ALLIANT ENERGY
Interstate Power and Light Company
Sutherland Generating Station

CCR SURFACE IMPOUNDMENT

STRUCTURAL STABILITY ASSESSMENT

Report Issued: March 05, 2018
Revision 0

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

EXECUTIVE SUMMARY

This Structural Stability Assessment (Report) is prepared in accordance with the requirements of the United States Environmental Protection Agency (USEPA) Hazardous and Solid Waste Management System – Disposal of Coal Combustion Residual from Electric Utilities (40 CFR Parts 257 and 261), also known as the CCR Rule.

This Report assesses the structural stability of each CCR unit at Sutherland Generating Station in Marshalltown, Iowa in accordance with §257.73(b), §257.73(d), and §257.100(a) of the CCR Rule. For purposes of this Report, "CCR unit" refers to an existing or inactive CCR surface impoundment.

Primarily, this Report is focused on documenting whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices for the maximum volume of CCR and CCR wastewater which can be impounded within each CCR unit.

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1 INTRODUCTION

The owner or operator of the Coal Combustion Residual (CCR) unit must conduct an initial and periodic structural stability assessments and document whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices for the maximum volume of CCR and CCR wastewater which can be impounded therein. This Report is prepared in accordance with the requirements of §257.73(b), §257.73(d), and §257.100(a) of the CCR Rule.

1.1 CCR Rule Applicability

The CCR Rule requires a periodic structural stability assessment by a qualified professional engineer (PE) for existing and inactive CCR surface impoundments with a height of 5 feet or more and a storage volume of 20 acre-feet or more; or the CCR surface impoundment has a height of 20 feet or more (§257.73(b) and §257.100(a)).

1.2 Structural Stability Assessment Applicability

The Sutherland Generating Station (SGS) in Marshalltown, Iowa (Figure 1 & Figure 2) has four inactive CCR surface impoundments, of which only one meets the CCR Rule applicability within Section 1.1. The CCR surface impoundment are identified as follows:

- SGS North Primary Pond
- SGS South Primary Pond
- SGS Main Pond
- SGS Polishing Pond

Only the SGS Main Pond meets the requirements of §257.73(b)(1) and/or §257.73(b)(2) and is subject to the structural stability assessment requirements of §257.73(d) and §257.100(a) of the CCR Rule. The SGS North Primary Pond, SGS South Primary Pond, and SGS Polishing Pond do not have an embankment height of 5 feet or more, and do not have a storage volume of 20 acre-feet or more. Thus, these ponds are not subject to the periodic safety factor assessment requirements.

2 FACILITY DESCRIPTION

SGS is located east of the City of Marshalltown and approximately one-half mile west of the Iowa River in Marshall County, at 3001 East Main Street, Marshalltown, Iowa.

SGS was a fossil-fueled electric generating station consisting of three steam turbine electric generating units and three combustion turbine units. SGS initiated operations in 1954. From 1954 to 2012 sub-bituminous coal was the primary fuel for producing steam. As of the end of 2012, SGS ceased using coal and modified facility operations in order to use natural gas as the primary fuel source. SGS ceased natural gas generation as of June 22, 2017 and retired. The external combustion turbines, located west of the main generating station, continue operations and are now associated with the nearby Marshalltown Generating Station.

When coal was the primary fuel for producing steam, a by-product of CCR was produced. The CCR at SGS is categorized into two types, bottom ash and precipitator fly ash.

The precipitator fly ash at SGS was collected by electrostatic precipitators and conveyed dry to a temporary on-site storage area. The precipitator fly ash was then transported off-site for beneficial reuse. If the dry conveying system malfunctioned, an emergency by-pass system would utilize water to sluice the precipitator fly ash from the generating plant to the CCR surface impoundments.

The bottom ash at SGS was sluiced from the generating plant to the CCR surface impoundments. Other influent flows that previously discharged into the CCR surface impoundments consisted of cooling tower blow down water, air compressor cooling water, boiler blow down water, storm water runoff from the former coal pile storage area, and other low-volume waste water streams from the generating plant via a basement sump pump.

General Facility Information:

State CCR Impoundment ID	64-UDP-02-15
Date of Initial Facility Operations	1954
NPDES Permit Number:	IA 6469103
Facility Title V Operating Permit:	98-TV-010R2
Latitude / Longitude:	42°2′51″N 92°51′35″W
Site Coordinates:	Section 32, Township 84 North, Range 17 West

2.1 SGS North Primary Pond and SGS South Primary Pond

The SGS North Primary Pond and SGS South Primary Pond, Figure 2, are located east of the generating plant and west of the SGS Main Pond. The two CCR surface impoundments are incised. The two CCR surface impoundments historically received sluiced bottom ash from the generating plant prior to SGS ceasing coal burning activities. The majority of the CCR that was sluiced from the generating plant settled out in the two primary CCR surface impoundments. The two primary CCR surface impoundments were dredged on a weekly basis with a long-reach excavator. The dredged CCR was stockpiled adjacent to the CCR surface impoundments for dewatering prior to transporting to a temporary stockpile area using a front-end loader. The CCR was then transported off-site for beneficial reuse or to a permitted landfill.

Process flows into the SGS North Primary Pond and SGS South Primary Pond ceased at the time of the facility retirement. The influent during rainfall events included surface water runoff from the former coal pile storage area that is pumped into the impoundments by the lift pumps, Figure 2. The water in the SGS South Primary Pond, in addition to discharging through the corrugated metal pipe, can overflow into a high-density polyethylene corrugated pipe, which discharges into the west end of the SGS Main Pond.

The SGS North Primary Pond and SGS South Primary Pond both have a surface area of approximately 0.25 acres each.

2.2 SGS Main Pond

The SGS Main Pond, Figure 2, is located east of the generating plant and east of the SGS North Primary Pond and SGS South Primary Pond. The SGS Main Pond receives influent flows from the SGS North Primary Pond and SGS South Primary Pond, as well as storm water runoff from the surrounding area. The SGS North Primary Pond discharges into the northwest corner of the SGS Main Pond, while the overflow pipe from the SGS South Primary Pond discharges into the west end of the SGS Main Pond.

The water within the SGS Main Pond flows around a series of intermediate berms to improve suspended solids settlement prior to discharging into the southern end of the SGS Polishing Pond, which is located north of the SGS Main Pond. The water in the SGS Main Pond discharges into the SGS Polishing Pond via a concrete mixing channel located in the northeast corner of the SGS Main Pond, Appendix B. Since SGS ceased coal burning activities, the water within the SGS Main Pond has receded below the invert elevation of the concrete mixing channel at 861.9 feet. Therefore, water no longer discharges into the SGS Polishing Pond during normal conditions.

The SGS Main Pond has a surface area of approximately 4.8 acres and has an embankment height of approximately 8 feet from the crest to the toe of the downstream slope. The top elevation of the embankment is elevation 865 feet. From the July 14, 2017 Annual Inspection Report, the total volume of impounded CCR and water within the SGS Main Pond is approximately 34,000 cubic yards.

2.3 SGS Polishing Pond

The SGS Polishing Pond, Figure 2, is located east of the generating plant and north of the SGS Main Pond. The SGS Polishing Pond receives influent flows from the SGS Main Pond, as well as storm water runoff from the surrounding area. The water in the SGS Main Pond discharges into the SGS Polishing Pond via a concrete mixing channel located in the northeast corner of the SGS Main Pond. Since SGS ceased coal burning activities the SGS Polishing Pond no longer receives normal inflow from the SGS Main Pond and the water elevation in the pond has receded well below the invert elevation of the influent concrete mixing channel. The water that previously discharged into the SGS Polishing Pond discharged through the facility's National Pollutant Discharge Elimination System (NPDES) Outfall 001, which consists of a Parshall flume and flow metering equipment, Figure 2. The invert elevation of the Parshall flume is 861.3 feet. The water that flows through NPDES Outfall 001 discharges into an outfall pond, which overflow drains towards the east into the Iowa River. The overflow drain is a 2-foot diameter corrugated steel riser pipe with a rim elevation at elevation 860.5 feet.

The SGS Polishing Pond has a surface area of approximately 1.2 acres. The storage volume of the CCR surface impoundment is negligible. The embankment on the east side of the CCR surface impoundment has a crest elevation of 865 feet and maximum height above outside grade of eight feet.

3 STRUCTURAL STABILITY ASSESSMENT- §257.73(d) and §257.100(a)

This Report documents whether the design, construction, operation, and maintenance of each CCR unit is consistent with recognized and generally accepted good engineering practices for maximum volume of CCR and CCR wastewater which can be impounded.

3.1 SGS Main Pond

The SGS Main Pond was constructed in 1954 using native clay from the area of the CCR surface impoundment. The SGS Main Pond originally included an area of approximately 15 acres which has since been filled or is part of the other smaller CCR surface impoundments discussed in Section 2.0. The native clay is Black Zook clay, Appendix B, classified as high plasticity clay (CH). Embankments with 2H to 1V side slopes, a crest width of 15 feet at elevation 865 were constructed by compacting the Zook clay removed from the interior of the original CCR surface impoundment. The soil stratigraphy below the Zook clay which ends at approximately elevation 850 feet is loose to medium dense sand to bedrock at approximately 250 feet below ground surface.

The embankments have remained unchanged since construction in 1954 with the exception of adding a thin base coarse road surface on top of the embankments. The depth of the SGS Main Pond has increased since construction, by the occasional dredging of CCR to maintain CCR surface impoundment capacity. The present SGS Main Pond has a soil bottom near the contact with the underlying sand at elevation 850, Appendix C.

Borings were installed through the embankment in March of 2006 and form the current understanding of embankment and foundation soils for the SGS Main Pond, Appendix C. The outfall structure for the SGS Main Pond is a concrete mixing channel, Appendix A. The concrete mixing channel discharges into the smaller SGS Polishing Pond.

3.1.1 CCR Unit Foundation and Abutments - §257.73(d)(1)(i) and §257.100(a)

The foundation soil is a very stiff high plasticity clay (CH) with an unconfined compressive strength of 2,000 to 4,000 pounds per square foot, Appendix D. The clay is underlain by a deposit of medium dense (SM) over rock at an elevation of approximately 600 feet. The foundation soils are adequate for the support of the approximately 8 foot high embankment with acceptable safety factors as shown in the SGS Safety Factor Assessment Report §257.73(b) and (e) and §257.100(a).

3.1.2 Slope Protection - §257.73(d)(1)(ii) and §257.100(a)

The impoundment is incised on the west side. The south and east sides have an embankment crest of approximately 15 feet wide and the downstream slope of the embankment is approximately a 2 horizontal to 1 vertical vegetated slope. The north side of the embankment abuts the SGS Polishing Pond.

Well established and managed vegetation will minimize surface erosion on both the upstream and downstream slopes. Additionally, storm water runoff is limited to the crest and downstream slope of the embankment, which limits the erosive force. Therefore, the CCR surface impoundment configuration protects against surface erosion. Additionally, erosion due to wave action will have minimal impacts to the embankments.

Sudden drawdown is addressed in Section 3.2.7.

3.1.3 CCR Embankment Density- §257.73(d)(1)(iii) and §257.100(a)

The embankment is constructed of compacted low plasticity clay. The borings shown in Appendix D indicate an unconfined compressive strength of 2,000 to 4,000 pounds per square foot where the embankment is saturated and higher strength where not saturated. The strength of the clay indicates that the clay was compacted at optimum moisture during construction of the embankments and that the density of the embankments are adequate. Analysis of the slope safety factor in the SGS Safety Factor Assessment Report §257.73(b) and (e) and §257.100(a) indicate the foundation soils or soil at the toe of the slope control the minimum safety factors for the slope.

3.1.4 Vegetation Management - §257.73(d)(1)(iv) and §257.100(a)

Historically vegetation management has been conducted on a periodic basis. Following the initial Annual Inspection in June 2017, the facility managed the vegetation to facilitate effective inspection. The facility plans to continue managing the vegetation on the embankments at a height that facilitates effective inspections.

3.1.5 Spillway Management - §257.73(d)(1)(v) and §257.100(a)

The SGS Main Pond discharges through a precast concrete mixing channel into the SGS Polishing Pond. The structure is constructed of non-erodible material and designed to carry sustained flows.

The mixing channel is checked for malfunction (e.g., blockages, deformations) during the 7-day inspections by the facility personnel.

This CCR surface impoundment currently has a hazard potential classification of "Low," which in turn requires an evaluation of the impacts of a 100-year rainfall event. The Inflow Flood Control Plan, which is a separate document developed to comply with §257.82 and §257.100(a), shows that the precipitation from this event will drain through the hydraulic structures without overtopping the embankments of the CCR surface impoundment.

3.1.6 Hydraulic Structures - §257.73(d)(1)(vi) and §257.100(a)

During the Annual Inspection in June 2017, the mixing channel structure showed minimal signs of deterioration, deformation, distortion, sedimentation, debris blockages, and no bedding deficiencies were observed.

