5.0 Groundwater Protection

The following provides additional information to supplement Sections 3.1.3 and 6.1.1 of the Technical Report and Section 1.2.6 of the Environmental Report.

Powertech undertakes to protect any and all water sources associated with the operation and undertakes to conduct all operations such that the risks of contamination are minimal. The following discussion indicates the extent that Powertech will act in order to meet these goals.

5.1 Location of Existing Wells

Supplemental Exhibit 3.1-1 depicts the location of all known water wells within the PAA as well as within the larger area of review (AOR), extending approximately 1 mile outside the proposed license boundary. There are a number of domestic and stock water wells within the AOR. Of these eleven (11) wells are located within the aquifer exemption boundary. Eight (8)___ wells are completed in zones within the aquifer exemption boundary (AEB) that are proposed to be in formations other than the Inyan Kara (includes the Fall River), the horizon of proposed operation. All wells outside the aquifer exemption boundary, either vertically or horizontally must be protected and no operations can occur where mine solutions could contaminate these wells. Powertech believes that it has described the character of aquitards and operational controls that will assure that no operating solutions could escape the mine area. There are three (3) well located within the Aquifer Exemption boundary that are completed in the Inyan Kara (includes Fall River), and they are all stock wells (ID#s 17, 49, and 628). In this case, Powertech has the right by land owner agreement to replace these wells with water wells that are not completed within the proposed zones of operations. Powertech undertakes to replace any such affected wells prior to the injection of lixiviant and beginning of leach operation.

5.1.1 Stock and Domestic Water Wells

The following language extracted from Powertech's lease demonstrates that Powertech has the right and responsibility to replace existing water wells or secure such other water so that the well owner's water quality and availability is not diminished.

POWERTECH shall compensate LESSOR for water wells owned by LESSOR at the execution of this Lease, follows:

Any such water which falls within an area to be mined by POWERTECH shall be removed from LESSOR's use. Prior to removal, POWERTECH 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 POWERTECH, as may be necessary to provide water in a quantity equal to the original well and of a quality which is suitable for a all uses the original water well served at the time such well was removed from LESSOR's use.

If any water well on the Property outside of a mining area or well field is materially and substantially diminished in quantity or quality due to POWERTECH's exploration, development or mining activities, POWERTECH will provide LESSOR with such additional water well or wells as may be necessary to provide water in a quantity equal to the original well and of a quality which was suitable for all uses the diminished well served.

Powertech has attached the map from the UIC application submitted to EPA Region 8 that demonstrates the proposed aquifer exemption boundary and the location of potential future operating areas based upon the potential mineralization discovered throughout the roll fronts described by TVA (Supplemental Exhibit 2.1-1).

A key component of groundwater protection is an effective groundwater monitoring system. During discussions with NRC, it became apparent that clarification of the rationale for locating monitoring wells was necessary. The following discussion provides information that addresses NRC's inquiry.

5.2 Basis for Monitor Well Spacing and Design

The proposed monitor well system consists of perimeter, underlying and/or overlying wells. Powertech's Dewey-Burdock monitoring well spacing and design is based on the demonstrated successful operation of this control system to regulate and remediate the leach fluids during 'In Situ Uranium Mining Operations and Restoration of Ground Water Quality' to pre-mining conditions. This system has been used at Hobson, Las Palmas, Mount Lucas, and TX-1 projects in Texas and the Highlands In Situ Project in Wyoming. In all these mines there was no movement of leach fluid to monitor well rings that was not detected and remediated in less than 120 days. In no case was there movement of leach fluids outside the Permit Area Boundary.

5.2.1 Description of the Monitoring Well Ring Detection System

The mine zone production and injection wells are surrounded by perimeter monitor wells utilized for early detection of horizontal excursions which are generally located between 300 and 500 ft from the outside Injection wells. The appropriate distance of the wells are located sufficiently

near enough to the production zone in order to insure no significant areas exists for potential production fluids to migrate without detection. The appropriate distance of the wells is located sufficiently close to the production zone to insure no significant area exists for production fluids to migrate without detection but is outside the radial extent of the production area so ordinary mining leach solutions will not be encountered. If the monitor wells are too close to the well field, the operator would be unable to operate without continually having to shut in the well field to pull back excursions of leach fluid. This distance was negotiated with the regulatory authorities and has proven to be completely effective.

5.2.2 Flow Models

There has been a lot of discussion in the industry recently about basing monitor well spacing on flow models. The reason flow models are not used to determine this distance is that too many generalizations must exist within the models resulting in one unique solution. That solution assumes perfect operation of balancing the injection and production flow patterns with no significant volume of leach fluid moving outside of the production zone well field. Flare is the theoretical movement of a portion of the flowlines outside the pattern area. This is based on the fact that flow away from injection wells is radial and the flow into production well is also radial. However, the flow rate in each of the flow lines is proportional to the pressure gradient in that flow line between the injector and the producer. The injection pressure and the production pressure is the same for each flow line, but the length of each flow line is different. The flow volume in the shortest lines is much greater than the flow volume in the longer lines. Therefore, the majority of fluid flows between injection and production wells. The flare out model only shows the potential movement of particles of fluid. With well field purge or bleed, these flare out lines are drawn back into the pattern area. Because the majority of injection fluid flows directly to the production wells, there is not significant volume of water flowing outside the well field. Dominantly the injection fluid has had the uranium removed prior to being reinjected. Any uranium in solution in the subsurface must be newly generated by putting sufficient oxygen into the formation to solubilize more uranium. Because the outside injection wells are placed at the edge of the uranium deposit there is only a minor amount of uranium to be solubilized outside the well fields. Because the volume of injection fluid is small extending away from the production wells, the flow that is considered flare does not contain significant oxygen. Therefore, flare out modeling is of limited practical significance in sizing the well field monitoring system.

5.2.3 Spacing between Perimeter Monitor Wells

The spacing between perimeter monitor wells is designed to detect any horizontal movement of fluid that may migrate between the monitor wells. The early detection system of wells ensure the operator sufficient time to implement preventative measures so fluid does not move past the monitor wells. Excursions begin at injection wells where the injection pressures must be higher than the ground water pressure in the formation. Installing monitor wells at a maximum angle of 70 degrees between the outside injection well and the two adjacent perimeter monitoring wells allows the operator to detect any radial flow that may migrate toward a well field boundary. Therefore, if the perimeter monitor wells are 400 ft from the outside injection wells, the monitor wells would be placed 400 ft apart. This means that the potential excursion would be detected as it expanded radially from an injection well. By shutting off external injection wells near the monitor well that is on excursion and maintaining the cone of depression via a bleed stream, it can be determined which injection well is the source of the excursion. By shutting in that injection well, the excursion can be pulled back. If the excursion is not being recovered fast enough, a well may be installed inside the perimeter monitor well ring near the well on excursion status to assist in the pull back of the excursion.

5.2.4 Overlying Aquifer Monitor Wells

Where there is an overlying aquifer or aquifers, vertical excursion monitor wells are installed to detect any leaks from the injection wells. Production wells are not a source of excursions as they operate at pressures below the ground water pressure and the flow direction is into the production wells. So the protection of shallow aquifers from excursions is by properly casing and cementing (grouting) all wells. However, to detect a leak, shallow (overlying) monitor wells may be installed over the production area. Because flow from a leaking injection well is radially out from the source of the leak, the shallow monitor wells will be space along the center line of the well fields about every four to eight acres. The spacing is designed to detect an excursion early, within a small area. Once an excursion is detected, injection wells can be shut in near the monitor well and the change in the pressure in the monitor well can be monitored to determine which well is leaking. By repairing the leaking well and by pumping the monitor well that is on excursion status, that aquifer can be cleaned up concurrently with ongoing operations.

5.2.5 Underlying Aquifer Monitor wells

Where a sufficiently adequate and substantial aquitard exists beneath the production zone well field, Powertech will avoid penetrating this aquifer with any wells. Therefore, Powertech prefers

not to use underlying aquifer monitor wells because this may create a potential avenue for an excursion to the lower aquifer. If there is not a substantial aquitard, underlying monitor wells will be installed using the same principles as the overlying aquifer monitor wells.

Table 5.2-1: Proposed Pattern Diameter and Monitoring Well Spacing Compared to NRC Approved Production-Injection Patterns

Location	Typical Production Pattern Diameter	Horizontal Monitor Wells	Vertical Monitor Wells
Crowe Butte Uranium Project, NE	12.2-30.5 m (40-100 ft)	122-183 m (400-600 ft) apart, 91.4 m (300 ft) from well field edge	1 per 5 acres in overlying aquifer only
Highland Uranium Project, WY	30.5-42.7 m (100-140 ft)	122-244 m (400-800 ft) apart, 76-183 m (250-600 ft) from well field edge	1 per 3 acres, not more than 1,000 ft apart, in both overlying and underlying aquifers
Smith Ranch Project, WY	22.9-45.7 m (75-150 ft)	Maximum 152 m (500 ft) apart, approximately 152 m (500 ft) from well field edge	1 per 4 acres, not more than 1,000 ft apart, in both overlying and underlying aquifers
Crown Point Uranium Project, NM	~30.5 m (~100 ft)	Approximately 122 m (400 ft) apart, approximately 122 m (400 ft) from well field edge	1 per 5 acres in overlying aquifer; 1 per 8 acres in any aquifers above the first overlying aquifer
Christensen Ranch Project, WY	15.2-30.5 m (50-100 *ft*)	Downgradient: 91.4 m (300 ft) apart, 91.4 m(300 ft) from well field edge; upgradient and sides: 152 m (500 ft) apart, 500 ft from well field edge	1 per 3.5 acres in both overlying and underlying aquifers
Proposed Dewey - Burdock Project, SD	22.9-45.7 (75-150 ft)	122 m (400 ft) apart, and 122 m (400 ft) from well field edge	1–3 wells every 4-8 acres in overlying aquifer; and underlying as needed (but not below Morrison)

Note: Approved production-injection patterns, horizontal and vertical monitoring well spacing data was obtained from NUREG-6733.

5.2.6 Aquifer Exemption Boundary

The aquifer exemption boundary was established as a buffer zone outside the monitor well rings to provide protection to adjacent water from the excursions that occur in the normal course of operations. It was established on the same basis as the Buffer Zone inside the permit area

boundary that was used in Texas and Wyoming. EPA Region 8 has stated that they want to limit the distance outside the monitor well ring to minimize potential environmental impact. There is an idea that if there is an excursion out to the aquifer exemption boundary, operations will be shut down. It is considered an action limiting boundary. The discussion with EPA considered the maximum probable rate of water movement in an excursion. Since the natural ground water movement is at maximum approximately 12 ft per year, Powertech provided the example of the maximum hydraulic gradient which exists between injection wells and production wells where water moves at about 10 ft per day. Consideration was given to 120 days as being how long it would take the average operator to mobilize drill rigs to control the excursion. So allowing for 120 days at 10 ft per day, it was concluded that 1200 ft was the maximum distance between the perimeter monitor well ring and the aquifer exemption boundary. The aquifer exemption boundary is considered the point of compliance and this provides a 120-day window to get the excursion under control.

5.2.7 Selection of Upper Control Limit (UCL) Parameters

Powertech's management has always used Chlorides, Sulfate and Uranium as Upper Control Limit Parameters. Sometimes Total Dissolved Solids is used. Powertech also uses pressure measurements in the monitor wells to detect the potential for excursions. These parameters were selected for the following reasons.

5.2.7.1 Chlorides

The Ion Exchange (IX) Process always increases the chloride level in the leach fluid because the chloride ion is used in the elution (stripping) solution to displace the uranium ion off of the ion exchange resin. The uranium ion, as it is exchanged onto the ion exchange resin, displaces chloride ion into the leach solution. The chloride ion solubility is not influenced by pH changes or by oxidation-reduction reactions so that it is highly mobile in the ground water therefore provides good early indication of leach fluid movement.

5.2.7.2 Sulfate

Since there is always pyrite (iron sulfide, a reduced mineral) present in uranium roll front deposits (it is the reason the uranium is there), an increase in sulfate means that there is oxygenated water moving in sufficient volume to change the sulfate levels.

5.2.7.3 Uranium

The uranium is selected because it is a uranium mine and this is the primary change that is made to the groundwater that is an adverse change. The uranium is not very mobile as it is insoluble in the reduced state and must be oxidized to be soluble and must have the correct pH at any oxidation level as well as sufficient carbonate ion in solution.

5.2.7.4 Total Dissolved Solids

Total Dissolved Solids (TDS) indicates the increase primarily in chlorides and sulfates when it is used as a UCL. It is easy to measure but can also indicate movement of outside water high in TDS into the monitor well ring. It is Powertech's opinion that it is not sufficiently specific to be useful.

An excursion must be confirmed by two or three parameters being elevated and must be based on repeated analysis to eliminate sampling and analytical error.

5.2.8 Control of Excursions

The limitation of the potential for excursions is based on the following:

1. Well installation- The wells must be installed with cemented casing from the point of injection or production (the well screens) to the surface to prevent movement of fluid up the annulus between the casing and the formations. The cement (grout) prevents this movement. The casing integrity prevents the leaks. A Mechanical Integrity Test (MIT) is performed on every well to be sure there are not any leaks in the casing.

2. Cone of depression- A cone of depression in the piezometric (pressure) surface is maintained by withdrawing more water than is injected. This withdrawal of water from the circulating leach fluid is called a production bleed. This is from 0.5 % to 3% of the water circulated through the well field. This keeps the outside natural ground water continually moving into the well field by maintaining a negative hydraulic gradient into the well field. This rate of withdrawal more than compensates by a very safe margin for error for the normal ground water movement of 10 to 12 ft per year.

