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Report on Tennessee Valley Authority's Johnsonville Ash Island Placement Area and Closure Plan Johnsonville Fossil Plant New Johnsonville TN

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1. Key Findings, Summary, and Recommendations

The Tennessee Valley Authority (TVA) is in the process of developing a final closure plan for the active coal combustion waste (CCW) impoundment at its Johnsonville Fossil Plant. This report discusses the hydrogeology, history, and construction of that impoundment. The report also offers several recommendations for improving the preliminary closure plan.

1.1 Key Findings

(1) The dikes around the active impoundment were initially constructed of surficial fine-grained floodplain sediments excavated from within the impoundment area. The use of the impoundment area for 'borrow' of construction material deprived the bottom of the impoundment of the low-permeability native sediments that would otherwise inhibit vertical leakage downward from the facility into high-permeability alluvial sand and gravel. These coarse alluvial sediments allow subsequent migration to Kentucky Lake or into the underlying permeable Camden Chert.

(2) The original dikes have been raised twice. The higher dike constructions in part borrowed additional fine-grained sediments from the floor of the impoundment and in part used coal combustion waste (CCW) as a construction material.

(3) CCW presents two distinct but interconnected problems when used in dike construction. First, CCW, unlike natural soil materials, reacts readily with environmental water. As a result, CCW weathers with time; original minerals dissolve, new minerals form, glass devitrifies to form minerals, and mass is transported away in solution. The CCW originally used in construction is fundamentally changed by water as it ages. Second, directly as a result of these chemical changes through time, the physical properties of zones constructed with CCW also change with time. The density of CCW zones will decline as mass is leached away. The cohesion of CCW degrades over time as its original mineralogy and composition change. The original permeability of the CCW zone increases with increased weathering, a change itself creating multiple effects. The higher permeability allows more water to flow through the CCW, accelerating the water-driven weathering. The increased permeability also allows greater flow velocities, increasing the potential for physical piping of fine sediments from the dike.[1]

(4) Contaminated leachate has escaped and is escaping from the impoundment through the berms directly into Kentucky Lake.

(5) TVA's study of leachate discharge from the impoundment into Kentucky Lake incorrectly concludes that the rate of discharge to the lake is minimal. First, the study relies on sediment borings that are located beneath the berms rather than beneath the impoundment. Borings advanced within the

[1] The collective effect of weathering of CCW used in structures such as dikes is that, while originally built to acceptable factors of safety, with the passage of time the decline of mass, the reduction in cohesion, and the increase in drainage velocity can reduce the safety factor below that which prevents failure.

impoundment would show the removal of low-permeability silt and clay between impoundment waste and high-permeability sand and gravel, as discussed in (1) above. Second, the study understates the permeability of CCW, ignoring data for TVA CCW and instead relying on analogy to earthen materials of a comparable grain-size.

(6) There is no effective separation between the CCW within the impoundment and water in Kentucky Lake. Under current conditions, all groundwater in the impoundment will discharge to the lake.

1.2 Summary

The TVA currently places most of the CCW that its Johnsonville Fossil Plant generates initially in a facility originally known as Ash Pond D. Nomenclature has changed through the years, and Ash Pond D is now known as the Active Ash Pond or Ash Disposal Area 2. It is also known commonly as the Ash Island. Ash Disposal Area 2 is now an elongate island, oriented north-south, in Kentucky Lake, a large impoundment of the Tennessee River, about 70 miles west-southwest of Nashville, near Camden, TN.

The Johnsonville Fossil Plant was constructed on the east shore of Kentucky Lake, just north of where US Route 70 crosses Kentucky Lake, near New Johnsonville, TN. Ash Disposal Area 2 is immediately west of the Johnsonville plant's generating units at the plant and is connected to the plant by a causeway for vehicular traffic and for the sluice pipes that carry the slurried CCW to the settling ponds. TVA constructed Ash Disposal Area 2 within Kentucky Lake by building a perimeter berm around slightly emergent and shallowly flooded land along the levee top of the eastern floodplain of the pre-dammed Tennessee River. The flooded channel of the Tennessee River is immediately west of the island, and submerged floodplain sediments lie beneath the island and between the island and the plant to the east.

