**In-Situ** Coal Combustion Products Impoundment Closure/Remediation Strategy

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EXECUTIVE SUMMARY

Silar Services Inc. (SSI) and Natural Resources Technology, Inc. (NRT) have developed an engineered ash impoundment closure approach that provides a technically sound and lower cost closure option to utilities.

The *in-situ* ash impoundment closure/remediation approach can eliminate leaching and reduce geotechnical instability that contributes to impoundment failures. To do so the ash is hydraulically isolated from the groundwater by constructing a hydraulic barrier at the bottom of the impoundment using engineered *in-situ* solidification/stabilization (ISS) applications on the ash and/or underlying natural material. These demonstrated ISS applications can also enhance geotechnical stability by increasing embankment strength, reducing saturated conditions and increasing the overall factor of safety for slope failure.

This approach would allow for engineered in-place closure of ash impoundments while satisfying a broad range of stakeholders. In summary, the intent of the approach is to:

- Meet regulatory requirements for closure and/or corrective action on impoundments;
- Facilitate groundwater corrective action by isolating the ash and providing a barrier to prevent continued contamination of groundwater;
- Eliminate the need to remove all ash from impoundments;
- Significantly reduce the amount of dewatering, treatment and disposal of ash contact water during impoundment closure;
- Eliminate the need to site and permit new landfill space for ash from existing impoundments; and
- Significantly reduce cost to close impoundments.
The following provides a presentation of the regulatory and technical considerations, a
discussion of the strategy, and recommendations on how to move forward with a
demonstration of the closure methods.

PROBLEM STATEMENT

Subject to the pending USEPA final rule for Disposal of Coal Combustion Residuals
from Electric Utilities, specifically 40 CFR, Part 257, Subpart D - Standards for the
Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments, ash
impoundments face a complex web of regulations that present significant compliance
risks to manage. This in-situ ash impoundment closure approach is designed to mitigate
the environmental risks and meet compliance requirements to the benefit of facility
owners and other stakeholders.

For decades, operators of coal fired power plants have managed coal combustion
products (CCPs) on-site in ash landfills and/or ash impoundments (or ponds). There are
two significant risks associated with these impoundments: potential leaching of CCP
contaminants and structural instability. Most coal fired power plants and their associated
ash disposal management facilities are constructed adjacent to rivers and other
waterways for cooling water requirements and to allow discharge via National Pollutant
Discharge Elimination System (NPDES) permit. At the time of construction and during
operation of many of these impoundments there were no regulatory requirements for
constructing liners and many of these impoundments remain unlined. The lack of a liner
allows the migration of groundwater through the ash, potentially leaching CCP
contaminants into the groundwater. Groundwater impacts have been documented at
several ash impoundments. In addition, because most impoundments are constructed
with earthen berms there are concerns with long term structural stability and the
potential for the impoundments to fail causing releases into the environment.

Stakeholders including ash impoundment owners, regulators, environmental groups,
and the general public are seeking an appropriate closure approach for these ash
impoundments that are facing pending federal regulation. Previous closure strategies
range from simply capping the ash impoundments to eliminate infiltration and reduce
potential leaching of CCP contaminants into the groundwater to complete removal of the
ash from the impoundment and relocation in a newly constructed lined landfill. The
pending regulatory framework further complicates the situation, renders some previous
closure strategies non-compliant, and includes imposing requirements that are difficult
to meet without implementing more complex and costly solutions that may also
introduce new risks.

TECHNICAL FACTORS

Many ash impoundments are of similar construction. Commonly, they are:

- Constructed as large scale settling basins, surrounded by soil berms or dikes to
  create storage for wet/sluiced ash;
constructed to discharge decant water to a receiving body of water through a permitted NPDES outfall or other permitted discharge; 

sometimes sited on natural depressions or ravines to increase storage capacity; and, 

often constructed without a liner, particularly in older impoundments.

