MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

**PSC Case No. 9482**
**PPRP Exhibit____ (SS-3)**

# PPRP

DRAFT

# Project Assessment Report for the Modification of the CP Crane Generating Station

**March 4, 2019**

**MARYLAND POWER PLANT RESEARCH PROGRAM**

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| | |
|---|---|
| AERMOD | EPA air model used in analysis |
| AQS | Air Quality System |
| ARM2 | Ambient Ratio Method 2 |
| ASOS | Automated Surface Observation System |
| AST | Aboveground storage tank |
| BACT | Best available control technology |
| BWI | Baltimore Washington International Airport |
| CAA | Clean Air Act |
| CAIR | Clean Air Interstate Rule |
| CAM | Compliance Assurance Monitoring |
| CBCA | Chesapeake Bay Critical Area |
| CEMS | Continuous Emissions Monitoring System |
| CFC | Chlorofluorocarbons |
| CFR | Code of Federal Regulations |
| $CH_4$ | Methane |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| $CO_2e$ | Carbon dioxide equivalent |
| COMAR | Code of Maryland Regulations |
| CPCN | Certificate of Public Convenience and Necessity |
| CSAPR | Cross State Air Pollution Rule |
| CT | Combustion Turbine |
| DNR | Maryland Department of Natural Resources |
| EPA | U.S. Environmental Protection Agency |
| ERD | Environmental Review Document |
| ESC | Erosion and sediment control |
| FIDS | Forest interior-dwelling species |
| GE | General Electric |
| GEP | Good Engineering Practice |
| GHG | Greenhouse gas |
| GWP | Global Warming Potential |

| | |
|---|---|
| HAA | Health Air Act |
| HAP | Hazardous air pollutant |
| HFC | Hydrofluorocarbons |
| IAD | Dulles International Airport |
| IPaC | Information for Planning and Consultation |
| LAER | Lowest achievable emission rate |
| LPH | Liquid phase hydrocarbon |
| MACT | Maximum Achievable Control Technology |
| MDE | Maryland Department of the Environment |
| MDE-ARA | MDE Air and Radiation Administration |
| MDE-WSP | MDE Water Supply Program |
| MIHP | Maryland Inventory of Historic Places |
| $N_2O$ | Nitrous oxide |
| NAAQS | National Ambient Air Quality Standard |
| NAMS | National Air Monitoring Stations |
| NA-NSR | Non-Attainment New Source Review |
| NESHAP | National Emissions Standards for Hazardous Air Pollutants |
| NOAA | National Oceanic and Atmospheric Association |
| $NO_2$ | Nitrogen dioxide |
| NO | Nitrogen monoxide |
| $NO_X$ | Nitrogen oxides |
| NR | National Register |
| NSPS | New Source Performance Standard |
| NWI | National Wetlands Inventory |
| NWS | National Weather Service |
| $O_3$ | Ozone |
| OTC | Ozone Transport Commission |
| OWS | Oil water separator |
| PAMS | Photochemical air monitoring stations |
| Pb | Lead |
| PFC | Perfluorocarbons |
| PJM | PJM Interconnection, LLC |

| | |
|---|---|
| PM | Particulate matter (filterable) |
| $PM_{10}$ | Particulate matter; 10 microns in diameter |
| $PM_{2.5}$ | Particulate matter; 2.5 microns in diameter (Fines) |
| PPRP | Power Plant Research Program |
| PSC | Maryland Public Service Commission |
| PSD | Prevention of Significant Deterioration |
| RICE | Reciprocating Internal Combustion Engine |
| SAM | Sulfuric acid mist |
| SAV | Submerged aquatic vegetation |
| SER | Significant Emission Rate |
| $SF_6$ | Sulfur hexafluoride |
| SLAMS | State and local air monitoring stations |
| SPCC | Spill Prevention, Control, and Countermeasures |
| $SO_2$ | Sulfur dioxide |
| SWM | Stormwater management |
| TAP | Toxic air pollutant |
| ULSD | Ultra low sulfur diesel |
| URDL | Urban Rural Demarcation Line |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| VOC | Volatile organic compounds |
| WHS | Wildlife and Heritage Service |

**UNITS**

| | |
|---|---|
| bgs | below ground surface |
| dB | decibels |
| dBA | A-weighted decibel |
| °F | degrees Fahrenheit |
| g/kW-hr | grams per horsepower hour |
| gpd | gallon per day |
| gpm | gallon per minute |
| g/s | grams per second |
| gr S/100 scf | grains sulfur per 100 standard cubic feet |
| hp | horsepower |
| hrs/yr | hours per year |
| kW | kilowatt |
| lb/event | pounds per event |
| lb/hr | pounds per hour |
| lb/MWh | pounds per megawatt hour |
| lb/MMBtu | pounds per millions of British thermal units |
| m/s | meters per second |
| MMBtu/hr | millions of British thermal units per hour |
| MW | megawatt |
| MWh | megawatt-hour |
| ppm | parts per million |
| ppmw | parts per million by weight |
| psi | pounds per square inch |
| tpy | tons per year |

## *EXECUTIVE SUMMARY*

On May 31, 2018, CP Crane, LLC (CP Crane) submitted an application to the Maryland Public Service Commission (PSC) for a Certificate of Public Convenience and Necessity (CPCN) that would authorize the modification of the existing Charles P. Crane Generating Station (Project), located in Baltimore, Maryland to permanently retire the two existing coal-fired units and install three new simple cycle combustion turbines (CTs). The PSC docketed the matter as Case No. 9482. In addition to the original application, CP Crane filed a supplement to the original application with revised pages of their Environmental Review Document (ERD) to correct air emissions netting errors on June 21, 2018. On August 31, 2018, CP Crane filed a second supplement to the original application to incorporate updated emissions performance data from the CT vendor into their ERD and testimony.

The proposed repowering Project will consist of three refurbished simple-cycle aeroderivative General Electric (GE) LM6000 CTs, with a water injection system to reduce nitrogen oxide emissions. The Project will result in a nominally rated 164-megawatt (MW) facility as each of the three turbines will be nominally rated at 50 MW and the facility will continue to use an existing 14-MW No. 2 fuel oil-fired CT. CP Crane has proposed to retire the two other existing generating units, two coal-fired boilers, at the facility.

To aid in their planned use as peaking units, the CTs will be designed to achieve full load after startup in no more than 10 minutes. CP Crane will limit the annual capacity factor of the units to 27%, equivalent to 2,365 hours per year (hrs/yr). The proposed Project will be completed with CTs that operate using natural gas as the primary fuel and No. 2 fuel oil as the backup fuel that can be used when natural gas supply is unavailable. The ultra low sulfur diesel (ULSD) fuel oil operations will be limited to 10% of the available hours or 237 hrs/yr.

The proposed Project will utilize the existing natural gas pipeline, water supply system, and electrical transmission system for the CP Crane facility. No new offsite natural gas supply or electrical transmission structures will be needed. All equipment, including the refurbished CTs, natural gas compressor, ULSD aboveground storage tanks and piping, water demineralization equipment, step-up transformers and substation, and other ancillary equipment, will be installed on areas of the site that have been previously developed.

The Department of Natural Resources (DNR) Power Plant Research Program (PPRP), coordinating with other State agencies, performed this environmental review of the Project as part of the licensing process administered by the Maryland PSC. Before the proposed Project can be constructed, CP Crane must obtain a CPCN from the PSC. PPRP's review was conducted to evaluate the potential impacts to environmental and cultural resources for the proposed Project, pursuant to Section 3-304 of the Natural Resources Article of the Annotated Code of Maryland. The review of the proposed Project was based on information filed by the company in its original CPCN Application, supplemental filings, and responses to PPRP Data Requests Nos. 1 through 6.

PPRP has evaluated the Applicant's proposed changes and has verified there will be no substantive impacts to water, terrestrial, ecological, or socioeconomic resources from the proposed Project. PPRP, in conjunction with the reviewing State agencies, conducted an analysis of the proposed Project and are making recommendations for appropriate license conditions to assure that the Project will not result in unacceptable impacts to environmental and cultural resources.

PPRP used the analysis of potential impacts as the basis for establishing recommended licensing conditions for operating the proposed facility, pursuant to Section 3-306 of the Natural Resources Article. The initial recommended licensing conditions are included as Appendix A. PPRP's recommendations are made in concert with other units within DNR, as well as the Maryland Departments of Environment, Agriculture, Commerce, Planning, and Transportation, and the Maryland Energy Administration.

## *1.0 INTRODUCTION*

### *1.1 BACKGROUND*

On May 31, 2018, CP Crane LLC (CP Crane) submitted an application to the Maryland Public Service Commission (PSC) for approval to modify the existing Charles P. Crane Generating Station (the "facility" or "site") in Baltimore County, Maryland by permanently retiring the two existing coal-fired units and installing three refurbished simple cycle combustion turbines (CTs). The repowering project (the "Project") will result in a nominally rated 164-megawatt (MW) facility as each of the three turbines will be nominally rated at 50 MW and the facility proposes to continue to use an existing 14-MW No. 2 fuel oil-fired CT.

CP Crane filed a supplement to the original application with revised pages of its Environmental Review Document (ERD) to correct air emissions netting errors on June 21, 2018. On August 31, 2018, CP Crane filed a second supplement to the original application to incorporate updated emissions performance data from the CT vendor. The second supplemental application included revised pages of the ERD and revised versions of the Applicant's direct testimony.

CP Crane has proposed to install three refurbished simple-cycle aeroderivative General Electric (GE) LM6000 CTs. While the existing coal fired generating units routinely took 20-24 hours to startup, the aero-derivative design of the proposed CTs will enable CP Crane to rapidly startup in significantly less time (typically less than 10 minutes) and allow for the needed shut down flexibility. CP Crane will limit the annual capacity factor of the proposed units to 27%, equivalent to 2,365 hours per year (hrs/yr). The proposed Project will be completed with CTs that operate using natural gas as the primary fuel and No. 2 fuel oil as the backup fuel that can be used when natural gas supply is unavailable. The ultra low sulfur diesel (ULSD) fuel oil operations will be limited to 10% of the available hours or 237 hrs/yr.

The proposed Project will utilize the existing natural gas pipeline, water supply system, and electrical transmission system for the CP Crane facility. No new offsite natural gas supply or modifications to the existing electrical transmission structures will be needed. All equipment, including the refurbished CTs, natural gas compressor, ULSD aboveground storage tanks and piping, water demineralization equipment, step-up transformers and substation, and other ancillary equipment, will be installed on areas of the site that have been previously developed.

The Department of Natural Resources (DNR) Power Plant Research Program (PPRP), coordinating with other State agencies, performed this environmental review of the CP Crane project as part of the PSC licensing process. Before the proposed facility can be constructed, the PSC must grant a Certificate of Public Convenience and Necessity (CPCN). The PSC has designated this case as PSC Case No. 9482. PPRP has evaluated the facility's potential impacts to environmental and cultural resources, pursuant to Section 3-304 of the Natural Resources Article of the Annotated Code of Maryland. This environmental and socioeconomic review was performed in coordination with other State agencies. PPRP used the analysis of potential impacts as the basis for establishing recommended license conditions (presented in Appendix A of this report) for construction and operation of the proposed facility, pursuant to Section 3-306 of the Natural Resources Article.

## *1.2 DOCUMENT ORGANIZATION*

This report synthesizes the evaluations that PPRP has conducted to assess potential environmental impacts from the Project. The information is organized into the following sections:

- **Section 2** provides a description of the proposed Project;
- **Section 3** describes the existing environmental and socioeconomic conditions at the site and in the vicinity;
- **Section 4** describes the air impacts associated with the proposed Project and the relevant regulatory requirements;
- **Section 5** addresses other impacts, including terrestrial, groundwater from construction and operation, socioeconomic, and noise; and
- **Section 6** summarizes the findings of PPRP's evaluations.

Two appendices are also included in the report, as follows:

- **Appendix A** provides the State's recommended license conditions for the proposed CP Crane modification; and
- **Appendix B** provides CP Crane's responses to PPRP Data Requests that are specifically referenced in this document or relied upon as a basis for the recommended license conditions.

## 2.0 PROJECT DESCRIPTION

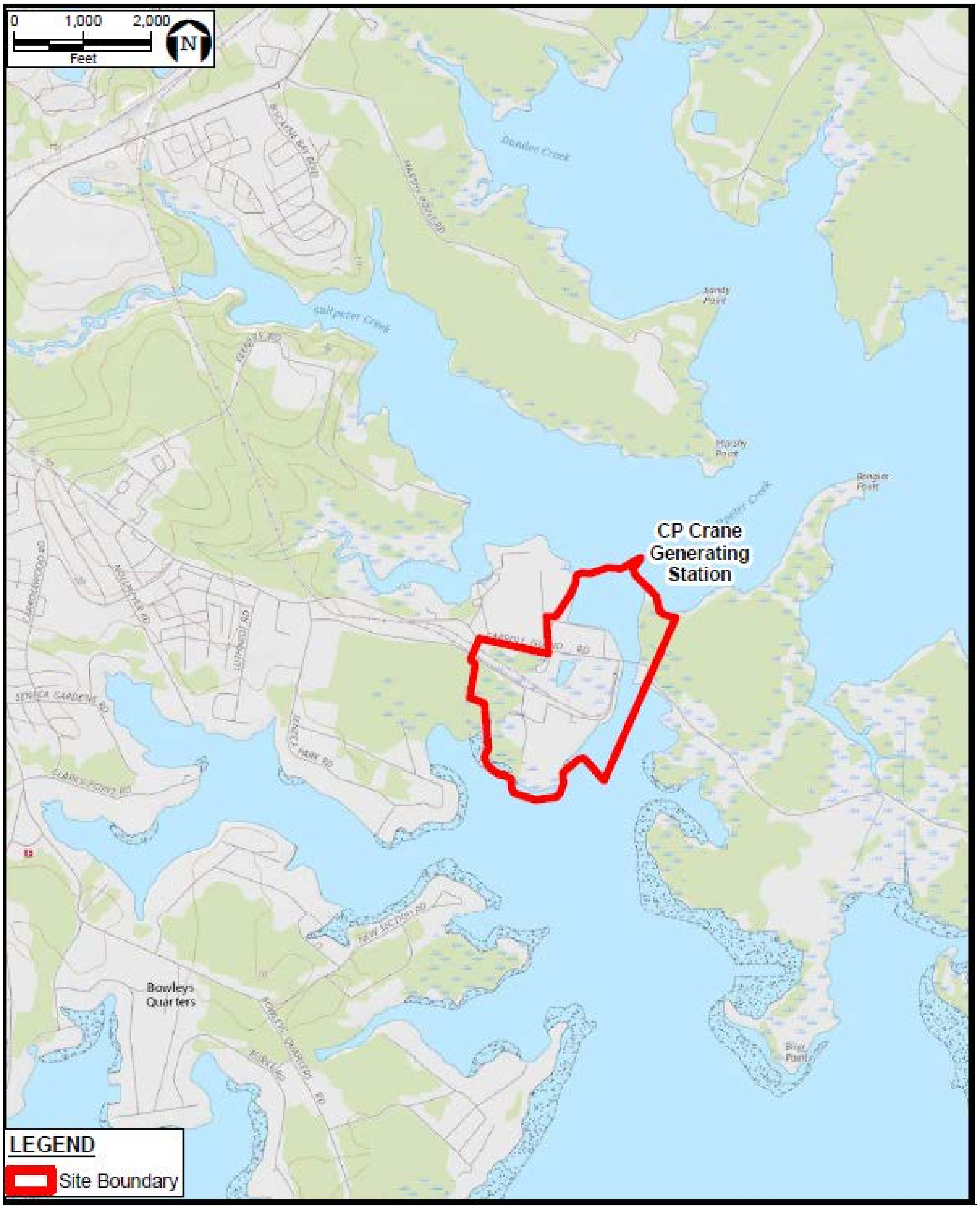
### 2.1 SITE DESCRIPTION

The site of the proposed modification is the existing CP Crane Generating Station. As show on Figure 2-1, the site occupies approximately 157 acres in Baltimore County at the end of a peninsula extending into Seneca Creek and the Chesapeake Bay. Carrol Island, which is connected to the peninsula via Carroll Island Road, is located to the east of the site. The site is bordered to the north by Saltpeter Creek and to the south by Seneca Creek with the land of the peninsula to the west. The Seneca Park Beach and Bowleys Quarters communities are the nearest neighborhoods and are located to the west and southwest of the site.

The site is located approximately at sea level and the topography is primarily flat. Portions of the site are located within the Chesapeake Bay Critical Area (CBCA) as further described in Section 3.5.3.

The proposed modification will occur in the southwestern portion of the site to the west of the existing power plant building. During construction, the Project construction is expected to disturb approximately eight acres of the site, while the post-construction Project area will be limited to approximately five acres. All equipment will be installed in areas of the site that have previously been developed.

*Figure 2-1 Topographical Map of Site Location*




Source: CP Crane ERD, 2018

## 2.2 EXISTING FACILITY

The CP Crane Generating Station was a coal-fired power plant that consisted of two solid fossil fuel-fired cyclone boilers with a combined

nominal generating capacity of 400 MW. The 190-MW Unit 1 and the 209-MW Unit 2 began operating in 1961 and 1963, respectively, as oil-fired units. The facility has been modified several times since initial operation began as follows:

- Modification to switch Units 1 and 2 from oil to coal firing (PSC Case No. 7443);

- Construction of a coal barge unloading system (PSC Case No. 9048);

- Installation of air pollution control devices to reduce nitrogen oxide ($NO_X$), sulfur dioxide ($SO_2$), and mercury (Hg) emissions to comply with Maryland Healthy Air Act (HAA) (PSC Case No. 9084). To meet the HAA requirements, CP Crane installed a Selective Non-Catalytic Reduction (SNCR) system to reduce $NO_x$ emissions, installed an Activated Carbon Injection (ACI) system to reduce Hg emissions, and switched to sub-bituminous coal to reduce $SO_2$ emissions; and

- Firing of reduced-sulfur subbituminous coal beginning on June 9, 2010 (PSC Case No. 9206).

The coal-fired units were retired on June 1, 2018. Two existing auxiliary boilers will no longer be operated as part of the proposed Project. CP Crane will continue to operate three existing air emissions units as part of the proposed Project as follows:

- One 14-MW No. 2 fuel oil-fired CT;

- One 399-horsepower (hp) diesel fuel-fired emergency fire water pump; and

- One 600-hp diesel fuel-fired emergency generator.

## 2.3 *PROPOSED PROJECT COMPONENTS*

CP Crane has proposed to install electric generating units and associated equipment for the Project including three refurbished 50 MW GE LM6000 SPray INTercooling® (SPRINT®) simple cycle CTs equipped with an inlet evaporative cooling system and one new 1,500-kilowatt (kW) black-start

generator. Ancillary equipment for the fuel, electric, and water systems will be installed to support the electric generating units.

The CTs will operate using natural gas as the primary fuel and ULSD as the backup fuel that can be used when natural gas supply is unavailable. The CTs will be fueled with the existing natural gas pipeline connected to the site. CP Crane anticipates the natural gas will contain a maximum of 0.5 grains of sulfur per 100 standard cubic feet (gr S/100 scf). CP Crane has proposed to install new electric-driven compression equipment to increase the natural gas pressure from 350 to 675 pounds per square inch (psi). The compression equipment will potentially include gas heaters, coalescing filters, and pressure-regulating equipment.

CP Crane has also proposed to install two 480,000-gallon aboveground storage tanks (ASTs) to allow the CTs to operate on No. 2 fuel oil at full load continuously for 72 hours. The No. 2 fuel oil will be ULSD and contain no more than 15 parts per million by weight (ppmw) of sulfur. The ASTs will be stored within a berm that provides secondary containment in the event of a fuel leak and will be supplied via tanker trucks.

Although the existing water supply system will be used to supply raw water for the CTs, a new treatment system will be installed to demineralize the water prior to use. CP Crane has proposed to install reverse osmosis and electrodeionization equipment to reduce metal deposition and scaling of the CTs. The demineralized water will be stored in a new water storage tank(s). Wastewater produced from the demineralizing equipment will piped to the existing wastewater system. Other wastewater generated that has the potential to contain oil will be routed a new oil water separator (OWS) that will be connected to the existing wastewater system.

The electricity generated by the CTs will be transmitted to the electric grid using the existing 115-kilovolt transmission line located on the site. The three proposed CTs and the existing 14 MW CT will each be connected to a step-up transformer and all four pieces of equipment will be connected to a new substation. In addition, CP Crane will install new electrical equipment needed to power the proposed Project components.

Lastly, CP Crane will be leaving open space in the redeveloped area for the future addition of a battery storage system with a 400 megawatt-hour (MWh) capacity.

# 3.0 EXISTING SITE CONDITIONS

## 3.1 GEOLOGY AND GROUNDWATER

### 3.1.1 Site Characteristics

CP Crane lies within the Atlantic Coastal Plain Province and is immediately underlain by Quaternary surficial silt, sand, and gravel approximately 10 to 20 feet thick (also referred to as the Quaternary Lowland Deposits (Bennett and Meyer, 1952)). Below the surficial deposits are unconsolidated, Cretaceous Age, Potomac Group Sediments that include the Patapsco, the Arundel, and the Patuxent Formations. These units extend approximately 500 to 600 feet below ground surface (bgs) in this area (DNR, 1982) before the Patuxent's contact with crystalline basement rock. The Soil Conservation Service has classified the soils beneath the station as belonging to the Sassafras series (USDA, 1976).

The Quaternary Lowland Deposits constitute the surficial aquifer at the site; regionally these deposits vary in thickness from 0 to 150 feet with variable transmissivities ranging from approximately 2,000 square feet per day to over 20,000 square feet per day (Bennett and Meyer, 1952). The deeper water bearing aquifers under the station, the uppermost Patapsco and the lower Patuxent, are generally formed of red and gray gravel, sand, and clay. The Patapsco is approximately 100 feet thick, while the Patuxent is 150 to 300 feet thick in this area of Baltimore County (DNR, 1982). Separating the two units is a confining unit, the Arundel Clay. The Patuxent and the Patapsco aquifers are both widely used for domestic and commercial purposes due to their high productivity, with estimated transmissivities of 4,000 and 2,000 square feet per day, respectively.

Groundwater is not currently used for potable or non-potable purposes at the station. Water used at the station is obtained from the City of Baltimore municipal water supply.

### 3.1.2 Groundwater Conditions

Groundwater beneath a portion of the CP Crane site is undergoing remediation to address historic contamination, under the supervision of the Maryland Department of the Environment (MDE) Oil Control Program. According to the 4th Quarter 2015 Groundwater Monitoring Report prepared by EA Engineering, Science, and Technology, Inc. (dated

11 January 2016) and submitted to MDE, fuel oil was encountered in the subsurface in the southwest side of the power plant while conducting construction activities in the late 1980s (Furlong, *pers. comm.)*. The source of the fuel oil was determined to be a former underground fuel line connecting a 10,000-gallon aboveground storage tank with the plant boilers. Reportedly, the line was capped in the 1970s.

Upon learning of the contamination, the facility owner (then Baltimore Gas & Electric) initiated an investigation into the extent of subsurface impacts. By 1992, Baltimore Gas & Electric was operating an oil recovery system of five wells (PRW-1, 2, 4, 5, and 6) while PRW-3 was used as a monitoring well. A bail-down test in 1994 estimated the subsurface fuel oil plume to be 12,300 gallons. However, based on recovery estimates from 2004, approximately 17,500 gallons of liquid phase hydrocarbon (LPH) had been recovered. The active oil recovery system was discontinued in 2001 due to operational difficulties caused by excessive fouling and limited LPH recovery.

In July 2013, upon request by MDE, CP Crane submitted a Subsurface Investigation and LPH Recovery Work Plan proposing the installation of temporary monitoring points, monitoring/recovery wells, if needed, and an expanded approach toward LPH recovery. In January 2014, MDE approved the Subsurface Investigation and LPH Recovery Work Plan. The subsurface investigation was initiated during the First Quarter 2014, and the additional recovery activities began in June 2014. The belt skimmer recovery systems were installed and initiated at wells PRW-4 and PRW-5 in June 2014. A passive skimmer at MW-2 was relocated to PRW-6 in February 2015 due to the reduced LPH recovery at MW-2. In September 2015, the active skimmer at PRW-5 was relocated to PRW-6, and the passive skimmer in PRW-6 was installed in PRW-5.

As of December 2015, remediation efforts have consisted of manual LPH recovery using bailers during monthly gauging and semi-annual sampling events, as well as both passive and active LPH recovery systems at four wells. From January 2009 through December 2015, approximately 1,400 gallons of LPH had been removed using manual, active, and vacuum enhanced recovery methods. The cumulative recovery at the site as of December 2015 is approximately 18,900 gallons of LPH.

## 3.2 SURFACE WATER RESOURCES

### 3.2.1 Surficial Hydrology

The CP Crane site is located within the Chesapeake Bay Watershed and the Gunpowder River Area (Sub-Basin 02-13-08; Crane ERD 2018). As shown in Figures 3-1, the site is bordered by Seneca and Saltpeter Creeks, both of which drain into Gunpowder River. According to Code of Maryland Regulations (COMAR) 26.08.02.07 and 08, the tidal Gunpowder River is designated for Use Class II (Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting). As with all surface waters of the state, it is protected for water contact recreation, fishing, and protection of aquatic life and wildlife. Use Class II waters are also specifically designated as protected for shellfish harvesting, shallows waters with submerged aquatic vegetation (SAV), and/or spawning and nursery for migratory fish. Portions of the mouth of Gunpowder River Oligohaline (designated GUNOH1, immediately north of the site) and the Middle River Oligohaline (MIDOH, immediately south) are also designated Class II for multiple uses.

*Figure 3-1 Surrounding Waterways at Site Location*


Source: CP Crane ERD, 2018

Each of these waters, GUNOH1 and MIDOH, is impaired for several water quality parameters. Each is listed as impaired for the nutrients nitrogen and phosphorous and for sediments (total suspended solids). Portions of both waters are also listed for polychlorinated biphenyls in fish tissue. A portion of the CP Crane site is within the flood plain, as shown in Figure 3-2.

*Figure 3-2 Flood Plains at Site Location*


Source: CP Crane ERD, 2018

### 3.3 AIR QUALITY

### 3.3.1 Ambient Air Quality

Air quality measurements have been taken at thousands of monitoring stations across the country for several decades, producing data that reflects ambient air concentrations of the "criteria" pollutants, nitrogen dioxide ($NO_2$), $SO_2$, particulate matter (PM), ozone ($O_3$), carbon monoxide (CO), and lead (Pb). State, local, and tribal air quality agencies operate and maintain most of the stations following nationally consistent procedures established by the EPA. The United States Environmental Protection Agency (EPA) routinely summarizes and posts reported data to the Air Quality System (AQS)[1].

The pollutant monitors are situated above the ground at a height as prescribed in 40 Code of Federal Regulations (CFR) Part 58, Appendix E. If ambient air quality monitoring indicates that the concentration of a pollutant exceeds a National Ambient Air Quality Standard (NAAQS) in any area of the country, that area is classified as a "nonattainment area" for that pollutant, meaning that the area is not meeting the NAAQS. Conversely, any area in which the concentration of a criteria pollutant is below the NAAQS is classified an "attainment area" indicating that the NAAQS are being met.

States and the EPA make the attainment/nonattainment designations on a pollutant-by-pollutant basis. Therefore, the air quality in an area may be designated attainment for some pollutants and nonattainment for other pollutants at the same time. For example, many cities are designated nonattainment for ozone, but are in attainment for the other criteria pollutants.

Since the late 1980s, the NAAQS for particulate matter covered "$PM_{10}$," which represents PM less than 10 microns in diameter. In 1997, EPA revised the NAAQS for PM and added a standard for a new form of PM known as $PM_{2.5}$, PM that is less than 2.5 microns in diameter. Further revisions to the $PM_{2.5}$ NAAQS were published in 2006 (24-hour NAAQS) and in 2012 (annual NAAQS). $PM_{2.5}$, or "fine particulates," is of concern because the particles' small size allows them to be inhaled deeply into the lungs and these fine particles contribute to haze and other air quality

[1] http://www.epa.gov/airdata/

issues. In December 2014, EPA published updated designations of $PM_{2.5}$ for the 2012 annual $PM_{2.5}$ standard.

EPA and states make attainment designations based on air quality surveillance programs that measure pollutants in a network of nationwide monitoring stations. Historically, these networks were known as the State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), and Photochemical Air Monitoring Stations (PAMS) (EPA, 1998). The SLAMS network designation is still maintained; however, NAMS and PAMS have been folded into the National Core Multipollutant Network and the $PM_{2.5}$ Chemical Speciation Network that provide specialized measurements focused on understanding the underlying causes of (and potential solutions to) nonattainment of the ozone and $PM_{2.5}$ NAAQS.

EPA's six stated objectives for the monitoring network design for the SLAMS are to (EPA, 1998):

- Determine highest concentrations expected to occur in the area covered by the network;
- Determine representative concentrations in the areas of high population density;
- Determine the impact on ambient pollution levels of significant sources or source categories;
- Determine general background concentration levels;
- Determine the extent of regional pollutant transport among populated areas, and in support of secondary standards; and
- Determine the welfare-related impacts in more rural and remote areas (such as visibility impairment and effects on vegetation).

EPA further explains that SLAMS monitors are intended to be located so that the samples they collect are representative of air quality over the entire area they are intended to cover. The EPA established "spatial scales of representativeness" to ensure that monitoring of specific pollutants is appropriate and representative. The scales of representativeness include microscale, middle scale, neighborhood scale, urban scale, and regional scale. The scale takes into consideration such factors as local terrain,

pollutant-specific criteria, and population density. EPA reviews the program annually to "improve the network to ensure that it provides adequate, representative, and useful air quality data" (EPA 1998).

In summary, EPA and state air agencies have established a monitoring network designed to allow collection of monitoring data sufficient for EPA and the state to determine ambient air quality of criteria pollutants. The monitoring data are used to determine background ambient concentrations of criteria pollutants, and to classify all areas of the country as attainment or nonattainment of the NAAQS.

Baltimore County, the location for the proposed CP Crane Repowering Project, is currently designated as attainment for $NO_X$, CO, PM, and Pb. Some counties in Maryland are designated ozone attainment areas and some are nonattainment areas. All of Baltimore County is designated a "marginal" ozone nonattainment area (on a scale that ranges from worst to best air quality of extreme – severe – serious – moderate – marginal) and is part of the Baltimore ozone nonattainment area (Baltimore, Carroll, Hartford, Howard, Anne Arundel counties and Baltimore City). In addition, the EPA, in June 2016, redesignated a portion of Baltimore County to be nonattainment for the 1-hour NAAQS for $SO_2$. The $SO_2$ non-attainment area extends 26.8 kilometers from the HA Wagner Generating Station Unit 3 stack in Anne Arundel County and encompasses the CP Crane Generating Station.

## *3.4 BIOLOGICAL RESOURCES*

The Applicant assembled existing information about biological resources from online sources (e.g., MERLIN Online) as summarized in Appendix B of its ERD. The Applicant's key findings supported by MERLIN data are as follows:

- Both the Maryland DNR and National Wetlands Inventory (NWI) maps indicated the presence of wetlands in the site area;
- Neither source indicated any wetlands of special state concern to be present anywhere in the vicinity of the site;
- Neither source indicated any natural heritage areas, agricultural preservation lands, or forest legacy lands to be present anywhere in the vicinity of the site; and

- These sources indicated the presence of sensitive species near the site, as well as habitat suitable for forest interior-dwelling species (FIDS), green infrastructure, and SAV.

In addition to MERLIN, the Applicant queried the U.S. Fish and Wildlife Service (USFWS) Information for Planning and Consultation (IPaC) tool for records of species and other resources, such as critical habitat, under the USFWS's jurisdiction that are known or expected to be within a 1-mile radius of the CP Crane site. The IPaC report (USFWS, 2018a) identified no federally threatened or endangered species under the Endangered Species Act of 1973. The Migratory Bird Treaty Act of 1981 listed 31 avian species as birds of conservation concern by USFWS; these are species that are of concern throughout their range anywhere within the United States. Additionally, the IPaC identified bald eagle and golden eagle occurring within one mile of the Project site. Eagles receive protection under the Bald and Golden Eagle Protection Act of 1940. The IPaC also identified sixteen additional avian species within a 1-mile radius of the site that are potentially susceptible in offshore areas to certain types of development or activities (e.g., offshore energy development or longline fishing).

No National Wildlife Refuge lands are within one mile of the site, nor are any fish hatcheries. The Applicant queried critical habitat under the jurisdiction of National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NOAA Fisheries) to identify any anadromous or marine species that may exist near the site. Based on this query, the closest designated critical habitat (for Maryland darter, *Etheostoma sellare*) is approximately 18 miles northeast of the site (USFWS, 2018b).

The CP Crane site is located within the Maryland Piedmont Plateau Province. Characteristically, the landscape in the site region is typified by rolling hills with incised stream valleys. This area of Maryland is included within the Southeastern Mixed Forest Ecological Province as defined by the U.S. Forest Service. Typical vegetation is deciduous and mixed pine oak forests.

The Applicant obtained DNR and NWI wetland maps from DNR's Geospatial Data website. Figures 3-3 and 3-4 show these maps overlaying an aerial photograph. While there are wetlands located within the site boundary, the areas to be developed as part of the proposed Project will not impact these wetlands. The Applicant also used the DNR data site to obtain the more detailed information regarding sensitive species review

areas as delineated by the Wildlife and Heritage Service (WHS). The highlighted areas indicate the presence or possible presence of listed species. The areas closest to the site are classified as either Group 2, 3, or 4. Group 2 relates to state-listed species; Group 3 relates to species or natural communities of concern to DNR, but with no official status; and Group 4 indicates buffered locations of bald eagle nests. None of these areas is located on the site.

*Figure 3-3 DNR Wetlands in the Site Vicinity*

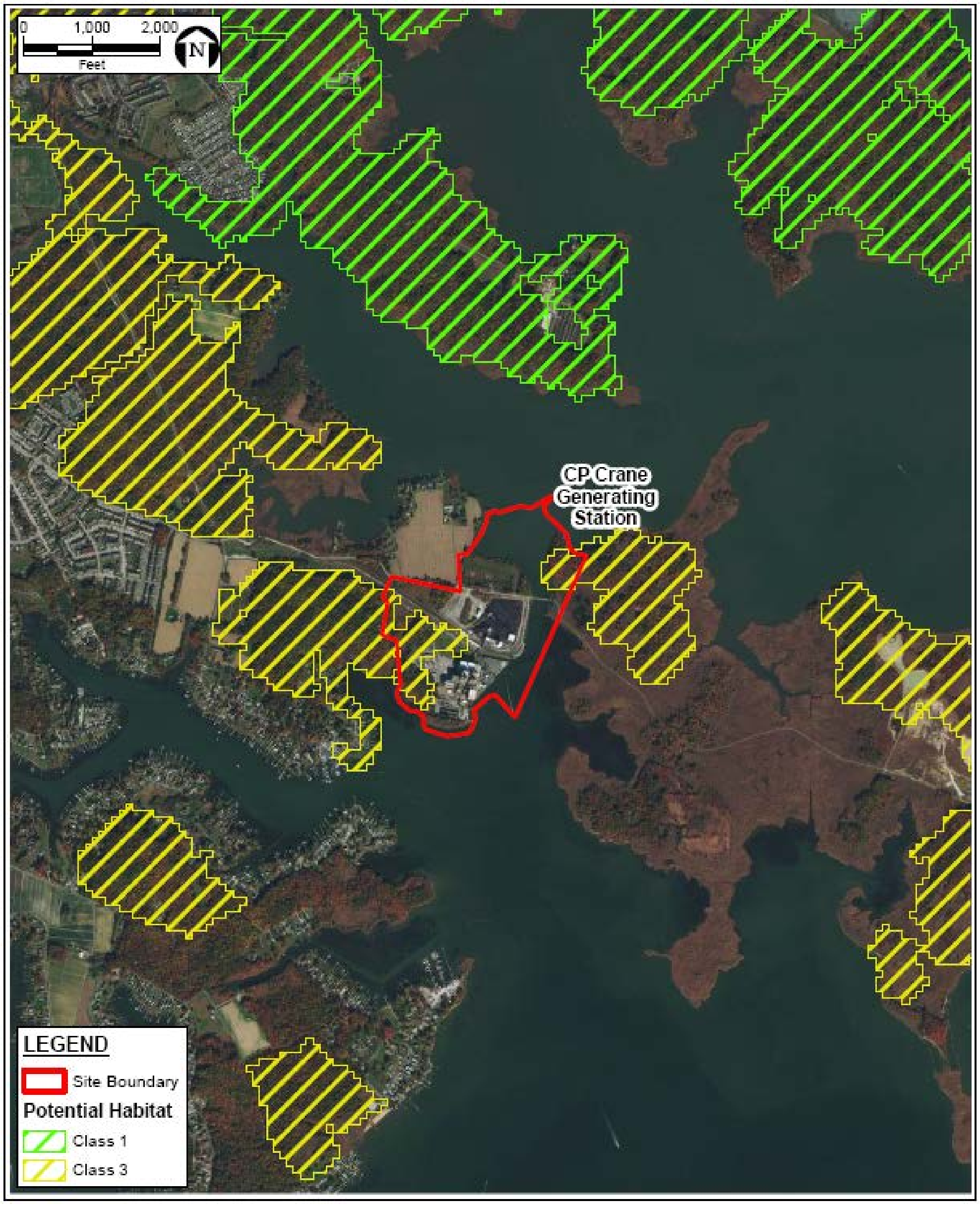

Source: CP Crane ERD, 2018

*Figure 3-4 NWI Wetlands in the Site Vicinity*


Source: CP Crane ERD, 2018

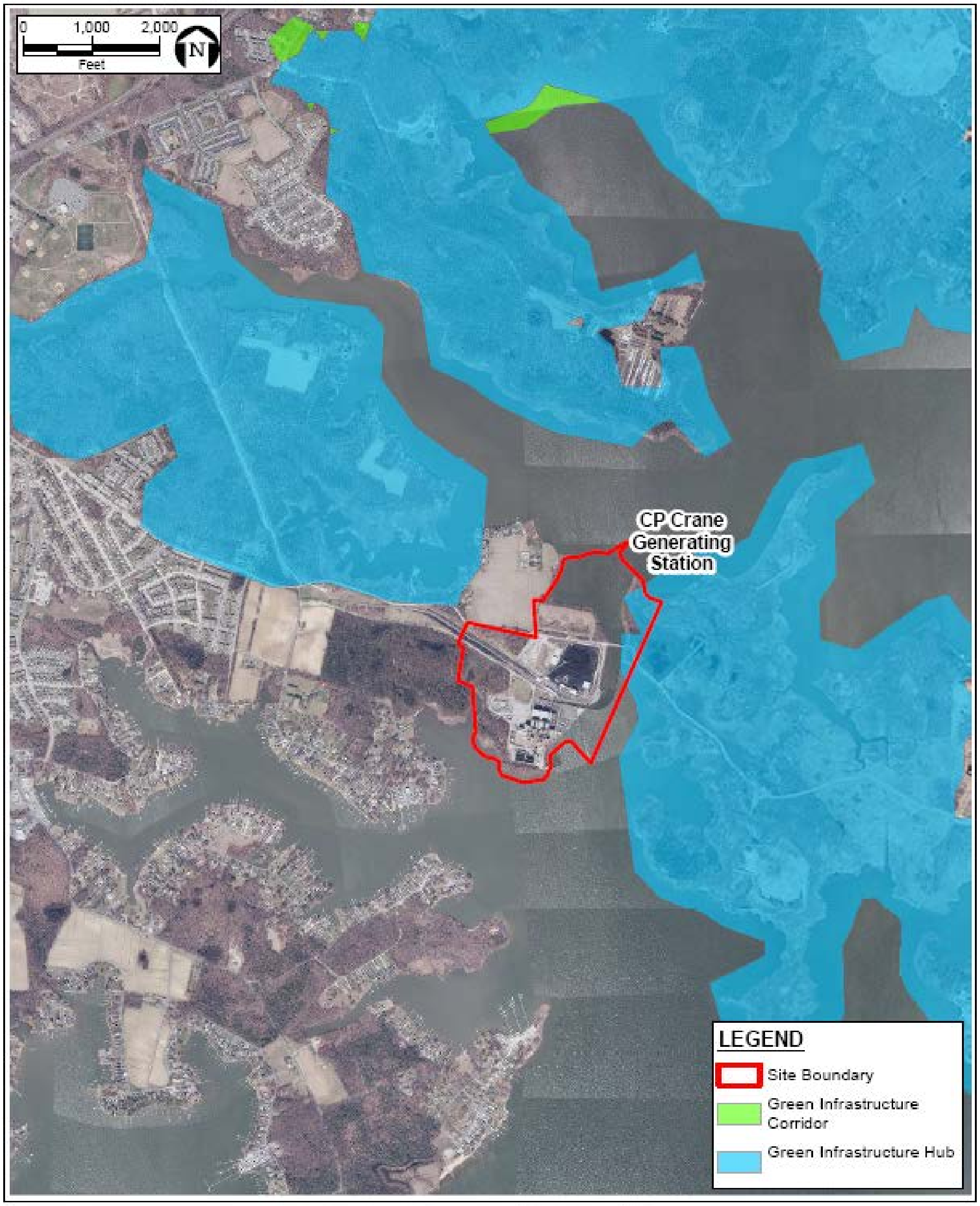
Potential habitat for FIDS and areas designated as green infrastructure were also obtained from the DNR. Figures 3-5 and 3-6 present this information.

*Figure 3-5 Forest Interior-Dwelling Species Potential Habitat in the Site Vicinity*




Source: CP Crane ERD, 2018

*Figure 3-6 Green Infrastructure in the Site Vicinity*

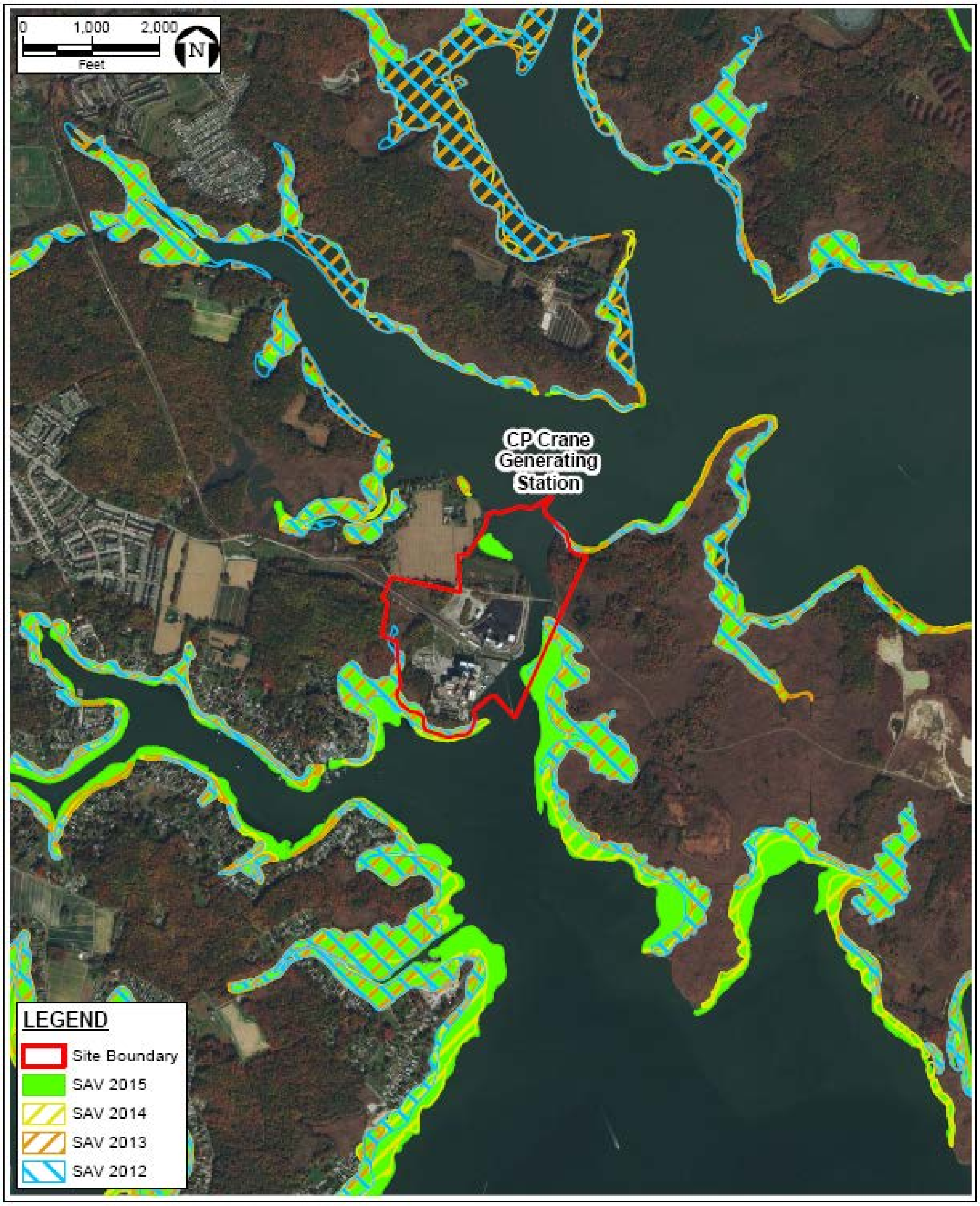



Source: CP Crane ERD, 2018

The Gunpowder River, including Seneca Creek, is an estuary with tidal characteristics. The average tidal range is approximately 1.4 ft with slightly higher spring tides. Estuarine systems consist of deep-water tidal wetlands and adjacent tidal wetlands. SAV is also established within this estuarine system (see Figure 3-7). The estuary supports numerous terrestrial and aquatic species. Terrestrial species include birds adapted to

urban environments, year-round and migratory fowl, raptors, mammals, reptiles, and amphibians. Aquatic species include zooplankton communities, benthic macroinvertebrates, and fish. For the latter, the Gunpowder River basin supports spawning and nursery areas for sport and commercial fish species.

*Figure 3-7 Submerged Aquatic Vegetation in the Site Vicinity*




Source: CP Crane ERD, 2018

### 3.5 *REGIONAL SOCIOECONOMIC SETTING*

#### 3.5.1 *Population Trends*

Baltimore County is Maryland's third most populous county. As of July 2017, the population of Baltimore County was 832,468, an increase of 3.4% over 2010 (MDP, 2018). Population is projected to grow 3.6% by 2030, to 862,200 (MDP, 2017).

#### 3.5.2 *Employment and Income*

The labor force in Baltimore County was estimated to be 453,926, with an unemployment rate of 4% in September 2018 (BLS, 2018). Baltimore County ranked second in Maryland in jobs by place of work (374,646 in 2017), with major employers accounting for more than 54,000 jobs. Major employers include Social Security Administration, University System of Maryland, Centers for Medicare and Medicaid Services, GBMC Healthcare, MedStar Franklin Square Medical Center, T. Row Price Group, and the Community College of Baltimore County (Baltimore County, undated).

Both the civilian and military branches of the federal government have a major presence in the county. Health care, professional and technical services, and finance and insurance industries have shown the largest job growth in Baltimore County, but manufacturing employment has declined, reflecting national trends. The county is projected to continue to experience positive employment growth, with employment projected to increase by 13,000 jobs by 2024.[2]

#### 3.5.3 *Land Use and Zoning*

The CP Crane site occupies approximately 157 acres adjacent to Seneca Creek in the Bowleys Quarters community. The Project will be constructed within an 88.4-acre parcel currently occupied by the retired coal units. Bowleys Quarters is within the Middle River Neck Peninsula extending northwest to Eastern Avenue and north to Carroll Island. The peninsula is bound by Frog Mortar Creek, Middle River, Chesapeake Bay,

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[2] https://www.baltimorecountymd.gov/Agencies/economicdev/meet-baltimore-county/stats-and-figures/econdev-statistics.html

Seneca Creek, and Saltpeter Creek. Bowleys Quarters has approximately 18 miles of shoreline, and approximately 85% of the community lies within the CBCA. The community is within the rural section Baltimore County's Urban Rural Demarcation Line (URDL), established in 1967. This concept was adopted to direct most employment, retail, and residential growth from the rural area by targeting public water and sewer infrastructure in the urban area.

Most of the land in Bowleys Quarters is zoned Rural Residential (RC-5), Resource Conservation Critical Area (RC-20), or Density Residential (DR-x). Water-based businesses are zoned Business Marine Boatyard (BMB) or Business Marine Marina (BMM).

The development pattern of Bowleys Quarters is one of waterfront homes, many originally constructed as summer residences (Baltimore County Council, 2001). Much of the interior of the peninsula is farmland or forested. Newer development is concentrated in the upper peninsula along Eastern Avenue, Carroll Island Road, and the east side of Bowleys Quarters Road at Seneca Garden Road. Residential development in these areas comprises both single-unit and multi-unit dwellings. Commercial development generally consists of restaurants, gas stations, and the Carroll Island Shopping Center, all concentrated on the upper peninsula. More than a dozen marinas are located on the rivers and creeks.

The CP Crane Generating Station is the only major industrial facility located in the community. Its 157 acres account for approximately 74% of the community's total industrial land use. Most of the remaining industrial land is at the intersection of Carroll Island Road and Bowleys Quarters Road. Overall, industrial lands comprise approximately eight percent of Bowleys Quarters. Land uses adjacent to the facility are forest along most of the site's western edge, with an agricultural/open space area at its northwest corner. Seneca Creek borders the station to the south and east, with Saltpeter Creek defining its northern boundary.

On July 9, 1957, the Zoning Commissioner of Baltimore County granted Baltimore Gas & Electric a special exception to the site's then-current zoning of R-6 to erect the original CP Crane facility. That decision was contested by a group of local landowners and the matter was brought before the Baltimore County Board of Appeals. The Board upheld the special exception and at the same time imposed the following conditions:

- This Special Exception shall apply only to the property petitioned for as amended by Petitioner's Exhibit #20;

- No more than four power producing units shall be constructed on the subject property;
- The temperature of the water at the point of expulsion in Saltpeter Creek shall at no time exceed 95 degrees Fahrenheit (°F);
- The requirements of the Maryland Water Pollution Control Law will at all times be met;
- An adequate sewage disposal plant shall be constructed and maintained;
- Bulkheading will be done where necessary to prevent erosion of neighboring property;
- Coal will be dumped within buildings only, and coal piles will be oiled when necessary to prevent leaching of sulfur, so as not to create acidity in the surrounding water; and
- No more than one shipment of coal per day per unit shall be received.

The land upon which the facility sits is currently zoned RC-5, a resource conservation zoning that provides for rural residential development in suitable areas where public water and sewer are not anticipated.

The Crane Station sits on land within the CBCA. The site is classified by Baltimore County as an Intensely Developed Area within the guidelines of the Chesapeake Bay Critical Area Act.

### 3.5.4 *Recreational, Scenic, and Cultural Sites*

Baltimore County retains significant cultural resources. More than 3,000 properties in the county, including county and National Register (NR) historic districts, are in the Maryland Inventory of Historic Places (MIHP). Several MIHP grids in the Bowleys Quarters peninsula indicate the potential presence of archeological resources, but are located outside the boundaries of the CP Crane site.

There are four MIHP-listed properties in Bowleys Quarters. The Scott-Andrew House (BA-1846) is unique in Baltimore County as a type of dwelling that characterized 18th century waterside tobacco plantations. The house stands on what was originally a 720-acre tract known as Scott's Improvement, recorded in 1725. The property was later divided and part now sits on the rail spur within the CP Crane property boundary. As noted in the MIHP inventory form, the historic orientation of the house toward Seneca Creek (and away from the CP Crane Generating Station)

has been compromised by the Seneca Park Beach subdivision on the waterfront.

The Mace-Luthardt House (BA-1847) is an undocumented property in the same vicinity of Seneca Park and the Scott-Andrew House. Bengies Community Center (BA-2823), located near the intersection of Eastern Avenue and Bowleys Quarter Road, is a former school dedicated to African-American students, probably erected in the late 19th or early 20th century. The property is not NR eligible. Bowleys Yacht Basin (BA-513) is a club house built in the early 20th century on land originally occupied by the Bowleys Quarters Ducking Club. The club reportedly entertained Presidents Grover Cleveland and Benjamin Harrison in the 19th century.

Historic properties of significance to Baltimore County are listed in the Baltimore County Landmarks List, which requires the Baltimore County Landmarks Preservation Commission to review and approve any proposal to change the exterior or demolish a listed structure. As of August 2018, the Baltimore County Council had placed 390 properties on the Landmarks List, including the Scott-Andrew House (Baltimore County, 2018).

Baltimore County has established 17 Historic Districts. Any exterior modification, addition, or demolition of a structure in a local historic district is subject to approval by the Baltimore County Landmarks Preservation Commission. Significantly, and in order to maintain the historical character of the district, the commission's authority within a local historic district extends to sites surrounding or adjoining a structure. There are no historic districts near the proposed Project.

There are nearly 350 properties on the National Register of Historic Places and 20 NR districts in Baltimore County. There are no NR properties in the Bowleys Quarters planning district. The closest NR District to Bowleys Quarters is the Dundalk National Register Historic District.

Although not on the MIHP, the Piney Grove United Methodist Church on Bowleys Quarters Road has been historically documented. Formed in 1874 after the Pennsylvania Railroad donated one acre of land to a congregation, the church was known as the Piney Grove Independent Evangelical Church until 1951. The original structure has since been replaced.

Baltimore County has 37 historically African-American communities, most of which are more than 100 years old and many of which were established and named by freed slaves (EHT Traceries, 2003). One of the county's top priorities is to improve basic services and infrastructure in these communities to retain their historical and cultural character. None of the nearby historically African-American communities of Chase, Hopewell Avenue, Back River Neck, or Goodwood is in Bowleys Quarters.

Baltimore County's scenic resources are among its many cultural resources. These resources consist of scenic corridors, scenic views, and gateways. Designation of scenic corridors or views is designed to inform development guidelines for protecting the county's scenic resources. Bowleys Quarters Road is identified as a County Scenic Route in Master Plan 2020, as are scenic views on the Chesapeake Bay from the shoreline of the peninsula, along Bay Road and from Miami Beach Park, and over the Middle River from Seneca Pointe. The closest designated Scenic Gateway leads to Rocky Point Park (Baltimore County Council, 2010).

The CP Crane site is within the Baltimore County Coastal Rural Legacy Area. Running from the Gunpowder River to the North Point State Park, it includes the highest concentration of forest and agricultural lands and fresh and tidal wetlands in Baltimore County. Baltimore County's Coastal Rural Legacy Plan seeks to protect large blocks of forest, wetlands, farms, and other open spaces having significant ecological value. There are two Rural Legacy land preservation easements flanking the CP Crane site to the west.

There is one county owned park in the Bowleys Quarters peninsula, Miami Beach Park, off Bowleys Quarters Road and Bay Drive, which is south of the CP Crane site and separated from it by Seneca Creek. The waterfront park contains 59 acres of trails, playgrounds, and picnic areas, plus restrooms and a pavilion. Just outside of Bowleys Quarters, the Marshy Point Nature Center is just north of the facility across Saltpeter Creek. A 492-acre park, the nature center is one of the newest facilities of the Baltimore County Department of Recreation and Parks, and offers trails and water-based recreation options in addition to an exhibit hall and outdoor decks for picnicking. Gunpowder Falls State Park is adjacent to the Marshy Point Nature Center across Dundee Creek. Near its junction with the Amtrak mainline, the rail spur to the CP Crane site traverses the 122-acre Eastern Regional Park at the tidal inlets of Saltpeter Creek in the vicinity of Eastern Avenue. The park has picnic facilities, a playground,

sport fields, trails, and a 9,000-square foot community center. The Aberdeen Proving Ground, a federal facility on Carroll Island, sits across from the CP Crane Generating Station.

### 3.5.5 *Public Services and Safety*

The Baltimore County water supply system is an extension of Baltimore City's metropolitan system. There are thirteen water service zones. Commerce and industry account for about 30 percent of water consumption in the county (Baltimore County Council, 2010). The county operates its own sewer system, but most sewage is treated at two Baltimore City waste water treatment plants. A new 120 million gallons per day (gpd) Fullerton water treatment facility is under construction. Located northeast of Baltimore City, construction began on February 1, 2017 and is expected to be completed by April or May 2020[3]. Although public water and sewer are generally limited to areas within the URDL, services have been extended to Bowleys Quarters to address pollution of Seneca Creek and Frogs Neck Creek from failing septic systems. The CP Crane Generating Station is serviced by public water and sewer. For solid waste, Baltimore County operates the Eastern Sanitary Landfill Solid Waste Management Facility, which includes a transfer station, composting operation, and recycling center. An additional 2,250 tons per day of municipal solid waste is processed by the Wheelabrator Baltimore waste-to-energy facility (Baltimore County Council, 2010).

Bowleys Quarters is in the Precinct 11 (Essex) service area of the Baltimore County Police Department. Fire and emergency medical services are handled by the Baltimore County Fire Department and Volunteer Firemen's Association. Bowleys Quarters is served by the Bowleys Quarters Volunteer Fire Company, located on Bowleys Quarters Road. The company maintains two engines and has a Marine Emergency Team for open water rescues on the Chesapeake Bay.

Education in Baltimore County is administered by the Baltimore County Board of Education. Bowleys Quarters is in the Southeast administrative area and is served by the Chase Elementary School on Eastern Avenue,

[3] http://www.wadekach.com/baltimore-county-council-agendas/baltimore-county-council-agenda-ws-may-15-2018-ls-may-24-2018/

the Middle River Middle School on Middle River Road, and Chesapeake High School on Turkey Point Road.

### *3.5.6 Transportation*

Road access to the CP Crane site is via Carroll Island Road, which intersects Eastern Avenue (MD 150), less than two miles to the northwest. Eastern Avenue connects with US 40, I-695 and other regional highways. The road has three marked lanes at its intersection with Carroll Island Road, with spurs leading to and from the minor road. The "T" intersection is signalized and the posted speed limit is 40 mph. The Bowleys Quarters Community Action Plan 2000 notes that the intersection is potentially dangerous because of traffic entering and leaving two fast food restaurants, a drive-in theatre, and service stations, creating hazardous conditions. A traffic study was performed in 1999 and the intersection was found to perform a Level-of-Service "A", meaning that the average overall wait time for a vehicle to pass through the intersection is ten seconds or less. There is additional congestion, particularly at peak hours, at the signalized intersection of Carroll Island Road and Bowleys Quarters Road due to left turns into the Carroll Island Shopping Center (Baltimore County Council, 2001).

Until retired in June 2018, the main generating units at the plant were two coal-fired units. While operating, coal was delivered by rail along a dedicated spur off Amtrak's Northeast Corridor. The spur is approximately 8,300 feet long, running from a mainline switch in the Chase manor section of Middle River to the site boundary at Carroll Island Road.

## *3.6 NOISE*

This licensing review incorporates an evaluation of noise impacts to ensure compliance with State noise regulations. The analysis of potential noise impacts focuses on the potential for sound pressure from generating equipment to exceed numerical limitations at the nearby noise sensitive areas.

### *3.6.1 Definition of Noise*

Noise generally consists of many frequency constituents of varying loudness. Three decibels (dB) is approximately the smallest change in

sound intensity that can be detected by the human ear. A tenfold increase in the intensity of sound is expressed by an additional 10 units on the dB scale, a 100-fold increase by an additional 20 dB. Because the sensitivity of the human ear varies according to the frequency of sound, a weighted noise scale is used to determine impacts of noise on humans. This A-weighted decibel (dBA) scale weights the various components of noise based on the response of the human ear. For example, the ear perceives middle frequencies better than low or very high frequencies; therefore, noise composed predominantly of the middle frequencies is assigned a higher loudness value on the dBA scale. Subjectively, a tenfold increase in sound intensity (10 dB increase) is perceived as an approximate doubling of sound. Typical A-weighted sound levels for various noise sources are shown in Table 3-1.

***Table 3-1 Typical Sound Levels for Common Sources***

| Noise Source | Typical Sound Pressure Level (dBA) |
|---|---|
| Lowest sound audible to human ear | 10 |
| Soft whisper in a quiet library | 30-40 |
| Light traffic, refrigerator motor, gentle breeze | 50 |
| Air conditioner at 6 meters, conversation | 60 |
| Busy traffic, noisy restaurant, freight train moving 30 mph at 30 meters | 70 |
| Subway, heavy city traffic, factory noise | 80 |
| Truck traffic, boiler room, lawnmower | 90 |
| Chain saw, pneumatic drill | 100 |
| Rock concert in front of speakers, sand blasting, thunder clap | 120 |
| Gunshot, jet plane | 140 |

Noise monitoring is typically conducted continuously over a period of time to obtain a representative picture of the acoustic environment. The length of time required for noise monitoring, and the frequency of individual measurements, will vary depending upon a number of factors, including surrounding land use, time of day, the purpose of noise monitoring, the number of locations at which sound levels are being measured, and the capabilities of the monitoring equipment being used.

Ambient sound pressure levels can also be expressed in various ways. Quite often, noise levels are measured or reported as equivalent sound levels, $L_{eq}$, over a given time period. A one-hour $L_{eq}$, for instance, is the constant sound level that has the same energy content as the actual sound variations over a one-hour monitoring period.

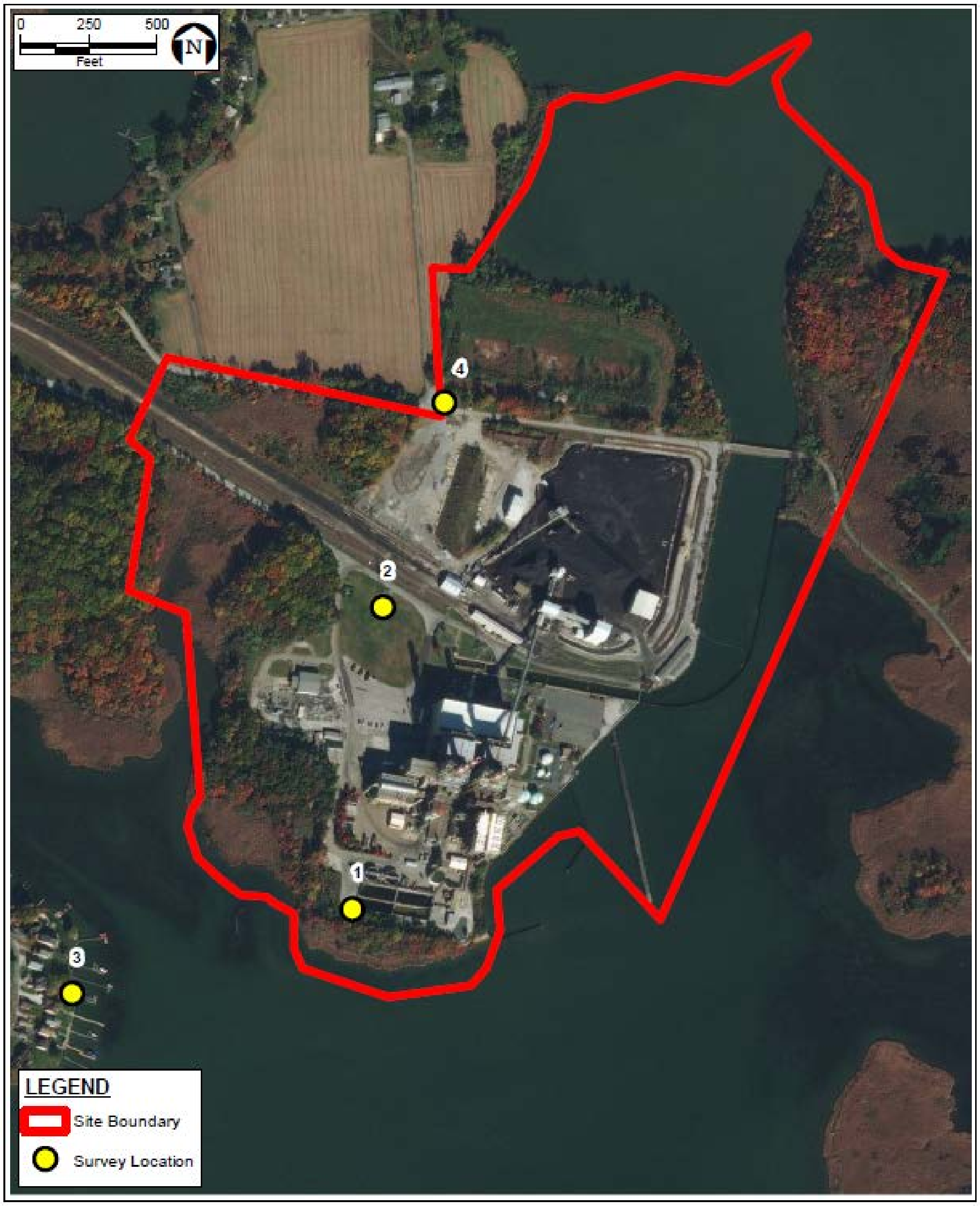
Sound energy dissipates with increasing distance from the noise source. For every doubling of the distance, the sound pressure level produced by a given noise source decreases by approximately 6 dBA.

### *3.6.2 Existing Noise Levels*

CP Crane conducted ambient noise surveys in January and April 2018 to characterize the existing acoustic environment in the area. The Applicant measured background noise at two locations on the site property (Locations 1 and 2) and two offsite locations (Locations 3 and 4). Locations 1 and 2 are within the property boundary to the south and north, respectively, of the proposed Project location. Location 3 is to the southwest of the site, in the nearest residential neighborhood. Location 4 is at the northern property boundary of the site.

The sample locations for the survey are shown in Figure 3-8. Sound levels were measured for short periods of time, less than one hour, between 10:30 and 17:50 over a two-day period.

*Figure 3-8 CP Crane Noise Monitoring Locations*




Source: CP Crane ERD, 2018

At Location 3, which is located in the nearest residential neighborhood, the highest $L_{eq}$ was measured at 49.1 dBA. During both sampling days, noise from the CP Crane Generating Station was stated as the predominant noise source. Table 3-2 summarizes the maximum $L_{eq}$ measured at each of the four monitoring locations.

*Table 3-2 Maximum $L_{eq}$ Sound Levels at Noise Monitoring Locations*

| Location | Maximum $L_{eq}$ (dBA) |
|---|---|
| 1 | 60.4 |
| 2 | 60.3 |
| 3 | 49.1 |
| 4 | 52.6 |

# 4.0 AIR QUALITY IMPACTS

## 4.1 AIR QUALITY IMPACT ASSESSMENT BACKGROUND AND METHODOLOGY

### 4.1.1 Overview

As part of the CPCN Application process, PPRP, in conjunction with the Maryland Department of the Environment Air and Radiation Administration (MDE-ARA), evaluates potential impacts to air quality resulting from proposed projects to be licensed in Maryland under COMAR 20.79. This evaluation includes emissions investigations and other studies, including air dispersion modeling assessments, to ensure that impacts to air quality from proposed projects are acceptable. PPRP and MDE-ARA also conduct a complete air quality regulatory review for two purposes: 1) to assist in the impact assessment, since air quality regulatory standards and emissions limitations define levels to protect against adverse health, welfare, and environmental effects, and 2) to ensure that the proposed Project will meet all applicable regulatory requirements.

For this proposed Project, MDE-ARA conducted an air quality evaluation of the proposed CP Crane Repowering Project to confirm that projected maximum potential air emissions would meet applicable regulatory thresholds and limits. The proposed Project was evaluated to determine whether emissions from the Project would have significant impacts on the existing ambient air quality in the region. MDE-ARA assessed the effects on current ambient air quality by performing air dispersion modeling analyses to predict the future ambient air concentrations resulting from emissions from the proposed Project.

### 4.1.2 Regulatory Considerations

EPA defines concentration-based NAAQS for several pollutants, which are set at levels considered to protect public health and welfare. Specifically, EPA defined the NAAQS for six "criteria" pollutants, including PM, $SO_2$, CO, $NO_2$, $O_3$, and Pb. Two forms of PM (or "total particulates") have specific NAAQS: particulate matter less than 10 microns ($PM_{10}$), and particulate matter less than 2.5 microns ($PM_{2.5}$).

Air emissions limitations and pollution control requirements are generally more stringent for sources located in areas that do not currently meet a NAAQS for a particular pollutant. Areas not meeting a NAAQS for a

pollutant are designated as "nonattainment areas", and areas achieving the NAAQS are known as "attainment areas".

Baltimore County, the location for the proposed CP Crane Repowering Project, is currently designated as attainment for NOx, CO, PM, and Pb. All of Baltimore County is designated non-attainment for ozone. Since ozone is a warm weather pollutant, Baltimore County has historically experienced high ozone concentrations during the ozone season (March – September). Baltimore County is part of the Baltimore Ozone Non-Attainment Area and has been designated as "Marginal" for the 8-hour ozone NAAQS. Emissions of the two pollutants that contribute to the formation of ozone, volatile organic compounds (VOCs) and $NO_X$, are regulated more stringently in ozone nonattainment areas such as Baltimore County to ensure that air quality is not further degraded (i.e., the ambient air concentration of ozone does not continue to increase as new sources of ozone forming pollutant emissions are constructed).

the EPA, in June 2016, redesignated a portion of Baltimore County to be non-attainment for the 1-hour NAAQS for $SO_2$. The $SO_2$ non-attainment area extends 26.8 kilometers from the HA Wagner Generating Station Unit 3 stack in Anne Arundel County and encompasses the CP Crane site. Also, it should be noted that EPA has changed the air quality designation of Baltimore County with respect to $PM_{2.5}$ NAAQS from nonattainment to attainment. Specifically, on October 6, 2014, EPA issued a final rule re-designating the Baltimore metropolitan area (which includes Baltimore County) to attainment for the 1997 annual $PM_{2.5}$ NAAQS. The EPA final rule became effective on November 5, 2014.

Potential emissions from new and modified sources in nonattainment areas are evaluated through the nonattainment new source review (NA-NSR) regulatory program. Major new and modified sources in designated nonattainment areas of Maryland must meet the regulatory requirements of COMAR 26.11.17. The goal of the NA-NSR program is to allow construction of new emission sources and modifications to existing sources, while ensuring that progress is made towards meeting, or attaining, the NAAQS. NA-NSR requires major sources to limit emissions of affected pollutants through the implementation of the most stringent levels of pollution control, known as Lowest Achievable Emission Rate (LAER).

Potential emissions from new and modified sources located in attainment areas are evaluated through the Prevention of Significant Deterioration (PSD) program. The goal of the PSD program is to ensure that emissions from major sources do not degrade air quality in areas that currently meet

NAAQS. Triggering PSD requires use of the Best Available Control Technology (BACT) and requires affected sources to evaluate impacts usually through dispersion modeling analysis.

Activities associated with the proposed Project have the potential to emit the following regulated pollutants: PM, $PM_{10}$, $PM_{2.5}$, CO, $NO_X$ (nitrogen oxide (NO) and $NO_2$), $SO_2$, sulfuric acid mist (SAM), Pb, ozone precursors (VOC and $NO_X$), greenhouse gases (GHGs) expressed as carbon dioxide equivalent ($CO_2e$), and hazardous air pollutants (HAPs). The potential emissions associated with the Project are discussed in Section 4.3. An applicability determination pertaining to major New Source Review regulations is discussed in Section 4.4.

Other federal and state air quality regulations also apply to the Project. These regulations apply because of either the type of emission source constructed or the pollutants that are emitted. These regulations, discussed in Sections 4.5.1 and 4.5.2, specify pollutant emissions limitations and provides details regarding notification, monitoring, testing, recordkeeping, and reporting requirements.

## *4.2 PROPOSED PROJECT SOURCE CHARACTERIZATION*

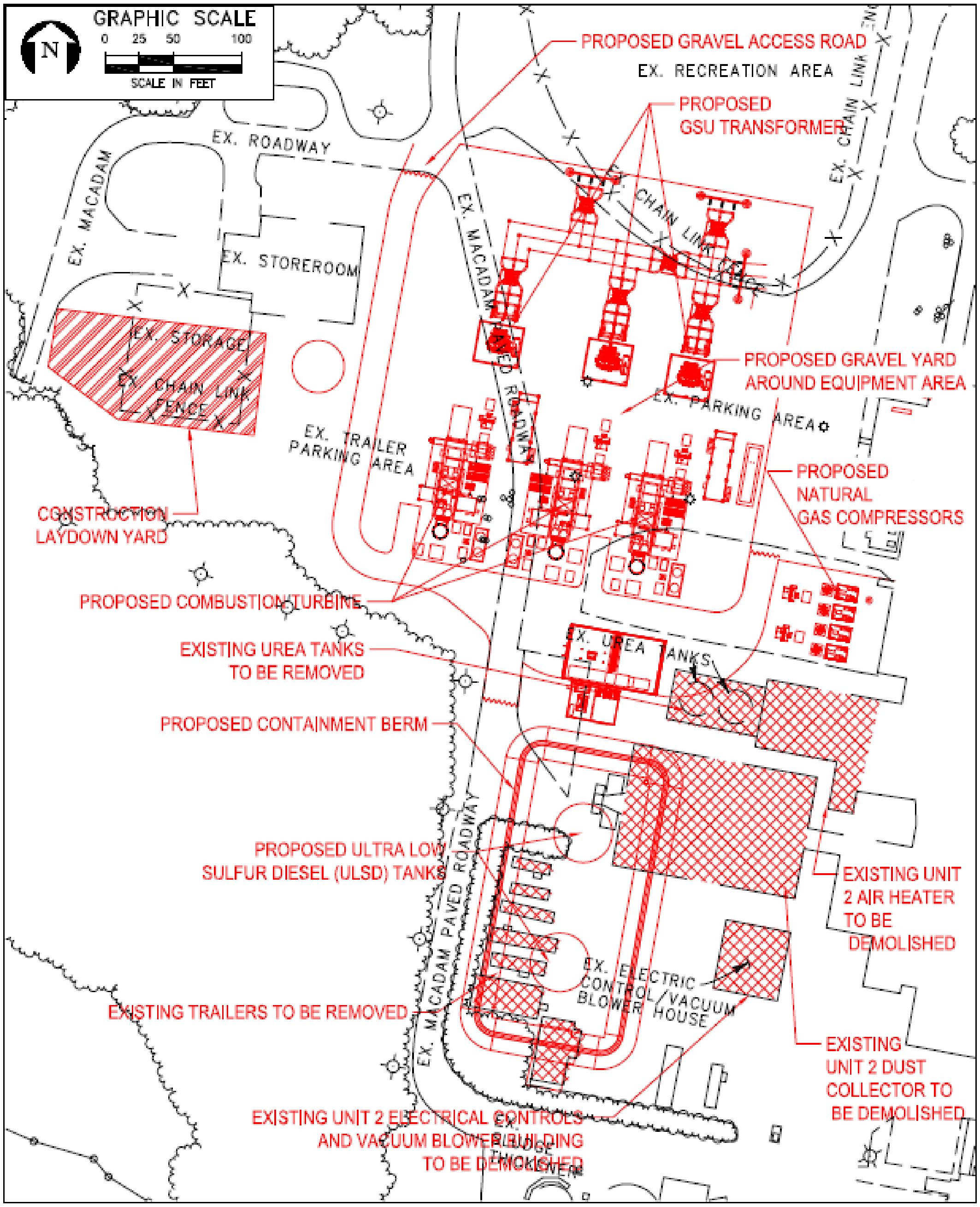
The proposed CP Crane Repowering Project involves the permanent shutdown of the coal-fired units (Unit 1 and Unit 2) and replaces them with three refurbished GE aero-derivative LM6000 CTs fired primarily with natural gas and with ULSD as backup. Table 4-1 provides a summary of the new emissions sources under review.

*Table 4-1 CP Crane Project Air Emissions Sources*

| Component (Number of Units) | Type/Model | Rated Capacity of Each Unit | Fuel | Maximum Allowable Operations |
|---|---|---|---|---|
| Combustion Turbines (3) | GE LM6000PC | 50 MW (nominal) | Natural gas<br>No. 2 oil backup | 2,365 hours/year per CT |
| Black Start Generator | Tier 1/Cummins Model KTA50G9 | 1,500 kW | ULSD | 100 hours/year for maintenance and testing |

Figure 4-1 depicts a detailed arrangement of the primary equipment associated with the Repowering Project.

*Figure 4-1 CP Crane Project Equipment Arrangement*




While the total generating capacity of the proposed Repowering Project will be less than the original coal fired power plant, the generating units will provide the PJM Interconnection, Inc. (PJM) system with additional and efficient generating flexibility, load changing capacity, and fast startup capability. Specifically, the CTs are expected to serve as peaking units and operate up to a 27% annual capacity factor or 2,365 hours per year. In addition, the aero-derivative design of the CTs will allow them to

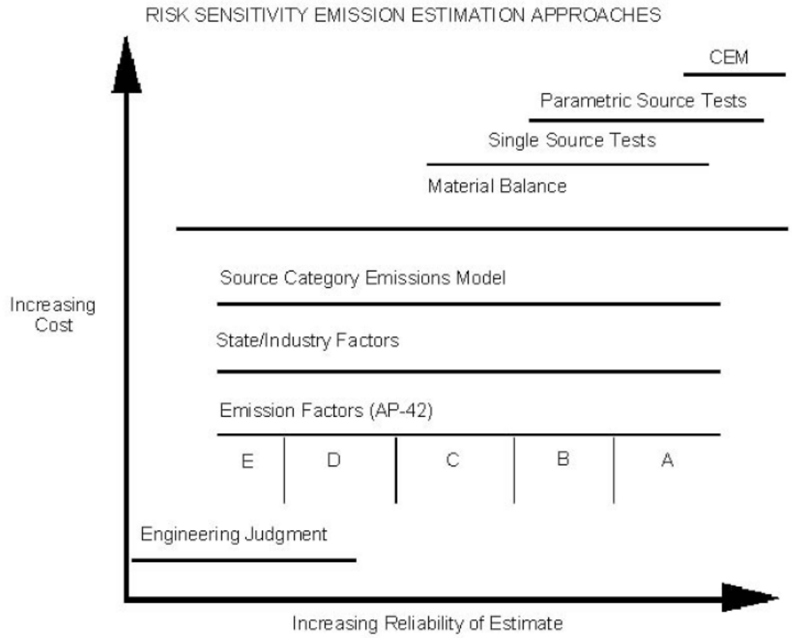
start up and reach full load in 10 minutes or less and shut down quickly numerous times a day if circumstances warrant.

The proposed Project will also include one new 1,500-kW black start generator that will be used to provide startup capability for the CTs when there is no electricity on the power grid. The black start generator will not be used to produce electricity for the grid and will be restricted to operating 100 hours per year for routine maintenance and testing. The black start generator will combust ULSD fuel exclusively.

CP Crane provided background information in the CPCN Application on the methods used to calculate potential emissions for the Project. MDE-ARA independently calculated emissions from the proposed modification Project, with results of this analysis summarized in Section 4.3. The State based its evaluation of emissions on the recommended hierarchy of emission factors discussed in EPA's Compilation of Air Pollutant Emission Factors (AP-42) introduction document[4] as shown in Figure 4-2. Potential emissions from the Project were estimated using vendor data, AP-42 emission factors, material balance calculations, New Source Performance Standards (NSPS) emission standards, and/or engineering calculations. MDE-ARA is generally in agreement with the methodologies adopted by CP Crane to determine emissions for the proposed Project.

[4] USEPA, 1995. Introduction to AP-42, Volume I, Fifth Edition. January 1995

*Figure 4-2 Recommended Approach to Estimating Emissions*




## 4.3 PROJECT AIR EMISSIONS

### 4.3.1 Combustion Turbines

CP Crane has selected ProEnergy Services (ProEnergy) as the vendor to refurbish the CTs in a manner that will comply with all applicable federal and State emission standards. Potential emissions for most pollutants emitted by the refurbished GE LM6000 CTs are based on vendor specifications provided by ProEnergy as included in CP Crane's August 31, 2018 Supplemental Filing to its CPCN Application. The CTs are designed to operate during periods of peak load or system outages up to a 27% annual capacity factor or 2,365 hours per year.

ProEnergy provided vendor specifications for 21 operational cases each for natural gas and No. 2 fuel oil combustion. The scenarios represent a combination of different ambient temperatures (°F) and operational loads (MW). These 42 operational cases include predicted emissions resulting from operating the CTs at various loads.

The concentration based turbine emissions, in parts per million (ppm), for $NO_X$, CO, PM, $SO_2$, and VOC were based on guarantees provided to CP Crane by ProEnergy. CP Crane based the short-term (lb/hr) emission

rates for $NO_X$, CO, PM, $SO_2$, and VOC on the ppm limit for each pollutant, and short term (lb/hr) lead emissions on an emissions factor from AP-42. The short-term emission rates for the CTs were calculated for each of the different operational cases to determine the worst-case short-term (lb/hr) emissions rate for each pollutant for any normal operational case. The worst-case short-term emissions rates for each fuel type are presented in Table 4-2.

The vendor specification for the CTs also included emissions rates for GHGs. GHGs are defined by EPA to include carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), sulfur hexafluoride ($SF_6$), hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs), perfluorocarbons (PFCs), and other fluorinated greenhouse gases[5]. For the proposed CTs the total GHG emissions are calculated as the sum of $CO_2$, $CH_4$, and $N_2O$, expressed as $CO_2e$. Each GHG pollutant has a varying potential to contribute to global warming, which is expressed in terms of a global warming potential (GWP). The GWP potential for $CO_2$ is 1, $CH_4$ is 25, and $N_2O$ is 298. CP Crane calculated projected GHG emissions from the CTs using emission factors from EPA's Mandatory GHG Reporting Rule for combustion sources codified at 40 CFR Part 98 Subpart C. The heat inputs for the CTs provided on the vendor specification sheets, along with the GHG Reporting Rule emission factors were used to calculate short-term (lb/hr) emission rates.

[5] USEPA, 2010. 40 CFR Part 98, 74 FR 16621

*Table 4-2 CT Short Term Emission Rates*

| Pollutant | Maximum Emissions Rate (lb/hr) | |
|---|---|---|
| | **Natural Gas** | **ULSD** |
| $NO_X$ | 44.73 | 75.07 |
| CO | 35.15 | 41.19 |
| VOC | 3.46 | 6.43 |
| PM # | 5.10 | 15.51 |
| $PM_{10}$ | 5.10 | 15.51 |
| $PM_{2.5}$ | 5.10 | 15.51 |
| $SO_2$ | 0.68 | 0.72 |
| Lead | 0.0002* | 0.0067" |
| $H_2SO_4$ | 0.10 | 0.11 |
| $CO_2e$ | 54,224 | 74,930 |

# All particulate matter is considered $PM_{2.5}$.
* Based on AP-42 Table 1.4-2 (EPA, 1998)
" Based on AP -42 Table 3.1-5 (EPA, 2000)
Source: ProEnergy, Performance Data, 2018. ECT, 2018

The aero-derivative design of the proposed CTs allow the units to achieve full load within 10 minutes and quickly shutdown within 8 minutes should circumstances warrant. CP Crane has assumed a maximum of 250 startups per year, including 25 startups using ULSD. Table 4-3 provides a summary of emissions associated with a typical startup/shutdown event when burning natural gas or ULSD fuel.

*Table 4-3 CT Startup/Shutdown Emissions Per Unit*

| Scenario | $NO_X$ (lb per event) | CO (lb per event) | VOC (lb per event) | Duration (minutes) |
|---|---|---|---|---|
| Natural Gas | | | | |
| Startup | 3.6 | 3.2 | 0.5 | 10 |
| Shutdown | 3.1 | 2.5 | 0.33 | 8 |
| ULSD | | | | |
| Startup | 12.8 | 11.6 | 0.4 | 10 |
| Shutdown | 10.9 | 9.9 | 0.4 | 8 |

Sources: ProEnergy, 2018; ECT, 2018

### 4.3.2 *Black Start Generator*

The 1500 kW black start generator will be used to provide startup capability for the proposed CTs when there is no electricity on the power grid. The black start generator will not be used to produce electricity for

the grid and will be restricted to operating 100 hours per year for routine maintenance and testing. As such, the projected emissions of $NO_X$ and other criteria pollutants are minimal and summarized in Table 4-4. The black start generators will combust ULSD fuel exclusively.

*Table 4-4 Black Start Generator Annual Emissions (tpy)*

| Unit | $NO_X$ | CO | VOC | PM | $CO_2e$ |
|---|---|---|---|---|---|
| Generator | 1.52 | 1.88 | 1.21 | 0.09 | 115.16 |

### 4.3.3 *HAP Emissions*

In addition to criteria pollutants, CP Crane presented estimated HAP emissions for the proposed Project. The Clean Air Act (CAA) major source thresholds for HAPs are 25 tons per year (tpy) for total HAPs and 10 tpy for any individual HAP. The potential annual HAP emissions associated with the Project are 1.82 tpy for total HAPs and 1.15 tpy for largest individual HAP (formaldehyde). Because the potential HAP emissions are below the applicable CAA emission threshold, the facility is classified as an area source of HAPs.

### 4.3.4 *Toxic Air Pollutant Emissions*

Toxic air pollutants (TAPs) are those pollutants that are known or suspected to cause serious health problems. TAPs are regulated by Maryland under COMAR 26.11.15 and 16 and are divided into two categories—Class I and Class II. Class I TAPs are known as potential carcinogens specifically identified in COMAR 26.11.16.06. Class II TAPs include all other chemical compounds that have other potential acute or chronic health effects.

The Maryland TAP regulations include provisions for exempting sources with low levels of TAP emissions. Further, certain types of sources, such as fuel burning equipment, are specifically exempt from the TAP regulations in accordance with COMAR 26.11.15.03B. As the CTs and black start generator are fuel burning equipment, they are not subject to TAP regulation and thus a TAPs evaluation is not required for the proposed modification.

### 4.3.5 *Greenhouse Gases*

Potential GHG emissions were estimated for all fuel burning equipment associated with the proposed Project. The emissions factors and

methodology were obtained from 40 CFR Part 98. The GHG emissions on a $CO_2e$ basis are summarized in Table 4-5 in Section 4.4.

## *4.4 NEW SOURCE REVIEW*

### *4.4.1 Applicability Evaluation*

Potential emissions from new and modified sources in nonattainment areas are evaluated through the NA-NSR regulatory program. Major new and modified sources located in areas designated as non-attainment in Maryland must meet the regulatory requirements of COMAR 26.11.17. The goal of the NA-NSR program is to allow construction of new emissions sources and modifications to existing sources, while ensuring that progress is made towards meeting, or attaining, the NAAQS.

Potential emissions from new and modified sources located in attainment areas are evaluated through the PSD program. The goal of the PSD program is to ensure that emissions from major sources do not degrade air quality in areas that currently meet NAAQS. Triggering PSD requires use of the BACT and requires affected sources to evaluate impacts, usually through dispersion modeling analysis.

Applicability of the NA-NSR and/or PSD programs for the proposed modification is determined by evaluating whether there is a "significant net emissions increase" of each PSD/NA-NSR regulated pollutant that could potentially be emitted by emissions units associated with the proposed Project. As the three (3) CTs and one (1) black start generator were the only emissions units to be installed as part of the Project, these were the only emission units evaluated for PSD applicability.

As discussed in Section 3.1.2 of this document, the Project is located in an attainment area for all criteria pollutants except ozone and $SO_2$. Therefore, project related NSR regulated pollutant emissions will be evaluated for NSR applicability for both PSD and NA-NSR. As an existing major stationary source, the proposed changes were evaluated to determine if they were considered a major modification. A major modification is a physical change or a change in the method of operation of a major stationary source that would result in a significant emissions increase of a regulated NSR pollutant (Step 1) and a significant net emissions increase of that pollutant (Step 2) from the major stationary source. An emissions increase is considered significant for a regulated pollutant if it exceeds the applicable Significant Emissions Rate (SER). The potential emissions for the Project and NSR applicability thresholds are presented in Table 4-5.

*Table 4-5 Projected Maximum Annual Emissions and Comparison to the Significant Emission Rate*

| Pollutant | Percent Load | Emissions for Three Turbines (tpy) | Emissions for Black-start Generator (tpy) | Project Total (tpy) | SER (tpy) | Netting Required |
|---|---|---|---|---|---|---|
| $NO_X$ | 100 | 169.93 | 1.52 | 171.45 | 25 | Yes |
| CO | 75 | 127.08 | 1.88 | 128.96 | 100 | Yes |
| VOC | 50 | 13.38 | 0.21 | 13.59 | 25 | No |
| PM | 100 | 21.82 | 0.09 | 21.91 | 25 | No |
| $PM_{10}$ | 100 | 21.82 | 0.09 | 21.91 | 15 | Yes |
| $PM_{2.5}$ | 100 | 21.82 | 0.09 | 21.91 | 10 | Yes |
| $SO_2$ | 100 | 2.44 | 1.22E-03 | 2.44 | 40 | No |
| $H_2SO_4$ | 100 | 3.73E-01 | 9.34E-05 | 3.73-01 | 7 | No |
| Lead | 100 | 3.23E-03 | --- | 3.23E-03 | 0.6 | No |
| $CO_2e$ | 100 | 200,060 | 115.16 | 200,175 | 75,000 | Yes |

Note: All pollutants assume normal operation, burning natural gas at 90 percent; ULSD fuel oil at 10 percent; and inclusive of startup/showdown.
Sources: ProEnergy, 2018; CP Crane, 2018; ECT, 2018

The proposed Project Results in a significant emissions increase in $NO_X$, CO, $PM_{10}$, $PM_{2.5}$, and GHGs. For those NSR regulated pollutants exceeding the SER, the Applicant has the option to conduct a netting analysis in order to avoid NSR. In Step 2 of the analysis, the net emissions increases from the Project were calculated for the five pollutants for which the Project resulted in emissions increases that exceeded the SER. The actual emissions decrease from the removal of the existing coal fired units were evaluated to determine if there would be a significant net emissions increase associated with the project. In accordance with COMAR 26.11.17.01, CP Crane established actual baseline pollutant emissions for Units 1 and 2 based on a consecutive 24 month period beginning June 2013 and concluding May 2015. Those emissions are summarized in Table 4-6.

*Table 4-6 Units 1 and 2 Baseline Actual Emissions (BAE) (tpy)*

| Parameter | $NO_X$ | CO | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|
| Baseline Actual Emissions | 1,235.03 | 131.83 | 82.87 | 35.87 | 776,674 |

Sources: ProEnergy, 2018; CP Crane, 2018; ECT, 2018

As there were no other contemporaneous changes that occurred at CP Crane in addition to the shutdown of Units 1 and 2, the netting analysis shown in Table 4-7 demonstrates that the projected emissions associated with the Project will not result in a significant net emissions increase for any NSR regulated pollutant. Consequently, the Repowering Project is not subject to NSR.

*Table 4-7 Project Net Emissions*

| Description | $NO_X$ | CO | $PM_{10}$ | $PM_{2.5}$ | $CO_2e$ |
|---|---|---|---|---|---|
| Project Emissions Increase (tpy) | 171.45 | 128.96 | 21.91 | 21.91 | 200,175 |
| Units 1 and 2 Baseline Actual Emissions Decrease (tpy) | 1235.03 | 131.83 | 82.87 | 35.87 | 776,674 |
| Other Contemporaneous Emissions (tpy) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Net emissions increases/decreases (tpy)** | **-1,063.57** | **-2.87** | **-60.95** | **-13.95** | **-576,499** |
| NSR SERs (tpy) | 25 | 100 | 15 | 10 | 75,000 |
| **Major Modifications (Yes/No)** | **No** | **No** | **No** | **No** | **No** |

### 4.4.2 *Air Quality Modeling Analysis*

#### 4.4.2.1 *Introduction*

As part of the CPCN Application process, MDE-ARA evaluated potential impacts to air quality resulting from proposed project to be licensed in Maryland under COMAR 20.79. This evaluation included dispersion modeling assessments, to ensure that impacts to air quality from proposed projects are acceptable.

As part of the air application for a CPCN, CP Crane submitted an air dispersion modeling analysis for the proposed Repowering Project. Dispersion modeling files were initially submitted to PPRP and MDE-ARA as part of CP Crane's initial and supplement CPCN Application. MDE-ARA as part of its assessment have reviewed the emission calculations and all model input parameter selections. In addition, MDE-ARA performed an independent modeling analysis, following the guidance found in Appendix W to 40 CFR Part 51 (The Guideline on Air Quality Models), published January 17, 2017 in the Federal Register.

The purpose of the modeling analysis was to demonstrate that the proposed Project will comply with all applicable NAAQS. It should be noted that a cumulative impact analysis is not required since the proposed Repowering Project is not a major modification under NSR, and hence does not trigger federal NSR requirements.

For NAAQS compliance demonstration, the pollutants modeled and their respective averaging periods were as follows: CO (1-hour and 8-hour), $NO_2$ (1-hour and annual), $PM_{10}$ (24-hour), $PM_{2.5}$ (24-hour and annual), $SO_2$ (1-hour and 3-hour), and Pb (3-month rolling average).

The MDE-ARA modeling methodology are provided in the following subsections.

#### 4.4.2.2 *Modeling Methodology*

##### ***4.4.2.2.1 Model Selection***

The EPA AERMOD (version 18081) dispersion model was used to perform the air quality impact analysis using the regulatory default option. The meteorological data used as input to AERMOD was processed by MDE-ARA using AERMET (version 16216). The terrain data used as input to AERMOD was processed by MDE-ARA using AERMAP (version 18081). In addition, the EPA LeadPost Processor (version 13262) was used to post-process model predicted monthly average Pb concentrations to obtain the 3-month rolling averages as required for comparison to the NAAQS. The dispersion coefficient selected was rural, which was consistent with previous modeling conducted for CP Crane.

##### ***4.4.2.2.2 Pollutant Averaging Times***

To demonstrate NAAQS compliance, model runs were conducted for pollutants and their respective averaging times below.

- CO: 1-hour and 8-hour
- $NO_2$: 1-hour and annual
- $PM_{2.5}$: 24-hour and annual
- $PM_{10}$: 24-hour
- $SO_2$: 1-hour and 3-hour
- Lead: monthly averages

#### 4.4.2.2.3 *Treatment of $NO_2$ in AERMOD*

EPA recommends a multi-tiered approach in obtaining hourly and annual estimates of $NO_2$ concentrations. The Tier I method conservatively assumes all $NO_X$ species are converted to $NO_2$. The Tier II method is a refinement over Tier I. For Tier II, the Ambient Ratio Method 2 (ARM2) is applied to the results of Tier I. ARM2 assigns a $NO_2/NO_X$ ambient ratio that is dependent on the total modeled concentration of $NO_X$. Representative equilibrium ratios of $NO_2/NO_X$ are derived from national data from the EPA's AQS.

For this modeling analysis, the ARM2 method was applied to the 1-hour $NO_2$ modeling. The EPA recommended national default minimum and maximum $NO_2/NO_X$ ratio of 0.5 and 0.9, respectively, were used in this modeling analysis. It should be noted that ARM2 does not allow for the use of multiple source scenarios as part of a single AERMOD run. In other words, multiple source groups cannot be applied when ARM2 was selected. In order to reduce the amount of model run time, also for the purpose of conservatism, the most conservative Tier I method was applied to the $NO_2$ annual modeling run.

#### 4.4.2.2.4 *Site Layout*

The CP Crane facility layout is shown in Figure 4-3. The sources and buildings layout is shown in Figure 4-4.

*Figure 4-3 CP Crane Site Layout*

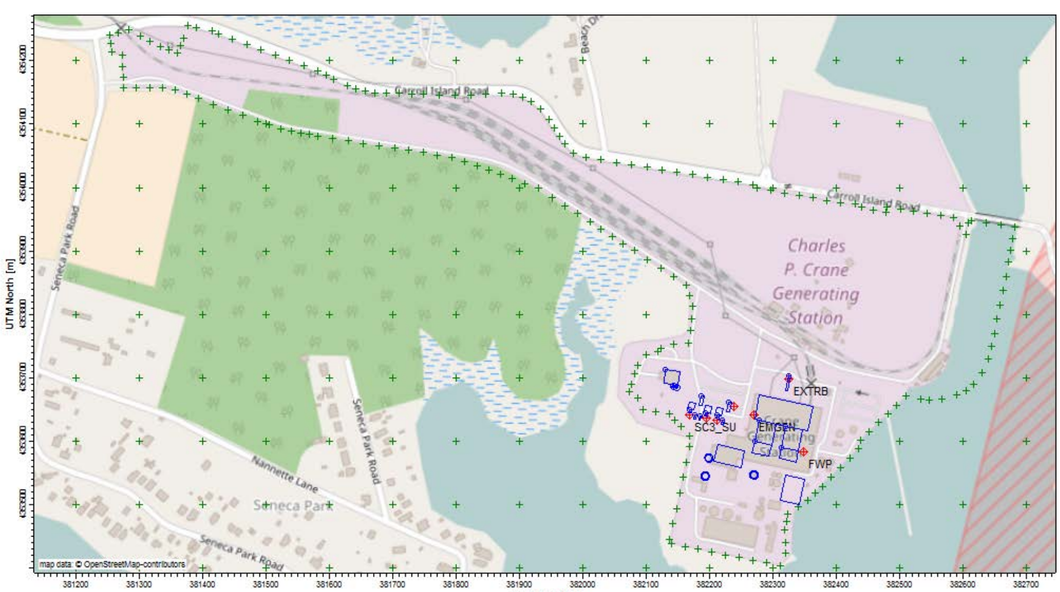
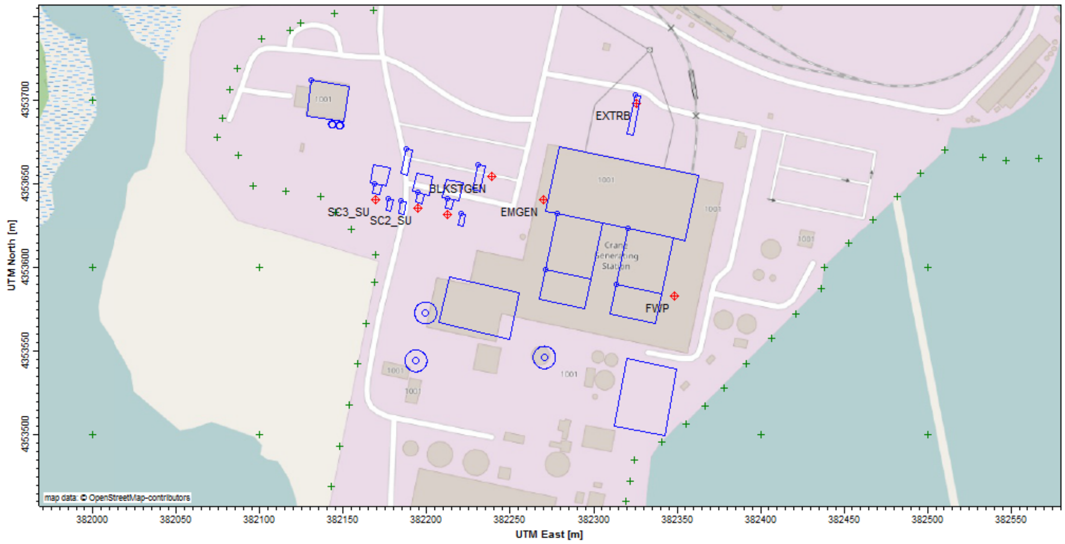


*Figure 4-4 CP Crane Emissions Sources and Buildings*




### 4.4.2.2.5 *Source Type and Emissions*

All emissions sources were modeled as point sources. The modeling analysis included the three proposed refurbished CTs and the new black start generator. Existing ancillary equipment that will remain operational, such as the 14 MW oil-fired CT, were also included in the modeling analysis.

#### *4.4.2.2.5.1 CT Operating Emissions*

CT emission rates vary with turbine load conditions and ambient temperature. For the purpose of this analysis, four operating loads were evaluated: 100%, 75%, 60% and 50%. ProEnergy provided specifications for 42 cases covering the above mentioned four operating loads, across the ambient temperature range of 0°F, 59°F, and 95°F. For the purposes of conservatism, maximum emission rates of each criteria pollutant, lowest exhaust temperature, and lowest exhaust flow rate (if applicable) across all cases under the same operating load and the same type of fuel were selected to be modeled.

The CTs will use natural gas as a primary fuel and ULSD as backup. For short term averaging periods, emissions from firing natural gas and ULSD were modeled separately. For annual averaging period, a scenario that included dual fuel firing was also modeled. This scenario assumed 90% operation on natural gas and 10% on ULSD. An annual capacity factor of 27% (excluding startups and shutdowns) was applied to calculate annualized emission rates.

Short-term emissions rates of CO, $NO_X$, $PM_{2.5}$, $PM_{10}$, and $SO_2$ were provided by ProEnergy. $SO_2$ emission rates were also calculated by CP Crane based on fuel usage and sulfur content of the fuel. The short-term emission rate of Pb was calculated based on EPA AP-42 emission factors. Annual emissions were estimated by CP Crane and annualized emission rates were used in model runs that require annual averaging.

All emission rates have been reviewed and verified by MDE-ARA. One notable difference in the calculated emission rates is the annual-averaged emission rates for $NO_X$ during startup and shutdown operations. MDE-ARA calculated annualized $NO_X$ emission rates were 0.20 lb/hr firing natural gas and 0.26 lb/hr firing dual fuel during startup and shutdown operations. The emission rates calculated by CP Crane were 0.030 lb/hr for natural gas and 0.038 lb/hr for dual fuel, respectively.

Table 4-8 summarizes varying emission rates and exhaust parameters for the proposed CTs for the load conditions evaluated.

***Table 4-8 CT Emissions Rates and Exhaust Parameters Varying with Load Conditions***

| Load Condition | | 100% | 75% | 60% | 50% |
|---|---|---|---|---|---|
| *Natural Gas* | | | | | |
| Exit Temperature (°F) | | 815 | 741 | 729 | 699 |
| Exit Velocity (ft/sec) | | 121.43 | 127.12 | 124.20 | 106.97 |
| Emission Rate (lb/hr) | CO | 32.67 | 35.15 | 35.05 | 34.64 |
| | $NO_X$ | 44.73 | 41.24 | 37.89 | 35.56 |
| | $PM_{2.5}/PM_{10}$ | 5.10 | 4.07 | 3.45 | 3.01 |
| | $SO_2$ | 0.68 | 0.55 | 0.46 | 0.40 |
| | Lead | 2.39E-04 | | | |
| *ULSD* | | | | | |
| Exit Temperature (°F) | | 828 | 761 | 740 | 711 |
| Exit Velocity (ft/sec) | | 122.72 | 128.72 | 123.62 | 108.24 |
| Emission Rate (lb/hr) | CO | 39.17 | 40.67 | 41.19 | 40.66 |
| | $NO_X$ | 75.07 | 68.45 | 63.16 | 59.70 |
| | $PM_{2.5}/PM_{10}$ | 15.51 | 12.37 | 10.56 | 9.37 |
| | $SO_2$ | 0.72 | 0.57 | 0.49 | 0.44 |
| | Lead | 6.66E-03 | | | |

Note: All particulate matter is considered $PM_{2.5}$. Source: ECT, 2018

#### *4.4.2.2.5.2 CT Startup and Shutdown Emissions*

The proposed CTs are designed to allow for multiple startups and shutdowns during a day. During startup and shutdown operations, there is the potential of elevated levels of emissions. These emissions combined with lower plume rise, could potentially result in higher ground level pollutant concentrations. Therefore, MDE-ARA evaluated startup and shutdown events using these assumptions/inputs as follows:

- Startup and shutdown modeling included emissions of CO (1-hour, 8-hour) and $NO_X$ (1-hour, annual) since these pollutants are most likely to have elevated emission rates during startup and shutdown events;
- Because emissions are higher for startup operations than shutdown, to be conservative it was assumed all startup/shutdown operations have emission rates equal to startup operations;
- Duration of startups is 10 minutes. Duration of shutdowns is 8 minutes;
- Startup emissions were provided as lb/event. It was assumed the CTs were operating at 100% load for the balance of the averaging period. For example, for 1-hour averaging period, emissions were calculated as a composite of startup emissions per event for 10 minutes and 100% load emissions for 50 minutes;
- For the annual averaging period, it was assumed 250 startup/shutdown events per year when firing natural gas. When firing dual fuel, it was assumed 225 startups/shutdowns for natural gas and 25 startups/shutdowns for ULSD;
- For the 8-hour averaging period, it was assumed 1 startup/shutdown event during the averaging period; and
- The annual capacity factor was not applicable to startup and shutdown emissions.

Table 4-9 summarizes CO and $NO_X$ emission rates during startup events.

*Table 4-9 Summary of CO and $NO_X$ Emissions During Startup Events*

| *Natural Gas* | | | | | |
|---|---|---|---|---|---|
| | Startup Emissions (lb/event) | Startup Emission Rate During Averaging Period (lb/hr) | Emission Rate for Balance of Averaging Period (lb/hr) | Startup Emissions (g/s) | Balance of Averaging Period (g/s) |
| CO (1-Hr) | 3.2 | 3.2 | 27.23 | 0.40 | 3.43 |
| CO (8-Hr) | 3.2 | 0.8 | 31.31 | 0.10 | 3.94 |
| $NO_X$ (1-Hr) | 3.6 | 3.6 | 37.28 | 0.45 | 4.70 |
| $NO_X$ (Annual) | 3.6 | 0.20 | 12.18 | 0.026 | 1.53 |
| *ULSD* | | | | | |
| | Startup Emissions (lb/event) | Startup Emission Rate During Averaging Period (lb/hr) | Balance of Averaging Period (lb/hr) | Startup Emissions (g/s) | Balance of Averaging Period (g/s) |
| CO (1-Hr) | 11.6 | 11.6 | 32.64 | 1.46 | 4.11 |
| CO (8-Hr) | 11.6 | 2.9 | 37.54 | 0.36 | 4.73 |
| $NO_X$ (1-Hr) | 12.8 | 12.8 | 62.56 | 1.61 | 7.88 |
| *Dual Fuel* | | | | | |
| | Startup Emissions (lb/event) | Startup Emission Rate During Averaging Period (lb/hr) | Balance of Averaging Period (lb/hr) | Startup Emissions (g/s) | Balance of Averaging Period (g/s) |
| $NO_X$ (Annual) | 3.6/12.8 | 0.26 | 12.48 | 0.032 | 1.57 |

##### 4.4.2.2.5.3 *Black Start Generator and Existing Ancillary Equipment Emissions*

The modeling analysis also included existing sources at CP Crane that will remain, including an existing CT, an existing emergency generator, and an existing emergency fire water pump. The proposed black start generator was also included in the modeling analysis. All ancillary equipment are fuel-oil fired.

Emission rates for the existing CT were calculated based on the maximum actual emissions for this unit during 2012 – 2016. The existing emergency generator is tested for 30 minutes every month and the existing emergency fire water pump is tested for 30 minutes every week. The new black start generator will be tested for 1 hour every year. For short term averaging periods (24-hour or less), the modeled emission rates were normalized to operate 30 minutes (or 1 hour) within the averaging period. The modeled emission rates for annual averaging period were based on 100 hours of annual operation for the internal combustion engines.

Testing of the emergency generator, emergency fire water pump, and the proposed black start generator was assumed to not occur during startup or shutdown periods and therefore were only included during the normal operation scenarios. Table 4-10 provides hourly emissions rates for all ancillary equipment.

*Table 4-10 Hourly Emissions Rates for Ancillary Equipment*

| Source | | Existing CT | Existing Emergency Generator | Existing Fire Water Pump | New Black Start Generator |
|---|---|---|---|---|---|
| Hours of Operation | | 192 hours/year * | 30 min/month; 100 hours/year | 30 min/week; 100 hours/year | 100 hours/year |
| Emission Rate (lb/hr) | CO | 0.90 | 2.00 | 1.33 | 37.7 |
| | $NO_X$ | 4.80 | 0.21 | 0.14 | 0.35 |
| | $PM_{2.5}$ | 1.04 | 0.028 | 0.018 | 0.074 |
| | $PM_{10}$ | 1.13 | 0.028 | 0.018 | 0.074 |
| | $SO_2$ | 28.06 | 0.62 | 0.41 | 0.024 |
| | Lead | 3.67E-03 | - | - | - |

* Maximum actual hours of operation during 2012 – 2016.

The EPA guidance document[6] allows for intermittent sources, such as emergency generators, to be omitted in the modeling of 1-hr $NO_2$. Due to the limited hours of operation, the ancillary equipment were considered

[6] EPA Memorandum, "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour $NO_2$ National Ambient Air Quality Standard", March 01, 2011.

intermittent sources and therefore were not included in the modeling of 1-hr $NO_2$.

#### *4.4.2.2.5.4 Model Input Summary*

The emissions rates and parameters MDE-ARA used in the modeling analysis are summarized in Tables 4-11 through 4-13.

*Table 4-11 CT Source Parameters and Short-Term Emissions Rates (Firing Natural Gas)*

| Description | CT 100% Load | CT 75% Load | CT 60% Load | CT 50% Load | CT Startup | CT Normal During Periods Including Startup |
|---|---|---|---|---|---|---|
| Release Height | 45.72 m (150 ft) | | | | | |
| Stack Diameter | 2.74 m (9 ft) | | | | | |
| Exit Temperature | 815 F (708.15 K) | 741 F (667.04 K) | 729 F (660.37 K) | 699 F (643.71 K) | 699 F (643.71 K) | 815 F (708.15 K) |
| Exit Velocity | 37.01 m/s (121.43 ft/sec) | 38.75 m/s (127.12 ft/sec) | 37.86 m/s (124.2 ft/sec) | 32.60 m/s (106.97 ft/sec) | 32.60 m/s (106.97 ft/sec) | 37.01 m/s (121.43 ft/sec) |
| Exit Flow Rate | 219 $m^3/s$ (7724 $ft^3/s$) | 229 $m^3/s$ (8087 $ft^3/s$) | 224 $m^3/s$ (7901 $ft^3/s$) | 193 $m^3/s$ (6803 $ft^3/s$) | 193 $m^3/s$ (6803 $ft^3/s$) | 219 $m^3/s$ (7724 $ft^3/s$) |
| Emission Rate (g/s) | | | | | | |
| CO 1-Hr | 4.116 | 4.429 | 4.416 | 4.365 | 0.403 | 3.430 |
| CO 8-Hr | 4.116 | 4.429 | 4.416 | 4.365 | 0.101 | 3.945 |
| $NO_X$ 1-Hr | 5.636 | 5.196 | 4.774 | 4.481 | 0.454 | 4.697 |
| $NO_X$ Annual | 1.522 | 1.403 | 1.289 | 1.210 | 0.026 | 1.535 |
| $NO_X$ Annual (Dual) | 1.370 | 1.263 | 1.160 | 1.089 | 0.023 | 1.326 |
| $PM_{2.5}$ 24-Hr | 0.643 | 0.513 | 0.435 | 0.379 | N/A | N/A |
| $PM_{2.5}$ Annual | 0.173 | 0.138 | 0.117 | 0.102 | N/A | N/A |
| $PM_{2.5}$ Annual (Dual) | 0.156 | 0.125 | 0.106 | 0.092 | N/A | N/A |
| $PM_{10}$ 24-Hr | 0.643 | 0.513 | 0.435 | 0.379 | N/A | N/A |
| $SO_2$ 1-Hr | 0.086 | 0.068 | 0.058 | 0.050 | N/A | N/A |
| $SO_2$ 3-Hr | 0.086 | 0.068 | 0.058 | 0.050 | N/A | N/A |
| Lead | 3.01E-05 | 3.01E-05 | 3.01E-05 | 3.01E-05 | N/A | N/A |

*Table 4-12 CT Source Parameters and Short-Term Emissions Rates (Firing ULSD)*

| Description | CT 100% Load | CT 75% Load | CT 60% Load | CT 50% Load | CT Startup | CT Normal During Periods Including Startup |
|---|---|---|---|---|---|---|
| Release Height | 45.72 m (150 ft) | | | | | |
| Stack Diameter | 2.74 m (9 ft) | | | | | |
| Exit Temperature | 828 F (715.4 K) | 761 F (678.2 K) | 740 F (666.5 K) | 711 F (650.4 K) | 711 F (650.4 K) | 828 F (715.4 K) |
| Exit Velocity | 37.41 m/s (122.74 ft/sec) | 39.23 m/s (128.71 ft/sec) | 37.68 m/s (123.62 ft/sec) | 32.99 m/s (108.24 ft/sec) | 32.99 m/s (108.24 ft/sec) | 37.41 m/s (122.74 ft/sec) |
| Exit Flow Rate | 221 $m^3/s$ (7807 $ft^3/s$) | 232 $m^3/s$ (8187 $ft^3/s$) | 223 $m^3/s$ (7863 $ft^3/s$) | 195 $m^3/s$ (6885 $ft^3/s$) | 195 $m^3/s$ (6885 $ft^3/s$) | 221 $m^3/s$ (7807 $ft^3/s$) |
| Emission Rate (g/s) | | | | | | |
| CO 1-Hr | 4.935 | 5.124 | 5.190 | 5.123 | 1.462 | 4.113 |
| CO 8-Hr | 4.935 | 5.124 | 5.190 | 5.123 | 0.365 | 4.730 |
| $NO_X$ 1-Hr | 9.459 | 8.625 | 7.958 | 7.522 | 1.613 | 7.882 |
| $NO_X$ Annual (Dual) | 0.255 | 0.233 | 0.215 | 0.203 | 0.009 | 0.246 |
| $PM_{2.5}$ 24-Hr | 1.954 | 1.559 | 1.331 | 1.181 | N/A | N/A |
| $PM_{2.5}$ Annual (Dual) | 0.053 | 0.042 | 0.036 | 0.032 | N/A | N/A |
| $PM_{10}$ 24-Hr | 1.954 | 1.559 | 1.331 | 1.181 | N/A | N/A |
| $SO_2$ 1-Hr | 0.091 | 0.072 | 0.062 | 0.055 | N/A | N/A |
| $SO_2$ 3-Hr | 0.091 | 0.072 | 0.062 | 0.055 | N/A | N/A |
| Lead | 8.39E-04 | 8.39E-04 | 8.39E-04 | 8.39E-04 | N/A | N/A |

*Table 4-13 Ancillary Equipment Source Parameters and Emissions Rates*

| Description | Existing CT | Existing Emergency Generator | Existing Fire Water Pump | Black Start Generator |
|---|---|---|---|---|
| Release Height | 9.75 m (32 ft) | 3.05 m (10 ft) | 2.44 m (8 ft) | 2.84 m (9.33 ft) |
| Stack Diameter | 2.29 m (7.5 ft) | 0.23 m (0.75 ft) | 0.15 m (0.5 ft) | 0.21 m (0.7 ft) |
| Exit Temperature | 900 F (755.37 K) | 695 F (641.48 K) | 853 F (729.26 K) | 750 F (672.04 K) |
| Exit Velocity | 46.05 m/s (151.08 ft/sec) | 29.20 m/s (95.79 ft/sec) | 59.43 m/s (194.98 ft/sec) | 44.91 m/s (147.34 ft/sec) |
| Exit Flow Rate | 189 $m^3/s$ (6674 $ft^3/s$) | 1.20 $m^3/s$ (42.3 $ft^3/s$) | 1.08 $m^3/s$ (38.3 $ft^3/s$) | 1.65 $m^3/s$ (58.3 $ft^3/s$) |
| Emission Rate (g/s) | | | | |
| CO 1-Hr | 0.113 | 0.253 | 0.168 | 4.750 |
| CO 8-Hr | 0.113 | 0.032 | 0.021 | 0.594 |
| $NO_X$ 1-Hr | * | * | * | * |
| $NO_X$ Annual | 0.604 | 0.027 | 0.018 | 0.044 |
| $PM_{2.5}$ 24-Hr | 0.131 | 0.0035 | 0.0023 | 0.0094 |
| $PM_{2.5}$ Annual | 2.88E-03 | 1.90E-03 | 1.27E-03 | 2.57E-03 |
| $PM_{10}$ 24-Hr | 0.142 | 0.0035 | 0.0023 | 0.0094 |
| $SO_2$ 1-Hr | 3.536 | 0.078 | 0.052 | 0.003 |
| $SO_2$ 3-Hr | 3.536 | 0.026 | 0.017 | 0.001 |
| Lead | 4.62E-04 | - | - | - |

*Not included; intermittent source.

#### 4.4.2.2.6 *Source Groups*

The startup event and balance of the averaging period were modeled as separate stacks and were source-grouped together to get the overall concentration. Similarly, for dual fuel scenarios, the two types of fuel were modeled as separate stacks and source-grouped together to get the overall concentration.

#### 4.4.2.2.7 *Building Downwash*

MDE-ARA performed a Good Engineering Practice stack height analysis using the USEPA approved Building Profile Input Program with Prime (BPIPPRM, v04274). The BPIPPRM output was used in the AERMOD modeling analysis.

#### 4.4.2.2.8 *Terrain Features*

MDE-ARA utilized the most recent version of AERMAP terrain processor (v18081) to develop elevations for receptors used in the air quality modeling analysis. U.S. Geological Survey (USGS) National Elevation Dataset 1/3 arc second resolution data in GeoTIFF format was used as source of input elevation data.

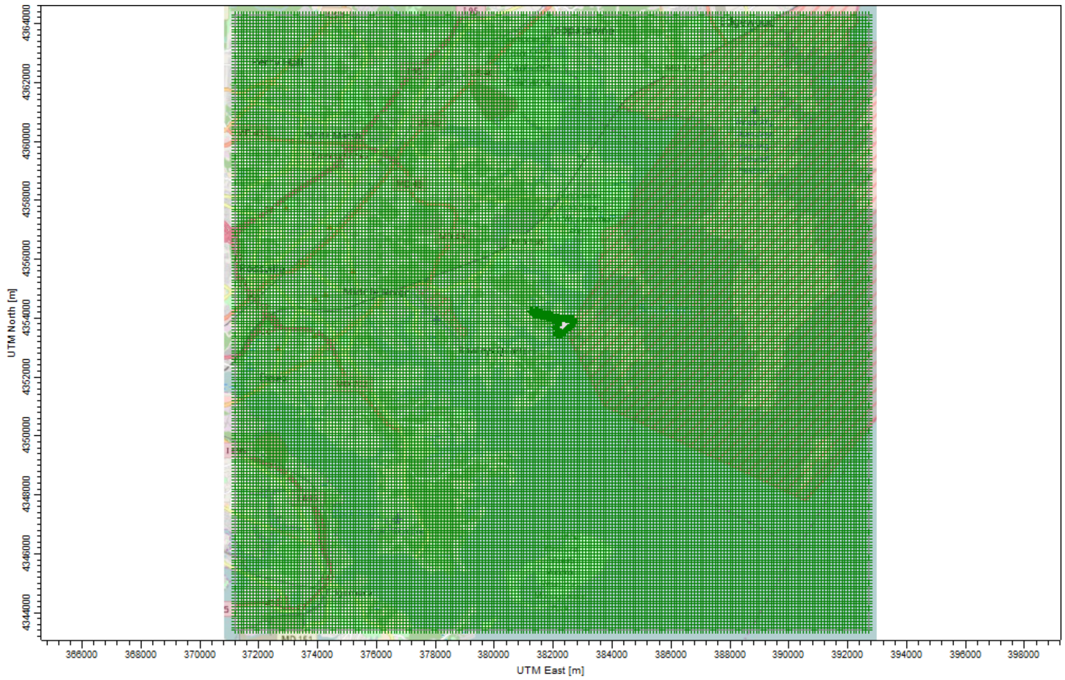
#### 4.4.2.2.9 *Receptor Grid*

A total of 45,531 discrete Cartesian receptors were used in the modeling analysis. The receptor grid is as follows:

- Receptors were placed along the site fence line and spaced in increments of 25 meters; and
- The receptor grid extends to approximately 10 kilometers starting at the site fence line using 100-meter spacing.

Figure 4-5 shows the receptor grid used in the modeling analysis.

*Figure 4-5 Receptor Grid*




#### 4.4.2.2.10 *Meteorological Data*

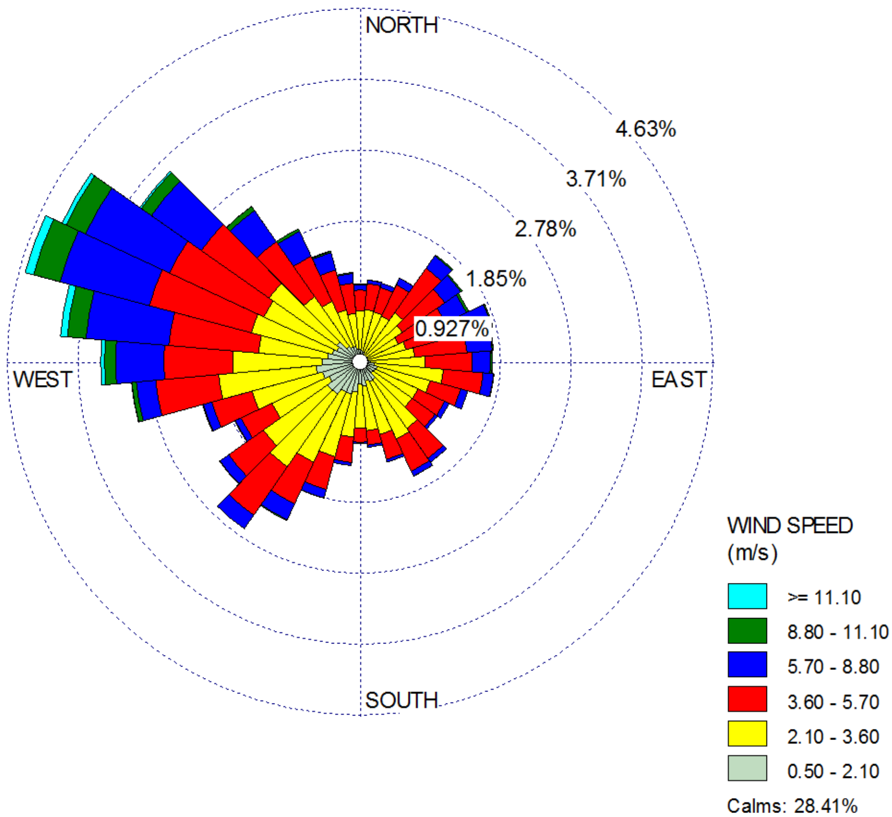
The meteorological data used in this modeling analysis was processed by MDE-ARA. Data from Baltimore Washington International Airport (BWI) national weather service (NWS) was used as the source of surface-based input meteorological data. MDE-ARA processed the BWI data for 2012 – 2016 in conjunction with upper air data from Dulles International Airport (IAD) in Sterling, VA, and followed all EPA recommended practices outlined in the AERMOD Implementation Guidance, including the use of AERSURFACE (version 13016) and one-minute Automated Surface Observation System (ASOS) archive data. The meteorological data from BWI/IAD has been used previously in air quality modeling analyses that involves CP Crane Station, including the modeling analysis in support of the development of the State Implementation Plan.

MDE-ARA has processed the meteorological data for BWI (WBAN 93721) with the most recent 5 years of data available (2012-2016) and corresponding upper air data from the NWS station in Sterling, VA (WBAN 93734). AERMET (version 16216) was used to process the met data.

A 5-year wind rose for BWI is presented in Figure 4-6. The prevailing wind is from west-northwest. The specific procedures and assumptions

used by MDE-ARA to process the BWI meteorological data in AERMET are described in the following paragraphs.

*Figure 4-6 5-year Wind Rose (2012-2016): BWI Airport*



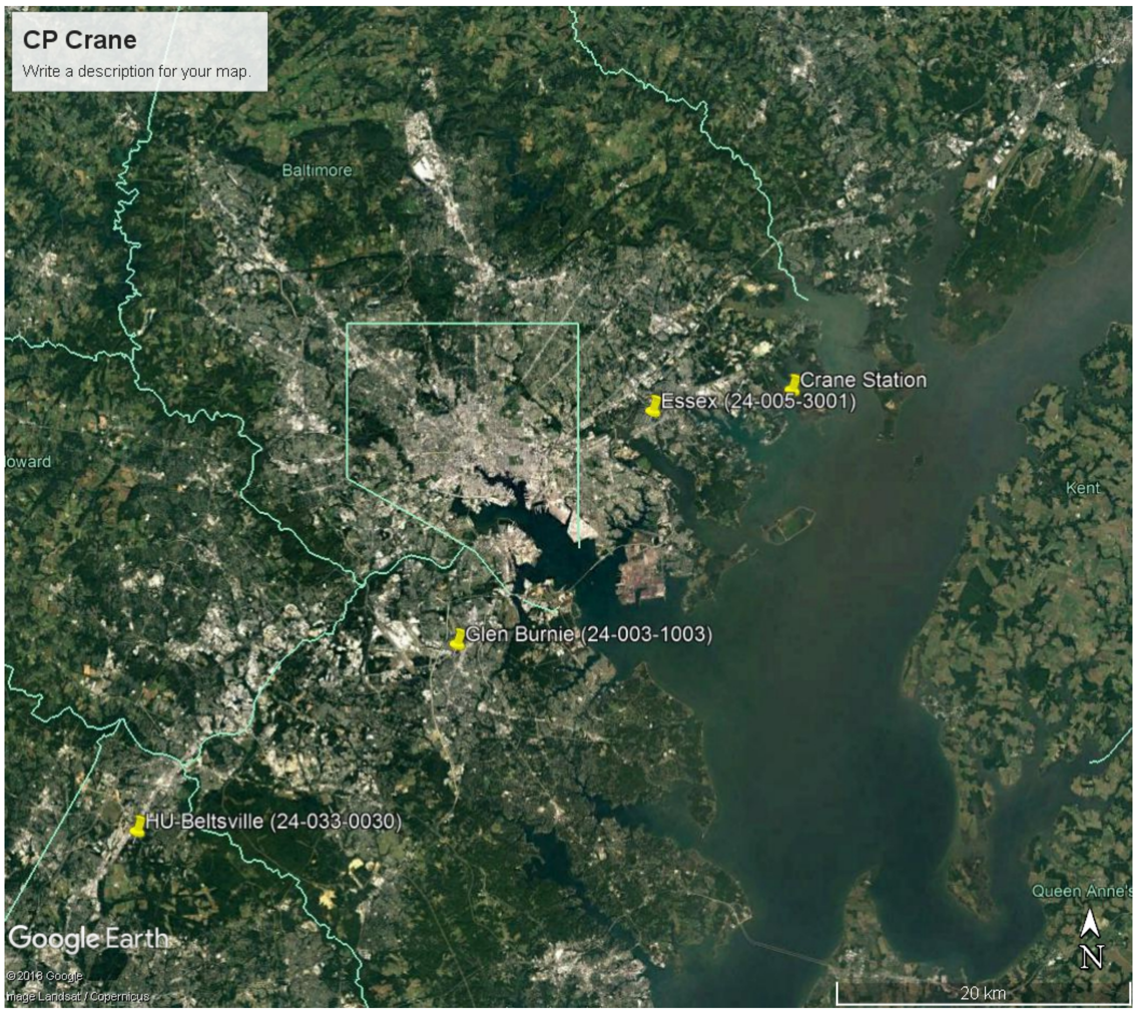

AERMET was run using EPA recommended settings to produce the meteorological data needed for AERMOD. The AERMET analysis included the use of both the AERMINUTE and AERSURFACE preprocessors. The AERMINUTE (version 15272) meteorological data processor was used to produce wind speed and direction data based on archived 1-minute ASOS data for BWI, for input into AERMET Stage 2. A 0.5 m/s wind speed threshold was applied to the 1-minute ASOS derived wind speeds in AERMET. The AERSURFACE run was based on USGS National Land Cover Data from 1992. AERSURFACE was configured assuming 12 wind direction sectors and a monthly temporal resolution.

