Two Bottom Ash Management/Handling System Enhancement Case Studies – From Technology Evaluation and Design through Construction and Performance Verification

Jason Obermeyer¹, George McKenzie², Aaron Davis³, Chris Pickelmann⁴

¹ Golder Associates Inc., 44 Union Boulevard, Lakewood, Colorado 80228
² Consumers Energy, 1945 West Parnall Road, Jackson, Michigan 49201
³ Consumers Energy, 17000 Croswell Street, West Olive, Michigan 49460
⁴ Consumers Energy, 2742 Weadock Highway, Essexville, Michigan 48732

KEYWORDS: Bottom ash handling, concrete tanks, geosynthetic-lined impoundment, Consumers Energy

ABSTRACT

Over the last several years, Consumers Energy has completed significant enhancements to the bottom ash management/handling systems at its J.H. Campbell and D.E. Karn Generating Plants. This paper provides a narrative summary of the projects, beginning with an evaluation of bottom ash management/handling technologies that included concrete tanks, lined surface impoundments, and mechanical dewatering. Concrete bottom ash tanks were sited, designed, and constructed at one of the sites, while a lined surface impoundment was sited, designed, and constructed at the other. Design and construction considerations for both technologies are discussed. With both systems now in operation and performing in accordance with Consumers Energy’s design objectives, in-service system performance and operational best practices are emphasized.

BACKGROUND

Consumers Energy (Consumers) owns and operates the J.H. Campbell Generating Plant (Campbell Plant), a 1,450-megawatt coal-fueled electric generating facility in West Olive, Michigan, and the D.E. Karn Generating Plant (Karn Plant), a 1,791-megawatt
coal- and gas/oil-fueled electric generating facility in Essexville, Michigan. Historically, bottom ash generated from the coal-fired electric generation units (three units at the Campbell Plant and two units at the Karn Plant) was sluiced to bottom ash handling areas (ponds or basins) for solids settling/treatment and temporary storage. Much of the bottom ash was sold for beneficial reuse. Periodically, the unsold bottom ash was removed and transported to an ash landfill for permanent containment.

In 2014, Consumers initiated projects to enhance and modernize the bottom ash management/handling systems at the Campbell Plant and the Karn Plant. Since that time, technology evaluations have been conducted, design of the selected technologies has been completed, enhanced bottom ash management/handling systems have been constructed and put into operation, and the actual performance of each system has been verified through field testing. A case study for each plant is described in the following sections.

TECHNOLOGY EVALUATION

Consumers initiated an evaluation of several technologies for enhanced bottom ash management at each site. The technologies considered were:

- Geosynthetic-lined impoundment for solids settling and bottom ash handling
- Concrete tanks for solids settling and bottom ash handling
- Submerged flight conveyor (SFC) system for bottom ash dewatering
- Remote submerged flight conveyor (RSFC) system for bottom ash dewatering

The geosynthetic-lined impoundment option would involve the design and construction of a bottom ash handling area meeting the requirements for new surface impoundments under the Coal Combustion Residuals (CCR) Rule. It would receive sluiced bottom ash and provide sufficient residence time for solids settling to enable continued compliance with the National Pollutant Discharge Elimination System (NPDES) permit for the relevant site in terms of total suspended solids (TSS) concentration. Bottom ash would be deposited into the impoundment, with periodic stacking (bottom ash dewatered readily when stacked above the water line) and removal using an excavator to load trucks for hauling, placement, and permanent storage in a permitted dry landfill on site.

The concrete tanks option would involve the design and construction of:

- Primary tank(s) to receive sluiced bottom ash and provide access for a front-end loader to remove bottom ash and stockpile it for beneficial use off site or load it into trucks for hauling, placement, and permanent storage in a permitted dry landfill on site.
- Secondary tanks to receive water decanted from the primary tank(s) and provide sufficient opportunity for solids settling to enable continued compliance with the NPDES permit for the relevant site, particularly in terms of TSS concentration.

Concrete tanks are not subject to the CCR Rule.

The SFC system and RSFC system options would involve the design and installation of mechanical equipment to receive sluiced bottom ash in troughs and move the ash (via horizontal flights) up a dewatering ramp and into concrete bunkers. The SFC system would have required significant boiler retrofits to install the dewatering conveyors beneath the boilers, so this option was not considered economically feasible. For the RSFC system, the dewatering conveyors would be located outside the plant building. From this location, trucks would be loaded and bottom ash would be hauled and placed for permanent storage in a permitted dry landfill on site. This option would include sluice water recirculation, which would reduce or eliminate the discharge of bottom ash transport water from the site.

