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Washington, DC 20585

January 12, 2017

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U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Deputy Director
Mail Stop T8-F5
Washington, DC 20555-0001

Subject: Interim Treatment System Evaluation (ITSE) Plan for
Tuba City, Arizona, Disposal Site

To Whom It May Concern:

The Interim Treatment System Evaluation Plan for the Tuba City, Arizona, Disposal Site is submitted for your review and concurrence. This plan describes field trials for enhanced evaporation, geochemical analyses, and testing of aquifer response to groundwater extraction strategies. The interim treatment system evaluation will be performed throughout 2017. Results will then be used to support revision of the site's Groundwater Compliance Action Plan.

Please call me at (970) 248-6073 if you have any questions. Please address any correspondence to:

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Sincerely,

Richard P. Bush
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DRAFT FINAL
Interim Treatment System Evaluation Plan
Tuba City, Arizona, Disposal Site

January 2017

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

DOE	U.S. Department of Energy
ESL	Environmental Sciences Laboratory
GCAP	Groundwater Compliance Action Plan
gpm	gallons per minute
HAZOP	Hazards and Operability
ITSE	Interim Treatment System Evaluation
LM	Office of Legacy Management
LMS	Legacy Management Support
N	nitrogen
NRC	U.S. Nuclear Regulatory Commission
P&ID	Piping and instrumentation diagram
UMTRCA	Uranium Mill Tailings Radiation Control Act
WAIV	Wind-Aided Intensified Evaporation

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1.0 Introduction

1.1 Site Background

The Tuba City, Arizona, Disposal Site is located 5 miles east of Tuba City (85 miles northeast of Flagstaff, Arizona) in the Navajo Nation and in close proximity to the Hopi Reservation, as shown in Figure 1. A uranium mill was operated at the site from 1956 to 1966, and during the operational period, milling process and tailings slurry water was stored in unlined ponds. This water was laden with metals (particularly uranium), nitrate, and sulfate. Because the ponds were unlined, process water infiltrated into the ground and eventually contaminated the underlying aquifer. When the mill closed, surface contamination was left behind in the form of abandoned buildings, unprocessed ore, and mill tailings. The U.S. Department of Energy (DOE) Office of Legacy Management (LM) now has responsibility for the Tuba City disposal site.

In 1978, the Uranium Mill Tailings Radiation Control Act (UMTRCA) was signed into law, mandating the protection of human health and the environment from radiation exposure at uranium mill sites. The Tuba City site is one of the 22 original sites identified under UMTRCA. The initial focus for the Tuba City site was on the remediation of surface contamination, with the objective of minimizing the environmental release of radon gas, a known carcinogen. Mill debris, tailings, and surrounding soils impacted by windborne contamination were consolidated in a disposal cell. Construction of the site's disposal cell started in 1988 and was completed in 1990.

Remediation of groundwater contamination was addressed in 1999, in the Groundwater Compliance Action Plan (GCAP) (DOE 1999). The GCAP prescribed a pump-and-treat remedy that included the extraction of contaminated groundwater, treatment through a distillation system, and return of treated water to the aquifer. The distillation system concentrated the groundwater contaminants into a low-volume waste stream, which was disposed onsite in a double-lined evaporation pond. The groundwater treatment system has an influent flow capacity of about 150 gallons per minute (gpm) maximum, producing high-quality distillate at an efficiency of 90%. About 10% of the treated flow is disposed in the evaporation pond.

The GCAP water-quality standards for aquifer restoration are a combination of regulatory requirements and negotiated goals. Regulatory requirements for water quality for UMTRCA sites are found in Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192) "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings." Other water-quality goals, beyond those specified in 40 CFR 192, were negotiated with the Navajo Nation and the Hopi Tribe. The regulatory authority for the site is the U.S. Nuclear Regulatory Commission (NRC). Regulatory standards and negotiated goals for treated water quality are summarized in Table 1.

