Contract No:

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Disclaimer:

Remediation of the Acidic Groundwater Impacting the Discharge Canal in D Area

Introduction

The Savannah River Site (SRS) is located in Aiken, Allendale and Barnwell Counties of South Carolina, adjacent to the Savannah River (Figure 1). The D Area Powerhouse was first operated in 1952 and was critical infrastructure for the start of heavy water production in 1952. Figures 2 and 3 are aerial oblique photographs of the D Area in 1951 and 1953. Figure 2 shows the powerhouse and bubble tower facilities under construction, while Figure 3 shows the operating powerhouse and bubble towers. The bubble tower facility recovered heavy water from the Savannah River which was used to moderate site nuclear reactors.

Both facilities used very large volumes of water from the Savannah River, which is the reason that the D Area had its own river water pumping station. The D Area effluent discharge canal system supported the return of river water to the upland/floodplain escarpment where the water was released into the floodplain. Figure 4 shows the powerhouse, coal storage area, various ash management basins and landfill (488-D, 488-1D, 488-2D, and 488-4D, respectively), bubble tower and thermal legs of the canal, the effluent discharge delta, and the downstream Beaver Dam Creek which ultimately carried water to the river.

The D Area Coal Pile Runoff Basin (489-D) received acidic storm water runoff from the D Area Coal Storage Area (484-17D). Water from the coal storage area was directed to the Coal Pile Runoff Basin (CPRB) through a network of ditches.

The acidic nature of the coal pile runoff water was due to leaching of coal by rainwater and the degradation of iron sulfide (pyrite) to sulfuric acid when mixed with rainwater. Sulfides are stable in strongly reducing conditions, abiotic oxidation of pyrite results in the following reaction which produces free iron, sulfuric acid, and energy:

$FeS_2(s) + 7/2\ O_2(g) + H_2O(l) \rightarrow Fe^{2+}(aq) + 2SO_4^{2-}(aq)$ + energy (Lottermoser, 2003)

Over 60 years of powerhouse operation with associated coal storage resulted in an acid and metal groundwater plume, under and down-gradient of the CPRB. The pH of the water within the CPRB was typically 2.5 to 3.0. Unimpacted groundwater at SRS has a pH of approximately 5.0 to 6.0, with sulfate being relatively uncommon. The contaminated groundwater plume is as expected high in sulfates. Metals within the plume are from metals released from the pyrite degradation and metals leached from the aquifer sediments by the acid.

Heavy water production ceased in January 1982, this change in operations resulted in diminished effluent to the discharge canal system. After the shutdown of powerhouse operations in April 2012 the powerhouse discharge canal no longer contained river water discharges. Groundwater currently discharges into the canal because the canal bottom is at a lower elevation than the water table surface.

Acidic groundwater from the upper water table is currently seeping into the base of the canal at a rate of less than 50 gallons per minute at a point down-gradient of the impacts of the CPRB. pH values from 3.0 to 3.4 have been measured in the surface water at the sampling locations illustrated on Figure 5. It is useful to recognize that the acidic water is diluted by a factor of approximately four by the time it approaches the D-001 outfall in the canal near the southern corner of the 488-1D basin. The dilution factor in the pH data is the result of near neutral pH water from the 488-1D mixing with the discharge canal water. After the closure of the 488-1D basin there will be little dilution and the pH is likely to fall near the D-001 outfall to close to 3.0.

Figure 6 illustrates the water table surface at a time when the coal ash basins and coal pile runoff basin was operational and filled with water. A large mound of groundwater is present under the 488-1D and 488-2D basins. A small mound of groundwater is also present under the Coal Pile Runoff Basin. Figure 7 illustrates the expected change in water table surface due to closure and capping of the 488-1D and 488-2D, and closure of the Coal Pile Runoff Basin. The realignment of water table surface is expected to be controlled by the elevation of bottom of the discharge canal because the canal will support draining of the water table.