#### 4.4.2.2.11 *Background Air Quality*

MDE-ARA reviewed locations of nearby ambient monitoring sites and selected representative monitor locations based on geographic proximity

and data availability. The Essex monitor (AQS # 24-005-3001) is located about 10 km to the west of the site. It measures ambient concentrations of CO, $NO_2$, $PM_{2.5}$, and $SO_2$. The Glen Burnie monitor (AQS # 24-003-1003) is located about 30 km to the southwest of the site and measures ambient concentration of $PM_{10}$. Ambient concentration of Pb is measured at the HU-Beltsville monitor (AQS # 24-033-0030) which is located at Howard University's Beltsville Laboratory, about 55 km southwest of the site. Figure 4-7 below shows the relative locations of the monitoring stations and the CP Crane site.

*Figure 4-7 Location of Monitoring Sites*




Ambient monitoring data for 2014 – 2016 was obtained from the EPA Air Data website. Table 4-14 below shows background concentrations used in the modeling analysis.

*Table 4-14 Background Ambient Concentrations*

| Pollutant | Averaging Period | Ambient Concentrations ($\mu g/m^3$) | | | Background Concentration ($\mu g/m^3$) | Monitor Name (AQS #) |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | | |
| $SO_2$ | 1-Hour | 68.1 | 47.1 | 34.0 | 49.7(1) | Essex (24-005-3001) |
| | 3-Hour | 84.0 | 60.0 | 29.1 | 84.0(2) | |
| $NO_2$ | 1-Hour | 86.5 | 90.3 | 92.2 | 89.7(3) | Essex (24-005-3001) |
| | Annual | 20.8 | 21.4 | 19.6 | 21.4(4) | |
| CO | 1-Hour | 2748 | 5268 | 2290 | 5268(2) | Essex (24-005-3001) |
| | 8-Hour | 1603 | 1947 | 1718 | 1947(2) | |
| $PM_{10}$ | 24-Hour | 29 | 33 | 30 | 33(5) | Glen Burnie (24-003-1003) |
| $PM_{2.5}$ | 24-Hour | 22 | 26 | 20 | 22.7(3) | Essex (24-005-3001) |
| | Annual | 9.7 | 10.1 | 8.6 | 9.5(6) | |
| Lead | Rolling 3-month | 0.006 | 0.042 | 0.013 | 0.042(2) | HU-Beltsville (24-033-0030) |

(1) Average of 99th percentile.
(2) Max of the 1st highs.
(3) Average of 98th percentile.
(4) Max of annual mean.
(5) Max of the 2nd highs.
(6) Average of annual mean.

*4.4.2.3 Modeling Results*

Maximum predicted criteria pollutant concentrations across all fuel types and all operating loads are provided in Table 4-15.

*Table 4-15 Maximum Predicted Criteria Pollutant Concentrations with Background*

| Pollutant | Averaging Period | Modeled Concentration (μg/m³) | Background Concentration (μg/m³) | Total Concentration (μg/m³) | NAAQS (μg/m³) | % of NAAQS |
|---|---|---|---|---|---|---|
| CO | 1-Hour | 5,293.17(1) | 5,268 | 10,561.17 | 40,000 | 26% |
| | 8-Hour | 262.28(1) | 1,947 | 2,209.28 | 10,000 | 22% |
| $NO_2$ | 1-Hour | 45.72(2) | 89.7 | 135.42 | 188 | 72% |
| | Annual | 3.03(3) | 21.4 | 24.43 | 100 | 24% |
| $PM_{2.5}$ | 24-Hour | 2.12(2) | 22.7 | 24.82 | 35 | 71% |
| | Annual | 0.19(4) | 9.5 | 9.69 | 12 | 81% |
| $PM_{10}$ | 24-Hour | 3.81(5) | 33 | 36.81 | 150(1) | 25% |
| $SO_2$ | 1-Hour | 116.23(6) | 49.7 | 165.97 | 196 | 85% |
| | 3-Hour | 68.39(1) | 84.0 | 152.41 | 1,300 | 12% |
| Lead | Rolling 3-Month Average | 0.0005 | 0.042 | 0.042 | 0.15 | 28% |

Notes:
(1) 1st high over five (5) years.
(2) 98th percentile (8th high) averaged over five (5) years.
(3) Highest annual mean of the five (5) years.
(4) Average of annual mean over five (5) years.
(5) 6th high over five (5) years.
(6) 99th percentile (4th high) averaged over five (5) years.

#### 4.4.2.4 *Conclusion*

The air quality modeling analyses conducted by CP Crane have been independently verified by MDE-ARA. Based on the air quality modeling analyses, the proposed CP Crane Repowering Project demonstrates compliance with all applicable NAAQS, and the results indicate that the proposed Project will not adversely impact air quality in the region.

## 4.5 *REGULATORY APPLICABILITY ANALYSIS*

As a part of its review of the CPCN Application, MDE-ARA determined the applicable air regulatory requirements for CT and black start generator air emissions sources proposed to be installed as a part of this Project. The applicable regulatory requirements and the associated compliance demonstration approaches are discussed in this section of the document.

### 4.5.1 Federal Regulatory Requirements

*4.5.1.1 New Source Performance Standards (NSPS)*

#### 4.5.1.1.1 Standards for Stationary Combustion Turbines (40 CFR Part 60 Subpart KKKK)

The CTs are subject to 40 CFR §60 Subpart KKKK, "Standards of Performance for Stationary Combustion Turbines." All stationary gas turbines with a heat input at a peak load equal to or greater than 10.7 gigajoules per hour (10 MMBtu/hr), based on the higher heating value of the fuel, which commenced construction, modification, or reconstruction after February 18, 2005 are subject to this Subpart. As per §60.4305(b), stationary CTs regulated under Subpart KKKK are exempt from the requirements of Subpart GG.

*Applicable Requirements*

The NSPS includes the following requirements: general compliance requirements (§60.4333), monitoring requirements (§60.4335-§60.4370), reporting requirements (§60.4375-§60.4395), and performance testing (§60.4400-§60.4415). CP Crane will also be subject to applicable notification, monitoring, and reporting and related applicable provisions of 40 CFR §60.7 and §60.8.

*Recommended Compliance Demonstration Approach*

a. **Monitoring –**

CP Crane will operate a continuous emissions monitoring system (CEMS) at the outlet of the CT stacks. The system will continuously analyze, monitor, and record the concentrations of $NO_X$. Compliance with the $SO_2$ emission standard shall be demonstrated by either of the following:

i. The fuel quality characteristics in a current, valid purchase contract, tariff sheet or transportation contract for the fuel, specifying that the maximum total sulfur content for natural gas is 20 grains of sulfur or less per 100 standard cubic feet, has potential sulfur emissions of less than 26 ng $SO_2$/J (0.060 lb $SO_2$/MMBtu) heat input; or

ii. Representative fuel sampling data which shows that the sulfur content of the fuel does not exceed 26 ng $SO_2$/J (0.060 lb

$SO_2$/MMBtu) heat input. At a minimum, the amount of fuel sampling data specified in Section 2.3.1.4 or 2.3.2.4 of Appendix D to 40 CFR Part 75 is required.

If CP Crane elects to comply with the minimum fuel sulfur content limit under 40 CFR §60.4330, CP Crane must monitor the total sulfur content of the CT's fuel using the methods described in 40 CFR §60.4415 at a frequency described in 40 CFR §60.4370. Alternatively, if the total sulfur content of the gaseous fuel during the most recent performance test was less than half the applicable limit, ASTM D4084-82, 94, 05, D4810-88 (1999), D5504-01, or D6228-98 (2003), or Gas Processors Association Standard 2377-86, may be used to assess compliance with the applicable fuel sulfur limit [40 CFR §60.4360].

b. **Reporting** – CP Crane must submit reports of excess emissions and monitor downtime, in accordance with §60.7(c). Excess emissions must be reported for all periods of unit operation, including startup, shutdown, and malfunction. Units that perform an annual performance test must submit these reports within 60 days of testing.

c. **Performance Testing** – As per §60.8, CP Crane is required to conduct an initial performance test. Subsequent $NO_X$ performance tests shall be conducted on an annual basis (no more than 14 calendar months following the previous performance test). EPA Method 7 or 7E will be used for performance testing.

##### *4.5.1.1.2 NSPS for Stationary Compression Ignition Internal Combustion Engines (40 CFR Part 60 Subpart IIII)*

The black start generator (1,500 kW) engine is subject to the requirements of this regulation as it is considered compression ignition reciprocating internal combustion engines (RICE) installed after July 2005. This engine is subject to the applicable monitoring, compliance, testing, notification, reporting, and recordkeeping requirements (40 CFR §60.4200 *et seq*.) and related applicable provisions of 40 CFR §60.7 and §60.8. Note that the engine is EPA Tier 1 certified and not subject to the Tier 4 requirements under Subpart IIII given the engine has cylinder displacement less than 10 liters per cylinder. The emissions standards for the black start generator are shown in Table 4-16.

*Table 4-16 Emissions Standards for the Black Start Generator (g/kW-hr)*

| Emergency Engine | Model Year | NOx | NMHC | CO | PM |
|---|---|---|---|---|---|
| 1,500 kW Black Start Generator Engine Displacement <10 and <2,237kW (3,000hp) | TBD | 9.2 | 1.3 | 11.4 | 0.54 |

*Notifications*

As the black start generator engine is used only for emergency purposes, it is not subject to the initial notification requirements of the rule.

*Compliance Demonstration*

a. **Fuel:** The sulfur content in the distillate fuel oil is limited to 15 ppm (0.0015%).

b. **Compliance**: CP Crane is required to install a non-resettable hour meter prior to the startup of the engine as per 40 CFR §60.4209(a).

c. **Recordkeeping:** CP Crane is required to maintain the following records:

   i. A copy of each notification submitted to comply with this subpart;

   ii. Records of the occurrence and duration of each malfunction of operation or the air pollution control and monitoring equipment;

   iii. Records of all required maintenance on the air pollution control and monitoring equipment;

   iv. Records of hours of operation and the reasons for operating the engines (maintenance, readiness, or emergency); and

   v. Records of actions taken during periods of malfunction to minimize emissions in accordance with 63.6605(b), including malfunctioning process and air pollution control and monitoring equipment to its normal or usual manner of operation.

#### 4.5.1.1.3 *NSPS for Greenhouse Gas Emissions for Electric Generating Units (40 CFR Part 60 Subpart TTTT)*

The CTs are subject to the NSPS TTTT requirements as they are stationary combustion turbines that commenced construction after January 8, 2014 or commenced reconstruction after June 18, 2014. The CTs are subject to the applicable monitoring, compliance, testing, notification, reporting, and recordkeeping requirements (40 CFR §60.5508 *et seq*.) and related applicable provisions of 40 CFR §60.7 and §60.8.

*Applicable Requirements*

The CTs are subject to a $CO_2$ limit of 1,000 lb/MWh gross energy output or 1,030 lb $CO_2$/MWh (net) based on a 12-month rolling average.

The NSPS includes the following requirements: general compliance requirements (§60.5525), monitoring requirements (§60.5535-§60.5540), reporting requirements (§60.5550-§60.5555), and record keeping requirements (§60.5560-§60.5565). CP Crane will also be subject to applicable notification, monitoring and reporting and related applicable provisions of 40 CFR §60.7 and §60.8.

*Recommended Compliance Demonstration Approach*

a. **Monitoring** – CP Crane must operate a CEMS at the outlet of the CT stacks. The system will continuously analyze, monitor, and record the concentrations of $CO_2$. Alternatively, CP Crane must demonstrate compliance with the emission standard by measuring fuel flow as specified in the applicable appendices to 40 CFR Part 75 and calculating emissions using this fuel rate.

   In addition, CP Crane shall install, calibrate, maintain, and operate a sufficient number of watt meters to continuously measure and record the hourly gross electric output or net electric output, as applicable, from the CTs.

b. **Reporting** – CP Crane must submit quarterly reports of the rolling average $CO_2$ emission rate in accordance with §60.5555.

c. **Record Keeping** – As CP Crane is subject to the Acid Rain Program, the facility must comply with Subpart TTTT by following the applicable recordkeeping requirements and maintaining records as required under Subpart F of 40 CFR Part 75.

### 4.5.1.2 *National Emission Standards for Hazardous Air Pollutants (NESHAPs)*

National Emission Standards for Hazardous Air Pollutants (NESHAPs) are federal HAP requirements in 40 CFR Part 63 that apply generally to "major" sources of HAPs, which are defined as facilities with the potential to emit 10 tpy or more of any single HAP, or 25 tpy or more of two or more HAPs. HAP standards, known as Maximum Achievable Control Technology (MACT) standards, for major HAP sources are established for classes or categories of sources. Some MACT standards, known as "area source MACT" standards, apply to minor source HAP facilities. The total potential HAP emissions for the facility are projected to be less than 25 tpy for all HAPs combined and less than 10 tpy for individual HAPs; therefore, CP Crane is considered an area HAP source.

#### ***4.5.1.2.1 NESHAP for Combustion Turbines (40 CFR Part 63 Subpart YYYY)***

NESHAP Subpart YYYY applies to stationary CTs located at a major source of HAP emissions. As an area source of HAPs, the requirements of this subpart do not apply to CP Crane.

#### ***4.5.1.2.2 NESHAP for RICE (40 CFR Part 63 Subpart ZZZZ)***

The black start generator is subject to the requirements of NESHAP Subpart ZZZZ for RICE. Pursuant to 40 CFR §63.6590(c)(1), a new stationary RICE located at an area source is required to comply with NESHAP ZZZZ by meeting the applicable requirements under 40 CFR Part 60 Subpart IIII.

***Notifications***

No additional notifications are required for emergency units.

#### ***4.5.1.2.3 NESHAP for Coal- and Oil-fired Electrical Utilities (40 CFR Part 63 Subpart UUUUU)***

The rule is applicable only to coal-and oil-fired electrical utility systems. Since the CTs are proposed to use oil for no more than 10% the annual average capacity factor, the CTs are not considered oil-fired under Subpart UUUUU. As such, these emissions units are exempt from applicability to this rule.

#### 4.5.1.3 *Acid Rain Program (40 CFR Parts 72 through 76)*

The CTs meet the definition of an "affected unit" as defined in 40 CFR §72.6, and therefore, are subject to the requirements of the Acid Rain program, including emissions standards (40 CFR §72.9) and monitoring requirements (40 Part 75), among other requirements. References to these requirements are included in the recommended license conditions. In addition, CP Crane was required to apply for, and obtain, an Acid Rain permit (under 40 CFR §72.30); terms of the Acid Rain permit will be incorporated into the facility's Title V operating permit by MDE-ARA.

#### 4.5.1.4 *Clean Air Interstate Rule (CAIR)/Cross-State Air Pollution Rule (CSAPR)*

The Clean Air Interstate Rule (CAIR) was a federal rule promulgated in March 2005 that implemented a cap and trade program on power plant $NO_X$ and $SO_2$ emissions in the eastern half of the United States. This rule was promulgated for implementation under 40 CFR Part 97. Maryland had promulgated implementing regulations under COMAR 26.11.28. According to 40 CFR §97.4, CAIR applied to any emission unit that, at any time after January 1, 1995, has a nameplate generating capacity of greater than 25 MW and sells any amount of electricity or has a maximum design heat input of greater than 250 MMBtu/hr.

On July 6, 2011, the EPA finalized the Cross-State Air Pollution Rule (CSAPR), which replaces CAIR. The first phase of compliance was scheduled to begin January 1, 2012 for annual $SO_2$ and annual $NO_X$ emissions and May 1, 2012 for ozone season $NO_X$ emissions. In August 2012, CSAPR was vacated, pending appeal. On April 29, 2014, the Supreme Court reversed the lower court's decision and reinstated the CSAPR.

Compliance with CSAPR Phase 1 emission budget program is required in 2015 and 2016, while the program's Phase 2 emission budgets and assurance provisions are effective in 2017 and beyond. The CSAPR requirements have been added to CP Crane's recommended license conditions.

#### 4.5.1.5 *Risk Management Planning*

This regulation covers the requirements for owners or operators of stationary sources concerning the prevention of accidental releases, and the State accidental release prevention programs approved under section 112(r) and codified as 40 CFR Part 68. This regulation applies to owners and operators of facilities that store regulated substances used in a process

in quantities greater than certain threshold levels. Under Subpart G of the regulation, a facility is required to develop a Risk Management Plan if the quantity of regulated substances exceeds the threshold quantities. CP Crane does not store quantities of any regulated substances in quantities that exceed the regulatory threshold.

#### 4.5.1.6 *Mandatory Reporting of Greenhouse Gases*

40 CFR Part 98 applies to direct GHG emitters, fossil fuel suppliers, industrial gas suppliers, and facilities that inject $CO_2$ underground for sequestration or other reasons. In general, the threshold for reporting is 25,000 metric tons or more of $CO_2$ per year. Reporting is at the facility level, except for certain suppliers of fossil fuels and industrial greenhouse gases.

At CP Crane, the CTs are addressed in Subpart D (Electricity Generation). Emergency equipment, including the black start generator, are not included in the source category under Subpart C as per 40 CFR §98.30(b)(2); therefore, the unit is exempt from the rule.

Under Subparts C and D, emissions of $CO_2$, $CH_4$ and $N_2O$ must be determined and reported to EPA in accordance with the following requirements:

- Procedure to estimate emissions (§98.33, §98.43);
- Monitoring and QA/QC Requirements (§98.34, §98.44);
- Procedures for Estimating Missing Data (§98.35, §98.45);
- Data Reporting Requirements (§98.36, §98.46); and
- Records that Must Be Retained (§98.37, §98.47).

CP Crane will be required to submit an annual report of GHG emissions and data for the previous calendar year. The facility will be required to use the electronic reporting tool developed by EPA. The annual report will be due by March 31st.

### 4.5.2 *State Regulatory Requirements*

In addition to the federal regulatory requirements, CP Crane is subject to several Maryland air regulations codified at COMAR 26.11. The following

list provides the requirements for the entire facility and for specific pieces of equipment, as applicable.

a) **COMAR 26.11.01.04A - Requirements for Testing:**

MDE-ARA may require CP Crane to conduct, or have conducted, testing to determine compliance with the permit. MDE-ARA, at its option, may witness or conduct these tests. This testing will be done at a reasonable time, and all information gathered during a testing operation will be provided to both parties.

b) **COMAR 26.11.01.04B - Requirements for Monitoring**:

MDE-ARA or the control officer (appropriate health officer at Baltimore County under COMAR 26.11.01.01B.12) may require CP Crane to install, use, and maintain monitoring equipment or employ other methods as specified by MDE-ARA or the control officer to determine the quantity or quality, or both, of emissions discharged into the atmosphere and to maintain records and make reports on these emissions to MDE-ARA or the control officer in a manner and on a schedule approved by MDE-ARA or the control officer.

i. MDE-ARA or the control officer, at reasonable times, shall have access to and be permitted to copy any records and inspect any monitoring equipment or methods required under this section.

ii. Except when otherwise specified by MDE-ARA or the control officer, records required under this regulation shall be available for inspection by MDE-ARA and the control officer for a period of not less than 90 days.

iii. All records and reports submitted to MDE-ARA or the control officer required under this regulation shall be available for public inspection.

c) **COMAR 26.11.01.04C - Emissions Test Methods:**

Compliance with the emissions standards and limitations in these Conditions shall be determined by the test methods designated and described in these Conditions or other test methods submitted to and approved by MDE-ARA.

d) **COMAR 26.11.01.05-1 and COMAR 26.11.02.19C and COMAR 26.11.02.19D - Emissions Certification Report:**

i. CP Crane is required to certify annual emissions of regulated pollutants from the facility on a calendar year basis.

1) The certification shall be on forms obtained from the Department and submitted to MDE-ARA not later than April 1 of the year following the year for which the certification is required;

2) The individual making the certification shall certify that the information is accurate to the individual's best knowledge. The individual shall be:

   a. Familiar with each source for which the certifications forms are submitted; and

   b. Responsible for the accuracy of the emissions information.

ii. CP Crane is required to maintain records necessary to support the emission certification, including the following information if applicable:

   1) The total amount of actual emissions of each regulated pollutant and the total of all regulated pollutants;

   2) An explanation of the methods used to quantify the emissions and the operating schedules and production data that were used to determine emissions, including significant assumptions made;

   3) Amounts, types, and analyses of all fuels used;

   4) Emission data from continuous emission monitors that are required by COMAR 26.11 or EPA regulations, including monitor calibration and malfunction information;

   5) Identification, description, and use records of all air pollution control equipment and compliance monitoring equipment, including significant maintenance performed, malfunctions and downtime, and episodes of reduced efficiency of this equipment;

   6) Limitations on source operation or any work practice standards that significantly affect emissions;

   7) Other relevant information as required by MDE-ARA; and

8) The logs and other records of information required by COMAR 26.11.02.19C(1) shall be retained for a period of five years and made available to MDE-ARA upon request.

**e) COMAR 26.11.01.07C-D - Malfunctions and Other Temporary Increases of Emissions:**

i. CP Crane is required, in the case of any occurrence of excess emissions expected to last or actually lasting for one hour or more, to report the onset and the termination of the occurrence to MDE-ARA by telephone. Telephone reports of excess emissions shall include the following information:

1) The identity of the installation and the person reporting;

2) The nature or characteristics of the emissions (for example, hydrocarbons, fluorides);

3) The time of occurrence of the onset of the excess emissions and the actual or expected duration of the occurrence; and

4) The actual or probable cause of the excess emissions.

ii. When requested by MDE-ARA, CP Crane shall submit a written report to MDE-ARA within ten days of receiving the request regarding excess emissions; the report shall contain the information required in COMAR 26.11.01.07D(2).

**f) COMAR 26.11.01.11 - Continuous Emission Monitoring Requirements:**

Before installing a CEM, CP Crane is required to submit to MDE-ARA a plan containing the CEM design specifications, proposed location, and a description of a proposed alternative measurement method. The location of the CEM, the amount and recording of measurements, and reporting requirements are specified by COMAR 26.11.01.11.

**g) COMAR 26.11.02.04B – Duration of Permits:**

CP Crane is required to commence substantial construction or modification within 18 months after the date of issuance of the approval, unless MDE-ARA specifies a longer period in the approval.

**h) COMAR 26.11.02.14D – Application for State Permit to Operate:**

CP Crane shall submit a complete application for an initial State permit to operate no later than 60 days before the source is to commence operating.

i) **COMAR 26.11.02.19A – Fee Schedule:**

CP Crane is required to pay annual Title V operating permit fees. **This is a state-only enforceable requirement.**

j) **COMAR 26.11.03.02B(4) - Applicability and General Requirement:**

CP Crane is required to apply for and obtain a Part 70 operating permit.

k) **COMAR 26.11.04.02 - Ambient Air Quality Standards, Definitions, Reference Conditions, and Methods of Measurement:**

CP Crane shall comply with applicable NAAQS using dispersion modeling. CP Crane has performed an air quality analysis, including air dispersion modeling, which demonstrates compliance with the NAAQS.

l) **COMAR 26.11.06.03B(1)(a) - Particulate Matter Emissions from Confined Sources:**

The CP Crane air emission sources including the CTs and black start generator are subject to this requirement. CP Crane may not cause or permit particulate matter to be discharged into the outdoor atmosphere from any other installation, particulate matter in excess of 0.05 gr/SCFD (115 5g/dscm).

m) **COMAR 26.11.06.03C – Particulate Matter Emissions from Unconfined Sources:**

CP Crane is prohibited from causing or permitting emissions from an unconfined source without taking reasonable precautions to prevent particulate matter from becoming airborne. These reasonable precautions shall include, when appropriate as determined by MDE-ARA, the installation and use of hoods, fans, and dust collectors to enclose, capture, and vent emissions. In making this determination, MDE-ARA shall consider technological feasibility, practicality, economic impact, and the environmental consequences of the decision.

n) **COMAR 26.11.06.03D – Particulate Matter From Materials Handling and Construction:**

CP Crane is prohibited from causing or permitting any material to be handled, transported, or stored, or a building, its appurtenances, or a road to be used, constructed, altered, repaired, or demolished without taking reasonable precautions to prevent particulate matter from becoming airborne.

**o) COMAR 26.11.06.08 – Nuisance:**

CP Crane is prohibited from operating or maintaining a source in such a manner that a nuisance or air pollution is created. **This is a state-only enforceable requirement**.

**p) COMAR 26.11.06.09 – Odors:**

CP Crane is prohibited from causing or permitting the discharge into the atmosphere of gases, vapors, or odors beyond the property line in such a manner that a nuisance or air pollution is created. **This is a state-only enforceable requirement.**

**q) COMAR 26.11.06.12 - Control of NSPS Sources:**

CP Crane is prohibited from constructing, modifying, or operating, or causing to be constructed, modified, or operated, a NSPS source as defined in COMAR 26.11.01.01B(23), which results or will result in violation of the provisions of 40 CFR Part 60, as amended.

**r) COMAR 26.11.09.05(A)(1) - Visible Emissions:**

Areas III and IV. CP Crane may not cause or permit the discharge of emissions from any fuel burning equipment, other than water in an uncombined form, which is visible to human observers, except that for the purpose of demonstrating compliance using COM data, emissions that are visible to a human observer are those that are equal to or greater than 10 percent opacity.

**s) COMAR 26.11.09.07 - Control of Sulfur Oxides From Fuel Burning Equipment:**

This requirement is applicable only to equipment burning diesel fuel which includes the CTs and black start generator. CP Crane may not burn, sell, or make available for sale any fuel with a sulfur content by weight in excess of or which otherwise exceeds 0.3% for distillate fuel oils.

t) **COMAR 26.11.09.08B(1)(a) and COMAR 26.11.09.08K – $NO_X$ Standards for Fuel Burning Equipment:**

CP Crane may comply with the $NO_X$ emission limits in COMAR 26.11.09.08B(1)(c) or the applicable $NO_X$ requirements in COMAR 26.11.09.08C - J. As an installation equipped with a CEM, compliance with the $NO_X$ emissions standards in COMAR 26.11.09.08 shall be established using CEM data for the CTs. CEMs shall be certified in accordance with or Part 75, Appendix A. CEMs shall meet the quality assurance criteria in the CAA (Acid Rain), 40 CFR Part 75, Appendix B. Except as otherwise established by MDE-ARA and approved by the EPA, for a person who establishes compliance with the $NO_X$ emissions standards in this regulation using a CEM, compliance shall be determined as 30-day rolling averages. When demonstration of compliance with the $NO_X$ emission standards in this regulation is based on CEM data, quarterly emission reports shall be submitted to MDE-ARA on or before the thirtieth day of the month following the end of each calendar quarter.

u) **COMAR 26.11.09.08G - Control of $NO_X$ Emissions for Major Stationary Sources, Requirements for Fuel-Burning Equipment with a Capacity Factor of 15 Percent or Less:**

This requirement is applicable to the black start generator. Requires CP Crane, for fuel-burning equipment with a capacity factor of 15% or less, to annually certify the capacity factor of the equipment to MDE-ARA in writing, and if the equipment operates for more than 500 hours during a calendar year, to conduct a combustion analysis and optimize combustion for that equipment.

v) **COMAR 26.11.15 and COMAR 26.11.16 - Toxic Air Pollutants and Procedures Related to Requirements for Toxic Air Pollutants:**

CP Crane is required to determine the applicability of the TAPs requirements and perform facility-wide air quality analyses, if applicable. **This is a state-only enforceable requirement.**

w) **COMAR 26.11.36 – Distributed Generation:**

The black start generator must comply with NESHAP ZZZZ and NSPS IIII to comply with this requirement. **This is a state-only enforceable requirement.**

x) **COMAR 26.09 - The Regional Greenhouse Gas Initiative:**

CP Crane is required to participate and adhere to the requirements of COMAR 26.09. An initial $CO_2$ Budget Permit will be issued in conjunction with the Part 70 permit. CP Crane is required to submit an initial $CO_2$ budget permit application 12 months before the date on which the $CO_2$ budget source commences operation. **This is a state-only enforceable requirement.**

# 5.0 ANALYSIS OF OTHER ENVIRONMENTAL IMPACTS

## 5.1 IMPACTS TO BIOLOGICAL RESOURCES

### 5.1.1 Overview

The following sections provide a review of the potential environmental effects of the proposed Project on biological resources, including wetlands; surface waters; vegetation; and wildlife and rare, threatened and endangered (RTE) species. The proposed CP Crane Project has minimal potential to negatively impact biological/ecological resources. There is little potential for the proposed modification to negatively impact either wetlands or terrestrial and aquatic resources; therefore, the applicant conducted no baseline monitoring of ecological resources. PPRP concurs that no baseline monitoring is needed.

The Applicant assembled existing information from online sources (e.g., MERLIN Online) as summarized in Appendix B of their ERD. The Applicant's key findings supported by MERLIN data are as follows:

- Both the Maryland DNR and NWI maps indicated the presence of wetlands in the site area;
- Neither source indicated any wetlands of special state concern to be present anywhere in the vicinity of the site;
- Neither source indicated any natural heritage areas, agricultural preservation lands, or forest legacy lands to be present anywhere in the vicinity of the site; and
- These sources indicated the presence of sensitive species near the site, as well as habitat suitable for FIDS, green infrastructure, and SAV.

In addition to MERLIN, the Applicant queried the USFWS IPaC tool for records of species and other resources, such as critical habitat, under the USFWS's jurisdiction that are known or expected to be within a 1-mile radius of the CP Crane site. The IPaC report (USFWS, 2018a) identified no federally threatened or endangered species under the Endangered Species Act of 1973. The Migratory Bird Treaty Act of 1981 listed 31 avian species as birds of conservation concern by USFWS; these are species that are of concern throughout their range anywhere within the United States. Additionally, the IPaC identified bald eagle and golden eagle occurring within one mile of the Project site. Eagles receive protection under the Bald and Golden Eagle Protection Act of 1940. The IPaC also identified sixteen additional avian species within a 1-mile radius of the site that are

potentially susceptible in offshore areas to certain types of development or activities (e.g., offshore energy development or longline fishing).

No National Wildlife Refuge lands are within one mile of the site, nor are any fish hatcheries. The Applicant queried critical habitat under the jurisdiction of NOAA Fisheries to identify any anadromous or marine species that may exist near the site. Based on this query, the closest designated critical habitat (for Maryland darter, *Etheostoma sellare*) is approximately 18 miles northeast of the site (USFWS, 2018b).

The CP Crane site is located within the Maryland Piedmont Plateau Province. Characteristically, the landscape in the site region is typified by rolling hills with incised stream valleys. This area of Maryland is included within the Southeastern Mixed Forest Ecological Province as defined by the U.S. Forest Service. Typical vegetation is deciduous and mixed pine oak forests.

### *5.1.2 Potential Impacts Due to Construction Activities*

#### *5.1.2.1 Wetlands and Surface Waters*

The Applicant obtained DNR and NWI wetland maps from DNR's Geospatial Data website. Figures 3-3 and 3-4 in Section 3.5 show these maps overlaying an aerial photograph. While there are wetlands located within the site boundary, the approximate 5-acre developed area proposed for the Project will not impact these wetlands.

Prior to the beginning of construction, the Applicant will prepare a grading permit application, stormwater management (SWM) permit, and erosion and sediment control (ESC) plan for submittal to Baltimore County. In addition, the facility will obtain coverage under the MDE General Permit for Construction Activity. These plans will form the basis for providing adequate protection of the surrounding surface waters (Seneca Creek and Saltpeter Creek) during construction.

Given the absence of plans to disturb existing wetlands and the establishment/modification of effective stormwater quantity and quality controls as well as Spill Prevention, Control, and Countermeasures (SPCC) procedures, no significant impacts on surface waters resulting from site construction are expected to occur.

The Applicant identified four potential sources of impacts to surface waters during Project construction and means to avoid or mitigate these impacts as described below.

- Direct Disturbance of Existing Wetlands – none of the areas proposed for the Project development are within any existing wetland areas. Therefore, no direct impacts on any of these areas are expected to occur during Project construction.
- Erosion of Disturbed Areas that May Transport Sediment – the Applicant will develop an ESC plan in accordance with Baltimore County Soil Conservation District requirements. Implementation of the approved ESC plan will prevent discharge of sediment-laden runoff from entering surrounding surface water bodies. The Applicant will modify the ESC plan as needed to account for site changes or if it is determined that sediment discharges are occurring.
- Significant Changes in Stormwater Quantities and/or Qualities Discharged Offsite – the Applicant will design the temporary construction sediment basin according to the 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control. Therefore, no significant impacts in surrounding surface water quality or quantities are expected to result during construction of Project improvements. The Applicant will modify the existing CP Crane stormwater management systems in association with Project construction. The applicant will also develop and install a combination of a temporary sediment basin and sediment control best management practices (BMPs) to accommodate construction activities. Key construction period controls will include:
    - The Applicant will leave existing vegetation in place wherever possible and will stabilize disturbed soils as necessary to prevent significant erosion;
    - The Applicant will install erosion and sediment controls and a temporary sediment basin as required at the initiation of construction to provide adequate stormwater facilities. The Applicant will modify or expand these facilities as needed during construction; and
    - The Applicant will compact the temporary sediment basin embankments as required and stabilize it with seed and mulch within three days of completion to prevent sediment basin bank erosion.
- Accidental Spills of Onsite Chemicals, Lubricants, or Other Potential Contaminants – the Applicant will develop and strictly follow SPCC procedures during construction activities. The Applicant will design these procedures to minimize the opportunity for accidental spills and provide adequate systems to contain accidental spills.

PPRP concurs that the implementation of the plans, in accordance with the approved erosion and sediment control plans, and the application of BMPs will prevent significant impacts from occurring to any onsite or nearby offsite surface waters or wetlands during Project construction. Further, as no development is proposed within the 100-year floodplain, it will not be impacted as part of the proposed Project.

#### *5.1.2.2 Vegetation and Land Cover*

The Applicant states that proposed construction activities will take place within approximately eight acres of developed or previously impacted areas of the CP Crane site. Therefore, few ecological impacts are expected. The proposed Project will involve demolishing several existing structures, but not all structures, and adding new project components at the site. This proposed construction will occur within previously developed portions of the site and none of it will result in permanent ecological impacts. In addition, the Applicant has indicated they will use existing developed areas of the site for construction laydown and parking areas. It is anticipated that the existing paved parking lot can accommodate construction parking. Space required for construction materials laydown will be modest, and the Applicant has determined that the area immediately south of the existing warehouse is adequate for that purpose. Thus, there will be no construction-related impacts to natural vegetation communities on site. No state or federally listed plants are likely to occur onsite due to lack of suitable habitat. PPRP concurs that the proposed Project will not cause significant impacts to the site's ecological resources and features.

#### *5.1.2.3 Wildlife and Rare, Threatened and Endangered Species*

The Applicant states there will be no impacts to natural communities on site, as the proposed development will take place within previously disturbed and developed portions of the site. The primary impacts of proposed Project construction activities on local wildlife resources will be temporary in nature and include the displacement of species in the immediate area due to noise, traffic, and human presence during construction. However, these impacts are expected to be relatively minor as the proposed Project site is currently developed and occupied. The current level of wildlife activity is expected to resume once construction is complete, and since there are no natural communities that will be cleared within the main Project location, there will be no permanent displacement of wildlife habitat or species.

There is FIDS habitat on the CP Crane site west of the Project area (refer to Figure 3-5 in Section 3.5), but this part of the site will not be developed as part of the proposed Project. As such, there should be no impacts to FIDS species resulting from Project development, with the possible exception of temporary disturbance (e.g., noise) caused by construction activities.

There is also green infrastructure just inside and surrounding the site boundary as previously shown in Figure 3-6. As these areas will be not disturbed as part of the proposed Project, there are no impacts anticipated in these areas.

Gunpowder River, including Seneca Creek, is an estuary with tidal characteristics. The average tidal range is approximately 1.4 ft with slightly higher spring tides. Estuarine systems consist of deep-water tidal wetlands and adjacent tidal wetlands. As previously shown in Figure 3-7, SAV is also established within this estuarine system. The estuary supports numerous terrestrial and aquatic species. Terrestrial species include birds adapted to urban environments, year-round and migratory fowl, raptors, mammals, reptiles, and amphibians. Aquatic species include zooplankton communities, benthic macroinvertebrates, and fish. For the latter, the Gunpowder River basin supports spawning and nursery areas for sport and commercial fish species.

No construction activity will take place within Seneca Creek or its buffer areas, so no direct impacts will result from construction of Project CTs or related facilities. The Applicant will control to the extent possible potential secondary impacts such as sedimentation and stormwater runoff using a county-approved ESC plan and SWM plan. Therefore, PPRP concludes that there will be no significant impacts to the creek or its aquatic habitats because of Project construction.

According to the USFWS IPaC tool queried on February 27, 2018 (Appendix B-3 of Crane ERD 2018), there are no endangered species under USFWS jurisdiction expected to occur within a 1-mile radius of the Project site. Additionally, there are no refuge lands or fish hatcheries. There are wetland areas (NWI and other) within a 1-mile radius of the site, as discussed previously, as well as the potential for bald and golden eagle and numerous migratory birds to occur. However, project construction will not result in alteration of existing land use, including tree clearing. Thus, no impacts to wetlands, migratory birds, or eagles will result from the Project.

The Applicant also used the DNR data site to obtain the more detailed information regarding sensitive species review areas as delineated by the

WHS. The highlighted areas indicate the presence or possible presence of listed species. The areas closest to the plant site are classified as either Group 2, 3, or 4. Group 2 relates to state-listed species; Group 3 relates to species or natural communities of concern to DNR, but with no official status; and Group 4 indicates buffered locations of bald eagle nests. None of these areas is located on the site. In the event that any RTE habitat or species are encountered during construction, PPRP recommends a licensing condition to consult with WHS to determine appropriate action if any RTE species are identified during planning, construction, or maintenance of this facility.

In summary, the CP Crane Repowering Project will take place primarily on a developed parcel of land that has housed an operational power plant since the early 1960s. No natural communities will be cleared for the Project; therefore, no direct impacts to natural communities will result. Temporary impacts to wildlife species inhabiting adjacent areas may result during the construction process due to human presence and noise. These disturbances will last only during the duration of Project construction and should have no long-term effect on the wildlife community.

### *5.1.3 Potential Impacts Due to Facility Operation*

#### *5.1.3.1 Wetlands and Surface Waters*

The proposed Project will occupy approximately five acres following construction. Operational SWM for facilities in Baltimore County must be designed in accordance with the Maryland Stormwater Design Manual. The Applicant will prepare a SWM plan following this guidance to demonstrate how the stormwater from the five acres will be managed.

There are four potential sources of impacts to onsite or nearby surface waters during Project operations:

- Direct Disturbance of Existing Wetlands or Surface Waters—The new CTs will be located in an existing developed area of the site, and the Applicant is proposing no disturbance to existing wetlands.
- Direct Discharge of Process Effluents—Process wastewater generated by Project operation will be discharged to a new OWS and ultimately the municipal waste water system. Since there will be no direct discharge of process wastewater to any surrounding surface waters, there will be no surface water impacts associated with Project operations. Shutting down of the coal-fired units' cooling system has

eliminated impingement and entrainment from the previous facility cooling water intake as well as the thermal load from its the discharge.

- Significant Changes in Stormwater Quantities and/or Qualities Discharged Offsite—The Applicant proposes to include a SWM system designed and installed to ensure water quality volume, groundwater recharge, and channel protection with the Project. The Applicant will also develop and implement operating and maintenance procedures designed to ensure the continued effectiveness of this system. Based on installation of a sound SWM system and proper operations and maintenance of these facilities, no significant impacts to any surrounding surface waters are expected because of Project operations.
- Accidental Spills of Onsite Chemicals, Lubricants, or Other Potential Contaminants— The Applicant will design the project to include spill containment and control features as developed under the overall SPCC plan and chemical/hazardous materials management procedures. The Applicant will design these procedures to minimize the opportunity for accidental spills and identify the appropriate and timely response procedures to be followed in case of an accidental spill.

To ensure that oil spills from the onsite substation will not impact the Gunpowder River, PPRP recommends a license condition requiring CP Crane to implement secondary containment for the substation. PPRP concurs that the implementation of these plans and procedures will prevent significant impacts from occurring to any onsite or nearby offsite surface waters or wetlands during Project operation.

#### *5.1.3.2 Vegetation and Land Cover*

No vegetation or land cover, beyond what was impacted during construction, will be impacted during the Project operation.

#### *5.1.3.3 Wildlife*

CP Crane maintains that the operation of the proposed Project will not cause impacts to wildlife for the following reasons:

- The existing CP Crane property is currently developed and occupied;
- RTE plant and wildlife species are not located at the site;
- The implementation of Project systems and operating procedures will be designed to minimize impacts to the site and surrounding natural environment; and
- Shutting down the existing coal-fired units will be environmentally beneficial.

As mentioned previously, Project impacts on ecological resources would be positive, overall, resulting from the shutting down of the cooling water intake and discharge. The presence of humans and noise are indirect effects of Project operation that could potentially affect surrounding wildlife. There will be less human presence at the CP Crane site following construction, as the number of employees will decrease relative to current levels. In addition, there will be no more coal deliveries to the site as Units 1 and 2 have been shut down. According to the noise modeling results (discussed in Section 5.5), noise levels will remain within the state noise regulation and should have little effect on the surrounding wildlife communities. Mammal and bird species would be expected to experience the most effects, since their auditory systems are the most developed. However, the mobility of these species and the fact that there is a substantial amount of similar habitats in the area should enable these species to relocate to more desirable locations, if necessary. Species typically onsite are well adapted to human presence and noise and will continue to coexist with the Project, just as they have done for many years with the existing CP Crane Generating Station.

## *5.2 IMPACTS TO GROUNDWATER*

Construction of the Project will involve excavation to pour concrete foundations for significant facility structures. These excavations may encounter groundwater, and therefore the excavations may require pumping to remove groundwater and allow for proper placement of foundation materials. There will be no ongoing use of groundwater for water supply during Project operation.

Operations at CP Crane will entail storage and handling of fuel oil and other hazardous liquids. Spills or leaks of these substances could adversely impact groundwater resources at the site. The Project will be designed to include spill containment and control features, which will be described in the required SPCC Plan. The Applicant will establish chemical/hazardous materials management procedures designed to minimize the risk of accidental spills and to identify appropriate and timely response measures to be taken if a spill occurs. With the implementation of best practices and compliance with regulatory requirements, the risk of groundwater impacts during operation will be minimal.

### 5.2.1 *Construction Dewatering Requirement*

Dewatering of groundwater during construction of footers, foundations, and subgrade structures will require a groundwater appropriation permit if dewatering, including any intermittent periods of non-pumping, exceeds 30 days or an annual average of 10,000 gpd, in accordance with COMAR 267.17.06.03.B(3). The withdrawal of groundwater for dewatering requires a new appropriation issued by the Maryland PSC through this CPCN proceeding. MDE does provide an exemption for groundwater uses that average less than 5,000 gpd annually (Annotated Code of Maryland Environment Title 5 Subtitle 5-502). Projects that fall below 5,000 gpd (regardless of duration) may file a Notice of Exemption with the Maryland Department of the Environment Water Supply Program (MDE-WSP) at least 30 days prior to beginning dewatering, in lieu of obtaining an appropriation permit.

### 5.2.2 *Dewatering Volume and Impacts*

This section describes the estimated amount of groundwater that will be withdrawn for dewatering, and evaluates the potential impacts from dewatering to the Quaternary Lowland Deposits.

According to the June 2018 Geotechnical Engineering Services Report prepared by Professional Service Industries, Inc. (PSI) on behalf of CP Crane (provided as Attachment 1 in Response to PPRP Data Request No. 4-1), groundwater was observed in onsite borings at depths ranging from six to ten feet bgs and it was estimated that seasonally, the depth to groundwater may be as shallow as 4 feet bgs. As indicated by the excavation dimensions provided in CP Crane's Response to PPRP Data Request No. 3-2 Attachment 1, shallow foundations will extend 5-6 feet bgs and driven piles will extend 36 to 41 feet bgs, creating the need to dewater to support construction. According to CP Crane's Response to PPRP Data Request No. 3-2 Attachment 1, the current design will require dewatering to facilitate construction of 21 individual structures, as follows:

- Three shallow foundations associated with the CT. These three subgrade structures will require excavation to a depth of five feet and dewatering to one foot below the water table;
- Three shallow foundations associated with stack structures. These three subgrade structures will require excavation to a depth of six feet and dewatering to two feet below the water table;

- The shallow foundation associated with the Fuel Gas Compressors. This subgrade structure will require excavation to a depth of five feet and dewatering to a depth of one foot below the water table;
- The shallow foundation associated with the demineralized water tank. This subgrade structure will require excavation to a depth of five feet and dewatering to a depth of one foot below the water table;
- Three shallow foundations associated with the ULSD tanks and liquid fuel unloading station. This subgrade structure will require excavation to a depth of five feet and dewatering to a depth of one foot below the water table;
- Three shallow foundations associated with the generator step-up transformers. This subgrade structure will require excavation to a depth of five feet and dewatering to a depth of one foot below the water table.
- Five piles to support the demineralized water tank. These piles will be 2.5-feet in diameter and will be driven to a depth of 41 feet, which is 37 feet below the water table;
- Sixteen piles to support the two ULSD tanks. These piles will be 2.5-feet in diameter and will be driven to a depth of 41 feet, which is 37 feet below the water table;
- Six piles to support the H-Frame. These piles will be 2.5-feet in diameter and will be driven to a depth of 36 feet, which is 32 feet below the water table; and
- Fifteen piles to support three stacks. These piles will be 2.5-feet in diameter and will be driven to a depth of 40 feet, which is 36 feet below the water table.

In CP Crane's Response to PPRP Data Request No. 3-2 Attachment 1, the estimated amount of dewatering that will occur during construction was calculated based on the dimensions of the excavation, with no factor included for groundwater recharge into the excavations. CP Crane clarified during a conference call with PPRP and MDE-WSP on 25 October 2018 that mud mats would be placed in each excavation once it was dewatered and that this was expected to prevent further infiltration of formation water. The Applicant further indicated in its response to PPRP Data Request No. 6-1 that the mud mats would consist of lean concrete, placed in a layer four to twelve inches thick. The lean concrete would be installed into the excavation using concrete pumps within 24 hours of initial dewatering. In cases where the local groundwater level is higher than the practical level of the mud mat, lean concrete walls will be poured or sheet pilings driven to seal off the sides of the excavation.

PPRP and MDE-WSP note that even with the assumption that mud mats will prevent further infiltration where they are applied, initial dewatering will create a flow of water from the aquifer toward the excavation. Furthermore, as a conservative assumption, some groundwater may continue to seep through the sidewalls into the excavation despite the construction of barriers to infiltration. For these reasons, PPRP and MDE-WSP considered recharge of groundwater from the formation to the excavation as a worst-case scenario when evaluating whether an appropriation permit would be required.

PPRP performed independent calculations of potential dewatering needs for the proposed excavations. The calculations are presented in Table 5-2. The initial volume of water expected to be removed from the excavation prior to placement of the mud mat is calculated as the length times width times the saturated thickness of the excavation, equivalent to one volume of water. Once the mud mat is placed, preventing further infiltration of formation water through the excavation floor, seepage of groundwater into the excavation through the sidewalls is calculated using the basic groundwater flow equation below where Q is the rate of groundwater flow; K is the hydraulic conductivity of the soil; i is the hydraulic gradient across the area, and A is the cross-sectional area of a plane oriented perpendicular to the flow direction.

$$Q=KiA$$

Values for these components were determined as follows:

- Q - The June 2018 Geotechnical Engineering Services Report (PSI, 2018) indicates that the surficial aquifer at the site is the Quaternary Lowland Deposits. Bennett and Meyer, 1952, reported that the characteristics of the Lowland Deposits vary widely and reported hydraulic conductivity measurements ranging from 72 to 1,780 feet per day (ft/day). The majority of these values were from laboratory tests of samples. However, one well pumping test was reported yielding a hydraulic conductivity of 120 ft/day. This was the hydraulic conductivity assumed for the site.
- i – As no groundwater contour maps were available for the site, a hydraulic gradient of 0.01 was assumed. This is believed to be a relatively high and therefore conservative value because, as the site is situated along the bank of the river in an area with very little topographic relief, the hydraulic gradient across the site is expected to be low.
- A – the length and width of each excavation, as well as the depth to which each excavation is anticipated to penetrate the water table, was

used to calculate a cross sectional area for the saturated portion of the four sidewalls of each excavation for shallow foundations.

In order to translate the groundwater flow rate into a volume of anticipated dewatering, the duration of dewatering is also needed. The Applicant indicated in is response to PPRP Data Request No. 1-4a that dewatering for any single structure could last from one to five days. As a conservative measure, a dewatering duration of five days was assumed for each foundation structure.

PPRP understands that piles will be installed in such a manner that grouting will be performed simultaneously with dewatering, thus there will be very little time for additional water to enter the pile borings. The maximum amount of dewatering for these structures is assumed to be the total volume of the borehole and this volumetric calculation is not affected by duration.

Table 5-1 below presents a summary of the dewatering amount determined by PPRP using excavation dimensions provided by CP Crane in response to PPRP Data Request No. 3-2 Attachment 1 and aquifer characteristics as determined from PPRP Data Request No. 4-1 Attachment 1 and the above-referenced literature values. PPRP's calculations also include a contingency factor of 50%, as included by the Applicant, to account for uncertainties as well as precipitation that may fall into the excavation.

## *Table 5-1 Construction Dewatering Calculations*

| No. | Excavation | Excavation Length - L (ft) | Excavation Width - W (ft) | Avg Depth to Water Table (ft) | Excavation Depth - D (ft) | Seepage Face Thickness - H (ft) | Saturated Area of Long Wall ($ft^2$) | Saturated Area of Short Wall ($ft^2$) | Hydraulic Conductivity - K (ft/d) | Average Hydraulic Gradient - i | Q (gpd) | Duration (days) | Total withdrawn design (gal) | Peak Month Total Withdrawn (gal) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CTG 1 | 61.25 | 19 | 4 | 5 | 1 | 61.25 | 19.00 | 120 | 0.01 | 10,145 | 5 | 51,891 | 51,891 |
| 2 | CTG 2 | 61.25 | 19 | 4 | 5 | 1 | 61.25 | 19.00 | 120 | 0.01 | 10,145 | 5 | 51,891 | 51,891 |
| 3 | CTG 3 | 61.25 | 19 | 4 | 5 | 1 | 61.25 | 19.00 | 120 | 0.01 | 10,145 | 5 | 51,891 | 51,891 |
| 4 | Stack 1 | 14 | 14 | 4 | 6 | 2 | 28.00 | 28.00 | 120 | 0.01 | 3,937 | 5 | 20,079 | 20,079 |
| 5 | Stack 2 | 14 | 14 | 4 | 6 | 2 | 28.00 | 28.00 | 120 | 0.01 | 3,937 | 5 | 20,079 | 20,079 |
| 6 | Stack 3 | 14 | 14 | 4 | 6 | 2 | 28.00 | 28.00 | 120 | 0.01 | 3,937 | 5 | 20,079 | 20,079 |
| 7 | Fuel Gas Compressrs | 40.5 | 26 | 4 | 5 | 1 | 40.50 | 26.00 | 120 | 0.01 | 9,070 | 5 | 46,404 | 46,404 |
| 8 | Demin Water Tank | 42 | 36.375 | 4 | 5 | 1 | 42.00 | 36.38 | 120 | 0.01 | 12,835 | 5 | 65,701 | 65,701 |
| 9 | Liquid Fuel Tank 1 | 42 | 36.375 | 4 | 5 | 1 | 42.00 | 36.38 | 120 | 0.01 | 12,835 | 5 | 65,701 | 65,701 |
| 10 | Liquid Fuel Tank 2 | 42 | 36.375 | 4 | 5 | 1 | 42.00 | 36.38 | 120 | 0.01 | 12,835 | 5 | 65,701 | 65,701 |
| 11 | Liquid Fuel Unloading Station | 23 | 11 | 4 | 5 | 1 | 23.00 | 11.00 | 120 | 0.01 | 2,503 | 5 | 12,767 | 12,767 |
| 12 | GSU 1 | 15 | 11.5 | 4 | 5 | 1 | 15.00 | 11.50 | 120 | 0.01 | 1,766 | 5 | 9,003 | 9,003 |
| 13 | GSU 2 | 15 | 11.5 | 4 | 5 | 1 | 15.00 | 11.50 | 120 | 0.01 | 1,766 | 5 | 9,003 | 9,003 |
| 14 | GSU 3 | 15 | 11.5 | 4 | 5 | 1 | 15.00 | 11.50 | 120 | 0.01 | 1,766 | 5 | 9,003 | 9,003 |
| | | | | | | | | | | | | | | |

| | | |
|---|---|---|
| Annual Total (gal) | 499,193 | |
| Annual Avg (gpd) | 1,368 | |
| Peak Month Total (gal) | | 499,193 |
| Peak Monthy Daily Rate (gpd) | | 16,640 |

Notes:
Cells highlighted yellow indicate literature values obtained by PPRP. All other cells represent data provided by Crane
Q=KiA (where A is the saturated sidewall area of the excavation: (L*H*2 +W*H*2)
Peak monthly withdrawal assumes pumping at rate Q consistently for 30 days.
Assumptions
1. Water table does not draw down at seepage face during pumping
2. Hydraulic gradient is based on site average regardless of direction
3. Floor is sealed instantaneously with mud mat to prevent upwelling of water:

| No. | Piles | # of Piles | Pile Diameter (ft) | Depth - D (ft) | Avg Depth to WT | Single Borehole Volume (ft3) | Total Dewatering Volume for all Piles (ft3) | Total Dewatering Volume for all Piles (gal) | Peak Month Total Withdrawn (gal) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Demin Tank | 5 | 2.5 | 30 | 4 | 147 | 736 | 5,505 | 5,505 |
| 2 | LF Tanks | 8 | 2.5 | 30 | 4 | 147 | 1178 | 8,808 | 8,808 |
| 3 | LF Tanks | 8 | 2.5 | 30 | 4 | 147 | 1178 | 8,808 | 8,808 |
| 4 | H-Frame | 6 | 2.5 | 30 | 4 | 147 | 883 | 6,606 | 6,606 |
| 5 | Stack | 5 | 2.5 | 30 | 4 | 147 | 736 | 5,505 | 5,505 |
| 6 | Stack | 5 | 2.5 | 30 | 4 | 147 | 736 | 5,505 | 5,505 |
| 7 | Stack | 5 | 2.5 | 30 | 4 | 147 | 736 | 5,505 | 5,505 |
| 6 | | | | | | | | | |

| | | | |
|---|---|---|---|
| Annual total (gal) | - | 46,244 | |
| Annual Avg (gpd) | - | 127 | |
| Peak Month Total (gal) | | - | 46,244 |
| Peak Month Pumping Rate (gpd) | | - | 1,541 |

Notes
Assumptions
1. The borehole initially fills with 1 volume of water
2. Water is removed as concrete is placed in the borehole.
3. Borehole Volume = Pi * $(1/2*D)^2$ * h * 7.48 gal/$ft^3$
4. Borehole Volume is multiplied by the number of piles.

| TOTALS | | | |
|---|---|---|---|
| Annual total (gal) | - | 545,436 | - |
| Annual Avg (gpd) | - | 1,494 | - |
| 50% Contingency | - | 747 | - |
| Annual Average with Contingency (gpd) | - | 2,242 | - |
| Peak Month Total (gal) | | - | 545,436 |
| Peak Month Pumping Rate (gpd) | | - | 18,181 |

Table 5-1 shows 545,436 gallons as the total estimated volume of groundwater to be removed during construction dewatering from 21 subgrade structures (499,193 gallons from the structures with shallow foundations and 46,244 gallons from the structures to be supported by piles). The annual average daily dewatering rate of approximately 1,494 gpd (545,436 gallons/365 days and rounded) is calculated based on the need to dewater all 21 subgrade structures and normalizing the dewatering amount over an entire year in accordance with MDE-WSP methods to calculate the average annual amount of the appropriation. The 50% contingency factor brings the total estimated dewatering to 2,242 gpd.

The 50% contingency value is further supported when the amount of precipitation that falls on the excavations is considered. Annual rainfall in Baltimore City is 41.88 inches per year (NOAA, 2018). There is uncertainty associated with the amount of rainfall that will evaporate versus the amount that will be captured in the excavation. Assuming two-thirds of the rainfall evaporates and one-third is captured in the excavated areas, the 14 inches spread over the estimated 10,500 square feet of proposed excavations will generate about 12,250 gallons per year or 34 gpd over a 365-day period. The 34 gpd is much less than the 747 gpd added by the 50% contingency, demonstrating the level of conservancy added by the contingency because there is low probability that all 21 excavations will be dewatered simultaneously.

The month of maximum use value of 4,376 gpd is based on the conservative assumption that all 21 excavations listed in Table 5-1 need to be dewatered for five days within a single 30 day period (545,436 gallons/30 days, rounded). This value does not include the 50% contingency factor.

PPRP’s calculations confirm CP Crane’s assertion in its response to Data Request 3-2 Attachment 1 that the estimated volume of dewatering will not exceed the 10,000 gpd threshold that would require a groundwater appropriation permit. CP Crane indicated in its response to PPRP Data Request No. 1-4a that, depending upon the construction schedule and dewatering needs, the period to complete all excavations and dewatering could exceed 30 days. However, because the total anticipated usage will be less than 5,000 gpd, in accordance with the stipulations of the Annotated Code of Maryland Environment Title 5 Subtitle 5-502, CP Crane will not require a groundwater appropriation permit, but will need to file a Notice of Exemption with MDE-WSP at least 30 days before the proposed dewatering will begin.

### 5.2.3 *Management of Construction Dewatering Discharge*

Dewatering may take place in areas of the site where groundwater is contaminated from past site activities (CP Crane Response to PPRP Data Request No. 1-4). MDE's Oil Control Program oversees an ongoing remediation effort at the site. Four of the subsurface support structures associated with the currently proposed Project will be constructed in the vicinity of the remediation well network: pile supports for the two ULSDs, shallow foundation for the liquid fuel unloading station, and the shallow foundation for the fuel gas compressor (CP Crane Response to PPRP Data Request No. 1-4 Exhibits A and C). The LPH-containing wells located closest to these excavations are GM-02 (LPH sheen), MW-5 (0.37 feet of LPH), PRW-5 (0.37 feet of LPH), and MW-2 (0.06 feet of LPH). The proposed excavations lie to the north and west of these wells at distances ranging from approximately 50 to 150 feet. The well containing the highest reported thickness of LPH is well PRW-6 at 0.85 feet of LPH. This well lies about 150 feet from the nearest pile support that will be drilled for the currently proposed repowering Project.

In the event that groundwater removed during construction is contaminated, CP Crane states that they will ensure it is handled and disposed in accordance with legal and regulatory requirements. If the groundwater is of acceptable quality, CP Crane may be able to discharge it directly to the sanitary sewer system; contaminated water may need to be hauled by truck to an appropriate treatment facility.

CP Crane will be required to obtain MDE approval for discharge of the groundwater, which will entail sampling and monitoring to detect any contamination. The reviewing State agencies recommend a license condition requiring CP Crane to obtain all necessary permits and approvals from MDE for discharging removed groundwater.

It should be further noted that dewatering at the site could have a temporary effect on the remediation system by drawing contaminated water away from the recovery wells for a short period of time. The reviewing State agencies' recommended license condition would also require CP Crane to coordinate with the MDE Oil Control Program regarding any impacts to ongoing remediation activities at the site. The Applicant shall provide documentation to the PSC and PPRP of its coordination with MDE and any permits or approvals obtained.

## 5.3 SOCIOECONOMIC IMPACTS

### 5.3.1 Employment and Income

Modification of the facility will create temporary construction jobs, most drawn from the Baltimore metropolitan labor force. The Applicant estimates that the project will employ approximately 60 construction workers over a 10-12 month period, with employment peaking at about 75 workers. The Project site is proximate to a large labor pool within the Baltimore metropolitan area, and most jobs will be sourced locally. Additional benefits are expected from expenditures of goods and services, although not all equipment will be sourced within Maryland.

Construction will generate a mild fiscal benefit for the State and Baltimore County from taxes on direct and indirect income, personal consumption expenditures, and sales of goods and services by Maryland firms. No State or county expenditures will be required for infrastructure improvements, and the project will have no effect on public services or facilities. As such, the net economic benefit to the State and Baltimore County will be positive.

Post-construction, the Project will benefit the Baltimore metropolitan area through property taxes, employment and purchases of goods, and services for maintenance. PPRP has concluded economic benefits from Project operation will be positive, even though plant staffing will be significantly less than when the facility was operated as a coal-fired generator. Local contractors will periodically be on site for maintenance. CP Crane estimates annual purchases of goods and services will be in the range of $400-500 thousand, much of which may be sourced from local suppliers.

### 5.3.2 Population and Housing

With construction workers commuting to the Project site on a daily basis, the project will have no effect upon population or housing. Post-construction, the Applicant states the project will require only a few employees that will be drawn from the Baltimore metropolitan labor market. PPRP has concluded no population, housing, fiscal, or traffic impacts are anticipated from project operations.

### 5.3.3 Land Use

Since development activities will be confined to previously developed areas of the site, no adverse effects on land use are anticipated during the

construction period. Post-construction, use of the land will not be significantly different from the facility as it existed previously.

As noted earlier, the original CP Crane Generating Station was permitted as a special exception to the site's then-current zoning, subject to a number of conditions that included a provision limiting the number of power producing units on the subject property to four. In its review of the project's ERD, PPRP noted the Applicant's plans to install three simple-cycle gas-fired CTs at the existing site, and retire two coal-fired units, although some Unit 1 & 2 ancillary buildings would be demolished to make room for the CTs. The project site also houses a 14 MW oil fired combustion turbine.

From the information provided, PPRP concluded there will be either four or six power producing units at the site, depending on how a retired unit is classified. The Project could therefore be in violation of its special exception condition for use of the parcel. In its response to PPRP Data Request No. 2-2, the Applicant provided evidence showing the Baltimore County Zoning Review Office has confirmed that site plan improvements and changes to the operation of the power plant use are within the spirit and intent of prior zoning cases applicable to the Project property and that no additional zoning relief is required.

### *5.3.4 Transportation*

CP Crane has stated the number of construction workers onsite will be roughly the same as the retired coal-fired units' operation and maintenance employment. PPRP has thus concluded existing roads are capable of handling the modest increment in traffic generated during construction. Trucks will deliver materials and equipment to the project site over the construction period. To the extent that any loads of materials or equipment for the project are oversized or overweight, the Maryland State Highway Administration requires hauling permits. Title 24, Subtitle 1 of the Transportation Article of the Annotated Code of Maryland defines an oversize or overweight vehicle, which are adopted by reference in Baltimore County regulations relating to maximum weights and sizes of vehicles.[7] To address any roadway permit requirements, PPRP has recommended a license condition requiring CP Crane to comply with all permit requirements for transport of oversize or overweight loads on State and county roads and obtain appropriate approvals as necessary.

[7] §18-3-108

Post-construction traffic will be limited to an estimated four employee vehicles and periodic contractor visits. USLD fuel oil will be delivered via truck, although only when natural gas is not available in sufficient quantities. Natural gas will be delivered via an existing pipeline. No rail traffic is anticipated.

### *5.3.5 Visual Impacts*

During construction, cranes may be visible from some perspectives, and local residents may notice an increase in the number of trucks entering or exiting the site. However, truck traffic is part of normal plant operations, and only a minor increase in the volume of truck traffic is anticipated.

Views of the CP Crane Generating Station will not change significantly. The CT power block will be west of the existing power plant, and much of the onsite infrastructure associated with the coal-fired units will remain, including the two 400-foot boiler stacks. The new CTs will have a low visual profile, as will other Project components. The tallest newly proposed structures will be the three CT stacks, which will be 160 feet above ground level.

Available views toward the CP Crane site from accessible vantage points are industrial, characterized by boiler buildings and tall stacks. Most structures associated with the proposed facility will not be visible. PPRP has concluded the project will have a minimal adverse effect on views from surrounding areas.

### *5.3.6 Fiscal Impacts*

Public service demand is expected to be unaffected by the project. PPRP has concluded the project will produce mild fiscal benefits for Baltimore County and Maryland.

## *5.4 CULTURAL RESOURCES IMPACTS*

PPRP has concluded construction will have no adverse effect on archeological or historic sites. No archeological or historic sites are within the boundaries of the CP Crane site, and offsite resources are outside the Project's area of potential effect.

Two properties listed in the MIHP, Scott-Andrew House and Mace-Luthardt House, are within one mile of the facility, but are visually buffered by intervening forested lands. Other MIHP and NR listed

properties are outside the area of potential effect of the CP Crane Generating Station. PPRP has concluded Project impacts on other cultural resources in the area, such as county and state parks, are likely to be minimal since views toward the facility are mitigated by woodlands and will be, for the most part, unchanged.

The CP Crane Station is located in Baltimore County's Coastal Rural Legacy Area, and two Rural Legacy easements to the west are adjacent to CP Crane parcels. Neither parcel is proximate to project components, and both parcels are separated from the nearest project structures by woodlands. With a similar or slightly reduced visual footprint, PPRP has concluded the Project will not affect nearby cultural, scenic, or other programmatic resources. In the event that relics from unforeseen archeological sites are identified during construction, PPRP has recommended a license condition requiring CP Crane, in consultation with the Maryland Historical Trust, to develop a plan for avoidance and protection, data recovery, or destruction without recovery of such relics.

## *5.5 NOISE IMPACTS*

### *5.5.1 Summary of Regulatory Requirements*

Maryland noise regulations specify maximum allowable noise levels, shown in Table 5-2 (COMAR 26.02.03). The maximum allowable noise levels specified in the regulations vary with zoning designation and time of day. The noise limit for residential areas is 55 dBA during nighttime hours and 65 dBA during daytime hours. A noise source may not create noise that exceeds the allowable levels, as measured at the receiving property.

*Table 5-2 Maximum Allowable Noise Levels (dBA) for Receiving Land Use Categories*

| | Zoning Designation | | |
|---|---|---|---|
| | **Industrial** | **Commercial** | **Residential** |
| Day | 75 | 67 | 65 |
| Night | 75 | 62 | 55 |

Source: COMAR 26.02.03

Note: Day refers to the hours between 7 AM and 10 PM; night refers to the hours between 10 PM and 7 AM.

The State regulations exempt certain noise sources and noise generating activities. For example, motor vehicles on public roads are exempt from Maryland noise regulations; however, while on industrial property, trucks are considered part of the industrial source and are regulated as such. The regulations also allow for construction activity to generate noise levels up to 90 dBA during daytime hours, but the nighttime standard may not be exceeded during construction.

While the State has established target levels for noise, enforcement authority for noise regulations rests with local government (in this case, Baltimore County).

### 5.5.2 Noise Impacts Due to Construction

Construction activities are likely to generate higher noise levels compared with operational noise associated with the Project. Construction noise is difficult to predict because it results from many different sources moving about the site and operating on different schedules. The Applicant estimated the sound pressure levels associated with major construction phases, using EPA data from 1971 on average sound levels for typical construction phases. The EPA estimated sound levels assume that all equipment in each phase operates concurrently at the acoustic center of the project's footprint. The loudest phase of construction, excavation, is estimated at 89 decibels at a distance 50 feet from the source. The nearest residence is approximately 1,200 feet from the proposed turbines and approximately 1,100 feet away from the nearest planned construction activity at the site. Daytime construction is not expected to exceed 90 dBA limit; the Applicant states that nighttime construction will be limited to low-noise activities.

### *5.5.3 Noise Impacts Due to Operation*

The Applicant stated in their CPCN Application that the turbines would be equipped with exhaust stack silencers that will limit turbine noise levels to 60 dBA at 400 feet. In their response to PPRP Data Request No. 5-1, the Applicant explained that they consulted various stack manufacturers to confirm that this technology would limit the noise to the stated value. The silencer technology is a common design in the industry and it has achieved 60 dBA at 400 feet at over 50 installations worldwide. PPRP compared CP Crane's proposed turbine sound power levels with other simple cycle combustion turbines at similarly sized facilities and literature estimation methods from the Edison Electric Institute's Electric Power Plant Environmental Noise Guide (EEI 1985). Literature estimations and similarly sized simple cycle turbines reviewed had similar sound power levels to the units proposed by CP Crane.

Using the source noise information, PPRP estimated the sound pressure levels that would result at the nearest residential receptor, as shown in Figure 5-1. The objective of this analysis was to verify the results that the Applicant presented in the CPCN Application. Sound pressure levels at varying distances were calculated using the following formula:

$$L_2 = L_1 - 20\ Log_{10}(\frac{R_2}{R_1})$$

where:

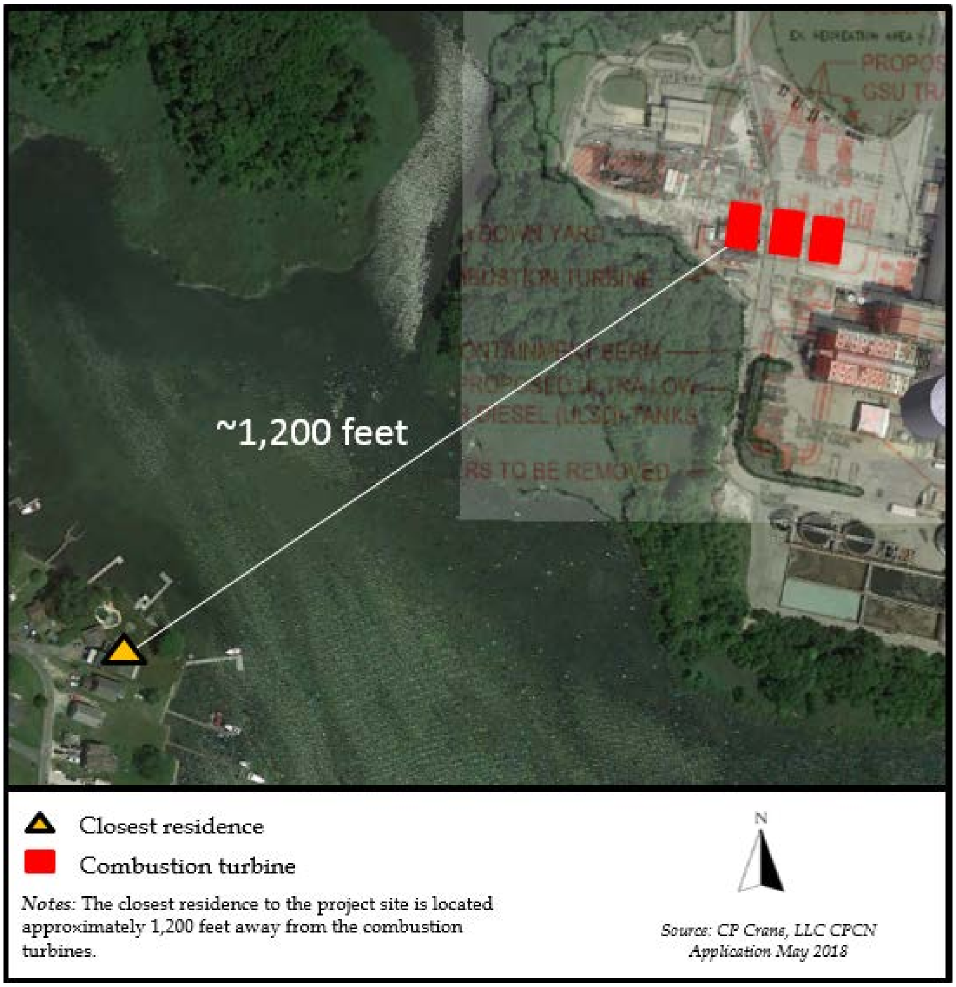
$L_2$ is the sound pressure level at the residential receptor;

$L_1$ is the sound pressure level at a known distance;

$R_1$ is the distance from the source for the known sound pressure level ($L_1$); and

$R_2$ is the distance from the source to the residential receptor.

*Figure 5-1 Location of Nearby Residences*




PPRP aggregated the three proposed combustions turbines into one sound pressure level, assuming full operation of all three turbines at the same time. This aggregation estimated that the sound pressure level from all three turbines at 400 feet would be 64.8 dBA. At the nearest residential receptor, located 1,200 feet to the southwest of the proposed turbine locations, PPRP estimated that the sound pressure level at the residential receptor is not expected to exceed 56 dBA.

These projections of noise from the proposed turbines are conservatively high. The projection methodology only considers distance spreading; the calculations do not take into account the atmospheric absorption of sound energy, or any effect of barriers (facility structures, trees, and other vegetation) between the noise sources and the receptors. Vegetative cover between the plant components and the receptor locations may have some noise reduction benefits, which are not reflected in this analysis. Actual sound pressure levels caused by the facility are expected to be lower.

PPRP's analysis suggest that the closest residents to the site will not experience noise levels exceeding Maryland regulatory standards, after the proposed facility is in full operation.

After the facility begins operation, CP Crane should conduct post-construction noise monitoring to verify that the facility is operating in compliance with applicable noise regulations. PPRP's recommended license condition would require the Applicant to submit a noise monitoring protocol within one year after receiving the CPCN, and to complete the noise monitoring within six months after the facility begins operating.

## 5.6 ANALYSIS OF OTHER ENGINEERING IMPACTS

### 5.6.1 Water Supply

CP Crane will use demineralized water for direct injection into the CTs for $NO_X$ emissions control and power augmentation. Evaporative cooling of inlet air will also be used as a secondary power augmentation. Increasing the air density with the use of water injection increases the mass flow through the CT, thus increasing power output. The Applicant provided the following expected flow rates for these water uses:

- $NO_X$ control when firing natural gas: 55 gallons per minute (gpm) per CT
- $NO_X$ control when firing ULSD fuel oil: 70 gpm per CT
- Power augmentation: 17 gpm per CT
- Evaporative cooling: 12 gpm per CT

Thus, the maximum water use for all three CTs would occur when firing fuel oil and using both methods of power augmentation, and would total approximately 300 gpm. The source of water would be the existing CP Crane plant supply, which is purchased from the Baltimore City municipal system (Response to PPRP Data Request No. 1-5). The facility holds a surface water appropriation for cooling water withdrawals that were needed for the coal-fired steam generating operations. While the coal-fired generation is being discontinued, the Applicant states that they intend to maintain the surface water appropriation permit pending future decisions regarding use of the remainder of the CP Crane site.

### 5.6.2 *Solid and Hazardous Waste Handling and Disposal*

Nonhazardous solid waste generated at the site will include small quantities of mixed office waste and general plant refuse, as well as used inlet air filters that are occasionally changed out. Such waste will be trucked offsite for disposal at a licensed landfill.

The facility will also produce maintenance and other wastes typical of power generation operations, including oil-contaminated waste. Small quantities of hazardous wastes will be generated periodically, resulting from plant maintenance, turbine cleaning, and similar processes. The Applicant will manage and dispose of all materials in accordance with regulatory requirements, including use of properly licensed transport and disposal services.

### 5.6.3 *Stormwater Management*

As described in the Applicant's ERD (pages 3-20 through 3-25), the Project will incorporate a comprehensive SWM system designed to manage onsite drainage and stormwater flows from within the Project footprint. Currently, stormwater runoff from the approximately 5-acre Project area is conveyed via sheet flow across the existing paved parking area to several inlets north of the parking lot area. These inlets are piped to a wooded area north and west of the parking area that drains south to Seneca Creek. The existing site SWM system will need to be modified both to accommodate the new facility footprint and to meet current regulatory requirements. Stormwater will be managed by a proposed bioretention pond. SWM within Baltimore County must conform to the specific design requirements of Article 33, Title 4 of the Baltimore County Code and MDE's Stormwater Design Manual.

During the final design phase, the details of the proposed SWM system and facilities will be completed, to ensure compliance with the requirements for a general permit under COMAR 26.08.04.09B and MDE's Stormwater Design Manual as adopted by Baltimore County. The Applicant will seek coverage for stormwater discharges under the State general permit program, as is the case currently for CP Crane, in accordance with National Pollutant Discharge Elimination System (NPDES) regulations.

Under the conceptual SWM design plans for the proposed Project, all runoff from nonprocess contact areas, such as rooftops, paved and gravel surfaces, and open space, will be collected and routed to generally follow the existing flow directions into the appropriate SWM control areas.

Wherever practical, noncontact stormwater will be conveyed via overland flow to a bioretention pond for physical and biological treatment prior to being discharged at a controlled rate. Where overland flow is not possible, runoff will be directed over the site via a closed stormwater sewer system that discharges into the bioretention pond.

Stormwater runoff from areas where potential oil contamination could occur – such as outdoor transformers or chemical storage or unloading areas – will be directed into an onsite OWS for treatment prior to release to the local municipal wastewater treatment facility. Oil collected will be trucked offsite for recycling or disposal.

The Applicant will prepare modifications to CP Crane's stormwater pollution prevention plan, which outlines procedures to manage stormwater runoff as well as erosion and sediment control. The SPCC Plan will also be updated to include specific containment measures for onsite storage and handling of chemicals, solvents, lubricants, and fuel oil.

## *6.0 CONCLUSIONS AND RECOMMENDATIONS*

### *6.1 AIR QUALITY*

The proposed Project will have the potential to emit several types of air pollutants. The emissions sources evaluated as part of MDE-ARA's environmental review included the following:

(a) The main power generating equipment with a power block consisting of three refurbished GE LM6000 CTs, operating in a simple cycle configuration, each with a nominal generating capacity of 50 MW, fueled primarily with natural gas, which will be backed up with ULSD fuel; and

(b) One Cummins model KTA50G9 Black-Start Generator rated at 1500 kW.

Based on the information provided in the CPCN Application filed in May 2018, a supplemental application filed in August 2018, additional information provided by CP Crane through responses to PPRP Data Requests, and independent analyses conducted by the State, MDE-ARA concluded that emissions from the proposed Repowering Project will not trigger major new source review (PSD or NA-NSR) requirements.

Air quality dispersion modeling evaluations demonstrate that while operating within the restrictions included in the recommended licensing conditions (Appendix A), emissions from the proposed Repowering Project are predicted to result in pollutant concentrations that will demonstrate compliance with all applicable NAAQS.

In conclusion, evaluation of the Project and its potential emissions indicate that, if designed, constructed, and operated in accordance with the recommended licensing conditions, the CP Crane Repowering Project will be able to comply with all applicable State and federal air quality requirements.

### *6.2 WATER RESOURCES*

Based on an analysis of the dewatering during construction, PPRP and MDE estimate that the volume of dewatering will be less than 5,000 gpd. Therefore, the proposed Project will qualify for an exemption for groundwater appropriation requirements. The Applicant will need to file

a Notice of Exemption with MDE at least 30 days before the proposed dewatering begins. Drawdown that may occur due to dewatering will not be significant enough to alter the direction of groundwater flow, and drawdown effects will be temporary and reversible after dewatering is complete. The reviewing State agencies' recommended license conditions will require CP Crane to coordinate with MDE to ensure that pumped groundwater is managed and discharged in compliance with all applicable regulations, and that MDE is aware of how dewatering may affect the ongoing hydrocarbon remediation activities at the CP Crane site.

Operations at CP Crane will entail storage and handling of fuel oil and other hazardous liquids. Spills or leaks of these substances could adversely impact groundwater resources at the site. The Project will be designed to include spill containment and control features, which will be described in the required SPCC Plan. The Applicant will establish chemical/hazardous materials management procedures designed to minimize the risk of accidental spills and to identify appropriate and timely response measures to be taken if a spill occurs. These measures will protect both groundwater and surface water resources from potential impacts during Project operation.

Operations at the CP Crane facility will require water for emission control and power augmentation. The maximum water demand will be approximately 300 gpm, to be supplied from the existing CP Crane plant supply, which is purchased from the Baltimore City municipal system. The facility holds a surface water appropriation for cooling water withdrawals that were needed for the coal-fired steam generating operations. While the coal-fired generation is being discontinued, the Applicant states that they intend to maintain the surface water appropriation permit pending future decisions regarding use of the remainder of the CP Crane site.

## *6.3 BIOLOGICAL RESOURCES*

Environmental impacts of the proposed construction and operation of the Project on biological resources include potential impacts on wetlands; surface waters; rare, threatened, or endangered species; green infrastructure and FIDS habitat; and vegetation. Proposed construction activities will take place within developed or previously impacted areas of the CP Crane site. Therefore, few ecological impacts will potentially result. There will be little to no impacts to natural communities on site, as the proposed development will take place within previously disturbed and developed portions of the site. There will be no changes in the land uses

or vegetation communities on site. The proposed Project will not occur in or near areas designated as green infrastructure or FIDS habitat. No impacts to wetlands, migratory birds, or eagles will result from the Project. There will be no significant impacts to Seneca Creek or its aquatic habitats because of Project construction. Temporary impacts to wildlife species inhabiting adjacent areas may result during the construction process due to human presence and noise. These disturbances will last only during the duration of Project construction and should have no long-term effect on the wildlife community. No significant ecological impacts are expected to occur due to Project operations. Recommendations to the PSC for licensing conditions are included that should be imposed upon the facility to minimize the potential for any adverse impacts.

## *6.4 SOCIOECONOMIC IMPACTS*

Modification of the facility will create temporary construction jobs, most drawn from the Baltimore metropolitan labor force. Construction will generate a mild fiscal benefit for the State and Baltimore County. Post-construction, PPRP has concluded economic benefits from project operation will be positive, even though plant staffing will be significantly less than when operated as a coal-fired generator. The Project will have no discernible effect upon population or housing during construction or operations.

Since development activities will be confined to previously developed areas of the site, no adverse effects on land use are anticipated during the construction period. Post-construction, use of the land will not be significantly different from the facility as it existed previously. The Baltimore County Zoning Review Office has confirmed the site plan improvements and changes to the operation of the power plant use are within the spirit and intent of prior zoning cases applicable to the Project site.

PPRP has concluded existing roads are capable of handling the modest increment in traffic generated during construction. Post-construction traffic will be limited to an estimated four employee vehicles and periodic contractor visits, plus occasional ULSD deliveries.

Views of the CP Crane Generating Station will not change significantly. Most structures associated with the proposed facility will not be visible. PPRP has concluded the Project will have a minimal adverse effect on views from surrounding areas. Public service demand is expected to be unaffected by the Project. PPRP has concluded construction will have no

adverse effect on archeological or historic sites. With a similar or slightly reduced visual footprint, PPRP has concluded the Project will not affect nearby cultural, scenic or other programmatic resources.

## *6.5 NOISE IMPACTS*

PPRP's analysis suggest that the closest residents to the site should not experience noise levels exceeding Maryland regulatory standards, after the proposed facility is in full operation. PPRP's recommended license condition, if imposed as a condition by the PSC, would require that the construction and operation of the proposed facility comply with the State's regulatory standards of 65 dBA (day) and 55 dBA (night), and the 90 dBA level during daytime construction. It is anticipated that noise from the Project, as proposed, will meet these construction and operational noise limits

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# *Appendix A*

**Initial Recommended Licensing Conditions**
**PSC Case No. 9482**
**CP Crane, LLC**

## A. CPCN GENERAL REQUIREMENTS

A-1 Except as otherwise provided for in the following provisions, the application for the Certificate of Public Convenience and Necessity (CPCN) is considered to be part of this CPCN for CP Crane, LLC (CP Crane) to modify the Charles P. Crane Generating Facility (CP Crane Project). In the application, estimates of dimensions, volumes, emission rates, operating rates, feed rates and hours of operation are not deemed to constitute enforceable numeric limits except to the extent that they are necessary to make a determination of applicable regulations. Construction and operation of the CP Crane Project shall be undertaken in accordance with the following:

- CPCN application dated May 31, 2018;
- CPCN application supplement dated June 21, 2018;
- CPCN application second supplement dated August 31, 2018; and
- CP Crane responses to data requests filed by the Power Plant Research Program (PPRP).

If there are any inconsistencies between any of the prior applications or supplements, the conditions in this CPCN shall take precedence. If CPCN conditions incorporate federal or state laws through paraphrased language, where there is any inconsistency between the paraphrased language and the actual state or federal laws being paraphrased, the applicable federal or state laws shall take precedence.

A-2 All provisions of this CPCN that apply to CP Crane shall apply to all subsequent owners and/or operators of the facility. In the event of any change in control or ownership, CP Crane shall notify the succeeding owner/operator of the existence of the requirements of this CPCN by letter and shall send a copy of that letter to the Maryland Public Service Commission (PSC) and the Maryland Department of the Environment (MDE).

A-3 If any provision of this CPCN shall be held invalid for any reason, the remaining provisions shall remain in full force and effect and such invalid provision shall be considered severed and deleted from this CPCN.

A-4 Representatives of the Maryland PSC shall be afforded access to the CP Crane Generating Station at any reasonable time to conduct inspections and evaluations necessary to assure compliance with the CPCN. CP Crane shall provide such assistance as reasonably may be necessary to conduct such inspections and evaluations by representatives of the PSC effectively and safely.

A-5 Representatives of MDE and the Baltimore County Health Department shall be afforded access to the CP Crane Project facility at any reasonable time to conduct inspections and evaluations necessary to assure compliance with the CPCN requirements. CP Crane

shall provide such assistance as reasonably may be necessary to conduct such inspections and evaluations effectively and safely, which may include but need not be limited to the following:

a) Inspecting construction authorized under this CPCN;

b) Sampling any materials stored or processed on site, or any waste or discharge into the environment;

c) Inspecting any monitoring or recording equipment required by this CPCN or applicable regulations;

d) Having access to or copying any records required to be kept by CP Crane pursuant to this CPCN or applicable regulations;

e) Obtaining any photographic documentation and evidence; and

f) Determining compliance with the conditions and regulations specified in the CPCN.

## B. AIR QUALITY REQUIREMENTS

## I. GENERAL

B-I-1 The Maryland Department of the Environment – Air and Radiation Administration (MDE-ARA) shall have concurrent jurisdiction with the PSC to enforce the air quality conditions of the CPCN.

B-I-2 The CPCN serves as the air quality construction permit for the CP Crane Project. The CPCN expires if the CP Crane project modification is not completed within a reasonable period of time as specified under Condition B-I-4.

B-I-3 For air permitting purposes, the CP Crane Project shall be defined as the following equipment:

a) Three General Electric model LM6000 natural gas combustion turbines (CTs), each with a nominal generating capacity of 50 MW; and

b) One Cummins model KTA50G9 diesel-fired black-start generator rated at 1500 kW.

B-I-4 In accordance with COMAR 26.11.02.04B, the air quality provisions expire if, as determined by MDE-ARA:

a) Substantial construction or modification is not commenced within 18 months after the date of issuance of the CPCN final order;

b) Construction or modification is substantially discontinued for a period of 18 months after the construction or modification has commenced; or

c) Construction is not completed within a reasonable period after the date of issuance of the CPCN final order.

B-I-5 **Permits, Approvals and Registrations** - At least 60 days prior to the anticipated date of start-up of the CP Crane Project, CP Crane shall submit to MDE-ARA an application for a State permit to operate [COMAR 26.11.02.14D].

B-I-6 **Permits, Approvals and Registrations** – CP Crane shall submit a complete Part 70 (Title V Operating Permit) application to MDE-ARA no later than 12 months after the date the CP Crane Project commences operations [COMAR 26 11.03.02B(4)].

B-I-7 All records and logs required by this CPCN shall be maintained at the facility for at least 5 years (unless otherwise noted) after the completion of the calendar year in which they were collected. These data shall be readily available for inspection by representatives of MDE-ARA.

## II. DEFINITIONS

B-II-1 "Commence" as applied to the construction of the Project means that the owner or operator either has:

a) Begun, or caused to begin, a continuous program of actual on-site construction of the source, to be completed within a reasonable time; or

b) Entered into binding agreements or contractual obligations, which cannot be canceled or modified without substantial loss to the owner or operator, to undertake a program of actual on-site construction of the source to be completed within a reasonable time.

B-II-2 "Excess emissions" means an emission rate which exceeds any applicable emission standard unless the emission rate is in compliance with an approved plan for compliance, departmental order, consent order, or condition of a permit.

B-II-3 "Malfunction" is defined as any sudden, infrequent, and not reasonably preventable failure of air pollution control equipment, process equipment, or a process that operates in an abnormal or unusual manner. Failures that are caused in part by poor maintenance or careless operation are not malfunctions.

## III. FACILITY-WIDE CONDITIONS

B-III-1 The CP Crane Project is subject to all applicable federally enforceable State air quality requirements including, but not limited to, the following regulations:

a) **Testing and Monitoring** - Requires CP Crane to follow test methods described in COMAR 26.11.01.04C to determine compliance. MDE-ARA may require CP Crane to install, use, and maintain monitoring equipment or employ other methods as specified by MDE-ARA to determine the quantity or quality, or both, of emissions discharged into the atmosphere and to maintain records and make reports on these emissions to MDE-ARA in a manner and on a schedule approved by MDE-ARA or the control officer; [COMAR 26.11.01.04]

b) **Emission Statements** - Requires CP Crane to submit a certified, facility-wide emission statement to MDE-ARA by April 1st of each year; [COMAR 26 11.01.05-1]

c) **Malfunctions and Other Temporary Increases of Emissions** - Requires CP Crane to report the onset and the termination of the occurrence of excess emissions, expected to last or actually lasting for one hour or more to MDE-ARA by telephone. Telephone reports shall include all information required by COMAR 26.11.01.07C(2); [COMAR 26.11.01.07]

d) **Particulate Matter From Confined Sources** - Prohibits CP Crane from causing or permitting particulate matter to be discharged from any installation constructed on or after January 17, 1972 in excess of 0.03 gr/SCFD (68.7 mg/dscm); [COMAR 26.11.06.03B(2)(a)]

e) **Particulate Matter From Unconfined Sources** - Prohibits CP Crane from causing or permitting emissions from an unconfined source without taking reasonable precautions to prevent particulate matter from becoming airborne. These reasonable precautions shall include, when appropriate as determined by MDE-ARA, the installation and use of hoods, fans, and dust collectors to enclose, capture, and vent emissions. In making this determination, MDE-ARA shall consider technological feasibility, practicality, economic impact, and the environmental consequences of the decision; [COMAR 26.11.06.03C]

f) **Particulate Matter from Materials Handling and Construction** - Prohibits CP Crane from causing or permitting any material to be handled, transported, or stored, or a building, its appurtenances, or a road to be used, constructed, altered, repaired, or demolished without taking reasonable precautions to prevent particulate matter from becoming airborne; [COMAR 26.11.06.03D]

g) **Control of NSPS Sources** - Prohibits CP Crane from constructing, modifying, or operating, or causing to be constructed, modified, or operated, a New Source Performance Standard (NSPS) source as defined in COMAR 26.11.01.01B(23), which results or will result in violation of the provisions of 40 CFR §60, as amended; [COMAR 26.11.06.12]

h) **Acid Rain Rule -** CP Crane shall comply with all applicable requirements of the Acid Rain Program; [40 CFR §72 and §75]

i) **Cross-State Air Pollution Rule (CSAPR)** - CP Crane shall comply with all applicable requirements of the Cross-State Air Pollution Rule (CSAPR); AND [40 CFR §97 Subparts AAAAA, BBBBB, and CCCCC]

j) **Mandatory Greenhouse Gas (GHG) Reporting** – Requires CP Crane to report GHG emissions [40 CFR 98, Subpart C].

B-III-2 The CP Crane Project is subject to all applicable State-only air quality requirements including, but not limited to, the following regulations:

a) **Fee Schedule** – Requires CP Crane to pay annual Title V operating permit fees; [COMAR 26.11.02.19A]

b) **Nuisance** – Prohibits CP Crane from operating or maintaining the facility in such a manner that a nuisance or air pollution is created; [COMAR 26.11.06.08]

c) **Odors** – Prohibits CP Crane from causing or permitting the discharge into the atmosphere of gases, vapors, or odors beyond the property line in such a manner that a nuisance or air pollution is created; [COMAR 26.11.06.09]

d) **Emission Certification** – Requires CP Crane to certify the actual emissions of regulated air pollutants from all installations at the plant or facility. Certification shall be on a form obtained from MDE-ARA and shall be submitted to MDE-ARA not later than April 1 of the year following the year for which certification is required. An emission certification submitted pursuant to this section and which contains all information required by COMAR 26.11.01.05-1 for $NO_x$ and VOC, satisfies the requirements of COMAR 26.11.01.05-1; and [COMAR 26.11.02.19D]

e) **Maryland $CO_2$ Budget Trading Program** – CP Crane shall comply with all applicable requirements of the Maryland $CO_2$ Budget Trading Program. [COMAR 26.09]

B-III-3 CP Crane shall provide MDE-ARA with the manufacturer, make, and model, vendor specifications, or other details requested by MDE-ARA upon selection of the black start generator no later than 15 days prior to startup.

## IV. COMBUSTION TURBINES

**Emission Unit Numbers: CT1, CT2, and CT3**

Three General Electric model LM6000 natural gas combustion turbines (CTs), each with a nominal generating capacity of 50 MW, and each with water injection to reduce nitrogen oxide ($NO_X$) emissions.

***Applicable Requirements***

B-IV-1 Only pipeline quality natural gas shall be used as fuel in the CTs except that ultra low sulfur diesel (ULSD) may be used when natural gas supply is unavailable.

B-IV-2 The CTs are subject to all applicable federally enforceable State air quality requirements including, but not limited to, the following regulations:

a) **Continuous Emission Monitoring Requirements** - Requires CP Crane to operate all continuous emission monitors (CEMS) under the requirements of COMAR 26.11.01.11. This requirement is applicable to the $NO_X$ and $CO_2$ CO CEMS that are planned to be installed at each CT exhaust stack; [COMAR 26.11.01.11]

b) **Visible Emissions** – Except as provided in COMAR 26.11.09.05A(3), prohibits CP Crane from causing or permitting the discharge of emissions from any fuel

burning equipment, other than water in an uncombined form, which is visible to human observers; [COMAR 26.11.06.01, COMAR 26.11.09.05A(2)]

c) **Control of $NO_X$ Emissions for Major Stationary Sources** – Requires CP Crane to meet an hourly average $NO_X$ emission rate of not more than 42 parts per million (ppm) for the combustion turbine with a capacity factor of greater than 15%, when burning process gas or meet applicable Prevention of Significant Deterioration limits, whichever is more restrictive; and [COMAR 26.11.09.08G(2)]

d) **Control of $NO_X$ Emissions for Major Stationary Sources, Reporting Requirements** – Requires CP Crane when using a CEMS to demonstrate compliance with the $NO_X$ emission standards in COMAR 26.11.09.08 to submit quarterly emission reports to MDE-ARA on or before the thirtieth day of the month following the end of each calendar quarter. [COMAR 26.11.09.08K]

B-IV-3 The CTs are subject to 40 CFR §60 Subpart KKKK - Standards of Performance for Stationary Combustion Turbines; 40 CFR §60.4300, et seq., which contain various requirements for emission limitations, monitoring, testing, recordkeeping, and reporting for $NO_X$ and $SO_2$, specified in Table B-1 and the following additional requirements:

a) $NO_X$ limits:

i. Natural gas firing: 25 ppm at 15 percent $O_2$ based on a 3-hour block average (excluding startup and shutdown);

ii. ULSD fuel firing: 74 ppm at 15 percent $O_2$ based on a 3-hour block average (excluding startup and shutdown);

b) $SO_2$ limit: 0.0015% Sulfur by weight;

c) Compliance with the $NO_X$ emission standard shall be demonstrated by use of a certified $NO_X$ CEM;

d) Compliance with the $SO_2$ emission standard (40 CFR §60.4365) shall be demonstrated by either of the following:

i. The fuel quality characteristics in a current, valid purchase contract, tariff sheet or transportation contract for the fuel, specifying that the maximum total sulfur content for natural gas is 20 grams of sulfur or less per 100 standard cubic feet and has potential sulfur emissions of less than 26 ng $SO_2$ /J (0.060 lb $SO_2$/MMBTU) heat input; or

ii. Representative fuel sampling data which show that the sulfur content of the fuel does not exceed 26 ng $SO_2$/J (0.060 lb $SO_2$/MMBTU) heat input. At a minimum, the amount of fuel sampling data specified in Section 2.3.1.4 or 2.3.1.4 or 2.3.2.4 of Appendix D to 40 CFR §75 is required.

e) Monitoring of Operations (40 CFR §60.4340(a)-(b)) – CP Crane shall install, calibrate, maintain, and operate a continuous $NO_X$ emissions monitoring system as described in the Quality Assurance Procedures under 40 CFR §75 is required;

f) Monitoring of Operations (40 CFR §60.4350) – CP Crane shall follow the calculation procedures set forth in 40 CFR §60.4350 for purposes of identifying Excess Emissions; and

g) Monitoring of Operations (40 CFR §60.4360) CP Crane may elect not to monitor the total sulfur content of the fuel combusted in the turbine, if the fuel is demonstrated not to exceed potential sulfur emissions of 26 ng $SO_2$/J (0.060 lb $SO_2$/MMBTU) heat input using one of the methods given in 40 CFR §60.4365. If CP Crane elects to comply with the minimum fuel sulfur content limit under 40 CFR §60.4330, CP Crane must monitor the total sulfur content of the combustion turbine's fuel using the methods described in 40 CFR §60.4415 at a frequency described in 40 CFR §60.4370. Alternatively, if the total sulfur content of the gaseous fuel during the most recent performance test was less than half the applicable limit, ASTM D4084-82, D4810-88 (1999), D5504-01, or D6228-98 (2003), or Gas Processors Association Standard 2377-86, may be used to assess compliance with the applicable fuel sulfur limit.

B-IV-4 The CTs are subject to 40 CFR 60, Subpart TTTT – Standards of Performance for Greenhouse Gas Emissions for Electric Generating Units, 40 CFR §60.5508, et seq., which contains various requirements for emission limitations, monitoring, testing, record keeping, and reporting for greenhouse gas (GHG) emissions as follows:

a) Emission Standard (40 CFR §60.5520) – CP Crane shall limit emissions to 1,000 lb $CO_2$ /MWh (gross) or 1,030 lb $CO_2$/MWh (net) based on a 12-month rolling average; [Table 2 of Subpart TTTT (40 CFR Part 60)]

b) Monitoring of Operations (40 CFR §60.5535(b) and (c)(1)-(c)(4)) – CP Crane shall demonstrate compliance with the emission standards by either installing a $CO_2$ CEMS or by measuring fuel flow as specified in the applicable appendices to 40 CFR 75;

c) Monitoring of Operations (40 CFR §60.5535(d)(1)) – CP Crane shall install, calibrate, maintain, and operate a sufficient number of watt meters to continuously measure and record the hourly gross electric output, as applicable, from each of the CTs; and

d) Monitoring of Operations (40 CFR §60.5540(a)(1)-(a)(7)) – CP Crane shall demonstrate compliance with the emission standard by monitoring or calculating $CO_2$ emissions using the procedures in §60.5540 (a)(1)-(a)(7).

B-IV-5 The CTs are subject to all applicable provisions of the Acid Rain program under 40 CFR §72, including, but not limited to:

a) Subpart A §72.30(b)(2)(i) requires CP Crane to submit an application for an Acid Rain Permit for the CT units;

b) Subpart A §72.9(b)(1) requires CP Crane, to the extent applicable, to comply with monitoring requirements in 40 CFR 75;

c) Subpart A §72.9(c) requires CP Crane to hold allowances in the source's compliance account not less than the total annual emissions of $SO_2$ for the previous year and comply with applicable Acid Rain limits for $SO_2$;

d) Subpart A §72.9(e) requires CP Crane to submit a proposed offset plan if emission limitations are exceeded; and

e) Subpart A §72.9(f) requires CP Crane, unless otherwise provided, to retain required documents for a period of 5 years from the date that the document was created. Documents may include, but are not limited to, certificates of representation, emissions monitoring information, copies of reports, compliance certifications, and other documentation pertaining to the Acid Rain program.

***Operational and Emission Limits***

B-IV-6 Operational Restriction – The aggregated hours of operation for the three CTs shall not exceed 7100 hours/year, including a maximum of 710 hours of burning ULSD fuel.

B-IV-7 Emissions Limits – The CTs shall comply with the emissions limits below, excluding startup and shutdown, on a 3-hour block average basis.

**Table B-1**

| Pollutant | Natural Gas | ULSD |
|---|---|---|
| NOx | COMAR: 42 ppm @ 15% $O_2$<br>Subpart KKKK: 25 ppm @ 15% $O_2$ | COMAR: 65 ppm @15% $O_2$<br>Subpart KKKK: 74 ppm @ 15% $O_2$ |
| SOx | COMAR: 65 ppm @ 15% $O_2$<br>Subpart KKKK: 0.5 gr/100 scf | Subpart KKKK 0.0015% S by wt |

***Compliance Demonstration***

**Testing and Monitoring Requirements**

B-IV-8 At least 30 days prior to conducting any compliance stack test, CP Crane shall submit a test protocol to MDE-ARA for review and approval.

a) Compliance stack testing shall be conducted in accordance with MDE-ARA Technical Memorandum (TM) 91-01, "Test Methods and Equipment Specifications for Stationary Sources" (January 1991), as amended by Supplement 3 (October 1 1997), 40 CFR §60, or subsequent test protocols approved by MDE-ARA; and

b) Test ports shall be located in accordance with TM 91-01 (January 1991), or subsequent or alternative measures approved by MDE-ARA.

B-IV-9 Initial compliance performance testing of each CT shall be conducted within 180 days after initial startup to quantify pollutant emissions and demonstrate compliance with the $NO_X$ emissions limits specified in the CPCN. Testing shall be conducted for both natural gas and ULSD while the CTs are operating at 90% or higher capacity. Subsequent and continuous compliance with the emission limits specified in the CPCN for compliance with $NO_X$ shall be demonstrated by installing and operating certified CEMS. The CEMS shall comply with applicable performance specifications in 40 CFR Part 60 Appendix B, Quality Assurance Procedures in 40 CFR Part §60 Appendix F, and applicable requirements in 40 CFR 75.

B-IV-10 Unless otherwise approved by MDE-ARA, CP Crane shall install on each CT a $CO_2$ CEMS or calibrated in-line fuel flow-meter as specified under 40 CFR §75.10(3) to measure $CO_2$ emissions associated with the production of electricity. Emissions of $CO_2$ from the CTs and duct burners are to be monitored and recorded hourly utilizing a data handling acquisition system (DHAS) installed, calibrated, and maintained in accordance with 40 CFR §75. [40 CFR 75.10(3)]

B-IV-11 CP Crane shall install a fuel flow meter as specified under 40 CFR 75 and continuously monitor the fuel flow for each CT. The total fuel usage per month shall be recorded.

B-IV-12 Methane ($CH_4$) and nitrous oxide ($N_2O$) emissions from the CTs shall be calculated in accordance with the methodology and emission factors noted in 40 CFR 98, Subpart D. On a monthly basis, fuel consumption, coupled with the appropriate emission factors and global warming potentials (25 for $CH_4$ and 298 for $N_2O$), shall be used to calculate the $CH_4$ and $N_2O$ emissions on a $CO_2e$ basis. These emission rates, summed with the monthly $CO_2$ emissions based on CEMS, shall be used to establish GHG emissions from the CTs on a $CO_2e$ basis.

B-IV-13 The CTs are subject to all applicable monitoring provisions of the Acid Rain program under 40 CFR 75, including, but not limited to:

a) Subpart A §75.4(b) which generally requires CP Crane, in accordance with 40 CFR §75.20, to ensure that all applicable monitoring systems for $NO_X$, $CO_2$, and volumetric flow required under 40 CFR 75 are installed and all certification tests completed no later than the earlier of 90 unit operating days or 180 calendar days after the date the unit commences commercial operations;

b) Subpart B §75.10 which generally requires CP Crane to measure, as applicable, $NO_X$ and $CO_2$ emissions; to ensure that CEMS required by 40 CFR 75 meet the equipment, installation, and performance specifications in 40 CFR 75; and to maintain the CEMS according to the quality assurance and quality control procedures in this part;

c) Subpart F §75.53(a) which generally requires CP Crane to prepare a monitoring plan with sufficient information on applicable continuous opacity or emissions monitoring systems to demonstrate that all $NO_X$ and $CO_2$ emissions, as required, are monitored and reported;

d) Subpart F §75.57(a) which requires CP Crane to keep a file for each affected unit of all measurements, data, reports, and other information required by 40 CFR 75 in a form suitable for inspection for at least three years from the date of each record;

a) Subpart F §75.57(b)-(f) which require CP Crane to record the following: $SO_2$ emissions, $NO_X$ emissions, CO emissions, opacity, and other information as specified; and

e) Subpart G §75.60(a) and (b) which generally require CP Crane to comply with all reporting requirements, with all signatory requirements of 40 CFR §72.21 of this chapter for all submissions, and with all required certifications and reports.

B-IV-14 Initial compliance with the visible emission limitation in COMAR 26.11.09.05A(2) shall be demonstrated using EPA Method 9 within 180 days of startup of the first CT. [COMAR 26.11.09.05A(2) and (5)]

**Recordkeeping and Reporting Requirements**

B-IV-15 Final results of each compliance stack test shall be submitted to MDE-ARA within 60 days after completion of the test. [COMAR 26.11.01.05B and C]

B-IV-16 Unless otherwise approved by MDE-ARA, CP Crane shall submit electronic quarterly reports from the DHAS to the EPA Clean Air Markets Division System as specified in 40 CFR §75.64. [40 CFR §75.64]

B-IV-17 CP Crane shall submit a Quarterly CEMS Summary Reports as required by COMAR 26.11.01.11E(2)(c), as well as CEMS System Downtime Reports as required by COMAR 26.11.01.11E(1). [COMAR 26.11.01.11E]

B-IV-18 CP Crane shall submit to MDE-ARA reports of excess emissions and monitor downtime associated with the CTs, in accordance with 40 CFR §60.7(c). Excess emissions as defined in 40 CFR §60.4380 ($NO_X$) and 40 CFR §60.4385 ($SO_2$) must be reported for all periods of unit operation, including startup, shutdown, and malfunction. [40 CFR §60.4375]

B-IV-19 CP Crane shall maintain annual fuel use records on site for not less than three years, and make these records available to MDE-ARA upon request. [COMAR 26.11.09.08K]

B-IV-20 CP Crane shall submit a quarterly report to MDE-ARA to be postmarked by the 30th day of the month following the end of each calendar quarter that includes the following information:

a) All instances of deviations from permit requirements for the CTs;

b) The downtime or malfunction of any CEMS equipment. The report shall include the date and time of each period during which the CEMS was inoperative and the nature of the monitoring system repairs or adjustments completed;

c) The monthly and consecutive rolling 12-month total fuel use and hours of operation for each CT;

d) The monthly (in tons per month) and consecutive rolling 12-month (tons per year) total emissions of $NO_X$, $SO_2$, and $CO_2e$ separately for each CT.

B-IV-21 If CP Crane elects to demonstrate compliance with the $SO_2$ emissions limit in 40 CFR §60.4330 using methods described in §60.4415(a), submit periodic representative fuel sampling records.

## V. DIESEL-FIRED BLACK START GENERATOR

**Emission Unit Number: EG1**

One ULSD-fired 1,500 kW black start generator.

***Applicable Requirements***

B-V-1 The black start generator is subject to all applicable federally enforceable State air quality requirements including, but not limited to, the following regulations:

a) **Visible Emissions During Idle Mode** – Prohibits CP Crane from causing or permitting the discharge of emissions from any internal combustion engine, operating at idle, greater than 10 percent opacity; [COMAR 26.11.09.05E(2)]

b) **Visible Emissions During Operating Mode -** Prohibits CP Crane from causing or permitting the discharge of emissions from any internal combustion engine, operating at other than idle conditions, greater than 40 percent opacity; [COMAR 26.11.09.05E(3)]

c) **Exceptions to Visible Emissions Standards for Internal Combustion Engines**:

(i) Standards do not apply for a period of two consecutive minutes after a period of idling of 15 consecutive minutes for the purpose of clearing the exhaust system; [COMAR 26.11.09.05E(4)(a)]

(ii) Standards do not apply to emissions resulting directly from cold engine start-up and warm-up for the following maximum periods:

(1) Engines that are idled continuously when not in service: 30 minutes;

(2) All other engines: 15 minutes; [COMAR 26.11.09.05E(4)(b)]

(iii) COMAR 26.11.09.05E(2) and (3) do not apply while maintenance, repair, or testing is being performed by qualified mechanics; [COMAR 26.11.09.05E(4)(c)]

d) **Control of Sulfur Oxides From Fuel Burning Equipment** – Prohibits CP Crane from burning, selling, or making available for sale distillate fuel oils with a sulfur content of greater than 0.3 percent; [COMAR 26.11.09.07A(2)(c)]

e) **Control of $NO_X$ Emissions for Major Stationary Sources – Fuel Burning Equipment with a Requirements for Fuel-Burning Equipment with a Capacity Factor of 15 Percent or Less** - Requires CP Crane to comply with the requirements of COMAR 26.11.09.08G, including providing certification of the capacity factor of the equipment to MDE-ARA in writing, conducting an annual combustion analysis for each installation if the equipment operates more than 500 hours during a calendar year, and attending operator training programs sponsored by MDE-ARA, EPA, or equipment vendors every three years; [COMAR 26.11.09.08G]

f) **Control of $NO_X$ Emissions for Major Stationary Sources** - Requires CP Crane, for all fuel burning equipment with a capacity factor (as defined in 40 CFR §72.2) of 15 percent or less, to comply with the following requirements:

(i) Provide certification of the capacity factor of the equipment to MDE in writing; and

(ii) Require each operator of an installation to attend operator training programs on combustion optimization that are sponsored by MDE-ARA, the EPA, or equipment vendors, at least once every three years. [COMAR 26.11.09.08G(1)]

B-V-2 The black start generator is subject to all applicable State-only air quality requirements including, but not limited to, the following regulations and operational limitations:

a) **Distributed Generation** - Requires CP Crane to comply with NESHAP ZZZZ and NSPS IIII to comply with this requirement. [COMAR 26.11.36]

***<u>Operational and Emission Limits</u>***

B-V-3 The black start generator is subject to NSPS 40 CFR 60, Subpart IIII, Standards of Performance for Stationary Compression Ignition Internal Combustion Engines. CP Crane shall meet the monitoring, compliance, testing, notification, reporting, and recordkeeping requirements of 40 CFR §60.4200 to 40 CFR §60.4219 and related applicable provisions of 40 CFR §60.7 and 40 CFR §60.8. The diesel fuel combusted in the black start generator shall meet the requirements of 40 CFR §60.4207.

CP Crane shall meet the following emissions limits for the emergency generator and the fire water pump engine:

a) Under 40 CFR §60.4202 and 40 CFR §89.112, Table 1, emissions from the 1,500 kW black start generator shall not exceed 9.2 g/kW-hr NOx, 1.3 g/kW-hr non-methane hydrocarbons (NMHC), 11.4 g/kW-hr CO, and 0.54 g/kW-hr PM filterable.

B-V-4 The black start generator is subject to the following requirements under 40 CFR Part 60 Subpart IIII:

a) CP Crane shall purchase an engine certified to the emission standards in 40 CFR §60.4204(b) or 40 CFR §60.4205(b) or (c), as applicable, for the same model year

and maximum engine power. The engine must be installed and configured according to the manufacturer's emission-related specifications; [40 CFR §60.4211(c)]

b) CP Crane shall operate and maintain the black start generator according to the manufacturer's written instructions or procedures developed by the owner or operator that are approved by the engine manufacturer, over the entire life of the engine; [40 CFR §60.4206]

c) The black start generator may be operated for the purpose of maintenance checks and readiness testing limited to 100 hours per year, provided that those tests are recommended by Federal, State, or local government, the manufacturer, the vendor, or the insurance company associated with the engine; [40 CFR §60.4211(f)]

d) There are no restrictions on hours of operation on the use of the black start generator for allowable emergency situations; [40 CFR §60.4211(f)]

e) CP Crane shall install and operate a non-resettable hour meter prior to startup of the engine. [40 CFR §60.4209(a)]

B-V-5 The black start generator is subject to 40 CFR 63 Subpart ZZZZ - National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines. The black start generator shall meet the requirements of this Subpart by complying with all the applicable requirements of NSPS Subpart IIII under 40 CFR §63.6590(c)(1).

B-V-6 The black start generator shall be fueled with ULSD fuel only with a sulfur content not to exceed 15 parts per million by weight (ppmw).

**Notification Requirements**

B-V-7 CP Crane shall furnish written notification to MDE-ARA and EPA of the following events related to the installation of the black start generator: [40 CFR §60.7(a)]

a) The date construction commenced within 30 days after such date; and

b) The actual startup date within 15 days after such date.

**Recordkeeping and Reporting Requirements**

B-V-8 CP Crane shall maintain records on site of the hours of operation of the black start generator, including date, time, and duration and an explanation of reasons for operation of the engine.

B-V-9 CP Crane shall comply with all applicable reporting and recordkeeping requirements for the black start generator specified in 40 CFR §60.4214.

B-V-10 CP Crane shall maintain fuel supplier certifications for each fuel delivery that documents the sulfur content of the ULSD is 15 ppm sulfur by weight or less. Fuel supplier certification shall include the following information:

a) The name of the oil supplier; and

b) The sulfur content of the oil.

B-V-11 CP Crane shall comply with the following recordkeeping and reporting requirements for the black start generator: [COMAR 26.11.09.08(G)]

a) Provide certification of the capacity factor of the equipment to MDE-ARA in writing as part of the April 1 certification report;

b) Maintain the results of the combustion analyses (if applicable) at the site for at least two years and make this data available to MDE-ARA and the EPA upon request; and

c) Maintain records of training program attendance for each operator at the site, and make these records available to MDE-ARA upon request.

B-V-12 CP Crane shall maintain annual fuel use records for the black start generator on site for not less than three years, and make these records available to MDE-ARA upon request. [COMAR 26.11.09.08K]

## VI. NOTIFICATION REQUIREMENTS

B-VI-1 All air quality notifications and reports required by this CPCN shall be submitted to:

Administrator, Compliance Program
Air and Radiation Administration
1800 Washington Boulevard
Baltimore, Maryland 21230

B-VI-2 All notifications and reports required by 40 CFR 60 Subpart KKKK, Subpart IIII, Subpart TTTT, and 40 CFR 63 Subpart ZZZZ shall be submitted to:

Director, Air Protection Division
U.S. EPA – Region 3
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

## C. CONSTRUCTION DEWATERING

C-1. At least 30 days prior to the start of construction dewatering activities, CP Crane shall file a Notice of Exemption with the MDE-Water Supply Program confirming that the amount of water to be withdrawn will not exceed 5,000 gallons per day (gpd) as an annual average.

C-2. CP Crane shall ensure that it manages water withdrawn during construction in a way that complies with all applicable federal, State, and local regulations, including compliance with relevant MDE-Water and Science Administration discharge permitting requirements. CP Crane shall coordinate with MDE’s Oil Control Program as appropriate regarding impacts of the proposed construction activities on the ongoing hydrocarbon remediation at the Crane site. Prior to the start of construction dewatering activities, CP Crane shall submit to PPRP and the PSC documentation describing how the water resulting from construction dewatering will be treated, stored, and disposed.

## D. TERRESTRIAL AND AQUATIC ECOLOGY

D-1. Construction and operation of the Crane repowering project shall be undertaken in accordance with this CPCN and shall comply with all applicable local, State, and federal laws and regulations, including but not limited to the following:

a) Nontidal Wetlands—COMAR 26.23.01 applies to activities conducted in nontidal wetlands and wetland buffer.

b) Waterway Construction — COMAR 26.17.04 applies to regulations governing construction activities in nontidal waters and floodplains.

c) Water Quality and Water Pollution Control—COMAR 26.08.01 through COMAR 26.08.04 apply to discharges to surface water and maintenance of surface water quality.

d) Erosion, Sediment, and Stormwater Control—COMAR 26.17.01 applies to the preparation, submittal, review, approval, and enforcement of erosion, sediment, and stormwater control plans, including any dewatering plans and associated water recycling plans.

e) Oil Pollution Control – 40 CFR Part 112 and COMAR 26.10.01.12 apply to the procedures of oil spill control.

f) Forest Conservation – Maryland's Forest Conservation Act, Md. Code, Sections 5- 1601 through 5-1613 of the Natural Resources Article.

g) Land Use Ordinance for Baltimore County, Maryland – Relevant portions of the ordinance that address site planning, forest conservation, floodplain management, sediment and erosion control, Critical Area development requirements, and stormwater management.

D-2. All direct or indirect impacts (temporary or permanent) to wetlands and to streams and their 100-year floodplains shall be assessed, and where possible quantified, by CP Crane prior to the start of any construction activities.

a) CP Crane shall apply for and obtain permits from MDE for all construction in or disturbance to permanent and intermittent streams ditches, floodplains, and non-tidal wetlands or their regulatory buffers, including but not limited to culverts to be installed in streams or ditches for access roads or other purposes.

b) All culverts in ditches or streams shall be inspected annually for structural damage and erosion at the outfall point. Structural damage or erosion below the outfall invert will be corrected as soon as practicable.

D-3. CP Crane shall notify and consult with DNR Wildlife and Heritage Services (WHS) to determine appropriate actions if rare, threatened, or endangered species are encountered during planning, construction, or maintenance of this facility.

D-4. CP Crane shall employ erosion and sediment control best management practices (BMPs) presented in the MDE document titled 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control, and as otherwise may be approved or required by Baltimore County. All portions of the Project site that are disturbed during construction shall be stabilized as soon as practicable after the cessation of construction activities within that portion of the site, followed by seed application, in accordance with the above cited document. In no instance shall non-native species be seeded or otherwise planted in these areas.

D-5. CP Crane shall ensure that the project undertaken in accordance with this CPCN shall comply to all requirements of Baltimore County's Critical Area Program. Any change to the size, scope, footprint, or use associated with the project, the repowering of the Crane Station by retiring two coal-fired units and adding three natural gas combustion turbines, shall require additional review by the Critical Area Commission in accordance with COMAR 27.02.04 and COMAR 27.02.05.

## E. STORMWATER MANAGEMENT/EROSION AND SEDIMENT CONTROL

E-1. CP Crane shall provide PPRP and the PSC Engineering Staff with copies of all plans that CP Crane submits to Baltimore County in connection with the Project for grading the site, and all permits received for such grading, within fifteen (15) calendar days of submitting such plans or receiving such permits. Grading and associated stormwater controls shall be designed to minimize hydrological changes to off-site streams and wetlands and to maintain the existing flow regime to these streams and wetlands. In addition, CP Crane shall demonstrate compliance with applicable sections of the Baltimore County Chesapeake Bay Critical Area law, section 33. In no case shall such plans include removal of topsoil from the site.

E-2. Soil inside the Project Limits of Construction should be effectively managed for compaction according to the guidance provided in the NRCS Soil Quality – Agronomy Technical Note No. 17 “Soil Compaction: Detection, Prevention and Alleviation”. Ripping (to a minimum depth of 12”) and compost amendment shall be performed in

compacted areas (e.g. graded areas, staging areas, or heavily trafficked areas) to ensure planting success and the proper post-construction runoff characteristics.

E-3. The CPCN is not an authorization to discharge stormwater or wastewater to waters of the State. If required by MDE, CP Crane shall obtain a discharge permit from MDE under the National Pollutant Discharge Elimination System (NPDES) for the facility.

## F. FUEL AND HAZARDOUS MATERIALS

F-1. CP Crane shall provide secondary containment for each of the onsite diesel storage tanks. All piping associated with the diesel storage tanks shall either be above ground or shall have secondary containment. Electric equipment that contains dielectric or fuel oil located in the substation and switchyards shall have secondary containment.

F-2. CP Crane shall prepare a Spill Prevention, Control and Countermeasures (SPCC) Plan, and have the plan reviewed and certified by a Professional Engineer in the State of Maryland as specified in 40 CFR 112.3. The SPCC Plan shall address onsite storage of diesel fuel and any other aboveground storage of petroleum products.

## G. NOISE LEVELS

G-1. CP Crane shall monitor noise levels at the boundaries of the CP Crane site, after the facility is operational, to verify results of the predictive analysis. The scope of work for the noise monitoring shall be provided to PPRP and the PSC for review and approval within one year after the effective date of this CPCN. Measurements shall be taken while the facility is in full operation, to represent maximum noise emissions. CP Crane shall provide results within six (6) months after the facility begins commercial operation.

G-2. Construction and operation of the proposed Project shall comply with the Maryland noise regulations in COMAR 26.02.03. If the post-construction noise monitoring indicates that the facility is not operating in compliance with those standards, CP Crane shall work with PPRP and the PSC to incorporate appropriate noise mitigation to ensure regulatory compliance.

## H. TRAFFIC

H-1. CP Crane shall comply with all permit requirements and restrictions for use, crossing, and occupancy of State and Baltimore County roads, and obtain appropriate approvals, as necessary.

## I. CULTURAL RESOURCES

I-1. In the event that relics from unforeseen archeological sites are revealed and identified during construction, CP Crane, in consultation with and as approved by the Maryland Historical Trust, shall develop and implement a plan for avoidance and protection, data recovery, or destruction without recovery of such relics or sites.

## J. GENERAL AND MISCELLANEOUS PROVISIONS

J-1. Informational copies of the required reports regarding change of ownership, cultural resources, and noise studies as described in the Licensing Conditions of Case 9482 (A-2, C-2, E-1, G-1) shall be sent to PPRP by e-mail (and by mail if requested) at:

Director
Power Plant Assessment Program
Department of Natural Resources
Tawes State Office Bldg., B-3
580 Taylor Avenue
Annapolis, Maryland 21401
e-mail: pprp.dnr@maryland.gov

# *Appendix B*

**Response of C.P. Crane LLC ("CP Crane") to PPRP Data Request No. 1**
**CP Crane Repowering Project**
**PSC Case No. 9482**
**Response Date: July 27, 2018**

1-4 The direct testimony of Jeffrey L. Meling (page 6, lines 11-18) describes plans for construction dewatering, which is "expected to be minimal and occur over a short period of time."

a. Will the dewatering period extend for 30 days or more?
b. Will the amount of water withdrawn exceed an annual average of 10,000 gallons per day (i.e more than a total of 3,650,000 gallons in any year)?
c. Please provide a map showing the areas that need to be dewatered, hydrogeologic data showing depth to groundwater in the areas needing dewatering, the level to which groundwater will need to be lowered in each area, hydraulic conductivity estimates of sediments in areas of dewatering and calculations of the amount of water needed for dewatering to enable the construction to be carried out properly and safely.
d. Will the dewatering take place in an area where the groundwater is contaminated from past site activities?
e. Has CP Crane made plans for the appropriate level of treatment and discharge permitting should the groundwater removed by the dewatering operation be contaminated?

Response:

a. Any foundation that will require dewatering due to groundwater should last between 1-5 days so that piles can be installed or engineered fill can be placed. Depending on the construction schedule and dewatering need, it may take more than 30 days combined of all the excavations.

b. Based on current estimates and due to the short duration of dewatering, the amount of water withdrawn is not expected to exceed an annual average of 10,000 gallons per day.

c. Please see the attached PPRP DR 1-4 Exhibit A, a map of "Possible Dewatering Locations" showing areas in green that may need dewatering and inclusive of groundwater elevations near those locations. The water table was observed at being 6-10 feet below grade and is predicted at being between 4-6 feet annually below existing grade. Please see the attached PPRP DR 1-4 Exhibit B for soil conductivity information from the site based on resistivity. At this time, CP Crane expects the total amount of water needed for dewatering to be approximately 210,000 gallons.

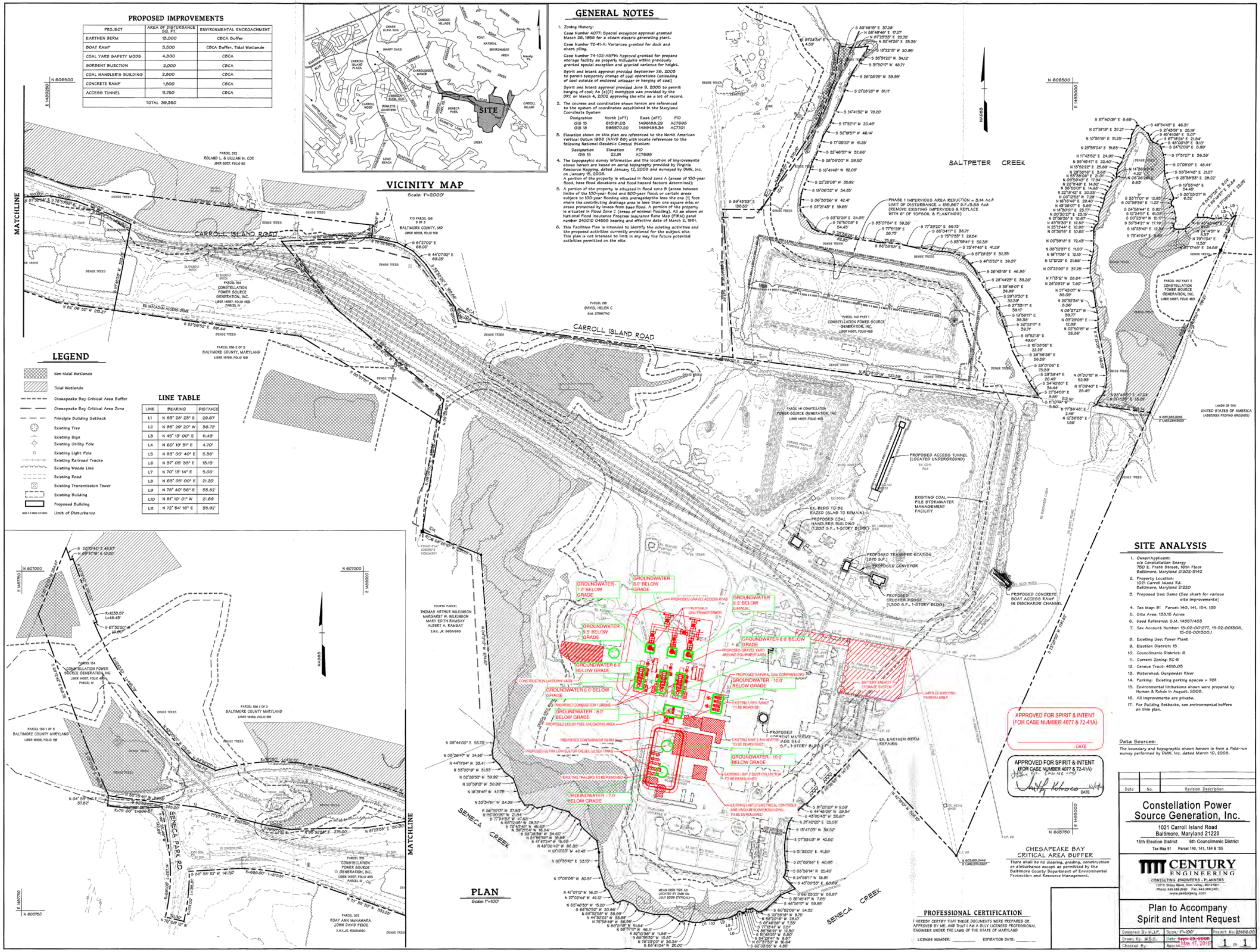
d. Dewatering may take place in areas where the groundwater is contaminated from past site activities. Please see the attached PPRP DR 1-4 Exhibit C, a map of "CP Crane Remediation Wells" for remediation well areas that may need dewatering during

construction of the proposed natural gas compression, liquid fuel unloading area, and liquid fuel storage tank area.

e. In the event that the groundwater removed by the dewatering operation is contaminated, CP Crane will ensure that it is handled in accordance with all legal requirements. Among the options for discharge of any contaminated groundwater removed by the dewatering operation include the potential of discharging to the sanitary sewer with approval of the local jurisdiction or pumping and hauling to a treatment facility.

