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

Columbia Power & Light Department

Columbia Municipal Power Plant
Columbia, 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 Columbia Municipal Power Plant's CCW management unit is based on a review of available documents, site assessments conducted by CDM Smith on August 22 and 23, 2012, and technical information provided subsequent to the site visit. In summary, the CCW impoundment at the Columbia Municipal Power Plant is classified as **POOR** for continued safe and reliable operation; static and seismic engineering studies for embankment stability to determine current safety factors have not been performed on the embankments. The impoundment is also given a Hazard Potential Rating of **HIGH** due to urban and commercial development downstream of the impoundment.

It is critical to note that the condition of the embankment(s) 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 embankment(s) will continue to represent the condition of the embankment(s) 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 an impoundment safety assessment at the Columbia Municipal Power Plant (CMPP), owned by Columbia Water & Light Department (CWLD) in Columbia, Missouri. CMPP had one CCW impoundment that received coal ash slurry from the plant. 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 management unit.

A site visit was conducted by CDM Smith representatives on August 22 and 23, 2012, to collect relevant information, to inventory the impoundment, and perform a visual assessment of the impoundment.

1.3 CONCLUSIONS

Conclusions are based on visual observations during the assessment on August 22 and 23, and review of technical documentation provided by CMPP.

1.3.1 Conclusions Regarding the Structural Soundness of the Management Unit(s)

A geotechnical investigation was performed by Terracon of Columbia, Missouri near the southeast corner of the impoundment. A report was issued by Terracon, dated March 2, 2004 with information on subsurface conditions and laboratory test results for soils encountered in borings drilled in the area (**Appendix C**). The report did not contain analysis of stability, seepage and/or settlement of the embankments of the existing impoundment

Information provided by CMPP did not include engineering analysis of the structural soundness of the impoundment (i.e. stability analyses). In general, engineering analyses for design of private facilities (the pond was originally constructed on private property for recreational purposes in the late 1800's) was much less common than it is today, and makes it unlikely that engineering analysis was performed for the dam forming the pond.

CDM Smith is unable to make an assessment of the structural soundness of the management unit, due to the lack of documentation. No apparent structural damage or evidence of previous repairs was observed in the impoundment during CDM Smith's site visit. From visual observations, the embankments appeared structurally sound, with no current evidence of erosion.

1.3.2 Conclusions Regarding the Hydrologic/Hydraulic Safety of the Management Unit(s)

A CMPP plant representative (Christian Johanningmeier, the Power Production Superintendent), indicated the CCW impoundment has not been overtopped since its first use as a CCW pond beginning in the 1950's. The CMPP representative also stated there has been no seepage failure of the CCW impoundment embankments. Visual examination of the impoundment earth structures did not show evidence of previous overtopping or seepage on the slopes of the embankment or in the area of the toe.

A United States Army of Corps of Engineers (USACE) Phase I inspection of the CCW impoundment was performed in 1980 and a follow-up report was prepared. A copy of this report was provided to CDM Smith during the site visit. The report found the CCW impoundment could only pass 50 percent of the Probable Maximum Precipitation (PMP) event without overtopping, According to the report, the impoundment outlet structure and drain line have the capacity to discharge water at a rate of about half of what is necessary to accommodate a PMP event. Currently, the Missouri Department of Natural Resources (MDNR) requires that the impoundment pass 75 percent of a PMP event. Therefore, a 75 percent PMP event would potentially result in overtopping (discharge of ash slurry) of the CCW impoundment embankment crest. The USACE report also mentioned three discharge pipes for the dam: a 4-inch diameter pipe, an 8-inch diameter pipe, and a 10 inch diameter pipe. CDM Smith observed only the 8-inch diameter pipe during the site visit; this pipe is also shown on the topographic survey drawing CMPP provided to CDM Smith. The other two pipes were not shown on the survey drawings, and CDM Smith did not observe them during the site visit. The absence of these two additional pipes could further reduce the capacity of the impoundment to pass the 75 percent PMP event.

Measurements of the embankment crest show a drop in crest elevation. Based on elevations provided in the USACE report and elevations provided in a recent topographic survey by CMPP, the crest of the dam portion of the impoundment confining embankment dropped from El. 773.0 in 1980, to El. 770.0 in 2012.

This drop in elevation could be the result of consolidation of the embankment and underlying foundation soils, or the result of differences in measurement of the crest elevation resulting from use of different datum during the USACE and recent topographic survey. Elevations in the USACE report referred to Mean Sea Level (no clear definition of the datum for this is given), while the recent CMPP topographic survey used the NAVD 1988 as a reference datum.

The drop in crest elevation reduces the freeboard above the normal pond level and decreases the excess capacity for storage of water in the case of heavy rainfall or a 75 percent PMP event. Regardless of some uncertainty in the crest elevations, the CMPP representative indicated that there has not been an overtopping of the impoundment since the USACE report was issued in 1980.

Although the impoundment has reportedly not been overtopped since 1980, there is no hydrologic/hydraulic analysis to confirm the impoundment can pass a 75 percent PMP event without overtopping. CDM Smith also understands that modifications have not been made to the embankment since the USACE report was issued. As the pond fills further with ash, the volume available for flood storage will diminish, and could eventually be less than used in the analysis, unless ash is excavated or other measures taken to restore available flood storage.

It is, therefore, CDM Smith's opinion that the hydrologic/hydraulic safety of the management unit is inadequate at the present time.

1.3.3 Conclusions Regarding the Adequacy of Supporting Technical Documentation

Technical documentation provided by the USACE inspection report of the impoundment and a recent survey of the impoundment and surrounding areas provided by the plant representative provided some of the documentation necessary to evaluate the various safety aspects of the impoundment. This information lacked detail on subsurface conditions, engineering analysis and historical records on performance of the facility. Therefore, supporting documentation was not sufficient with regard to a complete analysis of impoundment safety.

1.3.4 Conclusions Regarding the Description of the Management Unit(s)

The description of the management unit provided by CMPP for CDM Smith's review appears to be consistent with the visual observations made by CDM Smith during the site assessment. However, the information provided by CMPP did not include record drawings for the management unit to assess discrepancies with the description provided in the 1980 USACE report.

1.3.5 Conclusions Regarding the Field Observations

CDM Smith staff was provided access to all areas of the management unit for observation and inspection by plant personnel. In addition, a plant representative accompanied CDM Smith staff during visual inspection of the impoundment. No visual evidence of prior ash slurry releases, embankment failures, or repairs were observed during CDM Smith's site visit. In general, the embankments appeared to be in fair condition, with most of the vegetation on embankment outside slopes of the impoundment mowed allowing visual examination. Some inside slopes of the impoundment embankments (primarily forming the northeast and east perimeter of the impoundment) contained overgrown vegetation and trees with diameters as large as 36 inches.

Shrinkage cracks were observed on the crest of the west embankment, and also erosion features on the inside slopes of the west and south embankments. The collection basin for the outfall drain of the impoundment appeared to be in good condition, with water flowing freely through the top of the basin at the time our visit.

1.3.6 Conclusions Regarding the Adequacy of Maintenance and Methods of Operation

Documentation was not available to confirm these inspections. Observations of the embankment slopes showed evidence of recent mowing, and the plant representative indicated mowing occurs on a periodic basis (as needed). The plant representative also indicated the occasional need for removal of burrowing rodents and repair of the embankment associated with these animals. Documentation on the frequency of maintaining these mowed areas and removal of rodents was not included in information provided to CDM Smith by CMPP.

The limited amount of data available documenting the maintenance and operation procedures for the management unit is not sufficient to allow CDM Smith to make an evaluation of the adequacy of the maintenance and operations for the impoundment. The lack of regular documentation for current maintenance and methods of operation of this management unit makes these practices inadequate.

1.3.7 Conclusions Regarding the Adequacy of the Surveillance and Monitoring Program

According to the plant representative, the impoundment is inspected twice a year. The CMPP surveillance, recording, and monitoring program appears to comply with MDNR National Pollutant Discharge and Elimination System (NPDES) permit requirements. The NPDES permit does not require groundwater monitoring for the CMPP management unit since ash is dredged from the pond on a routine demand.

1.3.8 Classification Regarding Suitability for Continued Safe and Reliable Operation

Based on visual observations of the management unit, review of available documentation (i.e., USACE evaluation and Terracon report) and conversations with the plant representative, the impoundment will generally perform in a safe manner with regard to structural stability during a 50 percent PMP event.

Information provided by CMPP did not include engineering design information for the impoundment. Due to the lack of design information, CDM Smith believes the management unit's performance is vulnerable to potential problems during a variety of conditions beyond a 50 percent PMP.

The CMPP did not have a formal inspection, maintenance and operation programs. It is the opinion of CDM Smith that the condition of the CCW impoundment at the Columbia Municipal Power Plant for continued safe operation is **POOR** for continued safe and reliable operation.

1.4 RECOMMENDATIONS

1.4.1 Recommendations Regarding the Hydrologic/Hydraulic Safety

The previous hydrologic safety evaluation performed by the USACE found the impoundment did not meet requirements for drainage capacity for a design storm (75 percent of a PMP event.) Based on the previous hydrologic deficiencies and lack of documented improvements to the embankments associated with items, CDM Smith recommends that new hydrologic/hydraulic analysis be performed for the ash pond. This evaluation should include required actions to achieve safe and reliable operation of the facility, taking into consideration current operations and conditions.

1.4.2 Recommendations Regarding the Description of the Management Unit(s)

A current topographic survey, dated March 2012, was provided to CDM Smith by CMPP during the site visit. The elevations included on the drawings reference the North American Vertical Datum of 1988 (NAVD 88), while elevations referenced in the USACE Phase I report references the mean sea level (MSL) datum. The USACE Phase I report indicates the crest of the dam was at El. 773.0 MSL. The March 2012 survey shows the crest at El. 770.0 (NAVD 88). CDM Smith recommends a revision to the March 2012 survey drawings to include the conversion between NAVD88 and MSL to facilitate comparison of the dam's physical attributes over time.

1.4.3 Recommendations Regarding the Field Observations

The following are CDM Smith's recommendations:

a. The state of Missouri requires coal plants to have an emergency action plan (EAP) in case of a CCW impoundment release. CDM Smith was not provided with an EAP when requested. An EAP should be prepared for the impoundment.

b. Shrinkage cracks on the crest of the west embankment (dam) should be documented; backfilled and grass cover should be established to protect the surface from shallow erosion and slope failures. Irrigation and periodic inspections should be conducted to maintain these grass covered slopes.

c. Erosion was observed on the inside slopes of the west and south embankments. To restore areas of erosion, it is recommended to place and compact structural fill or riprap in eroded areas and grade to adjacent contours.

d. Animal burrows were observed and have reportedly been an ongoing problem. Areas disturbed by animal activity should be documented, the animals removed, and the burrows backfilled with compacted structural fill to protect the integrity of the embankments.

e. The removal of trees, shrubs and bushes on or near the embankment is recommended. The greatest density of this vegetation was observed along the east and north-east portions of the embankment. Vegetation removal should include the majority of roots within the footprint of the embankment. Compacted structural fill should be used to backfill excavations and holes made in the embankment areas before restoring final grades with compacted native materials free of debris and organic materials.

1.4.4 Recommendations Regarding the Surveillance and Monitoring Program

The CMPP surveillance, recording, and monitoring program appears to comply with MDNR NPDES permit requirements. The NPDES permit does not require groundwater monitoring for the CMPP management unit. Although there is no MDNR requirement for groundwater monitoring, CDM Smith recommends a system of groundwater monitoring wells be installed and regular measurements of water levels be recorded.

Although some potential inconsistences exist in regard to the datum used to measure the crest elevation, there has been a drop in crest elevation of the dam. CDM Smith recommends CMPP establish a settlement monitoring program for the embankment crest. Records of settlements should be kept regularly in order to monitor and address any unusual embankment movements. The settlement monitoring program could be part of a formal inspection program developed for the facility.

1.4.5 Recommendations Regarding Continued Safe and Reliable Operation

CDM Smith recommends the hydrologic/hydraulic analysis for drainage of the impoundment during a PMP event be completed within the next year. The analysis should necessarily ensure the impoundment can pass 75 percent of a PMP event without overtopping. Other recommendations, made above, should also be addressed within the next year if possible to ensure continued safe and reliable operation.

1.4.6 Recommendations Regarding the Technical Documentation for Structural Stability

It is recommended that a qualified professional engineer evaluate the static and seismic stability on representative embankment cross sections and perform liquefaction analyses for the ash pond. Also, because there is a lack of adequate information regarding foundation construction materials of the embankment, CDM recommends that boring and geotechnical analyses, including liquefaction analyses, be performed. If geotechnical analysis shows that foundation soils in the embankment are not susceptible to liquefaction, informal liquefaction analyses could be adequate.

1.5 PARTICIPANTS AND ACKNOWLEDGMENT

1.5.1 List of Participants

Company	Name
Columbia Municipal Power Plant	Christian Johanningmeier
CDM Smith Inc.	Clement Bommarito
CDM Smith Inc.	Albert Ayenu-Prah

1.5.2 Acknowledgment and Signature

CDM Smith acknowledges that the management unit referenced herein has been assessed on August 22 and August 23, 2012.

Clement Bommarito, P.E.	Albert Ayenu-Prah, Ph.D.

Section 2

DESCRIPTION OF THE COAL COMBUSTION WASTE MAMAGEMENT UNIT

2.1 LOCATION AND GENERAL DESCRIPTION

The Columbia Municipal Power Plant is located in Boone County at 1501 Business Loop 70 East, Columbia, Missouri 65201. The plant is located on the south side of Moore's Lake Road (Business Loop 70E), at the intersection of Edison Street as shown in **Figure 2-1**.

The plant has one Coal Combustion Waste management unit (CCW impoundment) that stores both fly ash and bottom ash slurries. An aerial view of the impoundment (locally known as Moore's Lake) is shown in **Figure 2-2**. The impoundment is located within the Columbia metropolitan area, between Interstate 70 and Business Loop 70. The CCW impoundment's perimeter embankments are approximately 2,800 feet long and approximately 15 feet high.

Table 2.1 shows a summary of the approximate size and dimensions of the CCW impoundment.

Table 2.1 – Summary of CCW Impoundment Dimensions and Geometry

	CCW Impoundment
Embankment Height (ft)[1]	30
Average Crest Width (ft)	15
Length (ft)[2]	2800
Interior Slopes H:V	3:1
Exterior Slopes H:V	4:1

[1]*Based on information on MDNR's website*

[2]*Length measured along perimeter crest of impoundment*

2.1.1 Horizontal and Vertical Datum

The topographic survey drawings CMPP provided CDM Smith reference the North American Horizontal Datum of 1983 (NAD 83). The elevations on the drawings reference the North American Vertical Datum of 1988 (NAVD 88).

2.1.2 Site Geology

The site is located on an unnamed tributary of Bear Creek in the Dissected Till Plains Section of the central Lowland Physiographic Province. Loess-mantled Kansas drift covers the surface of most of the Dissected Till Plains Section. The section is distinguished from the Young Drift Section to the north and from the Till Plains on the east b the stage it has reached in the post-glacial erosion cycle. Broadly generalized, this section is a nearly flat till plain sub-mature to mature in its erosion cycle.

The topography at the site is rolling to hilly with U- to V-shaped valleys. Elevation of the ground surface ranges from 710 feet above M.S.L. at the CCW impoundment to 750 feet above M.S.L. approximately 0.25 miles from the site. The regional geology beneath the glacial outwash deposits in the CCW impoundment area as shown on the Geologic Map of Missouri (1979) consist of Pennsylvania age undifferentiated age rocks, the Pennsylvania Marmaton-Cherokee Group (cyclic deposits of shale, limestone and sandstone), Mississippian age Burlington Limestone (cherty, grayish brown, sandy limestone), Devonian age rocks of Sulphur Springs Group (Glen Park Limestone and Grassy Creek Shale).

2.2 COAL COMBUSTION RESIDUE HANDLING

2.2.1 Fly and Bottom Ash

The CCW impoundment is used as a settling pond for CCW, receiving the following effluents from the power plant through three separate inlet pipes:

- Bottom ash and fly ash slurries , and boiler blow-down – approximately 10-inch metal pipe;
- Cooling towers blow-down and overflow slurries – approximately 7-inch PVC pipe; and
- Stormwater runoff – approximately 18-inch concrete pipe.

The ash slurry is discharged into the south-eastern portion of the impoundment. As the water evaporates from the ash slurry, it takes a more-solid form, separated out from the slurry and spread to air-dry. Dried ash is stockpiled, and in some cases distributed for other uses (such as traction control during winter and mine stabilization) or disposed offsite. There was no documentation for CDM Smith's review regarding ash and related impoundment operations at the time of the assessment.

2.2.2 Boiler Slag

Columbia Municipal Power Plant does not produce boiler slag.

2.2.3 Flue Gas Desulfurization Gypsum

Columbia Municipal Power Plant does not have flue gas desulfurization equipment.

2.3 SIZE AND HAZARD CLASSIFICATION

According to a 1980 report on Moore's Lake Dam by the USACE, St. Louis District (**See Appendix C**), the CCW impoundment dam was determined to fall in the "small" category as defined in the *"Recommended Guidelines for Safety Inspection of Dams"*. The size classification was a result of the impoundment having a capacity of about 45 acre-feet, and the height of the contained slurry falling within the range of 25 to 40 feet. The size of the dam forming the current impoundment is about the same as it was during the USACE study in 1980, and therefore would still be considered in the "small" size category.

The USACE report classified the dam as having a "high" hazard potential in the National Inventory of Dams. The classification was based on the determination that a failure in the impoundment perimeter would result in CCW discharge causing excessive damage to downstream property, and could result in loss of life.

The MDNR categorizes Moore's Lake Dam as Class I in terms of the Downstream Environment (Missouri Regulation 10 CSR 22-,040 describes three downstream environmental classes for the downstream environmental zone: classifications range from 1 to 3 with a Class 1 the highest hazard potential). According to the MDNR's website, a Class I dam's downstream zone contains 10 or more permanent dwellings or any public building.

According to the USACE Guidelines for Safety Inspection of Dams (1979) (ER 1110-2-106), impoundments are categorized per **Table 2.2**

Table 2.2 – USACE ER 1110-2-106 Size Classification		
Category	Impoundment	
	Storage (Ac-ft)	Height (Ft)
Small	50 to < 1000	25 to < 40
Intermediate	1000 to < 50,000	40 to < 100
Large	> 50,000	> 100

The total storage capacity of the CCW impoundment is approximately 15 Acre-feet. The impoundment has a maximum embankment height of 30 feet. Based on storage capacity and embankment heights, the CCW impoundment is considered a SMALL impoundment.

It is not known if the Station impoundments currently have an assigned Hazard Potential Classification. Based on the USEPA classification system as presented on Page 2 of the USEPA checklist (**Appendix**) 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
CCW Impoundment	High Hazard	High economic loss Loss of human life expected

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

The CCW impoundment stores both fly ash and bottom ash slurries. The amount of CCW slurry stored in the unit and capacities are summarized in **Table 2.4**. The impoundment is currently active and one acre is used for storing dry ash on the southern portion of the pond and is not considered an active area of the pond that receives sluiced ash. CCW is sluiced into the southern portion of the pond.

Table 2.4 – Summary of CCW Impoundment Capacity	
CCW Impoundment	
Surface Area (acre)[1]	7
Storage Volume – Normal Pool (Acre-Feet)[2]	15
Storage Volume – Top of Embankment (Acre-Feet) [2]	45

[1]*Based on information on MDNR's website*

[2]*Based on data in USACE St. Louis Report on Moore's Lake Dam dated December 1980.ength measured along perimeter crest of impoundment*

2.5 PRINCIPAL PROJECT STRUCTURES

2.5.1 Earth Embankment

The exterior slopes of the CCW impoundment's perimeter embankments were approximately 4H:1V and the interior slopes were approximately 3H:1V, with crest widths ranging from 20 feet for the west and north embankments, to 10 feet wide for the east embankment. The crest of the south embankment is not clearly defined because it is continuous with the adjacent plant grades to the south. The height of the west embankment, considered the "dam" (downstream containment) portion of the impoundment, is listed as 30 feet on MDNR's website. The recent topographic survey (2012) confirmed the height of the dam and indicated the lowest crest elevation of the embankment along the perimeter of the impoundment is approximately El. 770.0 (NAVD88).

2.5.2 Outlet Structure

The outlet structure serving to discharge water from the ash pond is located near the southwest corner of the impoundment. This was the only outlet structure observed during CDM Smiths site visit (4-inch and 10-inch diameter outlet pipes were referenced in the USACE report, but could not be located), and consisted of an 8-inch diameter ductile iron (DI) pipe with the following geometry:

A. Top-of-Pipe elevation of 765.8 for the horizontal portion of the pipe;

B. Top of the outfall elevation of 769.3, with a flow elevation of 767.5;

C. Connected to the DI pipe is an 8-inch diameter polyvinyl chloride (PVC) pipe that directs discharge water to a manhole located near the midpoint of the west side of the dam, close to the toe of the slope;

D. The manhole is connected to a 12-inch diameter reinforced concrete pipe (RCP) directing the water by gravity flow to an unnamed tributary of Bear Creek.

2.6 CRITICAL INFRASTRUCTURE WITHIN FIVE MILES DOWN GRADIENT

Critical infrastructure within five miles down gradient of the dam includes the City of Missouri Water and Light storage facilities, Interstate Highway 70, State Highway 763, an area of commercial development that includes a health care facility, and residential subdivisions. **Figure 2-3** shows a critical infrastructure map of the area.

A breach of one or more of the embankments forming the impoundment would inundate areas downstream containing infrastructure while also creating a high risk of loss of human life.

Section 3

SUMMARY OF RELEVANT REPORTS, PERMITS, AND INCIDENTS

3.1 SUMMARY OF REPORTS ON THE SAFETY OF THE MANAGEMENT UNIT

At the time of CDM Smith's onsite assessment, representatives of the plant did not provide safety reports or related documentation over the time the management unit has been in operation. According to the representatives, there have been no known structural or operational problems associated with the CCW impoundment. However, to date no documentation has been available to confirm or disprove this claim.

3.2 SUMMARY OF LOCAL, STATE, AND FEDERAL ENVIRONMENTAL PERMITS

Under the National Pollutant Discharge Elimination System (NPDES), the power plant is permitted by the MDNR, authorizing discharge of water from the impoundment into Moore's Lake. Water discharged into this lake will enter an outfall structure discharging excess water from the lake into Bear Creek via an unnamed tributary. The permit number is MO-0004979, with effective and expiration dates of July 6, 2012 and July 5, 2017, respectively.

3.3 SUMMARY OF SPILL/RELEASE INCIDENTS

According to the CMPP representatives, there have been no known spills or releases related to the impoundment. No documentation was available to confirm or disprove this claim.

Section 4

SUMMARY OF HISTORY OF CONSTRUCTION AND OPERATION

4.1 SUMMARY OF CONSTRUCTION HISTORY

4.1.1 Original Construction

Construction of Moore's Lake Dam (MLD) began in the late 1800's for recreational purposes. Completion of the dam occurred in 1904. A CMPP plant representative indicated MLD was first used as a CCW pond in the 1950's. MDNR's website states MLD is 30 feet high. Engineering Surveys and Services (ESS) performed a topographic survey of the impoundment and surrounding area in March, 2012. The ESS survey did not include the measurements necessary to confirm the total height of the dam. Design drawings or as-built drawings for the impoundment were also not available for comparison to MDNR records.

The CCW impoundment was originally constructed as a recreational site referred to as Moore's Lake. Overall grades in the area of the lake slopes down to the west/northwest. The lake was formed by constructing a dam northwest of the lake's current location to collect and retain surface water that flowed to the northwest (downstream) at the time of its construction (side-hill configuration). CMPP did not provide CDM Smith with information related to the original dam design parameters or the materials used on construction of the dam.

Moore's Lake Dam is a side-hill, earthen dam, with a pool area of approximately 7 acres. From the ESS survey drawings, the outside slope of the dam is approximately 4H: 1V, with a crest width of approximately 20 feet. The lowest dam crest elevation was approximately El. 770.0, with a pool elevation (measured on October 5, 2011) at El. 768.0. The embankment crest was generally higher in elevation (El. 778.0+) along portions of the east perimeter of the impoundment.

4.1.2 Significant Changes/Modifications in Design since Original Construction

The plant representative interviewed by CDM Smith was not aware of any major changes or modifications to the CCW impoundment design. The USACE report (describing an interview with a plant representative, Mr. Gary Anderson) indicates that the height of the dam was increased by 1 or 2 feet in 1970. Mr. Anderson also indicates he does not know the purpose of this modification.

The USACE Phase I report indicated the average exterior slope of the dam embankment (impoundment's west embankment) was 1.5H: 1V. The March 2012 ESS survey shows the exterior slope of the impoundment's west embankment is approximately 4H: 1V. CMPP plant representatives were not aware of any modifications made to the exterior slope of the impoundment's west embankment.

4.1.3 Significant Repairs/Rehabilitation since Original Construction

Visual observations of the management unit indicate no significant repairs/rehabilitations have been made to the CCW impoundment, and discussions with plant personnel confirmed there have not been any major repairs. Minor backfilling of rodent excavations have occurred in the past.

4.2 SUMMARY OF OPERATIONAL PROCEDURES

4.2.1 Original Operational Procedures

The plant representative did not have a written manual of operational procedures for the management unit. The plant representative provided a verbal description of the procedures for operation of the impoundment as follows:

1. Wet CCW is sluiced to the southeast corner of the ash pond as a product of the regular cleanout of the coal furnaces.
2. The sluiced ash discharges into the southeast corner of the impoundment, moving north and eventually west into the largest portion of the pond.
3. Over time, the ash from the sluiced water-ash mixture settles out of suspension, dropping to the bottom of the pond.
4. The water produced by the sedimentation process gradually migrates toward the outfall structure in the southwest corner of the impoundment where it is collected and discharged by gravity-flow into an unnamed tributary of Bear Creek.
5. The ash sediment accumulating at the bottom of the impoundment is periodically dredged out and placed in areas adjacent on the south side of the pond at/or above the water level of the pond to allow the materials to dry.
6. The dry ash materials are stockpiled in the central portion of the impoundment south perimeter, where it can eventually be transported offsite.

4.2.2 Significant Changes in Operational Procedures and Original Startup

There are no written operational procedures specifically addressing the management unit. Based on procedures described verbally by the plant representative and a history of procedures in the past, there have been no significant changes in operational procedures related to the management unit since original startup.

4.2.3 Current Operational Procedures

The plant representative did not indicate that significant changes to operation of the management unit have occurred since use of the unit as a CCW impoundment.

4.2.4 Other Notable Events since Original Startup

Based on discussions with the plant representative, there have been no notable events since original startup of the CCW impoundment since its first use for this purpose.

Section 5
FIELD OBSERVATIONS

5.1 PROJECT OVERVIEW AND SIGNIFICANT FINDINGS

CDM Smith performed a visual assessment at the Columbia Municipal Power Plant on August 22 and August 23, 2012. The task included performing a visual assessment of the ash pond, 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 a power plant representative, Christian Johanningmeier, who is the Power Production Superintendent.

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. Two USEPA forms were completed on-site for the impoundment during the site visit:

- A Coal Combustion Dam Inspection Checklist, and
- CCW Impoundment Inspection Form.

Copies of the forms are included in Appendix B. Photographs and photograph locations are included in **Appendix D**.

The weather on the days of the site visit was mostly clear with a high temperature of 99 degrees Fahrenheit and a low temperature of 61 degrees Fahrenheit. According to the National Weather Service, daily precipitation prior to, and on the day of, the assessment is shown in **Table 5.1**.

Table 5.1: Daily Total Precipitation for Week prior to Assessment

Site Visit on August 22 and August 23, 2012		
Day	**Date**	**Precipitation (inches)**
Wednesday	August 15	0.00
Thursday	August 16	0.00
Friday	August 17	0.00
Saturday	August 18	0.00
Sunday	August 19	0.00
Monday	August 20	0.00
Tuesday	August 21	0.00
Wednesday	August 22	0.00
Thursday	August 23	0.00
Total	**August 15 – 23**	**0.00**

5.2 CCW IMPOUNDMENT

The CCW impoundment was originally constructed as a recreational site referred to as Moore's Lake. Overall grades in the area of the pond slopes down to the west/northwest. The lake was formed by constructing a dam northwest of the lake's current location to collect and retain surface water that flowed to the northwest (downgrade) at the time of its construction (side-hill configuration). The remainder of the impoundment perimeter is defined by an east embankment and to the south, an irregular shoreline. Grades along the south perimeter of the impoundment generally match power plant areas to the south, making the crest and outer slope of any south embankment indistinguishable.

5.3 EARTH EMBANKMENT

5.3.1 Crest

The north and west embankment crest of the CCW impoundment appeared to be in fair condition (**See Photograph 5.1**), and the crest of the east embankment was in good condition (**See Photograph 5.2**). The widths of the west and north embankment crests are approximately 20 feet wide, and the crest of the eastern embankment is about 10 feet wide. The crest of the south and west embankment are partially covered by a gravel drive from the plant to the toe area of the west embankment (**See Photograph 5.3**). Grades along the south impoundment perimeter generally match the grades of the adjacent plant, so no clearly defined crest is apparent.

Shrinkage cracks were observed on the crest of the west embankment; the cracks were about an inch in width (**See Photograph 5.4**). Animal burrows were observed at sporadic locations on the west, north, and east embankments, with diameters of borrow excavations up to 5 inches wide. (**See Photograph 5.5**).

Embankment crests not covered in gravel were generally vegetated with trimmed grass of up to about 4 inches in height, with the exception of the west embankment crest where patches of grass up to 10 inches high were observed.

5.3.2 Inside Slope

The exposed portions of the inside slopes of the embankments appeared to be in fair condition. The inside slopes appeared to have a slope of approximately 3H: 1V.

The inside slope of the west embankment was generally covered with vegetation up to 24-inches high. The north embankment inside slope of the north embankment was covered with tall dense vegetation. Some of the eastern portions of this embankment contained trees up to 30 inches in diameter (**See Photograph 5.6**). The inside slope of the east embankment was also densely vegetated, with widely spaced trees up to 36 inches in diameter.

Most of the central and eastern areas of the south impoundment perimeter are covered with stockpiled dried coal ash (**See Photograph 5.7**). The western third of the inside slope of the south impoundment perimeter contained vegetation up to about 5 feet in height.

Evidence of erosion was observed on the inside slope of the west embankment (**See Photograph 5.8**). The inside slope of the south impoundment perimeter also showed evidence of isolated erosion soil loss at three locations, with one of these eroded areas about five feet in width (**See Photograph 5.9**).

There is riprap armoring along the southwest inside slope of the impoundment, possibly placed to mitigate prior erosion effects at this location (**See Photograph 5.10**).

5.3.3 Outside Slope and Toe

The outside slopes and toes of the embankments appeared to be in good condition (**See Photograph 5.11**). The outside slopes of the embankment perimeter were approximately 4H: 1V or flatter. In general, the slopes were vegetated with grass of approximately 4 to 18 inches in height (**See Photograph 5.12**), brush, and shrubs. No visual evidence of animal burrows, shrinkage cracks, erosion or seepage was observed on the outer slopes and at the toe of these slopes.

5.4 OUTLET STRUCTURES

5.4.1 Overflow Discharge Structure

The overflow discharge structure consists of an 8-inch ductile iron pipe that discharges into a manhole near the toe of the dam. This structure is part of the outlet conduit and visual observations indicated it was in good condition and functioning during CDM Smith's visit to the site. The inlet to this structure was covered with a steel grate to prevent trash flowing into the overflow system, and the structure was surrounded by a filtering pig sock. The top of the overflow structure was at El. 769.3 (**See Photograph 5.13**).

5.4.2 Outlet Conduit

The outlet conduit is an 8-inch diameter ductile iron pipe with a top-of-pipe elevation at El. 765.8. The 8-inch diameter pipe serves as a gravity-flow conduit from the overflow structure to a manhole located near the toe of the dam. This manhole is connected to a 12-inch diameter RCP (**See Photograph 5.14**) that directs the water to an unnamed tributary of Bear Creek.

5.4.3 Emergency Spillway

The overflow structure/outlet conduit system serves as the spillway for the CCW impoundment.

5.4.4 Low Level Outlet

Based on our visual observations at the site and limited information provided by CMPP representatives, the impoundment does not have a low level outlet.

Section 6

HYDROLOGIC/HYDRAULIC SAFETY

6.1 SUPPORTING TECHNICAL DOCUMENTATION

6.1.1 Flood of Record

The plant representative for CMPP did not have documentation related to flood history or the flood of record to provide to CDM Smith for review. According to the plant representative, there has been no known flooding of the impoundment.

6.1.2 Inflow Design Flood

The only information provided by CMPP related to the inflow design flood was contained in the USACE Inspection Report for Moore's Lake Dam, prepared by the St. Louis District, and issued in December 1980. In this report, a peak inflow of 592 cubic feet per second (cfs) into the impoundment was used for the hydraulic/hydrologic analysis related to a Probable Maximum Flood (PMP event). The USACE calculated a peak outflow capacity for the existing outflow system of the impoundment as PMP event of 282 cfs.

The USACE analytical model for hydraulic inflow and outflow during a PMP Event resulted in overtopping of the dam (northwestern portion of the perimeter embankment) by 0.8 feet for a duration of 9 hours. PMP event Based on the current reservoir/spillway system, approximately 50 percent of the PMP event could occur, before overtopping of the dam.

The USACE evaluation also indicated the reservoir/spillway system could accommodate a 100-year flood without overtopping. The elevation data used in the December 1980 USACE report are as shown in **Table 6.1**. The storage data for the reservoir used in the report are as shown in **Table 6.2**. For comparison, the elevation data from CDM Smith's recent on-site visit are as shown in **Table 6.3**. The Federal Emergency Management Agency (FEMA) *"Federal Guidelines for Dam Safety – Selecting and Accommodating Inflow Design Floods for Dams", (April 2004)*, considers the PMP event as the upper limit of the Inflow Design Flood (IDF):

Table 6.1: Elevation Data for Moore's Lake Dam in 1980[1] (Feet Above Mean Sea Level)	
Top of Dam (minimum)	773.0
Spillway Crest	769.0
Normal Pool	769.0
Maximum Experienced Pool	Unknown
Observed Pool	768.9

[1] *Based on data contained in Phase I Inspection Report – National Dam Safety Program by the USACE St. Louis District dated December 1980*

Table 6.2: Storage Data for Moore's Lake Dam in 1980[1] (Acre-Feet)	
Top of Dam (minimum)	45
Spillway Crest	15
Normal Pool	15
Maximum Experienced Pool	Unknown
Observed Pool	15

[1]*Based on data contained in Phase I Inspection Report – National Dam Safety Program by the USACE St. Louis District dated December 1980*

Table 6.3: Elevation Data for Moore's Lake Dam in 2012[1] (Feet Above Mean Sea Level)	
Top of Dam (minimum)	770.0
Spillway Crest	769.3
Normal Pool	768.0
Maximum Experienced Pool	Unknown
Observed Pool	Unknown

[1]*Based on ~~information~~ survey drawings provided by Columbia Power Plant during CDM Smith's on-site visit on August 22 – August 23, 2012 –* ***See Appendix C***

6.1.3 Spillway Rating

According to the December 1980 USACE report, the maximum capacity of the spillway just before overtopping the dam is 4 cfs.

6.1.4 Downstream Flood Analysis

No downstream flood analysis could be provided by CMPP for the impoundment at this facility. CDM Smith has reviewed a qualitative analysis based on data provided in the USACE report issued in 1980 and also made visual observations of areas downstream of the ash pond. Based on the December 1980 USACE evaluation, a dam breach would affect an area approximately 2 miles downstream of the reservoir. Facilities within this two-mile zone include the City of Columbia Water and Light Storage Facilities, Interstate Highway 70, and an area of commercial development that includes a health care facility. Based on this projected zone of influence, a breach of the dam or containment embankments could cause extensive damage to the property downstream of the dam and probable loss of human life.

6.2 ADEQUACY OF SUPPORTING TECHNICAL DOCUMENTATION

The supporting hydrologic/hydraulic documentation available with the CMPP is considered inadequate for this management unit by virtue of the fact that the available documentation is from December 1980.

6.3 ASSESSMENT OF HYDROLOGIC/HYDRAULIC SAFETY

According to the December 1980 USACE report, the management unit does not have adequate hydrologic/hydraulic safety. According to the report, the reservoir/spillway system could accommodate only 50 percent of the PMP event without overtopping the dam. MDNR requires that the impoundment passes 75 percent of the PMP event. Including the change in minimum top-of-dam elevation from El. 773.0 in December 1980 to El. 770.0 in August 2012 increases the likelihood of overtopping from a 75 percent PMP event.

Section 7

STRUCTURAL STABILITY

7.1 SUPPORTING TECHNICAL DOCUMENTATION

7.1.1 Stability Analyses and Load Cases Analyzed

CMPP did not provide documentation containing stability analyses for CDM Smith review. MDNR recommends 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 Safety 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, such as Moore's Lake Dam meet the stability criteria unless significant modifications are made to the height, slope or water storage elevation of the earthen structure.

7.1.2 Design Parameters and Dam Materials

The CMPP representative had limited information on soil conditions in one area of the impoundment, but otherwise did not have complete documentation to provide CDM Smith related to design parameters and dam materials. The representative provided CDM Smith with a copy of a geotechnical engineering report completed by Terracon of Columbia, Missouri, dated March 2, 2004 (**see Appendix C**). The report provides subsoil information near the southeast corner of the CCW impoundment in the vicinity of the discharge piping and related structures. The subsurface investigation included three (3) borings with sampling and three (3) cone penetrometer tests (CPT). Borings were extended to El. 719 (depth of 54.5 feet), with the exception of boring B-1, terminated at refusal in a layer of concrete rubble at El. 765.5 (depth of 8 feet.) CPT tests were terminated at El. 754 (depth of 19.5 feet) to El. 751 (depth of 22.5 feet).

The Terracon Logs of Boring identified the top 8 to 15 feet of soil as fill, typically soft to medium-stiff in consistency. This fill contained various amounts of gravel, cobbles, coal cinders and coal ash. The fill materials were underlain by medium stiff to very stiff, lean to fat clay. Occasional layers of sand and sandy silt were encountered as shallow as 18 feet, and extended as deep as 33 feet below the existing grade. Weathered shale was encountered at a depth of approximately 53 feet, extending to boring termination 54.5 feet below existing grade. More detailed descriptions of the subsurface conditions encountered and results of the CPT testing are provided in **Appendix C**.

Groundwater was encountered in the two deepest borings, stabilizing at a depth of approximately 6 feet below the existing grade. Groundwater was not observed in the boring terminated at a depth of 8 feet below the existing grade.

The purpose of the 2004 Terracon investigation report was to describe the subsurface conditions, evaluate test data, and provide geotechnical recommendations regarding earthwork necessary to complete design and construction of foundations and floor slabs for a proposed building near the southeast corner of the CCW impoundment. The Terracon investigation did not include borings through the embankments and does not provide material properties of embankment soils that are needed to perform stability analyses.

7.1.3 Uplift and/or Phreatic Surface Assumptions

Discussions with plant personnel indicated there are currently no piezometers or other groundwater monitoring devices for the impoundment. Without this groundwater information, assumptions on the uplift forces or water levels cannot be accurately estimated. The only water level information provided by the CMPP indicated water encountered at a depth of 6 feet below the existing ground surface (El. 766) at the location of borings B-2 and B-3. This water level generally corresponds to the water surface in the pond.

CDM Smith's visual observations of the outside embankment slopes, including the ground surface conditions at the toe, did not indicate seepage at the ground surface. The lack of seeps on the ground surface on these outside slopes is a general indication that the phreatic surface drops below elevations measured in the borings downslope of the locations where these borings were made (southeast corner of the site). CDM Smith cannot make assumptions on phreatic surface and potential for uplift of the earthen structures and surrounding areas without more detailed information of soil stratigraphy and groundwater levels in the area of the impoundment.

7.1.4 Factors of Safety and Base Stresses

CMPP did not have analysis of slope stability of critical sections of the embankment perimeter to provide CDM Smith for review. Without this documentation, CDM Smith cannot perform an evaluation of the adequacy of factors of safety of existing slopes and the magnitude of base stresses for the embankments.

As a general reference, **Table 7.1** 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 7.2** shows recommended minimum required seismic factors of safety by the *FEMA Federal Guidelines for Dam Safety, Earthquake Analyses and Design of Dams*.

Table 7.1: 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 7.2: 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

7.1.5 Liquefaction Potential

CDM Smith was not provided with documentation on liquefaction analysis. Available limited subsurface information indicates that soils below the embankments consist of fill underlain by medium stiff to stiff clay. Medium dense to very dense sandy soils predominate below the medium stiff to stiff clays. Stiff to hard clay is present below these sandy soils.

The liquefaction susceptibility of the dense sandy soils and the hard clay is generally considered to be low. However, the susceptibility can vary with the composition of the fill, and in some cases could potentially be high. Documentation provided by CMPP did not contain sufficient information for CDM Smith to assess liquefaction potential for the management unit.

7.1.6 Critical Geological Conditions and Seismicity

Moore's Lake is located on an unnamed tributary of Bear Creek in Boone County. The general area of the site has elevations ranging from about 800 feet to about 700 feet above mean sea level. The topography is characterized by medium and narrow ridges with moderate to steep side slopes. The geology of the area ranges from the lower Ordovician to the middle Pennsylvanian age. The formations include exposed dolomite and limestone outcrops to smaller areas of sandstone, coal and shale. Glacial till and loess overlie the Pennsylvanian age formation. The glacial till is a heterogeneous mixture of clay, sand, and gravel, with fragments of sandstone, limestone, and coal.

