PRELIMINARY DESIGN REPORT

DAM IMPROVEMENTS

BUCKEYE LAKE STATE PARK

PROJECT NO. DNR 736-730-93-006

Prepared for:

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Project No. DNR 736-730-93-006

1.0 INTRODUCTION

Buckeye Lake is located in Licking, Fairfield, and Perry Counties approximately 25 miles east of Columbus, Ohio. The reservoir was originally constructed as a feeder lake for the Ohio and Erie Canal System and was formerly known as the Licking Summit Reservoir. Records indicate that construction of the dam began in 1825 and ended in 1832. The earth embankment that impounds the lake is located on the west and northwest portion of the reservoir and is approximately four miles long. The maximum height of the embankment is about 15 feet. At some point during the project's history, a masonry wall was constructed along the upstream slope of the entire embankment to protect it from wave erosion.

The dam is generally divided into two parts: West Bank and North Bank. West Bank extends from the south end of the dam near Liebs Island to about Mud Island, and is characterized by a relatively low-height embankment (four to six feet high) and a masonry wall visible along the upstream face of the embankment. North Bank extends from near Mud Island to Picnic Point. The embankment along North Bank is generally higher (six to 15 feet high) and a sheet pile wall is visible along the upstream face of the embankment. The sheet pile wall was installed to replace the rock wall and serves to protect the earth embankment from erosion. It was constructed at different times but generally between 1948 and 1992. However, a new sheet pile wall was installed in 2000 along a 500-foot long section of North Bank near Mud Island. With the exception of a small portion of the sheet pile wall that was installed in 1982, the sheet pile wall is anchored or tied-back with steel rods connected to sheet pile or concrete deadmen.

Most of the downstream slope of the embankment is no longer owned by the State of Ohio. Houses have been and continue to be constructed on the downstream slope along essentially the entire length of the embankment, with their basements and foundations located within the embankment. Although the rest of the embankment is still owned by the State, residents have installed decks, walks, boat lifts, boat docks, and other small structures over the years. Many of these encroachments penetrate the embankment and rely upon the dam for support. There are also numerous large trees growing on the embankment, which conflicts with dam safety rules in the Ohio Administrative Code.

The outlet works for the lake consist of two spillways on the north shore. The primary spillway is located near State Route 79 and consists of a concrete sluiceway with a crest elevation of 884.85 feet. An Amil gate is located at the crest of the sluiceway to control water flow. The gate is set to be in the full open position when the pool is at elevation 892.2 feet. There is a staff gage located near the primary spillway which is used to measure the pool elevation. The gage's zero datum is at elevation 891.75 feet. There is also an intake structure that controls the flow to a 60-inch diameter pipe that outlets into the stilling basin. The invert elevation of the pipe is 881.8 feet. The secondary, or emergency, spillway is located near Sellers Point and consists of an ungated concrete gravity weir. The crest of the weir is at elevation 892.2 feet and is approximately 460 feet long. An intake structure controls flow to two pipes: a 30-inch diameter

pipe that outlets into the abandoned Ohio Canal and a 60-inch diameter pipe that outlets into the stilling basin. The invert elevation for both pipes is at 883.9 feet.

The lake has a surface area of approximately 2,700 acres at normal pool elevation 892.25. The total drainage area of the lake is 44.1 square miles. The lake is fed by several small streams and by a feeder canal that extends from the town of Kirkersville to the west side of the reservoir. This feeder canal was built as part of the original project construction to provide additional inflow into the reservoir and, therefore, additional inflow into the Ohio and Erie Canal System.

The reservoir outlets into the South Fork Licking River, a tributary of the Muskingum River. The project is presently used for public recreation and is operated and maintained by the Ohio Department of Natural Resources (ODNR), Division of Parks and Recreation. According to Division of Water standards, the dam is classified as a Class I structure. Currently, the project does not meet the spillway capacity criteria for a Class I structure and analyses show that it will overtop during the design storm event. The dam has been protected from overtopping in the past through emergency placement of sandbags by Division of Parks and Recreation staff.

2.0 PURPOSE AND SCOPE

ODNR contracted with DLZ Ohio, Inc. (DLZ) on September 28, 2001 to perform several items of work. These items of work are listed below and described in the following sections:

1. Prepare new topographic mapping and cross-sections for the project.

2. Evaluate the existing trees on the embankment and assist in the development of a tree management plan.

3. Evaluate the condition of the existing sheet pile walls.

4. Develop conceptual designs for the dam improvements to bring the dam into compliance with current dam safety standards.

   Initially, these improvements included potential modifications to the existing embankment. However, as the project progressed, the potential improvements considered were narrowed to a separate, free-standing structure that was constructed upstream of the existing embankment and did not rely on the existing embankment for strength or stability. This decision was made because the construction and condition of the existing earth embankment were unsatisfactory, and to eliminate the on-going problems caused by split ownership (public and private) of the dam.

5. Develop standard boat dock design options.

3.0 PREVIOUS STUDIES

Several earlier studies of the dam have been performed. These include:

- A spillway adequacy and embankment stability and seepage study performed by Dodson-Lindblom Associates in 1987.

- Mapping and an evaluation of the sheet pile wall performed by Dodson-Lindblom Associates between 1989 and 1995.

- A stability study performed by Paul C. Rizzo Associates between 1996 and 1997.

Please note that Dodson-Lindblom Associates was one of the companies that merged to form DLZ Ohio, Inc., the author of this report.

In addition to these engineering studies, the ODNR Division of Water has performed inspections of the dam. Their inspections, and reports from the ODNR Division of Parks & Recreation, indicate the reoccurrence of sinkholes, water seepage through the dam and into homes, and unconsolidated soils in the earth embankment that forms the dam.

4.0 MAPPING AND CROSS-SECTIONS

Original mapping for the project was prepared in 1990 as part of a previous evaluation of the project performed by Dodson-Lindblom. This mapping was updated to reflect the existing features on the project. A baseline was established in 1990 along the embankment. However, many of the points on this previous baseline had been removed or could not be found during the current surveying. Consequently, a new baseline was established along the top of the embankment as part of this evaluation.

Property lines shown on the mapping are approximate and are not the result of title research. As part of the final design phase of the project, the State's property line will need to be located along the embankment.

Cross-sections of the embankment and the lake bottom were determined approximately every 200 feet. During the field work for the cross-sections, the amount of muck present on the lakebed was estimated. The estimated amount of muck at each cross-section location is shown on the cross-section drawings. The mapping and cross-sections developed for the project are presented in Appendices VII and VIII.

5.0 GEOTECHNICAL INFORMATION

5.1 General

Several geotechnical explorations have been performed at the site. These included borings in the embankment for the 1987 and 1995 studies by Dodson-Lindblom Associates, Inc. and the 1997 study by Paul C. Rizzo, Inc. For the 1995 evaluation, Dodson-Lindblom reanalyzed the existing sheet pile walls and drilled 15 borings in the lake along the West Bank and North Bank walls.

The original scope of work for this evaluation considered numerous borings in the embankment to be drilled using hand methods. However, as the project progressed, the dam improvement alternatives considered did not include modifying the existing embankment, but rather constructing a new structure upstream of the existing embankment. Unfortunately, the lake level during this evaluation was lowered for an ODNR construction project along the lake and there was not sufficient draft for a barge.

Consequently, additional borings could not be taken for this evaluation and the 1995 lake borings drilled by Dodson-Lindblom were used for the analyses in this report. The locations of the 1995 borings are shown on the topographic mapping sheets in Appendix VII and the results of the borings are discussed below.

5.2 1995 Lake Borings

5.2.1 General

The 1995 exploration consisted of drilling a total of fifteen borings between the dates of April 20 and May 2, 1995. Borings B-1 through B-8 were located along West Bank, spaced approximately 800 feet apart. Borings B-9 through B-15 were located along North Bank at sections of the existing sheet pile wall that were identified as needing repair or replacement. The borings were drilled from a floating barge, and they were located as close to shore as possible. The borings extended to depths ranging from 5.0 to 40.0 feet. Information concerning the drilling procedures is presented in Appendix II. Logs of the borings are also presented in Appendix II. The following table lists the approximate boring locations.

Table 1. Boring Locations

Boring Number	Station	Boring Number	Station
B-1	11+30	B-9	104+10
B-2	19+70	B-10	110+60
B-3	27+25	B-11	128+50
B-4	35+15	B-12	137+00
B-5	43+60	B-13	145+00
B-6	50+90	B-14	157+15
B-7	59+00	B-15	165+75
B-8	67+45		

5.2.2 Geology of the Site

Generalized geological references report that the site was covered by both the Illinoian and Wisconsinan glaciers. A post-glacial lake or swamp developed over the glacial till deposits. Consequently, the soils at the project generally consist of lacustrine type soils (laminated silt and clay with interbedded sand and gravel layers) overlying glacial till. The underlying bedrock at the site is reported to be of Mississippian age and consist of shales, limestones, and sandstones of the Waverly and Maxville formations. However, bedrock is reported to lie at depths in excess of 100 feet beneath the surface.

5.2.3 Lakebed Conditions

East of Seller's point near Boring B-9, significant deposits of muck were encountered at the lakebed. From station 103+00 to 107+00 the muck was 1.5 to 5 feet thick, and at station 113+00 the muck was 1.5 feet thick. Along the rest of the shoreline of the project there was little (less than 0.5 feet) or no muck encountered.

5.2.4 Soil Conditions

The soils encountered by the borings along West Bank were as follows. Borings B-1 through B-6 encountered similar soils. These borings encountered soft to medium stiff clayey silts and silty clays to depths ranging from 3.7 to 7.2 feet, followed by very stiff to hard silty clays and layers of medium dense to very dense silty sands. Boring B-5 encountered medium dense silt from a depth of 5.5 to 7.2 feet. Boring B-7 encountered medium stiff to stiff silty clay to a depth of 4.7 feet followed by a very loose silty sand which became medium dense at 8.0 feet. Boring B-8 encountered very loose sand at the lake bottom and medium stiff to hard silty clay from 3.0 feet to the depth of boring. Medium dense silty sand layers were encountered from 15.5 to 18.0 feet and from 20.5 to 21.7 feet.

The soils encountered by the borings along North Bank (Borings B-9 through B-15) consisted of soft to very soft organic silty clays to depths ranging from 2.5 to 8 feet, followed by medium stiff to hard silty clays. Medium dense to dense silty sand was encountered by Borings B-10 and B-15, and medium stiff to very stiff clayey silt was encountered by Borings B-13 and B-14.

5.2.5 Groundwater Conditions

All of the borings were located within the lake so groundwater conditions could not be determined. All granular samples recovered were saturated.

5.2.6 Geotechnical Parameters

Based on the results of the borings, generalized cross-sections were developed to use in the structural analyses of the improvements. Both undrained and drained shear strengths were then assigned to the various materials in the cross-sections. The shear strengths were selected based on the results of previous shear strength tests for the project, typical values, hand penetrometer readings, and conservative judgment. Based on the results of the borings, the natural soils were divided into three soil types. The lakebed deposits were considered to be soft clays or medium stiff clays. The underlying glacial till was considered to be very stiff clay. Any granular fill in the analyses was assumed to be natural, bank-run gravel. The selected geotechnical parameters are presented in Table 2 below.

Table 2. Geotechnical Parameters

Soil Description	Unit Weight		Undrained Strength		Drained Strength	
	Moist	Saturated	c	ϕ	c'	ϕ'
Muck	---	110 pcf	0	0	0	0
Soft Clay	---	130 pcf	500 psf	0	0	28°
Medium Stiff Clay	---	130 pcf	750 psf	0	0	28°
Very Stiff Clay	---	130 pcf	2000 psf	0	0	28°
Bank Run Gravel	120 pcf	125 pcf	0	25°	0	25°

6.0 EXISTING TREE IDENTIFICATION AND EVALUATION

6.1 General

Although a new dam structure is to be constructed, due to the size of the dam it will need to be constructed in phases over a period of several years. Consequently, the existing trees on the dam are a continuing conflict with dam safety rules. ODNR decided to address this problem by developing a tree management plan. To develop the plan, and as part of the evaluation of the dam, all of the trees on the State-owned portion of the embankment were identified and inspected. The work was performed by T. Davis Sydnor, Ph.D, who is an arboricultural, urban forestry, and horticultural consultant. The inspection was performed between February 16 and March 10, 2002. All of the trees were identified by genus and species and tagged with an identifying number. The tree diameters were determined at a point 4.5 feet above the ground.

To help develop the tree management plan, the condition of each tree was evaluated and unusual situations or conditions noted. In addition, Dr. Sydnor estimated the amount of growth for each tree over the next 20 years and provided estimates on the amount of soil that might be dislodged (size of the rootplate) during a windfall at the present time and 20 years from now. The assist with the development of a tree management plan for the State-owned portion of the dam, the potential effect of windthrown trees on stability and piping of the embankment was considered in a simplified engineering analysis. The tree management plan will be utilized to effectively manage the risk posed by the trees until the new dam structure can be constructed.

6.2 Inspection Results

The tree type, current diameter, estimated diameter in 20 years, and current condition for each of the trees are presented in Table III-1 of Appendix III. Table III-2 in Appendix III presents the stem size and rootplate radius for each tree currently, as well as estimates of the stem size and rootplate radius 20 years from now. Additionally, the location of all of the trees and their identifying tag numbers are shown on the topographic mapping sheets in Appendix VII.

Based on the results of the inspection, Dr. Sydnor recommended that four of the trees on the embankment should be removed as soon as possible. Tree Nos. 163 (station 97+30) and 195 (station 111+10) are presently unstable due to root crown and fungus damage, respectively. Two additional trees, Nos. 93 (station 57+90) and 166 (station 97+60, are growing with their stems against the sheet pile wall. If either of these trees fell due to windthrow the stems could damage the sheet pile wall. It was noted that during the course of this investigation several residents asked to have trees removed. Therefore, another report recommendation that helped address the conflict of trees and dam safety rules was to have ODNR offer to remove those trees that private property owners requested to be removed. Dr. Sydnor also gave recommendations for tree maintenance. ODNR has commented that any recommendations that promote the growth of trees on dams are in conflict with dam safety rules. Therefore, ODNR suggests that these recommendations are more appropriate for the maintenance of trees on the privately-owned property after the new dam structure is in place.

7.0 EXISTING SHEET PILE WALL EVALUATION

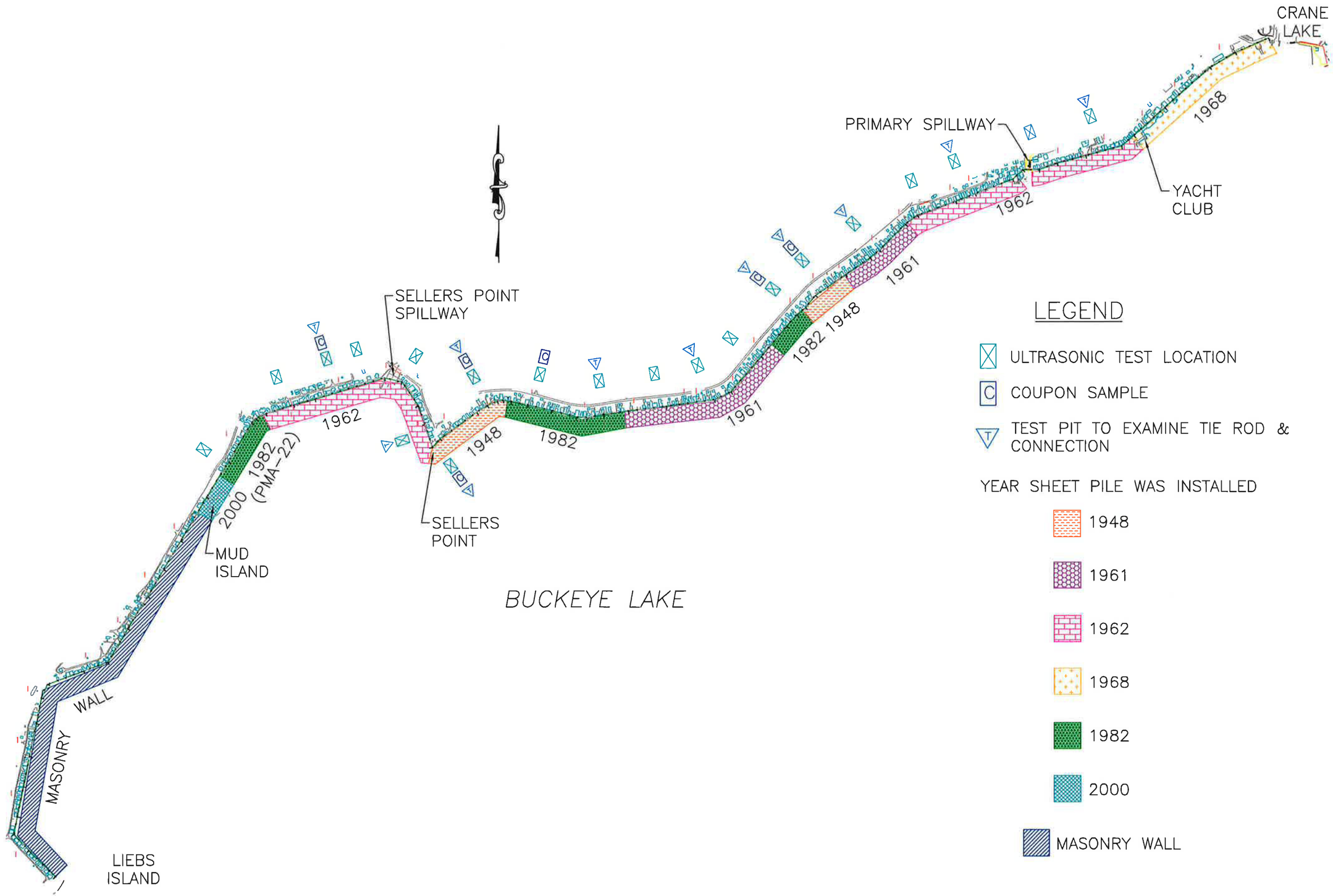
7.1 General

The earth embankment that forms the dam has far exceeded the expected service life of a structure of this nature. Therefore, it is especially important to protect the dam from overtopping and wave erosion that could lead to a catastrophic failure. Since the existing sheet pile wall performs the important function of protecting the earth embankment from erosion, an evaluation of the wall was performed as part of the project. The purpose of this evaluation was to determine the condition of the existing sheet pile wall and to estimate the remaining useful life of the structure. The steps in the evaluation included a field reconnaissance, ultrasonic testing to determine the thickness of the sheet pile, coupon sampling of the sheet pile to verify the results of the ultrasonic testing, test pit excavation to visually inspect the tie rod connections, and structural analyses of the existing walls to determine current safety factors and the remaining useful life of the sheet pile. Each of these steps is described in the following sections.

7.2 Reconnaissance and Test Pits

A field reconnaissance was performed to visually inspect the sheet pile wall along the embankment. Field reconnaissance was performed between December 13, 2001 and March 14, 2002, by structural and geotechnical engineers from DLZ. The purpose of the reconnaissance was to locate the different vintages of sheet pile wall and to document the observable condition of the sheet pile. In addition, construction documents from the various sheet pile wall installations were reviewed as part of the reconnaissance. Based on the results of the reconnaissance, the sheet pile walls were divided into several reaches, based on the year the sheet pile was installed. These results are presented on Exhibit 1 on the following page. The designs of some of the sheet pile walls are presented in Exhibits IV-1 through IV-6 in Appendix IV.

As part of the field reconnaissance, test pits were excavated at several representative locations to observe the condition of the tie rod and wall connections. The tie rods and



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ENGINEERING
Ohio Department of Natural Resources

BUCKEYE LAKE STATE PARK
DAM IMPROVEMENTS
FAIRFIELD & LICKING COUNTIES, OHIO

DESIGNED BY:	DNR 736 730-93-006
DRAWN BY:	SCALE:
CHECKED BY:	DATE: AUGUST 8, 2002
APPROVED BY:	REVISED: FEBRUARY 11, 2003

EXHIBIT 1

the connections appeared to be in good condition. A typical tie rod connection is shown in Photo 1. The locations of the test pits to observe the tie rods and their connections are shown on Exhibit 1.

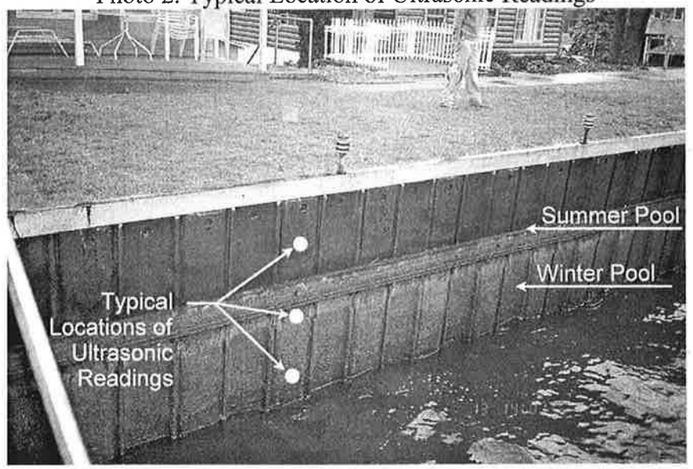
Photo 1. Anchor in front of House No. 4991

7.3 Ultrasonic Testing and Coupon Sampling

Ultrasonic testing was performed to determine the thickness of the existing sheet pile walls. Because the sheet pile wall is exposed to the elements, the steel corrodes over time. This is especially true in the zone between the summer and winter pool levels where the wave action of the lake results in continuous wetting and drying of the steel. During the 1995 evaluation, preliminary ultrasonic tests of sections above the summer pool indicated that the loss of steel might be significant enough to affect the stability of the wall in the near future. Consequently, for this evaluation, many ultrasonic tests were performed on representative sections of the variously aged sheet pile sections. In addition, coupon samples of the sheet pile were cut, removed, inspected, and measured to verify the results of the ultrasonic testing. The locations of the ultrasonic tests are shown on Exhibit 1.

At each ultrasonic test location, three readings were obtained: one above the summer pool level, one at or slightly below the summer pool level, and one below the winter pool level. Typical reading locations are shown in Photo 2.

Photo 2. Typical Location of Ultrasonic Readings

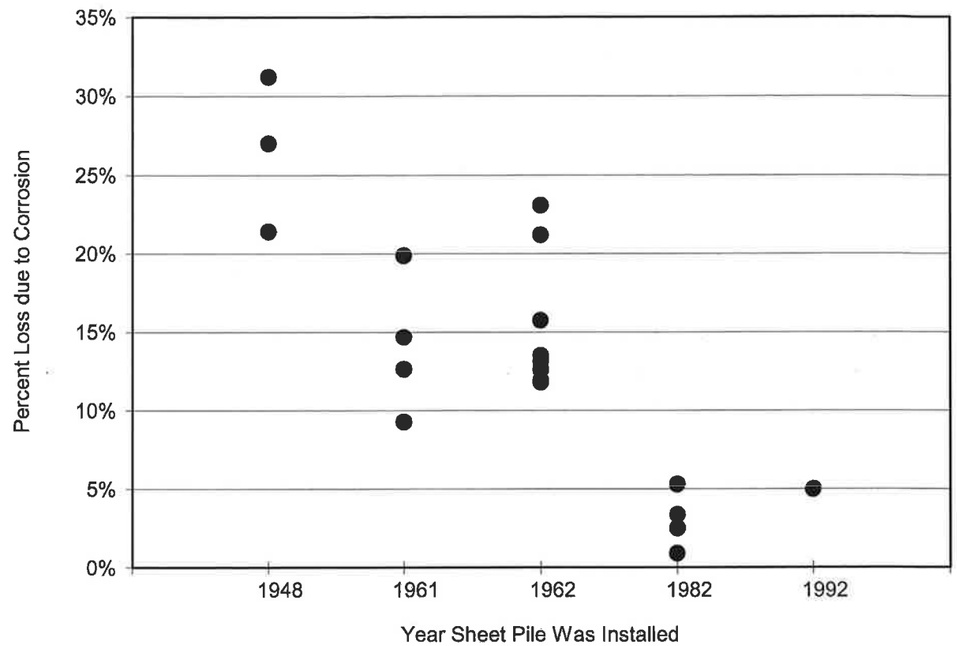


As expected, the lowest reading indicated the most loss. In general, the percentage of steel loss ranged from 10% to 30% and averaged 14%. These results are shown graphically on Exhibit 2 and the individual test results are presented in Appendix IV.

A total of six coupon samples of the sheet pile were cut from the wall and measured to verify the results of the ultrasonic testing. There was good agreement between the measured thicknesses of the samples and the thicknesses indicated by the ultrasonic testing.

Using the age of the sheet pile and the steel loss obtained from the ultrasonic testing, a rate of corrosion could be established for the sheet pile walls at Buckeye Lake. Exhibit 3 presents the age of the steel versus the reduction in steel thickness for all of the ultrasonic tests. Assuming a linear rate of corrosion, the average rate of corrosion from all of the ultrasonic test results was 0.0016 inches lost per year. The worst rate of corrosion based on the test results was 0.0023 inches lost per year.

Exhibit 2. Percent loss due to corrosion of existing sheet pile



7.4 Structural Analyses

7.4.1 Methods of Analysis

Using the results of the ultrasonic tests, the existing sheet pile walls were analyzed to determine the existing safety factors against yielding and to estimate the remaining useful life of the sheet pile walls. To perform the analyses the following assumptions were made. The top of the wall was assumed to be at elevation 895.0 and the embankment behind the wall was assumed to extend to the top of the wall. The ground surface in front of the wall (i.e. the lake bottom) was assumed to be at elevation 884.0. In addition, the water level in the lake was assumed to be at elevation 892.0 while the groundwater level in the embankment was assumed to be at elevation 894.0. This groundwater condition represents a storm occurring while the lake is at summer pool, after flow through the spillway has returned the lake to the normal summer pool level but while the groundwater in the embankment remains at the flood level. The analyses also assumed that there were no surcharge loads on top of the existing embankment, such as those created by vehicles.

For the analysis of the existing sheet pile wall, it was necessary to determine the existing section modulus for the sheet pile used in the wall. The section modulus is a property determined from the cross-section geometry of the sheet pile and is

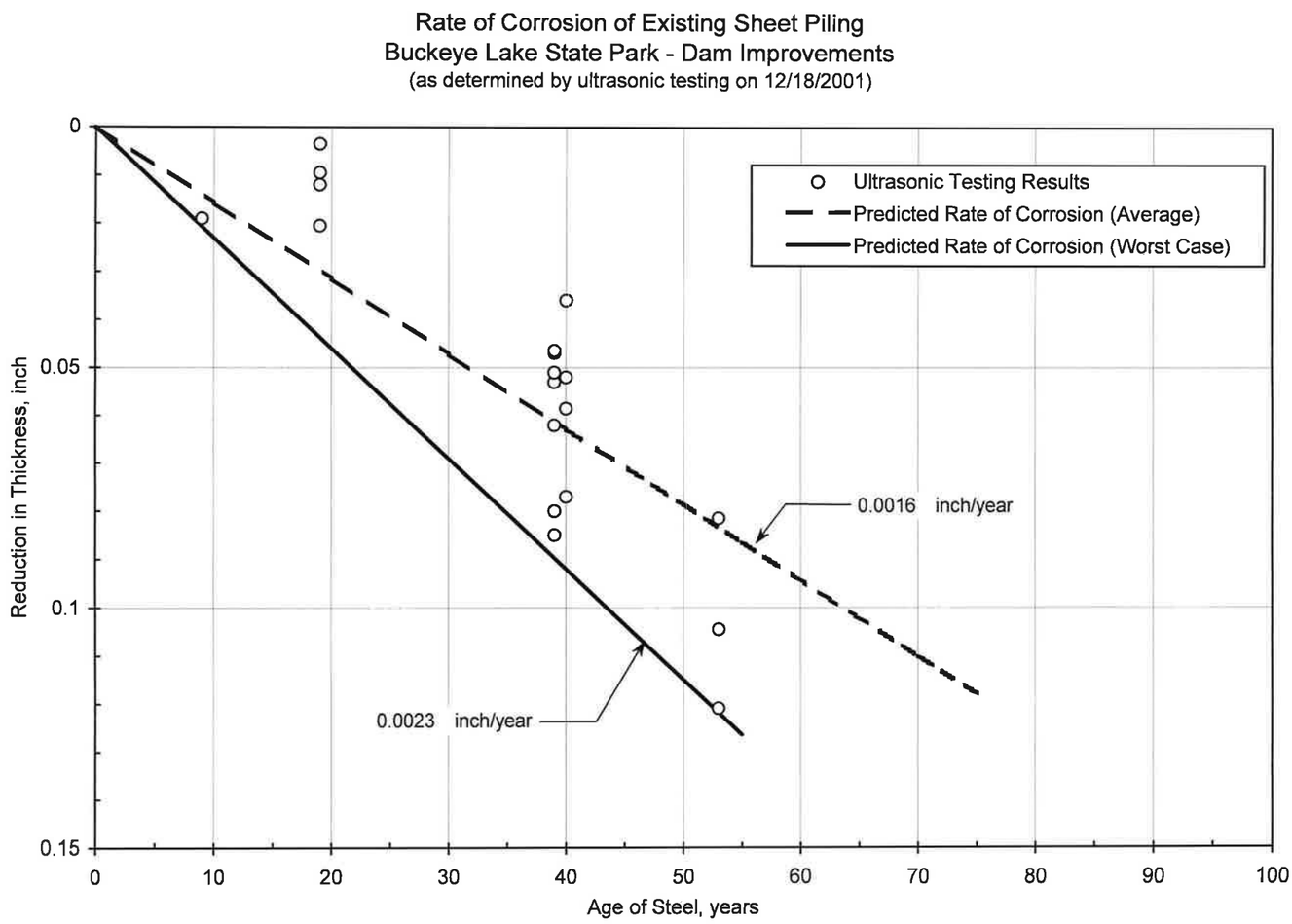

Rate of Corrosion of Existing Sheet Piling
Buckeye Lake State Park - Dam Improvements
(as determined by ultrasonic testing on 12/18/2001)
Ultrasonic Testing Results
Predicted Rate of Corrosion (Average)
Predicted Rate of Corrosion (Worst Case)
0.0016 inch/year
0.0023 inch/year
Reduction in Thickness, inch
0
0.05
0.1
0.15
0
10
20
30
40
50
60
70
80
90
100
Age of Steel, years

Exhibit 3

used in the determination of bending stresses in the wall. As the existing sheet pile wall has corroded, the section modulus has decreased. For these analyses, the section modulus was assumed to vary linearly with sheet pile thickness using the following equation:

$$S_{existing} = S_{original}\left(\frac{t_{existing}}{t_{original}}\right)$$

$S_{existing}$ is the existing section modulus of the sheet pile section; $S_{original}$ is the original section modulus of the sheet pile section; $t_{existing}$ is the existing web thickness of the sheet pile section; and $t_{original}$ is the original web thickness of the sheet pile section.

There are two types of sheet piling used along the embankment: PSA-23, with an original section modulus of 2.4 in.^{3} per foot of wall, and PMA-22, with an original section modulus of 5.4 in.^{3} per foot of wall. The sheet pile along the embankment mainly consists of type PSA-23 with a short section of PMA-22 northeast of Mud Island. Both types have an original web thickness of 3/8 (0.375) inch. The original section modulus and web thickness were obtained from the *US Steel Sheet Piling Handbook.*

7.4.2 Results

The results of the analyses are presented in Table 3. The factor of safety against yielding was determined by comparing the calculated yield stress to the yield strength of the steel. The calculated yield stress was determined from the existing wall thickness and the calculated maximum bending moment. The maximum bending moment for the two types of sheet piling was different because the wall consisting of type PSA-23 sheet piling is tied-back to deadman anchors while the wall consisting of type PMA-22 sheet piling is a cantilever wall.

The safety factors ranged between 1.2 and 1.9. A safety factor of 1.0 indicates failure, or yielding, of the sheet pile wall. In typical engineering practice, a sheet pile wall is designed for a safety factor of 1.5 or greater.

The results of the analyses are also shown graphically in Exhibit 4. In this exhibit, the thicknesses corresponding to the allowable stress limit (safety factor of approximately 1.5) and the yield stress (safety factor of 1.0) are shown. As can be seen on the exhibit, the corrosion in the splash zone has reduced the thickness of the 1948, 1961, and 1962 sheet piling to the point where the steel is at or below the allowable stress limit. It should be noted that the 1948 sheet piling is well below the allowable stress limit and approaching the yield stress. If the stress in the sheet piling were to reach the yield stress, it is very likely the structure would fail. The calculations for the analyses are presented in Appendix IV.

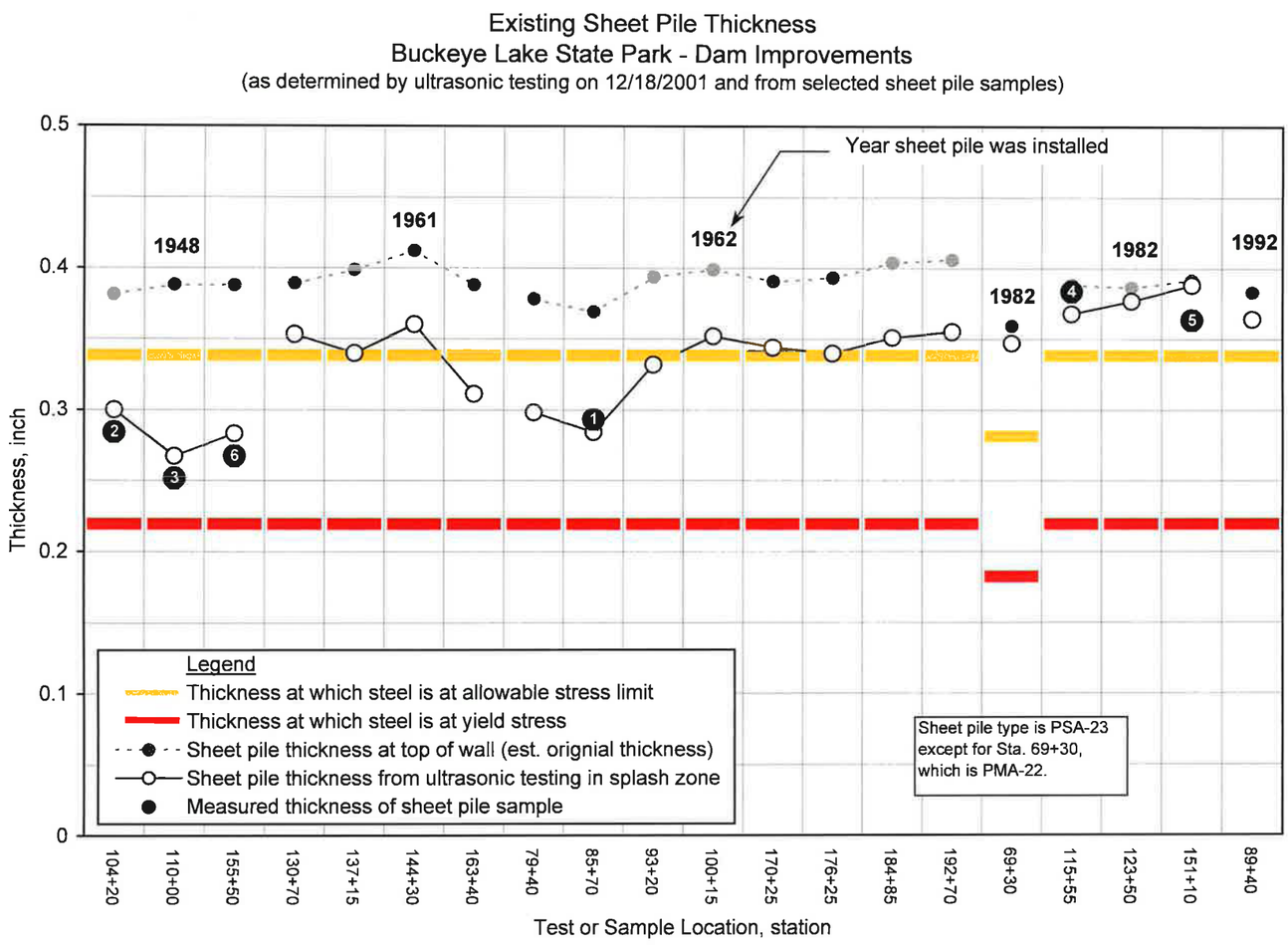

Existing Sheet Pile Thickness
Buckeye Lake State Park - Dam Improvements
(as determined by ultrasonic testing on 12/18/2001 and from selected sheet pile samples)
Year sheet pile was installed
1948
1961
1962
1982
1982
1992
Thickness, inch
0.5
0.4
0.3
0.2
0.1
0
Legend
Thickness at which steel is at allowable stress limit
Thickness at which steel is at yield stress
Sheet pile thickness at top of wall (est. orignial thickness)
Sheet pile thickness from ultrasonic testing in splash zone
Measured thickness of sheet pile sample
Sheet pile type is PSA-23 except for Sta. 69+30, which is PMA-22.
104+20
110+00
155+50
130+70
137+15
144+30
163+40
79+40
85+70
93+20
100+15
170+25
176+25
184+85
192+70
69+30
115+55
123+50
151+10
89+40
Test or Sample Location, station

Exhibit 4

Table 3. Safety Factors for Existing Sheet Pile Walls

Location (station)	Wall Type	Existing Wall Thickness Below Winter Pool (in.)	Original Design Section Modulus ($in.^3$)	Original Safety Factor *	Existing Section Modulus ($in.^3$)	Existing Safety Factor *
69+30	PMA-22	0.347	5.4	2.06	5.0	1.90
79+40	PSA-23	0.298	2.4	1.71	1.9	1.36
85+70	PSA-23	0.284	2.4	1.71	1.8	1.30
89+40	PSA-23	0.364	2.4	1.71	2.3	1.66
93+20	PSA-23	0.332	2.4	1.71	2.1	1.51
100+15	PSA-23	0.352	2.4	1.71	2.3	1.61
104+20	PSA-23	0.300	2.4	1.71	1.9	1.37
110+00	PSA-23	0.267	2.4	1.71	1.7	1.22
115+55	PSA-23	0.368	2.4	1.71	2.4	1.68
123+50	PSA-23	0.377	2.4	1.71	2.4	1.72
130+70	PSA-23	0.299	2.4	1.71	1.9	1.36
137+15	PSA-23	0.340	2.4	1.71	2.2	1.55
144+30	PSA-23	0.360	2.4	1.71	2.3	1.64
151+10	PSA-23	0.388	2.4	1.71	2.5	1.77
155+50	PSA-23	0.283	2.4	1.71	1.8	1.29
163+40	PSA-23	0.311	2.4	1.71	2.0	1.42
170+25	PSA-23	0.344	2.4	1.71	2.2	1.57
176+25	PSA-23	0.340	2.4	1.71	2.2	1.55
184+85	PSA-23	0.351	2.4	1.71	2.2	1.60
192+70	PSA-23	0.355	2.4	1.71	2.3	1.62

* - Based on steel yield strength of F_y = 38,500 psi (from *US Steel Sheet Piling Handbook*)
The safety factor against yielding for the PMA-22 section is based on a maximum bending moment of 101,046 in-lbs./foot of wall.
The safety factor against yielding for the PSA-23 section is based on a maximum bending moment of 54,028 in-lbs./foot of wall.

7.4.3 Useful Remaining Life

A second set of analyses was then performed to determine the remaining useful life of the existing sheet pile walls. Using the worst corrosion rate from the results of the ultrasonic testing (0.0023 inches per year), the estimated times until the steel reached its allowable stress limit and yield stress were calculated for each of the different walls. The results of these calculations are shown graphically on Exhibit 5. As can be seen from this exhibit, the 1948, 1961, and 1962 sheet pile walls are essentially already at or beyond their allowable stress limit.

8.0 DAM REPLACEMENT SCHEDULE

A schedule for replacing the existing dam was developed and is shown on Exhibit 6 and in Table 4. The condition of the existing sheet pile walls was the primary factor in developing this schedule, however, additional factors were also considered. These additional factors included the height and condition of the existing embankment and the absence of a sheet pile wall on the upstream side of the embankment.

ODNR currently anticipates replacing the dam in phases over a multi-year period. For budgeting purposes, the replacement schedule was developed for five phases. The first four phases were further subdivided into segments of approximately one-half mile or less so that it was reasonable to assume each segment could be completed by a contractor in less than a year. At the time of this report ODNR expected to be able to construct one phase each year starting in winter of 2004.

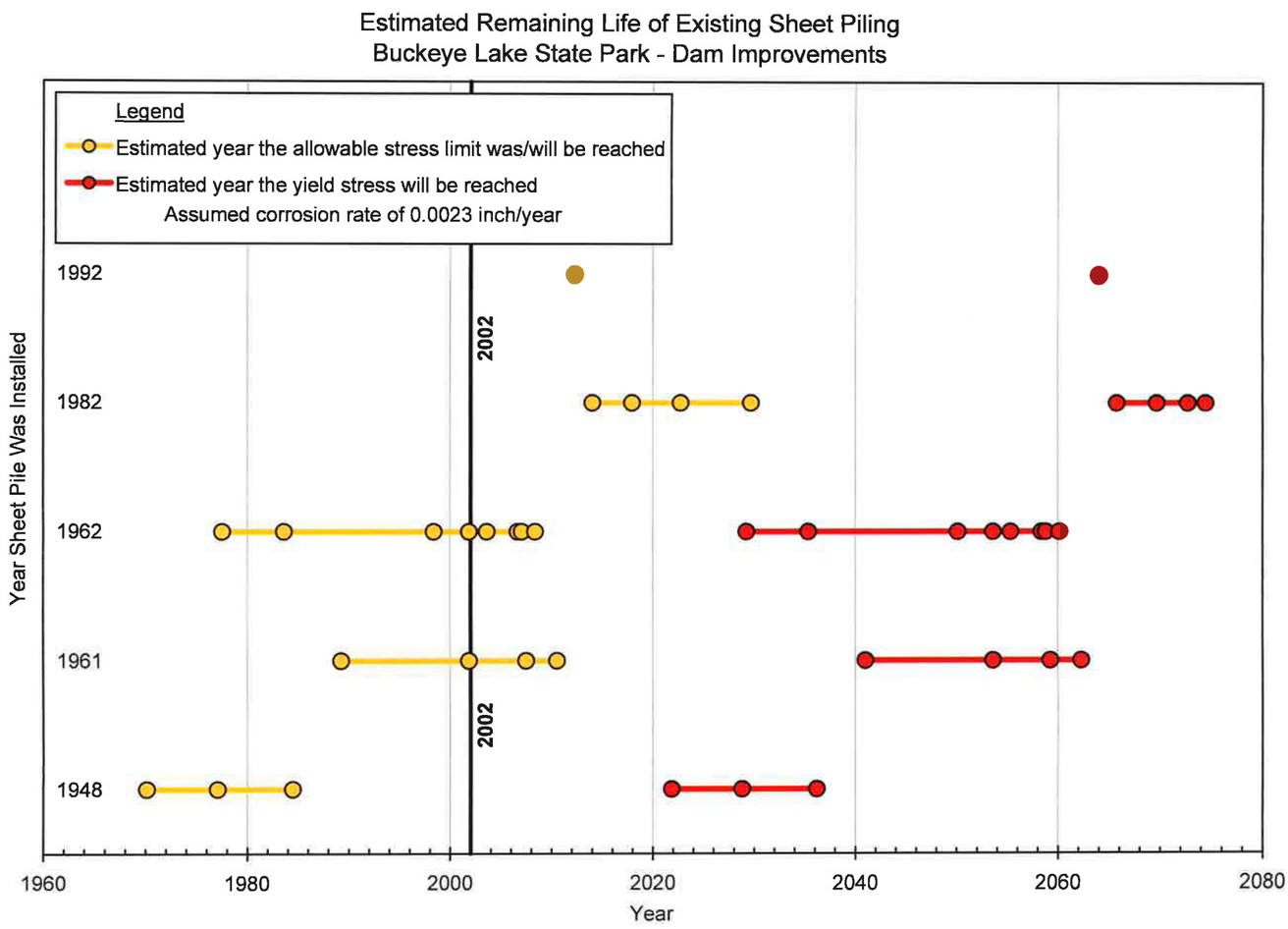
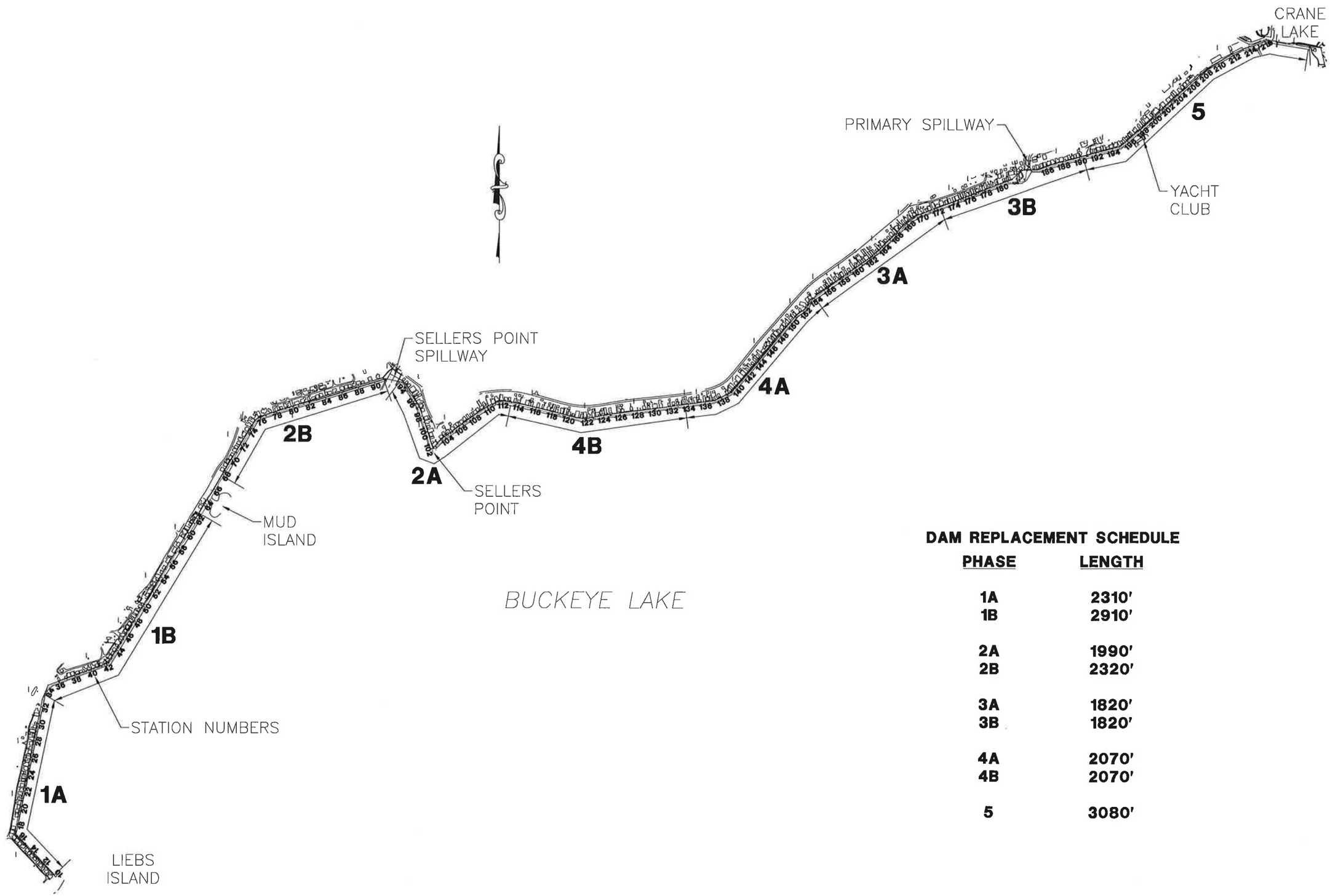

Estimated Remaining Life of Existing Sheet Piling
Buckeye Lake State Park - Dam Improvements
Legend
Estimated year the allowable stress limit was/will be reached
Estimated year the yield stress will be reached
Assumed corrosion rate of 0.0023 inch/year
Year Sheet Pile Was Installed
1992
1982
1962
1961
1948
2002
2002
1960
1980
2000
2020
2040
2060
2080
Year

Exhibit 5



DAM REPLACEMENT SCHEDULE

PHASE	LENGTH
1A	2310'
1B	2910'
2A	1990'
2B	2320'
3A	1820'
3B	1820'
4A	2070'
4B	2070'
5	3080'

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Ohio Department of Natural Resources

BUCKEYE LAKE STATE PARK
DAM IMPROVEMENTS
FAIRFIELD & LICKING COUNTIES, OHIO

DESIGNED BY:		DNR 736 730-93-006	
DRAWN BY:		SCALE:	
CHECKED BY:		DATE:	AUGUST 8, 2002
APPROVED BY:		REVISED:	

EXHIBIT 6

Table 4. Dam Replacement Schedule

Phase	Length (feet)	Description
1A	2,310	Liebs Island to open area between houses 12834 and 12910
1B	2,910	Open area between houses 12834 and 12910 to Mud Island
2A	1,990	Sellers Point spillway, around Sellers Point, to the access road near house 3709
2B	2,320	Mud Island to Sellers Point spillway
3A	1,820	Access road near house 4333 to house 4613
3B	1,820	House 4613 to condominiums at 4995
4A	2,070	House 4055 to access road near house 4333
4B	2,070	Access road near house 3709 to house 4055
5	3,080	Condominiums at 4995 to Crane Lake

The reasons for replacing the existing dam in the order shown are as follows:

- Phase 1 along West Bank was determined to have the highest priority because the upstream side of the embankment has a masonry wall and is not protected by a sheet pile wall.
- Phase 2 was selected to be the next priority because it contains sheet pile walls from 1948 and 1962 that are beyond their allowable stress limit and because of large cuts for houses into the embankment near Sellers Point.
- Phase 3 contains more sheet pile walls from 1948 and 1962 and the embankment is relatively high (up to 12 feet in portions).
- Phase 4 contains sheet pile walls from 1961 and 1982 that are in relatively better condition than the walls from 1948 and 1962, although the sheet pile walls from 1961 are still currently beyond their allowable stress limit. Embankment heights are also relatively high (up to 11 feet in portions).
- The dam along Phase 5 also needs to be replaced. However, because it has relatively low embankment heights, Phase 5 has the lowest priority.

9.0 DAM IMPROVEMENT ALTERNATIVES

9.1 General

Initially, many alternatives were considered to improve the dam at Buckeye Lake. These alternatives included upstream construction methods, such as earth or rock fill embankments upstream of the existing embankment, modifying the existing embankment, or constructing a new structure along the upstream face of the

embankment. In addition, lift-in or float-in structures were also considered. However, as the project progressed, discussions between DLZ, the ODNR Division of Engineering, and the ODNR Division of Water resulted in a refinement of the alternatives considered. It was decided that the new structure would be constructed in the lake and not rely on the existing embankment for stability, and that it would be able to withstand an overtopping event. Additionally, we also considered how the existing residential boat docks and lifts would be supported with the new structure in place. This narrowed the alternatives to a total of six that are described in the following section.

9.2 Alternatives Considered

9.2.1 General

The following six alternatives were considered for the dam improvements at Buckeye Lake. Each of the six alternatives is described in more detail below. Underseepage control was not an issue along North Bank where the existing sheet pile was present. However, for West Bank, each alternative would need to incorporate some type of underseepage control feature.

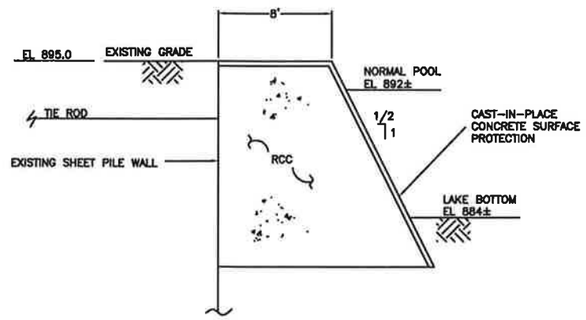
Preliminary design calculations were made for each of the alternatives and these calculations are presented in Appendix V. These include generalized cost estimates that assumed that all of the alternatives would be constructed from the lake side of the wall. Then each design concept was discussed with the State of Ohio dam regulatory agency, the ODNR Division of Water, to obtain guidance on which designs could be developed into an acceptable dam structure. Conceptual drawings of all six of the alternatives are shown on Exhibit 7.

9.2.2 Roller-Compacted Concrete (RCC)

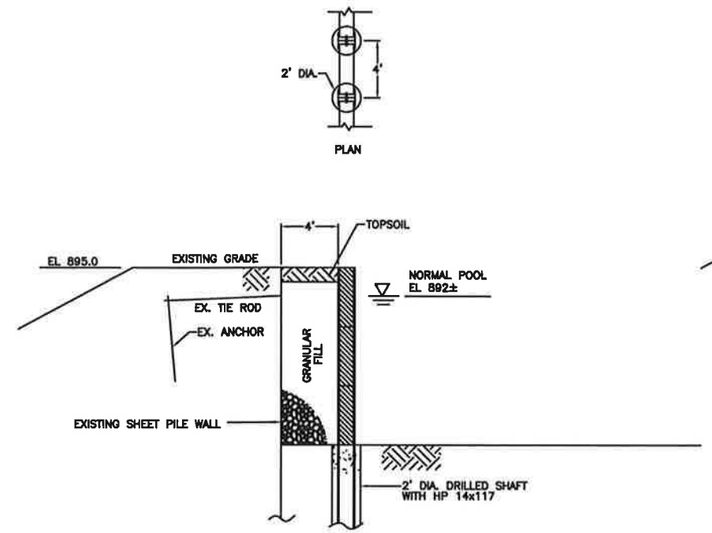
This alternative consisted of constructing a new structure in the lake using RCC. However, preliminary design calculations indicated that bearing capacity and settlement were a problem because of the soft, lakebed clays. Consequently, this alternative was not considered further.

9.2.3 Post and Panel Wall

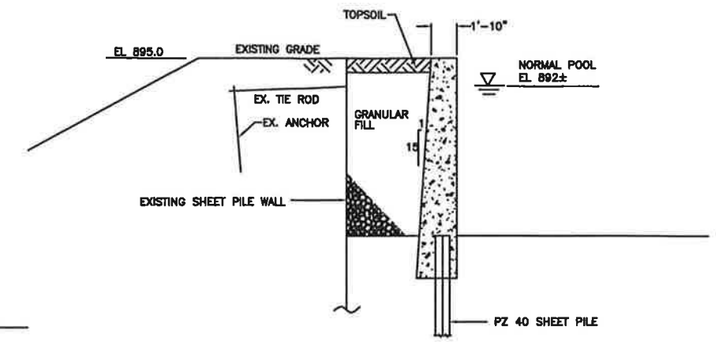
A post and panel wall would consist of steel H-piles placed in drilled shafts spaced every four feet along the wall alignment. Pre-cast concrete panels would then be placed between the flanges of the H-piles and the space between the wall and the existing sheet pile wall backfilled with granular fill. Advantages to this wall type would be the ease of construction (no cofferdam needed) and the aesthetic potential from the use of pre-cast panels. Disadvantages included constructibility and maintenance issues with the pre-cast concrete panels and their seals against the H section flanges. In addition, sheet pile would have been needed along West Bank for underseepage control. This wall type is also somewhat flexible so it is not possible to attach boat docks or lifts to the structure.



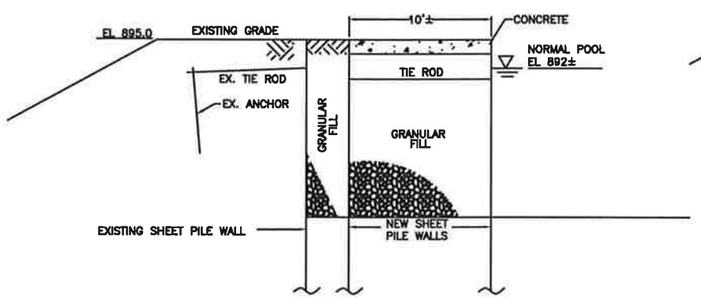
RCC EMBANKMENT



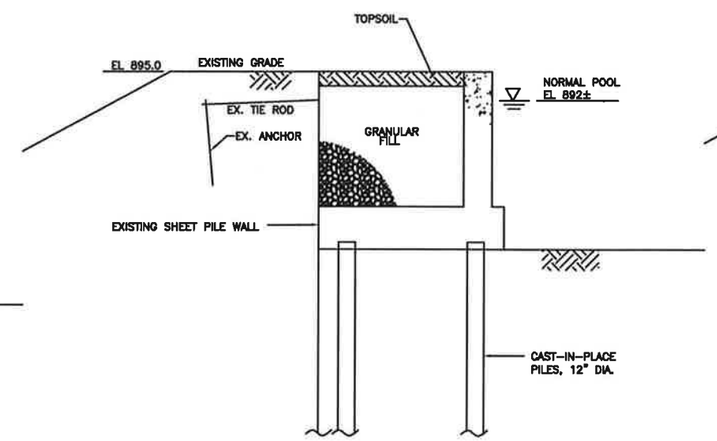
POST AND PANEL WALL



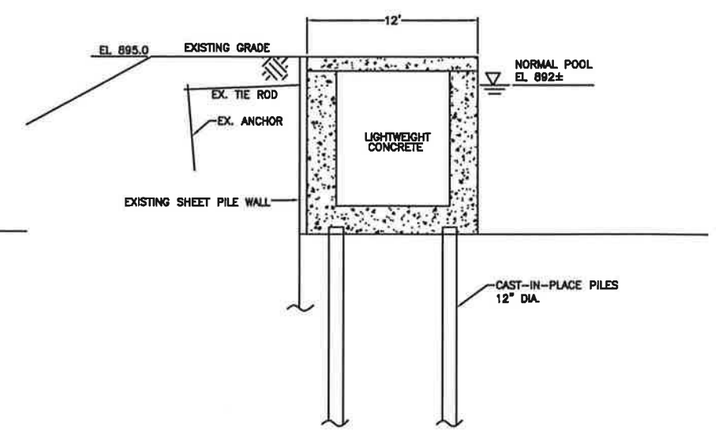
I-WALL



DOUBLE ROW SHEET PILE WALL



INVERTED T-WALL



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ENGINEERING
Ohio Department of Natural Resources

BUCKEYE LAKE STATE PARK
DAM IMPROVEMENTS
FAIRFIELD & LICKING COUNTIES, OHIO

DESIGNED BY:		JOB NUMBER:	736-730-93-006
DRAWN BY:		SCALE:	
CHECKED BY:		DATE:	AUGUST 8, 2002
APPROVED BY:		REVISED:	

EXHIBIT 7

Another concern with the post and panel wall was that although it is a common type of wall construction for retaining walls and sound barrier walls, its application as a dam structure is questionable. This fact and concerns about seepage through the panels and differential settlement of panels resulted in the Division of Water advising that a post and panel wall structure would not be suitable for this project.

9.2.4 I-Wall

An I-wall would consist of a concrete wall supported by continuous sheet pile. Advantages to this wall type would be the aesthetic potential from the use of decorative concrete forms for the panels and the fact that no separate underseepage control was needed along West Bank due to the sheet pile foundation. The disadvantages to this wall are that a cofferdam would be required and it is relatively flexible. Deflections may be excessive along deeper portions of the alignment, and because of the wall's flexibility, no boat docks or lifts could be attached to the wall.

9.2.5 Double Row Sheet Pile Wall

This alternative would consist of two rows of sheet pile driven about 10 feet apart and tied together. In between the two sheet pile walls, granular fill would be used as backfill and a concrete cap would be placed at the top to prevent erosion of the granular fill during an overtopping event. Advantages to this wall type would be the ease of construction (no cofferdam needed) and the fact that no separate underseepage control was needed along West Bank. A disadvantage to this wall type is that it is also flexible but not as flexible as an I-wall. Because of the wall's flexibility, no boat docks or lifts could be attached to the wall.

9.2.6 Inverted T-Wall

This wall type would consist of a large, cast-in-place concrete wall supported on piles. Advantages to this wall are that it is very rigid and both boat dock and boat lift attachments could be incorporated into the section. Disadvantages are the cost and the fact that a cofferdam would be needed. In addition, a sheet pile cutoff would be needed for underseepage control along West Bank.

9.2.7 Lift-In or Float-In Pre-Cast Concrete Box

This alternative would consist of hollow, pre-cast concrete boxes that would be lifted or floated into position. Because of the soft lakebed conditions, the sections would need to be supported on piles. However, preliminary calculations indicated that there is not sufficient draft to float in these sections. In addition, the small draft would require that the lift-in sections be very small making this construction technique impractical.

9.3 Selected Alternative

To select a preferred alternative, a comparison matrix was developed to evaluate the five alternatives (Exhibit 8.) Criteria included in the matrix were constructibility, durability and maintenance, aesthetics, cost, and whether or not boat docks or lifts can be attached to the structure. Each of the criteria is discussed below relative to each of the five alternatives considered.

For constructibility, it is believed that the post and panel wall and the double row sheet pile wall will be the easiest to construct of the five alternatives since they would not require cofferdams. The I-wall would require a cofferdam but the construction would be straightforward. The inverted T-wall would require a cofferdam and construction would be more complex than the other alternatives. As discussed above, construction of the pre-cast concrete box may not be practical, so it was given the least favorable value for constructibility.

It is believed that the inverted T-wall and the pre-cast concrete box alternatives would be the most durable and require the least maintenance of the alternatives due to the concrete construction. While the I-wall would also be constructed of concrete, there may be issues at joints due to the flexibility of the structure and it was given a slightly less favorable value. Because the double row sheet pile wall is constructed of steel, it was given a slightly less favorable value than the concrete structures since its useful life is probably slightly less than the concrete structures. The post and panel wall was given the lowest value because of the potential problems with seals and the concrete panels due to the flexibility of the walls. Post and panel walls on other projects have required significant maintenance.

The concrete structures (I-wall, inverted T-wall, and pre-cast concrete box) were given the highest criteria for aesthetics since the concrete could be finished or colored. These treatments would be expensive or not possible for the post and panel wall and the double row sheet pile wall, respectively, and they were both given a lower value.

The cost ratings were given based on the generalized cost of the least expensive alternative, which was the post and panel wall at $18.1 million. The ratings for the other alternatives were directly proportional to their respective cost compared to the cost for the post and panel wall. The cost of each of the alternatives is presented in Table 5.

Buckeye Lake State Park - Dam Improvements
Comparison Matrix

Criteria	**Constructibility**	**Durability & Maintenance**	**Aesthetics**	**Cost**	**Boat Docks**	
Weighting Factor	5	4	4	5	1	
Wall Option	**Score**					**Total**
Post and Panel Wall	5	2	3	5	1	71
Double Row Sheet Pile Wall	5	4	3	3.6	1	**72**
I-Wall	3	4	5	2.9	1	66.5
Inverted T-wall	2	5	5	2.1	5	65.5
Pre-Cast Concrete Box	1	5	5	2.2	5	61

Criteria are rated on a scale from 1 to 5, 5 being best and 1 being worst.

Cost: Score = (Minimum Cost for all Options / Option Cost) x 5
Constructibility: How easy is it to construct the wall? Is a cofferdam required? (5=easy, 1=difficult)
Maintenance/Durability: How much maintenance of the wall is required? How long is the expected useful life of the wall?
(5=low maintenance, long useful life, 1=high maintenance, short useful life)
Aesthetics: Is wall appearance pleasing? Will the wall become unsightly with time? Will the wall rust? (5=pleasing, 1=unsightly)
Boat Docks: Can boat docks be attached to the wall? (5=yes, 1=no)

Exhibit 8

Table 5. Estimated Cost for New Dam Options

Option	Estimated Total Cost (Millions of Dollars)
Post and Panel Wall	18.1
Double Row Sheet Pile Wall	24.8
I-Wall *	30.8
Inverted T-Wall *	42.3
Pre-Cast Concrete Box	41.6

* - Costs for I-Wall and Inverted T-Wall options include cost for required cofferdam.

The potential for boat dock attachment was also evaluated. If boat docks/lifts can be attached then the highest rating was given for that alternative. If boat docks/lifts cannot be attached then the lowest rating was given for that alternative.

Weighting factors were then selected for each criteria. Both constructibility and cost were given the most weight with durability and maintenance and aesthetics given slightly less weight. The boat dock attachment criteria was given the least weight.

Although not included in the weighting, each design concept was discussed with the regulatory agency (Division of Water) that has ultimate approval authority over what design will be permitted. The regulatory agency advised that the Double Row Sheet Pile and the Inverted T-Wall alternatives presented the least problems from their perspective.

Based on this comparison data, the preferred alternative is the double row sheet pile wall (see Exhibit 8.) However, this structure type is too flexible to attach boat docks or lifts. Consequently, a separate support for the boat docks and lifts will need to be provided upstream of the new wall. Additional information concerning the proposed dock and lift support is presented in the following section.

10.0 BOAT DOCK DESIGN

10.1 Introduction

Preliminary concept-level designs were developed for three types of boat docks. The simplest and least expensive boat dock design (referred to as Option 1) consists of a single pier that extends out into the lake from the dam. Option 2 consists of two parallel piers that form a single berth for a boat. Option 3 is similar to Option 2, with the addition that the structure can support the weight of an 8,000 pound boat. The different boat dock designs are presented in Exhibits 9, 10, and 11.

10.2 Analysis

Two load cases were considered for the design of Options 1 and 2, while three load cases were considered for the design of Option 3. Information and recommendations concerning the load cases, design criteria, and other items related to the boat dock design were provided by Mr. Fred Hunt, P.E., a marina consultant specializing in floating docks.

The first load case applied to all the boat dock options. It consisted of the combined weight of the structure plus a live load of 30 pounds per square foot (psf) over the entire surface of the pier. For this load case the pier had to deflect less than 1-inch for every 8 feet of length. At the end of the 28-foot long pier, the deflection had to be less than 3.5 inches.

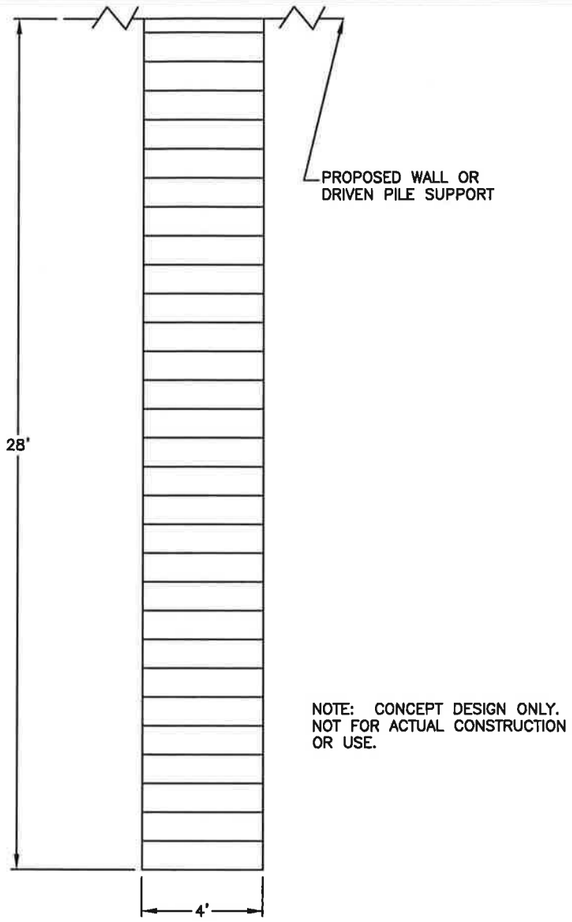
The second load case also applied to all the boat dock options. It consisted of a 400 pound load applied at the unsupported end of the pier. For this load case the pier had to deflect less than 4 inches where the load was applied.

