NUREG-1620, Rev. 1 – Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978

LEGEND

- No color – Not applicable to license amendment
- Green highlight – No change from prior licensing action
- Yellow highlight – Change from prior action, but no request for pre-review audit
- Red highlight – Request for pre-review audit

DOCUMENTS RECOMMENDED FOR NRC PRE-REVIEW AUDIT FOR LICENSE AMENDMENT

1. Pre-Design Studies Northeast Church Rock Mine Site Removal Action – Church Rock Mill Site Report, MWH, 2014.
2. Consolidation and Groundwater Evaluation Report, Interim Submittal, Dwyer Engineering, 2017 (in progress)
3. Northeast Church Rock 30% Design Report, Attachment G.7, Cover System Design Report, Interim Submittal, Dwyer Engineering, 2017 (in progress)
4. Northeast Church Rock 30% Design Report, Appendix I: Mill Site Stormwater Controls (jetty design only), 60% Design Interim Submittal, Stantec, 2017 (in progress)

Section	Requirement	Location of Information	Comments
1.0	**GEOLOGY & SEISMOLOGY**		
1.1	**Stratigraphic Features**		
1.	The regional and site-specific stratigraphy are described in sufficient detail to produce an adequate understanding of the site-specific subsurface characteristics, including descriptions of adequate understanding of the site-specific subsurface characteristics, including descriptions of major stratigraphic units and their orientations, age relationships, thicknesses, and distribution.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously
2.	Stratigraphic units are described in sufficient detail to provide input to a geotechnical stability analysis.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously
3.	Descriptions of regional and site-specific stratigraphic units contain sufficient information for input to an analysis of groundwater resources and the protection thereof.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously.
4.	Regional stratigraphic information is discussed in sufficient detail to support site-specific information.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously
5.	Descriptions of the regional and site stratigraphy are based on published literature and site data and conform to standard geological classifications.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously
6.	Discussions of regional stratigraphy are adequately referenced and supported by published reports, maps, logs, and cross-sections.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously
7.	Site descriptions are based on field investigations and adequate sampling to define physical and chemical properties of surface and subsurface materials such as soils and underlying geologic formations at the site.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously.
8.	Maps are at a scale sufficient to show the locations of all site explorations such as borings, geophysical surveys, trenches, and sample locations.	Geohydrologic Report (Canonie, 1987);	Characterization completed previously.
1.2	**Structural and Tectonic Features**		
1.	Descriptions of regional and site-specific structural and tectonic features are based on published literature and gathered data.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
2.	Regional structural and tectonic features, particularly faults, are defined in sufficient detail to present and adequate understanding of the structural geologic conditions in the region surrounding the site that may have a likelihood of impacting the site stability or groundwater regime.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
3.	Site-specific structural tectonic features, particularly faults are described in sufficient detail to present adequate information for an analysis of the site stability. Information presented should address the uncertainties and variability within the site area and the potential impacts on the disposal facility.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
4.	The structural and tectonic province or provinces that influence the site seismicity are identified and described.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1.
5.	The tectonic history of the pertinent province(s) is discussed in sufficient detail to support an analysis of the potential for disruption of the site by tectonic activity.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1.
6.	Discussions are adequately referenced and are supported by maps, logs, and cross sections showing locations of all site explorations and surveys, and depicting surface and subsurface structural tectonic features.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
7.	Descriptions contain discussions of age relationships of structural and tectonic features.	30% Design Report,	An updated seismic hazard analysis was conducted for the 30% design, and

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		Attachment G.1 (MWH, 2016)	is included as Attachment G.1
1.3	**Geomorphic Features**		
1.	Descriptions of the regional and site-specific geomorphology and geomorphic processes include information sufficient to allow the reviewer to assess the nature and extent of major active processes that may modify the present-day topography of the geomorphic province(s) and the site area.	Approved Rec. Plan (Canonie, 1991)	NRC-approved Jetty design in Canonie Rec. Plan.
		30% Design Report, Appendix I (MWH, 2016)	Updated design for pre-review audit; Appendix I 60% Design Interim Submittal (Jetty design only)
2.	The geomorphic features, particularly potential geomorphic hazards, are clearly delineated on topographic base maps of adequate scale to enable the reviewer to assess their occurrence and distribution.	Approved Rec. Plan (Canonie, 1991)	NRC-approved Jetty design in Canonie Rec. Plan.
		30% Design Report, Appendix I (MWH, 2016)	Updated design for pre-review audit; Appendix I 60% Design Interim Submittal (Jetty design only)
3.	Descriptions are adequately referenced and are supported by published reports and maps or site data.	Approved Rec. Plan (Canonie, 1991)	NRC-approved Jetty design in Canonie Rec. Plan.
		30% Design Report, Appendix I (MWH, 2016)	Updated design for pre-review audit; Appendix I 60% Design Interim Submittal (Jetty design only)
4.	The regional and site-specific geomorphology and geomorphic processes are described in sufficient detail to support an analysis of the geomorphic and geotechnical stability of the site.	Approved Rec. Plan (Canonie, 1991)	NRC-approved Jetty design in Canonie Rec. Plan.
		30% Design Report, Appendix I (MWH, 2016)	Updated design for pre-review audit; Appendix I 60% Design Interim Submittal (Jetty design only)
1.4	**Seismicity and Ground Motion Estimates**		
1.	The information presented on the regional and site-specific seismicity contains sufficient detail to allow the staff to determine the vibratory ground motion (peak horizontal acceleration) at the site caused by seismic events and to further use that determination to assess the geotechnical stability of the site. The geotechnical stability of the site is sufficient to control radiological hazards for 1,000 years to the extent reasonably achievable, and, in any case, for at least 200 years.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
2.	In conducting this review, the staff will consider a deterministic and/or a probabilistic seismic hazard analysis as an acceptable method for selecting the peak horizontal acceleration for a site. An analysis of the geotechnical stability of the design proposed in the reclamation plan will be based on the resultant peak horizontal acceleration (Chapter 2.0, "Geotechnical Stability," of this standard review plan).	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
a.	Deterministic Analysis: The use of a deterministic seismic hazard analysis is acceptable if:		
i.	Capability is determined by suitable methods, such as those outlined by Slemmons (1977).	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
ii.	Fault length versus magnitude relationships for determining the maximum magnitude earthquake that may be produced by each capable fault or capable tectonic source are developed using acceptable approaches such as those of Slemmons, et al. (1982); Bonilla, et al. (1984); or Wells and Coppersmith (1994).	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1

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iii.	For each maximum magnitude earthquake, the peak horizontal acceleration at the site is determined using the applicable attenuation relationship between earthquake magnitude and distance for the site. Campbell (1997); Campbell and Bozorgnia (1994); and Boore, et al. (1993, 1997) offer examples of acceptable attenuation relationships. In applying the relationship, the site-to-source distance should be the distance between the site and the closest approach of the fault.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
iv.	The peak horizontal acceleration value adopted for each capable fault or tectonic source is not less than the median value provided by the attenuation relationship. Possible soil amplification effects are considered.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
v.	To assess potential ground motion at the site from earthquakes not associated with known tectonic structures (i.e., random or floating earthquakes), the largest floating earthquakes reasonably expected within the tectonic province are identified. In addition, the largest floating earthquakes characteristic of any adjacent tectonic provinces are identified, if such earthquakes cause appreciable ground motion at the site. For each of these earthquakes, the peak horizontal acceleration at the site is calculated as stated previously, with 15 km [9 mi] used as the site-to-source distance for floating earthquakes within the host tectonic province. For floating earthquakes in other tectonic provinces, the distance between the site and the closest approach of the province boundary is used as the site-to-source distance.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
vi.	The peak horizontal acceleration for the site is the maximum value of the peak horizontal accelerations determined for earthquakes from all capable faults, tectonic sources, and tectonic provinces.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
b.	Probabilistic Analysis: The use of a probabilistic seismic hazard analysis as an alternative to the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), is acceptable, as is stated in the Introduction to Appendix A, if:		
i.	It is shown that the design proposed by the licensee will achieve a level of stabilization and containment, and a level of protection for public health and safety and the environment, which is equivalent to, to the extent practicable, or more stringent than that achieved by the requirements of 10 CFR Part 40, Appendix A.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
ii.	The licensee takes into account local conditions when estimating the seismic design of the facility because peak horizontal acceleration values are often calculated for hypothetical rock foundations. The effects of local site conditions on the peak ground acceleration are reviewed in Chapter 2.0 in the standard review plan.	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
2.0	**GEOTECHNICAL STABILITY**		
2.1	**Site and Uranium Mill Tailings Characteristics**		
1.	The site stratigraphy is described in sufficient detail to provide an understanding of the site-specific subsurface features, including structural features and other characteristics of underlying soil and rock.	PDS (MWH, 2014); 30% Design (MWH, 2016) Appendix I 60% Design Interim Submittal (MWH, 2017)	Characterization completed for the PDS Report and additional characterization for the Jetty (2017). Other characterization of the underlying rock is based on Canonie (1987) and previous site geotechnical information. PDS (MWH, 2014) and Appendix I 60% Design Interim Submittal (MWH, 2017) recommended for pre-review audit.
2.	Information on regional and local faults and seismicity, as obtained from field data, published literature, and historical records is presented in sufficient detail to effectively incorporate that information into a geotechnical stability analyses. (Note: This aspect of the review should be coordinated with the geology and seismology review performed in accordance with standard review plan Chapter 1.)	30% Design Report, Attachment G.1 (MWH, 2016)	An updated seismic hazard analysis was conducted for the 30% design, and is included as Attachment G.1
3.	Sampling scope and techniques are appropriate and sufficient to ensure that samples collected are representative of the range of *in situ* soil conditions, taking into consideration variability and uncertainties in such conditions within the site.	PDS (MWH, 2014);	Sampling program is described in the PDS report.
4.	For all soils that might be unstable because of their physical or chemical properties, locations and dimensions are identified and the properties have been documented.	PDS (MWH, 2014);	Collapse potential and dispersivity results are provided in the PDS report.
5.	Investigations (including laboratory and field testing) are conducted using appropriate standards published by the American Society for Testing and Materials or the International Society for Rock Mechanics and are sufficient to establish the static and dynamic engineering parameters of borrow materials, other materials, tailings, and underlying soil and rock materials at the site (NRC, 1978, 1979).	PDS (MWH, 2014);	ASTM standards used for field and laboratory testing.

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6.	A detailed discussion of laboratory sample preparation techniques is presented, when standard procedures are not used. For critical laboratory tests, details such as how saturation of the sample was determined and maintained during testing, or how the pore pressures changed are provided. A detailed and quantitative discussion of the criteria used to verify that the samples were properly taken and tested in sufficient number to define the critical soil parameters for the site is presented. In the case of tailings material (e.g., license amendment reviews), the evaluations of its strength and settlement characteristics are presented in detail.	PDS (MWH, 2014);	Sample preparation and testing procedures documented
7.	Parameter values are presented to enable evaluation of properties of mill tailings, borrow materials, other materials, and underlying soil and rock, including the following:		
a.	Compressibility and rate of consolidation	PDS (MWH, 2014);	New information on tailings, cover materials and mine spoil properties.
b.	Shear strength, including, for sensitive soils, possible loss of shear strength resulting from strain-softening	PDS (MWH, 2014);	New information on tailings, cover materials and mine spoil properties.
c.	Liquefaction potential	PDS (MWH, 2014);	New information on tailings, cover materials and mine spoil properties.
d.	Permeability	PDS (MWH, 2014);	New information on tailings, cover materials and mine spoil properties.
e.	Dispersion characteristics	PDS (MWH, 2014);	Non-dispersive materials present
f.	Swelling and shrinkage	PDS (MWH, 2014);	New information on tailings, cover materials and mine spoil properties.
g.	Long-term moisture content for radon barrier material	PDS (MWH, 2014);	New information on tailings, cover materials and mine spoil properties.
h.	Cover cracking	PDS (MWH, 2014);	New information on tailings, cover materials and mine spoil properties.
8.	Soil stratigraphy and relevant parameters that are used in the geotechnical evaluations (settlement, stability, liquefaction potential, etc.) are discussed in detail.	PDS (MWH, 2014); Consolidation and Groundwater Report (Dwyer, 2016b);	Soil stratigraphy used in the analysis is based on the PDS data and described in the Dwyer Report.
9.	Records of historical groundwater-level fluctuations at the site as obtained from monitoring local wells and springs and/or by analysis of piezometer and permeability data from tests conducted at the site are presented in sufficient detail to effectively incorporate the information into geotechnical stability analyses. (Note: This aspect of the review should be coordinated with the hydrogeologic characterization review performed according to standard review plan Chapter 4.0.) The information should be sufficient to provide the required input for the design of the facility and to enable the reviewer to assess compliance with the regulatory requirements, such as site features contributing to waste isolation; facility location with respect to an active fault; and reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable, and in any case, for at least 200 years.	Chester Engineers (2016);	Or most current information, for groundwater levels near the tailings area.
		PDS (MWH, 2014);	Previous records and recent characterization used in stability analyses
2.2	**Slope Stability**		
1.	Slope characteristics are properly evaluated.		
a.	Cross sections and profiles of natural and cut slopes whose instability would directly or indirectly affect the control of residual radioactive materials are presented in sufficient number and detail to enable the reviewer to select the cross sections for detailed stability evaluation.	30% Design Report, Appendix G (MWH, 2016)	Attachment G.2
b.	Slope steepness is a minimum of five horizontal units (5h) to one vertical unit (1v) or less. The use of slopes steeper than 5h:1v is considered an alternative to the requirements in 10 CFR Part 40, Appendix A, Criterion 4(c). When slopes steeper than 5h:1v are proposed, a technical justification should be offered as to why a 5h:1v or flatter slope cannot be constructed. Appropriate compensating factors and conditions are incorporated in the slope design for assuring long-term stability. In addition, the application must contain an evaluation showing the economic benefit of	30% Design Report, Appendix G (MWH, 2016)	All slopes are 5h:1v or less steep

