Non-Traditional Approaches for Management of Ash and Transport Water from Down Under

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1 Abstract
In 2017, over 100 million tons ($9\times10^{10}$ kg) of Coal Combustion Products (CCPs) were produced in the United States (US), of which flyash and bottom ash accounted for about 40% (ACAA, 2018). Although many US utilities have converted from wet fly ash management to predominantly dry systems, most bottom ash is still managed using wet transport systems. With tightening EPA regulation on coal ash management geared towards phasing out wet ash handling and surface ash impoundments, beneficial reuse of CCPs and alternative disposal approaches for the balance of the coal ash have become a focus.

This paper presents the non-traditional approaches undertaken by two Australian coal fired power stations in managing ash and associated transport water. The major driver for these projects was to convert their existing lean phase sluiced ash to a dense phase slurry to maximize ash storage capacity in the existing ash impoundment and to enable future mine void disposal. Within the surface impoundment, the dense phase slurry could be deposited sub-aerially on the beach rather than sub-aqueously, allowing the ash to desiccate and further reduce in volume. One of the stations also harvests floating cenospheres from the surface of the thickener for reuse.

Water recovered from the ash thickener (located closer to the ash source) is returned directly for sluicing which reduces pumping costs compared to pumping from the ash impoundment. Both systems still required an emergency discharge facility (portion of existing impoundment) to cater for process upsets or plant maintenance. Lessons learned from the project may be applied to US-based utilities which are currently faced with a no-discharge requirement for ash transport water.

2 Introduction
With a heightened US focus around coal ash storage and its impact on groundwater and surface water quality, the two case studies presented in this paper provide design concepts and experiences which US power stations may consider in steering their operations into compliance with the new regulatory landscape.

Between 2000 and 2010, GHD was involved in the retrofitting of ash slurry thickening processes at two Australian power stations. These projects focused on modification of traditional lean phase ash systems in a way that minimized the risk of impacting the
power generation operations. That meant avoiding modifications to existing sluicing systems which would have involved brownfields works and operation disruption to these power stations.

Thickening plants can be designed with a bypass facility to enable commissioning, troubleshooting, process upsets and maintenance downtime with little or no operational impact on the power generation process. This approach may be applicable to some power stations in US with traditional wet ash sluicing systems.

3 Traditional and More Recent Ash Management Approaches

Traditional ashing approaches in the US are based around sluicing flyash and bottom ash to large ash impoundments at low concentration (lean phase) slurries using significant quantities of transport water. Most US plants transport bottom ash separate from fly ash. In situations where water supply is plentiful, transport water was often not recovered but rather released to the environment.

In Australia the traditional approach to ash management is similar to that in the US. Wet ash sluicing systems are common in the older power stations, and these facilities can have one transport system for both fly ash and bottom ash. More recently constructed power stations tend to keep bottom ash and flyash separate. As in the US, many sell certain grades of flyash and bottom ash for use in construction and other applications.

One of the power plants in this case study, Tarong, burns bituminous (black) coal, while the other one burns lignite (brown) coal. Similar to North America, the majority of coal fired power stations in Australia burn bituminous or sub-bituminous coal. There are some differences in wet sluicing brown coal ash compared to black coal ash. For example, brown coal ash slurry has similar rheological properties to black coal ash slurry at significantly lower slurry density (ie, brown coal ash at 40% is similar to black coal ash at 60%).

Between the two projects discussed in this paper (2003), a study tour was undertaken by personnel from GHD and International Power to explore existing ash management approaches with a view to identifying approaches suitable for consideration at the ENGIE (formerly owned by International Power) Hazelwood Power Station. Five power stations and a coal washery reject reclaim beneficiation plant were visited in Queensland and New South Wales (Australia) and information gathered regarding ash collection and disposal systems. In particular, operational issues were explored with engineers and operators to gain an appreciation of the practical operability of the different systems.