The USACE evaluation of geologic conditions at Moore's Lake Dam completed in December of 1980 did not identify faults in the vicinity of the dam. The closest known fault designated as Fox Hollow, is located about 15 miles south of the dam site. The Fox Hollow fault had its last movement in post-Mississippian geologic time; thus, it is reasonable to assume the fault has had no recent activity and should not influence the Moore's Lake Dame and associated impoundment.

Information on the website of the United States Geological Survey (USGS) was used to evaluate the risks related to seismic activity. Based on a 2008 USGS seismic hazard map for Missouri, the dam site is located in an area with a potential to experience between 0.10g and 0.14g (horizontal) ground acceleration with a probability of exceedance of 2 percent in 50 years. This level of seismic forces is considered a low hazard for the impoundment.

7.2 ADEQUACY OF SUPPORTING TECHNICAL DOCUMENTATION

CMPP did not have all of the necessary information for CDM Smith's review to perform a review of structural stability or potential for liquefaction for the management unit. Based on this lack of documentation, it is CDM Smith's opinion the supporting technical documentation is inadequate for this facility.

7.3 ASSESSMENT OF STRUCTURAL STABILITY

Information provided by CMPP for use in CDM Smiths evaluation of the management unit did not include sufficient data regarding the structural adequacy or stability of the impoundment. The limited data on the soil stratgraphy and strength data is therefore insufficient to provide an assessment of the structural stability of the embankments and dam of this management unit.

Section 8

ADEQUACY OF MAINTENANCE AND METHODS OF OPERATION

8.1 OPERATING PROCEDURES

The information CMPP provided CDM Smith did not include a written set of operating procedures for the management unit. The operation of the CCW impoundment was described verbally by a plant representative as described in **Section 4.2.1**of this report, wet CCW from the Power Plant is sluiced to the ash pond, where the ash is allowed to settle out. Periodically, the ash is dredged out, allowed to dry and disposed offsite. The water in the ash pond discharges into an unnamed tributary of Bear Creek.

8.2 MAINTENANCE OF THE DAM AND PROJECT FACILITIES

CMPP provided no documentation on procedures or records of maintenance operations for the ash pond. According to a plant representative, the embankments are periodically mowed by plant staff on an as needed basis, but records of this are not kept. Although the inside slopes of the embankment were mowed at the time of our site visit, visual observations of the inside slopes of the north and east embankments were overgrown with trees and dense vegetation.

8.3 ASSESSMENT OF MAINTENANCE AND METHODS OF OPERATIONS

8.3.1 Adequacy of Operating Procedures

Based on CDM Smith's review of documents made available by CMPP, there are no written operating procedures for the ash pond. The verbal description of management unit operation generally appears adequate, but CDM Smith recommends implementation of a written set of operating procedures and the establishment of a system for consistent documentation of the management unit.

8.3.2 Adequacy of Maintenance

In general, maintenance of the embankments and outlet structures of the impoundment appear adequate with regard to mowing and repair of rodent damage. The overall maintenance of the impoundment is not considered adequate, particularly with regard to vegetation on the inside slopes of the north and east embankments and with regard to repair and protection of erosion of these slopes. CDM Smith recommends maintenance issues described in this report be addressed, and methods such as the installation of riprap on areas subject to erosion be implemented.

Section 9

ADEQUACY OF SURVEILLANCE AND MONITORING PROGRAM

9.1 SURVEILLANCE PROCEDURES

CMPP personnel indicated verbally they inspect the impoundment embankments twice a year. Documentation of these inspections, and any related actions taken with regard to their findings was not included in the information provided to CDM Smith.

9.2 INSTRUMENTATION MONITORING

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

9.3 ASSESSMENT OF SURVEILLANCE AND MONITORING PROGRAM

9.3.1 Adequacy of Surveillance Program

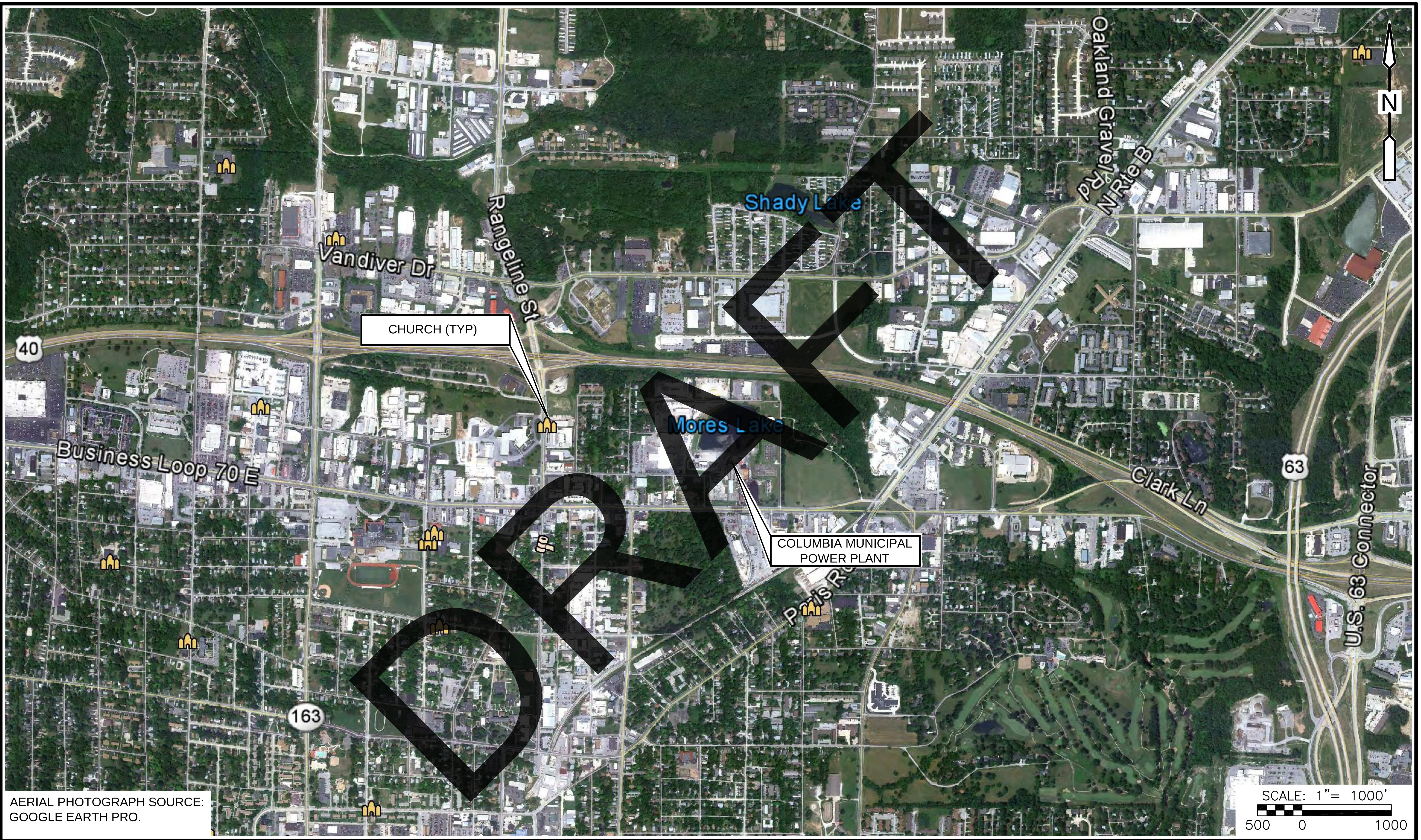
Based on the documents reviewed by CDM Smith, the inspection program appears to be inadequate.

9.3.2 Adequacy of Instrumentation Monitoring Program

The current lack of instrumentation (observation wells) prevents CMPP from establishing an adequate monitoring program

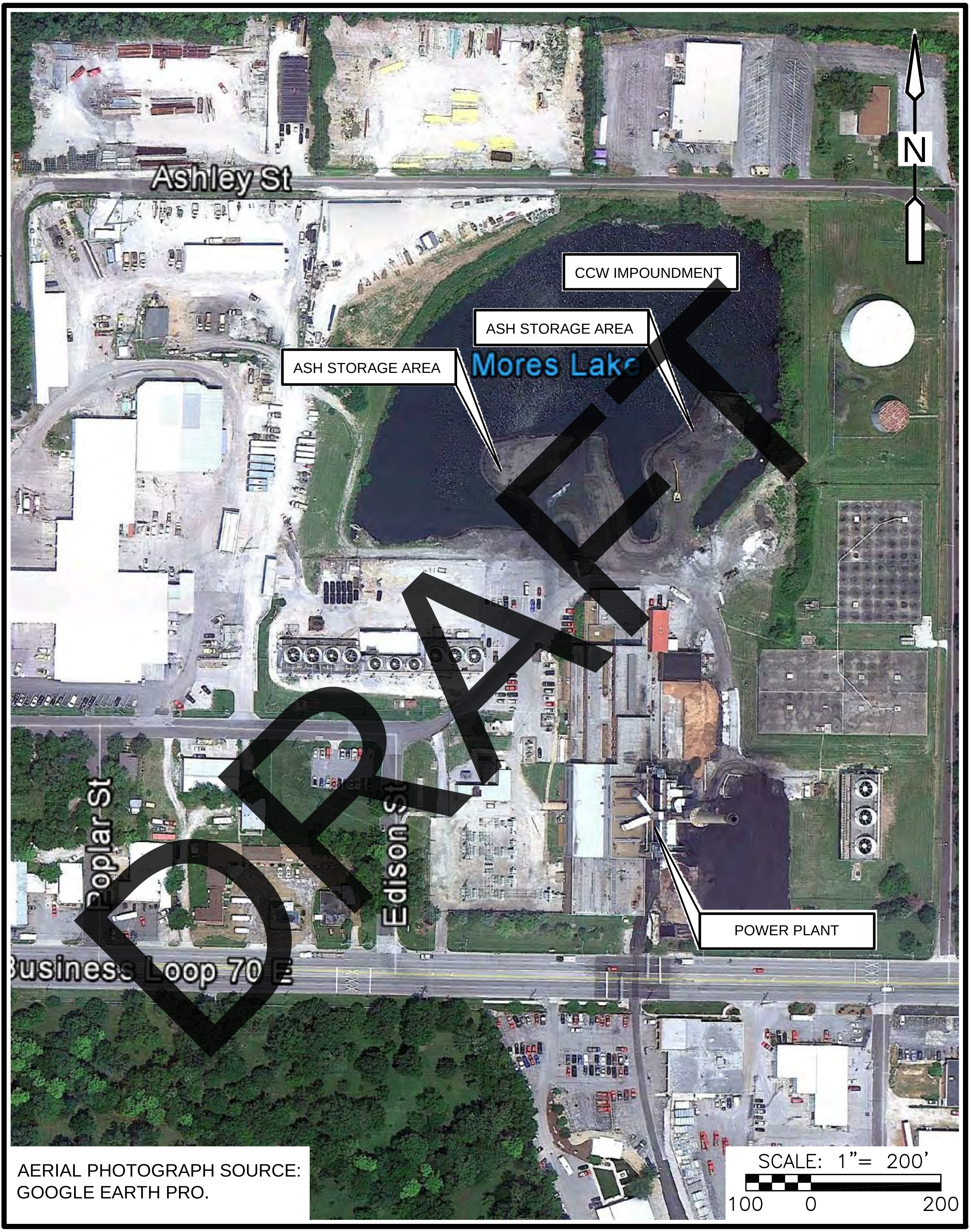
Appendix A

Figures



CDM Smith

COLUMBIA MUNICIPAL POWER PLANT
COLUMBIA, MISSOURI
LOCUS PLAN
FIGURE 2-1



CDM Smith

COLUMBIA MUNICIPAL POWER PLANT
COLUMBIA, MISSOURI
AERIAL PLAN
FIGURE 2-2

AERIAL PHOTOGRAPH SOURCE:
GOOGLE EARTH PRO.

CDM Smith

COLUMBIA MUNICIPAL POWER PLANT
COLUMBIA, MISSOURI
CRITICAL INFRASTRUCTURE PLAN
FIGURE 2-3

Appendix B

Assessment Checklists

Coal Combustion Dam Inspection Checklist Form

US Environmental Protection Agency

Site Name:	Columbia Power Plant	Date:	August 22, 2012 - August 23, 2012
Unit Name:	Ash Pond	Operator's Name:	City of Columbia Water & Light Dept.
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?	6 months		18. Sloughing or bulging on slopes?		X
2. Pool elevation (operator records)?	768.0'		19. Major erosion or slope deterioration?	X	
3. Decant inlet elevation (operator records)?	771.8'		20. Decant Pipes:		
4. Open channel spillway elevation (operator records)?	n/a		Is water entering inlet, but not exiting outlet?		X
5. Lowest dam crest elevation (operator records)?	770.0'		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)?	d/n/a		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?	d/n/a		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. Pool elevation at 768.0' on October 5, 2011 per operator records; Operator did not provide datum on survey drawings.

3, 5. According to drawings provided by Operator, Decant Inlet Elevation is higher than Lowest Dam Crest Elevation. Generally, elevation of ground surface decreases east to west, towards dam; lowest dam crest is located about 470 ft west of decant inlet, which probably results in a lower dam crest than decant inlet. Operator did not provide datum on survey drawings.

COMMENTS CONTINUE ON ATTACHED SHEET

n/a = not available

d/n/a = does not apply

EXTRA PAGE – CCD INSPECTION CHECKLIST FORM – CITY OF COLUMBIA POWER PLANT, MISSOURI

August 22, 2012 – August 23, 2012

4. 8"-diameter ductile iron pipe outlet with an outfall drain at elevation 769.3', discharging into a manhole located on the western downstream slope of dam; Operator did not provide datum on survey drawings.

6. No instrumentation installed.

9. Occasional cottonwood trees and dense, tall vegetation growing on interior slopes of north and east embankments; largest tree diameter is 36 inches on east embankment.

10. Cracks appear to be desiccation cracks.

19. Localized minor erosion on interior slope of south embankment.

Coal Combustion Waste (CCW)
Impoundment Inspection

Impoundment NPDES Permit # MO-0004979
INSPECTOR Clement Bommarito, Albert Ayenu-Prah
Date August 22, 2012 - August 23, 2012

Impoundment Name Ash Pond
Impoundment Company City of Columbia Water & Light Department, Missouri
EPA Region 7
State Agency (Field Office) Addresss N/A

Name of Impoundment 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 - Fly Ash and Bottom Ash

Nearest Downstream Town : Name City of Columbia
Distance from the impoundment 1 mile
Impoundment
Location: Longitude -92 Degrees 19 Minutes 2 Seconds (source: Google Earth)
Latitude 38 Degrees 57 Minutes 59 Seconds
State MO County Boone

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

If So Which State Agency?______

Note: 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.

______ **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.

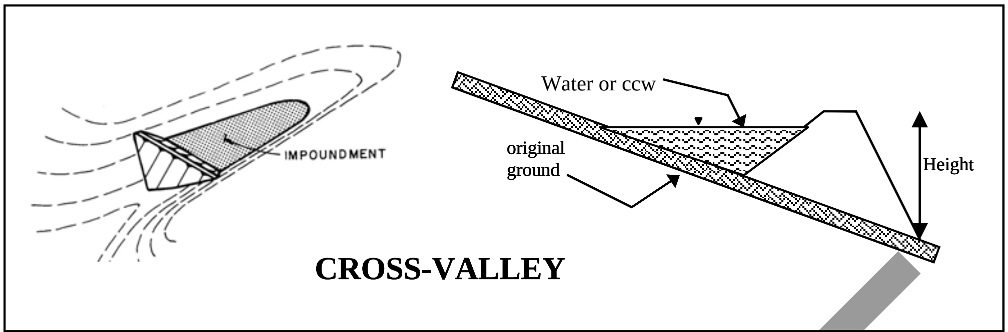
______ **SIGNIFICANT HAZARD POTENTIAL:** Dams assigned the significant hazard potential classification are those dams where failure or misoperation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. 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.

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

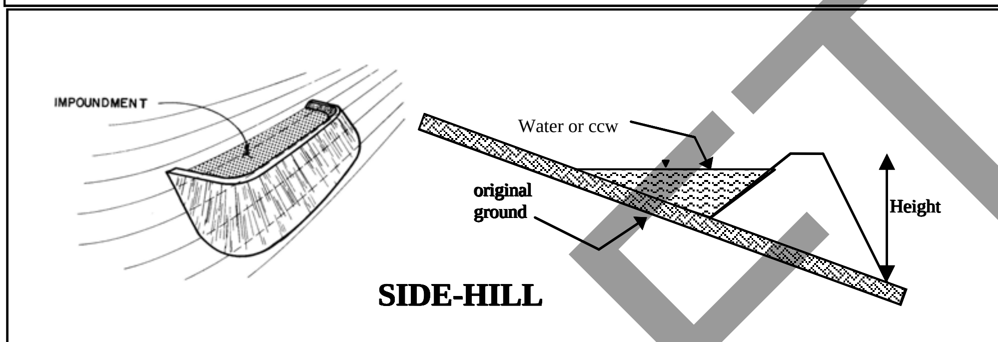
DESCRIBE REASONING FOR HAZARD RATING CHOSEN:

An evaluation of the coal ash retention pond performed in 1980 by the USACE St. Louis office estimated a dam breach would affect an area approximately 2 miles downstream of the pond. Facilities within this two-mile zone include the City of Missouri Water and Light Storage facilities, Interstate Highway 70, and an area of commercial development that includes a health care facility. Based on this projected zone of influence associated with breach of the dam or containment embankments, the pond has a high hazard potential because of the risk of economic loss and loss of human life.

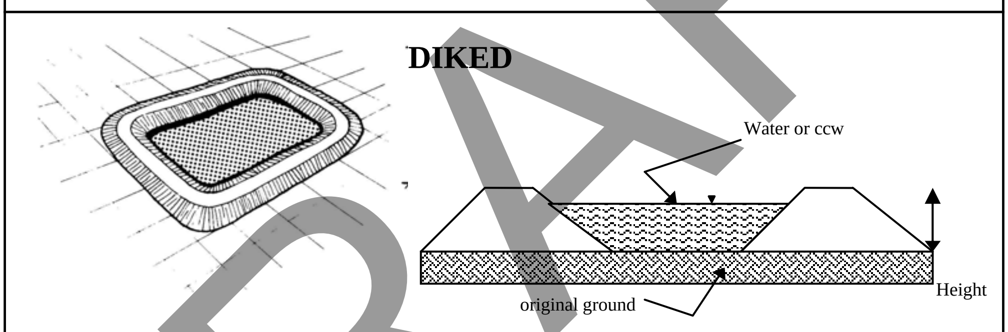
CONFIGURATION:



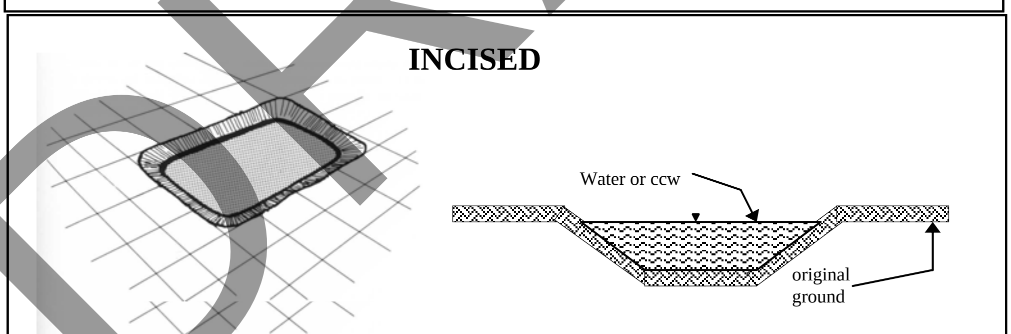
CROSS-VALLEY



SIDE-HILL



DIKED



INCISED

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

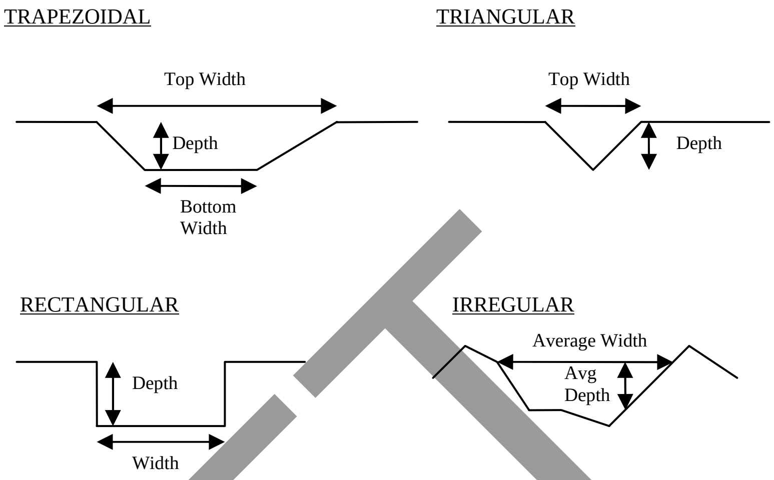
Embankment Height 14-15 feet
Pool Area Operator records: 6.5 acres
Current Freeboard 2 feet

Embankment Material CLAY/Assumed Native
Liner No
Liner Permeability N/A

TYPE OF OUTLET (Mark all that apply)

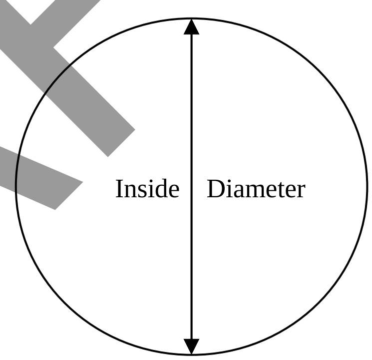
D/N/A **Open Channel Spillway**
_____ Trapezoidal
_____ Triangular
_____ Rectangular
_____ Irregular

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



X **Outlet**

8" inside diameter



Material
_____ corrugated metal
_____ welded steel
_____ concrete
_____ plastic (hdpe, pvc, etc.)
X other (specify) Ductile Iron

Is water flowing through the outlet? YES X NO _______

_____ **No Outlet**

_____ **Other Type of Outlet** (specify) ______________________________

The Impoundment was Designed By N/A: Design drawings or as-built drawings not available. Pond was originally constructed on private property for recreational purposes in late 1800's.

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.

It is unknown if the embankment construction was 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 C

Documentation from Columbia Municipal Power Plant

Appendix C

Doc 01: Survey Drawings

MUNICIPAL POWER PLANT

TOPOGRAPHIC SURVEY

BENCH MARK

BM – CHISELED SQUARE ON SOUTHEAST CORNER OF CONCRETE BOX AT NORTH SIDE OF LAKEVIEW DRIVE AND 65 FEET OF POPLAR STREET
ELEVATION = 751.15

TBM – CHISELED SQUARE ON SOUTHWEST CORNER OF CONCRETE WALL LOCATED 80 FEET NORTHEAST OF THE SMOKE STACK
ELEVATION = 775.55

TBM – CHISELED SQUARE ON WINDOW SILL LOCATED 7 FEET SOUTH OF NORTHEAST CORNER OF POWER PLANT
ELEVATION = 770.58

TBM – CHISELED SQUARE ON NORTHEAET CORNER OF EASTERNMOST COOLING TOWER
ELEVATION = 770.59

UTILITY NOTES

THE LOCATIONS AND SIZES OF UHDERGROUND UTILITIES INDICATED ON THE PLAT NOT VISIBLE OR APPARENT FROM THE SURFACE ARE FROM A MISSOURI ONE CALL SYSTEM LOCATE, OR UTILITY COMPANY RECORDS AND WERE NOT VERIFIED IN THE FIELD.

WATER
CITY OF COLUMBIA
WATER & LIGHT DEPARTMENT
P.O. BOX 6015
COLUMBIA, MISSOURI 65205
CONTACT: DAVID STORVICK 573-874-7317
6" PVC ALONG NORTH SIDE ASHLEY STREET
8" PVC ALONG EAST SIDE BOWLING STREET
12" C.I. WELL LINE ALONG WEST SIDE BOWLING STREET

ELECTRIC
CITY OF COLUMBIA
WATER & LIGHT DEPARTMENT
P.O. BOX 6015
COLUMBIA, MISSOURI 65205
CONTACT: DAN CLARK 573-874-7738
OVERHEAD LINES ALONG WEST SIDE BOWLING STREET
OVERHEAD LINES ALONG SOUTH SIDE ASHLEY STREET TO 350' WEST OF BOWLING, THEN CROSSES TO NORTH SIDE OF ASHLEY STREET

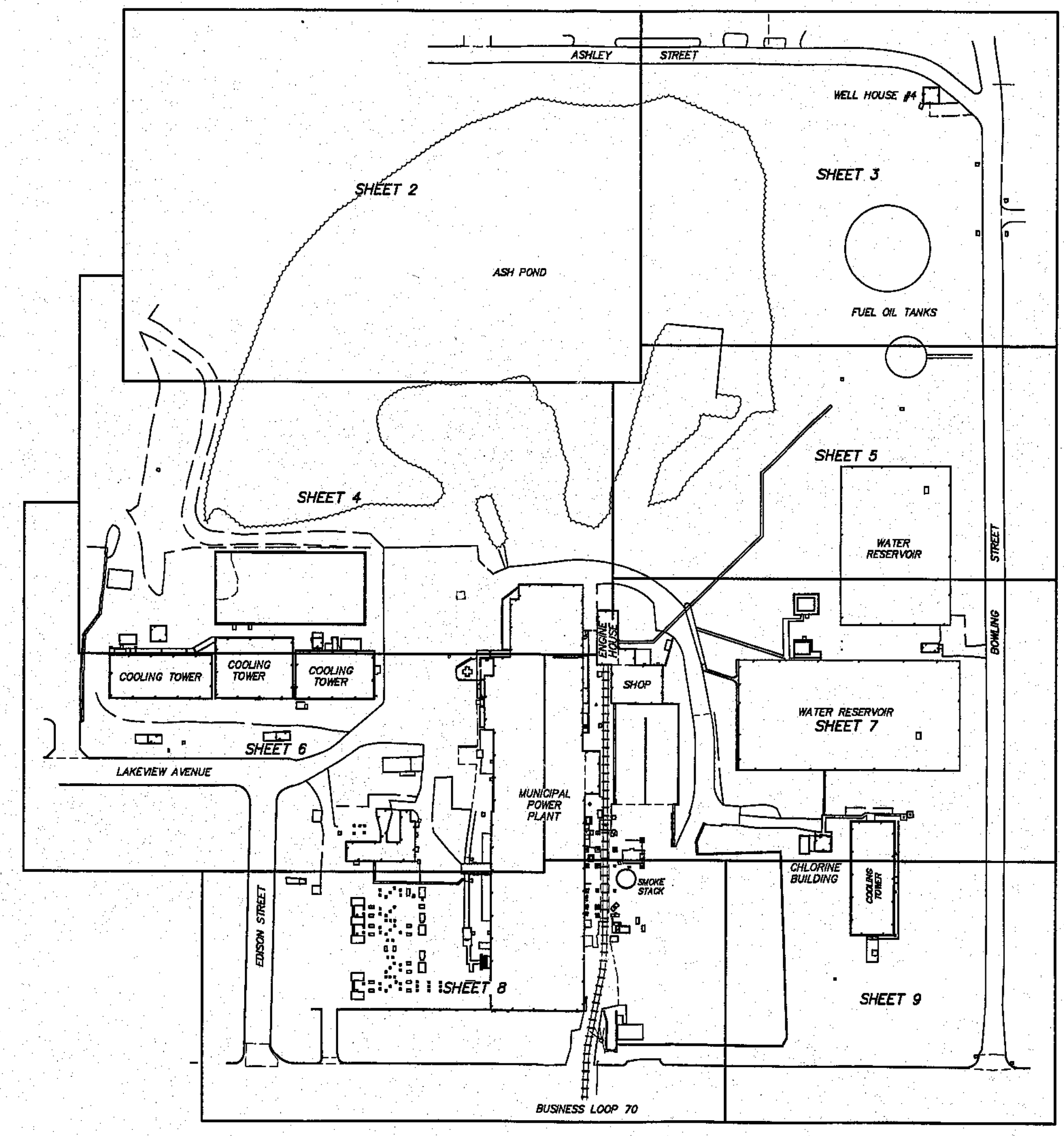
GAS
AMEREN MISSOURI
210 ORR STREET
COLUMBIA, MISSOURI 65201
CONTACT: BRUCE DARR 573-876-3030
2" PLASTIC ALONG NORTH SIDE ASHLEY STREET

TELEPHONE
CENTURYLINK
825 E. CHERRY STREET
COLUMBIA, MISSOURI 65201
CONYACT: DUANE JONES 573-886-3507
OVERHEAD LINES AS SHOWN

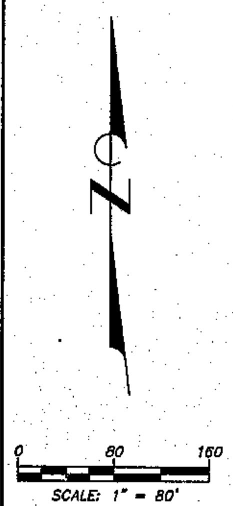
TELEVISION
MEDIACOM
901 N. COLLEGE AVENUE
COLUMBIA, MISSOURI 65201
CONTACT: BOB BONER 573-443-1536
OVERHEAD LINES AS SHOWN
UNDERGROUNO LINE ALONG WEST SIDE BOWLING STREET
UNDERGRGUND LIUNE ALONG SOUTH SIDE ASHLEY STREET

SANITARY SEWER
CITY OF COLUMBIA
PUBLIC WORKS DEPARTMENT
P.O. BOX 6015
COLUMBIA, MISSOURI 65205
CONTACT: STEVE HUNT 573-874-7250
AS SHOWN

STORM SEWER
CITY OF COLUMBIA
PUBLIC WORKS DEPARTMENT
P.O. BOX 6015
COLUMBIA, MISSOURI 65205
CONTACT: TOM WELLMAN 573-874-7250
AS SHOWN



KEY MAP



LEGEND

Symbol	Description
— — —	PROPERTY LINE
E	ELECTRIC LINE
T	TELEPHONE LINE
TV	TELEVISION LINE
FO	FIBER OPTIC LINE
UE	UNDERGROUND ELECTRIC LINE
UTV	UNDERGROUND TELEVISION LINE
S	SANITARY SEWER LINE
SS	STORM SEWER LINE
G	GAS LINE
W	WATER LINE
X	FENCE
	TREE & BRUSH LINE
	DRAINAGE SWALE
— — →	ANCHOR
UP	UTILITY POLE
LS	LIGHT STANDARD
RD	ROOF DRAIN
URD	UNDERGROUND ROOF DRAIN
GV	GAS VALVE
WM	WATER METER
WV	WATER VALVE
FH	FIRE HYDRANT
P.I.V.	POST INDICATOR VALVE
C.O.	CLEANOUT
CMP	CORRUGATED METAL PIPE
PVC	POLYVINYL CHLORIDE PIPE
RCP	REINFORCED CONCRETE PIPE
VCP	VITRIFIED CLAY PIPE
D.I.	DUCTILE IRON PIPE
CPP	CORRUGATED PLASTIC PIPE
⌖	IRON

SURVEY CONTROL POINTS

POINT NUMBER	NORTH	EAST	ELEVATION	DESCRIPTION
CP4	547.81	787.80	786.19	DRILL HOLE
CP5	482.92	1039.85	787.21	DRILL HOLE
CP6	834.00	1027.67	786.07	DRILL HOLE
CP351	1015.36	851.00	778.53	REBAR
CP364	1332.79	852.07	778.81	NAIL IN BOTTLECAP
CP408	168.71	1037.76	766.81	IRON
CP534	414.01	744.96	771.99	DRILL HOLE
CP625	424.67	633.97	766.00	DRILL HOLE
CP1369	698.61	734.29	769.85	IRON
CP1549	863.23	369.50	770.64	NAIL IN BOTTLECAP
CP1953	152.97	559.23	760.86	IRON
CP1954	138.66	251.39	750.69	IRON
CP1955	501.55	8.81	760.03	IRON
CP1957	780.28	141.99	770.28	IRON
CP2559	503.19	448.69	768.82	NAIL IN BOTTLECAP
CP2560	363.26	458.85	768.37	DRILL HOLE
CP2562	330.69	290.22	761.55	DRILL HOLE

NOTE:
ACCURATE ELEVATIONS HAVE BEEN SURVEYED AT THE TOP OF CURB, GUTTER, EDGE OF PAVEMENT, AND CENTERLINE OF THE STREETS. IF IMPROVEMENTS ARE PLANNED WITHIN THE STREET PAVEMENT, ADDITIONAL SURVEY INFORMATION MAY BE NECESSARY.

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PRELIMINARY

NOT FOR CONSTRUCTION, BIDDING, RECORDING, OR PERMIT REVIEW PURPOSES

FREDERICK E. CARROZ III
PROFESSIONAL LAND SURVEYOR
PLS – 2008016655

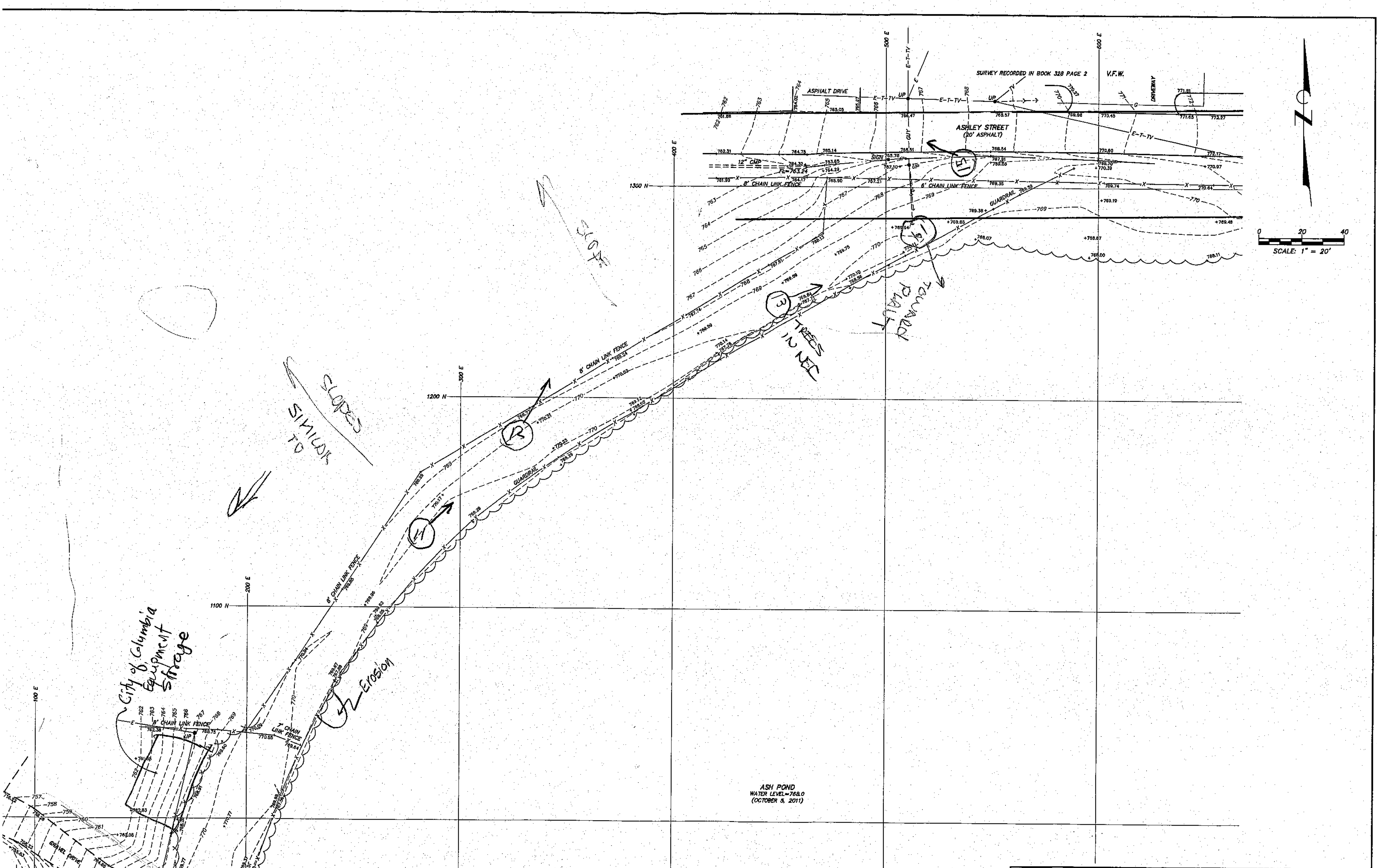
TOPOGRAPHIC SURVEY
MUNICIPAL POWER PLANT
COLUMBIA, MISSOURI

Surveyed: JEP
Drawn: BR
Checked: FEC

Engineering Surveys & Services
1113 Fay Street
Columbia, Missouri
573 - 449 - 2646
Missouri Land Surveying Corporation # 2004004672

Revised

Scale	Date	Job	Sheet
1" = 80'	MARCH ___, 2012	11923	1 of 9



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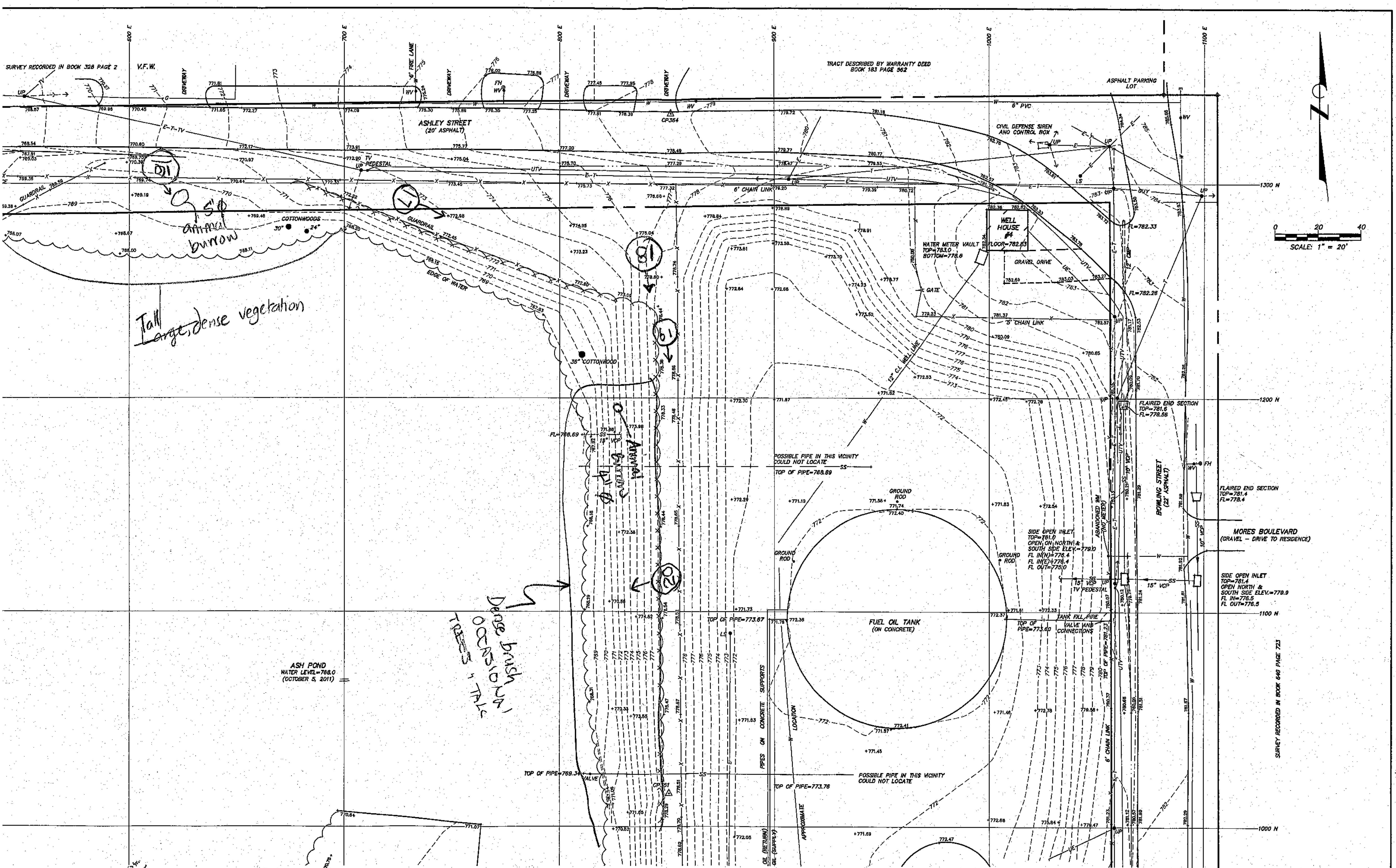