Response provided by: Dennis C. Corn, Consultant/Director of Development, Middle River Power, LLC

Case No. 9482 PPRP DR 1-4 Exhibit A



$$k_s = k\left(\frac{B+1}{2B}\right)^2 \text{ for cohesionless soil}$$

where:

$k_s$ = coefficient of vertical subgrade reaction for loaded area,
*k* = coefficient of vertical subgrade reaction for 1x1 square foot area, and
*B* = width of area loaded, in feet

- Isolation joints and crack control joints should be used to reduce cracking from concrete shrinkage and differential movement between piles and the cap. The American Concrete Institute (ACI) recommends a maximum panel size (in feet) equal to approximately two to three times the thickness of the caps (in inches) in both directions.

- ACI provides valuable recommendations for design and construction of grade caps that we recommend be followed. Details of the ACI recommendations for caps design and construction are provided in ACI 302.1.

Cracking of caps-on-grade is normal and should be expected. Cracking can occur not only as a result of heaving or compression of the supporting soil and/or bedrock material, but also as a result of concrete curing stresses. The occurrence of concrete shrinkage cracks, and problems associated with concrete curing may be reduced and/or controlled by limiting the slump of the concrete, proper concrete placement, finishing, and curing, and by the placement of crack control joints at frequent intervals, particularly, where re-entrant caps corners occur. The American Concrete Institute (ACI) recommends a maximum panel size (in feet) equal to approximately three times the thickness of the caps (in inches) in both directions. For example, joints are recommended at a maximum spacing of 12 feet assuming a four-inch thick caps. Using fiber reinforcement in the concrete can also control shrinkage cracking.

## 4.6 INFILTRATION TEST RESULTS

PSI also performed Infiltration Testing for planning and designing the future storm water facilities at the proposed development.

Infiltration testing was performed at locations I-1 through I-2. At each location one soil boring was advanced and soil samples were collected at regular intervals to ten feet. Wells were drilled using augers, casings were installed to a depth of 5 feet below grade and the wells were pre-soaked for 24 hours. After 24 hours PSI performed falling-head infiltration tests in accordance with Maryland State requirements.

The locations of the infiltration tests are shown on the Boring Location Plan. The findings of these borings are presented on the Boring Logs. The infiltration test results are shown in the following Table.

| Table 8 : Infiltration Test Results | | |
|---|---|---|
| **Test Location** | **Infiltration Test Result (Inches/Hour)** | **USCS Soil Classification At/Below Infiltration Test Elevation** |
| I-1 | 0.01 | silty SAND (SM) |
| I-2 | 0.01 | silty SAND (SM) |

As seen from the above table, the rate of infiltration was 0.01 inch per hour. Generally, soils having an infiltration rate of less than 0.52 inch per hour or higher than 12 inches per hour are not suitable for infiltration facilities.

Our experience indicates that there is a relatively high incidence of failure of infiltration facilities to achieve the designed infiltration rate. There are a number of reasons for this, but they can typically be grouped into two primary categories. There are reasons related to the in-situ soil conditions and those related to construction practices.

One soil condition of importance is the basic soil classification, often expressed by grain size, or textural analysis as well as plasticity testing. Small changes in the gradation of soil can result in large changes in infiltration rate. Permeability which is very similar to infiltration rate varies by over five orders of magnitude from sands to clays. Infiltration rates that are typically considered suitable for infiltration practices vary by just over one order of magnitude, making suitable soils a small subset of all soils. Additionally, the undisturbed soil has a structure or fabric that includes pores and features that are the result of natural processes. This soil fabric develops over time and is influenced by plant growth and other biological processes and this fabric often governs the infiltration rate. Both the soil classification and the fabric can change rapidly with elevation/depth in the soil profile. Hence results of testing that is performed at any elevation other than the invert elevation of the facility can be misleading, even when different by only a few inches. The effective infiltration rate of a facility is also very sensitive to construction practices. The general principal is that soils which become disturbed do not typically infiltrate as well as undisturbed soils. Since testing is performed on undisturbed soils, this creates a potential for unexpectedly low field infiltration rates in completed facilities. This makes grading of infiltration basins a challenge. Trafficking of earth moving equipment used to excavate basins can disturb the native soil at the base of the facility. This will cause the fabric described above to be destroyed, resulting in lower permeability. Where fill materials are placed in a basin, or where construction traffic compacts native soils, excess compaction will reduce permeability. Since contractors are typically encouraged to achieve high levels of compaction, this creates the potential for problems. Using the term broadly, this “disturbance” can also include sedimentation that occurs during construction. If at any stage during construction the basin receives runoff that carries sediment, it can clog pores in the native soils rendering them less permeable.

Beyond the disturbance of the native soils and compaction of soils placed in basin bottoms, the composition of any soils placed in basin bottoms is very important. The “engineered” soils placed in the bottom of some facilities consist of a combination of sand,

organic matter, and site soils. Getting the proportions of these materials right so that they have the desired infiltration capacity as well as the ability to support plant life and meet any other design requirements can be a challenge. In particular, site soils that are included can be quite variable in composition, and the blending of the soils on site can result in uneven mixing, even when done conscientiously.

Consequently, verification testing of infiltration rates should be required at the time of construction to confirm the design assumptions. This testing should include the native subgrade as well as engineered/amended soils, if present. Otherwise the system may fail to meet the design intent.

## 4.7 CONSTRUCTION DEWATERING

At the time of drilling activities, groundwater was encountered in all borings except B-07, B-09, B-10, and B-11 at average depth of 10 feet below the existing grade. On the other hand, groundwater level also observed upon drilling completion in borings B-01, B-02, B-04, B-05, B-10, and B-11 at average depth of 8 feet below the existing grade. Depending upon the depth of cuts with respect to the observed groundwater level, we anticipate that ground water may not be encountered for mat foundations. We highlight that the contractor is responsible for all dewatering by his means and methods.

In addition, water can enter the excavations due to surface runoff and local precipitation during construction. Past experience indicates that the foundation and subgrade bearing soils encountered on-site will soften considerably when exposed to free water. The contractor should keep excavations dry to prevent the softening of these materials. Methods such as sloping, ditching, and berming can be used to control surface water at the site.

Water should not be allowed to collect in the foundation excavation, on floor slab areas, or on prepared subgrades of the construction area either during or after construction. Undercut or excavated areas should be sloped toward one corner to facilitate removal of any collected rainwater, groundwater, or surface runoff. Positive site surface drainage should be provided to reduce infiltration of surface water around the perimeter of the building and beneath the floor slabs. The grades should be sloped away from the building and surface drainage should be collected and discharged such that water is not permitted to infiltrate the backfill and floor slab areas of the building.

Overall site drainage is to be arranged in a manner to direct surface water away from the construction area including the slab and pavement subgrades and foundation excavations. Based on PSI's experience on similar sites, planning and diligence will be required on the part of the contractor because of the gentle site grades.

We are providing this information solely as a service to our client. Psi is not assuming responsibility for construction site safety or the contractor's activities; such responsibility is not being implied and should not be inferred.

## 4.11 SOIL RESISTIVITY TEST

Soil resistivity testing is the process of measuring a volume of soil to determine the conductivity of the soil and it is the single most critical factor in electrical grounding design. Wenner test method is used for the site where the probe located at SR-1 and results for EW and NNE directions are presented as:

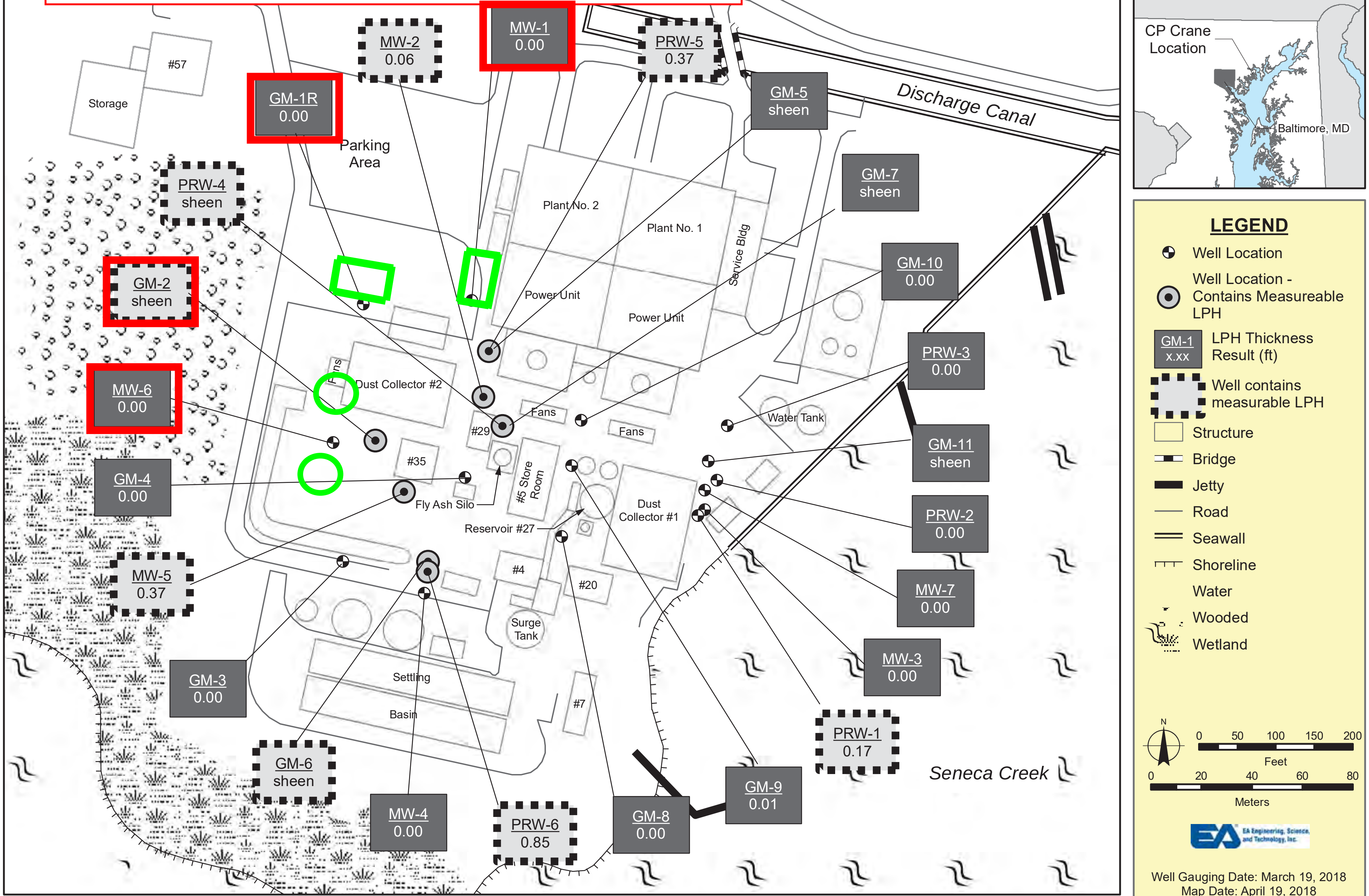
**Table 11: Estimated Soil Resistivity** (On field)

| Direction | Probe spacing (ft) | Resistance Measured 1 | Resistance Measured 2 | Resistance Measured 3 | Resistance Average (Ohm) | Calculated Resistivity (Ohm*m) |
|---|---|---|---|---|---|---|
| EW | 20 | 0.816 | 0.816 | 0.816 | 0.82 | 31.253 |
| EW | 100 | 0.202 | 0.201 | 0.202 | 0.20 | 38.619 |
| NNE | 5 | 12.5 | 12.5 | 12.5 | 12.50 | 119.688 |
| NNE | 10 | 6.56 | 6.56 | 6.56 | 6.56 | 125.624 |
| NNE | 20 | 3.21 | 3.22 | 3.21 | 3.21 | 123.071 |
| NNE | 30 | 1.944 | 1.943 | 1.945 | 1.94 | 111.683 |
| NNE | 40 | 1.267 | 1.269 | 1.269 | 1.27 | 97.154 |

**Appendix (E)** represents the resistivity testing layout where EW is centered at SR-1 and runs east to west and NNE is centered 160 ft north of SR-1 and runs south-southwest to north-northeast. It should be noted the estimated soil resistivity from field data is recommended rather laboratory tests since it represents the native soil behavior and environmental conditions.

Remediation well locations that may have excavation dewatering take place near their location. Excavation areas in green.

Case No. 9482 PPRP DR 1-4 Exhibit C




**C.P. Crane Generating Station**

Baltimore County, Maryland

Figure 7
1st Quarter 2018
March LPH Thickness

Data Sources:
C.P. Crane, LLC

Map Projection:
NAD 1983 UTM Zone 18N (feet)

**Response of C.P. Crane LLC ("CP Crane") to PPRP Data Request No. 1**
**CP Crane Repowering Project**
**PSC Case No. 9482**
**Response Date: July 20, 2018**

1-5 Please confirm that all water needs for the repowered CP Crane site will be met by purchased water from Baltimore City, and that the facility owner intends to deactivate its existing surface water appropriation.

**Response:**

The water needs for the repowered CP Crane site will be met by purchased water from Baltimore City. Whether the existing water appropriations permit will be deactivated depends on the future use of the remainder of the CP Crane site, which has not yet been determined.

Response provided by: David Dunbar, Vice President – Operations & Development, C.P. Crane LLC

**Response of C.P. Crane LLC ("CP Crane") to PPRP Data Request No. 2**
**CP Crane Repowering Project**
**PSC Case No. 9482**
**Response Date: August 13, 2018**

2-1 Pages 3-2 and 3-4 of the ERD reference a new natural gas compression system that will be capable of increasing the natural gas pressure from 350 psi to 675 psi. Please clarify if the natural gas compression system will use any fossil fuel driven equipment.

Response:

Under the proposed design, ProEnergy will supply and install a Gas Compressor System that is designed to provide sufficient pressure and flow to meet the needs of the gas turbine generator. The compressor will be skid mounted and utilize a compressor directly coupled to a horizontal induction electric motor. The proposed design of the gas compressor system does not utilize fossil fuel.

Response provided by: Thomas Pritcher, Senior Principal Engineer, ECT

**Response of C.P. Crane LLC ("CP Crane") to PPRP Data Request No. 2**
**CP Crane Repowering Project**
**PSC Case No. 9482**
**Response Date: August 13, 2018**

2-2 Section 3 of the ERD describes the Applicant's plans to install three simple-cycle gas-fired CT's at the existing CP Crane site, and "retire" (but not demolish) two coal-fired units, although some Unit 1 & 2 ancillary buildings will be demolished to make room for the CT's. The project site also houses a 14 MW oil fired combustion turbine. When BG&E constructed the original CP Crane facility (1957), Baltimore County imposed a number of conditions as part of granting the required special exception from its Zoning Commission, including one that stated no more than four power producing units shall be constructed on the property. Based on the proposed design, there will be either four or six power producing units at the site, depending on how a "retired" unit is classified.

a. How does the Applicant plan on complying with this special exception condition for use of the parcel?

b. Does the Applicant intent to demolish Units 1 & 2 as part of this project? Are there plans to demolish the coal-fired units at a later time?

c. Has the Applicant consulted with the Baltimore County to confirm that the Project is in conformance with the County's special exception conditions for use of the parcel?

Response:

a. CP Crane has consulted with Baltimore County to confirm that the improvements planned for the Property and the intended use of the Property are in conformance with the County's special exception conditions. See the attached PPRP DR 2-2 Attachment 1, Letter Request for Spirit and Intent Verification, reviewed and approved by Baltimore County on May 30, 2018; and PPRP DR 2-2 Attachment 2, Plan to Accompany Spirit and Intent Request approved by Baltimore County on June 5, 2018.

b. CP Crane does not currently have plans to demolish Units 1 & 2. As described in Section 3 of the ERD, several existing plant components will be demolished to allow space for the new site layout, including the Unit 2 air heater, Unit 2 dust collector, Unit 2 electrical control and vacuum blower building, and the urea tanks.

c. Yes. See the response to 2-2a.

Response provided by: Dennis C. Corn, Consultant/Director of Development, Middle River Power, LLC

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May 24, 2018

**<u>Hand-Delivered</u>**
W. Carl Richards, Jr., Supervisor
Zoning Review Office
Department of Permits, Approvals
and Inspections
County Office Building
111 West Chesapeake Avenue
Towson, Maryland 21204

**Re: REQUEST FOR SPIRIT AND INTENT VERIFICATION RELATED TO CASE NOS. R-1957-4077, 1972-41-A, 74-102-SPHA**
Location: 1021 Carroll Island Road
Parcel No. 141, Tax Account No. 1502001277
Legal Owner: CP Crane LLC
15th Election District, 6th Councilmanic District

Dear Mr. Richards:

This firm represents CP Crane, LLC ("CP Crane"), the legal owner of the above-referenced property, which consists of 88 ± acres and is located adjacent to and on the south side of Carroll Island Road in the Middle Rover area of Baltimore County (the "Property"). The Property is now split-zoned RC5 (Rural-Residential Zone) and RC20 (Critical Area). Copies of printouts from the State Department of Assessments and Taxation website for the Property are enclosed for your review and convenience. I am writing to confirm that improvements planned for the Property and the intended use of the Property are within spirit and intent of the prior special exception approved in Case No. R-1957-4077 and two subsequent zoning cases and that no additional zoning relief and/or a public hearing before the Administrative Law Judge will be required for the intended improvements to and use of the Property, as described in this letter below.

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Currently, a coal-fired power plant is located on the Property and has been for over 50 years. In its current configuration, the power plant has two nominal 200 megawatt coal-fired boilers and steam turbines and one diesel fueled GE Frame 5 combustion turbine. The planned repowering project by CP Crane on the Property, as shown and indicated on the enclosed site plan, labeled "Plan to Accompany Spirit and Intent Request" and dated May 17, 2018, will involve the design, construction, and operation of the following for conversion to a natural gas and ultra-low sulfur diesel power plant:

> Three state-of-the-art natural gas and ultra-low sulfur diesel ("ULSD") fired GE LM6000 aero-derivative combustion turbines (hereinafter "CTs");
>
> Liquid ULSD oil handling, piping, and storage, including a liquid fuel unloading area, and fuel tanks;
>
> A natural gas compression station with associated treatment, piping, and regulation equipment;
>
> Water treatment and wastewater handling facilities;
>
> Electrical interconnection facilities, including GSU transformers; and
>
> Related ancillary equipment to support the overall operation.

The electric generation units and associated equipment will be constructed on a portion of the approximately 88 ± acre Property, as shown on the site plan. Several existing power plant components will be demolished to allow space for the new site layout and improvements listed above. These components to be removed include a Unit 2 air heater, a Unit 2 dust collector, a Unit 2 electrical control and vacuum blower building, and urea storage tanks, all of which are shown on the site plan. These components are currently located on the south west side of the existing boiler structure. The Project will also result in the permanent retirement of the two existing coal-fired generating units and the installation of the three CTs and associated ancillary equipment. The existing GE Frame 5 CT will remain. The GE LM6000 CTs selected for the Repowering Project incorporate the latest advancements in clean, energy-efficient electrical power generation. They are expected to serve as peaking units (i.e., providing power during periods of high demand) and operate at an annual capacity factor of up to 30 percent. Clean natural gas will be their primary fuel (via the existing natural gas pipeline), but they will also be capable of firing ULSD in situations when natural gas is not available in sufficient

VENABLE LLP



quantities. The project may also include a battery energy storage system at some time in the future.

By way of brief history, in Zoning Case No. R-1957-4077 (the "1957 Case"), a special exception was granted for a steam electric generating station and related facilities. Subsequent to this 1957 Case, in Case No. 1972-41-A (the "1972 Case"), variances were granted, which related to "dock and sheet piling" on the Property. In a later case, Case No. 74-102-SPHA (the "1974 Case"), a special hearing was granted for an amendment to the prior approved special exception to permit construction of a propane storage facility with the existing special exception and a variance for the height of storage tank. Following these zoning cases, a series of administrative approvals were granted relating to power plant operations on the Property by way of spirit and intent letter requests, which related to the following:

> 2003 Spirit and Intent ("S & I") Letter – For a temporary change of coal operations;
>
> June, 2005 S & I Letter – Alternative for barging of coal to the Property;
>
> July 2005 S & I Letter – Confirmation of no zoning relief required for equipment 110 + feet in height;
>
> 2008 S & I Letter – For repairs and site improvements including coal safety yard modifications, installation of additional air quality emissions control equipment and other related site improvements; and
>
> 2011 S & I Letter – For improvements to facilitate addition of coal additives for improvement of boiler operations and reduction of air emissions.

The purpose of this letter is to confirm that conversion of the current improvements on the Property from a coal-fired power plant to a new state-of-the art natural gas/ULSD power plant, as shown and indicated on the enclosed site plan, is within the spirit and intent of 1957 Case and the subsequent 1972 and 1974 zoning cases for the Property. The intended use of the Property by CP Crane will continue to be a power plant and the overall operations on the Property for power plant purposes will be confined to and not extend outside of the special exception area originally approved in the 1957 Case. For these reason, please confirm on behalf of your office, by your countersignature below, that the site improvements and changes to the operation of the power plant use, as described in this letter and shown on the enclosed site plan, are within the

VENABLE® LLP



spirit and intent of the prior zoning cases applicable to the Property and that no additional zoning relief and/or another public hearing before the Administrative Law Judge will be required at this time.

I have enclosed with this letter a check in the amount of $500.00 made payable to "Baltimore County, Maryland" to cover the administrative costs associated with your review. If you have any questions or require any additional information regarding this request, please feel free to contact me. I appreciate your attention to this matter.

Very truly yours,

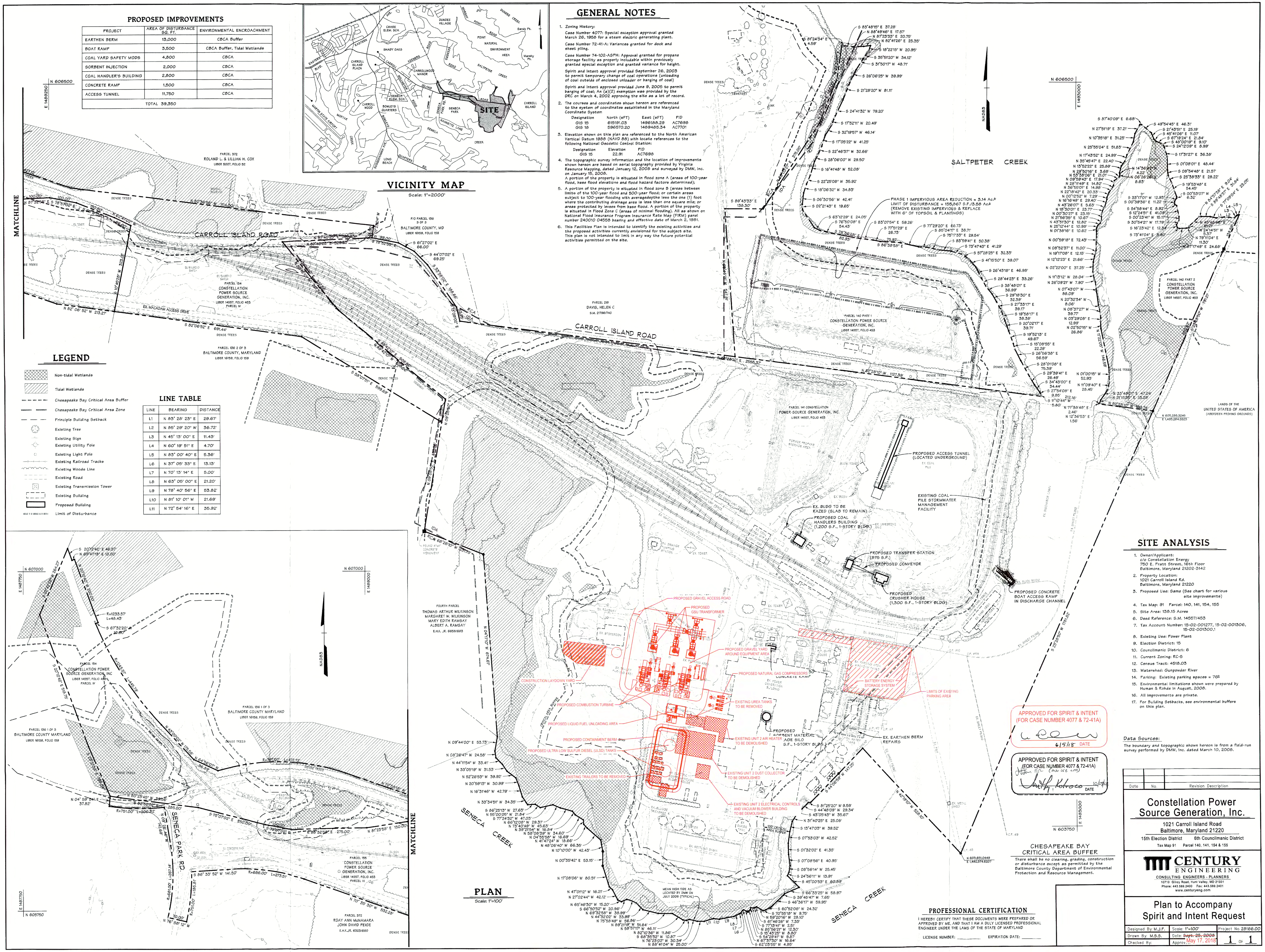
David H. Karceski

DHK
Enclosure

REVIEWED AND APPROVED

W. CARL RICHARDS, JR.
ZONING REVIEW OFFICE

5/30/18
DATE




## PROPOSED IMPROVEMENTS

| PROJECT | AREA OF DISTURBANCE SQ. FT. | ENVIRONMENTAL ENCROACHMENT |
|---|---|---|
| EARTHEN BERM | 13,000 | CBCA Buffer |
| BOAT RAMP | 3,500 | CBCA Buffer, Tidal Wetlands |
| COAL YARD SAFETY MODS | 4,800 | CBCA |
| SORBENT INJECTION | 2,000 | CBCA |
| COAL HANDLER'S BUILDING | 2,800 | CBCA |
| CONCRETE RAMP | 1,500 | CBCA |
| ACCESS TUNNEL | 11,750 | CBCA |
| TOTAL 39,350 | | |

## GENERAL NOTES

1. Zoning History:
   Case Number 4077: Special exception approval granted March 26, 1958 for a steam electric generating plant.
   Case Number 72-41-A: Variances granted for dock and sheet piling.
   Case Number 74-102-ASPH: Approval granted for propane storage facility as properly includable within previously granted special exception and granted variance for height.
   Spirit and Intent approval provided September 26, 2003 to permit temporary change of coal operations (unloading of coal outside of enclosed unloader or barging of coal)
   Spirit and Intent approval provided June 9, 2005 to permit barging of coal; An (a)(2) exemption was provided by the DRC on March 4, 2002 approving the site as a lot of record.
2. The courses and coordinates shown hereon are referenced to the system of coordinates established in the Maryland Coordinate System

| Designation | North (sFT) | East (sFT) | PID |
|---|---|---|---|
| GIS 15 | 615191.03 | 1496188.29 | AC7698 |
| GIS 18 | 596570.20 | 1489485.34 | AC7701 |

3. Elevation shown on this plan are referenced to the North American Vertical Datum 1988 (NAVD 88) with locate references to the following National Geodetic Control Station:

| Designation | Elevation | PID |
|---|---|---|
| GIS 15 | 22.91 | AC7698 |

4. The topographic survey information and the location of improvements shown hereon are based on aerial topography provided by Virginia Resource Mapping, dated January 12, 2008 and surveyed by DMW, Inc. on January 15, 2008.
   A portion of the property is situated in flood zone A (areas of 100-year flood, base flood elevations and flood hazard factors determined);
5. A portion of the property is situated in flood zone B (areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with averagedepths less the one (1) foot where the contributing drainage area is less than one square mile; or areas protected by levees from base flood. A portion of the property is situated in Flood Zone C (areas of minimal flooding). All as shown on National Flood Insurance Program Insurance Rate Map (FIRM) panel number 240010 0455B bearing and effective date of March 2, 1981.
6. This Facilities Plan is intended to identify the existing activities and the proposed activities currently envisioned for the subject site. This plan is not intended to limit in any way the future potential activities permitted on the site.

## LEGEND

- Non-tidal Wetlands
- Tidal Wetlands
- Chesapeake Bay Critical Area Buffer
- Chesapeake Bay Critical Area Zone
- Principle Building Setback
- Existing Tree
- Existing Sign
- Existing Utility Pole
- Existing Light Pole
- Existing Railroad Tracks
- Existing Woods Line
- Existing Road
- Existing Transmission Tower
- Existing Building
- Proposed Building
- Limit of Disturbance

## LINE TABLE

| LINE | BEARING | DISTANCE |
|---|---|---|
| L1 | N 83° 28' 23" E | 29.67' |
| L2 | N 85° 29' 20" W | 36.72' |
| L3 | N 45° 13' 00" E | 11.43' |
| L4 | N 60° 19' 51" E | 4.70' |
| L5 | N 83° 00' 40" E | 5.36' |
| L6 | N 37° 05' 33" E | 13.13' |
| L7 | N 70° 13' 14" E | 5.00' |
| L8 | N 63° 05' 00" E | 21.20' |
| L9 | N 78° 40' 56" E | 53.82' |
| L10 | N 81° 10' 01" W | 21.69' |
| L11 | N 72° 54' 16" E | 35.92' |

## SITE ANALYSIS

1. Owner/Applicant:
   c/o Constellation Energy
   750 E. Pratt Street, 16th Floor
   Baltimore, Maryland 21202-3142
2. Property Location:
   1021 Carroll Island Rd.
   Baltimore, Maryland 21220
3. Proposed Use: Same (See chart for various site improvements)
4. Tax Map: 91 Parcel: 140, 141, 154, 155
5. Site Area: 138.15 Acres
6. Deed Reference: S.M. 14557/453
7. Tax Account Number: 15-02-001277, 15-02-001306, 15-02-001300,1
8. Existing Use: Power Plant
9. Election District: 15
10. Councilmanic District: 6
11. Current Zoning: RC-5
12. Census Tract: 4518.03
13. Watershed: Gunpowder River
14. Parking: Existing parking spaces = 76±
15. Environmental limitations shown were prepared by Human & Rohde in August, 2008.
16. All improvements are private.
17. For Building Setbacks, see environmental buffers on this plan.

Data Sources:
The boundary and topographic shown hereon is from a field-run survey performed by DMW, Inc. dated March 10, 2008.

APPROVED FOR SPIRIT & INTENT
(FOR CASE NUMBER 4077 & 72-41A)
6/5/18
DATE

APPROVED FOR SPIRIT & INTENT
(FOR CASE NUMBER 4077 & 72-41A)
10/07/08
DATE

### CHESAPEAKE BAY CRITICAL AREA BUFFER

There shall be no clearing, grading, construction or disturbance except as permitted by the Baltimore County Department of Environmental Protection and Resource Management.

### PROFESSIONAL CERTIFICATION

I HEREBY CERTIFY THAT THESE DOCUMENTS WERE PREPARED OR APPROVED BY ME, AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MARYLAND

LICENSE NUMBER: ______ EXPIRATION DATE: ______

| Date | No. | Revision Description |
|---|---|---|

**Constellation Power Source Generation, Inc.**
1021 Carroll Island Road
Baltimore, Maryland 21220
15th Election District 6th Councilmanic District
Tax Map 91 Parcel 140, 141, 154 & 155

CENTURY ENGINEERING
CONSULTING ENGINEERS · PLANNERS
10710 Gilroy Road, Hunt Valley, MD 21031
Phone: 443.589.2400 Fax: 443.589.2401
www.centuryeng.com

**Plan to Accompany Spirit and Intent Request**

| Designed By: M.J.F. | Scale: 1"=100' | Project No. 28166.00 |
|---|---|---|
| Drawn By: M.S.S. | Date: ~~Sept. 26, 2008~~ May 17, 2018 | 1 of 1 |
| Checked By: | Approv. | |

**Response of C.P. Crane LLC ("CP Crane") to PPRP Data Request No. 3**
**CP Crane Repowering Project**
**PSC Case No. 9482**
**Response Date: August 24, 2018**

3-2 In the response to PPRP Data Request No. 1-4b, CP Crane stated that:

> "Based on current estimates and due to the short duration of dewatering, the amount of water withdrawn is not expected to exceed an annual average of 10,000 gallons per day."

In addition, in the response to PPRP Data Request No. 1-4c, CP Crane stated that:

> "CP Crane expects the total amount of water needed for dewatering to be approximately 210,000 gallons."

To confirm that dewatering will not exceed the 10,000 gallons per day threshold requiring a Water Appropriation and Use Permit, please provide the following:

a. The anticipated length, width, and depth of each foundation, footer and subgrade structure excavation as shown on Exhibit A of CP Crane's response to PPRP Data Request 1-4c;
b. An estimate of the depth excavations will extend below the water table (i.e., saturated thickness);
c. An estimate of the duration of dewatering of each excavation;
d. An estimate of the thickness of surficial aquifer, including the source of the information. If the information was obtained from studies conducted at the site, please provide copies of those studies; and
e. A calculation in spreadsheet form to estimate the amount of water that will be generated by each excavation.

Response:

Please see PPRP DR 3-2 Attachment 1 "Dewatering Estimate" in response to the above items (a), (b), (c) & (e).

d. The CP Crane site does not appear to be in the surficial aquifer system. The CP Crane site is in the Lower Patapsco aquifer system which is approximately 250 feet thick near the site. The source for this data is the Maryland Coastal Plain Aquifer Information System: Hydrogeologic Framework. See PPRP DR 3-2 Attachment 2 at pages 5-7, 39-40, and 77-78. The full report is available on the Maryland Geological Survey website at http://www.mgs.md.gov/reports/OFR_12-02-20.pdf

Response provided by: Mark Bendorf, Mechanical Engineer, ProEnergy Services

ProEnergy

Dewatering Estimate

8/24/2018

| Shallow Foundation | Length (ft) | Width (ft) | Foundation Depth (ft) | Water Table Depth Below Grade (ft) | Depth Excavation Below Water Table (ft) | Volume (ft3) | Volume (Gal) | Duration of Dewatering (hr) |
|---|---|---|---|---|---|---|---|---|
| CTG 1 | 61.25 | 19 | 5 | 4 | 1 | 1163.75 | 8705 | 7.3 |
| CTG 2 | 61.25 | 19 | 5 | 4 | 1 | 1163.75 | 8705 | 7.3 |
| CTG 3 | 61.25 | 19 | 5 | 4 | 1 | 1163.75 | 8705 | 7.3 |
| Stack 1 | 14 | 14 | 6 | 4 | 2 | 392 | 2932 | 2.4 |
| Stack 2 | 14 | 14 | 6 | 4 | 2 | 392 | 2932 | 2.4 |
| Stack 3 | 14 | 14 | 6 | 4 | 2 | 392 | 2932 | 2.4 |
| Fuel Gas Compressors | 40.5 | 26 | 5 | 4 | 1 | 1053 | 7877 | 6.6 |
| Demin Water Tank | 42 | 36.375 | 5 | 4 | 1 | 1527.75 | 11428 | 9.5 |
| Liquid Fuel Tank 1 | 42 | 36.375 | 5 | 4 | 1 | 1527.75 | 11428 | 9.5 |
| Liquid Fuel Tank 2 | 42 | 36.375 | 5 | 4 | 1 | 1527.75 | 11428 | 9.5 |
| Liquid Fuel Unloading Station | 23 | 11 | 5 | 4 | 1 | 253 | 1893 | 1.6 |
| GSU 1 | 15 | 11.5 | 5 | 4 | 1 | 172.5 | 1290 | 1.1 |
| GSU 2 | 15 | 11.5 | 5 | 4 | 1 | 172.5 | 1290 | 1.1 |
| GSU 3 | 15 | 11.5 | 5 | 4 | 1 | 172.5 | 1290 | 1.1 |
| **Sub Total** | | | | | | | **82,839.28** | **69.03** |

| Piles | QTY Piles | Diameter (in) | Diameter (ft) | Pile Depth Below Grade (ft) | Water Table Depth Below Grade (ft) | Depth Excavation Below Water Table (ft) | Volume (ft3) | Volume (Gal) | Duration of Dewatering (hr) |
|---|---|---|---|---|---|---|---|---|---|
| Demin Tank | 5 | 30 | 2.5 | 41 | 4 | 37 | 908.1166 | 6793.18 | 5.7 |
| LF Tank | 8 | 30 | 2.5 | 41 | 4 | 37 | 1452.987 | 10869.10 | 9.1 |
| LF Tank | 8 | 30 | 2.5 | 41 | 4 | 37 | 1452.987 | 10869.10 | 9.1 |
| H-Frame | 6 | 30 | 2.5 | 36 | 4 | 32 | 942.4778 | 7050.22 | 5.9 |
| Stack | 5 | 30 | 2.5 | 40 | 4 | 36 | 883.5729 | 6609.59 | 5.5 |
| Stack | 5 | 30 | 2.5 | 40 | 4 | 36 | 883.5729 | 6609.59 | 5.5 |
| Stack | 5 | 30 | 2.5 | 40 | 4 | 36 | 883.5729 | 6609.59 | 5.5 |
| **Sub Total** | | | | | | | | **55,410.35** | **46.18** |

| | | | |
|---|---|---|---|
| **Estimated Sub-totals** | | **138,249.63** | **115.21** |
| Contigency for over excavation and other unknowns. | 50% | 69,124.82 | 57.60 |
| **Estimated Total** | | **207,374.45** | **172.81** |
| **Estimated volume per day (based on 365 days of dewatering)** | | **568.15** | |

**Response of C.P. Crane LLC ("CP Crane") to PPRP Data Request No. 4**
**CP Crane Repowering Project**
**PSC Case No. 9482**
**Response Date: September 5, 2018**

4-1. Please provide a full copy of the Geotechnical Engineering Services Report dated June 14, 2018, PSI Project No. 0512843, extracted pages of which were included in Exhibit B of the Applicant's response to PPRP Data Request No. 1-4 as well as Attachment 1 of the Applicant's response to PPRP Data Request No. 3-3.

Response:

A full copy of the Geotechnical Engineering Services Report is attached as PPRP DR 4-1 Attachment 1.

Response sponsored by: Mark Bendorf, Mechanical Engineer, ProEnergy Services

# GEOTECHNICAL ENGINEERING SERVICES REPORT

For the proposed

**C. P. CRANE STATION**
**BOWLEYS QUARTERS**
**MARYLAND**

Prepared for

**Mr. Mark Bendorf**
**ProEnergy Services**
**2001 ProEnergy Boulevard**
**Sedalia, Missouri 65301**

Prepared by

**Professional Service Industries, Inc.**
**2930 Eskridge Rd**
**Fairfax, VA**
**Telephone (703) 698-9300**
**Fax (703) 560-7931**

**PSI PROJECT NO. 0512843-1**

**June 14, 2018**

intertek psi

Shahriar Shahrokhabadi, E.I.T
Project Engineer

Richard Weber
Principal Consultant

STATE OF MARYLAND
NASEER NAYEEM
35449
PROFESSIONAL ENGINEER

Naseer Nayeem, P.E.
Director/Principal Consultant

*Professional Certification. I hereby certify that these documents were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 35449, Expiration Date: 02/17/2020*

June 14, 2018

**ProEnergy Services**
**2001 ProEnergy Boulevard**
**Sedalia, Missouri 65301**

Attention: Mr. Mark Bendorf
Phone: 660-829-5100
E-mail: MBendorf@proenergyservices.com

Subject: Geotechnical Engineering Services Report
Proposed C. P. Crane Station Combustion Turbine Repowering Project
Bowleys Quarters, Maryland
PSI Project Number: 0512843

Dear Mr. Bendorf:

Thank you for choosing Professional Service Industries, Inc. (PSI) as your geotechnical consultant for C. P. Crane Station Combustion Turbine Repowering.

Per your authorization, PSI has completed a geotechnical engineering services report for the above referenced project. The results are discussed in the accompanying report.

Should there be any questions, please do not hesitate to contact our office at (703) 698-9300. PSI would be pleased to continue providing geotechnical services throughout the implementation of the project, and we are looking forward to working with you and your organization on this and future projects.

Respectfully submitted,

**PROFESSIONAL SERVICE INDUSTRIES, INC.**

| | | |
|---|---|---|
| Shahriar Shahrokhabadi, E.I.T<br>Project Engineer | Richard Weber<br>Principal Consultant | Naseer Nayeem, P.E.<br>Director/Principal Consultant |

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## APPENDICES

# 1 EXECUTIVE SUMMARY

PSI has completed a Geotechnical Engineering Services Report for the proposed development of the existing C. P. Crane Power Station located at Bowleys Quarters in Maryland.

The proposed site is overlain by an existing parking lot pavement. The topography of the existing grade is approximately flat over the entire site and the existing surface is approximately located at EL. 9.0 feet. However, we anticipate site grading may require cuts and fills in the order of 1 to 2 feet to reach the proposed finish grade elevation.

A total of sixteen (16) test borings were drilled for this project where fourteen (14) borings, B-1 to B-14, were drilled for the proposed power plant structures, and two (2) borings, I-1 and I-2 were drilled for the proposed Stormwater Management (SWM) facility. Borings B-1 through B-11 were drilled to a depth of 50 feet below ground surface while borings B-12 to B-14 were drilled to a depth of 100 feet below the exiting grade. In addition, infiltration borings (I-1 and I-2) were drilled to a depth of 10 feet below existing ground.

Based on the observed subsurface conditions, PSI recommends mat foundations for the supporting the GSU transformers, gas compressor, and combustion turbine generators bearing at a depth of 30 inches below finished grade for frost protection. PSI assumed that finished elevation of the EL. 10 feet for mat foundations. Based on our analysis of the medium to dense native materials, mat foundations can be proportioned using a net allowable soil bearing pressure of 4,500 pounds per square foot (psf) for these structures.

Based on the provided equipment weight, dimensions and our site characterization, two options as driven and Augur Cast Piles are recommended for supporting the liquid tanks, H-frames, and exhaust stacks. Preliminary analysis predicted excessive settlements for liquid tanks that are heavy weight equipment. On the other hand, H-frame and exhaust stacks are categorized as slender structures with slender ratio (Hight/Diameter) of 8 and 10, respectively. PSI anticipated deep foundations for the above-mentioned equipment to resist excessive settlement and overturning due to possibly high lateral loads.

During drilling, groundwater was encountered in borings B-01 through B-14 at depths ranging from 6 to 16 feet below ground surface. However, upon completion of drilling, groundwater was observed at depths ranging from 6 to 10 feet below the existing ground. We do not anticipate problems in the design and construction of the mat foundations due to the shallow water table. Based on our soil sample modeling and infiltration test data the predicted annual groundwater level varies between 4 feet (EL. 4) to 6 feet (EL. 2) below existing grade (EL. 8). However, special considerations may be required in the excavation below 6 feet from existing grade.

Recommendations relative to earthwork, slab on grade, and foundation design are detailed in the report. The owner/designer should not rely solely upon the executive summary and must read and understand the entire contents of this report, prior to utilizing our engineering recommendations in preparation of design and construction documents.

# 2 PROJECT INFORMATION

## 2.1 PROPOSAL AND PROJECT AUTHORIZATION

This report presents the findings and recommendations of the subsurface exploration and geotechnical evaluation performed by Intertek-PSI for the proposed development of C.P. Crane Power Station in the vicinity of existing power plant located at Bowleys Quarters in Maryland.

The contract was executed by ProEnergy Services LLC on March 28, 2018 and revised on April 13, 2018 with Purchase Order No. PES147793-EPC. PSI's scope of work is described under the "Geotechnical Exploration Services" section.

## 2.2 PROJECT DESCRIPTION

PSI was provided with a Request For Proposal (RFP) via email on March 16, 2018 by Mark Bendorf of ProEnergy Services, LLC. The RFP included a "Topography Survey" plan drawing prepared by Stantec dated February 8, 2018. The drawing shows the proposed development location of the planned structures and equipment, limited existing topographic information, and fourteen (14) requested boring locations. An additional two (2) SPT borings for the proposed SWM were added later.

We understand that the project consists of developing Combustion Turbine Repowering of the existing C. P. Crane Power Station. Based on the information provided by the client, the proposed Geotechnical services included subsurface exploration and assessment, Field Electrical Resistivity test, and Field Infiltration test within the proposed project area in Bowleys Quarters, Maryland. Boring locations are spread within the proposed development area of the power plant to provide coverage for all the structures.

Equipment types and structural loading were provided to us in Geotechnical RFP-Structural Loading. However, equipment information was updated later by Mark Bendorf of ProEnergy Services, LLC on May 9, 2018 via email. Based on the information provided, the estimated equipment loads ranged from 7 kips for H-frame to 850 kips for Demin and liquid fuel tanks. At the time of preparing this report we assumed that no dynamic soil will be transferred to the soil.

Based upon current site topography obtained from Google Earth, we expect site grading will require cuts and fills in the order of 1 to 2 feet to reach the proposed finish grade elevation. Finished grade elevation of the proposed various structures was not provided at the time of preparing this report and it was assumed approximately at an elevation of 10 feet. However, as per USGS and existing topographic plan, the existing site grades range from 7.0 to 10.0 feet. The highest elevation at the site is near boring B-9 with an elevation of 10.0 feet which is on the east side of the project area.

Should any of the above information or assumptions made by PSI be inconsistent with the planned construction, we request you to contact us immediately to make any necessary modifications to this report.

## 2.3 PURPOSE AND SCOPE OF WORK

The scope of services for this study included a site visit of the project area and the assessment of subsurface conditions through field exploration and laboratory testing. This report includes the assessment of the site, subsurface conditions relative to the proposed development, and engineering studies that were used in preparing this report. The subsurface exploration was developed to provide the following:

- Geologic review of the project site.
- Subsurface conditions encountered including pertinent soil properties, water levels and drainage.
- Soil data review and analysis as it relates to the proposed site construction and development.
- Measuring the soil resistivity and soil chemical constituents (i.e., PH etc.)
- Site preparation recommendation and recommendations for pavement design.
- Civil site recommendations for site preparation, placement and compaction of fill.
- Determine soil properties and its design parameters for “LPILE” program.
- Recommendations for foundation type (mat, shallow footings, and drilled piers) to support each structure.
- Comments relating to observed geotechnical conditions such as soft material, groundwater, buoyant forces, liquefiable soils which could impact development.
- Determine the Seismic Site Class per IBC 2015 based on the SPT N-values obtained during the field exploration.

The scope of our services did not include an environmental assessment for determining the presence or absence of wetlands, hazardous or toxic materials in the soil, bedrock, groundwater, or air, on or below or around this site. Any statement in this report or on the boring logs regarding odors, colors, unusual or unexpected items or conditions are strictly for the information of our client.

PSI did not provide, nor was it requested to provide, any service to investigate or detect the presence of moisture, mold or other biological contaminants in or around any

structure, or any service that was designed or intended to prevent or lower the risk of the occurrence of the amplification of the same. Client acknowledges that mold is ubiquitous to the environment with mold amplification occurring when building materials are impacted by moisture. Client further acknowledges that site conditions are outside of PSI's control, and that mold amplification will likely occur, or continue to occur, in the presence of moisture. As such, PSI cannot, and shall not, be held responsible for the occurrence or recurrence of mold amplification.

## 2.4 SUBSURFACE EXPLORATION

PSI subcontracted Connelly and Associates to provide drilling services for the exploration program at the site. The subsurface exploration consisted of sixteen (16) soil test borings including fourteen (14) for Standard Penetration Test (SPT) and two (2) for infiltration test. Eleven (11) soil test borings, designated as B-1 through B-11, were drilled to the depth of 50 feet below existing grades with respect to boring plan in **Appendix B**. Three additional borings (B-11 to B-14) were drilled to the depth of 100 feet below existing grade within the proposed footprints. In addition, the borings I-1 and I-2 were drilled to depth of 10 feet each for percolation/Infiltration testing. The location of each boring is shown on the attached Boring Location Plan, in **Appendix B**.

Our drilling subcontractor used a CME55 drill rig and a Hollow Stem Auger equipped with an automatic hammer to advance the boreholes B-1 through B11 and mud rotary method for boring B-11 to B-14. Subsequently, Standard Penetration Test (SPT) was conducted and soil samples were retrieved. SPTs were performed at selected depths within the borings as detailed in ASTM D1586 regardless of the drilling methods. The penetration resistance, in conjunction with soil classifications, provides an indication of engineering characteristics of a soil.

PSI located the borings in the field by measuring from known or identified reference points that were identified on the provided information. The boring elevations shown on the individual boring logs were estimated from the topographic information contained in the provided site layout plan.

Soil samples recovered during the drilling operations were transported to PSI laboratory in Fairfax, Virginia for visual classification and further evaluation/testing. Descriptions of the soils encountered during our subsurface exploration are provided in the Boring Logs. Groundwater conditions, penetration resistances, and other pertinent drilling and subsurface information are included in the Boring Logs in **Appendix C**.

Drilling and soil sampling were conducted in accordance with the procedures generally recognized and accepted as standard methods of exploration of subsurface conditions related to earthwork and foundation engineering projects at this time.

## 2.5 LABORATORY TESTING

Our geotechnical engineering staff visually classified the recovered soil samples in the laboratory in general accordance with the Unified Soil Classification System (USCS) (ASTM D2488). Natural moisture content determinations (ASTM D2216), Atterberg limits tests (ASTM D4318), grain size analyses (ASTM D6913), and hydrometer (ASTM D9728) were conducted on selected samples. In addition, chemical characterization of soil including PH, chloride, and sulfide determination was conducted based on AASHTO T289, AASHTO T290 - T291, and AWWA 4500-$S^2$ A.4c, respectively. Moreover, soil resistivity (AASHTO T288), soil ORP (ASTM G200) were also studied along with soil characterization. The laboratory test results are presented in the **Appendix D** and are shown on the individual boring logs.

Representative soil composite sample was selected by PSI for soil corrosivity testing from test borings B-6, B-7, B-8, B-13, B-14 and depths ranging from 2 to 6 feet. The boring location, sample depth and the soil corrosivity results are shown in the below table. A detailed report is included in **Appendix D**.

**Table 1: Soil Chemical Characterization**

| | |
|---|---|
| Borings | B-6, B-7, B-8, B-13, B-14 |
| Depth | 2.0 – 6.0 feet |
| PH (AASHTO T289) | 7.3 |
| Chloride (AASHTO T291) | 75 ppm |
| Sulfate (AASHTO T290) | 236 ppm |
| Sulfate (AWWA 4500-S2 A.4c) | Low |
| Soil Resistivity (AASHTO T288) | 1500 Ohm-cm |
| Soil ORP (ASTM G200) | 164 mV |

Both the initial visual/manual and the subsequent laboratory identification of the soils were consistent with the site geology.

The soil samples obtained during this exploration will be retained in our laboratory for sixty days, unless otherwise advised. Thereafter, the samples will be disposed. Descriptions of the soils encountered during our subsurface exploration are provided in the Boring Logs.

# 3 SITE AND SUBSURFACE CONDITIONS

## 3.1 SITE LOCATION AND DESCRIPTION

The proposed project site is located at Bowleys Quarters in Maryland. Based on site reconnaissance by PSI, the proposed construction/development area is currently used as Power plant. The existing grade within the proposed construction limits is relatively flat and varies from about EL. 7 to EL. 10 feet. The approximate location of the site is shown as the site location plan in **Appendix B.**

## 3.2 AREA GEOLOGY

The site lies entirely within the quaternary Lowland deposits of the Atlantic Coastal Plain Province. The Atlantic Coastal Plain Province forms a large wedge which feathers out on the piedmont to the west and thickens to the east. These lowland deposits consist of medium-to coarse-grained sand and gravel, with lesser amounts of silt, clay and mud. Cobbles and boulders are found near the base of the formation. Reworked Eocene glauconite are found along with varicolored silts and clays; brown to dark gray lignitic silty clay and estuarine to marine fauna may be found in some areas. This section is summarized from information found in: Cleaves, E.T., Edwards, J., Jr., Glaser, J.D., 1968, Geologic Map of Maryland: Maryland Geological Survey, Baltimore, Maryland.

## 3.3 SUBSURFACE CONDITIONS

Results from the PSI borings are presented on the Boring Logs which are presented in **Appendix C**. Based on the drilling and laboratory test performed on samples from the fourteen (16) soil test borings including B1 to B14 and SPT test results from I1 and I2, the encountered soils and their stratification are summarized in this section.

Based on our site observation, the project site was mostly located within an existing parking lot area. Ground surface was typically covered by bituminous concrete where its thickness varies from 2 to 6 inches. Gravel is the second encountered layer in the test borings with thicknesses ranging from 1 to 36 inches regarding test borings B1 and B11. However, boring B-1, B-6, B-9, B-12, and B-14 were exceptions where the existing grade was not covered by asphaltic pavement.

The general stratigraphy of the subsurface conditions at the project site consisted of interbedded-layers of poorly graded Sand (SP), silty Sand (SM), and sandy Silt (ML) where the layers were sequentially encountered beneath the surficial cover. The encountered soils within fourteen feet below the existing grade were observed as loose to dense poorly graded Sand with SPT N values ranging from 7 to 35 blows per foot (bpf), very loose to dense silty Sand with moisture contents ranging from 11 to 24% and SPT N values ranging from 2 to 43 bpf, and stiff to very stiff Silt with moisture contents ranging from 10 to 21% and SPT N values ranging from 6 to 17 bpf.

Within the depth interval from fourteen to forty feet below the existing ground, soils encountered were considerably poorly graded Sand (SP) and sandy Silt (ML), respectively. The relative density of poorly graded Sand was described as very loose to very dense with SPT N values ranging from 2 to 70 bpf. Moreover, low plasticity sandy Silts with moisture contents ranging from 17 to 22% and SPT N values ranging from 9 to 54 bpf represented stiff to hard consistency. In addition, regarding test boring B-10 within the depth interval from 14 to 18 feet below existing grade, medium silty Sand with SPT N value of 32 bfp was observed.

Within the depth interval from forty to fifty feet (the boring termination depth for B-01 through B-11), soils were dense to very dense poorly graded Sand with SPT N values ranging from 18 to 89 bpf, hard sandy Silt with moisture contents ranging from 12 to 19% and SPT N values ranging from 37 to 86 bpf, and stiff sandy Clay with moisture contents ranging from 15 to 17% and SPT N values ranging from 18 to 22 bpf. In addition, very dense clayey Sand with minimum SPT N value of 50 also found in boring tests B-05 and B-06.

Below 50 feet to the boring termination depth for B-12 through B-14 (100 feet), soils encountered were very dense poorly graded Sand with SPT N values ranging from 50 to 86 bpf. In addition, hard sandy Silts with moisture contents ranging from 14 to 23% and maximum SPT N values of 50 blows for 4 inches of penetration were also found in this interval.

In addition to general stratigraphy, lean to sandy Clay (CL) and clayey Sand (SC) pockets were also found near borings B-06, B-07, B-08 and B-11. The consistency of the lean to sandy Clay is medium to stiff where the moisture contents ranging from 15 to 32% and SPT N values ranging from 5 to 26 bpf. Regarding the test boring B-11, the clayey Sand was observed as medium dense, moist and dark gray with SPT N value of 19.

Sieve and Atterberg limits tests were performed on samples of the native soils from depths ranging from 3 to 24 feet below the existing grade in borings B-01 to B-14 (except B-03, B-04, and B-05). Based on the tests, the samples were classified as silty sand (SM) with maximum PI of 5 and 45.0 percent fines, lean/sandy Clay (CL) with maximum PI of 11 and 92.0 percent fines, sandy Silt and Silt (ML) with maximum PI of 5 and 94.2 percent fines.

The above subsurface description is to highlight the major soil strata encountered. The boring logs included in the appendices should be reviewed for specific information as to individual test boring locations. The stratification lines shown on the test boring logs represent the conditions only at the actual test boring locations. Any stratification lines represent the approximate boundaries ranging from subsurface materials and the actual transition may be gradual.

### 3.4 GROUNDWATER CONDITIONS

During drilling, groundwater was encountered in borings B-01 through B-14 (except B-07, B-09, B-10, and B-11) at depths ranging from 6 to 16 feet below ground surface. However, upon completion of drilling, groundwater was observed in borings B-01, B-02, B-04, B-05, B-10, and B-11 at depths ranging from 6 to 10 feet below the ground surface.

Based on the soil specimens modeling and infiltration data, the annual groundwater level may be estimated between 4 feet (EL. 4) and 6 feet (EL. 2) below existing grade. Detailed observation for groundwater table in the test borings and available solution for dewatering techniques are discussed in section 4.6.

Upon completion of drilling and removal of augers, soil cave-in was recorded in all borings below the existing grade. Especially, soil caved in borings B-12 through B-14 at few inches below the existing ground. Refer to attached test boring logs in **Appendix C** indicating the approximate depths of groundwater and soil cave-in depths at each test boring location. For safety reasons, the boreholes were backfilled upon completion.

The groundwater observations presented in this report and the attached boring logs reflect those observed at the time of our field activities. Based on our observation, due to shallow ground water elevation, the subsurface soil materials below the surface of this site are saturated. Therefore, the groundwater impact on the analysis and design procedure is recommended.

# 4 GEOTECHNICAL EVALUATION AND RECOMMENDATIONS

The following recommendations are based on information available on the data obtained from our borings, and our experience with subsurface conditions similar to those encountered at this site. Because the borings represent a relatively small statistical sampling of the subsurface materials, conditions encountered during construction may be substantially different from those encountered in our borings. In these instances, adjustments to the design and construction may be necessary depending on the actual conditions encountered.

Shallow foundations (mat foundations) supported by suitable native soils and/or newly-placed fill are recommended for the supporting the medium loaded equipment. However, we indicate that the reported allowable bearing pressure in this report is based on our analysis over available native materials and we recommend that the foundations will be placed on same materials. If this is not possible, structural joints should be added to accommodate the differential movement. In addition, based on soil characterization, deep foundations (driven piles) are recommended for heavily loaded equipment (i.e. liquid tanks) or anticipated high lateral loads for very tall equipment where overturning is anticipated (i.e. H-frame and exhaust stacks).

The following recommendations are based on the information available on the proposed construction, the data obtained from our borings, and our experience with soils and subsurface conditions similar to those encountered at this site. Because the borings represent a limited statistical sampling of the subsurface materials, conditions encountered during construction may be substantially different from those encountered in our borings. In these instances, adjustments to the design and construction may be necessary depending on the actual conditions encountered.

## 4.1 SEISMIC CONSIDERATIONS

The project site is located within a municipality that employs the International Building Code (IBC), 2015 edition. As part of this code, the design of structures must consider dynamic forces resulting from seismic events. These forces are dependent upon the magnitude of the earthquake event as well as the properties of the soils that underlie the site.

Part of the IBC code procedure to evaluate seismic forces requires the evaluation of the Seismic Site Class, which categorizes the site based upon the characteristics of the subsurface profile within the upper 100 feet of the ground surface.

To define the Seismic Site Class for this project, and in accordance with your requested level of assessment, we have interpreted the results of our soil test borings drilled within the project site per Section 1613.5 of the code. Material properties were estimated below the depth of the borings based upon data available in published geologic reports as well as our experience with subsurface conditions in the general site area.

Based upon our assessment, it is our opinion that the subsurface conditions within the areas of the site planned for building construction are consistent with the characteristics of **Site Class D** as defined in Table 1613.5.2 of the building code.

The associated IBC probabilistic ground motion values for latitude 39.324146° and longitude -76.366472° obtained from the *Java Ground Motion Parameter Calculator – Version 5.1.0* on the USGS Earthquake Hazards Program – Seismic Design for Buildings web page (https://earthquake.usgs.gov/designmaps/beta/us/) are as follows:

| **Table 2: Seismic Design Parameters*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Period (seconds)** | **Mapped MCE Spectral Response Acceleration (g)** | | **Site Coefficients** | | **Adjusted MCE Spectral Response Acceleration (g)** | | **Design Spectral Response Acceleration (g)** | |
| 0.2 | $S_s$ | 0.144 | $F_a$ | 1.6 | $SM_S$ | 0.231 | $SD_S$ | 0.154 |
| 1.0 | $S_1$ | 0.043 | $F_v$ | 2.4 | $SM_1$ | 0.104 | $SD_1$ | 0.069 |
| * 2% Probability of exceedance in 50 years.<br>MCE= Maximum Considered Earthquake | | | | | | | | |

The Site Coefficients, $F_a$ and $F_v$ presented in the above table were also obtained from the USGS calculator but can be interpolated from IBC Tables 1613.5.3(1) and 1613.5.3(2) as a function of the site classification and mapped spectral response acceleration at the short ($S_s$) and 1 second ($S_1$) periods.

## 4.2 LIQUEFACTION ANALYSIS

For Seismic Design Category designations of C, D, E or F, which are contingent on the structure “Occupancy Category”, the Code also requires an assessment of liquefaction, slope stability and surface rupture due to faulting or lateral spreading. Detailed evaluations of these factors were beyond the scope of this study. However, the following table presents a qualitative assessment of these issues considering the site class, the subsurface soil properties, the groundwater elevation and probabilistic ground motions.

| **Table 3: Seismic Hazards** | | |
|---|---|---|
| **Hazard** | **Relative Risk** | **Comments** |
| Liquefaction | Low | The materials with low SPT N-values have high fines contents and the seismicity potential is low. |
| Slope Stability | Low | The site is relatively level and does not incorporate significant cut or fill slopes. |
| Surface Rupture | Low | The site is not underlain by a mapped Holocene-aged fault. |

## 4.3 SITE PREPARATION AND EARTHWORK RECOMMENDATIONS

Since we are not provided with the final planned grades for the equipment at this time, the following recommendations are based on our assumption. We anticipate cuts and fills from one to three feet to achieve the bearing level of 9 feet (EL 9.0).

Site preparation procedures should include removing topsoil, vegetation, root mat and other deleterious material within the construction area or depressions left from removing tree's root balls and shrubs along the lot periphery which should be backfilled with compacted structural fill. Topsoil may be stockpiled for later use in landscape areas or may be removed from the site. Under no circumstances should topsoil or other organic-laden soil be placed as structural fill. Any underground utilities within the planned development area should also be removed. The Geotechnical Engineer of Record or his/her qualified representative should observe the site for proper stripping, excavation and preparation. A proof roll observed by the Geotechnical Engineer of Record is required within all development areas of the site.

All required backfill or new fill required to achieve design site grades should comply with the requirements for Structural Fill Material Placement presented below. Site soils may be used as structural fill if it would be tested and approved by the Geotechnical Engineer of Record. The contractor may also use low-expansive CL and ML materials satisfying the requirements and limitations below with the approval of the Geotechnical Engineer of Record and in accordance with IBC 2012 Code, Section 1806.6 Design for Expansive Soils. Non-expansive GC and SC material can be used in structural fills subject to the following limitations:

| | |
|---|---|
| Maximum Dry Density (per ASTM D698) | $\geq$ 105 pcf |
| Liquid Limit | $\leq$ 40 |
| Plasticity Index | $\leq$ 20 |

Organic soils and high plasticity clays and silts (CH, MH, OL, OH, PT) should not be used as engineered fill. The fill materials should be free from topsoil and debris, have less than 3 percent organics and should not contain rock fragments having a major dimension greater than 3 inches. The use of the excavated fill soils for controlled structural fill will be subject to acceptance by the Geotechnical Engineer of Record.

Place fill in loose, horizontal lifts no greater than 8 inches thick compacted uniformly with the proper equipment. Within small excavations such as footing excavations, we recommend using gasoline-powered tampers or diesel sled tampers to achieve the specified compaction. We recommend using loose lift thicknesses of no more than 5 inches in small or confined area fills.

The upper foot of fill required to support shallow foundations and concrete pads (pile caps) must be compacted to at least 98 percent of the maximum dry density as per ASTM D698 (Standard Proctor) test method. The moisture content of the fill should be within plus or minus two (±2) percentage points of the optimum moisture content.

It will be important to maintain positive site drainage during construction. Storm water runoff should be diverted, and the site should be graded at all times such that water is not allowed to pond. If any surface soils become wet due to rains, they should be removed or dried prior to further site work operations and/or fill placement.

## 4.4 FOUNDATIONS DISCUSSION

Following completion of the site exploration, it is our opinion that both shallow (mat foundations) and deep foundations should be used to support the planned equipment. Based on the conducted site characterization and equipment weight provided by **ProEnergy Services**, the following table represents our estimation for foundations type at the time of preparing this report:

**Table 4: Equipment weight and foundation type**

| Boring | Equipment | Dimensions ($ft^2$) | Equipment weight (kips) | Approx. Foundation weight (kips) | Approx. Fluid Load (kips) | Total load (kips) | Possible Foundation type |
|---|---|---|---|---|---|---|---|
| B-01 | Demin Tank | 50'dia x 30'h | 850 | - | 3500 | 4350 | Deep Foundation |
| B-10 | Liquid fuel Tank | 50'dia x 30'h | 850 | - | 3500 | 4350 | Deep Foundation |
| B-11 | Liquid fuel Tank | 50'dia x 30'h | 850 | - | 3500 | 4350 | Deep Foundation |
| B-02 | GSU Transformer | 15' x 15' | 140 | 100 | - | 240 | Mat Foundation |
| B-03 | GSU Transformer | 15' x 15' | 140 | 100 | - | 240 | Mat Foundation |
| B-04 | GSU Transformer | 15' x 15' | 140 | 100 | - | 240 | Mat Foundation |
| B-09 | Gas Compressor | 15' x 25' | 75 | 150 | - | 225 | Mat Foundation |
| B-05 | H-frame | 5'dia x 50'h | 7 | - | - | 7 | Deep Foundation |
| B-06 | Combustion Turbine Generator | 20' x 80' | 800 | 650 | - | 1450 | Mat Foundation |
| B-07 | Combustion Turbine Generator | 20' x 80' | 800 | 650 | - | 1450 | Mat Foundation |
| B-08 | Combustion Turbine Generator | 20' x 80' | 800 | 650 | - | 1450 | Mat Foundation |
| B-12 | Exhaust stack | 20'dia x 160'h | 250 | - | - | 250 | Deep Foundation |
| B-13 | Exhaust stack | 20'dia x 160'h | 250 | - | - | 250 | Deep Foundation |
| B-14 | Exhaust stack | 20'dia x 160'h | 250 | - | - | 250 | Deep Foundation |

### 4.4.1 MAT FOUNDATION

Conventional shallow foundations (mat) bearing on suitable native soils and/or engineered fill. Mat dimensions are estimated based on dimensions provided by **ProEnergy Services** and allowable soil bearing pressure is estimated as 4,500 psf based on the analysis over existing native soil. This recommended allowable soil bearing pressure may be increased/increased by factors such as wind, seismic, or dynamic loads. In addition, mat or concrete pads should be designed for a minimum embedment of 30 inches below final exterior grades to provide adequate cover for frost protection. However, we recommend placing a geotextile fabric and a 3-inch thick layer of ¾-inch crushed stone to protect the foundation soil and provide a clean working surface to form, tie reinforcing steel and cast the foundation.

Due to expected variations in subsurface conditions and soils and its effect on bearing capacity, all footing excavations should be observed by the Geotechnical Engineer of Record or his qualified representative prior to placing foundations. To verify the bearing capacity of the footings, Dynamic Cone Penetrometer (DCP) testing could be conducted at sufficient number of locations to verify bearing capacity along each side of the foundation footprint at the bottom of the excavations. These locations should be verified by the Geotechnical Engineer of Record or his qualified representative

Where unsuitable bearing conditions are encountered as determined by the PSI Geotechnical Engineer or designated representative, those unsuitable soils should be undercut and replaced with controlled structural fill. If backfilled up to the design bearing elevation, the over-excavation should extend laterally from all foundation edges by a minimum of one half the depth of the undercut. The backfill should consist of the materials described in Section 4.3. If the over-excavation is filled with concrete or flowable fill, the widening of the excavation will not be required.

If soft or loose soil pockets are observed or detected during the footing assessment, these materials should be removed and replaced with suitable compacted structural fill. Water and possibly some loose soil may collect in the footing excavations as a result of surface precipitation and near ground surface seepage. Therefore:

- Water, loose soil and soil softened by water should be removed from the bottom of the footing excavations before placing concrete. Use a flat blade shovel to preserve the integrity of the foundation material.

- Footing excavations should be covered immediately. If the concrete cannot be placed due to inclement weather conditions or any other unforeseen circumstances, the bottom of the footing excavations and trenches should be protected by undercutting 3 inches and placing a 3-inch thick lean-mix concrete (1,000 psi) working mat immediately upon approval and before reinforcing steel is placed.

- We recommend that foundations be cast the same day the excavations are made. If this is not possible, then the contractor must protect the foundation subgrade from becoming disturbed.

Once the footing concrete is placed, the foundation footings should be backfilled with structural fill as soon as it is safe to do so without causing damage. The backfill serves to protect the footing, is a component of overturning resistance and prevents accumulation of water around the foundations which can soften and weaken the bearing soils. The ground surface near the completed foundations should be sloped to drain away from the foundations throughout construction to avoid accumulation of moisture in the subgrade soils. Backfill around and above the footing should also satisfy the controlled fill requirements described in Section 4.3, Site Preparation and Earthwork.

### 4.4.2 UPLIFT AND SHEAR RESISTANCE OF MAT FOUNDATIONS

Mat foundations may be used to resist both uplift and lateral forces. For the case of uplift forces, the resistance should be calculated including the weight of the foundation and permanent equipment. We recommend using total unit weight of 150 pcf for the concrete materials in this calculation. Any continuously applied dead load above the foundation should be calculated also for the case of the resistance to uplift forces. The safety factor for uplift resistance for the transient loading condition is the ratio of the sum of the foundation and overburden weights divided by the uplift force and should be at least 1.5. Soil friction along the foundation base, may be used to resist sliding. PSI has assumed compacted structural fill as the backfill and foundation material to be used for computing passive earth pressures and soil friction. An allowable friction coefficient between the concrete footing and structural fill soils can be assumed to be 0.32. The ultimate passive earth pressure can be calculated using an estimated passive earth pressure coefficient of 3.0 for limited deflection. However, passive pressure should not include the upper 1 foot of backfill adjacent to the mat foundation.

### 4.4.3 DEEP FOUNDATION

PSI considered two choices (H-pile and Auger Cast Pile (ACP)) for supporting equipment including liquid tanks, H-frame, and exhaust stacks. H-piles are the type of driven elements to design depth or resistance. If penetration of dense soil is required, predrilling may be required for the pile to penetrate to the design depth. However, ACPs are installed by rotating a continuous flight hollow shaft auger into the soil to a specified depth.

**H-Pile**

Timber, pre-cast concrete, steel H-piles, and pipe piles are recognized as driven piles. Concrete piles may develop complete horizontal cracks in hard driving or develop partial horizontal cracks in easy driving. Based upon our analysis over SPT N values and overall site stratigraphy, the soil relative density is estimated as medium to dense. Subsequently, we recommend using steel H-piles. The following table presents recommended soil parameters for deep foundation analysis:

| Table 5: Recommended Design Soil Parameters for "L-pile" program | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Boring No. | Depth Below Ground Surface (ft) | Soil Type | Average SPT "N" Value | Unit Weight (pcf) | | Angle of Internal Friction (degrees) | Cohesion (psf) | Modulus of Lateral Subgrade Reaction (pci) |
| | | | | $\gamma_{moist}$ | $\gamma_{sat}$ | | | |
| B – 01 Denim Tank | 0 – 4 | SP | 18 | 110 | 135 | 33 | - | 67 |
| | 4 - 13 | SM | 7 | 115 | 125 | 29 | - | 20 |
| | 13 - 23 | ML | 21 | 100 | 120 | - | 2000 | 43 |
| | 23 – 50 | SP | 56 | 110 | 135 | 40 | - | 83 |
| B – 10 Liquid Tank | 0 - 19 | SM | 25 | 115 | 125 | 32 | - | 20 |
| | 19 - 29 | SP | 50⁺ | 120 | 135 | 40 | - | 67 |
| | 29 - 39 | SP | 10 | 100 | 120 | 30 | - | 45 |
| | 39 - 45 | SP | 50⁺ | 120 | 135 | 40 | - | 67 |
| | 45 - 48 | SC | 50⁺ | 110 | 125 | 38 | - | 55 |
| | 48 - 50 | SP | 50⁺ | 120 | 135 | 40 | - | 67 |
| B – 11* Liquid Tank | 0 - 5 | SM | 17 | 115 | 125 | 31 | - | 20 |
| | 5 - 14 | CL | 8 | 100 | 115 | - | 800 | 15 |
| | 14 - 34 | SP | 40 | 112 | 135 | 38 | - | 67 |
| | 34 - 50 | ML | 50⁺ | 110 | 125 | - | 3500 | 50 |
| B – 05* H-Frame | 0 - 10 | SM | 19 | 115 | 125 | 32 | - | 20 |
| | 10 - 39 | SP | 34 | 110 | 135 | 33 | - | 67 |
| | 39 - 48 | SC | 50⁺ | 110 | 125 | 35 | - | 55 |
| | 48 - 50 | CL | 22 | 105 | 120 | - | 2000 | 18 |
| B – 12 Exhaust Stack | 0 – 13 | SP | 16 | 110 | 135 | 33 | - | 67 |
| | 13 – 19 | ML | 18 | 100 | 120 | - | 2000 | 43 |
| | 19 – 24 | SM | 8 | 115 | 130 | 29 | - | 15 |
| | 24 – 98 | SP | 74 | 120 | 135 | 40 | - | 67 |
| | 98 – 100 | ML | 50⁺ | 110 | 125 | - | 3500 | 50 |
| B – 13 Exhaust Stack | 0 - 4 | SP | 13 | 110 | 135 | 33 | - | 67 |
| | 4 - 8 | SM | 10 | 115 | 125 | 31 | - | 20 |
| | 8 - 15 | ML | 19 | 100 | 120 | - | 2000 | 43 |
| | 15 – 38 | SP | 45 | 110 | 135 | 40 | - | 83 |
| | 38 - 49 | ML | 50⁺ | 110 | 125 | - | 3500 | 50 |
| | 49 – 99 | SP | 62 | 110 | 135 | 39 | - | 67 |
| | 99 - 100 | ML | 50+ | 110 | 125 | - | 3500 | 50 |
| B – 14* Exhaust Stack | 0 – 3 | SM | 42 | 115 | 125 | 38 | - | 30 |
| | 3 – 9 | SP | 25 | 110 | 135 | 32 | - | 67 |
| | 9 – 14 | SM | 17 | 115 | 125 | 31 | - | 20 |
| | 14 – 19 | ML | 10 | 100 | 120 | - | 1500 | 43 |
| | 19 -24 | SP | 9 | 110 | 135 | 29 | - | 25 |
| | 24 – 29 | ML | 9 | 100 | 120 | - | 1500 | 15 |
| | 29 – 34 | SP | 14 | 110 | 135 | 30 | - | 25 |
| | 34 – 49 | ML | 40 | 110 | 125 | - | 3500 | 50 |
| | 49 – 80 | SP | 75 | 110 | 135 | 40 | - | 67 |
| | 80 – 84 | ML | 50⁺ | 110 | 125 | - | 3500 | 50 |
| | 84 - 100 | SP | 50⁺ | 110 | 135 | 40 | - | 67 |

* Selected borings for pile capacity analysis.

A-pile 2015.7.8 and L-pile 2018.10.06 software was utilized for analyzing the axial and lateral pile capacities. A-Pile is a programing for analysis the axial capacity of driven piles under axial loading and L-pile is used for analyzing stress and deformation of individual piles or drilled shafts under lateral load. The detailed analysis is provided in **Appendix F** and **G**. The estimated capacities are provided in Table 6 below. Based on the type and soil conditions encountered at the site below subgrade elevation, groundwater conditions, and pile analysis, we considered factor of safety of 2.5 and recommended pile capacities in the following table. Since the detailed loading was not provided to us at the time of preparing this report (especially lateral loads), we estimated the pile properties based on two hypothetical length for each equipment. The following table provides pile properties which should optimize the foundation by approximately matching the geotechnical capacity with the structural capacity of the piles. It is noteworthy to mention that presented results are based on existing weight of equipment and further analysis is recommended upon detailed loading conditions (i.e. wind, seismic, or dynamic loads). In addition, final design pile lengths shall be determined as the result of the pile load tests that will be conducted at the start of construction.

**Table 6: Estimated Pile Capacities (H-Pile)***

| Equipment | Cross Section | Length (ft) | Allowable Axial Capacity (kips) | Shear Capacity (kips) | Maximum Bending Moment (kips-in) |
|---|---|---|---|---|---|
| Tanks | HP12x53 | 40 | 120 | 25 | 1300 |
| H-Frame | HP12x53 | 30 | 100 | 35 | 1800 |
| Exhaust Stacks | HP12x53 | 45 | 130 | 30 | 1500 |

*Maximum structural capacity for HP12x53 is 387 kips

We anticipate that the piles will be bearing into the competent stratum where the combination of tip and frictional resistance provides adequate bearing capacity. We anticipated that a concrete pad (cap pile) would be located on the piles head satisfying at least the deep frost of 2.5 feet below the bearing level (EL. 10). Subsequently, it is our understanding that minimum elevation for piles head would be at El. 7.5.

## Auger Cast Pile

Mr. Mark Bendorf from ProEnergy on June 11, 2018 suggested PSI to assess the possibility of using Auger Cast Piles (ACP) instead of driven piles. The results of our engineering calculations indicate that ACPs can be also used to support the proposed equipment including the liquid tanks, H-frame, and exhaust.

Auger cast piles are installed by rotating a continuous flight hollow shaft auger into the soil to a specified depth. High strength cement grout is pumped under pressure through the shaft as the auger is slowly withdrawn. Reinforcing steel is added per pile design specifications for seismic and lateral resistance forces. An auger cast pile is both end-bearing and friction-based. All piles must be designed in accordance with the latest edition of the International Building Code (IBC).

Regarding the data from designated borings in Table 5, Shaft 2017 was utilized for

analyzing the pile axial capacity. Shaft is a program for analyzing the axial capacity and short-term settlement of drilled shafts under axial loading and L-pile was used to estimate ACP lateral capacities. The detailed analysis is provided in **Appendix H** and **I**. The estimated capacities are provided in Table 7 below. Based on the type and soil conditions encountered at the site below subgrade elevation, groundwater conditions, and pile analysis, we applied a factor of safety of 2.5 and 3 for ultimate side friction and base capacity, respectively. The recommended pile capacities are shown in Table 7 where ACP with 30 inches in dimeter is assumed in the analysis. Since the detailed loading was not provided to us at the time of preparing this report extension (especially lateral loads), we estimated the pile properties based on hypothetical length for each equipment. The following table provides pile properties which should optimize the foundation by approximately matching the geotechnical capacity with the structural capacity of the piles. It is noteworthy to mention that presented results are based on existing weight of equipment and further analysis is recommended upon detailed loading conditions (i.e. wind, seismic, or dynamic loads). In addition, the final design pile lengths and allowable capacity shall be determined as the result of the pile load tests that will be conducted at the start of construction.

**Table 7: Estimated Pile Capacities (ACP)***

| Equipment | Cross Section | Length (ft) | Allowable Axial Capacity (kips) | Shear Capacity (kips) | Maximum Bending Moment (kips-in) |
|---|---|---|---|---|---|
| Tanks | ACP (30'' diameter) | 37 | 120 | 60 | 4500 |
| H-Frame | ACP (30'' diameter) | 32 | 100 | 80 | 5600 |
| Exhaust Stacks | ACP (30'' diameter) | 36 | 130 | 85 | 5600 |

*Maximum structural capacity for ACP is 930 kips in compression.

Like H-pile analysis, we anticipate that the ACP will be bearing into the competent stratum where the combination of tip and frictional resistance provides a satisfactory allowable bearing capacity. We expect that the drilled piles will be structurally connection to a pile cap or thickened slab. The depth of the pile cap or bottom of thickened slab must be at least 2.5 feet below exterior ground surface for frost protections. Based on a ground surface grade or EL. 10, piles would be cut off at EL 7.5.

### 4.4.4 CONSTRUCTION RECOMMENDATIONS FOR DEEP FOUNDATIONS

**H-Pile**

The minimum spacing between adjacent piles shall be 3 pile diameters, center-to-center to avoid a reduction in compression capacity. Driven piles shall require special attention during construction to assure that recently placed pile is not damaged by adjacent pile installation. A minimum edge-to-edge spacing of a least 6 pile diameters shall be maintained between piles installed on the same day.

Steel bearing piles shall be rolled "HP" sections of standard dimensions. They shall be new and un-used and conform to ASTM A36M materials standards. Steel Bearing Piles shall be furnished with a driving shoe, as detailed on the plans or approved by the State. Shoes shall be attached by a state DOT certified welder with a minimum 3/8-inch fillet weld along the outside edge of the flanges or welded in accordance with the plan details. Cast-in-Place pile ends shall be perpendicular to the longitudinal axis. They will be furnished with 3/4-inch minimum thickness round plate at the end, having a diameter no more than 19/32 inch larger than the casing. NOTE: If welding is not detailed on the plans, then an approved "welding procedure" is required.
Piles shall not be driven until the excavation has been made to the bottom of footer elevation. They shall be driven starting from the center of the foundation outwards or starting from an outside row and progressing across the foundation. Piles may be completely driven in one operation or, if directed by the state, be allowed to set for 2 to 24 hours (or as indicated on the plans) before driving is resumed.

Piles are either plumb (truly vertical) or battered per the plans. Batter is normally measured with a template in the field. Observe and record the method being followed. The pile shall not vary from the planned location by more than 4 inches. For abutments, this tolerance is 1 inch. Also, piles may not have more than 1/4 inch per foot variation at their tip from the vertical or batter.

Splices are a contingent item that are required when the engineer directs the contractor to drive pile more than 5 feet beyond the estimated plan length. All splices are subject to the approval of the DCES. For steel bearing piles, a second splice may be used at 25 feet beyond the estimated length subject to approval by the State. Welding will be performed by a State DOT certified welder following an approved Welding Procedure (state form).

Contractors shall obtain approval for pile driving equipment. Verify that the type, striking energy per blow, rated speed and serial number are listed on the approved state form, "Pile Driving Equipment" sheet. Note: the usual striking energy per blow is 17.6 Kilo-Joules (13, 000 foot-pounds) for both Cast-in-Place pile casings and Steel Bearing piles. Hammers shall have continuous compressor capacity to assure that the rated conditions are achieved (single acting: length-of-stroke or blows-per-minute; double acting: bounce chamber pressure). All diesel hammers shall have an acceptable means for measuring hammer energy pressure. When pressure gauges are included, manufacturers charts and graphs, showing calibration to energy, shall be furnished to the engineer. Check hammer operation and the details.

Pile cutoffs shall be made to the elevation shown on the plans or as established by the EIC. All cavities created by the pile driving shall be backfilled. Any pile sections remaining above ground shall be painted in accordance with the plans.

**Auger Cast Pile**

If pile shafts are passed through unstable soils and concrete is placed in an open-drilled shaft, following IBC 1810.3.3, we recommend using a steel liner to be installed in the

drilled hole prior placing the concrete. If it is necessary to withdraw the steel liner during concrete placement, the level of concrete must be maintained above the bottom of the liner at a sufficient height to resist the potential hydrostatic or lateral soil pressure. If pump is used to place concrete via a hollow-stem auger, the auger should be permitted to rotate in clockwise during withdrawal. It is strongly recommended to withdraw the auger in continuous increments. Induced pressures due to pumping shall be measured and maintained high enough to resist hydrostatic and lateral earth pressures. It is necessary to check the concrete volumes during installation to ensure that the volume of concrete placed in each pile is equal to or greater than the theoretical volume of the hole created by the auger. If the installation process of ACP is halted, or a loss of concreting pressure occurs, the pile shall be re-drilled to at least 5 feet below the elevation of the tip of the auger when the installation was interrupted, or concrete pressure was lost and reformed.

ACPs shall not be installed within six pile diameters center to center of a pile filled with concrete less than 12 hours old, unless approved by the building official. If the concrete level in any completed pile drops due to installation of an adjacent pile, the pile shall be replaced. IBC 1810.3.2 indicates that the minimum pile diameter should be restricted to12 inches and the pile length should be limited to 30 times the average diameter.

IBC 1810.3.2 present an exception for the above-mentioned limitations where it indicates "*The length of the pile is permitted to exceed 30 times the diameter, provided that the design and installation of the pile foundation are under the direct supervision of a registered design professional knowledgeable in the field of soil mechanics and pile foundations. The registered design professional shall certify to the building official that the piles were installed in compliance with the approved construction documents*".

If ACPs are installed with using a hollow-stem auger and full-length longitudinal steel reinforcement is placed without lateral ties, IBC 1810.3.4 clears that the reinforcement shall be placed through the hollow-stem of the auger prior to filling the pile with concrete.

All pile reinforcement should have a concrete cover of 2.5 inches at least. However, IBC 1810.3.4 indicates the exception where "*physical constraints do not allow the placement of the longitudinal reinforcement prior to filling the pile with concrete or where partial-length longitudinal reinforcement is placed without lateral ties; the reinforcement can be placed after the piles are completely concreted but while concrete is still in a semifluid state*."

### 4.4.5 PILE LOAD TEST RECOMMENDATIONS

We recommend that a test pile program be implemented for the purpose of assisting in the development of final tip elevations and to confirm that the contractor's equipment and installation methods are acceptable.

**Dynamic Testing for H-pile**

Dynamic testing was developed as a method of improving upon the reliability of the wave

equation and other dynamic predictions by actually measuring the acceleration and strain of a pile during production driving. This technique was developed in the mid-1960's and has been continually refined. The use of dynamic pile testing has permitted the possibility of checking the driving stresses in the pile and the hammer performance during pile driving. It is also possible to estimate the static capacity of the pile based upon the strain and acceleration measurements taken during pile driving. The following recommendations are based on FHWA-NHI-16009.

The installation of test piles should be monitored by the Geotechnical Engineer using the PDA, an electronic device that records driving stresses and pile/soil interactions among other things. The PDA results will confirm that the pile driving system (hammer type/energy, cushion type/ thickness, etc.) can successfully install the piles without over stressing them in compression or tension. We recommended the owner retain the services of the Geotechnical Engineer to perform the dynamic testing, not the contractor, to avoid possible conflicts of interest.

No sooner than 72 hours after installation, each test pile should be re-struck utilizing the PDA. The initial hammer blow during re-strike activities while being monitoring with a PDA is critical to the quality of dynamic data with respect to capacity interpretation. The contractor should make every effort to insure an initial high-energy blow of the hammer. After several blows during re-strike activities, pore pressures increase, soil setup diminishes, and ultimately pile capacities (as recorded by the PDA) decrease. Loss of soil by repeated hammer blows is the reason the initial blows are critical.

The dynamic data recorded by the PDA should be further refined by using CAPWAP® analysis. CAPWAP® analysis, not the initial assessment of capacity determined by the PDA, should be the basis of static pile capacity estimates. Interpretation of CAPWAP® data, in the context of the subsurface conditions and previous static pile capacity estimates, should allow the Geotechnical Engineer to evaluate ultimate pile capacities.

Our previous experience with the PDA indicates that a significant cost savings may be realized if the PDA is properly utilized to monitor the installation of test piles, confirm pile capacity in production installations and monitor potentially damaging stresses during driving. The use of the PDA permits the confirmation of allowable compression and uplift capacities and pile integrity on several piles for a cost similar to or less than that of a single full-scale static load test.

**H-Pile Installation recommendations**

The piles should be installed to embedment depths as described in Table 6 for the driven H piles, or as modified by the results of the pile testing program. These piles should be driven to the dynamic driving resistance determined during the pile test program. The acceptable driving resistance will be determined in the field by the Geotechnical Engineer. Based on our experience with pile installation, it is essential that driving be terminated immediately if refusal (i.e.10 blows per inch or 120 blows per foot) is reached to prevent damage to the piles.

Surface obstructions should be removed from the proposed pile cap locations. Pile driving should be as continuous an operation as possible and should proceed without stopping over the last 3 feet of penetration. During pile installation, the contractor should exercise caution as not to over stress the piles. Piles shall not be driven beyond practical refusal. At all times, the hammer should be operated at the chamber pressure, speed, etc. as recommended by the manufacturer.

The installation of piles should be monitored continuously by a qualified Geotechnical Engineer or representative. Driven piles should be checked for appropriate size, length, material and defects. Driven piles should be monitored for handling, location, plumbness, penetration, blow counts during driving and hammer action/performance. Written field records should be kept for every pile.

**Dynamic Low Strain Impact Load Testing for ACP**

Low strain impact loading test (ASTM D5882) includes a procedure to find the integrity of individual vertical or inclined piles by measuring and analyzing the velocity (required) and force (optional) response of the pile which is induced by either the hand-held hammer or other similar type. The impact device usually applied axially and perpendicularly to the pile head surface. This test method is applicable to long structural elements that serves as a deep foundation unit (such as driven piles, ACP, or drilled shafts), regardless of their method of installation provided that they are receptive to low strain impact testing.

ASTM D5882 provides minimum requirements for low strain impact testing of piles. Plans, specifications, and/or provisions prepared by a qualified engineer, and approved by the agency requiring the test(s), may provide additional requirements and procedures as needed to satisfy the objectives of an especial test program.

Low strain impact integrity testing provides acceleration or velocity and force (optional) data on slender structural elements (that is, structural columns, driven concrete piles, cast in place concrete piles, concrete filled steel pipe piles, timber piles, etc.). The method is suitable for solid concrete sections. The collected data is used to approximately evaluate pile geometry (cross-sectional area and length), the pile integrity and continuity. However, this test method will not provide information regarding the pile bearing capacity. In overall, it is suitable to consider the soil profile, construction method and site records. Other useful information to consider and compare with results of this test includes low strain integrity test results of similar piles at the same site, concrete cylinder or core strength test results, automated monitoring data on equipment placing the concrete when augered piles are used, or information obtained from cross hole sonic logging (Test Method D6760) or thermal integrity profiling (Test Methods D7949) if available. It is highlighted that this method has limited application to unfilled steel pipe piles, H piles, or steel sheet piles. Dynamic testing is recommended for H-pile in the following section.

Pulse Echo Method (PEM) and Transient Response Method (TRM) are two test methods that are used to perform load pile testing (ASTM D5882). The pile head motion is

measured as a function of time and the time domain record is then evaluated for pile integrity in PEM. On the other hand, the pile head motion and force (measured with an instrumented hammer) are measured as a function of time and the data is evaluated usually in the frequency domain.

## 4.5 PILE CAPS ON THE GROUND

The following recommendations are intended for constructing the concrete pad (cap) for piles.

- Caps subgrade should be proof rolled and prepared as described under Section 4.3 'Site Preparation and Earthwork Recommendations'.
- Areas supporting caps should be moisture conditioned to Proctor optimum moisture content and compacted.

  Construction activities and exposure to the environment often cause deterioration of the prepared caps-on-grade subgrade. Therefore, we recommend that the subgrade soils be evaluated by a representative of the geotechnical engineer immediately prior to caps construction. This evaluation may include a combination of visual observations, re-densification, and field density tests to verify that the subgrade has been prepared in accordance with project specifications. If soft or loose areas are encountered, undercut and fill with properly compacted structural fill.

  Provided the recommendations presented is this report are implemented, the concrete caps for the structure may be ground-supported (caps-on-grade). To provide a consistent subgrade reaction immediately beneath any concrete caps-on-grade and to provide uniform support, we recommend that floor caps be underlain by a minimum of 6 inches of free-draining (a maximum particle size of ¾ inch with less than 5 percent material passing the No. 200 sieve), well-graded gravel or crushed rock base course. Base course material should be moisture conditioned to within +/- 2 percent of optimum moisture content and compacted by mechanical means to a minimum of 95 percent of the material's maximum dry density as determined in accordance with ASTM D-698. The crushed rock is intended to provide a capillary break to limit migration of moisture through the caps. In areas with moisture sensitive floor finishes or if required by code, polyethylene sheeting should be also placed to act as a vapor retarder. A 10-mil vapor retarder has better survivability during construction and, if utilized, the vapor retarder should be installed in accordance with ACI 302.1.

- We recommend that a design modulus of subgrade reaction value of 150 pounds per cubic inch (pci), based on 1 foot x 1 foot values, be used for caps-on-grade. This recommended value is based on the site preparation being performed in accordance with the recommendations of this report. The value should be adjusted for larger areas using the following expressions for cohesive and cohesionless soil respectively:

  Modulus of Subgrade Reaction, $k_s = \left(\frac{k}{B}\right)$ for cohesive soil and

$$k_s = k\left(\frac{B+1}{2B}\right)^2 \text{ for cohesionless soil}$$

where:

$k_s$ = coefficient of vertical subgrade reaction for loaded area,
$k$ = coefficient of vertical subgrade reaction for 1x1 square foot area, and
$B$ = width of area loaded, in feet

- Isolation joints and crack control joints should be used to reduce cracking from concrete shrinkage and differential movement between piles and the cap. The American Concrete Institute (ACI) recommends a maximum panel size (in feet) equal to approximately two to three times the thickness of the caps (in inches) in both directions.

- ACI provides valuable recommendations for design and construction of grade caps that we recommend be followed. Details of the ACI recommendations for caps design and construction are provided in ACI 302.1.

Cracking of caps-on-grade is normal and should be expected. Cracking can occur not only as a result of heaving or compression of the supporting soil and/or bedrock material, but also as a result of concrete curing stresses. The occurrence of concrete shrinkage cracks, and problems associated with concrete curing may be reduced and/or controlled by limiting the slump of the concrete, proper concrete placement, finishing, and curing, and by the placement of crack control joints at frequent intervals, particularly, where re-entrant caps corners occur. The American Concrete Institute (ACI) recommends a maximum panel size (in feet) equal to approximately three times the thickness of the caps (in inches) in both directions. For example, joints are recommended at a maximum spacing of 12 feet assuming a four-inch thick caps. Using fiber reinforcement in the concrete can also control shrinkage cracking.

## 4.6 INFILTRATION TEST RESULTS

PSI also performed Infiltration Testing for planning and designing the future storm water facilities at the proposed development.

Infiltration testing was performed at locations I-1 through I-2. At each location one soil boring was advanced and soil samples were collected at regular intervals to ten feet. Wells were drilled using augers, casings were installed to a depth of 5 feet below grade and the wells were pre-soaked for 24 hours. After 24 hours PSI performed falling-head infiltration tests in accordance with Maryland State requirements.

The locations of the infiltration tests are shown on the Boring Location Plan. The findings of these borings are presented on the Boring Logs. The infiltration test results are shown in the following Table.

| Table 8 : Infiltration Test Results | | |
|---|---|---|
| **Test Location** | **Infiltration Test Result (Inches/Hour)** | **USCS Soil Classification At/Below Infiltration Test Elevation** |
| I-1 | 0.01 | silty SAND (SM) |
| I-2 | 0.01 | silty SAND (SM) |

As seen from the above table, the rate of infiltration was 0.01 inch per hour. Generally, soils having an infiltration rate of less than 0.52 inch per hour or higher than 12 inches per hour are not suitable for infiltration facilities.

Our experience indicates that there is a relatively high incidence of failure of infiltration facilities to achieve the designed infiltration rate. There are a number of reasons for this, but they can typically be grouped into two primary categories. There are reasons related to the in-situ soil conditions and those related to construction practices.

One soil condition of importance is the basic soil classification, often expressed by grain size, or textural analysis as well as plasticity testing. Small changes in the gradation of soil can result in large changes in infiltration rate. Permeability which is very similar to infiltration rate varies by over five orders of magnitude from sands to clays. Infiltration rates that are typically considered suitable for infiltration practices vary by just over one order of magnitude, making suitable soils a small subset of all soils. Additionally, the undisturbed soil has a structure or fabric that includes pores and features that are the result of natural processes. This soil fabric develops over time and is influenced by plant growth and other biological processes and this fabric often governs the infiltration rate. Both the soil classification and the fabric can change rapidly with elevation/depth in the soil profile. Hence results of testing that is performed at any elevation other than the invert elevation of the facility can be misleading, even when different by only a few inches. The effective infiltration rate of a facility is also very sensitive to construction practices. The general principal is that soils which become disturbed do not typically infiltrate as well as undisturbed soils. Since testing is performed on undisturbed soils, this creates a potential for unexpectedly low field infiltration rates in completed facilities. This makes grading of infiltration basins a challenge. Trafficking of earth moving equipment used to excavate basins can disturb the native soil at the base of the facility. This will cause the fabric described above to be destroyed, resulting in lower permeability. Where fill materials are placed in a basin, or where construction traffic compacts native soils, excess compaction will reduce permeability. Since contractors are typically encouraged to achieve high levels of compaction, this creates the potential for problems. Using the term broadly, this “disturbance” can also include sedimentation that occurs during construction. If at any stage during construction the basin receives runoff that carries sediment, it can clog pores in the native soils rendering them less permeable.

Beyond the disturbance of the native soils and compaction of soils placed in basin bottoms, the composition of any soils placed in basin bottoms is very important. The “engineered” soils placed in the bottom of some facilities consist of a combination of sand,

organic matter, and site soils. Getting the proportions of these materials right so that they have the desired infiltration capacity as well as the ability to support plant life and meet any other design requirements can be a challenge. In particular, site soils that are included can be quite variable in composition, and the blending of the soils on site can result in uneven mixing, even when done conscientiously.

Consequently, verification testing of infiltration rates should be required at the time of construction to confirm the design assumptions. This testing should include the native subgrade as well as engineered/amended soils, if present. Otherwise the system may fail to meet the design intent.

## 4.7 CONSTRUCTION DEWATERING

At the time of drilling activities, groundwater was encountered in all borings except B-07, B-09, B-10, and B-11 at average depth of 10 feet below the existing grade. On the other hand, groundwater level also observed upon drilling completion in borings B-01, B-02, B-04, B-05, B-10, and B-11 at average depth of 8 feet below the existing grade. Depending upon the depth of cuts with respect to the observed groundwater level, we anticipate that ground water may not be encountered for mat foundations. We highlight that the contractor is responsible for all dewatering by his means and methods.

In addition, water can enter the excavations due to surface runoff and local precipitation during construction. Past experience indicates that the foundation and subgrade bearing soils encountered on-site will soften considerably when exposed to free water. The contractor should keep excavations dry to prevent the softening of these materials. Methods such as sloping, ditching, and berming can be used to control surface water at the site.

Water should not be allowed to collect in the foundation excavation, on floor slab areas, or on prepared subgrades of the construction area either during or after construction. Undercut or excavated areas should be sloped toward one corner to facilitate removal of any collected rainwater, groundwater, or surface runoff. Positive site surface drainage should be provided to reduce infiltration of surface water around the perimeter of the building and beneath the floor slabs. The grades should be sloped away from the building and surface drainage should be collected and discharged such that water is not permitted to infiltrate the backfill and floor slab areas of the building.

Overall site drainage is to be arranged in a manner to direct surface water away from the construction area including the slab and pavement subgrades and foundation excavations. Based on PSI's experience on similar sites, planning and diligence will be required on the part of the contractor because of the gentle site grades.

## 4.8 CONSTRUCTION CONSIDERATIONS

To assess that the in-situ soil conditions or those conditions developed during the construction are as anticipated during the design stage, the recommended construction control, and continuous observation and testing are as follows:

- Areas supporting new construction should be proof-rolled following the requirements laid out in section 4.2 after being stripped and cleared of all plants, surficial soils, and pavement, in order to determine the presence of any poor soils at this site. Proof-rolling should occur after soils have been cut to proposed grade, and before any structural fill is placed. Proof-rolling should be monitored by the soils technician under the overall supervision of the Geotechnical Engineer of Record.

- Structural fill placement, for the building pad areas should be observed and inspected for compactions by a qualified soils technician working under the supervision of the Geotechnical Engineer of Record.

The Geotechnical Engineer of Record should inspect all footing and floor slab excavations, preparation of subgrade, placement of aggregate base course, etc.

## 4.9 PAVEMENT RECOMMENDATIONS

PSI understands that as part of the development in the area, new parking areas will be constructed. In designing the proposed pavement section for the parking lot or the access road, the existing subgrade conditions must be considered together with the expected traffic use and loading conditions. The conditions that will influence the pavement design include bearing values of the subgrade represented by a California Bearing Ratio (CBR), and daily vehicular traffic, in terms of the number and frequency of vehicles and their range of axle loads.

**This report is based on assuming a CBR of 3**. However, the subgrade soils should be tested for laboratory CBR values under soaked conditions in accordance with ASTM D1883 requirements. **Pavement thicknesses may change based on CBR values determined at the time of construction.** Standard and heavy-duty pavement 18-kip equivalent single axle loads (ESALs) were assumed as 30,000 and 50,000, respectively, for the evaluation. These design thicknesses assume that a properly compacted subgrade has been achieved.

**Table 9: Flexible Pavement Design Thickness**

| Flexible Pavement Layer | Standard Duty (inches) | Heavy Duty (inches) |
|---|---|---|
| *HMA Superpave 9.5mm Surface Course* | *1.5* | *2.0* |
| *HMA Superpave 25.0mm Base Course* | *3.0* | *3.0* |
| *Graded Aggregate Base Course* | *8.0* | *8.0* |

*NOTES:

1) Hot Mix Asphalt Surface and Base Course material should meet the specifications in Sections 901 and 904 of the 2008 Maryland Department of Transportation *Standard Specifications for Construction and Materials*.
2) Aggregate Base Course material should meet the specification in Section 901.01 of the 2008 Maryland Department of Transportation *Standard Specifications for Construction and Materials*.
3) Hot Mix Asphalt (HMA) Surface and Base Courses should be placed in accordance with Section 504 of the 2008 Maryland Department of Transportation *Standard Specifications for Construction and Materials*.
4) Aggregate Base Course should be placed in accordance with Section 501 of the 2008 Maryland Department of Transportation *Standard Specifications for Construction and Materials*.
5) Aggregate base course should be placed on a subgrade compacted to 100% of maximum dry density per Modified Proctor.

Partial construction of the pavement is strongly discouraged because of the likelihood of pavement and subgrade failure. This failure will occur because the partial pavement is inadequate for support of construction loads and maneuvering of equipment.

If concrete pavement is utilized, the concrete should be properly jointed, should be air-entrained, should have a minimum flexural strength of 550 psi and a compressive strength of at least 3,500 psi compressive at 28 days. Expansion joints should be sealed with a polyurethane sealant so that moisture infiltration into the subgrade soils and the resulting concrete deterioration at the joints is reduced.

Rigid pavements can be designed as jointed plain (unreinforced) concrete pavement, with or without dowels for load transfer at joints, or as jointed reinforced concrete pavement. If dowels are used, they, on one side of each joint, must be greased for proper function. In general, the use of reinforcement typically allows for a wider, or longer, joint spacing, but the reinforcement does not increase the structural capacity of the pavement. In accordance with AASHTO design procedures, the maximum joint spacing for unreinforced concrete pavements is two times the thickness of the pavement (i.e. for a 6-inch thick pavement, the maximum spacing is 12 feet). It should be noted that a larger joint spacing is possible for concrete with maximum aggregate sizes ¾-inch and larger and for concrete with slumps less than 4 to 6 inches. If reinforcement is used, then the joint spacing can also be increased, although most concrete pavement is designed as unreinforced concrete. Traffic should not be allowed on the finished pavement until the concrete has attained the design compressive strength.

Preliminary rigid concrete pavement sections are provided in the table below:

**Table 10: Rigid Pavement Design Thickness**

| Rigid Pavement Layer | Standard Duty (inches) | Heavy Duty (inches) |
|---|---|---|
| *Portland Cement Concrete Pavement* | *5.0* | *6.0* |
| *Dense Aggregate Base Stone* | *4.0* | *4.0* |
| *Compacted Subgrade (Minimum)* | *12.0* | *12.0* |

| *NOTES: | | |
|---|---|---|
| | 1) | Portland Cement Concrete Pavement material should meet the specifications in Sections 902 and 908 of the 2008 Maryland Department of Transportation Standard Specifications for Construction and Materials. |
| | 2) | Aggregate Base Course material should meet the specification in Section 901.01 of the 2008 Maryland Department of Transportation Standard Specifications for Construction and Materials. |
| | 3) | Reinforced Portland Cement Concrete Pavement should be placed in accordance with Section 520 of the 2008 Maryland Department of Transportation Standard Specifications for Construction and Materials. |
| | 4) | Aggregate Base Course should be placed in accordance with Section 501 of the 2008 Maryland Department of Transportation Standard Specifications for Construction and Materials. |
| | 5) | Aggregate base course should be placed on a subgrade compacted to 100% of maximum dry density per Modified Proctor. |

## 4.10 EXCAVATIONS AND SAFETY

In Federal Register, Volume 54, No. 209 (October, 1989), the United States Department of Labor, Occupational Safety and Health Administration (OSHA) amended its "Construction Standards for Excavations, 29 CFR, Part 1926, Subpart P". This document was established to better enhance the safety of workers entering trenches or excavations.

Federal regulation mandates that all excavations, whether they be utility trenches, basement or footing excavations or others (i.e. underground storage tanks), be constructed in accordance with the OSHA requirements. It is our understanding that these regulations are being strictly enforced and if they are not closely followed, the owner and the contractor could risk injury to workers and be liable for substantial financial penalties.

The contractor is solely responsible for designing and constructing stable, temporary excavations and should shore, slope, or bench the sides of the excavations as required to maintain stability of both the excavation sides and bottom. The contractor's responsible person, as defined in “29 CFR Part 1926”, should evaluate the soil exposed in the excavations as part of the contractor's safety procedures. In no case, should slope height, slope inclination, or excavation depth, including utility trench excavation depth, exceed those specified in local, state, and federal safety regulations.

We are providing this information solely as a service to our client. Psi is not assuming responsibility for construction site safety or the contractor's activities; such responsibility is not being implied and should not be inferred.

## 4.11 SOIL RESISTIVITY TEST

Soil resistivity testing is the process of measuring a volume of soil to determine the conductivity of the soil and it is the single most critical factor in electrical grounding design. Wenner test method is used for the site where the probe located at SR-1 and results for EW and NNE directions are presented as:

**Table 11: Estimated Soil Resistivity** (On field)

| Direction | Probe spacing (ft) | Resistance Measured 1 | Resistance Measured 2 | Resistance Measured 3 | Resistance Average (Ohm) | Calculated Resistivity (Ohm*m) |
|---|---|---|---|---|---|---|
| EW | 20 | 0.816 | 0.816 | 0.816 | 0.82 | 31.253 |
| EW | 100 | 0.202 | 0.201 | 0.202 | 0.20 | 38.619 |
| NNE | 5 | 12.5 | 12.5 | 12.5 | 12.50 | 119.688 |
| NNE | 10 | 6.56 | 6.56 | 6.56 | 6.56 | 125.624 |
| NNE | 20 | 3.21 | 3.22 | 3.21 | 3.21 | 123.071 |
| NNE | 30 | 1.944 | 1.943 | 1.945 | 1.94 | 111.683 |
| NNE | 40 | 1.267 | 1.269 | 1.269 | 1.27 | 97.154 |

**Appendix (E)** represents the resistivity testing layout where EW is centered at SR-1 and runs east to west and NNE is centered 160 ft north of SR-1 and runs south-southwest to north-northeast. It should be noted the estimated soil resistivity from field data is recommended rather laboratory tests since it represents the native soil behavior and environmental conditions.

# 5 RECOMMENDED ADDITIONAL SERVICES

Additional foundation engineering, testing, and consulting services recommended for this project are summarized below:

- Deep Foundation Evaluations: the proposed deep foundations as driven piles were evaluated based on introduced weight of equipment by **ProEnergy Services,** it is recommended to run pile load testing based on section 4.4.5 for the driven or ACP piles. We recommend that this work be accomplished by PSI during construction.

- Earthwork & Compaction Testing: It is recommended that an experienced engineering technician witness the required filling operations and take sufficient in-place density tests to verify that the specified degree of compaction has been achieved. Soil engineering judgments will be involved and should be made by the geotechnical engineer of record with information provided by the engineering technician. If any rock material is included in fills, earthwork inspection and monitoring must be full-time.

Soils Laboratory Testing: Testing to aid in the classification and verification of use of the on-site soils for structural fill and/or embankment material should be performed by PSI. Testing includes, but is not limited to, Atterberg Limits, Grain Size Analysis, California Bearing Ratio, Standard Moisture Density Relationship, and Moisture Content.

# 6 REPORT LIMITATIONS

The recommendations and discussions in this submittal are based on the available information obtained by PSI and design details furnished by **ProEnergy Services** and their consultants. If there are any revisions of the plans for this project or if deviations from the subsurface conditions noted in this report are encountered during construction, PSI should be notified immediately to determine if changes in the recommendations are required. If PSI is not retained to perform these functions, PSI cannot be responsible for the impact of those conditions on the performance of the project.

PSI warrants that the findings, recommendations, specifications, or professional advice contained herein have been made in accordance with generally accepted professional geotechnical engineering practices in the local area at the time of this report. No other warranties are implied or expressed.

The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, groundwater, or surface water within or beyond the site studied. Any statements in this report regarding odors, staining of soils, or other unusual conditions observed are strictly for the information of our client.

Upon completion of plans and specifications, PSI should be provided the opportunity to review the final design documents. This review process will allow PSI to verify whether or not our engineering recommendations have been properly incorporated into the design documents and that the earthwork and foundation recommendations have been properly interpreted and implemented. At that time, it may be necessary to submit supplementary recommendations. This report has been prepared for the exclusive use of **ProEnergy Services** for the specific application to the proposed **C. P. Crane Power Station, Bowleys, Maryland.**

# APPENDIX A: IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL REPORT

# Important Information about Your
# Geotechnical Engineering Report

*Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.*

*While you cannot eliminate all such risks, you can manage them. The following information is provided to help.*

## Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply the report for any purpose or project except the one originally contemplated.

## Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

## A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

## Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

## Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

## A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual

subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

## A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

## Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

## Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

## Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

## Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

## Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; ***none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.***

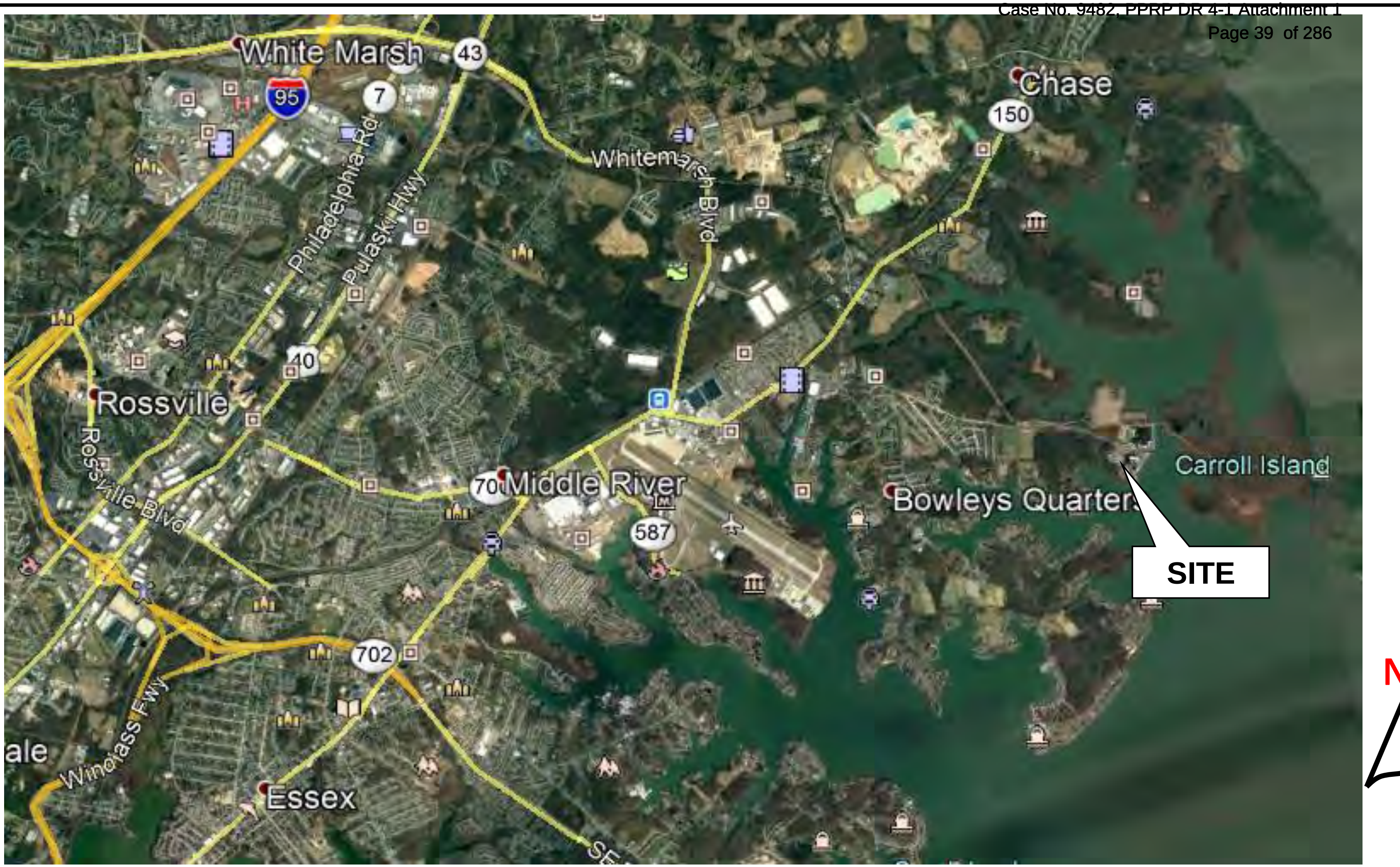
## Rely, on Your ASFE-Member Geotechncial Engineer for Additional Assistance

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with your ASFE-member geotechnical engineer for more information.