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	slopes steeper than 5h:1v as well as a demonstration of equivalent protection.		
c.	Locations selected for slope stability analysis are determined considering the location of maximum slope angle, slope height, weak foundation, piezometric level(s), the extent of rock mass fracturing (for an excavated slope in rock), and the potential for local erosion.	30% Design Report, Appendix G (MWH, 2016)	Critical locations selected
2.	An appropriate design static analysis is presented.		
a.	The analysis includes calculations with appropriate assumptions and methods of analysis (NRC, 1977). The effect of the assumptions and limitations of the methods used is discussed and accounted for in the analysis. Acceptable methods for slope stability analysis include various limit equilibrium analysis or numerical modeling methods.	30% Design Report, Appendix G (MWH, 2016)	Appropriate methods of analysis used (SLOPE/W program, Morgenstern-Price and Spencer methods)
b.	The uncertainties and variability in the shape of the slope, the boundaries and parameters of the several types of soils and rocks within and beneath the slope, the material properties of soil and rock within and beneath the slope, the forces acting on the slope, and the pore pressures acting within and beneath the slope are considered.	30% Design Report, Appendix G (MWH, 2016)	Uncertainties considered
c.	Appropriate failure modes during and after construction and the failure surface corresponding to the lowest factor of safety are determined. The analysis takes into account the failure surfaces within the slopes, including through the foundation, if any.	30% Design Report, Appendix G (MWH, 2016)	Appropriate failure modes included
d.	Adverse conditions such as high water levels from severe rain and the probable maximum flood are evaluated.	30% Design Report, Appendix G (MWH, 2016)	Adverse conditions considered, arroyo flooding can be evaluated for the 95% Design
e.	The effects of toe erosion, incision at the base of the slope, and other deleterious effects of surface runoff are assessed.	30% Design Report, Appendix G (MWH, 2016)	Erosion and runoff considered
f.	The resulting safety factors for slopes analyzed are comparable to the minimum acceptable values of safety factors for slope stability analysis given in NRC Regulatory Guide 3.11 (NRC, 1977).	30% Design Report, Appendix G (MWH, 2016)	Calculated factors of safety higher than accepted minimum values
3.	Appropriate analyses considering the effect of seismic ground motions on slope stability are presented		
a.	Evaluation of overall seismic stability, using pseudostatic analysis or dynamic analysis, as appropriate (U.S. Army Corps of Engineers, 1977; NRC, 1977). Alternatively, a dynamic analysis following Newmark (1965) can be carried out to establish that the permanent deformation of the disposal cell from the design seismic event will not be detrimental to the disposal cell. The reviewer should verify that the yield acceleration or pseudostatic horizontal yield coefficient necessary to reduce the factor of safety against slippage of a potential sliding mass to 1.0 in a “Newmark-type” analysis has been adequately estimated (Seed and Bonaparte, 1992).	30% Design Report, Appendix G (MWH, 2016)	Pseudostatic method used due to low seismicity
b.	An appropriate analytical method has been used. A number of different methods of analysis are available (e.g., slip circle method, method of slices, and wedge analysis) with several variants of each (Lambe and Whitman, 1979; U.S. Army Corps of Engineers, 1970b; NRC, 1977; Bromhead, 1992). Limit-equilibrium analysis methods do not provide information regarding the variation of strain within the slope and along the slip surface. Consequently, there is no assurance that the peak strength values used in the analysis can be mobilized simultaneously along the entire slip surface unless the material shows ductile behavior (Duncan, 1992). Residual strength values should be evaluated if mobilized shear strength at some points is less than the peak strength. The reviewer should ensure that appropriate conservatism has been incorporated in the analysis using the limit equilibrium methods. The limit equilibrium analysis methodologies may be replaced by other techniques, such as finite element or finite difference methods. If any important interaction effects cannot be included in an analysis, the reviewer must determine that such effects have been treated in an approximate but conservative fashion. The engineering judgment of the reviewer should be used in assessing the adequacy of the resulting safety factors (NRC, 1983a, b).	30% Design Report, Appendix G (MWH, 2016)	Appropriate methods used (Morgenstern-Price and Spencer), with consideration of residual shear strengths
c.	For dynamic loads, the dynamic analysis includes calculations with appropriate assumptions and methods (NRC, 1977; Seed, 1967; Lowe, 1967; Department of the Navy, 1982a,b,c; U.S. Army Corps of Engineers, 1970a,b, 1971, 1972; Bureau of Reclamation, 1968). The effect of the assumptions and limitations of the methods used is discussed and accounted for in the analysis.	--	N/A Dynamic loading not applicable, see 7d below
d.	For dynamic loads, a pseudostatic analysis is acceptable in lieu of dynamic analysis if the strength parameters used in the analysis are conservative, the materials are not subject to significant loss of strength and development of high pore pressures under dynamic loads, the design seismic coefficient is 0.20 or less, and the resulting minimum factor of safety suggests an adequate margin, as provided in NRC Regulatory Guide 3.11 (NRC, 1977).	30% Design Report, Appendix G (MWH, 2016)	Pseudostatic analyses used, seismic coefficient is 0.20 g

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e.	For pseudostatic analysis of slopes subjected to earthquake loads, an assumption is made that the earthquake imparts an additional horizontal force acting in the direction of the potential failure (U.S. Army Corps of Engineers, 1970b, 1977; Goodman, 1989). The critical failure surface obtained in the static analysis is used in this analysis with the added driving force. Minimum acceptable values for safety factors of slope stability analysis are given in Regulatory Guide 3.11 (NRC, 1977).	30% Design Report, Appendix G (MWH, 2016)	Pseudostatic analyses used, with comparison of calculated factors of safety with appropriate minimum values
f.	The assessment of the dynamic stability considers an appropriate design level seismic event and/or strong ground motion acceleration, consistent with that identified in Chapter 1 of this review plan. Influence of local site conditions on the ground motions associated with the design level event is evaluated. The design seismic coefficient to be used in the pseudostatic analysis is either 67 percent of the peak ground acceleration at the foundation level of the tailings piles for the site or 0.1 g, whichever is greater.	30% Design Report, Appendix G (MWH, 2016)	Pseudostatic analyses used with 67% of the PGA.
g.	If the design seismic coefficient is greater than 0.20 g, then the dynamic stability investigation (Newmark, 1965) should be augmented by other appropriate methods (i.e., finite element method), depending on specific site conditions.	30% Design Report, Appendix G (MWH, 2016)	Seismic coefficient is 0.20 g
h.	In assessing the effects of seismic loads on slope stability, the effect of dynamic stresses of the design earthquake on soil strength parameters is accounted for. As in a static analysis, the parameters such as geometry, soil strength, and hydrodynamic and pore pressure forces are varied in the analysis to show that there is an adequate margin of safety.	30% Design Report, Appendix G (MWH, 2016)	Seismic effects on shear strengths considered
i.	Seismically induced displacement is calculated and documented. There is no universally accepted magnitude of seismically induced displacement for determining acceptable performance of the disposal cell (Seed and Bonaparte, 1992; Goodman and Seed, 1966). Surveys of five major geotechnical consulting firms by Seed and Bonaparte (1992) indicate that the acceptable displacement is from 15 to 30 cm [6 to 12 in.] for tailings piles. The reviewer should ensure that this criterion is also augmented by provisions for periodic maintenance of the slope(s).	30% Design Report, Appendix G (MWH, 2016)	Seismic settlement is calculated in the design.
j.	Where there is potential for liquefaction, changes in pore pressure from cyclic loading are considered in the analysis to assess the effect of pore pressure increase on the stress-strain characteristics of the soil and the post-earthquake stability of the slopes. Liquefaction potential is reviewed using Section 2.4 of this review plan. Evaluations of dynamic properties and shear strengths for the tailings, underlying foundation material, radon barrier cover, and base liner system are based on representative materials properties obtained through appropriate field and laboratory tests (NRC, 1978, 1979).	30% Design Report, Appendix G (MWH, 2016)	Liquefaction of saturated materials is evaluated
k.	The applicant has demonstrated that impoundments will not be located near a capable fault on which a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand might occur.	Geohydrologic Report (Canonie, 1987); Approved Rec. Plan (Canonie, 1991)	Regional faults described in design. Siting of tailings impoundment previously approved.
4.	Provision is made to establish a vegetative cover, or other erosion prevention, to include the following considerations:		
a.	The vegetative cover and its primary functions are described in detail. This determination should be made with respect to any effect the vegetative cover may have on reducing slope erosion and should be coordinated with the reviewer of standard review plan Chapter 3. If strength enhancement from the vegetative cover is taken into account, the methodology should be appropriate (Wu, 1984).	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Erosion protection in the design does not rely on vegetation
b.	In arid and semi-arid regions, where a vegetative cover is deemed not self-sustaining, a rock cover is employed on slopes of the mill tailings. If credit is taken for strength enhancement from rock cover, the reviewer should confirm that appropriate methodology has been presented. The design of a rock cover, where a self-sustaining vegetative cover is not practical, is based on standard engineering practice. Standard review plan Chapter 3 discusses this item in detail.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Rock mulch cover surface designed.
5.	Any dams meet the requirements of the dam safety program if the application demonstrates the following :		
a.	The dam is correctly categorized as a low hazard potential or a high hazard potential structure using the definition of the U.S. Federal Emergency Management Agency.	-----	N/A; repository is not categorized as a dam
b.	If the dam is ranked as a high hazard potential, an acceptable emergency action plan consistent with the Federal Emergency Management Agency guide (U.S. Federal Emergency Management Agency, 1998) has been developed.	-----	N/A; repository is not categorized as a dam
6.	The use of steeper slopes as an alternative to the requirements in 10 CFR, Part 40, Appendix A, will be found acceptable if the following are met :		
a.	An equivalent level of stabilization and containment and protection of public health, safety, and the environment is achieved.	-----	N/A; maximum slopes are 5h:1v

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b.	A site-specific need for the alternate slopes and an appropriate economic benefit are demonstrated.	-----	N/A: maximum slopes are 5h:1v
2.3	**Settlement**		
1.	Computation of immediate settlement follows the procedure recommended in NAVFAC Section 7.1 (Department of the Navy, 1982). If a different procedure is used, the basis for the procedure is adequately explained. The procedure recommended in NAVFAC Section 7.1 (Department of the Navy, 1982) for calculation of immediate settlement is adequate if applied incrementally to account for different stages of tailings emplacement. If this method is used, the reviewer should verify that the computation of incremental tailings loading and the width of the loaded area, as well as the determination of the undrained modulus and Poisson's ratio, have been computed and documented. Settlement of tailings arises from compression of soil layers within the disposal cell and in the underlying materials. Because compression of sands occurs rapidly, compression of sand layers in the disposal cell and foundations must be considered in the assessment of immediate settlement. However, the contribution of immediate settlement to consolidation settlement cannot be ignored. Clay layers and slime undergo instantaneous elastic compression controlled by their undrained stiffness as well as long-term inelastic compression controlled by the processes of consolidation and creep (NRC, 1983a).	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit.
		30% Design Report, Appendix G (MWH, 2016)	Immediate settlement of unsaturated and coarse-grained tailings would occur incrementally during repository construction.
2.	Each of the following is appropriately considered in calculating stress increments for assessment of consolidation settlement :		
a.	Decrease in overburden pressure from excavation	-----	N/A; minimal excavation planned
b.	Increase in overburden pressure from tailings emplacement	Consolidation and Groundwater Report (Dwyer, 2016b);	Increase in overburden pressure from placement of mine spoils. Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit. The amount of porewater released from the tailings due to this loading is evaluated.
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	Increase in overburden pressure on tailings from placement of mine soils.
c.	Excess pore-pressure generated within the disposal cell	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit. The amount of porewater released from the tailings due to this loading is evaluated.
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	
d.	Changes in groundwater levels from dewatering of the tailings	-----	N/A; no tailings dewatering planned
e.	Any change in groundwater levels from the reclamation action	-----	N/A; no change in groundwater levels from action
3.	Material properties and thicknesses of compressible soil layers used in stress change and volume change calculations for assessment of consolidation settlement are representative of *in situ* conditions at the site.	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit.
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	The material properties and thicknesses of the tailings used in the consolidation analyses were based on CPT testing and drilling, sampling, and testing of tailings beneath the repository footprint.
4.	Material properties and thicknesses of embankment zones used in stress change and volume change calculations are consistent with as-built conditions of the disposal cell,	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit.
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	Properties are consistent, where applicable

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5.	Values of pore pressure within and beneath the disposal cell used in settlement analyses are consistent with initial and post-construction hydrologic conditions at the site.	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit. Pore pressures used are from drilling, sampling, and testing of tailings under current conditions. Confirmation of the data used for the analysis to estimate pore pressures would be requested from NRC.
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	
6.	Methods used for settlement analyses are appropriate for the disposal cell and soil conditions at the site. Contributions to settlement by drainage of mill tailings and by consolidation/compression of slimes and sands are considered. Both instantaneous and time-dependent components of total and differential settlements are appropriately considered in the analyses (NRC, 1983a,b,c). The procedure recommended in NAVFAC DM 7.1 (Department of the Navy, 1982) for calculation of secondary compression is adequate.	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit. Terzaghi consolidation theory was used for this analysis.
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	Terzaghi consolidation theory was used for this analysis.
7.	The disposal cell is divided into appropriate zones, depending on the field conditions, for assessment of differential settlement, and appropriate settlement magnitudes are calculated and assigned to each zone.	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit.
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	Settlement analyses reflect appropriate conditions in areas where fine-grained, near-saturated tailings are present.
8.	Results of settlement analyses are properly documented and are related to assessment of overall behavior of the reclaimed pile.	Consolidation and Groundwater Report (Dwyer, 2016b);	Consolidation and Groundwater Report (Dwyer, 2016b) report recommended for pre-review audit. Settlement analyses documented
		30% Design Report, Appendix G.3, G.4 (MWH, 2016)	Settlement analyses documented
9.	An adequate analysis of the potential for development of cracks in the radon/infiltration barrier as a result of differential settlements is provided (Lee and Shen, 1969).	30% Design Report, Appendix G.5 (MWH, 2016)	Cracking potential of the existing radon barrier analyzed
2.4	**Liquefaction Potential**		
1.	Applicable laboratory and/or field tests are properly conducted (NRC, 1978, 1979; U.S. Army Corps of Engineers, 1970, 1972).	PDS Report (MWH, 2014);	Appropriate laboratory tests conducted
2.	Data for all relevant parameters for assessing liquefaction potential are adequately collected and the variability has been quantified.	30% Design Report, Appendix G.6 (MWH, 2016)	Parameters for liquefaction appropriate.
3.	Methods used for interpretation of test data and assessment of liquefaction potential are consistent with current practice in the geotechnical engineering profession (Seed and Idriss, 1971, 1982; National Center for Earthquake Engineering Research, 1997). An assessment of the potential adverse effects that complete or partial liquefaction could have on the stability of the embankment may be based on cyclic triaxial test data obtained from undisturbed soil samples taken from the critical zones in the site area (Seed and Harder, 1990; Shannon & Wilson, Inc. and Agbabian-Jacobsen Associates, 1972).	30% Design Report, Appendix G.6 (MWH, 2016)	
4.	If procedures based on laboratory tests combined with ground response analyses are used, laboratory test results are corrected to account for the difference between laboratory and field conditions (NRC, 1978; Naval Facility Engineering Command, 1983).	-----	N/A; not used due to low seismicity
5.	The time history of earthquake ground motions used in the analysis is consistent with the design seismic event.	-----	N/A; not used due to low seismicity
6.	If the potential for complete or partial liquefaction exists, the effects such liquefaction could have on the stability of slopes and settlement of tailings are adequately quantified.	30% Design Report, Appendix G.6 (MWH, 2016)	Evaluated in terms of full liquefaction.
7.	If a potential for global liquefaction is identified, mitigation measures consistent with current engineering practice or redesign of tailings ponds/embankments are proposed and the proposed measures provide reasonable assurance that	-----	N/A; no potential for global liquefaction