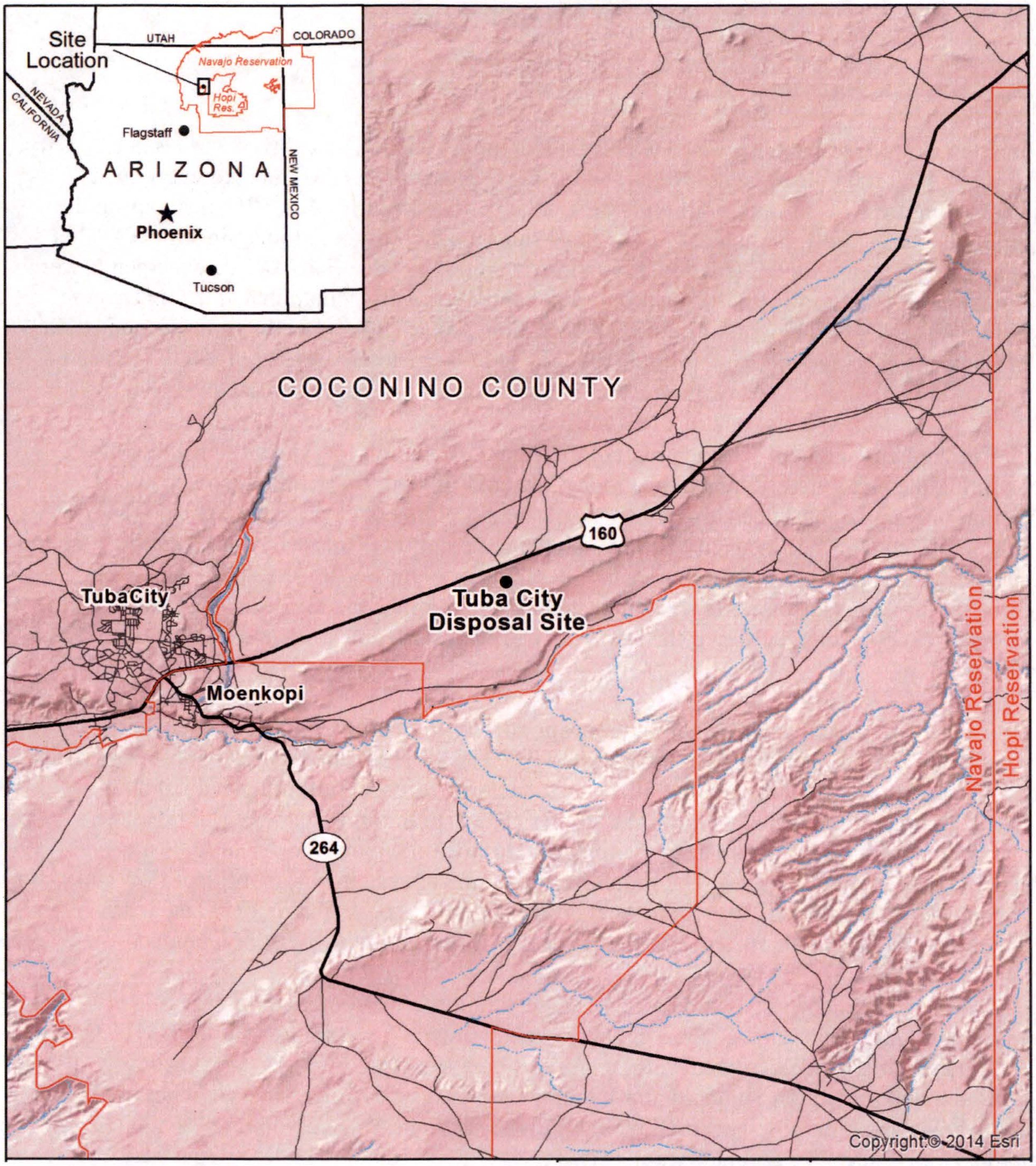

Figure 1. Site Location Map, Tuba City

Table 1. Tuba City Site Effluent Treatment Objectives

Parameter[a]	Treatment Objective	Treatment Objective Source
Chloride	250	Stakeholder agreement
Molybdenum	0.1	40 CFR 192
Nitrate (as N)	44 (10)	40 CFR 192
Selenium	0.01	40 CFR 192
Sulfate	250	Stakeholder agreement
Total dissolved solids	500	Stakeholder agreement
Uranium	0.044	40 CFR 192
pH (s.u.)	6.5–8.5	Stakeholder agreement

Note:
[a] Units are given in milligram per liter unless otherwise noted.

Abbreviations:
N = nitrogen
s.u. = standard units

The groundwater distillation treatment plant was started up in 2002 and was in operation until September 2014. Distillate water quality consistently met the regulatory standards and goals throughout this time period. The plant's on-stream factor (operating days per year) averaged 86% through the first six years of operations. The on-stream factor declined in the ensuing years mainly due to maintainability issues in the distillation system. The occurrence of operator safety-related incidents led to suspension of plant operations in September 2014. A Safe Standby Plan (DOE 2015c) was prepared to transition the site from operational status and disposition unused water treatment chemicals and treatment byproducts. The removal of excess sulfuric acid for reuse and the neutralization of residual acidic sludge, the final actions prescribed in the Safe Standby Plan, were completed in March and May 2016, respectively.

While the plant has been in safe standby condition, active groundwater remediation has continued through extraction and pond evaporation. In this configuration, contaminants are removed from the groundwater plume but there is no treated water available for return to the aquifer. Clean water is released as it evaporates from the pond surface, and contaminants are collected in solid or highly concentrated liquid form in the pond. On an annual basis, an extraction flow rate of about 10–15 gpm can be treated by this method.

The flow rate for groundwater remediation by pond evaporation is considerably lower than the GCAP prescribed rate of approximately 150 gpm over a 20-year duration. As such, the Interim Treatment Plan (DOE 2015b) presented:

- Guidance for the interim operation of extraction wells.
- Projection of an achievable annual average evaporative treatment rate.
- Description of how evaporative treatment performance is to be monitored.

The site has been operated under the Interim Treatment Plan since December 2015, following the concurrence of NRC.

Subsequent sections of this document provide:

- Interim Treatment System Evaluation (ITSE) background and objectives.
- Technical approach and reporting for the evaluation of enhanced evaporation, aquifer/formation geochemistry, and extraction pumping strategies.
- A milestone schedule.
- Progress reports.
- A staffing plan.

2.0 ITSE Background and Objectives

Prior to the September 2014 suspension of treatment plant operation, LM directed the preparation of an Alternatives Analysis of Contaminated Groundwater Treatment Technologies for the Tuba City Site (DOE 2015a). In this document, two remediation approaches were developed for:

- Replacement of the existing softening/distillation system, maintaining the throughput capacity at a nominal rate of 100 gpm and returning treated water to the aquifer.
- Replacement of the existing system with smaller capacity system (nominally 40 gpm) with no capability to return treated water to the aquifer.

The logic behind the smaller treatment capacity approach was based on an analysis of extraction well production rates and contaminant mass removal, indicating that a 40 gpm system could have an 80% contaminant removal efficiency rate relative to that of the 100 gpm system and would provide the benefit of long-term sustainability. However, a GCAP revision will be required before such a fundamental change in remediation approach can be made.

In early 2016, LM identified the need for planning, data collection and interpretation, and development of decision logic for a future remediation strategy. Consequently, LM directed that an ITSE be performed within a time frame of 2 years, with onsite test work completed within the first year. Initial plan development has utilized an observational approach that provides flexibility and the opportunity for future adjustments of strategies and goals as data collection and interpretation proceeds. Accordingly, changes in approach will be documented as the evaluation progresses.

In overview, the technical objectives of the ITSE are to optimize an evaporative treatment system, increase understanding of contaminant fate and transport in the aquifer, and optimize a groundwater extraction pumping strategy.

Whereas optimization of evaporative treatment is one of the main technical objectives, the ITSE is broadly intended to utilize the current interim operation status to treat as much contaminated water as possible. It is also intended to increase the site-specific knowledge base for the components of remediation (pond evaporation, contaminant geochemistry, and aquifer hydraulics), which can be evaluated while the groundwater treatment plant is in safe standby condition.

Ultimately, the three areas of ITSE focus noted above will be integrated to provide a basis for GCAP revision. The recommissioning of a groundwater treatment plant is not precluded by ITSE, and the "Alternatives Analysis" report (DOE 2015a) provides a basis for the future decision-making process, which could include groundwater treatment with return of treated water to the aquifer.

It is also important to note that if a groundwater treatment plant is recommissioned the site's evaporation pond will still be needed for the disposition of secondary waste. Optimization of the evaporative treatment process will provide operational benefit to the future remediation effort regardless of the overall remediation approach.

The evaluation objectives including technical, public affairs, and integrated GCAP input are described as follows.

2.1 Objective 1 – Evaporative Treatment Optimization

Determine one or more sustainable and efficient methods of evaporative treatment, capable of treating 40 gpm as the annual average flow rate. Prospective methods are described in Section 3.0, as "Technical Approach."

2.2 Objective 2 – Geochemical Analysis of Contaminant Mobility

Develop an understanding of contaminant and aquifer characteristics affecting contaminant fate and transport, independent of groundwater flow. Data will be collected for the determination of:

- Sorptive capacity of aquifer material in the area of contamination.
- Sorptive capacity of aquifer material downgradient from the contaminant plume.
- Solubility of contaminants in altered groundwater chemistry.

Physical and geochemical tests that will be performed in support of this objective are described in the "Technical Approach" section.

2.3 Objective 3 – Aquifer Response to Extraction Strategy

Utilize new water-level monitoring capability to determine aquifer response to groundwater extraction trials (various extraction locations, flow rates, pulsed operation).