The third load case that applied only to Option 3 consisted of the weight of the structure, an 8,000 pound boat, and a wind load. The boat was supported out of the water on a boat lift that was connected to the dock at four points (two points on each pier.) The boat lift was assumed to be a commercially available, hydraulic vertical lift. The wind load consisted of a 15 psf pressure on the side of a 24-foot long by 7-foot high boat, and it was applied horizontally to the pier. There was no maximum deflection associated with this load case, but the structure had to support the additional loads without failing.

10.3 Design

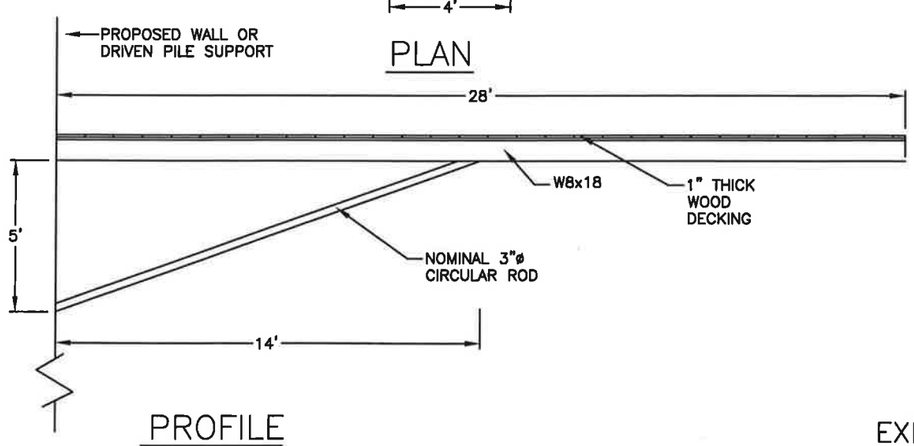
The piers for all the boat dock options are 28 feet long and 4 feet wide, and the berths between the piers in Options 2 and 3 are 12 feet wide. Each pier is designed to be attached to two vertical H-piles driven into the lakebed. However, if either the inverted T-wall or pre-cast concrete box options are selected for the new dam, the new dam could be designed so that the piers could be attached directly to the new dam.

Each pier consists of two horizontal wide-flange sections (i.e., I-beams) attached to the vertical H-piles and braced by two diagonal 3-inch diameter, standard weight steel rods attached between the H-piles and the midspan of the pier. The designs for all the options are similar, except for the size of the vertical H-piles and horizontal wide-flange sections. The H-piles for Options 1 and 2 are 22-foot long HP12x53 sections, while for Option 3 they are 32-foot long HP14x73 sections. The horizontal wide-flange sections for Options 1 and 2 are W8x18 sections, while for Option 3 they are W8x67 sections. Between the horizontal wide-flange sections, there is cross bracing and transverse bracing that consists of 3-inch diameter, standard weight steel rods. A 1-inch thick wood deck covers the steel dock structure. For further details regarding the boat docks, please refer to Appendix VI.



NOTE: CONCEPT DESIGN ONLY.
NOT FOR ACTUAL CONSTRUCTION
OR USE.

PLAN



PROFILE

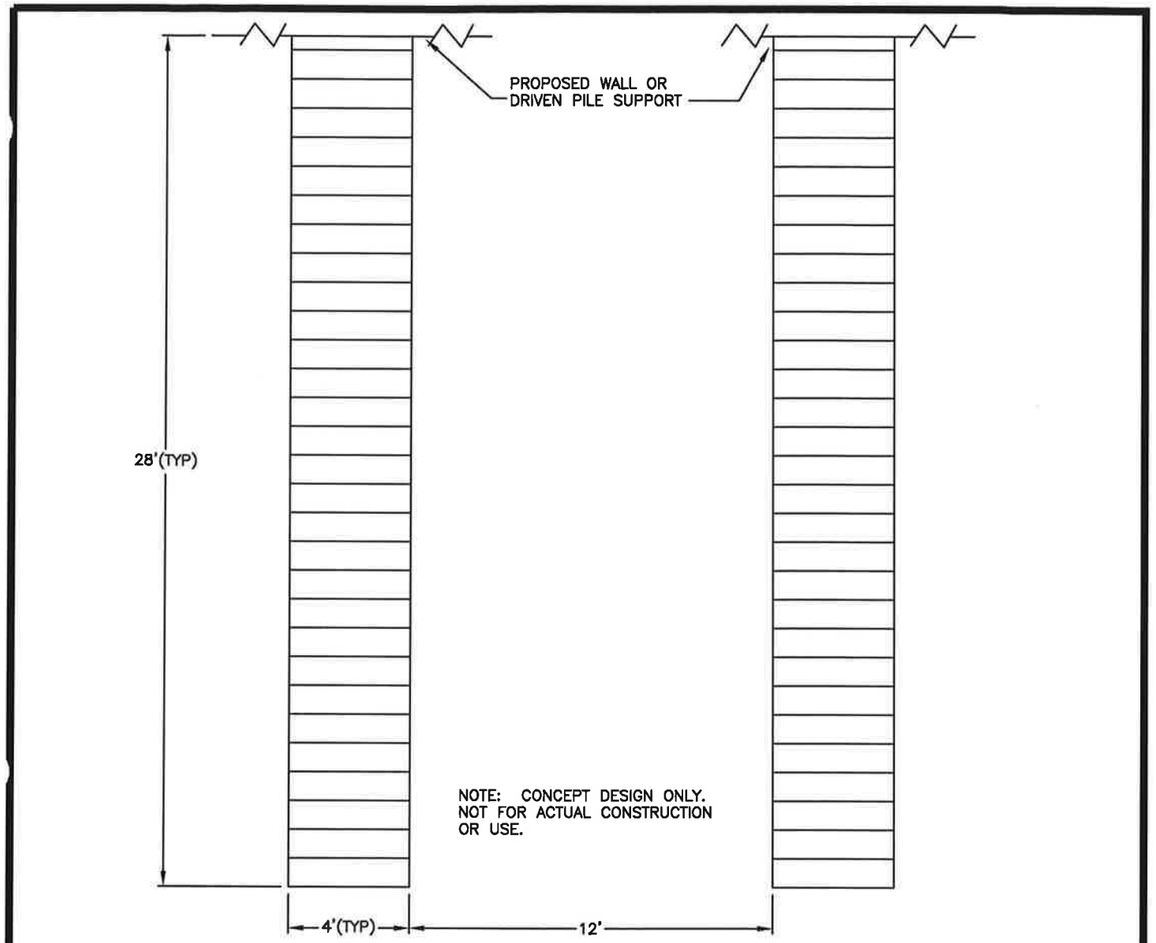
EXHIBIT 9

DLZ

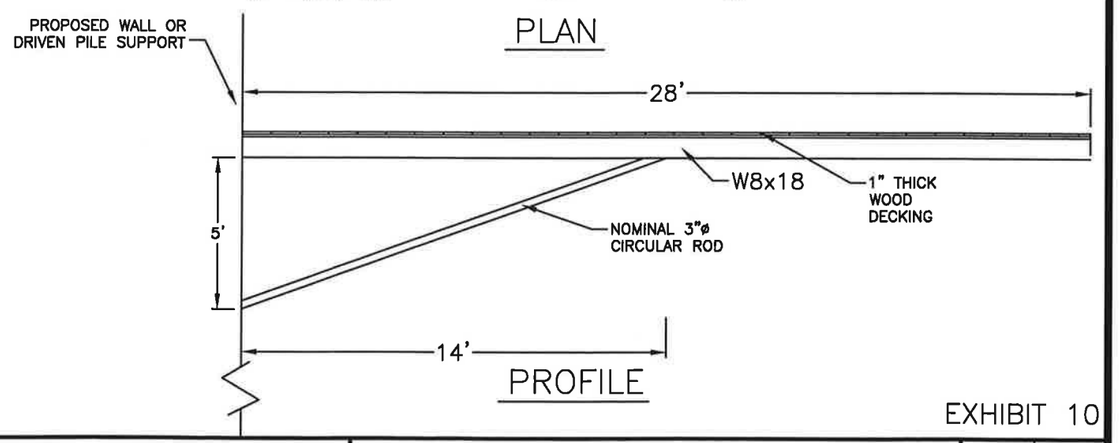
BUCKEYE LAKE STATE PARK
DAM IMPROVEMENTS

OPTION 1: SINGLE BOAT DOCK
WITHOUT BOAT LIFT

DRAWN: RLS	CHK'D. PAH
DESIGNED: PAH	APPRV'D: –
DATE: MAY 1, 2002	
SCALE:	1"=5'
PROJECT NUMBER	
0121-3074.00	



PLAN



PROFILE

EXHIBIT 10

DLZ

BUCKEYE LAKE STATE PARK
DAM IMPROVEMENTS

OPTION 2: DOUBLE BOAT DOCK
WITHOUT BOAT LIFT

DRAWN: RLS	CHK'D. PAH
DESIGNED: PAH	APPRV'D: -
DATE: MAY 1, 2002	
SCALE:	1"=5'
PROJECT NUMBER	
0121-3074.00	

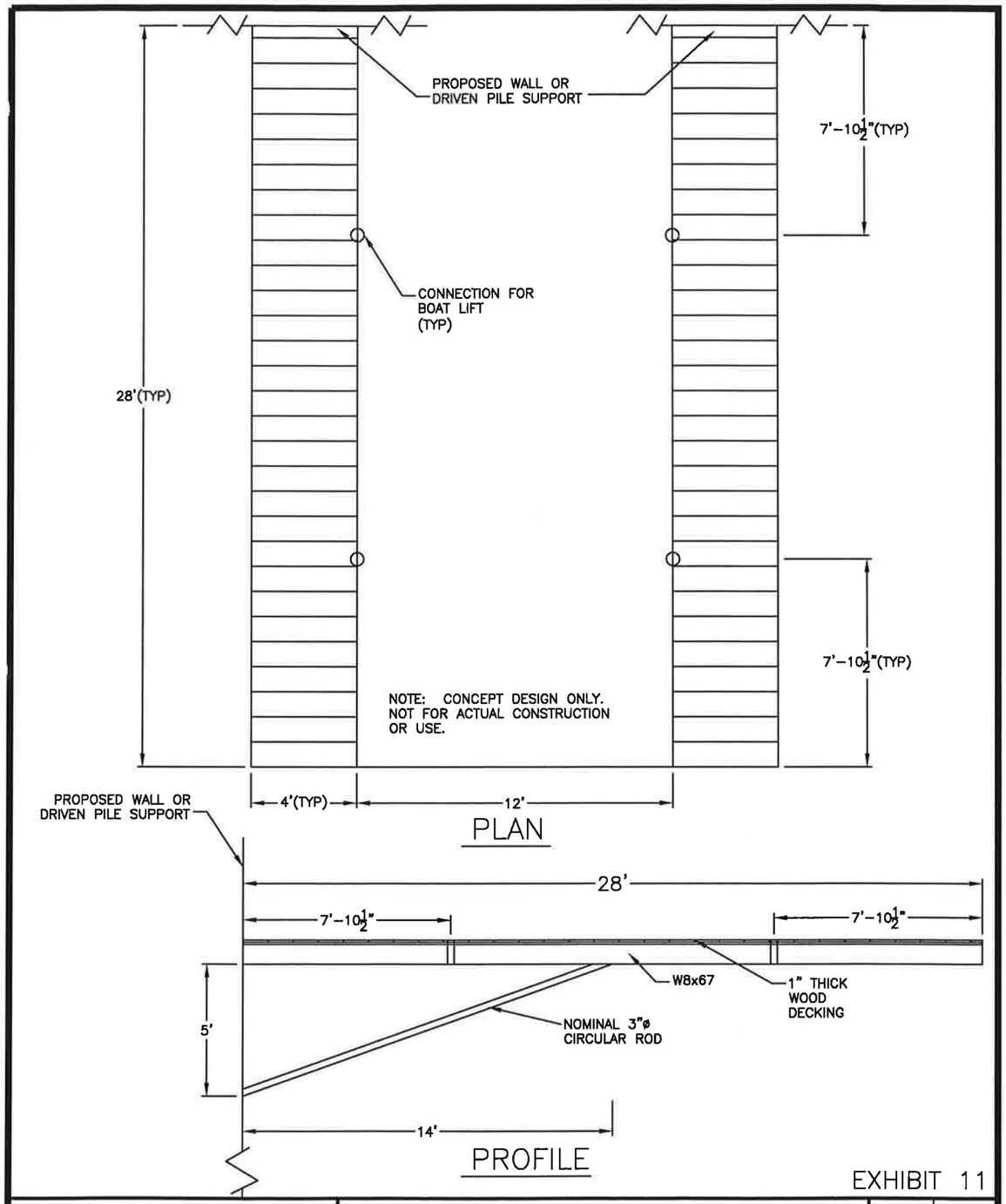


EXHIBIT 11

DLZ

BUCKEYE LAKE STATE PARK
DAM IMPROVEMENTS

OPTION 3: DOUBLE BOAT DOCK WITH BOAT LIFT
FOR 8000lb BOAT

DRAWN: RLS	CHK'D. PAN
DESIGNED: PAN	APPRV'D: –
DATE: MAY 1, 2002	
SCALE:	1"=5'
PROJECT NUMBER	
0121-3074.00	

APPENDIX I

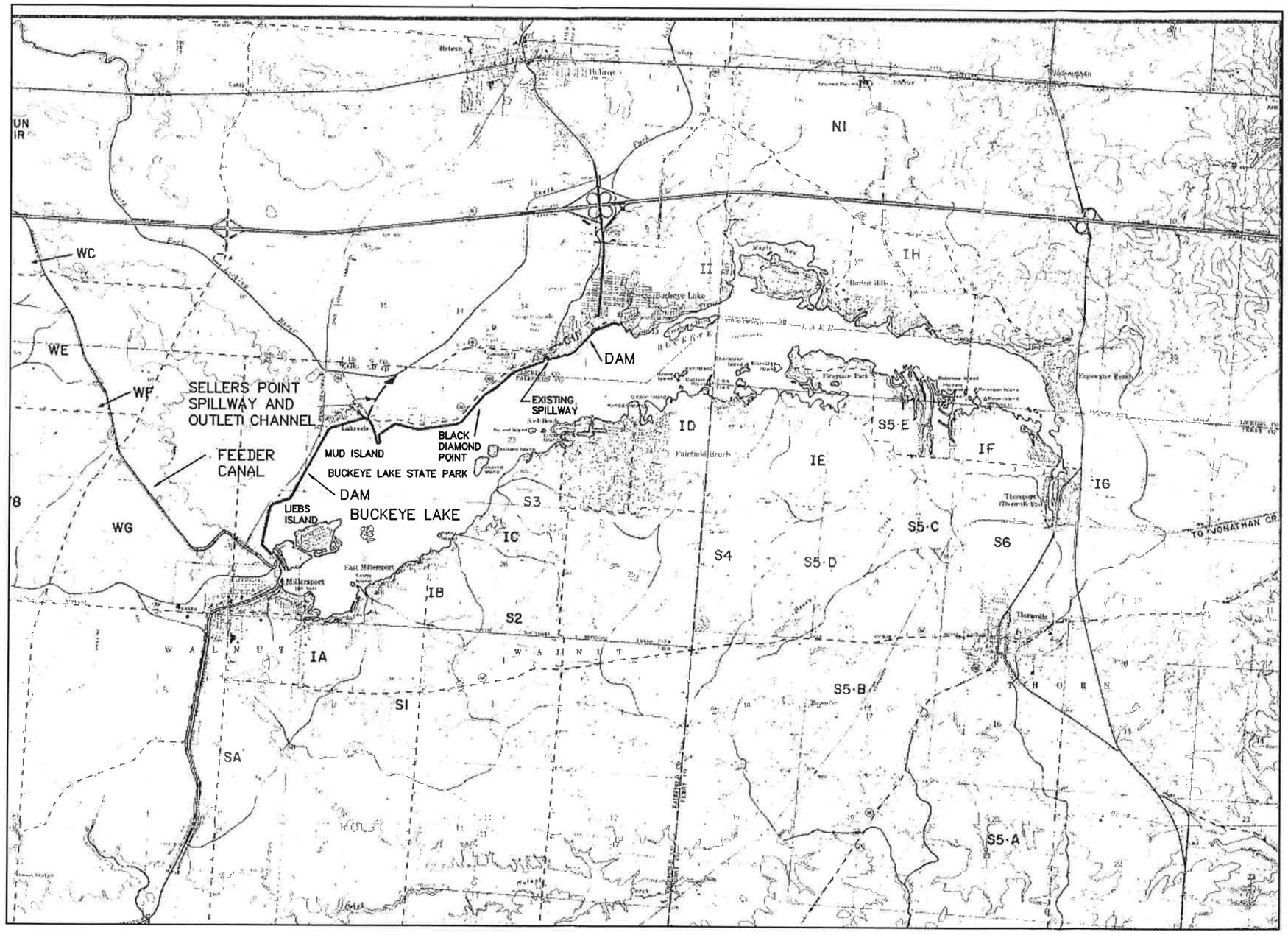
Location Map
General Plan of Buckeye Lake Area

DLZ

BUCKEYE LAKE STATE PARK
DAM IMPROVEMENTS

LOCATION MAP

DRAWN: PAN	CHK'D. -
DESIGNED: PAN	APPRV'D: -
DATE: August 8, 2002	
SCALE:	Not to scale
PROJECT NUMBER	
0121-3074.00	



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ENGINEERING
Ohio Department of Natural Resources

BUCKEYE LAKE STATE PARK
DAM EVALUATION
FAIRFIELD & LICKING COUNTIES, OH

DESIGNED BY:		JOB NUMBER:	DNR 736 730-93-006
DRAWN BY:		SCALE:	
CHECKED BY:		DATE:	MARCH 29, 2002
APPROVED BY:		REVISED:	

GENERAL PLAN
OF
BUCKEYE LAKE AREA

APPENDIX II

General Information – Drilling Procedures & Logs of Borings
Legend – Boring Log Terminology

GENERAL INFORMATION
DRILLING PROCEDURES AND LOGS OF BORINGS

Drilling and sampling were conducted in accordance with procedures generally recognized and accepted as standardized methods of investigation of subsurface conditions concerning geotechnical engineering considerations. Borings were drilled with either a truck-mounted or ATV-mounted drill rig.

Drive split-barrel sampling was performed in 1.5 foot increments at intervals not exceeding 5 feet. In the event the sampler encountered resistance to penetration of 6 inches or less after 50 blows of the drop hammer, the sampling increment was discontinued. Standard penetration data were recorded and one or more representative samples were preserved from each sampling increment.

In borings where rock was cored, NXM or NQ size diamond coring tools were used.

In the laboratory all samples were visually classified by a geotechnical engineer. Moisture contents of representative fine-grained soil samples were determined. A limited number of samples, considered representative of foundation materials present, were selected for performance of grain-size analyses and plasticity characteristics tests. The results of these tests are shown on the boring logs.

The boring logs included in the Appendix have been prepared on the basis of the field record of drilling and sampling, and the results of the laboratory examination and testing of samples. Stratification lines on the boring logs indicating changes in soil stratigraphy represent depths of changes approximated by the driller, by sampling effort and recovery, and by laboratory test results. Actual depths to changes may differ somewhat from the estimated depths, or transitions may occur gradually and not be sharply defined. The boring logs presented in this report therefore contain both factual and interpretative information and are not an exact copy of the field log.

Although it is considered that the borings have disclosed information generally representative of site conditions, it should be expected that between borings conditions may occur which are not precisely represented by any one of the borings. Soil deposition processes and natural geologic forces are such that soil and rock types and conditions may change in short vertical intervals and horizontal distances.

Soil/rock samples will be stored at our laboratory for a period of six months. After this period of time, they will be discarded, unless notified to the contrary by the client.

LEGEND – BORING LOG TERMINOLOGY

Explanation of each column, progressing from left to right

1. Depth (in feet) – refers to distance below the ground surface.

2. Elevation (in feet) – is referenced to mean sea level, unless otherwise noted.

3. Standard Penetration (N) – the number of blows required to drive a 2-inch O.D., 1-3/8 inch I.D., split-barrel sampler, using a 140-pound hammer with a 30-inch free fall. The blows are recorded in 6-inch drive increments. Standard penetration resistance is determined from the total number of blows required for one foot of penetration by summing the second and third 6-inch increments of an 18-inch drive.

   50/n – indicates number of blows (50) to drive a split-barrel sampler a certain number of inches (n) other than the normal 6-inch increment.

4. The length of the sampler drive is indicated graphically by horizontal lines across the "Standard Penetration" and "Recovery" columns.

5. Sample recovery from each drive is indicated numerically in the column headed "Recovery".

6. The drive sample location is designated by the heavy vertical bar in the "Sample No., Drive" column.

7. The length of hydraulically pressed "Undisturbed" samples is indicated graphically by horizontal lines across the "Press" column.

8. Sample numbers are designated consecutively, increasing in depth.

9. Soil Description

   a. The following terms are used to describe the relative compactness and consistency of soils:

   Granular Soils – Compactness

Term	Blows/Foot Standard Penetration
Very Loose	0 – 4
Loose	4 – 10
Medium Dense	10 – 30
Dense	30 – 50
Very Dense	over 50

   Cohesive Soils – Consistency

Term	Unconfined Compression tons/sq.ft.	Blows/Foot Standard Penetration	Hand Manipulation
Very Soft	less than 0.25	below 2	Easily penetrated by fist
Soft	0.25 – 0.50	2 – 4	Easily penetrated by thumb
Medium Stiff	0.50 – 1.0	4 – 8	Penetrated by thumb with moderate pressure
Stiff	1.0 – 2.0	8 – 15	Readily indented by thumb but not penetrated
Very Stiff	2.0 – 4.0	15 – 30	Readily indented by thumb nail
Hard	over 4.0	over 30	Indented with difficulty by thumb nail

   b. Color – If a soil is a uniform color throughout, the term is single, modified by such adjective as light and dark. If the predominant color is shaded by a secondary color, the secondary color precedes the primary color. If two major and distinct colors are swirled throughout the soil, the colors are modified by the term "mottled".

   c. Texture is based on the Unified Classification System. Soil particle size definitions are as follows:

Description		Size	Description		Size
Boulders		Larger than 8"	Sand	– Coarse	4.76 mm to 2.0 mm
Cobbles		8" to 3"		– Medium	2.0 mm to 0.42 mm
Gravel	– Coarse	3" to ¾"		– Fine	0.42 mm to 0.074 mm
	– Fine	¾" to 4.76 mm	Silt		0.074 mm to 0.005 mm
			Clay		smaller than 0.005 mm

d. The main soil component is listed first. The minor components are listed in order of decreasing percentage of particle size.

e. Modifiers to main soil descriptions are indicated as a percentage by weight of particle sizes.

trace	0 to 10%
little	10 to 20%
some	20 to 35%
"and"	35 to 50%

f. Moisture content of **cohesionless soils** (sands and gravels) is described as follows:

Term	Relative Moisture or Appearance
Dry	No moisture present
Damp	Internal moisture, but none to little surface moisture
Moist	Free water on surface
Wet	Voids filled with free water

g. The moisture content of **cohesive soils** (silts and clays) is expressed relative to plastic properties.

Term	Relative Moisture or Appearance
Dry	Powdery
Damp	Moisture content slightly below plastic limit
Moist	Moisture content above plastic limit but below liquid limit
Wet	Moisture content above liquid limit

10. Rock Hardness and Rock Quality Designation

a. The following terms are used to describe the relative hardness of the **bedrock**.

Term	Description
Very Soft	Permits denting by moderate pressure of the fingers. Resembles hard soil but has rock structure. (Crushes under pressure of fingers and/or thumb)
Soft	Resists denting by fingers, but can be abraded and pierced to shallow depth by a pencil point. (Crushes under pressure of pressed hammer)
Medium Hard	Resists pencil point, but can be scratched with a knife blade. (Breaks easily under single hammer blow, but with crumbly edges.)
Hard	Can be deformed or broken by light to moderate hammer blows. (Breaks under one or two strong hammer blow, but with resistant sharp edges.)
Very Hard	Can be broken only by heavy and in some rocks repeated hammer blows.

b. Rock Quality Designation, RQD – This value is expressed in percent and is an indirect measure of rock soundness. It is obtained by summing the total length of all core pieces which are at least four inches long, and then dividing this sum by the total length of the core run.

11. Gradation – when tests are performed, the percentage of each particle size is listed in the appropriate column (defined in Item 9c).

12. When a test is performed to determine the natural moisture content, liquid limit moisture content, or plastic limit moisture content, the moisture content is indicated graphically.

13. The standard penetration (N) value in blows per foot is indicated graphically.

Client: ODNR | **Project:** Bucke, Lake | **MV Job.** 9421.0023

LOG OF: Boring B-1 | **Location:** Sta. 11+30, 10' from shore | **Date Drilled:** 4/28/95

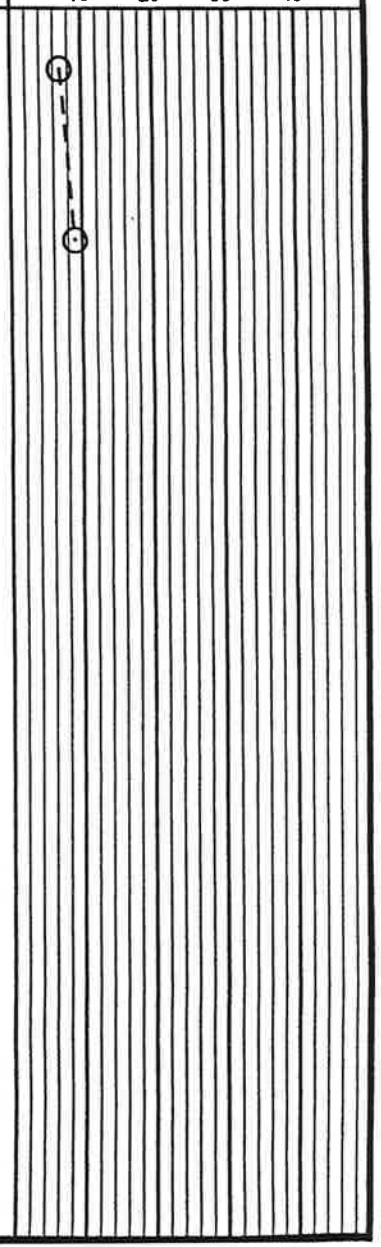
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	888.0												
		1 3 4	15	1		0.75	Medium stiff gray SILTY CLAY (CL), trace fine to coarse sand; slightly organic; moist.						
	884.3												
3.7		3 3 6	15	2		2.5	Very stiff mottled brown and gray SILTY CLAY (CL), trace to little fine to coarse sand, trace gravel; moist.						
5	883.0						Bottom of Boring - 5.0'						
10													
15													
20													
25													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODN

Project: Buck[illegible] Lake

MV Job No. 9421

LOG OF: Boring B-2

Location: Sta. 19+70, 10' from shore

Date Drilled: 4/28/95

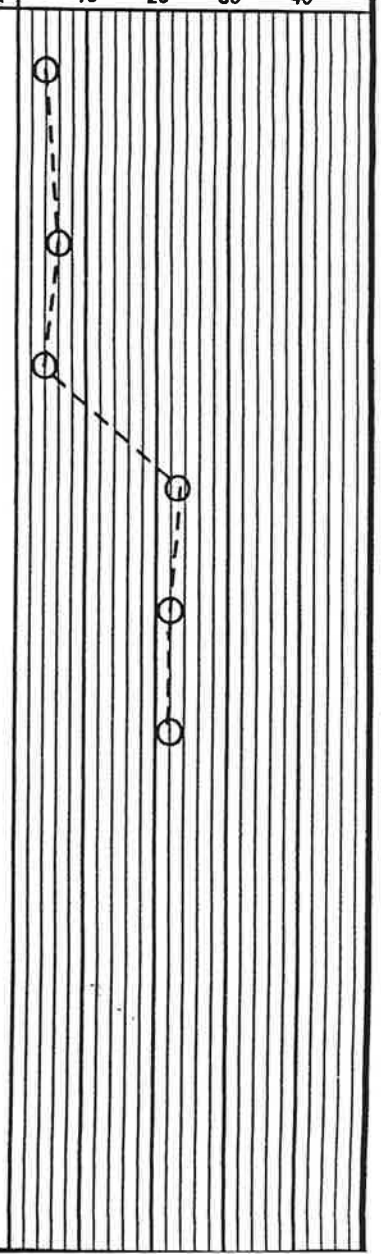
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	888.0												
		0 1 3	15	1		0.25	Soft gray CLAYEY SILT (CL-ML), trace fine to medium sand; slightly organic; moist to wet.						
2.5	885.5												
							Medium stiff black SILTY CLAY (CL), trace fine to coarse sand; slightly organic; moist.						
4.0	884.0	2 2 4	8	2		0.75							
5							Medium stiff mottled brown and gray SILTY CLAY (CL), little to some fine to coarse sand; trace to little gravel; moist.						
	880.8	1 2 2	12	3		0.5							
7.2													
							Stiff to very stiff brown and gray SILTY CLAY (CL), little to some fine to coarse sand, little gravel; damp to moist.						
		6 9 14	18	4		2.5							
10													
	875.9	6 8 14	18	5		1.5							
12.1													
							Medium dense gray fine to coarse SAND (SP-SM), trace silt, trace gravel; wet.						
		3 8 14	11	6									
15	873.0												
							Bottom of Boring - 15.0'						
20													
25													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | Project: Buck Lake | MV Job: 9421.0023

LOG OF: Boring B-3 | Location: Sta. 27+25, 10' from shore | Date Drilled: 4/28/95

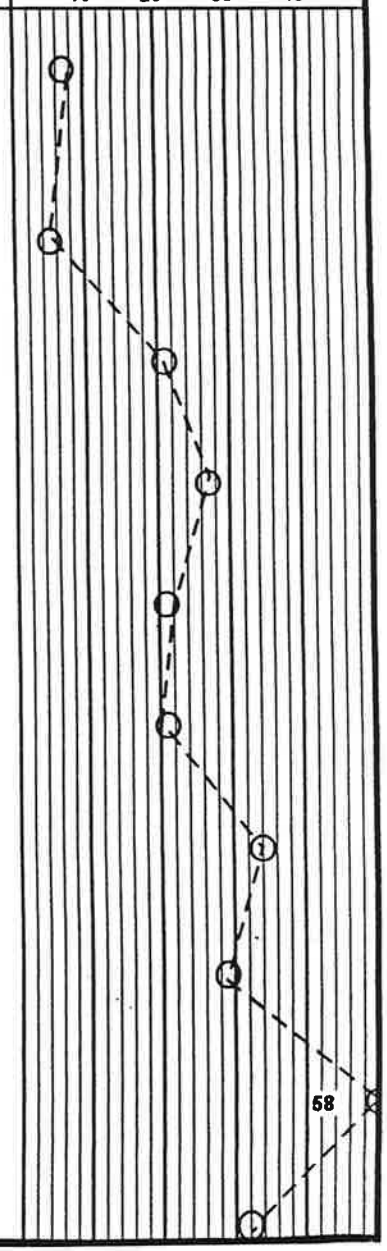
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	887.5	2 3 4	6	1		-	Soft black CLAYEY SILT (CL-ML), some fine to coarse sand; slightly organic; moist.						
2.0	885.5	2 2 3	11	2		0.75	Medium stiff mottled brown and gray SILTY CLAY (CL), little fine to coarse sand, trace gravel; moist.						
5.5	882.0	6 8 13	17	3		2.25	Very stiff to hard brown and gray SILTY CLAY (CL), little to some fine to coarse sand, little to some gravel; moist.						
10		12 12 15	10	4		2.5							
		6 10 11	11	5		4.0							
15		8 11 10	12	6		2.0	@ 13.5' - 15.0', contains sand heaves						
17.2	870.3	12 13 21	11	7		2.0							
19.7	867.8	6 11 18	13	8		2.25	Medium dense gray fine to coarse SAND (SM), some gravel, little silt; wet.						
20		44 30 28	14	9		4.5	Very stiff to hard gray SILTY CLAY (CL), some to "and" fine to coarse sand, little to some gravel; damp to moist.						
25		20 15 17	11	10		4.5+							

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | Project: Buck[illegible] Lake | MV Job [illegible] 9421.0023

LOG OF: Boring B-3 | Location: Sta. 27+25, 10' from shore | Date Drilled: 4/28/95

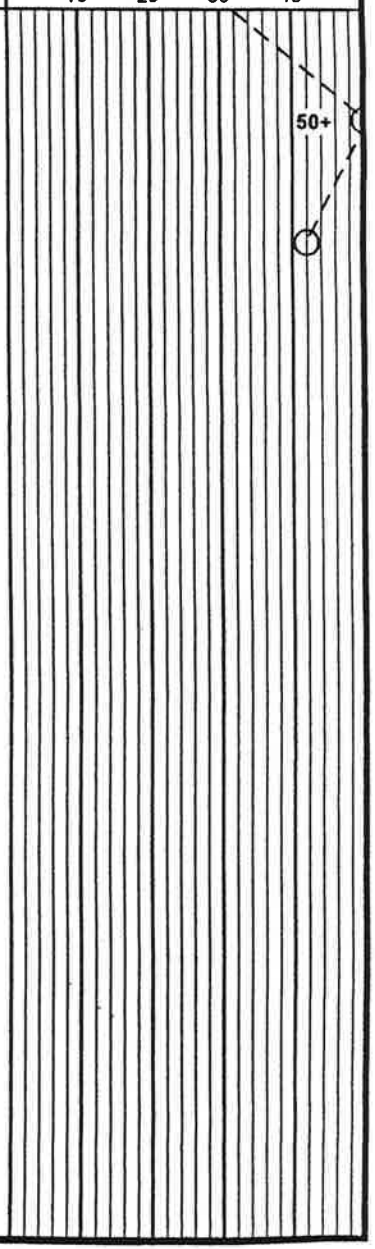
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
25	862.5												
							Very stiff gray SILTY CLAY (CL), some to "and" fine to coarse sand, little to some gravel; damp to moist.						
26.5	861.0	15 26 50/1	12	11									
							Very dense gray fine to coarse SAND (SM), little silt, some gravel; wet.						
28.0	859.5												
		14 18 24	10	12			Very stiff gray SILTY CLAY (CL), some fine to coarse sand, little to some gravel; damp to moist.						
30	857.5												
							Bottom of Boring - 30.0'						
35													
40													
45													
50													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | Project: Bucke, .ake | MV Job # 9421.0023

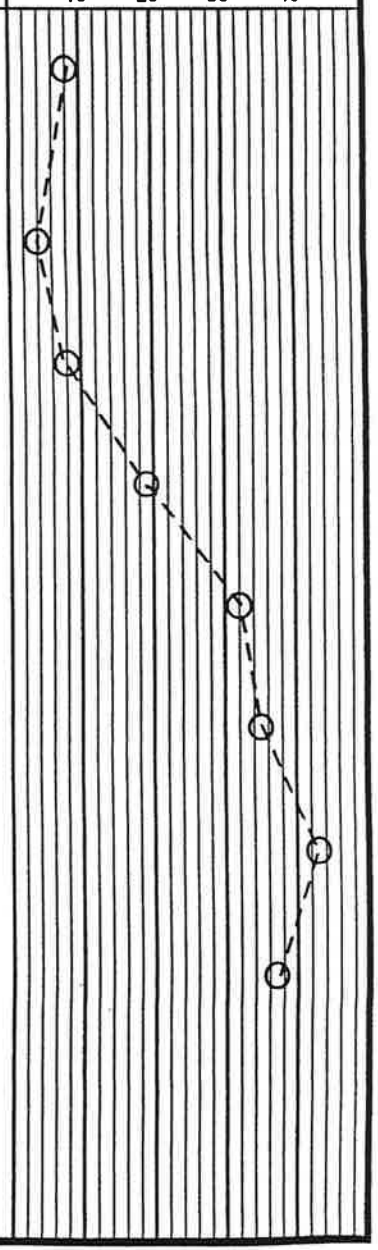
LOG OF: Boring B-4 | Location: Sta. 35+15, 6' from shore | Date Drilled: 4/26/95

WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	887.5												
		0 5 3	7	1		1.0	Medium stiff black CLAYEY SILT (CL-ML), trace to little fine to coarse sand; slightly organic; moist to wet.						
		2 2 2	1	2		-							
5.5	882.0												
		3 4 4	9	3		1.25	Stiff brown and gray SILTY CLAY (CL), trace fine to coarse sand; moist.						
8.0	879.5												
10		4 7 12	16	4		2.25	Very stiff to hard brown and gray SILTY CLAY (CL), little to some fine to coarse sand, little to some gravel; damp to moist.						
		11 13 19	16	5		4.5+							
15		10 14 21	11	6		4.5+							
		12 21 22	0	7									
20	867.5	10 13 24	12	8		3.5							
25							Bottom of Boring - 20.0'						

STANDARD PENETRATION (N) — Blows per foot: 10, 20, 30, 40

Moisture Content - %: PL, Natural, LL; 10, 20, 30, 40



Client: ODNR | **Project:** Bucke Lake | **MV Job** 9421.0023

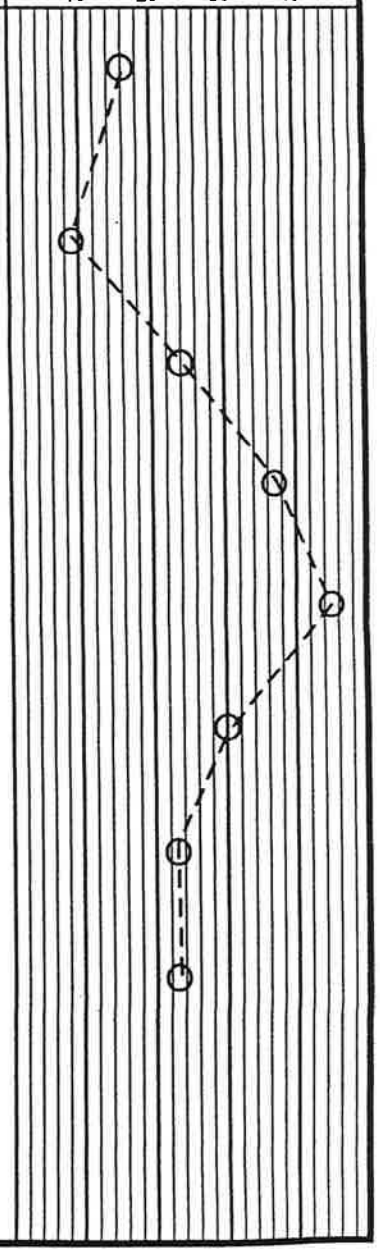
LOG OF: Boring B-5 | **Location:** Sta. 43+60, 5' from shore | **Date Drilled:** 4/25/95

WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	%Aggregate	%C. Sand	%M. Sand	%F. Sand	%Silt	%Clay
0	888.0												
		3 6 10	17	1		2.25	Very stiff brown and gray SILTY CLAY (CL), trace to little fine to coarse sand; damp to moist.						
2.0	886.0												
		2 3 6	17	2		0.5-1.25	Medium stiff to stiff brown and gray CLAYEY SILT (CL-ML), contains very soft silty clay seams; damp.						
5													
5.5	882.5												
	880.8	5 10 14	18	3			Medium dense brown SILT (ML), trace clay; damp.						
7.2													
		11 15 22	16	4		4.5+	Very stiff to hard brown and gray SILTY CLAY (CL), little to some fine to coarse sand, little gravel; damp to moist.						
10													
	875.8	10 22 23	13	5		2.0							
12.2													
13.0	875.0						Dense gray fine to coarse SAND (SM), some gravel, little silt; wet.						
		12 13 17	8	6		2.5	Very stiff gray SILTY CLAY (CL), little to some fine to coarse sand, little gravel; moist. @ 13.5', contains sandstone fragment						
15													
		5 10 13	11	7		2.5							
		7 9 14	11	8		2.5							
20	868.0						Bottom of Boring - 20.0'						
25													

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | **Project:** Buckeye Lake | **MV Job No.** 9421.0023

LOG OF: Boring B-6 | **Location:** Sta. 50+90, 12' from shore | **Date Drilled:** 4/25/95

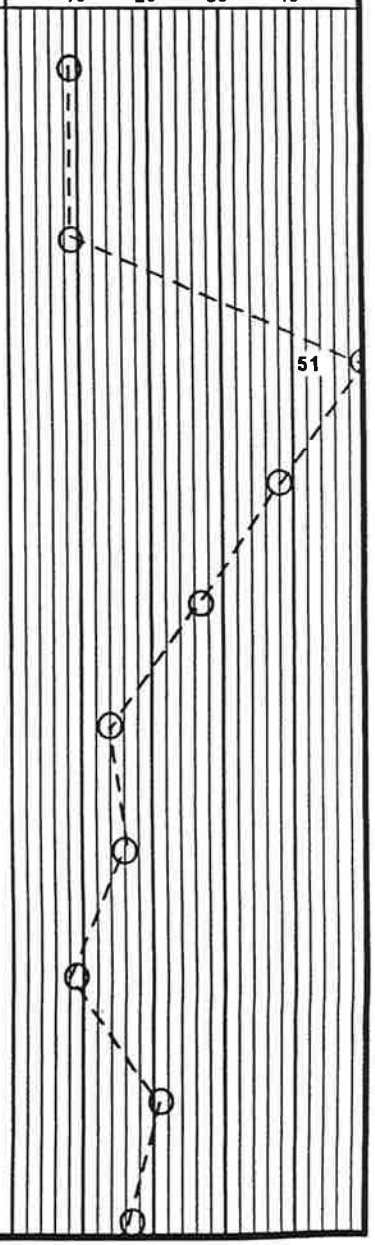
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	888.0	1 3 6	16	1		0.5-1.0	Medium stiff black and gray SILTY CLAY (CL), little fine to coarse sand, trace to little gravel; moist to wet.						
		2 3 6	9	2		0.25							
5.5	882.5	18 28 23	18	3		3.25	Very stiff to hard brown and gray SILTY CLAY (CL), little to some fine to coarse sand, little to some gravel; damp to moist.						
10		11 15 23	12	4		3.5							
		8 11 16	13	5		2.5							
15		4 5 9	10	6		4.5							
		3 6 10	0	7		-							
18.0	870.0	4 4 5	8	8		0.5-1.0	Medium stiff gray SILTY CLAY (CL), some fine to coarse sand, little to some gravel; contains fine sand seams; moist.						
20.5	867.5	6 10 11	6	9		3.5	Very stiff to hard gray SILTY CLAY (CL), little to some fine to coarse sand, little gravel; damp to moist.						
25		6 8 9	12	10		4.5							

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40

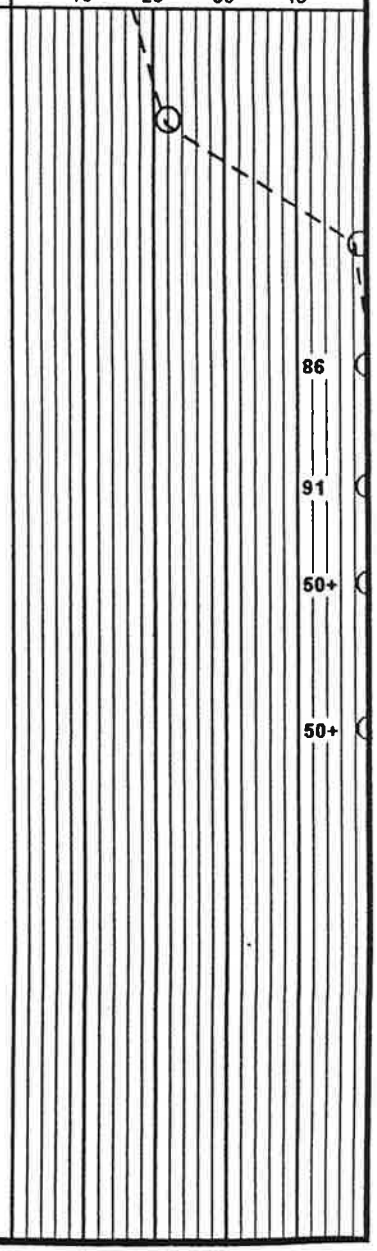


Client: ODNR | Project: Bucke, Lake | MV Job No. 9421.0023

LOG OF: Boring B-6 | Location: Sta. 50+90, 12' from shore | Date Drilled: 4/25/95

WATER OBSERVATIONS: Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	Standard Penetration (N) Blows per foot	Moisture Content - % PL / Natural / LL
25	863.0														
		6 9 13	8	11			Medium stiff gray SILTY CLAY (CL), some fine to coarse sand, some gravel; moist.								
27.0	861.0														
		22 26 23	11	12			Dense gray fine to coarse SAND (SM), little to some gravel, little silt; contains rock fragments; moist.								
30															
30.5	857.5														
		38 36 50	13	13			Very dense gray GRAVEL (GM), "and" fine to coarse sand, little silt; moist.							86	
33.0	855.0														
		54 46 45	13	14			Very dense gray fine to coarse SAND (SM), little to some silt, little gravel; moist to wet.							91	
35															
		48 50/5	9	15										50+	
		10 36 50/5		16											
40	848.0						@ 39.6', contains clay lenses							50+	
							Bottom of Boring - 40.0'								
45															
50															



Client: ODNR **Project:** Buck[illegible] Lake **MV Job [illegible]** 9421.0023

LOG OF: Boring B-7 **Location:** Sta. 59+00, 10' from shore **Date Drilled:** 4/21/95

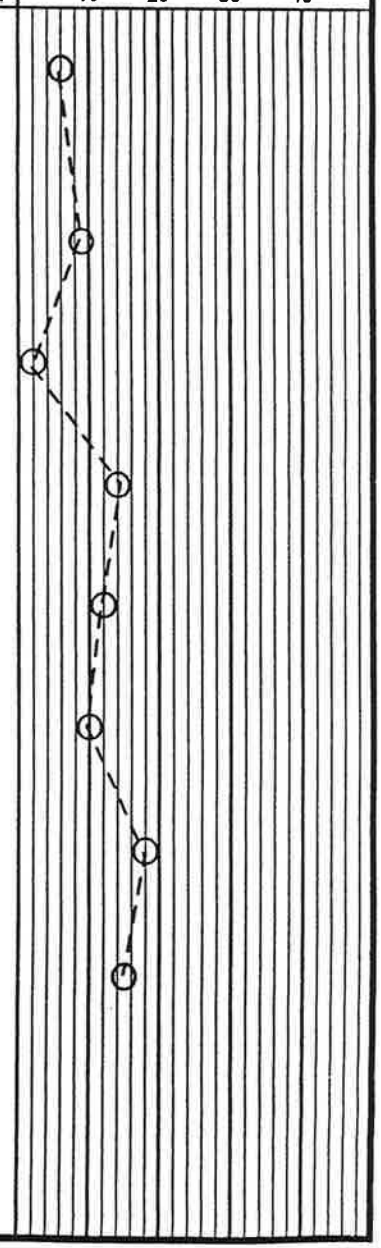
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	888.0												
		1 2 4	10	1		1.25	Medium stiff to stiff black SILTY CLAY (CL), little fine to coarse sand, trace gravel; slightly organic; moist.						
4.7	883.3	3 4 5	13	2		0.75							
5							Very loose gray fine to coarse SAND (SM), some silt, trace clay; wet.						
		1 1 1	7	3									
8.0	880.0												
		5 6 8	11	4			Medium dense gray fine to coarse SAND (SM), little to some silt, little gravel; wet.						
10													
		7 6 6	12	5									
		4 4 6	12	6									
15													
		5 9 9	9	7									
		6 7 8	12	8									
20	868.0												
							Bottom of Boring - 20.0'						
25													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | Project: Buck Lake | MV Job: 9421.0023

LOG OF: Boring B-8 | Location: Sta. 67+45, 6' from shore | Date Drilled: 4/20/95

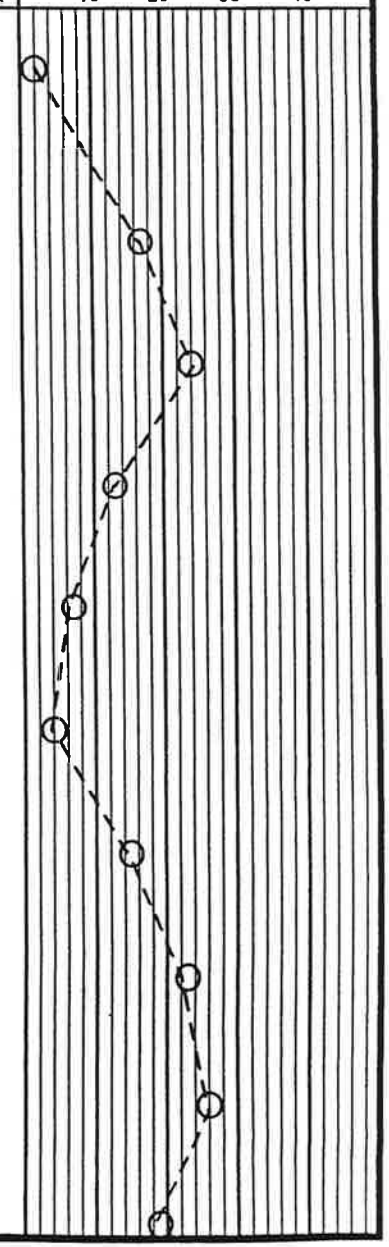
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	887.5	0 1 1	1	1			Very loose dark brown fine to coarse SAND (SP), trace silt; wet.						
3.0	884.5	4 6 11	17	2		3.25-4.0	Stiff to very stiff brown SILTY CLAY (CL), trace fine sand; damp to moist.						
5		9 10 14	11	3		2.0							
10		4 5 8	6	4		1.0							
10.5	877.0	2 3 4	18	5		1.5	Medium stiff to stiff mottled black and gray SILTY CLAY (CL); moist.						
15		1 2 2	18	6		0.5							
15.5	872.0	6 7 8	13	7			Medium dense brown fine to coarse SAND (SM), little to some silt, trace gravel; wet.						
18.0	869.5	5 10 13	12	8		3.0	Very stiff brown SILTY CLAY (CL), little fine to coarse sand, trace gravel; damp.						
20													
20.5	867.0												
	865.8	4 10 16	13	9			Medium dense gray fine to coarse SAND (SM), little silt, little gravel; wet.						
21.7							Hard gray SILTY CLAY (CL), some fine to coarse sand, trace gravel; damp.						
25		8 11 8	13	10		4.5+							

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | Project: Bucke, Lake | MV Job #: 9421.0023

LOG OF: Boring B-8 | Location: Sta. 67+45, 6' from shore | Date Drilled: 4/20/95

WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	Moisture Content - % (PL / Natural / LL)
25	862.5													
		1 4 6	5	11		1.5	Stiff gray SILTY CLAY (CL), some fine to coarse sand, trace gravel; damp to moist.							
28.0	859.5													
		4 12 21	13	12		4.5+	Hard gray SILTY CLAY (CL), little fine to coarse sand, little gravel; contains sand seams; damp.							
30														
		19 28 29	15	13		4.5+								57
		20 35 33	14	14		4.25								68
35														
		35 33 27	17	15		4.5								60
		22 21 38	15	16		4.5+								59
40	847.5						Bottom of Boring - 40.0'							
45														
50														

STANDARD PENETRATION (N) Blows per foot: 10 20 30 40

Moisture Content - %: PL Natural LL; 10 20 30 40

Client: ODNR | Project: Bucke, Lake | MV Job No. 9421.0023

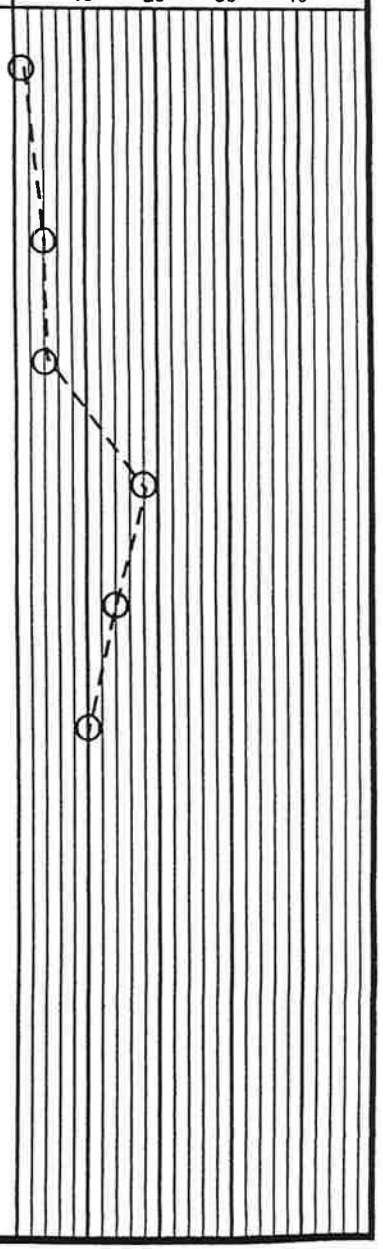
LOG OF: Boring B-9 | Location: Sta. 104+10, 10' from shore | Date Drilled: 5/1/95

WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	884.0												
		0 0 1	13	1		0.0	Very soft brown and black SILTY CLAY (CL), trace fine to coarse sand; organic; wet.						
		1 2 2	7	2		0.1							
5.5	878.5												
		1 2 2	6	3		0.25	Soft brown and gray SILTY CLAY (CL), some fine to coarse sand, little gravel; wet.						
8.0	876.0												
		4 7 11	11	4		2.0	Medium stiff to stiff brown and gray SILTY CLAY (CL), trace fine sand; contains silt seams; moist.						
		4 7 7	12	5		1.0							
		3 4 6	12	6		0.75							
15	869.0						Bottom of Boring - 15.0'						
20													
25													

STANDARD PENETRATION (N) — Blows per foot: 10, 20, 30, 40

Moisture Content - % — PL, Natural, LL: 10, 20, 30, 40



Client: ODNR | **Project:** Buck[illegible] Lake | **MV Job No.** 9421.0023

LOG OF: Boring B-10 | **Location:** Sta. 110+60, 10' from shore | **Date Drilled:** 5/1/95

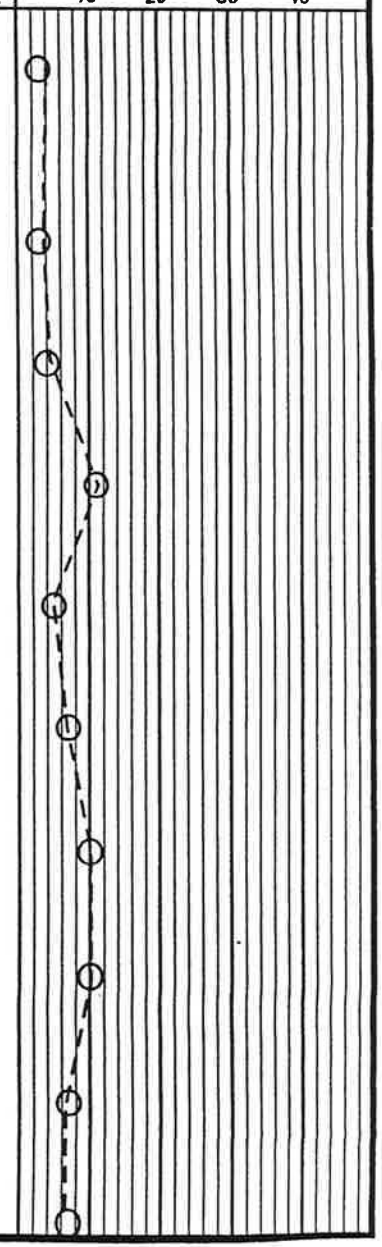
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	884.0												
		0 1 2	12	1		0.5	Soft black SILTY CLAY (CL), trace fine to coarse sand; organic; wet.						
3.0	881.0												
		3 2 1	6	2		1.0	Medium stiff mottled brown and gray SILTY CLAY (CL), some fine to coarse sand, little gravel; contains rock fragments; wet.						
5.5	878.5												
		2 2 2	18	3		1.5	Stiff brown SILTY CLAY (CL), trace fine sand; moist.						
8.0	876.0												
10		4 5 6	18	4		1.25	Medium stiff to stiff gray SILTY CLAY (CL), trace fine sand; laminated with fine sand and silt; moist to wet.						
		2 2 3	18	5		1.0							
15		3 3 4	18	6		0.75							
		2 5 5	18	7		0.75							
20		3 4 6	18	8		0.75							
		2 3 4	18	9		0.5							
25		2 3 4	18	10		0.75							

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR

Project: Buckey Lake

MV Job No. 9421.0023

LOG OF: Boring B-10

Location: Sta. 110+60, 10' from shore

Date Drilled: 5/1/95

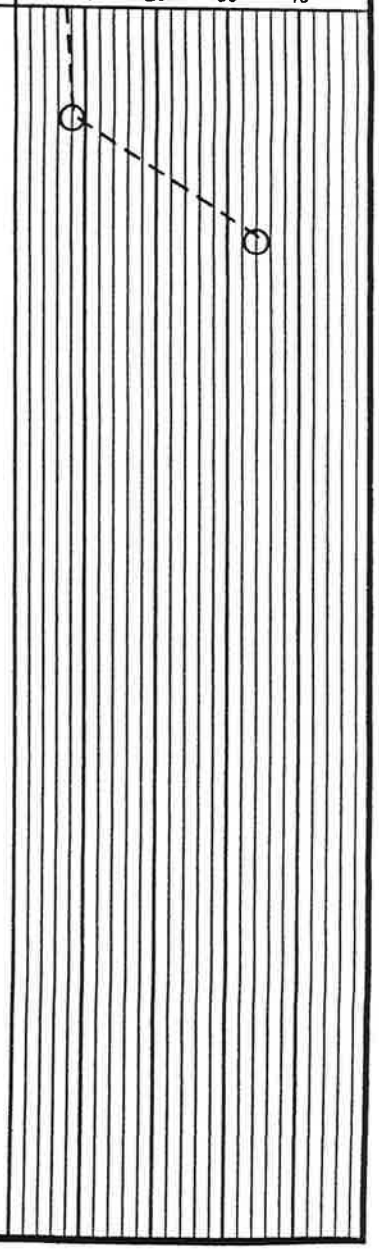
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
25	859.0												
		2 4 4	18	11		0.75	Medium stiff gray SILTY CLAY (CL); laminated with fine sand and silt; moist to wet.						
28.0	856.0												
		7 15 19	18	12			Dense gray fine SAND (SM), "and" silt; wet.						
30	854.0												
							Bottom of Boring - 30.0'						
35													
40													
45													
50													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



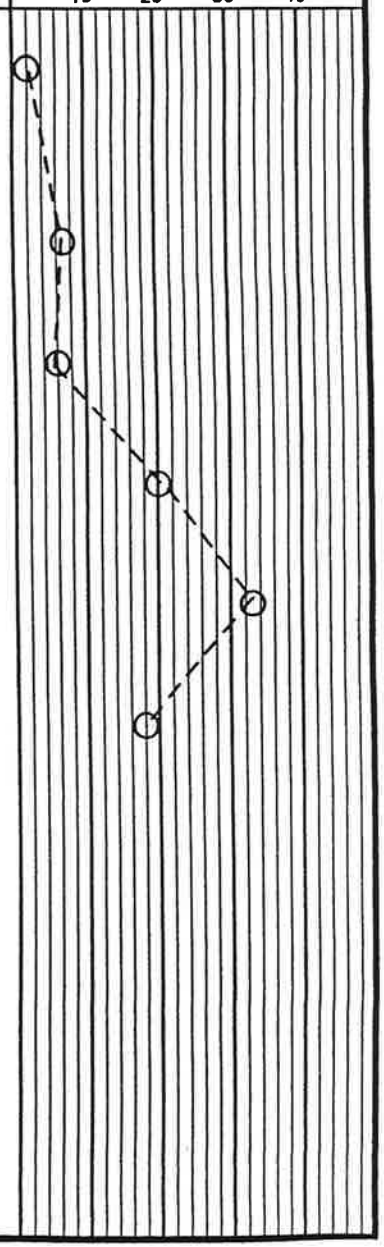
Client: ODNR	Project: Buck[illegible] Lake	MV Job [illegible] 9421.0023
LOG OF: Boring B-11	Location: Sta. 128+50, 5' from shore	Date Drilled: 5/2/95

WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	883.0												
		0 1 1	8	1		0.0	Very soft black and gray SILTY CLAY (CL), little fine to coarse sand; organic; wet.						
2.5	880.5												
		3 3 4	11	2		1.0	Medium stiff brown and gray SILTY CLAY (CL), trace fine to coarse sand, trace gravel; moist.						
5													
		1 2 4	12	3		1.0							
8.0	875.0												
		4 7 13	17	4		2.5	Very stiff brown SILTY CLAY (CL), trace fine sand; moist.						
10													
		8 14 19	18	5		3.5							
		5 8 10	18	6		2.25							
15	868.0												
							Bottom of Boring - 15.0'						
20													
25													

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODN

Project: Buck. . Lake

MV Job ... 9421.0023

LOG OF: Boring B-12

Location: Sta. 137+00, 5' from shore

Date Drilled: 5/2/95

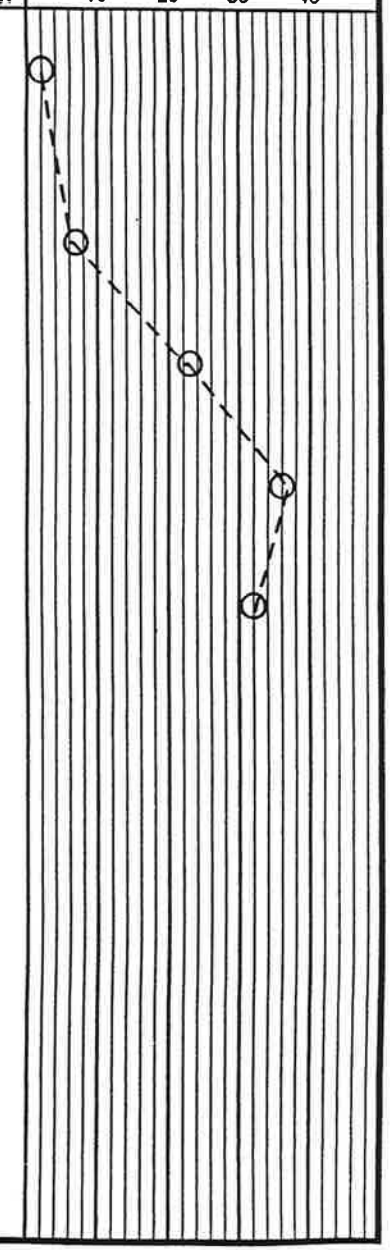
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	886.0												
		0 1 1	18	1		0.25	Very soft black SILTY CLAY (CL), little fine to coarse sand; organic; wet.						
2.5	883.5												
		2 3 4	16	2		0.75	Medium stiff mottled brown and gray SILTY CLAY (CL), little fine to coarse sand, trace gravel; moist.						
5													
5.5	880.5												
		6 9 14	14	3		4.0	Very stiff to hard brown and gray SILTY CLAY (CL), trace fine sand; damp to moist. @ 5.5' - 7.5', laminated						
10		9 15 21	18	4		4.5							
12.5	873.5	8 14 18	18	5		2.0							
15							Bottom of Boring - 12.5'						
20													
25													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | Project: Bucke Lake | MV Job: 9421.0023

LOG OF: Boring B-13 | Location: Sta. 145+00, 4' from shore | Date Drilled: 5/2/95

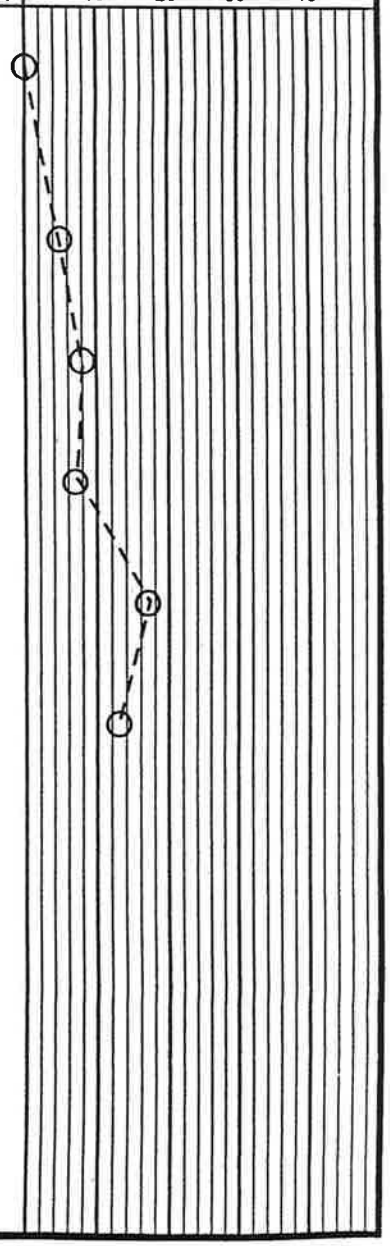
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	883.5												
		0 0 0	0	1			Very soft black SILTY CLAY (CL); organic; wet.						
2.5	881.0												
		2 2 3	17	2		0.75	Medium stiff mottled brown and gray SILTY CLAY (CL), little fine to coarse sand; moist.						
5.5	878.0												
		4 3 5	12	3		2.5	Very stiff mottled brown and blue gray SILTY CLAY (CL), little fine to coarse sand; moist.						
8.0	875.5												
		3 3 4	13	4		1.0	Stiff brown and gray SILTY CLAY (CL), trace fine sand; moist.						
10.5	873.0												
		5 8 9	14	5		0.75	Medium stiff gray CLAYEY SILT (CL-ML), little fine sand, trace clay; moist.						
		4 6 7	18	6		0.75							
15	868.5						Bottom of Boring - 15.0'						
20													
25													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR

Project: Buckeye Lake

MV Job No. 9421.0023

LOG OF: Boring B-14

Location: Sta. 157+15, 5' from shore

Date Drilled: 5/3/95

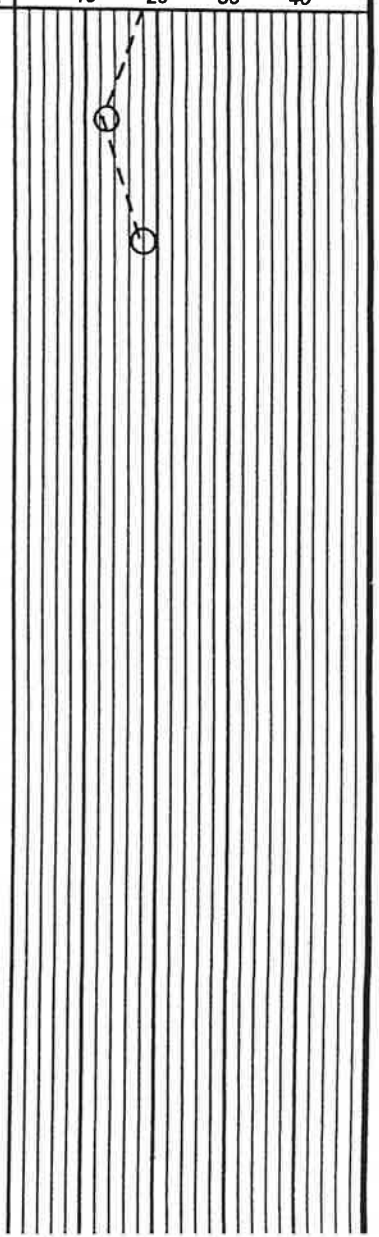
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
25	861.5												
		4 5 8	18	11		2.25	Very stiff gray CLAYEY SILT (CL-ML), trace to little fine to coarse sand, trace gravel; moist.						
		5 7 11	18	12		3.0							
30	856.5						Bottom of Boring - 30.0'						
35													
40													
45													
50													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODNR | **Project:** Buckeye Lake | **MV Job No.** 9421.0023

