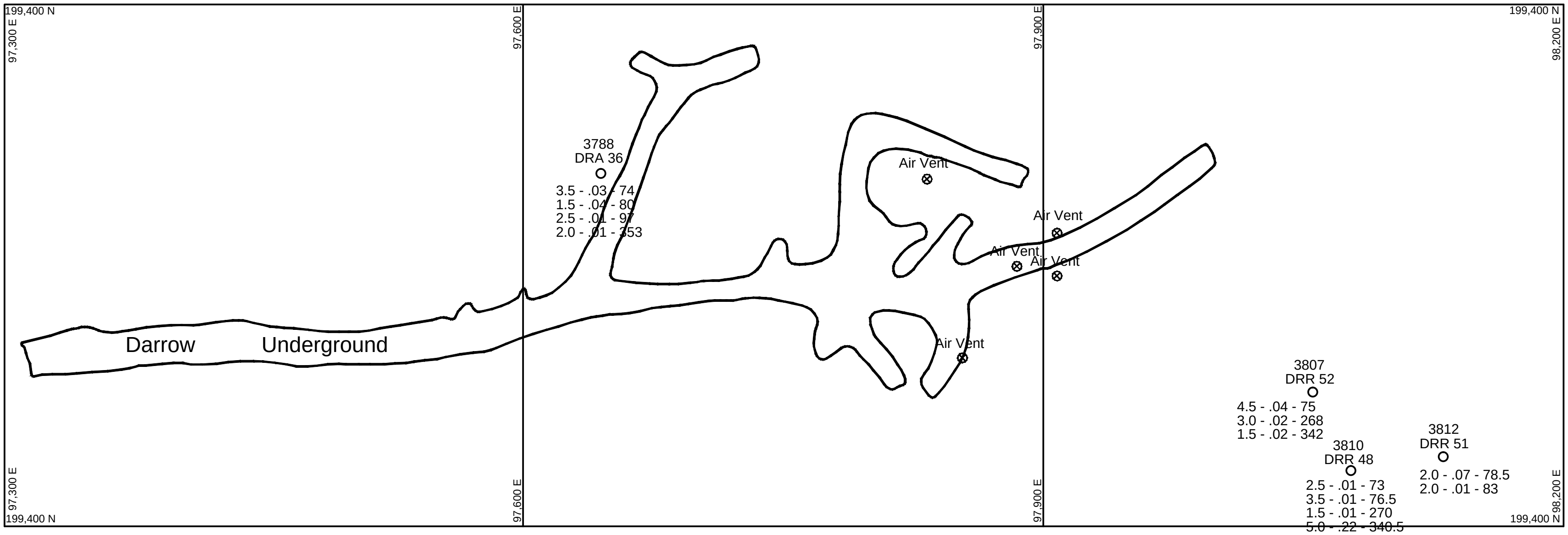


Photo 3-D: Former Freezeout Mine Decline



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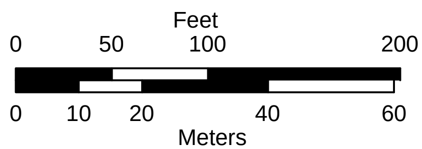
Legend

DRR 52 Boreholes



Source: TVA drill hole map

Figure 3.4

Plan View - Darrow Underground Mine

Dewey-Burdock Project

DRAWN BY	R. Patton
DATE	24-Jul-2012
FILENAME	Mine-DarrowPlanView.dwg

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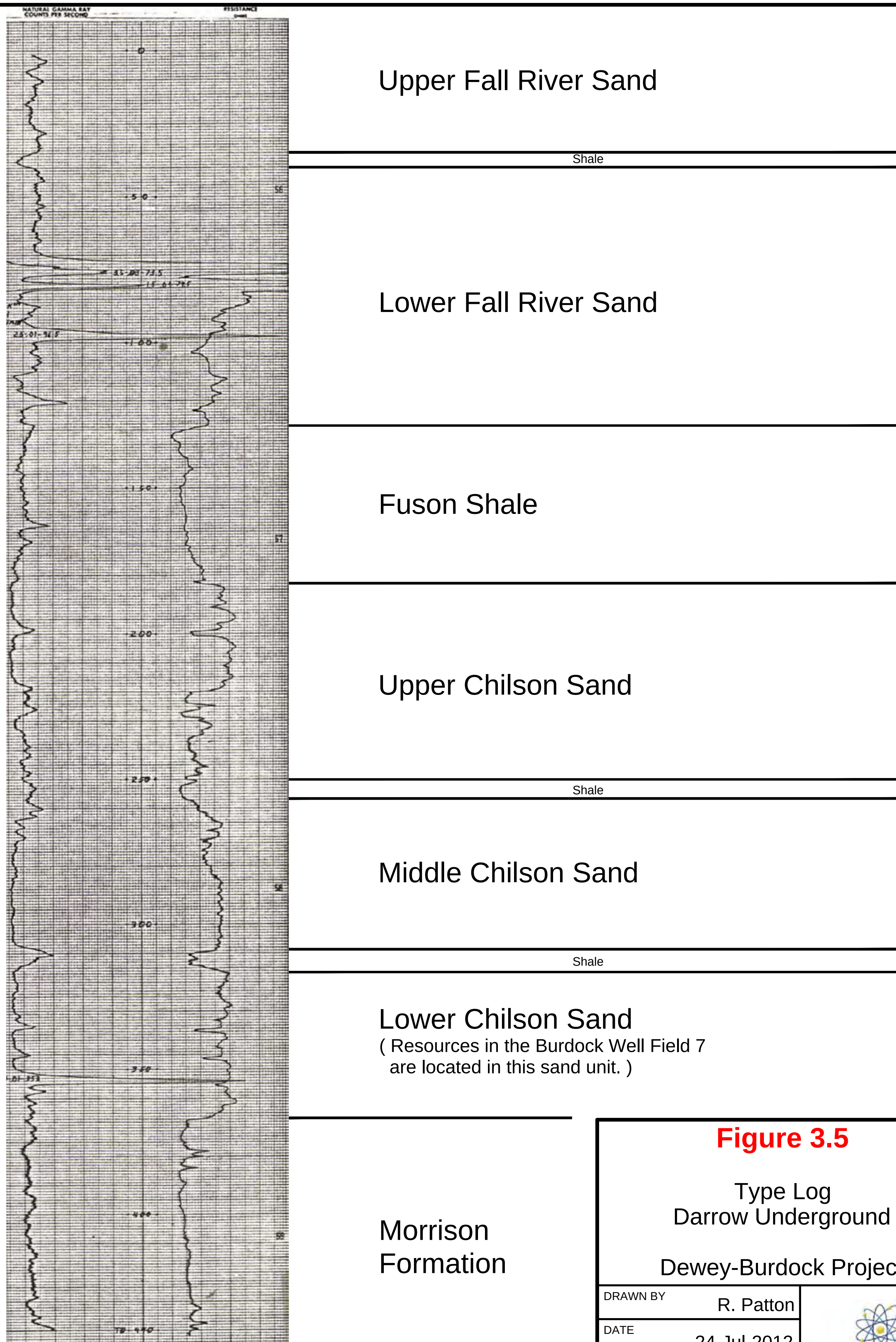

Figure 3.5

Type Log
Darrow Underground

Dewey-Burdock Project

DRAWN BY	R. Patton
DATE	24-Jul-2012
FILENAME	Mine-DarrowUGTypeLog.dwg

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mineralized sand interval, and these mining operations did not intersect or compromise the integrity of the underlying Fuson Shale confining unit.

Maps obtained from TVA show the locations of two adits within Darrow Pit No. 2 in the NE¼ Section 2, T7S, R1E (Figure 3.1). Although not classified as underground mines, these adits consisted of two separate horizontal tunnels that were driven into the pit walls in order to access additional uranium ore that was not recovered in the surface mining operations. These two adits total approximately 650 feet of workings. Because of the horizontal nature of the adits, these workings were conducted at elevations equal to or above the elevation of the bottom of the pit and were considered to be an extension of the surface mining operations. These small operations did not intersect or compromise the integrity of the underlying Fuson Shale confining unit.

As demonstrated above, neither the surface mining activity nor the shallow underground workings intersected or compromised the integrity of the underlying Fuson Shale confining unit. Cross section F-F' (Plate 6.18) illustrates the continuous Fuson Shale confining unit throughout this area. In addition, outcrop examinations of the Fuson Shale in Bennett Canyon, ½-mile up-dip from the Darrow Mine area, reveal the presence of continuous, low-permeability mudstones and shales.

4.0 ATTACHMENT C - CORRECTIVE ACTION PLAN AND WELL DATA

This attachment details the inventory of water wells, monitor wells, exploration drill holes, and oil and gas wells located within the AOR. It also describes Powertech's corrective action plan to prevent movement of ISR fluids into USDWs.

4.1 Well Inventory

Historical records and field investigations conducted within the 2-km (1.2-mile) AOR were used to develop the well inventory. An initial investigation of the wells was completed in 2007, and additional surveys were conducted in 2011 to evaluate the use and condition of the wells. A total of 122 wells have been identified within the AOR. There also are 27 wells with historical records that currently are not present at the surface and 17 wells with historical records that have been visually confirmed as plugged and abandoned. Appendix A contains the well inventory summary tables, and Appendix B contains the detailed well inventory, well completion records and associated documentation. Plate 3.1 depicts existing wells within the AOR.

Table 1 in Appendix A summarizes the well inventory. Listed wells have one of the following uses:

Domestic: Are currently used or reasonably can be expected to be used for domestic water use (e.g., drinking, washing, sanitary use, etc.), including wells which also are used for livestock watering. This category also includes formerly used domestic wells which through agreements with Powertech no longer will be used as drinking water wells (17 wells)

Stock: Watering of livestock is sole use; well cannot be used for domestic water use (i.e., no piping to domestic water system, etc.) (44 wells)

Irrigation: Permitted to be used for irrigation (1 well)

Monitor: Sole use is for monitoring (60 wells)

Table 2 in Appendix A lists the wells identified in historical records that were not evident at the surface during the field investigations. These wells are depicted on Figure 4.1. Several of these wells are suspected of being plugged and abandoned. Powertech will continue to search for these wells. During design of well fields, pump testing will be designed to locate any such wells and to detect any potential impacts from such wells on the ISR operations.

Table 3 in Appendix A lists all of the wells within the AOR that have been confirmed by Powertech to have been plugged and abandoned. Each well was visually inspected, and it has been determined that cement was placed within the well bores.

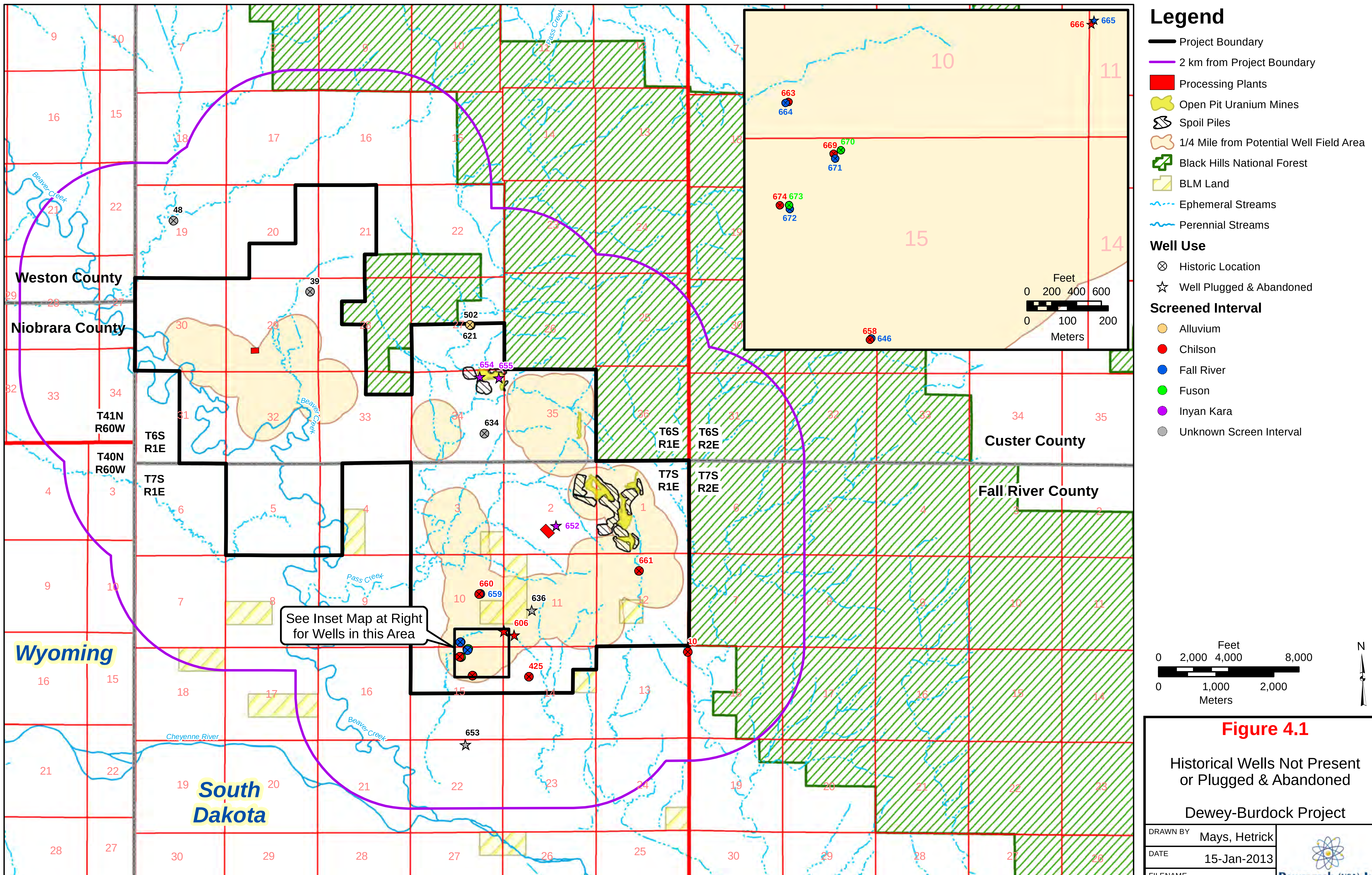

Figure 4.1

Historical Wells Not Present or Plugged & Abandoned

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	15-Jan-2013
FILENAME	Wells-Historic-NP-PA.mxd

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4.2 Oil and Gas Well Inventory

No formerly producing or actively producing oil and gas wells exist within the project boundary or within the AOR. Within the AOR, the locations of 13 plugged and abandoned oil test wells have been identified, 3 of which are within the project area. The locations of these abandoned test wells are depicted on Plate 3.1.

4.3 Exploration Drill Hole Inventory

As typical of a site proposed for ISR uranium extraction, historical exploration holes are present within the project area. Appendix C summarizes the available information for historical drill holes within one mile of the project area, including TVA and Powertech drill holes. While the exploration drill hole inventory area is slightly smaller than the AOR (1-mile inventory versus 1.2-mile AOR), it extends well beyond the area potentially affected by ISR operations and the area where exploration holes could potentially impact ISR operations. Exploration hole locations are depicted on Figure 4.2.

4.3.1 Evaluation of Potential Discharges to Alluvium through Unplugged Exploration Holes

Powertech performed extensive investigation into all surface water features within the project area. This included field investigations during the initial baseline monitoring period and the use of color infrared (CIR) imagery. All surface water features and sources of groundwater flow to the surface are believed to have been identified within the project area.

With one exception, groundwater discharging to the ground surface is limited to flowing artesian wells, which will be controlled and mitigated as described in the correction action discussed below. The only feature identified that was indicative of groundwater discharge from exploration boreholes at or near surface was the “alkali area” in the southwestern corner of the Burdock portion of the project area (N/2 NE/4 Section 15, T7S, R1E). This is an area of known discharge from the Fall River and Chilson to the surface through abandoned exploration holes documented by TVA. The significance of this area as it relates to ISR operations will be evaluated further after NRC license issuance during delineation drilling and well field-scale pumping tests prior to any well field development.

4.3.1.1 CIR Imagery

To evaluate possible groundwater discharge to the alluvium within the Beaver and Pass Creek drainages, CIR satellite imagery was obtained from the National Agriculture Imagery Program (NAIP) of the USDA Farm Services Agency for the project area and vicinity. The imagery was photographed in 2010 and produced with a resolution of one meter. CIR imagery is commonly used to delineate areas of active vegetative growth; in semiarid regions such as the project area,

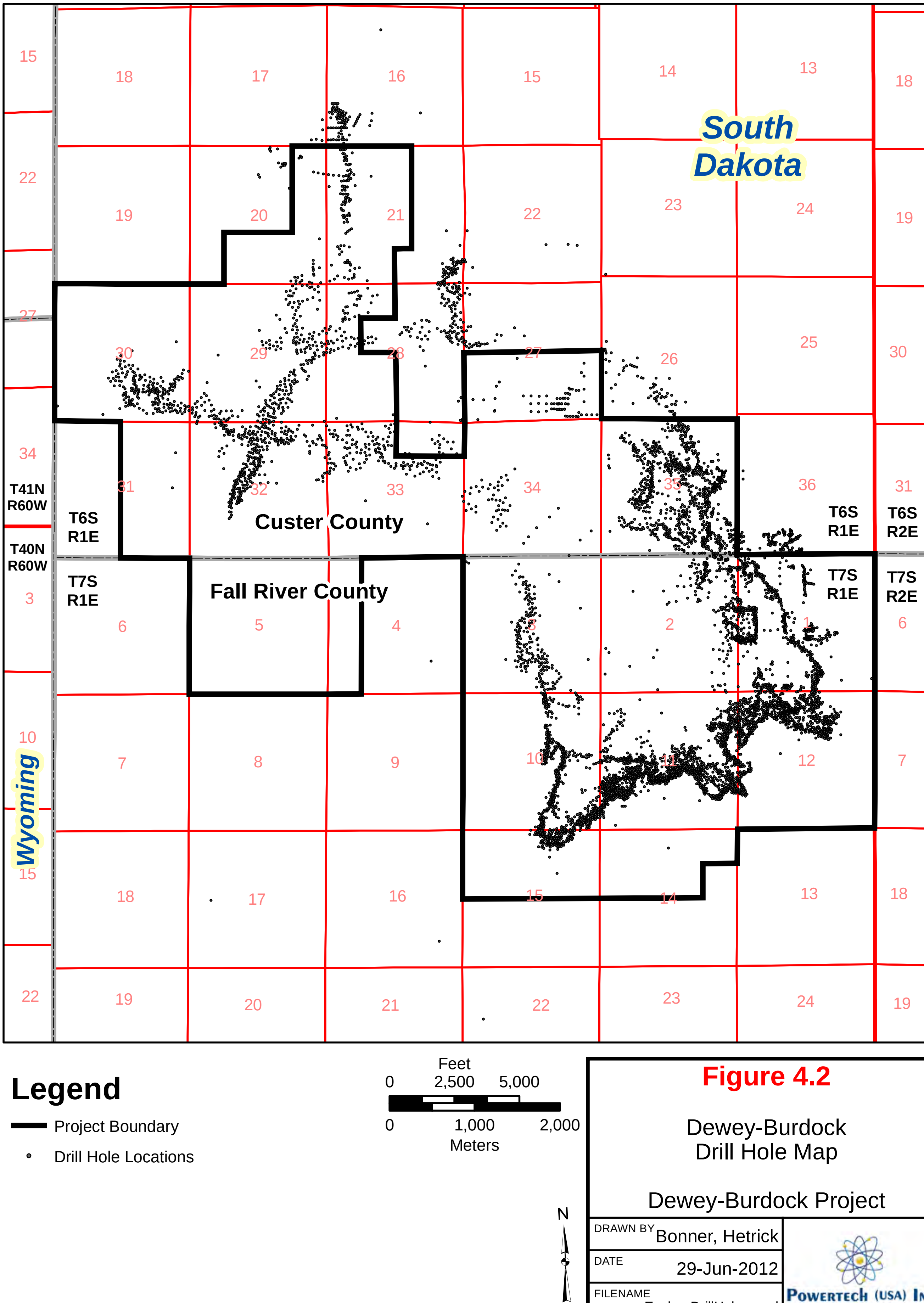

Figure 4.2

Dewey-Burdock Drill Hole Map

Dewey-Burdock Project

DRAWN BY Bonner, Hetrick

DATE 29-Jun-2012

FILENAME ExploreDrillHoles.mxd

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such areas are often indicative of enhanced water supply, such as occurs with irrigation or subirrigation.

CIR imagery for the project area and vicinity is presented in Figure 4.3. The CIR imagery was examined visually for any anomalies that may suggest groundwater discharge at or near the surface, such as from upward flow through an open borehole or a natural spring. Within the project area, there are several flowing artesian wells that at times are allowed to discharge groundwater to the surface. These areas are generally visible on the CIR imagery. The alkali area had a noticeable signature on CIR (ponded water surrounded by discolored soil) and is depicted on Figures 4.4 and 4.5.

The CIR imagery clearly shows two springs outside the project area near the town of Dewey along the Dewey Fault (Figure 4.6). These locations were later verified by Powertech personnel and the springs were sampled for water quality analysis. Results of those samples indicate the spring water most closely resembles Fall River water quality; those data clearly distinguish the spring water from the alluvium and Unkpapa. The results of this investigation strongly support the use of CIR data to identify areas of groundwater discharge, and with the exception of the alkali area support the lack of such discharge from exploration boreholes within the project area. Powertech will continue to use CIR imagery to assess the potential for groundwater discharge to the surface or alluvium within the project area. The obvious evidence of groundwater discharge in the alkali area suggests that if similar situations existed at other locations in the project area they would be readily detectable.

4.3.1.2 Potentiometric Surface Evaluation

Powertech also evaluated areas where the potentiometric surfaces of the Fall River and Chilson are above ground surface as an indicator of the potential for groundwater discharge to the alluvium. Those areas within the Beaver Creek and Pass Creek drainages where the potentiometric surfaces for the Fall River and Chilson are above the ground surface are depicted on Figures 4.7 and 4.8, respectively. Note that the potentiometric surfaces are anticipated to be above ground surface to the west and southwest of the areas depicted on Figures 4.7 and 4.8; the boundaries shown in these directions are due to lack of data. The potential for groundwater discharge to alluvium from an operating well field is limited to those areas where the well field overlaps alluvium and the potentiometric surface of the Fall River or Chilson is above the base of the alluvium.

4.3.1.3 Alluvial Drilling Program

An alluvial drilling program was completed in May 2011 to further address potential discharge to alluvium from underlying aquifers. Nineteen borings were drilled into the alluvium along Beaver

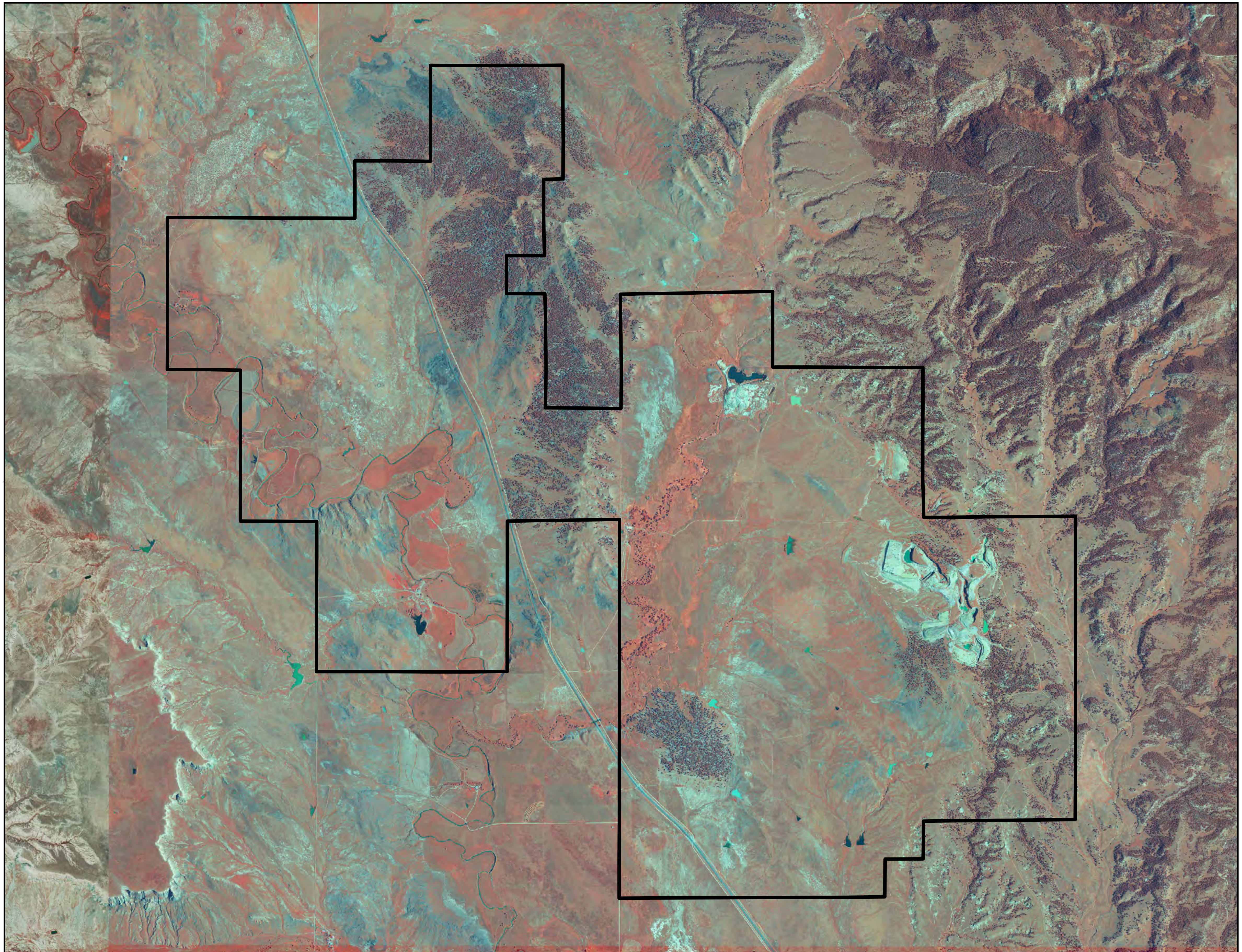

Figure 4.3

Color Infrared Imagery (2010 Data)

Dewey-Burdock Project

DRAWN BY	J. Medford
DATE	1-Nov-2011
FILENAME	2011_DB_Fig_2.7-22.mxd

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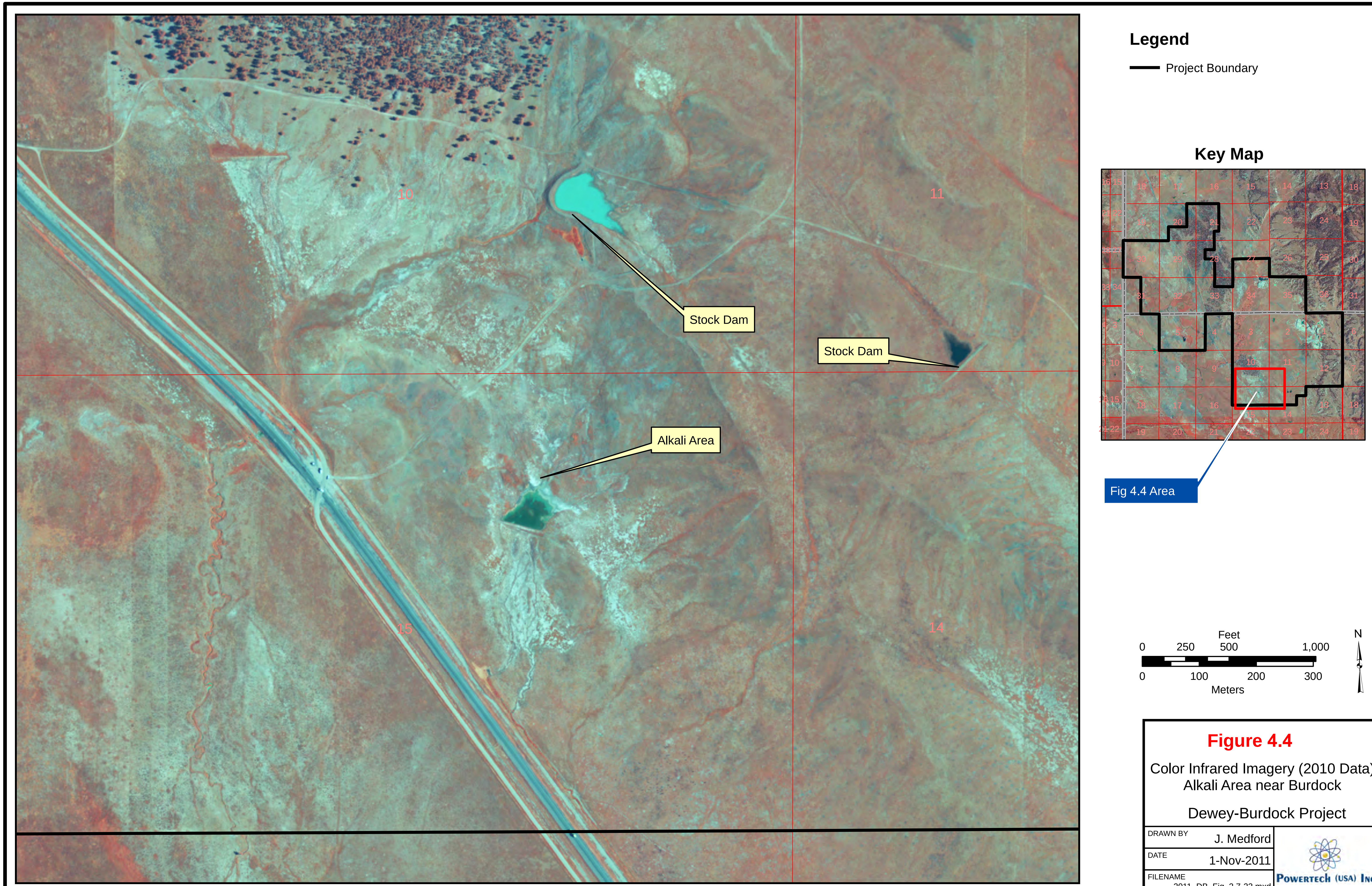

Figure 4.4

Color Infrared Imagery (2010 Data)
Alkali Area near Burdock

Dewey-Burdock Project

DRAWN BY	J. Medford
DATE	1-Nov-2011
FILENAME	2011_DB_Fig_2.7-23.mxd

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Legend

Project Boundary

Key Map

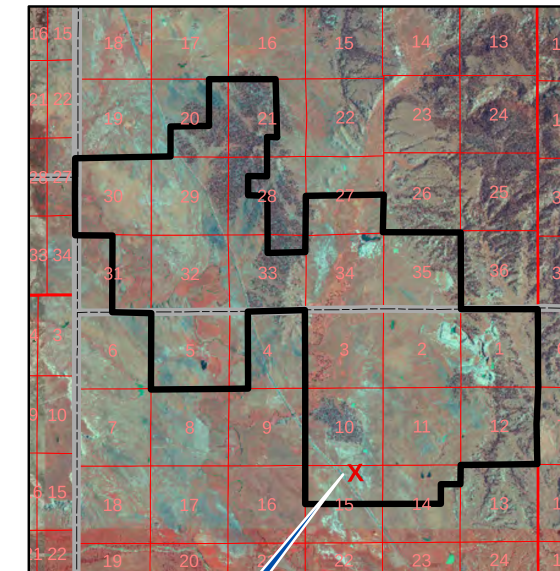

Photo taken at this location
Looking South

Scale: None

Figure 4.5

Photograph of Alkali Area, Looking South, near Burdock

Dewey-Burdock Project

DRAWN BY	J. Medford
DATE	1-Nov-2011
FILENAME	2011_DB_Fig_2.7-24.mxd

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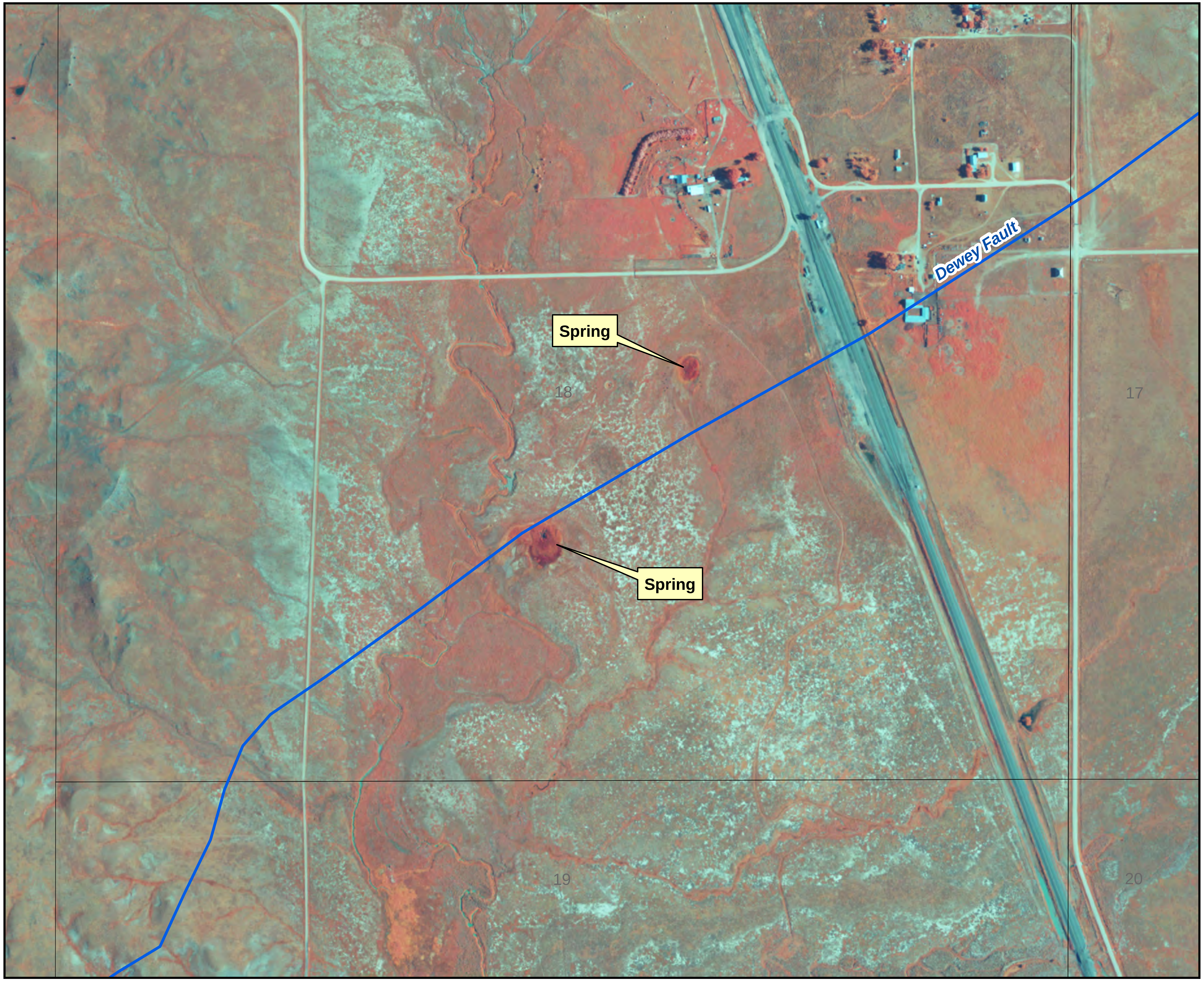
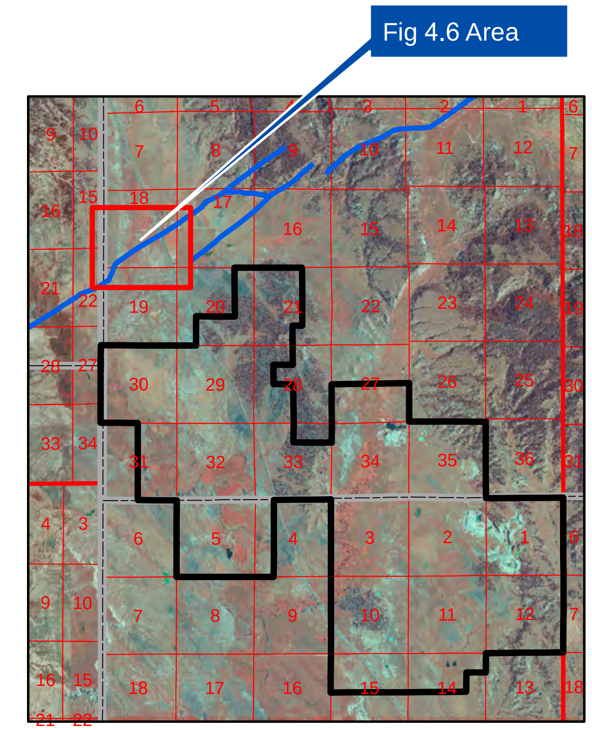


Legend

- Dewey Fault
- Project Boundary



Key Map

Feet: 0, 250, 500, 1,000
Meters: 0, 100, 200, 300

N

Figure 4.6

Color Infrared Imagery (2010 Data)
Springs near the Town of Dewey

Dewey-Burdock Project

DRAWN BY	J. Medford
DATE	1-Nov-2011
FILENAME	2011_DB_Fig_2.7-25.mxd

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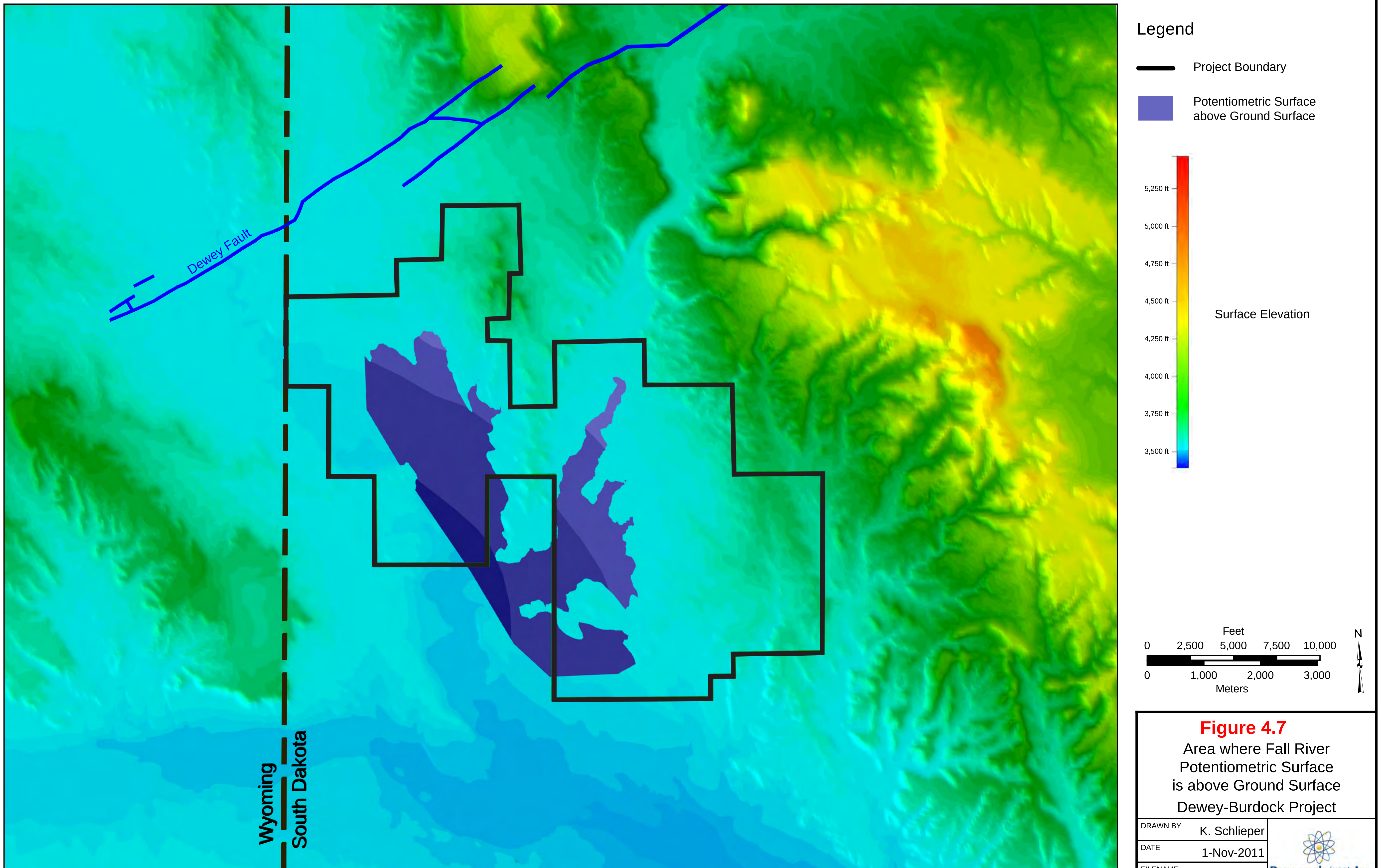

Figure 4.7
Area where Fall River Potentiometric Surface is above Ground Surface
Dewey-Burdock Project

DRAWN BY	K. Schlieper
DATE	1-Nov-2011
FILENAME	2011 DB_Fig_2.7-19.ai

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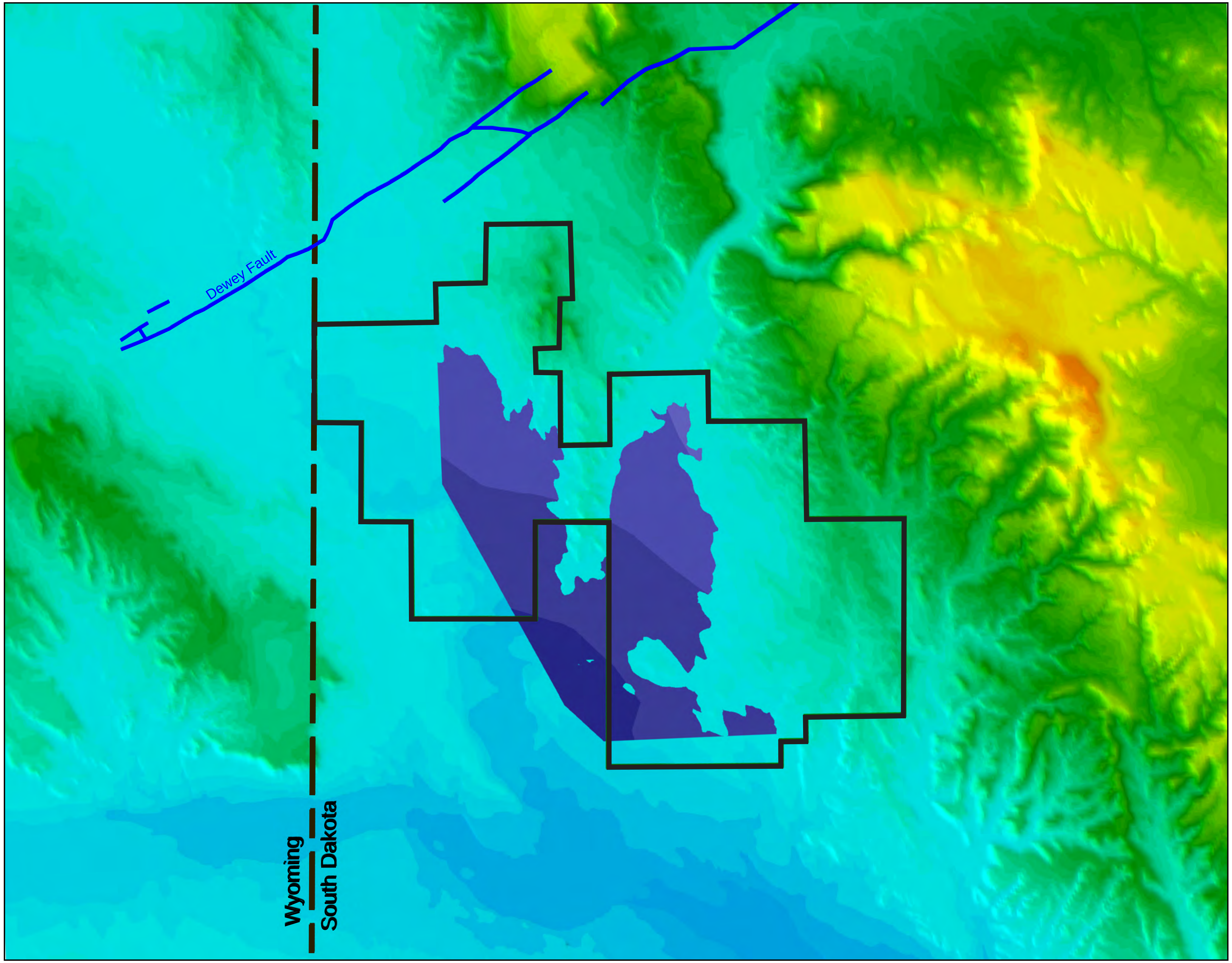

Figure 4.8
Area where Chilson Potentiometric Surface is above Ground Surface
Dewey-Burdock Project

DRAWN BY	K. Schlieper
DATE	1-Nov-2011
FILENAME	2011_DB_Fig_2.7-20.ai

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Creek and Pass Creek, many of which were dry. Three borings were completed as alluvial monitor wells. The thickness of the saturated alluvium at these wells ranged from 10 to 12 feet. The alluvium in the Pass Creek drainage is up to 50 feet thick; in the Beaver Creek drainage, the alluvium is up to 30 feet thick.

Results of the alluvial drilling program (occurrence/lack of water, potentiometric levels and water quality data) did not indicate any areas of discharge to the alluvium from underlying aquifers but rather were consistent with limited recharge occurring from surface waters in the upland portions of the project area. Figure 4.9 depicts the potentiometric surface of the Pass Creek and Beaver Creek alluvium.

The results from the May 2011 alluvial drilling program in the Beaver Creek and Pass Creek drainages are consistent with the historical field observations in that neither the past field investigations nor the recent drilling program identified any areas other than the "alkali area" noted above where there was evidence to suggest groundwater is discharging into the alluvium or at the ground surface from the underlying bedrock formations.

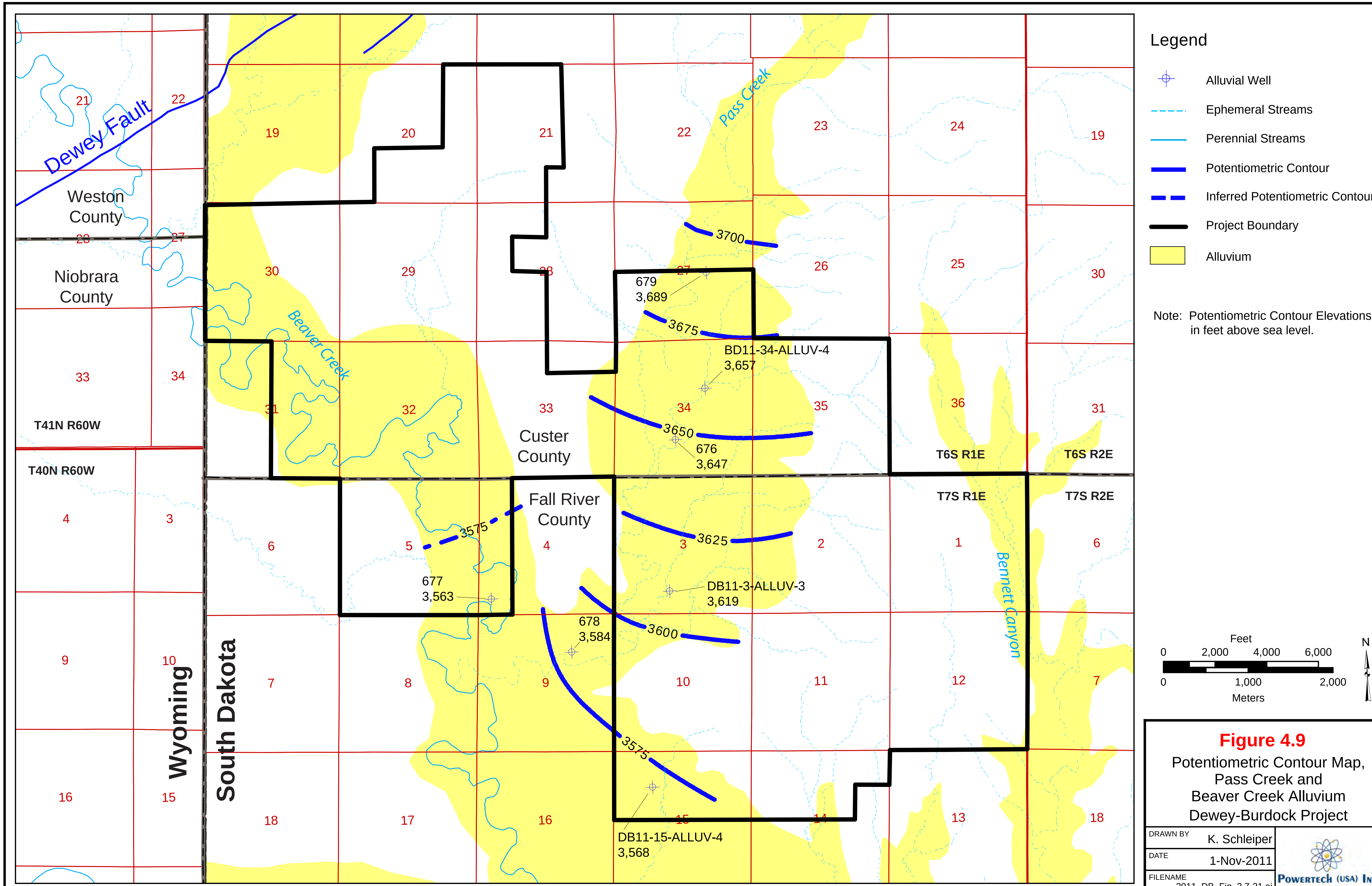
4.3.1.4 Well Field Delineation Drilling and Pump Testing

Further evaluation during the planned delineation drilling and well field-scale pump testing prior to the development of each well field will demonstrate adequate confinement to prevent potential upward groundwater movement through unplugged or improperly plugged boreholes or natural geologic features (refer to Section 8.2.3).

4.4 Corrective Action

Powertech will use the best available information and best professional practices to locate boreholes or wells in the vicinity of potential well field areas, including historical records, use of color infrared imagery, field investigations, and potentiometric surface evaluation and pump testing conducted for each well field as part of the development of well field hydrogeologic data packages (refer to Section 8.2.4) and injection authorization data packages (refer to Section 8.2.5). As with other ISR facilities, Powertech anticipates that some unplugged holes or wells may be encountered during well field development. Consistent with standard industry operating practices and experience, the following describes the procedures Powertech will implement to detect and mitigate any unplugged holes or wells that have the potential to impact the control and containment of well field solutions.