ASFE
THE BEST PEOPLE ON EARTH

8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733 Facsimile: 301/589-2017
e-mail: info@asfe.org www.asfe.org

# APPENDIX B – VICINITY MAP AND BORING LOCATION PLAN

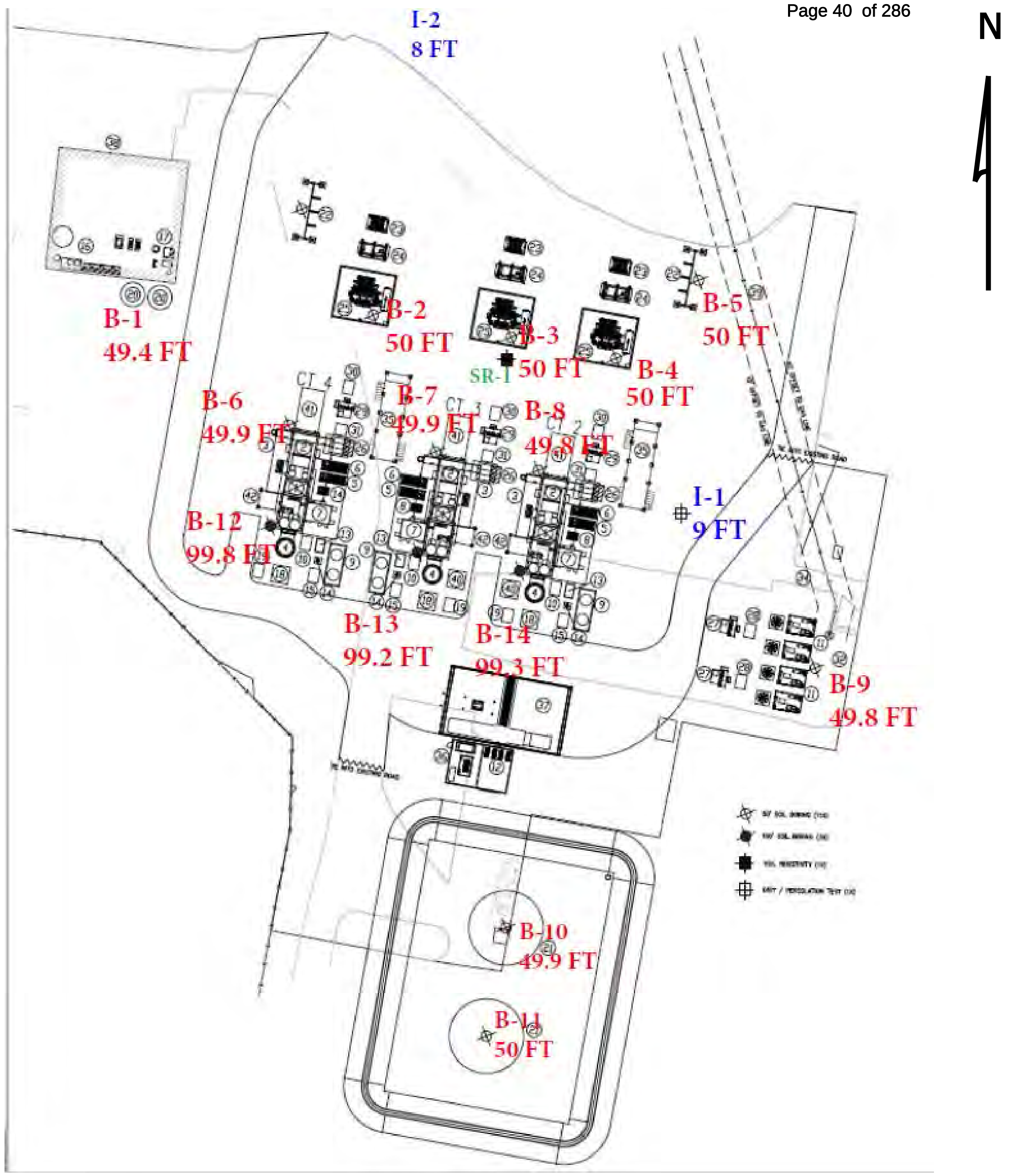



| intertek psi | REVISIONS |
|---|---|
| | |
| | |

**Site Vicinity Map**

**CP CRANE STATION**

| | | |
|---|---|---|
| Middle River, MD | | 05-03-2018 |
| P.K | Not Drawn To Scale | 0512843-1 |




LEGEND:

B-1 - PROPOSED BORING

49.4 FT - BORING DEPTH

NOTES:
1. SPT SAMPLING WILL BE PERFORMED IN ALL BORINGS.
2. BORING DEPTHS ARE AS SHOWN
3. BORING SPOILS WILL USED TO BACKFILL THE BORE HOLES.

| intertek psi | REVISIONS | |
|---|---|---|
| **Boring Location Plan**<br>**CP Crane Station** | | |
| Middle River, MD | | 06-04-2018 |
| P.K | Not Drawn To Scale | 0512843-1 |

# APPENDIX C: BORING LOGS

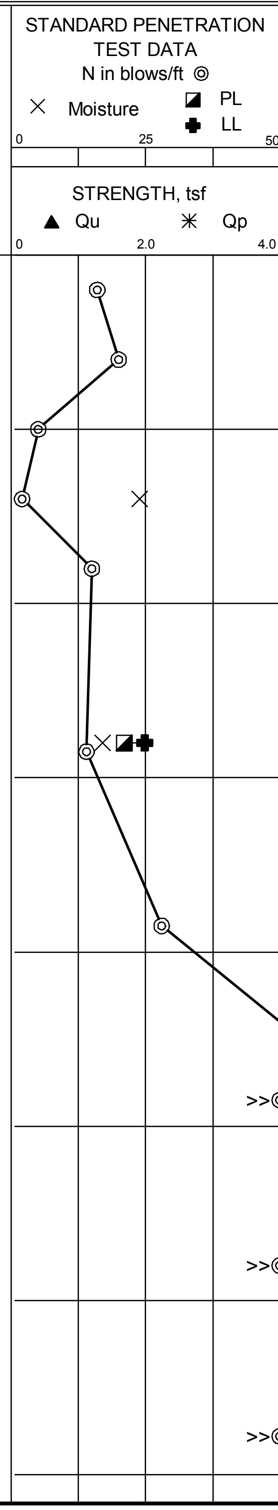
# BORING B-01

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/18/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/18/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.4 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.32454° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.367316° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

| **Water** | | |
|---|---|---|
| ▽ | While Drilling | 7.8 feet |
| ▼ | Upon Completion | 9.5 feet |
| ▽ | Cave-In | 21 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | Approximately 1" of GRAVEL | | | | |
| | | 1 | 20 | Medium dense, moist, gray and black, **poorly graded SAND (USCS : SP)** | SP | 3-9-7-11 N=16 | | |
| | | 2 | 24 | | | 12-11-9-7 N=20 | | |
| 5 | 5 | 3 | 24 | Very loose to medium dense, moist, gray and black, **silty SAND (USCS : SM)** | SM | 4-3-2-2 N=5 | | |
| | | 4 | 12 | | | 1-1-1-1 N=2 | 24 | |
| 0 | 10 | 5 | 24 | | | 4-6-9-11 N=15 | | |
| -5 | 15 | 6 | 18 | Stiff, moist, gray and red, **sandy SILT (USCS : ML)** | ML | 5-6-8 N=14 | 17 | LL = 25<br>PL = 21<br>Fines=58.2% |
| -10 | 20 | 7 | 18 | | | 5-10-18 N=28 | | |
| -15 | 25 | 8 | 18 | Medium dense to very dense, moist, tan and orange, **poorly graded SAND (USCS : SP)** | SP | 23-36-32 N=68 | | |
| -20 | 30 | 9 | 10 | | | 34-50/6" | | |
| -25 | 35 | 10 | 10 | | | 26-50/4" | | |

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Professional Service Industries, Inc.
2930 Eskridge Rd
Fairfax, VA 22031
Telephone: (703) 698-9300

| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-01

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/18/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/18/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.4 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.32454° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.367316° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

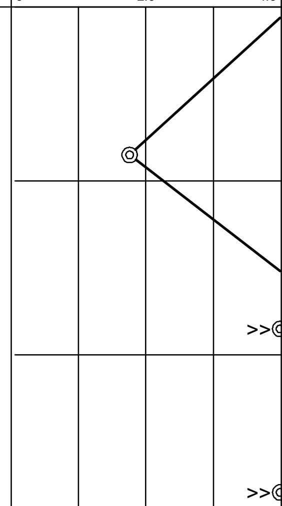
| Water | | |
|---|---|---|
| While Drilling | 7.8 | feet |
| Upon Completion | 9.5 | feet |
| Cave-In | 21 | feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Medium dense to very dense, moist, tan and orange, **poorly graded SAND (USCS : SP)** | | | | |
| -30 | | | | 11 | 10 | | | 10-12-10 N=22 | | |
| | 40 | | | | | | SP | | | |
| -35 | | | | 12 | 18 | | | 11-27-37 N=64 | | |
| | 45 | | | | | | | | | |
| -40 | | | | 13 | 11 | | | 28-50/5" | | |
| | | | | | | End of Boring approximately at 49.4 feet | | | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
Moisture PL LL
0 25 50
STRENGTH, tsf
Qu Qp
0 2.0 4.0



# BORING B-02

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/19/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/19/18 | **DRILLER:** Nadal | **LOGGED BY:** Pavan |
| **COMPLETION DEPTH** | 50.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 8 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324525° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.36682° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

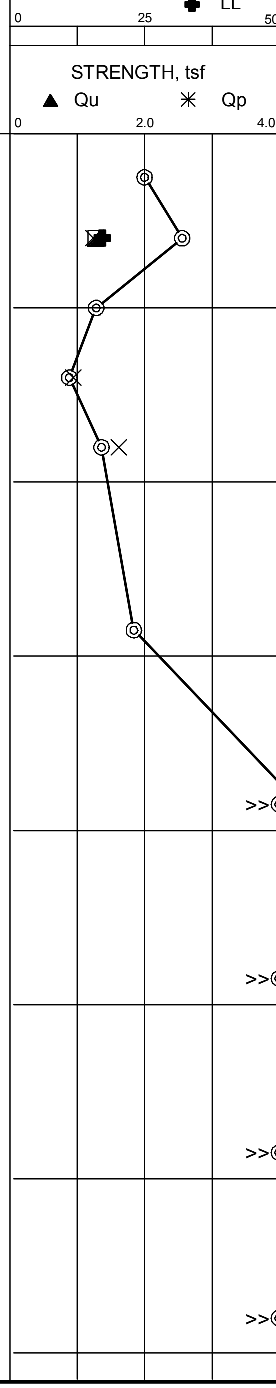
**Water**

| | |
|---|---|
| While Drilling | 10.5 feet |
| Upon Completion | 7 feet |
| Cave-In | 12 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | Approximately 4" of ASPHALT | | | | |
| | | | | Approximately 2" of GRAVEL BASE | | | | |
| | | 1 | 18 | Medium dense to dense, moist, gray, **silty SAND (USCS : SM)** | SM | 9-12-13 N=25 | | |
| 5 | | 2 | 22 | | | 12-15-17-11 N=32 | 15 | LL = 17 PL = 16 Fines=35.5% |
| | 5 | 3 | 24 | | | 5-7-9-5 N=16 | | |
| | | 4 | 24 | | | 6-6-5-5 N=11 | 12 | |
| 0 | | | | Stiff to very stiff, moist, brown, **SILT (USCS : ML)** | ML | | | |
| | | 5 | 24 | | | 3-7-10-14 N=17 | 20 | |
| | 10 | | | Very stiff, moist, red, **sandy SILT (USCS : ML)**, trace gravel | ML | | | |
| -5 | | | | | | | | |
| | | 6 | 18 | Medium dense to very dense, moist, tan and gray, **poorly graded SAND (USCS : SP)** | SP | 3-10-13 N=23 | | |
| | 15 | | | | | | | |
| -10 | | 7 | 18 | | | 7-13-41 N=54 | | |
| | 20 | | | | | | | |
| -15 | | 8 | 18 | | | 14-22-40 N=62 | | |
| | 25 | | | | | | | |
| -20 | | 9 | 14 | | | 11-31-39 N=70 | | |
| | 30 | | | | | | | |
| -25 | | 10 | 12 | | | 33-50/6" | | |
| | 35 | | | | | | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL

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intertek psi
Professional Service Industries, Inc.
2930 Eskridge Rd
Fairfax, VA 22031
Telephone: (703) 698-9300

| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

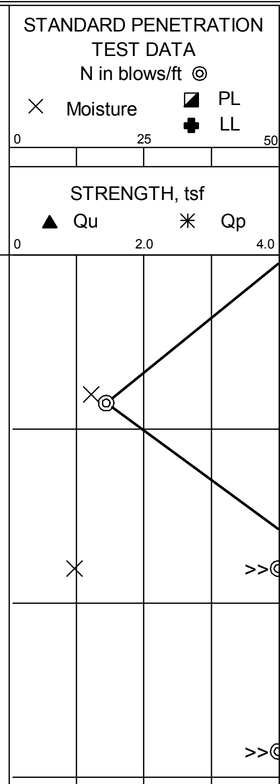
# BORING B-02

| | | | |
|---|---|---|---|
| DATE STARTED: | 4/19/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/19/18 | DRILLER: Nadal | LOGGED BY: Pavan |
| COMPLETION DEPTH | 50.0 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Hollow Stem Auger |
| ELEVATION: | 8 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.324525° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.36682° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

| Water | | |
|---|---|---|
| While Drilling | 10.5 | feet |
| Upon Completion | 7 | feet |
| Cave-In | 12 | feet |

BORING LOCATION:
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Medium dense to very dense, moist, tan and gray, **poorly graded SAND (USCS : SP)** | SP | | | |
| -30 | | | | 11 | 12 | | | 6-6-12 N=18 | 15 | |
| | 40 | | | | | Very stiff, moist, orange and gray, **sandy CLAY (USCS : CL)** | CL | | | |
| -35 | | | | 12 | 12 | Hard, moist, gray, **SILT (USCS : ML)** | ML | 22-50/6" | 12 | |
| | 45 | | | | | | | | | |
| -40 | | | | 13 | 18 | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 23-32-32 N=64 | | |
| | 50 | | | | | End of Boring approximately at 50 feet | | | | |



# BORING B-03

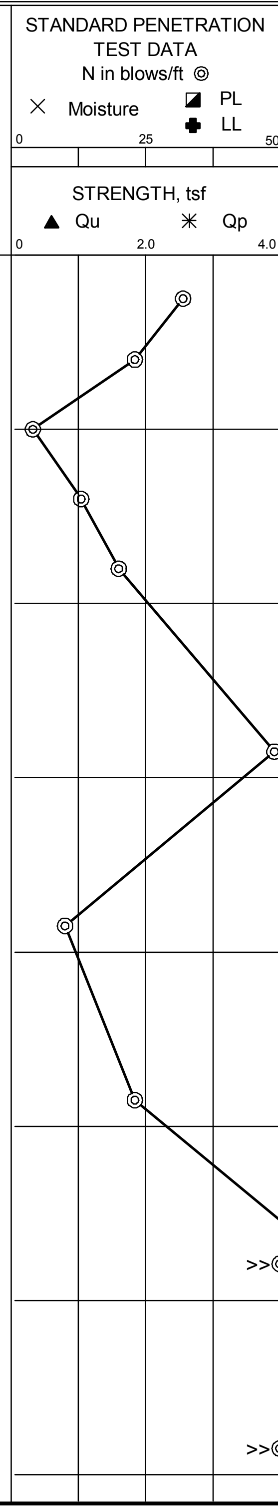
| | | | |
|---|---|---|---|
| DATE STARTED: | 4/17/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/17/18 | DRILLER: Nadal | LOGGED BY: Ethan |
| COMPLETION DEPTH | 50.0 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Hollow Stem Auger |
| ELEVATION: | 8 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.324518° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.366575° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

**Water**

| | | |
|---|---|---|
| While Drilling | 8 | feet |
| Upon Completion | DRY | |
| Cave-In | 5 | feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | Approximately 2" of ASPHALT | | | | |
| | | | | | | Approximately 2" of GRAVEL BASE | | | | |
| | | | | 1 | 12 | Very loose to dense, moist, brown and gray, **silty SAND (USCS : SM)** | | 11-15-17 N=32 | | |
| 5 | | | | 2 | 18 | | | 8-11-12-8 N=23 | | |
| | 5 | | | 3 | 24 | | | 2-2-2-4 N=4 | | |
| | | | | 4 | 18 | | SM | 6-6-7-5 N=13 | | |
| 0 | | | | | | | | | | |
| | 10 | | | 5 | 24 | | | 6-10-10-9 N=20 | | |
| -5 | | | | | | | | | | |
| | | | | 6 | 16 | Loose to very dense, moist, tan and gray, **poorly graded SAND (USCS : SP)** | | 12-22-27 N=49 | | |
| | 15 | | | | | | | | | |
| -10 | | | | 7 | 18 | | | 3-4-6 N=10 | | |
| | 20 | | | | | | | | | |
| -15 | | | | | | | | | | |
| | | | | 8 | 18 | | SP | 7-10-13 N=23 | | |
| | 25 | | | | | | | | | |
| -20 | | | | 9 | 11 | | | 40-50/5" | | |
| | 30 | | | | | | | | | |
| -25 | | | | | | | | | | |
| | 35 | | | 10 | 18 | | | 28-33-35 | | |

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Fairfax, VA 22031
Telephone: (703) 698-9300

| | |
|---|---|
| PROJECT NO.: | 0512843-1 |
| PROJECT: | CP Crane Power Station |
| LOCATION: | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-03

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/17/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/17/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 50.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 8 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324518° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366575° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

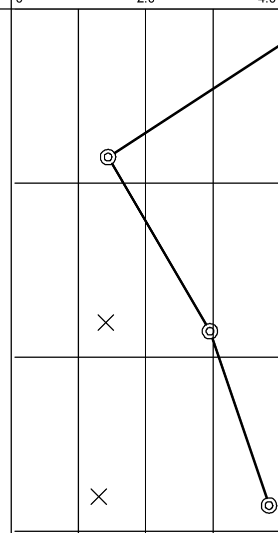
| | | |
|---|---|---|
| ▽ | While Drilling | 8 feet |
| ▼ | Upon Completion | DRY |
| ▽ | Cave-In | 5 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Loose to very dense, moist, tan and gray, **poorly graded SAND (USCS : SP)** | | N=68 | | |
| -30 | | | | | | | | | | |
| | | | | 11 | 18 | | SP | 14-11-7 N=18 | | |
| | 40 | | | | | | | | | |
| -35 | | | | | | | | | | |
| | | | | 12 | 18 | Hard, moist, gray and red, **SILT (USCS : ML)** | | 9-18-19 N=37 | 18 | |
| | 45 | | | | | | ML | | | |
| -40 | | | | | | | | | | |
| | | | | 13 | 18 | | | 9-17-31 N=48 | 16 | |
| | 50 | | | | | End of Boring approximately at 50 feet | | | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0



Professional Service Industries, Inc.
2930 Eskridge Rd
Fairfax, VA 22031
Telephone: (703) 698-9300

| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-04

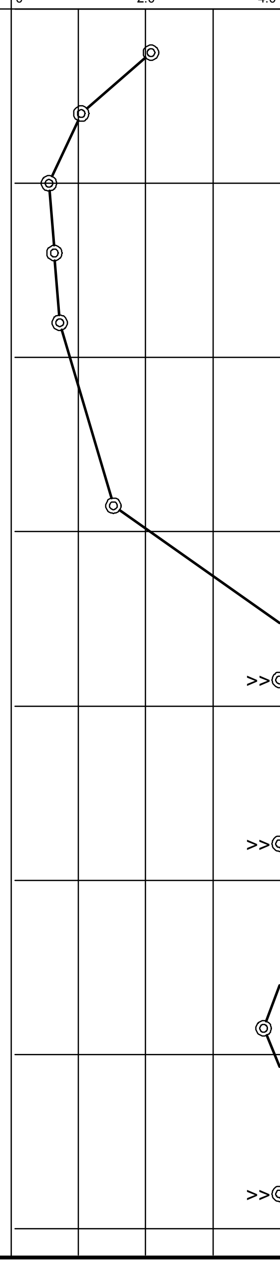
| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/17/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/17/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 50.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.32448° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366288° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

| **Water** | | |
|---|---|---|
| ▽ | While Drilling | 13 feet |
| ▼ | Upon Completion | 6.5 feet |
| ⊻ | Cave-In | 11.5 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| 9 | 0 | | | Approximately 4" of ASPHALT | | | | |
| | | 1 | 10 | Medium dense, moist, brown and black, **poorly graded SAND (USCS : SP)** with gravel, trace silt - FILL | SP | 10-12-14 N=26 | | |
| | | 2 | 24 | Loose to medium dense, moist, black and brown, **poorly graded SAND (USCS : SP)** with silt | SP | 4-9-4-5 N=13 | | |
| 5 | 5 | 3 | 23 | | | 3-3-4-5 N=7 | | |
| | | 4 | 18 | | | 5-4-4-4 N=8 | | |
| 0 | 10 | 5 | 23 | | | 3-4-5-6 N=9 | | |
| -5 | 15 | 6 | 18 | | | 3-9-10 N=19 | | |
| -10 | 20 | 7 | 18 | Loose to medium dense, moist, tan and black, **poorly graded SAND (USCS : SP)** with silt | SP | 22-29-36 N=65 | | |
| -15 | 25 | 8 | 1 | | | 41-50/5" | | |
| -20 | 30 | 9 | 18 | | | 8-19-28 N=47 | | |
| -25 | 35 | 10 | 12 | | | 38-50/6" | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0

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# BORING B-04

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/17/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/17/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 50.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.32448° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366288° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

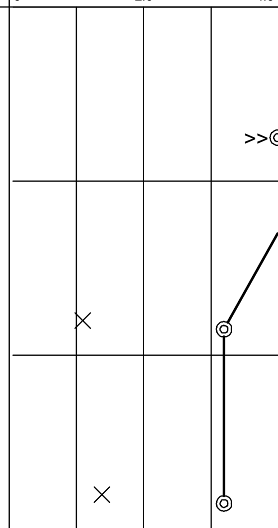
**Water**

| | | |
|---|---|---|
| While Drilling | 13 | feet |
| Upon Completion | 6.5 | feet |
| Cave-In | 11.5 | feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | Loose to medium dense, moist, tan and black, **poorly graded SAND (USCS : SP)** with silt | SP | | | |
| -30 | 40 | | 11 | 6 | | | 50/6" | | |
| -35 | 45 | | 12 | 18 | | | 12-13-27 N=40 | 14 | Fines=44.4% |
| | | | | | Hard, moist, tan and gray, **sandy CLAY (USCS : CL)** | CL | | | |
| -40 | 50 | | 13 | 18 | | | 11-15-25 N=40 | 17 | |
| | | | | | End of Boring approximately at 50 feet | | | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0




intertek psi
Professional Service Industries, Inc.
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Fairfax, VA 22031
Telephone: (703) 698-9300

**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters
Middle River, MD

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-05

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/18/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/18/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 50.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324589° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366156° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

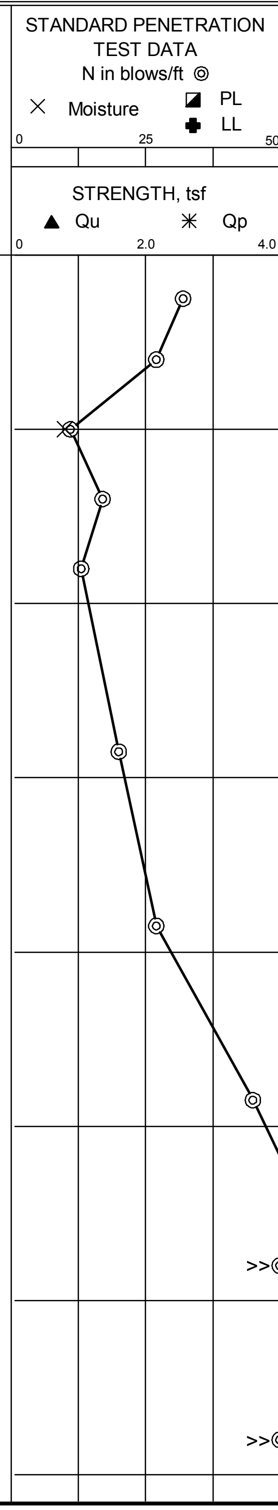
**Water**

| | | |
|---|---|---|
| While Drilling | 13 | feet |
| Upon Completion | 9 | feet |
| Cave-In | 11.2 | feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| 9 | 0 | | | Approximately 3" of ASPHALT | | | | |
| | | | | Approximately 2" of GRAVEL BASE | | | | |
| | | 1 | 16 | Medium dense to dense, moist, dark gray, **silty, clayey SAND (USCS : SC-SM)** | | 17-17-15 N=32 | | |
| | | 2 | 24 | | | 15-15-12-10 N=27 | | |
| 5 | 5 | 3 | 14 | | SC-SM | 6-4-7-11 N=11 | 10 | Fines=27.1% |
| | | 4 | 14 | | | 8-9-8-9 N=17 | | |
| 0 | | 5 | 22 | | | 2-3-10-16 N=13 | | |
| | 10 | | | Medium dense to very dense, moist, tan, **poorly graded SAND (USCS : SP)** | | | | |
| -5 | 15 | 6 | 18 | | | 5-8-12 N=20 | | |
| -10 | 20 | 7 | 18 | | | 9-12-15 N=27 | | |
| | | | | | SP | | | |
| -15 | 25 | 8 | 18 | | | 12-19-26 N=45 | | |
| -20 | 30 | 9 | 12 | | | 32-50/6" | | |
| -25 | 35 | 10 | 12 | | | 26-50/6" | | |

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# BORING B-05

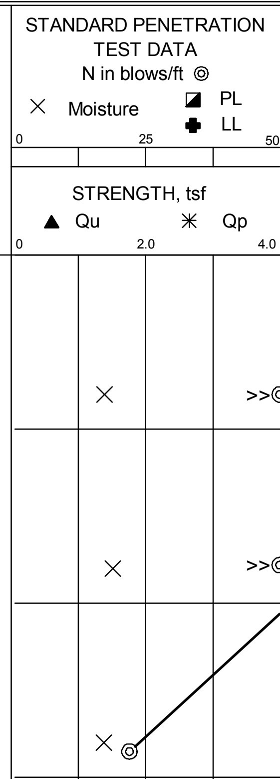
| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/18/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/18/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 50.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324589° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366156° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

| | |
|---|---|
| While Drilling | 13 feet |
| Upon Completion | 9 feet |
| Cave-In | 11.2 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | STANDARD PENETRATION TEST DATA | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Medium dense to very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | | | | |
| -30 | | | | 11 | 12 | Very dense, moist, tan, **clayey SAND (SC)** | | 20-50/6" | 17 | >> | |
| | 40 | | | | | | | | | | |
| -35 | | | | 12 | 9 | | SC | 36-50/3" | 19 | >> | |
| | 45 | | | | | | | | | | |
| -40 | | | | 13 | 18 | Very stiff, moist, tand and red, **sandy CLAY (CL)** | CL | 9-11-11 N=22 | 17 | | |
| | 50 | | | | | End of Boring approximately at 50 feet | | | | | |

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Telephone: (703) 698-9300

**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters
Middle River, MD

# BORING B-06

| | | | |
|---|---|---|---|
| DATE STARTED: | 4/18/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/18/18 | DRILLER: Nadal | LOGGED BY: Ethan |
| COMPLETION DEPTH | 49.9 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Hollow Stem Auger |
| ELEVATION: | 8 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.324386° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.367012° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

**Water**

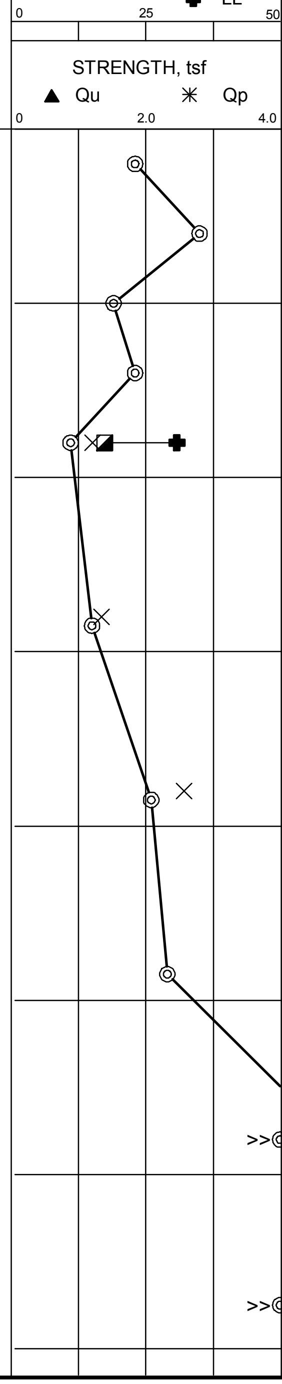
| | | |
|---|---|---|
| While Drilling | 16 feet |
| Upon Completion | DRY |
| Cave-In | 7.5 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| 8 | 0 | | | Medium dense, moist, brown, **poorly graded GRAVEL (USCS : GP)** with sand | GP | | | |
| | | 1 | 23 | Medium dense to dense, moist, brown, **poorly graded SAND (USCS : SP)** | SP | 5-13-10-12 N=23 | | |
| 5 | | 2 | 24 | | | 13-17-18-27 N=35 | | |
| | 5 | 3 | 24 | | | 7-12-7-10 N=19 | | |
| | | 4 | 12 | | | 10-14-9-9 N=23 | | |
| 0 | | 5 | 24 | Stiff, moist, reddish brown, **sandy CLAY (USCS : CL)** | CL | 6-5-6-7 N=11 | 15 | LL = 31<br>PL = 17<br>Fines=66.6% |
| -5 | 10 | | | | | | | |
| | 15 | 6 | 16 | Stiff to very stiff, moist, brown, **lean CLAY (USCS : CL)** with sand | CL | 5-7-8 N=15 | 17 | |
| -10 | 20 | 7 | 7 | | | 4-10-16 N=26 | 32 | |
| -15 | 25 | 8 | 18 | Medium dense to very dense, moist, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 12-15-14 N=29 | | |
| -20 | 30 | 9 | 12 | | | 19-50/6" | | |
| -25 | 35 | 10 | 6 | Very dense, moist, tan, **clayey SAND (USCS : SC)** | SC | 50/6" | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
STRENGTH, tsf
▲ Qu ✳ Qp

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Fairfax, VA 22031
Telephone: (703) 698-9300

| | |
|---|---|
| PROJECT NO.: | 0512843-1 |
| PROJECT: | CP Crane Power Station |
| LOCATION: | Bowleys Quarters<br>Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-06

| | | | |
|---|---|---|---|
| DATE STARTED: | 4/18/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/18/18 | DRILLER: Nadal | LOGGED BY: Ethan |
| COMPLETION DEPTH | 49.9 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Hollow Stem Auger |
| ELEVATION: | 8 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.324386° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.367012° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

**Water**

| | | |
|---|---|---|
| While Drilling | 16 | feet |
| Upon Completion | DRY | |
| Cave-In | 7.5 | feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL (0 25 50); STRENGTH, tsf ▲ Qu ✳ Qp (0 2.0 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Very dense, moist, tan, **clayey SAND (USCS : SC)** | SC | | | | |
| -30 | | | | | | | | | | | |
| | | | | 11 | 18 | Very dense, moist, tan and orange, **poorly graded SAND (USCS : SP)** | SP | 23-36-32 N=68 | | >>◎ | |
| | 40 | | | | | | | | | | |
| -35 | | | | | | | | | | | |
| | | | | 12 | 10 | | | 36-50/4" | | >>◎ | |
| | 45 | | | | | | | | | | |
| -40 | | | | | | | | | | | |
| | | | | 13 | 17 | | | 12-31-50/5" | | | |
| | | | | | | End of Boring approximately at 50 feet | | | | | |

# BORING B-07

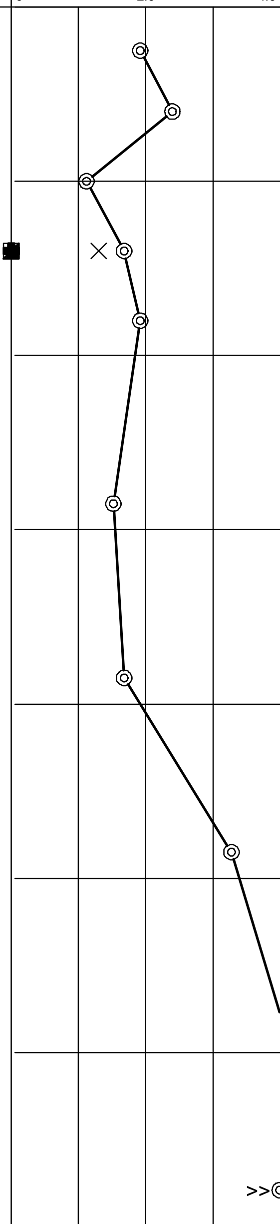
| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/13/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/13/18 | **DRILLER:** Shannon | **LOGGED BY:** Abram |
| **COMPLETION DEPTH** | 49.9 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 8 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324385° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366659° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

| **Water** | | |
|---|---|---|
| ▽ | While Drilling | DRY |
| ▼ | Upon Completion | DRY |
| ▽ | Cave-In | 2.5 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | Approximately 4" of ASPHALT | | | | |
| | | | | Approximately 2" of GRAVEL BASE | | | | |
| | | 1 | 15 | Medium dense, moist, dark gray and black, **poorly graded SAND (USCS : SP)** | SP | 12-12-12 N=24 | | |
| 5 | | 2 | 20 | | | 11-16-14-16 N=30 | | |
| | 5 | 3 | 16 | | | 4-6-8-6 N=14 | | |
| | | 4 | 18 | Medium dense, moist, dark gray and black, **silty SAND (USCS : SM)** | SM | 6-8-13-10 N=21 | 16 | Non-Plastic Fines=28.2% |
| 0 | | 5 | 20 | Medium dense, moist, dark gray and black, **poorly graded SAND (USCS : SP)** | SP | 6-10-14-18 N=24 | | |
| | 10 | | | | | | | |
| -5 | | | | | | | | |
| | 15 | 6 | 14 | Medium dense, moist, dark gray and black, **clayey SAND (USCS : SC)** | SC | 6-7-12 N=19 | | |
| -10 | | | | | | | | |
| | 20 | 7 | 14 | Medium dense to very dense, moist, tan and orange, **poorly graded SAND (USCS : SP)** | SP | 10-10-11 N=21 | | |
| -15 | | | | | | | | |
| | 25 | 8 | 17 | | | 10-14-27 N=41 | | |
| -20 | | | | | | | | |
| | 30 | 9 | 15 | | | 15-33-50/5" | | |
| -25 | | | | | | | | |
| | 35 | 10 | 18 | | | 33-50/5" | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0

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| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-07

| | | | |
|---|---|---|---|
| DATE STARTED: | 4/13/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/13/18 | DRILLER: | Shannon |
| | | LOGGED BY: | Abram |
| COMPLETION DEPTH | 49.9 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Hollow Stem Auger |
| ELEVATION: | 8 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.324385° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.366659° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

| Water | | |
|---|---|---|
| While Drilling | | DRY |
| Upon Completion | | DRY |
| Cave-In | | 2.5 feet |

BORING LOCATION:

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | Medium dense to very dense, moist, tan and orange, **poorly graded SAND (USCS : SP)** | SP | | | | |
| -30 | | 11 | 18 | | | 15-50/5" | | >> | |
| | 40 | | | | | | | | |
| -35 | | 12 | 18 | | | 22-43-46 N=89 | | >> | |
| | 45 | | | | | | | | |
| -40 | | 13 | 16 | | | 14-38-50/5" | | | |
| | | | | End of Boring approximately at 49.9 feet | | | | | |

Legend: × Moisture; PL; LL; STANDARD PENETRATION scale 0, 25, 50; STRENGTH, tsf: ▲ Qu, ✳ Qp; scale 0, 2.0, 4.0

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2930 Eskridge Rd
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| | |
|---|---|
| PROJECT NO.: | 0512843-1 |
| PROJECT: | CP Crane Power Station |
| LOCATION: | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-08

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/16/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/16/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.8 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324353° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366429° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

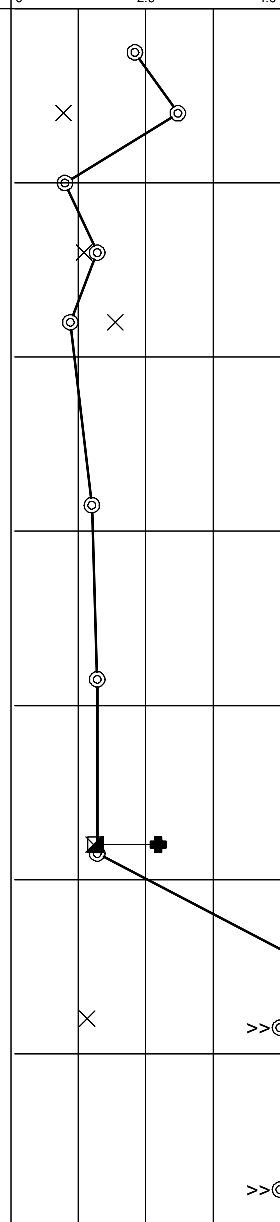
| **Water** | | |
|---|---|---|
| While Drilling | | 6 feet |
| Upon Completion | | DRY |
| Cave-In | | 4.5 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | MATERIAL DESCRIPTION | USCS Classification |
|---|---|---|---|
| 9 | 0 | Approximately 6" of ASPHALT | |
| | | Medium dense, moist, brown, **poorly graded GRAVEL (USCS : GP)** with silt | GP |
| | | Medium dense, moist, brown, **poorly graded SAND (USCS : SP)** | SP |
| | | Loose to dense, moist, gray, **silty SAND (USCS : SM)** | SM |
| | | Stiff to very stiff, moist, dark gray, **sandy SILT (USCS : ML)** | ML |
| | | Medium dense, moist, gray, **poorly graded SAND (USCS : SP)** | SP |
| | | Very stiff, moist, brown, **lean CLAY (USCS : CL)** | CL |
| | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP |

| Sample No. | Recovery (inches) | Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|
| 1 | 12 | 6-13-10 N=23 | | |
| 2 | 18 | 14-15-16-21 N=31 | 10 | |
| 3 | 24 | 9-5-5-6 N=10 | | |
| 4 | 24 | 6-8-8-8 N=16 | 13 | |
| 5 | 24 | 5-5-6-7 N=11 | 19 | |
| 6 | 18 | 5-6-9 N=15 | | |
| 7 | 18 | 5-7-9 N=16 | | |
| 8 | 18 | 4-6-10 N=16 | 15 | LL = 27 PL = 16 Fines=92.0% |
| 9 | 18 | 17-32-46 N=78 | 14 | |
| 10 | 10 | 46-50/4" | | |

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| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/16/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/16/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.8 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324353° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366429° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

# BORING B-08

| Water | | |
|---|---|---|
| ∇ | While Drilling | 6 feet |
| ▼ | Upon Completion | DRY |
| ∇ | Cave-In | 4.5 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ (X Moisture, PL, LL; 0 25 50) STRENGTH, tsf (▲ Qu, ✳ Qp; 0 2.0 4.0) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | | | | | |
| -30 | | | | 11 | 10 | | SP | 21-50/5" | | >>◎ | |
| | 40 | | | | | | | | | | |
| -35 | | | | 12 | 18 | Hard, moist, brown, **SILTY CLAY (USCS : CL-ML)** | CL-ML | 25-47-50/6" | 14 | X | |
| | 45 | | | | | Hard, moist, gray and brown, **sandy SILT (USCS : ML)** | ML | | | | |
| -40 | | | | 13 | 15 | | | 21-45-50/3" | 13 | X | |
| | | | | | | End of Boring approximately at 49.8 feet | | | | | |

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**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters
Middle River, MD

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-09

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/13/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/13/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.8 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 10 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324091° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366007° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

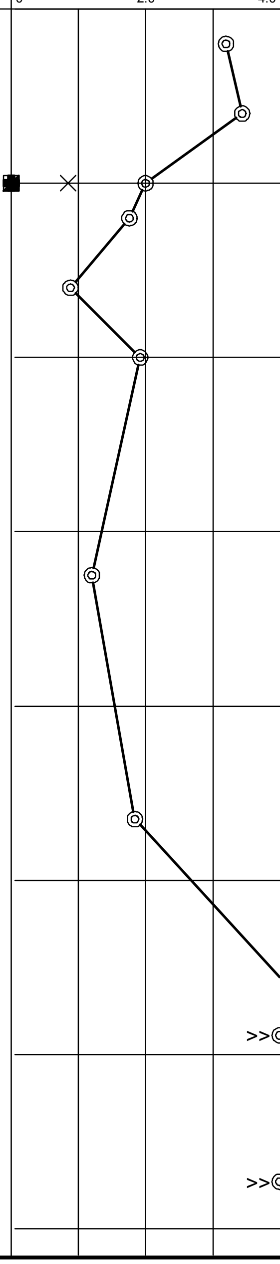
| | | |
|---|---|---|
| While Drilling | 16.5 | feet |
| Upon Completion | DRY | |
| Cave-In | 6 | feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blow Counts | Moisture, % | STANDARD PENETRATION TEST DATA | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | | | | | Approximately 2" of GRAVEL | | | | | |
| | | | | 1 | 24 | Dense, moist, gray and brown, **silty SAND (USCS : SM)** | SM | 7-18-22-25 N=40 | | | |
| | | | | 2 | 24 | Dense, moist, brown, **poorly graded GRAVEL (USCS : GP)** with sand | GP | 19-24-19-22 N=43 | | | |
| | | | | | | Medium dense to dense, moist, gray, **silty SAND (USCS : SM)** | SM | | | | |
| 5 | 5 | | | 3 | 24 | | | 9-12-13-14 N=25 | 11 | | Non-Plastic Fines=37.0% |
| | | | | 4 | 24 | | | 6-12-10-5 N=22 | | | |
| | | | | 5 | 24 | | | 5-5-6-6 N=11 | | | |
| 0 | 10 | | | 6 | 24 | | | 10-16-8-7 N=24 | | | |
| -5 | 15 | | | | | | | | | | |
| | | | | 7 | 12 | Medium dense to very dense, moist, tan, **poorly graded SAND (USCS SP)** | SP | 10-9-6 N=15 | | | |
| -10 | 20 | | | | | | | | | | |
| | | | | 8 | 18 | | | 9-8-15 N=23 | | | |
| -15 | 25 | | | | | | | | | | |
| -20 | 30 | | | 9 | 11 | | | 48-50/5" | | >> | |
| | | | | 10 | 4 | | | 50/4" | | >> | |
| -25 | 35 | | | | | | | | | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0



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2930 Eskridge Rd
Fairfax, VA 22031
Telephone: (703) 698-9300

| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/13/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/13/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.8 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 10 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324091° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366007° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

# BORING B-09

| Water | | |
|---|---|---|
| While Drilling | 16.5 feet |
| Upon Completion | DRY |
| Cave-In | 6 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture PL LL 0 25 50 STRENGTH, tsf ▲ Qu ✳ Qp 0 2.0 4.0 | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Medium dense to very dense, moist, tan, **poorly graded SAND (USCS SP)** | | | | |
| -30 | 40 | | | | | | | | | |
| | | | | 11 | 18 | | SP | 10-12-21 N=33 | | |
| -35 | 45 | | | | | | | | | |
| | | | | 12 | 15 | | | 22-24-50/3" | | |
| | | | | | | End of Boring approximately at 49.8 feet | | | | |

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**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters
Middle River, MD

# BORING B-10

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/20/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/20/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.9 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 8 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.323576° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366689° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

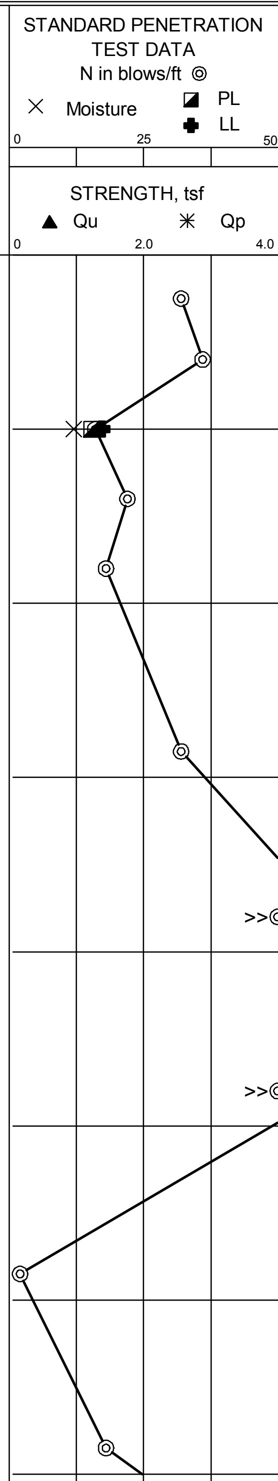
| | | |
|---|---|---|
| While Drilling | | DRY |
| Upon Completion | 10 | feet |
| Cave-In | 17 | feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | Approximately 3" of ASPHALT | | | | |
| | | | | Approximately 2" of GRAVEL BASE | | | | |
| | | 1 | 13 | Medium dense to dense, moist, gray, **silty SAND (USCS : SM)** | SM | 12-15-17 N=32 | | |
| 5 | | 2 | 20 | | | 17-17-19-17 N=36 | | |
| | 5 | 3 | 27 | | | 12-9-7-7 N=16 | 12 | LL = 17 PL = 15 Fines=45.5% |
| 0 | | 4 | 18 | | | 10-10-12-10 N=22 | | |
| | 10 | 5 | 24 | | | 8-9-9-12 N=18 | | |
| -5 | 15 | 6 | 18 | | | 7-14-18 N=32 | | |
| -10 | | 7 | 12 | Dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 19-50/6" | | |
| -15 | 20 | | | | | | | |
| | 25 | 8 | 12 | | | 13-50/6" | | |
| -20 | | | | | | | | |
| | 30 | 9 | 18 | Very loose to medium dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 1-1-1 N=2 | | |
| -25 | | | | | | | | |
| | 35 | 10 | 18 | | | 3-5-13 | | |

STANDARD PENETRATION TEST DATA
N in blows/ft

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# BORING B-10

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/20/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/20/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 49.9 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 8 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.323576° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366689° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

| | | |
|---|---|---|
| ∇ | While Drilling | DRY |
| ▼ | Upon Completion | 10 feet |
| ▼ | Cave-In | 17 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL (scale 0, 25, 50)
STRENGTH, tsf: ▲ Qu; ✳ Qp (scale 0, 2.0, 4.0)

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | SPT N | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | Very loose to medium dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | N=18 | | | |
| -30 | | 11 | 11 | Dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 33-50/5" | | >>◎ | |
| | 40 | | | | | | | | |
| -35 | | 12 | 16 | | | 23-33-50/4" | | | |
| | 45 | | | Dense, moist, tan, **clayey SAND (USCS : SC)** | SC | | | | |
| -40 | | 13 | 17 | Dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 28-39-50/5" | | | |
| | | | | End of Boring approximately at 49.9 feet | | | | | |

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| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-11

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/20/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/20/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 50.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 7 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.323227° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366713° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

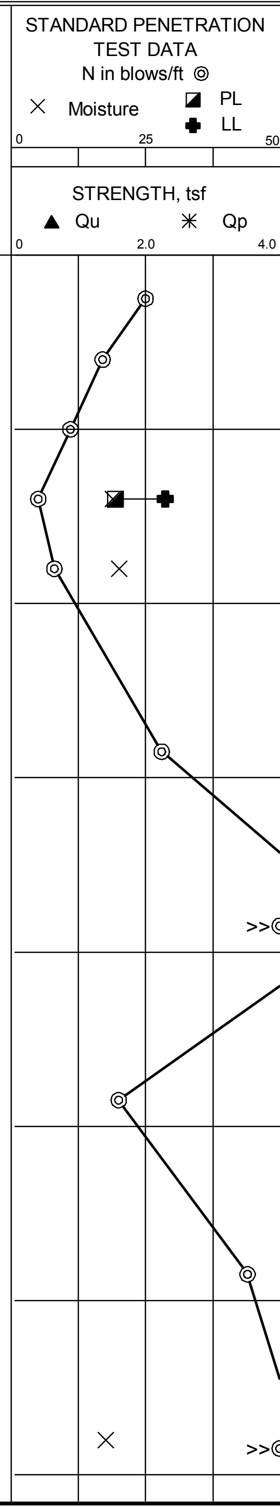
**Water**

| | |
|---|---|
| While Drilling | 7 feet |
| Upon Completion | 7 feet |
| Cave-In | 19 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| 7 | 0 | | | Approximately 6" of ASPHALT | | | | |
| | | 1 | 10 | Medium dense, moist, brown, **poorly graded GRAVEL (USCS : GP)** with sand | GP | 11-14-11 N=25 | | |
| 5 | | 2 | 18 | | | 7-8-9-9 N=17 | | |
| | | 3 | 16 | Loose to medium dense, moist, brown, **silty SAND (USCS : SM)** | SM | 5-6-5-5 N=11 | | |
| 0 | 5 | 4 | 17 | Medium stiff, moist, dark gray, **sandy CLAY (USCS : CL)** | CL | 3-2-3-4 N=5 | 19 | LL = 29 PL = 19 Fines=55.6% |
| | | 5 | 24 | | | 4-4-4-4 N=8 | 20 | |
| -5 | 10 | | | | | | | |
| | | 6 | 18 | Medium dense to very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 10-13-15 N=28 | | |
| -10 | 15 | 7 | 16 | | | 15-30-36 N=66 | | |
| -15 | 20 | 8 | 14 | | | 6-9-11 N=20 | | |
| -20 | 25 | 9 | 18 | | | 11-21-23 N=44 | | |
| -25 | 30 | 10 | 18 | Hard, moist, gray, **sandy SILT (USCS : ML)** | ML | 13-17-37 | 18 | |
| | 35 | | | | | | | |

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**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters, Middle River, MD

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-11

| | | | |
|---|---|---|---|
| DATE STARTED: | 4/20/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/20/18 | DRILLER: Nadal | LOGGED BY: Ethan |
| COMPLETION DEPTH | 50.0 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Hollow Stem Auger |
| ELEVATION: | 7 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.323227° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.366713° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

| Water | | |
|---|---|---|
| While Drilling | 7 | feet |
| Upon Completion | 7 | feet |
| Cave-In | 19 | feet |

BORING LOCATION:

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL 0 25 50 / STRENGTH, tsf ▲ Qu ✳ Qp 0 2.0 4.0 | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Hard, moist, gray, **sandy SILT (USCS : ML)** | | N=54 | | | |
| -30 | | | | | | | | | | | |
| | | | | 11 | 16 | | ML | 20-37-50/4" | 14 | | |
| | 40 | | | | | | | | | | |
| -35 | | | | | | | | | | | |
| | | | | 12 | 17 | Hard, moist, gray, **SILT (USCS : ML)** with sand | | 20-37-50/5" | 14 | | |
| | 45 | | | | | | | | | | |
| -40 | | | | | | | ML | | | | |
| | | | | 13 | 18 | | | 18-29-39 N=68 | 18 | >> | |
| | 50 | | | | | End of Boring approximately at 50 feet | | | | | |

# BORING B-12

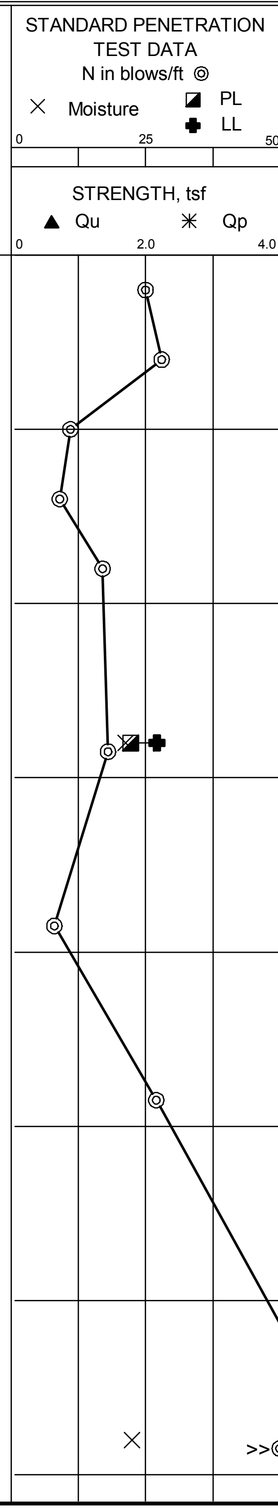
DATE STARTED: 4/23/18
DATE COMPLETED: 4/23/18
COMPLETION DEPTH: 99.8 ft
BENCHMARK: N/A
ELEVATION: 8 ft
LATITUDE: 39.324232°
LONGITUDE: -76.367021°
STATION: N/A OFFSET: N/A
REMARKS:

DRILL COMPANY: Connelly and Associates
DRILLER: Nadal LOGGED BY: Ethan
DRILL RIG: CME 55
DRILLING METHOD: Mud Rotary
SAMPLING METHOD: Standard
HAMMER TYPE: Automatic
EFFICIENCY: N/A
REVIEWED BY: V. Jha

**Water**
- While Drilling: 6 feet
- Upon Completion: DRY
- Cave-In: 0.5 feet

BORING LOCATION:
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | Blow counts | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| 8 | 0 | | | Medium dense, moist, brown, **poorly graded GRAVEL (USCS : GP)** with sand | GP | | | |
| | | 1 | 18 | Very stiff, moist, brown, **gravelly SILT (USCS : ML)** | ML | 8-15-10-10 N=25 | | |
| 5 | | 2 | 12 | Loose to medium dense, moist, gray, **poorly graded SAND (USCS : SP)** | SP | 10-15-13-12 N=28 | | |
| | 5 | 3 | 20 | | | 7-6-5-5 N=11 | | |
| | | 4 | 19 | | | 4-4-5-5 N=9 | | |
| 0 | | 5 | 22 | | | 6-8-9-8 N=17 | | |
| | 10 | | | | | | | |
| -5 | | 6 | 15 | Very stiff, moist, light brown, **SILT (USCS : ML)** | ML | 5-7-11 N=18 | 21 | LL = 27 PL = 22 Fines=94.2% |
| | 15 | | | | | | | |
| -10 | | 7 | 5 | Loose, moist, tan, **silty SAND (USCS : SM)** | SM | 3-4-4 N=8 | | |
| | 20 | | | | | | | |
| -15 | | 8 | 12 | Medium dense to very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 6-11-16 N=27 | | |
| | 25 | | | | | | | |
| -20 | | 9 | 12 | | | 23-41-50/5" | | |
| | 30 | | | | | | | |
| -25 | | 10 | 18 | Hard, moist, gray, **sandy SILT (USCS : ML)** | ML | 10-22-41 | 22 | |
| | 35 | | | | | | | |

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Telephone: (703) 698-9300

PROJECT NO.: 0512843-1
PROJECT: CP Crane Power Station
LOCATION: Bowleys Quarters
Middle River, MD

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-12

| | | | |
|---|---|---|---|
| DATE STARTED: | 4/23/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/23/18 | DRILLER: Nadal | LOGGED BY: Ethan |
| COMPLETION DEPTH | 99.8 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Mud Rotary |
| ELEVATION: | 8 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.324232° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.367021° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

**Water**
- While Drilling: 6 feet
- Upon Completion: DRY
- Cave-In: 0.5 feet

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 35 | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | N=63 | | |
| -30 | | 11 | 16 | | SP | 20-25-26 N=51 | | |
| | 40 | | | | | | | |
| -35 | | 12 | 18 | Hard, moist, gray, **sandy SILT (USCS : ML)** | ML | 20-36-50/6" | | |
| | 45 | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | | | | |
| -40 | | 13 | 14 | | SP | 24-30-30 N=60 | | |
| | 50 | | | | | | | |
| -45 | | 14 | 14 | Hard, moist, gray, **sandy CLAY (USCS : CL)** | CL | 14-35-30 N=65 | 23 | |
| | 55 | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | | | | |
| -50 | | 15 | 12 | | | 28-35-32 N=67 | | |
| | 60 | | | | SP | | | |
| -55 | | 16 | 16 | | | 17-28-50/4" | | |
| | 65 | | | | | | | |
| -60 | | 17 | 14 | | | 21-33-40 | | |
| | 70 | | | | | | | |

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL; 0 25 50
STRENGTH, tsf: ▲ Qu; ✳ Qp; 0 2.0 4.0

*Continued Next Page*

# BORING B-12

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/23/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/23/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 99.8 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Mud Rotary |
| **ELEVATION:** | 8 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324232° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.367021° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

| | |
|---|---|
| While Drilling | 6 feet |
| Upon Completion | DRY |
| Cave-In | 0.5 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL (0, 25, 50). STRENGTH, tsf: ▲ Qu; ✳ Qp (0, 2.0, 4.0)

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | SPT N | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | 70 | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | N=73 | | | |
| -65 | 75 | 18 | 14 | | | 32-39-45 N=84 | | >> | |
| -70 | 80 | 19 | 18 | | | 30-39-40 N=79 | | >> | |
| -75 | 85 | 20 | 14 | | | 31-21-28 N=49 | | | |
| -80 | 90 | 21 | 17 | | | 36-40-46 N=86 | | >> | |
| -85 | 95 | 22 | 8 | | | 39-50/4" | | >> | |
| -90 | | 23 | 15 | Hard, moist, gray, **SILT (USCS : ML)** | ML | 21-45-50/3" | 16 | | |
| | | | | End of Boring approximately at 99.8 feet | | | | | |

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Telephone: (703) 698-9300

**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters
Middle River, MD

The stratification lines represent approximate boundaries. The transition may be gradual.

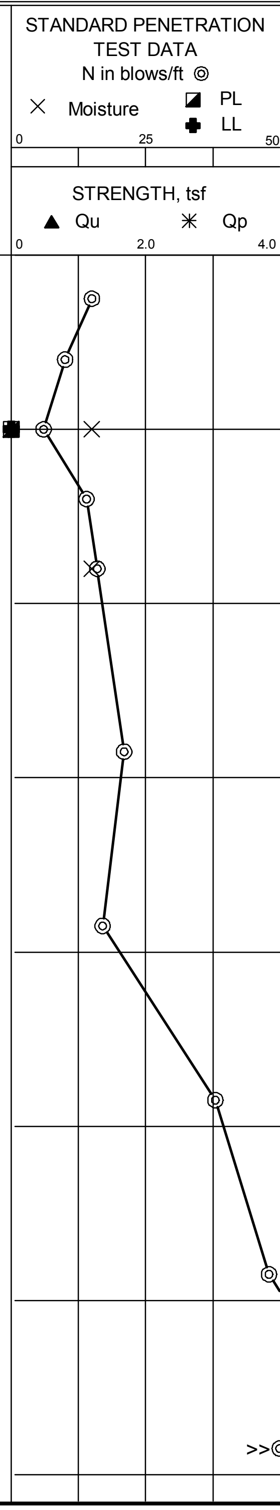
# BORING B-13

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/24/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/24/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 99.2 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Mud Rotary |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324172° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.36667° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**
- While Drilling: 6 feet
- Upon Completion: DRY
- Cave-In: 0.5 feet

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| 9 | 0 | | | Approximately 4" of ASPHALT | | | | |
| | | | | Approximately 3" of GRAVEL BASE | | | | |
| | | 1 | 12 | Loose to medium dense, moist, gray, **poorly graded SAND (USCS : SP)** | SP | 15-10-5 N=15 | | |
| | | 2 | 20 | | | 4-5-5-4 N=10 | | |
| 5 | 5 | 3 | 12 | Loose to medium dense, moist, gray, **silty SAND (USCS : SM)** | SM | 2-3-3-3 N=6 | 15 | Non-Plastic Fines=39.8% |
| | | 4 | 20 | | | 3-2-12-13 N=14 | | |
| 0 | 10 | 5 | 20 | Very stiff, moist, gray, **sandy SILT (USCS : ML)** | ML | 8-8-8-8 N=16 | 15 | |
| -5 | 15 | 6 | 15 | | | 4-8-13 N=21 | | |
| | | | | Medium dense to dense, moist, gray, **poorly graded SAND (USCS : SP)** | SP | | | |
| -10 | 20 | 7 | 10 | | | 7-7-10 N=17 | | |
| -15 | 25 | 8 | 16 | Hard, moist, gray, **sandy SILT (USCS : ML)** | ML | 10-16-22 N=38 | | |
| | | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | | | |
| -20 | 30 | 9 | 14 | | | 10-15-33 N=48 | | |
| -25 | 35 | 10 | 16 | | | 26-33-36 | | |

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**DATE STARTED:** 4/24/18
**DATE COMPLETED:** 4/24/18
**COMPLETION DEPTH** 99.2 ft
**BENCHMARK:** N/A
**ELEVATION:** 9 ft
**LATITUDE:** 39.324172°
**LONGITUDE:** -76.36667°
**STATION:** N/A **OFFSET:** N/A
**REMARKS:**

**DRILL COMPANY:** Connelly and Associates
**DRILLER:** Nadal **LOGGED BY:** Ethan
**DRILL RIG:** CME 55
**DRILLING METHOD:** Mud Rotary
**SAMPLING METHOD:** Standard
**HAMMER TYPE:** Automatic
**EFFICIENCY** N/A
**REVIEWED BY:** V. Jha

# BORING B-13

| Water | | |
|---|---|---|
| ▽ | While Drilling | 6 feet |
| ▼ | Upon Completion | DRY |
| ▽ | Cave-In | 0.5 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 35 | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | N=69 | | |
| -30 | 40 | 11 | 18 | Hard, moist, gray, **SILT (USCS : ML)** | ML | 13-16-31 N=47 | 19 | |
| -35 | 45 | 12 | 12 | | | 20-50/6" | 14 | |
| -40 | 50 | 13 | 12 | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 34-50/6" | | |
| -45 | 55 | 14 | 5 | | | 50/5" | | |
| -50 | 60 | 15 | 5 | | | 50/6" | | |
| -55 | 65 | 16 | 4 | | | 50/6" | | |
| -60 | 70 | 17 | 12 | | | 39-50/6" | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0

*Continued Next Page*

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**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters
Middle River, MD

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-13

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/24/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/24/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 99.2 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Mud Rotary |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324172° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.36667° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

| | | |
|---|---|---|
| ▽ | While Drilling | 6 feet |
| ▼ | Upon Completion | DRY |
| ▽ | Cave-In | 0.5 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL (0 – 25 – 50)
STRENGTH, tsf: ▲ Qu; ✳ Qp (0 – 2.0 – 4.0)

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | Blows | Moisture, % | N (SPT plot) | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | 70 | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | | | | |
| -65 | 75 | 18 | 16 | | | 25-29-43 N=72 | | >>◎ | |
| -70 | 80 | 19 | 5 | | | 50/5" | | >>◎ | |
| -75 | 85 | 20 | 18 | | | 37-39-38 N=77 | | >>◎ | |
| -80 | 90 | 21 | 16 | | | 38-36-37 N=73 | | >>◎ | |
| -85 | 95 | 22 | 10 | | | 18-20-19 N=39 | | ◎ | |
| -90 | | 23 | 8 | Hard, moist, gray, **sandy SILT (USCS : ML)** | ML | 36-50/2" | | >>◎ | |
| | | | | End of Boring approximately at 99.2 feet | | | | | |

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|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-14

| | | | |
|---|---|---|---|
| DATE STARTED: | 4/25/18 | DRILL COMPANY: | Connelly and Associates |
| DATE COMPLETED: | 4/25/18 | DRILLER: Nadal | LOGGED BY: Ethan |
| COMPLETION DEPTH | 99.3 ft | DRILL RIG: | CME 55 |
| BENCHMARK: | N/A | DRILLING METHOD: | Mud Rotary |
| ELEVATION: | 10 ft | SAMPLING METHOD: | Standard |
| LATITUDE: | 39.324146° | HAMMER TYPE: | Automatic |
| LONGITUDE: | -76.366472° | EFFICIENCY | N/A |
| STATION: N/A | OFFSET: N/A | REVIEWED BY: | V. Jha |
| REMARKS: | | | |

**Water**

| | | |
|---|---|---|
| While Drilling | 8 | feet |
| Upon Completion | DRY | |
| Cave-In | 0.5 | feet |

BORING LOCATION:

Bowleys Quarters, MD

STANDARD PENETRATION TEST DATA: N in blows/ft; Moisture; PL; LL (scale 0 – 25 – 50). STRENGTH, tsf: Qu; Qp (scale 0 – 2.0 – 4.0)

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | Blows / N | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | Dense, moist, gray, **poorly graded GRAVEL (USCS : GP)** with silt | GP | | | |
| | | 1 | 18 | Dense, moist, brown, **silty SAND (USCS : SM)** | SM | 12-13-29-25 N=42 | | |
| | | 2 | 24 | Medium dense to dense, moist, brown, **poorly graded SAND (USCS : SP)** | SP | 8-15-27-18 N=42 | | |
| 5 | 5 | 3 | 24 | | | 8-6-9-7 N=15 | | |
| | | 4 | 20 | | | 4-5-5-6 N=10 | | |
| | | 5 | 24 | Medium dense, moist, gray, **silty SAND (USCS : SM)** | SM | 9-8-9-10 N=17 | 13 | LL = 15<br>PL = 13<br>Fines=48.2% |
| 0 | 10 | | | | | | | |
| -5 | 15 | 6 | 16 | Stiff, moist, gray, **sandy SILT (USCS : ML)** | ML | 5-5-5 N=10 | 20 | |
| -10 | 20 | 7 | 12 | Loose, moist, gray, **poorly graded SAND (USCS : SP)** | SP | 5-4-5 N=9 | | |
| -15 | 25 | 8 | 12 | Stiff, moist, gray, **sandy SILT (USCS : ML)** | ML | 3-4-5 N=9 | 19 | |
| -20 | 30 | 9 | 12 | Medium dense, moist, gray, **poorly graded SAND (USCS : SP)** | SP | 5-6-8 N=14 | | |
| -25 | 35 | 10 | 16 | Stiff to hard, moist, gray, **SILT (USCS : ML)** | ML | 4-6-7 | 17 | |

*Continued Next Page*

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| | |
|---|---|
| PROJECT NO.: | 0512843-1 |
| PROJECT: | CP Crane Power Station |
| LOCATION: | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING B-14

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/25/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/25/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan |
| **COMPLETION DEPTH** | 99.3 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Mud Rotary |
| **ELEVATION:** | 10 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324146° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366472° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

| **Water** | | |
|---|---|---|
| ▽ | While Drilling | 8 feet |
| ▼ | Upon Completion | DRY |
| ▽ | Cave-In | 0.5 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Graphic Log | Sample Type | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | | Moisture, % | STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL 0 25 50 / STRENGTH, tsf ▲ Qu ✳ Qp 0 2.0 4.0 | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 35 | | | | | Stiff to hard, moist, gray, **SILT (USCS : ML)** | ML | N=13 | | | |
| | | | | 11 | 18 | | | 9-19-31 N=50 | 18 | | |
| -30 | 40 | | | | | | | | | | |
| | | | | 12 | 18 | | | 12-19-34 N=53 | 22 | >> | |
| -35 | 45 | | | | | | | | | | |
| | | | | 13 | 17 | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 32-35-50/5" | | | |
| -40 | 50 | | | | | | | | | | |
| | | | | 14 | 18 | | | 36-35-46 N=81 | | >> | |
| -45 | 55 | | | | | | | | | | |
| | | | | 15 | 12 | | | 45-50/6" | | >> | |
| -50 | 60 | | | | | | | | | | |
| | | | | 16 | 4 | | | 50/6" | | >> | |
| -55 | 65 | | | | | | | | | | |
| | | | | 17 | 15 | | | 28-43-50/6" | | | |
| -60 | 70 | | | | | | | | | | |

*Continued Next Page*

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| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

The stratification lines represent approximate boundaries. The transition may be gradual.

| | | | |
|---|---|---|---|
| **DATE STARTED:** 4/25/18 | **DRILL COMPANY:** Connelly and Associates | | |
| **DATE COMPLETED:** 4/25/18 | **DRILLER:** Nadal | **LOGGED BY:** Ethan | |
| **COMPLETION DEPTH** 99.3 ft | **DRILL RIG:** CME 55 | | |
| **BENCHMARK:** N/A | **DRILLING METHOD:** Mud Rotary | | |
| **ELEVATION:** 10 ft | **SAMPLING METHOD:** Standard | | |
| **LATITUDE:** 39.324146° | **HAMMER TYPE:** Automatic | | |
| **LONGITUDE:** -76.366472° | **EFFICIENCY** N/A | | |
| **STATION:** N/A **OFFSET:** N/A | **REVIEWED BY:** V. Jha | | |
| **REMARKS:** | | | |

# BORING B-14

| Water | | |
|---|---|---|
| While Drilling | 8 feet |
| Upon Completion | DRY |
| Cave-In | 0.5 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows per 6-inch (SS) | Moisture, % | N in blows/ft | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | 70 | | | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | | | | |
| | | 18 | 11 | | | 28-50/5" | | >> | |
| -65 | 75 | | | | | | | | |
| | | 19 | 11 | | | 31-50/5" | 14 | >> | |
| -70 | 80 | | | Hard, moist, gray, **SILT (USCS : ML)** | ML | | | | |
| | | 20 | 4 | Very dense, moist, tan, **poorly graded SAND (USCS : SP)** | SP | 50/6" | | >> | |
| -75 | 85 | | | | | | | | |
| | | 21 | 5 | | | 50/6" | | >> | |
| -80 | 90 | | | | | | | | |
| | | 22 | 4 | | | 50/6" | | >> | |
| -85 | 95 | | | | | | | | |
| | | 23 | 10 | | | 34-50/4" | | >> | |
| | | | | End of Boring approximately at 99.3 feet | | | | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0

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**PROJECT NO.:** 0512843-1
**PROJECT:** CP Crane Power Station
**LOCATION:** Bowleys Quarters
Middle River, MD

The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING I-1

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/19/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/19/18 | **DRILLER:** Nadal | **LOGGED BY:** Pavan |
| **COMPLETION DEPTH** | 10.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 9 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.32436° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366154° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

**Water**

| | |
|---|---|
| While Drilling | 4 feet |
| 24 hours | 7 feet |
| Cave-In | 6.5 feet |

**BORING LOCATION:**

Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | Approximately 3" of ASPHALT | | | | |
| | | | | Approximately 2" of GRAVEL BASE | | | | |
| | | | | Loose to medium dense, moist, dark gray and black, **poorly graded SAND (USCS : SP)** | SP | | | |
| | | 1 | 14 | | | 8-11-10 N=21 | | |
| | | 2 | 18 | | | 6-9-10-10 N=19 | | |
| 5 | | | | Loose to medium dense, moist, dark gray, **silty SAND (USCS : SM)** | SM | | | |
| | 5 | 3 | 24 | | | 4-5-4-6 N=9 | 13 | LL = 21 PL = 16 Fines=31.8% |
| | | 4 | 20 | | | 6-7-7-6 N=14 | | |
| 0 | | 5 | 24 | | | 7-8-4-5 N=12 | | |
| | 10 | | | End of Boring approximately at 10 feet | | | | |

STANDARD PENETRATION TEST DATA
N in blows/ft ◎
× Moisture ◪ PL ✚ LL
0 25 50
STRENGTH, tsf
▲ Qu ✳ Qp
0 2.0 4.0

| | |
|---|---|
| **PROJECT NO.:** | 0512843-1 |
| **PROJECT:** | CP Crane Power Station |
| **LOCATION:** | Bowleys Quarters |
| | Middle River, MD |

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The stratification lines represent approximate boundaries. The transition may be gradual.

# BORING I-2

| | | | |
|---|---|---|---|
| **DATE STARTED:** | 4/19/18 | **DRILL COMPANY:** | Connelly and Associates |
| **DATE COMPLETED:** | 4/19/18 | **DRILLER:** Nadal | **LOGGED BY:** Pavan |
| **COMPLETION DEPTH** | 10.0 ft | **DRILL RIG:** | CME 55 |
| **BENCHMARK:** | N/A | **DRILLING METHOD:** | Hollow Stem Auger |
| **ELEVATION:** | 8 ft | **SAMPLING METHOD:** | Standard |
| **LATITUDE:** | 39.324979° | **HAMMER TYPE:** | Automatic |
| **LONGITUDE:** | -76.366668° | **EFFICIENCY** | N/A |
| **STATION:** N/A | **OFFSET:** N/A | **REVIEWED BY:** | V. Jha |
| **REMARKS:** | | | |

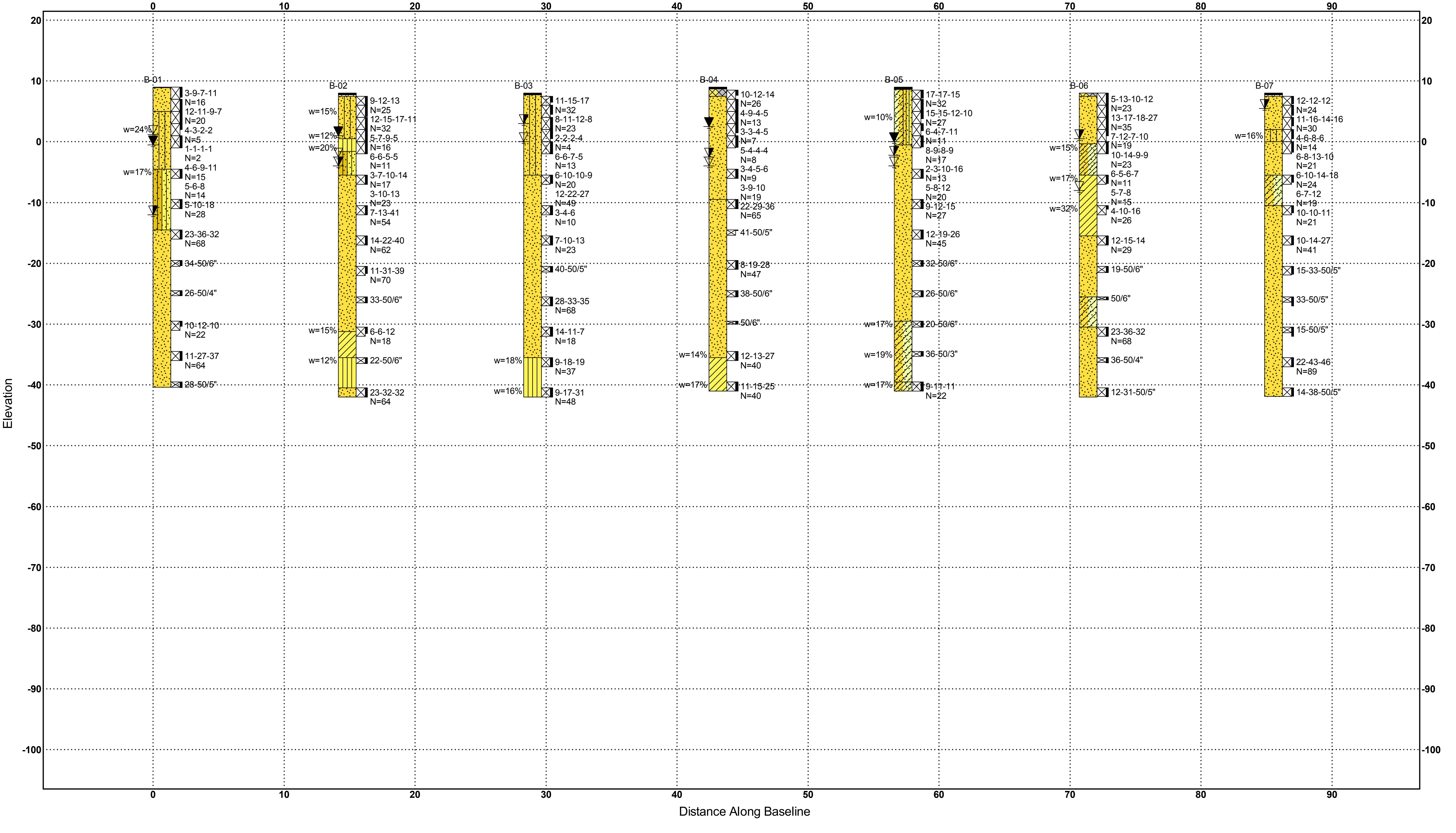
**Water**

| | |
|---|---|
| While Drilling | DRY |
| 24 hours | 6.5 feet |
| Cave-In | 6.2 feet |

**BORING LOCATION:**
Bowleys Quarters, MD

| Elevation (feet) | Depth, (feet) | Sample No. | Recovery (inches) | MATERIAL DESCRIPTION | USCS Classification | SPT Blows | N in blows/ft | Moisture, % | Additional Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | Approximately 6" of TOPSOIL | | | | | |
| | | 1 | 19 | Medium dense, moist, gray, **silty SAND (USCS : SM)** | SM | 1-3-10-13 | N=13 | | |
| 5 | | 2 | 18 | | SM | 9-10-11-9 | N=21 | | |
| | 5 | 3 | 24 | | SM | 6-8-6-6 | N=14 | 14 | Non-Plastic Fines=47.9% |
| | | 4 | 24 | | SM | 5-6-9-9 | N=15 | | |
| 0 | | | | Stiff, moist, purple, **SILT (USCS : ML)** | ML | | | | |
| | | 5 | 24 | | ML | 4-6-7-8 | N=13 | | |
| | 10 | | | End of Boring approximately at 10 feet | | | | | |

STANDARD PENETRATION TEST DATA: N in blows/ft ◎; × Moisture; PL; LL; scale 0, 25, 50
STRENGTH, tsf: ▲ Qu; ✳ Qp; scale 0, 2.0, 4.0

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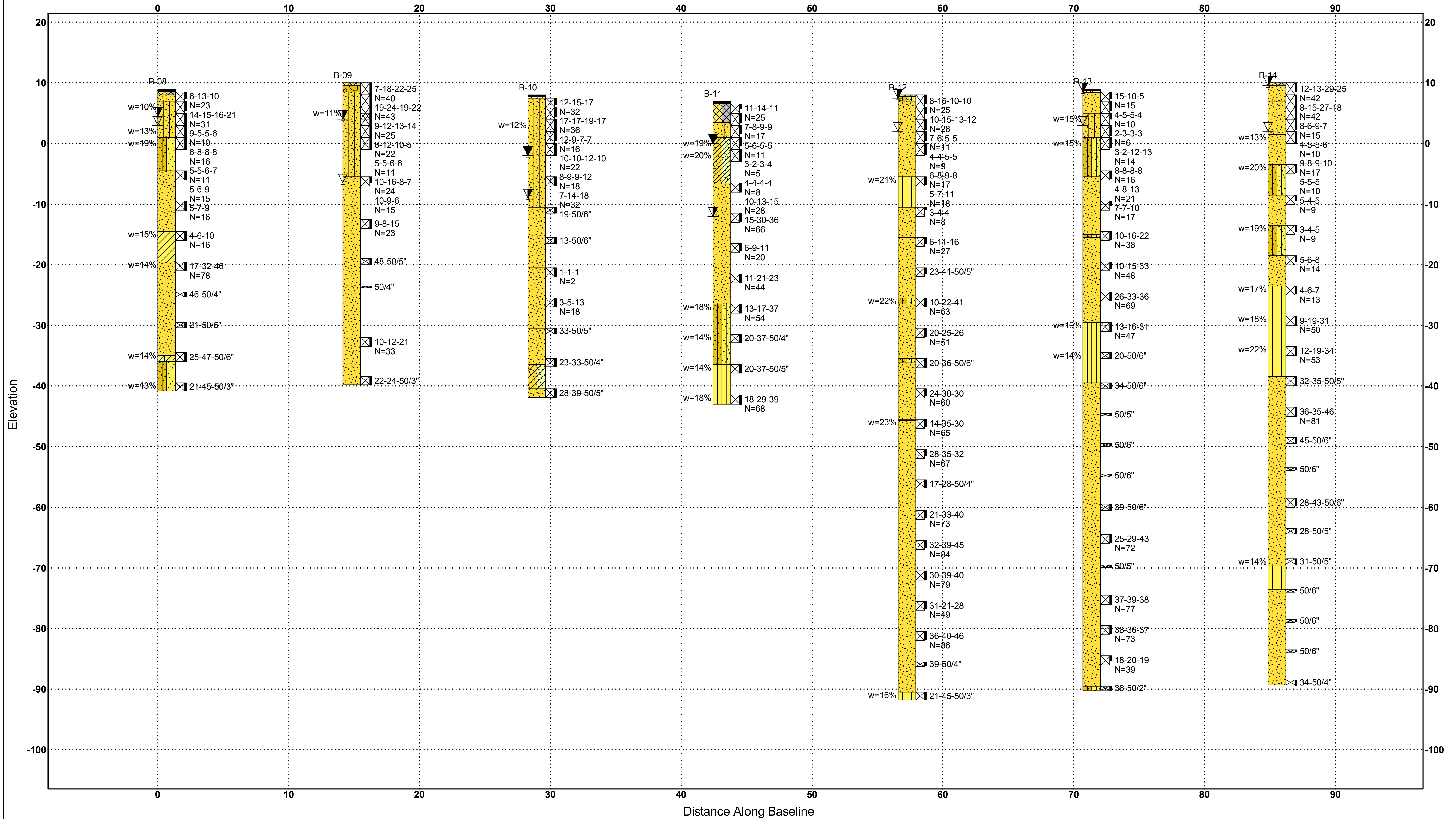
# Profile

CP Crane Power Station
PSI Project Number: 0512843-1

Bowleys Quarters
Middle River, MD

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# Profile

CP Crane Power Station
PSI Project Number: 0512843-1

Bowleys Quarters
Middle River, MD

# GENERAL NOTES

## SAMPLE IDENTIFICATION

The Unified Soil Classification System (USCS), AASHTO 1988 and ASTM designations D2487 and D-2488 are used to identify the encountered materials unless otherwise noted. Coarse-grained soils are defined as having more than 50% of their dry weight retained on a #200 sieve (0.075mm); they are described as: boulders, cobbles, gravel or sand. Fine-grained soils have less than 50% of their dry weight retained on a #200 sieve; they are defined as silts or clay depending on their Atterberg Limit attributes. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size.

## DRILLING AND SAMPLING SYMBOLS

SFA: Solid Flight Auger - typically 4" diameter flights, except where noted.
HSA: Hollow Stem Auger - typically 3¼" or 4¼ I.D. openings, except where noted.
M.R.: Mud Rotary - Uses a rotary head with Bentonite or Polymer Slurry
R.C.: Diamond Bit Core Sampler
H.A.: Hand Auger
P.A.: Power Auger - Handheld motorized auger

SS: Split-Spoon - 1 3/8" I.D., 2" O.D., except where noted.
ST: Shelby Tube - 3" O.D., except where noted.
RC: Rock Core
TC: Texas Cone
BS: Bulk Sample
PM: Pressuremeter
CPT-U: Cone Penetrometer Testing with Pore-Pressure Readings

## SOIL PROPERTY SYMBOLS

N: Standard "N" penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2-inch O.D. Split-Spoon.
$N_{60}$: A "N" penetration value corrected to an equivalent 60% hammer energy transfer efficiency (ETR)
$Q_u$: Unconfined compressive strength, TSF
$Q_p$: Pocket penetrometer value, unconfined compressive strength, TSF
w%: Moisture/water content, %
LL: Liquid Limit, %
PL: Plastic Limit, %
PI: Plasticity Index = (LL-PL),%
DD: Dry unit weight, pcf
▼,▽,▼ Apparent groundwater level at time noted

## RELATIVE DENSITY OF COARSE-GRAINED SOILS

| Relative Density | N - Blows/foot |
|---|---|
| Very Loose | 0 - 4 |
| Loose | 4 - 10 |
| Medium Dense | 10 - 30 |
| Dense | 30 - 50 |
| Very Dense | 50 - 80 |
| Extremely Dense | 80+ |

## ANGULARITY OF COARSE-GRAINED PARTICLES

| Description | Criteria |
|---|---|
| Angular: | Particles have sharp edges and relatively plane sides with unpolished surfaces |
| Subangular: | Particles are similar to angular description, but have rounded edges |
| Subrounded: | Particles have nearly plane sides, but have well-rounded corners and edges |
| Rounded: | Particles have smoothly curved sides and no edges |

## GRAIN-SIZE TERMINOLOGY

| Component | Size Range |
|---|---|
| Boulders: | Over 300 mm (>12 in.) |
| Cobbles: | 75 mm to 300 mm (3 in. to 12 in.) |
| Coarse-Grained Gravel: | 19 mm to 75 mm (¾ in. to 3 in.) |
| Fine-Grained Gravel: | 4.75 mm to 19 mm (No.4 to ¾ in.) |
| Coarse-Grained Sand: | 2 mm to 4.75 mm (No.10 to No.4) |
| Medium-Grained Sand: | 0.42 mm to 2 mm (No.40 to No.10) |
| Fine-Grained Sand: | 0.075 mm to 0.42 mm (No. 200 to No.40) |
| Silt: | 0.005 mm to 0.075 mm |
| Clay: | <0.005 mm |

## PARTICLE SHAPE

| Description | Criteria |
|---|---|
| Flat: | Particles with width/thickness ratio > 3 |
| Elongated: | Particles with length/width ratio > 3 |
| Flat & Elongated: | Particles meet criteria for both flat and elongated |

## RELATIVE PROPORTIONS OF FINES

| Descriptive Term | % Dry Weight |
|---|---|
| Trace: | < 5% |
| With: | 5% to 12% |
| Modifier: | >12% |

# GENERAL NOTES

(Continued)

## CONSISTENCY OF FINE-GRAINED SOILS

| $Q_U$ - TSF | N - Blows/foot | Consistency |
|---|---|---|
| 0 - 0.25 | 0 - 2 | Very Soft |
| 0.25 - 0.50 | 2 - 4 | Soft |
| 0.50 - 1.00 | 4 - 8 | Firm (Medium Stiff) |
| 1.00 - 2.00 | 8 - 15 | Stiff |
| 2.00 - 4.00 | 15 - 30 | Very Stiff |
| 4.00 - 8.00 | 30 - 50 | Hard |
| 8.00+ | 50+ | Very Hard |

## MOISTURE CONDITION DESCRIPTION

| Description | Criteria |
|---|---|
| Dry: | Absence of moisture, dusty, dry to the touch |
| Moist: | Damp but no visible water |
| Wet: | Visible free water, usually soil is below water table |

## RELATIVE PROPORTIONS OF SAND AND GRAVEL

| Descriptive Term | % Dry Weight |
|---|---|
| Trace: | < 15% |
| With: | 15% to 30% |
| Modifier: | >30% |

## STRUCTURE DESCRIPTION

| Description | Criteria |
|---|---|
| Stratified: | Alternating layers of varying material or color with layers at least ¼-inch (6 mm) thick |
| Laminated: | Alternating layers of varying material or color with layers less than ¼-inch (6 mm) thick |
| Fissured: | Breaks along definite planes of fracture with little resistance to fracturing |
| Slickensided: | Fracture planes appear polished or glossy, sometimes striated |

| Description | Criteria |
|---|---|
| Blocky: | Cohesive soil that can be broken down into small angular lumps which resist further breakdown |
| Lensed: | Inclusion of small pockets of different soils |
| Layer: | Inclusion greater than 3 inches thick (75 mm) |
| Seam: | Inclusion 1/8-inch to 3 inches (3 to 75 mm) thick extending through the sample |
| Parting: | Inclusion less than 1/8-inch (3 mm) thick |

## SCALE OF RELATIVE ROCK HARDNESS

| $Q_U$ - TSF | Consistency |
|---|---|
| 2.5 - 10 | Extremely Soft |
| 10 - 50 | Very Soft |
| 50 - 250 | Soft |
| 250 - 525 | Medium Hard |
| 525 - 1,050 | Moderately Hard |
| 1,050 - 2,600 | Hard |
| >2,600 | Very Hard |

## ROCK BEDDING THICKNESSES

| Description | Criteria |
|---|---|
| Very Thick Bedded | Greater than 3-foot (>1.0 m) |
| Thick Bedded | 1-foot to 3-foot (0.3 m to 1.0 m) |
| Medium Bedded | 4-inch to 1-foot (0.1 m to 0.3 m) |
| Thin Bedded | 1¼-inch to 4-inch (30 mm to 100 mm) |
| Very Thin Bedded | ½-inch to 1¼-inch (10 mm to 30 mm) |
| Thickly Laminated | 1/8-inch to ½-inch (3 mm to 10 mm) |
| Thinly Laminated | 1/8-inch or less "paper thin" (<3 mm) |

## ROCK VOIDS

| Voids | Void Diameter |
|---|---|
| Pit | <6 mm (<0.25 in) |
| Vug | 6 mm to 50 mm (0.25 in to 2 in) |
| Cavity | 50 mm to 600 mm (2 in to 24 in) |
| Cave | >600 mm (>24 in) |

## GRAIN-SIZED TERMINOLOGY

(Typically Sedimentary Rock)

| Component | Size Range |
|---|---|
| Very Coarse Grained | >4.76 mm |
| Coarse Grained | 2.0 mm - 4.76 mm |
| Medium Grained | 0.42 mm - 2.0 mm |
| Fine Grained | 0.075 mm - 0.42 mm |
| Very Fine Grained | <0.075 mm |

## ROCK QUALITY DESCRIPTION

| Rock Mass Description | RQD Value |
|---|---|
| Excellent | 90 -100 |
| Good | 75 - 90 |
| Fair | 50 - 75 |
| Poor | 25 -50 |
| Very Poor | Less than 25 |

## DEGREE OF WEATHERING

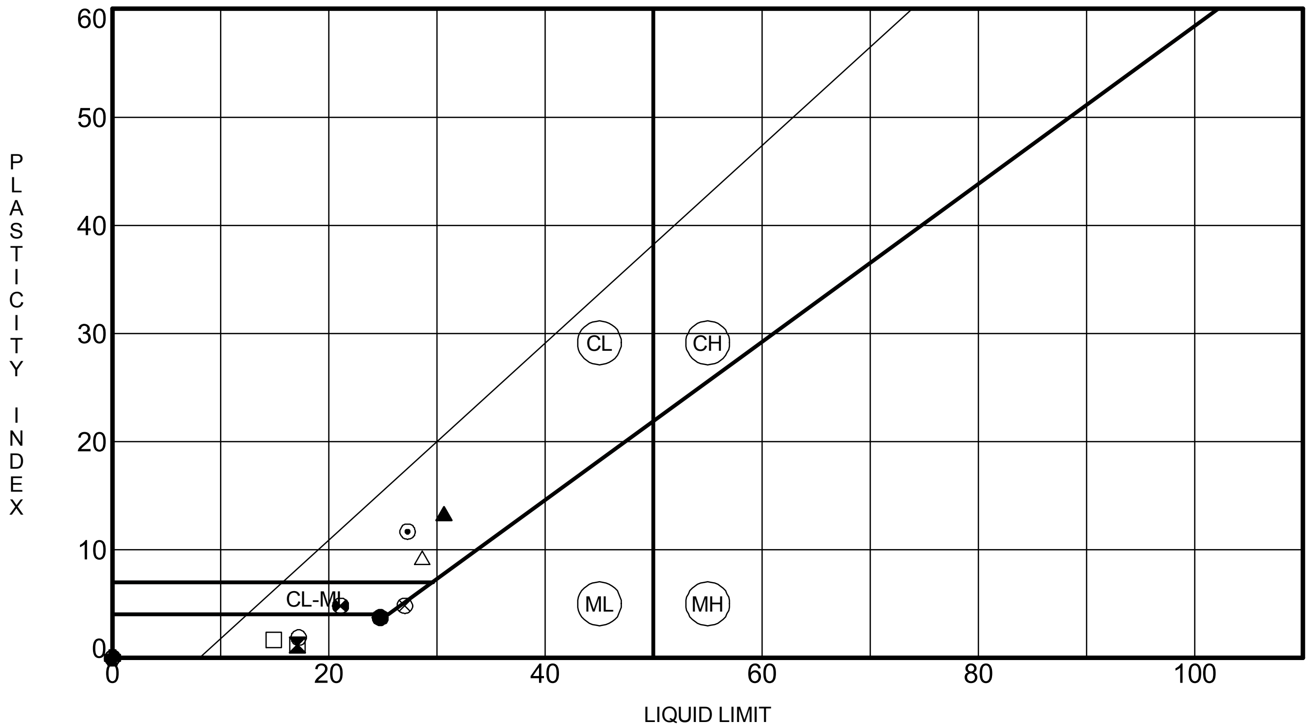
| | |
|---|---|
| Slightly Weathered: | Rock generally fresh, joints stained and discoloration extends into rock up to 25 mm (1 in), open joints may contain clay, core rings under hammer impact. |
| Weathered: | Rock mass is decomposed 50% or less, significant portions of the rock show discoloration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

# SOIL CLASSIFICATION CHART

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

| MAJOR DIVISIONS | | | SYMBOLS GRAPH | SYMBOLS LETTER | TYPICAL DESCRIPTIONS |
|---|---|---|---|---|---|
| COARSE GRAINED SOILS | GRAVEL AND GRAVELLY SOILS | CLEAN GRAVELS | | GW | WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES |
| | | (LITTLE OR NO FINES) | | GP | POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES |
| | MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE | GRAVELS WITH FINES | | GM | SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES |
| | | (APPRECIABLE AMOUNT OF FINES) | | GC | CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES |
| MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE | SAND AND SANDY SOILS | CLEAN SANDS | | SW | WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES |
| | | (LITTLE OR NO FINES) | | SP | POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES |
| | MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE | SANDS WITH FINES | | SM | SILTY SANDS, SAND - SILT MIXTURES |
| | | (APPRECIABLE AMOUNT OF FINES) | | SC | CLAYEY SANDS, SAND - CLAY MIXTURES |
| FINE GRAINED SOILS | SILTS AND CLAYS | LIQUID LIMIT LESS THAN 50 | | ML | INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY |
| | | | | CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS |
| | | | | OL | ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY |
| MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE | SILTS AND CLAYS | LIQUID LIMIT GREATER THAN 50 | | MH | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS |
| | | | | CH | INORGANIC CLAYS OF HIGH PLASTICITY |
| | | | | OH | ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS |
| HIGHLY ORGANIC SOILS | | | | PT | PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS |

# APPENDIX D: LABORATORY TESTING RESULTS




| | Boring | Depth (ft) | LL | PL | PI | Fines | Classification (*Visual) |
|---|---|---|---|---|---|---|---|
| ● | B-01 | 14.0 | 25 | 21 | 4 | 58.2 | sandy SILT (ML) |
| ⊠ | B-02 | 3.0 | 17 | 16 | 1 | 35.5 | silty SAND (SM) |
| ▲ | B-06 | 9.0 | 31 | 17 | 14 | 66.6 | sandy CLAY (CL) |
| ★ | B-07 | 7.0 | NP | NP | NP | 28.2 | silty SAND (SM) |
| ⊙ | B-08 | 24.0 | 27 | 16 | 11 | 92.0 | lean CLAY (CL) |
| ✪ | B-09 | 5.0 | NP | NP | NP | 37.0 | silty SAND (SM) |
| ○ | B-10 | 5.0 | 17 | 15 | 2 | 45.5 | silty SAND (SM) |
| △ | B-11 | 7.0 | 29 | 19 | 10 | 55.6 | sandy CLAY (CL) |
| ⊗ | B-12 | 14.0 | 27 | 22 | 5 | 94.2 | SILT (ML) |
| ⊕ | B-13 | 5.0 | NP | NP | NP | 39.8 | silty SAND (SM) |
| □ | B-14 | 9.0 | 15 | 13 | 2 | 48.2 | silty SAND (SM) |
| ◉ | I-1 | 5.0 | 21 | 16 | 5 | 31.8 | silty SAND (SM) |
| ◑ | I-2 | 5.0 | NP | NP | NP | 47.9 | silty SAND (SM) |

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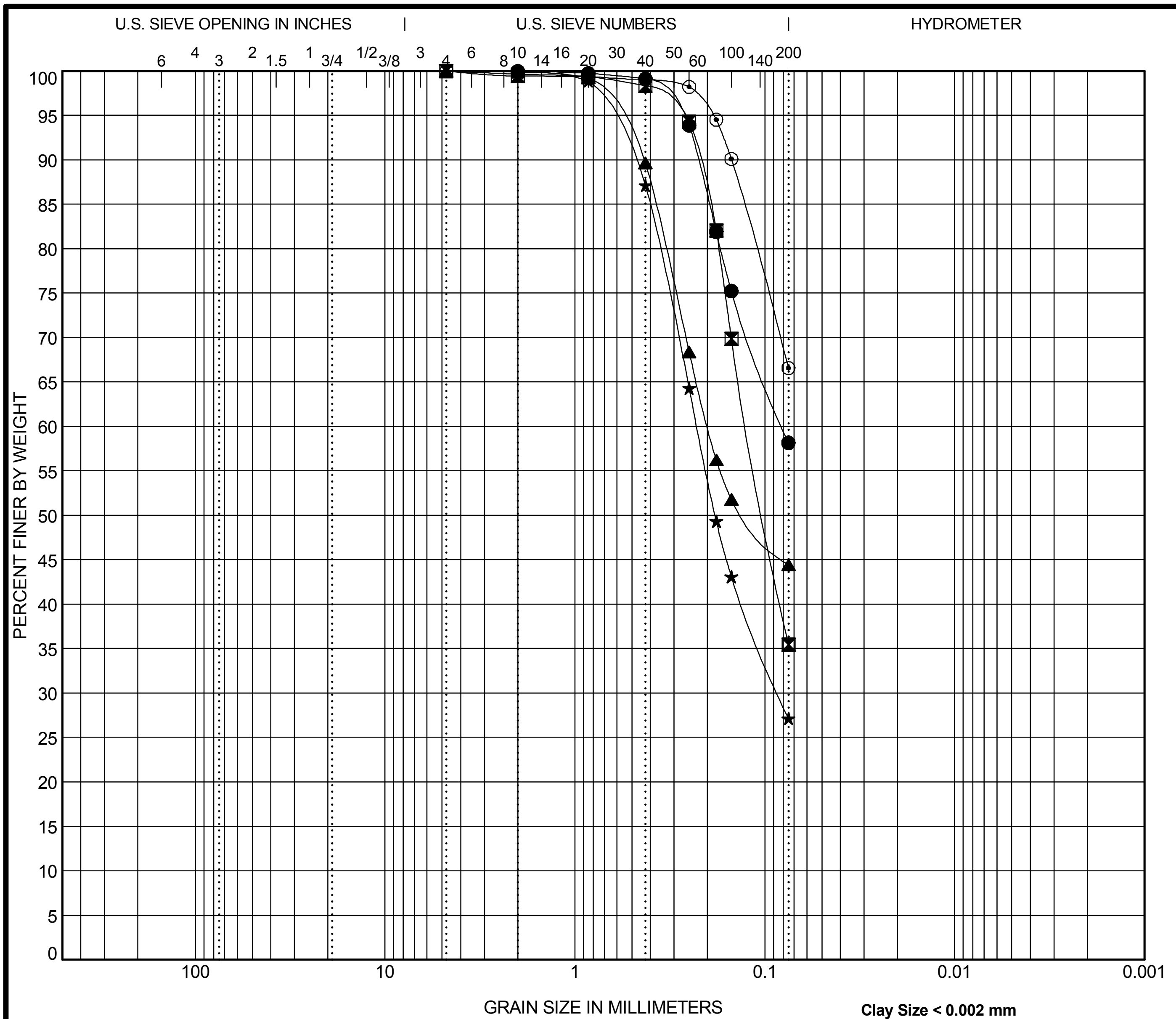
# ATTERBERG LIMIT RESULTS

PSI Job No.: 0512843-1
Project: CP Crane
Location: Bowleys Quarters
Middle River, MD




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| Specimen Identification | | | Classification | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|---|
| ● | B-01 | 14.0 | sandy SILT (ML) | 25 | 21 | 4 | | |
| ⌧ | B-02 | 3.0 | silty SAND (SM) | 17 | 16 | 1 | | |
| ▲ | B-04 | 44.0 | silty, clayey SAND (SC-SM) | | | | | |
| ★ | B-05 | 5.0 | silty, clayey SAND (SC-SM) | | | | | |
| ⊙ | B-06 | 9.0 | sandy CLAY (CL) | 31 | 17 | 14 | | |

| Specimen Identification | | | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|---|
| ● | B-01 | 14.0 | 2 | 0.081 | | | 0.0 | 41.8 | 58.2 | |
| ⌧ | B-02 | 3.0 | 4.75 | 0.123 | | | 0.0 | 64.5 | 35.5 | |
| ▲ | B-04 | 44.0 | 4.75 | 0.199 | | | 0.0 | 55.6 | 44.4 | |
| ★ | B-05 | 5.0 | 2 | 0.227 | 0.085 | | 0.0 | 72.9 | 27.1 | |
| ⊙ | B-06 | 9.0 | 4.75 | | | | 0.0 | 33.4 | 66.6 | |

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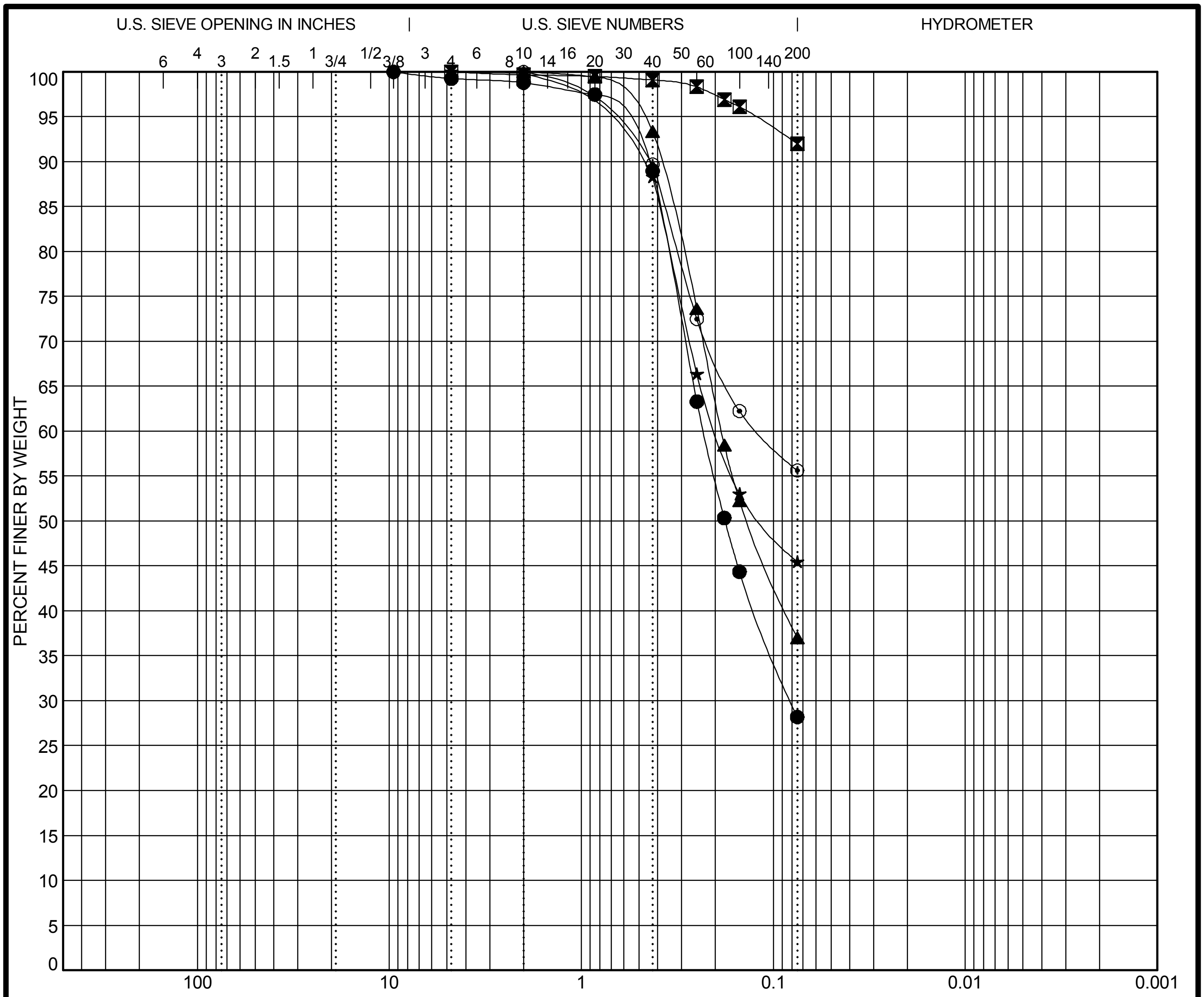
## GRAIN SIZE DISTRIBUTION

Project: CP Crane
PSI Job No.: 0512843-1
Location: Bowleys Quarters
Middle River, MD




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| | Specimen Identification | | Classification | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|---|
| ● | B-07 | 7.0 | silty SAND (SM) | NP | NP | NP | | |
| ⧗ | B-08 | 24.0 | lean CLAY (CL) | 27 | 16 | 11 | | |
| ▲ | B-09 | 5.0 | silty SAND (SM) | NP | NP | NP | | |
| ★ | B-10 | 5.0 | silty SAND (SM) | 17 | 15 | 2 | | |
| ⊙ | B-11 | 7.0 | sandy CLAY (CL) | 29 | 19 | 10 | | |

| | Specimen Identification | | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|---|
| ● | B-07 | 7.0 | 9.5 | 0.23 | 0.081 | | 0.7 | 71.1 | 28.2 | |
| ⧗ | B-08 | 24.0 | 4.75 | | | | 0.0 | 8.0 | 92.0 | |
| ▲ | B-09 | 5.0 | 2 | 0.186 | | | 0.0 | 63.0 | 37.0 | |
| ★ | B-10 | 5.0 | 4.75 | 0.196 | | | 0.0 | 54.5 | 45.5 | |
| ⊙ | B-11 | 7.0 | 2 | 0.119 | | | 0.0 | 44.4 | 55.6 | |

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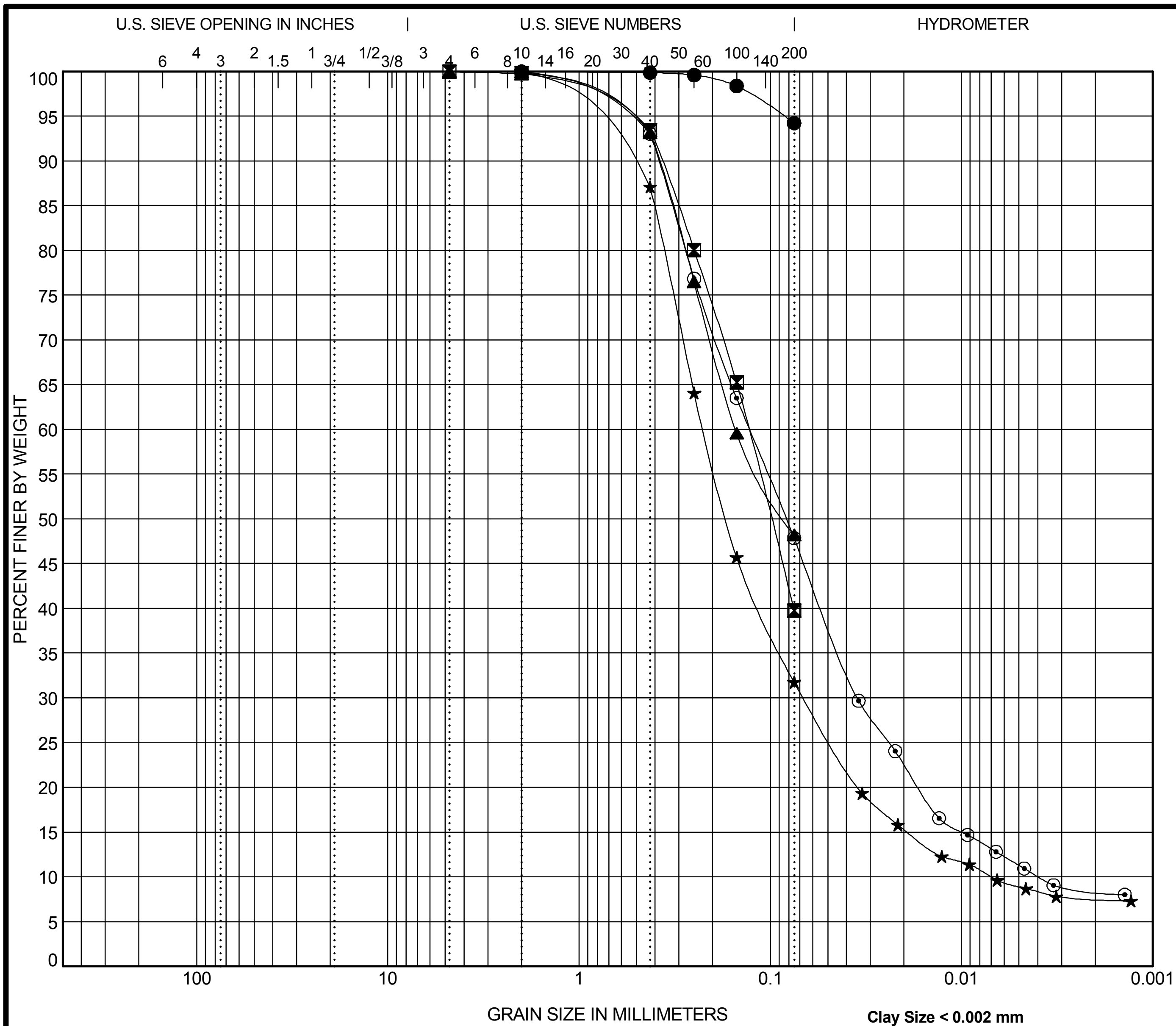
## GRAIN SIZE DISTRIBUTION

Project: CP Crane
PSI Job No.: 0512843-1
Location: Bowleys Quarters
Middle River, MD




**Clay Size < 0.002 mm**

| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| | Specimen Identification | | Classification | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|---|
| ● | **B-12** | **14.0** | **SILT (ML)** | **27** | **22** | **5** | | |
| ⧗ | **B-13** | **5.0** | **silty SAND (SM)** | **NP** | **NP** | **NP** | | |
| ▲ | **B-14** | **9.0** | **silty SAND (SM)** | **15** | **13** | **2** | | |
| ★ | **I-1** | **5.0** | **silty SAND (SM)** | **21** | **16** | **5** | **2.86** | **31.94** |
| ⊙ | **I-2** | **5.0** | **silty SAND (SM)** | **NP** | **NP** | **NP** | **2.42** | **32.52** |

| | Specimen Identification | | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|---|
| ● | **B-12** | **14.0** | **2** | | | | **0.0** | **5.8** | **94.2** | |
| ⧗ | **B-13** | **5.0** | **4.75** | **0.13** | | | **0.0** | **60.2** | **39.8** | |
| ▲ | **B-14** | **9.0** | **4.75** | **0.152** | | | **0.0** | **51.8** | **48.2** | |
| ★ | **I-1** | **5.0** | **2** | **0.223** | **0.067** | **0.007** | **0.0** | **68.2** | **24.2** | **7.5** |
| ⊙ | **I-2** | **5.0** | **2** | **0.128** | **0.035** | **0.004** | **0.0** | **52.1** | **39.4** | **8.4** |

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# GRAIN SIZE DISTRIBUTION

Project: CP Crane
PSI Job No.: 0512843-1
Location: Bowleys Quarters
Middle River, MD

## *Oxidation-Reduction Potential of Soil*
## *ASTM G200-09*

| | | | |
|---|---|---|---|
| Client | Professional Service Industries, Inc. (PSI) | | |
| Client Project | 0512843-1 CP Crane | Date Tested: | 5/29/2018 |
| Project No. | 40251 | Date Received: | 5/29/2018 |

| | | |
|---|---|---|
| Boring | B-6,7,8,13,14 | |
| Depth | 2.0'-6.0' | |
| Sample | Composite | |
| Lab Sample ID | 40251001 | |

| | | |
|---|---|---|
| Time Sampled | unknown | |

| **Measurements** | | | **Units** |
|---|---|---|---|
| 1 | 163 | | mV |
| 2 | 171 | | mV |
| 3 | 158 | | mV |
| Average | 164 | | |
| Time | 3:30PM | | |
| Ambient Temp (oC) | 24.7 | | |

| **ORP Meter** | | **Calibration Solution** | | |
|---|---|---|---|---|
| Manufacturer | Accumet Basic | Purchase Date | **12/15/2017** | |
| Model # | AB 15 | Expiration Date | **11/18/2018** | |
| Serial # | AB81206922 | | | |
| **ORP Probe** | | Calibration Check. | | |
| Manufacturer | Atlas-Scientific | Cal. Solution | 200mV | |
| Model # | Sen-102O | 1st Reading | 174mV | <30mV Difference Cal. Solution |
| Purchase Date | 9/13/2013 | 2nd Reading | 176mV | <10mV difference 1st Reading |
| | | | **Pass** | |

Input Validation: MAC    Reviewed By: ALO    Date: 6/4/2018

## Corrosivity Testing

Client Professional Service Industries, Inc. (PSI)
Client Project 0512843-1 CP Crane
Project No. 40251

| Lab Sample ID | Boring | Depth | Sample | Sample Received | Matrix | pH AASHTO T289 Result | pH Date Tested | pH Tested By | Chloride AASHTO T291 (Method A) Result mg/kg (ppm) | Chloride Date Tested | Chloride Tested By | Sulfate AASHTO T290 (Method B) Result mg/kg (ppm) | Sulfate Date Tested | Sulfate Tested By | Sulfide AWWA 4500-$S^{2-}$ A.4c Result | Sulfide Date Tested | Sulfide Tested By | Soil Resistivity AASHTO T288 Result, Ohm-cm | Soil Resistivity Date Tested | Soil Resistivity Tested By | Soil ORP ASTM G200 Average, mV | Soil ORP Date Tested | Soil ORP Tested By |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40251001 | B-6,7,8,13,14 | 2.0'-6.0' | Composite | 5/29/2018 | Soil | 7.3 | 5/29/2018 | MC | 75 | 5/31/2018 | MC | 236 | 5/30/2018 | MC | Low | 5/29/2018 | MC | 1,500 | 5/31/2018 | MC | 164 | 5/29/2018 | MC |

Input Validation: MAC Reviewed By: Date: 6/4/2018

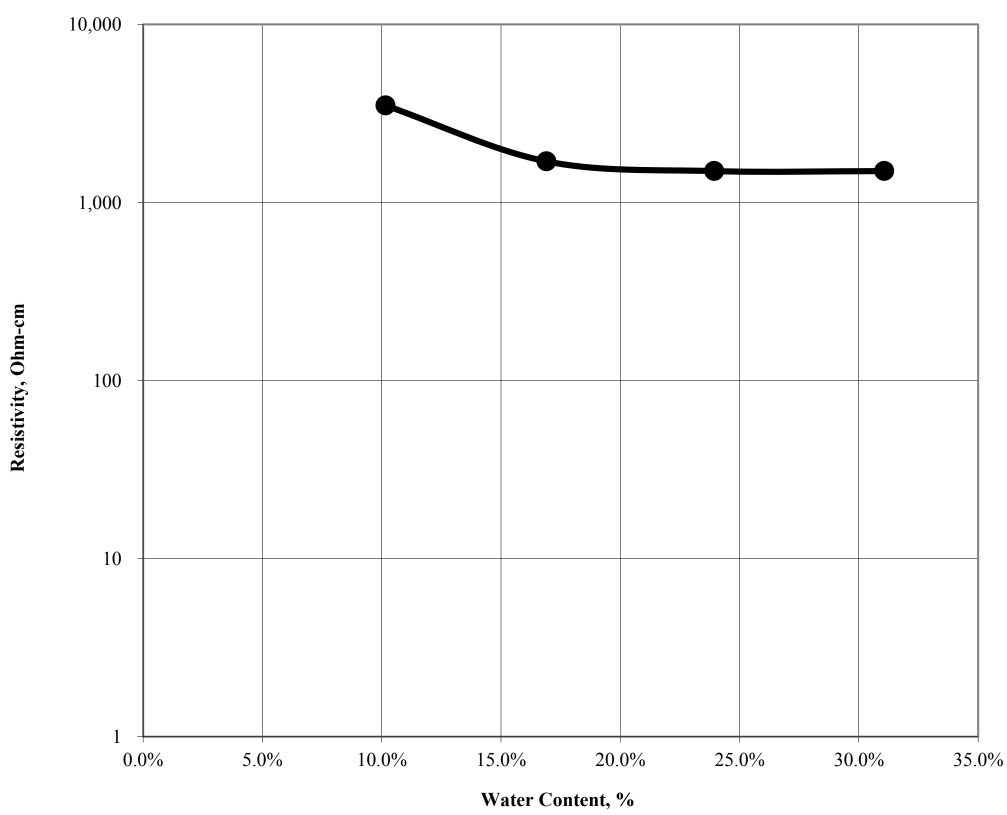
## Minimum Laboratory Soil Resistivity
### AASHTO - T288 Mod (4 electrode method)

| | | | |
|---|---|---|---|
| Client | Professional Service Industries, Inc. (PSI) | Boring | B-6,7,8,13,14 |
| Client Project | 0512843-1 CP Crane | Depth | 2.0'-6.0' |
| Project No. | 40251 | Sample | Composite |
| | | Lab Sample No. | 40251001 |

| SOIL BOX PARAMETERS | |
|---|---|
| Soil Box Length, cm | 11.15 |
| Soil Box Area, cm^2 | 7.20 |
| Electrode Spacing, cm | 7.20 |
| Soil Box Factor, cm (Area/Spacing) | 1 |
| Soil Box Volume, cc | 80 |

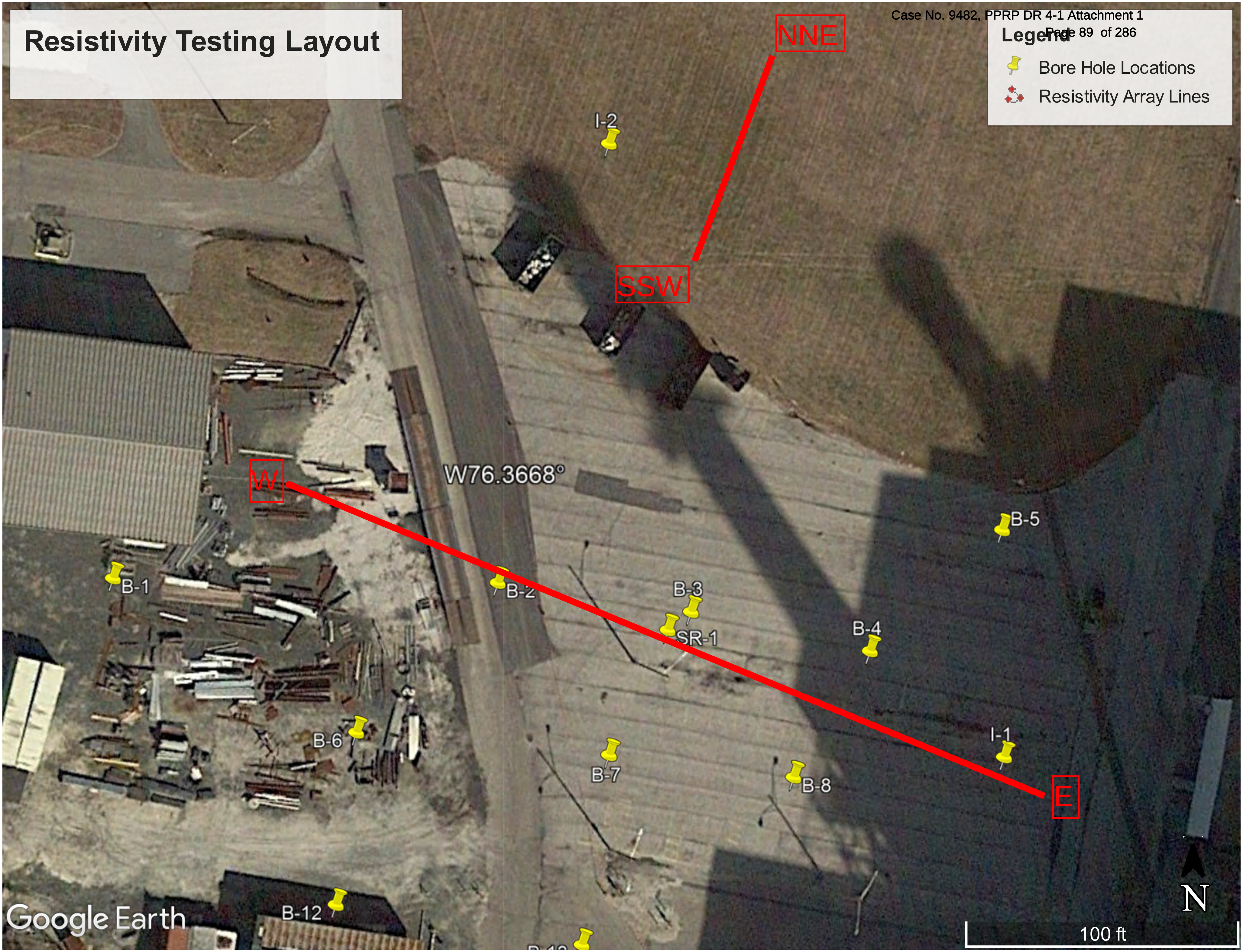
| MINIMUM RESISTIVITY TESTED | |
|---|---|
| WC at Min. Resistivity Tested, % | 23.9% |
| Min. Resistivity Tested, Ohm-cm | 1,500 |

| Water Content | | | | | Resistivity Ohm-cm | % Change |
|---|---|---|---|---|---|---|
| Tare # | Tare+WS grams | Tare+DS grams | Tare wt. grams | Water Content % | | |
| 232 | 46.65 | 43.81 | 15.88 | 10.2% | 3,500 | NA |
| 639 | 48.50 | 43.82 | 16.15 | 16.9% | 1,700 | 51% |
| 641 | 66.93 | 57.13 | 16.19 | 23.9% | 1,500 | 12% |
| 662 | 70.78 | 57.85 | 16.23 | 31.1% | 1,500 | 0% |
| | | | | | | |




Input Validation: . MAC Reviewed By: ALO Date Tested: 5/31/2018

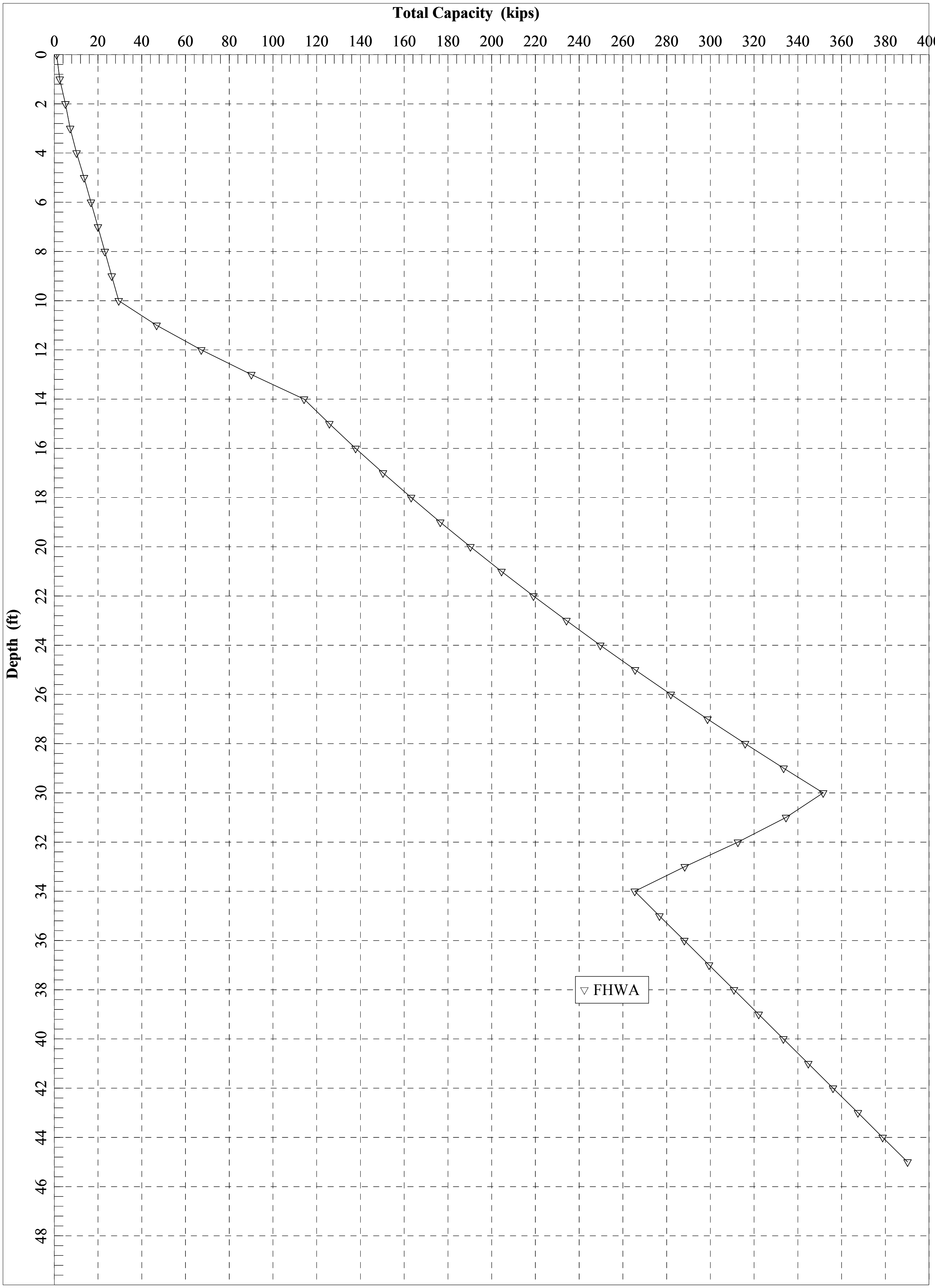
# APPENDIX E: SOIL RESISTIVITY TESTING


Resistivity Testing Layout
Legend
Bore Hole Locations
Resistivity Array Lines
NNE
SSW
W
E
I-2
W76.3668°
B-1
B-2
B-3
SR-1
B-4
B-5
B-6
B-7
B-8
I-1
B-12
Google Earth
100 ft
N

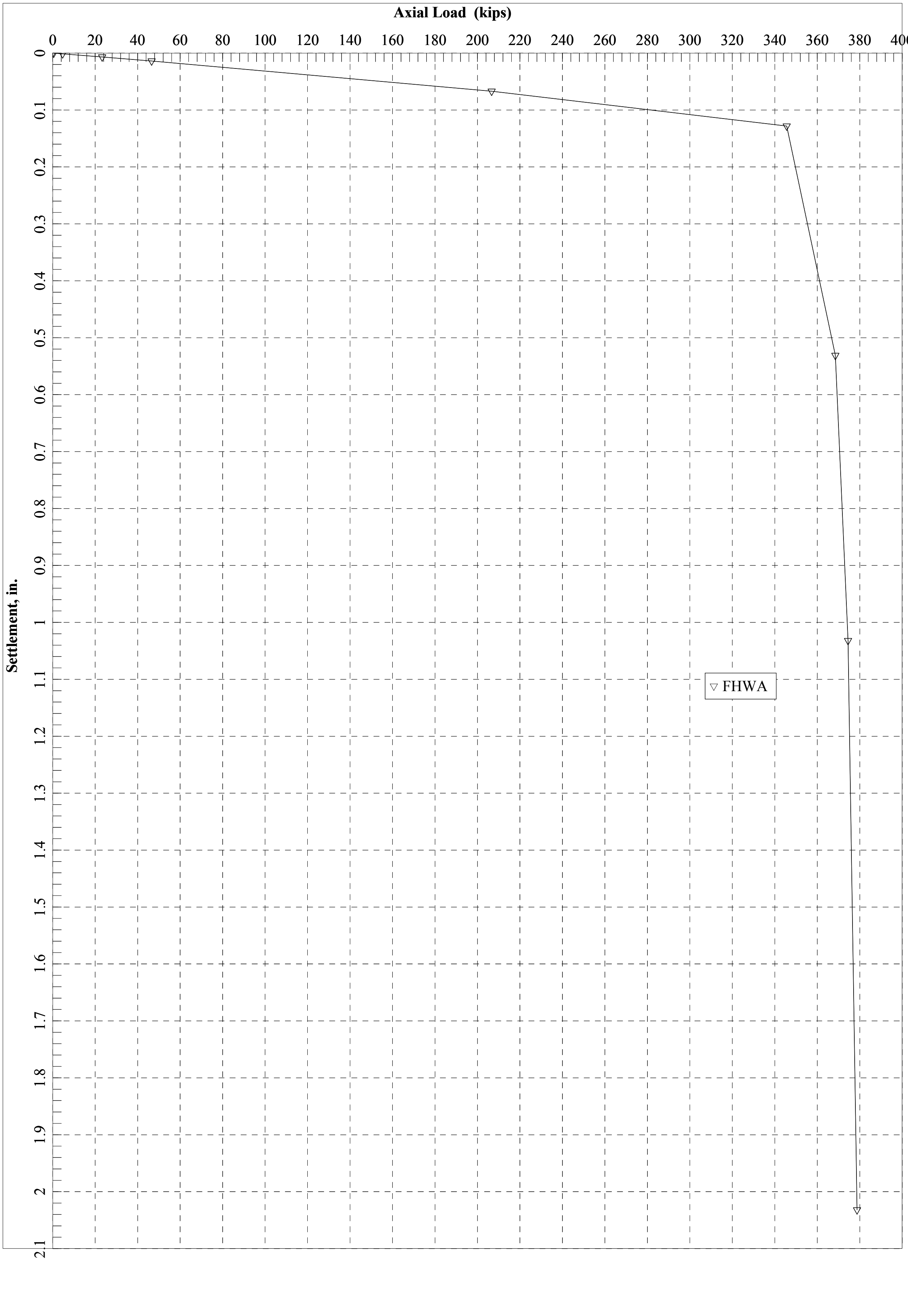
# Appendix F:
# APile analysis report (H-pile)

**Boring: B-11**
**Equipment: Liquid tanks**

# Ultimate Axial capacity Vs depth for the given H12x53



# Ultimate Pile settlement for given H12x53



CpCrane_ HP12x53 Pile_B11.ap7o

```
===========================================================================

                 APILE for Windows, Version 2015.7.8

                  Serial Number :  138584419

                  A Program for Analyzing the Axial Capacity
                  and Short-term Settlement of Driven Piles
                            under Axial Loading.
                (c) Copyright ENSOFT, Inc., 1987-2015
                      All Rights Reserved

===========================================================================


This program is licensed to :

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Path to file locations      : P:\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys
Quarters, MD\Engineering & Resources\Apile_analysis\
Name of input data file     : CpCrane_ HP12x53 Pile_B11.ap7d
Name of output file         : CpCrane_ HP12x53 Pile_B11.ap7o
Name of plot output file    : CpCrane_ HP12x53 Pile_B11.ap7p

---------------------------------------------------------------------------
                     Time and Date of Analysis
---------------------------------------------------------------------------

          Date:  June 01, 2018     Time:  19:44:34


1
     *********************
     * INPUT INFORMATION *
     *********************



     CP-Crane

     DESIGNER   : SS

     JOB NUMBER : 0512843


     METHOD FOR UNIT LOAD TRANSFERS :

     - FHWA (Federal Highway Administration)
       Unfactored Unit Side Friction and Unit Side Resistance are used.
```

CpCrane_ HP12x53 Pile_B11.ap7o

COMPUTATION METHOD(S) FOR PILE CAPACITY :

- FHWA (Federal Highway Administration)

TYPE OF LOADING :
- COMPRESSION

PILE TYPE :

H-Pile/Steel Pile

DATA FOR AXIAL STIFFNESS :

- MODULUS OF ELASTICITY = 0.290E+08 PSI
- CROSS SECTION AREA = 141.90 IN2

NONCIRCULAR PILE PROPERTIES :

- TOTAL PILE LENGTH, TL = 45.00 FT.
- PILE STICKUP LENGTH, PSL = 0.00 FT.
- ZERO FRICTION LENGTH, ZFL = 0.00 FT.
- PERIMETER OF PILE = 47.70 IN.
- TIP AREA OF PILE = 141.90 IN2
- INCREMENT OF PILE LENGTH USED IN COMPUTATION = 1.00 FT.