LOG OF: Boring B-14 | **Location:** Sta. 157+15, 5' from shore | **Date Drilled:** 5/3/95

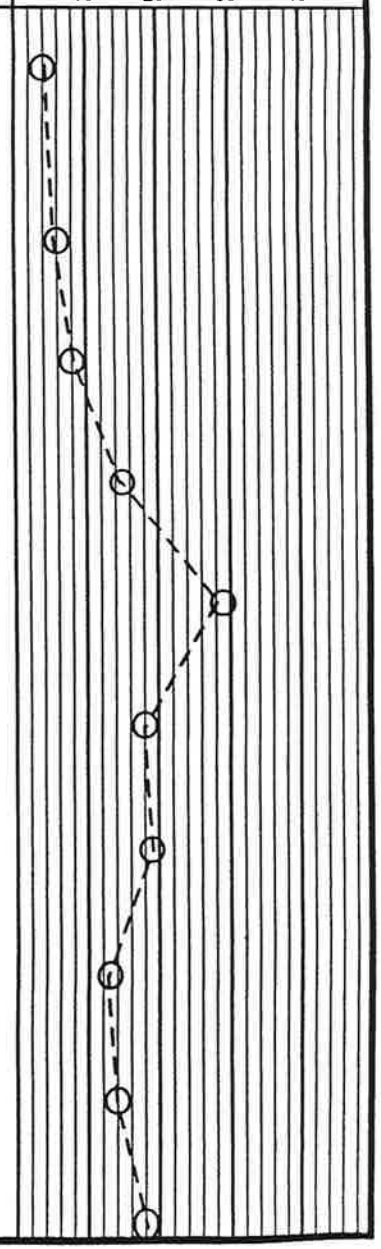
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	886.5												
		0 2 2	13	1		0.25	Very soft black SILTY CLAY (CL), some fine to coarse sand; organic; moist.						
2.5	884.0												
		3 2 4	14	2		1.0	Stiff to very stiff mottled brown and gray SILTY CLAY (CL), little fine to coarse sand; moist.						
		2 2 6	18	3		2.25							
8.0	878.5												
		3 7 8	15	4		1.25	Stiff brown CLAYEY SILT (CL-ML), little fine sand; moist.						
		10 12 17	17	5		2.0							
13.0	873.5												
		4 8 10	17	6		0.75	Medium stiff to stiff gray SILTY CLAY (CL); moist.						
		7 8 11	18	7		1.5							
		3 5 8	18	8		1.5							
		4 6 8	18	9		0.75							
23.0	863.5												
		5 7 11	18	10		0.25	Very stiff gray CLAYEY SILT (CL-ML), trace fine sand; moist.						
25													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



Client: ODN

Project: Buck Lake

MV Job No. 9421.0023

LOG OF: Boring B-15

Location: Sta. 165+75, 4' from shore

Date Drilled: 5/3/95

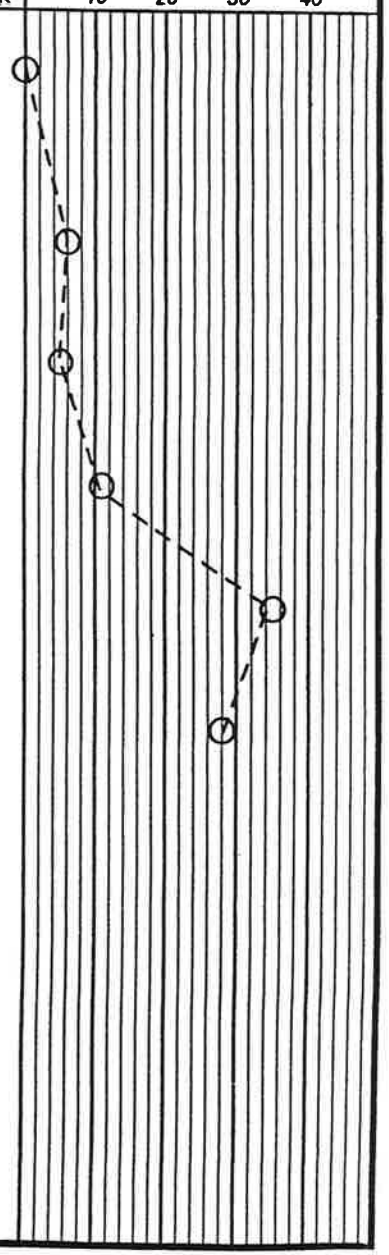
WATER OBSERVATIONS:
Water seepage at: Hole is located in the lake.
Water level at completion:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	884.5												
		1 0 0	1	1			Very soft black SILTY CLAY (CL), some gravel, little fine to coarse sand; organic; wet.						
3.0	881.5												
5		8 2 4	12	2		0.75	Soft to medium stiff mottled brown and gray SILTY CLAY (CL), trace to little fine to coarse sand; moist.						
		2 3 2	12	3		0.25							
9.1	875.4	4 5 6	11	4		2.25							
10							Medium dense to dense brown fine to coarse SAND (SM), some silt, little gravel; moist.						
		7 21 14	17	5									
13.0	871.5												
		8 12 16	15	6		4.0	Very stiff gray SILTY CLAY (CL), little fine to coarse sand, trace gravel; damp.						
15	869.5												
							Bottom of Boring - 15.0'						
20													
25													

GRADATION

STANDARD PENETRATION (N)
Blows per foot
10 20 30 40

Moisture Content - %
PL Natural LL
10 20 30 40



APPENDIX III

Tree Evaluation

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
1	Chamaecypraris obtusa	Hinoki Falsecypress	12	15	4	Shrubby
2	Juniperus squamata	Singleseed Juniper	4	9	5	
3	Picea pungens	Blue Spruce	1	8	5	
4	Fraxinus pennsylvanica	Green Ash	24.4	Dead	2	Topped
5	Malus hybrida	Flowering Crabapple	5.1	12	5	
6	Juniperus virginiana	Eastern Redcedar	4	9	5	
7	Juniperus virginiana	Eastern Redcedar	4.3	9	5	
8	Picea pungens	Blue Spruce	11.1	Dead	3	
9	Acer saccharum	Sugar Maple	26.2	29	3	
10	Acer saccharum	Sugar Maple	18.6	23	3	
11	Acer saccharum	Sugar Maple	23.6	28	3	
12	Acer saccharinum	Silver Maple	36.5	Dead	2	Topped, cavity @4.5 feet
13	Acer saccharinum	Silver Maple	26	30	2	Topped
14	Acer saccharinum	Silver Maple	26	30	2	Topped
15	Cornus florida	Flowering Dogwood	4	Dead	4	
16	Acer saccharinum	Silver Maple	34.4	36	3	Twin leadered
17	Gleditsia triacanthos	Common Honeylocust	25.5	29	3	
18	Morus rubra	Red Mulberry	25	33	1	50% cambium loss, Fall to house
19	Fraxinus americana	White Ash	25	29	3	Topped
20	Malus hybrida	Flowering Crabapple	12.2	15	3	
21	Acer saccharinum	Silver Maple	32.2	35	3	Twin leadered
22	Acer saccharinum	Silver Maple	24.6	32	3	Leans to house
23	Acer rubrum	Red Maple	10.1	14	5	
25	Acer saccharinum	Silver Maple	37	40	3	
26	Pinus strobus	White Pine	22.1	25	3	Cutout in concrete, lean to lake
27	Acer saccharum	Sugar Maple	20.5	25	3	Cutout in concrete
29	Juniperus chinensis	Chinese Juniper	3	9	5	
30	Cercis canadensis	Eastern Redbud	19	Dead	1	Declining no threat
31	Cercis canadensis	Eastern Redbud	13.3	Dead	1	Declining no threat
32	Celtis occidentalis	Common Hackberry	19.7	25	3	
33	Celtis occidentalis	Common Hackberry	14.6	18	2	Suppressed
34	Acer platanoides	Norway Maple	29.6	Dead	1	Unstable split to soil
35	Pyrus calleryana	Callery Pear	6	13	4	
36	Gleditsia triacanthos	Common Honeylocust	23.2	27	3	Armed

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
37	Acer negundo	Boxelder	29.4	Dead	2	Declining, no threat. 1:2.5 H:W ratio
38	Acer negundo	Boxelder	16.7	22	3	
39	Acer rubrum	Red Maple	19	24	3	Topped under power line
40	Acer saccharum	Sugar Maple	11.3	16	3	Topped under power line
41	Prunus serotina	Wild Black Cherry	32.8	Dead	2	Leans to lake pruned in rear
42	Magnolia soulangiana	Saucer Magnolia	7.5	10	4	
43	Ulmus pumila	Siberian Elm	24.4	28	3	Leans over lake
44	Acer saccharum	Sugar Maple	15	19	3	Suppressed, leans over lake
45	Fraxinus americana	White Ash	20.4	25	4	
46	Acer platanoides	Norway Maple	20.2	24	3	Topped, poor structure
47	Prunus serotina	Wild Black Cherry	6	12	4	
48	Acer saccharum	Sugar Maple	23.8	28	3	
49	Acer saccharum	Sugar Maple	24.5	29	3	Raised 3' cutout
50	Acer saccharum	Sugar Maple	20.2	24	3	Raised 3' cutout
51	Acer saccharum	Sugar Maple	17.8	21	3	Raised 3' cutout
52	Acer saccharum	Sugar Maple	15.8	20	3	
53	Acer saccharinum	Silver Maple	24.5	32	3	Topped
54	Acer saccharinum	Silver Maple	27.6	34	3	Topped
55	Acer negundo	Boxelder	30	Dead	1	Unstable, no threat
56	Acer platanoides	Norway Maple	19.8	22	2	Topped
57	Acer saccharum	Sugar Maple	15.9	20	3	Topped
58	Acer rubrum	Red Maple	16.2	20	3	Topped
59	Acer saccharinum	Silver Maple	28.4	31	2	Topped
60	Acer saccharinum	Silver Maple	22.5	30	3	
61	Acer rubrum	Red Maple	13.5	17	3	
62	Acer platanoides	Norway Maple	17.3	Dead	3	Girdling root
63	Celtis occidentalis	Common Hackberry	39	43	3	Girdled Branch, Failure into lake
64	Acer saccharinum	Silver Maple	28.5	34	3	Topped, Lightning strike
65	Acer saccharinum	Silver Maple	19	29	3	Topped
66	Acer saccharinum	Silver Maple	42	45	2	Topped, poor structure
67	Gleditsia triacanthos	Common Honeylocust	4	10	4	Suppressed
68	Gleditsia triacanthos	Common Honeylocust	11	15	4	
69	Acer platanoides	Norway Maple	16	21	2	Topped
70	Acer platanoides	Norway Maple	18.3	22	3	Topped

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
71	Acer platanoides	Norway Maple	20.8	25	3	Topped
72	Acer rubrum	Red Maple	23.2	25	3	
73	Betula pendula	European Birch	12	Dead	1	BBB, Dying, no threat
74	Cornus florida	Flowering Dogwood	2	Dead	4	
75	Acer saccharinum	Silver Maple	20.6	30	3	
76	Acer saccharinum	Silver Maple	23.1	30	3	Poor structure, lean to lake
77	Acer saccharinum	Silver Maple	19.7	29	3	
78	Picea abies	Norway Spruce	3	10	5	
79	Acer saccharinum	Silver Maple	34.2	36	3	Topped 1H:2W ratio
80	Acer saccharinum	Silver Maple	39.2	42	3	Topped, Poor structure
81	Acer saccharinum	Silver Maple	23.3	30	2	Topped, Poor, No threat
82	Acer rubrum	Red Maple	7.5	13	5	
83	Platanus occidentalis	Sycamore	36.5	41	4	
84	Acer negundo	Boxelder	17.5	23	3	
85	Acer negundo	Boxelder	22	Dead	3	Twin leadered
86	Acer negundo	Boxelder	24.5	Dead	3	
87	Acer negundo	Boxelder	19.8	25	3	
88	Acer negundo	Boxelder	18.9	23	3	
89	Acer saccharinum	Silver Maple	25.9	30	2	Topped, Poor structure, No threat
90	Acer saccharinum	Silver Maple	39.9	43	2	
91	Acer saccharinum	Silver Maple	25.3	35	4	
92	Acer saccharinum	Silver Maple	33.1	36	3	
93	Acer saccharinum	Silver Maple	36	38	3	**Flair over wall, Good structure, Wall threat**
94	Acer negundo	Boxelder	19.2	24	3	
95	Acer negundo	Boxelder	24.7	Dead	1	Near dead
96	Acer negundo	Boxelder	29	Dead	2	Twin leadered, no threat
97	Prunus serotina	Wild Black Cherry	23.2	26	3	
98	Acer rubrum	Red Maple	21.9	25	3	
99	Celtis occidentalis	Common Hackberry	24.8	30	4	
100	Acer rubrum	Red Maple	19	24	2	Topped, Poor structure, No threat
101	Populus deltoides	Eastern Cottonwood	57.5	60	3	
102	Acer saccharum	Sugar Maple	6.5	14	5	Tag 103 Missing
104	Prunus subhirtella	Weeping Cherry	2.2	12	5	
105	Prunus subhirtella	Weeping Cherry	2.5	12	5	

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
106	Celtis occidentalis	Common Hackberry	21	27	4	
107	Fraxinus americana	White Ash	20.7	25	3	
108	Acer saccharinum	Silver Maple	30.4	34	3	Topped, multileadered, no threat
109	Acer saccharum	Sugar Maple	14	18	3	
110	Prunus cerasifera	Purple-leaf Plum	13.9	Dead	3	
111	Juglans nigra	Black Walnut	6.4	16	5	
112	Acer saccharum	Sugar Maple	23.8	30	4	
113	Fraxinus americana	White Ash	23.4	28	4	
114	Acer saccharinum	Silver Maple	25.8	33	2	Top girdled, threat to house
115	Malus hybrida	Flowering Crabapple	1	8	3	Pruned as shrub
116	Acer saccharum	Sugar Maple	13.2	17	3	Poor structure
117	Fraxinus americana	White Ash	23.6	28	3	
118	Fraxinus americana	White Ash	29.9	35	3	
119	Celtis occidentalis	Common Hackberry	27.5	32	3	
120	Acer rubrum	Red Maple	4.7	9	3	
121	Acer saccharinum	Silver Maple	27.6	36	4	Good Structure
122	Acer platanoides	Norway Maple	8.7	19	4	
123	Celtis occidentalis	Common Hackberry	28.6	33	4	Good Structure
124	Quercus imbricaria	Shingle Oak	38.5	42	3	
125	Acer saccharum	Sugar Maple	26.9	Dead	1	Dying, no threat
126	Acer saccharinum	Silver Maple	40.8	44	3	Good structure, 1H:1.5W ratio
127	Acer negundo	Boxelder	14	Dead	2	Suppressed
128	Celtis occidentalis	Common Hackberry	24.2	28	3	
129	Celtis occidentalis	Common Hackberry	21.6	27	3	
130	Celtis occidentalis	Common Hackberry	31.1	34	3	
131	Celtis occidentalis	Common Hackberry	18.8	23	3	
132	Celtis occidentalis	Common Hackberry	17.8	21	2	
133	Celtis occidentalis	Common Hackberry	17.8	21	2	Leans to lake, lost leader, no threat
134	Fraxinus americana	White Ash	18.8	23	3	
135	Fraxinus americana	White Ash	20.7	26	3	Twin leadered
136	Celtis occidentalis	Common Hackberry	23.2	27	3	Top girdled
137	Malus hybrida	Flowering Crabapple	1	8	3	
138	Malus hybrida	Flowering Crabapple	7.9	14	4	
139	Platanus xacerifolia	London Planetree	25.8	30	3	

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
140	Platanus xacerifolia	London Planetree	26.5	30	3	
141	Acer saccharinum	Silver Maple	39	42	3	Multileadered, 1H:1W
142	Acer saccharinum	Silver Maple	36.4	Dead	2	Topped, decay, threat to house
143	Acer saccharinum	Silver Maple	25.9	30	2	Topped 1H:1W ratio
144	Acer saccharinum	Silver Maple	26.6	30	2	Topped
145	Acer saccharinum	Silver Maple	4	18	3	Twin leadered
146	Celtis occidentalis	Common Hackberry	42.6	45	3	Cabled, severed flair, twin leader, unstable
147	Gleditsia triacanthos	Common Honeylocust	11.8	16	3	
148	Celtis occidentalis	Common Hackberry	17.3	22	4	
149	Picea pungens	Blue Spruce	14	Dead	3	Lifted, unstable
150	Malus hybrida	Flowering Crabapple	6	13	3	
151	Gleditsia triacanthos	Common Honeylocust	46	48	3	Triple leadered, lightly armed, stable
152	Quercus palustris	Pin Oak	2.7	13	4	
153	Cornus florida	Flowering Dogwood	2	Dead	2	Sunscald
154	Picea pungens	Blue Spruce	3	10	4	
155	Fraxinus americana	White Ash	22.5	27	3	
156	Acer saccharum	Sugar Maple	16	20	3	
157	Betula pendula	European Birch	10	Dead	3	Twin leadered
158	Malus hybrida	Flowering Crabapple	8	14	3	
159	Acer platanoides	Norway Maple	7.2	17	5	
160	Acer saccharinum	Silver Maple	18.2	28	2	Topped, suppressed
161	Fraxinus americana	White Ash	25.6	30	3	
162	Acer saccharinum	Silver Maple	19.7	29	3	Suppressed
163	Acer saccharinum	Silver Maple	40.6	Dead	3	**Throw to lake, rootflair cut**
164	Acer saccharinum	Silver Maple	25.7	32	3	
165	Acer saccharinum	Silver Maple	30.5	34	3	
166	Morus rubra	Red Mulberry	13	21	3	**Trunk against piling**
167	Fraxinus americana	White Ash	16	Dead	2	Suppressed
168	Acer saccharinum	Silver Maple	34.5	36	3	
169	Acer saccharinum	Silver Maple	19.9	30	3	
170	Acer saccharinum	Silver Maple	21.2	30	2	Topped, suppressed
171	Acer saccharinum	Silver Maple	31.3	34	3	Poor structure
172	Acer saccharinum	Silver Maple	11	23	3	
173	Fraxinus pennsylvanica	Green Ash	22.3	26	3	Topped

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
174	Acer saccharinum	Silver Maple	28	31	2	Topped
175	Fraxinus pennsylvanica	Green Ash	25.2	28	3	
176	Acer saccharinum	Silver Maple	18.6	29	4	
177	Acer saccharum	Sugar Maple	23.1	27	3	
178	Acer saccharinum	Silver Maple	37.5	40	3	Decay in crown, hanger
179	Acer saccharinum	Silver Maple	29.2	34	3	
180	Acer saccharum	Sugar Maple	24.3	29	3	
181	Acer saccharinum	Silver Maple	30.9	33	2	Decay in stem
182	Acer saccharum	Sugar Maple	21.5	26	3	Multileadered, topped
183	Acer saccharum	Sugar Maple	21.8	26	3	
184	Acer saccharinum	Silver Maple	29	34	3	Hangers
185	Acer saccharum	Sugar Maple	26.6	30	3	
186	Acer saccharinum	Silver Maple	26.6	33	3	
187	Acer saccharinum	Silver Maple	30.2	34	3	
188	Acer saccharinum	Silver Maple	32.5	35	3	Slow growth
189	Acer saccharinum	Silver Maple	31.1	34	3	
190	Quercus palustris	Pin Oak	21.2	29	4	
191	Acer saccharum	Sugar Maple	11.2	17	4	
192	Acer saccharinum	Silver Maple	28.9	34	3	Triple leadered, threat to house
193	Quercus palustris	Pin Oak	4.1	16	4	
194	Quercus palustris	Pin Oak	3.9	14	3.9	
195	Fraxinus americana	White Ash	37.5	Dead	2	**Root flair severed, ash conk present at base**
196	Acer saccharinum	Silver Maple	30.2	30	2	Decay at base, girdling root
197	Fraxinus americana	White Ash	38.3	40	3	
198	Picea pungens	Blue Spruce	4	11	5	
199	Aesculus glabra	Ohio Buckeye	12.7	16	4	
200	Acer rubrum	Red Maple	15.2	18	3	Poor growth
201	Acer saccharum	Sugar Maple	14.1	18	3	
202	Fraxinus americana	White Ash	25.7	30	3	
203	Quercus imbricaria	Shingle Oak	26.5	31	3	Top removed
204	Taxodium distichum	Bald-cypress	2.8	5	3	Twin leadered, cold damaged
205	Acer saccharum	Sugar Maple	11.6	16	3	Topped
206	Acer saccharum	Sugar Maple	12.1	17	3	Topped
207	Acer saccharinum	Silver Maple	25.1	32	3	

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
208	Acer saccharinum	Silver Maple	28.2	34	3	
209	Acer saccharinum	Silver Maple	30.4	34	3	
210	Acer saccharinum	Silver Maple	44.4	46	3	Topped
211	Acer platanoides	Norway Maple	4.2	15	5	
212	Pinus strobus	White Pine	4	10	5	
213	Acer platanoides	Norway Maple	14.5	20	3	Twin leadered
214	Acer saccharinum	Silver Maple	48.6	50	3	Five leaders
215	Acer saccharinum	Silver Maple	25.8	33	3	
216	Acer saccharinum	Silver Maple	31.9	35	3	
217	Pseudotsuga menziesii	Douglas-fir	5.6	12	4	
218	Celtis occidentalis	Common Hackberry	27	31	3	Leans to lake
219	Cercis canadensis	Eastern Redbud	10.3	Dead	2	Triple leader, Botryosphaeria canker
220	Cercis canadensis	Eastern Redbud	10.3	Dead	2	Triple leader, Botryosphaeria canker
221	Juglans sp.	Walnut	17	19	3	Triple leader
222	Acer rubrum	Red Maple	9.3	13	2	
223	Picea glauca conica	Alberta Spruce	4	Dead	2	Spruce mite, dying
224	Picea abies	Norway Spruce	7	12	3	
225	Pinus nigra	Austrian Pine	11.3	16	3	
226	Salix babylonica	Weeping Willow	11.8	Dead	3	Suppressed
227	Quercus palustris	Pin Oak	20.1	28	3	
228	Salix babylonica	Weeping Willow	37.3	Dead	3	
229	Salix babylonica	Weeping Willow	26.8	Dead	2	Leans to lake, decay, suppressed
230	Acer saccharinum	Silver Maple	28.9	31	2	Leans to lake, girdled, suppressed
231	Acer saccharinum	Silver Maple	26	33	3	
232	Betula pendula	European Birch	8.3	Dead	2	BBB, Dying, no threat
233	Acer saccharinum	Silver Maple	14.2	26	3	Topped
234	Acer rubrum	Red Maple	7.8	12	3	Shrub pruned
235	Acer saccharinum	Silver Maple	25.1	32	3	Topped, decay
236	Acer saccharinum	Silver Maple	31.2	34	3	Topped
237	Acer platanoides	Norway Maple	14.8	20	3	
238	Fraxinus americana	White Ash	28.6	33	3	Leans to lake
239	Liriodendron tulipifera	Tulip-poplar	17.2	21	3	
240	Acer rubrum	Red Maple	13.1	13	3	Suppressed, leans to lake
241	Acer platanoides	Norway Maple	17.9	Dead	2	Declining no threat

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
242	Acer saccharum	Sugar Maple	22	26	3	Topped
243	Acer saccharinum	Silver Maple	24.1	32	3	Poor structure
244	Celtis occidentalis	Common Hackberry	25.6	29	3	
245	Celtis occidentalis	Common Hackberry	29.6	33	3	Twin leadered
246	Catalpa speciosa	Northern Catalpa	30.1	35	3	Four leaders
247	Acer platanoides	Norway Maple	8.3	18	4	
248	Acer saccharum	Sugar Maple	9.2	14	4	
249	Acer saccharum	Sugar Maple	29	33	3	Topped
250	Acer saccharum	Sugar Maple	30	33	3	Topped
251	Malus hybrida	Flowering Crabapple	2.7	9	4	
252	Malus hybrida	Flowering Crabapple	9.4	14	3	Suppressed
253	Acer saccharinum	Silver Maple	19.3	29	2	Triple leadered
254	Acer saccharinum	Silver Maple	23.6	31	3	
255	Acer saccharinum	Silver Maple	35.7	37	3	Triple leader
256	Acer saccharinum	Silver Maple	31.6	34	3	Root flair over walk
257	Acer saccharinum	Silver Maple	36.3	39	3	Root flair over walk
258	Acer platanoides	Norway Maple	13.5	19	3	
259	Acer saccharinum	Silver Maple	31.6	34	3	
260	Acer saccharinum	Silver Maple	14	26	3	Topped
261	Acer saccharinum	Silver Maple	38.3	41	3	
262	Acer saccharinum	Silver Maple	27.4	34	3	
263	Acer platanoides	Norway Maple	2.9	13	4	
264	Acer saccharinum	Silver Maple	32	35	3	
265	Acer rubrum	Red Maple	13.8	14	2	Slow growth
266	Acer saccharinum	Silver Maple	29.2	33	2	Topped, decay
267	Acer saccharinum	Silver Maple	25.8	33	3	Topped, decay
268	Acer saccharinum	Silver Maple	24.5	28	2	Topped, decay
269	Acer saccharinum	Silver Maple	14.5	27	3	
270	Acer saccharinum	Silver Maple	25.3	32	3	Topped
271	Pinus flexilis	Limber Pine	6.8	12	3	
272	Morus rubra	Red Mulberry	9.9	18	3	Twin leader
273	Acer saccharinum	Silver Maple	35.3	37	3	
274	Acer saccharinum	Silver Maple	30.2	31	2	Leans to lake, declining
275	Acer saccharinum	Silver Maple	46.3	48	3	Leans to lake, flair over walk

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
276	Cornus florida	Flowering Dogwood	3	Dead	3	Five leaders
277	Platanus occidentalis	Sycamore	37.9	42	3	
278	Quercus palustris	Pin Oak	16.2	24	3	
279	Ulmus pumila	Siberian Elm	24.5	28	3	Topped, slime flux
280	Ulmus pumila	Siberian Elm	29.8	33	3	Topped, slime flux
281	Acer saccharinum	Silver Maple	3.8	18	4	
282	Acer saccharinum	Silver Maple	29.6	34	3	Reduced crown
283	Picea abies	Norway Spruce	2	9	4	
284	Acer saccharinum	Silver Maple	33.2	36	3	Topped
285	Acer saccharinum	Silver Maple	30.8	34	3	Topped, flair over walk
286	Acer saccharinum	Silver Maple	37.8	40	3	Triple leader, flair over walk
287	Acer saccharinum	Silver Maple	20.5	30	3	Topped
288	Pinus nigra	Austrian Pine	8.6	14	3	
289	Acer saccharinum	Silver Maple	34	36	3	Topped, flair over walk
290	Tilia cordata	Little-leaf Linden	22.2	27	3	
291	Liquidambar styraciflua	Sweetgum	12.1	17	3	Girdling root
292	Pyrus calleryana	Callery Pear	17	Dead	3	
293	Acer platanoides	Norway Maple	12.1	Dead	2	Severe girdling roots
294	Acer saccharinum	Silver Maple	39.8	43	3	Topped, girdled, threat to house
295	Acer saccharinum	Silver Maple	26.9	33	3	Flair over walk
296	Alnus glutinosa	European Alder	8.2	Dead	3	
297	Platanus xacerifolia	London Planetree	19.3	25	3	
298	Quercus palustris	Pin Oak	24.6	32	3	
299	Liquidambar styraciflua	Sweetgum	17.1	21	3	
300	Gleditsia triacanthos	Common Honeylocust	6.9	12	3	Topped
301	Gleditsia triacanthos	Common Honeylocust	8.9	13	3	Topped
302	Acer saccharinum	Silver Maple	7.8	20	4	
303	Celtis occidentalis	Common Hackberry	25.8	29	3	
304	Acer saccharum	Sugar Maple	19.9	24	3	
305	Acer saccharinum	Silver Maple	17.9	27	3	
306	Betula nigra	River Birch	9.9	14	3	Twin leader
307	Betula nigra	River Birch	7.2	12	3	
308	Acer saccharum	Sugar Maple	13	17	3	
309	Acer saccharum	Sugar Maple	15	19	3	

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-1. Tree Size and Condition, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT CAL (IN)	CALIPER IN 20 YEARS (IN)	CURRENT CONDITION	NOTES
310	Acer rubrum	Red Maple	10	14	3	
311	Acer platanoides	Norway Maple	17.2	22	3	
312	Acer platanoides	Norway Maple	20.5	25	3	
313	Acer saccharinum	Silver Maple	31.9	35	3	Topped , hangers, and decay
314	Acer saccharinum	Silver Maple	29.2	34	3	
315	Acer saccharum	Sugar Maple	23.1	27	3	40% live crown, good structure
316	Acer saccharum	Sugar Maple	21.5	26	3	40% live crown, good structure
317	Fraxinus americana	White Ash	31	34	3	Flair over walk
318	Acer saccharinum	Silver Maple	29.8	34	2	Topped

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
1	Chamaecypraris obtusa	Hinoki Falsecypress	6.0	7.5	4	39	47
2	Juniperus squamata	Singleseed Juniper	2.0	4.5	5	17	31
3	Picea pungens	Blue Spruce	0.5	4.0	5	8	29
4	Fraxinus pennsylvanica	Green Ash	12.2	Dead	2	66	Dead
5	Malus hybrida	Flowering Crabapple	2.6	6.0	5	20	39
6	Juniperus virginiana	Eastern Redcedar	2.0	4.5	5	17	31
7	Juniperus virginiana	Eastern Redcedar	2.2	4.5	5	18	31
8	Picea pungens	Blue Spruce	5.6	Dead	3	37	Dead
9	Acer saccharum	Sugar Maple	13.1	14.5	3	70	74
10	Acer saccharum	Sugar Maple	9.3	11.5	3	55	64
11	Acer saccharum	Sugar Maple	11.8	14.0	3	65	73
12	Acer saccharinum	Silver Maple	18.3	Dead	2	85	Dead
13	Acer saccharinum	Silver Maple	13.0	15.0	2	69	76
14	Acer saccharinum	Silver Maple	13.0	15.0	2	69	76
15	Cornus florida	Flowering Dogwood	2.0	Dead	4	17	Dead
16	Acer saccharinum	Silver Maple	17.2	18.0	3	82	84
17	Gleditsia triacanthos	Common Honeylocust	12.8	14.5	3	68	74
18	Morus rubra	Red Mulberry	12.5	16.5	1	68	80
19	Fraxinus americana	White Ash	12.5	14.5	3	68	74
20	Malus hybrida	Flowering Crabapple	6.1	7.5	3	40	47
21	Acer saccharinum	Silver Maple	16.1	17.5	3	79	83
22	Acer saccharinum	Silver Maple	12.3	16.0	3	67	79
23	Acer rubrum	Red Maple	5.1	7.0	5	34	44
25	Acer saccharinum	Silver Maple	18.5	20.0	3	85	88
26	Pinus strobus	White Pine	11.1	12.5	3	62	68
27	Acer saccharum	Sugar Maple	10.3	12.5	3	59	68
29	Juniperus chinensis	Chinese Juniper	1.5	4.5	5	14	31
30	Cercis canadensis	Eastern Redbud	9.5	Dead	1	56	Dead
31	Cercis canadensis	Eastern Redbud	6.7	Dead	1	42	Dead
32	Celtis occidentalis	Common Hackberry	9.9	12.5	3	57	68
33	Celtis occidentalis	Common Hackberry	7.3	9.0	2	46	53
34	Acer platanoides	Norway Maple	14.8	Dead	1	75	Dead
35	Pyrus calleryana	Callery Pear	3.0	6.5	4	23	42
36	Gleditsia triacanthos	Common Honeylocust	11.6	13.5	3	64	71

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
37	Acer negundo	Boxelder	14.7	Dead	2	75	Dead
38	Acer negundo	Boxelder	8.4	11.0	3	51	62
39	Acer rubrum	Red Maple	9.5	12.0	3	56	66
40	Acer saccharum	Sugar Maple	5.7	8.0	3	37	49
41	Prunus serotina	Wild Black Cherry	16.4	Dead	2	80	Dead
42	Magnolia soulangiana	Saucer Magnolia	3.8	5.0	4	27	34
43	Ulmus pumila	Siberian Elm	12.2	14.0	3	66	73
44	Acer saccharum	Sugar Maple	7.5	9.5	3	47	56
45	Fraxinus americana	White Ash	10.2	12.5	4	59	68
46	Acer platanoides	Norway Maple	10.1	12.0	3	58	66
47	Prunus serotina	Wild Black Cherry	3.0	6.0	4	23	39
48	Acer saccharum	Sugar Maple	11.9	14.0	3	65	73
49	Acer saccharum	Sugar Maple	12.3	14.5	3	67	74
50	Acer saccharum	Sugar Maple	10.1	12.0	3	58	66
51	Acer saccharum	Sugar Maple	8.9	10.5	3	53	60
52	Acer saccharum	Sugar Maple	7.9	10.0	3	48	58
53	Acer saccharinum	Silver Maple	12.3	16.0	3	67	79
54	Acer saccharinum	Silver Maple	13.8	17.0	3	72	82
55	Acer negundo	Boxelder	15.0	Dead	1	76	Dead
56	Acer platanoides	Norway Maple	9.9	11.0	2	57	62
57	Acer saccharum	Sugar Maple	8.0	10.0	3	49	58
58	Acer rubrum	Red Maple	8.1	10.0	3	49	58
59	Acer saccharinum	Silver Maple	14.2	15.5	2	73	77
60	Acer saccharinum	Silver Maple	11.3	15.0	3	63	76
61	Acer rubrum	Red Maple	6.8	8.5	3	43	51
62	Acer platanoides	Norway Maple	8.7	Dead	3	52	Dead
63	Celtis occidentalis	Common Hackberry	19.5	21.5	3	87	91
64	Acer saccharinum	Silver Maple	14.3	17.0	3	74	82
65	Acer saccharinum	Silver Maple	9.5	14.5	3	56	74
66	Acer saccharinum	Silver Maple	21.0	22.5	2	90	92
67	Gleditsia triacanthos	Common Honeylocust	2.0	5.0	4	17	34
68	Gleditsia triacanthos	Common Honeylocust	5.5	7.5	4	37	47
69	Acer platanoides	Norway Maple	8.0	10.5	2	49	60
70	Acer platanoides	Norway Maple	9.2	11.0	3	54	62

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
71	Acer platanoides	Norway Maple	10.4	12.5	3	59	68
72	Acer rubrum	Red Maple	11.6	12.5	3	64	68
73	Betula pendula	European Birch	6.0	Dead	1	39	Dead
74	Cornus florida	Flowering Dogwood	1.0	Dead	4	11	Dead
75	Acer saccharinum	Silver Maple	10.3	15.0	3	59	76
76	Acer saccharinum	Silver Maple	11.6	15.0	3	64	76
77	Acer saccharinum	Silver Maple	9.9	14.5	3	57	74
78	Picea abies	Norway Spruce	1.5	5.0	5	14	34
79	Acer saccharinum	Silver Maple	17.1	18.0	3	82	84
80	Acer saccharinum	Silver Maple	19.6	21.0	3	87	90
81	Acer saccharinum	Silver Maple	11.7	15.0	2	64	76
82	Acer rubrum	Red Maple	3.8	6.5	5	27	42
83	Platanus occidentalis	Sycamore	18.3	20.5	4	85	89
84	Acer negundo	Boxelder	8.8	11.5	3	52	64
85	Acer negundo	Boxelder	11.0	Dead	3	62	Dead
86	Acer negundo	Boxelder	12.3	Dead	3	67	Dead
87	Acer negundo	Boxelder	9.9	12.5	3	57	68
88	Acer negundo	Boxelder	9.5	11.5	3	55	64
89	Acer saccharinum	Silver Maple	13.0	15.0	2	69	76
90	Acer saccharinum	Silver Maple	20.0	21.5	2	88	91
91	Acer saccharinum	Silver Maple	12.7	17.5	4	68	83
92	Acer saccharinum	Silver Maple	16.6	18.0	3	80	84
93	Acer saccharinum	Silver Maple	18.0	19.0	3	84	86
94	Acer negundo	Boxelder	9.6	12.0	3	56	66
95	Acer negundo	Boxelder	12.4	Dead	1	67	Dead
96	Acer negundo	Boxelder	14.5	Dead	2	74	Dead
97	Prunus serotina	Wild Black Cherry	11.6	13.0	3	64	69
98	Acer rubrum	Red Maple	11.0	12.5	3	62	68
99	Celtis occidentalis	Common Hackberry	12.4	15.0	4	67	76
100	Acer rubrum	Red Maple	9.5	12.0	2	56	66
101	Populus deltoides	Eastern Cottonwood	28.8	30.0	3	96	96
102	Acer saccharum	Sugar Maple	3.3	7.0	5	24	44
104	Prunus subhirtella	Weeping Cherry	1.1	6.0	5	11	39
105	Prunus subhirtella	Weeping Cherry	1.3	6.0	5	12	39

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
106	Celtis occidentalis	Common Hackberry	10.5	13.5	4	60	71
107	Fraxinus americana	White Ash	10.4	12.5	3	59	68
108	Acer saccharinum	Silver Maple	15.2	17.0	3	76	82
109	Acer saccharum	Sugar Maple	7.0	9.0	3	44	53
110	Prunus cerasifera	Purple-leaf Plum	7.0	Dead	3	44	Dead
111	Juglans nigra	Black Walnut	3.2	8.0	5	24	49
112	Acer saccharum	Sugar Maple	11.9	15.0	4	65	76
113	Fraxinus americana	White Ash	11.7	14.0	4	65	73
114	Acer saccharinum	Silver Maple	12.9	16.5	2	69	80
115	Malus hybrida	Flowering Crabapple	0.5	4.0	3	8	29
116	Acer saccharum	Sugar Maple	6.6	8.5	3	42	51
117	Fraxinus americana	White Ash	11.8	14.0	3	65	73
118	Fraxinus americana	White Ash	15.0	17.5	3	76	83
119	Celtis occidentalis	Common Hackberry	13.8	16.0	3	72	79
120	Acer rubrum	Red Maple	2.4	4.5	3	19	31
121	Acer saccharinum	Silver Maple	13.8	18.0	4	72	84
122	Acer platanoides	Norway Maple	4.4	9.5	4	30	56
123	Celtis occidentalis	Common Hackberry	14.3	16.5	4	74	80
124	Quercus imbricaria	Shingle Oak	19.3	21.0	3	87	90
125	Acer saccharum	Sugar Maple	13.5	Dead	1	71	Dead
126	Acer saccharinum	Silver Maple	20.4	22.0	3	89	92
127	Acer negundo	Boxelder	7.0	Dead	2	44	Dead
128	Celtis occidentalis	Common Hackberry	12.1	14.0	3	66	73
129	Celtis occidentalis	Common Hackberry	10.8	13.5	3	61	71
130	Celtis occidentalis	Common Hackberry	15.6	17.0	3	78	82
131	Celtis occidentalis	Common Hackberry	9.4	11.5	3	55	64
132	Celtis occidentalis	Common Hackberry	8.9	10.5	2	53	60
133	Celtis occidentalis	Common Hackberry	8.9	10.5	2	53	60
134	Fraxinus americana	White Ash	9.4	11.5	3	55	64
135	Fraxinus americana	White Ash	10.4	13.0	3	59	69
136	Celtis occidentalis	Common Hackberry	11.6	13.5	3	64	71
137	Malus hybrida	Flowering Crabapple	0.5	4.0	3	8	29
138	Malus hybrida	Flowering Crabapple	4.0	7.0	4	28	44
139	Platanus xacerifolia	London Planetree	12.9	15.0	3	69	76

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
140	Platanus xacerifolia	London Planetree	13.3	15.0	3	70	76
141	Acer saccharinum	Silver Maple	19.5	21.0	3	87	90
142	Acer saccharinum	Silver Maple	18.2	Dead	2	84	Dead
143	Acer saccharinum	Silver Maple	13.0	15.0	2	69	76
144	Acer saccharinum	Silver Maple	13.3	15.0	2	70	76
145	Acer saccharinum	Silver Maple	2.0	9.0	3	17	53
146	Celtis occidentalis	Common Hackberry	21.3	22.5	3	91	92
147	Gleditsia triacanthos	Common Honeylocust	5.9	8.0	3	39	49
148	Celtis occidentalis	Common Hackberry	8.7	11.0	4	52	62
149	Picea pungens	Blue Spruce	7.0	Dead	3	44	Dead
150	Malus hybrida	Flowering Crabapple	3.0	6.5	3	23	42
151	Gleditsia triacanthos	Common Honeylocust	23.0	24.0	3	93	94
152	Quercus palustris	Pin Oak	1.4	6.5	4	13	42
153	Cornus florida	Flowering Dogwood	1.0	Dead	2	11	Dead
154	Picea pungens	Blue Spruce	1.5	5.0	4	14	34
155	Fraxinus americana	White Ash	11.3	13.5	3	63	71
156	Acer saccharum	Sugar Maple	8.0	10.0	3	49	58
157	Betula pendula	European Birch	5.0	Dead	3	34	Dead
158	Malus hybrida	Flowering Crabapple	4.0	7.0	3	29	44
159	Acer platanoides	Norway Maple	3.6	8.5	5	26	51
160	Acer saccharinum	Silver Maple	9.1	14.0	2	54	73
161	Fraxinus americana	White Ash	12.8	15.0	3	69	76
162	Acer saccharinum	Silver Maple	9.9	14.5	3	57	74
163	Acer saccharinum	Silver Maple	20.3	Dead	3	89	Dead
164	Acer saccharinum	Silver Maple	12.9	16.0	3	69	79
165	Acer saccharinum	Silver Maple	15.3	17.0	3	77	82
166	Morus rubra	Red Mulberry	6.5	10.5	3	42	60
167	Fraxinus americana	White Ash	8.0	Dead	2	49	Dead
168	Acer saccharinum	Silver Maple	17.3	18.0	3	82	84
169	Acer saccharinum	Silver Maple	10.0	15.0	3	58	76
170	Acer saccharinum	Silver Maple	10.6	15.0	2	60	76
171	Acer saccharinum	Silver Maple	15.7	17.0	3	78	82
172	Acer saccharinum	Silver Maple	5.5	11.5	3	37	64
173	Fraxinus pennsylvanica	Green Ash	11.2	13.0	3	62	69

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
174	Acer saccharinum	Silver Maple	14.0	15.5	2	73	77
175	Fraxinus pennsylvanica	Green Ash	12.6	14.0	3	68	73
176	Acer saccharinum	Silver Maple	9.3	14.5	4	55	74
177	Acer saccharum	Sugar Maple	11.6	13.5	3	64	71
178	Acer saccharinum	Silver Maple	18.8	20.0	3	86	88
179	Acer saccharinum	Silver Maple	14.6	17.0	3	75	82
180	Acer saccharum	Sugar Maple	12.2	14.5	3	66	74
181	Acer saccharinum	Silver Maple	15.5	16.5	2	77	80
182	Acer saccharum	Sugar Maple	10.8	13.0	3	61	69
183	Acer saccharum	Sugar Maple	10.9	13.0	3	61	69
184	Acer saccharinum	Silver Maple	14.5	17.0	3	74	82
185	Acer saccharum	Sugar Maple	13.3	15.0	3	70	76
186	Acer saccharinum	Silver Maple	13.3	16.5	3	70	80
187	Acer saccharinum	Silver Maple	15.1	17.0	3	76	82
188	Acer saccharinum	Silver Maple	16.3	17.5	3	80	83
189	Acer saccharinum	Silver Maple	15.6	17.0	3	78	82
190	Quercus palustris	Pin Oak	10.6	14.5	4	60	74
191	Acer saccharum	Sugar Maple	5.6	8.5	4	37	51
192	Acer saccharinum	Silver Maple	14.5	17.0	3	74	82
193	Quercus palustris	Pin Oak	2.1	8.0	4	17	49
194	Quercus palustris	Pin Oak	2.0	7.0	3.9	17	44
195	Fraxinus americana	White Ash	18.8	Dead	2	86	Dead
196	Acer saccharinum	Silver Maple	15.1	15.0	2	76	76
197	Fraxinus americana	White Ash	19.2	20.0	3	87	88
198	Picea pungens	Blue Spruce	2.0	5.5	5	17	37
199	Aesculus glabra	Ohio Buckeye	6.4	8.0	4	41	49
200	Acer rubrum	Red Maple	7.6	9.0	3	47	53
201	Acer saccharum	Sugar Maple	7.1	9.0	3	44	53
202	Fraxinus americana	White Ash	12.9	15.0	3	69	76
203	Quercus imbricaria	Shingle Oak	13.3	15.5	3	70	77
204	Taxodium distichum	Bald-cypress	1.4	2.5	3	13	20
205	Acer saccharum	Sugar Maple	5.8	8.0	3	38	49
206	Acer saccharum	Sugar Maple	6.1	8.5	3	39	51
207	Acer saccharinum	Silver Maple	12.6	16.0	3	68	79

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
208	Acer saccharinum	Silver Maple	14.1	17.0	3	73	82
209	Acer saccharinum	Silver Maple	15.2	17.0	3	76	82
210	Acer saccharinum	Silver Maple	22.2	23.0	3	92	93
211	Acer platanoides	Norway Maple	2.1	7.5	5	18	47
212	Pinus strobus	White Pine	2.0	5.0	5	17	34
213	Acer platanoides	Norway Maple	7.3	10.0	3	45	58
214	Acer saccharinum	Silver Maple	24.3	25.0	3	94	95
215	Acer saccharinum	Silver Maple	12.9	16.5	3	69	80
216	Acer saccharinum	Silver Maple	16.0	17.5	3	79	83
217	Pseudotsuga menziesii	Douglas-fir	2.8	6.0	4	22	39
218	Celtis occidentalis	Common Hackberry	13.5	15.5	3	71	77
219	Cercis canadensis	Eastern Redbud	5.2	Dead	2	35	Dead
220	Cercis canadensis	Eastern Redbud	5.2	Dead	2	35	Dead
221	Juglans sp.	Walnut	8.5	9.5	3	51	56
222	Acer rubrum	Red Maple	4.7	6.5	2	32	42
223	Picea glauca conica	Alberta Spruce	2.0	Dead	2	17	Dead
224	Picea abies	Norway Spruce	3.5	6.0	3	26	39
225	Pinus nigra	Austrian Pine	5.7	8.0	3	37	49
226	Salix babylonica	Weeping Willow	5.9	Dead	3	39	Dead
227	Quercus palustris	Pin Oak	10.1	14.0	3	58	73
228	Salix babylonica	Weeping Willow	18.7	Dead	3	85	Dead
229	Salix babylonica	Weeping Willow	13.4	Dead	2	71	Dead
230	Acer saccharinum	Silver Maple	14.5	15.5	2	74	77
231	Acer saccharinum	Silver Maple	13.0	16.5	3	69	80
232	Betula pendula	European Birch	4.2	Dead	2	29	Dead
233	Acer saccharinum	Silver Maple	7.1	13.0	3	45	69
234	Acer rubrum	Red Maple	3.9	6.0	3	28	39
235	Acer saccharinum	Silver Maple	12.6	16.0	3	68	79
236	Acer saccharinum	Silver Maple	15.6	17.0	3	78	82
237	Acer platanoides	Norway Maple	7.4	10.0	3	46	58
238	Fraxinus americana	White Ash	14.3	16.5	3	74	80
239	Liriodendron tulipifera	Tulip-poplar	8.6	10.5	3	52	60
240	Acer rubrum	Red Maple	6.6	6.5	3	42	42
241	Acer platanoides	Norway Maple	9.0	Dead	2	53	Dead

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
242	Acer saccharum	Sugar Maple	11.0	13.0	3	62	69
243	Acer saccharinum	Silver Maple	12.1	16.0	3	66	79
244	Celtis occidentalis	Common Hackberry	12.8	14.5	3	69	74
245	Celtis occidentalis	Common Hackberry	14.8	16.5	3	75	80
246	Catalpa speciosa	Northern Catalpa	15.1	17.5	3	76	83
247	Acer platanoides	Norway Maple	4.2	9.0	4	29	53
248	Acer saccharum	Sugar Maple	4.6	7.0	4	32	44
249	Acer saccharum	Sugar Maple	14.5	16.5	3	74	80
250	Acer saccharum	Sugar Maple	15.0	16.5	3	76	80
251	Malus hybrida	Flowering Crabapple	1.4	4.5	4	13	31
252	Malus hybrida	Flowering Crabapple	4.7	7.0	3	32	44
253	Acer saccharinum	Silver Maple	9.7	14.5	2	56	74
254	Acer saccharinum	Silver Maple	11.8	15.5	3	65	77
255	Acer saccharinum	Silver Maple	17.9	18.5	3	84	85
256	Acer saccharinum	Silver Maple	15.8	17.0	3	78	82
257	Acer saccharinum	Silver Maple	18.2	19.5	3	84	87
258	Acer platanoides	Norway Maple	6.8	9.5	3	43	56
259	Acer saccharinum	Silver Maple	15.8	17.0	3	78	82
260	Acer saccharinum	Silver Maple	7.0	13.0	3	44	69
261	Acer saccharinum	Silver Maple	19.2	20.5	3	87	89
262	Acer saccharinum	Silver Maple	13.7	17.0	3	72	82
263	Acer platanoides	Norway Maple	1.5	6.5	4	14	42
264	Acer saccharinum	Silver Maple	16.0	17.5	3	79	83
265	Acer rubrum	Red Maple	6.9	7.0	2	44	44
266	Acer saccharinum	Silver Maple	14.6	16.5	2	75	80
267	Acer saccharinum	Silver Maple	12.9	16.5	3	69	80
268	Acer saccharinum	Silver Maple	12.3	14.0	2	67	73
269	Acer saccharinum	Silver Maple	7.3	13.5	3	45	71
270	Acer saccharinum	Silver Maple	12.7	16.0	3	68	79
271	Pinus flexilis	Limber Pine	3.4	6.0	3	25	39
272	Morus rubra	Red Mulberry	5.0	9.0	3	34	53
273	Acer saccharinum	Silver Maple	17.7	18.5	3	83	85
274	Acer saccharinum	Silver Maple	15.1	15.5	2	76	77
275	Acer saccharinum	Silver Maple	23.2	24.0	3	93	94

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
276	Cornus florida	Flowering Dogwood	1.5	Dead	3	14	Dead
277	Platanus occidentalis	Sycamore	19.0	21.0	3	86	90
278	Quercus palustris	Pin Oak	8.1	12.0	3	49	66
279	Ulmus pumila	Siberian Elm	12.3	14.0	3	67	73
280	Ulmus pumila	Siberian Elm	14.9	16.5	3	76	80
281	Acer saccharinum	Silver Maple	1.9	9.0	4	16	53
282	Acer saccharinum	Silver Maple	14.8	17.0	3	75	82
283	Picea abies	Norway Spruce	1.0	4.5	4	11	31
284	Acer saccharinum	Silver Maple	16.6	18.0	3	80	84
285	Acer saccharinum	Silver Maple	15.4	17.0	3	77	82
286	Acer saccharinum	Silver Maple	18.9	20.0	3	86	88
287	Acer saccharinum	Silver Maple	10.3	15.0	3	59	76
288	Pinus nigra	Austrian Pine	4.3	7.0	3	30	44
289	Acer saccharinum	Silver Maple	17.0	18.0	3	82	84
290	Tilia cordata	Little-leaf Linden	11.1	13.5	3	62	71
291	Liquidambar styraciflua	Sweetgum	6.1	8.5	3	39	51
292	Pyrus calleryana	Callery Pear	8.5	Dead	3	51	Dead
293	Acer platanoides	Norway Maple	6.1	Dead	2	39	Dead
294	Acer saccharinum	Silver Maple	19.9	21.5	3	88	91
295	Acer saccharinum	Silver Maple	13.5	16.5	3	71	80
296	Alnus glutinosa	European Alder	4.1	Dead	3	29	Dead
297	Platanus xacerifolia	London Planetree	9.7	12.5	3	56	68
298	Quercus palustris	Pin Oak	12.3	16.0	3	67	79
299	Liquidambar styraciflua	Sweetgum	8.6	10.5	3	51	60
300	Gleditsia triacanthos	Common Honeylocust	3.5	6.0	3	25	39
301	Gleditsia triacanthos	Common Honeylocust	4.5	6.5	3	31	42
302	Acer saccharinum	Silver Maple	3.9	10.0	4	28	58
303	Celtis occidentalis	Common Hackberry	12.9	14.5	3	69	74
304	Acer saccharum	Sugar Maple	10.0	12.0	3	58	66
305	Acer saccharinum	Silver Maple	9.0	13.5	3	53	71
306	Betula nigra	River Birch	5.0	7.0	3	34	44
307	Betula nigra	River Birch	3.6	6.0	3	26	39
308	Acer saccharum	Sugar Maple	6.5	8.5	3	42	51
309	Acer saccharum	Sugar Maple	7.5	9.5	3	47	56

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

Table No. III-2. Projected Stem Radius and Rootplate, Buckeye Lake State Park

TAG	SCIENTIFIC NAME	COMMON NAME	PRESENT STEM RADIUS (IN)	20 YR STEM RADIUS (IN)	CURRENT CONDITION	ROOTPLATE RADIUS (IN)	20 YR ROOTPLATE RADIUS (IN)
310	Acer rubrum	Red Maple	5.0	7.0	3	34	44
311	Acer platanoides	Norway Maple	8.6	11.0	3	52	62
312	Acer platanoides	Norway Maple	10.3	12.5	3	59	68
313	Acer saccharinum	Silver Maple	16.0	17.5	3	79	83
314	Acer saccharinum	Silver Maple	14.6	17.0	3	75	82
315	Acer saccharum	Sugar Maple	11.6	13.5	3	64	71
316	Acer saccharum	Sugar Maple	10.8	13.0	3	61	69
317	Fraxinus americana	White Ash	15.5	17.0	3	77	82
318	Acer saccharinum	Silver Maple	14.9	17.0	2	76	82

Current Condition: 5 - excellent, 4 - good, 3 - average, 2 - poor, 1 - declining or dead

APPENDIX IV

Evaluation of Existing Sheet Piling

Page: 4
Date: 7.16.02

Sheet: PMA-22
Pressure: Rankine
FOS: 1.0
Toe: Cantilever

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	0.0	0.0	3.4	0.0
0.16	4.5	0.0	3.4	0.4
0.31	9.0	0.2	3.4	1.5
0.47	13.0	0.5	3.3	3.2
0.63	17.5	1.2	3.3	5.7
0.78	22.0	2.3	3.2	8.9
0.94	26.0	3.9	3.2	12.5
1.10	35.5	6.2	3.1	17.4
1.25	46.6	9.2	3.1	23.5
1.41	58.7	13.6	3.0	32.1
1.57	70.9	19.6	3.0	42.7
1.72	82.0	26.6	2.9	54.1
1.88	94.1	36.4	2.9	68.5
2.04	106.3	48.7	2.9	84.8
2.19	117.3	62.3	2.8	101.4
2.35	129.5	80.1	2.8	121.5
2.50	140.5	99.4	2.7	141.4
2.66	152.7	124.0	2.7	165.3
2.82	164.9	152.7	2.6	191.1
2.97	175.9	182.5	2.6	216.3
3.13	179.3	219.8	2.5	245.3
3.29	181.4	261.7	2.5	274.5
3.44	183.3	303.9	2.4	301.4
3.60	185.3	355.0	2.4	331.3
3.76	187.2	405.7	2.4	358.8
3.91	189.2	466.1	2.3	389.3
4.07	191.3	531.5	2.3	420.2
4.23	193.1	595.3	2.2	448.5
4.38	195.2	670.4	2.2	480.0
4.54	197.0	743.1	2.1	508.9
4.70	199.1	827.9	2.1	541.1
4.85	201.1	918.1	2.0	573.5
5.01	203.0	1004.6	2.0	603.3
5.17	205.0	1104.9	1.9	636.4
5.32	207.1	1210.5	1.9	669.9
5.48	208.9	1311.3	1.9	700.5
5.64	211.0	1427.4	1.8	734.6
5.79	212.8	1537.8	1.8	765.9

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
5.95	214.9	1664.5	1.7	800.5
6.11	216.9	1796.9	1.7	835.6
6.26	218.8	1922.2	1.6	867.7
6.42	220.8	2065.5	1.6	903.4
6.58	222.9	2214.7	1.5	939.4
6.73	224.8	2355.3	1.5	972.4
6.89	226.8	2515.7	1.5	1009.0
7.04	228.7	2666.7	1.4	1042.6
7.20	230.7	2838.5	1.4	1079.8
7.36	232.8	3016.4	1.3	1117.4
7.51	234.6	3183.4	1.3	1151.9
7.67	236.7	3373.0	1.2	1190.1
7.83	238.5	3550.7	1.2	1225.2
7.98	240.6	3752.2	1.2	1264.0
8.14	236.3	3960.3	1.1	1304.9
8.30	199.3	4154.8	1.1	1336.7
8.45	158.5	4373.8	1.0	1365.5
8.61	117.8	4596.9	1.0	1387.6
8.77	80.8	4802.5	1.0	1401.9
8.92	40.1	5030.6	0.9	1411.4
9.08	3.1	5238.9	0.9	1414.3
9.24	-37.7	5468.1	0.9	1411.2
9.39	-78.4	5696.3	0.8	1401.5
9.55	-115.4	5902.0	0.8	1387.0
9.71	-156.1	6125.4	0.8	1364.6
9.86	-196.9	6344.6	0.7	1335.7
10.02	-233.9	6539.5	0.7	1303.7
10.18	-274.6	6747.9	0.6	1262.2
10.33	-311.6	6931.1	0.6	1218.7
10.49	-352.4	7124.9	0.6	1164.6
10.65	-393.1	7309.3	0.6	1103.8
10.80	-430.1	7468.0	0.5	1042.9
10.96	-470.8	7631.8	0.5	969.5
11.11	-507.9	7770.0	0.5	897.1
11.27	-548.6	7909.2	0.4	811.2
11.43	-589.3	8034.0	0.4	718.6
11.58	-626.3	8134.1	0.4	628.7
11.74	-667.0	8228.4	0.4	523.6

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
11.90	-707.8	8305.1	0.3	411.8
12.05	-744.8	8358.8	0.3	304.5
12.21	-785.5	8399.1	0.3	180.1
12.37	-822.5	8417.8	0.3	61.3
12.52	-863.3	8419.4	0.3	-47.4
12.68	-904.0	8408.2	0.2	-147.0
12.84	-941.0	8388.3	0.2	-231.8
12.99	-981.7	8348.4	0.2	-318.8
13.15	-1022.5	8299.0	0.2	-399.1
13.31	-1059.5	8244.7	0.2	-466.5
13.46	-1100.2	8169.6	0.1	-534.2
13.62	-1137.2	8092.1	0.1	-590.1
13.78	-1178.0	7989.8	0.1	-645.2
13.93	-1218.7	7872.4	0.1	-693.8
14.09	-1255.7	7739.4	0.1	-732.2
14.25	-1296.4	7590.6	0.1	-768.1
14.40	-1333.5	7446.9	0.1	-795.1
14.56	-1374.2	7267.1	0.1	-818.4
14.72	-1414.9	7070.2	0.1	-835.1
14.87	-1451.9	6883.6	0.0	-844.6
15.03	-1492.6	6653.5	0.0	-848.7
15.19	-1533.4	6405.1	0.0	-846.2
15.34	-1570.4	6138.0	0.0	-838.2
15.50	-1611.1	5851.8	0.0	-823.1
15.65	-1648.1	5585.4	0.0	-803.7
15.81	-1688.9	5262.3	0.0	-776.0
15.97	-1729.6	4918.9	0.0	-741.7
16.12	-1766.6	4601.4	0.0	-704.8
16.28	-1807.3	4218.8	0.0	-657.9
16.44	-1848.1	3814.7	0.0	-604.3
16.59	-1885.1	3388.7	0.0	-550.0
16.75	-1925.8	2940.5	0.0	-483.8
16.91	-1962.8	2529.6	0.0	-418.0
17.06	-2003.6	2038.4	0.0	-339.3
17.22	-2044.3	1523.7	0.0	-253.9
17.38	-2081.3	1053.8	0.0	-170.6
17.53	-2122.0	493.9	0.0	-72.7
17.69	-2159.0	-16.1	0.0	12.3

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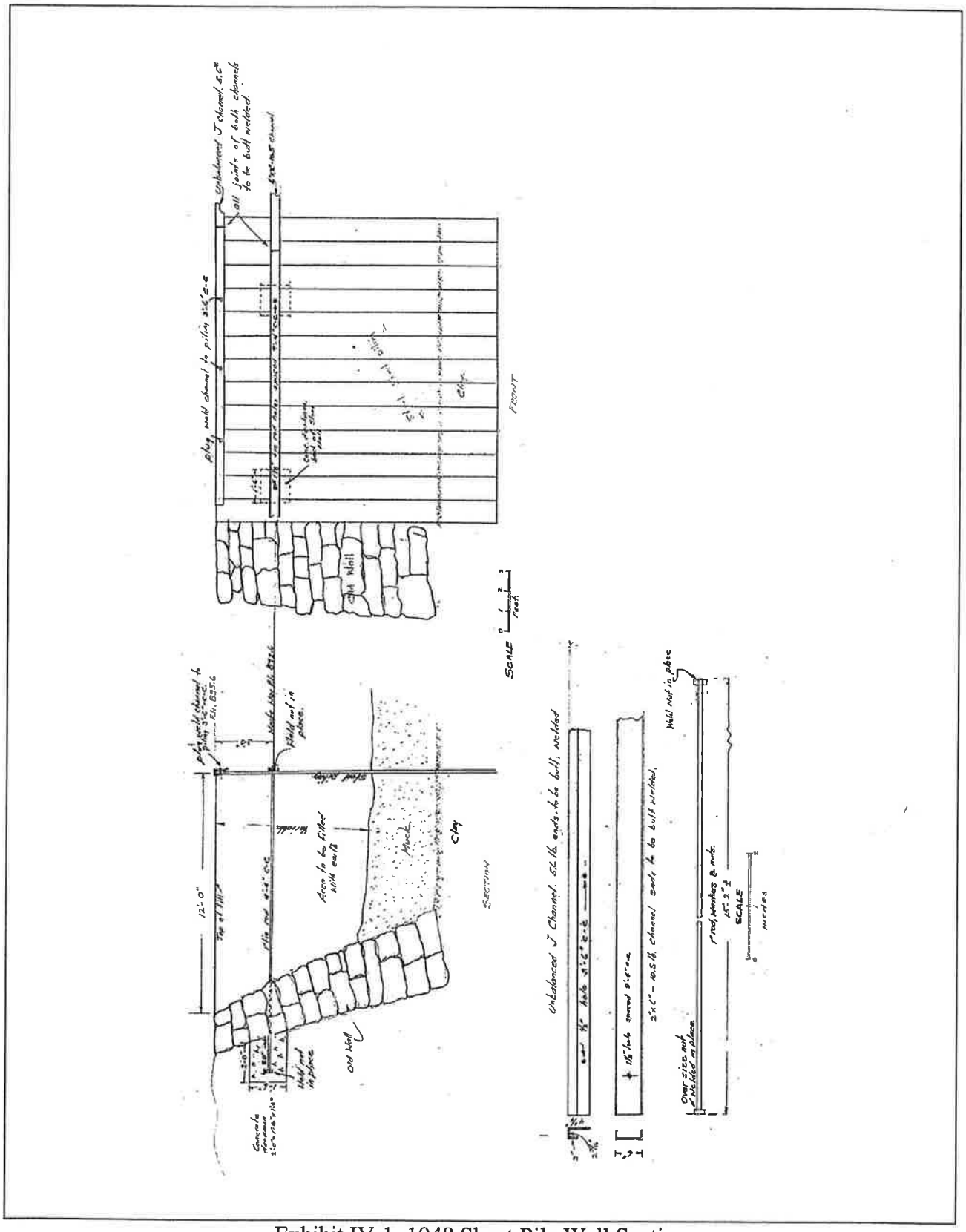