With the use of an expanded monitoring network to assess plume geometry, conduct startup and shutdown hydraulic testing to define capture zone geometry, overall hydraulic performance, and remedy effectiveness.

2.4 Objective 4 – Public Affairs, Community Outreach

Public Affairs community outreach activities will parallel the scientific and engineering efforts associated with ITSE. Community Relations efforts will be expanded in fiscal year 2017 to include as many as three open-house events in Tuba City. As the technical work progresses, informational products, such as fact sheets, press releases, and posters, can be developed for presentation at the open houses. Fact sheets can also be published on the LM public website.

Agency stakeholders can be kept informed of ITSE efforts through the regularly scheduled quarterly meetings.

2.5 Objective 5 – Provide Input Basis for GCAP Revision, Optimized Extraction and Treatment

The current GCAP requires the return of treated water to the aquifer. This, of course, cannot be accomplished with evaporative treatment alone. If future treatment is to rely only on pond evaporation (potentially enhanced), the current GCAP requirement to return treated water to the aquifer would have to be changed with the concurrence of NRC.

If the return of treated water to the aquifer must be reinstated after completion of the ITSE, enhanced evaporation is relevant as secondary treatment for concentrated wastes resulting from the main water-treatment process train. It is likely that a new groundwater treatment plant will include ion-exchange softening as a pretreatment step and a new main treatment step for the production of treated water (suitable for return to the aquifer). Waste streams from pretreatment and main treatment can be routed to a new enhanced evaporation process, as determined by the ITSE. Any treatment option other than the existing distillation system will produce a greater volume of secondary waste, and will require enhanced evaporation capacity.

In support of GCAP revision, the ITSE will provide technical and cost data for one or more evaporative treatment alternatives.

Extraction and treatment alternatives to be considered for GCAP revision will be based on the results of:

- Desktop studies and/or pilot tests for enhanced evaporation.
- Aquifer/formation geochemical analyses.
- Groundwater extraction strategy.

3.0 Technical Approach

The overall technical approach for the ITSE is important given the variety of evaluations to be performed, toward an end goal of integrating all results into an effective GCAP revision. This planned approach is tactical and may change as testing and data-collection progress. As an initial set of guidelines, the technical approach for the development of data-quality objectives, regulatory review, and the three major ITSE topics (enhanced evaporation, geochemistry, and extraction pumping strategy) are described in this section. Key site features such as the main evaporation pond, overflow pond, and solar concentrators are shown in Figure 2.

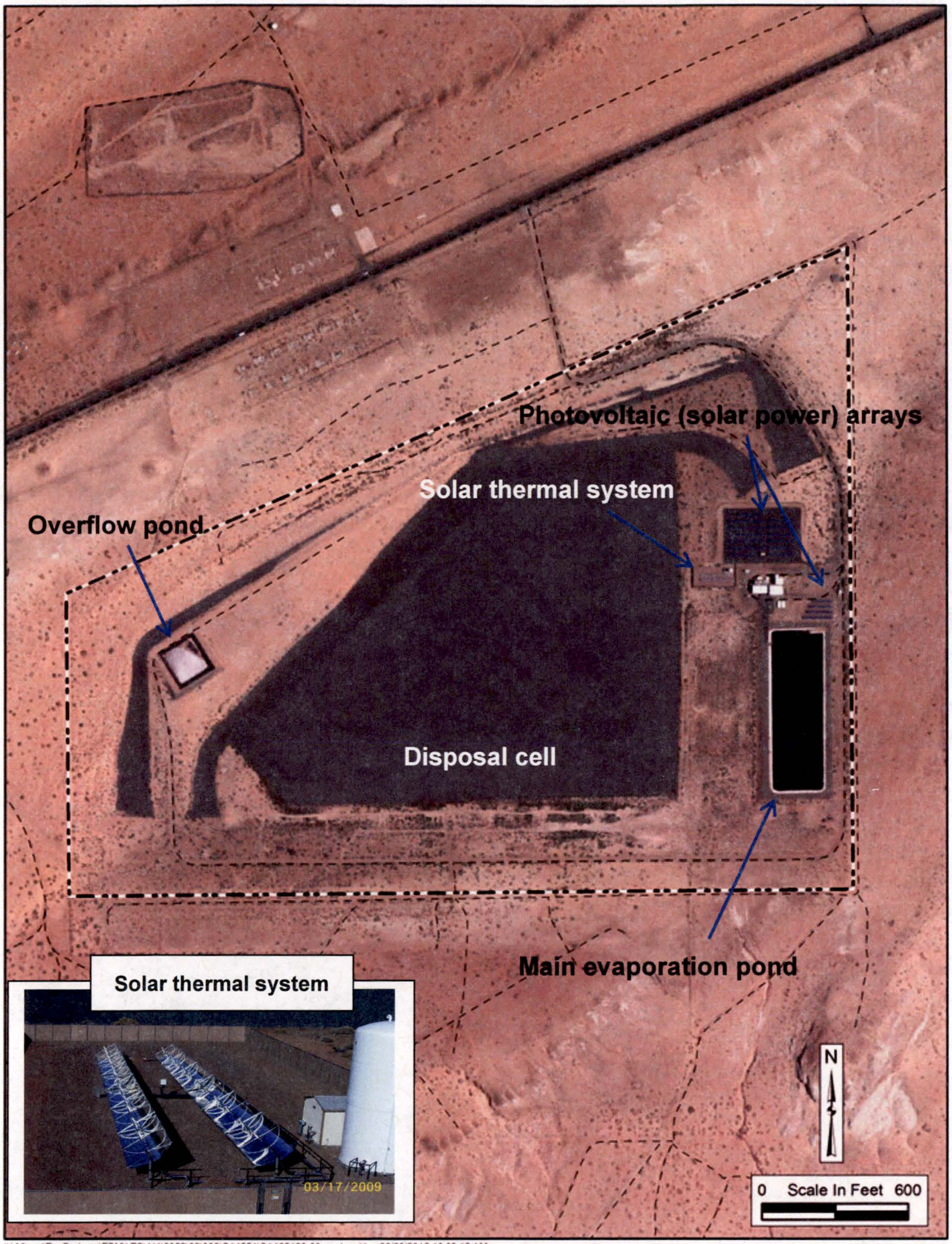

Figure 2. Site Features, Tuba City

3.1 Develop Data-Quality Objectives

Data-quality objectives will be developed to identify problems statements, focus data collection, ensure that each phase of evaluation will produce useful data, minimize data gaps and assumptions, and provide a solid basis for recommendations and conclusions. *Environmental Support Services Data Management Procedures* (LMS/PRO/S06690) will be utilized for guidance and as a reference to specific procedures that are relevant to the various phases of ITSE field trials and laboratory work.