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	the liquefaction potential has been eliminated or mitigated.		
8.	If minor liquefaction potential is identified and is evaluated to have only a localized effect that may not directly alter the stability of embankments, the effect of liquefaction is adequately accounted for in analyses of both differential and total settlement and is shown not to compromise the intended performance of the radon barrier. Additionally, the disposal cell is shown to be capable of withstanding the liquefaction potential associated with the expected maximum ground acceleration from earthquakes. The licensee may use post-earthquake stability methods (e.g., Ishihara and Yoshimine, 1990) based on residual strengths and deformation analysis to examine the effects of liquefaction potential. Furthermore, the effect of potential localized lateral displacement from liquefaction, if any, is adequately analyzed with respect to slope stability and disposal cell integrity.	30% Design Report, Appendix G.6 (MWH, 2016)	Localized liquefaction settlement will be quantified for the 95% Design.
2.5	**Design of Disposal Cell Cover Engineering Design**		
1.	Detailed descriptions of the disposal cell material types [e.g., Unified Soil Classification System (Holtz and Kovacs, 1981)] and/or soil mixtures (e.g., bentonite additive) and the basis for their selection are presented. An analysis is included demonstrating that an adequate quantity of the specified borrow material has been identified at the borrow source. The information on borrow material includes boring and test pit logs and compaction test data. The soils that are considered suitable include the Unified Classification System Classes CL, CH, SC, and CL-ML, with desirable characteristics and limitations as listed in Table 3-1 of the "Construction Methods and Guidance for Sealing Penetrations in Soil Covers" (Bennett and Homz, 1991; Bennett and Kimbrell, 1991). The preferred material for the low-permeability layers is inorganic clay soil. This soil should be compacted to a low saturated hydraulic conductivity of at least 1 x 10 $_{-7}$ cm/sec. For drainage layers, cobble types GW, GP, SP, and SW are recommended, with GW and GP being the preferred types (Bennett, 1991). Measures for resisting cracking, heaving, and settlement, and providing protection from burrowing animals, root penetration, and erosion over a long period of time are described.	PDS Report (MWH, 2014)	Borrow characterization is described in the PDS report, further detail is included in Appendix H of the 30% Design.
		30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The cover system planned for the repository is an evapotranspirative (ET) cover, which is more effective in the site environment than a compacted low-permeability material.
2.	A sufficiently detailed description of the applicable field and laboratory investigations and testing that were completed, and the material properties (e.g., permeability, moisture-density relationships, gradation, shrinkage and dispersive characteristics, resistance to freeze-thaw degradation, cracking potential, and chemical compatibility, including any amendment materials) are identified (U.S. Army Corps of Engineers, 1970, 1972; Fermulk and Haug, 1990; NRC, 1978, 1979; Lee and Shen, 1969; Spangler and Handy, 1982).	PDS Report (MWH, 2014)	Laboratory testing of cover materials followed appropriate references.
3.	Details are presented (including sketches) of the disposal cell cover termination at boundaries, with any considerations for safely accommodating subsurface water flows.	30% Design Report, Volume II (MWH, 2016)	Drawings
4.	A schematic diagram displaying various disposal cell layers and thicknesses is provided. The particle size gradation of the disposal cell bedding layer and the rock layer are established to ensure stability against particle migration during the period of regulatory interest (NRC, 1982).	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit.
		30% Design Report, Volume II (MWH, 2016)	Drawings
5.	The effect of possible freeze-and-thaw cycles on soil strength and radon barrier effectiveness is adequately considered (e.g., Aitken and Berg, 1968). If the region experiences prolonged freezing, the disposal cell cover may be affected by the freeze-thaw cycle. During freezing, ice crystals and lenses can form in the soil, causing heaving. On the other hand, during melting and thawing, the soil may lose its bearing capacity because of development of supersaturated conditions (Spangler and Handy, 1982). Major factors affecting growth of ice in soil are the temperature below the freezing point, the capillary characteristics of the soil, and the presence of water. The reviewer should check whether the soil is susceptible to frost heave, considering that uniformly graded soils containing more than 10 percent of particles smaller than 0.02 mm and well-graded soils with more than 3 percent of particles smaller than 0.02 mm are susceptible (Holtz and Kovacs, 1981; Spangler and Handy, 1982). After many freeze-thaw cycles, the soil may become a loose collection of aggregates with significantly reduced overall strength.	-----	N/A The existing radon barrier, where it will be part of the repository, will be protected from frost by the new repository.
6.	A description is given (with sketches) of any penetrations (e.g., monitoring wells) through the disposal cell system, including details of penetration sealing and disposal cell cover integrity. Bennett and Kimbrell (1991) suggest methods for seal design that are acceptable.	-----	N/A; no penetrations through the repository system are planned.
7.	An adequate analysis is presented of the potential for development of cracks in the disposal cell cover as a result of	30% Design Report,	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-

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	differential settlement and shrinkage. Note that cracking issues associated with settlement are discussed in standard review plan Section 2.3.3.	Appendix G.7 (Dwyer, 2016a)	review audit.
8.	An adequate description of the geomembranes and their major properties (e.g., physical, mechanical, and chemical) is provided if low permeability geomembranes are proposed as a part of the disposal cell cover. Methods for installation of the membranes in accordance with the manufacturer's recommendations are discussed. The shear strength of the interface between compacted clay and geomembranes used in the stability analyses under both static and dynamic loads is noted. The expected service life of the geomembrane is analyzed.	-----	N/A; no geomembranes are planned in the repository, to comply with USNRC long-term performance standards.
9.	Information on site characterization, slope stability, settlement, and liquefaction used in the disposal cell cover design appropriately reflects the staff evaluation, and therefore, constitutes inputs that would contribute to the demonstration of disposal cell design compliance with the regulations.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	Cover Design report (G.7) recommended for pre-review audit. Information is presented to demonstrate compliance with NRC performance standards
		30% Design Report, Appendix G (MWH, 2016) 30% Design Report,	Information is presented to demonstrate compliance with NRC performance standards
2.6	**Construction Considerations**		
1.	Engineering drawings are complete and clearly show the design features (e.g., embankments, riprap, and channels).	30% Design Report, Volume II (MWH, 2016)	Drawings are complete and show the design features.
2.	Sources and quantities of borrow material are identified, are shown to have been adequately characterized and quantified through field and laboratory tests, and are demonstrated to be adequate for meeting the geotechnical design requirements for the disposal cell (NRC, 1978, 1979). The background levels of contamination in the borrow materials, if any, are properly established.	PDS (MWH, 2014);	Borrow characterization
		Approved Rec. Plan (Canonie, 1991)	Background levels of contamination in borrow areas documented.
3.	Methods, procedures, and requirements for excavating, hauling, stockpiling, and placing of contaminated and non-contaminated materials and other disposal cell materials are provided and are shown to be consistent with commonly accepted engineering practice for earthen works (Department of the Navy, 1982a,b; Denson, et al., 1987). Material placement and compaction procedures are adequate to achieve the desired moisture content (drying, if needed) placement density and permeability. Recommendations made in NUREG/CR5041 (Denson, et al., 1987) for gradation, placement, and compaction necessary to achieve design drainage rates and volumes, prevent internal erosion or piping, and allow for collection and removal of liquids are acceptable. Compaction specifications include restrictions on work related to adverse weather conditions (e.g., rainfall, freezing conditions). Specifications for controlling the mixture of fine tailings (slime) with sand tailings are consistent with commonly accepted engineering practice and testing programs for determination of engineering properties of this mixture.	30% Design Report, Volume I (MWH, 2016)	
4.	A plan for embankment construction is presented, that demonstrates embankments can be constructed in accordance with the design.	30% Design Report, Volume I (MWH, 2016)	
5.	Plans, specifications, and requirements for disposal cell compaction are supported by field and laboratory tests and analyses to assure stability and reliable performance.	30% Design Report, Volume I (MWH, 2016) Appendices G, J, V	
6.	Testing and surveying programs to determine the extent of cleanup required are adequate. The contamination cleanup plan includes the method for determining the extent of the contaminated area and a confirmation program to demonstrate that the contaminated material has been removed. Details of the site cleanup (radiological aspects) are addressed in standard review plan Chapter 5.0.	30% Design Report, Appendix T	Restricted tailings area. Appendix T would apply to the mine haul road.
7.	A plan for settlement measurement is provided that is satisfactory for producing representative settlement data throughout the area of the disposal cell. Settlement measurement stations are of sufficient coverage and are strategically placed to yield adequate information for determination of total, differential, and residual settlements. Monitoring monuments are designed to be durable. The reviewer should also determine the reasonableness of the proposed monitoring frequency in accordance with NUREG/CR3356 (NRC, 1983). In the past, the staff has determined that the final radon barrier may be emplaced once 90 percent of expected settlement has occurred.	30% Design Report, Volume I, Appendix G (MWH, 2016)	Settlement monitoring program details will be included in the 95% design.

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8.	All tailings and contaminated materials at the site can be placed within the planned configuration of the stabilized pile.	30% Design Report, Volume I, Appendices C, G (MWH, 2016)	Additional justification of repository capacity has been provided in the mine volume memo.
9.	Procedures, specifications, and requirements for riprap, rock mulch, and filter production and placement are provided and are shown to be consistent with commonly accepted engineering practice and the design specifications (NRC, 1977, 1982).	30% Design Report, Volume I, Appendices G, H, I, J, V (MWH, 2016)	The design will describe the detailed sizing of the rock and the specifications will include requirements for placement.
10.	The construction sequence is described and demonstrated to be adequate to achieve the intended configuration for the tailings, particularly when tailings are to be relocated to new areas of the reclaimed pile. The proposed time to completion has been shown to be reasonably achievable, and the construction schedule provides for completing the radon barrier as expeditiously as practical after ceasing operations in accordance with an approved reclamation plan.	-----	N/A; covering of tailings is not applicable for the repository, since the radon barrier over the existing tailings will not be penetrated or removed.
11.	The vegetation program or rock cover design is described and demonstrated to be adequate (Wu, 1984; NRC, 1982).	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Erosional stability is provided by the rock mulch on the cover surface. A vegetation plan has been developed, but is not relied upon for erosional stability.
12.	Appropriate quality control provisions are provided to ensure that the construction will be in accordance with the reclamation plan. The descriptions of the methods, procedures, and frequencies by which the construction materials and activities are to be tested and inspected are reasonable and appropriate records will be maintained (NRC, 1983).	30% Design Report, Appendices J, V, (MWH, 2016)	Detailed in the quality assurance plan and the specifications.
13.	Tailings are placed below grade, or the licensee has demonstrated that the above-grade disposal design provides reasonably equivalent isolation of the tailings from natural erosional forces. Tailings pile topographic features take into account wind protection and vegetation cover.	30% Design Report, Appendix G (MWH, 2016);	The design demonstrates isolation of the mine waste from natural erosive forces and presents a stable final configuration on the existing tailings.
2.7	**Disposal Cell Hydraulic Conductivity**		
1.	A sufficient technical basis is provided for the design hydraulic conductivity (K) value for the disposal cell. The hydraulic conductivity is minimized by compacting fine-grained soil for a sufficient depth above the stabilized tailings. Natural borrow soils having insufficient silt and clay content to effectively reduce the hydraulic conductivity of the barrier can be amended with bentonite for improved effectiveness. (Note that construction issues are discussed separately using standard review plan Section 2.6.)	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Infiltration control is provided by the ET cover. Tailings are isolated from the repository by the existing radon barrier.
2.	A field testing program adequate to verify the constructability of the disposal cell with a design hydraulic conductivity K<10^{-7} cm/sec is provided unless the reclamation plan demonstrates that field testing is not required (Benson and Daniel, 1990; NRC, 1979). To meet to the U.S. Environmental Protection Agency (EPA) groundwater standards, designers of disposal cells for mill tailings sites are proposing increasingly smaller design hydraulic conductivity (K) values. It is not unusual for laboratory permeability test values to yield results of 10^{-8} to 10^{-10} cm/sec. Such tests are performed on compacted soil samples considered by the design engineer to represent the soil to be used for the disposal cell. However, several technical papers (Rogowski, 1990; Panno et al., 1991; Benson and Daniel, 1990) have raised serious questions concerning the exclusive use of laboratory testing for demonstrating hydraulic conductivity values in those cases in which a radon barrier K-value less than 10^{-7} cm/sec is specified. On the basis of these technical papers, field testing is necessary to confirm the radon barrier hydraulic conductivity, since construction operations and soil material variability can create preferred pathways, joints, seams, holes, and flaws that effectively increase the value of this parameter. Test results should take into consideration the variability and uncertainty in site conditions and material properties. The test results should be properly documented and available for inspection.	30% Design Report, Appendix G.7 (Dwyer, 2016a) 30% Design Report, Appendix G (MWH, 2016)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Infiltration control is provided by the ET cover. PDS data supports the design assumptions.
3.	An appropriate quality control program is followed for the field testing to determine hydraulic conductivity (NRC, 1983). For all cases in which K<10^{-7} cm/sec and the test fill program requirement has been defined, specifications and related documents (Remedial Action Inspection Plan, etc.) will require an adequate quality control program. An acceptable quality control program should contain mechanisms to ensure that as-built construction duplicates the test fill construction techniques on the cell barrier (NRC, 1983). The objective of the quality control program will be to provide assurance that uniform and high-quality construction of the cell barrier has been achieved. Records for implementation of the quality control program during the construction of the cell barrier should be properly maintained and available for inspection.	30% Design Report, Appendix G, V, J (MWH, 2016)	CQAP and specifications will include details and requirements for field testing.

