ASSESSMENT OF DAM SAFETY OF COAL COMBUSTION SURFACE IMPOUNDMENTS – FINAL REPORT

City Utilities of Springfield

John Twitty Energy Center
Springfield, Missouri

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Section 1

CONCLUSIONS AND RECOMMENDATIONS

1.1 INTRODUCTION

On December 22, 2008 the dike of a coal combustion waste (CCW) ash pond dredging cell failed at a facility owned by the Tennessee Valley Authority in Kingston, Tennessee. The failure resulted in a spill of over one billion gallons of coal ash slurry, which covered more than 300 acres, damaging infrastructure and homes. In light of the dike failure, the United States Environmental Protection Agency (USEPA) is assessing the stability and functionality of existing CCW impoundments at coal-fired electric utilities to ensure that lives and property are protected from the consequences of a failure.

The assessment of the stability and functionality of the John Twitty Energy Center (JTEC) CCW impoundments is based on a review of available documents, site assessment conducted by CDM Smith on August 27 and 28, 2012, and technical information provided subsequent to the site visit. The JTEC was formerly named as the Southwest Power Station and is owned by the City Utilities of Springfield in Springfield, Missouri. This report will refer to the subject facility as the John Twitty Energy Center (JTEC). The operation of the John Twitty Energy Center and the findings of this report are separate and distinct from any operations or findings that may have taken place at other facilities that have been assessed as part of this effort.

In summary, the East and West Impoundments' embankments at the JTEC are classified as **SATISFACTORY** for continued safe and reliable operation. Static and seismic engineering studies following standard-of-care professional engineering practice to support acceptable safety factors have been presented for the embankments and related elements of the impoundments. Based on United States Army Corps of Engineers (USACE) Guidelines for Safety Inspection of Dams (1979), the East and West Impoundments' embankments are classified as "small" and have a **LOW** Hazard Potential Rating due to a general absence of urban development downstream of the impoundments.

It is critical to note that the condition of the embankments forming the impoundments depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the embankments will continue to represent the condition of these earth structures at some point in the future. Only through continued care and inspection can there be likely detection of unsafe conditions.

1.2 PURPOSE AND SCOPE

CDM Smith Inc. was contracted by the USEPA to perform dam safety assessments of selected CCW surface impoundments. As part of the contract, CDM Smith performed a safety assessment on two CCW impoundments at JTEC, owned by the City Utilities of Springfield in Springfield, Missouri. The purpose of this report is to provide the results of the assessment and evaluation of the conditions and potential for waste release from the East and West Impoundments.

CDM Smith representatives performed a site visit on August 27 and 28, 2012 to collect relevant information, inventory the impoundments, and perform visual assessment of the impoundments.

1.3 CONCLUSIONS

Conclusions are based on visual observations during the assessment on August 27 and 28, and review of technical documentation provided by JTEC.

1.3.1 Conclusions Regarding the Structural Soundness of the Impoundments

Visual observations by CDM Smith during a field visit did not reveal any major structural defects; the embankments appeared structurally sound. JTEC personnel provided CDM Smith with full technical documentation to confirm the visual observations. CDM Smith concludes the structural soundness of the impoundments is adequate.

If a breach in the current embankments forming the impoundments were to occur, the path of water discharged from such a breach would generally flow south of the plant and enter Wilson's Creek. The route to Wilson's Creek and potential for overflow of the banks would be expected to remain on land used primarily for agricultural purposes, with no expected significant damage to infrastructure or loss of life.

1.3.2 Conclusions Regarding the Hydrologic/Hydraulic Safety of the Impoundments

According to plant personnel, there has been no overtopping of the impoundments since original operation of the impoundments first use. The toe of the embankment slope around the outer perimeter appeared dry, with no observed evidence of seepage at the time of our visit. The plant has two CCW impoundments, but plant personnel indicated only one impoundment is in service at any given time.

Hydrologic/hydraulic (H & H) analysis regarding potential overtopping of the perimeter embankment for the 100-year, 24-hour storm event was provided to CDM Smith. Plant personnel indicated that the impoundment not in service would be opened to retain excess water to avoid overtopping of the operational impoundment.

Information gathered during CDM Smith's investigation of plant records, visual observations of the facility, and H & H analyses provided by JTEC personnel indicate the impoundments have adequate capacity to pass the 100-year, 24-hour storm event.

1.3.3 Conclusions Regarding the Adequacy of Supporting Technical Documentation

Technical documentation available to CDM Smith with regard to the impoundments' design included a survey of the site around the CCW impoundments, and some cross sections of the embankments. Documentation of stability or hydrologic/hydraulic analyses of the impoundments were provided by JTEC. In the opinion of CDM Smith, the supporting technical documentation is adequate.

1.3.4 Conclusions Regarding the Description of the Impoundments

CDM Smith's on-site visit confirmed the presence of two impoundments with the capability to switch discharge into the impoundments from one impoundment to the other. The drawings and descriptions of the CCW impoundments provided by JTEC personnel appear to be consistent with the visual observations by CDM Smith during site assessment.

1.3.5 Conclusions Regarding the Field Observations

CDM Smith staff was provided access to all areas of the impoundments for observation and assessment. In addition, two plant representatives accompanied CDM Smith staff on the assessment. No evidence was observed of prior releases, failures, or repairs. In general, the embankments appeared to be in good condition. The outlet structures, located near the south end of the common dividing embankment, appeared to be in good condition with water flowing freely through the system during the time of our visit.

1.3.6 Conclusions Regarding the Adequacy of Maintenance and Methods of Operation

According to the plant representatives, the impoundments are inspected quarterly. A copy of a recently completed inspection checklist used by the plant staff was provided to CDM Smith. In addition, the embankments are periodically mowed. In general, methods of operation and maintenance for the impoundments appeared adequate based on on-site observations and conversations regarding operating procedures with the plant representatives.

1.3.7 Conclusions Regarding the Adequacy of the Surveillance and Monitoring Program

The impoundments are inspected by plant personnel on a daily basis. Inspection reports are completed and kept on file in the plant's administrative offices. There was no monitoring and surveillance instrumentation for the impoundments at the time of CDM Smith's on-site visit. Subsequent to CDM Smith's site visit JTEC installed a series of monitoring wells around the perimeter of the on-site landfill. City Utilities drawing "JTPS102", dated August 26, 2013, shows the well locations to be more than 500 feet from the CCW Impoundments. The location of the landfill monitoring will not facilitate measurement of the phreatic surface within the embankments.

Palmerton and Parrish, Inc. (PPI) installed four piezometers in borings completed January 2014, as part of their geotechnical exploration program and stability assessment of the CCW impoundments. Groundwater readings were provided in the PPI report for the dates of February 19 and March 3, 2014. PPI indicates in their report to JTEC dated March 17, 2014 that they plan to abandon/grout the piezometers. Because of the plan to abandon/grout the piezometers and due to the lack of other instrumentation to monitor phreatic surfaces at the CCW impoundments, the surveillance and monitoring of the impoundments is considered inadequate.

1.3.8 Classification Regarding Suitability for Continued Safe and Reliable Operation

Based on visual observations and conversations with plant personnel, it appeared the impoundments are currently providing acceptable performance. According to the NPDES permit for the impoundments, the design flow for the outfall is 9.6 million gallons per day (MGD) and the actual flow is 0.5 MGD, making the risk of overtopping unlikely. Although current performance is considered acceptable, conditions can change with time. Based on review of documentation provided by JTEC and observations made during our site visit, it is the opinion of CDM Smith that the impoundments at the JTEC should be classified as **SATISFACTORY** for continued safe and reliable operation.

1.4 RECOMMENDATIONS

1.4.1 Recommendations Regarding the Hydrologic/Hydraulic Safety

None.

1.4.2 Recommendations Regarding the Technical Documentation for Structural Stability

None.

1.4.3 Recommendations Regarding the Field Observations

The following are CDM Smith's recommendations:

a. The State of Missouri does not require coal plants to have an emergency action plan (EAP) in case of a CCW impoundment release; however the USEPA does require an EAP for CCW impoundments. Information JTEC provided CDM Smith did not contain an EAP. CDM Smith recommends an EAP be prepared for the impoundments;

b. JTEC should review and revise operating procedures to mitigate potential for long-term pumping of clear water from the impoundment(s) that could lead to a rapid drawdown condition.

c. Dense and tall vegetation on inside slopes should be trimmed and maintained to allow easy inspection of the embankment slopes;

d. Healthy grass cover should be established on the earth embankments to fill in the bare areas; and

e. Vegetation should be cut at least annually following the first cutting, and more often if necessary to allow a healthy grass cover to grow on the earth embankments.

1.4.4 Recommendations Regarding the Surveillance and Monitoring Program

There was no surveillance and monitoring instrumentation installed at the time of CDM Smith's onsite visit. Subsequent to our on-site visit two sets of monitoring wells were installed. The location of the landfill monitoring wells will not facilitate measurement of the phreatic surface CCW impoundment's embankments. Piezometers installed by PPI in January 2014 are scheduled to be abandoned/grouted full. CDM Smith recommends the PPI piezometers be left operational and monitored on a regular basis or that a system of groundwater monitoring wells be installed and regular measurements of water levels recorded.

1.4.5 Recommendations Regarding Continued Safe and Reliable Operation

CDM Smith does not consider the above recommendations urgent, but they should be implemented within the next year, if possible, to ensure continued safe and reliable operation of the impoundments.

1.5 PARTICIPANTS AND ACKNOWLEDGMENT

1.5.1 List of Participants

Company	Name
John Twitty Energy Center	Robert Belk
John Twitty Energy Center	Ted Salveter
CDM Smith Inc.	Clement Bommarito
CDM Smith Inc.	Albert Ayenu-Prah

1.5.2 Acknowledgment and Signature

CDM Smith acknowledges that the impoundments referenced herein have been assessed on August 27 and August 28, 2012.

STATE OF MISSOURI
CLEMENT BOMMARITO
NUMBER PE-2010008512
PROFESSIONAL ENGINEER

6/2/14

Clement Bommarito, P.E.

Section 2

DESCRIPTION OF THE COAL COMBUSTION WASTE IMPOUNDMENTS

2.1 LOCATION AND GENERAL DESCRIPTION

The John Twitty Energy Center (JTEC) is located in Greene County at 5100 West Farm Road 164, Springfield, Missouri 65619. The power station was formerly named the Southwest Power Station. JTEC is owned by the City Utilities of Springfield, Missouri (CUSM). The power station property is surrounded by crop fields, and the impoundments are south of the power plant, about half a mile south of State Highway 60. A vicinity map of the site is shown on **Figure 2-1**. The JTEC has two interconnected CCW impoundments as follows:

- West Impoundment – Considered the primary impoundment for storage of bottom ash.
- East Impoundment – Considered a backup impoundment during scheduled maintenance of the primary impoundment.

Typically, the two impoundments are operated with only one impoundment in service at any given time. The impoundments share a north-south embankment (common dividing embankment) and have a common pump station. An aerial view of the impoundments is shown on **Figure 2-2**.

2.2 COAL COMBUSTION WASTE HANDLING

2.2.1 Fly Ash

Fly ash is removed from the plant furnaces in a dry condition and is stored in silos, conditioned, and hauled by trucks to an on-site landfill located about a quarter of a mile southeast of the power station.

2.2.2 Bottom Ash

Bottom ash is transported by pipeline to the impoundments in clear supernatant form. The impoundments are primarily used for containment of filtered CCW bottom ash clear supernatant. This bottom ash clear supernatant is routed through a series of three small concrete detention/sedimentation basins to remove as many ash solids as possible, prior to its discharge of the clear supernatant into the impoundments. The bottom ash is periodically dredged from the sedimentation basins to air-dry, before it is disposed of at the on-site landfill.

The impoundments also receive water from a cooling system for plant equipment, boiler blow-down, rinse water from cleaning of the cooling towers north of the impoundments, and storm water from collection drains around the plant.

2.2.3 Boiler Slag

JTEC is a pulverized coal plant, so it does not produce boiler slag as a general rule. Any slag produced incidentally is handled and co-disposed with bottom ash.

2.2.4 Flue Gas Desulfurization Gypsum

The JTEC plant has produced flue gas desulfurization gypsum (FGD) in conjunction with a dry lime process. The FGD is handled and co-disposed with fly ash.

2.3 SIZE AND HAZARD CLASSIFICATION

According to the plant representative, the quality of the JTEC CCW impoundment's effluent is regulated by the Missouri Department of Natural Resources (MDNR). The impoundments do not have a federal or state hazard potential classification or a size classification at this time.

The MDNR is not actively involved in periodic inspections of the impoundments. These inspections are performed quarterly by power station staff. A copy of the checklist typically used for these inspections is included in **Appendix A**.

Based on United States Army Corps of Engineers (USACE) Guidelines for Safety Inspection of Dams (1979), the impoundments are classified as "small" and have a "low hazard" classification (see Tables 2.1 and 2.2).

Table 2.1: USACE ER 1110-2-106, Size Classification

Category	Impoundment	
	Storage (Ac-ft)	Height (Ft)
Small	< 1000 and 50	< 40 and 25
Intermediate	1000 and < 50,000	40 and < 100
Large	50,000	100

Table 2.2: USACE ER 1110-2-106, Hazard Potential Classification

Category	Loss of Life (Extent of Development)	Economic Loss (Extent of Development)
Low	None Expected (No permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agricultural)
Significant	Few (No urban development and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry, or structures)
High	More than a few	Excessive (Extensive community, industry, or agriculture)

Based on the USEPA classification system as presented on Page 2 of the USEPA checklist (**Appendix A**) and CDM Smith's review of the site and downstream areas, recommended hazard ratings have been assigned to the impoundments as summarized in **Table 2-3**:

Table 2-3 – Recommended Impoundment Hazard Classification Ratings

Unit	Recommended Hazard Rating	Basis
East & West Impoundments	Low Hazard	• A breach could release waste into Wilson's Creek, resulting in low economic and environmental loss. • Loss of human life is not anticipated

2.4 AMOUNT AND TYPE OF RESIDUALS CURRENTLY CONTAINED IN THE IMPOUNDMENT(S) AND MAXIMUM CAPACITY

At the time of the assessments, CDM Smith did not have information on the amounts of residuals currently stored in the impoundments. According to the plant representative, the West and East Impoundments have areas of 3.89 and 3.36 acres, respectively. The source of CCW ash clear supernatant is limited to bottom ash from the power plant furnaces. Other types of ash generated by the furnaces are not discharged into the impoundments, and are disposed of by other means and methods.

2.5 PRINCIPAL PROJECT STRUCTURES

2.5.1 Earth Embankment

The south embankment (East and West Impoundments) and the common dividing embankment of the impoundments have slopes of approximately 2H:1V, and a crest width of at least 12 feet. The crest of the common dividing embankment is at approximately El. 1235. The south embankment, which acts as a dam, is about 30 feet high. The crest of the south embankment is at approximately El. 1243.

The grades on the outside slope of the north (East and West Impoundments), east (East Impoundment), and west (West Impoundment) embankments are relatively flat and generally transition to match the surrounding grade, with no discernible downward outside slope. The crest of the East and West Impoundments' north embankment and the East Impoundment's east embankment generally match the surrounding natural grade at El. 1243.

2.5.2 Outlet Structure

The East Impoundment and the West Impoundment do not have a direct hydraulic connection. A common outlet structure is located between the two impoundments, near the south end of the common dividing embankment. Water from the impoundments flows through a 12-inch-diameter corrugated metal (CM) pipe to a covered weir located south of the impoundments. Two 12-inch-diameter CM pipes (one at each impoundment) serve as overflow spillways when water levels in the impoundments exceed El. 1237and directs this water by gravity flow to the weir structure. The weir is used by plant personnel to measure flow rate and discharge volume from the impoundments, before directing this water through a 24-inch-diameter gravity-flow CM pipeline to discharge into an unnamed tributary of Wilson's Creek. The Pump Station, located near the south end of the common dividing embankment, is used to recycle clean water from the impoundments back to the plant for boiler seals and bottom ash conveyance.

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AERIAL PHOTOGRAPH SOURCE:
GOOGLE EARTH PRO.

CDM Smith

JOHN TWITTY ENERGY CENTER
SPRINGFIELD, MISSOURI
LOCUS PLAN
FIGURE 2-1

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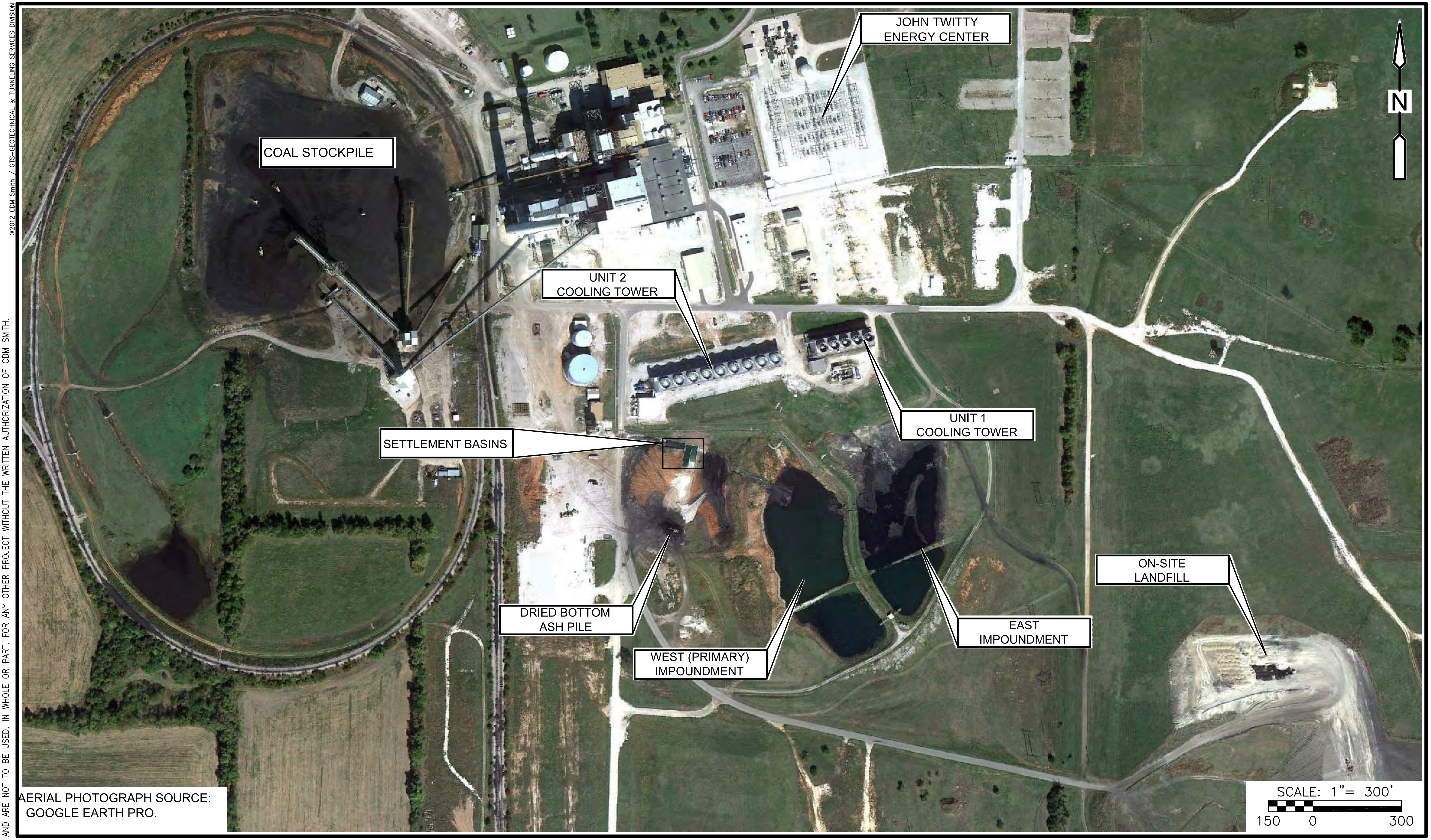

AERIAL PHOTOGRAPH SOURCE:
GOOGLE EARTH PRO.

CDM Smith

JOHN TWITTY ENERGY CENTER
SPRINGFIELD, MISSOURI
AERIAL PLAN
FIGURE 2-2

2.6 CRITICAL INFRASTRUCTURE WITHIN FIVE MILES DOWNGRADIENT

Discharge from the impoundments flows downslope into Wilson's Creek. This creek generally flows south, and shifts to the south-southwest approximately one mile north of the City of Battlefield (only infrastructure within 5 miles south of the plant). There is no critical infrastructure downgradient within the expected path (Wilson's Creek) of water discharged from the impoundments. A map illustrating the path of Wilson's Creek and its diversion around critical infrastructure to the south is shown on **Figure 2-3**.

A breach of the impoundments' embankments would most likely impact JTEC power station property and crop fields along the banks of Wilson's Creek, and is not expected to result in loss of human life or damage to critical infrastructure.

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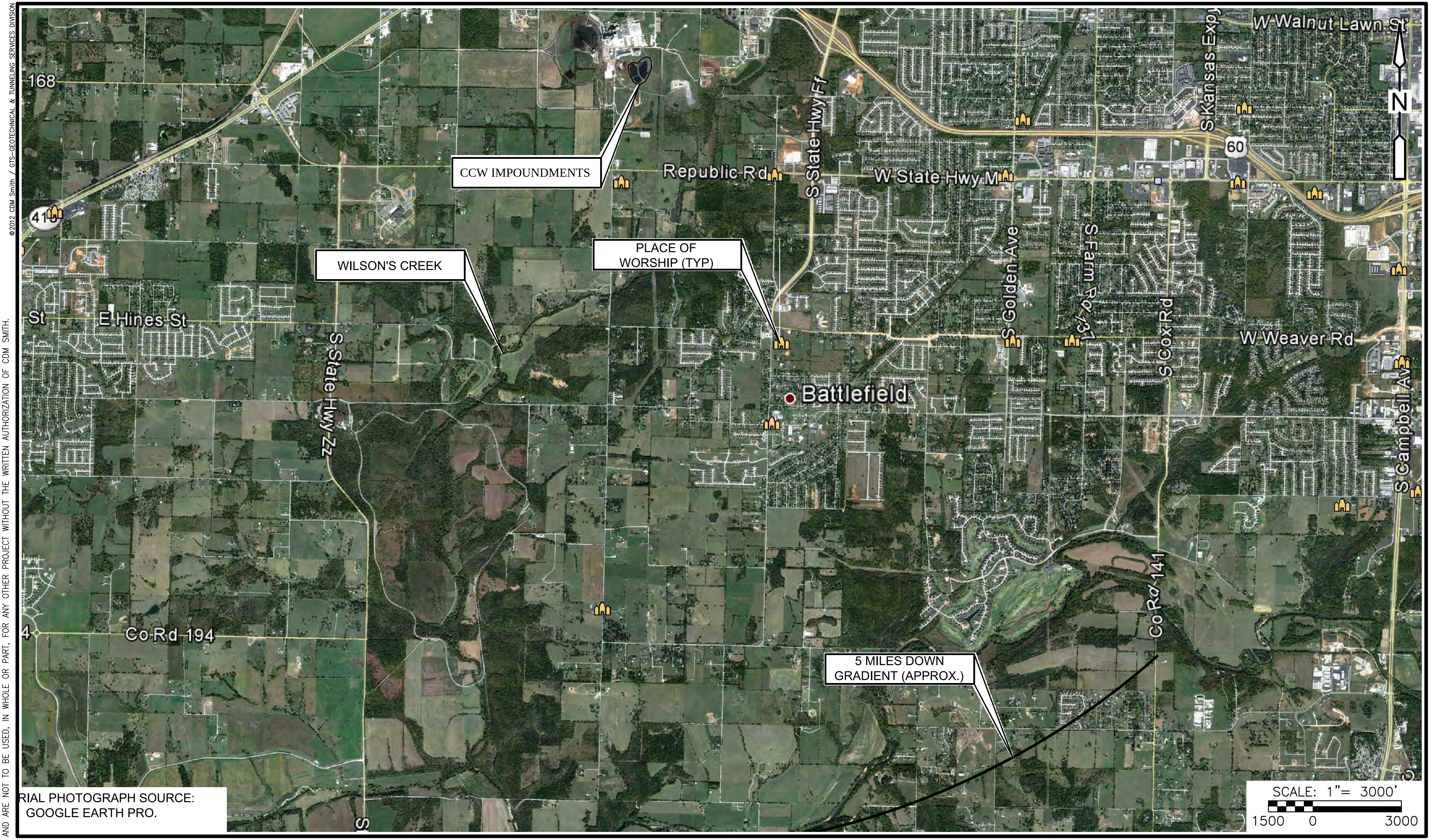

RIAL PHOTOGRAPH SOURCE:
GOOGLE EARTH PRO.

CDM Smith

JOHN TWITTY ENERGY CENTER
SPRINGFIELD, MISSOURI
CRITICAL INFRASTRUCTURE PLAN
FIGURE 2-3

Section 3 SUMMARY OF RELEVANT REPORTS, PERMITS, AND INCIDENTS

3.1 SUMMARY OF REPORTS ON THE SAFETY OF THE IMPOUNDMENTS

Information provided by JTEC included copies of South West Power Station's (SWPS) Dike Inspection Checklists and an example checklist used for quarterly inspections of the CCW impoundments. JTEC representatives indicated to their knowledge, there have been no known structural or operational problems or accidental CCW discharges associated with the impoundments.

3.2 SUMMARY OF LOCAL, STATE, AND FEDERAL ENVIRONMENTAL PERMITS

Under the National Pollutant Discharge Elimination System (NPDES), the power station is permitted by the MDNR, authorizing JTEC the right to discharge water into Wilson's Creek via an unnamed tributary in accordance with the terms of the permit. The permit number is MO-0089940, with effective and expiration dates of August 13, 2010 and August 12, 2015, respectively; there is also a modification date of January 25, 2012.

3.3 SUMMARY OF SPILL/RELEASE INCIDENTS

JTEC plant representatives indicated that there have been no known accidental spills or releases of water from the impoundments, to their knowledge. The representatives also indicated that documentation of performance of the impoundments is not kept on a regular basis.

Section 4

SUMMARY OF HISTORY OF CONSTRUCTION AND OPERATION

4.1 SUMMARY OF CONSTRUCTION HISTORY

4.1.1 Original Construction

The JTEC (formerly Southwest Power Station) started operations in 1976. According to the plant representatives, the CCW impoundments were designed by Burns & McDonnell Engineering Company (B&M). B&M drawings provided by JTEC are included in **Appendix B**.

Bottom ash from the power station is transferred as clear supernatant and discharged into the north end of the West Impoundment via a riprap-protected spillway. Dimensions of the spillway were not available from the representatives. The East Impoundment is used instead if the West Impoundment is due for maintenance.

The West and East Impoundments cover areas of 3.89 and 3.36 acres, respectively, and share a common dividing embankment. Each of these impoundments is divided into north and south cells by a divider rock berm. The purpose of the divider rock berm across the north and south cells is to filter clear supernatant, reducing the content of ash in suspension as water moves from the north cell to the south. Filtered water from the south cell is pumped back to the plant for reuse. Periodically, the north cell is dredged and the ash is disposed of in the plant's on-site landfill.

The crest of the north embankment of the East and West Impoundments' north embankment and the crest of the West Impoundment's west embankments and the west generally match the surrounding natural grade at El. 1243. According to the plant representatives, the impoundments were designed for a high water level at El. 1237, with a freeboard of 6 feet. The design drawings provided by JTEC did not include information for the other embankments.

Overall grades at the site indicate that the south embankment of the impoundments is at the downstream end of the impoundment footprint. Consistent with these conditions, the south embankment is the tallest (at the outside slope), and acts like a dam (although the MDNR does not consider it a dam in their records).

Based on the construction plans for the impoundments, the primary outlet from the impoundments consists of a 12-inch-diameter corrugated metal (CM) pipe that discharges to a regulated outfall in the form of a weir structure. Flow from the weir goes to an unnamed tributary of Wilson's Creek.

4.1.2 Significant Changes/Modifications in Design since Original Construction

The common dividing embankment (the embankment that creates the East and West Impoundments) was constructed in the mid-1990s. Construction plans for the common dividing embankment show the embankment was constructed of "compacted fill" with a cutoff trench located parallel to the embankment, directly beneath the centerline of the crest. The cutoff trench was constructed of select stockpile material, with a maximum particle size of 6 inches and a maximum depth and width of 7 feet and 8 feet, respectively. The inside and outside slopes of the dividing embankments were designed at 2H:1V. Plans show inside slopes protected by a minimum 3-foot-thick layer of riprap. The riprap consists of rock ranging from 10 percent passing a No. 4 sieve to 18 inches in size. B & M design plans show the common dividing embankment crest as 12 feet wide, with a final grade of El. 1235.0. A six-inch layer of crushed rock surfacing is shown on the embankment crest. The construction plans also show a 12-inch-thick pond liner (liner), comprised of compacted lime and fly ash. A pump station, located near the south end of the common dividing embankment was installed at the same time as the common dividing embankment. The pump station is used to recycle clean water from the impoundments back to the plant.

Two 12-inch-diameter CM pipes (one at each impoundment) were installed in 1986 at the direction of MDNR to ensure that any overflow discharge (water surface above El. 1237) would be directed to the measurement weir and reported in discharge monitoring reports. These discharge pipes replaced the original overflow spillways. Flow from the weir goes to an unnamed tributary of Wilson's Creek.

According to the plant representatives, there have been no other major changes or modifications to the impoundments since operations started, with the exception of three small sedimentation basins installed near the northeast corner of the impoundment. The basins are used for primary filtration and sedimentation of the bottom ash clear supernatant. The first basin was installed in 1995, and the second and third basins were installed in 2011, with final grade work in this area completed in 2012.

4.1.3 Significant Repairs/Rehabilitation since Original Construction

Discussions with the plant representatives and visual observations of the impoundments indicate no major repairs/rehabilitations have been performed on the impoundments since original construction, with the exception of the East Impoundment liner. An earthwork contractor was hired to clean out sediment from the East Impoundment, but the equipment operator over-excavated some areas and cut completely through the liner, requiring repair.

4.2 SUMMARY OF OPERATIONAL PROCEDURES

4.2.1 Original Operational Procedures

Documentation provided by the plant representatives did not include original operational procedures for the impoundments. According to the representatives, bottom ash was sluiced to the impoundment and allowed to accumulate in the entire volume of (each) pond and cleaned out periodically. The divider rock berm filtered the ash clear supernatant, allowing only filtered water into the south cell, which was pumped back to the plant for reuse. The ash in the north cell was then dredged out periodically and allowed to dry, after which it was disposed of at the on-site landfill. Some of the water in the south cell was also discharged by gravity flow through a 12-inch-diameter corrugated metal (CM) pipe, to a weir structure and ultimately to an unnamed tributary of Wilson's Creek. Fly ash was stored in silos, conditioned, and transported via trucks to the on-site landfill.

4.2.2 Significant Changes in Operational Procedures and Original Startup

As a result of the over-excavation and liner damage noted in Section 4.1.3, plant management elected to install the common dividing embankment. Construction of the common dividing embankment reduced the need to entirely drain the impoundment during cleaning, thereby reducing the potential for over-excavation and further liner damage.

As described in Section 4.1.2, three detention/sedimentation basins were added at the inlet riprap spillway of the West Impoundment. These basins act as a primary filter for the CCW clear supernatant, so that only filtered water enters the impoundments.

4.2.3 Current Operational Procedures

JTEC representatives provided CDM Smith with process flow and water balance diagrams representing current operations of the power plant and impoundments (See Appendix B). According to the diagrams and verbal descriptions by the representatives, the current operational procedure of the impoundments is as follows:

Bottom ash is sluiced to either the East Impoundment or the West Impoundment via three detention/sedimentation basins at the northwest portion of the impoundment. The basins are used for primary filtration and sedimentation of the ash clear supernatant. The divider rock berm in the impoundment acts as secondary filtration, so that currently only filtered water is stored in the impoundment. Bottom ash is periodically dredged from the basins and disposed of at the on-site landfill.

4.2.4 Other Notable Events since Original Startup

Based on available information to CDM Smith and discussions with the plant representatives, there have been no other notable events since original startup of the impoundments.

Section 5

FIELD OBSERVATIONS

5.1 PROJECT OVERVIEW AND SIGNIFICANT FINDINGS

CDM Smith performed an impoundment safety assessment at JTEC on August 27 and August 28, 2012. The task included performing a visual assessment of the impoundments and collecting relevant information regarding structural stability and design of the embankments and related structures. CDM Smith representatives Clement Bommarito and Albert Ayenu-Prah were accompanied by the following JTEC representatives:

- Robert Belk – JTEC, Supervisor-Operations
- Ted Salveter –City Utilities, Senior Engineer, Governmental Relations/Environmental Affairs

The assessments were completed following the general procedures and considerations contained in the Federal Emergency Management Agency's (FEMA) Federal Guidelines for Dam Safety (April 2004)regarding settlement, movement, erosion, seepage, leakage, cracking, and deterioration. These guidelines apply to management practices for dam safety of all Federal agencies responsible for planning, design, construction, operation, or regulation of dams and have been used throughout EPA's CCW Dam Assessment as a consistent and conservative approach to dam safety. Missouri Dam Safety Regulations define Jurisdictional Dams as any artificial or man-made barrier which does or may impound water and is 35 feet or more in height (Section 236.400(5) RSMo). The embankments of the East and West Impoundments are less than 35 feet in height. A USEPA Coal Combustion Dam Inspection Checklist and a USEPA CCW Impoundment Inspection Form were completed on-site for the impoundments during the site visit. Copies of the forms are included in **Appendix A.** Photograph locations are shown on **Figure 5-1.** Photograph locations were logged using a handheld GPS device. Photographs and coordinates are included in **Appendix C**.

The weather on the days of the site visit was mostly clear with a high temperature of 90 degrees and a low temperature of 60 degrees. According to the National Weather Service, daily total precipitation prior to, and on the day of, the assessment is shown in **Table 5.1**. The weather data were recorded at the Springfield-Branson National Airport, located approximately 6 miles south of JTEC.

Table 5.1: Daily Total Precipitation for Week prior to Assessment

Site Visit on August 27 and August 28, 2012		
Day	**Date**	**Precipitation (inches)**
Wednesday	August 20	0.00
Thursday	August 21	0.00
Friday	August 22	0.00
Saturday	August 23	0.00
Sunday	August 24	0.00
Monday	August 25	0.14
Tuesday	August 26	0.44
Wednesday	August 27	0.00
Thursday	August 28	0.00
Total	**August 20 – 28**	**0.58**

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ERIAL PHOTOGRAPH SOURCE:
GOOGLE EARTH PRO.

CDM Smith

JOHN TWITTY ENERGY CENTER
SPRINGFIELD, MISSOURI
PHOTOGRAPH LOCATIONS PLAN
FIGURE 5-1

5.2 WEST IMPOUNDMENT

At the time of the assessment, the West Impoundment had a freeboard of approximately 10 feet. The south side of the impoundment was constructed with a side-hill configuration. The site has a general downward grade towards the southeast. The East and West Impoundments share a north-south divider embankment (common dividing embankment). The west, north, and east embankments tie into the general grade of the power plant.

5.2.1 Crest

The crest of the embankments of the West Impoundment appeared to be generally in good condition (**Photograph 5.1**). The crest for the south embankment and the common dividing embankment between the East and West Impoundments are approximately 12 feet wide. Most of the embankment crests have crushed-rock visible at the surface to carry maintenance vehicle traffic (**Photograph 5.2**). At a few embankment crest locations, the crushed-rock surfacing appears deteriorated (**Photograph 5.3**). The south embankment crest has grass vegetation up to 12 inches in height, while the crest of the common dividing embankment has trimmed grass with a height up to about 4 inches (**Photograph 5.1**).

5.2.2 Inside Slope

The inside slopes of the impoundment's embankments were in fair condition. Visual observations and field measurements for estimation purposes indicate the inside slope of the south embankment and the common dividing are estimated to be 2H:1V (**Photograph 5.4**). The inside slope of the north embankment and the west embankment generally had slopes on the order of 6H:1V or flatter (**Photograph 5.5**).

The inside slope of the south embankment and the common dividing embankment were covered with thick vegetation growing to heights up to 4 feet with riprap protection near the normal level of the water when the impoundment is in use (**Photograph 5.4**). The inside slopes of the west and north embankments had sparse vegetation; however, plant personnel indicated the area was recently seeded (**Photograph 5.6**).

5.2.3 Outside Slope

The outside slope of the south embankment appeared to be uniformly graded and generally had a slope of about 2H:1V (**Photograph 5.7**). The outside slope of this embankment is covered with areas of grass and brush up to about 4 feet in height. Unvegetated areas have riprap protection. No evidence of animal burrows, cracks, or erosion was observed on the outside slope of this embankment; there was also no observed evidence of seepage on the ground surface. The grades on the outside slope of the north and west embankments are relatively flat and generally transition to match the surrounding grade, with no discernible downward outer slope.

5.3 EAST IMPOUNDMENT

5.3.1 Crest

The crest of the embankments of the East Impoundment appeared to be generally in good condition (**Photograph 5.1**). The crest for the south embankment and the common dividing embankment are approximately 12 feet wide. Most of the embankment crests have crushed-rock visible at the surface to carry maintenance vehicle traffic (**Photograph 5.2**). At a few embankment crest locations, the crushed-rock surfacing appears deteriorated (**Photograph 5.3**). The south embankment crest has grass vegetation up to 12 inches in height, while the crest of the common dividing embankment has trimmed grass with a height up to about 4 inches (**Photograph 5.1**).