Data necessary for enhanced evaporation evaluation will generally include extracted groundwater-quality parameters, flow rates from individual wells and total flow, meteorological data (temperature, wind speed, humidity, and solar radiation), and pond level and temperature. The existing data-collection routine will be modified as needed when various enhanced evaporation trials are defined. Frequency and duration of data collection will also be established as individual trials for enhanced evaporation are further defined.

Data for geochemical evaluations (column tests) will include column influent and effluent water-quality parameters collected periodically throughout the test duration and column material properties such as void ratio and hydraulic conductivity. Column tests are routinely performed by the LM Environmental Services Laboratory (ESL) personnel. Data requirements are well-understood, and existing protocols will be utilized, with potential trial-specific adjustments.

Data for extraction pumping evaluations will include those for wells in operation and duration, individual flow rates from extraction wells, water levels in relevant monitoring wells, and elapsed time to achieve drawdown. Specific parameters, frequency of measurement, and test durations will be determined as an initial step in planning extraction pumping tests.

The *Quality Assurance Manual* (LMS/POL/S04320) will be used to ensure that quality assurance policy and procedures are followed throughout ITSE field trials, laboratory work, and reporting.

3.2 Regulatory Review

NRC, the regulator for DOE under UMTRCA, has been informed of the ITSE scope (DOE 2016b); NRC responded (NRC 2016) stating that "NRC staff does not have any comments on the proposed evaluation at this time."

A completed National Environmental Policy Act (NEPA) Environmental Checklist concluded that the proposed actions relating to ITSE trials meet the criteria for categorical exclusion and are excluded from further NEPA review (DOE 2016a).

Review of other potentially relevant regulations will be performed as individual trials are defined. Federal, state, and tribal regulations will be considered, and all trials will be performed in compliance with applicable regulations. The need for permits (for example, for air emissions or groundwater withdrawal) will be researched, and the applicability of the permitting process to a short-term test will be determined. Descriptions of each trial will be provided in advance to stakeholder agencies.

3.2.1 Waste Management

The currently proposed ITSE field trials will not generate wastes that would require special handling or transport offsite for appropriate disposal. Waste management will follow guidance provided in the *Operating Manual for the Tuba City, Arizona, Disposal Site* (DOE 2015d).

3.3 Evaluation of Enhanced Evaporation Techniques

Enhanced evaporation techniques that may be evaluated include using the site's solar concentrators to preheat extracted groundwater, vertical mixing, dye addition, and the use of vendor-supplied pilot-scale test equipment. The preliminary technical approaches for these trials are summarized in this section.

3.3.1 Develop Baseline Capability for Evaporative Treatment

Prior to initiation of any evaluation of enhanced evaporation methods or technologies, the baseline performance of the existing pond must be documented. Baseline data collection will include:

- Total volume of water conveyed to pond.
- Seasonal (or monthly) flow rates.
- Projection of maximum annual volume that can be treated in the existing pond.

Background meteorological data represent a significant data gap for baselining. The nearest location at which data is routinely collected and is readily available by internet is Page, Arizona. Page is 56 miles north of Tuba City and at an elevation of 4100 feet (800 feet lower than Tuba City), which introduces differences in key parameters driving natural evaporation (ambient temperature, humidity, wind speed, and solar radiation). In addition to the uncertainty introduced by the use of long-term average climate data from a distant location, actual weather conditions in Tuba City throughout the duration of the evaluation could significantly vary from those in Page. Therefore, a meteorological data-collection unit was installed in June 2016 to provide a local basis for theoretical calculations of evaporation. Going forward, input data for evaporation rate calculations will be continuously collected and averaged monthly.

Baseline capability will be compared with the projected evaporative treatment nominal flow rate of 40 gpm. The efficiency increase to attain the higher flow rate will be calculated and documented as the target for ensuing trials.

3.3.2 Determine Viability of Overflow Pond for Use

The overflow pond could be utilized to collect passive evaporation (control) data for direct comparison with data collected in various onsite enhanced evaporation trials. It could also be used to increase the site's evaporative capacity.

The pond is located west of the disposal cell, as shown in Figure 1. It has a surface area of about 32,400 square feet and storage volume of approximately 2 million gallons. A transfer pump and pipeline from the evaporation pond to the overflow pond are in place but have not been used. The main evaporation pond has been utilized at a consistently safe water level throughout the site's operational history, and the overflow pond has been maintained to serve as a contingent storage unit for unexpected events.

The condition of the overflow pond was briefly described in the site's 2016 Annual Inspection Report (DOE 2016d), noting the presence of windblown sand and evaporites on the liner. A more rigorous operability review of the pond would be performed prior to use for the ITSE and would include inspections of the pond liner, transfer pump, and conveyance piping.

Repairs to the pond liner may be needed, resulting from years of exposure to wind and ultraviolet radiation from sunlight. Repairs to the transfer pump and pipeline should be limited to normal startup maintenance items (e.g., replacement of seals and lubrication of moving parts). Repairs, if any are needed, should be scheduled and executed to ensure that the overflow pond is usable within the ITSE scope and/or for future contingency storage needs.

If the overflow pond is not viable, temporary modular water containment units could be purchased or leased, to support data collection to establish the natural evaporation rate baseline. Modular containment units typically consist of a steel framework with liner material placed over the frame. Various sizes are available, and the units can be fit with inlet/outlet flow controls and secondary containment, as necessary.

The overflow pond should only be used if it is found to be in ready or very near ready condition. If significant repairs are deemed necessary, baseline data can be used in lieu of field trial control data.

3.3.3 Enhanced Evaporation Techniques

Enhanced evaporation techniques that may be evaluated include the following:

- Use of the onsite solar thermal system to heat extracted groundwater prior to inflow to the pond.
- Vertical mixing in the pond.
- Dye addition.
- Perimeter manifold for pond inflow.
- Wind-Aided Intensified Evaporation (WAIV).

Preliminary study will include research (internet searches for data or reports) and calculations leading to decisions on whether field testing is warranted. The decision point for preliminary work will be documented in technical memoranda, which will be provided by DOE to NRC. Following preliminary study, the need for communication to agency stakeholders and the local community will be considered as a second decision point. The process may then continue with engineering design, procurement, and field implementation. All field work will be performed with a graded approach for conformance to the Integrated Work Control Process (DOE 2015e) and the Integrated Safety Management System (DOE 2016e).

3.3.3.1 Solar Thermal System

The concept for evaluation of the solar thermal system (preheat extracted groundwater) is outlined below.

Preliminary Study. Calculations will be prepared to estimate:

- Achievable temperature increase for extracted groundwater flowing through the solar thermal system.
- Evaporation rate for the heated water only, prior to inflow to pond.
- Potential for gypsum precipitation due to temperature increase.
- Projected increase in evaporation rate based on higher temperature inflow to the pond.
- Pond temperature change over time, as heated water is added.