Of the five power stations considered, the following ash collection and disposal approaches were represented:

- Bottom and flyash slurried into dense phase and pumped to storage stack (2 sites)
• Traditional wet sluiced bottom and flyash, retrofitted ash thickener to produce dense phase (1 site)
• Flyash slurried into dense phase and pumped to storage stack, bottom ash trucked to storage (1 site)
• Bottom ash pumped as lean phase to storage, flyash slurried to dense phase (retrofitted dense phase system) and pumped to storage (1 site)

Operational comments and recommendations from sites operating dense phase ash slurry systems that were considered in the Hazlewood ash thickening plant design included:

• Recommend 100% redundancy in underflow pump/pipe systems to permit continued operation when pipe blockage occurs
• Pump damage and accelerated seal wear occur due to debris in bottom ash (eg metal) even though screened
• Dense phase ash pipelines block due to inconsistent slurry densities
• Thickener can be unnecessarily large if ashing cycles cannot be sequenced to minimise number of systems ashing simultaneously
• Recommend manual flushing connection capability at regular intervals along dense phase pipeline
• Rapid setting cementitious ash causes problems in mixing troughs and mixing tanks
• High equipment wear and erosion potential due to nature of solids in slurry

4 Tarong Power Station

Tarong Power Station is located in South East Queensland, Australia. Its four 350 megawatt (350 \times 10^6 \text{ m}^2.\text{kg}.\text{s}^{-3}) turbogenerators have been operating on black coal from the adjacent Meandu Coal Mine since 1984. The station utilised a traditional wet ash sluicing system to convey bottom ash and fly ash combined from the power generation units to the ash dam. Water recovered from the dam was returned for reuse as sluice water.

Cenospheres are produced at Tarong power station through the combustion process. These are hollow, spherical silica beads which are buoyant in water (when not fractured) due to their gaseous contents. Cenospheres were harvested from the surface of the ash dam and processed by a third party for commercial applications such as fillers in lightweight concrete blocks and refractory products.

The ash dam was originally designed with sufficient capacity to store the ash produced over the life of the power station. However, the station life was extended and the coal produced more ash than expected. A second power station (Tarong North Power Station) was also to be constructed at the same site which would generate additional ash that would require storage.
GHD was engaged by Tarong Energy (power station now owned by Stanwell Corporation) to investigate alternative ash management options for maximizing the storage capacity of the ash dam. Previous work by others had identified that some form of dense phase ash disposal was likely to be required as part of the solution.

The ash transport water increased in acidity through contact with the ash resulting in ash slurry pH values as low as pH 4-5. In the existing lean phase ashing system truckloads of lime were periodically dumped into the ash pits and transported to the ash dam with the ash slurry. Residence time in the ash dam allowed neutralization of the return water before reuse for ash sluicing.

4.1 Tarong Ash Thickener Project
GHD investigated options, conducted pilot trials and undertook preliminary and detailed design of a new ash thickening plant. GHD also assisted the construction contractor with commissioning.

All references to slurry density % solids are on a weight/weight basis.

Options considered by GHD at the concept stage included:

- Thickening ash slurry to 55% solids
- Thickening ash slurry to 55% solids and dewatering a portion of the underflow to recombine producing a 62% slurry
- Thickening ash slurry to 55% solids and adding dry ash producing a 62% slurry

The basic thickening option generating a 55% slurry had the lowest whole of life costs and was adopted as the preferred approach for further development.

A pilot plant was operated in 2001 to assess screening, thickening, cenosphere recovery and dewatering performance (in case 55% density could not be achieved through thickening alone). The pilot plant was also used to generate a considerable quantity of realistic dense phase ash sample for assessment of pumping, mixing and beaching characteristics.

Figure 1 shows the setup of the Tarong pilot system including the 1 m diameter pilot thickener (red), the disc filter and a 2 m diameter pilot thickener with skimming mechanism (blue).

Lean phase slurry was fed to a static sieve bend screen to separate out bottom ash prior to the thickening. Screen performance and blinding were qualitatively assessed and no blinding issues were encountered.

The thickening trials demonstrated that even for low bed depths, thickened slurry of density in excess of 60% solids could readily be generated in the 1 m diameter pilot thickener without the use of flocculant.
A ceramic disc filter was used to dewater the thickener underflow and cake densities of between 70 to 80% solids were achieved. The filter cake discharged from the filter plates without difficulty and filtrate quality was excellent.

Cenosphere recovery via the skimming mechanism was tested using the 2 m pilot thickener and found to be reasonably effective. The testing identified that the use of sprays to assist transport cenospheres down the launders may be beneficial at full scale. The proposed thickening plant would continue to add lime to the ash slurry for pH control. Laboratory testing was also undertaken to assess relative cenosphere recovery at different lime dose rates. The dosing rates expected to be utilised in the full scale showed no discernible impact on cenosphere recovery.

An important observation from the pilot operation was the susceptibility of the pumps and piping to blockages resulting from solids settling after stoppages. The full scale design incorporated dilution and automatic flushing in pipelines to minimise the risk of blockages and restart issues.