Powertech has committed to NRC to properly plugging and abandoning or mitigating any of the following should they pose the potential to impact the control and containment of well field solutions within the project area (Powertech, 2011):


Legend
Alluvial Well
Ephemeral Streams
Perennial Streams
Potentiometric Contour
Inferred Potentiometric Contour
Project Boundary
Alluvium
Note: Potentiometric Contour Elevations in feet above sea level.
Dewey Fault
Weston County
Niobrara County
Custer County
Fall River County
Wyoming
South Dakota
Pass Creek
Beaver Creek
Bennett Canyon
T41N R60W
T40N R60W
T6S R1E
T6S R2E
T7S R1E
T7S R2E
679
3,689
BD11-34-ALLUV-4
3,657
676
3,647
677
3,563
DB11-3-ALLUV-3
3,619
678
3,584
DB11-15-ALLUV-4
3,568
3700
3675
3650
3625
3600
3575
3575
Feet
0 2,000 4,000 6,000
0 1,000 2,000
Meters
N
Figure 4.9
Potentiometric Contour Map, Pass Creek and Beaver Creek Alluvium Dewey-Burdock Project
DRAWN BY K. Schleiper
DATE 1-Nov-2011
FILENAME 2011_DB_Fig_2.7-21.ai
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1) Historical wells and exploration holes
2) Holes drilled by Powertech for the purposes of delineation and exploration
3) Any wells failing mechanical integrity testing (MIT) including those installed by Powertech and those installed before Powertech

Powertech will attempt to locate with best professional practices any presently unknown boreholes or wells in the vicinity of every potential well field. Historical records will be used to determine the presence of previous boreholes and wells. Pump testing conducted as part of routine well field hydrogeologic package development will use an array of monitor wells designed to detect and locate effects of any unknown boreholes or wells. The pump testing also will be designed to provide sufficient hydrogeologic data to demonstrate that the well field design and monitoring systems are sufficient to control and detect any potential excursions. Details of the pump testing program are provided in Section 8.2.3.

Should any drill hole or well at or near potential well fields be suspected of being improperly plugged and abandoned, Powertech will use best professional practices to precisely locate and re-enter the suspected problem hole with a drill rig or tremie pipe. Powertech will evaluate mitigation alternatives including plugging and abandoning the hole or well with grout as described below. Powertech may enter the well with logging equipment prior to plugging and abandoning the well to confirm that the well poses a potential problem.

It is not surprising that there is little evidence of unplugged drill holes in the project area, even though there is a long history of mineral exploration in this area and much of this occurred prior to enactment of modern laws and regulations governing plugging and abandoning drill holes. This is because of the well-known natural tendency of drill holes to seal themselves by collapsing, caving and swelling of the formations through which the holes are drilled. During exploration, drill holes must be logged promptly after drilling in order to minimize the risk of losing logging tools or losing the ability to access the full depth of the holes due to the processes described above. During the pump testing that will be done for each well field, special attention will be paid to known or suspected locations of exploration holes to detect evidence of interaquifer communication that might be the result of unplugged drill holes.

4.4.1 Well Replacement Procedures

During the design of each potential well field, all nearby water supply wells will be evaluated for the potential to be impacted by ISR operations or the potential to interfere with ISR operations. If needed, this evaluation will also include groundwater modeling. The results of the evaluation will be contained within a well replacement plan described in the hydrogeologic data package for each well field.

At a minimum, all domestic wells within the project area and all stock wells within ¼ mile of well fields will be removed from private use, or, at a minimum, removed from drinking water use. Depending on the well condition, location and screen depth, Powertech may continue to use the well for monitoring or plug and abandon the well.

During operations, the monitor well ring will provide advance warning before any wells outside the ring have potential to be impacted. Operational monitoring of existing water supply wells is described in Section 14.3 (Attachment P).

The well owner will be notified in writing prior to removing any well from private use. Powertech will work with the well owner to determine whether a replacement well or alternate water supply is more appropriate. Lease agreements for the entire project area currently allow Powertech to remove and replace water supply wells as needed. The standard language from the lease agreements pertaining to removing wells from private use is provided below. (Note: all lease agreements formerly held by Denver Uranium have been assigned to Powertech.)

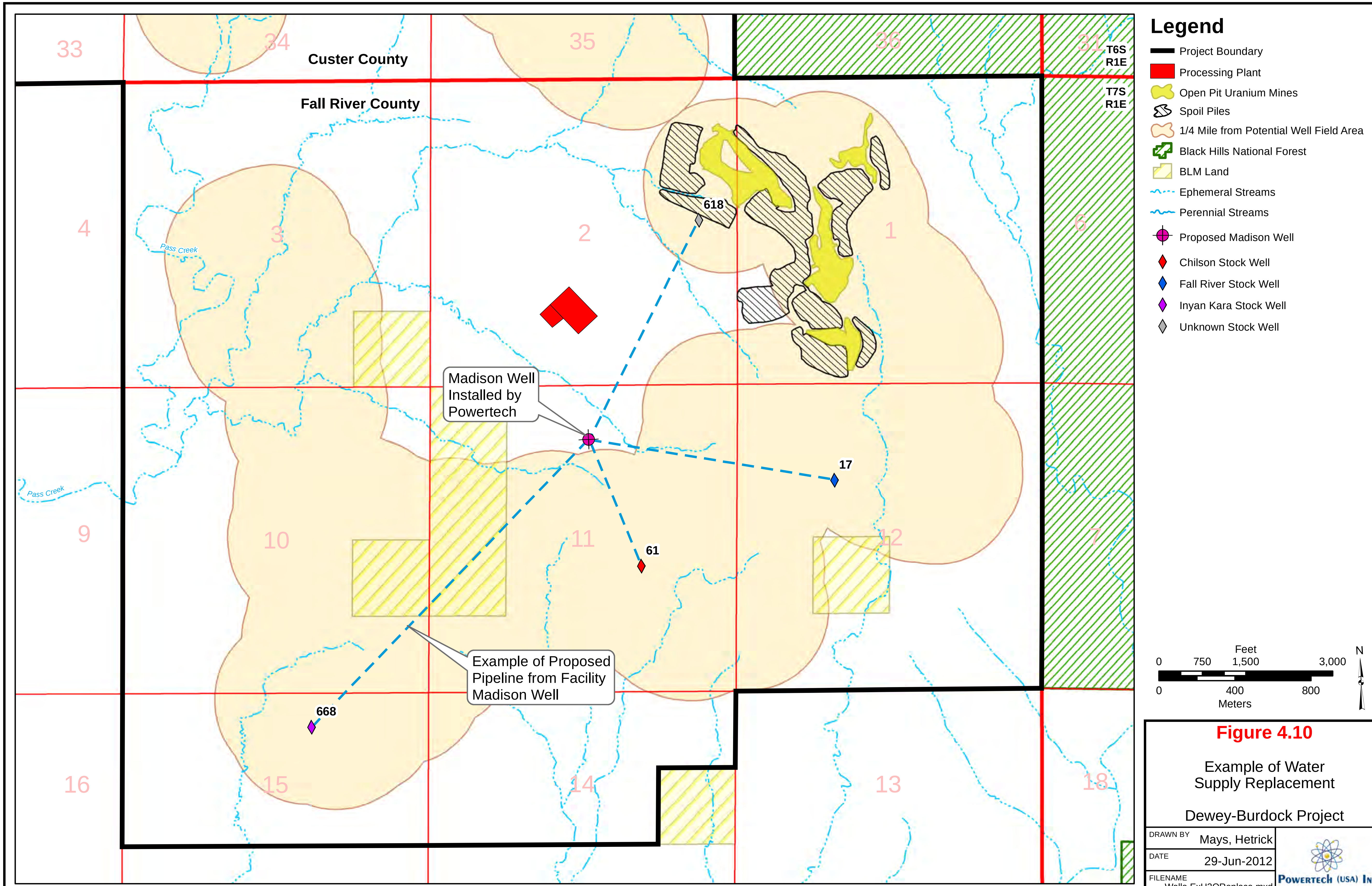
> DENVER URANIUM shall compensate LESSOR for water wells owned by LESSOR at the execution of this lease, as follows: Any such water which falls within an area to be mined by DENVER URANIUM, shall be removed from LESSOR's use. Prior to removal, DENVER URANIUM shall arrange for the drilling of a replacement water well or wells, outside of the mining area, in locations mutually agreed upon between LESSOR and DENVER URANIUM, as may be necessary to provide water in a quantity equal to the original well and of a quality which is suitable for all uses the original water well served at the time such well was removed from LESSOR's use.

Replacement wells will be located an appropriate distance from the potential well fields and will target an aquifer outside of the ore zone that provides water in a quantity equal to that of the original well and of a quality which is suitable for the same uses as the original well, subject to the lease agreement and South Dakota water law.

An example of a potential water supply replacement is provided in Figure 4.10, which shows use of the proposed project Madison well to supply water by pipeline to local stock tanks.

4.4.2 Wells to Be Removed from Use

Powertech has committed to NRC to remove all existing domestic wells within the project area from private use prior to ISR operations, or, at a minimum, from drinking water use. Depending on the well condition, location and screen depth, Powertech may continue to use the wells for monitoring or plug and abandon the wells.


33
34
35
36
31
Custer County
Fall River County
T6S R1E
T7S R1E
4
3
2
1
6
Pass Creek
618
Madison Well Installed by Powertech
17
9
10
11
12
7
61
Example of Proposed Pipeline from Facility Madison Well
668
16
15
14
13
18
Legend
Project Boundary
Processing Plant
Open Pit Uranium Mines
Spoil Piles
1/4 Mile from Potential Well Field Area
Black Hills National Forest
BLM Land
Ephemeral Streams
Perennial Streams
Proposed Madison Well
Chilson Stock Well
Fall River Stock Well
Inyan Kara Stock Well
Unknown Stock Well
Feet
0 750 1,500 3,000
0 400 800
Meters
N
Figure 4.10
Example of Water Supply Replacement
Dewey-Burdock Project
DRAWN BY Mays, Hetrick
DATE 29-Jun-2012
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Powertech (USA) Inc.

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Stock wells within the project area will be evaluated as potential well fields are designed. At a minimum all stock wells that are within ¼ mile of any well field will be removed from private use prior to operation of that well field. In addition, stock wells that could be adversely affected by or could adversely affect ISR operations will be removed from private use.

Figure 4.11 shows the location of all domestic and stock wells currently anticipated to be removed from private use. All of these wells are anticipated to be removed from all private use except well 16, which will be removed from drinking water use as described in Section 17.3.

Prior to ISR operations, Powertech will assume control of all wells within the project area boundary listed as "monitor" in Appendix A, Table 1. These will be secured at the well heads to prevent unauthorized access.

4.4.3 Plugging and Abandonment Procedures

Powertech's standard operating procedures will include plugging and abandoning all boreholes completed during the process of exploration and delineation drilling. Any wells installed by Powertech which fail MIT and cannot be repaired also will be plugged and abandoned. Plugging and abandonment procedures are discussed in Section 15 (Attachment Q).

4.4.4 Mitigation and Avoidance

Boreholes or wells which may potentially impact control of well field operations will be evaluated using pump test data and groundwater modeling. Should it be determined that it is not possible to mitigate potential adverse impacts from any unplugged borehole or well that is discovered, the affected well field will be designed to minimize any potential impacts. The monitoring system will be designed to demonstrate well field control. This may include monitor wells in addition to those provided for normal well field operations.

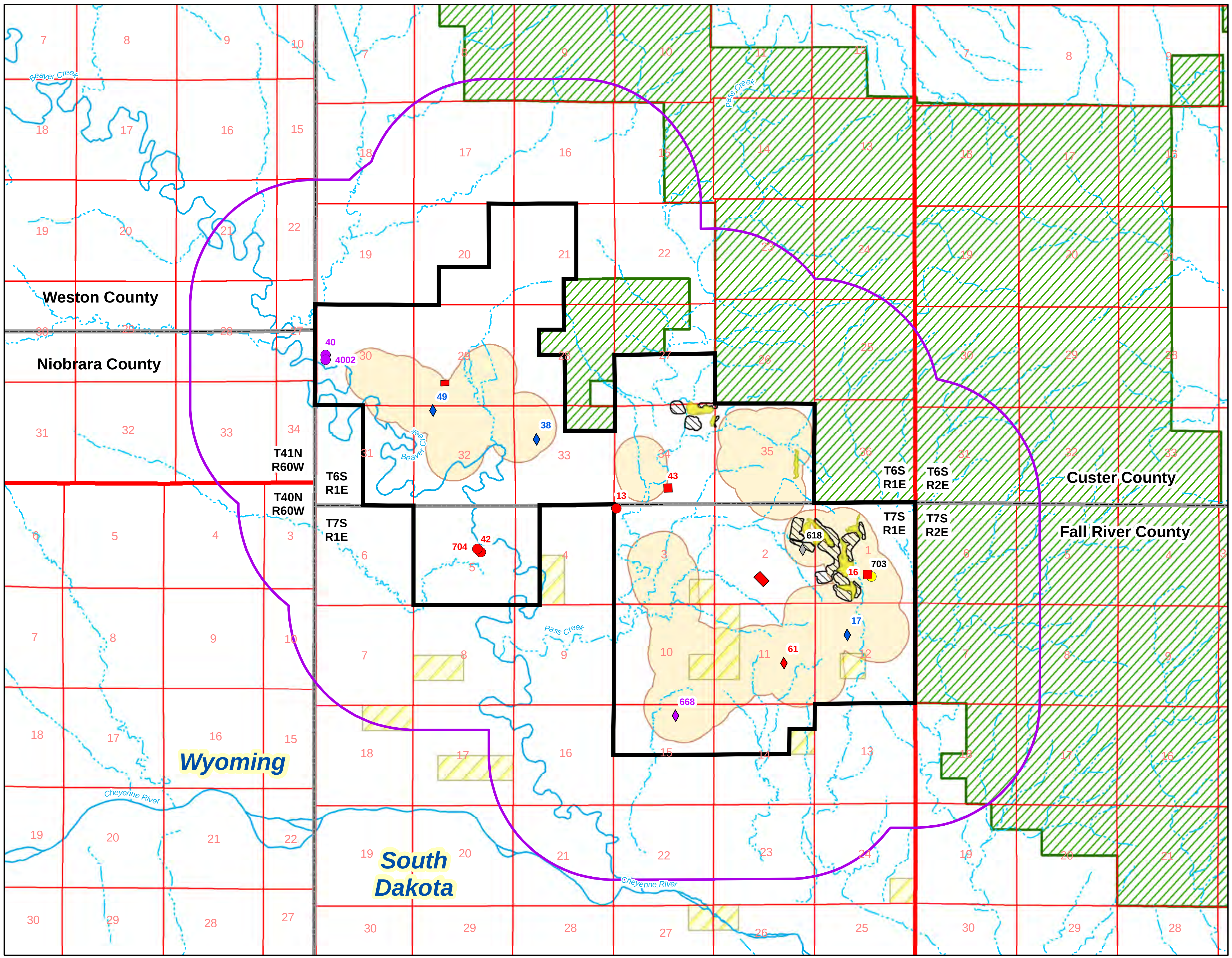

Figure 4.11

Wells to Be Removed from Private Use

Dewey-Burdock Project

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5.0 ATTACHMENT D - MAPS AND CROSS SECTIONS OF USDWs

This attachment includes regional scale maps and cross sections that show the geologic structure and overlying and underlying USDWs relevant to the Dewey-Burdock Project.

5.1 Regional Hydrogeologic Setting

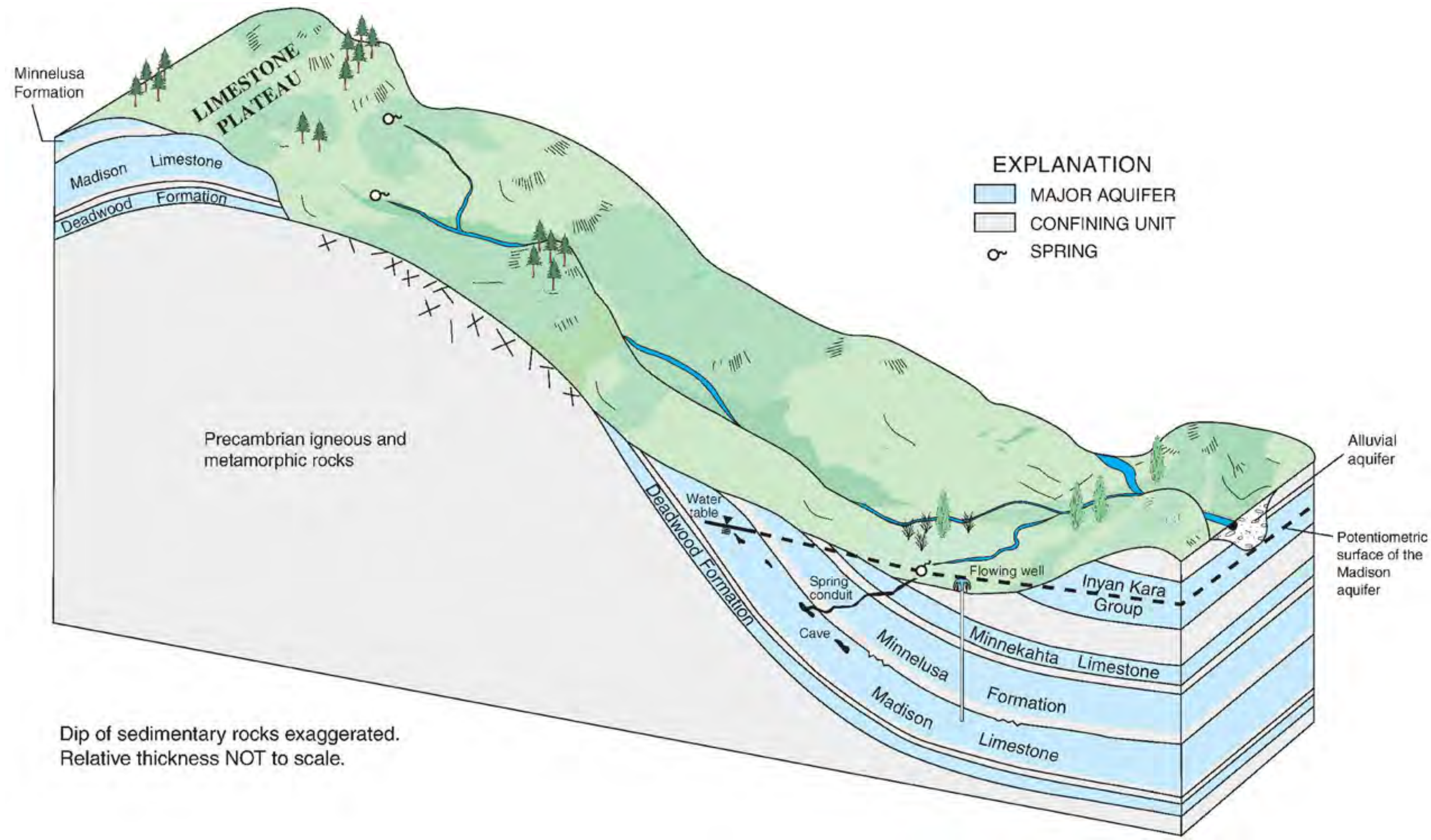
The geology of the southwestern Black Hills in South Dakota and the project area is described in Section 6. In this section, groundwater occurrence and flow are described specifically as they relate to the Dewey-Burdock Project. While the project area is generally similar to the Black Hills regional setting, the site hydrogeology has several unique characteristics as described below.

5.1.1 Regional Hydrostratigraphic Units

The Black Hills Uplift is the principal recharge area for the regional bedrock aquifer systems in southwestern South Dakota and northeastern Wyoming. The stratigraphy of the Black Hills area is summarized on Figure 6.2. Figure 5.1 provides an overview of the hydrologic setting and general hydrogeologic flow within the Black Hills. Regionally, four aquifers are utilized as major sources of water supply. These are the Inyan Kara Group, Minnelusa Formation, Madison Limestone, and Deadwood Formation. In addition to these four major aquifers, other units including the Precambrian, Minnekahta Limestone, Sundance Formation, and Unkpapa Sandstone are utilized locally as sources of water supply at or near the outcrop areas in the central portion of the Black Hills. Within the AOR, none of the deeper regional aquifers below the Sundance is used as a water supply, mainly because of the availability of shallower sources and/or the poor water quality in the deeper aquifers. There are no water supply wells within the AOR completed in aquifers below the Sundance Formation. The closest municipal wells are the Edgemont Madison wells, which are approximately 15 miles to the south-southeast of the center of the project area.

In the 1990s, the U.S. Geological Survey (USGS) undertook an extensive study focusing on the evaluation of the hydrologic significance of selected bedrock aquifers in the Black Hills area – specifically the Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers. In these evaluations, the USGS placed priority on the Madison and Minnelusa aquifers, both of which are used extensively elsewhere in the region for water supplies.

While the review of regional hydrology is prudent and necessary for this application, it should be noted that the site hydrology within the project area is unique compared to the regional Black Hills hydrology. In this regard, intermediate groundwater flow systems in the Fall River Formation and the Chilson Member of the Lakota Formation are independent of the regional



Source: Carter et al. (2003)

Figure 5.1
Diagram Showing a Simplified View of the Hydrogeologic Setting of the Black Hills Area

Dewey-Burdock Project

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flow system. These intermediate flow systems have their origin in the areas within the eastern portion of the project area (Fall River) and immediately to the east and north of the project area (Fall River and Chilson) where the Fall River and Chilson crop out at the land surface. Both of these flow systems are recharged directly by precipitation and infiltration of surface runoff along the outcrops in and near the eastern portion of the project area.

5.1.1.1 Inyan Kara Aquifer

At distance from the central core of the Black Hills Uplift, the Inyan Kara Group typically contains the first significant aquifer encountered. The Inyan Kara includes two sub-aquifers, the Chilson Member of the Lakota Formation and the Fall River Formation, which are separated by the Fuson Shale confining unit. Refer to Section 6.2.2 for a description of confining units relevant to ISR. The Inyan Kara aquifer is heterogeneous, which results in the two sub-aquifers exhibiting large variations in their hydraulic characteristics at some locations. Regionally, the Inyan Kara ranges from 250 to 500 feet thick, exhibits a large effective porosity (17 percent), and can yield considerable quantities of water from storage (Driscoll et al., 2002). Within the Black Hills, the transmissivity of the Inyan Kara ranges from 1 to 6,000 ft^2/day. Table 5.1 summarizes the hydraulic properties of the major regional aquifers, including the Inyan Kara, determined in previous investigations. The Inyan Kara is confined below by the Jurassic Morrison Formation and above by the Cretaceous Graneros Group.

5.1.1.2 Minnelusa Aquifer

The Minnelusa Formation consists of interbedded siltstone, sandstone, anhydrite, and limestone. The Minnelusa aquifer occurs primarily in saturated sandstone and anhydrite beds within the upper part of the formation (Williamson and Carter, 2001). Within the Black Hills, the Minnelusa ranges in thickness from 375 to 1,175 feet (Driscoll et al., 2002). The porosity is dominantly primary porosity within the sandstone beds, although secondary porosity is present in association with fractures and dissolution features (Williamson and Carter, 2001). Various studies have found the transmissivity of the Minnelusa to range from 1 to 12,000 ft^2/day (Table 5.1). The Minnelusa aquifer is confined above by the Opeche Shale and below by the lower permeability layers at the base of the Minnelusa.

Locally, the Minnelusa produces oil and gas in the Barker Dome to the east of the AOR.

5.1.1.3 Madison Aquifer

The Madison Limestone, also known as the Pahasapa Limestone, is the source of municipal water supplies in numerous communities within and near the Black Hills including Rapid City and Edgemont.

Table 5.1: Estimates of Hydraulic Properties of Major Aquifers from Previous Investigations

Source	Hydraulic conductivity (ft/d)	Transmissivity (ft^2/d)	Storage coefficient	Total porosity/ effective porosity	Area represented
Precambrian aquifer					
Rahn, 1985	--	--	--	0.03/0.01	Western South Dakota
Galloway and Strobel, 2000		450 - 1,435		0.10/--	Black Hills area
Deadwood aquifer					
Downey, 1984	--	250 - 1,000	--	--	Montana, North Dakota, South Dakota, Wyoming
Rahn, 1985	--	--	--	0.10/0.05	Western South Dakota
Madison aquifer					
Konikow, 1976	--	860 - 2,200	--	--	Montana, North Dakota, South Dakota, Wyoming
Miller, 1976	--	0.01 - 5,400	--	--	Southeastern Montana
Blankennagel and others, 1977	$2.4x10^{-5}$ - 1.9	--	--	--	Crook County, Wyoming
Woodward-Clyde Consultants, 1980	--	3,000	$2x10^{-4}$ - $3x10^{-4}$	--	Eastern Wyoming, western South Dakota
Blankennagel and others, 1981	--	5,090	$2x10^{-5}$	--	Yellowstone County, Montana
Downey, 1984	--	250 - 3,500	--	--	Montana, North Dakota, South Dakota, Wyoming
Plummer and others, 1990	--	--	$1.12x10^{-6}$ - $3x10^{-5}$	--	Montana, South Dakota, Wyo-ming
Rahn, 1985	--	--	--	0.10/0.05	Western South Dakota
Cooley and others, 1986	1.04	--	--	--	Montana, North Dakota, South Dakota, Wyoming, Nebr.
Kyllonen and Peter, 1987	--	4.3 - 8,600	--	--	Northern Black Hills
Imam, 1991	$9.0x10^{-6}$	--	--	--	Black Hills area
Greene, 1993	--	1,300 - 56,000	0.002	0.35/--	Rapid City area
Tan, 1994	5 - 1,300	--	--	0.05	Rapid City area
Greene and others, 1999	--	2,900 - 41,700	$3x10^{-4}$ - $1x10^{-3}$	--	Spearfish area
Carter, Driscoll, Hamade, and Jarrell, 2001	--	100 - 7,400	--	--	Black Hills area
Minnelusa aquifer					
Blankennagel and others, 1977	$<2.4x10^{-5}$ - 1.4	--	--	--	Crook County, Wyoming
Pakkong, 1979	--	880	--	--	Boulder Park area, South Dakota
Woodward-Clyde Consultants, 1980	--	30 - 300	$6.6x10^{-5}$ - $2.0x10^{-4}$	--	Eastern Wyoming, western South Dakota

Table 5.1: Estimates of Hydraulic Properties of Major Aquifers from Previous Investigations (cont'd)

Source	Hydraulic conductivity (ft/d)	Transmissivity (ft^2/d)	Storage coefficient	Total porosity/ effective porosity	Area represented
Minnelusa aquifer—Continued					
Rahn, 1985	--	--	--	0.10/0.05	Western South Dakota
Kyllonen and Peter, 1987	--	0.86 - 8,600	--	--	Northern Black Hills
Greene, 1993	--	12,000	0.003	0.1/--	Rapid City area
Tan, 1994	32	--	--	--	Rapid City area
Greene and others, 1999	--	267 - 9,600	$5.0x10^{-9}$ - $7.4x10^{-5}$	--	Spearfish area
Carter, Driscoll, Hamade, and Jarrell, 2001	--	100 - 7,400	--	--	Black Hills area
Minnekahta aquifer					
Rahn, 1985	--	--	--	0.08/0.05	Western South Dakota
Inyan Kara aquifer					
Niven, 1967	0 - 100	--	--	--	Eastern Wyoming, western South Dakota
Miller and Rahn, 1974	0.944	178	--	--	Black Hills area
Gries and others, 1976	1.26	250 - 580	$2.1x10^{-5}$ - $2.5x10^{-5}$	--	Wall area, South Dakota
Boggs and Jenkins, 1980	--	50 - 190	$1.4x10^{-5}$ - $1.0x10^{-4}$	--	Northwestern Fall River County
Bredehoeft and others, 1983	8.3	--	$1.0x10^{-5}$	--	South Dakota
Rahn, 1985	--	--	--	0.26/0.17	Western South Dakota
Kyllonen and Peter, 1987	--	0.86 - 6,000	--	--	Northern Black Hills

Source: Driscoll et al., 2002

The hydraulic characteristics of the Madison aquifer have been extensively studied; aquifer characteristics of the Madison based on the numerous regional investigations are summarized in Table 5.1. The Madison aquifer is mainly a dolomite unit and is characterized by extensive secondary porosity resulting from fractures and associated karstic features (Williamson and Carter, 2001). The thickness of the Madison ranges from 200 feet in the southern Black Hills to 1,000 feet regionally. In the Rapid City area, Greene (1993) found the transmissivity to vary between 1,300 and 56,000 ft^2/day. The aquifer varies from unconfined at its outcrop areas to confined, where reported storativity values range from 10^{-3} to 10^{-6} (Table 5.1). Regionally, water quality data indicate that low-permeability layers within the overlying Minnelusa Formation isolate the Madison from the Minnelusa. At some locations distant from the project area on the core of the Black Hills Uplift, these confining layers may be absent or exhibit poorly confining hydraulic characteristics such that communication between the Madison and Minnelusa occurs.

Regionally, the Madison may be in direct communication with the underlying Deadwood aquifer where the Whitewood and Winnipeg confining units are absent; locally, however, the available data indicate that the Madison Limestone and Deadwood Formations are isolated beneath the project area (Powertech, 2010).

5.1.1.4 Deadwood Aquifer

The Cambrian Deadwood Formation overlies the Precambrian basement and consists of basal conglomerates, sandstone, limestone, and mudstone. The Deadwood ranges from zero to 500 feet thick (Driscoll et al., 2002). Rahn (1985) estimated the effective porosity of the Deadwood to be about 5 to 10 percent. In the northern Black Hills, the effective porosity is presumably lower where the formation has undergone hydrothermal alteration. The transmissivity of the Deadwood is estimated to be in the range of 250 to 1,000 ft^2/day (Table 5.1) (Downey, 1984). Regionally, the Precambrian rocks act as a lower confining unit to the Deadwood although a localized direct connection between the two units can occur at or near the outcrop areas (Williamson and Carter, 2001). Regionally, the Deadwood may be in contact with the overlying Madison aquifer except where the Whitewood and Winnipeg Formations are present and act as semi-confining units (Strobel et al., 1999). As noted, available data indicate that the Madison and Deadwood Formations are isolated beneath the project area.

5.1.1.5 Minor Aquifers

Minor aquifers in the Black Hills include the Minnekahta Limestone, Sundance Formation, Unkpapa Sandstone, Newcastle Sandstone, and Quaternary alluvium. Where present and saturated, these units can yield small amounts of water. In isolated locations distant from the project area, beds within the confining units may also contain water-bearing units (Driscoll et al., 2002). These minor aquifers are generally not widely utilized because of the availability of more reliable water-supply sources.

5.1.2 Regional Potentiometric Surfaces

As part of its 1990s study of the hydrologic significance of selected bedrock aquifers, the USGS developed 1:100,000-scale potentiometric contour maps for the Inyan Kara, Minnekahta, Minnelusa, Madison, and the Deadwood (Strobel et al., 2000a thru 2000e). These maps provide a basis for evaluating regional groundwater flow direction and hydraulic gradients in the Black Hills. Appendix D depicts these regional potentiometric surfaces in relation to the project area. In the development of these potentiometric maps, structural features such as faults and folds were considered. Of significance, no major structural features were identified in or within the immediate vicinity of the project area other than the Dewey Fault, which is located north of the project area, and the Long Mountain Structural Zone, which is located approximately 7 miles south of the project area.

Based on the USGS potentiometric contour maps, regional groundwater flow within the five major aquifers is generally consistent and radially outward from the central Black Hills highlands toward the plains. All five of the aquifers are hydraulically unconfined (partially saturated) near their outcrops in the central highlands and become confined by the overlying strata with distance away from the central highlands. Locally, the potentiometric surface of the aquifers may be above land surface.

The Black Hills are relatively arid with the annual precipitation ranging from about 12 to 28 inches regionally and averaging approximately 16 inches in the project area. While most precipitation can be accounted for as surface runoff and evapotranspiration, regionally, the percentage of precipitation that recharges the aquifers is estimated to vary from 30 percent in the northwestern Black Hills to 2 percent or less in the drier southwestern Black Hills, which includes the project area.

Other sources of recharge to individual units can occur from leakage between aquifers. In general, the potentiometric elevation increases with depth within the stratigraphic section, which provides an upward potential for groundwater flow and limits the potential for downward recharge, which occurs regionally but not locally.

Most interconnection between aquifers appears to be associated with the thinning or absence of confining units between aquifers. Some investigators have suggested that solutioning and subsequent collapse (i.e., karsting) of the overlying strata may provide a pathway for upward groundwater movement (Gott et al., 1974). This is reported to occur some 6 miles northeast of the project area, but no evidence of karsting has been observed in the project area. A detailed analysis of the potential occurrence of breccia pipes and karsting north and east of the project area is presented in Appendix E.

5.2 Site Hydrogeology

The only aquifer in which Class III injection wells will be completed (the Inyan Kara) is recharged locally and isolated from the deep regional flow system in the Paleozoic formations that typically characterize regional groundwater flow and are the focus of numerous USGS research studies.

In the project area, the sedimentary rocks dip gently to the southwest at 2 to 6 degrees. As the land surface is generally flatter than the dip of the underlying bedrock strata, younger strata crop out at the ground surface sequentially from east to west.

The structure is illustrated by the structural contour maps on top of the Fall River (Plate 6.5), Chilson Member of the Lakota (6.3) and Unkpapa Sandstone (Plate 6.1). Based on the logs for thousands of exploration holes, no major faults or other structural features have been identified within the project area.

5.2.1 Site Hydrostratigraphic Units

Refer to Figure 6.2 in Section 6 for a regional stratigraphic column and Section 6.2.2 for a more detailed discussion of the site stratigraphy. The Fall River Formation and Chilson Member of the Lakota Formation are the principal sources of water in the vicinity of the project area for domestic, livestock, and agricultural uses. These same formations are the host rocks for the uranium mineralization within the project area. Within the project area, the deeper regional aquifers are not used as a source of water supply mainly because of their depth of occurrence, availability of shallower sources, relatively low productivity and low historical water demands. There are no water supply wells within the AOR completed in aquifers below the Sundance Formation. The closest municipal wells are the Edgemont Madison wells, which are approximately 15 miles south-southeast of the center of the project area.

In the following discussion, the site hydrogeological characterization focuses on groundwater occurrence and the groundwater flow regimes above the Morrison Formation. The Morrison Formation is the lowermost confining unit for the Dewey-Burdock Project. (See Section 6.2.2 for a discussion of the major confining units.) Because of the low vertical permeability, thickness and continuity of the Morrison Formation across the entire project area and due to the existence of an upward hydraulic gradient between the underlying Unkpapa Sandstone and the Inyan Kara, the proposed ISR activities will not impact any of the formations below the Morrison Formation. The only exception is potential pumping from the Madison or another suitable deep formation for aquifer restoration makeup water and for CPP water supply or use of the Minnelusa and/or Deadwood for management of wastewater in Class V disposal wells.

The Morrison Formation is underlain, in turn, by the Unkpapa Sandstone, Sundance Formation and Spearfish Formation. Based on the results of limited exploratory drilling, the Spearfish in the project area averages approximately 320 feet thick and due to its low vertical permeability is considered a hydrologic barrier between the overlying Jurassic and Cretaceous aquifers and the underlying Paleozoic aquifers.

The Spearfish Formation is overlain by the Sundance Formation, which consists of a 250 to 450-foot thick sequence of red shale and siltstone. In the project area, the Sundance consists mainly of shale and sandstone with an average thickness of 280 feet. In turn, the Sundance is overlain by the Unkpapa Sandstone. Where present, the Unkpapa consists of 50 to 80 feet of well-sorted, fine-grained, aeolian sandstone. Since there is not an intervening confining unit separating the two, the Sundance and Unkpapa are generally considered to be a single hydrostratigraphic unit. The Sundance/Unkpapa is used locally as a water supply within the project area.

5.2.1.1 Morrison Formation

The Morrison Formation, because of its low permeability and continuity beneath the project area, is the lowermost confining unit for the proposed ISR operations. The Morrison averages 100 feet thick and is composed of waxy, calcareous, non-carbonaceous massive shale with numerous limestone lenses and a few thin fine-grained sandstones. Analyses of core samples within the project area have shown the vertical permeability of the Morrison clays to be very low and to range from 9×10^{-9} to 3×10^{-8} cm/sec (0.012 to 0.043 millidarcies, see Table 8.2).

5.2.1.2 Inyan Kara Group

The Jurassic Morrison Formation is unconformably overlain by the Inyan Kara Group, which consists of the Lakota and the Fall River Formations. The sandstone packages within the Fall River and Chilson Member of the Lakota Formations are the host rocks to the uranium mineralization at the Dewey-Burdock Project. The Inyan Kara consists of interbedded sandstone, siltstone, and shale. Based on measured outcrop sections and drill hole data, the Inyan Kara averages about 350 feet thick in the project area.

The Lakota Formation regionally consists of three members which are, from oldest to youngest, the Chilson, Minnewaste Limestone, and the Fuson Members. The Minnewaste Limestone Member is not present in the project area.

Chilson Member

The Chilson Member consists of a complex of fluvial channel sandstone deposits and their fine-grained lateral equivalents and varies from about 100 to 240 feet thick. The Chilson Member is confined below by the Morrison Formation and above by the Fuson Shale. Analyses of core samples of Chilson sandstones within the project area indicate these units exhibit high horizontal permeabilities, ranging from 2.6×10^{-3} to 4.1×10^{-3} cm/sec (2,697 to 4,161 millidarcies, see Table 8.2).

Fuson Member

The Fuson Member is the uppermost member of the Lakota and separates the Chilson Member from the Fall River Formation. As discussed in Section 6.2.2, Powertech has differentiated the Fuson Shale from the Fuson Member of the Lakota Formation for the purpose of characterizing site geology. The Fuson Shale has been mapped by Powertech and consists of 20 to 80 feet of low-permeability shales and clays, which generally occur at or near the base of the unit (Plate 6.8).

The shales and mudstones within the Fuson Shale are highly stratified. Due to this stratification, the vertical permeability is several orders of magnitude smaller than the horizontal permeability. Based on analyses of core samples from the Fuson Shale within the project area, vertical permeabilities range from about 7.8 x 10^{-9} to 2.2 x 10^{-7} cm/sec (0.008 to 0.228 millidarcies, see Table 8.2). Estimates of vertical hydraulic conductivity of the Fuson Shale from the 1979 pumping tests conducted in the Fall River and Chilson near Burdock range from 4.6 x 10^{-8} to 1 x 10^{-7} cm/sec (Boggs and Jenkins, 1980). Well field-scale pumping tests will be conducted after NRC license issuance (refer to Section 8.2.3). This additional testing will provide further quantification of the low hydraulic conductivity of the confining units.

Fall River Formation

The Fall River Formation is composed of carbonaceous interbedded siltstone and sandstone, channel sandstones, and a sequence of interbedded sandstone and shale. The Fall River ranges from about 120 to 160 feet thick.

The Fall River is confined above by the Graneros Group, a thick sequence of dark shales that varies in thickness from zero, where the Inyan Kara outcrops near the eastern edge of the project area, to more than 500 feet in the northwestern portion of the project area. Because of its thickness and low permeability, the Graneros Group precludes vertical migration of water between the Inyan Kara, overlying alluvial aquifers, and the ground surface.

5.2.1.3 Graneros Group

The Cretaceous Graneros Group consists of several geologic units, including the Skull Creek Shale, Newcastle Sandstone (where present), Mowry Shale, and Belle Fourche Shale, which act as a single confining unit overlying the Inyan Kara. In the project area, the thickness of the Graneros Group ranges from zero at the outcrop of the Fall River to more than 500 feet (Plate 6.10).

The Skull Creek Shale, which directly overlies the Fall River Formation, consists of dark gray to black shale, organic material, and some silt-size quartz grains. The Skull Creek Shale has a thickness of approximately 200 feet and together with the overlying shales of the Graneros Group is the uppermost confining unit for the proposed ISR operations. Analyses of core samples of the Skull Creek clays within the project area indicate low vertical permeabilities on the order of 6.8 x 10^{-9} cm/sec (0.007 millidarcies, see Table 8.2). The Skull Creek and overlying Mowry Shales have been removed by erosion from the eastern parts of the project area.

The Mowry Shale consists of light gray marine shale with minor amounts of siltstone, fine-grained sandstone, and a few thin beds of bentonite. Dark gray to purple and black iron and manganese concretionary zones are common within the shale.

The Newcastle Sandstone, which is normally present between the Skull Creek Shale and the Mowry Shale, is absent across the project area.

The uppermost unit of the Graneros Group is the Belle Fourche Shale. This 300-foot thick unit consists of thin-bedded gray to black soft shale, containing black to reddish-brown ironstone concretions, which are particularly abundant in the basal 20-30 feet. There is bentonite production from the lower part of the Belle Fourche Shale, but not within the project area or AOR.

5.2.1.4 Terrace Deposits and Quaternary Alluvium

The most recent sedimentary units within the Dewey-Burdock project area are the Quaternary alluvial deposits present along the major drainages and their tributaries. The alluvium varies from 0 to 50 feet thick and consists of an unconsolidated mixture of silt, clay, sand and gravel.

An isopach map depicting the thickness of the alluvium in the Beaver Creek and Pass Creek drainages is shown on Plate 6.11.

5.2.2 Groundwater Occurrence and Flow

Potentiometric contour maps for the Fall River and the Chilson Member of the Lakota are shown on Figures 5.2 and 5.3, respectively. These maps were revised from those presented in the December 2008 Class III application and include more representative water level measurements taken over a 5-day period from April 25 through April 29, 2011. The data used to generate Figures 5.2 and 5.3 are presented in Appendix F, and the procedures for measuring the static water level are described in Powertech (2011).

The potentiometric surface map for the Fall River (Figure 5.2) shows a relatively uniform hydraulic gradient across the project area, with the potentiometric levels decreasing to the southwest. The potentiometric surface for the Chilson (Figure 5.3) shows a slight flattening of the hydraulic gradient across the northwestern portion of the project area but with heads also decreasing to the southwest.

5.2.2.1 Groundwater Flow Systems

Based on the regional and site-specific hydrogeological characterization, groundwater occurrence and flow in the project area can be subdivided into three main components, or flow regimes. These include the deep regional flow system, a shallow perched alluvial groundwater

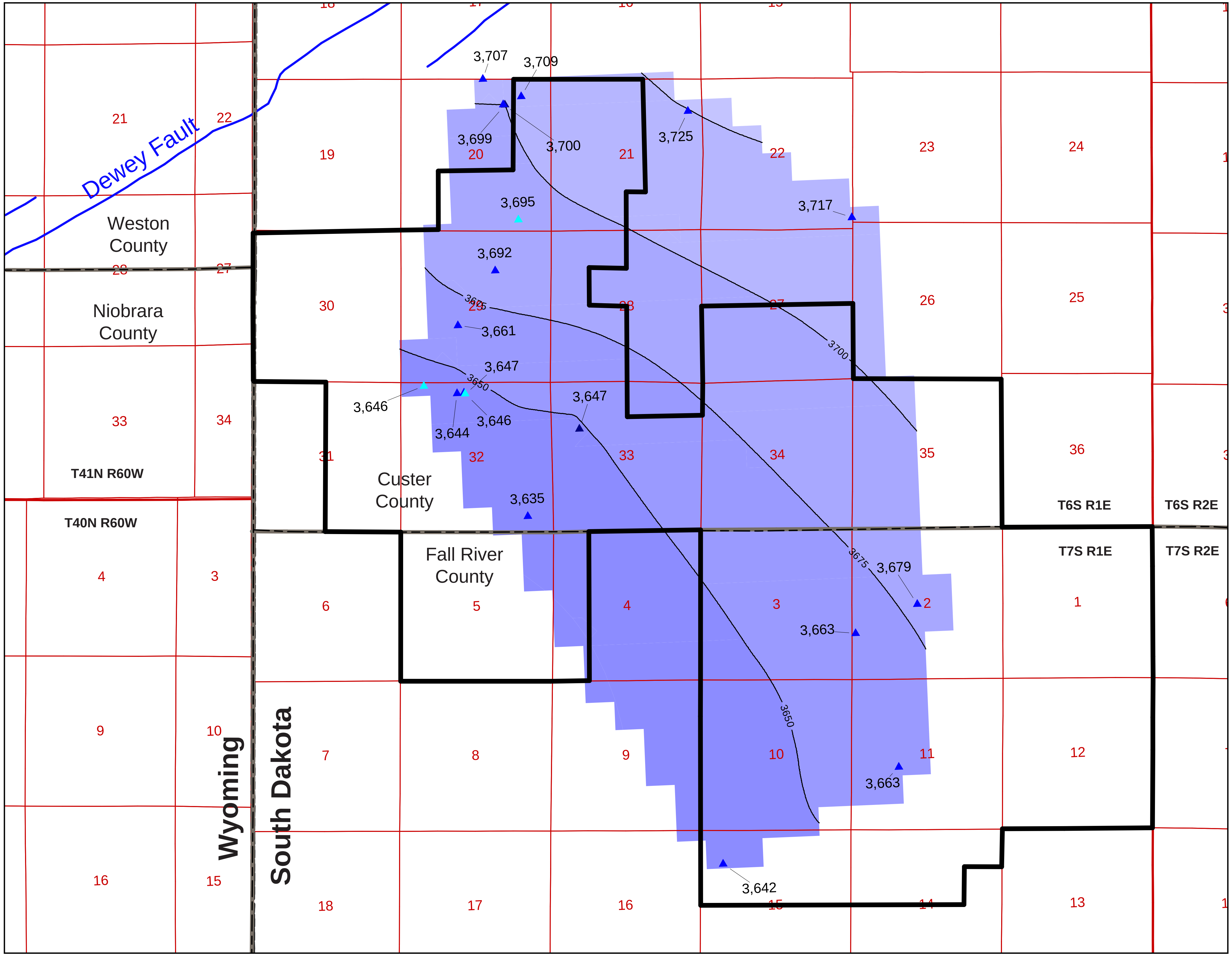

Figure 5.2

Potentiometric Contour Map, Fall River Formation

Dewey-Burdock Project

DRAWN BY	K. Schlieper
DATE	1-Nov-2011
FILENAME	2011_DB_Fig_2.7-16a.ai

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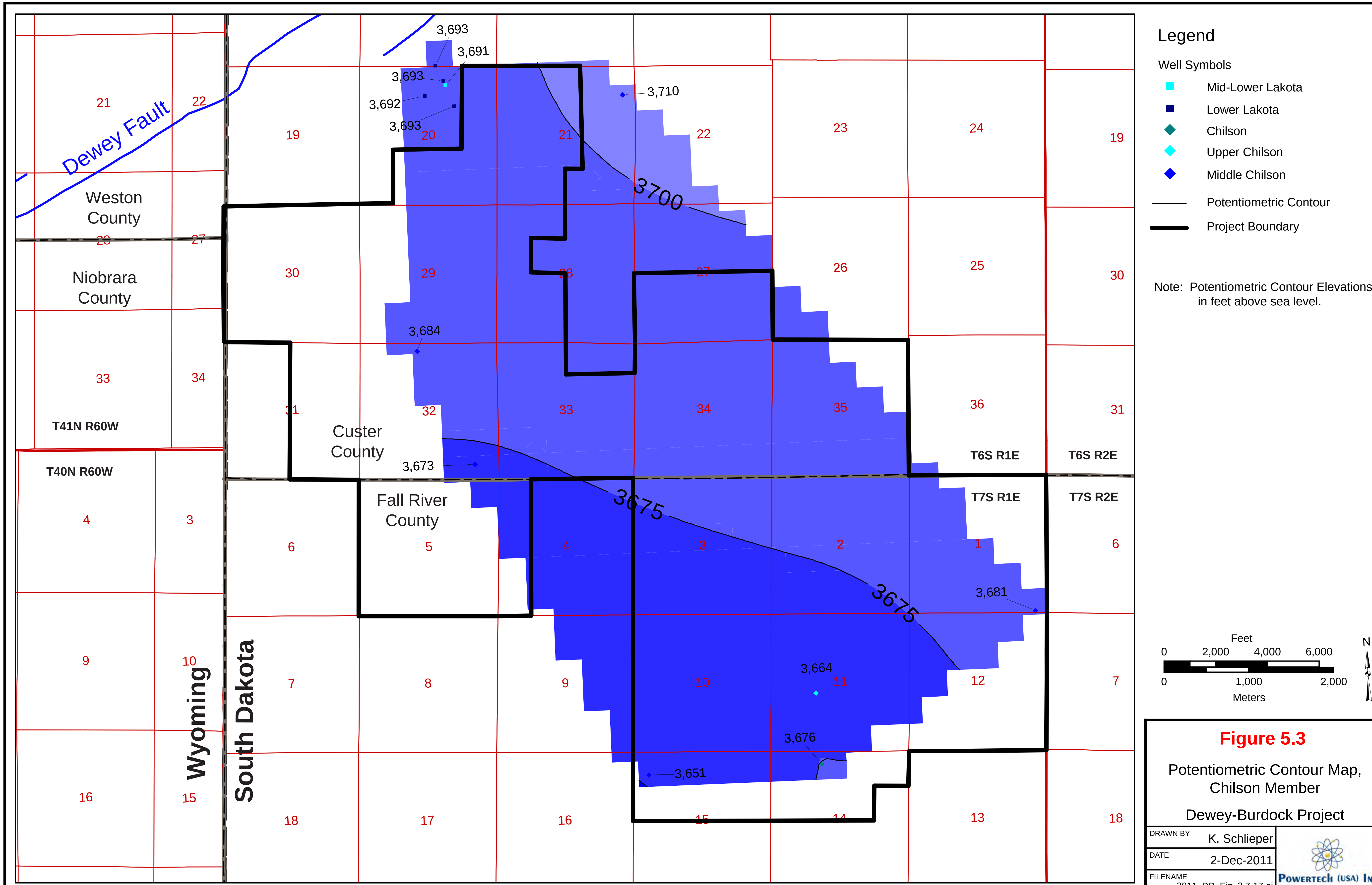

Legend
Well Symbols
Mid-Lower Lakota
Lower Lakota
Chilson
Upper Chilson
Middle Chilson
Potentiometric Contour
Project Boundary
Note: Potentiometric Contour Elevations in feet above sea level.
Feet
0 2,000 4,000 6,000
0 1,000 2,000
Meters
N
Dewey Fault
Weston County
Niobrara County
Custer County
Fall River County
Wyoming
South Dakota
T41N R60W
T40N R60W
T6S R1E
T6S R2E
T7S R1E
T7S R2E
3700
3675
3,693
3,691
3,693
3,692
3,693
3,710
3,684
3,673
3,681
3,664
3,676
3,651
Figure 5.3
Potentiometric Contour Map, Chilson Member
Dewey-Burdock Project
DRAWN BY K. Schlieper
DATE 2-Dec-2011
FILENAME 2011_DB_Fig_2.7-17.ai
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flow system, and an intermediate groundwater flow system that includes the Fall River and Chilson aquifers.