3. Daily balancing of individual well patterns- The potential for an excursion is minimized by "balancing " or adjusting the individual well flow rates in each pattern on every 8 or 12 hour shift. This means the flow from each production well is equally distributed in that pattern by distributing the injection flow equally, based on the screened interval of each injector feeding that producer. This ensures that the operator does not over-inject locally in one area or one zone of the production zone.

4. Water level measurement in monitor wells- the water pressures in all monitor wells are regularly monitored to detect any changes that might indicate a potential for an excursion is developing.

6.0 Operational Issues

6.1 Well Construction

The following provides additional information to supplement Section 3.1.2 of the Technical Report and Section 1.2.5 of the Environmental Report.

Polyvinyl Chloride (PVC), fiberglass and Polyethylene piping and casing is the standard used by industry in ISL production wells and pipelines. Powertech plans to use PVC casing in all wells to be constructed for both extraction and injection. In many pipelines, where higher pressures are typical, high density polyethylene (HDPE) piping is often used. These types of materials will be used by Powertech in its mining operation. In any case, Powertech will select piping and casing materials which have proven to have the corrosion resistance necessary to maintain the strength of the casing or pipe (non corrodible) and will select casing and piping materials with sufficient internal pressure rating to provide a 25% safety factor over the design pressures. The selection involves an evaluation of the expense, reuse, and reliability of the casing and piping systems including design for thermal expansion and water hammer.

6.2 Emissions Estimates

The following provides additional information to supplement Sections 7.1.1 and 7.2.1 of the Technical Report and Section 4.8 of the Environmental Report.

The Dewey-Burdock PAA is located within an area classified as attainment for National Ambient Air Quality Standards (NAAQS) parameters and the project is not classified as a major source under the New Source Review or operating (Title V) permit program administered by the State of South Dakota. However, as part of the State of South Dakota regulatory requirements, Powertech (USA) will submit an air permit application to the Department of Environmental and Natural Resources (DENR), for construction related activities, that will include a fugitive dust monitoring plan to assess potential impacts on human health and the environment.

The construction phase of the project is expected to result in potential minimal non-radiological gaseous emissions including fugitive dust and combustion emissions from dirt-moving activities during drilling and ground clearing using heavy equipment. However, it is anticipated that releases will be dispersed rapidly due to low atmospheric stability attributed to wind. The nearest off-site receptor is the Daniels Ranch located 1.32 miles to the west southwest of the PAA.

Well fields will be accessed via temporary roads. Potential air quality impacts will result from vehicular traffic on these roads and from gaseous emissions from vehicles and other heavy equipment. Construction vehicles will be equipped with the required emission control equipment.

Diesel engines from the drill rigs and other construction equipment are non-stationary sources of air pollutants. Drilling will be conducted as the well fields are developed contributing emissions throughout the year. Other ancillary equipment used sporadically will produce insignificant emissions.

Vehicular traffic, on unpaved roads will be another potential source of dust. Equations to calculate emissions from vehicles travelling on publicly accessible unpaved roads were obtained from Compilation of Air Pollutant Emission Factors, Volume 1 (EPA, 2006). Section 13.2.1 was used to calculate particulate emissions from traffic on paved roads.

Powertech (USA) estimates that during the three phases of the project, the project will require equipment and support vehicles as summarized in Tables 6.2-1, 6.2-2 and 6.2-3 below. Table 6.2-4 shows the estimated annual emissions from these vehicles during the construction, operation, and decommissioning phases. Vehicle emissions were calculated using Section 3.3, Gasoline and Diesel Engines of AP-42 (EPA, 2006). Emissions factors are given for criteria pollutants for diesel and gasoline powered engines. Detailed emissions calculations are show in tables of Appendix C. Emissions factors are used in the following equation to calculate annual emissions estimates for all activities:

$$E = A \ x \ EF \ x \ (1 - ER/100)$$

Where:

- E is the emissions;
- A is the activity rate;
- EF is the emissions factor;
- And ER is overall emission reduction efficiency.

No emission reduction efficiencies were accounted for in any of the estimated emissions for this project.

Table 6.2-1: Estimated Vehicle and Equipment Requirements during Initial Construction Phase

Period	Activity	Emission Vehicle	Number of Vehicles
Initial Construction	Earthworks Construction	Scraper	3
		Bulldozer	1
		Compactor	1
		Motor Grader	1
		Heavy Duty Water Truck	2
		Fueling Truck	1
		Light Duty pickup	3
	Facilities Construction	Crane	2
		Welding Equipment	8
		Forklift	2
		Man lift	4
		Heavy Duty Diesel Truck	2
		Light Duty Truck	10
	Well Field/Electrical Construction	HDPE Fusion Equipment	2
		Trackhoe	1
		Backhoe	1
		Welding Equipment	1
		Electrical Pole Truck	2
		Motor Grader	1
		Forklift	1
		Light Duty Truck	6
	Drilling	Truck Mount Rotary Drill Rig, Diesel Truck	13
		Heavy Duty Water Truck	13
		Backhoe	1
		Forklift	2
		Cementer (diesel)	4
		Logging Truck	4
		Light Duty Truck	15

Table 6.2-2: Estimated Vehicle and Equipment Requirements during Operations Phase

Period	Activity	Emission Vehicle	Number of Vehicles
Operations - Well Field Construction/Production/Groundwater Restoration	Central Processing Plant	Propane heating	1
		Thermal Fluid Heater - propane	2
		Emergancy Backup Generator - propane	1
		Fire Suppression System - Diesel pump	1
	Satellite Facility	Propane heating	1
		Emergancy Backup Generator - propane	1
		Fire Suppression System - Diesel pump	1
	Office Building	Propane heating	1
	Maintenance & Warehouse Bldg	Propane heating	1
	Well Field/Electrical Construction	HDPE Fusion Equipment - Gas Engine	2
		Hydraulic Excavator	1
		Backhoe	1
		Welding Equipment	1
		Electrical Pole Truck	2
		Motor Grader	1
		Forklift	1
		Light Duty Truck	6
	Drilling*	Truck Mount Rotary Drill Rig, Diesel Truck	13
		Heavy Duty Water Truck	13
		Backhoe	1
		Forklift	2
		Cementer (diesel)	4
		Logging Truck	4
		Light Duty Truck	15
	CPP Operations	Man Lift	1
		Welding Equipment	1
		Forklift	1
		Forklift	1
		Light Duty Truck	8
		Light Duty Vehicles	4
	SF/WF Operations	Resin Hauling Semi - Truck	1
		Pump pulling truck	4
		Motor Grader	1
		Logging Truck	1
		Light Duty Truck	2
		Light Duty Vehicles	2
	Restoration Operations	Cementer (diesel)	1
		Light Duty Truck	2
		Light Duty Vehicles	1
	Product Transport	Diesel Semi with Trailer to transport product	1

Table 6.2-3: Estimated Vehicle and Equipment Requirements during the Decommissioning Phase

Period	Activity	Emission Vehicle	Number of Vehicles
Decommissioning	Earthwork	Scraper	3
		Motor Grader	1
		Compactor	1
		Bulldozer	1
		Hydraulic Excavator	2
		Backhoe	2
		Loader	1
		Tractor	1
		Fueling Truck	1
		Light Duty Truck	2
	Demolition	Crane	1
		Welding/Cutting Equipment	4
		Man Lift	4
		Forklift	3
		Heavy Duty Truck (Diesel)	4
		Light Duty Truck	5
		Light Duty Vehicles	5

Table 6.2-4: Annual Estimated Vehicle Emissions (t/yr) Per Project Phase

Project Phase	PM_{10} (t/yr)	SO_x (t/yr)	NO_x (t/yr)	CO (t/yr)	CO_2 (t/yr)	TOC (t/yr)	Aldehydes (t/yr)
Initial Construction	36	34	513	124	21053	104	9
Operations	41	37	586	167	29990	228	12
Decommissioning	6	5	82	22	3730	28	2

For unpaved roads, the following equations from Section 13.2.2 were used:

$$EF = \left[\frac{k \left(\frac{s}{12}\right)^a \left(\frac{S}{30}\right)^d}{\left(\frac{M}{0.5}\right)^c} - C \right]$$

$$EF_{ext} = E \left[\frac{(365 - P)}{365} \right]$$

Where:

- EF = size specific emission factor in pounds per vehicle mile traveled (lb/VMT);
- k = particle size multiplier for particle size range (lb/VMT);
- s = surface material silt content (%);
- a, c and d are empirical constants given in Table 13.2.2-2 of this section of AP-42 and are also shown in tables of Appendix C.
- M = surface material moisture content (%);
- S = mean vehicle speed (miles per hour [mph]);
- C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear (lb/VMT);
- EF_{ext} = annual size-specific emission factor extrapolated for natural mitigation, lb/VMT
- P = number of "wet" days with at least 0.01 inches of precipitation during the averaging period.

The following estimates and assumptions were made in order to calculate particulate emissions from vehicles travelling on unpaved roads:

- Surface material silt content is approximately 32.1 % based on sieve analyses performed on 10 test pit samples located across the project site.
- Surface material moisture content is approximately 10.4 % based on geotechnical analyses performed on 10 test pit samples located across the project site.
- Mean vehicle speed for all vehicles traveling during each project phase is estimated to be approximately 11.5 mph during the construction phase, 13 mph during the operations phase, and 10.5 mph during the decommissioning phase based on several different vehicles and their respective average speeds.
- According to Figure 13.2.2-1 of AP-42, at the project location, there are 90 "wet" days with at least 0.01 inches of precipitation per year.

Table 6.2-5 lists the total annual estimated amount of particulate emissions from vehicles travelling on unpaved roads during construction, operations, and decommissioning phases. The estimated particulate emissions from vehicles traveling on paved roads are minimal and

durations of impacts will be very short during the project as compared to those for unpaved roads. Therefore, the estimated particulate emissions from paved roads are not included in these estimates.

Table 6.2-5: Annual Estimated Particulate Emissions (t/yr) Per Project Phase for Paved and Unpaved Roads

Project Phase	$PM_{2.5}$ (t/yr)	PM_{10} (t/yr)	PM_{30} (t/yr)
Initial Construction	53	527	1,297
Operations	29	290	715
Decommissioning	15	153	377

6.3 Disposal Agreement for 11e.(2)

The following provides additional information to supplement Section 4.2.2 of the Technical Report and Section 4.15.2 of the Environmental Report.

Powertech is aware that NUREG-1569, NRC's Standard Review Plan for In Situ Leach Uranium Extraction License Applications (SRP), indicates the applicant should possess an approved waste disposal agreement for 11e.(2) byproduct material disposal at an NRC or NRC Agreement State licensed disposal facility. However, due to costs associated with the contracting process by the waste disposal entity and the scheduling uncertainties associated with the licensing process of in situ leach (ISL) operations in the current business environment, Powertech has been unable to secure the required waste disposal agreement. Nevertheless, the requirement as stated in the guidance provided by the STP, appears to allow for acquisition of the required waste disposal agreement after receipt of the In Situ Leach Uranium Extraction License. Therefore, Powertech commits to comply with this requirement by acquiring an approved waste disposal agreement for 11e.(2) byproduct material disposal at an NRC or NRC Agreement State licensed facility at its earliest opportunity, and to provide evidence of such agreement to NRC prior to commencement of operations.

7.0 MILDOS Revision

The following provides supplemental information to Section 7.3 of the Technical Report and Section 4.14.2 of the Environmental Report. Revisions were made due to the reduction in the land application areas and changes in locations at the Dewey and Burdock sites since the initial license application submittal. These revisions include the following:

- Table 7.3-1 in the Technical Report was updated and is shown below.

Table 7.3.1: Parameters Used to Estimate Radionuclide Releases from the Dewey-Burdock Site

Parameter	Value	Unit	Variable Name	Source
Rate of land application - 1	1.27E-03	$m\ d^{-1}$	AR_1	Application
Rate of land application - 2	2.79E-3	$m\ d^{-1}$	AR_2	Application
Area of land application - Dewey	1.27E+06	m^2	LA_{Dewey}	Application
Area of land application - Burdock	1.27E+06	m^2	$LA_{Burdock}$	Application
Time of land application in a year - 1	80	d	t_{d1}	Application
Time of land application in a year - 2	137	d	t_{d2}	Application
Years of land application	15	y	t_y	Application
Concentration of natural uranium in water	300	$pCi\ L^{-1}$	$[U\text{-}nat]_{water}$	Application (NRC effluent values)
Concentration of thorium-230 in water	100	$pCi\ L^{-1}$	$[Th\text{-}230]_{water}$	Application (NRC effluent values)
Concentration of radium-226 in water	60	$pCi\ L^{-1}$	$[Ra\text{-}226]_{water}$	Application (NRC effluent values)
Concentration of lead-210 in water	10	$pCi\ L^{-1}$	$[Pb\text{-}210]_{water}$	Application (NRC effluent values)
Density of soil - Dewey	1.28	$g\ cm^{-3}$	$\square_{Dewey}$	Application
Density of soil - Burdock	1.24	$g\ cm^{-3}$	$\square_{Burdock}$	Application
Depth of contamination	0.15	m	x	Assumption
Distribution coefficient of natural uranium in loam soil	15	$cm^3\ g^{-1}$	$K_{d,U\text{-}nat}$	"Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" by Yu et al.
Distribution coefficient of thorium-230 in loam soil	3300	$cm^3\ g^{-1}$	$K_{d,Th\text{-}230}$	"Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" by Yu et al.
Distribution coefficient of radium-226 in loam soil	36000	$cm^3\ g^{-1}$	$K_{d,Ra\text{-}226}$	"Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" by Yu et al.