Mixing trials were undertaken offsite by a mixing equipment vendor. A range of slurry densities was assessed to confirm mixing system design parameters. Slurries up to about 60% were found to be readily suspendable but at higher densities resuspension following stoppage was more problematic.

Pumping tests were also conducted at a Commonwealth Scientific and Industrial Research Organization (CSIRO) laboratory to determine transport characteristics for a
number of different density slurries. 4 m$^3$ of underflow generated by the pilot plant thickener were sent to the laboratory in 0.2 m$^3$ drums. The slurries were readily pumpable using centrifugal pumps but restarting after pump stoppages proved more difficult. Once any vertical legs were unblocked, the horizontal pipe sections were more amenable to restarting.

Underflow was also pumped from the pilot thickener into lined bays adjacent to the pilot plant to enable assessment of geotechnical properties for ash stacking design.

Based on the beaching trials the target slurry density for stacking in the ash dam was determined to be approximately 58%. This enabled deposition sub-aerially onto the beach permitting the ash to desiccate and further reduce in volume.

Based on the piloting and testing work undertaken, preliminary and detailed design were completed by GHD on the basis of thickener underflow reaching approximately 55-58% solids and being pumped initially to the ash dam.

The option assessment and pilot testing aspects of the Tarong ash thickener project are discussed in more detail by McFadyen et al (2003).

### 4.2 Ash Thickening Process

A basic schematic of the Tarong ash thickening process is represented in Figure 2. The extension to the ash management system to pump dense phase ash slurry to the mine void (described in the following section) is also included in Figure 2.

Lean phase ash slurry from the sluicing system drained to the existing ash pits. The plant was designed to accept a variable and intermittent feed flow of feed of 0 m$^3$/s, 0.5 m$^3$/s or 1 m$^3$/s. Upgraded pumping was installed in the ash pits to transfer the slurry to an elevated vibrating screen which rejected oversize material to a pad, bypassed 10 to 65 mm material around the thickener to the mix tank and fed <10 mm materials to the 55 m diameter thickener. Slurry arrived at the thickening plant with a solids concentration of up to 10% solids.

The existing ash trench which was previously used to drain the lean phase slurry down to the ash dam was retained as an emergency bypass to the ash dam from a number of processes within the ash thickening plant. In plant bypass mode, the ash slurry was diverted into the emergency bypass trench before it entered the screen.

Lime and flocculant were dosed into the thickener feed for pH adjustment and to assist ash settling and thickening. Ash was thickened to a target density of around 55% solids and discharged from the thickener. Controlled dosing of lime compared to the previous batch dosing approach provided much more effective water quality control and resulted in less wastage of undissolved lime buried with the settling ash in the dam.
Figure 2: Tarong Ash Management Schematic

The duty/standby underflow pumps were designed to transfer slurry from the thickener to the slurry mix tank. A recycle pump was included to transfer slurry from the thickener discharge cone back up to the feedwell to enable development of the sludge bed after plant startup and to keep the sludge turning over when the underflow pumping system was stopped.

Supernatant from the thickener drains to the thickener overflow reservoir which provides service water to the thickening plant and also supplies the ash sluicing pumps for the power station operations. Separating this water from the lean phase slurry at the thickening plant and storing it in the associated reservoir saves considerable pumping costs associated with transferring return water from the ash dam back to the power station.

Cenospheres were removed from the surface of the thickener using a skimming system and flushed down to cenosphere flotation ponds, from which they were recovered using an excavator and drained on a concrete pad. Excess water from the ponds and pad was reprocessed through the thickener.
The target density for the ash slurry transferred to the ash dam was 55 to 58% by weight. The mix tank allowed for final adjustment of the ash slurry density before it was pumped to the ash dam for disposal. If the density of the ash slurry in the mix tank became too high service water could be added. The 10 to 65 mm screenings were introduced into the agitated tank and blended with the thickener underflow. The single stage mix tank slurry pumps pumped ash slurry from the mix tank to the ash dam.

A diesel flushing pump was incorporated into the design based on the difficulties associated with resuspending settled ash in process vessels, pipelines and particularly in vertical sections of pipe where it could form competent plugs of solids. Flushing would be initiated by loss of power to the plant (and cessation of pumping or mixing) or during controlled shutdown of the pumping systems.

Ash slurry was discharged at various locations around the dam and transport water in the slurry drained to the decant area from which it was pumped back to the ash sluicing system.

The Tarong ash thickening plant is shown in Figure 3.