Remediation of Acidic Groundwater Impacting the Discharge Canal (including approximate cost)

The vadose zone and groundwater beneath the Old Coal Storage Area and the Coal Pile Runoff Basin has been impacted by low pH and dissolved metals over approximately 60 years of power plant operation. The presence of a low pH plume demonstrates that the buffering capacity of the sediments in the vadose zone and the aquifer has been overcome by the sulfuric acid.

The sulfuric acid has changed the charge of the soil from mostly negative to mostly positive such that dissolved metals present in the groundwater remain in solution. The coating of the sediment with hydrogen$^+$ ion will cause the presence of the acid plume and impact on the discharge canal to persist for a very long time. Infiltrating water from the vadose zone, and groundwater flowing into the acidic zone from up-gradient will become strongly acidic when it comes into contact with the hydrogen$^+$ ions in the sediments until most of the acidity is depleted.

The sediments in D Area consist of relatively thinly interbedded sands, silts, and clays. The lack of massive clean sand strata does not support the injection of basic solutions to arrest the acid source term in the groundwater. The addition of alkaline earth metal solutions will tend to activate the clay bearing sediments near the site of injection. Activation will cause clay to swell and likely reduce sediment permeability to a level where treatment is not possible. A more reliable method of treatment is to simply wash the hydrogen$^+$ ion from the top of the water table with potable water and treat the acid conditions in the discharge canal.

Fortunately two potable water wells are present in D Area northwest of the powerhouse. Both wells were used for operations and are screened approximately 500 feet below the surface. The wells are artesian and produce over 60 gallons per minute (gpm) each without operating the pumps. The well head pressure of the wells is approximately 5 to 10 psi and would support more than enough flow and pressure to deliver large volumes of water to a potential injection field in the vicinity of the former Coal Yard and Coal Pile Runoff Basin. The production wells supplied water to the facility for approximately 60 years and still support artesian conditions, so the water supply is sufficient to supply remedial activities for many years.

Figure 8 illustrates a conceptual design of an injection well field and the expected effects on the water table surface. It should be noted that the potential mounding of the water table would effectively drive hydrogen $^+$ ion to the canal. Because no pumping is required there would be no energy demand, and the warm water from the artesian aquifer would preclude the need for freeze protection for the pipeline during the winter as long as flow is occurring and a sufficient pipe diameter is selected.

A water mound of 5 feet above the current water table surface would yield a pore volume of approximately 2,300,000 ft3 or 17,250,000 gallons of water. A combine flow rate of 120 gpm would supply a pore volume of water in approximately 100 days. Significant acid reduction should be achieved with 10 pore volumes of water, or approximately 1000 days of operation. There is currently no official cost estimate for construction of the injection well field and water delivery pipeline. Table 1 provides a bounding estimate of cost of approximately $385K for the water delivery pipeline and well field.

Acidic water treatment within the discharge canal can be provided by carbonate reactive structure as shown in Figure 5. A conceptual design of the carbonate reactive structures has been developed (SK-EC&ACP-DAOU-00007, and ERD-EN-2016-0042). A cost estimate for the structures is available; the total cost of two structures to be located along the canal south of the 488-1D is approximately $200K.

With the two estimates it is likely that the infield components of the remedy could be implemented for approximately $600K. The actual implementation would likely require some form of regulatory documentation and public involvement. The regulatory documentation, if implemented as an early action or removal action, would cost approximately $300K. Therefore the implemented remedy is likely to cost no more than $1000K.

References

Lottermoser, Brend, 2003, Mine Wastes; Characterization, Treatment and Environmental Impacts. ISBN 3-540-00526-9 Springer-Verlag Berlin Heidelberg New York.

ERD-EN-2016-0042, Feasibility of Treating The D Area Powerhouse Discharge Canal Low pH Surface Water with High Purity Calcium Carbonate; Use of Permeable Reactive Structures Composed of Carbonate Rock Aggregate.

SK-EC&ACP-DAOU-00007, D Area Operable Unit Discharge Canal Reactive Structure Conceptual Design.