Table 7.3.1: Parameters Used to Estimate Radionuclide Releases from the Dewey-Burdock Site

Parameter	Value	Unit	Variable Name	Source
Distribution coefficient of lead-210 in loam soil	16000	$cm^3\ g^{-1}$	$K_{d,Pb\text{-}210}$	"Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" by Yu et al.
Soil volume water content - Dewey	0.91	unitless	w_{Dewey}	Application
Soil volume water content - Burdock	0.80	unitless	$w_{Burdock}$	Application
Rate of resuspension of radionuclides in surface soil	4E-06	h^{-1}	ARR	DOE Handbook "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities" by the US Department of Energy
Respirable fraction of resuspended radionuclides in surface soil	1.0	unitless	RF	DOE Handbook "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities" by the US Department of Energy
Soil porosity - Dewey	0.5429	unitless	n_{Dewey}	Application
	0.5340	unitless	$n_{Burdock}$	Application
Lixiviant flow rate - production	1.49E+04	$L\ min^{-1}$	$M_{production}$	Application
Lixiviant flow rate - restoration	3.73E+03	$L\ min^{-1}$	$M_{restoration}$	Application
Lixiviant residence time	108	d	t	Application
Production days per year	360	d	D	Application
Formation porosity	0.34	unitless	n_{form}	"Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" by Yu et al. (coefficient for sandstone)
Content of radium in ore	592	$pCi\ g^{-1}$	$[Ra]_{ore}$	Application
Formation density	1.9	$g\ cm^{-3}$	ρ_{form}	Application
Storage time in mud pits	7	d	T	Application
Number of mud pits per year	725	y^{-1}	N	Application
Resin porosity	0.38	unitless	n_{resin}	Application
Resin transfers per day	0.5	d^{-1}	N_i	Application
Volume of resin per transfer	1.42E+04	L	V_i	Application
Average mass of ore material in mud pit	185	g	m	Application
Radon emanation coefficient	0.22	unitless	E	"Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil" by Yu et al.

- Equation 7.5 in the report was replaced with the equation shown below.

$$V_{cluster} = (AR_1 * t_{d1} + AR_2 * t_{d2}) * t_y * LA_{cluster} \quad \text{(Equation 7.5)}$$

- Table 7-3.2 in the Technical Report was updated as shown below.

Table 7.3-2: Estimated Soil Concentrations (pCi g^{-1}) and Release Rates (Ci y^{-1}) of Natural Uranium (U-Nat), Thorium-230 (Th-230), Radium-226 (Ra-226), and Lead-210 (Pb-210) from the Dewey-Burdock Site

Location	X (km)	Y (km)	U-Nat		Th-230		Ra-226		Pb-210	
			Soil Conc.	Rel. Rate	Soil Conc.	Rel. Rate	Soil Conc.	Rel. Rate	Soil Conc.	Rel. Rate
Land Application - Dewey	-6.02	3.80	10.8	0.0974	3.78	0.0325	2.27	0.0195	0.378	0.00325
Land Application - Burdock	-1.09	0.99	11.2	0.0974	3.91	0.0325	2.34	0.0195	0.391	0.00325

- Table 7-3.3 in the report was updated as shown below.

Table 7.3-3: Estimated Releases (Ci y^{-1}) of Radon-222 from the Dewey-Burdock Site

Location	X (km)	Y (km)	Production	Restoration	Drilling	Resin Transfer	Land Application	Total
Production Mine Unit (5)	-3.86	3.48	212	26.5	3.6E-05	0	0	238.5
Production Mine Unit (2)	1.83	-0.56	212	26.5	3.6E-05	0	0	238.5
SF	-5.00	3.54	134	16.7	0	0.523	0	
SF Deep Well	-5.00	3.54	57	7.1	0	0	0	
Total SF			191	23.8		0.523		215.3
CPP	0	0	134	16.7	0	0	0	
CPP Deep Well	0	0	57	7.1	0	0	0	
Total CPP			191	23.8	0	0	0	214.8
Land Application - Dewey	-6.02	3.80	0	0	0	0	6.08	6.08
Land Application - Burdock	-1.09	0.99	0	0	0	0	7.49	7.49
Total			806	100.6	7.2E-05	0.523	14.0	921

- In Section 7.3.3.4 of the Technical Report, the evaluations for the total effective dose equivalent (TEDE) Calculation was modified as follows:

"1) The maximum 40 CFR part 190 EDE at a boundary receptor is 2.50 mrem y^{-1}, located at the CPP WNW boundary, is 10.0 percent of the public dose limit of 25 mrem y^{-1}. The 40 CFR 109 TEDE public dose limit is not exceeded at any boundary receptor.

2) The maximum total TEDE at a boundary receptor is 4.92 mrem y^{-1}, located at CPP ESE boundary, is 4.92 percent of the 10 CFR 20 public dose limit of 100 mrem y^{-1}. The 10 CFR 20 public dose limit is not exceeded at any property boundary.

3) The maximum 40 CFR part 190 EDE at a resident is 6.83 mrem y^{-1}, located at BC Ranch. This is 27.3 percent of the public dose limit of 25 mrem y^{-1}. None of the resident receptors have 40 CFR part 190 EDEs exceeding the 25 mrem y^{-1} public dose limit. None of these estimated EDEs exceed the 10 CFR 20 constraint rule for airborne effluents of 10 mrem y^{-1}.

4) The maximum TEDE at a resident is 7.98 mrem y^{-1}, located at BC Ranch. It is 7.98 percent of the 10 CFR 20 public dose limit of 100 mrem y^{-1}. None of the residents have TEDEs exceeding the 100 mrem y^{-1} public dose limit."

- Table 7-3.5 in the Technical Report was updated as shown below.

Table 7-3.5: Estimated Dose Equivalents (EDE) to Receptors near the Dewey-Burdock Site

Receptor	Distance from Main Plant (km)	40 CFR Part 190 TEDE (mrem y^{-1})	Total EDE (mrem y^{-1})
Boundary - CPP - N	2.82	1.05	2.13
Boundary - CPP - NNE	2.96	0.717	1.62
Boundary - CPP - NE	1.65	1.61	3.12
Boundary - CPP - ENE	2.83	0.905	2.00
Boundary - CPP - E	2.60	1.10	2.89
Boundary - CPP - ESE	2.71	1.32	4.92
Boundary - CPP - SE	3.02	1.49	5.27
Boundary - CPP - SSE	2.41	1.59	4.83
Boundary - CPP - S	2.87	1.23	3.63
Boundary - CPP - SSW	3.04	1.12	2.89
Boundary - CPP - SW	3.44	0.790	2.32
Boundary - CPP - WSW	2.54	1.24	3.07
Boundary - CPP - W	2.32	1.80	3.88
Boundary - CPP - WNW	2.45	2.50	4.71
Boundary - CPP - NW	2.45	1.80	4.25
Boundary - CPP - NNW	3.96	1.02	2.08
Boundary - SF - N	7.22	0.810	1.89
Boundary - SF - NNE	6.74	0.676	1.78
Boundary - SF - NE	6.25	0.532	1.29
Boundary - SF - ENE	5.23	1.00	2.63
Boundary - SF - E	4.54	1.28	3.53
Boundary - SF - ESE	4.03	1.68	5.33
Boundary - SF - SE	3.10	2.07	4.90
Boundary - SF - SSE	3.55	1.34	3.71
Boundary - SF - S	4.92	0.961	2.88
Boundary - SF - SSW	5.86	1.54	3.86
Boundary - SF - SW	6.61	1.75	3.16
Boundary - SF - WSW	6.89	2.25	3.56
Boundary - SF - W	7.81	1.10	1.94
Boundary - SF - WNW	8.15	1.17	1.90
Boundary - SF - NW	7.81	1.10	2.06
Boundary - SF - NNW	7.14	0.922	2.17
Resident - Daniels Ranch	2.13	1.44	3.21
Resident - Spencer Ranch	2.34	3.33	5.43
Resident - BC Ranch	7.66	6.83	7.98
Resident - Puttman Ranch	8.88	0.426	1.05
Resident - Burdock School	2.98	0.952	2.59
Resident - Heck Ranch	6.61	0.570	2.06
Resident - Englebert Ranch	4.84	0.686	2.43
Town - Edgemont	21.61	0.159	0.528

- In Section 7.3.3.5 of the Technical Report, the maximum radiological effect of the Dewey-Burdock Operation changed to 0.0000074 percent of the TEDE of the continental population.
- Table 7-3.6 of the Technical Report was updated as shown below.

Table 7.3-6: Total Effective Dose Equivalent to the Population from One Year's Operation at the Dewey-Burdock Site

Criteria	TEDE (person rem/yr)
Dose received by population within 80 km of the facility	0.758
Dose received by population beyond 80 km of the facility	8.10
Total continental dose	8.86
Background North American dose	1.2E8
Fractional increase to background dose	7.4E-8

- Table 7-3.7 of the Technical Report was updated as shown below.

Table 7.3-7: Highest Surface Concentrations of Radium-226 and its Decay Products Resulting from Dewey-Burdock Site Operations

Radionuclide	Distance from site (km)	Direction	Surface Concentration (pCi m^{-2})	Soil concentration in upper 15cm (pCi g^{-1})
Radium-226	1.5	WNW	1.03E+04	0.0458
Polonium-218	1.5	WNW	1.03E+04	0.0458
Lead-214	1.5	WNW	1.03E+04	0.0458
Bismuth-214	1.5	WNW	1.03E+04	0.0458
Lead-210	15.0	S	253	1.12E-3

- In Section 7.3.3.6 of the Technical Report, the largest increase in soil concentration was changed to 0.0458 pCi g^{-1} of radium-226, polonium-218, lead-214, and bismuth-214.
- In Section 7.3.3.7.1 of the Technical Report, the second and third paragraphs were replaced with:

"The soil concentration parameters used in the model were the soil concentrations calculated for the Dewey cluster in Section 7.3.3.1. The soil concentrations for Dewey were chosen because they are they are the most conservative (higher than) when compared to the Burdock cluster. The soil concentrations are 11.2 pCi g^{-1} for U-nat, 3.91

pCi g^{-1} for Th-230, 2.34 pCi g^{-1} for Ra-226, and 0.391 pCi g^{-1} for Pb-210. However, U-nat is composed of three isotopes of uranium: urainium-234 (U-234), uranium-235 (U-235), and uranium-238 (U-238).

The activity composition of U-nat is 49.2 percent U-234, 2.2 percent U-235, and 48.6 percent U-238. Therefore the 11.2 pCi g^{-1} of U-nat is composed of 5.51 pCi g^{-1} U-234, 0.246 pCi g^{-1} U-235, and 5.44 pCi g^{-1} U-238. These concentrations were used in the model."

- In Section 7.3.3.7.1 of the Technical Report, the maximum annual dose rates from land applications area were changed to 63.3 mrem y^{-1} including radon and 15.6 mrem y^{-1} excluding radon.
- Appendix D contains the updated MILDOS and Residual Radioactive (RESRAD) outputs.

8.0 References

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POWERTECH (USA) INC.

Appendix A

Narrative of TVA and Powertech (USA) Inc. Pumping Tests: Conclusions and Results

Knight Piésold
CONSULTING

Powertech (USA) Inc.
Dewey-Burdock Project

Narrative of TVA and Powertech (USA) Inc.
Pumping Tests: Conclusions and Results

August 2009

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Powertech (USA) Inc.
Dewey-Burdock Project
Narrative of TVA and Powertech (USA) Inc.
Pumping Tests: Conclusions and Results

Table of Contents

List of Acronyms and Abbreviations

cm/sec	centimeters per second
ft^2/day	square feet per day
gpm	gallons per minute
TVA	Tennessee Valley Authority

Powertech (USA) Inc.
Dewey-Burdock Project
Narrative of TVA and Powertech (USA) Inc.
Pumping Tests: Conclusions and Results

1.0 Aquifer Pumping Tests

This document provides a summary of the results of the aquifer pumping tests conducted in 1979 and 1982 by the Tennessee Valley Authority (TVA) and in 2008 by Powertech (USA), Inc.

1.1 1982 and 2008 Tests in the Dewey Project Area

1.1.1 TVA Test

The TVA conducted a test in 1982 northeast of the Dewey Road at the northern boundary of the project area (see location map on Figure 1.1 in Appendix 2.7-B of the Technical Report). The test consisted of pumping in the Lakota formation for 11 days at an average rate of 495 gallons per minute (gpm). Observation wells were placed in overlying Fuson Member (i.e., within the confining unit per the method of Neuman and Witherspoon, 1973) and the overlying Fall River Formation. The test developed the following information:

- Transmissivity of the Lakota averaged about 590 square feet per day (ft^2/day).
- Storativity of the Lakota was about 1.0 x 10^{-4} (dimensionless).
- There was hydraulic response between the Fall River and Lakota formations through the intervening Fuson Member based on observation well responses; however, the response in the overlying Fall River started at relatively late time (3000 to 10000 minutes) and continued to the end of the test.
- The vertical hydraulic conductivity of the Fuson aquitard using the Neuman-Witherspoon ratio method was 2 x 10^{-4} ft/day (7.1 x 10^{-8} centimeters per second [cm/sec]).
- A barrier boundary, or a 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 Lakota and Fall River formations are structurally offset.
- A drawdown contour map was not developed; the drawdown at the most distance observation well (5,700 ft) was about 70 ft; a distance-drawdown graph (see Figure 3

in Boggs, 1983) indicates that the theoretical maximum radius of influence was about 8×10^4 ft, or about 15 miles.