5.3.2 Inside Slope

The inside slopes of the impoundment's embankments were in fair condition. Visual observations and field measurements for estimation purposes indicate the inside slope of the south embankment and the common dividing are estimated to be 2H:1V (**Photograph 5.4**). The inside slope of the north embankment and the east embankment generally had slopes on the order of 6H:1V or flatter (**Photograph 5.5**).

The inside slope of the south embankment and the common dividing embankment were covered with thick vegetation growing to heights up to 4 feet with riprap protection near the normal level of the water when the impoundment is in use (**Photograph 5.4**). The inside slope of the east embankment was grass-covered growing to heights up to 4 inches. The inside slope of the north embankment had sparse vegetation; however, plant personnel indicated the area was recently seeded (**Photograph 5.6**).

5.3.3 Outside Slope

The outside slope of the south embankment appeared to be uniformly graded and generally had a slope of about 2H:1V (**Photograph 5.7**). The outside slope of this embankment is covered with areas of grass and brush up to about 4 feet in height. Unvegetated areas have riprap protection. No evidence of animal burrows, cracks, or erosion was observed on the outside slope of this embankment; there was also no observed evidence of seepage on the ground surface. The grades on the outside slope of the north and east embankments are relatively flat and generally transition to match the surrounding grade, with no discernible downward outer slope.

5.4 OUTLET STRUCTURES

5.4.1 Overflow Discharge Structure

The overflow structure for each impoundment consisted of a 15-inch-diameter corrugated metal pipe that went through the south embankment. These overflow discharge pipes extended south through the embankment to a single outlet weir structure located near the toe of the outside slope. The visible portion of these pipes appeared to be in good condition (**Photograph 5.8**).

5.4.2 Outlet Conduit

The outlet system consists of a pump station, a weir structure and associated valves and piping. The system appeared to be in good condition, and water was flowing through the weir indicating it is operational (**Photographs 5.9, 5.10, 5.11**). Water is discharged by gravity discharge from the CCW impoundments through the weir structure. The pump station is used to recycle clear water from the CCW impoundments back to the power plant for boiler seals and bottom ash conveyance. The weir is a concrete structure covered with a steel grate located on the outside slope of the south embankment. According to the plant representatives, the weir structure is used to measure discharge through the outlet.

5.4.3 Emergency Spillway

CDM Smith's on-site visual observations indicated that the JTEC impoundments had no emergency spillway. The weir structure with its associate piping serves as the primary and emergency discharge from the impoundments.

5.4.4 Low-Level Outlet

Based on our visual observations at the site, discussions with JTEC personnel and review of the information provided by JTEC, the impoundments do not have low-level outlets.

Section 6

HYDROLOGIC/HYDRAULIC SAFETY

6.1 SUPPORTING TECHNICAL DOCUMENTATION

6.1.1 Flood of Record

Documentation provided by JTEC did not include information regarding the flood of record (FR) for the ash impoundments. Plant representatives verbally indicated that there has been no known flooding of the JTEC impoundments to their knowledge although written records of flood events and impoundment water levels have not been recorded in the past.

6.1.2 Inflow Design Flood/Design Maximum Precipitation Event

MDNR requires low hazard dams (MDNR Class III) built prior to August 13, 1981 to pass the 100-year storm event. Based on NOAA Atlas 14 Volume 8 Version 2 "Precipitation-Frequency Atlas of the United States" for Springfield, MO in "Mississippi Valley" Climate Region 4, the 100-year storm event in the vicinity of the site over a 24-hour period is approximately 7.72 inches. The drainage area contributing to the impoundments at this site appears to be limited to the storage area within the impoundments.

Information provided included City Utilities' hydrologic/hydraulic design calculations, dated November 1986, associated with the installation of a new overflow spillway and an undated memorandum documenting the capacity of the CCW impoundments to store a 100-year, 24-hour rainfall event.

In general terms, the size of the impoundments and allowable outflow rates provided in the NPDES Permit indicate complete filling of both impoundments leading to overtopping is unlikely.

6.1.3 Spillway Rating

Information provided by JTEC did not include the outfall rating for the impoundments. The NPDES Permit No. MO-0089940 for the power station provides an allowable flow for Outfall #002 (associated with discharge of water derived from the impoundments) of 9.6 million gallons per day (MGD). JTEC personnel indicated an actual flow of approximately 0.5 MGD.

6.1.4 Downstream Flood Analysis

A downstream flood analysis for the impoundments was not part of the documentation provided by JTEC. From CDM Smith's visual observations, overall grades in the area of the impoundments and surrounding areas slope to the south, roughly parallel to Wilson's Creek and the tributary where JTEC discharges water from the impoundments. Based on the grades south and the plant's property boundaries, a breach of the embankment would be expected to result in a discharge across undeveloped (grass-covered with occasional trees) JTEC property south of the plant and land further to the south used for agricultural purposes, eventually draining into the unnamed tributary of Wilson's Creek used for the current permitted discharge. Wilson's Creek continues several miles to the south-southwest through areas generally free of commercial or residential structures, and most areas are used for agricultural purposes. Based on these conditions, a breach in the embankments is not expected to result in significant damage to property and infrastructure or loss of human life.

6.2 ADEQUACY OF SUPPORTING TECHNICAL DOCUMENTATION

The supporting hydrologic/hydraulic documentation available with the JTEC is considered adequate for the impoundments.

6.3 ASSESSMENT OF HYDROLOGIC/HYDRAULIC SAFETY

There is adequate documentation to support an assessment of the hydrologic/hydraulic safety of the JTEC impoundments. During normal operations of the power station, one impoundment is usually in service while the other is kept off line. Plant personnel indicated that use of one impoundment at a time gives them the option to add the second impoundment in cases when there is a risk of overtopping in the operational impoundment. The option to increase the normal operating capacity of the operational impoundment with use of the second impoundment lessens the risk of overtopping, and is consistent with comments by JTEC personnel indicating there have not been any overtopping of the embankments since the impoundments' initial operation.

Section 7

STRUCTURAL STABILITY

7.1 SUPPORTING TECHNICAL DOCUMENTATION

7.1.1 Stability Analyses and Load Cases Analyzed

JTEC provided a geotechnical engineering report prepared by Palmerton and Parrish, Inc. (PPI) containing a description and test results of a subsurface exploration program completed in January 2014 and stability analyses for CDM Smith's review. The PPI analyses included evaluation of embankment factors of safety for steady-state conditions under maximum pool (deep failure); steady-state conditions under maximum pool (shallow failure); and steady-state conditions for a seismic event with 2% probability of exceedance in 50 years.

The PPI report did not present analyses for liquefaction potential, end-of-construction and sudden drawdown loading conditions. It is CDM Smith's opinion that the end-of-construction condition is not relevant due to the age of the CCW impoundments. Rapid drawdown of the impoundment is considered unlikely. A rapid drawdown of the impoundments would occur only in the event of an embankment failure or if discharge pumps were left running for more than several hours with no inflow to the impoundment. Based on the given pump discharge capacity of 300 gallons per minute (gpm), the East Impoundment would be drawn down approximately 3 feet over a 4-hour period and the West Impoundment would be drawn down approximately 2.5 feet in 4 hours. Rapid drawdown of the impoundments, due to prior embankment failure, would pose no risk of environmental contamination, because the pond must be empty for this condition to occur. A rapid drawdown condition could arise as a result of extended periods pump operation; however it is assumed unlikely. CDM Smith is in agreement that analyses of end-of-construction and rapid drawdown conditions are not necessary for the JTEC CCW impoundments. CDM Smith recommends JTEC review and revise operating procedures, as appropriate, to mitigate potential for long-term pumping of clear water from the impoundment(s) that could lead to a rapid drawdown condition.

MDNR has recommended guidelines for stability evaluation for new dams and modifications to existing dams. These guidelines include procedures established by the USACE, the United States Bureau of Reclamation, the Federal Energy Regulatory Commission, and the United States Natural Resources Conservation Service. MDNR requires that engineering analyses for new dams meet the minimum safety criteria in the Missouri Code of State Regulations (CSR) and the dam safety law. MDNR defines new dams as those constructed after August 13, 1981. According to the CSR, engineers do not have to show that existing dams meet the stability criteria unless significant modifications are made to the height, slope, or water storage elevation of the earthen structure.

The impoundments at JTEC were put in operation in 1976. Based on the MDNR requirements, the embankments forming the JTEC impoundments were constructed earlier than August 13, 1981, and therefore stability analyses are not mandatory for this facility.

7.1.2 Design Parameters and Dam Materials

The documentation CDM Smith received from JTEC included boring logs and laboratory test results for four borings. Two borings were completed on the crest of the East and West Impoundments' south embankment and two were performed near the toe of the embankments, in-line with the crest borings. Borings were advanced to refusal. Laboratory testing of samples included:

- Moisture Content (ASTM D2216);
- Direct Shear Tests (ASTM D3080);
- Particle Size Analyses (ASTM D422);
- Atterberg Limits (ASTM D4318);
- Pocket Penetrometers; and
- Torvane Shear Tests (ASTM D4648)

Slope stability analyses was performed using the computer program SLOPE/W, part of the GeoStudo 2012 software package. **Table 7.1** summarizes soil parameters used by PPI in the slope stability analyses.

7.1, Summary of Soil Parameters Utilized in Slope Stability Analyses

Stratum	Effective Stress			Total Stress		
	Unit Weight	Cohesion (psf)	Φ_{eff} (degrees)	Unit Weight	Cohesion (psf)	Φ_{eff} (degrees)
Earth Fill	120	100	28	120	1,100	0
Residual Soil - A	115	500	24	115	750	0
Residual Soil - B	100	600	15	100	1,750	0
Residual Soil - C	100	150	17	100	500	0
Limestone	140	5,000	45	140	5,000	45

7.1.3 Uplift and/or Phreatic Surface Assumptions

There was no monitoring and surveillance instrumentation for the impoundments at the time of CDM Smith's on-site visit. Subsequent to CDM Smith's site visit, JTEC installed a series of monitoring wells around the perimeter of the on-site landfill. City Utilities drawing "JTPS102", dated August 26, 2013, shows the well locations to be more than 500 feet from the CCW Impoundments. The location of the landfill monitoring will not facilitate measurement of the phreatic surface CCW impoundment's embankments.

Stability analyses performed by PPI were based on groundwater measurements observed in piezometers installed in the borings completed in January 2014. Groundwater readings from the PPI report for the dates of February 19 and March 3, 2014 are provided in **Table 7.2**. CCW impoundment water surface elevations were not provided for the corresponding days in the PPI report.

7.2, Groundwater Conditions

Monitoring Well	Sample Date	Depth to Water (feet)	Sample Date	Depth to Water (feet)
B-1B	2/19/14	Dry	3/4/14	Dry
B-1A	2/19/14	Dry	3/4/14	Dry
B-2A	2/19/14	41.0	3/4/14	41.1
B-2B	2/19/14	Dry	3/49/14	Dry

7.1.4 Factors of Safety

As a general reference, **Table 7.3** shows the minimum required factors of safety recommended by the USACE for new dams. According to the USACE, if stability analyses for an existing dam appear questionable, long-term stability under steady-state seepage conditions and rapid drawdown should be evaluated. It is not necessary to analyze end-of-construction stability for existing dams unless the cross section is modified. **Table 7.4** shows recommended minimum required seismic factors of safety by the *FEMA Federal Guidelines for Dam Safety, Earthquake Analyses and Design of Dams.*

Table 7.3: Minimum Required Factors of Safety: New Earth and Rock-Fill Dams[1]

Analysis Condition	Required Minimum Factor of Safety	Slope
End-of-Construction (including staged construction)	1.3	Upstream and Downstream
Long-term (steady seepage, maximum storage pool, spillway crest or top of gates)	1.5	Downstream
Maximum surcharge pool	1.4	Downstream
Rapid drawdown	1.1-1.3[2]	Upstream

[1] *Table 3-1 in USACE's EM 1110-2-1902, October 31, 2003*

[2] *FS = 1.1, drawdown from maximum surcharge pool; FS = 1.3, drawdown from maximum storage pool*

Table 7.4: Minimum Required Seismic Factors of Safety[1]

Analysis Condition	Required Minimum Factor of Safety
Seismic Condition at Normal Pool Elevation	1.0
Liquefaction	1.3

[1] *FEMA Federal Guidelines for Dam Safety – Earthquake Analyses and Design of Dams (pgs. 31, 32, 38), May 2005*

A summary of computed safety factors for the different cases of the CCW impoundments is included in **Table 7.5.**

Table 7.5, Computed Factors of Safety for Various Stability Conditions

Condition	Required Factor of Safety	Computed Factor of Safety
Steady-state Seepage Under Maximum Pool (Deep Failure)	1.5	1.89
Steady-state Seepage Under Maximum Pool (Shallow Failure)	1.5	1.58
Steady-state Seepage Under Maximum Pool with Seismic Event	1.0	1.39

Calculated factors of safety for the cross-sections analyzed were greater than USAC- specified minimum factors of safety.

7.1.5 Liquefaction Potential

CDM Smith was not provided documentation on liquefaction analysis. PPI stated that liquefaction is very unlikely at the site due to the subsurface soil and groundwater conditions, and low seismic hazard level at the Plant site. Foundation soils typically consist of medium stiff to lean clay and fat clay with gravel (CL and CH); dense to very dense clayey gravel (GC); or dense to very dense gravel with clay (GW- GC). The site contains significant quantities of relatively stiff clay. PPI states the embankment foundation soils should not be susceptible to liquefaction based on the Unified Soil Classification System (USCS) classification and in situ density. Based on this information provided by PPI, CDM Smith agrees with their rationale for not performing these analyses.

7.1.6 Critical Geological Conditions and Seismicity

The geology of the Springfield region consists primarily of sedimentary rocks of the Late Cambrian to Early Pennsylvanian age. The major types of sedimentary rocks present are carbonate rocks, with shale and siltstone being present in smaller quantities. Most of the bedrock consists of Gasconade, Roubidoux, Jefferson City and Cotter Dolomites. Towards the western portion of the region, Mississippian rocks of mostly cherty and fossiliferous limestone are also present. The Pennsylvanian rocks are mostly medium-grained, medium to thickly bedded sandstone, fissile shale, and pebble to cobble chert conglomerate.

The United States Department of Agriculture soil survey for Greene County indicates the top 5 feet of soils in the project area consist of gravelly clay and gravelly silt, underlain by bedrock.

Information on the website of the United States Geological Survey (USGS) indicates that the impoundments are in an area of generally low seismic hazard. Based on a 2008 USGS seismic hazard map for Missouri, the dam site is located in an area with a potential to experience 0.08g (horizontal) ground acceleration with a probability of exceedance of 2 percent in 50 years.

7.2 ADEQUACY OF SUPPORTING TECHNICAL DOCUMENTATION

JTEC provided necessary information for CDM Smith to perform a review of structural stability for the impoundments. Based on this documentation, it is CDM Smith’s opinion that the supporting technical documentation is adequate for the impoundments.

7.3 ASSESSMENT OF STRUCTURAL STABILITY

Information provided by representatives of JTEC for use in CDM Smith’s evaluation of the impoundments included sufficient data regarding the structural adequacy and stability of the impoundment embankments. CDM Smith considers the structural stability of the embankments of these impoundments adequate.

Section 8

ADEQUACY OF MAINTENANCE AND METHODS OF OPERATION

8.1 OPERATING PROCEDURES

The documentation JTEC provided CDM Smith did not include a manual on operating procedures for the impoundments. A verbal description of the method of operation for the impoundments was provided by a representative of JTEC as described in Section 4.2.3.

8.2 MAINTENANCE OF THE EMBANKMENTS AND PROJECT FACILITIES

Information JTEC provided CDM Smith did not include a written set of maintenance procedures for the impoundments. According to the plant representatives, the embankments are periodically inspected for any potential safety issues. In addition, the embankments are periodically mowed by plant staff. In general, regular mowing of the slopes is evident, although the inside slopes of the south and the common dividing embankments were overgrown with dense vegetation up to about 4 feet in height.

8.3 ASSESSMENT OF MAINTENANCE AND METHODS OF OPERATIONS

8.3.1 Adequacy of Operating Procedures

Documents made available by JTEC for operation of the impoundments were limited to a process flow diagram and a water balance diagram for the plant. The plant representatives' verbal description of operational procedures, in combination with the process flow and water balance diagrams, and CDM Smith's on-site observations, gives a general indication that the operational procedures for the impoundments appear adequate. Although the operational procedures for the impoundments appear adequate, CDM Smith recommends JTEC implement a written set of operational procedures and establish a system for consistent documentation of the impoundments.

8.3.2 Adequacy of Maintenance

In general, maintenance of the embankments and outlet structures of the impoundments appear adequate, with the exception noted in Section 8.2. Major maintenance issues were not apparent at the time of CDM Smith's site visit. Although visual observations of the impoundments and the maintenance procedures described by JTEC personnel appear to be adequate, CDM Smith recommends JTEC implement a written set of maintenance procedures and establish a system for consistent documentation of these procedures on a regular basis.

Section 9

ADEQUACY OF SURVEILLANCE AND MONITORING PROGRAM

9.1 SURVEILLANCE PROCEDURES

According to JTEC representatives, the impoundment embankments are inspected once every three months. Historical records of impoundment inspections are maintained in the JTEC administrative office. Plant representatives provided a completed checklist for a recent inspection. A copy of the checklist is included in **Appendix A**.

9.2 INSTRUMENTATION MONITORING

At the time of CDM Smith's on-site visual assessment, there were no monitoring instruments or observation wells installed. JTEC representatives confirmed that monitoring equipment has not been installed.

9.3 ASSESSMENT OF SURVEILLANCE AND MONITORING PROGRAM

9.3.1 Adequacy of Surveillance Program

Based on verbal communications with JTEC representatives and CDM Smith's review of the available information, the inspection program for the impoundments at JTEC appears adequate. CDM Smith suggests records of inspections and actions required and taken as a result of these inspections be retained for reference purposes.

9.3.2 Adequacy of Instrumentation Monitoring Program

At the time of CDM Smith's on-site visit, JTEC had no instrumentation monitoring available for the impoundments. JTEC representatives confirmed the absence of instrumentation monitoring for the impoundments. Subsequent to CDM Smith's site visit JTEC installed a series of monitoring wells around the perimeter of the on-site landfill. City Utilities drawing "JTPS102", dated August 26, 2013, shows the well locations to be more than 500 feet from the CCW Impoundments. The location of the landfill monitoring will not facilitate measurement of the phreatic surface in CCW impoundments' embankments.

Palmerton and Parrish, Inc. (PPI) installed four piezometers in borings completed January 2014, as part of their geotechnical exploration program and stability assessment of the CCW impoundments. Groundwater readings were provided in the PPI report for the dates of February 19 and March 3, 2014. PPI indicates in their report to JTEC dated March 17, 2014 that they plan to abandon/grout the piezometers. Because of the plan to abandon/grout the piezometers and due to the lack of other instrumentation to monitor phreatic surfaces at the CCW impoundments, the surveillance and monitoring of the impoundments is considered inadequate. Monitoring wells would need to be installed and regular measurements taken to begin an ongoing record of water levels in order to recognize and investigate unusual fluctuations and determine their source.

Appendix A

Assessment Checklists

Coal Combustion Dam Inspection Checklist Form

US Environmental
Protection Agency

Site Name: Southwest Power Station - Springfield, MO
Date: August 27, 2012 - August 28, 2012
Unit Name: East/West Ash Pond
Operator's Name: City Utilities of Springfield, MO
Unit I.D.: n/a
Hazard Potential Classification: High Significant [✓ Low]
Inspector's Name: Clement Bommarito, Albert Ayenu-Prah

Check the appropriate box below. Provide comments when appropriate. If not applicable or not available, record "N/A". Any unusual conditions or construction practices that should be noted in the comments section. For large diked embankments, separate checklists may be used for different embankment areas. If separate forms are used, identify approximate area that the form applies to in comments.

	Yes	No		Yes	No
1. Frequency of Company's Dam Inspections?	3 months		18. Sloughing or bulging on slopes?		x
2. Pool elevation (operator records)?	1225.0'		19. Major erosion or slope deterioration?		x
3. Decant inlet elevation (operator records)?	1225.0'		20. Decant Pipes:		
4. Open channel spillway elevation (operator records)?	1227.8'		Is water entering inlet, but not exiting outlet?		x
5. Lowest dam crest elevation (operator records)?	1235.0'		Is water exiting outlet, but not entering inlet?		x
6. If instrumentation is present, are readings recorded (operator records)?		x	Is water exiting outlet flowing clear?	x	
7. Is the embankment currently under construction?		x	21. Seepage (specify location, if seepage carries fines, and approximate seepage rate below):		
8. Foundation preparation (remove vegetation,stumps, topsoil in area where embankment fill will be placed)?		x	From underdrain?		x
9. Trees growing on embankment? (If so, indicate largest diameter below)		x	At isolated points on embankment slopes?		x
10. Cracks or scarps on crest?		x	At natural hillside in the embankment area?		x
11. Is there significant settlement along the crest?		x	Over widespread areas?		x
12. Are decant trashracks clear and in place?		x	From downstream foundation area?		x
13. Depressions or sinkholes in tailings surface or whirlpool in the pool area?		x	"Boils" beneath stream or ponded water?		x
14. Clogged spillways, groin or diversion ditches?		x	Around the outside of the decant pipe?		x
15. Are spillway or ditch linings deteriorated?		x	22. Surface movements in valley bottom or on hillside?		x
16. Are outlets of decant or underdrains blocked?		x	23. Water against downstream toe?		x
17. Cracks or scarps on slopes?		x	24. Were Photos taken during the dam inspection?	x	

Major adverse changes in these items could cause instability and should be reported for further evaluation. Adverse conditions noted in these items should normally be described (extent, location, volume, etc.) in the space below and on the back of this sheet.

Inspection Issue #	Comments

2, 3, 5: Elevations from Operator records and conversations with plant representative; datum is NAVD 88.

4: One open channel spillway with riprap armoring to west pond; spillway crest elevation from documentation provided by Owner.

U. S. Environmental Protection Agency

Coal Combustion Waste (CCW)
Impoundment Inspection

Impoundment NPDES Permit # MO-0089940

INSPECTOR Clement Bommarito,
Albert Ayenu-Prah

Date August 27, 2012 - August 28, 2012

Impoundment Name East/West Ash Pond
Impoundment Company Southwest Power Station, Springfield, MO
EPA Region 7
State Agency (Field Office) Addresss Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102

Name of Impoundment West Ash Pond
(Report each impoundment on a separate form under the same Impoundment NPDES Permit number)

New x Update ______

	Yes	No
Is impoundment currently under construction?		x
Is water or ccw currently being pumped into the impoundment?	x	

IMPOUNDMENT FUNCTION: Storage of CCW (bottom ash)

Nearest Downstream Town : Name Cape Fair, Missouri
Distance from the impoundment 20 miles
Impoundment
Location: Longitude -93 Degrees 23 Minutes 7 Seconds (Source: Google
Latitude 37 Degrees 8 Minutes 54 Seconds Earth)
State MO County Greene

Does a state agency regulate this impoundment? YES x NO ______

If So Which State Agency? Missouri Department of Natural Resources

In this Report:
n/a = not available
d/n/a = does not apply

HAZARD POTENTIAL (In the event the impoundment should fail, the following would occur):

______ **LESS THAN LOW HAZARD POTENTIAL:** Failure or misoperation of the dam results in no probable loss of human life or economic or environmental losses.

__x__ **LOW HAZARD POTENTIAL:** Dams assigned the low hazard potential classification are those where failure or misoperation results in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the owner's property.

______ **SIGNIFICANT HAZARD POTENTIAL:** Dams assigned the significant hazard potential classification are those dams where failure or misoperation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.

______ **HIGH HAZARD POTENTIAL:** Dams assigned the high hazard potential classification are those where failure or misoperation will probably cause loss of human life.

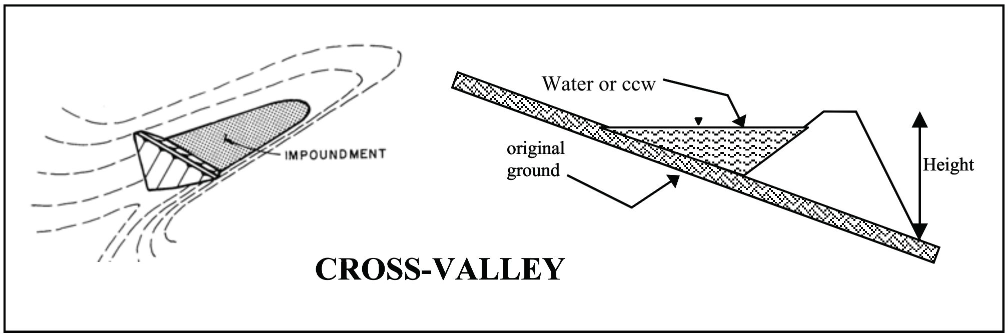
DESCRIBE REASONING FOR HAZARD RATING CHOSEN:

1. In the event of a breach, the downstream flow of waste would remain on Operator's property, consisting of grass and some small trees to its normal discharge into a tributary of Wilson Creek.

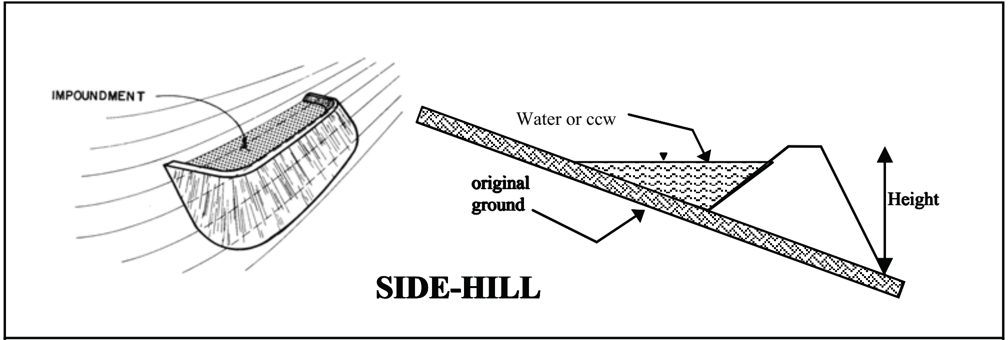
2. A breach could release waste into Wilson's Creek via an unnamed tributary, causing environmental impacts.

3. A breach in the embankment is not expected to result in loss of human life.

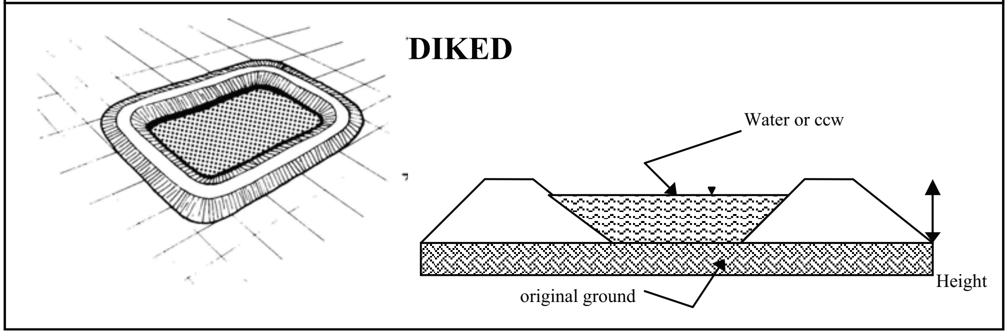
CONFIGURATION:



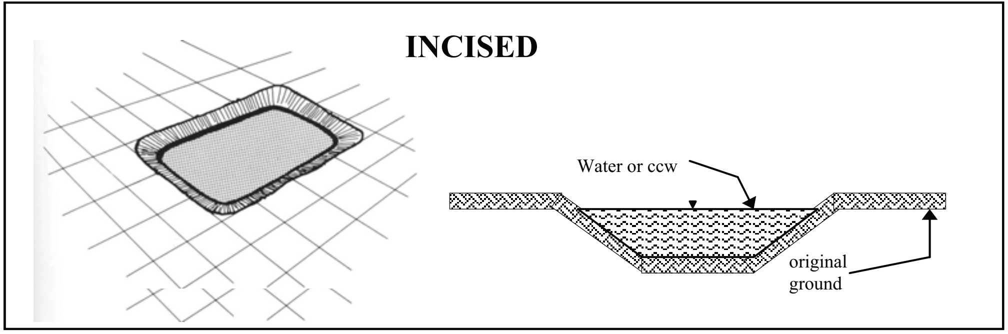
CROSS-VALLEY



SIDE-HILL



DIKED



INCISED

______ Cross-Valley
__x__ Side-Hill
______ Diked
______ Incised (form completion optional)
______ Combination Incised/Diked

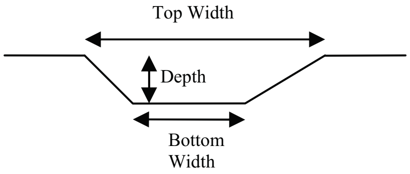
Embankment Height __30__ feet Embankment Material __Clay__
Pool Area (Source: Google Earth) 7 acres Liner __Compacted lime and fly ash__
Current Freeboard __10__ feet Liner Permeability __n/a__

TYPE OF OUTLET (Mark all that apply)

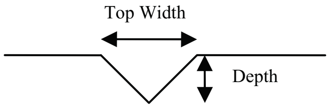
d/n/a **Open Channel Spillway**
______ Trapezoidal
______ Triangular
______ Rectangular
______ Irregular

______ depth
______ bottom (or average) width
______ top width

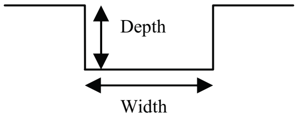
TRAPEZOIDAL



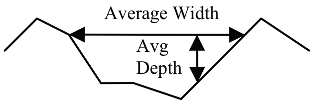
TRIANGULAR



RECTANGULAR

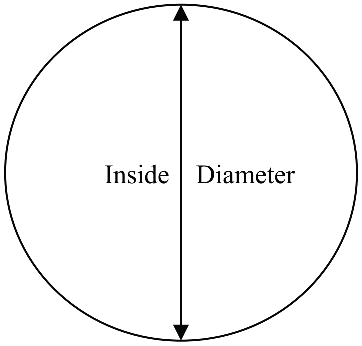


IRREGULAR



x **Outlet**

20" inside diameter



Material
x corrugated metal
______ welded steel
______ concrete
______ plastic (hdpe, pvc, etc.)
______ other (specify) ______________________

Is water flowing through the outlet? YES x NO ________

______ **No Outlet**

______ **Other Type of Outlet** (specify) ________________________________

The Impoundment was Designed By Burns & McDonald

Has there ever been a failure at this site? YES ___________ NO ____x______

If So When? ______________________________

If So Please Describe : ____

Has there ever been significant seepages at this site? YES _______ NO x

If So When? ____________________________

IF So Please Describe: ____

Has there ever been any measures undertaken to monitor/lower
Phreatic water table levels based on past seepages or breaches
at this site? YES ________ NO __x__

If so, which method (e.g., piezometers, gw pumping,...)? ____________________

If so Please Describe : ____________________

ADDITIONAL INSPECTION QUESTIONS

Concerning the embankment foundation, was the embankment construction built over wet ash, slag, or other unsuitable materials? If there is no information just note that.

Untitled and undated drawings provided by John Twitty Energy Center staff indicate the embankments were constructed over scarified and re-compacted "existing grade". Existing grade is not defined in the plans provided. It cannot be stated definitively that the embankments are not constructed over wet ash, slag or other unsuitable materials.

Did the dam assessor meet with, or have documentation from, the design Engineer-of-Record concerning the foundation preparation?

The assessor did not meet with, or have documentation from, the design Engineer of Record concerning foundation preparation.

From the site visit or from photographic documentation, was there evidence of prior releases, failures, or patchwork on the dikes?

There was no indication of prior releases, failures or patchwork on the embankments.

Appendix B

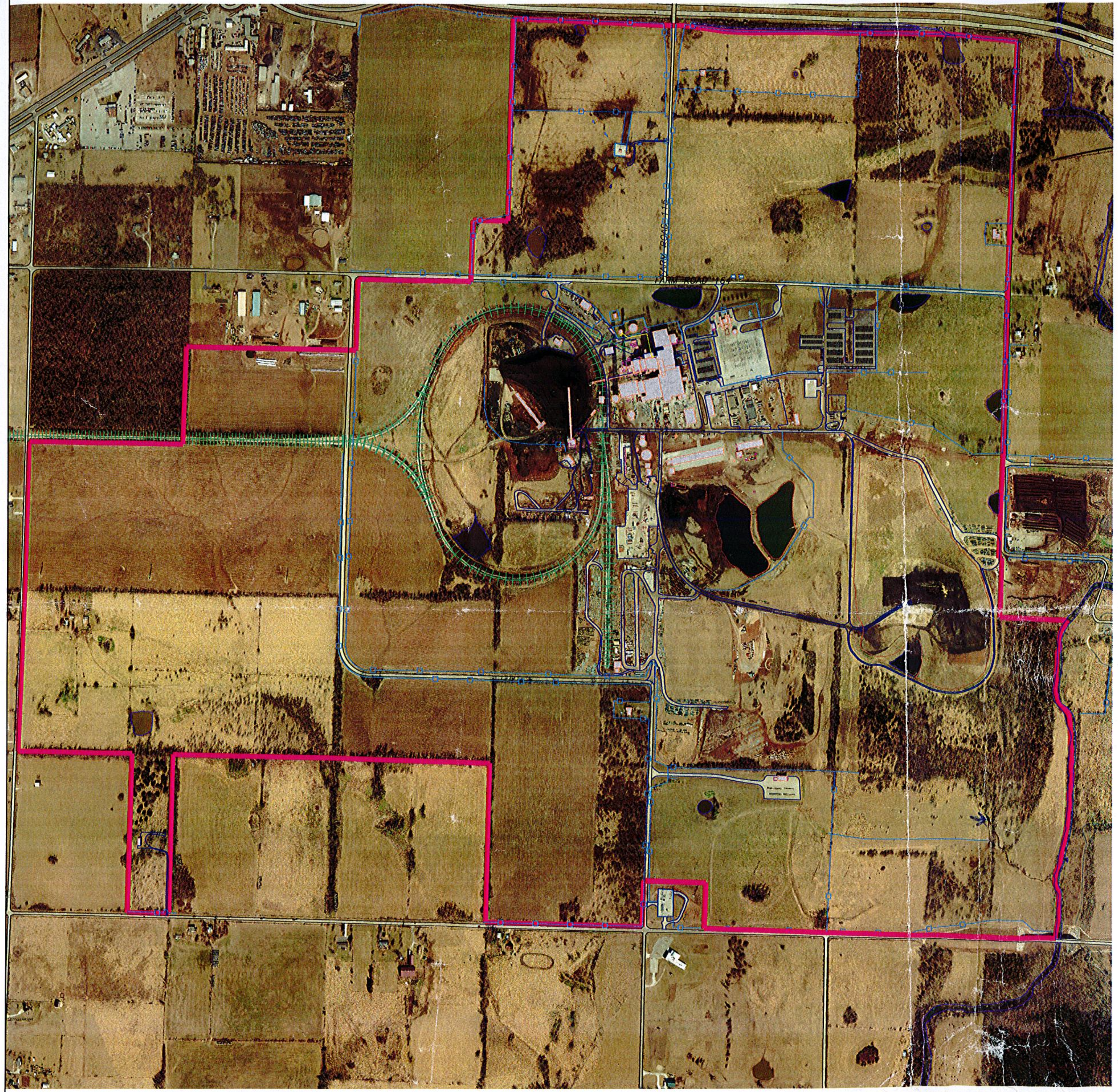
Documentation from John Twitty Energy Center

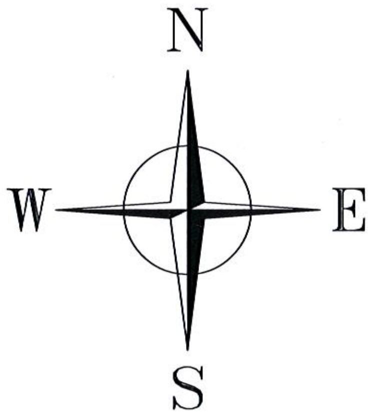
Appendix B

Doc 01: Power Station Property Map

MAP—1

CITY UTILITIES OF SPRINGFIELD, MISSOURI
SOUTHWEST POWER STATION
PLANT ID: 5265





CITY UTILITIES
Bringing Power Home.

SOUTHWEST POWER STATION

DRAWN BY: ASR	SCALE: 1" = 400'

Appendix B

Doc 02: Power Station Surveys

LOCATION SKETCH

SEC 7, T28N, R22W
SCALE: 1"=2000'

MISSOURI ONE CALL SYSTEM, INC
1-800-344-7483
STOP-CALL BEFORE YOU DIG!