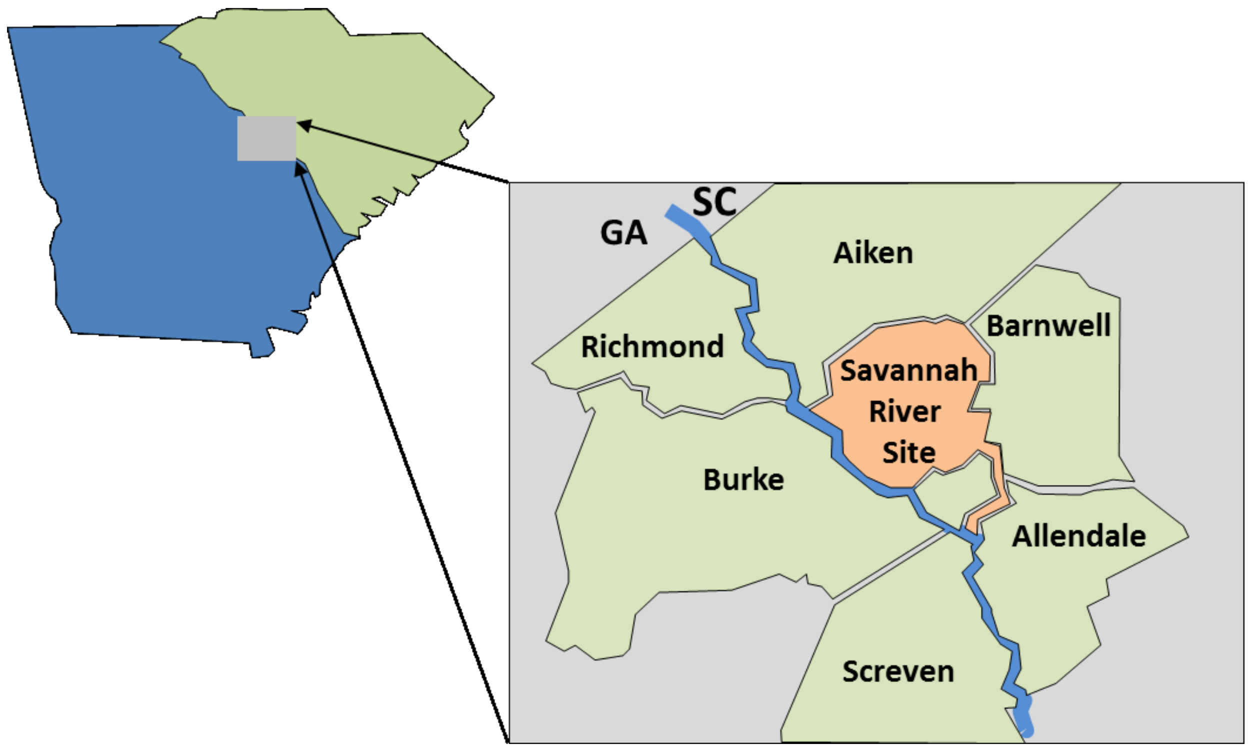

Figure 1. Location of the Savannah River Site in South Carolina; created from parts of Aiken, Barnwell, and Allendale Counties.

Figure 2. A 1951 Aerial Oblique photograph of D Area under construction; powerhouse in top center of photograph, bubble tower area in the foreground of the photograph.

Figure 3. A 1953 Aerial Oblique photograph of D Area in operation; powerhouse in top left of photograph, bubble tower area in the center of the photograph.