Exhibit IV-1. 1948 Sheet Pile Wall Section

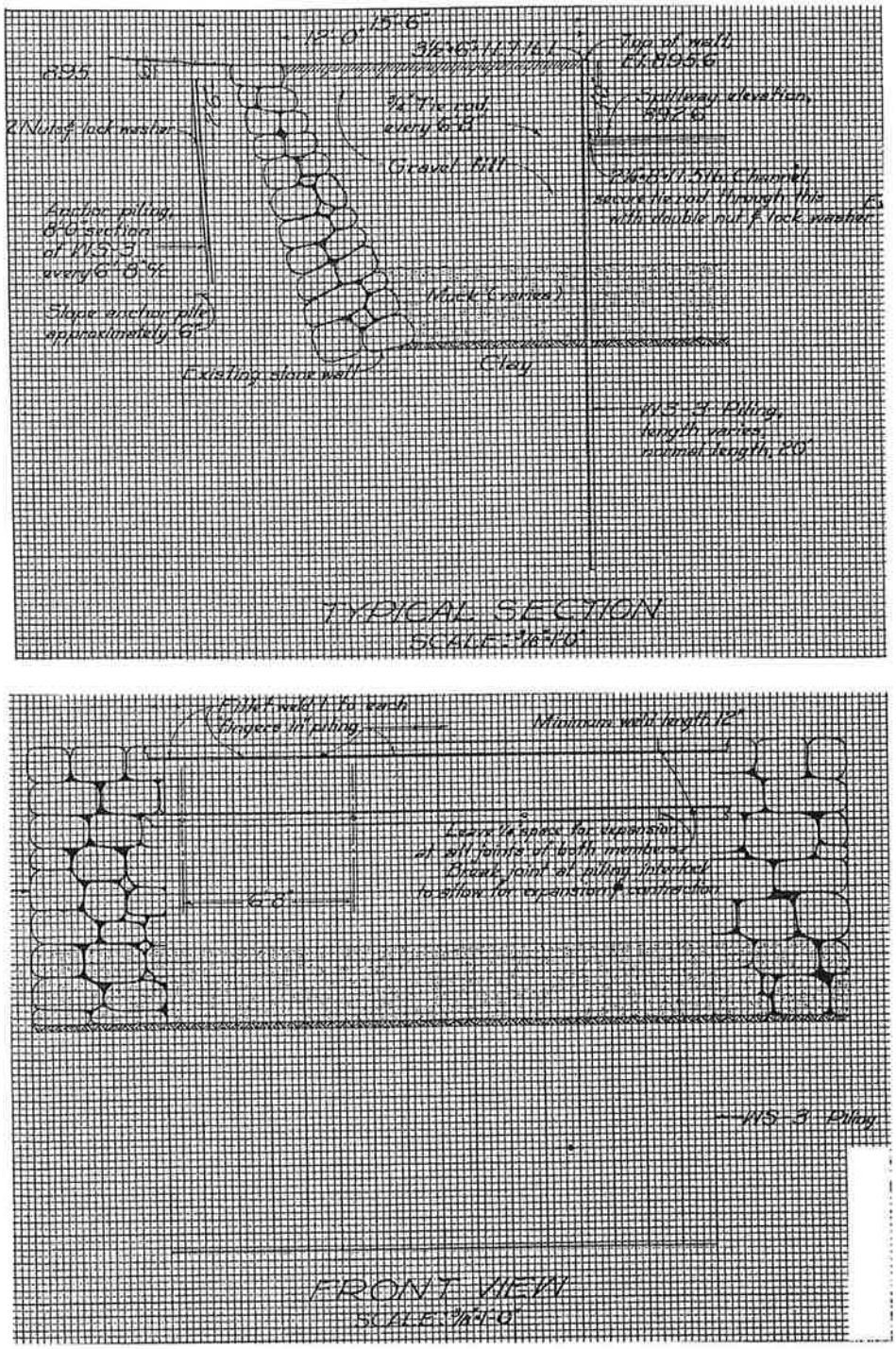


Exhibit IV- 2. 1961 Sheet Pile Wall Section

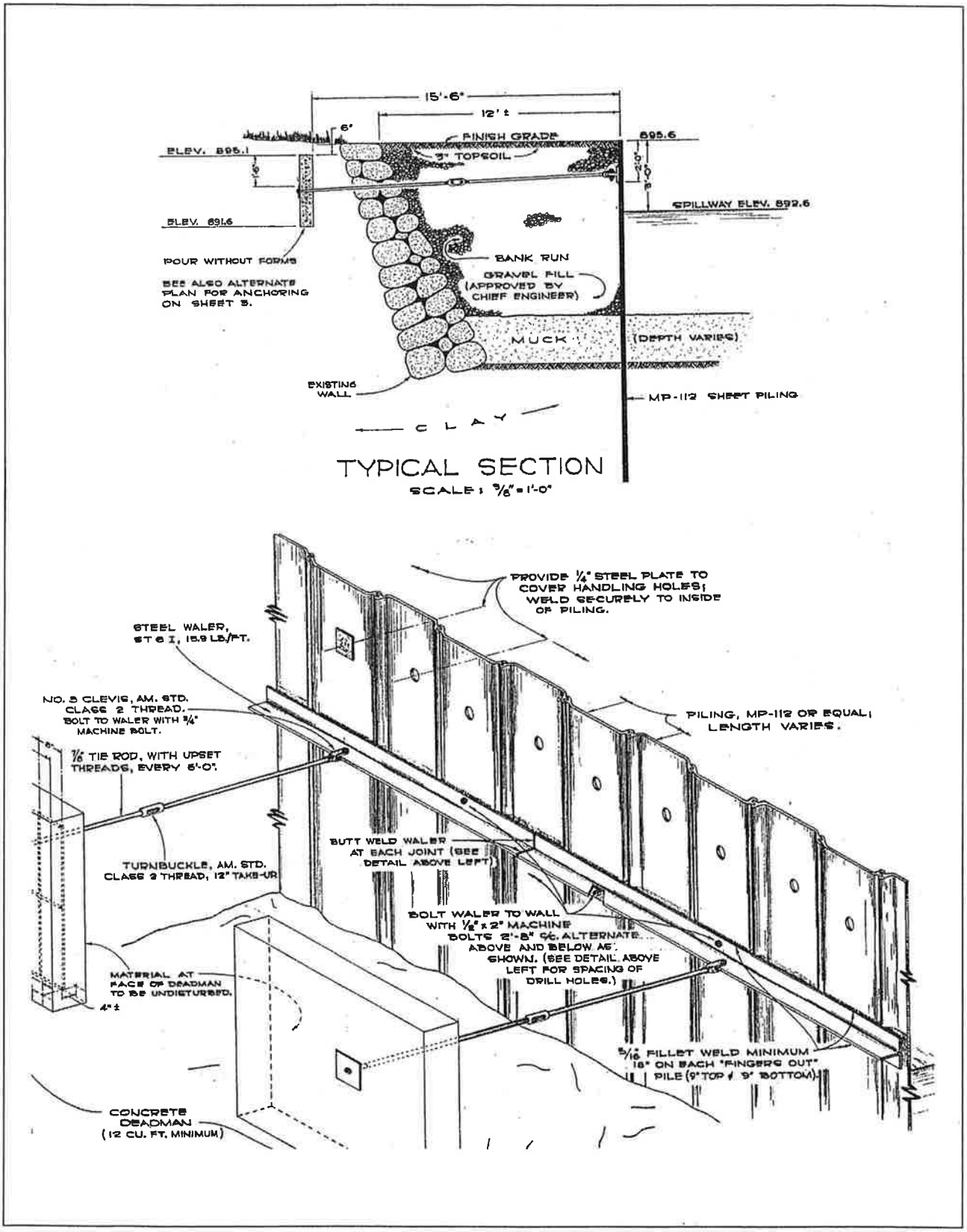
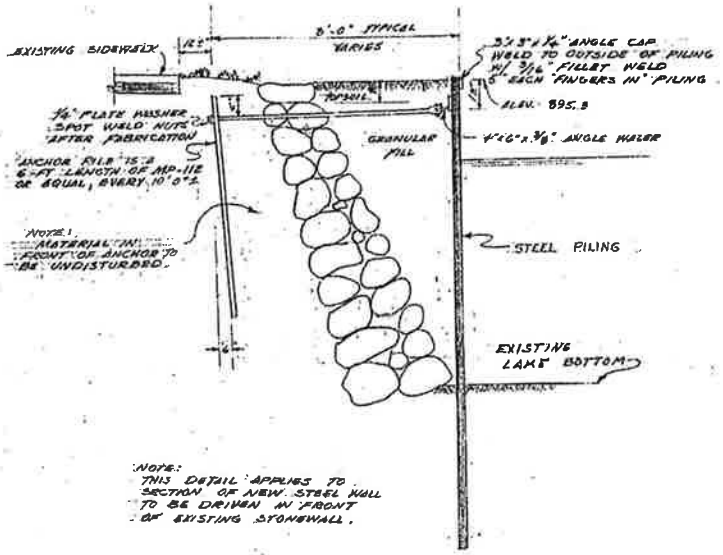
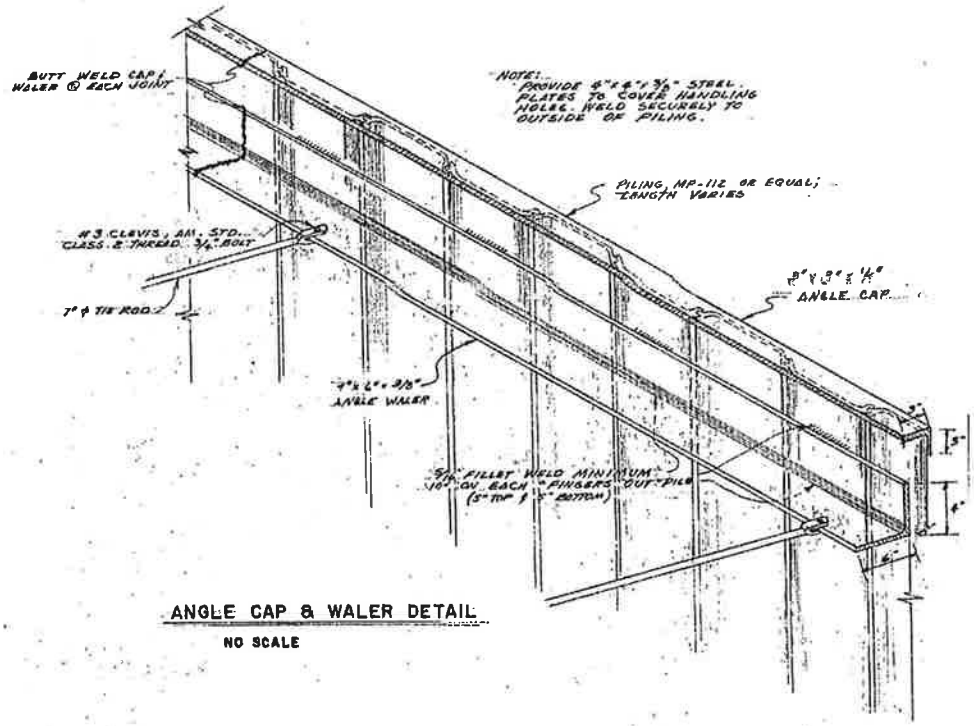


Exhibit IV- 3. 1962 Sheet Pile Wall Section



ANCHOR DETAIL

NO SCALE



ANGLE CAP & WALER DETAIL

NO SCALE

Exhibit IV- 4. 1968 Sheet Pile Wall Section

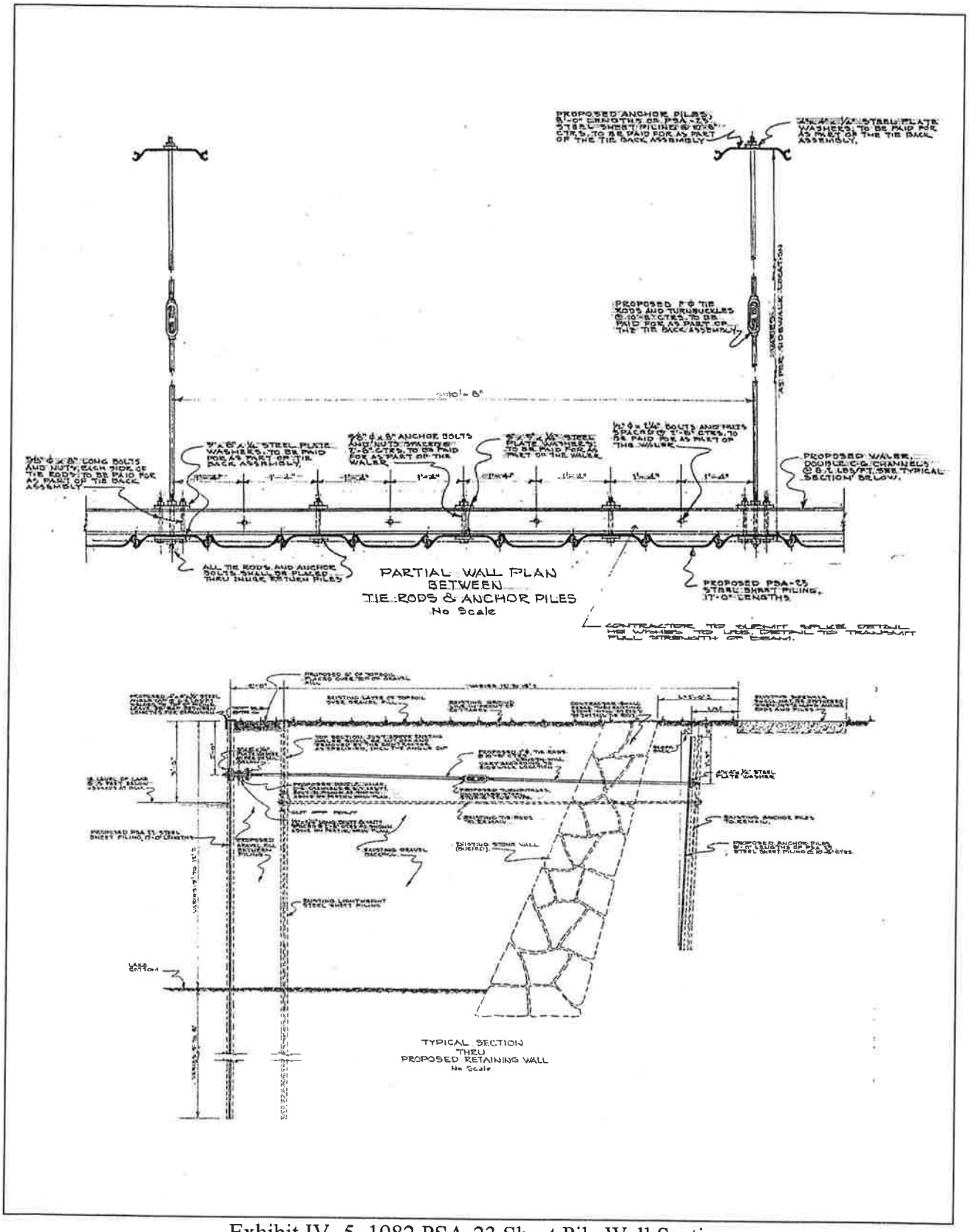


Exhibit IV- 5. 1982 PSA-23 Sheet Pile Wall Section

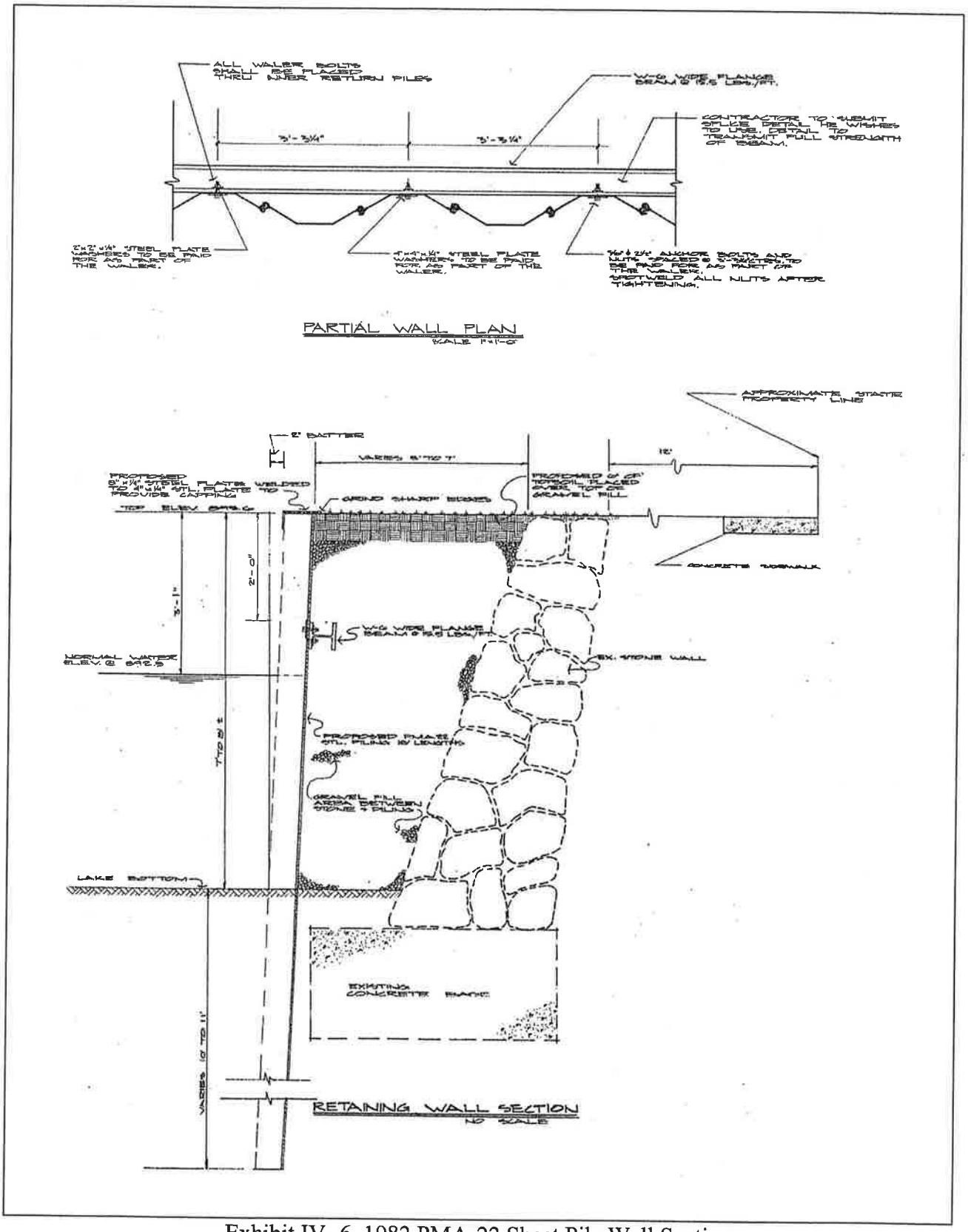


Exhibit IV- 6. 1982 PMA-22 Sheet Pile Wall Section

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	1 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	CTL DATE 12/18/2001
	2001 Testing	CHECKED BY	PAN DATE 12/19/2001

Station (2002 Baseline)	Location	Readings (thousandths of an inch)								Average	Loss, %
69+30	2.5 ft from top of sht. pile	362	353	344	353	365				355	
#13404	At summer pool	361	363	371	367	357	358			363	
PMA-22	Below winter pool	346	351	354	344	347	341			347	3.3%
79+40	2.5 ft from top of sht. pile	382	384	387	386	383	383			384	
#3214	At summer pool	369	375	372	371	374	373	372		372	
PSA-23	Below winter pool	344	294	313	282	283	291	279		298	21.2%
85+70	2 ft from top of sht. pile	378	375	376	378	381	376			377	
#3345	At summer pool	363	375	358	351	370	351			361	
PSA-23	Below winter pool	278	282	263	294	294	295			284	23.0%
89+40	2 ft from top of sht. pile	387	383	381	382	382	381			383	
#3415	At summer pool	375	372	374	372	359	350			367	
PSA-23	Below winter pool	361	359	357	359	371	374			364	5.0%
93+20	1.5 ft from top of sht. pile	382	385	389	388	404	405	406	402	395	
#3471	Below summer pool	397	379	391	391	401	401			393	
PSA-23	Below winter pool	323	318	348	337	330	336	333		332	15.7%
100+15	1.5 ft from top of sht. pile	392	396	402	401	394	393	399	401	397	
#3535	Below summer pool	406	409	401	396	396	400			401	
PSA-23	Below winter pool	365	359	344	346	352	347			352	11.8%
104+20	Between I-beam and waler	385	384	380	380	378	385			382	
#3555	Below summer pool	374	381	376	384	384	388			381	
PSA-23	Below winter pool	309	301	296	298	299	295			300	21.4%
110+00	Between I-beam and waler	385	390	384	389	400	399			391	
#3633	Below summer pool	374	382	382	382	396	394			385	
PSA-23	Below winter pool	228	282	280	250	269	276	276	272	267	31.2%

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	2 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	CTL DATE 12/18/2001
	2001 Testing	CHECKED BY	PAN DATE 12/19/2001

Station (2002 Baseline)	Location	Readings (thousandths of an inch)								Average	Loss, %
115+55	1.5 ft from top of sht. pile	383	385	372	396	385	396	396	392	388	
#3753	Below summer pool	397	392	396	383	385	383			389	
PSA-23	Below winter pool	369	369	373	361	368	370	369	364	368	5.3%
123+50	2.5 ft from top of sht. pile	387	387	380	393	390	387	396		389	
#3873	Below summer pool	378	392	386	383	385	379			384	
PSA-23	Below winter pool	385	372	388	366	384	379	370	374	377	2.5%
130+70	1.25 ft from top of sht. pile	389	391	397	396	391	391	392		392	
#4023	Below summer pool	389	386	385	385	388	380			386	
PSA-23	Below winter pool	343	344	351	364	361	353			353	9.3%
	Below winter pool, 2nd sheet	296	298	309	298	294				299	23.1%
7+15	2 ft from top of sht. pile	397	397	396	400	404	398			399	
#4119	Below summer pool	403	406	394	396	396	391	403		398	
PSA-23	Below winter pool	352	354	324	355	344	323	328		340	14.7%
144+30	1.5 ft from top of sht. pile	414	420	413	416	418	406			415	
#4219	Just above waler	411	408	411	409	408	406			409	
PSA-23	Below winter pool	380	378	340	357	367	337			360	12.6%
151+10	1.5 ft from top of waler	393	394	364	396	401	356			384	
#4307	Below summer pool	402	405	396	400	401	389			399	
PSA-23	Below winter pool	398	394	385	384	383	384			388	0.9%
155+50	Just below waler	385	393	388	390	390	387			389	
#4351	Below summer pool	387	385	383	386	383	390			386	
PSA-23	Below winter pool	316	283	264	283	282	268			283	27.0%

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	3 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	CTL DATE 12/18/2001
	2001 Testing	CHECKED BY	PAN DATE 12/19/2001

Station (2002 Baseline)	Location	Readings (thousandths of an inch)								Average	Loss, %
163+40	Just below top cap	387	377	390	380	378	392			384	
#4455	Below summer pool	396	390	394	389	394	386			392	
PSA-23	Below winter pool	282	321	314	296	298	311	355		311	19.8%
170+25	1 ft above summer pool										
#4583	At summer pool	393	381	385	390	389	384			387	
PSA-23	Just below summer pool	399	389	394	397	381	403			394	
	Below winter pool	339	328	333	341	364	365	337		344	11.9%
176+25	Above summer pool	384	394	402	380	400	396			393	
#4697	At summer pool	396	386	398	383	400	394			393	
PSA-23	Below winter pool	341	343	335	336	346	341			340	13.5%
184+85	2 ft from top of sht. pile	402	398	411	403	400	406			403	
#4847	At summer pool	396	406	411	406	402	406			405	
PSA-23	Below winter pool	347	364	365	339	326	365	339	361	351	13.1%
192+70	2 ft from top of sht. pile	406	406	405	406	405	406			406	
#5001	At summer pool	406	406	404	406	409	402			406	
PSA-23	Below winter pool	377	370	336	359	346	340			355	12.6%

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	1 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	SKB DATE 1995
	1995 Testing	CHECKED BY	PAN DATE 12/19/2001

Station (2002 Baseline)	Location	Readings (thousandths of an inch)								Average	Loss, %
69+30	2.5 ft from top of sht. pile	356	357	346	342	397	363	365	372	362	
#13404	At summer pool	378	374	382	372					377	-4.1%
PMA-22	Below winter pool	Water level too high									
79+40	2.5 ft from top of sht. pile	384	383	366	362					374	
#3214	At summer pool	369	387	384	371					378	-1.1%
PSA-23	Below winter pool	Water level too high									
85+70	2 ft from top of sht. pile	372	352	376	347					362	
#3345	At summer pool	346	375	369	371					365	-0.8%
PSA-23	Below winter pool	Water level too high									
89+40	2 ft from top of sht. pile										
415	At summer pool	Section not tested in 1995									
PSA-23	Below winter pool										
93+20	1.5 ft from top of sht. pile	375	376	377						376	
#3471	Below summer pool	355	357	360	374					362	3.7%
PSA-23	Below winter pool	Water level too high									
100+15	1.5 ft from top of sht. pile	369	372	375	395					378	
#3535	Below summer pool	368	367	368	364	366	365			366	3.2%
PSA-23	Below winter pool	Water level too high									
104+20	Between I-beam and waler	369	372	367	368					369	
#3555	Below summer pool	287	314	296	314	292	289	298		299	19.0%
PSA-23	Below winter pool	Water level too high									
110+00	Between I-beam and waler	361	363	391	390	359				373	
3633	Below summer pool	Too much crud/scaling to get accurate reading									
PSA-23	Below winter pool	Water level too high									

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	2 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	SKB DATE 1995
	1995 Testing	CHECKED BY	PAN DATE 12/19/2001

Station (2002 Baseline)	Location	Readings (thousandths of an inch)								Average	Loss, %
115+55	1.5 ft from top of sht. pile	378	382	380	376	397				383	
#3753	Below summer pool	364	390	361	385					375	2.1%
PSA-23	Below winter pool	Water level too high									
123+50	2.5 ft from top of sht. pile	364	365	371	390					373	
#3873	Below summer pool	380	384	356	363	364				369	1.1%
PSA-23	Below winter pool	Water level too high									
130+70	1.25 ft from top of sht. pile	375	372	377	381					376	
#4023	Below summer pool	331	330	328	326	311				325	13.6%
PSA-23	Below winter pool	Water level too high									
	Below winter pool, 2nd sheet	Water level too high									
37+15	2 ft from top of sht. pile	408	384	409	385					397	
#4119	Below summer pool	Could not test due to high water and waves									
PSA-23	Below winter pool	Water level too high									
144+30	1.5 ft from top of sht. pile	394	393	389	393	381	379			388	
#4219	Just above waler	373	374	401	368					379	2.3%
PSA-23	Below winter pool	Water level too high									
151+10	1.5 ft from top of waler	399	400	380	398	379				391	
#4307	Below summer pool	371	392	374	404					385	1.5%
PSA-23	Below winter pool	Water level too high									
155+50	Just below waler	390	395	397	400					396	
#4351	Below summer pool	Too wet to grind, could not test.									
PSA-23	Below winter pool	Water level too high									

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	3 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	SKB DATE 1995
	1995 Testing	CHECKED BY	PAN DATE 12/19/2001

Station (2002 Baseline)	Location	Readings (thousandths of an inch)								Average	Loss, %
163+40	Just below top cap										
#4455	Below summer pool	Section not tested in 1995									
PSA-23	Below winter pool										
170+25	1 ft above summer pool	402	403	380	388					393	
#4583	At summer pool	387	389	383	386					386	1.8%
PSA-23	Just below summer pool	419	418	406						414	
	Below winter pool	Water level too high									
176+25	Above summer pool	364	368	363	365					365	
#4697	At summer pool	370	362	367	368					367	-0.5%
PSA-23	Below winter pool	Water level too high									
184+85	2 ft from top of sht. pile	406	408	412	401					407	
#4847	At summer pool	391	406	383	387	407				395	2.9%
PSA-23	Below winter pool	Water level too high									
192+70	2 ft from top of sht. pile	373	369	367	370	402				376	
#5001	At summer pool	362	364	385	383	365				372	1.1%
PSA-23	Below winter pool	Water level too high									

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	1 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	PAN DATE 1/2/2002
	Comparison of 1995 and 2001 readings	CHECKED BY	DATE

Station (2002 Baseline)	Location	Average (.001") 1995	Average (.001") 2001	Loss in 2001
69+30	2.5 ft from top of sht. pile	362	355	
#13404	At summer pool	377	363	
PMA-22	Below winter pool	--	347	3.3%
79+40	2.5 ft from top of sht. pile	374	384	
#3214	At summer pool	378	372	
PSA-23	Below winter pool	--	298	21.2%
85+70	2 ft from top of sht. pile	362	377	
#3345	At summer pool	365	361	
PSA-23	Below winter pool	--	284	23.0%
89+40	2 ft from top of sht. pile	--	383	
#3415	At summer pool	--	367	
PSA-23	Below winter pool	--	364	5.0%
93+20	1.5 ft from top of sht. pile	376	395	
#3471	Below summer pool	362	393	
PSA-23	Below winter pool	--	332	15.7%
100+15	1.5 ft from top of sht. pile	378	397	
#3535	Below summer pool	366	401	
PSA-23	Below winter pool	--	352	11.8%
104+20	Between I-beam and waler	369	382	
#3555	Below summer pool	299	381	
PSA-23	Below winter pool	--	300	21.4%
110+00	Between I-beam and waler	373	391	
#3633	Below summer pool	--	385	
PSA-23	Below winter pool	--	267	31.2%

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	2 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	PAN DATE 1/2/2002
	Comparison of 1995 and 2001 readings	CHECKED BY	DATE

Station (2002 Baseline)	Location	Average (.001") 1995	Average (.001") 2001	Loss in 2001
115+55	1.5 ft from top of sht. pile	383	388	
#3753	Below summer pool	375	389	
PSA-23	Below winter pool	--	368	5.3%
123+50	2.5 ft from top of sht. pile	373	389	
#3873	Below summer pool	369	384	
PSA-23	Below winter pool	--	377	2.5%
130+70	1.25 ft from top of sht. pile	376	392	
#4023	Below summer pool	325	386	
PSA-23	Below winter pool	--	353	9.3%
	Below winter pool, 2nd sheet	--	299	
137+15	2 ft from top of sht. pile	397	399	
#4119	Below summer pool	--	398	
PSA-23	Below winter pool	--	340	14.7%
144+30	1.5 ft from top of sht. pile	388	415	
#4219	Just above waler	379	409	
PSA-23	Below winter pool	--	360	12.6%
151+10	1.5 ft from top of waler	391	384	
#4307	Below summer pool	385	399	
PSA-23	Below winter pool	--	388	0.9%
155+50	Just below waler	396	389	
#4351	Below summer pool	--	386	
PSA-23	Below winter pool	--	283	27.0%

DLZ

SUBJECT	Ohio Department of Natural Resources	JOB NUMBER	0121-3074.00
	Buckeye Lake Dam Evaluation	SHEET NO.	3 OF 3
	Ultrasonic Testing of Sheet Pile Wall	COMP. BY	PAN DATE 1/2/2002
	Comparison of 1995 and 2001 readings	CHECKED BY	DATE

Station (2002 Baseline)	Location	Average (.001") 1995	Average (.001") 2001	Loss in 2001
163+40	Just below top cap	--	384	
#4455	Below summer pool	--	392	
PSA-23	Below winter pool	--	311	19.8%
170+25	1 ft above summer pool	393	--	
#4583	At summer pool	386	387	
PSA-23	Just below summer pool	414	394	
	Below winter pool	--	344	11.9%
176+25	Above summer pool	365	393	
#4697	At summer pool	367	393	
PSA-23	Below winter pool	--	340	13.5%
184+85	2 ft from top of sht. pile	407	403	
#4847	At summer pool	395	405	
PSA-23	Below winter pool	--	351	13.1%
192+70	2 ft from top of sht. pile	376	406	
#5001	At summer pool	372	406	
PSA-23	Below winter pool	--	355	12.6%

Structural Calculations – Evaluation of Existing Sheet Pile Wall

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PLANNERS • SURVEYORS

CLIENT ODNR
PROJECT Buckeye lake
SUBJECT Evaluation of Existing Sheet Pile Wall

PROJECT NO. 0121-3074.00
SHEET NO. 1 OF 3
COMP. BY TAA DATE 7-16-02
CHECKED BY JAM DATE 7/16/02

- The goal is to determine the factor of safety of the existing sheet pile wall at Buckeye lake with respect to bending and shear.

- Ultrasonic testing has revealed minor to severe deterioration of the sheet pile walls (below Winter pool). See spreadsheet prepared by geotech with findings of the ultrasonic testing.

- The factor's of safety for bending and shear are to be determined at elevation 889.0 (near Winter pool). Per geotech this region generally exhibited the most deterioration. The maximum calculated/determined moment and shear values will be used to determine the factor's of safety.
- The two types of sheet piling making up the existing wall are presented below (types of sheet piling provided by geotech):

1) PMA-22: Original/nominal wall thickness = 0.375 in
Original $S_x = 5.4\ in^3$/ft of wall
Original $I_x = \left(\frac{12}{19.625}\right)(22.4\ in^4) = 13.7\ in^4$/ft of wall
Original $A = \left(\frac{12}{19.625}\right)(10.6\ in^2) = 6.48\ in^2$/ft of wall

2) PSA-23: Original/nominal wall thickness = 0.375 in
Original $S_x = 2.4\ in^3$/ft of wall
Original $I_x = \left(\frac{12}{16}\right)(5.5\ in^4) = 4.1\ in^4$/ft of wall
Original $A = \left(\frac{12}{16}\right)(8.99\ in^2) = 6.74\ in^4$/ft of wall

The above information was obtained from the USS Steel Sheet Piling Hand book

- Based on the original 1995 Dodson-Lindblom wall evaluation report, the steel sheet piling is assumed to be made of A328 steel. Per this report, and the USS Steel Sheet Piling Hand book, A328 Steel has a yield strength of $F_y = 38{,}500$ psi

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CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Evaluation of Existing Sheet Pile Wall

PROJECT NO. 0121-3074-00
SHEET NO. 3 OF 3
COMP. BY TAK DATE 7-16-02
CHECKED BY JAM DATE 7/16/02

- Per geotech, the groundsurface behind the wall is to be at elevation 895.0 while the groundsurface in front of the wall (i.e. lake bottom) is to be at elevation 887.0. Also, the ground water elevation behind the wall is to be at elevation 894.0 while the lake water elevation is to be at elevation 892.0. These numbers are for the analyses

- Per geotech, include wall friction in the analysis with $\delta = 20°$

- Use PileBuck sheet pile program to analyze both the PMA-22 and PSA-23 cases. The maximum shear and bending moment for each case was found to be:

PMA-22 (no anchor/tie back): $M_{max} = 8420.5$ ft lbs/ft of wall
$V_{max} = 1414.3$ lbs/ft of wall

PSA-23 (with anchor/tie back): $M_{max} = 4502.3$ ft lbs/ft of wall
$V_{max} = 1314.4$ lbs/ft of wall

- The section modulus for the existing sheet pile wall will be assumed to decrease linearly with decreasing wall thickness. That is, the existing sheet pile section modulus will be calculated from the equation

$$S_{x_{existing}} = S_{x_{original}} \left(\frac{\text{current wall thickness}}{0.375''} \right)$$

- In some locations the existing sheet pile wall is thicker than 0.375" (as measured in the field). This is assumed to be the result of manufacturing tolerances or field measurement tolerances. Where the measured wall thickness exceeds 0.375", the original section modulus is assumed to still exist.

- See attached spreadsheet for results of bending moment calculations (The spreadsheet is entitled "ODNR-Buckeye Lake Evaluation of Existing Sheet Pile Walls).

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CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Evaluation of Existing Sheet Pile Wall

PROJECT NO. 0121-3074-00
SHEET NO. 3 OF 3
COMP. BY TMA DATE 7-16-02
CHECKED BY JAM DATE 7/16/02

- For shear, assume the allowable shear stress is 0.4 Fy

$\therefore \tau_{all} = 0.4(38{,}500\ psi) = 15{,}400\ psi$

- With a maximum shear force of 1414.3 lbs/ft of wall (see previous sheet), the sheet piling would have to reduce to a cross-sectional area of:

$$A = \frac{1414.3\ lbs/ft}{15{,}400\ psi} = 0.09\ in^2/ft\ of\ wall$$

before shear failure might occur. Since this is <<< original area, shear failure should not be a concern

DLZ

CLIENT: Ohio Department of Natural Resources
PROJECT: Buckeye Lake Dam Eval.
SUBJECT: Critical Section thickness

PROJECT NO. 0121-3074.0
SHEET NO. 1 OF 1
COMP. BY PAN DATE 5/1/02
CHECKED BY TAM DATE 5-1-02

sheet pile	Design S (per ft. of wall)	Design thickness	Max. moment (per ft. of wall) (from calcs)
PSA 23 ✓	2.4 in^3 ✓	0.375" ✓	54,028 in-lbs ✓
PMA 22	5.4 in^3 ✓	0.375" ✓	101,046 in-lbs ✓

Above values are per foot of wall ✓

Strength of steel
allowable F_y = 25 ksi ✓ (from US Steel catalog) ✓
yield F_y = 38.5 ksi ✓

$$f = \frac{M}{S} \checkmark \qquad S = \frac{M}{f} \checkmark$$

PSA 23 ✓

allowable $S = 54{,}028 / 25{,}000 = 2.16\ in^3$ ✓
yield $S = 54{,}028 / 38{,}500 = 1.40\ in^3$ ✓

thickness allowable $\frac{t}{0.375''} = \frac{2.16\ in^3}{2.4\ in^3}$ $t = 0.338''$ ✓

yield $\frac{t}{0.375} = \frac{1.4\ in^3}{2.4\ in^3}$ $t = 0.219''$ ✓

PMA 22

		thickness
allowable	$S = 101{,}046 / 25{,}000 = 4.04\ in^3$ ✓	0.281" ✓
yield	$S = 101{,}046 / 38{,}500 = 2.62\ in^3$ ✓	0.182" ✓

ODNR - BUCKEYE LAKE
Evaluation of Existing Sheet Pile Walls
(Water level on lake side of wall at El. 892.0, water level on land side of wall at El. 894.0)
(No surcharge)
DLZ Job No. 0121-3074-00

Station	Wall Section	Design/Nominal Wall Thickness (in.)	Current/Measured Wall Thickness (Below Winter Pool) (in.)	Percent Loss (%)	Design/Nominal Section Modulus (in.^{3})	Original F.S. (against yielding)*	Current Section Modulus (in.^{3})	Current F.S. (against yielding)*
69+30	PMA-22	0.375	0.347	7.5	5.4	2.06	5.0	1.90
79+40	PSA-23	0.375	0.298	20.5	2.4	1.71	1.9	1.36
85+70	PSA-23	0.375	0.284	24.3	2.4	1.71	1.8	1.30
89+40	PSA-23	0.375	0.364	2.9	2.4	1.71	2.3	1.66
93+20	PSA-23	0.375	0.332	11.5	2.4	1.71	2.1	1.51
100+15	PSA-23	0.375	0.352	6.1	2.4	1.71	2.3	1.61
104+20	PSA-23	0.375	0.300	20.0	2.4	1.71	1.9	1.37
110+00	PSA-23	0.375	0.267	28.8	2.4	1.71	1.7	1.22
115+55	PSA-23	0.375	0.368	1.9	2.4	1.71	2.4	1.68
123+50	PSA-23	0.375	0.377	NA**	2.4	1.71	2.4	1.71
130+70	PSA-23	0.375	0.299	20.3	2.4	1.71	1.9	1.36
137+15	PSA-23	0.375	0.340	9.3	2.4	1.71	2.2	1.55
144+30	PSA-23	0.375	0.360	4.0	2.4	1.71	2.3	1.64
151+10	PSA-23	0.375	0.388	NA**	2.4	1.71	2.4	1.71
155+50	PSA-23	0.375	0.283	24.5	2.4	1.71	1.8	1.29
163+40	PSA-23	0.375	0.311	17.1	2.4	1.71	2.0	1.42
170+25	PSA-23	0.375	0.344	8.3	2.4	1.71	2.2	1.57
176+25	PSA-23	0.375	0.340	9.3	2.4	1.71	2.2	1.55
184+85	PSA-23	0.375	0.351	6.4	2.4	1.71	2.2	1.60
192+70	PSA-23	0.375	0.355	5.3	2.4	1.71	2.3	1.62

* - Based on steel yield strength of Fy = 38,500 psi
The factor of safety against yielding for the PMA-22 section is based on a maximum bending moment of 101046 in-lbs./foot of wall.
The factor of safety against yielding for the PSA-23 section is based on a maximum bending moment of 54028 in-lbs./foot of wall.
** - Current wall thickness is greater than design/nominal wall thickness

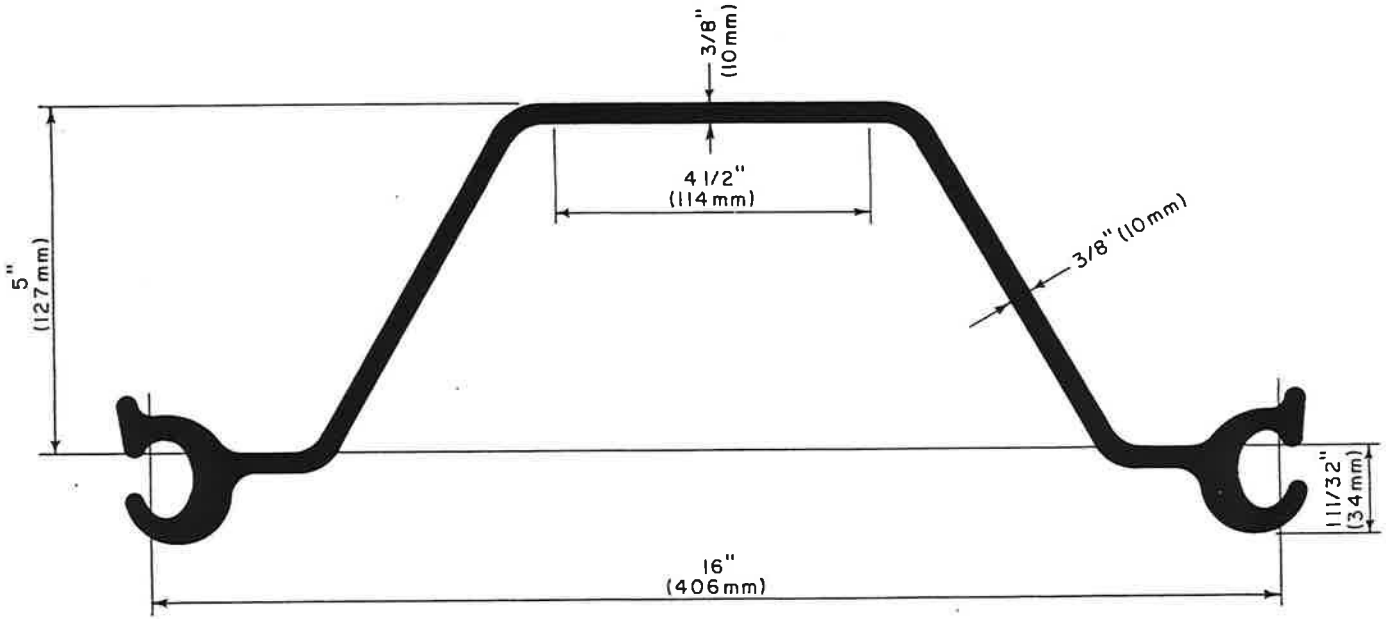
SHAPE	DRIVING DISTANCE PER PILE	WEB AND FLANGE THICK-NESS	WEIGHT		SECTION MODULUS		AREA	MOMENT OF INERTIA PER PILE	SURFACE AREA	
			Per Lineal Foot of Pile	Per Square Foot of Wall	Per Pile	Per Foot of Wall			Incl. Inter-lock	Coat-ing Area
	INCHES	INCHES	POUNDS	POUNDS	INCHES³	INCHES³	INCHES²	INCHES⁴	FT²/FT	FT²/FT
PDA27	16	⅜	36.0	27.0	14.3	10.7	10.6	53.0	4.52	3.86
PMA22	19⅝	⅜	36.0	22.0	8.8	5.4	10.6	22.4	4.54	3.88
	mm	mm	MASS Per Lineal m of Pile kg	Per Square m of Wall kg	Per Pile $mm^3 \times 10^3$	Per m of Wall $mm^3 \times 10^3$	$mm^2 \times 10^3$	$mm^4 \times 10^6$	m^2/m	m^2/m
PDA27	406	10	53.6	132	234	575	6.8	22.1	1.38	1.18
PMA22	498	10	53.6	107	144	290	6.8	9.3	1.38	1.18

To obtain number of pieces of PMA22 required for any length of wall in feet, see page 48. For PDA27, see page 50.
USS piling shapes PSA23, PSA28, PMA22 and PDA27 interlock with each other. While not normal practice, they will also interlock with PZ shapes.
All corners and standard fabricated connections for PMA22 and PDA27 are made from plain piling sections PSA23 or PSA28. Special Tee and Cross pieces can be fabricated from PMA22 and PDA27 or a combination of these with half-sections of PSA23 or PSA28.
For bent and fabricated corners, see page 39.
For cofferdam combinations, see page 70.
For standard fabricated connections, see pages 41 and 43.
For standard handling and pulling holes, see page 93.

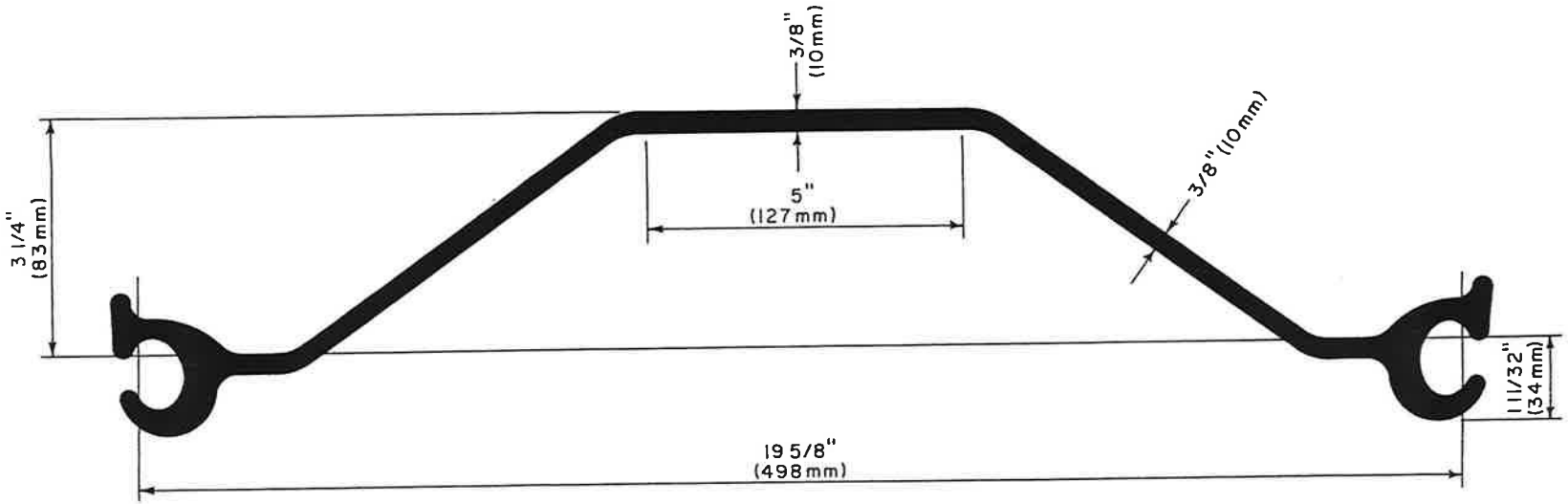
SHAPE	DRIVING DISTANCE PER PILE	WEB THICK-NESS	WEIGHT		SECTION MODULUS		AREA	MOMENT OF INERTIA PER PILE	SURFACE AREA	
			Per Lineal Foot of Pile	Per Square Foot of Wall	Per Pile	Per Foot of Wall			Incl. Inter-lock	Coat-ing Area
	INCHES	INCHES	POUNDS	POUNDS	INCHES³	INCHES³	INCHES²	INCHES⁴	FT²/FT	FT²/FT
PSA28	16	½	37.3	28.0	3.3	2.5	10.98	6.0	3.74	3.06
PSA23	16	⅜	30.7	23.0	3.2	2.4	8.99	5.5	3.76	3.08
	mm	mm	MASS Per Lineal m of Pile kg	Per Square m of Wall kg	Per Pile $mm^3 \times 10^3$	Per m of Wall $mm^3 \times 10^3$	$mm^2 \times 10^3$	$mm^4 \times 10^6$	m^2/m	m^2/m
PSA28	406	13	55.5	137	54	134	7.1	2.50	1.14	0.93
PSA23	406	10	45.7	112	52	129	5.8	2.30	1.15	0.94

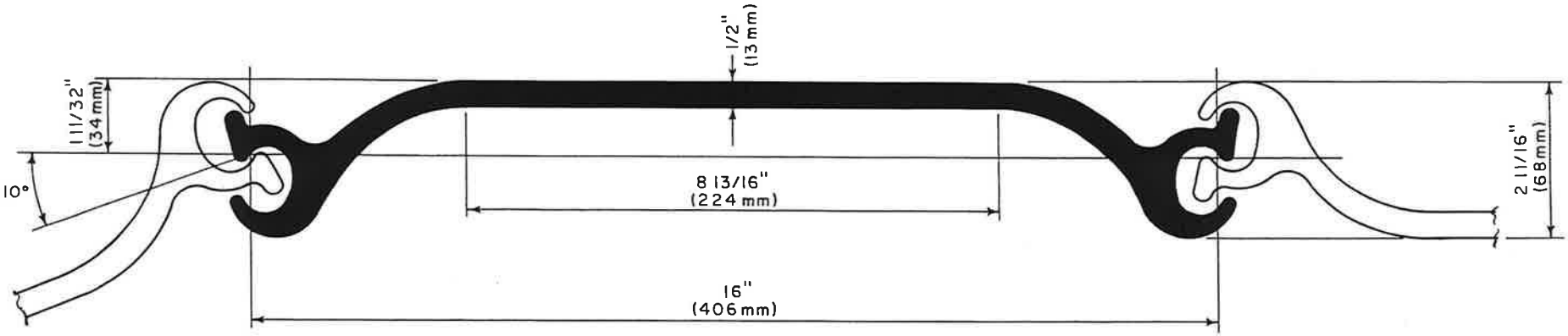
Minimum ultimate interlock strength is 12,000 lb per lineal inch 2.10×10^6 N/m—two representative tests per heat furnished in 3" (76 mm) specimens.
Recommended maximum design stresses in interlocks of sections PSA23 and PSA28 is 3,000 lb per lineal inch (0.525×10^6 N/m).
To obtain number of pieces required, multiply length of wall in feet by .75.
See table, page 50. USS piling shapes PSA23, PSA28, PMA22 and PDA27 interlock with each other. PSA23 and PSA28 are also fabricated into corners C12 and C13—which interlock with PZ shapes.
For bent and fabricated corners, see page 39.
For cofferdam combinations, see pages 55, 58, 59, 66, 67, 68 and 69.
For standard fabricated connections, see pages 41 and 43.
For standard handling and pulling holes, see page 93.

perties

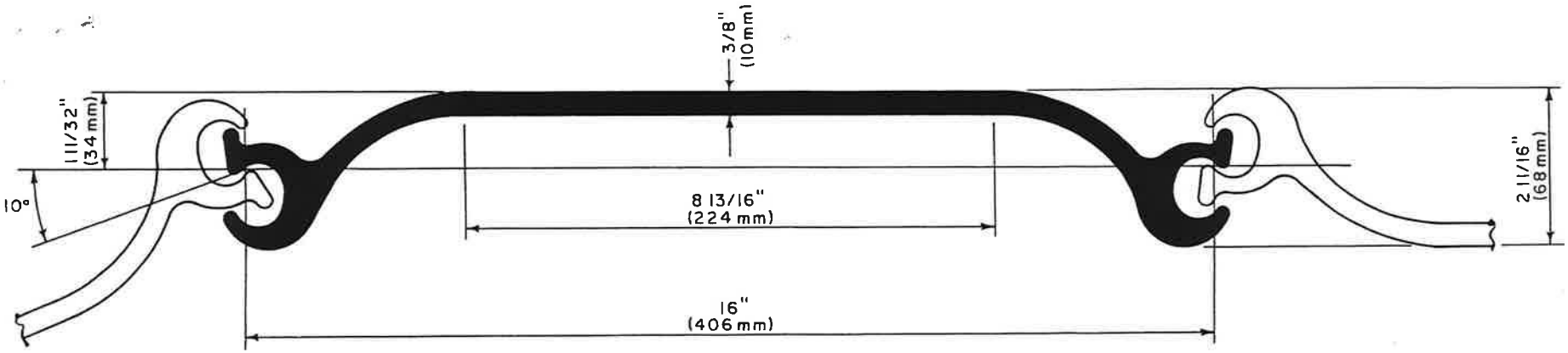


PMA 22




1/2"
(13 mm)
1 11/32"
(34 mm)
10°
8 13/16"
(224 mm)
2 11/16"
(68 mm)
16"
(406 mm)

PSA 23

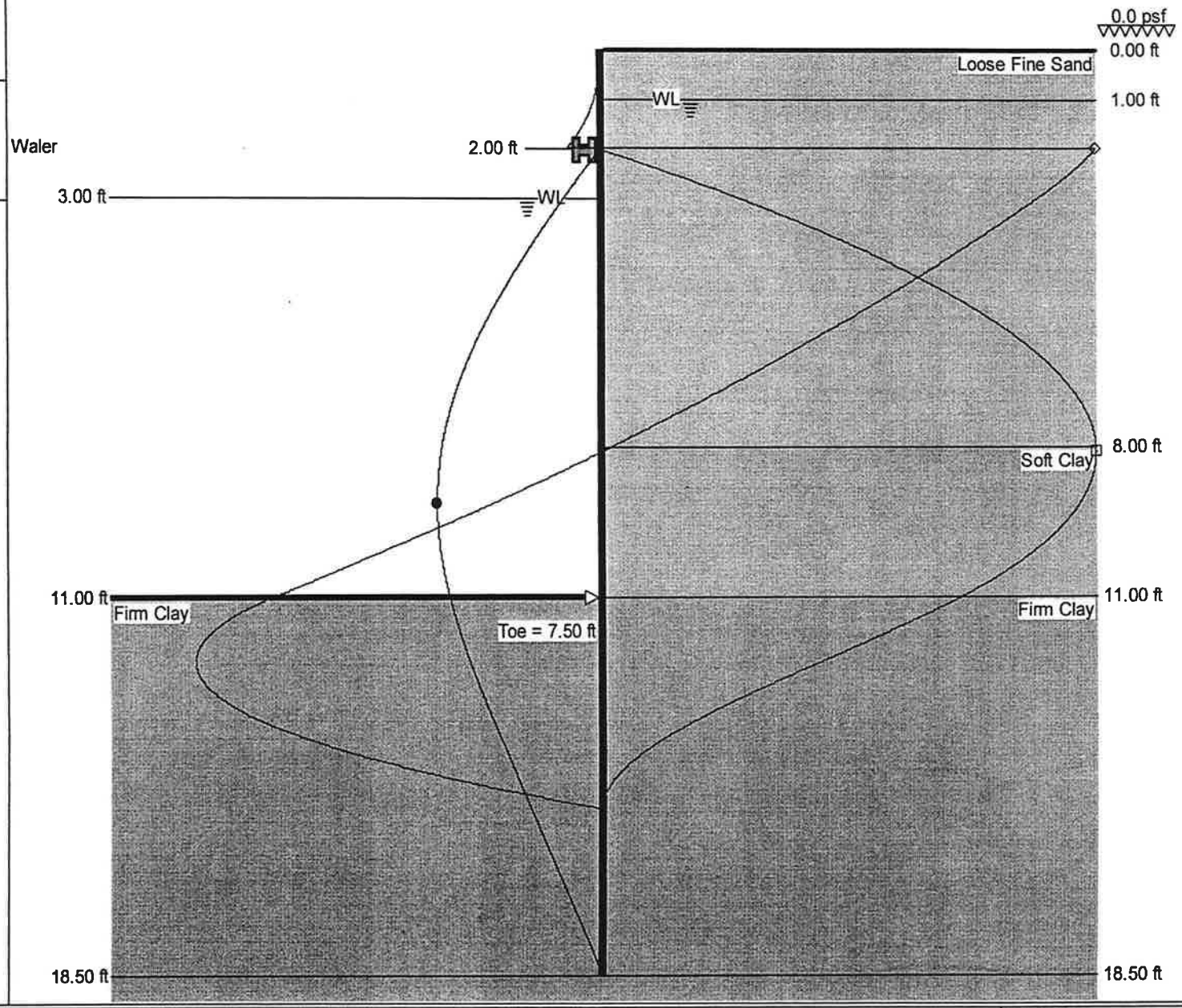

3/8"
(10 mm)
1 11/32"
(34 mm)
10°
8 13/16"
(224 mm)
2 11/16"
(68 mm)
16"
(406 mm)

Page: 1
Date: 7.16.02

Sheet: PSA-23
Pressure: Rankine
FOS: 5.3
Toe: Free Earth Support

Maximum	d (ft)
□ 4502.3 ftlb/ft	8.11
◇ 1314.4 lb/ft	2.00
● 1.4 in	9.14

54028 in-lbs/ft



SPW911, v2.00

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Page: 2
Date: 7.16.02

Sheet: PSA-23
Pressure: Rankine
FOS: 5.3
Toe: Free Earth Support

Input Data

Depth Of Excavation = 11.00 ft
Surcharge = 0.0 psf

Depth Of Active Water = 1.00 ft
Depth Of Passive Water = 3.00 ft

Water Density = 62.37 pcf
Minimum Fluid Density = 31.82 pcf

Soil Profile

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ (°)	δ (°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Loose Fine Sand	115.00	52.60	0.0	0.0	30.0	20.0	0.29	0.00	4.90	0.00
8.00	Soft Clay	120.00	57.60	0.0	0.0	28.0	20.0	0.31	0.00	4.67	0.00
11.00	Firm Clay	120.00	57.60	0.0	0.0	28.0	20.0	0.31	0.00	4.67	0.00

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PSA-23	4.10	2.9E+07	2.40	38500.0	7690.8	0.00	7.50	18.50

Load Model: Area Distribution

Supports

Depth (ft)	Type	Linear Load (lb/ft)
2.00	Waler	1404.6

Maxima

	Maximum	Depth
Bending Moment	4502.3 ftlb/ft	8.11 ft
Deflection	1.4 in	9.14 ft
Pressure	328.1 psf	11.00 ft
Shear Force	1314.4 lb/ft	2.00 ft

SPW911, v2.00

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Page: 4
Date: 7.16.02

Sheet: PSA-23
Pressure: Rankine
FOS: 5.3
Toe: Free Earth Support

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	0.0	0.0	0.0	0.0	6.22	237.8	-4032.5	1.2	-475.8	12.44	-37.7	-1877.3	1.1	1082.7
0.16	5.7	0.0	0.0	0.5	6.38	240.4	-4112.2	1.2	-435.3	12.61	-76.4	-1717.2	1.1	1073.6
0.33	11.3	0.3	0.0	2.0	6.55	242.8	-4178.5	1.2	-398.0	12.77	-119.0	-1543.2	1.1	1056.7
0.49	16.5	0.8	0.0	4.2	6.71	245.4	-4244.4	1.3	-356.6	12.93	-157.8	-1388.0	1.1	1035.1
0.65	22.1	1.8	0.0	7.5	6.88	247.9	-4303.1	1.3	-314.8	13.10	-200.3	-1221.6	1.0	1004.4
0.82	27.8	3.5	0.0	11.8	7.04	250.3	-4350.0	1.3	-276.3	13.26	-242.9	-1060.8	1.0	966.5
0.98	32.9	5.8	0.0	16.5	7.20	252.9	-4394.4	1.3	-233.6	13.42	-281.6	-920.5	1.0	925.7
1.15	45.5	9.3	0.0	23.2	7.37	255.2	-4428.3	1.3	-194.5	13.59	-324.2	-773.8	0.9	874.0
1.31	57.4	13.7	0.0	31.2	7.53	257.8	-4458.3	1.4	-150.9	13.75	-366.8	-636.2	0.9	815.1
1.47	70.6	20.2	0.0	42.2	7.69	260.4	-4480.6	1.4	-107.0	13.92	-405.5	-520.0	0.9	755.3
1.64	83.8	28.8	0.0	55.3	7.86	262.8	-4494.1	1.4	-66.6	14.08	-448.1	-403.0	0.8	682.6
1.80	95.7	38.8	0.0	69.3	8.02	274.8	-4501.6	1.4	-21.5	14.24	-486.8	-307.5	0.8	610.2
1.96	108.9	52.7	0.0	86.7	8.19	277.9	-4501.3	1.4	21.1	14.41	-529.4	-215.4	0.8	523.7
2.13	122.1	-154.6	0.0	-1298.2	8.35	280.9	-4493.7	1.4	68.5	14.57	-572.0	-138.1	0.8	430.0
2.29	134.0	-360.2	0.1	-1278.3	8.51	283.9	-4478.2	1.4	116.4	14.73	-610.7	-81.6	0.7	338.5
2.46	147.2	-582.5	0.2	-1254.4	8.68	286.7	-4457.3	1.4	160.4	14.90	-653.3	-35.8	0.7	231.0
2.62	159.2	-780.7	0.2	-1230.7	8.84	289.7	-4426.8	1.4	209.3	15.06	-692.0	-9.9	0.7	127.0
2.78	172.3	-994.2	0.3	-1202.5	9.00	292.7	-4388.2	1.4	258.7	15.23	-734.6	0.0	0.6	0.0
2.95	185.5	-1202.6	0.3	-1172.0	9.17	295.5	-4346.1	1.4	304.1	15.39	-777.2	0.0	0.6	0.0
3.11	190.3	-1387.2	0.4	-1142.9	9.33	298.5	-4291.9	1.4	354.5	15.55	-815.9	0.0	0.6	0.0
3.27	192.9	-1584.8	0.4	-1110.4	9.50	301.3	-4235.5	1.4	400.7	15.72	-858.5	0.0	0.5	0.0
3.44	195.5	-1776.8	0.5	-1077.4	9.66	304.3	-4165.5	1.4	452.1	15.88	-901.1	0.0	0.5	0.0
3.60	197.9	-1946.2	0.5	-1047.1	9.82	307.3	-4087.0	1.4	504.0	16.04	-939.8	0.0	0.5	0.0
3.77	200.4	-2126.9	0.6	-1013.3	9.99	310.1	-4008.3	1.4	551.6	16.21	-982.4	0.0	0.4	0.0
3.93	202.8	-2285.9	0.6	-982.2	10.15	313.1	-3913.5	1.4	604.4	16.37	-1021.1	0.0	0.4	0.0
4.09	205.4	-2455.2	0.7	-947.6	10.31	316.1	-3810.0	1.4	657.8	16.54	-1063.7	0.0	0.4	0.0
4.26	208.0	-2618.3	0.7	-912.5	10.48	318.9	-3708.3	1.4	706.8	16.70	-1106.3	0.0	0.3	0.0
4.42	210.3	-2761.2	0.7	-880.2	10.64	321.9	-3588.1	1.4	761.1	16.86	-1145.0	0.0	0.3	0.0
4.58	212.9	-2912.3	0.8	-844.3	10.81	324.6	-3471.0	1.4	811.0	17.03	-1187.6	0.0	0.3	0.0
4.75	215.3	-3044.3	0.8	-811.3	10.97	327.7	-3333.6	1.3	866.3	17.19	-1230.2	0.0	0.2	0.0
4.91	217.8	-3183.3	0.9	-774.6	11.13	291.4	-3187.3	1.3	919.0	17.35	-1268.9	0.0	0.2	0.0
5.08	220.4	-3315.8	0.9	-737.4	11.30	252.6	-3047.3	1.3	960.7	17.52	-1311.5	0.0	0.2	0.0
5.24	222.8	-3430.6	1.0	-703.2	11.46	210.1	-2886.8	1.3	999.6	17.68	-1350.2	0.0	0.2	0.0
5.40	225.4	-3550.4	1.0	-665.2	11.62	171.3	-2735.9	1.3	1028.7	17.84	-1392.8	0.0	0.1	0.0
5.57	228.0	-3663.6	1.0	-626.7	11.79	128.8	-2565.5	1.2	1053.8	18.01	-1435.4	0.0	0.1	0.0
5.73	230.3	-3760.6	1.1	-591.4	11.95	86.2	-2391.7	1.2	1071.7	18.17	-1474.1	0.0	0.1	0.0
5.89	232.9	-3860.7	1.1	-552.1	12.11	47.4	-2231.7	1.2	1081.7	18.34	-1516.7	0.0	0.0	0.0
6.06	235.2	-3945.7	1.1	-516.0	12.28	4.9	-2054.5	1.2	1085.8	18.50	-1555.4	0.0	0.0	0.0

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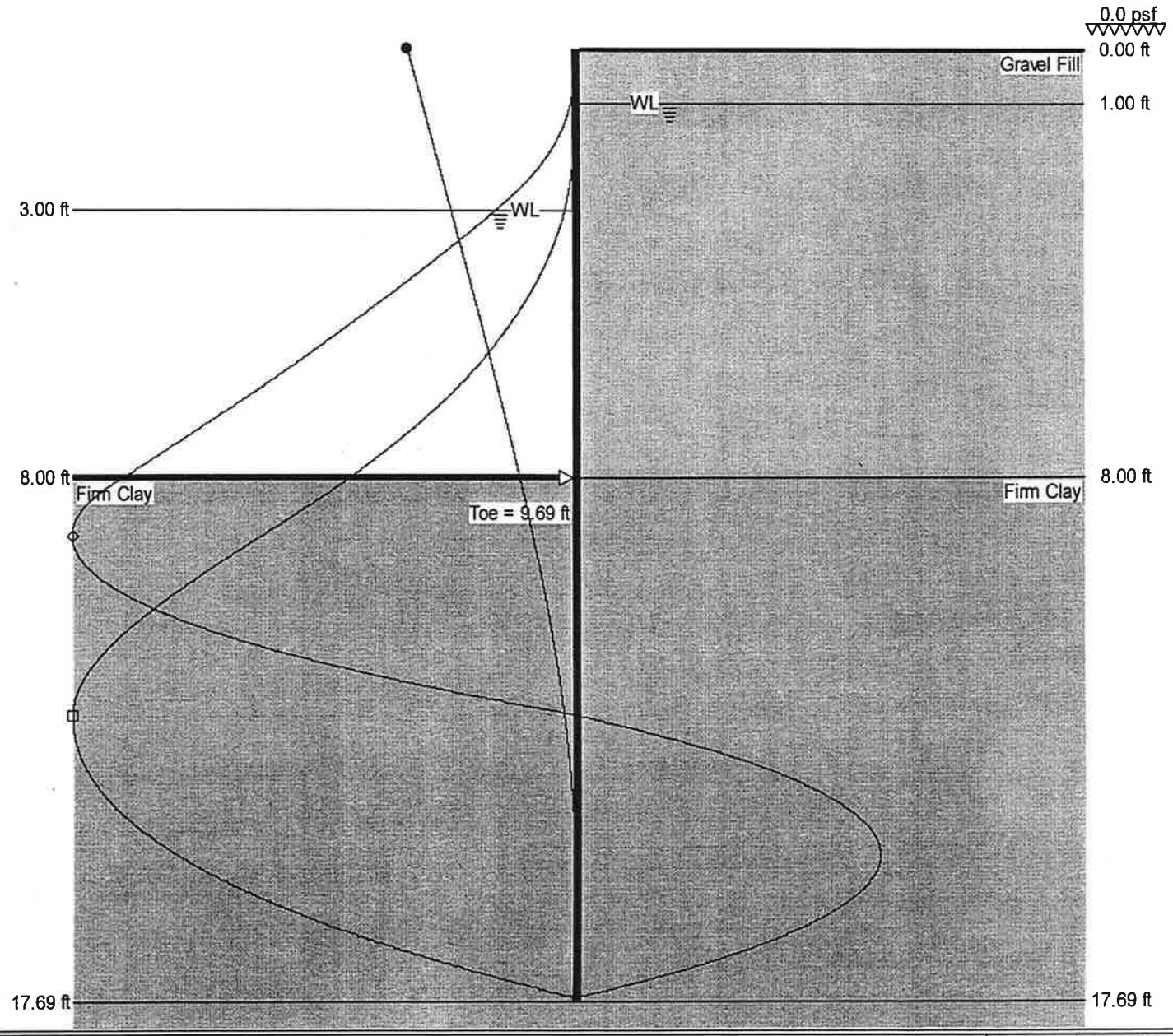
Date: 7.16.02

Sheet: PMA-22
Pressure: Rankine
FOS: 1.0
Toe: Cantilever

	Maximum	d (ft)
□	8420.5 ftlb/ft	12.44
◇	1414.3 lb/ft	9.08
●	3.5 in	0.00

101,046 in-lbs/ft



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Page: 2
Date: 7.16.02

Sheet: PMA-22
Pressure: Rankine
FOS: 1.0
Toe: Cantilever

Input Data

Depth Of Excavation = 8.00 ft
Surcharge = 0.0 psf

Depth Of Active Water = 1.00 ft
Depth Of Passive Water = 3.00 ft

Water Density = 62.37 pcf
Minimum Fluid Density = 31.82 pcf

Soil Profile

Depth (ft)	Soil Name	γ(pcf)	γ'(pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Gravel Fill	115.00	52.60	0.0	0.0	34.0	20.0	0.24	0.00	5.85	0.00
8.00	Firm Clay	120.00	57.60	0.0	0.0	28.0	20.0	0.31	0.00	4.67	0.00

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PMA-22	13.70	2.9E+07	5.40	38500.0	17304.4	0.00	9.69	17.69

Maxima

	Maximum	Depth
Bending Moment	8420.5 ftlb/ft	12.44 ft
Deflection	3.5 in	0.00 ft
Pressure	269.6 psf	8.00 ft
Shear Force	1414.3 lb/ft	9.08 ft