3.1.7 Sudden Drawdown - §257.73(d)(1)(vii) and §257.100(a)

The toe of the embankment is flooded if the Iowa River backwater exceeds elevation 857 feet. In extreme floods of the Iowa River, flood waters may rise higher than the outlet structure elevations, and the CCR surface impoundment may be filled by the Iowa River flood water. The external flood water may drain quickly as the flood abates creating sudden drawdown conditions on the outside slope. No sudden drawdown would occur on the inside slope since the water below the outlet structure must either evaporate or exfiltrate from the SGS Main Pond.

The embankment and the foundation soils immediately below the embankment are high plasticity clay and there will be no sudden drawdown seepage pressure from the short-term impacts when floodwaters receding.

4 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

To meet the requirements of 40 CFR §257.73(d)(3) and §257.100(a), I Mark W. Loerop hereby certify that I am a licensed professional engineer in the State of Iowa; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in 40 CFR §257.73(b), §257.73(d), and §257.100(a).

By: [signature]

Name: MARK LOEROP

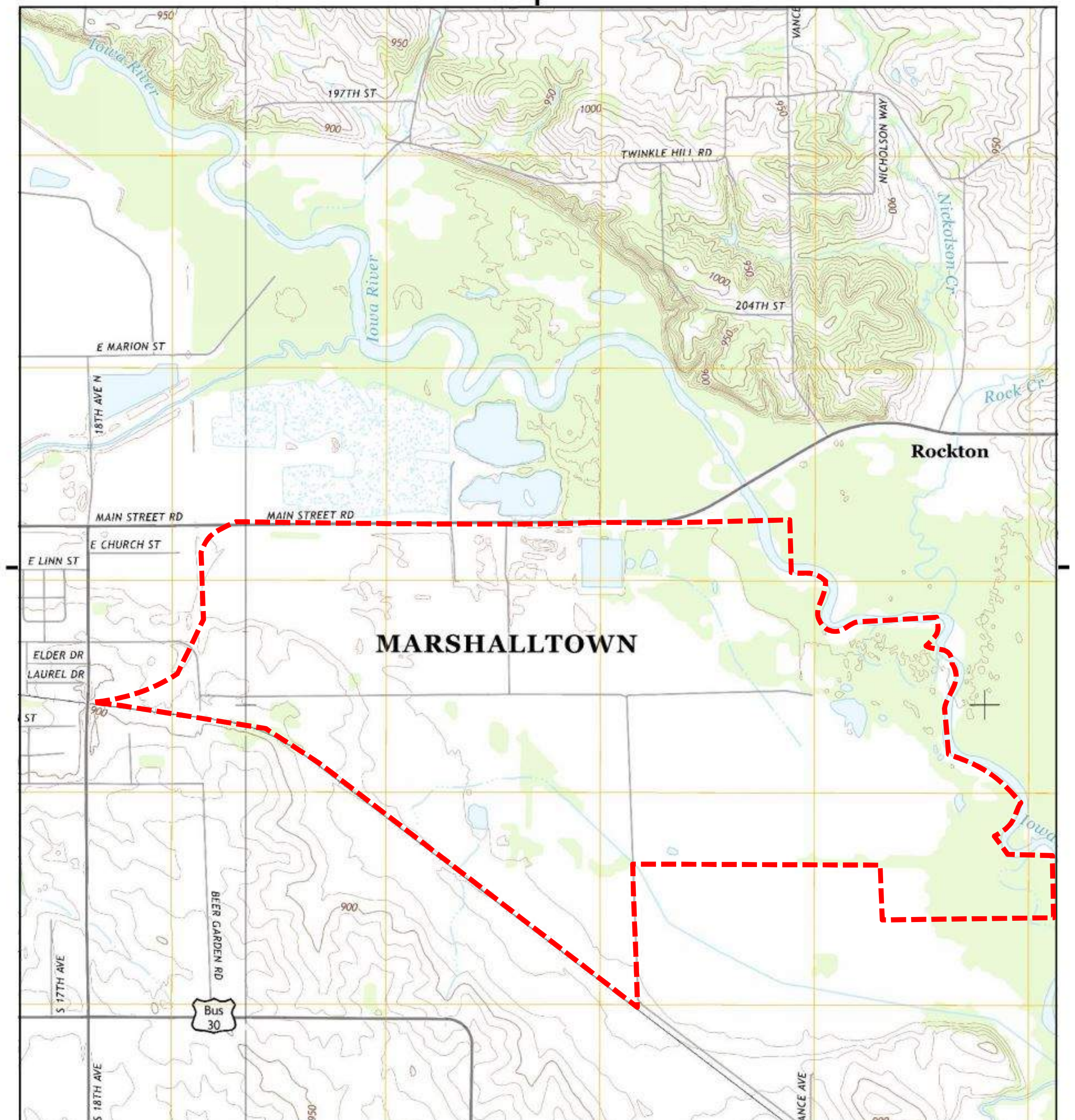
Date: MARCH 5, 2018

FIGURES

Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Structural Stability Assessment

Historical Topo Map



This report includes information from the following map sheet(s).

0 Miles 0.25 0.5 1 1.5

NW N NE W E SW S SE

TP, Le Grand, 2013, 7.5-minute
W, Marshalltown, 2013, 7.5-minute

SITE NAME: Sutherland Generating Station
ADDRESS: 3001 East Main Street Road
Marshalltown, IA 50158
CLIENT: Environmental Site Assessors

5087055 - 1 page 4

Historical Aerial Photo

Approximate Property Boundary

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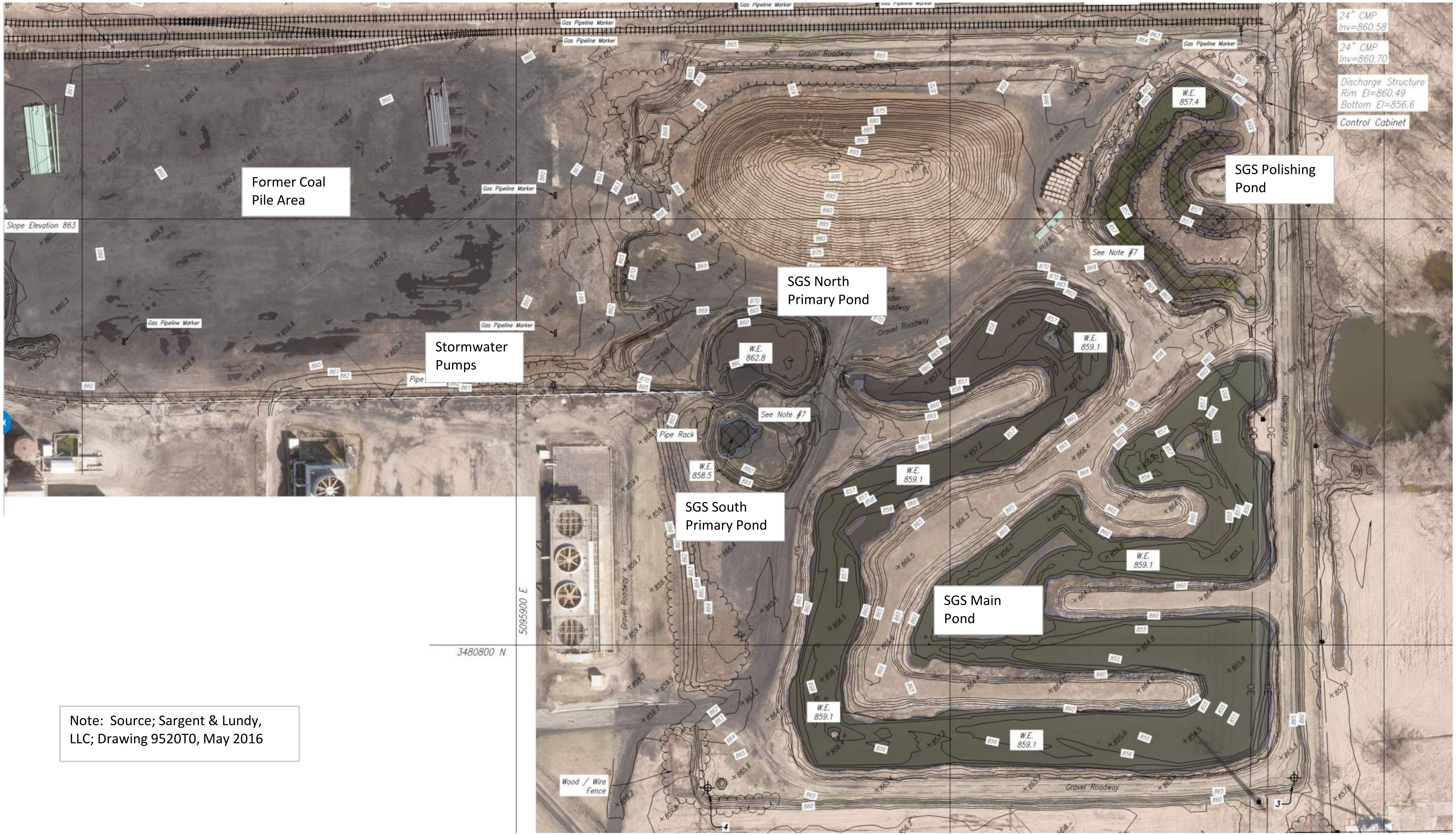
Site Location Sutherland Generating Station Interstate Power and Light Company	Drawing Figure 1
	Date 1/22/2018



Note: Source; Sargent & Lundy, LLC; Drawing 9520T0, May 2016

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CCR Impoundments
Sutherland Generating Station
Interstate Power and Light Company

Drawing: Figure 2

Date: 12/18/2017

APPENDIX A – SGS Main Pond Outlet Structure

Alliant Energy
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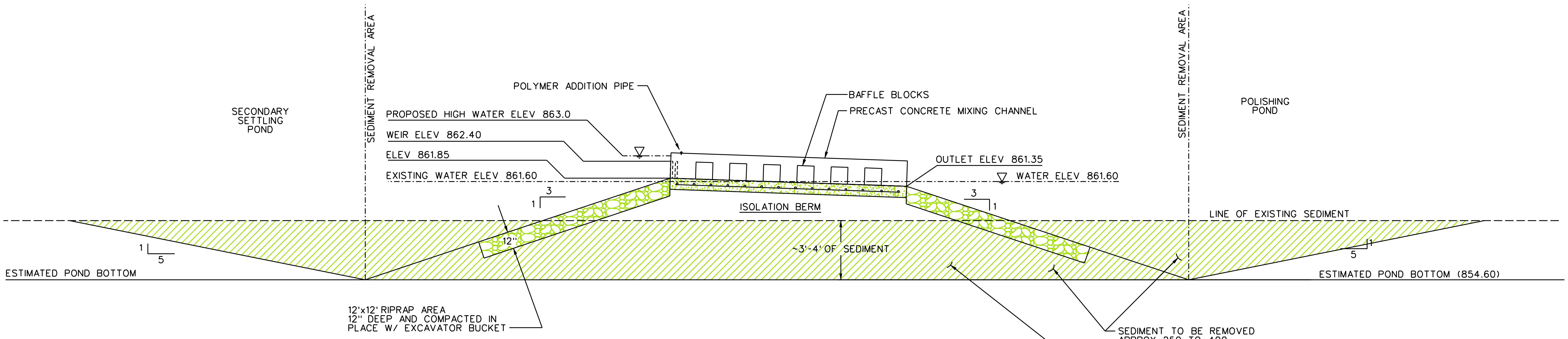
Sutherland Generating Station
Marshalltown, Iowa

Structural Stability Assessment



SECTION B/2

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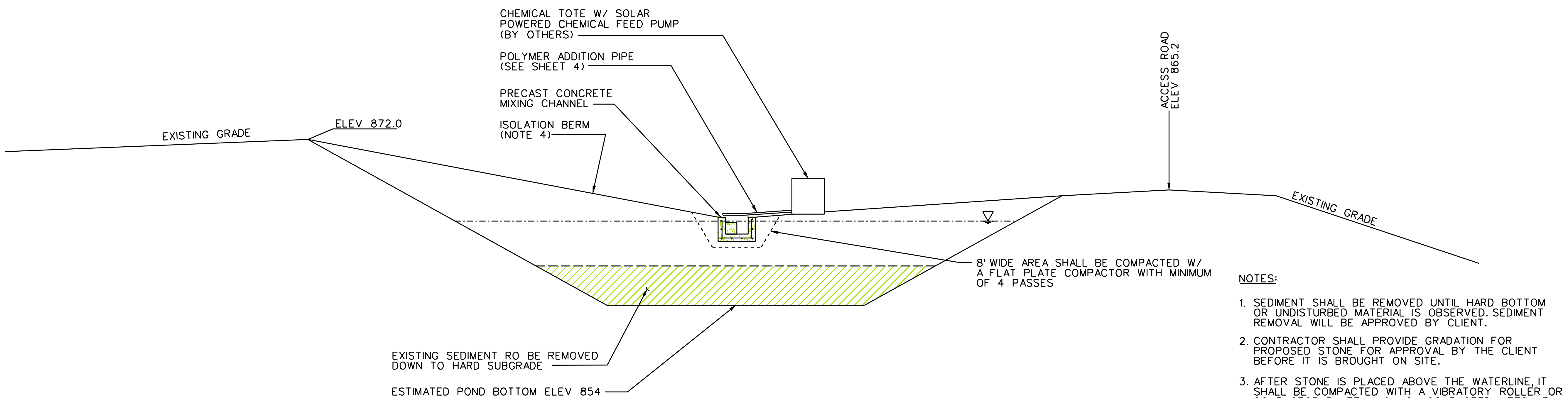
SCALE IN FEET