1.1.2 Fall River 2008 Test

The previous 1979 TVA test in the Fall River aquifer (see Section 1.2.1 below and Section 2.3 in Appendix 2.7-B of the Technical Report) was considered a regional test that had already been successfully conducted using pumping and observation wells mostly screening the entire aquifer. The 2008 test in the Dewey project area (see location map on Figure 1.1 in Appendix 2.7-B of the Technical Report) consisted of pumping in the lower Fall River Formation for 3.08 days at an average rate of 30.2 gpm. The test pumping well and three surrounding observation wells were screened in one of the three known ore horizons in lower portion of the Fall River that can be seen on the conceptual stratigraphic cross-sections for the pumping test site (see Drawings 4.1 and 4.2 in Appendix 2.7-B of the Technical Report). Each ore horizon was assumed to have its' own production zone, and the test screened one horizon to test what flow could be expected in a typical well field. Other observation wells and an existing stock well were monitored in the upper Fall River Formation; an observation well was constructed in the underlying lower Lakota formation, below the intervening Fuson Member; and an observation well also was constructed in the underlying Unkpapa/Sundance Formation, below the intervening clay-shale beds of the Morrison Formation.

The 2008 test at Dewey developed the following information (see Table 4.2 and Section 4 in Appendix 2.7-B of the Technical Report):

- Within the lower Fall River formation, the test results indicates a rapid response (starting in two to three minutes) between pumping and observation wells up to 467 ft apart with 10 to 14 ft of ultimate drawdown; response in the upper Fall River was nearly 9 ft ultimate drawdown at 1,400 ft distance starting within 40 minutes; and response in the lower Fall River was 1.5 ft ultimate drawdown at 2,400 ft distance in starting in 0.6 days; these results and good matches to type curves indicate the aquifer was sufficiently stressed during the test to produce good quality analytical results.

- Ten determinations of transmissivity ranged from 180 to 330 ft^2/day with a median value of 255 ft^2/day.

- Five storativity determinations ranged from 2.3×10^{-5} to 2.0×10^{-4} with a median value of 4.6×10^{-5}.

- The radius of influence of the pumping test determined by a distance-drawdown plot was 5,700 ft.

- The observation well located within the underlying lower Lakota Formation 61 ft laterally and 130 ft vertically below the screen in the pumping well exhibited no response to the drawdown or recovery phases at the pumping well.

- The observation well located within the underlying Unkpapa/Sundance Formation aquifer 50 ft radially and 325 ft vertically below the screen in the pumping well exhibited no response to the drawdown or recovery phases at the pumping well.

The 2008 test indicates 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 changing lithology, such as a channel boundary. The TVA test in 1982 also observed a barrier boundary in the underlying Lakota formation that was attributed to either a change in lithology or the Dewey Fault zone. Apparently, both the Lakota and Fall River formations in the general Dewey project area show barrier boundaries attributable to lithologic changes, suggesting the project ore zone area is a locally thick sedimentary section thinning laterally. The 2008 test results are more definitive than the 1982 TVA test concerning the proximity of the barrier boundary, because the 2008 radius of influence was about one mile compared to greater than two to three miles distance to the fault zone. The very high theoretical radius of influence of 15 miles in the TVA test is considered exaggerated due to possible barrier boundaries at: (1) the Fall River outcrop about 2.7 miles to the east, and (2) the Dewey Fault zone described above. However, regional drawdown in the Fall River aquifer can be predicted to be extensive for relatively small pumping rates, as reflected in the relatively low transmissivity (255 ft^2/day at a thick section) and very low storativity (5×10^{-5}).

In 2008 vertical hydraulic connection throughout the entire Fall River formation is indicated by the near instantaneous responses in the lower Fall River production zone wells followed by a delayed response at the upper Fall River observation well. The 11-minute delay in response at the upper observation well is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pumping test site (see Drawings 4.1 and 4.2 in Appendix 2.7-B of the Technical Report). The complete extent and continuity of the shale interbeds are not known from test results or current drilling in the area.

In the 2008 test there was no evidence of leakage or hydraulic communication through the Fuson Member, and the 2008 test demonstrates that vertical leakage through the Fuson may not occur over a mile-wide radius. In the 1982 TVA test of the Lakota formation (Boggs, 1983), response in both the Fuson Member and overlying Fall River Formation was observed only relatively late in the TVA tests, at 3,000 to 10,000 minutes, with a much greater pumping rate (495 gpm) and radius of influence. Because a leakage component was not identified in the solution for Lakota

aquifer parameters, the responses do not necessarily indicate large quantities of flow across the Fuson. In comparison to the similar test TVA conducted at the Burdock area (see Section 4 in Appendix 2.7-B of the Technical Report), Boggs (1983) concluded that the overall drawdown response through the Fuson was less and that the Fuson is a relatively more effective aquitard at the Dewey area.

The vertical hydraulic conductivity value of 2 x 10^{-4} ft/day (7.1 x 10^{-8} cm/sec) determined for the Fuson Member in the 1982 TVA regional test at Dewey using the Neuman-Witherspoon ratio method is sufficiently impermeable for the Fuson Member to be considered an aquitard and confining layer with limited potential for leakage. Because there was no evidence of leakage or response from the Unkpapa/Sundance aquifer in the 2008 test, the Morrison Formation is interpreted to have been acting as an aquiclude and ideal confining layer.

1.2 1979 and 2008 Tests in the Burdock Area

1.2.1 TVA Tests

The TVA Burdock tests were conducted in 1979 near the Dewey road at the location shown on the location map on Figure 1.1 in Appendix 2.7-B of the Technical Report. The Burdock tests consisted of separate pumping tests from the Lakota and Fall River aquifers, respectively in April and July of 1979 (Boggs and Jenkins, 1980). The tests used the same pumping well with packers to alternately isolate screens open to the respective formations. Test durations were 73 hours for the Lakota test and 49 hours for the Fall River test. Pumping rates were about 200 gpm from the Lakota 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. Observation wells were placed in the Lakota Formation, the Fuson Member (i.e., within the confining unit per the method of Neuman and Witherspoon, 1973) and the Fall River Formation. In addition, there was a single existing well in the Sundance Formation located 4,760 ft from the test well that was monitored periodically during the Lakota aquifer test.

The tests developed the following information:

- Interpreted transmissivity of the Lakota aquifer was based on analysis of later time data and inferred decreasing transmissivity with distance from the test site due to changes in lithology; overall transmissivity averaged about 190 ft^2/day and storativity about 1.8 x 10^{-4} (dimensionless); maximum transmissivity from early time data was about 310 ft^2/day.
- Transmissivity of the Fall River aquifer averaged about 54 ft^2/day and storativity about 1.4 x 10^{-5} (dimensionless).

- There was hydraulic response between the Fall River and Lakota formations through the intervening Fuson Member based on observation well responses; this is not an indication that the Fuson would not serve as an aquitard as described further below.

- Leaky behavior was observed in the Fall River Formation by a change in slope in time-drawdown data but aquifer parameters with a leaky, confined (e.g. Hantush-Jacob) solution were not obtained; leaky behavior is believed to also have affected the Lakota time-drawdown data, although "leakage effects in the Lakota drawdown data are masked by the conflicting effect of a decreasing transmissivity in site vicinity" (p. 16 in Boggs and Jenkins, 1980).

- The vertical hydraulic conductivity of the Fuson aquitard determined with the Neuman-Witherspoon ratio method (Neuman and Witherspoon, 1973) ranged from about 10^{-3} to 10^{-4} ft/day.

- Drawdown contour maps in both formations were developed for the Lakota pumping test at 200 gpm (see Figures 19 and 20 in Boggs and Jenkins, 1980); ultimate drawdowns at the most distant observation wells (at 2,507 ft in the Lakota and 2,540 ft in the Fall River) were about 18 ft and 3 ft respectively.

- A distance-drawdown graph indicates that the theoretical maximum radius of influence for the Lakota test was about 4,500 ft.

- A distance-drawdown graph for the Fall River pumping test was not produced, possibly due to significant anisotropy in transmissivity, but a rough distance-drawdown relationship in the most transmissive direction estimated for this report indicates a theoretical radius of influence of about 2,500 ft for the Fall River test.

- The response at the existing well monitored in the Sundance at 4,760 ft distance was not reported so a lack of response is therefore presumed; however, based on the radii of influence described above, a lack of response is not considered diagnostic for the Morrison Formation because the overlying Lakota and Fall River aquifers were likely not depressurized at the Sundance well location.

1.2.2 Lakota 2008 Test

The previous 1979 TVA tests in the Lakota and Fall River aquifers (see Section 1.2.1 above and Section 2.3 in Appendix 2.7-B of the Technical Report) were considered regional tests that had already been successfully conducted using pumping and observation wells mostly screening the entire aquifers. The 2008 test in the Burdock project area (see location map on Figure 1.1 in Appendix 2.7-B of the Technical Report) consisted of pumping in the lower Lakota Formation for 3.0 days at an average rate of 30.2 gpm. The test pumping well and three surrounding observation wells were screened in one of the known ore horizons in the lower portion of the Lakota that can be seen on the conceptual stratigraphic cross-sections for the pumping test site

(see Drawings 5.1, 5.2 and 5.3 in Appendix 2.7-B of the Technical Report). The test targeted the ore horizon to test what flow could be expected in a typical well field. An observation well was constructed in the upper Lakota Formation; an observation well was constructed in the overlying lower Fall River Formation, above the intervening Fuson Member; and an observation well was also constructed in the underlying Unkpapa/Sundance Formation, below the intervening clay-shale beds of the Morrison Formation.

The 2008 test at Burdock developed the following information (see Table 5.2 and Section 5 in Appendix 2.7-B of the Technical Report):

- Within the lower Lakota formation, the test results indicate a response between pumping and observation wells up to 250 ft apart with 10 to 17 ft of ultimate drawdown starting in 4 to 140 minutes; ultimate response was nearly 3 ft of drawdown at 1,290 ft distance starting at 280 minutes; these results and good matches to type curves indicate the aquifer was sufficiently stressed during the test to produce good quality analytical results.

- Nine determinations of transmissivity ranged from 120 to 223 ft^2/day with a median value of 150 ft^2/day.

- Four storativity determinations ranged from 6.8×10^{-5} to 1.9×10^{-4} with a median value of 1.2×10^{-4}.

- Hantush-Jacob type-curve matches were obtained at two observation wells with the vertical leakage parameter r/B calculated using TVA data for the Fuson Formation in good agreement with that empirically obtained using commercial automated type-curve-fitting software; thus the 1972 TVA data and 2008 test data have good internal agreement for the amount of vertical leakage through the Fuson Formation.

- The radius of influence of the pumping test determined by a distance-drawdown plot was 2,100 ft.

- The observation well in the upper Lakota aquifer at 50 ft radial distance and 100 ft upward vertical distance from the pumping well took 160 minutes to first respond and produced a relatively limited 3.4 ft ultimate drawdown.

- The observation well in the overlying lower Fall River aquifer at 50 ft radial and 185 ft upward vertical distance from the pumping well underwent a complex response (see Section 5.5 in Appendix 2.7-B of the Technical Report) that included a likely Noordbergum effect that appears to be a characteristic of the Inyan Kara aquifers in this and other pumping tests.

- The observation well in the underlying Unkpapa/Sundance aquifer at 50 ft radial and 180 downward vertical distance from the pumping well was judged not to have

responded after consideration of likely barometric and tidal responses during the test (see Section 5.6 in Appendix 2.7-B of the Technical Report).

The 2008 test indicates that the lower and upper portions of the Lakota formation behave as a single, confined, leaky aquifer, although the upper and lower portions are not perfectly connected. Within the Lakota formation, vertical hydraulic connection throughout the entire formation is indicated by the delayed and muted response at the upper Lakota observation well. The 160-minute delay in response at the upper Lakota observation well is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pumping test site (see Drawings 5.1, 5.2 and 5.3 in Appendix 2.7-B in the Technical Report). The extent and continuity of the shale interbeds are not known from test results or current drilling in the area, although the ultimately small response of 3.1 ft drawdown at 50-100 ft distance suggests the shale interbeds are continuous at the scale of the radius of influence (2,100 ft).

Confinement and leakage from the overlying Fuson member is evident in the matches to the Hantush-Jacob type curves at two of the three observation wells. These results are more definitive than the 1979 TVA test where confined, leaky behavior for the Lakota was predicted but not demonstrated with curve match results.

The Burdock pumping test in 2008 may be directly compared to the 1979 TVA test for the Lakota aquifer as the tests were nearly at the same location. The average transmissivity and storativity values determined from the TVA tests were 190 ft^2/day and 1.8 x 10^{-4}, respectively (see Section 1.2.1 above and p. 17 in Boggs and Jenkins, 1980). Comparing median transmissivity of 150 ft^2/day and storativity of 1.2 x 10^{-4} determined in the 2008 test to the TVA test, the new aquifer parameters for the lower Lakota are respectively about 80 and 70 percent of the 1979 results. Because transmissivity and storativity depend on aquifer thickness, comparing the results suggests that there may be some scaling effect between the tests due to the differing lengths of screened intervals. The scaling effect is attributed to partial disconnection between the lower and upper portions of the Lakota Formation aquifer as described above.

