

# TVA CCR Disposal Facility Assessment

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## BACKGROUND

The Tennessee Valley Authority (TVA) currently operates eleven coal-fired electric generating plants that are located in Tennessee, Kentucky and Alabama. The plants contain a total of 59 separate coal-fired generating units with a combined capacity of approximately 16,900 MW. In the process of burning coal, the eleven plants produce on an annual basis, approximately 2.8 million tons of fly ash, 1 million tons of bottom ash and boiler slag, and 2.8 million tons of gypsum.

Although some of these coal combustion products (CCPs) are recycled for a variety of beneficial uses, the plants must operate various types of impoundments and disposal facilities in order to properly handle, manage, and dispose of CCPs. These facilities generally include: ash ponds, dredge cells, dry ash or gypsum stacks, and wet gypsum stacks. Twenty four active impoundments and stacks were included in this assessment.

## SCOPE

Following the December 22, 2008 breach of the ash dredge cell at the TVA Kingston Fossil Plant, TVA requested Stantec to assess the condition of the active CCP disposal impoundments at its fossil plants and implement a program to address deficiencies and to reduce risk. Stantec proposed a four-phase approach for the assessment program.

Phase 1 consisted of an initial review of documentation and field reconnaissance to identify conditions that may affect the stability and functionality of the facilities reviewed; determine the need for short term or immediate corrective actions and engineering evaluations; and prioritize and schedule facilities for further engineering evaluations. Phase 1 was noninvasive and limited to field observations and review of historical documents. Phase 1 involved:

- Reviewing documents and records pertinent to the characterization, design, construction, operation, and maintenance of TVA's CCP disposal facilities.

- Site reconnaissance of disposal facilities including observation of embankment slopes, crests, freeboard, seepage, and slope instabilities. Observations and measurements were recorded using dam safety inspection checklists customized for the types of CCP management units encountered.
- Interviews of TVA staff and plant personnel to gain additional information.

Stantec performed initial walk-downs of the facilities over a two week period in early January 2009 to identify facilities that potentially represented the most risk from a structural perspective. These observations were used to provide TVA with preliminary recommendations for initiating geotechnical explorations and implementing known stabilization techniques to improve those facilities, rather than waiting until completion of the entire Phase 1 scope.

Phase 2 consisted of engineering evaluations including geotechnical explorations, hydraulic and hydrologic evaluations, conceptual designs for improvements, and general engineering and permitting support. In addition, the dam safety hazard classification for each impoundment was reviewed and updated as appropriate in accordance with national guidelines<sup>1</sup>. During Phase 2, pipe conduits were inventoried and assessed including the procedures previously used to abandon inactive conduits. Tasks performed included:

- Drilling, sampling and instrumenting of existing embankment and foundation materials to characterize subsurface conditions, and field and laboratory testing to determine engineering properties of these materials.
- Slope stability and seepage calculations.
- Hydrologic and hydraulic calculations of impoundments and spillway systems to assess freeboard requirements.
- Dam breach analyses including 1-dimensional and 2-dimensional routings of breach hydrographs to identify inundation impacts and assess dam safety hazard classifications.
- Additional field reconnaissance and observations.
- Developing recommendations and conceptual designs to address identified issues.

Phase 3 consists of a variety of engineering tasks including planning assistance for short- and long-term CCP management; final design of conceptual renovations; preparing construction plans, specifications, and cost opinions; providing construction observation, documentation, and quality assurance testing; developing applicable record drawings; and assisting TVA with environmental permitting. It is during this phase of the program that TVA will construct renovation projects to improve slope

stability, seepage, freeboard, and structural conditions of its CCP impoundments to reach a global slope stability factor of safety of 1.5.

Finally, Phase 4 involved improvements to TVA's dam safety program within the fossil power group. These improvements included dam safety training for TVA staff involved in the planning, design, and maintenance of CCP impoundments; developing programmatic guidance documents; and improving facility inspection procedures.

