# 4.0 PROTECTING WATER RESOURCES

The protection of water resources is a process that encompasses two distinct strategies. The first strategy is to prevent the spread of contaminants from disposal and processing sites into ground water or surface water. This strategy requires the staff to ensure that operations and decommissioning are conducted in such a manner as to minimize threats to ground water.

The second strategy is to mitigate the threat to public health and the environment from contaminants that have already been mobilized—particularly through ground water pathways—before initiation of decommissioning activities. This strategy applies only to those sites where ground-water contamination already exists and requires staff to review existing or proposed ground-water restoration activities to ensure that they will result in compliance with regulatory requirements. The NRC exercises exclusive, pre-emptive jurisdiction over all radiological and non-radiological ground-water contaminants from uranium mill tailings facilities, in accordance with Commission direction in Staff Requirements Memorandum SECY 099-277 (NRC, 2000).

Use of this chapter should be tailored to the specific situation and phase of operation at each site. The reviewer will select and emphasize the various aspects of the areas covered by this standard review plan chapter. The judgment on the areas to be given attention during the review is to be based on the specific licensee submittal being reviewed, an inspection of the material presented, and prior knowledge of the site and its operating history.

This chapter presents a standard approach for reviewing, evaluating, and documenting the evaluation findings for issues pertaining to water resource protection during the various phases of the license termination process at licensed uranium mill sites. Review of information concerning the protection of water resources shall be coordinated with the evaluation of the site stratigraphy, structural and tectonic information, and surface water and erosion protection information as described in standard review plan Chapters 1.0 and 3.0, respectively. Review procedures in this chapter pertain to the following four types of documents that are submitted for review by the staff:

(1) Licensees submit reclamation plans to obtain approval of surface reclamation and decontamination work, including stabilization of mill tailings, and elimination (or isolation) of present or potential contaminant sources.

(2) Licensees submit corrective action plans during operations or during the license termination process to obtain approval of ground-water restoration strategies at sites where ground-water contamination has been detected.

(3) Licensees submit ground-water restoration completion reports to confirm that the ground-water quality will remain stable after ground-water restoration strategies have been implemented and that ground-water protection standards have been correctly established.

(4) Long-term custodians submit long-term surveillance plans to describe the ground-water monitoring activities that will be implemented by the custodian.

The ultimate objective of the review is to determine if the proposed reclamation plans and corrective action plans will result in long-term compliance with 10 CFR Part 40, Appendix A. As stated in 10 CFR Part 40, Criterion 5, "Criteria 5A-5D and new Criterion 13 incorporate the basic ground-water protection standards imposed by the Environmental Protection Agency in 40 CFR Part 192, Subparts D and E (48 FR 45926; October 7, 1983), which apply during operations and prior to the end of closure. Ground-water monitoring to comply with these standards is required by Criterion 7A." To meet this regulatory objective, the following issues must be evaluated:

(1) Site characterization.

(2) Ground-water protection standards.

(3) Hazard and as low as is reasonably achievable assessment for alternate concentration limits, as defined by 10 CFR Part 40, Appendix A, Criteria 5B(5) and 5B(6).

(4) Ground-water corrective action and monitoring plans.

Accordingly, this chapter contains a section for each of these areas. Discussions in this chapter incorporate acceptable practices from all previous staff technical positions and guidance documents pertaining to uranium mill tailings reclamation. This standard review plan supercedes those documents. The NRC exercises exclusive jurisdiction over all radiological and non-radiological ground-water contaminants from uranium mill tailings facilities.

## 4.1 Site Characterization

### 4.1.1 Areas of Review

The staff should review the characterization information, given the circumstances and life cycle of a particular site, and the nature of the document under review (reclamation plan, corrective-action plan). The staff should also evaluate regional and site-specific hydrologic information related to both the former processing site and the proposed disposal site if they are different. The hydrologic information should include both surface-water and ground-water systems, along with any interrelations among those systems. Complete site characterization should include or reference the following:

(1) Site background data that include descriptions of:

    (a) The site history of mining and/or milling operations>

    (b) Surrounding land and water uses>

    (c) Site meteorological data.

(2) Ground-water and surface-water hydrology data, including:

   (a) Descriptions of hydrogeology and ground-water conditions.

   (b) Estimation of hydraulic and transport properties for each hydrogeologic unit.

   (c) Descriptions of surface-water hydrology and estimations of ground-water and surface-water interactions.

   (d) Assessment of potential for flooding and erosion.

(3) Information concerning geochemical conditions and water quality, including:

   (a) Identification of constituents of concern.

   (b) Determination of background ground-water quality.

   (c) Confirmation of proper statistical analysis.

   (d) Delineation of the nature and extent of contamination.

   (e) Identification of contaminant source terms.

   (f) Characterization of subsurface geochemical properties.

   (g) Identification of attenuation mechanisms and estimation of attenuation rates.

(4) Human health and environmental risk evaluations, including:

   (a) Radiological risks.

   (b) Non-radiological risks.

   (c) A summary of risk evaluations from the site environmental report.

### 4.1.2 Review Procedures

The level of effort necessary to adequately characterize a particular site depends on site-specific circumstances. For example, if a particular site has no ground-water contamination and tailings are disposed off site, there will be very little need for detailed site characterization in support of water resources protection. Conversely, at a site with an existing source of ground-water contamination, the site characterization must be sufficient to support selection of cleanup strategies and to determine the level of risk to human health and the environment.

There is not a single acceptable approach to conducting a site characterization, because the appropriate level of site characterization is specific to the methods of tailings disposal and ground-water corrective action selected for a particular site. As such, the reviewer should:

(1) Thoroughly evaluate the characterization information using the acceptance criteria in standard review plan Section 4.1.3, but reserve final judgment until all sections of the application have been reviewed.

(2) Assess whether the level of detail and technical merit of the characterization are sufficient to support the proposals, assumptions, and assertions in the application that are used to demonstrate regulatory compliance.

### 4.1.3 Acceptance Criteria

Knowledge of the site is needed to evaluate the existing and potential contamination. This characterization information shall include a description of activities and physical properties that may affect water resources at the mill site. The site characterization will be acceptable if it meets the following criteria:

(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 the 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 ground-water/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 the 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 ground-water or surface-water contamination.

(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).

Human water consumption is not the only water use that must be considered in the review. Any use that may bring someone into contact with the contaminated water must be considered when evaluating health hazards. For example, non-potable, radon-contaminated water piped to a public lavatory could pose a substantial health hazard.

(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.

Monthly averages are an acceptable means of presenting general meteorological conditions; however, the reviewer shall ensure that extreme weather conditions are adequately described.

(2) The ground-water and surface-water hydrology is described adequately to support modeling predictions of likely contaminant migration paths; selection of monitor well locations; and, when ground-water 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 ground-water pathways, including:

(i) Hydrostratigraphic 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 of such quality 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 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 10 CFR Part 40, Appendix A, Criterion 11.

(iv) Unsaturated zones, through which contaminants may be conveyed to the water-bearing units, are described. This 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 ground-water 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, ground-water flow direction, and proximity to offsite ground-water users. These maps are based on static water level observations at onsite and regional wells. Several measurements are taken at each observation well (American Society for Testing and Materials 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 ground water. 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 are only rigorously valid for horizontal flow in aquifers.

(b) Estimations of hydraulic and transport properties of the underlying aquifer

Hydrogeologic parameters used to support the choice of a ground-water 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 10 CFR 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 American Society for Testing and Materials standards for the measurement of geotechnical properties and for aquifer hydraulic tests are considered acceptable by the NRC. These American Society for Testing and Materials 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 transport modeling with those values cited in survey studies such as Gelhar, et al. (1992), and verify that they represent conservative estimates for the site.

(c) Estimation of ground-water/surface-water interactions at sites with nearby streams, rivers, or lakes.

The locations of surface-water bodies that are connected to the site ground-water flow system are identified. Surface-water elevations shall be used to help describe the site ground-water flow system if a stream or other surface-water body discharges into or drains the site ground-water 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.

Any chemical or radiological constituent that is reasonably expected to be in or derived from the tailings is a potential constituent of concern. 10 CFR Part 40, Appendix A, Criterion 13 provides a non-inclusive list of constituents of concern which standards must be set and complied with. Criterion 13 also provides flexibility to add constituents on a case-by-case basis.

Table 4.1.3-1 presents a list of constituents commonly associated with uranium mill tailings.[1] This list is based on a chemical survey performed by NRC staff at 17 licensed mill tailings sites.

Most of the constituents in 10 CFR Part 40, Appendix A, Criterion 13 are organic compounds that are not normally associated with uranium milling processes. The expected presence of organic compounds is assessed from knowledge of the chemicals used during the milling process or other materials that may have been disposed of in the tailings. If there is no record of organic compounds used in the process, screening tests for volatile and semi-volatile organic compounds are performed to confirm the absence of organic compounds in the tailings and ground water.