As described in Driscol et al. (2002), there are multiple deep regional groundwater flow systems within the Paleozoic section. These regional flow systems are associated with the permeable strata within various geologic formations at depth within the Deadwood, Madison, Minnelusa, Sundance/Unkpapa, and the minor aquifers. These deep regional flow systems and associated aquifers are isolated from the shallower formations that are the target of the proposed ISR operations in the Inyan Kara Group in the project area by low-permeability layers, or confining beds.

Shallow, perched groundwater systems exist within the alluvium associated with Beaver Creek, Pass Creek, and Bennett Canyon. These alluvial systems are perched above the top of the Graneros on the western portion of the project area. Groundwater flow within the alluvium is controlled by the configuration of the drainage channel on the top of bedrock and in most situations is generally parallel to surface drainage patterns. In the case of Bennett Canyon, the alluvium directly overlies the Chilson Member of the Lakota. As such, the alluvial groundwater is a potential source of recharge to the underlying Chilson. Bennett Canyon is approximately ½ mile east of the easternmost potential well fields within the project area.

Intermediate groundwater flow systems exist within the Fall River Formation and the Chilson Member of the Lakota. These intermediate flow systems have their origins in the areas within the eastern portion of the project area (Fall River) and immediately to the east and north of the project area where the Fall River and Chilson crop out at the land surface. Both of these flow systems are recharged directly by precipitation that falls on the land surface and by infiltration of surface runoff, primarily in the Pass Creek and Bennett Canyon drainages north and east of the project area, respectively.

Within the project area, the Fall River and the Chilson dip gently to the southwest at 2 to 6 degrees away from their outcrop areas. As a result, groundwater flow within the Fall River and the Chilson generally occurs from the northeast to the southwest toward the Powder River Basin. On a broad regional basis, water from lower Cretaceous aquifers including the Inyan Kara eventually moves northeastward to discharge areas in eastern North Dakota and South Dakota (Whitehead, 1996).

5.2.2.2 Groundwater Recharge and Discharge

The hydrologic characterization for the project area included the measurement of water levels in wells completed in the Inyan Kara, overlying alluvium, and the underlying Sundance/Unkpapa. The current data collection programs began in 2007 and are continuing.

Potentiometric surface maps for the Fall River and Chilson (Lakota) are shown on Figures 5.2 and 5.3, respectively. The water level data collected to date from the Unkpapa within the project area do not have sufficient spatial variability or temporal consistency to construct a potentiometric contour map of the Unkpapa. Information available to date shows substantially higher potentiometric head in the Unkpapa than in the Fall River and Chilson. Powertech anticipates that, with installation of additional wells, the monitoring in the Unkpapa conducted as part of the operational groundwater monitoring network (Section 14.3) will provide sufficient information to construct an Unkpapa potentiometric contour map prior to operations.

Alluvial groundwater flow systems occur within the alluvial deposits in the Pass Creek and Beaver Creek drainages, which are within the project area, and in Bennett Canyon, which is located on and beyond the eastern edge of the project area. Where these alluvial deposits overlie the Fall River and Chilson in Bennett Canyon, they represent a potential source of recharge to these underlying units.

The Pass Creek watershed north of the project area is a major source of recharge to both the Fall River and Chilson where they are exposed at the land surface or subcrop beneath the alluvium.

The Fall River Formation rises to the north and east and crops out at the ground surface. To the southwest the Fall River Formation dips at a steeper angle than the ground surface and is mantled by the overlying Graneros Group. The recharge areas for the Fall River and Lakota (Chilson) are where they are exposed at the ground surface and are shown on Figure 5.4.

The recharge areas for the regional groundwater flow systems within the Minnelusa Formation, Madison Limestone, and Deadwood Formation are in their outcrop areas further to the east on the flanks of the Black Hills Dome. As a result of the rise in elevation, the older formations outcrop closer to the center of the dome at higher elevations and exhibit greater potentiometric elevations. Because of this, the potentiometric levels within the geologic section increase with depth, as noted previously.

5.2.2.3 Groundwater/Surface Water Interactions

Extensive site investigations undertaken by Powertech and others have revealed no known natural springs within the project area. There is, however, an isolated area in the southwest corner of the Burdock portion of the project area, known as the “alkali area,” where groundwater

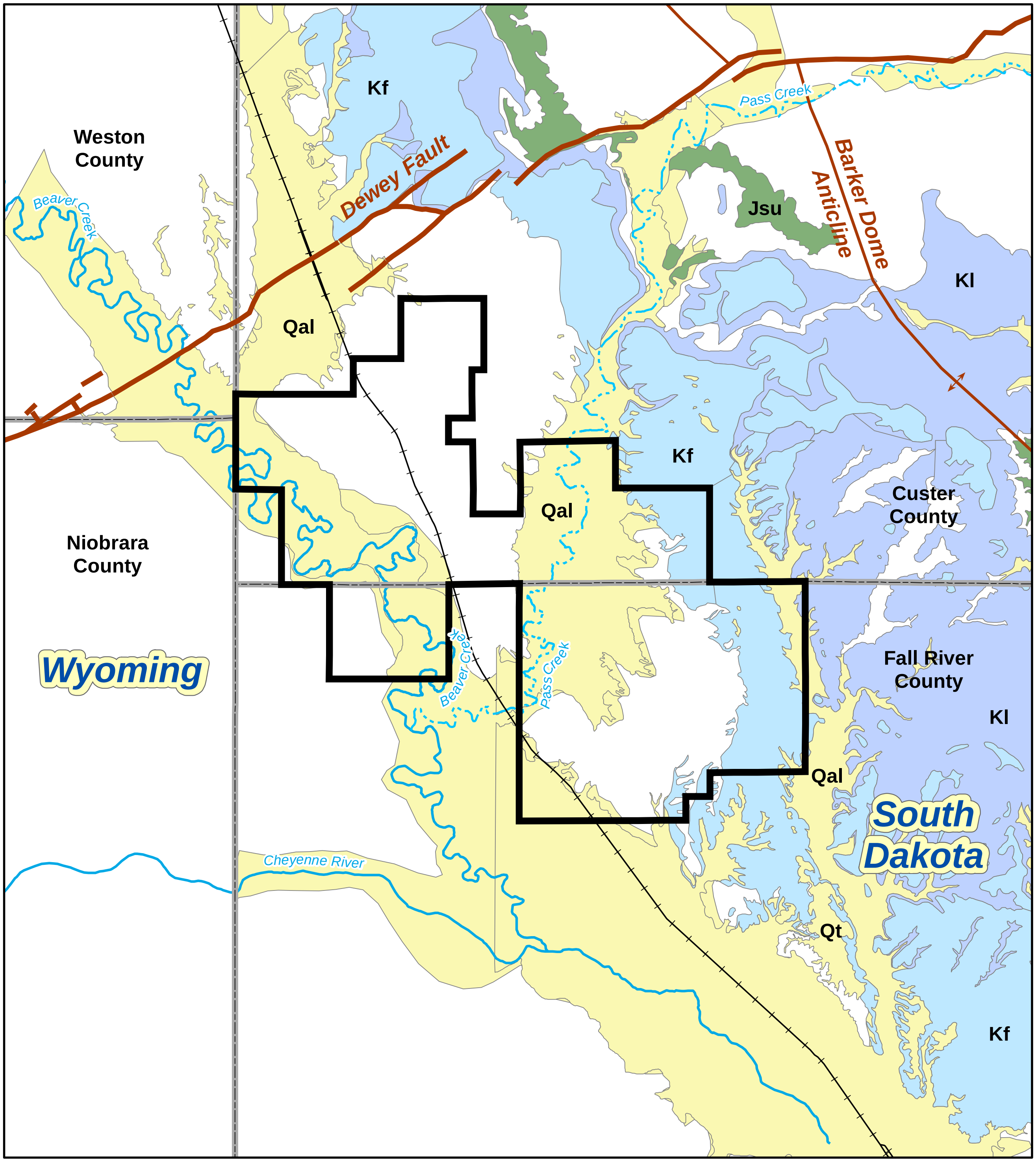

Figure 5.4

Recharge Areas for the Fall River and Lakota Formations

Dewey-Burdock Project

DRAWN BY	RESPEC, Hetrick
DATE	29-Jun-2012
FILENAME	RechargeAreas.mxd

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is discharging to the ground surface, presumably through unplugged or improperly plugged exploration drill holes. This area is discussed in Section 4.3.

The areas where the Fall River subcrops below the surface alluvium and crops out near the eastern edge of the project area are recharge areas for the Fall River sands. A similar area of recharge occurs north of the project area where Pass Creek alluvium crosses the subcrops of the Fall River and the Chilson. Recharge was observed during runoff events in 2011 where flowing streams disappeared into the Fall River and Chilson sandstones. Downgradient of the known recharge areas, there is no evidence of surface discharge from the Fall River via seeps or springs.

Refer to Section 3.2 for a discussion of the historical uranium mines within the AOR. The bottoms of the Darrow pits, with the exception of Pit #2, are above the Fall River potentiometric surface. These Darrow pits are usually dry but occasionally contain water that collects from runoff events. Darrow Pit #2, however, usually contains water suggesting that the base of the pit may be below the potentiometric surface of the Fall River. The pH of the water in Darrow Pit #2 is low (i.e., acidic) suggesting that surface drainage may be influencing the water chemistry in the pit. This implies that at least a portion of the water in Darrow Pit #2 is derived from surface runoff. The bottom of the Triangle Pit is below the potentiometric surface of the Fall River. The Triangle Pit is therefore hydraulically connected to the Fall River Formation.

5.2.2.4 Hydraulic Isolation of Aquifers

Regionally, the Inyan Kara Group is geologically confined. In the project area, the Graneros Group shale serves as the overlying confining unit above the Fall River in the western portion of the project area. There are no major aquifers above the Inyan Kara. Below the Inyan Kara, the Morrison Formation serves as a confining unit. In the project area, results from recent pump tests show that the Morrison effectively confines the underlying Unkpapa aquifer since no measureable drawdown in the Unkpapa was observed while pumping in the Inyan Kara. For a more detailed discussion on the regional and site hydrostratigraphic units see Sections 5.1.1 and 5.2.1.

As described in Section 10.5, the only area where the Fall River Formation is geologically unconfined is in the eastern part of the project area in the general vicinity of the Darrow pits. Powertech does not propose to conduct ISR operations in the Fall River in this area. The Chilson throughout the project area is physically and hydraulically isolated from the overlying Fall River Formation by the Fuson Shale.

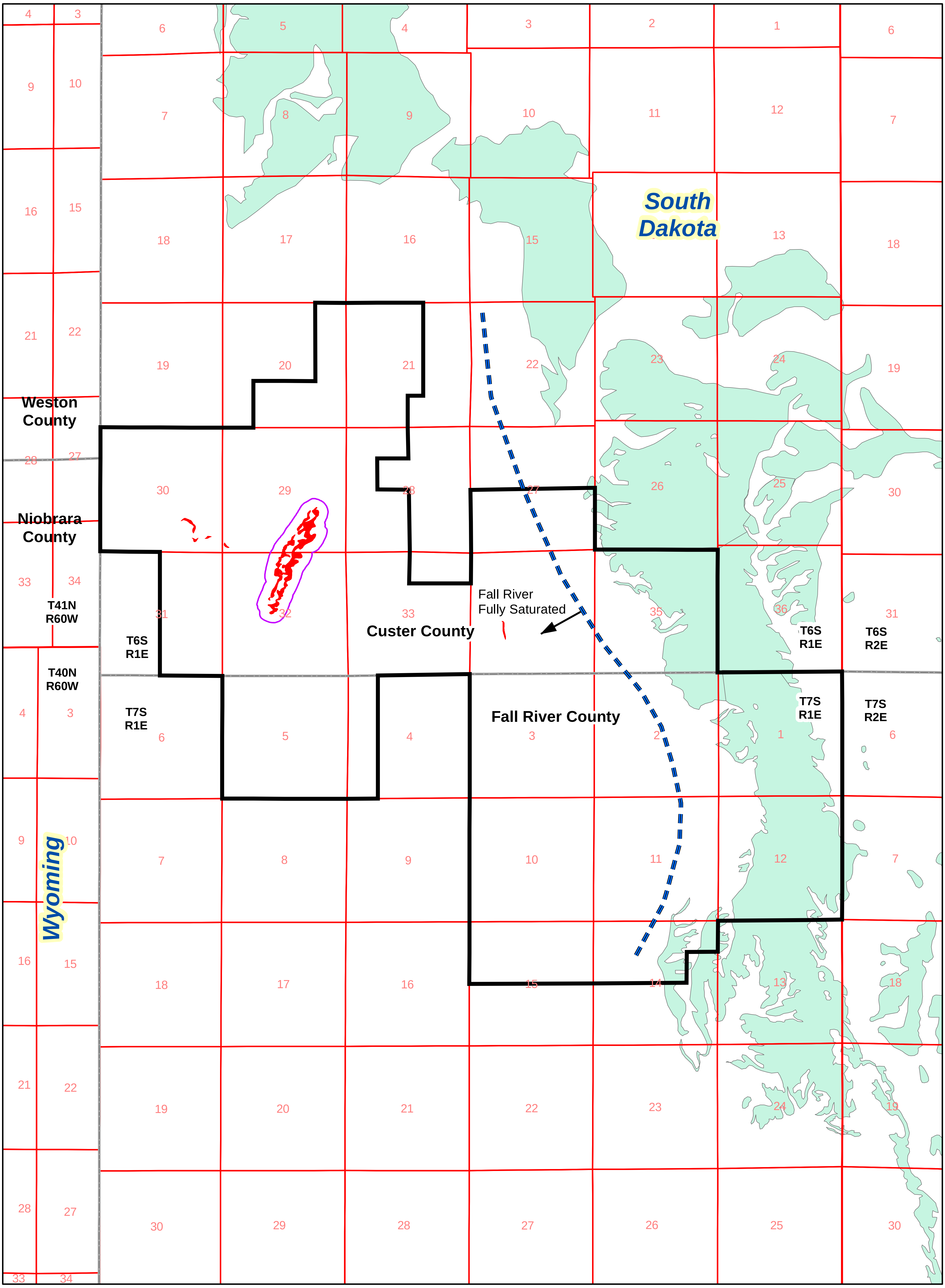
Based on Powertech's borehole and geophysical logs for thousands of exploration holes, the Fuson Shale is continuous and no less than 20 feet thick throughout the entire project area. An isopach map showing the thickness and continuity of the Fuson Shale throughout the project area is presented as Plate 6.8. The pervasive occurrence and continuity of the Fuson Shale throughout the project area are shown on the geologic cross sections (Plates 6.13 through 6.22).

5.2.2.5 Partially Saturated Conditions

The uppermost portion of the Fall River Formation crops out in the eastern portion of the project area in the vicinity of the Darrow pits, and the full section crops out further east in Bennett Canyon. In these areas, the Fall River is geologically unconfined. As the Fall River rises to the east, it becomes partially saturated as the top of the formation rises above the groundwater table, as shown on Plate 6.13 (Cross Section A-A'). The approximate boundaries between fully saturated and partially saturated conditions in the Fall River and underlying Chilson are shown in Figures 5.5 and 5.6, respectively. As the Fall River dips basinward to the southwest, the potentiometric surface is above the top of the formation, as shown on Plate 6.13. Beneath the Beaver Creek and Pass Creek drainages, the potentiometric surface for the Fall River is above the ground surface.

Similarly, the Chilson Member rises in elevation to the northeast and subcrops beneath the alluvium in Bennett Canyon. The potentiometric surface elevation for the Chilson is projected to be below the top of the formation on the eastern edge of the project area. Only in this limited area, the Chilson, although geologically confined by the overlying Fuson Shale, is partially saturated (i.e., the water table is below the top of the formation).

Refer to Section 10.5 for a description of well field development with respect to partially saturated conditions. After license/permit issuance but prior to well field development, delineation drilling and well field pumping tests will be conducted to fully characterize the existing geologic and hydrogeologic conditions and to confirm sufficient head is available to perform normal ISR operations.



Feet
0 2,000 4,000 8,000
0 1,000 2,000
Meters

N

Legend

- Project Boundary
- Potential Dewey Well Field #1
- Ore Bodies in Fall River
- Fall River Outcrop
- Approximate Edge of Fully Saturated Fall River

Figure 5.5

Location of Fully Saturated
Portion of Fall River

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	31-Jul-2012
FILENAME	Saturated-FR.mxd

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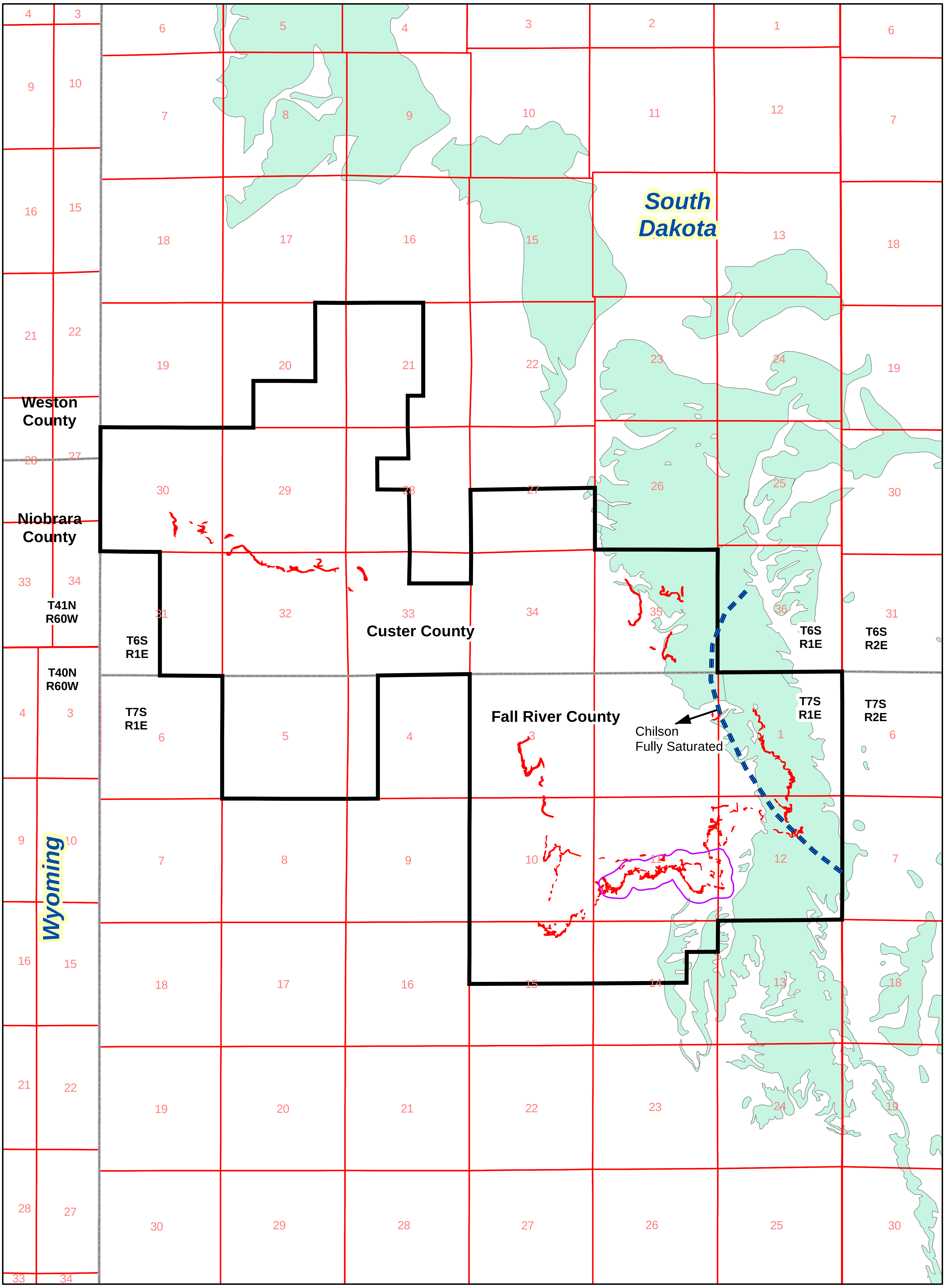

Feet
0 2,000 4,000 8,000
0 1,000 2,000
Meters

N

Legend

- Project Boundary
- Potential Burdock Well Field #1
- Ore Bodies in the Chilson Member
- Fall River Outcrop
- Approximate Edge of Fully Saturated Chilson

Figure 5.6

Location of Fully Saturated Portion of Chilson

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	31-Jul-2012
FILENAME	Saturated-Chil.mxd

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6.0 ATTACHMENT F - MAPS AND CROSS SECTIONS OF GEOLOGIC STRUCTURE OF AREA

This attachment includes maps and cross sections that show detailed geologic structure affecting local stratigraphy, lithology of injection intervals and lithology of confining intervals. Supporting information is provided in appendices.

6.1 Regional Geology

The Dewey-Burdock Project is located in the Great Plains Physiographic province on the southwestern flank of the Black Hills Uplift in southwestern South Dakota. To the west of the project area is the Powder River Basin of Wyoming. The regional geologic map of this region is shown on Figure 6.1.

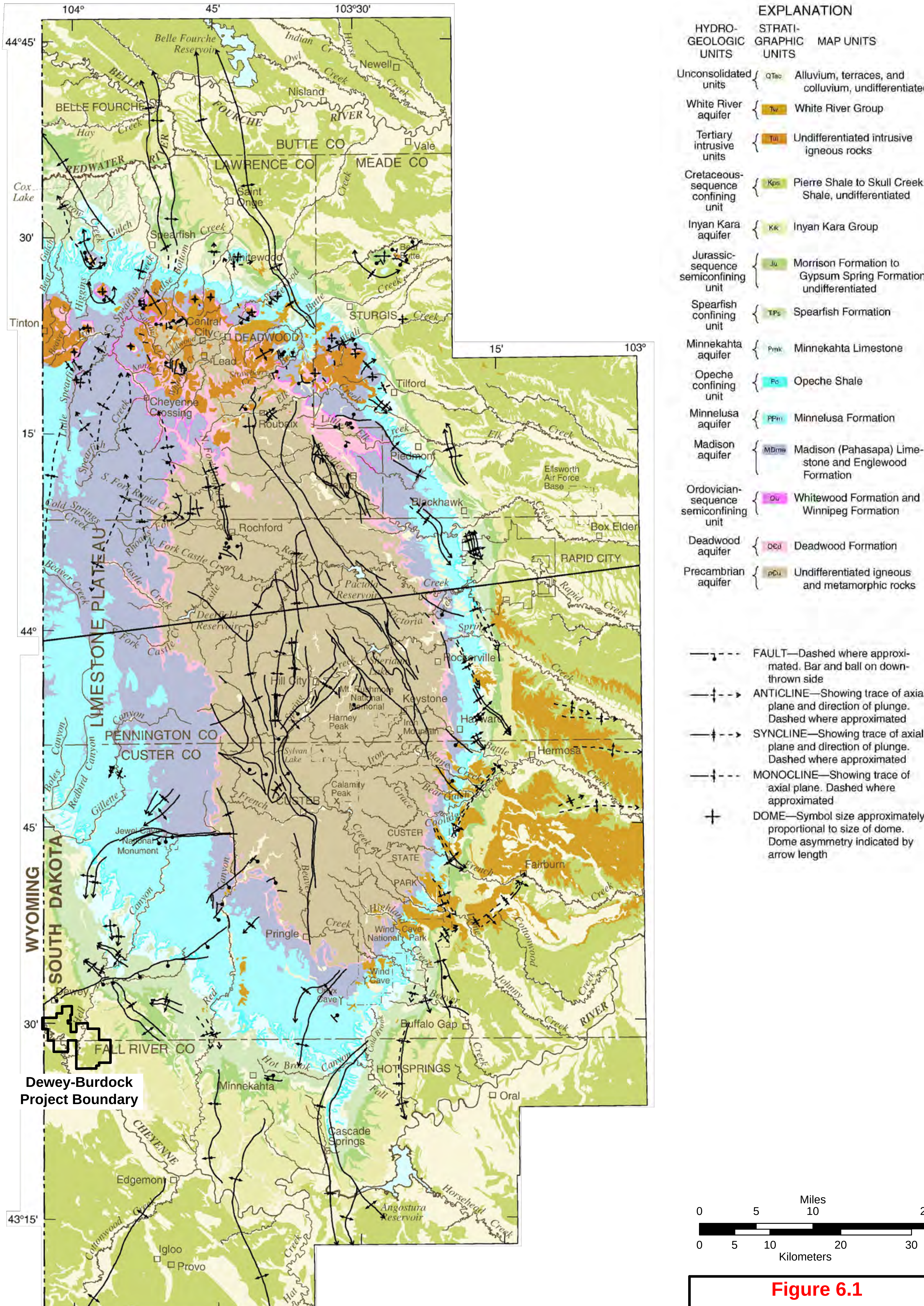
6.1.1 Regional Structure

The dominant structural feature in this region is the Black Hills Uplift. This uplift is of Laramide age (65 million years ago) and is an elongate northwest trending dome about 125 miles long and 60 miles wide. Igneous and metamorphic Precambrian-age rocks are exposed in the core of the uplift and are surrounded by outward-dipping Paleozoic and Mesozoic rocks that form cuestas and hogbacks around the core of the uplift. Folds constitute the major structural features in the Black Hills. During the early Cretaceous period, minor deformation along concealed northeast-trending remnant structures of the Precambrian age affected the courses of the northwest-flowing streams and their tributaries, thereby influencing the location of the fluvial sandstone deposits of the Inyan Kara Group.

6.1.2 Regional Stratigraphy

The oldest rocks in the region are Precambrian metamorphic rocks and granites. These form the core of the Black Hills Uplift and are exposed at the surface of this structural feature. Overlying these crystalline rocks as one moves radially outward from the core of the uplift are 2,000-3,000 feet of Paleozoic sediments. This sedimentary sequence contains several regional aquifers, including the Deadwood Formation of Cambrian age, the Mississippian Madison Limestone and the Pennsylvanian/Permian-age Minnelusa Formation.

Mesozoic sediments include the Triassic-age Spearfish Formation and the Sundance Formation, Unkpapa Sandstone, and Morrison Formation of Jurassic age. The Sundance Formation is a minor aquifer in the southern Black Hills region. A thick sequence of Cretaceous-age sediments completes the Mesozoic section.



Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
Rapid City, Office of City Engineer map, 1:18,000, 1996; Universal Transverse Mercator projection, zone 13

Source: Carter et al. (2003)

Figure 6.1

Geologic Map of the Black Hills

Dewey-Burdock Project

DRAWN BY	Bonner, Hetrick
DATE	24-Jul-2012
FILENAME	BlackHillsGeoMap.dwg

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The Early Cretaceous sediments of the Inyan Kara Group consist of the Lakota and Fall River formations. The Inyan Kara Group is a transitional unit, exhibiting a change from terrestrial to marine deposition. The basal Lakota Formation (Chilson Member) is a fluvial sequence, which grades upward into marginal marine sediments where the Cretaceous Seaway inundated a stable land surface. Basal units of the Lakota Formation scour into clays of the underlying Morrison Formation and display the depositional nature of a large braided stream system, crossing a broad, flat coastal plain and flowing toward the northwest. Younger fluvial sand units of the Lakota become progressively thinner and less continuous and are separated by thin deposits of overbank and floodplain silts and clays. At the top of the Lakota is the Fuson Member. The Fuson consists of shale with minor beds of fine-grained sandstone and siltstone. The Fuson separates the underlying Lakota Formation from the overlying Fall River Formation. The Fall River consists of thick, widespread fluvial sands in the lower portion, grading to thinner, less continuous, marginal sands in the upper part. The Cretaceous Lakota and Fall River formations are hosts of the roll-front uranium mineralization in the Black Hills region.

Following deposition of the Fall River, the region was covered by the North American Cretaceous Seaway, which resulted in the accumulation of vast thicknesses of marine sediments (from 3,000-5,000 feet thick). These marine sediments are represented by the Skull Creek Shale, Newcastle Sandstone, Mowry Shale, Belle Fourche Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation and Pierre Shale. In Late Cretaceous time, the modern Rocky Mountain Uplift began, forcing the retreat of the Cretaceous Seaway.

Unconformably overlying the Cretaceous sediments in the Black Hills region is the Tertiary-age (Oligocene) White River Group. This thick sequence is primarily composed of tuffaceous mudstones and siltstones, with minor amounts of fluvial, coarse sandstone, lacustrine limestone and gypsum, and tuff beds. The tuff beds were deposited from volcanic eruptions to the west (Larson and Evanoff, 1998). The majority of the White River sediments have been removed by erosion and the remainder can be found as erosional remnants. This unit is thought to be the source of the uranium deposits found in the Black Hills region and the Powder River Basin of Wyoming.

The most recent sediments in the region are Quaternary-age deposits consisting of local material derived as a result of post-Laramide-uplift erosion. Recent deposits include alluvium and floodplain terrace deposits.

A stratigraphic column of the Black Hills is illustrated in Figure 6.2.

ERATHEM	SYSTEM	ABBREVIATION FOR STRATIGRAPHIC INTERVAL	STRATIGRAPHIC UNIT	THICKNESS IN FEET	DESCRIPTION
CENOZOIC	QUATERNARY & TERTIARY (?)	QTac	UNDIFFERENTIATED ALLUVIUM AND COLLUVIUM	0 - 50	Sand, gravel. boulder and clay.
		Tw	WHITE RIVER GROUP	0 - 300	Light colored clays with sandstone channel fillings and local limestone lenses.
	TERTIARY	Tui	INTRUSIVE IGNEOUS ROCKS	--	Included rhyolite, latite, trachyte and phonolite.
MESOZOIC	CRETACEOUS	Kps	PIERRE SHALE	1,200 - 2,700	Principal horizon of limestone lenses giving teepee buttes. Dark-gray shale containing scattered concretions. Widely scattered limestone masses giving small teepee buttes. Black fissile shale with concretions.
			NIOBRARA FORMATION	80 - 300 §	Impure chalk and calcareous shale.
			CARLILE SHALE — Turner Sandy Member, Wall Creek Member	350 - 750 §	Light-gray shale with numerous large concretions and sandy layers. Dark-gray shale.
			GREENHORN FORMATION	225 - 380	Impure slabby limestone. Weathers buff. Dark-gray calcareous shale with thin Oman Lake limestone at base.
			GRANEROS GROUP — BELLE FOURCHE SHALE	150 - 850	Gray shale with scattered limestone concretions. Clay spur bentonite at base.
			GRANEROS GROUP — MOWRY SHALE	125 - 230	Light-gray siliceous shale. Fish scales and thin layers of bentonite.
			GRANEROS GROUP — MUDDY SANDSTONE / NEWCASTLE SANDSTONE	0 - 150	Brown to light-yellow and white sandstone.
			GRANEROS GROUP — SKULL CREEK SHALE	150 - 270	Dark-gray to black siliceous shale.
		Kik	INYAN KARA GROUP — FALL RIVER FORMATION	10 - 200	Massive to thin-bedded, brown to reddish-brown sandstone.
			INYAN KARA GROUP — LAKOTA FORMATION — Fuson Shale Minnewaste Limestone Chilson Member	10 - 190 0 - 25 25 - 485	Yellow, brown and reddish brown massive to thinly bedded sandstone, pebble conglomerate, siltstone and claystone. Local fine-grained limestone and coal.
	JURASSIC	Ju	MORRISON FORMATION	0 - 220	Green to maroon shale. Thin sandstone.
			UNKPAPA SANDSTONE	0 - 225	Massive fine-grained sandstone.
			SUNDANCE FORMATION — Redwater Member Lak Member Hulett Member Stockade Beaver Member Canyon Spr Member	250 - 450	Greenish-gray shale, thin limestone lenses. Glauconitic sandstone, red sandstone near middle.
			GYPSUM SPRING FORMATION	0 - 45	Red siltstone, gypsum and limestone.
	TRIASSIC	TRPs	SPEARFISH FORMATION — Goose Egg Equivalent	375 - 800	Red silty shale, soft red sandstone and siltstone with gypsum and thin limestone layers. Gypsum locally near the base.
PALEOZOIC	PERMIAN	Pmk	MINNEKAHTA LINESTONE	25 - 65 §	Thin to medium-bedded, fine-grained, purplish gray laminated limestone.
		Po	OPECHE SHALE	25 - 150 §	Red shale and sandstone.
	PENNSYLVANIAN	PIPm	MINNELUSA FORMATION	375 - 1,175 §	Yellow to red cross-bedded sandstone, limestone and anhydrite locally at top. Interbedded sandstone, limestone, dolomite, shale and anhydrite. Red shale with interbedded limestone and sandstone at base.
	MISSISSIPPIAN	MDme	MADISON (PAHASAPA) LIMESTONE	< 200 - 1,000 §	Massive light-colored limestone. Dolomite in part. Cavernous in upper part.
	DEVONIAN		ENGLEWOOD FORMATION	30 - 60	Pink to buff limestone. Shale locally at base.
	ORDOVIOAN	Ou	WHITEWOOD (RED RIVER) FORMATION	0 - 235 §	Buff dolomite and limestone.
			WINNIPEG FORMATION	0 - 150 §	Green shale with siltstone.
	CAMBRIAN	O€d	DEADWOOD FORMATION	0 - 500 §	Massive to thin-bedded buff to purple sandstone. Greenish glauconitic shale flaggy dolomite and flat-pebble limestone conglomerate. Sandstone with conglomerate locally at the base.
PRECAMBRIAN		p€u	UNDIFFERENTIATED IGNEOUS AND METAMORPHIC ROCKS		Schist, slate, quartzite and arkosic grit. Intruded by diorite, metamorphosed to amphibolite, and by granite and pegmatite.

Source: Driscoll et al. (2002)

§ Modified based on drill-hole data

Figure 6.2

Stratigraphic Column of the Black Hills Area

Dewey-Burdock Project

DRAWN BY Mays, Hetrick

DATE 24-Jul-2012

FILENAME StratColBlackHills.dwg

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6.2 Site Geology

The site surface geology is shown in Figure 6.3. The Fall River Formation crops out across the eastern part of the project area and the Skull Creek Shale, Mowry Shale and Belle Fourche Shale (collectively referred to as the Graneros Group) crop out across the western part of the project area. The formations dip west and southwest at 2 to 6 degrees.

The geology of the project area was developed through the interpretation of data gathered from thousands of exploration drill holes. For each drill hole a suite of down-hole electric logs was run to characterize natural radioactivity and the lithology of the sediments in the subsurface. Resistivity and self potential define the rock types encountered in the subsurface (sandstone, siltstone, shale, etc.). This is further enhanced by a geologist's description of the drill cuttings. Figure 6.4 is an example of a "type log" from the project area.

6.2.1 Site Structure

The structure across the project area is simple and shows sediments dipping gently 2 to 6 degrees to the southwest. This is illustrated by structure contour maps on the tops of the Unkpapa Sandstone (Plate 6.1), the Morrison Formation (Plate 6.2), the Chilson Member of the Lakota Formation (Plate 6.3), the Fuson Shale (Plate 6.4), and the Fall River Formation (Plate 6.5). Isopach maps also are provided for the Morrison Formation (Plate 6.6), Chilson Member (Plate 6.7), Fuson Shale (Plate 6.8), Fall River Formation (Plate 6.9), Graneros Group (Plate 6.10) and Alluvium (Plate 6.11).

The Dewey Fault, a northeast to southwest trending fault zone, is present approximately one mile north of the project area. The Dewey Fault is a steeply dipping to vertical normal fault with the north side uplifted approximately 500 feet by a combination of displacement and drag. The USGS considers the area 7 miles southeast of the project as the Long Mountain Structural Zone. This northeast-southwest trend contains several small, shallow surface faults in the Inyan Kara Group. No faults were identified along this trend on subsurface structure maps of the underlying Madison Limestone, Minnelusa Formation or the Deadwood Formation.

Despite the presence of faulting north and south of the site, there are no identified faults within the project area. There is some folding in the areas surrounding the project area. East of the project area is a northwest-southeast trending anticline that ends in a closed structure called the Barker Dome. To the west is the Fanny Peak Monocline. This monocline is the structural boundary between the Black Hills and the Powder River Basin.

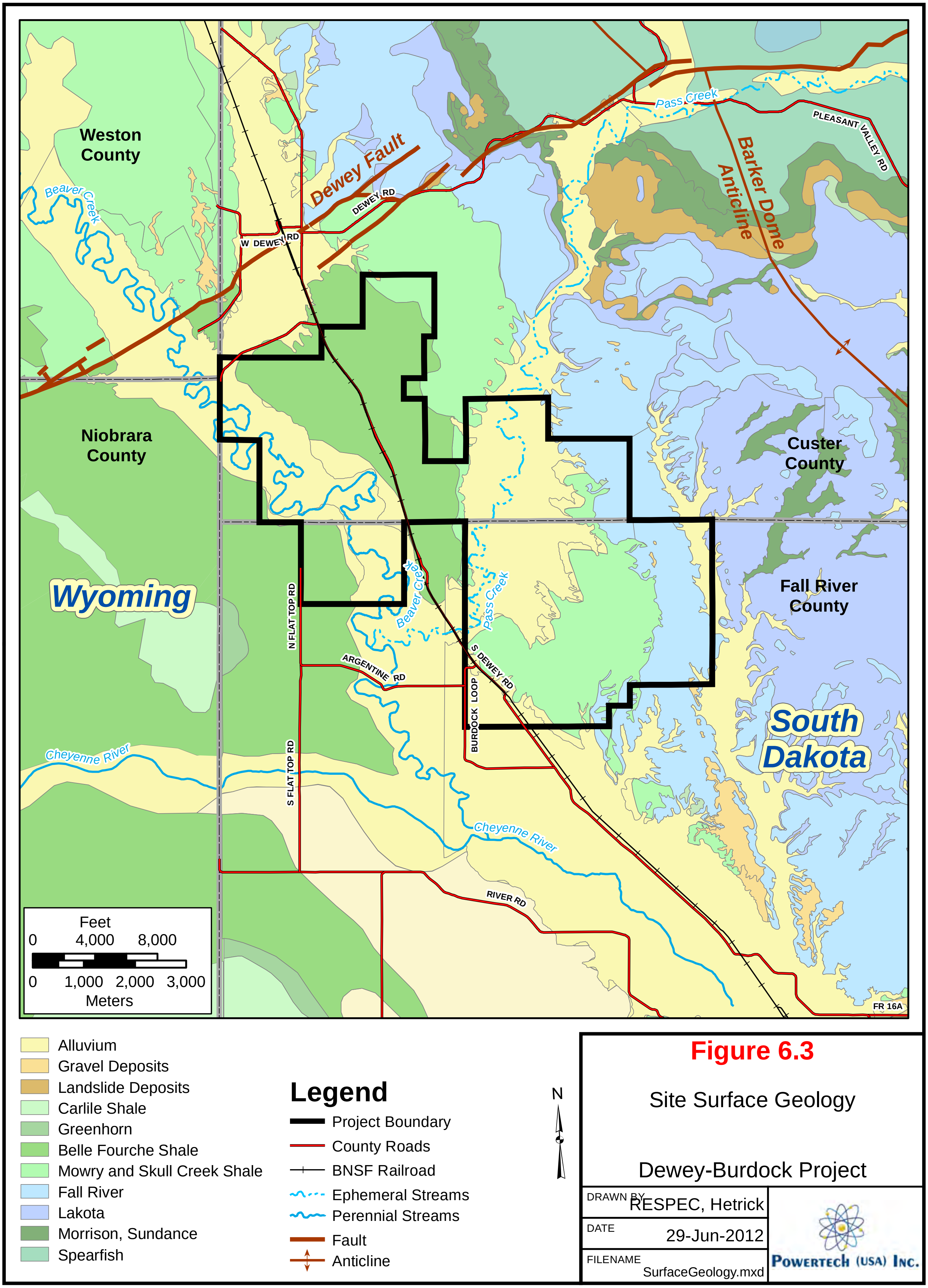

Figure 6.3

Site Surface Geology

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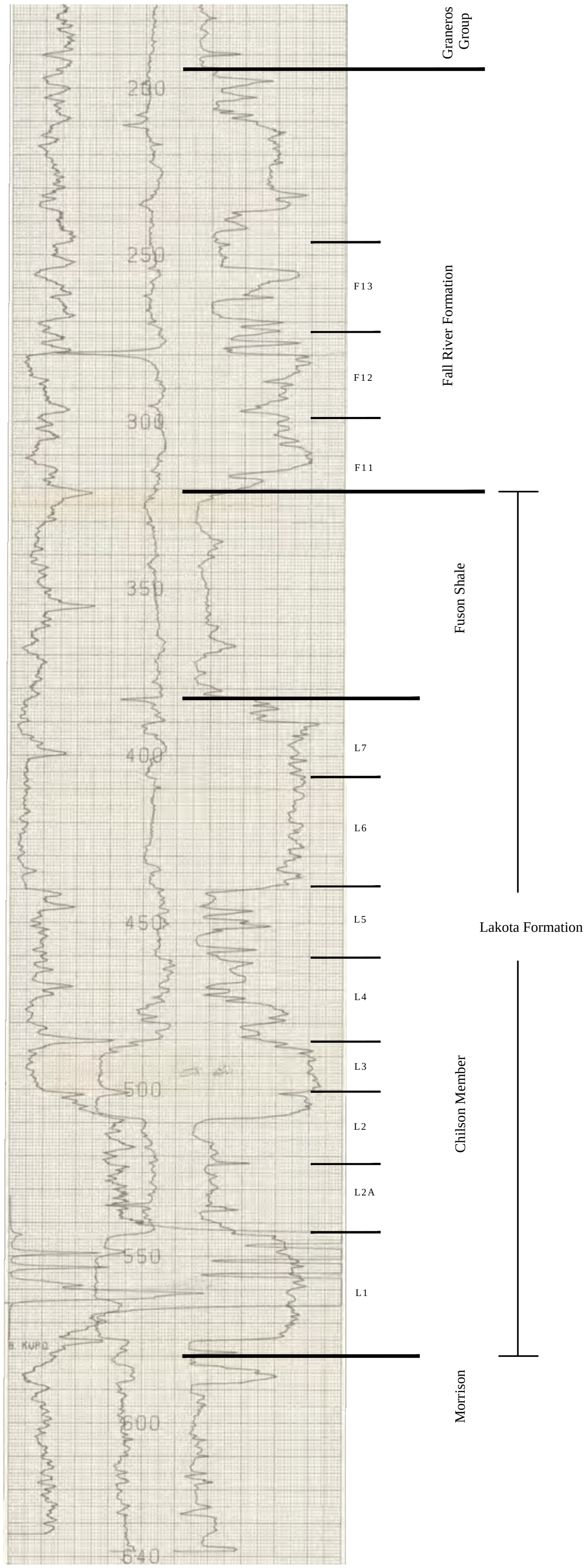

Figure 6.4

Type Log

Dewey-Burdock Project

DRAWN BY	R. Lichnovsky
DATE	24-Jul-2012
FILENAME	TypTypeLog.dwg

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6.2.2 Site Stratigraphy

The sedimentary rocks that underlie the project area range in age from Upper Jurassic to Early Cretaceous. The Upper Jurassic Morrison Formation is the lowermost confining unit for ISR operations (see discussion below). The uranium mineralization is within the Inyan Kara Group (specifically within the Fall River Formation and Chilson Member of the Lakota Formation). The Graneros Group is the uppermost confining unit for ISR operations. Figure 6.4 is a type log for the project, illustrating the relationship between these sedimentary units. Figure 6.2 demonstrates the relationship between these sedimentary units and underlying rocks, ranging in age from Jurassic to Precambrian.

Plate 6.12 is a cross section index map for nine geologic cross sections (Plates 6.13 through 6.21) covering the project area. In addition to showing the scaled vertical location of each ore body proposed for uranium recovery, the nine cross sections also illustrate the continuity of the Graneros Group, the Fuson Shale and the Morrison Formation, the major confining units, across the entire project area:

1) The Graneros Group is the uppermost confining unit and overlies the Fall River Formation. This marine shale sequence has a maximum thickness of 550 feet in the project area. The Graneros Group is composed of several geologic formations including the Skull Creek, Newcastle (not present in the project area), Mowry and Belle Fourche.
2) The Fuson Member is the confining unit between the Fall River Formation and the Chilson Member of the Lakota Formation. The Fuson Shale is a low-permeability shale unit within the Fuson Member that ranges in thickness from 20 to 80 feet across the entire project area and crops out east of the project boundary.
3) The Morrison Formation is the lowermost confining unit and underlies the Chilson Member of the Lakota Formation. This low-permeability shale unit that ranges in thickness from 60 to 140 feet across the entire project area crops out east of the project boundary.

The nine cross sections presented in Plates 6.13 through 6.21 also provide detailed lithologic interpretations of the host sandstones within the Fall River Formation and the Chilson Member of the Lakota Formation. These interpretations show that interbedded clay beds are found locally within both the Fall River and Chilson sandstones and may be sufficiently continuous as to further subdivide the Fall River and Chilson into discrete, mappable fluvial sandstone packages (i.e., Upper Fall River, Lower Fall River, Upper Chilson, etc.). These interbedded clay beds may act as confining units within individual well fields. However, they cannot be considered as regional confining units because they are discontinuous. This will be confirmed through delineation drilling and aquifer pump tests. Potential use of these interbedded clay beds, as they relate to operational fluid control and monitoring, will be addressed in hydrogeologic packages prepared for each well field (refer to Section 8.2.4).

The three major confining units (Graneros Group, or uppermost confining unit, Fuson Shale, and Morrison Formation, or lowermost confining unit) are depicted on Figure 6.4 in their typical relationship to the host sands, which are in the Fall River and Lakota formations.

The following is a brief description of the formations of interest at the project area:

Sundance Formation and Unkpapa Sandstone - The Sundance Formation is composed primarily of shale and sandstone with an average thickness of 280 feet near the project area. Where present, the Unkpapa Sandstone is 50 to 80 feet of well sorted, fine-grained, eolian sandstone.

Morrison Formation - The Upper Jurassic Morrison Formation was deposited as floodplain deposits. It is composed of waxy, unctuous, calcareous, noncarbonaceous massive shale with numerous limestone lenses and a few thin fine grained sandstones. Below the site, this formation has an average thickness of approximately 100 feet and is the lowermost confining unit for ISR operations. The confining properties of the Morrison Formation are well documented. An article entitled "Clay Mineralogy of the Morrison Formation – Black Hills Area," published in the Bulletin of the American Association of Petroleum Geologists, Vol. 40, No. 5, by Ronald Warren Tank (1956), provides an excellent description of Morrison clays in this area. The Morrison Formation is an extensive, low-permeability, terrestrial clay unit, with illite being the dominant clay mineral. Illite is a stable clay mineral that is usually deposited in fairly stagnant waters in an alkaline pH. Analyses of Morrison Formation core samples by Powertech indicate very small vertical permeabilities ranging from 0.004 to 0.04 millidarcies. The continuity, thickness, and lithology of the Morrison Formation ensure hydraulic isolation of the overlying Chilson sandstones from any potential aquifers below the Morrison.

Exploration holes drilled to evaluate the economic geology of the Lakota Formation were generally not continued the additional 100 feet required to penetrate the entire Morrison Formation. Powertech drilled eight holes that penetrated through the Morrison Formation, and records indicate that 16 historical TVA exploration holes penetrated the entire Morrison Formation. Two electric logs from plugged and abandoned oil test holes in the project area are also available to assist with evaluation of the Morrison Formation. Table 6.1 provides a listing of these 26 identified Morrison Formation penetrations.

Table 6.1: Drill Holes Penetrating the Morrison Formation

	Hole No.	Easting (ft)	Northing (ft)	Elevation (ft amsl)
1.	CAT1	1028330	444666	3738
2.	DRJ90	1037602	438720	3762
3.	FBR31	1038131	433097	3800
4.	RONA81	1033459	429385	3688
5.	PM159	1032551	433100	3651
6.	DWT48	1025864	444053	3702
7.	DWT49	1025235	442634	3661
8.	ELT14	1017626	444849	3617
9.	DWT40	1022610	445875	3681
10.	DWW190	1032799	450521	3760
11.	DWW192	1033149	450479	3740
12.	DY12	1025946	450088	3820
13.	DY17	1027335	455821	3818
14.	DY308	1012901	445124	3616
15.	HDA1	1028537	448585	3780
16.	TRM38	1035605	441152	3749
17.	DB07-11-31	1038312	429998	3731
18.	DB07-11-16C	1035139	429992	3698
19.	DB08-11-18	1035133	429986	3700
20.	DB08-32-12	1022352	439368	3590
21.	DB08-32-11	1020339	443666	3627
22.	DB08-5-1	1017626	444849	3629
23.	DB08-1-7	1042271	434137	3913
24.	DB09-21-1	1028628	453319	3822
25.	API 40 047 05095	1038166	433840	3792
26.	API 40 047 05093	1032429	423452	3576

Note: Coordinate system is NAD 27 South Dakota State Plane South

Plate 6.2 is a structure contour map of the top of the Morrison Formation. This map was developed in response to an NRC staff request for information on holes that penetrated into the Morrison Formation. This structure map shows the Morrison Formation generally dipping 2½ degrees to the southwest – away from the southwestern flank of the Black Hills Uplift. The irregular contour lines on Plate 6.2 in the Dewey and Burdock areas may indicate some minor scouring into the top of the Morrison Formation and subsequent deposition of the Lower Chilson sands. This minor scouring has not cut deeply into the Morrison clays, and the overall 60- to 140-foot thickness of this formation has not been significantly affected.

A good understanding of the Morrison Formation is important to the Dewey-Burdock Project. For this reason, in addition to providing the structure contour map of the Morrison Formation, Plate 6.6 provides an isopach map of the Morrison Formation. This map was based on the

26 drill holes that fully penetrated the Morrison Formation and shows the thickness of the Morrison varying from approximately 60 to 140 feet beneath the project area. Also shown on this isopach map is the location of cross section A-A’-A”, which is shown on Plate 6.22.

Cross section A-A’-A” depicts the surface to the base of the Morrison Formation based on 10 of the drill holes used in the development of the isopach map. The electric logs shown on this cross section illustrate a consistent thick sequence of Morrison clays across the project area. Copies of all electric logs from test holes that penetrate the Morrison Formation are contained in Appendix G. The A–A’ portion of the cross section traverses the project in an “updip” direction through the initial proposed well field in the Dewey area. Due to the 2½ degree dip, the Fall River Formation is shown to rise from a depth of 550 feet below ground surface in the Dewey area and crop out along the eastern edge of the project area near A’ (drill hole DB08-1-7). The A’-A” portion of the cross section proceeds in a “downdip” direction from the outcrop and continues through the initial proposed well field in the Burdock area.