Consumers retained Golder Associates Inc. (Golder) to assist with the technology evaluation for each site. The technology evaluation included consideration of the following key factors:

- Environmental performance
- Longevity
- Operational complexity
- Impacts to existing facilities
- Disruption/impacts to existing operational practices (both during and after installation)
- Estimated capital cost
- Estimated operations and maintenance (O&M) cost
- Regulatory compliance and flexibility
- Duration of plant outage required for installation and commissioning
- Schedule conformance relative to the target in-service date
- Winter operation

The technology evaluation also included a stakeholder meeting held at each site. Plant personnel from departments including engineering/project management, environmental, plant operation, and plant maintenance were invited to participate in an interactive presentation of the options (including conceptual-level design renderings), a question-and-answer session, and a feedback session in which preferences and concerns regarding the options could be shared openly.
The concrete tanks option was found to achieve the best balance for the Campbell Plant, particularly on the basis of:

- Impact on existing facilities and operations – limited modifications in the plant, operationally similar to existing practices, could be constructed in existing bottom ash pond locations
- Environmental performance – watertight, using a specially designed concrete mix and waterstops at construction joints
- Capital cost – most cost-beneficial
- Longevity – plant life through 2040, fewer concerns over mechanical equipment longevity and protection of a geosynthetic liner system over more than 20 years
- Schedule conformance – approximately 22 months to design and construct, with minimal outage time required to transition from the bottom ash pond system to the concrete tanks system
- Regulatory compliance and flexibility – flexibility to meet potential future Steam Electric Effluent Guidelines implementation requirements for zero discharge of bottom ash transport water and flexibility to install additional water treatment alternatives to meet changing water quality standards

The geosynthetic-lined impoundment option was ultimately found to achieve the best balance for the Karn Plant, particularly on the basis of:

- Capital cost – most cost-beneficial for plant life through 2023 (less than five years of operation)
- Impact on existing facilities and operations – no modifications in the plant, operationally similar to existing practices (with added need to protect the geosynthetic liner system)
- Environmental performance – dual composite liner system
- Schedule conformance – approximately 14 months to design and construct, with only a one-day outage required for each unit for system commissioning

CAMPBELL PLANT – CONCRETE TANKS

Design
The primary tanks at the Campbell Plant were designed to control and contain the anticipated bottom ash sluice water flow rates, contain accumulated bottom ash for a period of at least one week, and allow for ramp access (including turning) by a front-end loader to remove and stack bottom ash (see Photograph 1). The footprint of each primary tank is approximately 60 meters by 20 meters (200 feet by 65 feet), and the maximum operating depth is 2.3 meters (7.5 feet). The secondary tanks at the Campbell Plant were sized to provide additional hydraulic residence time for solids settling in conformance with the design objective for TSS concentration of 30 milligrams per liter.
(mg/L) or less. Golder and Consumers worked together to obtain samples of sluiced bottom ash and conduct settling rate tests. Each secondary tank has a flow length of approximately 125 meters (410 feet), surface area of 625 square meters (6,720 square feet), and operating depth of about 3 meters (10 feet) to accommodate a flow rate up to 32,175 liters per minute (8,500 gallons per minute).

The maximum anticipated bottom ash generation rate is approximately 100 tonnes per day. Sluiced bottom ash is received at the west end of each primary tank, and the coarse solids form a pile beneath the pipe outlet. Water decants and flows by gravity through buried crossover piping into a secondary tank for further clarification. A pinch valve is installed on each crossover pipe to enable flow rate control. Flow rate control can be programmed to respond to the water level in the primary tank as a means to equalize the outflow rate from the primary tank based on the driving hydraulic head. After entering and flowing through either one or two secondary tank(s), treated water enters a buried outlet pipe, then routes through a series of channels and an equalization pond to the permitted outfall. Design measures were implemented to facilitate the possible future need for a closed-loop system.

Photograph 1: Concrete tanks system layout

Redundancy was a key consideration in the design. The system (e.g., piping configurations, valving, tank capacities) was designed so that bottom ash sluice water
from all three units could route into either primary tank, in case the other primary tank needs to be taken out of service temporarily. The option to use one or two secondary tanks is available regardless of the primary tank(s) that is/are in service. Any of the secondary tanks can be temporarily taken out of service at any given time, if needed for cleaning or maintenance.

The design included an optional chemical (polymer) addition system to assist with solids settling in the secondary tanks. Pilot testing of the tanks indicated that the target water quality could be met without installing the chemical addition system. If water quality standards change, the infrastructure is in place to install the chemical treatment system in the future.

Construction
The concrete tanks were constructed in two phases between April 2017 and January 2018. The first phase involved clean closure of the historical bottom ash handling area where the concrete tanks were sited, followed by earthwork construction to establish base grades. The second phase involved forming and placement of concrete (see Photograph 2), installation of process piping and valves, extension/rerouting of bottom ash sluice piping and installation of valves, backfill placement and site grading, electrical installation, and instrumentation and controls integration into the Campbell Plant's distributed control system (DCS). Construction quality assurance included full-time observation, density testing of embankment fill, and concrete testing.