Preliminary study will also include an inspection of the extraction well piping and solar thermal system to identify any required pipe/valve/fittings modifications to establish the preheating flow path (from wells through solar thermal system to pond). It is expected that a significant increase in evaporation rate is achievable with relatively minor piping modifications and that field testing will be justified. Calculations and preliminary engineering of piping modifications will be documented.

Inform Stakeholders. Throughout the ITSE duration, agency stakeholders and the local community will be informed when field trials are being performed. The purpose, duration, and anticipated results of field trials will be described. Communications with regard to field trials may occur through open-house events, quarterly meetings, and public website postings.

Specific to the solar thermal system trial, stakeholders will initially be informed that existing equipment will be utilized, which presents no new risks to operators, the public, or wildlife. Stakeholders will also be informed that the pond may have a steamy appearance in periods of cold weather and that the trial duration may be 6 months or longer.

Design and Operability Review. As-built drawings for the extraction well piping and solar thermal systems will be reviewed and marked up with the modifications identified in the preliminary inspection. Piping and instrumentation diagrams (P&IDs) will be reviewed and potentially revised to include modifications to manual and automated controls and measurement devices needed during operation of the solar thermal field trial.

The modifications will require the flow of contaminated groundwater through some piping and equipment (heat exchanger and solar thermal water tank) that were previously exposed only to treated water (evaporator system distillate). Potential issues arising from this change in equipment service will be considered and resolved.

The effects of higher pond temperature on the pond liners and on sediments will be considered. Pond temperature will be monitored throughout the trial and will be controlled to maintain liner integrity and prevent environmental release.

A Hazards and Operability (HAZOP) review will be performed when the modified P&IDs are available. Through review of the P&IDs the HAZOP team will identify process-related hazards, qualitatively assess the probability of occurrence and severity of consequences, and determine mitigative or preventive controls needed to reduce process hazards to acceptable levels. The HAZOP review will also identify any operability issues, to ensure that the functions of manual and automated controls are understood by field staff. HAZOP review results and recommendations will be incorporated in to the Trial Plan, discussed below.

Procurement and Installation. It is anticipated that piping and controls modifications will be minor and that most of the materials will be available in onsite inventory. Any items that are not readily available will likely be catalog orders, which can be executed using the existing field purchase process.

Piping modifications will be made by onsite staff. Preoperational testing will be performed to ensure that the modifications are water-tight and that monitoring instrumentation and controls are functional. Modifications will be checked in the field against the revised P&IDs.

Trial Plan. In tandem with the design work, a trial plan will be prepared. The plan will describe operation of the modified flow path, flow and temperature control and monitoring points, pond inflow and evaporation rates, projected duration, and data collection and management. The plan will also include routine startup, operating, and shutdown procedures.

Reporting. A report will be prepared at the conclusion of the trial documenting results and operational issues encountered. A fact sheet may also be prepared, and as noted above, progress and final results for field trials will be communicated to agency stakeholders and the local community through regularly scheduled outreach events.

3.3.3.2 Vertical Circulation in Pond

Preliminary Study. Contact has been made with an equipment supplier regarding the potential for increased evaporation through the use of circulation pumps. The pumps draw in water from depth and circulate it to near the pond surface. An increase in evaporation rate of approximately 20% has been documented. Evaporation is enhanced by maintaining a consistent temperature through a greater depth profile than would naturally occur.

In some cases, water near the bottom of an evaporation pond can be denser and have a higher concentration of dissolved solids than water near the pond surface. This high-density, high-concentration layer may also have a higher capacity for holding heat, which would result in a temperature increase at depth. Circulation of the warmer water from depth to the surface of the pond provides a mechanism for increasing evaporation. Generally, this situation would be more likely to occur in a relatively deep pond, in which natural vertical mixing is minimal. The Tuba City site pond is relatively shallow and is well-mixed by wind action, so vertical mixing by pumping may be less effective.

Preliminary study will be primarily done by the equipment supplier. The supplier's questionnaire will be completed and returned. The questionnaire covers water quality and quantity, climate conditions, and pond design parameters, which allows the supplier to estimate vertical circulation pumping requirements for evaporation enhancement.

Preliminary study will also include an inspection of the extraction well piping and pond to identify any required pipe/valve/fittings modifications to establish the vertical circulation flow path. The preliminary study effort (completion of the supplier's questionnaire) and supplier's recommendations will be documented.

The decision to proceed with a field trial will be primarily based on the supplier's recommendations and prediction of the achievable increase in rate of evaporation. If a relatively small increase is projected, cost and logistics may preclude performance of field testing. Potential radiological contamination of supplier's equipment may also present an obstacle to field trials. If effort is curtailed based on the supplier's recommendations, the decision will be documented in a technical memorandum. If field trials are justified, the general process will be followed as outlined below.

Inform Stakeholders. Prior to the pond circulation trial, stakeholders will initially be informed that new equipment will be installed, but it will not present new risks to operators, the public, or wildlife. The equipment will be placed in the pond, and the water circulation will be completely below the pond water-level surface. Circulation does not involve spraying water and presents no potential for increased air emissions. The trial duration may be 6 months or longer and will be determined based on data analysis throughout the trial.

Design and Operability Review. As-built drawings for the extraction well piping and pond will be reviewed and revised in collaboration with the supplier. Modifications to manual and automated controls and measurement devices needed in the duration of the vertical mixing field trial will be designed.

The vertical mixing trial will require the flow of contaminated groundwater through the supplier's equipment. Potential issues arising from equipment contamination will be discussed with the supplier. An acceptable decontamination method will be determined, or if equipment cannot be decontaminated and returned to the supplier's fleet, outright purchase may be considered.

A HAZOP review will be performed when the trial equipment design is available. Mitigative/preventive controls will be recommended for any unacceptable process hazards identified. HAZOP review results and recommendations will be incorporated in to the Trial Plan, discussed below.

Procurement and Installation. If available for short-term field testing in uranium-contaminated water, circulation pumps will be ordered from a supplier. Extracted groundwater flow rates and pond design parameters will be provided to facilitate installation design and planning by the supplier.

Installation will be performed by subcontracted personnel from the equipment supply company. Preoperational testing will be performed to ensure that the process, monitoring, and control components are functional. Actual installed conditions will be checked in the field against the supplier's plan/design.

Trial Plan. Parallel with the design work, a trial plan will be prepared. The plan will describe operation of the mixing pumps, pond temperature monitoring points, pond inflow and evaporation measurements, projected duration, and data collection and management. The plan will also include routine startup, operating, and shutdown procedures.

Reporting. A report will be prepared at the conclusion of the trial documenting results and operational issues encountered. A fact sheet may also be prepared, and as noted above, progress and final results for field trials will be communicated to agency stakeholders and the local community through regularly scheduled outreach events.