As ash disposal within the berm filled the initial volume, TVA raised the berm approximately 20 feet to allow additional disposal. In part due to the cost of transporting soils for construction from off-site to build the berm, CCW was also used as construction material for the berm.

Ash Disposal Area 2 is not now used for net disposal. Now, CCW is initially placed on the island by sluicing, and then it is allowed to settle in ponds. The wastes are then dewatered and transported to other sites for ultimate disposal or use.

Most of the water introduced to the island (sluicing and precipitation) is discharged directly to Kentucky Lake as an NPDES-permitted release over a spillway. The remainder discharges to Kentucky Lake through seeps through the berm, discharges to groundwater beneath the island, is trucked from the island with moist wastes taken to other sites, or evaporates. It is presumed that the discharge to groundwater subsequently discharges to Kentucky Lake as well.[2]

[2] If the Camden Chert were being used as a major water supply, leachate from Ash Disposal Area 2 could readily migrate into that formation and water supply. No such water supply is described in the materials that have been reviewed. However, in as

TVA has committed to decommission the Johnsonville Fossil Plant by 2017. As part of that operation, TVA will also close Ash Disposal Area 2. The preliminary plans include eliminating anthropogenically introduced water to the island, grading the top of ash to encourage run-off of precipitation, installing a cap (of a design yet to be determined) to restrict infiltration from precipitation, and monitoring using a voluntary monitoring system of indeterminate duration. These efforts will significantly reduce the discharge of contaminants from Ash Disposal Area 2 into Kentucky Lake from levels that occur today. They will not, however, stop discharge to the lake.

1.3 Recommendations

Based on the analyses developed below, the following issues should be addressed through the final closure plan:

(1) Water that enters into the CCW in Ash Disposal Area 2 discharges to Kentucky Lake. Therefore, the cap installed at closure should be a composite cap to minimize infiltration of water into the disposal area;

(2) The final closure plan should recognize that installation of the cap is a construction measure that is not a permanent solution; degradation of even a composite cap is inevitable. To properly maintain a composite cap, thereby minimizing future discharge, and to address groundwater contamination, the final closure plan should establish maintenance and monitoring over an indefinite post-closure care period;

(3) TVA constructed portions of the perimeter dike encircling the impoundment using CCW. Continued contact with water, even at a lower rate post-closure due to a composite cap, will continue to weaken the stability of the CCW construction. Monitoring of dike stability post-closure should also be specified in the final closure plan for an indefinite period; and

(4) Removal of the CCW from within the disposal area is the only permanent and certain means to eliminate all leachate discharge and to prevent dike failure resulting from further degradation of CCW in the dike construction. Such removal is recommended in the final closure plan as preferable to monitoring and maintenance for an indefinite care period.

2. History and Operations

The Johnsonville plant began generating power in 1952 (Stantec, 2011). The initial disposal area for CCW from the Johnsonville plant was immediately north of the generating station, on upper terrace levels in order to prevent contamination by placing CCW directly in water (TVA, 1958). This original disposal area was filled and leveled for use as the coal yard storage area for the station within the first

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much as the materials reviewed are mute with respect to groundwater usage in the vicinity, the lack of such migration is a presumption.

seven years of station operation. This initial area was designated Ash Pond A. Ash Ponds B and C were sequentially north of Ash Pond A, also along the east side of Kentucky Lake, but at elevations low enough to require lakeside berms and filling in areas partially below lake level (*ibid.*). Ash Pond B, also known as Area A, was filled and is the problematic area between the Dupont property and the lake, north of the coal piles. From the available records, it is not clear whether disposal occurred in Area C.