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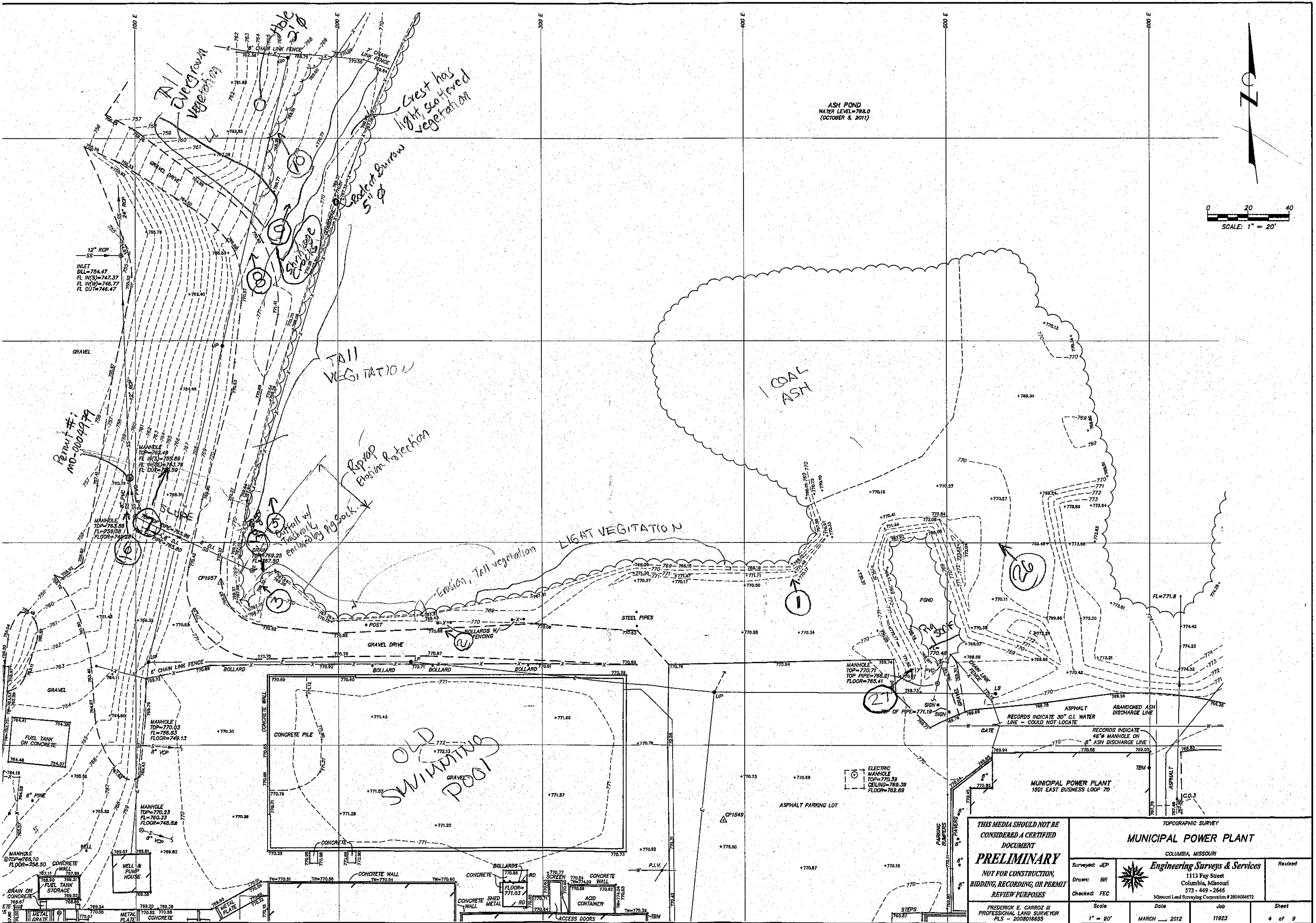

ASH POND
WATER LEVEL=768.0
(OCTOBER 5, 2011)
SCALE: 1" = 20'
100 E
200 E
300 E
400 E
500 E
600 E
Tall overgrown vegetation
Crest has light, scattered vegetation
Rodent Burrow 5" ϕ
Hole 2" ϕ
Shrinkage Cracks
TALL VEGITATION
COAL ASH
Riprap Erosion Protection
Outfall w/ Trashrack enclosed by pig sock
LIGHT VEGITATION
Erosion, Tall vegetation
Permit #: MO-0004979
GRAVEL
GRAVEL DRIVE
12" RCP
24" RCP
INLET
SILL=754.47
FL IN(S)=747.37
FL IN(W)=746.77
FL OUT=746.47
MANHOLE
TOP=762.49
FL IN(S)=755.89
FL IN(SE)=753.76
FL OUT=753.59
MANHOLE
TOP=763.88
FL=759.58
FLOOR=749.28
MANHOLE
TOP=770.03
FL=756.63
FLOOR=749.13
MANHOLE
TOP=770.23
FL=760.33
FLOOR=748.8±
MANHOLE
TOP=766.10
FLOOR=758.50
8" VCP
6" PINE
CP1957
CP1549
6' CHAIN LINK FENCE
7' CHAIN LINK FENCE
8' CHAIN LINK FENCE
BOLLARD
BOLLARDS W/ FENCING
POST
STEEL PIPES
POND
FL=771.8
MANHOLE
TOP=770.71
TOP PIPE=766.21
FLOOR=765.41
TOP OF PIPE=771.19
SIGN
GATE
LS
ASPHALT
ABANDONED ASH DISCHARGE LINE
RECORDS INDICATE 30" C.I. WATER LINE - COULD NOT LOCATE
RECORDS INDICATE 48"ϕ MANHOLE ON 6" ASH DISCHARGE LINE
TBM
ELECTRIC MANHOLE
TOP=770.39
CEILING=769.39
FLOOR=762.89
ASPHALT PARKING LOT
MUNICIPAL POWER PLANT
1501 EAST BUSINESS LOOP 70
CONCRETE WALL
CONCRETE PILE
OLD SWIMMING POOL
GRAVEL
FUEL TANK ON CONCRETE
FUEL TANK STORAGE
WELL & PUMP HOUSE
WELL
DRAIN ON CONCRETE
METAL GRATE
METAL PLATE
CONCRETE
SHED METAL
ACID CONTAINER
ACCESS DOORS
SCREEN
STEPS
P.I.V.
UP
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Drawn: BR
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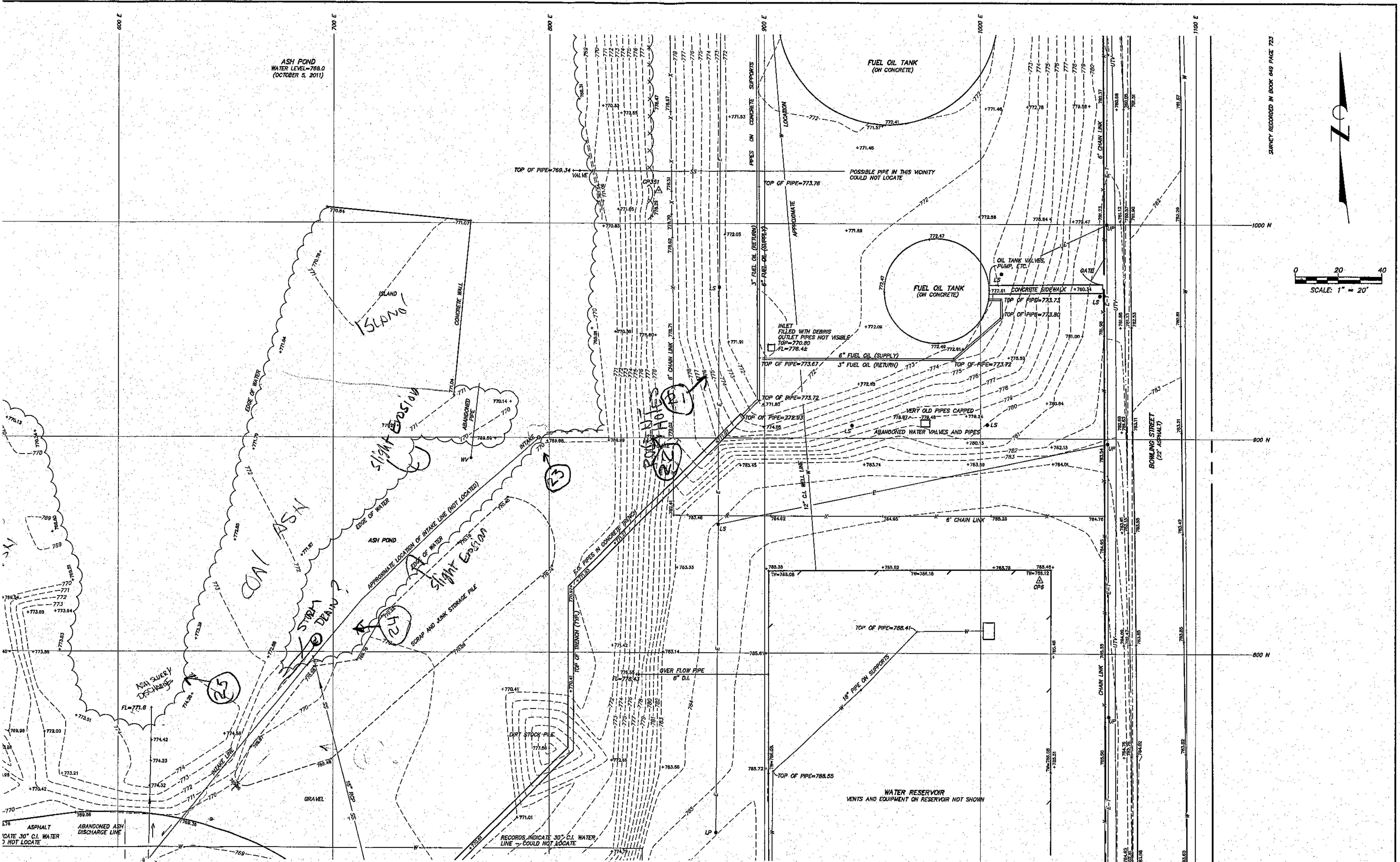
Revised
Scale 1" = 20'
Date MARCH __ 2012
Job 11923
Sheet 4 of 9



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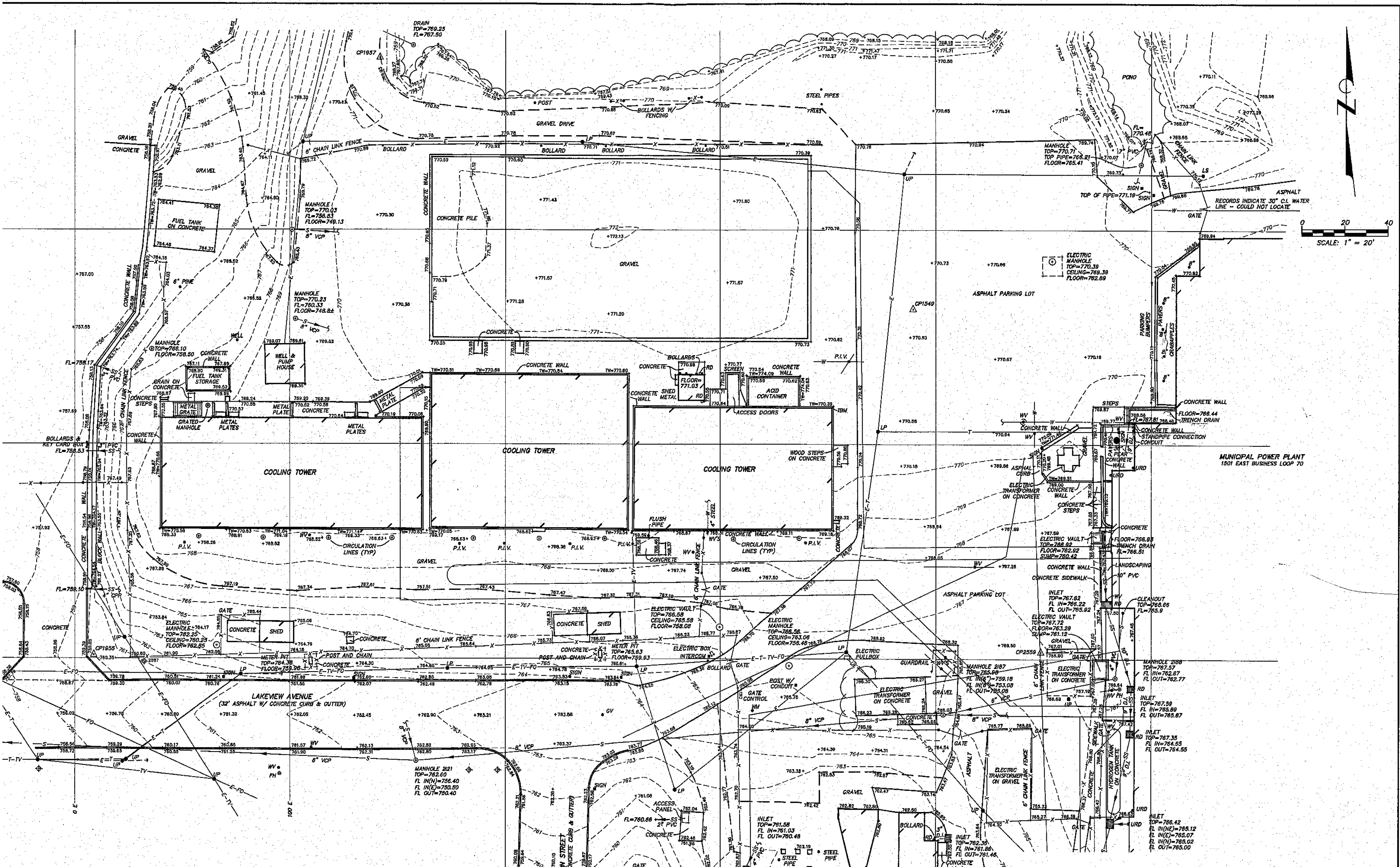
Scale	Date	Job	Sheet
1" = 20'	MARCH __, 2012	11923	5 of 9



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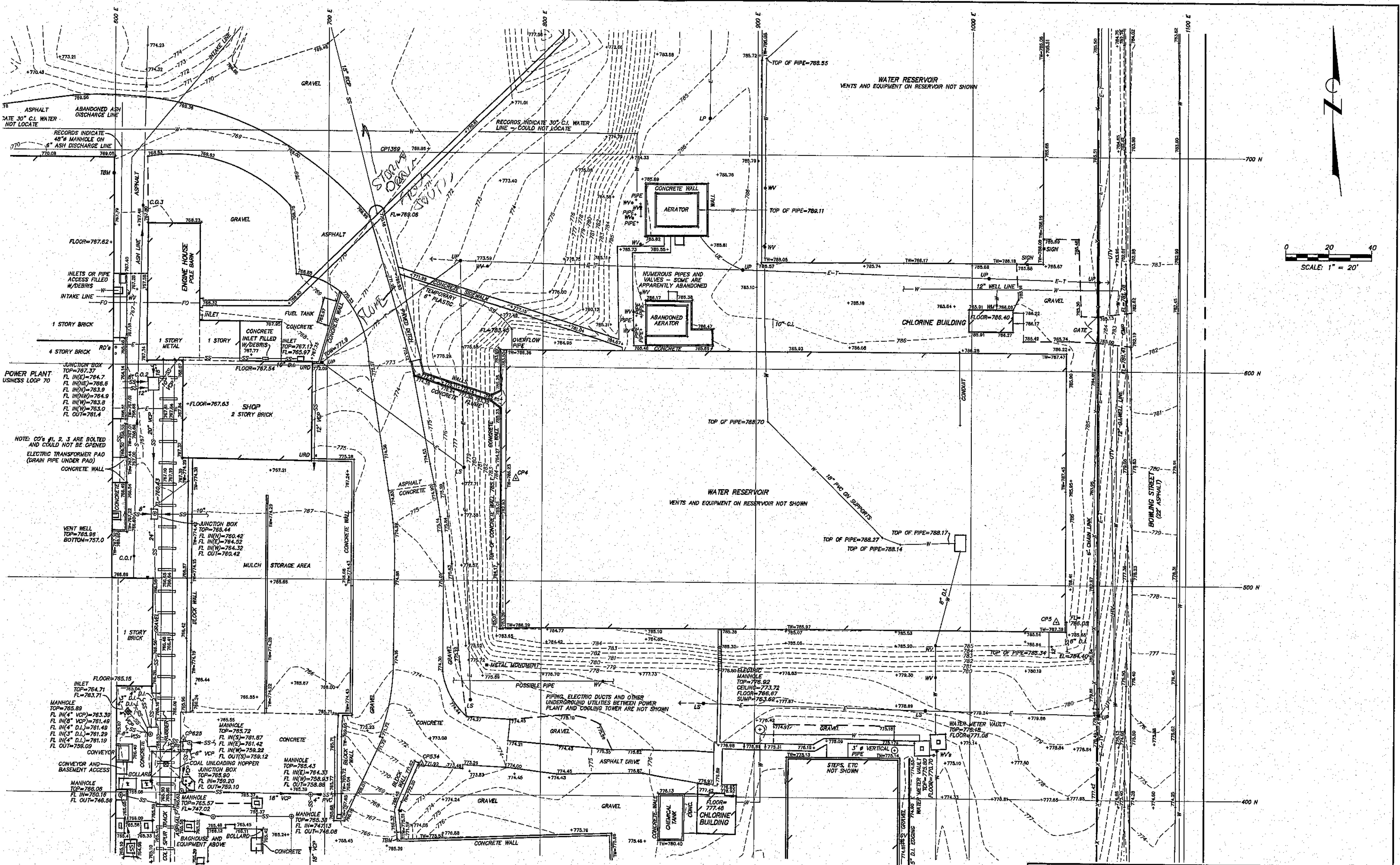

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PLS - 2008016655

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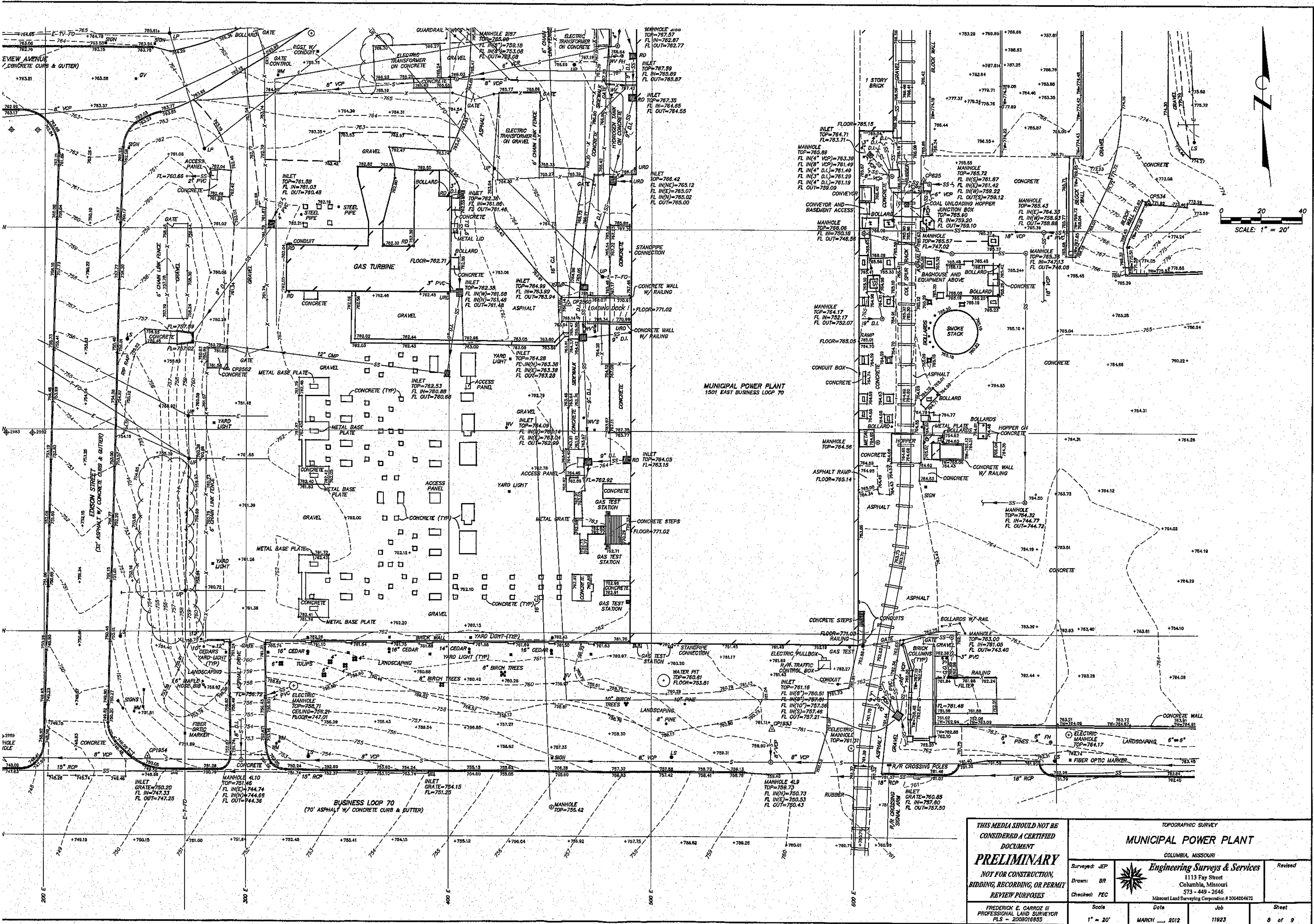
1" = 20'	MARCH __ 2012	11923	7 of 9



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PROFESSIONAL LAND SURVEYOR
PLS - 2008016855

TOPOGRAPHIC SURVEY

MUNICIPAL POWER PLANT

COLUMBIA, MISSOURI

Surveyed: JEP
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Missouri Land Surveying Corporation # 2004004672

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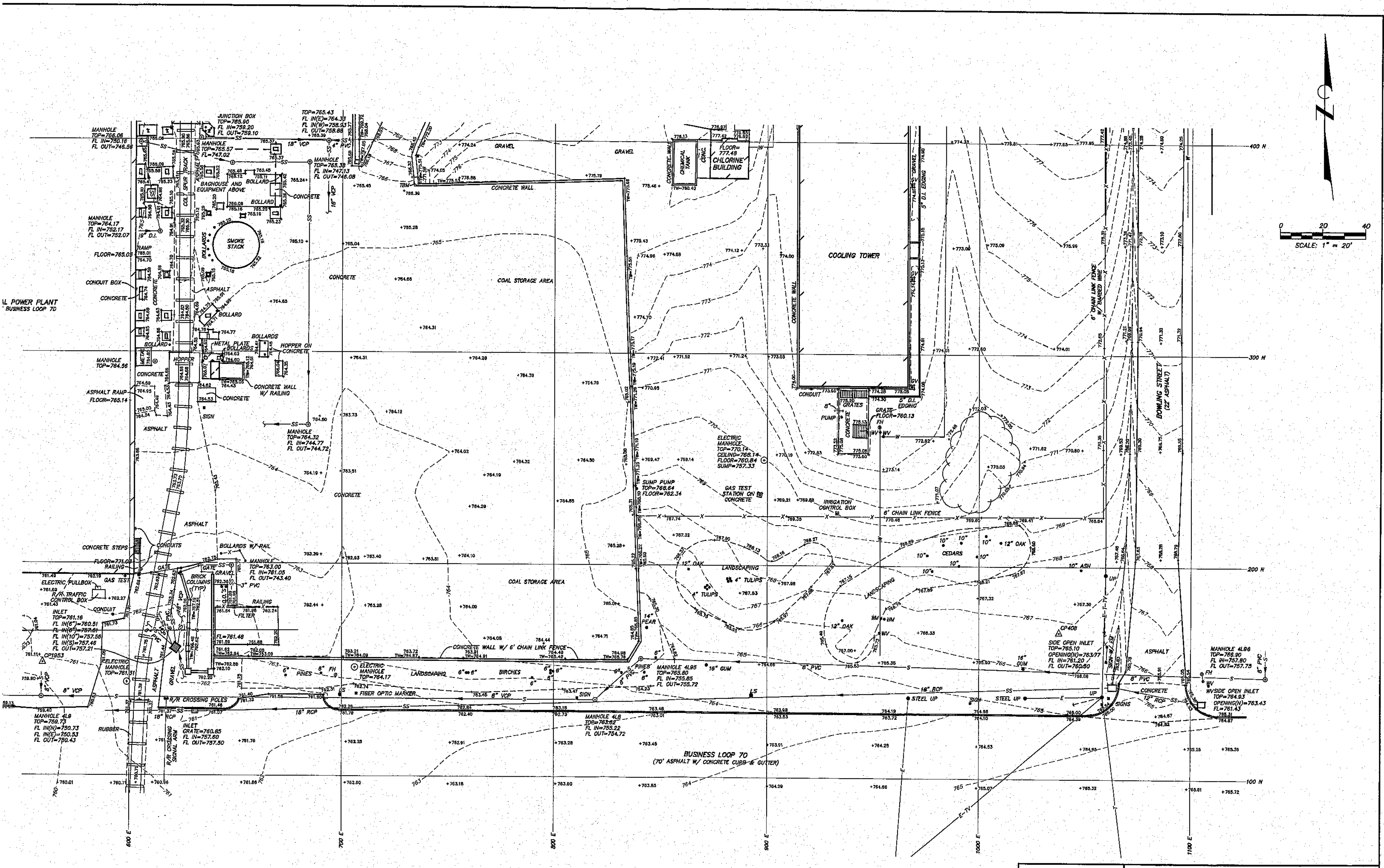
1" = 20'	MARCH __ 2012	11923	8 of 9



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NOT FOR CONSTRUCTION, BIDDING, RECORDING, OR PERMIT REVIEW PURPOSES

FREDERICK E. CARROZ III
PROFESSIONAL LAND SURVEYOR
PLS – 2008016555

TOPOGRAPHIC SURVEY

MUNICIPAL POWER PLANT

COLUMBIA, MISSOURI

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Checked: FEC

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Missouri Land Surveying Corporation # 2004004672

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Scale	Date	Job	Sheet
1" = 20'	MARCH ___ 2012	11923	9 of 9

Appendix C

Doc 02: Geotechnical Engineering Report by Terracon

GEOTECHNICAL ENGINEERING REPORT
LOCOMOTIVE MAINTENANCE BUILDING
COLUMBIA, MISSOURI

Project No. 09045217
March 2, 2004

Prepared for:

CITY OF COLUMBIA
WATER & LIGHT DEPARTMENT
Columbia, Missouri

Prepared by:

Terracon
Columbia, Missouri

Terracon

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ENGINEERING RECOMMENDATIONS 5
- Geotechnical Considerations 5
- Earthwork 5
- Foundation and Floor Slab Systems 6
- Seismicity 7
- Additional Considerations 7

GENERAL COMMENTS 8

APPENDIX A
- Vicinity Map
- Boring Location Diagram
- Boring Logs
- CPT Logs

APPENDIX B
- Chemical Analysis of Soils – Sulfate Content & Chloride Content

APPENDIX C
- General Notes
- Unified Soil Classification System
- General Notes: Description of Rock Properties

March 2, 2004

Terracon
3601 Mojave Court, Suite A
Columbia, Missouri 65202
(573) 214-2677 Fax: (573) 214-2714

City of Columbia – Water & Light Department
310 East Walnut
Columbia, Missouri 65205

Attention: Mr. Christian Johanningmeier
PHN 573.874.6373
FAX 573.815.0868

Regarding: Geotechnical Engineering Report
Locomotive Maintenance Building
Columbia, Missouri
Project No. 09045217

Dear Mr. Johanningmeier:

Terracon has completed the geotechnical engineering services for the proposed locomotive maintenance building at the Columbia Water and Light power plant in Columbia, Missouri. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork, and the design and construction of foundations and floor slabs for the proposed building.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
Terracon

Eric H. Lidholm, P. E.
Associate Principal
Missouri: E-23265

for Steve Levorson, P.E., Ph.D.
Associate Principal

State of Missouri
Eric H. Lidholm
Number E-23265
Registered Professional Engineer
3-3-04

Enclosures
3xc: Above
1xc: File

GEOTECHNICAL ENGINEERING REPORT
LOCOMOTIVE MAINTENANCE BUILDING
COLUMBIA, MISSOURI

Project No. 09045217
March 2, 2004

INTRODUCTION

A subsurface exploration has been completed for the proposed locomotive maintenance building at the Columbia Water and Light power plant in Columbia, Missouri. Five (5) borings, designated B-1 through B-5, were performed. Sampling was performed in borings B-1 through B-3, which were drilled to depths of approximately 8 to 54.5 feet below the existing ground surface in the building area. Sonic cone penetrometer soundings were performed in borings B-3 through B-5 to a depth of 16 to 22 feet in the building area. Logs of the borings, CPT logs, and a boring location diagram are included in Appendix A of this report.

The purpose of this report is to describe the subsurface conditions encountered in the borings, evaluate the test data and provide geotechnical recommendations regarding earthwork, and the design and construction of foundations and floor slabs for the proposed building. Global stability analysis is beyond the scope of this service. A proposal can be propovided for this service if requested.

PROJECT DESCRIPTION

We understand the proposed locomotive maintenance building will consist of a new 5,600 square foot pre-engineered one-(1) story steel building. This slab-on-grade structure is planned to house a single locomotive for maintenance and repair. No basement or below grade areas are planned. The finished floor elevation for this structure is planned at 772.5 feet. We understand the locomotives that will be housed in this structure weigh approximately 120 tons each, with axle loads of 60 kips. Some heavy earth-moving equipment, such as skid loaders, will also be housed in this structure.

The proposed structure will be constructed within the boundaries of the existing ash pond at the power plant site. One arm of the present-day water-filled ash pond traverses the proposed building site. Historical maps indicate this ash pond has been utilized since at least 1935. We understand that the existing power plant began operation in 1904 and, prior to being used as an ash pond, the body of water was a public swimming lake. The present-day water depth in the ash pond, within the vicinity of the proposed structure, is estimated to be 5 to 8 feet.

Site grading is expected to involve cuts on the order of 1 to feet and fills as great as 8 to 11 feet (to fill in the ash pond). Column and wall loads are expected to be on the order of 60 kips and 2 kips per lineal feet, respectively. Floor loads are expected to be on the order of 200 to 500 psf in portions of the structure and the track beds may exert pressures on the order of 2,900 psf.

SITE EXPLORATION PROCEDURES

Field Exploration

The boring locations were laid out on the site by Terracon personnel using a scaled drawing provided by the client. Distances from site references to the boring locations were measured in the field with a tape and by pacing. Right angles for the boring location measurements were estimated. Approximate boring locations are shown on the boring location diagram in Appendix A. Ground surface elevations indicated on the boring logs were determined in the field using the finished floor at the north bay door of the existing power plant. This finished floor elevation was assumed to be 768 feet, as interpolated from topographic information provided by the client. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

Borings were drilled with a truck-mounted, rotary drill rig using continuous flight hollow stem augers to advance the boreholes. Representative samples were obtained by the split-barrel sampling procedures. In the split-barrel sampling procedure, the number of blows required to advance a standard 2-inch O.D. split-barrel sampler the last 12 inches of the typical total 18-inch penetration by means of a 140-pound hammer with a free fall of 30 inches, is the standard penetration resistance value (N). This value is used to estimate the in-situ relative density of cohesionless soils and consistency of cohesive soils. The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further examination, testing, and classification.

The sonic cone penetrometer (CPTU) soundings were performed with a cordless piezocone penetrometer manufactured by Geotech, A.B. This device consists of a cone shaped sounding tip attached to steel rods with flush point couplings. The cone tip contains load cells to measure cone tip penetration resistance and sleeve friction resistance. Pore pressure measurements are made through a porous element located directly behind the cone tip. The tilt angle of the penetrometer is also measure by an inclinometer located within the sounding tip. All data are transmitted acoustically, i.e. the digitized coded data string is converted into a high frequency acoustic signal by a piezoelectric element in the probe. The signal is transmitted up through the steel rods to a microphone attached to the rig. The signals are then recorded in a laptop computer interfaced with the depth encoder attached to the rig. All CPTU soundings were logged in the field by an experienced geotechnical engineer.

The resistance to penetration and pore pressures generated during penetration can be correlated with soil engineering properties and the soil classification can be estimated.

Results of the CPTU testing are used to evaluate undrained shear strength and compressibility parameters for fine-grained soils.

Field logs of the borings were prepared by the drill crew. These logs included visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer's interpretation of the field logs and include modifications based on laboratory observation and tests of the samples.

Laboratory Testing

Split spoon samplers were tested to determine their natural water content. A calibrated hand penetrometer was used to estimate the approximate unconfined compressive strength of some samples. The calibrated hand penetrometer has been correlated with unconfined compression tests and provides a better estimate of soil consistency than visual examination alone. The test results are provided on the boring logs.

Selected samples were tested to determine their soluble sulfate and chloride content. These test results can be found in Appendix B of this report.

Descriptive classifications of the material indicated on the boring logs are in accordance with the enclosed General Notes, the Unified Soil Classification System, and the General Notes: Description of Rock Properties. Also shown are estimated Unified Soil Classification Symbols. A brief description of this classification system is attached to this report. Classification was generally by visual-manual procedures.

SITE AND SUBSURFACE CONDITIONS

The proposed structure will be constructed within the boundaries of the existing ash pond at the power plant site. One arm of the present-day water-filled ash pond traverses the proposed building site. Historical maps indicate this ash pond has been utilized since at least 1935. We understand that the existing power plant began operation in 1904 and, prior to being used as an ash pond, the body of water was a public swimming lake. The present-day water depth in the ash pond, within the vicinity of the proposed structure, is estimated to be 5 to 8 feet

Soil Conditions

Conditions encountered at each boring location are indicated on the individual boring logs. Stratification boundaries on the boring logs represent the approximate location of changes in soil types; in-situ, the transition between materials may be gradual. Details for each of the borings can be found on the boring logs in Appendix A of this report. Based on the results of the borings, subsurface conditions on the project site can be generalized as follows:

Each boring encountered uncontrolled fill and possible fill. The uncontrolled fill and possible fill consisted of various amounts of cinders, bottom ash, lean clay, lean to fat clay, fat clay, gravel, and trace amounts of coal, sand and silt. Concrete rubble was also encountered in boring B-1 below an approximate depth of 6 feet. Boring B-1 terminated with auger refusal in the concrete rubble at an approximate depth of 8 feet below the existing grade at the time of drilling. The uncontrolled fill was typically soft to medium-stiff in consistency and extended to approximate depths of 13 to 18 feet below the existing grade in the borings.

Underlying the uncontrolled fill and possible fill in the borings was glacial drift consisting of lean to fat clay and fat clay. The glacial drift was typically slightly jointed, contained sand, gravel, sandy zones, and possible cobbles and boulders, and was medium stiff to hard in consistency. The glacial drift also contained significant sandy zones, which were medium dense to very dense. These sandy zones extended from a depth of 18 feet to 27 feet and from a depth of 28 feet to 33 feet in borings B-2 and B-3, respectively. Underlying the significant sandy zones, the consistency of the glacial drift material was very stiff to hard. The glacial drift extended to an approximate depth of 53 feet in the borings.

Underlying the glacial drift, in the borings, was shale. The shale was weathered and contained trace sand, gravel and cobbles, and possible boulders. The shale caused split spoon sampler refusal (i.e. standard penetration test blow count greater than 100 blows per foot) and extended to the boring termination depth of 54.5 feet below existing grade. Both borings, B-2 and B-3, terminated in the shale.

Groundwater Conditions

The boreholes were observed while drilling and after completion for the presence and level of groundwater. Groundwater was observed in borings B-2 and B-3 during drilling at a depth of 6 feet. Groundwater was encountered in boring B-2 after at a depth of 6 feet at drilling completion. Groundwater levels are expected to be closely related to the water levels encountered in the adjacent, and partially surrounding, ash pond.

Due to the low permeability of the soils encountered in the borings, a relatively long period of time may be necessary for a groundwater level to develop and stabilize in a borehole in these materials. Long term observations in piezometers or observation wells sealed from the influence of surface water are often required to define groundwater levels in materials of this type.

It should be recognized that fluctuations in groundwater levels may occur and perched groundwater can develop due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the structure may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations and the occurrence of seasonally perched groundwater in the near surface soils, glacial drift sand lenses and underlying bedrock should be considered when developing the design and construction plans for the project.

ENGINEERING RECOMMENDATIONS

Geotechnical Considerations

Borings for the proposed locomotive maintenance building encountered a sequence of uncontrolled fill and possible fill material underlain by glacial drift with significant sand zones and, in turn, by shale. These materials will form the subgrade for the proposed floor slab, and foundations.

Existing fill material was encountered on the project site. The existing fill, as encountered in the borings, was soft to medium-stiff in consistency and contained various amounts of cinders, bottom ash, concrete rubble, lean clay, lean to fat clay, fat clay, gravel, coal, sand and silt. However, variations may exist between the borings.

Risk associated with construction on uncontrolled fill must be assumed by the owner. These risks can be eliminated by removing and replacing the existing fill material with controlled, compacted, engineered fill material. We understand that the existing fill is planned to remain in-place. In order to reduce, but not eliminate, the risk of construction on uncontrolled fill, we recommend that the exposed subgrade be thoroughly evaluated after stripping of topsoil and creation of all cut areas, but prior to the start of fill operations.

We recommended that Terracon be retained to evaluate the bearing material for the foundations and the pavement and floor slab subgrade soils. Subsurface conditions, as identified by the field and laboratory testing programs, have been reviewed and evaluated with respect to the proposed building plans known to us at this time. Based on our findings, we have developed the following recommendations.

Earthwork

Prior to placing fill, all vegetation, topsoil, and debris should be removed from the construction areas. The slough that traverse part of the building site will need to be dammed, pumped out, and backfilled. We understand that you plan to use cinders/bottom ash for fill.

Wet or dry material should either be removed or moisture conditioned and recompacted. After stripping and grubbing, the subgrade should be proof-rolled to aid in locating loose or soft areas. Proofrolling can be performed with a loaded tandem axle dump truck. Soft, dry and low-density soil should be removed or compacted in place prior to placing fill.

Fill should consist of approved materials that are free of organic matter and debris. A sample of each material type should be submitted to the geotechnical engineer for evaluation. In general, low plasticity cohesive soil or granular soil having at least 18% low plasticity fines should be used for fill. The liquid limit of low plasticity fill should be less than 50 and the plasticity index should be less than 20.

Existing uncontrolled fill material and site soils removed from the building area and consisting of lean clays, lean to fat clays and fat clays which are free of organic matter and debris may be reused to construct controlled, compacted fills.

Controlled, compacted fill should be placed in lifts of 9 inches or less in loose thickness and should be compacted to at least 95% of the material's maximum standard Proctor dry density (ASTM D-698). The moisture content of clay fill should be within the range of the optimum moisture content to 4% above the optimum moisture content value determined by the standard Proctor test at the time of placement and compaction. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved. Granular fill should be placed at workable moisture contents and compacted as recommended for controlled, compacted fill.

The geotechnical engineer should be retained during construction to observe earthwork and to perform necessary tests and observations during subgrade preparation; placement and compaction of controlled compacted fills; when backfilling of excavations into the completed subgrade are made as well as just prior to construction of building floor slabs.

Foundation and Floor Slab Systems

We analyzed the subsurface data obtained from the borings and CPTU soundings to evaluate potential shallow foundation design alternatives. Based on our analyses, in our opinion, it would not be feasible to develop shallow foundations at this site without substantial preparatory site work. Based on the loads provided, we anticipate settlement of shallow foundations, rails, and heavily loaded floor slabs, placed on new fill over the existing ash pond could experience total settlements on the order of 8 inches or more, with differential settlements on the order of 6 inches across parts of the building.

We also considered four other possible construction alternatives: partial removal and replacement of the existing ash pond, preloading the site to prestress the foundation bearing stratum, deep foundations bearing in the underlying glacial till, and intermediate foundation elements consisting of Geopiers. Our analyses indicated that the first three options would likely not be either technically or economically feasible. Partial removal and replacement would not control the differential settlement to within acceptable tolerances. To reduce the differential settlement to acceptable levels would essentially require complete removal and replacement of existing fill. Preloads on the order of 15 to 20 feet tall would be required to reduce settlements to acceptable levels. This was deemed uneconomical. Deep foundations could be used, but would require use of a structural floor slab system, also uneconomical.

We therefore recommend the project be designed using Geopier foundation elements to support foundation and floor slab loads. The Geopier foundation system is a proprietary design-build system, therefore the subsurface exploration information contained in this report should be provided to the Geopier Foundation Company for detailed analysis and design.

Geopiers typically consist of 30-inch diameter drilled holes that are filled in thin lifts with highly compacted, well-graded aggregate to form very stiff, high-density aggregate piers. For this project we anticipate the Geopiers would extend about 10 - 20 feet below existing grade to penetrate the existing fill. The compacted aggregate piers produce high lateral stresses within the surrounding soil matrix; thereby stiffening the reinforced composite soil/aggregate mass. This results in significant strengthening and stiffening of the foundation bearing layer to support heavily loaded floor slabs and high-capacity footings within strict settlement tolerances. It is our opinion that this type of foundation system would most economically meet the requirements for this project.

Seismicity

The 2000 International Building Code (IBC) requires structural design to be in accordance with the appropriate seismic site classifications based upon subsurface rock and soil conditions. Based upon the nature of the subsurface materials, and assuming Geopiers will be used to support the structural loads, floor slab, and tracks, a Site Class C should be used for seismic evaluation in accordance with the 2000 International Building Code, Table 1615.1.1. If Geopiers are not used, the seismic site coefficient should be reevaluated.

