Dewatering Ash – Progress Over the Last 5 Years

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ABSTRACT

The past five years have seen numerous applications of dewatering techniques in CCR. Those techniques include rim ditching and sumping, wellpoints, deep wells, as well as horizontal methods.

Access to the surface of any ash pond still remains the initial challenge. Deeper ponds lend themselves to the use of widely spaced wells for dewatering; however, wells are typically installed with sizable drill rigs. Access had been facilitated with installation from barges, floating roads, or a shallow crust provided with wellpoint dewatering. Wellpoints are now commonly installed by hand from very wet and unstable pond surfaces.

Based on preliminary CPT data, the target depth of penetration of the dewatering system is anticipated. CPT data will provide some indication of the ponds hydrogeological behavior. Early field testing is typically performed to verify the hydrogeological behavior and depth of penetration of the dewatering devices. Pilot tests have been performed with shallow wellpoints and wells up to 46 m in depth.

Advancements in dewatering techniques in CCR include high capacity well / wellpoint screen that is compatible with the difficult behavior of ash, the use of variable frequency driven pumps that are effective in very low yielding conditions, and where the ash water chemistry is prone to well fouling.

This paper and presentation includes lessons learned from Keller's experience on more than 35 ponds.

INTRODUCTION

Prior to the publication of the final rule entitled "Disposal of Coal Combustion Residuals From Electric Utilities" in April 2015, excavation and handling of in-situ saturated CCR materials was a specialty niche within the earth moving industry, populated by local and regional contractors and only a few ash-handling specialists. Safely working on the impounded CCR was at least as much art as it was science, and relied upon experienced local contractors and plant personnel.

The publication of the rule and its associated requirements has spawned a multi-billion dollar industry surrounding closure activity and has attracted larger, but also less experienced, contractors. Closure activity on many ponds also requires that more people and equipment have access to the CCR surface than was the case in the past.

Dewatering techniques common in the construction industry have been used successfully to remove pore water from CCR to improve both geotechnical and personnel safety. These techniques include using drainage ditches, wellpoints, and deep wells. An overview of these techniques, including their principles of operation and typical uses, was given in previous World of Coal Ash technical papers (Landry and Schmall 2017[1] and 2019[2]). However, as closure activity at various sites has advanced, dewatering experience has been gained in new contexts and environments.

Saturated CCR is typically characterized by low cohesion and shear strength. This is compounded when water in the ash pores becomes excited by construction induced energy, resulting in elevated pore pressures. The excitation may be caused by static or montonic loading. Under these loading conditions, even previously stable ash may fail, undoing careful grading work, delaying a project, engulfing equipment or even causing injury or death.

Removing the pore water from the CCR removes this failure mechanism. The use of standard construction dewatering methods to remove pore water in the context of CCR closures is described at length in the two papers cited above. In short, the two main dewatering tools, wellpoints, and deep wells have different characteristics and applications. Wellpoints are typically small in diameter, 50 mm or less, and installed in rows close together. Spacings of 3 m are typical. Because wellpoints work on vacuum and because of the close spacing, wellpoints are typically installed on relatively thin ponds (6 m thick or less), particularly when the pond is underlain by a natural or anthropogenic layer of low permeability. By contrast, deep wells are larger in diameter, 100 mm or larger, and installed in a pattern with relatively large spacing. Spacings of 30 m or more are common depending on the application, well yield, allowable pumping time, and other factors. Because there is no practical depth which limits the effectiveness of wells, they are typically installed on deeper ponds (9 m thick or more). Higher saturated thickness in contact with the well screen allows each well to be more effective.

Figure 1. Wellpoints dewatering an excavation cut in CCR.

Figure 2. Widely spaced deep wells in a CCR impoundment.

SLOPE STABILIZATION

The widespread approach of the “hybrid closure” has resulted in significant constructed slopes in CCR. Slopes represent a combination of the thin and thick pond conditions described above and present an opportunity to use different dewatering tools in concert. Slopes requiring dewatering of saturated CCR are typically cut slopes where the excavation starts from an exposed ash surface above the water table and the slope is extended downward.

A slope stability analysis, typically performed by the project Owner’s geotechnical engineer, takes into account the proposed slope angle, and estimated ash properties including cohesion and shear strength, and will determine the required phreatic level to maintain the desired factor of safety against failure.