Consequently, there are common concerns and technical challenges for closure of the impoundments that include the following:

- Coal ash fill located below the water table can serve as a continual source for leaching of CCP constituents to groundwater (e.g., boron and sulfate, trace metals);
- Placement of saturated coal ash within the impoundment can lead to an increase in hydraulic head above the naturally occurring groundwater table, which can exacerbate leaching of coal ash constituents;
- Standard excavation and dewatering construction techniques are often not feasible for excavation and removal of saturated ash. Specialized construction techniques are needed;
- Extensive dewatering required to close impoundments introduces a significant water treatment challenge. Ash constituents including boron, sulfate, and other trace metals can be difficult and expensive to treat – especially for remote impoundments where no viable disposal alternatives exist (e.g., disposal to a local public owned treatment works);
- Historic infrastructure near and within ash impoundments (e.g., abandoned storm water pipes, abandoned discharge structures) can serve as potential migration pathways for leaching from the impoundment to surface water and groundwater and also contribute to geotechnical instability; and,
- Saturated and differential hydraulic conditions can potentially compromise impoundment geotechnical stability along surface water bodies (e.g., adjacent river).

To fully resolve these technical factors, the waste must be hydraulically isolated from the groundwater and the geotechnical strength characteristics maintained or enhanced to decrease the potential for instability.

REGULATORY FRAMEWORK AND STRATEGY APPLICABILITY

This section presents a discussion of the regulatory framework surrounding CCP impoundments which has changed significantly over time and has contributed to the challenges the industry is facing. This section also demonstrates the applicability of the closure strategy presented in this document relative to the regulatory framework. Given that responsibility for oversight and enforcement has been shared with states, individual state regulations are relevant, contributing to the complexity of addressing requirements. Existing Illinois and North Carolina regulations are reviewed as illustrative of these complexities.
Illinois has proposed regulations under Title 35 Part 841 Coal Combustion Waste Surface Impoundments at Power Generating Facilities. These regulations would be similar to those proposed by USEPA under Subtitle D. The regulations would allow construction of new impoundments if constructed with liners with a permeability less than or equal to $1 \times 10^{-7}$ centimeters per second (cm/sec). Hydrogeologic characterization and groundwater monitoring would be required at all impoundments. If groundwater standards were exceeded, it would be addressed via corrective action or closure. Corrective action could consist of groundwater collection and treatment and discharge under a NPDES permit. Closure would require a final cover with a permeability less than or equal to that of the liner (if present) or less than or equal to $1 \times 10^{-7}$ cm/sec. Closure would also include groundwater collection and discharge, if determined to be necessary. Post closure monitoring would also be required.

North Carolina has promulgated regulations under Senate Bill 729, the Coal Ash Management Act that became law in September 2014. The law prohibits utilities from the construction of new impoundments or expansion of existing impoundments for the disposal of coal ash. The law also prohibits use of impoundments at closed electric generating facilities for coal ash disposal. The provision prevents a utility from transporting coal ash from an active generation plant to a closed facility for disposal in an impoundment.

The law requires utilities to submit groundwater assessment plans for all 33 impoundments identified. In addition, it sets much more stringent standards for use of coal ash in large structural fill projects and puts a moratorium on smaller structural fill projects to study appropriate standards for those projects. The new standards include setbacks from surface waters and drinking water wells; a requirement for synthetic liners and a leachate collection system; a four-foot separation between the lowest level of fill and groundwater; financial assurance; and standards for closure.

The law requires the removal of ash from four high priority impoundments and the assessment, classification and closure of the remaining impoundments. The law sets timeframes for these activities. The law creates a Coal Ash Management Commission within the North Carolina Department of Public Safety. The Commission’s responsibilities include: review and approve the classification of coal ash impoundments; review and approve closure plans for coal ash impoundments; and, review and make recommendations on statues and rules related to management of coal ash.