## IMPLEMENTATION

Since January 2009, Stantec and TVA have assessed the stability of TVA's CCP disposal facilities and implemented construction activities to improve conditions as deficiencies have been identified. During this process, Stantec and TVA have worked together to establish priorities and schedules based on the most current findings and observations. In certain instances, TVA has directed Stantec to proceed with engineering evaluations and mitigation designs for improvement of its facilities as deficiencies have been identified, rather than wait until the completion of the phases or delivery of final reports. The implementation schedule is provided as Figure 1.

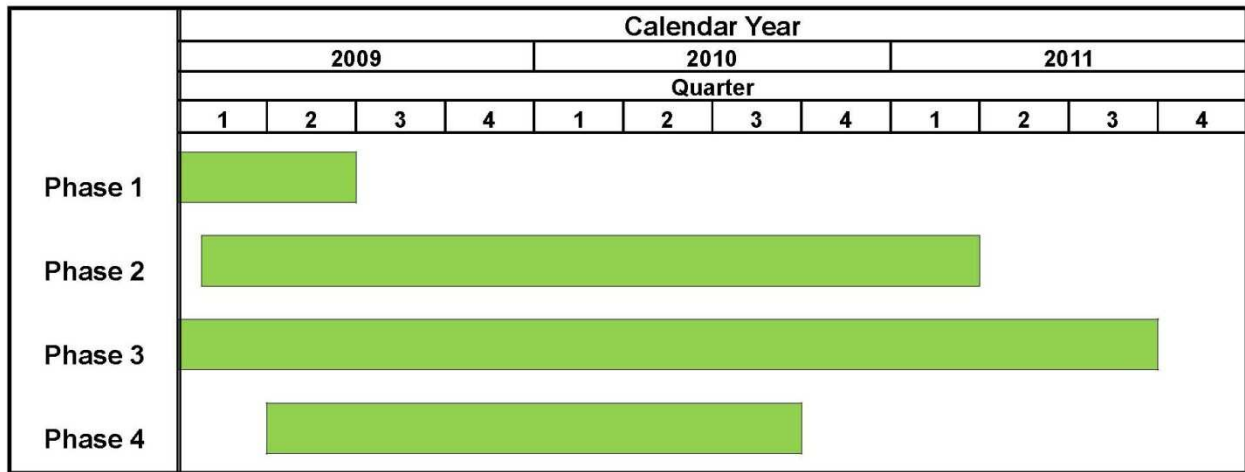


Figure 1 – Implementation Schedule

As shown in the schedule, all phases were implemented in parallel with Phases 1, 2 and 4 complete. During FY2009, nearly 170,000 engineering man-hours were spent on assessments and designs of remedial work. In FY2010, nearly 475,000 man-hours were expended characterizing and improving slope stability, seepage, spillway, and freeboard conditions. Over 780 borings have been drilled representing 48,000 feet of drilling footage, and 630 geotechnical instruments have been installed. To improve conditions, over 500,000 tons of rock and 30,000 tons of sand have been placed.

Phase 1 is complete and the final reports <sup>2, 3, 4</sup> were submitted to TVA on June 24, 2009. During this phase of the work, over 8,000 documents provided by TVA were reviewed. These documents included: annual inspections reports; quarterly inspection reports; geotechnical and geologic related reports, data and analyses; design and construction drawings; design feasibility and CCP management reports; permit documents; design calculations; project and internal correspondence; and aerial photography.

Stantec assembled six assessment teams to perform field reconnaissance and observe site conditions. Teams consisted of at least two engineers; one of which was a licensed professional engineer with experience in dam design, dam safety, and geotechnical engineering. Items of primary concern included: active seepage areas; evidence of slope instability; sinkholes; depressions; insufficient freeboard; steepness and height of slopes; and condition of spillways through embankments. During January and February 2009, Stantec reviewed and photographed conditions at all of TVA's CCP impoundments. As needed, follow-up visits occurred to further review and assess conditions.