Cross section A-A’-A” also illustrates the presence of the project’s uppermost confining unit (the Graneros Group) and the Fuson Shale confining unit between the Fall River Formation and the Chilson Member of the Lakota Formation. The thickness of the Graneros Group ranges from 0 feet at its outcrop within the eastern portion of the project area to over 550 feet in the southwestern portion of the project area. The Fuson Shale ranges from 20 to 80 feet thick throughout the project area.

Inyan Kara Group – This Group consists of the Lakota Formation and the Fall River Formation. Sandstones within these two formations are hosts to all the uranium mineralization for the project.

Lakota Formation - The Lakota Formation regionally consists of three members: from lower to upper they are the Chilson Member, the Minnewaste Limestone Member and the Fuson Member.

<u>The Chilson Member</u> (commonly referred to as the Lakota Sandstone) is composed largely of fluvial deposits. These deposits consist of sandstone, shale, and siltstone. The member consists of a complex of channel sandstone deposits and their laterally fine-grained equivalents. The Chilson Member consists of two units: a basal carbonaceous black mudstone and an overlying unit of channel sandstones with laterally fine-grained equivalents and interbedded shales. The sandstones are very fine to medium-grained and well sorted and were deposited by a northwest flowing river system. The massive sandstone is made up of numerous individual sand filled channels, which contain the uranium deposits.

The isopach map of the Chilson Member of the Lakota Formation (Plate 6.7) shows the thickness of the channel sandstones and interbedded shales within the Chilson Member. Thicknesses vary from 100 to 240 feet. This isopach map may not adequately show the total thickness of the Chilson Member because drilling was usually stopped in the lower carbonaceous shale unit of the Chilson Member and did not reach the Morrison Formation.

The Minnewaste Limestone Member, although present in the region, is not present in the project area. Darton (1909) noted that the Minnewaste Limestone is some 20 feet thick at its type locality at the falls of the Cheyenne River (25 miles east of the project area, now under Angostura Reservoir). In USGS Professional Paper 763 (Gott et al., 1974), the Minnewaste Limestone is described in the type locality as being a pure limestone, but grading out laterally to a sandy limestone and to a calcareous sandstone at its margins. Gott et al. also state that it is discontinuous west and northwest of the type locality (toward the project area).

A review of all drill hole and geologic lithology logs confirms the Minnewaste Limestone does not occur within the project area. Geologic cross section E-E’ (Plate 6.17), along the northeastern portion of the project area, illustrates the geologic section where, if present, the Minnewaste Limestone would occur. If present, this limestone unit would occur immediately beneath the Fuson Shale confining unit and above the Chilson Member of the Lakota Formation. A limestone would have a characteristically high (off-scale) response on the resistivity curve on the electric logs. As shown on cross section E-E’ no limestone is present.

The Fuson Member is the uppermost member of the Lakota Formation. The shale-siltstone portion of the Fuson (Fuson Shale) has been used to divide the Lakota Formation from the Fall River Formation.

For clarification, the Fuson Shale is differentiated from the Fuson Member of the Lakota Formation by Powertech for the purpose of characterizing the site geology. The Fuson Shale has been mapped by Powertech and consists of 20 to 80 feet of low-permeability shales and clays, which generally occur at or near the base of the unit. The Fuson Member of the Lakota, in comparison, has been mapped based on outcrop by the USGS and others to be from 40 to 80 feet thick and consisting of interbedded fluvial shales, clays, mudstones, and sands.

The Fuson Member is described as having a lower discontinuous sandstone unit at its base and an upper discontinuous sandstone at the top of the member. If present the lower sandstone unit was mapped as Lakota sandstone. Similarly if the upper sandstone was present it was mapped as Fall River sandstone. The isopach map of the Fuson Shale shows the thickness of the shale-siltstone unit ranging from 20 to 80 feet (Plate 6.8). It shows thinning of the shale under the overlying channel sandstones of the Fall River Formation.

The shales and mudstones within the Fuson Shale are highly stratified. Due to this stratification, the vertical permeability is estimated to be several orders of magnitude smaller than the horizontal permeability. Measurements of vertical permeability from core samples and estimates from pumping tests are provided in Section 5.2.1.2.

The Fuson Member, being of fluvial origin, locally contains sand deposits (Schnabel and Charlesworth, 1963). The presence of the sand facies within the Fuson Member does not diminish the confining capacity of the Fuson Shale within the Fuson Member as defined and mapped by Powertech. The geologic map of the Burdock quadrangle (Schnabel and Charlesworth, 1963) indicates that the Fuson Shale may pinch out in some areas. In particular, the interpretive fence diagram presented by Schnabel and Charlesworth shows an area approximately 1½ miles east and northeast of the project area, across Bennett Canyon, in the E/2 Section 30, T6S, R2E, where the Fuson Member pinches out. However, based on available borehole logs the Fuson Shale is continuous and no less than 20 feet thick throughout the entire project area. The pervasive occurrence and continuity of the Fuson Shale throughout the project area is shown on the geologic cross sections (Plates 6.13 through 6.22).

Fall River Formation - The Fall River Formation is composed of carbonaceous interbedded siltstone and sandstone, channel sandstones, and a sequence of interbedded sandstone and shale. The lower part of the Fall River consists of dark carbonaceous siltstone interbedded with thin laminations of fine-grained sandstone. Channels were cut into this interbedded sequence by northwest-flowing rivers and fluvial sandstones were deposited. These channel sandstones occur across various parts of the project and generally contain the uranium deposits. Overlying the channel sandstones is another sequence of alternating sandstones and shales. The sandstones are cross-bedded to massive, fine to medium-grained, and well sorted.

The isopach map of the Fall River Formation (Plate 6.9) shows a range of thickness of 120 to 160 feet. The thickening of the formation indicates the presence of channel sandstones. Along the northeastern portion of the project area, this formation is exposed on the surface and erosion has taken place.

Graneros Group - The Cretaceous Graneros Group consists of several geologic units, including the Skull Creek Shale, Newcastle Sandstone (where present), Mowry Shale, and Belle Fourche Shale, which act as a single confining unit overlying the Inyan Kara. In the project area, the thickness of the Graneros Group ranges from zero at the outcrop of the Fall River to more than 500 feet (Plate 6.10). The members which comprise the Graneros Group and described in Section 5.2.1.3.

Terrace Deposits - Along the sides of drainages are relatively thin and flat-lying terrace deposits representing floodplains and former levels of streams. The terraces are primarily overbank deposits of clay and silt with gravel beds. Gravel deposits consist of boulders and pebbles of chert, sandstone, and limestone.

Alluvium - The most recent sedimentary units deposited within the project area are the Quaternary-age alluvium deposits. Alluvium is present in the major drainages and their tributaries. The alluvium consists of silt, clay, sand and gravel. An isopach of the alluvium is presented as Plate 6.11.

6.2.3 Clarification of Breccia Pipes

Powertech evaluated the potential for breccia pipes in and around the project area and concluded that there is no evidence of breccia pipes. The detailed evaluation is presented in Appendix E and summarized below.

Breccia pipes have been studied and mapped in the southern Black Hills and are known to originate in anhydrite and gypsum sequences within the upper portion of the Minnelusa Formation. Dissolution of these evaporite sequences by underlying Minnelusa and/or Madison artesian water created solution cavities into which overlying Permian sediments collapsed. The aerial extent of dissolution is limited to a few miles downgradient from the Minnelusa outcrop. The probable maximum downgradient limit of dissolution, or dissolution front, has been mapped by the USGS and is more than 6 miles northeast of the project area. There is no evidence of dissolution of the Minnelusa in the project area based on evaluation of an electric log from an abandoned oil and gas test well within the project area. In areas where there has been no dissolution, there is no geologic foundation for the creation of breccia pipes in overlying sediments.

Further evidence against the presence of breccia pipes is presented in Appendix E and includes exploration drilling, field investigations for breccia pipes, an evaluation of Inyan Kara water temperatures, regional pumping tests, and evaluation of CIR imagery. Further, calibration of the groundwater model submitted to the NRC in February 2012 (Petrotek, 2012) does not support inflow to the Inyan Kara from deeper formations including through breccia pipes.

6.3 Seismology

The project area is located in an area of historically low seismic potential. There are no known capable faults within 100 km and a relatively low number of historical earthquakes. Seismic hazards at the project site include low to moderate ground shaking associated with regional and local earthquake sources. Figures 6.5 and 6.6 illustrate seismicity and peak ground acceleration (PGA) maps for the project area, and Appendix H provides a summary of the USGS database

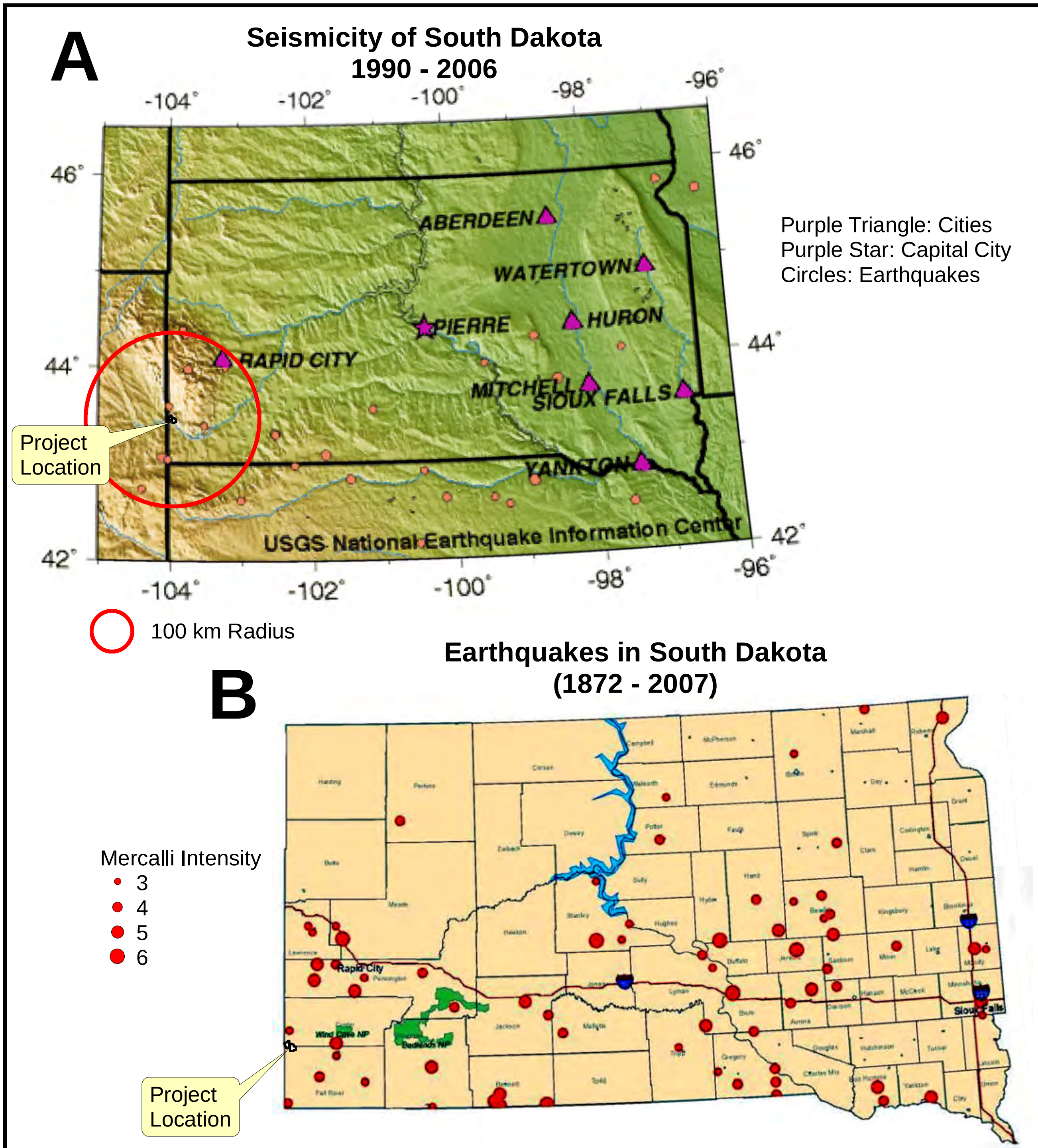

Figure 6.5
Seismicity of South Dakota
1990 - 2006
and Earthquakes in South Dakota
1872 - 2007
Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	29-Jun-2012
FILENAME	SDQuakesSeismic.mxd

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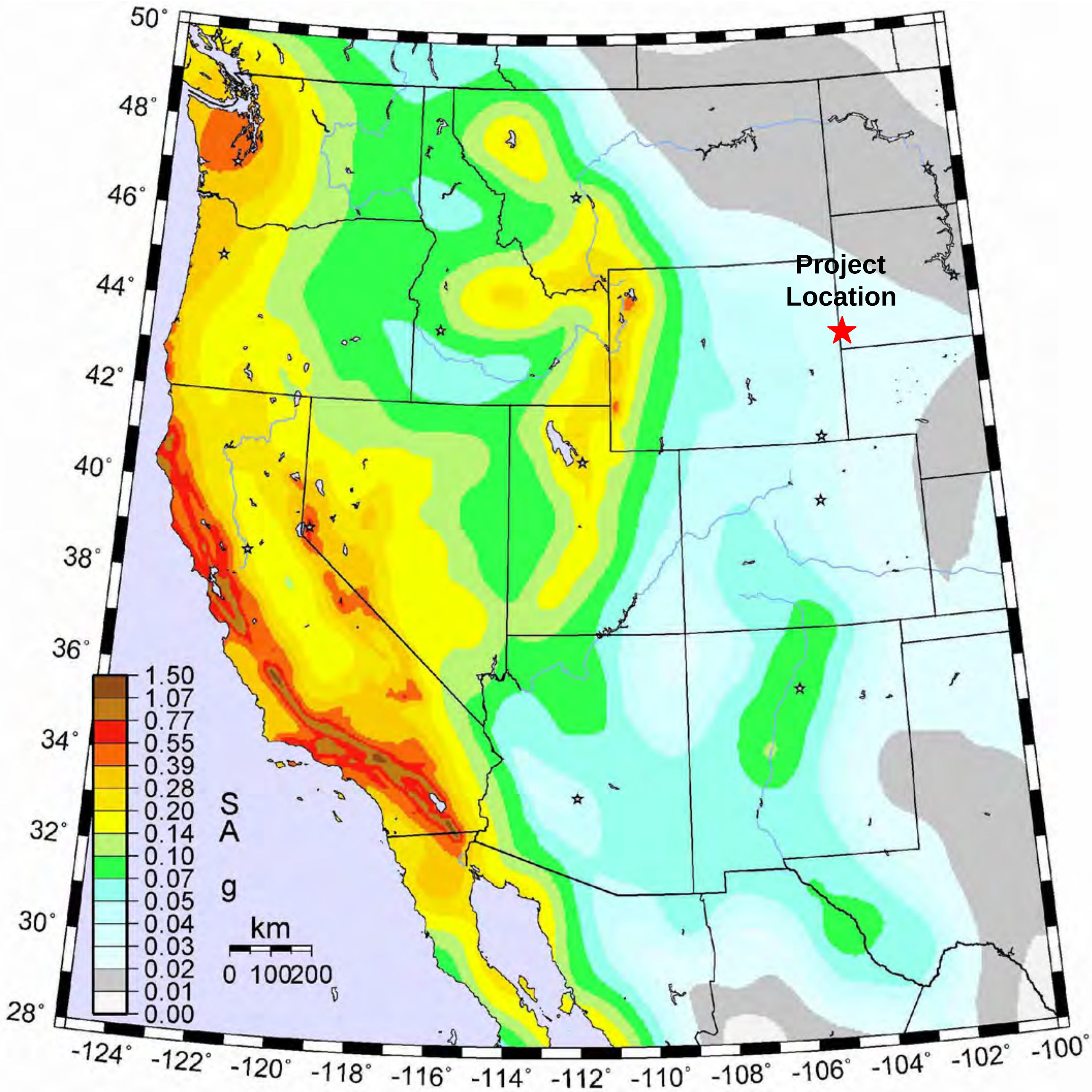
Source: USGS/DEIC PDE Catalog
Map A: USGS website:
http://earthquake.usgs.gov/regional/states/south_dakota/seismicity.php
Map B: USGS website:
http://www.sdgs.usd.edu/digitalpubmaps/quakemap.html



Source: USGS (2008)

Figure 6.6

Peak Ground Acceleration (PGA), Illustrating 10 Percent Probability of Exceedance in the Next 50 Years Dewey-Burdock Project

DRAWN BY	S. Hetrick
DATE	24-Jul-2012
FILENAME	PGA10Pct50Yr.dwg

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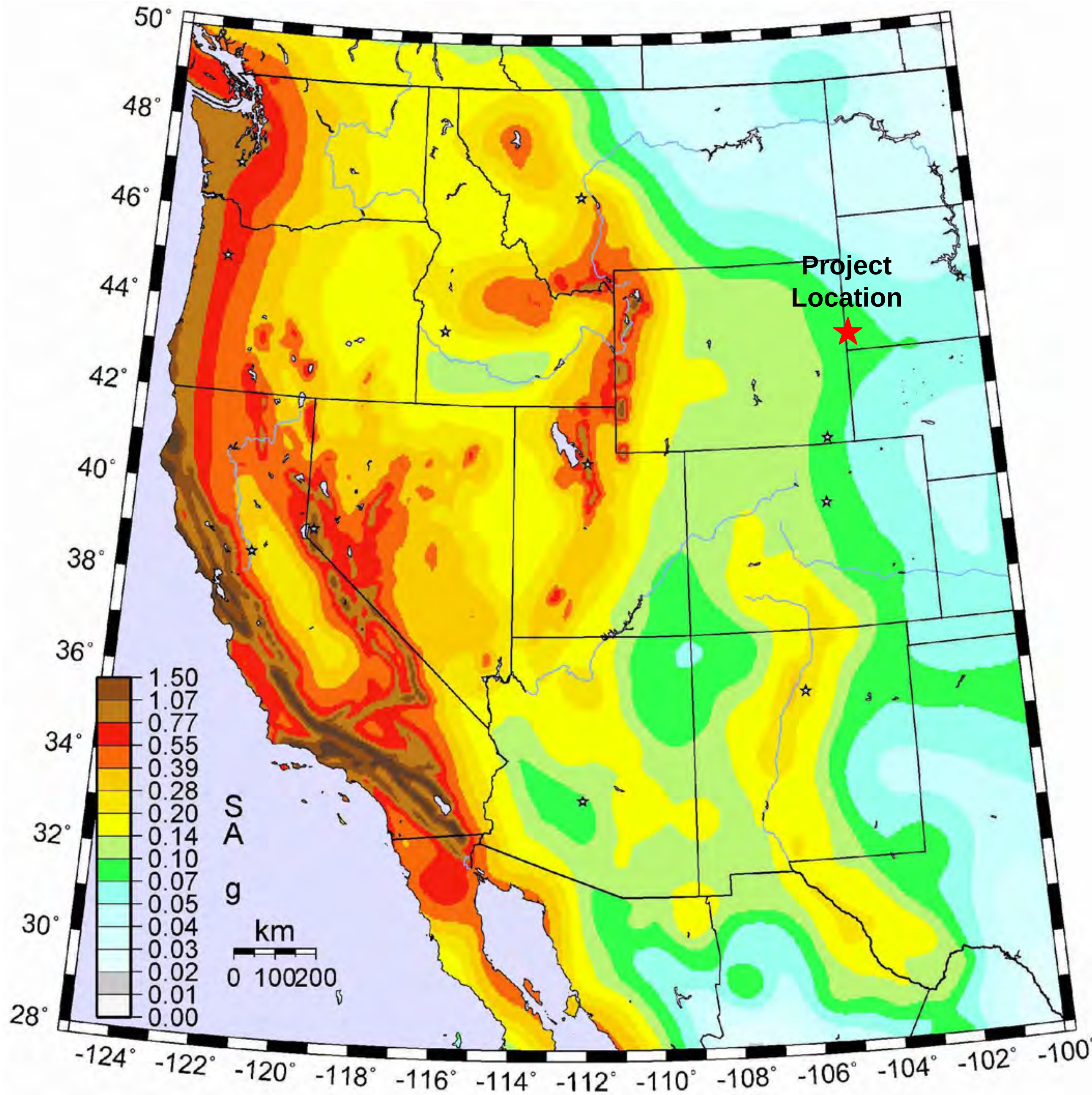
results for historical earthquakes recorded within 100 and 200 km from the project area since 1973.

There are no capable faults (as defined in 10 CFR Part 100, Appendix A, Section III(g)) known to be present within 100 km of the project area. The closest capable fault zone to the project area is located nearly 345 km (200 miles) west of the site in central Wyoming. Therefore, the most significant seismic hazard is considered to be the randomly occurring or “floating” earthquake. This is the maximum credible earthquake estimated for the project area based on available literature, geologic information of the surrounding area, and historical data. A magnitude M_{max} = 6.1 is estimated for this event.

According to the USGS 2008 Seismic Hazard Mapping Program, PGA derived from the probabilistic maximum bedrock acceleration with a 10 percent exceedance in 50 years (475-year return period) is 0.02 to 0.03g (Figure 6.6) for the southwestern part of South Dakota. The probabilistic maximum bedrock acceleration with a 2 percent chance of exceedance in 50 years (2,475-year return period) is 0.07 to 0.10g for the region (Figure 6.7). Both of these estimates reflect a low ground motion hazard.

As discussed further in Section 13.5.2, all buildings, structures, foundations, and equipment will be designed in accordance with recommendations in the latest versions of the International Building Code and ASCE-7 published by the American Society of Civil Engineers. Maps published in ASCE-7, and the latest version of the USGS Earthquake Ground Motion Tool, along with information regarding soil characteristics provided by the project professional geotechnical engineer, will be used to determine seismic loadings and design requirements.



Source: USGS (2008)

Figure 6.7
Peak Ground Acceleration (PGA), Illustrating 2 Percent Probability of Exceedance in the Next 50 Years
Dewey-Burdock Project

DRAWN BY	S. Hetrick
DATE	24-Jul-2012
FILENAME	PGA2Pct50Yr.dwg

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7.0 ATTACHMENT H - OPERATING DATA

This attachment discusses the operating data for the injection wells, including the typical and anticipated maximum injection rate, injection pressure range, and range in concentrations of the injected fluids.

7.1 Injection Flow Rate

The injection flow rates for individual Class III injection wells are anticipated to range from approximately 5 to 30 gpm. The project-wide injection flow rate will fluctuate depending on the number of well fields undergoing uranium recovery and aquifer restoration. The project-wide injection flow rate is expected to increase from the onset of uranium recovery in the first well field through the period of concurrent uranium recovery and aquifer restoration. Powertech estimates that individual well field uranium recovery times will be about 2 years, with multiple well fields typically in uranium recovery at any given time. Aquifer restoration will be completed following uranium recovery in each well field. Therefore, concurrent uranium recovery and aquifer restoration is anticipated to begin approximately 2 years after initial well field operation. Figure 10.2 in Section 10 depicts the anticipated project schedule.

Table 7.1 summarizes the typical project-wide flow rates during concurrent uranium recovery and aquifer restoration. The maximum gross pumping rate from producing well fields is anticipated to be 8,000 gpm. This will be limited by NRC license conditions. Although the NRC license application currently requests a maximum gross pumping rate of 4,000 gpm, Powertech anticipates submitting an amendment application to NRC to increase the maximum allowable gross pumping rate in order to provide operational flexibility. The production bleed is estimated to range from approximately 0.5% to 3%. At a maximum gross pumping rate of 8,000 gpm, the typical injection rate would therefore range from about 7,760 to 7,960 gpm. This demonstrates that the vast majority of water pumped from the production zone will be reinjected, such that the net withdrawal rate will be only a small fraction of the gross pumping rate. The maximum anticipated gross pumping rate from well fields undergoing aquifer restoration will be 500 gpm, with a typical restoration bleed of 1.0%. The typical injection rate for aquifer restoration therefore will be up to 495 gpm. The total estimated bleed during concurrent uranium recovery and aquifer restoration is estimated to be about 75 gpm, or about 0.88% of the maximum gross pumping rate of 8,500 gpm. The production and restoration bleed may vary, but the total injection rate is not anticipated to exceed 8,500 gpm or 12.24 mgd. This estimate of the maximum injection flow rate is provided for information purposes only; Powertech is not requesting that the proposed Class III UIC permit include flow limits.

Table 7.1: Typical Project-Wide Injection Flow Rates Corresponding to Maximum Anticipated Gross Pumping Rates

Operation Phase	Injection Flow Rate (gpm)	Production Flow Rate (gpm)	Bleed (gpm)	Bleed (%)
Uranium Recovery	7,930	8,000	70	0.875%
Aquifer Restoration	495	500	5	1.0%
Concurrent Uranium Recovery and Aquifer Restoration	8,425	8,500	75	0.88%

Figure 7.1 depicts the typical project-wide flow rates during concurrent uranium recovery and aquifer restoration. With respect to the Class III UIC permit application, the key streams are identified as C, E, L, and M on Figure 7.1. Streams C and L represent the primary injection streams into the Burdock and Dewey well fields, respectively. Streams E and M represent injection of makeup water from the Madison Limestone or another suitable aquifer. During uranium recovery, the sum of C and L is typically 7,930 gpm, which matches the project-wide value in Table 7.1. During aquifer restoration, the sum of C, E, L and M is typically 416 to 495 gpm. The lower value corresponds to the optional use of groundwater sweep, which is described in Section 10.8.2.1.3. The cumulative injection flow rate at the maximum gross pumping rate of 8,500 gpm, a typical production bleed rate of 0.875%, and no groundwater sweep, will be about 8,425 gpm, which matches the value shown in Table 7.1.

7.2 Injection Pressure

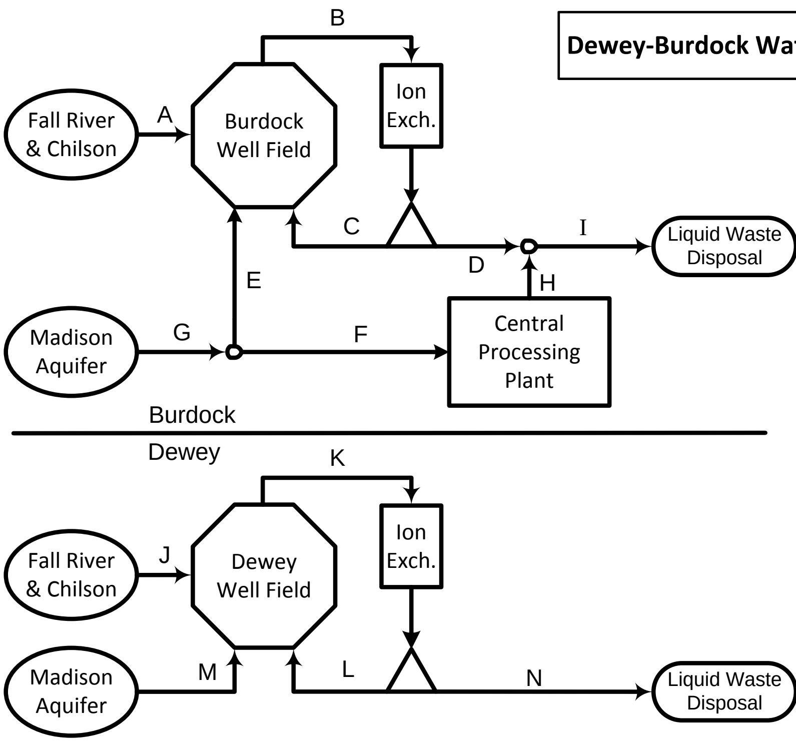
Powertech will specify the maximum injection pressure for each header house. The designated maximum pressure will be posted near the injection trunk line gauge used to monitor injection pressure. The maximum injection pressure will be calculated as the lowest value of the following:

- The lowest value of maximum allowable wellhead pressure for all injection wells connected to the header house based on fracture pressure calculations presented in Section 8.1.
- The manufacturer-specified maximum operating pressure for the well casing.
- The manufacturer-specified maximum operating pressure of the injection piping and fittings.

This pressure will not initiate new fractures or propagate existing fractures in the injection or confining zone or cause the migration of lixiviant into any USDW in accordance with 40 CFR § 144.28(f)(6)(i).

The anticipated range of injection pressures, measured at each header house, is 20 to 150 psig.

Dewey-Burdock Water Balance



Stream ID	Description
A	Burdock Aquifer Bleed
B	Burdock Extraction Composite
C	Burdock Reinjection
D	Burdock Well Field Bleed
E	Burdock Madison Make-up
F	Burdock Fresh Brine Make-up
G	Burdock Madison, Total
H	Burdock CPP Brine
I	Burdock Liquid Waste
J	Dewey Aquifer Bleed
K	Dewey Extraction Composite
L	Dewey Reinjection
M	Dewey Madison Make-up
N	Dewey Liquid Waste

Water Balance Flow Rates (gpm)											
Operation Phase	Aquifer Bleed Option	Disposal Option	Burdock								
			Stream ID								
			A	B	C	D	E	F	G	H	I
Recovery	0.875%	DDW	42	4800	4758	42	0	12	12	12	54
		LA	42	4800	4758	42	0	12	12	12	54
Restoration	Without Groundwater Sweep	DDW	2.5	250	175	75	73	0	73	0	75
		LA	2.5	250	0	250	247.5	0	247.5	0	250
	With Groundwater Sweep	DDW	42	250	175	75	33	0	33	0	75
		LA	42	250	0	250	208	0	208	0	250

Water Balance Flow Rates (gpm)							
Operation Phase	Aquifer Bleed Option	Disposal Option	Dewey				
			Stream ID				
			J	K	L	M	N
Recovery	0.875%	DDW	28	3200	3172	0	28
		LA	28	3200	3172	0	28
Restoration	Without Groundwater Sweep	DDW	2.5	250	175	73	75
		LA	2.5	250	0	247.5	250
	With Groundwater Sweep	DDW	42	250	175	33	75
		LA	42	250	0	208	250

Figure 7.1: Typical Project-wide Flow Rates during Uranium Recovery and Aquifer Restoration

7.3 Injection Fluid Composition

Two different types of fluid will be injected into the well fields. During uranium recovery, lixiviant consisting of production zone groundwater fortified with oxygen and carbon dioxide will be injected into the well fields. During aquifer restoration, permeate and/or clean makeup water from the Madison Limestone or another suitable aquifer will be injected into well fields. Table 7.2 describes the anticipated range of concentrations for various constituents in the lixiviant injected during uranium recovery. The lixiviant formulation is consistent with that used in typical U.S. ISR operations, will minimize potential groundwater quality impacts during uranium recovery, and will enable restoration goals to be achieved in a timely manner (NRC, 2003). The anticipated water quality of permeate and/or makeup water from the Madison Limestone or another suitable aquifer during restoration will be at the low end of the range of concentrations in Table 7.2.

Table 7.2: Typical Lixiviant Chemistry

Constituent	Units	Concentration Range	
		Minimum	Maximum
Sodium	mg/L	≤400	6,000
Calcium	mg/L	≤20	500
Magnesium	mg/L	≤3	100
Potassium	mg/L	≤15	300
Carbonate	mg/L	≤0.5	2,500
Bicarbonate	mg/L	≤400	5,000
Chloride	mg/L	≤200	5,000
Sulfate	mg/L	≤400	5,000
Uranium	mg/L	≤0.01	<2
Vanadium	mg/L	≤0.01	100
Total Dissolved Solids, TDS	mg/L	≤1,650	12,000
pH	std units	≤6.5	10.5

Source: Modified from NRC (2009) to reflect that uranium will be removed prior to injection.

8.0 ATTACHMENT I - FORMATION TESTING PROGRAM

This attachment provides a description of the formation testing program for the Dewey-Burdock Project. The formation testing program description includes information about geohydrologic properties of the ore zone and the confining zones from previous tests and information about the pump testing program that will be performed for each well field.

8.1 Fracture Pressure

Powertech will not use hydraulic fracturing as part of the ISR process, and no fracture pressure testing is planned. Fracture testing could increase the probability of creating a pathway for loss of fluid control in the immediate vicinity of the tested well. Powertech will operate its injection wells below the estimated fracture pressure of the injection zone. Maintaining the native hydraulic properties of the host sand is important to uranium recovery and control of well field solutions. Instead of fracture testing Powertech will rely on conservative and accepted methods of estimating fracture pressure as described below.

Fracture pressure varies with well depth, strength of formation rock and overburden pressure. Hydraulic pressure is the sum of the overburden pressure and the hydrostatic pressure of fluids within the wellbore. The hydrostatic pressure can be calculated based on the pressure gradient of the fluid multiplied by the fluid depth. The total hydraulic pressure or downhole pressure is calculated as follows:

total hydraulic pressure (psi) = overburden pressure (psi) +
[(fluid pressure gradient (psi/ft) x depth (ft)]

To prevent formation fracturing, the total hydraulic pressure or downhole pressure must not exceed the formation fracture pressure. Since the hydrostatic pressure is calculated as the fluid pressure gradient multiplied by the depth, the maximum surface pressure or maximum allowable well head pressure (max WHP) can be calculated as follows:

max WHP = formation fracture pressure (psi) – hydrostatic pressure (psi)

The formation fracture pressure can be calculated based on the fracture gradient multiplied by the depth.

Fracture gradient is defined by the EPA (2012) as follows:

> The fracture gradient is a measure of how the pressure required to fracture rock in the earth changes with depth. It is usually measured in units of "pounds per square inch per foot" (psi/ft) and varies with the type of rock and the stress history of the rock. The default value used by Region 5 in Michigan is 0.8 psi/ft. This means,

> for example, that at a depth of 100 ft, a pressure of 80 psi would be required to fracture the rock, while at a depth of 500 ft, the required pressure would be 400 psi; at 1,000 ft, 800 psi.

To be conservative, Powertech will use a fracture gradient value of 0.7 psi/ft, which is used for Class V UIC permits in Wyoming. Therefore, the max WHP will be calculated based on the following equation, which uses a fluid pressure gradient of 0.433 psi/ft for the injected fluid:

max WHP = [0.7 psi/ft – 0.433 psi/ft] x [well depth or depth to open interval (ft)]

Based on a range of depths to the target mineralization of approximately 200 to 800 feet, the max WHP will range from approximately 53 to 214 psi. The maximum allowable WHP will be calculated on a well-by-well basis, and operational controls will be put in place to prevent exceeding designated pressures. The maximum injection pressure will be designated for each header house as described in Section 7.2. The designated maximum injection pressure will be posted near the injection trunk line gauge used to monitor injection pressure. This practice will ensure the formation fracture pressure is not exceeded according to 40 CFR § 144.28(f)(6)(i).

8.2 Pumping Tests

Appendices I and J provide reports documenting pumping tests that have been conducted at the project area. A summary of the reports in these appendices is provided below.

8.2.1 Summary of TVA Pumping Tests

TVA conducted groundwater pumping tests from 1977 through 1982 as part of its uranium mine development project near the towns of Edgemont and Dewey, South Dakota. The results of these tests are summarized in two reports provided in Appendix I: “Analysis of Aquifer Test Conducted at the Proposed Burdock Uranium Mine Site” (Boggs and Jenkins, 1980) and “Hydrogeologic Investigations at Proposed Uranium Mine near Dewey, South Dakota” (Boggs, 1983).

Two pumping tests conducted by TVA at the Burdock site in 1977 were unsuccessful. The results of these tests were considered inconclusive because of questionable discharge measurements, improperly constructed observation wells, and malfunctioning pressure gauges. No data from the 1977 tests are available.

TVA conducted two successful pumping tests in 1979 near the Burdock portion of the project area and one in 1982 about 2 miles north of the Dewey portion of the project area. The results of these tests are described below.

8.2.1.1 Burdock Area

The Burdock tests were conducted in 1979 near S. Dewey Road at the location shown on Figure 8.1. The Burdock tests consisted of separate pumping tests from the Lakota (Chilson) and Fall River in April and July of 1979. The tests used the same pumping well with packers to alternatively isolate screens open to the respective formations. Test durations were 73 hours for the Lakota (Chilson) test and 49 hours for the Fall River test. Pumping rates were about 200 gpm from the Lakota (Chilson) aquifer and 8.5 gpm from the Fall River. The reason for the unexpected low pumping rate from the Fall River aquifer was not specified in the TVA report.

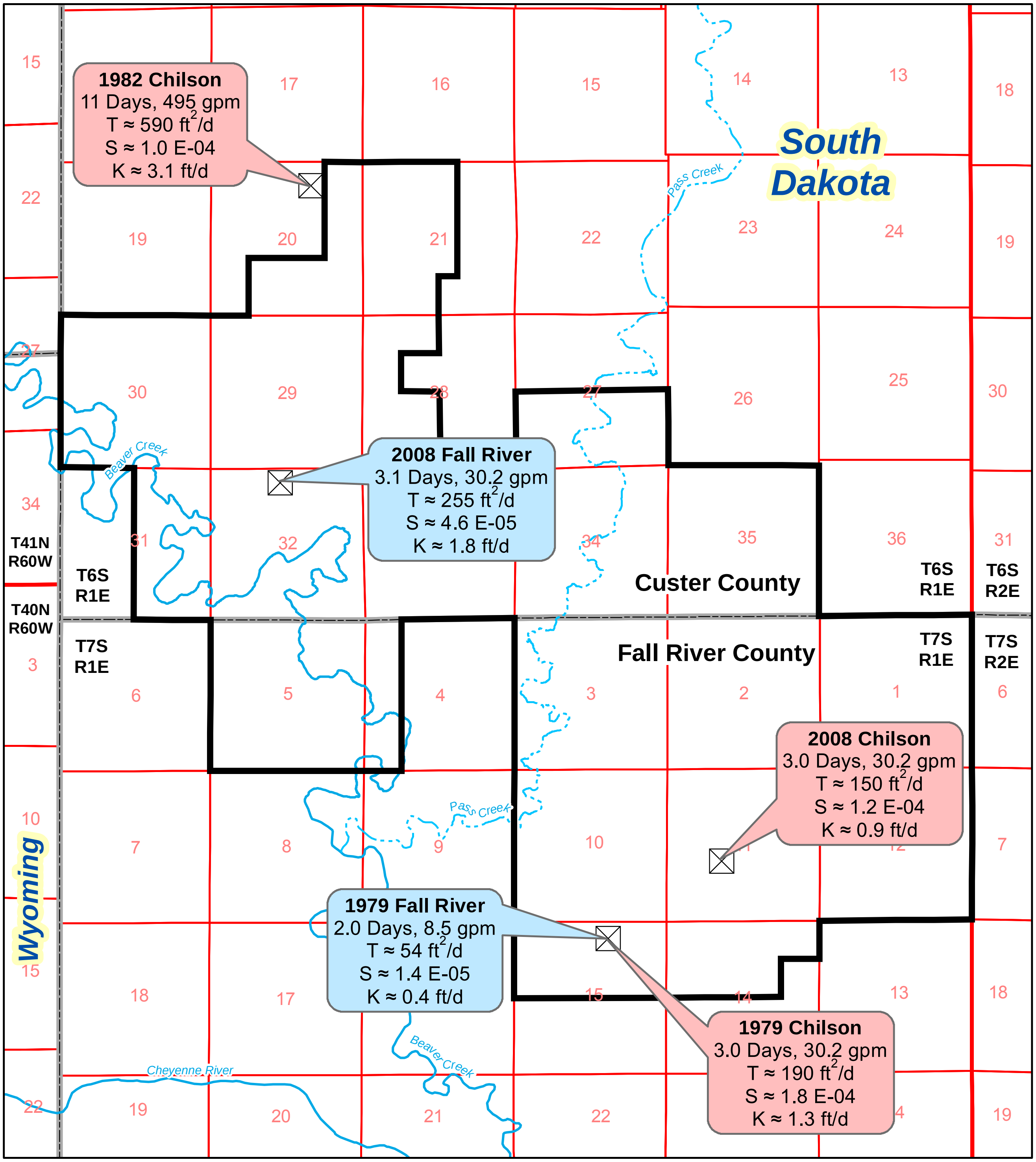
Based on review of the testing results by Powertech, significant conclusions from the TVA testing indicate:

- Transmissivity of the Chilson based on the analysis of late time data averaged about 1,400 gpd/ft (190 ft^2/day) and storativity was determined to be approximately 1.8 x 10^{-4} (dimensionless).
- Transmissivity of the Fall River averaged about 400 gpd/ft (54 ft^2/day) and storativity approximately 1.4 x 10^{-5} (dimensionless).
- The vertical hydraulic conductivity of the Fuson aquitard calculated using the Neuman-Witherspoon ratio method (Neuman and Witherspoon, 1972) ranged from 1 x 10^{-3} to 1 x 10^{-4} ft/day; storativity was not determined, and specific storage was assumed to be about 10^{-6} ft^{-1}.
- The reported "leaky aquifer" response likely is related to (1) Well 668 that is completed in both the Chilson and Fall River and can provide a direct communication pathway, and/or (2) the presence of open boreholes that may provide communication between the Fall River and Lakota (Chilson) in a limited area near the Burdock test, or communication between the Fall River and land surface. The test results do not support a leaky confining zone (Fuson Shale).

8.2.1.2 Dewey Area

The Dewey test was conducted in 1982 northeast of S. Dewey Road at the location shown on Figure 8.1. The test consisted of pumping in the Lakota Formation (Chilson) at an average rate of 495 gpm for 11 days. The significant results are as follows:

- Transmissivity of the Chilson averaged about 4,400 gpd/ft (590 ft^2/day).
- Storativity of the Chilson was about 1.0 x 10^{-4} (dimensionless).
- The vertical hydraulic conductivity of the Fuson aquitard using the Neuman-Witherspoon ratio method (Neuman and Witherspoon, 1972) was 2 x 10^{-4} ft/day; storativity of the Fuson Shale was not determined and specific storage was about 7 x 10^{-7} ft^{-1}.



Feet
0 2,500 5,000
0 1,000 2,000
Meters

N

Legend

- Project Boundary
- Ephemeral Streams
- Perennial Streams

Figure 8.1

Location of Historical TVA and Recent Powertech Pumping Tests

Dewey-Burdock Project

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- A barrier boundary or decrease in transmissivity due to lithologic changes with distance from the test site, or both, were observed; a possible geologic feature corresponding to a barrier was noted to be the Dewey Fault Zone, located about 1.5 miles north of the test site, where the Chilson and Fall River formations are structurally offset.

8.2.2 2008 Pumping Tests

In 2008 pumping tests were performed in the Dewey and Burdock portions of the project area (Figure 8.1), along with laboratory tests on related core samples, to assess aquifer properties. A work plan (Knight Piésold, 2008a) was prepared and distributed to interested representatives of state and federal agencies, including South Dakota DENR and the EPA.

A detailed description of the aquifer testing methodology and analysis of the results are contained in the aquifer test report (Knight Piésold, 2008b) (Appendix I). The report results are briefly summarized in the following sections.

8.2.2.1 Burdock Area

Summary of Burdock Pumping Test Results

Pump testing was conducted within the lower Lakota (Chilson) at pumping well DB07-11-11C. Three observation wells were monitored in the same horizon. An observation well was also monitored in the upper Chilson. Single observation wells were monitored in the overlying Fall River and underlying Unkpapa. The well was pumped at an average rate of 30.2 gpm for 4,320 minutes (3.0 days).

Drawdown at the pumping well was approximately 91 feet, and between 3.1 feet and 17.0 feet in the lower Lakota (Chilson) observation wells. The upper Lakota (Chilson) well response was delayed, but 3.4 ft of drawdown was observed in this well. Approximately 1 foot of drawdown was observed in the overlying Fall River well and no response was observed in the underlying Unkpapa well.

A summary of aquifer parameters for the 2008 Burdock pumping test (conducted in the Chilson Member of the Lakota Formation) and related laboratory core testing follows:

- Nine determinations of transmissivity (Table 8.1) ranged from 120 to 223 ft^2/day with the median value of 150 ft^2/day.
- Based on 170 feet of saturated thickness in the aquifer, hydraulic conductivities range from 0.7 ft/day to 1.3 ft/day, with a median value of 0.9 ft/day.
- Four storativity determinations (Table 8.1) ranged from 6.8×10^{-5} to 1.9×10^{-4} with a median value of 1.2×10^{-4}.
- The radius of influence of the pumping test determined by a distance-drawdown plot was 2,100 feet.

Table 8.1: Summary of Aquifer Hydraulic Characteristics for the Burdock Pumping Test

Well I.D.	Well Type	Radial Dist. (ft)	Interpretation Method	Transmissivity (ft^2/day)	u or u' (unitless)	Storativity (unitless)	Note
Ore zone (lower Chilson Sandstone)							
11-11C	Pumping	0.25 (0.33)	Theis DD(1)	145	-	2.9E-09(a)	-
			CJ DD (3)	150	<0.01	-	-
Pumping Well Efficiency = 65%(3)							
			CJ Recovery (3)	140	<0.01	-	-
15-Nov	Obs #1	243	Theis DD(1)	67	-	1.30E-03	-
			CJ Recovery (3)	100	<0.1	-	-
11-14C	Obs #2	250	Theis DD(1)	128	-	6.80E-05	-
			H-J DD(1)	120	-	6.90E-05	
			Theis Recovery(1)	174	<0.01	-	-
			CJ Recovery (3)	160	<0.01	-	-
2-Nov	Obs #3	1,292	Theis DD(1)	223	-	1.90E-04	-
			H-J DD(1)	185	-	1.70E-04	-
			CJ Recovery (3)	260	<0.15	-	-
Upper Chilson Sandstone							
19-Nov	Obs	50	Theis DD(2)	260	-	1.00E-01	-
			CJ Recovery (3)	190	<0.15	-	-
Fall River (lower sandstone layer)							
17-Nov	Obs	50	Noordbergum Effect and response cannot be interpreted analytically				
Unkpapa Sandstone							
18-Nov	Obs	35	No response during pumping test.				-
Distance Drawdown (11-14C, 11-15, 11-02)(2)				145	<0.08	2.20E-04	r^2 = 0.76 (3 point line)
Pumping Well Efficiency = 61% to 63%							
Summary:	Median			150		1.20E-04	
Average/Geometric Mean(5)				158		1.12E-04	
	TVA(4)			190		1.80E-04	

(1) Calculated by automated curve fitting in AquiferWin32™ software (ESI, 2003).
(2) Knight Piésold spreadsheet after methods in Driscoll (1986).
(3) Spreadsheet methods in U.S. Geol. Surv. Open File Rept. 02-197, Halford and Kuniansky (2002).
(4) Summary values from p. 17 in Boggs and Jenkins (1980).
(5) Average value calculated for Transmissivity, Geometric Mean value calculated for Storativity.
(a) Storativity not valid at pumping well.
(b) Based on 6 inch casing (8 inch borehole).

'158' = Accepted value based on conformance with theory discussed in the text

- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 8.2) were made on sandstone layers similar to that tested in the pump test; measured horizontal hydraulic conductivity ranged from 5.9 to 9.1 ft/day, the mean value was 7.4 ft/day and mean ratio of horizontal to vertical hydraulic conductivity in Burdock area sandstone was 2.47:1.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 8.2) were made on shale layers from two major confining units for the Lakota (Chilson) in the pump test area with the following results:
  - Fuson Shale: the laboratory core data indicated vertical permeabilities of about 2×10^{-7} to 1×10^{-8} cm/sec (average 2.7×10^{-4} ft/day) for shale samples from the Fuson Shale.
  - Morrison Shale: the laboratory core data for the shales in the underlying Morrison Formation indicated vertical permeabilities of 9×10^{-9} to 3×10^{-8} cm/sec (average 6.0×10^{-5} ft/day).

<u>Burdock Pumping Test Conclusions</u>

The Burdock pumping test in 2008 may be directly compared to the 1979 TVA test for the Lakota (Chilson) aquifer as the tests were nearly at the same location (Figure 8.1). The average transmissivity and storativity values determined from the TVA tests were 190 ft^2/day and 1.8×10^{-4} (see p. 17 in Boggs and Jenkins, 1980). Comparing the median transmissivity of 150 ft^2/day and storativity of 1.2×10^{-4} determined in the 2008 test to the TVA test, the new aquifer parameters for the lower Chilson are respectively about 80 and 70 percent of the 1979 results. Because transmissivity and storativity depend on aquifer thickness, comparison of the results suggests that there may be some scaling effect between the tests due to the different lengths of screened intervals.

The 1979 TVA test transmissivity of 190 ft^2/day is considered representative of the entire Chilson aquifer for a regional application (Table 8.1).

Previous conclusions and interpretations from this pump test submitted to NRC and EPA indicated that the Chilson behaved as a leaky aquifer system (e.g., a drawdown response was observed in the overlying Fall River observation well and the Chilson wells consistent with a leaky system based on a match of the data to the Hantush-Jacob solution). Further review of the site geology and hydrology suggest that those interpretations were not representative of site conditions.

The laboratory core data from samples collected within the project area indicate an average vertical permeability of 9.3×10^{-8} cm/s (2.7×10^{-4} ft/day) for shale samples from the Fuson Shale (Table 8.2). The shale core permeability values are about one to two orders of magnitude smaller than the pumping test values determined in the 1979 TVA test at Burdock, where the vertical

Table 8.2: Laboratory Core Analyses at Project Site

Sample Number	Depth (ft)	Confining Stress (psig)	Porosity (%)	Air Intrinsic Permeability(1) ka (mD)	Particle Density (g/cm^3)	Notes	Water Hydraulic Conductivity Kw(2)(3) (cm/s)	Core Kh (ft/day)	Core Kv (ft/day)
DB 07-11-11C Burdock									
1H	252.20	600	10.50	1.040	2.356	Fuson Shale	8.0073E-07		
1V	252.35	600	10.15	0.228	2.356	Fuson Shale	1.7555E-07		
4H	412.30	600	9.68	0.041	2.511	Fuson Shale	3.1567E-08		
4V	412.45	600	9.59	0.015	2.514	Fuson Shale	1.1549E-08		
DB 07-29-1C Dewey									
2H	480.70	600	8.90	0.078	2.613	Skull Creek shale	6.0055E-08		
2V	480.80	600	9.30	0.007	2.610	Skull Creek shale	5.3896E-09		
3H	609.10	600	12.26	0.073	2.603	Fuson Shale	5.6205E-08		
3V	609.10	600	10.84	0.008	2.793	Fuson Shale	6.1595E-09		
DB 07-11-14C Burdock									
5H	423.60	600	29.56	3,207	2.645	Lakota Sand	2.4692E-03	7.0	
5V	423.35	600	30.34	1,464	2.645	Lakota Sand	1.1272E-03		3.2
6H	430.20	600	31.90	4,161	2.640	Lakota Sand	3.2037E-03	9.1	
6V	430.35	600	30.16	939	2.646	Lakota Sand	7.2297E-04		2.1
7H	453.50	600	10.86	1.000	2.519	Morrison Shale	7.6994E-07		
7V	453.45	600	11.82	0.043	2.543	Morrison Shale	3.3107E-08		
DB-07-11-16C Burdock									
8H	420.40	600	30.50	2,697	2.643	Lakota Sand	2.0765E-03	5.9	
8V	420.10	600	30.17	1,750	2.651	Lakota Sand	1.3474E-03		3.8
9H	455.90	600	6.99	0.004	2.536	Morrison Shale	3.0797E-09		
9V	455.45	600	7.65	0.012	2.556	Morrison Shale	9.2392E-09		
10H	503.30	600	12.96	0.697	2.474	Morrison Shale	5.3665E-07		
10V	503.45	600	No data						
DB 07-32-4C Dewey									
11H	573.25	600	29.15	2,802	2.641	Fall River Sand	2.1574E-03	6.1	
11V	573.40	600	29.04	619	2.645	Fall River Sand	4.7659E-04		1.4
Summary									
Average Lakota Sand Kh, Kv								7.4	3.0

(1) Assumed air temperature = 70°F.
(2) Assumed water temperature = 52.8°F, water density = 0.999548 g/cm^3, and water dynamic viscosity = 0.012570 g/cm-s.
(3) $K_w = k_a \times (\rho_w g/\mu_w)$, and 1.0 mD = 0.987×10^{-11} cm^2

hydraulic conductivity of the Fuson aquitard was calculated using the Neuman-Witherspoon ratio method to be about 1 x 10^{-3} ft/day (see pg. [i] in Boggs and Jenkins, 1980).