3.3.3.3 Dye Addition

Preliminary Study. Contact has been made with an operating potash mine regarding the potential for increased evaporation through dye addition. The Intrepid Mine, near Moab, Utah, utilizes a blue dye in their ponds to increase the evaporation rate through increased absorption of natural solar heat. The mine uses ponds to recover their main products, sodium chloride (table salt) and potassium chloride (potash), by evaporating the ponds to dryness then collecting the accumulated salts. While no quantitative evaluation of dye addition has yet been done, it is estimated that a 10% increase in evaporation rate is achieved. A food-grade dye is used, which does not evaporate. The dye is a residual within the recovered salts.

In mine operation a dye concentration of 1 to 1.5 parts per million is targeted but is not tightly controlled. The volume of dye addition is calculated based on volume of water present and the desired dye concentration range. No special mixing methods are employed. Dye is added batchwise, and mixing is achieved by wind and wave action over a period of several days.

Preliminary study will include identification of a dye supplier and a review of the Safety Data Sheet to ensure that there are no potential unforeseen adverse impacts. The volume of dye needed for the duration of the field trial will be calculated.

It is assumed that the dye addition field trial will be justified, primarily because of its relative simplicity of execution and low cost. The decision to proceed (or not) with a field trial will be documented in a technical memorandum.

Inform Stakeholders. Specific to the dye addition trial, stakeholders will initially be informed that a food-grade dye will be used to give the pond a blue color and that it will not present new risks to operators, the public, or wildlife.

Results of the dye addition trial will be documented and communicated to stakeholders through routine Public Affairs events.

Design and Operability Review. Design will include consideration of an optimum method of adding dye to the pond. If a relatively small volume is needed, it may be possible to manually dump dye in to the pond using 5-gallon pails. If larger volumes are needed, an influent injection system may be beneficial. The need for mechanical mixing will be evaluated after the initial manual addition of dye through observation of the pond's natural (wind and wave) mixing potential.

It is anticipated that a basic job safety analysis will adequately identify hazards and any mitigative/preventive controls needed. The method of dye addition will be covered in an operability review.

Procurement and Installation. Dye will be ordered and added to the pond to reach a calculated set point concentration. The method of addition will be determined after calculating the volume of dye needed to reach a set point concentration.

Trial Plan. The dye addition trial plan will describe the mechanism for increase in evaporation rate resulting from dye, pond temperature measurement points, pond inflow and evaporation measurements, projected duration, and data collection and management. Assuming that results for this trial can be obtained within a 1-month duration, the previous month's weather and evaporation data may be used as a control against which the dye-enhanced evaporation rate can be calculated.

Multiple trials using different dye concentrations may be performed. In order to evaluate a range of dye concentrations, the lowest concentration will be tested first such that later trials of increasing concentration can proceed without lag time between trials.

Reporting. A report will be prepared at the conclusion of the trial documenting results and operational issues encountered. A fact sheet may also be prepared, and as noted above, progress and final results for field trials will be communicated to agency stakeholders and the local community through regularly scheduled outreach events.

3.3.3.4 Pond Berm Perimeter Influent Manifold

Preliminary Study. An increase in evaporation rate may be achieved by distributing the pond influent on the full perimeter of the pond, running it down the berm liner to the water surface. This method theoretically provides additional surface area and heat transfer from the liner to increase the evaporation rate. A perimeter manifold has been used at the Shiprock, New Mexico, site. Preliminary study will involve review of Shiprock site pond inflow and evaporation data and operational issues that have occurred.

The Tuba City site pond is not conducive to this type of evaporation enhancement technique. The pond level is routinely maintained at a level that does not leave a significant area of the berm liner exposed. Additionally, the pond liner is white and, thus, does not absorb as much solar heat as a liner of darker color would.

It is unlikely that a pond berm perimeter influent manifold will be field tested at the Tuba City site unless warranted by results of the preliminary study. Further definition of this field trial planning proposal is not justified at this time.

3.3.3.5 Wind-Aided Intensified Evaporation

Preliminary Study. Wind-Aided Intensified Evaporation is a vendor-supplied enhanced evaporation system. The WAIV units consist of a series of textile sheets hanging from a frame with inlet water distributed evenly on the sheets from a manifold above. Increased surface area is the primary method of evaporation rate enhancement. The WAIV technology was previously evaluated in the *Alternatives Analysis of Contaminated Groundwater Treatment Technologies, Tuba City, Arizona, Disposal Site* (DOE 2015a).

As the technology has been previously evaluated for potential implementation at the site, preliminary study will involve providing the supplier with site data (water flow rate and quality, pond design parameters, availability of footprint space and utility power) and receiving their recommendations for pilot-scale field testing.

Preliminary study will also include an inspection of the extraction well piping and pond to identify any required pipe/valve/fittings modifications to establish the path for WAIV inlet and outlet flows. The preliminary study effort (completion of the supplier's questionnaire), supplier's recommendations, and observations from the inspection will be documented.

The decision to proceed with field trial will be primarily based on the supplier's recommendations and prediction of the achievable increase in rate of evaporation. Potential radiological contamination of the supplier's equipment may also present an obstacle to field trials. If the supplier can quantitatively model the WAIV system performance based on available data, a field trial may not be needed. If the effort is curtailed based on the supplier's recommendations, the decision will be documented in a technical memorandum. If field trials are justified, the general process will be followed as outlined below.

Inform Stakeholders. Specific to a WAIV system trial, stakeholders will initially be informed that new equipment will be installed for a short-term trial, but it will present no new risks to operators, the public, or wildlife.

Design and Operability Review. As-built drawings for the extraction well piping and pond will be reviewed and marked up in cooperation with the supplier. Modifications to manual and automated controls and measurement devices needed in the duration of the WAIV system field trial will be designed.

The WAIV system trial will require the flow of contaminated groundwater through the supplier's equipment. Potential issues arising from equipment contamination will be discussed with the supplier. An acceptable decontamination method will be determined, or if equipment cannot be decontaminated and returned to the supplier's fleet, outright purchase may be considered.

A HAZOP review will be performed when the trial equipment design is available. Mitigative/preventive controls will be recommended for any unacceptable process hazards identified. Maintenance requirements and procedures will be evaluated as will the potential for contaminant migration beyond the limits of the radiological control area. HAZOP review results and recommendations will be incorporated in to the Trial Plan, discussed below.

Procurement and Installation. If available for short-term field testing in uranium-contaminated water, a WAIV system pilot-scale unit will be ordered from a supplier. Extracted groundwater flow rates and pond design parameters will be provided to facilitate installation design and planning by the supplier.

Installation will be performed by subcontracted personnel from the equipment supply company. Preoperational testing will be performed to ensure that the process, monitoring, and control components are functional. Actual installed conditions will be checked in the field against the supplier's plan/design.

Trial Plan. A trial plan will be prepared in tandem with the design work. The plan will describe the operation of the WAIV system, pond, system inflow and evaporation measurements, contaminant concentrations at the WAIV outlet (return to evaporation pond) projected duration, and data collection and management. The plan will also include routine startup, maintenance, operating, and shutdown procedures.