SOIL INFORMATIONS :

| DEPTH FT. | SOIL TYPE | LATERAL EARTH PRESSURE | EFFECTIVE UNIT WEIGHT LB/CF | FRICTION ANGLE DEGREES | BEARING CAPACITY FACTOR |
|---|---|---|---|---|---|
| 0.00 | SAND | 0.00 | 115.00 | 31.00 | 0.00 |
| 3.00 | SAND | 0.00 | 115.00 | 31.00 | 0.00 |
| 3.00 | CLAY | 0.00 | 52.60 | 0.00 | 0.00 |
| 12.00 | CLAY | 0.00 | 52.60 | 0.00 | 0.00 |
| 12.00 | SAND | 0.00 | 72.60 | 38.00 | 0.00 |
| 32.00 | SAND | 0.00 | 72.60 | 38.00 | 0.00 |
| 32.00 | CLAY | 0.00 | 62.60 | 0.00 | 0.00 |
| 50.00 | CLAY | 0.00 | 62.20 | 0.00 | 0.00 |

CpCrane_ HP12x53 Pile_B11.ap7o

| MAXIMUM UNIT FRICTION KSF | MAXIMUM UNIT BEARING KSF | UNDISTURB SHEAR STRENGTH KSF | REMOLDED SHEAR STRENGTH KSF | BLOW COUNT | UNIT SKIN FRICTION KSF | UNIT END BEARING KSF |
|---|---|---|---|---|---|---|
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 |

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
WERE SET TO BE 0.10E+08 BECAUSE THE USER DOES NOT
PLAN TO LIMIT THE COMPUTED DATA.

| DEPTH FT. | LRFD FACTOR ON UNIT FRICTION | LRFD FACTOR ON UNIT BEARING |
|---|---|---|
| 0.00 | 1.000 | 1.000 |
| 3.00 | 1.000 | 1.000 |
| 3.00 | 1.000 | 1.000 |
| 12.00 | 1.000 | 1.000 |
| 12.00 | 1.000 | 1.000 |
| 32.00 | 1.000 | 1.000 |
| 32.00 | 1.000 | 1.000 |
| 50.00 | 1.000 | 1.000 |

1

**********************
* COMPUTATION RESULT *
**********************

**********************
* FED. HWY. METHOD *
**********************

| PILE PENETRATION FT. | TOTAL SKIN FRICTION KIP | END BEARING KIP | ULTIMATE CAPACITY KIP |
|---|---|---|---|
| 0.00 | 0.0 | 1.1 | 1.1 |
| 1.00 | 0.1 | 2.3 | 2.5 |
| 2.00 | 0.6 | 4.5 | 5.1 |
| 3.00 | 1.3 | 6.0 | 7.3 |
| 4.00 | 3.3 | 6.9 | 10.2 |

| | | | |
|---|---|---|---|
| 5.00 | 6.5 | 7.1 | 13.6 |
| 6.00 | 9.7 | 7.1 | 16.8 |
| 7.00 | 12.9 | 7.1 | 20.0 |
| 8.00 | 16.1 | 7.1 | 23.1 |
| 9.00 | 19.2 | 7.1 | 26.3 |
| 10.00 | 22.4 | 7.1 | 29.5 |
| 11.00 | 25.6 | 21.2 | 46.8 |
| 12.00 | 28.8 | 38.4 | 67.2 |
| 13.00 | 33.0 | 57.1 | 90.1 |
| 14.00 | 38.5 | 75.7 | 114.2 |
| 15.00 | 44.4 | 81.4 | 125.8 |
| 16.00 | 50.7 | 87.1 | 137.8 |
| 17.00 | 57.5 | 92.8 | 150.3 |
| 18.00 | 64.7 | 98.5 | 163.2 |
| 19.00 | 72.3 | 104.2 | 176.5 |
| 20.00 | 80.4 | 109.9 | 190.3 |
| 21.00 | 88.9 | 115.6 | 204.5 |
| 22.00 | 97.8 | 121.3 | 219.1 |
| 23.00 | 107.2 | 127.0 | 234.2 |
| 24.00 | 116.9 | 132.7 | 249.7 |
| 25.00 | 127.1 | 138.4 | 265.6 |
| 26.00 | 137.8 | 144.1 | 281.9 |
| 27.00 | 148.8 | 149.8 | 298.7 |
| 28.00 | 160.3 | 155.5 | 315.9 |
| 29.00 | 172.3 | 161.2 | 333.5 |
| 30.00 | 184.6 | 166.9 | 351.6 |
| 31.00 | 197.4 | 137.2 | 334.6 |
| 32.00 | 210.6 | 102.0 | 312.6 |
| 33.00 | 223.0 | 65.3 | 288.3 |
| 34.00 | 234.3 | 31.0 | 265.4 |
| 35.00 | 245.7 | 31.0 | 276.7 |
| 36.00 | 257.0 | 31.0 | 288.1 |
| 37.00 | 268.4 | 31.0 | 299.4 |
| 38.00 | 279.7 | 31.0 | 310.8 |
| 39.00 | 291.1 | 31.0 | 322.1 |
| 40.00 | 302.4 | 31.0 | 333.4 |
| 41.00 | 313.7 | 31.0 | 344.8 |
| 42.00 | 325.1 | 31.0 | 356.1 |
| 43.00 | 336.4 | 31.0 | 367.5 |
| 44.00 | 347.8 | 31.0 | 378.8 |
| 45.00 | 359.1 | 31.0 | 390.2 |

NOTES:
- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN
  IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION
  OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

```
**************************************************
* COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
* CURVES FOR AXIAL LOADING                       *
```

CpCrane_ HP12x53 Pile_B11.ap7o
**********************************************

| T-Z CURVE NO. | NO. OF POINTS | DEPTH TO CURVE FT. | LOAD TRANSFER PSI | PILE MOVEMENT IN. |
|---|---|---|---|---|
| 1 | 10 | 0.0000E+00 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.7609E-01 | 0.1000E-01 |
| | | | 0.1522E+00 | 0.2000E-01 |
| | | | 0.3044E+00 | 0.4000E-01 |
| | | | 0.4565E+00 | 0.6000E-01 |
| | | | 0.6087E+00 | 0.8000E-01 |
| | | | 0.6848E+00 | 0.9000E-01 |
| | | | 0.7609E+00 | 0.1000E+00 |
| | | | 0.7609E+00 | 0.5000E+00 |
| | | | 0.7609E+00 | 0.2000E+01 |
| 2 | 10 | 0.1525E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1015E+00 | 0.1000E-01 |
| | | | 0.2029E+00 | 0.2000E-01 |
| | | | 0.4058E+00 | 0.4000E-01 |
| | | | 0.6087E+00 | 0.6000E-01 |
| | | | 0.8116E+00 | 0.8000E-01 |
| | | | 0.9131E+00 | 0.9000E-01 |
| | | | 0.1015E+01 | 0.1000E+00 |
| | | | 0.1015E+01 | 0.5000E+00 |
| | | | 0.1015E+01 | 0.2000E+01 |
| 3 | 10 | 0.2958E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2403E+00 | 0.1000E-01 |
| | | | 0.4807E+00 | 0.2000E-01 |
| | | | 0.9614E+00 | 0.4000E-01 |
| | | | 0.1442E+01 | 0.6000E-01 |
| | | | 0.1923E+01 | 0.8000E-01 |
| | | | 0.2163E+01 | 0.9000E-01 |
| | | | 0.2403E+01 | 0.1000E+00 |
| | | | 0.2403E+01 | 0.5000E+00 |
| | | | 0.2403E+01 | 0.2000E+01 |
| 4 | 10 | 0.3000E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1364E+01 | 0.2429E-01 |
| | | | 0.2274E+01 | 0.4707E-01 |
| | | | 0.3410E+01 | 0.8655E-01 |
| | | | 0.4092E+01 | 0.1215E+00 |
| | | | 0.4547E+01 | 0.1518E+00 |
| | | | 0.4092E+01 | 0.3037E+00 |
| | | | 0.4092E+01 | 0.4555E+00 |
| | | | 0.4092E+01 | 0.7592E+00 |
| | | | 0.4092E+01 | 0.3037E+01 |
| 5 | 10 | 0.7525E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1667E+01 | 0.2429E-01 |

| | | | | |
|---|---|---|---|---|
| | | | 0.2778E+01 | 0.4707E-01 |
| | | | 0.4167E+01 | 0.8655E-01 |
| | | | 0.5000E+01 | 0.1215E+00 |
| | | | 0.5556E+01 | 0.1518E+00 |
| | | | 0.5000E+01 | 0.3037E+00 |
| | | | 0.5000E+01 | 0.4555E+00 |
| | | | 0.5000E+01 | 0.7592E+00 |
| | | | 0.5000E+01 | 0.3037E+01 |
| 6 | 10 | 0.1196E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1940E+01 | 0.2429E-01 |
| | | | 0.3234E+01 | 0.4707E-01 |
| | | | 0.4851E+01 | 0.8655E-01 |
| | | | 0.5821E+01 | 0.1215E+00 |
| | | | 0.6468E+01 | 0.1518E+00 |
| | | | 0.5821E+01 | 0.3037E+00 |
| | | | 0.5821E+01 | 0.4555E+00 |
| | | | 0.5821E+01 | 0.7592E+00 |
| | | | 0.5821E+01 | 0.3037E+01 |
| 7 | 10 | 0.1200E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.8481E+00 | 0.1000E-01 |
| | | | 0.1696E+01 | 0.2000E-01 |
| | | | 0.3392E+01 | 0.4000E-01 |
| | | | 0.5089E+01 | 0.6000E-01 |
| | | | 0.6785E+01 | 0.8000E-01 |
| | | | 0.7633E+01 | 0.9000E-01 |
| | | | 0.8481E+01 | 0.1000E+00 |
| | | | 0.8481E+01 | 0.5000E+00 |
| | | | 0.8481E+01 | 0.2000E+01 |
| 8 | 10 | 0.2203E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1671E+01 | 0.1000E-01 |
| | | | 0.3341E+01 | 0.2000E-01 |
| | | | 0.6683E+01 | 0.4000E-01 |
| | | | 0.1002E+02 | 0.6000E-01 |
| | | | 0.1337E+02 | 0.8000E-01 |
| | | | 0.1504E+02 | 0.9000E-01 |
| | | | 0.1671E+02 | 0.1000E+00 |
| | | | 0.1671E+02 | 0.5000E+00 |
| | | | 0.1671E+02 | 0.2000E+01 |
| 9 | 10 | 0.3196E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2236E+01 | 0.1000E-01 |
| | | | 0.4472E+01 | 0.2000E-01 |
| | | | 0.8944E+01 | 0.4000E-01 |
| | | | 0.1342E+02 | 0.6000E-01 |
| | | | 0.1789E+02 | 0.8000E-01 |
| | | | 0.2012E+02 | 0.9000E-01 |
| | | | 0.2236E+02 | 0.1000E+00 |
| | | | 0.2236E+02 | 0.5000E+00 |
| | | | 0.2236E+02 | 0.2000E+01 |
| 10 | 10 | 0.3200E+02 | | |

| | | | | |
|---|---|---|---|---|
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.6218E+01 | 0.2429E-01 |
| | | | 0.1036E+02 | 0.4707E-01 |
| | | | 0.1555E+02 | 0.8655E-01 |
| | | | 0.1865E+02 | 0.1215E+00 |
| | | | 0.2073E+02 | 0.1518E+00 |
| | | | 0.1865E+02 | 0.3037E+00 |
| | | | 0.1865E+02 | 0.4555E+00 |
| | | | 0.1865E+02 | 0.7592E+00 |
| | | | 0.1865E+02 | 0.3037E+01 |
| 11 | 10 | 0.4103E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5945E+01 | 0.2429E-01 |
| | | | 0.9908E+01 | 0.4707E-01 |
| | | | 0.1486E+02 | 0.8655E-01 |
| | | | 0.1783E+02 | 0.1215E+00 |
| | | | 0.1982E+02 | 0.1518E+00 |
| | | | 0.1783E+02 | 0.3037E+00 |
| | | | 0.1783E+02 | 0.4555E+00 |
| | | | 0.1783E+02 | 0.7592E+00 |
| | | | 0.1783E+02 | 0.3037E+01 |
| 12 | 10 | 0.4996E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5945E+01 | 0.2429E-01 |
| | | | 0.9908E+01 | 0.4707E-01 |
| | | | 0.1486E+02 | 0.8655E-01 |
| | | | 0.1783E+02 | 0.1215E+00 |
| | | | 0.1982E+02 | 0.1518E+00 |
| | | | 0.1783E+02 | 0.3037E+00 |
| | | | 0.1783E+02 | 0.4555E+00 |
| | | | 0.1783E+02 | 0.7592E+00 |
| | | | 0.1783E+02 | 0.3037E+01 |

| TIP LOAD KIP | TIP MOVEMENT IN. |
|---|---|
| 0.0000E+00 | 0.0000E+00 |
| 0.1940E+01 | 0.7592E-02 |
| 0.3880E+01 | 0.1518E-01 |
| 0.7760E+01 | 0.3037E-01 |
| 0.1552E+02 | 0.1974E+00 |
| 0.2328E+02 | 0.6377E+00 |
| 0.2794E+02 | 0.1108E+01 |
| 0.3104E+02 | 0.1518E+01 |
| 0.3104E+02 | 0.2278E+01 |
| 0.3104E+02 | 0.3037E+01 |

LOAD VERSUS SETTLEMENT CURVE
***************************

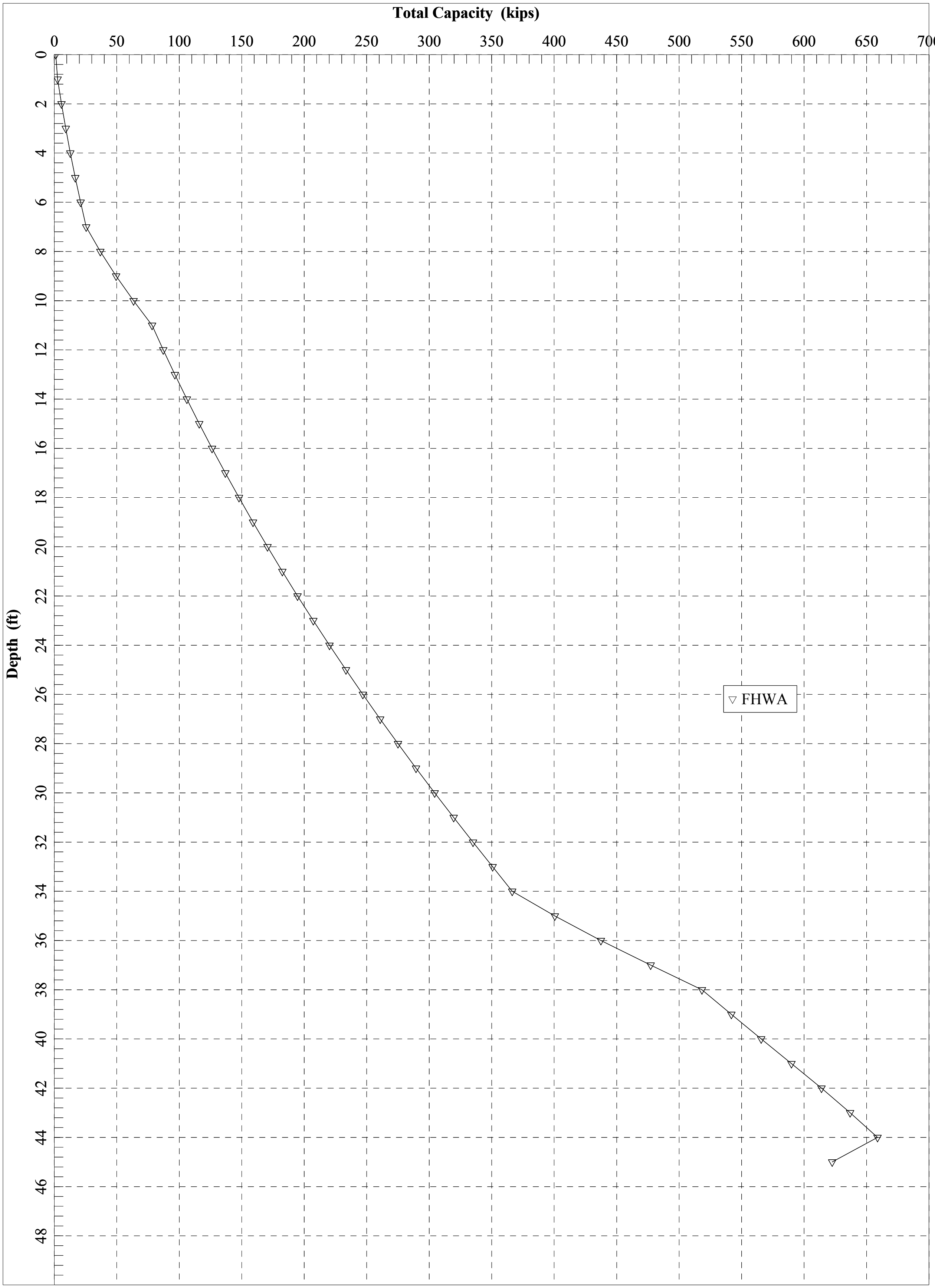
CpCrane_ HP12x53 Pile_B11.ap7o

| TOP LOAD KIP | TOP MOVEMENT IN. | TIP LOAD KIP | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.4656E+00 | 0.1392E-03 | 0.2555E-01 | 0.1000E-03 |
| 0.4656E+01 | 0.1392E-02 | 0.2555E+00 | 0.1000E-02 |
| 0.2328E+02 | 0.6959E-02 | 0.1278E+01 | 0.5000E-02 |
| 0.4656E+02 | 0.1392E-01 | 0.2555E+01 | 0.1000E-01 |
| 0.2067E+03 | 0.6714E-01 | 0.8672E+01 | 0.5000E-01 |
| 0.3456E+03 | 0.1283E+00 | 0.1100E+02 | 0.1000E+00 |
| 0.3685E+03 | 0.5311E+00 | 0.2085E+02 | 0.5000E+00 |
| 0.3745E+03 | 0.1032E+01 | 0.2686E+02 | 0.1000E+01 |
| 0.3787E+03 | 0.2032E+01 | 0.3104E+02 | 0.2000E+01 |

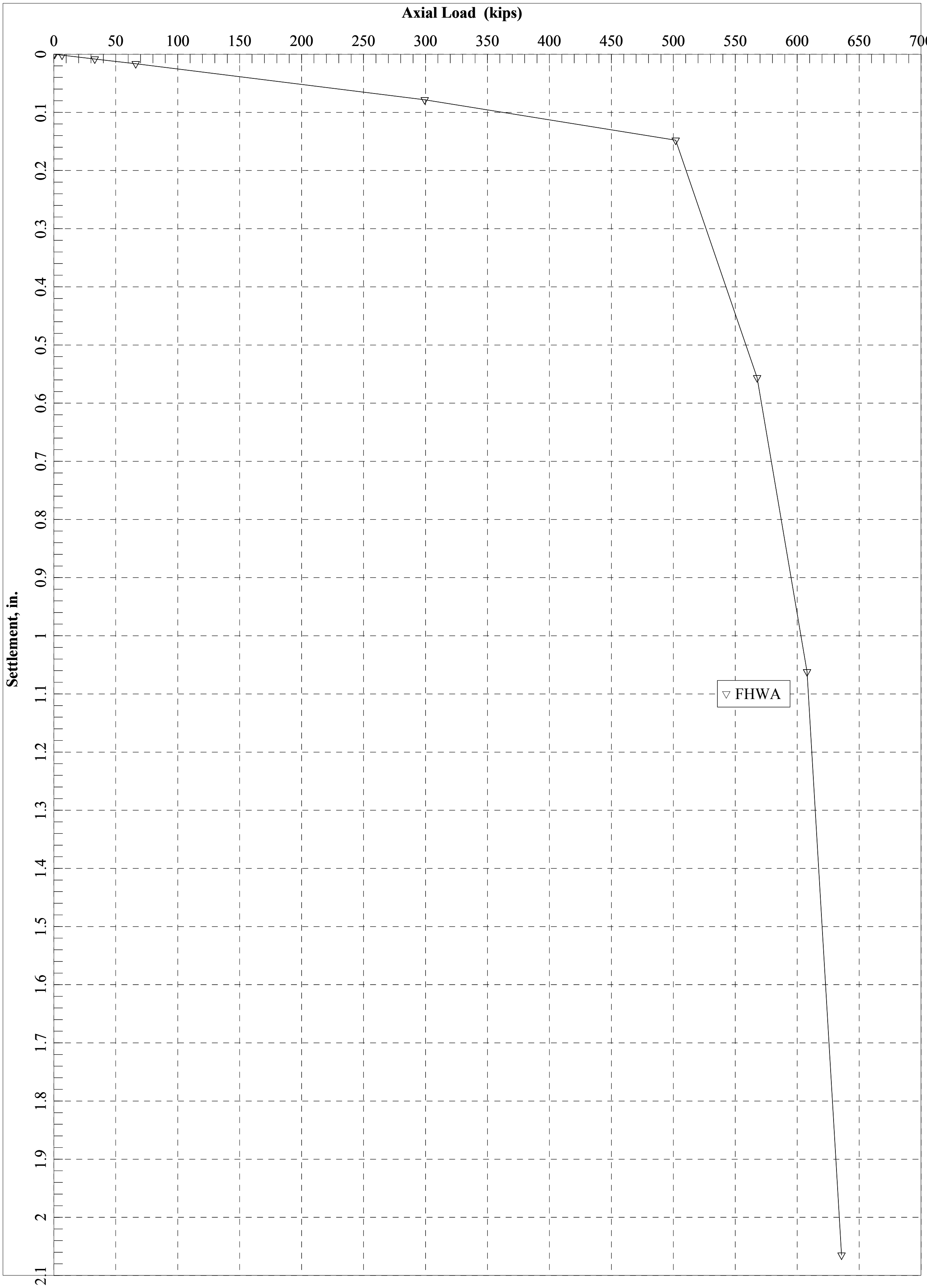
# Apile analysis report (H-pile)

**Boring: B-5**
**Equipment: H-frame**

# Ultimate Axial capacity Vs depth for the given H12x53



# Ultimate Pile settlement for given H12x53



```
                              CpCrane_ HP12x53 Pile_B5.ap7o
     =========================================================================

                     APILE for Windows, Version 2015.7.8

                      Serial Number :  138584419

                      A Program for Analyzing the Axial Capacity
                      and Short-term Settlement of Driven Piles
                                under Axial Loading.
                    (c) Copyright ENSOFT, Inc., 1987-2015
                          All Rights Reserved

     =========================================================================


     This program is licensed to :

     PSI, INC.
     Various, Global License

     Path to file locations      : P:\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys
Quarters, MD\Engineering & Resources\Apile_analysis\
     Name of input data file     : CpCrane_ HP12x53 Pile_B5.ap7d
     Name of output file         : CpCrane_ HP12x53 Pile_B5.ap7o
     Name of plot output file    : CpCrane_ HP12x53 Pile_B5.ap7p

     -------------------------------------------------------------------------
                         Time and Date of Analysis
     -------------------------------------------------------------------------

               Date:  June 01, 2018     Time:  16:30:06



1
          *********************
          * INPUT INFORMATION *
          *********************



          CP-Crane_Boring B13;

          DESIGNER   : SS

          JOB NUMBER : 0512843


          METHOD FOR UNIT LOAD TRANSFERS :

          - FHWA (Federal Highway Administration)
            Unfactored Unit Side Friction and Unit Side Resistance are used.
```

COMPUTATION METHOD(S) FOR PILE CAPACITY :

- FHWA (Federal Highway Administration)

TYPE OF LOADING :
- COMPRESSION

PILE TYPE :

H-Pile/Steel Pile

DATA FOR AXIAL STIFFNESS :

```
- MODULUS OF ELASTICITY     = 0.290E+08 PSI
- CROSS SECTION AREA        =    141.90 IN2
```

NONCIRCULAR PILE PROPERTIES :

```
- TOTAL PILE LENGTH, TL     =     45.00 FT.
- PILE STICKUP LENGTH, PSL  =      0.00 FT.
- ZERO FRICTION LENGTH, ZFL =      0.00 FT.
- PERIMETER OF PILE         =     47.70 IN.
- TIP AREA OF PILE          =    141.90 IN2
- INCREMENT OF PILE LENGTH
  USED IN COMPUTATION       =      1.00 FT.
```

SOIL INFORMATIONS :

| DEPTH FT. | SOIL TYPE | LATERAL EARTH PRESSURE | EFFECTIVE UNIT WEIGHT LB/CF | FRICTION ANGLE DEGREES | BEARING CAPACITY FACTOR |
|---|---|---|---|---|---|
| 0.00 | SAND | 0.00 | 105.00 | 32.00 | 0.00 |
| 9.00 | SAND | 0.00 | 105.00 | 32.00 | 0.00 |
| 9.00 | SAND | 0.00 | 72.60 | 36.00 | 0.00 |
| 36.00 | SAND | 0.00 | 72.60 | 36.00 | 0.00 |
| 36.00 | SAND | 0.00 | 67.60 | 38.00 | 0.00 |
| 46.00 | SAND | 0.00 | 67.60 | 38.00 | 0.00 |
| 46.00 | CLAY | 0.00 | 42.60 | 0.00 | 0.00 |
| 50.00 | CLAY | 0.00 | 42.60 | 0.00 | 0.00 |

CpCrane_ HP12x53 Pile_B5.ap7o

| MAXIMUM UNIT FRICTION KSF | MAXIMUM UNIT BEARING KSF | UNDISTURB SHEAR STRENGTH KSF | REMOLDED SHEAR STRENGTH KSF | BLOW COUNT | UNIT SKIN FRICTION KSF | UNIT END BEARING KSF |
|---|---|---|---|---|---|---|
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 2.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 2.50 | 0.00 | 0.00 | 0.00 | 0.00 |

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING
WERE SET TO BE 0.10E+08 BECAUSE THE USER DOES NOT
PLAN TO LIMIT THE COMPUTED DATA.

| DEPTH FT. | LRFD FACTOR ON UNIT FRICTION | LRFD FACTOR ON UNIT BEARING |
|---|---|---|
| 0.00 | 1.000 | 1.000 |
| 9.00 | 1.000 | 1.000 |
| 9.00 | 1.000 | 1.000 |
| 36.00 | 1.000 | 1.000 |
| 36.00 | 1.000 | 1.000 |
| 46.00 | 1.000 | 1.000 |
| 46.00 | 1.000 | 1.000 |
| 50.00 | 1.000 | 1.000 |

1

**********************
* COMPUTATION RESULT *
**********************

**********************
*  FED. HWY. METHOD  *
**********************

| PILE PENETRATION FT. | TOTAL SKIN FRICTION KIP | END BEARING KIP | ULTIMATE CAPACITY KIP |
|---|---|---|---|
| 0.00 | 0.0 | 1.2 | 1.2 |
| 1.00 | 0.1 | 2.5 | 2.7 |
| 2.00 | 0.6 | 5.2 | 5.8 |
| 3.00 | 1.3 | 7.8 | 9.2 |
| 4.00 | 2.4 | 10.5 | 12.8 |

| | | | |
|---|---|---|---|
| 5.00 | 3.7 | 13.1 | 16.8 |
| 6.00 | 5.4 | 15.7 | 21.1 |
| 7.00 | 7.3 | 18.3 | 25.6 |
| 8.00 | 9.5 | 27.3 | 36.9 |
| 9.00 | 12.1 | 37.4 | 49.5 |
| 10.00 | 15.7 | 47.8 | 63.5 |
| 11.00 | 20.5 | 57.8 | 78.3 |
| 12.00 | 25.6 | 61.6 | 87.2 |
| 13.00 | 31.0 | 65.5 | 96.5 |
| 14.00 | 36.8 | 69.3 | 106.1 |
| 15.00 | 42.8 | 73.2 | 116.0 |
| 16.00 | 49.3 | 77.0 | 126.3 |
| 17.00 | 56.0 | 80.9 | 136.9 |
| 18.00 | 63.1 | 84.7 | 147.8 |
| 19.00 | 70.4 | 88.6 | 159.0 |
| 20.00 | 78.2 | 92.4 | 170.6 |
| 21.00 | 86.2 | 96.3 | 182.5 |
| 22.00 | 94.6 | 100.1 | 194.7 |
| 23.00 | 103.3 | 104.0 | 207.3 |
| 24.00 | 112.3 | 107.8 | 220.2 |
| 25.00 | 121.7 | 111.7 | 233.4 |
| 26.00 | 131.4 | 115.5 | 246.9 |
| 27.00 | 141.4 | 119.4 | 260.8 |
| 28.00 | 151.8 | 123.2 | 275.0 |
| 29.00 | 162.4 | 127.1 | 289.5 |
| 30.00 | 173.5 | 130.9 | 304.4 |
| 31.00 | 184.8 | 134.8 | 319.6 |
| 32.00 | 196.5 | 138.6 | 335.1 |
| 33.00 | 208.4 | 142.4 | 350.8 |
| 34.00 | 220.8 | 145.6 | 366.4 |
| 35.00 | 233.4 | 167.1 | 400.5 |
| 36.00 | 246.4 | 191.0 | 437.4 |
| 37.00 | 261.7 | 215.4 | 477.2 |
| 38.00 | 279.5 | 238.8 | 518.3 |
| 39.00 | 297.7 | 244.1 | 541.8 |
| 40.00 | 316.3 | 249.4 | 565.7 |
| 41.00 | 335.3 | 254.7 | 589.9 |
| 42.00 | 354.7 | 259.2 | 613.9 |
| 43.00 | 374.4 | 262.4 | 636.8 |
| 44.00 | 394.6 | 264.2 | 658.8 |
| 45.00 | 415.2 | 207.3 | 622.5 |

NOTES:
- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN
  IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION
  OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

```
**************************************************
* COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
* CURVES FOR AXIAL LOADING                       *
```

CpCrane_ HP12x53 Pile_B5.ap7o
***********************************************

| T-Z CURVE NO. | NO. OF POINTS | DEPTH TO CURVE FT. | LOAD TRANSFER PSI | PILE MOVEMENT IN. |
|---|---|---|---|---|
| 1 | 10 | 0.0000E+00 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.7818E-01 | 0.1000E-01 |
| | | | 0.1564E+00 | 0.2000E-01 |
| | | | 0.3127E+00 | 0.4000E-01 |
| | | | 0.4691E+00 | 0.6000E-01 |
| | | | 0.6254E+00 | 0.8000E-01 |
| | | | 0.7036E+00 | 0.9000E-01 |
| | | | 0.7818E+00 | 0.1000E+00 |
| | | | 0.7818E+00 | 0.5000E+00 |
| | | | 0.7818E+00 | 0.2000E+01 |
| 2 | 10 | 0.4525E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2606E+00 | 0.1000E-01 |
| | | | 0.5212E+00 | 0.2000E-01 |
| | | | 0.1042E+01 | 0.4000E-01 |
| | | | 0.1564E+01 | 0.6000E-01 |
| | | | 0.2085E+01 | 0.8000E-01 |
| | | | 0.2345E+01 | 0.9000E-01 |
| | | | 0.2606E+01 | 0.1000E+00 |
| | | | 0.2606E+01 | 0.5000E+00 |
| | | | 0.2606E+01 | 0.2000E+01 |
| 3 | 10 | 0.8958E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5398E+00 | 0.1000E-01 |
| | | | 0.1080E+01 | 0.2000E-01 |
| | | | 0.2159E+01 | 0.4000E-01 |
| | | | 0.3239E+01 | 0.6000E-01 |
| | | | 0.4318E+01 | 0.8000E-01 |
| | | | 0.4858E+01 | 0.9000E-01 |
| | | | 0.5398E+01 | 0.1000E+00 |
| | | | 0.5398E+01 | 0.5000E+00 |
| | | | 0.5398E+01 | 0.2000E+01 |
| 4 | 10 | 0.9000E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.7347E+00 | 0.1000E-01 |
| | | | 0.1469E+01 | 0.2000E-01 |
| | | | 0.2939E+01 | 0.4000E-01 |
| | | | 0.4408E+01 | 0.6000E-01 |
| | | | 0.5878E+01 | 0.8000E-01 |
| | | | 0.6612E+01 | 0.9000E-01 |
| | | | 0.7347E+01 | 0.1000E+00 |
| | | | 0.7347E+01 | 0.5000E+00 |
| | | | 0.7347E+01 | 0.2000E+01 |
| 5 | 10 | 0.2253E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1550E+01 | 0.1000E-01 |

CpCrane_ HP12x53 Pile_B5.ap7o

| | | | | |
|---|---|---|---|---|
| | | | 0.3100E+01 | 0.2000E-01 |
| | | | 0.6200E+01 | 0.4000E-01 |
| | | | 0.9299E+01 | 0.6000E-01 |
| | | | 0.1240E+02 | 0.8000E-01 |
| | | | 0.1395E+02 | 0.9000E-01 |
| | | | 0.1550E+02 | 0.1000E+00 |
| | | | 0.1550E+02 | 0.5000E+00 |
| | | | 0.1550E+02 | 0.2000E+01 |
| 6 | 10 | 0.3596E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2475E+01 | 0.1000E-01 |
| | | | 0.4951E+01 | 0.2000E-01 |
| | | | 0.9901E+01 | 0.4000E-01 |
| | | | 0.1485E+02 | 0.6000E-01 |
| | | | 0.1980E+02 | 0.8000E-01 |
| | | | 0.2228E+02 | 0.9000E-01 |
| | | | 0.2475E+02 | 0.1000E+00 |
| | | | 0.2475E+02 | 0.5000E+00 |
| | | | 0.2475E+02 | 0.2000E+01 |
| 7 | 10 | 0.3600E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2895E+01 | 0.1000E-01 |
| | | | 0.5790E+01 | 0.2000E-01 |
| | | | 0.1158E+02 | 0.4000E-01 |
| | | | 0.1737E+02 | 0.6000E-01 |
| | | | 0.2316E+02 | 0.8000E-01 |
| | | | 0.2606E+02 | 0.9000E-01 |
| | | | 0.2895E+02 | 0.1000E+00 |
| | | | 0.2895E+02 | 0.5000E+00 |
| | | | 0.2895E+02 | 0.2000E+01 |
| 8 | 10 | 0.4103E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3421E+01 | 0.1000E-01 |
| | | | 0.6842E+01 | 0.2000E-01 |
| | | | 0.1368E+02 | 0.4000E-01 |
| | | | 0.2052E+02 | 0.6000E-01 |
| | | | 0.2737E+02 | 0.8000E-01 |
| | | | 0.3079E+02 | 0.9000E-01 |
| | | | 0.3421E+02 | 0.1000E+00 |
| | | | 0.3421E+02 | 0.5000E+00 |
| | | | 0.3421E+02 | 0.2000E+01 |
| 9 | 10 | 0.4596E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3595E+01 | 0.1000E-01 |
| | | | 0.7191E+01 | 0.2000E-01 |
| | | | 0.1438E+02 | 0.4000E-01 |
| | | | 0.2157E+02 | 0.6000E-01 |
| | | | 0.2876E+02 | 0.8000E-01 |
| | | | 0.3236E+02 | 0.9000E-01 |
| | | | 0.3595E+02 | 0.1000E+00 |
| | | | 0.3595E+02 | 0.5000E+00 |
| | | | 0.3595E+02 | 0.2000E+01 |
| 10 | 10 | 0.4600E+02 | | |

| | | | | |
|---|---|---|---|---|
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1079E+02 | 0.2429E-01 |
| | | | 0.1798E+02 | 0.4707E-01 |
| | | | 0.2697E+02 | 0.8655E-01 |
| | | | 0.3236E+02 | 0.1215E+00 |
| | | | 0.3595E+02 | 0.1518E+00 |
| | | | 0.3236E+02 | 0.3037E+00 |
| | | | 0.3236E+02 | 0.4555E+00 |
| | | | 0.3236E+02 | 0.7592E+00 |
| | | | 0.3236E+02 | 0.3037E+01 |
| 11 | 10 | 0.4803E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1079E+02 | 0.2429E-01 |
| | | | 0.1798E+02 | 0.4707E-01 |
| | | | 0.2697E+02 | 0.8655E-01 |
| | | | 0.3236E+02 | 0.1215E+00 |
| | | | 0.3595E+02 | 0.1518E+00 |
| | | | 0.3236E+02 | 0.3037E+00 |
| | | | 0.3236E+02 | 0.4555E+00 |
| | | | 0.3236E+02 | 0.7592E+00 |
| | | | 0.3236E+02 | 0.3037E+01 |
| 12 | 10 | 0.4996E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1079E+02 | 0.2429E-01 |
| | | | 0.1798E+02 | 0.4707E-01 |
| | | | 0.2697E+02 | 0.8655E-01 |
| | | | 0.3236E+02 | 0.1215E+00 |
| | | | 0.3595E+02 | 0.1518E+00 |
| | | | 0.3236E+02 | 0.3037E+00 |
| | | | 0.3236E+02 | 0.4555E+00 |
| | | | 0.3236E+02 | 0.7592E+00 |
| | | | 0.3236E+02 | 0.3037E+01 |

| TIP LOAD KIP | TIP MOVEMENT IN. |
|---|---|
| 0.0000E+00 | 0.0000E+00 |
| 0.1296E+02 | 0.7592E-02 |
| 0.2591E+02 | 0.1518E-01 |
| 0.5183E+02 | 0.3037E-01 |
| 0.1037E+03 | 0.1974E+00 |
| 0.1555E+03 | 0.6377E+00 |
| 0.1866E+03 | 0.1108E+01 |
| 0.2073E+03 | 0.1518E+01 |
| 0.2073E+03 | 0.2278E+01 |
| 0.2073E+03 | 0.3037E+01 |

LOAD VERSUS SETTLEMENT CURVE
****************************

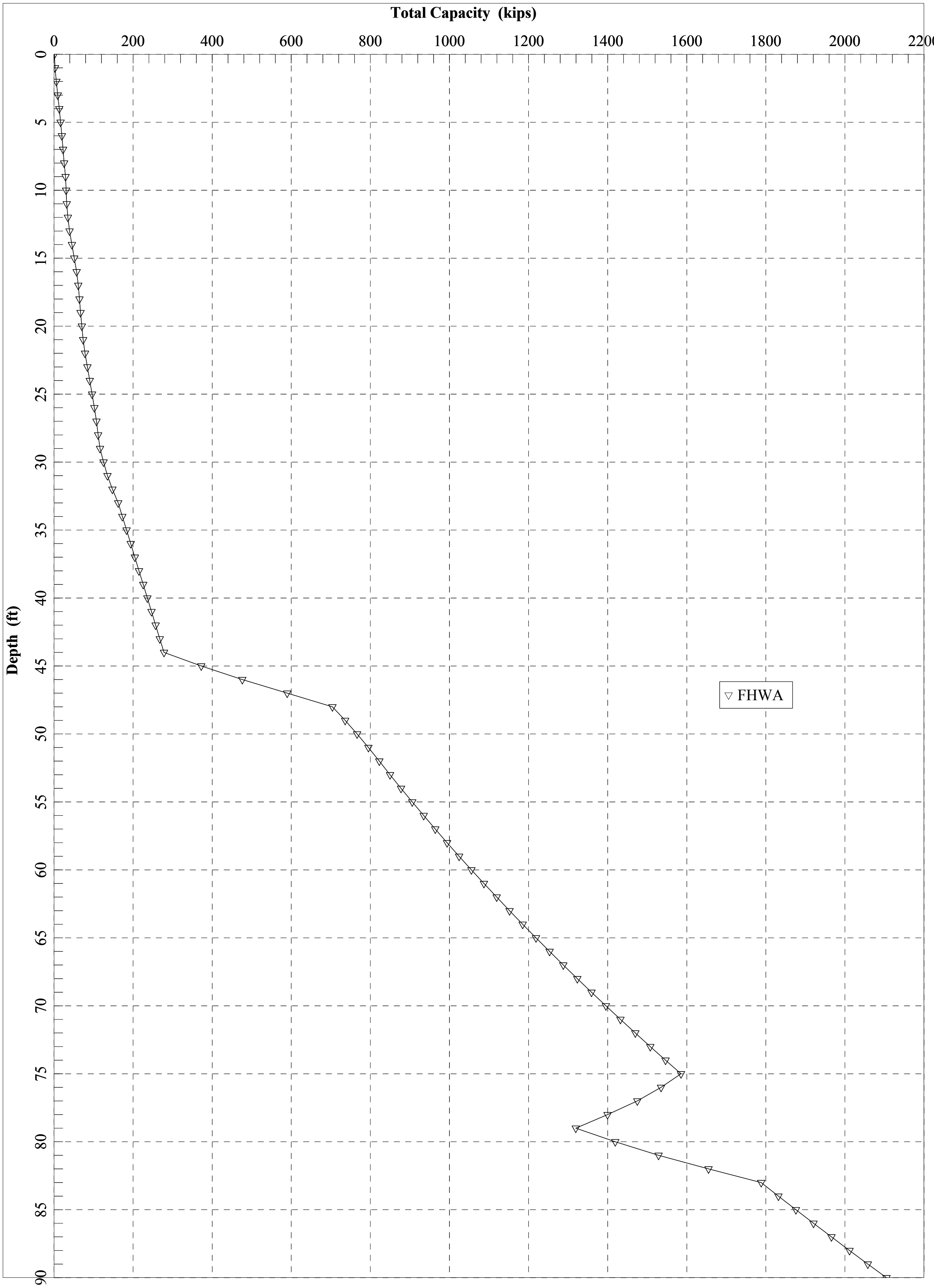
CpCrane_ HP12x53 Pile_B5.ap7o

| TOP LOAD KIP | TOP MOVEMENT IN. | TIP LOAD KIP | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.6615E+00 | 0.1642E-03 | 0.1707E+00 | 0.1000E-03 |
| 0.6615E+01 | 0.1642E-02 | 0.1707E+01 | 0.1000E-02 |
| 0.3307E+02 | 0.8212E-02 | 0.8534E+01 | 0.5000E-02 |
| 0.6615E+02 | 0.1642E-01 | 0.1707E+02 | 0.1000E-01 |
| 0.2994E+03 | 0.7829E-01 | 0.5792E+02 | 0.5000E-01 |
| 0.5019E+03 | 0.1478E+00 | 0.7344E+02 | 0.1000E+00 |
| 0.5677E+03 | 0.5564E+00 | 0.1393E+03 | 0.5000E+00 |
| 0.6079E+03 | 0.1062E+01 | 0.1794E+03 | 0.1000E+01 |
| 0.6358E+03 | 0.2065E+01 | 0.2073E+03 | 0.2000E+01 |

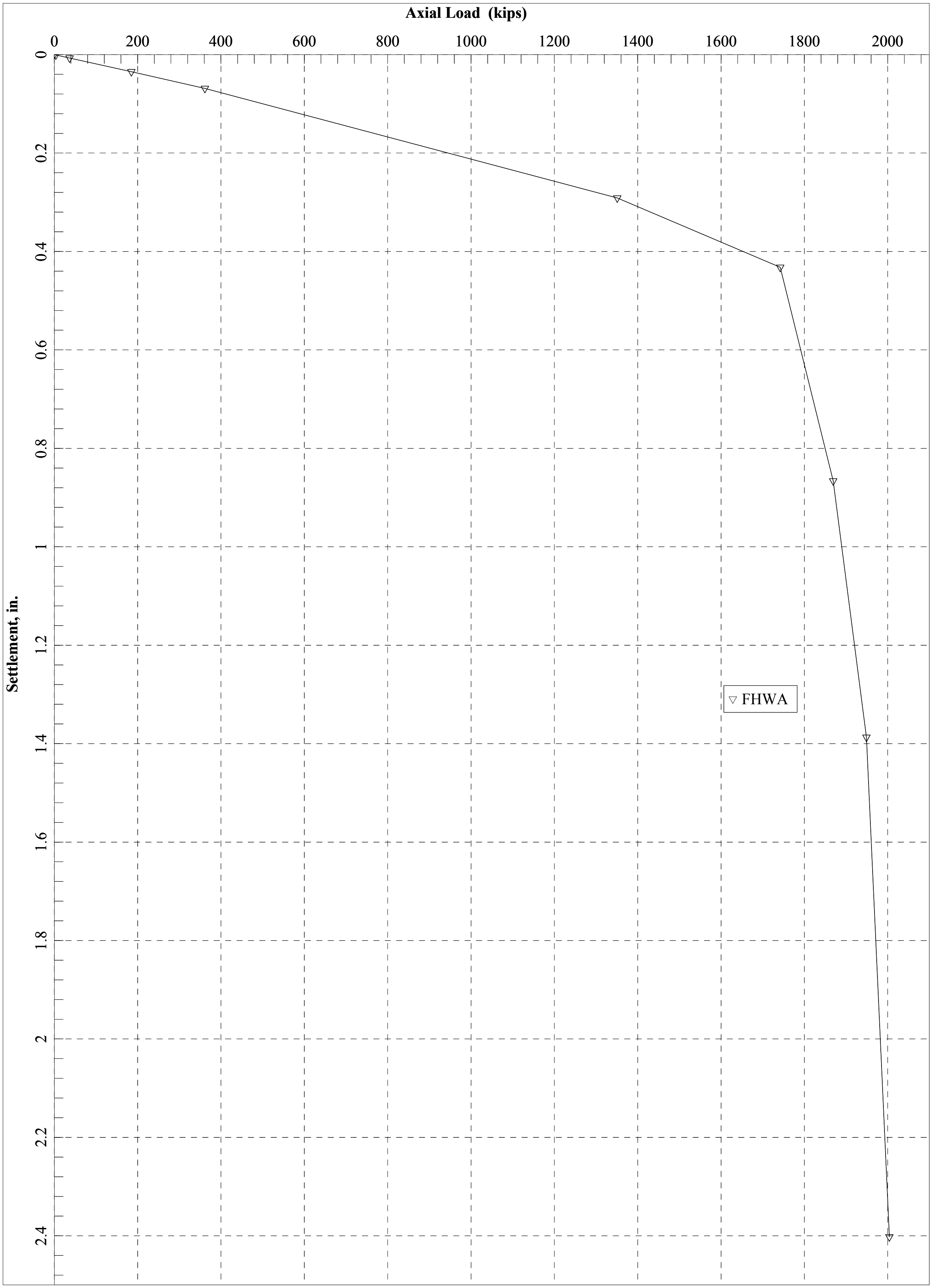
# Apile analysis report (H-pile)

**Boring: B-14**
**Equipment: Exhaust stack**

# Ultimate axial capacity Vs depth for the given H12x53



# Ultimate Pile settlement for given H12x53



```
                          CpCrane_ HP12x53 Pile_B14.ap7o
==========================================================================

                 APILE for Windows, Version 2015.7.8

                  Serial Number :  138584419

                  A Program for Analyzing the Axial Capacity
                  and Short-term Settlement of Driven Piles
                            under Axial Loading.
                (c) Copyright ENSOFT, Inc., 1987-2015
                      All Rights Reserved

==========================================================================


This program is licensed to :

PSI, INC.
Various, Global License

Path to file locations      : P:\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys
Quarters, MD\Engineering & Resources\Apile_analysis\
Name of input data file     : CpCrane_ HP12x53 Pile_B14.ap7d
Name of output file         : CpCrane_ HP12x53 Pile_B14.ap7o
Name of plot output file    : CpCrane_ HP12x53 Pile_B14.ap7p

--------------------------------------------------------------------------
                     Time and Date of Analysis
--------------------------------------------------------------------------

          Date:  June 01, 2018     Time:  18:09:40



1
     *********************
     * INPUT INFORMATION *
     *********************



     CP-Crane_Boring B13;

     DESIGNER   : SS

     JOB NUMBER : 0512843


     METHOD FOR UNIT LOAD TRANSFERS :

     - FHWA (Federal Highway Administration)
       Unfactored Unit Side Friction and Unit Side Resistance are used.
```

CpCrane_ HP12x53 Pile_B14.ap7o

COMPUTATION METHOD(S) FOR PILE CAPACITY :

- FHWA (Federal Highway Administration)

TYPE OF LOADING :
- COMPRESSION

PILE TYPE :

H-Pile/Steel Pile

DATA FOR AXIAL STIFFNESS :

- MODULUS OF ELASTICITY = 0.290E+08 PSI
- CROSS SECTION AREA = 141.90 IN2

NONCIRCULAR PILE PROPERTIES :

- TOTAL PILE LENGTH, TL = 90.00 FT.
- PILE STICKUP LENGTH, PSL = 0.00 FT.
- ZERO FRICTION LENGTH, ZFL = 0.00 FT.
- PERIMETER OF PILE = 47.70 IN.
- TIP AREA OF PILE = 141.90 IN2
- INCREMENT OF PILE LENGTH
  USED IN COMPUTATION = 1.00 FT.

SOIL INFORMATIONS :

| DEPTH FT. | SOIL TYPE | LATERAL EARTH PRESSURE | EFFECTIVE UNIT WEIGHT LB/CF | FRICTION ANGLE DEGREES | BEARING CAPACITY FACTOR |
|---|---|---|---|---|---|
| 0.00 | SAND | 0.00 | 110.00 | 32.00 | 0.00 |
| 6.00 | SAND | 0.00 | 110.00 | 32.00 | 0.00 |
| 6.00 | SAND | 0.00 | 62.60 | 31.00 | 0.00 |
| 11.00 | SAND | 0.00 | 62.60 | 31.00 | 0.00 |
| 11.00 | CLAY | 0.00 | 57.60 | 0.00 | 0.00 |
| 16.00 | CLAY | 0.00 | 57.60 | 0.00 | 0.00 |
| 16.00 | SAND | 0.00 | 72.60 | 29.00 | 0.00 |
| 21.00 | SAND | 0.00 | 72.60 | 29.00 | 0.00 |
| 21.00 | CLAY | 0.00 | 57.60 | 0.00 | 0.00 |
| 26.00 | CLAY | 0.00 | 57.60 | 0.00 | 0.00 |
| 26.00 | SAND | 0.00 | 72.60 | 30.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| 31.00 | SAND | 0.00 | 72.60 | 30.00 | 0.00 |
| 31.00 | CLAY | 0.00 | 62.60 | 0.00 | 0.00 |
| 46.00 | CLAY | 0.00 | 62.60 | 0.00 | 0.00 |
| 46.00 | SAND | 0.00 | 72.60 | 40.00 | 0.00 |
| 77.00 | SAND | 0.00 | 72.60 | 40.00 | 0.00 |
| 77.00 | CLAY | 0.00 | 62.60 | 0.00 | 0.00 |
| 81.00 | CLAY | 0.00 | 62.60 | 0.00 | 0.00 |
| 81.00 | SAND | 0.00 | 72.60 | 40.00 | 0.00 |
| 97.00 | SAND | 0.00 | 76.20 | 40.00 | 0.00 |

| MAXIMUM UNIT FRICTION KSF | MAXIMUM UNIT BEARING KSF | UNDISTURB SHEAR STRENGTH KSF | REMOLDED SHEAR STRENGTH KSF | BLOW COUNT | UNIT SKIN FRICTION KSF | UNIT END BEARING KSF |
|---|---|---|---|---|---|---|
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.10E+08* | 0.10E+08* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

* MAXIMUM UNIT FRICTION AND/OR MAXIMUM UNIT BEARING WERE SET TO BE 0.10E+08 BECAUSE THE USER DOES NOT PLAN TO LIMIT THE COMPUTED DATA.

| DEPTH FT. | LRFD FACTOR ON UNIT FRICTION | LRFD FACTOR ON UNIT BEARING |
|---|---|---|
| 0.00 | 1.000 | 1.000 |
| 6.00 | 1.000 | 1.000 |
| 6.00 | 1.000 | 1.000 |
| 11.00 | 1.000 | 1.000 |
| 11.00 | 1.000 | 1.000 |
| 16.00 | 1.000 | 1.000 |

| | | |
|---|---|---|
| 16.00 | 1.000 | 1.000 |
| 21.00 | 1.000 | 1.000 |
| 21.00 | 1.000 | 1.000 |
| 26.00 | 1.000 | 1.000 |
| 26.00 | 1.000 | 1.000 |
| 31.00 | 1.000 | 1.000 |
| 31.00 | 1.000 | 1.000 |
| 46.00 | 1.000 | 1.000 |
| 46.00 | 1.000 | 1.000 |
| 77.00 | 1.000 | 1.000 |
| 77.00 | 1.000 | 1.000 |
| 81.00 | 1.000 | 1.000 |
| 81.00 | 1.000 | 1.000 |
| 97.00 | 1.000 | 1.000 |

1

**********************
* COMPUTATION RESULT *
**********************

**********************
*  FED. HWY. METHOD  *
**********************

| PILE PENETRATION FT. | TOTAL SKIN FRICTION KIP | END BEARING KIP | ULTIMATE CAPACITY KIP |
|---|---|---|---|
| 0.00 | 0.0 | 1.3 | 1.3 |
| 1.00 | 0.2 | 2.7 | 2.8 |
| 2.00 | 0.6 | 5.5 | 6.1 |
| 3.00 | 1.4 | 8.2 | 9.6 |
| 4.00 | 2.5 | 11.0 | 13.5 |
| 5.00 | 3.9 | 12.9 | 16.8 |
| 6.00 | 5.6 | 14.4 | 20.1 |
| 7.00 | 7.5 | 15.6 | 23.1 |
| 8.00 | 9.4 | 16.4 | 25.8 |
| 9.00 | 11.4 | 17.7 | 29.2 |
| 10.00 | 13.7 | 17.2 | 30.9 |
| 11.00 | 16.0 | 16.2 | 32.2 |
| 12.00 | 20.2 | 14.8 | 35.1 |
| 13.00 | 26.2 | 13.3 | 39.5 |
| 14.00 | 32.2 | 13.3 | 45.5 |
| 15.00 | 38.1 | 13.3 | 51.4 |
| 16.00 | 44.1 | 13.2 | 57.3 |
| 17.00 | 48.4 | 13.2 | 61.6 |
| 18.00 | 51.2 | 13.1 | 64.4 |
| 19.00 | 54.2 | 13.1 | 67.3 |
| 20.00 | 57.3 | 13.2 | 70.4 |
| 21.00 | 60.5 | 13.2 | 73.7 |

CpCrane_ HP12x53 Pile_B14.ap7o

| | | | |
|---|---|---|---|
| 22.00 | 65.2 | 13.3 | 78.4 |
| 23.00 | 71.1 | 13.3 | 84.4 |
| 24.00 | 77.1 | 13.3 | 90.4 |
| 25.00 | 83.0 | 13.3 | 96.3 |
| 26.00 | 89.0 | 13.2 | 102.2 |
| 27.00 | 94.2 | 13.2 | 107.4 |
| 28.00 | 98.7 | 13.1 | 111.8 |
| 29.00 | 103.3 | 13.1 | 116.5 |
| 30.00 | 108.1 | 17.4 | 125.5 |
| 31.00 | 113.1 | 22.1 | 135.2 |
| 32.00 | 120.9 | 26.8 | 147.7 |
| 33.00 | 131.4 | 31.0 | 162.5 |
| 34.00 | 141.9 | 31.0 | 173.0 |
| 35.00 | 152.5 | 31.0 | 183.5 |
| 36.00 | 163.0 | 31.0 | 194.0 |
| 37.00 | 173.5 | 31.0 | 204.5 |
| 38.00 | 184.0 | 31.0 | 215.1 |
| 39.00 | 194.5 | 31.0 | 225.6 |
| 40.00 | 205.0 | 31.0 | 236.1 |
| 41.00 | 215.6 | 31.0 | 246.6 |
| 42.00 | 226.1 | 31.0 | 257.1 |
| 43.00 | 236.6 | 31.0 | 267.6 |
| 44.00 | 247.1 | 31.0 | 278.2 |
| 45.00 | 257.6 | 114.5 | 372.2 |
| 46.00 | 266.7 | 209.6 | 476.3 |
| 47.00 | 282.7 | 307.0 | 589.7 |
| 48.00 | 307.2 | 396.9 | 704.2 |
| 49.00 | 332.4 | 403.8 | 736.2 |
| 50.00 | 358.0 | 408.5 | 766.5 |
| 51.00 | 384.2 | 410.9 | 795.1 |
| 52.00 | 410.9 | 411.5 | 822.5 |
| 53.00 | 438.2 | 411.5 | 849.7 |
| 54.00 | 466.0 | 411.5 | 877.5 |
| 55.00 | 494.4 | 411.5 | 905.9 |
| 56.00 | 523.2 | 411.5 | 934.8 |
| 57.00 | 552.7 | 411.5 | 964.2 |
| 58.00 | 582.6 | 411.5 | 994.1 |
| 59.00 | 613.1 | 411.5 | 1024.6 |
| 60.00 | 644.1 | 411.5 | 1055.6 |
| 61.00 | 675.7 | 411.5 | 1087.2 |
| 62.00 | 707.8 | 411.5 | 1119.3 |
| 63.00 | 740.4 | 411.5 | 1151.9 |
| 64.00 | 773.6 | 411.5 | 1185.1 |
| 65.00 | 807.3 | 411.5 | 1218.8 |
| 66.00 | 841.6 | 411.5 | 1253.1 |
| 67.00 | 876.4 | 411.5 | 1287.9 |
| 68.00 | 911.7 | 411.5 | 1323.2 |
| 69.00 | 947.5 | 411.5 | 1359.1 |
| 70.00 | 983.9 | 411.5 | 1395.5 |
| 71.00 | 1020.9 | 411.5 | 1432.4 |
| 72.00 | 1058.4 | 411.5 | 1469.9 |
| 73.00 | 1096.4 | 411.5 | 1507.9 |
| 74.00 | 1134.9 | 411.5 | 1546.4 |

| | | | |
|---|---|---|---|
| 75.00 | 1174.0 | 411.5 | 1585.5 |
| 76.00 | 1213.6 | 321.5 | 1535.1 |
| 77.00 | 1253.8 | 221.3 | 1475.1 |
| 78.00 | 1278.9 | 121.0 | 1399.9 |
| 79.00 | 1288.6 | 31.0 | 1319.6 |
| 80.00 | 1298.3 | 121.0 | 1419.3 |
| 81.00 | 1307.6 | 221.3 | 1528.9 |
| 82.00 | 1333.5 | 321.5 | 1655.0 |
| 83.00 | 1376.6 | 411.5 | 1788.1 |
| 84.00 | 1420.2 | 411.5 | 1831.7 |
| 85.00 | 1464.4 | 411.5 | 1875.9 |
| 86.00 | 1509.1 | 411.5 | 1920.6 |
| 87.00 | 1554.4 | 411.5 | 1965.9 |
| 88.00 | 1600.2 | 411.5 | 2011.7 |
| 89.00 | 1646.5 | 411.5 | 2058.0 |
| 90.00 | 1693.4 | 411.5 | 2105.0 |

NOTES:
- AN ASTERISK IS PLACED IN THE END-BEARING COLUMN
  IF THE TIP RESISTANCE IS CONTROLLED BY THE FRICTION
  OF SOIL PLUG INSIDE AN OPEN-ENDED PIPE PILE.

```
*************************************************
* COMPUTE LOAD-DISTRIBUTION AND LOAD-SETTLEMENT *
* CURVES FOR AXIAL LOADING                      *
*************************************************
```

| T-Z CURVE NO. | NO. OF POINTS | DEPTH TO CURVE FT. | LOAD TRANSFER PSI | PILE MOVEMENT IN. |
|---|---|---|---|---|
| 1 | 10 | 0.0000E+00 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.8190E-01 | 0.1000E-01 |
| | | | 0.1638E+00 | 0.2000E-01 |
| | | | 0.3276E+00 | 0.4000E-01 |
| | | | 0.4914E+00 | 0.6000E-01 |
| | | | 0.6552E+00 | 0.8000E-01 |
| | | | 0.7371E+00 | 0.9000E-01 |
| | | | 0.8190E+00 | 0.1000E+00 |
| | | | 0.8190E+00 | 0.5000E+00 |
| | | | 0.8190E+00 | 0.2000E+01 |
| 2 | 10 | 0.3025E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2184E+00 | 0.1000E-01 |
| | | | 0.4368E+00 | 0.2000E-01 |
| | | | 0.8736E+00 | 0.4000E-01 |
| | | | 0.1310E+01 | 0.6000E-01 |
| | | | 0.1747E+01 | 0.8000E-01 |
| | | | 0.1966E+01 | 0.9000E-01 |

| | | | | |
|---|---|---|---|---|
| | | | 0.2184E+01 | 0.1000E+00 |
| | | | 0.2184E+01 | 0.5000E+00 |
| | | | 0.2184E+01 | 0.2000E+01 |
| 3 | 10 | 0.5958E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3117E+00 | 0.1000E-01 |
| | | | 0.6235E+00 | 0.2000E-01 |
| | | | 0.1247E+01 | 0.4000E-01 |
| | | | 0.1870E+01 | 0.6000E-01 |
| | | | 0.2494E+01 | 0.8000E-01 |
| | | | 0.2806E+01 | 0.9000E-01 |
| | | | 0.3117E+01 | 0.1000E+00 |
| | | | 0.3117E+01 | 0.5000E+00 |
| | | | 0.3117E+01 | 0.2000E+01 |
| 4 | 10 | 0.6000E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3279E+00 | 0.1000E-01 |
| | | | 0.6557E+00 | 0.2000E-01 |
| | | | 0.1311E+01 | 0.4000E-01 |
| | | | 0.1967E+01 | 0.6000E-01 |
| | | | 0.2623E+01 | 0.8000E-01 |
| | | | 0.2951E+01 | 0.9000E-01 |
| | | | 0.3279E+01 | 0.1000E+00 |
| | | | 0.3279E+01 | 0.5000E+00 |
| | | | 0.3279E+01 | 0.2000E+01 |
| 5 | 10 | 0.8525E+01 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3740E+00 | 0.1000E-01 |
| | | | 0.7479E+00 | 0.2000E-01 |
| | | | 0.1496E+01 | 0.4000E-01 |
| | | | 0.2244E+01 | 0.6000E-01 |
| | | | 0.2992E+01 | 0.8000E-01 |
| | | | 0.3366E+01 | 0.9000E-01 |
| | | | 0.3740E+01 | 0.1000E+00 |
| | | | 0.3740E+01 | 0.5000E+00 |
| | | | 0.3740E+01 | 0.2000E+01 |
| 6 | 10 | 0.1096E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5754E+00 | 0.1000E-01 |
| | | | 0.1151E+01 | 0.2000E-01 |
| | | | 0.2302E+01 | 0.4000E-01 |
| | | | 0.3452E+01 | 0.6000E-01 |
| | | | 0.4603E+01 | 0.8000E-01 |
| | | | 0.5179E+01 | 0.9000E-01 |
| | | | 0.5754E+01 | 0.1000E+00 |
| | | | 0.5754E+01 | 0.5000E+00 |
| | | | 0.5754E+01 | 0.2000E+01 |
| 7 | 10 | 0.1100E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2666E+01 | 0.2429E-01 |
| | | | 0.4443E+01 | 0.4707E-01 |
| | | | 0.6664E+01 | 0.8655E-01 |
| | | | 0.7997E+01 | 0.1215E+00 |

| | | | | |
|---|---|---|---|---|
| | | | 0.8885E+01 | 0.1518E+00 |
| | | | 0.7997E+01 | 0.3037E+00 |
| | | | 0.7997E+01 | 0.4555E+00 |
| | | | 0.7997E+01 | 0.7592E+00 |
| | | | 0.7997E+01 | 0.3037E+01 |
| 8 | 10 | 0.1353E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3125E+01 | 0.2429E-01 |
| | | | 0.5208E+01 | 0.4707E-01 |
| | | | 0.7812E+01 | 0.8655E-01 |
| | | | 0.9375E+01 | 0.1215E+00 |
| | | | 0.1042E+02 | 0.1518E+00 |
| | | | 0.9375E+01 | 0.3037E+00 |
| | | | 0.9375E+01 | 0.4555E+00 |
| | | | 0.9375E+01 | 0.7592E+00 |
| | | | 0.9375E+01 | 0.3037E+01 |
| 9 | 10 | 0.1596E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2701E+01 | 0.2429E-01 |
| | | | 0.4501E+01 | 0.4707E-01 |
| | | | 0.6751E+01 | 0.8655E-01 |
| | | | 0.8102E+01 | 0.1215E+00 |
| | | | 0.9002E+01 | 0.1518E+00 |
| | | | 0.8102E+01 | 0.3037E+00 |
| | | | 0.8102E+01 | 0.4555E+00 |
| | | | 0.8102E+01 | 0.7592E+00 |
| | | | 0.8102E+01 | 0.3037E+01 |
| 10 | 10 | 0.1600E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.6237E+00 | 0.1000E-01 |
| | | | 0.1247E+01 | 0.2000E-01 |
| | | | 0.2495E+01 | 0.4000E-01 |
| | | | 0.3742E+01 | 0.6000E-01 |
| | | | 0.4990E+01 | 0.8000E-01 |
| | | | 0.5613E+01 | 0.9000E-01 |
| | | | 0.6237E+01 | 0.1000E+00 |
| | | | 0.6237E+01 | 0.5000E+00 |
| | | | 0.6237E+01 | 0.2000E+01 |
| 11 | 10 | 0.1853E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5276E+00 | 0.1000E-01 |
| | | | 0.1055E+01 | 0.2000E-01 |
| | | | 0.2110E+01 | 0.4000E-01 |
| | | | 0.3165E+01 | 0.6000E-01 |
| | | | 0.4220E+01 | 0.8000E-01 |
| | | | 0.4748E+01 | 0.9000E-01 |
| | | | 0.5276E+01 | 0.1000E+00 |
| | | | 0.5276E+01 | 0.5000E+00 |
| | | | 0.5276E+01 | 0.2000E+01 |
| 12 | 10 | 0.2096E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.6885E+00 | 0.1000E-01 |
| | | | 0.1377E+01 | 0.2000E-01 |

CpCrane_ HP12x53 Pile_B14.ap7o

| | | | | |
|---|---|---|---|---|
| | | | 0.2754E+01 | 0.4000E-01 |
| | | | 0.4131E+01 | 0.6000E-01 |
| | | | 0.5508E+01 | 0.8000E-01 |
| | | | 0.6196E+01 | 0.9000E-01 |
| | | | 0.6885E+01 | 0.1000E+00 |
| | | | 0.6885E+01 | 0.5000E+00 |
| | | | 0.6885E+01 | 0.2000E+01 |
| 13 | 10 | 0.2100E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2778E+01 | 0.2429E-01 |
| | | | 0.4630E+01 | 0.4707E-01 |
| | | | 0.6946E+01 | 0.8655E-01 |
| | | | 0.8335E+01 | 0.1215E+00 |
| | | | 0.9261E+01 | 0.1518E+00 |
| | | | 0.8335E+01 | 0.3037E+00 |
| | | | 0.8335E+01 | 0.4555E+00 |
| | | | 0.8335E+01 | 0.7592E+00 |
| | | | 0.8335E+01 | 0.3037E+01 |
| 14 | 10 | 0.2353E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3125E+01 | 0.2429E-01 |
| | | | 0.5208E+01 | 0.4707E-01 |
| | | | 0.7812E+01 | 0.8655E-01 |
| | | | 0.9375E+01 | 0.1215E+00 |
| | | | 0.1042E+02 | 0.1518E+00 |
| | | | 0.9375E+01 | 0.3037E+00 |
| | | | 0.9375E+01 | 0.4555E+00 |
| | | | 0.9375E+01 | 0.7592E+00 |
| | | | 0.9375E+01 | 0.3037E+01 |
| 15 | 10 | 0.2596E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.2921E+01 | 0.2429E-01 |
| | | | 0.4869E+01 | 0.4707E-01 |
| | | | 0.7303E+01 | 0.8655E-01 |
| | | | 0.8764E+01 | 0.1215E+00 |
| | | | 0.9738E+01 | 0.1518E+00 |
| | | | 0.8764E+01 | 0.3037E+00 |
| | | | 0.8764E+01 | 0.4555E+00 |
| | | | 0.8764E+01 | 0.7592E+00 |
| | | | 0.8764E+01 | 0.3037E+01 |
| 16 | 10 | 0.2600E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.8450E+00 | 0.1000E-01 |
| | | | 0.1690E+01 | 0.2000E-01 |
| | | | 0.3380E+01 | 0.4000E-01 |
| | | | 0.5070E+01 | 0.6000E-01 |
| | | | 0.6760E+01 | 0.8000E-01 |
| | | | 0.7605E+01 | 0.9000E-01 |
| | | | 0.8450E+01 | 0.1000E+00 |
| | | | 0.8450E+01 | 0.5000E+00 |
| | | | 0.8450E+01 | 0.2000E+01 |
| 17 | 10 | 0.2853E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |

| | | | | |
|---|---|---|---|---|
| | | | 0.8264E+00 | 0.1000E-01 |
| | | | 0.1653E+01 | 0.2000E-01 |
| | | | 0.3306E+01 | 0.4000E-01 |
| | | | 0.4959E+01 | 0.6000E-01 |
| | | | 0.6612E+01 | 0.8000E-01 |
| | | | 0.7438E+01 | 0.9000E-01 |
| | | | 0.8264E+01 | 0.1000E+00 |
| | | | 0.8264E+01 | 0.5000E+00 |
| | | | 0.8264E+01 | 0.2000E+01 |
| 18 | 10 | 0.3096E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.1114E+01 | 0.1000E-01 |
| | | | 0.2229E+01 | 0.2000E-01 |
| | | | 0.4458E+01 | 0.4000E-01 |
| | | | 0.6687E+01 | 0.6000E-01 |
| | | | 0.8916E+01 | 0.8000E-01 |
| | | | 0.1003E+02 | 0.9000E-01 |
| | | | 0.1114E+02 | 0.1000E+00 |
| | | | 0.1114E+02 | 0.5000E+00 |
| | | | 0.1114E+02 | 0.2000E+01 |
| 19 | 10 | 0.3100E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.4797E+01 | 0.2429E-01 |
| | | | 0.7994E+01 | 0.4707E-01 |
| | | | 0.1199E+02 | 0.8655E-01 |
| | | | 0.1439E+02 | 0.1215E+00 |
| | | | 0.1599E+02 | 0.1518E+00 |
| | | | 0.1439E+02 | 0.3037E+00 |
| | | | 0.1439E+02 | 0.4555E+00 |
| | | | 0.1439E+02 | 0.7592E+00 |
| | | | 0.1439E+02 | 0.3037E+01 |
| 20 | 10 | 0.3853E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5513E+01 | 0.2429E-01 |
| | | | 0.9188E+01 | 0.4707E-01 |
| | | | 0.1378E+02 | 0.8655E-01 |
| | | | 0.1654E+02 | 0.1215E+00 |
| | | | 0.1838E+02 | 0.1518E+00 |
| | | | 0.1654E+02 | 0.3037E+00 |
| | | | 0.1654E+02 | 0.4555E+00 |
| | | | 0.1654E+02 | 0.7592E+00 |
| | | | 0.1654E+02 | 0.3037E+01 |
| 21 | 10 | 0.4596E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.6557E+01 | 0.2429E-01 |
| | | | 0.1093E+02 | 0.4707E-01 |
| | | | 0.1639E+02 | 0.8655E-01 |
| | | | 0.1967E+02 | 0.1215E+00 |
| | | | 0.2186E+02 | 0.1518E+00 |
| | | | 0.1967E+02 | 0.3037E+00 |
| | | | 0.1967E+02 | 0.4555E+00 |
| | | | 0.1967E+02 | 0.7592E+00 |
| | | | 0.1967E+02 | 0.3037E+01 |

| | | | | |
|---|---|---|---|---|
| 22 | 10 | 0.4600E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.3541E+01 | 0.1000E-01 |
| | | | 0.7083E+01 | 0.2000E-01 |
| | | | 0.1417E+02 | 0.4000E-01 |
| | | | 0.2125E+02 | 0.6000E-01 |
| | | | 0.2833E+02 | 0.8000E-01 |
| | | | 0.3187E+02 | 0.9000E-01 |
| | | | 0.3541E+02 | 0.1000E+00 |
| | | | 0.3541E+02 | 0.5000E+00 |
| | | | 0.3541E+02 | 0.2000E+01 |
| 23 | 10 | 0.6153E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5655E+01 | 0.1000E-01 |
| | | | 0.1131E+02 | 0.2000E-01 |
| | | | 0.2262E+02 | 0.4000E-01 |
| | | | 0.3393E+02 | 0.6000E-01 |
| | | | 0.4524E+02 | 0.8000E-01 |
| | | | 0.5090E+02 | 0.9000E-01 |
| | | | 0.5655E+02 | 0.1000E+00 |
| | | | 0.5655E+02 | 0.5000E+00 |
| | | | 0.5655E+02 | 0.2000E+01 |
| 24 | 10 | 0.7696E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.5698E+01 | 0.1000E-01 |
| | | | 0.1140E+02 | 0.2000E-01 |
| | | | 0.2279E+02 | 0.4000E-01 |
| | | | 0.3419E+02 | 0.6000E-01 |
| | | | 0.4559E+02 | 0.8000E-01 |
| | | | 0.5128E+02 | 0.9000E-01 |
| | | | 0.5698E+02 | 0.1000E+00 |
| | | | 0.5698E+02 | 0.5000E+00 |
| | | | 0.5698E+02 | 0.2000E+01 |
| 25 | 10 | 0.7700E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.9119E+01 | 0.2429E-01 |
| | | | 0.1520E+02 | 0.4707E-01 |
| | | | 0.2280E+02 | 0.8655E-01 |
| | | | 0.2736E+02 | 0.1215E+00 |
| | | | 0.3040E+02 | 0.1518E+00 |
| | | | 0.2736E+02 | 0.3037E+00 |
| | | | 0.2736E+02 | 0.4555E+00 |
| | | | 0.2736E+02 | 0.7592E+00 |
| | | | 0.2736E+02 | 0.3037E+01 |
| 26 | 10 | 0.7903E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.4995E+01 | 0.2429E-01 |
| | | | 0.8325E+01 | 0.4707E-01 |
| | | | 0.1249E+02 | 0.8655E-01 |
| | | | 0.1499E+02 | 0.1215E+00 |
| | | | 0.1665E+02 | 0.1518E+00 |
| | | | 0.1499E+02 | 0.3037E+00 |
| | | | 0.1499E+02 | 0.4555E+00 |

| | | | | |
|---|---|---|---|---|
| | | | 0.1499E+02 | 0.7592E+00 |
| | | | 0.1499E+02 | 0.3037E+01 |
| 27 | 10 | 0.8096E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.9231E+01 | 0.2429E-01 |
| | | | 0.1538E+02 | 0.4707E-01 |
| | | | 0.2308E+02 | 0.8655E-01 |
| | | | 0.2769E+02 | 0.1215E+00 |
| | | | 0.3077E+02 | 0.1518E+00 |
| | | | 0.2769E+02 | 0.3037E+00 |
| | | | 0.2769E+02 | 0.4555E+00 |
| | | | 0.2769E+02 | 0.7592E+00 |
| | | | 0.2769E+02 | 0.3037E+01 |
| 28 | 10 | 0.8100E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.6025E+01 | 0.1000E-01 |
| | | | 0.1205E+02 | 0.2000E-01 |
| | | | 0.2410E+02 | 0.4000E-01 |
| | | | 0.3615E+02 | 0.6000E-01 |
| | | | 0.4820E+02 | 0.8000E-01 |
| | | | 0.5422E+02 | 0.9000E-01 |
| | | | 0.6025E+02 | 0.1000E+00 |
| | | | 0.6025E+02 | 0.5000E+00 |
| | | | 0.6025E+02 | 0.2000E+01 |
| 29 | 10 | 0.8903E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.8194E+01 | 0.1000E-01 |
| | | | 0.1639E+02 | 0.2000E-01 |
| | | | 0.3278E+02 | 0.4000E-01 |
| | | | 0.4917E+02 | 0.6000E-01 |
| | | | 0.6556E+02 | 0.8000E-01 |
| | | | 0.7375E+02 | 0.9000E-01 |
| | | | 0.8194E+02 | 0.1000E+00 |
| | | | 0.8194E+02 | 0.5000E+00 |
| | | | 0.8194E+02 | 0.2000E+01 |
| 30 | 10 | 0.9696E+02 | | |
| | | | 0.0000E+00 | 0.0000E+00 |
| | | | 0.8194E+01 | 0.1000E-01 |
| | | | 0.1639E+02 | 0.2000E-01 |
| | | | 0.3278E+02 | 0.4000E-01 |
| | | | 0.4917E+02 | 0.6000E-01 |
| | | | 0.6556E+02 | 0.8000E-01 |
| | | | 0.7375E+02 | 0.9000E-01 |
| | | | 0.8194E+02 | 0.1000E+00 |
| | | | 0.8194E+02 | 0.5000E+00 |
| | | | 0.8194E+02 | 0.2000E+01 |

| TIP LOAD KIP | TIP MOVEMENT IN. |
|---|---|
| 0.0000E+00 | 0.0000E+00 |

| | |
|---|---|
| 0.2572E+02 | 0.7592E-02 |
| 0.5144E+02 | 0.1518E-01 |
| 0.1029E+03 | 0.3037E-01 |
| 0.2058E+03 | 0.1974E+00 |
| 0.3086E+03 | 0.6377E+00 |
| 0.3704E+03 | 0.1108E+01 |
| 0.4115E+03 | 0.1518E+01 |
| 0.4115E+03 | 0.2278E+01 |
| 0.4115E+03 | 0.3037E+01 |

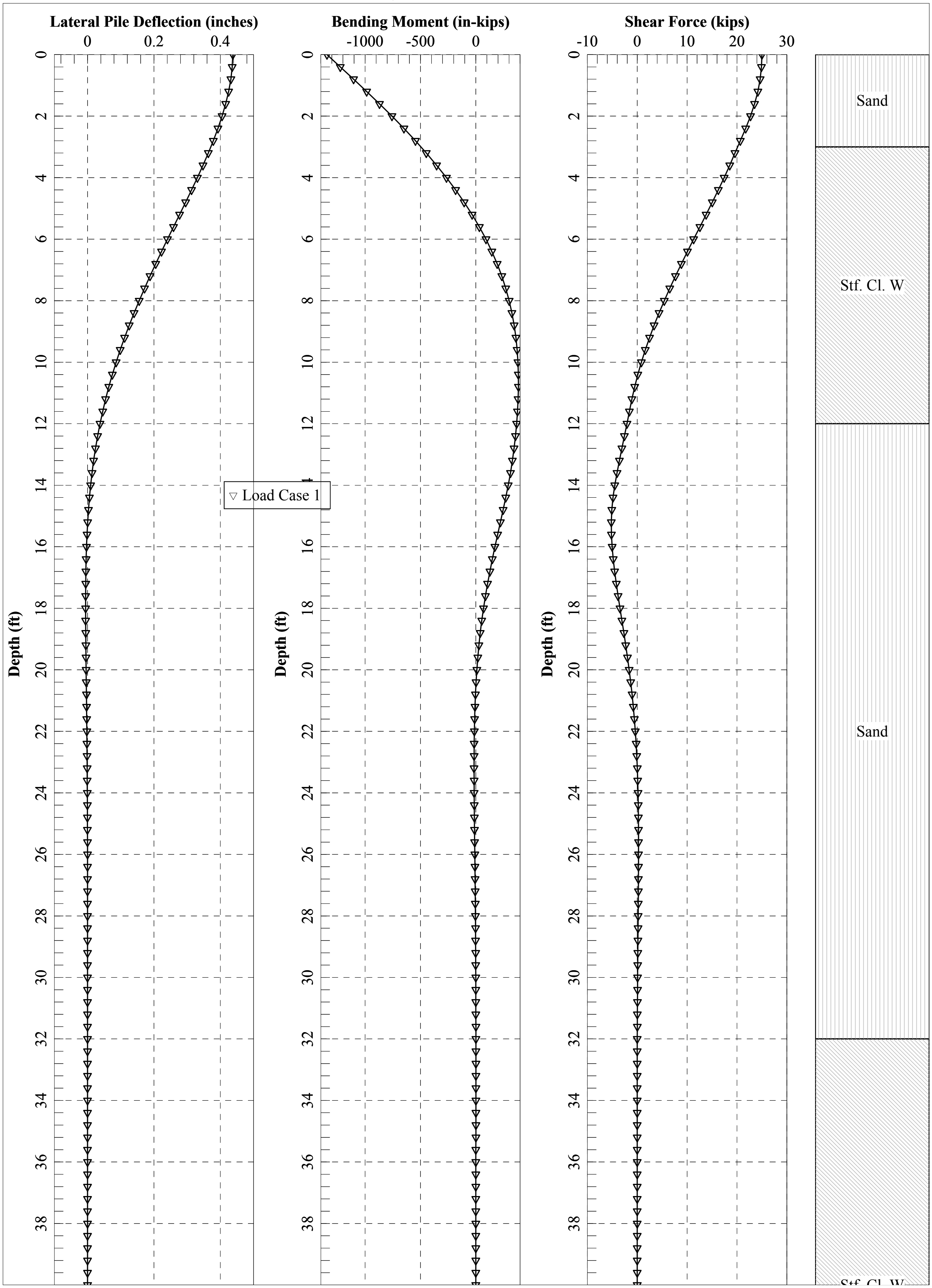
LOAD VERSUS SETTLEMENT CURVE
***************************

| TOP LOAD KIP | TOP MOVEMENT IN. | TIP LOAD KIP | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.3673E+01 | 0.6898E-03 | 0.3388E+00 | 0.1000E-03 |
| 0.3673E+02 | 0.6898E-02 | 0.3388E+01 | 0.1000E-02 |
| 0.1849E+03 | 0.3466E-01 | 0.1694E+02 | 0.5000E-02 |
| 0.3613E+03 | 0.6879E-01 | 0.3388E+02 | 0.1000E-01 |
| 0.1351E+04 | 0.2914E+00 | 0.1150E+03 | 0.5000E-01 |
| 0.1742E+04 | 0.4322E+00 | 0.1458E+03 | 0.1000E+00 |
| 0.1869E+04 | 0.8662E+00 | 0.2765E+03 | 0.5000E+00 |
| 0.1949E+04 | 0.1387E+01 | 0.3561E+03 | 0.1000E+01 |
| 0.2004E+04 | 0.2402E+01 | 0.4115E+03 | 0.2000E+01 |

# Appendix G:
# Lpile analysis report (H-pile)

**Boring: B-11**
**Equipment: Liquid tanks**

# Allowable Bending Moment and Shear force with respect to 0.5" head deflection for given H12x53



```
================================================================================

                   LPile for Windows, Version 2018-10.006

               Analysis of Individual Piles and Drilled Shafts
              Subjected to Lateral Loading Using the p-y Method
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                            All Rights Reserved

================================================================================

This copy of LPile is being used by:

2001917
PSI

Serial Number of Security Device: 138584532

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is a violation of the software license agreement.

--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters, MD\Engineering &
Resources\Hpile\LPile_analysis\

Name of input data file:
DeminTank_B11_Factored.lp10

Name of output report file:
DeminTank_B11_Factored.lp10

Name of plot output file:
DeminTank_B11_Factored.lp10

Name of runtime message file:
DeminTank_B11_Factored.lp10


--------------------------------------------------------------------------------
                            Date and Time of Analysis
--------------------------------------------------------------------------------

               Date:  June 14, 2018              Time:  12:54:58


--------------------------------------------------------------------------------
                                  Problem Title
--------------------------------------------------------------------------------
```

DeminTank_B11_Factored.lp10o

Project Name: CP Crane Power plant

Job Number:0512843

Client:ProEnergy

Engineer: SS

Description: Axial Capacity of Dirven Pile in Boring B1

---

Program Options and Settings

---

Computational Options:
- Use unfactored loads in computations (conventional analysis)

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

| | | |
|---|---|---|
| - Maximum number of iterations allowed | = | 1000 |
| - Deflection tolerance for convergence | = | 1.0000E-05 in |
| - Maximum allowable deflection | = | 100.0000 in |
| - Number of pile increments | = | 100 |

Loading Type and Number of Cycles of Loading:
- Static loading specified

- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

---

Pile Structural Properties and Geometry

---

```
Number of pile sections defined                           =            1
Total length of pile                                      =       40.000 ft
Depth of ground surface below top of pile                 =       0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

            Depth Below          Pile
Point        Pile Head         Diameter
 No.           feet             inches
-----      -------------     -------------
  1            0.000           12.0000
  2           40.000           12.0000


Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is a AISC strong axis steel pile
   Length of section                                      =    40.000000 ft
   AISC Section Type                                      = HP



   AISC Section Name                                      = HP12X53



   Pile width                                             =    12.000000 in
   Shear capacity of section                              =       0.0000 lbs




--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                        =        0.000 degrees
                                                          =        0.000 radians

Pile Batter Angle                                         =        0.000 degrees
                                                          =        0.000 radians


--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 4 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer              =       0.0000 ft
```

```
   Distance from top of pile to bottom of layer        =     3.000000 ft
   Effective unit weight at top of layer               =   115.000000 pcf
   Effective unit weight at bottom of layer            =   115.000000 pcf
   Friction angle at top of layer                      =    31.000000 deg.
   Friction angle at bottom of layer                   =    31.000000 deg.
   Subgrade k at top of layer                          =    20.000000 pci
   Subgrade k at bottom of layer                       =    20.000000 pci


Layer 2 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =     3.000000 ft
   Distance from top of pile to bottom of layer        =    12.000000 ft
   Effective unit weight at top of layer               =    52.600000 pcf
   Effective unit weight at bottom of layer            =    52.500000 pcf
   Undrained cohesion at top of layer                  =   800.000000 psf
   Undrained cohesion at bottom of layer               =   800.000000 psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    15.000000 pci
   Subgrade k at bottom of layer                       =    15.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 3 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer           =    12.000000 ft
   Distance from top of pile to bottom of layer        =    32.000000 ft
   Effective unit weight at top of layer               =    72.600000 pcf
   Effective unit weight at bottom of layer            =    72.600000 pcf
   Friction angle at top of layer                      =    38.000000 deg.
   Friction angle at bottom of layer                   =    38.000000 deg.
   Subgrade k at top of layer                          =    67.000000 pci
   Subgrade k at bottom of layer                       =    67.000000 pci


Layer 4 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    32.000000 ft
   Distance from top of pile to bottom of layer        =    48.000000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.600000 pcf
   Undrained cohesion at top of layer                  =        3500. psf
   Undrained cohesion at bottom of layer               =        3500. psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    50.000000 pci
   Subgrade k at bottom of layer                       =    50.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


 (Depth of the lowest soil layer extends 8.000 ft below the pile tip)


--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
```

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| Layer Num. | Soil Type Layer Name (p-y Curve Type) | Layer Depth ft | Effective Unit Wt. pcf | Undrained Cohesion psf | Angle of Friction deg. | E50 or krm | kpy pci |
|---|---|---|---|---|---|---|---|
| 1 | Sand | 0.00 | 115.0000 | -- | 31.0000 | -- | 20.0000 |
| | (Reese, et al.) | 3.0000 | 115.0000 | -- | 31.0000 | -- | 20.0000 |
| 2 | Stiff Clay | 3.0000 | 52.6000 | 800.0000 | -- | default | 15.0000 |
| | with Free Water | 12.0000 | 52.5000 | 800.0000 | -- | default | 15.0000 |
| 3 | Sand | 12.0000 | 72.6000 | -- | 38.0000 | -- | 67.0000 |
| | (Reese, et al.) | 32.0000 | 72.6000 | -- | 38.0000 | -- | 67.0000 |
| 4 | Stiff Clay | 32.0000 | 62.6000 | 3500. | -- | default | 50.0000 |
| | with Free Water | 48.0000 | 62.6000 | 3500. | -- | default | 50.0000 |

## Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

## Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

| Load No. | Load Type | Condition 1 | Condition 2 | Axial Thrust Force, lbs | Compute Top y vs. Pile Length |
|---|---|---|---|---|---|
| 1 | 2 | V = 25000. lbs | S = 0.0000 in/in | 120000. | Yes |

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

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Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Steel AISC Strong Axis:

| | | |
|---|---|---|
| Length of Section | = | 40.000000 ft |
| Flange Width | = | 12.000000 in |
| Section Depth | = | 11.800000 in |
| Flange Thickness | = | 0.435000 in |
| Web Thickness | = | 0.435000 in |
| Yield Stress of Pipe | = | 50.000000 ksi |
| Elastic Modulus | = | 27000. ksi |
| Cross-sectional Area | = | 15.500000 sq. in. |
| Moment of Inertia | = | 393.000000 in^4 |
| Elastic Bending Stiffness | = | 10611000. kip-in^2 |
| Plastic Modulus, Z | = | 74.000000in^3 |
| Plastic Moment Capacity = Fy Z | = | 3700.in-kip |

Axial Structural Capacities:

| | | |
|---|---|---|
| Nom. Axial Structural Capacity = Fy As | = | 775.000 kips |
| Nominal Axial Tensile Capacity | = | -775.000 kips |

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

| Number | Axial Thrust Force kips |
|---|---|
| 1 | 120.000 |

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 120.000 kips

| Bending Curvature rad/in. | Bending Moment in-kip | Bending Stiffness kip-in2 | Depth to N Axis in | Max Total Stress ksi | Run Msg |
|---|---|---|---|---|---|
| 0.00000595 | 61.7167449 | 10373849. | 55.0661913 | 8.8358087 | |
| 0.00001190 | 123.4334898 | 10373849. | 30.4830957 | 9.7740489 | |
| 0.00001785 | 185.1502347 | 10373849. | 22.2887304 | 10.7122892 | |
| 0.00002380 | 246.8669796 | 10373849. | 18.1915478 | 11.6505294 | |
| 0.00002975 | 308.5837244 | 10373849. | 15.7332383 | 12.5887696 | |
| 0.00003570 | 370.3004693 | 10373849. | 14.0943652 | 13.5270099 | |

| | | | | | |
|---|---|---|---|---|---|
| 0.00004164 | 432.0172142 | 10373849. | 12.9237416 | 14.4652502 | |
| 0.00004759 | 493.7339591 | 10373849. | 12.0457739 | 15.4034903 | |
| 0.00005354 | 555.4507040 | 10373849. | 11.3629101 | 16.3417306 | |
| 0.00005949 | 617.1674489 | 10373849. | 10.8166191 | 17.2799708 | |
| 0.00006544 | 678.8841938 | 10373849. | 10.3696538 | 18.2182110 | |
| 0.00007139 | 740.6009387 | 10373849. | 9.9971826 | 19.1564513 | |
| 0.00007734 | 802.3176836 | 10373849. | 9.6820147 | 20.0946915 | |
| 0.00008329 | 864.0344285 | 10373849. | 9.4118708 | 21.0329317 | |
| 0.00008924 | 925.7511733 | 10373849. | 9.1777461 | 21.9711720 | |
| 0.00009519 | 987.4679182 | 10373849. | 8.9728870 | 22.9094122 | |
| 0.0001011 | 1049. | 10373849. | 8.7921289 | 23.8476524 | |
| 0.0001071 | 1111. | 10373849. | 8.6314551 | 24.7858927 | |
| 0.0001130 | 1173. | 10373849. | 8.4876943 | 25.7241329 | |
| 0.0001190 | 1234. | 10373849. | 8.3583096 | 26.6623731 | |
| 0.0001249 | 1296. | 10373849. | 8.2412472 | 27.6006133 | |
| 0.0001309 | 1358. | 10373849. | 8.1348269 | 28.5388536 | |
| 0.0001368 | 1419. | 10373849. | 8.0376605 | 29.4770938 | |
| 0.0001428 | 1481. | 10373849. | 7.9485913 | 30.4153340 | |
| 0.0001487 | 1543. | 10373849. | 7.8666477 | 31.3535743 | |
| 0.0001547 | 1605. | 10373849. | 7.7910074 | 32.2918145 | |
| 0.0001606 | 1666. | 10373849. | 7.7209700 | 33.2300547 | |
| 0.0001666 | 1728. | 10373849. | 7.6559354 | 34.1682949 | |
| 0.0001725 | 1790. | 10373849. | 7.5953859 | 35.1065352 | |
| 0.0001785 | 1852. | 10373849. | 7.5388730 | 36.0447754 | |
| 0.0001844 | 1913. | 10373849. | 7.4860062 | 36.9830156 | |
| 0.0001904 | 1975. | 10373849. | 7.4364435 | 37.9212559 | |
| 0.0001963 | 2037. | 10373849. | 7.3898846 | 38.8594961 | |
| 0.0002023 | 2098. | 10373849. | 7.3460645 | 39.7977363 | |
| 0.0002082 | 2160. | 10373849. | 7.3047483 | 40.7359765 | |
| 0.0002142 | 2222. | 10373849. | 7.2657275 | 41.6742168 | |
| 0.0002201 | 2284. | 10373849. | 7.2288160 | 42.6124570 | |
| 0.0002261 | 2345. | 10373849. | 7.1938471 | 43.5506972 | |
| 0.0002320 | 2407. | 10373849. | 7.1606716 | 44.4889375 | |
| 0.0002439 | 2530. | 10373849. | 7.0991754 | 46.3654179 | |
| 0.0002558 | 2654. | 10373849. | 7.0433998 | 48.2418984 | |
| 0.0002677 | 2776. | 10369816. | 6.9942651 | 50.0000000 | Y |
| 0.0002796 | 2863. | 10239547. | 7.0028375 | 50.0000000 | Y |
| 0.0002915 | 2905. | 9965073. | 7.0779426 | 50.0000000 | Y |
| 0.0003034 | 2942. | 9695056. | 7.1548238 | 50.0000000 | Y |
| 0.0003153 | 2975. | 9436518. | 7.2301177 | 50.0000000 | Y |
| 0.0003272 | 3007. | 9188677. | 7.3039283 | 50.0000000 | Y |
| 0.0003391 | 3036. | 8951651. | 7.3759235 | 50.0000000 | Y |
| 0.0003510 | 3062. | 8724854. | 7.4461296 | 50.0000000 | Y |
| 0.0003629 | 3088. | 8507766. | 7.5145627 | 50.0000000 | Y |
| 0.0003748 | 3111. | 8299912. | 7.5812296 | 50.0000000 | Y |
| 0.0003867 | 3133. | 8100864. | 7.6461291 | 50.0000000 | Y |
| 0.0003986 | 3153. | 7910228. | 7.7092528 | 50.0000000 | Y |
| 0.0004105 | 3172. | 7727642. | 7.7705856 | 50.0000000 | Y |
| 0.0004224 | 3190. | 7552457. | 7.8303136 | 50.0000000 | Y |
| 0.0004343 | 3207. | 7384482. | 7.8883463 | 50.0000000 | Y |
| 0.0004462 | 3223. | 7223214. | 7.9448115 | 50.0000000 | Y |
| 0.0004581 | 3238. | 7068473. | 7.9996332 | 50.0000000 | Y |
| 0.0004700 | 3252. | 6919600. | 8.0530866 | 50.0000000 | Y |
| 0.0004819 | 3266. | 6776566. | 8.1050131 | 50.0000000 | Y |
| 0.0004938 | 3278. | 6639026. | 8.1554903 | 50.0000000 | Y |
| 0.0005057 | 3290. | 6506666. | 8.2045877 | 50.0000000 | Y |
| 0.0005176 | 3302. | 6379094. | 8.2524532 | 50.0000000 | Y |
| 0.0005295 | 3313. | 6256191. | 8.2990290 | 50.0000000 | Y |
| 0.0005414 | 3323. | 6137716. | 8.3443638 | 50.0000000 | Y |

| | | | | | |
|---|---|---|---|---|---|
| 0.0005533 | 3332. | 6023111. | 8.3873214 | 50.0000000 | Y |
| 0.0005652 | 3341. | 5911202. | 8.4243030 | 50.0000000 | Y |
| 0.0005771 | 3349. | 5803283. | 8.4604663 | 50.0000000 | Y |
| 0.0005890 | 3357. | 5699043. | 8.4959585 | 50.0000000 | Y |
| 0.0006009 | 3364. | 5597697. | 8.5277194 | 50.0000000 | Y |
| 0.0006128 | 3370. | 5498804. | 8.5541899 | 50.0000000 | Y |
| 0.0006247 | 3375. | 5403371. | 8.5801768 | 50.0000000 | Y |
| 0.0006366 | 3381. | 5311082. | 8.6059321 | 50.0000000 | Y |
| 0.0006485 | 3385. | 5220410. | 8.6238111 | 50.0000000 | Y |
| 0.0006604 | 3389. | 5132091. | 8.6373979 | 50.0000000 | Y |
| 0.0006723 | 3393. | 5046624. | 8.6513446 | 50.0000000 | Y |
| 0.0006842 | 3395. | 4962958. | 8.6585012 | 50.0000000 | Y |
| 0.0006961 | 3397. | 4880651. | 8.6585911 | 50.0000000 | Y |
| 0.0007080 | 3399. | 4801085. | 8.6588333 | 50.0000000 | Y |
| 0.0007556 | 3405. | 4506652. | 8.6584306 | 50.0000000 | Y |
| 0.0008032 | 3410. | 4245800. | 8.6585911 | 50.0000000 | Y |
| 0.0008507 | 3414. | 4013200. | 8.6586619 | 50.0000000 | Y |
| 0.0008983 | 3418. | 3804524. | 8.6586456 | 50.0000000 | Y |
| 0.0009459 | 3421. | 3616300. | 8.6585417 | 50.0000000 | Y |
| 0.0009935 | 3423. | 3445703. | 8.6583462 | 50.0000000 | Y |
| 0.0010411 | 3426. | 3290360. | 8.6588403 | 50.0000000 | Y |

---

Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1

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| Load No. | Axial Thrust kips | Nominal Moment Capacity in-kips |
|---|---|---|
| 1 | 120.0000000000 | 3426. |

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

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Layering Correction Equivalent Depths of Soil & Rock Layers

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| Layer No. | Top of Layer Below Pile Head ft | Equivalent Top Depth Below Grnd Surf ft | Same Layer Type As Layer Above | Layer is Rock or is Below Rock Layer | F0 Integral for Layer lbs | F1 Integral for Layer lbs |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | N.A. | No | 0.00 | 5159. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | 3.0000 | 31.9964 | No | No | 5159. | 6945. |
| 3 | 12.0000 | 4.5834 | No | No | 12104. | 1252357. |
| 4 | 32.0000 | 401.1451 | No | No | 1264460. | N.A. |

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

--------------------------------------------------------------------------------

Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

Shear force at pile head = 25000.0 lbs
Rotation of pile head = 0.000E+00 radians
Axial load at pile head = 120000.0 lbs

(Zero slope for this load indicates fixed-head conditions)

| Depth X feet | Deflect. y inches | Bending Moment in-lbs | Shear Force lbs | Slope S radians | Total Stress psi* | Bending Stiffness in-lb^2 | Soil Res. p lb/inch | Soil Spr. Es*h lb/inch | Distrib. Lat. Load lb/inch |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.4373 | -1343860. | 25000. | 0.00 | 28259. | 1.04E+10 | 0.00 | 0.00 | 0.00 |
| 0.4000 | 0.4358 | -1223681. | 24916. | -5.94E-04 | 26424. | 1.04E+10 | -35.0529 | 386.1021 | 0.00 |
| 0.8000 | 0.4316 | -1103984. | 24649. | -0.00113 | 24597. | 1.04E+10 | -75.9432 | 844.6616 | 0.00 |
| 1.2000 | 0.4249 | -985742. | 24186. | -0.00162 | 22791. | 1.04E+10 | -117.0076 | 1322. | 0.00 |
| 1.6000 | 0.4161 | -869933. | 23535. | -0.00205 | 21023. | 1.04E+10 | -154.4610 | 1782. | 0.00 |
| 2.0000 | 0.4053 | -757451. | 22714. | -0.00242 | 19306. | 1.04E+10 | -187.7406 | 2224. | 0.00 |
| 2.4000 | 0.3928 | -649092. | 21748. | -0.00275 | 17652. | 1.04E+10 | -214.4122 | 2620. | 0.00 |
| 2.8000 | 0.3789 | -545501. | 20662. | -0.00302 | 16070. | 1.04E+10 | -238.2454 | 3018. | 0.00 |
| 3.2000 | 0.3638 | -447254. | 19587. | -0.00325 | 14570. | 1.04E+10 | -209.5357 | 2765. | 0.00 |
| 3.6000 | 0.3477 | -353715. | 18544. | -0.00344 | 13142. | 1.04E+10 | -225.2870 | 3110. | 0.00 |
| 4.0000 | 0.3308 | -265272. | 17432. | -0.00358 | 11792. | 1.04E+10 | -238.1525 | 3456. | 0.00 |
| 4.4000 | 0.3133 | -182246. | 16264. | -0.00369 | 10524. | 1.04E+10 | -248.1181 | 3802. | 0.00 |
| 4.8000 | 0.2954 | -104887. | 15056. | -0.00375 | 9343. | 1.04E+10 | -255.2159 | 4147. | |

```
0.00
  5.2000     0.2773    -33381.     13821.   -0.00378       8252.   1.04E+10  -259.5193       4493.
0.00
  5.6000     0.2591     32154.     12572.   -0.00378       8233.   1.04E+10  -261.1379       4838.
0.00
  6.0000     0.2409     91665.     11320.   -0.00376       9141.   1.04E+10  -260.2131       5184.
0.00
  6.4000     0.2230    145155.     10079.   -0.00370       9958.   1.04E+10  -256.9124       5530.
0.00
  6.8000     0.2054    192688.      8859.   -0.00362      10684.   1.04E+10  -251.4253       5875.
0.00
  7.2000     0.1882    234377.      7670.   -0.00352      11320.   1.04E+10  -243.9583       6221.
0.00
  7.6000     0.1716    270382.      6521.   -0.00341      11870.   1.04E+10  -234.7304       6566.
0.00
  8.0000     0.1555    300907.      5421.   -0.00327      12336.   1.04E+10  -223.9692       6912.
0.00
  8.4000     0.1402    326191.      4374.   -0.00313      12722.   1.04E+10  -211.9069       7258.
0.00
  8.8000     0.1255    346507.      3389.   -0.00297      13032.   1.04E+10  -198.7769       7603.
0.00
  9.2000     0.1116    362150.      2468.   -0.00281      13271.   1.04E+10  -184.8103       7949.
0.00
  9.6000    0.09851    373438.      1616.   -0.00264      13443.   1.04E+10  -170.2334       8294.
0.00
 10.0000    0.08626    380705.  834.8896   -0.00247      13554.   1.04E+10  -155.2651       8640.
0.00
 10.4000    0.07485    384293.  125.9782   -0.00229      13609.   1.04E+10  -140.1147       8986.
0.00
 10.8000    0.06429    384551. -510.2499   -0.00211      13613.   1.04E+10  -124.9804       9331.
0.00
 11.2000    0.05459    381826.     -1074.   -0.00193      13571.   1.04E+10  -110.0476       9677.
0.00
 11.6000    0.04573    376464.     -1568.   -0.00176      13489.   1.04E+10   -95.4883      10022.
0.00
 12.0000    0.03771    368802.     -2058.   -0.00159      13373.   1.04E+10  -108.8291      13852.
0.00
 12.4000    0.03051    358534.     -2572.   -0.00142      13216.   1.04E+10  -105.4249      16584.
0.00
 12.8000    0.02411    345742.     -3078.   -0.00125      13020.   1.04E+10  -105.1908      20943.
0.00
 13.2000    0.01847    330434.     -3576.   -0.00110      12787.   1.04E+10  -102.3047      26582.
0.00
 13.6000    0.01357    312680.     -4052.  -9.49E-04      12516.   1.04E+10   -96.1757      34016.
0.00
 14.0000    0.00936    292628.     -4490.  -8.09E-04      12210.   1.04E+10   -86.3906      44284.
0.00
 14.4000    0.00581    270506.     -4859.  -6.79E-04      11872.   1.04E+10   -67.2257      55572.
0.00
 14.8000    0.00285    246764.     -5102.  -5.59E-04      11509.   1.04E+10   -33.9102      57116.
0.00
 15.2000   4.41E-04    222175.     -5196.  -4.50E-04      11134.   1.04E+10    -5.3905      58660.
0.00
 15.6000   -0.00147    197403.     -5164.  -3.53E-04      10756.   1.04E+10    18.4895      60204.
0.00
 16.0000   -0.00295    173004.     -5029.  -2.68E-04      10383.   1.04E+10    37.9615      61747.
0.00
 16.4000   -0.00404    149433.     -4810.  -1.93E-04      10023.   1.04E+10    53.3169      63291.
0.00
```

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 16.8000 | -0.00480 | 127051. | -4526. | -1.29E-04 | 9682. | 1.04E+10 | 64.8923 | 64835. | 0.00 |
| 17.2000 | -0.00528 | 106130. | -4195. | -7.51E-05 | 9362. | 1.04E+10 | 73.0548 | 66378. | 0.00 |
| 17.6000 | -0.00553 | 86865. | -3832. | -3.05E-05 | 9068. | 1.04E+10 | 78.1896 | 67922. | 0.00 |
| 18.0000 | -0.00558 | 69377. | -3451. | 5.66E-06 | 8801. | 1.04E+10 | 80.6886 | 69466. | 0.00 |
| 18.4000 | -0.00547 | 53730. | -3063. | 3.41E-05 | 8562. | 1.04E+10 | 80.9403 | 71009. | 0.00 |
| 18.8000 | -0.00525 | 39934. | -2678. | 5.58E-05 | 8352. | 1.04E+10 | 79.3212 | 72553. | 0.00 |
| 19.2000 | -0.00494 | 27954. | -2305. | 7.15E-05 | 8169. | 1.04E+10 | 76.1891 | 74097. | 0.00 |
| 19.6000 | -0.00456 | 17723. | -1950. | 8.21E-05 | 8013. | 1.04E+10 | 71.8779 | 75640. | 0.00 |
| 20.0000 | -0.00415 | 9143. | -1617. | 8.83E-05 | 7882. | 1.04E+10 | 66.6930 | 77184. | 0.00 |
| 20.4000 | -0.00371 | 2097. | -1311. | 9.09E-05 | 7774. | 1.04E+10 | 60.9090 | 78728. | 0.00 |
| 20.8000 | -0.00327 | -3546. | -1033. | 9.06E-05 | 7796. | 1.04E+10 | 54.7680 | 80271. | 0.00 |
| 21.2000 | -0.00284 | -7927. | -785.4668 | 8.79E-05 | 7863. | 1.04E+10 | 48.4791 | 81815. | 0.00 |
| 21.6000 | -0.00243 | -11188. | -567.7916 | 8.35E-05 | 7913. | 1.04E+10 | 42.2189 | 83359. | 0.00 |
| 22.0000 | -0.00204 | -13474. | -379.7482 | 7.78E-05 | 7948. | 1.04E+10 | 36.1325 | 84902. | 0.00 |
| 22.4000 | -0.00168 | -14923. | -220.2257 | 7.12E-05 | 7970. | 1.04E+10 | 30.3352 | 86446. | 0.00 |
| 22.8000 | -0.00136 | -15670. | -87.6249 | 6.41E-05 | 7981. | 1.04E+10 | 24.9151 | 87990. | 0.00 |
| 23.2000 | -0.00107 | -15839. | 20.0149 | 5.68E-05 | 7984. | 1.04E+10 | 19.9349 | 89533. | 0.00 |
| 23.6000 | -8.13E-04 | -15543. | 104.9035 | 4.96E-05 | 7979. | 1.04E+10 | 15.4353 | 91077. | 0.00 |
| 24.0000 | -5.93E-04 | -14889. | 169.3990 | 4.25E-05 | 7969. | 1.04E+10 | 11.4378 | 92621. | 0.00 |
| 24.4000 | -4.05E-04 | -13966. | 215.9222 | 3.59E-05 | 7955. | 1.04E+10 | 7.9469 | 94164. | 0.00 |
| 24.8000 | -2.48E-04 | -12857. | 246.8839 | 2.97E-05 | 7938. | 1.04E+10 | 4.9538 | 95708. | 0.00 |
| 25.2000 | -1.20E-04 | -11630. | 264.6255 | 2.40E-05 | 7919. | 1.04E+10 | 2.4385 | 97252. | 0.00 |
| 25.6000 | -1.81E-05 | -10344. | 271.3720 | 1.89E-05 | 7900. | 1.04E+10 | 0.3725 | 98796. | 0.00 |
| 26.0000 | 6.12E-05 | -9047. | 269.1963 | 1.44E-05 | 7880. | 1.04E+10 | -1.2790 | 100339. | 0.00 |
| 26.4000 | 1.20E-04 | -7777. | 259.9944 | 1.05E-05 | 7861. | 1.04E+10 | -2.5551 | 101883. | 0.00 |
| 26.8000 | 1.62E-04 | -6563. | 245.4693 | 7.21E-06 | 7842. | 1.04E+10 | -3.4971 | 103427. | 0.00 |
| 27.2000 | 1.90E-04 | -5428. | 227.1230 | 4.44E-06 | 7825. | 1.04E+10 | -4.1472 | 104970. | 0.00 |
| 27.6000 | 2.05E-04 | -4388. | 206.2557 | 2.17E-06 | 7809. | 1.04E+10 | -4.5475 | 106514. | 0.00 |
| 28.0000 | 2.10E-04 | -3451. | 183.9704 | 3.56E-07 | 7795. | 1.04E+10 | -4.7381 | 108058. | 0.00 |
| 28.4000 | 2.08E-04 | -2622. | 161.1812 | -1.05E-06 | 7782. | 1.04E+10 | -4.7574 | 109601. | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.00 | | | | | | | | |
| 28.8000 | 2.00E-04 | -1902. | 138.6267 | -2.10E-06 | 7771. | 1.04E+10 | -4.6404 | 111145. |
| 0.00 | | | | | | | | |
| 29.2000 | 1.88E-04 | -1289. | 116.8839 | -2.83E-06 | 7762. | 1.04E+10 | -4.4191 | 112689. |
| 0.00 | | | | | | | | |
| 29.6000 | 1.73E-04 | -776.9394 | 96.3856 | -3.31E-06 | 7754. | 1.04E+10 | -4.1219 | 114232. |
| 0.00 | | | | | | | | |
| 30.0000 | 1.56E-04 | -359.7612 | 77.4371 | -3.57E-06 | 7747. | 1.04E+10 | -3.7733 | 115776. |
| 0.00 | | | | | | | | |
| 30.4000 | 1.39E-04 | -29.4250 | 60.2343 | -3.66E-06 | 7742. | 1.04E+10 | -3.3945 | 117320. |
| 0.00 | | | | | | | | |
| 30.8000 | 1.21E-04 | 222.7093 | 44.8807 | -3.62E-06 | 7745. | 1.04E+10 | -3.0028 | 118863. |
| 0.00 | | | | | | | | |
| 31.2000 | 1.04E-04 | 405.6003 | 31.4050 | -3.47E-06 | 7748. | 1.04E+10 | -2.6121 | 120407. |
| 0.00 | | | | | | | | |
| 31.6000 | 8.79E-05 | 528.2002 | 19.7760 | -3.26E-06 | 7750. | 1.04E+10 | -2.2333 | 121951. |
| 0.00 | | | | | | | | |
| 32.0000 | 7.28E-05 | 599.2038 | 11.0592 | -3.00E-06 | 7751. | 1.04E+10 | -1.3987 | 92160. |
| 0.00 | | | | | | | | |
| 32.4000 | 5.91E-05 | 637.8216 | 4.9437 | -2.71E-06 | 7752. | 1.04E+10 | -1.1494 | 93312. |
| 0.00 | | | | | | | | |
| 32.8000 | 4.68E-05 | 649.7873 | -0.02613 | -2.41E-06 | 7752. | 1.04E+10 | -0.9214 | 94464. |
| 0.00 | | | | | | | | |
| 33.2000 | 3.60E-05 | 640.3513 | -3.9563 | -2.12E-06 | 7752. | 1.04E+10 | -0.7162 | 95616. |
| 0.00 | | | | | | | | |
| 33.6000 | 2.65E-05 | 614.2432 | -6.9580 | -1.82E-06 | 7751. | 1.04E+10 | -0.5345 | 96768. |
| 0.00 | | | | | | | | |
| 34.0000 | 1.84E-05 | 575.6567 | -9.1434 | -1.55E-06 | 7751. | 1.04E+10 | -0.3761 | 97920. |
| 0.00 | | | | | | | | |
| 34.4000 | 1.16E-05 | 528.2522 | -10.6223 | -1.29E-06 | 7750. | 1.04E+10 | -0.2402 | 99072. |
| 0.00 | | | | | | | | |
| 34.8000 | 6.01E-06 | 475.1735 | -11.4999 | -1.06E-06 | 7749. | 1.04E+10 | -0.1255 | 100224. |
| 0.00 | | | | | | | | |
| 35.2000 | 1.44E-06 | 419.0770 | -11.8740 | -8.55E-07 | 7748. | 1.04E+10 | -0.03040 | 101376. |
| 0.00 | | | | | | | | |
| 35.6000 | -2.20E-06 | 362.1684 | -11.8342 | -6.74E-07 | 7747. | 1.04E+10 | 0.04700 | 102528. |
| 0.00 | | | | | | | | |
| 36.0000 | -5.04E-06 | 306.2460 | -11.4603 | -5.20E-07 | 7747. | 1.04E+10 | 0.1088 | 103680. |
| 0.00 | | | | | | | | |
| 36.4000 | -7.19E-06 | 252.7481 | -10.8224 | -3.91E-07 | 7746. | 1.04E+10 | 0.1570 | 104832. |
| 0.00 | | | | | | | | |
| 36.8000 | -8.78E-06 | 202.8012 | -9.9799 | -2.85E-07 | 7745. | 1.04E+10 | 0.1940 | 105984. |
| 0.00 | | | | | | | | |
| 37.2000 | -9.93E-06 | 157.2692 | -8.9826 | -2.02E-07 | 7744. | 1.04E+10 | 0.2216 | 107136. |
| 0.00 | | | | | | | | |
| 37.6000 | -1.07E-05 | 116.8009 | -7.8702 | -1.38E-07 | 7744. | 1.04E+10 | 0.2419 | 108288. |
| 0.00 | | | | | | | | |
| 38.0000 | -1.13E-05 | 81.8746 | -6.6737 | -9.25E-08 | 7743. | 1.04E+10 | 0.2567 | 109440. |
| 0.00 | | | | | | | | |
| 38.4000 | -1.16E-05 | 52.8400 | -5.4157 | -6.13E-08 | 7743. | 1.04E+10 | 0.2675 | 110592. |
| 0.00 | | | | | | | | |
| 38.8000 | -1.18E-05 | 29.9542 | -4.1119 | -4.21E-08 | 7742. | 1.04E+10 | 0.2758 | 111744. |
| 0.00 | | | | | | | | |
| 39.2000 | -1.20E-05 | 13.4140 | -2.7719 | -3.21E-08 | 7742. | 1.04E+10 | 0.2826 | 112896. |
| 0.00 | | | | | | | | |
| 39.6000 | -1.22E-05 | 3.3808 | -1.4007 | -2.82E-08 | 7742. | 1.04E+10 | 0.2888 | 114048. |
| 0.00 | | | | | | | | |
| 40.0000 | -1.23E-05 | 0.00 | 0.00 | -2.74E-08 | 7742. | 1.04E+10 | 0.2948 | 57600. |
| 0.00 | | | | | | | | |

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* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection            =     0.43726830 inches
Computed slope at pile head     =       0.000000 radians
Maximum bending moment          =      -1343860. inch-lbs
Maximum shear force             =         25000. lbs
Depth of maximum bending moment =       0.000000 feet below pile head
Depth of maximum shear force    =       0.000000 feet below pile head
Number of iterations            =              6
Number of zero deflection points =             3
```

--------------------------------------------------------------------------------
Pile-head Deflection vs. Pile Length for Load Case 1
--------------------------------------------------------------------------------

Boundary Condition Type 2, Shear and Slope

```
Shear      =         25000. lbs
Slope      =        0.00000
Axial Load =        120000. lbs
```

| Pile Length feet | Pile Head Deflection inches | Maximum Moment ln-lbs | Maximum Shear lbs |
|---|---|---|---|
| 40.00000 | 0.43726895 | -1343861. | 25000. |
| 38.00000 | 0.43868249 | -1346048. | 25000. |
| 36.00000 | 0.43674224 | -1342731. | 25000. |
| 34.00000 | 0.43821665 | -1345219. | 25000. |
| 32.00000 | 0.43672977 | -1342911. | 25000. |
| 30.00000 | 0.43837566 | -1345957. | 25000. |
| 28.00000 | 0.43752479 | -1344478. | 25000. |
| 26.00000 | 0.43711625 | -1343491. | 25000. |
| 24.00000 | 0.43688660 | -1343531. | 25000. |
| 22.00000 | 0.43721728 | -1343856. | 25000. |
| 20.00000 | 0.43853632 | -1343705. | 25000. |
| 18.00000 | 0.44298472 | -1340135. | 25000. |
| 16.00000 | 0.46341247 | -1353378. | 25000. |
| 14.00000 | 0.50166583 | -1423780. | 25000. |
| 12.00000 | 0.53506914 | -1541310. | 25000. |
| 10.00000 | 0.53949723 | -1592179. | 25000. |

--------------------------------------------------------------------------------
Summary of Pile-head Responses for Conventional Analyses
--------------------------------------------------------------------------------

Definitions of Pile-head Loading Conditions:

DeminTank_B11_Factored.lp10o

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

| Load Case No. | Load Type 1 | Pile-head Load 1 | Load Type 2 | Pile-head Load 2 | Axial Loading lbs | Pile-head Deflection inches | Pile-head Rotation radians | Max Shear in Pile lbs | Max Moment in Pile in-lbs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | V, lb | 25000. | S, rad | 0.00 | 120000. | 0.4373 | 0.00 | 25000. | -1343860. |

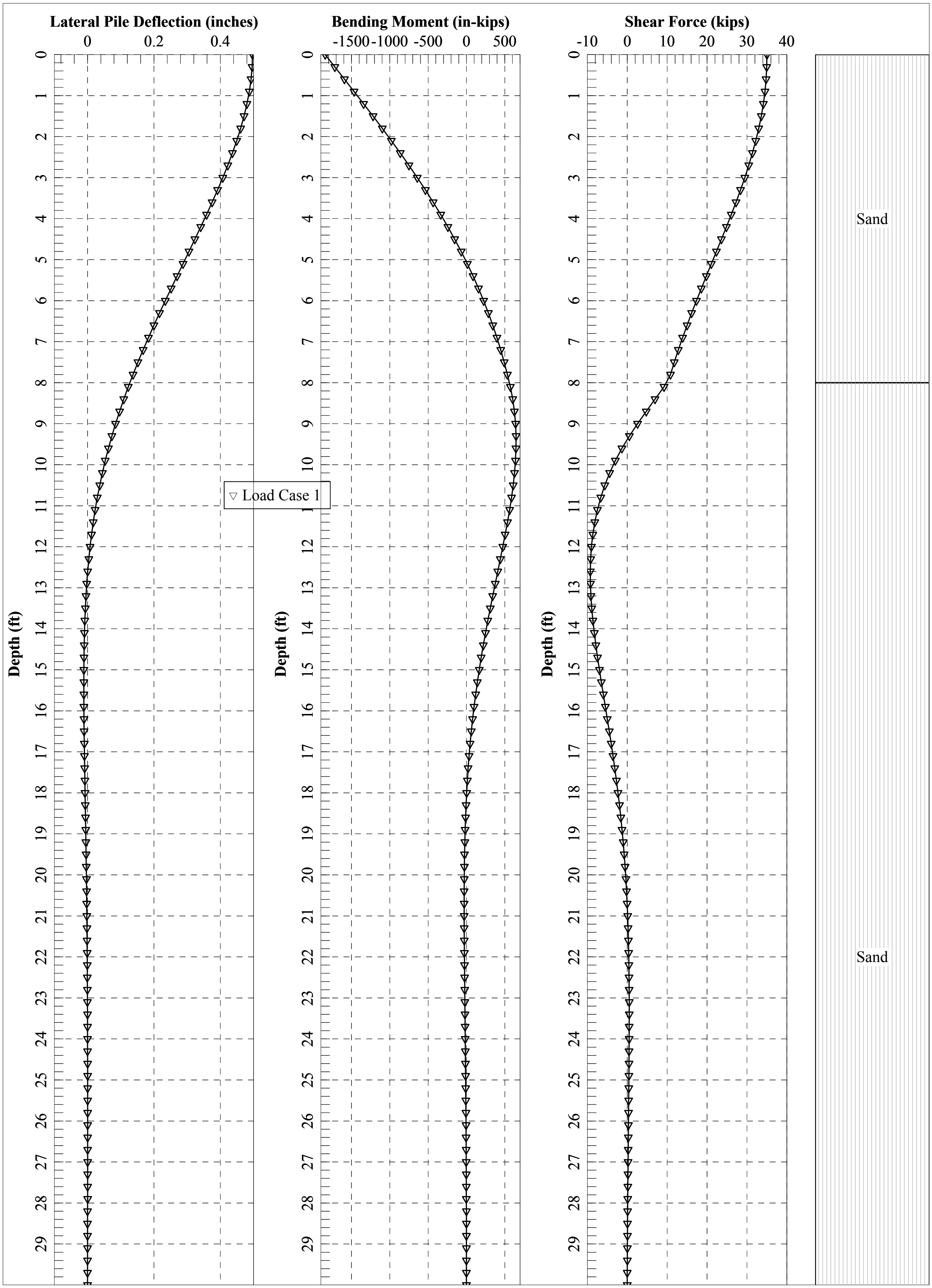
Maximum pile-head deflection = 0.4372683009 inches
Maximum pile-head rotation = -0.0000000000 radians = -0.000000 deg.

The analysis ended normally.

# Lpile analysis report (H-pile)

**Boring: B-5**
**Equipment: H-frame**

# Allowable Bending Moment and Shear force with respect to 0.5" head deflection for given H12x53



```
================================================================================

                    LPile for Windows, Version 2018-10.006

                 Analysis of Individual Piles and Drilled Shafts
                Subjected to Lateral Loading Using the p-y Method
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================================================================================

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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters, MD\Engineering &
Resources\Hpile\LPile_analysis\

Name of input data file:
Hframe_B5_Factored.lp10

Name of output report file:
Hframe_B5_Factored.lp10

Name of plot output file:
Hframe_B5_Factored.lp10

Name of runtime message file:
Hframe_B5_Factored.lp10


--------------------------------------------------------------------------------
                            Date and Time of Analysis
--------------------------------------------------------------------------------

               Date:  June 14, 2018              Time:  12:56:24


--------------------------------------------------------------------------------
                                  Problem Title
--------------------------------------------------------------------------------
```

Project Name: CP Crane Power plant

Job Number:0512843

Client:ProEnergy

Engineer: SS

Description: Axial Capacity of Dirven Pile in Boring B13

--------------------------------------------------------------------------------

## Program Options and Settings

--------------------------------------------------------------------------------

```
Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed              =          500
 - Deflection tolerance for convergence              =   1.0000E-05 in
 - Maximum allowable deflection                      =     100.0000 in
 - Number of pile increments                         =          100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats
```

--------------------------------------------------------------------------------

## Pile Structural Properties and Geometry

--------------------------------------------------------------------------------

```
Number of pile sections defined                         =           1
Total length of pile                                    =      30.000 ft
Depth of ground surface below top of pile               =      0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

            Depth Below          Pile
Point        Pile Head         Diameter
 No.           feet             inches
-----      -------------     -------------
  1            0.000          12.0000
  2           30.000          12.0000


Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is a AISC strong axis steel pile
   Length of section                                    =    30.000000 ft
   AISC Section Type                                    = HP



   AISC Section Name                                    = HP12X53



   Pile width                                           =    12.000000 in
   Shear capacity of section                            =       0.0000 lbs




--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                      =        0.000 degrees
                                                        =        0.000 radians

Pile Batter Angle                                       =        0.000 degrees
                                                        =        0.000 radians


--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 4 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer            =       0.0000 ft
```

```
   Distance from top of pile to bottom of layer       =     8.000000 ft
   Effective unit weight at top of layer              =   115.000000 pcf
   Effective unit weight at bottom of layer           =   115.000000 pcf
   Friction angle at top of layer                     =    32.000000 deg.
   Friction angle at bottom of layer                  =    32.000000 deg.
   Subgrade k at top of layer                         =    20.000000 pci
   Subgrade k at bottom of layer                      =    20.000000 pci


Layer 2 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer          =     8.000000 ft
   Distance from top of pile to bottom of layer       =    36.000000 ft
   Effective unit weight at top of layer              =    72.600000 pcf
   Effective unit weight at bottom of layer           =    72.600000 pcf
   Friction angle at top of layer                     =    33.000000 deg.
   Friction angle at bottom of layer                  =    33.000000 deg.
   Subgrade k at top of layer                         =    67.000000 pci
   Subgrade k at bottom of layer                      =    67.000000 pci


Layer 3 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer          =    36.000000 ft
   Distance from top of pile to bottom of layer       =    47.000000 ft
   Effective unit weight at top of layer              =    62.600000 pcf
   Effective unit weight at bottom of layer           =    62.400000 pcf
   Friction angle at top of layer                     =    35.000000 deg.
   Friction angle at bottom of layer                  =    35.000000 deg.
   Subgrade k at top of layer                         =    55.000000 pci
   Subgrade k at bottom of layer                      =    55.000000 pci


Layer 4 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer          =    47.000000 ft
   Distance from top of pile to bottom of layer       =    48.000000 ft
   Effective unit weight at top of layer              =    87.600000 pcf
   Effective unit weight at bottom of layer           =    57.600000 pcf
   Undrained cohesion at top of layer                 =        2000. psf
   Undrained cohesion at bottom of layer              =        2000. psf
   Epsilon-50 at top of layer                         =       0.0000
   Epsilon-50 at bottom of layer                      =       0.0000
   Subgrade k at top of layer                         =    18.000000 pci
   Subgrade k at bottom of layer                      =    18.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


 (Depth of the lowest soil layer extends 18.000 ft below the pile tip)



--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
--------------------------------------------------------------------------------