[1]Smith, R.D. “Memorandum (February 9) Sampling of Uranium Mill Tailings Impoundments for Hazardous Constituents.” 1987.

| Table 4.1.3-1. Common Uranium Mill Chemical Constituents | |
|---|---|
| **Inorganic Constituents** | **Organic Constituents** |
| Arsenic | Carbon Disulfide |
| Barium | Chloroform |
| Beryllium | Diethyl Phthalate |
| Cadmium | 2—Butanone |
| Chromium | 1,2—Dichloroethane |
| Cyanide | Naphthalene |
| Lead | |
| Mercury | |
| Molybdenum | |
| Net Gross Alpha* | |
| Nickel | |
| Radium-226 and -228 | |
| Selenium | |
| Silver | |
| Thorium-230 | |
| Uranium | |
| * Excluding Radon, Radium, and Uranium | |

Staff may require the addition of constituents associated with the milling process that are not specifically listed in 10 CFR Part 40, Appendix A, Criterion 13, to ground-water monitoring programs. These constituents may be added on a case-by-case basis, if they are capable of posing a substantial present or potential hazard to human health or the environment. If the staff requires a constituent to be added to the list in Criterion 13, the NRC must establish an associated compliance limit for each added constituent at a level that will be protective of human health and the environment.

Some constituents which typically do not present a hazard to human heath and the environment may pose such a hazard to some specific human or environmental populations, under site-specific circumstances. As an example, three constituents associated with uranium mill tailings may be candidates for site-specific evaluations during licensing reviews and potential NRC regulation on a case-by-case basis, under specific circumstances. Illustrative constituents, circumstances, and potential harm are tabulated in Table 4.1.3-2.

The above examples are not all inclusive. The reviewer should examine these and other constituents that produce similar potential harm under specific circumstances. Non-radiological constituents that degrade the water quality and produce and impact on the designated water use beyond the proposed long-term

**Table 4.1.3-2. Non-Radiological Ground-Water Constituents That May Produce Harm**

| Constituent | Exposure Circumstance | Potential Harm |
|---|---|---|
| Sodium | Drinking water pathway, human exposure | Some segments of the human population with elevated blood pressure may be sensitive to sodium intake above a recommended limit. The EPA added sodium to its Drinking Water Contaminant Candidate List for further evaluation. |
| Sulfate | Drinking water pathway, human exposure | Some segments of the human population are sensitive to elevated sulfate in drinking water, which can produce osmotic diarrhea. The EPA added sulfate to its Drinking Water Contaminant Candidate List for further evaluation. |
| Ammonia, Ammonium ion | Surface water pathway, aquatic organism exposure | Various aquatic species are sensitive to ammonia levels as low as 0.38 mg/L. These levels are far lower than exposure limits that would produce an adverse impact to human populations. |

The above examples are not all-inclusive.  The reviewer should examine these and other constituents that produce similar potential harm under specific circumstances.  Non-radiological constituents that degrade the water quality and produce and impact on the designated water use beyond the proposed long-term care boundary must also be evaluated to determine whether they should be included in the license.  The reviewer should consult with the appropriate non-Agreement State agency on the designated water use for the ground-water resource an any numerical limits the State has determined to be a hazard.

Close coordination with the State may be needed to determine the need for including such constituents in the license, along with evaluating the benefits and costs of potential mitigative measures.

In identifying additional constituents, the staff should ensure that any additions are made based on a sound technical and regulatory basis.  Examples of sound technical bases are the following:

(1) NRC and the U.S. Environmental Protection Agency agree to use one federal contact with a licensee, which is NRC.  This approach requires NRC to include some constituents in its licenses, that are not normally licensed by the NRC.

(2) Trends in ground-water contamination show that after several years of decreases in the level of contamination, the level of contamination is beginning to rise again.

(3 )Surrogate parameters that cover a family of constituents show an increase in concentration in ground water.  Therefore, the staff may require licensees to monitor for all constituents found in that family.

(4) Some constituents used in the milling process, but not listed in Criterion 13, may pose a hazard to some specific human and environmentally sensitive populations, under site-specific circumstances, including degradation of a designated water use beyond the proposed long-term care boundary.

Even if the criteria for identifying a constituent of concern are met, NRC may still decide to exclude certain constituents on a site-specific basis if it can be shown that the constituents are not capable of posing a substantial present or potential hazard to human health or the environment.  In considering such exclusions, the reviewer must consider potential adverse effects on ground-water quality and hydraulically connected surface-water quality.  NRC may decide to exclude a constituent if the dissolved concentration of the constituent in the tailing fluids is equal to or less than the concentration of that constituent in the background water quality.  Alternately, NRC may decide to exclude a constituent if the dissolved concentration of the constituent in the tailing fluids is equal to or less than the maximum value for ground-water protection listed in 10 CFR Part 40, Appendix A, Table 5C.

New constituents of concern should be added in a timely manner. This is done either at the time the corrective action plan is accepted for review, or at some time during the lifetime of the corrective action plan. New constituents will not be required at the time of the license termination monitoring submittal, unless the one-time, pre-termination ground-water sampling identifies constituents at concentrations that pose a hazard to human health and the environment. The reviewer should consult Appendix E (Section E3.3.2(1)) for those sites nearing license termination, regarding the one-time, pre-termination ground-water sampling and analysis.

(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.

Water quality data available from studies conducted in conjunction with initial licensing for operation of the facility are used to establish the background. If constituents of concern identified by NRC were not sampled in the original background monitoring program, the licensee should have conducted additional sampling to establish background levels. When adequate site-specific baseline data cannot be obtained for identified constituents of concern, samples of adjacent, and up-gradient, uncontaminated water are taken as proxies to onsite baseline samples.

To determine acceptability of the determination of background water quality, the following information is provided:

(i) Maps are of sufficient detail and legibility to show the background monitoring locations.

(ii) Descriptions of sampling methods, monitoring devices, and quality assurance practices are provided. Examples of acceptable methods are those that are consistent with American Society for Testing and Materials 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 pre-operational monitoring program has been in place for 1 year, consistent with the requirements of 10 CFR 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 ground-water compliance provisions of 10 CFR Part 40, Appendix A, will have one full year of monthly baseline data from a pre-operational monitoring program.

Alternatively, background water quality may already be defined by a condition in the license. If this is the case, background limits for a ground-water protection standard have already been identified, and the reviewer should rely on those along with any constituents and standards listed in Criterion 5(c) as the regulatory limits applicable to this site.

(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 ground-water protection standards for compliance monitoring; (iii) determining the extent of ground-water contamination; and (iv) establishing the ground-water 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:

(i) The constituent is reasonably expected to be in or derived from the byproduct material in the disposal area.

(ii) The constituent has been detected in the ground water in the uppermost aquifer.

(iii) The constituent is listed in Part 40, Appendix A, Criterion 13.[2]

For each hazardous constituent, the licensee determines the extent of contamination in ground water at the site. Ground-water contamination at uranium mill sites is usually limited to the uppermost aquifer. Maps showing the locations of sampling wells should be included, along with a discussion of sampling practices. The most useful way to present this information is on a map showing concentration contours for each hazardous constituent and water surface elevation contours. In this manner, the reviewer readily examines the size, shape, source, and direction of movement.

[2]Including a constituent which may pose a hazard to some specific human or environmentally sensitive populations, under site-specific circumstances, and can, therefore, be added to the list in Criterion 13 on a case-by-case basis.

The extent of contamination is delineated in three dimensions. This typically involves drilling a number of characterization wells and determining whether the water quality in each of these wells meets background water quality or whether the ground water is contaminated. It may not be necessary to sample all hazardous constituents to delineate the extent of contamination. Two or three indicator parameters (e.g., total dissolved solids, and chloride) might be selected. These indicators should be conservative—meaning that they are neither reactive, nor are they easily sorbed to soil—so that they provide a good indication of the maximum extent of contamination.

The transition from contaminated to uncontaminated ground water is often gradual. Thus, difficulty arises in determining where the contaminated water ends and the background water begins. The background sample data provide the easiest means for comparison of characterization well measurements to background measurements for the indicator parameters. Statistical methods described in American Society for Testing and Materials Standard D 6312 are suitable for determining whether contaminant concentrations exceed background levels.

Complications in delineating the extent of contamination arise at sites that have zones of differing water quality, or where onsite background water quality is not properly determined before discovery of ground-water contamination. Where zones of differing water quality are present, the reviewer shall verify that characterization wells are compared with the background sample from the appropriate water quality zone. Where onsite background water quality has not been properly determined, then upgradient or offsite samples are obtained.

The reviewer shall verify that the licensee has presented the following information to support determining the extent of contamination.

(i) A map or maps showing the distribution of surface wastes and contaminated materials at and near the site.

(ii) A map or maps showing the approximate shape and extent of ground-water contamination (e.g., concentration contour maps for indicator parameters in ground water).

(iii) Identification of any offsite sources of water contamination or other factors that may have a bearing on observed water quality.

(e) Properly estimate the source term.

Existing sources of ground-water 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 ground-water 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.

(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, 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 ground-water 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 move away from the source. Mixing is the result of uncontaminated water being added to the ground-water 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 through use of 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 $K_D$. Batch or column equilibria experiments, using representative leachate and soil samples, are performed to support estimations of $K_D$ for each hazardous constituent.

(iii) Attenuation from geochemical or biochemical equilibrium reactions is estimated by use of acceptable modeling software packages such as MINTEQA2 (Allison, et al., 1991) and PHREEQE (Parkhurst, et al., 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). More recently developed reactive transport models [e.g., PHREEQC Version 2 (Parkhurst and Appello, 1999)] are also acceptable for constructing a geochemical model for the site. 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 ground-water 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.