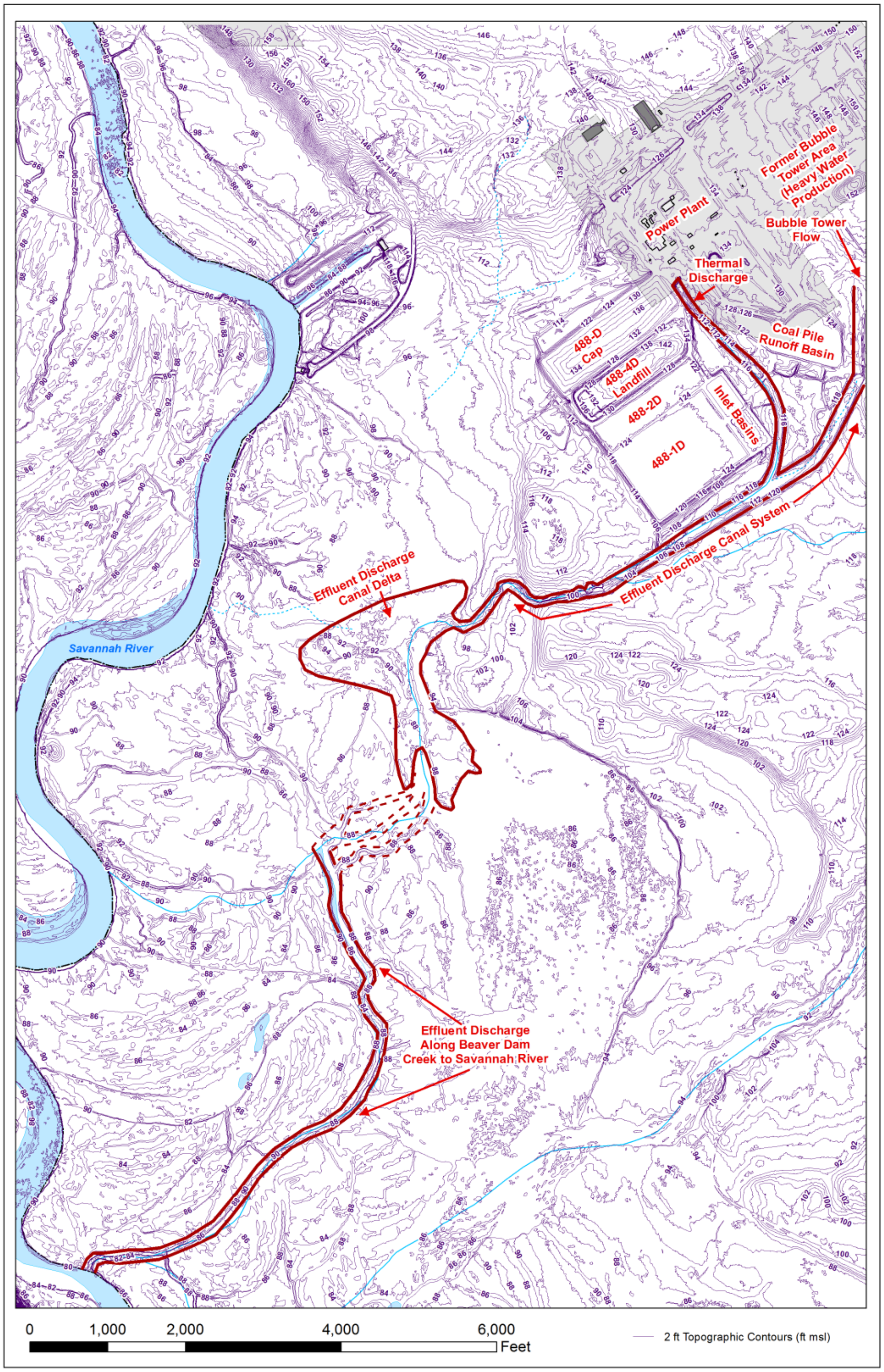

Figure 4. Map of D Area Powerhouse, Former Coal Storage Area, Coal Pile Runoff Basin, Ash Basins and Ash Landfill, Former Bubble Tower Area, and D Area Effluent Discharge Canal, and Delta.