Additional Considerations

Based upon the results of chemical analysis tests performed on soils samples obtained from this project site, we recommend a Type II cement be used. Test results for chloride content and sulfate content are included in Appendix B of this report.

Utility trenches should be backfilled with controlled engineered fill placed and compacted as recommended. All trench excavations should be made with sufficient working space to permit construction including backfill.

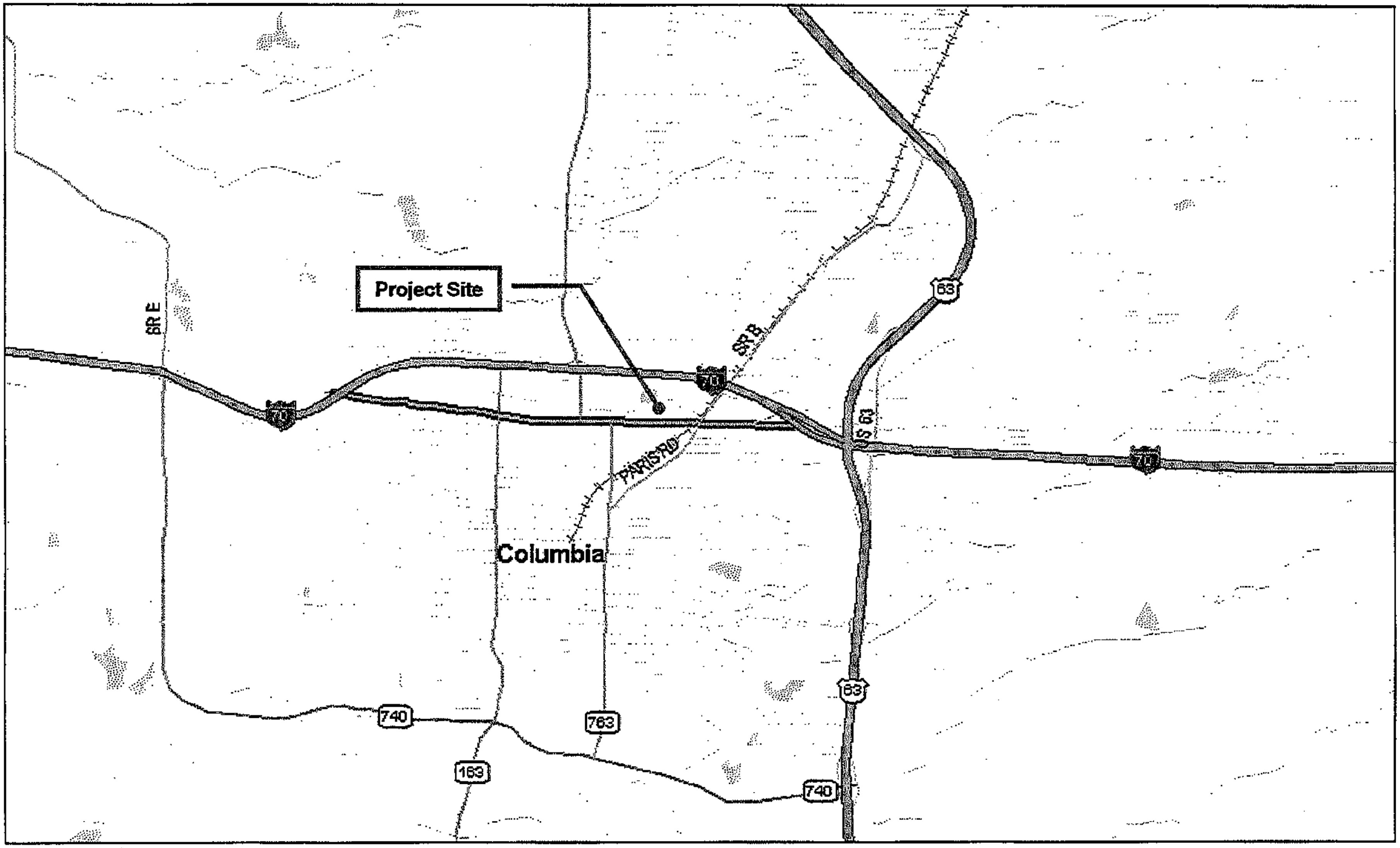
GENERAL COMMENTS

Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon also should be retained to provide testing and observation during excavation, grading, foundation and construction phases of the project.

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.



NOT TO SCALE

VICINITY MAP LOCOMOTIVE MAINTENANCE BUILDING COLUMBIA, MISSOURI		
Project Manager: EHL	Terracon	Project No. 09045217
Reviewed by: EHL	3601 Mojave Court, Suite A Columbia, MO 65202	
Drawn by: WMS		February 6, 2004

LOCOMOTIVE MAINTENANCE BUILDING
COLUMBIA, MISSOURI
09045217
2/27/2004

REPORT OF CHEMICAL ANALYSIS

BORING NUMBER	SAMPLE NUMBER	SULFATE (ppm)	CHLORIDE (ppm)
Note 1	1	1500	< 6.0
Note 2	2	1200	< 6.0

SULFATE MDL*	CHLORIDE MDL*
25	6.0

* MDL — Minimum Detection Limit

Note 1 — Composite sample of the cinders/ash

Note 2 — Composite sample of the clay

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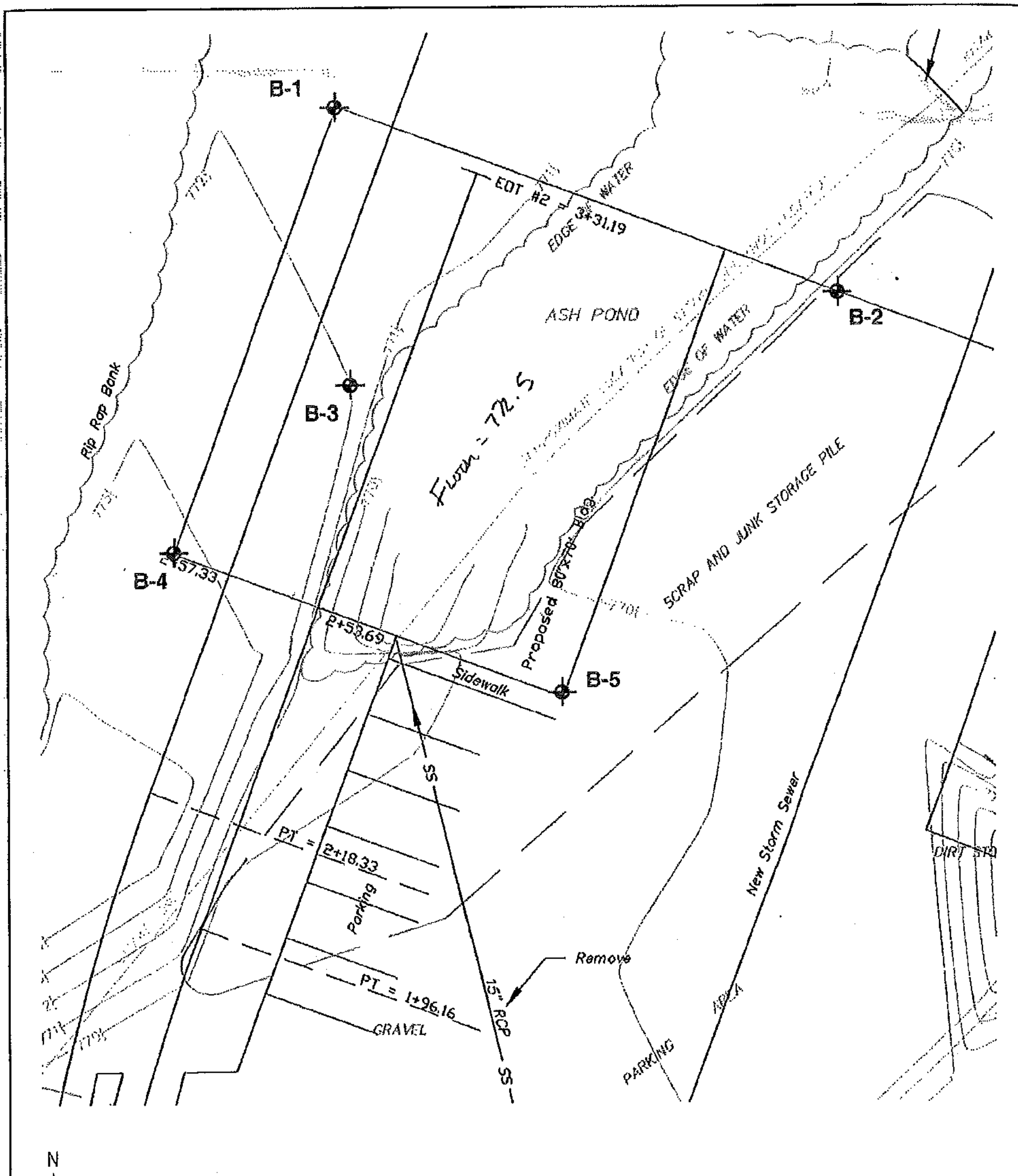

NOT TO SCALE

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES.

BORING LOCATION DIAGRAM LOCOMOTIVE MAINTENANCE BUILDING COLUMBIA, MISSOURI		
Project Manager: EHL	Terracon	Project No. 09045217
Reviewed by: EHL	3601 MOJAVE COURT, SUITE A COLUMBIA, MISSOURI 65202	
Drawn by: WMS		February 6, 2004

LOG OF BORING NO. B-01

CLIENT	ARCHITECT / ENGINEER
CITY OF COLUMBIA - WATER & LIGHT	
SITE: COLUMBIA, MISSOURI	PROJECT: LOCOMOTIVE MAINTENANCE BUILDING

Boring Location: North Corner of Proposed Building

Approx. Surface Elev.: 773.5 ft

DESCRIPTION	Depth/Elev.	DEPTH, ft.	USCS SYMBOL	NUMBER	TYPE	RECOVERY, in.	SPT - N BLOWS / ft.	WATER CONTENT, %	DRY UNIT WT pcf	UNCONFINED STRENGTH, psf
FILL: cinders, bottom ash, trace coal, medium stiff to stiff					PA					
				1	SS	18	11	15.0		
					HS					
-: lean to fat clay with cinders, and bottom ash, trace coal, trace gravel, light brown and gray, mottled				2	SS	17	4	25.0		2000*
		5			HS					
	6 / 767.5									
CONCRETE RUBBLE	8 / 765.5									
BOTTOM OF BORING AT 8 FEET										

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME 140H SPT automatic hammer

WATER LEVEL OBSERVATIONS, ft				BORING STARTED	1-21-04		
WL	▽ NONE	WD ▼ NONE	AB	BORING COMPLETED	1-21-04		
WL	▽	▽		RIG	CME 75	FOREMAN	JD
WL				APPROVED	EHL	JOB #	09045217

Terracon

BOREHOLE 09045217.GPJ TERRACON.GDT 3/4/04

LOG OF BORING NO. B-02

CLIENT	ARCHITECT / ENGINEER
CITY OF COLUMBIA - WATER & LIGHT	
SITE	PROJECT
COLUMBIA, MISSOURI	LOCOMOTIVE MAINTENANCE BUILDING

Boring Location: East of East Corner of Proposed Building

Approx. Surface Elev.: 770.0 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY, in.	SAMPLES: SPT - N BLOWS / ft.	TESTS: WATER CONTENT, %	TESTS: DRY UNIT WT pcf	TESTS: UNCONFINED STRENGTH, psf
	FILL: cinders, bottom ash, trace coal, medium stiff to stiff				PA					
				1	SS	12	6	23.0		2000*
	-: lean to fat clay, trace cinders, bottom ash and coal, trace sand and gravel, trace cobbles, gray and brown, mottled				HS					
				2	SS	18	6	25.0		2500*
		5			HS					
	8 — 762									
	FAT CLAY: slightly jointed, trace gravel, greenish gray, gray and brown, mottled, stiff (Possible Fill)			3	SS	18	10	24.0		4000*
		10			HS					
	13 — 757									
	FAT CLAY: slightly jointed, trace sand and gravel, yellow brown and gray, mottled, very stiff (Glacial Drift)			4	SS	18	12	18.0		6500*
		15			HS					
	18 — 752									
	SAND: with silt and clay, trace gravel, brown, trace gray, very dense			5	SS	18	52	17.0		
		20			HS					
				6	SS	18	52	19.0		
		25			HS					
	27 — 743									
	LEAN TO FAT CLAY: trace sand and gravel, yellow brown, trace gray, very stiff to hard (Glacial Drift)			7	SS	18	47	12.0		9000*
		30								

Continued Next Page

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME 140H SPT automatic hammer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ 6	WD ▼ 6	AB
WL	▽	▽	
WL			

Terracon

BORING STARTED			1-22-04
BORING COMPLETED			1-22-04
RIG	CME 75	FOREMAN	JD
APPROVED	EHL	JOB #	09045217

LOG OF BORING NO. B-02

CLIENT	ARCHITECT / ENGINEER
CITY OF COLUMBIA - WATER & LIGHT	
SITE: COLUMBIA, MISSOURI	PROJECT: LOCOMOTIVE MAINTENANCE BUILDING

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, in.	SAMPLES SPT - N BLOWS / ft.	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
					HS					
	-: possible cobbles, dark gray			8	SS	12	58	12.0		7500*
		35			HS					
				9	SS	18	30	17.0		6500*
		40			HS					
				10	SS	3	38	20.0		9000*
		45			HS					
				11	SS	18	43	16.0		9000*
		50			HS					
	53 — 717									
	***SHALE: weathered, possible cobbles and boulders, gray			12	SS	0	50/2"			
	54.5 — 715.5									
	SPLIT SPOON SAMPLER REFUSAL AT 54.5 FEET									
	***Classifications estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.									

The stratification lines represent the approximate boundary lines between soil and rock types: In-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME 140H SPT automatic hammer

WATER LEVEL OBSERVATIONS, ft			
WL	∇ 6	WD ▼ 6	AB
WL	∇	∇	
WL			

Terracon

BORING STARTED			1-22-04
BORING COMPLETED			1-22-04
RIG	CME 75	FOREMAN	JD
APPROVED	EHL	JOB #	09045217

LOG OF BORING NO. B-03

CLIENT	ARCHITECT / ENGINEER
CITY OF COLUMBIA - WATER & LIGHT	
SITE: COLUMBIA, MISSOURI	PROJECT: LOCOMOTIVE MAINTENANCE BUILDING

Boring Location: West of Center of Proposed Building

Approx. Surface Elev.: 773.5 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY, in.	SPT - N BLOWS / ft.	TESTS WATER CONTENT, %	DRY UNIT WT pcf	UNCONFINED STRENGTH, psf
	FILL: cinders, bottom ash, trace coal, trace clay, trace gravel and cobbles, soft to stiff				PA					
				1	SS	18	5	19.0		3000*
					HS					
				2	SS	10	2	17.0		1500*
	∇	5			HS					
	-: clayey, with gravel			3	SS	18	2	14.0		
	-: lean clay, trace sand, silt and gravel, trace cinders, bottom ash and coal, gray and brown	10			HS					
				4	SS	18	4	16.0		500*
	14.5 — 759									
	FAT CLAY: slightly jointed, trace sand and gravel, with sandy zones, yellow brown and gray, mottled, medium stiff to stiff	15			HS					
				5	SS	18	6	26.0		1500*
		20			HS					
	-: possible cobbles and boulders, light brown			6	SS	18	9	16.0		3000*
		25			HS					
	28 — 745.5									
	SILTY SAND: trace gravel, brown, medium dense			7	SS	18	26	20.0		
		30								

Continued Next Page

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME 140H SPT automatic hammer

WATER LEVEL OBSERVATIONS, ft			
WL	∇ 6 WD	▼ NONE AB	
WL	∇	∇	
WL			

Terracon

BORING STARTED	1-21-04		
BORING COMPLETED	1-21-04		
RIG	CME 75	FOREMAN	JD
APPROVED	EHL	JOB #	09045217

LOG OF BORING NO. B-03

CLIENT	ARCHITECT / ENGINEER
CITY OF COLUMBIA - WATER & LIGHT	
SITE	PROJECT
COLUMBIA, MISSOURI	LOCOMOTIVE MAINTENANCE BUILDING

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY, in.	SAMPLES: SPT - N BLOWS / ft.	TESTS: WATER CONTENT, %	TESTS: DRY UNIT WT pcf	TESTS: UNCONFINED STRENGTH, psf
					HS					
	33 — 740.5									
	LEAN TO FAT CLAY: trace sand and gravel, possible cobbles, light brown, with gray, very stiff to hard (Glacial Drift)			8	SS	18	85	15.0		6500*
		35			HS					
	38 — 735.5									
	FAT CLAY: trace gravel, possible cobbles, dark gray, very stiff to hard (Glacial Drift)			9	SS	18	63	13.0		9000*
		40			HS					
	-: slightly jointed			10	SS	18	37	14.0		6500*
		45			HS					
				11	SS	2	50/2"	16.0		9000*
		50			HS					
	53 — 720.5									
	***SHALE: weathered, trace sand, gravel and cobbles, possible boulders, light gray			12	SS	3	50/3"	13.0		9000*
	54.5 — 719									
	SPLIT SPOON SAMPLER REFUSAL AT 54.5 FEET									
	***Classifications estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME 140H SPT automatic hammer

WATER LEVEL OBSERVATIONS, ft				
WL	∇ 6	WD	▼ NONE	AB
WL	∇		▼	
WL				

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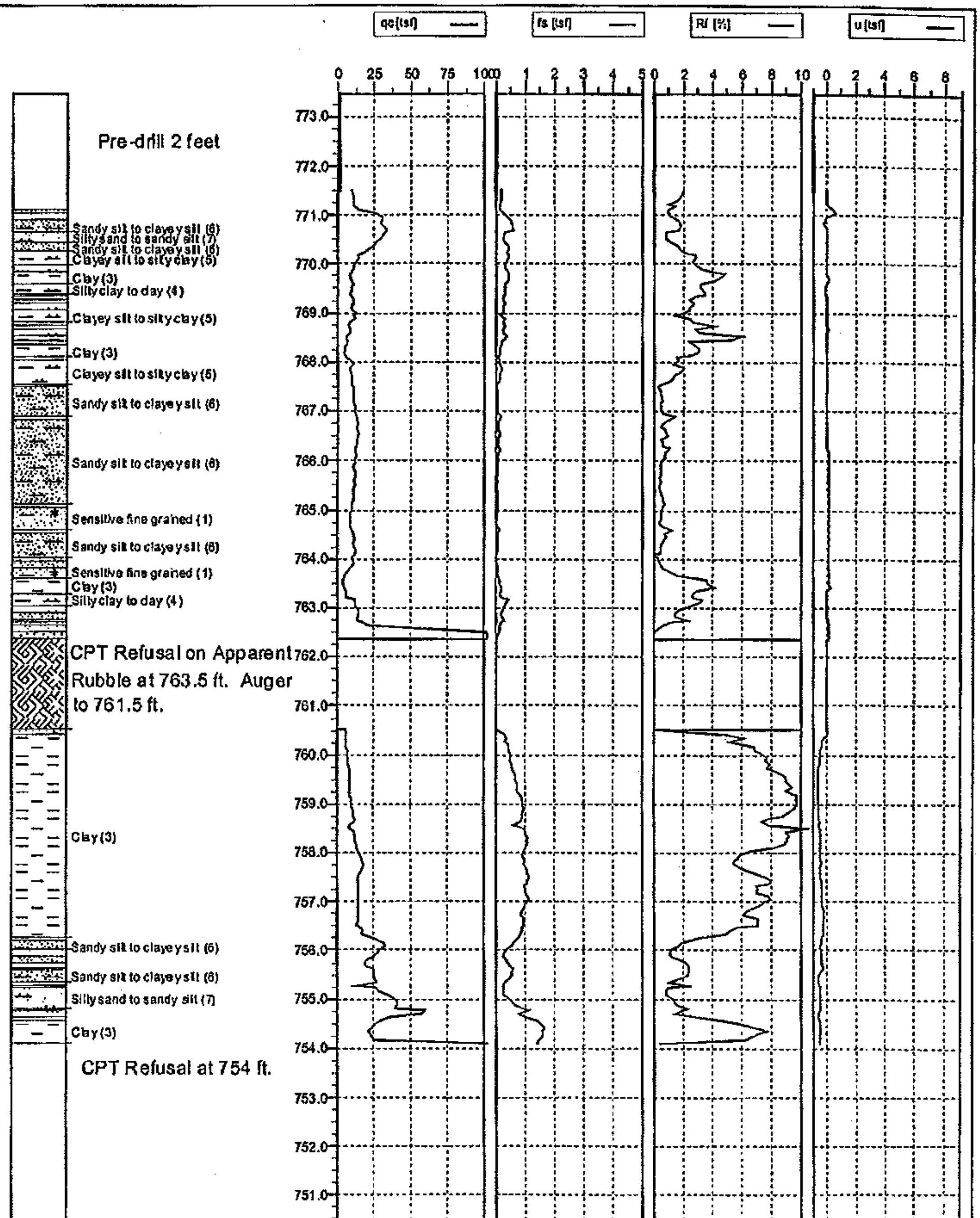
BORING STARTED			1-21-04
BORING COMPLETED			1-21-04
RIG	CME 75	FOREMAN	JD
APPROVED	EHL	JOB #	09045217

BOREHOLE 09045217.GPJ TERRACON.GDT 3/4/04



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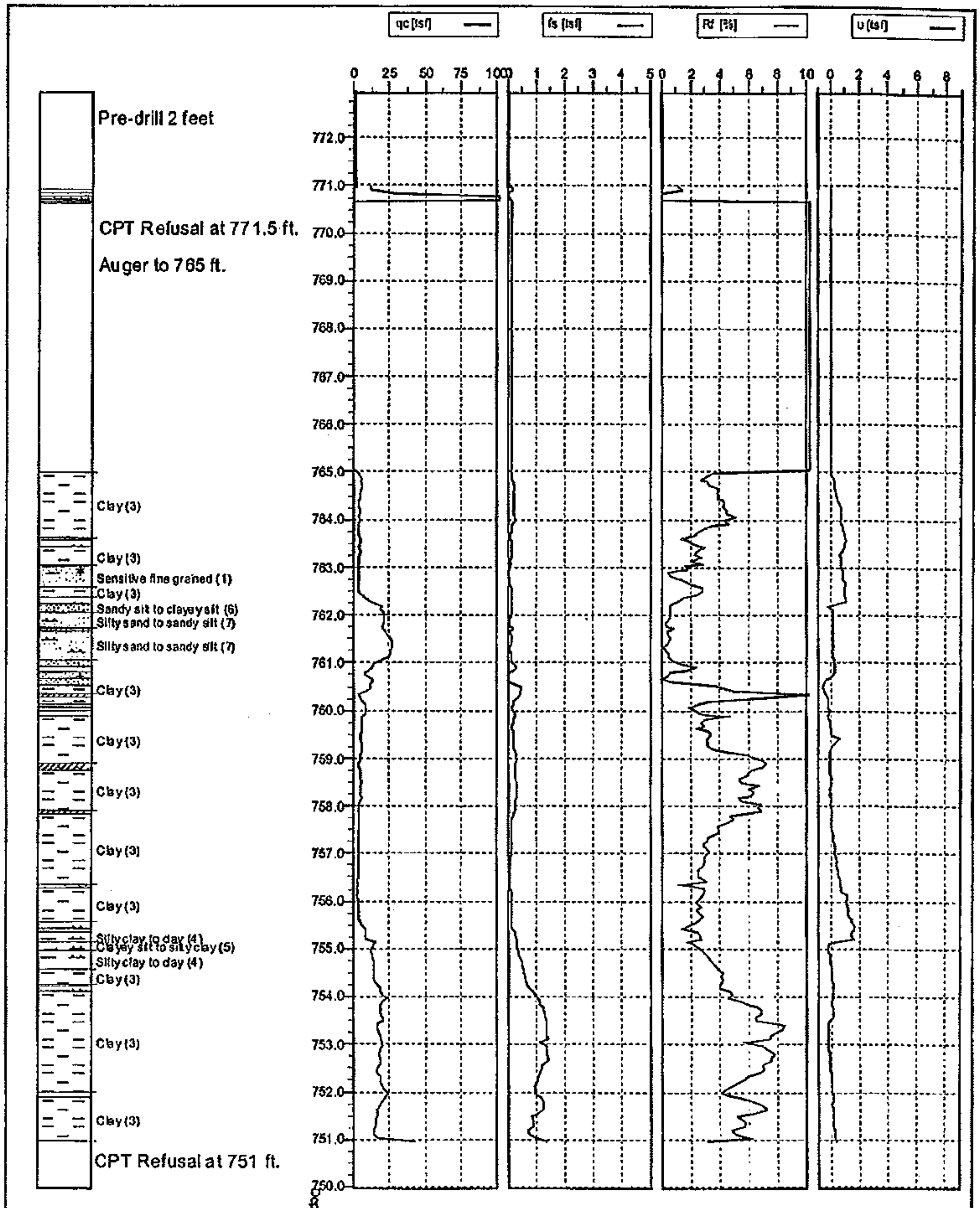
Test no: C-3	Position: West of Center of, Proposed Building	Ground level: 773.5 ft	
Client:	City of Columbia - Water & Light	Date: 1/22/2004	Scale:
Project:	Locomotive Maintenace Building	Page: 1/1	Fig:
	Terracon Project No. 09045217	File: B-3.cpd	



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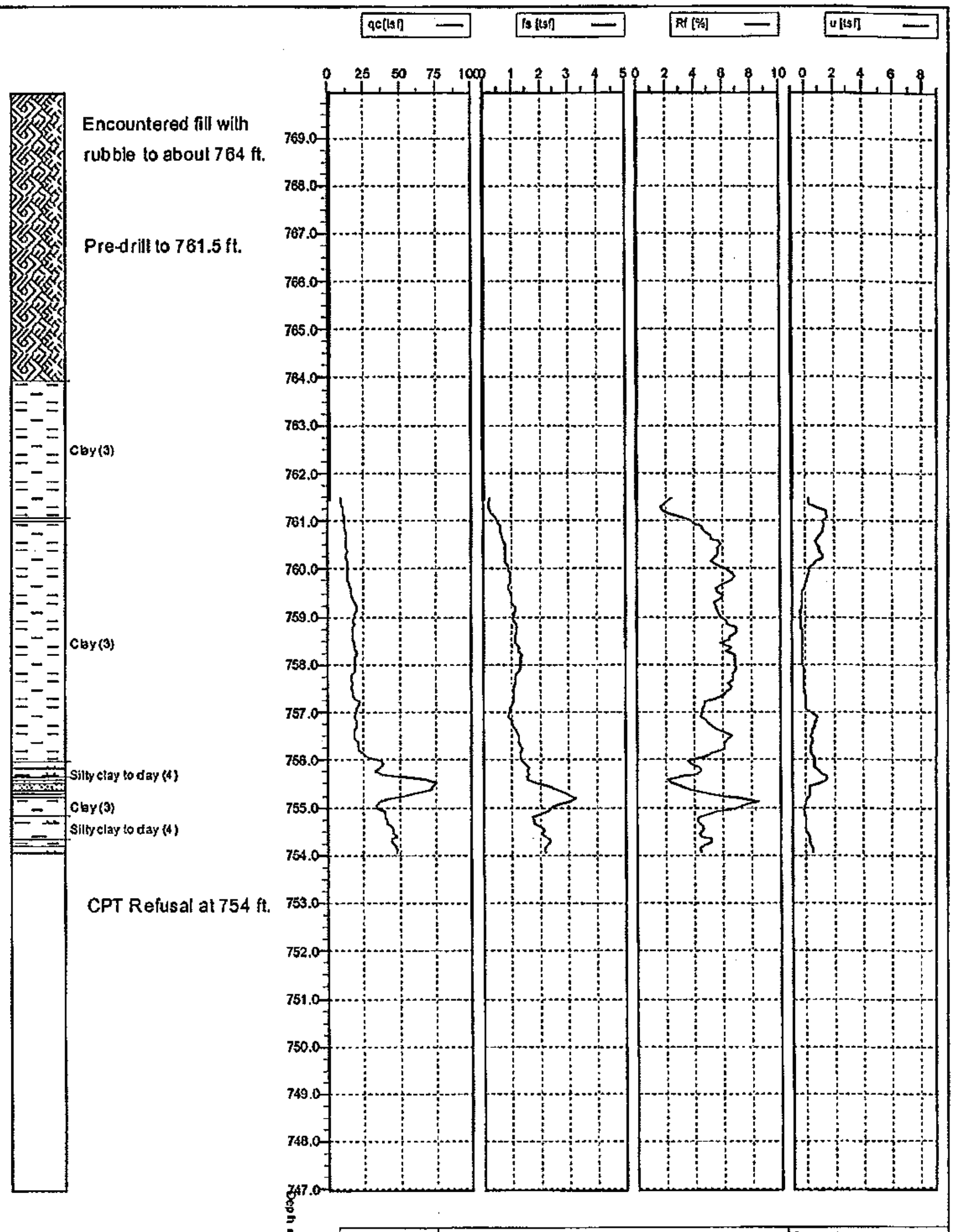
Test no: C-4	Position: Southwest Corner of, Proposed Building	Ground level: 773.0 ft
Client:	City of Columbia - Water & Light	Date: 1/22/2004 / Scale:
Project:	Locomotive Maintenance Building	Page: 1/1 / Fig:
	Terracon Project No. 09045217	File: 8-4.cpd



Test no: C-5	Position: Southeast Corner of, Proposed Building	Ground level: 770.0 ft	
Client:	City of Columbia - Water & Light	Date: 1/22/04	Scale:
Project:	Locomotive Maintenance Building	Page: 1/1	Fig:
	Terracon Project No. 09045217	File: B-5.cpd	

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GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon - 1-3/8" I.D., 2" O.D., unless otherwise noted	HS:	Hollow Stem Auger
ST:	Thin-Walled Tube - 2" O.D., unless otherwise noted	PA:	Power Auger
RS:	Ring Sampler - 2.42" I.D., 3" O.D., unless otherwise noted	HA:	Hand Auger
DB:	Diamond Bit Coring - 4", N, B	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	WB:	Wash Boring or Mud Rotary

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the "Standard Penetration" or "N-value".

WATER LEVEL MEASUREMENT SYMBOLS:

WL:	Water Level	WS:	While Sampling
WCI:	Wet Cave in	WD:	While Drilling
DCI:	Dry Cave In	BCR:	Before Casing Removal
AB:	After Boring	ACR:	After Casing Removal

Water levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels may not be possible with only short-term observations.

DESCRIPTIVE SOIL CLASSIFICATION: Soil classification is based on the Unified Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

CONSISTENCY OF FINE-GRAINED SOILS

Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-value (SS) Blows/Ft.	Consistency
< 500	<2	Very Soft
500 – 1,000	2-3	Soft
1,001 – 2,000	4-6	Medium Stiff
2,001 – 4,000	7-12	Stiff
4,001 – 8,000	13-26	Very Stiff
8,000+	26+	Hard

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Standard Penetration or N-value (SS) Blows/Ft.	Relative Density
0 – 3	Very Loose
4 – 9	Loose
10 – 29	Medium Dense
30 – 49	Dense
50+	Very Dense

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 – 29
Modifier	> 30

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 – 12
Modifiers	> 12

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300mm)
Cobbles	12 in. to 3 in. (300mm to 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 Sieve (0.075mm)

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1-10
Medium	11-30
High	30+

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UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]					Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]		GW	Well-graded gravel[F]
			$Cu < 4$ and/or $1 > Cc > 3$[E]		GP	Poorly graded gravel[F]
		Gravels with Fines More than 12% fines[C]	Fines classify as ML or MH		GM	Silty gravel[F,G,H]
			Fines classify as CL or CH		GC	Clayey gravel[F,G,H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]		SW	Well-graded sand[I]
			$Cu < 6$ and/or $1 > Cc > 3$[E]		SP	Poorly graded sand[I]
		Sands with Fines More than 12% fines[D]	Fines classify as ML or MH		SM	Silty sand[G,H,I]
			Fines Classify as CL or CH		SC	Clayey sand[G,H,I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line[J]		CL	Lean clay[K,L,M]
			PI < 4 or plots below "A" line[J]		ML	Silt[K,L,M]
		organic	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OL	Organic clay[K,L,M,N]
						Organic silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line		CH	Fat clay[K,L,M]
			PI lots below "A" line		MH	Elastic Silt[K,L,M]
		organic	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OH	Organic clay[K,L,M,P]
						Organic silt[K,L,M,O]
Highly organic soils	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

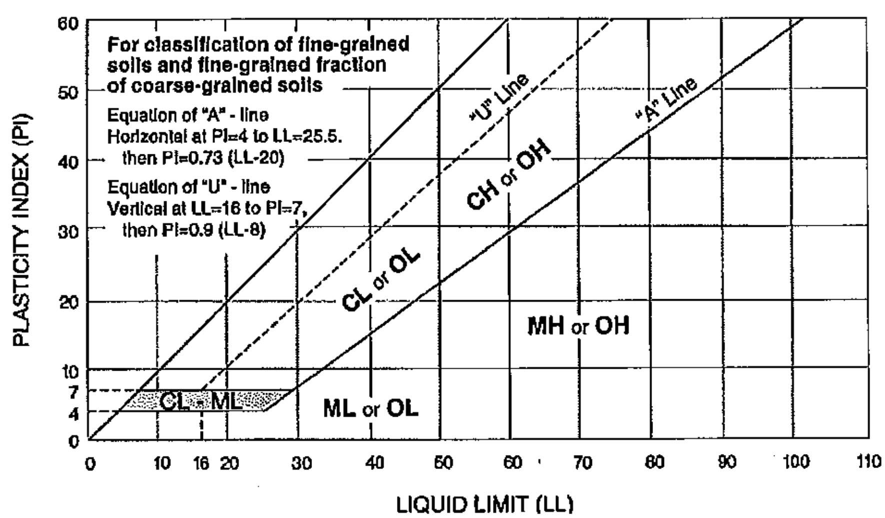
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[O] PI plots below "A" line.



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GENERAL NOTES
Description of Rock Properties

WEATHERING

Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil". Rock "fabric" not discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)

Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Joint, Bedding and Foliation Spacing in Rock[a]

Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

Rock Quality Designator (RQD)[b]		Joint Openness Descriptors	
RQD, as a percentage	Diagnostic description	Openness	Descriptor
Exceeding 90	Excellent	No Visible Separation	Tight
90 – 75	Good	Less than 1/32 in.	Slightly Open
75 – 50	Fair	1/32 to 1/8 in.	Moderately Open
50 – 25	Poor	1/8 to 3/8 in.	Open
Less than 25	Very poor	3/8 in. to 0.1 ft.	Moderately Wide
		Greater than 0.1 ft.	Wide

a. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.
b. RQD (given as a percentage) = length of core in pieces 4 in. and longer/length of run.

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976.
U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.

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Appendix C

Doc 03: USACE Report on Moores Lake Dam

MISSOURI · KANSAS CITY RIVER BASIN

MOORES LAKE DAM
BOONE COUNTY, MISSOURI
MO. 11173

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

PREPARED BY: U. S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

DECEMBER 1980

mbia, Mo., Thursday, June 30, 1983

Deadline near for dam inspections

JEFFERSON CITY (AP) — As part of a statewide dam safety program, the owners of non-agricultural dams more than 70 feet high will have until Aug. 13 to inspect their dams and have them registered with the Missouri Department of Natural Resources, says department Director Fred Lafser.

Lafser said yesterday the department's Dam and Reservoir Safety Council set the deadline as part of an inspection program to make sure all dams in the state were structurally sound, Lafser said.

"Our main goal is to protect the public from dam failure," Lafser said. "To do this, we must make sure that all dams meet safety standards."

Non-agricultural dams more than 35 feet high are regulated by the department's Dam and Reservoir Safety Program.

The program's chief engineer, Robert Myers, said owners of old and new dams that are more than 70 feet high must register this year. Owners of dams 50 feet to 70 feet high must register their dams in two years, and owners of dams 35 feet to 50 feet high must register no later than the two years after that, Myers said.

A dam owner would receive a registration permit by having a registered professional engineer inspect the dam. After the owner corrected any deficiencies found by the engineer and the dam had been reinspected, the engineer would file a report with the natural resources department and receive the permit, which is free.

Myers said dam owners who did not register their dams could be fined up to $1,000 a day. About 50 dams must be registered this year, and several owners have already complied with the policy, Myers said.

"In 1980, an inventory of dams in Missouri showed that 74 percent of the dams were considered unsafe," Myer said. "Through this program, we want to make sure that they are brought up to safe levels."

Water and Light Department

FROM Gary Date 6/7/83

TO: Acknowledge initials and date

1. D. Malon
2.
3.
4.

- ☐ APPROVAL
- ☐ SIGNATURE
- ☐ COMMENT
- ☐ SEE ME
- ☐ AS REQUESTED
- ☑ INFORMATION
- ☐ READ AND RETURN
- ☐ READ AND FILE
- ☐ READ AND FORWARD
- ☐ NECESSARY ACTION
- ☐ INVESTIGATE
- ☐ RECOMMENDATION
- ☐ PREPARE ROUGH DRAFT FOR MY SIGNATURE
- ☐ ADVISE COMPLETION
- ☐ PLEASE ANSWER WITH COPY TO ME
- ☐

Gary St Ivory from DNR indicated that we are not required to register our Myers lake dam. The low limit for registration is 35 feet. Our Dam is 30 feet.

314-364 1752

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

SUBJECT: Moores Lake Dam (MO 11173)

This report presents the results of field inspection and evaluation of the Moores Lake Dam . It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY: ______________________ 20 Jan 81
Chief, Engineering Division — Date

APPROVED BY: ______________________ LTC, CE 21 Jan 81
Colonel, CE, District Engineer — Date

MOORES LAKE DAM

BOONE COUNTY, MISSOURI

MISSOURI INVENTORY NO. 11173

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY

CONSOER, TOWNSEND AND ASSOCIATES, LTD.

ST. LOUIS, MISSOURI

AND

PRC ENGINEERING CONSULTANTS, INC.

ENGLEWOOD, COLORADO

A JOINT VENTURE

UNDER DIRECTION OF

ST. LOUIS DISTRICT, CORPS OF ENGINEERS

FOR

GOVERNOR OF MISSOURI

DECEMBER 1980

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam: Moores Lake Dam, Missouri Inv. No. 11173
State Located: Missouri
County Located: Boone
Stream: An unnamed tributary of Bear Creek
Date of Inspection: July 11, 1980

Assessment of General Condition

Moores Lake Dam was inspected by the engineering firms of Consoer, Townsend and Associates, Ltd. of St. Louis, Missouri and PRC Engineering Consultants, Inc. of Englewood, Colorado (A Joint Venture) according to the U. S. Army Corps of Engineers' "Recommended Guidelines for Safety Inspection of Dams" and additional guidelines furnished by the St. Louis District of the Corps of Engineers. Based upon the criteria in the guidelines, the dam is in the high hazard potential classification, which means that loss of life and appreciable property loss could occur in the event of failure of the dam. Within the estimated damage zone of two miles downstream of the dam are the crossing of Interstate Highway I-70 immediately downstream of the dam, three commercial buildings, one trailer, one gas station and two large buildings which may be subjected to flooding, with possible damage and/or destruction, and possible loss of life. Moores Lake Dam is in the small size classification since it is less than 40 feet and more than 25 feet high, and impounds 45 acre-feet of water.