Based on this review and assessment, Stantec identified the following system-wide concerns:

- Limited Record Drawings and Construction Testing/Observation Records. These records are important to illustrate how facilities were actually constructed, compliance with project plans and specifications, and any design or construction adjustments made to deal with changes or unexpected conditions encountered during construction.
- Construction of Stacks over Ash Ponds and the Operation of Fly Ash Dredge Cells. Hydraulically-placed fly ash in ponds and dredge cells is generally very loose in terms of relative density, and high in porosity and void ratio. These conditions can sometimes result in significant and sudden loss of shear strength within the sluiced ash at low strains due to embankment loading. TVA has several active facilities that have been constructed over ash ponds. Operating CCP disposal facilities on top of ash that has been sluiced into ponds is not an uncommon practice in the industry. While this practice can pose greater risk than constructing over natural earth materials, the risk is typically managed by performing appropriate geotechnical analyses to support design and operation, and by installing instrumentation to monitor pore pressures, settlement, and slope



movement. Load rates must also be controlled to manage the build-up of excess pore pressures.

- Tall, Unsupported Weir Structures. A number of the facilities have weir structures that are tall and unsupported. System-wide, weir structures are typically vertical, push-together, reinforced concrete pipe or manhole sections. This type of weir system is prone to developing leaking joints and leaning. In addition, outlet pipes from the weir structures are constructed of reinforced concrete culvert pipe. This type of pipe does not employ a restrained joint system and is also susceptible to developing leaking joints. Some past TVA inspection reports have documented such problems.
- Conduit and Weir Abandonment Procedures. As various disposal facilities have been raised in the past to increase CCP storage capacity, process water conduits and weirs have been abandoned in place. The abandonment procedures have varied from site to site over the years and are not well documented. Improper abandonment can lead to internal piping and loss of embankment and/or foundation materials through joint separation in the conduits.
- Maintenance. Annual dike inspection reports appear to be adequate in identifying items for maintenance. However, there is a trend of not executing all of the maintenance recommendations provided in these reports. In many instances, the same maintenance recommendations were made repeatedly in the annual reports from year to year. Tree and other vegetation removal from dikes and surface drainage ditches is an example of one of the typical recurring items.
- Limited Operation and Maintenance Manuals (OM) and Emergency Action Plans (EAP). During the historical research/document review phase, Stantec found a general lack of Emergency Action Plans (EAP) for the disposal facilities. These plans are important for the safe operation of a dam/impoundment, and for the protection of downstream communities, as well as plant personnel.
- Limited Geotechnical Instrumentation. Dam safety management of significant impoundments should include an instrumentation program to monitor performance and condition changes during operation of the facility. In general, instrumentation may consist of piezometers to monitor pore pressures within embankments and foundations, slope inclinometers and surface monuments to monitor movement, and plates for monitoring settlement. Only limited geotechnical instrumentation and related monitoring programs were observed at a majority of the facilities during Phase 1 reviews. Plans are currently being executed to establish instrumentation automation at each site.

To address these concerns, further assessment scopes and improvements were implemented.

Phase 2 activities were completed September 30, 2010. For Phase 2, geotechnical explorations were performed on 24 CCP impoundments or dry stacks over former ash ponds. The program criteria for minimum global slope stability factor of safety is 1.5<sup>5,6</sup>. Explorations determined that 12 of these facilities met this criteria. Of the remaining facilities, none exhibited factors of safety less than 1.0 and conditions suggesting imminent failure were not observed at any facility.

Over 100 capital projects and work plans to improve conditions at the facilities are currently in planning, design construction, or completed phases. Figure 2 presents progress made and the implementation schedule for improvements addressing global factors of safety at each respective facility. By September 2011, improvements will be implemented such that all CCP disposal facilities assessed will meet the program minimum global slope stability factor of safety ( $\geq 1.5$ ). These improvements generally involved rock buttressing, rock armoring, and seepage control blankets. In some cases, operating pools have been lowered, slopes re-graded, and toe drains installed. Figure 3 shows rock buttressing of the gypsum stack at the Paradise Fossil Plant.