Layer         Soil Type          Layer      Effective    Undrained    Angle of       E50
```

Hframe_B5_Factored.lp10o

| Layer Num. | Name (p-y Curve Type) | Depth ft | Unit Wt. pcf | Cohesion psf | Friction deg. | or krm | kpy pci |
|---|---|---|---|---|---|---|---|
| 1 | Sand | 0.00 | 115.0000 | -- | 32.0000 | -- | 20.0000 |
| | (Reese, et al.) | 8.0000 | 115.0000 | -- | 32.0000 | -- | 20.0000 |
| 2 | Sand | 8.0000 | 72.6000 | -- | 33.0000 | -- | 67.0000 |
| | (Reese, et al.) | 36.0000 | 72.6000 | -- | 33.0000 | -- | 67.0000 |
| 3 | Sand | 36.0000 | 62.6000 | -- | 35.0000 | -- | 55.0000 |
| | (Reese, et al.) | 47.0000 | 62.4000 | -- | 35.0000 | -- | 55.0000 |
| 4 | Stiff Clay | 47.0000 | 87.6000 | 2000. | -- | default | 18.0000 |
| | with Free Water | 48.0000 | 57.6000 | 2000. | -- | default | 18.0000 |

---

Static Loading Type

---

Static loading criteria were used when computing p-y curves for all analyses.

---

Pile-head Loading and Pile-head Fixity Conditions

---

Number of loads specified = 1

| Load No. | Load Type | Condition 1 | Condition 2 | Axial Thrust Force, lbs | Compute Top y vs. Pile Length |
|---|---|---|---|---|---|
| 1 | 2 | V = 35000. lbs | S = 0.0000 in/in | 100000. | Yes |

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

---

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Hframe_B5_Factored.lp10o

Number of Pile Sections Analyzed = 1

Pile Section No. 1:
-------------------

Dimensions and Properties of Steel AISC Strong Axis:
---------------------------------------------

| | | |
|---|---|---|
| Length of Section | = | 30.000000 ft |
| Flange Width | = | 12.000000 in |
| Section Depth | = | 11.800000 in |
| Flange Thickness | = | 0.435000 in |
| Web Thickness | = | 0.435000 in |
| Yield Stress of Pipe | = | 50.000000 ksi |
| Elastic Modulus | = | 27000. ksi |
| Cross-sectional Area | = | 15.500000 sq. in. |
| Moment of Inertia | = | 393.000000 in^4 |
| Elastic Bending Stiffness | = | 10611000. kip-in^2 |
| Plastic Modulus, Z | = | 74.000000in^3 |
| Plastic Moment Capacity = Fy Z | = | 3700.in-kip |

Axial Structural Capacities:
----------------------------

| | | |
|---|---|---|
| Nom. Axial Structural Capacity = Fy As | = | 775.000 kips |
| Nominal Axial Tensile Capacity | = | -775.000 kips |

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

| Number | Axial Thrust Force kips |
|---|---|
| 1 | 100.000 |

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 100.000 kips

| Bending Curvature rad/in. | Bending Moment in-kip | Bending Stiffness kip-in2 | Depth to N Axis in | Max Total Stress ksi | Run Msg |
|---|---|---|---|---|---|
| 0.00000605 | 62.7703481 | 10373849. | 46.1841121 | 7.5355646 | |
| 0.00001210 | 125.5406962 | 10373849. | 26.0420560 | 8.4898221 | |
| 0.00001815 | 188.3110443 | 10373849. | 19.3280374 | 9.4440795 | |
| 0.00002420 | 251.0813925 | 10373849. | 15.9710280 | 10.3983371 | |
| 0.00003025 | 313.8517406 | 10373849. | 13.9568224 | 11.3525945 | |
| 0.00003630 | 376.6220887 | 10373849. | 12.6140187 | 12.3068520 | |
| 0.00004236 | 439.3924368 | 10373849. | 11.6548732 | 13.2611095 | |
| 0.00004841 | 502.1627849 | 10373849. | 10.9355140 | 14.2153670 | |
| 0.00005446 | 564.9331330 | 10373849. | 10.3760125 | 15.1696245 | |
| 0.00006051 | 627.7034811 | 10373849. | 9.9284112 | 16.1238820 | |

| | | | | | |
|---|---|---|---|---|---|
| 0.00006656 | 690.4738293 | 10373849. | 9.5621920 | 17.0781394 | |
| 0.00007261 | 753.2441774 | 10373849. | 9.2570093 | 18.0323969 | |
| 0.00007866 | 816.0145255 | 10373849. | 8.9987779 | 18.9866544 | |
| 0.00008471 | 878.7848736 | 10373849. | 8.7774366 | 19.9409119 | |
| 0.00009076 | 941.5552217 | 10373849. | 8.5856075 | 20.8951694 | |
| 0.00009681 | 1004. | 10373849. | 8.4177570 | 21.8494269 | |
| 0.0001029 | 1067. | 10373849. | 8.2696537 | 22.8036844 | |
| 0.0001089 | 1130. | 10373849. | 8.1380062 | 23.7579418 | |
| 0.0001150 | 1193. | 10373849. | 8.0202164 | 24.7121993 | |
| 0.0001210 | 1255. | 10373849. | 7.9142056 | 25.6664568 | |
| 0.0001271 | 1318. | 10373849. | 7.8182911 | 26.6207143 | |
| 0.0001331 | 1381. | 10373849. | 7.7310960 | 27.5749718 | |
| 0.0001392 | 1444. | 10373849. | 7.6514831 | 28.5292293 | |
| 0.0001452 | 1506. | 10373849. | 7.5785047 | 29.4834868 | |
| 0.0001513 | 1569. | 10373849. | 7.5113645 | 30.4377442 | |
| 0.0001573 | 1632. | 10373849. | 7.4493889 | 31.3920017 | |
| 0.0001634 | 1695. | 10373849. | 7.3920042 | 32.3462592 | |
| 0.0001694 | 1758. | 10373849. | 7.3387183 | 33.3005167 | |
| 0.0001755 | 1820. | 10373849. | 7.2891073 | 34.2547742 | |
| 0.0001815 | 1883. | 10373849. | 7.2428037 | 35.2090317 | |
| 0.0001876 | 1946. | 10373849. | 7.1994875 | 36.1632892 | |
| 0.0001936 | 2009. | 10373849. | 7.1588785 | 37.1175466 | |
| 0.0001997 | 2071. | 10373849. | 7.1207307 | 38.0718041 | |
| 0.0002057 | 2134. | 10373849. | 7.0848268 | 39.0260616 | |
| 0.0002118 | 2197. | 10373849. | 7.0509746 | 39.9803191 | |
| 0.0002178 | 2260. | 10373849. | 7.0190031 | 40.9345766 | |
| 0.0002239 | 2323. | 10373849. | 6.9887598 | 41.8888341 | |
| 0.0002299 | 2385. | 10373849. | 6.9601082 | 42.8430916 | |
| 0.0002360 | 2448. | 10373849. | 6.9329260 | 43.7973490 | |
| 0.0002481 | 2574. | 10373849. | 6.8825393 | 45.7058640 | |
| 0.0002602 | 2699. | 10373849. | 6.8368398 | 47.6143790 | |
| 0.0002723 | 2825. | 10373849. | 6.7952025 | 49.5228940 | |
| 0.0002844 | 2930. | 10304345. | 6.7862975 | 50.0000000 | Y |
| 0.0002965 | 2982. | 10058700. | 6.8564449 | 50.0000000 | Y |
| 0.0003086 | 3021. | 9788501. | 6.9404013 | 50.0000000 | Y |
| 0.0003207 | 3056. | 9529522. | 7.0223071 | 50.0000000 | Y |
| 0.0003328 | 3089. | 9281137. | 7.1022588 | 50.0000000 | Y |
| 0.0003449 | 3119. | 9043426. | 7.1800065 | 50.0000000 | Y |
| 0.0003570 | 3147. | 8815791. | 7.2556367 | 50.0000000 | Y |
| 0.0003691 | 3173. | 8597720. | 7.3292077 | 50.0000000 | Y |
| 0.0003812 | 3198. | 8388926. | 7.4006618 | 50.0000000 | Y |
| 0.0003933 | 3221. | 8188867. | 7.4700949 | 50.0000000 | Y |
| 0.0004054 | 3242. | 7997103. | 7.5375590 | 50.0000000 | Y |
| 0.0004175 | 3262. | 7813337. | 7.6030290 | 50.0000000 | Y |
| 0.0004296 | 3281. | 7637180. | 7.6665448 | 50.0000000 | Y |
| 0.0004417 | 3299. | 7467955. | 7.7283510 | 50.0000000 | Y |
| 0.0004538 | 3315. | 7305679. | 7.7882510 | 50.0000000 | Y |
| 0.0004659 | 3331. | 7149642. | 7.8465457 | 50.0000000 | Y |
| 0.0004780 | 3346. | 6999738. | 7.9031372 | 50.0000000 | Y |
| 0.0004901 | 3360. | 6855337. | 7.9571411 | 50.0000000 | Y |
| 0.0005022 | 3372. | 6713986. | 8.0028183 | 50.0000000 | Y |
| 0.0005143 | 3383. | 6578098. | 8.0474995 | 50.0000000 | Y |
| 0.0005264 | 3393. | 6446314. | 8.0874130 | 50.0000000 | Y |
| 0.0005385 | 3402. | 6317771. | 8.1202498 | 50.0000000 | Y |
| 0.0005506 | 3411. | 6194212. | 8.1525942 | 50.0000000 | Y |
| 0.0005627 | 3417. | 6072429. | 8.1734361 | 50.0000000 | Y |
| 0.0005748 | 3423. | 5954357. | 8.1905348 | 50.0000000 | Y |
| 0.0005869 | 3427. | 5838811. | 8.1988312 | 50.0000000 | Y |
| 0.0005990 | 3430. | 5725690. | 8.1988750 | 50.0000000 | Y |

| | | | | | |
|---|---|---|---|---|---|
| 0.0006111 | 3433. | 5616728. | 8.1988354 | 50.0000000 | Y |
| 0.0006232 | 3435. | 5511806. | 8.1988775 | 50.0000000 | Y |
| 0.0006353 | 3438. | 5410592. | 8.1988329 | 50.0000000 | Y |
| 0.0006474 | 3440. | 5312995. | 8.1988734 | 50.0000000 | Y |
| 0.0006595 | 3442. | 5218788. | 8.1988236 | 50.0000000 | Y |
| 0.0006716 | 3444. | 5127763. | 8.1988628 | 50.0000000 | Y |
| 0.0006837 | 3446. | 5039918. | 8.1988073 | 50.0000000 | Y |
| 0.0006958 | 3448. | 4954814. | 8.1988455 | 50.0000000 | Y |
| 0.0007079 | 3450. | 4872620. | 8.1988823 | 50.0000000 | Y |
| 0.0007200 | 3451. | 4793015. | 8.1988211 | 50.0000000 | Y |
| 0.0007685 | 3457. | 4498675. | 8.1988587 | 50.0000000 | Y |
| 0.0008169 | 3462. | 4238042. | 8.1988823 | 50.0000000 | Y |
| 0.0008653 | 3466. | 4005650. | 8.1988927 | 50.0000000 | Y |
| 0.0009137 | 3469. | 3797170. | 8.1988903 | 50.0000000 | Y |
| 0.0009621 | 3472. | 3609132. | 8.1988750 | 50.0000000 | Y |
| 0.0010105 | 3475. | 3438716. | 8.1988463 | 50.0000000 | Y |
| 0.0010589 | 3477. | 3283602. | 8.1988030 | 50.0000000 | Y |
| 0.0011073 | 3479. | 3141769. | 8.1988991 | 50.0000000 | Y |

--------------------------------------------------------------------------------
Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1
--------------------------------------------------------------------------------

| Load No. | Axial Thrust kips | Nominal Moment Capacity in-kips |
|---|---|---|
| 1 | 100.0000000000 | 3479. |

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

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Layering Correction Equivalent Depths of Soil & Rock Layers
--------------------------------------------------------------------------------

| Layer No. | Top of Layer Below Pile Head ft | Equivalent Top Depth Below Grnd Surf ft | Same Layer Type As Layer Above | Layer is Rock or is Below Rock Layer | F0 Integral for Layer lbs | F1 Integral for Layer lbs |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | N.A. | No | 0.00 | 51320. |
| 2 | 8.0000 | 7.7646 | Yes | No | 51320. | 1310198. |
| 3 | 36.0000 | 36.0000 | No | No | 1361518. | 0.00 |
| 4 | 47.0000 | 47.0000 | No | No | 0.00 | N.A. |

Hframe_B5_Factored.lp10o

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

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Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

Shear force at pile head = 35000.0 lbs
Rotation of pile head = 0.000E+00 radians
Axial load at pile head = 100000.0 lbs

(Zero slope for this load indicates fixed-head conditions)

| Depth X feet | Deflect. y inches | Bending Moment in-lbs | Shear Force lbs | Slope S radians | Total Stress psi* | Bending Stiffness in-lb^2 | Soil Res. p lb/inch | Soil Spr. Es*h lb/inch | Distrib. Lat. Load lb/inch |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.4969 | -1843346. | 35000. | 0.00 | 34594. | 1.04E+10 | 0.00 | 0.00 | 0.00 |
| 0.3000 | 0.4958 | -1717231. | 34951. | -6.18E-04 | 32669. | 1.04E+10 | -27.3563 | 198.6457 | 0.00 |
| 0.6000 | 0.4925 | -1591256. | 34794. | -0.00119 | 30746. | 1.04E+10 | -59.7121 | 436.4981 | 0.00 |
| 0.9000 | 0.4872 | -1465856. | 34517. | -0.00172 | 28831. | 1.04E+10 | -94.1960 | 696.0459 | 0.00 |
| 1.2000 | 0.4801 | -1341493. | 34116. | -0.00221 | 26932. | 1.04E+10 | -128.7935 | 965.8055 | 0.00 |
| 1.5000 | 0.4713 | -1218632. | 33594. | -0.00265 | 25057. | 1.04E+10 | -161.1459 | 1231. | 0.00 |
| 1.8000 | 0.4610 | -1097708. | 32955. | -0.00306 | 23211. | 1.04E+10 | -193.7118 | 1513. | 0.00 |
| 2.1000 | 0.4493 | -979156. | 32206. | -0.00342 | 21401. | 1.04E+10 | -222.5079 | 1783. | 0.00 |
| 2.4000 | 0.4364 | -863367. | 31366. | -0.00374 | 19633. | 1.04E+10 | -243.9270 | 2012. | 0.00 |
| 2.7000 | 0.4224 | -750630. | 30451. | -0.00402 | 17912. | 1.04E+10 | -264.3948 | 2253. | 0.00 |
| 3.0000 | 0.4075 | -641226. | 29468. | -0.00426 | 16241. | 1.04E+10 | -281.6272 | 2488. | 0.00 |
| 3.3000 | 0.3917 | -535393. | 28407. | -0.00446 | 14626. | 1.04E+10 | -307.7840 | 2829. | 0.00 |
| 3.6000 | 0.3753 | -433481. | 27270. | -0.00463 | 13070. | 1.04E+10 | -324.2912 | 3110. | 0.00 |
| 3.9000 | 0.3584 | -335717. | 26082. | -0.00476 | 11577. | 1.04E+10 | -335.4626 | 3370. | 0.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.2000 | 0.3410 | -242260. | 24860. | -0.00486 | 10150. | 1.04E+10 | -343.7724 | 3629. | 0.00 |
| 4.5000 | 0.3234 | -153227. | 23612. | -0.00493 | 8791. | 1.04E+10 | -349.2559 | 3888. | 0.00 |
| 4.8000 | 0.3055 | -68702. | 22350. | -0.00497 | 7500. | 1.04E+10 | -351.9761 | 4147. | 0.00 |
| 5.1000 | 0.2876 | 11270. | 21083. | -0.00498 | 6624. | 1.04E+10 | -352.0208 | 4406. | 0.00 |
| 5.4000 | 0.2697 | 86679. | 19820. | -0.00496 | 7775. | 1.04E+10 | -349.5009 | 4666. | 0.00 |
| 5.7000 | 0.2519 | 157547. | 18571. | -0.00492 | 8857. | 1.04E+10 | -344.5484 | 4925. | 0.00 |
| 6.0000 | 0.2342 | 223931. | 17343. | -0.00485 | 9870. | 1.04E+10 | -337.3141 | 5184. | 0.00 |
| 6.3000 | 0.2169 | 285915. | 16146. | -0.00477 | 10817. | 1.04E+10 | -327.9659 | 5443. | 0.00 |
| 6.6000 | 0.1999 | 343612. | 14985. | -0.00466 | 11698. | 1.04E+10 | -316.6870 | 5702. | 0.00 |
| 6.9000 | 0.1834 | 397163. | 13869. | -0.00453 | 12515. | 1.04E+10 | -303.6739 | 5962. | 0.00 |
| 7.2000 | 0.1673 | 446728. | 12802. | -0.00438 | 13272. | 1.04E+10 | -289.1349 | 6221. | 0.00 |
| 7.5000 | 0.1518 | 492490. | 11789. | -0.00422 | 13971. | 1.04E+10 | -273.2885 | 6480. | 0.00 |
| 7.8000 | 0.1369 | 534649. | 10836. | -0.00404 | 14614. | 1.04E+10 | -256.3624 | 6739. | 0.00 |
| 8.1000 | 0.1227 | 573418. | 9236. | -0.00385 | 15206. | 1.04E+10 | -632.5512 | 18554. | 0.00 |
| 8.4000 | 0.1092 | 603918. | 6975. | -0.00364 | 15672. | 1.04E+10 | -623.6705 | 20554. | 0.00 |
| 8.7000 | 0.09649 | 626260. | 4752. | -0.00343 | 16013. | 1.04E+10 | -611.1139 | 22800. | 0.00 |
| 9.0000 | 0.08453 | 640604. | 2581. | -0.00321 | 16232. | 1.04E+10 | -594.8895 | 25334. | 0.00 |
| 9.3000 | 0.07337 | 647158. | 522.9780 | -0.00299 | 16332. | 1.04E+10 | -548.6277 | 26918. | 0.00 |
| 9.6000 | 0.06302 | 646521. | -1340. | -0.00276 | 16322. | 1.04E+10 | -486.4303 | 27786. | 0.00 |
| 9.9000 | 0.05348 | 639498. | -2982. | -0.00254 | 16215. | 1.04E+10 | -425.6685 | 28655. | 0.00 |
| 10.2000 | 0.04473 | 626880. | -4408. | -0.00232 | 16022. | 1.04E+10 | -366.8546 | 29523. | 0.00 |
| 10.5000 | 0.03677 | 609428. | -5628. | -0.00211 | 15756. | 1.04E+10 | -310.4337 | 30391. | 0.00 |
| 10.8000 | 0.02957 | 587877. | -6649. | -0.00190 | 15427. | 1.04E+10 | -256.7833 | 31260. | 0.00 |
| 11.1000 | 0.02311 | 562925. | -7482. | -0.00170 | 15046. | 1.04E+10 | -206.2138 | 32128. | 0.00 |
| 11.4000 | 0.01734 | 535230. | -8139. | -0.00151 | 14623. | 1.04E+10 | -158.9712 | 32996. | 0.00 |
| 11.7000 | 0.01225 | 505408. | -8633. | -0.00133 | 14168. | 1.04E+10 | -115.2386 | 33864. | 0.00 |
| 12.0000 | 0.00779 | 474029. | -8976. | -0.00116 | 13689. | 1.04E+10 | -75.1407 | 34733. | 0.00 |
| 12.3000 | 0.00392 | 441617. | -9181. | -9.98E-04 | 13194. | 1.04E+10 | -38.7465 | 35601. | 0.00 |
| 12.6000 | 6.00E-04 | 408648. | -9261. | -8.51E-04 | 12691. | 1.04E+10 | -6.0744 | 36469. | 0.00 |
| 12.9000 | -0.00221 | 375549. | -9231. | -7.15E-04 | 12185. | 1.04E+10 | 22.9036 | 37338. | |

```
0.00
 13.2000   -0.00455    342700.      -9103.  -5.90E-04     11684.   1.04E+10    48.2569     38206.
0.00
 13.5000   -0.00646    310434.      -8890.  -4.77E-04     11191.   1.04E+10    70.0915     39074.
0.00
 13.8000   -0.00798    279037.      -8604.  -3.75E-04     10712.   1.04E+10    88.5448     39943.
0.00
 14.1000   -0.00915    248753.      -8258.  -2.83E-04     10249.   1.04E+10   103.7808     40811.
0.00
 14.4000   -0.01002    219782.      -7862.  -2.02E-04      9807.   1.04E+10   115.9853     41679.
0.00
 14.7000   -0.01061    192288.      -7428.  -1.30E-04      9387.   1.04E+10   125.3612     42548.
0.00
 15.0000   -0.01096    166394.      -6965.  -6.80E-05      8992.   1.04E+10   132.1241     43416.
0.00
 15.3000   -0.01110    142192.      -6481.  -1.44E-05      8622.   1.04E+10   136.4980     44284.
0.00
 15.6000   -0.01106    119741.      -5986.   3.10E-05      8280.   1.04E+10   138.7118     45153.
0.00
 15.9000   -0.01087     99072.      -5486.   6.90E-05      7964.   1.04E+10   138.9955     46021.
0.00
 16.2000   -0.01056     80193.      -4988.   1.00E-04      7676.   1.04E+10   137.5772     46889.
0.00
 16.5000   -0.01015     63087.      -4498.   1.25E-04      7415.   1.04E+10   134.6801     47758.
0.00
 16.8000   -0.00966     47718.      -4021.   1.44E-04      7180.   1.04E+10   130.5205     48626.
0.00
 17.1000   -0.00911     34035.      -3560.   1.58E-04      6971.   1.04E+10   125.3053     49494.
0.00
 17.4000   -0.00852     21971.      -3120.   1.68E-04      6787.   1.04E+10   119.2305     50363.
0.00
 17.7000   -0.00790     11450.      -2703.   1.74E-04      6626.   1.04E+10   112.4798     51231.
0.00
 18.0000   -0.00727      2385.      -2311.   1.76E-04      6488.   1.04E+10   105.2236     52099.
0.00
 18.3000   -0.00663     -5316.      -1946.   1.76E-04      6533.   1.04E+10    97.6181     52968.
0.00
 18.6000   -0.00601    -11751.      -1609.   1.73E-04      6631.   1.04E+10    89.8050     53836.
0.00
 18.9000   -0.00539    -17022.      -1299.   1.68E-04      6711.   1.04E+10    81.9114     54704.
0.00
 19.2000   -0.00480    -21228.      -1019.   1.61E-04      6776.   1.04E+10    74.0495     55572.
0.00
 19.5000   -0.00423    -24472.  -766.0259   1.53E-04      6825.   1.04E+10    66.3170     56441.
0.00
 19.8000   -0.00369    -26854.  -540.8195   1.44E-04      6862.   1.04E+10    58.7977     57309.
0.00
 20.1000   -0.00319    -28470.  -342.1725   1.35E-04      6886.   1.04E+10    51.5618     58177.
0.00
 20.4000   -0.00272    -29414.  -168.9614   1.25E-04      6901.   1.04E+10    44.6666     59046.
0.00
 20.7000   -0.00229    -29776.   -19.8778   1.14E-04      6906.   1.04E+10    38.1576     59914.
0.00
 21.0000   -0.00190    -29640.   106.5300   1.04E-04      6904.   1.04E+10    32.0690     60782.
0.00
 21.3000   -0.00154    -29084.   211.8187   9.39E-05      6896.   1.04E+10    26.4247     61651.
0.00
 21.6000   -0.00122    -28182.   297.6143   8.40E-05      6882.   1.04E+10    21.2395     62519.
0.00
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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 21.9000 | -9.38E-04 | -27002. | 365.5813 | 7.44E-05 | 6864. | 1.04E+10 | 16.5199 | 63387. | 0.00 |
| 22.2000 | -6.87E-04 | -25604. | 417.3942 | 6.53E-05 | 6843. | 1.04E+10 | 12.2650 | 64256. | 0.00 |
| 22.5000 | -4.68E-04 | -24044. | 454.7131 | 5.67E-05 | 6819. | 1.04E+10 | 8.4677 | 65124. | 0.00 |
| 22.8000 | -2.79E-04 | -22371. | 479.1623 | 4.86E-05 | 6793. | 1.04E+10 | 5.1152 | 65992. | 0.00 |
| 23.1000 | -1.18E-04 | -20629. | 492.3130 | 4.12E-05 | 6767. | 1.04E+10 | 2.1907 | 66861. | 0.00 |
| 23.4000 | 1.74E-05 | -18856. | 495.6681 | 3.43E-05 | 6739. | 1.04E+10 | -0.3267 | 67729. | 0.00 |
| 23.7000 | 1.29E-04 | -17085. | 490.6509 | 2.81E-05 | 6712. | 1.04E+10 | -2.4606 | 68597. | 0.00 |
| 24.0000 | 2.20E-04 | -15343. | 478.5961 | 2.25E-05 | 6686. | 1.04E+10 | -4.2365 | 69466. | 0.00 |
| 24.3000 | 2.91E-04 | -13655. | 460.7437 | 1.74E-05 | 6660. | 1.04E+10 | -5.6815 | 70334. | 0.00 |
| 24.6000 | 3.45E-04 | -12038. | 438.2345 | 1.30E-05 | 6635. | 1.04E+10 | -6.8235 | 71202. | 0.00 |
| 24.9000 | 3.84E-04 | -10509. | 412.1090 | 9.05E-06 | 6612. | 1.04E+10 | -7.6906 | 72071. | 0.00 |
| 25.2000 | 4.10E-04 | -9078. | 383.3069 | 5.65E-06 | 6590. | 1.04E+10 | -8.3106 | 72939. | 0.00 |
| 25.5000 | 4.25E-04 | -7753. | 352.6689 | 2.73E-06 | 6570. | 1.04E+10 | -8.7106 | 73807. | 0.00 |
| 25.8000 | 4.30E-04 | -6540. | 320.9397 | 2.54E-07 | 6551. | 1.04E+10 | -8.9167 | 74676. | 0.00 |
| 26.1000 | 4.27E-04 | -5443. | 288.7726 | -1.83E-06 | 6535. | 1.04E+10 | -8.9539 | 75544. | 0.00 |
| 26.4000 | 4.17E-04 | -4460. | 256.7344 | -3.54E-06 | 6520. | 1.04E+10 | -8.8451 | 76412. | 0.00 |
| 26.7000 | 4.01E-04 | -3592. | 225.3117 | -4.94E-06 | 6506. | 1.04E+10 | -8.6120 | 77280. | 0.00 |
| 27.0000 | 3.81E-04 | -2834. | 194.9170 | -6.06E-06 | 6495. | 1.04E+10 | -8.2739 | 78149. | 0.00 |
| 27.3000 | 3.58E-04 | -2184. | 165.8967 | -6.93E-06 | 6485. | 1.04E+10 | -7.8485 | 79017. | 0.00 |
| 27.6000 | 3.31E-04 | -1635. | 138.5374 | -7.59E-06 | 6477. | 1.04E+10 | -7.3511 | 79885. | 0.00 |
| 27.9000 | 3.03E-04 | -1181. | 113.0738 | -8.08E-06 | 6470. | 1.04E+10 | -6.7953 | 80754. | 0.00 |
| 28.2000 | 2.73E-04 | -814.8200 | 89.6960 | -8.42E-06 | 6464. | 1.04E+10 | -6.1923 | 81622. | 0.00 |
| 28.5000 | 2.42E-04 | -528.9574 | 68.5568 | -8.66E-06 | 6460. | 1.04E+10 | -5.5517 | 82490. | 0.00 |
| 28.8000 | 2.11E-04 | -314.9783 | 49.7783 | -8.80E-06 | 6456. | 1.04E+10 | -4.8808 | 83359. | 0.00 |
| 29.1000 | 1.79E-04 | -164.2154 | 33.4587 | -8.89E-06 | 6454. | 1.04E+10 | -4.1856 | 84227. | 0.00 |
| 29.4000 | 1.47E-04 | -67.6772 | 19.6785 | -8.93E-06 | 6453. | 1.04E+10 | -3.4701 | 85095. | 0.00 |
| 29.7000 | 1.15E-04 | -16.1030 | 8.5055 | -8.94E-06 | 6452. | 1.04E+10 | -2.7371 | 85964. | 0.00 |
| 30.0000 | 8.24E-05 | 0.00 | 0.00 | -8.94E-06 | 6452. | 1.04E+10 | -1.9881 | 43416. | 0.00 |

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses

are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection            =     0.49692156 inches
Computed slope at pile head     =       0.000000 radians
Maximum bending moment          =      -1843346. inch-lbs
Maximum shear force             =         35000. lbs
Depth of maximum bending moment  =      0.000000 feet below pile head
Depth of maximum shear force     =      0.000000 feet below pile head
Number of iterations            =              6
Number of zero deflection points =             2
```

---

Pile-head Deflection vs. Pile Length for Load Case 1

---

Boundary Condition Type 2, Shear and Slope

```
Shear      =          35000. lbs
Slope      =         0.00000
Axial Load =         100000. lbs
```

| Pile Length feet | Pile Head Deflection inches | Maximum Moment ln-lbs | Maximum Shear lbs |
|---|---|---|---|
| 30.00000 | 0.49692353 | -1843350. | 35000. |
| 28.50000 | 0.50037874 | -1845136. | 35000. |
| 27.00000 | 0.49708714 | -1843367. | 35000. |
| 25.50000 | 0.49849372 | -1844185. | 35000. |
| 24.00000 | 0.49859334 | -1844204. | 35000. |
| 22.50000 | 0.49757703 | -1843817. | 35000. |
| 21.00000 | 0.49963555 | -1845135. | 35000. |
| 19.50000 | 0.49978954 | -1844973. | 35000. |
| 18.00000 | 0.49910115 | -1843508. | 35000. |
| 16.50000 | 0.50441555 | -1845488. | 35000. |
| 15.00000 | 0.52225553 | -1861497. | 35000. |
| 13.50000 | 0.56192980 | -1917000. | 35000. |
| 12.00000 | 0.62385647 | -2042611. | 35000. |
| 10.50000 | 0.68269451 | -2218882. | 35000. |
| 9.00000 | 0.68854279 | -2293083. | 35000. |
| 7.50000 | 0.78024681 | -2114264. | 35000. |

---

Summary of Pile-head Responses for Conventional Analyses

---

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians

Hframe_B5_Factored.lp10o

Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

| Load Case No. | Load Type 1 | Pile-head Load 1 | Load Type 2 | Pile-head Load 2 | Axial Loading lbs | Pile-head Deflection inches | Pile-head Rotation radians | Max Shear in Pile lbs | Max Moment in Pile in-lbs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | V, lb | 35000. | S, rad | 0.00 | 100000. | 0.4969 | 0.00 | 35000. | -1843346. |

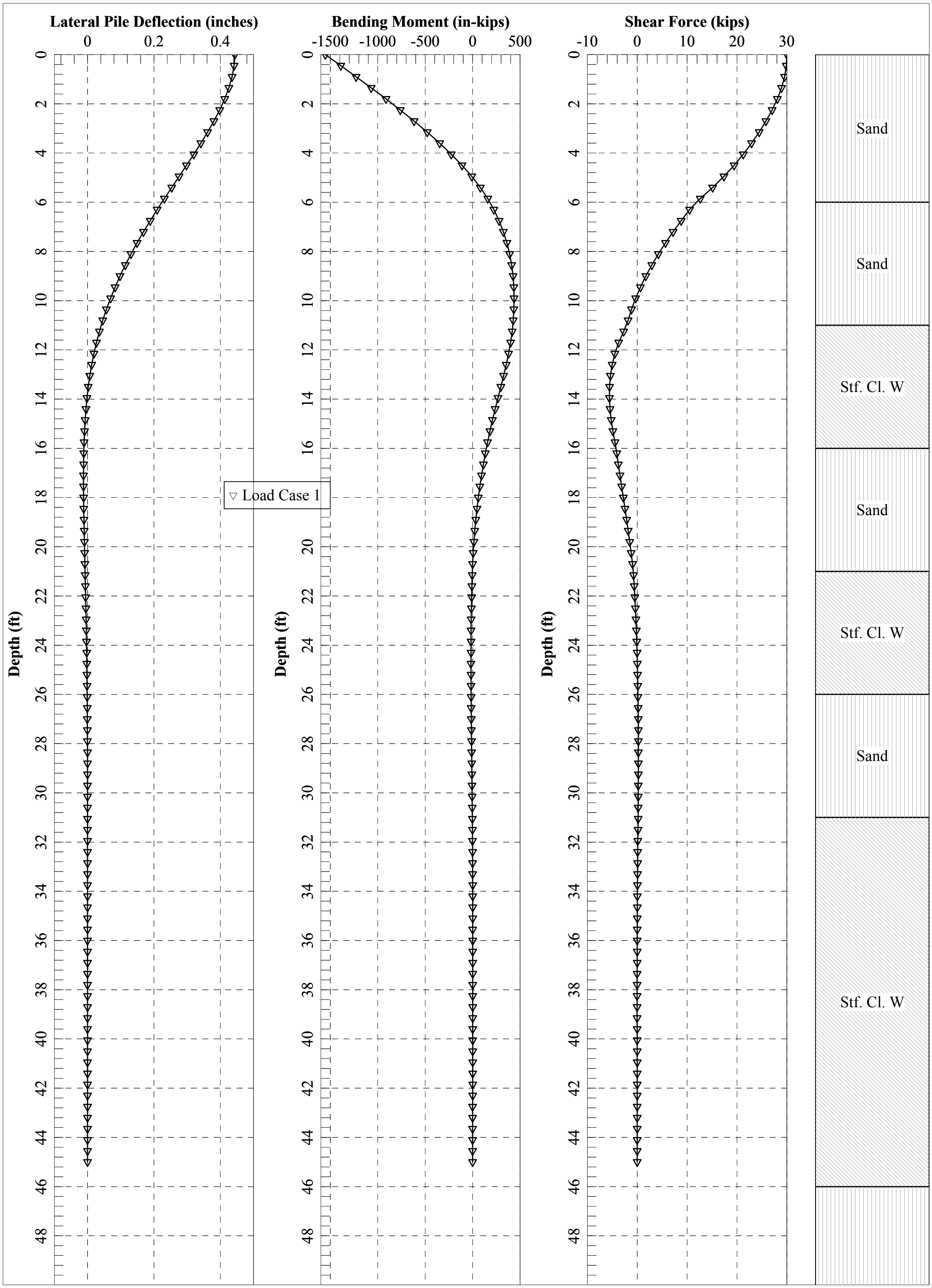
Maximum pile-head deflection = 0.4969215563 inches
Maximum pile-head rotation = 0.0000000000 radians = 0.000000 deg.

The analysis ended normally.

# Lpile analysis report (H-pile)

**Boring: B-14**
**Equipment: Exhaust stacks**

# Allowable Bending Moment and Shear force with respect to 0.5" head deflection for given H12x53



ExhaustStack_B14_Factored.lp10o

```
================================================================================

                    LPile for Windows, Version 2018-10.006

                 Analysis of Individual Piles and Drilled Shafts
                Subjected to Lateral Loading Using the p-y Method
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================================================================================

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--------------------------------------------------------------------------------
                            Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters, MD\Engineering &
Resources\Hpile\LPile_analysis\

Name of input data file:
ExhaustStack_B14_Factored.lp10

Name of output report file:
ExhaustStack_B14_Factored.lp10

Name of plot output file:
ExhaustStack_B14_Factored.lp10

Name of runtime message file:
ExhaustStack_B14_Factored.lp10


--------------------------------------------------------------------------------
                           Date and Time of Analysis
--------------------------------------------------------------------------------

               Date:  June 14, 2018              Time:  12:57:35


--------------------------------------------------------------------------------
                                 Problem Title
--------------------------------------------------------------------------------
```

ExhaustStack_B14_Factored.lp10o

Project Name: CP Crane Power plant

Job Number:0512843

Client:ProEnergy

Engineer: SS

Description: Axial Capacity of Dirven Pile in Boring B1

---

Program Options and Settings

---

Computational Options:
- Use unfactored loads in computations (conventional analysis)

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

| | | |
|---|---|---|
| - Maximum number of iterations allowed | = | 500 |
| - Deflection tolerance for convergence | = | 1.0000E-05 in |
| - Maximum allowable deflection | = | 100.0000 in |
| - Number of pile increments | = | 100 |

Loading Type and Number of Cycles of Loading:
- Static loading specified

- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

---

Pile Structural Properties and Geometry

---

```
Number of pile sections defined                      =           1
Total length of pile                                 =      45.000 ft
Depth of ground surface below top of pile            =      0.0000 ft
```

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

| Point No. | Depth Below Pile Head feet | Pile Diameter inches |
|---|---|---|
| 1 | 0.000 | 12.0000 |
| 2 | 45.000 | 12.0000 |

Input Structural Properties for Pile Sections:

Pile Section No. 1:

```
   Section 1 is a AISC strong axis steel pile
   Length of section                                 =   45.000000 ft
   AISC Section Type                                 = HP



   AISC Section Name                                 = HP12X53



   Pile width                                        =   12.000000 in
   Shear capacity of section                         =      0.0000 lbs
```

## Ground Slope and Pile Batter Angles

```
Ground Slope Angle                                   =       0.000 degrees
                                                     =       0.000 radians

Pile Batter Angle                                    =       0.000 degrees
                                                     =       0.000 radians
```

## Soil and Rock Layering Information

The soil profile is modelled using 10 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

```
   Distance from top of pile to top of layer         =      0.0000 ft
```

```
   Distance from top of pile to bottom of layer        =     6.000000 ft
   Effective unit weight at top of layer               =   110.000000 pcf
   Effective unit weight at bottom of layer            =   110.000000 pcf
   Friction angle at top of layer                      =    32.000000 deg.
   Friction angle at bottom of layer                   =    32.000000 deg.
   Subgrade k at top of layer                          =    67.000000 pci
   Subgrade k at bottom of layer                       =    67.000000 pci


Layer 2 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer           =     6.000000 ft
   Distance from top of pile to bottom of layer        =    11.000000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.600000 pcf
   Friction angle at top of layer                      =    31.000000 deg.
   Friction angle at bottom of layer                   =    31.000000 deg.
   Subgrade k at top of layer                          =    20.000000 pci
   Subgrade k at bottom of layer                       =    20.000000 pci


Layer 3 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    11.000000 ft
   Distance from top of pile to bottom of layer        =    16.000000 ft
   Effective unit weight at top of layer               =    57.600000 pcf
   Effective unit weight at bottom of layer            =    57.600000 pcf
   Undrained cohesion at top of layer                  =        1500. psf
   Undrained cohesion at bottom of layer               =        1500. psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    43.000000 pci
   Subgrade k at bottom of layer                       =    43.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 4 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer           =    16.000000 ft
   Distance from top of pile to bottom of layer        =    21.000000 ft
   Effective unit weight at top of layer               =    72.600000 pcf
   Effective unit weight at bottom of layer            =    72.600000 pcf
   Friction angle at top of layer                      =    29.000000 deg.
   Friction angle at bottom of layer                   =    29.000000 deg.
   Subgrade k at top of layer                          =    25.000000 pci
   Subgrade k at bottom of layer                       =    25.000000 pci


Layer 5 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    21.000000 ft
   Distance from top of pile to bottom of layer        =    26.000000 ft
   Effective unit weight at top of layer               =    57.600000 pcf
   Effective unit weight at bottom of layer            =    57.600000 pcf
   Undrained cohesion at top of layer                  =        1500. psf
   Undrained cohesion at bottom of layer               =        1500. psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
```

```
   Subgrade k at top of layer                        =    15.000000 pci
   Subgrade k at bottom of layer                     =    15.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 6 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer         =    26.000000 ft
   Distance from top of pile to bottom of layer      =    31.000000 ft
   Effective unit weight at top of layer             =    72.600000 pcf
   Effective unit weight at bottom of layer          =    72.600000 pcf
   Friction angle at top of layer                    =    30.000000 deg.
   Friction angle at bottom of layer                 =    30.000000 deg.
   Subgrade k at top of layer                        =    25.000000 pci
   Subgrade k at bottom of layer                     =    25.000000 pci


Layer 7 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer         =    31.000000 ft
   Distance from top of pile to bottom of layer      =    46.000000 ft
   Effective unit weight at top of layer             =    62.600000 pcf
   Effective unit weight at bottom of layer          =    62.600000 pcf
   Undrained cohesion at top of layer                =        3500. psf
   Undrained cohesion at bottom of layer             =        3500. psf
   Epsilon-50 at top of layer                        =      0.0000
   Epsilon-50 at bottom of layer                     =      0.0000
   Subgrade k at top of layer                        =    50.000000 pci
   Subgrade k at bottom of layer                     =    50.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 8 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer         =    46.000000 ft
   Distance from top of pile to bottom of layer      =    77.000000 ft
   Effective unit weight at top of layer             =    72.600000 pcf
   Effective unit weight at bottom of layer          =    72.600000 pcf
   Friction angle at top of layer                    =    40.000000 deg.
   Friction angle at bottom of layer                 =    40.000000 deg.
   Subgrade k at top of layer                        =    67.000000 pci
   Subgrade k at bottom of layer                     =    67.000000 pci


Layer 9 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer         =    77.000000 ft
   Distance from top of pile to bottom of layer      =    81.000000 ft
   Effective unit weight at top of layer             =    62.600000 pcf
   Effective unit weight at bottom of layer          =    62.600000 pcf
   Undrained cohesion at top of layer                =        3500. psf
   Undrained cohesion at bottom of layer             =        3500. psf
   Epsilon-50 at top of layer                        =      0.0000
   Epsilon-50 at bottom of layer                     =      0.0000
   Subgrade k at top of layer                        =    50.000000 pci
   Subgrade k at bottom of layer                     =    50.000000 pci
```

NOTE: Default values for Epsilon-50 will be computed for this layer.

Layer 10 is sand, p-y criteria by Reese et al., 1974

| | | |
|---|---|---|
| Distance from top of pile to top of layer | = | 81.000000 ft |
| Distance from top of pile to bottom of layer | = | 97.000000 ft |
| Effective unit weight at top of layer | = | 72.600000 pcf |
| Effective unit weight at bottom of layer | = | 72.600000 pcf |
| Friction angle at top of layer | = | 40.000000 deg. |
| Friction angle at bottom of layer | = | 40.000000 deg. |
| Subgrade k at top of layer | = | 67.000000 pci |
| Subgrade k at bottom of layer | = | 67.000000 pci |

(Depth of the lowest soil layer extends 52.000 ft below the pile tip)

--------------------------------------------------------------------------------
Summary of Input Soil Properties
--------------------------------------------------------------------------------

| Layer Layer Num. | Soil Type Name (p-y Curve Type) | Layer Depth ft | Effective Unit Wt. pcf | Undrained Cohesion psf | Angle of Friction deg. | E50 or krm | kpy pci |
|---|---|---|---|---|---|---|---|
| 1 | Sand | 0.00 | 110.0000 | -- | 32.0000 | -- | 67.0000 |
| | (Reese, et al.) | 6.0000 | 110.0000 | -- | 32.0000 | -- | 67.0000 |
| 2 | Sand | 6.0000 | 62.6000 | -- | 31.0000 | -- | 20.0000 |
| | (Reese, et al.) | 11.0000 | 62.6000 | -- | 31.0000 | -- | 20.0000 |
| 3 | Stiff Clay | 11.0000 | 57.6000 | 1500. | -- | default | 43.0000 |
| | with Free Water | 16.0000 | 57.6000 | 1500. | -- | default | 43.0000 |
| 4 | Sand | 16.0000 | 72.6000 | -- | 29.0000 | -- | 25.0000 |
| | (Reese, et al.) | 21.0000 | 72.6000 | -- | 29.0000 | -- | 25.0000 |
| 5 | Stiff Clay | 21.0000 | 57.6000 | 1500. | -- | default | 15.0000 |
| | with Free Water | 26.0000 | 57.6000 | 1500. | -- | default | 15.0000 |
| 6 | Sand | 26.0000 | 72.6000 | -- | 30.0000 | -- | 25.0000 |
| | (Reese, et al.) | 31.0000 | 72.6000 | -- | 30.0000 | -- | 25.0000 |
| 7 | Stiff Clay | 31.0000 | 62.6000 | 3500. | -- | default | 50.0000 |
| | with Free Water | 46.0000 | 62.6000 | 3500. | -- | default | 50.0000 |

```
  8          Sand             46.0000      72.6000       --          40.0000       --
67.0000
          (Reese, et al.)     77.0000      72.6000       --          40.0000       --
67.0000
  9        Stiff Clay         77.0000      62.6000       3500.        --          default
50.0000
          with Free Water     81.0000      62.6000       3500.        --          default
50.0000
 10          Sand             81.0000      72.6000       --          40.0000       --
67.0000
          (Reese, et al.)     97.0000      72.6000       --          40.0000       --
67.0000
```

--------------------------------------------------------------------------------
Static Loading Type
--------------------------------------------------------------------------------

Static loading criteria were used when computing p-y curves for all analyses.

--------------------------------------------------------------------------------
Pile-head Loading and Pile-head Fixity Conditions
--------------------------------------------------------------------------------

Number of loads specified = 1

| Load No. | Load Type | Condition 1 | Condition 2 | Axial Thrust Force, lbs | Compute Top y vs. Pile Length |
|---|---|---|---|---|---|
| 1 | 2 | V = 30000. lbs | S = 0.0000 in/in | 130000. | Yes |

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

--------------------------------------------------------------------------------
Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness
--------------------------------------------------------------------------------

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:
-------------------

Dimensions and Properties of Steel AISC Strong Axis:
---------------------------------------------

Length of Section = 45.000000 ft

```
Flange Width                                         =    12.000000 in
Section Depth                                        =    11.800000 in
Flange Thickness                                     =     0.435000 in
Web Thickness                                        =     0.435000 in
Yield Stress of Pipe                                 =    50.000000 ksi
Elastic Modulus                                      =       27000. ksi
Cross-sectional Area                                 =    15.500000 sq. in.
Moment of Inertia                                    =   393.000000 in^4
Elastic Bending Stiffness                            =    10611000. kip-in^2
Plastic Modulus, Z                                   =    74.000000in^3
Plastic Moment Capacity = Fy Z                       =        3700.in-kip

Axial Structural Capacities:
----------------------------

Nom. Axial Structural Capacity = Fy As               =      775.000 kips
Nominal Axial Tensile Capacity                       =     -775.000 kips



Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

   Number     Axial Thrust Force
                   kips
   ------     ------------------
      1             130.000

Definition of Run Messages:

   Y = part of pipe section has yielded.


Axial Thrust Force =    130.000 kips
```

| Bending Curvature rad/in. | Bending Moment in-kip | Bending Stiffness kip-in2 | Depth to N Axis in | Max Total Stress ksi | Run Msg |
|---|---|---|---|---|---|
| 0.00000590 | 61.1899433 | 10373849. | 59.6219335 | 9.4859308 | |
| 0.00001180 | 122.3798866 | 10373849. | 32.7609667 | 10.4161626 | |
| 0.00001770 | 183.5698298 | 10373849. | 23.8073112 | 11.3463940 | |
| 0.00002359 | 244.7597731 | 10373849. | 19.3304834 | 12.2766256 | |
| 0.00002949 | 305.9497164 | 10373849. | 16.6443867 | 13.2068572 | |
| 0.00003539 | 367.1396597 | 10373849. | 14.8536556 | 14.1370889 | |
| 0.00004129 | 428.3296029 | 10373849. | 13.5745619 | 15.0673204 | |
| 0.00004719 | 489.5195462 | 10373849. | 12.6152417 | 15.9975520 | |
| 0.00005309 | 550.7094895 | 10373849. | 11.8691037 | 16.9277837 | |
| 0.00005898 | 611.8994328 | 10373849. | 11.2721933 | 17.8580152 | |
| 0.00006488 | 673.0893761 | 10373849. | 10.7838121 | 18.7882468 | |
| 0.00007078 | 734.2793193 | 10373849. | 10.3768278 | 19.7184785 | |
| 0.00007668 | 795.4692626 | 10373849. | 10.0324564 | 20.6487101 | |
| 0.00008258 | 856.6592059 | 10373849. | 9.7372810 | 21.5789417 | |
| 0.00008848 | 917.8491492 | 10373849. | 9.4814622 | 22.5091733 | |
| 0.00009438 | 979.0390924 | 10373849. | 9.2576208 | 23.4394049 | |
| 0.0001003 | 1040. | 10373849. | 9.0601137 | 24.3696365 | |
| 0.0001062 | 1101. | 10373849. | 8.8845519 | 25.2998681 | |
| 0.0001121 | 1163. | 10373849. | 8.7274702 | 26.2300997 | |
| 0.0001180 | 1224. | 10373849. | 8.5860967 | 27.1603313 | |

| | | | | | |
|---|---|---|---|---|---|
| 0.0001239 | 1285. | 10373849. | 8.4581873 | 28.0905629 | |
| 0.0001298 | 1346. | 10373849. | 8.3419061 | 29.0207945 | |
| 0.0001357 | 1407. | 10373849. | 8.2357362 | 29.9510261 | |
| 0.0001416 | 1469. | 10373849. | 8.1384139 | 30.8812577 | |
| 0.0001475 | 1530. | 10373849. | 8.0488773 | 31.8114893 | |
| 0.0001534 | 1591. | 10373849. | 7.9662282 | 32.7417209 | |
| 0.0001593 | 1652. | 10373849. | 7.8897012 | 33.6719525 | |
| 0.0001652 | 1713. | 10373849. | 7.8186405 | 34.6021841 | |
| 0.0001711 | 1775. | 10373849. | 7.7524805 | 35.5324157 | |
| 0.0001770 | 1836. | 10373849. | 7.6907311 | 36.4626473 | |
| 0.0001829 | 1897. | 10373849. | 7.6329656 | 37.3928789 | |
| 0.0001888 | 1958. | 10373849. | 7.5788104 | 38.3231105 | |
| 0.0001946 | 2019. | 10373849. | 7.5279374 | 39.2533421 | |
| 0.0002005 | 2080. | 10373849. | 7.4800569 | 40.1835737 | |
| 0.0002064 | 2142. | 10373849. | 7.4349124 | 41.1138053 | |
| 0.0002123 | 2203. | 10373849. | 7.3922759 | 42.0440369 | |
| 0.0002182 | 2264. | 10373849. | 7.3519441 | 42.9742685 | |
| 0.0002241 | 2325. | 10373849. | 7.3137351 | 43.9045001 | |
| 0.0002300 | 2386. | 10373849. | 7.2774855 | 44.8347317 | |
| 0.0002418 | 2509. | 10373849. | 7.2102911 | 46.6951949 | |
| 0.0002536 | 2631. | 10373849. | 7.1493473 | 48.5556581 | |
| 0.0002654 | 2750. | 10359551. | 7.0997878 | 50.0000000 | Y |
| 0.0002772 | 2827. | 10198121. | 7.1174779 | 50.0000000 | Y |
| 0.0002890 | 2866. | 9916623. | 7.1917459 | 50.0000000 | Y |
| 0.0003008 | 2902. | 9646761. | 7.2649766 | 50.0000000 | Y |
| 0.0003126 | 2935. | 9388204. | 7.3370079 | 50.0000000 | Y |
| 0.0003244 | 2965. | 9140950. | 7.4075215 | 50.0000000 | Y |
| 0.0003362 | 2994. | 8904257. | 7.4765823 | 50.0000000 | Y |
| 0.0003480 | 3020. | 8677809. | 7.5440572 | 50.0000000 | Y |
| 0.0003598 | 3044. | 8461190. | 7.6098816 | 50.0000000 | Y |
| 0.0003716 | 3067. | 8253910. | 7.6740478 | 50.0000000 | Y |
| 0.0003834 | 3088. | 8055523. | 7.7365419 | 50.0000000 | Y |
| 0.0003952 | 3108. | 7865480. | 7.7974342 | 50.0000000 | Y |
| 0.0004070 | 3127. | 7683323. | 7.8567615 | 50.0000000 | Y |
| 0.0004188 | 3145. | 7508866. | 7.9144023 | 50.0000000 | Y |
| 0.0004306 | 3161. | 7341381. | 7.9706039 | 50.0000000 | Y |
| 0.0004424 | 3177. | 7180839. | 8.0251675 | 50.0000000 | Y |
| 0.0004542 | 3191. | 7026486. | 8.0784075 | 50.0000000 | Y |
| 0.0004660 | 3205. | 6878316. | 8.1301296 | 50.0000000 | Y |
| 0.0004778 | 3218. | 6735952. | 8.1804134 | 50.0000000 | Y |
| 0.0004896 | 3231. | 6598877. | 8.2294661 | 50.0000000 | Y |
| 0.0005014 | 3242. | 6466985. | 8.2771977 | 50.0000000 | Y |
| 0.0005132 | 3253. | 6340006. | 8.3236508 | 50.0000000 | Y |
| 0.0005250 | 3264. | 6217676. | 8.3688782 | 50.0000000 | Y |
| 0.0005368 | 3274. | 6099753. | 8.4129269 | 50.0000000 | Y |
| 0.0005486 | 3284. | 5986012. | 8.4558394 | 50.0000000 | Y |
| 0.0005604 | 3293. | 5876246. | 8.4976533 | 50.0000000 | Y |
| 0.0005722 | 3301. | 5770266. | 8.5384025 | 50.0000000 | Y |
| 0.0005839 | 3310. | 5667893. | 8.5781174 | 50.0000000 | Y |
| 0.0005957 | 3317. | 5568095. | 8.6133113 | 50.0000000 | Y |
| 0.0006075 | 3324. | 5471215. | 8.6459643 | 50.0000000 | Y |
| 0.0006193 | 3330. | 5377486. | 8.6780459 | 50.0000000 | Y |
| 0.0006311 | 3337. | 5286882. | 8.7094112 | 50.0000000 | Y |
| 0.0006429 | 3343. | 5199110. | 8.7392760 | 50.0000000 | Y |
| 0.0006547 | 3348. | 5112937. | 8.7628575 | 50.0000000 | Y |
| 0.0006665 | 3352. | 5029539. | 8.7861297 | 50.0000000 | Y |
| 0.0006783 | 3357. | 4948895. | 8.8088704 | 50.0000000 | Y |
| 0.0006901 | 3361. | 4870632. | 8.8315698 | 50.0000000 | Y |
| 0.0007019 | 3365. | 4793939. | 8.8479708 | 50.0000000 | Y |

| | | | | | |
|---|---|---|---|---|---|
| 0.0007491 | 3376. | 4506093. | 8.8884137 | 50.0000000 | Y |
| 0.0007963 | 3381. | 4245452. | 8.8882868 | 50.0000000 | Y |
| 0.0008435 | 3385. | 4012988. | 8.8883886 | 50.0000000 | Y |
| 0.0008907 | 3388. | 3804428. | 8.8883652 | 50.0000000 | Y |
| 0.0009379 | 3392. | 3616302. | 8.8882157 | 50.0000000 | Y |
| 0.0009850 | 3394. | 3445756. | 8.8883419 | 50.0000000 | Y |
| 0.0010322 | 3397. | 3290455. | 8.8888977 | 50.0000000 | Y |

---

Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1

---

| Load No. | Axial Thrust kips | Nominal Moment Capacity in-kips |
|---|---|---|
| 1 | 130.0000000000 | 3397. |

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

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Layering Correction Equivalent Depths of Soil & Rock Layers

---

| Layer No. | Top of Layer Below Pile Head ft | Equivalent Top Depth Below Grnd Surf ft | Same Layer Type As Layer Above | Layer is Rock or is Below Rock Layer | F0 Integral for Layer lbs | F1 Integral for Layer lbs |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | N.A. | No | 0.00 | 23280. |
| 2 | 6.0000 | 6.1899 | Yes | No | 23280. | 78170. |
| 3 | 11.0000 | 161.7435 | No | No | 101450. | 7234. |
| 4 | 16.0000 | 13.1599 | No | No | 108684. | 154845. |
| 5 | 21.0000 | 189.1276 | No | No | 263528. | 7234. |
| 6 | 26.0000 | 18.1037 | No | No | 270762. | 261013. |
| 7 | 31.0000 | 170.2278 | No | No | 531775. | 47261. |
| 8 | 46.0000 | 46.0000 | No | No | 579036. | 0.00 |
| 9 | 77.0000 | 77.0000 | No | No | 0.00 | 0.00 |
| 10 | 81.0000 | 81.0000 | No | No | 0.00 | N.A. |

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays,

non-liquefied sands, and cemented c-phi soil.

---

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

---

Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

| | | |
|---|---|---|
| Shear force at pile head | = | 30000.0 lbs |
| Rotation of pile head | = | 0.000E+00 radians |
| Axial load at pile head | = | 130000.0 lbs |

(Zero slope for this load indicates fixed-head conditions)

| Depth X feet | Deflect. y inches | Bending Moment in-lbs | Shear Force lbs | Slope S radians | Total Stress psi* | Bending Stiffness in-lb^2 | Soil Res. p lb/inch | Soil Spr. Es*h lb/inch | Distrib. Lat. Load lb/inch |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.4434 | -1552565. | 30000. | 0.00 | 32090. | 1.04E+10 | 0.00 | 0.00 | 0.00 |
| 0.4500 | 0.4412 | -1390281. | 29890. | -7.66E-04 | 29613. | 1.04E+10 | -40.8507 | 499.9650 | 0.00 |
| 0.9000 | 0.4351 | -1228681. | 29540. | -0.00145 | 27146. | 1.04E+10 | -88.6620 | 1100. | 0.00 |
| 1.3500 | 0.4256 | -1069217. | 28935. | -0.00205 | 24711. | 1.04E+10 | -135.3593 | 1717. | 0.00 |
| 1.8000 | 0.4130 | -913309. | 28091. | -0.00256 | 22331. | 1.04E+10 | -177.4759 | 2320. | 0.00 |
| 2.2500 | 0.3979 | -762243. | 27039. | -0.00300 | 20024. | 1.04E+10 | -211.9340 | 2876. | 0.00 |
| 2.7000 | 0.3807 | -617078. | 25821. | -0.00336 | 17808. | 1.04E+10 | -239.2817 | 3394. | 0.00 |
| 3.1500 | 0.3617 | -478665. | 24455. | -0.00364 | 15695. | 1.04E+10 | -266.6455 | 3981. | 0.00 |
| 3.6000 | 0.3413 | -347853. | 22933. | -0.00386 | 13698. | 1.04E+10 | -297.0755 | 4700. | 0.00 |
| 4.0500 | 0.3200 | -225576. | 21268. | -0.00401 | 11831. | 1.04E+10 | -319.5800 | 5393. | 0.00 |
| 4.5000 | 0.2981 | -112535. | 19431. | -0.00409 | 10105. | 1.04E+10 | -360.8739 | 6538. | 0.00 |
| 4.9500 | 0.2758 | -9977. | 17381. | -0.00413 | 8539. | 1.04E+10 | -398.3799 | 7800. | 0.00 |
| 5.4000 | 0.2535 | 80968. | 15119. | -0.00411 | 9623. | 1.04E+10 | -439.2990 | 9358. | 0.00 |
| 5.8500 | 0.2314 | 159074. | 12641. | -0.00405 | 10816. | 1.04E+10 | -478.6025 | 11167. | 0.00 |
| 6.3000 | 0.2098 | 223165. | 10492. | -0.00395 | 11794. | 1.04E+10 | -317.2306 | 8165. | 0.00 |
| 6.7500 | 0.1888 | 277925. | 8809. | -0.00382 | 12630. | 1.04E+10 | -305.8808 | 8748. | 0.00 |
| 7.2000 | 0.1686 | 323663. | 7197. | -0.00366 | 13329. | 1.04E+10 | -291.3464 | 9331. | |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | | | | | | | | | |
| 7.6500 | 0.1493 | 360787. | 5670. | -0.00348 | 13895. | 1.04E+10 | -274.1166 | 9914. | 0.00 |
| 8.1000 | 0.1310 | 389787. | 4242. | -0.00329 | 14338. | 1.04E+10 | -254.6890 | 10498. | 0.00 |
| 8.5500 | 0.1138 | 411217. | 2924. | -0.00308 | 14665. | 1.04E+10 | -233.5595 | 11081. | 0.00 |
| 9.0000 | 0.09778 | 425686. | 1723. | -0.00286 | 14886. | 1.04E+10 | -211.2131 | 11664. | 0.00 |
| 9.4500 | 0.08294 | 433841. | 644.9832 | -0.00264 | 15011. | 1.04E+10 | -188.1166 | 12247. | 0.00 |
| 9.9000 | 0.06932 | 436352. | -307.6544 | -0.00241 | 15049. | 1.04E+10 | -164.7122 | 12830. | 0.00 |
| 10.3500 | 0.05693 | 433901. | -1134. | -0.00218 | 15012. | 1.04E+10 | -141.4125 | 13414. | 0.00 |
| 10.8000 | 0.04576 | 427167. | -1836. | -0.00196 | 14909. | 1.04E+10 | -118.5970 | 13997. | 0.00 |
| 11.2500 | 0.03578 | 416819. | -2717. | -0.00174 | 14751. | 1.04E+10 | -207.7112 | 31347. | 0.00 |
| 11.7000 | 0.02698 | 400261. | -3718. | -0.00153 | 14498. | 1.04E+10 | -162.8806 | 32601. | 0.00 |
| 12.1500 | 0.01930 | 378808. | -4484. | -0.00132 | 14170. | 1.04E+10 | -121.0160 | 33855. | 0.00 |
| 12.6000 | 0.01269 | 353688. | -5034. | -0.00113 | 13787. | 1.04E+10 | -82.5093 | 35109. | 0.00 |
| 13.0500 | 0.00707 | 326032. | -5385. | -9.55E-04 | 13365. | 1.04E+10 | -47.6265 | 36363. | 0.00 |
| 13.5000 | 0.00237 | 296868. | -5558. | -7.93E-04 | 12919. | 1.04E+10 | -16.5187 | 37616. | 0.00 |
| 13.9500 | -0.00150 | 267115. | -5574. | -6.47E-04 | 12465. | 1.04E+10 | 10.7656 | 38870. | 0.00 |
| 14.4000 | -0.00461 | 237577. | -5452. | -5.15E-04 | 12014. | 1.04E+10 | 34.2668 | 40124. | 0.00 |
| 14.8500 | -0.00706 | 208952. | -5214. | -3.99E-04 | 11577. | 1.04E+10 | 54.0979 | 41378. | 0.00 |
| 15.3000 | -0.00892 | 181828. | -4878. | -2.97E-04 | 11163. | 1.04E+10 | 70.4290 | 42632. | 0.00 |
| 15.7500 | -0.01027 | 156692. | -4462. | -2.09E-04 | 10779. | 1.04E+10 | 83.4707 | 43886. | 0.00 |
| 16.2000 | -0.01118 | 133932. | -4090. | -1.34E-04 | 10432. | 1.04E+10 | 54.3357 | 26244. | 0.00 |
| 16.6500 | -0.01171 | 112708. | -3785. | -6.94E-05 | 10108. | 1.04E+10 | 58.5069 | 26973. | 0.00 |
| 17.1000 | -0.01193 | 93148. | -3462. | -1.58E-05 | 9809. | 1.04E+10 | 61.1969 | 27702. | 0.00 |
| 17.5500 | -0.01188 | 75339. | -3128. | 2.81E-05 | 9537. | 1.04E+10 | 62.5666 | 28431. | 0.00 |
| 18.0000 | -0.01163 | 59327. | -2790. | 6.31E-05 | 9293. | 1.04E+10 | 62.7804 | 29160. | 0.00 |
| 18.4500 | -0.01120 | 45124. | -2453. | 9.03E-05 | 9076. | 1.04E+10 | 62.0017 | 29889. | 0.00 |
| 18.9000 | -0.01065 | 32712. | -2122. | 1.11E-04 | 8887. | 1.04E+10 | 60.3893 | 30618. | 0.00 |
| 19.3500 | -0.01001 | 22049. | -1802. | 1.25E-04 | 8724. | 1.04E+10 | 58.0942 | 31347. | 0.00 |
| 19.8000 | -0.00930 | 13073. | -1496. | 1.34E-04 | 8587. | 1.04E+10 | 55.2574 | 32076. | 0.00 |
| 20.2500 | -0.00856 | 5703. | -1207. | 1.39E-04 | 8474. | 1.04E+10 | 52.0070 | 32805. | 0.00 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20.7000 | -0.00780 | -153.1044 | -935.3139 | 1.40E-04 | 8389. | 1.04E+10 | 48.4568 | 33534. | 0.00 |
| 21.1500 | -0.00705 | -4596. | -732.0587 | 1.39E-04 | 8457. | 1.04E+10 | 26.8228 | 20558. | 0.00 |
| 21.6000 | -0.00630 | -8255. | -593.4894 | 1.36E-04 | 8513. | 1.04E+10 | 24.4991 | 20995. | 0.00 |
| 22.0500 | -0.00558 | -11196. | -467.5451 | 1.31E-04 | 8558. | 1.04E+10 | 22.1469 | 21433. | 0.00 |
| 22.5000 | -0.00489 | -13487. | -354.2742 | 1.24E-04 | 8593. | 1.04E+10 | 19.8053 | 21870. | 0.00 |
| 22.9500 | -0.00424 | -15197. | -253.5268 | 1.17E-04 | 8619. | 1.04E+10 | 17.5086 | 22307. | 0.00 |
| 23.4000 | -0.00363 | -16390. | -164.9811 | 1.09E-04 | 8637. | 1.04E+10 | 15.2861 | 22745. | 0.00 |
| 23.8500 | -0.00307 | -17131. | -88.1690 | 9.98E-05 | 8649. | 1.04E+10 | 13.1628 | 23182. | 0.00 |
| 24.3000 | -0.00255 | -17482. | -22.5004 | 9.08E-05 | 8654. | 1.04E+10 | 11.1589 | 23620. | 0.00 |
| 24.7500 | -0.00209 | -17501. | 32.7128 | 8.17E-05 | 8654. | 1.04E+10 | 9.2905 | 24057. | 0.00 |
| 25.2000 | -0.00167 | -17243. | 78.2354 | 7.27E-05 | 8650. | 1.04E+10 | 7.5697 | 24494. | 0.00 |
| 25.6500 | -0.00130 | -16758. | 114.8879 | 6.38E-05 | 8643. | 1.04E+10 | 6.0053 | 24932. | 0.00 |
| 26.1000 | -9.80E-04 | -16092. | 151.8136 | 5.53E-05 | 8633. | 1.04E+10 | 7.6709 | 42282. | 0.00 |
| 26.5500 | -7.04E-04 | -15196. | 187.6627 | 4.71E-05 | 8619. | 1.04E+10 | 5.6065 | 43011. | 0.00 |
| 27.0000 | -4.71E-04 | -14131. | 213.0975 | 3.95E-05 | 8603. | 1.04E+10 | 3.8137 | 43740. | 0.00 |
| 27.4500 | -2.77E-04 | -12950. | 229.5644 | 3.24E-05 | 8585. | 1.04E+10 | 2.2851 | 44469. | 0.00 |
| 27.9000 | -1.21E-04 | -11698. | 238.4586 | 2.60E-05 | 8566. | 1.04E+10 | 1.0090 | 45198. | 0.00 |
| 28.3500 | 3.51E-06 | -10411. | 241.1023 | 2.03E-05 | 8546. | 1.04E+10 | -0.02985 | 45927. | 0.00 |
| 28.8000 | 9.83E-05 | -9122. | 238.7285 | 1.52E-05 | 8526. | 1.04E+10 | -0.8493 | 46656. | 0.00 |
| 29.2500 | 1.67E-04 | -7855. | 232.4679 | 1.08E-05 | 8507. | 1.04E+10 | -1.4694 | 47385. | 0.00 |
| 29.7000 | 2.15E-04 | -6627. | 223.3397 | 6.99E-06 | 8488. | 1.04E+10 | -1.9114 | 48114. | 0.00 |
| 30.1500 | 2.43E-04 | -5452. | 212.2450 | 3.85E-06 | 8470. | 1.04E+10 | -2.1977 | 48843. | 0.00 |
| 30.6000 | 2.56E-04 | -4340. | 199.9637 | 1.30E-06 | 8453. | 1.04E+10 | -2.3509 | 49572. | 0.00 |
| 31.0500 | 2.57E-04 | -3294. | 180.6881 | -6.87E-07 | 8437. | 1.04E+10 | -4.7882 | 100602. | 0.00 |
| 31.5000 | 2.49E-04 | -2387. | 155.0702 | -2.17E-06 | 8424. | 1.04E+10 | -4.7000 | 102060. | 0.00 |
| 31.9500 | 2.34E-04 | -1617. | 130.2881 | -3.21E-06 | 8412. | 1.04E+10 | -4.4786 | 103518. | 0.00 |
| 32.4000 | 2.14E-04 | -975.8686 | 106.9619 | -3.88E-06 | 8402. | 1.04E+10 | -4.1607 | 104976. | 0.00 |
| 32.8500 | 1.92E-04 | -456.0339 | 85.5266 | -4.26E-06 | 8394. | 1.04E+10 | -3.7783 | 106434. | 0.00 |
| 33.3000 | 1.68E-04 | -46.2065 | 66.2585 | -4.39E-06 | 8388. | 1.04E+10 | -3.3581 | 107892. | 0.00 |
| 33.7500 | 1.44E-04 | 265.7161 | 49.3008 | -4.33E-06 | 8391. | 1.04E+10 | -2.9225 | 109350. | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 0.00 |
| 34.2000 | 1.21E-04 | 492.3202 | 34.6883 | -4.13E-06 | 8395. | 1.04E+10 | -2.4895 | 110808. | 0.00 |
| 34.6500 | 9.97E-05 | 646.1509 | 22.3702 | -3.84E-06 | 8397. | 1.04E+10 | -2.0728 | 112266. | 0.00 |
| 35.1000 | 7.99E-05 | 739.3028 | 12.2304 | -3.47E-06 | 8398. | 1.04E+10 | -1.6827 | 113724. | 0.00 |
| 35.5500 | 6.22E-05 | 783.1177 | 4.1065 | -3.08E-06 | 8399. | 1.04E+10 | -1.3262 | 115182. | 0.00 |
| 36.0000 | 4.67E-05 | 787.9749 | -2.1949 | -2.67E-06 | 8399. | 1.04E+10 | -1.0077 | 116640. | 0.00 |
| 36.4500 | 3.33E-05 | 763.1603 | -6.8846 | -2.27E-06 | 8399. | 1.04E+10 | -0.7292 | 118098. | 0.00 |
| 36.9000 | 2.22E-05 | 716.8028 | -10.1794 | -1.88E-06 | 8398. | 1.04E+10 | -0.4911 | 119556. | 0.00 |
| 37.3500 | 1.30E-05 | 655.8637 | -12.2938 | -1.52E-06 | 8397. | 1.04E+10 | -0.2921 | 121014. | 0.00 |
| 37.8000 | 5.73E-06 | 586.1685 | -13.4331 | -1.20E-06 | 8396. | 1.04E+10 | -0.1299 | 122472. | 0.00 |
| 38.2500 | 7.09E-08 | 512.4712 | -13.7882 | -9.14E-07 | 8395. | 1.04E+10 | -0.00163 | 123930. | 0.00 |
| 38.7000 | -4.15E-06 | 438.5390 | -13.5327 | -6.67E-07 | 8394. | 1.04E+10 | 0.09626 | 125388. | 0.00 |
| 39.1500 | -7.13E-06 | 367.2535 | -12.8207 | -4.57E-07 | 8393. | 1.04E+10 | 0.1675 | 126846. | 0.00 |
| 39.6000 | -9.08E-06 | 300.7171 | -11.7860 | -2.83E-07 | 8392. | 1.04E+10 | 0.2158 | 128304. | 0.00 |
| 40.0500 | -1.02E-05 | 240.3620 | -10.5426 | -1.42E-07 | 8391. | 1.04E+10 | 0.2448 | 129762. | 0.00 |
| 40.5000 | -1.06E-05 | 187.0569 | -9.1851 | -3.10E-08 | 8390. | 1.04E+10 | 0.2580 | 131220. | 0.00 |
| 40.9500 | -1.05E-05 | 141.2065 | -7.7905 | 5.44E-08 | 8389. | 1.04E+10 | 0.2585 | 132678. | 0.00 |
| 41.4000 | -1.00E-05 | 102.8428 | -6.4199 | 1.18E-07 | 8389. | 1.04E+10 | 0.2491 | 134136. | 0.00 |
| 41.8500 | -9.25E-06 | 71.7060 | -5.1203 | 1.63E-07 | 8388. | 1.04E+10 | 0.2322 | 135594. | 0.00 |
| 42.3000 | -8.26E-06 | 47.3144 | -3.9269 | 1.94E-07 | 8388. | 1.04E+10 | 0.2098 | 137052. | 0.00 |
| 42.7500 | -7.15E-06 | 29.0222 | -2.8655 | 2.14E-07 | 8388. | 1.04E+10 | 0.1834 | 138510. | 0.00 |
| 43.2000 | -5.95E-06 | 16.0664 | -1.9539 | 2.26E-07 | 8387. | 1.04E+10 | 0.1543 | 139968. | 0.00 |
| 43.6500 | -4.71E-06 | 7.6030 | -1.2044 | 2.32E-07 | 8387. | 1.04E+10 | 0.1233 | 141426. | 0.00 |
| 44.1000 | -3.44E-06 | 2.7330 | -0.6253 | 2.35E-07 | 8387. | 1.04E+10 | 0.09115 | 142884. | 0.00 |
| 44.5500 | -2.17E-06 | 0.5197 | -0.2224 | 2.36E-07 | 8387. | 1.04E+10 | 0.05808 | 144342. | 0.00 |
| 45.0000 | -9.00E-07 | 0.00 | 0.00 | 2.36E-07 | 8387. | 1.04E+10 | 0.02429 | 72900. | 0.00 |

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

ExhaustStack_B14_Factored.lp10o

Output Summary for Load Case No. 1:

```
Pile-head deflection              =     0.44340054 inches
Computed slope at pile head       =       0.000000 radians
Maximum bending moment            =      -1552565. inch-lbs
Maximum shear force               =         30000. lbs
Depth of maximum bending moment   =       0.000000 feet below pile head
Depth of maximum shear force      =       0.000000 feet below pile head
Number of iterations              =              9
Number of zero deflection points  =              4
```

--------------------------------------------------------------------------------
Pile-head Deflection vs. Pile Length for Load Case 1
--------------------------------------------------------------------------------

Boundary Condition Type 2, Shear and Slope

```
Shear      =          30000. lbs
Slope      =         0.00000
Axial Load =         130000. lbs
```

| Pile Length feet | Pile Head Deflection inches | Maximum Moment ln-lbs | Maximum Shear lbs |
|---|---|---|---|
| 45.00000 | 0.44340272 | -1552568. | 30000. |
| 42.75000 | 0.44045857 | -1550694. | 30000. |
| 40.50000 | 0.44737591 | -1555842. | 30000. |
| 38.25000 | 0.44555209 | -1555394. | 30000. |
| 36.00000 | 0.44553464 | -1554997. | 30000. |
| 33.75000 | 0.44601603 | -1555512. | 30000. |
| 31.50000 | 0.44102525 | -1551449. | 30000. |
| 29.25000 | 0.44415371 | -1553751. | 30000. |
| 27.00000 | 0.44251175 | -1552446. | 30000. |
| 24.75000 | 0.44299164 | -1552693. | 30000. |
| 22.50000 | 0.44454266 | -1554410. | 30000. |
| 20.25000 | 0.44543440 | -1553130. | 30000. |
| 18.00000 | 0.45014063 | -1552405. | 30000. |
| 15.75000 | 0.46406862 | -1562575. | 30000. |
| 13.50000 | 0.50741442 | -1629334. | 30000. |
| 11.25000 | 0.55718038 | -1795633. | 30000. |
| 9.00000 | 0.56299986 | -1861751. | 30000. |
| 6.75000 | 0.74702622 | -1698520. | 30000. |

--------------------------------------------------------------------------------
Summary of Pile-head Responses for Conventional Analyses
--------------------------------------------------------------------------------

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

ExhaustStack_B14_Factored.lp10o

| Load Case No. | Load Type 1 | Pile-head Load 1 | Load Type 2 | Pile-head Load 2 | Axial Loading lbs | Pile-head Deflection inches | Pile-head Rotation radians | Max Shear in Pile lbs | Max Moment in Pile in-lbs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | V, lb | 30000. | S, rad | 0.00 | 130000. | 0.4434 | 0.00 | 30000. | -1552565. |

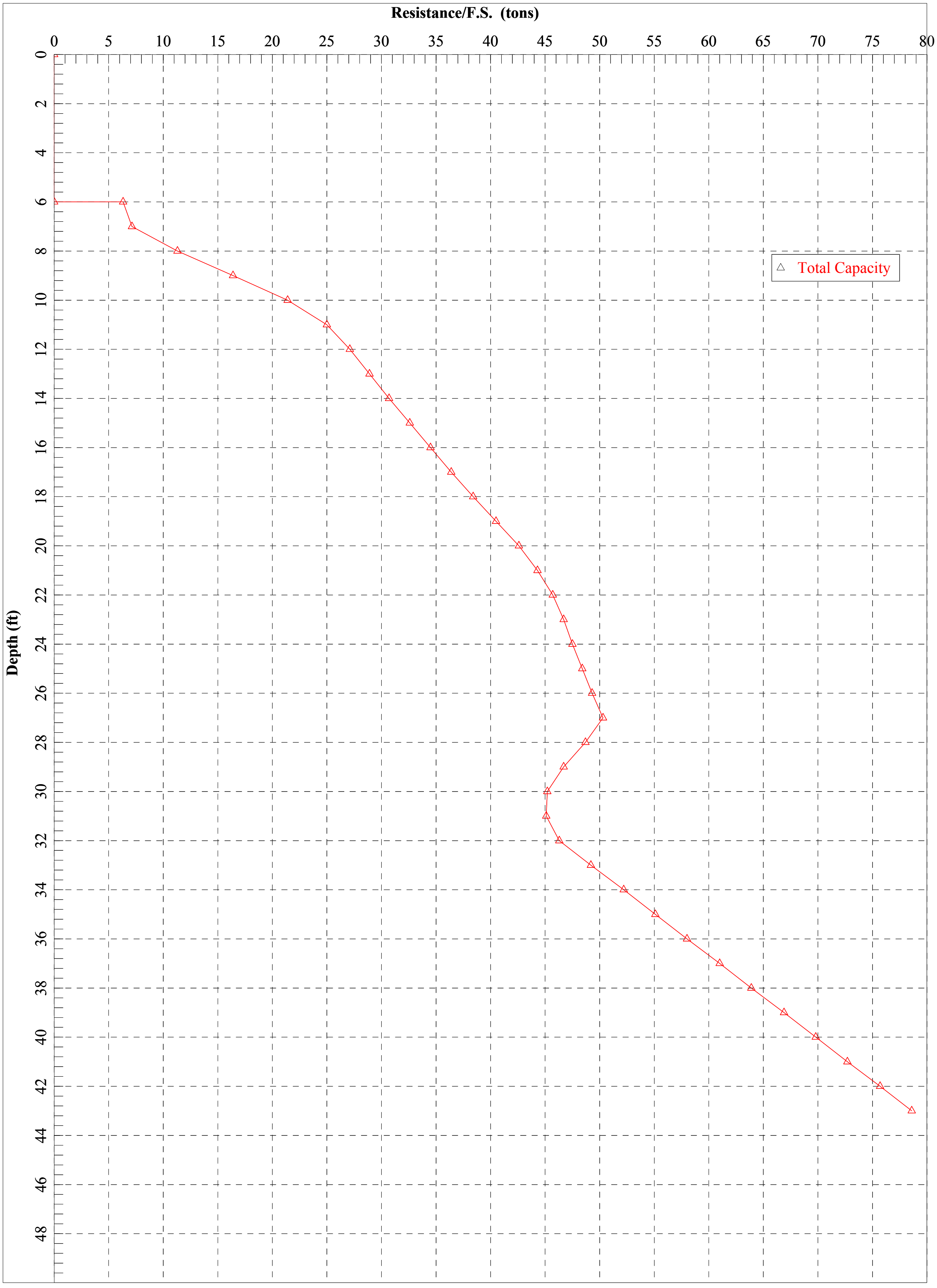
Maximum pile-head deflection = 0.4434005400 inches
Maximum pile-head rotation = 0.0000000000 radians = 0.000000 deg.

The analysis ended normally.

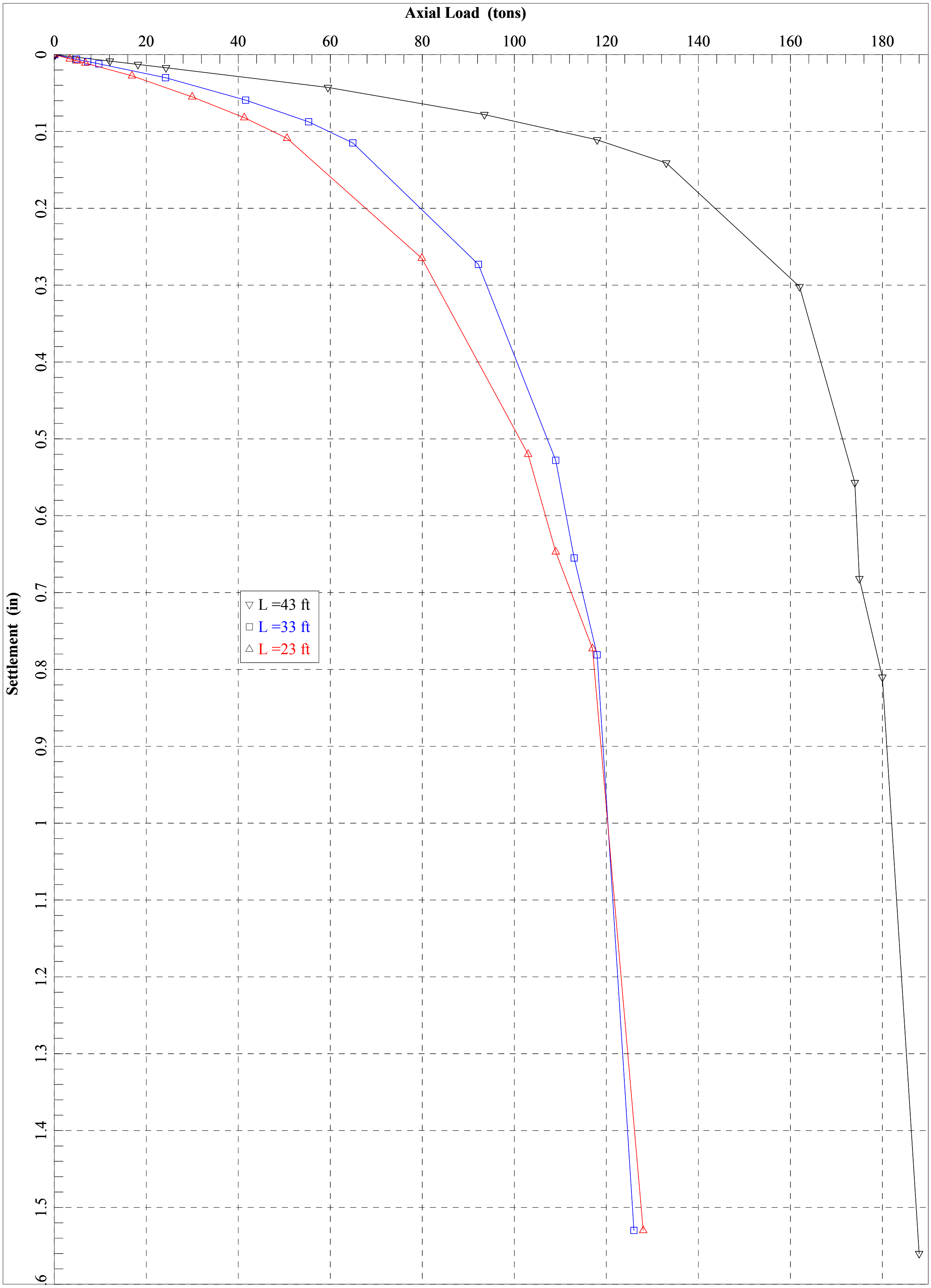
# Appendix H:
# Shaft analysis report (ACP)

**Boring: B-11**
**Equipment: Liquid tanks**

# Allowable Axial Capacity Vs Depth for Given ACP (30" diameter)



# Allowable Settlement for Given ACP
# (30" diameter)



DenimTanks_B11.sf8o

```
===========================================================================

                 SHAFT for Windows, Version 2017.8.5

                  Serial Number :  138585005

               VERTICALLY LOADED DRILLED SHAFT ANALYSIS
                (c) Copyright ENSOFT, Inc., 1987-2017
                      All Rights Reserved

===========================================================================


Path to file locations      : P:\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters, MD\Engineering & Resources\AugerCastPiles\Shaft\
Name of input data file     : DenimTanks_B11.sf8d
Name of output file         : DenimTanks_B11.sf8o
Name of plot output file    : DenimTanks_B11.sf8p
Name of runtime file        : DenimTanks_B11.sf8r


---------------------------------------------------------------------------
                     Time and Date of Analysis
---------------------------------------------------------------------------

          Date:  June 13, 2018     Time:  08:12:19

C.P. Crane Station, Fluid Tanks-B11


PROPOSED DEPTH =      43.0 FT
----------------


NUMBER OF LAYERS =    4
------------------


WATER TABLE DEPTH =       7.0 FT.
-------------------



FACTOR OF SAFETY APPLIED TO THE ULTIMATE SIDE FRICTION CAPACITY = 2.50
-------------------------------------------------------
FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE CAPACITY = 3.00
------------------------------------------------------


SOIL INFORMATION
---------------

LAYER NO  1----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.485E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.310E+02
```

```
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.000E+00

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.485E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.310E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.300E+01

LAYER NO  2----CLAY

  AT THE TOP

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.744E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.800E+03
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.115E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.300E+01


  AT THE BOTTOM

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.800E+03
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.000E+00
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.120E+02


LAYER NO  3----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.485E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.380E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.120E+02

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.485E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.380E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
```

```
  DEPTH, FT                                         = 0.320E+02

LAYER NO  4----CLAY

  AT THE TOP

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.535E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.350E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.320E+02


  AT THE BOTTOM

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.535E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.350E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.500E+02


(*) ESTIMATED BY THE PROGRAM BASED ON OTHER PARAMETERS


INPUT DRILLED SHAFT INFORMATION
------------------------------

 MINIMUM SHAFT DIAMETER    =    2.500  FT.
 MAXIMUM SHAFT DIAMETER    =    2.500  FT.
 RATIO BASE/SHAFT DIAMETER =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN



VARY SHAFT LENGTH FOR INITIAL DIAMETER
--------------------------------------

 MAXIMUM SHAFT LENGTH      =   43.000  FT.
 MINIMUM SHAFT LENGTH      =   20.000  FT.
 SHAFT LENGTH INCREMENT    =   10.000  FT.




COMPUTATION RESULTS
-------------------
```

```
- CASE ANALYZED      :     1
  VARIATION LENGTH   :     1
  VARIATION DIAMETER :     1
```

DRILLED SHAFT INFORMATION

-------------------------

```
 DIAMETER OF STEM          =    2.500  FT.
 DIAMETER OF BASE          =    2.500  FT.
 END OF STEM TO BASE       =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM       =    0.000  CU.YDS.
 SHAFT LENGTH              =   43.000  FT.
```

PREDICTED RESULTS
-----------------

```
QS      = ULTIMATE SIDE RESISTANCE;
QB      = ULTIMATE BASE RESISTANCE;
WT      = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU      = TOTAL ULTIMATE RESISTANCE;
QBD     = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY
          APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN     = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY
          APPLIED TO THE ULTIMATE SIDE RESISTANCE AND
          THE ULTIMATE BASE RESISTANCE.
```

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 1.73 | 16.90 | 18.63 | 7.36 | 6.32 | 17.07 |
| 7.0 | 1.27 | 3.46 | 17.24 | 20.70 | 9.20 | 7.13 | 16.26 |
| 8.0 | 1.45 | 5.18 | 27.71 | 32.89 | 14.42 | 11.31 | 22.61 |
| 9.0 | 1.64 | 6.91 | 40.92 | 47.84 | 20.55 | 16.41 | 29.23 |
| 10.0 | 1.82 | 8.64 | 53.70 | 62.34 | 26.54 | 21.35 | 34.28 |
| 11.0 | 2.00 | 10.37 | 62.47 | 72.84 | 31.19 | 24.97 | 36.42 |
| 12.0 | 2.18 | 12.10 | 66.71 | 78.81 | 34.33 | 27.08 | 36.12 |
| 13.0 | 2.36 | 13.03 | 70.95 | 83.98 | 36.68 | 28.86 | 35.53 |
| 14.0 | 2.55 | 14.07 | 75.19 | 89.26 | 39.13 | 30.69 | 35.06 |
| 15.0 | 2.73 | 15.21 | 79.44 | 94.65 | 41.69 | 32.56 | 34.70 |
| 16.0 | 2.91 | 16.47 | 83.68 | 100.15 | 44.36 | 34.48 | 34.42 |
| 17.0 | 3.09 | 17.83 | 87.92 | 105.75 | 47.14 | 36.44 | 34.21 |
| 18.0 | 3.27 | 19.30 | 92.16 | 111.47 | 50.02 | 38.44 | 34.06 |
| 19.0 | 3.45 | 20.88 | 96.40 | 117.29 | 53.02 | 40.49 | 33.95 |
| 20.0 | 3.64 | 22.57 | 100.64 | 123.22 | 56.12 | 42.58 | 33.88 |
| 21.0 | 3.82 | 24.37 | 103.73 | 128.10 | 58.94 | 44.32 | 33.55 |
| 22.0 | 4.00 | 26.27 | 105.46 | 131.74 | 61.43 | 45.66 | 32.93 |
| 23.0 | 4.18 | 28.28 | 106.04 | 134.33 | 63.63 | 46.66 | 32.12 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 24.0 | 4.36 | 30.40 | 106.04 | 136.45 | 65.75 | 47.51 | 31.27 |
| 25.0 | 4.55 | 32.63 | 106.04 | 138.67 | 67.98 | 48.40 | 30.51 |
| 26.0 | 4.73 | 34.97 | 106.04 | 141.01 | 70.31 | 49.33 | 29.83 |
| 27.0 | 4.91 | 37.41 | 106.04 | 143.45 | 72.76 | 50.31 | 29.22 |
| 28.0 | 5.09 | 39.96 | 98.21 | 138.17 | 72.70 | 48.72 | 27.14 |
| 29.0 | 5.27 | 42.62 | 89.07 | 131.69 | 72.31 | 46.74 | 24.98 |
| 30.0 | 5.45 | 45.39 | 81.24 | 126.63 | 72.47 | 45.24 | 23.21 |
| 31.0 | 5.64 | 48.27 | 77.32 | 125.59 | 74.04 | 45.08 | 22.28 |
| 32.0 | 5.82 | 51.25 | 77.32 | 128.57 | 77.03 | 46.27 | 22.10 |
| 33.0 | 6.00 | 58.60 | 77.32 | 135.92 | 84.38 | 49.21 | 22.65 |
| 34.0 | 6.18 | 65.95 | 77.32 | 143.27 | 91.72 | 52.15 | 23.18 |
| 35.0 | 6.36 | 73.30 | 77.32 | 150.62 | 99.07 | 55.09 | 23.67 |
| 36.0 | 6.55 | 80.65 | 77.32 | 157.97 | 106.42 | 58.03 | 24.13 |
| 37.0 | 6.73 | 88.00 | 77.32 | 165.32 | 113.77 | 60.97 | 24.57 |
| 38.0 | 6.91 | 95.35 | 77.32 | 172.67 | 121.12 | 63.91 | 24.99 |
| 39.0 | 7.09 | 102.70 | 77.32 | 180.02 | 128.47 | 66.85 | 25.39 |
| 40.0 | 7.27 | 110.05 | 77.32 | 187.37 | 135.82 | 69.79 | 25.76 |
| 41.0 | 7.45 | 117.40 | 77.32 | 194.72 | 143.17 | 72.73 | 26.12 |
| 42.0 | 7.64 | 124.75 | 77.32 | 202.07 | 150.52 | 75.67 | 26.46 |
| 43.0 | 7.82 | 132.10 | 77.32 | 209.42 | 157.87 | 78.61 | 26.78 |

AXIAL LOAD VS SETTLEMENT CURVES
-------------------------------

RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.2416E-01 | 0.1707E-04 | 0.2036E-02 | 0.1000E-04 |
| 0.1208E+00 | 0.8535E-04 | 0.1018E-01 | 0.5000E-04 |
| 0.2416E+00 | 0.1707E-03 | 0.2036E-01 | 0.1000E-03 |
| 0.1215E+02 | 0.8551E-02 | 0.1018E+01 | 0.5000E-02 |
| 0.1822E+02 | 0.1283E-01 | 0.1527E+01 | 0.7500E-02 |
| 0.2430E+02 | 0.1710E-01 | 0.2036E+01 | 0.1000E-01 |
| 0.5955E+02 | 0.4265E-01 | 0.5090E+01 | 0.2500E-01 |
| 0.9352E+02 | 0.7807E-01 | 0.1018E+02 | 0.5000E-01 |
| 0.1179E+03 | 0.1109E+00 | 0.1527E+02 | 0.7500E-01 |
| 0.1325E+03 | 0.1410E+00 | 0.2036E+02 | 0.1000E+00 |
| 0.1622E+03 | 0.3015E+00 | 0.3905E+02 | 0.2500E+00 |
| 0.1737E+03 | 0.5567E+00 | 0.5625E+02 | 0.5000E+00 |
| 0.1745E+03 | 0.6824E+00 | 0.6157E+02 | 0.6250E+00 |
| 0.1798E+03 | 0.8095E+00 | 0.6688E+02 | 0.7500E+00 |
| 0.1878E+03 | 0.1563E+01 | 0.7500E+02 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.3617E-01 | 0.2043E-04 | 0.3041E-02 | 0.1000E-04 |
| 0.1808E+00 | 0.1021E-03 | 0.1521E-01 | 0.5000E-04 |
| 0.3617E+00 | 0.2043E-03 | 0.3041E-01 | 0.1000E-03 |
| 0.1823E+02 | 0.1025E-01 | 0.1521E+01 | 0.5000E-02 |
| 0.2734E+02 | 0.1537E-01 | 0.2281E+01 | 0.7500E-02 |
| 0.3646E+02 | 0.2050E-01 | 0.3041E+01 | 0.1000E-01 |

| | | | |
|---|---|---|---|
| 0.8706E+02 | 0.5086E-01 | 0.7603E+01 | 0.2500E-01 |
| 0.1247E+03 | 0.8784E-01 | 0.1521E+02 | 0.5000E-01 |
| 0.1437E+03 | 0.1193E+00 | 0.2281E+02 | 0.7500E-01 |
| 0.1556E+03 | 0.1486E+00 | 0.3041E+02 | 0.1000E+00 |
| 0.1848E+03 | 0.3098E+00 | 0.5387E+02 | 0.2500E+00 |
| 0.1927E+03 | 0.5636E+00 | 0.6779E+02 | 0.5000E+00 |
| 0.1932E+03 | 0.6890E+00 | 0.7101E+02 | 0.6250E+00 |
| 0.1965E+03 | 0.8153E+00 | 0.7423E+02 | 0.7500E+00 |
| 0.1992E+03 | 0.1566E+01 | 0.7694E+02 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD<br>TON | TOP MOVEMENT<br>IN. | TIP LOAD<br>TON | TIP MOVEMENT<br>IN. |
|---|---|---|---|
| 0.1344E-01 | 0.1397E-04 | 0.1031E-02 | 0.1000E-04 |
| 0.6719E-01 | 0.6983E-04 | 0.5155E-02 | 0.5000E-04 |
| 0.1344E+00 | 0.1397E-03 | 0.1031E-01 | 0.1000E-03 |
| 0.6739E+01 | 0.6988E-02 | 0.5155E+00 | 0.5000E-02 |
| 0.1011E+02 | 0.1048E-01 | 0.7732E+00 | 0.7500E-02 |
| 0.1348E+02 | 0.1398E-01 | 0.1031E+01 | 0.1000E-01 |
| 0.3364E+02 | 0.3494E-01 | 0.2577E+01 | 0.2500E-01 |
| 0.6159E+02 | 0.6832E-01 | 0.5155E+01 | 0.5000E-01 |
| 0.8448E+02 | 0.1003E+00 | 0.7732E+01 | 0.7500E-01 |
| 0.1002E+03 | 0.1303E+00 | 0.1031E+02 | 0.1000E+00 |
| 0.1396E+03 | 0.2932E+00 | 0.2423E+02 | 0.2500E+00 |
| 0.1519E+03 | 0.5489E+00 | 0.4472E+02 | 0.5000E+00 |
| 0.1558E+03 | 0.6758E+00 | 0.5213E+02 | 0.6250E+00 |
| 0.1632E+03 | 0.8038E+00 | 0.5954E+02 | 0.7500E+00 |
| 0.1761E+03 | 0.1559E+01 | 0.7268E+02 | 0.1500E+01 |

```
- CASE ANALYZED      :     2
  VARIATION LENGTH   :     2
  VARIATION DIAMETER :     1
```

DRILLED SHAFT INFORMATION

-------------------------

```
 DIAMETER OF STEM          =    2.500  FT.
 DIAMETER OF BASE          =    2.500  FT.
 END OF STEM TO BASE       =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM       =    0.000  CU.YDS.
 SHAFT LENGTH              =   33.000  FT.
```

PREDICTED RESULTS

-----------------

QS = ULTIMATE SIDE RESISTANCE;
QB = ULTIMATE BASE RESISTANCE;
WT = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU = TOTAL ULTIMATE RESISTANCE;
QBD = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY APPLIED TO THE ULTIMATE SIDE RESISTANCE AND THE ULTIMATE BASE RESISTANCE.

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 1.73 | 16.90 | 18.63 | 7.36 | 6.32 | 17.07 |
| 7.0 | 1.27 | 3.46 | 17.24 | 20.70 | 9.20 | 7.13 | 16.26 |
| 8.0 | 1.45 | 5.18 | 27.71 | 32.89 | 14.42 | 11.31 | 22.61 |
| 9.0 | 1.64 | 6.91 | 40.92 | 47.84 | 20.55 | 16.41 | 29.23 |
| 10.0 | 1.82 | 8.64 | 53.70 | 62.34 | 26.54 | 21.35 | 34.28 |
| 11.0 | 2.00 | 10.37 | 62.47 | 72.84 | 31.19 | 24.97 | 36.42 |
| 12.0 | 2.18 | 12.10 | 66.71 | 78.81 | 34.33 | 27.08 | 36.12 |
| 13.0 | 2.36 | 13.03 | 70.95 | 83.98 | 36.68 | 28.86 | 35.53 |
| 14.0 | 2.55 | 14.07 | 75.19 | 89.26 | 39.13 | 30.69 | 35.06 |
| 15.0 | 2.73 | 15.21 | 79.44 | 94.65 | 41.69 | 32.56 | 34.70 |
| 16.0 | 2.91 | 16.47 | 83.68 | 100.15 | 44.36 | 34.48 | 34.42 |
| 17.0 | 3.09 | 17.83 | 87.92 | 105.75 | 47.14 | 36.44 | 34.21 |
| 18.0 | 3.27 | 19.30 | 92.16 | 111.47 | 50.02 | 38.44 | 34.06 |
| 19.0 | 3.45 | 20.88 | 96.40 | 117.29 | 53.02 | 40.49 | 33.95 |
| 20.0 | 3.64 | 22.57 | 100.64 | 123.22 | 56.12 | 42.58 | 33.88 |
| 21.0 | 3.82 | 24.37 | 103.73 | 128.10 | 58.94 | 44.32 | 33.55 |
| 22.0 | 4.00 | 26.27 | 105.46 | 131.74 | 61.43 | 45.66 | 32.93 |
| 23.0 | 4.18 | 28.28 | 106.04 | 134.33 | 63.63 | 46.66 | 32.12 |
| 24.0 | 4.36 | 30.40 | 106.04 | 136.45 | 65.75 | 47.51 | 31.27 |
| 25.0 | 4.55 | 32.63 | 106.04 | 138.67 | 67.98 | 48.40 | 30.51 |
| 26.0 | 4.73 | 34.97 | 106.04 | 141.01 | 70.31 | 49.33 | 29.83 |
| 27.0 | 4.91 | 37.41 | 106.04 | 143.45 | 72.76 | 50.31 | 29.22 |
| 28.0 | 5.09 | 39.96 | 98.21 | 138.17 | 72.70 | 48.72 | 27.14 |
| 29.0 | 5.27 | 42.62 | 89.07 | 131.69 | 72.31 | 46.74 | 24.98 |
| 30.0 | 5.45 | 45.39 | 81.24 | 126.63 | 72.47 | 45.24 | 23.21 |
| 31.0 | 5.64 | 48.27 | 77.32 | 125.59 | 74.04 | 45.08 | 22.28 |
| 32.0 | 5.82 | 51.25 | 77.32 | 128.57 | 77.03 | 46.27 | 22.10 |
| 33.0 | 6.00 | 58.60 | 77.32 | 135.92 | 84.38 | 49.21 | 22.65 |

AXIAL LOAD VS SETTLEMENT CURVES
-------------------------------

RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.9664E-02 | 0.1205E-04 | 0.2036E-02 | 0.1000E-04 |
| 0.4832E-01 | 0.6027E-04 | 0.1018E-01 | 0.5000E-04 |
| 0.9664E-01 | 0.1205E-03 | 0.2036E-01 | 0.1000E-03 |
| 0.4842E+01 | 0.6029E-02 | 0.1018E+01 | 0.5000E-02 |
| 0.7265E+01 | 0.9044E-02 | 0.1527E+01 | 0.7500E-02 |
| 0.9687E+01 | 0.1206E-01 | 0.2036E+01 | 0.1000E-01 |
| 0.2422E+02 | 0.3015E-01 | 0.5090E+01 | 0.2500E-01 |

| | | | |
|---|---|---|---|
| 0.4160E+02 | 0.5920E-01 | 0.1018E+02 | 0.5000E-01 |
| 0.5530E+02 | 0.8749E-01 | 0.1527E+02 | 0.7500E-01 |
| 0.6488E+02 | 0.1150E+00 | 0.2036E+02 | 0.1000E+00 |
| 0.9218E+02 | 0.2728E+00 | 0.3905E+02 | 0.2500E+00 |
| 0.1086E+03 | 0.5281E+00 | 0.5625E+02 | 0.5000E+00 |
| 0.1131E+03 | 0.6546E+00 | 0.6157E+02 | 0.6250E+00 |
| 0.1184E+03 | 0.7813E+00 | 0.6688E+02 | 0.7500E+00 |
| 0.1264E+03 | 0.1534E+01 | 0.7500E+02 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1387E-01 | 0.1293E-04 | 0.3041E-02 | 0.1000E-04 |
| 0.6937E-01 | 0.6463E-04 | 0.1521E-01 | 0.5000E-04 |
| 0.1387E+00 | 0.1293E-03 | 0.3041E-01 | 0.1000E-03 |
| 0.6959E+01 | 0.6466E-02 | 0.1521E+01 | 0.5000E-02 |
| 0.1044E+02 | 0.9700E-02 | 0.2281E+01 | 0.7500E-02 |
| 0.1392E+02 | 0.1293E-01 | 0.3041E+01 | 0.1000E-01 |
| 0.3477E+02 | 0.3233E-01 | 0.7603E+01 | 0.2500E-01 |
| 0.5684E+02 | 0.6273E-01 | 0.1521E+02 | 0.5000E-01 |
| 0.7190E+02 | 0.9174E-01 | 0.2281E+02 | 0.7500E-01 |
| 0.8281E+02 | 0.1198E+00 | 0.3041E+02 | 0.1000E+00 |
| 0.1100E+03 | 0.2780E+00 | 0.5387E+02 | 0.2500E+00 |
| 0.1228E+03 | 0.5322E+00 | 0.6779E+02 | 0.5000E+00 |
| 0.1255E+03 | 0.6581E+00 | 0.7101E+02 | 0.6250E+00 |
| 0.1288E+03 | 0.7841E+00 | 0.7423E+02 | 0.7500E+00 |
| 0.1315E+03 | 0.1535E+01 | 0.7694E+02 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.5662E-02 | 0.1121E-04 | 0.1031E-02 | 0.1000E-04 |
| 0.2831E-01 | 0.5604E-04 | 0.5155E-02 | 0.5000E-04 |
| 0.5662E-01 | 0.1121E-03 | 0.1031E-01 | 0.1000E-03 |
| 0.2833E+01 | 0.5604E-02 | 0.5155E+00 | 0.5000E-02 |
| 0.4251E+01 | 0.8406E-02 | 0.7732E+00 | 0.7500E-02 |
| 0.5669E+01 | 0.1121E-01 | 0.1031E+01 | 0.1000E-01 |
| 0.1417E+02 | 0.2802E-01 | 0.2577E+01 | 0.2500E-01 |
| 0.2646E+02 | 0.5570E-01 | 0.5155E+01 | 0.5000E-01 |
| 0.3697E+02 | 0.8304E-01 | 0.7732E+01 | 0.7500E-01 |
| 0.4526E+02 | 0.1100E+00 | 0.1031E+02 | 0.1000E+00 |
| 0.7436E+02 | 0.2676E+00 | 0.2423E+02 | 0.2500E+00 |
| 0.9387E+02 | 0.5239E+00 | 0.4472E+02 | 0.5000E+00 |
| 0.1006E+03 | 0.6511E+00 | 0.5213E+02 | 0.6250E+00 |
| 0.1080E+03 | 0.7784E+00 | 0.5954E+02 | 0.7500E+00 |
| 0.1209E+03 | 0.1532E+01 | 0.7268E+02 | 0.1500E+01 |

- CASE ANALYZED : 3
  VARIATION LENGTH : 3
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

-------------------------

| | | |
|---|---|---|
| DIAMETER OF STEM | = | 2.500 FT. |
| DIAMETER OF BASE | = | 2.500 FT. |
| END OF STEM TO BASE | = | 0.000 FT. |
| ANGLE OF BELL | = | 0.000 DEG. |
| IGNORED TOP PORTION | = | 5.000 FT. |
| IGNORED BOTTOM PORTION | = | 0.000 FT. |
| AREA OF ONE PERCENT STEEL | = | 7.069 SQ.IN. |
| ELASTIC MODULUS, Ec | = | 0.360E+07 LB/SQ IN |
| VOLUME OF UNDERREAM | = | 0.000 CU.YDS. |
| SHAFT LENGTH | = | 23.000 FT. |

PREDICTED RESULTS

-----------------

QS = ULTIMATE SIDE RESISTANCE;
QB = ULTIMATE BASE RESISTANCE;
WT = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU = TOTAL ULTIMATE RESISTANCE;
QBD = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY APPLIED TO THE ULTIMATE SIDE RESISTANCE AND THE ULTIMATE BASE RESISTANCE.

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 1.73 | 16.90 | 18.63 | 7.36 | 6.32 | 17.07 |
| 7.0 | 1.27 | 3.46 | 17.24 | 20.70 | 9.20 | 7.13 | 16.26 |
| 8.0 | 1.45 | 5.18 | 27.71 | 32.89 | 14.42 | 11.31 | 22.61 |
| 9.0 | 1.64 | 6.91 | 40.92 | 47.84 | 20.55 | 16.41 | 29.23 |
| 10.0 | 1.82 | 8.64 | 53.70 | 62.34 | 26.54 | 21.35 | 34.28 |
| 11.0 | 2.00 | 10.37 | 62.47 | 72.84 | 31.19 | 24.97 | 36.42 |
| 12.0 | 2.18 | 12.10 | 66.71 | 78.81 | 34.33 | 27.08 | 36.12 |
| 13.0 | 2.36 | 13.03 | 70.95 | 83.98 | 36.68 | 28.86 | 35.53 |
| 14.0 | 2.55 | 14.07 | 75.19 | 89.26 | 39.13 | 30.69 | 35.06 |
| 15.0 | 2.73 | 15.21 | 79.44 | 94.65 | 41.69 | 32.56 | 34.70 |
| 16.0 | 2.91 | 16.47 | 83.68 | 100.15 | 44.36 | 34.48 | 34.42 |
| 17.0 | 3.09 | 17.83 | 87.92 | 105.75 | 47.14 | 36.44 | 34.21 |
| 18.0 | 3.27 | 19.30 | 92.16 | 111.47 | 50.02 | 38.44 | 34.06 |
| 19.0 | 3.45 | 20.88 | 96.40 | 117.29 | 53.02 | 40.49 | 33.95 |
| 20.0 | 3.64 | 22.57 | 100.64 | 123.22 | 56.12 | 42.58 | 33.88 |
| 21.0 | 3.82 | 24.37 | 103.73 | 128.10 | 58.94 | 44.32 | 33.55 |
| 22.0 | 4.00 | 26.27 | 105.46 | 131.74 | 61.43 | 45.66 | 32.93 |
| 23.0 | 4.18 | 28.28 | 106.04 | 134.33 | 63.63 | 46.66 | 32.12 |

AXIAL LOAD VS SETTLEMENT CURVES

------------------------------

RESULT FROM TREND (AVERAGED) LINE

DenimTanks_B11.sf8o

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.6758E-02 | 0.1109E-04 | 0.2792E-02 | 0.1000E-04 |
| 0.3379E-01 | 0.5546E-04 | 0.1396E-01 | 0.5000E-04 |
| 0.6758E-01 | 0.1109E-03 | 0.2792E-01 | 0.1000E-03 |
| 0.3384E+01 | 0.5546E-02 | 0.1396E+01 | 0.5000E-02 |
| 0.5076E+01 | 0.8319E-02 | 0.2094E+01 | 0.7500E-02 |
| 0.6769E+01 | 0.1109E-01 | 0.2792E+01 | 0.1000E-01 |
| 0.1692E+02 | 0.2773E-01 | 0.6981E+01 | 0.2500E-01 |
| 0.3001E+02 | 0.5506E-01 | 0.1396E+02 | 0.5000E-01 |
| 0.4134E+02 | 0.8214E-01 | 0.2094E+02 | 0.7500E-01 |
| 0.5063E+02 | 0.1090E+00 | 0.2792E+02 | 0.1000E+00 |
| 0.7990E+02 | 0.2651E+00 | 0.5355E+02 | 0.2500E+00 |
| 0.1028E+03 | 0.5202E+00 | 0.7715E+02 | 0.5000E+00 |
| 0.1094E+03 | 0.6467E+00 | 0.8444E+02 | 0.6250E+00 |
| 0.1167E+03 | 0.7733E+00 | 0.9173E+02 | 0.7500E+00 |
| 0.1278E+03 | 0.1526E+01 | 0.1029E+03 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.9827E-02 | 0.1159E-04 | 0.4171E-02 | 0.1000E-04 |
| 0.4914E-01 | 0.5793E-04 | 0.2086E-01 | 0.5000E-04 |
| 0.9827E-01 | 0.1159E-03 | 0.4171E-01 | 0.1000E-03 |
| 0.4925E+01 | 0.5794E-02 | 0.2086E+01 | 0.5000E-02 |
| 0.7387E+01 | 0.8691E-02 | 0.3128E+01 | 0.7500E-02 |
| 0.9850E+01 | 0.1159E-01 | 0.4171E+01 | 0.1000E-01 |
| 0.2462E+02 | 0.2897E-01 | 0.1043E+02 | 0.2500E-01 |
| 0.4208E+02 | 0.5721E-01 | 0.2086E+02 | 0.5000E-01 |
| 0.5596E+02 | 0.8499E-01 | 0.3128E+02 | 0.7500E-01 |
| 0.6792E+02 | 0.1125E+00 | 0.4171E+02 | 0.1000E+00 |
| 0.1018E+03 | 0.2697E+00 | 0.7388E+02 | 0.2500E+00 |
| 0.1200E+03 | 0.5238E+00 | 0.9296E+02 | 0.5000E+00 |
| 0.1241E+03 | 0.6497E+00 | 0.9738E+02 | 0.6250E+00 |
| 0.1285E+03 | 0.7757E+00 | 0.1018E+03 | 0.7500E+00 |
| 0.1322E+03 | 0.1526E+01 | 0.1055E+03 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

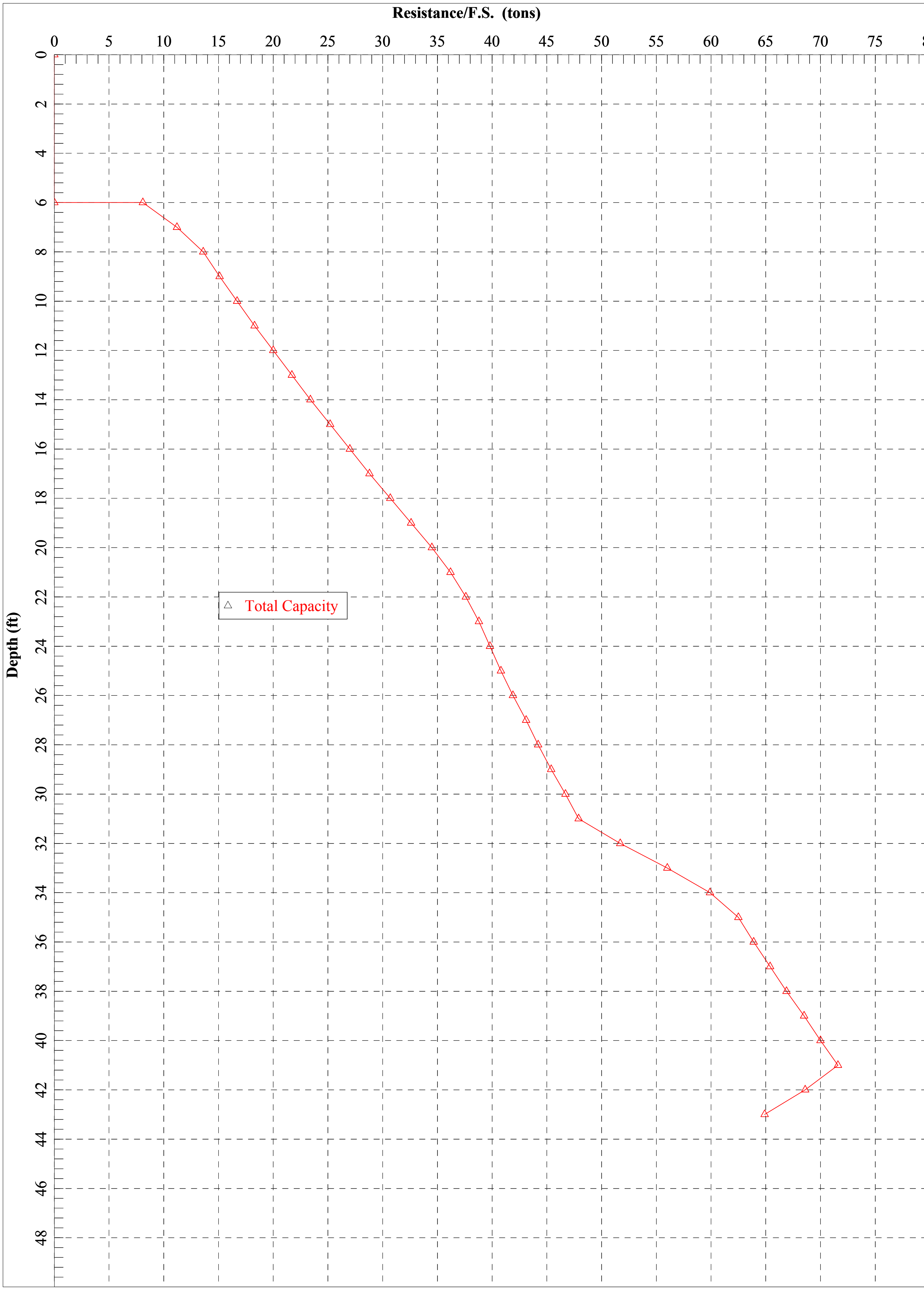
| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.3784E-02 | 0.1061E-04 | 0.1414E-02 | 0.1000E-04 |
| 0.1892E-01 | 0.5303E-04 | 0.7070E-02 | 0.5000E-04 |
| 0.3784E-01 | 0.1061E-03 | 0.1414E-01 | 0.1000E-03 |
| 0.1892E+01 | 0.5303E-02 | 0.7070E+00 | 0.5000E-02 |
| 0.2840E+01 | 0.7954E-02 | 0.1060E+01 | 0.7500E-02 |
| 0.3787E+01 | 0.1061E-01 | 0.1414E+01 | 0.1000E-01 |
| 0.9468E+01 | 0.2652E-01 | 0.3535E+01 | 0.2500E-01 |
| 0.1798E+02 | 0.5291E-01 | 0.7070E+01 | 0.5000E-01 |
| 0.2560E+02 | 0.7920E-01 | 0.1060E+02 | 0.7500E-01 |
| 0.3204E+02 | 0.1054E+00 | 0.1414E+02 | 0.1000E+00 |
| 0.5802E+02 | 0.2605E+00 | 0.3323E+02 | 0.2500E+00 |
| 0.8514E+02 | 0.5166E+00 | 0.6133E+02 | 0.5000E+00 |
| 0.9481E+02 | 0.6437E+00 | 0.7149E+02 | 0.6250E+00 |
| 0.1050E+03 | 0.7709E+00 | 0.8165E+02 | 0.7500E+00 |

```
0.1229E+03      0.1525E+01      0.9968E+02      0.1500E+01
```

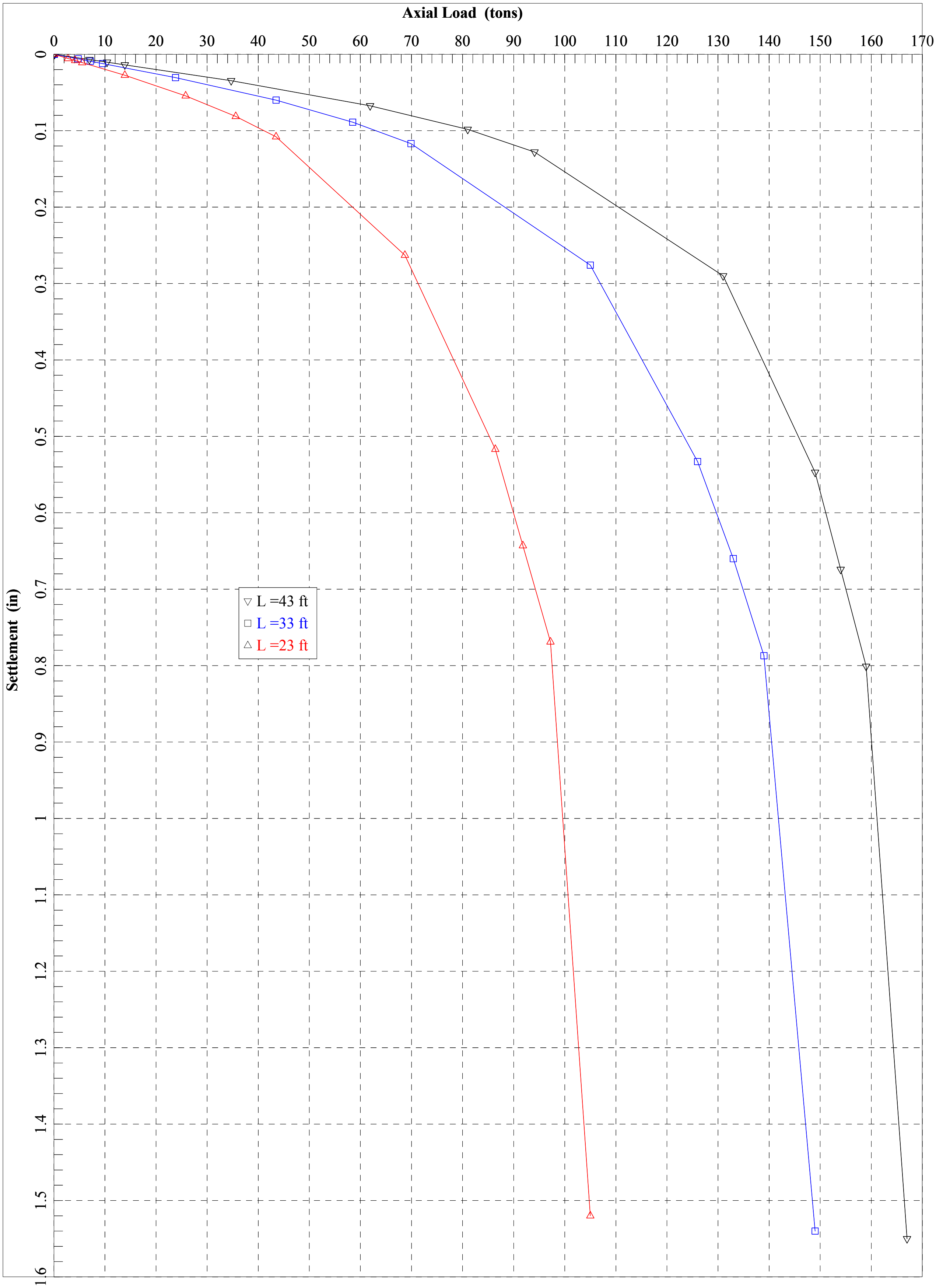
# Shaft analysis report (ACP)

**Boring: B-5**
**Equipment: H-frame**

# Allowable Axial Capacity Vs Depth for Given ACP (30" diameter)



# Allowable Settlement for Given ACP
# (30" diameter)



```
                                   Hframe_B5.sf8o
    ==========================================================================

                 SHAFT for Windows, Version 2017.8.5

                  Serial Number :  138585005

               VERTICALLY LOADED DRILLED SHAFT ANALYSIS
                (c) Copyright ENSOFT, Inc., 1987-2017
                      All Rights Reserved

    ==========================================================================


    Path to file locations      : P:\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters,
MD\Engineering & Resources\AugerCastPiles\Shaft\
    Name of input data file     : Hframe_B5.sf8d
    Name of output file         : Hframe_B5.sf8o
    Name of plot output file    : Hframe_B5.sf8p
    Name of runtime file        : Hframe_B5.sf8r


    --------------------------------------------------------------------------
                     Time and Date of Analysis
    --------------------------------------------------------------------------

              Date:  June 13, 2018     Time:  08:16:39

    C.P. Crane Station, H-Frame - B-5


    PROPOSED DEPTH =      43.0 FT
    ----------------


    NUMBER OF LAYERS =    4
    ------------------


    WATER TABLE DEPTH =       7.0 FT.
    -------------------



    FACTOR OF SAFETY APPLIED TO THE ULTIMATE SIDE FRICTION CAPACITY = 2.50
    -------------------------------------------------------
    FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE CAPACITY = 3.00
    ------------------------------------------------------


    SOIL INFORMATION
    ---------------

    LAYER NO  1----SAND

      AT THE TOP

      SIDE FRICTION PROCEDURE: Ko METHOD
      LATERAL EARTH-PRESSURE COEFFICIENT - Ko          = 0.470E+00
      INTERNAL FRICTION ANGLE, DEG.                    = 0.320E+02
```

```
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.000E+00

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.470E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.320E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.900E+01

LAYER NO  2----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.413E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.360E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.900E+01

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.413E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.360E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.360E+02

LAYER NO  3----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.385E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.380E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.130E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.360E+02

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.385E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.380E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.130E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.460E+02
```

```
LAYER NO  4----CLAY

  AT THE TOP

  STRENGTH REDUCTION FACTOR-ALPHA                    = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                         = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                 = 0.250E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST      = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                         = 0.105E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT           = 0.100E+11
  DEPTH, FT                                          = 0.460E+02


  AT THE BOTTOM

  STRENGTH REDUCTION FACTOR-ALPHA                    = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                         = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                 = 0.250E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST      = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                         = 0.105E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT           = 0.100E+11
  DEPTH, FT                                          = 0.500E+02


(*) ESTIMATED BY THE PROGRAM BASED ON OTHER PARAMETERS


INPUT DRILLED SHAFT INFORMATION
------------------------------

 MINIMUM SHAFT DIAMETER    =    2.500  FT.
 MAXIMUM SHAFT DIAMETER    =    2.500  FT.
 RATIO BASE/SHAFT DIAMETER =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN



VARY SHAFT LENGTH FOR INITIAL DIAMETER
--------------------------------------

 MAXIMUM SHAFT LENGTH      =   43.000  FT.
 MINIMUM SHAFT LENGTH      =   20.000  FT.
 SHAFT LENGTH INCREMENT    =   10.000  FT.




COMPUTATION RESULTS
-------------------
```

Hframe_B5.sf8o

- CASE ANALYZED : 1
  VARIATION LENGTH : 1
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

-------------------------

| | | |
|---|---|---|
| DIAMETER OF STEM | = 2.500 | FT. |
| DIAMETER OF BASE | = 2.500 | FT. |
| END OF STEM TO BASE | = 0.000 | FT. |
| ANGLE OF BELL | = 0.000 | DEG. |
| IGNORED TOP PORTION | = 5.000 | FT. |
| IGNORED BOTTOM PORTION | = 0.000 | FT. |
| AREA OF ONE PERCENT STEEL | = 7.069 | SQ.IN. |
| ELASTIC MODULUS, Ec | = 0.360E+07 | LB/SQ IN |
| VOLUME OF UNDERREAM | = 0.000 | CU.YDS. |
| SHAFT LENGTH | = 43.000 | FT. |

PREDICTED RESULTS
-----------------

QS = ULTIMATE SIDE RESISTANCE;
QB = ULTIMATE BASE RESISTANCE;
WT = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU = TOTAL ULTIMATE RESISTANCE;
QBD = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY APPLIED TO THE ULTIMATE SIDE RESISTANCE AND THE ULTIMATE BASE RESISTANCE.

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.93 | 23.14 | 24.07 | 8.65 | 8.09 | 22.07 |
| 7.0 | 1.27 | 2.02 | 31.14 | 33.16 | 12.40 | 11.19 | 26.06 |
| 8.0 | 1.45 | 3.20 | 36.85 | 40.05 | 15.48 | 13.56 | 27.53 |
| 9.0 | 1.64 | 4.46 | 39.99 | 44.45 | 17.79 | 15.11 | 27.16 |
| 10.0 | 1.82 | 5.83 | 43.14 | 48.96 | 20.21 | 16.71 | 26.93 |
| 11.0 | 2.00 | 7.28 | 46.28 | 53.56 | 22.71 | 18.34 | 26.78 |
| 12.0 | 2.18 | 8.82 | 49.42 | 58.25 | 25.30 | 20.00 | 26.69 |
| 13.0 | 2.36 | 10.45 | 52.56 | 63.02 | 27.97 | 21.70 | 26.66 |
| 14.0 | 2.55 | 12.16 | 55.71 | 67.87 | 30.73 | 23.43 | 26.66 |
| 15.0 | 2.73 | 13.96 | 58.85 | 72.81 | 33.58 | 25.20 | 26.70 |
| 16.0 | 2.91 | 15.85 | 61.99 | 77.84 | 36.51 | 27.00 | 26.76 |
| 17.0 | 3.09 | 17.82 | 65.13 | 82.95 | 39.53 | 28.84 | 26.84 |
| 18.0 | 3.27 | 19.87 | 68.28 | 88.15 | 42.63 | 30.71 | 26.93 |
| 19.0 | 3.45 | 22.01 | 71.42 | 93.43 | 45.82 | 32.61 | 27.04 |
| 20.0 | 3.64 | 24.24 | 74.56 | 98.80 | 49.09 | 34.55 | 27.17 |
| 21.0 | 3.82 | 26.55 | 76.85 | 103.40 | 52.17 | 36.24 | 27.08 |
| 22.0 | 4.00 | 28.95 | 78.13 | 107.08 | 54.99 | 37.62 | 26.77 |
| 23.0 | 4.18 | 31.43 | 78.56 | 109.99 | 57.62 | 38.76 | 26.30 |
| 24.0 | 4.36 | 34.00 | 78.56 | 112.56 | 60.19 | 39.79 | 25.79 |
| 25.0 | 4.55 | 36.65 | 78.56 | 115.21 | 62.84 | 40.85 | 25.35 |

Hframe_B5.sf8o

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 26.0 | 4.73 | 39.39 | 78.56 | 117.95 | 65.58 | 41.94 | 24.95 |
| 27.0 | 4.91 | 42.22 | 78.56 | 120.78 | 68.40 | 43.07 | 24.60 |
| 28.0 | 5.09 | 45.13 | 78.56 | 123.69 | 71.32 | 44.24 | 24.29 |
| 29.0 | 5.27 | 48.13 | 78.56 | 126.68 | 74.31 | 45.44 | 24.03 |
| 30.0 | 5.45 | 51.21 | 78.56 | 129.77 | 77.39 | 46.67 | 23.79 |
| 31.0 | 5.64 | 54.37 | 78.56 | 132.93 | 80.56 | 47.94 | 23.58 |
| 32.0 | 5.82 | 57.63 | 86.06 | 143.68 | 86.31 | 51.74 | 24.69 |
| 33.0 | 6.00 | 60.97 | 94.80 | 155.77 | 92.57 | 55.99 | 25.96 |
| 34.0 | 6.18 | 64.39 | 102.29 | 166.69 | 98.49 | 59.85 | 26.96 |
| 35.0 | 6.36 | 67.90 | 106.04 | 173.94 | 103.25 | 62.51 | 27.33 |
| 36.0 | 6.55 | 71.50 | 106.04 | 177.54 | 106.84 | 63.95 | 27.12 |
| 37.0 | 6.73 | 75.18 | 106.04 | 181.22 | 110.53 | 65.42 | 26.94 |
| 38.0 | 6.91 | 78.94 | 106.04 | 184.99 | 114.29 | 66.92 | 26.77 |
| 39.0 | 7.09 | 82.79 | 106.04 | 188.83 | 118.13 | 68.46 | 26.63 |
| 40.0 | 7.27 | 86.71 | 106.04 | 192.75 | 122.06 | 70.03 | 26.50 |
| 41.0 | 7.45 | 90.71 | 106.04 | 196.76 | 126.06 | 71.63 | 26.39 |
| 42.0 | 7.64 | 94.80 | 92.18 | 186.98 | 125.53 | 68.65 | 24.48 |
| 43.0 | 7.82 | 98.96 | 76.02 | 174.98 | 124.30 | 64.92 | 22.38 |

AXIAL LOAD VS SETTLEMENT CURVES
-------------------------------

RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1384E-01 | 0.1385E-04 | 0.2002E-02 | 0.1000E-04 |
| 0.6918E-01 | 0.6924E-04 | 0.1001E-01 | 0.5000E-04 |
| 0.1384E+00 | 0.1385E-03 | 0.2002E-01 | 0.1000E-03 |
| 0.6939E+01 | 0.6928E-02 | 0.1001E+01 | 0.5000E-02 |
| 0.1041E+02 | 0.1039E-01 | 0.1501E+01 | 0.7500E-02 |
| 0.1388E+02 | 0.1386E-01 | 0.2002E+01 | 0.1000E-01 |
| 0.3465E+02 | 0.3464E-01 | 0.5004E+01 | 0.2500E-01 |
| 0.6188E+02 | 0.6746E-01 | 0.1001E+02 | 0.5000E-01 |
| 0.8099E+02 | 0.9827E-01 | 0.1501E+02 | 0.7500E-01 |
| 0.9411E+02 | 0.1275E+00 | 0.2002E+02 | 0.1000E+00 |
| 0.1313E+03 | 0.2901E+00 | 0.3839E+02 | 0.2500E+00 |
| 0.1490E+03 | 0.5471E+00 | 0.5530E+02 | 0.5000E+00 |
| 0.1541E+03 | 0.6742E+00 | 0.6053E+02 | 0.6250E+00 |
| 0.1593E+03 | 0.8013E+00 | 0.6575E+02 | 0.7500E+00 |
| 0.1670E+03 | 0.1555E+01 | 0.7374E+02 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1939E-01 | 0.1538E-04 | 0.2990E-02 | 0.1000E-04 |
| 0.9697E-01 | 0.7690E-04 | 0.1495E-01 | 0.5000E-04 |
| 0.1939E+00 | 0.1538E-03 | 0.2990E-01 | 0.1000E-03 |
| 0.9740E+01 | 0.7699E-02 | 0.1495E+01 | 0.5000E-02 |
| 0.1461E+02 | 0.1155E-01 | 0.2243E+01 | 0.7500E-02 |
| 0.1948E+02 | 0.1540E-01 | 0.2990E+01 | 0.1000E-01 |
| 0.4841E+02 | 0.3847E-01 | 0.7475E+01 | 0.2500E-01 |
| 0.8434E+02 | 0.7394E-01 | 0.1495E+02 | 0.5000E-01 |

| | | | |
|---|---|---|---|
| 0.1067E+03 | 0.1061E+00 | 0.2243E+02 | 0.7500E-01 |
| 0.1202E+03 | 0.1358E+00 | 0.2990E+02 | 0.1000E+00 |
| 0.1505E+03 | 0.2972E+00 | 0.5296E+02 | 0.2500E+00 |
| 0.1642E+03 | 0.5528E+00 | 0.6664E+02 | 0.5000E+00 |
| 0.1674E+03 | 0.6790E+00 | 0.6981E+02 | 0.6250E+00 |
| 0.1706E+03 | 0.8053E+00 | 0.7298E+02 | 0.7500E+00 |
| 0.1732E+03 | 0.1556E+01 | 0.7564E+02 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.8541E-02 | 0.1236E-04 | 0.1014E-02 | 0.1000E-04 |
| 0.4271E-01 | 0.6181E-04 | 0.5068E-02 | 0.5000E-04 |
| 0.8541E-01 | 0.1236E-03 | 0.1014E-01 | 0.1000E-03 |
| 0.4278E+01 | 0.6182E-02 | 0.5068E+00 | 0.5000E-02 |
| 0.6418E+01 | 0.9274E-02 | 0.7602E+00 | 0.7500E-02 |
| 0.8559E+01 | 0.1237E-01 | 0.1014E+01 | 0.1000E-01 |
| 0.2140E+02 | 0.3091E-01 | 0.2534E+01 | 0.2500E-01 |
| 0.3975E+02 | 0.6107E-01 | 0.5068E+01 | 0.5000E-01 |
| 0.5512E+02 | 0.9047E-01 | 0.7602E+01 | 0.7500E-01 |
| 0.6756E+02 | 0.1191E+00 | 0.1014E+02 | 0.1000E+00 |
| 0.1121E+03 | 0.2829E+00 | 0.2382E+02 | 0.2500E+00 |
| 0.1337E+03 | 0.5415E+00 | 0.4396E+02 | 0.5000E+00 |
| 0.1409E+03 | 0.6694E+00 | 0.5125E+02 | 0.6250E+00 |
| 0.1481E+03 | 0.7974E+00 | 0.5853E+02 | 0.7500E+00 |
| 0.1604E+03 | 0.1552E+01 | 0.7146E+02 | 0.1500E+01 |

- CASE ANALYZED : 2
  VARIATION LENGTH : 2
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

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```
 DIAMETER OF STEM          =    2.500  FT.
 DIAMETER OF BASE          =    2.500  FT.
 END OF STEM TO BASE       =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM       =    0.000  CU.YDS.
 SHAFT LENGTH              =   33.000  FT.
```

PREDICTED RESULTS
-----------------

QS = ULTIMATE SIDE RESISTANCE;
QB = ULTIMATE BASE RESISTANCE;

WT = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU = TOTAL ULTIMATE RESISTANCE;
QBD = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY APPLIED TO THE ULTIMATE SIDE RESISTANCE AND THE ULTIMATE BASE RESISTANCE.