### 4.1.4 Evaluation Findings

If the staff review, as described in standard review plan Section 4.1, results in the acceptance of the site characterization, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the site characterization at the _____________ uranium mill facility. This review included an evaluation using the review procedures in Section 4.1.2 and the acceptance criteria outlined in Section 4.1.3 of this standard review plan.

The licensee has presented an acceptable history of the site, including (1) a description of leaching solutions and other chemicals used in the process and their relative quantities; (2) a description of (a) the wastes generated at the site during the milling process, and (b) the waste handling facilities; (3) a summary of the known impact of site activities on the hydrologic system and water quality; and (4) a description of activities unrelated to uranium milling that may have altered the hydrologic system.

The licensee has presented acceptable information pertaining to the surrounding land and water use including (1) an overview of water uses, quantity available, and potential uses to which the water is suited; (2) definitions of the class-of-use category of each water source; (3) identification of potential receptors of ground-water or surface-water contamination; (4) assessment of variations in dilution effects of stream flow on contaminants; and (5) assessments of the effects of meteorological conditions on erosion, infiltration, and water-table elevation.

The licensee has presented acceptable meteorologic data, including (1) wind speed and direction, (2) rainfall, (3) evaporation data (4) temperature, and (5) humidity, to allow an evaluation of potential impacts of the meteorologic conditions on disposal cell performance.

The ground-water and surface-water hydrology is adequately described, including (1) geometry, lateral extent, and thickness of potentially affected aquifers and confining units; (2) a determination of which aquifers constitute the uppermost aquifer where regulatory compliance will be evaluated; (3) descriptions of the unsaturated units that convey hazardous constituents to the water-bearing units; (4) maps of acceptable detail showing the relative dimensions and locations of hydrogeologic units that have been impacted by milling activities; (5) information on geologic characteristics that may affect ground-water flow beneath the site; and (6) hydraulic head contour maps of both local and regional scale for the uppermost aquifer beneath the site.

The estimation of hydraulic and transport properties is acceptable and includes (1) hydraulic conductivity and storage coefficients determined by conducting aquifer pump tests on several wells; (2) determination of hydraulic gradients using hydraulic head contour maps; (3) calculations of storage coefficients, as applicable; and (4) longitudinal and transverse dispersivities, as appropriate. The evaluation of ground-water/surface-water interactions with nearby streams, rivers, or lakes is acceptable.

Geochemical conditions and water quality are adequately analyzed, including identification of constituents of concern that are reasonably expected to be derived from the tailings. Each constituent of concern is found in 10 CFR Part 40, Appendix A, Table 5C or 10 CFR Part 40,

Appendix A, Criterion 13, or has been included as a specific condition in the license. The licensee has made an acceptable determination of baseline water quality, including (1) maps of appropriate scale and legibility; (2) descriptions of sampling methods, monitoring devices, and quality assurance practices; (3) where applicable, delineation of zones of differing water quality and their possible origin; and (4) a table of summary statistics for each zone of differing quality. The applicant has presented an acceptable delineation of the extent of contamination supported by appropriate samples, maps of surface wastes and contaminated materials, maps of the approximate shape and extent of ground-water contamination, and identification of any off-site sources of water contamination. The description of the source term is acceptable and includes not only mill tailings constituents but those contaminants that might mobilize by contact with tailings leachate.

The characterization of the subsurface geochemical properties is acceptable. Attenuation mechanisms have been described, including the technical bases for determining that contamination will be reduced by dilution, sorption on the soil matrix, or geochemical or biochemical reactions. The licensee has presented direct measurements in support of attenuation of contaminants where the source has been eliminated by surface reclamation.

On the basis of the information presented in the application and the detailed review conducted of the site characterization for the _______________ uranium mill facility, the NRC staff concludes that the information is acceptable and is in compliance with the following criteria in 10 CFR Part 40, Appendix A: Criterion 5B, which requires the NRC to establish a list of hazardous constituents, concentration limits, a point of compliance, and a compliance period; Criterion 5C, which provides a table of concentration limits for certain constituents when they are present in ground water above background concentrations; Criterion 5E, which requires licensees conducting ground-water protection programs to consider the use of bottom liners, recycle of solutions and conservation of water, dewatering of tailings, and neutralization to immobilize hazardous constituents; Criterion 5F, which requires that, where ground-water impacts caused by seepage are occurring at an existing site, action be taken to alleviate the conditions that lead to seepage and restore ground-water quality. Technical specifications for the seepage control system must be established, and a quality assurance, testing and inspection program must be established to insure the specifications are met. Criterion 5G, which requires that licensees/operators perform site characterization in support of a tailings disposal system proposal; Criterion 5H, which requires steps be taken during stockpiling of ore to minimize penetration of radionuclides into underlying soils; Criterion 7 which requires a year of monitoring prior to mill operations; Criterion 7A, which requires three types of monitoring systems: detection, compliance, and corrective action; and Criterion 13, which provides a list of hazardous constituents that must be considered when establishing the list of hazardous constituents in ground water at any site.

### 4.1.5 References

Allison, J.D., D.S. Brown, and K.J. Novo-Gradac. "MINTEQA2/PRODEFA2, A Geochemical Assessment Model for Environmental Systems: Version 3.0 User's Manual." EPA Publication EPA/600/3–91/021. Washington, DC: EPA. 1991.

American Society for Testing and Materials Standards:

D 4044, "Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers."

D 4050, "Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems."

D 4104, "Standard Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)."

D 4105, "Standard Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method."

D 4106, "Standard Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method."

D 4448, "Standard Guide for Sampling Ground-water Monitoring Wells."

D 4630, "Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by *In Situ* Measurements Using the Constant Head Injection Test."

D 4750, "Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)."

D 4840, "Standard Guide for Sampling Chain-of-Custody Procedures."

D 5092, "Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers."

D 5269, "Standard Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method."

D 5270-96, "Standard Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers."

D 5472, "Standard Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well."

D 5473, "Standard Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer."

D 5521, "Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers."

D 5737, "Standard Guide for Methods for Measuring Well Discharge."

D 5785, "Standard Test Method for (Analytical Procedure for) Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)."

D 5786, "Standard Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer System."

D 5787, "Standard Practice for Monitoring Well Protection."

D 5850, "Standard Test Method for (Analytical Procedure for) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells."

D 5855, "Standard Test Method for (Analytical Procedure for) Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well."

D 5881, "Standard Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)."

D 5912, "Standard Test Method for (Analytical Procedure for) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)."

D 5978, "Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells."

D 6312, "Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs."

Gelhar, L.W., C. Welty, and K.R. Rehfeldt. "A Critical Review of Data on Field-scale Dispersion in Aquifers." *Water Resources Research.* Vol. 28, No. 7. 1992.

NRC. "Concurrent Jurisdiction of Non-Radiological Hazards of Uranium Mill Tailings." Staff Requirements Memorandum to SECY–99–0277. Washington DC: NRC; Office of the Executive Director of Operations. August 11, 2000.

———. NUREG–1748, “Environmental Review Guidance for Licensing Actions Associated with NMSS Programs.” Washington, DC: NRC, Office of Nuclear Material Safety and Safeguards. 2001

Parkhurst, D.L. and A.A.J. Appello. “User’s Guide to PHREEQC (Version 2)—A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Modeling.” 99-4259. Washington, DC: U.S. Geological Survey. 1999.

Parkhurst, D.L., Thorstensen, and L.N. Plummer. “PHREEQEM-A Computer Program for Geochemical Calculations.” U.S. Geological Survey Water Resources Investigation 80-96. 1980.

## 4.2 Ground-Water Protection Standards

### 4.2.1 Areas of Review

Ground-water protection standards are established for each hazardous constituent. 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.

(3) The constituent is listed in 10 CFR Part 40, Appendix A, Criterion 13.

Even when constituents meet the three aforementioned tests, the Commission may exclude a detected constituent from the set of hazardous constituents, on a site-specific basis, if it finds that the constituent is not capable of posing a substantial present or potential hazard to human health or the environment. In deciding whether to exclude constituents, the considerations identified in 10 CFR Part 40, Appendix A, Criterion 5B(3), must be considered. In addition, as required by 10 CFR Part 40, Appendix A, Criterion 5B(4), any underground sources of drinking water and aquifers exempted by the EPA will be considered. Relevant EPA guidance is presented in 40 CFR 144.7, 144.3, and 146.4. The staff should review the technical basis the licensee has presented for the following elements of acceptable ground-water protection standards:

(1) The list of hazardous constituents.

(2) A description of the point of compliance.

(3) Ground-water protection standards for hazardous constituents that may be either:

(a) Commission-approved background concentrations.

(b) Maximum concentration limits.

(c) Alternate concentration limits.

The staff should also review additional ground-water protection standards that contain provisions for ground-water protection dealing with the design of surface impoundments and tailings disposal cells. Evaluation of disposal system performance is addressed in standard review plan Section 4.3.3.

### 4.2.2 Review Procedures

The reviewer should examine the ground-water protection standards to verify that they have been defined consistent with the acceptance criteria in standard review plan Section 4.3.2. Specifically, the reviewer should reference the existing license or:

(1) Verify that the licensee has identified all constituents of concern that are present in the tailings leachate.