The USEPA regulatory history extends back to the original Resource Conservation and Recovery Act (RCRA) regulations (1978) and Solid Waste Disposal Act regulations (1980) in which coal combustion residuals were exempted and regulatory requirements were determined by the individual states. In 1993, USEPA issued a determination that large volume utility coal combustion wastes were not hazardous wastes. In 2000, the USEPA made a determination that coal combustion wastes in landfills, impoundments and surface mines should be regulated under RCRA Subtitle D (non-hazardous solid waste). In June 2010 USEPA issued a proposed rule that presented two options for
regulation as hazardous waste under RCRA Subtitle C or regulation as solid waste under RCRA Subtitle D. If regulated as hazardous waste, all solids would have had been required to be removed from existing impoundments and meet land disposal restrictions (LDRs) for disposal.

On December 19, 2014, the USEPA Administrator signed the final Disposal of Coal Combustion Residuals from Electric Utilities rule that establishes a set of requirements for disposal of coal combustions residuals (CCR) in landfills and impoundments. The requirements were finalized under the solid waste provisions of RCRA Subtitle D. The final rule establishes minimum criteria for CCR landfills, CCR surface impoundments, and all lateral expansions of CCR units including location restrictions, liner design criteria, structural integrity requirements, operating criteria, groundwater monitoring and corrective action requirements, closure and post-closure care requirements, and recordkeeping, notification, and internet posting requirements. Some components of the final rule relating to existing impoundments and applicability of the closure/management strategy presented herein are summarized below.

Pursuant to pending regulation under Subtitle D, existing impoundments are required to meet the following location requirements:

- Constructed with a base that is located no less than 5 feet (1.52 meters) above the upper limit of the uppermost aquifer;
- The CCR unit is not located in wetlands;
- The CCR unit is not located within 200 feet (60 meters) of the outermost damage zone of a fault that has had displacement in Holocene time;
- The CCR unit is not located in seismic impact zones; and
- The CCR unit is not located in an unstable area.

The owner or operator of the existing impoundment must demonstrate within 42 months of the rule posting in the Federal Register that the existing impoundment either meets the location requirements summarized above or that an impoundment not complying with any of the location requirements will not have adverse impacts or be impacted adversely. If the demonstration is not made within 42 months or if any of the location requirements are not met, the impoundment must cease receiving CCR and close.

Existing impoundments, except for those that are incised, also must meet structural integrity requirements to help prevent the damages associated with structural failures of CCR surface impoundments. The final rule establishes structural integrity criteria for new and existing surface impoundments (and all lateral expansions of them) as part of the design criteria. While the applicability of the structural integrity requirements to individual CCR surface impoundments varies depending on factors such as dike heights and the potential for loss of life, environmental damage and economic loss if there is a dike failure, the final rule establishes requirements for owner or operators to conduct a number of structural integrity-related assessments regularly. These include conducting periodic hazard potential classification assessments to assess the potential adverse incremental consequences that would occur if there was a failure of the CCR surface
impoundment; conducting periodic structural stability assessments by a qualified professional engineer to document whether the design, construction, operation and maintenance is consistent with recognized and generally accepted good engineering practices; and conducting periodic safety factor assessments to document whether the CCR unit achieves minimum factors of safety for slope stability. The rule stipulates the following requirements for factors of safety:

- The calculated static factor of safety under the long-term, maximum storage pool loading condition in the impoundment must equal or exceed 1.50;
- The calculated static factor of safety under the maximum surcharge pool loading condition in the impoundment must equal or exceed 1.40;
- The calculated seismic factor of safety of the impoundment must equal or exceed 1.00; and
- For dikes constructed of soils that have susceptibility to liquefaction, the calculated liquefaction factor of safety for the impoundment dike must equal or exceed 1.20.

If a CCR unit required to conduct a safety factor assessment fails to demonstrate that the unit achieves the specified factors of safety, the owner or operator must close the unit.