LEGEND

● CP	CONTROL POINT
● IP	FOUND IRON PIN
○ IP	SET IRON PIN
△ RWM	RIGHT-OF-WAY MARKER
PP GY △	POWER POLE W/ GUY
MH	MANHOLE
SCO	SEWER CLEANOUT
□ GM	GAS METER
LP	LIGHT POLE
▲	SIGN
WM	WATER METER
WV	WATER VALVE
GV	GAS VALVE
○ FH	FIRE HYDRANT
▲ TR	TELEPHONE RISER
●	BUMPER POST
▬	GRATE INLET
~	TREELINE
○	BUSH
□ ER	ELECTRICAL RISER
□ TS	TRAFFIC SIGNAL BOX
□ MB	MAIL BOX
PROPERTY LINE	——
SANITARY SEWER	—— SS ——
STORM SEWER	—— SW ——
TELEPHONE LINE	----- T -----
UNDERGROUND TELEPHONE	----- UT -----
GAS LINE	----- G -----
WATER LINE	----- W -----
ELECTRIC LINE	—— E ——
UNDERGROUND ELECTRIC	—— UE ——
FENCE LINE	——x——x——
RETAINING WALL	═//═//═
LINE LABELS	MEASURED / DEED 100' M / 100' D

SURVEYOR'S DECLARATION

I, THE UNDERSIGNED, DO HEREBY DECLARE THAT THE TOPOGRAPHIC SURVEY SHOWN HEREON WAS MADE UNDER MY SUPERVISION AND TO THE BEST OF MY KNOWLEDGE THE INFORMATION IS AS SHOWN AND IN ACCORDANCE WITH THE CURRENT MINIMUM STANDARDS FOR URBAN PROPERTY SURVEYS, DATE OF LAST REVISION OCTOBER 11, 2010.

ANDERSON ENGINEERING, INC. LC 62
BY:

KEVIN L. LAMBETH, P.L.S. 2695

10-15-2010
DATE

DATE OF FIELD SURVEY OCTOBER 08, 2010

ANDERSON ENGINEERING, INC
ENGINEERS · SURVEYORS · LABORATORIES · DRILLING
2045 W. WOODLAND · SPRINGFIELD, MISSOURI 65807 · PHONE (417) 866-2741
COA # 000062

REVISIONS				DRAWING INFO.	
NO.	DESCRIPTION	BY	DATE	FIELD BY:	AP & JE
				DRAWN BY:	BAC
				CHECK BY:	KLL
				DATE:	10-11-10
				FIELD BOOK:	
				JOB NUMBER:	38207

CITY UTILITIES OF SPRINFIELD

WEST ASH POND
ASBUILT SURVEY

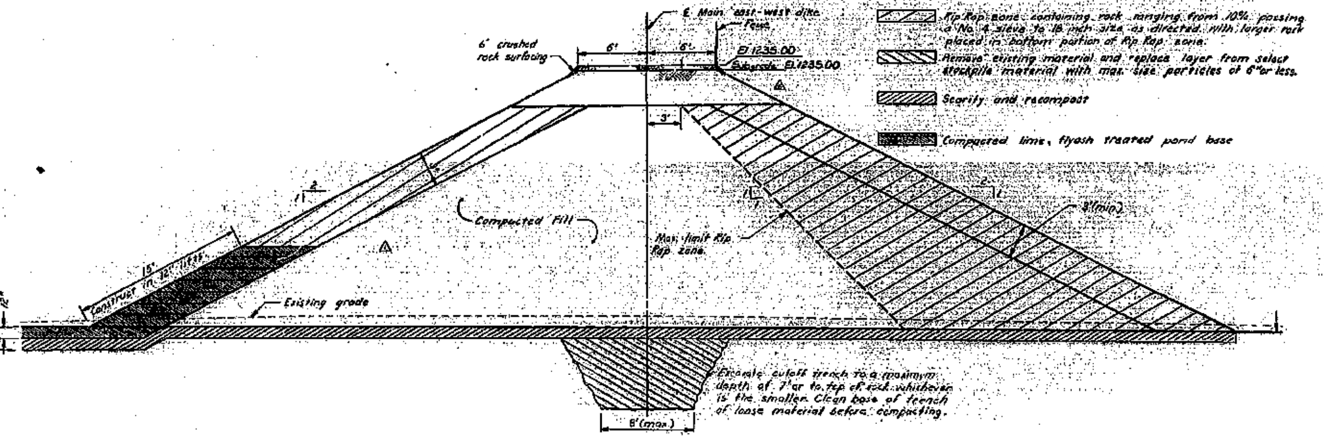
SOUTHWEST POWER STATION
SPRINGFIELD, MISSOURI

DRAWING NO.
WB 108-826
SHEET NUMBER
1
OF 1


AREA UPDATED
OCTOBER 30, 2003
132 KV
KV
1240
1230
GRASS
1220
1208
1200
1210
1197.5
LANDFILL HAUL ROAD
1230
1230
1236
GREASE TRAP
1240
1240
LANDFILL SCRUBBER RESTORED

Appendix B

Doc 03: Power Station Drawings



▨ Rip Rap zone containing rock ranging from 10% passing a No. 4 sieve to 18 inch size as directed with larger rock placed in bottom portion of Rip Rap zone.

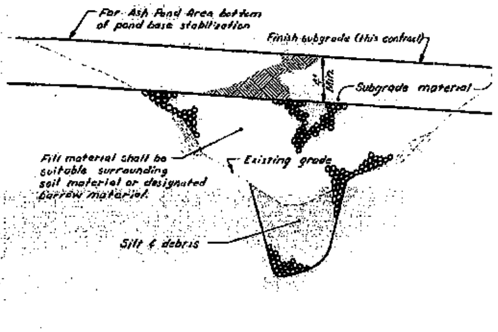
▨ Remove existing material and replace layer from select stockpile material with max. size particles of 6" or less.

▨ Scarify and recompact

▨ Compacted lime, flyash treated pond base

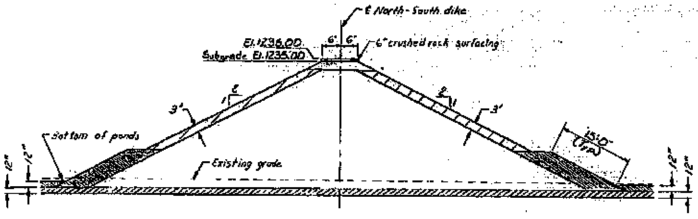
Excavate cutoff trench to a maximum depth of 7' or to top of rock whichever is the smaller. Clean base of trench of loose material before compacting.

SECTION 45-E-43
Not to Scale

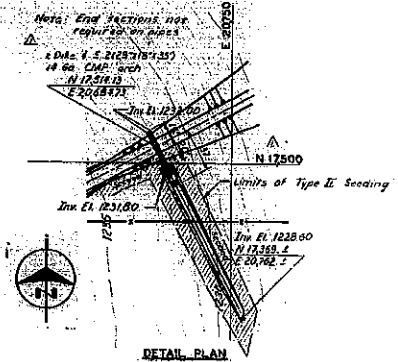


NOTES:
1. All encountered sinkholes shall be cleaned to a min. depth of 4' below proposed grade. Remove all silt & debris prior to filling to a min. depth of 4'

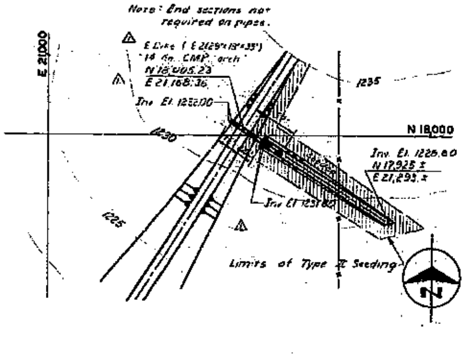
SINKHOLE REPAIR DETAIL
TYPICAL EMBANKMENT AREAS
Not to Scale



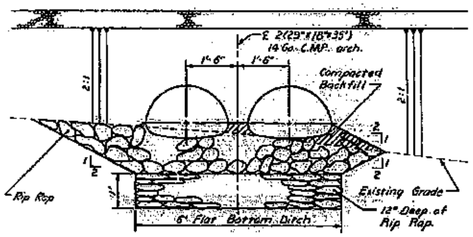
SECTION 45-H-49 △
Not to Scale



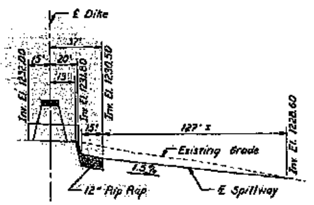
DETAIL PLAN
ASH POND SPILLWAY NO. 1



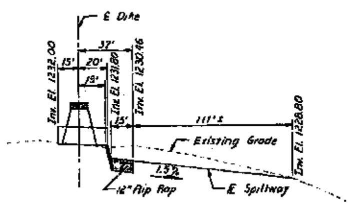
DETAIL PLAN
ASH POND SPILLWAY NO. 2



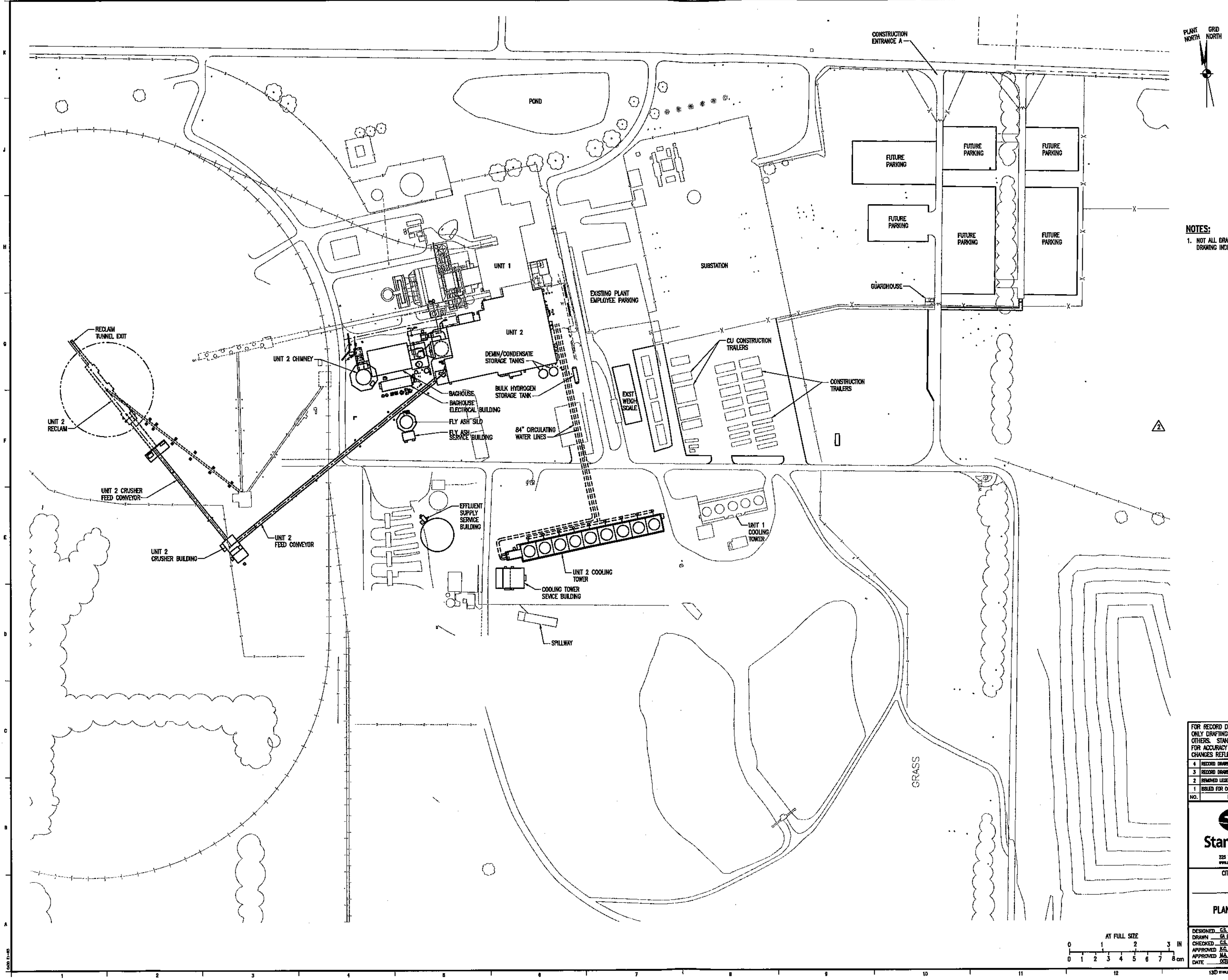
TYPICAL SECTION
SPILLWAY NO. 1 & 2
Not to Scale



PROFILE
ASH POND SPILLWAY NO. 1
Not to Scale



PROFILE
ASH POND SPILLWAY NO. 2
Not to Scale



NOTES:

1. NOT ALL DRAWINGS ARE ISSUED WITH EACH CONTRACT, SEE DRAWING INDEX FOR DRAWINGS INCLUDED.

THE ORIGINAL OF THIS DRAWING WAS SIGNED, SEALED, AND CERTIFIED BY:
REV:0 KENT C. TURNER 11-10-07
MO.REG.NO. PE-2006020712 EXP. DATE 12-31-08
REV:1 KENT C. TURNER 12-14-07
MO.REG.NO. PE-2006020712 EXP. DATE 12-31-08
REV:2 CATHERINE S. WEIKEL 3-12-08
MO.REG.NO. PE-2007032447 EXP. DATE 12-31-09
REV:3 CATHERINE S. WEIKEL 9-13-10
MO.REG.NO. PE-2007032447 EXP. DATE 12-31-11
REV:4
MO.REG.NO. EXP. DATE
REV:5
MO.REG.NO. EXP. DATE

FOR RECORD DRAWINGS, STANLEY CONSULTANTS PROVIDED ONLY DRAFTING SERVICES BASED ON MARK-UP PROVIDED BY OTHERS. STANLEY CONSULTANTS TAKES NO RESPONSIBILITY FOR ACCURACY OF THE MARK-UP OR ANY FIELD DESIGN CHANGES REFLECTED THEREIN.

NO.	REVISIONS	DWN	APVD	APVD	DATE
4	RECORD DRAWING FOR CONTRACT 281	DLW	CSW	MAE	6-1-11
3	RECORD DRAWING FOR CONTRACT 282	DLW	CSW	MAE	9-13-10
2	REMOVED LEGEND	BER	CSW	MAE	3-12-08
1	ISSUED FOR CONSTRUCTION	GAG	KCT	MAE	12-14-07

Stanley Consultants INC.
225 Iowa Avenue, Muscatine, Iowa 52761-3764
www.stanleyconsultants.com

CITY UTILITIES OF SPRINGFIELD MISSOURI
SOUTHWEST UNIT 2
SPRINGFIELD, MISSOURI

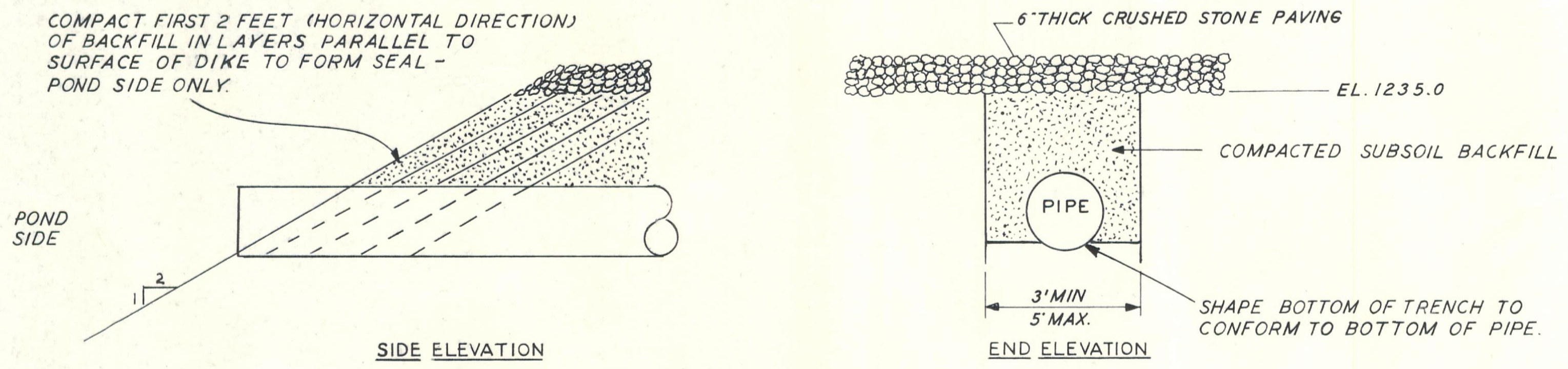
PLANT SITE ARRANGEMENT PLAN

DESIGNED C.S. WEIKEL
DRAWN GA GOOS
CHECKED C.S. WEIKEL
APPROVED K.C. TURNER
APPROVED M.A. ELLIOTT
DATE OCTOBER 11, 2007

SCALE: 1"=100'
NO. 18000
GG200
REV. 4

R:\01-Gen\04-Sheet\18000GG200.dwg

AF 37978C

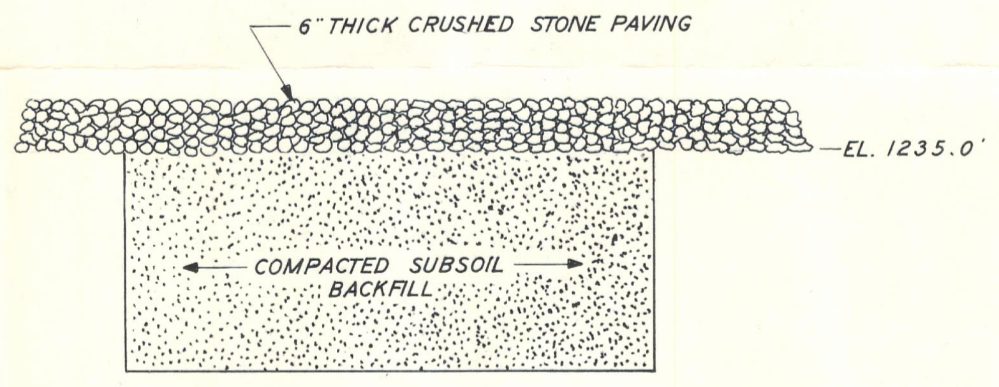


SIDE ELEVATION

END ELEVATION

DETAIL 1 - TRENCH

N.T.S.



DETAIL 2-TRENCH

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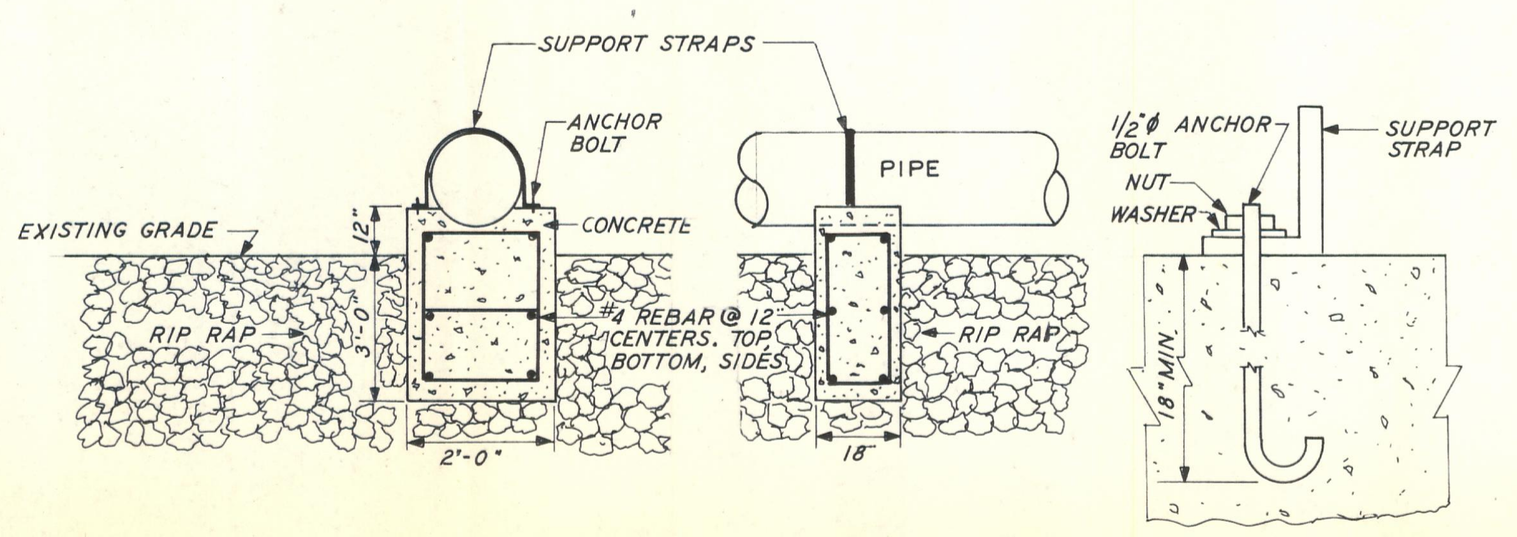
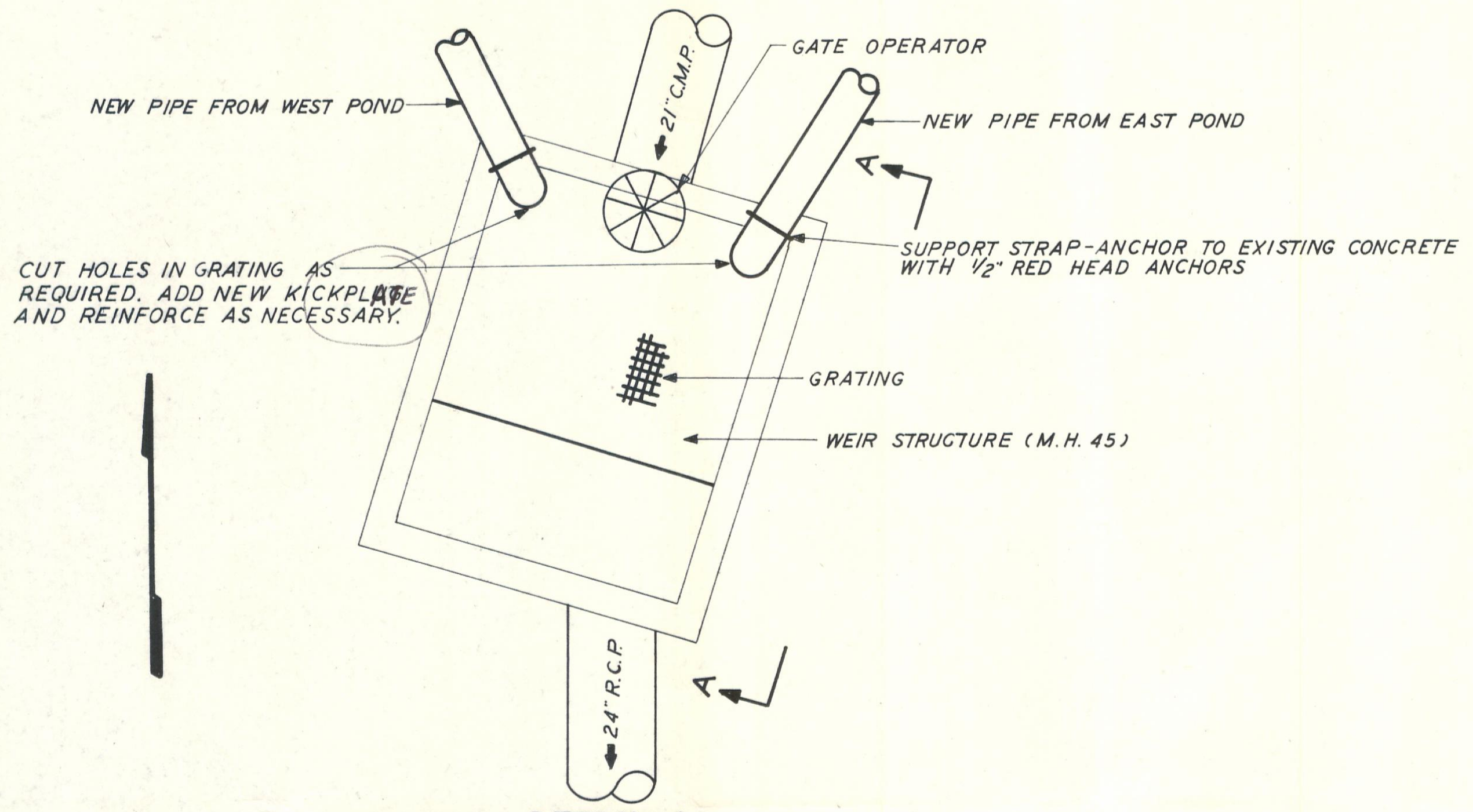


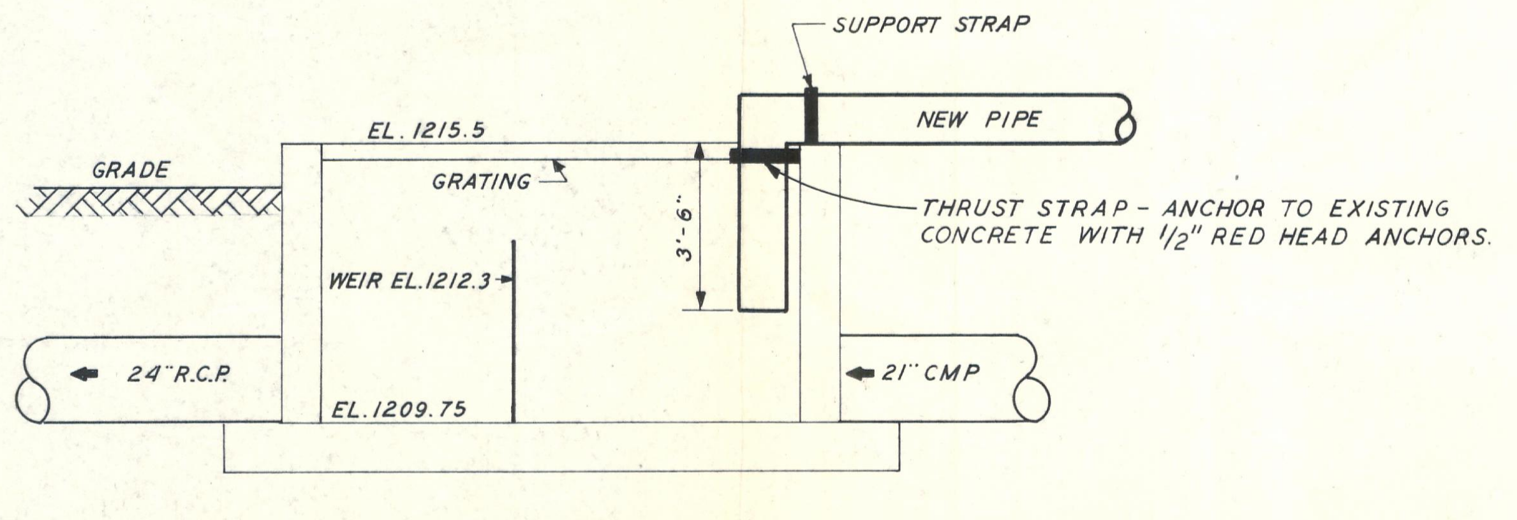
DETAIL 3 - TYPICAL SUPPORT

N.T.S.



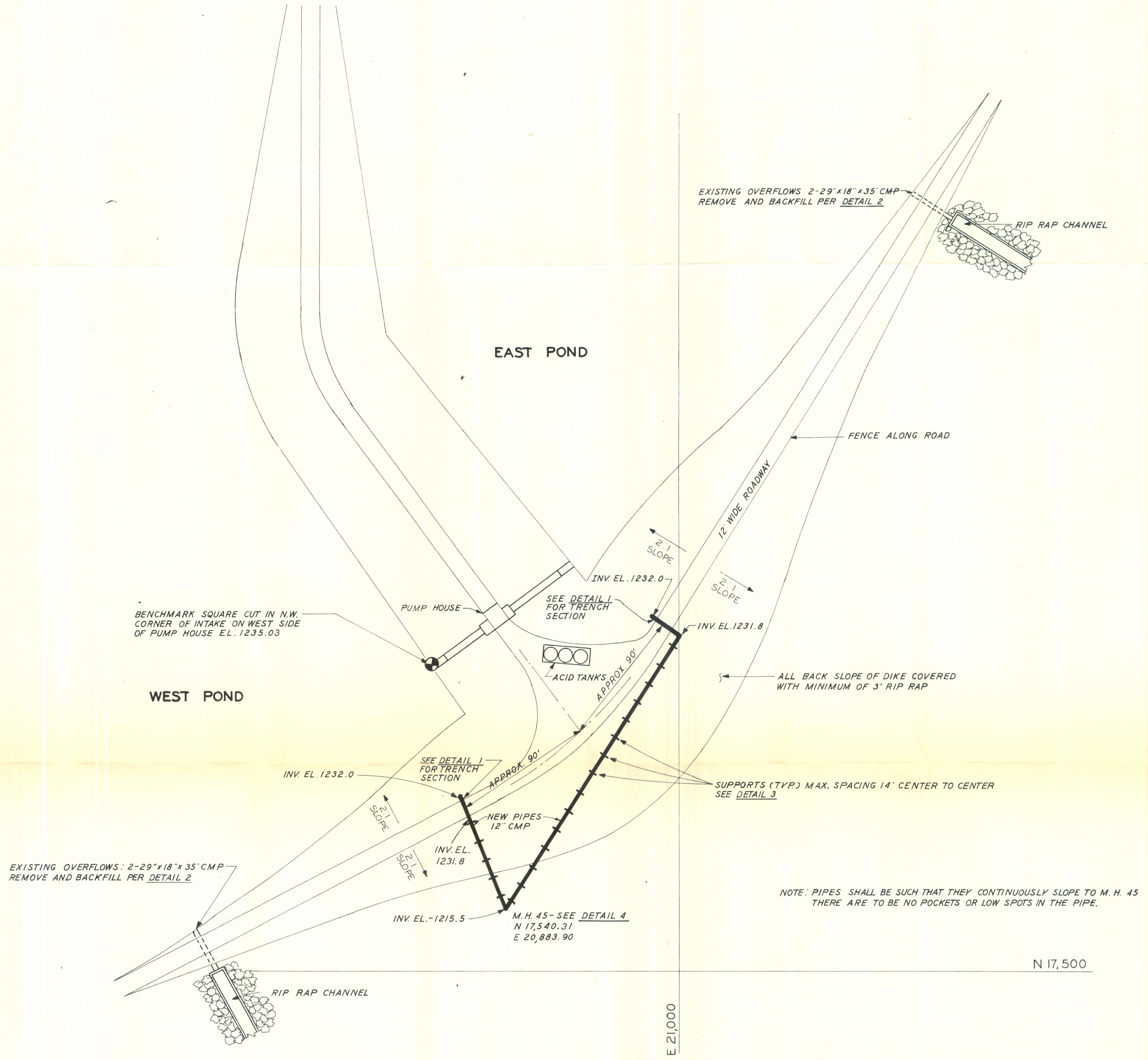
DETAIL 4
WATER STRUCTURE DETAIL

N.T.S.



SECTION A-A

N.T.S.



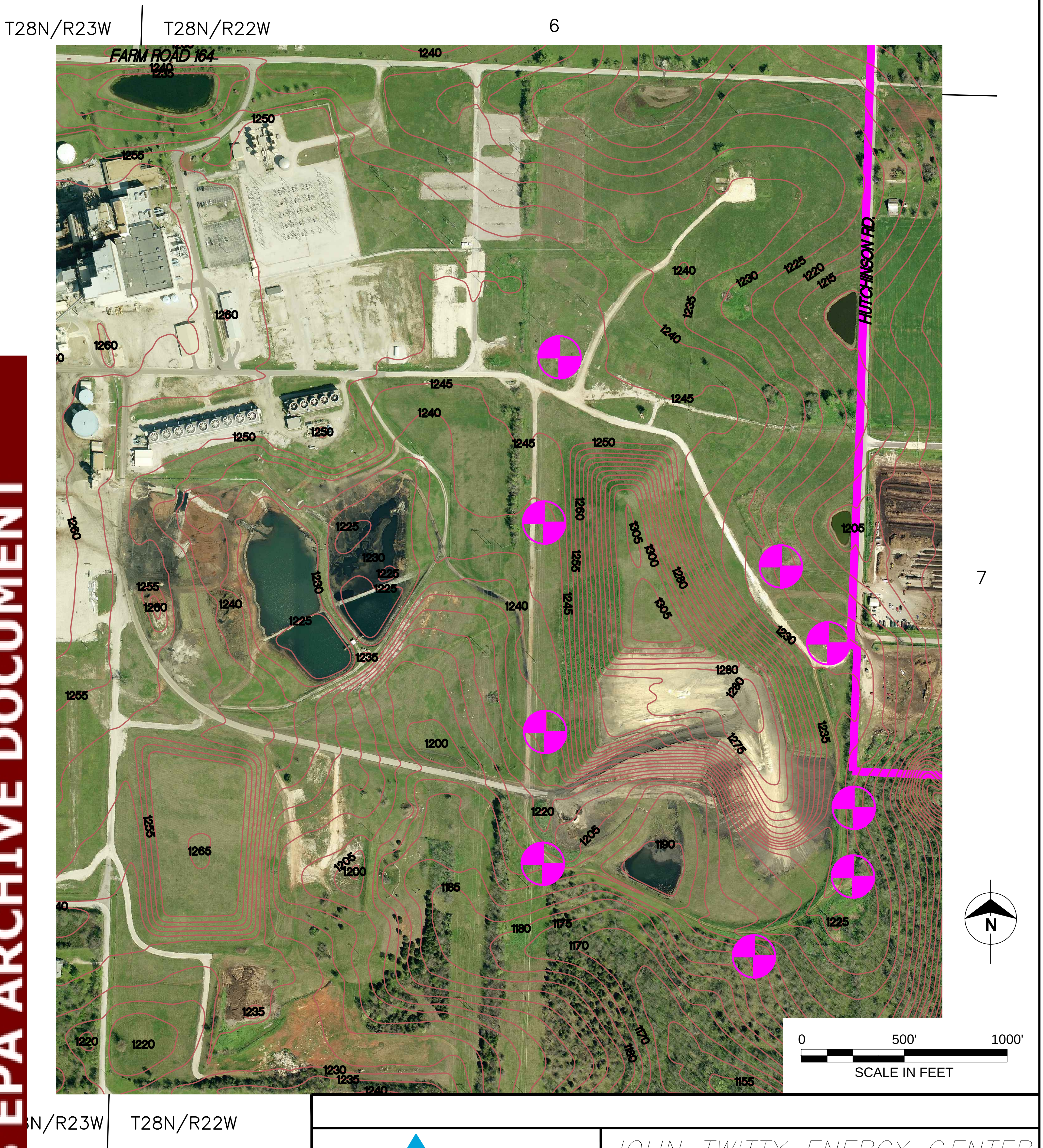
NOTE: PIPES SHALL BE SUCH THAT THEY CONTINUOUSLY SLOPE TO M. H. 45
THERE ARE TO BE NO POCKETS OR LOW SPOTS IN THE PIPE.

PROPOSED PIPE ROUTING - PLAN VIEW

SCALE 1" = 50'

CITY UTILITIES OF SPRINGFIELD, MO.

AUTH J.O. 151242-652		ASH PONDS OVERFLOW MODIFICATIONS SOUTHWEST POWER STATION		
DATE ISSUED				
ELECTRIC WATER				
ENGR. BY M.R.W	APPD. BY	REVISED	BELL ENGR.	SCALE AS NOTED ABOVE
DWN. BY RW	DATE 12-31-85	MAP NO.	SHEET 1 OF 1	DWG. NO. 24,879-B



LEGEND:

◐	LANDFILL MONITORING WELLS
—℄—	CITY UTILITIES JTEC PROPERTY BOUNDARY(TOTAL ACRES: 980±)

CONTOURS ARE LIDAR DATA, GREENE COUNTY, FEB 2011 AND ARE ON 5-FT INTERVALS

AERIAL PHOTOGRAPH TAKEN FEBRUARY 2012

CITY UTILITIES

Bringing Power Home.