For the Lakota (Chilson) sandstone, the laboratory core data within the project area indicate an average horizontal hydraulic conductivity of 2.5 x 10^{-3} cm/sec (7 ft/day) and a range as high as 3.2 x 10^{-3} cm/sec (9.1 ft/day) (Table 8.2). Pump test results indicate an average horizontal hydraulic conductivity of approximately 0.9 ft/day (3.2 x 10^{-4} cm/s).

Site-wide geologic data (logs, cross sections and isopach maps) clearly demonstrate the continuity of the Fuson Shale across the project area. Those data, combined with data from the pump tests and core results, indicate that the leaky behavior observed in the 2008 Chilson test likely is the result of (1) communication between the Chilson and Fall River via Well 668 that is completed in both sands, and/or (2) the presence of open boreholes that may provide communication between the Fall River and Lakota (Chilson) in a limited area near the Burdock test.

8.2.2.2 Dewey Area

Summary of Dewey Pumping Test Results

Pump testing was conducted in the lower sandstone interval of the Fall River at pumping well DB07-32-3C. This well was pumped at a rate of 30.2 gpm for 3.1 days (4,440 minutes). Three observation wells between 240 and 2,400 feet from the pumping well were monitored in the same horizon. An upper Fall River observation well was also monitored. Single observation wells were monitored in the underlying Lakota (Chilson) and Unkpapa aquifers.

Drawdown at the pumping well was 44.8 feet, and drawdown in the lower Fall River observation wells varied with distance from the pumping well to between 1.5 and 13 feet. Drawdown in the upper Fall River approximately 40 feet from the pumping well was approximately 4 feet. No drawdown response was observed in the underlying Lakota (Chilson) or Unkpapa aquifers.

A summary of aquifer parameters for the 2008 Dewey pumping test (conducted in the Fall River Formation) and related laboratory core testing is as follows:

- Ten determinations of transmissivity (Table 8.3) ranged from 180 to 330 ft^2/day with a median value of 255 ft^2/day.
- Based on 140 feet of saturated thickness in the Fall River, hydraulic conductivities range from 1.3 ft/day to 2.4 ft/day, with a median value of approximately 1.8 ft/day.
- Five storativity determinations (Table 8.3) ranged from 2.3 x 10^{-5} to 2.0 x 10^{-4} with a median value of 4.6 x 10^{-5}.

Table 8.3: Summary of Aquifer Hydraulic Characteristics for the Dewey Pumping Test

Well I.D.	Well Type	Radial Dist. (ft)	Interpretation Method	Transmissivity (ft^2/day)	u or u' (unitless)	Storativity (unitless)	Note
Ore zone (lower Fall River Sandstone)							
32-3C	Pumping	0.25 (0.33)	Theis DD(1)	250	-	1.2E-06(d)	-
			CJ DD (3)	250	<0.01	-	-
Pumping Well Efficiency = 80%(3)							
			CJ Recovery (3)	270	<0.01	-	-
32-5	Obs #1	243	Theis DD(1)	294	-	3.30E-05	--
			Theis Recovery(1)	260	<0.01	-	-
			CJ Recovery(3)	280	<0.01	-	-
32-4C	Obs #2	467	Theis DD(1)	333	-	5.60E-05	-
			CJ Recovery (3)	120(a)	<0.01	-	
29-7	Obs #3	2,400	Theis DD(2)	178	-	2.00E-04	
			CJ Recovery (3)	Insufficient recovery for analysis			-
Fall River Aquifer Stock Well (Screened in top half of Fall River)							
GW-49	Stock	1,400	Theis DD(1)	177	-	2.30E-05	-
			CJ Recovery (3)	110	<0.05	-	-
Upper Fall River Sandstone							
32-9C	Obs	41	Theis DD(1)	217	-	1.60E-02	-
			CJ Recovery (3)	150	<0.05	-	--
Chilson Sandstone Layer							
32-10	Obs	61	No response during pumping test.				--
Unkpapa Sandstone							
32-11	Obs	50	No response during pumping test.				-
Distance Drawdown (32-5, 32-4C, 29-7, GW-49)(2)				218	<0.05	4.60E-05	r^2 = 0.78 (4 point line)
Pumping Well Efficiency = 93% to 95%							
Summary:	Median			255		4.60E-05	
Average/Geometric Mean(4)				251		5.23E-05	

Notes/References: DD = drawdown, CJ = Cooper -Jacob, Obs = Observation Well
(1) Calculated by automated curve fitting in AquiferWin32™ software (ESI, 2003).
(2) Knight Piésold spreadsheet after methods in Driscoll (1986).
(3) Spreadsheet methods in U.S. Geol. Surv. Open File Rept. 02-197, Halford and Kuniansky (2002).
(4) Average value calculated for Transmissivity, Geometric Mean value calculated for Storativity.
(a) Only slope satisfying u 'criterion occurs after intersection with barrier boundary.
(b) Not accepted due to anomalous response at well, see text.

- The radius of influence of the pumping test determined by a distance-drawdown plot was 5,700 feet.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 8.2) were made on shale samples from the two major confining units overlying and underlying the pump test area with the following results:
  - Skull Creek Shale: laboratory core data for the shale sample from the overlying Skull Creek Shale (Graneros Group) indicate a vertical permeability of 5.4×10^{-9} cm/sec (1.5×10^{-5} ft/day).
  - Fuson Shale: laboratory core data for the shale sample from the underlying Fuson Shale indicate a vertical permeability of 6.2×10^{-9} cm/sec (1.8×10^{-5} ft/day).

Dewey Pumping Test Conclusions

The Dewey pumping test in 2008 in the Fall River aquifer is not directly comparable to the 1982 TVA test because the underlying Lakota (Chilson) aquifer was tested in 1982.

The 2008 test indicated that the lower and upper sandstone portions of the Fall River Formation behave as a single, confined aquifer with some form of lateral barrier due to changing lithology, such as a channel boundary. The TVA test in 1982 observed a barrier boundary in the underlying Lakota Formation, likely the result of the Dewey Fault Zone. Apparently, both the Chilson and Fall River Formation in the general Dewey area are highly transmissive and show barrier boundaries. These test results are more definitive than the 1982 TVA test concerning the effect of the barrier boundary, because the 2008 radius of influence was about one mile, or about one-half to one-third the distance to the fault zone.

Confinement provided by the Fuson Shale between the Fall River and underlying Chilson Member of the Lakota was demonstrated by the 2008 testing. The Chilson and Fall River aquifers at the Dewey test site are hydraulically isolated by the intervening Fuson Shale with nearly 40 feet of head difference between the two units. The laboratory core data indicate a very low vertical permeability of 6.2×10^{-9} cm/sec (1.8×10^{-5} ft/day) for a shale sample from the Fuson Shale within the project area (Table 8.2).

The laboratory core data for the shale sample from the Skull Creek Shale, which overlies the Fall River Formation, indicate a very low vertical permeability of 5.4×10^{-9} cm/sec (1.5×10^{-5} ft/day), which is representative of an effective aquitard or aquiclude (Table 8.2).

For the sandstone of the Fall River Formation, the laboratory core data indicate a horizontal hydraulic conductivity of 6.1 ft/day (2.2×10^{-3} cm/s) (Table 8.2). Based on pump test results, the average horizontal conductivity is approximately 1.8 ft/day (6.4×10^{-4} cm/s). Within the lower Fall River Formation, the test results indicate transmissive, rapid response (2 to 3 minutes) between pumping and observation wells up to 467 feet apart with nearly 10 feet of drawdown.

Response was nearly 9 feet of drawdown at 1,400 feet distance. This indicates that the aquifer was stressed to produce good quality analytical results.

8.2.3 Pre-Operational Pump Testing for Each Well Field

The following pump testing procedures will be used to establish that the production and injection wells are hydraulically connected to the perimeter production zone monitor wells, that the production and injection wells are hydraulically isolated from non-production zone vertical monitor wells, and to detect potentially improperly plugged wells or exploration holes. Pump testing results will be included in the well field hydrogeologic data packages described in Section 8.2.4 and the injection authorization data packages described in Section 8.2.5.

Pump Testing Design

An extensive pump test program will be designed and implemented prior to operation of each well field to evaluate the hydrogeology and assess the ability to operate the well field. Prior to pump testing several important well field development steps will be completed:

1) Delineation drilling at spacing sufficient to finalize well field design. As standard procedure, all delineation holes will be plugged and abandoned after drilling.
2) Detailed mapping of the ore bodies targeted for ISR operations and the lithology of overlying and underlying sand units and aquitards.
3) Revision of the conceptual geology and hydrogeology including definition of aquitards and sand units to be produced or monitored.
4) Design of the production and injection wells including well locations and screened intervals.
5) Design of the monitor well system based on production and injection well locations and refined conceptual geology and hydrogeology.
6) Specification of all monitor well locations and screened intervals.
7) Installation of all monitor wells and production wells to be used during pump testing.
8) Plugging and abandoning all water supply wells within ¼ mile of the well field or that have been determined through preliminary evaluation to be potentially impacted by ISR operations or to impact ISR operations.

Pump Testing Procedures

Appropriate wells as needed for characterization and regulatory purposes will be monitored during the pumping test, including but not necessarily limited to the following wells:

1) Pumping wells,
2) Monitor wells within the production zone,
3) Perimeter production zone monitor wells,

4) Monitor wells in the immediately overlying non-production zone sand unit,
5) Monitor wells in each subsequently overlying non-production zone sand unit,
6) Monitor wells in the alluvium, if present,
7) Monitor wells in the immediately underlying non-production zone sand unit, if the production zone does not occur immediately above the Morrison,
8) Any additional wells installed for investigating other hydrogeologic features, and
9) Any other wells within proximity to the well field that have been identified as having the potential to impact or be impacted by ISR operations.

In general, the monitoring system wells will be monitored using downhole data logging pressure transducers, which will be corrected for variations in barometric pressure. Some manual measurements with electronic meters also may be made.

Prior to testing, static potentiometric water levels will be measured in every well in the monitoring system. Where a sufficient number of data points exist, these data will be used to map the pre-operational potentiometric surface for each unit including alluvium, where present. Because of the high density of wells and artesian conditions at the site, any leakage across aquitards due to improperly plugged boreholes or wells typically will become apparent while preparing potentiometric surface maps. Water samples will be collected from selected monitor wells and analyzed for baseline parameters. The water quality will be evaluated to identify any potential areas of leakage across aquitards due to improperly plugged boreholes or wells.

Pump testing will involve inducing stress on the production zone sand unit by operating pumping wells. The goal of the test will be to demonstrate suitable conditions for ISR operations. This will be done by causing drawdown in the production zone extending to all perimeter monitor wells, creating a cone of depression across the well field area to test the confinement between the production zone and the overlying and underlying sand units and alluvium, if present, and addressing potential leakage through confining units via improperly sealed or unplugged exploration boreholes, or associated with naturally occurring geologic features. The presence or lack of response in vertical monitor wells will be used for evaluation of confinement between these units and for identification of leakage due to anomalies such as improperly plugged boreholes. If leakage is present, the relative responses in the overlying, underlying, and/or alluvial monitor wells will indicate the proximity and direction toward the source of leakage.

If saturated alluvium is present within the well field, alluvial monitor wells will be installed and monitored above the production zone and within an appropriate distance from the well field. The water level in the alluvium will be measured prior to testing and monitored during pump testing. If there are anomalous conditions that cause communication between the production zone and alluvium such as an improperly plugged borehole, these conditions will be identified through responses in the alluvial monitor wells.

The pumping test duration will be sufficient to create a suitable response in the perimeter monitor wells, typically a minimum drawdown of 1 foot. If hydrogeologic conditions dictate, less response may be adequate to show a direct cause and effect from pumping.

The flow rate of the pumping test will be based on well capacity and design requirements. More than one pumping well may be required to create drawdown in all perimeter wells.

Measurements during pump testing will include instantaneous and totalized flow, periodic pressure transducer measurements, barometric pressure, and time. A step rate test will be performed initially. There will be an initial stabilization phase with no flow, a stress period of constant flow, and a recovery period with no flow.

Pump Test Evaluation

Evaluation of pump test data will address the following:

1) Demonstration of hydraulic connection between the production and injection wells and all perimeter monitor wells and across the production zone.
2) Verification of the geologic conceptual model for the well field.
3) Evaluation of the vertical confinement and hydraulic isolation between the production zone and overlying and underlying units.
4) Calculation of the hydraulic conductivity, storativity, and transmissivity of the production zone sand unit.
5) Evaluation of anisotropy within the production zone sand unit.

8.2.4 Well Field Hydrogeologic Data Packages

Pump testing data and results will be included in the well field hydrogeologic data packages, which will be prepared in accordance with NRC license requirements. This section describes the contents and evaluation of the well field hydrogeologic data packages. These will be reviewed by the SERP and, as necessary, NRC. Refer to Section 8.2.5 for a description of the injection authorization data packages, which will be prepared and presented to EPA for each well field.

Upon completion of field data collection and laboratory analysis, the well field hydrogeologic data packages will be assembled and submitted for review by the SERP for evaluation. The SERP evaluation will determine whether the results of the hydrologic testing and the planned ISR operations are consistent with standard operating procedures and technical requirements stated in the NRC license. The evaluation will include review of the potential impacts to human health and environment. Relevant portions also will be included in the injection authorization data packages described in Section 8.2.5. If anomalous conditions are present or the SERP evaluation indicates potential to impact human health or the environment, the well field hydrogeologic data package will be submitted to NRC for review and approval. The well field hydrogeologic data package and written SERP evaluation will be maintained at the site and available for regulatory agency review.

Each well field hydrogeologic data package will contain the following:

1) A description of the proposed well field (location, extent, etc.).
2) Map(s) showing the proposed production and injection well patterns and locations of all monitor wells.
3) Geologic cross sections and cross section location maps.
4) Isopach maps of the production zone sand and overlying and underlying confining units.
5) Discussion of how pump testing was performed, including well completion reports.
6) Discussion of the results and conclusions of the pump testing, including pump testing raw data, drawdown match curves, potentiometric surface maps, water level graphs, drawdown maps and, when appropriate, directional transmissivity data and graphs.
7) Sufficient information to show that wells in the monitor well ring are in adequate communication with the production patterns.
8) Baseline water quality information including proposed UCLs for monitor wells and target restoration goals (TRGs).
9) Any other information pertinent to the proposed well field area tested will be included and discussed.

8.2.5 Injection Authorization Data Packages

Injection authorization data packages will be prepared and presented to EPA for each well field. Each injection authorization data package will contain the following:

1) A description of the proposed well field (location, extent, etc.).
2) Map(s) showing the proposed production and injection well patterns and locations of all monitor wells.
3) Geologic cross sections and cross section location maps.
4) Discussion of how pump testing was performed, including well completion reports and MIT results.
5) Discussion of the results and conclusions of the pump testing, including pump testing raw data, drawdown match curves, potentiometric surface maps, water level graphs, drawdown maps and, when appropriate, directional transmissivity data and graphs.
6) Sufficient information to show that wells in the monitor well ring are in adequate communication with the production patterns.

7) The calculated formation fracture pressure for each header house and the designated maximum injection pressure for each header house.
8) Commitment to completing MIT and preparing well completion reports for all injection wells prior to initiating injection into the well field.
9) Schedule for proceeding with operation of the well field.

9.0 ATTACHMENT J - STIMULATION PROGRAM

A stimulation program is not proposed for the Dewey-Burdock Project injection wells.

Well development (described in Section 11.4), which will include swabbing, will be used to improve well yield by enhancing hydraulic communication between the aquifer and the well.

10.0 ATTACHMENT K - INJECTION PROCEDURES

This attachment presents an overview of ISR operations, including injection procedures. It describes the general design of ISR well fields and specific design considerations for partially saturated conditions, historical mining operations, alluvium, and surface water features. It also discusses hydraulic well field control, groundwater restoration, lined retention ponds, and the project schedule.

10.1 Overview of Operations

The Dewey-Burdock Project will implement ISR methods for uranium extraction using a satellite facility and associated well fields within the Dewey portion of the project area and a CPP and associated well fields within the Burdock portion of the project area. The CPP will be used to produce the final uranium product (yellowcake or U_3O_8).

Uranium will be recovered by injecting lixiviant fortified with oxygen and carbon dioxide (barren lixiviant) into injection wells and recovering the resulting solution (pregnant lixiviant) from production wells. The uranium will be recovered from solution in IX vessels in the satellite facility or CPP. The CPP will include elution, precipitation, drying and packaging systems to recover the yellowcake.

Aquifer restoration will be completed following uranium recovery in each well field. During aquifer restoration, the groundwater in the well field will be restored in accordance with NRC requirements.

The vast majority of water withdrawn from the production wells will be reinjected as part of the ISR process, such that the net withdrawal rate will be only a small fraction of the gross pumping rate. A small portion of the production and restoration streams will not be reinjected to maintain an inward hydraulic gradient within each well field. This is referred to as the production or restoration bleed. The production and restoration bleed will be disposed using one of the two liquid waste disposal options.

The preferred liquid waste disposal option is underground injection of treated liquid waste in Class V deep disposal wells (DDWs). In this disposal option liquid waste will be treated to meet EPA non-hazardous waste requirements and injected into the Minnelusa and/or Deadwood Formations in four to eight DDWs being permitted pursuant to the Safe Drinking Water Act through the EPA UIC Program. It is anticipated that all liquid waste will be disposed using this option if sufficient capacity is available in DDWs.

The alternate liquid waste disposal option is land application. This option involves treatment in lined radium settling ponds followed by seasonal land application of treated liquid waste through center pivot sprinklers. Land application would be carried out under a groundwater discharge plan, which is currently being permitted through DENR. Depending on the availability and capacity of DDWs, Powertech may use land application in conjunction with DDWs or by itself.

Ponds will be used in both liquid waste disposal options to treat the liquid waste, temporarily store liquid processing waste from the CPP, and temporarily store treated wastewater prior to disposal. Ponds will be designed and constructed in accordance with NRC license and DENR large scale mine permit requirements. Pond design information is found in Powertech (2011).

Solid wastes such as pond sludge; soils contaminated by spills or leaks; spills of loaded or spent IX resin; filter sand or other process media; and parts, equipment, debris (e.g., pipe fittings and hardware) and PPE that cannot be decontaminated for unrestricted release will be considered Atomic Energy Act-regulated wastes and will be disposed at an NRC or state-licensed facility in accordance with NRC license requirements.

Monitoring systems will be implemented to minimize potential impacts to the environment and public health. These include extensive groundwater monitoring, including establishing a perimeter monitor well ring around each well field and monitoring overlying and underlying water-bearing intervals to identify any unintended movement of ISR solutions. It also includes instrumentation and control systems to rapidly detect any potential pipeline leaks or spills.

A reclamation plan will be implemented in accordance with NRC license and DENR large scale mine permit conditions to restore groundwater, remove equipment, reclaim disturbed areas, and ensure that the project area meets all postmining land uses following ISR activities. See Section 15.3 for additional information.

10.2 Chemistry of Uranium ISR

The ISR process involves the oxidation and solubilization of uranium from its reduced state using a leaching solution (lixiviant). The lixiviant will consist of circulated groundwater with gaseous oxygen added to oxidize the solid-phase uranium to a soluble valence state and gaseous carbon dioxide added to form a complex with the soluble uranium ions so they remain in solution as they are transported through the ore body. As described in NRC guidance document NUREG-1569 (NRC, 2003), this lixiviant formulation will minimize potential groundwater quality impacts during uranium recovery and enable restoration goals to be achieved in a timely manner.

The chemistry of uranium oxidation and dissolution is described with the following equations:

Oxidation: UO_2 (solid) + ½O_2 (in solution) $\rightarrow$ UO_3 (at solid surface)

Dissolution: $UO_3 + 2\ HCO_3^- \rightarrow UO_2(CO_3)_2^{2-} + H_2O$

$UO_3 + CO_3^{2-} + 2HCO_3^- \rightarrow UO_2(CO_3)_3^{4-} + H_2O$

The principal uranyl carbonate ions formed as shown above are uranyl dicarbonate, $UO_2(CO_3)_2^{2-}$ [i.e., UDC], and uranyl tricarbonate, $UO_2(CO_3)_3^{4-}$ [i.e., UTC]. The relative abundance of each is a function of pH and total carbonate strength.

Once solubilized, the uranium-bearing groundwater will be pumped by submersible pumps in the well field production wells to the surface, where it will be ionically bonded onto IX resin. After the uranium is removed, the groundwater will be fortified with oxygen and carbon dioxide, recirculated and reinjected via the well field injection wells. When the IX resin is loaded with uranium, the loaded resin will be transferred to an elution (stripping) column, where the uranium will be eluted (stripped) from the resin using a saltwater solution. The resulting barren resin then will be recycled to recover more uranium. The saltwater eluate solution will be pumped to a precipitation process, where the uranium will be precipitated as a yellow, solid uranium oxide (yellowcake or U_3O_8). The precipitated uranium oxide then will be filtered, washed, dried and packaged in sealed containers for shipment for further processing to be used in the uranium fuel cycle.

10.3 Well Field Design

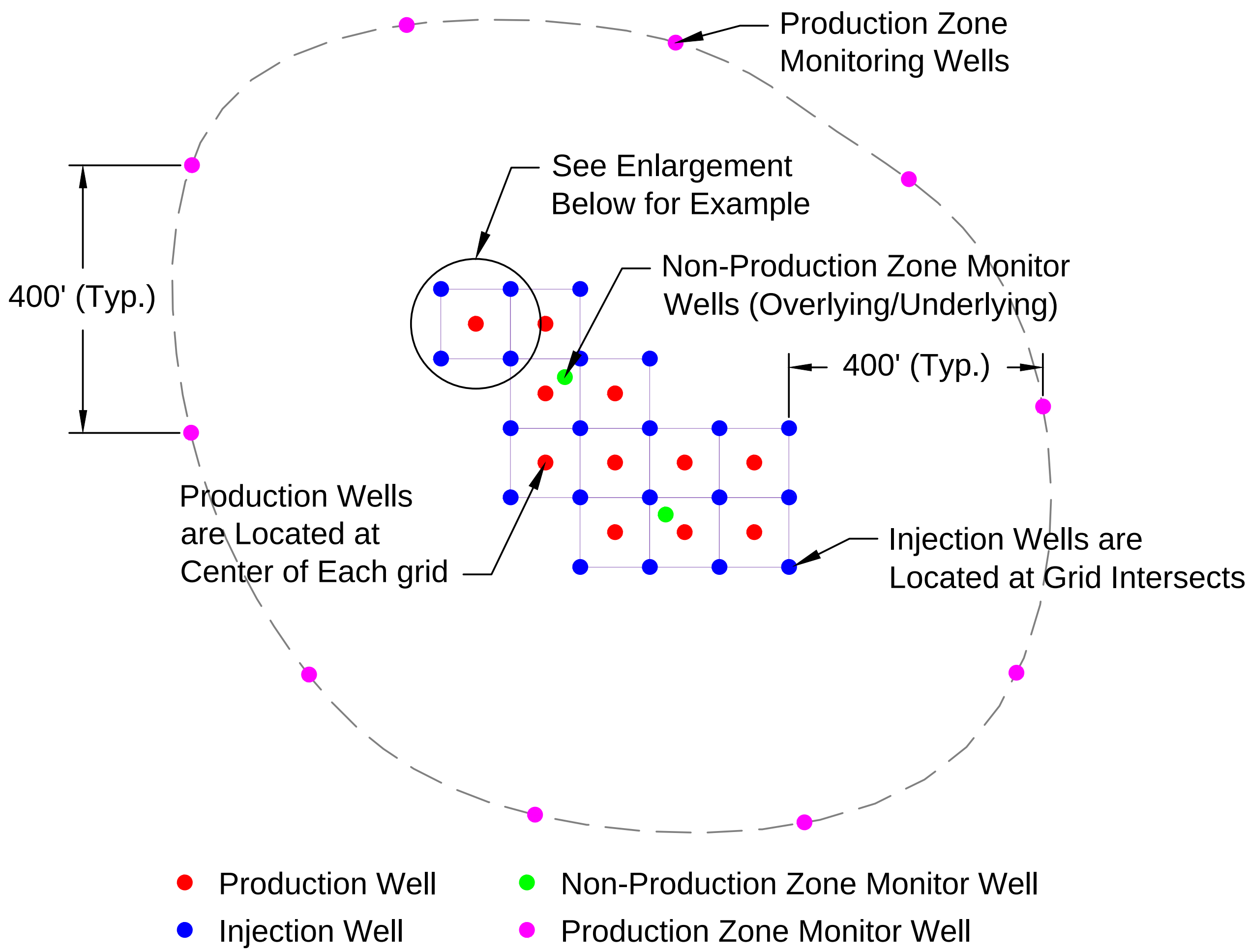
Each ISR well field will consist of a series of injection and production wells completed within the target mineralization zone. Prior to design and layout of the wells, the ore bodies will be delineated with exploration holes. These holes will be geologically and geophysically logged. Before drilling, each injection and production well will be assigned lateral coordinates, a ground surface elevation, depth to top of screened interval, and length of screened interval.

10.3.1 Injection and Production Wells

For all injection and production wells, the top of the screened interval will be at or below the base of the confining unit overlying the mineralized zone. The screened interval will be completed only across the targeted ore zone.

A typical (100 x 100 ft grid) well field layout is illustrated on Plate 10.1. This typical layout is based on the lateral distribution and grade of one of the uranium deposits within the project area.

The well patterns may differ from well field to well field, but a typical pattern will consist of five wells, with one well in the center and four wells surrounding it oriented in four corners of a square measuring between 50 and 150 feet on a side. Typically, a production well will be located in the center of the pattern, and the four corner wells will be injection wells. Figure 10.1 depicts a typical 5-spot well field pattern. The pattern dimensions will be modified as needed to fit the characteristics of each ore body. Other well field designs may be considered and evaluated in the well field hydrogeologic data packages.



TYPICAL FIVE SPOT GRID PATTERN

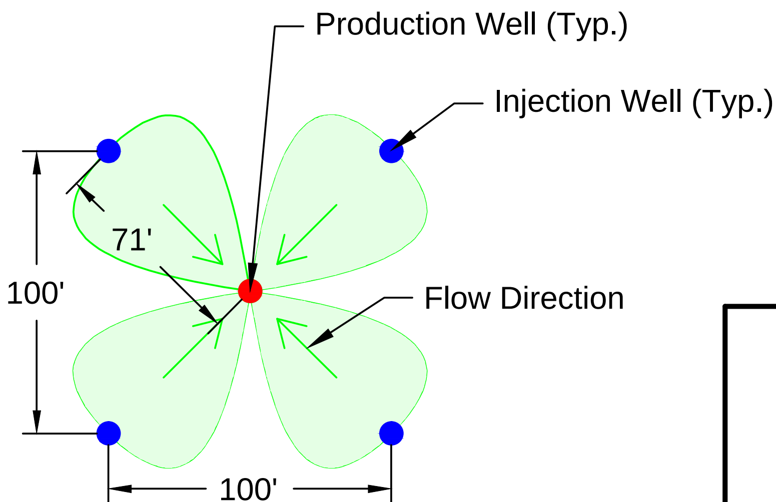


Figure 10.1

Typical 5-Spot
Well Field Pattern

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	24-Jul-2012
FILENAME	FiveSpotPattern.dwg

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Modified from Power Resources

All wells will be completed for use as either injection or production wells, so that flow patterns can be changed as needed to recover uranium and restore groundwater quality in the most efficient manner.

Figure 17.1 in Section 17 depicts the project ore bodies proposed for uranium recovery and shows all lower Fall River ore bodies in blue, all ore bodies within the upper Chilson Member of the Lakota Formation in green and middle/lower Chilson ore bodies in red. No well fields will be located within 1,600 feet of the project boundary in order to establish an operational buffer between the well fields and the project boundary. In addition, no well fields are proposed for partially saturated or unsaturated Fall River ore bodies in the eastern portion of the project area. All well fields and perimeter monitor wells will be located within the project boundary.

Production and injection wells will be connected to a header house, as shown on Plate 10.2. Well head connection details for injection and production wells are illustrated on Figures 11.2 and 11.3, respectively. Typically, one header house will service up to 20 production wells and 80 injection wells. Piping between the wells and header house will consist of high density polyethylene (HDPE) pipe with heat-welded joints, buried at least 5 feet below grade. The piping will be designed to withstand an operating pressure of 150 psig. The piping will terminate at the header house where it will be connected to manifolds equipped with control valves, flow meters, check valves, pressure sensors, oxygen and carbon dioxide feed systems (injection only), and programmable logic controllers. Electrical power to the header houses will be delivered via overhead power lines and via buried cable. Electrical power to individual wells will be delivered via buried cable from the header house.

As a well field expands, additional header houses will be constructed. They will be connected to one another via buried piping that is sized to accommodate the necessary injection and production flow rates and pressures. In turn, header pipes from entire well fields will be connected to either the satellite facility or CPP. A piping detail that shows the connection between the main header piping and laterals to header houses is shown on Plate 10.2.

10.3.2 Monitor Wells

Monitor wells will be installed in and around each well field to detect the potential migration of ISR solutions away from the target production zone. Perimeter monitor wells will be completed in the production zone around the perimeter of each well field. Non-production zone monitoring wells will be completed within each well field in the overlying and underlying aquifers. A detailed description of the monitor well design and sampling procedures is contained in Section 14 (Attachment P).

10.4 Hydraulic Well Field Control

Powertech will maintain hydraulic control of each well field from the first injection of lixiviant through the end of aquifer restoration. During uranium recovery, the groundwater removal rate in each well field will exceed the lixiviant injection rate, creating a cone of depression within each well field. During aquifer restoration, the groundwater removal rate in each well field will exceed the injection rate of permeate and clean makeup water from the Madison Limestone or another suitable formation. If there are any delays between uranium recovery and aquifer restoration, production wells will continue to be operated as needed to maintain water levels within the perimeter monitor rings below baseline water levels. This activity may be intermittent or continuous.

Verification of hydraulic control will be performed through water level measurements in perimeter monitor wells. Water levels will be measured using pressure transducers or manual electronic meters and recorded at a frequency appropriate to confirm hydraulic well field control as described in Section 14.2.3.

10.4.1 Flare Control

Flaring (movement of lixiviant outside of the well field pattern area) will be limited by maintaining hydraulically balanced well fields and adequate bleed during uranium recovery and aquifer restoration. The financial assurance calculations for aquifer restoration that are reviewed and approved by NRC will account for flare. Powertech has provided a flare estimate in the NRC license application that is justified by numerical groundwater modeling and is comparable to values that have been approved recently by NRC for other ISR facilities (Powertech, 2009b).

10.5 Approach to Well Field Development with Respect to Partially Saturated Conditions

Refer to Section 5.2.2.5 for a description of partially saturated conditions. The only instance where hydrologically unconfined (partially saturated) conditions exist within an area proposed for ISR operations occurs in the eastern portion of the project area. Powertech does not intend to conduct ISR operations in the Fall River sands in the eastern portion of the project area where the Fall River is partially saturated (i.e., hydraulically unconfined). Powertech is, however, proposing to conduct ISR operations in the underlying Chilson at these locations. The Chilson is physically and hydraulically isolated from the Fall River by the Fuson Shale. Although the Chilson is not fully saturated near the eastern edge of the project area, the mineralization occurs near the base of the formation. As a result, any ISR operations will occur within the portion of the Chilson where confining layers and sufficient head above the ore body will provide ample means to control ISR solutions.

Geologic Cross Section B-B' (Plate 6.14) shows the potentiometric surfaces as well as the interbedded shales and siltstones within the Fall River and Chilson. The cross section depicts the location of the mineralization in the Chilson in relation to the Chilson potentiometric surface. Near the eastern portion of the project area the potentiometric surface is nearly 100 feet higher than the mineralization. Locally occurring shale units may serve to further confine the mineralization within the Chilson. As such, Powertech does not anticipate that ISR operations will occur where there is less than 50 feet of potentiometric head over the ore body.

After license/permit issuance but prior to well field development, delineation drilling and well field pumping tests will be conducted to fully characterize the existing geologic and hydrogeologic conditions and to confirm sufficient head is available to perform normal ISR operations. As an integral component of the characterization activities, a detailed evaluation will be made, based on actual site conditions, regarding the application of ISR under partially saturated conditions should it be necessary. Partially saturated conditions, if encountered, would be similar in many respects to what has been licensed by NRC at other ISR projects (e.g., Moore Ranch in Wyoming) and would be addressed similarly with modeling.

10.6 Approach to Well Field Development with Respect to Historical Mine Workings

As described in Section 3.2 the former Darrow and Triangle open-pit mines and associated underground workings in the eastern portion of the project area extracted ore from the Fall River Formation. There are no underground mines within the project area that are not associated with, adjacent to, or extensions of the open pits, all of which are within the Upper Fall River Formation. These open-pit mines and underground workings did not penetrate the underlying Fuson Shale, which physically and hydraulically separates the Fall River from the underlying Chilson Member of the Lakota Formation across the entire project area.

Powertech will not conduct ISR operations in ore bodies in the Fall River in the vicinity of the Darrow and Triangle pits. Powertech proposes to conduct ISR operations within the Chilson in this area. Because of the physical and hydraulic separation of the Chilson from the overlying Fall River Formation, ISR operations in the Chilson will not affect the Fall River or create or enhance migration of constituents of concern from the surface (open-pit) or underground mines.

Figure 3.1 shows the spatial relationship between the potential ISR well fields and the historical mine areas. An examination of this figure shows that proposed Burdock Well Field 7 (B-WF7) underlies portions of the historical Darrow mine area. The targeted production zone for B-WF7 is the Lower Chilson. Figure 3.5 illustrates the stratigraphic separation of this Lower Chilson sand unit from the historical mining operations in sands of the Fall River Formation. The gamma activity shown within the Lower Chilson sand on the type log is representative of the proposed uranium recovery horizon in B-WF7. This interval is over 200 feet below the base of the Fall River Formation and is separated by 40 feet of the Fuson Shale confining unit, as well as two interbedded shale intervals within the Chilson Member – one 12 feet thick and the other 23 feet thick.

As also shown on Figure 3.1, potential Burdock Well Field 8 (B-WF8) is below and horizontally adjacent to the surface expression of an area of past mining disturbance in Section 35, T6S, R1E. Excavation in this area was underway when the Edgemont mill was closed. This operation was on land owned by the Spencer family, and Donald Spencer (2011) related that all mining operations ceased before reaching the ore horizon. The pit was backfilled and reclaimed. Powertech's targeted uranium recovery horizon for B-WF8 is the Lower Chilson. This unit is at least 200 feet beneath the base of the Fuson Shale and is well below the historical mining disturbance in the Fall River Formation.

Powertech also will install and sample operational monitor wells in the Fall River, Chilson, and alluvium between the surface (open-pit) mines and well field areas. For additional information, refer to Section 14.

10.7 Approach to Well Field Development with Respect to Alluvium

This section summarizes Powertech's approach to well field development in areas of Beaver Creek and Pass Creek alluvium, including alluvial characterization, pump testing, and operational monitoring. This section consolidates information presented elsewhere in the application and includes references to the applicable sections.

<u>Alluvial Characterization</u>

Powertech completed an alluvial drilling program in 2011 to characterize the thickness, extents, and saturated thickness (if water was present) of the alluvium along Beaver Creek and Pass Creek. Alluvial characteristics will be further evaluated during well field delineation drilling described in Section 8.2.3.

<u>Pump Testing</u>

As described in Section 8.2.3, an extensive pump testing program will be designed and implemented prior to operation of each well field to evaluate the hydrogeology and assess the ability to operate the well field. Monitor wells will be completed in the alluvium, if present.

<u>Operational Monitoring</u>

Section 14.2 describes how alluvium will be treated as an overlying hydrogeologic unit and monitored appropriately during operational groundwater monitoring. Powertech also will

monitor potential changes in alluvial water quality throughout the project area through the monitoring network described in Section 14.3.

10.8 Groundwater Restoration

The plans for groundwater restoration are discussed below. Groundwater restoration in each well field will be conducted in accordance with NRC license requirements.

10.8.1 Target Restoration Goals

Groundwater restoration, or aquifer restoration, will be performed pursuant to NRC requirements to protect USDWs. The groundwater restoration program for all well fields will be conducted pursuant to 10 CFR Part 40, Appendix A, Criterion 5, which sets forth groundwater quality standards for uranium milling facilities. Currently, Criterion 5 states that groundwater quality at such facilities shall have primary goals of baseline (background) or an MCL, whichever is higher, or an alternate concentration limit (ACL). An ACL is a site-specific, constituent-specific, risk-based standard that demonstrates that maintaining groundwater quality at the requested level at a designated point of compliance (POC) will be adequately protective of human health and the environment at the point of exposure (POE) and that groundwater quality outside the boundary of the aquifer exemption approved by EPA will meet background (baseline) levels or MCLs. Satisfaction of prior class-of-use can be proposed as a factor in demonstrating justification for an ACL.

In the event that an ACL is requested, Powertech will be required by NRC license conditions to submit an ACL application to NRC staff in accordance with regulatory requirements under 10 CFR Part 40, Appendix A, Criterion 5(B)(5). Any ACL application will be in the form of a license amendment application that addresses, at a minimum, all of the relevant factors in 10 CFR Part 40, Appendix A, Criterion 5(B)(6), including but not limited to:

(a) Potential adverse effects on ground-water quality, considering:
- (i) The physical and chemical characteristics of the waste in the licensed site including its potential for migration;
- (ii) The hydrogeological characteristics of the facility and surrounding land;
- (iii) The quantity of ground water and the direction of ground-water flow;
- (iv) The proximity and withdrawal rates of ground-water users;
- (v) The current and future uses of ground water in the area;
- (vi) The existing quality of ground water, including other sources of contamination and their cumulative impact on the ground-water quality;
- (vii) The potential for health risks caused by human exposure to waste constituents;
- (viii) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents;
- (ix) The persistence and permanence of the potential adverse effects.

(b) Potential adverse effects on hydraulically-connected surface water quality, considering:
   (i) The volume and physical and chemical characteristics of the waste in the licensed site;
   (ii) The hydrogeological characteristics of the facility and surrounding land;
   (iii) The quantity and quality of ground water, and the direction of ground-water flow;
   (iv) The patterns of rainfall in the region;
   (v) The proximity of the licensed site to surface waters;
   (vi) The current and future uses of surface waters in the area and any water quality standards established for those surface waters;
   (vii) The existing quality of surface water including other sources of contamination and the cumulative impact on surface water quality;
   (viii) The potential for health risks caused by human exposure to waste constituents;
   (ix) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; and
   (x) The persistence and permanence of the potential adverse effects.

Should it become necessary to submit an ACL application, Powertech will follow relevant NRC guidance and policy in effect at the time that an ACL would be requested.

Prior to operation, the baseline groundwater quality will be determined through the sampling and analysis of water quality indicator constituents in wells screened in the mineralized zone(s) across each well field. Section 14.4.1 describes the methods used to select baseline wells, sample the wells, and calculate baseline water quality statistics. The target restoration goals (TRGs) will be established as a function of the average baseline water quality and the variability in each parameter according to statistical methods approved by NRC.

10.8.2 Groundwater Restoration Process

Groundwater restoration will be conducted in accordance with NRC license requirements in a manner that will protect human health and the environment. The methods for achieving this objective are discussed in the following sections.

10.8.2.1 Groundwater Restoration Methods

During aquifer restoration, Powertech will restore groundwater quality consistent with the groundwater protection standards contained in 10 CFR Part 40, Appendix A, Criterion 5(B)(5), in accordance with NRC license requirements. The technology selected will depend on the liquid waste disposal option as described below. In the deep disposal well liquid waste disposal option, reverse osmosis (RO) treatment with permeate injection will be the primary restoration method. If land application is used to dispose liquid waste, then groundwater sweep with injection of clean makeup water from the Madison Limestone or another suitable formation will be used to restore the aquifer. In either case, aquifer restoration will be conducted in accordance with NRC license requirements, which will establish the minimum number of pore volumes and the pore volume calculation method. Refer to Powertech (2011) for additional information.

10.8.2.1.1 Deep Disposal Well Option

In the deep disposal well liquid waste disposal option, the primary method of aquifer restoration will be RO treatment with permeate injection. In this method, water will be pumped from one or more well fields to the CPP or satellite facility for treatment. Treatment will begin with removal of uranium and other dissolved species in IX columns. The water will then pass through the restoration RO unit, which will remove over 90% of dissolved constituents using high pressure RO membranes. The treated effluent, or permeate, will be returned to the well field(s) for injection. The RO reject, or brine, will undergo radium removal in radium settling ponds and will then be disposed in one or more deep disposal wells.

The RO units will operate at a recovery rate of approximately 70%. Therefore, about 70% of the water that is withdrawn from the well fields and passed through the restoration RO unit will be recovered as nearly pure water, or permeate. In order to avoid excessive restoration bleed and consumptive use of Fall River and Chilson groundwater, permeate will be supplemented with clean makeup water from the Madison Limestone or another suitable formation. Permeate and makeup water will be reinjected into the well field(s) at an amount slightly less than the amount withdrawn from the well field(s). This will be done to maintain a slight restoration bleed, which will maintain hydraulic control of the well field(s) throughout active aquifer restoration. The restoration bleed typically will be 1% of the restoration flow rate unless groundwater sweep is used in conjunction with RO treatment with permeate injection, in which case the restoration bleed will average approximately 17%. Refer to the "Optional Groundwater Sweep" discussion in Section 10.8.2.1.3.

10.8.2.1.2 Land Application Option

In the land application liquid waste disposal option, the primary method of aquifer restoration will be groundwater sweep with Madison Limestone water injection. A groundwater discharge permit application through DENR was submitted in March 2012 for the land application option. This method will begin the same as the method described above for RO treatment with permeate injection; water will be pumped to the CPP or satellite facility for removal of uranium and other dissolved species in IX columns. The partially treated water will undergo radium removal in radium settling ponds and then will be disposed in the land application systems.

RO will not be used if there are no deep disposal wells available to accept the RO brine. Instead, clean makeup water from the Madison Limestone or another suitable formation will be injected into the well field(s) at a flow rate sufficient to maintain the restoration bleed. As before, the restoration bleed will typically be 1% of the restoration flow rate unless the optional groundwater sweep method is used.

The water quality of the Madison Limestone is expected to be equal to or better than the baseline ore zone water quality, and injection of Madison Limestone water will therefore be similar to injection of permeate under the deep disposal well option.

10.8.2.1.3 Optional Groundwater Sweep

Although a 1% restoration bleed will be adequate to maintain hydraulic control of well fields undergoing active aquifer restoration, additional bleed may be required at times. For example, additional restoration bleed may be used to recover flare of ISR solutions outside of the well field pattern area. In addition to the restoration methods described above, Powertech may withdraw up to one pore volume of water through groundwater sweep over the course of aquifer restoration. This will result in an average restoration bleed of approximately 17%.

10.8.2.2 Effectiveness of Groundwater Restoration Techniques

This section describes how the groundwater restoration process that will be conducted in accordance with NRC license requirements is the same process that has been used successfully at other NRC and agreement state-licensed facilities. The preferred aquifer restoration method is RO treatment with permeate injection. This is the aquifer restoration method that will be used if deep disposal wells are used to dispose liquid waste. As described in Section 2.5.3 of NUREG-1910 (NRC, 2009), this method of aquifer restoration is responsible for returning “total dissolved solids, trace metal concentrations, and aquifer pH to baseline values.” RO treatment with permeate injection has proven effective at achieving successful aquifer restoration as described in Uranium One (2008):

> Results of the effectiveness of groundwater sweep (or lack of it) were clearly demonstrated in the Christensen Ranch Wellfield Restoration report (CRWR) (COGEMA 2008[a]). Example plots from that report of mean well field water quality at the end of mining, groundwater sweep, RO and stabilization monitoring… indicate minimal improvement following groundwater sweep at MU3 and MU5 and an actual increase [in dissolved constituents] at MU6. Following application of RO, the TDS values at MU5 and MU6 decreased to levels below the target Restoration Goal. Uranium increased in MU5 and MU6 following groundwater sweep…and then was significantly lowered during RO. Approximately 1.8, 4.8 and 1.5 PVs of groundwater were removed from MU3, MU5 and MU6, respectively, during groundwater sweep. This water removal was totally consumptive by design, in that none of it was returned to the aquifer.
>
> Based on the results, minimal benefit, if any, was derived from [the groundwater sweep] phase of restoration. Eliminating groundwater sweep, an unnecessary,

ineffective and consumptive step in the restoration process, will reduce the number of PVs required to reach restoration goals.

Terminating RO once water quality has stabilized will minimize the consumptive use of groundwater and reduce the number of PVs of treatment.

10.8.3 Groundwater Restoration Monitoring

Refer to Section 14.4 for a discussion of groundwater restoration monitoring, including monitoring the progress of active restoration, excursion monitoring during groundwater restoration, and stability monitoring.

10.9 Stormwater Control and Mitigation

Powertech has evaluated flood inundation boundaries and will construct facilities outside of these boundaries to avoid potential impacts to facilities from flooding and potential impacts to Beaver Creek and Pass Creek in the event of any potential spills or leaks.

HEC-HMS models were used to calculate peak discharges, and HEC-RAS models were used to compute water-surface profiles and inundated areas during runoff events for Pass Creek, Beaver Creek and local small drainages.

Where possible, facilities will be located out of the 100-year flood inundation boundaries. Facilities which must be located within such boundaries will be protected from flood damage by the use of straw bales, collector ditches, and/or berms. If it is necessary to place a well head within the flood inundation boundary, diversions or erosion control structures will be constructed to divert flow and protect the well head. The well head also will be sealed to withstand brief periods of submergence. Pipelines will be buried below the frost line and will not be subject to flooding. Pipeline valve stations will be located outside of the 100-year flood inundation boundaries.

10.10 Schedule

Following the issuance of an NRC uranium recovery license, DENR large scale mine permit, EPA Class III UIC permit, and other relevant permits, it is anticipated that construction will commence on the first Burdock well field, CPP and ancillary facilities including storage ponds and land application pivots and/or deep disposal wells. It is anticipated that construction of the first Dewey well field and ancillary facilities will occur at the same time or follow shortly thereafter. Alternately, Powertech may develop either the Burdock or Dewey area well fields first, followed by the well fields in the other area. Uranium recovery operations within the permit area will continue for approximately 7 to 20 years during which additional well fields will be completed along the roll fronts at both the Dewey and Burdock portions of the permit area. Following operation of each well field, aquifer restoration will restore groundwater quality.

Following regulatory approval of successful aquifer restoration, each well field will be decommissioned. It is likely that the CPP will continue to operate for several years following decommissioning of the well fields. The CPP may continue to process uranium-loaded ion exchange resin from other ISR projects such as the nearby Powertech Aladdin and Dewey Terrace ISR projects planned in Wyoming, as well as possible tolling arrangements with other operators. The entire Dewey-Burdock Project will then be decommissioned and reclaimed in accordance with NRC, EPA, BLM and DENR requirements. The projected construction, operation, restoration and decommissioning schedule is provided in Figure 10.2.

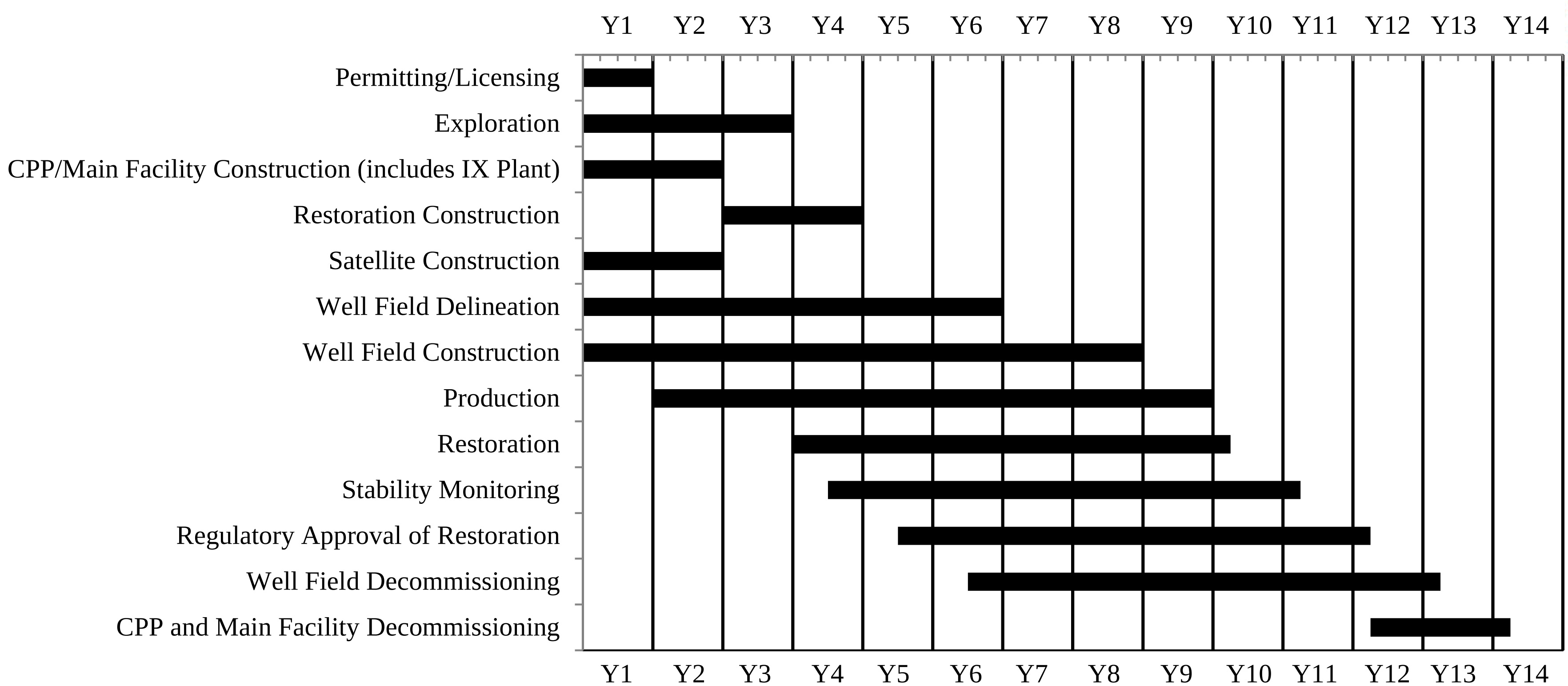

Figure 10.2: Projected Construction, Operation and Decommissioning Schedule

11.0 ATTACHMENT M - CONSTRUCTION DETAILS

This attachment details the construction procedures that will be utilized for injection, production and monitor wells at the Dewey-Burdock Project. All injection and production wells will be completed in accordance with South Dakota well construction standards and EPA standards for Class III UIC wells.