The final rule also establishes liner design criteria to help prevent contaminants from leaching from the CCR unit and contaminating groundwater. Existing CCR surface impoundments can continue to operate as designed. However, within 18 months of the final rule posting in the Federal Register existing impoundments must document whether or not the CCR unit was constructed with any of the following:

- A liner consisting of a minimum of two feet (0.61 meters) of compacted soil with a hydraulic conductivity of no more than $1 \times 10^{-7}$ cm/sec;
- A composite liner that consist of two components; the upper component consisting of a minimum 30-mil (0.76 millimeter) geomembrane liner (GM), and the lower component consisting of at least a two-foot (0.61 meters) layer of compacted soil with a hydraulic conductivity of no more than $1 \times 10^{-7}$ cm/sec; or
- An alternative composite liner that consists of two components; the upper component consisting of a minimum 30-mil (0.76 millimeter) GM, and a lower component, that is not a geomembrane, with a liquid flow rate no greater than the liquid flow rate of two feet (0.61 meters) of compacted soil with a hydraulic conductivity of no more than $1 \times 10^{-7}$ cm/sec.

If an existing CCR surface impoundment was not constructed with a composite (or alternative composite) liner or with at least two feet (0.61 meters) of compacted soil with a specified hydraulic conductivity it is considered unlined and the rule requires the unit to retrofit or close. Further, if an unlined CCR surface impoundment detects concentrations of one or more regulated constituents at statistically significant levels above the groundwater protection standard established by the rule, the CCR unit must retrofit or close.
Lastly, the final rule establishes groundwater monitoring and corrective action criteria. The rule requires an owner or operator of a CCR unit to install a system of monitoring wells to detect the presence of hazardous constituents and other monitoring parameters potentially released from the units. The rule specifies procedures for sampling these wells and methods for analyzing the groundwater data collected. The groundwater monitoring program consists of detection monitoring, assessment monitoring, and corrective action. Once a groundwater monitoring system and groundwater monitoring program has been established for a CCR unit under the rule, the owner or operator must conduct groundwater monitoring. If the monitoring demonstrates exceedance of a groundwater protection standard for identified constituents in CCR, corrective action throughout the active life and post-closure care period of the CCR unit is required.

The closure strategy or components of the strategy presented herein can provide a means of addressing federal and state requirements for impoundment closure, stability, and groundwater or other corrective action.

This complex web of regulation poses significant compliance and economic risks that be monitored and managed. A solution that mitigates the environmental risks and meets compliance requirements would be of significant benefit to all, facility owners and stakeholders alike.

APPROACH – IN-SITU WASTE IMPOUNDMENT CLOSURE

While construction of a final cover has often been the chosen and presumptive low cost closure strategy for non-compliant impoundments often considered by facility owners, this approach alone is unlikely to be accepted by other stakeholders as there may be continued leaching of ash constituents into surrounding groundwater. In addition this approach may not be compliant with all existing and pending regulations as it does not address the barrier between the ash and surrounding material. This is exemplified for example by a recent North Carolina Superior Court Decision wherein the court reversed a ruling by the North Carolina Environmental Management Commission (EMC) and determined that utilities must take immediate action to eliminate sources of groundwater contamination at ash impoundments. Most companies are now considering construction of new lined facilities and moving ash from non-compliant impoundments to new compliant sites. That approach would be disadvantageous in several ways: it is costly, there is risk in moving the material, and the timeline for the solution is expected to be long due to permitting and other complications.