JOHN TWITTY ENERGY CENTER SITE PLAN

ENGINEERED BY: TCS	APPROVED BY: TCS	DATE: 8/26/2013	DATE ISSUED:	MAP NO.:
DRAWN BY: JET	AGENCY NO.:		PLOT DATE/TIME: 1/15/2014	SCALE: 1" = 500'
APPLICATION NO.:	PERMIT NO.:		SHEET OF	DRAWING NO.: JTPS102

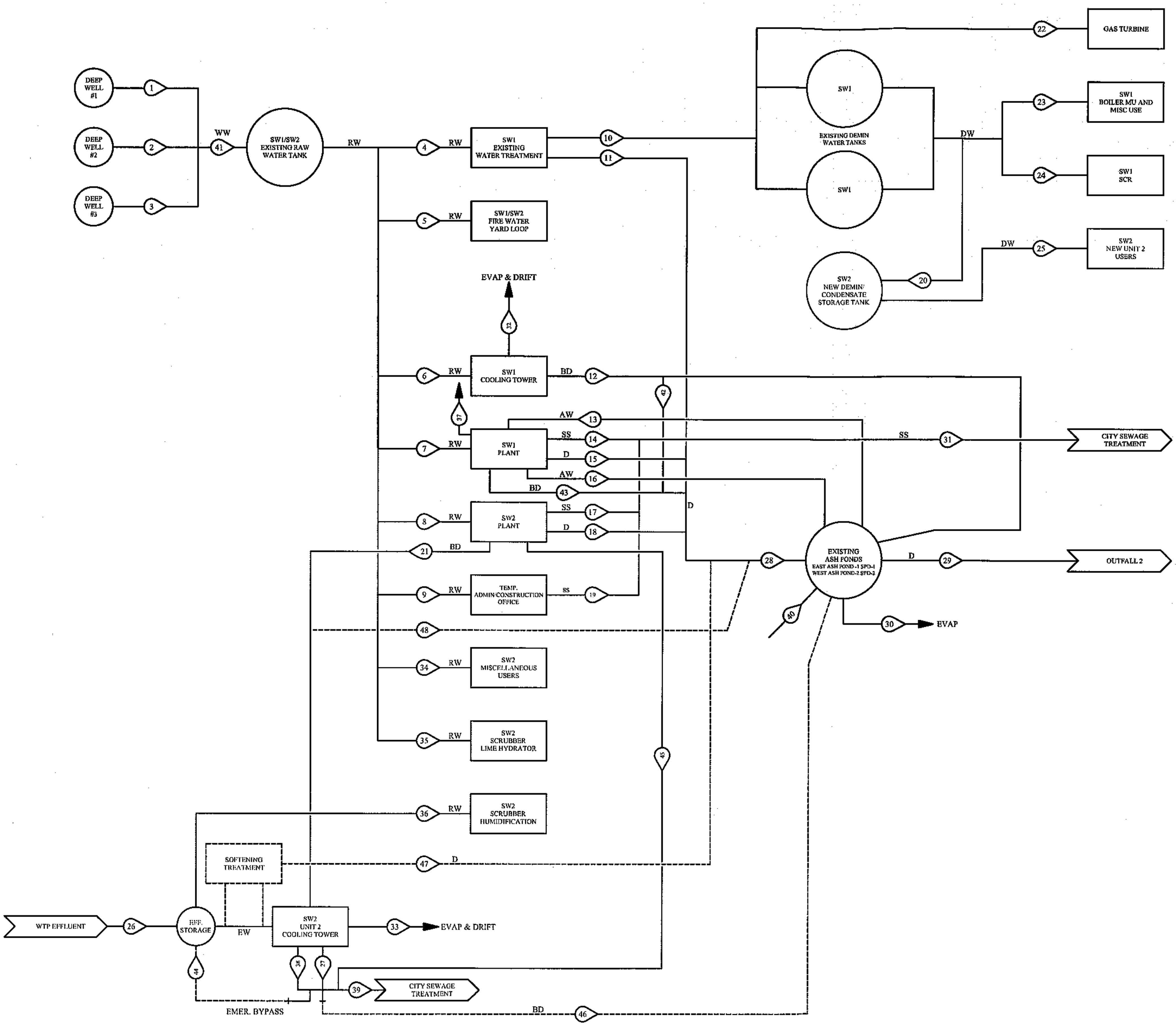
Appendix B

Doc 04: Power Station Process Diagrams

v

WB-1

CITY UTILITIES OF SPRINGFIELD, MISSOURI
SOUTHWEST POWER STATION
PLANT ID: 5265



CU LINE NO.	GENERAL DESCRIPTION	WATER TYPE	GPM PEAK	MGD PEAK	GPM AVG	MGD AVG
1	DEEP WELL #1	WELL	1600	2.30	1162	1.67
2	DEEP WELL #2	WELL	500	0.72	0	-
3	DEEP WELL #3	WELL	1600	2.30	1162	1.67
4	ION EXCHANGE RAW FEED	RAW	450	0.65	58	0.08
5	FIRE LINE FEED	RAW	3700	5.33	5	<0.01
6	SW1 COOLING TOWER MAKEUP	RAW	2217	3.19	2176	3.13
7	SW1 MISC. MAKEUP	RAW	26	0.04	15	0.02
8	SW2 RAW WATER IN	RAW	416	0.59	56	0.08
9	SW2 TEMP. CONST. OFF	RAW	12	0.02	1	<0.01
10	ION EXCHANGE WATER OUT	IX	250	0.36	40	0.06
11	ION EXCHANGE WASTE WATER	WASTE	450	0.65	18	0.03
12	SW1 COOLING TOWER BLOWDOWN	WASTE	312	0.45	271	0.39
13	SW1 ASH SLUICE IN	RECYCLE	2842	4.09	300	0.43
14	SW1 SEWER	SEWER	12	0.02	1	<0.01
15	SW1 PLANT DRAINS	WASTE	14	.02	14	0.02
16	SW1 ASH SLUICE OUT	RECYCLE	2775	4.0	233	0.36
17	SW2 SEWER	WASTE	2	<0.01	2	<0.01
18	SW2 PLANT DRAINS	WASTE	14	0.02	14	0.02
19	SW2 TEMP. CONST. OFF	SEWER	12	0.02	1	<0.01
20	ION EXCHANGE TRANSFER SW1 TO SW2	IX	40	0.03	20	0.06
21	SW2 BLR. BLOWDOWN TO SW2 CT	WASTE	400	0.58	40	0.06
22	ION EXCHANGE TO GAS TURBINE	IX	250	0.36	X	-
23	SW1 BLR. MAKEUP/MISC	IX	22	0.03	18	0.03
24	SW1 SCR	IX	2	<0.01	2	<0.01
25	SW2 BLR. MAKEUP/MISC	IX	40	0.06	20	0.03
26	SWTP EFFLUENT IN	EFF	3826	5.51	3460	4.98
27	SW2 COOLING TOWER BLOWDOWN	WASTE	1314	1.89	644	0.93
28	SW1 & SW2 WASTE STREAM TO ASH POND	WASTE	618	0.89	129	0.19
29	FLOW TO 002 OUTFALL	WASTE	2847	4.10	361	0.52
30	ASH POND EVAP		-	-	17	0.02
31	SW1/SW2 SANITARY SEWER	SEWER	24	0.03	2	<0.01
32	SW1 COOLING TOWER EVAP/DRIFT		1905	2.74	1905	2.74
33	SW2 COOLING TOWER EVAP/DRIFT		-	-	2635	3.79
34	SW2 MISCELLANEOUS	RAW	40	0.06	5	<0.01
35	RAW WATER TO LIME HYDRATER	RAW	7	0.01	7	0.01
36	SWTP EFFLUENT TO SW2 SCRUBBER	EFF	221	0.32	221	0.32
37	SW1 FURNACE SEAL AND BOTTOM ASH EVAP	RECYCLE	67	0.01	67	0.01
38	SW2 COOLING TOWER OUTAGE DRAIN	CIRC	1350	1.94	0	-
39	SW2 CT TO SWTP	CIRC	970	1.40	644	0.93
40	STORM WATER RUNOFF		2550	3.67	118	0.17
41	DEEPWELL TO RAW WATER TANK		3700	5.33	2323	3.35
42	SW1 COOLING TOWER BLOWDOWN TO SW1 FLASH TANK	CIRC	125	0.18	75	0.11
43	SW1 BLR. BLOWDOWN	BLR	15	0.02	8	0.01
44	EXCESS SW2 COOLING TOWER BLOWDOWN	CIRC	344	0.49	0	-
45	CLOSED COOLING WATER MAINT.	CIRC	43	0.06	0	<0.01
46	COOLING TOWER BLOWDOWN (CONTINGENCY)	CIRC	970	1.40	644	0.93
47	SOFTENING TREATMENT WASTE FLOW	WASTE			0.1	0.1
48	SW2 BLR. BLOWDOWN (CONTINGENCY)	WASTE	400	0.58	40	0.06

XX - FLOW STREAM NUMBER AND DIRECTION

AW - ASH WATER
BD - BLOWDOWN
D - DRAIN
DW - DEMINERALIZED WATER
EW - WTP EFFLUENT WATER
PW - POTABLE WATER
RW - RAW WATER
SS - SANITARY SEWER
WW- WELL WATER

——— = EXISTING SW1 AND COMMON
——— = SW2
- - - = CONTINGENCY

SOUTHWEST POWER PLANT

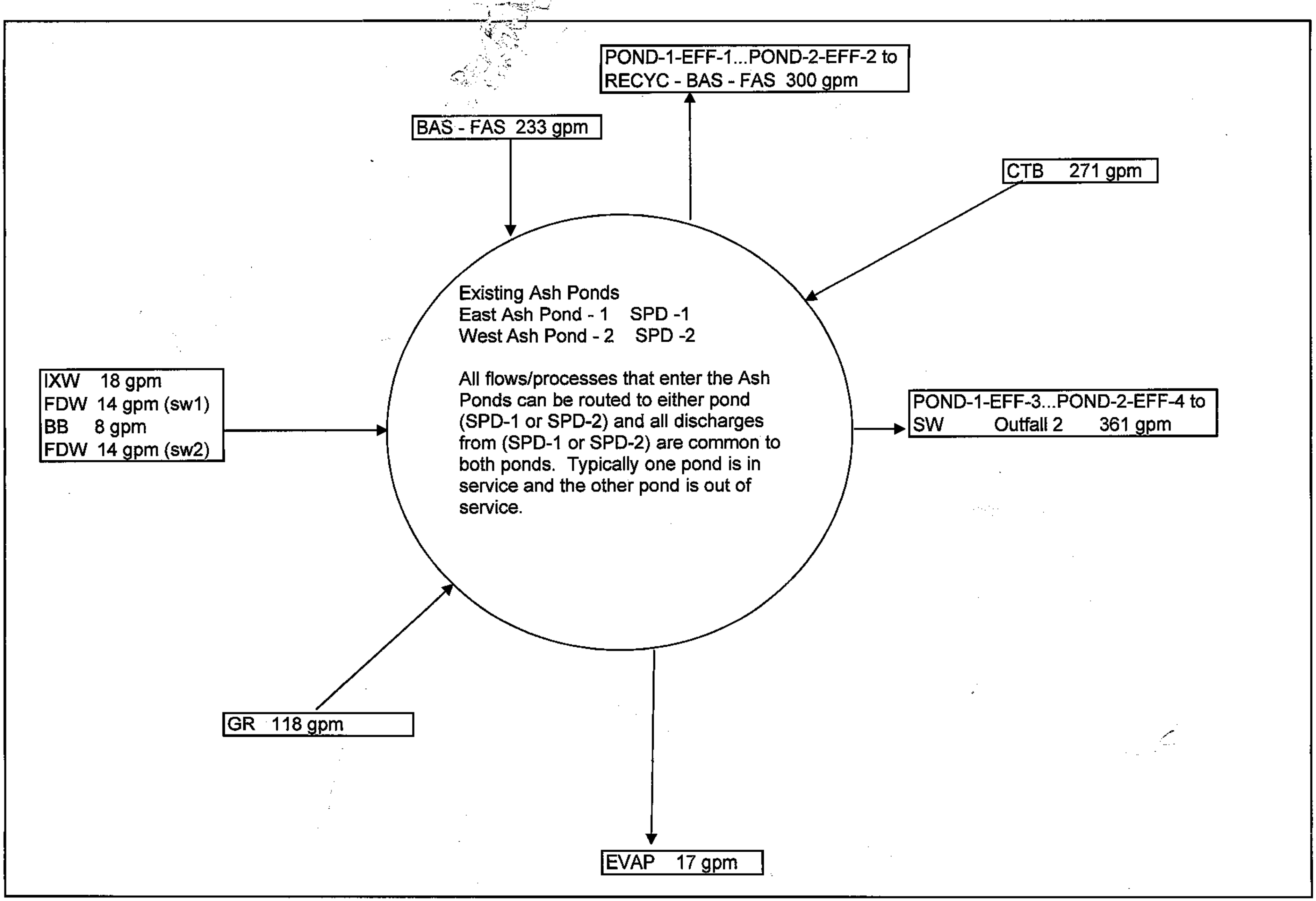
CITY UTILITIES
Bringing Power Home.

PROCESS FLOW DIAGRAM
WATER BALANCE
SOUTHWEST UNITS 1 & 2

ENGINEERED BY: JH	APPROVED BY: JH	DATE:	DATE ISSUED: 9/29/2010	MAP NO.:	REV.:
DRAWN BY: B.HAWKINS	AGENCY NO.:		PLOT DATE/TIME: 9/30/2010	SCALE: NTS	
APPLICATION NO.:	PERMIT NO.:		SHEET 2 OF 2	DRAWING NO.: CU-XM102	

Water Balance Block Diagram

WB-2
Plant ID: 5265
Southwest Power Station



Data for this diagram based on 4/28/2010 NPDES water balance

Appendix B

Doc 05: Stability Analyses

GEOTECHNICAL ENGINEERING REPORT

SITE STRUCTURAL ASSESSMENT

COAL COMBUSTION WASTE IMPOUNDMENTS

CITY UTILITIES OF SPRINGFIELD

JOHN TWITTY ENERGY CENTER

SPRINGFIELD, MISSOURI

Prepared for:

CITY UTLILITIES OF SPRINGFIELD
P.O. Box 551
Springfield, Missouri 65801-0551

Prepared by:

PPI
- Geotechnical Services
- Environmental Services
- Material Testing Services

PALMERTON & PARRISH, INC.

Springfield, MO
4168 W. Kearney Springfield, MO 65803
Call 417.864.6000 Fax 417.864.6004
www.ppimo.com

PROJECT NUMBER: 219892

March 17, 2014

PPI
PALMERTON & PARRISH, INC.

GEOTECHNICAL & MATERIALS ENGINEERS
MATERIALS TESTING LABORATORIES
ENVIRONMENTAL SERVICES

4168 W. Kearney Street.
Springfield, MO 65803
Ph: (417) 864-6000
www.ppimo.com

March 17, 2014

Mr. Ted C. Salveter, P.E.
City Utilities of Springfield
P.O. Box 551
Springfield, Missouri 65801-0551

RE: Geotechnical Engineering Report
Site Structural Assessment – Coal Combustion Waste Impoundments
City Utilities of Springfield – John Twitty Energy Center
Springfield, Missouri
PPI Project Number: 219892

Dear Mr. Salveter:

Please find the attached Report summarizing the results of a Geotechnical Subsurface Investigation and Slope Stability Analysis conducted for the above-referenced Project. PPI appreciates this opportunity to be of services. Please don't hesitate to contact this office if you have any questions regarding our Report or need additional information.

PALMERTON & PARRISH, INC.
By:

Taylor L. Anderson, E.I.
Geotechnical Engineer

PALMERTON & PARRISH, INC.
By:

Rachel J. Goeke, P.E.
Geotechnical Engineer

STATE OF MISSOURI
RACHEL
JEANNE GOEKE
NUMBER
PE-2007020268
PROFESSIONAL ENGINEER

PALMERTON & PARRISH, INC.
By:

Brad R. Parrish, P.E.
President

Submitted: Three (3) Bound Copies
One (1) Electronic .pdf Copy

BRP:RJG::TLA:/jrh

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FIGURE 1 – BORING LOCATION PLAN

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APPENDIX III – LABORATORY TEST RESULTS

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APPENDIX V – SLOPE STABILITY ANALYSIS RESULTS

APPENDIX VI – DIRECT SHEAR RESULTS

EXECUTIVE SUMMARY

A Geotechnical Investigation was performed at the John Twitty Energy Center located at 5100 West Farm Road 164, Springfield, Missouri 65801. The investigation was performed to investigate the nature of the existing embankment and underlying residual soils.

Palmerton & Parrish (PPI) drilled, a total of four (4) geotechnical borings were drilled in two (2) sets of two (2) borings (one at the slope crest and one at the slope toe), in order to develop two (2) geologic cross sections. Borings were discontinued at auger refusal in limestone bedrock at depths ranging from 9.7 to 47.3 feet below the existing ground surface. Temporary piezometers were installed in all four (4) borings, and water levels were recorded during two (2) separate measuring events.

A slope stability analysis was performed on the downstream slopes using data from the field and laboratory investigation, as well as groundwater level readings from the temporary piezometers. The slope stability analysis considered the following cases:

- Steady state seepage, maximum pool (effective stress conditions); and
- Steady state seepage, maximum pool, earthquake loading (total stress conditions).

Factors of safety determined from the slope stability analysis were compared to safety factors considered to be adequate in guidelines published by various government agencies. Based upon this comparison and the information developed from the field and laboratory studies as well as literature research, the Factors of Safety obtained are considered satisfactory for the Coal Combustion Waste (CCW) impoundment slope.

Analyses Summary		
Condition	**Required Factor of Safety**	**Computed Factor of Safety**
Steady State Seepage Under Maximum Pool (Deep Failure)	1.5	1.89
Steady State Seepage Under Maximum Pool (Shallow Failure)	1.5	1.58
Steady State Seepage Under Maximum Pool with Seismic Event	1.1	1.39

EXECUTIVE SUMMARY CONTINUED

Important geotechnical considerations for the project are summarized below. However, users of the information contained in the report must review the entire report for specific details pertinent to geotechnical design considerations.

GEOTECHNICAL ENGINEERING REPORT
JTEC SITE STRUCTURAL ASSESSMENT
COAL COMBUSTION WASTE IMPOUNDMENTS
SPRINGFIELD, MISSOURI

1.0 INTRODUCTION

This is the Report of the Geotechnical Investigation and subsequent slope stability analysis performed at the John Twitty Energy Center located at 5100 West Farm Road 164 in Springfield, Missouri. This investigation was conducted in accordance with a letter proposal dated January 21, 2014 and approved by Mr. Ted C. Salveter, P.E. representing City Utilities of Springfield. The work was performed under a Blanket Contract for Services between Palmerton & Parrish, Inc. and the City Utilities of Springfield. The purpose of this Geotechnical Investigation is to analyze the stability of waste impoundment slopes containing coal combustion waste (CCW). The approximate site location is shown in the aerial photograph below.

2.0 SCOPE OF SERVICES

Specific tasks completed by PPI include the following:

- Review of site documents provided by CU;
- Completion of a Subsurface Investigation program to investigate the condition of the coal ash impoundment levees. The Subsurface Investigation included completion of subsurface borings, collection of soil samples, installation of groundwater level piezometers, and completion of laboratory testing;
- Field reconnaissance by an Engineer from our staff to document the condition of the existing impoundment levees;
- Laboratory soil testing to determine soil classifications and soil strength parameters;
- Literature research to assist selection of soil strength parameters;
- Slope stability analysis of existing CCW impoundment levee slopes, including seismic analysis; and
- Evaluation of the liquefaction potential of the levee embankment soils, and underlying natural soils.

3.0 PROJECT & SITE DESCRIPTION

The John Twitty Energy Center is a coal fired power plant initially constructed in the early 1970s with a major upgrade to generating capacity in recent years. The major electrical generating facility is heavily developed with building foundations, two (2) emission stacks, cooling towers, overhead power lines, buried utilities and combustion coal waste impoundments. The earth embankments forming these CCW impoundments are the focus of this study. The impoundments have a maximum height on the order of 31 feet. Background information and history of these embankments is described in more detail in Sections 4.0 and 5.0 of this report.

4.0 PROJECT BACKGROUND INFORMATION

CDM Smith was one of several Engineering Consultants (Contractors) retained by the United States Environmental Protection Agency (EPA) to perform Site Structural Assessments of the structural stability and hydrologic / hydraulic safety of selected coal combustion waste (CCW) impoundments located across the United States. CDM Smith visited CU's John Twitty Energy Center (JTEC) on August 27 and 28, 2012, and completed a site reconnaissance and interviews with CU Staff. CDM Smith issued a Draft Report in July 2013.

CDM Smith's Draft Report is entitled "Assessment of Dam Safety of Coal Combustion Surface Impoundments – Draft Report; City Utilities of Springfield; John Twitty Energy Center; Springfield, Missouri". The Report is referred to as the "CDM Smith Draft Report" throughout this letter. The CDM Smith Draft Report discusses the two (2) CCW Impoundments at JTEC, identified as the West CCW Impoundment and the East CCW Impoundment.

Discussion throughout the CDM Smith Draft Report gives the impression that the structural stability, hydrologic / hydraulic safety, and operating procedures of the CCW Impoundments are generally adequate. The list below summarizes statements of that nature that are included in the CDM Smith Draft Report.

1. The CCW Impoundments have a "Low" Hazard Rating, based upon their total height, storage capacity, and the extent of downstream development.
2. The CCW Impoundment embankments were observed to be in overall good condition at the time of CDM Smith's Site Visit.
3. The CCW Impoundments appear to have adequate capacity with regard to hydrologic / hydraulic safety.
4. CU's Operating and Maintenance Procedures appear to be generally adequate.

However, the CDM Smith Draft Report ultimately rates the CCW Impoundments as POOR due to a lack of specific documentation of the structural stability, hydrologic and hydraulic safety, and operating and maintenance procedures. The CDM Smith Draft

Report outlines the need for documentation of several Studies, Operating and Maintenance Procedures, and Surveillance and Monitoring Plans before they will change the POOR rating.

5.0 SITE HISTORY

The CCW Impoundments were originally constructed in 1976. The Impoundments are identified as the West CCW Impoundment (approximately 3.89 acres) and the East CCW Impoundment (approximately 3.36 acres). Based upon information provided on the original Design Drawings and Supplemental Cross Sections prepared by Burns & McDonnell Engineering Company, Inc., the Impoundment embankments were originally constructed with controlled earth fill and 2 Horizontal to 1 Vertical (2H:1V) side slopes. A cutoff trench was constructed out of select fill material beneath the center of the embankments.

The exterior levees and water handling system remain basically unchanged from original construction. CU has added an interior dike in the approximate north-south center of both Impoundments. The dike allows for additional sedimentation and filtering before water reaches the downstream portion of the channel.

Flow through the Impoundments generally trends north to south. Bottom ash is transported to the Impoundments in slurry form via pipeline. Prior to reaching the Impoundments, the bottom ash slurry passes through a series of three (3) tiered concrete detention basins. A large portion of the bottom ash settles out, and is periodically dredged and stockpiled prior to eventual disposal at the JTEC Landfill.

The bottom ash slurry that reaches the Impoundments is retained in the northern portion of the Impoundment, north of the interior dikes added by CU. Additional bottom ash settles out in the northern portion of the Impoundments. CU periodically schedules maintenance of the Impoundments to remove the accumulated bottom ash, and reworks the clay bottom liner as necessary to maintain an approximate 2-foot thickness of well-compacted clay.

In addition to the bottom ash slurry, the Impoundments receive water from the cooling tower blowdown, boiler blowdown, Plant drain water, and storm water from the ponds' approximately 67 acre drainage area around the Plant. The East and West CCW Impoundments share a common Recycle Pump House and Outlet Structure located near the southern end of the interior embankment that divides the Impoundments. A large portion of the water that enters the Impoundments is recirculated back to the Power Plant for reuse as bottom ash sluice water. Water that is discharged downstream exits the Outlet Structure via a 24-inch diameter corrugated metal outlet pipe to a weir south of the Impoundments. The discharged water is tested and routed to eventual discharge under CU's NPDES Operating Permit MO-0089940.

Each impoundment has a high water outlet pipe near the top of the embankment, consisting of a 12-inch diameter corrugated metal pipe. The pipe invert elevations on the upstream, interior embankment slope are 1232.1 feet and 1232.4 feet for the West and East CCW Impoundments, respectively. Based upon information provided by CU, the water elevation in the Impoundments has never approached the high water outlet pipe invert elevation, and the pipes have never been utilized.

During normal operations, only one (1) of the CCW Impoundments is in service at any given time. The normal operating water elevation is maintained near the top elevation of the interior dikes, at approximate elevation 1227 feet. Only the West CCW Impoundment was in service on January 13, 2014 during PPI's Site Visit and completion of Anderson Engineering's topographic survey. The water elevation in the northern portion of the West CCW Impoundment was approximately 1227.3 feet, while the water elevation in the southern portion was a couple feet below normal pool elevation at approximate elevation 1223.7 feet.

The maximum embankment cross section occurs on the south side of the Impoundments. At its approximate lowest point, the top elevation of the embankment is 1235.3 feet. The embankment crest width is a minimum of approximately 10 feet, and more typically on the order of 12 to 15 feet. The maximum cross section height is approximately 31 feet, with a corresponding toe of slope elevation of 1204 feet.

6.0 ENGINEER'S SITE VISIT

An engineer from PPI's staff, Ms. Rachel Goeke, P.E., visited the JTEC CCW Impoundment Site with Mr. Ted Salveter, P.E., CU Environmental Affairs, on Monday, January 13, 2014. Mr. Salveter and Ms. Goeke walked and/or drove around the perimeter of the CCW Impoundments. Mr. Salveter described the typical operating procedures of the Impoundments. A survey crew from Anderson Engineering, Inc. (AE) was on-site at the same time, completing a current topographic survey of the CCW Impoundments and surrounding areas.

7.0 DOCUMENTS REVIEWED BY PPI

CU provided the documents listed below to PPI via email during the period from January 13, 2014 through January 16, 2014.

- CDM Smith; July 1, 2013; "Assessment of Dam Safety of Coal Combustion Surface Impoundments – Draft Report; City Utilities of Springfield; John Twitty Energy Center; Springfield, Missouri", prepared for the United States Environmental Protection Agency
- Burns & McDonnell Engineering Company, Inc.; July 10, 1974; "Sheet Y49, Rev. 2; Contract No. 343: Yard Structures; Ash Pond Grading Details"
- Burns & McDonnell Engineering Company, Inc.; July 10, 1974; "Sheet Y45, Rev. 4, Contract No. 343: Yard Structures; Area V Grading and Drainage Plan"
- Burns & McDonnell Engineering Company, Inc.; Excerpt from the Project Specifications: Contract No. 343: Division 2: Site Work
- Burns & McDonnell Engineering Company, Inc.; April 10, 1975; Letter Correspondence to Martin K. Eby Construction Company, Revised Design Cross Sections
- Anderson Engineering, Inc.; December 15, 2005, "City Utilities of Springfield, Ash Pond Topographic Survey, Southwest Power Station, Springfield, Missouri"
- Anderson Engineering, Inc.; December 9, 2011, Excerpts from "AEWO#70045-11: Ash Landfill Slope Stability and Engineering Analyses; John Twitty Energy Center, Springfield, MO"

- Anderson Engineering, Inc.; January 15, 2014; "City Utilities of Springfield, East and West Ash Pond Topographic Survey, JTEC, Springfield, Missouri"

In Addition, PPI reviewed the documents listed below during development of assumed soil strength parameters for use in slope stability analysis

- NAVFAC Design Manual 7.2 - Foundations and Earth Structures, SN 0525-LP-300-7071, REVALIDATED BY CHANGE 1 SEPTEMBER 1986
- Swiss Standard SN 670 010b, Characteristic Coefficients of Soils, Association of Swiss Road and Traffic Engineers
- Subsurface Exploration using the Standard Penetration Test and the Cone Penetrometer Test J.D. Rogers. 2006. The Geological Society of America. Environmental and Engineering Geoscience, Vol. XIII, No.2, pp. 161-179.

8.0 SUBSURFACE INVESTIGATION

Subsurface conditions were investigated through completion of subsurface borings, collection of soil samples during drilling, installation of groundwater level piezometers, and laboratory testing of collected soil samples.

8.1 Subsurface Borings

Subsurface conditions at this site were investigated by drilling a total of four (4) sample borings in the vicinity of the Coal Combustion Waste impound levees. The boings were drilled in two (2) sets of two (2) borings with one (1) at the slope crest and one (1) boring at the slope toe. Temporary piezometers were installed in all four (4) borings for the purpose of more accurately monitoring groundwater levels in the borings. Boring locations were selected and staked in the field by PPI using the January 15, 2014 topographic survey completed by Anderson Engineering and provided to PPI by CU. Approximate boring locations are shown on Figure 1: Boring Location Plan.

The Missouri One-Call System was notified prior to the investigation to assist in locating buried public utilities. PPI coordinated the field drilling schedule, as well as private utility locations with representatives of CU.

Borings were drilled on January 28 through January 31, 2014 using 4.5-inch O.D. continuous flight augers powered by a CME-75 truck-mounted drill rig. Soil samples were collected at 2.5 to 5-ft. centers during drilling. Soil sample types included split spoon samples collected while performing the Standard Penetration Test (SPT) in general accordance with ASTM D1586 and thin walled Shelby tubes pushed hydraulically in advance of drilling in accordance with ASTM D1587.

As discussed in greater detail later in this report, collection of good quality thin-walled Shelby tube samples was not possible in the embankment fill zone due to significant chert content. PPI remobilized to the site later and attempted to collect Shelby tube samples in certain zones adjacent to Boring 2A. Collected Shelby tube samples from the embankment fill were not viable for triaxial or direct shear testing, but were useful in determining soil classifications.

Logs of the borings showing descriptions of soil and rock units encountered, as well as results of field and laboratory tests are presented in Appendix I. Please refer to Appendix II for general notes regarding boring logs and additional soil sampling information.

8.2 Laboratory Testing

Collected samples were sealed and transported to the laboratory for further evaluation and visual examination. Laboratory soil testing included the following:

- Moisture Content (ASTM D2216);
- Direct Shear Tests (ASTM D3080);
- Particle Size Analysis (ASTM D422);
- Atterberg Limits (ASTM D4318);
- Pocket Penetrometers; and
- Torvane Shear Tests (ASTM D4648).

“High end” shear strength testing was performed on selected thin-walled Shelby tube samples for determination of shear strength parameters for use in slope stability analysis. Drained direct shear tests were performed on three (3) representative soil samples from the levee embankment foundation soils. Results of the direct shear tests are shown graphically in Appendix V.

As previously mentioned, procurement of undisturbed samples of embankment fill satisfactory for triaxial or direct shear laboratory strength testing was attempted, but could not be recovered due to high gravel content within embankment fill. To assist characterization of shear strength of these embankment soils, torvane shear strength tests were performed in the laboratory, and literature research was conducted for the soil types characterized in the embankment fill. Laboratory test results are shown on each boring log in Appendix I and are summarized in the following table.

Boring	**Depth (ft.)**	**Liquid Limit (LL)**	**Plastic Limit (PL)**	**Plasticity Index (PI)**	**Moisture Content (%)**	**USCS Symbol**	**Cohesion (psf) (eff)**	**Friction Angle (deg) (eff)**	**Dry Unit Wt. (pcf)**	***Torvane Cohesion (psf) (total)**
B-1A	29-30.5	83	38	45	56.3	CH	-	-	-	
B-1A	39-40.17	85	37	48	95.4	CH	133	17	51.6	
B-1A	43.3-44.8	-	-	-	49.9	CH	-	-	-	500
B-1B	0-1.5	-	-	-	19.2	CL	-	-	-	750
B-1B	5-6.33	86	30	56	49.1	CH	492	24	74.3	
B-1B	10-11.5	-	-	-	57.0	CH	-	-	-	1750
B-1B	18-20.08	-	-	-	67.2	CH	580	15	60.3	
B-1B	23.5-24.58	87	32	55	-	CH	424	18	67.1	
B-2A	9-10.5	-	-	-	35.9	GC	-	-	-	1700
B-2A	19.5-21.5	38	17	21	-	GC	-	-	-	1100
B-2A	39-40.5	-	-	-	46.5	CH	-	-	-	1200
B-2B	0-1.5	34	17	17	20.5	CL	-	-	-	
B-2B	8.5-9.25	74	35	39	38.0	CH	-	-	-	

*Torvane Shear was determined for multiple surfaces in each sample. The reported cohesion reported represents lowest value measured upon each specimen.

9.0 SITE GEOLOGY

The general site area is underlain at depth by the Mississippian Age Burlington Limestone Formation. This unit characteristically consists of coarse-grained gray limestone, which is nearly pure calcium carbonate. Isolated chert nodules and discontinuous chert layers are present throughout the formation. The upper surface of this limestone unit is generally irregular due to the effects of differential vertical weathering and solution activity. Limestone pinnacles, some of which are 10 to 15 feet high, are common in the general area. In upland areas, overburden soils are usually composed of red clay and chert and are residual having developed from physical and chemical weathering of the parent limestone. The chert fragments were interbedded with the limestone, but are much more resistant to weathering and retain rock-like properties. The contact between comparatively unweathered bedrock and the residual soils is usually abrupt.

The general site area is located within the Ozarks Physiographic Region of Missouri, which is characterized by rugged to rolling hill terrain, meandering streams and karst topography. Karst topography forms over areas of carbonate bedrock where groundwater has solutionally enlarged openings to form a subsurface drainage system. Springs, caves, losing streams and sinkholes are common in karst areas. Sinkholes are defined as a depression in the landscape with an internal drainage system. Although there are indications of a pinnacled limestone surface from the boring data, indications of sinkhole development were not observed along impoundment slopes.

10.0 GENERAL SITE & SUBSURFACE CONDITIONS

Based upon subsurface conditions encountered within the borings drilled at the project site, generalized subsurface conditions are summarized in the table below. Soil stratification lines on the boring logs indicate approximate boundary lines between different types of soil and rock units based upon observations made during drilling. In-situ transitions between soil and some rock types are typically gradual.

10.1 Generalized Subsurface Conditions

Description	Borings	Approx. Depth to Bottom of Stratum	Material Encountered	Moisture	Consistency/ Density
Stratum 1	B-1A & B-2A	28 to 32 ft.	Fill – Clayey Gravel, Lean Clay, Fat Clay w/Varying Amounts of Chert Sand & Gravel	Moist	Medium Dense to Dense, Very Stiff
Stratum 2	B-2B	5 ft.	Lean Clay w/Silt	Moist	Medium Stiff
Stratum 3	All	9.3 to 45 ft.	Fat Clay w/Varying Amounts of Chert Sand & Gravel	Moist to Wet	Medium Stiff to Stiff
Stratum 4	All	Boring Completion	Limestone	-	Moderately Hard

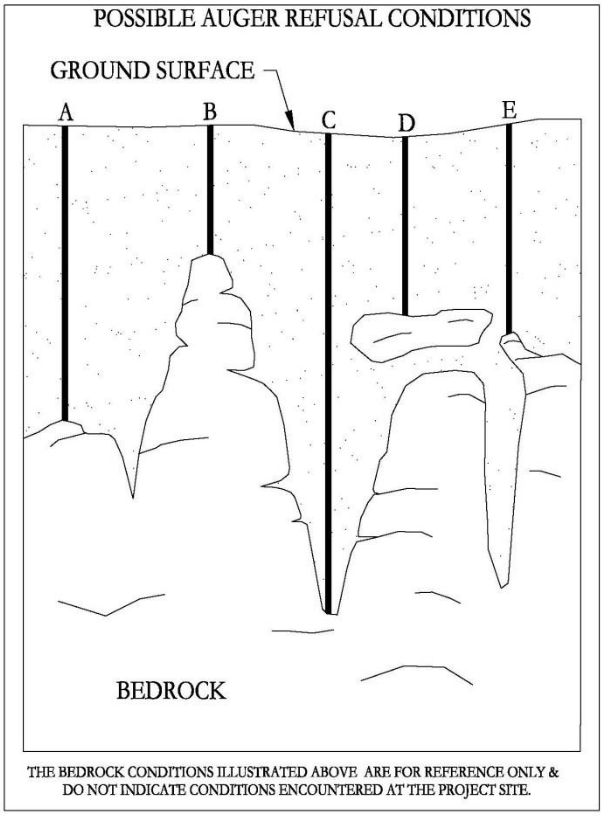
Three (3) general earth and bedrock material types were encountered in the borings. Existing fill was encountered within the embankments consisting primarily of dense to medium dense clayey gravel or stiff to medium stiff gravelly lean to fat clay. These soils classify as CL, CH, and GC in accordance with the Unified Soils Classification System (USCS). SPT N-values were 12 blows per foot or greater, but generally on the order of 15 to 30 or more blows per foot. Construction records documenting fill compaction were not available. Based upon drilling resistance and SPT values, the fill appears to be fairly well compacted.

Natural foundation soils below the fill material consist primarily of medium stiff to very stiff fat clay with variable quantities of chert, although medium stiff lean clay was encountered in Boring B-2B to a depth of 5 ft. Fat clay was found to be soft immediately above limestone in Boring B-1A, which is typical condition in the site area. SPT values recorded in the natural overburden soils were 7-blows per foot or greater, except within the soft clay.

Limestone bedrock was encountered in all borings drilled. Limestone was encountered at depths of 44.8 and 45.5 in Borings B-1A and B-2A drilled from the crest of the slope. In Borings B-1B and B-2B, several feet from the toe of slope limestone was found at depths of 24.7 and 9.3 ft. respectively. The sometimes erratic depth to bedrock is typical of the Burlington Limestone Formation which can have a pinnacled top of rock surface.

10.2 Auger Refusal

Auger refusal is defined as the depth below the ground surface at which a boring can no longer be advanced with the soil drilling technique being used. Auger refusal is subjective and is based upon the type of drilling equipment and types of augers being used, as well as the effort exerted by the driller. Several different auger refusal conditions are possible in the general site area. These conditions are represented graphically in the adjacent figure: (A) on the upper surface of continuous bedrock, (B) on rock “pinnacles”, (C) in widened joints that may extend well below the surrounding bedrock surface, (D) slabs of unweathered rock suspended in the residual soil matrix, or “floaters”, or (E) on the upper surface of discontinuous bedrock.