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APPENDIX V

Concept Design of Dam Improvement Alternatives
Cost Estimate

Concept Design
Anchored Sheet Pile Wall
And
Double Row Sheet Pile Wall

Client: Ohio Department of Natural Resources

Title: Buckeye Lake Embankment Evaluation North Bank Section 4

Designer: PAN

Ref: 1

Page: 1

Date: 2.26.02

Sheet: PZ22

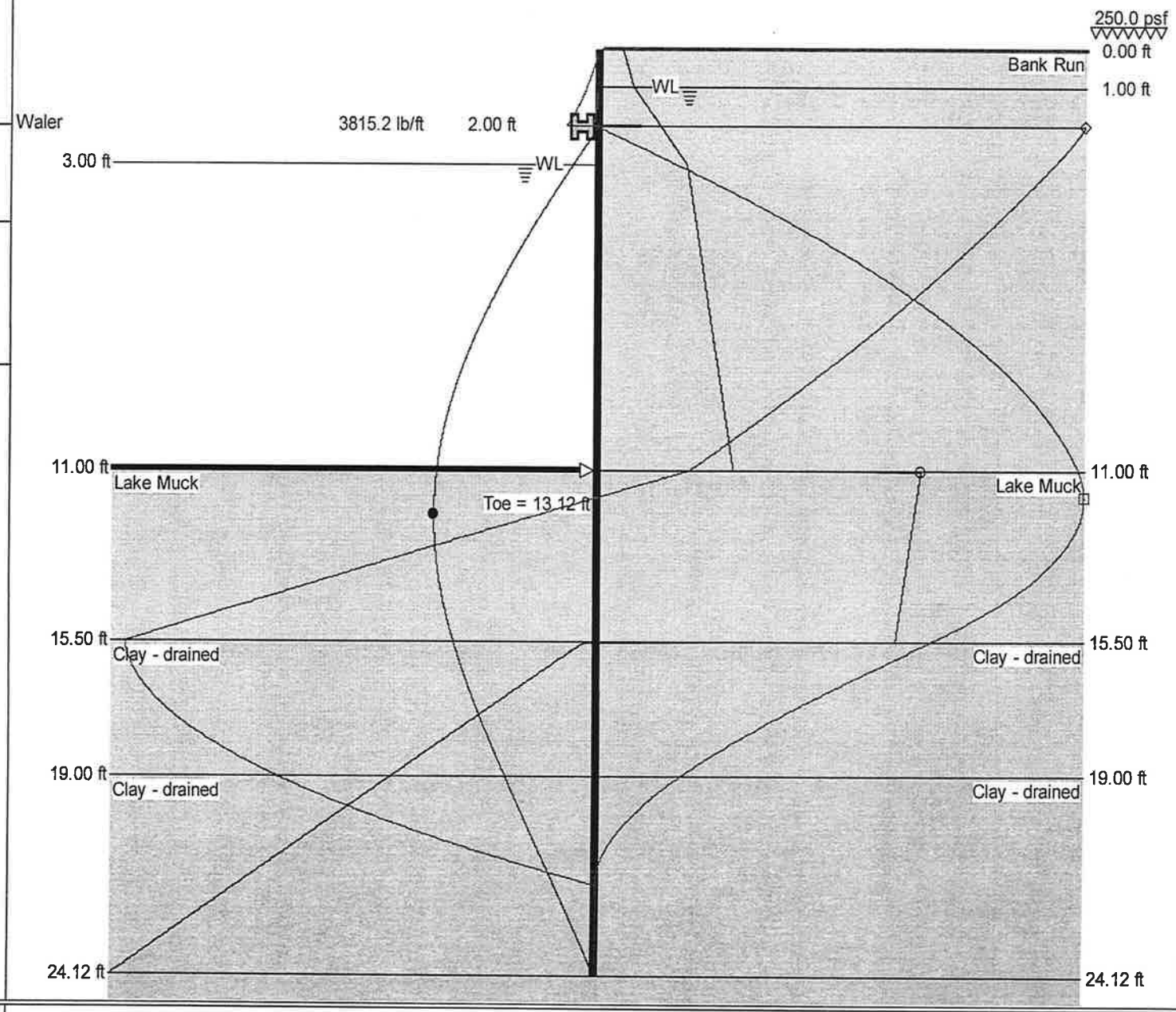
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

Maximum	d (ft)
○ 960.9 psf	11.04
□ 20449.4 ftlb/ft	11.72
◇ 3580.5 lb/ft	2.00
● 0.6 in	12.18

Drained Analysis



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Title: Buckeye Lake Embankment Evaluation North Bank Section 4

Designer: PAN

Ref: 1

Page: 2

Date: 2.26.02

Sheet: PZ22

Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

Drained Analysis

Input Data

Depth Of Excavation = 11.00 ft

Surcharge = 250.0 psf

Depth Of Active Water = 1.00 ft

Depth Of Passive Water = 3.00 ft

Water Density = 62.40 pcf

Minimum Fluid Density = 31.82 pcf

Soil Profile

Depth (ft)	Soil Name	γ(pcf)	γ'(pcf)	C (psf)	C_a (psf)	ϕ (°)	δ (°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Bank Run	120.00	62.60	0.0	0.0	32.0	17.0	0.28	0.00	6.02	0.00
11.00	Lake Muck	110.00	47.60	0.0	0.0	5.0	0.0	0.84	0.00	1.19	0.00
15.50	Clay - drained	125.00	67.60	0.0	0.0	28.0	0.0	0.36	0.00	2.77	0.00
19.00	Clay - drained	125.00	67.60	0.0	0.0	28.0	0.0	0.36	0.00	2.77	0.00

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PZ22	84.40	2.9E+07	18.10	32000.0	48209.2	0.00	13.12	24.12

Load Model: Area Distribution

Supports

Depth (ft)	Type	Linear Load (lb/ft)	Strut Angle (°)	
2.00	Waler	3815.2	0.0	Anchor

Maxima

	Maximum	Depth
Bending Moment	20449.4 ftlb/ft	11.72 ft
Deflection	0.6 in	12.18 ft
Pressure	960.9 psf	11.04 ft
Shear Force	3580.5 lb/ft	2.00 ft

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Title: Buckeye Lake Embankment Evaluation North Bank Section 4

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Page: 3

Date: 2.26.02

Sheet: PZ22

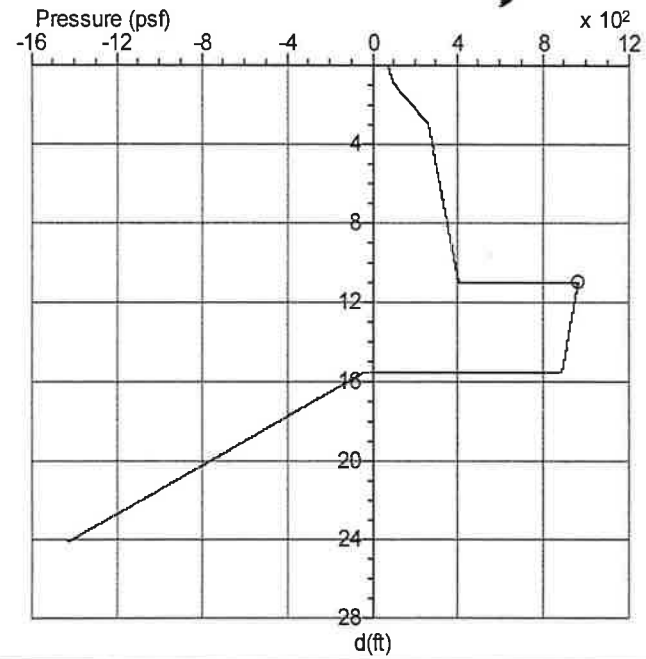
Pressure: Coulomb

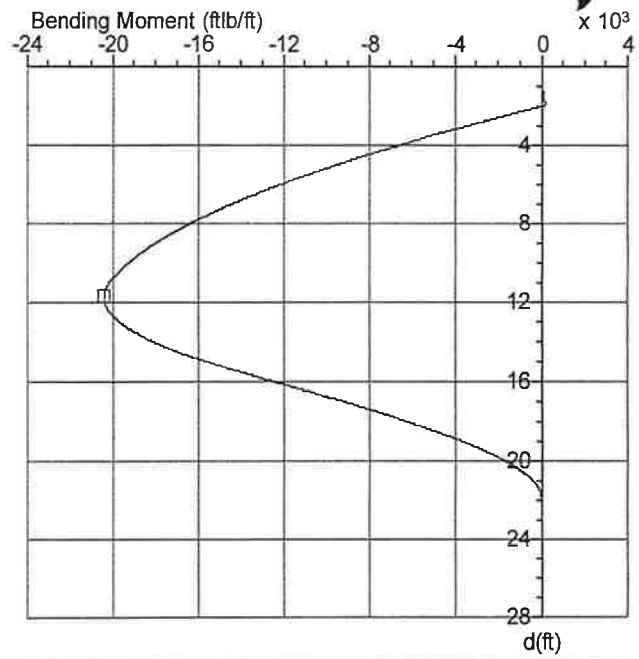
FOS: 2.0

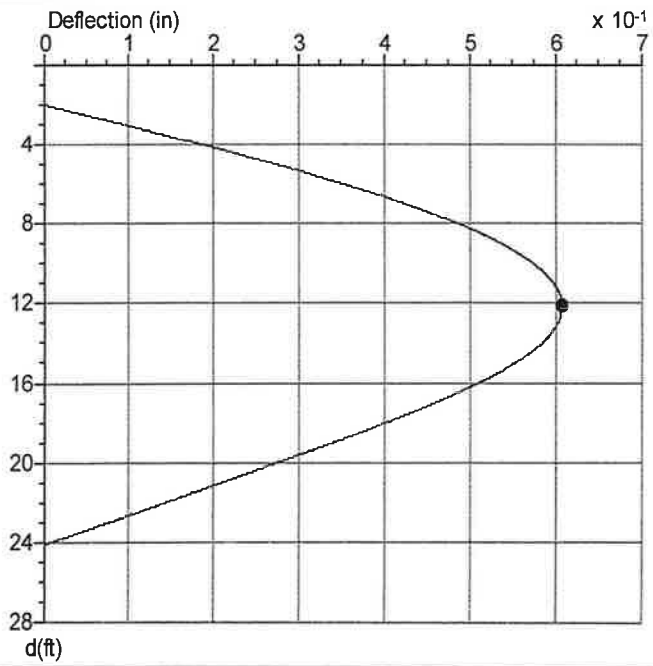
Toe: Free Earth Support

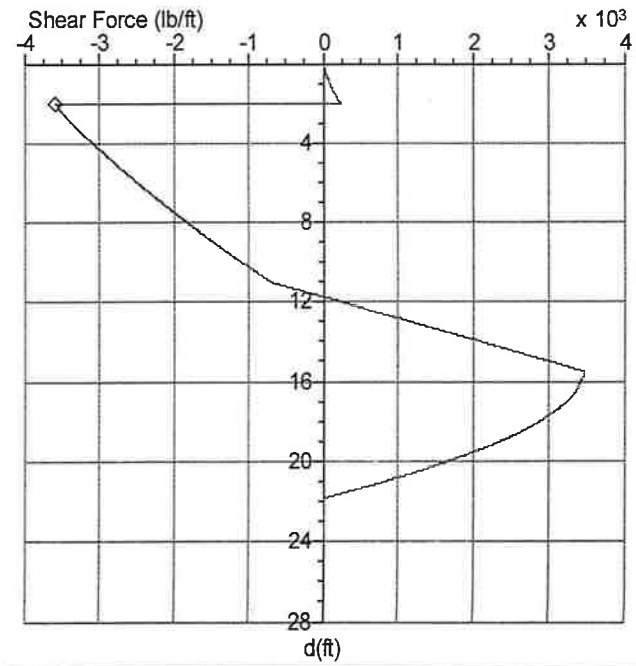
	Maximum	d (ft)
○	960.9 psf	11.04
□	20449.4 ftlb/ft	11.72
◇	3580.5 lb/ft	2.00
●	0.6 in	12.18

Drained Analysis









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Page: 4

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Sheet: PZ22

Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

Drained Analysis

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	70.7	0.1	0.0	2.8
0.21	77.4	2.3	0.0	17.8
0.43	84.9	8.2	0.0	35.8
0.64	91.6	17.3	0.0	53.6
0.85	99.0	31.4	0.0	74.8
1.07	110.4	50.4	0.0	97.8
1.28	126.5	72.4	0.0	121.7
1.49	144.2	102.4	0.0	151.8
1.71	160.2	135.8	0.0	182.6
1.92	177.9	180.0	0.0	220.1
2.13	195.6	-375.2	0.0	-3553.6
2.35	211.6	-1080.8	0.0	-3512.5
2.56	229.3	-1847.1	0.1	-3463.6
2.77	247.0	-2602.3	0.1	-3410.8
2.99	263.1	-3278.4	0.1	-3359.3
3.20	267.2	-4010.1	0.1	-3300.6
3.42	270.8	-4664.0	0.1	-3246.5
3.63	274.6	-5370.9	0.2	-3186.2
3.84	278.5	-6064.6	0.2	-3125.0
4.06	282.0	-6683.5	0.2	-3068.6
4.27	285.9	-7351.3	0.2	-3005.8
4.48	289.8	-8005.3	0.2	-2942.1
4.70	293.3	-8587.7	0.2	-2883.5
4.91	297.2	-9214.8	0.3	-2818.2
5.12	300.7	-9772.5	0.3	-2758.0
5.34	304.6	-10372.1	0.3	-2691.1
5.55	308.5	-10957.0	0.3	-2623.3
5.76	312.0	-11475.8	0.3	-2560.9
5.98	315.9	-12032.1	0.4	-2491.4
6.19	319.4	-12524.6	0.4	-2427.6
6.40	323.3	-13051.6	0.4	-2356.5
6.62	327.1	-13563.1	0.4	-2284.5
6.83	330.7	-14014.3	0.4	-2218.4
7.04	334.5	-14495.5	0.4	-2144.8
7.26	338.4	-14960.4	0.4	-2070.4
7.47	341.9	-15369.0	0.5	-2002.0
7.68	345.8	-15802.6	0.5	-1925.9
7.90	349.3	-16182.4	0.5	-1856.0

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
8.11	353.2	-16584.0	0.5	-1778.3
8.32	357.1	-16968.6	0.5	-1699.7
8.54	360.6	-17303.2	0.5	-1627.6
8.75	364.5	-17654.8	0.5	-1547.4
8.97	368.4	-17988.7	0.5	-1466.3
9.18	371.9	-18276.8	0.5	-1391.9
9.39	375.8	-18576.7	0.6	-1309.2
9.61	379.3	-18833.5	0.6	-1233.3
9.82	383.2	-19098.6	0.6	-1148.9
10.03	387.0	-19345.1	0.6	-1063.8
10.25	390.6	-19553.1	0.6	-985.6
10.46	394.4	-19763.8	0.6	-898.7
10.67	398.0	-19938.9	0.6	-819.1
10.89	401.8	-20113.2	0.6	-730.6
11.10	959.5	-20264.1	0.6	-580.7
11.31	956.2	-20363.8	0.6	-388.2
11.53	952.5	-20429.5	0.6	-177.2
11.74	948.8	-20448.9	0.6	32.9
11.95	945.5	-20427.6	0.6	223.3
12.17	941.8	-20360.3	0.6	431.9
12.38	938.4	-20259.7	0.6	620.8
12.59	934.7	-20105.9	0.6	827.8
12.81	931.1	-19907.0	0.6	1034.0
13.02	927.7	-19687.2	0.6	1220.8
13.23	924.0	-19402.8	0.6	1425.5
13.45	920.3	-19073.9	0.6	1629.4
13.66	917.0	-18736.4	0.6	1814.0
13.87	913.3	-18362.4	0.6	2016.3
14.09	910.0	-17951.9	0.6	2199.5
14.30	906.3	-17458.6	0.6	2400.2
14.52	902.6	-16921.6	0.6	2600.2
14.73	899.2	-16395.6	0.6	2781.2
14.94	895.6	-15775.7	0.6	2979.6
15.16	892.2	-15174.6	0.5	3159.2
15.37	888.5	-14472.4	0.5	3356.1
15.58	-48.8	-13730.3	0.5	3468.7
15.80	-81.6	-13117.3	0.5	3455.3
16.01	-117.6	-12371.7	0.5	3432.9

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
16.22	-153.6	-11631.7	0.5	3402.6
16.44	-186.4	-10965.1	0.5	3368.1
16.65	-222.4	-10240.3	0.5	3322.5
16.86	-255.1	-9590.6	0.5	3274.2
17.08	-291.2	-8887.5	0.5	3213.4
17.29	-327.2	-8198.4	0.4	3144.7
17.50	-359.9	-7585.3	0.4	3075.3
17.72	-396.0	-6927.5	0.4	2991.4
17.93	-432.0	-6345.8	0.4	2899.5
18.14	-464.7	-5781.1	0.4	2809.0
18.36	-500.8	-5181.0	0.4	2701.9
18.57	-533.5	-4656.1	0.4	2597.7
18.78	-569.5	-4103.0	0.4	2475.4
19.00	-605.5	-3577.1	0.3	2345.1
19.21	-638.3	-3124.0	0.3	2219.8
19.42	-674.3	-2654.7	0.3	2074.3
19.64	-707.1	-2255.9	0.3	1935.1
19.85	-743.1	-1885.1	0.3	1774.5
20.06	-779.1	-1511.0	0.3	1605.8
20.28	-811.9	-1203.0	0.3	1445.6
20.49	-847.9	-901.2	0.2	1261.8
20.71	-883.9	-639.8	0.2	1069.9
20.92	-916.6	-438.7	0.2	888.7
21.13	-952.7	-259.2	0.2	681.6
21.35	-985.4	-135.4	0.2	486.5
21.56	-1021.4	-44.3	0.2	264.3
21.77	-1057.5	-1.9	0.2	34.1
21.99	-1090.2	0.0	0.1	0.0
22.20	-1126.2	0.0	0.1	0.0
22.41	-1162.3	0.0	0.1	0.0
22.63	-1195.0	0.0	0.1	0.0
22.84	-1231.0	0.0	0.1	0.0
23.05	-1263.8	0.0	0.1	0.0
23.27	-1299.8	0.0	0.1	0.0
23.48	-1335.8	0.0	0.0	0.0
23.69	-1368.6	0.0	0.0	0.0
23.91	-1404.6	0.0	0.0	0.0
24.12	-1434.1	0.0	0.0	0.0

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Sheet: Shoreline SZ-10

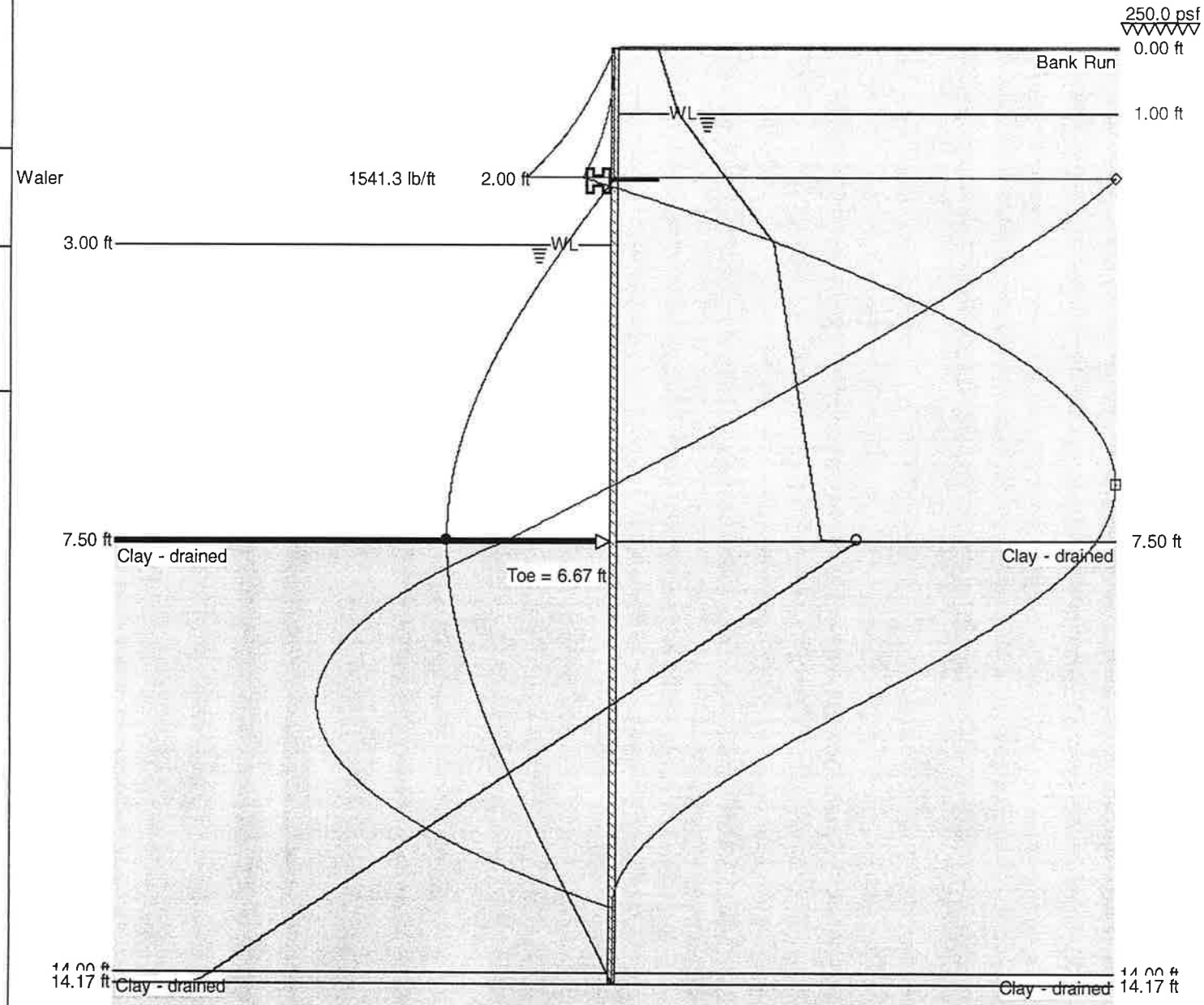
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

	Maximum	d (ft)
○	401.2 psf	7.50
□	3146.1 ftlb/ft	6.67
◇	1308.2 lb/ft	2.00
●	0.1 in	7.50

Drained case



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Page: 1

Date: 2.26.02

Sheet: Shoreline SZ-10

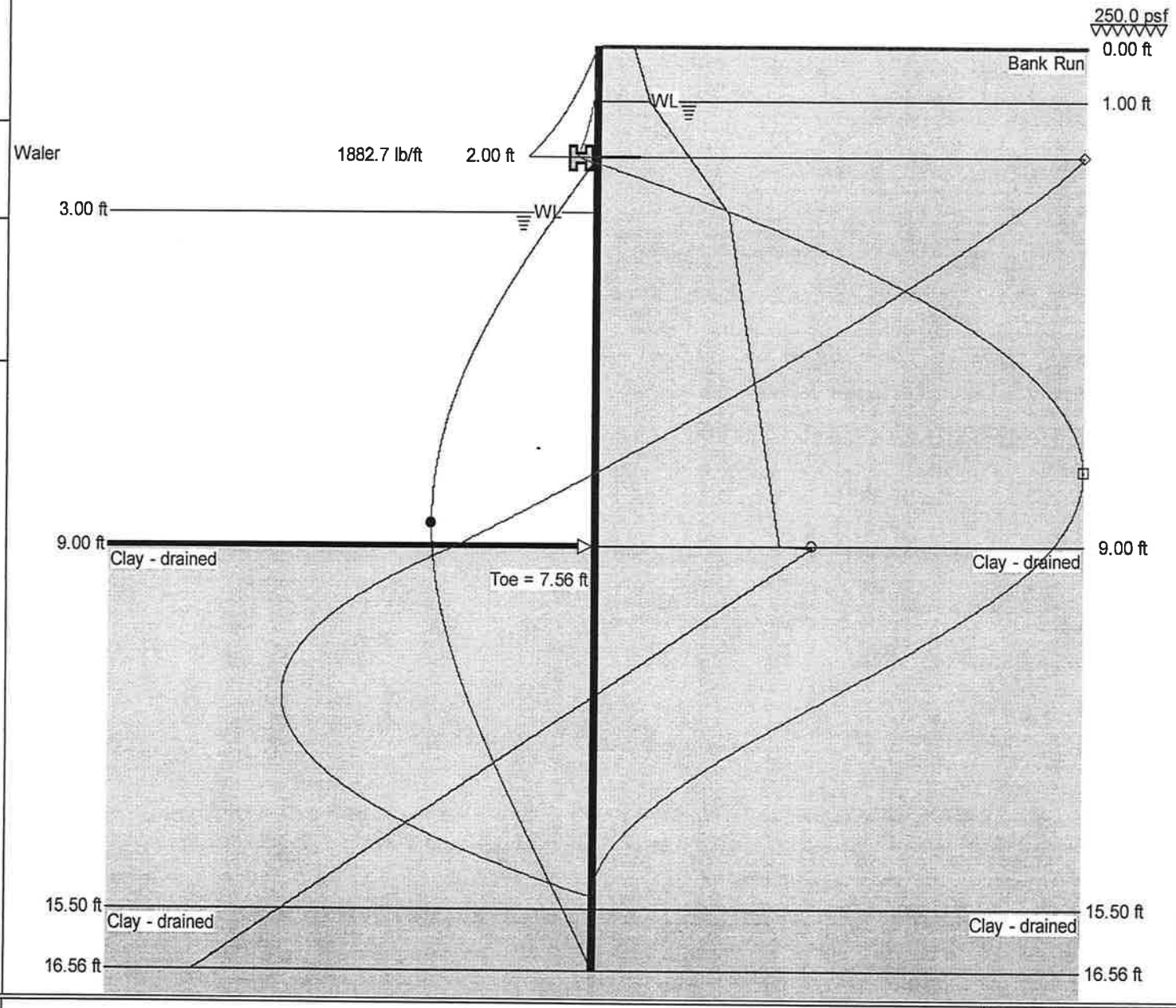
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

	Maximum	d (ft)
○	434.4 psf	9.00
□	4989.6 ftlb/ft	7.67
◇	1650.5 lb/ft	2.00
●	0.2 in	8.60

Drained Analysis



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Designer: PAN
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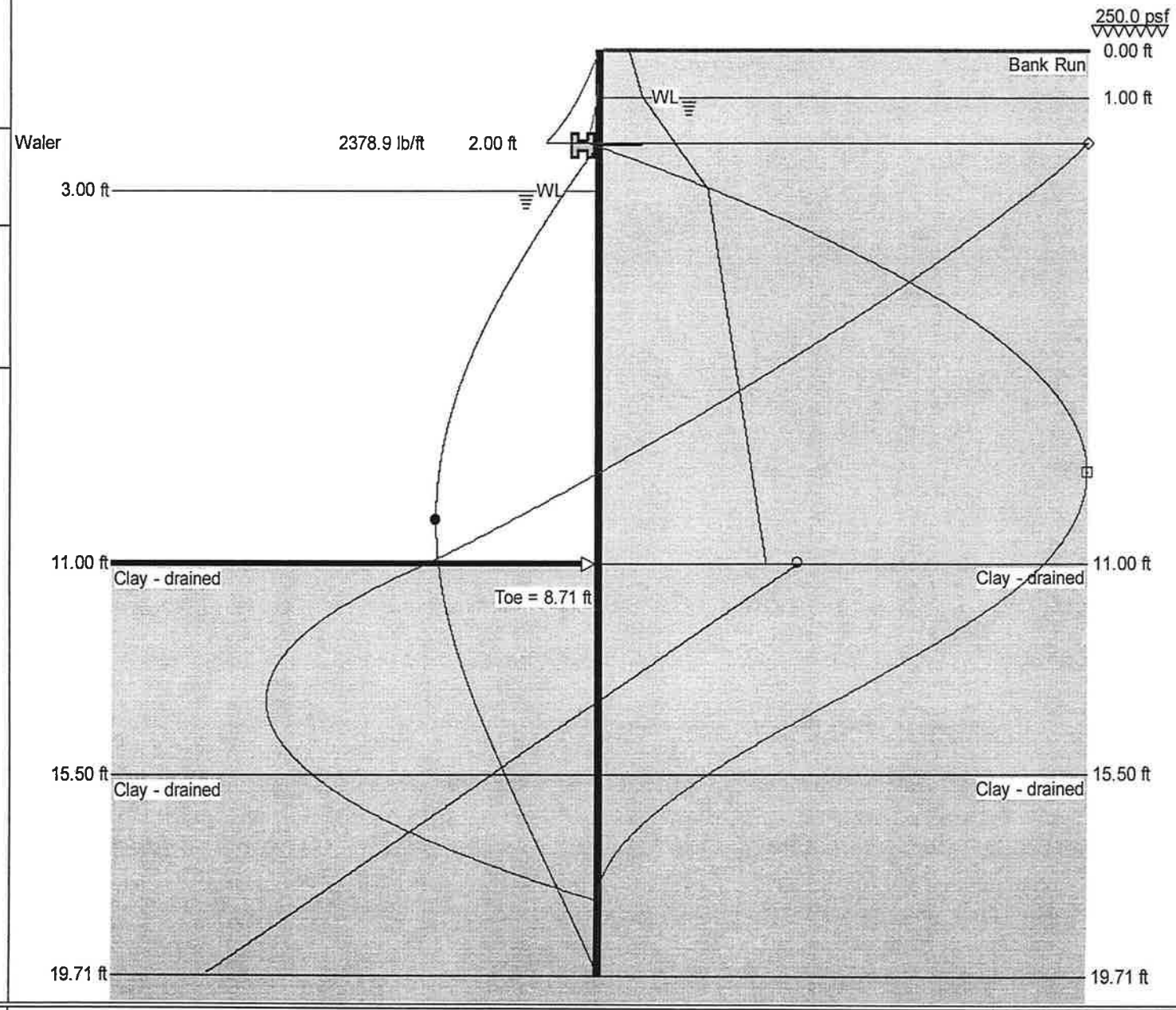
Page: 1
Date: 2.26.02

Sheet: Shoreline SZ-10
Pressure: Coulomb
FOS: 2.0
Toe: Free Earth Support

	Maximum	d (ft)
○	480.0 psf	11.00
□	8217.2 ftlb/ft	9.07
◇	2145.8 lb/ft	2.00
●	0.5 in	10.07

Drained Analysis



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Page: 1

Date: 2.26.02

Sheet: PZ22

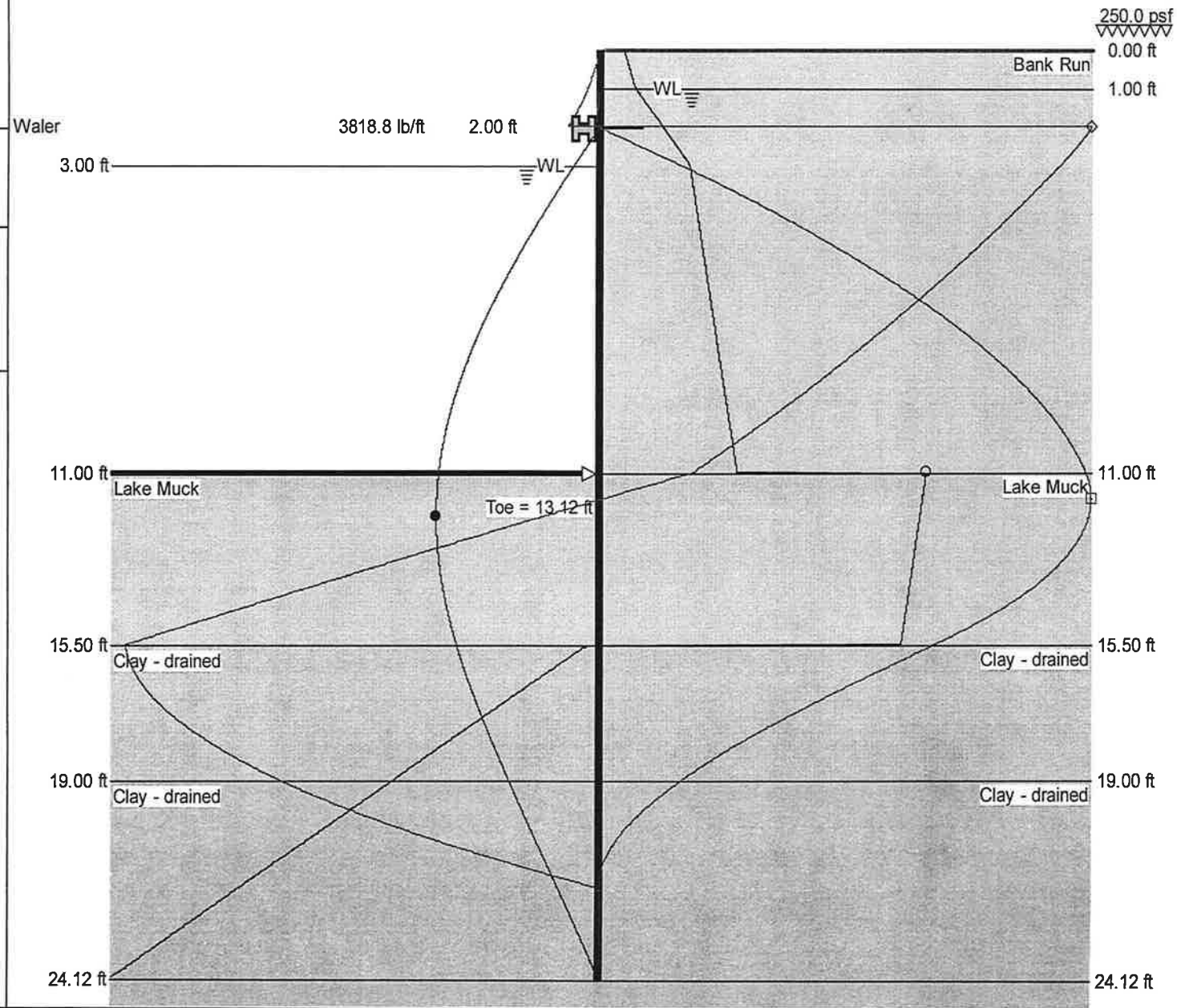
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

	Maximum	d (ft)
○	960.9 psf	11.00
□	20730.0 ftlb/ft	11.72
◇	3584.1 lb/ft	2.00
●	0.6 in	12.16

Drained Analysis



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Designer: PAN

Ref: 1

Page: 1

Date: 2.26.02

Sheet: Shoreline SZ-14.5

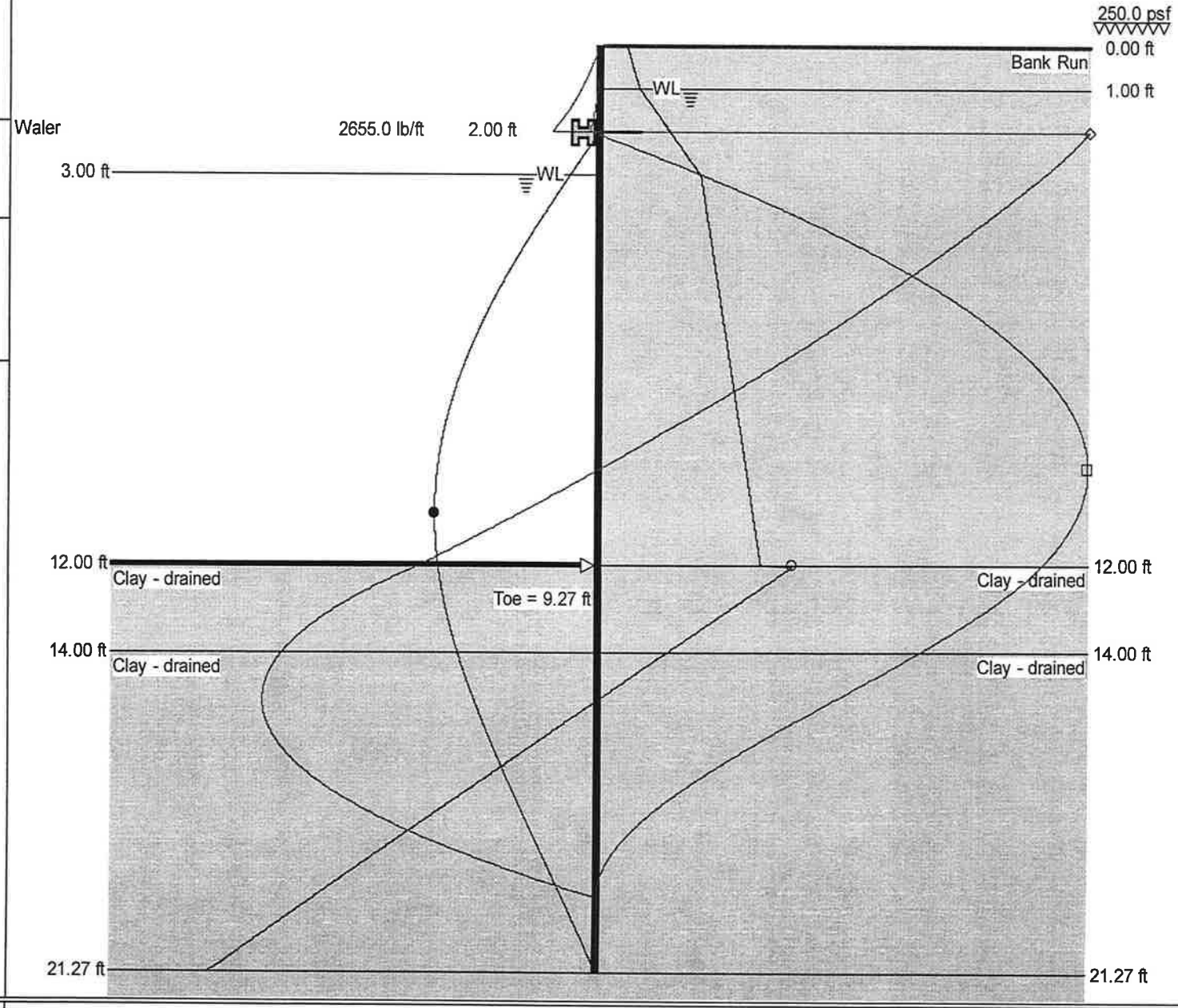
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

	Maximum	d (ft)
○	502.8 psf	12.00
□	10178.6 ftlb/ft	9.79
◇	2421.8 lb/ft	2.00
●	0.3 in	10.80

Drained Analysis



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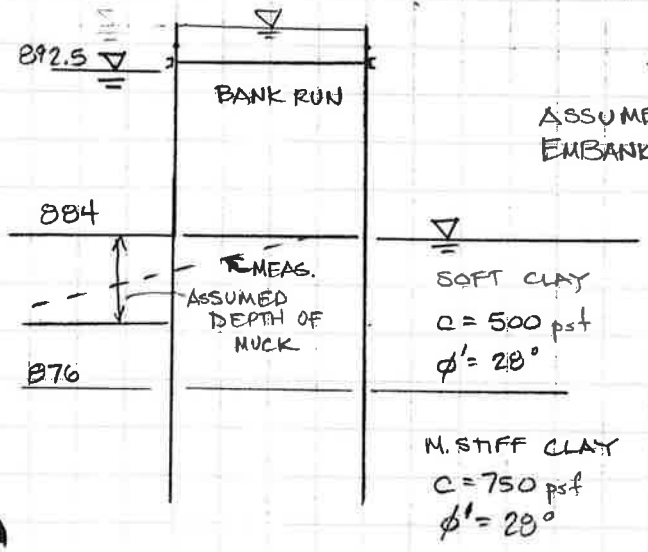
SUBJECT ODNR
Buckeye Lake
Double Sheet Pile Wall
Flooding Case

JOB NUMBER 0121-3074.00
SHEET NO. ____ OF ____
COMP. BY PAN DATE 3/1/02
CHECKED BY DAA DATE 7/19/02

SECTION 4



ASSUME EXISTING EMBANKMENT WASHED AWAY

Client: Ohio Department of Natural Resources

Title: Buckeye Lake Embankment Evaluation West Bank Section 1

Designer: PAN

Ref: 1

Page: 1

Date: 3.15.02

Sheet: Shoreline SZ-10

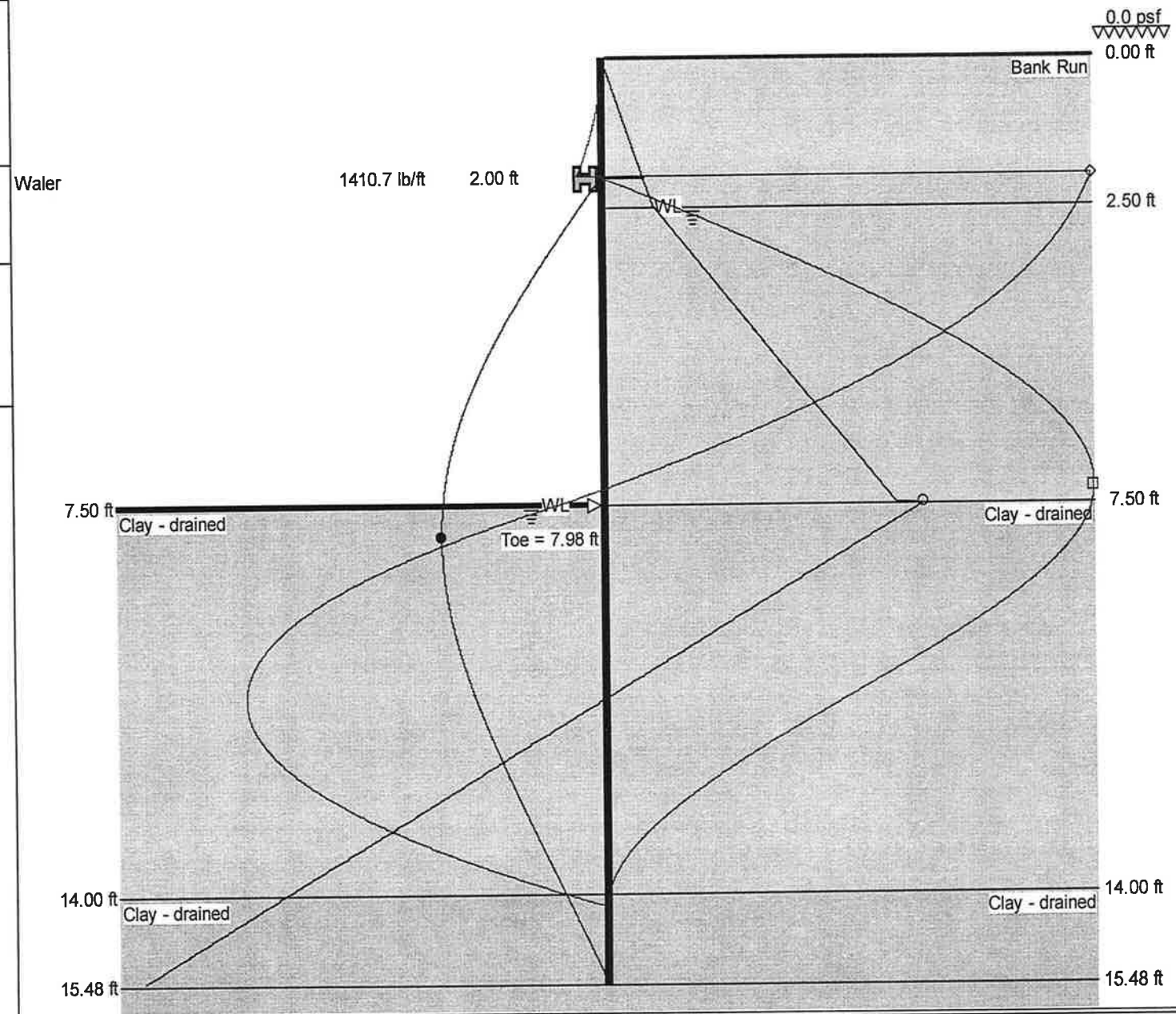
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

	Maximum	d (ft)
○	529.0 psf	7.50
□	4426.7 ftlb/ft	7.25
◇	1342.2 lb/ft	2.00
●	0.1 in	8.05

Double Sheet Pile Wall
Flooding Case
Drained Analysis



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Title: Buckeye Lake Embankment Evaluation West Bank Section 2

Designer: PAN

Ref: 1

Page: 1

Date: 3.15.02

Sheet: Shoreline SZ-10

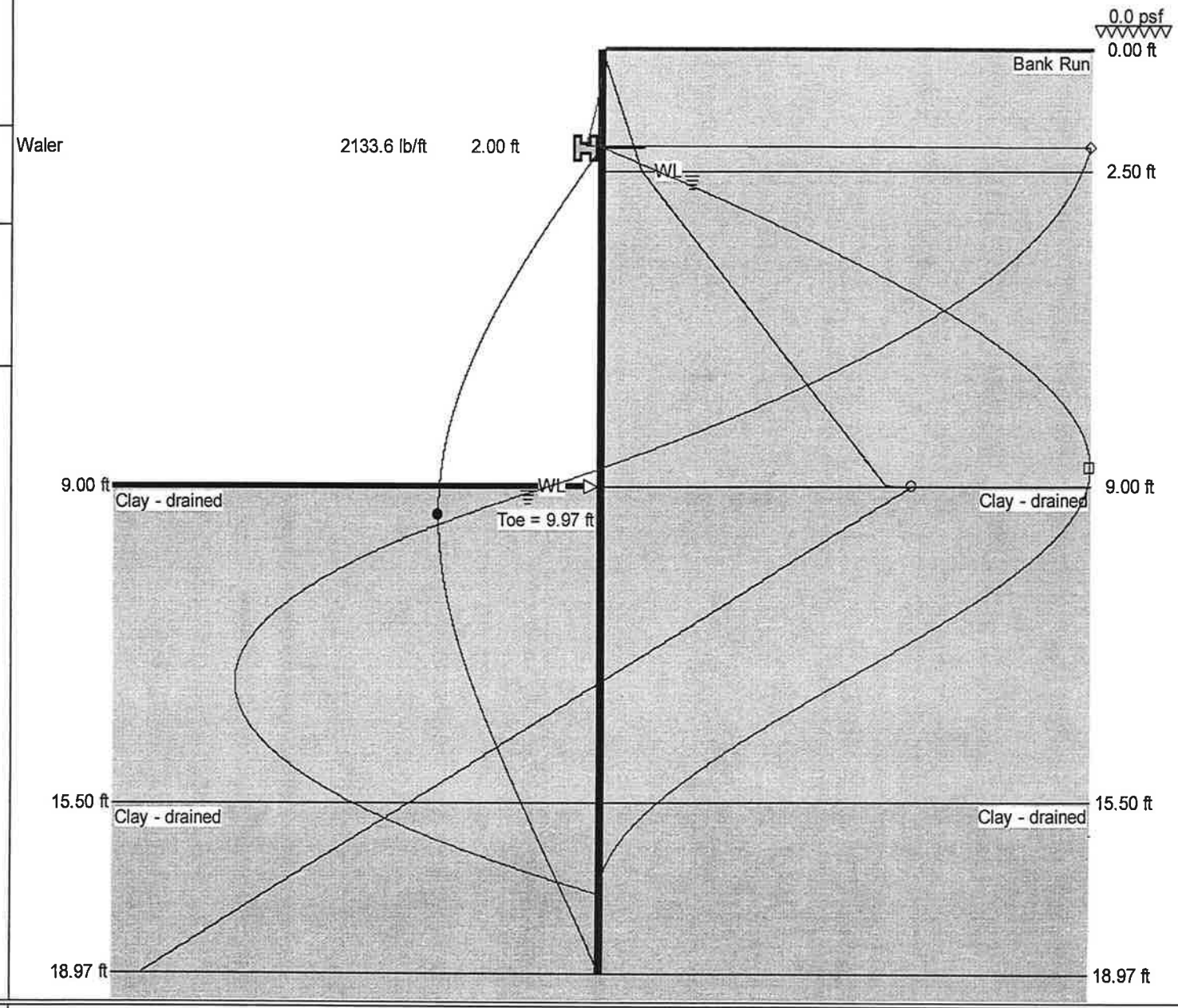
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

Maximum		d (ft)
○	655.9 psf	9.00
□	8751.8 ftlb/ft	8.63
◇	2065.3 lb/ft	2.00
●	0.5 in	9.61

Double Sheet Pile Wall
Flooding Case
Drained Analysis



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Client: ...io Department of Natural Resources

Title: Buckeye Lake Embankment Evaluation North Bank Section 3

Designer: PAN

Ref: 1

Page: 1

Date: 3.4.02

Sheet: Shoreline SZ-14.5

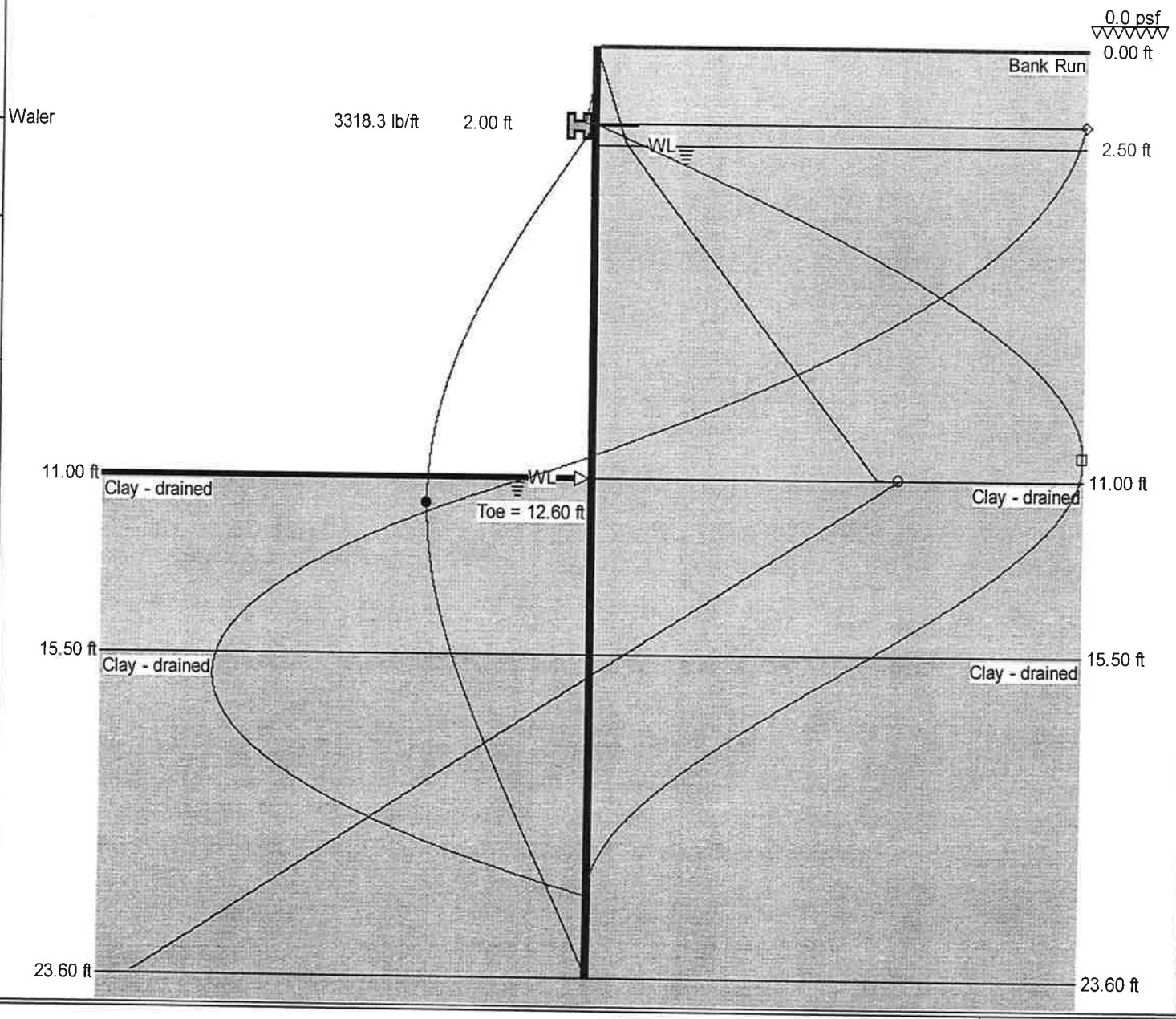
Pressure: Coulomb

FOS: 2.0

Toe: Free Earth Support

Maximum	d (ft)
○ 824.4 psf	11.03
□ 17749.2 ftlb/ft	10.46
◇ 3250.0 lb/ft	2.00
● 0.7 in	11.68

Double Sheet Pile Wall
Flooding Case
Drained Analysis



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Title: Buckeye Lake Embankment Evaluation North Bank Section 4

Designer: PAN

Ref: 1

Page: 1

Date: 3.4.02

Sheet: PZ22

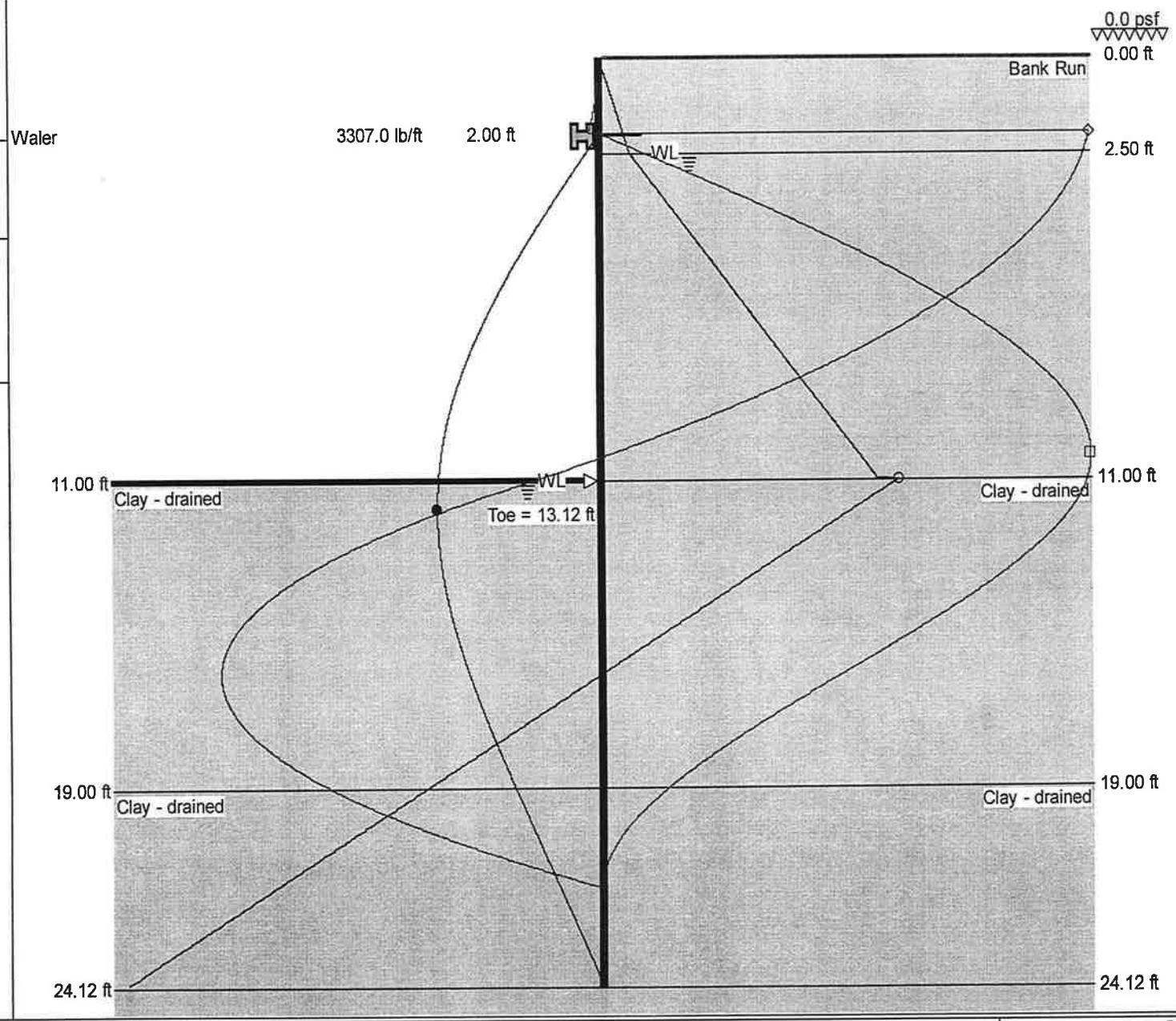
Pressure: Coulomb

FOS: 2.3

Toe: Free Earth Support

	Maximum	d (ft)
○	824.3 psf	11.03
□	17641.0 ftlb/ft	10.43
◇	3238.4 lb/ft	2.00
●	0.5 in	11.80

Double Sheet Pile Wall
Flooding Case
Drained Analysis



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Title: Buckeye Lake Embankment Evaluation North Bank Section 4

Designer: PAN

Ref: 1

Page: 1

Date: 3.4.02

Sheet: PZ22

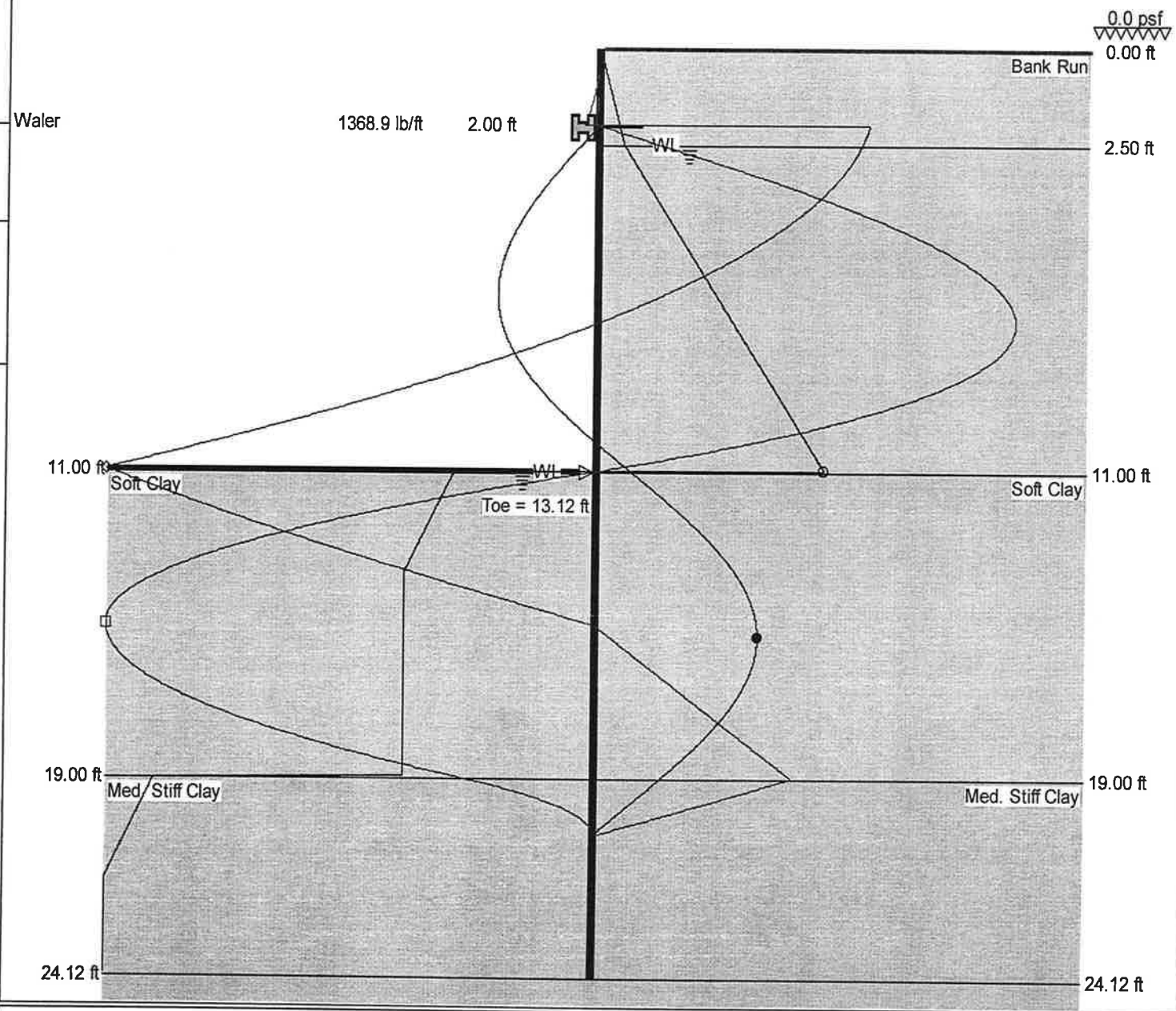
Pressure: Coulomb

FOS: 7.1

Toe: Fixed Earth Support

	Maximum	d (ft)
○	763.0 psf	11.00
□	4921.4 ftlb/ft	15.03
◇	2345.8 lb/ft	11.01
●	0.0 in	15.34

Double Sheet Pile Wall
Flooding Case
Undrained Analysis



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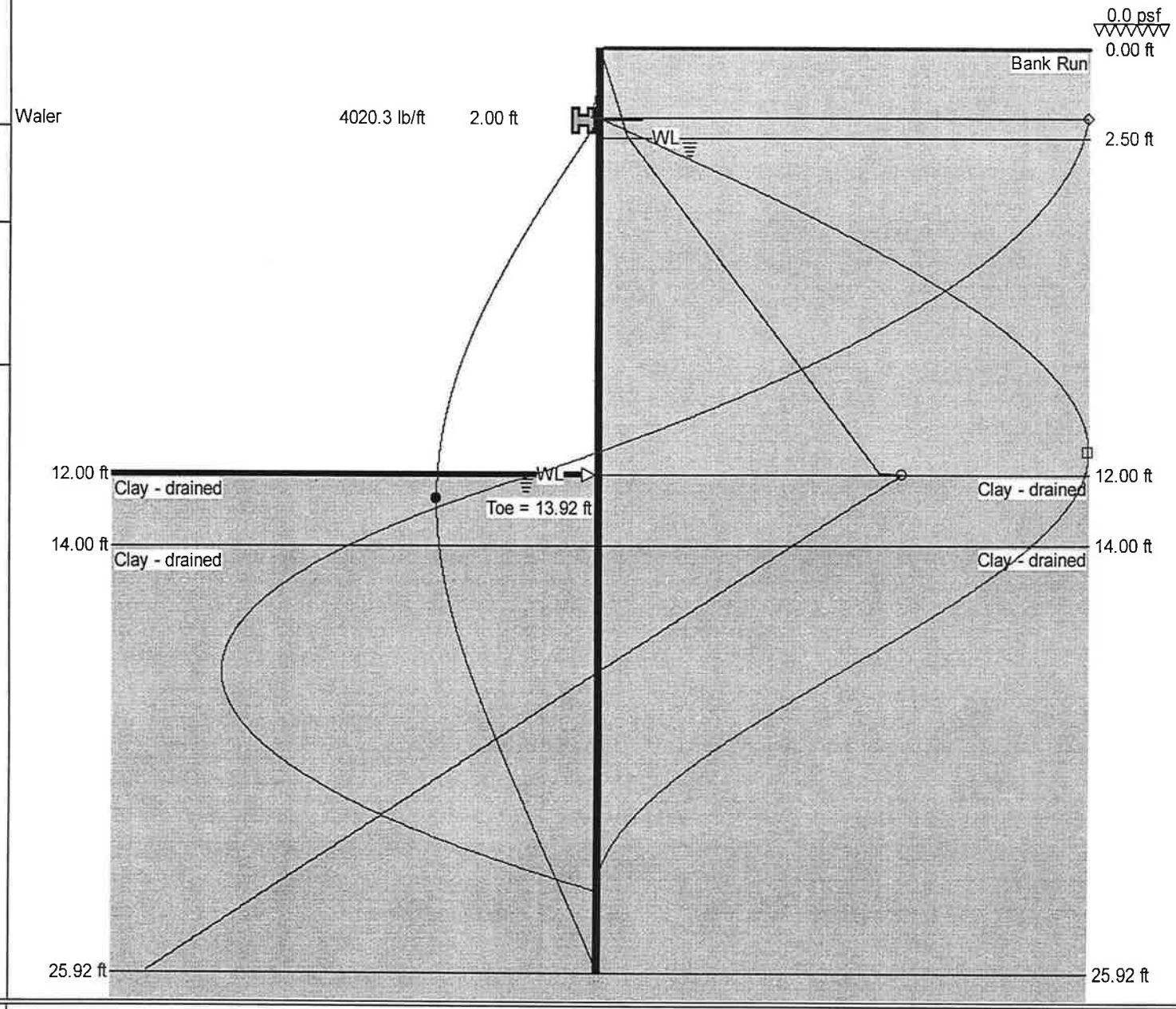
Client: Ohio Department of Natural Resources

Title: Buckeye Lake Embankment Evaluation North Bank Section 5
Designer: PAN
Ref: 1
Page: 1
Date: 3.15.02

Sheet: Shoreline SZ-14.5
Pressure: Coulomb
FOS: 2.0
Toe: Free Earth Support

	Maximum	d (ft)
○	909.5 psf	12.03
□	24014.2 ftlb/ft	11.38
◇	3951.7 lb/ft	2.00
●	1.1 in	12.72

Double Sheet Pile Wall
Flooding Case
Drained Analysis



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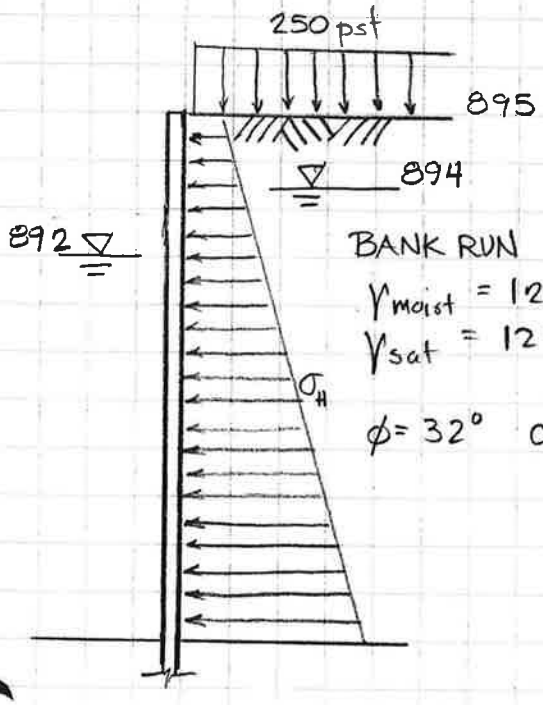
Concept Design
Post and Panel Wall

DLZ

SUBJECT ODNR
Buckeye Lake
Post & Panel Wall
Design Loads

JOB NUMBER 0121-3074.00
SHEET NO. ____ OF ____
COMP. BY PAN DATE 2/27/02
CHECKED BY DAA DATE 7/19/02



BANK RUN

$\gamma_{moist} = 120$ pcf

$\gamma_{sat} = 125$ pcf

$\phi = 32°$ $c = 0$

USE $K_a = 0.278$

AT 895 $\sigma_H = 0.278(250)$
$= 69.5$ psf

AT 894 $\sigma_H = 0.278(250 + 120 \times 1')$
$= 102.9$ psf

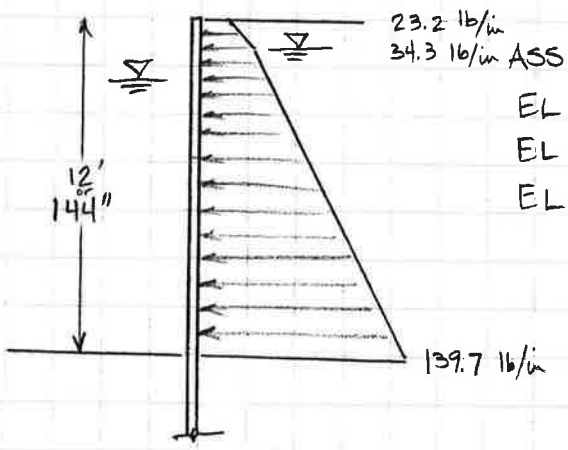
LOAD DUE TO SOIL AND WATER

SECTION 1, 887.5 $\sigma_H = 0.278(250 + 120 \times 1' + (125 - 62.4)(894 - 887.5))$
$+ 62.4$ pcf $\times 2'$
$= 340.8$ psf (113.6 lb/in)

SECTION 2, 886 $\sigma_H = 366.9$ psf (122.3 lb/in)

SECTION 3, 884 $\sigma_H = 401.7$ psf (133.9 lb/in)

SECTION 5, 883 $\sigma_H = 419.1$ psf ☆ DESIGN FOR SECTION 5



ASSUME 4 ft spacing

EL 895 $\sigma_H = 69.5 \frac{lb}{ft^2} \times 4' \times \frac{1 ft}{12 in} = 23.2$ lb/in

EL 894 $\sigma_H = 102.9 \times 4/12 = 34.3$ lb/in

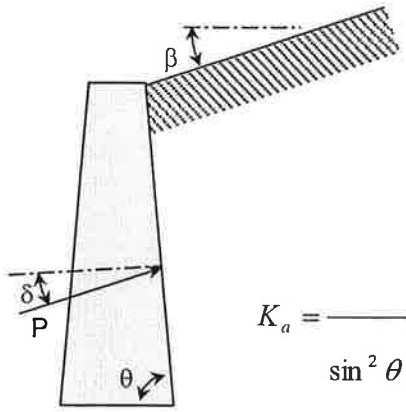
EL 883 $\sigma_H = 419.1 \times 4/12 = 139.7$ lb/in

SECTION 4 (ASSUME MUCK BEHIND WALL WILL BE REPLACED WITH BANK RUN) EL 879.5 $\sigma_H = 480$ psf (160 lb/in)

EARTH PRESSURE COEFFICIENTS

Ref: EM 1110-2-2502 (1989) Retaining and Floodwalls

with corrections based on Bowles, J.E. (1988) Foundation Analysis and Design, 4th ed.