The lowered phreatic surface will typically be defined by specifying a separation distance between the measured water table and the current excavation grade or a target elevation beneath a bench or other feature of the slope.

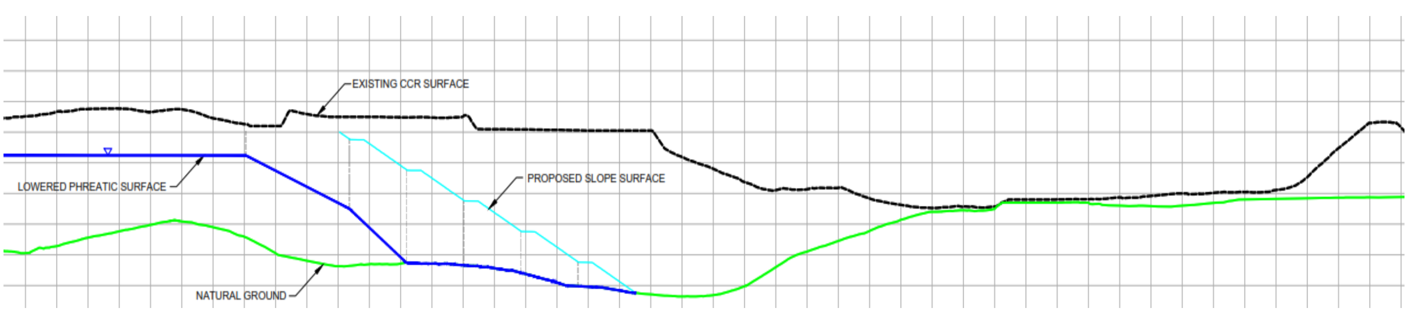

Figure 3. Conceptualized design water table beneath a proposed slope.

Based on the required phreatic surface, the closure contractor, often with the help of a specialty dewatering contractor, will propose and implement a dewatering system. Deep wells are typically used at the uppermost part of the slope, where the CCR is thicker. Wellpoints are effective nearer the bottom of the slope where their close spacing allows for lowering the pore water as close as possible to the CCR/soil interface.

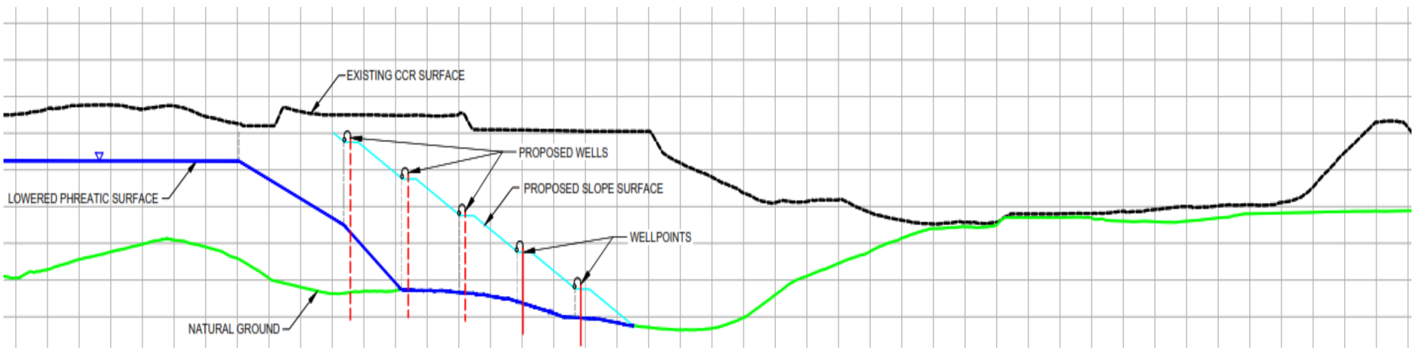

Figure 4. Conceptualized dewatering system on a proposed slope.

Figure 5. Deep wells on benches on a CCR slope. The upper and lower rows of wells are highlighted by the red ovals.

Verification that the target water levels have been achieved and that the slope is stable is obtained from a network of instruments including piezometers and real time inclinometers (shape arrays) located on the slope, typically with CPTs to evaluate shear strength. Proper placement, reading, and reporting of these instruments is vital to ensuring slope stability and safety. A detailed discussion of these instruments is beyond the scope of this paper. However, the topic is well covered by others in this context.