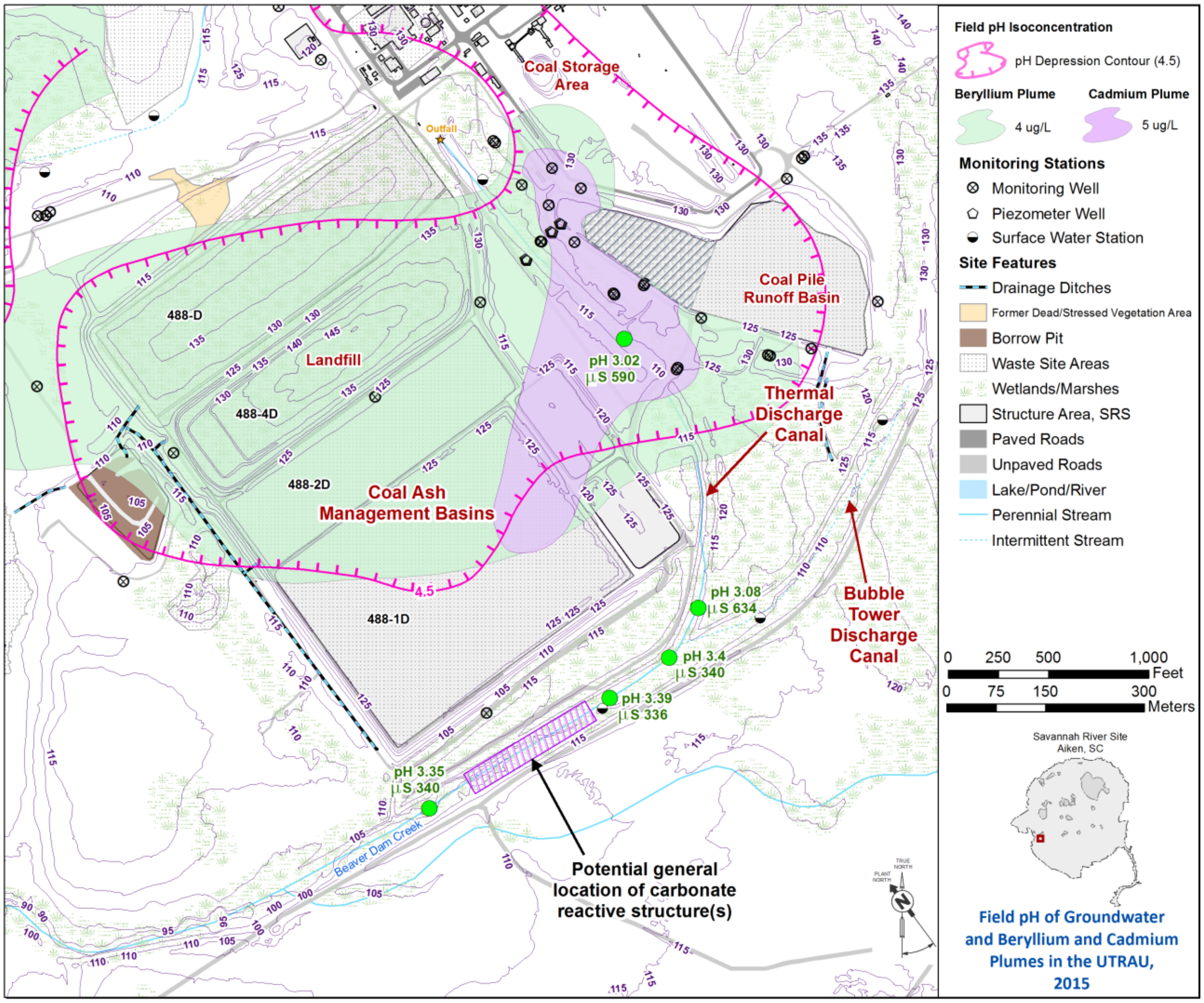

Figure 5. pH, beryllium, and cadmium groundwater plume sourced from the Coal Pile Runoff Basin, and the coal storage area. The proposed general location of carbonate reactive structure(s) is also shown, along with pH measurements in the water within the canal.