![Tarong Ash Thickening Plant](image)

Figure 3: Tarong Ash Thickening Plant

### 4.3 Tarong Mine Void Ash Disposal Project

Several years after the implementation of the ash thickening system (commissioned 2004) and the construction of the 450 megawatt \((450 \times 10^6 \text{ m}^2\text{.kg.s}^{-3})\) Tarong North Power Station (commissioned 2003), GHD were engaged by BMD e*3 Pty Ltd under a Design and Construction contract to undertake detailed design of a new ash disposal system transferring ash to the mine void in lieu of the ash dam.
Dense phase ash slurry from both power stations was being pumped to the ash dam which was approaching capacity. The mine voids at Meandu Coal Mine, located about 4.5 km away from the ash thickening plant, had been identified as the preferred deposition location for ash from Tarong Power Station and Taong North Power Station.

Stanwell Corporation was ultimately awarded a high commendation at the Engineers Australia Engineering Excellence Awards (Queensland Division) in 2012 for the Ash to Mine Void project.

4.4 Mine Void Disposal Process

Tarong North Power Station was designed to discharge a dense phase ash slurry of about 62% solids by mixing dry flyash and water in the appropriate ratio. Positive displacement pumps were initially used to pump the slurry to the ash dam.

Figure 2 shows the ash system modification to enable blending of the Tarong North dense phase ash and the thickened ash and pumping to the mine void. Water is recovered from the void for reuse. The Tarong North mixing and pumping system model and photograph of the dual, four stage pumping arrangement are shown in Figure 4.

Figure 4: Tarong North Mixing and Pumping System

The 1 megalitre ($10^3$ m$^3$) slurry mix tank receives the two dense phase slurries and the ash is kept in suspension using an agitator. Dilution water is added to achieve a target density setpoint for pumping to the mine void.

A duty/standby arrangement of four centrifugal slurry pumps in series was designed to transport ash slurry over a range of flowrates and solids concentrations from the tank to the mine void. The dual pipelines include sections of HDPE Lined Steel, PN25 and PN16 HDPE, providing a durable and economic solution.

As with the ash thickening plant, a diesel flushing pump was incorporated in the design to flush slurry from the pipes to avoid resuspension and blockage issues.
4.5 Tarong Lessons Learned

The ash thickening system was commissioned in 2004. Since then the main challenges in the plant are understood to have been:

- The compromise between adding sufficient flocculant to achieve adequate removal of suspended solids from the thickener supernatant to generate a good quality service water and the resultant reduction in cenosphere recovery through flocculation of cenospheres with the settling ash.
- Difficulty in consistently thickening a feed stream with considerable variability in flow and solids concentration due to the sequencing of ash sluicing from the four units. Changes to the sequencing were made to minimise the variability but at times there is still intermittent feed to the thickener. Stanwell is currently considering an investigation into increasing the thickener underflow density and improving overflow quality.
- Oversize reject trucking requirements in excess of anticipated volumes due to a recent reduction in the size of material sent to the thickener in an attempt to improve thickening performance.

The mixing and mine void pumping system was commissioned by GHD and BMD e*3 in 2010. There were two main difficulties encountered during commissioning of the mine void pumping system:

- Suspended solids in the recovered water from the ash thickening plant service water tank caused the filters to blind rapidly. Filtration of recovered ash water was required for gland seal flushing service use in the slurry pumps. The problem was overcome by backflushing the filters more regularly than initially set and increasing the backflush pressure.
- The remote solar powered valves took some effort to correctly commission to the telemetry system; however they functioned successfully to drain the pipeline in the event of a pump outage.

5 Hazelwood Power Station

Located in Victoria, Australia, ENGIE’s Hazelwood Power Station’s first power generation unit was commissioned in 1964. Additional units and capacity were progressively added and ultimately the power station provided 1760MW, a significant proportion of Victoria’s power demand. Hazelwood Power Station ceased operation in 2017 based on economic and environmental considerations. Power station site decommissioning is complete and demolition planning is well underway.

Hazelwood was fired using brown coal (lignite) from the dedicated Hazelwood mine (formally Morwell Mine). Flyash and bottom ash were sluiced with ash return water to an ash dam in a traditional wet ash sluicing system. Prior to the ash thickening system, the lean phase slurry was managed by pumping to an EPA approved and constructed ash
dam which was reaching capacity. Decant water was returned to power station for ash sluicing.

All landfills on the ENGIE Hazelwood site are EPA licenced and are operated under strict EPA management guidelines with each landfill having a Landfill Environmental Management Plan (LEMP).