(2) Verify that the point of compliance has been properly delineated.

(3) Evaluate whether the proposed concentration limits for each ground-water protection standard are within a range that is reasonably expected to represent background concentrations; or, if any alternate concentration limits are proposed, verify that the appropriate evaluations have been presented in accordance with Criterion 5(B)(6) of 10 CFR Part 40, Appendix A.

### 4.2.3 Acceptance Criteria

Ground-water protection standards establish a concentration limit for each hazardous constituent at the point of compliance. The development of ground-water protection standards will be acceptable if it meets the following criteria:

(1) Hazardous constituents are identified using the definition given in 10 CFR Part 40, Appendix A, Criterion 5(B).

(2) A point of compliance is established in accordance with 10 CFR Part 40, Appendix A, Criterion 5B(1).

The point of compliance is the location at which the ground water is monitored to determine compliance with the ground-water protection standards. The objective in selecting the point of compliance is to provide the earliest practicable warning that the impoundment is releasing hazardous constituents to the ground water. The point of compliance must be selected to provide prompt indication of ground-water contamination on the hydraulically downgradient edge of the disposal area. The point of compliance 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 point of compliance includes identification of point of compliance 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. Those limits may be:

(a) Commission-Approved Background Concentrations.

10 CFR Part 40, Appendix A, requires that the Commission-approved background concentration be the concentration limit, except for constituents listed in Table 5C of 10 CFR Part 40, Appendix A, which, if present in excess of background, are subject to the respective maximum concentration limits listed in Table 5C.

Proper statistical methods, such as those discussed in American Society for Testing and Materials Standard D 6312, 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) Maximum Concnetration Limits

The respective values given in the table in paragraph 5C of 10 CFR Part 40, Appendix A, must not exceed if the constituent is listed in the table and if the background level of the constituent is below the value listed. Note that the U.S. EPA has revised some of these limits under the Safe Drinking Water Act, therefore, for risk assessments used for an alternate concentration limit proposal, where a drinking water exposure pathway is estimated, the reviewer should refer to the most recent Safe Drinking Water Act maximum concentration limits.

(c) Alternate Concentration Limits

Alternate concentration limits 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 alternate concentration limits are not exceeded and (ii) the alternate concentration limits are as low as is reasonably achievable, 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. Standard review plan Sections 4.3.3 and 4.4.3 contain acceptance criteria for determining potential hazards, and for "as low as is reasonably achievable" demonstrations, respectively.

When an applicant proposes alternate concentration limits, the reviewer should recognize that additional site characterization may be necessary to demonstrate the potential risk to human health and the environment is acceptable. Typically, long-term ground-water monitoring will be required to assure that human health and the environment are protected.

### 4.2.4 Evaluation Findings

If the staff review, as described in standard review plan Section 4.2, results in the acceptance of the site ground-water protection standards, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the ground-water protection standards at the _______________ uranium mill facility. This review included an evaluation using the review procedures in Section 4.2.2 and the acceptance criteria outlined in Section 4.2.3 of this standard review plan.

The licensee has acceptably identified the hazardous constituents and has established acceptable concentration limits and cleanup standards. Established background levels are acceptable. Acceptable statistical methods have been used to establish the concentration limits. If alternate concentration limits have been requested, the licensee has acceptably supported the request with appropriate data and calculations. The licensee has established an acceptable point of compliance at the edge of the tailings impoundment on the downgradient direction of hydraulic flow.

On the basis of the information presented in the application and the detailed review conducted of the ground-water protection standards for the _______________ uranium milling facility, the NRC staff concludes that the information is acceptable and is in compliance with the following criteria in 10 CFR Part 40, Appendix A: Criterion 5B, which requires the NRC to establish a list of hazardous constituents, concentration limits, a point of compliance, and a compliance period and, which allows use of alternate concentration limits under certain conditions; Criterion 5C, which provides a table of secondary concentration limits for certain constituents when they are present in ground water above background concentrations; Criterion 7A, which requires three types of monitoring systems: detection, compliance, and corrective action; and Criterion 13, which provides a list of hazardous constituents that must be considered when establishing the list of hazardous constituents in ground water at any site.

### 4.2.5 References

American Society for Testing and Materials Standards

D 6312, "Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs."

Haan, C.T. *Statistical Methods in Hydrology*. Iowa State University Press. 1977.

Hirsch, R.M., D.R. Helsel, T.A. Cohn, and E.J. Gilroy. *Statistical Analysis of Hydrologic Data, Handbook of Hydrology.* D.R. Maidment, ed. New York, New York: McGraw-Hill, Inc. 1992.

## 4.3 Hazard Assessment, Exposure Assessment, Corrective Action Assessment, and Compliance Monitoring for Alternate Concentration Limits

### 4.3.1 Areas of Review

The staff shall review the following elements of an alternate concentration limit application to determine regulatory compliance with 10 CFR Part 40, Appendix A, Criterion 5B(6):

(1) Hazardous constituent(s) and the associated human and environmental risks of those constituent(s), including human cancer risk and environmental hazards. Characterization of the hazardous constituent source term and the extent of ground-water contamination.

(2) Assessment of hazardous constituent transport in the ground water and hydraulically connected surface waters, and its adverse effects on water quality, including present and potential health and environmental consequences of exposure to the identified hazards.

(3) A demonstration that a hazardous constituent concentration will not pose substantial present or potential hazard to human health or the environment at the point of exposure, and that the proposed alternate concentration limit is as low as is reasonably achievable, considering practicable corrective actions.

In addition, the implementation of the proposed alternate concentration limit and any modifications to the compliance monitoring program must be reviewed.

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## .3.2 Review Procedures

Appendix K provides a description of a standardized content and format for an alternate concentration limit application. Strict conformance with the standard format is not a requirement, but review effectiveness and efficiency should be enhanced through its use. The proposed alternate concentration limit should be supported by a hazard assessment, an exposure assessment, and a corrective action assessment. Although separately listed, the information contained within each assessment should be integrated with the information that is developed in the subsequent assessment, so that all three assessments will collectively support the proposed alternate concentration limit. Appropriate portions of standard review plan Section 4.1 should also be consulted when performing a review of an alternate concentration limit application. The reviewer shall examine the provided information and assessments to determine that:

(1) The source term has been adequately characterized to provide a realistic estimate of the types, characteristics, and the release rates of constituents of concern, which have been, or are expected to be, released to the ground water.

(2) The risks and hazards that the released or potentially mobile constituents of concern may have on human health and the environment have been identified.

(3) The extent of existing and potential ground-water contamination from the source term has been defined. The rates and directions of hazardous constituent migration and transport in the ground water and hydraulically connected surface waters have been determined. The point of compliance and point of exposure are identified.

(4) The pathways for human and environmental exposure to the hazardous constituent(s) have been identified, and exposure magnitudes and consequences, including the human cancer risk, have been acceptably evaluated.

(5) The proposed alternate concentration limit(s) for the point of compliance will result in a hazardous constituent concentration that is protective of human health and the environment at the point of exposure. The attenuation capacity of the aquifer between the point of compliance and the point of exposure has been adequately considered. There will be no adverse effects on the ground-water or on surface-water quality that would cause unacceptable health or environmental hazards at or beyond the point of exposure.

The applicant’s assessment of ground-water corrective action alternatives shall be reviewed in conjunction with the hazard and exposure assessments. Previous, current, and potential future practicable corrective actions shall be evaluated against the costs and benefits of those actions to determine if the proposed alternate concentration limit is as low as is reasonably achievable. This demonstration should identify alternate corrective actions; assess their technical feasibility for implementation, and evaluate all associated costs and benefits of those corrective actions.

An alternate concentration limit must be protective of human health and the environment at the point of exposure, which is any location at or beyond the long-term care site boundary. A proposed alternate concentration limit that is not protective of human health and the environment, by itself, will not comply with the regulatory requirements for an alternate concentration limit. In this instance the applicant must submit the proposed numerical limit and any additional measures to protect human health and the environment to the Commission as an alternative to the specific requirements of 10 CFR Part 40, Appendix A, Criterion 5B (6), as permitted by section 84(c) of the Atomic Energy Act of 1954, as amended. The NRC staff will evaluate these alternatives on a case-by-case basis and determine the acceptability of the proposed alternative. A proposed alternate concentration limit that is not protective of human health and the environment and does not include additional alternate measures to provide such protection is not acceptable.

If the proposed alternate concentration limit is found acceptable, the compliance monitoring program must be evaluated before the license is terminated to determine that it is properly designed and implemented to ensure ground-water constituent concentrations in excess of the approved alternate concentration limit will be detected and that human health and the environment will be protected. Standard review plan Section 4.4 should be consulted.