Our alternative approach can eliminate leaching and reduce geotechnical instability that contributes to impoundment failures. To do so the ash is hydraulically isolated from the groundwater by constructing a hydraulic barrier at the bottom of the impoundment using engineered ISS applications on the ash and/or underlying natural material. These demonstrated ISS applications can also enhance geotechnical stability by increasing embankment strength, reducing saturated conditions and increasing the overall factor of safety for slope failure.
An effective hydraulic barrier can be constructed at the base and the sidewalls of the ash impoundment using ISS techniques on the ash and/or underlying native material. Solidification and stabilization encapsulates the ash within a cured monolithic material/cement structure, reducing hazards by converting ash constituents into a less soluble and mobile form. Typically this process consists of advancing continuously overlapping large diameter augers (e.g., 4 to 12 feet [1.22 to 3.66 meters]) from ground surface to the desired depth (impoundment bottom) while injecting an ash/soil specific engineered cementitious grout comprised of water and amendment materials (e.g., Portland cement, ground granulated blast furnace slag, bentonite) that is blended with the ash/soil *in situ*.

Typically, prior to implementation a laboratory treatability study is conducted to select and test appropriate amendment materials, amendment proportions, and application rates with the objective of designing an engineered grout specific to the waste (e.g., fly ash, bottom ash and other CCP materials) and waste constituents targeted for solidification. Laboratory testing of the waste/soil and engineered grout mixture is used to confirm that the selected amendments, amendment proportions, and application rates can successfully solidify the waste/soil material and meet established performance goals; including unconfined compressive strength (UCS), hydraulic conductivity, as well as reduce the leaching rate and concentration of leachate. Following laboratory confirmation, a pilot scale evaluation is typically implemented at the waste site to verify laboratory results are indicative of in-field conditions, and to identify potential operational problems and evaluate operational parameters such as auger diameter and vertical advancement rate. In-field construction success during pilot scale and full scale implementation is measured by the collection of construction quality assurance (CQA) samples; discrete samples of the waste/soil and engineered grout mixtures are collected and tested to evaluate compliance with established strength and permeability requirements.

Using this technology a permanent in-place engineered solution that mitigates groundwater impacts can be achieved in a short timeframe. In addition, ISS can be effectively constructed to enhance geotechnical stability. Tailored engineered grout mix designs can be developed to improve strength and stability of ash impoundment embankments. Previous ISS applications at other types of infrastructure and waste sites have included geotechnical and structural improvements along waterways, embankments for roadways, bridges, building foundations and other structures.

Ash contact water collected during impoundment dewatering can be collected, recycled and treated during construction of an ISS application. The ISS construction process requires a significant volume of water for preparation of the engineered grout prior to solidification/stabilization of the ash or other materials. The volume of recycled water can range in the millions of gallons, significantly reducing water treatment costs. Contact water from other waste sites has been successfully collected and recycled in the ISS construction process.
ISS has been used at waste and construction sites for many years to isolate impacted media from groundwater, reduce leaching of constituents of concern, and to improve structural stability in ground improvement applications. More recently ISS has been demonstrated to be effective in solidifying/stabilizing coal ash, contaminated sediments, mining wastes, acid tar wastes, and drill cuttings. Solidified/stabilized media can achieve specified strengths (e.g., > 50 lbs/square inch (psi) [344.74 kilopascal]) and hydraulic conductivity endpoints (e.g., < 1x10^-7 cm/sec).

Discrete ISS (ISS of only a selected depth interval or zone) has been successfully demonstrated. Unlike conventional ISS where engineered cementitious grout is mixed with soil/waste from the ground surface to a desired depth, application of discrete ISS applies the engineered cementitious grout only to the depth where the amendments are needed. This strategy utilizes ISS at a discrete depth to specifically solidify the ash and/or native material to create a low permeable barrier at the bottom of the existing impoundment to isolate the ash from groundwater and significantly reduce leaching. Concurrently, fully penetrating conventional ISS columns would be constructed at the impoundment perimeter to strengthen the embankment sidewalls to reduce geotechnical instability and tie into the low permeability barrier at the impoundment bottom.