The fourth disposal area, Ash Pond D, was constructed west of the generating station, within Kentucky Lake. The generating station was built along the edge of older terraces of alluvial sediments, above lake level. The station is separated from the natural channel of the Tennessee River by the width of floodplain that was inundated when Kentucky Lake filled. The floodplain was characterized by a natural levee along the river channel that stood at a slightly higher elevation than the floodplain adjacent to the station. At normal lake level, the old levee along the channel was near the lake surface or slightly emergent and separated from the station by deeper water.

TVA selected this linear area of shallow water or emergent sediments for construction of the fourth disposal area, Ash Pond D. From the discussions in recent documents, it is unclear when and how construction of the disposal area within the lake began. One understanding of the sequence was that a low island was passively created along the levee as a result of dredging unrelated to CCW disposal (MMA, 2011). Under this scenario, the initial island was developed as a breakwater during plant construction (1949-1952) by placement of dredged sediments from areas for water inlets and the boat harbor. In as much as TVA, by 1958, fully anticipated using the area “between the west dike of the boat harbor and the old river channel” as disposal area D (TVA 1958), this narrative seems plausible.

The design of Ash Pond D was to encircle the shallow or emergent area between the boat harbor dike on the east and the old river channel on the west with a continuous berm what would create a ponded area to which the plant could sluice CCW for disposal. The ring shaped berm-island was connected to the plant with a causeway allowing access of both the sluice pipes and the construction equipment. The construction of the perimeter berm in 1968 and 1969 (MMA, 2011), with a berm elevation of around 370 feet, allowed the site to begin receiving CCW.

In 1970, TVA raised the berms to an elevation of about 378 feet, sufficient to protect the disposal area from high lake levels (*ibid*.). The silt and clay used for raising the berm at this time were largely obtained from a borrow area “A” located within the perimeter dike. TVA raised the dikes by mining the upper, finer-grained floodplain sediments within the dike, in part because the alternative borrow area was more than a mile away (McCraw, 1969). TVA again raised the ring berm in the late[3] 1970s (Stantec, 2011) to the current elevation of 390 feet (MMA, 2011, and Stantec, 2011) to increase disposal volume. Less material for the second lift was available from borrow area “A” which then had only 3 to 10 feet of appropriately fine-grained sediments remaining (Farmer, 1977). In addition to testing other borrow areas for usable sediments, compacted CCW was evaluated for its geotechnical properties (*ibid*).

[3] MMA, 2011, indicates this lift was constructed in 1974, but other documents indicate that 1978 is a likelier time.

Subsequent to the second raising of the berm around Ash Disposal Area 2, the operation of the area became a mix of CCW disposal and CCW processing for disposal elsewhere on the Johnsonville facility or off site (MMA, 2011, and Stantec, 2011). By the early 1990s, structural and containment problems began to develop with the perimeter berm. These problems were particularly critical in areas near the sluice water discharge structures. The discharge pipes were shifting and leaking; severe seepage through the berm was observed; and locally, the surface of the berms developed subsidence features and sink holes. Geotechnical investigations revealed layers within the berms that had been constructed of CCW. In areas where problems had been identified with the surface of the berms or with the discharge structures, the CCW within the berms had little or no cohesion, were highly conductive of water, and had low density (Law, 1994). The character of the CCW in the berm in this area is consistent with what would occur as placed and compacted CCW weathers and subsequently leached with time in reaction to water passing through it, unlike natural earthen materials.

In immediate response to these problems and investigations, TVA made repairs to the areas in immediate need and replaced the discharge pipes with a spillway. However, problems with the integrity of the berm have continued. Borings elsewhere through the berms have identified thick CCW layers constructed into the berm, often with loss of strength and/or cohesion (*ibid*). The general inadequacy of the remaining strength of the berm is, in part, driving the need to close the facility (MMA, 2011, Stantec, 2011). It is notable that discussions of materials used in berm construction that were written during the 1990s unhesitatingly identify CCW as a material used and identifiable in borings through the berms (*e.g.*, Lindquist, et al., 1995, Law, 1994), while contemporary documents do not mention the construction uses of fly ash at all (*e.g.*, Stantec, 2011).