The primary tanks and secondary tanks were subjected to hydrostatic tightness testing in accordance with ACI 350.1-10. All of the tanks met the criteria for hydrostatic tightness.
Operation
The changes to previous practices upon switching to the concrete tanks has required some adjustment on the part of Consumers’ plant operators, maintenance technicians, and ash handling personnel, but the transition is complete and operation of the concrete tanks is going smoothly. A front-end loader is used for about an hour each day to reposition ash in the primary tank and stack bottom ash on the concrete ramp and apron above the water line (see Photograph 3). Within a period of an hour or less, the bottom ash dewatera sufficiently to stockpile it for beneficial reuse or load it into trucks. Bottom ash stockpiling and/or loading and hauling occurs daily. As in the past, bottom ash is sluiced from each unit two or three times per day; two sluice events per day has been found to be operationally favorable. The pinch valve position is typically fully open/fully closed to maximize hydraulic residence time in the primary tank (instead of adjusting the pinch valve to equalize flow rate as a function of water level in the primary tank). Freezing has not been an issue, even during a period of extreme cold weather in early 2019, due to the heat contributed by the sluice water.
Performance Verification
After construction, Consumers and Golder conducted performance verification sampling and testing to provide assurance that target TSS concentrations were being achieved reliably. Sampling and testing locations were established at the following locations:

- At the outlets of primary tanks to indicate the TSS concentration in water decanted into the secondary tanks
- At the outlet of the secondary tanks to indicate the treated TSS concentration
- At various locations along the series of channels and equalization pond downstream to indicate possible continued reduction in TSS concentration

A correlation between turbidity and TSS concentration was developed for the site-specific bottom ash sluice water so that a portable turbidimeter and/or permanent turbidimeters installed in the tanks could be used to provide a real-time approximation of TSS concentration as an indication of solids settling performance. Samples were also collected for direct analysis (testing) of TSS concentration. An initial testing program took place over a period of four weeks, during which time treated water was not
discharged pending confirmation of system performance. Bottom ash sluicing operations and pinch valve operating mode (fully open/closed or variable based on primary tank water level) were varied to evaluate performance across a range of operating scenarios and strategies. A second testing program took place over a period of one week to provide final verification of system performance under the operating procedures that were found to be most favorable during the first testing program.

At the outlet of primary tanks, TSS concentration varied considerably. Predictably, relatively high TSS concentrations (sometimes higher than 50 mg/L) were measured for samples taken during or soon after bottom ash sluicing. Between sluice events, TSS concentrations often dropped below 20 mg/L. At the outlet of secondary tanks, TSS concentration was consistently between 10 mg/L and 30 mg/L under the selected operating procedures. Further reduction in TSS concentration was found to be nominal using an additional secondary tank. Observed performance of the concrete tanks met expectations, and the testing program established a high degree of confidence that TSS concentrations at the outfall will continue to meet permit requirements.

KARN PLANT – GEOSYNTHETIC-LINED IMPOUNDMENT

Design
The geosynthetic-lined impoundment at the Karn Plant was sized to provide sufficient hydraulic residence time for solids settling in conformance with the design objective for TSS concentration of 30 milligrams per liter (mg/L) or less. Golder and Consumers worked together to obtain samples of sluiced bottom ash and conduct settling rate tests. The impoundment has an area of approximately 0.5 hectares (1.2 acres) and an operating depth of about 1.5 meters (5 feet) to accommodate a design flow rate of approximately 9,000 liters per minute (2,370 gallons per minute) for about 9 hours per day. The maximum anticipated bottom ash generation rate is approximately 50 tonnes per day.

Sluiced bottom ash is received at the western end of the impoundment (see Photograph 4). Treated water passively decants through overflow piping at the eastern end of the impoundment. From there, it enters a surge basin and routes through a series of channels to the permitted outfall.

The liner system design for the impoundment comprises the following components, from bottom to top:

- Prepared subgrade
- Secondary geosynthetic clay liner (GCL)
- Secondary geomembrane
- Drainage layer (sand layer across the floor, geocomposite on slopes)
• Primary GCL
• Primary geomembrane

In the area where equipment access is needed for bottom ash handling (approximately 0.16 hectares or 0.4 acres, labeled as “handling area” on Photograph 4), a protective cover system was installed over the liner system. The protective cover system consists of a geotextile (for cushioning and drainage) overlain by a cellular confinement (or geocell) layer with concrete infill.