Therefore, the 1979 TVA test transmissivity of 190 ft^2/day and 1.8 x 10^{-4} is considered representative of the entire Lakota aquifer for a regional application, such as groundwater flow model. The 2008 test provides transmissivity and storativity data at the operational-scale of a prospective well field.

In summary, the aquifer tests in 1979 and 2008 indicate that the Lakota Formation is a confined aquifer with a leaky confining layer, which is demonstrably the Fuson Member. As described in

Section 5.1 in Appendix 2.7-B of the Technical Report, the potentiometric surface in the Fall River aquifer is close to that in the Lakota aquifer at the Burdock pumping test site, indicating some local connection between the two formations through the intervening Fuson Member is a background condition at the Burdock test area. No leakage from the underlying Morrison Formation was evident throughout the 2008 test.

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Dewey-Burdock Project

Pond Design Report

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Powertech (USA) Inc.
Dewey-Burdock Project
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Executive Summary

This report provides the preliminary pond design for the land application option and for the deep well disposal option at the Dewey-Burdock project. These designs have been completed following United States Nuclear Regulatory Commission (USNRC) Regulatory Guide 3.11, NUREG 1569, 10 CFR Part 40, Appendix A, Criterion 5 and State of South Dakota Administrative Rule 74:29:11:23.

Land Application Option

The land application option includes six categories of ponds:

- Radium settling ponds containing bleed and restoration water and used to settle radium out of solution
- Outlet ponds used to intercept treated water from the radium settling ponds and to store stormwater falling on the radium settling ponds
- Storage ponds used to store treated water during the non-irrigation season
- A central plant pond containing brine produced at the Burdock Plant site
- Spare ponds used for emergency containment should the radium settling or central plant ponds fail
- Spare storage ponds used for emergency containment should any of the storage ponds fail, or portions of the land application system become temporarily inoperable

The design makes allowance for the following:

- Two radium settling ponds, one each at the Dewey and Burdock having a storage capacity of 39.4-acre-ft each
- Two outlet ponds, one each at the Dewey and Burdock sites having a storage capacity of 4.9-acre-ft each
- Two sets of storage ponds:
  - A system of four ponds constructed at the Dewey Site each having a storage capacity of 63.8-acre-ft

- A system of four ponds constructed at the Burdock Site each having a capacity of 63.8-acre-ft
- Two spare storage ponds, one each at the Dewey and Burdock Sites having a storage capacity of 63.8-acre-ft each
- A central plant pond at the Burdock site having a capacity of 36.2-acre-ft
- Two spare ponds, one each at the Dewey and Burdock Sites having a capacity of 39.4-acre-ft each

Deep Well Disposal Option

The deep well disposal option includes five categories of ponds:

- Radium settling ponds, containing bleed water and restoration water and used to settle radium out of solution
- Outlet ponds used to intercept treated water from the radium settling ponds and to store stormwater falling on the radium settling ponds
- Surge ponds, containing water that has been treated and which is to be pumped to the disposal wells
- Spare ponds, used for emergency containment should any of the ponds fail
- A central plant pond containing brine produced at the Burdock Plant site

The design makes allowance for the following:

- Two radium settling ponds, one each at the Dewey and Burdock having a storage capacity of 15.9-acre-ft each
- Two outlet ponds, one each at the Dewey and Burdock sites having a storage capacity of 5.1-acre-ft each
- Two surge ponds, one each at the Dewey and Burdock sites having a storage capacity of 8.4-acre-ft each
- A central plant pond at the Burdock site having a capacity of 15.9-acre-ft
- Two spare ponds, one each at the Dewey and Burdock sites having a capacity of 15.9-acre-ft each

The ponds have been designed to store water reporting to them while maintaining 3 feet (ft) of freeboard. The geometry and storage characteristics of the radium settling ponds have also been checked to verify that they will allow the efficient removal of radium from solution.

The radium settling, spare and central plant ponds will be provided with the following lining system:

- An 80-milli-inch (mil) high density polyethylene (HDPE) primary liner
- A 60-mil-HDPE secondary liner
- A 1-ft-thick clay liner below the secondary liner
- A geonet drainage layer sandwiched between the primary and secondary HDPE liners
- A leak detection sump and access port system

All other ponds will contain treated water that is either to be used for land application or deep well disposal. These ponds will include a single 40-mil-HDPE liner underlain by a 1-ft-thick clay liner.

The results of the stability analyses calculated for the embankments using three different methods of analysis; Bishop Method, Janbu Method, and Morgenstern-Prices Method indicate that the slopes are stable under both static and MCE seismic loading conditions.

Precipitation falling in the land application areas will be contained within those areas and in evaporation pans located adjacent to them, from where it will evaporate. The Soil Plant Air Water (SPAW) modeling indicates that there will be no percolation beyond the base of the soil profile from the land application system and therefore no potential impact to groundwater. Also the underlying Graneros Group provides a low permeability barrier to any potential seepage from land application.

The ponds provided for the land application design all have larger storage volumes than the ponds provided for the deep well disposal option, which is discussed in Section 4.0. Therefore, the land application ponds would also operate satisfactorily for deep well disposal.

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List of Acronyms and Abbreviations

acre-ft	unit of volume (1 acre-foot = 43,560.2 cubic feet)
Client	Powertech (USA) Inc.
cm/sec	centimeters per second
CPP	central processing plant
ft	feet
ft^3/year	cubic feet per year
gpm	gallons per minute
HDPE	high density polyethylene
H:V	horizontal to vertical
Knight Piésold	Knight Piésold and Co.
MCE	maximum credible earthquake
mil	milli-inch (one thousandth of an inch)
SAR	sodium adsorption ratio
SOC	soil organic carbon
SPAW	Soil Plant Air Water
USNRC	United States Nuclear Regulatory Commission

Powertech (USA) Inc.
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1.0 Introduction

1.1 Background

Knight Piésold was retained by Powertech (USA) Inc. to design the water containment storage ponds associated with land application and deep well disposal at the proposed Dewey-Burdock Project. The project is located in the Fall River and Custer Counties in South Dakota, on the southwest flank of the Black Hills uplift. It will involve in situ leaching to recover uranium from the Fall River and Lakota Formations.

This report describes the results of the pond design and stability, seepage and seismic analysis in accordance with NRC Regulatory Guide 3.11, NUREG 1569, 10 CFR Part 40 Appendix A, Criterion 5 and South Dakota Administrative Rule 74:29:11:23. These regulatory requirements are provided in Appendix A. The ponds have been sized to store and treat water resulting from the in situ leach process, stormwater runoff from the land application areas, and the 100-year, 24-hour design storm event.

1.2 Limitations and Disclaimer

This report titled Dewey-Burdock Project Pond Design Report has been prepared by Knight Piésold and Co. (Knight Piésold) for the exclusive use of Powertech (USA) Inc. (Client). No other party is an intended beneficiary of this report or the information, opinions, and conclusions contained herein. Any use by any party other than the Client of any of the information, opinions, or conclusions is the sole responsibility of said party. The use of this report shall be at the sole risk of the user regardless of any fault or negligence of the Client or Knight Piésold.

The information and analyses contained herein have been completed to a level of detail commensurate with the objectives of the assignment and in light of the information made available to Knight Piésold at the time of preparation. This report and its supporting documentation have been reviewed and/or checked for conformance with industry-accepted norms and applicable government regulations. Calculations and computer simulations have been checked and verified for reasonableness, and the content of the report has been reviewed for completeness, accuracy, and appropriateness of conclusions. To the best of the information and

belief of Knight Piésold, the information presented in this report is accurate to within the limitations specified herein.

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1.3 Contributors and Approvals

This report was prepared, reviewed, and approved by the undersigned.

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2.0 Site Investigation

2.1 General

Knight Piésold carried out a site investigation at the Dewey-Burdock site during July 2008. The investigation was limited to excavating test pits and was targeted at obtaining the following:

- Parameters required for land application modeling
- Engineering characteristics of the soils for pond design

Eleven test pits were excavated as part of the investigation, ranging in depth form 6 to 13 ft. Five of the test pits were excavated at the Dewey Site, with the remainder being excavated at the Burdock Site. The locations of the test pits in relation to land application and irrigation, and to deep well disposal options are illustrated in Figures 2.1-1 and 2.1-2, respectively. Test pit logs are included in Appendix B. Samples obtained from the test pits were tested at Knight Piésold's geotechnical laboratory in Denver for the following properties:

- Visual classification
- Particle size distribution
- Specific gravity
- Natural moisture content
- Dry bulk density
- Atterberg limits
- Compaction testing
- Triaxial testing
- Flexible wall permeability

Samples were also sent to an outside laboratory where they were evaluated for sodium absorption ratio (SAR) and soil organic carbon (SOC).

2.2 Subsurface Conditions

The soils underlying the site consist primarily of lean clays, lean clays with sand, fat clays, and fat clays with sand. Clayey gravel was encountered in test pit TP03 and sandy lean clay was encountered in test pits TP04 and TP08. Bedrock, where encountered, consisted of either claystone or shale. Results from the laboratory tests indicate that the materials are suitable for

the construction of the proposed ponds. Stability analysis results that are presented in Sections 3.11 and 4.9 confirm this.

Test pit logs are provided in Appendix B, and geotechnical laboratory test results are provided in Appendix C.

3.0 Land Application Pond Design

3.1 SPAW Modeling Assumptions

The design of the land application system was developed based on modeling using the SPAW model, as described further in Appendix D. Two land application areas, one at the Dewey site and one at the Burdock site will be used. The total irrigated area at any given time at the Dewey site would be 315 acres, consisting of four 50-acre pivots, four 25-acre pivots, plus one 15-acre pivot. In addition, there would be one 50-acre pivot and one 15-acre pivot on standby (total pivots at Dewey is five 50-acre pivots, four 25-acre pivots, and two 15-acre pivots). Pumping at Dewey would occur for 24 hours every day from March 29 to May 10 at a rate of 297 gallons per minute (gpm); from May 11 to September 24 at a rate of 653 gpm; and from September 25 to October 31 at a rate of 297 gpm.

The total irrigated area at any given time at the Burdock site would also be 315 acres (six 50-acre pivots plus one 15-acre pivot). In addition, there would be two 25-acre pivots and one 15-acre pivot on standby. The total pivots at Burdock would be six 50-acre pivots, two 25-acre pivots, and two 15-acre pivots. Pumping at Burdock would also occur for 24 hours on every day from March 29 to May 10 at 297 gpm, from May 11 to September 24 at a rate of 653 gpm, and from September 25 to October 31 at a rate of 297 gpm.

Precipitation falling in the land application areas will be contained within those areas and in evaporation pans located adjacent to them, from where it will evaporate. The SPAW modeling indicates that there will be no percolation beyond the base of the soil profile from the land application system and therefore no potential impact to groundwater. Also the underlying Graneros Group provides a low permeability barrier to any potential seepage from land application (reference Plates 315, 335, 337 and 338).

Four single-lined impoundments (ponds) would be constructed at the Dewey site for the temporary storage of the irrigation water. Each pond will be 465 ft wide x 465 ft long x 30 ft deep including 3 ft of freeboard, with an operating capacity of 61.8-acre-ft. In addition to the storage ponds, double-lined radium settling and spare ponds with leak detection, and single-lined spare storage and outlet ponds will also be constructed at Dewey. The radium settling pond and spare ponds will be 880 ft long x 200 ft wide x 25.5 ft deep, including 3 ft of freeboard, and will have an operational storage of 39.4-acre-ft. The outlet pond will be 280 ft wide x 162 ft

long x 14 ft deep including 3 ft of freeboard, and will have an operational storage of 4.9-acre-ft. The spare storage pond will be geometrically identical to the storage ponds.

Four single-lined impoundments (ponds) would be constructed at the Burdock site for the temporary storage of the irrigation water. Each pond will be 465 ft wide x 465 ft long x 30 ft deep including 3 ft of freeboard, with an operating capacity of 61.8-acre-ft. In addition to the storage ponds, double-lined radium settling, spare, and central plant ponds with leak detection, and single-lined spare storage and outlet ponds will also be constructed at Burdock. The radium settling and spare ponds will be 880 ft wide x 200 ft long x 25.5 ft deep, including 3 ft of freeboard, and will have an operational storage of 39.4-acre-ft. The central plant pond will be 362 ft wide x 362 ft long x 25 ft deep including 3 ft of freeboard, and will have an operational storage of 36.2-acre-ft. The outlet pond will be 280 ft wide x 162 ft long x 14 ft deep including 3 ft of freeboard, and will have an operational storage of 4.9-acre-ft. The spare storage pond will geometrically identical to the storage ponds

The ponds provided for the land application design all have larger storage volumes than the ponds provided for the deep well disposal option, which is discussed in Section 4.0. Therefore, the land application ponds would also operate satisfactorily for deep well disposal.

3.2 Design Flows

Three water streams resulting from mining activities report to the ponds:

- Bleed water from the production wells
- Restoration water from the restoration wells
- Process water from the plant

Bleed and restoration water is pumped to the radium settling ponds where it is treated before overflowing into the outlet pond and pumped to the storage ponds where it is used for land application. Process water from the central processing plant (CPP) is pumped to the central plant pond, where it is stored. Allowance has been made for all ponds to store water resulting from the 100-year, 24-hour storm event while maintaining 3 ft of freeboard.