SECTION A/2

0 5 10
SCALE IN FEET

NOTES:

1. SEDIMENT SHALL BE REMOVED UNTIL HARD BOTTOM OR UNDISTURBED MATERIAL IS OBSERVED. SEDIMENT REMOVAL WILL BE APPROVED BY CLIENT.
2. CONTRACTOR SHALL PROVIDE GRADATION FOR PROPOSED STONE FOR APPROVAL BY THE CLIENT BEFORE IT IS BROUGHT ON SITE.
3. AFTER STONE IS PLACED ABOVE THE WATERLINE, IT SHALL BE COMPACTED WITH A VIBRATORY ROLLER OR COMPACTOR PLATE IN 6-INCH COMPACTED LIFTS AT NO LESS THAN 4 PASSES.
4. ISOLATION BERM TO BE CONSTRUCTED WITH IDOT SPEC 4120.04 OR 4120.05 GRANULAR STONE W/ FINES, EXCEPT FOR RIPRAP AT THE CHANNEL INLET AND OUTLET
5. APPROXIMATE QUANTITY OF IOWA DOT SPEC 4120.04 OR 4120.05 IS 470 CU YDS AND 11 CU YDS OF RIPRAP.

REV	DATE	BY	DESCRIPTION

SCALE: AS SHOWN
DESIGNED: M. Loerop
DRAWN: HHSI
CHECKED: T. Blair

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Naperville, IL 60563
(630) 637-9470

CLIENT: ALLIANT ENERGY
SUTHERLAND GENERATING STATION

TITLE: PHASE 1 - POLISHING POND DESIGN
ISOLATION BERM SECTIONS

SHEET 3

...\SECTIONS.dgn
2/17/2006

APPENDIX B – Soil Survey of Marshall County, Iowa

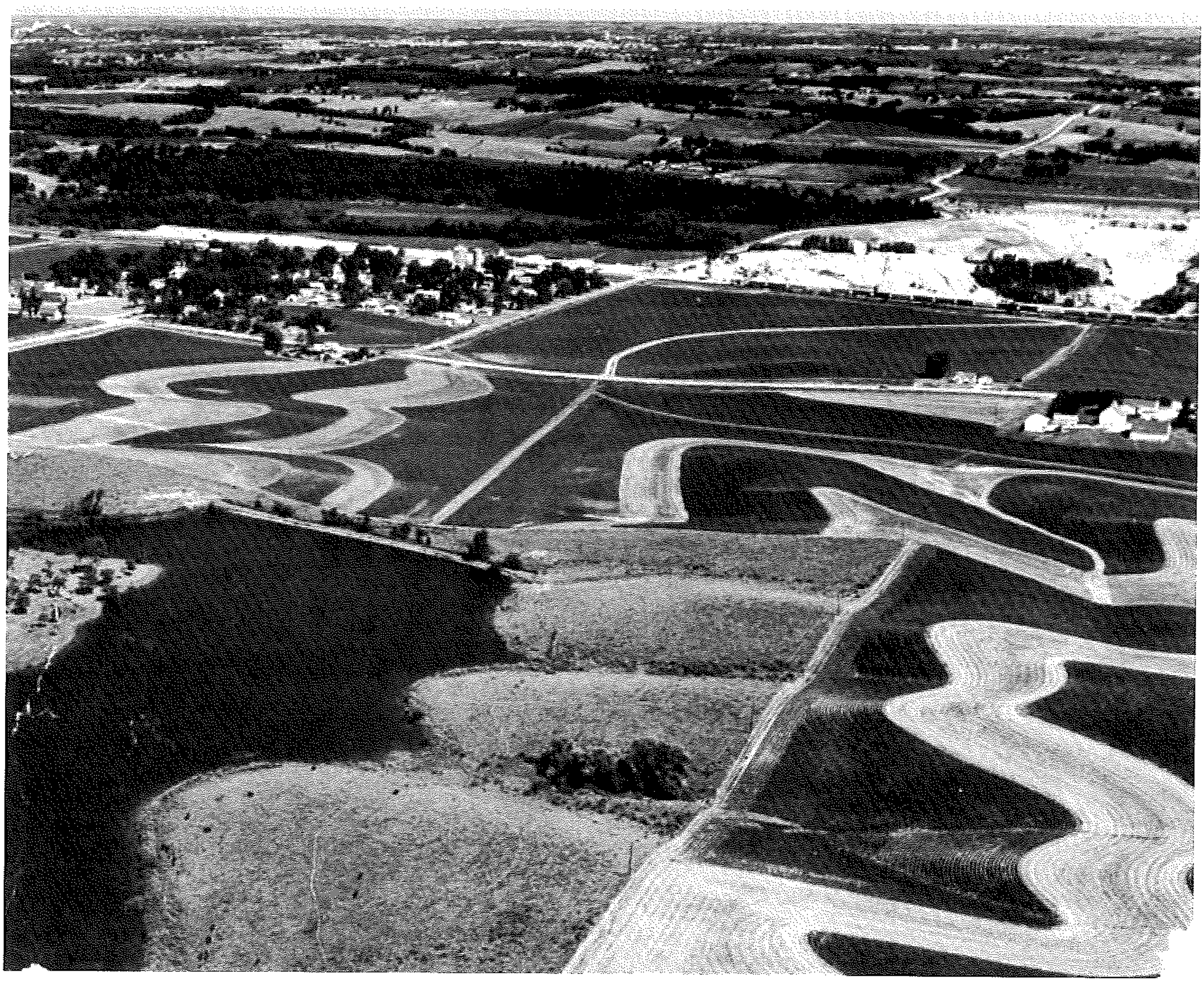
Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Structural Stability Assessment

Soil Survey of

Marshall County, Iowa

United States Department of Agriculture, Soil Conservation Service
in cooperation with the
Iowa Agriculture and Home Economics Experiment Station
Cooperative Extension Service, Iowa State University
and Department of Soil Conservation, State of Iowa



general soil map units

The general soil map at the back of this publication shows broad areas, called soil associations, that have a distinctive pattern of soils, relief, and drainage. Each soil association on the general soil map is a unique natural landscape. Typically, a soil association consists of one or more major soils and some minor soils. It is named for the major soils. The soils making up one association can occur in other associations but in a different pattern.

The general soil map can be used to compare the suitability of large areas for general land uses. Areas of suitable soils can be identified on the map. Likewise, areas where the soils are not suitable can be identified.

Because of its small scale, the map is not suitable for planning the management of a farm or field or for selecting a site for a road or building or other structure. The soils in any one association differ from place to place in slope, depth, drainage, and other characteristics that affect management.

1. Colo-Lawson-Zook association

Nearly level, poorly drained and somewhat poorly drained, silty soils formed in alluvium; on bottom lands and alluvial fans

This association consists of nearly level soils on flood plains and fans along major streams and in river valleys. These soils are subject to flooding. In places near the natural water course, the flood plains are severely dissected, and water stands in old channels.

This association makes up 10 percent of the county. It is about 29 percent Colo soils, 13 percent Lawson soils, 10 percent Zook soils, and 48 percent soils of minor extent (fig. 2).

Colo soils, on flood plains and alluvial fans, are nearly level and are poorly drained. Typically, the surface layer is black silty clay loam about 11 inches thick. The subsurface layer is black silty clay loam about 26 inches thick. The next layer is very dark gray silty clay loam about 14 inches thick. The substratum to a depth of about 60 inches is light brownish gray silty clay loam.

Lawson soils, on first and second bottoms, are nearly level and are somewhat poorly drained. Typically, the surface layer is black silty clay loam about 6 inches thick. The subsurface layer is black and very dark brown silty clay loam in the upper part and very dark grayish brown silty clay loam in the lower part. The substratum to a depth of about 60 inches is dark grayish brown silty clay loam.

Zook soils, on low flood plains, are nearly level and are poorly drained. Typically, the surface layer is black silty clay loam about 9 inches thick. The subsurface layer is black silty clay loam and silty clay about 31 inches thick. The subsoil to a depth of about 60 inches is very dark gray and grayish brown, friable silty clay loam.

Soils of minor extent in this association are the Ackmore, Hanlon, Lawler, Nevin, Nodaway, Saude, and Wiota soils. The poorly drained and somewhat poorly drained Ackmore soils and moderately well drained Nodaway and Hanlon soils are on broad flood plains and bottom lands near the natural stream channel. In addition, Ackmore and Nodaway soils are on alluvial fans near tributaries. The somewhat poorly drained Lawler soils and well drained Saude soils are on stream benches and outwash plains. The somewhat poorly drained Nevin soils are on high bottoms and low stream benches. The well drained and moderately well drained Wiota soils are on stream benches.

Most areas of this association are used for cultivated crops. Channeled and dissected areas of the flood plain are used for pasture and trees. The main enterprise is growing cash grain crops. The soils are well suited to cultivated crops if they are adequately drained and protected from flooding. They are poorly suited to building site development and sanitary facilities.

Corn, soybeans, oats, hay, and pasture grow well on the soils of this association. The organic matter content and the available water capacity of these soils are high. The main concerns of management are improving drainage and protecting the soils from flooding. These soils can be drained by tile and surface drains if adequate outlets are available. Diversions, levees, and channel improvements help to provide flood protection and control runoff from adjacent areas.

2. Muscatine-Tama-Garwin association

Nearly level and gently sloping, somewhat poorly drained, well drained, and poorly drained, silty soils formed in loess; on uplands

This association consists of wide areas of nearly level soils on divides and gently sloping soils on side slopes. The landscape is mostly gently undulating and undulating.

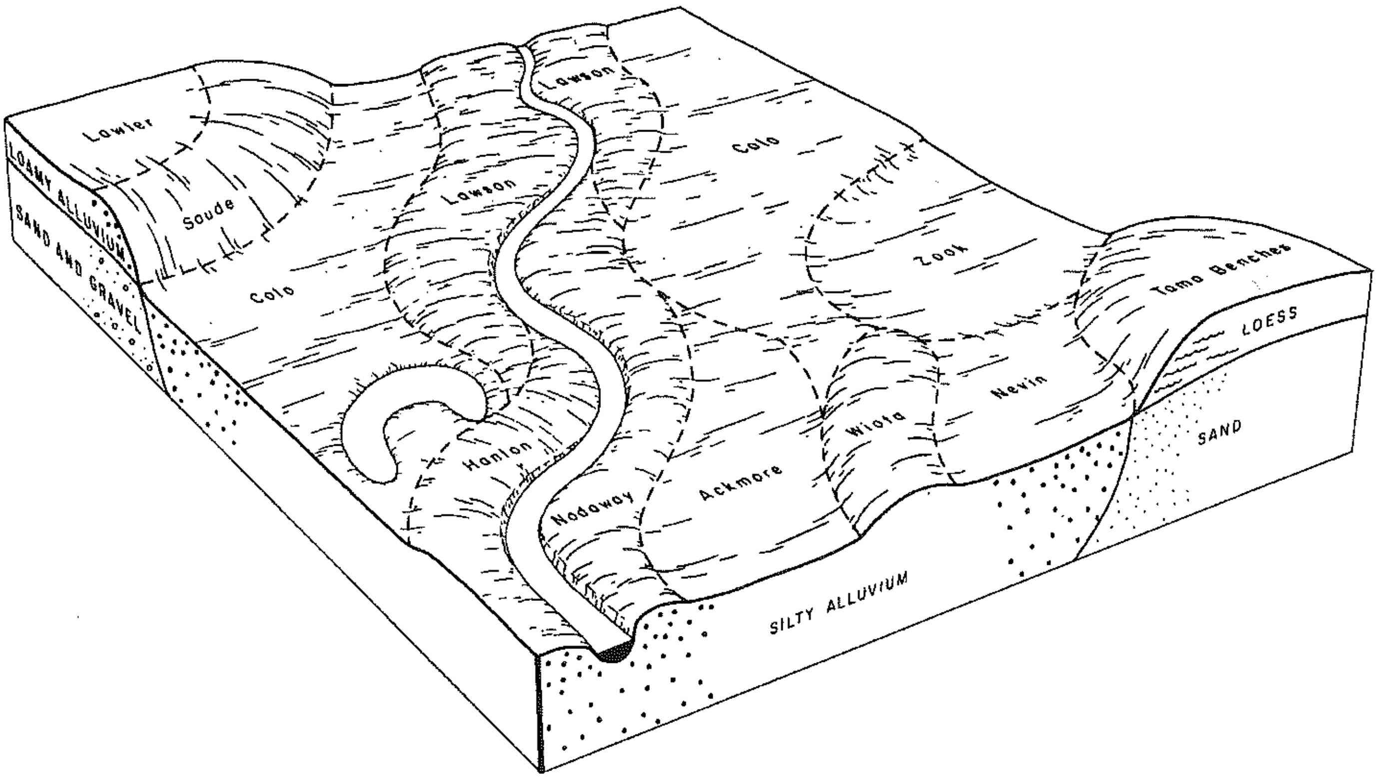


Figure 2.—Typical pattern of soils and parent material in the Colo-Lawson-Zook soil association.