Pore Water Chemistry and Dewatering System Performance

Adverse pore water chemistry can be an issue in both traditional construction dewatering and dewatering of CCR. In construction dewatering, the most common (but not the only) fouling agent is naturally occurring iron dissolved in groundwater. When subjected to the conditions inside a pumped dewatering well, the iron may either form a solid precipitate and deposit itself on the pump, internal piping, and eventually work itself into the well filter pack. The growth of iron-phyllic bacteria species, if present, will significantly accelerate and exacerbate the condition. Either way, clogging and degradation of dewatering performance will eventually occur.

Figure 6. Dewatering pipe encrusted with iron and iron bacteria after approximately four months.

The same phenomenon has been observed in CCR dewatering systems. However, the unique chemistry of CCR pore water means that different chemical constituents may be involved. Dewatering wells are typically pumped at their maximum sustainable yield, meaning the water level in the pumped well is drawn down as closely as possible to the intake of the submersible pump. This maximizes the draw down in the well and theoretically reduces the number of wells required for the project compared to a dewatering system where some amount of water is deliberately maintained above the pump. However, this “maximized” way of operating the system also causes turbulent flow around the pump intake resulting in the pumped water mixing with oxygen from the air in the well.

The changing redox conditions in the well encourage previously dissolved pore water constituents to fall out of solution. The most common precipitate (aside from iron) is calcium based and clogging can be as rapid as several days.

Steps may be taken to mitigate these effects. For instance, a mild acid may be introduced into the well in order to dissolve the precipitate or to prevent its formation in the first place. In cases of severe encrustation, affected components may be bathed in the acid solution for several hours as a form of rehabilitation. This approach may be labor intensive, requires taking wells out of service while they are treated, and, for large systems, may involve the use of large quantities of acid. Acid dose, time between treatments, and the type of acid used will all vary depending on the application and concentrations of the offending constituents. The authors recommend analysis of the precipitate by a qualified laboratory specializing in groundwater and well fouling issues before committing to a course of action.

The problem may also be alleviated by changing how the system is operated. If wells are pumped such that a column of water is maintained above the pump intake, then the opportunity for air/water mixing is minimized. Based on experience, the authors recommend at least 3 m of water column. As discussed above, this limits the drawdown (and therefore the yield) of each well, potentially requiring the installation of more wells to achieve the same system flow rate or dewatering effect. For projects with planned long-term operation of a dewatering system, the larger initial cost of installing more devices is likely outweighed by ease and lower cost of maintenance. Analyses should be done on a case by case basis.

One method of allowing a column of water to remain over the intake is to drill the wells deeper than they otherwise would be, allowing the pumps to be set deeper. One potential drawback of this method is that it in many cases requires drilling and installing the wells through CCR and into underlying native soil. This should be carefully considered, as it may not be desirable or permitted.

Well flow and the water level within the well are typically regulated manually by adjusting a valve at the well head. This method has proven effective over the years but requires a skilled and experienced operator who is willing to spend time adjusting the valves and checking water levels to ensure proper operation.

An alternative is to use pump motors controlled by a variable frequency drive (VFD). In this scenario, the pumping well would be equipped with a pressure transducer set just above the pump. The transducer senses the height of the water column and sends a 4-20 mA signal to the pump motor control panel at the surface. The control panel is programmed to adjust the frequency of the power sent to the pump motor in order to maintain height of water at a pre-programmed level. Special equipment including control panels, transducers, and motors, is required for this. However, once programmed and set in motion, this method of operating the system requires very little human attention.

Figure 7. Deep well on CCR with a VFD control panel.

One final method that has produced good results in preventing well fouling is the use of pneumatic pumps. These pumps are typically used in aggressive chemical environments, such as pumping landfill leachate. The authors have anecdotally noted that these pumps have avoided fouling issues where conventional submersible turbine pumps have failed. It is worth noting that the applicability of pneumatic pumps may be limited to situations with very low flow and head requirements, typically between 0.8 and 3.7 l/min. At the high end of the flow range, these pumps may only be capable of heads of 6 m.

Figure 8. Typical pneumatic pump.

The authors also note that nearly all significant dewatering system fouling they have observed in both conventional dewatering and CCR dewatering has been in aggressively pumped deep wells, not wellpoints. Since wellpoints operate on vacuum, the water is actually de-aerated and the opportunity for air/water mixing is fairly low, even if the water flow is turbulent.