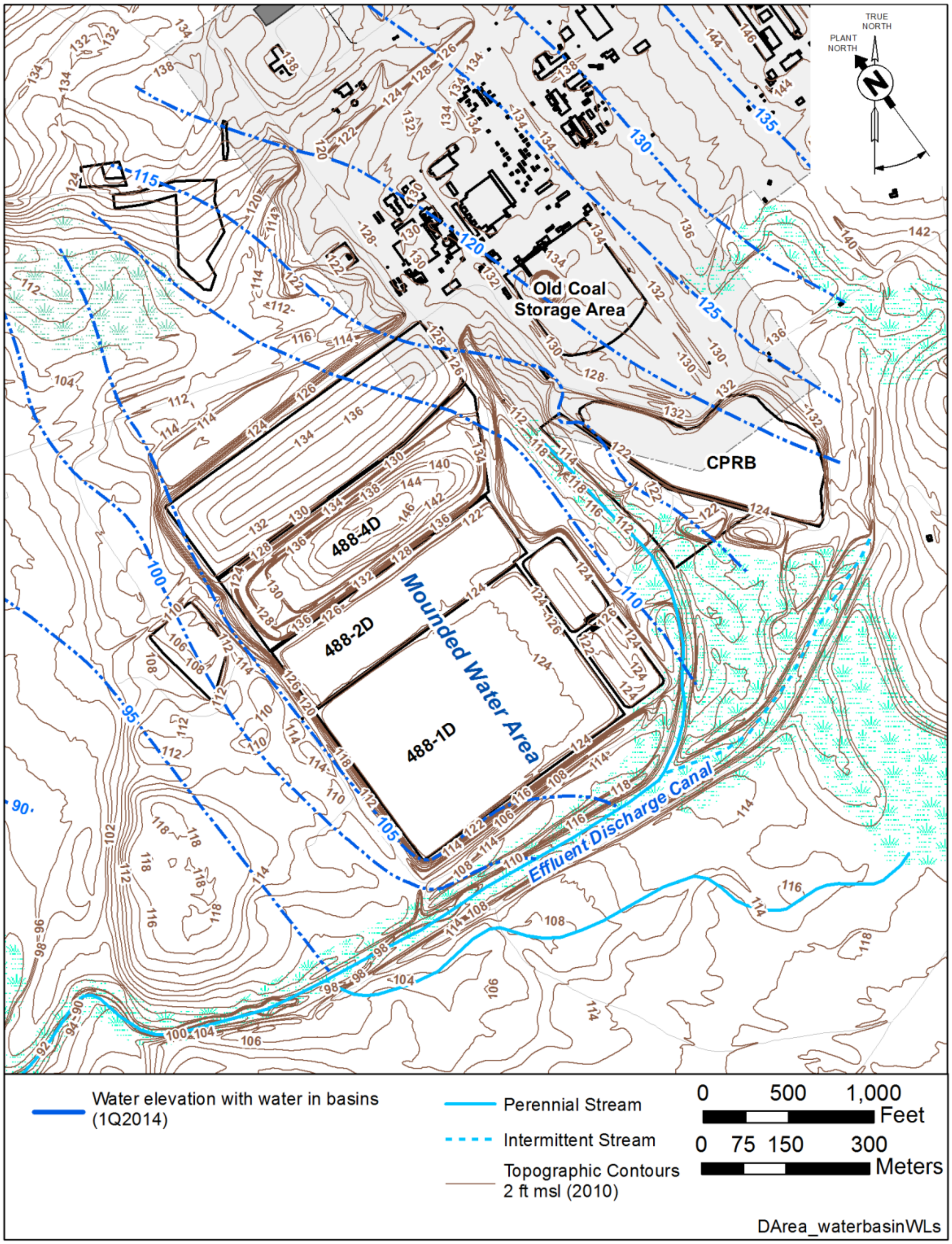

Figure 6. Water table surface before closure of the Coal Ash Basins and Coal Pile Runoff Basin.