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4.	A reasonable construction schedule is proposed. The proposed construction schedule should promote completion of the radon barrier as expeditiously as practical after ceasing operations in accordance with a written, Commission-approved reclamation plan.	30% Design Report, Appendix K (MWH, 2016)	A construction schedule is included with the design.
3.0	**SURFACE WATER HYDROLOGY AND EROSION PROTECTION**		
3.1	**Hydrologic Description of Site**		
1.	The description of structures, facilities, and erosion protection designs is sufficiently complete to allow independent evaluation of the impact of flooding and intense rainfall.	30% Design Report, Appendix I (MWH, 2016)	
2.	Site topographic maps are of good quality and of sufficient scale to allow independent analysis of pre- and post-construction drainage patterns.	30% Design Report, Appendix I (MWH, 2016)	
3.	The reclamation plan contains sufficient information for the staff to independently evaluate the hydraulic designs presented. In general, detailed information is needed for each method that is used to determine the hydraulic designs and erosion protection provided to meet NRC regulations. NUREG 1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and thus conform to NRC requirements. NUREG 1623 (NRC, 1998) also provides discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement, without the use of active maintenance. Specific design methods are provided and form the primary basis for staff review of erosion protection designs.	30% Design Report, Appendix I (MWH, 2016)	The newer version of NUREG 1623 (NRC, 2002) was used for guidance on analysis methods.
3.2	**Flooding Determinations**		
1.	The designs conform to the suggested criteria in Appendix D to NUREG 1623 (NRC, 1998). NUREG 1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and to meet NRC requirements. It also presents discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Acceptable design methods are presented and form the primary basis for staff review of erosion protection designs. These methods were derived from regulatory requirements, other regulatory guidance, staff experience, and various technical studies.	30% Design Report, Appendix I (MWH, 2016)	The probable maximum precipitation has been used for evaluation of erosional stability for the repository and channels to meet the 1,000-year longevity requirement.
2.	Information pertinent to computation of the design flood is submitted in sufficient detail to enable the staff to perform an independent flood estimate, specifically : • Model input parameters are adequate. • Staff and the reclamation plan estimates of flood levels and peak discharges are in agreement. • Computational methods for design flood estimates are adequate.	30% Design Report, Appendix I (MWH, 2016)	
1.	"Worst conditions" postulated in the analysis of upstream dam failures are (1) an approximate 25-year flood on a normal operating reservoir pool level coincident with the dam-site equivalent of the earthquake for which the remedial action project is designed, (2) a flood of about one-half the severity of a probable maximum flood on a normal reservoir pool level coincident with the dam-site equivalent of one-half of the earthquake for which the remedial action project is designed; and (3) a probable maximum flood (or design flood) on a normal reservoir pool. Surface Water Hydrology and Conditions 1 and 2 are applied when the dam is not designed with adequate seismic resistance; Condition 3 is applied when the dam is not designed to safely store or pass the design flood. If the proposed design is based on less than a probable maximum flood event, the licensee offers reasonable assurance of conforming to the stability requirement of 200 years. Dam failure analyses are either realistic or conservative, and include locations and sizes of upstream dams, instantaneous failure (complete removal) of the dam embankment, and compute the peak outflow rate.	-----	N/A
3.3	**Water Surface Profiles, Channel Velocities, And Shear Stresses**		
	The proposed designs conform to the suggested criteria in Appendix D to NUREG 1623 (NRC, 1998). NUREG1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and to comply with NRC requirements. This document also contains discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Specific design methods are presented, and reasonable similarity to these methods forms the primary	30% Design Report, Appendix I (MWH, 2016)	

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	basis for staff acceptance of erosion protection designs. Specifically :		
1.	Localized flood depths, velocities, and shear stresses used in models for rock size determination or soil cover slope analysis conform to the guidance presented in Appendix D to NUREG 1623 (NRC, 1998).	30% Design Report, Appendix I (MWH, 2016)	
2.	For off-site flooding effects, computational models have been correctly and appropriately used and that the data from the model have been correctly interpreted.	30% Design Report, Appendix I (MWH, 2016)	
3.	Acceptable models and input parameters have been used in all the various portions of the flood analyses and that the resulting flood forces have been adequately accommodated.	30% Design Report, Appendix I (MWH, 2016)	
3.4	**Design of Erosion Protection**		
	The proposed designs conform to the suggested criteria in NUREG 1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and to comply with NRC requirements. This document also contains discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Specific design methods are presented, and reasonable similarity to these methods forms the primary basis for staff acceptance of erosion protection designs. NUREG 1623 (NRC, 1998) updates and expands the final staff technical position (NRC, 1990). If active maintenance is proposed as an alternative to the designs suggested above, such an approach will be found acceptable if the following criteria are met :	30% Design Report, Appendix G.7 (Dwyer, 2016a)	Pre-review audit recommended for cover erosion protection design.
		30% Design Report, Appendix I (MWH, 2016)	No active maintenance is anticipated. Details for O&M inspections will be provided in the 95% Design Report.
1.	The maintenance approach must achieve an equivalent level of stabilization and containment and protection of public health, safety, and the environment	30% Design Report, Appendix W	No active maintenance is anticipated. Details for O&M inspections will be provided in the 95% Design Report.
2.	The licensee must demonstrate a site-specific need for the use of active maintenance and an economic benefit	30% Design Report, Appendix W	No active maintenance is anticipated. Details for O&M inspections will be provided in the 95% Design Report.
3.	The licensee must provide funding for the maintenance by increasing the amount of the required surety. The staff should determine if the licensee's estimate of funding required for active maintenance is adequate. The licensee should also work with the long-term custodian to assess any additional funding requirements related to long-term surveillance and monitoring	30% Design Report, Appendix W	No active maintenance is anticipated. Details for O&M inspections will be provided in the 95% Design Report.
3.5	**Design of Unprotected Soil Covers And Vegetative Soil Covers**		
	The designs conform to the suggested criteria in NUREG 1623 (NRC, 1998). NUREG 1623 (NRC, 1998) discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and thus meet NRC requirements. This document also provides discussions and technical bases for use of specific criteria to meet the 1,000-year longevity requirement without the use of active maintenance. Specific acceptance criteria for many of the review areas are presented and form the primary basis for staff review of erosion protection designs. These criteria were derived from regulatory requirements, other regulatory guidance, staff experience, and various technical references. If active maintenance is proposed as an alternative to the designs suggested above, such an approach will be found acceptable if the following criteria are met:	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The repository cover surface is designed to provide erosional stability based on a rock mulch and not on vegetation or unprotected soil
1.	The maintenance approach must achieve an equivalent level of stabilization and containment and protection of public health, safety, and the environment	30% Design Report, Appendix W	No active maintenance is anticipated. Details for O&M will be provided in the 95% Design Report.
2.	The licensee must demonstrate a site-specific need for the use of active maintenance and an economic benefit	30% Design Report, Appendix W	No active maintenance is anticipated. Details for O&M will be provided in the 95% Design Report.
3.	The licensee must provide funding for the maintenance by increasing the amount of the required surety. The licensee should also work with the long-term custodian to assess any additional funding requirements related to long-term surveillance and monitoring	30% Design Report, Appendix W	No active maintenance is anticipated. Details for O&M will be provided in the 95% Design Report.
4.0	**PROTECTING WATER RESOURCES**	Protection of water resources related to the repository's influence on the tailings area is demonstrated by the quantified seepage presented in the Consolidation and Groundwater Report (Dwyer, 2016b). Based on the fill placement not influencing the existing groundwater, the checklist items in Section 4.0 of this checklist are tied to the groundwater corrective action program and not a change in conditions resulting from the construction	

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		of the repository. Therefore, Section 4.0 is not applicable to the request for source materials license amendment.	
4.1	**Site Characterization**		
1.	It contains a description of the site that is sufficient to assess the environmental impact the former mill site may have on the surrounding area; the populations that may be affected by such impacts; and meteorological conditions that may act to transport contaminants off site. An acceptable site description will contain the following specific information:		
a.	A site history that includes:		
i.	A list of known leaching solutions and other chemicals used in the milling process and their relative quantities in mill wastes. The list should also identify any constituent listed in 10 CFR Part 40, Appendix A, Criterion 13 that may have been disposed of in the tailings pile.		
ii.	A description of the wastes generated at the site during milling operations, waste discharge locations, types of retaining structures used (e.g., tailings piles, ponds, landfills), quantities of waste generated, and a chronology of waste management practices.		
iii.	A summary of the known impacts of the site activities on the hydrologic system and background water quality.		
iv.	If applicable, descriptions of any human activities or natural processes unrelated to the milling operation that may have altered the hydrogeologic system. Such human activities include ground water use, crop irrigation, mine dewatering, ore storage, municipal waste land filling, oil and gas development, or exploratory drilling. Natural processes include geothermal springs, natural concentration of soluble salts by evaporation, erosion processes, and groundwater/surface-water interactions.		
b.	Information pertaining to surrounding land and water uses that includes:		
i.	A general overview of water uses, locations, quantities of water available, and the potential uses to which quality of water is suited;		
ii.	Definitions of the class-of-use category for each water source (e.g., drinking water, agricultural, livestock, limited use);		
iii.	Identification of potential receptors of present or future groundwater or surface-water contamination; and		
iv.	Descriptions of non-mill related human activities or natural processes that may affect water quality or water uses (e.g., oil and gas development, municipal waste landfills, crop irrigation, drought, and erosion).		
c.	Sufficient meteorologic data for the region, including rainfall, temperature, humidity and evaporation data in sufficient detail to assess projected water infiltration through the disposal cell.		
2.	The groundwater and surface-water hydrology is described adequately to support modeling predictions of likely contaminant migration paths; selection of monitor well locations; and, when groundwater contamination exists, selection of a restoration strategy. The following specific information is provided to support these objectives:		
a.	A description of hydrogeologic units that may affect transport of contaminants away from the site via groundwater-pathways.		
i.	Hydro-stratigraphic cross-sections and maps are included to delineate the geometry, lateral extent, thickness, and rock or sediment type of all potentially affected aquifers and confining zones beneath the processing and disposal sites and quantity to support a technically defensible interpretation.		
ii.	The hydrogeologic units that constitute the uppermost aquifer (where regulatory compliance will be evaluated) are identified. The uppermost aquifer is the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility's property boundary.		
iii.	If local perched aquifers are found at the site, their presence is noted. These formations may cause contaminated water to be diverted around monitoring systems, or may be improperly interpreted as the uppermost aquifer. Any saturated zone created by uranium or thorium recovery operations would not be considered an aquifer unless the zone is or potentially is (1) hydraulically interconnected to a natural aquifer, (2) capable of discharge to surface water, or (3) reasonably accessible because of migration beyond the vertical projection of the boundary, of the land transferred for long-term government ownership and care in accordance with Part 40, Appendix A, Criterion 11.		
iv.	Unsaturated zones, through which contaminants may be conveyed to the water-bearing units, are described. This		

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	information is adequate to support the assumptions used in estimating the source term for contaminant transport pathways. This information includes identification of potential preferential flow pathways that are either natural (e.g., buried stream channels), or man-made (e.g., abandoned wells or mine shafts).		
v.	Information is presented on geologic characteristics that may affect groundwater flow beneath the former mill site. Examples of pertinent geologic characteristics include identification of significant faulting in the area, fracture and joint orientation and spacing for the underlying bedrock, and geomorphology of soil and sedimentary deposits (e.g., fluvial, glacial, or volcanic deposits).		
vi.	Hydraulic-head contour maps, of both local and regional scale, for the uppermost aquifer and any units connected hydraulically beneath the site are sufficient to determine hydraulic gradients, groundwater flow direction, and proximity to offsite groundwater users. These maps are based on static water level observations at onsite and regional wells. Several measurements are taken at each observation well [(ASTM) Standards D 4750, D 5092, D 5521, D 5787, and D 5978]. These measurements are sufficiently spaced in time to capture water-level fluctuations caused by seasonal changes or local pumping of groundwater. Enough observation wells are sampled to produce an adequate water elevation contour map. The appropriate number of wells is dependent on the size of the site and the choice of contour interval. However, as a rough estimate, there is at least one observation well for each contour line on the map. A more detailed contour map (small contour interval) is produced for the site and surrounding properties. The level of detail used for the regional contour map may be limited by the number of observation wells available offsite. The reviewer shall bear in mind that calculations of hydraulic gradients from hydraulic head contour maps is only rigorously valid for horizontal flow in aquifers.		
b.	Estimations of hydraulic and transport properties of the underlying aquifer. Hydro-geologic parameters used to support the choice of a groundwater restoration strategy or to demonstrate compliance include hydraulic conductivity, saturated thickness of hydro-geologic units, hydraulic gradient, effective porosity, storage coefficient, and dispersivity. The reviewer shall consider the influence of each of these parameters on evaluating compliance with standards established pursuant to Part 40, Appendix A, and determine whether estimates for each parameter are reasonably conservative, based on the data provided.		
i.	Hydraulic conductivity and storage coefficients are determined by conducting aquifer pump tests on several wells at the site. Pump test methods that are consistent with ASTM standards for the measurement of geotechnical properties and for aquifer hydraulic tests are considered acceptable by the NRC. These ASTM standards are D 4044, D 4050, D 4104, D 4105, D 4106, D 4630, D 5269, D 5270, D 5472, D 5473, D 5737, D 5785, D 5786, D 5850, D 5855, D 5881, and D 5912. Any other peer-reviewed method or commonly accepted practice for aquifer parameter estimation may be used. When curve fitting is used to analyze pump test data, deviations of observation data from ideal curves are explained in terms of likely causes (e.g., impermeable or recharge boundaries, leaky aquitards, or heterogeneities). When average hydraulic parameters are reported, the reviewer shall consider that many hydrogeologic parameters, including hydraulic conductivity, typically exhibit a log-normal distribution. Consequently, the geometric mean may be more representative of the overall conditions within a unit than the arithmetic mean.		
ii.	Horizontal components of hydraulic gradient are estimated by measurement of the distance between contour intervals on hydraulic head contour maps. Vertical components of hydraulic gradient are estimated from head measurements in different aquifers or at different depths in the same aquifer.		
iii.	Generally, analyses considering steady-state conditions are acceptable unless site conditions indicate otherwise. If transient conditions are modeled, storage coefficients estimated from standard tests indicated in (i) above are used.		
iv.	If contaminant transport is modeled, then longitudinal and transverse dispersivity values are either obtained from a tracer test or conservative values based on published literature are used. Because dispersivities depend on the size of the modeled region, the reviewer shall carefully compare the values for dispersivity used in the licensee's transport modeling with those values cited in survey studies such as Gelhar, Welty, and Rehfeldt (1992), and verify that they represent conservative estimates for the site.		
c.	Estimation of groundwater/surface-water interactions at sites with nearby streams, rivers, or lakes. The location of surface-water bodies that are connected to the site groundwater flow system are identified. Surface-water elevations shall be used to help describe the site groundwater flow system if a stream or other surface-water body discharges		