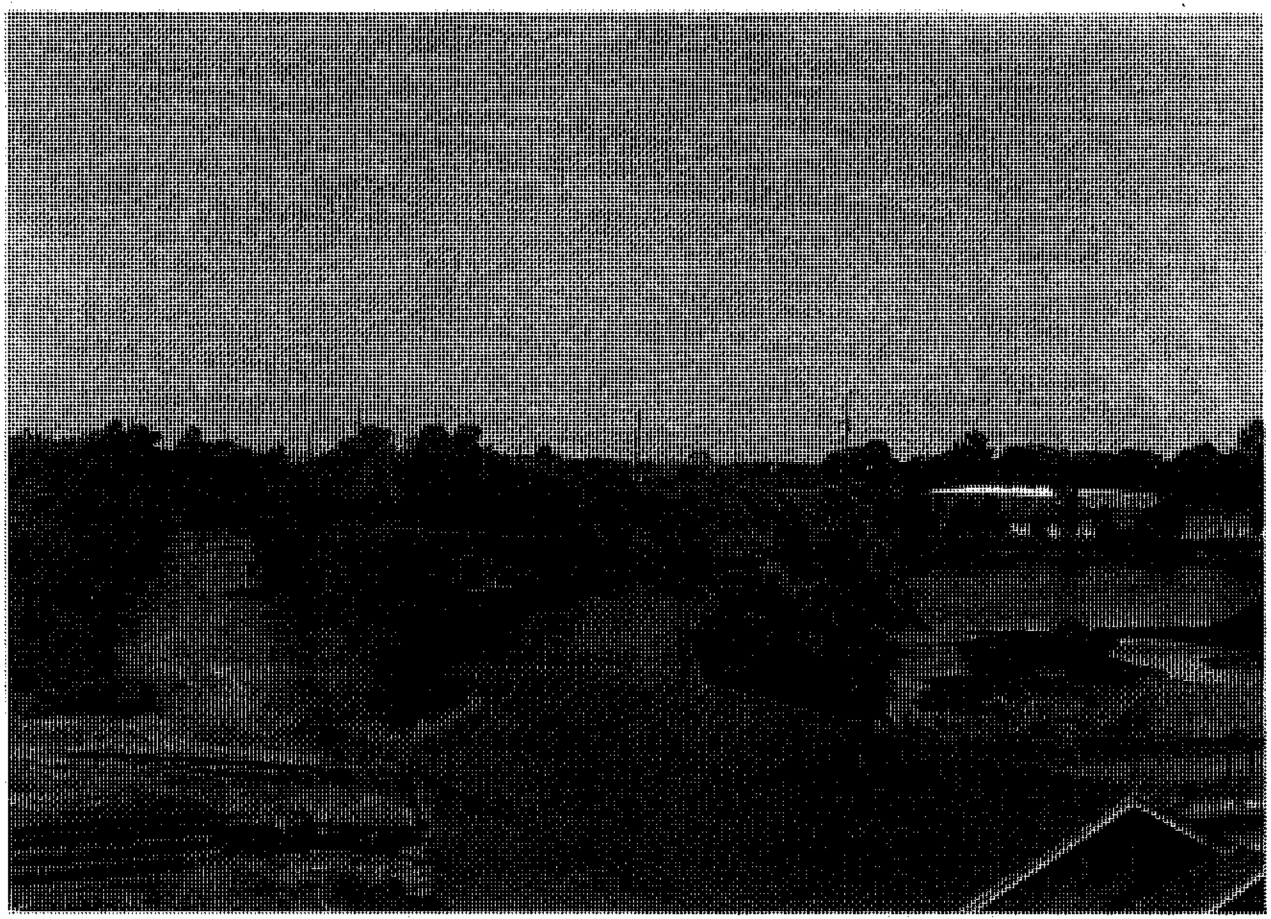
The inspection and evaluation by the consultant's inspection team indicate that the spillway of Moores Lake Dam does not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. Moores Lake Dam being a small size dam with a high hazard potential is required by the guidelines to pass from one-half of the Probable Maximum Flood to the Probable Maximum Flood without overtopping. Considering an Interstate Highway (I-70), located immediately below the dam, and several other commercial buildings along the banks of the same stream within two miles downstream of the dam, the PMF is considered the appropriate spillway design flood for Moores Lake Dam. The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region. It was determined that the reservoir/spillway system can accommodate approximately 50 percent of the Probable Maximum Flood without overtopping the dam. The evaluation also indicates that the reservoir/spillway system can accommodate the one-percent chance flood (100-year flood) without overtopping.

Other deficiencies noted by the inspection team were: the sloughing on the downstream slope, undermining of the downstream toe adjacent to the low level outlet, erosion due to wave action on the upstream slope, trees and bushes on the embankment, voids and rodent holes in the embankment, a need for periodic inspection by a qualified engineer and a lack of maintenance schedule. The lack of seepage and stability analyses on record is also a deficiency that should be corrected.

It is recommended that the owner take action to correct or control the deficiencies described above.

Walter G. Shifrin, P.E.

STATE OF MISSOURI
WALTER G SHIFRIN
NUMBER E-8834
REGISTERED PROFESSIONAL ENGINEER



Overview of Moores Lake Dam

NATIONAL DAM SAFETY PROGRAM

MOORES LAKE DAM, I.D. No. 11173

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

MOORES LAKE DAM, Missouri Inv. No. 11173

SECTION 1: PROJECT INFORMATION

1.1 General

a. Authority

The Dam Inspection Act, Public Law 92-367 of August, 1972, authorizes the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspections. Inspection for Moores Lake Dam was carried out under Contract DACW 43-80-C-0094 between the Department of the Army, St. Louis District, Corps of Engineers, and the engineering firms of Consoer, Townsend & Associates, Ltd., and PRC Engineering Consultants, Inc. (A Joint Venture), of St. Louis, Missouri.

b. Purpose of Inspection

The visual inspection of Moores Lake Dam was made on July 11, 1980. The purpose of the inspection was to make a general assessment as to the structural integrity and operational adequacy of the dam embankment and its appurtenant structures.

c. Scope of Report

This report summarizes available pertinent data relating to the project, presents a summary of visual observations made during the field inspection, presents an assessment of hydrologic and hydraulic conditions at the site and of the structural adequacy of the various project features and assesses the general condition of the dam with respect to safety.

Subsurface investigations, laboratory testing and detailed analyses were not within the scope of this study. No warranty as to the absolute safety of the project features is implied by the conclusions presented in this report.

It should be noted that in this report reference to left or right abutments is viewed as looking downstream. Where left abutment or left side of the dam is used in this report, this also refers to the south abutment or side, and right abutment or right side of the dam to the east abutment or side.

d. Evaluation Criteria

The inspection and evaluation of the dam is performed in accordance with the U.S. Army Corps of Engineers' "Recommended Guidelines for Safety Inspectiuon of Dams" and additional guidelines furnished by the St. Louis District office of the Corps of Engineers for Phase 1 Dam Inspection.

1.2 Description of the Project

a. Description of Dam and Appurtenances

It should be noted that neither design drawings nor "as-built" drawings were available for the dam or appurtenant structures. The following description is based exclusively upon observations and measurements made during the visual inspection and conversations with Mr. Gary Anderson, the owner's representative.

The dam embankment is an earthfill structure with variable section dimensions along its crest length. A plan and elevation of the dam are shown on Plate 2 and Photos 1 through 4 show views of the dam. The axis of dam is approximately a quarter circle in shape and measures 752 feet long. The top width varies from 30 feet at the left abutment to approximately 90 feet at the midpoint of the dam and back to about 20 feet at the right abutment. The top of dam elevation varies non-uniformly (See Plate 2). The left and right sides of the dam were assumed to be at 773 feet above mean sea level (M.S.L.) with elevation increases of up to about 6.5 feet towards the middle of the embankment. The top of dam is crowned slightly and has many depressions. The maximum height of the embankment was measured to be 30 feet at approximately the mid-point along the axis of dam. The height of the dam at the left abutment near the two spillway pipes is 13 feet.

The average downstream slope of the embankment was measured as 1 vertical on 1.5 horizontal (1V on 1.5H). Where possible, the upstream slope was measured as 1V on 1.75H from the top of dam to the water surface. However, erosion, due to wave action, and dense vegetative cover made accurate measurements impossible. No riprap was placed on the upstream slope.

On the day of the inspection, there were three pipes at the damsite which allowed water to flow out of the reservoir. A 4-inch, an 8-inch, and a 10-inch diameter pipe have been provided.

The 4-inch pipe, according to Mr. Anderson, is located at the left abutment of the dam. The pipe was not located on the day of the inspection; however, the outlet structure for the pipe, according to Mr. Anderson, was a manhole on the downstream slope which was observed (see photo 8 and Plate 3). The outlet structure consists of a 2.25-foot wide diameter manhole with the bottom of the manhole located about 7 feet below the top of the manhole, which is also assumed to be the location of the outlet of the 4-inch diameter pipe (see Photo 10). The manhole is of brick and concrete mortar construction. The crest elevation of the pipe is unknown. According to Mr. Anderson, this pipe is controlled by a valve. Therefore, this pipe is considered to be a low level outlet type structure. Nevertheless, the valve was not located on the day of the inspection.

The 10-inch diameter pipe is a cast iron pipe laid through the embankment on a slope of 2 percent and is located at the left abutment of the dam. The inlet of the pipe can be seen in Photo 9 and the outlet end of the conduit is shown in Photo 8 to the left (in the photo) and just above the manhole described above. The crest elevation of the pipe is assumed to be at 769 feet above M.S.L. Flows through the pipe will discharge down the dam embankment.

The 8-inch diameter pipe is located at the southeast corner of the reservoir (for the actual location see Plate 2). Flows through the pipe discharge into a creek to the south of the power plant. The top of the pipe was about 4 inches below the reservoir water surface level on the day of the inspection. This pipe, according to Mr. Gary Anderson, is going to be plugged in October of 1980. On the day of the inspection, very little water was observed flowing through the pipe, which leads the inspection team to believe that the pipe is already partially plugged. Therefore, this pipe is assumed to be abandoned and was not used to determine the capacity of the spillway system. Therefore, there are essentially only one spillway and one low level outlet utilized at this damsite.

There are two structures at the damsite which discharge water into the reservoir. One of the structures consists of a 6-inch pipe through which a coal ash slurry from the power plant is pumped (see Photo 12). According to Mr. Anderson, between 200,000 to 300,000 gallons per day of the slurry are pumped into the reservoir. The second structure consists of a 10-inch cast iron pipe which is used to drain excess water from a cooling pond located adjacent to the cooling towers used for the power plant (see Photo 11). The location of the two structures are shown on Plate 2.

Average daily ash discharge into pond?

There were no other low level outlets or outlet works provided for this dam other than the 4-inch pipe mentioned above. Nevertheless, according to Mr. Anderson, in September of 1980, a recirculation system is going to be installed at the damsite in which water is going to be pumped from the reservoir to the power plant to be used in the coal ash slurry. This is possibly the existing intake-discharge system in place.

b. Location

Moores Lake Dam is located in Boone County in the State of Missouri, and crosses an unnamed tributary of Bear Creek. The damsite is at the northeast edge of the City of Columbia, Missouri. Moores Lake Dam location on the 7.5 minute series of the U.S. Geological Survey maps is found in Section 6 of Township 48 North, Range 12 West of the Columbia, Missouri Quadrangle Sheet.

c. Size Classification

Drainage Area = 21 acres
→ Chk pg 7.
Reservoir Surface Area @ normal pool = 6.5 acres
→ Chk pg 17
Vol. 1 acre-ft = 325,851.429 U.S. Gal.

The impoundment of Moores Lake Dam is 45 acre-feet, and the height is within the 25 to 40 foot range. Therefore, the size is determined to fall in the "small" category, according to the "Recommended Guidelines for Safety Inspection of Dams" by the U.S. Department of the Army, Office of the Chief Engineer.

d. Hazard Classification

The dam has been classified as having a "high" hazard potential in the National Inventory of Dams, on the basis that in the event of failure of the dam or its appurtenances, excessive damage could occur to downstream property, together with the possibility of the loss of life. Our findings concur with this classification. Within the estimated damage zone, extending two miles downstream of the dam, there are the crossing of Interstate Highway I-70 (immediately downstream of the dam), three commercial buildings, one trailer, a gas station and two large buildings.

e. Ownership

Moores Lake Dam is owned by the City of Columbia, Missouri. The person responsible for operation and maintenance of the dam is Mr. Richard Malon, Director of Utilities, City of Columbia, Water & Light Department. His mailing address is as follows: P.O. Box N, Columbia, Missouri, 65201.

f. Purpose of Dam

According to Mr. Gary Anderson, an employee of the City Power Plant, the reservoir is used as a settling pond for the cinders and ash which are a by-product of the Municipal Power Plant. Originally, when the power plant was first put into operation, the lake was used as a source of cooling water for the plant, however, this is no longer the case. Mr. Anderson also mentioned that the dam was originally constructed to impound water for recreational use. This is evidenced by the fact that a recreational platform still exists at the eastern edge of the lake. — The concrete island observed.

g. Design and Construction History

Dam built ca. 1904

It is not known who was responsible for the original design or construction, however, Mr. Anderson believes that the dam was built around 1904. According to Mr. Anderson, in 1970 the height of the dam was increased by 1 or 2 feet, however, it is unknown why the dam height was increased. In June of 1980, the 10-inch pipe was added near the left abutment to act as a spillway, according to Mr. Anderson.

h. Normal Operational Procedures

Normal operational procedure at Moores Lake Dam is to allow the reservoir to remain as full as possible with the water level being controlled by rainfall, evaporation, the elevation of the spillway crest, and the rate at which the coal ash slurry is pumped into the reservoir from the power plant.

1914-1957 Cooling pond + park
1965+ ASH

1.3 Pertinent Data

a. Drainage Area (acres). 21

b. Discharge at Damsite

Estimated experienced maximum flood (cfs):	Unknown
Estimated ungated spillway capacity with reservoir at top of dam elevation (cfs):	4

c. Elevation (Feet above M.S.L.)

Top of dam (minimum):.	773
Spillway crest*:	769
Normal Pool:	769
Maximum Experienced Pool:.	Unknown
Observed Pool:	768.9

d. Reservoir

Length of pool with water surface at top of dam elevation (feet):.	600

e. Storage (Acre-Feet)

Top of dam (minimum):.	45
Spillway crest:	15
Normal Pool:	15
Maximum Experienced Pool:.	Unknown
Observed Pool:	15

f. Reservoir Surfaces (Acres)

Top of dam (minimum):.	8.5
Spillway crest:.	6.5
Normal Pool:	6.5
Maximum Experienced Pool:.	Unknown
Observed Pool:	6.5

g. Dam

Type:	Rolled, Earthfill
Length:	752 feet
Structural Height:	30 feet
Hydraulic Height**:	30 feet
Top width:	Varies, from 20 feet to 90 feet
Side slopes:	
Downstream	1V on 1.5H
Upstream	1V on 1.75H (Above water surface)
Zoning:	Unknown
Impervious Core:	Unknown
Cutoff:	Unknown
Grout curtain:	Unknown
Freeboard above normal reservoir level:	4 feet (Minimum) What is the current Freeboard?
Volume:	65,000 cu. yds. (Estimated)

h. Diversion and Regulating Tunnel. . None

i. Spillway

Type:	Cast iron pipe, Uncontrolled
Length of crest:	NA, (10-inch diameter pipe)
Crest Elevation (feet above MSL):	769

j. Regulating Outlets

Type:	4-inch diameter pipe
Location:	Left abutment
Length:	Unknown
Closure:	Valve (Reportedly)
Maximum Capacity:	Unknown

* The elevation of the Spillway crest was assumed from the U.S.G.S. Columbia, Missouri Quadrangle topographic map. The elevations of other features of the dam were derived using this elevation and field measurements.

** The hydraulic height of the dam is the vertical distance from the lowest point on the downstream toe to the top of dam or the maximum water surface if below the top of dam.

SECTION 2: ENGINEERING DATA

2.1 Design

No design data are available for the dam and the appurtenant structures.

2.2 Construction

No construction records or data are available for the dam or the appurtenant structures.

2.3 Operation

No operational records are available for Moores Lake Dam.

2.4 Evaluation

a. Availability

No design drawings, design computations, construction data or operation data are available. Also, no pertinent data were available for review of hydrology, spillway capacity, flood routing through the reservoir, slope stability, or foundation conditions. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams", were not available which is considered a deficiency.

b. Adequacy

The lack of engineering data did not allow a definitive review and evaluation. Therefore, the adequacy of this dam could not be assessed from the standpoint of reviewing and evaluating design, operation and construction data, but is based primarily on visual inspection, past performance history, and sound engineering judgement. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Validity

No engineering data were available which would allow a valid evaluation of original design concepts.

SECTION 3: VISUAL INSPECTION

3.1 Findings

a. General

A visual inspection of the Moores Lake Dam was made on July 11, 1980. The following persons were present during the inspection:

Name	Affiliation	Disciplines
Dr. M.A. Samad	PRC Engineering Consultants, Inc.	Project Engineer, Hydraulics and Hydrology
Mark Haynes, P.E.	PRC Engineering Consultants, Inc.	Civil and Mechanical
Razi Quraishi, R.P.G.	PRC Engineering Consultants, Inc.	Geology
Zoran Batchko	PRC Engineering Consultants, Inc.	Soils
Kevin J. Blume	Consoer, Townsend & Assoc., Ltd.	Civil and Structural
Gary Anderson	Employee of the City of Columbia, Water and Light Department	

Specific observations are discussed below.

b. Dam

The top of dam has a grass cover which adequately protects the embankment material from surface erosion (see Photo 2). The grass was mowed at the time of our inspection and, according to Mr. Gary Anderson, is mowed periodically. The irregularity in the top of dam is apparently due to the addition of on site spoils materials in the past and not due to settlements. It is unknown whether or not the dam has ever been overtopped; however, no evidence was observed indicating that the dam had been overtopped.

Is dam vegetation cover mowed periodically?

The upstream slope has no riprap protection and although the grass cover is dense, it has been eroded by wave action. Nearly vertical faces up to 3 feet high are exposed with a nearly horizontal bench at the water line. The material exposed on these faces is a low plasticity clay with a trace of gravels. The upstream slope also has medium-sized trees and large bushes growing on it.

This has been corrected according to our visual observation.

The downstream embankment slope is, in general, not adequately protected by grass cover, especially the middle two-thirds of the embankment. Consequently, erosion due to surface runoff has been most severe. There are erosion channels up to 6 feet deep by 10 feet wide (see Photo 7). Large trees and bushes cover the downstream face (see Photo 4). The left and right sides of the downstream face are covered with tall grass and fewer and smaller trees are growing on the slope in these areas. There are several large rodent holes, up to 16-inches wide (see Photo 5), on the downstream face.

Where the new spillway pipe was installed through the left side of the embankment, there is no vegetative cover on the pipe backfill (see Photo 2). Near the low level outlet manhole, located at the left abutment, the downstream slope is covered with dumped debris such as boulders and concrete block fragments. The downstream toe has been undermined in this area by the water, which has discharged through the low level outlet pipe (see Photo 8). The discharge channel for the spillway and low level outlet parallels the toe of the western embankment section. Approximately 60 feet to the right of the left abutment, there is a large scarp on the downstream face, which appears to be due to flows through the discharge channel (see Photo 6). The dish shaped, nearly vertical scarp extends from the toe to a point 10 feet above the toe, and is about 15 feet wide. The tall grass growing in the scarp and lack of slough material in the discharge channel indicates that the slough did not occur recently.

There is no evidence of seepage along the northern half of the embankment. Due to the flow of water through the discharge channel along the toe of the western portion of the dam, any seepage through the foundation was undetected. Nevertheless, there were no signs of seepage on the embankment face of the western portion of the dam.

No signs of past or present instability were observed on the embankment. However, several signs were observed on the embankment that could lead to a future instability. Both abutments are at approximately the same elevation as the top of dam. No instabilities, seepage, or erosion were observed on either abutment.

c. Project Geology and Soils

(1) Project Geology

Bear Creek is currently cut off from Moves Lake

The damsite is located on an unnamed tributary of Bear Creek in the Dissected Till Plains Section of the central Lowland Physiographic Province. Loess-mantled Kansas drift covers the surface of most of the Dissected Till Plains Section. The section is distinguished from the Young Drift Section to the north and from the Till Plains on the east by the stage it has reached in the post-glacial erosion cycle. Broadly generalized, this section is a nearly flat till plain submature to mature in its erosion cycle.

The topography at the damsite is rolling to hilly with U- to V-shaped valleys. Elevation of the ground surface ranges from 710 feet above M.S.L. at the damsite to 750 feet above M.S.L. approximately 0.25 miles from the damsite. The reservoir rim slopes are in the range of 14° to 20° from the horizontal and appear to be stable. The area near the damsite is covered with slope wash of glacial-fluvial deposits and loess.

The regional geology beneath the glacial outwash deposits in the damsite area as shown on the Geologic Map of Missouri (1979) (see Plate 6), consists of Pennsylvanian age undifferentiated age rocks, the Pennsylvanian Marmaton-Cherokee Group (cyclic deposits of shale, limestone, and sandstone), Mississippian age Burlington Limestone (cherty, grayish brown, sandy limestone), Devonian age rocks of the Sulphur Springs Group (Glen Park Limestone and Grassy Creek Shale), and Ordovician age rocks consisting of St. Peter Sandstone and Powell Dolomite.

No outcropping of bedrock was observed at the site. The predominent bedrock in the site vicinity underlying the glacial-fluvial deposits consists of the Cherokee Group and Burlington Limestone. Inlet and outlet areas of the unnamed tributary of Bear Creek contain Quaternary alluvium.

No faults have been identified in the vicinity of the damsite. The closest trace of a fault to the damsite is Fox Hollow fault nearly 15 miles south of the damsite. The Fox Hollow fault had its last movement in post-Mississippian time. Thus, the fault has no effect on the damsite.

Moores Lake Dam consists of homogeneous earthfill embankment, a spillway pipe located near the left end of the embankment and a low level outlet pipe located below the spillway pipe.

No boring logs or construction reports were available which would indicate foundation conditions encountered during the construction. Based on the visual inspection and conversations with Mr. Gary Anderson, the embankment probably rests on glacial-fluvial deposits. The spillway and outlet pipes rest on compacted embankment fill (mottled, yellowish brown to red, medium plastic, silty clay).

(2) Project Soils

According to the "Soil Survey-Boone County Missouri" published by the Soil Conservation Service, the materials in the general area of the dam belong to the Gara Loam soil series in the deep loess and drift family. The soils were basically formed from erosion, leaching, and weathering of the glacial till and limestone. The permeability of these soils is moderate to slow. The Gara soil is generally quite susceptible to erosion. It is unknown whether the Gara soil type was used in the embankment, however, if it was used the potential of failure of the embankment would be increased due to erosion during overtopping.

Materials were removed from the upstream slope in two locations. One location was approximatley 300 feet to the left of the right abutment contact and the other location was near the spillway outlet. Both samples were obtained from below the vegetative cover. Downstream slope material samples were readily obtained from the surface. Typically, the embankment material appeared to be a brown, moderately plastic, silty to sandy clay with traces of fine to medium gravel. Based upon the Unified Soil Classification System, the soil would probably be classified as a CL. This soil type generally has the following characteristics: it is semipervious to impervious with a coefficient of permeability less than 400 feet per year, has medium shear strength and an intermediate resistance to piping and erosion.

d. Appurtenant Structures

(1) Spillway

The 10-inch pipe was recently placed through the embankment using what appeared to be a "cut and cover" type of construction due to the fact that the soil over the pipe appeared to have been disturbed recently and had no vegetative cover. The only major concern with the spillway is that the flows through the pipe will flow down the embankment in an area which has already undergone some erosion at the toe as described in Section 3.1b. The pipe was unobstructed and appeared to be able to function properly. No seepage was observed around the pipe.

(2) Low Level Outlet

The 4-inch pipe is, reportedly, controlled by a valve, however, neither the pipe nor the valve were observed on the day of the inspection. Because the valve was not visible and water was observed flowing through the pipe, it is believed that the valve always remains open and could possibly be inoperable. The outlet does not appear to be obstructed since water was observed flowing over the top of the manhole structure. The only condition of any concern with the low level outlet is the erosion at the toe of the embankment apparently caused by discharges through the pipe as mentioned above and in Section 3.1b.

e. Reservoir Area

The water surface elevation was 768.9 feet above M.S.L. at the time of inspection. The surface area of the reservoir at the normal water level is about 6.5 acres. The reservoir rim, south and west sides, is flat with trees and shrubs growing at the shore line. With the exception of a small undercut along most of the natural reservoir rim, there was no evidence of instability. The power plant and its appurtenant structures are located on the reservoir rim.

f. Downstream Channel

The downstream channel, which carries flows from the spillway and the low level outlet, is overgrown with the tall vegetation and trees (see Photo 13). The width of the channel is approximately 10 feet for approximately 50 feet with side slopes of about 1V on 1H on both sides and a depth of about 3 feet. The channel then widens out to about 100 feet until it flows into another sedimentation pond directly downstream of the reservoir. The heavy growth of vegetation in the channel will affect the hydraulic efficiency of the channel.

3.2 Evaluation

The following deficiencies were observed during the visual inspection which could affect the safety of the dam. Remedial measures should be undertaken in the near future to correct these deficiencies.

1. The trees observed on the embankment pose a potential danger to the safety of the dam. Depending upon the extent of the root system, the roots of large trees present possible paths for piping through the embankment. The root systems can also do damage to the embankment from being uprooted by a storm.

2. The vegetation on the embankment, especially on the upstream slope, should be properly maintained. A heavy growth of vegetation on the embankment hinders a comprehensive inspection of the dam and potential problems could go undetected.

3. The wave erosion on the upstream slope, the surface runoff erosion on the downstream slope, and the sloughing and undermining of the downstream slope and toe adjacent to the left abutment do not appear to affect the stability of the dam in their present condition. However, continual erosion of the slope can only be detrimental to the stability of the dam.

4. Rodent activity observed on the embankment could jeopardize the safety of the dam. The holes created by the animals make avenues for possible piping.

5. The practice of allowing the low level outlet and the spillway on the left abutment to discharge directly onto the embankment can only be detrimental to the stability of the dam.

SECTION 4: OPERATIONAL PROCEDURES

4.1 Procedures

There are no specific operational procedures for Moores Lake Dam. However, a coal ash slurry from the Municipal Power Plant is pumped into the reservoir three times a day for aproximately 2 to 3 hours. The coal ash is then allowed to settle out of the solution. According to Mr. Anderson, the reservoir is dredged periodically to remove the accumulation of coal ash and the reservoir was last dredged in June of 1980. Also, Mr. Anderson stated that the depth of the reservoir, on the day of the inspection, was probably 5 feet at its deepest point.

4.2 Maintenance of Dam

The dam is maintained by work crews employed by the Columbia Water and Light Department. Mr. Anderson mentioned that the top of dam is mowed periodically. The upstream and downstream slopes are overgrown with large trees and dense vegetation. There was evidence of an abundance of rodent activity on the dam embankment.

4.3 Maintenance of Operating Facilities

According to Mr. Anderson, there is a 4-inch pipe and valve, which serves as a low level outlet, located adjacent to the new 10-inch spillway pipe. This could not be verified; however, the operable facilities associated with the dam are maintained by the Water and Light Department employees.

4.4 Description of Any Warning System in Effect

The inspection team is not aware of any warning system in use at the damsite.

4.5 Evaluation

Is it adequate @ present?

The maintenance at Moores Lake Dam is inadequate. The remedial measures described in Section 7 should be undertaken to improve the condition of the dam.

SECTION 5: HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. Design Data

No hydrologic and hydraulic design data are available for Moores Lake Dam. The sizes of physical features utilized to develop the stage-outflow relation for the spillway and overtopping of the dam were prepared from field notes and sketches prepared during the field inspection. The reservoir elevation-area data were based on the U.S.G.S. Columbia, Missouri Quadrangle topographic maps (7.5 minute series). The spillway and overtop release rates and the reservoir elevation-area data are presented in Appendix B.

The hydrologic soil group of the watershed was determined from information available in the U.S.D.A. Soil Conservation Service publication "Missouri General Soil Map and Soil Association Descriptions", 1979. The Probable Maximum Precipitation (PMP) used to determine the Probable Maximum Flood (PMF) was determined by using the U.S. Weather Bureau publication, "Hydrometeorological Report No. 33" (April 1956). The 100-year flood were derived by using the 100-year rainfall of Jefferson City, Missouri.

b. Experience Data

It is believed that records of reservoir stage or spillway dischrage are not maintained for this site.

c. Visual Observations

Observations made of the spillway during the visual inspection are discussed in Section 3.1d and evaluated in Section 3.2.

d. Overtopping Potential

Only the Probable Maximum Flood when routed through the reservoir, resulted in overtopping of the dam. The peak inflows of the PMF and one half of the PMF are 592 cfs and 296 cfs respectively. The peak outflow discharges for the PMF and one-half of the PMF are 282 and 3 cfs, respectively. The maximum capacity of the spillway just before overtopping the dam is only 4 cfs. The PMF overtopped the dam by 0.8 feet. The total duration of flow over the dam is 9 hours during the occurrence of the PMF. The reservoir/spillway system of Moores Lake Dam is capable of accommodating a flood equal to approximately 50 percent of the PMF just before overtopping the dam. The reservoir/spillway system of Moores Lake Dam will accommodate the one-percent chance flood without overtopping. The dam may be susceptible to erosion due to overtopping during the occurrence of the PMF.

The failure of the dam could cause extensive damage to the property downstream of the dam and possible loss of life. The estimated damage zone extends approximately two miles downstream of the dam. Within the damage zone there are the crossing of Interstate Highway I-70 immediately downstream of the dam, three commercial buildings, one trailer, a gas station and two large buildings.

SECTION 6: STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

There were no signs of settlement on the embankment. Items of distress observed on the embankment include the wave erosion of the upstream slope, the slough on the downstream slope, the undermining of the downstream toe, the rodent holes, and the deep surface erosion of the downstream face. In the absence of seepage and stabilty analyses, no quantitative evaluation of the structural stability can be made.

The spillway and the low level outlet appeared structurally stable; however, discharges through the low level outlet have caused erosion along the downstream slope.

b. Design and Construction Data

Design computations pertaining to the embankment were not available during the report preparation phase. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available. No embankment or foundation soil parameters were available for carrying out a conventional stability analysis on the embankment. No construction data or specifications relating to the degree of embankment compaction were available for use in a stability analysis.

c. Operating Records

No operating records were available relating to the stability of the dam or appurtenant structures. The water level on the day of the visual inspection was only an inch below the spillway crest. Due to the practices of pumping the coal ash slurry into the reservoir and periodically dredging the accumulated coal ash out of the reservoir, it is unknown what elevation is considered the normal operating pool for the reservoir. However, for all intents and purposes, the normal operating level is assumed to be at the spillway crest.

d. Post Construction Changes

The inspection team was informed of two post construction changes made at the damsite. In 1970, spoil material was placed on top of the embankment crest; hence, the irregular surface and the 1 to 2 foot increase in the crest elevation of the top of dam Also, a new spillway pipe was recently installed through the left side of the embankment by cut and cover methods; the excavation extended to about a 4-foot depth below crest elevation. Both of these changes could have both negative and positive effects on the stability of the dam. No other changes are known to exist.

e. Seismic Stability

The dam is located in Seismic Zone 1, as defined in "Recommended Guidelines for Safety Inspection of Dams" prepared by the Corps of Engineers, and will not require a seismic stability analysis. An earthquake of the magnitude which would be expected in Seismic Zone 1 will not cause significant distress to a well designed and constructed earth dam. Available literature indicates that no active faults exist near the vicinity of the damsite.

SECTION 7: ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

The assessment of the general condition of the dam is based upon available data and visual inspection. Detailed investigations, testing and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies. The dam generally appears to be in poor physical condition. However, considering the reservoir depth and the ratio of the width to height at several sections of the dam, the functional condition of the dam appears to be fair.

It should be realized that the reported condition of the dam is based upon observations of field conditions at the time of inspection along with the field measurements made by the inspection team.

It is also important to note that the condition of a dam depends upon 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 dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be assurance that an unsafe condition could be detected.

a. Safety

The spillway capacity of Moores Lake Dam is found to be "Inadequate". The spillway/reservoir system will accommodate approximately 50 percent of the PMF without overtopping the dam. The surface soils in the embankment appear to be silty to sandy clay. The dam is overtopped by approximately one foot during the occurrence of the PMF. The dam may be susceptible to erosion due to overtopping of the dam during the PMF.

A quantitative evaluation of the safety of the embankment could not be made in view of the absence of seepage and stability analyses. The present embankment and appurtenant structures, however, reportedly have performed satisfactorily since their construction without failure. No evidence of the dam having ever been overtopped was observed. The safety of the dam can be improved if the deficiencies described in Sections 3.2 and 6.1.a are properly corrected as described in Section 7.2.

b. Adequacy of Information

The conclusions presented in this report are based upon field measurement, past performance and the present condition of the dam. Information on the design hydrology, hydraulic design, and operation and maintenance of the dam were not available. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency

The remedial measures recommended in Paragraph 7.2 should be accomplished within a reasonable period of time, and the item recommended in paragraph 7.2a should be pursued on a high priority basis.

d. Necessity for Phase II Inspection

Based upon results of the Phase I inspection, a Phase II inspection is not felt to be necessary.

7.2 Remedial Measures

a. Alternatives

One of the following mitigation measures should be undertaken under the guidance of an Engineer experienced in design and construction of earth dams to avoid severe consequences of dam failure from overtopping.

1. Increase the spillway capacity to pass the PMF without overtopping the dam.

2. Increase the height of the dam enough to pass the PMF without overtopping the dam; an investigation should also be done which includes studying the effects on the structural stability of the existing embankment. The overtopping depth during the occurrence of the PMF, stated in Section 5.1.d, is not the required or recommended increase in the height of the dam.

3. A combination of 1 and 2 above.

4. Provide a highly reliable flood warning system (generally does not prevent damage but avoids loss of life).

b. O & M Procedures

1. The downstream slope where the sloughing and the undermining of the downstream toe adjacent to the low level outlet have occurred should be stabilized and the areas should be protected from further damage.

2. The trees and bushes should be removed from the embankment and future growth should be prevented. Removal of large trees should be under the guidance of an engineer experienced in the design and construction of earth dams.

3. The vegetation on the embankment, especially the vegetation on the upstream slope, should be properly maintained and an adequate vegetative cover should be retained on the embankment to protect it from surface erosion. Large vegetation, such as bushes and trees, should be prevented from growing on the embankment.

4. The erosion due to wave action on the upstream slope and due to surface runoff on the downstream slope should be properly repaired and adequately protected from further damage.

5. All burrowing animals should be eliminated from the embankment and their burrows properly backfilled and compacted.

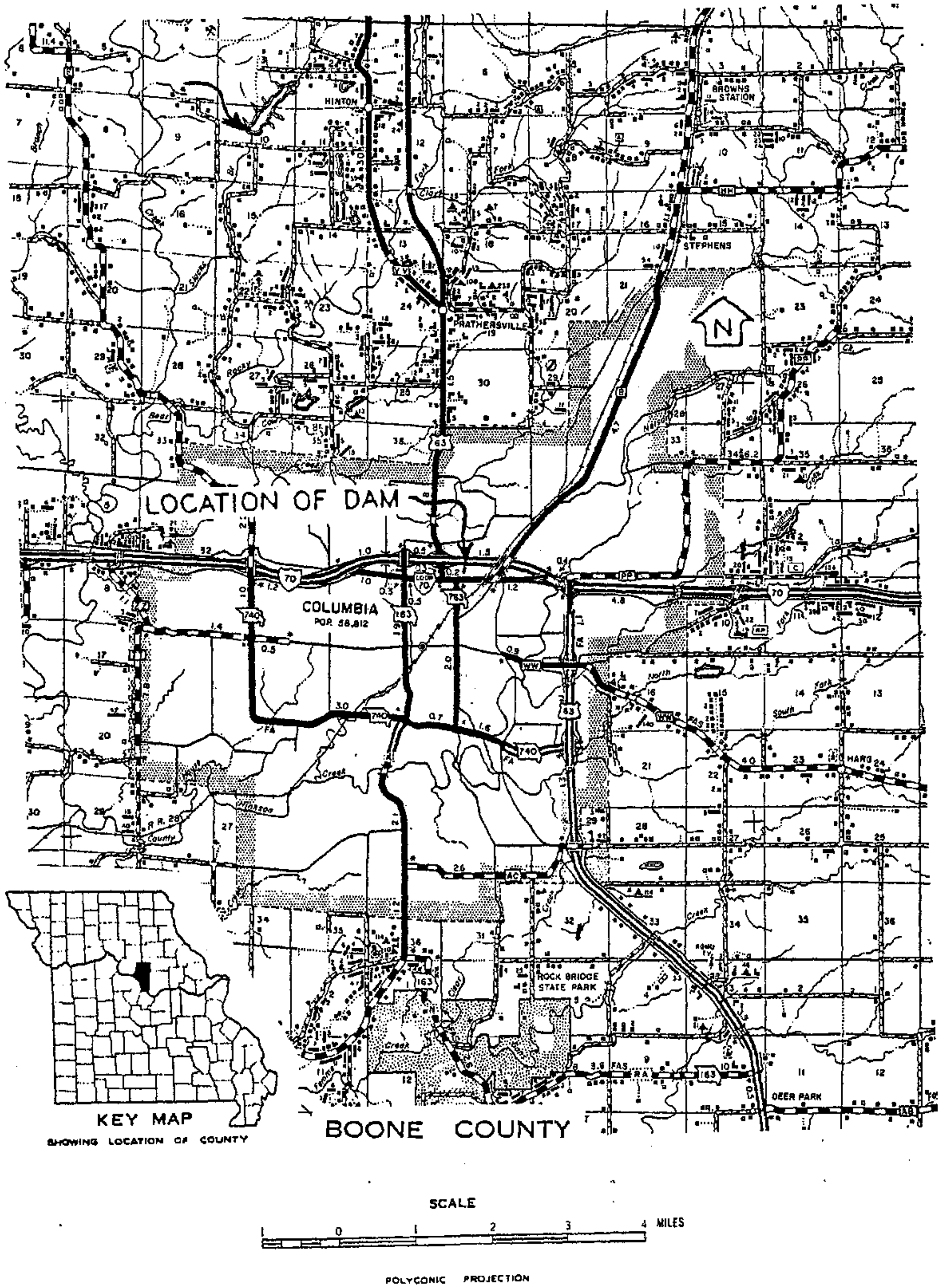
6. Measures should be undertaken either to protect the embankment slope to be able to withstand discharges through the spillway and low level outlet or to direct the two structures' discharges away from the embankment.

7. Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of earth dams.

8. The owner should initiate the following programs:

   (a) Periodic inspection of the dam by a professional engineer experienced in the design and construction of earth dams.

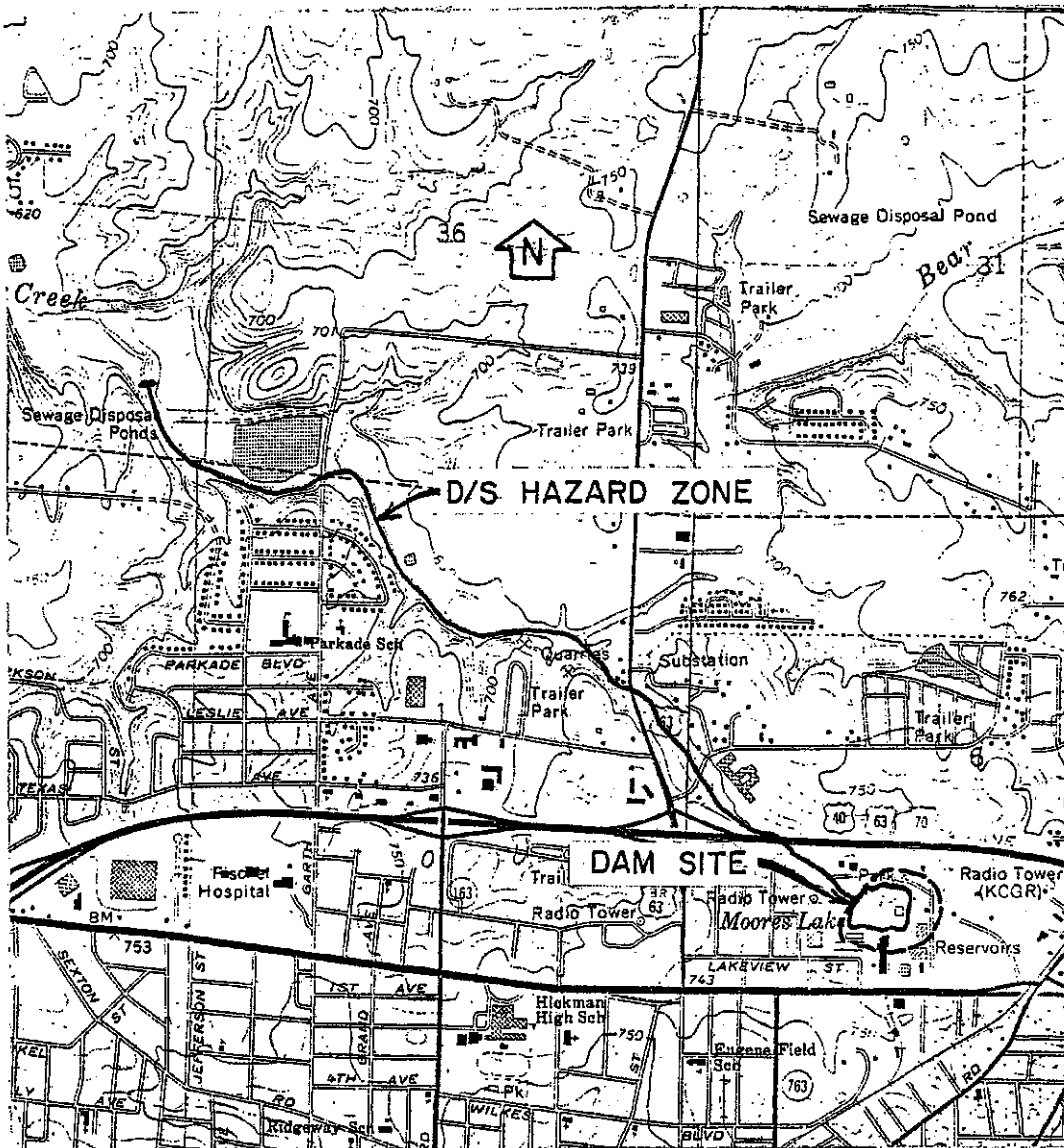
   (b) Set up a maintenance schedule and log all visits to the dam for operation, repairs and maintenance.