Parameters

ϕ	=	32	deg.	internal friction angle of soil
δ	=	16	deg.	angle of wall friction
θ	=	90	deg.	angle of wall face from horizontal
β	=	0	deg.	angle of backfill slope from horizontal

$$K_a = \frac{\sin^2(\theta+\phi)}{\sin^2\theta \cdot \sin(\theta-\delta)\left[1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\beta)}{\sin(\theta-\delta)\sin(\theta+\beta)}}\right]^2}$$

$$K_p = \frac{\cos^2\phi}{\left[1-\sqrt{\frac{\sin\phi \cdot \sin(\phi+\beta)}{\cos\beta}}\right]^2}$$

K_a = 0.2782

K_p = 3.2546

Recommended values for angle of wall friction, δ

- from U.S. Army Corps of Engineers, EM 1110-2-2502 (1989), page 3-37 $\delta \leq \phi/2$
- from NAVFAC 7.2 (1986) Foundations & Earth Structures, page 7.2-63

Mass concrete on the following foundation materials:	
Clean sound rock	35
Clean gravel, gravel-sand mixtures, coarse sand	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	24 to 29
Clean fine sand, silty or clayey fine to medium sand	19 to 24
Fine sandy silt, nonplastic silt	17 to 19
Very stiff and hard residual or preconsolidated clay	22 to 26
Medium stiff and stiff clay and silty clay	17 to 19
(Masonry on foundation materials has same friction factors)	
Steel sheet piles against the following soils:	
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls	22
Clean sand, silty sand-gravel mixture, single size hard rock fill	17
Silty sand, gravel or sand mixed with silt or clay	14
Fine sandy silt, nonplastic silt	11
Formed concrete or concrete sheet piling against the following soils:	
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill	17 to 22
Silty sand, gravel or sand mixed with silt or clay	17
Fine sandy silt, nonplastic silt	14

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SUBJECT ODNR
BUCKEYE LAKE
POST & PANEL WALL
SOIL PROPERTIES

JOB NUMBER 0121-3074.00
SHEET NO. ____ OF ____
COMP. BY PAN DATE 2/28/02
CHECKED BY DAA DATE 7/19/02

SOIL PROPERTIES FOR LPILE (FOUNDATION SOILS)

SOFT CLAY

$\gamma_{sub} = (130 - 62.4)/12^3 = 0.0391 \ lb/in^3$

$C = 500 \ psf / 144 = 3.47 \ lb/in^2$

$\varepsilon_{50} = 0.02$

M. STIFF CLAY

$\gamma_{sub} = 0.0391 \ lb/in^3$

$C = 750 \ psf / 144 = 5.21 \ lb/in^2$

$\varepsilon_{50} = 0.010$

$k = 100 \ pci$

VERY STIFF CLAY

$\gamma_{sub} = 0.0391 \ lb/in^3$

$C = 2000 \ psf / 144 = 13.9 \ lb/in^2$

$k = 500 \ pci$

$\varepsilon_{50} = 0.007$

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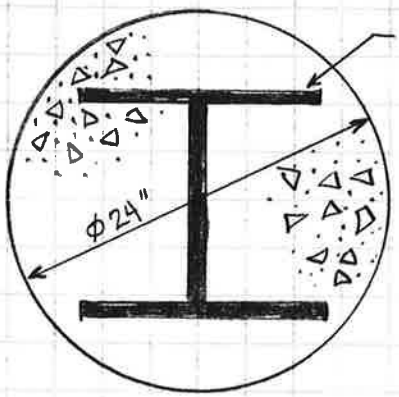
SUBJECT ODNR
Buckeye Lake
POST & PANEL WALL
POST DESIGN

JOB NUMBER 0121-3074.00
SHEET NO. ____ OF ____
COMP. BY PAN DATE 2/28/02
CHECKED BY DAA DATE 7/19/02



HP 14×117 : $b = 14.9''$ $I = 1220\ in^4$
$A = 34.4\ in^2$ $S = 172\ in^3$
$E_{STEEL} = 29 \times 10^6$ psi

DRILLED SHAFT DIA = 24"
$A = \pi/4\, D^2 = 452\ in^2$
$I = \pi/64\, D^4 = 16{,}290\ in^4$
$E_{CONC} = 3 \times 10^6$ psi

FOR APPROX. DEFLECTION CALCS, USE
$EI = 3 \times 10^6$ psi $\times$ 16,290 in^4 FOR COMPOSITE SECTION
(RECOMMENDED BY J. NG, STRUCT. ENG., DLZ)

SPACE POSTS AT 4 ft C-C.

DLZ

SUBJECT ODNR
Buckeye Lake
POST & PANEL WALL
P-Y modification factor

JOB NUMBER 0121-3074.00
SHEET NO. ____ OF ____
COMP. BY PAN DATE 2/28/02
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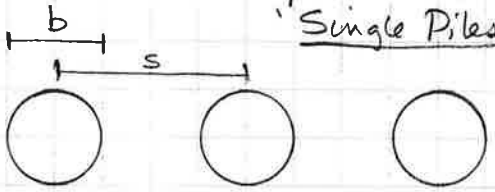
P-y modification factors for pile groups
ref: Reese, L.C. and Van Impe, W.F. (2001)
'Single Piles and Pile Groups under Lateral Loading



$$e = 0.64\left(\frac{s}{b}\right)^{0.34} \quad \text{for } 1 \le \frac{s}{b} \le 3.75 \qquad \text{(eq 5.39)}$$

for $s = 4$ ft & $b = 2$ ft

$$e = 0.64\left(\frac{4}{2}\right)^{0.34} = 0.81$$

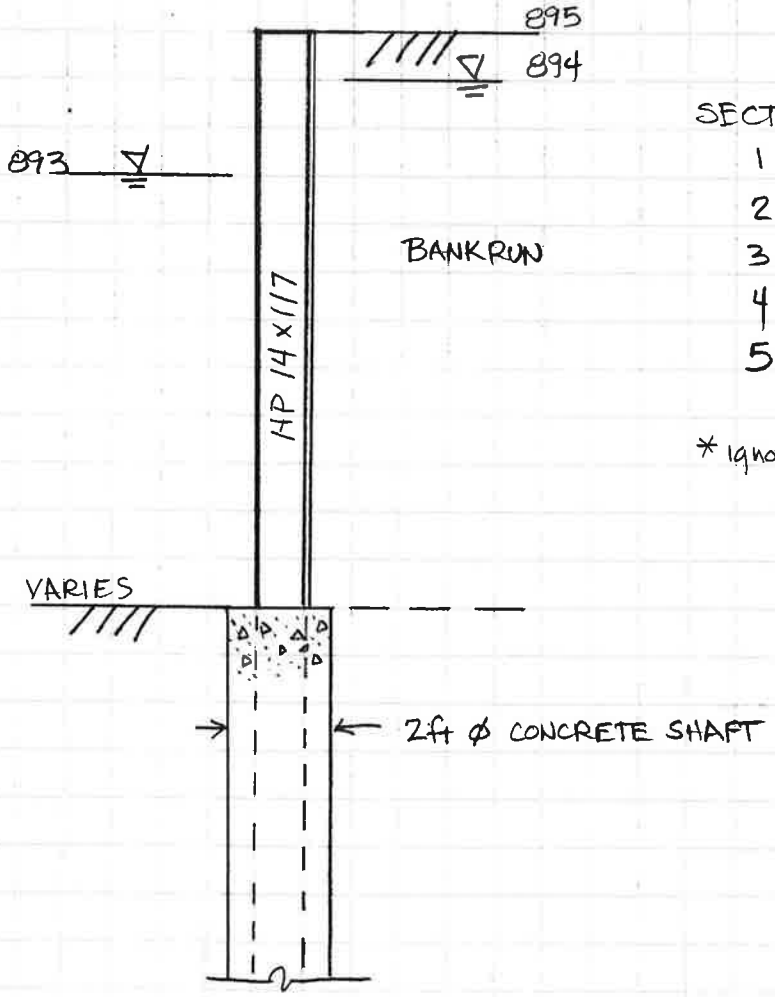
each pile is influenced by piles on either side, so

$$e_{TOTAL} = (0.81)(0.81) = 0.656$$

DLZ

SUBJECT: ODNR
Buckeye Lake
Post & Panel Wall
Calculated Deflections

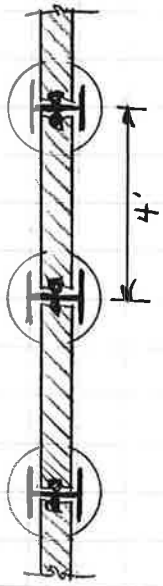
JOB NUMBER: 0121-3074.00
SHEET NO. ____ OF ____
COMP. BY: PAN DATE: 3/1/02
CHECKED BY: DAA DATE: 7/19/02



SECTION	HEIGHT OF WALL	LENGTH OF PILE	DEFLECTION
1	7.5'	25'	0.23"
2	9'	30'	0.39"
3	11'	30'	0.52"
4	15.5' *	40'	2.0"
5	12'	35'	0.72"

* ignores muck

PLAN VIEW



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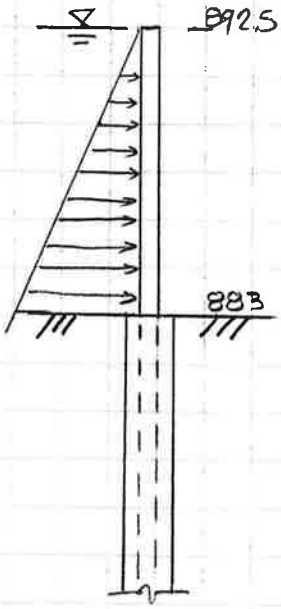
SUBJECT ODNR
Buckeye Lake
Post & Panel Wall
Flood Case

JOB NUMBER 0121-3074.00
SHEET NO. ____ OF ____
COMP. BY PAN DATE 3/1/02
CHECKED BY DAA DATE 7/19/02



CONSIDER SECTION 5, LAKE AT 892.5' AND NO EMBANKMENT OR WATER ON DOWNSTREAM SIDE (FLOODING)

σ_{hw} at 883 = $62.4 \times (892.5 - 883) = 592.8$ psf

$592.8 \text{ psf} \times 4'/12 \text{ in/ft} = 197.6 \text{ lb/in}$
spacing

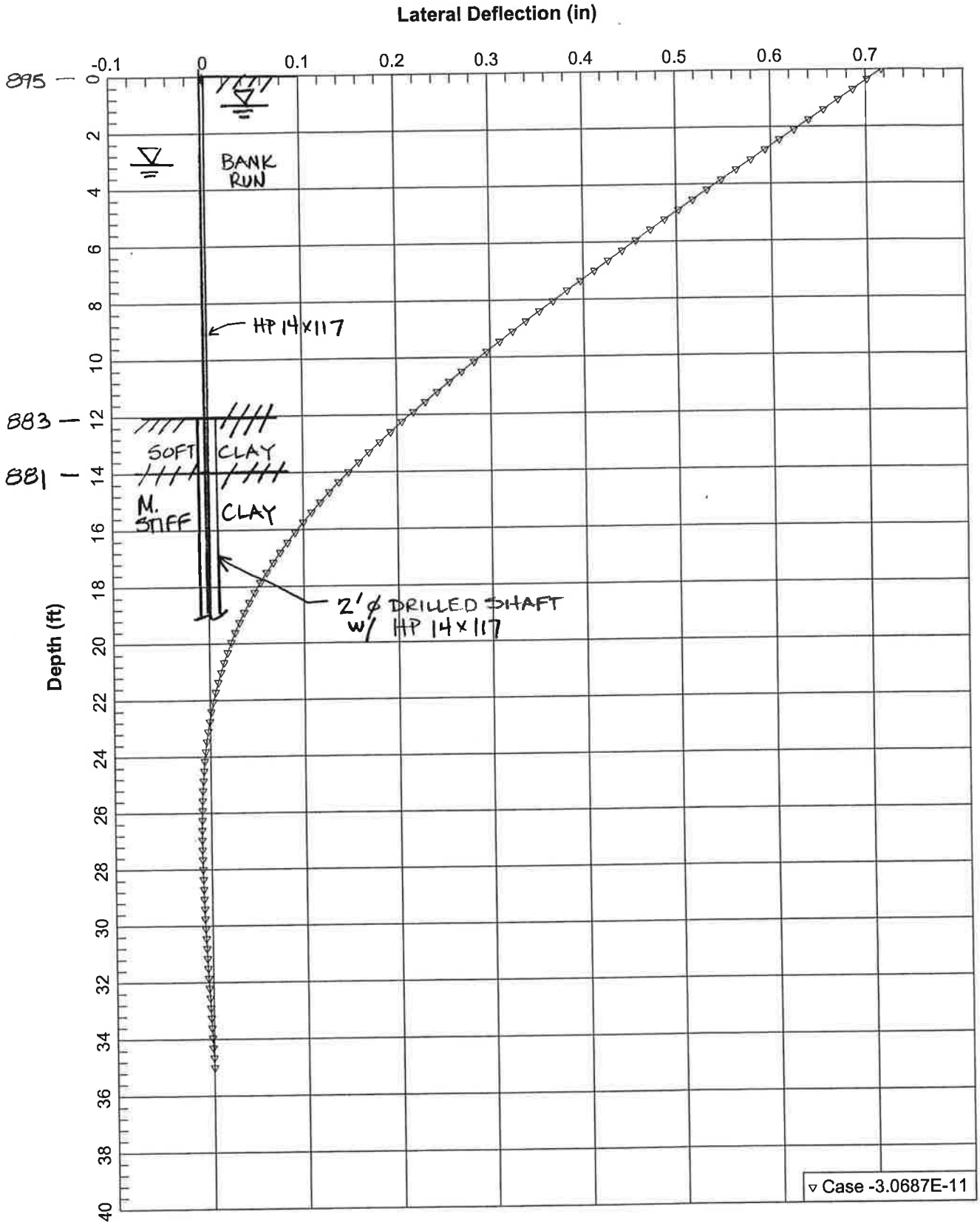
$\Delta = \underline{0.54''}$

$M_{MAX} = 869$ in-kips (in composite section, but check w/ steel only)

$f_b = \frac{M}{S}$ $S = 172 \text{ in}^3$ $F_b = 0.6F_y = 0.6(36) = 21.6$ ksi

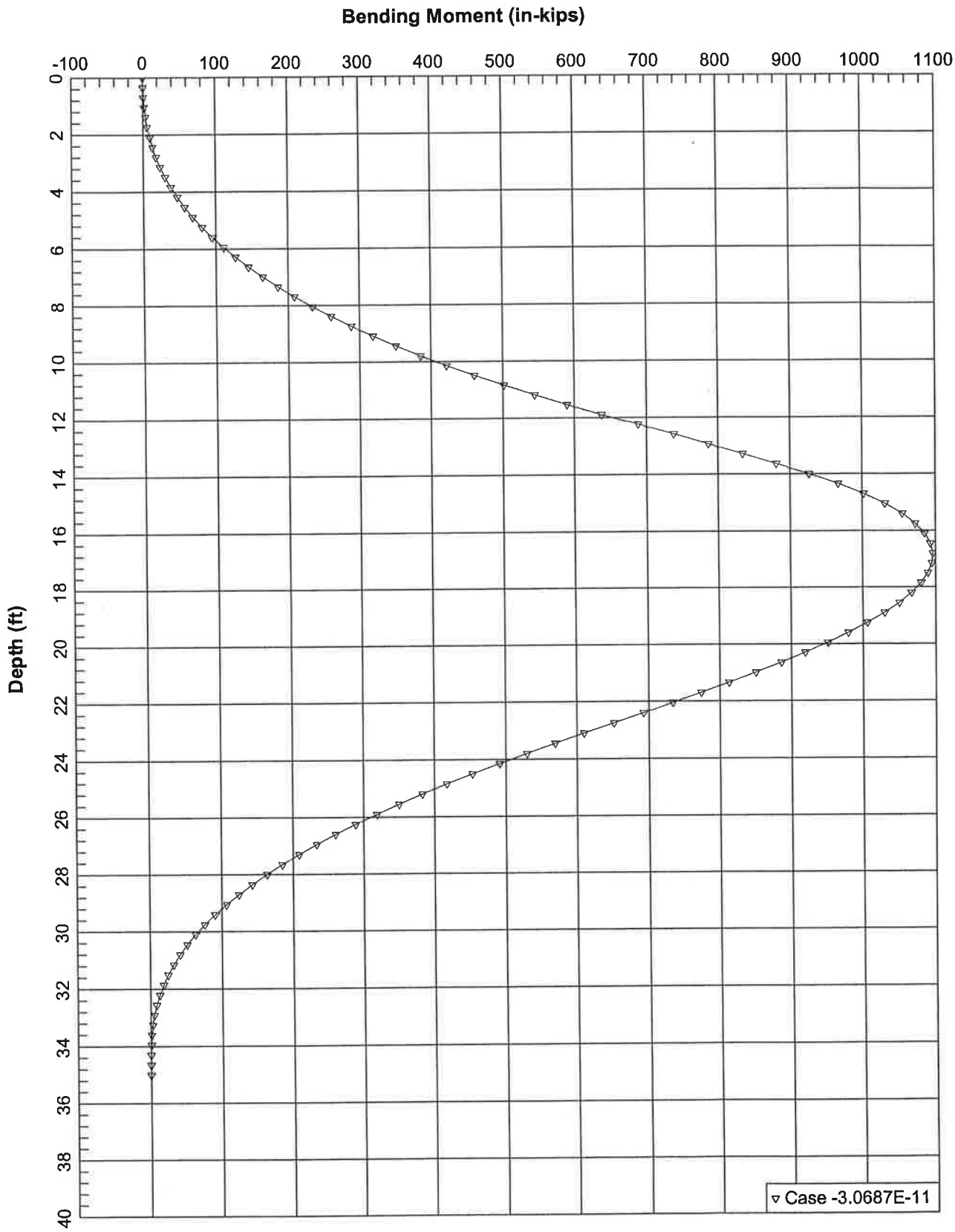
$f_b = \frac{869}{172} = 5.1$ ksi

$f_b < F_b$ OK



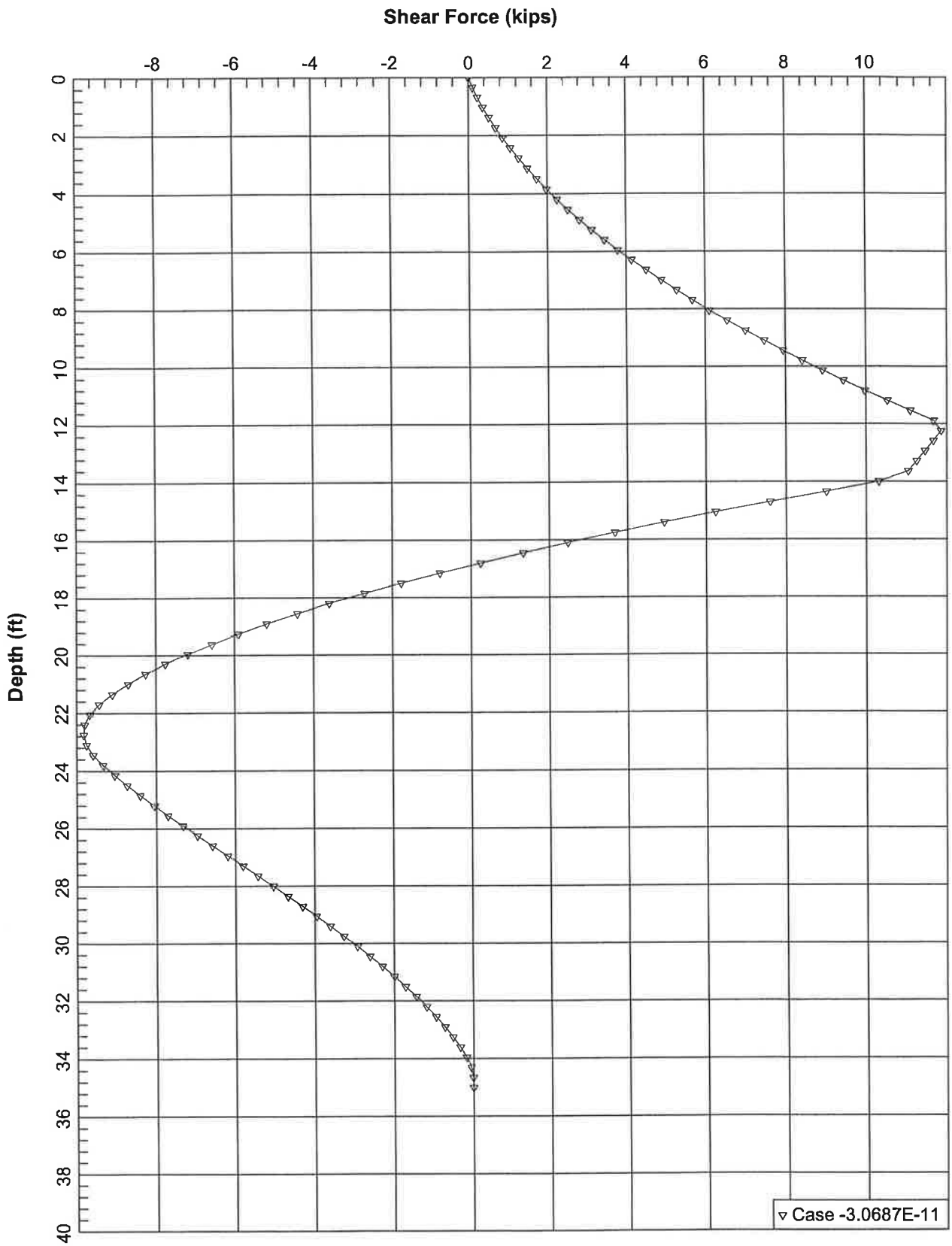
Buckeye Lake - Post and Panel Wall - HP14x117 with 2 ft dia. concrete shaft

SECTION 5



Buckeye Lake - Post and Panel Wall - HP14x117 with 2 ft dia. concrete shaft

SECTION 5



Buckeye Lake - Post and Panel Wall - HP14x117 with 2 ft dia. concrete shaft

SECTION 5

DLZ

CLIENT ODNR
PROJECT Buckeye lake
SUBJECT Inverted T-wall Preliminary Design

PROJECT NO. 0121-3074-06
SHEET NO. 5 OF 7
COMP. BY FAM DATE 3-3-02
CHECKED BY JAM DATE 4/18/02

$\circlearrowleft + \Sigma M_A = 0 = (9)(W_1) + (4.5)(W_2) - (4.5)(U_1) - (3.167)(H_1) - (9)(R_B)$

$-(9)(2.7k) + (4.5)(5.9) - (4.5)(7.7k) - (3.167)(2.8k) - 9R_B$

$\Rightarrow R_B = 0.8\ K$

$+\uparrow \Sigma F_V = 0 = R_A + R_B + U_1 - W_1 - W_2$

$R_A + 0.8 + 7.7 - 2.7 - 5.9$

$\Rightarrow R_A = 0.1\ K$

$\rightarrow \Sigma F_H = 0 = -2.8\ K$ (Piles will have to carry a lateral load)
(Pile @ "A" will carry the lateral load)

- Max. vertical load to be carried by a pile is during the normal operating conditions and is 9.6 Kips. Assume 12" ϕ, 50 ton allowable capacity steel pipe piles;

$(50\ \text{tons})(2000\ \text{lbs/ton})/(9.6\ \text{Kips/ft}) = 10.4\ \text{ft}$

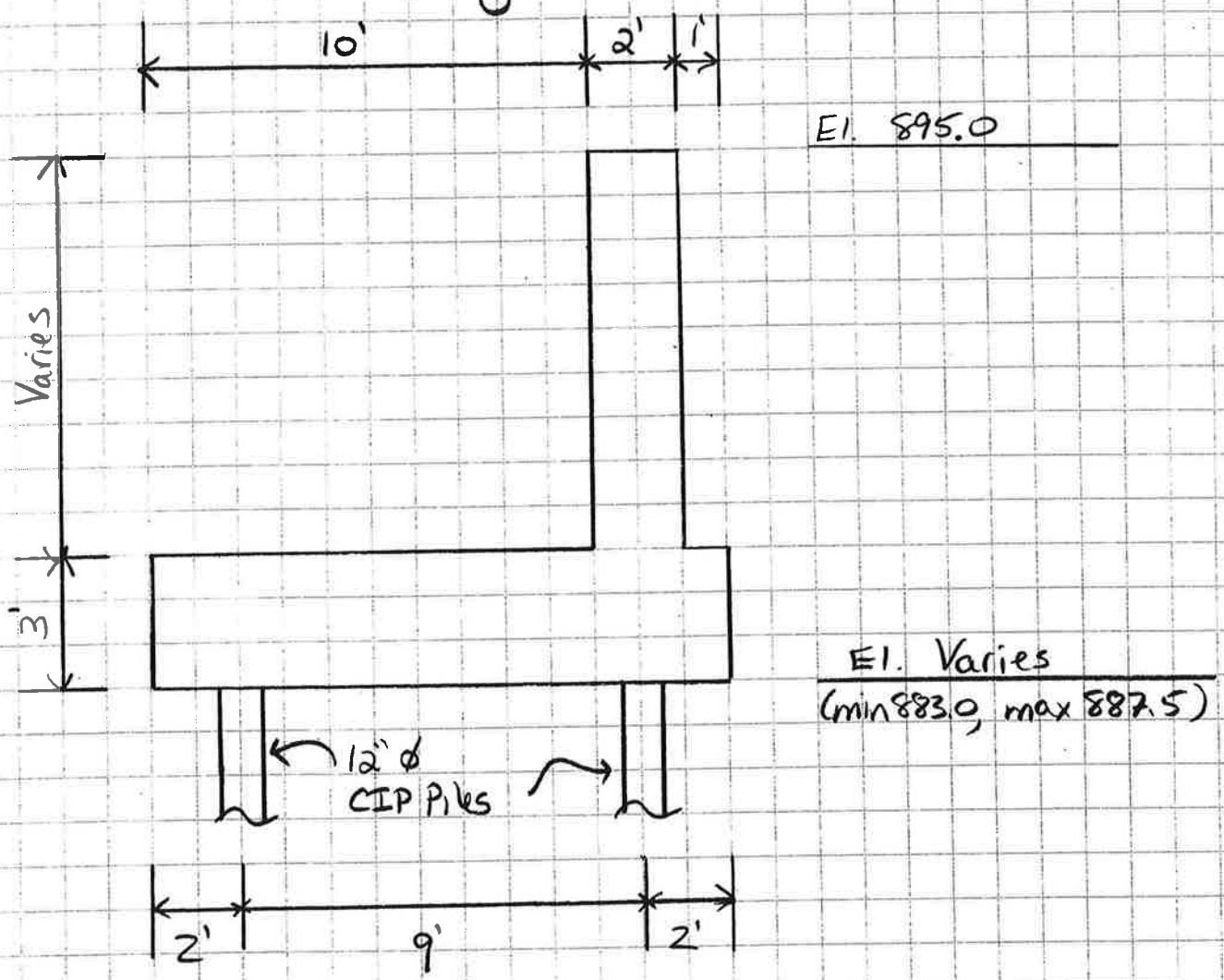
- Therefore, place piles @ 10' c/c spacing.

DLZ

CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Inverted T-Wall Preliminary Design

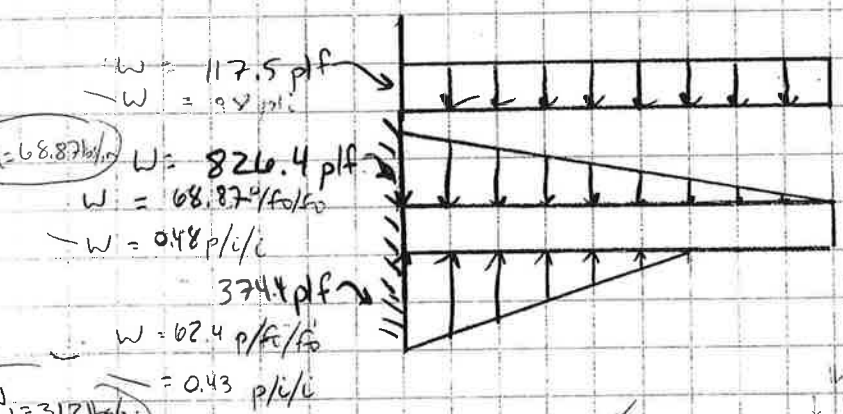
PROJECT NO. 0121-3074-00
SHEET NO. 6 OF 7
COMP. BY TAA DATE 3-7-02
CHECKED BY J+M DATE 4/18/02

Final T-Wall Preliminary Cross Section (w/ 3' Thick footing)



- Now Estimate maximum deflection at top of wall

- Normal Conditions $E_{concrete} = 57{,}000\sqrt{f'_c} = 57000\sqrt{4000} = 3.6\times10^6$ psi



① Surcharge

② Retained Soil

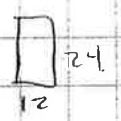
③ Water load (a = 3')

lbs/in/in

$$\Delta_{total} = \Delta_1 + \Delta_2 - \Delta_3 = \frac{Wl^4}{8EI} + \frac{Wl^4}{30EI} - \frac{W}{120EI}(l-a)^3(4l+a)$$

$$I = \frac{bd^3}{12} = \frac{(12")(24")^3}{12}$$

$$= 13824\ in^4$$



0.0033"

0.063

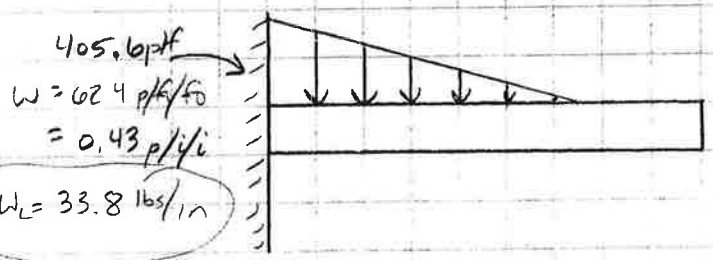
$$= \frac{(9.79\ lbs/in)(108")^4}{8(3.6\times10^6 psi)(13824\ in^4)} + \frac{(68.87\ lbs/in)(108")^4}{30(3.6\times10^6 psi)(13824\ in^4)}$$

$$- \frac{(31.2\ lbs/in)(108"-36")^3(432"+36")}{120(3.6\times10^6 psi)(13824\ in^4)}$$

0.0091"

$$\boxed{= .009\ in \quad \text{(Towards lake)}}$$

Now consider "after flood" conditions



① Water load (a = 2.5')

$$\Delta_{total} = \Delta_1 = \frac{W}{120EI}(l-a)^3(4l+a) = \frac{(33.8\ lbs/in)(108"-30")^3(432"+30")}{120(3.6\times10^6 psi)(13824\ in^4)}$$

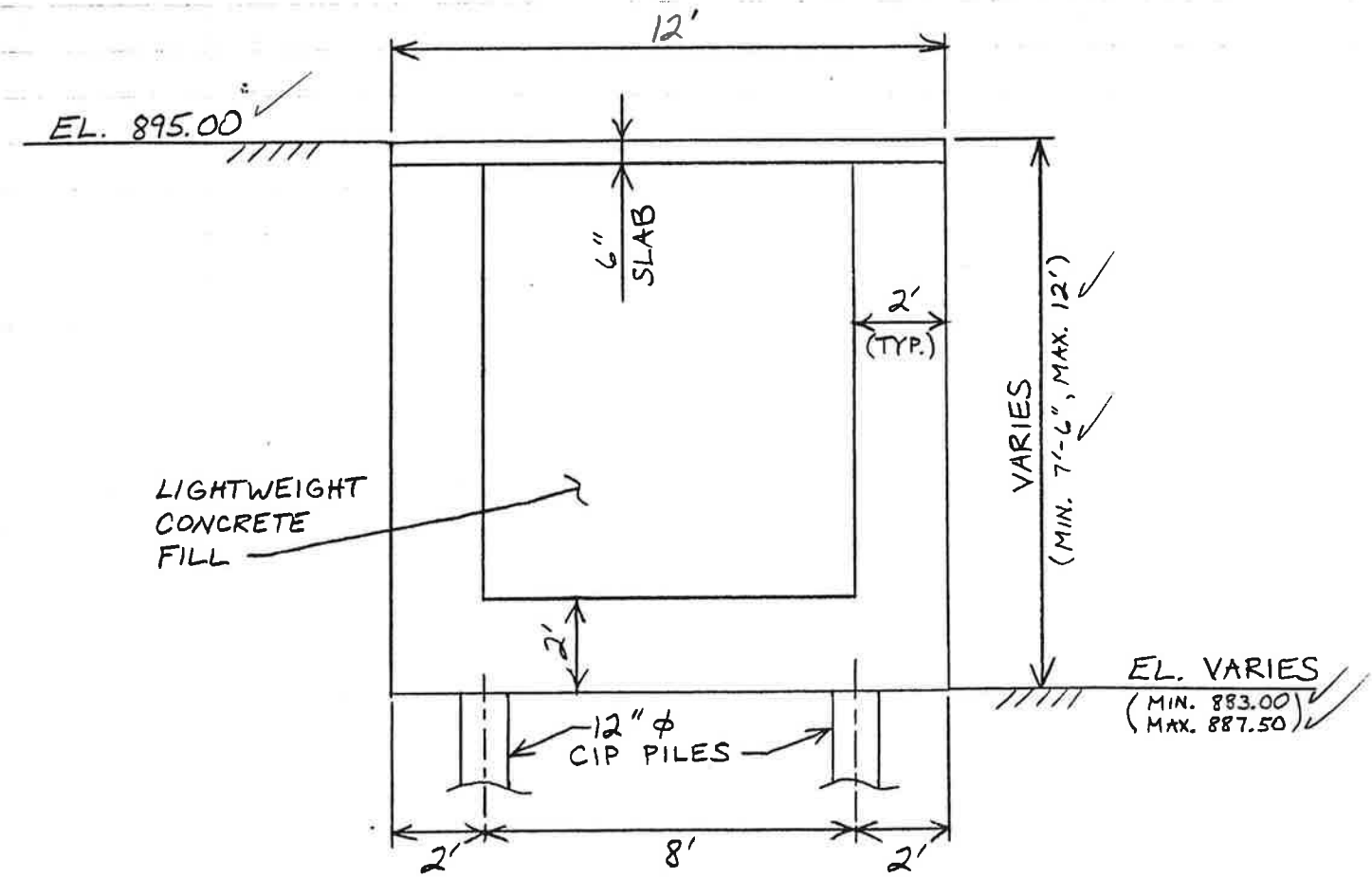
$$\boxed{= 0.001" \quad \text{(Towards land)}}$$

Concept Design – Concrete Box

DLZ

CLIENT OHIO DEPT. OF NATURAL RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT CONCRETE BOX
REVISED PRELIMINARY DESIGN

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMP. BY JAM DATE 3/12/02
CHECKED BY HAM DATE 4-19-02

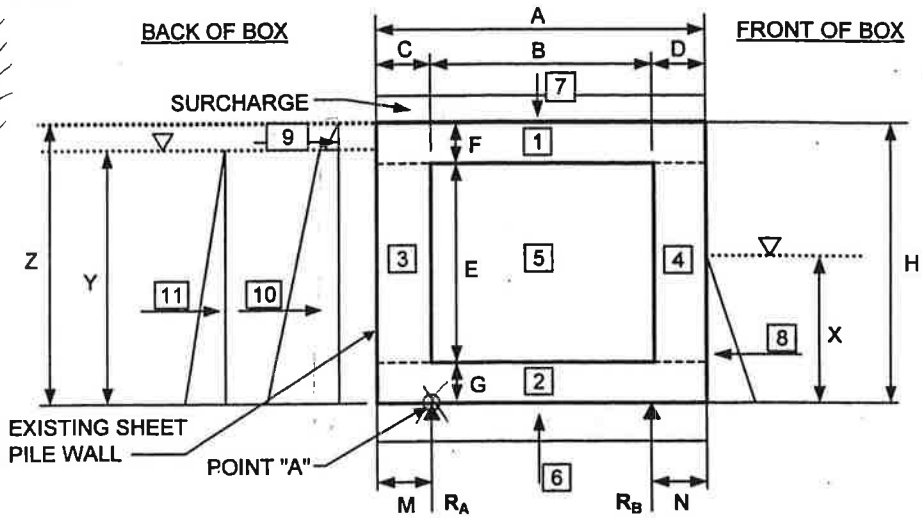


DLZ

CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00
PROJECT	BUCKEYE LAKE	SHEET NO.	1 OF 1
SUBJECT	CONCRETE BOX DESIGN (MAX. HEIGHT DESIGN)	COMPUTED BY	JAM DATE 3/12/02
		CHECKED BY	TAN DATE 4-19-02

BOTTOM OF BOX EL. =	883.00	FT
GROUND EL. (FRONT) =	883.00	FT
GROUND EL. (BACK) =	895.00	FT
WATER EL. (FRONT) =	892.00	FT
WATER EL. (BACK) =	894.00	FT

A =	12.00	FT
B =	8.00	FT
C =	2.00	FT
D =	2.00	FT
E =	9.50	FT
F =	0.50	FT
G =	2.00	FT
H =	12.00	FT
M =	2.00	FT
N =	2.00	FT
X =	9.00	FT
Y =	11.00	FT
Z =	12.00	FT



DRAWING IS NOT TO SCALE

ϕ = ANGLE OF INTERNAL FRICTION = 32.00 °

K_O = AT REST EARTH PRESSURE COEFFICIENT = 1 - SIN ϕ = 0.470

NOTES:
** ABOUT POINT "A" (CCW = "+")*
*** TAKEN 1 FT INTO PAGE*

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	HEIGHT (FT)	WIDTH (FT)	WT/AREA (KSF)**	WEIGHT (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
1	CONCRETE	-	0.50	12.00	0.150	-0.900	-	4.00	-3.600
2	CONCRETE	-	2.00	12.00	0.150	-3.600	-	4.00	-14.400
3	CONCRETE	-	9.50	2.00	0.150	-2.850	+	1.00	2.850
4	CONCRETE	-	9.50	2.00	0.150	-2.850	-	9.00	-25.650
5	LIGHTWT. CONC	-	9.50	8.00	0.120	-9.120	-	4.00	-36.480
6	WATER (UPLIFT)	+	0.56	12.00	0.062	6.739	+	4.00	26.957
7	SURCHARGE	-	N/A	12.00	0.250	-3.000	-	4.00	-12.000
					ΣW =	-15.581		M_R =	-62.323

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	WT/AREA (KSF)**	HEIGHT (FT)	AVG. LAT. LD. (KIP/FT)	TOTAL LAT. LD. (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
8	WATER, OT (FRNT.)	-	0.062	9.00	0.28	-2.527	+	3.00	7.582
9	SOIL (MOIST), OT	+	0.120	1.00	0.03	0.028	-	11.33	-0.320
10	SOIL (BOUY.), OT	+	0.063	11.00	0.22	2.401	-	3.67	-8.803
11	WATER, OT (BACK)	+	0.062	11.00	0.34	3.775	-	3.67	-13.842
			$\Sigma H = \Sigma$(TOTAL LATERAL LOAD) =			3.677		M_{OT} =	-15.384
								$\Sigma M = M_R + M_{OT}$ =	-77.707 KIP-FT

PILE REACTIONS

$\Sigma M_A = 0$: $R_B = -\Sigma M/(A-(M+N))$ = **9.71** KIP

$\Sigma F_V = 0$: $R_A = -\Sigma W - R_B$ = **5.87** KIP

PILE SPACING

d_P = PILE DIAMETER = 1.00 FT

P_A = ALLOWABLE PILE AXIAL LOAD = 50.00 TONS *(COMPRESSION)*

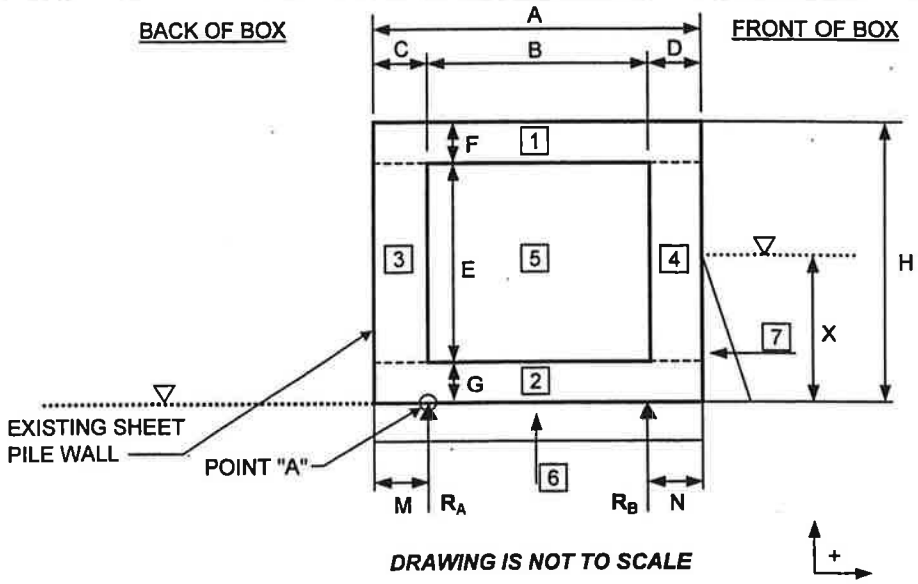
S_{MAX} = MAX. PILE SPACING = $((P_A)*(2\ KIPS/TON))/(MAX(|R_A|, |R_B|))$ 10.30 FT

S = SELECTED PILE SPACING = 10.00 FT (O.K.)

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00		
	PROJECT	BUCKEYE LAKE	SHEET NO.	1	OF	1
	SUBJECT	CONCRETE BOX DESIGN	COMPUTED BY	JAM	DATE	3/12/02
		(MAX. HEIGHT W/O BACKFILL DESIGN)	CHECKED BY	TAW	DATE	4-9-02

BOTTOM OF BOX EL. =	883.00	FT
GROUND EL. (FRONT) =	883.00	FT
GROUND EL. (BACK) =	883.00	FT
WATER EL. (FRONT) =	892.50	FT
WATER EL. (BACK) =	883.00	FT

A =	12.00	FT
B =	8.00	FT
C =	2.00	FT
D =	2.00	FT
E =	9.50	FT
F =	0.50	FT
G =	2.00	FT
H =	12.00	FT
M =	2.00	FT
N =	2.00	FT
X =	9.50	FT



DRAWING IS NOT TO SCALE

ϕ = ANGLE OF INTERNAL FRICTION = 32.00 °

K_O = AT REST EARTH PRESSURE COEFFICIENT = 1 - SIN ϕ = 0.470

NOTES:
** ABOUT POINT "A" (CCW = "+")*
*** TAKEN 1 FT INTO PAGE*

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	HEIGHT (FT)	WIDTH (FT)	WT/AREA (KSF)**	WEIGHT (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
1	CONCRETE	-	0.50	12.00	0.150	-0.900	-	4.00	-3.600
2	CONCRETE	-	2.00	12.00	0.150	-3.600	-	4.00	-14.400
3	CONCRETE	-	9.50	2.00	0.150	-2.850	+	1.00	2.850
4	CONCRETE	-	9.50	2.00	0.150	-2.850	-	9.00	-25.650
5	LIGHTWT. CONC.	-	9.50	8.00	0.120	-9.120	-	4.00	-36.480
6	WATER (UPLIFT)	+	0.59	12.00	0.062	7.114	+	4.00	28.454
					ΣW =	-12.206		M_R =	-48.826

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	WT/AREA (KSF)**	HEIGHT (FT)	AVG. LAT. LD. (KIP/FT)	TOTAL LAT. LD. (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
7	WATER, OT (FRNT.)	-	0.062	9.50	0.30	-2.816	+	3.17	8.917
			ΣH = Σ(TOTAL LATERAL LOAD) =			-2.816		M_{OT} =	8.917

$\Sigma M = M_R + M_{OT}$ = -39.909 KIP-FT

PILE REACTIONS

$\Sigma M_A = 0$: $R_B = -\Sigma M/(A-(M+N))$ = 4.99 KIP

$\Sigma F_V = 0$: $R_A = -\Sigma W - R_B$ = 7.22 KIP

PILE SPACING

d_P = PILE DIAMETER = 1.00 FT

P_A = ALLOWABLE PILE AXIAL LOAD = 50.00 TONS (COMPRESSION)

S_{MAX} = MAX. PILE SPACING = $((P_A)*(2\ KIPS/TON))/(MAX(|R_A|, |R_B|))$ 13.85 FT

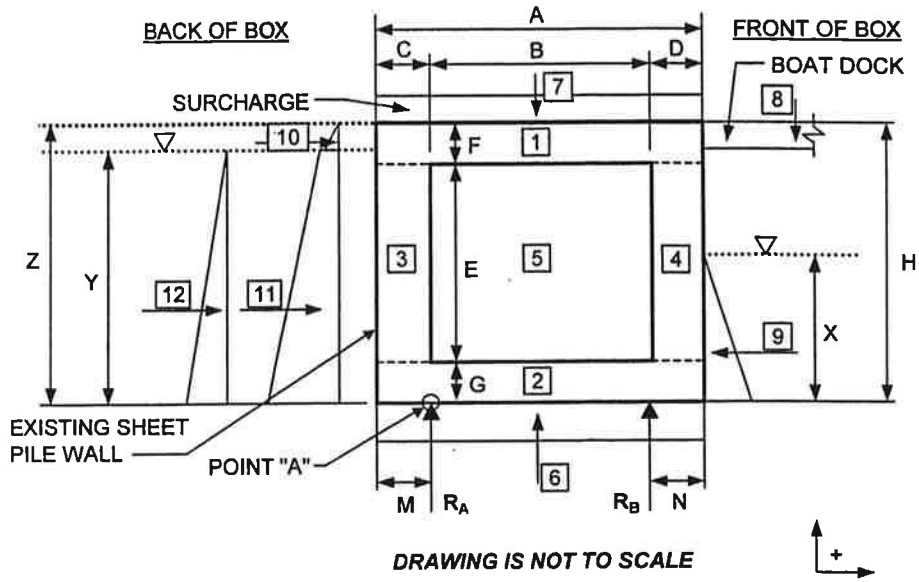
S = SELECTED PILE SPACING = 10.00 FT (O.K.)

DLZ

CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00
PROJECT	BUCKEYE LAKE	SHEET NO.	1 OF 1
SUBJECT	CONCRETE BOX DESIGN (MAX. HEIGHT W/ BOAT DOCK DESIGN)	COMPUTED BY	JAM DATE 3/12/02
		CHECKED BY	TAA DATE 4-18-02

BOTTOM OF BOX EL. =	883.00	FT
GROUND EL. (FRONT) =	883.00	FT
GROUND EL. (BACK) =	895.00	FT
WATER EL. (FRONT) =	892.00	FT
WATER EL. (BACK) =	894.00	FT

A =	12.00	FT
B =	8.00	FT
C =	2.00	FT
D =	2.00	FT
E =	9.50	FT
F =	0.50	FT
G =	2.00	FT
H =	12.00	FT
M =	2.00	FT
N =	2.00	FT
X =	9.00	FT
Y =	11.00	FT
Z =	12.00	FT



DRAWING IS NOT TO SCALE

ϕ = ANGLE OF INTERNAL FRICTION = 32.00 °

K_O = AT REST EARTH PRESSURE COEFFICIENT = 1 - SIN ϕ = 0.470

NOTES:
** ABOUT POINT "A" (CCW = "+")*
*** TAKEN 1 FT INTO PAGE*

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	HEIGHT (FT)	WIDTH (FT)	WT/AREA (KSF)**	WEIGHT (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
1	CONCRETE	-	0.50	12.00	0.150	-0.900	-	4.00	-3.600
2	CONCRETE	-	2.00	12.00	0.150	-3.600	-	4.00	-14.400
3	CONCRETE	-	9.50	2.00	0.150	-2.850	+	1.00	2.850
4	CONCRETE	-	9.50	2.00	0.150	-2.850	-	9.00	-25.650
5	LIGHTWT. CONC.	-	9.50	8.00	0.120	-9.120	-	4.00	-36.480
6	WATER (UPLIFT)	+	0.56	12.00	0.062	6.739	+	4.00	26.957
7	SURCHARGE	-	N/A	12.00	0.250	-3.000	-	4.00	-12.000
8	BOAT DOCK	-	N/A	N/A	N/A	-6.472	-	22.00	-142.384
					ΣW =	-22.053		M_R =	-204.707

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	WT/AREA (KSF)**	HEIGHT (FT)	AVG. LAT. LD. (KIP/FT)	TOTAL LAT. LD. (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
9	WATER, OT (FRNT.)	-	0.062	9.00	0.28	-2.527	+	3.00	7.582
10	SOIL (MOIST), OT	+	0.120	1.00	0.03	0.028	-	11.33	-0.320
11	SOIL (BOUY.), OT	+	0.063	11.00	0.22	2.401	-	3.67	-8.803
12	WATER, OT (BACK)	+	0.062	11.00	0.34	3.775	-	3.67	-13.842
			ΣH = Σ(TOTAL LATERAL LOAD) =			3.677		M_{OT} =	-15.384

$\Sigma M = M_R + M_{OT}$ = -220.091 KIP-FT

PILE REACTIONS

$\Sigma M_A = 0$: $R_B = -\Sigma M/(A-(M+N))$ = **27.51** KIP

$\Sigma F_V = 0$: $R_A = -\Sigma W - R_B$ = **-5.46** KIP

PILE SPACING

d_P = PILE DIAMETER = 1.00 FT

P_A = ALLOWABLE PILE AXIAL LOAD = 50.00 TONS (COMPRESSION)

S_{MAX} = MAX. PILE SPACING = $((P_A)*(2\ KIPS/TON))/(MAX(|R_A|, |R_B|))$ 3.63 FT

S = SELECTED PILE SPACING = 3.00 FT (O.K.)

Uplift:
Allowable pile uplift (Tension) load = 30 tons
(30X2000lbs)/(5.46) = 10.99 ft > 3 feet O.K

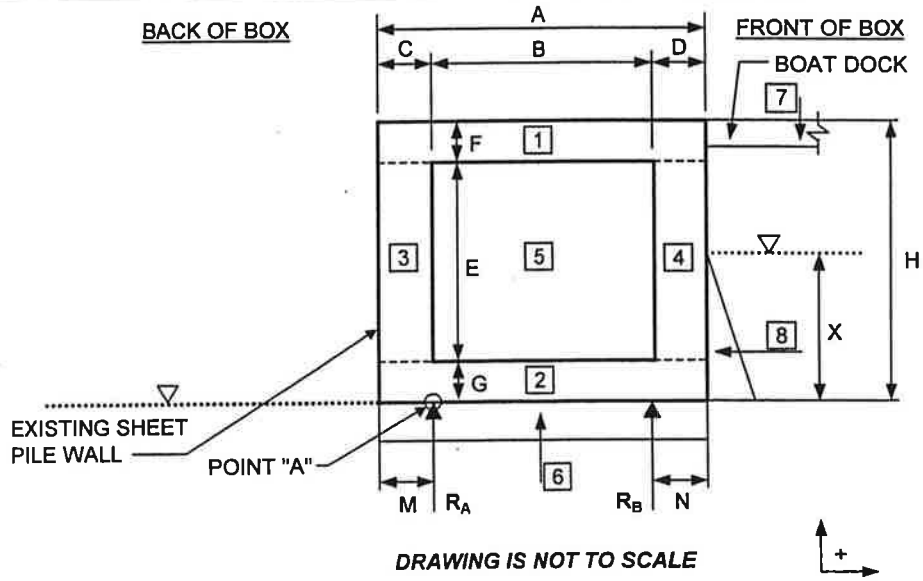
DLZ

CLIENT: OHIO DEPT. OF NATURAL RESOURCES
PROJECT: BUCKEYE LAKE
SUBJECT: CONCRETE BOX DESIGN (MAX. HT. W/O BACKFILL & W/ BOAT DOCK DESIGN)

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMPUTED BY JAM DATE 3/12/02
CHECKED BY TRA DATE 4-19-02

BOTTOM OF BOX EL. =	883.00	FT
GROUND EL. (FRONT) =	883.00	FT
GROUND EL. (BACK) =	883.00	FT
WATER EL. (FRONT) =	892.50	FT
WATER EL. (BACK) =	883.00	FT

A =	12.00	FT
B =	8.00	FT
C =	2.00	FT
D =	2.00	FT
E =	9.50	FT
F =	0.50	FT
G =	2.00	FT
H =	12.00	FT
M =	2.00	FT
N =	2.00	FT
X =	9.50	FT



ϕ = ANGLE OF INTERNAL FRICTION = 32.00 °

K_O = AT REST EARTH PRESSURE COEFFICIENT = 1 - SIN ϕ = 0.470

NOTES:
** ABOUT POINT "A" (CCW = "+")*
*** TAKEN 1 FT INTO PAGE*

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	HEIGHT (FT)	WIDTH (FT)	WT/AREA (KSF)**	WEIGHT (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
1	CONCRETE	-	0.50	12.00	0.150	-0.900	-	4.00	-3.600
2	CONCRETE	-	2.00	12.00	0.150	-3.600	-	4.00	-14.400
3	CONCRETE	-	9.50	2.00	0.150	-2.850	+	1.00	2.850
4	CONCRETE	-	9.50	2.00	0.150	-2.850	-	9.00	-25.650
5	LIGHTWT. CONC.	-	9.50	8.00	0.120	-9.120	-	4.00	-36.480
6	WATER (UPLIFT)	+	0.59	12.00	0.062	7.114	+	4.00	28.454
7	BOAT DOCK	-	N/A	N/A	N/A	-6.472	-	22.00	-142.384
					ΣW =	-18.678		M_R =	-191.210

AREA	MATERIAL/ PRESSURE	FORCE DIRECT. ("+"/"-")	WT/AREA (KSF)**	HEIGHT (FT)	AVG. LAT. LD. (KIP/FT)	TOTAL LAT. LD. (KIP)	MOMENT ROTAT.* ("+"/"-")	C.G.* (FT)	MOMENT (KIP-FT)
8	WATER, OT (FRNT.)	-	0.062	9.50	0.30	-2.816	+	3.17	8.917
					$\Sigma H = \Sigma$(TOTAL LATERAL LOAD) =	-2.816		M_{OT} =	8.917

$\Sigma M = M_R + M_{OT}$ = -182.293 KIP-FT

PILE REACTIONS

$\Sigma M_A = 0$: $R_B = -\Sigma M/(A-(M+N))$ = 22.79 KIP

$\Sigma F_V = 0$: $R_A = -\Sigma W - R_B$ = -4.11 KIP

PILE SPACING

d_P = PILE DIAMETER = 1.00 FT

P_A = ALLOWABLE PILE AXIAL LOAD = 50.00 TONS (COMPRESSION)

S_{MAX} = MAX. PILE SPACING = $((P_A)*(2\ KIPS/TON))/(MAX(|R_A|, |R_B|))$ 4.39 FT

S = SELECTED PILE SPACING = 3.00 FT (O.K.)

Uplift: (30 tons)(2000 lbs/ton)/(4.11 k)(1000 lbs/kip) = 14.6 ft > 3 ft O.K.!

DLZ

CLIENT OHIO DEPT. OF NATURAL RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT BOAT DOCK LOADS

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMP. BY JAM DATE 4/24/02
CHECKED BY TAM DATE 4-25-02

W_S = Wt. of W8x21 steel beams = (21 lb/ft.)(20 ft.) = 420 lb.

W_W = Wt. of wood deck = (1 in.)($\frac{1 \text{ ft.}}{12 \text{ in.}}$)(2 ft.)(20 ft.)(50 lb./ft.^{3}) = 167 lb.

LL = Live Load = (20 ft.)(2 ft.)(30 lb./ft.^{2}) = 1200 lb.

Per Fred Hunt

W_T = Total weight = $W_S + W_W + LL$ = (420 lb.) + (167 lb.) + (1200 lb.) = 1787 lb.

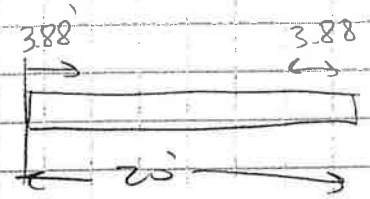
M_D = Boat dock moment = (1787 lb.)(10 ft.) = 17,870 lb.-ft.

at each attachment

W_L = Wt. of boat lift load = ($\frac{1}{4}$)(9000 lb.) = 2250 lb.

M_L = Boat lift moment = (2250 lb.)(3.88 ft. + (3.88 ft. + 12.25 ft.))
= 45,023 lb.-ft.

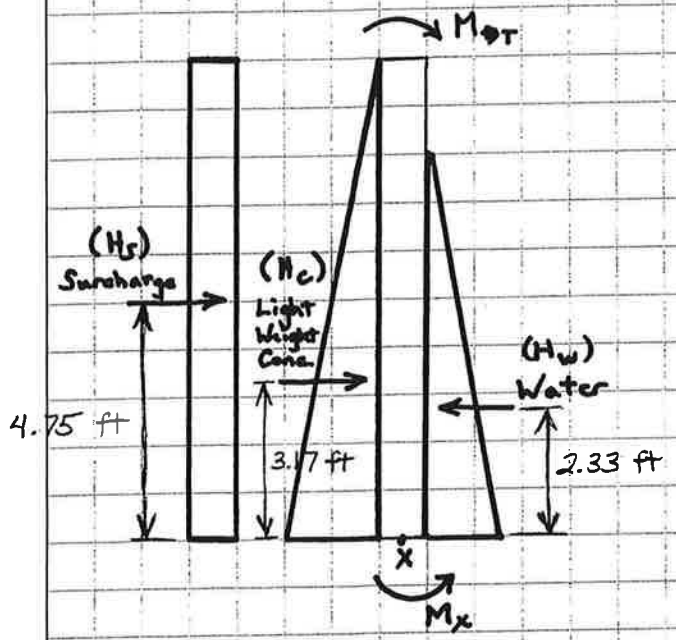
M_T = Total moment = $M_D + M_L$ = (17,870 lb.-ft.) + (45,023 lb.-ft.)
= 62,893 lb.-ft.



DLZ

CLIENT OHIO DEPT. OF NATURAL RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT CONCRETE BOX
FRONT WALL LOADS

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMP. BY JAM DATE 4/24/02
CHECKED BY TAK DATE 4-25-02



$M_T = 62.893$ kip-ft

$H_s = (0.25\ \text{kip/ft}^2)(4.5\ \text{ft})(1\ \text{ft})(0.47)^2 = 1.116$ kip

$H_w = (\frac{1}{2})(0.0624\ \text{kip/ft}^3)(1\ \text{ft})(7\ \text{ft})^2 = 1.529$ kip

$\phi_c = 32°$

$K_c = 1 - \sin\phi_w = 1 - \sin 32° = 0.470$

$H_c = (\frac{1}{2})(0.120\ \text{kip/ft}^3)(0.47)(9.5\ \text{ft})^2(1\ \text{ft})$
$= 2.545$ kip

$\circlearrowleft + \Sigma M_x = 0$: $M_x + H_w(2.33\ \text{ft}) - H_c(3.17\ \text{ft}) - H_s(4.75\ \text{ft}) - M_T = 0$

$M_x + (1.529\ \text{kip})(2.33\ \text{ft}) - (2.545\ \text{kip})(3.17\ \text{ft})$
$- (1.116\ \text{kip})(4.75\ \text{ft}) - (62.893\ \text{kip-ft}) = 0$

$M_x = 72.6991$ kip-ft.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

Dimensions of Concrete Section

Width(B) inches	Height(H) inches
6.000	24.000

Reinforcement Areas and Positions

Layer No.	No. Bars	Area Bar	Y (in.)	X1 (in.)	X2 (in.)
1	1	1.00	3.56	3.00	3.00
2	1	1.00	20.44	3.00	3.00

* *One #9 bar (area = 1.00 sq. in., diameter = 1.128 in.) was selected for each layer.*

Material Constants

F'C = 3.000 ksi
FY = 60.000 ksi

Factor p-max/p-bal, PEROB = 0.375

Analysis follows ACI Code 318-89:
Stress Block Depth Ratio, B1 = 0.850
Maximum Concrete Strain, EMAX = 0.003000
Concrete Stress Ratio fc/f'c, FCR = 0.8500
Phi for Flexure, PHIF = 0.900
Phi for Axial Load, PHIA = 0.700

ACI Code 318-89:

$\rho_{req} = \frac{200}{F_y} = .00333$

Required Strength

P(U) = 0.0 k PHI = 0.9000
M(U) = 61.8 k-ft ASTOT/B*H = 0.0139

$\rho_{actual} = \frac{.0139}{2} = .00695$

* *M(U) = 1.7*(M(x)/2) = 61.7942 k-ft.*

ok!

Results

Section falls within admissible range.
Meets input data reinforcement limit requirement.

Minimum D for no comp steel = 17.75 inches

74.94 % of design strength used, in tensile zone.

Cost Estimate

Estimated Total Cost for Different Wall Options at Buckeye Lake

Option	Estimated Cost per Foot (Dollars)	Estimated Total Cost (Millions of Dollars)
Anchored Sheet Pile Wall	$ 522	$ 10.2
Post and Panel Wall	$ 925	$ 18.1
Double Row Sheet Pile Wall	$ 1,266	$ 24.8
I-Wall [1]	$ 1,570	$ 30.8
Inverted T-Wall [1]	$ 2,156	$ 42.3
Pre-Cast Concrete Box	$ 2,120	$ 41.6

Option	Estimated Cost (Millons of Dollars) Section 1 (West Bank)	Sections 2-6 (Mud Island to Boat Ramp)
Anchored Sheet Pile Wall	$ 2.0	$ 8.2
Post and Panel Wall	$ 3.8	$ 14.3
Double Row Sheet Pile Wall	$ 5.1	$ 19.7
I-Wall [1]	$ 6.8	$ 24.0
Inverted T-Wall [1]	$ 10.4	$ 31.9
Pre-Cast Concrete Box	$ 9.2	$ 32.4

Notes:

[1] Estimated costs for I-Wall and Inverted T-Wall options include cost for a required cofferdam.