This association makes up about 21 percent of the county. It is about 43 percent Muscatine soils, 38 percent Tama soils, 13 percent Garwin soils, and 6 percent soils of minor extent.

Muscatine soils, on moderately wide divides, are very gently sloping and are somewhat poorly drained. Typically, the surface layer is black silty clay loam about 9 inches thick. The subsurface layer is black and very dark brown silty clay loam about 10 inches thick. The subsoil is silty clay loam about 27 inches thick. It is very dark grayish brown and dark grayish brown in the upper part and mottled grayish brown and light olive brown in the lower part. The substratum to a depth of about 60 inches is grayish brown, mottled silty clay loam.

Tama soils, on broad convex ridgetops and side slopes, are nearly level and gently sloping and are well drained. Typically, the surface layer is very dark brown silty clay loam about 7 inches thick. The subsurface layer is very dark brown and very dark grayish brown silty clay loam about 9 inches thick. The subsoil is friable silty clay loam about 31 inches thick. It is brown in the upper part, yellowish brown in the middle part, and dark yellowish brown and yellowish brown in the lower part. The substratum to a depth of about 60 inches is yellowish brown, mottled silty clay loam.

Garwin soils, on wide divides and concave heads of drainageways, are nearly level and are poorly drained. Typically, the surface layer is black silty clay loam about 8 inches thick. The subsurface layer is black and very dark gray silty clay loam about 9 inches thick. The subsoil is friable silty clay loam about 26 inches thick. It is dark gray and gray in the upper part and mottled olive gray in the lower part. The substratum to a depth of about 60 inches is light olive gray, mottled silty clay loam.

The soils of minor extent in this association are the Colo, Ely, Harpster, and Sperry soils. The poorly drained Colo soils are in upland drainageways. The somewhat poorly drained Ely soils are on foot slopes. The poorly drained, calcareous Harpster soils are on wide divides and at the heads of drainageways. The very poorly drained Sperry soils are in slight depressions on wide divides.

Most areas of this association are used for row crops (fig. 3). The main enterprise is growing cash grain crops. These soils are well suited to all cultivated crops commonly grown in the county.

Corn, soybeans, oats, and hay grow well on the soils of this association. The available water capacity is high to very high. The organic matter content of these soils is moderate to high. The main concerns of management are controlling erosion and improving drainage.

phosphorus, and low in available potassium. This soil has good tilth.

Most areas of this soil are in cropland. This soil is well suited to cultivated crops, hay, and pasture if protected from run-on water and if tile outlets are available. It is poorly suited to sanitary facilities and building site development.

This soil is well suited to corn and soybeans if drainage is adequate. Open drains and tile outlets are necessary to adequately drain this soil. This soil generally occurs as small areas within larger areas of better drained soils. Areas of this soil are subject to flooding because of runoff from adjoining soils. Return of all crop residue helps to maintain tilth.

This Vesser soil is in capability subclass IIw.

54—Zook silty clay loam, 0 to 2 percent slopes. This nearly level, poorly drained soil is on flood plains. Areas of this soil are subject to occasional flooding. Typical areas are broad and irregular in shape and range from 5 to more than 100 acres.

Typically, the surface layer is black silty clay loam about 9 inches thick. The subsurface layer is black silty clay loam and silty clay about 31 inches thick. The subsoil is very dark gray and grayish brown, friable silty clay loam to a depth of about 60 inches. Some areas have about 12 inches of silt loam overwash.

Included with this soil in mapping are small depressional areas that are high in organic matter content. These areas contain marsh vegetation. Marsh areas pond water for long periods and are not cultivated. These areas make up 5 percent of this map unit.

Permeability of this Zook soil is slow, and surface runoff is slow to very slow. The available water capacity is high. This soil has a seasonal high water table. The content of organic matter in the surface layer is 5 to 7 percent. The surface layer is slightly acid or neutral, and the subsoil is medium acid to mildly alkaline, low in available phosphorus, and very low in available potassium. This soil has poor tilth.

Most areas of this soil are in cropland. This soil is well suited to cultivated crops if adequately drained and if protected from flooding. It is poorly suited to sanitary facilities and building site development.

This soil is well suited to corn and soybeans if drainage is adequate. Areas can be drained by tile and surface drains if adequate outlets are available. Diversions, levees, and channel improvements are used to control flooding and runoff from adjacent areas. Artificial drainage improves the timeliness of field operations and helps to improve tilth.

This Zook soil is in capability subclass IIw.

55—Nicollet loam, 1 to 3 percent slopes. This very gently sloping, somewhat poorly drained soil is on slightly convex or plane, sloping ground moraines that have low relief. In places, this soil is on toe slopes or in the upper part of drainageways. Individual areas are irregular in shape and range from 5 to 40 acres.

Typically, the surface layer is black loam about 8 inches thick. The subsurface layer is loam about 12 inches thick. It is black in the upper part and very dark gray in the lower part. The subsoil is friable clay loam about 13 inches thick. It is dark grayish brown with dark yellowish brown mottles in the upper and middle parts and dark grayish brown and mottled in the lower part. The substratum to a depth of about 60 inches is grayish brown, mottled loam.

Included with this soil in mapping are a few small areas of Webster and Okoboji soils that are poorly drained or very poorly drained. These soils are on lower areas and have a heavier textured subsoil. The Okoboji soils pond water. These soils make up 5 to 10 percent of this map unit.

Permeability of this Nicollet soil is moderate, and surface runoff is slow. This soil has a seasonal high water table. The available water capacity is high. The surface layer is slightly acid or neutral, and the subsoil is slightly acid or medium acid. The content of organic matter is about 5 to 6 percent in the surface layer. The subsoil is very low in available phosphorus and very low to low in available potassium. This soil has good tilth.

Most areas of this soil are cultivated. This soil is well suited to cultivated crops, hay, and pasture. It is poorly suited to sanitary facilities and moderately suited to building site development.

This soil is well suited to corn and soybeans. If the soil is used for cultivated crops, there is a very slight hazard of erosion on the more sloping areas. Adequate drainage for the fluctuating water table may be beneficial. Conservation tillage, a practice that leaves crop residue on the surface throughout the year, helps to prevent soil loss caused by wind erosion. Returning crop residue helps to maintain good tilth.

If used for pasture or hay, overgrazing or grazing when the soil is wet causes surface compaction and decreased infiltration. Proper stocking rates, pasture rotation, timely deferment of grazing, and restricted use during wet periods help to keep the pasture and soil in good condition.

This Nicollet soil is in capability class I.

62D2—Storden loam, 9 to 14 percent slopes, moderately eroded. This strongly sloping, well drained soil is on convex side slopes of the uplands. Typically, the slopes are short. Individual areas are long and narrow and range from 10 to 20 acres.

Typically, the surface layer is light yellowish brown and dark grayish brown, calcareous loam. The substratum to a depth of about 60 inches is calcareous loam. The upper part is light yellowish brown, the middle part is pale brown, and the lower part is light brownish gray.

Included with this soil in mapping are a few small areas that contain more sand and gravel and are droughty. They make up 5 to 10 percent of the map unit.

Permeability of this Storden soil is moderate, and surface runoff is rapid. The available water capacity is roots; few worm channels; slightly acid; gradual smooth boundary.

A13—13 to 18 inches; very dark gray (10YR 3/1) light silty clay loam, very dark grayish brown (10YR 3/2) kneaded, dark grayish brown (10YR 4/2) dry; moderate very fine and fine subangular blocky structure; friable; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

A3—18 to 26 inches; very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) silty clay loam, very dark gray (10YR 3/1) coatings on peds, brown (10YR 5/3) dry; moderate fine subangular blocky structure; friable; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

B2t—26 to 37 inches; brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) coatings on peds; weak medium prismatic structure parting to moderate medium subangular blocky; friable; thin discontinuous clay films; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

B3—37 to 49 inches; brown (10YR 4/3) silty clay loam; weak medium prismatic structure parting to weak medium subangular blocky; friable; thin discontinuous silt coats; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

C—49 to 60 inches; yellowish brown (10YR 5/4) silty clay loam; few fine faint grayish brown (10YR 5/2) mottles; massive; friable; thin discontinuous silt coats; few fibrous roots; slightly acid.

The solum ranges from 36 to 60 inches in thickness. The mollic epipedon ranges from 18 to 32 inches in thickness.

The A horizon is 25 to 32 percent clay. Reaction ranges from slightly acid to strongly acid. The B horizon is brown (10YR 4/3) or dark yellowish brown (10YR 4/4). The C horizon is silt loam or silty clay loam and is stratified in some pedons.

Zook series

The Zook series consists of poorly drained soils on flood plains commonly adjacent to foot slopes and bench escarpments. Permeability is slow. Zook soils formed in silty alluvium that is less than 15 percent sand. Native vegetation was prairie grasses. Slope ranges from 0 to 2 percent.

Zook soils are similar to Colo soils and are commonly adjacent to Bremer and Nevin soils. Colo soils have less clay in the solum. Bremer soils have thinner A horizons and less clay in the B horizon. They are on second bottoms or low stream benches. Nevin soils have thinner A horizons, are somewhat poorly drained, and are on high second bottoms and low stream benches.

Typical pedon of Zook silty clay loam, 0 to 2 percent slopes, 1,040 feet south and 198 feet east of the northwest corner of sec. 20, T. 84 N., R. 18 W.

Ap—0 to 9 inches; black (N 2/0) silty clay loam, black (N 2/0) dry; weak fine granular structure; friable; common fibrous roots; neutral; abrupt smooth boundary.

A12—9 to 18 inches; black (N 2/0) heavy silty clay loam, black (N 2/0) dry; moderate very fine subangular blocky structure; friable; few fibrous roots; neutral; gradual smooth boundary.

A13—18 to 25 inches; black (N 2/0) light silty clay, black (N 2/0) dry; moderate very fine and fine subangular blocky structure; firm; few fibrous roots; slightly acid; gradual smooth boundary.

A31—25 to 32 inches; black (10YR 2/1) light silty clay, dark gray (10YR 4/1) dry; weak medium prismatic structure parting to fine and medium subangular blocky; firm; few fibrous roots; slightly acid; gradual smooth boundary.

A32—32 to 40 inches; black (10YR 2/1) heavy silty clay loam, dark gray (10YR 4/1) dry; weak medium prismatic structure parting to fine and medium subangular blocky; firm; few fibrous roots; slightly acid; gradual smooth boundary.

B2g—40 to 48 inches; very dark gray (10YR 3/1) silty clay loam; weak medium prismatic structure parting to weak fine subangular blocky; friable; few fibrous roots; slightly acid; gradual smooth boundary.

B3g—48 to 60 inches; grayish brown (2.5Y 5/2) silty clay loam; few fine distinct strong brown (7.5YR 5/6) mottles; weak medium prismatic structure; friable; few fibrous roots; neutral.

The solum ranges from 45 to 64 inches in thickness. The entire solum is 5 to 15 percent sand and below a depth of 16 inches, it is 38 to 46 percent clay.

The A horizon ranges from 30 to 40 inches in thickness. It is black (10YR 2/1, N 2/0) silty clay loam or silty clay. The A horizon is 32 to 42 percent clay. Reaction ranges from neutral to medium acid. The B and C horizons are very dark gray (10YR 3/1), dark gray (10YR to 5Y 4/1), gray (5Y 5/1), or grayish brown (2.5Y 5/2).

formation of the soils

This section discusses the factors of soil formation and relates these factors to the soils in Marshall County.

factors of soil formation

Soil is produced by the action of soil-forming processes on materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by the physical and mineralogical composition of the parent material; the climate under which the soil material has accumulated and existed since accumulation; the plant and animal life on and in the soil; the relief, or lay of the land; and the length of time the forces of soil development have acted on the soil materials (*8*).