Reporting. A report will be prepared at the conclusion of the trial documenting the results and operational issues encountered. A fact sheet may also be prepared, and as noted above, progress and final results for field trials will be communicated to agency stakeholders and the local community through regularly scheduled Public Affairs events.

3.3.4 Enhanced Evaporation Report

In addition to the reporting described for each of the potential field trials, ITSE reports are scheduled for submittal at 6-month and 12-month milestones. The milestone reports will document progress in all phases of the ITSE. Enhanced evaporation will be reported on when all trials are complete, as follows.

3.3.4.1 Screening of Techniques

Enhanced evaporation techniques that were subject to desktop study or field trials will be summarized. The summaries will include discussion of:

- Technical advantages and disadvantages.
- Comparative (high, medium, and low) capital expense.
- Comparative operations and maintenance expense.

Enhanced evaporation techniques will be screened based on achievable improvements in evaporation rates and implementability. Techniques will be evaluated individually and in combination if potential synergies are apparent (e.g., vertical mixing and dye addition, or solar thermal preheat with any in-pond option). A retain or reject decision will be documented for each technique.

3.3.4.2 Evaporative Treatment Alternatives Development

With the use of retained techniques, complete conceptual alternatives for evaporative treatment (groundwater extraction and conveyance, influent storage, enhanced evaporation technique, concentrate management) will be developed. Alternative development will include process descriptions and schematics and estimated capital and operating expenses.

3.3.4.3 Analysis

An evaluation matrix will be developed. Evaluation criteria may be selected from the following: implementability, technical effectiveness, maintainability, reliability, operability, cost, flexibility, safety, environmental hazards (treatment chemicals and secondary wastes), capital and operating expense, and schedule. Criteria will be weighted by their relative importance and then scored. The highest scoring alternative (or highest two) will be documented as the preferred selection(s).

3.3.4.4 Conclusions and Recommendations

The conclusions and recommendations will include a proposed path forward for further development of the preferred alternative. Implementation of an evaporative treatment alternative is dependent upon stakeholder acceptability, as it would fundamentally change the previous approach, which included the return of treated water to the aquifer. Assuming that stakeholder and NRC approval can be obtained, the path forward will include:

- Preparing capital and operating expense estimates at a greater level of accuracy.
- Identifying viable suppliers of enhanced evaporation process equipment and appurtenances.
- Preparing a request for bids (technical and commercial information).
- Developing a budget estimate and preliminary schedule for implementation.

If stakeholder and NRC approval of an evaporative treatment alternative cannot be obtained, enhanced evaporation may still be beneficial as a secondary process for handling the waste stream from a new treatment system (distillation or membrane filtration). A path forward, similar to the one outlined above, would also be applicable to further development of enhanced evaporation as a process for handling secondary wastes. In this case, continued use of the existing pond without modifications would also be considered.

3.4 Geochemical Analyses

Geochemical analyses are proposed as a method to determine how contaminant migration is affected by subsurface physical (sorption) and chemical (speciation and solubility) interactions.

3.4.1 Potential for Long-Term Contaminant Leaching

Contaminants may be bound in relatively insoluble forms in the aquifer formation and may be gradually released over time into the groundwater plume through dissolution as unimpacted groundwater moves in to the site. This transport mechanism can be tested through the use of core material collected from the contaminant plume. Batch testing will precede continuous flow column testing.

Batch sorption and leaching tests (also known as “flask tests”) will initially be performed as indicators of the contaminant sorption capacity for unimpacted core material, and the rate of contaminant desorption from impacted core material, respectively. The initial understanding of sorption capacity and desorption rate can be used to plan the sampling and analytical intervals for the continuous flow column tests. Planned sampling intervals will allow for a more accurate determination of the number of pore volumes required to reach equilibrium conditions as determined by column testing.

Column tests, flowing unimpacted water through impacted (contaminated) core material, will be performed. Leachate (column effluent) will be analyzed for contaminants of concern at several time steps throughout the column test. Analytical results will be indicative of the potential for long-term release of contamination through the dissolution and desorption of contaminants that may be bound in the aquifer formation.

Materials required for the test include core material from the contaminant plume and unimpacted water from the site. Core material will be collected during the drilling of new monitoring wells, currently scheduled for December 2016–January 2017. Unimpacted site water may be recovered from monitoring wells in upgradient locations. The quantity of water required for the completion of column testing will be estimated in advance, and an adequate supply will be available when testing is initiated. The supply well for onsite plumbing (sinks, shower, toilets) could be utilized as the primary source of unimpacted water for column tests.

Testing will be performed in the Environmental Sciences Laboratory in Grand Junction, Colorado. Bench-scale equipment and written procedures are readily available, and ESL personnel are experienced in the execution of column tests. ESL analytical capabilities will be utilized, along with external laboratory services as needed. The *Environmental Sciences Laboratory Procedures Manual* (LMS/PRO/S04343) will be utilized for all geochemical evaluation and analytical chemistry test work performed at the ESL.

Leachate sampling and analysis will be performed at a predetermined interval, typically once per 25 pore volumes passed. Column tests will continue until influent and effluent concentrations are indicative of equilibrium conditions (i.e., no changes in water quality are occurring). Preliminarily, 15 column tests are proposed utilizing a total of 12 core samples (six samples each from two new wells drilled through the contaminant plume) and 3 additional tests run at slower (to be determined) flow rates. Three columns tests can be run simultaneously, and the expected duration for completion of 15 column tests is 3 months.

Progress will be reported in the 6-month milestone report. Final results will be reported in the 12-month report. Column leachate water quality and pore volumes required to reach equilibrium will be indicative of the potential to remediate groundwater and the contaminated aquifer material.

3.4.2 Potential for Long-Term Natural Attenuation

Movement of dissolved contaminants may be limited by natural attenuation. If plume migration is occurring, dissolved contaminants may become bound in the aquifer formation, through sorption to material that has not been previously impacted. This transport mechanism can be tested through the use of core material collected from an area downgradient from the current contaminant plume. Column tests, flowing impacted (contaminated) water collected from extraction wells in the plume area, through unimpacted core material, will be performed.

Column testing for the determination of long-term attenuation will utilize unimpacted core material, which will be collected when new monitoring wells are drilled. Contaminated groundwater collected from an extraction well (or wells) will be used in the column tests, with column leachate periodically sampled until an equilibrium condition (no change in leachate concentration between samples) is reached. Fifteen column tests are proposed, using 6 core samples from 2 wells and an additional 3 tests at slower flow rate.

The long-term attenuation column tests will be performed after the contaminant leaching tests. It is unlikely that these tests will be initiated before the 6-month milestone. Results will be reported in the final report. Column leachate quality and pore volumes to reach equilibrium will be indicative of the potential for natural attenuation of contamination.