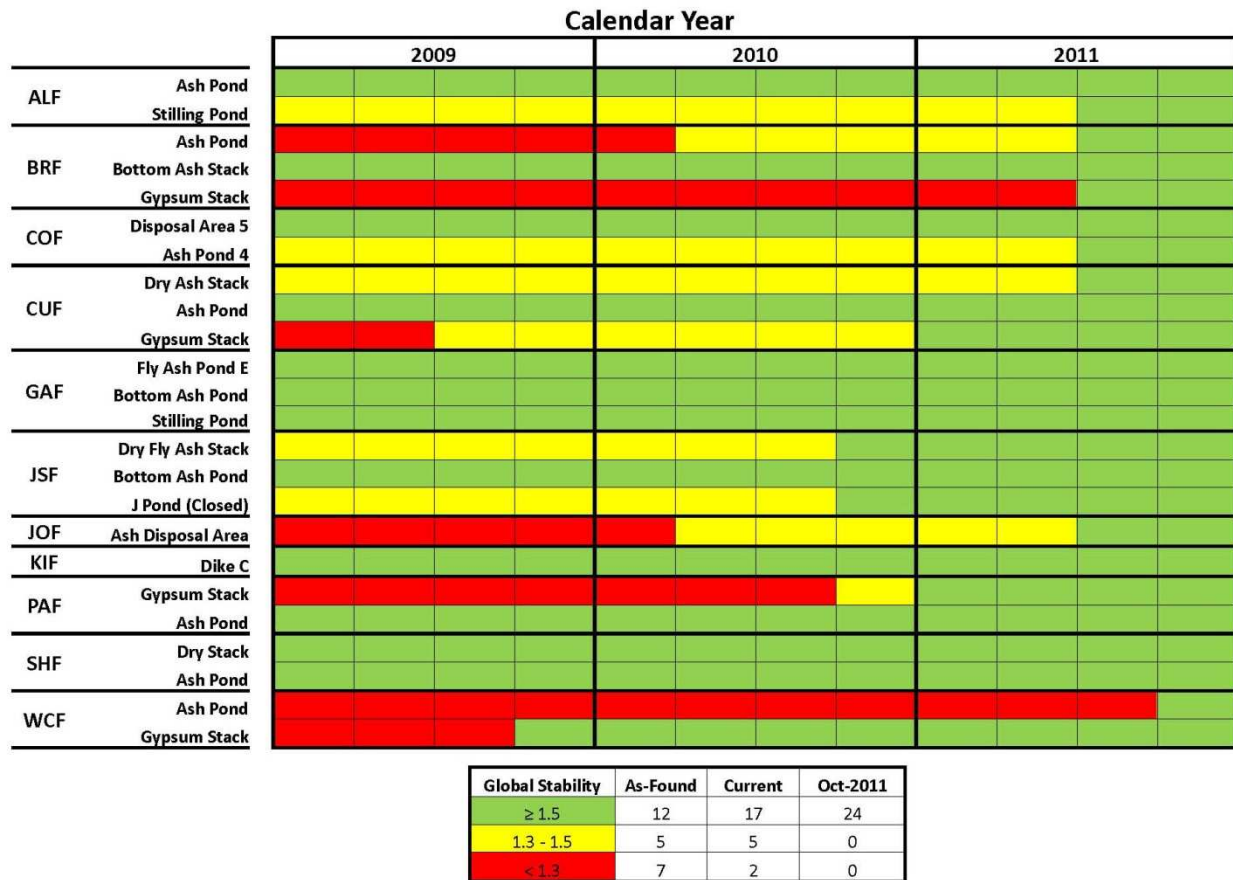


Figure 2 – Stability Improvements Status

During Phase 2, an inventory of pipe penetrations was also completed for active CCP impoundments. The inventory focused on spillway location, material, previous problems, and observed conditions. A geographic information system data file and database were developed as tools to allow TVA to track future improvements, modifications and issues. The inventory data is being used to prioritize spillways for replacement or rehabilitation. TVA has spillway replacement and abandonment projects underway or completed at 5 impoundments. Photographs representing a typical replacement project are presented as Figure 4. Abandoned spillways are grouted full and seepage diaphragms are constructed at the downstream end.



**East Pond South Slope Buttress - Before**



**East Pond South Slope Buttress - After**

**Figure 3 – PAF Gypsum Pond Buttress**



**South Spillway Inlets - Before**



**South Spillway Inlets - After**

**Figure 4 – JOF Spillway Replacement**



As part of the geotechnical exploration, Stantec was also asked to compare each facility to the conclusions of the Kingston Root Cause Analysis. The root cause analysis identified the following issues: increased loading due to higher fill; fill geometry and setbacks; unusual weak silt/ash slime foundation and hydraulically placed loose wet ash. This combination of conditions was not observed at any other facility.