### 4.3.3 Acceptance Criteria

The hazard assessment, exposure assessment, and corrective action assessment supporting a proposed alternate concentration limit will be acceptable if they meet the following criteria:

#### 4.3.3.1 Hazard Assessment

The hazard assessment identifies all potential constituents of concern at a site. A potential constituent of concern is any compound that may be in or could be derived from the uranium mill tailings at a licensed site. A non-inclusive list of constituents of concern is in 10 CFR Part 40, Appendix A, Criterion 13. The risks and hazards to human health and the environment associated with those constituents are also identified and evaluated to determine whether an alternate concentration limit should be proposed for those constituents, if the subsequent exposure assessment concludes that an exposure is reasonably likely. Once a constituent of concern is released into the ground-water, it is classified as a hazardous constituent for the purpose of regulatory compliance, as described in 10 CFR Part 40, Appendix A, Criterion 5B(2). The hazard assessment should include the following:

(1) The source term for all constituents of concern is adequately characterized and the extent of existing and potential future ground-water 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 non-carcinogenic constituents that are chemically toxic will be evaluated considering their risk-specific dose levels. It may be necessary to calculate a hazard 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 alternate 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 Radiation Protection and Measurement.

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) 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 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.

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. The exposure assessment takes into account site-specific circumstances that may reduce or enhance the potential for exposure to hazardous constituents. This assessment identifies and evaluates hazardous constituent exposure pathways, and provides forecasts of human and environmental population responses, based on the projected constituent concentrations, dose levels, and available information on the radiological and chemical toxicity effects of the constituents. The assessment also addresses the underlying assumptions, variability, and uncertainty of the projected health and environmental effects. Exposure pathways should be identified and evaluated using water classification and water use standards, along with existing and anticipated water uses. Agricultural, industrial, domestic, municipal, environmental, and recreational water uses should also be considered, as they pertain to the site and surrounding areas. The exposure assessment must provide adequate information regarding potential effects on ground-water resources, and the above water uses, to support NRC's environmental review under 10 CFR Part 51. NUREG–1748 (NRC, 2001) should be consulted for the details of this review.

The exposure assessment must identify the point of compliance, where the proposed alternate concentration limit will be measured; and the points of exposure, where the human health and environmental exposures could occur. The assessment identifies the maximum permissible levels of hazardous constituents at the point of compliance that are protective of human health and the environment at the point of exposure. This is accomplished by evaluating human and environmental exposure to each of those constituents evaluated in the hazard assessment, and then showing the proposed alternate concentration limit will not result in an unacceptable exposure of human health or the environment to those hazards. The exposure assessment should include the following:

(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 ground-water 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 ground-water 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 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 ground-water 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. 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) ground-water 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 ground-water 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 uses: 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. Guidance for cumulative impact assessment is contained in NUREG–1748 (NRC, 2001) and additional guidance is found in Council on Environmental Quality (1997).

(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 ground-water 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 ground-water 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 ground-water 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, an alternate 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 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:

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[3]A distant point of exposure refers to a point of exposure that is spatially beyond the area that the appropriate federal or State agency is required to accept for perpetual care under the land transfer provisions of the Uranium Mill Tailings Radiation Control Act of 1978, as amended.

(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 ground-water 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 ground-water 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 ground-water 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 ground-water protection standards established at the site. The corrective action assessment should include the following:

(1) A complete range of realistic and reasonable corrective action alternatives for achieving compliance with the ground-water 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 alternate 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 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 ground-water value should be based on water rights, availability of alternate 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 alternate source to replace the contaminated resource. The absence of available alternate 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 levels 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. Additionally, once nonradiological constituent are below regulatory maximum concentration levels, the licensee ha no further obligation to reduce the constituent concentrations.

#### 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 ground-water 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.

### 4.3.4 Evaluation Findings

The following conclusions may be presented in the technical evaluation report, if the staff review, as described in standard review plan Section 4.3 results in the acceptance of the hazard assessment, exposure assessment, and corrective action assessment supporting the proposed alternate concentration limit:

The staff completed its review of the proposed alternate concentration limit for ground-water compliance at the ______________ uranium mill tailings facility. This review included an evaluation using the review procedures in Section 4.3.2 and the acceptance criteria outlined in Section 4.3.3 of this standard review plan.

The licensee conducted an acceptable hazard assessment by considering present and potential human health and environmental hazards, including human cancer risk from exposure to radioactive and non-radioactive constituents and other health hazards resulting from the chemical toxicity of the constituents. The source term for constituents of concern and the extent of ground-water contamination have been acceptably characterized.

The licensee conducted an acceptable exposure assessment. The point of exposure has been identified and is acceptably sited at the downgradient edge of the affected land. When a distant point of exposure is used, written assurance has been secured, either by the licensee or NRC, 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. The transport of the hazardous constituent in ground water and surface water has been defined and any adverse effects on water quality, including present and future impacts have been assessed.

The human cancer risk and other health and environmental hazards from exposures to hazardous constituents have been evaluated and are acceptable, including (a) identification of maximum levels permissible at the point of compliance; (b) evaluation of health and environmental hazards using water classification and use standards and existing and anticipated water uses; (c) appropriate consideration of impact, based on site-specific water uses; (d) consideration of ingestion of contaminated water and food; (e) consideration of response of environmental and non-human populations to the various hazardous constituents, including terrestrial and aquatic wildlife, plants, livestock, and crops; and (f) consideration of potential damage to physical structures.

The acceptable corrective action assessment includes (1) an assessment of ground-water corrective actions dealing with identification of practicable corrective action alternatives; (2) an evaluation of ability of corrective action to reduce contaminant levels appropriately; (3) a demonstration that action will achieve desired concentration levels; and (4) demonstration that practicable corrective actions are not likely to result in reduction of contamination below the proposed alternate concentration limit, and that alternate concentration limits are, therefore, as low as is reasonably achievable.

The NRC staff concludes that the information submitted to support the proposed alternate concentration limit(s) at the _________________ uranium milling facility is acceptable and complies with the following criteria in 10 CFR Part 40, Appendix A, Criterion 5B, which requires NRC to establish a list of hazardous constituents, concentration limits, a point of compliance, and a compliance period; Criterion 5C, which contains a table of secondary concentration limits for certain constituents when they are present in ground water above background concentrations; Criterion 5F, which requires that where ground-water impacts from seepage are occurring at an existing site, action must be taken to alleviate the conditions that lead to seepage, and ground-water quality must be restored, including technical specifications for the seepage control system and implementation of a quality assurance program; Criterion 5G, which requires licensees/operators to perform site characterization; Criterion 6(1), which provides performance lifetime and radioactive material release standards; and Criterion 7A, which establishes detection, compliance and corrective action monitoring programs in support of a tailings disposal system proposal. The information also complies with 10 CFR 40.31(f), which requires inclusion of an environmental report in the license application, and 10 CFR 51.45, which requires a description of the affected environment containing sufficient data to aid the Commission in its conduct of an independent analysis.

### 4.3.5 References

Council on Environmental Quality. "Considering Cumulative Effects Under the National Environmental Policy Act." Washington, DC: Council on Environmental Quality. 1997.

NRC. NUREG–1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs." Washington, DC: NRC. 2001.

## 4.4 Ground-Water Corrective Action and Compliance Monitoring Plan

The staff should review any ground-water corrective action and compliance monitoring plans that may be presented by the licensee either as a part of the reclamation plan, or as a separate licensing submittal. A separately submitted corrective action and compliance monitoring plans will contain much of the same information that is required for the reclamation plan (e.g., a site characterization plan). Any information that was presented in a previously approved reclamation plan may be incorporated by reference. For review of some information, the reviewer may use review procedures in other chapters of this standard review plan.

### 4.4.1 Areas of Review

In determining compliance, the reviewers should consider the information specified in Criteria 1–8 of Appendix A of 10 CFR Part 40 that is relevant to the technical adequacy of the ground-water corrective action and compliance monitoring plans. Models of unsaturated flow and transport can be used if the tailings pile is located in the unsaturated zone. A reactive transport model of the plume of hazardous constituents for the saturated zone away from the mill tailings pile should be constructed if the licensee takes credit for chemical processes that may mitigate the spread of contaminants. The technical adequacy of any detailed models should be reviewed. Findings from detailed models (that incorporate complexities not treated in any large-scale numerical models) can be used as input to a large-scale numerical model of ground-water flow and transport for the site. Models should be calibrated using site data.

The staff should review the following aspects of ground-water corrective action and compliance monitoring plans.

(1) The sufficiency of data and parameters.

(2) The technical bases for parameter ranges.

(3) Descriptions of features and physical phenomena.

(4) Use of alternate models.

(5) Consistency of models.

(6) Waste management practices.

(7) Site access controls.

(8) Ground-water monitoring plans.

(9) Design, operation, and inspection of surface impoundments.

(10) Surety.

### 4.4.2 Review Procedures

In conducting the review of the technical adequacy of the ground-water corrective action and complaince monitoring plans, the staff should recognize that review procedures and models used in the technical assessment of the selected ground-water cleanup methods, cleanup time, and sureties may range from detailed, small-scale process models to large-scale, simplified models. The small-scale process models incorporate the important complexities and mechanisms that govern the evolution of the hazardous constituent plume, while the large-scale simplified models do not consider all the important complexities. Model adequacy should be evaluated regardless of the level of complexity. The following areas should be evaluated:

(1) The staff should evaluate the sufficiency of the data and parameters supporting models considered in any site-scale numerical model used to estimate the cleanup time. The staff should also evaluate the technical basis for data on design features, physical phenomena, geology, hydrology, geotechnical engineering, and geochemistry used to model or assess ground-water cleanup. This basis may include a combination of techniques such as laboratory experiments and site-specific field measurements.