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.93 | 23.14 | 24.07 | 8.65 | 8.09 | 22.07 |
| 7.0 | 1.27 | 2.02 | 31.14 | 33.16 | 12.40 | 11.19 | 26.06 |
| 8.0 | 1.45 | 3.20 | 36.85 | 40.05 | 15.48 | 13.56 | 27.53 |
| 9.0 | 1.64 | 4.46 | 39.99 | 44.45 | 17.79 | 15.11 | 27.16 |
| 10.0 | 1.82 | 5.83 | 43.14 | 48.96 | 20.21 | 16.71 | 26.93 |
| 11.0 | 2.00 | 7.28 | 46.28 | 53.56 | 22.71 | 18.34 | 26.78 |
| 12.0 | 2.18 | 8.82 | 49.42 | 58.25 | 25.30 | 20.00 | 26.69 |
| 13.0 | 2.36 | 10.45 | 52.56 | 63.02 | 27.97 | 21.70 | 26.66 |
| 14.0 | 2.55 | 12.16 | 55.71 | 67.87 | 30.73 | 23.43 | 26.66 |
| 15.0 | 2.73 | 13.96 | 58.85 | 72.81 | 33.58 | 25.20 | 26.70 |
| 16.0 | 2.91 | 15.85 | 61.99 | 77.84 | 36.51 | 27.00 | 26.76 |
| 17.0 | 3.09 | 17.82 | 65.13 | 82.95 | 39.53 | 28.84 | 26.84 |
| 18.0 | 3.27 | 19.87 | 68.28 | 88.15 | 42.63 | 30.71 | 26.93 |
| 19.0 | 3.45 | 22.01 | 71.42 | 93.43 | 45.82 | 32.61 | 27.04 |
| 20.0 | 3.64 | 24.24 | 74.56 | 98.80 | 49.09 | 34.55 | 27.17 |
| 21.0 | 3.82 | 26.55 | 76.85 | 103.40 | 52.17 | 36.24 | 27.08 |
| 22.0 | 4.00 | 28.95 | 78.13 | 107.08 | 54.99 | 37.62 | 26.77 |
| 23.0 | 4.18 | 31.43 | 78.56 | 109.99 | 57.62 | 38.76 | 26.30 |
| 24.0 | 4.36 | 34.00 | 78.56 | 112.56 | 60.19 | 39.79 | 25.79 |
| 25.0 | 4.55 | 36.65 | 78.56 | 115.21 | 62.84 | 40.85 | 25.35 |
| 26.0 | 4.73 | 39.39 | 78.56 | 117.95 | 65.58 | 41.94 | 24.95 |
| 27.0 | 4.91 | 42.22 | 78.56 | 120.78 | 68.40 | 43.07 | 24.60 |
| 28.0 | 5.09 | 45.13 | 78.56 | 123.69 | 71.32 | 44.24 | 24.29 |
| 29.0 | 5.27 | 48.13 | 78.56 | 126.68 | 74.31 | 45.44 | 24.03 |
| 30.0 | 5.45 | 51.21 | 78.56 | 129.77 | 77.39 | 46.67 | 23.79 |
| 31.0 | 5.64 | 54.37 | 78.56 | 132.93 | 80.56 | 47.94 | 23.58 |
| 32.0 | 5.82 | 57.63 | 86.06 | 143.68 | 86.31 | 51.74 | 24.69 |
| 33.0 | 6.00 | 60.97 | 94.80 | 155.77 | 92.57 | 55.99 | 25.96 |

AXIAL LOAD VS SETTLEMENT CURVES
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RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.9499E-02 | 0.1218E-04 | 0.2496E-02 | 0.1000E-04 |
| 0.4750E-01 | 0.6090E-04 | 0.1248E-01 | 0.5000E-04 |
| 0.9499E-01 | 0.1218E-03 | 0.2496E-01 | 0.1000E-03 |
| 0.4759E+01 | 0.6091E-02 | 0.1248E+01 | 0.5000E-02 |
| 0.7141E+01 | 0.9138E-02 | 0.1872E+01 | 0.7500E-02 |
| 0.9521E+01 | 0.1218E-01 | 0.2496E+01 | 0.1000E-01 |
| 0.2380E+02 | 0.3046E-01 | 0.6241E+01 | 0.2500E-01 |
| 0.4346E+02 | 0.6011E-01 | 0.1248E+02 | 0.5000E-01 |
| 0.5849E+02 | 0.8886E-01 | 0.1872E+02 | 0.7500E-01 |

| | | | |
|---|---|---|---|
| 0.6992E+02 | 0.1169E+00 | 0.2496E+02 | 0.1000E+00 |
| 0.1047E+03 | 0.2764E+00 | 0.4787E+02 | 0.2500E+00 |
| 0.1262E+03 | 0.5331E+00 | 0.6897E+02 | 0.5000E+00 |
| 0.1327E+03 | 0.6601E+00 | 0.7548E+02 | 0.6250E+00 |
| 0.1392E+03 | 0.7872E+00 | 0.8200E+02 | 0.7500E+00 |
| 0.1490E+03 | 0.1540E+01 | 0.9196E+02 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1333E-01 | 0.1307E-04 | 0.3729E-02 | 0.1000E-04 |
| 0.6665E-01 | 0.6536E-04 | 0.1864E-01 | 0.5000E-04 |
| 0.1333E+00 | 0.1307E-03 | 0.3729E-01 | 0.1000E-03 |
| 0.6687E+01 | 0.6540E-02 | 0.1864E+01 | 0.5000E-02 |
| 0.1003E+02 | 0.9810E-02 | 0.2797E+01 | 0.7500E-02 |
| 0.1337E+02 | 0.1308E-01 | 0.3729E+01 | 0.1000E-01 |
| 0.3342E+02 | 0.3270E-01 | 0.9322E+01 | 0.2500E-01 |
| 0.6005E+02 | 0.6409E-01 | 0.1864E+02 | 0.5000E-01 |
| 0.7887E+02 | 0.9398E-01 | 0.2797E+02 | 0.7500E-01 |
| 0.9225E+02 | 0.1228E+00 | 0.3729E+02 | 0.1000E+00 |
| 0.1257E+03 | 0.2827E+00 | 0.6604E+02 | 0.2500E+00 |
| 0.1427E+03 | 0.5380E+00 | 0.8311E+02 | 0.5000E+00 |
| 0.1467E+03 | 0.6642E+00 | 0.8706E+02 | 0.6250E+00 |
| 0.1506E+03 | 0.7905E+00 | 0.9101E+02 | 0.7500E+00 |
| 0.1540E+03 | 0.1541E+01 | 0.9433E+02 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.5768E-02 | 0.1130E-04 | 0.1264E-02 | 0.1000E-04 |
| 0.2884E-01 | 0.5651E-04 | 0.6320E-02 | 0.5000E-04 |
| 0.5768E-01 | 0.1130E-03 | 0.1264E-01 | 0.1000E-03 |
| 0.2886E+01 | 0.5651E-02 | 0.6320E+00 | 0.5000E-02 |
| 0.4331E+01 | 0.8477E-02 | 0.9480E+00 | 0.7500E-02 |
| 0.5776E+01 | 0.1130E-01 | 0.1264E+01 | 0.1000E-01 |
| 0.1444E+02 | 0.2826E-01 | 0.3160E+01 | 0.2500E-01 |
| 0.2714E+02 | 0.5617E-01 | 0.6320E+01 | 0.5000E-01 |
| 0.3811E+02 | 0.8374E-01 | 0.9480E+01 | 0.7500E-01 |
| 0.4738E+02 | 0.1110E+00 | 0.1264E+02 | 0.1000E+00 |
| 0.8360E+02 | 0.2702E+00 | 0.2970E+02 | 0.2500E+00 |
| 0.1097E+03 | 0.5282E+00 | 0.5483E+02 | 0.5000E+00 |
| 0.1187E+03 | 0.6560E+00 | 0.6391E+02 | 0.6250E+00 |
| 0.1277E+03 | 0.7838E+00 | 0.7300E+02 | 0.7500E+00 |
| 0.1435E+03 | 0.1539E+01 | 0.8911E+02 | 0.1500E+01 |

- CASE ANALYZED : 3
  VARIATION LENGTH : 3
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

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```
 DIAMETER OF STEM          =    2.500  FT.
 DIAMETER OF BASE          =    2.500  FT.
 END OF STEM TO BASE       =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM       =    0.000  CU.YDS.
 SHAFT LENGTH              =   23.000  FT.
```

PREDICTED RESULTS
-----------------

```
QS     = ULTIMATE SIDE RESISTANCE;
QB     = ULTIMATE BASE RESISTANCE;
WT     = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU     = TOTAL ULTIMATE RESISTANCE;
QBD    = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY
         APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN    = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY
         APPLIED TO THE ULTIMATE SIDE RESISTANCE AND
         THE ULTIMATE BASE RESISTANCE.
```

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.93 | 23.14 | 24.07 | 8.65 | 8.09 | 22.07 |
| 7.0 | 1.27 | 2.02 | 31.14 | 33.16 | 12.40 | 11.19 | 26.06 |
| 8.0 | 1.45 | 3.20 | 36.85 | 40.05 | 15.48 | 13.56 | 27.53 |
| 9.0 | 1.64 | 4.46 | 39.99 | 44.45 | 17.79 | 15.11 | 27.16 |
| 10.0 | 1.82 | 5.83 | 43.14 | 48.96 | 20.21 | 16.71 | 26.93 |
| 11.0 | 2.00 | 7.28 | 46.28 | 53.56 | 22.71 | 18.34 | 26.78 |
| 12.0 | 2.18 | 8.82 | 49.42 | 58.25 | 25.30 | 20.00 | 26.69 |
| 13.0 | 2.36 | 10.45 | 52.56 | 63.02 | 27.97 | 21.70 | 26.66 |
| 14.0 | 2.55 | 12.16 | 55.71 | 67.87 | 30.73 | 23.43 | 26.66 |
| 15.0 | 2.73 | 13.96 | 58.85 | 72.81 | 33.58 | 25.20 | 26.70 |
| 16.0 | 2.91 | 15.85 | 61.99 | 77.84 | 36.51 | 27.00 | 26.76 |
| 17.0 | 3.09 | 17.82 | 65.13 | 82.95 | 39.53 | 28.84 | 26.84 |
| 18.0 | 3.27 | 19.87 | 68.28 | 88.15 | 42.63 | 30.71 | 26.93 |
| 19.0 | 3.45 | 22.01 | 71.42 | 93.43 | 45.82 | 32.61 | 27.04 |
| 20.0 | 3.64 | 24.24 | 74.56 | 98.80 | 49.09 | 34.55 | 27.17 |
| 21.0 | 3.82 | 26.55 | 76.85 | 103.40 | 52.17 | 36.24 | 27.08 |
| 22.0 | 4.00 | 28.95 | 78.13 | 107.08 | 54.99 | 37.62 | 26.77 |
| 23.0 | 4.18 | 31.43 | 78.56 | 109.99 | 57.62 | 38.76 | 26.30 |

AXIAL LOAD VS SETTLEMENT CURVES
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RESULT FROM TREND (AVERAGED) LINE

TOP   LOAD     TOP MOVEMENT       TIP LOAD      TIP   MOVEMENT

| TON | IN. | TON | IN. |
|---|---|---|---|
| 0.5547E-02 | 0.1095E-04 | 0.2069E-02 | 0.1000E-04 |
| 0.2773E-01 | 0.5476E-04 | 0.1034E-01 | 0.5000E-04 |
| 0.5547E-01 | 0.1095E-03 | 0.2069E-01 | 0.1000E-03 |
| 0.2776E+01 | 0.5477E-02 | 0.1034E+01 | 0.5000E-02 |
| 0.4166E+01 | 0.8215E-02 | 0.1552E+01 | 0.7500E-02 |
| 0.5555E+01 | 0.1095E-01 | 0.2069E+01 | 0.1000E-01 |
| 0.1389E+02 | 0.2738E-01 | 0.5172E+01 | 0.2500E-01 |
| 0.2582E+02 | 0.5449E-01 | 0.1034E+02 | 0.5000E-01 |
| 0.3556E+02 | 0.8128E-01 | 0.1552E+02 | 0.7500E-01 |
| 0.4350E+02 | 0.1078E+00 | 0.2069E+02 | 0.1000E+00 |
| 0.6869E+02 | 0.2628E+00 | 0.3967E+02 | 0.2500E+00 |
| 0.8642E+02 | 0.5167E+00 | 0.5715E+02 | 0.5000E+00 |
| 0.9180E+02 | 0.6428E+00 | 0.6255E+02 | 0.6250E+00 |
| 0.9719E+02 | 0.7690E+00 | 0.6795E+02 | 0.7500E+00 |
| 0.1053E+03 | 0.1521E+01 | 0.7620E+02 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD | TOP MOVEMENT | TIP LOAD | TIP MOVEMENT |
|---|---|---|---|
| TON | IN. | TON | IN. |
| 0.7806E-02 | 0.1135E-04 | 0.3090E-02 | 0.1000E-04 |
| 0.3903E-01 | 0.5676E-04 | 0.1545E-01 | 0.5000E-04 |
| 0.7806E-01 | 0.1135E-03 | 0.3090E-01 | 0.1000E-03 |
| 0.3910E+01 | 0.5677E-02 | 0.1545E+01 | 0.5000E-02 |
| 0.5865E+01 | 0.8515E-02 | 0.2318E+01 | 0.7500E-02 |
| 0.7820E+01 | 0.1135E-01 | 0.3090E+01 | 0.1000E-01 |
| 0.1955E+02 | 0.2838E-01 | 0.7725E+01 | 0.2500E-01 |
| 0.3599E+02 | 0.5632E-01 | 0.1545E+02 | 0.5000E-01 |
| 0.4881E+02 | 0.8375E-01 | 0.2318E+02 | 0.7500E-01 |
| 0.5886E+02 | 0.1108E+00 | 0.3090E+02 | 0.1000E+00 |
| 0.8522E+02 | 0.2663E+00 | 0.5473E+02 | 0.2500E+00 |
| 0.9936E+02 | 0.5194E+00 | 0.6887E+02 | 0.5000E+00 |
| 0.1026E+03 | 0.6451E+00 | 0.7214E+02 | 0.6250E+00 |
| 0.1059E+03 | 0.7708E+00 | 0.7542E+02 | 0.7500E+00 |
| 0.1087E+03 | 0.1521E+01 | 0.7817E+02 | 0.1500E+01 |

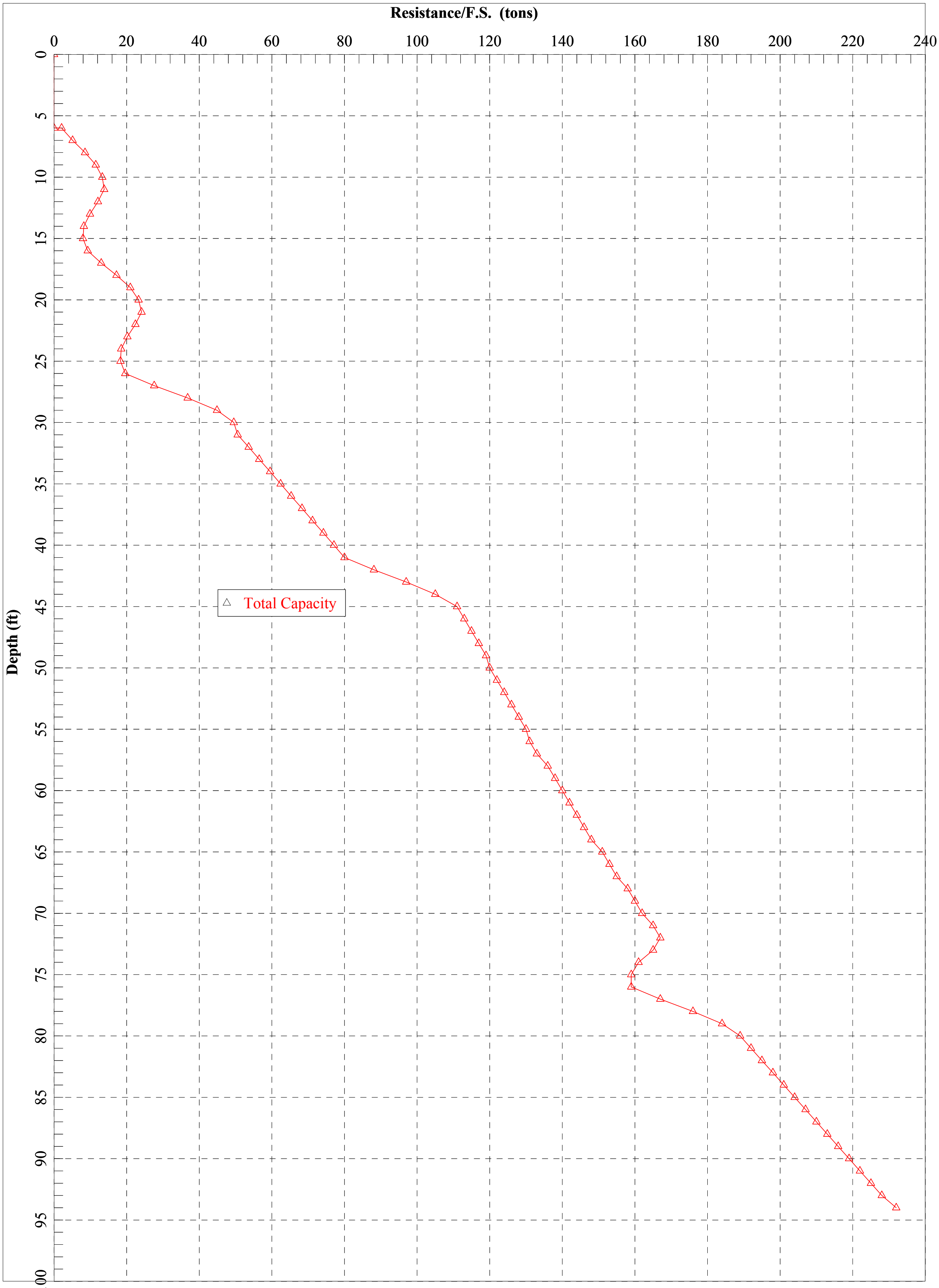
RESULT FROM LOWER-BOUND LINE

| TOP LOAD | TOP MOVEMENT | TIP LOAD | TIP MOVEMENT |
|---|---|---|---|
| TON | IN. | TON | IN. |
| 0.3310E-02 | 0.1056E-04 | 0.1047E-02 | 0.1000E-04 |
| 0.1655E-01 | 0.5278E-04 | 0.5237E-02 | 0.5000E-04 |
| 0.3310E-01 | 0.1056E-03 | 0.1047E-01 | 0.1000E-03 |
| 0.1655E+01 | 0.5278E-02 | 0.5237E+00 | 0.5000E-02 |
| 0.2484E+01 | 0.7917E-02 | 0.7856E+00 | 0.7500E-02 |
| 0.3313E+01 | 0.1056E-01 | 0.1047E+01 | 0.1000E-01 |
| 0.8283E+01 | 0.2639E-01 | 0.2619E+01 | 0.2500E-01 |
| 0.1572E+02 | 0.5266E-01 | 0.5237E+01 | 0.5000E-01 |
| 0.2232E+02 | 0.7881E-01 | 0.7856E+01 | 0.7500E-01 |
| 0.2808E+02 | 0.1048E+00 | 0.1047E+02 | 0.1000E+00 |
| 0.5215E+02 | 0.2593E+00 | 0.2462E+02 | 0.2500E+00 |
| 0.7348E+02 | 0.5139E+00 | 0.4543E+02 | 0.5000E+00 |
| 0.8097E+02 | 0.6406E+00 | 0.5296E+02 | 0.6250E+00 |
| 0.8847E+02 | 0.7672E+00 | 0.6049E+02 | 0.7500E+00 |
| 0.1016E+03 | 0.1520E+01 | 0.7385E+02 | 0.1500E+01 |

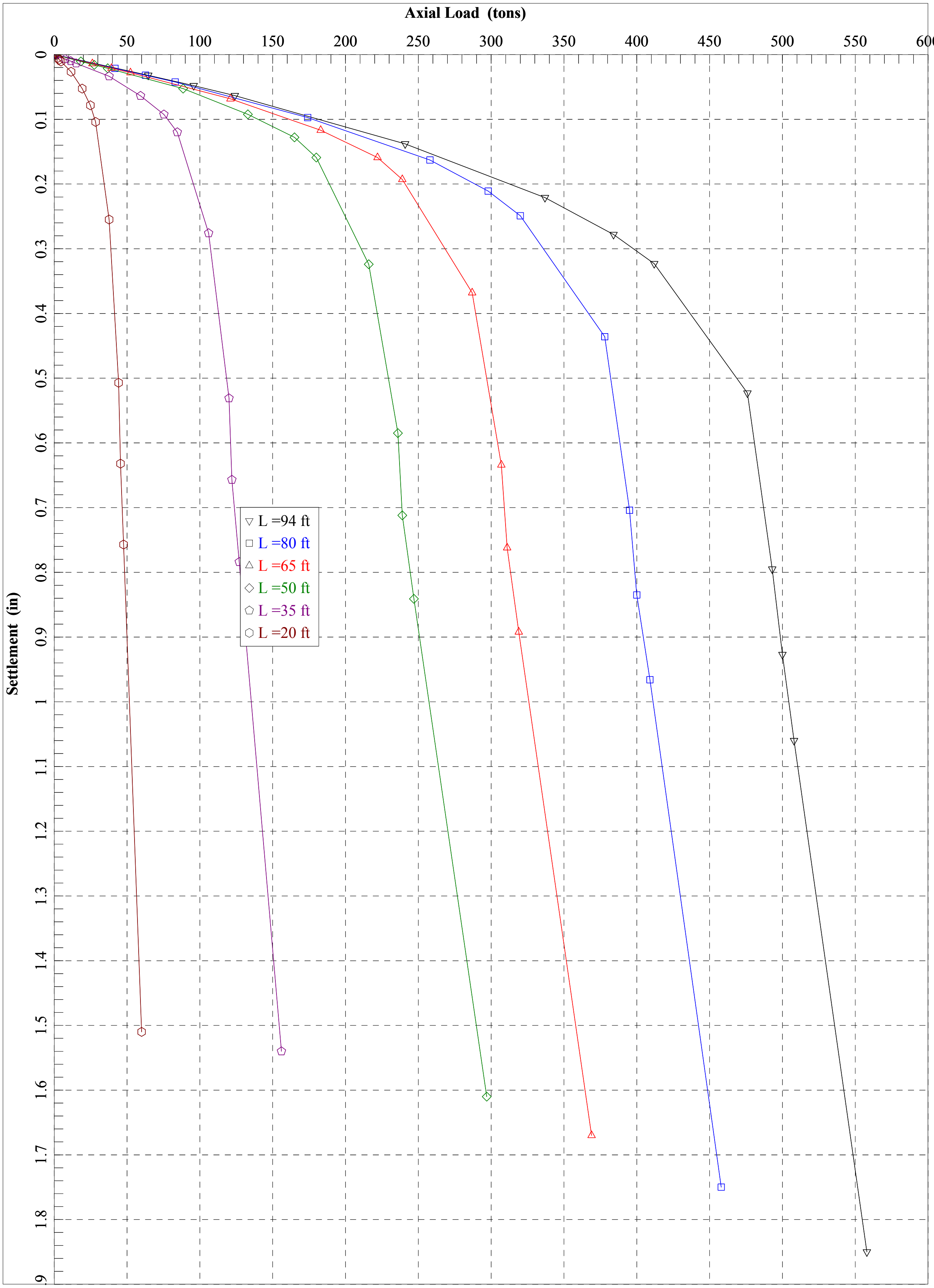
# Shaft analysis report (ACP)

**Boring: B-14**
**Equipment: Exhaust stack**

# Allowable Axial Capacity Vs Depth for Given ACP (30" diameter)



# Allowable Settlement for Given ACP
## (30" diameter)



```
                                 ExhastStacks_B14.sf8o
=========================================================================

                 SHAFT for Windows, Version 2017.8.5

                  Serial Number :  138585005

               VERTICALLY LOADED DRILLED SHAFT ANALYSIS
                (c) Copyright ENSOFT, Inc., 1987-2017
                      All Rights Reserved

=========================================================================


Path to file locations      : P:\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters,
MD\Engineering & Resources\AugerCastPiles\Shaft\
Name of input data file     : ExhastStacks_B14.sf8d
Name of output file         : ExhastStacks_B14.sf8o
Name of plot output file    : ExhastStacks_B14.sf8p
Name of runtime file        : ExhastStacks_B14.sf8r


-------------------------------------------------------------------------
                     Time and Date of Analysis
-------------------------------------------------------------------------

          Date:  June 13, 2018     Time:  08:14:16

C.P. Crane Station, ExhastStacks_B14


PROPOSED DEPTH =      95.0 FT
----------------


NUMBER OF LAYERS =   10
------------------


WATER TABLE DEPTH =       7.0 FT.
-------------------



FACTOR OF SAFETY APPLIED TO THE ULTIMATE SIDE FRICTION CAPACITY = 2.50
-------------------------------------------------------
FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE CAPACITY = 3.00
------------------------------------------------------


SOIL INFORMATION
---------------

LAYER NO  1----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.471E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.320E+02
```

```
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.000E+00

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.471E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.320E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.600E+01

LAYER NO  2----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.485E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.310E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.600E+01

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.485E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.310E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.110E+02

LAYER NO  3----CLAY

  AT THE TOP

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.150E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.120E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.110E+02


  AT THE BOTTOM

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.150E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.120E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.160E+02
```

```
LAYER NO  4----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.516E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.290E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.160E+02

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.516E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.290E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.210E+02

LAYER NO  5----CLAY

  AT THE TOP

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.150E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.120E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.210E+02


  AT THE BOTTOM

  STRENGTH REDUCTION FACTOR-ALPHA                   = 0.550E+00  (*)
  END BEARING COEFFICIENT-Nc                        = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                = 0.150E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.120E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.260E+02


LAYER NO  6----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko           = 0.500E+00
  INTERNAL FRICTION ANGLE, DEG.                     = 0.300E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST     = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                        = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT          = 0.100E+11
  DEPTH, FT                                         = 0.260E+02
```

```
  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko          = 0.500E+00
  INTERNAL FRICTION ANGLE, DEG.                    = 0.300E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST    = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                       = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT         = 0.100E+11
  DEPTH, FT                                        = 0.310E+02

LAYER NO  7----CLAY

  AT THE TOP

  STRENGTH REDUCTION FACTOR-ALPHA                  = 0.535E+00  (*)
  END BEARING COEFFICIENT-Nc                       = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT               = 0.350E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST    = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                       = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT         = 0.100E+11
  DEPTH, FT                                        = 0.310E+02


  AT THE BOTTOM

  STRENGTH REDUCTION FACTOR-ALPHA                  = 0.535E+00  (*)
  END BEARING COEFFICIENT-Nc                       = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT               = 0.350E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST    = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                       = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT         = 0.100E+11
  DEPTH, FT                                        = 0.460E+02


LAYER NO  8----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko          = 0.357E+00
  INTERNAL FRICTION ANGLE, DEG.                    = 0.400E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST    = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                       = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT         = 0.100E+11
  DEPTH, FT                                        = 0.460E+02

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko          = 0.357E+00
  INTERNAL FRICTION ANGLE, DEG.                    = 0.400E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST    = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                       = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT         = 0.100E+11
  DEPTH, FT                                        = 0.770E+02

LAYER NO  9----CLAY
```

```
  AT THE TOP

  STRENGTH REDUCTION FACTOR-ALPHA                      = 0.535E+00  (*)
  END BEARING COEFFICIENT-Nc                           = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                   = 0.350E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST        = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                           = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT             = 0.100E+11
  DEPTH, FT                                            = 0.770E+02


  AT THE BOTTOM

  STRENGTH REDUCTION FACTOR-ALPHA                      = 0.535E+00  (*)
  END BEARING COEFFICIENT-Nc                           = 0.900E+01  (*)
  UNDRAINED SHEAR STRENGTH, LB/SQ FT                   = 0.350E+04
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST        = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                           = 0.125E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT             = 0.100E+11
  DEPTH, FT                                            = 0.810E+02


LAYER NO 10----SAND

  AT THE TOP

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko              = 0.357E+00
  INTERNAL FRICTION ANGLE, DEG.                        = 0.400E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST        = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                           = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT             = 0.100E+11
  DEPTH, FT                                            = 0.810E+02

  AT THE BOTTOM

  SIDE FRICTION PROCEDURE: Ko METHOD
  LATERAL EARTH-PRESSURE COEFFICIENT - Ko              = 0.357E+00
  INTERNAL FRICTION ANGLE, DEG.                        = 0.400E+02
  BLOWS PER FOOT FROM STANDARD PENETRATION TEST        = 0.000E+00
  SOIL UNIT WEIGHT, LB/CU FT                           = 0.135E+03
  MAXIMUM LOAD TRANSFER FOR SOIL, LB/SQ FT             = 0.100E+11
  DEPTH, FT                                            = 0.100E+03


(*) ESTIMATED BY THE PROGRAM BASED ON OTHER PARAMETERS



INPUT DRILLED SHAFT INFORMATION
------------------------------

 MINIMUM SHAFT DIAMETER    =    2.500  FT.
 MAXIMUM SHAFT DIAMETER    =    2.500  FT.
 RATIO BASE/SHAFT DIAMETER =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
```

ExhastStacks_B14.sf8o

VARY SHAFT LENGTH FOR INITIAL DIAMETER
------------------------------------

```
 MAXIMUM SHAFT LENGTH      =   95.000  FT.
 MINIMUM SHAFT LENGTH      =   20.000  FT.
 SHAFT LENGTH INCREMENT    =   15.000  FT.
```

COMPUTATION RESULTS
-------------------

```
- CASE ANALYZED      :     1
  VARIATION LENGTH   :     1
  VARIATION DIAMETER :     1
```

DRILLED SHAFT INFORMATION

-------------------------

```
 DIAMETER OF STEM          =    2.500  FT.
 DIAMETER OF BASE          =    2.500  FT.
 END OF STEM TO BASE       =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM       =    0.000  CU.YDS.
 SHAFT LENGTH              =   95.000  FT.
```

PREDICTED RESULTS
-----------------

```
QS      = ULTIMATE SIDE RESISTANCE;
QB      = ULTIMATE BASE RESISTANCE;
WT      = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU      = TOTAL ULTIMATE RESISTANCE;
QBD     = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY
          APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN     = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY
          APPLIED TO THE ULTIMATE SIDE RESISTANCE AND
          THE ULTIMATE BASE RESISTANCE.

LENGTH  VOLUME     QS      QB      QU       QBD      QDN      QU/VOLUME
 (FT)   (CU.YDS) (TONS)   (TONS)  (TONS)   (TONS)   (TONS)  (TONS/CU.YDS)
```

ExhastStacks_B14.sf8o

end 215

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.94 | 5.09 | 6.03 | 2.63 | 2.07 | 5.53 |
| 7.0 | 1.27 | 2.01 | 12.94 | 14.95 | 6.32 | 5.12 | 11.74 |
| 8.0 | 1.45 | 3.15 | 21.87 | 25.02 | 10.44 | 8.55 | 17.20 |
| 9.0 | 1.64 | 4.36 | 29.41 | 33.77 | 14.16 | 11.55 | 20.63 |
| 10.0 | 1.82 | 5.65 | 33.14 | 38.79 | 16.69 | 13.31 | 21.33 |
| 11.0 | 2.00 | 7.00 | 33.14 | 40.14 | 18.05 | 13.85 | 20.07 |
| 12.0 | 2.18 | 10.24 | 24.10 | 34.35 | 18.28 | 12.13 | 15.74 |
| 13.0 | 2.36 | 13.48 | 13.56 | 27.04 | 18.00 | 9.91 | 11.44 |
| 14.0 | 2.55 | 16.72 | 4.52 | 21.24 | 18.23 | 8.20 | 8.35 |
| 15.0 | 2.73 | 19.97 | 0.00 | 19.97 | 19.97 | 7.99 | 7.32 |
| 16.0 | 2.91 | 23.21 | 0.00 | 23.21 | 23.21 | 9.28 | 7.98 |
| 17.0 | 3.09 | 24.94 | 9.04 | 33.98 | 27.95 | 12.99 | 10.99 |
| 18.0 | 3.27 | 26.76 | 19.58 | 46.34 | 33.29 | 17.23 | 14.16 |
| 19.0 | 3.45 | 28.66 | 28.62 | 57.28 | 38.20 | 21.00 | 16.58 |
| 20.0 | 3.64 | 30.64 | 33.14 | 63.78 | 41.69 | 23.30 | 17.54 |
| 21.0 | 3.82 | 32.71 | 33.14 | 65.84 | 43.75 | 24.13 | 17.24 |
| 22.0 | 4.00 | 35.95 | 24.10 | 60.05 | 43.98 | 22.41 | 15.01 |
| 23.0 | 4.18 | 39.19 | 13.56 | 52.74 | 43.70 | 20.19 | 12.61 |
| 24.0 | 4.36 | 42.43 | 4.52 | 46.94 | 43.93 | 18.48 | 10.76 |
| 25.0 | 4.55 | 45.67 | 0.00 | 45.67 | 45.67 | 18.27 | 10.05 |
| 26.0 | 4.73 | 48.91 | 0.00 | 48.91 | 48.91 | 19.56 | 10.35 |
| 27.0 | 4.91 | 51.40 | 21.09 | 72.49 | 58.43 | 27.59 | 14.76 |
| 28.0 | 5.09 | 53.97 | 45.69 | 99.66 | 69.20 | 36.82 | 19.58 |
| 29.0 | 5.27 | 56.63 | 66.78 | 123.41 | 78.89 | 44.91 | 23.40 |
| 30.0 | 5.45 | 59.37 | 77.32 | 136.69 | 85.14 | 49.52 | 25.06 |
| 31.0 | 5.64 | 62.19 | 77.32 | 139.51 | 87.96 | 50.65 | 24.75 |
| 32.0 | 5.82 | 69.54 | 77.32 | 146.86 | 95.31 | 53.59 | 25.24 |
| 33.0 | 6.00 | 76.88 | 77.32 | 154.21 | 102.66 | 56.53 | 25.70 |
| 34.0 | 6.18 | 84.23 | 77.32 | 161.56 | 110.01 | 59.47 | 26.13 |
| 35.0 | 6.36 | 91.58 | 77.32 | 168.91 | 117.36 | 62.41 | 26.54 |
| 36.0 | 6.55 | 98.93 | 77.32 | 176.26 | 124.71 | 65.35 | 26.93 |
| 37.0 | 6.73 | 106.28 | 77.32 | 183.61 | 132.06 | 68.29 | 27.29 |
| 38.0 | 6.91 | 113.63 | 77.32 | 190.96 | 139.41 | 71.23 | 27.64 |
| 39.0 | 7.09 | 120.98 | 77.32 | 198.30 | 146.76 | 74.17 | 27.96 |
| 40.0 | 7.27 | 128.33 | 77.32 | 205.65 | 154.11 | 77.11 | 28.28 |
| 41.0 | 7.45 | 135.68 | 77.32 | 213.00 | 161.46 | 80.05 | 28.57 |
| 42.0 | 7.64 | 143.03 | 92.65 | 235.68 | 173.91 | 88.10 | 30.86 |
| 43.0 | 7.82 | 150.38 | 110.54 | 260.92 | 187.23 | 97.00 | 33.37 |
| 44.0 | 8.00 | 157.73 | 125.87 | 283.60 | 199.69 | 105.05 | 35.45 |
| 45.0 | 8.18 | 165.08 | 133.54 | 298.61 | 209.59 | 110.54 | 36.50 |
| 46.0 | 8.36 | 172.43 | 133.54 | 305.96 | 216.94 | 113.48 | 36.58 |
| 47.0 | 8.55 | 176.55 | 133.54 | 310.08 | 221.06 | 115.13 | 36.28 |
| 48.0 | 8.73 | 180.75 | 133.54 | 314.28 | 225.26 | 116.81 | 36.01 |
| 49.0 | 8.91 | 185.04 | 133.54 | 318.57 | 229.55 | 118.53 | 35.76 |
| 50.0 | 9.09 | 189.41 | 133.54 | 322.94 | 233.92 | 120.28 | 35.52 |
| 51.0 | 9.27 | 193.87 | 133.54 | 327.40 | 238.38 | 122.06 | 35.31 |
| 52.0 | 9.46 | 198.41 | 133.54 | 331.95 | 242.92 | 123.88 | 35.11 |
| 53.0 | 9.64 | 203.04 | 133.54 | 336.58 | 247.55 | 125.73 | 34.93 |
| 54.0 | 9.82 | 207.76 | 133.54 | 341.29 | 252.27 | 127.61 | 34.76 |
| 55.0 | 10.00 | 212.56 | 133.54 | 346.09 | 257.07 | 129.54 | 34.61 |
| 56.0 | 10.18 | 217.44 | 133.54 | 350.98 | 261.96 | 131.49 | 34.47 |
| 57.0 | 10.36 | 222.42 | 133.54 | 355.95 | 266.93 | 133.48 | 34.34 |
| 58.0 | 10.55 | 227.47 | 133.54 | 361.01 | 271.99 | 135.50 | 34.23 |
| 59.0 | 10.73 | 232.62 | 133.54 | 366.15 | 277.13 | 137.56 | 34.13 |
| 60.0 | 10.91 | 237.84 | 133.54 | 371.38 | 282.36 | 139.65 | 34.04 |
| 61.0 | 11.09 | 243.16 | 133.54 | 376.69 | 287.67 | 141.77 | 33.96 |
| 62.0 | 11.27 | 248.56 | 133.54 | 382.09 | 293.07 | 143.93 | 33.89 |
| 63.0 | 11.46 | 254.04 | 133.54 | 387.57 | 298.55 | 146.13 | 33.83 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 64.0 | 11.64 | 259.61 | 133.54 | 393.14 | 304.12 | 148.36 | 33.78 |
| 65.0 | 11.82 | 265.26 | 133.54 | 398.80 | 309.78 | 150.62 | 33.74 |
| 66.0 | 12.00 | 271.00 | 133.54 | 404.54 | 315.52 | 152.91 | 33.71 |
| 67.0 | 12.18 | 276.83 | 133.54 | 410.36 | 321.34 | 155.24 | 33.68 |
| 68.0 | 12.36 | 282.74 | 133.54 | 416.28 | 327.25 | 157.61 | 33.67 |
| 69.0 | 12.55 | 288.74 | 133.54 | 422.27 | 333.25 | 160.01 | 33.66 |
| 70.0 | 12.73 | 294.82 | 133.54 | 428.35 | 339.33 | 162.44 | 33.65 |
| 71.0 | 12.91 | 300.99 | 133.54 | 434.52 | 345.50 | 164.91 | 33.66 |
| 72.0 | 13.09 | 307.24 | 133.54 | 440.78 | 351.75 | 167.41 | 33.67 |
| 73.0 | 13.27 | 313.58 | 118.20 | 431.78 | 352.98 | 164.83 | 32.53 |
| 74.0 | 13.46 | 320.00 | 100.32 | 420.32 | 353.44 | 161.44 | 31.24 |
| 75.0 | 13.64 | 326.51 | 84.99 | 411.50 | 354.84 | 158.93 | 30.17 |
| 76.0 | 13.82 | 333.11 | 77.32 | 410.43 | 358.88 | 159.02 | 29.70 |
| 77.0 | 14.00 | 339.79 | 92.65 | 432.44 | 370.67 | 166.80 | 30.89 |
| 78.0 | 14.18 | 347.14 | 110.54 | 457.67 | 383.98 | 175.70 | 32.27 |
| 79.0 | 14.36 | 354.49 | 125.87 | 480.35 | 396.44 | 183.75 | 33.44 |
| 80.0 | 14.55 | 361.83 | 133.54 | 495.37 | 406.35 | 189.25 | 34.05 |
| 81.0 | 14.73 | 369.18 | 133.54 | 502.72 | 413.70 | 192.19 | 34.13 |
| 82.0 | 14.91 | 376.24 | 133.54 | 509.78 | 420.76 | 195.01 | 34.19 |
| 83.0 | 15.09 | 383.39 | 133.54 | 516.92 | 427.90 | 197.87 | 34.25 |
| 84.0 | 15.27 | 390.62 | 133.54 | 524.16 | 435.13 | 200.76 | 34.32 |
| 85.0 | 15.46 | 397.94 | 133.54 | 531.47 | 442.45 | 203.69 | 34.39 |
| 86.0 | 15.64 | 405.34 | 133.54 | 538.87 | 449.85 | 206.65 | 34.46 |
| 87.0 | 15.82 | 412.83 | 133.54 | 546.36 | 457.34 | 209.64 | 34.54 |
| 88.0 | 16.00 | 420.40 | 133.54 | 553.93 | 464.91 | 212.67 | 34.62 |
| 89.0 | 16.18 | 428.06 | 133.54 | 561.59 | 472.57 | 215.73 | 34.70 |
| 90.0 | 16.36 | 435.80 | 133.54 | 569.34 | 480.31 | 218.83 | 34.79 |
| 91.0 | 16.55 | 443.63 | 133.54 | 577.16 | 488.14 | 221.96 | 34.88 |
| 92.0 | 16.73 | 451.54 | 133.54 | 585.08 | 496.06 | 225.13 | 34.98 |
| 93.0 | 16.91 | 459.54 | 133.54 | 593.08 | 504.06 | 228.33 | 35.07 |
| 94.0 | 17.09 | 467.63 | 133.54 | 601.16 | 512.14 | 231.56 | 35.17 |

AXIAL LOAD VS SETTLEMENT CURVES
-------------------------------

RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1273E+00 | 0.6352E-04 | 0.1558E-02 | 0.1000E-04 |
| 0.6364E+00 | 0.3176E-03 | 0.7790E-02 | 0.5000E-04 |
| 0.1273E+01 | 0.6352E-03 | 0.1558E-01 | 0.1000E-03 |
| 0.6463E+02 | 0.3209E-01 | 0.7790E+00 | 0.5000E-02 |
| 0.9578E+02 | 0.4800E-01 | 0.1168E+01 | 0.7500E-02 |
| 0.1243E+03 | 0.6343E-01 | 0.1558E+01 | 0.1000E-01 |
| 0.2408E+03 | 0.1383E+00 | 0.3895E+01 | 0.2500E-01 |
| 0.3375E+03 | 0.2212E+00 | 0.7790E+01 | 0.5000E-01 |
| 0.3841E+03 | 0.2780E+00 | 0.1168E+02 | 0.7500E-01 |
| 0.4122E+03 | 0.3225E+00 | 0.1558E+02 | 0.1000E+00 |
| 0.4762E+03 | 0.5233E+00 | 0.3850E+02 | 0.2500E+00 |
| 0.4928E+03 | 0.7950E+00 | 0.6821E+02 | 0.5000E+00 |
| 0.5000E+03 | 0.9266E+00 | 0.7684E+02 | 0.6250E+00 |
| 0.5084E+03 | 0.1059E+01 | 0.8546E+02 | 0.7500E+00 |
| 0.5576E+03 | 0.1853E+01 | 0.1355E+03 | 0.1500E+01 |

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RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.2244E+00 | 0.9789E-04 | 0.2226E-02 | 0.1000E-04 |
| 0.1122E+01 | 0.4895E-03 | 0.1113E-01 | 0.5000E-04 |
| 0.2247E+01 | 0.9793E-03 | 0.2226E-01 | 0.1000E-03 |
| 0.1128E+03 | 0.4951E-01 | 0.1113E+01 | 0.5000E-02 |
| 0.1604E+03 | 0.7283E-01 | 0.1669E+01 | 0.7500E-02 |
| 0.1987E+03 | 0.9361E-01 | 0.2226E+01 | 0.1000E-01 |
| 0.3243E+03 | 0.1818E+00 | 0.5564E+01 | 0.2500E-01 |
| 0.4139E+03 | 0.2674E+00 | 0.1113E+02 | 0.5000E-01 |
| 0.4537E+03 | 0.3217E+00 | 0.1669E+02 | 0.7500E-01 |
| 0.4736E+03 | 0.3619E+00 | 0.2226E+02 | 0.1000E+00 |
| 0.5161E+03 | 0.5500E+00 | 0.5386E+02 | 0.2500E+00 |
| 0.5419E+03 | 0.8284E+00 | 0.9147E+02 | 0.5000E+00 |
| 0.5461E+03 | 0.9573E+00 | 0.9648E+02 | 0.6250E+00 |
| 0.5511E+03 | 0.1087E+01 | 0.1015E+03 | 0.7500E+00 |
| 0.5938E+03 | 0.1875E+01 | 0.1442E+03 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.6092E-01 | 0.3797E-04 | 0.8902E-03 | 0.1000E-04 |
| 0.3046E+00 | 0.1899E-03 | 0.4451E-02 | 0.5000E-04 |
| 0.6092E+00 | 0.3797E-03 | 0.8902E-02 | 0.1000E-03 |
| 0.3075E+02 | 0.1909E-01 | 0.4451E+00 | 0.5000E-02 |
| 0.4613E+02 | 0.2864E-01 | 0.6677E+00 | 0.7500E-02 |
| 0.6146E+02 | 0.3818E-01 | 0.8902E+00 | 0.1000E-01 |
| 0.1440E+03 | 0.9285E-01 | 0.2226E+01 | 0.2500E-01 |
| 0.2412E+03 | 0.1684E+00 | 0.4451E+01 | 0.5000E-01 |
| 0.3011E+03 | 0.2282E+00 | 0.6677E+01 | 0.7500E-01 |
| 0.3425E+03 | 0.2785E+00 | 0.8902E+01 | 0.1000E+00 |
| 0.4352E+03 | 0.4964E+00 | 0.2315E+02 | 0.2500E+00 |
| 0.4431E+03 | 0.7611E+00 | 0.4496E+02 | 0.5000E+00 |
| 0.4539E+03 | 0.8959E+00 | 0.5720E+02 | 0.6250E+00 |
| 0.4658E+03 | 0.1032E+01 | 0.6944E+02 | 0.7500E+00 |
| 0.5215E+03 | 0.1831E+01 | 0.1269E+03 | 0.1500E+01 |

- CASE ANALYZED : 2
  VARIATION LENGTH : 2
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

-------------------------

| | | | |
|---|---|---|---|
| DIAMETER OF STEM | = | 2.500 | FT. |
| DIAMETER OF BASE | = | 2.500 | FT. |
| END OF STEM TO BASE | = | 0.000 | FT. |
| ANGLE OF BELL | = | 0.000 | DEG. |
| IGNORED TOP PORTION | = | 5.000 | FT. |

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```
 IGNORED BOTTOM PORTION     =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM       =    0.000  CU.YDS.
 SHAFT LENGTH              =   80.000  FT.
```

PREDICTED RESULTS
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```
QS     = ULTIMATE SIDE RESISTANCE;
QB     = ULTIMATE BASE RESISTANCE;
WT     = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU     = TOTAL ULTIMATE RESISTANCE;
QBD    = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY
         APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN    = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY
         APPLIED TO THE ULTIMATE SIDE RESISTANCE AND
         THE ULTIMATE BASE RESISTANCE.
```

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.94 | 5.09 | 6.03 | 2.63 | 2.07 | 5.53 |
| 7.0 | 1.27 | 2.01 | 12.94 | 14.95 | 6.32 | 5.12 | 11.74 |
| 8.0 | 1.45 | 3.15 | 21.87 | 25.02 | 10.44 | 8.55 | 17.20 |
| 9.0 | 1.64 | 4.36 | 29.41 | 33.77 | 14.16 | 11.55 | 20.63 |
| 10.0 | 1.82 | 5.65 | 33.14 | 38.79 | 16.69 | 13.31 | 21.33 |
| 11.0 | 2.00 | 7.00 | 33.14 | 40.14 | 18.05 | 13.85 | 20.07 |
| 12.0 | 2.18 | 10.24 | 24.10 | 34.35 | 18.28 | 12.13 | 15.74 |
| 13.0 | 2.36 | 13.48 | 13.56 | 27.04 | 18.00 | 9.91 | 11.44 |
| 14.0 | 2.55 | 16.72 | 4.52 | 21.24 | 18.23 | 8.20 | 8.35 |
| 15.0 | 2.73 | 19.97 | 0.00 | 19.97 | 19.97 | 7.99 | 7.32 |
| 16.0 | 2.91 | 23.21 | 0.00 | 23.21 | 23.21 | 9.28 | 7.98 |
| 17.0 | 3.09 | 24.94 | 9.04 | 33.98 | 27.95 | 12.99 | 10.99 |
| 18.0 | 3.27 | 26.76 | 19.58 | 46.34 | 33.29 | 17.23 | 14.16 |
| 19.0 | 3.45 | 28.66 | 28.62 | 57.28 | 38.20 | 21.00 | 16.58 |
| 20.0 | 3.64 | 30.64 | 33.14 | 63.78 | 41.69 | 23.30 | 17.54 |
| 21.0 | 3.82 | 32.71 | 33.14 | 65.84 | 43.75 | 24.13 | 17.24 |
| 22.0 | 4.00 | 35.95 | 24.10 | 60.05 | 43.98 | 22.41 | 15.01 |
| 23.0 | 4.18 | 39.19 | 13.56 | 52.74 | 43.70 | 20.19 | 12.61 |
| 24.0 | 4.36 | 42.43 | 4.52 | 46.94 | 43.93 | 18.48 | 10.76 |
| 25.0 | 4.55 | 45.67 | 0.00 | 45.67 | 45.67 | 18.27 | 10.05 |
| 26.0 | 4.73 | 48.91 | 0.00 | 48.91 | 48.91 | 19.56 | 10.35 |
| 27.0 | 4.91 | 51.40 | 21.09 | 72.49 | 58.43 | 27.59 | 14.76 |
| 28.0 | 5.09 | 53.97 | 45.69 | 99.66 | 69.20 | 36.82 | 19.58 |
| 29.0 | 5.27 | 56.63 | 66.78 | 123.41 | 78.89 | 44.91 | 23.40 |
| 30.0 | 5.45 | 59.37 | 77.32 | 136.69 | 85.14 | 49.52 | 25.06 |
| 31.0 | 5.64 | 62.19 | 77.32 | 139.51 | 87.96 | 50.65 | 24.75 |
| 32.0 | 5.82 | 69.54 | 77.32 | 146.86 | 95.31 | 53.59 | 25.24 |
| 33.0 | 6.00 | 76.88 | 77.32 | 154.21 | 102.66 | 56.53 | 25.70 |
| 34.0 | 6.18 | 84.23 | 77.32 | 161.56 | 110.01 | 59.47 | 26.13 |
| 35.0 | 6.36 | 91.58 | 77.32 | 168.91 | 117.36 | 62.41 | 26.54 |
| 36.0 | 6.55 | 98.93 | 77.32 | 176.26 | 124.71 | 65.35 | 26.93 |
| 37.0 | 6.73 | 106.28 | 77.32 | 183.61 | 132.06 | 68.29 | 27.29 |
| 38.0 | 6.91 | 113.63 | 77.32 | 190.96 | 139.41 | 71.23 | 27.64 |
| 39.0 | 7.09 | 120.98 | 77.32 | 198.30 | 146.76 | 74.17 | 27.96 |
| 40.0 | 7.27 | 128.33 | 77.32 | 205.65 | 154.11 | 77.11 | 28.28 |
| 41.0 | 7.45 | 135.68 | 77.32 | 213.00 | 161.46 | 80.05 | 28.57 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 42.0 | 7.64 | 143.03 | 92.65 | 235.68 | 173.91 | 88.10 | 30.86 |
| 43.0 | 7.82 | 150.38 | 110.54 | 260.92 | 187.23 | 97.00 | 33.37 |
| 44.0 | 8.00 | 157.73 | 125.87 | 283.60 | 199.69 | 105.05 | 35.45 |
| 45.0 | 8.18 | 165.08 | 133.54 | 298.61 | 209.59 | 110.54 | 36.50 |
| 46.0 | 8.36 | 172.43 | 133.54 | 305.96 | 216.94 | 113.48 | 36.58 |
| 47.0 | 8.55 | 176.55 | 133.54 | 310.08 | 221.06 | 115.13 | 36.28 |
| 48.0 | 8.73 | 180.75 | 133.54 | 314.28 | 225.26 | 116.81 | 36.01 |
| 49.0 | 8.91 | 185.04 | 133.54 | 318.57 | 229.55 | 118.53 | 35.76 |
| 50.0 | 9.09 | 189.41 | 133.54 | 322.94 | 233.92 | 120.28 | 35.52 |
| 51.0 | 9.27 | 193.87 | 133.54 | 327.40 | 238.38 | 122.06 | 35.31 |
| 52.0 | 9.46 | 198.41 | 133.54 | 331.95 | 242.92 | 123.88 | 35.11 |
| 53.0 | 9.64 | 203.04 | 133.54 | 336.58 | 247.55 | 125.73 | 34.93 |
| 54.0 | 9.82 | 207.76 | 133.54 | 341.29 | 252.27 | 127.61 | 34.76 |
| 55.0 | 10.00 | 212.56 | 133.54 | 346.09 | 257.07 | 129.54 | 34.61 |
| 56.0 | 10.18 | 217.44 | 133.54 | 350.98 | 261.96 | 131.49 | 34.47 |
| 57.0 | 10.36 | 222.42 | 133.54 | 355.95 | 266.93 | 133.48 | 34.34 |
| 58.0 | 10.55 | 227.47 | 133.54 | 361.01 | 271.99 | 135.50 | 34.23 |
| 59.0 | 10.73 | 232.62 | 133.54 | 366.15 | 277.13 | 137.56 | 34.13 |
| 60.0 | 10.91 | 237.84 | 133.54 | 371.38 | 282.36 | 139.65 | 34.04 |
| 61.0 | 11.09 | 243.16 | 133.54 | 376.69 | 287.67 | 141.77 | 33.96 |
| 62.0 | 11.27 | 248.56 | 133.54 | 382.09 | 293.07 | 143.93 | 33.89 |
| 63.0 | 11.46 | 254.04 | 133.54 | 387.57 | 298.55 | 146.13 | 33.83 |
| 64.0 | 11.64 | 259.61 | 133.54 | 393.14 | 304.12 | 148.36 | 33.78 |
| 65.0 | 11.82 | 265.26 | 133.54 | 398.80 | 309.78 | 150.62 | 33.74 |
| 66.0 | 12.00 | 271.00 | 133.54 | 404.54 | 315.52 | 152.91 | 33.71 |
| 67.0 | 12.18 | 276.83 | 133.54 | 410.36 | 321.34 | 155.24 | 33.68 |
| 68.0 | 12.36 | 282.74 | 133.54 | 416.28 | 327.25 | 157.61 | 33.67 |
| 69.0 | 12.55 | 288.74 | 133.54 | 422.27 | 333.25 | 160.01 | 33.66 |
| 70.0 | 12.73 | 294.82 | 133.54 | 428.35 | 339.33 | 162.44 | 33.65 |
| 71.0 | 12.91 | 300.99 | 133.54 | 434.52 | 345.50 | 164.91 | 33.66 |
| 72.0 | 13.09 | 307.24 | 133.54 | 440.78 | 351.75 | 167.41 | 33.67 |
| 73.0 | 13.27 | 313.58 | 118.20 | 431.78 | 352.98 | 164.83 | 32.53 |
| 74.0 | 13.46 | 320.00 | 100.32 | 420.32 | 353.44 | 161.44 | 31.24 |
| 75.0 | 13.64 | 326.51 | 84.99 | 411.50 | 354.84 | 158.93 | 30.17 |
| 76.0 | 13.82 | 333.11 | 77.32 | 410.43 | 358.88 | 159.02 | 29.70 |
| 77.0 | 14.00 | 339.79 | 92.65 | 432.44 | 370.67 | 166.80 | 30.89 |
| 78.0 | 14.18 | 347.14 | 110.54 | 457.67 | 383.98 | 175.70 | 32.27 |
| 79.0 | 14.36 | 354.49 | 125.87 | 480.35 | 396.44 | 183.75 | 33.44 |
| 80.0 | 14.55 | 361.83 | 133.54 | 495.37 | 406.35 | 189.25 | 34.05 |

AXIAL LOAD VS SETTLEMENT CURVES
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RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.8245E-01 | 0.4210E-04 | 0.1558E-02 | 0.1000E-04 |
| 0.4122E+00 | 0.2105E-03 | 0.7790E-02 | 0.5000E-04 |
| 0.8245E+00 | 0.4210E-03 | 0.1558E-01 | 0.1000E-03 |
| 0.4174E+02 | 0.2121E-01 | 0.7790E+00 | 0.5000E-02 |
| 0.6262E+02 | 0.3182E-01 | 0.1168E+01 | 0.7500E-02 |
| 0.8311E+02 | 0.4238E-01 | 0.1558E+01 | 0.1000E-01 |
| 0.1743E+03 | 0.9743E-01 | 0.3895E+01 | 0.2500E-01 |
| 0.2576E+03 | 0.1631E+00 | 0.7790E+01 | 0.5000E-01 |

| | | | |
|---|---|---|---|
| 0.2984E+03 | 0.2107E+00 | 0.1168E+02 | 0.7500E-01 |
| 0.3204E+03 | 0.2488E+00 | 0.1558E+02 | 0.1000E+00 |
| 0.3776E+03 | 0.4363E+00 | 0.3850E+02 | 0.2500E+00 |
| 0.3947E+03 | 0.7045E+00 | 0.6821E+02 | 0.5000E+00 |
| 0.4005E+03 | 0.8345E+00 | 0.7684E+02 | 0.6250E+00 |
| 0.4090E+03 | 0.9660E+00 | 0.8546E+02 | 0.7500E+00 |
| 0.4585E+03 | 0.1753E+01 | 0.1355E+03 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1375E+00 | 0.6071E-04 | 0.2226E-02 | 0.1000E-04 |
| 0.6875E+00 | 0.3036E-03 | 0.1113E-01 | 0.5000E-04 |
| 0.1375E+01 | 0.6071E-03 | 0.2226E-01 | 0.1000E-03 |
| 0.6997E+02 | 0.3072E-01 | 0.1113E+01 | 0.5000E-02 |
| 0.1039E+03 | 0.4597E-01 | 0.1669E+01 | 0.7500E-02 |
| 0.1341E+03 | 0.6063E-01 | 0.2226E+01 | 0.1000E-01 |
| 0.2438E+03 | 0.1272E+00 | 0.5564E+01 | 0.2500E-01 |
| 0.3182E+03 | 0.1937E+00 | 0.1113E+02 | 0.5000E-01 |
| 0.3527E+03 | 0.2396E+00 | 0.1669E+02 | 0.7500E-01 |
| 0.3704E+03 | 0.2757E+00 | 0.2226E+02 | 0.1000E+00 |
| 0.4129E+03 | 0.4569E+00 | 0.5386E+02 | 0.2500E+00 |
| 0.4381E+03 | 0.7307E+00 | 0.9147E+02 | 0.5000E+00 |
| 0.4419E+03 | 0.8588E+00 | 0.9648E+02 | 0.6250E+00 |
| 0.4469E+03 | 0.9875E+00 | 0.1015E+03 | 0.7500E+00 |
| 0.4896E+03 | 0.1770E+01 | 0.1442E+03 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.4183E-01 | 0.2737E-04 | 0.8902E-03 | 0.1000E-04 |
| 0.2092E+00 | 0.1369E-03 | 0.4451E-02 | 0.5000E-04 |
| 0.4183E+00 | 0.2737E-03 | 0.8902E-02 | 0.1000E-03 |
| 0.2107E+02 | 0.1374E-01 | 0.4451E+00 | 0.5000E-02 |
| 0.3161E+02 | 0.2061E-01 | 0.6677E+00 | 0.7500E-02 |
| 0.4215E+02 | 0.2748E-01 | 0.8902E+00 | 0.1000E-01 |
| 0.1018E+03 | 0.6784E-01 | 0.2226E+01 | 0.2500E-01 |
| 0.1775E+03 | 0.1265E+00 | 0.4451E+01 | 0.5000E-01 |
| 0.2286E+03 | 0.1761E+00 | 0.6677E+01 | 0.7500E-01 |
| 0.2623E+03 | 0.2182E+00 | 0.8902E+01 | 0.1000E+00 |
| 0.3421E+03 | 0.4157E+00 | 0.2315E+02 | 0.2500E+00 |
| 0.3497E+03 | 0.6775E+00 | 0.4496E+02 | 0.5000E+00 |
| 0.3591E+03 | 0.8103E+00 | 0.5720E+02 | 0.6250E+00 |
| 0.3712E+03 | 0.9445E+00 | 0.6944E+02 | 0.7500E+00 |
| 0.4274E+03 | 0.1737E+01 | 0.1269E+03 | 0.1500E+01 |

- CASE ANALYZED : 3
  VARIATION LENGTH : 3
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

ExhastStacks_B14.sf8o

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```
 DIAMETER OF STEM          =    2.500  FT.
 DIAMETER OF BASE          =    2.500  FT.
 END OF STEM TO BASE       =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
 IGNORED TOP PORTION       =    5.000  FT.
 IGNORED BOTTOM PORTION    =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec       = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM       =    0.000  CU.YDS.
 SHAFT LENGTH              =   65.000  FT.
```

PREDICTED RESULTS
-----------------

```
QS      = ULTIMATE SIDE RESISTANCE;
QB      = ULTIMATE BASE RESISTANCE;
WT      = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU      = TOTAL ULTIMATE RESISTANCE;
QBD     = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY
          APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN     = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY
          APPLIED TO THE ULTIMATE SIDE RESISTANCE AND
          THE ULTIMATE BASE RESISTANCE.
```

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.94 | 5.09 | 6.03 | 2.63 | 2.07 | 5.53 |
| 7.0 | 1.27 | 2.01 | 12.94 | 14.95 | 6.32 | 5.12 | 11.74 |
| 8.0 | 1.45 | 3.15 | 21.87 | 25.02 | 10.44 | 8.55 | 17.20 |
| 9.0 | 1.64 | 4.36 | 29.41 | 33.77 | 14.16 | 11.55 | 20.63 |
| 10.0 | 1.82 | 5.65 | 33.14 | 38.79 | 16.69 | 13.31 | 21.33 |
| 11.0 | 2.00 | 7.00 | 33.14 | 40.14 | 18.05 | 13.85 | 20.07 |
| 12.0 | 2.18 | 10.24 | 24.10 | 34.35 | 18.28 | 12.13 | 15.74 |
| 13.0 | 2.36 | 13.48 | 13.56 | 27.04 | 18.00 | 9.91 | 11.44 |
| 14.0 | 2.55 | 16.72 | 4.52 | 21.24 | 18.23 | 8.20 | 8.35 |
| 15.0 | 2.73 | 19.97 | 0.00 | 19.97 | 19.97 | 7.99 | 7.32 |
| 16.0 | 2.91 | 23.21 | 0.00 | 23.21 | 23.21 | 9.28 | 7.98 |
| 17.0 | 3.09 | 24.94 | 9.04 | 33.98 | 27.95 | 12.99 | 10.99 |
| 18.0 | 3.27 | 26.76 | 19.58 | 46.34 | 33.29 | 17.23 | 14.16 |
| 19.0 | 3.45 | 28.66 | 28.62 | 57.28 | 38.20 | 21.00 | 16.58 |
| 20.0 | 3.64 | 30.64 | 33.14 | 63.78 | 41.69 | 23.30 | 17.54 |
| 21.0 | 3.82 | 32.71 | 33.14 | 65.84 | 43.75 | 24.13 | 17.24 |
| 22.0 | 4.00 | 35.95 | 24.10 | 60.05 | 43.98 | 22.41 | 15.01 |
| 23.0 | 4.18 | 39.19 | 13.56 | 52.74 | 43.70 | 20.19 | 12.61 |
| 24.0 | 4.36 | 42.43 | 4.52 | 46.94 | 43.93 | 18.48 | 10.76 |
| 25.0 | 4.55 | 45.67 | 0.00 | 45.67 | 45.67 | 18.27 | 10.05 |
| 26.0 | 4.73 | 48.91 | 0.00 | 48.91 | 48.91 | 19.56 | 10.35 |
| 27.0 | 4.91 | 51.40 | 21.09 | 72.49 | 58.43 | 27.59 | 14.76 |
| 28.0 | 5.09 | 53.97 | 45.69 | 99.66 | 69.20 | 36.82 | 19.58 |
| 29.0 | 5.27 | 56.63 | 66.78 | 123.41 | 78.89 | 44.91 | 23.40 |
| 30.0 | 5.45 | 59.37 | 77.32 | 136.69 | 85.14 | 49.52 | 25.06 |
| 31.0 | 5.64 | 62.19 | 77.32 | 139.51 | 87.96 | 50.65 | 24.75 |
| 32.0 | 5.82 | 69.54 | 77.32 | 146.86 | 95.31 | 53.59 | 25.24 |
| 33.0 | 6.00 | 76.88 | 77.32 | 154.21 | 102.66 | 56.53 | 25.70 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 34.0 | 6.18 | 84.23 | 77.32 | 161.56 | 110.01 | 59.47 | 26.13 |
| 35.0 | 6.36 | 91.58 | 77.32 | 168.91 | 117.36 | 62.41 | 26.54 |
| 36.0 | 6.55 | 98.93 | 77.32 | 176.26 | 124.71 | 65.35 | 26.93 |
| 37.0 | 6.73 | 106.28 | 77.32 | 183.61 | 132.06 | 68.29 | 27.29 |
| 38.0 | 6.91 | 113.63 | 77.32 | 190.96 | 139.41 | 71.23 | 27.64 |
| 39.0 | 7.09 | 120.98 | 77.32 | 198.30 | 146.76 | 74.17 | 27.96 |
| 40.0 | 7.27 | 128.33 | 77.32 | 205.65 | 154.11 | 77.11 | 28.28 |
| 41.0 | 7.45 | 135.68 | 77.32 | 213.00 | 161.46 | 80.05 | 28.57 |
| 42.0 | 7.64 | 143.03 | 92.65 | 235.68 | 173.91 | 88.10 | 30.86 |
| 43.0 | 7.82 | 150.38 | 110.54 | 260.92 | 187.23 | 97.00 | 33.37 |
| 44.0 | 8.00 | 157.73 | 125.87 | 283.60 | 199.69 | 105.05 | 35.45 |
| 45.0 | 8.18 | 165.08 | 133.54 | 298.61 | 209.59 | 110.54 | 36.50 |
| 46.0 | 8.36 | 172.43 | 133.54 | 305.96 | 216.94 | 113.48 | 36.58 |
| 47.0 | 8.55 | 176.55 | 133.54 | 310.08 | 221.06 | 115.13 | 36.28 |
| 48.0 | 8.73 | 180.75 | 133.54 | 314.28 | 225.26 | 116.81 | 36.01 |
| 49.0 | 8.91 | 185.04 | 133.54 | 318.57 | 229.55 | 118.53 | 35.76 |
| 50.0 | 9.09 | 189.41 | 133.54 | 322.94 | 233.92 | 120.28 | 35.52 |
| 51.0 | 9.27 | 193.87 | 133.54 | 327.40 | 238.38 | 122.06 | 35.31 |
| 52.0 | 9.46 | 198.41 | 133.54 | 331.95 | 242.92 | 123.88 | 35.11 |
| 53.0 | 9.64 | 203.04 | 133.54 | 336.58 | 247.55 | 125.73 | 34.93 |
| 54.0 | 9.82 | 207.76 | 133.54 | 341.29 | 252.27 | 127.61 | 34.76 |
| 55.0 | 10.00 | 212.56 | 133.54 | 346.09 | 257.07 | 129.54 | 34.61 |
| 56.0 | 10.18 | 217.44 | 133.54 | 350.98 | 261.96 | 131.49 | 34.47 |
| 57.0 | 10.36 | 222.42 | 133.54 | 355.95 | 266.93 | 133.48 | 34.34 |
| 58.0 | 10.55 | 227.47 | 133.54 | 361.01 | 271.99 | 135.50 | 34.23 |
| 59.0 | 10.73 | 232.62 | 133.54 | 366.15 | 277.13 | 137.56 | 34.13 |
| 60.0 | 10.91 | 237.84 | 133.54 | 371.38 | 282.36 | 139.65 | 34.04 |
| 61.0 | 11.09 | 243.16 | 133.54 | 376.69 | 287.67 | 141.77 | 33.96 |
| 62.0 | 11.27 | 248.56 | 133.54 | 382.09 | 293.07 | 143.93 | 33.89 |
| 63.0 | 11.46 | 254.04 | 133.54 | 387.57 | 298.55 | 146.13 | 33.83 |
| 64.0 | 11.64 | 259.61 | 133.54 | 393.14 | 304.12 | 148.36 | 33.78 |
| 65.0 | 11.82 | 265.26 | 133.54 | 398.80 | 309.78 | 150.62 | 33.74 |

AXIAL LOAD VS SETTLEMENT CURVES
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RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD<br>TON | TOP MOVEMENT<br>IN. | TIP LOAD<br>TON | TIP MOVEMENT<br>IN. |
|---|---|---|---|
| 0.5189E-01 | 0.2793E-04 | 0.1558E-02 | 0.1000E-04 |
| 0.2594E+00 | 0.1397E-03 | 0.7790E-02 | 0.5000E-04 |
| 0.5189E+00 | 0.2793E-03 | 0.1558E-01 | 0.1000E-03 |
| 0.2620E+02 | 0.1404E-01 | 0.7790E+00 | 0.5000E-02 |
| 0.3930E+02 | 0.2106E-01 | 0.1168E+01 | 0.7500E-02 |
| 0.5240E+02 | 0.2808E-01 | 0.1558E+01 | 0.1000E-01 |
| 0.1214E+03 | 0.6831E-01 | 0.3895E+01 | 0.2500E-01 |
| 0.1826E+03 | 0.1175E+00 | 0.7790E+01 | 0.5000E-01 |
| 0.2221E+03 | 0.1595E+00 | 0.1168E+02 | 0.7500E-01 |
| 0.2390E+03 | 0.1926E+00 | 0.1558E+02 | 0.1000E+00 |
| 0.2873E+03 | 0.3684E+00 | 0.3850E+02 | 0.2500E+00 |
| 0.3066E+03 | 0.6335E+00 | 0.6821E+02 | 0.5000E+00 |
| 0.3108E+03 | 0.7622E+00 | 0.7684E+02 | 0.6250E+00 |
| 0.3193E+03 | 0.8925E+00 | 0.8546E+02 | 0.7500E+00 |
| 0.3691E+03 | 0.1673E+01 | 0.1355E+03 | 0.1500E+01 |

ExhastStacks_B14.sf8o

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.8149E-01 | 0.3718E-04 | 0.2226E-02 | 0.1000E-04 |
| 0.4074E+00 | 0.1859E-03 | 0.1113E-01 | 0.5000E-04 |
| 0.8149E+00 | 0.3718E-03 | 0.2226E-01 | 0.1000E-03 |
| 0.4131E+02 | 0.1874E-01 | 0.1113E+01 | 0.5000E-02 |
| 0.6197E+02 | 0.2811E-01 | 0.1669E+01 | 0.7500E-02 |
| 0.8259E+02 | 0.3748E-01 | 0.2226E+01 | 0.1000E-01 |
| 0.1750E+03 | 0.8714E-01 | 0.5564E+01 | 0.2500E-01 |
| 0.2330E+03 | 0.1377E+00 | 0.1113E+02 | 0.5000E-01 |
| 0.2606E+03 | 0.1763E+00 | 0.1669E+02 | 0.7500E-01 |
| 0.2762E+03 | 0.2092E+00 | 0.2226E+02 | 0.1000E+00 |
| 0.3179E+03 | 0.3835E+00 | 0.5386E+02 | 0.2500E+00 |
| 0.3448E+03 | 0.6532E+00 | 0.9147E+02 | 0.5000E+00 |
| 0.3474E+03 | 0.7804E+00 | 0.9648E+02 | 0.6250E+00 |
| 0.3524E+03 | 0.9084E+00 | 0.1015E+03 | 0.7500E+00 |
| 0.3952E+03 | 0.1685E+01 | 0.1442E+03 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.2792E-01 | 0.2006E-04 | 0.8902E-03 | 0.1000E-04 |
| 0.1396E+00 | 0.1003E-03 | 0.4451E-02 | 0.5000E-04 |
| 0.2792E+00 | 0.2006E-03 | 0.8902E-02 | 0.1000E-03 |
| 0.1404E+02 | 0.1005E-01 | 0.4451E+00 | 0.5000E-02 |
| 0.2106E+02 | 0.1508E-01 | 0.6677E+00 | 0.7500E-02 |
| 0.2808E+02 | 0.2011E-01 | 0.8902E+00 | 0.1000E-01 |
| 0.6932E+02 | 0.5012E-01 | 0.2226E+01 | 0.2500E-01 |
| 0.1241E+03 | 0.9555E-01 | 0.4451E+01 | 0.5000E-01 |
| 0.1655E+03 | 0.1367E+00 | 0.6677E+01 | 0.7500E-01 |
| 0.1913E+03 | 0.1723E+00 | 0.8902E+01 | 0.1000E+00 |
| 0.2568E+03 | 0.3534E+00 | 0.2315E+02 | 0.2500E+00 |
| 0.2658E+03 | 0.6129E+00 | 0.4496E+02 | 0.5000E+00 |
| 0.2741E+03 | 0.7440E+00 | 0.5720E+02 | 0.6250E+00 |
| 0.2862E+03 | 0.8765E+00 | 0.6944E+02 | 0.7500E+00 |
| 0.3429E+03 | 0.1661E+01 | 0.1269E+03 | 0.1500E+01 |

- CASE ANALYZED : 4
  VARIATION LENGTH : 4
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

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DIAMETER OF STEM = 2.500 FT.
DIAMETER OF BASE = 2.500 FT.
END OF STEM TO BASE = 0.000 FT.
ANGLE OF BELL = 0.000 DEG.

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 IGNORED TOP PORTION        =    5.000  FT.
 IGNORED BOTTOM PORTION     =    0.000  FT.
 AREA OF ONE PERCENT STEEL =    7.069  SQ.IN.
 ELASTIC MODULUS, Ec        = 0.360E+07 LB/SQ IN
 VOLUME OF UNDERREAM        =    0.000  CU.YDS.
 SHAFT LENGTH               =   50.000  FT.
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PREDICTED RESULTS
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QS = ULTIMATE SIDE RESISTANCE;
QB = ULTIMATE BASE RESISTANCE;
WT = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU = TOTAL ULTIMATE RESISTANCE;
QBD = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY APPLIED TO THE ULTIMATE SIDE RESISTANCE AND THE ULTIMATE BASE RESISTANCE.

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.94 | 5.09 | 6.03 | 2.63 | 2.07 | 5.53 |
| 7.0 | 1.27 | 2.01 | 12.94 | 14.95 | 6.32 | 5.12 | 11.74 |
| 8.0 | 1.45 | 3.15 | 21.87 | 25.02 | 10.44 | 8.55 | 17.20 |
| 9.0 | 1.64 | 4.36 | 29.41 | 33.77 | 14.16 | 11.55 | 20.63 |
| 10.0 | 1.82 | 5.65 | 33.14 | 38.79 | 16.69 | 13.31 | 21.33 |
| 11.0 | 2.00 | 7.00 | 33.14 | 40.14 | 18.05 | 13.85 | 20.07 |
| 12.0 | 2.18 | 10.24 | 24.10 | 34.35 | 18.28 | 12.13 | 15.74 |
| 13.0 | 2.36 | 13.48 | 13.56 | 27.04 | 18.00 | 9.91 | 11.44 |
| 14.0 | 2.55 | 16.72 | 4.52 | 21.24 | 18.23 | 8.20 | 8.35 |
| 15.0 | 2.73 | 19.97 | 0.00 | 19.97 | 19.97 | 7.99 | 7.32 |
| 16.0 | 2.91 | 23.21 | 0.00 | 23.21 | 23.21 | 9.28 | 7.98 |
| 17.0 | 3.09 | 24.94 | 9.04 | 33.98 | 27.95 | 12.99 | 10.99 |
| 18.0 | 3.27 | 26.76 | 19.58 | 46.34 | 33.29 | 17.23 | 14.16 |
| 19.0 | 3.45 | 28.66 | 28.62 | 57.28 | 38.20 | 21.00 | 16.58 |
| 20.0 | 3.64 | 30.64 | 33.14 | 63.78 | 41.69 | 23.30 | 17.54 |
| 21.0 | 3.82 | 32.71 | 33.14 | 65.84 | 43.75 | 24.13 | 17.24 |
| 22.0 | 4.00 | 35.95 | 24.10 | 60.05 | 43.98 | 22.41 | 15.01 |
| 23.0 | 4.18 | 39.19 | 13.56 | 52.74 | 43.70 | 20.19 | 12.61 |
| 24.0 | 4.36 | 42.43 | 4.52 | 46.94 | 43.93 | 18.48 | 10.76 |
| 25.0 | 4.55 | 45.67 | 0.00 | 45.67 | 45.67 | 18.27 | 10.05 |
| 26.0 | 4.73 | 48.91 | 0.00 | 48.91 | 48.91 | 19.56 | 10.35 |
| 27.0 | 4.91 | 51.40 | 21.09 | 72.49 | 58.43 | 27.59 | 14.76 |
| 28.0 | 5.09 | 53.97 | 45.69 | 99.66 | 69.20 | 36.82 | 19.58 |
| 29.0 | 5.27 | 56.63 | 66.78 | 123.41 | 78.89 | 44.91 | 23.40 |
| 30.0 | 5.45 | 59.37 | 77.32 | 136.69 | 85.14 | 49.52 | 25.06 |
| 31.0 | 5.64 | 62.19 | 77.32 | 139.51 | 87.96 | 50.65 | 24.75 |
| 32.0 | 5.82 | 69.54 | 77.32 | 146.86 | 95.31 | 53.59 | 25.24 |
| 33.0 | 6.00 | 76.88 | 77.32 | 154.21 | 102.66 | 56.53 | 25.70 |
| 34.0 | 6.18 | 84.23 | 77.32 | 161.56 | 110.01 | 59.47 | 26.13 |
| 35.0 | 6.36 | 91.58 | 77.32 | 168.91 | 117.36 | 62.41 | 26.54 |
| 36.0 | 6.55 | 98.93 | 77.32 | 176.26 | 124.71 | 65.35 | 26.93 |
| 37.0 | 6.73 | 106.28 | 77.32 | 183.61 | 132.06 | 68.29 | 27.29 |
| 38.0 | 6.91 | 113.63 | 77.32 | 190.96 | 139.41 | 71.23 | 27.64 |
| 39.0 | 7.09 | 120.98 | 77.32 | 198.30 | 146.76 | 74.17 | 27.96 |
| 40.0 | 7.27 | 128.33 | 77.32 | 205.65 | 154.11 | 77.11 | 28.28 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 41.0 | 7.45 | 135.68 | 77.32 | 213.00 | 161.46 | 80.05 | 28.57 |
| 42.0 | 7.64 | 143.03 | 92.65 | 235.68 | 173.91 | 88.10 | 30.86 |
| 43.0 | 7.82 | 150.38 | 110.54 | 260.92 | 187.23 | 97.00 | 33.37 |
| 44.0 | 8.00 | 157.73 | 125.87 | 283.60 | 199.69 | 105.05 | 35.45 |
| 45.0 | 8.18 | 165.08 | 133.54 | 298.61 | 209.59 | 110.54 | 36.50 |
| 46.0 | 8.36 | 172.43 | 133.54 | 305.96 | 216.94 | 113.48 | 36.58 |
| 47.0 | 8.55 | 176.55 | 133.54 | 310.08 | 221.06 | 115.13 | 36.28 |
| 48.0 | 8.73 | 180.75 | 133.54 | 314.28 | 225.26 | 116.81 | 36.01 |
| 49.0 | 8.91 | 185.04 | 133.54 | 318.57 | 229.55 | 118.53 | 35.76 |
| 50.0 | 9.09 | 189.41 | 133.54 | 322.94 | 233.92 | 120.28 | 35.52 |

AXIAL LOAD VS SETTLEMENT CURVES
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RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.3636E-01 | 0.2117E-04 | 0.1558E-02 | 0.1000E-04 |
| 0.1818E+00 | 0.1059E-03 | 0.7790E-02 | 0.5000E-04 |
| 0.3636E+00 | 0.2117E-03 | 0.1558E-01 | 0.1000E-03 |
| 0.1832E+02 | 0.1062E-01 | 0.7790E+00 | 0.5000E-02 |
| 0.2749E+02 | 0.1593E-01 | 0.1168E+01 | 0.7500E-02 |
| 0.3665E+02 | 0.2125E-01 | 0.1558E+01 | 0.1000E-01 |
| 0.8848E+02 | 0.5264E-01 | 0.3895E+01 | 0.2500E-01 |
| 0.1330E+03 | 0.9229E-01 | 0.7790E+01 | 0.5000E-01 |
| 0.1648E+03 | 0.1283E+00 | 0.1168E+02 | 0.7500E-01 |
| 0.1803E+03 | 0.1591E+00 | 0.1558E+02 | 0.1000E+00 |
| 0.2164E+03 | 0.3242E+00 | 0.3850E+02 | 0.2500E+00 |
| 0.2364E+03 | 0.5852E+00 | 0.6821E+02 | 0.5000E+00 |
| 0.2387E+03 | 0.7120E+00 | 0.7684E+02 | 0.6250E+00 |
| 0.2473E+03 | 0.8411E+00 | 0.8546E+02 | 0.7500E+00 |
| 0.2972E+03 | 0.1615E+01 | 0.1355E+03 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.5569E-01 | 0.2676E-04 | 0.2226E-02 | 0.1000E-04 |
| 0.2785E+00 | 0.1338E-03 | 0.1113E-01 | 0.5000E-04 |
| 0.5569E+00 | 0.2676E-03 | 0.2226E-01 | 0.1000E-03 |
| 0.2816E+02 | 0.1346E-01 | 0.1113E+01 | 0.5000E-02 |
| 0.4224E+02 | 0.2019E-01 | 0.1669E+01 | 0.7500E-02 |
| 0.5632E+02 | 0.2691E-01 | 0.2226E+01 | 0.1000E-01 |
| 0.1302E+03 | 0.6557E-01 | 0.5564E+01 | 0.2500E-01 |
| 0.1739E+03 | 0.1058E+00 | 0.1113E+02 | 0.5000E-01 |
| 0.1933E+03 | 0.1382E+00 | 0.1669E+02 | 0.7500E-01 |
| 0.2047E+03 | 0.1678E+00 | 0.2226E+02 | 0.1000E+00 |
| 0.2434E+03 | 0.3352E+00 | 0.5386E+02 | 0.2500E+00 |
| 0.2710E+03 | 0.5997E+00 | 0.9147E+02 | 0.5000E+00 |
| 0.2723E+03 | 0.7258E+00 | 0.9648E+02 | 0.6250E+00 |
| 0.2773E+03 | 0.8531E+00 | 0.1015E+03 | 0.7500E+00 |
| 0.3200E+03 | 0.1623E+01 | 0.1442E+03 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1983E-01 | 0.1621E-04 | 0.8902E-03 | 0.1000E-04 |
| 0.9917E-01 | 0.8107E-04 | 0.4451E-02 | 0.5000E-04 |
| 0.1983E+00 | 0.1621E-03 | 0.8902E-02 | 0.1000E-03 |
| 0.9960E+01 | 0.8118E-02 | 0.4451E+00 | 0.5000E-02 |
| 0.1494E+02 | 0.1218E-01 | 0.6677E+00 | 0.7500E-02 |
| 0.1992E+02 | 0.1624E-01 | 0.8902E+00 | 0.1000E-01 |
| 0.4958E+02 | 0.4056E-01 | 0.2226E+01 | 0.2500E-01 |
| 0.8983E+02 | 0.7843E-01 | 0.4451E+01 | 0.5000E-01 |
| 0.1219E+03 | 0.1139E+00 | 0.6677E+01 | 0.7500E-01 |
| 0.1423E+03 | 0.1459E+00 | 0.8902E+01 | 0.1000E+00 |
| 0.1896E+03 | 0.3133E+00 | 0.2315E+02 | 0.2500E+00 |
| 0.1980E+03 | 0.5693E+00 | 0.4496E+02 | 0.5000E+00 |
| 0.2051E+03 | 0.6983E+00 | 0.5720E+02 | 0.6250E+00 |
| 0.2172E+03 | 0.8291E+00 | 0.6944E+02 | 0.7500E+00 |
| 0.2744E+03 | 0.1606E+01 | 0.1269E+03 | 0.1500E+01 |

- CASE ANALYZED : 5
  VARIATION LENGTH : 5
  VARIATION DIAMETER : 1

DRILLED SHAFT INFORMATION

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| | | |
|---|---|---|
| DIAMETER OF STEM | = 2.500 | FT. |
| DIAMETER OF BASE | = 2.500 | FT. |
| END OF STEM TO BASE | = 0.000 | FT. |
| ANGLE OF BELL | = 0.000 | DEG. |
| IGNORED TOP PORTION | = 5.000 | FT. |
| IGNORED BOTTOM PORTION | = 0.000 | FT. |
| AREA OF ONE PERCENT STEEL | = 7.069 | SQ.IN. |
| ELASTIC MODULUS, Ec | = 0.360E+07 | LB/SQ IN |
| VOLUME OF UNDERREAM | = 0.000 | CU.YDS. |
| SHAFT LENGTH | = 35.000 | FT. |

PREDICTED RESULTS
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QS = ULTIMATE SIDE RESISTANCE;
QB = ULTIMATE BASE RESISTANCE;
WT = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU = TOTAL ULTIMATE RESISTANCE;
QBD = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY APPLIED TO THE ULTIMATE SIDE RESISTANCE AND THE ULTIMATE BASE RESISTANCE.

ExhastStacks_B14.sf8o

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.94 | 5.09 | 6.03 | 2.63 | 2.07 | 5.53 |
| 7.0 | 1.27 | 2.01 | 12.94 | 14.95 | 6.32 | 5.12 | 11.74 |
| 8.0 | 1.45 | 3.15 | 21.87 | 25.02 | 10.44 | 8.55 | 17.20 |
| 9.0 | 1.64 | 4.36 | 29.41 | 33.77 | 14.16 | 11.55 | 20.63 |
| 10.0 | 1.82 | 5.65 | 33.14 | 38.79 | 16.69 | 13.31 | 21.33 |
| 11.0 | 2.00 | 7.00 | 33.14 | 40.14 | 18.05 | 13.85 | 20.07 |
| 12.0 | 2.18 | 10.24 | 24.10 | 34.35 | 18.28 | 12.13 | 15.74 |
| 13.0 | 2.36 | 13.48 | 13.56 | 27.04 | 18.00 | 9.91 | 11.44 |
| 14.0 | 2.55 | 16.72 | 4.52 | 21.24 | 18.23 | 8.20 | 8.35 |
| 15.0 | 2.73 | 19.97 | 0.00 | 19.97 | 19.97 | 7.99 | 7.32 |
| 16.0 | 2.91 | 23.21 | 0.00 | 23.21 | 23.21 | 9.28 | 7.98 |
| 17.0 | 3.09 | 24.94 | 9.04 | 33.98 | 27.95 | 12.99 | 10.99 |
| 18.0 | 3.27 | 26.76 | 19.58 | 46.34 | 33.29 | 17.23 | 14.16 |
| 19.0 | 3.45 | 28.66 | 28.62 | 57.28 | 38.20 | 21.00 | 16.58 |
| 20.0 | 3.64 | 30.64 | 33.14 | 63.78 | 41.69 | 23.30 | 17.54 |
| 21.0 | 3.82 | 32.71 | 33.14 | 65.84 | 43.75 | 24.13 | 17.24 |
| 22.0 | 4.00 | 35.95 | 24.10 | 60.05 | 43.98 | 22.41 | 15.01 |
| 23.0 | 4.18 | 39.19 | 13.56 | 52.74 | 43.70 | 20.19 | 12.61 |
| 24.0 | 4.36 | 42.43 | 4.52 | 46.94 | 43.93 | 18.48 | 10.76 |
| 25.0 | 4.55 | 45.67 | 0.00 | 45.67 | 45.67 | 18.27 | 10.05 |
| 26.0 | 4.73 | 48.91 | 0.00 | 48.91 | 48.91 | 19.56 | 10.35 |
| 27.0 | 4.91 | 51.40 | 21.09 | 72.49 | 58.43 | 27.59 | 14.76 |
| 28.0 | 5.09 | 53.97 | 45.69 | 99.66 | 69.20 | 36.82 | 19.58 |
| 29.0 | 5.27 | 56.63 | 66.78 | 123.41 | 78.89 | 44.91 | 23.40 |
| 30.0 | 5.45 | 59.37 | 77.32 | 136.69 | 85.14 | 49.52 | 25.06 |
| 31.0 | 5.64 | 62.19 | 77.32 | 139.51 | 87.96 | 50.65 | 24.75 |
| 32.0 | 5.82 | 69.54 | 77.32 | 146.86 | 95.31 | 53.59 | 25.24 |
| 33.0 | 6.00 | 76.88 | 77.32 | 154.21 | 102.66 | 56.53 | 25.70 |
| 34.0 | 6.18 | 84.23 | 77.32 | 161.56 | 110.01 | 59.47 | 26.13 |
| 35.0 | 6.36 | 91.58 | 77.32 | 168.91 | 117.36 | 62.41 | 26.54 |

AXIAL LOAD VS SETTLEMENT CURVES
-------------------------------

RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.1502E-01 | 0.1345E-04 | 0.9021E-03 | 0.1000E-04 |
| 0.7508E-01 | 0.6723E-04 | 0.4510E-02 | 0.5000E-04 |
| 0.1502E+00 | 0.1345E-03 | 0.9021E-02 | 0.1000E-03 |
| 0.7535E+01 | 0.6728E-02 | 0.4510E+00 | 0.5000E-02 |
| 0.1130E+02 | 0.1009E-01 | 0.6766E+00 | 0.7500E-02 |
| 0.1507E+02 | 0.1346E-01 | 0.9021E+00 | 0.1000E-01 |
| 0.3767E+02 | 0.3364E-01 | 0.2255E+01 | 0.2500E-01 |
| 0.5930E+02 | 0.6375E-01 | 0.4510E+01 | 0.5000E-01 |
| 0.7529E+02 | 0.9260E-01 | 0.6766E+01 | 0.7500E-01 |
| 0.8452E+02 | 0.1200E+00 | 0.9021E+01 | 0.1000E+00 |
| 0.1064E+03 | 0.2762E+00 | 0.2229E+02 | 0.2500E+00 |
| 0.1200E+03 | 0.5310E+00 | 0.3950E+02 | 0.5000E+00 |
| 0.1221E+03 | 0.6570E+00 | 0.4449E+02 | 0.6250E+00 |
| 0.1270E+03 | 0.7836E+00 | 0.4949E+02 | 0.7500E+00 |
| 0.1560E+03 | 0.1543E+01 | 0.7848E+02 | 0.1500E+01 |

ExhastStacks_B14.sf8o

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.2191E-01 | 0.1500E-04 | 0.1289E-02 | 0.1000E-04 |
| 0.1095E+00 | 0.7499E-04 | 0.6444E-02 | 0.5000E-04 |
| 0.2191E+00 | 0.1500E-03 | 0.1289E-01 | 0.1000E-03 |
| 0.1101E+02 | 0.7509E-02 | 0.6444E+00 | 0.5000E-02 |
| 0.1652E+02 | 0.1126E-01 | 0.9665E+00 | 0.7500E-02 |
| 0.2202E+02 | 0.1502E-01 | 0.1289E+01 | 0.1000E-01 |
| 0.5477E+02 | 0.3752E-01 | 0.3222E+01 | 0.2500E-01 |
| 0.7896E+02 | 0.6835E-01 | 0.6444E+01 | 0.5000E-01 |
| 0.9093E+02 | 0.9640E-01 | 0.9665E+01 | 0.7500E-01 |
| 0.9771E+02 | 0.1233E+00 | 0.1289E+02 | 0.1000E+00 |
| 0.1206E+03 | 0.2803E+00 | 0.3119E+02 | 0.2500E+00 |
| 0.1385E+03 | 0.5366E+00 | 0.5297E+02 | 0.5000E+00 |
| 0.1396E+03 | 0.6621E+00 | 0.5587E+02 | 0.6250E+00 |
| 0.1425E+03 | 0.7881E+00 | 0.5877E+02 | 0.7500E+00 |
| 0.1672E+03 | 0.1546E+01 | 0.8351E+02 | 0.1500E+01 |

RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.8649E-02 | 0.1199E-04 | 0.5155E-03 | 0.1000E-04 |
| 0.4324E-01 | 0.5995E-04 | 0.2577E-02 | 0.5000E-04 |
| 0.8649E-01 | 0.1199E-03 | 0.5155E-02 | 0.1000E-03 |
| 0.4332E+01 | 0.5996E-02 | 0.2577E+00 | 0.5000E-02 |
| 0.6499E+01 | 0.8995E-02 | 0.3866E+00 | 0.7500E-02 |
| 0.8667E+01 | 0.1199E-01 | 0.5155E+00 | 0.1000E-01 |
| 0.2167E+02 | 0.2998E-01 | 0.1289E+01 | 0.2500E-01 |
| 0.3980E+02 | 0.5919E-01 | 0.2577E+01 | 0.5000E-01 |
| 0.5480E+02 | 0.8772E-01 | 0.3866E+01 | 0.7500E-01 |
| 0.6532E+02 | 0.1153E+00 | 0.5155E+01 | 0.1000E+00 |
| 0.9220E+02 | 0.2721E+00 | 0.1340E+02 | 0.2500E+00 |
| 0.9977E+02 | 0.5250E+00 | 0.2603E+02 | 0.5000E+00 |
| 0.1045E+03 | 0.6518E+00 | 0.3312E+02 | 0.6250E+00 |
| 0.1116E+03 | 0.7791E+00 | 0.4021E+02 | 0.7500E+00 |
| 0.1447E+03 | 0.1540E+01 | 0.7346E+02 | 0.1500E+01 |

```
- CASE ANALYZED      :     6
  VARIATION LENGTH   :     6
  VARIATION DIAMETER :     1
```

DRILLED SHAFT INFORMATION

-------------------------

```
 DIAMETER OF STEM          =    2.500  FT.
 DIAMETER OF BASE          =    2.500  FT.
 END OF STEM TO BASE       =    0.000  FT.
 ANGLE OF BELL             =    0.000  DEG.
```

ExhaustStacks_B14.sf8o

| | | |
|---|---|---|
| IGNORED TOP PORTION | = 5.000 | FT. |
| IGNORED BOTTOM PORTION | = 0.000 | FT. |
| AREA OF ONE PERCENT STEEL | = 7.069 | SQ.IN. |
| ELASTIC MODULUS, Ec | = 0.360E+07 | LB/SQ IN |
| VOLUME OF UNDERREAM | = 0.000 | CU.YDS. |
| SHAFT LENGTH | = 20.000 | FT. |

PREDICTED RESULTS
-----------------

QS = ULTIMATE SIDE RESISTANCE;
QB = ULTIMATE BASE RESISTANCE;
WT = WEIGHT OF DRILLED SHAFT (FOR UPLIFT CAPACITY ONLY);
QU = TOTAL ULTIMATE RESISTANCE;
QBD = TOTAL ALLOWABLE LOAD USING A FACTOR OF SAFETY APPLIED TO THE ULTIMATE BASE RESISTANCE;
QDN = TOTAL ALLOWABLE LOAD USING FACTORS OF SAFETY APPLIED TO THE ULTIMATE SIDE RESISTANCE AND THE ULTIMATE BASE RESISTANCE.

| LENGTH (FT) | VOLUME (CU.YDS) | QS (TONS) | QB (TONS) | QU (TONS) | QBD (TONS) | QDN (TONS) | QU/VOLUME (TONS/CU.YDS) |
|---|---|---|---|---|---|---|---|
| 6.0 | 1.09 | 0.94 | 5.09 | 6.03 | 2.63 | 2.07 | 5.53 |
| 7.0 | 1.27 | 2.01 | 12.94 | 14.95 | 6.32 | 5.12 | 11.74 |
| 8.0 | 1.45 | 3.15 | 21.87 | 25.02 | 10.44 | 8.55 | 17.20 |
| 9.0 | 1.64 | 4.36 | 29.41 | 33.77 | 14.16 | 11.55 | 20.63 |
| 10.0 | 1.82 | 5.65 | 33.14 | 38.79 | 16.69 | 13.31 | 21.33 |
| 11.0 | 2.00 | 7.00 | 33.14 | 40.14 | 18.05 | 13.85 | 20.07 |
| 12.0 | 2.18 | 10.24 | 24.10 | 34.35 | 18.28 | 12.13 | 15.74 |
| 13.0 | 2.36 | 13.48 | 13.56 | 27.04 | 18.00 | 9.91 | 11.44 |
| 14.0 | 2.55 | 16.72 | 4.52 | 21.24 | 18.23 | 8.20 | 8.35 |
| 15.0 | 2.73 | 19.97 | 0.00 | 19.97 | 19.97 | 7.99 | 7.32 |
| 16.0 | 2.91 | 23.21 | 0.00 | 23.21 | 23.21 | 9.28 | 7.98 |
| 17.0 | 3.09 | 24.94 | 9.04 | 33.98 | 27.95 | 12.99 | 10.99 |
| 18.0 | 3.27 | 26.76 | 19.58 | 46.34 | 33.29 | 17.23 | 14.16 |
| 19.0 | 3.45 | 28.66 | 28.62 | 57.28 | 38.20 | 21.00 | 16.58 |
| 20.0 | 3.64 | 30.64 | 33.14 | 63.78 | 41.69 | 23.30 | 17.54 |

AXIAL LOAD VS SETTLEMENT CURVES
-------------------------------

RESULT FROM TREND (AVERAGED) LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.4649E-02 | 0.1062E-04 | 0.3866E-03 | 0.1000E-04 |
| 0.2325E-01 | 0.5312E-04 | 0.1933E-02 | 0.5000E-04 |
| 0.4649E-01 | 0.1062E-03 | 0.3866E-02 | 0.1000E-03 |
| 0.2326E+01 | 0.5312E-02 | 0.1933E+00 | 0.5000E-02 |
| 0.3491E+01 | 0.7968E-02 | 0.2900E+00 | 0.7500E-02 |
| 0.4654E+01 | 0.1062E-01 | 0.3866E+00 | 0.1000E-01 |
| 0.1164E+02 | 0.2656E-01 | 0.9665E+00 | 0.2500E-01 |
| 0.1918E+02 | 0.5259E-01 | 0.1933E+01 | 0.5000E-01 |

| | | | |
|---|---|---|---|
| 0.2476E+02 | 0.7836E-01 | 0.2900E+01 | 0.7500E-01 |
| 0.2844E+02 | 0.1039E+00 | 0.3866E+01 | 0.1000E+00 |
| 0.3772E+02 | 0.2554E+00 | 0.9555E+01 | 0.2500E+00 |
| 0.4420E+02 | 0.5067E+00 | 0.1693E+02 | 0.5000E+00 |
| 0.4549E+02 | 0.6320E+00 | 0.1907E+02 | 0.6250E+00 |
| 0.4762E+02 | 0.7574E+00 | 0.2121E+02 | 0.7500E+00 |
| 0.6001E+02 | 0.1510E+01 | 0.3364E+02 | 0.1500E+01 |

RESULT FROM UPPER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.6590E-02 | 0.1088E-04 | 0.5523E-03 | 0.1000E-04 |
| 0.3295E-01 | 0.5442E-04 | 0.2762E-02 | 0.5000E-04 |
| 0.6590E-01 | 0.1088E-03 | 0.5523E-02 | 0.1000E-03 |
| 0.3300E+01 | 0.5443E-02 | 0.2762E+00 | 0.5000E-02 |
| 0.4951E+01 | 0.8164E-02 | 0.4142E+00 | 0.7500E-02 |
| 0.6601E+01 | 0.1089E-01 | 0.5523E+00 | 0.1000E-01 |
| 0.1651E+02 | 0.2721E-01 | 0.1381E+01 | 0.2500E-01 |
| 0.2557E+02 | 0.5346E-01 | 0.2762E+01 | 0.5000E-01 |
| 0.3060E+02 | 0.7919E-01 | 0.4142E+01 | 0.7500E-01 |
| 0.3358E+02 | 0.1047E+00 | 0.5523E+01 | 0.1000E+00 |
| 0.4324E+02 | 0.2564E+00 | 0.1337E+02 | 0.2500E+00 |
| 0.5154E+02 | 0.5080E+00 | 0.2270E+02 | 0.5000E+00 |
| 0.5227E+02 | 0.6332E+00 | 0.2394E+02 | 0.6250E+00 |
| 0.5351E+02 | 0.7584E+00 | 0.2519E+02 | 0.7500E+00 |
| 0.6411E+02 | 0.1510E+01 | 0.3579E+02 | 0.1500E+01 |

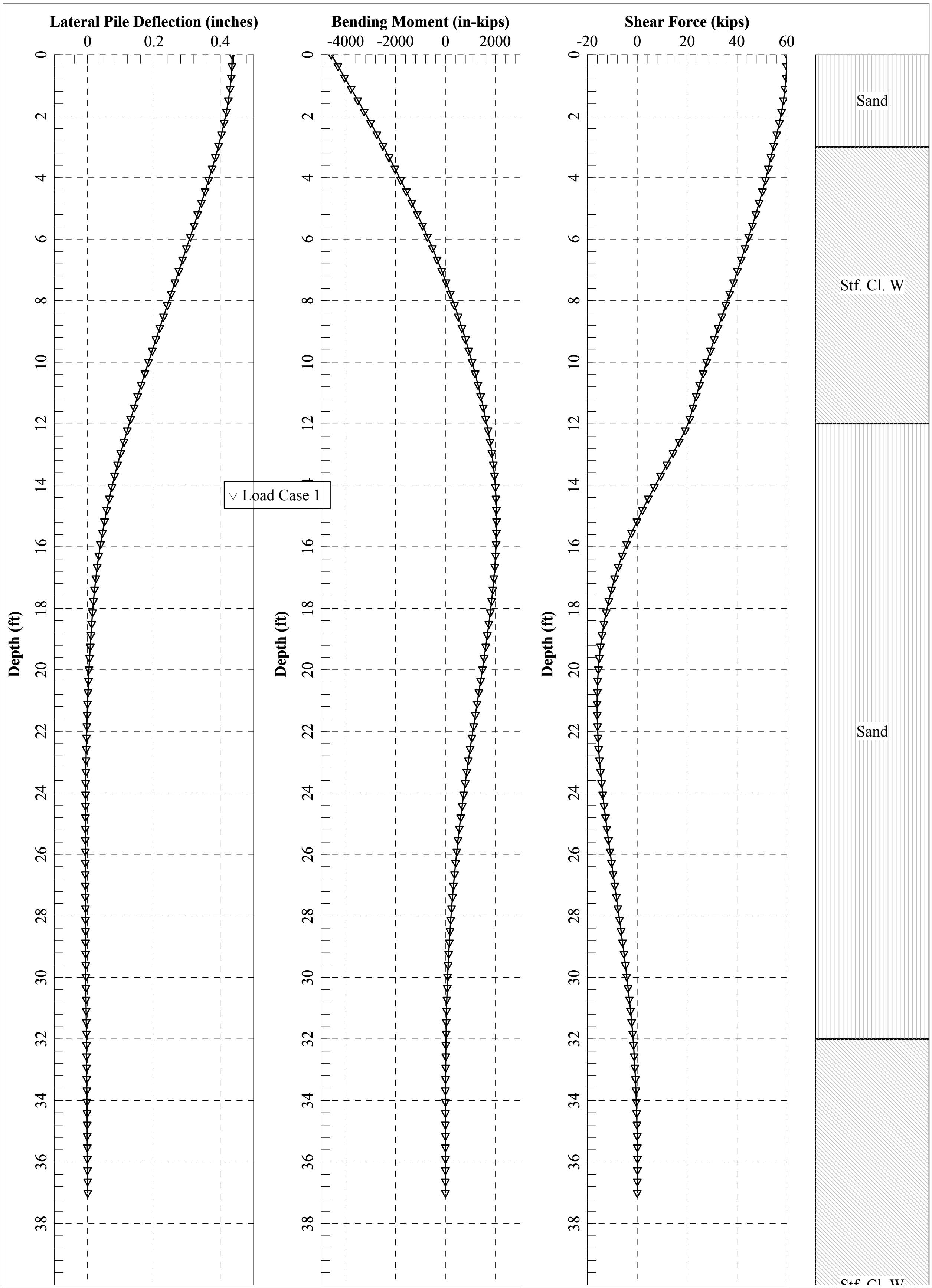
RESULT FROM LOWER-BOUND LINE

| TOP LOAD TON | TOP MOVEMENT IN. | TIP LOAD TON | TIP MOVEMENT IN. |
|---|---|---|---|
| 0.2773E-02 | 0.1037E-04 | 0.2209E-03 | 0.1000E-04 |
| 0.1387E-01 | 0.5185E-04 | 0.1105E-02 | 0.5000E-04 |
| 0.2773E-01 | 0.1037E-03 | 0.2209E-02 | 0.1000E-03 |
| 0.1387E+01 | 0.5185E-02 | 0.1105E+00 | 0.5000E-02 |
| 0.2081E+01 | 0.7778E-02 | 0.1657E+00 | 0.7500E-02 |
| 0.2775E+01 | 0.1037E-01 | 0.2209E+00 | 0.1000E-01 |
| 0.6938E+01 | 0.2593E-01 | 0.5523E+00 | 0.2500E-01 |
| 0.1286E+02 | 0.5172E-01 | 0.1105E+01 | 0.5000E-01 |
| 0.1784E+02 | 0.7740E-01 | 0.1657E+01 | 0.7500E-01 |
| 0.2159E+02 | 0.1029E+00 | 0.2209E+01 | 0.1000E+00 |
| 0.3220E+02 | 0.2545E+00 | 0.5744E+01 | 0.2500E+00 |
| 0.3634E+02 | 0.5053E+00 | 0.1116E+02 | 0.5000E+00 |
| 0.3871E+02 | 0.6308E+00 | 0.1419E+02 | 0.6250E+00 |
| 0.4173E+02 | 0.7564E+00 | 0.1723E+02 | 0.7500E+00 |
| 0.5590E+02 | 0.1509E+01 | 0.3148E+02 | 0.1500E+01 |

# Appendix I:
# Lpile analysis report (ACP)

**Boring: B-11**
**Equipment: Liquid tanks**

# Bending Moment and Shear force with respect 0.5" head deflection for given ACP (30" diameter)



DeminTank_B11_ACP.lp10o

```
================================================================================

                    LPile for Windows, Version 2018-10.006

                Analysis of Individual Piles and Drilled Shafts
               Subjected to Lateral Loading Using the p-y Method
                         © 1985-2018 by Ensoft, Inc.
                             All Rights Reserved

================================================================================

This copy of LPile is being used by:

2001917
PSI

Serial Number of Security Device: 138584532

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is a violation of the software license agreement.

--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters, MD\Engineering &
Resources\AugerCastPiles\LPile_analysis\

Name of input data file:
DeminTank_B11_ACP.lp10

Name of output report file:
DeminTank_B11_ACP.lp10

Name of plot output file:
DeminTank_B11_ACP.lp10

Name of runtime message file:
DeminTank_B11_ACP.lp10


--------------------------------------------------------------------------------
                            Date and Time of Analysis
--------------------------------------------------------------------------------

               Date:  June 14, 2018              Time:  13:01:17


--------------------------------------------------------------------------------
                                  Problem Title
--------------------------------------------------------------------------------
```

DeminTank_B11_ACP.lp10o

Project Name: CP Crane Power plant

Job Number:0512843

Client:ProEnergy

Engineer: SS

Description: Axial Capacity of Dirven Pile in Boring B1

---

## Program Options and Settings

---

Computational Options:
 - Use unfactored loads in computations (conventional analysis)

Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:

```
 - Maximum number of iterations allowed              =        1000
 - Deflection tolerance for convergence              =   1.0000E-05 in
 - Maximum allowable deflection                      =     100.0000 in
 - Number of pile increments                         =         100
```

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats

---

## Pile Structural Properties and Geometry

---

```
Number of pile sections defined                           =            1
Total length of pile                                      =       37.000 ft
Depth of ground surface below top of pile                 =       0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

           Depth Below          Pile
Point       Pile Head         Diameter
 No.          feet             inches
-----     -------------    -------------
  1           0.000           30.0000
  2          37.000           30.0000


Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is a round drilled shaft, bored pile, or CIDH pile
   Length of section                                      =    37.000000 ft
   Shaft Diameter                                         =    30.000000 in
   Shear capacity of section                              =       0.0000 lbs



--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                        =        0.000 degrees
                                                          =        0.000 radians

Pile Batter Angle                                         =        0.000 degrees
                                                          =        0.000 radians


--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 4 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer              =       0.0000 ft
   Distance from top of pile to bottom of layer           =     3.000000 ft
   Effective unit weight at top of layer                  =   115.000000 pcf
   Effective unit weight at bottom of layer               =   115.000000 pcf
   Friction angle at top of layer                         =    31.000000 deg.
   Friction angle at bottom of layer                      =    31.000000 deg.
   Subgrade k at top of layer                             =    20.000000 pci
   Subgrade k at bottom of layer                          =    20.000000 pci
```

DeminTank_B11_ACP.lp10o

```
Layer 2 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =     3.000000 ft
   Distance from top of pile to bottom of layer        =    12.000000 ft
   Effective unit weight at top of layer               =    52.600000 pcf
   Effective unit weight at bottom of layer            =    52.500000 pcf
   Undrained cohesion at top of layer                  =   800.000000 psf
   Undrained cohesion at bottom of layer               =   800.000000 psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    15.000000 pci
   Subgrade k at bottom of layer                       =    15.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 3 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer           =    12.000000 ft
   Distance from top of pile to bottom of layer        =    32.000000 ft
   Effective unit weight at top of layer               =    72.600000 pcf
   Effective unit weight at bottom of layer            =    72.600000 pcf
   Friction angle at top of layer                      =    38.000000 deg.
   Friction angle at bottom of layer                   =    38.000000 deg.
   Subgrade k at top of layer                          =    67.000000 pci
   Subgrade k at bottom of layer                       =    67.000000 pci


Layer 4 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    32.000000 ft
   Distance from top of pile to bottom of layer        =    48.000000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.600000 pcf
   Undrained cohesion at top of layer                  =        3500. psf
   Undrained cohesion at bottom of layer               =        3500. psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    50.000000 pci
   Subgrade k at bottom of layer                       =    50.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


 (Depth of the lowest soil layer extends 11.000 ft below the pile tip)



--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
--------------------------------------------------------------------------------

Layer         Soil Type          Layer      Effective    Undrained    Angle of        E50

Layer           Name             Depth       Unit Wt.    Cohesion     Friction        or            kpy

 Num.     (p-y Curve Type)        ft          pcf          psf          deg.          krm           pci
```

DeminTank_B11_ACP.lp10o

```
-----   ------------------   ----------   ----------   ----------   ----------   ----------
----------
  1          Sand                0.00     115.0000       --          31.0000       --
20.0000
          (Reese, et al.)       3.0000     115.0000       --          31.0000       --
20.0000
  2        Stiff Clay           3.0000      52.6000     800.0000       --         default
15.0000
          with Free Water      12.0000      52.5000     800.0000       --         default
15.0000
  3          Sand              12.0000      72.6000       --          38.0000       --
67.0000
          (Reese, et al.)      32.0000      72.6000       --          38.0000       --
67.0000
  4        Stiff Clay          32.0000      62.6000       3500.        --         default
50.0000
          with Free Water      48.0000      62.6000       3500.        --         default
50.0000
```

```
--------------------------------------------------------------------------------
                              Static Loading Type
--------------------------------------------------------------------------------
```

Static loading criteria were used when computing p-y curves for all analyses.

```
--------------------------------------------------------------------------------
               Pile-head Loading and Pile-head Fixity Conditions
--------------------------------------------------------------------------------
```

Number of loads specified = 1

```
Load    Load         Condition               Condition            Axial Thrust      Compute Top y
 No.    Type             1                       2                 Force, lbs      vs. Pile Length
-----   ----    --------------------   -----------------------   ----------------   ---------------
   1     2      V =       60000. lbs   S =       0.0000 in/in           120000.          Yes
```

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

```
--------------------------------------------------------------------------------
     Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness
--------------------------------------------------------------------------------
```

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

```
-------------------

Dimensions and Properties of Drilled Shaft (Bored Pile):
--------------------------------------------------------

Length of Section                                       =    37.000000 ft
Shaft Diameter                                          =    30.000000 in
Concrete Cover Thickness                                =     3.000000 in
Number of Reinforcing Bars                              =            8 bars
Yield Stress of Reinforcing Bars                        =       60000. psi
Modulus of Elasticity of Reinforcing Bars               =    29000000. psi
Gross Area of Shaft                                     =   706.858347 sq. in.
Total Area of Reinforcing Steel                         =    12.480000 sq. in.
Area Ratio of Steel Reinforcement                       =         1.77 percent
Edge-to-Edge Bar Spacing                                =     7.234819 in
Maximum Concrete Aggregate Size                         =     0.750000 in
Ratio of Bar Spacing to Aggregate Size                  =         9.65
Offset of Center of Rebar Cage from Center of Pile      =       0.0000 in
Confined Section
Type: Hoop
Number of Confinement Bars                              =            1
Spacing of Confinement Bars                             =    12.000000 in
Yield Stress of Confinement Bars                        =       60000. psi
Total Area of Confinement Steel                         =     0.310000 sq. in.
rho_s                                                   =     0.004196
ke                                                      =     0.789730
f'cc                                                    =        4651. psi
f'l                                                     =    99.417766 psi
Epsilon cc                                              =     0.003627
Epsilon cu                                              =     0.010821
r                                                       =     1.552070

Axial Structural Capacities:
----------------------------

Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As     =     3109.686 kips
Tensile Load for Cracking of Concrete                   =     -330.553 kips
Nominal Axial Tensile Capacity                          =     -748.800 kips


Reinforcing Bar Dimensions and Positions Used in Computations:
```

| Bar Number | Bar Diam. inches | Bar Area sq. in. | X inches | Y inches |
|---|---|---|---|---|
| 1 | 1.410000 | 1.560000 | 11.295000 | 0.00000 |
| 2 | 1.410000 | 1.560000 | 7.986771 | 7.986771 |
| 3 | 1.410000 | 1.560000 | 0.00000 | 11.295000 |
| 4 | 1.410000 | 1.560000 | -7.986771 | 7.986771 |
| 5 | 1.410000 | 1.560000 | -11.295000 | 0.00000 |
| 6 | 1.410000 | 1.560000 | -7.986771 | -7.986771 |
| 7 | 1.410000 | 1.560000 | 0.00000 | -11.295000 |
| 8 | 1.410000 | 1.560000 | 7.986771 | -7.986771 |

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero =  7.235 inches
between bars 1 and 2.