Construction
The geosynthetic-lined impoundment was constructed between March and June 2018. The perimeter embankment was constructed with imported sand, followed by installation of the dual composite liner system. Construction quality assurance included full-time observation, density testing of embankment fill, destructive and non-destructive testing of geomembrane seams, and concrete testing.

The impoundment was sited away from (but adjacent to) the existing bottom ash pond so that normal bottom ash deposition could occur during construction. During this time, extensions of the bottom ash pipelines (Nuvaloy abrasion-resistant piping) were being installed between the intended intersection point with the existing bottom ash pipelines and the new impoundment. When the new impoundment was ready to receive sluiced bottom ash, carefully coordinated rerouting through alternate piping allowed for the ability to install a connection between the existing bottom ash pipeline and the new bottom ash pipeline extension. This sequencing required careful planning by Consumers and the contractor, so as not to impact the generation operations of the plant.

Photograph 4: Geosynthetic-lined impoundment in operation
Operation
The transition to operating the geosynthetic-lined impoundment has been relatively straightforward for Consumers. An excavator is used for less than an hour each day to reposition and stack bottom ash, which facilitates loading into trucks. Bottom ash loading and hauling occurs on a weekly to bi-weekly basis. The excavator moves out onto the bottom ash pad in the handling area and excavates from north (farthest from the truck loading area) to south (nearest to the truck loading area). The excavator operator is careful to keep the excavator bucket at least 0.6 meters (2 feet) above the top of the liner system and uses an equipment-mounted global positioning system (GPS) to assist with this. The concrete protective cover provides an additional safeguard. A bottom ash berm/weir constructed at the downstream end of the handling area has been found to enhance solids settling. As in the past, bottom ash is sluiced from each unit three times per day (once per shift). Freezing has not been an issue with this sluicing schedule, due to the heat contributed by the sluice water. There are no active controls for management of inflow or outflow rates; the system was designed with operational simplicity in mind.

Performance Verification
Immediately after construction, Consumers and Golder conducted performance verification sampling and testing to provide assurance that target TSS concentrations were being achieved. Sampling and testing locations were established at the following locations:

- Point INT – at the plant water intake location to indicate baseline TSS concentrations in raw water used for bottom ash sluicing
- Point SP1 – near the bottom ash deposition point (labeled as “deposition point” on Photograph 4) to indicate the initial TSS concentration
- Point SP2 – at the downstream (eastern) end of the impoundment (labeled as “outlet” on Photograph 4) to indicate the treated TSS concentration
- Point SP3 – at the outlet of the surge basin (labeled as “surge basin” on Photograph 4) into the series of channels downstream to verify the treated TSS concentration

A correlation between turbidity and TSS concentration was developed for the site-specific bottom ash sluice water so that a portable turbidimeter could be used to provide a real-time approximation of TSS concentration as an indication of solids settling performance. Samples were also collected for direct analysis (testing) of TSS concentration. The testing program took place over a period of six days with normal bottom ash sluicing operations.
At Point SP1, near the deposition point, TSS concentration varied considerably. Predictably, relatively high TSS concentrations (sometimes higher than 100 mg/L) were measured for samples taken during or soon after bottom ash sluicing. Between sluice events, TSS concentrations at Point SP1 often dropped below 25 mg/L. At Point SP2, near the downstream end of the impoundment, TSS concentration was consistently less than 20 mg/L. Some variability was still evident as a response to bottom ash sluicing, but the target TSS concentration was consistently achieved. At Point SP3, near the outlet of the surge basin, TSS concentration ranged between 12 and 15 mg/L on a consistent basis. Variability associated with bottom ash sluicing was noticeably reduced relative to Point SP2, indicating the effectiveness of the surge basin in providing some level of equalization. Notably, TSS concentrations for Point INT, at the raw water intake, were also between 12 and 15 mg/L. That is, effluent from the surge basin had approximately the same TSS concentration as the raw water taken into the plant for bottom ash sluicing. Observed performance of the geosynthetic-lined impoundment exceeded expectations, and the testing program established a high degree of confidence that TSS concentrations at the outfall will continue to meet permit requirements.

CONCLUSION

The recent bottom ash management/handling enhancements implemented by Consumers at the Campbell Plant and the Karn Plant provide an example of different technical approaches being appropriate for different scenarios. Concrete tanks at the Campbell Plant represent a robust and resilient solution with considerable operational flexibility to serve three coal-fired units that will be relied upon to generate electricity for more than two decades into the future. Solids settling performance of the concrete tanks has been in line with expectations, without the need for chemical (polymer) addition. The geosynthetic-lined impoundment at the Karn Plant represents an environmentally responsible and economical solution with operational simplicity that is appropriate for two coal-fired units retiring in the next four years. Solids settling performance of the geosynthetic-lined impoundment has also been in line with expectations.