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	into or drains the site groundwater flow system. Another acceptable approach is to evaluate hydraulic head contour based on data from monitor wells in the vicinity of streams.		
3.	Geochemical conditions and water quality are characterized sufficiently to:		
a.	Identify the constituents of concern.		
b.	Present a determination of background (baseline) water quality. Background water quality is defined as the chemical quality of water that would be expected at a site if contamination had not occurred from the uranium milling operation.		
i.	Maps are of sufficient detail and legibility to show the background monitoring locations.		
ii.	Descriptions of sampling methods, monitoring devices, and quality assurance (QA) practices are provided. Examples of acceptable methods are those that are consistent with ASTM Standards D 4448, D 4696, and D 4840. Other methods, if used, are properly referenced and justified.		
iii.	When they exist, zones of differing background water quality are delineated. The possible causes of these differing water quality zones are discussed (e.g., changes from geochemically oxidizing to reducing zones in the aquifer; changes in rock type across a fault boundary).		
iv.	A table for each zone of distinct water quality, listing summary statistics (i.e., mean, standard deviation, and number of samples) for baseline water quality sampling for each constituent of concern, is provided.		
v.	A preoperational monitoring program has been in place for 1 year consistent with the requirements of Part 40, Appendix A, Criterion 7. Samples are taken at least monthly under this program. However, it is unlikely that mills in existence prior to the groundwater compliance provisions of 10 CFR 40 Appendix A will have one full year of monthly baseline data from a preoperational monitoring program.		
c.	(c) Confirm the proper use of statistical techniques for assessing water quality. Statistical hypothesis testing methods used for (i) establishing background water quality; (ii) establishing groundwater protection standards for compliance monitoring; (iii) determining the extent of groundwater contamination; and (iv) establishing the groundwater cleanup goals, are described in American Society for Testing and Materials Standard D 6312.		
d.	Define the extent of contamination. A hazardous constituent is defined in 10 CFR Part 40, Appendix A, Criterion 5B(2) as a constituent that meets all three of the following tests: (1) The constituent is reasonably expected to be in or derived from the byproduct material in the disposal area; (2) The constituent has been detected in the ground water in the uppermost aquifer; and (3) The constituent is listed in Part 40, Appendix A, Criterion 13. The reviewer shall verify that the licensee has presented the following information to support determining the extent of contamination.		
i.	(i) A map or maps showing the distribution of surface wastes and contaminated materials at and near the site,		
ii.	(ii) A map or maps showing the approximate shape and extent of groundwater contamination (e.g., concentration contour maps for indicator parameters in ground water), and		
iii.	(iii) Identification of any offsite sources of water contamination or other factors that may have a bearing on observed water quality.		
e.	(e) Properly estimate the source term. Existing sources of groundwater contamination are defined in terms of location and rate of entry into the subsurface. At some sites, the contaminant sources have been effectively eliminated through stabilization or removal of tailings piles. However, residual sources may still exist in contaminated subsurface soils at the site. For groundwater contamination that originates from an onsite tailings pile, the source term is determined based on the chemical properties of the leachate and the rate at which leachate is released from the disposal area. The level of review given to source term calculations is commensurate with the overall importance of source term estimations to the selection of the restoration strategy.		
i.	Source terms are reasonably correlated to the history of ore processing. All facilities from which leakage can occur are identified. Leaking constituents are identified based on the nature of the processing fluids. The volume of leakage is estimated in a realistic yet conservative manner. This can be done using water balance calculations, infiltration modeling, or seepage monitoring approaches.		

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ii.	When geochemical models are used to predict the fate and transport of existing contamination where the original source has been eliminated, the distribution of each hazardous constituent in place is taken as the source term.		
f.	Characterize the subsurface geochemical properties. To effectively model the fate and transport of contaminants in ground water, it is important to characterize the geochemical properties of the natural waters and the aquifer mineralogy. Characterization of the underlying lithologies includes measurements of buffering capacity, total organic carbon, cation exchange capacity, and identification of the clay mineralogy. The general chemical characteristics of fluids within the lithologies are described by measurements of pH, temperature, dissolved oxygen, redox potential (Eh), buffering capacity, and the concentrations of major ions and trace metals.		
i.	Aquifer geochemistry data are adequate to model the attenuation of contaminants. The values of the geochemical parameters used in transport models are justified. Acceptable parameter estimation methods are direct measurement, use of a conservative bounding estimate, reference to literature values for similar aquifer conditions, and laboratory studies of aquifer materials.		
g.	Identify contaminant attenuation mechanisms. The major attenuation mechanisms that work to mitigate the effects of groundwater contamination are dilution in surrounding ground water, sorption of contaminants to the soil matrix, and immobilization of contaminants from geochemical and biochemical reactions.		
i.	Claims that contamination is reduced by dilution are supported by a sufficient technical basis. There are two mechanisms for dilution of a contaminant plume in ground water: dispersion and mixing. Dispersion is a process whereby contaminant plumes tend to spread out and become less concentrated as they are advected away from the source. Mixing is the result of uncontaminated water being added to the groundwater system through natural recharge, injection, or upward movement of water from underlying aquifers, which reduces the concentration of contaminants. Estimation of surface recharge or upward flow through leaky aquitards is either established from field measurements, or conservative assumptions are used.		
ii.	The values of sorption coefficients are based on the nature of the constituent and site-specific geochemical conditions. The degree of sorption of contaminants to the soil matrix depends on the affinity of each constituent for the soil in a particular aquifer. Constituents that carry a positive charge, as do most trace metals in solution, are good candidates for cation exchange adsorption to clay and oxide surfaces. However, because surface charges of clays and oxides decrease with decreasing pH, the reviewer shall carefully examine claims of attenuation from cation exchange under low pH conditions. Organic contaminants tend to be hydrophobic and are strongly attenuated in soils that have high organic carbon content. Most contaminant fate and transport models quantify the affinity of contaminants for soil by use of a distribution coefficient or *KD*. Batch or column equilibria experiments, using representative leachate and soil samples, are performed to support estimations of *KD* for each hazardous constituent.		
iii.	Attenuation from geochemical or biochemical equilibrium reactions are estimated by use of acceptable modeling software packages such as MINTEQA2 (Allison, Brown, and Novo-Gradac, 1991) and PHREEQE (Parkhurst, Thorstensen, and Plummer, 1980). However, these packages are limited in that they do not consider transport of contaminants. Thus, results are only valid for reactions within a confined space (e.g., within the disposal cell). The reviewer shall determine that all model input parameters have sufficient technical bases and represent reasonably conservative estimations. Additionally, conclusions drawn from such models are supported by field observation; that is, they are consistent with site characterization data.		
iv.	At sites from which the contamination source has been effectively eliminated, monitoring data are used to assess attenuation of contaminants. If the contaminant source has been eliminated by surface reclamation, changes in the nature and extent of contamination over time are monitored. In such situations the center of mass of the contaminant plume moves along the direction of groundwater flow. The effects of dispersion are also observable over time as a decrease in peak concentrations near the center of the contaminant plume and a lateral spreading of the plume. If significant precipitation or adsorption is occurring, it is reflected in a decrease in the mass of contaminants in the aqueous phase.		
4.2	**Groundwater Protection Standards**		
1.	Hazardous constituents are identified using the definition given in Part 40, Appendix A, Criterion 5(b).		

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2.	A POC is established in accordance with Part 40, Appendix A, Criterion 5B(1). The POC is the location at which the ground water is monitored to determine compliance with the groundwater protection standards. The objective in selecting the POC is to provide the earliest practicable warning that the impoundment is releasing hazardous constituents to the ground water. The POC must be selected to provide prompt indication of groundwater contamination on the hydraulically downgradient edge of the disposal area. The POC is defined as the intersection of a vertical plane with the uppermost aquifer at the hydraulically downgradient limit of the waste management area. The “uppermost aquifer” is defined in 10 CFR Part 40, Appendix A, as “the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility’s property boundary.” Therefore, a proper selection of the POC includes identification of POC locations in the aquifer nearest to the ground surface, as well as other aquifers that are hydraulically interconnected with that aquifer, as warranted by site-specific conditions. When tailings are disposed of on site, the NRC generally interprets the downgradient limit of the waste management area to be the edge of the reclaimed tailings side slopes. However, it is not recommended that licensees be required to compromise the cover integrity to install monitoring wells at the actual edge of the reclaimed tailings.		
3.	A concentration limit is specified for each of the hazardous constituents.		
a.	Commission-Approved Background Concentrations Part 40, Appendix A, requires that the Commission-approved background concentration be the background concentration, except for constituents listed in Table 5C of Part 40, Appendix A, which, if present in excess of background, are subject to the respective MCL s listed in Table 5C. Proper statistical methods, as discussed in SRP Appendix A, are used to determine the expected range of naturally occurring background (baseline) concentrations for each constituent of concern. Acceptable statistical techniques are also presented in Haan (1977) and Hirsch, et al. (1992).		
b.	Alternate Concentration Limits ACLs are established on a site-specific basis, provided it can be demonstrated that (i) the constituents will not pose a substantial present or potential hazard to human health or the environment, as long as the ACLs are not exceeded and (ii) the ACLs are ALARA, considering practicable corrective actions. Licensees are required to implement detection-monitoring programs to detect and identify site-specific hazardous constituents, and compliance monitoring programs to verify compliance with the established site-specific standards for individual constituents. SRP Sections 4.3.3 and 4.4.3 contain acceptance criteria for determining potential hazards, and for ALARA demonstrations, respectively.		
4.3	**Hazard Assessment, Exposure Assessment, Corrective Action Assessment and Compliance Monitoring for Alternate Concentration Limits**		
4.3.3.1	**Hazard Assessment** The hazard assessment identifies all potential constituents of concern at a site.		
1.	The source term for all constituents of concern is adequately characterized and the extent of existing and potential future groundwater contamination is determined. The source term characterization provides relevant information about the facility including: (a) the mechanical and chemical processes used to recover the uranium, (b) the types and quantities of the reagents used in milling, (c) the physical and chemical composition of the uranium-bearing ore, and (d) the historical and current waste and tailings management practices. This information is considered, in conjunction with the physical and chemical composition of the tailings and the type and distribution of existing contaminants, such as the location of waste discharge points, retaining structures for wastes, and waste constituents. The source characterization should provide reliable estimates of the release rates of hazardous constituents as well as constituent distributions.		
2.	The assessment identifies and evaluates the risks and hazards presented by the identified constituents of concern, including the human cancer risk caused by exposure to radioactive and non-radioactive constituents of concern, along with other health hazards that may be caused by the chemical toxicity of those constituents. The human cancer risk should be evaluated for individual constituents, including radioactive and carcinogenic chemicals, and compared with the maximum permitted risk level. The health effects of non-radioactive and noncarcinogenic constituents that are chemically toxic will be evaluated considering their risk-specific dose levels. It may be necessary to calculate a hazard		

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	index using the reference doses for those chemicals that have threshold effects. The hazard index is the ratio of calculated intake to the reference dose. An acceptable hazard index must be less than one. These evaluations distinguish between the health effects associated with threshold and non-threshold constituents. Mutagenic, teratogenic, and synergistic effects are considered in the analysis, if applicable, based on toxicological testing, or structure-activity relationships. The following additional information on constituent properties is provided, as applicable: (a) density, solubility, valence state, vapor pressure, viscosity, and partitioning coefficient; (b) presence and effects of complexing ligands and chelating agents that may enhance constituent mobility; (c) potential for a constituent to degrade because of biological, chemical, and physical processes; and (d) constituent attenuation properties, considering such processes as ion exchange, sorption, precipitation, dissolution, and ultrafiltration. This information would also be applied in the exposure assessment.		
3.	The assessment provides a reasonably conservative or best estimate of the potential health effects caused by human exposure to the hazardous constituent. The potential health effects for each constituent with a proposed alternative concentration limit must be identified, and related to appropriate exposure limits and dose-response relationships from available literature or databases. Sources of exposure limit and dose-response information include the EPA's maximum concentration limits for drinking water, reference doses, or risk-specific doses. Reference doses are the amounts of chemically toxic constituents to which humans may be daily exposed without suffering adverse effects. Risk-specific doses are the amounts of proven or suspected carcinogenic constituents to which humans can be daily exposed, without increasing their risk of contracting cancer above a specified risk level. The reference dose and risk-specific dose assessment assume a human mass of 70 kg [154 lb] and consumption of 2 liters of water per day [0.53 gal/day]. More stringent criteria may apply if sensitive populations are exposed to hazardous constituents. Maximum concentration limits, reference doses, and/or risk-specific doses, can be used to show compliance with the risk level and hazard indexes. The technical basis for a risk assessment can be based on the dose-response relationships described in the scientific literature searches or toxicological research, in the absence of applicable maximum concentration limits, reference doses, or risk-specific doses. The exposure analysis should distinguish between threshold (toxic) and non-threshold (carcinogenic) effects associated with human exposure, as well as teratogenic, fetotoxic, mutagenic, and synergistic effects. The maximum concentration limits, reference doses, and risk-specific doses for most hazardous constituents can be obtained from the EPA (http://www.epa.gov), the Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/atsdrhome.html), or other government institutions and universities. Effects from radioactivity can be obtained from the International Commission on Radiological Protection, and the National Council on Previously established and documented health-based constituent concentration limits are used in the hazard assessment as a basis for proposing alternate concentration limit values at specific sites.		
4.	(4) The assessment identifies and evaluates the risks posed by the hazardous constituents to environmental populations. Adverse effects on aquatic and terrestrial wildlife, plants, agricultural crops, livestock, and physical structures should be considered. Examples of these adverse effects are: (a) contaminant-induced changes in the biota, (b) loss or reduction of unique or critical habitats, and (c) jeopardy to endangered or threatened species. The NRC must initiate special consultation with the US Fish and Wildlife Service, in accordance with 50 CFR Part 17, if endangered or threatened species occur on the site or could be impacted by site activities. NUREG 1748 (NRC, 2001) should be consulted for initiating this consultation. Similar to the human risk evaluation, the environmental risk evaluation identifies any acute and sub-chronic effects on environmental populations caused by exposure to the hazardous constituents. Bioaccumulation and food chain interactions are considered when evaluating adverse effects. A comparison of the estimated constituent concentrations to the appropriate federal or State water-quality criteria should be part of the evaluation of potential effects on aquatic wildlife. When appropriate, the hazard assessment considers potential damage to physical structures such as foundations, underground pipes, and roads. The applicant should demonstrate that the forecasted constituent concentrations will not result in any significant degradation or loss of function, as a result of contamination exposure. As an example, excessive concentrations of dissolved salts could result in accelerated corrosion of underground utility piping.		
4.3.3.2	**Exposure Assessment.** The purpose of the exposure assessment is to evaluate the potential harm to human health and the environment from the hazards identified in the hazard assessment.		