THE BEDROCK CONDITIONS ILLUSTRATED ABOVE ARE FOR REFERENCE ONLY & DO NOT INDICATE CONDITIONS ENCOUNTERED AT THE PROJECT SITE.

11.0 GROUNDWATER

Groundwater was observed in Boring 2A at depth of 34 ft. below the existing ground surface on the date drilled. After drilling completion Piezometers were installed in all four (4) boreholes with a 5 foot length of 2-inch diameter PVC screen at the bottom of boring. The borehole was then backfilled with sand to 4 ft. below the surface. PPI plans to close the Piezometers by drilling them and grouting full depth via tremie. Results of groundwater monitoring are summarized in the table below.

11.1 Generalized Groundwater Conditions

Monitoring Well	Sample Date	Water Level	Sample Date	Water Level	Notes
B-1B	2/19/14	Dry	3/4/14	Dry	Riser 2.8 ft. above ground
B-1A	2/19/14	Dry	3/4/14	Dry	Riser 0.4 ft. below ground
B-2A	2/19/14	41.0 ft.	3/4/14	41.1 ft.	Riser 3.0 ft. above ground
B-2B	2/19/14	Dry	3/4/14	Dry	Riser 0.3 ft. below ground

12.0 SLOPE STABILITY ANALYSIS

PPI completed slope stability analysis on the approximate maximum cross section which occurs on the south side of the East CCW Impoundment. PPI Utilized the topographic survey data collected by Anderson Engineering during the week of January 13, 2014 to determine the cross section geometry. Assumptions regarding the approximate bottom elevation of the East CCW Impoundment were made using data from the original Design Drawings. The tallest slope of the East CCW Impoundment was used in this analysis since the slope height is appreciably greater than the slopes of the West CCW Impoundment and soil types and strengths do not vary appreciably.

Soil stratigraphy was assumed based upon information shown on the original Design Drawings, as well as data provided by the boring logs from the subsurface investigation. For the purposes of the analysis, only maximum pool, steady sate seepage conditions were analyzed. The water level on the embankment interior was assumed at elevation 1232.4 ft. Soil Strength parameters were assumed from data collected using effective stress conditions for steady state seepage conditions and total stress conditions for seismic analysis.

Effective soil strength parameters for natural foundation soils used in the slope stability analysis were based upon the results of laboratory direct shear testing upon natural foundation soils. Total strength (undrained) parameters for natural foundation soils were based upon the results of Torvane Cohesion Testing and assuming $\Phi = 0$ conditions. As previously mentioned, torvane cohesion was determined upon multiple surfaces for each sample. The more conservative torvane cohesion determined was reported and used in this analysis.

For embankment fill containing high gravel content, strength parameters were selected based upon classification testing (particle size distribution and plasticity), torvane cohesion testing, and the results of Standard Penetration Tests (SPT values used only as an indication of strength and density), as well as the following documents. Strength parameters were selected by literature research using conservative assumptions plus the more conservative torvane cohesion values for each sample were used for this analysis.

- Subsurface Exploration using the Standard Penetration Test and the Cone Penetrometer Test J.D. Rogers. 2006. The Geological Society of America. Environmental and Engineering Geoscience, Vol. XIII, No.2, pp. 161-179
- NAVFAC Design Manual 7.2 - Foundations and Earth Structures, SN 0525-LP-300-7071, REVALIDATED BY CHANGE 1 SEPTEMBER 1986
- Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers

The following table summarizes soil parameters utilized in the slope stability analysis.

Natural Foundation Soils – Table 1

Sample	Depth (ft.)	Description	Direct Shear Test Results (3 Point)			W (%)	Atterberg Limits		Torvane Testing	
			C_{eff} (psf)	Φ_{eff}	γ_d		LL	PI	C_{total} (psf)	ϕ_{total}
B-1B	0-1.5	Lean Clay	-	-	-	19.2	-	-	750	0
B-1B	5 to 6.3	Fat Clay	492	24	74.3	49.1	86	30	-	-
B-1B	10-11.5	Fat Clay	-	-	-	57.0	-	-	1750	0
B-1B	18.8 to 20	Fat Clay	580	15	60.3	67.2	-	-	-	-
B-1B	24-24.7	Fat Clay	424	18	67.1	-	87	55	-	-
B-1A	39 to 40	Fat Clay	133	17	51.6	95.4	85	37	-	-
B-1A	43.3-44.8	Fat Clay	-	-	-	49.9	-	-	500	0
B-2A	39-40.5	Fat Clay	-	-	-	46.5	-	-	1200	0

Embankment Fill – Table 2

Sample	Depth (ft.)	Description	Direct Shear Test Results (3 Point)			W (%)	Atterberg Limits		% - No. 200 Sieve	Torvane Test	
			*C_{eff} (psf)	*Φ_{eff}	γ_d		LL	PI		C_{total} (psf)	ϕ_{total}
B-1A	5 to 6.5	Clayey Gravel w/Sand	-	-	-	19.7	-	-	34.5	-	-
B-2A	4 to 5.5	Clayey Gravel w/Sand	-	-	-	18.9	-	-	36.3	-	-
B-2A	9-10.5	Clayey Gravel w/Sand	-	-	-	35.9	-	-	-	1700	0
B-2A	14 to 15	Clayey Gravel w/Sand	-	-	-	-	-	-	37.7	-	-
B-2A	19.5 to 21.5	Gravelly Lean Clay	-	-	-	18.8	38	17	68.0	1100	0

*Based upon classification tests and literature research, use C_{eff} = 100 psf and Φ_{eff} = 28°

Slope Stability Analysis Values – Table 3

Stratum	Effective Stress			Total Stress		
	Unit Weight (pcf)	Cohesion (psf)	ϕ_{eff}	Unit Weight (pcf)	Cohesion (psf)	ϕ_{total}
Earth Fill	120	100	28	120	1100	0
Residual Soil – A	115	500	24	115	750	0
Residual Soil – B	100	600	15	100	1750	0
Residual Soil – C	100	150	17	100	500	0
Limestone	140	5000	45	140	5000	45

Slope stability analysis was performed using the computer program Slope/W, part of the GeoStudio 2012 software package. Spencer's method was selected as the finite difference analysis method, since it achieves both moment and force equilibrium. The grid and radius method was utilized to search for the critical slope failure surface.

The project site is located in an area of low seismicity. The project site lies within Seismic Zone 1 according to the Uniform Building Code map, which is presented as Appendix C within the USACE ER 1110-2-1806 Engineering and Design: Earthquake Design and Evaluation for Civil Works Projects.

Probabilistic seismic hazard analysis (PSHA) was utilized to evaluate earthquake design accelerations at the project site in accordance with guidance provided in ER 1110-2-1806. The PSHA was performed using the 2008 Interactive Deaggregation Program available on the United States Geological Survey (USGS) Earthquake Hazards Mapping Website (http://earthquake.usgs.gov/).

A 2,475-year return period earthquake event (2% Probability of Exceedance in 50-years) is commonly accepted as the Design Earthquake Event for seismic slope stability analysis.

Graphical output from the PSHA run is included in Appendix IV. Resultant peak horizontal ground acceleration (pga) data from PSHA run is summarized in the following table.

Summary of PSHA Runs – Table 4

Earthquake Return Period	Peak Horizontal Ground Acceleration (pga) for BC Rock
2,475-year (2% PE in 50 years)	0.08132g

The required minimum Factor of Safety for steady state seepage and seismic conditions required by various United States Army Corps of Engineers, Federal Emergency Management Association, and Missouri Department of Natural Resources guidelines is 1.5 and 1.1 respectively. PPI completed two (2) different slope stability analysis runs, using data collected during drilling as well as subsequent laboratory testing. Results of the analyses are summarized below in Table 3. Copies of the slope stability analysis output are included in Appendix II.

Analyses Summary – Table 5

Condition	Required Factor of Safety	Computed Factor of Safety
Steady State Seepage Under Maximum Pool (Deep Failure)	1.5	1.89
Steady State Seepage Under Maximum Pool (Shallow Failure)	1.5	1.58
Steady State Seepage Under Maximum Pool with Seismic Event	1.1	1.39

13.0 LIQUEFACTION ANALYSIS

PPI reviewed the subsurface conditions encountered at the project site with regard to their susceptibility to liquefaction during a large earthquake event.

The levee embankment foundation soils should not be susceptible to liquefaction based upon their Unified Soil Classification System (USCS) classification and in situ density. Foundation soils typically consist of medium stiff to stiff lean clay and fat clay with gravel (CL and CH); dense to very dense clayey gravel (GC); or dense to very dense gravel with clay (GC).

The sub-sections below discuss the technical references used for review of liquefaction potential, and PPI's evaluation of liquefaction potential of the embankment foundation soils and impounded CCW.

13.1 Liquefaction Reference Documents

The EM 1110-2-1902 Engineering and Design: Slope Stability discusses liquefaction and emphasizes the importance of evaluating the liquefaction potential of foundation soils. The EM 1110-2-1902 provides the following summary restated below regarding liquefaction (pg. 1-6).

> "d. *Liquefaction.* The phenomenon of soil liquefaction, or significant reduction in soil strength and stiffness as a result of shear-induced increase in pore water pressure, is a major cause of earthquake damage to embankments and slopes. Most instances of liquefaction have been associated with saturated loose sandy or silty soils. Loose gravelly soil deposits are also vulnerable to liquefaction…. Cohesive soils with more than 20 percent of particles finer than 0.005 mm, or with liquid limit (LL) of 34 or greater, or with the plasticity index (PI) of 14 or greater are generally considered not susceptible to liquefaction."

The technical paper "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils" (Youd & Idriss, et al, 2001) gives the following definition of liquefaction:

> "Liquefaction is defined as the transformation of a granular material from a solid to a liquefied state as a consequence of increased pore-water pressure and reduced effective stress (Marcuson 1978). Increased pore-water pressure is induced by the tendency of granular materials to compact when subjected to cyclic shear deformations. The change of state occurs most readily in loose to moderately dense granular soils with poor drainage, such as silty sands or sands and gravels capped by or containing seams of impermeable sediment."

The levee embankment foundation soils should not be susceptible to liquefaction based upon their Unified Soil Classification System (USCS) classification and in situ density. Foundation soils typically consist of medium stiff to stiff lean clay and fat clay with gravel (CL and CH); dense to very dense clayey gravel (GC); or dense to very dense gravel with clay (GC).

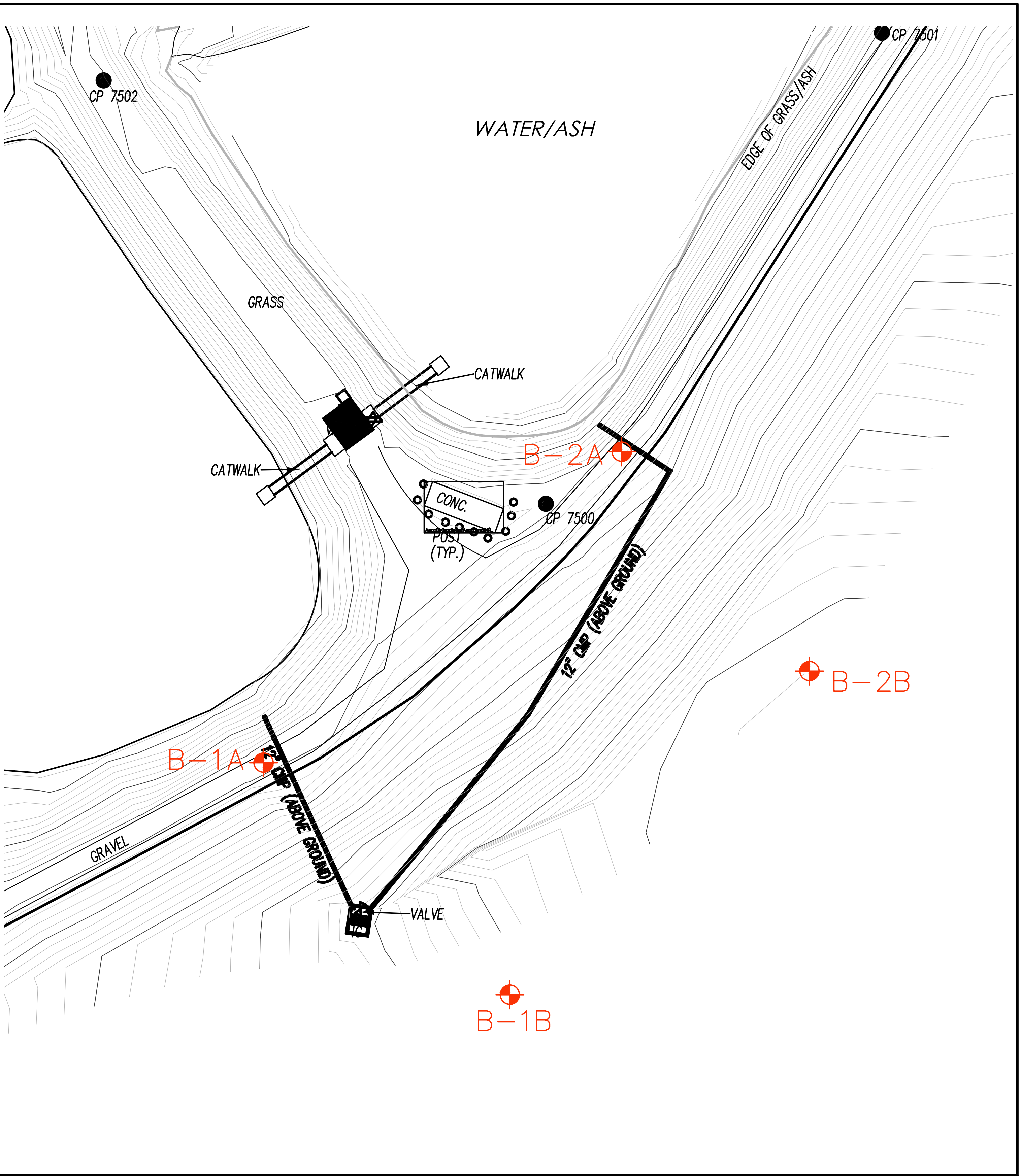
14.0 CONCLUSIONS & RECOMMENDATIONS

From the results of the slope stability analyses and the minimum Factor of Safety required by the various United States Army Corps of Engineers, Federal Emergency Management Association, and Missouri Department of Natural Resources guidelines stated in Section 12.0, it is our opinion that the JTEC Coal Combustion Waste Impoundment site conforms with the minimum requirements for global slope stability. It is recommended that C.U. continue to perform periodic inspections of the impoundment embankments. Any change in profile, tension cracks, bulging, etc., should be reported immediately to the Geotechnical Engineer for evaluation. Large rooted vegetation should be prevented from growing in the earthen embankments. Embankments should be inspected for animal bore holes and repaired as necessary.

15.0 REPORT LIMITATIONS

This Report has been prepared in accordance with generally accepted practices of other consultants undertaking similar studies at the same time and in the same geographical area. PPI observed that degree of care and skill generally exercised by other consultants under similar circumstances and conditions. Palmerton & Parrish's findings and conclusions must be considered not as scientific certainties, but as opinions based on our professional judgment concerning the significance of the data gathered during the course of this investigation. Other than this, no warranty is implied or intended.

FIGURE



LEGEND

⊕ BORING LOCATION

SCALE
1"=50'

Project: JTEC Site Structural Assessment
Client: City Utilities of Springfield

Boring Location Plan

DATE: March 6, 2014
Project Number: 219892

PALMERTON & PARRISH, INC.
GEOTECHNICAL AND MATERIALS ENGINEERS/MATERIALS TESTING LABORATORIES/ENVIRONMENTAL SERVICES

FIGURE 1

APPENDIX I

BORING LOGS

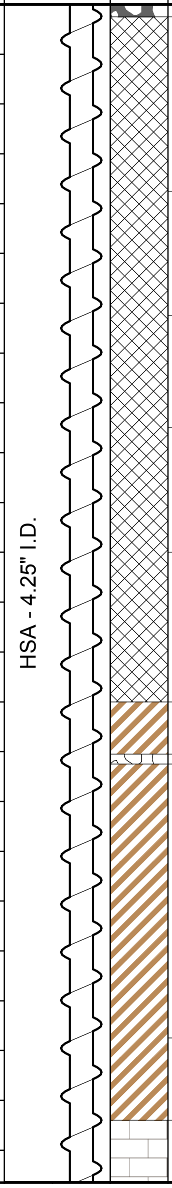
4168 W. Kearney St.
Springfield, Missouri 65803
Telephone: (417) 864-6000
Fax: (417) 864-6004

GEOTECHNICAL BORING LOG

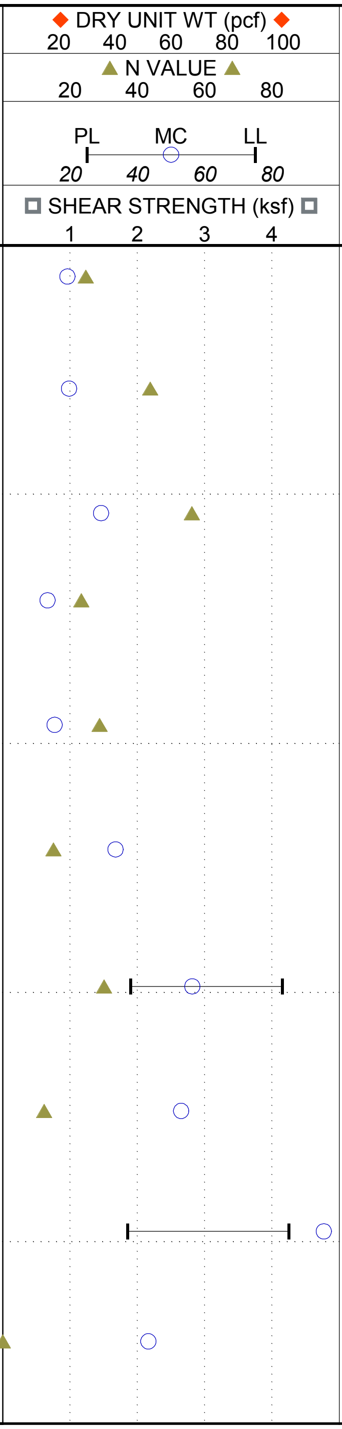
BORING NUMBER **B-1A**

PAGE 1 OF 1

CLIENT City Utilities
PROJECT NAME JTEC CCW Impoundments - SSA
PROJECT NO. 219892
PROJECT LOCATION Springfield, Missouri
DATE STARTED 1/28/14 **COMPLETED** 1/29/14
SURFACE ELEVATION
BENCHMARK EL.
DRILLER RD **DRILL RIG** CME 75
GROUND WATER LEVELS
HAMMER TYPE Auto
AT TIME OF DRILLING None
LOGGED BY CC **CHECKED BY** RG
AT END OF DRILLING
NOTES Installed Piezometer in borehole. 5-ft. of 2-inch PVC screen. Sand to 4-ft. below the surface.



DEPTH (ft)	MATERIAL DESCRIPTION Unified Soil Classification System	SAMPLE TYPE NUMBER	RECOVERY % (RQD %)	CORRECTED BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	ELEVATION (ft)
0.5 ft	BASE ROCK					
7.5 ft	FILL - CLAYEY GRAVEL with Silt and Sand, Brown Red, Medium Dense to Dense, Moist (GC)	SPT 1 SPT 2		16-12-12 (24) 49-21-23 (44)		
12.5 ft	FILL - CLAYEY GRAVEL with Sand, Red, Dense, Moist (GC)	SPT 3		7-25-32 (57)		
17.0 ft	FILL - CHERT GRAVEL and Cobbles with Sand and Brown Clay, White, Medium Dense, Moist (GP)	SPT 4		22-10-14 (24)		
22.0 ft	FILL - GRAVELLY LEAN CLAY, Brown, Very Stiff, Moist (CL)	SPT 5		16-15-14 (29)		
28.0 ft	FILL - FAT CLAY with Scattered Chert Sand and Gravel, Red Brown to Red, Very Stiff, Moist (CH)	SPT 6		7-8-7 (15)		
30.1 ft	FAT CLAY with Trace Chert Sand & Gravel, Red, Very Stiff, Moist (CH)	SPT 7		3-16-14 (30)		
30.5 ft	CHERT, White, Hard (GP)					
41.5 ft	FAT CLAY with Scatterd Chert Sand and Gravel, Red, Stiff, Moist (CH) Weathered Limestone in Tip of Split Spoon	SPT 8 ST 9	 100	1-7-5 (12)		
44.8 ft	FAT CLAY with Weathered Limeston, Red, Soft, Wet (CH)	SPT 10		0-0-0 (0)		
47.3 ft	LIMESTONE, Hard					



Refusal at 47.3 feet.
Bottom of borehole at 47.3 feet.

4168 W. Kearney St.
Springfield, Missouri 65803
Telephone: (417) 864-6000
Fax: (417) 864-6004

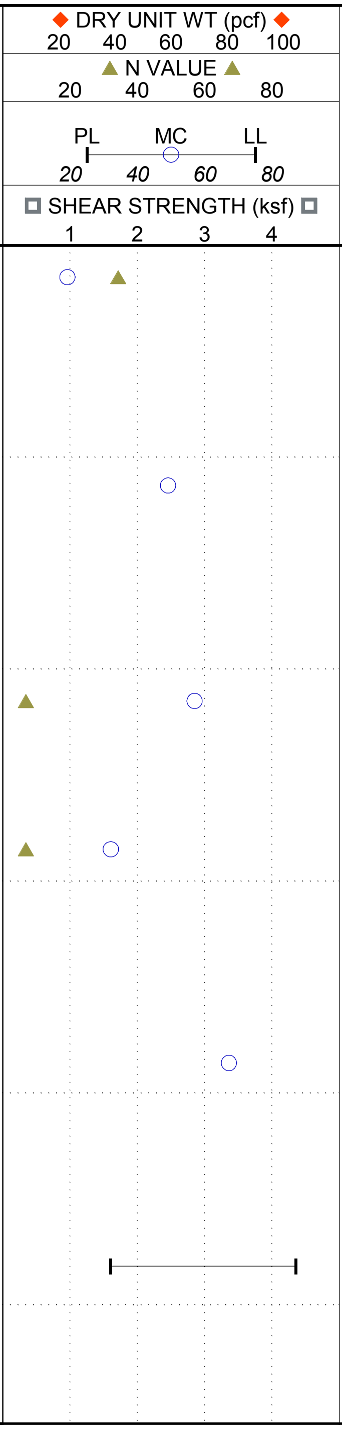
GEOTECHNICAL BORING LOG

BORING NUMBER B-1B

PAGE 1 OF 1

CLIENT City Utilities
PROJECT NAME JTEC CCW Impoundments - SSA
PROJECT NO. 219892
PROJECT LOCATION Springfield, Missouri
DATE STARTED 1/27/14 **COMPLETED** 1/28/14
SURFACE ELEVATION **BENCHMARK EL.**
DRILLER RD **DRILL RIG** CME 75
GROUND WATER LEVELS
HAMMER TYPE Auto
AT TIME OF DRILLING 0 ft
LOGGED BY CC **CHECKED BY** RG
AT END OF DRILLING
NOTES Piezometer installed at boring completion. 5-ft. of 2-inch PVC screen. Sand to 4-ft. below the surface.

DEPTH (ft)	DRILLING METHOD	MATERIAL DESCRIPTION Unified Soil Classification System	SAMPLE TYPE NUMBER	RECOVERY % (RQD %)	CORRECTED BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	ELEVATION (ft)
0	HSA - 4.25" I.D.	▽ FAT CLAY with Chert Gravel and Sand, Red Brown to Red, Very Stiff to Stiff, Moist, Grass Covered (CH)	SPT 1		7-14-21 (35)		
5		6.3 ft	ST 2	100			
		FAT CLAY with Scattered Chert Gravel and Sand, Red, Medium Stiff, Moist (CH)					
10			SPT 3		4-3-4 (7)		
		12.5 ft					
		FAT CLAY with Chert Gravel and Sand, Red, Medium Stiff, Moist (CH)					
15			SPT 4		7-4-3 (7)		
		16.5 ft					
		FAT CLAY with Scattered Chert Gravel and Sand, Red, Medium Stiff, Moist (CH)					
20			ST 5	100			
		23.5 ft					
		FAT CLAY, Red, Medium Stiff, Moist, Weathered limestone in Tip of Split Spoon (CH) 24.7 ft	ST 6	100			
25		LIMESTONE, Weathered					
		27.5 ft					
		27.8 ft					
		LIMESTONE, Hard					



Refusal at 27.8 feet.
Bottom of borehole at 27.8 feet.

PPI
4168 W. Kearney St.
Springfield, Missouri 65803
Telephone: (417) 864-6000
Fax: (417) 864-6004

GEOTECHNICAL BORING LOG

BORING NUMBER B-2A

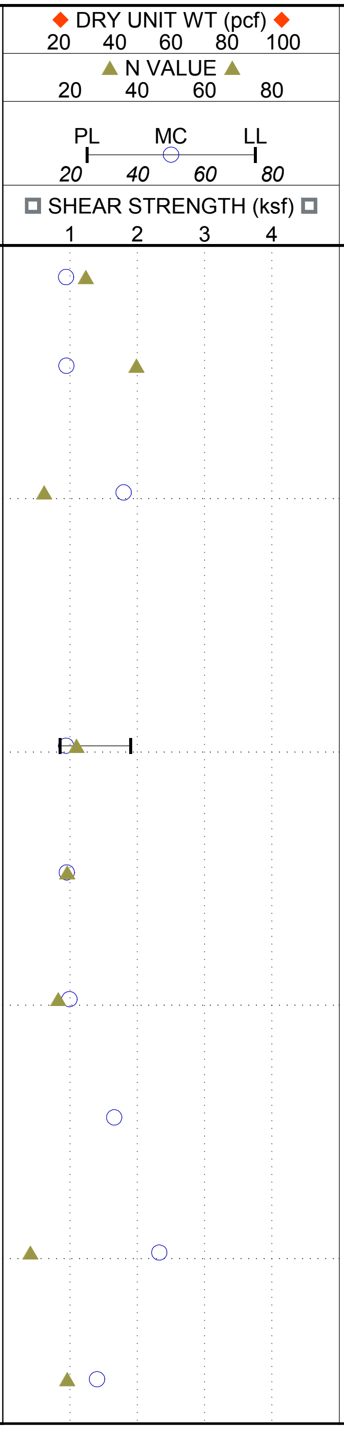
PAGE 1 OF 1

CLIENT City Utilities
PROJECT NAME JTEC CCW Impoundments - SSA
PROJECT NO. 219892
PROJECT LOCATION Springfield, Missouri
DATE STARTED 1/30/14 **COMPLETED** 1/31/14
SURFACE ELEVATION **BENCHMARK EL.**
DRILLER RD **DRILL RIG** CME 75
GROUND WATER LEVELS
HAMMER TYPE Auto
AT TIME OF DRILLING 34 ft
LOGGED BY CC **CHECKED BY** RG
AT END OF DRILLING
NOTES Piezometer installed at boring completion. 5-ft. of 2-inch PVC screen. Sand to 4-ft. below the surface.

DRILLING METHOD: HSA - 4.25" I.D.

DEPTH (ft)	MATERIAL DESCRIPTION Unified Soil Classification System	SAMPLE TYPE NUMBER	RECOVERY % (RQD %)	CORRECTED BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)
0	BASE ROCK (to 1.1 ft)				
	FILL - CLAYEY GRAVEL with Sand, Red Brown, Medium Dense to Dense, Moist (GC)	SPT 1		12-10-15 (25)	
		SPT 2		18-18-22 (40)	
	9.0 ft				
10	FILL - CLAYEY GRAVEL with Sand, Red, Dense, Moist (GC)	SPT 3		4-5-7 (12)	
		ST 4	42		
	17.0 ft				
20	FILL - GRAVELLY LEAN CLAY, Red Brown to Brown, Stiff, Moist (CL)	SPT 5		8-10-12 (22)	
		SPT 6		8-8-11 (19)	
30		SPT 7		8-11-5 (16)	
	32.0 ft				
	▽ FAT CLAY with Abundant Chert Gravel and Sand, Red, Stiff to Medium Stiff, Wet (CH)	ST 8	100		
40		SPT 9		4-3-5 (8)	
	45.5 ft	SPT 10		10-8-11 (19)	
	LIMESTONE, Weathered (to 46.5 ft)				
	LIMESTONE, Hard				

Refusal at 46.5 feet.
Bottom of borehole at 46.5 feet.



ELEVATION (ft)

4168 W. Kearney St.
Springfield, Missouri 65803
Telephone: (417) 864-6000
Fax: (417) 864-6004

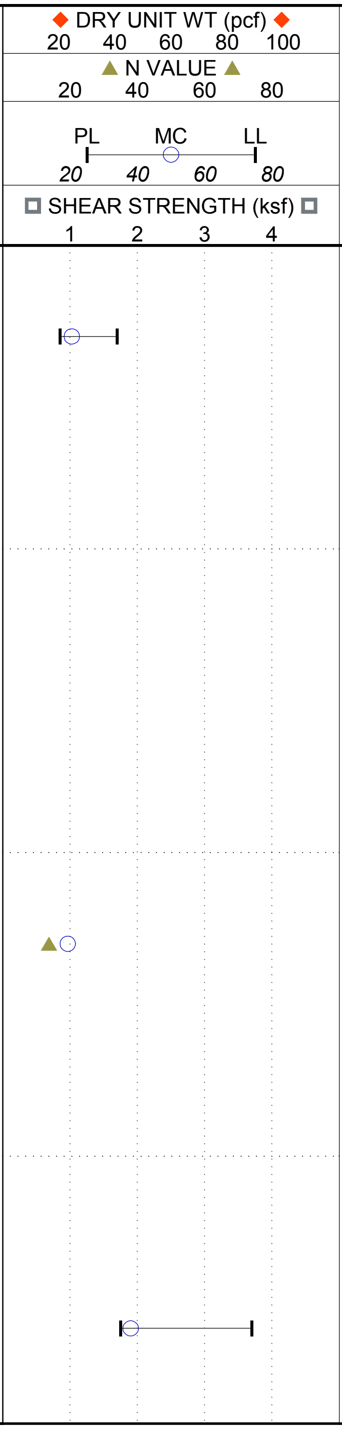
GEOTECHNICAL BORING LOG

BORING NUMBER B-2B

PAGE 1 OF 1

CLIENT City Utilities
PROJECT NAME JTEC CCW Impoundments - SSA
PROJECT NO. 219892
PROJECT LOCATION Springfield, Missouri
DATE STARTED 1/30/14 **COMPLETED** 1/31/14
SURFACE ELEVATION **BENCHMARK EL.**
DRILLER RD **DRILL RIG** CME 75
GROUND WATER LEVELS
HAMMER TYPE Auto
AT TIME OF DRILLING 0 ft
LOGGED BY CC **CHECKED BY** RG
AT END OF DRILLING
NOTES Piezometer installed at boring completion. 5-ft. of 2-inch PVC screen. Sand to 4-ft. below the surface.

DEPTH (ft)	DRILLING METHOD	STRATA SYMBOL	MATERIAL DESCRIPTION Unified Soil Classification System	SAMPLE TYPE NUMBER	RECOVERY % (RQD %)	CORRECTED BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	ELEVATION (ft)
0.0 2.5	HSA - 4.25" I.D.	▨	▽ LEAN CLAY with Silt, Brown, Medium Stiff, Moist, Grass Covered (CL) 5.0 ft	ST 1	67			
5.0 7.5		▨	FAT CLAY with Chert Gravel and Sand, Red, Stiff, Moist (CH) 8.5 ft	SPT 2		5-8-5 (13)		
		▨	FAT CLAY, Red Brown, Medium Stiff, Moist, Weathered Limestone in Tip of Split Spoon (CH) 9.3 ft	ST 3	100			
		▦	LIMESTONE, Weathered 9.7 ft					



LIMESTONE, Hard
Refusal at 9.7 feet.
Bottom of borehole at 9.7 feet.

APPENDIX II

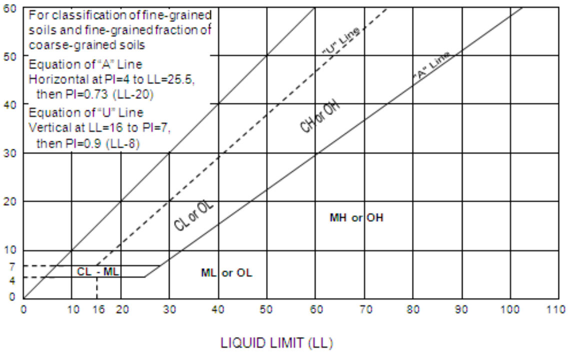
GENERAL NOTES

GENERAL NOTES

SOIL PROPERTIES & DESCRIPTIONS

COHESIVE SOILS

Consistency	Unconfined Compressive Strength (Qu)	Pocket Penetrometer Strength	N-Value
	(psf)	(tsf)	(blows/ft)
Very Soft	<500	<0.25	0-1
Soft	500-1000	0.25-0.50	2-4
Medium Stiff	1001-2000	0.50-1.00	5-8
Stiff	2001-4000	1.00-2.00	9-15
Very Stiff	4001-8000	2.00-4.00	16-30
Hard	>8000	>4.00	31-60
Very Hard			>60



Group Symbol	Group Name
CL –	Lean Clay
ML –	Silt
OL –	Organic Clay or Silt
CH –	Fat Clay
MH –	Elastic Silt
OH –	Organic Clay or Silt
PT –	Peat
CL-CH –	Lean to Fat Clay

Plasticity		Moisture	
Description	Liquid Limit (LL)	Descriptive Term	Guide
Lean	<45%	Dry	No indication of water
Lean to Fat	45-49%	Moist	Indication of water
Fat	≥50%	Wet	Visible water

Fine Grained Soil Subclassification	Percent (by weight) of Total Sample
Terms: SILT, LEAN CLAY, FAT CLAY, ELASTIC SILT	PRIMARY CONSTITUENT
Sandy,gravelly, abundant cobbles, abundant boulders	>30-50]
with sand, with gravel, with cobbles, with boulders	>15-30] – secondary coarse grained constituents
scattered sand, scattered gravel, scattered cobbles, scattered boulders	5-15]
a trace sand, a trace gravel, a few cobbles, a few boulders	<5]
The relationship of clay and silt constituents is based on plasticity and normally determined by performing index tests. Refined classifications are based on Atterberg Limits tests and the Plasticity Chart.	

NON-COHESIVE (GRANULAR) SOILS

RELATIVE DENSITY	N-VALUE
Very Loose	0-4
Loose	5-10
Medium Dense	11-24
Dense	25-50
Very Dense	≥51

MOISTURE CONDITION	
Descriptive Term	Guide
Dry	No indication of water
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table.

**GRAIN SIZE IDENTIFICATION		
Name	Size Limits	Familiar Example
Boulder	12 in. or more	Larger than basketball
Cobbles	3 in. to 12 in.	Grapefruit
Coarse Gravel	¾-in. to 3 in.	Orange or lemon
Fine Gravel	No. 4 sieve to ¾-in.	Grape or pea
Coarse Sand	No. 10 sieve to No. 4 sieve	Rock salt
Medium Sand	No. 40 sieve to No. 10 sieve	Sugar, table salt
Fine Sand*	No. 200 sieve to No. 40 sieve	Powdered sugar
Fines	Less than No. 200 sieve	
*Particles finer than fine sand cannot be discerned with the naked eye at a distance of 8 in.		

Coarse Grained Soil Subclassification	Percent (by weight) of Total Sample
Terms: GRAVEL, SAND, COBBLES, BOULDERS	PRIMARY CONSTITUENT
Sandy,gravelly, abundant cobbles, abundant boulders	>30-50]
with gravel, with sand, with cobbles, with boulders	>15-30] – secondary coarse grained constituents
scattered gravel, scattered sand, scattered cobbles, scattered boulders	5-15]
a trace gravel, a trace sand, a few cobbles, a few boulders	<5]
Silty (MH & ML)*, clayey (CL & CH)*	<15]
(with silt, with clay)*	5-15] – secondary fine grained constituents
(trace silt, trace clay)*	<5]
*Index tests and/or plasticity tests are performed to determine whether the term "silt" or "clay" is used.	

*Modified after Ref. ASTM D2487-93 & D2488-93
**Modified after Ref. Oregon DOT 1987 & FHWA 1997
***Modified after Ref. AASHTO 1988, DM 7.1 1982, and Oregon DOT 1987

PALMERTON & PARRISH, INC.

GENERAL NOTES

BEDROCK PROPERTIES & DESCRIPTIONS

ROCK QUALITY DESIGNATION (RQD)	
Description of Rock Quality	*RQD (%)
Very Poor	< 25
Poor	25-50
Fair	50-75
Good	75-90
Excellent	90-100

*RQD is defined as the total length of sound core pieces 4 in. or greater in length, expressed as a percentage of the total length cored. RQD provides an indication of the integrity of the rock mass and relative extent of seams and bedding planes.