3.2.1 Production Well Bleed Water

The in situ leach process includes for up to 3 percent of the water pumped from the production wells to be bled from the system. Total production water is approximately 4,000 gpm, resulting

in a bleed flow of approximately 120 gpm. This water will be pumped to the radium settling ponds.

3.2.2 Wellfield Restoration Water

This water, having a flow rate of approximately 500 gpm, will be used to flush the mineralized target zone following uranium recovery. Once it returns to the surface, the water will be pumped to the radium settling ponds.

3.2.3 Process Water

The uranium recovery process will result in a brine stream of approximately 12 gpm. Allowance has been made for some of this water to be stored in a central plant pond.

3.2.4 Precipitation

All precipitation falling on the land application areas will be stored within those areas where it will either evaporate or infiltrate into the soil. Water falling directly on the pond surfaces will be stored in the ponds and used for land application.

3.3 Pond Design Requirements

Active storage requirements for the radium settling, outlet, storage, and central plant ponds are provided below. In addition to the active storage requirements and the design storm event, all ponds will be provided with 3 ft of freeboard. The catchment areas of the ponds will be minimized by grading all roads away from them, and by providing stormwater diversions to prevent water from upstream catchments from reporting to them.

Figure 3.3-1 provides the Burdock Plant Site Plan and Figures 3.3-2 and 3.3-3 includes the pond cross sections.

Figure 3.3-4 provides the Dewey Plant Site Plan and Figures 3.3-5 and 3.3-6 include the pond cross sections.

3.3.1 Radium Settling Ponds

Radium is settled out of solution by adding barium chloride to the water. Co-precipitation of radium occurs when natural sulfate (SO_4) in the water combines with radium (Ra) and barium (Ba) to form $RaBaSO_4$. The requirements for efficient settlement of solids out of a solution have been incorporated into the design of the ponds and include the following:

- Sufficient retention time for the settlement of radium out of solution
- Providing adequate surface area to prevent the development of large surface currents
- Providing a pond geometry or arrangement that will prevent short circuiting of flows through the pond

Radium is settled out of solution by adding barium chloride to the water. Co-precipitation of radium occurs when natural sulfate (SO_4) in the water combines with radium (Ra) and barium (Ba) to form $RaBaSO_4$. All discussions in the following sections, therefore, refer to the settlement of radium barium sulfate.

3.3.1.1 Retention Time and Storage

Water in the ponds must be retained for sufficient length of time to allow radium barium sulfate to settle out of solution. A literature survey of radium settling ponds indicated that typical retention times range from eight to 14 days. A retention time of 14 days has been adopted for this project. This requires that the ponds have a minimum storage volume of 38.4-acre-ft. In addition, the ponds are expected to accumulate 790-cubic-ft per year (ft^3/year) of radium barium sulfate sludge. For a 10-year project life, this will amount to 0.18-acre-ft of storage. The design allows identical radium settling ponds to be constructed at Dewey and Burdock Sites, capable of storing 39.4-acre-ft each, allocated as follows:

- 39.2-acre-ft for bleed and restoration water
- 0.2-acre-ft for sludge accumulation

Stormwater will overflow into the outlet pond, which has been sized to accommodate the 100-year, 24-hour storm event from both itself and the radium settling pond.

3.3.1.2 Surface Area

To promote settling, the pond surface area should be large enough to prevent significant surface currents from developing. Should these develop, they could keep the radium barium sulfate in suspension. They could also result in short circuiting, with water flowing directly from the pond inlet to the outlet.

The literature survey indicated that a minimum area of 0.6 acres should be allowed for every 100 gpm of flow. For a flow of 620 gpm, this results in area of 3.72 acres with the designed ponds having a water surface area of 3.85 acres.

3.3.1.3 Pond Geometry

Unless baffles are provided, the length of a settling pond should ideally be at least four times its width. The radium settling ponds have a crest length of 880 ft and a width of 220 ft, satisfying this requirement.

3.3.2 Outlet Ponds

Identical outlet ponds have been designed for the Dewey and Burdock Sites. They have been sized to accommodate one day's production water, equating to 2.7-acre-ft, and precipitation from the 100-year, 24-hour storm event falling on both the radium settling and outlet pond.

The ponds have been designed to store the following:

- 2.7-acre-ft for treated irrigation water
- 1.7-acre-ft for the 100-year, 24-hour design storm event falling on the radium settling pond
- 0.4-acre-ft for the 100-year, 24-hour design storm event falling on the radium settling pond

3.3.3 Storage Ponds

Outflow from the storage ponds to land application areas exceeds water inflow during the period of land application (March 29 to October 31). However, water generated during the remainder of the year needs to be stored until it can be used for land application. Total storage requirements were modeled using the SPAW Model, and were calculated to be 216.4-acre-ft at both the Dewey satellite plant site and the Burdock central processing plant site. Allowance has been made for an additional 27.5-acre-ft of storage at each site to allow for the possibility that the start of the land application may be delayed.

The design allows four storage ponds to be constructed at both the Dewey and Burdock Sites, for a total of eight ponds, each capable of storing 63.8-acre-ft, allocated as follows:

- 61.8-acre-ft for treated irrigation water
- 2-acre-ft for the 100-year, 24-hour design storm event

3.3.4 Central Plant Pond

The central plant pond is located at the Burdock Site, and has been sized to accommodate a discharge of 10.81 gpm over a period of two years, equating to 34.9-acre-ft.

The pond has been designed to store the following:

- 35-acre-ft for brine from the CPP
- 1.2-acre-ft for the 100-year, 24-hour design storm event

3.3.5 Spare Ponds

The spare ponds have been designed to be identical to the radium settling ponds, which are the largest double-lined ponds in the system. The spare ponds are located adjacent to the radium settling pond. They have been designed to accommodate water from any of the radium settling or central plant ponds, should the ponds fail.

A spare storage pond has been designed at both the Dewey and Burdock sites to provide emergency containment for the single-lined storage and outlet ponds.

3.4 Water Flow Configurations

Water will be routed through the storage ponds to maximize retention time. Figure 3.4-1 provides the Burdock Plant Site Flow Diagram and Figure 3.4-2 provides the Dewey Plant Site Flow Diagram.

3.5 Pond Lining Systems

The lining system for the radium settling, spare and central plant ponds will consist of the following:

- An 80-mil-textured primary HDPE liner.
- A 60-mil-smooth secondary HDPE liner.
- A 12-inch-thick compacted clay liner, having a maximum permeability of 1×10^{-7} cm/sec. This liner will be constructed below the secondary HDPE liner.
- A geonet sandwiched between the primary and secondary HDPE liners.

The outlet and storage ponds will contain treated water that will be used for land application. The liner requirement on these ponds is therefore less stringent, and will consist of the following:

- An 40-mil-textured HDPE liner.
- A 12-inch-thick compacted clay liner, having a maximum permeability of 1×10^{-7} cm/sec. This liner will be constructed below the HDPE liner.

3.6 Leak Detection Systems

The radium settling, spare and central plant ponds will include a geonet drainage layer installed between the primary and secondary HDPE liners. The geonet will drain into a leak detection sump. A minimum grade of 2 percent will be maintained across the bottom of the ponds to facilitate the drainage of water into the leak detection sump should a leak develop. A leak detection access port and pump will be provided at the sump to allow any water collecting there to be pumped out and monitored. Pipes feeding into the double-lined ponds will be dual contained, with the carrier and containment pipes being connected to the primary and secondary HDPE liners, respectively. The leak detection system is shown on Figure 3.6-1.

3.7 Foundation Preparation

Foundation preparation on the ponds will include the following:

- Removing vegetation, existing structures and unsuitable foundation materials
- Subgrade preparation
- Site grading

More detail on the items listed above is provided in Table 3.7-1.

Table 3.7-1 – Foundation Preparation Requirements

Item	Description
Vegetation	Clear and grub vegetation
Structures	Remove any existing structures
Surface soils	- Strip organic soil matter for a minimum of 10 ft beyond the pond embankment limits. - Place the stripped soil in temporary stockpiles for final reclamation. - Stockpiles should be located as close to the stripped areas as possible. - Proposed stockpile locations are indicated on Figures 3.7-1, 3.3-1, and 3.3-3.
	Scarify, moisture condition and compact the top 6-inches of the stripped ground surface in fill areas to a minimum of 90 percent of the maximum Modified Proctor Dry Density (ASTM D 1557).
Site Grading	Undertake site grading cut and fill. Compact graded materials to a minimum of 90 percent of the maximum dry density (ASTM D 1557) within ± 2 percent of the optimum moisture content.

3.8 Embankment Drainage

An embankment drainage system will be installed in the outer face of all embankments to prevent the outer toe of the embankment from becoming saturated should a HDPE liner system fail. Water collected by the drain system will be conveyed to a sump from where it will be pumped back to the ponds.

3.9 Pond Connectivity

All storage ponds will be connected via spillways. The radium settling and spare ponds will also be connected to the outlet pond via a spillway. The proposed flow of water through the ponds system is shown on Figures 3.4-1 and 3.4-2.

3.10 Pond Seepage Analysis

Seepage analyses were undertaken for the outer embankments of the ponds to model the phreatic surface through the outer embankments of the ponds should the HDPE liners fail. The phreatic surface determined from the seepage analysis was then used to model embankment slope stability for that condition.

All ponds will be HDPE lined, with the HDPE liner being underlain by a 1-ft-thick clay liner. Negligible seepage is expected from them under normal operating conditions.

3.10.1 Material Properties

Flexible wall permeability tests were undertaken on both undisturbed and remolded samples collected from site. The results were further subdivided depending on which site the samples were collected at, and are summarized in Table 3.10-1.

Table 3.10-1 – Permeability Test Results

Site	Test Type*	No. of Samples	Permeability (cm/sec)			
			Min	Max	Average	Median
Dewey	Undisturbed	12	2.30×10^{-7}	4.90×10^{-4}	7.63×10^{-5}	2.80×10^{-5}
	Remolded	11	3.70×10^{-9}	2.90×10^{-6}	5.45×10^{-7}	8.70×10^{-8}
Burdock	Undisturbed	10	4.20×10^{-8}	5.70×10^{-4}	8.03×10^{-5}	7.20×10^{-6}
	Remolded	8	7.90×10^{-9}	9.30×10^{-5}	1.87×10^{-5}	7.55×10^{-6}

*Undisturbed samples were collected using Shelby tubes; remolded samples were compacted to 95 percent of maximum dry density.

The median undisturbed permeabilities have been assumed for the in situ soils, while the median remolded permeabilities have been assumed for the embankments. In addition, regulatory requirements specify that a 1-ft-thick clay liner having a maximum permeability of 1×10^{-7} be used below the HDPE liners in the ponds. Material from the pond excavation will be selected to meet this criterion. If necessary, borrow areas will be developed to source this material.

Sand used in the embankment drainage system was assumed to have a permeability of 5×10^{-4} cm/sec.

3.10.2 Analysis

For the seepage analysis, it was assumed that the HDPE liners in the ponds fail completely, with the 1-ft-thick clay liner providing the only barrier to seepage through the embankment. The seepage analysis was completed using the GeoStudio 2007 software package.

3.11 Pond Stability Analyses

Stability analyses on the pond embankments were completed using the GeoStudio 2007 software package. The sections selected for the analysis are located at the highest points of the embankments.

3.11.1 Analyses

The following analyses were conducted on each of the ponds:

- A static stability analysis, assuming that the liners are intact (no phreatic surface in the embankment)

- A pseudostatic analysis, assuming the liners are intact and modeling the Maximum Credible Earthquake (MCE) acceleration
- A static analysis, assuming that the liners have completely failed, allowing a phreatic surface to develop in the embankment
- A pseudostatic analysis, assuming that the liners have completely failed, allowing a phreatic surface to develop in the embankment, and modeling the MCE acceleration

3.11.2 Soil Strengths

Soil strengths were obtained from three tri-axial tests that were conducted on material samples collected during the site investigation. The results from these tests are provided in Table 3.11-1.

Table 3.11-1 – Material Strength Characteristics

Site	Sample Number	Angle of Friction (°)	Cohesion (ksi)	Description
Dewey	TP 02-7	25.0	0.10	Lean clay with sand
Burdock	TP 08-6	28.5	0.06	Sandy lean clay
	TP 09-4	27.0	0.15	Lean clay with sand

Test pits TP 08-6 and TP 09-4 are located close to the Burdock Site, with test pit TP 02-7 being located close to the Dewey Site. As the material strength values obtained from test pit TP 09-4 are lower than those obtained from test pit TP 08-6, those values were used for the analyses undertaken at the Burdock Site. The material strength values obtained from test pit TP 02-7 were used for the analyses undertaken on the ponds at the Dewey Site.

3.11.3 Material Densities

In situ material densities were obtained from undisturbed samples collected during the site investigation. The densities of embankment materials were obtained from compaction tests undertaken on samples collected from site. Results for the Dewey and Burdock Sites are summarized separately in Table 3.11-2.

Table 3.11-2 – Soil Densities

Site	Test Type	No. of Samples	Moist Soil Density (pcf)			
			Min	Max	Average	Median
Dewey	Undisturbed	12	86.3	113.3	98.3	97.6
	Compaction test	7	120.4	124.2	123.0	124.0
Burdock	Undisturbed	11	92.4	101.0	97.9	98.3
	Compaction test	6	123.7	130.7	127.4	126.7

Median undisturbed densities have been assumed for in situ soils, while the median densities from the compaction tests have been assumed for the embankments and clay liners.