LOCATION MAP - MOORES LAKE DAM

MO-11173

PLATE 1A



COLUMBIA QUADRANGLE

QUADRANGLE LOCATION

DRAINAGE BOUNDARY - - - - - - - - - - -

SCALE 1:24 000

1 ½ 0 1 MILE

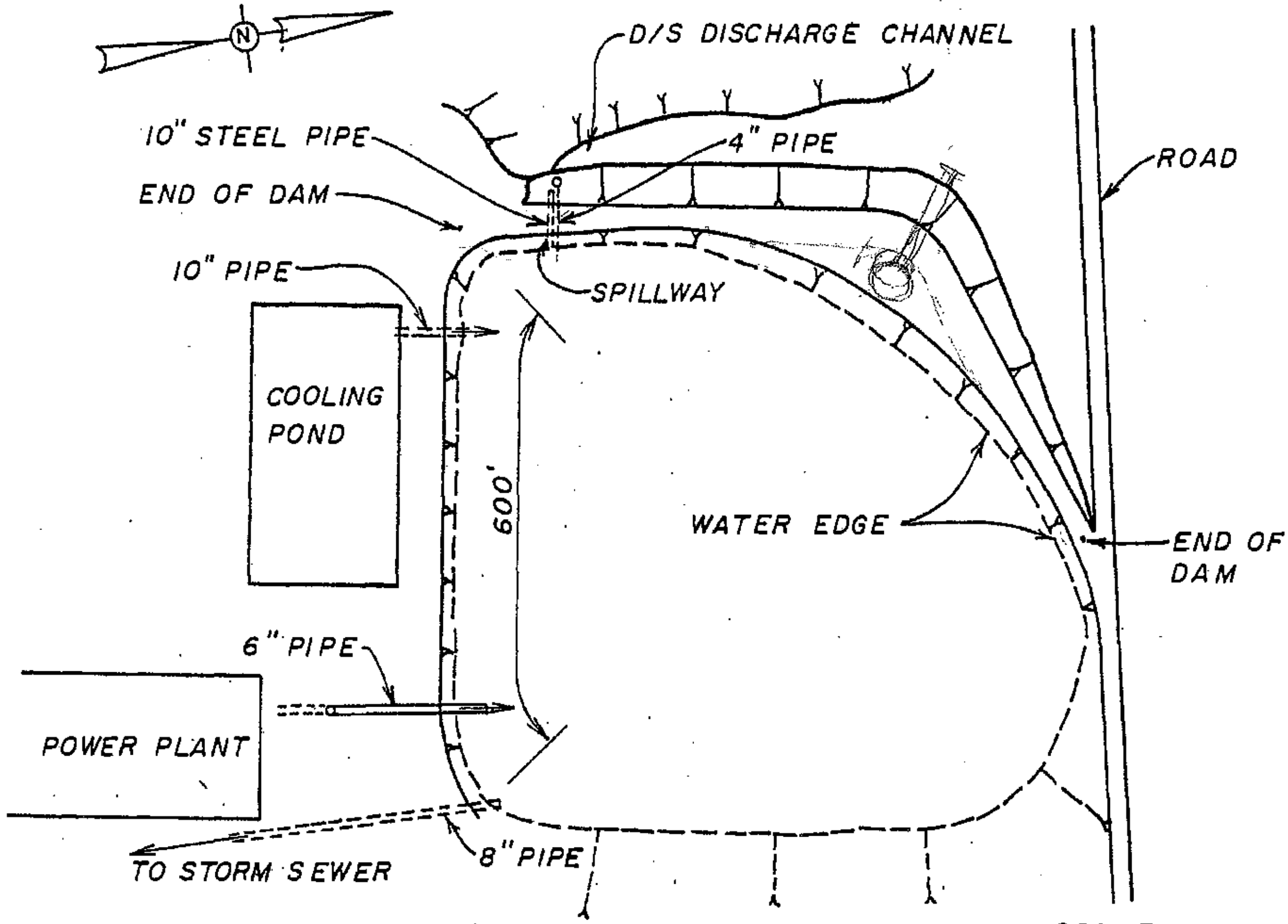
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

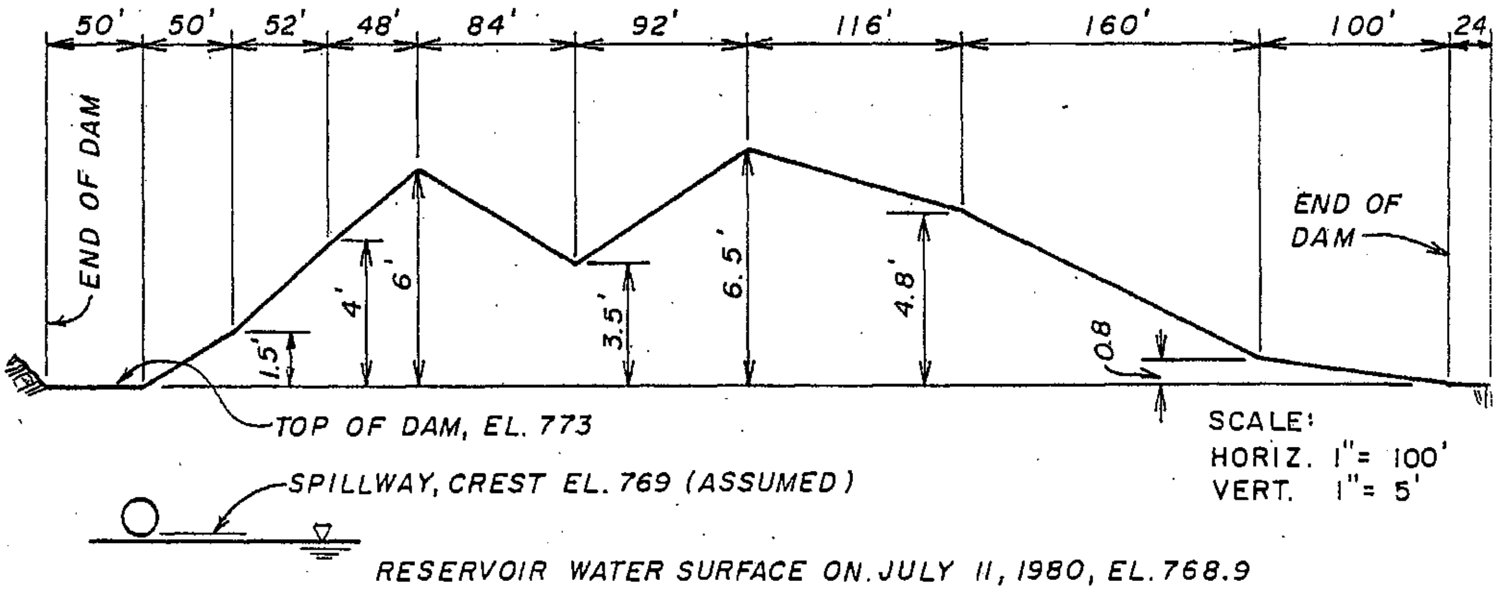
MOORES LAKE DAM (MO. 11173)

DRAINAGE BASIN AND DOWNSTREAM HAZARD ZONE



PLAN

SCALE:
HORIZ. 1" = 200'

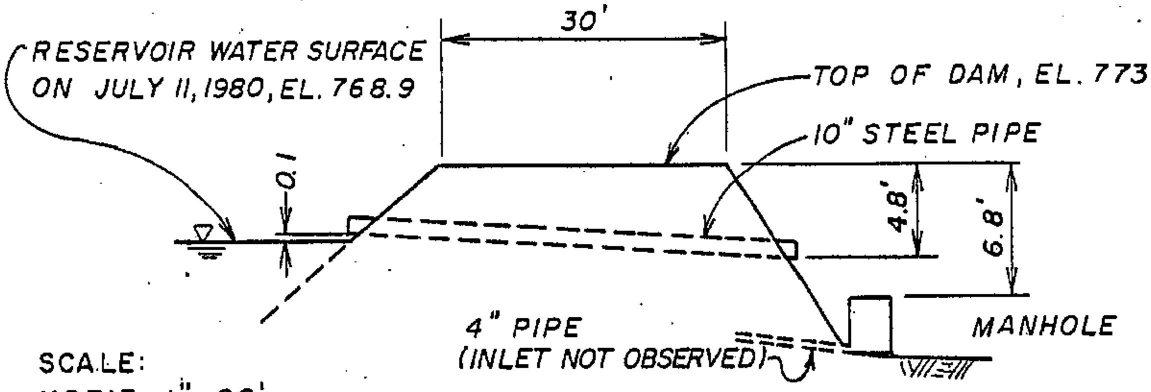


SCALE:
HORIZ. 1" = 100'
VERT. 1" = 5'

ELEVATION

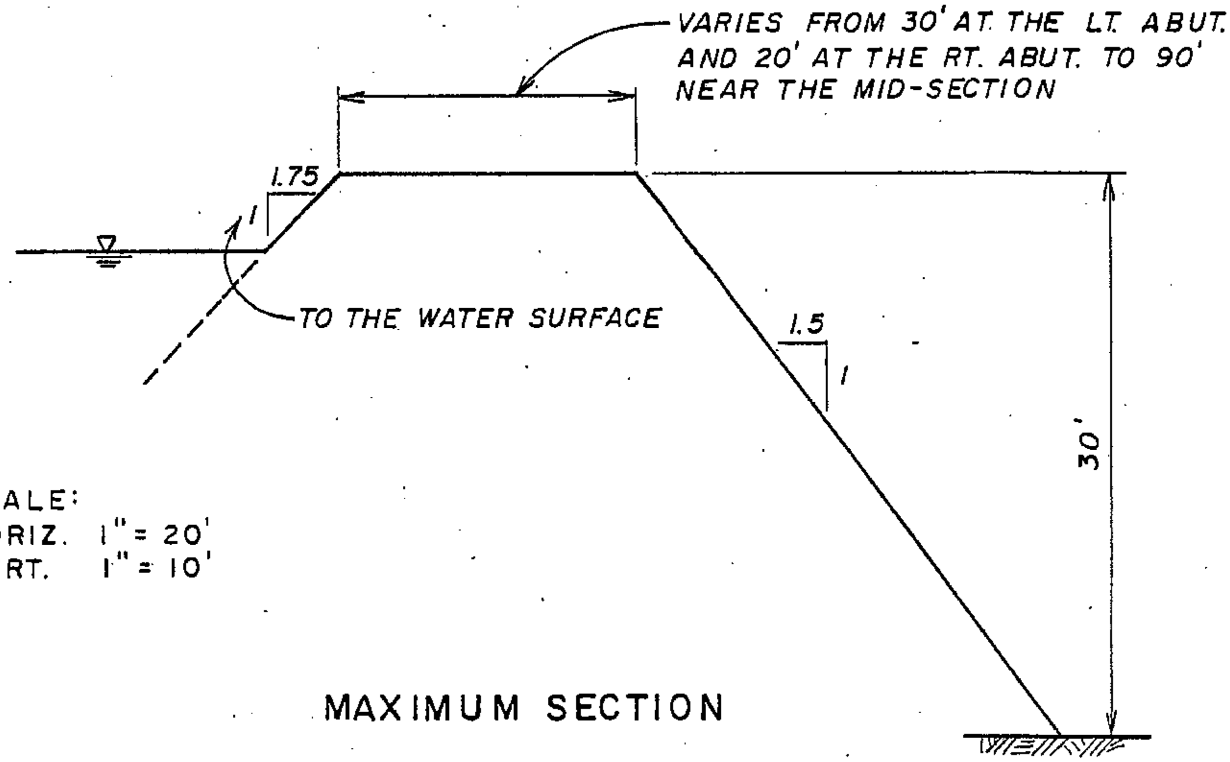
OTE: ALL ELEVATIONS ARE SHOWN AS FEET ABOVE M.S.L.

MOORES LAKE DAM (MO. 11173)
PLAN AND ELEVATION



SCALE:
HORIZ. 1" = 20'
VERT. 1" = 10'

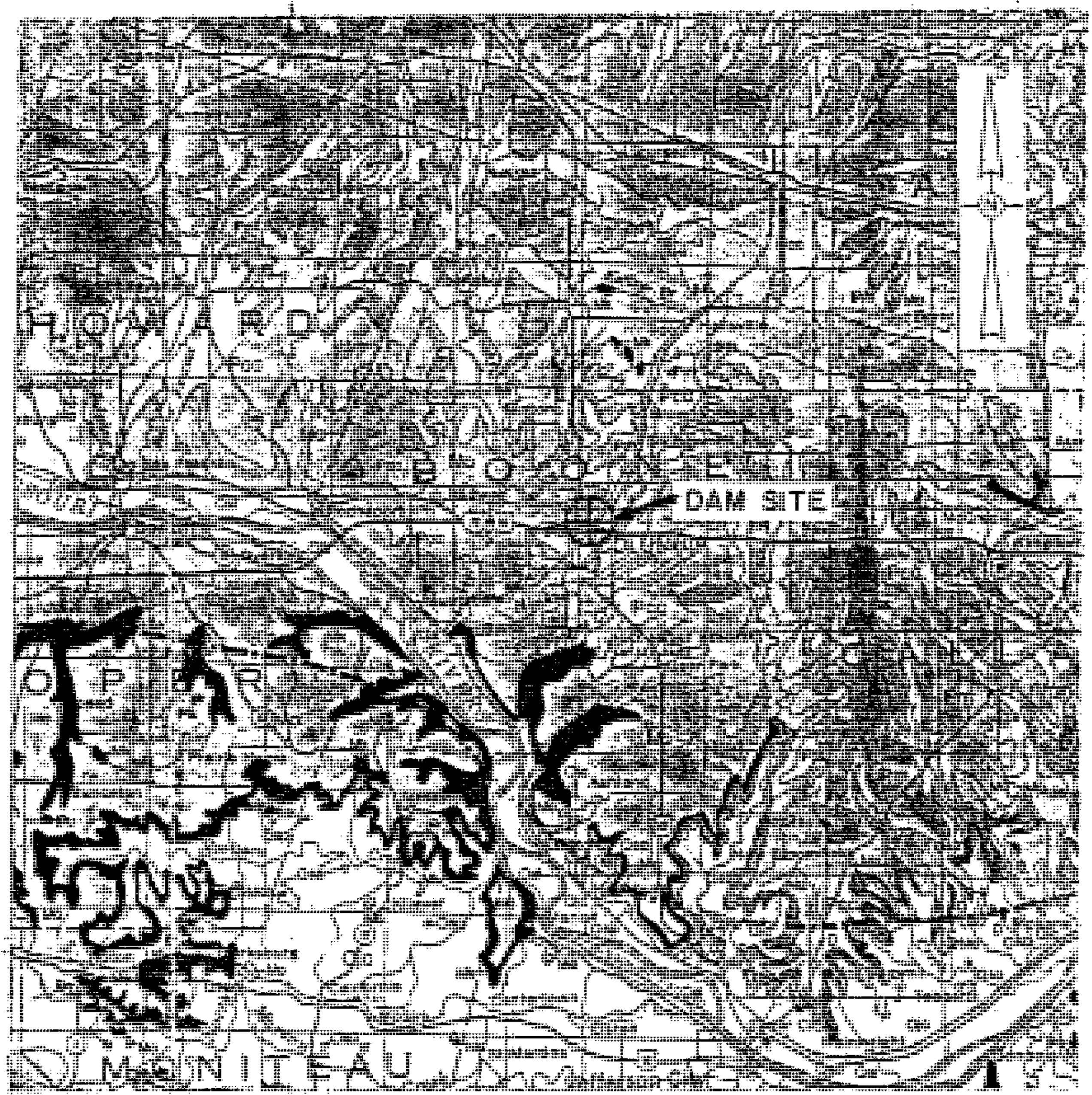
SECTION THROUGH EMBANKMENT
AT LEFT ABUTMENT



SCALE:
HORIZ. 1" = 20'
VERT. 1" = 10'

MAXIMUM SECTION

MOORES LAKE DAM (MO. 11173)
MAXIMUM SECTION OF EMBANKMENT



SCALE

10 0 10 20 30 40 Miles

⊕ LOCATION OF DAM

NOTE: LEGEND OF THIS DAM IS ON PLATE 5

REFERENCE:

GEOLOGIC MAP OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES
MISSOURI GEOLOGICAL SURVEY
KENNETH H. ANDERSON, 1979

REGIONAL GEOLOGICAL MAP
OF
MOORES LAKE DAM

LEGEND

PERIOD	SYMBOL	DESCRIPTION
QUATERNARY	Qal	ALLUVIUM: SAND, SILT, GRAVEL
PENNSYLVANIAN	Pu	PENNSYLVANIAN UNDIFFERENTIATED
	Pm	MARMATON GROUP: CYCLIC DEPOSITS OF SHALE, LIMESTONE AND SANDSTONE
	Pcc	CHEROKEE GROUP: CYCLIC DEPOSITS OF SHALE, LIMESTONE AND SANDSTONE
MISSISSIPPIAN	Mo	KEOKUK-BURLINGTON FORMATION: CHERTY GRAYISH BROWN SANDY LIMESTONE
	Mk	CHOUTEAU GROUP: NORTHVIEW AND BACHELOR FORMATION (LIMESTONE AND SHALE)
DEVONIAN	D	SULPHUR SPRING GROUP: GLEN PARK LIMESTONE AND GRASSY CREEK SHALE
ORDOVICIAN	Osp	ST PETER SANDSTONE
	Ojc.	SMITHVILLE FORMATION, POWELL DOLOMITE

APPENDIX A

PHOTOGRAPHS

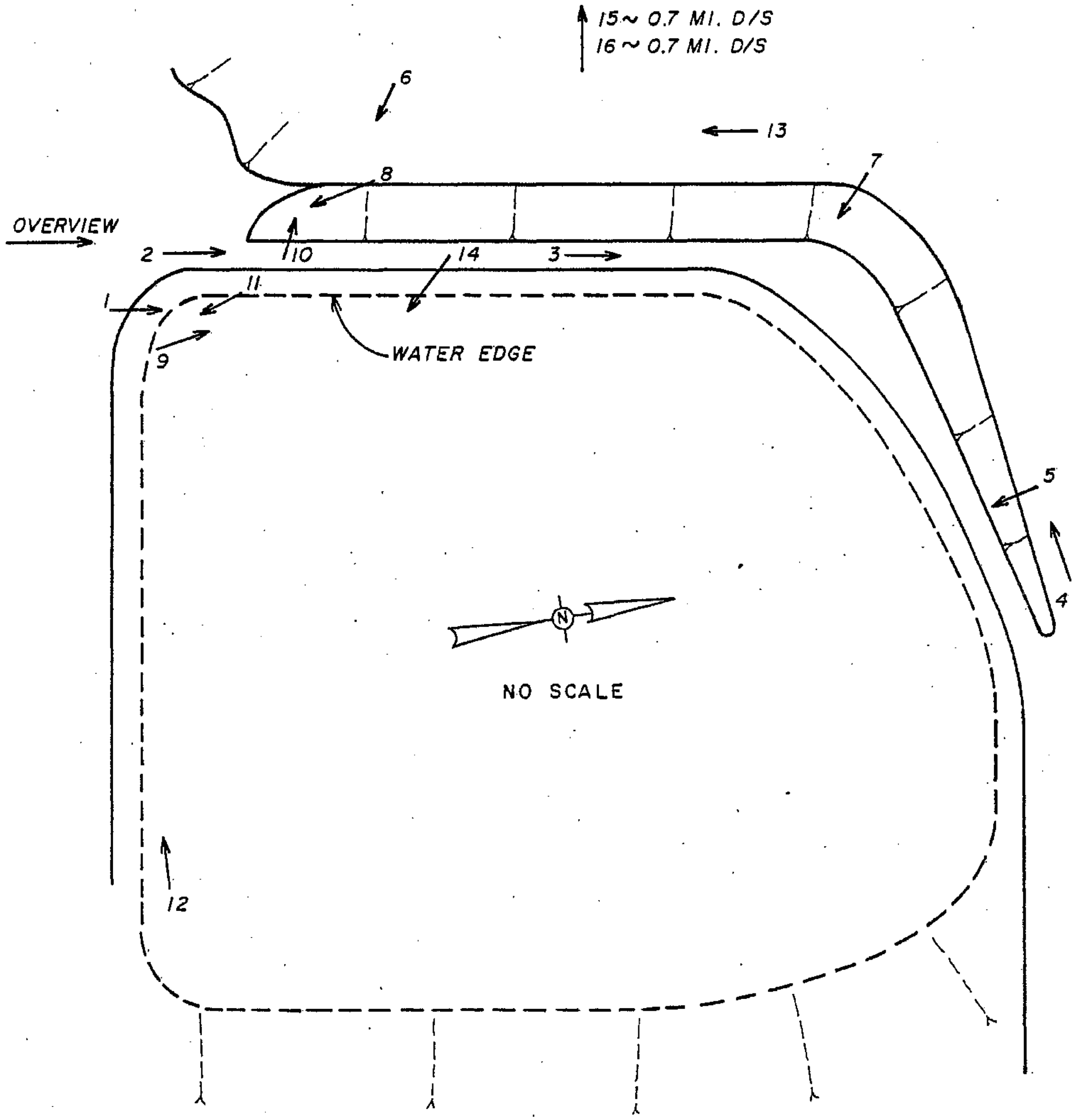


PHOTO INDEX
FOR
MOORES LAKE DAM

Moores Lake Dam

Photographs

Photo 1 - View of the upstream slope from the left abutment showing the dense vegetation.

Photo 2 - View of a portion of the top of dam from the left abutment. Note the disturbed area of soil in the foreground due to the recently constructed 10-inch spillway pipe.

Photo 3 - View of the top of dam showing the maximum top width at the mid-section of the dam.

Photo 4 - View of the downstream slope from the right abutment showing the dense vegetation on the slope.

Photo 5 - View of an animal burrow on the downstream slope.

Photo 6 - View of a large erosion scarp on the downstream slope just downstream of the two spillway pipes at the left abutment.

Photo 7 - View of a large erosional gully on the downstream slope.

Photo 8 - View of the discharge over the top of the manhole of the 4-inch outlet pipe showing the undermining of the toe of the embankment to the left of the manhole (in photo). Note the location of the outlet of the 10-inch pipe above and to the left (in photo) of the manhole.

Photo 9 - View of the inlet to the 10-inch spillway pipe.

Photo 10 - View of the top of the manhole used as the outlet structure for the 4-inch outlet pipe.

Photo 11 - View of the 10-inch pipe that drains the excess water from the cooling pond into the reservoir.

Photo 12 - View of the outlet end of the 6-inch pipe through which the coal ash slurry from the power plant is pumped.

Photo 13 - View of the downstream channel.

Photo 14 - View of the reservoir and rim.

Photo 15 - View of buildings believed to be in the downstream hazard zone.

Photo 16 - View of a gas station believed to be in the downstream hazard zone.

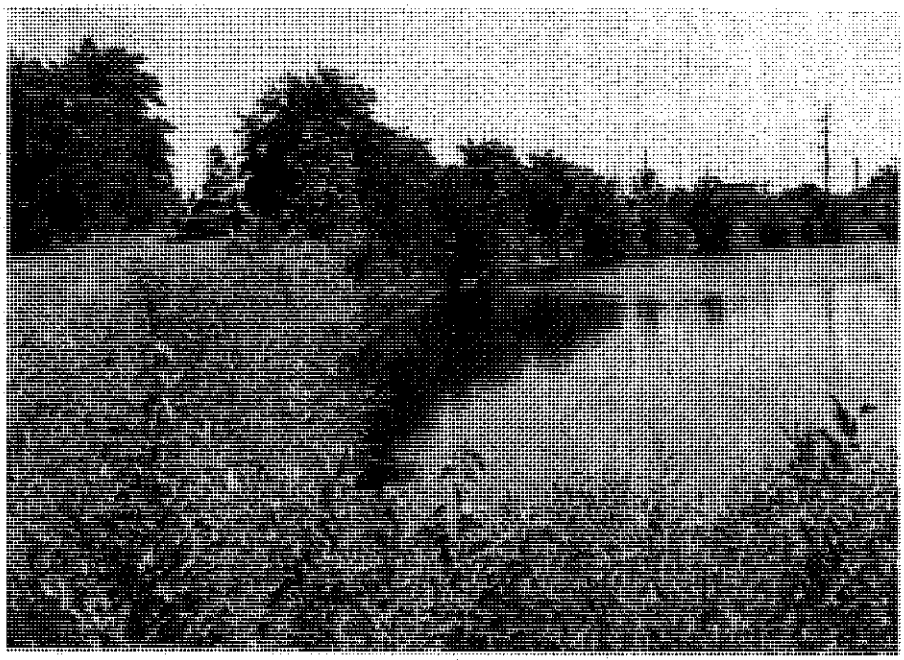


Photo 1

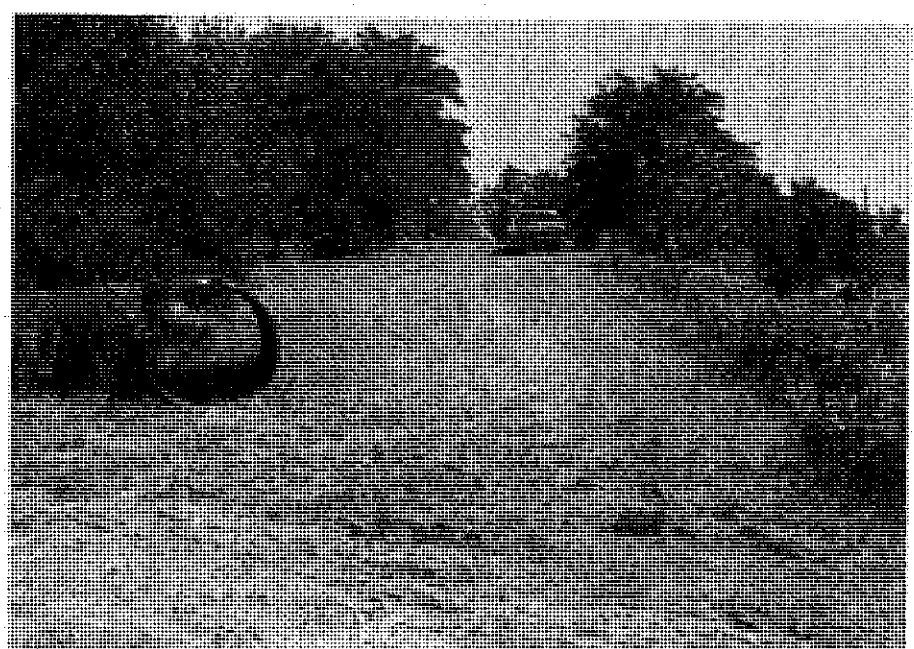


Photo 2

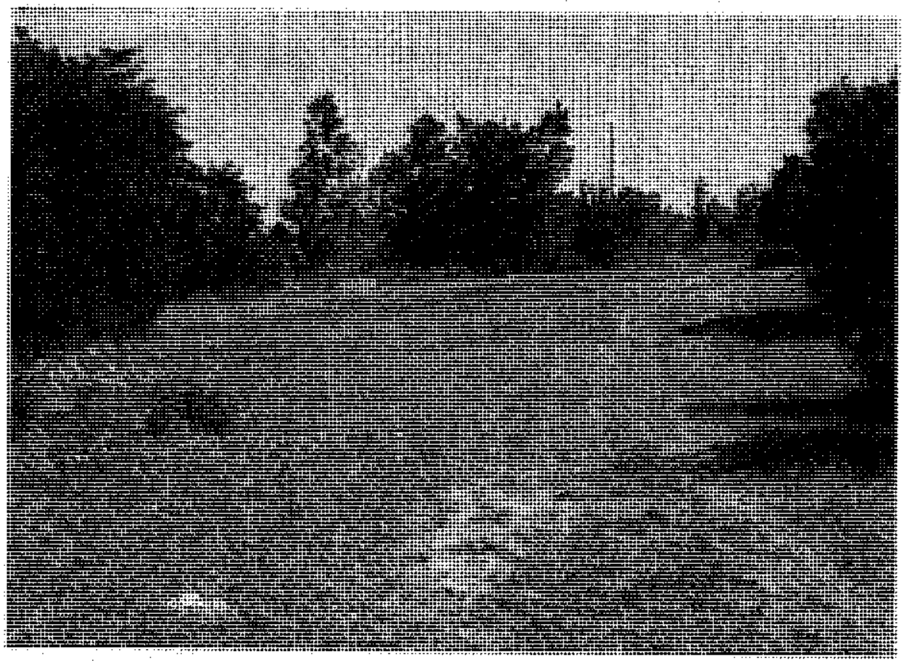


Photo 3

Photo 4

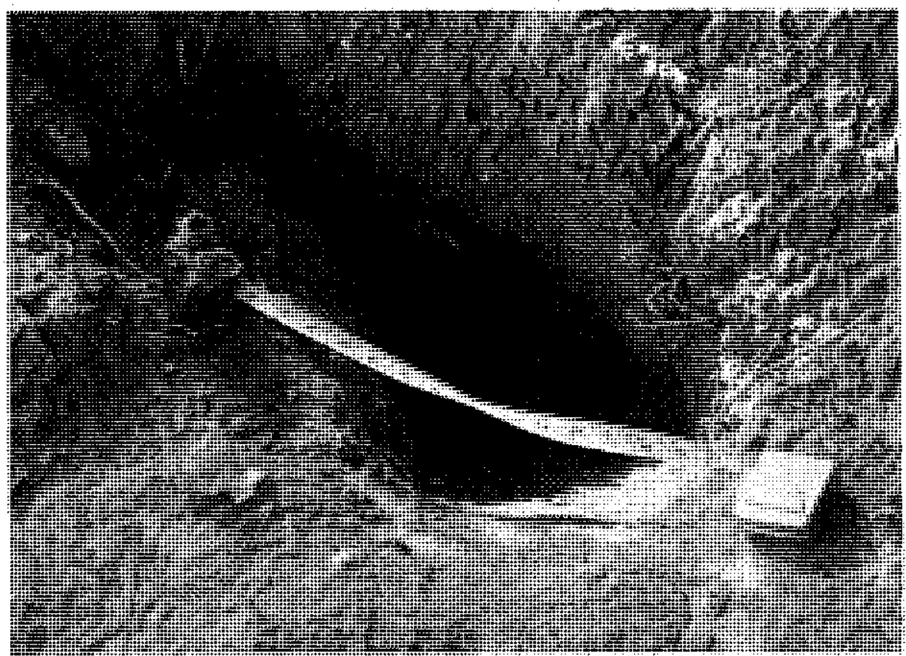


Photo 5

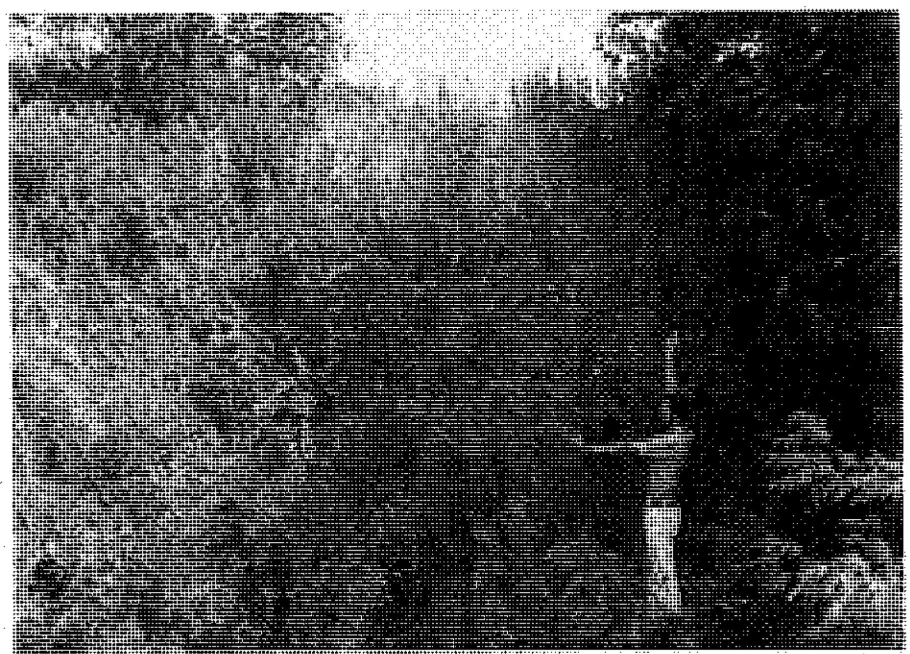


Photo 6

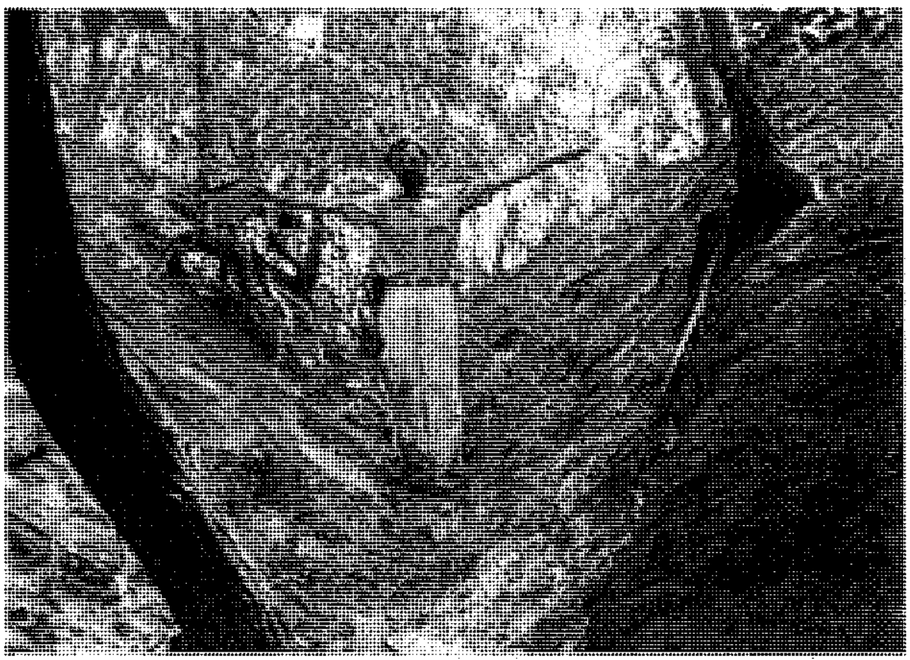


Photo 7

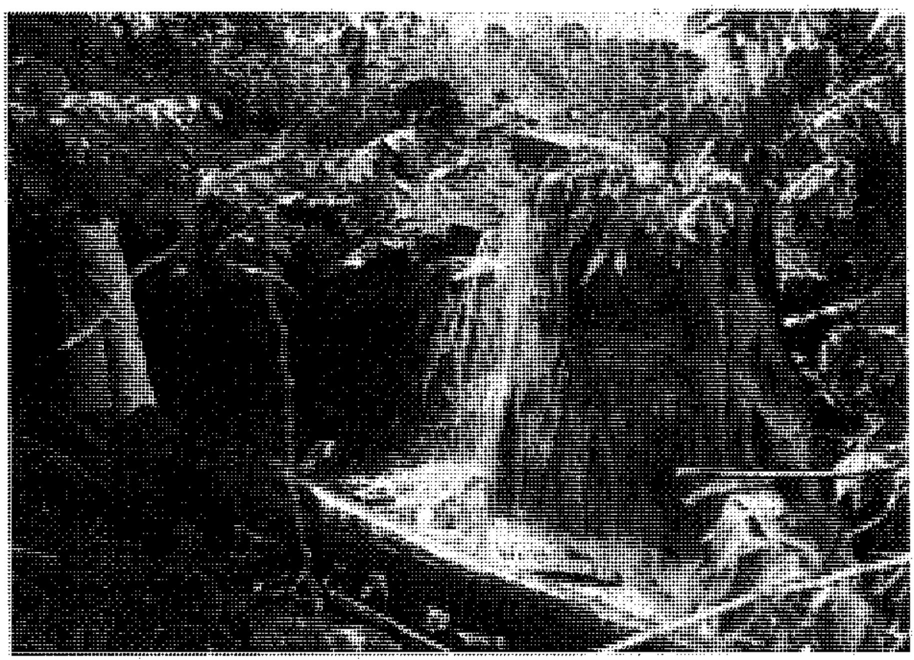


Photo 8

Photo 9

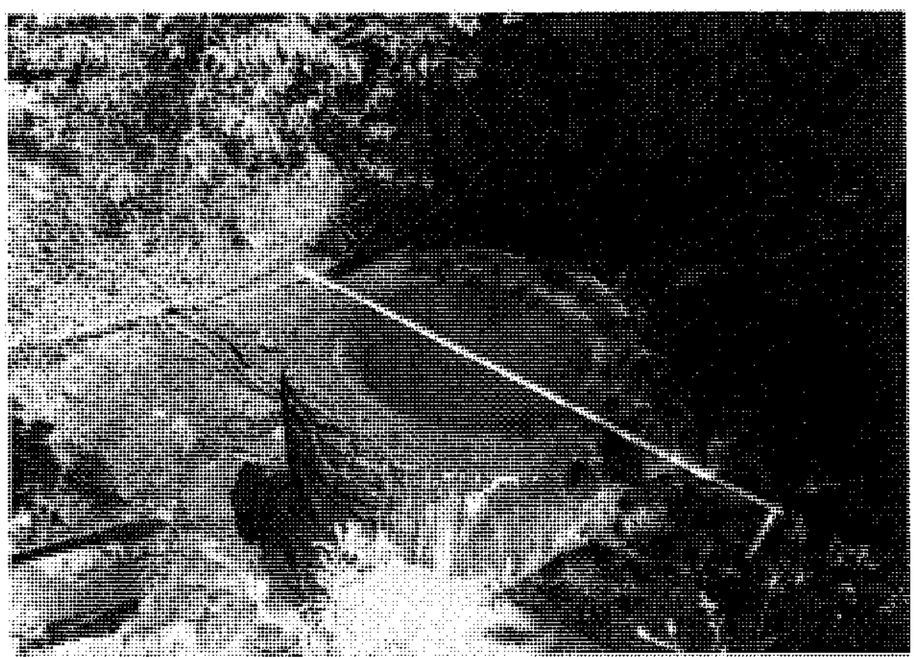


Photo 10

Photo 11

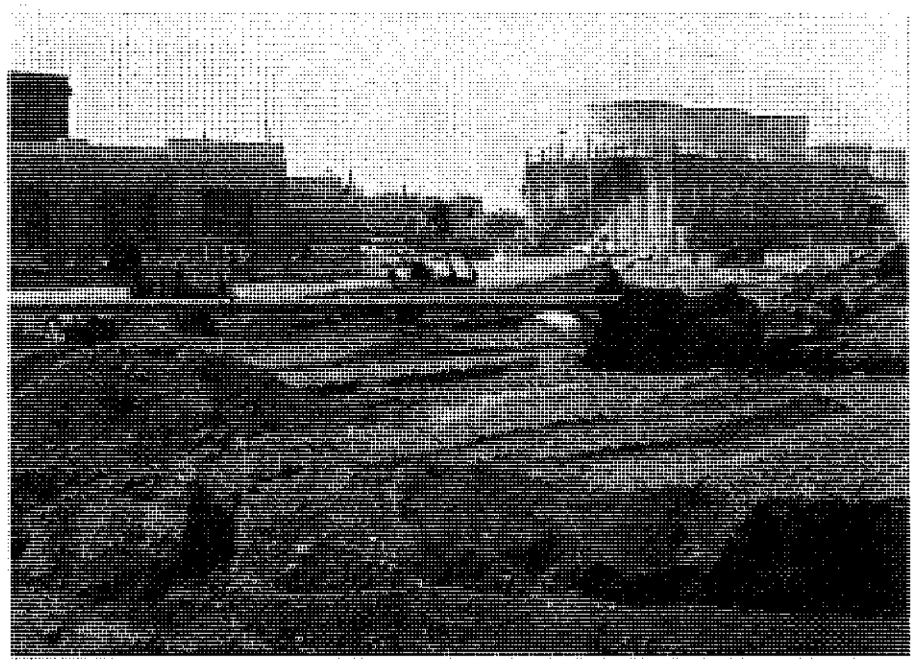


Photo 12

Photo 13

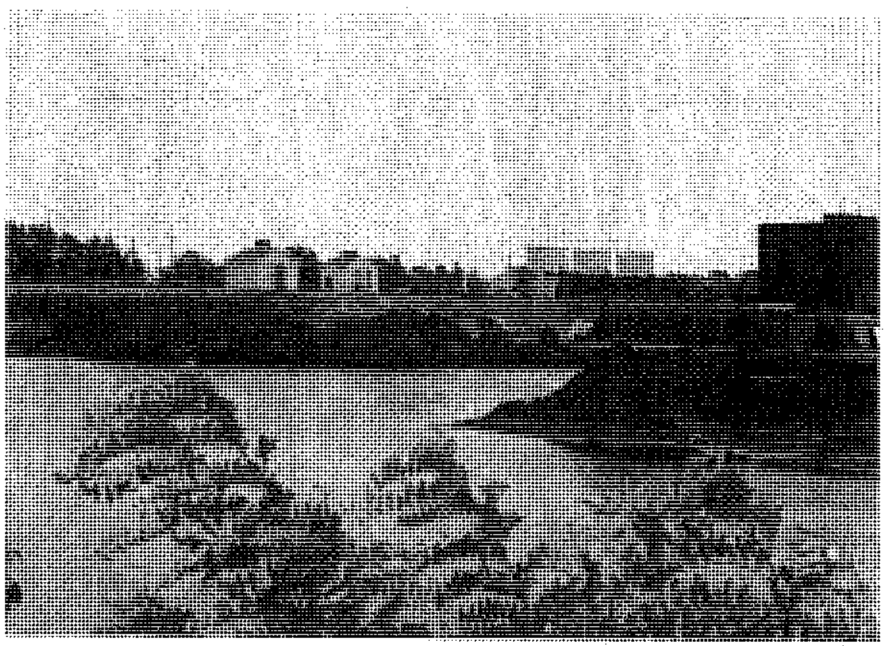


Photo 14

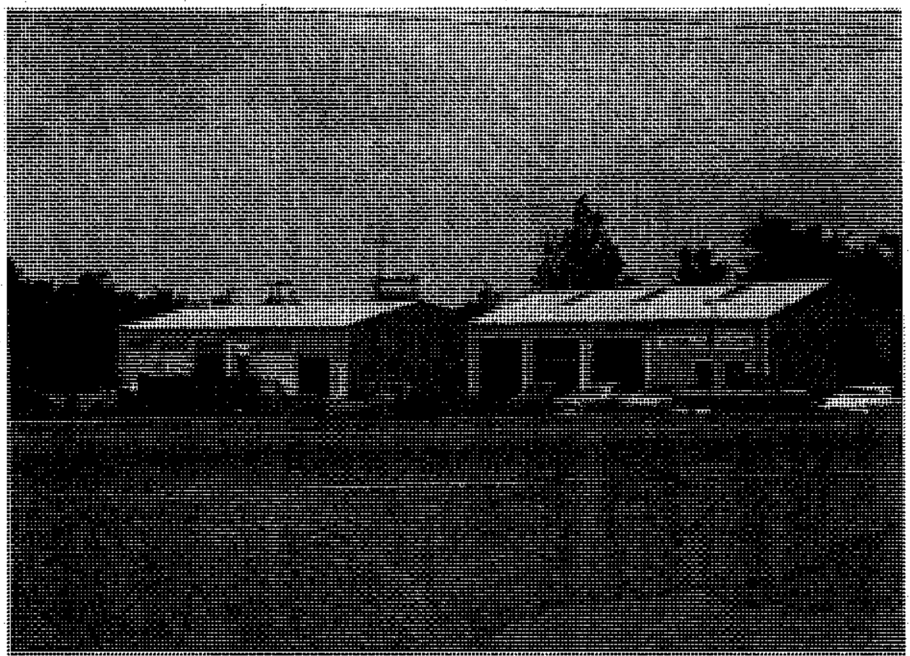


Photo 15

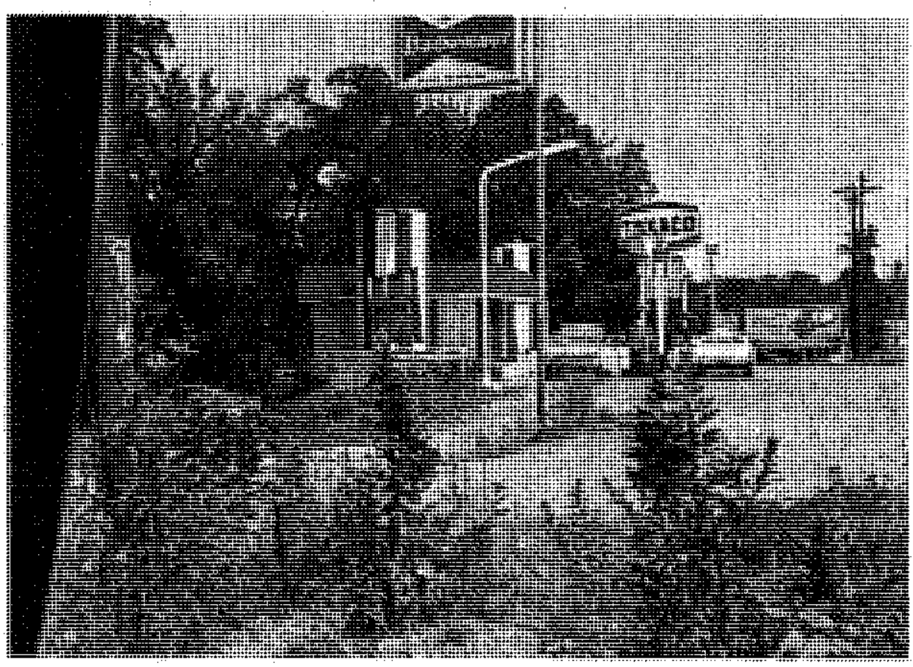


Photo 16

APPENDIX B

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

MOORES LAKE DAM

HYDROLOGIC AND HYDRAULIC DATA, ASSUMPTIONS AND METHODOLOGY

1. SCS Unit Hydrograph and HEC-1DB are used to develop the inflow hydrographs, and the hydrologic inputs are as follows:

   (a) Twenty-four hour probable maximum precipitation from Hydrometeorological Report No. 33, and 100-year 24-hour rainfall of Jefferson City, Missouri.