11.1 Well Construction Materials

Well casing material typically will be thermoplastic such as polyvinyl chloride (PVC) with at least SDR 17 wall thickness. The wells typically will be 4.5 to 6-inch nominal diameter and will meet or exceed the specifications of ASTM Standard F480 and NSF Standard 14. In order to provide an adequate annular seal, the drill hole diameter will be at least 2 inches larger than the outside diameter of the well casing.

The annulus will be pressure-grouted and sealed with neat cement grout composed of sulfate-resistant Portland cement in accordance with South Dakota wells construction standards. Water used to make the cement grout will not contain oil or other organic material. Cement grout could contain adequate bentonite to maintain the cement in suspension in accordance with Halliburton cement tables.

Casing will be joined using methods recommended by the casing manufacturer. PVC casing joints approximately 20 feet apart will be joined mechanically (with a watertight O-ring seal and a high strength nylon spline) to ensure watertight joints above the perforations or screens. Casings and annular material will be routinely inspected and maintained throughout the operating life of the wells.

11.1.1 Thermoplastic Well Casing Variance Request

Powertech requests a variance from the requirement in 40 CFR § 147.2104(b)(1) that plastic well casing materials, including PVC, ABS or others, not be used in new injection wells deeper than 500 feet in the State of South Dakota. This variance is requested on the following basis:

1. Collapse pressure calculations and well casing manufacturer specifications indicate that PVC well casing can be used at depths greater than 500 feet considering the site-specific well construction methods (see Section 11.1.1.1).
2. PVC well casing has been used successfully for wells deeper than 500 feet at uranium ISR facilities for many years (see Section 11.1.1.2).
3. PVC well casing is commonly used for other wells in South Dakota deeper than 500 feet (see Section 11.1.1.3).
4. Thermoplastic well casing is the preferred well casing material for ISR facilities due to corrosion resistance. The corrosion resistance of PVC compared to carbon steel well casing is well documented.

5. Each new injection, production and monitor well will be pressure tested to confirm the integrity of the casing prior to being used for ISR operations. MIT will be repeated every 5 years and after any repair where a downhole drill bit or under-reaming tool is used (see Section 11.5).
6. The injection pressure for each injection well will be maintained below the maximum pressure rating of the well casing (see Section 7.2).
7. An extensive excursion monitoring program will be implemented by installing and sampling monitor wells in the perimeter of the production zone and in overlying and underlying hydrogeologic units to detect potential excursions of ISR solutions into USDWs such as would occur with a leaking injection well (see Section 14.2).
8. Injection pressures will be monitored through automated control and data recording systems that will include alarms and automatic controls to detect and control a potential release such as would occur through an injection well casing failure (see Section 14.1).

The variance is requested pursuant to 40 CFR § 147.2104(d)(4), which states that the Regional Administrator may approve alternate casing provided that the owner or operator demonstrates that such practices will adequately protect USDWs.

11.1.1.1 Hydraulic Collapse Pressure Calculations

When specifying well casing and installation, Powertech will adhere to the requirements in ASTM F480, Standard Specifications for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80. ASTM F480 requires that "the depth at which thermoplastic well casing can be used is a design judgment." There is no depth of installation limit in ASTM F480 except that PVC well casing should be "used under conditions that meet manufacturer's recommendations for its type" and that "the driller shall install the thermoplastic casing in a manner that does not exceed the casing hydraulic collapse resistance." In accordance with these requirements, Powertech will ensure that all thermoplastic well casing meets the manufacturer's recommendations for its type and is installed in a manner that does not exceed the hydraulic collapse resistance.

The net hydrostatic pressure on the well casing is calculated as the difference between the exterior and interior hydrostatic pressure. The hydrostatic pressure is calculated as the fluid density multiplied by the fluid depth. Powertech will use cement to grout the annulus on all injection, production and monitor wells. Using a typical cement grout density of 90 lb/ft^3, and recognizing that the inside of the well casing will always be full of water before the cement cures (with a density of at least 62.4 lb/ft^3 depending on whether additives are used), the pressure versus depth gradient will be about 27.6 lb/ft^3 or about 0.2 psi/ft of depth. According to CertainTeed (2011), the hydraulic collapse pressure for SDR 17 PVC well casing is about 224 psi. Therefore, it would take an installation depth much greater than 1,000 ft to exceed this pressure as long as cement grout were used and the well casing remains full until the cement hardens. Both of these conditions will be met in all injection, production and monitor well casing installations using the installation procedures described in Section 11.2. Water will be used to displace the cement and force it upward into the annulus; therefore, the well casing will always be full of water while the cement cures.

When designing and installing injection, production and monitor wells, Powertech will adhere to the requirements of ASTM F480 and manufacturer's criteria to ensure that the installation does not exceed the casing hydraulic collapse resistance.

11.1.1.2 Use of PVC Well Casing at Other ISR Facilities

There are numerous successful applications of PVC well casing at uranium ISR projects where the well depths are in excess of 500 feet. For example, at the Crow Butte project, where the average ore depth is 650 feet, 4.5-inch ID PVC well casing has been successfully used for many years (IAEA, 1994). There are also numerous Wyoming examples, including Irigaray/Christensen Ranch, where PVC well casing is routinely used at depths greater than 500 feet. According to COGEMA (2008b), SDR 17 PVC well casing is used for injection wells at Irigaray and Christensen, where the average depth of the ore zone in some mine units is between 500 and 600 feet.

11.1.1.3 South Dakota Well Construction Standards

South Dakota has tolled DENR administrative rules on UIC Class III wells and ISR until the department obtains primary enforcement authority. Therefore, South Dakota does not directly regulate well casing materials for injection, production and monitor wells. However, general South Dakota well construction standards in ARSD 74:02:04 allow the use of PVC well casing for other types of wells to depths greater than 500 feet. For example, Section 36 of ARSD 74:02:04 provides construction requirements for SCH 80 PVC private domestic and non-commercial livestock wells more than 1,000 feet deep.

ARSD 74:02:04, Sections 42 and 43 discuss general well casing requirements. Section 42 says, "Casing materials may be thermoplastic, steel, nonferrous metal, fiberglass, precast curbing, or concrete" but that, "Casing may only be used under conditions that meet manufacturer's recommendations and specifications for its type." Section 43 provides thermoplastic casing requirements, including that PVC well casing 5 inches or greater in diameter must have a minimum wall thickness of 0.250 inch. Powertech will ensure that all PVC well casing 5 inches or greater in diameter has a minimum wall thickness of 0.250 inch. This means that 5-inch PVC well casing will be SCH 40 or heavier or SDR 17 or heavier. Section 43 also requires thermoplastic pipe to conform to ASTM F480. Compliance with the requirements in ASTM F480 is described in Section 11.1.1.1.

11.1.2 Compliance with 40 CFR § 147.2104(d)

The injection wells will comply with the following 40 CFR § 147.2104(d) regulations for protection of USDWs in South Dakota:

- (1)(i) Setting surface casing 50 feet below the lowermost USDW: The Fall River Formation and Chilson are the shallowest aquifers potentially classified as USDWs in the project area. Since the portion of the Fall River and Chilson within the well fields will be in an exempted aquifer and since injection wells will not target aquifers deeper than the Fall River or Chilson, there will not typically be any USDWs between the ground surface and the total injection well depth. Should saturated alluvium be present, surface casing will be installed through the alluvium regardless of whether it would be classified as a USDW.
- (1)(ii) Cementing surface casing by recirculating the cement to the surface from a point 50 feet below the lowermost USDW (see above); or
- (1)(iii) Isolating all USDWs by placing cement between the outermost casing and the well bore: The annular seal will be pressure grouted with neat cement grout as described above.
- (2) Isolate any injection zones by placing sufficient cement to fill the calculated space between the casing and the well bore to a point 250 feet above the injection zone: The entire annular seal will be pressure grouted with neat cement as described above.

In addition, Powertech will comply with the 40 CFR § 147.2104(d)(3) requirements for cement, including using cement (i) of sufficient quantity and quality to withstand the maximum operating pressure; (ii) which is resistant to deterioration from formation and injection fluids; and (iii) in a quantity no less than 120% of the calculated volume necessary to cement off a zone.

11.2 Well Construction Methods

Typical production and injection well installation will begin by drilling a pilot bore hole through the ore zone to obtain a measurement of the uranium grade and thickness. The ore depth is anticipated to range from 200 to 800 feet. Typical monitor well construction will begin with drilling a pilot bore hole through the target completion zone. For all wells, the pilot bore hole will be geologically and geophysically logged. After logging, the pilot bore hole will be reamed to the appropriate diameter to the top of the target completion zone. A continuous string of PVC casing will be placed into the reamed borehole. Casing centralizers will be installed as appropriate. With the casing in place a cement/bentonite grout will be pumped into the casing. The grout will circulate out the bottom of the casing and back up the casing annulus to the ground surface. The volume of grout necessary to cement the annulus will be calculated from the bore hole diameter of the casing with sufficient additional allowance to achieve grout returning to surface. Grout remaining inside the well casing may be displaced by water or heavy drill mud to minimize the column of the grout plug remaining inside the casing. Care will be taken to assure that a grout plug remains inside the casing at completion. The casing and grout then will be allowed to set undisturbed for a minimum of 24 hours. When the grout has set, if the annular seal observed from the ground surface has settled below the ground surface, additional grout will be placed into the annular space to bring the grout seal to the ground surface.

After the 24-hour (minimum) setup period, a drill rig will be mobilized to finish well construction by drilling through the grout plug and through the target completion zone to the specified total well depth. The open borehole will then be underreamed to a larger diameter. Figure 11.1 depicts the typical well construction. Figures 11.2 and 11.3 depict the typical injection and production well heads, respectively. Figure 11.1 and the following discussion represent the anticipated typical injection well construction methods. The actual methods may vary.

A well screen assembly (if used) will be lowered through the casing into the open hole. The top of the well screen assembly will be positioned inside the well casing and centralized and sealed inside the casing using K packers. With the drill pipe attached to the well screen, a 1-inch diameter tremie pipe will be inserted through drill pipe and screen and through the sand trap check valves at the bottom of well screen assembly. Filter sand (if used), composed of well-rounded silica sand sized to optimize hydraulic communication between the target zone and well screen, then will be placed between the well screen and the formation. The volume of sand introduced will be calculated such that it fills the annular space. The sand will not extend upward beyond the K packers due to packer design. A well completion report then will be prepared for each well.

11.3 Geophysical Logging

Ore grade gamma log, self potential and single point resistivity electric logs will be run in the pilot holes prior to reaming the hole to final diameter to run casing. These logs will determine the location and grade of uranium and the sand and clay unit depths to properly plan each pattern.

11.4 Well Development

The primary goals of well development will be to allow formation water to enter the well screen, flush out drilling fluids, and remove the finer clays and silts to maximize flow from the formation through the well screen. This process is necessary to allow representative samples of groundwater to be collected, if applicable, and to ensure efficient injection and production operations. Wells will be developed immediately after construction using air lifting, swabbing, pumping or other accepted development techniques which will remove water and drilling fluids

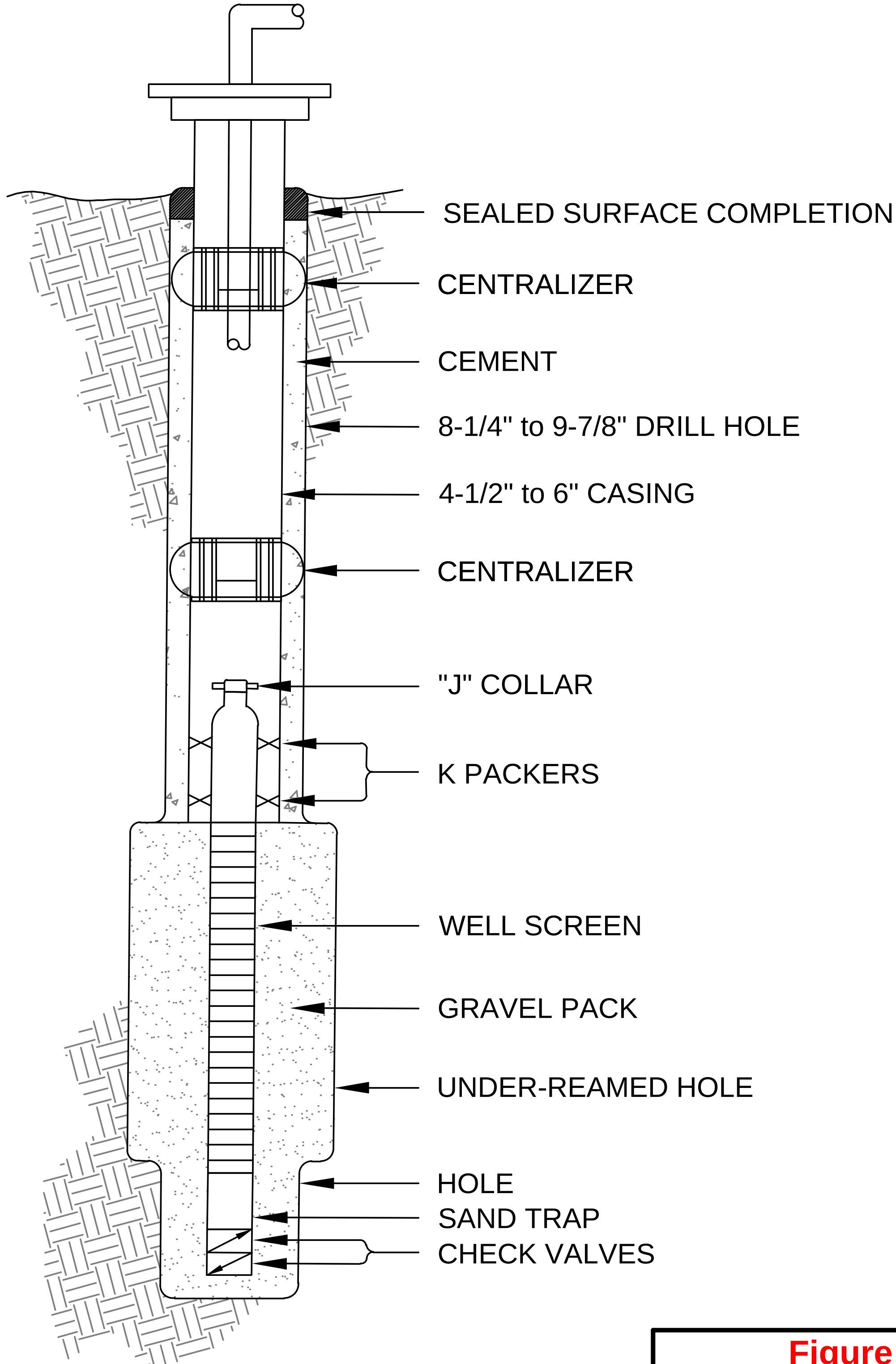

Figure 11.1

Typical Well Construction

Dewey-Burdock Project

DRAWN BY	L. Tafoya
DATE	24-Jul-2012
FILENAME	Wells-TypConstruction.dwg

POWERTECH (USA) INC.

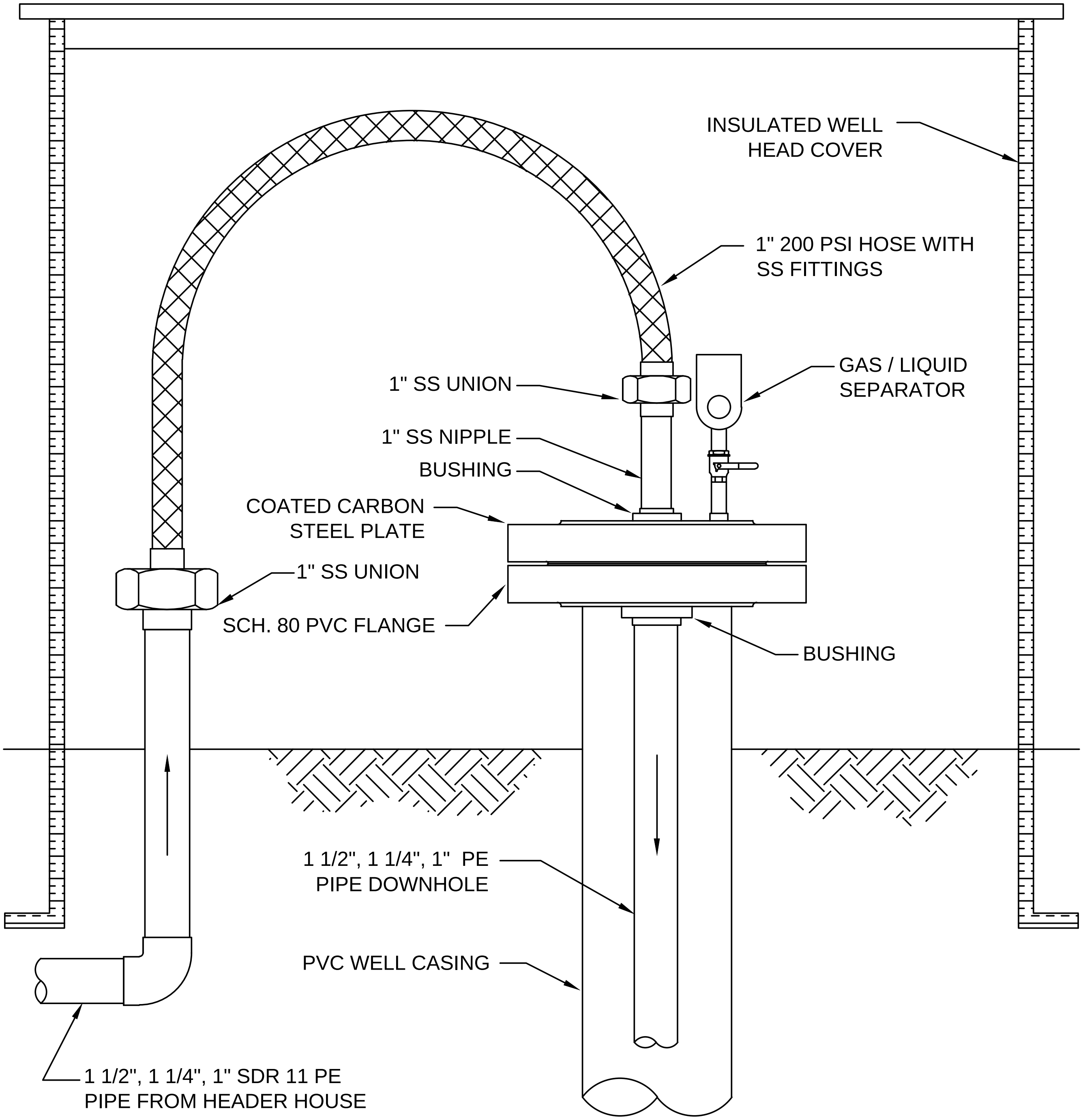

Figure 11.2

Typical Injection Wellhead

Dewey-Burdock Project

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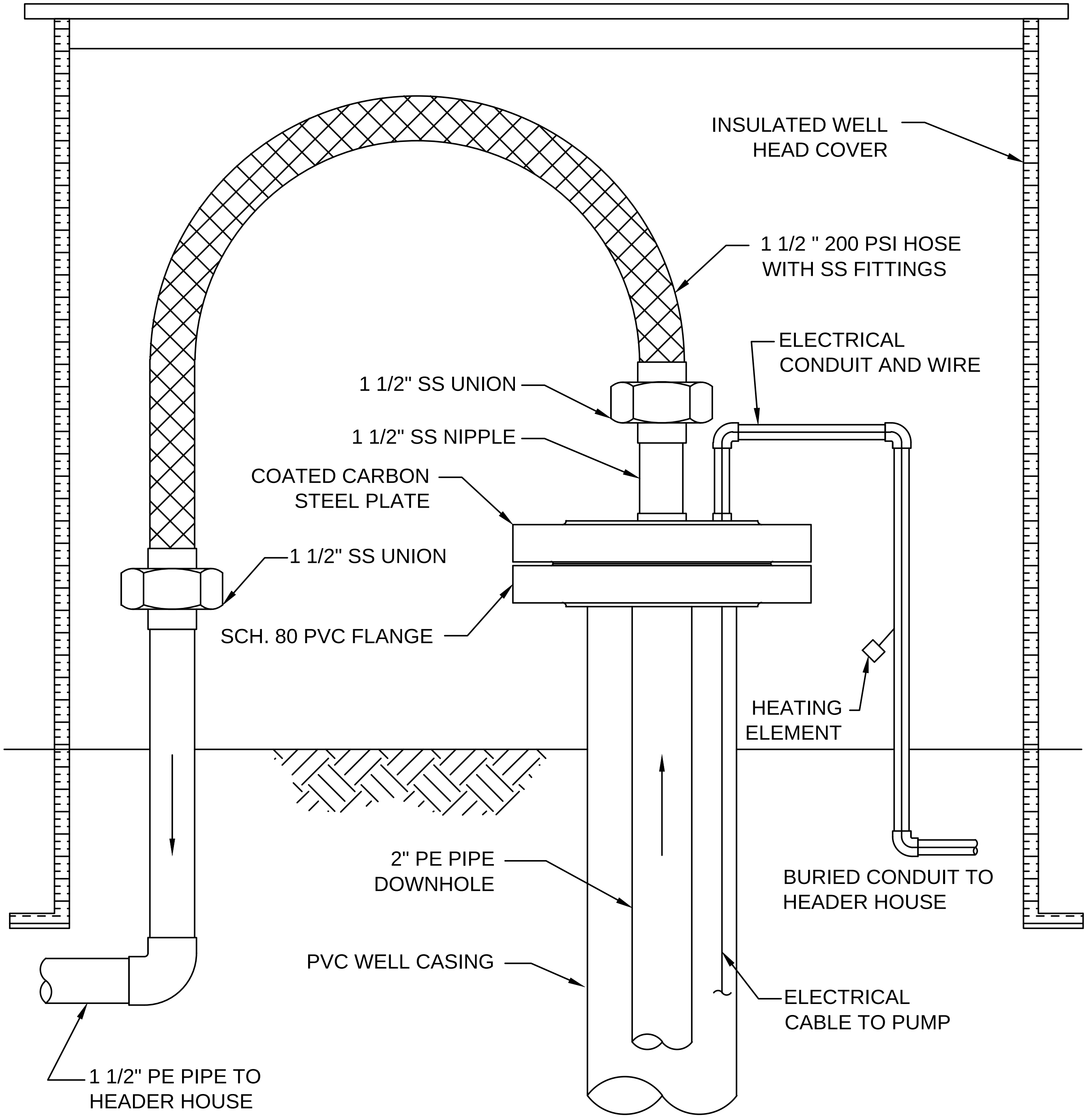

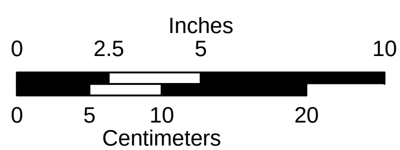

Figure 11.3

Typical Production Wellhead

Dewey-Burdock Project

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FILENAME	Wells-ProdWellhead.dwg

POWERTECH (USA) INC.

from the casing and borehole walls along the screened interval. Prior to obtaining baseline samples from monitor wells, additional well development will be conducted to ensure that representative formation water is sampled. The water will be pumped sufficiently to show stabilization of pH and conductivity values prior to sampling to indicate that development activities have been effective.

11.5 Mechanical Integrity Testing

All injection, production, and monitor wells will be field tested to demonstrate the mechanical integrity of the well casing. The mechanical integrity testing (MIT) will be performed using pressure-packer tests. The bottom of the casing will be sealed with a plug, downhole inflatable packer, or other suitable device. The casing will be filled with water and the top of the casing will be sealed with a threaded cap, mechanical seal or downhole inflatable packer. The well casing then will be pressurized with water or air and monitored with a calibrated pressure gauge. Internal casing pressure will be increased to 125 percent of the maximum operating pressure of the well field, 125 percent of the maximum operating pressure rating of the well casing (which is always less than the maximum pressure rating of the pipe), or 90 percent of the formation fracture pressure (see Section 8.1), whichever is less. A well must maintain 90 percent of this pressure for a minimum of 10 minutes to pass the test.

If there are obvious leaks, or the pressure drops by more than 10 percent during the 10-minute period, the seals and fittings on the packer system will be checked and/or reset and another test will be conducted. If the pressure drops less than 10 percent the well casing will have demonstrated acceptable mechanical integrity.

11.5.1 Loss of Mechanical Integrity

If a well casing does not meet the MIT criteria, the well will be removed from service. The casing may be repaired and the well re-tested, or the well may be plugged and abandoned. Well plugging procedures are described in Section 15 (Attachment Q). EPA will be notified of any well that fails MIT following the reporting procedures described in Section 14.5. If a repaired well passes MIT, it will be employed in its intended service following demonstration that the well meets MIT criteria. If an acceptable test cannot be demonstrated following repairs, the well will be plugged and abandoned.

11.5.2 Subsequent Mechanical Integrity Testing

In addition to the initial testing after well construction, MIT will be conducted on any well following any repair where a downhole drill bit or under-reaming tool is used. Any well with evidence of subsurface damage will require new MIT prior to the well being returned to service. MIT also will be repeated once every 5 years for all active wells.

11.5.3 Reporting

MIT documentation will include the well designation, test date, test duration, beginning and ending pressures, and the signature of the individual responsible for conducting each test. MIT documentation will be available for inspection by the EPA. MIT results will be reported on a quarterly basis as described in Section 14.5 (Attachment P).

12.0 ATTACHMENT N - CHANGES IN INJECTED FLUID

This attachment details anticipated changes in pressure, native fluid displacement, and the direction of movement of injection fluid. It also describes how the chemical composition of the injected fluid will vary during the operational life of each well field.

Injection pressure will remain within the injection pressure limitations described in Section 7.2. Native fluid displacement and the direction of movement of injection fluid will be controlled through the production and restoration bleed, which will be used to maintain a cone of depression within each well field. If there are any delays between production and restoration, production wells will continue to be operated as needed to maintain the water levels within the perimeter monitor rings below baseline conditions. Within well field patterns, the direction of movement of injection fluid may be modified by reversing the function of some production and injection wells. Hydraulic well field control measures that include balancing each well field pattern and each well field and maintaining bleed from the onset of injection through active aquifer restoration will ensure that injection fluids are controlled.

The chemical composition of the injection fluid will vary during the operational life of each well field. Groundwater from well field(s) undergoing uranium recovery will be combined in the satellite facility or CPP and injected into the same well field(s) following uranium removal and oxygen and carbon dioxide addition. During the course of operating each well field, the dissolved constituent concentrations in the production zone and therefore in the injected fluid will increase due to ion exchange and the dissolution of soluble ions in the production zone. The chemical composition of the injection fluid is anticipate to increase from the baseline production zone groundwater quality (refer to Section 17.7 for the approximate baseline groundwater quality based on pre-operational monitoring completed to date) to levels at or below the maximum values shown in Table 7.2.

During aquifer restoration, permeate and/or clean makeup water from the Madison Limestone or another suitable formation will be injected into the well field(s). The chemical composition of the injection fluid during aquifer restoration is anticipated to be at or below the minimum values shown in Table 7.2.

13.0 ATTACHMENT O - PLANS FOR WELL FAILURES

This attachment outlines contingency plans to cope with system shut-ins or failures to prevent migration of fluids into any USDWs.

13.1 Introduction

The endangerment of USDWs may occur via any combination of at least six contamination pathways in which fluids can escape the injection zone and enter USDWs (EPA, 2002). These pathways include:

1) Migration of fluids through a faulty injection well casing;

2) Migration of fluids upward through the annulus located between the casing and the drilled hole;

3) Migration of fluids from an injection horizon through the confining zone (strata);

4) Vertical migration of fluids through improperly abandoned or completed wells;

5) Lateral migration of fluids from within an injection zone into a protected portion of that stratum (a portion that is defined as a USDW); and

6) Direct injection of fluids into or above a USDW.

The extent to which a USDW is threatened will depend on a number of factors including (EPA, 2002):

- The nature of the fluid being injected;
- The volume of the fluid being injected;
- The hydraulics of the flow system (pressure in the injection zone and overlying USDWs); and
- The amount of fluid that may enter the USDW via one or more of the pathways.

Proper construction and MIT of injection wells as outlined in Section 11 (Attachment M) and effective monitoring as described in Section 14 (Attachment P) will reduce the likelihood that any USDWs will be threatened.

13.2 Prevention Measures

13.2.1 Integrity Testing of Casing

Each new injection, production and monitor well will be pressure tested to confirm the integrity of the casing prior to being used for ISR operations. Mechanical integrity will be demonstrated after a well is constructed and before it is put into use. MIT procedures are discussed in

Section 11.5. Wells that fail MIT criteria will be repaired or plugged and abandoned and replaced as necessary.

13.2.2 Shutdown

13.2.2.1 General

All production, injection and monitor wells will be constructed of well casing that is cemented on the exterior to prevent vertical migration of ISR solutions up the annulus between the drill hole and the casing. Both production and injection wells will be piped into a collection header inside a header house.

Each production well will have a submersible pump associated with a circuit breaker in the header house that will be labeled with the corresponding well number (e.g., P-100). Each circuit breaker will have a start and stop switch that can be used to energize or de-energize the pump motor. The circuit breaker will be the main source of electrical power and will be used to de-energize and lock out the pump motor as necessary for repairs or maintenance.

Each injection well will have a block valve between the header and the flow meter so that the injection well may be blocked off to service the meter and the well. There will be a manual flow control valve and a flow meter on each production and injection well to regulate the flow to and from each well and to balance the individual well patterns. The flow meters will be labeled with designated well identification numbers. The block valves will be closed for the appropriate injection or production well for shutdown and tag out.

13.2.2.2 Emergency Shutdown

Powertech will install automated control and data recording systems at the Dewey satellite facility and the Burdock CPP which will provide centralized monitoring and control of the process variables including the flows and pressures of production and injection streams. The systems will include alarms and automatic shutoffs to detect and control a potential release or spill.

Pressure and flow sensors will be installed, for the purpose of leak detection, on the main trunklines that connect the CPP and satellite facility to the well fields. In addition, the flow rate of each production and injection well will be measured automatically. Measurements will be collected and transmitted to both the CPP and satellite facility control systems. Should pressures or flows fluctuate outside of normal operating ranges, alarms will provide immediate warning to operators which will result in a timely response and appropriate corrective action.

Both external and internal shutdown controls will be installed at each header house to provide for operator safety and spill control. The external and internal shutdown controls are designed for automatic and remote shutdown of each header house. In the event of a header house shutdown, an alarm will occur and the flows of all injection and production wells in that header house will be automatically stopped. The alarm will activate a blinking light on the outside of the header house and will cause an alarm signal to be sent to the CPP and satellite facility control rooms.

An external header house shutdown will activate an electrical disconnect switch located on the outside of the header house or at the transformer pole which will shut down all electrical power to the header house. This will mitigate potential electrical hazards while de-energizing the header house and operating equipment. The production pumps will be de-energized which will result in flow stopping from all production wells. A control valve that will close when de-energized will be used on the injection header, which will stop the flow to all injection wells.

Internal shutdown controls will not involve de-energization of the header house but will result in the same alarm condition and shutdown of flow to all production and injection wells feeding the header house.

Each header house also will include a sump equipped with a water level sensor so that if a leak occurs, and the water level approaches a preset level, the sensor will cause an automatic shutdown of the header house. A pressure switch will be installed on each injection header to ensure that fluid pressure does not exceed the maximum designated pressure of the injection wells served by that header house (refer to Section 7.2). If the injection pressure reaches the maximum set value in the pressure switch, an automatic header house shutdown will occur.

13.3 Excursion Control

During production operations, lixiviant will be injected into the production zone through the injection wells, and recovery solution will be withdrawn by the submersible pumps in the production wells. During aquifer restoration, permeate and/or clean makeup water from the Madison Limestone or another suitable formation will be injected into injection wells and recovery solution pumped from the production wells. Recovering more groundwater than is injected during production and restoration will maintain a localized cone of depression for each well field. This induced gradient from the surrounding area toward the well field will serve as a control over the movement of ISR solutions and minimize the potential for lateral excursions.

Pre-operational excursion preventative measures will include, but will not be limited to:

1) Proper well construction and MIT of each well before use;

2) Monitor well design schema based upon delineation drilling to further characterize the zones of mineralization and to identify the target completion zones for all monitor wells; and

3) Pre-operational pumping tests with monitoring systems in place to obtain a detailed understanding of the local hydrogeology and to demonstrate the adequacy of the monitoring system.

Operational excursion preventative measures will include but will not be limited to:

1) Regular monitoring of flow and pressure on each production and injection well;

2) Regular flow balancing and adjustment of all production and injection flows appropriate for each production pattern;

3) Operation of bleed, and continuous measurement of bleed rate;

4) Monitoring of hydrostatic water levels in monitor wells to verify the cone of depression; and

5) Regular collection of samples from all monitor wells to determine the presence of any indicators of the migration of ISR solutions horizontally or vertically from the production zone.

Monitor wells will be positioned to detect any ISR solutions that may potentially migrate away from the production zone due to an imbalance in well field pressure. The monitoring well detection system described in Section 14 (Attachment P) is a proven method used at historically and currently operated facilities. Prior to injecting chemicals into each well field, pre-operational pump testing will be conducted to demonstrate hydraulic connection between the production and injection wells and all perimeter monitor wells (see Section 8.2.3). The results of the pump testing will be included within the hydrogeologic data packages and injection authorization data packages prepared for each well field as described in Sections 8.2.4 and 8.2.5. Additional monitor wells will be installed within overlying and underlying hydrogeologic units. The pre-operational pump testing also will demonstrate vertical confinement and hydraulic isolation between the production zone and overlying and underlying units. Sampling of monitor wells will occur according to the schedule described in Section 14.2 (Attachment P). The monitoring system and operational procedures have proven effective in early detection of potential excursions of ISR solutions for a number of reasons:

- Regular sampling for indicator parameters (such as chloride) that are highly mobile can detect ISR solutions at low levels well before an excursion is created.

- Monitoring hydrostatic water levels in perimeter monitor wells will provide immediate verification of the cone of depression, draw rapid attention in the event of a change, and provide the ability for measurement and implementation of corrective response.
- Bleed will create a cone of depression that will maintain an inward hydraulic gradient toward the well field area.
- The natural groundwater gradient and slow rate of natural groundwater flow is small relative to ISR activities and the induced gradient caused by the production and restoration bleed.

Controls for preventing migration of ISR solutions to overlying and underlying aquifers consist of:

- Regular monitoring of hydrostatic water levels and sampling for analysis of indicator species;
- Routine MIT of all wells on a regular basis (at least every 5 years) to reduce any possibility of casing leakage;
- Completion of MIT on all wells before putting them into service or after work which involves drilling equipment inside of the casing;
- Proper plugging and abandonment of all wells which do not pass MIT or that become unnecessary for use;
- Proper plugging and abandonment of exploration holes with potential to impact ISR operations; and
- Sampling monitor wells located within the overlying and underlying hydrogeologic units on a frequent schedule.

These controls work together to prevent and detect ISR solution migration. Plugging any exploration holes that pose the potential to impact the control and containment of ISR solutions prevents connection of the production zone to overlying and underlying units. The EPA UIC requirements for MIT assure proper well construction, which is the first line of defense for maintaining appropriate pressure without leakage. Sampling the monitor wells will enable early detection of any ISR solutions should an excursion occur. Additional preventative measures are described in Section 14 - Monitoring Program (Attachment P).

13.3.1 Excursion Corrective Action

Powertech will implement the following corrective action plan for excursions occurring during production or restoration operations. Corrective actions to correct and retrieve an excursion will include but will not be limited to:

- Adjusting the flow rates of the production and injection wells to increase the aquifer bleed in the area of the excursion;

- Terminating injection into the portion of the well field affected by the excursion;
- Installing pumps in injection wells in the portion of the well field affected by the excursion to retrieve ISR solutions;
- Replacing injection or production wells; and
- Installing new pumping wells adjacent to the well on excursion status to recover ISR solutions.

In the event of an excursion, the sampling frequency will be increased to weekly. The NRC will be notified within 24 hours by telephone or email and within 7 days in writing from the time an excursion is verified. In addition, if the excursion has potential to affect a USDW, EPA will be notified verbally within 24 hours and in writing within 5 days. A written report describing the excursion event, corrective actions taken and the corrective action results will be submitted to all involved regulatory agencies within 60 days of the excursion confirmation.

If wells are still on excursion status when the report is submitted, the report will also contain a schedule for submittal of future reports describing the excursion event, corrective actions taken, and results obtained. If an excursion is not corrected within 60 days of confirmation, Powertech will terminate injection into the affected portion of the well field until the excursion is retrieved, or provide an increase to the reclamation financial assurance obligation in an amount that is agreeable to NRC and that would cover the expected full cost of correcting and cleaning up the excursion. The financial assurance increase will remain in force until the excursion is corrected. The written 60-day excursion report will state and justify which course of action will be followed. If wells are still on excursion status at the time the 60-day report is submitted to NRC, and the financial assurance option is chosen, the well field restoration financial assurance obligation will be adjusted upward. When the excursion is corrected, the additional financial assurance obligations resulting from the excursion will be removed.

13.3.2 Potential Impacts from Excursions

By properly designing, pump testing, and operating each well field and its associated monitor well network, including specifically addressing those areas having the greatest potential for excursions, Powertech will minimize the risk of excursions and the potential impacts resulting from excursions. By routinely sampling monitor wells for changes in water level and concentrations of the highly mobile and conservative excursion parameters of chloride, total alkalinity and conductivity, Powertech will ensure that any potential excursions are identified and corrected quickly. As described by NUREG-1910, Supplement 1 (NRC, 2010), "An excursion is defined as an event where a monitoring well in overlying, underlying, or perimeter well ring detects an increase in specific water quality indicators, usually chloride, alkalinity and conductivity, which may signal that fluids are moving out from the wellfield … The perimeter monitoring wells are located in a buffer region surrounding the wellfield within the exempted portion of the aquifer. These wells are specifically located in this buffer zone to detect and correct an excursion before it reaches a USDW … To date, no excursion from an NRC-licensed ISR facility has contaminated a USDW.”

13.4 Well Casing Failure

Injection well casing failure is unlikely to occur due to accepted and proven well completion techniques, MIT prior to operations and at least every 5 years, and routine monitoring of the injection pressure for each well. Should an injection well casing failure occur, the well will be removed from service and examined to verify the condition of the casing. If possible, MIT will be conducted. Resistivity or video logs may be used to identifying the location of the well casing failure. Following identification of a defective well casing, the well will be repaired or plugged and abandoned as described in Section 15 - Plugging and Abandonment Plan (Attachment Q). MIT will be conducted prior to use and after any repair that involves entering a well with a cutting tool such as a drill bit or under-reamer.

The monitoring program described in Section 14 - Monitoring Program (Attachment P) will be used to rapidly detect any excursions in the event of a well casing failure. The corrective action plan described in Section 13.3.1 will be used to minimize potential impacts from excursions and protect USDWs.

13.5 Mitigation Measures for Other Potential Environmental Impacts

This section briefly summarizes the mitigation measures for other potential environmental impacts resulting from the Dewey-Burdock Project. Additional information is found in the NRC license application (Powertech, 2009a) and the responses to the Technical Report requests for additional information submitted to NRC in June 2011 (Powertech, 2011).

13.5.1 Spills and Leaks

Well field features such as header houses, well heads or pipelines could contribute to pollution in the unlikely event of a release of ISR solution due to pipeline or well failure. Potential impacts will be minimized by routine MIT of all injection, production and monitor wells and hydrostatic leak testing of all pipelines during construction; implementing an instrumentation and control system to monitor pressure and flow and immediately detect and correct an anomalous condition; and implementing a spill response and cleanup program in accordance with NRC license requirements and DENR permit conditions.

13.5.2 Potential Natural Disaster Risk

NRC guidance in NUREG/CR-6733 (NRC, 2001) evaluates potential risks associated with ISR facilities for the release of radioactive materials or hazardous chemicals due to the effects of an earthquake or tornado strike. The NRC determined that in the event of a tornado strike, chemical storage tanks could fail resulting in the release of chemicals. This risk will be minimized by implementing secondary containment measures for chemical storage. NUREG/CR-6733 concluded that the risk of a tornado strike on an ISR facility is very low and that no design or operational changes are necessary to mitigate the potential risks, but that it is important to locate chemical storage tanks far enough from each other to prevent contact of reactive chemicals in the event of an accident. Chemical storage tanks will be separated at the Dewey-Burdock Project.

Considering the relative remoteness of the project area, the potential consequences of a tornado strike would be considerably less than if the facilities were in a more populated area. Nevertheless, there are risks to workers that will be addressed. Powertech will prepare and have available onsite for regulatory inspection an Emergency Response Plan that will contain emergency procedures to be followed in the event of severe weather or other emergencies. Included in the plan will be procedures for notification of personnel, evacuation procedures, damage inspection and reporting. It also will address cleanup and mitigation of spills that may result from severe weather.

The NRC determined that the radiological consequences of materials released and dispersed due to earthquake damage at an ISR facility were no greater than for a tornado strike. NUREG-0706 (NRC, 1980a) determined that mitigation of earthquake damage could be attained following adequate design criteria. NUREG/CR-6733 concluded that risk from earthquakes is very low at uranium ISR facilities and that no design or operational changes are required to mitigate the risk, but that it is important to locate chemical storage tanks far enough from each other to prevent contact of reactive chemicals in the event of an accident.

All buildings, structures, foundations, and equipment will be designed in accordance with recommendations in the latest versions of the International Building Code and ASCE-7 published by the American Society of Civil Engineers. Maps published in ASCE-7, and the latest version of the USGS Earthquake Ground Motion Tool, along with information regarding soil characteristics provided by the project professional geotechnical engineer, will be used to determine seismic loadings and design requirements.

13.5.3 Potential Fire and Explosion Risk

Powertech has addressed the risk of fire and explosions in the Technical Report request for additional information responses (Powertech, 2011). The design criteria for chemical storage and feeding systems include applicable sections of the International Building Code, International Fire Code, OSHA regulations, RCRA regulations, and Homeland Security regulations. Additional measures for preventing fires and explosions within processing facilities include items such as designing facilities and chemical storage areas to minimize risk of exposure in the event of an accident and developing emergency response procedures. In order to protect facilities from wildfires, vegetation will be controlled around processing facilities, header houses, and well fields. In the event of an approaching wildfire, operators will be trained to shut down well field operations and, if necessary, to evacuate facilities until the danger to personnel has passed. Damage, if any, will be assessed and remediated prior to re-starting operations.

Powertech will maintain firefighting equipment on site and will provide training for local emergency response personnel in the specific hazards present in the project area.

13.5.4 Potential Power Outage

Loss of power to the project site will cause production wells to stop operating, resulting in shutdown of all production and injection flows. This condition avoids flow imbalance within the well fields, but a well field bleed would not be maintained during the power failure. The time span for the aquifer to recover from operational drawdown back to its natural groundwater gradient is much longer than the duration of a typical power outage. Since ISR solutions would not begin to travel to the monitoring ring until the cone of depression caused by the bleed had recovered and groundwater had returned to its natural gradient, excursions are very unlikely within the short time period of a typical power outage.

Power outages in the project area would not be likely to last more than a few days or weeks under most conceivable scenarios. Powertech will use generators onsite and may also contract for temporary generators to operate well field pumps sufficiently to maintain a cone of depression within the well field if unforeseen power outages occur with expected duration of more than a few weeks. Backup generators will be installed to maintain continuous instrumentation monitoring and alarms in the CPP, satellite facility, and well fields. Backup power also will be provided for lights and emergency exits.

14.0 ATTACHMENT P - MONITORING PROGRAM

This attachment describes the monitoring programs directly related to the proposed Class III UIC permit, including monitoring the pressure, flow rate and chemical characteristics of the injection fluid. It also describes monitoring programs that will be conducted in accordance with NRC license requirements designed to protect groundwater quality outside of the exempted aquifer. These programs include excursion monitoring and monitoring domestic, stock, and other wells in the vicinity of the ISR well fields.

14.1 Injection Fluid Monitoring

Powertech will install automated control and data recording systems at the Dewey satellite facility and the Burdock CPP which will provide centralized monitoring and control of the process variables including the flow rate and pressure of the injection stream in each header house. In addition, the flow rate of each injection well will be automatically measured. Pressure gauges installed at each injection wellhead or in the injection manifold also will be manually recorded at least daily.

The volumetric flow rate of oxygen and carbon dioxide will be measured at the point of injection into the barren lixiviant using calibrated gas flow meters. The flow meters will be routinely calibrated according to manufacturer recommendations.

The injection fluid in each operating well field will be sampled monthly. Samples will be collected from the injection manifold, individual injection flow lines, or the injection wellheads following the appropriate quality assurance/quality control (QA/QC) procedures (refer to Section 14.7). Samples will be submitted to an EPA-certified laboratory and analysed for the parameters in Table 14.1.

14.2 Excursion Monitoring

Following is a brief summary of the excursion monitoring program that will be conducted in accordance with NRC license requirements to detect potential horizontal or vertical excursions of ISR solutions. Additional details regarding the excursion monitoring program can be found in Powertech (2011).

14.2.1 Monitoring Network Design

Monitor wells will be installed in and around each well field to detect the potential migration of ISR solutions away from the production zone. Perimeter monitor wells will be completed in the ore zone around the perimeter of each well field. Non-production zone monitoring wells will be completed within each well field in the overlying and underlying hydrogeologic units.

Table 14.1: Injection Fluid Characterization Parameters

Test Analyte/Parameter	Units	Method
Physical Properties		
pH	pH Units	A4500-H B
Total Dissolved Solids (TDS)	mg/L	A2540 C
Conductivity	µmhos/cm	A2510 B
Common Elements and Ions		
Alkalinity (as $CaCO_3$)	mg/L	A2320 B
Chloride	mg/L	A4500-Cl B; E300.0
Sulfate	mg/L	A4500-SO4 E; E300.0
Metals - Dissolved		
Arsenic, As	mg/L	E200.8
Iron, Fe	mg/L	E200.7
Lead, Pb	mg/L	E200.8
Manganese, Mn	mg/L	E200.8
Strontium, Sr	mg/L	E200.8
Uranium, U	mg/L	E200.7, E200.8
Vanadium, V	mg/L	E200.7, E200.8
Radionuclides		
Gross alpha	pCi/L	E900.0
Gross beta	pCi/L	E900.0
Radium-226	pCi/L	E903.0

14.2.1.1 Perimeter Monitor Wells

Perimeter monitor wells will be positioned around the perimeter of each well field as illustrated on Plate 10.1 and Figure 10.1. The perimeter monitor well "ring" serves two purposes: 1) to monitor any horizontal migration of fluid outside of the production zone, and 2) to determine baseline water quality data and characterize the area outside the production pattern area.

Perimeter monitor wells will be located no farther than 400 feet from the well field patterns. Refer to Powertech (2011) for additional information including perimeter monitor well spacing for stacked roll fronts. They will be evenly spaced with a maximum spacing of either 400 feet or the spacing that will ensure a 70 degree angle between adjacent perimeter monitor wells and the nearest injection well. This maximum distance is based on and consistent with standard monitoring practices at operating ISR facilities. It also is supported by site-specific data and evaluation through numerical groundwater modeling, which was submitted to NRC in support of the license application (Powertech, 2009b) and demonstrates that the maximum perimeter monitor ring spacing of 400 feet is adequate to detect an excursion and that an excursion can be controlled.

Perimeter wells will be screened across the entire thickness of the production zone, which will be determined following completion of delineation drilling for each well field. In cases where a localized confining unit is present between stacked ore bodies within one of the primary geologic units (Fall River or Chilson), the monitoring approach may be modified such that perimeter monitor wells are screened only within the portion of the hydrogeologic unit in which the ore body is located. In all cases, the screens will fully penetrate the hydrogeologic unit to be monitored, i.e., spanning the entire interval between the overlying and underlying confining beds. As described in Section 6.2.2, the Fuson Shale is pervasive throughout the project area and forms a confining unit between the Fall River and Chilson. No monitor well will be screened across the Fuson Shale. Prior to initiating ISR operations in each well field, pre-operational pumping tests will be conducted to confirm that the perimeter monitor wells are hydraulically connected to the production zone. Additional information is found in Section 8.2.3.

14.2.1.2 Non-Production Zone Monitor Wells

Depending on site-specific conditions, non-production zone monitor wells may consist of two types of monitor wells, termed overlying and underlying. The overlying and underlying monitor wells will be used to obtain baseline water quality data and used in the development of compliance limits for the overlying and underlying zones that will be used to determine if vertical migration of lixiviant is occurring. The screened zone for the overlying and underlying monitor wells will be determined from electric logs by qualified geologists or hydrogeologists. The following criteria will be applied for installing overlying and underlying monitor wells that are effective at detecting potential vertical excursions. These will be determined based on the hydrogeologic data obtained and analyzed during the development of each hydrogeologic well field data package (Section 8.2.4) and injection authorization data package (Section 8.2.5).

- Areas which may be associated with leakage around the injection well casing.
- Areas where the confining unit may be uncharacteristically thin or absent.
- Areas which may be associated with leakage through improperly abandoned boreholes.
- Areas identified during hydrologic testing as having hydraulic communication with the overlying or underlying aquifer.

If necessary, additional overlying and underlying monitor wells may be added beyond the minimum density specified below in order to detect a potential vertical excursion. Following is a description of each of the non-production zone monitor well types.

Overlying Monitor Wells

The overlying monitor wells will be designed to provide monitoring of any upward movement of ISR solutions that may occur from the production zone and to guard against potential leakage from production and injection well casing into any overlying aquifer. The term “overlying aquifer” refers to any hydrogeologic unit(s) above the production zone and separated by a confining layer. The terms “overlying aquifer” and “overlying hydrogeologic unit” are used interchangeably when describing well field design and operations.