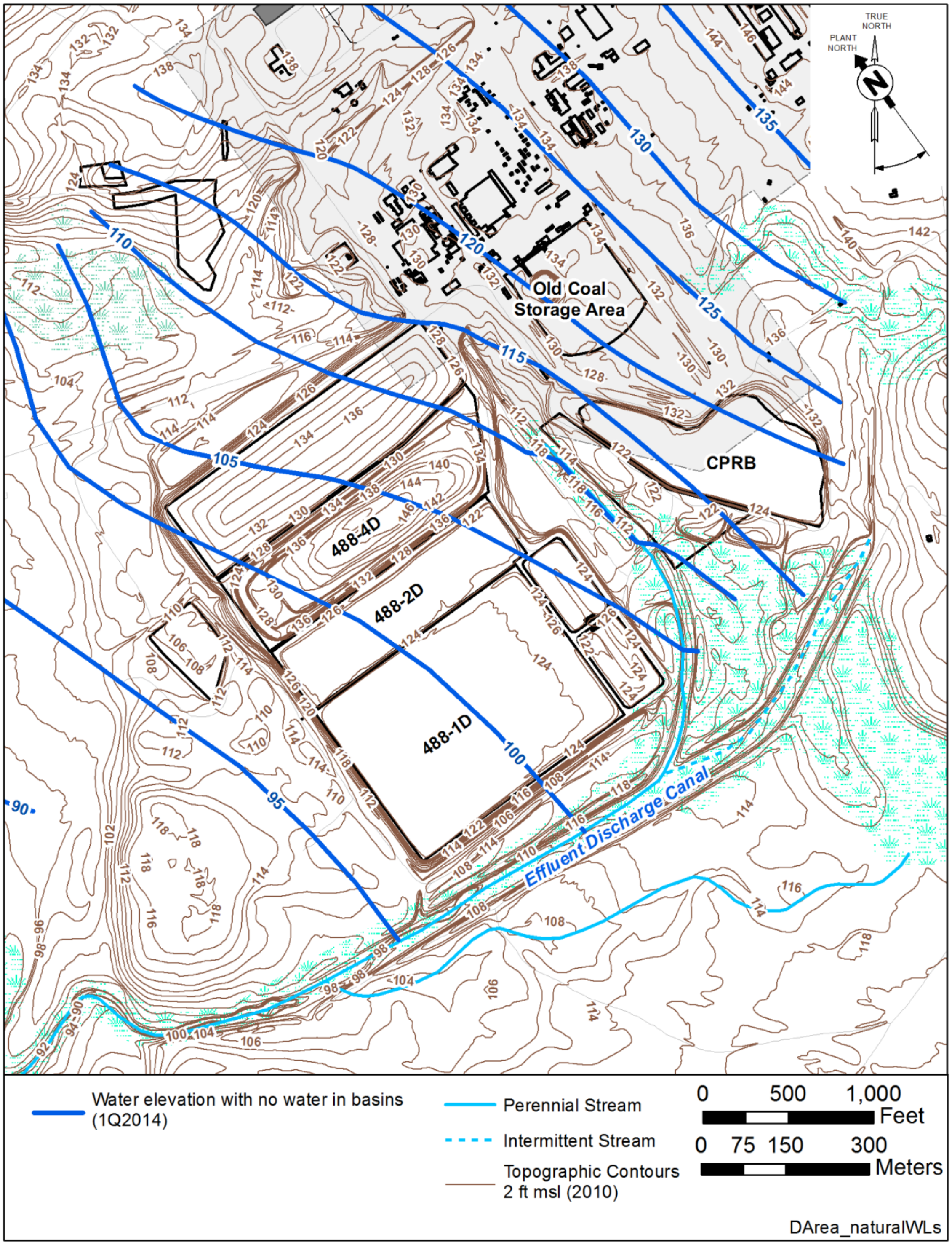

Figure 7. Expected water table surface after closure of the Coal Ash Basins and Coal Pile Runoff Basin.