SCALE OF RELATIVE ROCK HARDNESS		
Term	Field Identification	Approx. Unconfined Compressive Strength (tsf)
Extremely Soft	Can be indented by thumbnail	2.6-10
Very Soft	Can be peeled by pocket knife	10-50
Soft	Can be peeled with difficulty by pocket knife	50-260
Medium Hard	Can be grooved 2 mm deep by firm pressure of knife	260-520
Moderately Hard	Requires one hammer blow to fracture	520-1040
Hard	Can be scratched with knife or pick only with difficulty	1040-2610
Very Hard	Cannot be scratched by knife or sharp pick	>2610

DEGREE OF WEATHERING	
Slightly Weathered	Rock generally fresh, joints stained and discoloration extends into rock up to 25mm (1 in), open joints may contain clay, core rings under hammer impact.
Weathered	Rock mass is decomposed 50% or less, significant portions of rock show discoloration and weathering effects, cores cannot be broken by hand or scraped by knife.
Highly Weathered	Rock mass is more than 50% decomposed, complete discoloration of rock fabric, core may be extremely broken and gives clunk sound when struck by hammer, may be shaved with a knife.

GRAIN SIZE (TYPICALLY FOR SEDIMENTARY ROCKS)		
Description	Diameter (mm)	Field Identification
Very Coarse Grained	>4.76	
Coarse Grained	2.0-4.76	Individual grains can easily be distinguished by eye.
Medium Grained	0.42-2.0	Individual grains can be distinguished by eye.
Fine Grained	0.074-0.42	Individual grains can be distinguished by eye with difficulty.
Very Fine Grained	<0.074	Individual grains cannot be distinguished by unaided eye.

VOIDS	
Pit	Voids barely seen with naked eye to 6mm (¼-in)
Vug	Voids 6 to 50mm (¼ to 2 in) in diameter
Cavity	50 to 6000mm (2 to 24 in) in diameter
Cave	>600mm

BEDDING THICKNESS	
Very Thick Bedded	> 3’ thick
Thick Bedded	1’ to 3’ thick
Medium Bedded	4” to 1’ thick
Thin Bedded	1¼” to 4” thick
Very Thin Bedded	½” to 1¼” thick
Thickly Laminated	⅛” to ½” thick
Thinly Laminated	⅛” or less (paper thin)

DRILLING NOTES

Drilling and Sampling Symbols

NQ – Rock Core (2-in. diameter)
HQ – Rock Core (3 in. diameter)
HSA – Hollow Stem Auger

CFA – Continuous Flight (Solid Stem) Auger
SS – Split Spoon Sampler
ST – Shelby Tube

WB – Wash Bore or Mud Rotary
TP – Test-Pit
HA – Hand Auger

Soil Sample Types

Shelby Tube Samples: Relatively undisturbed soil samples were obtained from the borings using thin wall (Shelby) tube samplers pushed hydraulically into the soil in advance of drilling. This sampling, which is considered to be undisturbed, was performed in accordance with the requirements of ASTM D 1587. This type of sample is considered best for the testing of "in-situ" soil properties such as natural density and strength characteristics. The use of this sampling method is basically restricted to soil containing little to no chert fragments and to softer shale deposits.

Split Spoon Samples: The Standard Penetration Test is conducted in conjunction with the split-barrel sampling procedure. The “N” value corresponds to the number of blows required to drive the last 1 foot of an 18-in. long, 2-in. O.D. split-barrel sampler with a 140 lb. hammer falling a distance of 30 in. The Standard Penetration Test is carried out according to ASTM D-1586.

Water Level Measurements

Water levels indicated on the boring logs are levels measured in the borings at the times indicated. In permeable materials, the indicated levels may reflect the location of groundwater. In low permeability soils, shallow groundwater may indicate a perched condition. Caution is merited when interpreting short-term water level readings from open bore holes. Accurate water levels are best determined from piezometers.

Automatic Hammer

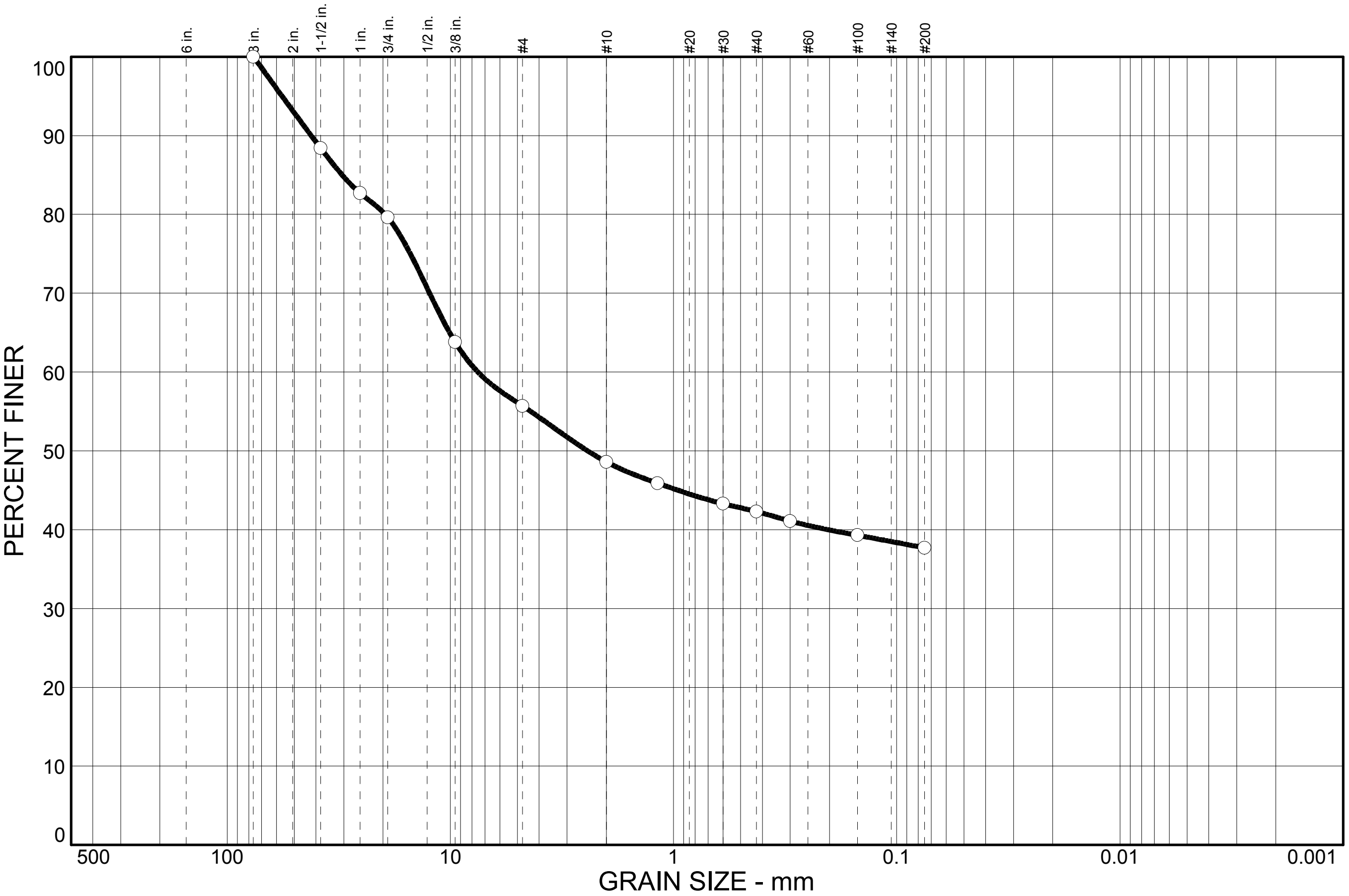
Palmerton and Parrish’s CME’s are equipped with automatic hammers. The conventional method used to obtain disturbed soil samples used a safety hammer operated by company personnel with a cat head and rope. However, use of an automatic hammer allows a greater mechanical efficiency to be achieved in the field while performing a Standard Penetration resistance test based upon automatic hammer efficiencies calibrated using dynamic testing techniques.

*Modified after Ref. ASTM D2487-93 & D2488-93
**Modified after Ref. Oregon DOT 1987 & FHWA 1997
***Modified after Ref. AASHTO 1988, DM 7.1 1982, and Oregon DOT 1987

APPENDIX III

LABORATORY TEST RESULTS

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	20.4	23.9	7.1	6.3	4.6	37.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	100.0		
1-1/2 in.	88.4		
1 in.	82.7		
3/4 in.	79.6		
3/8 in.	63.8		
#4	55.7		
#10	48.6		
#16	45.9		
#30	43.3		
#40	42.3		
#50	41.1		
#100	39.3		
#200	37.7		

* (no specification provided)

Material Description

Clayey gravel with sand

Atterberg Limits

PL= 17 LL= 38 PI= 21

Coefficients

D_{85}= 30.5 D_{60}= 7.53 D_{50}= 2.43
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= GC AASHTO=

Remarks

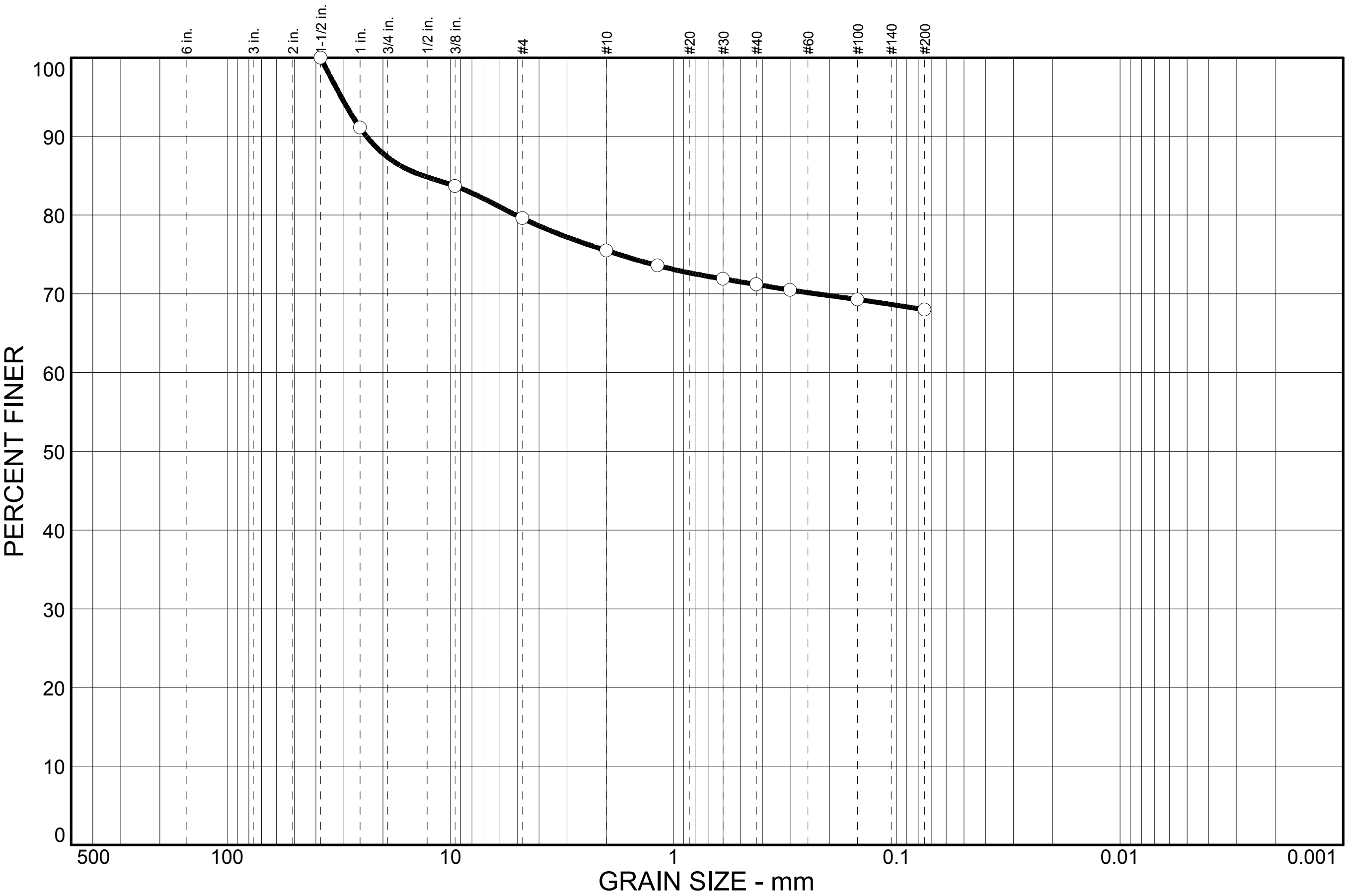
Sample No.: **Source of Sample:** **Date:** 2/19/2014
Location: B-2A **Elev./Depth:** 14'-15'

PALMERTON
& PARRISH, INC.
Springfield, MO

Client: City Utilities of Springfield
Project: JTEC CCW Impoundments-SSA

Project No: 219892 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	12.7	7.7	4.1	4.3	3.2	68.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2 in.	100.0		
1 in.	91.1		
3/8 in.	83.7		
#4	79.6		
#10	75.5		
#16	73.6		
#30	71.9		
#40	71.2		
#50	70.5		
#100	69.3		
#200	68.0		

* (no specification provided)

Material Description

Gravelly lean clay

Atterberg Limits

PL= 17 LL= 38 PI= 21

Coefficients

D_{85}= 13.2 D_{60}= D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO=

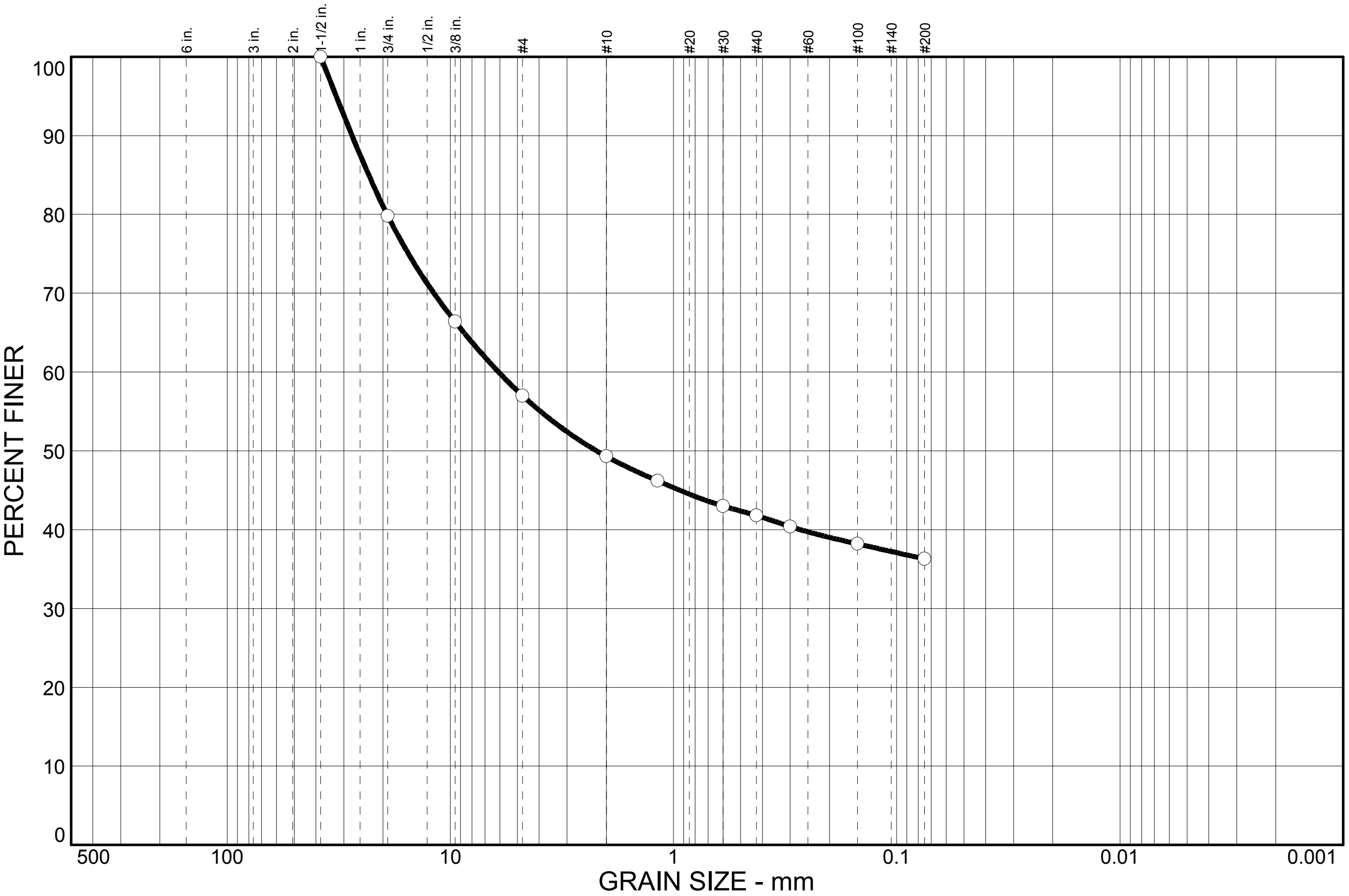
Remarks

Sample No.:
Location: B-2A
Source of Sample:
Date: 2/19/2014
Elev./Depth: 19.5'-21.5'

PALMERTON
& PARRISH, INC.
Springfield, MO

Client: City Utilities of Springfield
Project: JTEC CCW Impoundments-SSA
Project No: 219892 **Figure**

Particle Size Distribution Report



<table>
<tr><th rowspan="2">% COBBLES</th><th colspan="2">% GRAVEL</th><th colspan="3">% SAND</th><th colspan="2">% FINES</th></tr>
<tr><th>CRS.</th><th>FINE</th><th>CRS.</th><th>MEDIUM</th><th>FINE</th><th>SILT</th><th>CLAY</th></tr>
<tr><td>0.0</td><td>20.2</td><td>22.8</td><td>7.7</td><td>7.5</td><td>5.5</td><td colspan="2">36.3</td></tr>
</table>

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2 in.	100.0		
3/4 in.	79.8		
3/8 in.	66.4		
#4	57.0		
#10	49.3		
#16	46.2		
#30	43.0		
#40	41.8		
#50	40.4		
#100	38.2		
#200	36.3		

* (no specification provided)

Material Description

Clayey gravel with sand

Atterberg Limits

PL= 17 LL= 38 PI= 21

Coefficients

D_{85}= 23.2 D_{60}= 6.08 D_{50}= 2.21
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= GC AASHTO=

Remarks

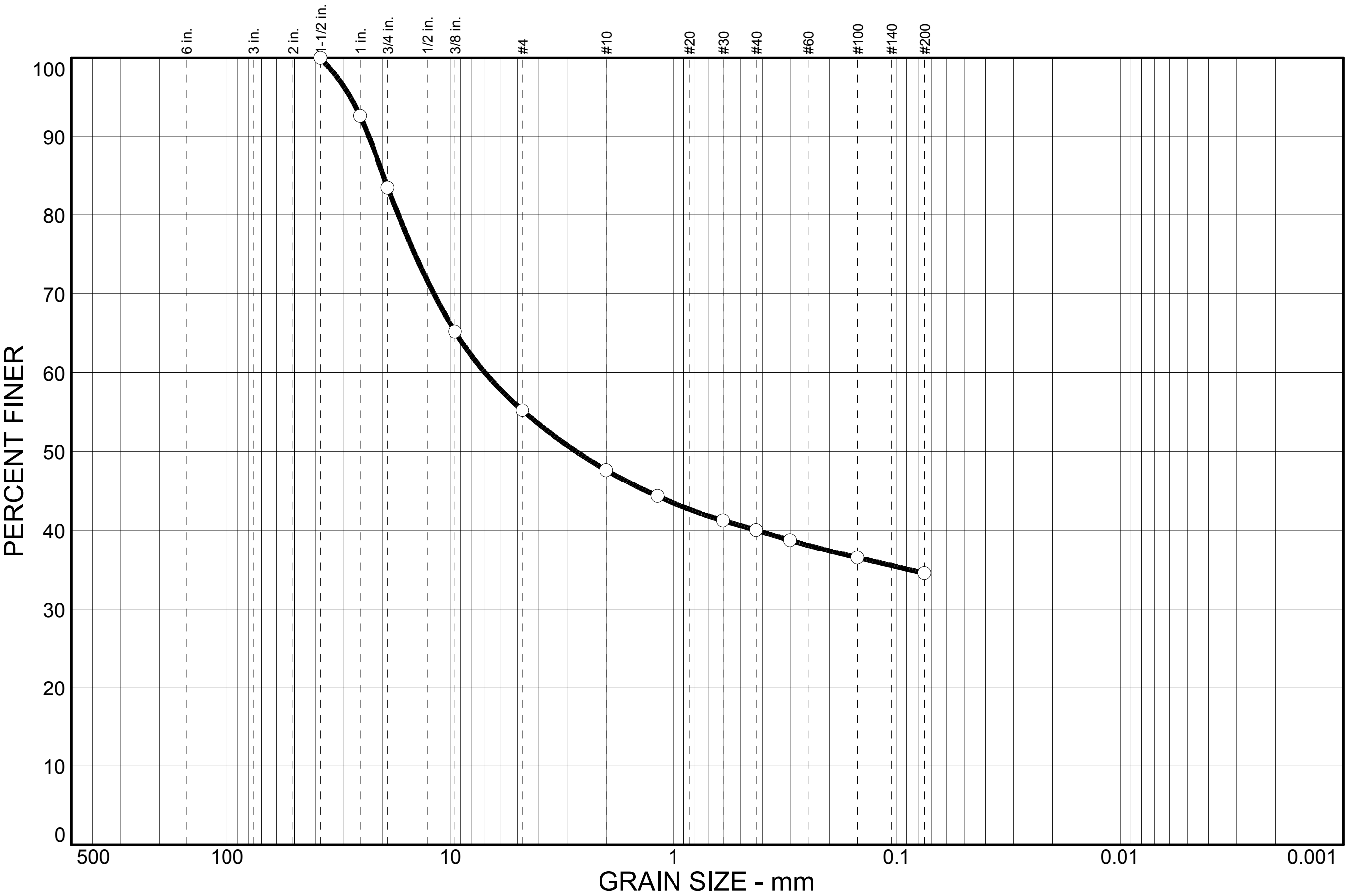
Sample No.: **Source of Sample:** **Date:** 2/19/2014
Location: B-2A **Elev./Depth:** 4'-5.5'

**PALMERTON & PARRISH, INC.
Springfield, MO**

Client: City Utilities of Springfield
Project: JTEC CCW Impoundments-SSA

Project No: 219892 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	16.5	28.3	7.6	7.6	5.5	34.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2 in.	100.0		
1 in.	92.6		
3/4 in.	83.5		
3/8 in.	65.2		
#4	55.2		
#10	47.6		
#16	44.3		
#30	41.2		
#40	40.0		
#50	38.7		
#100	36.5		
#200	34.5		

* (no specification provided)

Material Description

Clayey gravel with sand

Atterberg Limits

PL= 17 LL= 38 PI= 21

Coefficients

D_{85}= 19.9 D_{60}= 7.00 D_{50}= 2.74
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= GC AASHTO=

Remarks

Sample No.: **Source of Sample:** **Date:** 2/19/2014
Location: B-1A **Elev./Depth:** 5'-6.5'

PALMERTON
& PARRISH, INC.
Springfield, MO

Client: City Utilities of Springfield
Project: JTEC CCW Impoundments-SSA

Project No: 219892 **Figure**

APPENDIX IV

EARTHQUAKE PSHA OUTPUT

PSH Deaggregation on NEHRP BC rock

CU_JTEC 93.385° W, 37.147 N.

Peak Horiz. Ground Accel.>=0.08132 g

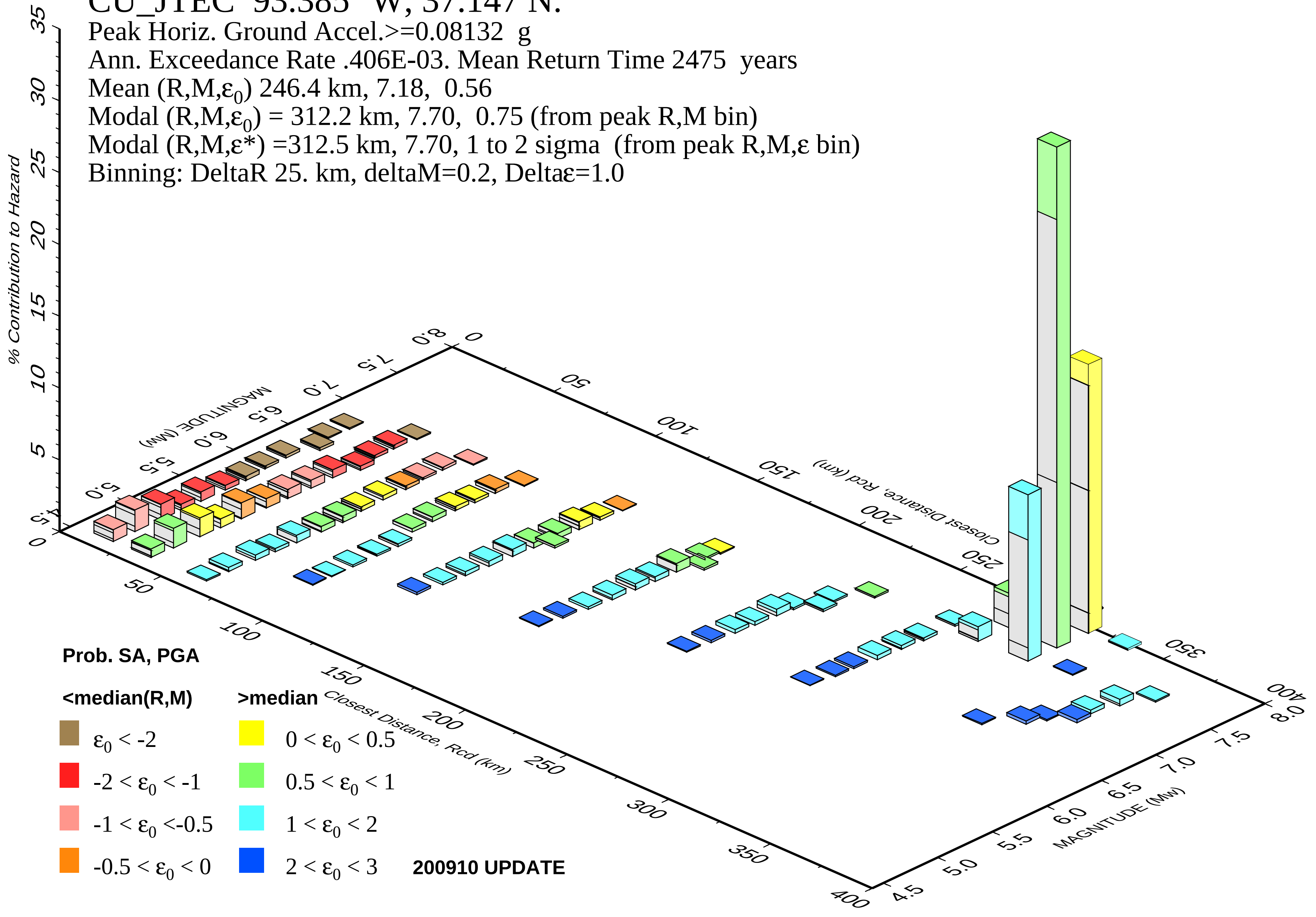
Ann. Exceedance Rate .406E-03. Mean Return Time 2475 years

Mean (R,M,ε_0) 246.4 km, 7.18, 0.56

Modal (R,M,ε_0) = 312.2 km, 7.70, 0.75 (from peak R,M bin)

Modal (R,M,ε^*) =312.5 km, 7.70, 1 to 2 sigma (from peak R,M,ε bin)

Binning: DeltaR 25. km, deltaM=0.2, Deltaε=1.0

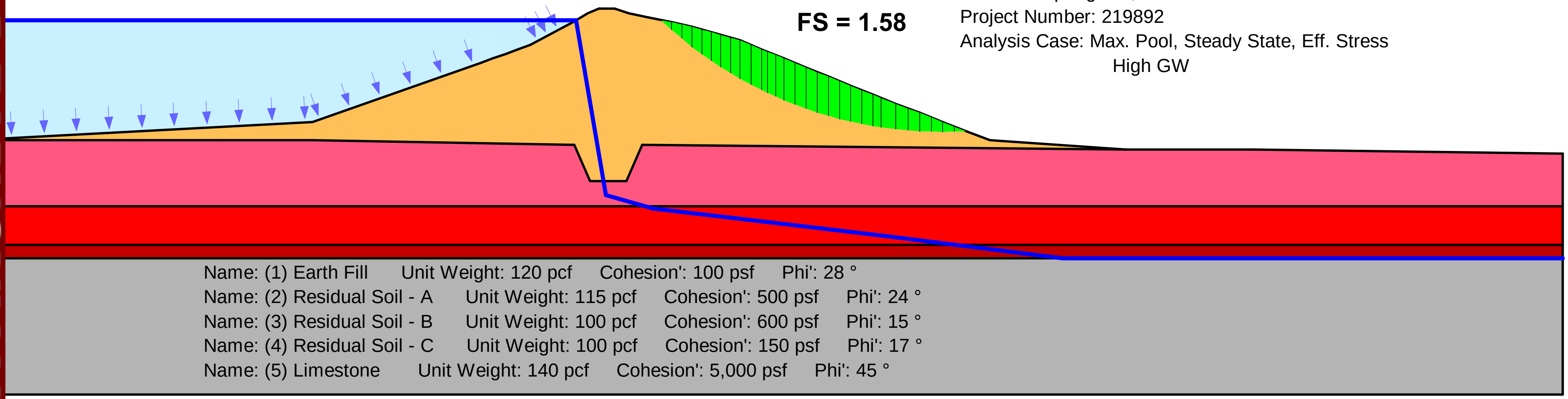


GMT 2014 Feb 24 20:47:35 Distance (R), magnitude (M), epsilon (E0,E) deaggregation for a site on rock with average vs= 760. m/s top 30 m. USGS CGHT PSHA2008 UPDATE Bins with lt 0.05% contrib. omitted

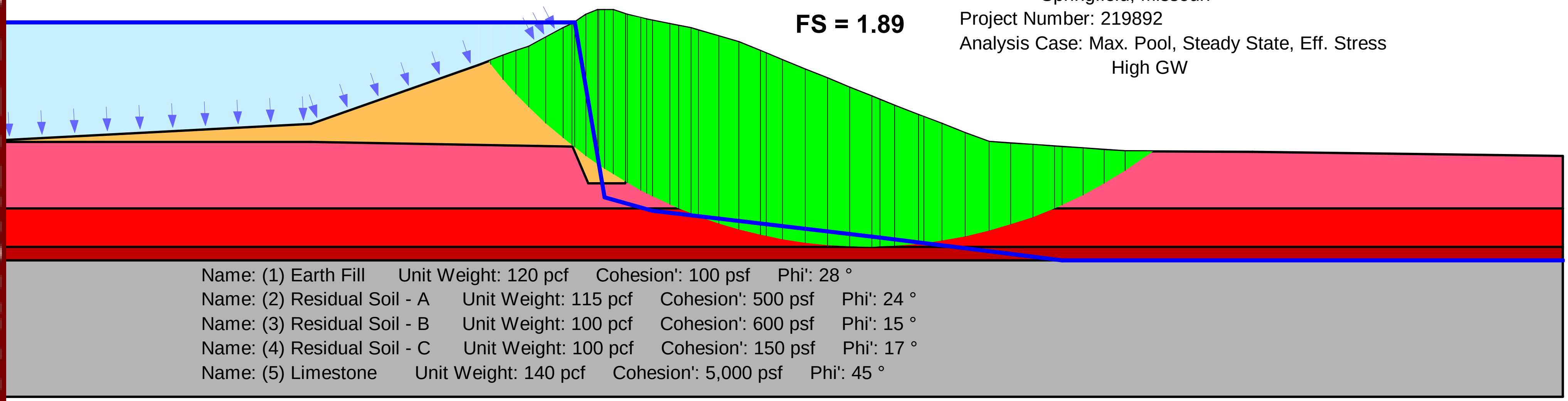
APPENDIX V

SLOPE STABILITY ANALYSIS RESULTS

Project: Site Structural Assessment of CCW Impoundments
City Utilities John Twitty Energy Center
Springfield, Missouri
Project Number: 219892
Analysis Case: Max. Pool, Steady State, Eff. Stress
High GW

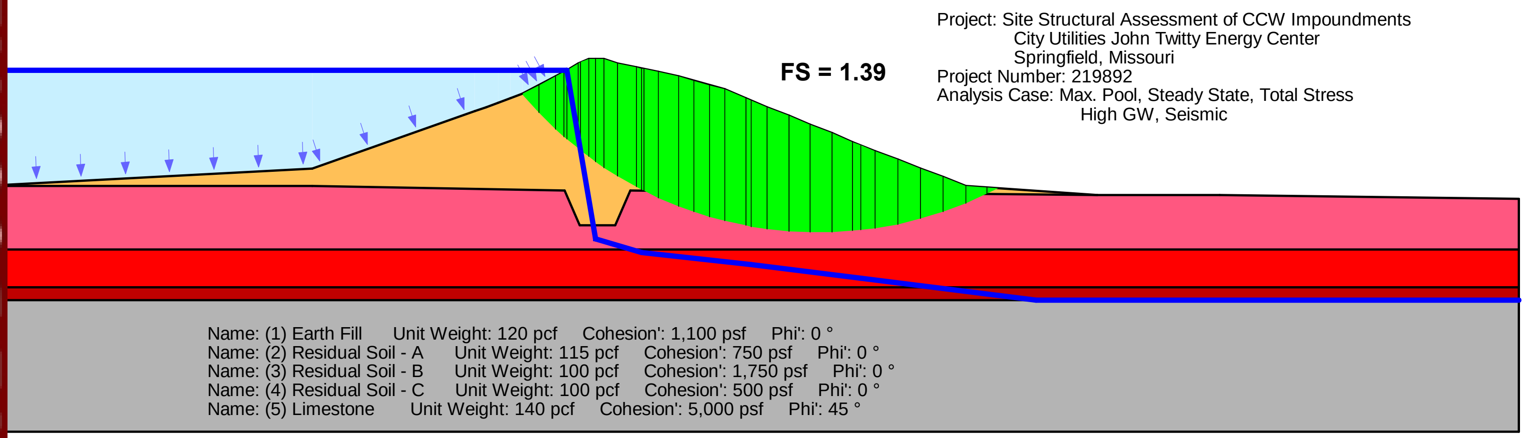


Project: Site Structural Assessment of CCW Impoundments
City Utilities John Twitty Energy Center
Springfield, Missouri
Project Number: 219892
Analysis Case: Max. Pool, Steady State, Eff. Stress
High GW



FS = 1.89

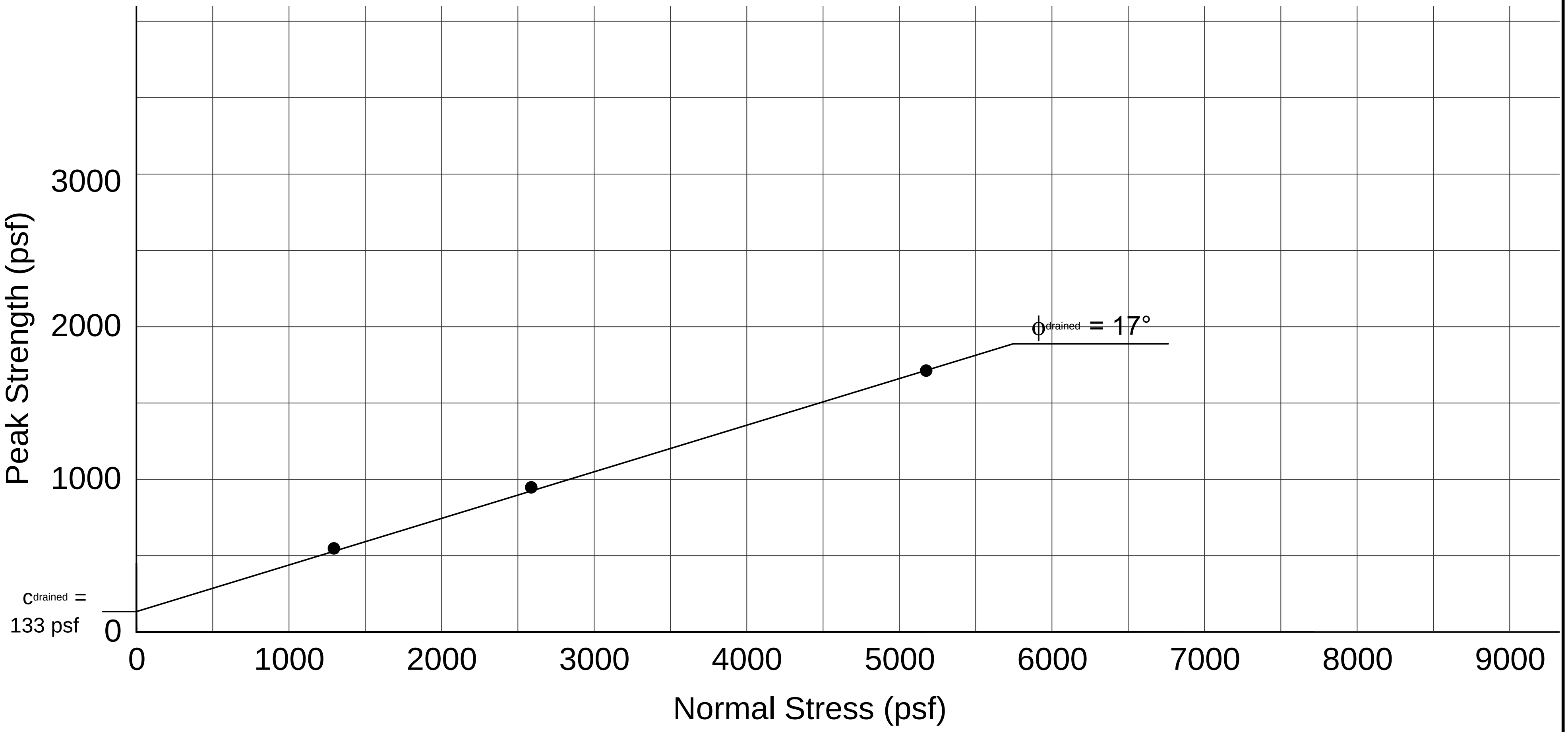
Name: (1) Earth Fill Unit Weight: 120 pcf Cohesion': 100 psf Phi': 28 °
Name: (2) Residual Soil - A Unit Weight: 115 pcf Cohesion': 500 psf Phi': 24 °
Name: (3) Residual Soil - B Unit Weight: 100 pcf Cohesion': 600 psf Phi': 15 °
Name: (4) Residual Soil - C Unit Weight: 100 pcf Cohesion': 150 psf Phi': 17 °
Name: (5) Limestone Unit Weight: 140 pcf Cohesion': 5,000 psf Phi': 45 °