   (b) Drainage area = 21 acrea.

   (c) Lag time = 0.03 hour.

   (d) Hydrologic Soil Group:
   Soil Group "C"

   (e) Runoff curve number:
   CN = 82 for AMC II and CN = 92 for AMC III.

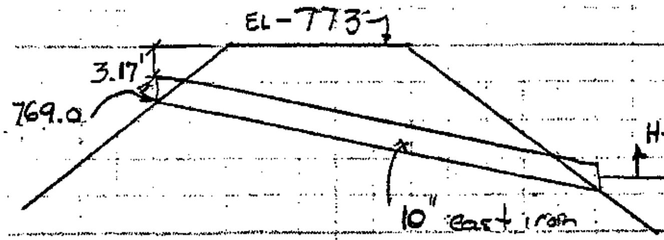
2. Spillway release rates are based on pipe flow assuming Manning's n = 0.02. Flow rates over the dam are based on broad crested weir equation $Q = CLH^{3/2}$ and critical depth assumption.

3. Floods are routed through Moores Lake to determine the capability of its spillway.

DAM SAFETY INSPECTION — SHEET NO. ____ OF ____

MOORES LAKE DAM (MO 11173) — JOB NO. ____

SPILLWAY DISCHARGE — BY DC — DATE 7/23/80



L = 45'

S = 1.48%

n = .02

Pressure Flow:

$K_e = 0.5$ (entrance loss)

$K_c = \frac{29.16\,n^2}{R^{4/3}}$ $R = \frac{A}{P} = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = 2.5''/12\,in/ft$

$K_c = \frac{29.16\,(.02)^2}{(.2083)^{4/3}} = .094$

$Q = A\sqrt{\frac{2g H_T}{1 + K_e + K_c L}} = \pi\left(\frac{5}{12}\right)^2\sqrt{\frac{64.4\,H_T}{5.75}} = 1.85\sqrt{H_T}$

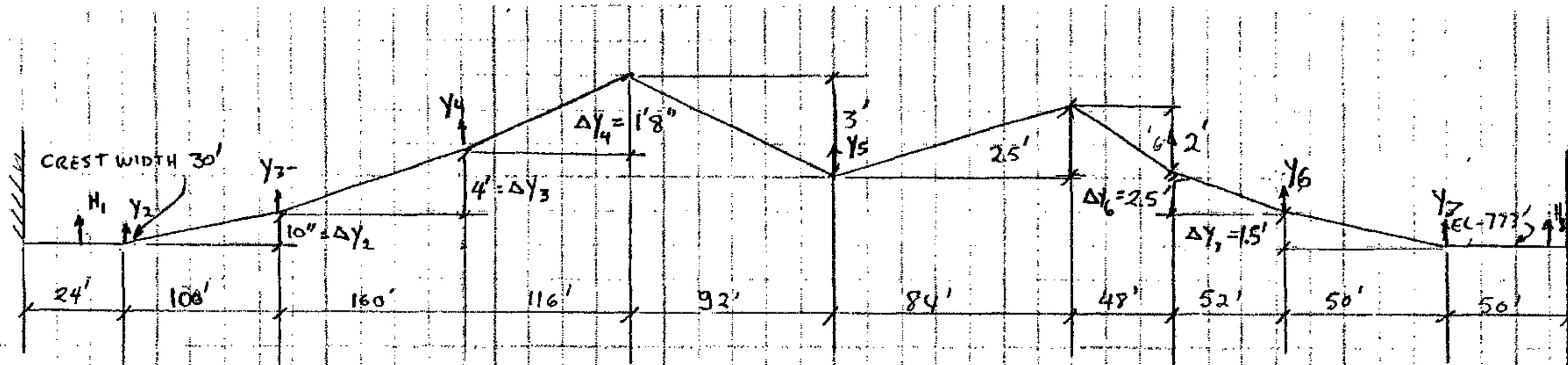
H_T = WSEL − 768.58

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION — SHEET NO. ____ OF ____

MOORES LAKE DAM - (MO 11173) — JOB NO. ____

OVERTOP RATING CURVE — BY D.C — DATE 7/23/80



H_1	C_1	L_1	$Q_1 = C_1 L_1 H_1^{3/2}$	C_8	L_8	$Q_8 = C_8 L_8 H_8^{3/2}$	H_2	$Y_2 = \frac{2}{3}\left(H_2 + \frac{\Delta Y_2}{4}\right)$	T_2	A_2	$Q_2 = \sqrt{\frac{A_2^3 g}{T_2}}$	H_3	$Y_3 = \frac{2}{3}\left(H_3 + \frac{\Delta Y_3}{4}\right)$	T_3	A_3	$Q_3 = \sqrt{\frac{A_3^3 g}{T_3}}$	H_4	$Y_4 = \frac{2}{3}\left(H_4 + \frac{\Delta Y_4}{4}\right)$	T_4	A_4
0	—	24'	—	—	50'	—	—	—	—	—		—	—	—	—	—	—	—	—	—
.3	2.99	24	[redacted]	2.99	50	[redacted]	.3	.24	28.8	3.84	[redacted]	—	—	—	—	—	—	—	—	—
.6	3.03	24	[redacted]	3.03	50	[redacted]	.6	.48	57.6	13.82	[redacted]	—	—	—	—	—	—	—	—	—
1.0	3.04	24	[redacted]	3.64	50	[redacted]	1.07	.80	96.0	38.0	[redacted]	.17	.13	5.3	.36	[redacted]	—	—	—	—
1.3	3.04	24	[redacted]	3.64	50	[redacted]	1.3	1.01	100.0	59.89	[redacted]	.47	.37	14.93	2.79	[redacted]	—	—	—	—
1.6	3.04	24	[redacted]	3.04	50	[redacted]	1.61	1.21	100.0	79.89	[redacted]	.77	.61	24.53	7.52	[redacted]	—	—	—	—
2.0	3.05	24	[redacted]	3.05	50	[redacted]	2.0	1.47	100.0	105.56	[redacted]	1.17	.93	37.33	17.42	[redacted]	—	—	—	—
2.3	3.05	24	[redacted]	3.05	50	[redacted]	2.3	1.67	100.0	125.56	[redacted]	1.47	1.17	46.93	27.53	[redacted]	—	—	—	—
2.6	3.05	24	[redacted]	3.05	50	[redacted]	2.6	1.87	100.0	145.56	[redacted]	1.77	1.41	56.53	39.95	[redacted]	—	—	—	—
3.0	3.05	24	[redacted]	3.05	50	[redacted]	3.0	2.14	100.0	172.2	[redacted]	2.17	1.73	69.33	60.07	[redacted]	—	—	—	—

B-4

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION — SHEET NO. ____ OF ____

MOORES LAKE DAM (Mo 11173) — JOB NO. ____

OVERTOP RATING CURVE — BY KLB — DATE ____

$Q_4=\sqrt{\frac{A_4^3 g}{T_4}}$	H_5	$y_5=\frac{2}{3}(H_5+\frac{\Delta y_5}{4})$	T_5	A_5	$Q_5=\sqrt{\frac{A_5^3 g}{T_5}}$	H_6	$y_6=\frac{2}{3}(H_6+\frac{\Delta y_6}{4})$	T_6	A_6	$Q_6=\sqrt{\frac{A_6^3 g}{T_6}}$	H_7	$\Delta y_7=\frac{2}{3}(H_7+\frac{\Delta y_7}{4})$	T_7	A_7	$Q_7=\sqrt{\frac{A_7^3 g}{T_7}}$	$Q_1+Q_2+Q_3$ $Q_T=+Q_4+Q_7+Q_8+Q_5+Q_6$	WSEL
–	–	–	–	–	–	–	–	–	–	–	–					0	773.0
–	–	–	–	–	–	–	–	–	–	–	.3	.24	8.0	.96	1[illegible]89	45	773.3
–	–	–	–	–	–	–	–	–	–	–	.6	.48	16.0	3.84	10[illegible]67	153	773.6
–	–	–	–	–	–	–	–	–	–	–	1	.80	26.67	10.67	3[illegible]28	401	774.0
–	–	–	–	–	–	–	–	–	–	–	1.3	1.04	34.67	18.03	7[illegible]76	670	774.3
–	–	–	–	–	–	.1	.08	1.66	.07	[illegible]8	1.6	1.28	42.67	27.31	12[illegible].96	1001	774.6
–	–	–	–	–	–	.5	.40	8.32	1.66	4[illegible]2.2	2.0	1.58	50.0	41.67	21[illegible].84	1540	775.0
–	–	–	–	–	–	.8	.64	13.31	4.16	1[illegible]6.7	2.3	1.78	50.0	51.67	2[illegible]3.03	2016	775.3
–	–	–	–	–	–	1.1	.88	18.3	8.65	3[illegible]31	2.6	1.98	50.0	61.67	3[illegible].61	2552	775.6
–	–	–	–	–	–	1.5	1.20	24.96	14.98	6[illegible].83	3.0	2.25	50.0	75.0	52[illegible].24	3360	776.0

ECI-4 PRC ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION /MISSOURI — SHEET NO. ____ OF ____

MOORES LAKE DAM (MO 11173) — JOB NO. 1263

COMBINED RATING CURVE — BY DC / KLB — DATE 7/23/80

Datum = 768.58 → H_T

Reservoir Water Surface Elev.	H_T	Spillway Discharge $Q = 1.8\sqrt{H_T}$	Emergency Spillway Discharge	Discharge Over Top of Dam	Combined Discharge
769.0	—	—		—	0
769.83	1.25	2.0		—	2
771.0	2.42	2.8		—	3
772.0	3.42	3.3		—	3
773.0	4.42	3.8		—	4
773.3	4.72	3.9		45	49
773.6	5.02	4.0		153	157
774.0	5.42	4.2		401	405
774.3	5.72	4.3		670	674
774.6	6.02	4.4		1001	1005
775.0	6.42	4.5		1540	1546
775.3	6.72	4.7		2016	2021
775.6	7.02	4.8		2552	2557
776.0	7.42	4.9		3360	3365

ECI-4 PRC ENGINEERING CONSULTANTS, INC.

Dam Safety Inspection - Missouri — SHEET NO. 1 OF 1

Dam Name: Moores Lake Dam / ID No.: 11173 — JOB NO. 1263

Reservoir Elevation - Area Data — BY B.M. / FZ — DATE 7/8 / 7/26

ELEV. (M.S.L.) (Ft.)	RESERVOIR SURFACE AREA (Acres)	REMARKS
762	0	Estimated Streambed U/S of Dam
769	6.5	Spillway Crest (Assumed)
770	7.0	Measured on USGS Quad
773	8.5	Top of dam.
780	11.0	Measured on USGS Quad

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI — SHEET NO. 1 OF 1

DAM NAME: MOORES LAKE DAM (MO 11173) — JOB NO. 1263

UNIT HYDROGRAPH PARAMETERS — BY D.C. KLB — DATE 7/23/80

1) DRAINAGE AREA, A = .033 sq. mi = (21.0 acres)

2) LENGTH OF STREAM, L = (.25 " × 2000 ' = 500 ') = 0.095 mi.

3) ELEVATION AT DRAINAGE DIVIDE ALONG THE LONGEST STREAM,

$H_1 = 792'$

4) ELEVATION OF RESERVOIR AT SPILLWAY CREST, $H_2 = 769$

5) ELEVATION OF CHANNEL BED AT 0.85L, $E_{85} = 788'$

6) ELEVATION OF CHANNEL BED AT 0.10L, $E_{10} = 771$

7) AVERAGE SLOPE OF THE CHANNEL, $S_{AVG} = (E_{85} - E_{10}) / 0.75L = .045$

8) TIME OF CONCENTRATION:

A) BY KIRPICH'S EQUATION,

$t_c = [(11.9 \times L^3)/(H_1 - H_2)]^{0.385} = \left[\frac{11.9(.095)^3}{792-769}\right]^{.385} = .05$ hr

B) BY VELOCITY ESTIMATE,

SLOPE = 4.5% ⟹ AVG. VELOCITY = 3 fps

$t_c = L/V = 500/3(60)(60) = 0.05$ hr

USE $t_c = .05$

9) LAG TIME, $t_l = 0.6\, t_c = .03$

10) UNIT DURATION, $D \le t_l/3 = .015$ < 0.083 hr.

USE D = .083

11) TIME TO PEAK, $T_p = D/2 + t_l = .07$

12) PEAK DISCHARGE,

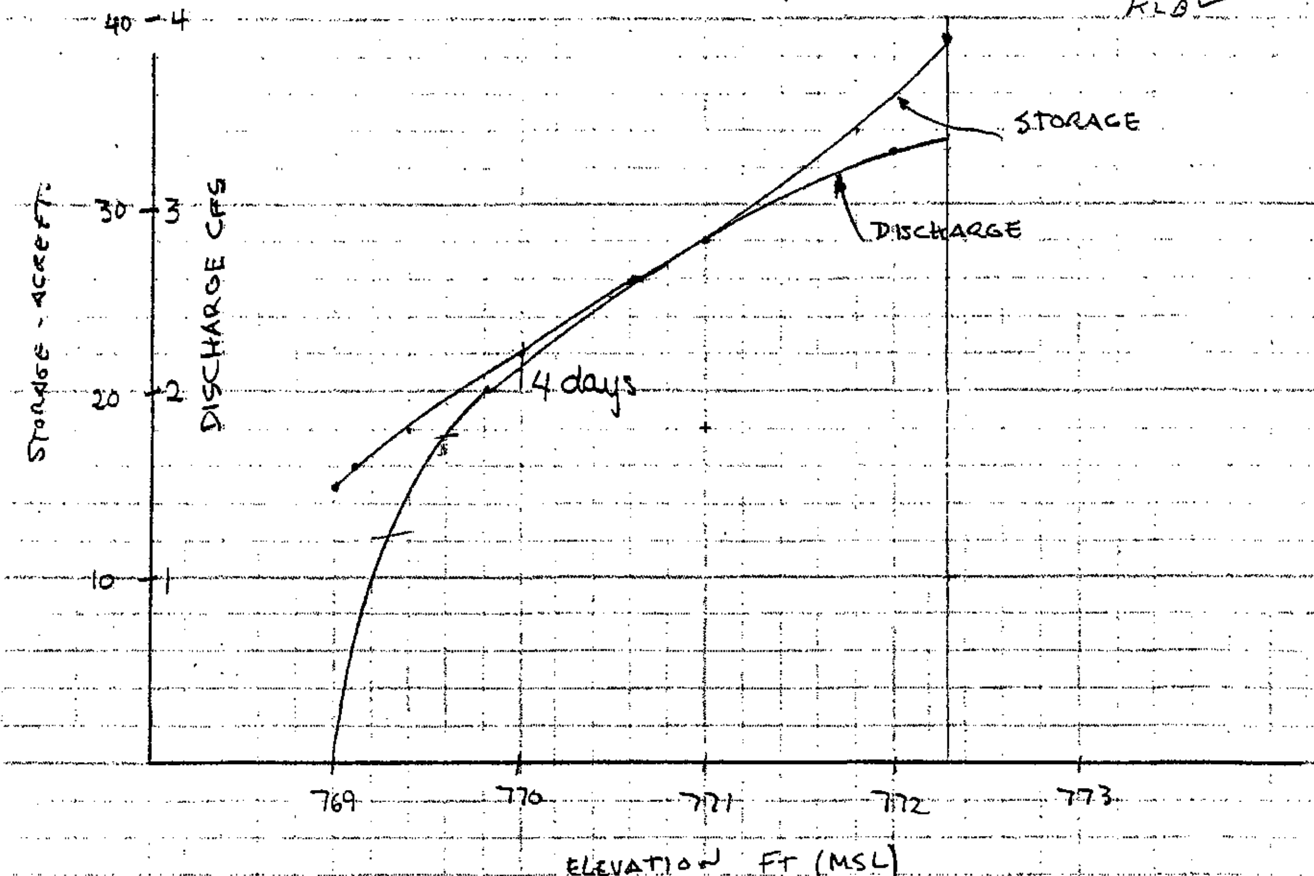
$q_p = (484 \times A)/T_p = $ 228 cfs

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

SHEET NO. 1 OF 1

MOORES LAKE DAM (MO 11173) JOB NO. 1263

STARTING ELEVATION FOR PMF BY D.C. KLB DATE 7/31/80



Stage	Storage	Discharge	Δt	Σt
772.3	39	3.35	0	1
772.0	36	3.3	.45	1.45
771.4	31	3.05	.79	2.25
771.0	28	2.8	.52	2.77
770.6	26	2.6	.37	3.14
770.0	22	2.1	.86	4.00 days

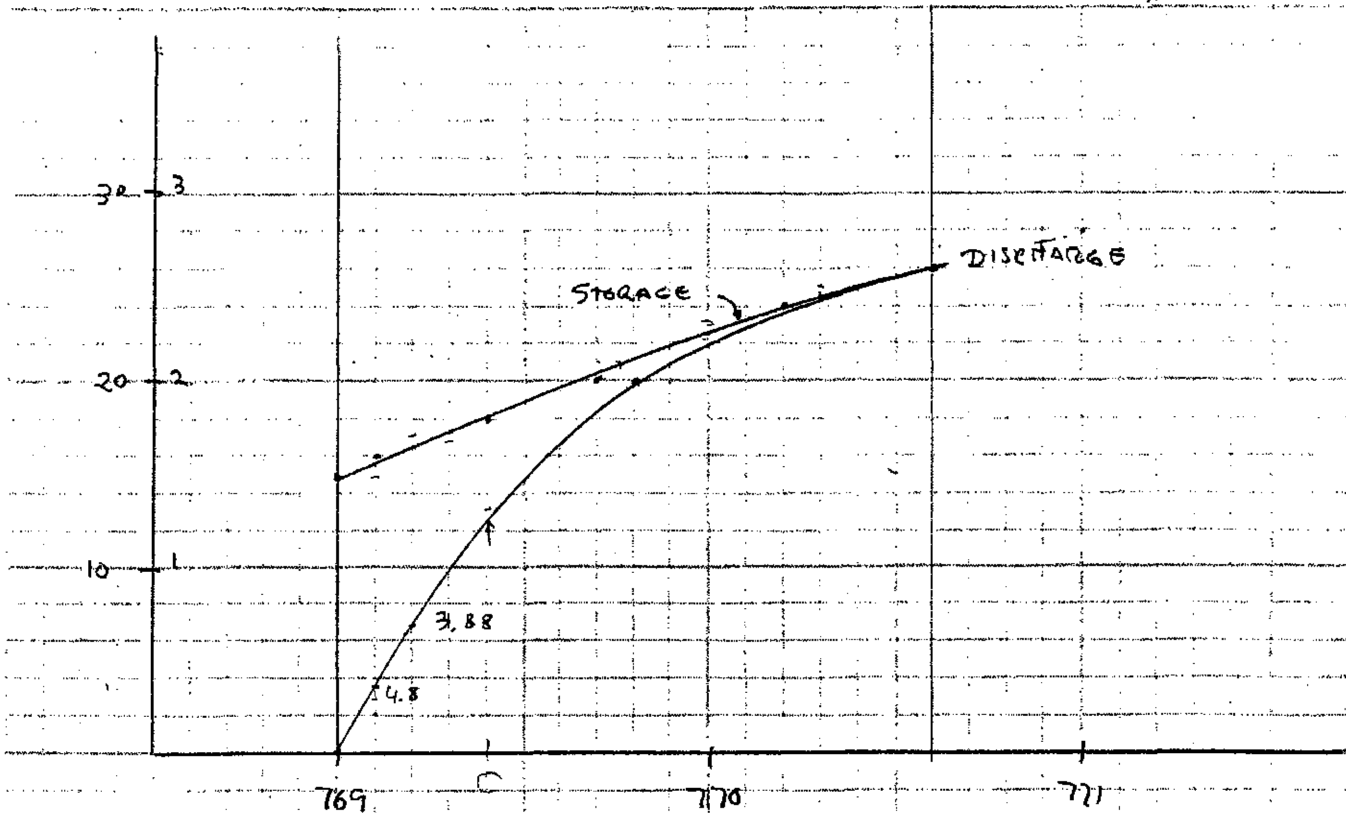
∴ start PMF Routing at 770'

ECI-4 PRC ENGINEERING CONSULTANTS, INC.

SHEET NO. 1 OF 1

MOORES LAKE DAM (MO 11173) JOB NO. 1263

STARTING ELEVATION FOR 50% PMF BY D.C. / RLB DATE 7/31/80



Stage	Storage	Discharge	Δt	Σt
770.6	26	2.6	0	1 days
770.2	24	2.35	.39	1.39
770	23	2.2	.21	1.60
769.8	21	2.0	.48	2.08
769.5	19	1.5	.58	2.65
769.4	18	1.25	.37	3.02
769.2	16.5	.7	.78	3.80
769.1	15.5	.35	.96	4.76

Use 769.2 for starting 50% PMF Routing

```
*********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
*********************************
A1     DAM SAFETY INSPECTION MISSOURI
A2     MOORES LAKE DAM (MO 11173)
A3     PMF
B     300       0       5       0       0       0       0       0       0       0
B1      5
J1      1       1       1
J1      1
K        MO11173                                        1
K1     INPUT PRECIPITATION INDEX, RATIOS, AND UNIT HYDROGRAPH PARAMETERS
M       1       2    .033            .033       1                               1
P            24.8     100     120     130
T                                                      -1     -92
W2            .03
X                       1
K       1 MO11173                                       1
K1     ROUTE HYDROGRAPH THROUGH MOORES LAKE DAM (MO 11173)
Y                               1       1
Y1                                                   -770      -1
Y4    769  769.83     771     772     773   773.3   773.6     774   774.3   774.6
Y4    775   775.3   775.6     776
Y5      0       2       3       3       4      49     157     405     674    1005
Y5   1546    2021    2557    3365
$A      0     6.5       7     8.5      11
$E    762     769     770     773     780
$$    769
$D    773
K      99
```

B-11

```
*************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
*************************************

RUN  DATE* 80/07/30.
     TIME* 14.43.33.

                     DAM SAFETY INSPECTION MISSOURI
                     MOORES LAKE DAM (MO 11173)
                     PMF

                                  JOB SPECIFICATION
     NQ     NHR    NMIN    IDAY    IHR    IMIN   METRC    IPLT    IPRT   NSTAN
    300       0       5       0      0       0       0       0       0       0
                          JOPER    NWT   LROPT   TRACE
                              5      0       0       0

                       MULTI-PLAN ANALYSES TO BE PERFORMED
                          NPLAN= 1 NRTIO= 1 LRTIO= 1
          RTIOS=   1.00

**********          **********          **********          **********          **********

                          SUB-AREA RUNOFF COMPUTATION

             INPUT PRECIPITATION INDEX, RATIOS, AND UNIT HYDROGRAPH PARAMETERS

          ISTAQ   ICOMP   IECON   ITAPE   JPLT    JPRT   INAME  ISTAGE   IAUTO
         011173       0       0       0      0       0       1       0       0

                               HYDROGRAPH DATA
   IHYDG   IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
       1      2     .03    0.00     .03    1.00   0.000       0       1       0

                                 PRECIP DATA
          SPFE     PMS      R6     R12     R24     R48     R72     R96
          0.00   24.80  100.00  120.00  130.00    0.00    0.00    0.00

                                  LOSS DATA
   LROPT  STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
       0   0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -92.00    0.00    0.00

       CURVE NO = -92.00  WETNESS =  -1.00  EFFECT CN =  92.00

                            UNIT HYDROGRAPH DATA
                       TC=  0.00    LAG=   .03

                               RECESSION DATA
               STRTQ=    0.00   QRCSN=    0.00   RTIOR= 1.00

       TIME INCREMENT TOO LARGE--(NHQ IS GT LAG/2)

       UNIT HYDROGRAPH  5 END OF PERIOD ORDINATES, TC=   0.00 HOURS, LAG=   .03  VOL= 1.00
```

190. 53. 10. 2. 0.

0

END-OF-PERIOD FLOW

NO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	NO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	0.00	.01	0.	1.01	12.35	151	.21	.20	.00	52.
1.01	.10	2	.01	0.00	.01	0.	1.01	12.40	152	.21	.20	.00	52.
1.01	.15	3	.01	0.00	.01	0.	1.01	12.45	153	.21	.20	.00	52.
1.01	.20	4	.01	0.00	.01	0.	1.01	12.50	154	.21	.20	.00	52.
1.01	.25	5	.01	0.00	.01	0.	1.01	12.55	155	.21	.20	.00	52.
1.01	.30	6	.01	0.00	.01	0.	1.01	13.00	156	.21	.20	.00	52.
1.01	.35	7	.01	0.00	.01	0.	1.01	13.05	157	.25	.25	.00	60.
1.01	.40	8	.01	0.00	.01	0.	1.01	13.10	158	.25	.25	.00	62.
1.01	.45	9	.01	0.00	.01	0.	1.01	13.15	159	.25	.25	.00	63.
1.01	.50	10	.01	0.00	.01	0.	1.01	13.20	160	.25	.25	.00	63.
1.01	.55	11	.01	0.00	.01	0.	1.01	13.25	161	.25	.25	.00	63.
1.01	1.00	12	.01	0.00	.01	0.	1.01	13.30	162	.25	.25	.00	63.
1.01	1.05	13	.01	.00	.01	0.	1.01	13.35	163	.25	.25	.00	63.
1.01	1.10	14	.01	.00	.01	0.	1.01	13.40	164	.25	.25	.00	63.
1.01	1.15	15	.01	.00	.01	0.	1.01	13.45	165	.25	.25	.00	63.
1.01	1.20	16	.01	.00	.01	0.	1.01	13.50	166	.25	.25	.00	63.
1.01	1.25	17	.01	.00	.01	0.	1.01	13.55	167	.25	.25	.00	63.
1.01	1.30	18	.01	.00	.01	0.	1.01	14.00	168	.25	.25	.00	63.
1.01	1.35	19	.01	.00	.01	1.	1.01	14.05	169	.31	.31	.00	75.
1.01	1.40	20	.01	.00	.01	1.	1.01	14.10	170	.31	.31	.00	78.
1.01	1.45	21	.01	.00	.01	1.	1.01	14.15	171	.31	.31	.00	79.
1.01	1.50	22	.01	.00	.01	1.	1.01	14.20	172	.31	.31	.00	79.
1.01	1.55	23	.01	.00	.01	1.	1.01	14.25	173	.31	.31	.00	79.
1.01	2.00	24	.01	.00	.01	1.	1.01	14.30	174	.31	.31	.00	79.
1.01	2.05	25	.01	.00	.01	1.	1.01	14.35	175	.31	.31	.00	79.
1.01	2.10	26	.01	.00	.01	1.	1.01	14.40	176	.31	.31	.00	79.
1.01	2.15	27	.01	.00	.01	1.	1.01	14.45	177	.31	.31	.00	79.
1.01	2.20	28	.01	.00	.01	1.	1.01	14.50	178	.31	.31	.00	79.
1.01	2.25	29	.01	.00	.01	1.	1.01	14.55	179	.31	.31	.00	79.
1.01	2.30	30	.01	.01	.01	1.	1.01	15.00	180	.31	.31	.00	79.
1.01	2.35	31	.01	.01	.01	1.	1.01	15.05	181	.19	.19	.00	56.
1.01	2.40	32	.01	.01	.01	1.	1.01	15.10	182	.38	.38	.00	85.
1.01	2.45	33	.01	.01	.01	1.	1.01	15.15	183	.38	.38	.00	94.
1.01	2.50	34	.01	.01	.01	2.	1.01	15.20	184	.57	.56	.00	131.
1.01	2.55	35	.01	.01	.01	2.	1.01	15.25	185	.66	.66	.00	160.
1.01	3.00	36	.01	.01	.01	2.	1.01	15.30	186	1.60	1.60	.00	345.
1.01	3.05	37	.01	.01	.01	2.	1.01	15.35	187	2.64	2.63	.00	593.
1.01	3.10	38	.01	.01	.01	2.	1.01	15.40	188	1.04	1.04	.00	359.
1.01	3.15	39	.01	.01	.01	2.	1.01	15.45	189	.66	.66	.00	211.
1.01	3.20	40	.01	.01	.01	2.	1.01	15.50	190	.57	.56	.00	158.
1.01	3.25	41	.01	.01	.01	2.	1.01	15.55	191	.38	.38	.00	110.
1.01	3.30	42	.01	.01	.01	2.	1.01	16.00	192	.38	.38	.00	99.
1.01	3.35	43	.01	.01	.01	2.	1.01	16.05	193	.29	.29	.00	80.
1.01	3.40	44	.01	.01	.01	2.	1.01	16.10	194	.29	.29	.00	75.
1.01	3.45	45	.01	.01	.01	2.	1.01	16.15	195	.29	.29	.00	74.
1.01	3.50	46	.01	.01	.01	2.	1.01	16.20	196	.29	.29	.00	74.
1.01	3.55	47	.01	.01	.01	2.	1.01	16.25	197	.29	.29	.00	74.
1.01	4.00	48	.01	.01	.01	2.	1.01	16.30	198	.29	.29	.00	74.
1.01	4.05	49	.01	.01	.01	2.	1.01	16.35	199	.29	.29	.00	74.
1.01	4.10	50	.01	.01	.01	2.	1.01	16.40	200	.29	.29	.00	74.
1.01	4.15	51	.01	.01	.01	2.	1.01	16.45	201	.29	.29	.00	74.
1.01	4.20	52	.01	.01	.01	2.	1.01	16.50	202	.29	.29	.00	74.
1.01	4.25	53	.01	.01	.01	2.	1.01	16.55	203	.29	.29	.00	74.
1.01	4.30	54	.01	.01	.01	2.	1.01	17.00	204	.29	.29	.00	74.
1.01	4.35	55	.01	.01	.00	2.	1.01	17.05	205	.23	.23	.00	62.

1.01	4.40	56	.01	.01	.00	2.	1.01	17.10	206	.23	.23	.00	59.
1.01	4.45	57	.01	.01	.00	2.	1.01	17.15	207	.23	.23	.00	58.
1.01	4.50	58	.01	.01	.00	2.	1.01	17.20	208	.23	.23	.00	58.
1.01	4.55	59	.01	.01	.00	2.	1.01	17.25	209	.23	.23	.00	58.
1.01	5.00	60	.01	.01	.00	2.	1.01	17.30	210	.23	.23	.00	58.
1.01	5.05	61	.01	.01	.00	2.	1.01	17.35	211	.23	.23	.00	58.
1.01	5.10	62	.01	.01	.00	2.	1.01	17.40	212	.23	.23	.00	58.
1.01	5.15	63	.01	.01	.00	2.	1.01	17.45	213	.23	.23	.00	58.
1.01	5.20	64	.01	.01	.00	2.	1.01	17.50	214	.23	.23	.00	58.
1.01	5.25	65	.01	.01	.00	2.	1.01	17.55	215	.23	.23	.00	58.
1.01	5.30	66	.01	.01	.00	2.	1.01	18.00	216	.23	.23	.00	58.
1.01	5.35	67	.01	.01	.00	2.	1.01	18.05	217	.02	.02	.00	19.
1.01	5.40	68	.01	.01	.00	3.	1.01	18.10	218	.02	.02	.00	8.
1.01	5.45	69	.01	.01	.00	3.	1.01	18.15	219	.02	.02	.00	6.
1.01	5.50	70	.01	.01	.00	3.	1.01	18.20	220	.02	.02	.00	5.
1.01	5.55	71	.01	.01	.00	3.	1.01	18.25	221	.02	.02	.00	5.
1.01	6.00	72	.01	.01	.00	3.	1.01	18.30	222	.02	.02	.00	5.
1.01	6.05	73	.07	.05	.02	10.	1.01	18.35	223	.02	.02	.00	5.
1.01	6.10	74	.07	.05	.02	13.	1.01	18.40	224	.02	.02	.00	5.
1.01	6.15	75	.07	.05	.02	14.	1.01	18.45	225	.02	.02	.00	5.
1.01	6.20	76	.07	.05	.01	14.	1.01	18.50	226	.02	.02	.00	5.
1.01	6.25	77	.07	.06	.01	14.	1.01	18.55	227	.02	.02	.00	5.
1.01	6.30	78	.07	.06	.01	14.	1.01	19.00	228	.02	.02	.00	5.
1.01	6.35	79	.07	.06	.01	15.	1.01	19.05	229	.02	.02	.00	5.
1.01	6.40	80	.07	.06	.01	15.	1.01	19.10	230	.02	.02	.00	5.
1.01	6.45	81	.07	.06	.01	15.	1.01	19.15	231	.02	.02	.00	5.
1.01	6.50	82	.07	.06	.01	15.	1.01	19.20	232	.02	.02	.00	5.
1.01	6.55	83	.07	.06	.01	15.	1.01	19.25	233	.02	.02	.00	5.
1.01	7.00	84	.07	.06	.01	15.	1.01	19.30	234	.02	.02	.00	5.
1.01	7.05	85	.07	.06	.01	16.	1.01	19.35	235	.02	.02	.00	5.
1.01	7.10	86	.07	.06	.01	16.	1.01	19.40	236	.02	.02	.00	5.
1.01	7.15	87	.07	.06	.01	16.	1.01	19.45	237	.02	.02	.00	5.
1.01	7.20	88	.07	.06	.01	16.	1.01	19.50	238	.02	.02	.00	5.
1.01	7.25	89	.07	.06	.01	16.	1.01	19.55	239	.02	.02	.00	5.
1.01	7.30	90	.07	.06	.01	16.	1.01	20.00	240	.02	.02	.00	5.
1.01	7.35	91	.07	.06	.01	16.	1.01	20.05	241	.02	.02	.00	5.
1.01	7.40	92	.07	.06	.01	16.	1.01	20.10	242	.02	.02	.00	5.
1.01	7.45	93	.07	.06	.01	16.	1.01	20.15	243	.02	.02	.00	5.
1.01	7.50	94	.07	.06	.01	16.	1.01	20.20	244	.02	.02	.00	5.
1.01	7.55	95	.07	.06	.00	16.	1.01	20.25	245	.02	.02	.00	5.
1.01	8.00	96	.07	.06	.00	16.	1.01	20.30	246	.02	.02	.00	5.
1.01	8.05	97	.07	.06	.00	16.	1.01	20.35	247	.02	.02	.00	5.
1.01	8.10	98	.07	.06	.00	16.	1.01	20.40	248	.02	.02	.00	5.
1.01	8.15	99	.07	.06	.00	17.	1.01	20.45	249	.02	.02	.00	5.
1.01	8.20	100	.07	.06	.00	17.	1.01	20.50	250	.02	.02	.00	5.
1.01	8.25	101	.07	.06	.00	17.	1.01	20.55	251	.02	.02	.00	5.
1.01	8.30	102	.07	.07	.00	17.	1.01	21.00	252	.02	.02	.00	5.
1.01	8.35	103	.07	.07	.00	17.	1.01	21.05	253	.02	.02	.00	5.
1.01	8.40	104	.07	.07	.00	17.	1.01	21.10	254	.02	.02	.00	5.
1.01	8.45	105	.07	.07	.00	17.	1.01	21.15	255	.02	.02	.00	5.
1.01	8.50	106	.07	.07	.00	17.	1.01	21.20	256	.02	.02	.00	5.
1.01	8.55	107	.07	.07	.00	17.	1.01	21.25	257	.02	.02	.00	5.
1.01	9.00	108	.07	.07	.00	17.	1.01	21.30	258	.02	.02	.00	5.
1.01	9.05	109	.07	.07	.00	17.	1.01	21.35	259	.02	.02	.00	5.
1.01	9.10	110	.07	.07	.00	17.	1.01	21.40	260	.02	.02	.00	5.
1.01	9.15	111	.07	.07	.00	17.	1.01	21.45	261	.02	.02	.00	5.
1.01	9.20	112	.07	.07	.00	17.	1.01	21.50	262	.02	.02	.00	5.
1.01	9.25	113	.07	.07	.00	17.	1.01	21.55	263	.02	.02	.00	5.
1.01	9.30	114	.07	.07	.00	17.	1.01	22.00	264	.02	.02	.00	5.
1.01	9.35	115	.07	.07	.00	17.	1.01	22.05	265	.02	.02	.00	5.