Climate and vegetation are the active factors in the formation of soil. They act on the parent material and slowly change it into a natural body that has genetically related horizons. The effects of climate and vegetation are conditioned by relief. The parent material also affects the kind of profile that can be formed and, in extreme cases, determines it almost entirely. Finally, time is needed for the changing of the parent material into a soil. It may be much or little, but some time is always required for horizon differentiation. A long period generally is required for the development of distinct horizons.

The factors of soil formation are so closely interrelated in their effects on the soil that few generalizations can be made regarding the effect of any one unless conditions are specified for the other four. Many of the processes of soil development are unknown.

parent material and its geologic origin

Most of the soils in Marshall County developed from loess (windblown materials), glacial till (ice-laid materials), and alluvium (water-laid materials). A few areas of eolian sand are along the Iowa River and Minerva and Honey Creeks. Parent materials in most places are built up like layers of a cake. These layers can be observed in road cuts and in places on side slopes. In this county, parent material was important in developing the general character of the soil profile.

The major Pleistocene deposits of pre-Wisconsin age are either Kansan drift, Nebraskan drift, or both. The different drifts, or tills, are not readily differentiated in Marshall County. The glacial till ranges from none to over 300 feet in thickness.

Soils developed on the Kansan till plain during the Yarmouth and Sangamon interglacial ages. This soil development was before loess deposition. On nearly level interstream divides, the soils were strongly weathered and had a gray plastic subsoil called gumbotil. This gumbotil remains; it is several feet thick and very slowly permeable. The Clarinda soils developed in this gumbotil (*15*).

Geologic erosion has cut into and below the Yarmouth-Sangamon paleosol and into the Kansan till and older deposits. On the surface formed by this erosion, there is a stone line on top of till and erosional sediment called pedisediment. Soils that have a red clayey subsoil developed in the pedisediment, stone line, and subjacent till. This period of erosion and soil formation is called Late Sangamon. The Adair soils formed in the Late Sangamon paleosols (*9*).

The Kansan till is exposed mostly in hilly areas. The unweathered till is firm, calcareous clay loam. It contains pebbles, boulders, and sand as well as silt and clay. The soils that formed in Kansan till during the Yarmouth and Sangamon ages were covered by loess. Geologic erosion has removed the loess and paleosols on many side slopes. In these places, the till is only slightly weathered at the surface and has been exposed only during the Wisconsin State of the Quaternary period (*15*). Shelby, Gara, and Lindley soils formed in slightly weathered glacial till.

Glacial till is exposed in many rolling areas in the northeastern part of Marshall County. The till in this part of the county was truncated during the early part of loess deposition in the Wisconsin age. The truncated till surface is called the Iowan Erosion Surface (*15*).

The Iowan Erosion Surface is multi-leveled. Several levels of summits occur in a gradual progression from the stream valleys toward the low crests that mark the drainage divides. Other features typical of the Iowan Erosion Surface are erratics and paha. Erratics are large boulders partially buried or lying on the surface. Paha are prominent elongated ridges and are oriented in a distinct northwest-southeast direction. The core of the paha is an erosional remnant of the Kansan till, but the Yarmouth-Sangamon paleosol is intact (*16*). The paha are capped with thick loess or sand and loess.

The Iowan Erosion Surface is about 15 to 60 feet lower than the adjacent Kansan surface. The loess cap on the summits thins on shoulders and side slopes. Dinsdale soils formed in thin loess and glacial till.

The glacial till is less than 100 feet thick in most of the Iowan Erosion Surface areas. Geologic erosion has reworked the glacial till on hillslopes. Liscomb soils formed in loamy surface sediment and glacial till.

Loess of Wisconsin age covers most of Marshall County and is an extensive parent material. It consists mainly of silt and clay particles that have been deposited by wind. Variations in the loess are related to the distance from the source of loess. The source of loess in Marshall County is probably the bottom lands to the northwest and the Iowa River. The major deposits of loess in Marshall County are older than 14,000 years (*15*).

On the stable upland divides of the Kansan till plain, the loess is about 21 feet thick. Killduff, Tama, Muscatine, Garwin and Sperry soils are formed in loess on this landform. On the Iowan Surface, the loess is about 12 feet thick. Tama, Muscatine, Garwin, Sperry, and Harpster soils formed in loess on this landscape. Dinsdale soils formed in both loess and glacial till.

Along the rivers, loess deposits are twice as thick on both the Kansan plain and Iowan Surface. Downs, Fayette, Tama, and Killduff soils formed in this loess. Some of the high stream benches along the major streams and rivers are covered with loess deposits as thin as 7 feet. Tama, Muscatine, and Downs soils formed in this loess.

A glacial till lies above the loess in the western part of Marshall County. This till is part of the Bemis moraine system of the Des Moines Lobe. The till is of Cary age, a subdivision of the Wisconsin Glacial Stage. The evidence for the geologic youth of the Cary Glaciation is the lack of deep weathering, the unleached calcareous till at a shallow depth, the poorly developed surface drainage, and many closed depressions (*15*).

Two major erosional and depositional episodes in recent time have modified the Cary till surface. The initial relief has been reduced by the movement of material from hill summits to depressions and lowland areas. The sediment on hillslopes has selectively sorted from the summits to the toe slopes and into the depressions (*15*). Clarion, Nicollet, Webster, Canisteo, Harps, Lester, and Storden soils formed in the Cary glacial drift.

Alluvium consists of sediment that has been removed and laid down by water. As it moves, this sediment is sorted to some extent, but only in a few places is it as well sorted as the loess. Also, alluvium does not have the wide range of particle sizes that occurs in glacial drift. Because the alluvium in Marshall County is derived from loess and glacial drift, it is largely a mixture of silt and clay, silt and sand, or sand and gravel.

Alluvial sediment is the parent material for the soils on flood plains, on low benches, and in long drainageways. As the river overflows its channels and the water spreads over the flood plains, coarse textured material, such as sand and coarse silt, are deposited first. As the floodwater continues to spread, it moves more slowly, and finer textured sediment is deposited. After the flood has passed, the finest particles, or clay, settle from the water that is left standing in the lowest part of the flood plain. The Hanlon, Spillville, Nodaway, and Lawson soils commonly are closest to the stream channel and are coarser textured than the other soils on flood plains. The Ackmore, Coland, and Colo soils are on upland drainageways as well as on the flood plains of larger streams. Colo soils are extensive. Zook soils commonly are on the lower part of the bottom land and are one of the finest textured soils derived from alluvium in the county.

Alluvial stream benches are intermediate in elevation between the flood plains and the loess-covered benches. The Wiota, Nevin, Koszta, and Bremer soils formed in the silty alluvium on this landform. The Saude, Waukee, Lawler, and Hanska soils formed in loamy-over-sandy alluvium on these benches.

Sediment that has accumulated at the foot of the slope on which it originated is called colluvium or local alluvium. The Ely, Judson, Terril, and Vesser soils formed in the sediment on the foot slopes. Downslope from these soils is alluvial sediment carried in to the area from distant sources.

A secondary topographic form associated with alluvial plains is sand dunes. Fine sand is blown by the wind from stream channel and flood plain surfaces to higher elevations (*12*). Accumulations of dune sand are found on low stream benches, on high loess-covered benches, and upland fringing the leeward side of valleys. Dickinson, Sparta, and Chelsea soils are formed in eolian sand that is more than 5 feet thick.

climate

The soils in Marshall County have been developing under a midcontinental, subhumid climate for the past 5,000 years. The morphology and properties of most of the soils indicate that this climate was similar to the present climate. From 6,500 to 16,000 years ago, however, the climate probably was cool and moist and conducive mostly to the growth of forest vegetation.

The influence of the general climate in a region is modified by local conditions in or near the developing soils. For example, soils on south-facing slopes formed under a microclimate that is warmer and drier than the average climate of nearby areas. The low-lying, poorly drained soils on bottom lands formed under a wetter and colder climate than that in most areas around them. These local differences influence the characteristics of the soil and account for some of the differences among soils in the same climatic region.

vegetation and animal life

Many changes in climate and vegetation have taken place in Iowa during the past 28,000 years (*14*). The period between 28,000 to 11,000 years ago was dominated by coniferous forest with a transitional period of birch and alder. Deciduous forest dominated 11,000 to

9,000 years ago. A very dry period occurred between 9,000 to 3,200 years ago, with prairie vegetation dominating. Trees, especially oak, have invaded the prairie since 3,200 years ago, but the prairie still dominates.

For the past 5,000 years, the soils of Marshall County appear to have been influenced by two main kinds of vegetation—prairie grasses and trees. Big bluestem and little bluestem were the main prairie grasses. The main trees were deciduous, mainly oak, hickory, ash, elm, and maple.

The effects of vegetation on soils similar to those in Marshall County have been studied recently. Evidence shows that vegetation shifted while soils developed in areas bordering both trees and grasses. The morphology of the Downs, Sparta, Gara, and Lester soils reflect the influence of both trees and grasses. The Chelsea, Fayette, and Lindley soils formed under the influence of trees (*11*). Grasses influenced the development of the Tama, Muscatine, Garwin, Clarion, Colo, Dickinson, Killduff, Shelby, and Zook soils and the remaining minor soils in the county.

In most places, the soils that formed under trees are lighter colored, are more acid, and have a thinner surface layer that is lower in organic matter content than soils that formed under grasses. The soils in the county that formed under shifting vegetation or mixed grasses and trees have properties that are intermediate between the properties of soils formed under grasses and those of soils formed under trees.

Animals, such as earthworms and burrowing animals, help to keep the soil open and porous. Bacteria and fungi decompose the vegetation, thus releasing nutrients for plant food.

relief

Relief also may cause important differences among soils. It indirectly influences soil development through its effect on drainage. In Marshall County, the soils range from level to very steep. In many areas of the bottom lands, the nearly level soils are frequently flooded and have a permanently or periodically high water table. In depressions, water soaks into the nearly level soils that are subject to flooding. Much of the rainfall runs off the steep soils or uplands.

Level soils are on the broad upland flats and on the stream bottoms. The very steepest soils in the county are generally on slopes near the major streams and their tributaries. The intricate pattern of upland drainageways indicates that in most of the county the landscape has been modified by geological processes.

Generally, the soils in Marshall County that formed where the seasonal water table was well below the subsoil have a subsoil that is yellowish brown. Examples of such soils are the Clarion, Dickinson, Downs, Killduff, Shelby, and Tama soils. The Lawler, Muscatine, Nevin, and similar soils formed where the seasonal water table fluctuated and was periodically high. The Garwin, Webster, and similar soils formed where the seasonal water table is high and have a subsoil that is dominantly grayish. The Colo, Garwin, Webster, Zook and similar soils developed under prairie grasses and have a high water table. These poorly drained soils contain more organic matter in the surface layer than do well drained soils formed under prairie grasses. Clay accumulates in the subsoil of such soils as Sperry soils that are slightly depressional or nearly level. This is because a large amount of water enters the soils and carries clay particles downward. Sperry soils are called claypan soils because they have a hard layer where the greatest amount of clay accumulates.

The Killduff, Shelby, Tama, and similar soils that have wide slope ranges have some properties that change as slope increases. Two of these properties are the depth to carbonates and the thickness of the surface layer. Depth to carbonates is shallow where slopes are steepest. The surface layer becomes thin in stronger sloping soils.

time

Time is required for a soil to develop. An older and more strongly developed soil shows well defined genetic horizons. A soil with less development shows no horizons, or only weakly defined ones. Most soils on the flood plains are of this kind because these materials have not been in place long enough for distinct horizons to develop.

As an example, the effects of time can be seen by the increase of clay in the subsoil. A high clay content in the subsoil compared to that in the surface soil indicates a high degree of soil profile development has taken place. This can be important because soils with a high clay content in the subsoil generally have poorer drainage.

Material is generally removed from soils on steep slopes before there has been time for a thick profile with strong horizons to develop. Also, much of the water runs off the slopes rather than through the soil material, so that even though the material has been in place for a long time, the soil may exhibit little development.

Most of the parent materials in Marshall County are thousands of years old. The present land surface and many soils are much younger because of recent geologic erosion (*15*).