SSi and NRT have demonstrated experience with ISS construction and ash impoundment closure. Together, we have implemented the a discrete ISS pilot test; on a USEPA CERCLA site presented at the 2010 International S/S Forum, Sydney, Nova Scotia, Canada. In addition, we have conducted multiple remedial applications of ISS at waste sites and treatability studies on coal ash and other industrial residuals and waste. The profile of our combined experience is unique and well positioned to effectively deliver this solution to ash impoundments and their stakeholders. These successes provide evidence that an effective hydraulic barrier could be constructed at the base of waste ash impoundment from the waste ash and/or underlying natural material.

The following narrative and attached pictorials detail the proposed approach for implementing ISS to facilitate ash impoundment closure.
An illustration of an ash impoundment profile that highlights the aforementioned technical challenges is provided in Figure 1. Figure 2 through Figure 5 and the following narrative describes the conceptual approach and phases for implementing an ISS strategy to facilitate ash impoundment closure.

Figure 1. Conceptual Ash Impoundment Profile
Phase I - Ash Impoundment Investigation and Constructability Evaluation:

Figure 2 illustrates the initial steps to plan the ISS implementation which include:

- Records review to develop an understanding of impoundment construction;
- Pre-design data collection for laboratory treatability study and geotechnical testing;
- Evaluation of impoundment dewatering requirements including discharge options, treatment options, on-site management options, and ash contact water reuse during dike and liner ISS construction;
- Constructability evaluation and selection of final cover, ISS liner, and embankment stability including groundwater assessment and geotechnical analysis, if appropriate; and,
- ISS laboratory treatability study to determine appropriate amendment materials, amendment proportions, and application rates and evaluate verify compliance with performance criteria/construction parameters (e.g., permeability, strength, leaching). If applicable, the treatability evaluation will also include an evaluation of reuse of water from the existing impoundment as part of the cementitious grout preparation for the solidification/stabilization process.
Phase II - Site Preparation:

Figure 3 illustrates initial construction steps to prepare the impoundment for ISS construction. Key steps may include phased dewatering of the ash impoundment and grading to establish a stable construction platform for ISS operations. Dewatering could be coincidental to Phase III - ISS Construction (Figure 4) through reuse of water as part of cementitious grout preparation for ISS, on-site water management strategies, or treatment and discharge. Dewatering activities of the impoundment could be continued following implementation and during post closure to further reduce water within the impoundment.

Figure 3. Phase II: Site Preparation
Phase III - ISS Construction:

**Figure 4** illustrates ISS construction of a horizontal liner at the bottom of the impoundment and perimeter vertical containment and structural integrity fortifying wall. Construction of the ISS horizontal liner would be performed by advancing the auger to the desired depth below the impoundment and performing discrete ISS to construct the liner (e.g., permeability less than $1 \times 10^{-7}$ cm/sec). The constructed horizontal liner would be tied into a surrounding vertical barrier constructed of fully penetrating conventional ISS columns from ground surface through the ash or surrounding native material to prevent potential horizontal migration of groundwater through the pond and provide structural stability. The result would prevent both the vertical and horizontal migration of groundwater through the ash impoundment, effectively isolating the ash. In addition, the constructed horizontal liner could be contoured to facilitate groundwater/leachate monitoring and/or collection.
Phase IV - Final Cover Construction:

**Figure 5** illustrates construction of a final cover designed to cap the impoundment. The cover would be constructed by importing fill (or on-site borrow materials) to raise the impoundment to an appropriate subgrade, constructing the cover with low permeability materials (e.g., geomembrane, compacted clay, ClosureTurf™), and construction of a soil layer designed to protect the low permeability layer. The low permeability cover could also be constructed by applying ISS techniques using the available surficial ash. The final cover would have permeability less than or equal to the liner (achievable with readily available materials) and would result in reduced surface water infiltration to the encapsulated waste. Additionally, the cover would include an infiltration layer that contains a minimum of 18 inches (0.46 meters) of earthen material and an erosion layer that contains a minimum of 6 inches (0.15 meters) of earthen material that is capable of sustaining plant growth.