					Unit	Unit Cost	Qty.	Line Total
1.	**COFFERDAM**							
1.1	Section 1							
a.	Sheet Pile	Total height	28	ft	ft^2	$ 15	146,580	$ 2,198,700.00
		Length of section	5,235	ft				
1.2	Section 2							
a.	Sheet Pile	Total height	31	ft	ft^2	$ 15	66,185	$ 992,775.00
		Length of section	2,135	ft				
1.3	Section 3							
a.	Sheet Pile	Total height	31	ft	ft^2	$ 15	27,745	$ 416,175.00
		Length of section	895	ft				
1.4	Section 4							
a.	Sheet Pile	Total height	47	ft	ft^2	$ 15	25,850	$ 387,750.00
		Length of section	550	ft				
1.5	Section 5							
a.	Sheet Pile	Total height	28	ft	ft^2	$ 15	250,320	$ 3,754,800.00
		Length of section	8,940	ft				
1.6	Section 6							
a.	Sheet Pile	Total height	28	ft	ft^2	$ 15	52,080	$ 781,200.00
		Length of section	1,860	ft				
							TOTAL	**$ 8,531,400**
							COST PER FOOT	$ 434.94

2.	ANCHORED SHEET PILE WALL (SINGLE ROW)				*Unit*	*Unit Cost*	*Qty.*	*Line Total*
2.1	Section 1							
a.	Sheet Pile	Total height	16	ft	ft^2	$ 20	83,760	$ 1,675,200
		Length of section	5,235	ft				
	1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	6.3	$ 16,961
		Length of rod	4	ft				
		Spacing	10	ft				
		Length of section	5,235	ft				
		Weight	12,564	lbs				
	Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	80.1	$ 44,053
		Length of section	5,235	ft				
		Weight	160,191	lbs				
b.	Granular backfill	Height	7.5	ft	CY	$ 40	5,817	$ 232,667
		Width	4	ft				
		Length	5,235	ft				
							Subtotal Section 1	**$ 1,968,881**
2.2	Section 2							
a.	Sheet Pile	Total height	19	ft	ft^2	$ 20	40,565	$ 811,300
		Length of section	2,135	ft				
	1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	2.6	$ 6,917
		Length of rod	4	ft				
		Spacing	10	ft				
		Length of section	2,135	ft				
		Weight	5,124	lbs				
	Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	32.7	$ 17,966
		Length of section	2,135	ft				
		Weight	65,331	lbs				
b.	Granular backfill	Height	9	ft	CY	$ 40	2,847	$ 113,867
		Width	4	ft				
		Length	2,135	ft				
							Subtotal Section 2	**$ 950,050**

2.	ANCHORED SHEET PILE WALL (SINGLE ROW)				*Unit*	*Unit Cost*	*Qty.*	*Line Total*
2.3	Section 3							
a.	Sheet Pile	Total height	24	ft	ft^2	$ 20	21,480	$ 429,600
		Length of section	895	ft				
	1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	1.1	$ 2,900
		Length of rod	4	ft				
		Spacing	10	ft				
		Length of section	895	ft				
		Weight	2,148	lbs				
	Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	13.7	$ 7,531
		Length of section	895	ft				
		Weight	27,387	lbs				
b.	Granular backfill	Height	11	ft	CY	$ 40	1,459	$ 58,341
		Width	4	ft				
		Length	895	ft				
							Subtotal Section 3	**$ 498,372**
2.4	Section 4							
a.	Sheet Pile	Total height	25	ft	ft^2	$ 20	13,750	$ 275,000
		Length of section	550	ft				
	1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	0.7	$ 1,782
		Length of rod	4	ft				
		Spacing	10	ft				
		Length of section	550	ft				
		Weight	1,320	lbs				
	Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	8.4	$ 4,628
		Length of section	550	ft				
		Weight	16,830	lbs				
b.	Granular backfill	Height	11	ft	CY	$ 40	896	$ 35,852
		Width	4	ft				
		Length	550	ft				
							Subtotal Section 4	**$ 317,262**

2.	ANCHORED SHEET PILE WALL (SINGLE ROW)				*Unit*	*Unit Cost*	*Qty.*	*Line Total*
2.5	Section 5							
a.	Sheet Pile	Total height	26	ft	ft^2	$ 20	232,440	$ 4,648,800
		Length of section	8,940	ft				
	1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	10.7	$ 28,966
		Length of rod	4	ft				
		Spacing	10	ft				
		Length of section	8,940	ft				
		Weight	21,456	lbs				
	Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	136.8	$ 75,230
		Length of section	8,940	ft				
		Weight	273,564	lbs				
b.	Granular backfill	Height	12	ft	CY	$ 40	15,893	$ 635,733
		Width	4	ft				
		Length	8,940	ft				
							Subtotal Section 5	**$ 5,388,729**
2.6	Section 6							
a.	Sheet Pile	Total height	26	ft	ft^2	$ 20	48,360	$ 967,200
		Length of section	1,860	ft				
	1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	2.2	$ 6,026
		Length of rod	4	ft				
		Spacing	10	ft				
		Length of section	1,860	ft				
		Weight	4,464	lbs				
	Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	28.5	$ 15,652
		Length of section	1,860	ft				
		Weight	56,916	lbs				
b.	Granular backfill	Height	12	ft	CY	$ 40	3,307	$ 132,267
		Width	4	ft				
		Length	1,860	ft				
							Subtotal Section 6	**$ 1,121,145**

2. ANCHORED SHEET PILE WALL (SINGLE ROW)

		Unit	Unit Cost	Qty.	Line Total
	SUBTOTALS - ANCHORED SHEET PILE WALL (SINGLE ROW)				
2.1	Section 1				$ 1,968,881
2.2	Section 2				$ 950,050
2.3	Section 3				$ 498,372
2.4	Section 4				$ 317,262
2.5	Section 5				$ 5,388,729
2.6	Section 6				$ 1,121,145
				TOTAL	**$ 10,244,439**
				COST PER FOOT	$ 522.28

3.	DOUBLE ROW OF ANCHORED SHEET PILE WALL					*Unit*	*Unit Cost*	*Qty.*	*Line Total*
3.1	Section 1								
a.	Sheet Pile	Two rows	Total height	16	ft	ft^2	$ 20	167,520	$ 3,350,400
			Length of section	5,235	ft				
		1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	15.7	$ 42,404
			Length of rod	10	ft				
			Spacing	10	ft				
			Length of section	5,235	ft				
			Weight	31,410	lbs				
		Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	160.2	$ 88,105
			Length of section	5,235	ft				
			Weight (x2)	320,382	lbs				
b.	Granular backfill		Height	6.5	ft	CY	$ 40	12,603	$ 504,111
			Width	10	ft				
			Length	5,235	ft				
c.	Concrete Cap		Height	1	ft	CY	$ 550	1,939	$ 1,066,389
			Width	10	ft				
			Length	5,235	ft				
								Subtotal Section 1	**$ 5,051,409**
3.2	Section 2								
a.	Sheet Pile	Two rows	Total height	19	ft	ft^2	$ 20	81,130	$ 1,622,600
			Length of section	2,135	ft				
		1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	6.4	$ 17,294
			Length of rod	10	ft				
			Spacing	10	ft				
			Length of section	2,135	ft				
			Weight	12,810	lbs				
		Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	65.3	$ 35,932
			Length of section	2,135	ft				
			Weight (x2)	130,662	lbs				
b.	Granular backfill		Height	8	ft	CY	$ 40	6,326	$ 253,037
			Width	10	ft				
			Length	2,135	ft				
c.	Concrete Cap		Height	1	ft	CY	$ 550	791	$ 434,907
			Width	10	ft				
			Length	2,135	ft				
								Subtotal Section 2	**$ 2,363,770**

3.	DOUBLE ROW OF ANCHORED SHEET PILE WALL					*Unit*	*Unit Cost*	*Qty.*	*Line Total*
3.3	Section 3								
a.	Sheet Pile	Two rows	Total height	24	ft	ft^2	$ 20	42,960	$ 859,200
			Length of section	895	ft				
		1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	2.7	$ 7,250
			Length of rod	10	ft				
			Spacing	10	ft				
			Length of section	895	ft				
			Weight	5,370	lbs				
		Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	27.4	$ 15,063
			Length of section	895	ft				
			Weight (x2)	54,774	lbs				
b.	Granular backfill		Height	10	ft	CY	$ 40	3,315	$ 132,593
			Width	10	ft				
			Length	895	ft				
c.	Concrete Cap		Height	1	ft	CY	$ 550	331	$ 182,315
			Width	10	ft				
			Length	895	ft				
								Subtotal Section 3	**$ 1,196,420**
3.4	Section 4								
a.	Sheet Pile	Two rows	Total height	25	ft	ft^2	$ 20	27,500	$ 550,000
			Length of section	550	ft				
		1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	1.7	$ 4,455
			Length of rod	10	ft				
			Spacing	10	ft				
			Length of section	550	ft				
			Weight	3,300	lbs				
		Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	16.8	$ 9,257
			Length of section	550	ft				
			Weight (x2)	33,660	lbs				
b.	Granular backfill		Height	10	ft	CY	$ 40	2,037	$ 81,481
			Width	10	ft				
			Length	550	ft				
c.	Concrete Cap		Height	1	ft	CY	$ 550	204	$ 112,037
			Width	10	ft				
			Length	550	ft				
								Subtotal Section 4	**$ 757,230**

3.	DOUBLE ROW OF ANCHORED SHEET PILE WALL					Unit	Unit Cost	Qty.	Line Total
3.5	Section 5								
a.	Sheet Pile	Two rows	Total height	26	ft	ft^2	$ 20	464,880	$ 9,297,600
			Length of section	8,940	ft				
		1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	26.8	$ 72,414
			Length of rod	10	ft				
			Spacing	10	ft				
			Length of section	8,940	ft				
			Weight	53,640	lbs				
		Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	273.6	$ 150,460
			Length of section	8,940	ft				
			Weight (x2)	547,128	lbs				
b.	Granular backfill		Height	11	ft	CY	$ 40	36,422	$ 1,456,889
			Width	10	ft				
			Length	8,940	ft				
c.	Concrete Cap		Height	1	ft	CY	$ 550	3,311	$ 1,821,111
			Width	10	ft				
			Length	8,940	ft				
								Subtotal Section 5	**$ 12,798,474**
3.6	Section 6								
a.	Sheet Pile	Two rows	Total height	26	ft	ft^2	$ 20	96,720	$ 1,934,400
			Length of section	1,860	ft				
		1.5" Ø Tie Rods	Unit Weight	6	lb/ft	tons	$ 2,700	5.6	$ 15,066
			Length of rod	10	ft				
			Spacing	10	ft				
			Length of section	1,860	ft				
			Weight	11,160	lbs				
		Waler, (2) C 10x15.3	Unit Weight	30.6	lb/ft	tons	$ 550	56.9	$ 31,304
			Length of section	1,860	ft				
			Weight (x2)	113,832	lbs				
b.	Granular backfill		Height	11	ft	CY	$ 40	7,578	$ 303,111
			Width	10	ft				
			Length	1,860	ft				
c.	Concrete Cap		Height	1	ft	CY	$ 550	689	$ 378,889
			Width	10	ft				
			Length	1,860	ft				
								Subtotal Section 6	**$ 2,662,770**

3.	DOUBLE ROW OF ANCHORED SHEET PILE WALL	*Unit*	*Unit Cost*	*Qty.*	*Line Total*
	SUBTOTALS - DOUBLE ROW OF ANCHORED SHEET PILE WALL				
3.1	Section 1				$ 5,051,409
3.2	Section 2				$ 2,363,770
3.3	Section 3				$ 1,196,420
3.4	Section 4				$ 757,230
3.5	Section 5				$ 12,798,474
3.6	Section 6				$ 2,662,770
				TOTAL	**$ 24,830,072**
				COST PER FOOT	$ 1,265.87

						Unit	Unit Cost	Qty.	Line Total
4.	**POST AND PANEL WALL**								
4.1	Section 1								
a.	Post	2' Ø Drilled Shaft (incl. concrete)	Depth	17.5	ft	feet	$ 60	22,903	$ 1,374,188
			Spacing	4	ft				
			Length of section	5,235	ft				
		HP 14x117	Length	25	ft	feet	$ 45	32,719	$ 1,472,344
			Spacing	4	ft				
			Length of section	5,235	ft				
b.	Panel	Reinforced Concrete	Height	7.5	ft	CY	$ 550	1,277	$ 702,595
			Length	46	in				
			Thickness	11	in				
			Spacing	4	ft				
			Length of section	5,235	ft				
c.	Granular backfill		Height	7.5	ft	CY	$ 40	5,817	$ 232,667
			Width	4	ft				
			Length of section	5,235	ft				
								Subtotal Section 1	**$ 3,781,793**
4.2	Section 2								
a.	Post	2' Ø Drilled Shaft (incl. concrete)	Depth	21	ft	feet	$ 60	11,209	$ 672,525
			Spacing	4	ft				
			Length of section	2,135	ft				
		HP 14x117	Length	30	ft	feet	$ 45	16,013	$ 720,563
			Spacing	4	ft				
			Length of section	2,135	ft				
b.	Panel	Reinforced Concrete	Height	9	ft	CY	$ 550	625	$ 343,849
			Length	46	in				
			Thickness	11	in				
			Spacing	4	ft				
			Length of section	2,135	ft				
c.	Granular backfill		Height	9	ft	CY	$ 40	2,847	$ 113,867
			Width	4	ft				
			Length of section	2,135	ft				
								Subtotal Section 2	**$ 1,850,803**

4.	POST AND PANEL WALL					Unit	Unit Cost		Qty.		Line Total
4.3	Section 3										
a.	Post	2' Ø Drilled Shaft	Depth	19	ft	feet	$	60	4,251	$	255,075
		(incl. concrete)	Spacing	4	ft						
			Length of section	895	ft						
		HP 14x117	Length	30	ft	feet	$	45	6,713	$	302,063
			Spacing	4	ft						
			Length of section	895	ft						
b.	Panel	Reinforced Concrete	Height	11	ft	CY	$	550	320	$	176,174
			Length	46	in						
			Thickness	11	in						
			Spacing	4	ft						
			Length of section	895	ft						
c.	Granular backfill		Height	11	ft	CY	$	40	1,459	$	58,341
			Width	4	ft						
			Length of section	895	ft						
									Subtotal Section 3	**$**	**791,653**
4.4	Section 4										
a.	Post	2' Ø Drilled Shaft	Depth	24.5	ft	feet	$	60	3,369	$	202,125
		(incl. concrete)	Spacing	4	ft						
			Length of section	550	ft						
		HP 14x117	Length	40	ft	feet	$	45	5,500	$	247,500
			Spacing	4	ft						
			Length of section	550	ft						
b.	Panel	Reinforced Concrete	Height	15.5	ft	CY	$	550	277	$	152,553
			Length	46	in						
			Thickness	11	in						
			Spacing	4	ft						
			Length of section	550	ft						
c.	Granular backfill		Height	15.5	ft	CY	$	40	1,263	$	50,519
			Width	4	ft						
			Length of section	550	ft						
									Subtotal Section 4	**$**	**652,697**

4.	POST AND PANEL WALL					Unit	Unit Cost		Qty.		Line Total
4.5	Section 5										
a.	Post	2' Ø Drilled Shaft (incl. concrete)	Depth	23	ft	feet	$	60	51,405	$	3,084,300
			Spacing	4	ft						
			Length of section	8,940	ft						
		HP 14x117	Length	35	ft	feet	$	45	78,225	$	3,520,125
			Spacing	4	ft						
			Length of section	8,940	ft						
b.	Panel	Reinforced Concrete	Height	12	ft	CY	$	550	3,490	$	1,919,755
			Length	46	in						
			Thickness	11	in						
			Spacing	4	ft						
			Length of section	8,940	ft						
c.	Granular backfill		Height	12	ft	CY	$	40	15,893	$	635,733
			Width	4	ft						
			Length of section	8,940	ft						
									Subtotal Section 5	**$**	**9,159,913**
4.6	Section 6										
a.	Post	2' Ø Drilled Shaft (incl. concrete)	Depth	23	ft	feet	$	60	10,695	$	641,700
			Spacing	4	ft						
			Length of section	1,860	ft						
		HP 14x117	Length	35	ft	feet	$	45	16,275	$	732,375
			Spacing	4	ft						
			Length of section	1,860	ft						
b.	Panel	Reinforced Concrete	Height	12	ft	CY	$	550	726	$	399,412
			Length	46	in						
			Thickness	11	in						
			Spacing	4	ft						
			Length of section	1,860	ft						
c.	Granular backfill		Height	12	ft	CY	$	40	3,307	$	132,267
			Width	4	ft						
			Length of section	1,860	ft						
									Subtotal Section 6	**$**	**1,905,754**

4.	**POST AND PANEL WALL**	*Unit*	*Unit Cost*	*Qty.*	*Line Total*
	SUBTOTALS - POST AND PANEL WALL				
4.1	Section 1				$ 3,781,793
4.2	Section 2				$ 1,850,803
4.3	Section 3				$ 791,653
4.4	Section 4				$ 652,697
4.5	Section 5				$ 9,159,913
4.6	Section 6				$ 1,905,754
				TOTAL	**$ 18,142,612**
				COST PER FOOT	$ 924.94

Estimated Total Cost for Different Wall Options at Buckeye Lake
Approximate Length of Sections

		Length	
Section 1	West Bank	5,235	ft
Section 2	Mud Island to Emergency Spillway	2,135	ft
Section 3	Emergency Spillway to Sellers Point	895	ft
Section 4	East of Sellers Point	550	ft
Section 5a	East of Sellers Point to Primary Spillway	7,570	ft
Section 5b	Primary Spillway to Buckeye Lake Yacht Club	1,370	ft
Section 6	Buckeye Lake Yacht Club to Boat Ramp	1,860	ft

Total Length	
19,615	ft

Quantities and Cost Estimate – Concrete Box and I-Wall

DLZ

CLIENT OHIO DEPT. OF NAT. RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT COST ESTIMATE

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMPUTED BY JAM DATE 4/23/02
CHECKED BY TAW DATE 7-16-02

CONCRETE BOX				
ITEM	UNIT COST	QUANT.	UNITS	TOTAL COST
PILES	$38	265,650	FT	$10,094,700
CONCRETE	$550	40,389	CU YD	$22,213,950
TOP SLAB CONCRETE	$550	4,357	CU YD	$2,396,350
LIGHTWEIGHT CONCRETE	$150	45,907	CU YD	$6,886,050
			CONCRETE BOX TOTAL COST =	$41,591,050

CONCRETE BOX (COSTS PER SECTION)							
ITEM	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5A	SECTION 5B	SECTION 6
PILES	$2,690,400	$1,098,200	$461,700	$286,900	$3,891,200	$706,800	$959,500
CONCRETE	$4,692,050	$2,174,700	$1,057,650	$649,550	$9,560,650	$1,730,300	$2,349,050
TOP SLAB CONCRETE	$639,650	$260,700	$109,450	$67,100	$925,100	$167,200	$227,150
LIGHTWEIGHT CONCRETE	$1,163,400	$616,800	$338,100	$207,750	$3,196,200	$578,400	$785,400
TOTAL SECTION COST =	$9,185,500	$4,150,400	$1,966,900	$1,211,300	$17,573,150	$3,182,700	$4,321,100

Σ = 41591050

I-WALL				
ITEM	UNIT COST	QUANT.	UNITS	TOTAL COST
EXCAVATION	$40	11,111	CU YD	$444,440
SHEET PILING (PZ40)	$20	387,310	SQ FT	$7,746,200
CONCRETE	$550	22,287	CU YD	$12,257,850
BACKFILL	$40	45,604	CU YD	$1,824,160
			TOTAL COST =	$22,272,650

I-WALL (COSTS PER SECTION)							
ITEM	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5A	SECTION 5B	SECTION 6
EXCAVATION	$105,480	$43,960	$18,960	$44,040	$162,600	$29,440	$39,960
SHEET PILING (PZ40)	$1,675,200	$683,200	$393,800	$242,000	$3,330,800	$602,800	$818,400
CONCRETE	$2,444,750	$1,165,450	$586,850	$360,800	$5,397,150	$976,800	$1,326,050
BACKFILL	$357,720	$171,760	$86,160	$85,320	$787,280	$142,480	$193,440
TOTAL SECTION COST =	$4,583,150	$2,064,370	$1,085,770	$732,160	$9,677,830	$1,751,520	$2,377,850

Σ = 22272650

DLZ

CLIENT OHIO DEPT. OF NAT. RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT ESTIMATED QUANTITIES

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 2
COMPUTED BY JAM DATE 4/23/02
CHECKED BY DATE 7-16-02

CONCRETE BOX - PILES
(UNIT COST = $38)

SECTION	LENGTH (FT)	PILE SPACING (FT)	NUMBER OF PILES	PILE LENGTH (FT)	EXTRA DOCK PILES	TOTAL PILE LEN. (FT)	COST
1	5235.00	10.00	1048	50.00	368.00	70,800	$2,690,400
2	2135.00	10.00	428	50.00	150.00	28,900	$1,098,200
3	895.00	10.00	180	50.00	63.00	12,150	$461,700
4	550.00	10.00	112	50.00	39.00	7,550	$286,900
5A	7570.00	10.00	1516	50.00	532.00	102,400	$3,891,200
5B	1370.00	10.00	276	50.00	96.00	18,600	$706,800
6	1860.00	10.00	374	50.00	131.00	25,250	$959,500
					TOTALS =	***265,650***	***$10,094,700***

CONCRETE BOX - CONCRETE
(UNIT COST = $550)

SECTION	LENGTH (FT)	TOP OF BOX EL. (FT)	BOT. OF BOX EL. (FT)	HEIGHT OF BOX (FT)	WIDTH OF BOX (FT)	WALL THICK. (FT)	TOP SLAB THICK. (FT)	X-SEC. AREA (SQ FT)	TOTAL VOLUME (CU YD)	COST
1	5235.00	895.00	887.50	7.50	12.00	2.00	0.50	44.00	8,531	$4,692,050
2	2135.00	895.00	886.00	9.00	12.00	2.00	0.50	50.00	3,954	$2,174,700
3	895.00	895.00	884.00	11.00	12.00	2.00	0.50	58.00	1,923	$1,057,650
4	550.00	895.00	884.00	11.00	12.00	2.00	0.50	58.00	1,181	$649,550
5A	7570.00	895.00	883.00	12.00	12.00	2.00	0.50	62.00	17,383	$9,560,650
5B	1370.00	895.00	883.00	12.00	12.00	2.00	0.50	62.00	3,146	$1,730,300
6	1860.00	895.00	883.00	12.00	12.00	2.00	0.50	62.00	4,271	$2,349,050
								TOTALS =	***40,389***	***$22,213,950***

CONCRETE BOX - TOP SLAB CONCRETE
(UNIT COST = $550)

SECTION	LENGTH (FT)	WIDTH OF BOX (FT)	TOP SLAB THICK. (FT)	TOTAL VOLUME (CU YD)	COST
1	5235.00	12.00	0.50	1,163	$639,650
2	2135.00	12.00	0.50	474	$260,700
3	895.00	12.00	0.50	199	$109,450
4	550.00	12.00	0.50	122	$67,100
5A	7570.00	12.00	0.50	1,682	$925,100
5B	1370.00	12.00	0.50	304	$167,200
6	1860.00	12.00	0.50	413	$227,150
			TOTALS =	***4,357***	***$2,396,350***

CONCRETE BOX - LIGHTWEIGHT CONCRETE
(UNIT COST = $150)

SECTION	LENGTH (FT)	TOP OF BOX EL. (FT)	BOT. OF BOX EL. (FT)	HEIGHT OF BOX (FT)	WIDTH OF BOX (FT)	WALL THICK. (FT)	TOP SLAB THICK. (FT)	X-SEC. AREA (SQ FT)	TOTAL VOLUME (CU YD)	COST
1	5235.00	895.00	887.50	7.50	12.00	2.00	0.50	40.00	7,756	$1,163,400
2	2135.00	895.00	886.00	9.00	12.00	2.00	0.50	52.00	4,112	$616,800
3	895.00	895.00	884.00	11.00	12.00	2.00	0.50	68.00	2,254	$338,100
4	550.00	895.00	884.00	11.00	12.00	2.00	0.50	68.00	1,385	$207,750
5A	7570.00	895.00	883.00	12.00	12.00	2.00	0.50	76.00	21,308	$3,196,200
5B	1370.00	895.00	883.00	12.00	12.00	2.00	0.50	76.00	3,856	$578,400
6	1860.00	895.00	883.00	12.00	12.00	2.00	0.50	76.00	5,236	$785,400
								TOTALS =	***45,907***	***$6,886,050***

DLZ

CLIENT OHIO DEPT. OF NAT. RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT ESTIMATED QUANTITIES

PROJECT NO. 0121-3074-00
SHEET NO. 2 OF 2
COMPUTED BY JAM DATE 4/18/02
CHECKED BY TKB DATE 4-19-02

I-WALL - EXCAVATION

(UNIT COST = $40)

1 ft on either side of wall

SECTION	LENGTH (FT)	TOP OF WALL EL. (FT)	BOT. OF WALL EL. (FT)	HEIGHT OF WALL (FT)	BOT. WL. WIDTH (FT)	WIDTH OF EXC. (FT)	DEPTH OF EXC. (FT)	X-SEC. AREA (SQ FT)	ADD. EXC. AREA (SQ FT)	TOTAL VOLUME (CU YD)	COST
1	5235.00	895.00	884.50	10.50	2.53	4.53	3.00	13.60	0.00	2,637	$105,480
2	2135.00	895.00	883.00	12.00	2.63	4.63	3.00	13.90	0.00	1,099	$43,960
3	895.00	895.00	881.00	14.00	2.77	4.77	3.00	14.30	0.00	474	$18,960
4	550.00	895.00	881.00	14.00	2.77	4.77	3.00	14.30	39.75	1,101	$44,040
5A	7570.00	895.00	880.00	15.00	2.83	4.83	3.00	14.50	0.00	4,065	$162,600
5B	1370.00	895.00	880.00	15.00	2.83	4.83	3.00	14.50	0.00	736	$29,440
6	1860.00	895.00	880.00	15.00	2.83	4.83	3.00	14.50	0.00	999	$39,960
									TOTALS =	***11,111***	***$444,440***

I-WALL - SHEET PILING (PZ40)

(UNIT COST = $20)

Top of sheet pile

SECTION	LENGTH (FT)	TOP OF WALL EL. (FT)	BOT. OF WALL EL. (FT)	HEIGHT OF WALL (FT)	DEPTH OF PEN. (FT)	TOTAL AREA (SQ FT)	COST
1	5235.00	895.00	887.50	7.50	16.00	83,760	$1,675,200
2	2135.00	895.00	886.00	9.00	16.00	34,160	$683,200
3	895.00	895.00	884.00	11.00	22.00	19,690	$393,800
4	550.00	895.00	884.00	11.00	22.00	12,100	$242,000
5A	7570.00	895.00	883.00	12.00	22.00	166,540	$3,330,800
5B	1370.00	895.00	883.00	12.00	22.00	30,140	$602,800
6	1860.00	895.00	883.00	12.00	22.00	40,920	$818,400
					TOTALS =	***387,310***	***$7,746,200***

I-WALL - CONCRETE

(UNIT COST = $550)

1:15 batter

SECTION	LENGTH (FT)	TOP OF WALL EL. (FT)	BOT. OF WALL EL. (FT)	HEIGHT OF WALL (FT)	TOP WL. WIDTH (FT)	BOT. WL. WIDTH (FT)	X-SEC. AREA (SQ FT)	TOTAL VOLUME (CU YD)	COST
1	5235.00	895.00	884.50	10.50	1.83	2.53	22.93	4,445	$2,444,750
2	2135.00	895.00	883.00	12.00	1.83	2.63	26.80	2,119	$1,165,450
3	895.00	895.00	881.00	14.00	1.83	2.77	32.20	1,067	$586,850
4	550.00	895.00	881.00	14.00	1.83	2.77	32.20	656	$360,800
5A	7570.00	895.00	880.00	15.00	1.83	2.83	35.00	9,813	$5,397,150
5B	1370.00	895.00	880.00	15.00	1.83	2.83	35.00	1,776	$976,800
6	1860.00	895.00	880.00	15.00	1.83	2.83	35.00	2,411	$1,326,050
							TOTALS =	***22,287***	***$12,257,850***

I-WALL - BACKFILL

(UNIT COST = $40)

SECTION	LENGTH (FT)	TOP OF WALL EL. (FT)	TOP OF GR. EL. (FT)	CANT. WALL HT. (FT)	TOP WL. WIDTH (FT)	WL.WID. AT GRND. (FT)	TOP BF. WIDTH (FT)	X-SEC. AREA (SQ FT)	ADD. BF. AREA (SQ FT)	TOTAL VOLUME (CU YD)	COST
1	5235.00	895.00	887.50	7.50	1.83	2.33	6.00	46.13	0.00	8,943	$357,720
2	2135.00	895.00	886.00	9.00	1.83	2.43	6.00	54.30	0.00	4,294	$171,760
3	895.00	895.00	884.00	11.00	1.83	2.57	6.00	64.97	0.00	2,154	$86,160
4	550.00	895.00	884.00	11.00	1.83	2.57	6.00	64.97	39.75	2,133	$85,320
5A	7570.00	895.00	883.00	12.00	1.83	2.63	6.00	70.20	0.00	19,682	$787,280
5B	1370.00	895.00	883.00	12.00	1.83	2.63	6.00	70.20	0.00	3,562	$142,480
6	1860.00	895.00	883.00	12.00	1.83	2.63	6.00	70.20	0.00	4,836	$193,440
									TOTALS =	***45,604***	***$1,824,160***

DLZ

CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Cost Estimates for Sheet Piling for I-Wall

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMP. BY TRK DATE 3-13-02
CHECKED BY JAM DATE 4/18/02

- Per Pete Nix, assume contractor can install 40 ft of piling (along length of wall) per day from a barge.
- Length of piling (into ground) = ~20'
- Total area of sheet piling installed per day = 800 ft^2
- Barge rental price per day = \$1500/day
- Therefore, additional unit cost of sheet piling for barge is:

  \$1500/800 ft^2 = \$1.88/ft^2

- Research has indicated sheet piling normally costs \$14-\$20/ft^2 to install. Therefore, stick with \$20/ft^2

Quantities and Cost Estimate – Inverted T-Wall

DLZ

SUBJECT	ODNR	JOB NUMBER	0121-3074-00
	Buckeye Lake	SHEET NO.	1 OF 8
	Inverted T-Wall Preliminary Design	COMP. BY	TAH DATE 4/18/2002
	Quantity and Cost Estimate	CHECKED BY	JAM DATE 4/18/02

Quantities and cost per section

Section 1: Section length = 5235 ft

Average property width = 56.89 ft

No. of properties in section = 92

x 4 extra piles per property = 368 extra piles for boat docks

Quantities:

Concrete:	1.78	yds^3/ft	x	5235	ft =	9318	yds^3				
Backfill:	1.67	yds^3/ft	x	5235	ft =	8742	yds^3				
Piles	1050	+	368	=	1418	piles x	50	ft/pile =	70900	ft	

Cost:

Concrete:	9318	yds^3 x	$550	$/yds^3$ =	$5,124,900
Backfill:	8742	yds^3 x	$40	$/yds^3$ =	$349,680
Piles:	70900	ft x	$38	/ft =	$2,694,200

Total cost Section 1:	$8,168,780

DLZ

SUBJECT	ODNR	JOB NUMBER	0121-3074-00
	Buckeye Lake	SHEET NO.	2 OF 8
	Inverted T-Wall Preliminary Design	COMP. BY	TAH DATE 4/18/2002
	Quantity and Cost Estimate	CHECKED BY	J+M DATE 4/18/02

Quantities and cost per section

Section 2: Section length = 2135 ft

Average property width = 56.89 ft

No. of properties in section = 38

x 4 extra piles per property = 152 extra piles for boat docks

Quantities:

Concrete:	1.89	yds^3/ft	x	2135	ft =	4035	yds^3				
Backfill:	2.22	yds^3/ft	x	2135	ft =	4740	yds^3				
Piles	430	+	152	=	582	piles x	50	ft/pile =	29100	ft	

Cost:

Concrete:	4035	yds^3 x	$550	/yds^3 =	$2,219,250
Backfill:	4740	yds^3 x	$40	/yds^3 =	$189,600
Piles:	29100	ft x	$38	/ft =	$1,105,800

Total cost Section 2:	$3,514,650

```
==========================================================================

                    LPILE Plus for Windows, Version 4

            Analysis of Individual Piles and Drilled Shafts
          Subjected to Lateral Loading Using the p-y Method

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                        All Rights Reserved

==========================================================================

This program is licensed to:

Peter Narsavage
DLZ Ohio, Inc.

Path to file locations:       M:\proj\0121\3074.00\geot\Lpile\
Name of input data file:      Sect5-hp14.lpd
Name of output file:          Sect5-hp14.lpo
Name of plot output file:     Sect5-hp14.lpp
Name of runtime file:         Sect5-hp14.lpr

--------------------------------------------------------------------------
                         Time and Date of Analysis
--------------------------------------------------------------------------

               Date:  March  1, 2002     Time:   9:17:45

--------------------------------------------------------------------------
                               Problem Title
--------------------------------------------------------------------------

Buckeye Lake - Post and Panel Wall - Section 5

--------------------------------------------------------------------------
                               Program Options
--------------------------------------------------------------------------

Units Used in Computations - US Customary Units, inches, pounds

Basic Program Options:

Analysis Type 1:
- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:
- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multiplers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis for fixed-length pile or shaft only
- No computation of foundation stiffness matrix elements
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:
- Number of pile increments              =          100
- Deflection tolerance for closure       =   1.0000E-05 in
- Maximum number of iterations allowed   =          100
- Maximum allowable deflection           =   1.0000E+03 in

Printing Options:
- Values of pile-head deflection, bending moment, shear force, and
  soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) =  1

--------------------------------------------------------------------------
                   Pile Structural Properties and Geometry
--------------------------------------------------------------------------
```

Pile Length = 420.00 in
Depth of ground surface below top of pile = 144.00 in
Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 4 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq.in	Modulus of Elasticity lbs/Sq.in
1	0.0000	14.90	1220.0000	34.4000	29000000.00
2	144.0000	14.90	1220.0000	34.4000	29000000.00
3	144.0000	24.00	16290.0000	452.0000	3000000.00
4	420.0000	24.00	16290.0000	452.0000	3000000.00

Soil and Rock Layering Information

The soil profile is modelled using 2 layers

Layer 1 is soft clay, p-y criteria by Matlock, 1970
Distance from top of pile to top of layer = 144.000 in
Distance from top of pile to bottom of layer = 168.000 in

Layer 2 is stiff clay with water-induced erosion
Distance from top of pile to top of layer = 168.000 in
Distance from top of pile to bottom of layer = 860.000 in
p-y subgrade modulus k for top of soil layer = 100.000 lbs/in**3
p-y subgrade modulus k for bottom of layer = 100.000 lbs/in**3

(Depth of lowest layer extends 440.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Distribution of effective unit weight of soil with depth
is defined using 4 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	144.00	.03912
2	168.00	.03912
3	168.00	.03912
4	860.00	.03912

Shear Strength of Soils

Distribution of shear strength parameters with depth
defined using 4 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k_rm	RQD %
1	144.000	3.47000	.00	.02000	.0
2	168.000	3.47000	.00	.02000	.0
3	168.000	5.21000	.00	.01000	.0
4	860.000	5.21000	.00	.01000	.0

Notes:

(1) Cohesion = uniaxial compressive strength for rock materials.
(2) Values of E50 are reported for clay strata.
(3) Default values will be generated for E50 when input values are 0.
(4) RQD and k_rm are reported only for weak rock strata.

Distribution of p-y multipliers with depth defined
using 2 points

Point No.	Depth X in	p-mult	y-mult
1	144.000	.6560	1.0000
2	860.000	.6560	1.0000

Static loading criteria was used for computation of p-y curves

Distributed lateral load intensity defined using 3 points

Point No.	Depth X in	Dist. Load lbs/in
1	.000	23.20000
2	12.000	34.30000
3	144.000	139.70000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Shear force at pile head = .000 lbs
Bending moment at pile head = .000 in-lbs
Axial load at pile head = .000 lbs

(Zero moment at pile head for this load indicates a free-head condition)

Computed Values of Load Distribution and Deflection
for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Specified shear force at pile head = .000 lbs
Specified bending moment at pile head = .000 in-lbs
Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res p lbs/in
0.000	.717231	-4.453E-07	0.0000	-.003662	2.720E-09	0.0000
4.200	.701851	204.6240	105.5985	-.003662	1.2495	0.0000
8.400	.686472	887.0274	227.5140	-.003662	5.4167	0.0000
12.600	.671092	2115.7416	365.5871	-.003662	12.9199	0.0000
16.800	.655714	3957.9590	518.7019	-.003661	24.1695	0.0000
21.000	.640338	6472.8376	685.9020	-.003661	39.5268	0.0000
25.200	.624965	9719.5358	867.1874	-.003660	59.3529	0.0000
29.400	.609597	13757.2115	1062.5580	-.003658	84.0092	0.0000
33.600	.594235	18645.0230	1272.0139	-.003656	113.8569	0.0000
37.800	.578883	24442.1283	1495.5551	-.003654	149.2573	0.0000
42.000	.563543	31207.6857	1733.1815	-.003650	190.5715	0.0000
46.200	.548219	39000.8533	1984.8933	-.003646	238.1609	0.0000
50.400	.532914	47880.7892	2250.6903	-.003641	292.3868	0.0000
54.600	.517633	57906.6516	2530.5725	-.003635	353.6103	0.0000
58.800	.502381	69137.5986	2824.5401	-.003627	422.1927	0.0000
63.000	.487164	81632.7884	3132.5929	-.003618	498.4953	0.0000
67.200	.471987	95451.3790	3454.7310	-.003608	582.8793	0.0000
71.400	.456857	1.107E+05	3790.9544	-.003596	675.7060	0.0000
75.600	.441783	1.273E+05	4141.2630	-.003582	777.3366	0.0000

79.800	.426773	1.454E+05	4505.6569	-.003565	888.1324	0.0000
84.000	.411834	1.651E+05	4884.1361	-.003547	1008.4547	0.0000
88.200	.396979	1.865E+05	5276.7005	-.003526	1138.6646	0.0000
92.400	.382216	2.095E+05	5683.3503	-.003503	1279.1235	0.0000
96.600	.367557	2.342E+05	6104.0853	-.003476	1430.1925	0.0000
100.800	.353016	2.607E+05	6538.9055	-.003447	1592.2330	0.0000
105.000	.338604	2.891E+05	6987.8111	-.003414	1765.6062	0.0000
109.200	.324337	3.194E+05	7450.8019	-.003378	1950.6734	0.0000
113.400	.310228	3.517E+05	7927.8780	-.003338	2147.7957	0.0000
117.600	.296295	3.860E+05	8419.0394	-.003294	2357.3345	0.0000
121.800	.282555	4.224E+05	8924.2860	-.003246	2579.6510	0.0000
126.000	.269025	4.610E+05	9443.6179	-.003194	2815.1065	0.0000
130.200	.255725	5.018E+05	9977.0351	-.003137	3064.0622	0.0000
134.400	.242676	5.448E+05	10524.5375	-.003075	3326.8793	0.0000
138.600	.229897	5.902E+05	11086.1253	-.003007	3603.9192	0.0000
142.800	.217414	6.379E+05	11661.7983	-.002934	3895.5430	0.0000
147.000	.205248	6.881E+05	11854.5622	-.002867	506.9106	-46.9495
151.200	.193330	7.375E+05	11655.1116	-.002806	543.2826	-48.0270
155.400	.181679	7.860E+05	11451.3435	-.002740	579.0306	-49.0054
159.600	.170312	8.337E+05	11243.6784	-.002671	614.1418	-49.8827
163.800	.159245	8.805E+05	11032.5452	-.002597	648.6047	-50.6569
168.000	.148496	9.264E+05	10317.6868	-.002519	682.4095	-289.7519
172.200	.138082	9.671E+05	8990.5834	-.002438	712.4490	-342.2021
176.400	.128017	1.002E+06	7580.0213	-.002353	738.0418	-329.4942
180.600	.118313	1.031E+06	6222.8865	-.002266	759.3530	-316.7605
184.800	.108982	1.054E+06	4919.2633	-.002176	776.5481	-304.0124
189.000	.100031	1.072E+06	3669.1904	-.002085	789.7926	-291.2604
193.200	.091467	1.085E+06	2472.6651	-.001992	799.2524	-278.5136
197.400	.083294	1.093E+06	1329.6478	-.001899	805.0931	-265.7803
201.600	.075516	1.096E+06	240.0676	-.001805	807.4801	-253.0674
205.800	.068134	1.095E+06	-796.1719	-.001711	806.5786	-240.3800
210.000	.061147	1.089E+06	-1779.1855	-.001617	802.5535	-227.7217
214.200	.054553	1.080E+06	-2709.0977	-.001524	795.5693	-215.0937
218.400	.048349	1.067E+06	-3586.0326	-.001431	785.7900	-202.4944
222.600	.042531	1.050E+06	-4410.1008	-.001340	773.3795	-189.9190
226.800	.037091	1.030E+06	-5181.3824	-.001251	758.5010	-177.3579
231.000	.032022	1.006E+06	-5899.9051	-.001163	741.3179	-164.7958
235.200	.027317	9.801E+05	-6565.6145	-.001078	721.9933	-152.2087
239.400	.022966	9.512E+05	-7178.3316	-9.951E-04	700.6909	-139.5613
243.600	.018958	9.198E+05	-7737.6919	-9.147E-04	677.5749	-126.8007
247.800	.015282	8.862E+05	-8243.0508	-8.371E-04	652.8112	-113.8464
252.000	.011926	8.506E+05	-8693.3313	-7.625E-04	626.5682	-100.5728
256.200	.008877	8.132E+05	-9086.7524	-6.910E-04	599.0182	-86.7706
260.400	.006122	7.742E+05	-9416.8429	-6.228E-04	570.3408	-70.4153
264.600	.003646	7.341E+05	-9654.8885	-5.580E-04	540.7483	-42.9397
268.800	.001435	6.931E+05	-9781.3782	-4.967E-04	510.5978	-17.2935
273.000	-5.26E-04	6.519E+05	-9804.0730	-4.389E-04	480.2226	6.4865
277.200	-.002252	6.108E+05	-9730.8512	-3.846E-04	449.9317	28.3810
281.400	-.003757	5.702E+05	-9569.6388	-3.339E-04	420.0096	48.3868
285.600	-.005056	5.304E+05	-9330.5237	-2.866E-04	390.7163	65.4775
289.800	-.006164	4.918E+05	-9041.1974	-2.426E-04	362.2738	72.2969
294.000	-.007094	4.545E+05	-8726.4943	-2.020E-04	334.7707	77.5617
298.200	-.007860	4.185E+05	-8392.1629	-1.645E-04	308.2756	81.6437
302.400	-.008476	3.840E+05	-8042.6755	-1.300E-04	282.8413	84.7789
306.600	-.008952	3.509E+05	-7681.6661	-9.840E-05	258.5087	87.1303
310.800	-.009302	3.194E+05	-7312.1761	-6.960E-05	235.3084	88.8173
315.000	-.009537	2.895E+05	-6936.8054	-4.343E-05	213.2621	89.9307
319.200	-.009667	2.612E+05	-6557.8118	-1.977E-05	192.3845	90.5425
323.400	-.009703	2.344E+05	-6177.1805	1.529E-06	172.6834	90.7105
327.600	-.009654	2.093E+05	-5796.6749	2.060E-05	154.1611	90.4826
331.800	-.009530	1.857E+05	-5417.8746	3.757E-05	136.8145	89.8985
336.000	-.009339	1.638E+05	-5042.2052	5.259E-05	120.6361	88.9917
340.200	-.009088	1.434E+05	-4670.9625	6.578E-05	105.6141	87.7905
344.400	-.008786	1.245E+05	-4305.3327	7.730E-05	91.7329	86.3189
348.600	-.008439	1.072E+05	-3946.4102	8.725E-05	78.9734	84.5966
352.800	-.008053	91377.5589	-3595.2126	9.579E-05	67.3131	82.6403
357.000	-.007634	77006.5534	-3252.6959	1.030E-04	56.7267	80.4629
361.200	-.007188	64054.9130	-2919.7684	1.091E-04	47.1859	78.0740
365.400	-.006718	52480.4987	-2597.3050	1.141E-04	38.6597	75.4800
369.600	-.006229	42237.5514	-2286.1624	1.182E-04	31.1142	72.6831
373.800	-.005725	33276.7342	-1987.1967	1.214E-04	24.5132	69.6815
378.000	-.005209	25545.0987	-1701.2827	1.239E-04	18.8178	66.4680
382.200	-.004684	18985.9597	-1429.3386	1.258E-04	13.9860	63.0291
386.400	-.004152	13538.6544	-1172.3583	1.272E-04	9.9732	59.3425
390.600	-.003615	9138.1501	-931.4545	1.282E-04	6.7316	55.3736

394.800	-.003075	5714.4367	-707.9227	1.289E-04	4.2095	51.0701
399.000	-.002533	3191.5997	-503.3406	1.292E-04	2.3511	46.3499
403.200	-.001990	1486.3757	-319.7393	1.294E-04	1.0949	41.0793
407.400	-.001446	505.7897	-169.2750	1.295E-04	.3726	30.5704
411.600	-9.02E-04	64.4655	-64.5194	1.296E-04	.047488	19.3132
415.800	-3.57E-04	-36.1731	-7.6745	1.296E-04	.026647	7.7558
420.000	1.87E-04	0.0000	0.0000	1.296E-04	0.0000	-4.1013

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

Pile-head deflection	=	.71723106	in
Computed slope at pile head	=	-.00366186	
Maximum bending moment	=	1096154.23	lbs-in
Maximum shear force	=	11854.56	lbs
Depth of maximum bending moment	=	201.60	in
Depth of maximum shear force	=	147.00	in
Number of iterations	=	14	
Number of zero deflection points	=	2	

Summary of Pile-head Response

Definition of symbols for pile-head boundary conditions:

y = pile-head displacment, in
M = pile-head moment, lbs-in
V = pile-head shear force, lbs
S = pile-head slope, radians
R = rotational stiffness of pile-head, in-lbs/rad

BC Type	Boundary Condition 1	Boundary Condition 2	Axial Load lbs	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V= 0.000	M= 0.000	0.0000	.7172	1.096E+06	11854.5622

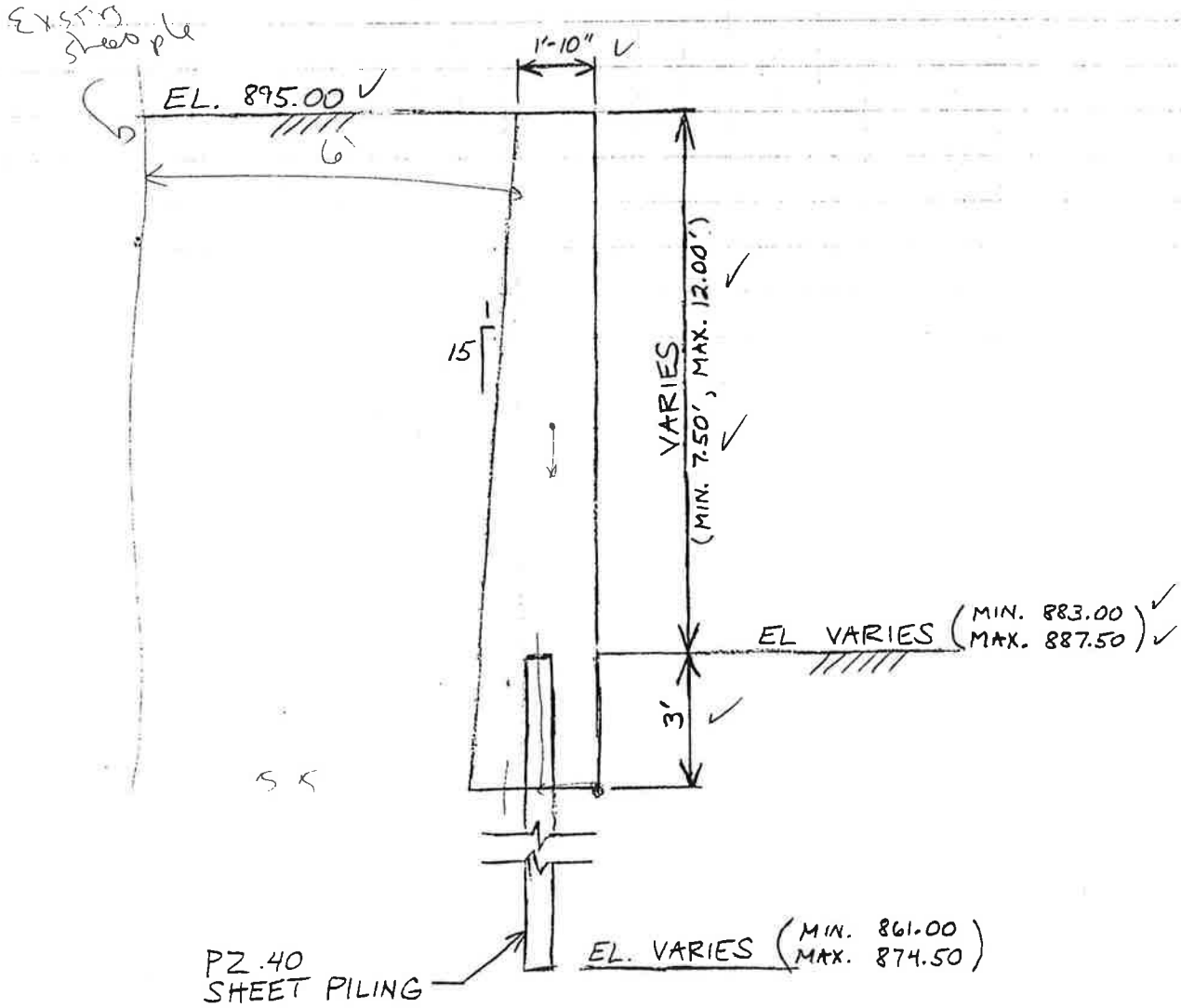
The analysis ended normally.

Concept Design – I-Wall

DLZ

CLIENT OHIO DEPT. OF NATURAL RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT I-WALL
PRELIMINARY DESIGN

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMP. BY JAM DATE 3/7/02
CHECKED BY TAN DATE 4-19-02



* CONCRETE IS 4,000 PSI

CANTILEVERED I-WALL DESIGN

*** Denotes design reference used:** *EM 1110-2-2504 (Design of Sheet Pile Walls)*
**** Denotes computer program used:** *Design and Analysis of Sheet Pile Walls by Classical Methods - CWALSHT (X0031)*

station =	-	
top of wall elevation =	*895.00*	ft
ground elevation behind wall =	*895.00*	ft
ground elevation in front of wall =	*883.00*	ft
bottom of concrete wall elevation =	880.00	ft
L = cantilevered length =	**12.00**	**ft**

Sheet Pile Penetration - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [1]	Factor of Safety - Active "FSA" [2]	Factor of Safety - Passive "FSP" [3]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
1. usual	*1.00*	*1.50*	*892.00*	*894.00*	*862.26*	*20.74*	*52159*	*9340*	*7.3044*	*9.5373*	*8.3955*	*27.7710*

Notes: [1] The depth of 'sheet pile penetration' is determined by running the program (**) in the design mode for all load cases. *[6-1., pg. 6-1]
[2] FSA for all load cases from *[5-2.d., pg. 5-5].
[3] FSP for all load cases determined using the '*Retaining Walls*,' '*Fine-Grained Soils*,' '*S-Case*' value from *[Table 5-1, pg. 5-5].
(For the definitions of 'Q' and 'S' cases, see *[3-3.c.5., pg. 3-4].)

	Pile Penetration		**(load case 1: usual)[1]**
maximum load case penetration =	**20.74**	**ft**	
bottom of sheet piling elevation =	**862.00**	**ft**	O.K.

Sheet Pile Section - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [4]	Factor of Safety - Active "FSA" [5]	Factor of Safety - Passive "FSP" [5]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
2. usual	*1.00*	*1.00*	*892.00*	*894.00*	*868.58*	*14.42*	*37227*	*9387*	*1.8798*	*2.9251*	*2.3782*	*12.7640*

Notes: [4] The required sheet pile section is determined by running the program (**) in the design mode for all load cases. Then, a sheet pile section is selected by checking 'flexure,' 'shear,' 'combined loads,' and 'deflection.' *[6-1., pg. 6-1]
[5] To determine the required sheet pile section, FSA and FSP are equal to 1.00 for all load cases. *[6-1., pg. 6-1]

Concrete Wall Properties

top width of wall =	*1.833*	ft
front face of I-wall slope =	*0.0000*	
rear face of I-wall slope =	*0.0667*	
I_{WALL} = moment of inertia = (1/12)*(1 ft section)*(top width of wall)^3 =	10648.00	in^4
w_c = unit weight of concrete =	*150.00*	lb/ft^3
f_c' = compressive strength of concrete =	*4000.00*	psi
E_c = modulus of elasticity of concrete = $(w_c)^{1.5}*33*(f_c')^{0.5}$ =	3.83	x10^6 psi

1'-10" 12"

$\frac{bd^3}{12}$

ACI Section 8.5.1

Steel Sheet Piling Material Properties

selected sheet piling section: ***PZ40*** **Hot Rolled**

Sheet Piling Properties for Selected "Z" Section

A = area =	11.76	in^2 per ft of wall	t_w = web thickness =	0.500	in
x = nominal width =	19.69	in per section	t_f = flange thickness =	0.600	in
w = weight =	40.00	lb per ft^2 of wall	I_{PILING} = moment of inertia =	490.80	in^4 per ft of wall
h = wall depth =	16.10	in	S = section modulus =	60.70	in^3 per ft of wall

selected steel (A 328, A 572, or A 690): *A 572* HEAVY-GAUGE STEEL, O.K.
select grade: *50.00* O.K.
f_y = yield stress of selected steel = 50.00 ksi
E_S = modulus of elasticity of selected steel = 29.00 $x10^6$ psi

Allowable Stresses for Sheet Piling *[6-3.a.1., pg. 6-1]

Usual Load Case

f_b = combined bending and axial load = $0.5*f_y$
f_v = shear = $0.33*f_y$

	Load Case		
	Usual	Unusual	Extreme
f_b (psi)	25000	33250	43750
f_v (psi)	16500	21945	28875

Note: For unusual loadings the allowable stresses may be increased by 33%.
For extreme loadings the allowable stresses may be increased by 75%.

Required Pile Cross Section for Cantilever Walls *[6-3.c., pg. 6-3]

Flexure *[6-3.c.1.a., pg. 6-3] **(load case 2: usual)[4]**

M_{max} = maximum bending moment = 37227 lb-ft per ft of wall
$S_{min,f}$ = minimum section modulus = M_{max}/f_b = 17.87 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Shear *[6-3.c.1.b., pg. 6-3] **(load case 2: usual)[4]**

V_{max} = maximum shear = 9387 lb per ft of wall
$A_{v,min}$ = minimum shear area = V_{max}/f_v = 0.57 in^2 per ft of wall
A_v = provided shear area of the Z section = $(t_w*h)/x$ = 4.91 in^2 per ft of wall O.K.

Combined Loads *[6-3.c.1.c., pg. 6-4] **(load case 2: usual)[4]**

Note: Combined loads analysis required where external effects (e.g. a concrete cap) may produce an axial load in the pile.

t_{wall} = avg. concrete wall thickness = 2.33 ft
P = applied axial load = self-weight load = 5250.00 lb
y_p = lateral deflection at the point of application of 'P' = 0.97 in
e_p = eccentricity of 'P' from centroidal axis of piling (+ or -) = 0.706 in ('+' direction, towards front face half of wall)

$P*(y_p + e_p)$ = 733.20 lb-ft per ft of wall
$M_{max}/10$ = 3722.70 lb-ft per ft of wall O.K.

$S_{min,cl}$ = min. section modulus = $[M_{max} + P*(y_p + e_p)]/f_b$ = 18.22 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Deflection **(load case 2: usual)[4]**

$\Delta_{TOP(C)}$ = [(scaled defl. at top) - (scaled defl. at bot.)]/(E_C*I_{WALL}) = 0.25 in (elev. = 895.00 ft)
L_{CONC} = top of wall elevation - bottom of concrete wall elevation = 15.00 ft
θ_{PILING} = $\tan^{-1}$[((change in scaled defl. at bottom)/(E_S*I_{PILING}))/(2 ft)] = 0.18 °
$\Delta_{TOP(P)}$ = $L_{CONC}*\tan(\theta_{PILING})$ = 0.55 in (elev. = 895.00 ft)
Δ_{BOT} = (scaled defl. at bot.)/(E_S*I_{PILING}) = 0.17 in (elev. = 880.00 ft)
Δ = total concrete wall deflection = $\Delta_{TOP(C)} + \Delta_{TOP(P)} + \Delta_{BOT}$ = 0.97 in conservative
Δ_{allow} = max. allowable deflection = 1.00 in O.K.

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00	
	PROJECT	BUCKEYE LAKE	SHEET NO.	3	OF 3
	SUBJECT	I-WALL DESIGN (MAX. HEIGHT DESIGN - S-CASE)	COMPUTED BY	JAM	DATE 2/21/02
			CHECKED BY		DATE

"Z" SHAPED SHEET PILING

(information from Pile Buck, Inc. <http://www.pilespecs.com>)

COLD FORMED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
CZ148	8.88	24.02	30.31	13.39	0.433	0.433	273.90	40.92
CZ141	8.48	24.02	28.88	13.39	0.413	0.413	261.40	39.06
CZ128	7.68	24.02	26.22	13.39	0.375	0.375	236.50	35.34
SZ27	7.81	22.00	26.60	12.25	0.375	0.375	195.60	32.00
CZ114	6.88	24.02	23.40	13.39	0.335	0.335	211.60	31.62
CZ114RD	6.43	24.02	21.88	13.39	0.315	0.315	199.24	29.76
SZ25	7.29	22.00	24.80	12.25	0.350	0.350	182.00	29.70
SZ24	7.08	22.00	24.10	12.25	0.340	0.340	177.90	29.00
SZ222	6.50	22.00	22.10	12.25	0.312	0.312	163.40	26.70
SZ22	6.41	26.75	21.80	9.46	0.375	0.375	91.90	19.30
CZ113	6.80	21.65	23.10	7.88	0.375	0.375	72.70	18.40
SZ21	5.98	26.75	20.30	9.46	0.350	0.350	85.90	18.10
SZ20	5.81	26.75	19.80	9.46	0.340	0.340	83.40	17.50
CZ107	6.44	21.65	21.91	7.88	0.354	0.354	68.84	17.48
CZ101	6.08	21.65	20.70	7.88	0.335	0.335	65.01	16.50
SZ18	5.33	26.75	18.10	9.46	0.312	0.312	76.70	16.20
CZ95	5.72	21.65	19.46	7.88	0.315	0.315	61.15	15.53
CZ95RD	5.58	21.65	19.00	7.88	0.308	0.308	59.73	15.16
CZ84	5.05	21.65	17.21	7.88	0.276	0.276	53.63	13.62
SZ14.5	4.27	26.75	14.50	9.46	0.250	0.250	61.40	13.00
CZ72	4.36	21.65	14.83	7.88	0.236	0.236	46.00	11.68
NSZ15	4.17	22.00	13.92	7.50	0.250	0.250	41.71	10.94
CZ67	4.03	21.65	13.72	7.88	0.217	0.217	42.11	10.69
NSZ14	3.99	22.00	13.34	7.50	0.239	0.239	39.90	10.45
SZ15	4.49	20.00	15.40	7.50	0.250	0.250	36.40	10.40
SZ14	4.29	20.00	14.80	7.50	0.239	0.239	34.40	9.80
NSZ12	3.49	22.00	11.66	7.50	0.209	0.209	34.84	9.19
SZ12	3.75	20.00	13.20	7.50	0.209	0.209	30.10	8.60
NSZ11	2.98	22.00	10.01	7.50	0.179	0.179	29.79	7.90
NSZ10	2.74	22.00	9.18	7.50	0.164	0.164	27.39	7.27
SZ11	3.22	20.00	11.40	7.50	0.179	0.179	27.70	7.20
SZ10	2.95	20.00	10.50	7.50	0.165	0.165	25.40	6.60
LZ250	3.69	24.00	12.30	4.50	0.250	0.250	12.40	5.44
LZ3	3.52	24.00	11.79	4.50	0.239	0.239	11.85	5.21
LZ5	3.09	24.00	10.30	4.50	0.209	0.209	10.35	4.58
LZ7	2.64	24.00	8.85	4.50	0.179	0.179	8.85	3.95
LZ8	2.92	24.00	8.11	4.50	0.164	0.164	8.11	3.63

HOT ROLLED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
PZ27 (C)	7.95	18.00	27.00	12.07	0.375	0.375	186.90	31.00
PZ27 (N)	7.94	18.00	27.00	12.00	0.375	0.375	184.20	30.20
PZ22 (C)	6.49	22.00	22.00	9.21	0.375	0.375	85.70	18.60
PZ22 (N)	6.47	22.00	22.00	9.00	0.375	0.375	84.40	18.10

NOTE: For hot rolled sections, "(C)" designates piling manufactured by Chaparral and "(N)" designates piling manufactured by Nucor.

CANTILEVERED I-WALL DESIGN

*** Denotes design reference used:** *EM 1110-2-2504 (Design of Sheet Pile Walls)*
**** Denotes computer program used:** *Design and Analysis of Sheet Pile Walls by Classical Methods - CWALSHT (X0031)*

station = -
top of wall elevation = *895.00* ft
ground elevation behind wall = *895.00* ft
ground elevation in front of wall = *883.00* ft
bottom of concrete wall elevation = 880.00 ft

L = cantilevered length = 12.00 ft

Sheet Pile Penetration - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [1]	Factor of Safety - Active "FSA" [2]	Factor of Safety - Passive "FSP" [3]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
1. usual	*1.00*	*2.00*	*892.00*	*894.00*	*868.36*	*14.64*	*29251*	*5284*	*1.1805*	*1.9344*	*1.5345*	*9.7668*

Notes: [1] The depth of 'sheet pile penetration' is determined by running the program (**) in the design mode for all load cases. *[6-1., pg. 6-1]
[2] FSA for all load cases from *[5-2.d., pg. 5-5].
[3] FSP for all load cases determined using the '*Retaining Walls*,' '*Fine-Grained Soils*,' '*Q-Case*' value from *[Table 5-1, pg. 5-5].
(For the definitions of 'Q' and 'S' cases, see *[3-3.c.5., pg. 3-4].)

Pile Penetration **(load case 1: usual)[1]**
maximum load case penetration = 14.64 ft
bottom of sheet piling elevation = 868.00 ft O.K.

Sheet Pile Section - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [4]	Factor of Safety - Active "FSA" [5]	Factor of Safety - Passive "FSP" [5]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
2. usual	*1.00*	*1.00*	*892.00*	*894.00*	*872.79*	*10.21*	*23077*	*5259*	*0.2173*	*0.5309*	*0.3543*	*5.1120*

Notes: [4] The required sheet pile section is determined by running the program (**) in the design mode for all load cases. Then, a sheet pile section is selected by checking 'flexure,' 'shear,' 'combined loads,' and 'deflection.' *[6-1., pg. 6-1]
[5] To determine the required sheet pile section, FSA and FSP are equal to 1.00 for all load cases. *[6-1., pg. 6-1]

Concrete Wall Properties

top width of wall = *1.833* ft
front face of I-wall slope = *0.0000*
rear face of I-wall slope = *0.0667*

I_{WALL} = moment of inertia = (1/12)*(1 ft section)*(top width of wall)^3 = 10648.00 in^4

w_c = unit weight of concrete = *150.00* lb/ft^3
f_c' = compressive strength of concrete = *4000.00* psi
E_c = modulus of elasticity of concrete = $(w_c)^{1.5}*33*(f_c')^{0.5}$ = 3.83 x10^6 psi

Steel Sheet Piling Material Properties

selected sheet piling section: *PZ40* **Hot Rolled**

Sheet Piling Properties for Selected "Z" Section

A = area =	11.76	in^2 per ft of wall	t_w = web thickness =	0.500	in
x = nominal width =	19.69	in per section	t_f = flange thickness =	0.600	in
w = weight =	40.00	lb per ft^2 of wall	I_{PILING} = moment of inertia =	490.80	in^4 per ft of wall
h = wall depth =	16.10	in	S = section modulus =	60.70	in^3 per ft of wall

selected steel (A 328, A 572, or A 690): *A 572* HEAVY-GAUGE STEEL, O.K.
select grade: *50.00* O.K.
f_y = yield stress of selected steel = 50.00 ksi
E_S = modulus of elasticity of selected steel = 29.00 $x10^6$ psi

Allowable Stresses for Sheet Piling *[6-3.a.1., pg. 6-1]

Usual Load Case
f_b = combined bending and axial load = $0.5*f_y$
f_v = shear = $0.33*f_y$

	Load Case		
	Usual	Unusual	Extreme
f_b (psi)	25000	33250	43750
f_v (psi)	16500	21945	28875

Note: For unusual loadings the allowable stresses may be increased by 33%.
For extreme loadings the allowable stresses may be increased by 75%.

Required Pile Cross Section for Cantilever Walls *[6-3.c., pg. 6-3]

Flexure *[6-3.c.1.a., pg. 6-3] **(load case 2: usual)[4]**

M_{max} = maximum bending moment = 23077 lb-ft per ft of wall
$S_{min,f}$ = minimum section modulus = M_{max}/f_b = 11.08 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Shear *[6-3.c.1.b., pg. 6-3] **(load case 2: usual)[4]**

V_{max} = maximum shear = 5259 lb per ft of wall
$A_{v,min}$ = minimum shear area = V_{max}/f_v = 0.32 in^2 per ft of wall
A_v = provided shear area of the Z section = $(t_w*h)/x$ = 4.91 in^2 per ft of wall O.K.

Combined Loads *[6-3.c.1.c., pg. 6-4] **(load case 2: usual)[4]**

Note: Combined loads analysis required where external effects (e.g. a concrete cap) may produce an axial load in the pile.

t_{wall} = avg. concrete wall thickness = 2.33 ft
P = applied axial load = self-weight load = 5250.00 lb
y_p = lateral deflection at the point of application of 'P' = 0.31 in
e_p = eccentricity of 'P' from centroidal axis of piling (+ or -) = 0.706 in ('+' direction, towards front face half of wall)

$P*(y_p + e_p)$ = 444.45 lb-ft per ft of wall
$M_{max}/10$ = 2307.70 lb-ft per ft of wall O.K.

$S_{min,cl}$ = min. section modulus = $[M_{max} + P*(y_p + e_p)]/f_b$ = 11.29 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Deflection **(load case 2: usual)[4]**

$\Delta_{TOP(C)}$ = [(scaled defl. at top) - (scaled defl. at bot.)]/(E_C*I_{WALL}) = 0.12 in (elev. = 895.00 ft)
L_{CONC} = top of wall elevation - bottom of concrete wall elevation = 15.00 ft
θ_{PILING} = $\tan^{-1}$[((change in scaled defl. at bottom)/(E_S*I_{PILING}))/(2 ft)] = 0.05 °
$\Delta_{TOP(P)}$ = $L_{CONC}*\tan(\theta_{PILING})$ = 0.17 in (elev. = 895.00 ft)
Δ_{BOT} = (scaled defl. at bot.)/(E_S*I_{PILING}) = 0.02 in (elev. = 880.00 ft)
Δ = total concrete wall deflection = $\Delta_{TOP(C)} + \Delta_{TOP(P)} + \Delta_{BOT}$ = 0.31 in Conservative
Δ_{allow} = max. allowable deflection = 1.00 in O.K.

"Z" SHAPED SHEET PILING

(information from Pile Buck, Inc. <http://www.pilespecs.com>)

COLD FORMED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
CZ148	8.88	24.02	30.31	13.39	0.433	0.433	273.90	40.92
CZ141	8.48	24.02	28.88	13.39	0.413	0.413	261.40	39.06
CZ128	7.68	24.02	26.22	13.39	0.375	0.375	236.50	35.34
SZ27	7.81	22.00	26.60	12.25	0.375	0.375	195.60	32.00
CZ114	6.88	24.02	23.40	13.39	0.335	0.335	211.60	31.62
CZ114RD	6.43	24.02	21.88	13.39	0.315	0.315	199.24	29.76
SZ25	7.29	22.00	24.80	12.25	0.350	0.350	182.00	29.70
SZ24	7.08	22.00	24.10	12.25	0.340	0.340	177.90	29.00
SZ222	6.50	22.00	22.10	12.25	0.312	0.312	163.40	26.70
SZ22	6.41	26.75	21.80	9.46	0.375	0.375	91.90	19.30
CZ113	6.80	21.65	23.10	7.88	0.375	0.375	72.70	18.40
SZ21	5.98	26.75	20.30	9.46	0.350	0.350	85.90	18.10
SZ20	5.81	26.75	19.80	9.46	0.340	0.340	83.40	17.50
CZ107	6.44	21.65	21.91	7.88	0.354	0.354	68.84	17.48
CZ101	6.08	21.65	20.70	7.88	0.335	0.335	65.01	16.50
SZ18	5.33	26.75	18.10	9.46	0.312	0.312	76.70	16.20
CZ95	5.72	21.65	19.46	7.88	0.315	0.315	61.15	15.53
CZ95RD	5.58	21.65	19.00	7.88	0.308	0.308	59.73	15.16
CZ84	5.05	21.65	17.21	7.88	0.276	0.276	53.63	13.62
SZ14.5	4.27	26.75	14.50	9.46	0.250	0.250	61.40	13.00
CZ72	4.36	21.65	14.83	7.88	0.236	0.236	46.00	11.68
NSZ15	4.17	22.00	13.92	7.50	0.250	0.250	41.71	10.94
CZ67	4.03	21.65	13.72	7.88	0.217	0.217	42.11	10.69
NSZ14	3.99	22.00	13.34	7.50	0.239	0.239	39.90	10.45
SZ15	4.49	20.00	15.40	7.50	0.250	0.250	36.40	10.40
SZ14	4.29	20.00	14.80	7.50	0.239	0.239	34.40	9.80
NSZ12	3.49	22.00	11.66	7.50	0.209	0.209	34.84	9.19
SZ12	3.75	20.00	13.20	7.50	0.209	0.209	30.10	8.60
NSZ11	2.98	22.00	10.01	7.50	0.179	0.179	29.79	7.90
NSZ10	2.74	22.00	9.18	7.50	0.164	0.164	27.39	7.27
SZ11	3.22	20.00	11.40	7.50	0.179	0.179	27.70	7.20
SZ10	2.95	20.00	10.50	7.50	0.165	0.165	25.40	6.60
LZ250	3.69	24.00	12.30	4.50	0.250	0.250	12.40	5.44
LZ3	3.52	24.00	11.79	4.50	0.239	0.239	11.85	5.21
LZ5	3.09	24.00	10.30	4.50	0.209	0.209	10.35	4.58
LZ7	2.64	24.00	8.85	4.50	0.179	0.179	8.85	3.95
LZ8	2.92	24.00	8.11	4.50	0.164	0.164	8.11	3.63

HOT ROLLED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
PZ27 (C)	7.95	18.00	27.00	12.07	0.375	0.375	186.90	31.00
PZ27 (N)	7.94	18.00	27.00	12.00	0.375	0.375	184.20	30.20
PZ22 (C)	6.49	22.00	22.00	9.21	0.375	0.375	85.70	18.60
PZ22 (N)	6.47	22.00	22.00	9.00	0.375	0.375	84.40	18.10

NOTE: For hot rolled sections, "(C)" designates piling manufactured by Chaparral and "(N)" designates piling manufactured by Nucor.