All overlying hydrogeologic units will be monitored. Monitor wells completed in the first overlying hydrogeologic unit will be designated with the prefix MO and will have a density of at least one well per 4 acres of well field pattern area. Monitor wells completed in subsequent overlying hydrogeologic units will be designated with prefixes MO2, MO3, etc. and will have a density of at least one well per 8 acres of well field pattern area.

Underlying Monitor Wells

The underlying monitor wells will be designed to provide monitoring of any downward movement of ISR solutions from the production zone. Monitor wells completed in the first underlying hydrogeologic unit will be named with the prefix MU and will have a density of one well per 4 acres of pattern area. Only the first underlying hydrogeologic unit will be monitored, unless the production zone is the lowermost hydrogeologic unit above the Morrison Formation, in which case the Unkpapa Sandstone will be the underlying aquifer. Excursion monitoring will not occur in the Unkpapa Sandstone. The justification for not performing excursion monitoring is as follows:

1) The Unkpapa Sandstone shows substantially higher potentiometric head than the Fall River and Chilson throughout the permit area. During ISR operations, the potentiometric head will be reduced (creating a cone of depression) in the Chilson and Fall River due to a net withdrawal (production flow greater than injection flow) in order to maintain well field bleed. Flow into the Unkpapa from production zones in the Fall River and Chilson operating at a substantially lower potentiometric head would be impossible.
2) The Morrison Formation is prevalent across the entire permit area, with a thickness ranging from 60 to 140 feet, and will act as an aquitard to prevent flow between the Unkpapa and the Fall River and Chilson. This was demonstrated by the pumping tests conducted by Powertech, where no response occurred in the Unkpapa during pumping of either the Fall River or Chilson.
3) The Unkpapa is a low-yield aquifer determined by a recent water supply well installation by Powertech. Water samples from the Unkpapa can no longer be obtained from well 704 because this well was cemented off in the Unkpapa in 2009 and perforated in the Chilson due to low yield from the Unkpapa.

4) NRC guidance in NUREG/CR-6733 (NRC, 2001) allows that, “Where confining layers are shown to be very thick and of negligible permeability, requirements for vertical excursion monitoring can be relaxed or eliminated.”

14.2.1.3 Monitor Well Layout

The generalized monitoring scheme is depicted in Figure 14.1. This approach will be used when there are no substantial confining layers between ore bodies within the Fall River or Chilson.

Local confining units within the Fall River or Chilson generally are anticipated to be utilized in the monitoring scheme. The presence or absence of these will be confirmed with delineation drilling and mapped in more detail in the process of developing each well field hydrogeologic data package (refer to Section 8.2.4). Figures 14.2 and 14.3 depict the conceptual monitoring schemes for the initial Burdock and Dewey well fields, respectively. Following is a brief summary of the conceptual monitor well layouts. Note that additional monitor wells may be installed as needed.

For Burdock Well Field 1 (Figure 14.2), the anticipated production zone is the Lower Chilson. Since the production zone is anticipated to be in the lowermost hydrogeologic unit above the Morrison Formation, no monitoring would occur in the underlying hydrogeologic unit (Unkpapa). Refer to the previous section for additional explanation. Monitor wells would be installed in the first overlying hydrogeologic unit (Middle Chilson) with a minimum density of one well per 4 acres. Monitor wells would be installed in all other overlying hydrogeologic units with a minimum density of one well per 8 acres. This includes the Upper Chilson, Lower and Upper Fall River, and alluvium (where present).

For Burdock Well Field 3 (Figure 14.2), the anticipated production zone is the Upper Chilson. In this case the immediately overlying hydrogeologic unit would be the Lower Fall River Formation and would be monitored at a minimum density of one well per 4 acres. Other overlying hydrogeologic units would be monitored at a minimum density of one well per 8 acres, including the Upper Fall River and alluvium (where present). The first underlying hydrogeologic unit would be the Middle Chilson and would be monitored at a minimum density of one well per 4 acres.

For Dewey Well Field 1 (Figure 14.3), the anticipated production zone is the Lower Fall River. In this case overlying hydrogeologic units would only include the Upper Fall River and alluvium (where present). The first underlying hydrogeologic unit would be the Upper Chilson. Similar conventions are shown for Dewey Well Fields 2 and 4.

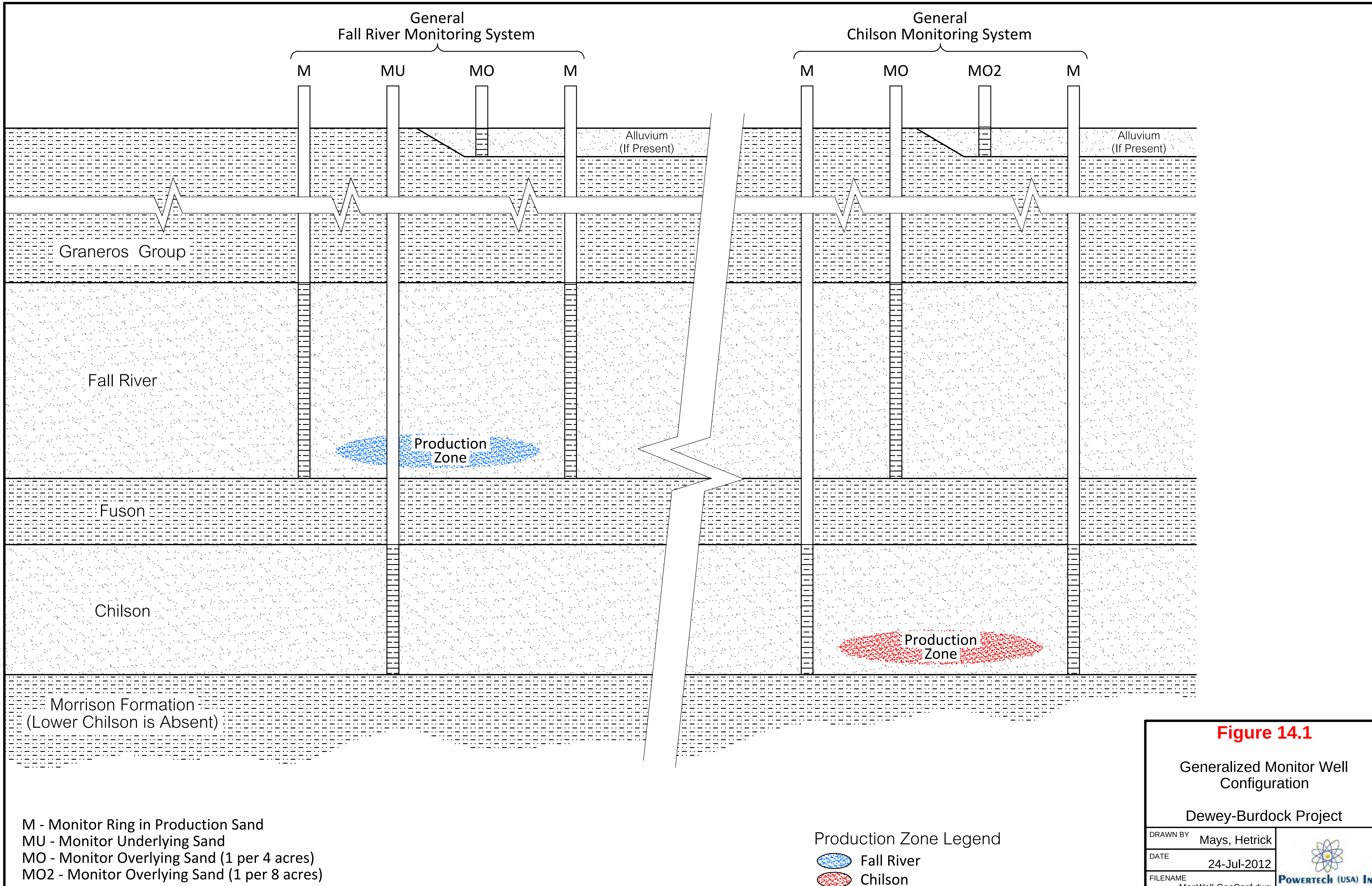


Figure 14.1

Generalized Monitor Well Configuration

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	24-Jul-2012
FILENAME	MonWell-GenConf.dwg

Powertech (USA) Inc.

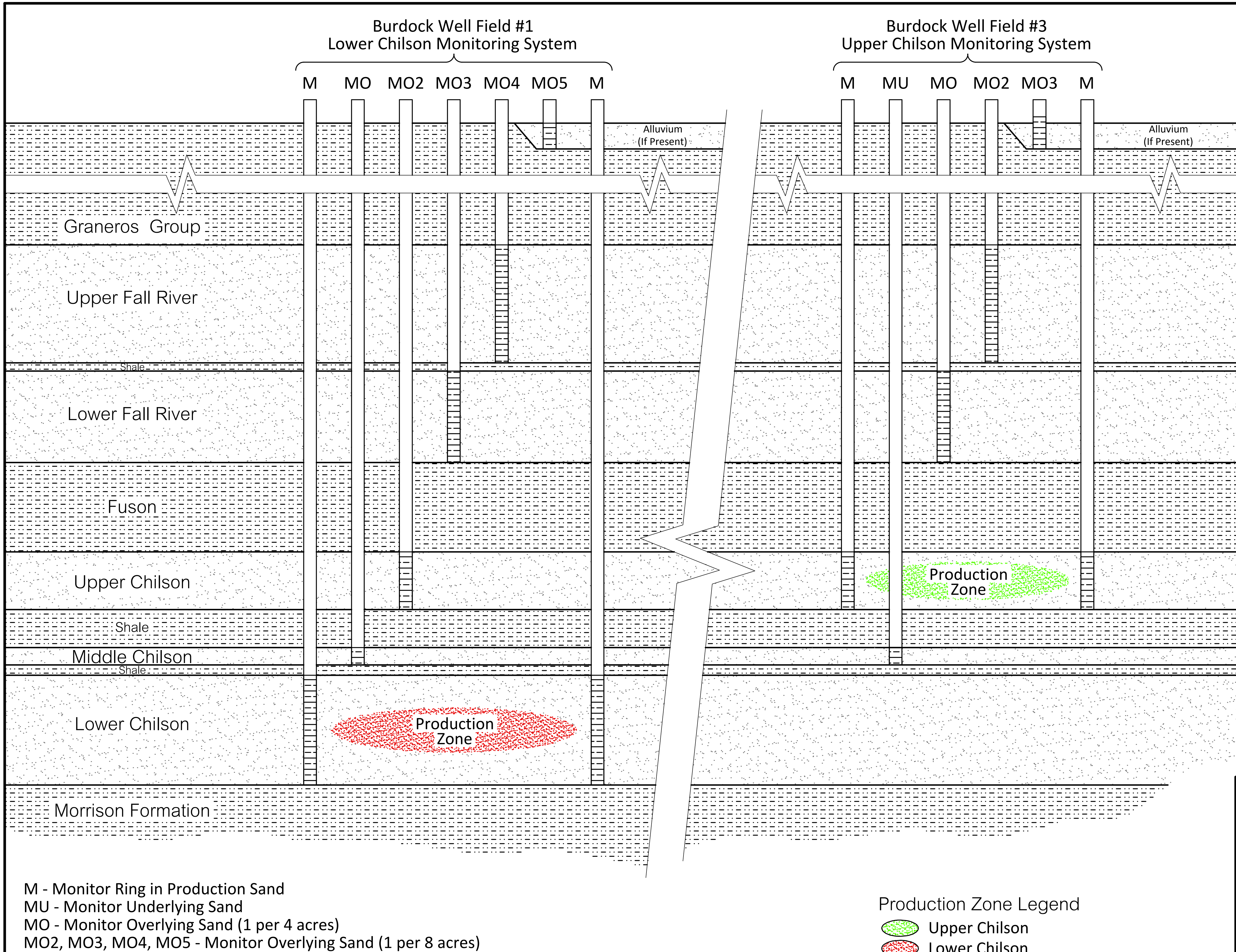


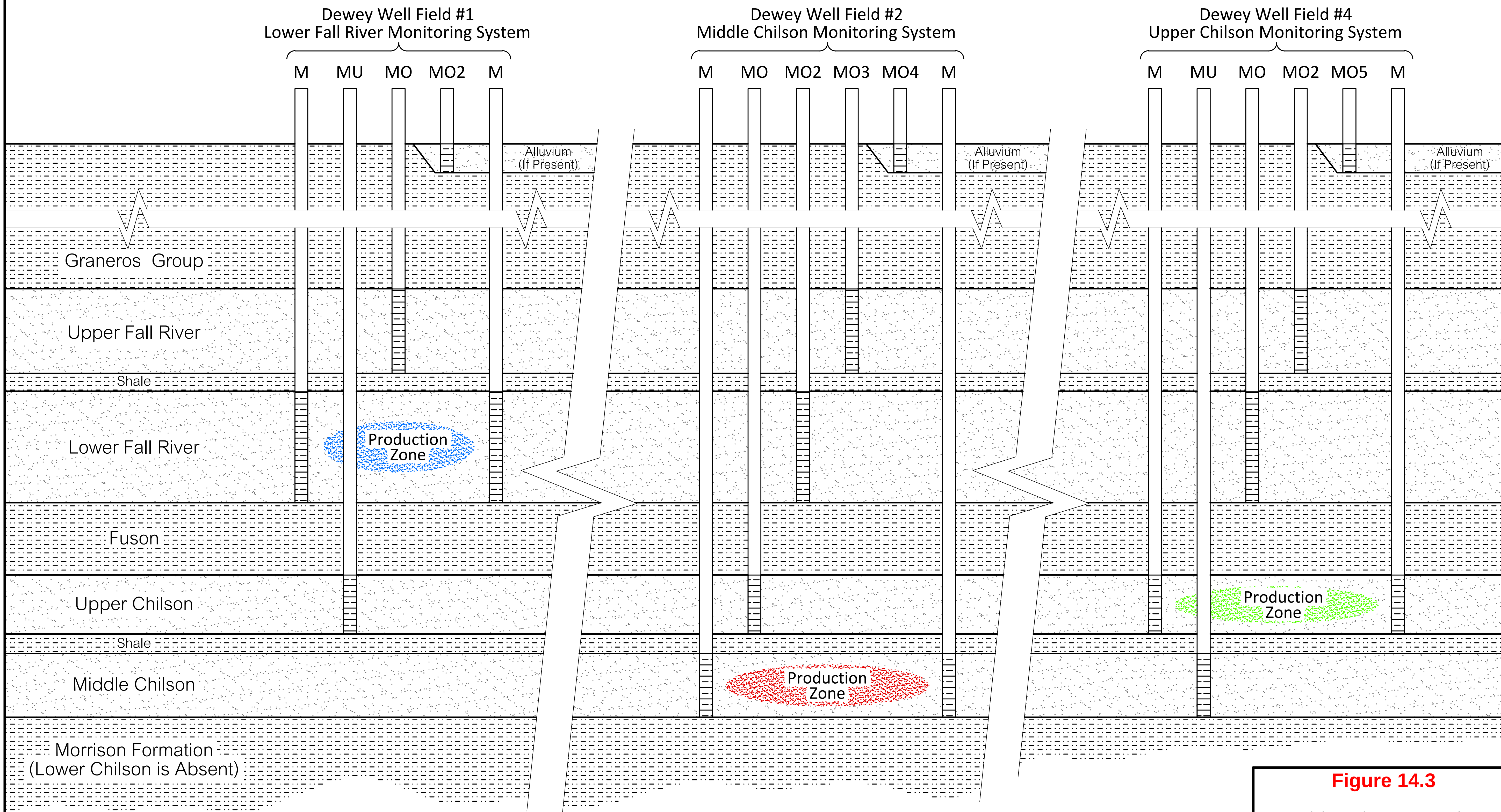
Figure 14.2

Anticipated Burdock Monitor Well Configuration

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	24-Jul-2012
FILENAME	MonWell-BurdConf.dwg

POWERTECH (USA) INC.



M - Monitor Ring in Production Sand
MU - Monitor Underlying Sand
MO - Monitor Overlying Sand (1 per 4 acres)
MO2, MO3, MO4, MO5, MO6 - Monitor Overlying Sand (1 per 8 acres)

Production Zone Legend
- Lower Fall River
- Upper Chilson
- Middle Chilson

Figure 14.3

Anticipated Dewey Monitor Well Configuration

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	24-Jul-2012
FILENAME	MonWell-DeweyConf.dwg

POWERTECH (USA) INC.

Refer to Powertech (2011) for additional details on monitor well layout, including instances where a producing well field will be located in an overlying or underlying hydrogeologic unit associated with another producing well field (i.e., overlapping well fields).

14.2.2 Establishing Upper Control Limits

Powertech will establish baseline water quality in the perimeter wells and non-production zone monitor wells according to NRC license requirements. Baseline water quality will be calculated based on the analysis of multiple samples from each monitor well. Baseline water quality will be used to establish upper control limits (UCLs). UCLs will be established as a function of the average baseline water quality and the variability in each parameter according to statistical methods approved by NRC.

UCLs will be established for constituents that provide early indication of a potential excursion. The anticipated excursion indicators include chloride, conductivity and total alkalinity. These are commonly used excursion indicators that are highly mobile in groundwater not influenced significantly by pH changes or oxidation-reduction reactions.

14.2.3 Excursion Sampling

Excursion sampling will occur in accordance with NRC license requirements. The sampling frequency will be twice monthly during uranium recovery operations and once every 60 days during aquifer restoration. As previously described, the anticipated excursion indicators include chloride, conductivity and total alkalinity. Water levels will be recorded during excursion sampling events.

Water levels will be measured using downhole pressure transducers or manual electronic meters. These measurements will alert operators to any significant change in the water levels within the monitor wells to provide an early warning of a potential excursion. Operators may then follow standard operating procedures to make adjustments to well field production and/or injection flow rates to avoid an excursion due to any unbalanced flow condition in a well field. Water level readings will be recorded at a minimum frequency of twice monthly from production zone monitor wells and monitor wells installed in the overlying and underlying hydrogeologic units.

14.2.4 Excursion Confirmation

An excursion will be deemed to have occurred if two or more excursion indicators in any monitor well exceed their UCLs. A verification sample will be taken within 48 hours after results of the first analyses are received. If the results of the verification sampling are not complete within 30 days of the initial sampling event, then the excursion will be considered confirmed for the purpose of meeting the reporting requirements described below. If the excursion is not confirmed by the verification sample, a third sample will be taken within 48 hours after the second set of sampling data are received. If neither the second nor the third sample confirms the excursion by two indicators exceeding their UCLs, the first sample will be considered to have been in error, and the well will be removed from excursion status. If either the second or third sample exhibits two or more indicators above their UCLs, an excursion will be confirmed, the well will be placed on confirmed excursion status, and corrective action will be initiated. Corrective actions are described in Section 13.3.1.

14.3 Operational Groundwater Monitoring

Operational groundwater monitoring will be conducted in accordance with NRC license conditions and will be used to detect potential changes in groundwater quality in and around the project area as a result of ISR operations. The operational groundwater monitoring program will include domestic wells, stock wells and wells located hydrologically upgradient and downgradient of ISR operations. The operational monitoring program is designed to provide a comprehensive baseline evaluation of water supply wells located within the AOR. Wells to be included in the operational monitoring program include domestic wells within 2 km of the project area, stock wells within the project area, and additional monitor wells within the project area in the alluvium, Fall River, Chilson and Unkpapa.

Prior to operations all domestic and stock wells within 2 km of the project area will be sampled to establish baseline water quality. A complete list of the wells is provided in Appendix A. To meet NRC license requirements, Powertech will monitor all domestic and stock wells within 2 km of the project area quarterly for one year prior to operation (including monitoring already completed). All samples will be analyzed for constituents listed in Table 14.2.

<u>Operational Groundwater Monitoring - Domestic Wells</u>

Powertech has committed to NRC to remove all domestic wells within the project area from private use prior to ISR operations, or, at a minimum, from drinking water use. Depending on the well construction, location and screen interval, Powertech may continue to use the well for monitoring or plug and abandon the well. During operations, Powertech will monitor all domestic wells within 2 km of the project boundary. Samples will be collected annually and analyzed for the constituents listed in Table 14.2.

<u>Operational Groundwater Monitoring - Stock Wells</u>

During the design of each well field, all nearby stock wells will be evaluated for the potential to be adversely affected by ISR operations or to adversely affect ISR operations. At a minimum, all stock wells within ¼ mile of well fields will be removed from private use prior to operation of

Table 14.2: Baseline Water Quality Parameter List

Test Analyte/Parameter	Units	Analytical Method
Physical Properties		
pH ♯	pH units	A4500-H B
Total Dissolved Solids (TDS) +	mg/L	A2540 C
Conductivity	µmhos/cm	A2510 B
Common Elements and Ions		
Alkalinity (as $CaCO_3$)	mg/L	A2320 B
Bicarbonate Alkalinity (as $CaCO_3$)	mg/L	A2320 B (as HCO_3)
Calcium	mg/L	E200.7
Carbonate Alkalinity (as $CaCO_3$)	mg/L	A2320 B
Chloride, Cl	mg/L	A4500-Cl B; E300.0
Magnesium, Mg	mg/L	E200.7
Nitrate, NO_3^- (as Nitrogen)	mg/L	E300.0
Potassium, K	mg/L	E200.7
Sodium, Na	mg/L	E200.7
Sulfate, SO_4	mg/L	A4500-SO4 E; E300.0
Trace and Minor Elements		
Arsenic, As	mg/L	E200.8
Barium, Ba	mg/L	E200.8
Boron, B	mg/L	E200.7
Cadmium, Cd	mg/L	E200.8
Chromium, Cr	mg/L	E200.8
Copper, Cu	mg/L	E200.8
Fluoride, F	mg/L	E300.0
Iron, Fe	mg/L	E200.7
Lead, Pb	mg/L	E200.8
Manganese, Mn	mg/L	E200.8
Mercury, Hg	mg/L	E200.8
Molybdenum, Mo	mg/L	E200.8
Nickel, Ni	mg/L	E200.8
Selenium, Se	mg/L	E200.8, A3114 B
Silver, Ag	mg/L	E200.8
Uranium, U	mg/L	E200.7, E200.8
Vanadium, V	mg/L	E200.7, E200.8
Zinc, Zn	mg/L	E200.8
Radiological Parameters		
Gross Alpha††	pCi/L	E900.0
Gross Beta	pCi/L	E900.0
Radium, Ra-226§	pCi/L	E903.0

♯ Field and Laboratory

+ Laboratory only

††Excluding radon, radium, and uranium

§ If initial analysis indicates presence of Th-232, then Ra-228 will be considered within the baseline sampling program or an alternative may be proposed.

nearby well fields. Depending on the well construction, location and screen interval, Powertech may continue to use the well for monitoring or plug and abandon the well. During operation, Powertech will monitor all stock wells within the project area. Samples will be collected quarterly and analyzed for water level and the three excursion indicators of chloride, total alkalinity, and conductivity.

<u>Operational Groundwater Monitoring - Monitor Wells</u>

Powertech will monitor wells located hydrologically upgradient and downgradient of ISR operations as part of the operational groundwater monitoring program. Monitor wells included in the operational monitoring program will include wells completed in the alluvium, Fall River, Chilson, and Unkpapa. The monitor wells will be monitored quarterly and analyzed for constituents listed in Table 14.2.

<u>Operational Groundwater Sampling Methods and Parameters</u>

Groundwater sampling methods will be in accordance with an accepted Quality Assurance Project Plan (see Section 14.7).

14.4 Groundwater Restoration Monitoring

During all phases of groundwater restoration, including active restoration and stability monitoring, excursion monitoring will continue in accordance with NRC license conditions. The following additional monitoring associated with groundwater restoration will be conducted in accordance with NRC license requirements.

14.4.1 Establishing Production Zone Baseline Water Quality

Production zone baseline water quality and TRGs will be established according to NRC license requirements. Prior to uranium ISR, a subset of wells within each well field to be utilized as production wells will be identified for baseline water quality sampling. The sample density is anticipated to be one well per 4 acres of well field pattern area or six wells, whichever is greater, except that fewer than six wells may be used for well fields smaller than 6 acres. The expected sample frequency is four sample events spaced at least 14 days apart, with samples analyzed for the constituents listed in Table 14.2. Baseline water quality and TRGs will be established according to statistical methods approved by NRC.

14.4.2 Monitoring during Active Restoration

Powertech will monitor the progress of aquifer restoration by sampling ore zone monitor wells in each well field at a frequency sufficient to determine the success of aquifer restoration, optimize the efficiency of aquifer restoration, and determine if any areas need additional attention. The results of active restoration monitoring will be used to evaluate potential areas of flare or hot spots. If potential flare or hot spots are identified, appropriate corrective measures will be taken such as adjusting the flow in the area, changing wells from injection to production, or adjusting the restoration bleed in a specific area.

14.4.3 Restoration Stability Monitoring

A groundwater stability monitoring period will be implemented to show that the restoration goal has been adequately maintained. The stability monitoring period proposed in the NRC license includes 12 months with quarterly sampling (at least five sample events, including one at the beginning of the stability monitoring period and following each of the following four quarters). The sample results will be analyzed using statistical methods approved by the NRC to evaluate stability.

If a constituent does not meet the stability criteria, Powertech will take appropriate action considering the constituent and the status of the restored groundwater system. Potential actions may include extending the stability period or returning the well field to a previous phase of active restoration to resolve the issue.

If the analytical results from the stability period continue to meet the TRGs and meet the stability criteria, then Powertech will submit supporting documentation to the NRC showing that the restoration parameters have remained at or below the restoration standards and requesting that the well field be declared restored.

14.5 Reporting

Prior to operation of each well field, Powertech will prepare and submit an injection authorization data package as described in Section 8.2.5. The data package will provide the planned locations of injection, production and monitor wells and the results of formation testing. The data packages will request authorization to initiate injection into each well field. Powertech will complete MIT and a well completion report for each injection well prior to initiating injection into that well.

Quarterly monitoring reports will be submitted to EPA Region 8. At minimum, the quarterly monitoring reports will include the following information:

- Physical, chemical and other relevant characteristics of injection fluids
- Monthly average, maximum and minimum values for injection pressure, flow rate and volume
- Quarterly MIT results, a list of any wells failing MIT and corrective actions taken, and a list of wells anticipated to undergo MIT during the next quarter
- Any well maintenance activities

Appendix K contains an example of the quarterly monitoring report form (EPA Form 7520-8, Rev. 8-01).

Signed quarterly reports will be submitted electronically unless otherwise directed by the EPA. If required, a signature letter from the Project Manager will accompany the disk to certify the report. Reports will consist of monthly summary information for the project. Monitoring reports will include raw data and graphical analysis for the current reporting period to date. Each calendar quarter, the maximum, minimum, and average monthly values for each continuously monitored parameter specified for the injection wells will be tabulated. A narrative description of any deviations from permit limitations will be given. Maintenance activities, MIT activities, and other significant events that took place during the reporting period will be described. If an excursion has potential to impact a USDW, it will be reported verbally to EPA within 24 hours and followed up within 5 days in written form.

14.6 Recordkeeping

Well completion records and all monitoring information, including calibration and maintenance records and data from the continuous monitoring instrumentation will be retained for at least three (3) years after all wells have been plugged and abandoned. This includes:

- Injection well completion reports.
- Information on the nature, volume, and composition of all injected fluids.
- MIT results, description and results of any other tests required by EPA, and any well work-overs completed.

The records discussed above (originals or copies) will be retained on site unless written approval to discard the records is provided by the EPA. Copies of these records (or originals) will be maintained for all observation records throughout the operating life of each well. Powertech also will maintain an electronic database containing well completion and MIT records for all injection wells. The database will be provided for EPA use upon request.

14.7 Quality Assurance

After license issuance but prior to operations, Powertech will prepare and submit to NRC a Quality Assurance Project Plan (QAPP) consistent with the recommendations contained in NRC Regulatory Guide 4.15, Quality Assurance for Radiological Monitoring Programs (Inception through Normal Operations to License Termination) -- Effluent Streams and the Environment. The purpose of the QAPP is to ensure that all radiological and nonradiological measurements that support the radiological monitoring program are reasonably valid and of a defined quality. These programs are needed (1) to identify deficiencies in the sampling and measurement processes and report them to those responsible for these operations so that licensees may take corrective action and (2) to obtain some measure of confidence in the results of the monitoring programs to assure the regulatory agencies and the public that the results are valid.

15.0 ATTACHMENT Q - PLUGGING AND ABANDONMENT PLAN

This attachment describes the plugging and abandonment plan for the Class III injection wells. The plugging and abandonment methods are designed to prevent movement of fluids through the well, out of the production zone, and into USDWs or the land surface. The same procedures will be followed for production and monitor wells. The attachment also summarizes the surface reclamation, decontamination and decommissioning activities that will be carried out in accordance with NRC license and DENR permit requirements.

15.1 Well Plugging and Abandonment Plan

Powertech will plug all wells in accordance with ARSD 74:02:04:67 with bentonite or cement grout. The weight and composition of the grout will be sufficient to control artesian conditions and meet the well abandonment standards of the State of South Dakota. Cementing will be completed from total depth to surface using a drill pipe. Records will be kept of each well cemented including at a minimum the following information:

- well ID, total depth, and location
- driller, company, or person doing the cementing work
- total volume of grout placed down hole
- viscosity and density of the grout

Powertech will remove surface casing or cut off surface casing below ground and set a cement surface plug on each well plugged and abandoned.

15.2 Plugging and Abandonment Reporting

According to 40 CFR § 144.51(p) the operator is to notify the EPA within 60 days after plugging or at the time of the next quarterly report (whichever is less). In accordance with this requirement, a Plugging and Abandonment Report will be submitted to the EPA. The person that performs the plugging operation will certify the report as accurate. The report will contain either:

- A statement that the well was plugged in accordance with the approved Plugging and Abandonment Plan; or
- If the actual plugging differed from the Plugging and Abandonment Plan, a statement specifying the different procedures followed.

Documentation will be provided to verify that the quantity of sealing material placed in the well is at least equal to the volume of the empty hole.

The Plugging and Abandonment Reports will be retained for at least 3 years from the date of the submission unless the EPA requests an extension. If requested, at the conclusion of the retention period, the reports will be delivered to the EPA.

15.3 Facility Decontamination and Decommissioning

Following regulatory approval of successful aquifer restoration in all well fields, Powertech will decommission all well fields, processing facilities, ponds, and equipment within the project area. Decontamination and decommissioning activities will be done in accordance with NRC license and DENR large scale mine permit requirements. During decommissioning, all well field equipment (including pumps, tubing, pressure transducers, wellhead covers and surface piping and equipment), pipelines, header houses, processing buildings/equipment, and pond liners will be surveyed for radiological contamination and decontaminated for unrestricted release, transferred to an NRC or NRC agreement state-licensed facility, or disposed at an appropriately permitted facility. Surface soils will be surveyed for radiological contamination and affected soils removed and appropriately disposed. Surface reclamation and revegetation will be conducted in accordance with DENR large scale mine permit requirements. The decommissioning program will ensure that the project area is closed in a manner that permits release for unrestricted use.

16.0 ATTACHMENT R - NECESSARY RESOURCES

This attachment demonstrates that the necessary resources will be available to plug and abandon the injection wells. Table 16.1 presents a preliminary estimate of the cost to plug and abandon the injection wells that will be in place at the end of the first year of ISR operations. The preliminary cost estimate is based on the anticipated number of installed injection wells and cost estimates from independent contractors to plug and abandon the injection wells and to supply cement grout (refer to Appendix L for cost estimates). The preliminary estimate in Table 16.1 is subject to change prior the Class III UIC permit issuance based on ongoing facility planning efforts. The number of injection wells installed during the first financial assurance period, which is anticipated to be the first year after license/permit issuance, may be significantly fewer, since most of this time period will be used for well field delineation, monitor well installation, and preparation of the well field hydrogeologic and injection authorization data packages. Powertech anticipates submitting a revised financial assurance estimate for EPA approval prior to Class III UIC permit issuance.

Table 16.1: Preliminary Well Plugging and Abandonment Cost Estimate

	Value	Units	Source
Assumptions			
Total injection wells to be plugged and abandoned	411	wells	Powertech (2011)
Average well depth	550	ft	Burdock ~450'; Dewey ~600'
Inside casing diameter	4.90	in	5" SDR 17 PVC
Quantity Calculations			
Plugging volume per well	72.0	ft^3	Calculated
Volume cement grout per 94-lb bag	1.27	ft^3	Assumes approximately 6 gal. water per bag
Volume cement grout per ton bulk cement	27.0	ft^3/ton	Calculated
Mass cement per well	2.7	tons	Calculated
Unit Cost Estimates			
Equipment and Labor (includes water and water hauling)			
Wells plugged per week per 3-man crew	16	wells	Quote
Equipment and labor cost per well	$1,000	$/well	Quote
Bulk cement			
Bulk cement cost	$140.42	$/ton	Quote
Cement cost per well	$380	$/well	Calculated
Cement storage pig rental			
Rental cost per week	$625	$/week	Quote
Rental cost per well	$40	$/well	Calculated
Total cost per well	$1,420	$/well	Calculated
Total cost estimate	**$583,620**		Calculated

Following review and approval of the plugging and abandonment cost estimate, a financial assurance instrument will be submitted to EPA to assure the required plugging and abandonment activities will be completed to safeguard potential USDWs.

Each year Powertech will submit a financial assurance update indicating the anticipated number of injection wells to be installed during the next year and providing an updated financial assurance instrument to include the plugging and abandonment costs for the additional injection wells. During decommissioning, the financial assurance instrument will be updated annually to reflect the wells injection plugged and abandoned during the previous year.

17.0 ATTACHMENT S - AQUIFER EXEMPTION

This attachment describes the requested aquifer exemption boundary for the Dewey-Burdock Project. An aquifer exemption is required to inject lixiviant for the purpose of extracting uranium. The aquifer exemption from protection as a drinking water source is requested for portions of the Inyan Kara Group on the basis that these portions do not currently serve as sources of drinking water and are anticipated to be commercially mineral producing.

17.1 Introduction

40 CFR § 146.4 allows EPA to exempt an aquifer or portion of an aquifer for the purpose of injection provided:

(a) It does not currently serve as a source of drinking water; and

(b) It cannot now and will not in the future serve as a source of drinking water because:

   (1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quality and location are expected to be commercially producible.

   (2) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical;

   (3) It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or

   (4) It is located over a Class III well mining area subject to subsidence or catastrophic collapse; or

(c) The total dissolved solids content of the ground water is more than 3,000 and less than 10,000 mg/L and it is not reasonably expected to supply a public water system.

The following sections describe the basis for the requested aquifer exemption, which include:

- The proposed exempted aquifer does not currently serve as a source of drinking water, and
- The proposed exempted aquifer is capable of producing minerals and contains minerals that considering their quantity and location are expected to be commercially producible.

The requested horizontal and vertical extents of the aquifer exemption boundary (AEB) are provided along with additional information in support of the aquifer exemption request, including proximity of drinking water wells, commercial producibility of the ore deposits, a description of the requested exempted aquifer, quality of water in the requested exempted aquifer, and ISR process considerations.

17.2 Requested Aquifer Exemption Boundary

The requested AEB is depicted on Figure 17.1 and includes currently identified potential well field areas, the associated perimeter monitor well rings, and an additional area outside the perimeter monitor well rings for which scientific justification is provided in Section 17.2.1. The requested AEB includes portions of Section 29-35, Township 6 South, Range 1 East, Custer County, South Dakota and Sections 1-3, 10-12, and 14-15, Township 7 South, Range 1 East, Fall River County, South Dakota. The justification is provided below for the horizontal and vertical extents of the requested AEB. When developing the requested AEB, Powertech considered the following:

- 40 CFR § 146.4, Criteria for Exempted Aquifers
- Ground Water Protection Branch Guidance 34 (EPA, 1984)
- Meetings with EPA Region 8 staff
- The recent (August 2011) precedent for the Lost Creek Project AEB in Wyoming based on similar criteria

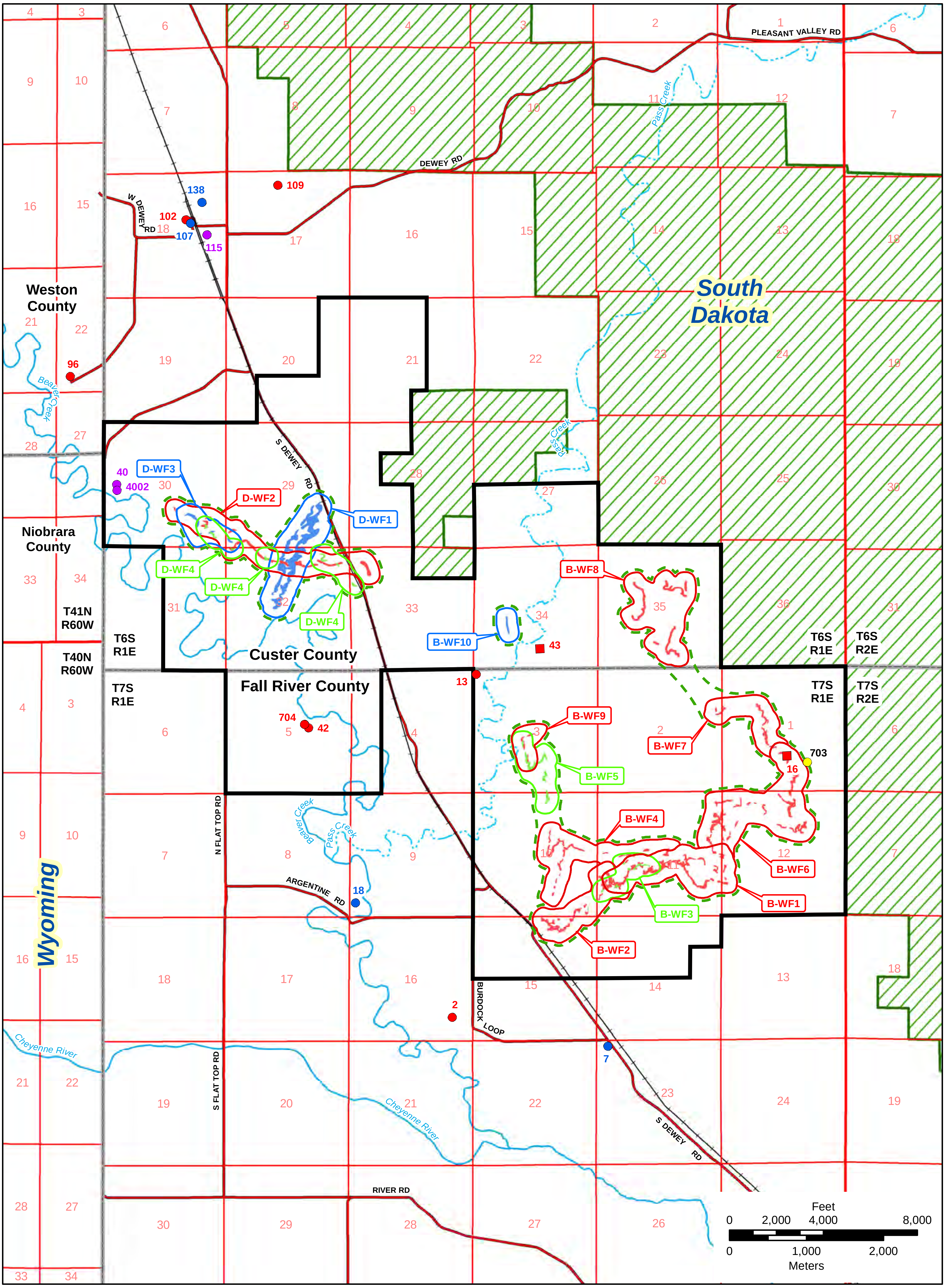
17.2.1 Horizontal Boundary Justification

The requested AEB depicted on Figure 17.1 includes the currently identified potential well field areas, the perimeter monitor well rings 400 feet from the potential well field areas, and an additional area 120 feet outside of the perimeter monitor well rings. The additional area is based on a science-based calculation that considers the distance that a potential excursion could travel prior to being detected and recovered. The justification is included in Appendix M and summarized below.

Based on meetings between Powertech and EPA Region 8 staff, it was agreed that the aquifer exemption request should include some distance beyond the monitor well ring and that a scientific approach would be used similar to that recently approved for the Lost Creek Project AEB. The proposed distance past the monitor well ring is calculated using the following equation:

$$\Delta E_b = \Delta T + \Delta d + DF$$

where ΔE_b is the distance beyond the perimeter monitor well boundary requested for inclusion in the exempted aquifer, ΔT is the calculated distance that a potential excursion could extend beyond a monitor ring outline before being detected at a perimeter monitor well, Δd is the distance that a potential excursion could travel from the time of initial detection to the time that recovery operations are implemented, and DF is a dispersivity factor.



Legend

- Project Boundary
- Proposed Aquifer Exemption Boundary
- BNSF Railroad
- County Roads
- Ephemeral Streams
- Perennial Streams
- Black Hills National Forest

Ore Bodies

- Lower Fall River
- Upper Chilson
- Middle/Lower Chilson

Potential Well Field Areas

- Lower Fall River
- Upper Chilson
- Middle/Lower Chilson

Domestic Well Screened Interval

- Chilson
- Fall River
- Inyan Kara
- Unkpapa

Domestic Non-Drinking Water Well Screened Interval

- Chilson

Figure 17.1

Proposed Aquifer Exemption Boundary

Dewey-Burdock Project

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The maximum distance that a potential excursion could travel before detection (ΔT) is approximately 47 feet based on the geometry of the monitor well rings. The estimated distance of potential excursion migration between initial detection and implementation of excursion recovery (Δd) is 24 feet based on a Darcy calculation using a hydraulic gradient representative of a well field imbalance that could cause an excursion. The dispersion factor (DF) is estimated as 10 percent of the total travel distance or 47 feet. The science-based calculation of 118 feet for ΔE_b was rounded to 120 feet for ease of surveying and plotting on maps. A distance of 120 feet provides a reasonable extension beyond the monitor ring boundary to conduct uranium recovery while remaining protective of USDWs.

17.2.2 Vertical Boundary Justification

The requested vertical extents of the AEB include the entire Inyan Kara Group. This includes the Fall River Formation and Chilson Member of the Lakota Formation, which contain the uranium mineralization targeted for ISR. As described in Sections 6.2.2 and 17.5.2, the Inyan Kara Group is bounded above throughout most of the project area by the Graneros Group shales, which serve as the uppermost confining unit for ISR operations. The Inyan Kara Group is bounded below throughout the entire project area by the Morrison Formation, which is the lowermost confining unit for ISR operations.

17.3 Proximity to Drinking Water Wells

Figure 17.1 depicts the requested AEB in relation to domestic wells. This figure shows that there is one domestic, non-drinking water well within the requested AEB. Powertech has executed an agreement with the owner of Well 16 that prohibits this well from being used for drinking water. Under the agreement the well owner may continue to use the well for other, non-drinking or culinary domestic uses such as laundry and sanitary use. Powertech will provide drinking water to the Well 16 owner through a replacement well drilled in a formation deeper than the Inyan Kara Group, a water supply pipeline, or bottled water. No other domestic wells (drinking or non-drinking water) are within the requested AEB and completed in the Inyan Kara Group.

Aside from Well 16, only one domestic well is within ¼ mile of the requested AEB and completed in the Inyan Kara Group. Well 43 was formerly used as a domestic well but is now associated with an uninhabitable residence. Powertech has committed to plugging and abandoning this well if land application is used in the Burdock area. If land application is not used, well 43 will be converted to a monitor well or plugged and abandoned. Powertech has an agreement with the well 43 owner to remove the well from private use. No currently used drinking water wells are within ¼ mile of the requested AEB and completed in the Inyan Kara Group.

17.4 Commercial Producibility of the Ore Deposits

The commercial producibility of the Dewey-Burdock Project is demonstrated by the Preliminary Economic Assessment of the Dewey Burdock Project (SRK, 2012). The Preliminary Economic Assessment was originally filed on July 14, 2010 and updated on February 8, 2011 and April 17, 2012. This document is published on SEDAR (System for Electronic Document Analysis and Retrieval) and is compliant with the National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101) of the British Columbia Securities Commission. The document was completed by a third party and confirms the resource calculations as well as the technical and economic viability of uranium recovery by ISR methods at the Dewey-Burdock Project. The report demonstrates the economic viability of the Dewey-Burdock Project using only a fraction of the historical TVA resource estimate within the project area of approximately 23 million pounds U_3O_8. Plate 17.1 depicts the historical TVA resource map.

17.5 Requested Exempted Aquifer Properties

The aquifer proposed for exemption is the Inyan Kara Group. The Inyan Kara Group contains the Fall River Formation and Chilson Member of the Lakota Formation, which contain the uranium mineralization proposed for ISR. The Inyan Kara Group within the proposed AEB has the geologic and hydrologic features that make a uranium deposit suitable for ISR as detailed in NRC (2009) based on Holen and Hatchell (1986):

- The deposit geometry generally is horizontal and of sufficient size and lateral continuity to economically extract uranium.
- The sandstone host rock is permeable enough to allow the ISR solutions to access and interact with the uranium mineralization.
- The major confining units (Graneros Group, Fuson Shale and Morrison Formation) plus local confining units within the Fall River and Chilson will prevent ISR solution from migrating vertically into overlying or underlying aquifers.
- The mineralization targeted for ISR is located in a hydrologically saturated zone.

17.5.1 Aquifer Elevation and Thickness

Within the project area, the elevation of the top of the Inyan Kara Group (i.e., Fall River Formation) ranges from approximately 3,050 feet in the western portion of the project area to approximately 3,900 feet in the eastern portion of the project area, where the Fall River Formation crops out. The elevation of the base of the Inyan Kara Group (i.e., base of the Chilson

Member) ranges from approximately 2,700 to 3,600 feet. The thickness of the Inyan Kara Group averages approximately 350 feet within the project area.

Within the requested AEB, the depth to the top of the Inyan Kara Group ranges from approximately 0 to 550 feet.

17.5.2 Confining Formations

Section 6.2.2 describes the major confining units across the project area. The Inyan Kara Group is confined above by the Graneros Group except where the Fall River Formation crops out in the eastern portion of the project area. Section 5.2.1.3 describes how analyses of core samples of the Skull Creek Shale, which is the lowest member of the Graneros Group and directly overlies the Fall River Formation, indicate low vertical permeabilities on the order of 6.8×10^{-9} cm/sec (0.007 millidarcies). The thickness of the Graneros Group ranges from 0 to more than 500 feet within the project area.

As described in Section 10.5, the only area where the Fall River Formation is geologically unconfined is in the eastern portion of the project area. Powertech does not propose to conduct ISR operations in the Fall River in this area. The Chilson throughout the project area is physically and hydraulically isolated from the overlying Fall River Formation by the Fuson Shale. The Fuson Shale consists of 20 to 80 feet of low-permeability shales and clays, with vertical permeabilities estimated from core samples to range from 7.8×10^{-9} to 2.2×10^{-7} cm/sec (0.008 to 0.228 millidarcies).

Throughout the entire project area the Inyan Kara Group is confined below by the Morrison Formation, which is a low-permeability shale unit with a thickness of 60 to 140 feet. Analyses of core samples have shown the vertical permeability to be very low and range from 3.9×10^{-9} to 4.2×10^{-8} cm/sec (0.004 to 0.04 millidarcies).

17.5.3 Hydraulic Properties

Hydraulic properties of the Fall River Formation and Chilson Member of the Lakota Formation have been determined from TVA and Powertech pumping tests as described in Section 8.2. Table 17.1 summarizes the approximate range of transmissivity, storativity, and hydraulic conductivity determined from these tests. The hydraulic properties of each well field will be determined prior to operations as described in Section 8.2.3.

Table 17.1: Hydraulic Properties of the Fall River Formation and Chilson Member of the Lakota Formation from Pumping Tests

Aquifer	Transmissivity	Hydraulic Conductivity	Storativity
Fall River	54 - 255 ft^2/day	0.4 - 1.8 ft/day	1.4 E-05 - 4.6 E-05
Chilson Member	150 - 590 ft^2/day	0.9 - 3.1 ft/day	1.0 E-04 - 1.8 E-04

17.6 ISR Process Considerations

17.6.1 Lixiviant Compatibility with Ore Body

The lixiviant will consist of groundwater pumped from the production zone and fortified with dissolved oxygen and carbon dioxide. As described in Section 7.3, this lixiviant formulation is consistent with that used in typical U.S. ISR operations, will minimize potential groundwater quality impacts during uranium recovery, and will enable restoration goals to be achieved in a timely manner.

The effectiveness of this type of lixiviant is demonstrated by leach amenability studies conducted on core samples collected within the project area. The leach amenability study results are provided in the Preliminary Economic Assessment of the Dewey-Burdock Project (SRK, 2012) and summarized as follows.

Leach amenability studies were conducted at Energy Laboratories in Casper, Wyoming in July and August 2007. Sequential leach bottle roll tests were conducted on four core intervals sampled from the Fall River and Chilson ore-bearing sandstones within the project area. The lixiviant was prepared using hydrogen peroxide and sodium bicarbonate dissolved in deionized water. This is the same type of lixiviant proposed for ISR but using chemicals compatible with ambient pressure leach studies (i.e., hydrogen peroxide as the oxidant and bicarbonate as the complexing agent instead of gaseous oxygen and carbon dioxide, which cannot be dissolved in sufficient quantities at ambient pressure).

In each test, a crushed ore sample was successively contacted with approximately 30 pore volumes of lixiviant. Tails analysis indicated recovery efficiencies of 71% to 98%. The Preliminary Economic Analysis concludes that, "These preliminary leach tests indicate that the uranium deposits at Dewey-Burdock appear to be readily mobilized in oxidizing solutions and potentially well suited for ISR mining."