3.4.3 Potential To Chemically Mobilize or Immobilize Contaminants

The geochemistry within the plume and the affected aquifer formation material may be altered to either immobilize contaminants in place or more rapidly dissolve/desorb contaminants that are bound to formation material.

Immobilizing contaminants will limit future plume migration and should reduce the concentrations of contaminants present in dissolved (mobile in groundwater) form. Immobilization could be accomplished through addition of ferric chloride, which is expected to increase the sorption capacity of aquifer formation materials. This mechanism can be tested through the use of column tests, running impacted water augmented with ferric chloride through impacted or unimpacted core material. Leachate will be analyzed for contaminants of concern, and results will be indicative of the potential for immobilization.

Conversely, an approach to alter the geochemistry to mobilize sorbed contaminants may also be tested. Mobilization could be accomplished through the addition of sodium bicarbonate in a manner similar to that of solution mining (also known as *in situ* recovery). The existing system of extraction wells would be relied upon to capture the mobilized contaminants. Some supplemental wellfield design, including the use of injection wells, would likely be needed in order move forward with a mobilization approach to groundwater remediation. As an alternative to injection wells, the existing infiltration trench with addition of a crushed limestone bed will also be considered as a method of introducing contaminant mobilization chemistry into the aquifer.

The viability of the mobilization approach can be tested through use of crushed contaminated core material and unimpacted water, with added limestone or sodium bicarbonate. Leachate collected from column tests would be analyzed for contaminants of concern for comparison with an experimental control column (contaminated core material with unimpacted water but no sodium bicarbonate added). Analytical results from column leachate samples are expected to show an increased concentration of uranium, indicative that immobile contaminants (sorbed and relatively insoluble) can be mobilized and removed. Analytical results may be utilized as input data for reactive transport modeling, predictive of the potential to remediate the plume.

Contaminant mobilization/immobilization testing will be scoped as results from the contaminant leaching and natural attenuation column test results become available.

3.4.4 Geochemical Analyses Report

Results of geochemical analyses will be reported in the 6-month and 12-month ITSE reports. Recommendations for further study will be provided.

3.5 Aquifer Response to Extraction Strategies

A groundwater extraction strategy that will support a consistent flow rate of at least 40 gpm will be developed. The objectives will be to identify the extraction wells that will consistently produce the needed flow, remove contaminants from the plume, and optimally manage plume migration.

3.5.1 Extraction Strategies

The groundwater flow model for the site may be used to simulate the aquifer and plume response to various extraction strategies including static and dynamic pumping approaches. Those that show promise for improvement in contaminant mass removal or plume migration control or both may be field tested.

Strategies include the following:

- Pulsed operation of extraction wells (brief shutdowns to allow water level and contaminant concentrations to rebound).
- Operational rotation of extraction wells.
- Operation of downgradient injection wells.

Note that the operation of injection wells would require pilot operation of a treatment system (ion exchange/reverse osmosis) to generate treated water for reinjection. The current scope, schedule, and budget do not include advanced water treatment on a pilot scale.

Extraction well testing strategies (i.e., the selection of wells, flow rates, duration of extraction pumping, and monitoring wells utilized to measure aquifer response) beyond the general approach described above are still to be determined. The draft *Annual Groundwater Report April 2015 Through March 2016, Tuba City, Arizona, Disposal Site* (DOE 2016c) will initially be utilized as guidance for extraction strategies development. Additionally, the *Plan for Interim Treatment During Distillation Shutdown for the Tuba City, Arizona, Disposal Site* (DOE 2015d) provides an "Extraction Productivity Ranking for Uranium Removal," which documents historical extraction well flow rates and the percentage of uranium removed, on a well-by-well basis. This ranking may also be used in the planning of extraction strategies to be tested.

3.5.2 Aquifer Response Predictions and Data Collection

The results of groundwater flow model simulations of extraction strategies will be reviewed to determine if field testing is warranted. Field tests may be undertaken to validate and verify model results.

Twenty monitoring wells will be equipped with pressure transducers and programmable data loggers to obtain automated water-level measurements. Aquifer and plume response to variations in extraction strategy will be monitored through water-level data (depth of drawdown and radius of influence around extraction wells).

Groundwater samples will be collected and analyzed for comparison of mass removal achieved in the various extraction strategies.

3.5.3 Extraction Strategies and Aquifer Response Reporting

Results of model simulations and field tests will be reported in the milestone reports.

4.0 Schedule

A summary of proposed ITSE milestones is presented in Table 2.

Table 2. Proposed ITSE Milestones for the Tuba City Site

Item	Completion Date
Draft ITSE plan (as PEMP submittal)	August 30, 2016
Final ITSE plan	October 2016
Procure and install monitoring and data logging equipment	October 2016
Geochemical testing	July 2017
Field trials and data collection (enhanced evaporation and extraction)	August 2017
Progress reporting	6-month intervals
Final report (as PEMP submittal)	February 2018

5.0 Reporting

Progress reports covering all aspects of the technical approach (enhanced evaporation, geochemical evaluation, aquifer response to extraction) will be provided at 6-month and 12-month milestones in the year-long data-collection phase of the project. A final report, integrating the results of all evaluations into recommendations for GCAP revision, will be submitted within 3 months after the completion of the data-collection phase. The final report will be a PEMP submittal.

Other technical memoranda will be prepared throughout the ITSE duration, as described in the Section 3.0 "Technical Approach" part of this plan, to document specific pieces of the technical approach. Scope and schedule requirements for these documents are to be determined as the ITSE progresses.

Materials for communication with agency stakeholders and the local community will be prepared throughout the ITSE duration. These may include fact sheets, posters for presentation at open-house events, and quarterly meeting presentation materials.

6.0 Staffing

Staffing and budgeting plans for ITSE were prepared as part of the Baseline Change Proposal process. The plan is for all work to be done by the Legacy Management Support (LMS) contractor, Navarro Research and Engineering, Inc. (Navarro), as summarized here.

It is anticipated that effort related to enhanced evaporation evaluations can be handled by current site-assigned Navarro staff (site lead, site operations manager, plant operators, and others as needed). Staffing needs will be continually evaluated, and action will be taken if staff availability begins to impact the planned ITSE scope or schedule.

Effort related to geochemical evaluations can be handled by in-house LMS Navarro subject matter experts (SMEs) in the areas of geochemistry and hydrology. All laboratory work related to the execution of column tests will be performed by Navarro ESL personnel. Analytical chemistry may be performed internally (ESL) or by an external accredited laboratory.

Groundwater extraction strategy evaluations can also be handled by in-house SMEs in the area of hydrology and groundwater hydrology/geochemistry modeling.

7.0 References

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NRC (U.S. Nuclear Regulatory Commission), 2016. Staff Review of the Proposed Interim Treatment System Evaluation for the Tuba City, Arizona, Disposal Site (Docket Number: WM-73), mail correspondence from NRC to DOE LM, July 28.

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