Preventing the mixing of oxygen and water may also have beneficial effects on the treatment of the dewatering effluent. Dissolved metals including arsenic and selenium often exist primarily in a reduced form in pore water. These metal species may be readily removed from the dewatering effluent using conventional techniques. Mixing with air tends to push the ions to an oxidized state with a stronger tendency to remain dissolved in water, thereby increasing the effort required to remove them. This phenomenon is discussed in more detail in a separate paper by the same authors.

CONE PENETROMETER TESTING FOR DEWATERING PLACEMENT

Although it is tempting to think of the CCR impounded in a pond as one homogenous mass, the actual composition of impounded material may vary greatly horizontally and vertically. The history of the point of deposition (i.e. the location of the sluice pipe), the type of coal burned, the age and efficiency of the boilers, and most importantly, the mixture of bottom and fly ash in the pond all make the hydraulic properties of the CCR variable.

In dewatering it is axiomatic that the pumping effort should be targeted at the most permeable layer. Ideally, the most permeable layer is well below the target water level. This provides an underdrain from which to pump water and acts as a sink to drain less permeable layers above. If the permeable layer is near the surface (i.e. above the target water level) this presents a more difficult dewatering scenario in that the permeable layer, as the largest source of water, must be addressed. However, simply pumping from this layer will not draw the water down below the target. Additional, deeper dewatering devices will be needed to address the deeper, less permeable material.

In the context of CCR, the more and less permeable layers are bottom ash and fly ash. The fact that the CCR was deposited hydraulically makes it very layered and anisotropic (having very different properties in the horizontal and vertical directions). Depending on the depostional history of the pond, bottom ash may be present in thin layers if it was deposited intermittently, in a thick layer if it was continuously deposited at a single location for a long period of time, or not present at all if bottom ash and fly ash were segregated at the facility.

Clearly, dewatering designers require some knowledge of the conditions beneath the surface of the pond before installing dewatering wells or wellpoints. Cone penetrometer testing (CPT) has proven to be a useful tool in developing a conceptual model of the subsurface in CCR impoundments as it pertains to relatively permeable and impermeable layers. CPTs have advantages over traditional borings in that CPTs provide near-continuous sampling, and measure pore pressure. However, unlike traditional borings, CPTs do not provide a physical sample of the material for laboratory analysis. The authors feel that CPTs supplemented or “ground truthed” with traditional borings provide good information about the subsurface.

CPTs may be used to inform the placement of dewatering devices and screens by identifying zones of high permeability where it would be advantageous to position well screens. When the CPT is pushed through very fine, low permeability CCR or soil it causes a zone of excess pore pressure in front of the probe. The speed at which the excess pressure dissipates is a function of the material's permeability. Material with high permeability will allow the excess pressure to dissipate quickly and the recorded pore pressure will track closely with the expected hydrostatic pressure based on the depth of the probe below the water table. In material with low permeability, the excess pressure will dissipate more slowly and the recorded pore pressure will be consistently above the hydrostatic line. Zones of higher permeability also often have higher tip resistance (the resisting force generated by the CCR or soil at the tip of the advancing probe) since they are coarser layers, not saturated layers of very soft fly ash.