3. Hydrogeology

The hydrogeology around and under the ash island is a major control on the risks associated with the disposal area. Kellberg (1948) described the geology of the site, as it was understood prior to the construction of the Johnsonville station. The uppermost bedrock beneath the ash island is the Camden Chert. This unit is highly fractured and readily conducts water. Kellberg reports, “The fractured condition of the chert allows ground water to circulate freely between the joints, bedding planes, and fractures, and does not provide a watertight foundation.”

Overlying the Camden Chert are the alluvial sediments of the Tennessee River floodplain. As with floodplain sediments generally, these are characterized at their bottom, where in contact with bedrock, by coarse-grained and highly permeable sands and gravels. Moving upward through floodplain sediments, the grain size typically becomes finer and the sediments are less permeable. This pattern is seen in the shallow alluvial sediments generally in the area (*ibid*) and directly under the perimeter berm of the ash island (Betson, *et al*., 1986).

The natural distribution of materials under the area where TVA constructed the ash island is one of increasing permeability as one moves away from the land's surface and into the bedrock. A corollary of this observation is that, absent a disturbance to the natural system, nature provides some natural isolation between Kentucky Lake water and the underlying groundwater.

The ash island fundamentally alters the relationship between surface water and groundwater and the potential for impacts to Kentucky Lake. The water levels that TVA maintains in the settling ponds within Ash Disposal Area 2 provide the driving force to move leachate from the CCW within Ash Disposal Area 2 to Kentucky Lake. Leachate moves downward into groundwater and radially away from the ash island into the lake. This flow pattern is expected; it has been recognized as likely for decades, and monitoring wells have documented the pattern (Betson, *et al*., 1986, Lindquist, *et al*., 1995, and Stantec, 2011, *e.g*.). In addition to the groundwater pathway for the leachate to Kentucky Lake, there is the direct discharge of leachate to Kentucky Lake via seepage through the berm. This, too, is an expected and documented pathway (Lindquist, *et al*., 1995). It is also expected and known that the leachate migrating from Ash Disposal Area 2 is significantly contaminated (Lindquist, *et al*., 1995; Unknown, 1997; Stantec, 2011).

Although what happens between the ash island and Kentucky Lake is not disputed, the magnitude and the significance of the flows are seriously in doubt. The United Stated Environmental Protection Agency (EPA) expressed concern in the mid-1980s about the rate of migration through the groundwater into Kentucky Lake and requested an assessment. The result was the *Assessment of Leachate Containment, Ash Pond D*, Report No. WR28-2-30-101 (Betson, *et al*., 1986). This report has remained the single and definitive assessment. It concluded that, while the pathway of migration exists, the rates of discharge are so slow that the impact to Kentucky Lake is minimal and not of concern. This assessment is seriously flawed for at least two fundamental reasons.

First, Betson developed its conclusions using the data from 14 exploratory penetrations of the sediments that underlie the berms around Ash Disposal Area 2. TVA constructed the berms upon the natural sequence of sediments, *i.e*., the fine-grained river deposits with low permeability that exist *beneath* the berms. Those sediments do not, however, exist any longer *within* the berm because these sediments were excavated to provide the soils with which the berm lifts were constructed (McCraw, 1969 and Farmer, 1977). The Betson calculations of very slow flow into the alluvial sediments beneath the disposed ash presume the existence of low-permeability, fine-grained sediments impeding significant flow into the high-permeability sands and gravels beneath. Since those fine-grained sediments are no longer there, there is no impediment to flow and the CCW leachate can flow directly from Ash Disposal Area 2 into the high-permeability sediments. The discharge is orders of magnitude greater than computed by Betson, *et al*.