5.1 Hazelwood Ash Thickener Project

GHD were engaged by International Power, the power station owner at the time, to assess ash management options for Hazelwood and a number of relevant studies were conducted.

An ash handling trial was undertaken to assess the feasibility of using trucks and the overburden conveyor to transport different blends of ash excavated ash and overburden to an overburden dump. Ash leachability was also investigated in a range of ash-overburden blends. A flocculant supplier also conducted testwork on the ash slurry and identified that relatively low dose rates of several flocculants were able to assist in thickening the slurry to 50-60% solids.

GHD undertook a more detailed options assessment for ash management which considered three shortlisted options:

- Twin Pond system (drain, excavate, blend to dense phase slurry for pumping)
- Ash thickening system (ash thickener to produce dense phase slurry for pumping)
- Ash mixing system (pneumatic conveying of flyash, blend to dense phase slurry, continue to sluice bottom ash)

Based on whole of life costs, the preferred option was determined to be the ash thickening system. Additional testing was undertaken to inform the preliminary and detailed design phases.

Water in the ash system at pH 13 had previously led to calcium carbonate and calcium sulphate scaling problems in equipment and pipework. Provision for antiscalant dosing to manage the calcite scale growth rates was included and the expected scale deposition rate was taken into account in the design. Scale deposition without antiscalant was estimated at 10 mm per month. With antiscalant addition, actual calcite deposition was estimated at 5 to 6 mm per year.

A water quality evaluation was also conducted to evaluate the potential for other scale forming constituents. This analysis concluded that if 10% of the flow was blown down or discharged from the system, the water chemistry stayed at equilibrium. Blowdown from the Hazelwood ash transport system was transferred with other excess, used water to another nearby power station for reuse as ash transport water.
Further sampling and characterization of the ash was undertaken. A pilot ash screening trial was also carried out to better understand the properties of the >10 mm proportion of the ash.

Laboratory scale thickening testwork was undertaken by a thickener vendor in order to recommend full scale design parameters. A pilot thickener was also operated on site to obtain full scale thickener design parameters and flocculant dose rates. Despite difficulties associated with the highly variable feed concentration, underflow densities of 49 to 53% were able to be generated.

The Hazelwood pilot thickener is shown in Figure 5.

![Hazelwood Pilot Thickener](image)

Figure 5: Hazelwood Pilot Thickener (New, 2007)

Rheological testing was conducted by a number of different parties on pilot thickener underflow and slurries prepared from dry ash samples. The differences in rheological properties were concluded to be associated with a change in coal feed, sample processing and preparation, and difficulties associated with obtaining representative samples from 3% solids slurry. Despite the rheological variance, testing generally concluded that a considerable increase in yield stress of the slurry occurred at concentrations of about 46% solids and above.
Beaching and deposition trials were also undertaken to assess the behaviour of the slurry when discharged into an impoundment. The limited underflow sample generated from the pilot thickener trial reduced the effectiveness of the beaching trial and the results were deemed to be of limited value. Instead, modelling was undertaken which concluded that the storage area could accommodate the design ash volumes under a range of likely beach slope conditions.

5.2 Ash Thickening Process

The simplified flowsheet of the Hazelwood ash thickening plant is provided in Figure 6.

![Figure 6: Hazelwood Ash Thickening Process (New, 2007)](image)

Flow and solids concentration in the ash slurry pumped from the station was considerably variable ranging up to about 3% solids. The power station had eight generating units which were serviced by four that contributed to the variability. Multiple slurry pipelines from the ash handling stages were received in a feed box to provide a well distributed feed to the vibrating banana screen for separation of larger bottom ash and dislodged scale from the pipelines. Antiscalant was also dosed into the feed box.

The screen separated >10 mm material into an oversize storage bin which facilitated loading of 50 t (50x10^3 kg) haul trucks using a vibrating feeder. The screen underflow was directed into the 22 m diameter high rate thickener and dosed with flocculant in the feed launder. The thickener underflow was discharged at about 30 to 35% (design basis
was 40 to 45%) and pumped into an approved EPA licensed ash storage area constructed in the mine void.

Thickener overflow drained to the existing storage dam and was returned to the power station for ash sluice water. Decant (excess) water from the ash storage area was also returned to the power station for reuse.

Nucleonic density meters were installed and the underflow pump speed and dilution water was adjusted to manage slurry densities. Manual intervention and pump control could also be engaged to increase speeds to help avoid excess slurry densities and blockage risk.

Automatic flushing was provided to empty the pipelines of ash on pump shutdown and avoid pump restart blockage issues. Dual power supply to the thickening plant, a backup generator and dual dense phase pipelines provide some operational redundancy.