The oldest soils in Marshall County are those formed in loess on upland summits and on nearly level, loess-covered stream benches. The Garwin, Harpster, Muscatine, Sperry, and Tama soils might be as old as 14,000 years (*13*). The Clarion and other soils that formed in Cary glacial drift are as young as 3,000 years. The Liscomb and other strongly sloping soils on the Iowan Erosion Surface area are as young as or younger than 2,000 years. The Shelby and other strongly sloping or steeper soils on the Kansan till plain are as young as or younger than 6,800 years. Soils formed in alluvium and eolian sand are only a few thousand years old or less. The Wiota, Saude, and other soils that formed in materials on stream benches are the oldest alluvial soils. The Colo, Hanlon, Spillville, and other soils that formed in materials on the flood plains are younger than Wiota and Saude soils. The Dickinson, Sparta, and Chelsea soils are of an age intermediate between Hanlon and Wiota soils. Two soils that formed in alluvium, Nodaway and Ackmore soils, are less than 125 years old.

man's influence on the soil

Important changes take place if the soil is cultivated. Some of these changes have little effect on productivity; others have a drastic effect. Changes caused by erosion generally are most apparent. On many of the cultivated soils in the county, particularly the gently rolling to hilly soils, part or all of the original surface layer has been lost through sheet erosion. In some places, shallow to deep gullies have formed.

A study of eroded soils in Iowa, including Marshall County, was started in 1974 by the Iowa Cooperative Soil Survey. Soil descriptions and laboratory data of selected sites are available. Initial results show a lower organic matter content in eroded soils.

Nodaway and Ackmore soils formed in stratified silt loam alluvium on alluvial fans and flood plains. This alluvium has been deposited on the bottom during the past 125 years of cultivation. Many sloping soils have lost topsoil through water erosion to form these recent flood plain deposits. About 23 percent of the soils in Marshall County are eroded.

In many continuously cultivated fields, the granular structure that was apparent when the grassland was undisturbed is no longer present. In these fields the surface tends to bake and harden when it dries. Fine textured soils that have been plowed when too wet tend to puddle and are less permeable than similar soils in undisturbed areas. Poor seedling emergence and root penetration result in these areas.

Man has done much to increase the productivity of the soils and to reclaim areas not suitable for crops. He has made large areas of bottom land suitable for cultivation by digging drainage ditches and constructing diversions and dikes. Broad flats and nearly level soils, such as Garwin and Webster soils, have been greatly improved for cultivation by installing some kind of drainage system. By adding commercial fertilizers, man has counteracted deficiencies in plant nutrients and has made some soils more productive than they were in their natural state.

processes of horizon differentiation

Horizon differentiation is caused by four basic kinds of change—additions, removals, transfers, and transformation in the soil system (*18*). Each of these four kinds of change affects many substances that compose soils, such as organic matter, soluble salts, carbonates, sesquioxides, or silicate clay materials. In general, these processes tend to promote horizon differentiation, but some tend to offset or retard it. These processes and the changes brought about proceed simultaneously in soils, and the ultimate nature of the profile is governed by the balance of these changes within the profile.

An accumulation of organic matter is an early step in the process of horizon differentiation in most soils. Soils in Marshall County range from very high to very low in the amount of organic matter that has accumulated in their surface layers. Some soils that were formerly quite high in organic matter content are now low because of erosion. The accumulation of organic matter has been an important process in the differentiation of soil horizons in Marshall County.

The process through which substances are removed from parts of the soil profile is important in the differentiation of soil horizons. The movement of calcium carbonates and bases downward in soils is an example. All the soils in the county, except Canisteo, Harps, Harpster, and Storden soils, have been leached free of calcium carbonates in the upper part of their profile. Some soils have been so strongly leached that they are strongly acid or very strongly acid even in their subsoil.

Phosphorus is removed from the subsoil by plant roots and transferred to other parts of the plant. It is then returned to the surface layer in the plant residue. These processes affect the forms and distribution of phosphorus in the profile.

The translocation of silicate clay minerals is another important process. The clay minerals are carried downward in suspension in percolating water from the surface layer. They accumulate in the subsoil in pores and root channels and as clay films. In Marshall County, this process has had an influence on the profiles of many of the soils. In other soils, the clay content of the horizons are not markedly different and other evidence of clay movement is minimal.

Another kind of transfer that is minimal in most soils, but occurs to some extent in very clayey soils, is that brought about by shrinking and swelling. This causes cracks to form and incorporates some material from the surface layer into lower parts of the profile. Clarinda soils are examples of soils with potential for this kind of physical transfer.

Transformations are physical and chemical. For example, soil particles are weathered to smaller sizes. The reduction of iron is another example of a transformation. This process is called gleying and involves the saturation of the soil with water for long periods in the presence of organic matter. It is characterized by the presence of ferrous iron and gray colors. Gleying is associated with poorly drained soils, such as the Garwin soils. Reductive extractable iron, or free iron, is normally lower in somewhat poorly drained soils, such as Muscatine soils (*20*). Still another kind of transformation is the weathering of the primary apatite mineral present in soil parent materials to secondary phosphorous compounds.

geologic profile of Marshall County

Marshall County has a gently undulating to rolling and steep landscape. It is mainly dissected by the Iowa River and the North Skunk River. Clear Creek, the three Timber Creeks, Linn Creek and three Minerva Creeks, and the two Asher Creeks are the principal interior streams (*4*).

The broad upland areas are dominated by loess at the surface. The soils formed in loess, such as the Muscatine and Tama soils, are the most productive soils in Marshall County and in Iowa. Strongly sloping to steep soils, such as the Shelby soils, formed in glacial till and till-derived materials. These soils are on slopes that descend to the major streams. Along the bottom of the streams are complex patterns of alluvium and related areas of wind-reworked sands. In the western part of the county are Clarion soils formed in Wisconsin glacial till.

Although the unconsolidated materials dominate the present land surface, such bedrock as limestone and sandstone is exposed locally. All the bedrock material would be exposed if the unconsolidated materials were removed. However, the surface exposed would not be flat but would exhibit landforms much like the present surface. There are bedrock valleys and ridges which can affect water movement within the overlying unconsolidated materials.

Bedrock is exposed in about 21 different sections in Marshall County. In most places the natural outcrops are small. The bedrock exposed in Marshall County is primarily of Mississippian and Pennsylvanian age (*7*). The general rock types are mostly dolomite and sandstone. The dolomite is quarried and provides stone for aggregate, road surfacing, and agstone. Some coal measure shales are exposed by Honey Creek.

Information collected during the drilling of wells and test holes is available for over 180 wells in Marshall County (*6*). Detailed information is available for many of these wells. Some of these wells are drilled into rocks that are aquifers. Three distinct levels of rocks that are aquifers occur in Marshall County (*5*).

TABLE 15.--ENGINEERING INDEX PROPERTIES--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Frag- ments > 3 inches	Percentage passing sieve number--				Liquid limit	Plas- ticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
51---------------- Vesser	0-17	Silt loam---------	CL	A-6	0	100	100	98-100	95-100	30-40	10-20
	17-28	Silt loam---------	CL	A-6	0	100	100	98-100	95-100	30-40	10-20
	28-60	Silty clay loam	CL, CH	A-7	0	100	100	98-100	95-100	40-55	20-30
54---------------- Zook	0-18	Silty clay loam	CH, CL	A-7	0	100	100	95-100	95-100	45-65	20-35
	18-60	Silty clay, silty clay loam.	CH	A-7	0	100	100	95-100	95-100	60-85	35-55
55---------------- Nicollet	0-20	Loam--------------	OL, ML, CL	A-6, A-7	0	95-100	95-100	85-98	55-85	35-50	10-25
	20-33	Clay loam, loam	CL	A-6, A-7	0-5	95-100	95-100	80-95	55-80	35-50	15-25
	33-60	Loam--------------	CL, ML	A-6, A-4	0-5	95-100	90-100	75-90	50-75	30-40	5-15
62D2-------------- Storden	0-8	Loam--------------	ML, CL	A-4, A-6	0-5	95-100	95-100	70-85	55-70	30-40	5-15
	8-60	Loam--------------	CL-ML, CL	A-4, A-6	0-5	95-100	85-97	70-85	55-70	20-40	5-15
63C, 63E---------- Chelsea	0-8	Loamy fine sand	SM, SP-SM	A-2-4	0	100	100	65-80	10-35	---	NP
	8-60	Fine sand, sand, loamy sand.	SP, SM, SP-SM	A-3, A-2-4	0	100	100	65-80	3-15	---	NP
65F, 65G---------- Lindley	0-7	Loam--------------	CL-ML, CL	A-4, A-6	0	95-100	90-100	85-95	50-65	15-30	5-15
	7-50	Clay loam, loam	CL	A-6, A-7	0	95-100	90-100	85-95	55-75	30-45	15-25
	50-60	Loam, clay loam	CL	A-6	0	95-100	90-100	85-95	50-70	30-40	15-25
88---------------- Nevin	0-24	Silty clay loam	CL, OL	A-6, A-7	0	100	100	100	90-95	35-45	10-20
	24-47	Silty clay loam	CL	A-7	0	100	100	95-100	90-95	40-50	20-30
	47-60	Silty clay loam, silt loam.	CL	A-7	0	100	100	95-100	90-95	40-50	20-30
93D2*, 93E2*:											
Shelby-----------	0-7	Loam--------------	CL	A-6	0	95-100	85-95	75-90	55-70	30-40	10-20
	7-45	Clay loam---------	CL	A-6, A-7	0-5	90-95	85-95	75-90	55-70	30-45	15-25
	45-60	Clay loam---------	CL	A-6, A-7	0-5	90-95	85-95	75-90	55-70	30-45	15-25
Adair------------	0-6	Clay loam---------	CL	A-6	0	95-100	80-95	75-90	60-80	30-40	10-20
	6-60	Silty clay, clay, clay loam.	CL, CH	A-7	0	95-100	80-95	70-90	55-80	40-55	20-30
95---------------- Harps	0-18	Loam, clay loam	CL, CH	A-6, A-7	0-5	100	95-100	80-90	65-80	30-55	15-35
	18-43	Loam, clay loam, sandy clay loam.	CL, CH	A-6, A-7	0-5	95-100	95-100	80-90	65-80	30-60	15-35
	43-60	Loam--------------	CL	A-6	0-5	95-100	90-100	70-80	50-75	25-40	10-25
107--------------- Webster	0-20	Silty clay loam	CL, CH	A-7, A-6	0-5	100	95-100	85-95	70-90	35-60	15-30
	20-39	Clay loam, silty clay loam, loam.	CL	A-6, A-7	0-5	95-100	95-100	85-95	60-80	35-50	15-30
	39-60	Loam, sandy loam, clay loam.	CL	A-6	0-5	95-100	90-100	75-85	50-75	30-40	10-20
118--------------- Garwin	0-17	Silty clay loam	CL, CH	A-7	0	100	100	100	95-100	45-55	20-30
	17-60	Silty clay loam	CH, CL	A-7	0	100	100	100	95-100	45-55	25-35
119--------------- Muscatine	0-19	Silty clay loam	CL	A-7	0	100	100	100	95-100	40-50	15-25
	19-60	Silty clay loam	CL	A-7	0	100	100	100	95-100	40-50	20-30
120, 120B, 120C, 120C2, 120D2, 120E2------------ Tama	0-16	Silty clay loam	ML	A-6, A-7	0	100	100	100	95-100	35-50	10-20
	16-47	Silty clay loam	CL	A-7	0	100	100	100	95-100	40-50	15-25
	47-60	Silty clay loam, silt loam.	CL	A-6, A-7	0	100	100	100	95-100	35-45	15-25
122--------------- Sperry	0-22	Silt loam---------	CL	A-6	0	100	100	100	95-100	30-40	10-20
	22-37	Silty clay loam, silty clay.	CH	A-7	0	100	100	100	95-100	50-65	25-35
	37-60	Silty clay loam, silt loam.	CL	A-7	0	100	100	100	95-100	40-50	20-30
133--------------- Colo	0-11	Silty clay loam	CL, CH	A-7	0	100	100	90-100	90-100	40-60	15-30
	11-60	Silty clay loam	CL, CH	A-7	0	100	100	90-100	90-100	40-55	20-30

See footnote at end of table.