1.01	9.40	116	.07	.07	.00	17.	1.01	22.10	266	.02	.02	.00	5.
1.01	9.45	117	.07	.07	.00	17.	1.01	22.15	267	.02	.02	.00	5.
1.01	9.50	118	.07	.07	.00	17.	1.01	22.20	268	.02	.02	.00	5.
1.01	9.55	119	.07	.07	.00	17.	1.01	22.25	269	.02	.02	.00	5.
1.01	10.00	120	.07	.07	.00	17.	1.01	22.30	270	.02	.02	.00	5.
1.01	10.05	121	.07	.07	.00	17.	1.01	22.35	271	.02	.02	.00	5.
1.01	10.10	122	.07	.07	.00	17.	1.01	22.40	272	.02	.02	.00	5.
1.01	10.15	123	.07	.07	.00	17.	1.01	22.45	273	.02	.02	.00	5.
1.01	10.20	124	.07	.07	.00	17.	1.01	22.50	274	.02	.02	.00	5.
1.01	10.25	125	.07	.07	.00	17.	1.01	22.55	275	.02	.02	.00	5.
1.01	10.30	126	.07	.07	.00	17.	1.01	23.00	276	.02	.02	.00	5.
1.01	10.35	127	.07	.07	.00	17.	1.01	23.05	277	.02	.02	.00	5.
1.01	10.40	128	.07	.07	.00	17.	1.01	23.10	278	.02	.02	.00	5.
1.01	10.45	129	.07	.07	.00	17.	1.01	23.15	279	.02	.02	.00	5.
1.01	10.50	130	.07	.07	.00	17.	1.01	23.20	280	.02	.02	.00	5.
1.01	10.55	131	.07	.07	.00	17.	1.01	23.25	281	.02	.02	.00	5.
1.01	11.00	132	.07	.07	.00	17.	1.01	23.30	282	.02	.02	.00	5.
1.01	11.05	133	.07	.07	.00	17.	1.01	23.35	283	.02	.02	.00	5.
1.01	11.10	134	.07	.07	.00	17.	1.01	23.40	284	.02	.02	.00	5.
1.01	11.15	135	.07	.07	.00	17.	1.01	23.45	285	.02	.02	.00	5.
1.01	11.20	136	.07	.07	.00	17.	1.01	23.50	286	.02	.02	.00	5.
1.01	11.25	137	.07	.07	.00	17.	1.01	23.55	287	.02	.02	.00	5.
1.01	11.30	138	.07	.07	.00	17.	1.02	0.00	288	.02	.02	.00	5.
1.01	11.35	139	.07	.07	.00	17.	1.02	.05	289	0.00	0.00	0.00	1.
1.01	11.40	140	.07	.07	.00	17.	1.02	.10	290	0.00	0.00	0.00	0.
1.01	11.45	141	.07	.07	.00	17.	1.02	.15	291	0.00	0.00	0.00	0.
1.01	11.50	142	.07	.07	.00	17.	1.02	.20	292	0.00	0.00	0.00	0.
1.01	11.55	143	.07	.07	.00	17.	1.02	.25	293	0.00	0.00	0.00	0.
1.01	12.00	144	.07	.07	.00	17.	1.02	.30	294	0.00	0.00	0.00	0.
1.01	12.05	145	.21	.20	.00	43.	1.02	.35	295	0.00	0.00	0.00	0.
1.01	12.10	146	.21	.20	.00	50.	1.02	.40	296	0.00	0.00	0.00	0.
1.01	12.15	147	.21	.20	.00	52.	1.02	.45	297	0.00	0.00	0.00	0.
1.01	12.20	148	.21	.20	.00	52.	1.02	.50	298	0.00	0.00	0.00	0.
1.01	12.25	149	.21	.20	.00	52.	1.02	.55	299	0.00	0.00	0.00	0.
1.01	12.30	150	.21	.20	.00	52.	1.02	1.00	300	0.00	0.00	0.00	0.

SUM 32.24 31.22 1.02 7952.
(819.)(793.)(26.)(225.18)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	593.	87.	28.	27.	7974.
CMS	17.	2.	1.	1.	226.
INCHES		24.61	31.22	31.22	31.22
MM		625.17	792.97	792.97	792.97
AC-FT		43.	55.	55.	55.
THOUS CU M		53.	68.	68.	68.

HYDROGRAPH AT STA011173 FOR PLAN 1, RTIO 1

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	3.	3.	3.
3.	3.	10.	13.	14.	14.	14.	14.	15.	15.
15.	15.	15.	15.	16.	16.	16.	16.	16.	16.
16.	16.	16.	16.	16.	16.	16.	16.	17.	17.

17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
17.	17.	17.	17.	43.	50.	52.	52.	52.	52.
52.	52.	52.	52.	62.	62.	60.	62.	63.	63.
63.	63.	63.	63.	63.	63.	63.	63.	75.	78.
79.	79.	79.	79.	79.	79.	79.	79.	79.	79.
56.	85.	94.	131.	160.	385.	593.	354.	211.	158.
110.	99.	80.	75.	74.	74.	74.	74.	74.	74.
74.	74.	74.	74.	62.	59.	58.	58.	58.	58.
58.	58.	58.	58.	58.	58.	19.	8.	6.	5.
5.	5.	5.	5.	5.	5.	5.	5.	5.	5.
5.	5.	6.	6.	5.	5.	5.	5.	5.	5.
5.	5.	5.	5.	5.	5.	5.	5.	5.	5.
5.	5.	5.	5.	5.	5.	5.	5.	5.	5.
5.	5.	5.	5.	5.	5.	5.	5.	5.	5.
5.	5.	5.	5.	5.	5.	5.	5.	5.	5.
5.	5.	5.	5.	5.	5.	5.	5.	1.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	593.	87.	28.	27.	7974.
CMS	17.	2.	1.	1.	226.
INCHES		24.61	31.22	31.22	31.22
MM		625.17	792.97	792.97	792.97
AC-FT		43.	55.	55.	55.
THOUS CU M		53.	68.	68.	68.

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTE HYDROGRAPH THROUGH MOORES LAKE DAM (MO 11173)

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
011173	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP		LSTR
0.0	0.000	0.00	1	1	0	0		0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
0	0	0	0.000	0.000	0.000	-770.	-1

STAGE	769.00	769.83	771.00	772.00	773.00	773.30	773.60	774.00	774.30	774.60
	775.00	775.30	775.60	776.00						
FLOW	0.00	2.00	3.00	3.00	4.00	49.00	167.00	405.00	674.00	1005.00
	1546.00	2021.00	2557.00	3368.00						

SURFACE AREA=	0.	7.	7.	9.	11.
CAPACITY=	0.	15.	22.	45.	113.
ELEVATION=	762.	769.	770.	773.	780.

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

RATIOS APPLIED TO FLOWS

OPERATION	STATION	AREA	PLAN	RATIO 1 1.00
HYDROGRAPH AT	011173	.03 (.09)	1	593. (16.79)(
ROUTED TO	011173	.03 (.09)	1	282. (8.00)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	770.00	769.00	773.00
STORAGE	22.	15.	45.
OUTFLOW	2.	0.	4.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	773.80	.80	58.	282.	9.00	15.75	0.00

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
  LAST MODIFICATION  26 FEB 79
**********************************
      1             A1     DAM SAFETY INSPECTION MISSOURI
      2             A2     MOORES LAKE DAM (MO 11173)
      3             A3     50 PERCENT PMF
      4             B    300       0       5       0       0       0       0       0       0       0
      5             B1     5
      6             J1     1       1       1
      7             J1    .5
      8             K        MO11173                                         1
      9             K1     INPUT PRECIPITATION INDEX, RATIOS, AND UNIT HYDROGRAPH PARAMETERS
     10             M      1       2    .033            .033       1                        1
     11             P           24.8     100     120     130
     12             T                                                       -1     -92
     13             W2           .03
     14             X                      1
     15             K      1 MO11173                                         1
     16             K1     ROUTE HYDROGRAPH THROUGH MOORES LAKE DAM (MO 11173)
     17             Y                              1       1
     18             Y1                                                  -769.2      -1
     19             Y4   769  769.83     771     772     773   773.3   773.6     774   774.3   774.6
     20             Y4   775   775.3   775.6     776
     21             Y5     0       2       3       3       4      49     157     405     674    1005
     22             Y5  1546    2021    2557    3365
     23             $A     0     6.5       7     8.5      11
     24             $E   752     769     770     773     780
     25             $$   769
     26             $D   773
     27             K     99
```

B-19

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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
**********************************

RUN  DATE= 80/07/30.
     TIME= 14.42.56.

                    DAM SAFETY INSPECTION MISSOURI
                    MOORES LAKE DAM (MO 11173)
                    50 PERCENT PMF

                                  JOB SPECIFICATION
          NQ     NHR    NMIN    IDAY     IHR    IMIN   METRC    IPLT    IPRT   NSTAN
         300       0       5       0       0       0       0       0       0       0
                                 JOPER     NWT   LROPT   TRACE
                                     5       0       0       0

                          MULTI-PLAN ANALYSES TO BE PERFORMED
                               NPLAN= 1 NRTIO= 1 LRTIO= 1
                 RTIOS=    .50

      **********         **********         **********         **********         **********

                              SUB-AREA RUNOFF COMPUTATION

                  INPUT PRECIPITATION INDEX, RATIOS, AND UNIT HYDROGRAPH PARAMETERS

                      ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                     011173       0       0       0       0       0       1       0       0

                                     HYDROGRAPH DATA
               IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
                   1       2     .03    0.00     .03    1.00   0.000       0       1       0

                                       PRECIP DATA
                     SPFE     PMS      R6     R12     R24     R48     R72     R96
                     0.00   24.80  100.00  120.00  130.00    0.00    0.00    0.00

                                        LOSS DATA
         LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
             0    0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -92.00    0.00    0.00

                CURVE NO =  -92.00  WETNESS =  -1.00  EFFECT CN =   92.00

                                  UNIT HYDROGRAPH DATA
                             TC=   0.00    LAG=    .03

                                      RECESSION DATA
                      STRTQ=     0.00   QRCSN=     0.00   RTIOR= 1.00

                TIME INCREMENT TOO LARGE--(NHQ IS GT LAG/2)

                UNIT HYDROGRAPH  5 END-OF-PERIOD ORDINATES, TC=     0.00 HOURS, LAG=    .03  VOL= 1.00
```

190. 55. 10. 2. 0.

0

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	0.00	.01	0.	1.01	12.35	151	.21	.20	.00	52.
1.01	.10	2	.01	0.00	.01	0.	1.01	12.40	152	.21	.20	.00	52.
1.01	.15	3	.01	0.00	.01	0.	1.01	12.45	153	.21	.20	.00	52.
1.01	.20	4	.01	0.00	.01	0.	1.01	12.50	154	.21	.20	.00	52.
1.01	.25	5	.01	0.00	.01	0.	1.01	12.55	155	.21	.20	.00	52.
1.01	.30	6	.01	0.00	.01	0.	1.01	13.00	156	.21	.20	.00	52.
1.01	.35	7	.01	0.00	.01	0.	1.01	13.05	157	.25	.25	.00	60.
1.01	.40	8	.01	0.00	.01	0.	1.01	13.10	158	.25	.25	.00	62.
1.01	.45	9	.01	0.00	.01	0.	1.01	13.15	159	.25	.25	.00	63.
1.01	.50	10	.01	0.00	.01	0.	1.01	13.20	160	.25	.25	.00	63.
1.01	.55	11	.01	0.00	.01	0.	1.01	13.25	161	.25	.25	.00	63.
1.01	1.00	12	.01	0.00	.01	0.	1.01	13.30	162	.25	.25	.00	63.
1.01	1.05	13	.01	.00	.01	0.	1.01	13.35	163	.25	.25	.00	63.
1.01	1.10	14	.01	.00	.01	0.	1.01	13.40	164	.25	.25	.00	63.
1.01	1.15	15	.01	.00	.01	0.	1.01	13.45	165	.25	.25	.00	63.
1.01	1.20	16	.01	.00	.01	0.	1.01	13.50	166	.25	.25	.00	63.
1.01	1.25	17	.01	.00	.01	0.	1.01	13.55	167	.25	.25	.00	63.
1.01	1.30	18	.01	.00	.01	0.	1.01	14.00	168	.25	.25	.00	63.
1.01	1.35	19	.01	.00	.01	1.	1.01	14.05	169	.31	.31	.00	75.
1.01	1.40	20	.01	.00	.01	1.	1.01	14.10	170	.31	.31	.00	78.
1.01	1.45	21	.01	.00	.01	1.	1.01	14.15	171	.31	.31	.00	79.
1.01	1.50	22	.01	.00	.01	1.	1.01	14.20	172	.31	.31	.00	79.
1.01	1.55	23	.01	.00	.01	1.	1.01	14.25	173	.31	.31	.00	79.
1.01	2.00	24	.01	.00	.01	1.	1.01	14.30	174	.31	.31	.00	79.
1.01	2.05	25	.01	.00	.01	1.	1.01	14.35	175	.31	.31	.00	79.
1.01	2.10	26	.01	.00	.01	1.	1.01	14.40	176	.31	.31	.00	79.
1.01	2.15	27	.01	.00	.01	1.	1.01	14.45	177	.31	.31	.00	79.
1.01	2.20	28	.01	.00	.01	1.	1.01	14.50	178	.31	.31	.00	79.
1.01	2.25	29	.01	.00	.01	1.	1.01	14.55	179	.31	.31	.00	79.
1.01	2.30	30	.01	.01	.01	1.	1.01	15.00	180	.31	.31	.00	79.
1.01	2.35	31	.01	.01	.01	1.	1.01	15.05	181	.19	.19	.00	56.
1.01	2.40	32	.01	.01	.01	1.	1.01	15.10	182	.38	.38	.00	85.
1.01	2.45	33	.01	.01	.01	1.	1.01	15.15	183	.38	.38	.00	94.
1.01	2.50	34	.01	.01	.01	2.	1.01	15.20	184	.57	.56	.00	131.
1.01	2.55	35	.01	.01	.01	2.	1.01	15.25	185	.66	.66	.00	160.
1.01	3.00	36	.01	.01	.01	2.	1.01	15.30	186	1.60	1.60	.00	345.
1.01	3.05	37	.01	.01	.01	2.	1.01	15.35	187	2.64	2.63	.00	593.
1.01	3.10	38	.01	.01	.01	2.	1.01	15.40	188	1.04	1.04	.00	354.
1.01	3.15	39	.01	.01	.01	2.	1.01	15.45	189	.66	.66	.00	211.
1.01	3.20	40	.01	.01	.01	2.	1.01	15.50	190	.57	.56	.00	158.
1.01	3.25	41	.01	.01	.01	2.	1.01	15.55	191	.38	.38	.00	110.
1.01	3.30	42	.01	.01	.01	2.	1.01	16.00	192	.38	.38	.00	99.
1.01	3.35	43	.01	.01	.01	2.	1.01	16.05	193	.29	.29	.00	80.
1.01	3.40	44	.01	.01	.01	2.	1.01	16.10	194	.29	.29	.00	75.
1.01	3.45	45	.01	.01	.01	2.	1.01	16.15	195	.29	.29	.00	74.
1.01	3.50	46	.01	.01	.01	2.	1.01	16.20	196	.29	.29	.00	74.
1.01	3.55	47	.01	.01	.01	2.	1.01	16.25	197	.29	.29	.00	74.
1.01	4.00	48	.01	.01	.01	2.	1.01	16.30	198	.29	.29	.00	74.
1.01	4.05	49	.01	.01	.01	2.	1.01	16.35	199	.29	.29	.00	74.
1.01	4.10	50	.01	.01	.01	2.	1.01	16.40	200	.29	.29	.00	74.
1.01	4.15	51	.01	.01	.01	2.	1.01	16.45	201	.29	.29	.00	74.
1.01	4.20	52	.01	.01	.01	2.	1.01	16.50	202	.29	.29	.00	74.
1.01	4.25	53	.01	.01	.01	2.	1.01	16.55	203	.29	.29	.00	74.
1.01	4.30	54	.01	.01	.01	2.	1.01	17.00	204	.29	.29	.00	74.
1.01	4.35	55	.01	.01	.00	2.	1.01	17.05	205	.23	.23	.00	62.

1.01	4.40	56	.01	.01	.00	2.	1.01	17.10	206	.23	.23	.00	59.
1.01	4.45	57	.01	.01	.00	2.	1.01	17.15	207	.23	.23	.00	58.
1.01	4.50	58	.01	.01	.00	2.	1.01	17.20	208	.23	.23	.00	58.
1.01	4.55	59	.01	.01	.00	2.	1.01	17.25	209	.23	.23	.00	58.
1.01	5.00	60	.01	.01	.00	2.	1.01	17.30	210	.23	.23	.00	58.
1.01	5.05	61	.01	.01	.00	2.	1.01	17.35	211	.23	.23	.00	58.
1.01	5.10	62	.01	.01	.00	2.	1.01	17.40	212	.23	.23	.00	58.
1.01	5.15	63	.01	.01	.00	2.	1.01	17.45	213	.23	.23	.00	58.
1.01	5.20	64	.01	.01	.00	2.	1.01	17.50	214	.23	.23	.00	58.
1.01	5.25	65	.01	.01	.00	2.	1.01	17.55	215	.23	.23	.00	58.
1.01	5.30	66	.01	.01	.00	2.	1.01	18.00	216	.23	.23	.00	58.
1.01	5.35	67	.01	.01	.00	2.	1.01	18.05	217	.02	.02	.00	19.
1.01	5.40	68	.01	.01	.00	3.	1.01	18.10	218	.02	.02	.00	8.
1.01	5.45	69	.01	.01	.00	3.	1.01	18.15	219	.02	.02	.00	6.
1.01	5.50	70	.01	.01	.00	3.	1.01	18.20	220	.02	.02	.00	5.
1.01	5.55	71	.01	.01	.00	3.	1.01	18.25	221	.02	.02	.00	5.
1.01	6.00	72	.01	.01	.00	3.	1.01	18.30	222	.02	.02	.00	5.
1.01	6.05	73	.07	.05	.02	10.	1.01	18.35	223	.02	.02	.00	5.
1.01	6.10	74	.07	.05	.02	13.	1.01	18.40	224	.02	.02	.00	5.
1.01	6.15	75	.07	.05	.02	14.	1.01	18.45	225	.02	.02	.00	5.
1.01	6.20	76	.07	.05	.01	14.	1.01	18.50	226	.02	.02	.00	5.
1.01	6.25	77	.07	.06	.01	14.	1.01	18.55	227	.02	.02	.00	5.
1.01	6.30	78	.07	.06	.01	14.	1.01	19.00	228	.02	.02	.00	5.
1.01	6.35	79	.07	.06	.01	15.	1.01	19.05	229	.02	.02	.00	5.
1.01	6.40	80	.07	.06	.01	15.	1.01	19.10	230	.02	.02	.00	5.
1.01	6.45	81	.07	.06	.01	15.	1.01	19.15	231	.02	.02	.00	5.
1.01	6.50	82	.07	.06	.01	15.	1.01	19.20	232	.02	.02	.00	5.
1.01	6.55	83	.07	.06	.01	15.	1.01	19.25	233	.02	.02	.00	5.
1.01	7.00	84	.07	.06	.01	15.	1.01	19.30	234	.02	.02	.00	5.
1.01	7.05	85	.07	.06	.01	16.	1.01	19.35	235	.02	.02	.00	5.
1.01	7.10	86	.07	.06	.01	16.	1.01	19.40	236	.02	.02	.00	5.
1.01	7.15	87	.07	.06	.01	16.	1.01	19.45	237	.02	.02	.00	5.
1.01	7.20	88	.07	.06	.01	16.	1.01	19.50	238	.02	.02	.00	5.
1.01	7.25	89	.07	.06	.01	16.	1.01	19.55	239	.02	.02	.00	5.
1.01	7.30	90	.07	.06	.01	16.	1.01	20.00	240	.02	.02	.00	5.
1.01	7.35	91	.07	.06	.01	16.	1.01	20.05	241	.02	.02	.00	5.
1.01	7.40	92	.07	.06	.01	16.	1.01	20.10	242	.02	.02	.00	5.
1.01	7.45	93	.07	.06	.01	16.	1.01	20.15	243	.02	.02	.00	5.
1.01	7.50	94	.07	.06	.01	16.	1.01	20.20	244	.02	.02	.00	5.
1.01	7.55	95	.07	.06	.00	16.	1.01	20.25	245	.02	.02	.00	5.
1.01	8.00	96	.07	.06	.00	16.	1.01	20.30	246	.02	.02	.00	5.
1.01	8.05	97	.07	.06	.00	16.	1.01	20.35	247	.02	.02	.00	5.
1.01	8.10	98	.07	.06	.00	16.	1.01	20.40	248	.02	.02	.00	5.
1.01	8.15	99	.07	.06	.00	17.	1.01	20.45	249	.02	.02	.00	5.
1.01	8.20	100	.07	.06	.00	17.	1.01	20.50	250	.02	.02	.00	5.
1.01	8.25	101	.07	.06	.00	17.	1.01	20.55	251	.02	.02	.00	5.
1.01	8.30	102	.07	.07	.00	17.	1.01	21.00	252	.02	.02	.00	5.
1.01	8.35	103	.07	.07	.00	17.	1.01	21.05	253	.02	.02	.00	5.
1.01	8.40	104	.07	.07	.00	17.	1.01	21.10	254	.02	.02	.00	5.
1.01	8.45	105	.07	.07	.00	17.	1.01	21.15	255	.02	.02	.00	5.
1.01	8.50	106	.07	.07	.00	17.	1.01	21.20	256	.02	.02	.00	5.
1.01	8.55	107	.07	.07	.00	17.	1.01	21.25	257	.02	.02	.00	5.
1.01	9.00	108	.07	.07	.00	17.	1.01	21.30	258	.02	.02	.00	5.
1.01	9.05	109	.07	.07	.00	17.	1.01	21.35	259	.02	.02	.00	5.
1.01	9.10	110	.07	.07	.00	17.	1.01	21.40	260	.02	.02	.00	5.
1.01	9.15	111	.07	.07	.00	17.	1.01	21.45	261	.02	.02	.00	5.
1.01	9.20	112	.07	.07	.00	17.	1.01	21.50	262	.02	.02	.00	5.
1.01	9.25	113	.07	.07	.00	17.	1.01	21.55	263	.02	.02	.00	5.
1.01	9.30	114	.07	.07	.00	17.	1.01	22.00	264	.02	.02	.00	5.
1.01	9.35	115	.07	.07	.00	17.	1.01	22.05	265	.02	.02	.00	5.

1.01	9.40	116	.07	.07	.00	17.	1.01	22.10	266	.02	.02	.00	5.
1.01	9.45	117	.07	.07	.00	17.	1.01	22.15	267	.02	.02	.00	5.
1.01	9.50	118	.07	.07	.00	17.	1.01	22.20	268	.02	.02	.00	5.
1.01	9.55	119	.07	.07	.00	17.	1.01	22.25	269	.02	.02	.00	5.
1.01	10.00	120	.07	.07	.00	17.	1.01	22.30	270	.02	.02	.00	5.
1.01	10.05	121	.07	.07	.00	17.	1.01	22.35	271	.02	.02	.00	5.
1.01	10.10	122	.07	.07	.00	17.	1.01	22.40	272	.02	.02	.00	5.
1.01	10.15	123	.07	.07	.00	17.	1.01	22.45	273	.02	.02	.00	5.
1.01	10.20	124	.07	.07	.00	17.	1.01	22.50	274	.02	.02	.00	5.
1.01	10.25	125	.07	.07	.00	17.	1.01	22.55	275	.02	.02	.00	5.
1.01	10.30	126	.07	.07	.00	17.	1.01	23.00	276	.02	.02	.00	5.
1.01	10.35	127	.07	.07	.00	17.	1.01	23.05	277	.02	.02	.00	5.
1.01	10.40	128	.07	.07	.00	17.	1.01	23.10	278	.02	.02	.00	5.
1.01	10.45	129	.07	.07	.00	17.	1.01	23.15	279	.02	.02	.00	5.
1.01	10.50	130	.07	.07	.00	17.	1.01	23.20	280	.02	.02	.00	5.
1.01	10.55	131	.07	.07	.00	17.	1.01	23.25	281	.02	.02	.00	5.
1.01	11.00	132	.07	.07	.00	17.	1.01	23.30	282	.02	.02	.00	5.
1.01	11.05	133	.07	.07	.00	17.	1.01	23.35	283	.02	.02	.00	5.
1.01	11.10	134	.07	.07	.00	17.	1.01	23.40	284	.02	.02	.00	5.
1.01	11.15	135	.07	.07	.00	17.	1.01	23.45	285	.02	.02	.00	5.
1.01	11.20	136	.07	.07	.00	17.	1.01	23.50	286	.02	.02	.00	5.
1.01	11.25	137	.07	.07	.00	17.	1.01	23.55	287	.02	.02	.00	5.
1.01	11.30	138	.07	.07	.00	17.	1.02	0.00	288	.02	.02	.00	5.
1.01	11.35	139	.07	.07	.00	17.	1.02	.05	289	0.00	0.00	0.00	0.
1.01	11.40	140	.07	.07	.00	17.	1.02	.10	290	0.00	0.00	0.00	0.
1.01	11.45	141	.07	.07	.00	17.	1.02	.15	291	0.00	0.00	0.00	0.
1.01	11.50	142	.07	.07	.00	17.	1.02	.20	292	0.00	0.00	0.00	0.
1.01	11.55	143	.07	.07	.00	17.	1.02	.25	293	0.00	0.00	0.00	0.
1.01	12.00	144	.07	.07	.00	17.	1.02	.30	294	0.00	0.00	0.00	0.
1.01	12.05	145	.21	.20	.00	43.	1.02	.35	295	0.00	0.00	0.00	0.
1.01	12.10	146	.21	.20	.00	50.	1.02	.40	296	0.00	0.00	0.00	0.
1.01	12.15	147	.21	.20	.00	52.	1.02	.45	297	0.00	0.00	0.00	0.
1.01	12.20	148	.21	.20	.00	52.	1.02	.50	298	0.00	0.00	0.00	0.
1.01	12.25	149	.21	.20	.00	52.	1.02	.55	299	0.00	0.00	0.00	0.
1.01	12.30	150	.21	.20	.00	52.	1.02	1.00	300	0.00	0.00	0.00	0.

SUM 32.24 31.22 1.02 7952.
(819.)(793.)(26.)(225.18)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	593.	87.	28.	27.	7974.
CMS	17.	2.	1.	1.	226.
INCHES		24.61	31.22	31.22	31.22
MM		625.17	792.97	792.97	792.97
AC-FT		43.	55.	55.	55.
THOUS CU M		53.	68.	68.	68.

HYDROGRAPH AT STA011173 FOR PLAN 1, RTIO 1

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	5.	6.	7.	7.	7.	7.	7.	7.
7.	8.	8.	8.	8.	8.	8.	8.	8.	8.
8.	8.	8.	8.	8.	8.	8.	8.	8.	8.

8.	8.	8.	8.	8.	8.	8.	8.	8.	8.
8.	8.	8.	8.	8.	8.	8.	9.	9.	9.
9.	9.	9.	9.	9.	9.	9.	9.	9.	9.
9.	9.	9.	9.	9.	9.	9.	9.	9.	9.
9.	9.	9.	9.	22.	26.	26.	26.	26.	26.
26.	26.	26.	26.	26.	26.	30.	31.	31.	31.
31.	31.	31.	31.	31.	31.	31.	32.	37.	39.
39.	39.	39.	39.	39.	39.	39.	39.	39.	39.
28.	43.	47.	56.	80.	172.	296.	177.	105.	79.
55.	49.	60.	37.	37.	37.	37.	37.	37.	37.
37.	37.	37.	37.	31.	29.	29.	29.	29.	29.
29.	29.	29.	29.	29.	29.	9.	9.	3.	3.
13.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	1.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	296.	44.	14.	13.	3987.
CMS	8.	1.	0.	0.	113.
INCHES		12.31	15.61	15.61	15.61
MM		312.58	396.49	396.49	396.49
AC-FT		22.	27.	27.	27.
THOUS CU M		27.	34.	34.	34.

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTE HYDROGRAPH THROUGH MOORES LAKE DAM (MO 11173)

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
011173	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP		LSTR
0.0	0.000	0.00	1	1	0	0		0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	-769.	-1

STAGE	769.00	769.83	771.00	772.00	773.00	773.30	773.60	774.00	774.30	774.60
	775.00	775.30	775.60	776.00						
FLOW	0.00	2.00	3.00	3.00	4.00	49.00	157.00	405.00	674.00	1005.00
	1546.00	2021.00	2557.00	3368.00						

SURFACE AREA=	0.	7.	7.	9.	11.
CAPACITY=	0.	15.	22.	45.	113.
ELEVATION=	762.	769.	770.	773.	780.

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS

FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)

AREA IN SQUARE MILES (SQUARE KILOMETERS)

RATIOS APPLIED TO FLOWS

OPERATION	STATION	AREA	PLAN	RATIO 1 .50
HYDROGRAPH AT	D11173	.03 (.09)	1	296. (8.39)(
ROUTED TO	D11173	.03 (.09)	1	3. (.10)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	769.20	769.00	773.00
STORAGE	16.	15.	45.
OUTFLOW	0.	0.	4.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.50	772.44	0.00	40.	3.	0.00	18.17	0.00

```
*************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
  LAST MODIFICATION  26 FEB 79
*************************************

RUN  DATE* 80/07/30.
     TIME* 15.05.56.

                    DAM SAFETY INSPECTION MISSOURI
                    MOORES LAKE DAM (MO 11173)
                    PERCENT PMF

                                        JOB SPECIFICATION
          NQ     NHR    NMIN    IDAY     IHR    IMIN  METRC    IPLT    IPRT  NSTAN
         300       0       5       0       0       0      0       0      -4      0
                                 JOPER     NWT   LROPT  TRACE
                                     5       0       0      0

                              MULTI-PLAN ANALYSES TO BE PERFORMED
                                NPLAN= 1 NRTIO= 6 LRTIO= 1
                RTIOS=   .35     .40    .45    .50    .55    .60

      **********        **********        **********        **********        **********

                              SUB-AREA RUNOFF COMPUTATION

                  INPUT PRECIPITATION INDEX, RATIOS, AND UNIT HYDROGRAPH PARAMETERS

                        ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE  IAUTO
                       011173       0       0       0       0       0       1       0      0
                                          HYDROGRAPH DATA
          IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
              1       2     .03    0.00     .03    1.00   0.000       0       1       0
                                           PRECIP DATA
                   SPFE     PMS      R6     R12     R24     R48     R72     R96
                   0.00   24.80  100.00  120.00  130.00    0.00    0.00    0.00
                                            LOSS DATA
       LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
           0    0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -92.00    0.00    0.00

                  CURVE NO = -92.00  WETNESS =  -1.00  EFFECT CN =  92.00

                                       UNIT HYDROGRAPH DATA
                                    TC=  0.00    LAG=   .03

                                          RECESSION DATA
                           STRTQ=   0.00   QRCSN=   0.00   RTIOR= 1.00

                                        END-OF-PERIOD FLOW
          MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q    MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q
```

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                                                                   SUM   32.24  31.22   1.02    7952.
                                                                       ( 819.)( 793.)(  26.)( 225.18)

         **********        **********        **********        **********        **********

                                          HYDROGRAPH ROUTING

                     ROUTE HYDROGRAPH THROUGH MOORES LAKE DAM (MO 11173)
                             ISTAQ   ICOMP   IECON   ITAPE   JPLT    JPRT   INAME  ISTAGE  IAUTO
                            DI1173       1       0       0      0       0       1       0      0
                                              ROUTING DATA
                    QLOSS    CLOSS    AVG    IRES   ISAME    IOPT    IPMP           LSTR
                      0.0    0.000   0.00       1       1       0       0              0

                             NSTPS   NSTDL    LAG   AMSKK       X     TSK   STORA  ISPRAT
                                 0       0      0   0.000   0.000   0.000   -770.     -1

   STAGE      769.00     769.83     771.00     772.00     773.00     773.30     773.60     774.00     774.30     774.60
              775.00     775.30     775.60     776.00

    FLOW        0.00       2.00       3.00       3.00       4.00      49.00     157.00     405.00     674.00    1005.00
             1546.00    2021.00    2557.00    3365.00

 SURFACE AREA=      0.        7.        7.        9.       11.

     CAPACITY=      0.       15.       22.       45.      113.

    ELEVATION=    762.      769.      770.      773.      780.

                         CREL    SPWID    COQW    EXPW    ELEVL    COQL   CAREA    EXPL
                        769.0      0.0     0.0     0.0      0.0     0.0     0.0     0.0
                                                   DAM DATA
                                         TOPEL    COQD    EXPD   DAMWID
                                         773.0     0.0     0.0       0.

 PEAK OUTFLOW IS         3. AT TIME  15.50 HOURS

 PEAK OUTFLOW IS         3. AT TIME  18.17 HOURS

 PEAK OUTFLOW IS         9. AT TIME  18.17 HOURS

 PEAK OUTFLOW IS         4. AT TIME  18.17 HOURS

 PEAK OUTFLOW IS        21. AT TIME  18.00 HOURS

 PEAK OUTFLOW IS        32. AT TIME  18.00 HOURS
```

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO 1 .35	RATIO 2 .40	RATIO 3 .45	RATIO 4 .50	RATIO 5 .55	RATIO 6 .60
HYDROGRAPH AT	011173	.03 (.09)	1	207. (5.88)(	237. (6.72)(	267. (7.55)(	296. (8.39)(	326. (9.23)(	356. (10.07)(
ROUTED TO	011173	.03 (.09)	1	3. (.08)(	3. (.09)(	4. (.10)(	4. (.11)(	21. (.60)(	32. (.91)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

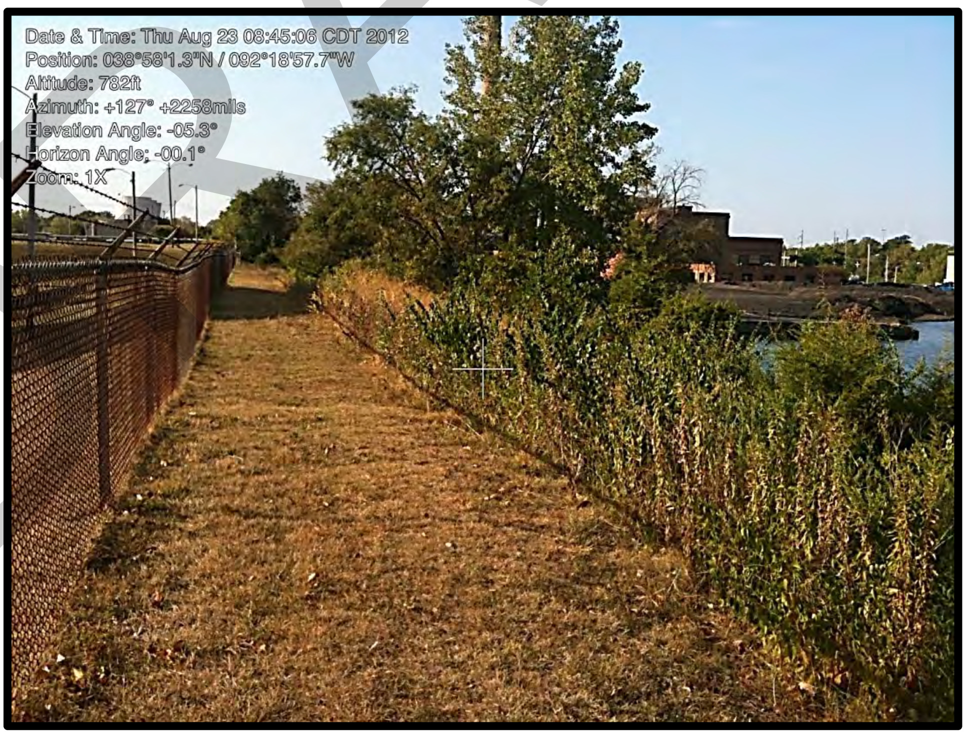
	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	770.00	769.00	773.00
STORAGE	22.	15.	45.
OUTFLOW	2.	0.	4.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.35	771.98	0.00	37.	3.	0.00	15.50	0.00
.40	772.29	0.00	39.	3.	0.00	18.17	0.00
.45	772.60	0.00	42.	4.	0.00	18.17	0.00
.50	772.90	0.00	44.	4.	0.00	18.17	0.00
.55	773.12	.12	46.	21.	2.75	18.00	0.00
.60	773.19	.19	47.	32.	4.00	18.00	0.00

Appendix D

Photographs

Photograph 5.1. Crest of Dam Looking Northeast



Photograph 5.2. Crest of East Embankment with Overgrown Vegetation and Tree on Inside Slope Looking South

Photograph 5.3. Gravel Road on Downstream Slope of Dam

Photograph 5.4. Crest of Dam Showing Shrinkage Cracks Looking North

Photograph 5.5. Animal Burrow on North Embankment

Photograph 5.6. North Embankment with Trees in Background Looking East

Photograph 5.7. Drying Coal Ash on South Embankment Looking Northwest

Photograph 5.8. Erosion Features on Inside Slope of West Embankment Looking North

Photograph 5.9. Erosion Feature on Inside Slope of South Embankment

Photograph 5.10. Riprap near Outfall Drain at Southwest Inside Slope

Photograph 5.11. Outside Slope of Dam (West Embankment) Looking North

Photograph 5.12. Outside Slope of Dam towards Equipment Storage Yard Looking Northwest

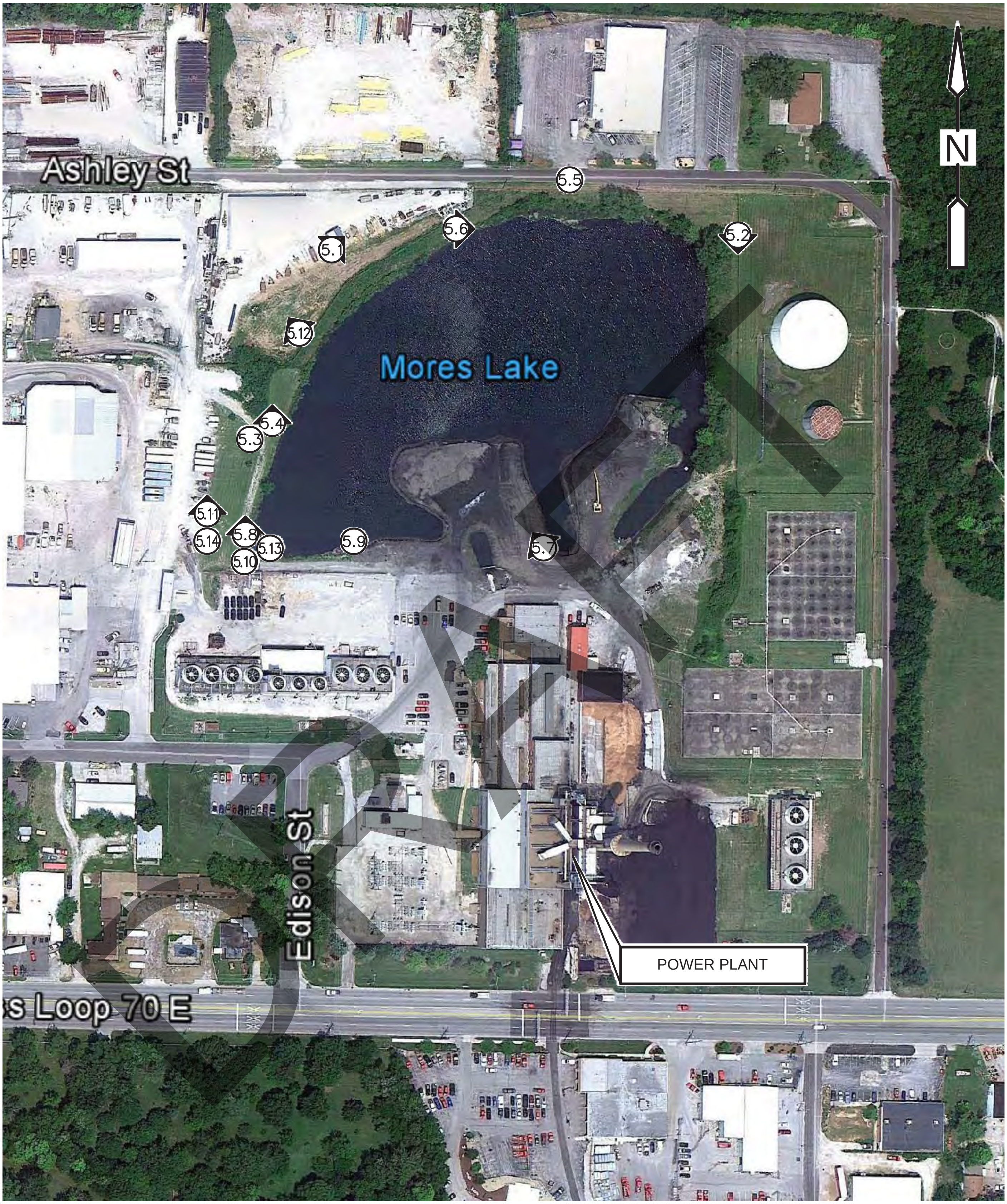
Photograph 5.13. Overflow Structure Southwest of CCW Impoundment

Photograph 5.14. Manholes for Overflow Structure on Exterior Slope of West Embankment Looking North

Appendix D
Photo GPS Locations

Site: Columbia Municipal Power Plant
Datum: NAD 1983
Coordinate Units: Decimal Degrees

Photograph	Latitude	Longitude
5.1	38.96697	-92.31811
5.2	38.96703	-92.31603
5.3	38.96625	-92.31847
5.4	38.96628	-92.31842
5.5	38.96725	-92.31689
5.6	38.96706	-92.31747
5.7	38.96578	-92.31703
5.8	38.96583	-92.31856
5.9	38.96581	-92.31800
5.10	38.96586	-92.31856
5.11	38.96592	-92.31875
5.12	38.96664	-92.31828
5.13	38.96583	-92.31847
5.14	38.96592	-92.31872



AERIAL PHOTOGRAPH SOURCE:
GOOGLE EARTH PRO.

LEGEND:

5.2 PHOTOGRAPH NUMBER AND ORIENTATION

SCALE: 1"= 200'

100 0 200

CDM Smith

COLUMBIA MUNICIPAL POWER PLANT
COLUMBIA, MISSOURI
PHOTOGRAPH LOCATIONS PLAN