    The reviewer should evaluate whether additional data are likely to provide new information that could invalidate the modeling results and significantly affect the corrective action and compliance monitoring plans.

(2) The reviewer should evaluate the technical bases for parameter ranges, probability distributions, or bounding values. The reviewer should determine whether the parameter values are derived from site-specific data or, alternatively, an analysis is

included to show that the assumed parameter values lead to a conservative assessment of performance.

The staff should examine the initial conditions and boundary conditions used in sensitivity analyses for consistency with available data. The staff should also consider the temporal and spatial variations in boundary conditions and source terms used to support the ground-water corrective action and compliance monitoring plan.

The staff should evaluate the licensee assessment of uncertainty and variability in parameters used in the modeling. The reviewer should determine whether uncertainty in data due to both temporal and spatial variations in conditions affecting the ground-water cleanup and estimation of cleanup time was incorporated into parameter ranges.

(3) The staff should examine the descriptions of features and physical phenomena and the descriptions of the geological, hydrological, geotechnical, and geochemical aspects of the mill tailings and the underlying aquifer. The staff should verify that the descriptions are adequate and that the conditions and assumptions used in the modeling are realistic or reasonably conservative and are supported by the body of data presented in the descriptions. The staff should assess the technical bases for these descriptions and for incorporating them in the numerical model of the site.

The reviewer should examine the technical bases for the identification of hazardous constituents from the mill tailings that have entered the underlying aquifer and surface water bodies. The staff should evaluate how these constituents have been incorporated into any detailed models. The staff should also verify that, given the concentrations and locations of the hazardous constituents, estimates of cleanup time and surety amounts are reasonable.

The reviewer should examine the assumptions used to develop any model of reactive transport that accounts for site geochemical processes. These processes may include phase changes induced by interaction of contaminants with ground water and surface water. The modeling should consider available data about the native ground-water downgradient of the tailings pile, the geochemical environment, hydraulic and transport properties, and the spatial variations of properties of aquifers and ground-water volumetric fluxes along the flow paths.

The staff should evaluate the initial and boundary conditions and how they have been propagated through the models. For example, the reviewer should determine whether the conditions and assumptions used in the site-scale model are consistent with other conditions and assumptions used in any model that describes the flow and transport of hazardous constituents from the mill tailings.

(4) The staff should evaluate models used for the ground-water cleanup and estimation of cleanup time. The staff should examine the model parameters in the context of available site characterization data, laboratory experiments, and field measurements.

Where appropriate, and when surety estimates are highly uncertain, the reviewer should use an alternate site model to evaluate the effects on the technical assessment of ground-water cleanup and estimation of cleanup time.

(5) The staff should evaluate the output from any site model of ground-water cleanup and the estimation of cleanup time and compare the results with an appropriate combination of site characterization and design data.

The staff should examine the model results obtained by the licensee against comparable mathematical models to judge their robustness. The reviewer should use an alternate model to evaluate selected parts of the licensee model results, as appropriate. The reviewer should evaluate whether the licensee has appropriately reduced the dimensionality and complexity of models. The dimensionality of models, heterogeneity of aquifer parameters, and significant process couplings may be reduced if it is shown that the simplified model bounds the prediction of the more complex model. The staff should evaluate the acceptability of the sensitivity analyses used to support the model of the ground-water cleanup and the estimation of cleanup time.

(6) The staff should verify that waste management practices are in compliance with environmental protection regulations.

(7) The reviewer should assess whether site access controls during the cleanup period are sufficient to prevent significant hazards to human health and the environment.

(8) The staff should evaluate whether the ground-water monitoring system is sufficient to verify the performance of the selected cleanup strategy, and to monitor the long-term performance of any on-site tailings disposal cells.

(9) The staff should ensure that any surface impoundments constructed as part of the program are designed to meet the requirements of 10 CFR Part 40, Appendix A criteria and are included in the dam safety program, if appropriate. The reviewer should also verify that adequate inspection, documentation, and reporting procedures exist for tailings or waste retention systems.

(10) The staff should confirm that the applicant has provided adequate financial surety. This confirmation may be conducted using cost estimating software such as the RACER 2000™ computer code (Talisman Partners, Ltd., 2000). Guidance on the preparation of sureties and cost estimates is available in Appendix C of this standard review plan and in NRC (1988, 1997).

### 4.4.3 Acceptance Criteria

In 10 CFR Part 40, Appendix A, Criterion 5D, NRC requires tha,t if the ground-water protection standards established under Criterion 5B(1) of 10 CFR Part 40, Appendix A are exceeded at a licensed site, a corrective action program must be put into operation as soon as is practicable, and in no event later than 18 months after the Commission finds that the standards have been exceeded. Unless otherwise directed by the Commission, before putting the program into operation, the licensee should submit the supporting rationale for the proposed corrective action program. The objective of the program is to return hazardous constituent concentration levels in ground water to the concentration limits set as standards. The licensee should provide an assessment of practicable corrective actions available for returning contaminant concentrations to the standards established in the license. The corrective action assessment incorporates information and findings from the site characterization activities, which are described in standard review plan Section 4.1.3. Site specific characteristics may have a strong influence on which corrective action alternative will be practicable for a particular site. If additional site characterization is needed, details of the characterization plan should be included.

The corrective action should result in conformance with the established concentration limits, address either removing the hazardous constituents or treating them in place, and should include a program to monitor compliance with cleanup standards. Regulations do not require any specific designs or methods to be used for the ground-water corrective action program. Because of the nearly limitless possibilities for designing and implementing ground-water corrective actions, staff reviewers should focus on the technical feasibility from an engineering perspective and evaluate whether the proposed design is likely to result in timely compliance with established concentration limits and whether the monitoring program is adequate to verify the effectiveness of the design. Useful guidance for the application of ground-water flow and transport modeling can be obtained from American Standard for Testing and Material D 5447, D 5490, D 5609, D 5611, D 5718, D 5880, and D 5981.

The ground-water corrective action and compliance monitoring plans are acceptable if they meet the following criteria.

(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 ground-water cleanup and the estimation of cleanup time. The data are also sufficient to assess the degree to which processes related to the ground-water 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.

    (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 ground-water/surface-water interactions with nearby streams, rivers, or lakes.

(i) Areal recharge rates.

(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.

(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) ground-water 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.

(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.

Sufficient data are available to justify models used to validate the ground-water corrective action plan. American Standard for Testing and Materials D 5490 provides acceptable guidance for comparing model simulations to site-specific information. Alternatively, in the case of sparse data and/or low confidence in the quality of available data or data interpretations, the licensee demonstrates by sensitivity analyses or other methods that the proposed ground-water corrective action plan is appropriate, and the contingency built into the surety is compatible with the uncertainties. American Standard for Testing and Materials D 5611 provides acceptable guidance for conducting sensitivity analyses on ground-water flow models. Guidance on preparing cost estimates and establishing sureties for uranium mills is provided in the "Technical Position on Financial Assurances and Reclamation, Decommissioning, and Long-Term Surveillance and Control of Uranium Recovery Facilities" (NRC, 1988).

Sufficient information is provided to substantiate that any mathematical flow and transport modeling approach is appropriate for site conditions considering (i) factors pertaining to the specific purpose or intended use of the model(s); (ii) the flow media at the site and along the flow path from the mill tailings to the point of compliance, and downgradient to it, including aquifer properties and transport parameters (e.g., porous media versus fracture flow, aquifer confinement, the number of active layers); (iii) modeling assumptions (e.g., steady-state versus transient flow, assignment of initial and boundary conditions); and (iv) model-related factors (e.g., underlying flow equations; solution methods; model history; model verification, validation and calibration; expertise and experience of the personnel responsible for model development; and quality of model documentation). Amiercan Standard for Testing and Materials D 5718 provides guidance for documenting ground-water flow model applications.

An adequate assessment is provided of the low and high permeability features (heterogeneities), their spatial distributions, and statistical properties; and the available and acquired data are suitable and sufficient for modeling based on observations, independent analyses, or published reports and databases of those features.

Initial and boundary conditions used by the licensee in modeling the ground-water cleanup are justified by the available data, are used consistently throughout the modeling process, and are adequately documented. American Standard for Testing and Materials D 5609 provides acceptable guidance for defining boundary conditions for ground-water flow models.

Where sufficient data do not exist, the definition of parameter values and conceptual models are based on appropriate sources from the literature or are otherwise technically justified.

Adequate site geochemical data are provided. Contaminants are identified sufficiently to support the ground-water corrective action plan and models. In addition to helping set cleanup goals, background water chemical data support assessments of geochemical evolution as ambient ground water is restored in the subsurface. Generally, a three-dimensional delineation of contaminant distribution and a source term are necessary for defining needed actions and for model development. The important geochemical parameters that should be delineated for both contaminated and background waters are pH, Eh, dissolved oxygen, temperature, major cation and anion concentrations, and concentrations of potential contaminants. Host rock properties affect both the water chemistry and the specific geochemical mechanisms affecting contaminants. Identifying possible attenuation mechanisms ensures that cleanup is based on reasonable models for contaminant transport.