FS = 1.39
Project: Site Structural Assessment of CCW Impoundments
City Utilities John Twitty Energy Center
Springfield, Missouri
Project Number: 219892
Analysis Case: Max. Pool, Steady State, Total Stress
High GW, Seismic
Name: (1) Earth Fill Unit Weight: 120 pcf Cohesion': 1,100 psf Phi': 0 °
Name: (2) Residual Soil - A Unit Weight: 115 pcf Cohesion': 750 psf Phi': 0 °
Name: (3) Residual Soil - B Unit Weight: 100 pcf Cohesion': 1,750 psf Phi': 0 °
Name: (4) Residual Soil - C Unit Weight: 100 pcf Cohesion': 500 psf Phi': 0 °
Name: (5) Limestone Unit Weight: 140 pcf Cohesion': 5,000 psf Phi': 45 °

APPENDIX VI

DIRECT SHEAR RESULTS

Results:
C = 133 psf
ϕ = 17°



Sample: CU B-1A, ST 39'-40.17'
Sample Description: Fat Clay (CH)

Avg. Initial Specimen Data

γ_d = 51.6 pcf
w = 95.4%

LL = 85, PL= 37, PI = 48

Project: JTEC Site Slope Stability - Springfield, Missouri
Client: City Utilities of Springfield

Drained Direct Shear Test

DATE: February 24, 2014

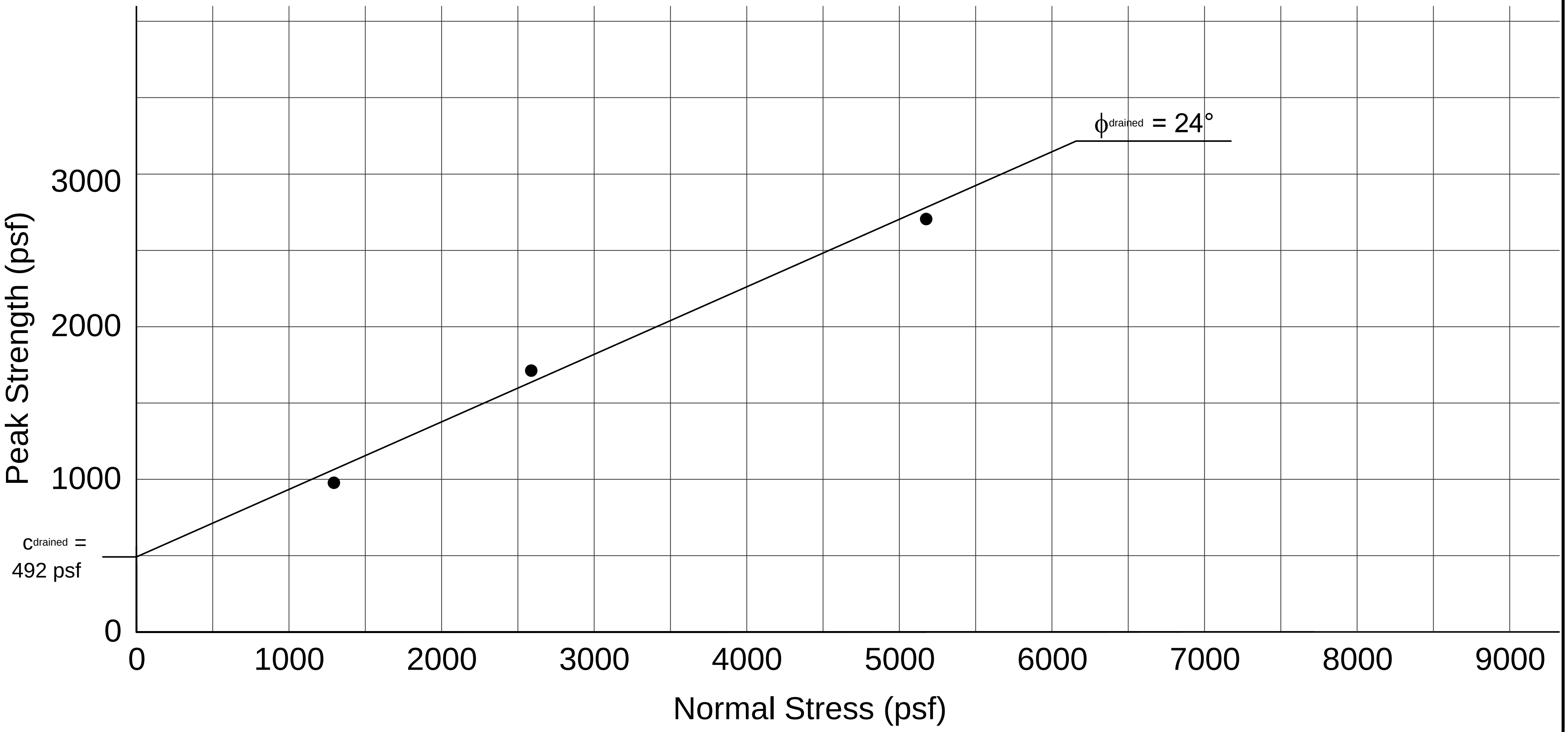
Project Number: 219892

PALMERTON & PARRISH, INC.
GEOTECHNICAL, AND MATERIALS ENGINEERS / MATERIALS TESTING LABORATORIES / ENVIRONMENTAL SERVICES

CU B-1A

S:_MASTER PROJECT FILE\C\City Utilities of Spfld-219892-JTEC Site Structural Assessment-CCW Imp.-Sub\Direct Shear\B-1A 39-40.17\CU B-1A 39-40.17.dwg

Results:
C = 492 psf
ϕ = 24°



Sample: CU B-1B, ST 5'-6.33'
Sample Description: Fat Clay (CH)

Avg. Initial Specimen Data
γ_d = 74.3 pcf
w = 49.1%

LL = 86, PL= 30, PI = 56

Project: JTEC Site Slope Stability - Springfield, Missouri
Client: City Utilities of Springfield

Drained Direct Shear Test

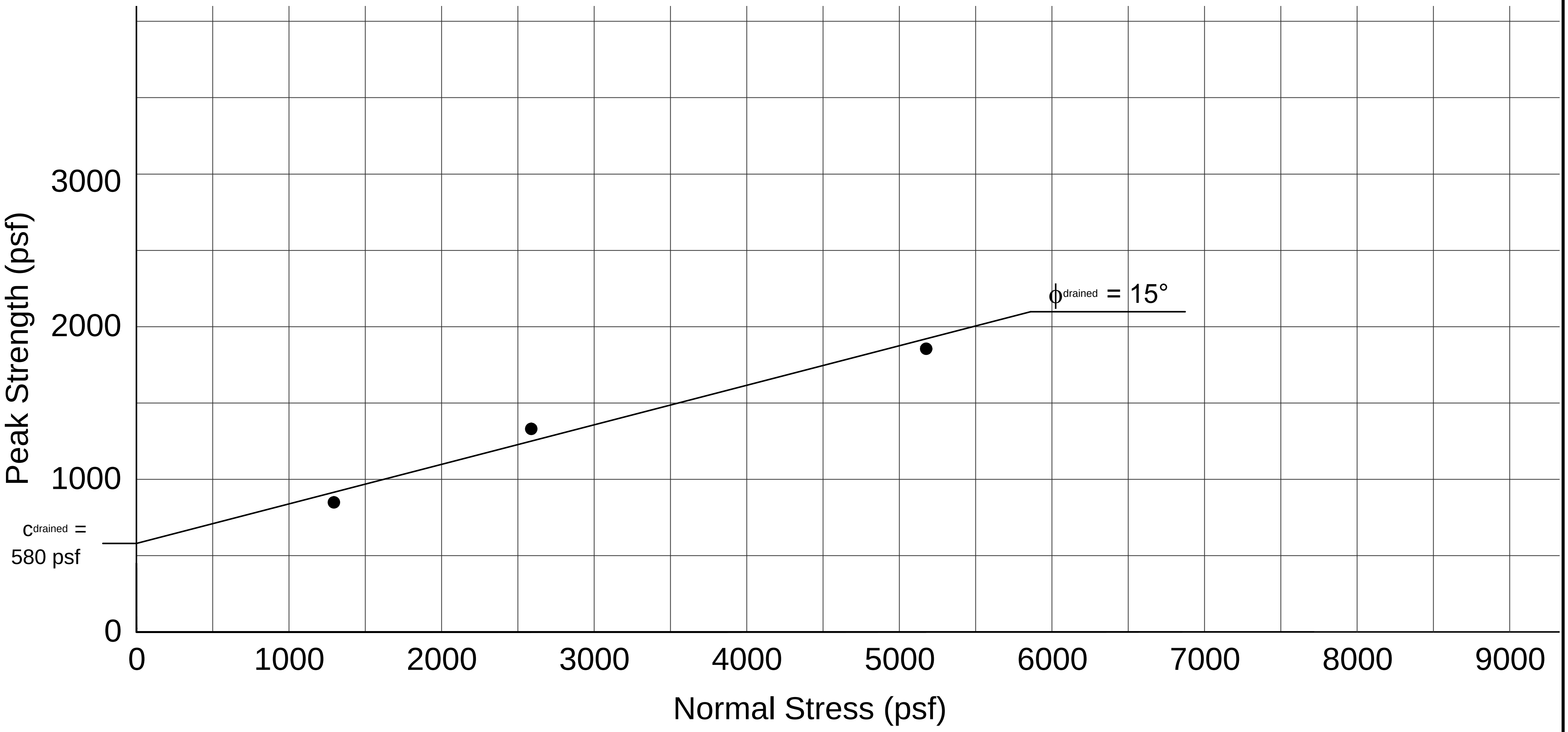
DATE: February 24, 2014

Project Number: 219892

PPI PALMERTON & PARRISH, INC.
GEOTECHNICAL, AND MATERIALS ENGINEERS / MATERIALS TESTING LABORATORIES / ENVIRONMENTAL SERVICES

CU B-1B

Results:
C = 580 psf
ϕ = 15°



Sample: CU B-1B, ST 18.5'-20.08'
Sample Description: Fat Clay (CH)

Avg. Initial Specimen Data
γ_d = 60.3 pcf
w = 67.2%

Project: JTEC Site Slope Stability - Springfield, Missouri
Client: City Utilities of Springfield

Drained Direct Shear Test

DATE: February 24, 2014
Project Number: 219892

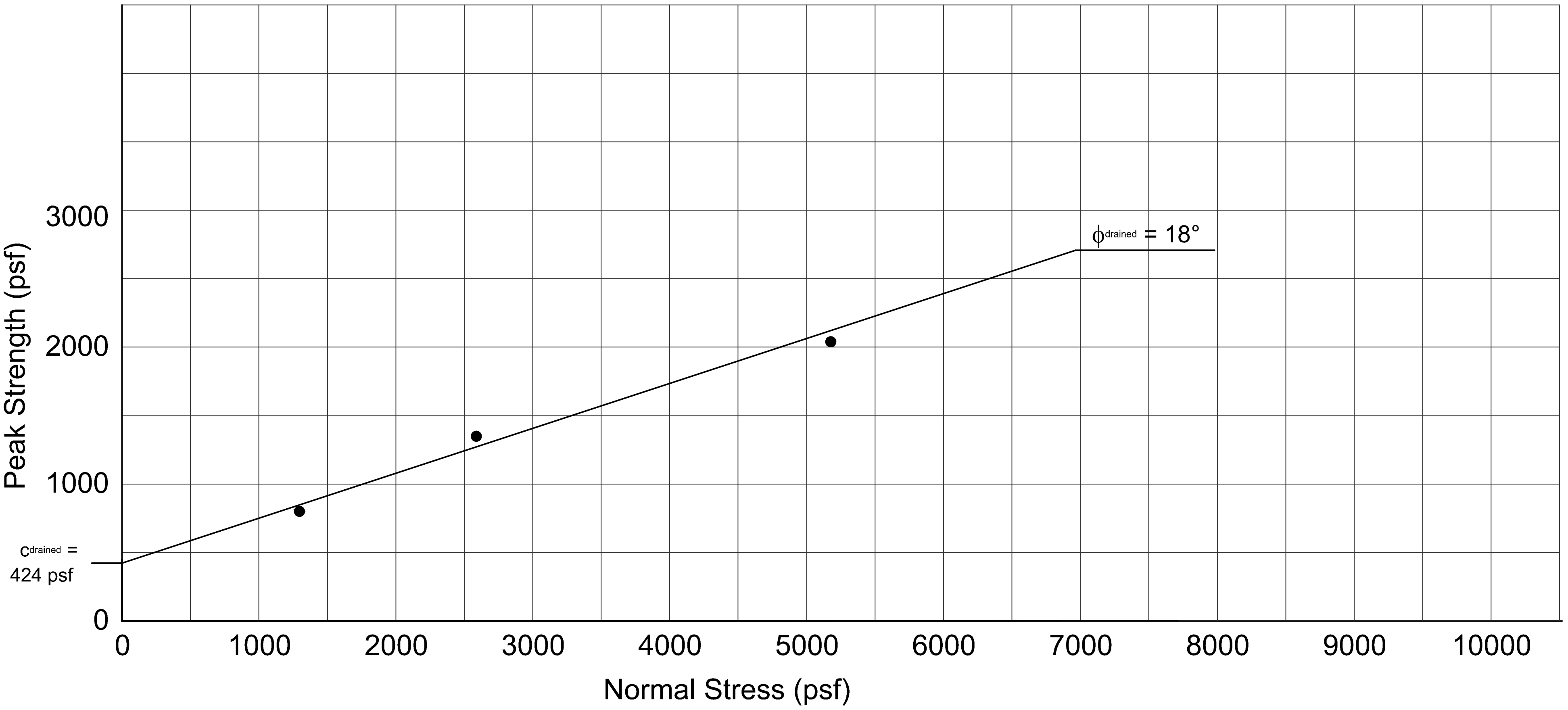
PPI PALMERTON & PARRISH, INC.
GEOTECHNICAL, AND MATERIALS ENGINEERS / MATERIALS TESTING LABORATORIES / ENVIRONMENTAL SERVICES

CU B-1B

S:_MASTER PROJECT FILE\C\City Utilities of Spfld-219892-JTEC Site Structural Assessment-CCW Imp.-Sub\Direct Shear\B-1B 18.5-20.08\CU B-1B 18.5-20.08.dwg

S:_MASTER PROJECT FILE\C\City Utilities of Spfld–219892–JTEC Site Structural Assessment–CCW Imp.–Sub\Direct Shear\B–1B24\CU B–1B 24.dwg

Results:
C = 424 psf
ϕ = 18°



Sample: CU B-1B, ST 24'-24.7'
Sample Description: Fat Clay (CH)

Avg. Initial Specimen Data
γ_d = 67.1 pcf
w = 57.7%

LL = 87, PL= 32, PI = 55

Project: JTEC Site Slope Stability - Springfield, Missouri
Client: City Utilities of Springfield

Drained Direct Shear Test

DATE: February 24, 2014

Project Number: 219892

PALMERTON & PARRISH, INC.
GEOTECHNICAL, AND MATERIALS ENGINEERS / MATERIALS TESTING LABORATORIES / ENVIRONMENTAL SERVICES

CU B-1B

Appendix B

Doc 06: H & H Analyses

CAPACITY OF ASH PONDS TO CONTAIN DESIGN RAINFALL EVENT

Purpose:

Document that ash ponds have adequate capacity above the normal pool elevation to store a 100-year, 24-hour rainfall event and maintain adequate freeboard.

Assumptions

- Total precipitation from a 100-year, 24-hour rainfall event is **8.18 inches**. (Source: City of Springfield Drainage Design Manual)
- Normal pool elevation of both east and west ponds is 1226 to 1227 feet (use 1227 feet)
- Low point along top of embankment (both ponds) is 1235 feet
- East pond storage volume (1227 to 1234 feet) is **46,564 cubic yards** (2014 Anderson survey)
- West pond storage volume (1227 to 1234 feet) is **60,631 cubic yards** (2014 Anderson survey)
- Drainage area for east pond is 30.4 acres
- Drainage area for west pond is 36.6 acres

Calculate total rainfall volume from design storm event in E. and W. pond drainage areas

East Pond: [30.4 acres] [43,560 sq. ft/acre] [8.18 in.] [1 ft/12 in.] [cubic yard/27 cubic ft.] = **33,432 yd3**

West pond: [36.6 ac.] [43,560 sq. ft./ac.] [8.18 in.] [1 ft./12 in.] [cubic yard/27 cubic ft.] = **40,251 yd3**

Conclusion

Both the east and west ponds will contain a 100-year, 24-hour rainfall event and maintain a freeboard greater than one foot. This is a very conservative estimate in that it:

1. Assumes that the total rainfall produced in the drainage areas actually drains to the pond (i.e no infiltration).
2. Does not account for the additional routing capacity of the two 12" diameter corrugated spillway overflow pipes which have a discharge capacity of 2 to 3 cfs each.
3. Does not account for the maximum routing capacity of the ponds outlet structure which is capable of discharging approximately 6.5 million gallons per day (mgd) and which could be utilized in the event of major storm event. For reference the average pond discharge is 0.2 mgd.

Clarification on JTEC ash pond overflow modifications, 1985

In 1985 the Missouri Department of Natural Resources performed an inspection of the JTEC (then Southwest Power Station, SWPS) ash ponds and concluded that they required modification of the overflow system. As originally designed, each pond was constructed with an overflow pipe directed to a riprap spillway channel. The state agency was concerned that any overflow through such a structure would not be captured in the permitted discharge stream of Outfall 002.

To remedy this, the SWPS Plant Engineer designed an overflow modification that replaced the open channel spillways with closed piping to divert overflow to the common discharge weir at the base of the ash pond embankment. At this point it could be measured and sampled with the ordinary underflow discharge stream. To reduce piping costs and introduce slope to the new structure, the original overflow inlets were abandoned in favor of new inlets located closer to the centerline separating the two ponds. These changes are shown in plan view on the accompanying drawing entitled “Modification Details.”

In addition, Mr. Wehrly performed calculations to ensure that the modified overflow structure would perform as adequately as the original design. These hand calculations are included in two separate files as “Modification Study.” It should be noted that the hydraulic calculations in that study are overly conservative compared to current conditions. In this original study it appears that the slope of the new discharge lines, a limiting hydraulic factor, assumed that the inlet structures would remain in their original spread locations. Moving them laterally toward the discharge point increased the respective slopes dramatically. In addition, rainfall runoff tributary to the ash pond was calculated assuming a contribution from the coal pile storage area to the west. Several years after these modifications, the plant modified its discharge permit by diverting all coal pile runoff away from Outfall 002 and directing it to dedicated storm water Outfall 001.

FORM 1047.

JOB NO. ______ PAGE NO. 1

COMPUTED BY MRW DATE 11/21/85

CHECKED BY ______ DATE ______

REVIEWED BY ______ DATE ______

APPROVED BY ______ DATE ______

SUBJECT ______

SHEET NO. ______ OF ______

INVESTIGATION

ASH POND OVERFLOW
MODIFICATIONS

FORM 1047.

CU

JOB NO. ________ PAGE NO. 2

SUBJECT ________

COMPUTED BY ________ DATE ________
CHECKED BY ________ DATE ________
REVIEWED BY ________ DATE ________
APPROVED BY ________ DATE ________

SHEET NO. ________ OF ________

ASH POND OVERFLOW MODIFICATIONS

PURPOSE: TO MODIFY THE EXISTING ASH PONDS OVERFLOW SYSTEM SUCH THAT ALL OVERFLOW IS CAPTURERED AND ROUTED THROUGH THE EXISTING OUTFALL WEIR STRUCTURE (M.H. 45). IF NOT DONE, MISSOURI DNR WILL REQUIRE THAT THE OVERFLOW DISCHARGE BE PERMITTED AND MONITORED. THE DISCHARGE FROM M.H. 45 IS ALREADY PERMITTED.

OPTIONS:

I - TIE INTO THE EXISTING OVERFLOW PIPES AND ROUTE NEW PIPES FROM THERE TO M.H. 45. ROUTING WOULD BE ABOVE GROUND AND GENERALLY WOULD FOLLOW THE TOE OF THE DAM.

II. - PLUG OR REMOVE THE EXISTING OVERFLOW PIPES AND INSTALL NEW OVERFLOW PIPES AND ROUTE THESE NEW PIPES DIRECTLY TO M.H. 45. ROUTING WOULD BE THROUGH THE DAM AND DOWN THE BACKSIDE OF THE DAM.

PIPING OPTIONS TO INVESTIGATE:

A. REINFORCED CONCRETE PIPE (RCP)
B. CORRUGATED METAL PIPE (CMP)
  a. GALVANIZED ONLY
  b. POLYMER COATED INSIDE & OUTSIDE.
C. DUCTILE IRON PIPE (D.I.)

FORM 1047.

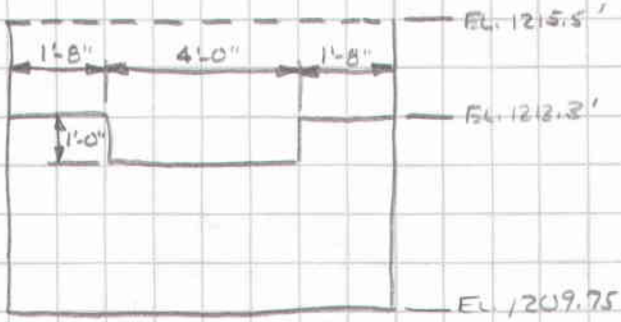
JOB NO. ______ PAGE NO. 3

SUBJECT ______

COMPUTED BY ______ DATE ______
CHECKED BY ______ DATE ______
REVIEWED BY ______ DATE ______
APPROVED BY ______ DATE ______

SHEET NO. ______ OF ______

CHECK CAPACITY OF EXISTING WEIR:



REHBOCK FORMULA:

$$Q = \frac{2}{3}\sqrt{2g}\,LH^{3/2}\left(0.605 + \frac{1}{320H - 3} + \frac{0.05H}{P}\right)$$

$L = L' - 0.1NH$ BELOW EL. 1213.3 $L = 4 - 0.1(2)(1) = 3.8'$

ABOVE EL. 1213.3 $L = 7.33'$

H - BELOW EL 1213.3 = 1'

ABOVE EL. 1213.3 = 2.2'

P - BELOW EL 1213.3 = 2.55'

ABOVE EL 1213.3 = 3.55'

$$Q_{BELOW\,1213.3} = \frac{2}{3}\sqrt{2(32.2)}(3.8)(1)^{3/2}\left(0.605 + \frac{1}{320(1) - 3} + \frac{0.05(1)}{2.55}\right)$$

= 13.00 ft³/sec = 5834.4 GPM = 8.4 MGD

$$Q_{ABOVE\,1213.3} = \frac{2}{3}\sqrt{2(32.2)}(7.33)(2.2)^{3/2}\left(0605 + \frac{1}{320(2.2) - 3} + \frac{0.05(2.2)}{3.55}\right)$$

= 83.95 ft³/sec = 37676.8 GPM = 54.3 MGD

Q_{TOTAL} FOR WEIR STRUCTURE = 13 + 83.95 = 96.95 ft³/sec

= 43,511.2 GPM = 62.7 MGD

CHECK CAPACITY OF DOWNSTREAM PIPE:

PIPE IS 24" RCP, CLASS IV, SLOPE = 0.2%

MANNING FORMULA:

$$Q = \frac{1.486}{n}\,a\,r^{2/3}S^{1/2}$$

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$n = 0.013$ FOR CONCRETE PIPE

$$a = \frac{\pi d^2}{4} = \pi\frac{(24/12)^2}{4} = 3.14 \text{ ft}^2$$

$$r = a/p = 3.14/\pi(24/12) = 0.5 \text{ ft}$$

$$S = 0.2\% = 0.002 \text{ ft/ft}$$

$$Q = \frac{1.486}{0.013}(3.14)(0.5)^{2/3}(0.002)^{1/2}$$

$$= 10.11 \text{ ft}^3/\text{SEC}$$

THE DOWNSTREAM PIPE IS THE LIMITING FACTOR

CALCULATE RAINFALL RUNOFF

USE 10 YEAR, 24 HOUR STORM - FOR SPRINGFIELD AREA
THIS GIVES 5.57 INCHES OF WATER OVER ENTIRE AREA
IN A 24 HOUR PERIOD.

RATIONAL FORMULA: $Q = CIA$

C = RUNOFF COEFFICIENT = 0.20 FOR GENERAL PLANT AREA
= 0.90 FOR COAL PILE AREA

I = INTENSITY = $5.57/24 = 0.232$ IN/HR

A = AREA IN ACRES - FROM OVERALL PLAN VIEW - ESTIMATED:

EAST CELL $A = 1{,}350{,}000 \text{ ft}^2 / 43{,}560 \text{ ft}^2/\text{acre} = 30.99$ SAY 32 ACRES

WEST CELL $A = 840{,}000 \text{ ft}^2 = 19.28$ SAY 20 ACRES

COAL PILE $A = 900{,}000 \text{ ft}^2 = 20.66$ SAY 21 ACRES

$$Q_{EAST} = (0.2)(0.232)(32) = 1.485 \text{ ft}^3/\text{SEC}$$

$$Q_{WEST} = (0.2)(0.232)(20) = 0.928 \text{ ft}^3/\text{SEC}$$

$$Q_{COAL\ PILE} = (0.9)(0.232)(21) = 4.385 \text{ ft}^3/\text{SEC}$$

WORST CASE IS EAST CELL WITH COAL PILE RUNOFF

$$Q_{TOTAL} = 1.485 + 4.385 = 5.87 \text{ ft}^3/\text{SEC}$$

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CHECK CAPACITY OF EXISTING OVERFLOWS

EACH OVERFLOW HAS 2 - 29"x18", 14GA, CMP.

MANNING FORMULA:

$$Q = \frac{1.486}{n} a r^{2/3} s^{1/2}$$

$n = 0.024$ FOR CMP

$a = \pi a b = \pi \left(\frac{29/2}{12}\right)\left(\frac{18/2}{12}\right) = 2.847 \text{ ft}^2$

$r = a/p = 2.847/\pi(a+b)k \quad k = 1.0144$

$= 0.456 \text{ ft}$

$S = \frac{1232 - 1231.8}{35} = 0.0057 \text{ ft/ft}$

$$Q = \frac{1.486}{0.024}(2.847)(0.456)^{2/3}(0.0057)^{1/2}$$

$= 7.88 \text{ ft}^3/\text{sec}$ PER PIPE

$= 15.76 \text{ ft}^3/\text{sec}$ TOTAL FOR EACH POND

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CAPACITY OF NEW OVERFLOW PIPE:

THE PIPE DOWNSTREAM OF THE WEIR IS THE LIMITING FACTOR WITH A MAXIMUM FLOW OF 10.11 ft^3/sec. THE OVERFLOW PIPE CAN BE SIZED IN TWO DIFFERENT WAYS. THE FIRST WAY TO SIZE THE PIPE WOULD BE TO ASSUME THE TOTAL MAXIMUM CAPACITY OF THE INLET PIPES SHOULD NOT EXCEED THE MAXIMUM DOWNSTREAM FLOW. THE SECOND WAY TO SIZE THE PIPE WOULD BE TO ASSUME A NORMAL FLOW THROUGH THE EXISTING INLET PIPE AND SIZE THE OVERFLOW FOR THE CAPACITY UP TO THE MAXIMUM DOWNSTREAM FLOW.

I. CHECK THE CAPACITY OF THE EXISTING INLET PIPE:

PIPE IS 21" CMP, 12 GAUGE.

SLOPE: VERTICAL DROP - 1211.0' - 1209.75' = 1.25'

HORIZONTAL DISTANCE - 196'

$S = 1.25/196 = 0.0064$

MANNINGS FORMULA:

$$Q = \frac{1.486}{n} a r^{2/3} S^{1/2}$$

$$= \frac{1.486}{0.024}\left(\frac{\pi(\frac{21}{12})^2}{4}\right)\left(\frac{21/12}{4}\right)^{2/3}(0.0064)^{1/2}$$

$$= 6.87\ ft^3/sec$$

DIFFERENCE = 10.11 - 6.87 = 3.24 ft^3/sec

SIZE NEW OVERFLOW PIPE BASED ON MAXIMUM FLOW OF 3.24 ft^3/sec.

SLOPE OF NEW PIPE THROUGH DIKE IS LIMITING FACTOR

$S = 0.0057$

MANNINGS FORMULA:

$$3.24 = \frac{1.486}{n}\left(\frac{\pi d^2}{4}\right)\left(\frac{d}{4}\right)^{2/3}(0.0057)^{1/2}$$

$$3.24 = \frac{d^{2\,2/3}}{n}\,0.035$$

$$\frac{d^{2\,2/3}}{n} = 92.57$$

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FOR RCP $n = 0.013$ $d = 1.072' = 12.86''$ use 12"
FOR CMP(HELICAL) $n = 0.011$ $d = 1.007' = 12.08''$ use 12"
FOR D.I. $n = 0.012$ $d = 1.040' = 12.48''$ use 12"

II. "NORMAL" FLOW THROUGH THE EXISTING INLET PIPE
IS 692,000 GAL/DAY = 1.07 ft³/sec

DIFFERENCE = 10.11 - 1.07 = 9.04 ft³/sec

SIZE NEW OVERFLOW PIPES BASED ON MAXIMUM
FLOW OF 9.04 ft³/sec
SLOPE OF NEW PIPE THROUGH DAM IS LIMITING FACTOR
$S = 0.0057$
MANNINGS FORMULA:

$$9.04 = \frac{1.486}{n}\left(\frac{\pi d^2}{4}\right)\left(\frac{d}{4}\right)^{2/3}(0.0057)^{1/2}$$

$$9.04 = \frac{d^{2\,2/3}}{n}\,0.035$$

$$\frac{d^{2\,2/3}}{n} = 258.29$$

FOR RCP $n = 0.013$ $d = 1.575' = 18.90''$ use 18"
FOR CMP(HELICAL) $n = 0.013$ $d = 1.575' = 18.90''$ use 18"
FOR D.I. $n = 0.012$ $d = 1.528' = 18.34''$ use 18"

CAPACITY OF POND

WITH EITHER OF THE ABOVE SOLUTIONS, WE WILL BE LIMITING THE OVERFLOW CAPACITY TO A MUCH LOWER VALUE THAN WE'VE HAD AVAILABLE IN THE PAST. A CHECK OF THE POND CAPACITY IS NEEDED.

THE MAIN ITEM TO CHECK AGAINST THE OVERFLOW CAPACITY IS THE RAINFALL RUNOFF. THE NORMAL FLOW OUT OF THE POND WOULD NOT GENERALLY BE CHANGED DUE ONLY TO A RAINFALL, SO THE OVERFLOW WOULD HANDLE RUNOFF ONLY.

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THE TOTAL FLOW INTO THE POND DUE TO RUNOFF IS $5.87\ ft^3/sec$ BASED ON THE EAST POND INCLUDING COAL PILE RUNOFF. THIS IS BASED ON A 10 YEAR, 24 HOUR STORM.

ACTUAL OVERFLOW CAPACITIES:

CASE I: 12" RCP $Q = \frac{1.486}{0.013}\left(\frac{\pi}{4}\right)\left(\frac{1}{4}\right)^{2/3}(0.0057)^{1/2} = 2.69\ ft^3/sec$

12" CMP $Q = \frac{1.486}{0.011}\left(\frac{\pi}{4}\right)\left(\frac{1}{4}\right)^{2/3}(0.0057)^{1/2} = 2.64\ ft^3/sec$

12" D.I. $Q = \frac{1.486}{0.012}\left(\frac{\pi}{4}\right)\left(\frac{1}{4}\right)^{2/3}(0.0057)^{1/2} = 2.91\ ft^3/sec$

CASE II: 18" RCP $Q = 7.93\ ft^3/sec$

18" CMP $Q = 7.93\ ft^3/sec$

18" D.I. $Q = 8.59\ ft^3/sec$

} ALL VALUES FOR CASE II ARE HIGHER THAN RUNOFF RATE.

WORST CASE IS FOR 12" CMP WITH A DIFFERENCE OF $5.87 - 2.64 = 3.23\ ft^3/sec$

SURFACE AREA OF POND AT EL. 1232'-0" IS APPROXIMATELY 160,000 ft^2:

$$\frac{160,000}{3.23} = 49536\ sec/ft = 13.75\ HR/ft.$$

VERY CONSERVATIVELY - IT WOULD TAKE APPROXIMATELY 14 HOURS TO RAISE THE LEVEL OF THE POND 1 FOOT WITH THE 10 YEAR, 24 HOUR STORM. THE NEW OVERFLOW CAPACITY IS ADEQUATE IN EITHER CASE.

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PIPE SELECTION

FOR ALL PIPE, THE MAXIMUM STRENGTH REQUIRED WILL BE IN OPTION II WHERE THE NEW OVERFLOW PIPE WILL BE BURIED UNDER THE EXISTING ROADWAY AND WILL NEED TO SUPPORT THE LOADS IMPOSED BY ACID TRUCKS FOR DELIVERIES.

ASSUME FOR ALL PIPE THAT THE TRENCH BACKFILL WILL BE COMPACTED (90% OR BETTER) GRANULAR MATERIAL AND THE TOP OF THE PIPE WILL BE BURIED 2 FEET UNDER THE SURFACE. LOADING WILL BE ON AN ELASTIC ROADWAY SURFACE AND SHALL CONFORM TO H20/S16 LOADING.

I. REINFORCED CONCRETE PIPE (RCP)

A. 12" SIZE, ASSUME 2" WALL (CALCULATIONS BASED ON AMERON ENGINEERING INFO)

$$B_c = 1 + 2(2/12) = 1.333'$$

$$B_d = 1.333 + 2 = 3.333'$$

$$\frac{H}{B_d} = \frac{2}{3.33} = 0.60$$

$$C_d = 0.555$$

$$W_d = C_d\, w\, B_d^2 = (0.555)(120)(3.333)^2 = 739 \text{ lbs.}$$

$$W_t = \frac{1}{A} I_c C_t T$$

$$\left.\begin{aligned} m &= \frac{A/2}{H} = \frac{3/2}{2} = 0.75 \\ n &= \frac{B_c/2}{H} = \frac{1.333/2}{2} = 0.33 \end{aligned}\right\}\ \begin{aligned} C_t &= 0.075 \\ &\times 4 \end{aligned} = 0.30$$

$$W_t = \frac{1}{3}(1.2)(0.30)(16000) = 1920 \text{ lb}$$

$$D = \left[\frac{DL}{DL_f} + \frac{LL}{LL_f}\right]\left(\frac{FS}{ID}\right)$$

$$= \left[\frac{739}{1.1} + \frac{1920}{1.5}\right]\left(\frac{1.0}{1}\right)$$

$$= 1952 \text{ lb}$$

NEED 12", CLASS IV, WALL B, RCP $D_{0.01} = 2000$

B. 18" SIZE, ASSUME 2½" WALL

$$B_c = 1.5 + 2\left(\tfrac{2\frac{1}{2}}{12}\right) = 1.92'$$

$$B_d = 1.92 + 2 = 3.92'$$

$$\frac{H}{B_d} = \frac{2}{3.92} = 0.51$$

$$C_d = 0.469$$

$$W_d = C_d\, w\, B_d^{\,2} = (0.469)(120)(3.92)^2 = 865\ lb$$

$$W_t = \frac{1}{A} I_c C_t T$$

$$\left.\begin{aligned} m &= \frac{A/2}{H} = \frac{3/2}{2} = 0.75 \\ n &= \frac{B_c/2}{H} = \frac{1.92/2}{2} = 0.48 \end{aligned}\right\} C_t = 0.105 \times 4 = 0.42$$

$$W_t = \frac{1}{3}(1.2)(0.42)(16000) = 2688\ lb$$

$$D = \left[\frac{DL}{DL_f} + \frac{LL}{LL_f}\right]\left(\frac{FS}{ID}\right)$$

$$= \left[\frac{865}{1.1} + \frac{2688}{1.5}\right]\left(\frac{1.0}{1.5}\right)$$

$$= 1719\ lb$$

NEED 18", CLASS IV, WALL B, RCP $D_{0.01} = 2000$

II. CORRUGATED METAL PIPE (CMP)

A. 12" SIZE, FIND WALL THICKNESS & TYPE OF CORRUGATIONS

PER TOM BARON - THOMPSON CULVERT COMPANY - THE STANDARD CMP IN THIS SIZE IS 16 GUAGE, 2⅔" x ½" CORRUGATIONS. ALL CALCULATIONS BASED ON "HANDBOOK OF STEEL DRAINAGE & HIGHWAY CONSTRUCTION PRODUCTS".