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1.	The exposure assessment evaluates the pathways the hazardous constituents will likely follow and the concentration or dose those constituents will likely produce at the location where humans or environmental populations could be reasonably exposed. All likely pathways that could transport significant amounts of hazardous constituents in the ground water and hydraulically connected surface water should be identified and evaluated. The hazardous constituent concentrations and projected distributions for each pathway should be best estimates or reasonably conservative representations of the rate, extent, and direction of the constituent transport. The groundwater pathway evaluation provides projected contaminant distributions, including contaminant transport, degradation, and attenuation mechanisms between the point of compliance and the point of exposure. The evaluation generally provides information on: (a) site hydrogeologic characteristics, including groundwater flow direction and rates; (b) background water quality; and (c) estimated transport rates, geochemical attenuation, and concentrations of hazardous constituents in the ground water and hydraulically connected surface water. Projections should be calibrated on the basis of site-specific information. The projected attenuation rate may rely on constituent concentration measurements at the point of compliance and the point of exposure, taken over an adequate period of time, when there is great uncertainty in the attenuation rate derived from laboratory measurements or literature sources.		
2.	The pathway evaluation provides the spatial distribution of the various hazardous constituents of existing contaminant plumes. This information can be used to calibrate contaminant fate and transport models in the exposure assessment and also identifies the components of the source term that have already been released from the tailings. The contaminant extent characterization includes: (a) the type and distribution of hazardous constituents in the ground water and the source(s) of the contamination; (b) the monitoring program used to delineate and characterize hazardous constituent. Protecting Water Resources distribution; and (c) supporting documentation of the sampling, laboratory analysis, and quality assurance programs that show the fulfillment of the site monitoring programs. Such information is used to assess present human and environmental population exposure to elevated concentrations of hazardous constituents, calibrate contaminant transport models, and evaluate projected future exposures. Computer codes may be used to evaluate the pathways for hazardous constituent transport. The acceptance criteria for groundwater fate and transport computer modeling are contained in standard review plan Section 4.4.3.		
3.	The human exposure evaluation considers two potential exposure pathways: (a) ingestion of contaminated water and (b) ingestion of contaminated foods. Or epidemiological studies. Other pathways that may impact human health, such as dermal contact and inhalation, are also to be considered, but need not always be assessed, unless it is determined that these exposures could result in significant hazards to human health or the environment. Human exposure is evaluated primarily on the basis of the extent to which people are using, and are likely to use, contaminated water from the site. Site-specific water uses are determined on the basis of the following considerations: (a) groundwater quality in the site area and present water uses; (b) statutory or legal constraints and institutional controls on water use in the site area; (c) federal, state, or other groundwater classification criteria and guidelines; (d) applicable water-use criteria, standards, and guidelines; and (e) availability and characteristics of alternate water supplies. Exposure determinations should consider existing and potential water uses. Potential uses include those that are reasonably expected to occur (i.e., anticipated use) and uses that are compatible with the untreated background water quality (i.e., possible use). Past water uses may be included as existing or potential uses. Water resource classification of existing and potential water use should include (a) domestic and municipal drinking water use; (b) fish and wildlife propagation, (c) special ecological communities; and (d) industrial, agricultural, and recreational uses. The classification of existing and potential water-uses at the facility should be consistent with federal, state, and local water-use inventories. The cumulative effects of human exposure to hazardous constituents at the proposed alternate concentration limits, and to other constituents present in contaminated ground water, will be maintained at a level adequate to protect public health. The combined effects from both radiological and non-radiological constituents should be considered. Proposed human exposure levels should be reasonably conservative, defensible, and sufficiently protective to avoid a substantial present or potential hazard to people for the forecasted duration of the contamination. A proposed alternate concentration limit that does not exceed an excess lifetime risk of fatal cancer on the order of 10_{-4} is acceptable for an average exposed individual at the point of exposure, when considering the potential for health risks from human exposure to known or suspected carcinogens contained in untreated ground water used for drinking water.		

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4.	Potential responses of environmental or non-human populations to the various hazardous constituents are evaluated if such populations can realistically be exposed to contaminated ground water or hydraulically connected surface water. Terrestrial and aquatic wildlife, plants, livestock, and crops are included in this evaluation. A detailed environmental exposure evaluation should be performed in the absence of available information that could readily be used to show there will be no substantial environmental impacts caused by groundwater contamination from the site. The evaluation should provide: (a) inventories of potentially exposed environmental populations; (b) recommended tolerance or exposure limits; (c) contaminant interactions and their cumulative effects on exposed populations; (d) projected responses of environmental populations that result from exposure to hazardous constituents; and (e) anticipated changes in populations, independent of the hazardous constituent exposure. Alternatively, the evaluation may demonstrate that environmental hazards are not anticipated, because exposure will not occur. The potential for adverse effects, such as (a) contamination-induced biotic changes; (b) loss or reduction of unique or critical habitats; and (c) jeopardizing endangered species, should also be described. Aquatic wildlife effects are evaluated by comparing estimated constituent concentrations with federal and state water quality criteria. Terrestrial wildlife exposure to constituents through direct exposure and food-web interactions should be considered. The NRC must initiate special consultation with the U.S. Fish and Wildlife Service, in accordance with 50 CFR Part 17, if endangered or threatened species occur on the site or could be impacted by site activities. NUREG 1748 (NRC, 2001) should be consulted for initiating this consultation. Agricultural effects from both direct and indirect exposure pathways, crop impacts, reduced productivity, and bioaccumulation of constituents should be considered. Reasonably conservative estimates of constituent concentrations are compared with federal and state water quality criteria to estimate agricultural effects associated with constituent exposure. Additionally, crop exposures through contaminated soil, shallow groundwater uptake, and irrigation, along with livestock exposure through direct ingestion of contaminated water and indirect exposure through grazing, should be assessed.		
5.	Points of exposure are identified. A point of exposure is any location where people, wildlife, or other species could reasonably be exposed to hazardous constituents from ground water contaminated by uranium mill tailings. For example, the point(s) of exposure may be represented by one or more domestic wells that might withdraw contaminated ground water; or it may be represented by springs, rivers, streams, or lakes into which contaminated ground water might discharge. The point of exposure is used to assess the potential hazard(s) to human health and the environment and effects on the groundwater resource. An alternate concentration limit for a hazardous constituent is established at the point of compliance. The point of exposure may be situated at some distance from the point of compliance, allowing hazardous constituent concentrations to diminish through dispersion, attenuation, or sorption within the aquifer. As a result, a concentration limit may be set at a concentration that is higher at the point of compliance location than a limit that would be protective of human health and environment, as long as the hazardous constituent will not result in an unacceptable hazard to human health and the environment at the point of exposure. In most cases, the point of exposure is located at the downgradient edge of land that will be transferred to either the federal government or the state for long-term institutional control. The applicant for an alternate concentration limit should make every reasonable effort to keep the point of exposure at the long-term care site boundary. If this cannot be achieved, a good-faith effort must be made to acquire the land between the license area boundary and the point of exposure, for ultimate transfer to the long-term custodian. If the land cannot be acquired through a good-faith effort, then institutional controls other than ownership by the long-term custodian may be initiated. These institutional controls must be enforceable, durable, and legally defensible; and will be applied in addition to the numerical limits of the proposed alternate concentration limit. This approach must be reviewed as an alternative to the specific regulatory requirements contained in 10 CFR Part 40, Appendix A, Criterion 5B(6). A distant point of exposure 3 may be justified when human or environmental exposure is effectively impossible. This option could be justified on the basis that extremely rugged terrain cannot be physically accessed or the long-term care custodian would ensure that ground water from the contaminated aquifers between the disposal site and the point of exposure would not be used. In some rare instances, a distant point of exposure could be established without invoking land ownership by a long-term custodian. Under these circumstances, the previously described institutional controls should be invoked. Human and environmental exposure are considered effectively impossible when the ground water is inaccessible or unsuitable for		

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	use. Land ownership or long-term custody will not be an issue for establishing a distant point of exposure if human and environmental exposure are effectively impossible. When a distant point of exposure is involved, the applicant must coordinate the use of this option with the NRC. The NRC and the applicant must verify whether the state or the federal government will be the long-term site custodian, after the license is terminated. The applicant must then secure a commitment from that party to take custody of the site. The applicant or the NRC must then secure written assurance that the appropriate federal or state agency will accept the transfer of the specific property, including land in excess of that needed for tailings disposal. Alternate concentration limits may not be established at sites involving a distant point of exposure until the licensee agrees to transfer the title to the land, and the appropriate federal or state government commits to take such land, including the land between the point of compliance and point of exposure that is in excess of the land used for disposal of byproduct material. If the licensee chooses to keep the mill property under a specific license and apply for an alternate concentration limit as part of a compliance monitoring program, the licensee must still coordinate the use of a distant point of exposure with the NRC as described above.		
6.	The likelihood of human and environmental exposure is determined. The probability of human and environmental exposure is often difficult to establish quantitatively. Consequently, defensible qualitative estimates of the exposure likelihood are often necessary. These can be characterized as either: (a) Reasonably likely - when exposure has or could have occurred in the past, or available information indicates that exposure to contamination may reasonably occur during the contamination period. (b) Reasonably unlikely - when exposure could have occurred in the past, but will probably not occur in the future, either because initial incentives for water use have been removed, or because available information indicates that no incentives for water use are currently identifiable, based on foreseeable technological developments.		
7.	Exposure impacts are adequately evaluated through time. It is acceptable to project impacts at the point of exposure during a 1,000-year time frame. This is consistent with the design standard of 10 CFR Part 40, Appendix A, Criterion 6(1).		
4.3.3.3	**Corrective Action Assessment.** The applicant's assessment of groundwater corrective action alternatives should be reviewed in conjunction with the hazard assessment and the exposure assessment. Past, current, and proposed practicable corrective actions are identified and evaluated against the costs and benefits associated with implementing each corrective action alternative. The corrective action assessment should demonstrate that the proposed alternate concentration limit is as low as is reasonably achievable, considering practicable corrective actions, as required by 10 CFR Part 40 Appendix A, Criterion 5B(6). A principal way of demonstrating this is by estimating and comparing the benefits imparted by a corrective action measure against the cost of implementing that measure. For some sites, a corrective action assessment may have already been completed, as part of a groundwater corrective action program under Criterion 5D of Appendix A to 10 CFR Part 40, as described in standard review plan Section 4.4.3. A groundwater corrective action assessment typically (a) identifies several practicable corrective action alternatives; (b) assesses the technical feasibility, costs, and benefits of each alternative; and (c) selects an appropriate corrective action for achieving compliance with the groundwater protection standards established at the site.		
1.	A complete range of realistic and reasonable corrective action alternatives for achieving compliance with the groundwater standards currently in the license and the proposed alternate concentration limit is described and evaluated. The identified alternatives should be comprehensive, including all engineering-feasible alternatives, both passive and active, or any appropriate sequential combination of alternatives. The analyzed corrective action alternative should not simply be a compendium of the most elaborate and expensive alternatives. The description of each alternative should be conceptual in nature, but contain sufficient detail so the reviewer can independently verify the reasonableness of each corrective action measure. Although conceptual, the alternative descriptions should also contain sufficient detail for completing a coarse cost estimate of each alternative for the cost and benefit analysis. For past and current corrective actions, site-specific operational and monitoring data should be included to show the effectiveness of those measures. The evaluation may include information from literature sources or documented experience from other sites for those corrective actions that have not been implemented at the site but appear to be practicable. The evaluation should also include projections of the hazardous constituent concentration that each corrective action would likely produce at specific times at the point of compliance and the point of exposure. It is		