3.11.4 Seismic Ground Acceleration Values

MCE ground accelerations were obtained from the document "Dewey-Burdock Project, Application for NRC Uranium Recovery License, Fall River and Custer Counties, South Dakota, Technical Report," dated February 2009. The MCE was determined in Section 2.6.6 of the report to have a maximum ground acceleration of 0.09 g.

3.11.5 Stability Analysis Results

The factors of safety for the embankments are provided in Table 3.11-3. The table provides results for three methods of analysis, namely:

- Bishop method
- Janbu method
- Morgenstern-Price method

The analyses shown in Table 3.11-3 below indicate that the outer slopes of the ponds have a minimum factor of safety of approximately 2.51 under normal static loading conditions assuming that the HDPE liners remain intact, preventing a phreatic surface from developing in the embankment. The minimum factor of safety reduces to approximately 1.79 during the MCE seismic event.

Should the HDPE liner fail, a drain installed in the embankment will help to lower the phreatic surface and prevent the downstream toe from becoming saturated. The factors of safety do reduce, with the minimum factor of safety under normal static loading conditions reducing to

approximately 1.67. Under MCE seismic loading conditions the minimum factor of safety reduces to approximately 1.15.

The inner slope is less critical in terms of preventing a breach of the embankment, but was evaluated for stability assuming the HDPE liners remain intact. The minimum factor of safety under normal static loading conditions was calculated to be 1.90, while under MCE seismic loading conditions this reduces to approximately 1.47.

The factors of safety indicate that both the inner and outer the slopes are stable under both static and MCE seismic loading conditions.

Table 3.11-3 – Stability Analysis Factors of Safety

Pond	Description	Analysis	Factor of Safety		
			Bishop	Janbu	Morgenstern-Price
Dewey Radium Settling Pond	Outer slope – assuming intact HDPE liner	Static	2.87	2.63	2.87
		Seismic (MCE)	2.04	1.89	2.04
	Outer slope – assuming HDPE liner has failed	Static	2.10	1.87	2.11
		Seismic (MCE)	1.44	1.29	1.45
	Inner slope – assuming intact HDPE liner	Static	2.03	1.91	2.03
		Seismic (MCE)	1.56	1.47	1.56
Dewey Outlet Pond	Outer slope – assuming intact HDPE liner	Static	3.00	2.76	3.00
		Seismic (MCE)	2.14	1.98	2.14
	Outer slope – assuming HDPE liner has failed	Static	2.23	1.95	2.23
		Seismic (MCE)	1.51	1.35	1.52
	Inner slope – assuming intact HDPE liner	Static	2.99	2.79	2.99
		Seismic (MCE)	2.13	1.99	2.13
Dewey Storage Ponds	Outer slope – assuming intact HDPE liner	Static	2.68	2.51	2.68
		Seismic (MCE)	1.91	1.79	1.91
	Outer slope – assuming HDPE liner has failed	Static	1.97	1.74	1.98
		Seismic (MCE)	1.36	1.22	1.37
	Inner slope – assuming intact HDPE liner	Static	2.58	2.43	2.58
		Seismic (MCE)	1.83	1.73	1.83
Burdock Radium Settling/Spare Ponds	Outer slope – assuming intact HDPE liner	Static	2.93	2.74	2.93
		Seismic (MCE)	2.08	1.96	2.09
	Outer slope – assuming HDPE liner has failed	Static	2.03	1.80	2.04
		Seismic (MCE)	1.40	1.25	1.41
	Inner slope – assuming intact HDPE liner	Static	2.12	1.98	2.12
		Seismic (MCE)	1.63	1.53	1.63
Burdock Outlet Pond	Outer slope – assuming intact HDPE liner	Static	2.93	2.76	2.93
		Seismic (MCE)	2.09	1.97	2.10
	Outer slope – assuming HDPE liner has failed	Static	2.01	1.80	2.02
		Seismic (MCE)	1.38	1.24	1.40
	Inner slope – assuming intact HDPE liner	Static	3.14	2.92	3.14
		Seismic (MCE)	2.24	2.09	2.24
Burdock Storage Ponds	Outer slope – assuming intact HDPE liner	Static	2.75	2.60	2.75
		Seismic (MCE)	1.94	1.84	1.95
	Outer slope – assuming HDPE liner has failed	Static	1.87	1.67	1.87
		Seismic (MCE)	1.28	1.15	1.29
	Inner slope – assuming intact HDPE liner	Static	2.46	2.33	2.46
		Seismic (MCE)	1.81	1.72	1.82

Table 3.11-3 – Stability Analysis Factors of Safety

Pond	Description	Analysis	Factor of Safety		
			Bishop	Janbu	Morgenstern-Price
Central Plant Pond (Burdock)	Outer slope – assuming intact HDPE liner	Static	3.04	2.86	3.04
		Seismic (MCE)	2.16	2.02	2.16
	Outer slope – assuming HDPE liner has failed	Static	2.09	1.86	2.10
		Seismic (MCE)	1.45	1.29	1.46
	Inner slope – assuming intact HDPE liner	Static	2.03	1.90	2.03
		Seismic (MCE)	1.59	1.48	1.59

3.12 Embankment Settlement

Elastic theory was used to obtain an estimate of embankment settlements using material characteristics derived from the triaxial test results. Assuming a maximum embankment height of 30 ft, elastic theory predicts that the elastic settlement of an embankment having a crest width of 40 ft and 1(v):4.5(h) side slopes is likely to be less than 1 ft. This settlement will occur during construction, and will be accommodated by placing fill to ensure that final design crest elevations are achieved. Due to the relatively low embankments that are being constructed, settlement due to consolidation is not expected to be significant.

3.13 Summary of Pond Characteristics

Table 3.13-1 summarizes the pond characteristics at the Dewey-Burdock Uranium Project.

Table 3.13-1 – Pond Characteristics and Design Features

Parameter	Radium Settling/Spare Ponds	Central Plant Pond	Outlet Ponds	Storage and Spare Storage Ponds
Number of Ponds:				
Dewey	1 Radium Settling 1 Spare	-	1	4 Storage 1 Spare Storage
Burdock	1 Radium Settling 1 Spare	1	1	4 Storage 1 Spare Storage
Active Storage (per pond):				
Process water and stormwater from land application areas	39.4*	35.0	2.8	61.8
Stormwater falling on ponds	0**	1.2	2.1	2.0
Total	**39.4**	**36.2**	**4.9**	**63.8**
Crest width	220 ft	465 ft	162 ft	362 ft
Crest length	880 ft	465 ft	280 ft	362 ft
Depth	Varies 10.0 to 25.5 ft	Varies: 18.4 to 25.0 ft	Varies 12.3 to 14.0 ft	Varies 27.1 to 30.0 ft
Freeboard	3 ft	3 ft	3 ft	3 ft
Upstream embankment slope	3H:1V	3H:1V	4.5H:1V	4.5H:1V
Downstream embankment slope	4.5H:1V	4.5H:1V	4.5H:1V	4.5H:1V
Exterior embankment crest width	40 ft	40 ft	40 ft	40 ft
Interior embankment crest width	30 ft	N/A	30 ft	30 ft
Bottom grade	2 percent - graded towards leak detection sump		1 percent - graded towards a corner	
Lining system	Prepared subgrade or compacted random fill 1-ft-thick soil liner compacted to 95 percent standard proctor density 60-mil-smooth HDPE bottom (secondary) geomembrane 80-mil-textured HDPE top (primary) geomembrane Leak detection system consisting of geonet placed between primary and secondary geomembranes Leak detection sump and access port system 3-ft-deep by 3-ft-wide geomembrane anchor trench		Prepared subgrade or compacted random fill 1-foot-thick soil liner compacted to 95 percent standard proctor density 40-mil-textured HDPE geomembrane 3-ft-deep by 3-ft-wide geomembrane anchor trench	

*Includes 0.2-acre-ft storage for sludge

**Stormwater from the radium settling pond overflows into the outlet pond where it is stored

4.0 Deep Well Disposal Pond Design

4.1 Design Flows

Three water streams resulting from mining activities report to the ponds:

- Bleed water from the production wells
- Restoration water from the restoration wells
- Brine from the CPP

Bleed and restoration water is pumped to the radium settling ponds, where it is treated and used for deep well disposal. Some water from the CPP will be pumped to the CENTRAL PLANT pond where it will be stored. Allowance has been made for all ponds to store water resulting from the 100-year, 24-hour storm event while maintaining 3 ft of freeboard.

4.1.1 Production Well Bleed Water

The in situ leach process includes for up to 3 percent of the water pumped from the production wells to be bled from the system. Total production water is approximately 4,000 gpm, resulting in a bleed flow of approximately 120 gpm.

4.1.2 Wellfield Restoration Water

This water, having a flow rate of approximately 500 gpm, will be used to flush the mineralized target zone following uranium recovery. Once it returns to the surface, 120 gpm of this will be pumped to the radium settling ponds for treatment and deep well disposal, with the remainder being recycled as restoration water.

4.1.3 Brine from the Central Processing (Burdock) Plant Site

This water, having a flow rate of approximately 12 gpm, will be produced as part of the uranium extraction process.

4.1.4 Precipitation

Water falling directly on the pond surfaces will be stored in the ponds and either used for restoration water or deep well disposal.

4.2 Pond Design Requirements

Active storage requirements for the radium settling, outlet, surge and central plant ponds are provided below. In addition to active storage requirements, all ponds will be provided with 3 ft of freeboard. The catchment areas of the ponds will be minimized by grading all roads away from them, and by providing stormwater diversions to prevent water from upstream catchments from reporting to them.

Figure 4.2-1 provides the Dewey Plant Site Plan, and Figure 4.2-2 includes the pond cross sections.

Figure 4.2-3 provides the Burdock Plant Site Plan, and Figure 4.2-4 includes the pond cross sections.

4.2.1 Radium Settling Ponds

Radium is settled out of solution by adding barium chloride to the water. Co-precipitation of radium occurs when natural sulfate (SO_4) in the water combines with radium (Ra) and barium (Ba) to form $RaBaSO_4$. The requirements for efficient settlement of solids out of a solution include have been incorporated into the design of the ponds and include the following:

- Sufficient retention time for the settlement of radium out of solution
- Providing adequate surface area to prevent the development of large surface currents
- Providing a pond geometry or arrangement that will prevent short circuiting of flows through the pond

Radium is settled out of solution by adding barium chloride to the water. Co-precipitation of radium occurs when natural sulfate (SO_4) in the water combines with radium (Ra) and barium (Ba) to form $RaBaSO_4$. All discussions in the following sections, therefore, refer to the settlement of radium barium sulfate.

4.2.1.1 Retention Time and Storage

Water in the ponds must be retained for sufficient length of time to allow barium radium sulfate to settle out of solution. A literature survey of radium settling ponds indicated that typical retention times range from eight to 14 days. A retention time of 14 days has been adopted for this project. For a flow rate of 252 gpm, this requires that the pond have a minimum storage volume of 15.6-acre-ft. In addition, the ponds are expected to accumulate 321 ft^3/year of radium

barium sulfate sludge. For a 10-year project life, this will amount to 0.074-acre-ft of storage. The design allows identical radium settling ponds to be constructed at the Dewey and Burdock Sites, capable of storing 15.9-acre-ft each, allocated as follows:

- 15.8-acre-ft for bleed and restoration water
- 0.1-acre-ft for sludge accumulation

Stormwater will overflow into the outlet pond, which has been designed to accommodate the 100-year, 24-hour storm event for both itself and the radium settling pond.

4.2.1.2 Surface Area

To promote settling, the pond surface area should be large enough to prevent significant surface currents from developing. Should these develop, they could keep the radium barium sulfate in suspension. They could also result in short circuiting, with water flowing directly from the pond inlet to the outlet.

The literature survey indicated that a minimum area of approximately 0.6 acre should be allowed for every 100 gpm of flow. For a flow of 252 gpm, this results in area of 1.51 acres. The radium settling pond has been designed to have a water surface area of 2.20 acres.

4.2.1.3 Pond Geometry

Unless baffles are provided, the length of a settling pond should ideally be at least 4 times its width. To meet this criterion, the radium settling pond has been designed to have a crest length of 680 ft and a crest width of 170 ft.

4.2.2 Outlet Ponds

Identical outlet ponds have been designed for the Dewey and Burdock Sites. They have been designed to accommodate approximately three day's production water, equating to 3.3-acre-ft, and precipitation from the 100-year, 24-hour storm event falling on both the radium settling and outlet ponds. The ponds have been designed to store the following:

- 3.4-acre-ft for treated water for deep well injection
- 1.2-acre-ft for the 100-year, 24-hour design storm event falling on the radium settling pond
- 0.5-acre-ft for the 100-year, 24-hour design storm event falling on the outlet pond

4.2.3 Surge Ponds

Identical surge ponds have been designed for the Dewey and Burdock Sites. They serve as a volume buffer for water flowing out of the radium settling ponds and have been sized to accommodate seven day's production water. They have been designed to have a total storage of 8.4-acre-ft, allocated as follows:

- 7.8-acre-ft for treated water for deep well injection
- 0.6-acre-ft for the 100-year, 24-hour design storm event falling on the pond surface

4.2.4 Central Plant Pond

The central plant pond is located at the Burdock Site, and is provided to store brine from the plant. The central plant pond has been designed to have the same active storage as the spare pond, and has a total storage of 15.9-acre-ft, allocated as follows:

- 15.2-acre-ft brine
- 0.7-acre-ft for the 100-year, 24-hour design storm event falling on the pond surface

4.2.5 Spare Pond

The spare ponds have been designed to be identical to the radium settling ponds, which are the largest ponds in the system. The spare ponds are located adjacent to the radium settling ponds, and have been designed to accommodate water from any of the other ponds should their liners fail.