Second, Betson calculations assume low permeability that was assigned to the CCW material. The values that are used were based upon the very fine-grained character of fly ash and an assumption of comparable permeability to natural earth materials of similar grain size. That assumption is based upon a false analogy and underestimates the permeability by, again, orders of magnitude. Among the documents that were reviewed is a set of analyses of the geotechnical properties of CCW as it exists within the disposed area and not, for example, as it would exist if compacted for construction purposes (Unknown, 1995). These two errors compound to create an underestimation of contaminant migration to Kentucky Lake by 1000-fold or more.

4. Proposed Closure

TVA has had prepared a preliminary closure plan for Ash Disposal Area 2 (Stantec, 2011). This plan discusses closure in an appropriate series of contexts; eliminating anthropogenic water from the facility, grading the final waste in a manner to encourage precipitation to run off the facility and not infiltrate, monitoring the groundwater, providing post-closure care, and considering statutory requirements for successful closure. Unfortunately, as a preliminary plan for closure, there are insufficient details to determine the likelihood of successful closure.

There are a number of important points to keep in focus as the preliminary plan moves toward a plan that can be successfully implemented. First and foremost is minimizing, to the extent possible, all water introduction into the closed facility. All water that enters Ash Disposal Area 2 after closure will migrate into Kentucky Lake. There is a 1:1 reduction of contaminant loading to the lake with a reduction of infiltration. The connection between the waste and the lake is far greater than previously computed or considered (Betson, *et al*., 1986). However, if water is kept from entering the landfill, the effective connection that exists will allow head levels within Ash Disposal Area 2 to decline to lake levels, reducing outward groundwater flow to virtually zero and eliminating seepage through the berm above lake level. Clearly, given this consideration, the easy choice for capping the Ash Disposal Area 2 is the composite cap system, not simply clay.

Another important consideration as one moves from a preliminary to an implementable plan is post-closure care. The CCW in Ash Disposal Area 2 is effectively perpetual. If denied water to move its contaminants, they remain isolated. But if the integrity of the confinement is compromised, the migration to the lake immediately resumes. In Attachment B – Ash Pond Closure Schedule (Stantec, 2011), a post-closure period of only 18 months is implied. Eighteen months of post-closure care would be inadequate. To successfully isolate the CCW at Ash Disposal Area 2, TVA needs to maintain the cap, and therefore post-closure care, indefinitely.

An earlier ash disposal area at Johnsonville, north of the plant itself, demonstrates the long-term problems that result from inadequate closure and that long term post-closure care period is correspondingly necessary. The disposal area, Ash Pond A, was closed in 1976. The most recent post-closure monitoring found was 1994, less than 20 years after closure (Unknown, 1997). In the early 1990s, monitoring results showed consistently high levels of contamination, with arsenic frequently above 50 ppb and as high as 570 ppb (*ibid*). The quantity of contaminated groundwater entering Kentucky Lake from post-closure Area A was simulated by groundwater modeling as 590 m^3/day (Lindquist, *et al*., 1995, p. 32), a value substantially greater than that simulated for the active Ash Disposal Area 2 (Betson, *et al*., 1986). This level, or higher, of contaminant loading to Kentucky Lake may well persist to this day, but is no longer monitored after 'successful' closure.

The problem of long term potential for post-closure contamination is not limited to this neighboring storage facility at the Johnsonville plant. The EPA determined that "[a]lthough leaching does occur during a landfill's operating life, risks from these releases are insignificant when compared to post-closure releases, given the long time it take metal-bearing wastes to leach and reach peak concentrations in groundwater wells surrounding the landfill." (U.S. EPA, 2010, 3-21, n 11).[4] .

In subsection 1.3 Regulatory Framework for Design, Stantec observes, "The Tennessee Water Quality Control Act prohibits the discharge of any substance into the waters of the state that could cause damages or pollution to such waters. Therefore, each wastewater impoundment must be properly closed to eliminate discharge of potential pollutants to both the surface and ground water." So long as these wastes remain in place in a disposal area with an open bottom, that performance standard cannot be met. In a disposal setting like this, open to flow to Kentucky Lake should recharge ever recur, discharge can be permanently eliminated only by eliminating the waste.

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