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	important that the reviewer assure that the range of reasonable corrective actions listed in the application is complete. The suitability of a corrective action should be determined strictly on the technical and engineering information needed to design and implement a particular measure. The economic constraints for implementing a particular measure should not be used to eliminate a corrective action method from the evaluation.		
2.	The direct benefits of implementing the corrective actions have been determined by estimating the current and projected resource value of the pre-contaminated ground water. Estimates of pre-contaminated groundwater value should be based on water rights, availability of alternative water supplies, and forecasted water use demands. The value of a contaminated water resource is generally equal to the cost of a domestic or municipal drinking water supply or the cost of water supplied from an alternative source to replace the contaminated resource. The absence of available alternative water supplies increases the relative value of a potentially contaminated water resource. The indirect benefits are determined by assessing the avoidance of adverse health effects from exposure to contaminated water, the prevention of land value depreciation, and any benefits accrued from performing the corrective action, including timeliness of remediation. The reviewer should verify the water yields; costs for developing alternate water supply sources; and legal, statutory, or other administrative constraints on the use and development of the water resources.		
3.	The costs associated with performing a corrective action alternative to achieve the target concentrations include (a) the capital costs for designing, and constructing the alternative; (b) operation and maintenance costs; (c) costs associated with demonstrating compliance with the standards; and (d) decommissioning costs after the corrective action is completed.		
4.	The as low as is reasonably achievable analysis is performed on target concentration levels that are at or below the limit determined to be protective of human health and the environment. At least three target concentration levels that can reasonably be attained by the practicable corrective actions should be evaluated. The goals should be (a) meaningfully different, (b) reasonably attainable by practicable corrective action, and (c) at or below the level identified in the hazard assessment. The as low as is reasonably achievable analysis typically considers (a) the direct and indirect benefits of implementing each corrective action to achieve the target concentration levels; (b) the costs of performing the corrective action to achieve the target concentrations; and (c) a determination whether any of the evaluated corrective action alternatives will reduce contaminant levels below the proposed alternate concentration limit, considering the benefits and costs of implementing the alternative. The applicant should also provide a comparison among the costs associated with performing the various corrective action alternatives to achieve the target concentrations, the value of the pre-contaminated ground- water resource, and the benefits of achieving each target concentration. A proposed alternate concentration limit is considered as low as is reasonably achievable if the comparison of the costs to achieve the target concentrations lower than the alternate concentration limit are far in excess of the value of the resource and the benefits associated with performing the corrective action alternative. If the value and benefits clearly exceed the costs or the comparison is nearly equal, the proposed alternate concentration limit should be revised to the lower target concentration providing the greatest value and benefit compared to the cost. The cost and benefit analysis should not be limited to a simple financial accounting of the costs for each corrective action alternative. Costs and benefits should also be discussed for qualitative subjects, such as environmental degradation or enhancement. The cost and benefit analysis is not simply a mathematical formula from which to justify economic parameters. Other qualitative factors should be discussed and weighed in the decision. The cost and benefits analysis provides input to determine the relative merits of various corrective action alternatives; however, the proposed alternate concentration limit must ultimately assure protection of public health and the environment. The as low as is reasonably achievable analysis for non-radiological constituents should be similar to the as low as is reasonably achievable analysis for radiological constituents except a “dollar per person-rem avoided” value would not be calculated.		
4.3.3.4	**Examination of the Compliance Monitoring Program.** Standard review plan Section 4.4.3 provides the acceptance criteria for corrective action assessments, corrective action monitoring, and compliance monitoring. The reviewer should examine the existing compliance monitoring program at a licensed mill tailings facility, if a proposed alternate concentration limit is found acceptable. Specifically, the compliance monitoring program should monitor all		

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	groundwater exposure pathways to assure that any potential exceedances of the proposed alternate concentration limit will be detected before the license is terminated. The compliance monitoring well locations should not be restricted solely to the point of compliance. Some locations between the point of compliance and the points of exposure should be included to assure the identified aquifer attenuation mechanisms are reducing the hazardous constituent concentrations to the predicted levels. The applicable maximum contaminant level, background concentration, or other maximum permissible limit should be used as the compliance monitoring limit for wells at the points of exposure, in those cases where compliance monitoring is conducted at the points of exposure.		
4.4	**Groundwater Corrective-Action and Compliance Monitoring Plan**		
1.	Sufficient data are available to adequately define relevant parameters and to support models, assumptions, and boundary conditions necessary for developing detailed and site-scale models of the groundwater cleanup and the estimation of cleanup time. The data are also sufficient to assess the degree to which processes related to the groundwater cleanup that affect compliance with the technical criteria in Appendix A of 10 CFR Part 40 have been characterized. Information required for site-scale reactive transport models can include:		
a.	Site description: (i) Chronology/history of uranium milling operations (ii) List of known leaching solutions and other chemicals used in the milling process (iii) Summary of known impacts of the site activities on the hydrologic system and background water quality. Protecting Water Resources (iv) Quantity and chemical/textural characteristics of wastes generated at the mill site (v) Information pertaining to surrounding land and water uses (vi) Meteorological data for the region including precipitation and other data to support estimates of evapotranspiration		
b.	Description of hydrogeologic units: (i) Hydrostratigraphic cross sections/maps (ii) Hydrogeologic units that constitute the aquifer(s) (iii) Description of perched aquifers (areal/volumetric extent) (iv) Description of the unsaturated zone (thickness, extent) (v) Geologic characteristics (presence of layers, continuity, faults)		
c.	Data on the hydraulic and transport properties of each aquifer: (i) Hydraulic conductivity (ii) Thickness of each unit (iii) Hydraulic head contour maps (of each aquifer) (iv) Information on background horizontal and vertical hydraulic gradients and temporal variations to determine flow directions (v) Vertical hydraulic gradients and inter-aquifer flow within and between multiple aquifer systems (vi) Effective porosity (vii) Storativity or specific yield (for transient simulations) (viii) Longitudinal, vertical and horizontal transverse dispersivity (ix) Retardation factors		
c.	Data on regional recharge rates and groundwater/surface-water interactions with nearby streams, rivers, or lakes: (i) Areal recharge rates. Protecting Water Resources 4-43 (ii) Information on water fluxes to and from rivers, aquifers, and surface water bodies (iii) Data on surface water bodies (e.g., stream flow rates, dimensions of nearby surface water bodies) (iv) Concentration of hazardous constituents in surface water bodies		
d.	Characteristics of the mill tailings: (i) Identification of contaminant source terms (ii) Hydraulic properties of mill tailings material (iii) Unsaturated flow and transport parameters of mill tailings material		

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	(iv) Design and materials for mill tailings cover (v) Information on the spatial and temporal distribution of seepage fluxes from the mill tailings to the upper-most aquifer (including the historical variation in rates) (vi) Information on mill tailings draining mechanisms and drainage volume (vii) Geotechnical properties of the mill tailings and their temporal variation due to drainage of leachates (viii) Tailings volume (ix) Data on the volume, chemical and mineralogical characteristics, and concentration of mill tailings and tailings solution/leachate (x) Mass of hazardous constituents placed in the tailings pile and other disposal or storage areas		
e.	Data on geochemical conditions and water quality: (i) Concentration of hazardous constituents (ii) Background (baseline) groundwater quality (iii) Delineation of the nature and extent of the hazardous constituent plume (iv) Characterization of subsurface geochemical properties (v) Identification of attenuation mechanisms and estimation of attenuation rates. Protecting Water Resources (vi) Mass of hazardous constituents in the aquifer		
f.	Site cleanup data: (i) Information on grout curtains, slurry walls, drains, interceptor ditches, and other facilities designed to reduce the spreading of the hazardous constituent plume (if used) (ii) Information on pumping, injection, and sampling wells (coordinates, depths, completion diagrams, flow rates) (iii) Pumping/injection rates and rate history for each well (if pumping has been ongoing) (iv) Information on the presence or the absence of liners for the mill tailings pile and evaporation ponds (v) Mass of hazardous constituents recovered to date		
2.	Parameter values, assumed ranges, probability distributions, and/or bounding assumptions used in the modeling of groundwater cleanup are technically defensible and reasonably account for uncertainties and variabilities. The technical bases for each parameter value, ranges of values, or probability distributions used in the modeling of the groundwater cleanup are provided. Sensitivity analyses are provided that (i) identify aquifer flow and transport parameters that are expected to significantly affect the site model outcome; (ii) test the degree to which the performance of the groundwater cleanup may be affected if a range of parameter values must be used as input to the model due to sparsity of, or uncertainty in, available data; and (iii) test for the need for additional data. Sufficient bases are provided for parameter values, representative parameter values are taken from the literature, and the bounds and statistical distributions are provided for hydrologic and transport parameters that are important to the estimation of cleanup time and that are included in the modeling of the groundwater cleanup. Site data fitted to theoretical models compare reasonably well. American Standard for Testing and Materials D 5490 provides guidance for comparing groundwater flow model simulations to site-specific information. If there is departure of site data from the theoretical model, then an alternative model is considered. The assumptions used in modeling are consistent with site data and observations. Models used to describe local phenomena, such as the fluxes through the tailings pile, are based on consistently applied conditions.		
3.	Important design features, physical phenomena, and consistent and appropriate assumptions are identified and described sufficiently for incorporation into any modeling that supports the groundwater cleanup, including the estimate of cleanup time, and the technical bases are provided. Detailed models and site-scale models used to support the corrective action plan, or other supporting documents, and identify and describe aspects that are important to the cleanup and the estimate of cleanup time.		
4.	Alternative modeling approaches consistent with available data and current scientific understanding are investigated where necessary, and results and limitations are appropriately factored into the groundwater corrective action plan. The licensee provides sufficient evidence that relevant site features have been considered, that the models are consistent with available data and current scientific understanding, and that the effects on cleanup time have been evaluated. Specifically, the licensee adequately considers alternative modeling approaches where necessary to incorporate uncertainties in site parameters and ensure they are propagated through the modeling. Uncertainty in data		

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	interpretations is considered by analyzing reasonable conceptual models that are supported by site data, or by demonstrating through sensitivity studies that the uncertainties have little impact on the groundwater corrective action plan.		
5.	The site-scale model for groundwater cleanup provides results consistent with the output of detailed or site data. Specifically, the site model is consistent with detailed models of geological, hydrological, and geochemical processes for the site. For example, for flow and transport through the aquifer, hydraulic conductivity distributions are reasonably consistent with sensitivity studies of the range of hydraulic conductivities and varying statistical distributions, field observations, and laboratory tests, when applicable. The licensee documents how the model output is validated in relation to site characteristics. Where appropriate, in developing the site model for groundwater cleanup, the licensee considers and evaluates alternative models that are reasonably justified by the available database, with reasonable values assigned to distribution statistics to compensate for limited data availability. The licensee uses numerical and analytical modeling approaches reflecting varying degrees of complexity consistent with information obtained from site characterization. The licensee employs the upper and lower bounds of input parameter ranges to examine the robustness of the modeling.		
6.	Adequate waste management practices are defined. The disposition of effluent generated during active remediation is addressed in the corrective action plan. Appendix F to this standard review plan contains NRC staff policy for effluent disposal at licensed uranium recovery facilities for conventional mills. When retention systems such as evaporation ponds are used, design considerations from erosion protection and stability along with construction plans reviewed by a qualified engineer are included. Evaporation and retention ponds should meet the design requirements of 10 CFR Part 40, Appendix A, Criterion 5A. Ideally, the ponds should have leak detection systems capable of reliably detecting a leak from the pond into the ground water and should be located where they will not impede the timely surface reclamation of the tailings impoundment. If water is to be treated and reinjected, either into an upper aquifer or into a deep disposal well, the injection program is approved by the appropriate state or federal authority. If effluent is to be discharged to a surface- water body, licensees obtain a National Pollutant Discharge Elimination System permit for discharge to surface water. If plans to manage effluents are in place from earlier operations, they may be included in the corrective action plan by reference.		
7.	Appropriate site access control is provided by the licensee. Site access control should be provided by the licensee until site closure to protect human health and the environment from potential harm. Site access is controlled by limiting access to the site with a fence and by conducting periodic inspections of the site.		
8.	Effective corrective action and compliance monitoring programs are provided. Licensees are required, by Criterion 7 of Appendix A to 10 CFR Part 40, to implement corrective action and compliance monitoring programs. The licensee monitoring programs are adequate to evaluate the effectiveness of groundwater cleanup and control activities, and to monitor compliance with groundwater cleanup standards. The description of the monitoring program includes or references the following information:		
a.	(a) QA procedures used for collecting, handling, and analyzing groundwater samples;		
b.	(b) The number of monitor wells and their locations;		
c.	(c) A list of constituents that are sampled and the monitoring frequency for each monitored constituent;		
d.	(d) Action levels that trigger implementation of enhanced monitoring or revisions to cleanup activities (i.e., timeliness and effectiveness of the corrective action).		
9.	Design of Surface Impoundments. The reviewer shall determine that any lined impoundment built as part of the corrective-action program to contain wastes is acceptably designed, constructed, and installed. The design, installation, and operation of these surface impoundments must meet relevant guidance provided in Regulatory Guide 3.11, Section 1 (NRC 1977). Materials used to construct the liner shall be reviewed to determine that they have acceptable chemical properties and sufficient strength for the design application. The reviewer shall determine that the liner will not be overtopped. The reviewer shall determine that a proper quality control program is in place. (see source doc for more information on this)		
10.	Financial Surety is Provided. The licensee must maintain a financial surety, within the specific license, for the		