DESIGN PRESSURE: $P_v = DL + LL$

$DL = H \times w = 2 \times 120 = 240\ lb/ft^2$

LL (H20), 2' COVER, $= 800\ lb/ft^2$

$P_v = 240 + 800 = 1040\ lb/ft^2$

RING COMPRESSION : $C = P_v \times S/2$

$= 1040 \times \frac{12/12}{2} = 520$ lb/ft²

ALLOWABLE WALL STRESS

$f_c = 19{,}200$ lb/in² FOR $2\frac{2}{3}$" x ½" CORRUGATIONS

WALL CROSSECTIONAL AREA

$A = C/f_c = 520/19{,}200 = 0.027$ in²/ft REQUIRED

FOR $2\frac{2}{3}$" x ½", 16 GUAGE - $A = 0.775$ in²/ft - OK.

HANDLING STIFFNESS

$$FF = \frac{D^2}{EI}$$

$D = 12"$

$E = 30 \times 10^6$

$I = 0.0227$ in⁴/ft FOR $2\frac{2}{3}$" x ½", 16 GUAGE

$FF = 12^2/(30 \times 10^6)(0.0227) = 0.00021$

$0.0021 < 0.0433 \Rightarrow$ O.K.

NEED 12", $2\frac{2}{3}$" x ½", 16 GUAGE GALVANIZED CMP

LOOK AT POLYMER COATED AS AN OPTION

B. 18" SIZE, FIND WALL THICKNESS AND TYPE OF CORRUGATION

DESIGN PRESSURE : $P_v = 1040$ lb/ft²

RING COMPRESSION : $C = P_v \times S/2$

$= 1040 \times \frac{18/12}{2} = 780$ lb/ft²

ALLOWABLE WALL STRESS:

$f_c = 19{,}200$ lb/in² FOR $2\frac{2}{3}$" x ½" CORRUGATIONS

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WALL CROSSECTIONAL AREA

$A = C/f_c = 780/19{,}200 = 0.041\ in^2/ft$ REQUIRED

FOR $2\frac{2}{3}" \times \frac{1}{2}"$, 16 GUAGE - CROSSECTIONAL AREA $= 0.775\ in^2/ft$

OK

HANDLING STIFFNESS

$FF = D^2/EI$

$D = 21"$

$E = 30 \times 10^6$

$I = 0.0227\ in^4/ft$ FOR $2\frac{2}{3}" \times \frac{1}{2}"$, 16 GUAGE

$$FF = \frac{21^2}{(30\times10^6)(0.0227)} = 0.00065$$

$0.00065 < 0.0433$ OK

NEED 18", $2\frac{2}{3}" \times \frac{1}{2}"$, 16 GUAGE GALVANIZED CMP

LOOK AT POLYMER COATED AS AN OPTION

III. DUCTILE IRON PIPE

ALL CALCULATIONS ARE BASED ON "U.S. PIPE - DUCTILE IRON PIPE DESIGN, 4" THROUGH 48"".

A. 12" SIZE

LAYING CONDITION 5 - 90% COMPACTED GRANULAR BACKFILL

TABLE 3 - THICKNESS FOR EARTH LOAD PLUS TRUCK LOAD

12", $2\frac{1}{2}'$ COVER, TYPE 5 LAYING CONDITION

TOTAL CALCULATED THICKNESS = 0.18" => USE CLASS 50

TABLE 4 - THICKNESS FOR INTERNAL PRESSURE

12", 150 PSI WORKING PRESSURE

TOTAL CALCULATED THICKNESS = 0.22" => USE CLASS 50

NEED 12", CLASS 50 DUCTILE IRON PIPE

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B. 18" SIZE

LAYING CONDITION 5 - 90% COMPACTED GRANULAR BACKFILL

TABLE 3 - THICKNESS FOR EARTH LOAD PLUS TRUCK LOAD
18", 2½' COVER, TYPE 5 LAYING CONDITION
TOTAL CALCULATED THICKNESS = 0.20" => USE CLASS 50

TABLE 4 - THICKNESS FOR INTERNAL PRESSURE
18", 150 PSI WORKING PRESSURE
TOTAL CALCULATED THICKNESS = 0.27" => USE CLASS 50

NEED 18", CLASS 50, DUCTILE IRON PIPE

ESTIMATED COSTS

PIPE & FITTINGS

REINFORCED CONCRETE PIPE
FROM ROSE CON : 12", CLASS IV, WALL B - 7.25 $/ft.
18", CLASS IV, WALL B - 11.05 $/ft.
FITTINGS - 12 x $/ft.
FROM RICHARDSONS (INSTALLATION) : 12" RCP - 3.00 $/ft.
18" RCP - 3.75 $/ft.
FOR FITTINGS - ESTIMATE - 10 x $/ft (INST)

CORRUGATED METAL PIPE
FROM THOMPSON CULVERT: 12", 2⅔"x½", 16 GA - 8.79 $/ft , 11.51 $/ft COATED
18", 2⅔"x½", 16 GA - 11.82 $/ft , 16.28 $/ft COATED
12" FITTINGS - $65.65 LABOR + 4' MATERIAL
18" FITTINGS - $93.77 LABOR + 4' MATERIAL
FROM RICHARDSONS (INSTALLATION): 12" CMP - 1.10 $/ft.
18" CMP - 2.75 $/ft.
FOR FITTINGS - ESTIMATE - 10 x $/ft (INST)

DUCTILE IRON PIPE
FROM STOREROOM : 12", CLASS 50 - 8.88 $/ft.
FITTINGS AVG - 125 $/EA
FROM HARRY CONNORS : 18" CLASS 50 - 22 $/ft.
FITTINGS AVG - 175 $/EA
FROM RICHARDSONS (INSTALLATION) : 12" D.I. - 3.00 $/ft.
18" D.I. - 3.75 $/ft.
FOR FITTINGS - ESTIMATE 10 x $/ft (INST)

PIPE LENGTHS: (SEE APPENDIX A FOR DRAWINGS)
OPTION I - 750' STRAIGHT + 30' DRAINAGE
10 FITTINGS

OPTION II - 330' STRAIGHT
6 FITTINGS

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COSTS:

OPTION I

12" RCP	PIPE	(7.25 + 3.00)(780')	7995	$9,195
	FITTINGS	(12 × 7.25 + 10 × 3.00)(10)	1200	
12" CMP	PIPE	(8.79 + 1.10)(780')	7714	$8832
	FITTINGS	(65.65 + 4(8.79) + 10 × 1.10)(10)	1118	
12" CMP COATED	PIPE	(11.81 + 1.10)(780')	10,070	$11,309
	FITTINGS	(65.65 + 4(11.81) + 10 × 1.10)(10)	1239	
12" D.I.	PIPE	(8.88 + 3.00)(780)	9266	$10816
	FITTINGS	(125 + 10(3.00))(10)	1530	
18" RCP	PIPE	(11.05 + 3.75)(780)	11,544	$13,245
	FITTINGS	(12 × 11.05 + 10 × 3.75)(10)	1701	
18" CMP	PIPE	(11.82 + 2.75)(780)	11365	$13,051
	FITTINGS	(93.77 + 4(11.82) + 10 × 2.75)(10)	1686	
18" CMP COATED	PIPE	(16.28 + 2.75)(780)	14,843	$16,707
	FITTINGS	(93.77 + 4(16.28) + 10(2.75))(10)	1864	
18" DI.	PIPE	(22 + 3.75)(780)	20,085	$22,210
	FITTINGS	(175 + 10(3.75))(10)	2125	

OPTION II

12" RCP	PIPE	(7.25 + 3.00)(330')	3383	$4085
	FITTINGS	(12 × 7.25 + 10 × 3.00)(6)	702	
12" CMP	PIPE	(8.79 + 1.10)(330')	3264	$3935
	FITTINGS	(65.65 + 4(8.79) + 10 × 1.10)(6)	671	
12" CMP COATED	PIPE	(11.81 + 1.10)(330')	4260	$5499
	FITTINGS	(65.65 + 4(11.81) + 10(1.10))(10)	1239	
12" DI.	PIPE	(8.88 + 3.00)(330)	3920	$5470
	FITTINGS	(125 + 10(3.00))(10)	1530	
18" RCP	PIPE	(11.05 + 3.75)(330)	4884	$5905
	FITTINGS	(12 × 11.05 + 10 × 3.75)(6)	1021	
18" CMP	PIPE	(11.82 + 2.75)(330)	4808	$5819
	FITTINGS	(93.77 + 4(11.82) + 10(2.75))(6)	1011	
18" CMP COATED	PIPE	(16.28 + 2.75)(330)	6280	$7398
	FITTINGS	(93.77 + 4(16.28) + 10(2.75))(6)	1118	

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18" D.I. PIPE (22+3.75)(330) = 8498 } $9773
FITTINGS (175 + 10(3.75))(6) = 1275 }

EXCAVATION

USING A BACKHOE WITH A 12" BUCKET - 20 $/yd³

OPTION I

12" PIPE - 3' WIDE x 750' LONG x 1' DEEP = 2250 ft³ = 83.3 yd³
COST = 83.3 x 20 = $1666
18" PIPE - 3.5' WIDE x 750' LONG x 1' DEEP = 2625 ft³ = 97.2 yd³
COST = 97.2 x 20 = $1944

OPTION II

12" PIPE - 3' WIDE x 270' LONG x 1' DEEP = 810 ft³ = 30 yd³
+ TRENCHES (4' WIDE x 25' LONG x 4' DEEP)2 = 768 ft³ = 284 yd³
COST = (30+284)(20) = $1168
18" PIPE - 3.5' WIDE x 270' LONG x 1' DEEP = 945 ft³ = 35 yd³
+ TRENCHES (5' WIDE x 25' LONG x 4' DEEP)(2) = 1000 ft³ = 37 yd³
COST = (35+37)(20) = $1440

BACKFILL

STRUCTURAL BACKFILL - COMPACTED - 6 $/yd³

OPTION I

(190' + 160')(144 ft²) = 50,400 ft³ = 1867 yd³
COST = (1867)(6) = $11,202

OPTION II

(85')(25 ft²) = 2125 ft³ = 78.7 yd³
COST = (78.7)(6) = $473

GRANULAR BACKFILL

COMPACTED - 10 $\$/yd^3$

QUANTITIES ARE THE SAME AS FOR EXCAVATION

OPTION I

12" PIPE COST = 83.3 x 10 = \$833

18" PIPE - COST = 97.2 x 10 = \$972

OPTION II

12" PIPE COST = 58.4 x 10 = \$584

18" PIPE COST = 72 x 10 = 720

SUPPORTS

PIPE TYPE (OPTION I)

EACH SUPPORT -	25'	2" GALV. PIPE	25 x \$2.30 =	57.50
	4	2" GALV. CAPS	4 x \$2.40 =	9.60
	2	CLAMPS	2 x \$2.00 =	4.00
				71.10
			x	2 (INST)
				142.2

SAY 150 \$/EACH

FOR ALIGNMENT AND STABILITY - NEED 1 SUPPORT EVERY 25' FOR OPTION 1

750/25 = 30 SUPPORTS x 150 \$/EA = \$4500

CONCRETE TYPE (OPTION II)

2 MEN FORMING, POURING & FINISHING 1 DAY - 2 x 8 x 20 =	\$320
CONCRETE - 1 yd^3	50
FORMS, STRAPS, ANCHORS, etc.	50
	\$420 EACH

270/25 = 11 SUPPORTS NEEDED x 420 = \$4620

SUMMARY - ESTIMATED COSTS

OPTION I	PIPE & FITTINGS INSTALLED	EXCAVATION	BACKFILL	GRANULAR BACKFILL	SUPPORTS	TOTAL*
A. 12" RCP	9195	1666	11202	833	4500	#27,396
B. 12" CMP	8832	1666	11202	833	4500	27,033
C. 12" CMP-COATED	11309	1666	11202	833	4500	29,510
D. 12" D.I.	10816	1666	11202	833	4500	29,017
A1. 18" RCP	13245	1944	11202	972	4500	31,724
B1. 18" CMP	13051	1944	11202	972	4500	31,530
C1. 18" CMP-COATED	16707	1944	11202	972	4500	35,186
D1. 18 D.I.	22210	1944	11202	972	4500	40,689
OPTION II						
A. 12" RCP	4085	1168	473	584	4620	#10,930
B. 12" CMP	3935	1168	473	584	4620	10,780
C. 12" CMP-COATED	5499	1168	473	584	4620	12,344
D. 12" D.I.	5470	1168	473	584	4620	12,315
A1. 18" RCP	5905	1440	473	720	4620	13,022
B1. 18" CMP	5819	1440	473	720	4620	12,936
C1. 18" CMP-COATED	7398	1440	473	720	4620	14,515
D1. 18" D.I.	9773	1440	473	720	4620	16,890

* DOES NOT INCLUDE ANY CONTRACTOR OVERHEAD OR PROFIT

FORM 1047

JOB NO. ____

SUBJECT ____

PAGE NO. 18

COMPUTED BY ____ DATE ____

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REVIEWED BY ____ DATE ____

APPROVED BY ____ DATE ____

SHEET NO. ____ OF ____

FORM 1047

CU

JOB NO. ______ PAGE NO. 19

SUBJECT ______

COMPUTED BY ______ DATE ______

CHECKED BY ______ DATE ______

REVIEWED BY ______ DATE ______

APPROVED BY ______ DATE ______

SHEET NO. ______ OF ______

CONCLUSION

EITHER OF THE MAIN OPTIONS, I OR II, IF IMPLEMENTED, WOULD GIVE THE DESIRED RESULTS. A 12" DIAMETER PIPING SYSTEM IS REQUIRED IF THE OVERFLOW SYSTEM IS SIZED BASED UPON NOT EXCEEDING THE DOWNSTREAM PIPE CAPACITY. AN 18" DIAMETER PIPING SYSTEM IS REQUIRED IF THE OVERFLOW SYSTEM IS SIZED WITH RESPECT TO THE NORMAL OUTFALL FLOW. OPTION I IS MUCH MORE COSTLY THAN OPTION II. THE REINFORCED CONCRETE PIPING SYSTEM AND THE CORRUGATED METAL PIPING SYSTEMS HAVE ESSENTIALLY THE SAME COSTS.

RECOMMENDATION

1. SELECT OPTION II DUE TO MUCH LESS COST.

2. SELECT 12" PIPING SYSTEM DUE TO LESSER COST AND TO MINIMIZE THE POSSIBILITY OF OVERFLOWING THE WEIR STRUCTURE.

3. DUE TO CLOSENESS OF ESTIMATED COSTS, SPECIFICATIONS SHOULD ALLOW CONTRACTORS TO BID EITHER REINFORCED CONCRETE PIPE OR CORRUGATED METAL PIPE.

4. COATING ON CMP WOULD ADD DURABILITY, BUT IS NOT CONSIDERED NECESSARY FOR THIS APPLICATION.

FORM 1047

CU

JOB NO. ______ PAGE NO. ______

SUBJECT ______

COMPUTED BY ______ DATE ______
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REVIEWED BY ______ DATE ______
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APPENDIX A

DRAWINGS

FORM 1047

JOB NO. ______ PAGE NO. ______

SUBJECT OPTION I - DETAILS

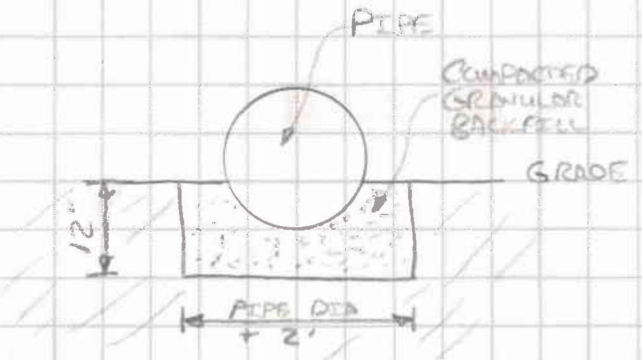
COMPUTED BY ______ DATE 11/19/85

CHECKED BY ______ DATE ______

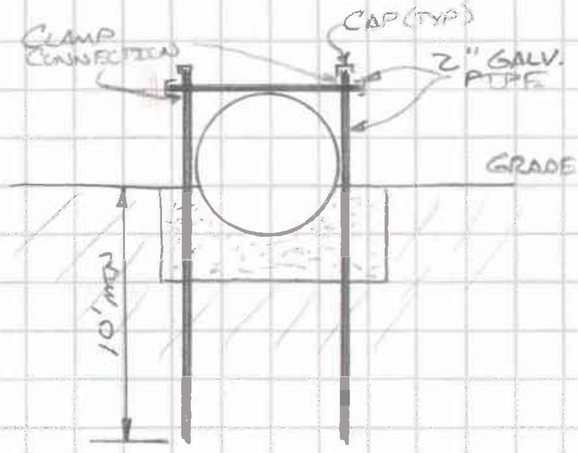
REVIEWED BY ______ DATE ______

APPROVED BY ______ DATE ______

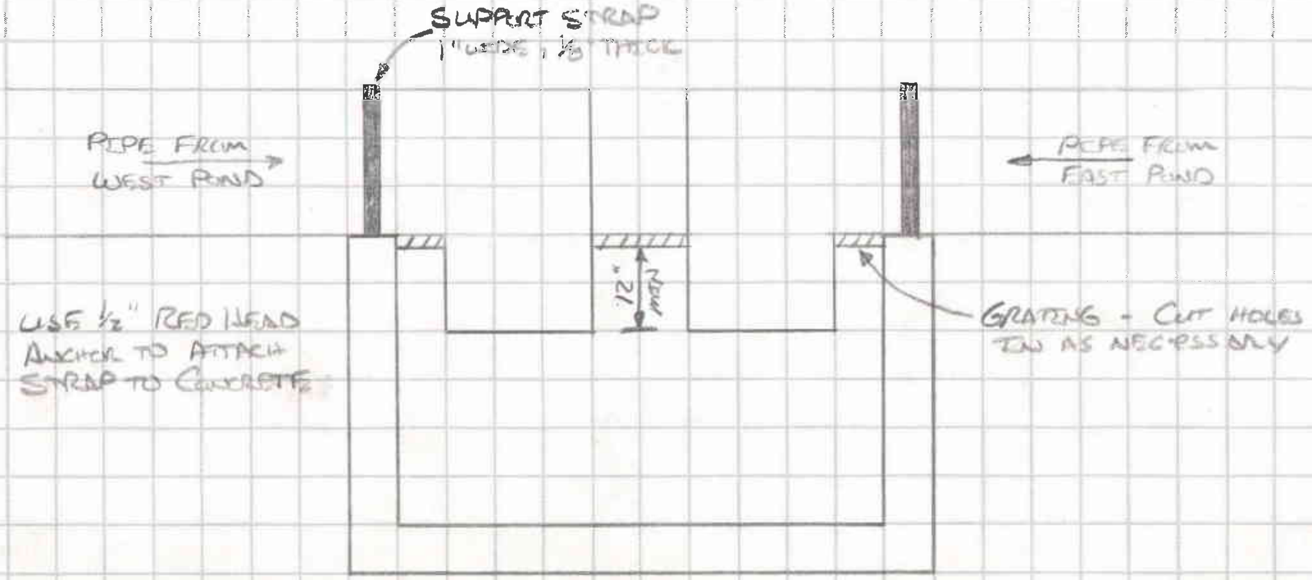
SHEET NO. ______ OF ______



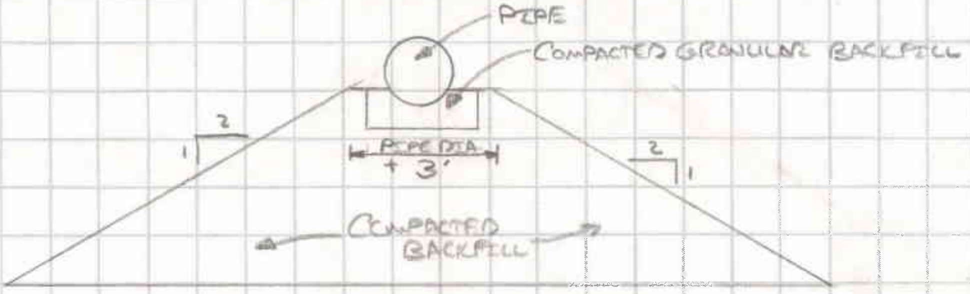
TYPICAL SECTION
N.T.S.



TYPICAL SUPPORT
N.T.S.



M.H. 45 DETAIL
N.T.S.



BACKFILL SECTION

Appendix B

Doc 07: Inspection Checklist

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE:
COUNTY: GREENE
DATE INSPECTED: 02-11-2013
WEATHER: Sunny & Warm
TEMPERATURE: 45° F.
TYPE OF DIKE: EARTH EMBANKMENT
PERSON MAKING INSPECTION: W. Painter

ITEM	YES	NO	
1. CREST	**YES**	**NO**	
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		001 Outfall / East & West Ash Ponds
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?			
F. ADEQUATE RIP-RAP PROTECTION?			
G. ANY STONE DETERIORATION?	✓		East Ash Pond Dividing Rip Rap not Sufficient
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?		✓	
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		001 Outfall / East & West Ash Ponds
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?		✓	
I. IS SEEPAGE PRESENT?		✓	
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE: 001, 002, 004
COUNTY: GREENE
TYPE OF DIKE: EARTH EMBANKMENT

DATE INSPECTED: 11/15/12
WEATHER: Clear
TEMPERATURE: 53°
PERSON MAKING INSPECTION: SD

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		001, 002, 004
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. ADEQUATE RIP-RAP PROTECTION?	✓		
G. ANY STONE DETERIORATION?		✓	
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?	✓		The Roads 001, 002, 004
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		001, 002, 004
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?	✓		
I. IS SEEPAGE PRESENT?		✓	
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE:
COUNTY: GREENE
TYPE OF DIKE: EARTH EMBANKMENT
DATE INSPECTED: 10-13-12
WEATHER: CLOUDY
TEMPERATURE: 72°
WESTER
PERSON MAKING INSPECTION:

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?		✓	
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. ADEQUATE RIP-RAP PROTECTION?	✓		
G. ANY STONE DETERIORATION?		✓	
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?		✓	
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?		✓	
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?	✓		
I. IS SEEPAGE PRESENT?		✓	
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE: 001, 002, 003, 004

COUNTY: GREENE

DATE INSPECTED: 9/24/12

WEATHER: Sunny

TEMPERATURE: 58°

TYPE OF DIKE: EARTH EMBANKMENT

PERSON MAKING INSPECTION: Shane Williams

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		002 004
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. ADEQUATE RIP-RAP PROTECTION?	✓		
G. ANY STONE DETERIORATION?		✓	
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?		✓	
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?	✓		004 Erosion SE Corner Truck Tracks
C. ARE TREES GROWING ON SLOPE?	✓		002
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?	✓		
I. IS SEEPAGE PRESENT?		✓	
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE: 002
COUNTY: GREENE
TYPE OF DIKE: EARTH EMBANKMENT
DATE INSPECTED: 8-4-12
WEATHER: Sunny /DRY
TEMPERATURE: 100°
PERSON MAKING INSPECTION: Shane Williams

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		East Pond
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. ADEQUATE RIP-RAP PROTECTION?	✓		
G. ANY STONE DETERIORATION?		✓	
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?		✓	
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		Some Small Tree's starting to grow
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?	✓		
I. IS SEEPAGE PRESENT?		✓	
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE:
COUNTY: GREENE
TYPE OF DIKE: EARTH EMBANKMENT

DATE INSPECTED: 6-12-12
WEATHER: FAIR
TEMPERATURE: 82
PERSON MAKING INSPECTION: TIM SMITH JON INGERSON GARY KLEEMAN

ITEM	YES	NO
1. CREST		
A. ANY VISUAL SETTLEMENT?		✓
B. MISALIGNMENTS		✓
C. CRACKING?		✓
2. UPSTREAM SLOPE		
A. ADEQUATE GRASS COVER?	✓	
B. ANY EROSION?		✓
C. ARE TREES GROWING ON SLOPE?		✓
D. LONGITUDINAL CRACKS?		✓
E. TRANSVERSE CRACKS?		✓
F. ADEQUATE RIP-RAP PROTECTION?	✓	
G. ANY STONE DETERIORATION?		✓
H. VISUAL DEPRESSIONS OR BULGES?		✓
I. VISUAL SETTLEMENTS?		✓
J. DEBRIS OR TRASH PRESENT?		✓
3. DOWNSTREAM SLOPE		
A. ADEQUATE GRASS COVER?	✓	
B. ANY EROSION?		✓
C. ARE TREES GROWING ON SLOPE?		✓
D. LONGITUDINAL CRACKS?		✓
E. TRANSVERSE CRACKS?		✓
F. VISUAL DEPRESSIONS OR BULGES?		✓
G. VISUAL SETTLEMENTS?		✓
H. IS TOE DRAIN DRY?	✓	
I. IS SEEPAGE PRESENT?		✓
J. SOFT OR SPONGY ZONES PRESENT?		✓

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE: 001/002/003/004
COUNTY: GREENE
TYPE OF DIKE: EARTH EMBANKMENT

DATE INSPECTED: 05/13/12
WEATHER: Clear
TEMPERATURE: 76
PERSON MAKING INSPECTION:

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		002, 004
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. ADEQUATE RIP-RAP PROTECTION?	✓		
G. ANY STONE DETERIORATION?		✓	
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?		✓	
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		001, 002
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?	✓		
I. IS SEEPAGE PRESENT?		✓	
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE:

COUNTY: GREENE

TYPE OF DIKE: EARTH EMBANKMENT

DATE INSPECTED: 23 Apr 12

WEATHER: Clear

TEMPERATURE: 53°

PERSON MAKING INSPECTION: T Hardy

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?	✓		East pond
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. ADEQUATE RIP-RAP PROTECTION?	✓		
G. ANY STONE DETERIORATION?		✓	
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?		✓	
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?		✓	
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?		✓	outfall 001 is dry. The outfall on the Southeast of the property is draining.
I. IS SEEPAGE PRESENT?	✓		
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE: Ash Pond III

COUNTY: GREENE

TYPE OF DIKE: EARTH EMBANKMENT

DATE INSPECTED: 3/19/12

WEATHER: Cloudy

TEMPERATURE: 75

Steven Lee

PERSON MAKING INSPECTION:

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		✓	
B. MISALIGNMENTS		✓	
C. CRACKING?		✓	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?		✓	
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. ADEQUATE RIP-RAP PROTECTION?	✓		
G. ANY STONE DETERIORATION?		✓	
H. VISUAL DEPRESSIONS OR BULGES?		✓	
I. VISUAL SETTLEMENTS?		✓	
J. DEBRIS OR TRASH PRESENT?		✓	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	✓		
B. ANY EROSION?		✓	
C. ARE TREES GROWING ON SLOPE?		✓	
D. LONGITUDINAL CRACKS?		✓	
E. TRANSVERSE CRACKS?		✓	
F. VISUAL DEPRESSIONS OR BULGES?		✓	
G. VISUAL SETTLEMENTS?		✓	
H. IS TOE DRAIN DRY?	✓		
I. IS SEEPAGE PRESENT?		✓	
J. SOFT OR SPONGY ZONES PRESENT?		✓	

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE: East Ash Pond Dam

COUNTY: GREENE

DATE INSPECTED: 12-5-11

WEATHER: Overcast

TEMPERATURE: 34°

TYPE OF DIKE: EARTH EMBANKMENT

PERSON MAKING INSPECTION: K. King

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		X	
B. MISALIGNMENTS		X	
C. CRACKING?		X	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	X		
B. ANY EROSION?		X	
C. ARE TREES GROWING ON SLOPE?		X	
D. LONGITUDINAL CRACKS?		X	
E. TRANSVERSE CRACKS?		X	
F. ADEQUATE RIP-RAP PROTECTION?	X		
G. ANY STONE DETERIORATION?		X	
H. VISUAL DEPRESSIONS OR BULGES?		X	
I. VISUAL SETTLEMENTS?		X	
J. DEBRIS OR TRASH PRESENT?		X	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	X		
B. ANY EROSION?		X	
C. ARE TREES GROWING ON SLOPE?		X	
D. LONGITUDINAL CRACKS?		X	
E. TRANSVERSE CRACKS?		X	
F. VISUAL DEPRESSIONS OR BULGES?		X	
G. VISUAL SETTLEMENTS?		X	
H. IS TOE DRAIN DRY?		X	
I. IS SEEPAGE PRESENT?		X	
J. SOFT OR SPONGY ZONES PRESENT?			

SWPS DIKE INSPECTION CHECKLIST

NAME OF DIKE: West Bottom Ash Pond

COUNTY: GREENE

DATE INSPECTED: 12-5-11

WEATHER: overcast

TEMPERATURE: 34°

TYPE OF DIKE: EARTH EMBANKMENT

PERSON MAKING INSPECTION: K. King

ITEM	YES	NO	
1. CREST			
A. ANY VISUAL SETTLEMENT?		X	
B. MISALIGNMENTS		X	
C. CRACKING?		X	
2. UPSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	X		
B. ANY EROSION?		X	
C. ARE TREES GROWING ON SLOPE?		X	
D. LONGITUDINAL CRACKS?		X	
E. TRANSVERSE CRACKS?		X	
F. ADEQUATE RIP-RAP PROTECTION?	X		
G. ANY STONE DETERIORATION?		X	
H. VISUAL DEPRESSIONS OR BULGES?		X	
I. VISUAL SETTLEMENTS?		X	
J. DEBRIS OR TRASH PRESENT?		X	
3. DOWNSTREAM SLOPE			
A. ADEQUATE GRASS COVER?	X		
B. ANY EROSION?		X	
C. ARE TREES GROWING ON SLOPE?		X	
D. LONGITUDINAL CRACKS?		X	
E. TRANSVERSE CRACKS?		X	
F. VISUAL DEPRESSIONS OR BULGES?		X	
G. VISUAL SETTLEMENTS?		X	
H. IS TOE DRAIN DRY?			
I. IS SEEPAGE PRESENT?		X	
J. SOFT OR SPONGY ZONES PRESENT?		X	

Appendix C

Photographs

Photograph 5.1. Crest of Embankment Dividing East and West Impoundments Looking South

Photograph 5.2. Crest of South Embankment showing West Impoundment Looking West

Photograph 5.3. Crest of South Embankment showing East Impoundment Looking West (showing traces of gravel pavement)

Rock berm across impoundment (Typ.)

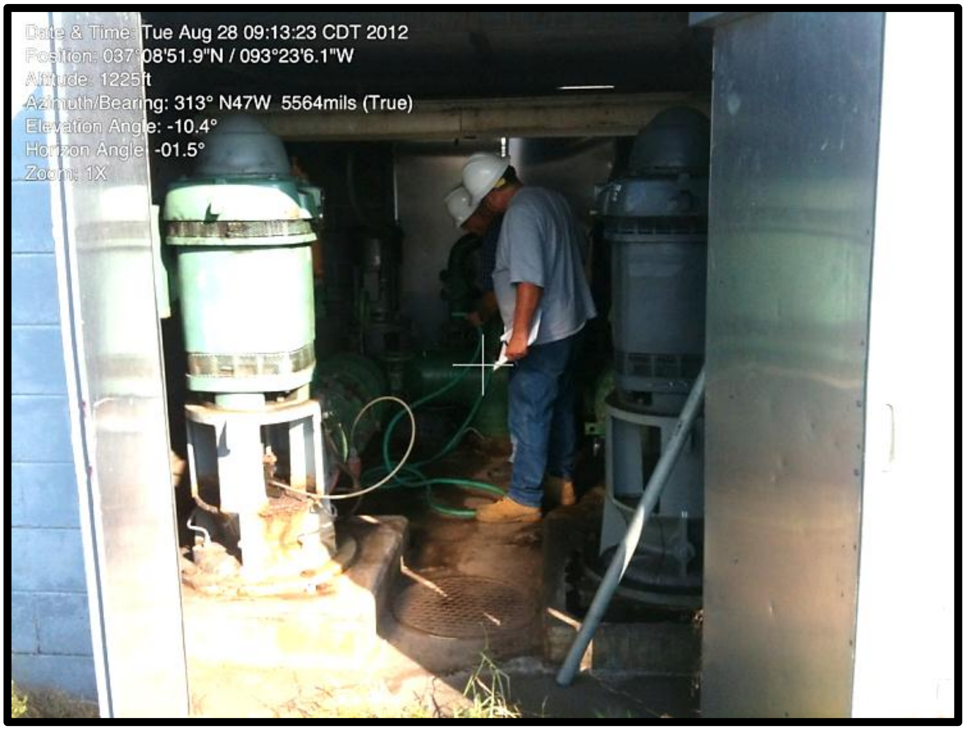
Photograph 5.4. Inside Slope of Embankment Dividing East and West Impoundments Showing East Impoundment Looking North

Photograph 5.5. Inside Slope of West Embankment for West Impoundment Looking North

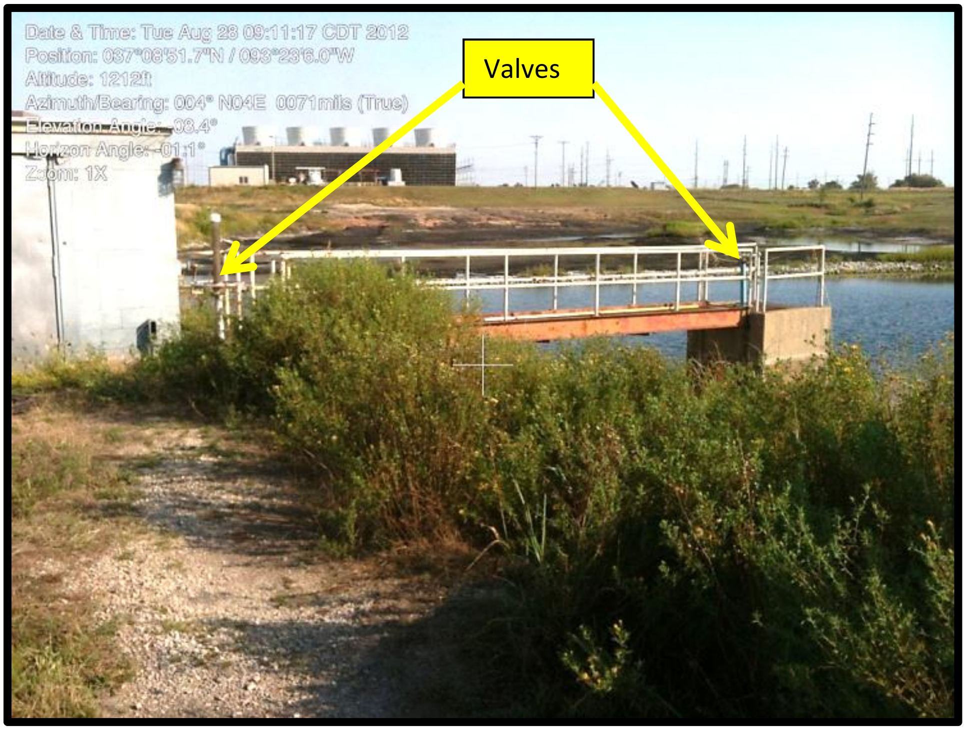
Photograph 5.6. Inside Slope of West Embankment of West Impoundment Looking South

Photograph 5.7. Outside Slope of South Embankment (Dam) of East Impoundment Looking West (Typ.)

Photograph 5.8. 15-in Overflow Pipe for West Impoundment Looking South



Photograph 5.9. Pump Station Regulating Outlets for both Impoundments



Photograph 5.10. Valves Regulating East Impoundment Outlet Looking North

Photograph 5.11. Covered Outlet Weir with Valve for both Impoundments (also showing overflow pipes)

Appendix D
Photo GPS Locations

Site: Southwest Power Station
Datum: NAD 1983
Coordinate Units: Decimal Degrees

Photograph	Latitude	Longitude
5.1	37.14900	-93.38564
5.2	37.14744	-93.38508
5.3	37.14847	-93.38417
5.4	37.14769	-93.38478
5.5	37.14717	-93.38578
5.6	37.14964	-93.38733
5.7	37.14769	-93.38444
5.8	37.14775	-93.38514
5.9	37.14775	-93.38503
5.10	37.14769	-93.38500
5.11	37.14719	-93.38506

PW:\\PW_XM1\Documents\5111\93083_Southwest\03 Reports and Studies\09 CADD Figures and Graphics\B004PHFG.DWG

AERIAL PHOTOGRAPH SOURCE: GOOGLE EARTH PRO.

CDM Smith

SOUTHWEST POWER STATION
SPRINGFIELD, MISSOURI
PHOTOGRAPH LOCATIONS PLAN