![Figure 5. Phase IV: Final Cover Construction](image-url)
Additional activities would include preparation and implementation of a Post-Closure Plan. The plan would include post closure care requirements, maintenance requirements, groundwater sampling and analysis plan and structural inspections. In addition, land use restrictions would be placed limiting future use of the closed impoundment.

This approach would allow in-place closure and/or management of ash impoundments if needed and possibly allow some impoundments to stay in use by meeting regulatory requirements regarding stability or groundwater corrective action. It would effectively isolate CCPs from groundwater and provide structural stability to the impoundment perimeter and would therefore be more effective than simply capping the impoundment. This closure strategy is also a less environmentally disruptive approach than excavation and on-site or off-site disposal. The approach can be implemented in a timely basis and at significantly reduced costs while meeting divest objectives of multiple stakeholder groups. Typical ISS operations have a small environmental footprint because the on-site operations require only a few pieces of equipment and the majority of the work is conducted below the ground surface (e.g., limited off-site transportation of materials or on-site excavation). Potential cost savings of this approach are illustrated below.

COST EVALUATION

SSI and NRT have prepared a cost evaluation that compares in-situ closure outlined above to excavation and off-site disposal. We recognize that at many ash impoundment locations it is unlikely that off-site landfills will have the capacity to receive the ash. We also understand that some utilities are evaluating the possibility of constructing on-site landfills; however, this approach may not be practical at all plants. Regardless of the final disposal option, the cubic yard disposal costs (total) for off-site and on-site disposal are likely comparable. Costs are based on our experience, along with recent costs provided by contractors for various ISS projects. Table 1 summarizes the assumptions and anticipated costs for closure of an existing ash impoundment.
Table 1. Cost Evaluation

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<th>Item</th>
<th>Estimated Quantity</th>
<th>Units</th>
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<th>Amount $</th>
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<td>Excavate Ash, Dewater, and</td>
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<td>$ 24,000</td>
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<td></td>
</tr>
<tr>
<td>Site Water Management</td>
<td>104</td>
<td>Week</td>
<td>$ 25,000</td>
<td>$ 2,600,000</td>
<td>$ -</td>
<td>$ -</td>
</tr>
<tr>
<td>Dewatering - ISS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frac Tank Mobilization,</td>
<td>4</td>
<td>Each</td>
<td>$ -</td>
<td>$ -</td>
<td>$ 3,000</td>
<td>$ 12,000</td>
</tr>
<tr>
<td>Setup and Demobilization</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Water Management</td>
<td>52</td>
<td>Week</td>
<td>$ -</td>
<td>$ -</td>
<td>$ 5,000</td>
<td>$ 260,000</td>
</tr>
<tr>
<td>Site Restoration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsoil</td>
<td>32,267</td>
<td>Cubic Yard</td>
<td>$ -</td>
<td>$ -</td>
<td>$ 26</td>
<td>$ 838,942</td>
</tr>
<tr>
<td>Seed and Mulch</td>
<td>40</td>
<td>Acres</td>
<td>$ 2,000</td>
<td>$ 80,000</td>
<td>$ 2,000</td>
<td>$ 80,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>$ 151,945,000</td>
<td>$ 35,919,000</td>
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</tbody>
</table>

Assumptions

**Excavation and Off-Site Disposal Closure Assumptions**

- Excavation volume is 1,290,667 cubic yards (40 acres by 20 feet depth)
- Excavation will be backfilled with off-site fill and vegetated
- Ash will be disposed off-site within 50 miles of the plant
- One cubic yard of excavated fly ash weighs 2,700 lbs
- Dewatering of excavation will be required with water treatment

**In-Situ Closure Assumptions**

- ISS volume is approx. 366,000 cubic yards, including 323,000 cubic yards to ISS
  - 5' thick bottom liner (1 feet of fly ash plus 4 feet of underlying natural material) and
Based on the cost included in Table 1 the costs for excavation/off-site disposal of ash for the existing 40 acre (16.2 hectare) ash impoundment are approximately $152 million. The costs for the *in situ* closure (ISS) approach approximately $36 million, less than 25% of the excavation/off-site disposal alternative. This translates to a cubic yards remedial cost of $118/cubic yard ($154/cubic meter) for excavation/off-site disposal compared to $28/cubic yard ($36/cubic meter) for *in situ* closure (ISS).