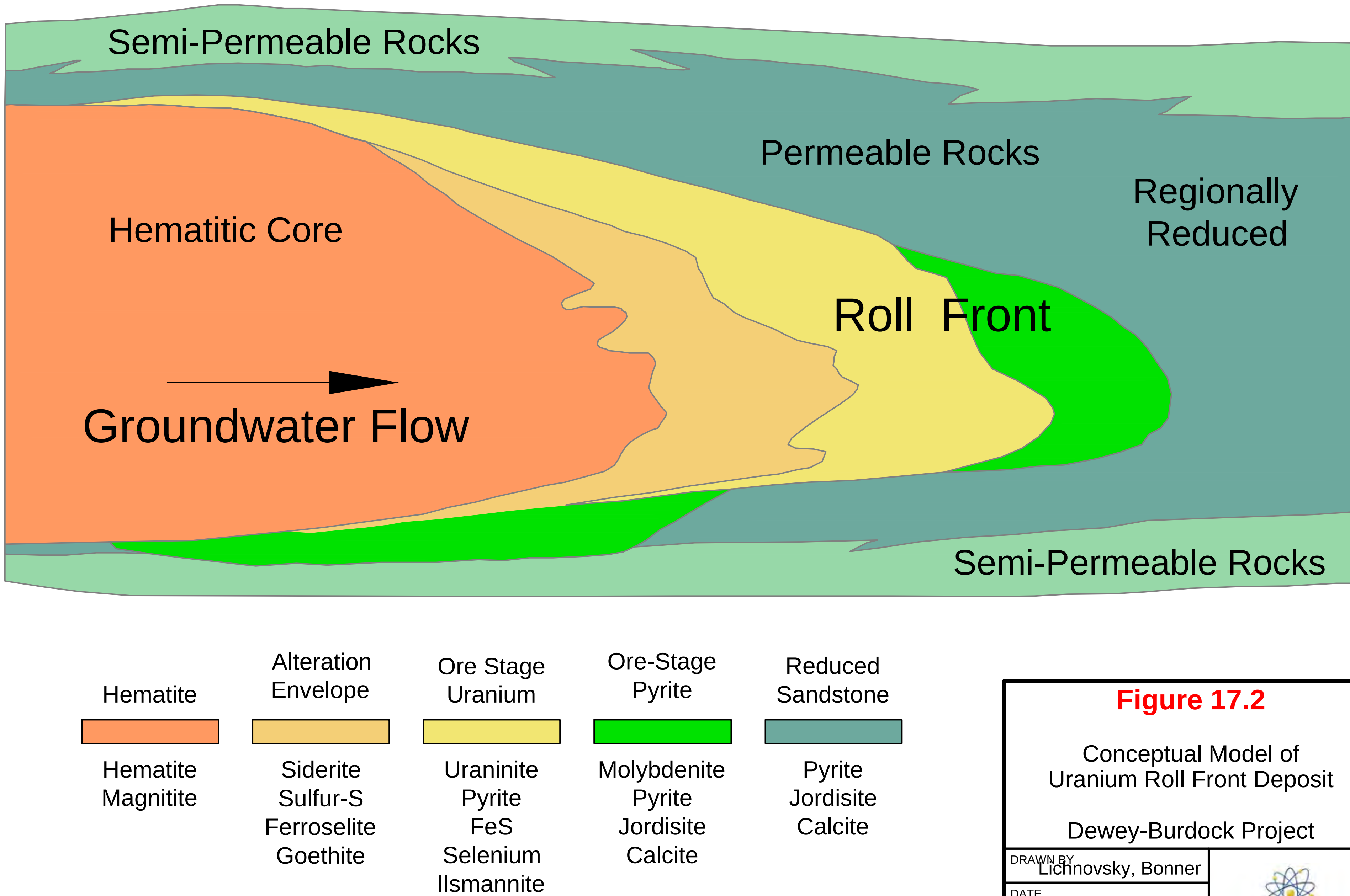
17.6.2 Mineralogy of the Uranium Ore

Uranium deposits within the project area are classic, sandstone, roll-front type deposits, located along oxidation-reduction boundaries, similar to those in Wyoming, Nebraska and Texas. These type deposits are usually “C” shaped in cross section, with the concave side of the deposit facing up-dip, toward the outcrop. Roll-front deposits are a few tens of feet to 100 or more feet wide and often thousands of feet long. It is generally believed these epigenetic uranium deposits are the result of uranium minerals leached from the surface environment, transported downgradient by oxygenated groundwater and precipitated in the subsurface upon encountering a reducing environment at depth. These roll-front deposits are centered at and follow the interface of naturally occurring chemical boundaries between oxidized and reduced sands (See Figure 17.2). Roll-front deposits similar to those in the project area are generally described in NRC (2009).

Within the project area, roll-front deposits occur at depths ranging from less than 100 feet in the outcrop area of the Fall River Formation up to 800 feet in sands of the Chilson Member of the Lakota Formation in the northwestern part of the project area. The mineralized sandstones are typically fine to medium-grained quartz sands that are moderately to very well sorted and show sub-angular to sub-rounded grain angularity. Scattered pyrite concretions up to 1" in diameter are sometimes present as are very thin carbonaceous stringers and very well cemented calcite zones. The average thickness of this mineralization is 4.6 feet and the average grade is 0.21 percent U_3O_8 in the project area.

There is a geochemical “footprint” associated with these uranium roll-front systems, consisting of 1) a reduced zone, 2) an oxidized zone, and 3) an ore zone. The following is a geological and geochemical description of each of these zones for uranium deposits within the project area. Information included in this description was obtained from a 1971 petrographic study of core samples from the Dewey portion of the project area by Homestake-Wyoming Partners utilizing microscopic, thin section, polished section, X-ray powder diffraction and spectrographic analyses (Honea, 1971).

> **Reduced Zone –** This zone represents the original character of the Inyan Kara sediments, unaffected by any mineralizing events. Today, it is the unaltered portion of the system, ahead of or down-gradient of the roll front. Reduced sandstones are grey in color, pyritic and/or carbonaceous. Organic material consists of carbonized wood fragments and interstitial humates. Pyrite is abundant within the host sandstones and present as very small cubic crystals or as very fine grained aggregates. Marcasite is also present as nodular masses in the sandstones. This disseminated pyrite resulted from replacement of original iron (magnetite or similar minerals) and organic material. This early-stage pyrite precipitation contains trace amounts of transition metals (Cu, Ni, Zn, Mo and Se) and



Source: Uranium Geology and Exploration, 1978, Richard H. DeVoto

Figure 17.2

Conceptual Model of
Uranium Roll Front Deposit

Dewey-Burdock Project

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resulted from either biogenic (bacterial) or inorganic reduction of groundwater sulfate. Plagioclase and potassium feldspar clasts are fresh and, with the exception of localized areas of calcite cementing, calcite is sparse - averaging only 0.15%. A heavy mineral suite (ranging from trace to 3%) of tourmaline, ilmenite, apatite, zircon and garnet is typical of those found in mature, siliceous sandstones.

Oxidized Zone – This portion of the system, behind or upgradient of the roll front, is characterized by the presence of iron oxides resulting in a brown, pink, orange or red staining of host sandstones. The oxidized zone marks the progression of the down-gradient movement of mineralizing solutions through the host sandstones. Within the oxidized zone, original iron has been altered and is present as hematite or goethite as grain coatings, clastic particles or as pseudomorphs after original pyrite. Goethite is considered to be metastable and is found near the oxidation/reduction boundary, while the more stable hematite is found greater distances upgradient from the roll front. The heavy mineral leucoxene – a white titanium oxide – is also present as a pseudomorph of ilmenite. All organic material has been destroyed in the oxidized zone, where quartz particles show solution or etching effects and feldspars have been replaced with clays.

In the oxidation process of the original pyrite, it is believed the transition metals (Cu, Ni, Zn, Mo and Se) were liberated and incorporated into the mineralizing solution. This solution was slightly alkaline, initially having a positive oxidation potential. Uranium was in solution as the anionic uranyl dicarbonate complex. Other metals associated with uranium were also carried in anionic complexes. Within the project area, the oxidized zone in Inyan Kara sands has been mapped over a lateral distance of 15 miles and found to extend up to 4-5 miles down-dip from the outcrop.

Ore Zone – This portion of the system is located at the oxidation/reduction boundary where metals were precipitated when mineralizing solutions encountered a steep Eh (oxidation/reduction potential) gradient and a strongly negative oxidation potential. Sandstones in this zone are greenish-black, black, or dark grey in color. The primary uranium minerals are uraninite and coffinite, which occur interstitial to and coating sand grains and as intergrowths with montroseite (VO(OH)) and pyrite. Other vanadium minerals (haggite and doloresite) are found adjacent to the uranium mineralization, extending up to 500 feet into the oxidized portion of the system. Overall, the V:U ratios can be as high as 1.5:1. The high concentrations of uranium and vanadium within the ore zone indicate the original source of these metals was external to the Inyan Kara sediments.

Transition metals were also precipitated at or adjacent to the oxidation/reduction boundary. Native arsenic and selenium are found adjacent to the uranium, in the oxidized portion of the front - filling pore spaces between quartz grains. Molybdenum is found as jordisite adjacent to the uranium on the reduced portion of the front. The relatively low concentrations of transition metals indicate their source could have been internal to the Inyan Kara sediments rather than having been introduced from overlying tuffaceous material which is believed to be the source of the uranium and vanadium.

Late stage deposition of calcite and pyrite also appear to be part of the ore-forming process. Filling of pore spaces by nodular and concretionary calcite is found with the uranium mineralization and extending out into the reduced portion of the front. It is believed that uranium was transported as a uranyl dicarbonate complex and carbonate deposition took place along with the precipitation of uranium. Late stage, coarse grained, nodular or concretionary pyrite is also found associated with uranium ore and adjacent to the uranium in the reduced portion of the front.

17.6.3 Well Field Construction and Completion

Section 11 (Attachment M) describes the well construction materials and methods. Typical well casing will be 4.5 to 6-inch nominal diameter PVC with at least SDR 17 wall thickness. Powertech will adhere to the requirements of ASTM F480 and manufacturer's criteria to ensure that the installations do not exceed the casing hydraulic collapse resistance. Casing joints will be mechanical joints with watertight O-ring seals and high-strength nylon splines to ensure watertight joints. The drill holes will be at least 2 inches larger than the outside well casing diameters, and the annular spaces will be pressure-grouted with sufficient additional grout to achieve return to surface. Centralizers will be used to ensure the casings are centered in the holes. After allowing the grout to set, the target completion zone will be underreamed and a well screen assembly will be centralized and sealed inside the casing using K packers. Filter sand will be placed between the well screen and formation. Geophysical logs will be used to determine the target completion intervals.

17.6.4 Mechanical Integrity Testing

Section 11.5 describes MIT that will be performed on all injection, production, and monitor wells prior to operation, at least every 5 years, and following any repair where a downhole drill bit or underreaming tool is used. For injection wells, MIT will be performed at 125 percent of the maximum operating pressure of the well field, 125 percent of the maximum operating pressure of the well casing, or 90 percent of the formation fracture pressure, whichever is less. A well must maintain 90 percent of the MIT hydrostatic test pressure for a minimum of 10 minutes to pass the test.

17.6.5 Hydraulic Well Field Control

Section 10.4 describes how Powertech will maintain hydraulic control of each well field from the first injection of lixiviant through the end of aquifer restoration. This will be done by maintaining a production and restoration bleed, which will create a cone of depression within each well field. The typical production bleed is estimated at 0.875%, and the typical restoration bleed will range from about 1 to 17%. Verification of hydraulic control will be performed through water level measurements in perimeter monitor wells.

17.6.6 Groundwater Monitoring

Section 14.2 describes the excursion monitoring program that will be conducted to detect potential horizontal or vertical excursions of ISR solutions. Perimeter monitor wells will be completed in the ore zone around the perimeter of each well field at a maximum distance of 400 feet from the well field. They will be used to monitor any potential horizontal migration of fluid outside the production zone and to determine baseline water quality and characterize the area outside of the production pattern area. Non-production zone monitor wells will consist of overlying and underlying monitor wells that will be used to monitor any potential vertical migration of ISR solutions. Monitor wells will be sampled during uranium recovery and aquifer restoration operations. Corrective actions will be initiated in the event of an excursion to correct a potential well field balance and recover ISR solutions well before they can reach the AEB (refer to Section 13.3.1).

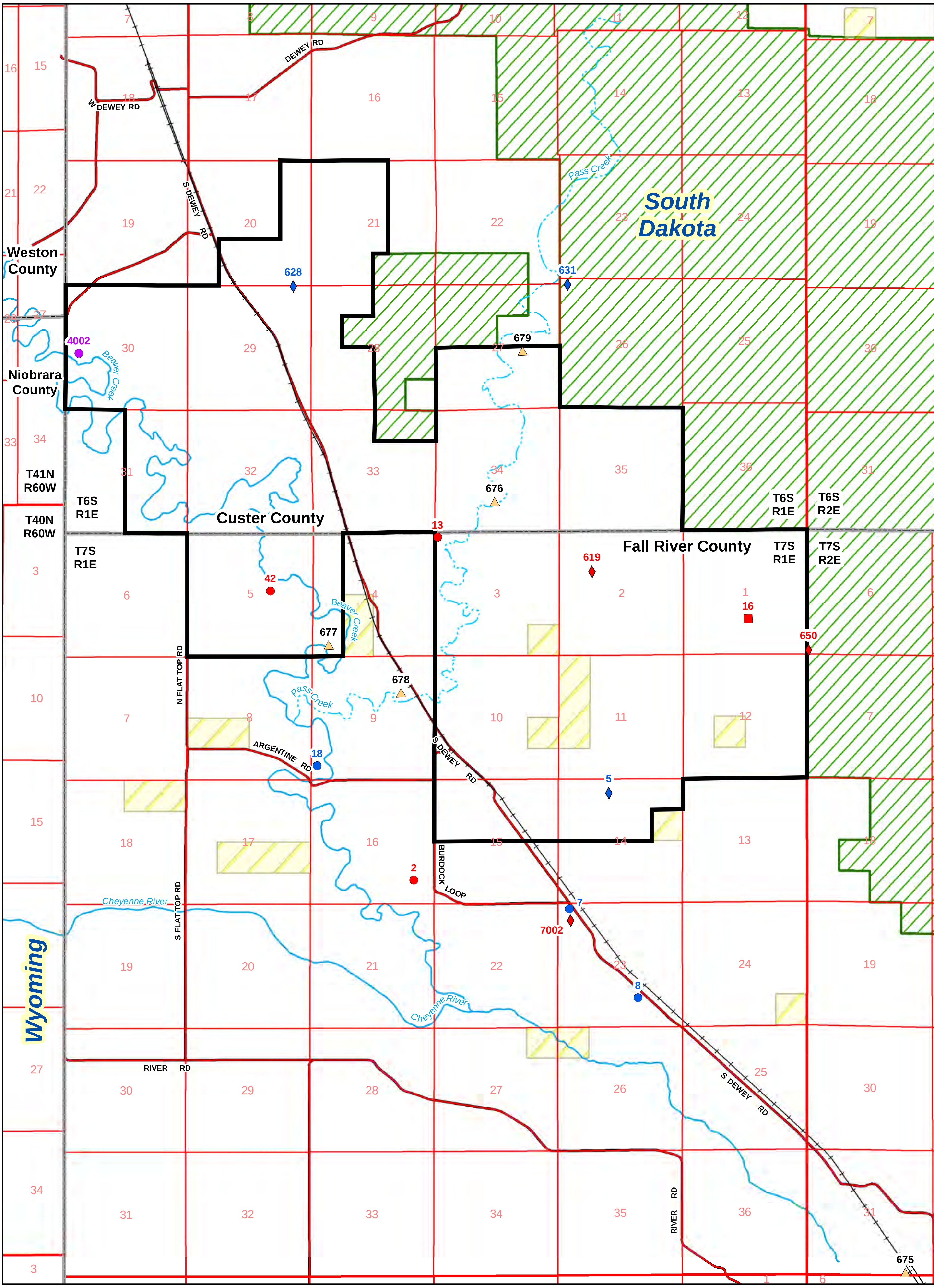
Section 14.3 describes the operational groundwater monitoring program that will be used to detect potential changes in groundwater quality in and around the project area as result of ISR operations. The operational groundwater monitoring program will include domestic wells, stock wells, and wells located hydrologically upgradient and downgradient from ISR well fields.

17.7 Water Quality of the Requested Exempted Aquifer

This section describes the results of baseline water quality sampling in the Inyan Kara Group within the project area, including the Fall River and Chilson Member of the Lakota formations. Water quality summary tables for the Inyan Kara Group and other aquifers (alluvium and Unkpapa) are provided in Appendix N, and analytical data are provided in Appendix O. Additional baseline characterization of the requested exempted aquifer will occur as part of the development of the well field hydrogeologic data packages described in Section 8.2.4.

17.7.1 Groundwater Monitoring Network and Parameters

Baseline groundwater sampling was conducted in accordance with NRC Regulatory Guide 4.14 (NRC, 1980b) as appropriate to ISR operations. The wells were selected based on type of use, aquifer, and location in relation to the ore bodies. For the NRC license baseline study, 19 wells (14 existing and 5 newly drilled) were selected in response to an NRC suggestion to characterize point of contact water quality and water within overlying, production, and underlying aquifers (Figure 17.3, Table 17.2). The wells selected for quarterly sampling included domestic, stock, and monitor wells. The subset included wells within the Fall River Formation, Chilson Member of the Lakota Formation, Inyan Kara Group (Fall River and Chilson), and alluvium. Initial



Legend

- Permit Boundary
- BNSF Railroad
- County Roads
- Ephemeral Streams
- Perennial Streams
- BLM Land
- Black Hills National Forest

Screened Interval

- Alluvium
- Fall River
- Inyan Kara
- Chilson

Well Use

- Monitor
- Stock
- Domestic
- Domestic Non-Drinking Water

Feet: 0, 2,000, 4,000, 8,000

Meters: 0, 1,000, 2,000

N

Figure 17.3

Baseline Water Quality
Quarterly Sampled Wells

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	12-Jul-2012
FILENAME	Wells-BLQtrGndH2OQlty.mxd

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019140

Table 17.2: Quarterly Sampled Groundwater Quality Well Data

Hydro ID	Twn (N)	Rng (E)	Sec	Qtr Qtr	Easting[1]	Northing[1]	Screened Location[2]	Well Use
2	7	1	16	SESE	1026724	423922	Chilson	Domestic
5	7	1	14	NENW	1035181	427284	Fall River	Stock
7	7	1	23	NWNW	1033304	422417	Fall River	Domestic
8	7	1	23	SWSE	1036052	418515	Fall River	Domestic
13	7	1	3	NWNW	1028360	438470	Chilson	Domestic
16	7	1	1	NESW	1041428	434446	Chilson	Domestic
18	7	1	9	SWSW	1022812	428960	Fall River	Domestic
42	7	1	5	SWNE	1021144	436481	Chilson	Domestic
619	7	1	2	SENW	1034866	436729	Chilson	Stock
628	6	1	20	SESE	1022496	449718	Fall River	Stock
631	6	1	26	SWSW	1034177	449309	Fall River	Stock
650	7	1	1	SESE	1043781	433331	Chilson	Stock
675	7	2	31	SWSE	1046941	406352	Alluvium	Monitor
676	6	1	34	SESW	1030846	439891	Alluvium	Monitor
677	7	1	4	SWSW	1023527	434077	Alluvium	Monitor
678	7	1	9	SWNE	1026522	431925	Alluvium	Monitor
679	6	1	27	NWSE	1032294	446245	Alluvium	Monitor
4002	6	1	30	NWSW	1013414	446931	Inyan Kara	Domestic
7002	7	1	23	NWNW	1033333	421931	Chilson	Stock

Notes: [1] Coordinate system is NAD 27 South Dakota State Plane South.
[2] Inyan Kara indicates that screened interval includes both Chilson and Fall River.

baseline sampling of these wells was conducted quarterly, generally from the 3rd Quarter 2007 through the 2nd Quarter 2008.

Following consultation with DENR, Powertech sampled 14 additional wells on a monthly basis (Figure 17.4, Table 17.3). Of these 14 wells, 6 wells are in the Dewey area, 6 wells are in the Burdock area and 2 wells are north of the project area. The goal of the monthly sampling program was to select wells upgradient, within, and downgradient of the proposed ISR activities.

Figure 17.5 depicts the location of the wells in relation to proposed ISR activities. As part of the 2008 pumping tests, one water quality sample was collected from 10 additional wells (49, 682, 684, 685, 686, 687, 690, 691, 692 and 693 in Table 17.4). One sample also was collected from two new Unkpapa domestic wells (703 and 704 in Table 17.4). One sample also was collected from well 704 after it was completed in the Chilson.

Groundwater samples were analyzed for a constituent list developed based on NUREG-1569 groundwater parameters (NRC, 2003), Regulatory Guide 4.14 parameters (NRC, 1980b), and added parameters from a constituent-list review with DENR.

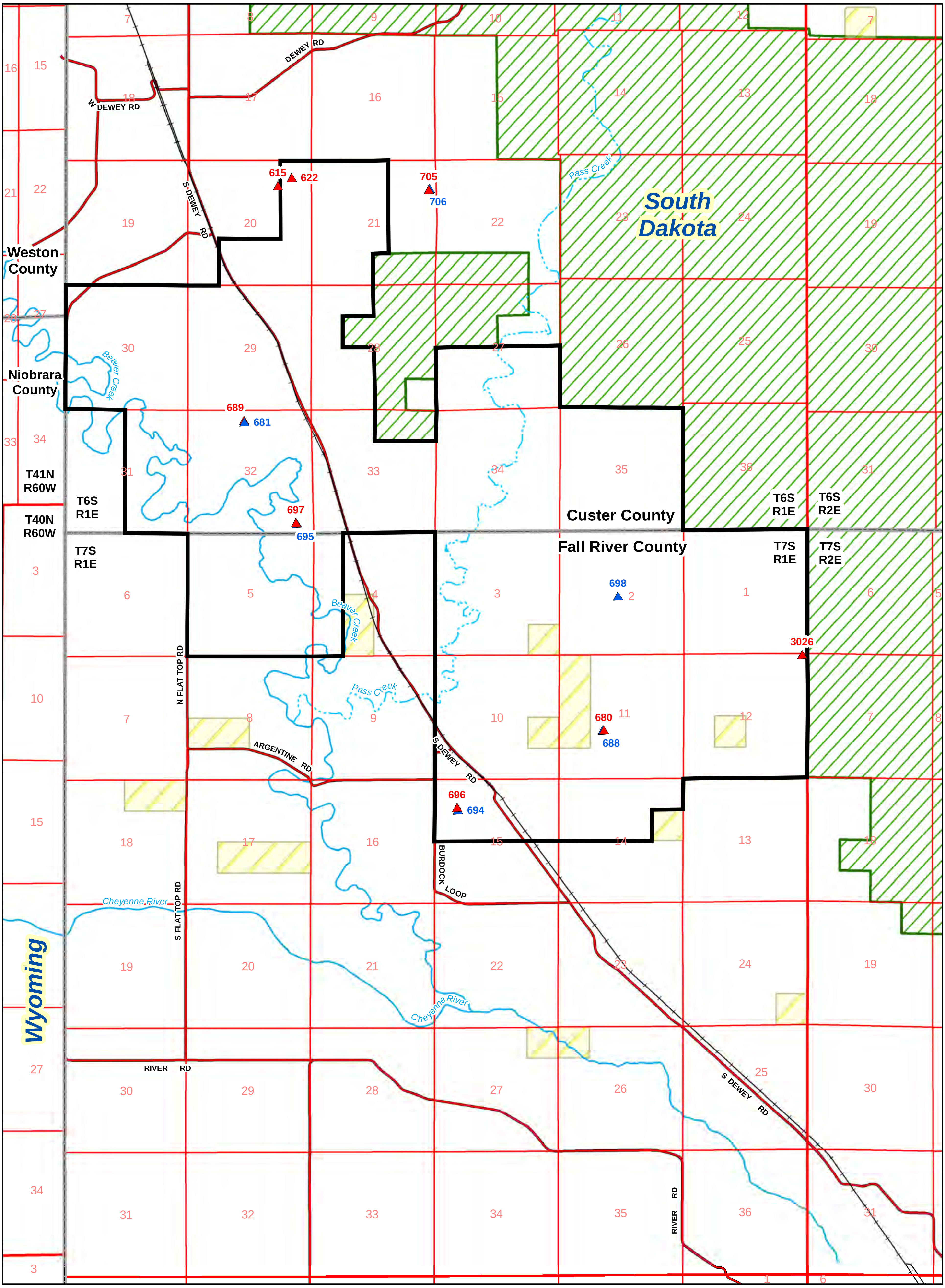
17.7.2 Groundwater Quality Sampling Results

Water quality summary tables providing groundwater quality results for all aquifers are provided in Appendix N, and analytical data are provided in Appendix O.

Consistent with NRC guidance in Section 2.7.4 of NUREG-1569 (NRC, 2003), groundwater and surface water analytical data are presented in tables on a date-by-date, parameter-by-parameter, and well-by-well basis. The following describes the presentation of data in Appendix N.

All field-measured parameters, including water level elevations for groundwater sampling locations, are presented with the corresponding laboratory data. For concentrations reported as non-detect by the laboratory, the data are reported as "< RL" where RL is the laboratory reporting limit. The summary tables present the minimum, maximum and mean concentrations for each parameter at each sample location. Means were calculated using a value of ½ of the RL when non-detect data occurred. Maximum values were calculated as the highest detected value for each constituent at each well, even where a detected concentration is lower than a previous RL.

Groundwater quality summary tables are provided at the beginning of Appendix N describing the mean, standard deviation, minimum, and maximum values for each constituent in the four zones monitored. The monitored zones, in descending order, are the alluvium, Fall River Formation,



Legend

- Permitt Boundary
- BNSF Railroad
- County Roads
- Ephemeral Streams
- Perennial Streams
- BLM Land
- Black Hills National Forest

Aquifer

- Fall River Monitor Well
- Chilson Monitor Well

Figure 17.4

Baseline Water Quality
Monthly Sampled Wells

Dewey-Burdock Project

DRAWN BY	Mays, Hetrick
DATE	03-Jul-2012
FILENAME	Wells-BLQtrGndH2OMthly.mxd

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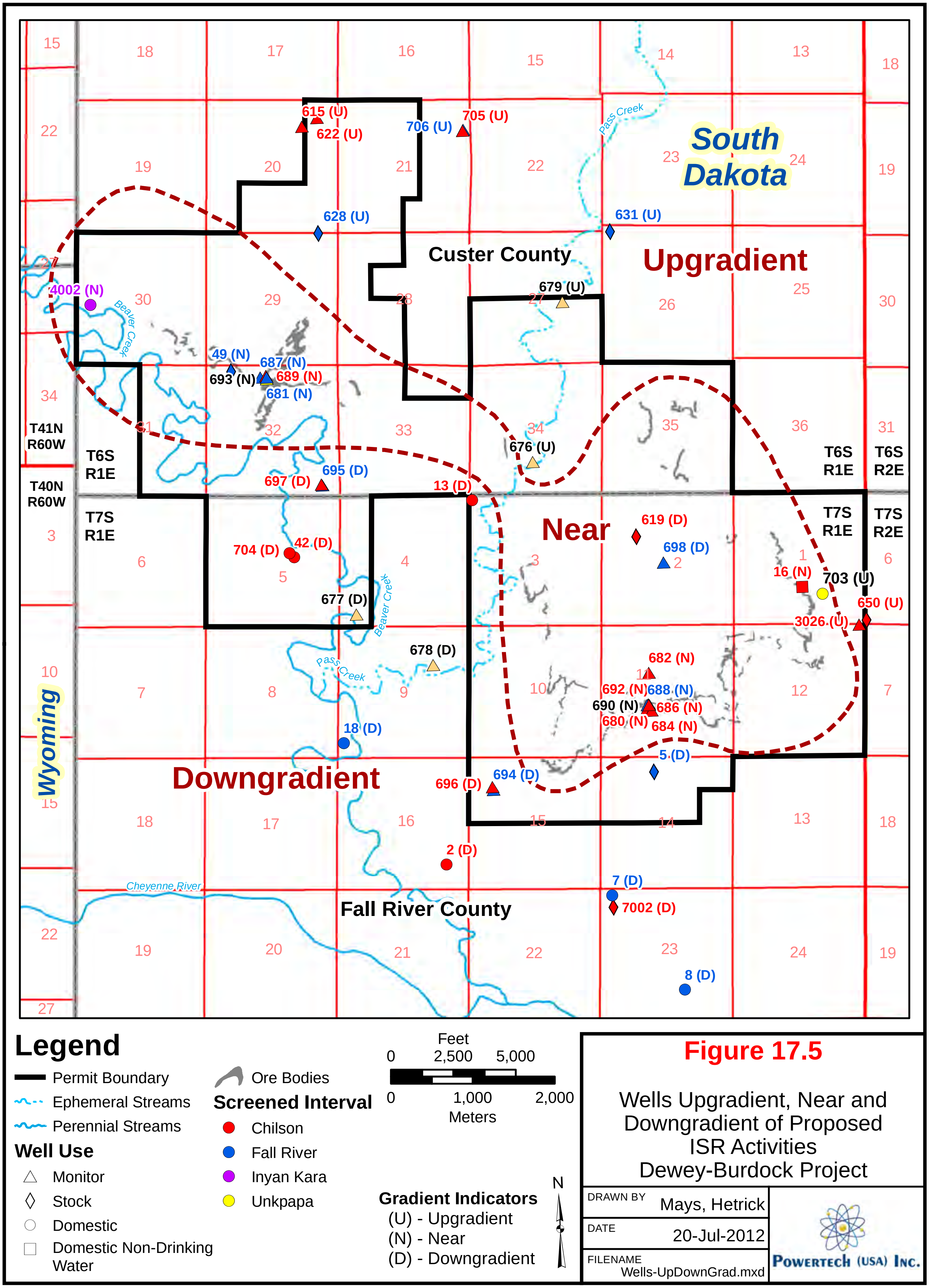
Table 17.3: Monthly Sampled Groundwater Quality Well Data

Hydro ID	Twn (N)	Rng (E)	Sec	Qtr Qtr	Easting[1]	Northing[1]	Screened Location	Well Use
615	6	1	20	NWNE	1022172	453708	Chilson	Monitor
622	6	1	20	NENE	1022776	454033	Chilson	Monitor
680	7	1	11	NESW	1035078	429969	Chilson	Monitor
681	6	1	32	NENW	1020330	443725	Fall River	Monitor
688	7	1	11	NESW	1035027	429974	Fall River	Monitor
689	6	1	32	NENW	1020316	443789	Chilson	Monitor
694	7	1	15	NWNW	1028717	426836	Fall River	Monitor
695	6	1	32	SESE	1022385	439312	Fall River	Monitor
696	7	1	15	NWNW	1028538	427141	Chilson	Monitor
697	6	1	32	SESE	1022350	439347	Chilson	Monitor
698	7	1	2	NESW	1035909	435651	Fall River	Monitor
705	6	1	21	NENE	1028624	453314	Chilson	Monitor
706	6	1	21	NENE	1028589	453276	Fall River	Monitor
3026	7	1	12	NENE	1043638	432833	Chilson	Monitor

Note: [1] Coordinate system is NAD 27 South Dakota State Plane South.



South Dakota
Wyoming
Custer County
Fall River County
Upgradient
Near
Downgradient
T41N R60W
T40N R60W
T6S R1E
T7S R1E
T6S R2E
T7S R2E
Beaver Creek
Pass Creek
Cheyenne River
615 (U)
622 (U)
706 (U)
705 (U)
628 (U)
631 (U)
679 (U)
4002 (N)
49 (N)
687 (N)
693 (N)
689 (N)
681 (N)
676 (U)
695 (D)
697 (D)
13 (D)
619 (D)
698 (D)
704 (D)
42 (D)
16 (N)
703 (U)
650 (U)
3026 (U)
677 (D)
678 (D)
682 (N)
692 (N)
688 (N)
690 (N)
686 (N)
680 (N)
684 (N)
18 (D)
5 (D)
694 (D)
696 (D)
2 (D)
7 (D)
7002 (D)
8 (D)
Legend
Permit Boundary
Ephemeral Streams
Perennial Streams
Ore Bodies
Screened Interval
Chilson
Fall River
Inyan Kara
Unkpapa
Well Use
Monitor
Stock
Domestic
Domestic Non-Drinking Water
Feet
0 2,500 5,000
0 1,000 2,000
Meters
Gradient Indicators
(U) - Upgradient
(N) - Near
(D) - Downgradient
N
Figure 17.5
Wells Upgradient, Near and Downgradient of Proposed ISR Activities
Dewey-Burdock Project
DRAWN BY Mays, Hetrick
DATE 20-Jul-2012
FILENAME Wells-UpDownGrad.mxd
POWERTECH (USA) INC.

Table 17.4: Additional Well Data

Hydro ID	Twn (N)	Rng (E)	Sec	Qtr Qtr	Easting[1]	Northing[1]	Screened Location	Well Use
49	6	1	32	NWNW	1018932	444022	Fall River	Stock
682	7	1	11	SENW	1035139	431257	Chilson	Monitor
684	7	1	11	NESW	1035191	429744	Chilson	Monitor
685	6	1	32	NWNE	1020690	443409	Fall River	Monitor
686	7	1	11	NESW	1034970	429749	Chilson	Monitor
687	6	1	32	NENW	1020081	443724	Fall River	Monitor
690	7	1	11	NESW	1035114	429970	Unkpapa	Monitor
691	6	1	32	NENW	1020364	443698	Fall River	Monitor
692	7	1	11	NESW	1035075	430014	Chilson	Monitor
693	6	1	32	NENW	1020327	443661	Unkpapa	Monitor
703	7	1	1	SWSE	1041621	434334	Unkpapa	Domestic
704	7	1	5	SWNE	1020966	436647	Unkpapa/Chilson[2]	Domestic

Notes: [1] Coordinate system is NAD 27 South Dakota State Plane South.
[2] Well was originally completed in the Unkpapa and later in the Chilson.

Chilson Member of the Lakota Formation, and Unkpapa Sandstone. Only the results of the Fall River and Chilson, the primary focus of this Class III UIC application, are discussed below. Refer to Powertech (2011) for additional description of sample results including relationships between dissolved, suspended, and total fractions of various constituents.

Fall River Formation Sample Results

Table 17.5 provides a summary of the water quality within the Fall River and Chilson. The ranges shown represent the range of the average concentrations for the wells in each monitoring zone. They do not represent the minimum and maximum absolute sample concentrations for any one well. Table 17.6 summarizes the major ion chemistry of the Fall River wells. The water quality in the Fall River Formation is characterized by moderate TDS (774 to 2,250 mg/L), relatively consistent major ion chemistry, and high radionuclide concentrations. Sodium is the dominant cation in 75% of wells (9 of 12). Of the remaining three wells, two exhibited calcium dominance and one well did not have a dominant cation (i.e., all less than 50%). All of the Fall River baseline wells exhibited strong sulfate dominance, with sulfate accounting for 73% to 92% of the anion concentration (in meq/L). While many of the Fall River Formation baseline wells were outside of the ore zone and yielded low to non-detectable radionuclide concentrations, the maximum radionuclide concentrations in the Fall River Formation were often relatively high. For example, the highest average gross alpha concentration (dissolved) was 1,505 pCi/L in well 698, and the highest average radon-222 concentration was 278,030 pCi/L in well 681.

Chilson Sample Results

The water quality in the Chilson Member of the Lakota Formation is characterized by moderate TDS (708 to 2,358 mg/L), relatively consistent major ion chemistry, and often high radionuclide concentrations. Table 17.7 summarizes the major ion chemistry of the Chilson wells. Sodium is the dominant cation in 53% of wells (8 of 15). Four wells (27%) exhibited calcium dominance and three wells (20%) did not have a dominant cation. All of the Chilson baseline wells exhibited strong sulfate dominance, with sulfate accounting for 71% to 92% of the anion concentration (in meq/L). Many of the Chilson baseline wells yielded relatively high radionuclide concentrations. For example, the highest average gross alpha concentration (dissolved) was 4,991 pCi/L in well 680, and the highest average radon-222 concentration was 180,750 pCi/L in well 42.

17.7.3 Comparison with Drinking Water Standards

Table 17.8 compares the Fall River and Chilson groundwater sample results with EPA MCLs and one secondary standard (sulfate). The table shows that most of the Inyan Kara wells exceeded the gross alpha and radium-226 MCLs in one or more samples, and some of the wells

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Table 17.5: Summary of Water Quality by Formation

Constituent	Units	Fall River	Chilson
Field Parameters			
Water Level Elevation	ft AMSL	3,574.6 - 3,725.1	3,647.9 - 3,709.7
Field Temperature	°C	11.1 - 14.9	9.4 - 15.4
Field pH	s.u.	6.7 - 8.4	6.9 - 8.3
Field Dissolved Oxygen	mg/L	0.07 - 5.4	0.1 - 3.3
Field Conductivity	umhos/cm	1,223 - 2,623	958 - 2,750
Field Turbidity	NTU	0.1 - 13.1	0.4 - 29.3
Physical Properties			
Conductivity @ 25°C	umhos/cm	1,201 - 2,870	1,055 - 2,688
Oxidation-Reduction Potential	mV	129 - 258	32 - 236
pH	s.u.	7.1 - 8.5	7.1 - 8.1
Sodium Adsorption Ratio (SAR)	unitless	1.0 - 11.4	0.9 - 10.2
Solids, Total Dissolved TDS @ 180 C	mg/L	774 - 2,250	708 - 2,358
Common Elements and Ions			
Alkalinity, Total as $CaCO_3$	mg/L	117 - 197	71 - 261
Carbonate as CO3	mg/L	<5 - 7.9	<5 - 3.1
Bicarbonate as HCO_3	mg/L	143 - 240	87 - 318
Calcium	mg/L	30 - 368	35 - 386
Chloride	mg/L	9.5 - 47	5.0 - 17.5
Fluoride	mg/L	0.3 - 0.5	0.1 - 0.6
Magnesium	mg/L	10.5 - 134	11.8 - 124
Nitrogen, Ammonia as N	mg/L	<0.1 - 0.4	<0.1 - 0.6
Nitrogen, Nitrate as N	mg/L	<0.1 - 0.06	<0.1 - 0.08
Nitrogen, Nitrite as N	mg/L	<0.1	<0.1 - 0.15
Potassium	mg/L	7.1 - 16	7.2 - 21
Sodium	mg/L	87 - 503	47 - 283
Sulfate	mg/L	425 - 1,443	389 - 1,509
Silica	mg/L	5.2 - 11.2	1.2 - 8.6
Metals - Dissolved			
Aluminum	mg/L	<0.1	<0.1 - 0.19
Arsenic	mg/L	<0.001 - 0.002	<0.01 - 0.016
Barium	mg/L	<0.1	<0.1
Boron	mg/L	<0.1 - 0.43	<0.1 - 0.15
Cadmium	mg/L	<0.005 - <0.01	<0.005 - <0.01
Chromium	mg/L	<0.05	<0.05
Copper	mg/L	<0.01	<0.01 - 0.025
Iron	mg/L	<0.03 - 2.58	<0.03 - 6.2
Lead	mg/L	<0.001 - 0.0011	<0.001 - 0028
Manganese	mg/L	0.03 - 2.41	0.04 - 1.5
Mercury	mg/L	<0.001	<0.001
Molybdenum	mg/L	<0.1	<0.1 - 0.067
Nickel	mg/L	<0.05 - 0.03	<0.05 - 0.024
Selenium	mg/L	<0.001 - 0.0014	<0.001 - 0.0014
Silver	mg/L	<0.005 - <0.01	<0.005 - <0.01

Table 17.5: Summary of Water Quality by Formation (cont'd)

Constituent	Units	Fall River	Chilson
Metals - Dissolved			
Thorium-232	mg/L	<0.005	<0.005
Uranium	mg/L	<0.0003 - 0.11	<0.0003 - 0.034
Vanadium	mg/L	<0.1 - 0.06	<0.1 - 0.05
Zinc	mg/L	<0.01 - 0.0125	<0.01 - 0.06
Metals - Dissolved - Speciated			
Selenium-IV	mg/L	<0.001 - 0.0007	<0.001 - 0.0005
Selenium-VI	mg/L	<0.001 - 0.0007	<0.001 - 0.0010
Metals - Suspended			
Uranium	mg/L	<0.0003 - 0.0031	<0.0003 - 0.0014
Metals - Total			
Antimony	mg/L	<0.003	<0.003 - 0.002
Arsenic	mg/L	0.0008 - 0.0038	0.001 - 0.023
Barium	mg/L	<0.1	<0.1 - 0.067
Beryllium	mg/L	<0.001 - <0.005	<0.001 - 0.0005
Boron	mg/L	<0.1 - 0.45	<0.001 - 0.17
Cadmium	mg/L	<0.005	<0.005
Chromium	mg/L	<0.05	<0.05
Copper	mg/L	<0.01	<0.01 - 0.043
Iron	mg/L	0.04 - 4.8	0.08 - 15.3
Lead	mg/L	<0.001 - 0.002	<0.001 - 0.026
Manganese	mg/L	0.03 - 2.49	0.04 - 1.74
Mercury	mg/L	<0.001	<0.001
Molybdenum	mg/L	<0.01 - 0.03	<0.01 - 0.075
Nickel	mg/L	<0.05	<0.05
Selenium	mg/L	<0.001 - 0.001	<0.001 - 0.0019
Silver	mg/L	<0.005 - <0.02	<0.005 - <0.02
Strontium	mg/L	0.65 - 6.2	0.7 - 7.5
Thallium	mg/L	<0.001	<0.001 - 0.0006
Uranium	mg/L	<0.0003 - 0.11	<0.0003 - 0.02
Zinc	mg/L	<0.01 - 0.01	<0.01 - 0.13
Radionuclides - Dissolved			
Gross Alpha	pCi/L	5.6 - 1,505	3.6 - 4,991
Gross Beta	pCi/L	3.2 - 484	7.8 - 1,629
Gross Gamma	pCi/L	216 - 4,994	70 - 15,530
Lead-210	pCi/L	-1.9 - 29.7	-5.6 - 19.3
Polonium-210	pCi/L	0.02 - 2.36	0.02 - 2.03
Radium-226	pCi/L	1.2 - 388	1.2 - 1,289
Thorium-230	pCi/L	0.01 - 0.13	0.04 - 0.20
Radionuclides - Suspended			
Lead-210	pCi/L	-1.5 - 11.8	-1.65 - 22.1
Polonium-210	pCi/L	0.03 - 2.2	0.02 - 4.1
Radium-226	pCi/L	-0.2 - 7.9	-0.15 - 6.3
Thorium-230	pCi/L	-0.07 - 1.29	-0.14 - 0.3

Table 17.5: Summary of Water Quality by Formation (cont'd)

Constituent	Units	Fall River	Chilson
Radionuclides - Total			
Lead-210	pCi/L	<1	<1 - 57
Polonium-210	pCi/L	<1 - 6.4	<1 - 13
Radium-226	pCi/L	<0.2 - 15.2	1.1 - 120
Radon-222	pCi/L	277 - 278,030	197 - 180,750
Thorium-230	pCi/L	<0.2	<0.2

Table 17.6: Fall River Formation Major Ion Chemistry

Major Cations							
Hydro ID	Calcium		Magnesium		Sodium		Dominant Cation
	meq/L	%	meq/L	%	meq/L	%	
5	6.2	19%	4.1	13%	21.9	68%	sodium
7	1.8	12%	1.2	8%	11.9	80%	sodium
8	2.7	19%	1.9	14%	9.6	67%	sodium
18	1.7	12%	1.0	7%	12.0	82%	sodium
628	2.0	11%	1.4	8%	13.9	81%	sodium
631	15.9	58%	7.5	27%	4.0	15%	calcium
681	3.1	22%	2.0	14%	9.2	64%	sodium
688	2.3	19%	1.6	13%	8.3	68%	sodium
694	1.5	10%	0.9	6%	12.3	84%	sodium
695	3.8	23%	2.2	13%	10.5	64%	sodium
698	18.4	55%	11.0	33%	3.8	11%	calcium
706	8.3	47%	3.9	22%	5.6	31%	not any
Major Anions							
Hydro ID	Bicarbonate		Chloride		Sulfate		Dominant Anion
	meq/L	%	meq/L	meq/L	%	meq/L	
5	2.4	7%	0.7	2%	30.1	91%	sulfate
7	3.4	22%	0.3	2%	11.6	76%	sulfate
8	3.4	23%	0.3	2%	11.0	75%	sulfate
18	3.6	25%	0.4	3%	10.7	73%	sulfate
628	3.0	16%	1.3	7%	14.7	77%	sulfate
631	3.3	11%	0.3	1%	25.8	88%	sulfate
681	3.5	25%	0.4	3%	10.1	72%	sulfate
688	2.7	23%	0.3	3%	8.9	75%	sulfate
694	3.6	26%	0.4	3%	10.1	72%	sulfate
695	3.5	22%	0.3	2%	12.1	76%	sulfate
698	2.3	8%	0.3	1%	28.5	92%	sulfate
706	3.9	21%	0.3	1%	14.1	77%	sulfate

Note: Concentrations in milliequivalents per liter represent the average concentration for each well.

Table 17.7: Chilson Member of the Lakota Formation Major Ion Chemistry

Major Cations							
Hydro ID	**Calcium**		**Magnesium**		**Sodium**		**Dominant Cation**
	meq/L	**%**	**meq/L**	**%**	**meq/L**	**%**	
2	2.6	16%	1.4	9%	12.3	75%	sodium
13	3.1	24%	2.0	16%	7.6	60%	sodium
16	5.9	50%	3.8	32%	2.1	18%	calcium
42	1.7	12%	1.0	7%	11.6	81%	sodium
615	3.7	33%	1.8	16%	5.8	51%	sodium
619	16.0	55%	9.4	32%	3.8	13%	calcium
622	4.1	29%	2.4	17%	7.7	54%	sodium
650	8.3	41%	6.5	32%	5.3	26%	not any
680	19.2	54%	10.2	29%	6.0	17%	calcium
689	2.3	21%	1.3	12%	7.7	68%	sodium
696	4.9	31%	3.0	19%	7.7	49%	not any
697	2.6	20%	1.4	11%	9.2	70%	sodium
705	4.2	30%	2.6	18%	7.1	51%	sodium
3026	19.0	52%	9.3	26%	8.2	22%	calcium
7002	11.5	44%	7.3	28%	7.6	29%	not any
Major Anions							
Hydro ID	**Bicarbonate**		**Chloride**		**Sulfate**		**Dominant Anion**
	meq/L	**%**	**meq/L**	**meq/L**	**%**	**meq/L**	
2	4.2	25%	0.3	2%	12.4	73%	sulfate
13	3.2	23%	0.3	2%	10.0	74%	sulfate
16	3.1	24%	0.1	1%	9.4	74%	sulfate
42	3.6	25%	0.3	2%	10.3	72%	sulfate
615	2.8	25%	0.1	1%	8.2	74%	sulfate
619	2.3	8%	0.3	1%	26.9	91%	sulfate
622	3.5	25%	0.3	2%	10.2	73%	sulfate
650	1.4	6%	0.5	2%	20.6	92%	sulfate
680	5.0	15%	0.4	1%	28.2	84%	sulfate
689	3.0	27%	0.1	1%	8.1	72%	sulfate
696	4.0	27%	0.3	2%	10.7	71%	sulfate
697	3.3	26%	0.2	2%	9.4	72%	sulfate
705	2.7	19%	0.2	2%	11.1	79%	sulfate
3026	3.5	10%	0.5	1%	31.4	89%	sulfate
7002	5.2	19%	0.3	1%	22.4	80%	sulfate

Note: Concentrations in milliequivalents per liter represent the average concentration for each well.

Table 17.8: Groundwater Quality Comparison with Federal Drinking Water Standards

Parameter	Arsenic, Dissolved	Gross Alpha, Dissolved	Radium-226, Dissolved	Uranium, Dissolved	Sulfate
MCL	0.010 mg/L	15 pCi/L	5 pCi/L*	0.030 mg/L	250 mg/L**
Fall River Wells					
Hydro ID					
5	---	---	---	---	X
7	---	**X**	**X**	---	X
8	---	---	---	---	X
18	---	**X**	**X**	---	X
628	---	**X**	**X**	---	X
631	---	**X**	**X**	---	X
681	---	**X**	**X**	---	X
688	---	**X**	**X**	---	X
694	---	**X**	---	---	X
695	---	**X**	**X**	---	X
698	---	**X**	**X**	**X**	**X**
706	---	**X**	---	---	X
Percentage exceeding MCL in one or more samples:	0% (0/12)	83% (10/12)	67% (8/12)	8% (1/12)	100% (12/12)
Chilson Wells					
Hydro ID					
2	---	---	---	---	X
13	---	**X**	---	---	X
16	---	**X**	**X**	---	X
42	---	**X**	**X**	**X**	**X**
615	**X**	**X**	**X**	---	X
619	---	**X**	**X**	---	X
622	---	**X**	**X**	---	X
650	---	---	---	---	X
680	**X**	**X**	**X**	**X**	**X**
689	---	**X**	**X**	---	X
696	---	**X**	---	---	X
697	---	**X**	**X**	---	X
705	---	---	---	---	X
3026	**X**	**X**	**X**	---	X
7002	---	**X**	**X**	---	X
Percentage exceeding MCL in one or more samples:	20% (3/15)	80% (12/15)	67% (10/15)	13% (2/15)	100% (15/15)

Notes: **X** denotes that one or more analyses exceed the MCL.
* MCL applies to radium-226 and radium-228 combined.
** Secondary drinking water standard.

exceeded the arsenic and uranium MCLs in one or more samples. Table 17.8 notes that the radium MCL applies to radium-226 and 228 combined. Powertech had some of the earlier samples analyzed for radium-226 and 228 and determined that the concentration of radium-228 was insignificant (see Appendix N). Therefore, radium-228 was not measured in subsequent samples. Table 17.8 compares the sample results for radium-226 with the combined radium-226 and 228 MCL. The groundwater quality summary tables in Appendix N highlight sample results that exceeded EPA secondary standards. Secondary standards exceeded in one or more Inyan Kara water samples include aluminium, iron, manganese, pH, sulfate and TDS. Table 17.8 shows that all of the Fall River and Chilson wells exceeded the secondary sulfate standard.

Table 17.5 shows that the radon-222 concentration was up to 278,030 pCi/L in the Fall River and up to 180,750 pCi/L in the Chilson. These values are 600 to 900 times greater than the ARSD 74:54:01:04 South Dakota drinking water standard of 300 pCi/L, which is the same as the previously proposed federal radon-222 MCL. Appendix N compares sample results with primary and secondary drinking water standards for all sample results from each well.

17.8 Future Operations

With future exploration drilling, there is the potential of locating additional recoverable resources within the project area that are outside the currently requested AEB. A future amendment for a modified AEB might be requested by Powertech if additional potential well field areas are delineated.

18.0 ATTACHMENT U - DESCRIPTION OF BUSINESS

The Class III UIC permit application is submitted by Powertech (USA) Inc. or Powertech, which is the U.S.-based wholly owned subsidiary of the Powertech Uranium Corporation, a corporation registered in British Columbia. Powertech Uranium Corporation shares are publicly traded on the Toronto Stock Exchange as PWE and the Frankfurt Stock Exchange as P8A. Powertech Uranium Corporation owns 100 percent of the shares of Powertech. The corporate office of Powertech Uranium Corporation is located in Vancouver, British Columbia. Powertech is a U.S.-based corporation incorporated in the State of South Dakota.

The addresses and telephone numbers for the general office (Colorado), the New Mexico office and the local office (South Dakota) of the applicant are listed as follows:

COLORADO Powertech (USA) Inc. 5575 DTC Parkway, Suite 140 Greenwood Village, CO 80111	SOUTH DAKOTA Powertech (USA) Inc. 310 2nd Avenue P.O. Box 812 Edgemont, SD 57735	NEW MEXICO Powertech (USA) Inc. 8910 Adams Street NE Albuquerque, NM 87113

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