The Hazelwood ash thickening plant is shown in Figure 7.

Figure 7: Hazelwood Ash Thickening Plant

If the ash thickening plant was shut down due to process problems or scheduled maintenance, the plant was bypassed and the lean phase ash slurry directed into other ash storage areas on the site.
The Hazelwood ash thickening project from inception to commissioning is discussed in more detail by New et al (2007).

5.3 Hazelwood Lessons Learned
The Hazelwood ash thickening plant was originally commissioned in 2006. Issues identified during commissioning and subsequent operations were:

- Considerable variability in the feed (flow and density) due to the batched nature of the wet ash sluicing process and the number of power generation units operating hampered the ability of the thickener to perform consistently. Changes to the sequencing of the bottom ashing for the eight units were implemented to more evenly deliver feed to the thickening plant.
- The solids in the lean phase slurry comprised char, flyash, bottom ash and dislodged scale deposits from the lean phase ash pipelines. The variability in feed flow, concentration and composition required flexibility and robustness in the ash thickening process.
- Such variability in the feed also made representative sampling for material characterization difficult.
- Provision of a dedicated and expert operations team is essential and leads to improved plant understanding, reliability and performance consistency.
- The underflow (dense phase) pumping system needs to be able to operate over a wide range of slurry conditions to accommodate changes in thickener consolidation performance.
- Flocculant and antiscalant dosing needs to be carefully managed to achieve the target underflow density and to avoid rapid pipeline scaling and constriction.
- Comprehensive commissioning and configuration of the automated density control of underflow pump speed and dilution water system can ensure the pumping system maintains resilience and reliability.
- Proposed plant modifications should be referred to the plant designer to maintain plant functionality.

5.4 Ash Thickening Plant Upgrade
In 2013 GHD, under instruction from GDF Suez (formally International Power), investigated the feasibility of reprocessing the bypassed ash which had been deposited in the EPA approved storage dam (now return water pond) through the thickening plant and discharging it as dense phase slurry to the ash storage area. At that time the plant was regularly bypassed during periods when the bottom ash was being sluiced to avoid dense phase pumping problems. The additional feed to the plant, as well as the capacity and performance of the various process units were assessed.

The following upgrades were identified to enable reprocessing of the additional ash through the plant:
• A re-pulping system to macerate the lumpy dredged material was required prior to before delivery to the thickening plant.
• Since the original plant commissioning, the vibrating screen had been changed from 10 mm to 5 mm aperture to improve the underflow pumping system reliability. The Screen decks needed to be changed to a combination of 5 mm and 10 mm apertures to handle the additional ash load.
• A third underflow pump system was required to manage the increased ash load via a new larger-bore pipeline and improve the overall pumping system reliability.

Detailed design of the system was undertaken in parallel with ordering of long lead components. The upgrades were implemented in 2016 and following commissioning, the re-pulping and thickening plant operated successfully and with much greater availability through to the closure of the power station.

6 Conclusions

The two case studies presented herein demonstrate successful approaches to retrofitting traditional wet ash sluicing systems with more modern, but relatively simple, technology to convert the ash deposition to a dense phase approach which may:

• improve water efficiency by reducing evaporative losses due to lower exposed water surface area in surface impoundments and reduced exfiltration losses through reduction in the stored volume and area
• reduce return water pumping costs by recycling from the thickener location closer to the reuse demands (sluicing, etc)
• reduce ash water inventory to store and manage
• enable ash beach desiccation and consolidation by retaining the ash above the ash water level, reducing overall ash storage volume requirements
• permit implementation of water quality amendment as part of the upgrade by treating the lean phase ash slurry or return water before reuse in the ashing circuit or to service other demands

Given the increasing focus on arresting or treating ash water discharge from power stations, the ability to treat and recycle water coupled with the other benefits listed above may be a beneficial approach to some power stations.

These dense phase systems have been designed and operated within the appropriate Australian regulatory legislation and industry guidelines which are expected to meet or exceed the Coal Combustion Residuals Rule and other US regulations.

Savings associated with reduced raw water demand, reduced return water pumping costs, more effective use of ash storage facility capacity and avoidance of implementing costly water treatment systems to permit environmental discharge of ash water may offset to some degree the ash thickening system construction and operating costs.
The lessons learned presented in this paper should assist in consideration of issues experienced with design and operation of dense phase ash systems (both retrofitted thickening approaches and dry ash slurrying systems).

7 Acknowledgment
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8 References