**STAKEHOLDER ACCEPTANCE**

Primary stakeholder groups include: ash impoundment owners, regulators, environmental groups, and the general public. Ash impoundment owners are generally utility companies but also include municipalities, government entities and public and private corporations. Regulators primarily include federal and state environmental agencies and the Public Utility Commission. Many Environmental Groups are actively involved in ash impoundment rule making. The general public is a primary stakeholder as utility rates may be affected by rule making and the cost of ash impoundment closures. Table 2 summaries the primary stakeholders, their primary concerns regarding CCP impoundments and how the ISS closure approach addresses these concerns. As illustrated in Table 2 the ISS closure strategy will address stakeholder concerns.

**Table 2. Stakeholder Summary**

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>CCP Impoundment Objectives</th>
<th>How ISS Strategy Meets Objectives</th>
</tr>
</thead>
</table>
| CCP Impoundment Owners | ▪ Achieve regulatory requirements.  
▪ Address concerns of environmental groups and the general public.  
▪ Provide the lowest possible cost to rate payers and/or shareholders.  
▪ Perform timely closures. | ▪ Provide a safe, cost effective means for managing ash impoundments in a timely way.  
▪ Support safe and timely closure of obsolete ash impoundments and offer a path for extending life of impoundments in use if required and permitted. |
| Regulators | ▪ Secure CCP impoundments to prevent catastrophic failure and leaching of CCP constituent into groundwater.  
▪ Timely implementation of sustainable closure.  
▪ For the Public Utilities | ▪ Will provide structural stability of impoundments and mitigation of leaching via installation of side walls, liner, and cap, mitigating risk of catastrophic failure.  
▪ Closures can be implemented in-place reducing potential environmental impacts of siting. |
<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>CCP Impoundment Objectives</th>
<th>How ISS Strategy Meets Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commission</td>
<td>Commission, closure must be most cost effective remedy that meets regulatory requirements.</td>
<td>and permitting new landfills, ash handling, ash transportation, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Closure/management can be implemented in a timely way, reducing windows of risk.</td>
</tr>
</tbody>
</table>
| Environmental Groups | ▪ Insure structural stability of impoundments to protect nearby bodies of water.  
                          ▪ Prevent leaching of CCP constituents into groundwater. | ▪ Addresses the primary concerns of environmental groups related to structural stability and continual groundwater impacts.  
                          ▪ Has the added advantage of timely implementation and in-place solution which is greener due to elimination of need for additional development of compliant landfills.  
                          ▪ Reduces of carbon footprint of solution by eliminating of ash excavation and transportation. |
| General Public    | ▪ Address safety issues in a cost effective way that minimizes impact on rates. | ▪ Addresses perceived safety issues through timely resolution and significant reduction in risk of contamination through leaching or failure.  
                          ▪ Provides the lowest cost closure minimizing impact on rates. |

**SUMMARY AND RECOMMENDATION**

This *in-situ* ash impoundment closure approach would allow in-place closure and/or management of ash impoundments if needed and even allow some impoundments to stay in use by meeting regulatory requirements regarding stability or groundwater corrective action. It would effectively isolate ash from groundwater and provide structural stability to the impoundment perimeter and would therefore be more effective than simply capping the impoundment. This strategy is also a less environmentally disruptive approach than excavation and on-site or off-site disposal.

Based on available information, the constructed ISS closure approach would provide an acceptable and desirable closure strategy for ash impoundments. A field demonstration of this closure approach would be beneficial to gain acceptance by the various stakeholder groups.
REFERENCES