(2) Parameter values, assumed ranges, probability distributions, and/or bounding assumptions used in the modeling of ground-water 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 ground-water 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 ground-water 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 ground-water cleanup.

Site data fitted to theoretical models compare reasonably well. American Standard for Testing and Materials D 5490 provides guidance for comparing ground-water flow model simulations to site-specific information. If there is departure of site data from the theoretical model, then an alternate 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 ground-water 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.

The licensee delineates the extent of the hazardous constituent plume, contaminant flow paths in the aquifer considering natural site conditions, any effects that can be expected to result from construction of additional facilities and operations (i.e., tailings ponds, evaporation ponds, excavations), and events that may affect the spatial and temporal distribution of the hazardous constituent plume. More specifically, the licensee's models of the ground-water cleanup consider and are consistent with (i) natural climatic, geologic, and hydrologic conditions at the site and in the vicinity of the site; (ii) tailings pile design and construction features and their potential impact on local recharge and consequent flow paths in the aquifer; (iii) geochemical and other processes that can affect the performance of the ground-water cleanup and estimation of cleanup time; and (iv) future events, including additional construction and changes of plans for operations that may occur at the site. The licensee also has determined the range of concentrations of hazardous constituents that can be expected in the aquifer and their changes with time during the ground-water cleanup.

The licensee estimates the total mass of hazardous constituents produced by the leaching process and the quantity of the mass that is in the mill tailings, the aquifer, in surface water bodies (including evaporation ponds, disposal cells, nearby ponds, and rivers) and the portion that has been removed by means of the ground-water cleanup, and accounts for the mass that will be removed for final disposal.

The licensee makes reasonable assumptions, if taking credit for dispersion of hazardous constituents and consequent reduction of concentrations during transport from the mill tailings to the point of compliance, for such processes as mechanical dispersion and mixing with native ground water and surface water. These assumptions are based on available data about the hydraulic and transport properties of the site and the spatial variations of properties of aquifers and ground-water volumetric fluxes along the flow paths.

The licensee provides an adequate basis for considering the effect of any reactive transport and geochemical processes in simulating the ground-water cleanup operation, if taking credit for sorption or any other geochemical reaction of hazardous constituents and consequent reduction or retardation of concentrations during transport from the mill tailings. Predicting the effects of proposed ground-water cleanup actions may include forward, site-specific contaminant transport modeling. Often, such modeling has taken a simple approach employing a retardation factor to describe all geochemical effects on contaminant concentration. This approach may be too simplistic. The use of a constant retardation factor and the neglect of speciation and water-mineral reactions is likely to lead to prediction errors. Reactive transport models using codes such as PHREEQC Version 2 (Parkhurst and Appello, 1999) are acceptable for constructing a geochemical model for the site. Hostetler and Erickson (1993) discuss examples of the effect of extending reactive transport models beyond simply including retardation in advective-dispersive models. In one example involving cadmium transport at a uranium mill tailings site, concentration profiles from the site suggest the importance of otavite ($CdCO_3$) solubility control on aqueous cadmium in the low-pH zones near the tailings pond, and the inadequacy of modeling sorption alone.

Reactive transport models incorporate thermodynamic data on solid phases and aqueous species, allowing the mass action calculations that determine estimated aqueous concentrations and solid phase evolution. Thermodynamic parameters constitute a major source of uncertainty in geochemical modeling [see Murphy and Shock (1999) for a discussion of uranium], with potentially large effects on predicted aqueous ion concentrations. Therefore, geochemical modeling supporting ground-water corrective action plans includes sensitivity analyses that provide assurance that contaminant concentrations will not be underestimated. Likewise, any kinetic models employed are subjected to critical analysis because of the large influence of kinetic effects at low temperatures.

Reactive transport model results are subject to the assumptions and limitations of the conceptual and numerical models employed. For example, Zhu et al.[4] list model limitations and briefly discuss how they may affect predictions. Geochemical limitations include:

(a) The assumption of local equilibrium (i.e., kinetic rates were not employed).

(b) Modeled porosity not being affected by reactions affecting the solid phase.

(c) Omitting colloidal transport.

(d) Neglecting density effects due to varying total dissolved solids.

(e) Simplifying the mineralogical suite.

(f) Neglecting surface reactions such as ion exchange.

(g) Relying on bulk mineralogy rather than on mineral surface compositions.

Limitations such as these are typically due to factors such as lack of data, inadequate computational equipment, or insufficient model development. Consideration of model limitations and their effects on uncertainty is an important component of the review by the NRC.

The numerical model of the site constructed by the licensee incorporates site-specific information, is adequately validated and calibrated, and reasonably represents the

[4] Zhu C., F.Q. Hu, and D.S. Burden. "Multi-Component Reactive Transport Modeling of Natural Attenuation of an Acid Ground-Water Plume at a Uranium Mill Tailings Site." *Journal of Contaminant Hydrology*. 2001. Accepted for publication.

physical system. American Standard for Testing and Materials Reports D 5490 and D 5981 provide guidance for ground-water flow model validation and calibration. The professional experience and judgment of the reviewer should be applied in assessing these aspects of the analyses.

The licensee identifies and properly integrates factors that are expected to affect, or that are affected by, the ground-water cleanup. These include, but are not limited to, the spatial and temporal variation of the flux of leachates from the mill tailings to the underlying aquifer, drainage mechanisms of leachates from the mill tailings, spatial variability in flow and transport properties of the aquifer underlying the mill tailings, and geochemical processes that may affect the concentrations of hazardous constituents.

The licensee evaluates and documents the degree of conservatism in modeling the ground-water cleanup, and the level of conservatism presumed by the licensee is commensurate with the data and conceptual model uncertainty.

(4) Alternate modeling approaches consistent with available data and current scientific understanding are investigated where necessary, and results and limitations are appropriately factored into the ground-water 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 alternate modeling approaches where necessary to incorporate uncertainties in site parameters and ensure they are propagated through the modeling.

Uncertainty in data 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 ground-water corrective action plan.

(5) The site-scale model for ground-water 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 ground-water cleanup, the licensee considers and evaluates alternate 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 ground-water cleanup and control activities, and to monitor compliance with ground-water cleanup standards. The description of the monitoring program includes or references the following information:

(a) Quality assurance procedures used for collecting, handling, and analyzing ground-water samples.

(b) The number of monitor wells and their locations.

(c) A list of constituents that are sampled and the monitoring frequency for each monitored constituent.

(d) Action levels that trigger implementation of enhanced monitoring or revisions to cleanup activities (i.e., timeliness and effectiveness of the corrective action).

For corrective action monitoring:

> The same wells used to determine the nature and extent of contamination may be used to monitor the progress of ground-water corrective action activities. However, once the extent of contamination is delineated, it may be possible to adequately monitor compliance with fewer wells. Once selected, major changes to monitored locations are avoided, because it is important to be able to directly compare measurements made at different times.
>
> Licensees choose a monitoring interval that is appropriate for monitoring corrective action progress. Not all hazardous constituents need to be monitored at each interval. It is generally acceptable for licensees to choose a list of more easily measured constituents that serve as good indicators of performance. These indicators include conservative constituents that are less likely to be attenuated, such as chloride, total dissolved solids, and alkalinity. However, if a hazardous constituent is causing a demonstrated risk to human health or the environment, that constituent must be monitored during the corrective action. Ground water at designated monitor wells is sampled for all hazardous constituents at the end of each major phase of corrective action and again before license termination and transfer of the site to the custodial agency for long-term custody.
>
> For compliance monitoring, after a corrective action program has been terminated, compliance monitoring at the point of compliance will resume for the duration of the compliance period, until license termination, as defined in 10 CFR Part 40, Appendix A, Criterion 7A.

(9) Design of Surface Impoundments.

The reviewer should verify that any 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 in Regulatory Guide 3.11, Section 1 (NRC 1977). Materials used to construct the liner should be reviewed to determine that they have acceptable chemical properties and sufficient strength for the design application. The reviewer should confirm that the liner will not be overtopped. The reviewer should also confirm that a proper quality control program is in place.

The review should ensure that the applicable requirements of 10 CFR Part 40, Appendix A, Criterion 5(A) have been met. If the waste water retention impoundments are located below grade, the reviewer should determine that the surface impoundments have an acceptable liner to ensure protection of ground water. The location of a surface impoundment below grade will eliminate the likelihood of embankment failure that could result in release of waste water. The reviewer should determine that the design of associated dikes is such that they will not experience massive failure.

The design of a clay or synthetic liner and its component parts should be presented. At a minimum, design details, drawings, and pertinent analyses should be provided.

Expected construction methods, testing criteria, and quality assurance programs should be presented. Planned modes of operation, inspection, and maintenance should be discussed in the application. Deviations from these plans should be submitted to the staff for approval before implementation.

The liner for a surface impoundment used to manage uranium and thorium byproduct material must be designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the subsurface soil, ground water, or surface water at any time during the active life of the surface impoundment. The liner may be constructed of materials that allow wastes to migrate into the liner provided that the impoundment decommissioning includes removal or decontamination of all waste residues, contaminated containment system components, contaminated subsoils, and structures and equipment contaminated with waste and leachate.