TABLE 16.--PHYSICAL AND CHEMICAL PROPERTIES OF SOILS--Continued

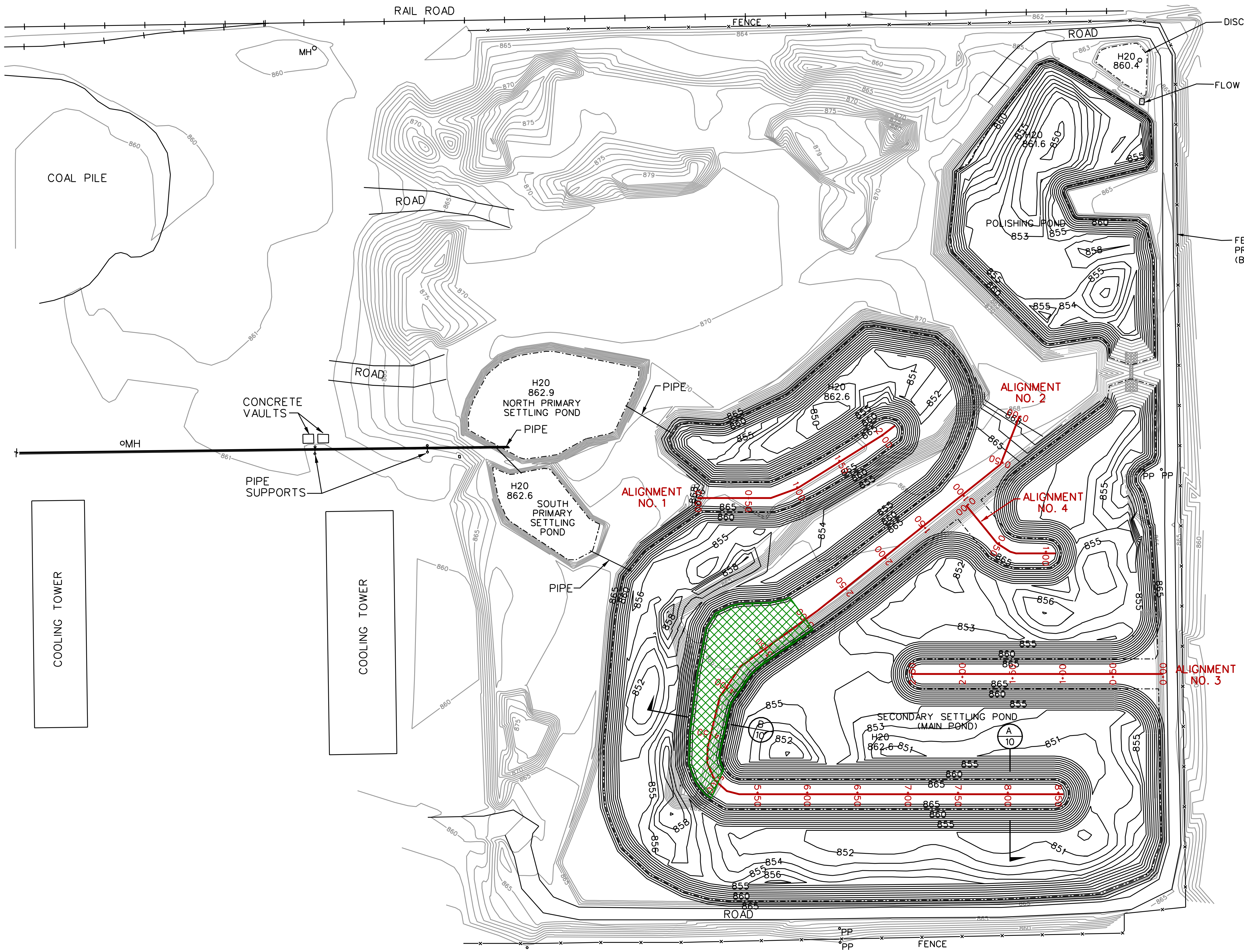
Soil name and map symbol	Depth	Clay	Moist bulk density	Permeability	Available water capacity	Soil reaction	Shrink-swell potential	Erosion factors		Wind erodibility group	Organic matter
								K	T		
	In	Pct	G/cm³	In/hr	In/in	pH					Pct
54------------- Zook	0-18	32-38	1.30-1.35	0.2-0.6	0.21-0.23	5.6-7.3	High---------	0.28	5	7	5-7
	18-60	36-45	1.30-1.45	0.06-0.2	0.11-0.13	5.6-7.8	High---------	0.28			
55------------- Nicollet	0-20	24-35	1.15-1.25	0.6-2.0	0.17-0.22	5.6-7.3	Moderate-----	0.24	5	6	5-6
	20-33	24-35	1.25-1.35	0.6-2.0	0.15-0.19	5.6-7.8	Moderate-----	0.32			
	33-60	22-28	1.35-1.45	0.6-2.0	0.14-0.19	7.4-7.8	Low----------	0.32			
62D2----------- Storden	0-8	18-27	1.35-1.45	0.6-2.0	0.20-0.22	7.4-8.4	Low----------	0.28	5	4L	.5-2
	8-60	18-27	1.35-1.65	0.6-2.0	0.17-0.19	7.4-8.4	Low----------	0.37			
63C, 63E--------- Chelsea	0-8	8-15	1.50-1.55	6.0-20	0.10-0.15	5.6-7.3	Low----------	0.17	5	2	<.5
	8-60	5-10	1.55-1.70	6.0-20	0.06-0.08	5.1-5.5	Low----------	0.17			
65F, 65G--------- Lindley	0-7	18-27	1.20-1.40	0.6-2.0	0.16-0.18	4.5-7.3	Low----------	0.32	5	6	.5-1
	7-50	25-35	1.50-1.75	0.2-0.6	0.14-0.18	4.5-6.5	Moderate-----	0.32			
	50-60	18-32	1.75-1.85	0.2-0.6	0.12-0.16	6.1-7.8	Moderate-----	0.32			
88------------- Nevin	0-24	26-29	1.30-1.35	0.6-2.0	0.21-0.23	5.6-7.3	Moderate-----	0.32	5	7	4-6
	24-47	30-35	1.30-1.40	0.6-2.0	0.18-0.20	6.1-6.5	Moderate-----	0.43			
	47-60	25-36	1.40-1.45	0.6-2.0	0.18-0.20	6.6-7.3	Moderate-----	0.43			
93D2*, 93E2*:											
Shelby----------	0-7	24-27	1.50-1.55	0.6-2.0	0.20-0.22	5.6-7.3	Moderate-----	0.28	5	6	.5-2
	7-45	30-35	1.55-1.75	0.2-0.6	0.16-0.18	5.6-7.8	Moderate-----	0.28			
	45-60	30-35	1.75-1.85	0.2-0.6	0.16-0.18	6.6-8.4	Moderate-----	0.37			
Adair-----------	0-6	27-35	1.45-1.50	0.2-0.6	0.17-0.19	5.6-7.3	Moderate-----	0.32	2	6	1-3
	6-60	38-50	1.50-1.60	0.06-0.2	0.13-0.16	5.1-6.5	High---------	0.32			
95------------- Harps	0-18	25-35	1.35-1.40	0.6-2.0	0.19-0.21	7.9-8.4	Moderate-----	0.24	5	4L	4-6
	18-43	18-32	1.40-1.50	0.6-2.0	0.17-0.19	7.9-8.4	Moderate-----	0.32			
	43-60	20-26	1.50-1.70	0.6-2.0	0.17-0.19	7.9-8.4	Moderate-----	0.32			
107------------ Webster	0-20	26-36	1.35-1.40	0.6-2.0	0.19-0.21	6.6-7.3	Moderate-----	0.24	5	6	6-7
	20-39	25-35	1.40-1.50	0.6-2.0	0.16-0.18	6.6-7.8	Moderate-----	0.32			
	39-60	18-29	1.50-1.70	0.6-2.0	0.17-0.19	7.4-8.4	Moderate-----	0.32			
118------------ Garwin	0-17	30-35	1.30-1.35	0.6-2.0	0.21-0.23	5.6-7.3	High---------	0.28	5	7	6-7
	17-60	28-34	1.28-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High---------	0.28			
119------------ Muscatine	0-19	28-30	1.30-1.35	0.6-2.0	0.22-0.24	5.1-7.3	Moderate-----	0.28	5	6	5-6
	19-60	30-34	1.28-1.35	0.6-2.0	0.18-0.20	5.1-7.3	Moderate-----	0.43			
120, 120B, 120C, 120C2, 120D2, 120E2---------- Tama	0-16	24-29	1.25-1.30	0.6-2.0	0.22-0.24	5.1-7.3	Moderate-----	0.32	5	7	1-5
	16-47	28-34	1.30-1.35	0.6-2.0	0.18-0.20	5.1-6.0	Moderate-----	0.43			
	47-60	22-28	1.35-1.40	0.6-2.0	0.18-0.20	5.6-7.3	Moderate-----	0.43			
122------------ Sperry	0-22	18-22	1.35-1.40	0.6-2.0	0.22-0.24	5.6-7.3	Moderate-----	0.28	5	6	3-4
	22-37	38-45	1.40-1.45	0.06-0.2	0.14-0.16	5.1-6.5	High---------	0.43			
	37-60	26-34	1.45-1.50	0.2-0.6	0.19-0.21	5.6-6.5	High---------	0.43			
133------------ Colo	0-11	27-32	1.28-1.32	0.6-2.0	0.21-0.23	5.6-7.3	High---------	0.28	5	7	5-7
	11-60	30-35	1.25-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High---------	0.28			
133+----------- Colo	0-11	20-26	1.25-1.30	0.6-2.0	0.22-0.24	6.6-7.3	Moderate-----	0.28	5	6	3-5
	11-60	30-35	1.25-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High---------	0.28			
133B----------- Colo	0-11	27-32	1.28-1.32	0.6-2.0	0.21-0.23	5.6-7.3	High---------	0.28	5	7	5-7
	11-60	30-35	1.25-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High---------	0.28			
135------------ Coland	0-40	27-35	1.40-1.50	0.6-2.0	0.20-0.22	6.1-7.3	High---------	0.28	5	7	5-7
	40-60	27-35	1.40-1.50	0.6-2.0	0.20-0.22	6.1-7.3	High---------	0.28			

See footnote at end of table.

APPENDIX C – Pond Configuration, Sampling Location and Boring Logs

Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Structural Stability Assessment



LEGEND:

MH∘	MANHOLE
PP∘	POWER POLE
— 860 —	CONTOUR FROM GROUND SURVEY (NOV, 2005)
— · — · —	WATER LINE
— 855 —	POND RECONFIGURATION AND POST DREDGING CONTOURS
(green hatch)	EXISTING BERM TO BE STABILIZED (APPROX. 10,000 SQ FT) (SEE DETAIL B ON SHEET 10)
— 0+00	ALIGNMENT

NOTE:

1. QUANTITIES OF MATERIALS ARE LOCATED ON SHEET 12.

REV	DATE	BY	DESCRIPTION

SCALE: 0 50 100 SCALE IN FEET

DESIGNED: M. Loerop
DRAWN: HHSI
CHECKED: T. Blair

HARD HAT SERVICES ™
Engineering, Construction and Management Solutions

940 E. Diehl Rd, Suite 150
Naperville, IL 60563
(630) 637-9470

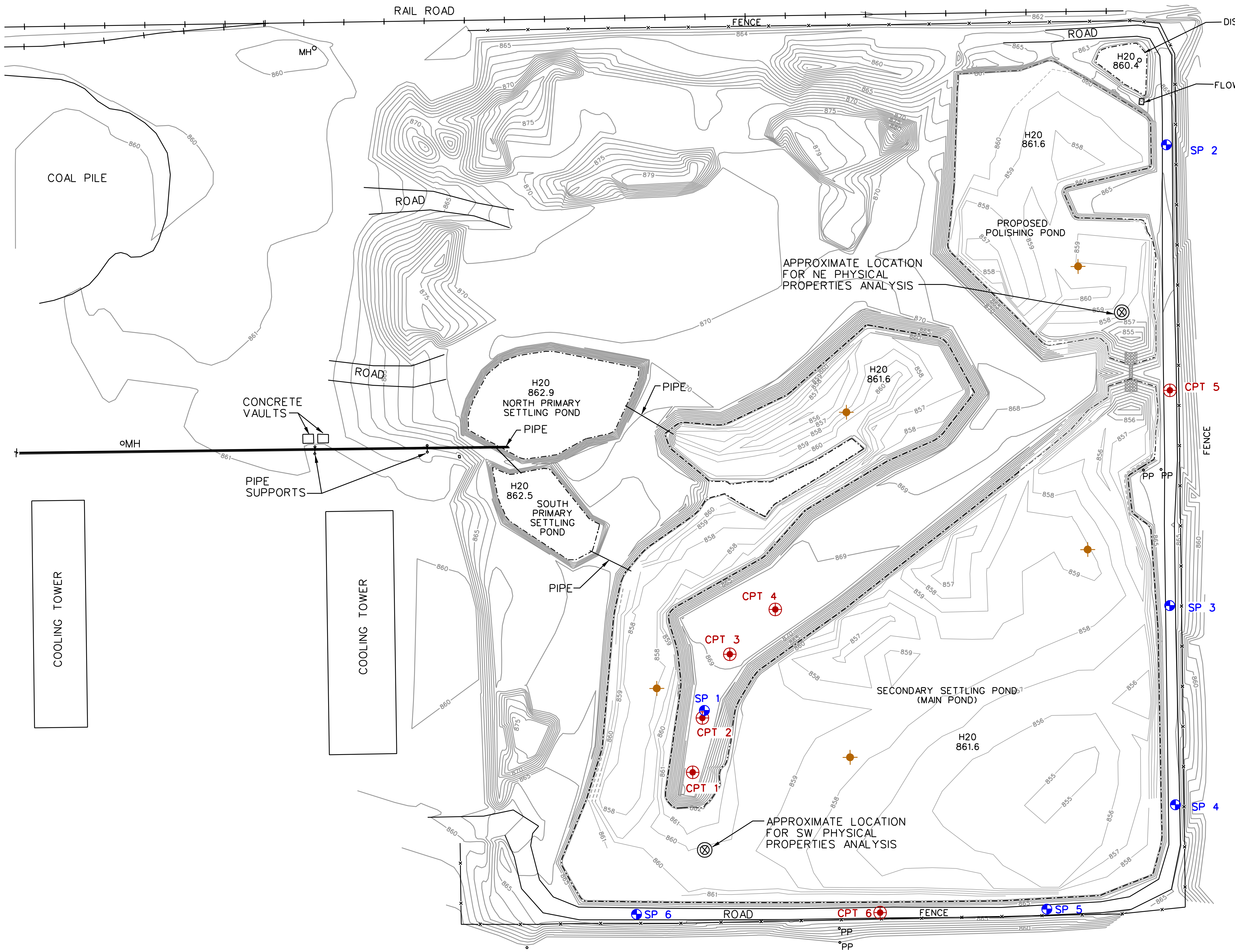
CLIENT: INTERSTATE POWER & LIGHT SUTHERLAND GENERATING STATION

TITLE: PHASE 2 SETTLING POND RECONFIGURATION

DRAWING NUMBER: 1-2060-0-D-C5001-003

SHEET 3

...\reconfiguration.dgn
4/19/2006



N

0 100
SCALE IN FEET

LEGEND:

- SOIL PROBE LOCATION
- CONE PENETRATION TEST LOCATION
- COMPOSITE SAMPLE LOCATION
- MH MANHOLE
- PP POWER POLE
- 860 CONTOUR FROM GROUND SURVEY (NOV, 2005)
- WATER LINE

NOTES:

1. CONE PREPARATION TESTS WERE CONDUCTED TO A DEPTH OF 15' OR UNTIL REFUSAL.
2. SOIL PROBES WERE COMPLETED WITH A SPLIT SPOON SAMPLER TO A DEPTH OF 15' OR UNTIL REFUSAL.
3. SAMPLING ACTIVITIES WERE CONDUCTED ON 3-14-06.
4. ALL FIVE COMPOSITE SAMPLE LOCATIONS WERE PLACED IN A FIVE GALLON BUCKET. IT WAS MIXED FOR 15 MINUTES, SAMPLED, AND SENT TO THE LABORATORY FOR TOTAL METALS AND SFLP ANALYSIS.

DRAWING NUMBER:

REV	DATE	BY	DESCRIPTION

SCALE: 0 50 100 SCALE IN FEET
DESIGNED: M. Loerop
DRAWN: HHSI
CHECKED: T. Blair

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

940 E. Diehl Rd, Suite 150
Naperville, IL 60563
(630) 637-9470

CLIENT: INTERSTATE POWER & LIGHT
SUTHERLAND GENERATING STATION

TITLE: GEOTECHNICAL AND SEDIMENT SAMPLE TEST LOCATIONS

FIGURE 1

$FILEABBREV$
$DATE$

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

PROJECT: Alliant Energy

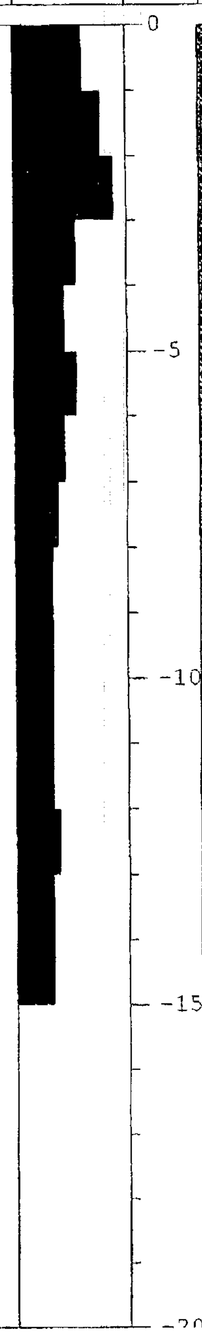
COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

BORING NO.: *SP2*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS
				0
				2.75
				3.5
	GP 1	5'/5'		
				4.0
				2.5
				2.0
				2.5
	GP 2	2'/5'		
				1.5
				1.5
				1.75
	GP 3	5'/5'		
				1.5
				1.5

POCKET PENETROMETER HISTOGRAM



DEPTH IN FEET	DESCRIPTION
0 to -15	CLAY; brown;; low to high plasticity; moist; trace sand and gravel.
-15	Bottom of boring @ 15.0'. Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

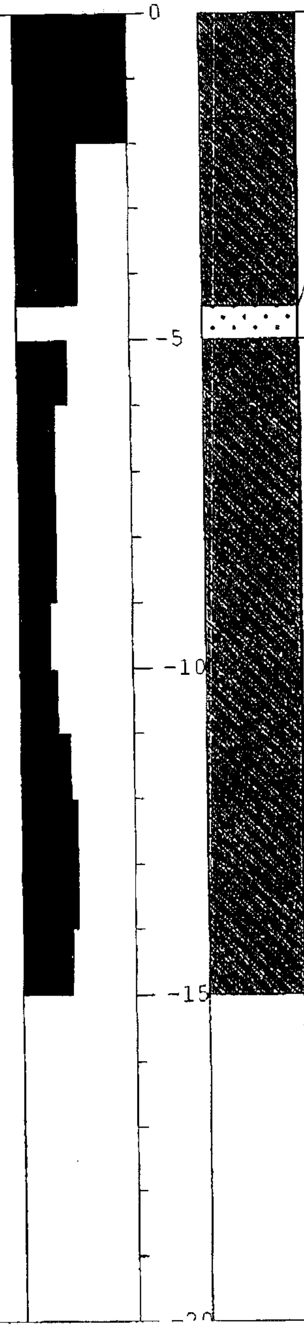
PROJECT: Alliant Energy

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SP3*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	DEPTH IN FEET	DESCRIPTION
				0, 4.5, 4.5, 2.5	0	CLAY; yellowish brown to black; non-plastic to low plasticity; moist; trace ash, sand and gravel.
	GP 1	5'/5'				
						SAND; yellow; poorly graded; medium grained; moist.
				2.0, 1.5, 1.5, 1.25	-5	CLAY; olive; low plasticity; moist; some sand.
	GP 2	2'/5'				@ 8' grades some organic matter
				1.5, 2.0, 2.25, 2.25, 2.0	-10	@11' organic matter grades out
	GP 3	5'/5'				@ 13' grades olive
					-15	Bottom of boring @ 15.0'. Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
					-20	



CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

PROJECT: Alliant Energy

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SP4*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	POCKET PENETROMETER HISTOGRAM	DEPTH IN FEET	PROFILE	DESCRIPTION
	GP 1	5'/5'		0 3.0 4.0 4.5		0		CLAY; yellowish brown to black; non-plastic to low plasticity; moist; trace ash, sand and gravel.
	GP 2	2'/5'		1.25 1.25 2.0 2.0		-5		CLAY; olive; low plasticity; moist; some sand. @ 8' grades some organic matter
	GP 3	5'/5'		1.5 1.5 1.5 1.0 1.0		-10		@11' organic matter grades out @ 13' grades olive
						-15		Bottom of boring @ 15.0'. Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
						-20		

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

PROJECT: Alliant Energy

COORDINATES: N NOT SURVEYED, E NOT SURVEYED

BORING NO.: *SP5*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	DEPTH IN FEET	DESCRIPTION
				0	0	CLAY; brown; low plasticity; moist; trace sand and gravel.
				>4.5		
				>4.5		
	GP 1	5'/5'		>4.5		
						CLAY & ASH; black; non-plastic to low plasticity; moist.
				1.5	-5	
				1.75		CLAY; olive; low plasticity; moist; trace sand and gravel.
	GP 2	2'/5'		1.25		
				1.25		@ 9' grades black
				2.0	-10	
						@11' grades olive
	GP 3	5'/5'		1.25		
				1.5		
				1.5		
				1.5	-15	Bottom of boring @ 15.0'.
						Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
					-20	

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

PROJECT: Alliant Energy

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SP6*

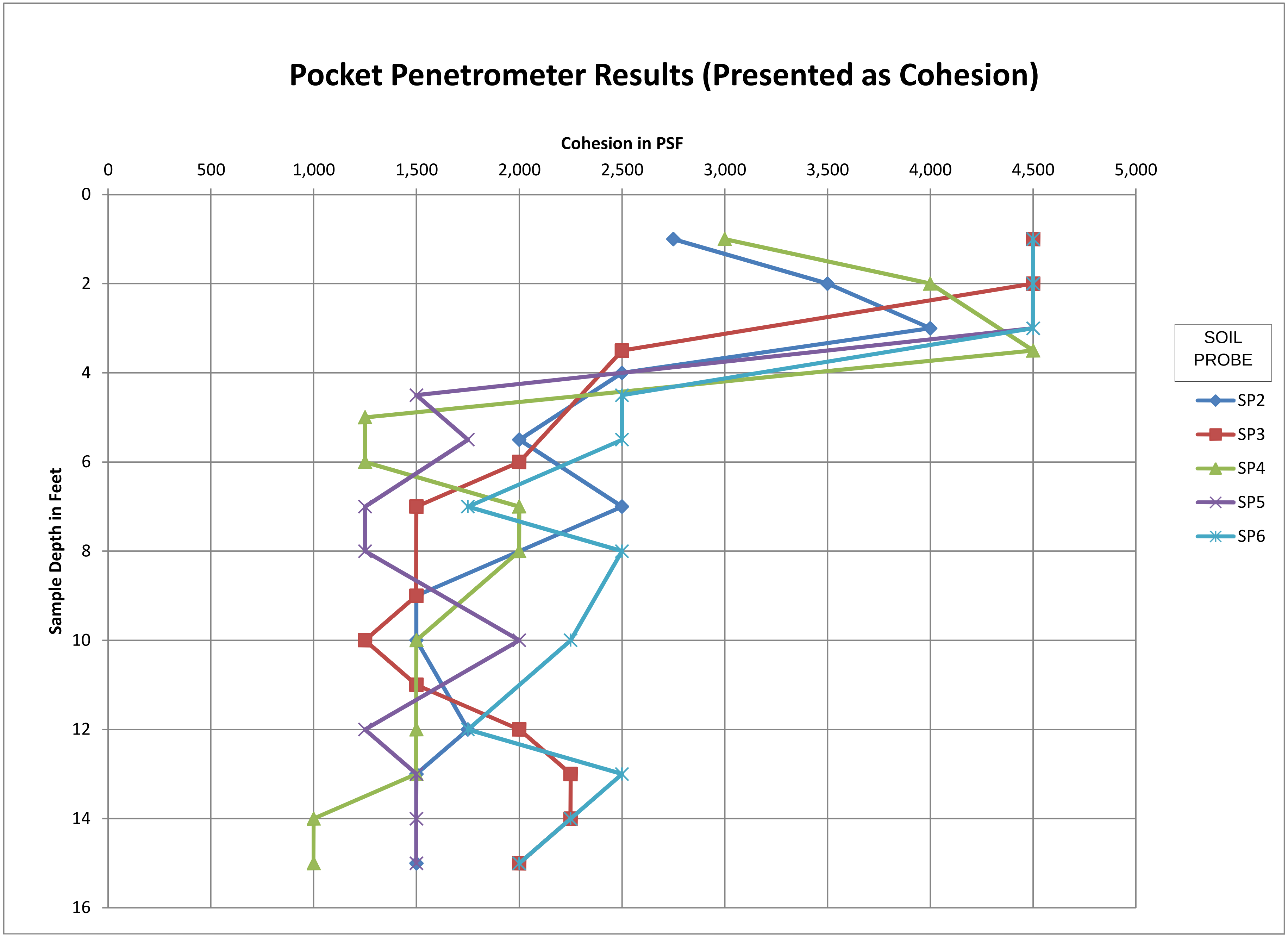
LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	POCKET PENETROMETER HISTOGRAM	DEPTH IN FEET	PROFILE	DESCRIPTION
				0		0		CLAY; brown; low plasticity; moist; trace sand and gravel.
				> 4.5				
				> 4.5				
	GP 1	5'/5'		> 4.5				
				2.5		-5		
				2.5				
				1.75				
	GP 2	2'/5'		2.5				
								@ 9' grades some organic material
				2.25		-10		
								@11' organic material grades out
				1.75				
	GP 3	5'/5'		2.5				
				2.25				
				2.0		-15		Bottom of boring @ 15.0'.
								Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
						-20		

APPENDIX D – Summary of Pocket Penetrometer Results

Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Structural Stability Assessment


Pocket Penetrometer Results (Presented as Cohesion)
Cohesion in PSF
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Sample Depth in Feet
0
2
4
6
8
10
12
14
16
SOIL PROBE
SP2
SP3
SP4
SP5
SP6