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	restoration of groundwater, with the surety sufficient to recover the anticipated cost and time frame for achieving compliance before the land is transferred to the long-term custodian. The financial surety must be sufficient to cover the cost of corrective action measures that will have to be implemented if required to restore groundwater quality to the established site-specific standards (including an ACL standard) before the site is transferred to the government for long-term custody.		
5.0	**RADIATION PROTECTION**		
5.1	**Cover Radon and Gamma Attenuation and Radioactivity Content**		
5.1.3.1	**Radon Attenuation**		
1.	The one-dimensional, steady-state gas diffusion theory for calculating radon flux and/or minimum cover thickness is used. An acceptable analytical method for determining the necessary cover thickness to reduce radon flux to acceptable limits or to determine the long-term radon flux from the proposed cover is the computer code RAECOM (NRC, 1984) and the comparable RADON code (NRC, 1989). The main difference between the two codes is that RADON does not have an optimization for cost-benefit. The staff will use the RADON code to verify the analysis. Other methods that estimate the average surface radon release from the covered tailings may be acceptable, if it can be shown that these methods produce reliable estimates of radon flux.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The RADON model was used in radon emanation analyses
2.	With the RAECOM and RADON computer codes, the radon concentration above the top layer is either set to a conservative value of zero or a measured background value is used. The precision number (the level of computational error that is acceptable) is set at 0.001.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. These settings were used in the analyses
3.	The estimates of the material parameters used in the radon flux calculations are reasonably conservative, considering the uncertainty of the values. For all site-specific parameters, supporting information describing the test method and its precision, accuracy, and applicability is provided. The basis for the parameter values and the methods in which the values are used in the analyses are adequately presented. Moisture-dependent parameter values are based on the estimated long-term moisture content of the materials at the disposal site (e.g., radon emanation coefficient and diffusion coefficient). The materials testing programs employ appropriate analytical methods and sufficient and representative samples were collected to adequately determine material property values for both cover soils and contaminated materials. In the absence of sufficient test data, conservative estimates are chosen and justified. The quality assurance program for parameter data is adequate and the data will be available for inspection. All parameter values are consistent with anticipated construction specifications and represent expected long-term conditions at the site.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Material density and long-term moisture content values in the analyses were consistent with long-term values from material placement specifications and long-term site conditions.
4.	The estimate of the tailings thickness is determined from estimates of total tailings production and the tailings areal extent, from boring logs, or changes in elevation from pre- to post-operation. Either the estimated thickness of a tailings source is used, or alternatively, the RADON code default value of 500 cm (16.4 feet) is used (NRC, 1989).	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The profiles evaluated are based on the mine spoils or the actual thickness of tailings near the edges of the repository.
5.	Dry bulk densities of the cover soils and tailings material are determined from Standard Proctor Test data (ASTM D 698) or Modified Proctor Test data (ASTM D 1557). Radon barrier materials are usually compacted to a minimum of 95 percent of the maximum dry density as determined by ASTM D 698 or to a minimum of 90 percent of the maximum dry density as determined by ASTM D 1557. Field or placement densities to be achieved following the construction specifications are used in the calculations. If the pile is stabilized in place, the in situ bulk density for the tailings is used in the analysis. Porosities are measured by mercury porosimetry or another reliable method, or the method for estimating the porosity of cover soils and tailings materials using the bulk density and specific gravity given in Regulatory Guide 3.64 (NRC, 1989) is used. If a portion of the modeled cover could be affected by freeze-thaw events, that portion is represented in the model with lower density and corresponding higher porosity values than the unaffected portion. The U.S. Army Corps of Engineers (1988) and the DOE (1988) have demonstrated that freeze-thaw cycles can increase the permeability of compacted clay by 40 to 300 times the original value. For fine-grained soils with some sand (50-percent fines), the DOE conservatively estimated that freeze-thaw cycles could lower the density by 14 percent (DOE, 1992). Also see the discussion in Section 2.5.3 of this standard review plan.	30% Design Report, Appendix G.7 (Dwyer, 2016a) PDS (MWH, 2014);	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Material density and long-term moisture content values in the analyses were consistent with long-term values from material placement specifications and long-term site conditions. These long-term values incorporate the effects of freeze-thaw and wetting-drying cycles, and are represented by densities equivalent to approximately 85 to 90 percent of ASTM D 698 and significantly drier than optimum moisture content. Data is based on the PDS.
6.	The long-term moisture content that approximates the lower moisture retention capacities of the materials or another justified value is used. Estimated values for the long-term moisture content can be compared with present in situ	30% Design Report, Appendix G.7 (Dwyer,	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Long-term moisture content values were used in the analyses,

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	values to assure that the assumed long-term value does not exceed the present field value. Borrow samples can be taken at a depth of 120 to 500 cm (3.9 to 16.4 feet), but not close to the water table, and the borrow site conditions should be correlated to conditions at the disposal site.	2016a)	based on measured moisture content at depth, measured values at wilting point, and correlations with clay content in NRC (1984).
7.	Values for Ra-226 activity (pCi/g) are measured directly from tailings samples and other large volume sources of contaminated material by radon equilibrium gamma spectroscopy (allow at least 10 days for the sealed sample to equilibrate), wet chemistry alpha spectrometry, or an equivalent procedure. If the tailings are fairly uniform in Ra-226 content and the Ra-226 and uranium (U-238) in the ore were approximately in equilibrium, the Ra-226 activity can be estimated from the average ore grade processed at the site, as discussed in Regulatory Guide 3.64 (NRC, 1989). Generally, tailings should be sampled at 60- to 90-cm [2- to 3-ft] intervals to a depth of 366 cm [12 ft], including representative sampling of slime tailings. More than one layer of contaminated material is represented in the flux model if there are significant differences in Ra-226 content with depth. Since the disposal cell performance standard deals only with radon generated by the contaminated material, it is acceptable to neglect the Ra-226 activity in the cover soils for modeling flux, provided the cover soils are obtained from materials not associated with ore formations or other radium-enriched materials. If deep {below 61 cm [2 ft]} cover layers contain elevated Ra-226 or Th-230, that material layer is represented in the flux model.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Ra-226 activity concentrations used in the analyses are based on measured values for mine spoils and tailings.
8.	The emanation coefficient has been obtained by using methods provided in Nielson et al. (1982) and properly documented, or otherwise set to the reasonably conservative (for most soils) code default value of 0.35. A value of 0.20 may be estimated for tailings based on the literature, if supported by limited site-specific measurements.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The conservative default emanation value of 0.35 was used, in the absence of measured values.
9.	The radon diffusion coefficient, D, represents the long-term properties of the materials. The D value can be determined from direct measurements. The soil should be tested at the design compaction density, with a range of moisture content values that includes the lower moisture retention capacity of the soil so that a radon breakthrough curve can be obtained (DOE, 1989). The calculation of diffusion coefficient, based on the long-term moisture saturation, and porosity, as proposed in Regulatory Guide 3.64, Section C.1.1.5 (NRC, 1989) and the optional calculation in the RADON code, is acceptable.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The calculated value of radon diffusion coefficient from NRC (1989) was used, in the absence of measured values.
10.	The estimated soil cover thickness in the reclamation design is such that the calculated average long-term radon flux is reduced to a level that meets the requirement in 10 CFR Part 40, Appendix A, Criterion 6(1).	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The flux requirement was met in the cover thickness calculations.
5.1.3.2	**Gamma Attenuation** Most radon barriers should be thick enough to reduce the gamma level of the disposal cell to background. To demonstrate compliance with this aspect of Criterion 6(1), the cover gamma attenuation is calculated based on the shielding value of the cover soil. Alternatively, the licensee commits to (1) measure the gamma level at 1 meter above the completed cover (or radon barrier) with at least one measurement per acre and (2) demonstrate that the average gamma level for the cell is comparable to the local background value.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. The planned cover thickness of 4 feet is sufficient for attenuation of gamma radiation from the mine spoils. The existing radon barrier is sufficient for attenuation of gamma radiation form the underlying tailings.
5.1.3.3	**Cover Radioactivity Content** At least the upper 61 cm [2 ft] of the disposal cell cover will contain levels of radioactivity essentially the same as surrounding soils, as demonstrated by an appropriate procedure. The data will be in the reclamation completion report if not available for the reclamation plan.	30% Design Report, Appendix G.7 (Dwyer, 2016a)	30% Design Report, Appendix G.7 (Dwyer, 2016a) recommended for pre-review audit. Borrow areas for cover materials have been evaluated for radioactivity. Analytical data in the PDS. Confirmation sampling will be performed during construction.
5.2	**Decommissioning Plan for Land and Structures**		
1.	The plan contains procedures to identify and place within the disposal cell, all soils on, and adjacent to, the processing site that are in excess of the standards in Part 40, Appendix A, Criterion 6(6), due to site activities. The plan is substantiated by the radiological characterization data and site history.	30% Design Report, Appendix T (MWH, 2016)	Specifics on the cleanup procedures for the mine site are described in Appendix T.
2.	Appropriate soil background values (different geological areas may need separate background values) for Ra226, and for U-nat, Th-230, and/or Th-232 as appropriate, have been proposed with supporting data.	30% Design Report, Appendix T (MWH, 2016)	Specifics on the cleanup procedures for the mine site are described in Appendix T.
3.	If elevated levels of uranium or thorium are expected to remain in the soil after the Ra-226 criteria have been met, the licensee has used the radium benchmark dose approach in Appendix H for developing decommissioning criteria.		N/A
4.	To ensure consistency of measurements, instrumentation and procedures used for soil background analyses and the Ra-gamma correlation are the same or very similar to those proposed to provide verification data. The instrumentation	30% Design Report, Appendix T (MWH, 2016)	Specifics on the instruments are described in Appendix T.

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	has the appropriate sensitivity and procedures are adequate to provide reliable data.		
5.	A detailed quality assurance and quality control plan for all aspects of decommissioning is provided. In addition to the basis for accepting or rejecting data, a procedure for sampling additional grids when a verification Ra-226 sample fails to meet the standard is provided.	30% Design Report, Appendix T (MWH, 2016)	Specifics on the cleanup procedures for the mine site are described in Appendix T.
6.	Final verification (status survey) procedures are adequate to demonstrate compliance with the soil and structure cleanup standards. Survey instruments are specified and will be properly calibrated and tested. The proposed verification soil sampling density takes into consideration detection limits of sample analyses, the extent of expected contamination (unaffected area would have fewer measurements than affected areas), and limits to the gamma survey for the potentially contaminated area to be sampled. The gamma guideline value to be used for verification has been appropriately chosen. Also, there is a commitment to provide the verification soil Ra-226-gamma correlation and the number of grids that had additional removal because of excessive Ra226 values, to confirm that the gamma guideline value was adequate. The plan provides adequate data collection beyond the expected excavation boundary (buffer zone).	30% Design Report, Appendix T (MWH, 2016)	Specifics on the cleanup procedures for the mine site are described in Appendix T.
7.	The plan indicates the location of records important to decommissioning, discusses protection of health and safety, and demonstrates that decommissioning will be completed as soon as practicable.	30% Design Report, Appendix T (MWH, 2016)	Appendix L Health and Safety Plan to be prepared for the 95% Design
8.	The decommissioning cost estimate is itemized in sufficient detail and a basis (source) for each cost is provided. The total cost is reasonable for the area of the site and the expected decommissioning activities.	-----	To be prepared for the 95% Design
9.	The plan adequately describes the non-radiological hazards of decommissioning to human health and the environment as required by 10 CFR Part 40, Appendix A, Criterion 6(7). The licensee must maintain a financial surety, within the specific license, for the surface reclamation and decommissioning, with the surety sufficient to recover the anticipated cost and time frame for achieving compliance, before the land is transferred to the long-term custodian. Guidance on establishing financial surety is presented in NRC (1988, 1997b). Appendix C to this standard review plan provides an outline of the cost elements appropriate for establishing surety amounts for conventional uranium mills. Any staff assessment of surety amounts is reasonably consistent with the applicant's.	-----	Updated surety to be provided to NRC with the radioactive materials license amendment application.
5.3	**Radiation Safety Controls and Monitoring**		
1.	The RP identifies the radiation safety concerns that are unique to reclamation and decommissioning activities. These concerns include characterization of radiation hazards associated with inhalation of resuspended tailings material or yellowcake, gamma exposure from working close to tailings, and inhalation of radon gas and its progeny (decay products) emanating from tailings material.	95% Design Report, Appendices L, Q, R (MWH, 2016)	Appendices L (HASP) & R (Release Contingency and Prevention Plan) to be prepared for the 95% Design
2.	The RP describes any changes to an existing radiation safety or monitoring program that would be necessary to ensure worker or public safety during reclamation or decommissioning activities.	95% Design Report, Appendices L, Q (MWH, 2016)	Appendix L (HASP) to be prepared for the 95% Design
3.	Regular wetting and/or phased stabilization efforts are used for control of windblown tailings material or yellowcake dust.	95% Design Report Appendices Q, J (MWH, 2016)	Plans in place for control of dust from mine waste during removals.
4.	Any proposed changes to established monitoring programs will meet acceptable criteria of the applicable parts of Regulatory Guide 8.22, ".Bioassay at Uranium mills" (NRC, 1988) and Regulatory Guide 8.9, Revision 1, "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program" (NRC, 1993), or an acceptable justification is provided for selecting an alternative approach.	95% Design Report, Appendix L (MWH, 2016)	Appendix L (HASP) to be prepared for the 95% Design. Alternative approach may be proposed due to relatively low radioactivity.
5.	The existing or proposed workplace airborne radiological monitoring program is consistent with applicable parts of Regulatory Guide 8.25, "Air Sampling in the Workplace" (NRC, 1992) and Regulatory Guide 8.30, "Health Physics Surveys in Uranium Mills" (NRC, 1983), or an acceptable justification is provided for selecting an alternate approach. The monitoring program is sufficient to provide adequate protection of workers from radon gas exposures to maintain compliance with the inhalation limits in Part 20. If sampling locations will be revised, the RP contains one or more maps of the site that indicate the location of samplers for airborne radiation and provides the criteria for determining the revised locations.	95% Design Report, Appendix L, Q (MWH, 2016)	Appendix L (HASP) to be prepared for the 95% Design.
6.	The existing or proposed contamination control program is consistent with the guidance on conducting surveys for	95% Design Report,	Appendix L (HASP) to be prepared for the 95% Design

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	contamination of skin and of personal clothing presented in Regulatory Guide 8.30 (NRC, 1983).	Appendix L (MWH, 2016)	
7.	The existing or proposed environmental radiological monitoring program is consistent with applicable parts of Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills" (NRC, 1980), or an acceptable justification is provided for selecting an alternative approach. The licensee has adequately considered site-specific aspects of climate and topography in determining locations of offsite airborne monitoring stations and environmental sampling areas so that detection of maximum offsite concentrations of windblown tailings material and contamination from any other significant transport pathways applicable to the site is ensued.	95% Design Report, Appendix L (MWH, 2016)	Appendix L (HASP) to be prepared for the 95% Design
8.	The proposed radiation protection program contains plans for documentation of exposures to all monitored workers and contractors and for availability of exposure records in a single location for inspection. The program provides for record-keeping that meets the requirements of 10 CFR 20.2102; at least annual review of the program content and implementation; and implementation of the ALARA requirements of 20.1101(d).	30% Design Report, Appendix L (MWH, 2016)	Appendix L (HSAP) to be prepared for the 95% Design
9.	The applicant commits to verifying the radon barrier effectiveness and to maintaining adequate records of this verification as required by 10 CFR Part 40, Appendix A, Criterion 6(4).	30% Design Report, Appendices G, Q (MWH, 2016)	Radon testing method described in Appendix G

DOCUMENT REFERERNCES

Geohydrologic Report (Canonie, 1987);
Approved Tailings Reclamation Plan, Canonie, 1991.
Annual Review Report – 2016 Groundwater Corrective Action, Church Rock Site, Church Rock, New Mexico (Chester Engineers, 2016)
Dwyer Engineering (Dwyer), 2016a. 30% Design Report, Appendix G.7. Cover System Design Report.
Dwyer Engineering (Dwyer), 2016b. Consolidation and Groundwater Evaluation Report. Northeast Church Rock Site Closure. 30% Draft. July 29.
PDS Report. MWH, 2014. Pre-Design Studies Report
30% Design Report Volume 1, Appendices A-W MWH, 2016
30% Design Report Volume 2, Design Drawings, MWH, 2016
Appendix I: Mill Site Stormwater Controls (Jetty design only), 60% Design Interim Submittal, MWH, 2017 (in progress)