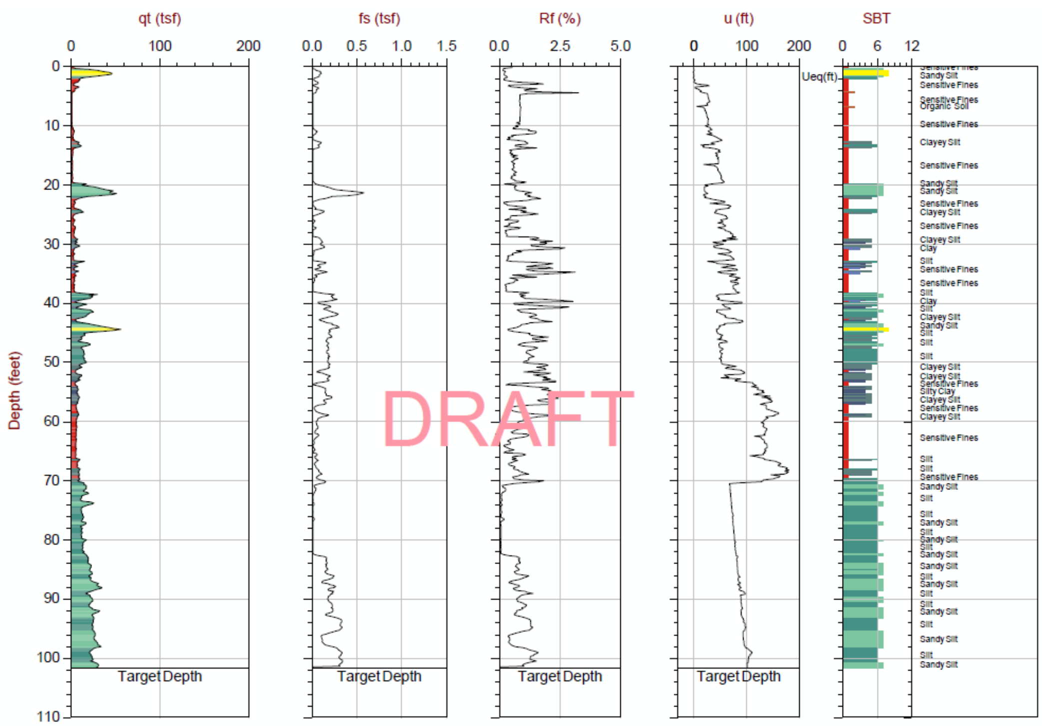

Figure 9. CPT output showing a zone of high permeability between 21 and 30 m.

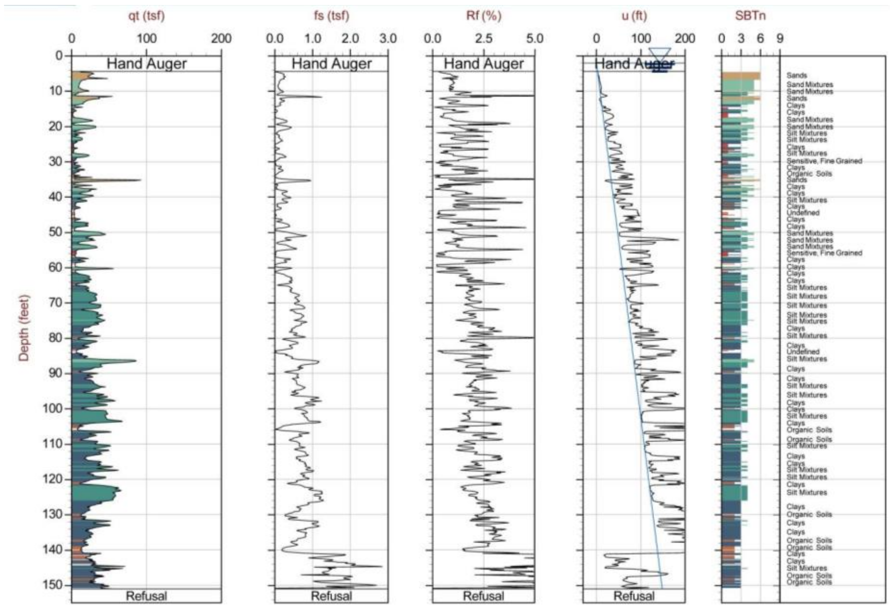

Figure 10. CPT output showing discrete layers of high permeability. High permeability zones are where the pore pressure (u) tracks the light blue hydrostatic line.

Identifying these zones may also inform the details of the well or wellpoint design. For instance, if CPTs indicate a consistent and relatively thick layer of bottom ash, the dewatering designer may choose to construct the dewatering device using a special high capacity screen rather than standard machine slotted well screen.

Figure 11. Wire-wrapped high capacity screen (left) and machine slotted screen (right).

Although the high capacity screen will be several times more expensive than standard screen, it is likely worth the cost if the dewatering system is able to take advantage of a known transmissive zone, thereby pumping more water with fewer wells.

CONCLUSION

Traditional construction dewatering techniques are broadly applicable and have had good success in CCR pond closures. The unique combination of demanding construction, pore water chemistry, and the way in which the CCR was deposited means that adjustments will need to be made continuously both in terms of the installation and operation of dewatering systems and the overall dewatering philosophy.

REFERENCES

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