Ratio of bar spacing to maximum aggregate size = 9.65

Concrete Properties:
--------------------

| | | |
|---|---|---|
| Compressive Strength of Concrete | = | 4000. psi |
| Modulus of Elasticity of Concrete | = | 3604997. psi |
| Modulus of Rupture of Concrete | = | -474.341649 psi |
| Compression Strain at Peak Stress | = | 0.001886 |
| Tensile Strain at Fracture of Concrete | = | -0.0001154 |
| Maximum Coarse Aggregate Size | = | 0.750000 in |

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

| Number | Axial Thrust Force kips |
|---|---|
| 1 | 120.000 |

Definitions of Run Messages and Notes:
--------------------------------------

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318, Section 10.3.4.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 120.000 kips

| Bending Curvature rad/in. | Bending Moment in-kip | Bending Stiffness kip-in2 | Depth to N Axis in | Max Comp Strain in/in | Max Tens Strain in/in | Max Conf Stress ksi | Max Conc Stress ksi | Max Steel Stress ksi | Run Msg |
|---|---|---|---|---|---|---|---|---|---|
| 0.00000125 | 223.8764529 | 179101162. | 46.4039570 | 0.00005800 | 0.00002050 | 0.2078209 | 0.2414556 | 1.6767059 | |
| 0.00000250 | 447.7221368 | 179088855. | 30.7211275 | 0.00007680 | 0.00000180 | 0.2742790 | 0.3175767 | 2.2164068 | |
| 0.00000375 | 671.5737344 | 179086329. | 25.5026256 | 0.00009563 | -0.00001687 | 0.3405696 | 0.3930567 | 2.7570980 | |
| 0.00000500 | 896.9553883 | 179391078. | 22.9112572 | 0.0001146 | -0.00003544 | 0.4068506 | 0.4681113 | 3.3003823 | |
| 0.00000625 | 1123. | 179672368. | 21.3683263 | 0.0001336 | -0.00005395 | 0.4730323 | | | |

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0.5426699     3.8458217
   0.00000750         1349.    179802109.    20.3451318     0.0001526   -0.00007241     0.5389637
0.6165918     4.3924412
   0.00000875         1573.    179795583.    19.6169243     0.0001716   -0.00009085     0.6045546
0.6898042     4.9397321
   0.00001000         1797.    179684871.    19.0721954     0.0001907    -0.0001093     0.6697483
0.7622702     5.4874367
   0.00001125         1797.    159719885.    16.1614048     0.0001818    -0.0001557     0.6384153
0.7274785     5.2237209 C
   0.00001250         1797.    143747897.    15.5732433     0.0001947    -0.0001803     0.6820146
0.7758726     5.5909256 C
   0.00001375         1797.    130679906.    15.0758869     0.0002073    -0.0002052     0.7246429
0.8230679     5.9516974 C
   0.00001500         1797.    119789914.    14.6489131     0.0002197    -0.0002303     0.7664215
0.8692111    -6.6124728 C
   0.00001625         1797.    110575305.    14.2787471     0.0002320    -0.0002555     0.8075013
0.9144793    -7.3379529 C
   0.00001750         1797.    102677069.    13.9540357     0.0002442    -0.0002808     0.8479331
0.9589372    -8.0672019 C
   0.00002000         1797.     89842436.    13.4101070     0.0002682    -0.0003318     0.9270771
1.0456990    -9.5351383 C
   0.00002250         1844.     81942095.    12.9732382     0.0002919    -0.0003831     1.0043463
1.1300889   -11.0120872 C
   0.00002500         1970.     78796577.    12.6142270     0.0003154    -0.0004346     1.0799840
1.2124136   -12.4959354 C
   0.00002750         2095.     76176562.    12.3142445     0.0003386    -0.0004864     1.1542053
1.2929411   -13.9847650 C
   0.00003000         2219.     73959795.    12.0599599     0.0003618    -0.0005382     1.2271444
1.3718450   -15.4773348 C
   0.00003250         2342.     72060429.    11.8422828     0.0003849    -0.0005901     1.2989461
1.4493052   -16.9722734 C
   0.00003500         2464.     70407840.    11.6521773     0.0004078    -0.0006422     1.3694740
1.5251952   -18.4707899 C
   0.00003750         2586.     68962602.    11.4868118     0.0004308    -0.0006942     1.4390364
1.5998643   -19.9699671 C
   0.00004000         2707.     67683438.    11.3407307     0.0004536    -0.0007464     1.5075246
1.6732103   -21.4707523 C
   0.00004250         2828.     66545061.    11.2117415     0.0004765    -0.0007985     1.5750879
1.7454054   -22.9716535 C
   0.00004500         2948.     65520915.    11.0957841     0.0004993    -0.0008507     1.6415570
1.8162794   -24.4742516 C
   0.00004750         3068.     64598258.    10.9928716     0.0005222    -0.0009028     1.7072163
1.8861444   -25.9756943 C
   0.00005000         3188.     63758896.    10.8996887     0.0005450    -0.0009550     1.7718601
1.9547884   -27.4779513 C
   0.00005250         3307.     62991457.    10.8150817     0.0005678    -0.0010072     1.8355216
2.0222526   -28.9806630 C
   0.00005500         3426.     62288305.    10.7389194     0.0005906    -0.0010594     1.8983568
2.0887068   -30.4821734 C
   0.00006000         3662.     61040474.    10.6065143     0.0006364    -0.0011636     2.0213239
2.2183576   -33.4836649 C
   0.00006500         3898.     59962174.    10.4949821     0.0006822    -0.0012678     2.1405652
2.3435444   -36.4842085 C
   0.00007000         4131.     59020230.    10.4019100     0.0007281    -0.0013719     2.2564384
2.4646363   -39.4796225 C
   0.00007500         4364.     58186095.    10.3228632     0.0007742    -0.0014758     2.3687791
2.5814386   -42.4715223 C
   0.00008000         4595.     57438693.    10.2546864     0.0008204    -0.0015796     2.4774862
2.6938124   -45.4611273 C
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  0.00008500         4825.     56764036.    10.1967919     0.0008667    -0.0016833     2.5828354
2.8019959   -48.4451576 C
  0.00009000         5053.     56149715.    10.1475151     0.0009133    -0.0017867     2.6848376
2.9059398   -51.4234853 C
  0.00009500         5281.     55585928.    10.1055431     0.0009600    -0.0018900     2.7835116
3.0055930   -54.3959785 C
  0.00010000         5506.     55064825.    10.0698271     0.0010070    -0.0019930     2.8788834
3.1009024   -57.3625011 C
   0.0001050         5731.     54579836.    10.0391813     0.0010541    -0.0020959     2.9709167
3.1917455   -60.0000000 CY
   0.0001150         6175.     53698522.     9.9905973     0.0011489    -0.0023011     3.1451522
3.3598408   -60.0000000 CY
   0.0001250         6608.     52860958.     9.9541733     0.0012443    -0.0025057     3.3062992
3.5091767   -60.0000000 CY
   0.0001350         6936.     51376720.     9.8839693     0.0013343    -0.0027157     3.4460544
3.6319347   -60.0000000 CY
   0.0001450         7233.     49881498.     9.8170213     0.0014235    -0.0029265     3.5732181
3.7360425   -60.0000000 CY
   0.0001550         7504.     48414897.     9.7532771     0.0015118    -0.0031382     3.6888769
3.8221309   -60.0000000 CY
   0.0001650         7643.     46318282.     9.6328476     0.0015894    -0.0033606     3.7824235
3.8837248   -60.0000000 CY
   0.0001750         7731.     44179830.     9.5054160     0.0016634    -0.0035866     3.8649854
3.9302562   -60.0000000 CY
   0.0001850         7818.     42258427.     9.3922043     0.0017376    -0.0038124     3.9416134
3.9649926   -60.0000000 CY
   0.0001950         7902.     40520968.     9.2912721     0.0018118    -0.0040382     4.0126631
3.9879052   -60.0000000 CY
   0.0002050         7983.     38943338.     9.2030384     0.0018866    -0.0042634     4.0788189
3.9989612   -60.0000000 CY
   0.0002150         8063.     37501193.     9.1247410     0.0019618    -0.0044882     4.1400995
3.9994947   -60.0000000 CY
   0.0002250         8139.     36174786.     9.0540740     0.0020372    -0.0047128     4.1965740
3.9996416   -60.0000000 CY
   0.0002350         8214.     34951927.     8.9923268     0.0021132    -0.0049368     4.2488654
3.9995582    60.0000000 CY
   0.0002450         8286.     33820393.     8.9383501     0.0021899    -0.0051601     4.2971281
3.9991728    60.0000000 CY
   0.0002550         8356.     32770013.     8.8911351     0.0022672    -0.0053828     4.3415137
3.9982209    60.0000000 CY
   0.0002650         8425.     31792206.     8.8497870     0.0023452    -0.0056048     4.3821721
3.9962406    60.0000000 CY
   0.0002750         8492.     30878564.     8.8115167     0.0024232    -0.0058268     4.4190030
3.9997974    60.0000000 CY
   0.0002850         8557.     30023426.     8.7781044     0.0025018    -0.0060482     4.4525005
3.9992539    60.0000000 CY
   0.0002950         8620.     29221877.     8.7487713     0.0025809    -0.0062691     4.4827897
3.9962658    60.0000000 CY
   0.0003050         8681.     28463387.     8.7215772     0.0026601    -0.0064899     4.5098785
3.9999825    60.0000000 CY
   0.0003150         8733.     27722568.     8.6910177     0.0027377    -0.0067123     4.5334893
3.9975848    60.0000000 CY
   0.0003250         8773.     26995362.     8.6553788     0.0028130    -0.0069370     4.5538203
3.9998504    60.0000000 CY
   0.0003350         8804.     26279941.     8.6150219     0.0028860    -0.0071640     4.5712546
3.9965385    60.0000000 CY
   0.0003450         8823.     25575185.     8.5690166     0.0029563    -0.0073937     4.5860476
3.9996861    60.0000000 CY
   0.0003550         8832.     24879029.     8.5152455     0.0030229    -0.0076271     4.5983787
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3.9942339   60.0000000 CY
    0.0003650         8838.     24214416.     8.4619146     0.0030886    -0.0078614     4.6090392
3.9963574   60.0000000 CY
    0.0003750         8844.     23582921.     8.4110855     0.0031542    -0.0080958     4.6182813
3.9992480   60.0000000 CY
    0.0003850         8849.     22983935.     8.3632826     0.0032199    -0.0083301     4.6262251
3.9983249   60.0000000 CY
    0.0003950         8854.     22414831.     8.3184040     0.0032858    -0.0085642     4.6329426
3.9924865   60.0000000 CY
    0.0004050         8859.     21873219.     8.2763448     0.0033519    -0.0087981     4.6384989
3.9968300   60.0000000 CY
    0.0004150         8862.     21355247.     8.2367580     0.0034183    -0.0090317     4.6429468
3.9993380   60.0000000 CY
    0.0004250         8866.     20860159.     8.1971116     0.0034838    -0.0092662     4.6462987
3.9988238   60.0000000 CY
    0.0004350         8869.     20387526.     8.1596998     0.0035495    -0.0095005     4.6486829
3.9899834   60.0000000 CY
    0.0004450         8871.     19935104.     8.1250442     0.0036156    -0.0097344     4.6501538
3.9940293   60.0000000 CY
    0.0004550         8873.     19500798.     8.0936827     0.0036826    -0.0099674     4.6507472
3.9975801   60.0000000 CY
    0.0004650         8875.     19085031.     8.0638981     0.0037497    -0.0102003     4.6504925
3.9995589   60.0000000 CY
    0.0004750         8876.     18686593.     8.0356352     0.0038169    -0.0104331     4.6507073
3.9978348   60.0000000 CY
    0.0004850         8876.     18301302.     8.0358157     0.0038974    -0.0106526     4.6505009
3.9890592   60.0000000 CY
    0.0004950         8876.     17931579.     8.0121027     0.0039660    -0.0108840     4.6506606
3.9939217   60.0000000 CY
    0.0005050         8876.     17576498.     8.0379467     0.0040592    -0.0110908     4.6504879
3.9993601   60.0000000 CY
    0.0005450         8876.     16286480.     8.0939532     0.0044112    -0.0119388     4.6505361
3.9999024   60.0000000 CY
    0.0005850         8876.     15172874.     8.1061975     0.0047421    -0.0128079     4.6506985
3.9982107   60.0000000 CY
    0.0006250         8876.     14201810.     8.2289286     0.0051431    -0.0136069     4.6501606
3.9993285   60.0000000 CY
    0.0006650         8876.     13347566.     8.3653985     0.0055630    -0.0143870     4.6506020
3.9997787   60.0000000 CY
    0.0007050         8876.     12590258.     8.4084918     0.0059280    -0.0152220     4.6501486
3.9923419   60.0000000 CY
    0.0007450         8876.     11914271.     8.4357828     0.0062847    -0.0160653     4.6500357
3.9874160   60.0000000 CY
    0.0007850         8876.     11307174.     8.4518422     0.0066347    -0.0169153     4.6503704
3.9929259   60.0000000 CY
    0.0008250         8876.     10758947.     8.4629491     0.0069819    -0.0177681     4.6507442
3.9931300   60.0000000 CY
    0.0008650         8876.     10261424.     8.4714510     0.0073278    -0.0186222     4.6503819
3.9786784   60.0000000 CY


--------------------------------------------------------------------------------
   Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1
--------------------------------------------------------------------------------

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

 Load           Axial Thrust        Nominal Mom. Cap.      Max. Comp.
```

| No. | kips | in-kip | Strain |
|---|---|---|---|
| 1 | 120.000 | 8829.091 | 0.00300000 |

Note that the values of moment capacity in the table above are not factored by a strength reduction factor (phi-factor).

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.70).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, Section 9.3.2.2 or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

| Axial Load No. | Resist. Factor for Moment | Nominal Moment Cap in-kips | Ult. (Fac) Ax. Thrust kips | Ult. (Fac) Moment Cap in-kips | Bend. Stiff. at Ult Mom kip-in^2 |
|---|---|---|---|---|---|
| 1 | 0.65 | 8829. | 78.000000 | 5739. | 54563921. |
| 1 | 0.70 | 8829. | 84.000000 | 6180. | 53688769. |
| 1 | 0.75 | 8829. | 90.000000 | 6622. | 52796754. |

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Layering Correction Equivalent Depths of Soil & Rock Layers

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| Layer No. | Top of Layer Below Pile Head ft | Equivalent Top Depth Below Grnd Surf ft | Same Layer Type As Layer Above | Layer is Rock or is Below Rock Layer | F0 Integral for Layer lbs | F1 Integral for Layer lbs |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | N.A. | No | 0.00 | 12719. |
| 2 | 3.0000 | 31.8161 | No | No | 12719. | 17361. |
| 3 | 12.0000 | 4.6432 | No | No | 30080. | 1386646. |
| 4 | 32.0000 | 225.6375 | No | No | 1416726. | N.A. |

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

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DeminTank_B11_ACP.lp10o
Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

Shear force at pile head = 60000.0 lbs
Rotation of pile head = 0.000E+00 radians
Axial load at pile head = 120000.0 lbs

(Zero slope for this load indicates fixed-head conditions)

| Depth X feet | Deflect. y inches | Bending Moment in-lbs | Shear Force lbs | Slope S radians | Total Stress psi* | Bending Stiffness in-lb^2 | Soil Res. p lb/inch | Soil Spr. Es*h lb/inch | Distrib. Lat. Load lb/inch |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.4358 | -4578979. | 60000. | 0.00 | 0.00 | 5.75E+10 | 0.00 | 0.00 | 0.00 |
| 0.3700 | 0.4350 | -4312485. | 59914. | -3.43E-04 | 0.00 | 5.75E+10 | -38.6290 | 394.2720 | 0.00 |
| 0.7400 | 0.4327 | -4046574. | 59658. | -6.61E-04 | 0.00 | 5.93E+10 | -76.8560 | 788.5440 | 0.00 |
| 1.1100 | 0.4291 | -3782018. | 59233. | -9.51E-04 | 0.00 | 6.05E+10 | -114.3228 | 1183. | 0.00 |
| 1.4800 | 0.4243 | -3519568. | 58645. | -0.00122 | 0.00 | 6.18E+10 | -150.7109 | 1577. | 0.00 |
| 1.8500 | 0.4183 | -3259953. | 57898. | -0.00146 | 0.00 | 6.33E+10 | -185.7404 | 1971. | 0.00 |
| 2.2200 | 0.4114 | -3003879. | 56999. | -0.00167 | 0.00 | 6.51E+10 | -219.1697 | 2366. | 0.00 |
| 2.5900 | 0.4035 | -2752015. | 55956. | -0.00187 | 0.00 | 6.72E+10 | -250.7937 | 2760. | 0.00 |
| 2.9600 | 0.3948 | -2505000. | 54777. | -0.00204 | 0.00 | 6.99E+10 | -280.4434 | 3154. | 0.00 |
| 3.3300 | 0.3854 | -2263427. | 53641. | -0.00219 | 0.00 | 7.32E+10 | -230.9880 | 2661. | 0.00 |
| 3.7000 | 0.3754 | -2026336. | 52573. | -0.00231 | 0.00 | 7.76E+10 | -249.9853 | 2957. | 0.00 |
| 4.0700 | 0.3648 | -1794111. | 51425. | -0.00240 | 0.00 | 1.31E+11 | -267.2715 | 3253. | 0.00 |
| 4.4400 | 0.3540 | -1567122. | 50204. | -0.00245 | 0.00 | 1.80E+11 | -282.9392 | 3548. | 0.00 |
| 4.8100 | 0.3431 | -1345690. | 48916. | -0.00249 | 0.00 | 1.80E+11 | -297.0198 | 3844. | 0.00 |
| 5.1800 | 0.3319 | -1130096. | 47570. | -0.00252 | 0.00 | 1.80E+11 | -309.5017 | 4140. | 0.00 |
| 5.5500 | 0.3207 | -920588. | 46171. | -0.00254 | 0.00 | 1.79E+11 | -320.3789 | 4436. | 0.00 |
| 5.9200 | 0.3094 | -717384. | 44728. | -0.00256 | 0.00 | 1.79E+11 | -329.6509 | 4731. | 0.00 |
| 6.2900 | 0.2979 | -520669. | 43248. | -0.00258 | 0.00 | 1.79E+11 | -337.3228 | 5027. | 0.00 |
| 6.6600 | 0.2865 | -330597. | 41736. | -0.00259 | 0.00 | 1.79E+11 | -343.4046 | 5323. | 0.00 |
| 7.0300 | 0.2749 | -147291. | 40202. | -0.00260 | 0.00 | 1.79E+11 | -347.9114 | 5618. | 0.00 |
| 7.4000 | 0.2634 | 29159. | 38650. | -0.00260 | 0.00 | 1.79E+11 | -350.8627 | 5914. | 0.00 |
| 7.7700 | 0.2519 | 198692. | 37089. | -0.00259 | 0.00 | 1.79E+11 | -352.2826 | 6210. | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | | | | | | | | | |
| 8.1400 | 0.2404 | 361277. | 35525. | -0.00259 | 0.00 | 1.79E+11 | -352.1990 | 6505. | 0.00 |
| 8.5100 | 0.2289 | 516915. | 33965. | -0.00258 | 0.00 | 1.79E+11 | -350.6437 | 6801. | 0.00 |
| 8.8800 | 0.2175 | 665633. | 32415. | -0.00256 | 0.00 | 1.79E+11 | -347.6520 | 7097. | 0.00 |
| 9.2500 | 0.2062 | 807489. | 30881. | -0.00254 | 0.00 | 1.79E+11 | -343.2626 | 7393. | 0.00 |
| 9.6200 | 0.1949 | 942567. | 29370. | -0.00252 | 0.00 | 1.79E+11 | -337.5169 | 7688. | 0.00 |
| 9.9900 | 0.1838 | 1070979. | 27887. | -0.00250 | 0.00 | 1.80E+11 | -330.4592 | 7984. | 0.00 |
| 10.3600 | 0.1727 | 1192863. | 26438. | -0.00247 | 0.00 | 1.80E+11 | -322.1363 | 8280. | 0.00 |
| 10.7300 | 0.1619 | 1308380. | 25029. | -0.00244 | 0.00 | 1.80E+11 | -312.5974 | 8575. | 0.00 |
| 11.1000 | 0.1511 | 1417718. | 23665. | -0.00240 | 0.00 | 1.80E+11 | -301.8939 | 8871. | 0.00 |
| 11.4700 | 0.1405 | 1521086. | 22351. | -0.00237 | 0.00 | 1.80E+11 | -290.0791 | 9167. | 0.00 |
| 11.8400 | 0.1301 | 1618715. | 21091. | -0.00233 | 0.00 | 1.80E+11 | -277.2082 | 9463. | 0.00 |
| 12.2100 | 0.1198 | 1710858. | 19287. | -0.00229 | 0.00 | 1.80E+11 | -535.6169 | 19848. | 0.00 |
| 12.5800 | 0.1098 | 1792420. | 16872. | -0.00224 | 0.00 | 1.30E+11 | -552.2588 | 22341. | 0.00 |
| 12.9500 | 0.09996 | 1863062. | 14393. | -0.00215 | 0.00 | 8.14E+10 | -564.2802 | 25064. | 0.00 |
| 13.3200 | 0.09062 | 1922526. | 11877. | -0.00205 | 0.00 | 7.99E+10 | -568.9004 | 27874. | 0.00 |
| 13.6900 | 0.08175 | 1970718. | 9358. | -0.00194 | 0.00 | 7.88E+10 | -566.1133 | 30746. | 0.00 |
| 14.0600 | 0.07338 | 2007690. | 6866. | -0.00183 | 0.00 | 7.79E+10 | -556.2671 | 33660. | 0.00 |
| 14.4300 | 0.06551 | 2033636. | 4437. | -0.00171 | 0.00 | 7.74E+10 | -538.0438 | 36467. | 0.00 |
| 14.8000 | 0.05816 | 2048913. | 2106. | -0.00160 | 0.00 | 7.71E+10 | -511.5587 | 39053. | 0.00 |
| 15.1700 | 0.05133 | 2054042. | -112.8246 | -0.00148 | 0.00 | 7.70E+10 | -488.1036 | 42217. | 0.00 |
| 15.5400 | 0.04504 | 2049486. | -2218. | -0.00136 | 0.00 | 7.71E+10 | -460.0696 | 45358. | 0.00 |
| 15.9100 | 0.03926 | 2035797. | -4185. | -0.00124 | 0.00 | 7.74E+10 | -426.1941 | 48198. | 0.00 |
| 16.2800 | 0.03400 | 2013644. | -5991. | -0.00113 | 0.00 | 7.78E+10 | -387.3777 | 50580. | 0.00 |
| 16.6500 | 0.02926 | 1983793. | -7617. | -0.00101 | 0.00 | 7.85E+10 | -344.7705 | 52318. | 0.00 |
| 17.0200 | 0.02501 | 1947086. | -9048. | -9.02E-04 | 0.00 | 7.93E+10 | -299.7498 | 53211. | 0.00 |
| 17.3900 | 0.02125 | 1904412. | -10283. | -7.95E-04 | 0.00 | 8.03E+10 | -256.7005 | 53641. | 0.00 |
| 17.7600 | 0.01795 | 1856621. | -11390. | -6.92E-04 | 0.00 | 8.16E+10 | -241.7872 | 59802. | 0.00 |
| 18.1300 | 0.01510 | 1804010. | -12415. | -6.01E-04 | 0.00 | 1.00E+11 | -220.1614 | 64720. | 0.00 |
| 18.5000 | 0.01261 | 1747016. | -13320. | -5.40E-04 | 0.00 | 1.80E+11 | -187.5791 | 66041. | 0.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 18.8700 | 0.01031 | 1686301. | -14084. | -4.97E-04 | 0.00 | 1.80E+11 | -156.4213 | 67361. | 0.00 |
| 19.2400 | 0.00819 | 1622480. | -14713. | -4.57E-04 | 0.00 | 1.80E+11 | -126.7555 | 68682. | 0.00 |
| 19.6100 | 0.00626 | 1556140. | -15213. | -4.17E-04 | 0.00 | 1.80E+11 | -98.6361 | 70003. | 0.00 |
| 19.9800 | 0.00449 | 1487834. | -15592. | -3.80E-04 | 0.00 | 1.80E+11 | -72.1044 | 71324. | 0.00 |
| 20.3500 | 0.00288 | 1418087. | -15857. | -3.44E-04 | 0.00 | 1.80E+11 | -47.1901 | 72645. | 0.00 |
| 20.7200 | 0.00144 | 1347391. | -16015. | -3.10E-04 | 0.00 | 1.80E+11 | -23.9115 | 73965. | 0.00 |
| 21.0900 | 1.34E-04 | 1276206. | -16073. | -2.77E-04 | 0.00 | 1.80E+11 | -2.2758 | 75286. | 0.00 |
| 21.4600 | -0.00103 | 1204960. | -16039. | -2.47E-04 | 0.00 | 1.80E+11 | 17.7193 | 76607. | 0.00 |
| 21.8300 | -0.00206 | 1134047. | -15919. | -2.18E-04 | 0.00 | 1.80E+11 | 36.0856 | 77928. | 0.00 |
| 22.2000 | -0.00296 | 1063830. | -15722. | -1.91E-04 | 0.00 | 1.80E+11 | 52.8432 | 79249. | 0.00 |
| 22.5700 | -0.00375 | 994641. | -15453. | -1.65E-04 | 0.00 | 1.80E+11 | 68.0203 | 80569. | 0.00 |
| 22.9400 | -0.00443 | 926780. | -15121. | -1.41E-04 | 0.00 | 1.79E+11 | 81.6517 | 81890. | 0.00 |
| 23.3100 | -0.00500 | 860517. | -14732. | -1.19E-04 | 0.00 | 1.79E+11 | 93.7786 | 83211. | 0.00 |
| 23.6800 | -0.00549 | 796090. | -14292. | -9.87E-05 | 0.00 | 1.79E+11 | 104.4479 | 84532. | 0.00 |
| 24.0500 | -0.00588 | 733713. | -13807. | -7.98E-05 | 0.00 | 1.79E+11 | 113.7115 | 85853. | 0.00 |
| 24.4200 | -0.00619 | 673567. | -13285. | -6.24E-05 | 0.00 | 1.79E+11 | 121.6250 | 87174. | 0.00 |
| 24.7900 | -0.00643 | 615810. | -12730. | -4.64E-05 | 0.00 | 1.79E+11 | 128.2475 | 88494. | 0.00 |
| 25.1600 | -0.00661 | 560573. | -12149. | -3.18E-05 | 0.00 | 1.79E+11 | 133.6415 | 89815. | 0.00 |
| 25.5300 | -0.00672 | 507963. | -11546. | -1.85E-05 | 0.00 | 1.79E+11 | 137.8712 | 91136. | 0.00 |
| 25.9000 | -0.00677 | 458065. | -10927. | -6.57E-06 | 0.00 | 1.79E+11 | 141.0022 | 92457. | 0.00 |
| 26.2700 | -0.00678 | 410940. | -10296. | 4.20E-06 | 0.00 | 1.79E+11 | 143.1006 | 93778. | 0.00 |
| 26.6400 | -0.00673 | 366630. | -9658. | 1.38E-05 | 0.00 | 1.79E+11 | 144.2325 | 95098. | 0.00 |
| 27.0100 | -0.00665 | 325160. | -9017. | 2.24E-05 | 0.00 | 1.79E+11 | 144.4634 | 96419. | 0.00 |
| 27.3800 | -0.00653 | 286532. | -8377. | 3.00E-05 | 0.00 | 1.79E+11 | 143.8579 | 97740. | 0.00 |
| 27.7500 | -0.00639 | 250737. | -7742. | 3.67E-05 | 0.00 | 1.79E+11 | 142.4789 | 99061. | 0.00 |
| 28.1200 | -0.00621 | 217748. | -7114. | 4.25E-05 | 0.00 | 1.79E+11 | 140.3872 | 100382. | 0.00 |
| 28.4900 | -0.00601 | 187523. | -6496. | 4.75E-05 | 0.00 | 1.79E+11 | 137.6416 | 101702. | 0.00 |
| 28.8600 | -0.00579 | 160009. | -5893. | 5.18E-05 | 0.00 | 1.79E+11 | 134.2977 | 103023. | 0.00 |
| 29.2300 | -0.00555 | 135140. | -5305. | 5.55E-05 | 0.00 | 1.79E+11 | 130.4083 | 104344. | 0.00 |
| 29.6000 | -0.00530 | 112841. | -4736. | 5.85E-05 | 0.00 | 1.79E+11 | 126.0229 | 105665. | |

```
 0.00
  29.9700   -0.00503     93024.      -4187.   6.11E-05       0.00   1.79E+11   121.1873    106986.
 0.00
  30.3400   -0.00475     75595.      -3661.   6.32E-05       0.00   1.79E+11   115.9437    108307.
 0.00
  30.7100   -0.00447     60451.      -3158.   6.49E-05       0.00   1.79E+11   110.3302    109627.
 0.00
  31.0800   -0.00418     47481.      -2682.   6.62E-05       0.00   1.79E+11   104.3811    110948.
 0.00
  31.4500   -0.00388     36568.      -2232.   6.72E-05       0.00   1.79E+11    98.1266    112269.
 0.00
  31.8200   -0.00358     27589.      -1811.   6.80E-05       0.00   1.79E+11    91.5927    113590.
 0.00
  32.1900   -0.00328     20415.      -1467.   6.86E-05       0.00   1.79E+11    63.2846     85754.
 0.00
  32.5600   -0.00297     14489.      -1198.   6.91E-05       0.00   1.79E+11    58.0378     86740.
 0.00
  32.9300   -0.00266      9706.  -952.0029   6.94E-05       0.00   1.79E+11    52.6237     87726.
 0.00
  33.3000   -0.00235      5961.  -730.7234   6.95E-05       0.00   1.79E+11    47.0518     88711.
 0.00
  33.6700   -0.00205      3143.  -534.5168   6.97E-05       0.00   1.79E+11    41.3296     89697.
 0.00
  34.0400   -0.00174      1140.  -364.0369   6.97E-05       0.00   1.79E+11    35.4631     90683.
 0.00
  34.4100   -0.00143  -163.6241  -219.9149   6.97E-05       0.00   1.79E+11    29.4567     91668.
 0.00
  34.7800   -0.00112  -886.8471  -102.7659   6.97E-05       0.00   1.79E+11    23.3131     92654.
 0.00
  35.1500  -8.08E-04     -1150.   -13.1948   6.97E-05       0.00   1.79E+11    17.0342     93640.
 0.00
  35.5200  -4.98E-04     -1078.    48.1987   6.97E-05       0.00   1.79E+11    10.6205     94625.
 0.00
  35.8900  -1.89E-04  -796.6989    80.8164   6.96E-05       0.00   1.79E+11     4.0721     95611.
 0.00
  36.2600   1.20E-04  -434.8342    84.0583   6.96E-05       0.00   1.79E+11    -2.6117     96597.
 0.00
  36.6300   4.29E-04  -124.4506    57.3217   6.96E-05       0.00   1.79E+11    -9.4318     97582.
 0.00
  37.0000   7.38E-04       0.00       0.00   6.96E-05       0.00   1.79E+11   -16.3888     49284.
 0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection              =     0.43579682 inches
Computed slope at pile head       =       0.000000 radians
Maximum bending moment            =      -4578979. inch-lbs
Maximum shear force               =         60000. lbs
Depth of maximum bending moment   =       0.000000 feet below pile head
Depth of maximum shear force      =       0.000000 feet below pile head
Number of iterations              =             21
```

Number of zero deflection points = 2

---

Pile-head Deflection vs. Pile Length for Load Case 1

---

Boundary Condition Type 2, Shear and Slope

Shear = 60000. lbs
Slope = 0.00000
Axial Load = 120000. lbs

| Pile Length feet | Pile Head Deflection inches | Maximum Moment ln-lbs | Maximum Shear lbs |
|---|---|---|---|
| 37.00000 | 0.43579682 | -4578979. | 60000. |
| 35.15000 | 0.43796621 | -4582702. | 60000. |
| 33.30000 | 0.43714795 | -4570198. | 60000. |
| 31.45000 | 0.43688396 | -4585835. | 60000. |
| 29.60000 | 0.43618662 | -4571714. | 60000. |
| 27.75000 | 0.43995299 | -4566156. | 60000. |
| 25.90000 | 0.44343629 | -4544773. | 60000. |
| 24.05000 | 0.45120766 | -4513793. | 60000. |
| 22.20000 | 0.48285104 | -4607605. | 60000. |
| 20.35000 | 0.52375308 | -4825020. | 60000. |
| 18.50000 | 0.56148347 | -5071444. | 60000. |
| 16.65000 | 0.58892599 | -5296835. | 60000. |
| 14.80000 | 0.60286267 | -5487506. | 60000. |
| 12.95000 | 0.60498021 | -5355082. | 60000. |
| 11.10000 | 0.63541932 | -4851183. | 60000. |
| 9.25000 | 0.74050807 | -4217312. | 60000. |
| 7.40000 | 1.09913350 | -3376499. | 60000. |

---

Summary of Pile-head Responses for Conventional Analyses

---

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

| Load Case No. | Load Type 1 | Pile-head Load 1 | Load Type 2 | Pile-head Load 2 | Axial Loading lbs | Pile-head Deflection inches | Pile-head Rotation radians | Max Shear in Pile lbs | Max Moment in Pile in-lbs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | V, lb | 60000. | S, rad | 0.00 | 120000. | 0.4358 | 0.00 | 60000. | -4578979. |

Maximum pile-head deflection = 0.4357968232 inches
Maximum pile-head rotation = -0.0000000000 radians = -0.000000 deg.

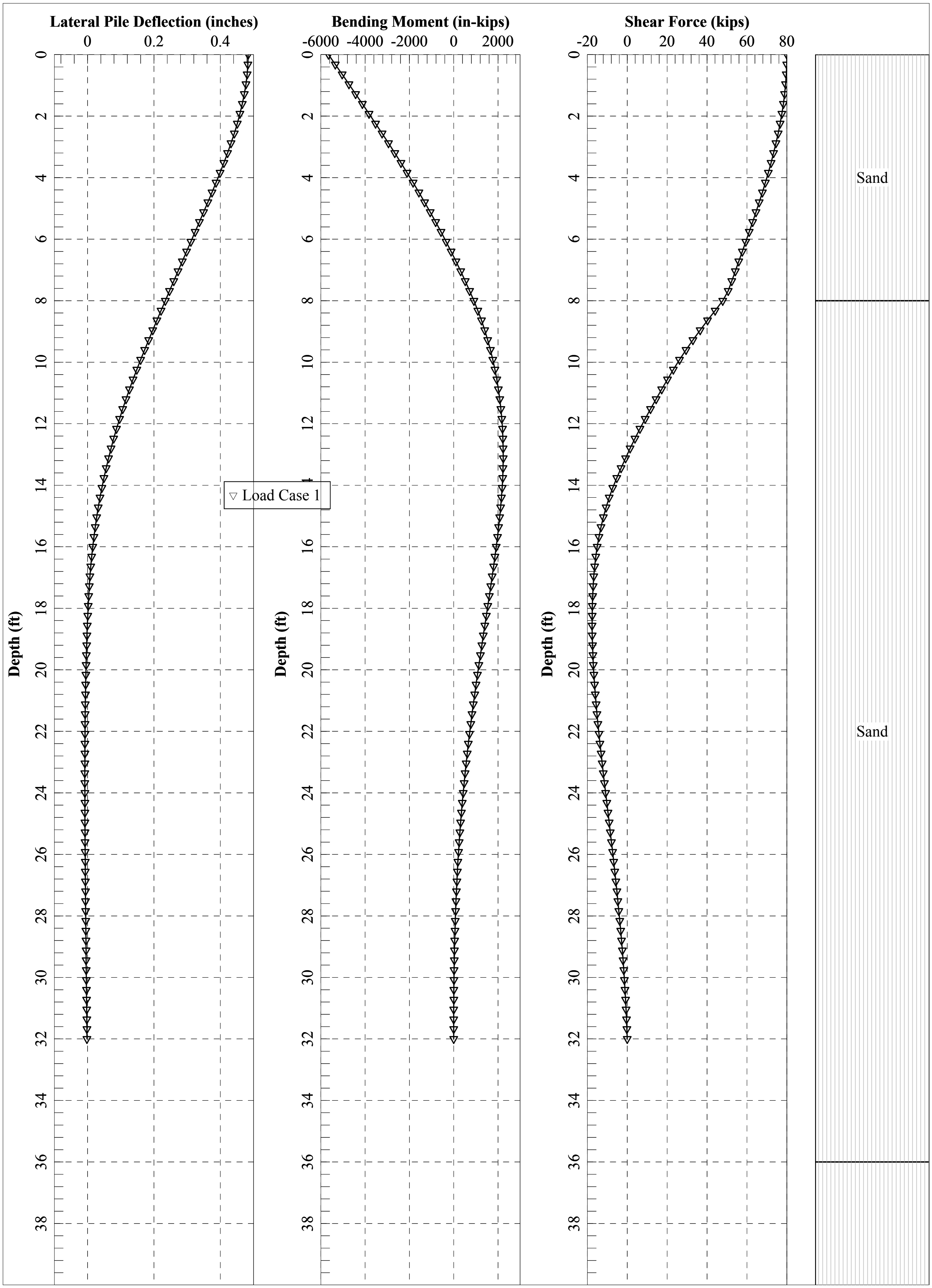
DeminTank_B11_ACP.lp10o

The analysis ended normally.

# Lpile analysis report (ACP)

**Boring: B-5**
**Equipment: H-frame**

# Bending Moment and Shear force with respect 0.5" head deflection for given ACP (30" diameter)



Hframe_B5_ACP.lp10o

================================================================================

LPile for Windows, Version 2018-10.006

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method


================================================================================

This copy of LPile is being used by:

2001917
PSI

Serial Number of Security Device: 138584532

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--------------------------------------------------------------------------------
Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters, MD\Engineering &
Resources\AugerCastPiles\LPile_analysis\

Name of input data file:
Hframe_B5_ACP.lp10

Name of output report file:
Hframe_B5_ACP.lp10

Name of plot output file:
Hframe_B5_ACP.lp10

Name of runtime message file:
Hframe_B5_ACP.lp10

--------------------------------------------------------------------------------
Date and Time of Analysis
--------------------------------------------------------------------------------

Date:  June 14, 2018              Time:  13:02:16

--------------------------------------------------------------------------------
Problem Title
--------------------------------------------------------------------------------

Hframe_B5_ACP.lp10o

Project Name: CP Crane Power plant

Job Number:0512843

Client:ProEnergy

Engineer: SS

Description: Axial Capacity of Dirven Pile in Boring B13

--------------------------------------------------------------------------------
Program Options and Settings
--------------------------------------------------------------------------------

Computational Options:
- Use unfactored loads in computations (conventional analysis)

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

```
 - Maximum number of iterations allowed              =          500
 - Deflection tolerance for convergence              =   1.0000E-05 in
 - Maximum allowable deflection                      =     100.0000 in
 - Number of pile increments                         =          100
```

Loading Type and Number of Cycles of Loading:
- Static loading specified

- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

--------------------------------------------------------------------------------
Pile Structural Properties and Geometry
--------------------------------------------------------------------------------

Hframe_B5_ACP.lp10o

```
Number of pile sections defined                           =            1
Total length of pile                                      =       32.000 ft
Depth of ground surface below top of pile                 =       0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

            Depth Below          Pile
Point        Pile Head         Diameter
 No.           feet             inches
-----      -------------     -------------
  1            0.000           30.0000
  2           32.000           30.0000


Input Structural Properties for Pile Sections:
----------------------------------------------

Pile Section No. 1:

   Section 1 is a round drilled shaft, bored pile, or CIDH pile
   Length of section                                      =    32.000000 ft
   Shaft Diameter                                         =    30.000000 in
   Shear capacity of section                              =       0.0000 lbs



--------------------------------------------------------------------------------
                       Ground Slope and Pile Batter Angles
--------------------------------------------------------------------------------

Ground Slope Angle                                        =        0.000 degrees
                                                          =        0.000 radians

Pile Batter Angle                                         =        0.000 degrees
                                                          =        0.000 radians


--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 4 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer              =       0.0000 ft
   Distance from top of pile to bottom of layer           =     8.000000 ft
   Effective unit weight at top of layer                  =   115.000000 pcf
   Effective unit weight at bottom of layer               =   115.000000 pcf
   Friction angle at top of layer                         =    32.000000 deg.
   Friction angle at bottom of layer                      =    32.000000 deg.
   Subgrade k at top of layer                             =    20.000000 pci
   Subgrade k at bottom of layer                          =    20.000000 pci
```

Hframe_B5_ACP.lp10o

Layer 2 is sand, p-y criteria by Reese et al., 1974

```
   Distance from top of pile to top of layer           =     8.000000 ft
   Distance from top of pile to bottom of layer        =    36.000000 ft
   Effective unit weight at top of layer               =    72.600000 pcf
   Effective unit weight at bottom of layer            =    72.600000 pcf
   Friction angle at top of layer                      =    33.000000 deg.
   Friction angle at bottom of layer                   =    33.000000 deg.
   Subgrade k at top of layer                          =    67.000000 pci
   Subgrade k at bottom of layer                       =    67.000000 pci
```

Layer 3 is sand, p-y criteria by Reese et al., 1974

```
   Distance from top of pile to top of layer           =    36.000000 ft
   Distance from top of pile to bottom of layer        =    47.000000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.400000 pcf
   Friction angle at top of layer                      =    35.000000 deg.
   Friction angle at bottom of layer                   =    35.000000 deg.
   Subgrade k at top of layer                          =    55.000000 pci
   Subgrade k at bottom of layer                       =    55.000000 pci
```

Layer 4 is stiff clay with water-induced erosion

```
   Distance from top of pile to top of layer           =    47.000000 ft
   Distance from top of pile to bottom of layer        =    48.000000 ft
   Effective unit weight at top of layer               =    87.600000 pcf
   Effective unit weight at bottom of layer            =    57.600000 pcf
   Undrained cohesion at top of layer                  =        2000. psf
   Undrained cohesion at bottom of layer               =        2000. psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    18.000000 pci
   Subgrade k at bottom of layer                       =    18.000000 pci
```

NOTE: Default values for Epsilon-50 will be computed for this layer.

(Depth of the lowest soil layer extends 16.000 ft below the pile tip)

--------------------------------------------------------------------------------

Summary of Input Soil Properties

--------------------------------------------------------------------------------

| Layer Layer Num. | Soil Type Name (p-y Curve Type) | Layer Depth ft | Effective Unit Wt. pcf | Undrained Cohesion psf | Angle of Friction deg. | E50 or krm | kpy pci |
|---|---|---|---|---|---|---|---|
| 1 | Sand | 0.00 | 115.0000 | -- | 32.0000 | -- | 20.0000 |

```
         (Reese, et al.)        8.0000     115.0000       --          32.0000       --
20.0000
  2          Sand               8.0000      72.6000       --          33.0000       --
67.0000
         (Reese, et al.)       36.0000      72.6000       --          33.0000       --
67.0000
  3          Sand              36.0000      62.6000       --          35.0000       --
55.0000
         (Reese, et al.)       47.0000      62.4000       --          35.0000       --
55.0000
  4       Stiff Clay           47.0000      87.6000       2000.        --         default
18.0000
         with Free Water       48.0000      57.6000       2000.        --         default
18.0000
```

--------------------------------------------------------------------------------
Static Loading Type
--------------------------------------------------------------------------------

Static loading criteria were used when computing p-y curves for all analyses.

--------------------------------------------------------------------------------
Pile-head Loading and Pile-head Fixity Conditions
--------------------------------------------------------------------------------

Number of loads specified = 1

| Load No. | Load Type | Condition 1 | Condition 2 | Axial Thrust Force, lbs | Compute Top y vs. Pile Length |
|---|---|---|---|---|---|
| 1 | 2 | V = 80000. lbs | S = 0.0000 in/in | 100000. | Yes |

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

--------------------------------------------------------------------------------
Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness
--------------------------------------------------------------------------------

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:
-------------------

Dimensions and Properties of Drilled Shaft (Bored Pile):
--------------------------------------------------------

Hframe_B5_ACP.lp10o

| | | |
|---|---|---|
| Length of Section | = | 32.000000 ft |
| Shaft Diameter | = | 30.000000 in |
| Concrete Cover Thickness | = | 3.000000 in |
| Number of Reinforcing Bars | = | 8 bars |
| Yield Stress of Reinforcing Bars | = | 60000. psi |
| Modulus of Elasticity of Reinforcing Bars | = | 29000000. psi |
| Gross Area of Shaft | = | 706.858347 sq. in. |
| Total Area of Reinforcing Steel | = | 12.480000 sq. in. |
| Area Ratio of Steel Reinforcement | = | 1.77 percent |
| Edge-to-Edge Bar Spacing | = | 7.234819 in |
| Maximum Concrete Aggregate Size | = | 0.750000 in |
| Ratio of Bar Spacing to Aggregate Size | = | 9.65 |
| Offset of Center of Rebar Cage from Center of Pile | = | 0.0000 in |
| Confined Section | | |
| Type: Hoop | | |
| Number of Confinement Bars | = | 1 |
| Spacing of Confinement Bars | = | 12.000000 in |
| Yield Stress of Confinement Bars | = | 60000. psi |
| Total Area of Confinement Steel | = | 0.310000 sq. in. |
| rho_s | = | 0.004196 |
| ke | = | 0.789730 |
| f'cc | = | 4651. psi |
| f'l | = | 99.417766 psi |
| Epsilon cc | = | 0.003627 |
| Epsilon cu | = | 0.010821 |
| r | = | 1.552070 |

Axial Structural Capacities:
----------------------------

| | | |
|---|---|---|
| Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As | = | 3109.686 kips |
| Tensile Load for Cracking of Concrete | = | -330.553 kips |
| Nominal Axial Tensile Capacity | = | -748.800 kips |

Reinforcing Bar Dimensions and Positions Used in Computations:

| Bar Number | Bar Diam. inches | Bar Area sq. in. | X inches | Y inches |
|---|---|---|---|---|
| 1 | 1.410000 | 1.560000 | 11.295000 | 0.00000 |
| 2 | 1.410000 | 1.560000 | 7.986771 | 7.986771 |
| 3 | 1.410000 | 1.560000 | 0.00000 | 11.295000 |
| 4 | 1.410000 | 1.560000 | -7.986771 | 7.986771 |
| 5 | 1.410000 | 1.560000 | -11.295000 | 0.00000 |
| 6 | 1.410000 | 1.560000 | -7.986771 | -7.986771 |
| 7 | 1.410000 | 1.560000 | 0.00000 | -11.295000 |
| 8 | 1.410000 | 1.560000 | 7.986771 | -7.986771 |

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero = 7.235 inches
between bars 1 and 2.

Ratio of bar spacing to maximum aggregate size = 9.65

Hframe_B5_ACP.lp10o

Concrete Properties:
--------------------

| | | |
|---|---|---|
| Compressive Strength of Concrete | = | 4000. psi |
| Modulus of Elasticity of Concrete | = | 3604997. psi |
| Modulus of Rupture of Concrete | = | -474.341649 psi |
| Compression Strain at Peak Stress | = | 0.001886 |
| Tensile Strain at Fracture of Concrete | = | -0.0001154 |
| Maximum Coarse Aggregate Size | = | 0.750000 in |

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

| Number | Axial Thrust Force kips |
|---|---|
| 1 | 100.000 |

Definitions of Run Messages and Notes:
--------------------------------------

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318, Section 10.3.4.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 100.000 kips

| Bending Curvature rad/in. | Bending Moment in-kip | Bending Stiffness kip-in2 | Depth to N Axis in | Max Comp Strain in/in | Max Tens Strain in/in | Max Conf Stress ksi | Max Conc Stress ksi | Max Steel Stress ksi | Run Msg |
|---|---|---|---|---|---|---|---|---|---|
| 0.00000125 | 224.3830446 | 179506436. | 41.1502865 | 0.00005144 | 0.00001394 | 0.1843081 | 0.2144087 | 1.4862604 | |
| 0.00000250 | 448.7312275 | 179492491. | 28.0939439 | 0.00007023 | -0.00000477 | 0.2508557 | 0.2908011 | 2.0259359 | |
| 0.00000375 | 673.8540030 | 179694401. | 23.7576346 | 0.00008909 | -0.00002341 | 0.3173387 | 0.3666543 | 2.5673303 | |
| 0.00000500 | 900.6515232 | 180130305. | 21.6103789 | 0.0001081 | -0.00004195 | 0.3838772 | 0.4421419 | 3.1117550 | |
| 0.00000625 | 1127. | 180381071. | 20.3308388 | 0.0001271 | -0.00006043 | 0.4502585 | 0.5170550 | 3.6577771 | |
| 0.00000750 | 1353. | 180446320. | 19.4815700 | 0.0001461 | -0.00007889 | 0.5163551 | 0.5912815 | 4.2046165 | |
| 0.00000875 | 1578. | 180374721. | 18.8766956 | 0.0001652 | -0.00009733 | 0.5820926 | | | |

```
0.6647676     4.7518990
   0.00001000         1578.    157827881.    15.7753175     0.0001578    -0.0001422     0.5556514
0.6352487     4.5313421 C
   0.00001125         1578.    140291450.    15.1474044     0.0001704    -0.0001671     0.5989595
0.6835711     4.8929032 C
   0.00001250         1578.    126262305.    14.6257910     0.0001828    -0.0001922     0.6412419
0.7306199    -5.5187757 C
   0.00001375         1578.    114783913.    14.1860130     0.0001951    -0.0002174     0.6827175
0.7766518    -6.2460148 C
   0.00001500         1578.    105218587.    13.8091612     0.0002071    -0.0002429     0.7234686
0.8217693    -6.9777648 C
   0.00001625         1578.     97124850.    13.4828890     0.0002191    -0.0002684     0.7636175
0.8661176    -7.7130010 C
   0.00001750         1578.     90187360.    13.1973360     0.0002310    -0.0002940     0.8032235
0.9097700    -8.4512269 C
   0.00002000         1604.     80222212.    12.7216879     0.0002544    -0.0003456     0.8810671
0.9953018    -9.9344210 C
   0.00002250         1730.     76908523.    12.3397859     0.0002776    -0.0003974     0.9572226
1.0786586   -11.4254146 C
   0.00002500         1855.     74210383.    12.0274764     0.0003007    -0.0004493     1.0320159
1.1602363   -12.9213296 C
   0.00002750         1979.     71969412.    11.7673705     0.0003236    -0.0005014     1.1055827
1.2402152   -14.4208969 C
   0.00003000         2102.     70078689.    11.5480295     0.0003464    -0.0005536     1.1780701
1.3187823   -15.9227143 C
   0.00003250         2225.     68455021.    11.3587912     0.0003692    -0.0006058     1.2493381
1.3958098   -17.4279642 C
   0.00003500         2347.     67051245.    11.1962474     0.0003919    -0.0006581     1.3197165
1.4716745   -18.9335588 C
   0.00003750         2468.     65820216.    11.0538662     0.0004145    -0.0007105     1.3890532
1.5462298   -20.4407954 C
   0.00004000         2589.     64734619.    10.9296895     0.0004372    -0.0007628     1.4575641
1.6197226   -21.9475601 C
   0.00004250         2710.     63764301.    10.8185220     0.0004598    -0.0008152     1.5249814
1.6918789   -23.4562965 C
   0.00004500         2830.     62895416.    10.7205743     0.0004824    -0.0008676     1.5916214
1.7630485   -24.9639004 C
   0.00004750         2950.     62111047.    10.6333080     0.0005051    -0.0009199     1.6574077
1.8331586   -26.4709931 C
   0.00005000         3070.     61396044.    10.5537816     0.0005277    -0.0009723     1.7221372
1.9020010   -27.9795165 C
   0.00005250         3189.     60743631.    10.4826051     0.0005503    -0.0010247     1.7860665
1.9698551   -29.4868586 C
   0.00005500         3308.     60145223.    10.4186478     0.0005730    -0.0010770     1.8491867
2.0367162   -30.9930066 C
   0.00006000         3545.     59081561.    10.3075999     0.0006185    -0.0011815     1.9727718
2.1672309   -34.0037760 C
   0.00006500         3780.     58160962.    10.2145963     0.0006639    -0.0012861     2.0927675
2.2934299   -37.0127357 C
   0.00007000         4015.     57354700.    10.1374010     0.0007096    -0.0013904     2.2094467
2.4155990   -40.0165758 C
   0.00007500         4248.     56639599.    10.0729049     0.0007555    -0.0014945     2.3227851
2.5336947   -43.0151817 C
   0.00008000         4480.     55997425.    10.0178131     0.0008014    -0.0015986     2.4325860
2.6474820   -46.0106734 C
   0.00008500         4710.     55415425.     9.9708501     0.0008475    -0.0017025     2.5389319
2.7570053   -49.0021043 C
   0.00009000         4940.     54883831.     9.9312967     0.0008938    -0.0018062     2.6419596
2.8623511   -51.9878155 C
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   0.00009500          5167.     54394410.      9.8980319      0.0009403     -0.0019097      2.7416839
2.9634688   -54.9676719 C
   0.00010000          5394.     53940568.      9.8701605      0.0009870     -0.0020130      2.8381270
3.0603061   -57.9415344 C
    0.0001050          5619.     53516961.      9.8469592      0.0010339     -0.0021161      2.9313181
3.1528086   -60.0000000 CY
    0.0001150          6066.     52743678.      9.8123105      0.0011284     -0.0023216      3.1080895
3.3245812   -60.0000000 CY
    0.0001250          6493.     51944284.      9.7842336      0.0012230     -0.0025270      3.2710268
3.4771104   -60.0000000 CY
    0.0001350          6813.     50465654.      9.7184317      0.0013120     -0.0027380      3.4118808
3.6026226   -60.0000000 CY
    0.0001450          7111.     49042793.      9.6583581      0.0014005     -0.0029495      3.5408690
3.7103825   -60.0000000 CY
    0.0001550          7371.     47553704.      9.5932745      0.0014870     -0.0031630      3.6568357
3.7992593   -60.0000000 CY
    0.0001650          7490.     45392433.      9.4698569      0.0015625     -0.0033875      3.7502125
3.8634651   -60.0000000 CY
    0.0001750          7579.     43306225.      9.3456440      0.0016355     -0.0036145      3.8338881
3.9137189   -60.0000000 CY
    0.0001850          7665.     41434502.      9.2369595      0.0017088     -0.0038412      3.9120035
3.9526700   -60.0000000 CY
    0.0001950          7750.     39744662.      9.1418709      0.0017827     -0.0040673      3.9848730
3.9801567   -60.0000000 CY
    0.0002050          7832.     38206075.      9.0552017      0.0018563     -0.0042937      4.0521202
3.9958572   -60.0000000 CY
    0.0002150          7912.     36801538.      8.9793761      0.0019306     -0.0045194      4.1147293
3.9969067   -60.0000000 CY
    0.0002250          7990.     35512205.      8.9131925      0.0020055     -0.0047445      4.1729183
3.9972395   -60.0000000 CY
    0.0002350          8066.     34323271.      8.8554886      0.0020810     -0.0049690      4.2268646
3.9969623   -60.0000000 CY
    0.0002450          8139.     33221086.      8.8028267      0.0021567     -0.0051933      4.2763569
3.9959084    60.0000000 CY
    0.0002550          8210.     32197745.      8.7565822      0.0022329     -0.0054171      4.3219500
3.9992452    60.0000000 CY
    0.0002650          8280.     31244680.      8.7162852      0.0023098     -0.0056402      4.3638507
3.9997888    60.0000000 CY
    0.0002750          8348.     30354902.      8.6811454      0.0023873     -0.0058627      4.4021978
3.9986066    60.0000000 CY
    0.0002850          8414.     29522383.      8.6504710      0.0024654     -0.0060846      4.4371338
3.9956594    60.0000000 CY
    0.0002950          8478.     28739008.      8.6230829      0.0025438     -0.0063062      4.4687382
3.9999566    60.0000000 CY
    0.0003050          8537.     27989096.      8.5961006      0.0026218     -0.0065282      4.4969244
3.9979970    60.0000000 CY
    0.0003150          8586.     27255891.      8.5652072      0.0026980     -0.0067520      4.5215401
3.9973290    60.0000000 CY
    0.0003250          8620.     26524214.      8.5255884      0.0027708     -0.0069792      4.5425049
3.9980447    60.0000000 CY
    0.0003350          8643.     25799167.      8.4778585      0.0028401     -0.0072099      4.5603041
3.9999990    60.0000000 CY
    0.0003450          8656.     25089326.      8.4262453      0.0029071     -0.0074429      4.5756444
3.9951079    60.0000000 CY
    0.0003550          8663.     24403436.      8.3731826      0.0029725     -0.0076775      4.5889643
3.9988458    60.0000000 CY
    0.0003650          8669.     23750882.      8.3222196      0.0030376     -0.0079124      4.6006892
3.9995017    60.0000000 CY
    0.0003750          8675.     23132437.      8.2746443      0.0031030     -0.0081470      4.6110088
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3.9933294    60.0000000 CY
   0.0003850          8680.     22544752.     8.2281929     0.0031679    -0.0083821     4.6198897
3.9975517    60.0000000 CY
   0.0003950          8684.     21985316.     8.1824646     0.0032321    -0.0086179     4.6274270
3.9996771    60.0000000 CY
   0.0004050          8689.     21453198.     8.1393943     0.0032965    -0.0088535     4.6338028
3.9959449    60.0000000 CY
   0.0004150          8693.     20946425.     8.0987864     0.0033610    -0.0090890     4.6390755
3.9925281    60.0000000 CY
   0.0004250          8696.     20462351.     8.0611720     0.0034260    -0.0093240     4.6433182
3.9967190    60.0000000 CY
   0.0004350          8700.     19999542.     8.0262322     0.0034914    -0.0095586     4.6465680
3.9992336    60.0000000 CY
   0.0004450          8703.     19557363.     7.9931179     0.0035569    -0.0097931     4.6488569
3.9993991    60.0000000 CY
   0.0004550          8706.     19134310.     7.9618534     0.0036226    -0.0100274     4.6502375
3.9905559    60.0000000 CY
   0.0004650          8708.     18727436.     7.9315836     0.0036882    -0.0102618     4.6507556
3.9925629    60.0000000 CY
   0.0004750          8710.     18335915.     7.9029333     0.0037539    -0.0104961     4.6504647
3.9964584    60.0000000 CY
   0.0004850          8711.     17960423.     7.8756664     0.0038197    -0.0107303     4.6506989
3.9989319    60.0000000 CY
   0.0004950          8711.     17597586.     7.8770778     0.0038992    -0.0109508     4.6505272
3.9974502    60.0000000 CY
   0.0005050          8711.     17249119.     7.8520939     0.0039653    -0.0111847     4.6506017
3.9894071    60.0000000 CY
   0.0005450          8711.     15983129.     7.8840700     0.0042968    -0.0120532     4.6503306
3.9875226    60.0000000 CY
   0.0005850          8711.     14890265.     7.9767564     0.0046664    -0.0128836     4.6502371
3.9849719    60.0000000 CY
   0.0006250          8711.     13937288.     8.0039694     0.0050025    -0.0137475     4.6506699
3.9929582    60.0000000 CY
   0.0006650          8711.     13098955.     8.1383332     0.0054120    -0.0145380     4.6500054
3.9891926    60.0000000 CY
   0.0007050          8711.     12355752.     8.1848184     0.0057703    -0.0153797     4.6501640
3.9990725    60.0000000 CY
   0.0007450          8711.     11692356.     8.2372812     0.0061368    -0.0162132     4.6503999
3.9869486    60.0000000 CY
   0.0007850          8711.     11096567.     8.2700918     0.0064920    -0.0170580     4.6501439
3.9957670    60.0000000 CY
   0.0008250          8711.     10558552.     8.2906807     0.0068398    -0.0179102     4.6494280
3.9837547    60.0000000 CY
   0.0008650          8711.     10070295.     8.3061316     0.0071848    -0.0187652     4.6504762
3.9994939    60.0000000 CY
   0.0009050          8711.      9625199.     8.3188324     0.0075285    -0.0196215     4.6506410
3.9760084    60.0000000 CY


--------------------------------------------------------------------------------
   Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1
--------------------------------------------------------------------------------

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

 Load           Axial Thrust         Nominal Mom. Cap.       Max. Comp.
  No.               kips                   in-kip              Strain
 ----         ----------------     ------------------     ------------
```

| | | | |
|---|---|---|---|
| 1 | 100.000 | 8665.692 | 0.00300000 |

Note that the values of moment capacity in the table above are not factored by a strength reduction factor (phi-factor).

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.70).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, Section 9.3.2.2 or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

| Axial Load No. | Resist. Factor for Moment | Nominal Moment Cap in-kips | Ult. (Fac) Ax. Thrust kips | Ult. (Fac) Moment Cap in-kips | Bend. Stiff. at Ult Mom kip-in^2 |
|---|---|---|---|---|---|
| 1 | 0.65 | 8666. | 65.000000 | 5633. | 53493707. |
| 1 | 0.70 | 8666. | 70.000000 | 6066. | 52742815. |
| 1 | 0.75 | 8666. | 75.000000 | 6499. | 51915463. |

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Layering Correction Equivalent Depths of Soil & Rock Layers

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| Layer No. | Top of Layer Below Pile Head ft | Equivalent Top Depth Below Grnd Surf ft | Same Layer Type As Layer Above | Layer is Rock or is Below Rock Layer | F0 Integral for Layer lbs | F1 Integral for Layer lbs |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | N.A. | No | 0.00 | 98086. |
| 2 | 8.0000 | 7.7042 | Yes | No | 98086. | 2304403. |
| 3 | 36.0000 | 36.0000 | No | No | 2402489. | 0.00 |
| 4 | 47.0000 | 47.0000 | No | No | 0.00 | N.A. |

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

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Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

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Shear force at pile head = 80000.0 lbs
Rotation of pile head = 0.000E+00 radians
Axial load at pile head = 100000.0 lbs

(Zero slope for this load indicates fixed-head conditions)

| Depth X feet | Deflect. y inches | Bending Moment in-lbs | Shear Force lbs | Slope S radians | Total Stress psi* | Bending Stiffness in-lb^2 | Soil Res. p lb/inch | Soil Spr. Es*h lb/inch | Distrib. Lat. Load lb/inch |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.4836 | -5650999. | 80000. | 0.00 | 0.00 | 5.35E+10 | 0.00 | 0.00 | 0.00 |
| 0.3200 | 0.4829 | -5343721. | 79929. | -3.95E-04 | 0.00 | 5.35E+10 | -37.0834 | 294.9120 | 0.00 |
| 0.6400 | 0.4806 | -5036842. | 79716. | -7.64E-04 | 0.00 | 5.47E+10 | -73.8206 | 589.8240 | 0.00 |
| 0.9600 | 0.4770 | -4730917. | 79363. | -0.00110 | 0.00 | 5.54E+10 | -109.8988 | 884.7360 | 0.00 |
| 1.2800 | 0.4721 | -4426485. | 78874. | -0.00142 | 0.00 | 5.61E+10 | -145.0350 | 1180. | 0.00 |
| 1.6000 | 0.4661 | -4124076. | 78252. | -0.00171 | 0.00 | 5.70E+10 | -178.9765 | 1475. | 0.00 |
| 1.9200 | 0.4590 | -3824200. | 77502. | -0.00198 | 0.00 | 5.80E+10 | -211.4995 | 1769. | 0.00 |
| 2.2400 | 0.4509 | -3527345. | 76630. | -0.00222 | 0.00 | 5.92E+10 | -242.4090 | 2064. | 0.00 |
| 2.5600 | 0.4420 | -3233976. | 75644. | -0.00243 | 0.00 | 6.05E+10 | -271.5383 | 2359. | 0.00 |
| 2.8800 | 0.4322 | -2944533. | 74549. | -0.00263 | 0.00 | 6.21E+10 | -298.7476 | 2654. | 0.00 |
| 3.2000 | 0.4218 | -2659425. | 73353. | -0.00280 | 0.00 | 6.42E+10 | -323.9242 | 2949. | 0.00 |
| 3.5200 | 0.4107 | -2379032. | 72065. | -0.00295 | 0.00 | 6.67E+10 | -346.9810 | 3244. | 0.00 |
| 3.8400 | 0.3991 | -2103703. | 70692. | -0.00307 | 0.00 | 7.01E+10 | -367.8557 | 3539. | 0.00 |
| 4.1600 | 0.3871 | -1833755. | 69244. | -0.00318 | 0.00 | 7.46E+10 | -386.5101 | 3834. | 0.00 |
| 4.4800 | 0.3747 | -1569469. | 67728. | -0.00324 | 0.00 | 1.55E+11 | -402.9289 | 4129. | 0.00 |
| 4.8000 | 0.3622 | -1311110. | 66154. | -0.00328 | 0.00 | 1.80E+11 | -417.2738 | 4424. | 0.00 |
| 5.1200 | 0.3496 | -1058893. | 64528. | -0.00330 | 0.00 | 1.80E+11 | -429.5623 | 4719. | 0.00 |
| 5.4400 | 0.3369 | -813001. | 62858. | -0.00332 | 0.00 | 1.80E+11 | -439.7965 | 5014. | 0.00 |
| 5.7600 | 0.3241 | -573588. | 61154. | -0.00334 | 0.00 | 1.80E+11 | -447.9841 | 5308. | 0.00 |
| 6.0800 | 0.3112 | -340776. | 59422. | -0.00335 | 0.00 | 1.79E+11 | -454.1382 | 5603. | 0.00 |
| 6.4000 | 0.2984 | -114658. | 57670. | -0.00335 | 0.00 | 1.80E+11 | -458.2773 | 5898. | 0.00 |
| 6.7200 | 0.2855 | 104704. | 55906. | -0.00335 | 0.00 | 1.80E+11 | -460.4250 | 6193. | 0.00 |
| 7.0400 | 0.2726 | 317275. | 54138. | -0.00335 | 0.00 | 1.79E+11 | -460.6094 | 6488. | |

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0.00

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7.3600 | 0.2598 | 523052. | 52372. | -0.00334 | 0.00 | 1.80E+11 | -458.8635 | 6783. | 0.00 |
| 7.6800 | 0.2470 | 722059. | 50617. | -0.00333 | 0.00 | 1.80E+11 | -455.2243 | 7078. | 0.00 |
| 8.0000 | 0.2342 | 914347. | 47863. | -0.00331 | 0.00 | 1.80E+11 | -979.1075 | 16051. | 0.00 |
| 8.3200 | 0.2216 | 1092190. | 44058. | -0.00329 | 0.00 | 1.80E+11 | -1003. | 17382. | 0.00 |
| 8.6400 | 0.2090 | 1255234. | 40247. | -0.00326 | 0.00 | 1.80E+11 | -981.8648 | 18040. | 0.00 |
| 8.9600 | 0.1965 | 1403791. | 36530. | -0.00323 | 0.00 | 1.80E+11 | -954.0236 | 18641. | 0.00 |
| 9.2800 | 0.1842 | 1538268. | 32933. | -0.00320 | 0.00 | 1.80E+11 | -919.3616 | 19169. | 0.00 |
| 9.6000 | 0.1719 | 1659176. | 29482. | -0.00314 | 0.00 | 7.87E+10 | -877.8855 | 19607. | 0.00 |
| 9.9200 | 0.1600 | 1767108. | 26203. | -0.00306 | 0.00 | 7.61E+10 | -830.1912 | 19923. | 0.00 |
| 10.2400 | 0.1484 | 1862764. | 23118. | -0.00297 | 0.00 | 7.41E+10 | -776.6824 | 20093. | 0.00 |
| 10.5600 | 0.1372 | 1946930. | 20170. | -0.00287 | 0.00 | 7.25E+10 | -758.7400 | 21231. | 0.00 |
| 10.8800 | 0.1264 | 2019869. | 17280. | -0.00276 | 0.00 | 7.13E+10 | -746.2130 | 22667. | 0.00 |
| 11.2000 | 0.1160 | 2081762. | 14444. | -0.00265 | 0.00 | 7.04E+10 | -730.7041 | 24184. | 0.00 |
| 11.5200 | 0.1061 | 2132837. | 11674. | -0.00253 | 0.00 | 6.96E+10 | -712.2886 | 25788. | 0.00 |
| 11.8400 | 0.09656 | 2173364. | 8979. | -0.00242 | 0.00 | 6.91E+10 | -691.0689 | 27483. | 0.00 |
| 12.1600 | 0.08752 | 2203654. | 6372. | -0.00229 | 0.00 | 6.87E+10 | -667.1748 | 29274. | 0.00 |
| 12.4800 | 0.07895 | 2224060. | 3860. | -0.00217 | 0.00 | 6.85E+10 | -640.7625 | 31166. | 0.00 |
| 12.8000 | 0.07086 | 2234968. | 1455. | -0.00204 | 0.00 | 6.83E+10 | -612.1833 | 33176. | 0.00 |
| 13.1200 | 0.06325 | 2236802. | -861.2395 | -0.00192 | 0.00 | 6.83E+10 | -594.0647 | 36067. | 0.00 |
| 13.4400 | 0.05612 | 2229827. | -3104. | -0.00179 | 0.00 | 6.84E+10 | -573.9729 | 39271. | 0.00 |
| 13.7600 | 0.04948 | 2214341. | -5257. | -0.00167 | 0.00 | 6.86E+10 | -547.4019 | 42482. | 0.00 |
| 14.0800 | 0.04331 | 2190736. | -7249. | -0.00155 | 0.00 | 6.89E+10 | -490.3053 | 43470. | 0.00 |
| 14.4000 | 0.03761 | 2159853. | -9027. | -0.00142 | 0.00 | 6.93E+10 | -435.4645 | 44458. | 0.00 |
| 14.7200 | 0.03237 | 2122504. | -10598. | -0.00131 | 0.00 | 6.98E+10 | -383.1315 | 45446. | 0.00 |
| 15.0400 | 0.02758 | 2079460. | -11974. | -0.00119 | 0.00 | 7.04E+10 | -333.5252 | 46434. | 0.00 |
| 15.3600 | 0.02323 | 2031454. | -13166. | -0.00108 | 0.00 | 7.11E+10 | -286.8320 | 47422. | 0.00 |
| 15.6800 | 0.01929 | 1979177. | -14183. | -9.72E-04 | 0.00 | 7.20E+10 | -243.2071 | 48410. | 0.00 |
| 16.0000 | 0.01576 | 1923274. | -15040. | -8.68E-04 | 0.00 | 7.29E+10 | -202.7743 | 49398. | 0.00 |
| 16.3200 | 0.01262 | 1864341. | -15747. | -7.69E-04 | 0.00 | 7.40E+10 | -165.6284 | 50386. | 0.00 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 16.6400 | 0.00985 | 1802929. | -16318. | -6.75E-04 | 0.00 | 7.53E+10 | -131.8350 | 51374. | 0.00 |
| 16.9600 | 0.00744 | 1739537. | -16766. | -5.85E-04 | 0.00 | 7.67E+10 | -101.4330 | 52362. | 0.00 |
| 17.2800 | 0.00536 | 1674617. | -17104. | -5.01E-04 | 0.00 | 7.83E+10 | -74.4351 | 53350. | 0.00 |
| 17.6000 | 0.00359 | 1608567. | -17344. | -4.21E-04 | 0.00 | 8.04E+10 | -50.8301 | 54338. | 0.00 |
| 17.9200 | 0.00212 | 1541738. | -17500. | -3.67E-04 | 0.00 | 1.80E+11 | -30.5668 | 55325. | 0.00 |
| 18.2400 | 7.77E-04 | 1474446. | -17581. | -3.34E-04 | 0.00 | 1.80E+11 | -11.3951 | 56313. | 0.00 |
| 18.5600 | -4.47E-04 | 1406974. | -17590. | -3.04E-04 | 0.00 | 1.80E+11 | 6.6701 | 57301. | 0.00 |
| 18.8800 | -0.00156 | 1339588. | -17532. | -2.75E-04 | 0.00 | 1.80E+11 | 23.6198 | 58289. | 0.00 |
| 19.2000 | -0.00256 | 1272540. | -17411. | -2.47E-04 | 0.00 | 1.80E+11 | 39.4502 | 59277. | 0.00 |
| 19.5200 | -0.00345 | 1206064. | -17231. | -2.20E-04 | 0.00 | 1.80E+11 | 54.1628 | 60265. | 0.00 |
| 19.8400 | -0.00425 | 1140376. | -16997. | -1.95E-04 | 0.00 | 1.80E+11 | 67.7637 | 61253. | 0.00 |
| 20.1600 | -0.00495 | 1075678. | -16713. | -1.72E-04 | 0.00 | 1.80E+11 | 80.2638 | 62241. | 0.00 |
| 20.4800 | -0.00557 | 1012155. | -16383. | -1.50E-04 | 0.00 | 1.80E+11 | 91.6777 | 63229. | 0.00 |
| 20.8000 | -0.00610 | 949975. | -16011. | -1.29E-04 | 0.00 | 1.80E+11 | 102.0240 | 64217. | 0.00 |
| 21.1200 | -0.00656 | 889292. | -15601. | -1.09E-04 | 0.00 | 1.80E+11 | 111.3245 | 65205. | 0.00 |
| 21.4400 | -0.00694 | 830243. | -15158. | -9.07E-05 | 0.00 | 1.80E+11 | 119.6042 | 66193. | 0.00 |
| 21.7600 | -0.00725 | 772951. | -14684. | -7.36E-05 | 0.00 | 1.80E+11 | 126.8910 | 67181. | 0.00 |
| 22.0800 | -0.00750 | 717524. | -14185. | -5.77E-05 | 0.00 | 1.80E+11 | 133.2150 | 68169. | 0.00 |
| 22.4000 | -0.00770 | 664055. | -13663. | -4.30E-05 | 0.00 | 1.80E+11 | 138.6085 | 69157. | 0.00 |
| 22.7200 | -0.00783 | 612625. | -13122. | -2.93E-05 | 0.00 | 1.80E+11 | 143.1055 | 70145. | 0.00 |
| 23.0400 | -0.00792 | 563300. | -12566. | -1.68E-05 | 0.00 | 1.80E+11 | 146.7419 | 71133. | 0.00 |
| 23.3600 | -0.00796 | 516134. | -11997. | -5.22E-06 | 0.00 | 1.80E+11 | 149.5548 | 72121. | 0.00 |
| 23.6800 | -0.00796 | 471169. | -11419. | 5.33E-06 | 0.00 | 1.80E+11 | 151.5820 | 73109. | 0.00 |
| 24.0000 | -0.00792 | 428435. | -10834. | 1.50E-05 | 0.00 | 1.79E+11 | 152.8619 | 74097. | 0.00 |
| 24.3200 | -0.00785 | 387952. | -10246. | 2.37E-05 | 0.00 | 1.79E+11 | 153.4330 | 75085. | 0.00 |
| 24.6400 | -0.00774 | 349728. | -9657. | 3.16E-05 | 0.00 | 1.79E+11 | 153.3342 | 76073. | 0.00 |
| 24.9600 | -0.00760 | 313762. | -9070. | 3.87E-05 | 0.00 | 1.79E+11 | 152.6038 | 77061. | 0.00 |
| 25.2800 | -0.00744 | 280044. | -8486. | 4.50E-05 | 0.00 | 1.80E+11 | 151.2798 | 78048. | 0.00 |
| 25.6000 | -0.00726 | 248555. | -7909. | 5.07E-05 | 0.00 | 1.80E+11 | 149.3992 | 79036. | 0.00 |
| 25.9200 | -0.00705 | 219266. | -7340. | 5.57E-05 | 0.00 | 1.80E+11 | 146.9982 | 80024. | |

```
 0.00
  26.2400   -0.00683    192143.     -6781.   6.01E-05       0.00   1.80E+11   144.1119     81012.
 0.00
  26.5600   -0.00659    167143.     -6234.   6.39E-05       0.00   1.80E+11   140.7738     82000.
 0.00
  26.8800   -0.00634    144218.     -5700.   6.73E-05       0.00   1.80E+11   137.0162     82988.
 0.00
  27.2000   -0.00608    123312.     -5182.   7.01E-05       0.00   1.80E+11   132.8697     83976.
 0.00
  27.5200   -0.00580    104365.     -4681.   7.26E-05       0.00   1.80E+11   128.3631     84964.
 0.00
  27.8400   -0.00552     87309.     -4197.   7.46E-05       0.00   1.80E+11   123.5235     85952.
 0.00
  28.1600   -0.00523     72074.     -3733.   7.63E-05       0.00   1.80E+11   118.3759     86940.
 0.00
  28.4800   -0.00493     58584.     -3288.   7.77E-05       0.00   1.80E+11   112.9435     87928.
 0.00
  28.8000   -0.00463     46759.     -2866.   7.88E-05       0.00   1.80E+11   107.2473     88916.
 0.00
  29.1200   -0.00433     36515.     -2465.   7.97E-05       0.00   1.80E+11   101.3065     89904.
 0.00
  29.4400   -0.00402     27764.     -2088.   8.04E-05       0.00   1.80E+11    95.1378     90892.
 0.00
  29.7600   -0.00371     20416.     -1735.   8.09E-05       0.00   1.80E+11    88.7564     91880.
 0.00
  30.0800   -0.00340     14377.     -1407.   8.13E-05       0.00   1.80E+11    82.1748     92868.
 0.00
  30.4000   -0.00309      9549.     -1104.   8.16E-05       0.00   1.80E+11    75.4041     93856.
 0.00
  30.7200   -0.00277      5833.  -828.0995   8.17E-05       0.00   1.80E+11    68.4531     94844.
 0.00
  31.0400   -0.00246      3127.  -578.9185   8.18E-05       0.00   1.80E+11    61.3287     95832.
 0.00
  31.3600   -0.00214      1324.  -357.4177   8.19E-05       0.00   1.80E+11    54.0363     96820.
 0.00
  31.6800   -0.00183   318.6881  -164.2356   8.19E-05       0.00   1.80E+11    46.5794     97808.
 0.00
  32.0000   -0.00151       0.00       0.00   8.19E-05       0.00   1.80E+11    38.9600     49398.
 0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection              =     0.48363589 inches
Computed slope at pile head       =       0.000000 radians
Maximum bending moment            =      -5650999. inch-lbs
Maximum shear force               =         80000. lbs
Depth of maximum bending moment   =       0.000000 feet below pile head
Depth of maximum shear force      =       0.000000 feet below pile head
Number of iterations              =             25
Number of zero deflection points =              1
```

Hframe_B5_ACP.lp10o

---

Pile-head Deflection vs. Pile Length for Load Case 1

---

Boundary Condition Type 2, Shear and Slope

Shear = 80000. lbs
Slope = 0.00000
Axial Load = 100000. lbs

| Pile Length feet | Pile Head Deflection inches | Maximum Moment ln-lbs | Maximum Shear lbs |
|---|---|---|---|
| 32.00000 | 0.48363589 | -5650999. | 80000. |
| 30.40000 | 0.48911555 | -5665374. | 80000. |
| 28.80000 | 0.48571587 | -5650447. | 80000. |
| 27.20000 | 0.48900431 | -5653770. | 80000. |
| 25.60000 | 0.49160835 | -5652675. | 80000. |
| 24.00000 | 0.49449085 | -5644601. | 80000. |
| 22.40000 | 0.50041145 | -5640021. | 80000. |
| 20.80000 | 0.51834224 | -5666974. | 80000. |
| 19.20000 | 0.54303103 | -5723407. | 80000. |
| 17.60000 | 0.58845268 | -5985791. | 80000. |
| 16.00000 | 0.62865109 | -6335232. | 80000. |
| 14.40000 | 0.65941666 | -6675123. | 80000. |
| 12.80000 | 0.66940616 | -6901244. | 80000. |
| 11.20000 | 0.67556805 | -6771677. | 80000. |
| 9.60000 | 0.75646318 | -6055696. | 80000. |
| 8.00000 | 0.98915371 | -5034941. | 80000. |

---

Summary of Pile-head Responses for Conventional Analyses

---

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

| Load Case No. | Load Type 1 | Pile-head Load 1 | Load Type 2 | Pile-head Load 2 | Axial Loading lbs | Pile-head Deflection inches | Pile-head Rotation radians | Max Shear in Pile lbs | Max Moment in Pile in-lbs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | V, lb | 80000. | S, rad | 0.00 | 100000. | 0.4836 | 0.00 | 80000. | -5650999. |

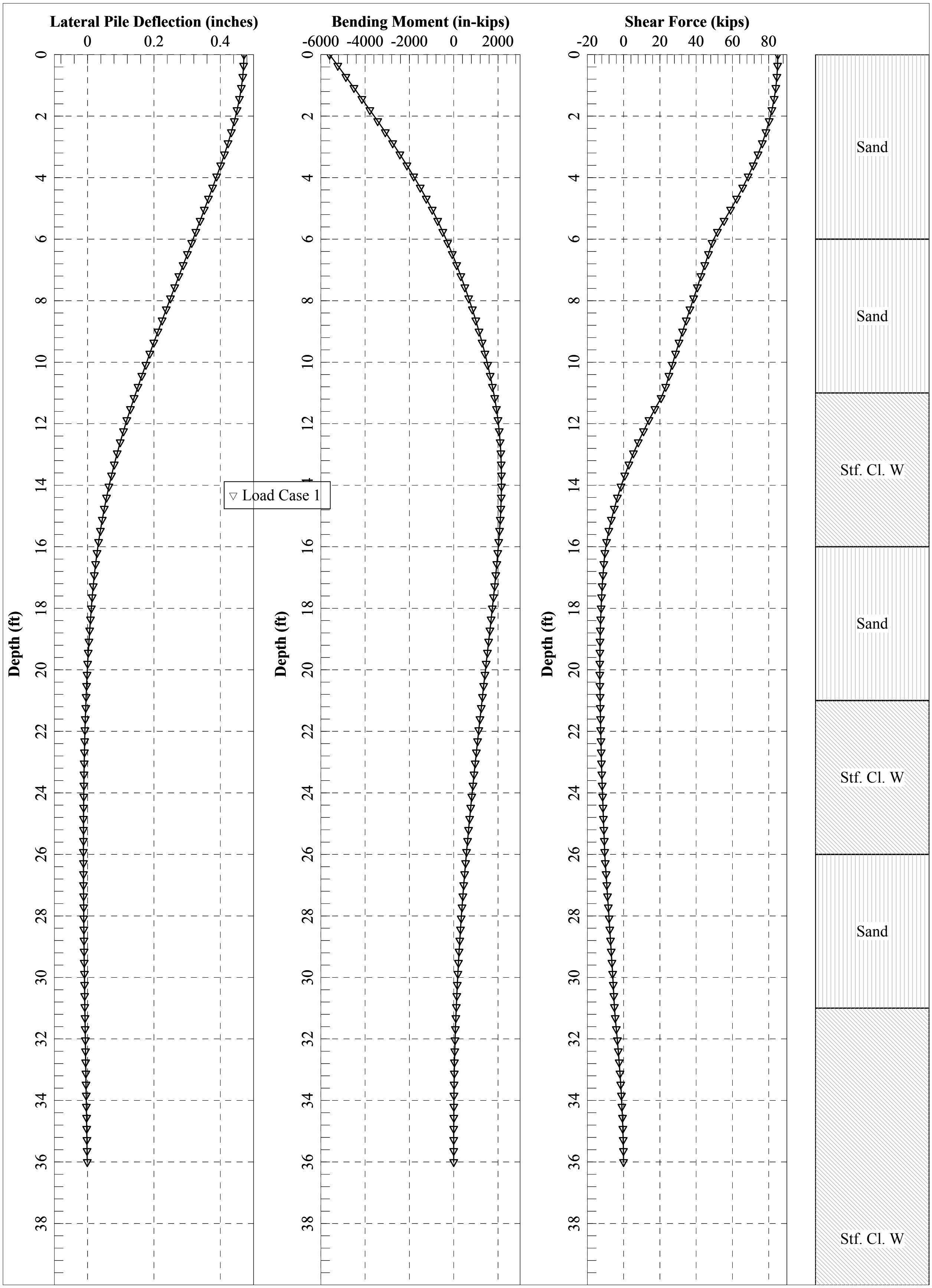
Maximum pile-head deflection = 0.4836358872 inches
Maximum pile-head rotation = -0.0000000000 radians = -0.000000 deg.

The analysis ended normally.

# Lpile analysis report (ACP)

**Boring: B-14**
**Equipment: Exhaust stacks**

# Bending Moment and Shear force with respect 0.5" head deflection for given ACP (30" diameter)



ExhaustStack_B14_ACP.lp10o

```
===============================================================================

                    LPile for Windows, Version 2018-10.006

                Analysis of Individual Piles and Drilled Shafts
               Subjected to Lateral Loading Using the p-y Method
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===============================================================================

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-------------------------------------------------------------------------------
                            Files Used for Analysis
-------------------------------------------------------------------------------

Path to file locations:
\512 GEO Dept\2018\0512-843 CP Crane Station Bowleys Quarters, MD\Engineering &
Resources\AugerCastPiles\LPile_analysis\

Name of input data file:
ExhaustStack_B14_ACP.lp10

Name of output report file:
ExhaustStack_B14_ACP.lp10

Name of plot output file:
ExhaustStack_B14_ACP.lp10

Name of runtime message file:
ExhaustStack_B14_ACP.lp10


-------------------------------------------------------------------------------
                           Date and Time of Analysis
-------------------------------------------------------------------------------

               Date:  June 14, 2018              Time:  13:03:31


-------------------------------------------------------------------------------
                                 Problem Title
-------------------------------------------------------------------------------
```

```
Project Name: CP Crane Power plant


Job Number:0512843


Client:ProEnergy


Engineer: SS


Description: Axial Capacity of Dirven Pile in Boring B1




--------------------------------------------------------------------------------
                          Program Options and Settings
--------------------------------------------------------------------------------

Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed                =          500
 - Deflection tolerance for convergence                =   1.0000E-05 in
 - Maximum allowable deflection                        =     100.0000 in
 - Number of pile increments                           =          100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats



--------------------------------------------------------------------------------
                     Pile Structural Properties and Geometry
--------------------------------------------------------------------------------
```

```
Number of pile sections defined                          =           1
Total length of pile                                     =      36.000 ft
Depth of ground surface below top of pile                =      0.0000 ft
```

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

| Point No. | Depth Below Pile Head feet | Pile Diameter inches |
|---|---|---|
| 1 | 0.000 | 30.0000 |
| 2 | 36.000 | 30.0000 |

Input Structural Properties for Pile Sections:

Pile Section No. 1:

```
   Section 1 is a round drilled shaft, bored pile, or CIDH pile
   Length of section                                     =    36.000000 ft
   Shaft Diameter                                        =    30.000000 in
   Shear capacity of section                             =       0.0000 lbs
```

## Ground Slope and Pile Batter Angles

```
Ground Slope Angle                                       =       0.000 degrees
                                                         =       0.000 radians

Pile Batter Angle                                        =       0.000 degrees
                                                         =       0.000 radians
```

## Soil and Rock Layering Information

The soil profile is modelled using 10 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

```
   Distance from top of pile to top of layer             =       0.0000 ft
   Distance from top of pile to bottom of layer          =     6.000000 ft
   Effective unit weight at top of layer                 =   110.000000 pcf
   Effective unit weight at bottom of layer              =   110.000000 pcf
   Friction angle at top of layer                        =    32.000000 deg.
   Friction angle at bottom of layer                     =    32.000000 deg.
   Subgrade k at top of layer                            =    67.000000 pci
   Subgrade k at bottom of layer                         =    67.000000 pci
```

```
Layer 2 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer          =     6.000000 ft
   Distance from top of pile to bottom of layer       =    11.000000 ft
   Effective unit weight at top of layer              =    62.600000 pcf
   Effective unit weight at bottom of layer           =    62.600000 pcf
   Friction angle at top of layer                     =    31.000000 deg.
   Friction angle at bottom of layer                  =    31.000000 deg.
   Subgrade k at top of layer                         =    20.000000 pci
   Subgrade k at bottom of layer                      =    20.000000 pci


Layer 3 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer          =    11.000000 ft
   Distance from top of pile to bottom of layer       =    16.000000 ft
   Effective unit weight at top of layer              =    57.600000 pcf
   Effective unit weight at bottom of layer           =    57.600000 pcf
   Undrained cohesion at top of layer                 =        1500. psf
   Undrained cohesion at bottom of layer              =        1500. psf
   Epsilon-50 at top of layer                         =       0.0000
   Epsilon-50 at bottom of layer                      =       0.0000
   Subgrade k at top of layer                         =    43.000000 pci
   Subgrade k at bottom of layer                      =    43.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 4 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer          =    16.000000 ft
   Distance from top of pile to bottom of layer       =    21.000000 ft
   Effective unit weight at top of layer              =    72.600000 pcf
   Effective unit weight at bottom of layer           =    72.600000 pcf
   Friction angle at top of layer                     =    29.000000 deg.
   Friction angle at bottom of layer                  =    29.000000 deg.
   Subgrade k at top of layer                         =    25.000000 pci
   Subgrade k at bottom of layer                      =    25.000000 pci


Layer 5 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer          =    21.000000 ft
   Distance from top of pile to bottom of layer       =    26.000000 ft
   Effective unit weight at top of layer              =    57.600000 pcf
   Effective unit weight at bottom of layer           =    57.600000 pcf
   Undrained cohesion at top of layer                 =        1500. psf
   Undrained cohesion at bottom of layer              =        1500. psf
   Epsilon-50 at top of layer                         =       0.0000
   Epsilon-50 at bottom of layer                      =       0.0000
   Subgrade k at top of layer                         =    15.000000 pci
   Subgrade k at bottom of layer                      =    15.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 6 is sand, p-y criteria by Reese et al., 1974
```

```
   Distance from top of pile to top of layer           =    26.000000 ft
   Distance from top of pile to bottom of layer        =    31.000000 ft
   Effective unit weight at top of layer               =    72.600000 pcf
   Effective unit weight at bottom of layer            =    72.600000 pcf
   Friction angle at top of layer                      =    30.000000 deg.
   Friction angle at bottom of layer                   =    30.000000 deg.
   Subgrade k at top of layer                          =    25.000000 pci
   Subgrade k at bottom of layer                       =    25.000000 pci


Layer 7 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    31.000000 ft
   Distance from top of pile to bottom of layer        =    46.000000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.600000 pcf
   Undrained cohesion at top of layer                  =        3500. psf
   Undrained cohesion at bottom of layer               =        3500. psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    50.000000 pci
   Subgrade k at bottom of layer                       =    50.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 8 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer           =    46.000000 ft
   Distance from top of pile to bottom of layer        =    77.000000 ft
   Effective unit weight at top of layer               =    72.600000 pcf
   Effective unit weight at bottom of layer            =    72.600000 pcf
   Friction angle at top of layer                      =    40.000000 deg.
   Friction angle at bottom of layer                   =    40.000000 deg.
   Subgrade k at top of layer                          =    67.000000 pci
   Subgrade k at bottom of layer                       =    67.000000 pci


Layer 9 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    77.000000 ft
   Distance from top of pile to bottom of layer        =    81.000000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.600000 pcf
   Undrained cohesion at top of layer                  =        3500. psf
   Undrained cohesion at bottom of layer               =        3500. psf
   Epsilon-50 at top of layer                          =       0.0000
   Epsilon-50 at bottom of layer                       =       0.0000
   Subgrade k at top of layer                          =    50.000000 pci
   Subgrade k at bottom of layer                       =    50.000000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.


Layer 10 is sand, p-y criteria by Reese et al., 1974

   Distance from top of pile to top of layer           =    81.000000 ft
   Distance from top of pile to bottom of layer        =    97.000000 ft
   Effective unit weight at top of layer               =    72.600000 pcf
```

```
   Effective unit weight at bottom of layer           =    72.600000 pcf
   Friction angle at top of layer                     =    40.000000 deg.
   Friction angle at bottom of layer                  =    40.000000 deg.
   Subgrade k at top of layer                         =    67.000000 pci
   Subgrade k at bottom of layer                      =    67.000000 pci
```

(Depth of the lowest soil layer extends 61.000 ft below the pile tip)

## Summary of Input Soil Properties

| Layer Layer Num. | Soil Type Name (p-y Curve Type) | Layer Depth ft | Effective Unit Wt. pcf | Undrained Cohesion psf | Angle of Friction deg. | E50 or krm | kpy pci |
|---|---|---|---|---|---|---|---|
| 1 | Sand | 0.00 | 110.0000 | -- | 32.0000 | -- | 67.0000 |
| | (Reese, et al.) | 6.0000 | 110.0000 | -- | 32.0000 | -- | 67.0000 |
| 2 | Sand | 6.0000 | 62.6000 | -- | 31.0000 | -- | 20.0000 |
| | (Reese, et al.) | 11.0000 | 62.6000 | -- | 31.0000 | -- | 20.0000 |
| 3 | Stiff Clay | 11.0000 | 57.6000 | 1500. | -- | default | 43.0000 |
| | with Free Water | 16.0000 | 57.6000 | 1500. | -- | default | 43.0000 |
| 4 | Sand | 16.0000 | 72.6000 | -- | 29.0000 | -- | 25.0000 |
| | (Reese, et al.) | 21.0000 | 72.6000 | -- | 29.0000 | -- | 25.0000 |
| 5 | Stiff Clay | 21.0000 | 57.6000 | 1500. | -- | default | 15.0000 |
| | with Free Water | 26.0000 | 57.6000 | 1500. | -- | default | 15.0000 |
| 6 | Sand | 26.0000 | 72.6000 | -- | 30.0000 | -- | 25.0000 |
| | (Reese, et al.) | 31.0000 | 72.6000 | -- | 30.0000 | -- | 25.0000 |
| 7 | Stiff Clay | 31.0000 | 62.6000 | 3500. | -- | default | 50.0000 |
| | with Free Water | 46.0000 | 62.6000 | 3500. | -- | default | 50.0000 |
| 8 | Sand | 46.0000 | 72.6000 | -- | 40.0000 | -- | 67.0000 |
| | (Reese, et al.) | 77.0000 | 72.6000 | -- | 40.0000 | -- | 67.0000 |
| 9 | Stiff Clay | 77.0000 | 62.6000 | 3500. | -- | default | 50.0000 |
| | with Free Water | 81.0000 | 62.6000 | 3500. | -- | default | 50.0000 |

```
 10          Sand              81.0000      72.6000       --          40.0000       --
67.0000
         (Reese, et al.)       97.0000      72.6000       --          40.0000       --
67.0000
```

--------------------------------------------------------------------------------

Static Loading Type

--------------------------------------------------------------------------------

Static loading criteria were used when computing p-y curves for all analyses.

--------------------------------------------------------------------------------

Pile-head Loading and Pile-head Fixity Conditions

--------------------------------------------------------------------------------

Number of loads specified = 1

| Load No. | Load Type | Condition 1 | Condition 2 | Axial Thrust Force, lbs | Compute Top y vs. Pile Length |
|---|---|---|---|---|---|
| 1 | 2 | V = 85000. lbs | S = 0.0000 in/in | 130000. | Yes |

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

--------------------------------------------------------------------------------

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

--------------------------------------------------------------------------------

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:
-------------------

Dimensions and Properties of Drilled Shaft (Bored Pile):
--------------------------------------------------------

```
Length of Section                                   =    36.000000 ft
Shaft Diameter                                      =    30.000000 in
Concrete Cover Thickness                            =     3.000000 in
Number of Reinforcing Bars                          =            8 bars
Yield Stress of Reinforcing Bars                    =       60000. psi
Modulus of Elasticity of Reinforcing Bars           =    29000000. psi
Gross Area of Shaft                                 =   706.858347 sq. in.
Total Area of Reinforcing Steel                     =    12.480000 sq. in.
Area Ratio of Steel Reinforcement                   =         1.77 percent
```

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```
Edge-to-Edge Bar Spacing                                =     7.234819 in
Maximum Concrete Aggregate Size                         =     0.750000 in
Ratio of Bar Spacing to Aggregate Size                  =        9.65
Offset of Center of Rebar Cage from Center of Pile      =       0.0000 in
Confined Section
Type: Hoop
Number of Confinement Bars                              =            1
Spacing of Confinement Bars                             =    12.000000 in
Yield Stress of Confinement Bars                        =       60000. psi
Total Area of Confinement Steel                         =     0.310000 sq. in.
rho_s                                                   =     0.004196
ke                                                      =     0.789730
f'cc                                                    =        4651. psi
f'l                                                     =    99.417766 psi
Epsilon cc                                              =     0.003627
Epsilon cu                                              =     0.010821
r                                                       =     1.552070
```

Axial Structural Capacities:
----------------------------

```
Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As     =     3109.686 kips
Tensile Load for Cracking of Concrete                   =     -330.553 kips
Nominal Axial Tensile Capacity                          =     -748.800 kips
```

Reinforcing Bar Dimensions and Positions Used in Computations:

| Bar Number | Bar Diam. inches | Bar Area sq. in. | X inches | Y inches |
|---|---|---|---|---|
| 1 | 1.410000 | 1.560000 | 11.295000 | 0.00000 |
| 2 | 1.410000 | 1.560000 | 7.986771 | 7.986771 |
| 3 | 1.410000 | 1.560000 | 0.00000 | 11.295000 |
| 4 | 1.410000 | 1.560000 | -7.986771 | 7.986771 |
| 5 | 1.410000 | 1.560000 | -11.295000 | 0.00000 |
| 6 | 1.410000 | 1.560000 | -7.986771 | -7.986771 |
| 7 | 1.410000 | 1.560000 | 0.00000 | -11.295000 |
| 8 | 1.410000 | 1.560000 | 7.986771 | -7.986771 |

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero =  7.235 inches
between bars 1 and 2.

Ratio of bar spacing to maximum aggregate size = 9.65

Concrete Properties:
--------------------

```
Compressive Strength of Concrete                        =        4000. psi
Modulus of Elasticity of Concrete                       =     3604997. psi
Modulus of Rupture of Concrete                          =  -474.341649 psi
Compression Strain at Peak Stress                       =     0.001886
Tensile Strain at Fracture of Concrete                  =   -0.0001154
Maximum Coarse Aggregate Size                           =     0.750000 in
```

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Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

| Number | Axial Thrust Force kips |
|---|---|
| 1 | 130.000 |

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318, Section 10.3.4.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 130.000 kips

| Bending Curvature rad/in. | Bending Moment in-kip | Bending Stiffness kip-in2 | Depth to N Axis in | Max Comp Strain in/in | Max Tens Strain in/in | Max Conf Stress ksi | Max Conc Stress ksi | Max Steel Stress ksi | Run Msg |
|---|---|---|---|---|---|---|---|---|---|
| 0.00000125 | 223.6200871 | 178896070. | 49.0343267 | 0.00006129 | 0.00002379 | 0.2195816 | 0.2549609 | 1.7720568 | |
| 0.00000250 | 447.2096777 | 178883871. | 32.0364633 | 0.00008009 | 0.00000509 | 0.2859928 | 0.3309459 | 2.3117686 | |
| 0.00000375 | 670.7059091 | 178854909. | 26.3788227 | 0.00009892 | -0.00001358 | 0.3522193 | 0.4062775 | 2.8523845 | |
| 0.00000500 | 895.2907560 | 179058151. | 23.5644714 | 0.0001178 | -0.00003218 | 0.4183701 | 0.4811155 | 3.3950984 | |
| 0.00000625 | 1121. | 179332277. | 21.8889752 | 0.0001368 | -0.00005069 | 0.4844435 | 0.5554887 | 3.9401893 | |
| 0.00000750 | 1346. | 179483386. | 20.7782556 | 0.0001558 | -0.00006916 | 0.5502845 | 0.6292508 | 4.4866456 | |
| 0.00000875 | 1571. | 179504575. | 19.9880524 | 0.0001749 | -0.00008760 | 0.6157967 | 0.7023213 | 5.0339058 | |
| 0.00001000 | 1794. | 179420532. | 19.3971268 | 0.0001940 | -0.0001060 | 0.6809179 | 0.7746568 | 5.5816668 | |
| 0.00001125 | 1794. | 159484918. | 16.6472482 | 0.0001873 | -0.0001502 | 0.6572609 | 0.7484124 | 5.3822272 | C |
| 0.00001250 | 1794. | 143536426. | 16.0275482 | 0.0002003 | -0.0001747 | 0.7014995 | 0.7974596 | 5.7556112 | C |
| 0.00001375 | 1794. | 130487660. | 15.5027938 | 0.0002132 | -0.0001993 | 0.7446838 | 0.8452160 | 6.1219266 | C |
| 0.00001500 | 1794. | 119613688. | 15.0521368 | 0.0002258 | -0.0002242 | 0.7869675 | | | |

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```
0.8918645     6.4824295 C
   0.00001625         1794.    110412635.    14.6607172     0.0002382    -0.0002493     0.8284783
0.9375568    -7.1579495 C
   0.00001750         1794.    102526019.    14.3174366     0.0002506    -0.0002744     0.8693136
0.9824093    -7.8827759 C
   0.00002000         1794.     89710266.    13.7422457     0.0002748    -0.0003252     0.9491725
1.0698615    -9.3424978 C
   0.00002250         1899.     84398537.    13.2794977     0.0002988    -0.0003762     1.0270152
1.1547904   -10.8122529 C
   0.00002500         2026.     81041442.    12.8984787     0.0003225    -0.0004275     1.1030971
1.2375170   -12.2898529 C
   0.00002750         2152.     78241081.    12.5797240     0.0003459    -0.0004791     1.1776739
1.3183535   -13.7730450 C
   0.00003000         2276.     75868210.    12.3090088     0.0003693    -0.0005307     1.2508742
1.3974677   -15.2606623 C
   0.00003250         2400.     73832201.    12.0766154     0.0003925    -0.0005825     1.3228362
1.4750330   -16.7514149 C
   0.00003500         2522.     72064986.    11.8750889     0.0004156    -0.0006344     1.3936386
1.5511540   -18.2445347 C
   0.00003750         2644.     70512078.    11.6976169     0.0004387    -0.0006863     1.4632038
1.6257649   -19.7407166 C
   0.00004000         2766.     69143064.    11.5425394     0.0004617    -0.0007383     1.5318755
1.6992487   -21.2366542 C
   0.00004250         2887.     67917726.    11.4031903     0.0004846    -0.0007904     1.5992996
1.7712389   -22.7356928 C
   0.00004500         3007.     66821724.    11.2802043     0.0005076    -0.0008424     1.6659090
1.8422081   -24.2335833 C
   0.00004750         3127.     65829183.    11.1688491     0.0005305    -0.0008945     1.7313969
1.9118376   -25.7332853 C
   0.00005000         3246.     64927940.    11.0687015     0.0005534    -0.0009466     1.7959527
1.9803361   -27.2328827 C
   0.00005250         3366.     64106676.    10.9788729     0.0005764    -0.0009986     1.8596757
2.0478137   -28.7312909 C
   0.00005500         3484.     63351408.    10.8964981     0.0005993    -0.0010507     1.9223356
2.1140309   -30.2308353 C
   0.00006000         3721.     62011381.    10.7530425     0.0006452    -0.0011548     2.0449031
2.2431557   -33.2287058 C
   0.00006500         3956.     60857589.    10.6338529     0.0006912    -0.0012588     2.1640072
2.3680888   -36.2224371 C
   0.00007000         4189.     59846555.    10.5316808     0.0007372    -0.0013628     2.2792581
2.4884127   -39.2161877 C
   0.00007500         4422.     58953398.    10.4455632     0.0007834    -0.0014666     2.3911174
2.6045861   -42.2046497 C
   0.00008000         4652.     58155710.    10.3725403     0.0008298    -0.0015702     2.4995794
2.7165628   -45.1877063 C
   0.00008500         4882.     57435018.    10.3091334     0.0008763    -0.0016737     2.6044153
2.8240572   -48.1682359 C
   0.00009000         5110.     56778980.    10.2543668     0.0009229    -0.0017771     2.7057769
2.9271663   -51.1446023 C
   0.00009500         5337.     56177769.    10.2075027     0.0009697    -0.0018803     2.8038128
3.0259703   -54.1150797 C
   0.00010000         5562.     55622888.    10.1674034     0.0010167    -0.0019833     2.8985506
3.1204156   -57.0795298 C
    0.0001050         5786.     55107450.    10.1331492     0.0010640    -0.0020860     2.9900240
3.2104465   -60.0000000 CY
    0.0001150         6230.     54173306.    10.0793049     0.0011591    -0.0022909     3.1633407
3.3770323   -60.0000000 CY
    0.0001250         6664.     53309291.    10.0391917     0.0012549    -0.0024951     3.3236870
3.5248382   -60.0000000 CY
```

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.0001350 | 6997. | 51829965. | 9.9667621 | 0.0013455 | -0.0027045 | 3.4628756 | 3.6461738 | -60.0000000 | CY |
| 0.0001450 | 7293. | 50297845. | 9.8952863 | 0.0014348 | -0.0029152 | 3.5889097 | 3.7482617 | -60.0000000 | CY |
| 0.0001550 | 7570. | 48838979. | 9.8308305 | 0.0015238 | -0.0031262 | 3.7041237 | 3.8327192 | -60.0000000 | CY |
| 0.0001650 | 7719. | 46779910. | 9.7151653 | 0.0016030 | -0.0033470 | 3.7983584 | 3.8933390 | -60.0000000 | CY |
| 0.0001750 | 7807. | 44611973. | 9.5838802 | 0.0016772 | -0.0035728 | 3.8799287 | 3.9377341 | -60.0000000 | CY |
| 0.0001850 | 7894. | 42667757. | 9.4697880 | 0.0017519 | -0.0037981 | 3.9560756 | 3.9704558 | -60.0000000 | CY |
| 0.0001950 | 7977. | 40907534. | 9.3666363 | 0.0018265 | -0.0040235 | 4.0263515 | 3.9910897 | -60.0000000 | CY |
| 0.0002050 | 8058. | 39308127. | 9.2756271 | 0.0019015 | -0.0042485 | 4.0916034 | 3.9997293 | -60.0000000 | CY |
| 0.0002150 | 8137. | 37847240. | 9.1960665 | 0.0019772 | -0.0044728 | 4.1522231 | 3.9999613 | -60.0000000 | CY |
| 0.0002250 | 8214. | 36504679. | 9.1254157 | 0.0020532 | -0.0046968 | 4.2082256 | 3.9999963 | -60.0000000 | CY |
| 0.0002350 | 8287. | 35264914. | 9.0616248 | 0.0021295 | -0.0049205 | 4.2596905 | 3.9999859 | 60.0000000 | CY |
| 0.0002450 | 8359. | 34117900. | 9.0057877 | 0.0022064 | -0.0051436 | 4.3071548 | 3.9998736 | 60.0000000 | CY |
| 0.0002550 | 8429. | 33053313. | 8.9568702 | 0.0022840 | -0.0053660 | 4.3507696 | 3.9994043 | 60.0000000 | CY |
| 0.0002650 | 8497. | 32062435. | 8.9139701 | 0.0023622 | -0.0055878 | 4.3906866 | 3.9981269 | 60.0000000 | CY |
| 0.0002750 | 8563. | 31137849. | 8.8762947 | 0.0024410 | -0.0058090 | 4.4270583 | 3.9953895 | 60.0000000 | CY |
| 0.0002850 | 8628. | 30272787. | 8.8428166 | 0.0025202 | -0.0060298 | 4.4600006 | 3.9999398 | 60.0000000 | CY |
| 0.0002950 | 8691. | 29460802. | 8.8121961 | 0.0025996 | -0.0062504 | 4.4895999 | 3.9982968 | 60.0000000 | CY |
| 0.0003050 | 8752. | 28694166. | 8.7841271 | 0.0026792 | -0.0064708 | 4.5160618 | 3.9952539 | 60.0000000 | CY |
| 0.0003150 | 8805. | 27953515. | 8.7544719 | 0.0027577 | -0.0066923 | 4.5392372 | 3.9992187 | 60.0000000 | CY |
| 0.0003250 | 8849. | 27229220. | 8.7207819 | 0.0028343 | -0.0069157 | 4.5592269 | 3.9935463 | 60.0000000 | CY |
| 0.0003350 | 8883. | 26516530. | 8.6819375 | 0.0029084 | -0.0071416 | 4.5762821 | 3.9987704 | 60.0000000 | CY |
| 0.0003450 | 8903. | 25805689. | 8.6348548 | 0.0029790 | -0.0073710 | 4.5905294 | 3.9981176 | 60.0000000 | CY |
| 0.0003550 | 8915. | 25113549. | 8.5850043 | 0.0030477 | -0.0076023 | 4.6026630 | 3.9954891 | 60.0000000 | CY |
| 0.0003650 | 8923. | 24445823. | 8.5332721 | 0.0031146 | -0.0078354 | 4.6129607 | 3.9989282 | 60.0000000 | CY |
| 0.0003750 | 8928. | 23807798. | 8.4807818 | 0.0031803 | -0.0080697 | 4.6216700 | 3.9999146 | 60.0000000 | CY |
| 0.0003850 | 8933. | 23202405. | 8.4315943 | 0.0032462 | -0.0083038 | 4.6291153 | 3.9920945 | 60.0000000 | CY |
| 0.0003950 | 8938. | 22627486. | 8.3851856 | 0.0033121 | -0.0085379 | 4.6353493 | 3.9965530 | 60.0000000 | CY |
| 0.0004050 | 8942. | 22078720. | 8.3429326 | 0.0033789 | -0.0087711 | 4.6404819 | 3.9992322 | 60.0000000 | CY |
| 0.0004150 | 8946. | 21556116. | 8.3030768 | 0.0034458 | -0.0090042 | 4.6445108 | 3.9989792 | 60.0000000 | CY |
| 0.0004250 | 8950. | 21057740. | 8.2655355 | 0.0035129 | -0.0092371 | 4.6474964 | | | |

```
3.9899246    60.0000000 CY
   0.0004350          8952.     20580310.     8.2288981     0.0035796    -0.0094704     4.6494803
3.9947325    60.0000000 CY
   0.0004450          8954.     20121652.     8.1945198     0.0036466    -0.0097034     4.6505429
3.9980207    60.0000000 CY
   0.0004550          8956.     19683011.     8.1618905     0.0037137    -0.0099363     4.6507294
3.9997347    60.0000000 CY
   0.0004650          8957.     19263031.     8.1309718     0.0037809    -0.0101691     4.6504594
3.9964318    60.0000000 CY
   0.0004750          8959.     18860532.     8.1016588     0.0038483    -0.0104017     4.6507570
3.9880024    60.0000000 CY
   0.0004850          8959.     18471655.     8.1037159     0.0039303    -0.0106197     4.6504002
3.9951445    60.0000000 CY
   0.0004950          8959.     18098490.     8.0789139     0.0039991    -0.0108509     4.6507626
3.9981598    60.0000000 CY
   0.0005050          8959.     17740104.     8.1045429     0.0040928    -0.0110572     4.6503500
3.9969358    60.0000000 CY
   0.0005450          8959.     16438078.     8.1620068     0.0044483    -0.0119017     4.6501561
3.9912926    60.0000000 CY
   0.0005850          8959.     15314107.     8.2666193     0.0048360    -0.0127140     4.6503169
3.9833907    60.0000000 CY
   0.0006250          8959.     14334004.     8.2912509     0.0051820    -0.0135680     4.6506152
3.9954505    60.0000000 CY
   0.0006650          8959.     13471808.     8.4261512     0.0056034    -0.0143466     4.6501349
3.9917325    60.0000000 CY
   0.0007050          8959.     12707450.     8.4684394     0.0059702    -0.0151798     4.6499691
3.9981768    60.0000000 CY
   0.0007450          8959.     12025171.     8.4949253     0.0063287    -0.0160213     4.6499132
3.9781846    60.0000000 CY
   0.0007850          8959.     11412424.     8.5098740     0.0066803    -0.0168697     4.6496302
3.9987179    60.0000000 CY
   0.0008250          8959.     10859094.     8.5200734     0.0070291    -0.0177209     4.6504075
3.9783544    60.0000000 CY
   0.0008650          8959.     10356939.     8.5274694     0.0073763    -0.0185737     4.6507450
3.9910430    60.0000000 CY
```

---------------------------------------------------------------------------------

Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1

---------------------------------------------------------------------------------

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

| Load No. | Axial Thrust kips | Nominal Mom. Cap. in-kip | Max. Comp. Strain |
|---|---|---|---|
| 1 | 130.000 | 8906.735 | 0.00300000 |

Note that the values of moment capacity in the table above are not
factored by a strength reduction factor (phi-factor).

In ACI 318, the value of the strength reduction factor depends on whether
the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.70).

The above values should be multiplied by the appropriate strength reduction
factor to compute ultimate moment capacity according to ACI 318, Section
9.3.2.2 or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

| Axial Load No. | Resist. Factor for Moment | Nominal Moment Cap in-kips | Ult. (Fac) Ax. Thrust kips | Ult. (Fac) Moment Cap in-kips | Bend. Stiff. at Ult Mom kip-in^2 |
|---|---|---|---|---|---|
| 1 | 0.65 | 8907. | 84.500000 | 5789. | 55100932. |
| 1 | 0.70 | 8907. | 91.000000 | 6235. | 54163775. |
| 1 | 0.75 | 8907. | 97.500000 | 6680. | 53236564. |

---

Layering Correction Equivalent Depths of Soil & Rock Layers

---

| Layer No. | Top of Layer Below Pile Head ft | Equivalent Top Depth Below Grnd Surf ft | Same Layer Type As Layer Above | Layer is Rock or is Below Rock Layer | F0 Integral for Layer lbs | F1 Integral for Layer lbs |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | N.A. | No | 0.00 | 53677. |
| 2 | 6.0000 | 6.2180 | Yes | No | 53677. | 102023. |
| 3 | 11.0000 | 126.7401 | No | No | 155700. | 18085. |
| 4 | 16.0000 | 13.9800 | No | No | 173785. | 199970. |
| 5 | 21.0000 | 119.1143 | No | No | 373755. | 18085. |
| 6 | 26.0000 | 19.2009 | No | No | 391840. | 339008. |
| 7 | 31.0000 | 116.1090 | No | No | 730848. | 42198. |
| 8 | 46.0000 | 46.0000 | No | No | 773045. | 0.00 |
| 9 | 77.0000 | 77.0000 | No | No | 0.00 | 0.00 |
| 10 | 81.0000 | 81.0000 | No | No | 0.00 | N.A. |

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

---

Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

| | | |
|---|---|---|
| Shear force at pile head | = | 85000.0 lbs |
| Rotation of pile head | = | 0.000E+00 radians |
| Axial load at pile head | = | 130000.0 lbs |

(Zero slope for this load indicates fixed-head conditions)

ExhaustStack_B14_ACP.lp10o

| Depth X feet | Deflect. y inches | Bending Moment in-lbs | Shear Force lbs | Slope S radians | Total Stress psi* | Bending Stiffness in-lb^2 | Soil Res. p lb/inch | Soil Spr. Es*h lb/inch | Distrib. Lat. Load lb/inch |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.4710 | -5601804. | 85000. | 0.00 | 0.00 | 5.55E+10 | 0.00 | 0.00 | 0.00 |
| 0.3600 | 0.4700 | -5234482. | 84882. | -4.22E-04 | 0.00 | 5.55E+10 | -54.5233 | 501.1236 | 0.00 |
| 0.7200 | 0.4673 | -4867948. | 84517. | -8.08E-04 | 0.00 | 5.75E+10 | -114.5269 | 1059. | 0.00 |
| 1.0800 | 0.4630 | -4503347. | 83884. | -0.00116 | 0.00 | 5.87E+10 | -178.3581 | 1664. | 0.00 |
| 1.4400 | 0.4573 | -4141887. | 82970. | -0.00147 | 0.00 | 6.00E+10 | -244.8289 | 2313. | 0.00 |
| 1.8000 | 0.4503 | -3784830. | 81766. | -0.00175 | 0.00 | 6.17E+10 | -312.7270 | 3000. | 0.00 |
| 2.1600 | 0.4422 | -3433459. | 80269. | -0.00200 | 0.00 | 6.37E+10 | -380.2271 | 3715. | 0.00 |
| 2.5200 | 0.4330 | -3089054. | 78485. | -0.00222 | 0.00 | 6.61E+10 | -445.9229 | 4449. | 0.00 |
| 2.8800 | 0.4230 | -2752858. | 76419. | -0.00241 | 0.00 | 6.93E+10 | -510.2884 | 5211. | 0.00 |
| 3.2400 | 0.4122 | -2426088. | 74085. | -0.00256 | 0.00 | 7.34E+10 | -570.6642 | 5980. | 0.00 |
| 3.6000 | 0.4009 | -2109888. | 71500. | -0.00269 | 0.00 | 7.91E+10 | -625.7611 | 6744. | 0.00 |
| 3.9600 | 0.3890 | -1805302. | 68682. | -0.00279 | 0.00 | 8.92E+10 | -678.9583 | 7541. | 0.00 |
| 4.3200 | 0.3767 | -1513337. | 65640. | -0.00286 | 0.00 | 1.79E+11 | -729.4391 | 8365. | 0.00 |
| 4.6800 | 0.3643 | -1234966. | 62394. | -0.00289 | 0.00 | 1.79E+11 | -773.4205 | 9172. | 0.00 |
| 5.0400 | 0.3518 | -971011. | 58972. | -0.00292 | 0.00 | 1.79E+11 | -810.7700 | 9957. | 0.00 |
| 5.4000 | 0.3391 | -722174. | 55390. | -0.00294 | 0.00 | 1.79E+11 | -847.3516 | 10795. | 0.00 |
| 5.7600 | 0.3264 | -489141. | 51667. | -0.00295 | 0.00 | 1.79E+11 | -876.4912 | 11601. | 0.00 |
| 6.1200 | 0.3136 | -272459. | 48779. | -0.00296 | 0.00 | 1.79E+11 | -460.6406 | 6345. | 0.00 |
| 6.4800 | 0.3008 | -64369. | 46773. | -0.00296 | 0.00 | 1.79E+11 | -467.8302 | 6718. | 0.00 |
| 6.8400 | 0.2880 | 134990. | 44741. | -0.00296 | 0.00 | 1.79E+11 | -472.7969 | 7092. | 0.00 |
| 7.2000 | 0.2752 | 325524. | 42693. | -0.00296 | 0.00 | 1.79E+11 | -475.5748 | 7465. | 0.00 |
| 7.5600 | 0.2625 | 507178. | 40637. | -0.00295 | 0.00 | 1.79E+11 | -476.2038 | 7838. | 0.00 |
| 7.9200 | 0.2498 | 679939. | 38583. | -0.00293 | 0.00 | 1.79E+11 | -474.7286 | 8211. | 0.00 |
| 8.2800 | 0.2371 | 843830. | 36540. | -0.00291 | 0.00 | 1.79E+11 | -471.1988 | 8585. | 0.00 |
| 8.6400 | 0.2246 | 998916. | 34516. | -0.00289 | 0.00 | 1.79E+11 | -465.6680 | 8958. | 0.00 |
| 9.0000 | 0.2121 | 1145299. | 32521. | -0.00287 | 0.00 | 1.79E+11 | -458.1938 | 9331. | |

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```
0.00
  9.3600     0.1998   1283115.     30561.    -0.00284       0.00   1.79E+11  -448.8372      9704.
0.00
  9.7200     0.1876   1412537.     28647.    -0.00280       0.00   1.79E+11  -437.6623     10078.
0.00
 10.0800     0.1756   1533772.     26784.    -0.00277       0.00   1.80E+11  -424.7362     10451.
0.00
 10.4400     0.1637   1647060.     24981.    -0.00273       0.00   1.79E+11  -410.1285     10824.
0.00
 10.8000     0.1520   1752671.     23244.    -0.00269       0.00   1.79E+11  -393.9112     11197.
0.00
 11.1600     0.1404   1850908.     20646.    -0.00262       0.00   8.67E+10  -808.7400     24877.
0.00
 11.5200     0.1293   1934000.     17239.    -0.00253       0.00   8.34E+10  -768.6559     25679.
0.00
 11.8800     0.1186   2002690.     14008.    -0.00242       0.00   8.16E+10  -727.0889     26482.
0.00
 12.2400     0.1084   2057752.     10959.    -0.00232       0.00   8.03E+10  -684.4395     27284.
0.00
 12.6000    0.09861   2099978.      8096.    -0.00220       0.00   7.93E+10  -641.0952     28087.
0.00
 12.9600    0.08934   2130176.      5421.    -0.00209       0.00   7.87E+10  -597.4276     28889.
0.00
 13.3200    0.08057   2149158.      2934.    -0.00197       0.00   7.83E+10  -553.7890     29692.
0.00
 13.6800    0.07232   2157739.   635.3195    -0.00185       0.00   7.81E+10  -510.5109     30494.
0.00
 14.0400    0.06459   2156726.     -1478.    -0.00173       0.00   7.81E+10  -467.9019     31297.
0.00
 14.4000    0.05737   2146913.     -3409.    -0.00161       0.00   7.83E+10  -426.2466     32099.
0.00
 14.7600    0.05066   2129080.     -5163.    -0.00149       0.00   7.87E+10  -385.8040     32902.
0.00
 15.1200    0.04445   2103980.     -6746.    -0.00138       0.00   7.92E+10  -346.8077     33704.
0.00
 15.4800    0.03874   2072344.     -8163.    -0.00127       0.00   7.99E+10  -309.4643     34507.
0.00
 15.8400    0.03352   2034869.     -9424.    -0.00116       0.00   8.08E+10  -273.9542     35309.
0.00
 16.2000    0.02876   1992221.    -10317.    -0.00105       0.00   8.19E+10  -139.7851     20995.
0.00
 16.5600    0.02446   1946905.    -10882.   -9.45E-04       0.00   8.30E+10  -121.5236     21462.
0.00
 16.9200    0.02060   1899265.    -11370.   -8.46E-04       0.00   8.44E+10  -104.5540     21928.
0.00
 17.2800    0.01715   1849618.    -11788.   -7.51E-04       0.00   8.67E+10   -88.9272     22395.
0.00
 17.6400    0.01411   1798260.    -12141.   -6.65E-04       0.00   9.71E+10   -74.6627     22861.
0.00
 18.0000    0.01141   1745464.    -12436.   -6.04E-04       0.00   1.79E+11   -61.6058     23328.
0.00
 18.3600    0.00889   1691494.    -12674.   -5.63E-04       0.00   1.79E+11   -48.9656     23795.
0.00
 18.7200    0.00655   1636588.    -12860.   -5.23E-04       0.00   1.79E+11   -36.7692     24261.
0.00
 19.0800    0.00437   1580974.    -12993.   -4.84E-04       0.00   1.80E+11   -25.0409     24728.
0.00
 19.4400    0.00237   1524871.    -13077.   -4.46E-04       0.00   1.80E+11   -13.8020     25194.
0.00
```

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19.8000 | 5.17E-04 | 1468489. | -13114. | -4.10E-04 | 0.00 | 1.79E+11 | -3.0710 | 25661. | 0.00 |
| 20.1600 | -0.00118 | 1412031. | -13105. | -3.76E-04 | 0.00 | 1.79E+11 | 7.1361 | 26127. | 0.00 |
| 20.5200 | -0.00273 | 1355686. | -13053. | -3.43E-04 | 0.00 | 1.79E+11 | 16.8059 | 26594. | 0.00 |
| 20.8800 | -0.00414 | 1299637. | -12961. | -3.11E-04 | 0.00 | 1.79E+11 | 25.9275 | 27060. | 0.00 |
| 21.2400 | -0.00541 | 1244054. | -12860. | -2.80E-04 | 0.00 | 1.79E+11 | 20.6954 | 16516. | 0.00 |
| 21.6000 | -0.00656 | 1188841. | -12760. | -2.51E-04 | 0.00 | 1.79E+11 | 25.4963 | 16796. | 0.00 |
| 21.9600 | -0.00758 | 1134087. | -12640. | -2.23E-04 | 0.00 | 1.79E+11 | 29.9566 | 17076. | 0.00 |
| 22.3200 | -0.00848 | 1079877. | -12502. | -1.96E-04 | 0.00 | 1.79E+11 | 34.0751 | 17356. | 0.00 |
| 22.6800 | -0.00927 | 1026289. | -12347. | -1.71E-04 | 0.00 | 1.79E+11 | 37.8518 | 17636. | 0.00 |
| 23.0400 | -0.00996 | 973392. | -12176. | -1.47E-04 | 0.00 | 1.79E+11 | 41.2877 | 17916. | 0.00 |
| 23.4000 | -0.01054 | 921254. | -11991. | -1.24E-04 | 0.00 | 1.79E+11 | 44.3852 | 18196. | 0.00 |
| 23.7600 | -0.01102 | 869931. | -11793. | -1.02E-04 | 0.00 | 1.79E+11 | 47.1475 | 18476. | 0.00 |
| 24.1200 | -0.01142 | 819476. | -11584. | -8.17E-05 | 0.00 | 1.79E+11 | 49.5792 | 18756. | 0.00 |
| 24.4800 | -0.01173 | 769935. | -11365. | -6.25E-05 | 0.00 | 1.79E+11 | 51.6857 | 19036. | 0.00 |
| 24.8400 | -0.01196 | 721349. | -11138. | -4.45E-05 | 0.00 | 1.79E+11 | 53.4734 | 19316. | 0.00 |
| 25.2000 | -0.01211 | 673750. | -10904. | -2.76E-05 | 0.00 | 1.79E+11 | 54.9495 | 19596. | 0.00 |
| 25.5600 | -0.01220 | 627168. | -10664. | -1.19E-05 | 0.00 | 1.79E+11 | 56.1223 | 19875. | 0.00 |
| 25.9200 | -0.01222 | 581625. | -10420. | 2.66E-06 | 0.00 | 1.79E+11 | 57.0006 | 20155. | 0.00 |
| 26.2800 | -0.01218 | 537138. | -10089. | 1.62E-05 | 0.00 | 1.79E+11 | 95.9906 | 34059. | 0.00 |
| 26.6400 | -0.01208 | 494435. | -9674. | 2.86E-05 | 0.00 | 1.79E+11 | 96.5232 | 34525. | 0.00 |
| 27.0000 | -0.01193 | 453526. | -9256. | 4.01E-05 | 0.00 | 1.79E+11 | 96.6168 | 34992. | 0.00 |
| 27.3600 | -0.01173 | 414414. | -8840. | 5.06E-05 | 0.00 | 1.79E+11 | 96.2898 | 35459. | 0.00 |
| 27.7200 | -0.01149 | 377094. | -8425. | 6.01E-05 | 0.00 | 1.79E+11 | 95.5607 | 35925. | 0.00 |
| 28.0800 | -0.01121 | 341552. | -8015. | 6.88E-05 | 0.00 | 1.79E+11 | 94.4484 | 36392. | 0.00 |
| 28.4400 | -0.01090 | 307768. | -7610. | 7.66E-05 | 0.00 | 1.79E+11 | 92.9718 | 36858. | 0.00 |
| 28.8000 | -0.01055 | 275715. | -7212. | 8.37E-05 | 0.00 | 1.79E+11 | 91.1496 | 37325. | 0.00 |
| 29.1600 | -0.01017 | 245360. | -6823. | 9.00E-05 | 0.00 | 1.79E+11 | 89.0009 | 37791. | 0.00 |
| 29.5200 | -0.00977 | 216662. | -6444. | 9.55E-05 | 0.00 | 1.79E+11 | 86.5443 | 38258. | 0.00 |
| 29.8800 | -0.00935 | 189576. | -6076. | 1.00E-04 | 0.00 | 1.79E+11 | 83.7984 | 38724. | 0.00 |
| 30.2400 | -0.00890 | 164051. | -5721. | 1.05E-04 | 0.00 | 1.79E+11 | 80.7815 | 39191. | |

```
 0.00
  30.6000   -0.00844    140032.     -5379.   1.08E-04       0.00   1.79E+11    77.5116     39658.
 0.00
  30.9600   -0.00797    117458.     -5051.   1.12E-04       0.00   1.79E+11    74.0065     40124.
 0.00
  31.3200   -0.00748     96263.     -4588.   1.14E-04       0.00   1.79E+11   140.5670     81181.
 0.00
  31.6800   -0.00698     77690.     -3998.   1.16E-04       0.00   1.79E+11   132.7194     82115.
 0.00
  32.0400   -0.00648     61593.     -3442.   1.18E-04       0.00   1.79E+11   124.5010     83048.
 0.00
  32.4000   -0.00596     47818.     -2923.   1.19E-04       0.00   1.79E+11   115.9390     83981.
 0.00
  32.7600   -0.00545     36207.     -2441.   1.20E-04       0.00   1.79E+11   107.0577     84914.
 0.00
  33.1200   -0.00493     26593.     -1998.   1.21E-04       0.00   1.79E+11    97.8777     85847.
 0.00
  33.4800   -0.00440     18805.     -1596.   1.22E-04       0.00   1.79E+11    88.4169     86780.
 0.00
  33.8400   -0.00388     12667.     -1235.   1.22E-04       0.00   1.79E+11    78.6900     87713.
 0.00
  34.2000   -0.00335      7998.  -916.6319   1.22E-04       0.00   1.79E+11    68.7087     88646.
 0.00
  34.5600   -0.00282      4610.  -641.8990   1.22E-04       0.00   1.79E+11    58.4824     89580.
 0.00
  34.9200   -0.00229      2314.  -411.8583   1.22E-04       0.00   1.79E+11    48.0179     90513.
 0.00
  35.2800   -0.00176   914.3440  -227.5285   1.22E-04       0.00   1.79E+11    37.3200     91446.
 0.00
  35.6400   -0.00123   210.9086   -89.9116   1.22E-04       0.00   1.79E+11    26.3916     92379.
 0.00
  36.0000  -7.05E-04       0.00       0.00   1.22E-04       0.00   1.79E+11    15.2342     46656.
 0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.47096665 inches
Computed slope at pile head      =       0.000000 radians
Maximum bending moment           =      -5601804. inch-lbs
Maximum shear force              =         85000. lbs
Depth of maximum bending moment  =       0.000000 feet below pile head
Depth of maximum shear force     =       0.000000 feet below pile head
Number of iterations             =             73
Number of zero deflection points =              1
```

--------------------------------------------------------------------------------
Pile-head Deflection vs. Pile Length for Load Case 1
--------------------------------------------------------------------------------

ExhaustStack_B14_ACP.lp10o

Boundary Condition Type 2, Shear and Slope

Shear = 85000. lbs
Slope = 0.00000
Axial Load = 130000. lbs

| Pile Length feet | Pile Head Deflection inches | Maximum Moment ln-lbs | Maximum Shear lbs |
|---|---|---|---|
| 36.00000 | 0.47096665 | -5601804. | 85000. |
| 34.20000 | 0.47025639 | -5603848. | 85000. |
| 32.40000 | 0.46718299 | -5593460. | 85000. |
| 30.60000 | 0.46783852 | -5604220. | 85000. |
| 28.80000 | 0.47430190 | -5604281. | 85000. |
| 27.00000 | 0.47158394 | -5573452. | 85000. |
| 25.20000 | 0.48666744 | -5613234. | 85000. |
| 23.40000 | 0.50012094 | -5619989. | 85000. |
| 21.60000 | 0.52005976 | -5726010. | 85000. |
| 19.80000 | 0.55879855 | -5967951. | 85000. |
| 18.00000 | 0.60828335 | -6292419. | 85000. |
| 16.20000 | 0.63892016 | -6561617. | 85000. |
| 14.40000 | 0.66847997 | -6846736. | 85000. |
| 12.60000 | 0.67041360 | -6886083. | 85000. |
| 10.80000 | 0.70562174 | -6409102. | 85000. |
| 9.00000 | 0.84293449 | -5800665. | 85000. |

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Summary of Pile-head Responses for Conventional Analyses

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Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

| Load Case No. | Load Type 1 | Pile-head Load 1 | Load Type 2 | Pile-head Load 2 | Axial Loading lbs | Pile-head Deflection inches | Pile-head Rotation radians | Max Shear in Pile lbs | Max Moment in Pile in-lbs |
|---|---|---|---|---|---|---|---|---|---|
| 1 | V, lb | 85000. | S, rad | 0.00 | 130000. | 0.4710 | 0.00 | 85000. | -5601804. |

Maximum pile-head deflection = 0.4709666464 inches
Maximum pile-head rotation = -0.0000000000 radians = -0.000000 deg.

The analysis ended normally.

**Response of C.P. Crane LLC (CP Crane) PPRP Data Request No. 5**
**CP Crane Repowering Project**
**PSC Case No. 9482**
**Response Date: November 6, 2018**

5-1. In section 5.5.3 of their Environmental Review Document (page 5-7), the Applicant states that the noise attenuation measures employed for each proposed combustion turbine will result in sound power levels of 60 dBA or less at a distance of 400 feet. Please provide supporting documentation that can provide the basis for this statement. Possible documentation may include, for example, technical specifications for the turbines and stack silencers, vendor guarantees, or noise monitoring results from similar units already in operation.

Response:

ProEnergy consulted numerous exhaust stack manufacturers to confirm that they could meet the sound power levels of 60 dBA or less at a distance of 400 feet from the source. Their applications engineering teams reviewed the following specifications provided by ProEnergy: gas path, exhaust flow rate, temperature and exhaust stack height. The method being used to dampen the noise levels to the desired sound requirement are baffles in a silencer section just above the breech opening of the exhaust stack, which is the typical design used in the industry.

Based on a discussion with a stack manufacturer, Innova Braden an Innova Global Company (http://www.braden.com/), we were able to confirm that the proposed exhaust stack will utilize Innova's Higgott-Kane silencing technology which is comprised of parallel absorptive silencing baffles installed in the stack approximately one (1) diameter downstream of the elbow duct/section. PPRP DR 5-1 Attachment 1 contains a diagram of the stack/elbow section illustrating the location of the silencing baffles (in blue) to achieve the acoustical requirements. The diagram is also pasted below. This is a common design supplied by Innova to achieve 60 dBA at 400ft with over 50 installations worldwide.

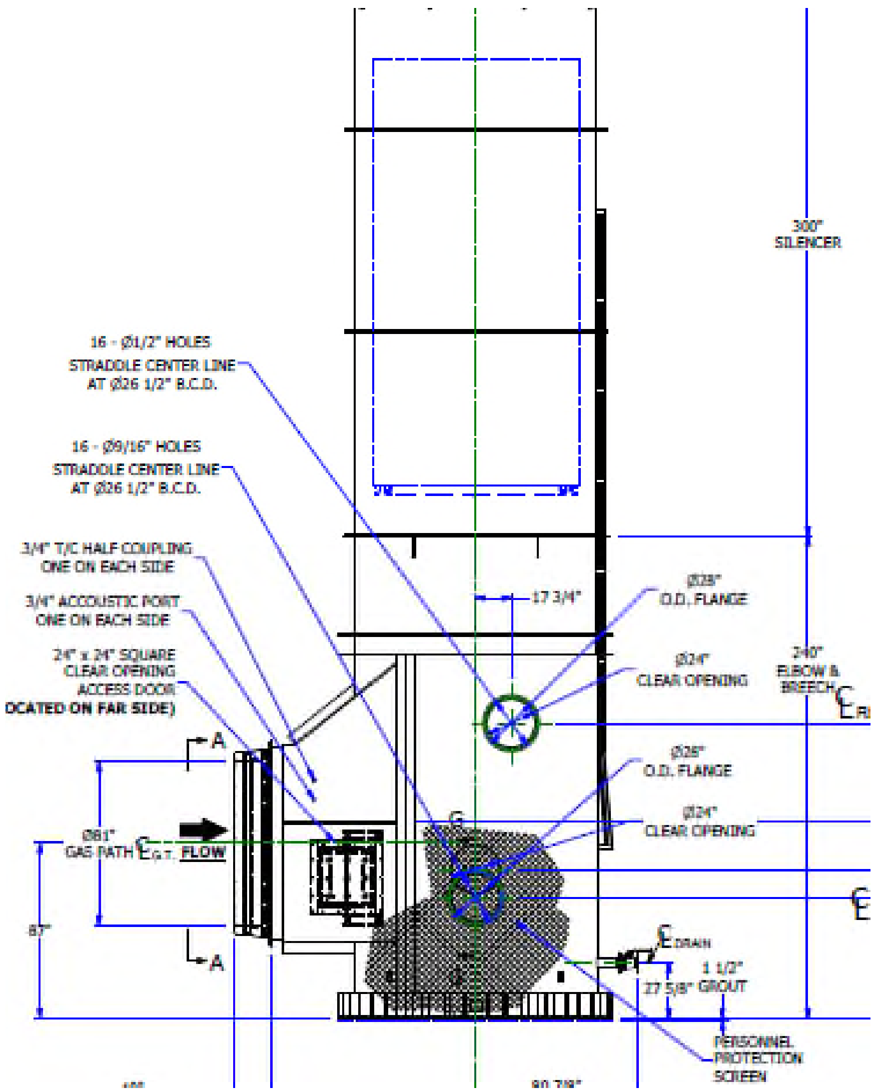
Response provided by: Mark Bendorf, Mechanical Engineer, ProEnergy Services

INNOVA BRADEN
AN INNOVA GLOBAL COMPANY

2018-11-06

**LM6000 Design Experience**

Further to our discussion earlier today, we confirm the proposed exhaust stack will utilize Innova's Higgott-Kane silencing technology which comprises of parallel absorptive silencing baffles installed in stack approx. 1 diameter downstream of the elbow duct/section. Below is screen shot of the lower stack/elbow section illustrating the location of the silencing baffles (in blue) to achieve the acoustical requirements. This is a common design supplied by Innova to achieve 60 dBA at 400ft with over 50 installations worldwide.




5199 North Mingo Road | Tulsa, OK, USA | 74117 | P. 1.800.272.3360
Braden.com | INNOVA-gl.com

Response of C.P. Crane LLC ("CP Crane") to PPRP Data Request No. 6
CP Crane Repowering Project
PSC Case No. 9482
Response Date: December 19, 2018

Construction Dewatering

6-1. In response to PPRP Data Request No. 3-2, the Applicant indicated that no groundwater recharge into the excavations was expected after the initial dewatering was completed. Please provide a detailed description of the construction techniques that will be used to prevent infiltration, in the event that groundwater is encountered during construction excavation activities.

a. What type of materials will be used to temporarily block infiltration into the excavated void spaces?
b. What will be the thickness of the materials placed into the excavation for this purpose?
c. How far up the sides of the typical excavation will the materials extend?
d. How will the materials be placed into the excavations?
e. How much time is typically required to complete the material placement for an excavation after it has been initially dewatered?
f. How long will the typical excavation be expected to remain open following the initial dewatering?
g. Describe the method that will be used to remove any additional water that enters the excavation due to infiltration, precipitation, etc.

Response:

a. Lean concrete will be placed into the open excavation.
b. Thickness will vary based on final slab thickness. Typically thickness of the lean concrete mat is 4"-12". The lean concrete mat serves a dual purpose by blocking additional infiltration and providing a stable working service.
c. Lean concrete is poured as a slab, which typically has a thickness of 4"-12". If groundwater elevation is above a practical mat thickness, lean concrete walls will be poured or sheet piling driven to seal the sides of the excavation, if required. PPRP DR 3-2 Attachment 1 "Dewatering Estimate" shows that groundwater height is not expected to be more than two feet above the bottom of any foundation.
d. Lean concrete will be placed in the excavation using a concrete pump truck.
e. The lean concrete is typically placed within 24 hours of the initial dewatering.
f. After the excavation is sealed, foundation construction begins and is completed in a timeframe that depends largely on the complexity of the formwork, size of the pour, and coordination with other work in the area.

Activities and estimated durations for representative short and long foundation pours follow.

Short scenario:

1. Dewatering – up to 4 hours
2. Completed 2 hours before mat
3. 24 hours for mat to cure
4. Forms erected – 1 day
5. Rebar tied – 1 day
6. Foundation poured (3 days after mat)
7. Forms removed 1 day later
8. Backfill placed around foundation later that day
9. TOTAL TIME: 110 hours

Long scenario:

1. Dewatering – up to 10 hours
2. Completed 8 hours before mat
3. 24 hours for mat to cure
4. Forms erected – 2 days
5. Rebar tied – 3 days
6. Foundation poured (7 days after mat)
7. Forms removed 2 days later
8. Backfill placed around foundation 14 days after foundation
9. TOTAL TIME: 558 hours

g. If any ground water or precipitation enters the excavation around the forms before it is covered and closed, the water will be removed with pumps.

Response provided by: Catherine Blake, Engineering Manager, ProEnergy Services