TVA reviewed and updated the dam safety hazard classification for each of its CCP impoundments. Based on the initial review, TVA determined that 5 met criteria for “High Hazard” classification as defined by Federal Guidelines for Dam Safety <sup>1</sup>. These impoundments were Bull Run Fly Ash Pond, Colbert Ash Pond 4, Cumberland Ash Pond, Cumberland Gypsum Stack, and Widows Creek Gypsum Stack. Breach analyses were performed and inundation mapping developed to assess consequences of failure. An example of the inundation mapping for the Widows Creek Gypsum Stack is shown as Figure 5. Based on these detailed studies TVA was able to lower the hazard classification to “Significant Hazard” for the Bull Run Fly Ash Pond and Cumberland Gypsum Stack. In addition, TVA has taken the necessary actions to reduce the hazard classifications of the Widows Creek Gypsum Stack and the Colbert Ash Pond No. 4. TVA purchased impacted structures at Widows Creek to mitigate impacts and reduced the size of the Colbert Ash Pond 4 such that it no longer classifies “High Hazard”. Finally, TVA is addressing potential scour impacts at a bridge immediately downstream of the Cumberland Ash Pond. Once this issue is addressed, the hazard classification will be lowered to “Significant Hazard”. It is anticipated scour protection will be in place by September 2011, at which time none of TVA’s impoundments will be classified as “High Hazard”.

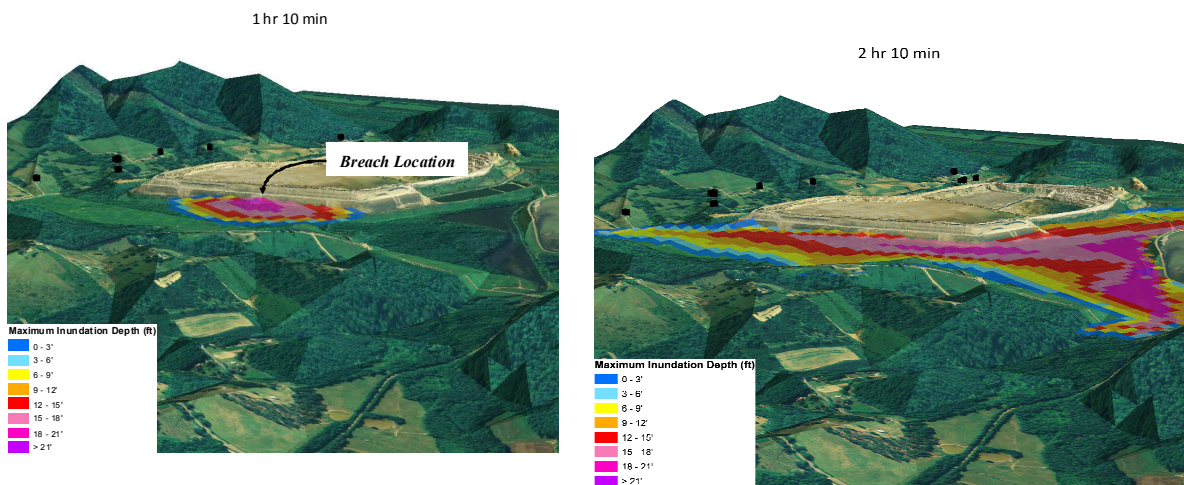


Figure 5 – WCF Gypsum Stack Breach Inundation Mapping

Programmatic improvements have included dam safety inspection training. To date, over 300 TVA staff involved in CCP engineering, operation, maintenance, and monitoring have received training. Elements of the training include: roles and responsibilities; review of failure modes and case histories; discussion of plant specific CCP features; review of design philosophy and critical elements; and inspection observation and reporting.

Finally, TVA developed programmatic guidance documents<sup>5</sup> for their CCP program. These documents address all elements of TVA's program including: program management and responsibilities; facilities design and construction requirements; and operation, maintenance, and inspection. The programmatic documents were first issued in December 2009. Subsequent revisions and updates are underway.

## REFERENCES

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