4.3 Water Flow Configurations

Water will be routed through the radium settling ponds to maximize retention time and facilitate the settlement of barium sulfate. Figure 4.3-1 provides the Dewey Plant Site Flow Diagram and Figure 4.3-2 provides the Burdock Plant Site Flow Diagram.

4.4 Pond Lining Systems

The lining system for the radium settling, spare and central plant ponds will consist of the following:

- An 80-mil-textured primary HDPE liner.
- A 60-mil-smooth secondary HDPE liner.

- A 12-inch-thick compacted clay liner, having a maximum permeability of $1x10^{-7}$ cm/sec. This liner will be constructed below the secondary HDPE liner.
- A geonet sandwiched between the primary and secondary HDPE liners.

The outlet and surge ponds will contain treated water that will be used for deep well injection. The liner requirement on those ponds is therefore less stringent, and will consist of the following:

- An 40-mil-textured HDPE liner.
- A 12-inch-thick compacted clay liner, having a maximum permeability of $1x10^{-7}$ cm/sec. This liner will be constructed below the HDPE liner.

4.5 Leak Detection Systems

The radium settling, spare and central plant ponds will include a geonet drainage layer installed between the primary and secondary HDPE liners. The geonet will drain into a leak detection sump. A minimum grade of 2 percent will be maintained across the bottom of the ponds to facilitate the drainage of water into the leak detection sump should a leak develop. A leak detection access port and pump will be provided at the sump to allow any water collecting there to be pumped out and monitored. Pipes feeding into the double-lined ponds will be dual contained, with the carrier and containment pipes being connected to the primary and secondary HDPE liners, respectively. The leak detection system is shown on Figure 4.5-1.

4.6 Foundation Preparation

Foundation preparation on all ponds will include the following:

- Removing vegetation, existing structures and unsuitable foundation materials
- Subgrade preparation
- Site grading

More detail on the items listed above is provided in Table 4.6-1.

Table 4.6-1 – Foundation Preparation Requirements

Item	Description
Vegetation	Clear and grub vegetation
Structures	Remove any existing structures
Surface soils	- Strip organic soil matter for a minimum of 10 ft beyond the pond embankment limits - Place the stripped soil in temporary stockpiles for final reclamation - Stockpiles should be located as close to the stripped areas as possible - Proposed stockpile locations are indicated on Figures 4.6-1, 4.2-1, and 4.2-3
	Scarify, moisture condition and compact the top 6 inches of the stripped ground surface in fill areas to a minimum of 90 percent of the maximum Modified Proctor Dry Density (ASTM D 1557)
Site Grading	Undertake site grading cut and fill. Compact graded materials to a minimum of 90 percent of the maximum dry density (ASTM D 1557) within ± 2 percent of the optimum moisture content

4.7 Embankment Drainage

An embankment drainage system will be installed in the outer face of all embankments to prevent the outer toe of the embankment from becoming saturated should a HDPE liner system fail. Water collected by the drain system will be conveyed to a sump, from where it will be pumped back to the ponds.

4.8 Pond Seepage Analyses

Seepage analyses were undertaken for the outer embankments of the ponds to model the phreatic surface through the outer embankments of the ponds should the HDPE liners fail. The phreatic surface determined from the seepage analysis was then used to model embankment slope stability for that condition.

All ponds will be HDPE lined, with the HDPE liner being underlain by a 1-ft-thick clay liner. Negligible seepage is expected from them under normal operating conditions.

4.8.1 Material Properties

Flexible wall permeability tests are summarized in Table 3.10-1. The median undisturbed permeabilities have been assumed for the in situ soils, while the median remolded permeabilities have been assumed for the embankments. In addition, regulatory requirements specify that a 1-ft-thick clay liner having a maximum permeability of $1x10^{-7}$ be used below the HDPE liners in

the ponds. Material from the pond excavation will be selected to meet this criterion. If necessary, borrow areas will be developed to source this material.

Sand used in the embankment drainage system was assumed to have a permeability of $5x10^{-4}$ cm/sec.

4.8.2 Analysis

For the seepage analysis, it was assumed that the HDPE liners in the ponds fail completely, with the 1-ft-thick clay liner providing the only barrier to seepage through the embankment. The seepage analysis was completed using the GeoStudio 2007 software package.

4.9 Pond Stability Analyses

Stability analyses on the pond embankments were completed using the GeoStudio 2007 software package. The sections selected for the analysis are located at the highest points of the embankments.

4.9.1 Analyses

The following analyses were conducted on each of the ponds:

- A static stability analysis, assuming that the liners are intact (no phreatic surface in the embankment)
- A pseudostatic analysis, assuming the liners are intact and modeling the MCE acceleration
- A static analysis assuming that the liners have completely failed, allowing a phreatic surface to develop in the embankment
- A pseudostatic analysis assuming that the liners have completely failed, allowing a phreatic surface to develop in the embankment, and modeling the MCE acceleration

4.9.2 Soil Strengths

Soil strengths were obtained from three tri-axial tests that were conducted on material samples collected during the site investigation, and are presented in Table 3.11-1.

The material strength values obtained from test pit TP 02-7 were used for the analyses undertaken on the ponds at the Dewey Site.

4.9.3 Material Densities

In situ material densities were obtained from undisturbed samples collected during the site investigation. The densities of embankment materials were obtained from compaction tests undertaken on samples collected from site, and are summarized in Table 3.11-2.

Median undisturbed densities have been assumed for in situ soils, while the median densities from the compaction tests have been assumed for the embankments and clay liners.

4.9.4 Seismic Ground Acceleration Values

MCE ground accelerations were obtained from the document "Dewey-Burdock Project, Application for NRC Uranium Recovery License, Fall River and Custer Counties, South Dakota, Technical Report" dated February 2009. The MCE was determined in Section 2.6.6 of the report to have a maximum ground acceleration of 0.09 g.

4.9.5 Stability Analysis Results

The factors of safety for the embankments are provided in Table 4.9-1. The table provides results for three methods of analysis, namely:

- Bishop method
- Janbu method
- Morgenstern-Price method

Table 4.9-1 – Stability Analysis Factors of Safety

Pond	Description	Analysis	Factor of Safety		
			Bishop	Janbu	Morgenstern-Price
Dewey Radium Settling/Spare Ponds	Outer slope – assuming intact HDPE liner	Static	3.00	2.76	3.00
		Seismic (MCE)	2.14	1.97	2.14
	Outer slope – assuming HDPE liner has failed	Static	2.22	1.97	2.23
		Seismic (MCE)	1.52	1.36	1.53
	Inner slope – assuming intact HDPE liner	Static	2.19	2.04	2.19
		Seismic (MCE)	1.69	1.57	1.69
Dewey Outlet Pond	Outer slope – assuming intact HDPE liner	Static	2.88	2.66	2.87
		Seismic (MCE)	2.05	1.90	2.05
	Outer slope – assuming HDPE liner has failed	Static	2.10	1.86	2.11
		Seismic (MCE)	1.44	1.29	1.46
	Inner slope – assuming intact HDPE liner	Static	3.09	2.86	3.08
		Seismic (MCE)	2.17	2.02	2.18
Dewey Surge Pond	Outer slope – assuming intact HDPE liner	Static	3.57	3.20	3.56
		Seismic (MCE)	2.52	2.28	2.52
	Outer slope – assuming HDPE liner has failed	Static	2.64	2.35	2.65
		Seismic (MCE)	1.78	1.59	1.79
	Inner slope – assuming intact HDPE liner	Static	2.97	2.77	2.97
		Seismic (MCE)	2.09	1.96	2.09
Burdock Radium Settling Pond	Outer slope – assuming intact HDPE liner	Static	3.02	2.81	3.02
		Seismic (MCE)	2.15	2.01	2.15
	Outer slope – assuming HDPE liner has failed	Static	2.16	1.92	2.17
		Seismic (MCE)	1.49	1.33	1.50
	Inner slope – assuming intact HDPE liner	Static	2.33	2.18	2.33
		Seismic (MCE)	1.79	1.68	1.79
Burdock Outlet Pond	Outer slope – assuming intact HDPE liner	Static	2.93	2.74	2.93
		Seismic (MCE)	2.09	1.96	2.09
	Outer slope – assuming HDPE liner has failed	Static	2.07	1.84	2.07
		Seismic (MCE)	1.42	1.28	1.43
	Inner slope – assuming intact HDPE liner	Static	3.35	3.11	3.35
		Seismic (MCE)	2.35	2.19	2.35
Burdock Surge Pond	Outer slope – assuming intact HDPE liner	Static	3.17	2.93	3.17
		Seismic (MCE)	2.26	2.10	2.26
	Outer slope – assuming HDPE liner has failed	Static	2.30	2.03	2.30
		Seismic (MCE)	1.57	1.41	1.59
	Inner slope – assuming intact HDPE liner	Static	3.07	2.85	3.06
		Seismic (MCE)	2.18	2.04	2.19

Table 4.9-1 – Stability Analysis Factors of Safety

Pond	Description	Analysis	Factor of Safety		
			Bishop	Janbu	Morgenstern-Price
Central Plant Pond (Burdock)	Outer slope – assuming intact HDPE liner	Static	3.10	2.88	3.10
		Seismic (MCE)	2.21	2.06	2.21
	Outer slope – assuming HDPE liner has failed	Static	2.22	1.96	2.22
		Seismic (MCE)	1.52	1.36	1.53
	Inner slope – assuming intact HDPE liner	Static	2.19	2.03	2.19
		Seismic (MCE)	1.70	1.58	1.70

The above analyses indicate that the outer slopes of the ponds have a minimum factor of safety of approximately 2.66 under normal static loading conditions assuming that the HDPE liners remain intact, preventing a phreatic surface from developing in the embankment. The minimum factor of safety reduces to approximately 1.90 during the MCE seismic event.

Should the HDPE liner fail, a drain installed in the embankment will help to lower the phreatic surface and prevent the downstream toe from becoming saturated. The factors of safety do reduce, with the minimum factor of safety under normal static loading conditions reducing to approximately 1.84. Under MCE seismic loading conditions the minimum factor of safety reduces to approximately 1.28.

The inner slope is less critical in terms of preventing a breach of the embankment, but was evaluated for stability assuming the HDPE liners remain intact. The minimum factor of safety under normal static loading conditions was calculated to be 2.03, while under MCE seismic loading conditions this reduces to approximately 1.58.

The above factors of safety indicate that the slopes are stable under both static and MCE seismic loading conditions.

4.9.6 Embankment Settlement

Elastic theory was used to obtain an estimate of embankment settlements using material characteristics derived from the triaxial test results. Assuming a maximum embankment height of 30 ft, elastic theory predicts that the elastic settlement of an embankment having a crest width of 40 feet and 1(v):4.5(h) side slopes is likely to be less than 1 ft. This settlement will occur during construction, and will be accommodated by placing fill to ensure that final design crest

elevations are achieved. Due to the relatively low embankments that are being constructed, settlement due to consolidation is not expected to be significant.

4.9.7 Summary of Pond Characteristics

Table 4.9-2 summarizes the pond characteristics at the Dewey-Burdock Project.

Table 4.9-2 – Pond Characteristics and Design Features

Parameter	Radium Settling/Spare Ponds	Central Plant Pond	Outlet Ponds	Surge Ponds
Number of Ponds:				
Dewey	1 Radium Settling 1 Spare	-	1	1
Burdock	1 Radium Settling 1 Spare	1	1	1
Active Storage (per pond):				
Process water and stormwater from land application areas	15.9*	15.2	3.4	7.8
Stormwater falling on ponds	0**	0.7	1.7	0.6
Total	**15.9**	**15.9**	**5.1**	**8.4**
Crest width	170	275	160	250
Crest length	680	275	370	250
Depth	Varies 7.5 to 19.5 ft	Varies: 15.8 to 20.5 ft	Varies 11.4 to 14.0 ft	Varies 15.0 to 16.5 ft
Freeboard	3 ft	3 ft	3 ft	3 ft
Upstream embankment slope	3H:1V	3H:1V	4.5H:1V	4.5H:1V
Downstream embankment slope	4.5H:1V	4.5H:1V	4.5H:1V	4.5H:1V
Exterior embankment crest width	40 ft	40 ft	40 ft	40 ft
Interior embankment crest width	30 ft	N/A	30 ft	N/A
Bottom grade	2 percent - graded towards leak detection sump		1 percent - graded towards a corner	
Lining system	Prepared subgrade or compacted random fill 1-foot-thick soil liner compacted to 95 percent standard proctor density 60-mil-smooth HDPE bottom (secondary) geomembrane 80-mil-textured HDPE top (primary) geomembrane Leak detection system consisting of geonet placed between primary and secondary geomembranes Leak detection sump and access port system 3-ft-deep by 3-ft-wide geomembrane anchor trench		Prepared subgrade or compacted random fill 1-foot-thick soil liner compacted to 95 percent standard proctor density 40-mil-textured HDPE geomembrane 3-ft-deep by 3-ft-wide geomembrane anchor trench	

*Includes 0.1 acre-ft storage for sludge

**Stormwater from the radium settling pond overflows into the outlet pond where it is stored

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