The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure caused by pressure gradients, physical contact with the waste or leachate, climatic conditions, and the stresses of installation and daily operation. The subgrade must be sufficient to prevent failure of the liner caused by settlement, compression, or uplift. Liners must be installed to cover all surrounding earth that is likely to be in contact with the wastes or leachate.

Tests should show conclusively that the liner will not deteriorate when subjected to the waste products and expected environmental and temperature conditions at the site. Applicant test data and all available manufacturers test data should be submitted with the application for this purpose. For clay liners, tests, at a minimum, should consist of falling head permeameter tests performed on columns of liner material obtained during and after liner installation. The expected reaction of the impoundment liner to any combination of solutions or environmental conditions should be known before the liner is exposed to them. Field seams of synthetic liners should be tested along the entire length of the seam. Representative sampling may be used for factory seams. The testing should use state-of-the-art test methods recommended by the liner manufacturer. Compatibility tests that document the compatibility of the field seam material with the waste products and expected environmental conditions should be submitted for staff review and approval. If it is necessary to repair the liner, representatives of the liner manufacturer should be called on to supervise the repairs.

Proper preparation of the subgrade and slopes of an impoundment is very important to the success of the surface impoundment. The strength of the liner is heavily dependent on the stability of the slopes of the subgrade. The subgrade should be treated with a soil sterilant. The subgrade surface for a synthetic liner should be graded to a surface tolerance of less than 2.54 cm [1 in.] across a 30.3-cm [1-ft] straightedge. NRC Regulatory Guide 3.11, Section 2 (NRC, 1977) outlines acceptable methods for slope stability and settlement analyses, and should be used for design. If a surface impoundment with a synthetic liner is located in an area in which the water table could rise above the bottom of the liner, underdrains may be required. The impoundment will be inspected in accordance with Regulatory Guide 3.11.1 (NRC, 1980).

To prevent damage to liners, some form of protection should be provided, such as (a) soil covers, (b) venting systems, (c) diversion ditches, (d) side slope protection, or (e) game-proof fences. A program for maintenance of the liner features should be developed, and repair techniques should be planned in advance.

The surface impoundment must have sufficient capacity and must be designed, constructed, maintained, and operated to prevent overtopping resulting from (a) normal or abnormal operations, overfilling, wind and wave actions, rainfall, or run-on; (b) malfunctions of level controllers, alarms, and other equipment; and (c) human error. If dikes are used to form the surface impoundment, they must be designed, constructed, and maintained with sufficient structural integrity to prevent their massive failure. In ensuring structural integrity, the applicant must not assume that the liner system will function without leakage during the active life of the impoundment.

Controls should be established over access to the impoundment, including access during routine maintenance. A procedure should be developed that ensures unnecessary traffic is not directed to the impoundment area. A program should be established to ensure that daily inspections of tailings or waste impoundment systems are conducted and recorded and that failures or unusual conditions are reported to the NRC.

In addition, the reviewer should evaluate the proposed surface impoundment to determine if it meets the definition of a dam as given in Regulatory Guide 3.11 (NRC, 1977). If this is the case, the surface impoundment should be included in the NRC dam safety program, and be subject to Section 215, “National Dam Safety Program,” of the Water Resources Development Act of 1996. If the reviewer finds that the impoundment conforms to the definition of a dam, the dam ranking (low or high hazard) should be evaluated. If the dam is considered a high hazard, an emergency action plan is needed consistent with Federal Emergency Management Agency requirements. For low hazard dams, no emergency action plan is required. For either ranking of dam, the reviewer should also verify that the licensee has an acceptable inspection program in place to ensure that the dikes are routinely checked, and that performance is properly maintained.

A quality control program should be established for the following factors: (a) clearing, grubbing, and stripping; (b) excavation and backfill; (c) rolling; (d) compaction and moisture control; (e) finishing; (f) subgrade sterilization; and (g) liner subdrainage and gas venting.

(10) Financial Surety Is Provided.

The licensee must maintain a financial surety, within the specific license, for the cleanup of ground water, 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 ground-water quality to the established site-specific standards (including an alternate concentration limit standard) before the site is transferred to the government for long-term custody. Guidance on establishing financial surety is presented in NRC (1988, 1997). 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.

### 4.4.4 Evaluation Findings

If the staff review, as described in standard review plan Section 4.4, results in the acceptance of the ground-water corrective action plan and compliance-monitoring plans, the following conclusions may be presented in the technical evaluation report:

The staff has completed its review of the ground-water corrective action and compliance monitoring plans at the ________________ uranium mill facility. This review included an evaluation using the review procedures in Section 4.4.2 and the acceptance criteria outlined in Section 4.4.3 of this standard review plan. The ground-water corrective action program should achieve the goal of returning hazardous constituent concentration levels in ground water to the concentration limits set as standards in 10 CFR Part 40, Appendix A, Criterion 5D. The monitoring program will provide reasonable assurance that, after the corrective actions have been taken, the ground-water protection standard will not be exceeded.

The licensee has established a ground-water compliance strategy that is acceptable for the site. The strategy consists either of no remediation or active remediation when contaminants are present at concentrations above background levels, maximum concentration limits, or alternate concentration limits. When active remediation is necessary, the remedial action design and implementation are acceptable. The licensee has acceptably presented pumping/injection rates, treatment methods, equipment and maintenance requirements, and plans and schedules for construction, and has produced maps showing locations of remediation equipment. An analysis has been conducted that demonstrates (1) the chosen active remediation system technology is appropriate for the site conditions, (2) design pumping rates are sustainable and will control migration of contaminants away from the site, and (3) the natural heterogeneity of the system has been acceptably accounted for in a conservative remediation strategy. The licensee has identified acceptable waste management practices. Qualified engineers, state authorities, and national agencies have provided appropriate oversight. Institutional controls are appropriate for the site, including (1) controlling access to the site, (2) conducting periodic inspections, and (3) periodically monitoring cleanup performance. The monitoring program includes (1) a description of quality assurance procedures; (2) the number of monitoring wells and their locations; (3) a list of constituents that will be sampled, along with the sampling frequency for each monitored constituent; and (4) action levels for triggering enhanced monitoring or revisions to cleanup activities. The licensee has described an acceptable scheme for cleanup and compliance monitoring. The licensee will sample ground water at the point of compliance for all hazardous constituents of concern. An adequate surety mechanism and fund has been established to support the ground-water cleanup.

On the basis of the information presented in the application and the detailed review conducted of the ground-water corrective action and compliance monitoring plans for the _______________ uranium mill facility, the NRC staff concludes that the information is acceptable and is in compliance with the following criteria in 10 CFR Part 40, Appendix A: Criteria 5A(4) and 5A(5), which require proper operation of impoundments and design of dikes;

Criterion 5B, which requires NRC to establish a list of hazardous constituents, concentration limits, a point of compliance, and a compliance period; Criterion 5C, which provides a table of secondary concentration limits for certain constituents when they are present in ground water above background concentrations; Criterion 5(D), which provides requirements for a ground-water corrective action program; Criterion 5E, which requires licensees conducting ground-water protection programs to consider the use of bottom liners, recycle of solutions and conservation of water, dewatering of tailings, and neutralization to immobilize hazardous constituents; Criterion 5F, which requires that, where ground-water impacts from seepage are occurring at an existing site, action must be taken to alleviate the conditions that lead to seepage, and ground-water quality must be restored, including providing technical specifications for the seepage control system and implementation of a quality assurance program; Criterion 5G, which requires licensees to perform site characterization in support of a tailings disposal system proposal; Criterion 5H, which requires steps be taken during stockpiling of ore to minimize penetration of radionuclides into underlying soils; Criterion 7A, which provides for establishment of three types of monitoring systems: detection, compliance, and corrective action; Criterion 8A, which requires proper inspection and documentation of the operation of tailings and waste retention systems; and Criterion 13, which provides a list of hazardous constituents that must be considered when establishing the list of hazardous constituents in ground water at any site.

If surface impoundments are to be used at the facility to manage byproduct material, the design of dikes used to construct surface-water impoundments has been demonstrated to comply with Regulatory Guide 3.11, Sections 2 and 3 (NRC, 1977) and, therefore, comply with requirements of 10 CFR Part 40, Appendix A, Criterion 5(A)5.  In addition, because the impoundment dikes may conform to the definition of a dam as given in the Federal Guidelines for Dam Safety, they are subject to the NRC dam safety program, and to Section 215, “National Dam Safety Program, of the Water Resources Development Act of 1966.”

Surety funds and funding methods proposed by the applicant comply with 10 CFR Part 40, Appendix A, Criteria 9 and 10, which establish financial requirements for conventional uranium mills.

### 4.4.5 References

American Society for Testing and Materials Standards

D 5447, “Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem.”

D 5490, “Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information.”

D 5609, “Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling.”

D 5611, “Standard Guide for Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application.”

D 5718, “Standard Guide for Documenting a Ground-Water Flow Model Application.”

D 5880, “Standard Guide for Subsurface Flow and Transport Modeling.”

D 5981, “Standard Guide for Calibrating a Ground-Water Flow Model Application.”

Hostetler, C.J. and R. L. Erickson. “Coupling of Speciation and Transport Models.” *Metals in Groundwater*. H.E. Allen, E.M. Perdue, and D.S. Brown, eds. Chelsea, Michigan: Lewis Publishers. pp. 173–208. 1993.

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