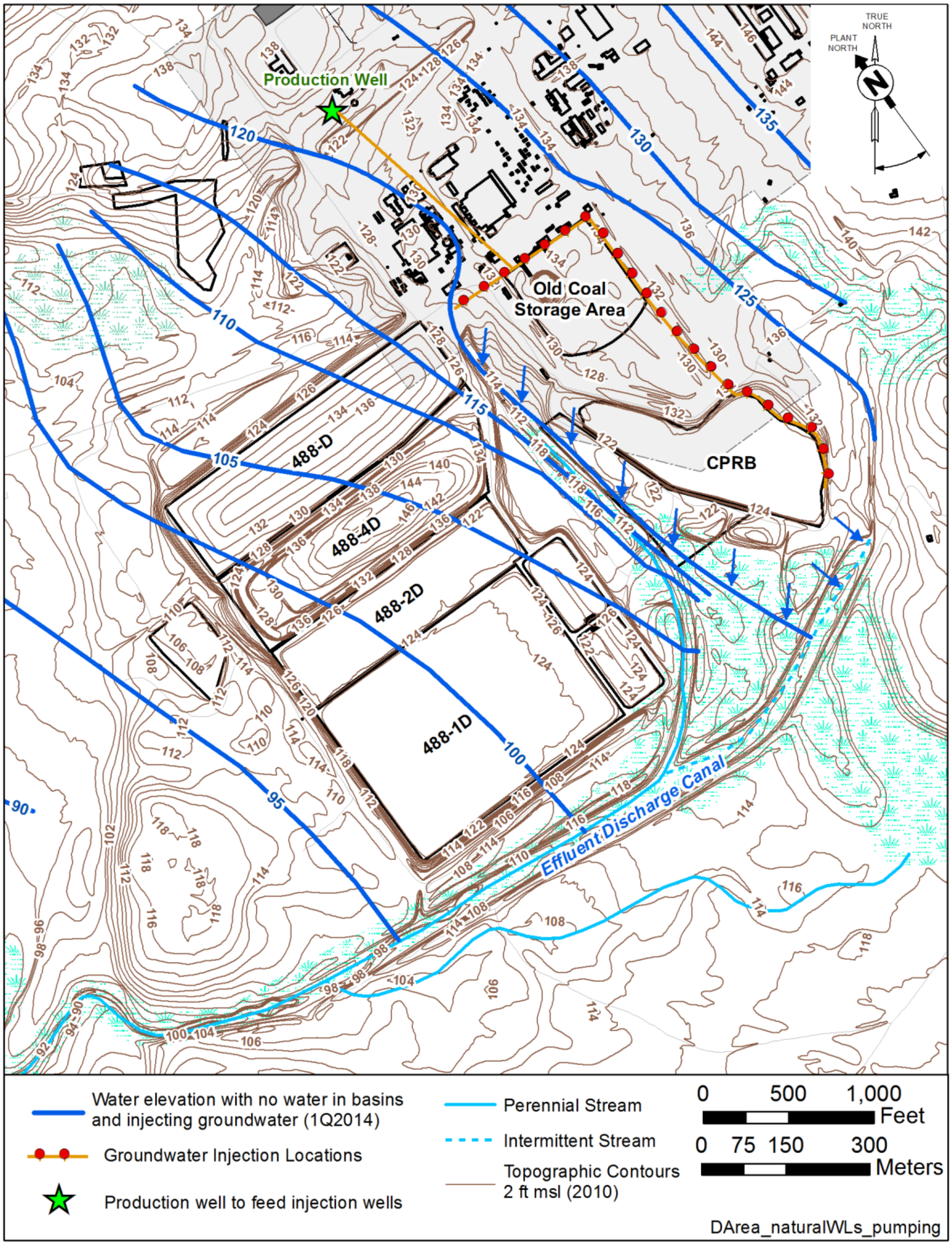

Figure 8. Expected water table surface after injection of potable water below the former Coal Yard and Coal Pile Runoff Basin; with washout of sulfuric acid into the Discharge Canal, with acid treatment via carbonate reactive structures (location in Figure 5).

Generalized Estimate for Potable Water Pipeline and Injection Field of 22 Wells

	Estimated Cost	Notes
UIC Permit	$25,000	Relatively simple because the water injected is potable (wells permitted as potable).
Potable Water Well Connections	$10,000	Wellhead connection, manifold and valves, etc.
10 Inch Schedule 40 PVC Pipeline (~4000 feet)	$90,000	Pipe (10 inch pipe to minimize friction losses, 4000 feet at $10/foot) and above ground installation labor. Installation should be considered temporary.
Injection Wellhead Connections	$22,000	22 injection wellheads
Injection Wells	$110,000	22 injection wells at $5K each.
Total Material and Labor Cost	$257,000	
Markups (50%)	$128,500	Typical of current rates.
Estimated Total Cost	$385,500	Probably an over estimate.

Table 1. Generalized cost estimate for installation of potable water pipeline and injection well field; an official estimate of approximately $200K is available for the carbonate reactive structures.