CANTILEVERED I-WALL DESIGN

*** Denotes design reference used:** *EM 1110-2-2504 (Design of Sheet Pile Walls)*
**** Denotes computer program used:** *Design and Analysis of Sheet Pile Walls by Classical Methods - CWALSHT (X0031)*

station = -
top of wall elevation = *895.00* ft
ground elevation behind wall = *883.00* ft
ground elevation in front of wall = *883.00* ft
bottom of concrete wall elevation = 880.00 ft

L = cantilevered length = 12.00 ft

Sheet Pile Penetration - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [1]	Factor of Safety - Active "FSA" [2]	Factor of Safety - Passive "FSP" [3]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
1. unusual	*1.00*	*1.25*	*883.00*	*892.50*	*864.69*	*18.31*	*35943*	*6954*	*3.4391*	*4.7179*	*4.0619*	*15.0190*

Notes: [1] The depth of 'sheet pile penetration' is determined by running the program (**) in the design mode for all load cases. *[6-1., pg. 6-1]
[2] FSA for all load cases from *[5-2.d., pg. 5-5].
[3] FSP for all load cases determined using the *'Retaining Walls,' 'Fine-Grained Soils,' 'S-Case'* value from *[Table 5-1, pg. 5-5].
(For the definitions of 'Q' and 'S' cases, see *[3-3.c.5., pg. 3-4].)

Pile Penetration **(load case 1: unusual)[1]**
maximum load case penetration = 18.31 ft
bottom of sheet piling elevation = 864.00 ft O.K.

Sheet Pile Section - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [4]	Factor of Safety - Active "FSA" [5]	Factor of Safety - Passive "FSP" [5]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
2. unusual	*1.00*	*1.00*	*883.00*	*892.50*	*868.31*	*14.69*	*28271*	*6507*	*1.4109*	*2.1843*	*1.7813*	*8.9407*

Notes: [4] The required sheet pile section is determined by running the program (**) in the design mode for all load cases. Then, a sheet pile section is selected by checking 'flexure,' 'shear,' 'combined loads,' and 'deflection.' *[6-1., pg. 6-1]
[5] To determine the required sheet pile section, FSA and FSP are equal to 1.00 for all load cases. *[6-1., pg. 6-1]

Concrete Wall Properties

top width of wall = *1.833* ft
front face of I-wall slope = *0.0000*
rear face of I-wall slope = *0.0667*

I_{WALL} = moment of inertia = (1/12)*(1 ft section)*(top width of wall)^3 = 10648.00 in^4

w_C = unit weight of concrete = *150.00* lb/ft^3
f_C' = compressive strength of concrete = *4000.00* psi
E_C = modulus of elasticity of concrete = $(w_C)^{1.5}*33*(f_C')^{0.5}$ = 3.83 x10^6 psi

Steel Sheet Piling Material Properties

selected sheet piling section: ***PZ40*** **Hot Rolled**

Sheet Piling Properties for Selected "Z" Section

A = area =	11.76	in^2 per ft of wall	t_w = web thickness =	0.500	in
x = nominal width =	19.69	in per section	t_f = flange thickness =	0.600	in
w = weight =	40.00	lb per ft^2 of wall	I_{PILING} = moment of inertia =	490.80	in^4 per ft of wall
h = wall depth =	16.10	in	S = section modulus =	60.70	in^3 per ft of wall

selected steel (A 328, A 572, or A 690): *A 572* HEAVY-GAUGE STEEL, O.K.
select grade: *50.00* O.K.
f_y = yield stress of selected steel = 50.00 ksi
E_S = modulus of elasticity of selected steel = 29.00 $x10^6$ psi

Allowable Stresses for Sheet Piling *[6-3.a.1., pg. 6-1]

Usual Load Case
f_b = combined bending and axial load = $0.5*f_y$
f_v = shear = $0.33*f_y$

	Load Case		
	Usual	Unusual	Extreme
f_b (psi)	25000	33250	43750
f_v (psi)	16500	21945	28875

Note: For unusual loadings the allowable stresses may be increased by 33%.
For extreme loadings the allowable stresses may be increased by 75%.

Required Pile Cross Section for Cantilever Walls *[6-3.c., pg. 6-3]

Flexure *[6-3.c.1.a., pg. 6-3] **(load case 2: unusual)[4]**

M_{max} = maximum bending moment = 28271 lb-ft per ft of wall
$S_{min,f}$ = minimum section modulus = M_{max}/f_b = 10.20 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Shear *[6-3.c.1.b., pg. 6-3] **(load case 2: unusual)[4]**

V_{max} = maximum shear = 6507 lb per ft of wall
$A_{v,min}$ = minimum shear area = V_{max}/f_v = 0.30 in^2 per ft of wall
A_v = provided shear area of the Z section = $(t_w*h)/x$ = 4.91 in^2 per ft of wall O.K.

Combined Loads *[6-3.c.1.c., pg. 6-4] **(load case 2: unusual)[4]**

Note: Combined loads analysis required where external effects (e.g. a concrete cap) may produce an axial load in the pile.

t_{wall} = avg. concrete wall thickness = 2.33 ft
P = applied axial load = self-weight load = 5250.00 lb
y_p = lateral deflection at the point of application of 'P' = 0.72 in
e_p = eccentricity of 'P' from centroidal axis of piling (+ or -) = 0.706 in ('+' direction, towards front face half of wall)

$P*(y_p + e_p)$ = 623.82 lb-ft per ft of wall
$M_{max}/10$ = 2827.10 lb-ft per ft of wall O.K.

$S_{min,cl}$ = min. section modulus = $[M_{max} + P*(y_p + e_p)]/f_b$ = 10.43 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Deflection **(load case 2: unusual)[4]**

$\Delta_{TOP(C)}$ = [(scaled defl. at top) - (scaled defl. at bot.)]/(E_C*I_{WALL}) = 0.18 in (elev. = 895.00 ft)
L_{CONC} = top of wall elevation - bottom of concrete wall elevation = 15.00 ft
θ_{PILING} = $\tan^{-1}$[((change in scaled defl. at bottom)/(E_S*I_{PILING}))/(2 ft)] = 0.13 °
$\Delta_{TOP(P)}$ = $L_{CONC}*\tan(\theta_{PILING})$ = 0.41 in (elev. = 895.00 ft)
Δ_{BOT} = (scaled defl. at bot.)/(E_S*I_{PILING}) = 0.13 in (elev. = 880.00 ft)
Δ = total concrete wall deflection = $\Delta_{TOP(C)} + \Delta_{TOP(P)} + \Delta_{BOT}$ = 0.72 in Conservative
Δ_{allow} = max. allowable deflection = 1.00 in O.K.

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00		
	PROJECT	BUCKEYE LAKE	SHEET NO.	3	OF	3
	SUBJECT	I-WALL DESIGN (MAX. HEIGHT DESIGN (WASHOUT) - S-CASE)	COMPUTED BY	JAM	DATE	3/4/02
			CHECKED BY		DATE	

"Z" SHAPED SHEET PILING

(information from Pile Buck, Inc. <http://www.pilespecs.com>)

COLD FORMED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
CZ148	8.88	24.02	30.31	13.39	0.433	0.433	273.90	40.92
CZ141	8.48	24.02	28.88	13.39	0.413	0.413	261.40	39.06
CZ128	7.68	24.02	26.22	13.39	0.375	0.375	236.50	35.34
SZ27	7.81	22.00	26.60	12.25	0.375	0.375	195.60	32.00
CZ114	6.88	24.02	23.40	13.39	0.335	0.335	211.60	31.62
CZ114RD	6.43	24.02	21.88	13.39	0.315	0.315	199.24	29.76
SZ25	7.29	22.00	24.80	12.25	0.350	0.350	182.00	29.70
SZ24	7.08	22.00	24.10	12.25	0.340	0.340	177.90	29.00
SZ222	6.50	22.00	22.10	12.25	0.312	0.312	163.40	26.70
SZ22	6.41	26.75	21.80	9.46	0.375	0.375	91.90	19.30
CZ113	6.80	21.65	23.10	7.88	0.375	0.375	72.70	18.40
SZ21	5.98	26.75	20.30	9.46	0.350	0.350	85.90	18.10
SZ20	5.81	26.75	19.80	9.46	0.340	0.340	83.40	17.50
CZ107	6.44	21.65	21.91	7.88	0.354	0.354	68.84	17.48
CZ101	6.08	21.65	20.70	7.88	0.335	0.335	65.01	16.50
SZ18	5.33	26.75	18.10	9.46	0.312	0.312	76.70	16.20
CZ95	5.72	21.65	19.46	7.88	0.315	0.315	61.15	15.53
CZ95RD	5.58	21.65	19.00	7.88	0.308	0.308	59.73	15.16
CZ84	5.05	21.65	17.21	7.88	0.276	0.276	53.63	13.62
SZ14.5	4.27	26.75	14.50	9.46	0.250	0.250	61.40	13.00
CZ72	4.36	21.65	14.83	7.88	0.236	0.236	46.00	11.68
NSZ15	4.17	22.00	13.92	7.50	0.250	0.250	41.71	10.94
CZ67	4.03	21.65	13.72	7.88	0.217	0.217	42.11	10.69
NSZ14	3.99	22.00	13.34	7.50	0.239	0.239	39.90	10.45
SZ15	4.49	20.00	15.40	7.50	0.250	0.250	36.40	10.40
SZ14	4.29	20.00	14.80	7.50	0.239	0.239	34.40	9.80
NSZ12	3.49	22.00	11.66	7.50	0.209	0.209	34.84	9.19
SZ12	3.75	20.00	13.20	7.50	0.209	0.209	30.10	8.60
NSZ11	2.98	22.00	10.01	7.50	0.179	0.179	29.79	7.90
NSZ10	2.74	22.00	9.18	7.50	0.164	0.164	27.39	7.27
SZ11	3.22	20.00	11.40	7.50	0.179	0.179	27.70	7.20
SZ10	2.95	20.00	10.50	7.50	0.165	0.165	25.40	6.60
LZ250	3.69	24.00	12.30	4.50	0.250	0.250	12.40	5.44
LZ3	3.52	24.00	11.79	4.50	0.239	0.239	11.85	5.21
LZ5	3.09	24.00	10.30	4.50	0.209	0.209	10.35	4.58
LZ7	2.64	24.00	8.85	4.50	0.179	0.179	8.85	3.95
LZ8	2.92	24.00	8.11	4.50	0.164	0.164	8.11	3.63

HOT ROLLED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
PZ27 (C)	7.95	18.00	27.00	12.07	0.375	0.375	186.90	31.00
PZ27 (N)	7.94	18.00	27.00	12.00	0.375	0.375	184.20	30.20
PZ22 (C)	6.49	22.00	22.00	9.21	0.375	0.375	85.70	18.60
PZ22 (N)	6.47	22.00	22.00	9.00	0.375	0.375	84.40	18.10

NOTE: For hot rolled sections, "(C)" designates piling manufactured by Chaparral and "(N)" designates piling manufactured by Nucor.

CANTILEVERED I-WALL DESIGN

*** Denotes design reference used:** *EM 1110-2-2504 (Design of Sheet Pile Walls)*
**** Denotes computer program used:** *Design and Analysis of Sheet Pile Walls by Classical Methods - CWALSHT (X0031)*

station = -
top of wall elevation = *895.00* ft
ground elevation behind wall = *883.00* ft
ground elevation in front of wall = *883.00* ft
bottom of concrete wall elevation = 880.00 ft

L = cantilevered length = 12.00 ft

Sheet Pile Penetration - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [1]	Factor of Safety - Active "FSA" [2]	Factor of Safety - Passive "FSP" [3]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
1. unusual	*1.00*	*1.75*	*883.00*	*892.50*	*867.36*	*15.64*	*21677*	*4187*	*1.2065*	*1.8442*	*1.5107*	*7.5984*

Notes: [1] The depth of 'sheet pile penetration' is determined by running the program (**) in the design mode for all load cases. *[6-1., pg. 6-1]
[2] FSA for all load cases from *[5-2.d., pg. 5-5].
[3] FSP for all load cases determined using the '*Retaining Walls*,' '*Fine-Grained Soils*,' '*Q-Case*' value from *[Table 5-1, pg. 5-5].
(For the definitions of 'Q' and 'S' cases, see *[3-3.c.5., pg. 3-4].)

Pile Penetration **(load case 1: unusual)[1]**
maximum load case penetration = 15.64 ft
bottom of sheet piling elevation = 867.00 ft O.K.

Sheet Pile Section - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [4]	Factor of Safety - Active "FSA" [5]	Factor of Safety - Passive "FSP" [5]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 881.00 (10^9 lb-in^3)	Scaled Defl. at El. 880.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
2. unusual	*1.00*	*1.00*	*883.00*	*892.50*	*872.84*	*10.16*	*15171*	*3751*	*0.1602*	*0.3803*	*0.2575*	*3.1567*

Notes: [4] The required sheet pile section is determined by running the program (**) in the design mode for all load cases. Then, a sheet pile section is selected by checking 'flexure,' 'shear,' 'combined loads,' and 'deflection.' *[6-1., pg. 6-1]
[5] To determine the required sheet pile section, FSA and FSP are equal to 1.00 for all load cases. *[6-1., pg. 6-1]

Concrete Wall Properties

top width of wall = *1.833* ft
front face of I-wall slope = *0.0000*
rear face of I-wall slope = *0.0667*

I_{WALL} = moment of inertia = (1/12)*(1 ft section)*(top width of wall)^3 = 10648.00 in^4

w_c = unit weight of concrete = *150.00* lb/ft^3
f_c' = compressive strength of concrete = *4000.00* psi
E_c = modulus of elasticity of concrete = $(w_c)^{1.5}*33*(f_c')^{0.5}$ = 3.83 x10^6 psi

Steel Sheet Piling Material Properties

selected sheet piling section: *PZ40* **Hot Rolled**

Sheet Piling Properties for Selected "Z" Section

A = area =	11.76	in^2 per ft of wall	t_w = web thickness =	0.500	in
x = nominal width =	19.69	in per section	t_f = flange thickness =	0.600	in
w = weight =	40.00	lb per ft^2 of wall	I_{PILING} = moment of inertia =	490.80	in^4 per ft of wall
h = wall depth =	16.10	in	S = section modulus =	60.70	in^3 per ft of wall

selected steel (A 328, A 572, or A 690):	*A 572*	HEAVY-GAUGE STEEL, O.K.
select grade:	*50.00*	O.K.
f_y = yield stress of selected steel =	50.00	ksi
E_S = modulus of elasticity of selected steel =	29.00	$x10^6$ psi

Allowable Stresses for Sheet Piling *[6-3.a.1., pg. 6-1]

Usual Load Case

f_b = combined bending and axial load = $0.5*f_y$

f_v = shear = $0.33*f_y$

	Load Case		
	Usual	Unusual	Extreme
f_b (psi)	25000	33250	43750
f_v (psi)	16500	21945	28875

Note: For unusual loadings the allowable stresses may be increased by 33%.
For extreme loadings the allowable stresses may be increased by 75%.

Required Pile Cross Section for Cantilever Walls *[6-3.c., pg. 6-3]

Flexure *[6-3.c.1.a., pg. 6-3] **(load case 2: unusual)[4]**

M_{max} = maximum bending moment =	15171	lb-ft per ft of wall	
$S_{min,f}$ = minimum section modulus = M_{max}/f_b =	5.48	in^3 per ft of wall	
S = provided section modulus =	60.70	in^3 per ft of wall	O.K.

Shear *[6-3.c.1.b., pg. 6-3] **(load case 2: unusual)[4]**

V_{max} = maximum shear =	3751	lb per ft of wall	
$A_{v,min}$ = minimum shear area = V_{max}/f_v =	0.17	in^2 per ft of wall	
A_v = provided shear area of the Z section = $(t_w*h)/x$ =	4.91	in^2 per ft of wall	O.K.

Combined Loads *[6-3.c.1.c., pg. 6-4] **(load case 2: unusual)[4]**

Note: Combined loads analysis required where external effects (e.g. a concrete cap) may produce an axial load in the pile.

t_{wall} = avg. concrete wall thickness =	2.33	ft	
P = applied axial load = self-weight load =	5250.00	lb	
y_p = lateral deflection at the point of application of 'P' =	0.21	in	
e_p = eccentricity of 'P' from centroidal axis of piling (+ or -) =	0.706	in	('+' direction, towards front face half of wall)
$P*(y_p + e_p)$ =	400.70	lb-ft per ft of wall	
$M_{max}/10$ =	1517.10	lb-ft per ft of wall	O.K.
$S_{min,cl}$ = min. section modulus = $[M_{max} + P*(y_p + e_p)]/f_b$ =	5.62	in^3 per ft of wall	
S = provided section modulus =	60.70	in^3 per ft of wall	O.K.

Deflection **(load case 2: unusual)[4]**

$\Delta_{TOP(C)}$ = [(scaled defl. at top) - (scaled defl. at bot.)]/(E_C*I_{WALL}) =	0.07	in	(elev. = 895.00 ft)
L_{CONC} = top of wall elevation - bottom of concrete wall elevation =	15.00	ft	
θ_{PILING} = $\tan^{-1}$[((change in scaled defl. at bottom)/(E_S*I_{PILING}))/(2 ft)] =	0.04	°	
$\Delta_{TOP(P)}$ = $L_{CONC}*\tan(\theta_{PILING})$ =	0.12	in	(elev. = 895.00 ft)
Δ_{BOT} = (scaled defl. at bot.)/(E_S*I_{PILING}) =	0.02	in	(elev. = 880.00 ft)
Δ = total concrete wall deflection = $\Delta_{TOP(C)} + \Delta_{TOP(P)} + \Delta_{BOT}$ =	0.21	in	Conservative
Δ_{allow} = max. allowable deflection =	1.00	in	O.K.

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00		
	PROJECT	BUCKEYE LAKE	SHEET NO.	3	OF	3
	SUBJECT	I-WALL DESIGN (MAX. HEIGHT DESIGN (WASHOUT) - Q-CASE)	COMPUTED BY	JAM	DATE	3/4/02
			CHECKED BY		DATE	

"Z" SHAPED SHEET PILING

(information from Pile Buck, Inc. <http://www.pilespecs.com>)

COLD FORMED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
CZ148	8.88	24.02	30.31	13.39	0.433	0.433	273.90	40.92
CZ141	8.48	24.02	28.88	13.39	0.413	0.413	261.40	39.06
CZ128	7.68	24.02	26.22	13.39	0.375	0.375	236.50	35.34
SZ27	7.81	22.00	26.60	12.25	0.375	0.375	195.60	32.00
CZ114	6.88	24.02	23.40	13.39	0.335	0.335	211.60	31.62
CZ114RD	6.43	24.02	21.88	13.39	0.315	0.315	199.24	29.76
SZ25	7.29	22.00	24.80	12.25	0.350	0.350	182.00	29.70
SZ24	7.08	22.00	24.10	12.25	0.340	0.340	177.90	29.00
SZ222	6.50	22.00	22.10	12.25	0.312	0.312	163.40	26.70
SZ22	6.41	26.75	21.80	9.46	0.375	0.375	91.90	19.30
CZ113	6.80	21.65	23.10	7.88	0.375	0.375	72.70	18.40
SZ21	5.98	26.75	20.30	9.46	0.350	0.350	85.90	18.10
SZ20	5.81	26.75	19.80	9.46	0.340	0.340	83.40	17.50
CZ107	6.44	21.65	21.91	7.88	0.354	0.354	68.84	17.48
CZ101	6.08	21.65	20.70	7.88	0.335	0.335	65.01	16.50
SZ18	5.33	26.75	18.10	9.46	0.312	0.312	76.70	16.20
CZ95	5.72	21.65	19.46	7.88	0.315	0.315	61.15	15.53
CZ95RD	5.58	21.65	19.00	7.88	0.308	0.308	59.73	15.16
CZ84	5.05	21.65	17.21	7.88	0.276	0.276	53.63	13.62
SZ14.5	4.27	26.75	14.50	9.46	0.250	0.250	61.40	13.00
CZ72	4.36	21.65	14.83	7.88	0.236	0.236	46.00	11.68
NSZ15	4.17	22.00	13.92	7.50	0.250	0.250	41.71	10.94
CZ67	4.03	21.65	13.72	7.88	0.217	0.217	42.11	10.69
NSZ14	3.99	22.00	13.34	7.50	0.239	0.239	39.90	10.45
SZ15	4.49	20.00	15.40	7.50	0.250	0.250	36.40	10.40
SZ14	4.29	20.00	14.80	7.50	0.239	0.239	34.40	9.80
NSZ12	3.49	22.00	11.66	7.50	0.209	0.209	34.84	9.19
SZ12	3.75	20.00	13.20	7.50	0.209	0.209	30.10	8.60
NSZ11	2.98	22.00	10.01	7.50	0.179	0.179	29.79	7.90
NSZ10	2.74	22.00	9.18	7.50	0.164	0.164	27.39	7.27
SZ11	3.22	20.00	11.40	7.50	0.179	0.179	27.70	7.20
SZ10	2.95	20.00	10.50	7.50	0.165	0.165	25.40	6.60
LZ250	3.69	24.00	12.30	4.50	0.250	0.250	12.40	5.44
LZ3	3.52	24.00	11.79	4.50	0.239	0.239	11.85	5.21
LZ5	3.09	24.00	10.30	4.50	0.209	0.209	10.35	4.58
LZ7	2.64	24.00	8.85	4.50	0.179	0.179	8.85	3.95
LZ8	2.92	24.00	8.11	4.50	0.164	0.164	8.11	3.63

HOT ROLLED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
PZ27 (C)	7.95	18.00	27.00	12.07	0.375	0.375	186.90	31.00
PZ27 (N)	7.94	18.00	27.00	12.00	0.375	0.375	184.20	30.20
PZ22 (C)	6.49	22.00	22.00	9.21	0.375	0.375	85.70	18.60
PZ22 (N)	6.47	22.00	22.00	9.00	0.375	0.375	84.40	18.10

NOTE: For hot rolled sections, "(C)" designates piling manufactured by Chaparral and "(N)" designates piling manufactured by Nucor.

CANTILEVERED I-WALL DESIGN

*** Denotes design reference used:** *EM 1110-2-2504 (Design of Sheet Pile Walls)*
**** Denotes computer program used:** *Design and Analysis of Sheet Pile Walls by Classical Methods - CWALSHT (X0031)*

station = -
top of wall elevation = *895.00* ft
ground elevation behind wall = *895.00* ft
ground elevation in front of wall = *884.00* ft
bottom of concrete wall elevation = *878.00* ft

L = cantilevered length = 11.00 ft

Sheet Pile Penetration - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [1]	Factor of Safety - Active "FSA" [2]	Factor of Safety - Passive "FSP" [3]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 877.00 (10^9 lb-in^3)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 878.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
1. usual	*1.00*	*1.25*	*892.00*	*894.00*	*858.06*	*25.94*	*85367*	*12938*	*14.7480*	*18.7960*	*16.7300*	*56.2130*

Notes: [1] The depth of 'sheet pile penetration' is determined by running the program (**) in the design mode for all load cases. *[6-1., pg. 6-1]
[2] FSA for all load cases from *[5-2.d., pg. 5-5].
[3] FSP for all load cases determined using the '*Retaining Walls*,' '*Fine-Grained Soils*,' '*S-Case*' value from *[Table 5-1, pg. 5-5].
(For the definitions of 'Q' and 'S' cases, see *[3-3.c.5., pg. 3-4].)

Pile Penetration (load case 1: usual)[1]

maximum load case penetration = 25.94 ft
bottom of sheet piling elevation = 858.00 ft O.K.

Sheet Pile Section - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [4]	Factor of Safety - Active "FSA" [5]	Factor of Safety - Passive "FSP" [5]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 877.00 (10^9 lb-in^3)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 878.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
2. usual	*1.00*	*1.00*	*892.00*	*894.00*	*864.93*	*19.07*	*63401*	*13216*	*4.1264*	*6.1158*	*5.0806*	*26.9400*

Notes: [4] The required sheet pile section is determined by running the program (**) in the design mode for all load cases. Then, a sheet pile section is selected by checking 'flexure,' 'shear,' 'combined loads,' and 'deflection.' *[6-1., pg. 6-1]
[5] To determine the required sheet pile section, FSA and FSP are equal to 1.00 for all load cases. *[6-1., pg. 6-1]

Concrete Wall Properties

top width of wall = *1.833* ft
front face of I-wall slope = *0.0000*
rear face of I-wall slope = *0.0667*

I_{WALL} = moment of inertia = (1/12)*(1 ft section)*(top width of wall)^3 = 10648.00 in^4

w_c = unit weight of concrete = *150.00* lb/ft^3
f_c' = compressive strength of concrete = *4000.00* psi
E_c = modulus of elasticity of concrete = $(w_c)^{1.5}*33*(f_c')^{0.5}$ = 3.83 x10^6 psi

Steel Sheet Piling Material Properties

selected sheet piling section: ***PZ40*** **Hot Rolled**

Sheet Piling Properties for Selected "Z" Section

A = area =	11.76	in^2 per ft of wall	t_w = web thickness =	0.500	in
x = nominal width =	19.69	in per section	t_f = flange thickness =	0.600	in
w = weight =	40.00	lb per ft^2 of wall	I_{PILING} = moment of inertia =	490.80	in^4 per ft of wall
h = wall depth =	16.10	in	S = section modulus =	60.70	in^3 per ft of wall

selected steel (A 328, A 572, or A 690): *A 572* HEAVY-GAUGE STEEL, O.K.
select grade: *50.00* O.K.
f_y = yield stress of selected steel = 50.00 ksi
E_S = modulus of elasticity of selected steel = 29.00 $x10^6$ psi

Allowable Stresses for Sheet Piling *[6-3.a.1., pg. 6-1]

Usual Load Case

f_b = combined bending and axial load = $0.5*f_y$
f_v = shear = $0.33*f_y$

	Load Case		
	Usual	Unusual	Extreme
f_b (psi)	25000	33250	43750
f_v (psi)	16500	21945	28875

Note: For unusual loadings the allowable stresses may be increased by 33%.
For extreme loadings the allowable stresses may be increased by 75%.

Required Pile Cross Section for Cantilever Walls *[6-3.c., pg. 6-3]

Flexure *[6-3.c.1.a., pg. 6-3] **(load case 2: usual)[4]**

M_{max} = maximum bending moment = 63401 lb-ft per ft of wall
$S_{min,f}$ = minimum section modulus = M_{max}/f_b = 30.43 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Shear *[6-3.c.1.b., pg. 6-3] **(load case 2: usual)[4]**

V_{max} = maximum shear = 13216 lb per ft of wall
$A_{v,min}$ = minimum shear area = V_{max}/f_v = 0.80 in^2 per ft of wall
A_v = provided shear area of the Z section = $(t_w*h)/x$ = 4.91 in^2 per ft of wall O.K.

Combined Loads *[6-3.c.1.c., pg. 6-4] **(load case 2: usual)[4]**

Note: Combined loads analysis required where external effects (e.g. a concrete cap) may produce an axial load in the pile.

t_{wall} = avg. concrete wall thickness = 2.40 ft
P = applied axial load = self-weight load = 6120.00 lb
y_p = lateral deflection at the point of application of 'P' = 2.09 in
e_p = eccentricity of 'P' from centroidal axis of piling (+ or -) = 0.866 in ('+' direction, towards front face half of wall)

$P*(y_p + e_p)$ = 1507.52 lb-ft per ft of wall
$M_{max}/10$ = 6340.10 lb-ft per ft of wall O.K.

$S_{min,cl}$ = min. section modulus = $[M_{max} + P*(y_p + e_p)]/f_b$ = 31.16 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Deflection **(load case 2: usual)[4]**

$\Delta_{TOP(C)}$ = [(scaled defl. at top) - (scaled defl. at bot.)]/(E_C*I_{WALL}) = 0.54 in (elev. = 895.00 ft)
L_{CONC} = top of wall elevation - bottom of concrete wall elevation = 17.00 ft
θ_{PILING} = $\tan^{-1}$[((change in scaled defl. at bottom)/(E_S*I_{PILING}))/(2 ft)] = 0.33 °
$\Delta_{TOP(P)}$ = $L_{CONC}*\tan(\theta_{PILING})$ = 1.19 in (elev. = 895.00 ft)
Δ_{BOT} = (scaled defl. at bot.)/(E_S*I_{PILING}) = 0.36 in (elev. = ~~878.00~~ ft)
Δ = total concrete wall deflection = $\Delta_{TOP(C)} + \Delta_{TOP(P)} + \Delta_{BOT}$ = 2.09 in
Δ_{allow} = max. allowable deflection = 1.00 in

Noted!

WARNING! REDUCE DEFLECTION!

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00		
	PROJECT	BUCKEYE LAKE	SHEET NO.	3	OF	3
	SUBJECT	I-WALL DESIGN (MAX. HT. DES. (MUCK) - S-CASE)	COMPUTED BY	JAM	DATE	3/4/02
			CHECKED BY		DATE	

"Z" SHAPED SHEET PILING

(information from Pile Buck, Inc. <http://www.pilespecs.com>)

COLD FORMED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
CZ148	8.88	24.02	30.31	13.39	0.433	0.433	273.90	40.92
CZ141	8.48	24.02	28.88	13.39	0.413	0.413	261.40	39.06
CZ128	7.68	24.02	26.22	13.39	0.375	0.375	236.50	35.34
SZ27	7.81	22.00	26.60	12.25	0.375	0.375	195.60	32.00
CZ114	6.88	24.02	23.40	13.39	0.335	0.335	211.60	31.62
CZ114RD	6.43	24.02	21.88	13.39	0.315	0.315	199.24	29.76
SZ25	7.29	22.00	24.80	12.25	0.350	0.350	182.00	29.70
SZ24	7.08	22.00	24.10	12.25	0.340	0.340	177.90	29.00
SZ222	6.50	22.00	22.10	12.25	0.312	0.312	163.40	26.70
SZ22	6.41	26.75	21.80	9.46	0.375	0.375	91.90	19.30
CZ113	6.80	21.65	23.10	7.88	0.375	0.375	72.70	18.40
SZ21	5.98	26.75	20.30	9.46	0.350	0.350	85.90	18.10
SZ20	5.81	26.75	19.80	9.46	0.340	0.340	83.40	17.50
CZ107	6.44	21.65	21.91	7.88	0.354	0.354	68.84	17.48
CZ101	6.08	21.65	20.70	7.88	0.335	0.335	65.01	16.50
SZ18	5.33	26.75	18.10	9.46	0.312	0.312	76.70	16.20
CZ95	5.72	21.65	19.46	7.88	0.315	0.315	61.15	15.53
CZ95RD	5.58	21.65	19.00	7.88	0.308	0.308	59.73	15.16
CZ84	5.05	21.65	17.21	7.88	0.276	0.276	53.63	13.62
SZ14.5	4.27	26.75	14.50	9.46	0.250	0.250	61.40	13.00
CZ72	4.36	21.65	14.83	7.88	0.236	0.236	46.00	11.68
NSZ15	4.17	22.00	13.92	7.50	0.250	0.250	41.71	10.94
CZ67	4.03	21.65	13.72	7.88	0.217	0.217	42.11	10.69
NSZ14	3.99	22.00	13.34	7.50	0.239	0.239	39.90	10.45
SZ15	4.49	20.00	15.40	7.50	0.250	0.250	36.40	10.40
SZ14	4.29	20.00	14.80	7.50	0.239	0.239	34.40	9.80
NSZ12	3.49	22.00	11.66	7.50	0.209	0.209	34.84	9.19
SZ12	3.75	20.00	13.20	7.50	0.209	0.209	30.10	8.60
NSZ11	2.98	22.00	10.01	7.50	0.179	0.179	29.79	7.90
NSZ10	2.74	22.00	9.18	7.50	0.164	0.164	27.39	7.27
SZ11	3.22	20.00	11.40	7.50	0.179	0.179	27.70	7.20
SZ10	2.95	20.00	10.50	7.50	0.165	0.165	25.40	6.60
LZ250	3.69	24.00	12.30	4.50	0.250	0.250	12.40	5.44
LZ3	3.52	24.00	11.79	4.50	0.239	0.239	11.85	5.21
LZ5	3.09	24.00	10.30	4.50	0.209	0.209	10.35	4.58
LZ7	2.64	24.00	8.85	4.50	0.179	0.179	8.85	3.95
LZ8	2.92	24.00	8.11	4.50	0.164	0.164	8.11	3.63

HOT ROLLED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
PZ27 (C)	7.95	18.00	27.00	12.07	0.375	0.375	186.90	31.00
PZ27 (N)	7.94	18.00	27.00	12.00	0.375	0.375	184.20	30.20
PZ22 (C)	6.49	22.00	22.00	9.21	0.375	0.375	85.70	18.60
PZ22 (N)	6.47	22.00	22.00	9.00	0.375	0.375	84.40	18.10

NOTE: For hot rolled sections, "(C)" designates piling manufactured by Chaparral and "(N)" designates piling manufactured by Nucor.

CANTILEVERED I-WALL DESIGN

*** Denotes design reference used:** *EM 1110-2-2504 (Design of Sheet Pile Walls)*
**** Denotes computer program used:** *Design and Analysis of Sheet Pile Walls by Classical Methods - CWALSHT (X0031)*

station = -
top of wall elevation = *895.00* ft
ground elevation behind wall = *895.00* ft
ground elevation in front of wall = *884.00* ft
bottom of concrete wall elevation = *878.00* ft

L = cantilevered length = 11.00 ft

Sheet Pile Penetration - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [1]	Factor of Safety - Active "FSA" [2]	Factor of Safety - Passive "FSP" [3]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 877.00 (10^9 lb-in^3)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 878.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
1. usual	*1.00*	*1.75*	*892.00*	*894.00*	*856.32*	*27.68*	*77379*	*9067*	*14.3660*	*18.2280*	*16.2550*	*54.2140*

Notes: [1] The depth of 'sheet pile penetration' is determined by running the program (**) in the design mode for all load cases. *[6-1., pg. 6-1]
[2] FSA for all load cases from *[5-2.d., pg. 5-5].
[3] FSP for all load cases determined using the '*Retaining Walls*,' '*Fine-Grained Soils*,' '*Q-Case*' value from *[Table 5-1, pg. 5-5].
(For the definitions of 'Q' and 'S' cases, see *[3-3.c.5., pg. 3-4].)

Pile Penetration **(load case 1: usual)[1]**
maximum load case penetration = 27.68 ft
bottom of sheet piling elevation = 856.00 ft O.K.

Sheet Pile Section - Computer Program (**) Output
[output from program (**) based on per ft. of wall]

Load Case [4]	Factor of Safety - Active "FSA" [5]	Factor of Safety - Passive "FSP" [5]	Left Water Elevation (ft)	Right Water Elevation (ft)	Wall Bottom Elevation (ft)	Pene-tration (ft)	Max. Bending Moment (lb-ft)	Max. Shear (lb)	Scaled Defl. at El. 877.00 (10^9 lb-in^3)	Scaled Defl. at El. 879.00 (10^9 lb-in^3)	Scaled Defl. at El. 878.00 (10^9 lb-in^3)	Scaled Defl. at El. 895.00 (10^9 lb-in^3)
2. usual	*1.00*	*1.00*	*892.00*	*894.00*	*863.17*	*20.83*	*60797*	*9170*	*4.4183*	*6.4202*	*5.3791*	*27.3360*

Notes: [4] The required sheet pile section is determined by running the program (**) in the design mode for all load cases. Then, a sheet pile section is selected by checking 'flexure,' 'shear,' 'combined loads,' and 'deflection.' *[6-1., pg. 6-1]
[5] To determine the required sheet pile section, FSA and FSP are equal to 1.00 for all load cases. *[6-1., pg. 6-1]

Concrete Wall Properties

top width of wall = *1.833* ft
front face of I-wall slope = *0.0000*
rear face of I-wall slope = *0.0667*

I_{WALL} = moment of inertia = (1/12)*(1 ft section)*(top width of wall)^3 = 10648.00 in^4

w_c = unit weight of concrete = *150.00* lb/ft^3
f_c' = compressive strength of concrete = *4000.00* psi
E_c = modulus of elasticity of concrete = $(w_c)^{1.5}*33*(f_c')^{0.5}$ = 3.83 x10^6 psi

Steel Sheet Piling Material Properties

selected sheet piling section: *PZ40* **Hot Rolled**

Sheet Piling Properties for Selected "Z" Section

A = area =	11.76	in^2 per ft of wall	t_w = web thickness =	0.500	in
x = nominal width =	19.69	in per section	t_f = flange thickness =	0.600	in
w = weight =	40.00	lb per ft^2 of wall	I_{PILING} = moment of inertia =	490.80	in^4 per ft of wall
h = wall depth =	16.10	in	S = section modulus =	60.70	in^3 per ft of wall

selected steel (A 328, A 572, or A 690): *A 572* HEAVY-GAUGE STEEL, O.K.
select grade: *50.00* O.K.
f_y = yield stress of selected steel = 50.00 ksi
E_S = modulus of elasticity of selected steel = 29.00 $x10^6$ psi

Allowable Stresses for Sheet Piling *[6-3.a.1., pg. 6-1]

Usual Load Case

f_b = combined bending and axial load = $0.5*f_y$
f_v = shear = $0.33*f_y$

	Load Case		
	Usual	Unusual	Extreme
f_b (psi)	25000	33250	43750
f_v (psi)	16500	21945	28875

Note: For unusual loadings the allowable stresses may be increased by 33%.
For extreme loadings the allowable stresses may be increased by 75%.

Required Pile Cross Section for Cantilever Walls *[6-3.c., pg. 6-3]

Flexure *[6-3.c.1.a., pg. 6-3] **(load case 2: usual)[4]**

M_{max} = maximum bending moment = 60797 lb-ft per ft of wall
$S_{min,f}$ = minimum section modulus = M_{max}/f_b = 29.18 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Shear *[6-3.c.1.b., pg. 6-3] **(load case 2: usual)[4]**

V_{max} = maximum shear = 9170 lb per ft of wall
$A_{v,min}$ = minimum shear area = V_{max}/f_v = 0.56 in^2 per ft of wall
A_v = provided shear area of the Z section = $(t_w*h)/x$ = 4.91 in^2 per ft of wall O.K.

Combined Loads *[6-3.c.1.c., pg. 6-4] **(load case 2: usual)[4]**

Note: Combined loads analysis required where external effects (e.g. a concrete cap) may produce an axial load in the pile.

t_{wall} = avg. concrete wall thickness = 2.40 ft
P = applied axial load = self-weight load = 6120.00 lb
y_p = lateral deflection at the point of application of 'P' = 2.12 in
e_p = eccentricity of 'P' from centroidal axis of piling (+ or -) = 0.866 in ('+' direction, towards front face half of wall)

$P*(y_p + e_p)$ = 1522.82 lb-ft per ft of wall
$M_{max}/10$ = 6079.70 lb-ft per ft of wall O.K.

$S_{min,cl}$ = min. section modulus = $[M_{max} + P*(y_p + e_p)]/f_b$ = 29.91 in^3 per ft of wall
S = provided section modulus = 60.70 in^3 per ft of wall O.K.

Deflection **(load case 2: usual)[4]**

$\Delta_{TOP(C)}$ = [(scaled defl. at top) - (scaled defl. at bot.)]/(E_C*I_{WALL}) = 0.54 in (elev. = 895.00 ft)
L_{CONC} = top of wall elevation - bottom of concrete wall elevation = 17.00 ft
θ_{PILING} = $\tan^{-1}$[((change in scaled defl. at bottom)/(E_S*I_{PILING}))/(2 ft)] = 0.34 °
$\Delta_{TOP(P)}$ = $L_{CONC}*\tan(\theta_{PILING})$ = 1.20 in (elev. = 895.00 ft)
Δ_{BOT} = (scaled defl. at bot.)/(E_S*I_{PILING}) = 0.38 in (elev. = 878.00 ft)
Δ = total concrete wall deflection = $\Delta_{TOP(C)} + \Delta_{TOP(P)} + \Delta_{BOT}$ = 2.12 in
Δ_{allow} = max. allowable deflection = 1.00 in

Noted!

WARNING! REDUCE DEFLECTION!

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00		
	PROJECT	BUCKEYE LAKE	SHEET NO.	3	OF	3
	SUBJECT	I-WALL DESIGN (MAX. HT. DES. (MUCK) - Q-CASE)	COMPUTED BY	JAM	DATE	3/4/02
			CHECKED BY		DATE	

"Z" SHAPED SHEET PILING

(information from Pile Buck, Inc. <http://www.pilespecs.com>)

COLD FORMED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
CZ148	8.88	24.02	30.31	13.39	0.433	0.433	273.90	40.92
CZ141	8.48	24.02	28.88	13.39	0.413	0.413	261.40	39.06
CZ128	7.68	24.02	26.22	13.39	0.375	0.375	236.50	35.34
SZ27	7.81	22.00	26.60	12.25	0.375	0.375	195.60	32.00
CZ114	6.88	24.02	23.40	13.39	0.335	0.335	211.60	31.62
CZ114RD	6.43	24.02	21.88	13.39	0.315	0.315	199.24	29.76
SZ25	7.29	22.00	24.80	12.25	0.350	0.350	182.00	29.70
SZ24	7.08	22.00	24.10	12.25	0.340	0.340	177.90	29.00
SZ222	6.50	22.00	22.10	12.25	0.312	0.312	163.40	26.70
SZ22	6.41	26.75	21.80	9.46	0.375	0.375	91.90	19.30
CZ113	6.80	21.65	23.10	7.88	0.375	0.375	72.70	18.40
SZ21	5.98	26.75	20.30	9.46	0.350	0.350	85.90	18.10
SZ20	5.81	26.75	19.80	9.46	0.340	0.340	83.40	17.50
CZ107	6.44	21.65	21.91	7.88	0.354	0.354	68.84	17.48
CZ101	6.08	21.65	20.70	7.88	0.335	0.335	65.01	16.50
SZ18	5.33	26.75	18.10	9.46	0.312	0.312	76.70	16.20
CZ95	5.72	21.65	19.46	7.88	0.315	0.315	61.15	15.53
CZ95RD	5.58	21.65	19.00	7.88	0.308	0.308	59.73	15.16
CZ84	5.05	21.65	17.21	7.88	0.276	0.276	53.63	13.62
SZ14.5	4.27	26.75	14.50	9.46	0.250	0.250	61.40	13.00
CZ72	4.36	21.65	14.83	7.88	0.236	0.236	46.00	11.68
NSZ15	4.17	22.00	13.92	7.50	0.250	0.250	41.71	10.94
CZ67	4.03	21.65	13.72	7.88	0.217	0.217	42.11	10.69
NSZ14	3.99	22.00	13.34	7.50	0.239	0.239	39.90	10.45
SZ15	4.49	20.00	15.40	7.50	0.250	0.250	36.40	10.40
SZ14	4.29	20.00	14.80	7.50	0.239	0.239	34.40	9.80
NSZ12	3.49	22.00	11.66	7.50	0.209	0.209	34.84	9.19
SZ12	3.75	20.00	13.20	7.50	0.209	0.209	30.10	8.60
NSZ11	2.98	22.00	10.01	7.50	0.179	0.179	29.79	7.90
NSZ10	2.74	22.00	9.18	7.50	0.164	0.164	27.39	7.27
SZ11	3.22	20.00	11.40	7.50	0.179	0.179	27.70	7.20
SZ10	2.95	20.00	10.50	7.50	0.165	0.165	25.40	6.60
LZ250	3.69	24.00	12.30	4.50	0.250	0.250	12.40	5.44
LZ3	3.52	24.00	11.79	4.50	0.239	0.239	11.85	5.21
LZ5	3.09	24.00	10.30	4.50	0.209	0.209	10.35	4.58
LZ7	2.64	24.00	8.85	4.50	0.179	0.179	8.85	3.95
LZ8	2.92	24.00	8.11	4.50	0.164	0.164	8.11	3.63

HOT ROLLED

Section Desig.	Area "A" (in^2/ft)	Nominal Width "x" (in)	Weight "w" (lb/ft^2)	Wall Depth "h" (in)	Web Thickness "t_w" (in)	Flange Thickness "t_f" (in)	Mom. of Inertia "I" (in^4/ft)	Section Modulus "S" (in^3/ft)
PZ27 (C)	7.95	18.00	27.00	12.07	0.375	0.375	186.90	31.00
PZ27 (N)	7.94	18.00	27.00	12.00	0.375	0.375	184.20	30.20
PZ22 (C)	6.49	22.00	22.00	9.21	0.375	0.375	85.70	18.60
PZ22 (N)	6.47	22.00	22.00	9.00	0.375	0.375	84.40	18.10

NOTE: For hot rolled sections, "(C)" designates piling manufactured by Chaparral and "(N)" designates piling manufactured by Nucor.

Concept Design – Inverted T-Wall

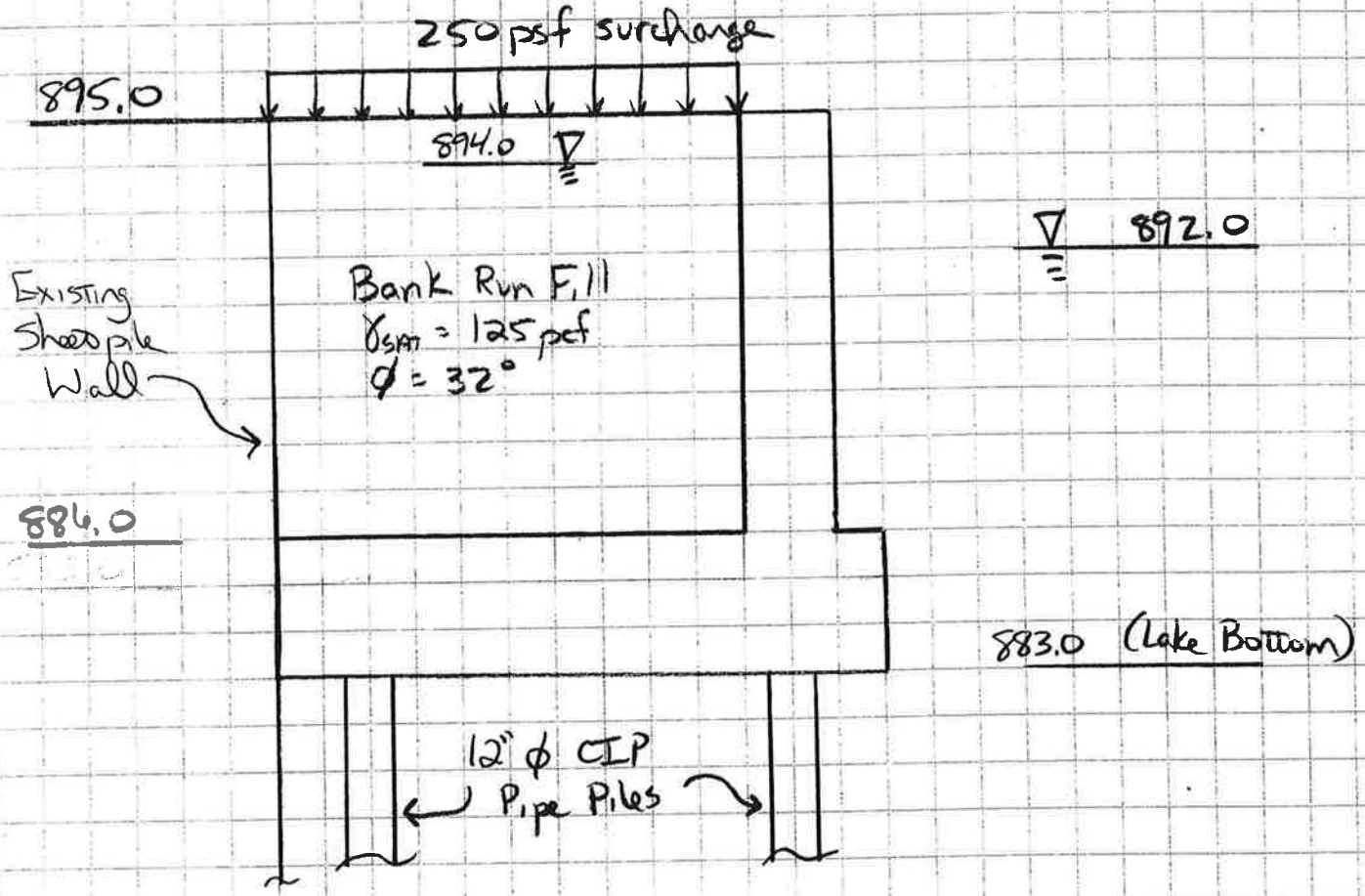
DLZ

CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Inverted T-Wall Preliminary Design

PROJECT NO. 0121-3074 00
SHEET NO. 1 OF 7
COMP. BY TRM DATE 3-1-02
CHECKED BY JAM DATE 4/18/02

Concept Wall Cross-Section

- Normal Operating Conditions



The drawing above shows ~~the~~ "normal" operating conditions. The FBD of ~~the~~ section is presented on ~~the~~ following page.

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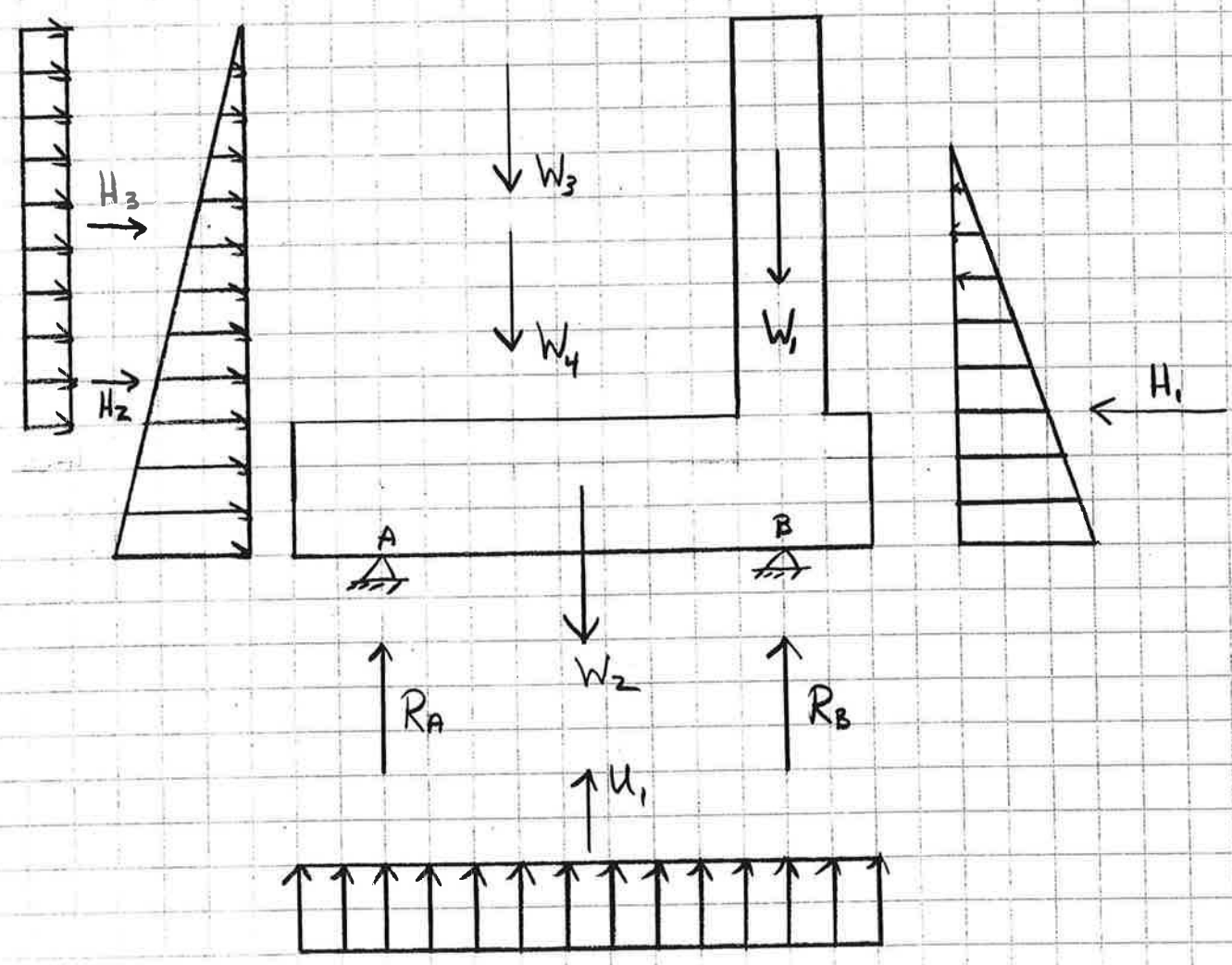
CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Inverted T-Wall Preliminary Design

PROJECT NO. 0121-3074-00
SHEET NO. 2 OF #7
COMP. BY TAM DATE 3-1-02
CHECKED BY JAM DATE 4/18/02

FBD - Normal Operating Conditions



for fill: $1-\sin\phi = 1-\sin(32°) = 0.47$

- Consider a 1' strip of the wall.

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PROJECT Buckeye Lake
SUBJECT Inverted T-Wall Preliminary Design

PROJECT NO. 0121-3074-00
SHEET NO. 3 OF 7
COMP. BY TAA DATE 3-1-02
CHECKED BY JAM DATE 4/18/02

W_1 = Weight of concrete Wall = (1')(2')(9')(.150 kcf) = 2.7 K

W_2 = Weight of concrete footing = (1')(3')(13')(.150 kcf) = 5.9 K

W_3 = Vehicle surcharge = (1')(10')(.250 Ksf) = 2.5 K

W_4 = Weight of soil fill = (1')(10')(9')(.125 kcf) = 11.3 K

U_1 = Uplift under footing = (9')(.0624 kcf)(1')(13') = 7.3 K

H_1 = Horizontal load from water in lake = (1')(9')(.0624 kcf)(9')(1/2) = 2.5 K
(located 3' above bottom of footing)

H_2 = Soil lateral load on wall = [62.4+(0.47)(125-62.4)](12')(1/2)(12') = 6.6 K
(located 4' above bottom of footing)

H_3 = lateral load from vehicle surcharge = (1')(9')(.250 ksf)(.47) = 1.1 K
(located 7.5' above bottom of footing)

Determine Pile reactions:

$$\circlearrowleft + \Sigma M_A = 0 = (9')(W_1) + (4.5')(W_2) + (3')(W_3) + (3')(W_4) + (4')(H_2) + (7.5')(H_3) - (4.5')(U_1) - (3')(H_1) - (9')R_B$$

$$= (9)(2.7) + (4.5)(5.9) + (3)(2.5) + (3)(11.3) + (4)(6.6) + (7.5)(1.1) - (4.5)(7.3) - (3)(2.5) - (9)R_B$$

$$\Rightarrow R_B = 9.6 \text{ K}$$

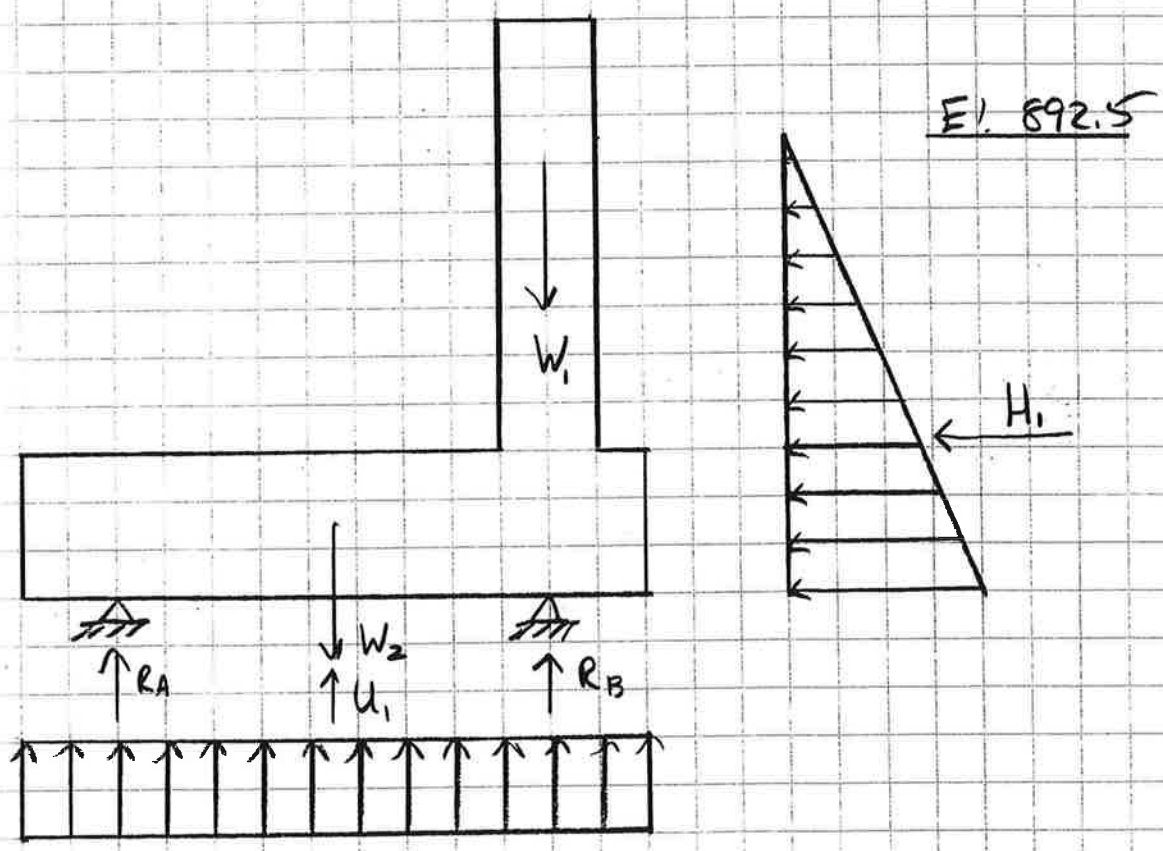
$$+\uparrow \Sigma F_V = 0 = 7.3\text{K} + 9.6\text{K} + R_A - 2.7 - 5.9 - 2.5 - 11.3 \Rightarrow R_A = 5.5 \text{ K}$$

$$\xrightarrow{+} \Sigma F_V = 0 = 6.6\text{K} + 1.1 - 2.5 = 5.2 \text{ K}$$

(Piles will need to carry lateral load)
(Pile @ "B" needs to carry ~~the~~ lateral load)

- Now consider conditions after a flood has occured and washed out all ~~the~~ fill behind ~~the~~ wall.

- <u>After Flood Conditions</u>



H_1 = Horizontal load from Water in lake = $(1')(9.5')(.0624\ kcf)(9.5')(1/2) = 2.8\ K$

U_1 = Uplift under footing = $(9.5')(.0624\ kcf)(13')(1') = 7.7\ K$

$W_1 = 2.7\ K$ (from before)

$W_2 = 5.9\ K$ (from before)

DLZ

SUBJECT	ODNR	JOB NUMBER	0121-3074-00
	Buckeye Lake	SHEET NO.	3 OF 8
	Inverted T-Wall Preliminary Design	COMP. BY	TAH DATE 4/18/2002
	Quantity and Cost Estimate	CHECKED BY	JAM DATE 4/18/02

Quantities and cost per section

Section 3: Section length = 895 ft

Average property width = 56.89 ft

No. of properties in section = 16

x 4 extra piles per property = 64 extra piles for boat docks

Quantities:

Concrete:	2.04	yds^3/ft	x	895	ft =	1826	yds^3				
Backfill:	2.96	yds^3/ft	x	895	ft =	2649	yds^3				
Piles	182	+	64	=	246	piles x	50	ft/pile =	12300	ft	

Cost:

Concrete:	1826	yds^3 x	$550	/yds^3 =	$1,004,300
Backfill:	2649	yds^3 x	$40	/yds^3 =	$105,960
Piles:	12300	ft x	$38	/ft =	$467,400

Total cost Section 3:	$1,577,660

DLZ

SUBJECT	ODNR	JOB NUMBER	0121-3074-00
	Buckeye Lake	SHEET NO.	4 OF 8
	Inverted T-Wall Preliminary Design	COMP. BY	TAH DATE 4/18/2002
	Quantity and Cost Estimate	CHECKED BY	JAM DATE 4/18/02

Quantities and cost per section

Section 4: Section length = 550 ft

Average property width = 56.89 ft

No. of properties in section = 10

x 4 extra piles per property = 40 extra piles for boat docks

Quantities:

Concrete:	2.04	yds^3/ft	x	550	ft =	1122	yds^3					
Backfill:	2.96	yds^3/ft	x	550	ft =	1628	yds^3					
Piles	112	+	40	=	152	piles x	50	ft/pile =	7600	ft		

Cost:

Concrete:	1122	yds^3 x	$550	/yds^3 =	$617,100
Backfill:	1628	yds^3 x	$40	/yds^3 =	$65,120
Piles:	7600	ft x	$38	/ft =	$288,800

Total cost Section 4:	$971,020

DLZ

SUBJECT	ODNR	JOB NUMBER	0121-3074-00
	Buckeye Lake	SHEET NO.	5 OF 8
	Inverted T-Wall Preliminary Design	COMP. BY	TAH DATE 4/18/2002
	Quantity and Cost Estimate	CHECKED BY	J+M DATE 4/18/02

Quantities and cost per section

Section 5a: Section length = 7570 ft

Average property width = 56.89 ft

No. of properties in section = 133

x 4 extra piles per property = 532 extra piles for boat docks

Quantities:

Concrete:	2.11	yds^3/ft	x	7570	ft =	15973	yds^3				
Backfill:	3.33	yds^3/ft	x	7570	ft =	25208	yds^3				
Piles	1516	+	532	=	2048	piles x	50	ft/pile =	102400	ft	

Cost:

Concrete:	15973	yds^3 x	$550	/yds^3 =	$8,785,150
Backfill:	25208	yds^3 x	$40	/yds^3 =	$1,008,320
Piles:	102400	ft x	$38	/ft =	$3,891,200

Total cost Section 5a:	$13,684,670

DLZ

SUBJECT	ODNR	JOB NUMBER	0121-3074-00
	Buckeye Lake	SHEET NO.	6 OF 8
	Inverted T-Wall Preliminary Design	COMP. BY	TAH DATE 4/18/2002
	Quantity and Cost Estimate	CHECKED BY	JAM DATE 4/18/02

Quantities and cost per section

Section 5b: Section length = 1370 ft

Average property width = 56.89 ft

No. of properties in section = 24

x 4 extra piles per property = 96 extra piles for boat docks

Quantities:

Concrete:	2.11	yds^3/ft	x	1370	ft =	2891	yds^3
Backfill:	3.33	yds^3/ft	x	1370	ft =	4562	yds^3
Piles	276	+	96	=	372	piles x	50 ft/pile = 18600 ft

Cost:

Concrete:	2891	yds^3 x	$550	$/yds^3$ =	$1,590,050
Backfill:	4562	yds^3 x	$40	$/yds^3$ =	$182,480
Piles:	18600	ft x	$38	/ft =	$706,800

Total cost Section 5b:	$2,479,330

DLZ

SUBJECT	ODNR	JOB NUMBER	0121-3074-00
	Buckeye Lake	SHEET NO.	7 OF 8
	Inverted T-Wall Preliminary Design	COMP. BY	TAH DATE 4/18/2002
	Quantity and Cost Estimate	CHECKED BY	JAM DATE 4/18/02

Quantities and cost per section

Section 6: Section length = 1860 ft

Average property width = 56.89 ft

No. of properties in section = 33

x 4 extra piles per property = 132 extra piles for boat docks

Quantities:

Concrete:	2.11	yds^3/ft	x	1860	ft =	3925	yds^3				
Backfill:	3.33	yds^3/ft	x	1860	ft =	6194	yds^3				
Piles	374	+	132	=	506	piles x	50	ft/pile =	25300	ft	

Cost:

Concrete:	3925	yds^3 x	$550	/yds^3 =	$2,158,750
Backfill:	6194	yds^3 x	$40	/yds^3 =	$247,760
Piles:	25300	ft x	$38	/ft =	$961,400

Total cost Section 6:	$3,367,910

DLZ

SUBJECT ODNR
Buckeye Lake
Inverted T-Wall Preliminary Design
Quantity and Cost Estimate

JOB NUMBER 0121-3074-00
SHEET NO. 8 OF 8
COMP. BY TAH DATE 4/18/02
CHECKED BY JAM DATE 4/18/02

Summary of quantities and cost

SECTION 1	Quantity		Cost
Concrete	9318	yds^3	$5,124,900
Backfill	8742	yds^3	$349,680
Piles	70900	lin. Ft	$2,694,200
	Total Cost:		$8,168,780

SECTION 2	Quantity		Cost
Concrete	4035	yds^3	$2,219,250
Backfill	4740	yds^3	$189,600
Piles	29100	lin. Ft	$1,105,800
	Total Cost:		$3,514,650

SECTION 3	Quantity		Cost
Concrete	1826	yds^3	$1,004,300
Backfill	2649	yds^3	$105,960
Piles	12300	lin. Ft	$467,400
	Total Cost:		$1,577,660

SECTION 4	Quantity		Cost
Concrete	1122	yds^3	$617,100
Backfill	1628	yds^3	$65,120
Piles	7600	lin. Ft	$288,800
	Total Cost:		$971,020

SECTION 5a	Quantity		Cost
Concrete	15973	yds^3	$8,785,150
Backfill	25208	yds^3	$1,008,320
Piles	102400	lin. Ft	$3,891,200
	Total Cost:		$13,684,670

SECTION 5b	Quantity		Cost
Concrete	2891	yds^3	$1,590,050
Backfill	4562	yds^3	$182,480
Piles	18600	lin. Ft	$706,800
	Total Cost:		$2,479,330

SECTION 6	Quantity		Cost
Concrete	3925	yds^3	$2,158,750
Backfill	6194	yds^3	$247,760
Piles	25300	lin. Ft	$961,400
	Total Cost:		$3,367,910

TOTAL	Quantity		Cost
Concrete	39090	yds^3	$21,499,500
Backfill	53723	yds^3	$2,148,920
Piles	266200	lin. Ft	$10,115,600
	Total Cost:		$33,764,020

DLZ

CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Inverted T-Wall Preliminary Design

PROJECT NO. 0121-3094-00
SHEET NO. 1 OF 2
COMP. BY TRA DATE 3-11-02
CHECKED BY JAM DATE 4/18/02

Cost Estimate

- For cost estimate, use (from Peter Nix on 3/6/02):

$40/yd^3$ for excavation
$40/yd^3$ for fill

- Concrete: - Assume concrete will be delivered to row wall via barge
  - Barge can carry one fully loaded concrete truck
  - Assume 1 hour total travel time for barge (½ each way to/from wall from mud Island) and 1 hour unload time. Assume 10 hour work day.

- Therefore, in a 10 hour day,

10 hours/(2 hours/truck) = 5 trucks/day

- Barge reportedly costs $1500/day

$1500/5 trucks = $300/truck

- Assume 8 yds^3/truck

$300/8 yds^3 = $37.50/$yd^3$

Therefore, costs for concrete will be

$500 + 37.50 = $537.50 say $550/$yd^3$ reinforced

$100 + 37.50 = $137.50 say $150/$yd^3$ unreinforced

DLZ

CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Inverted T-Wall Preliminary Design

PROJECT NO. 012-3070.00
SHEET NO. 2 OF 2
COMP. BY TRR DATE 3-12-02
CHECKED BY JAM DATE 4/18/02

CIP Piles

- Assume contractor can install 10 CIP's per day from a barge

$1500/10 = $150/CIP extra to install from barge

- Assume 50' long CIP piles

$150/50' = $~~30~~ 3/ft of CIP pile

Therefore, cost of CIP piles will be

$25/ft + $~~30~~ 3/ft = $~~55~~ 28/ft

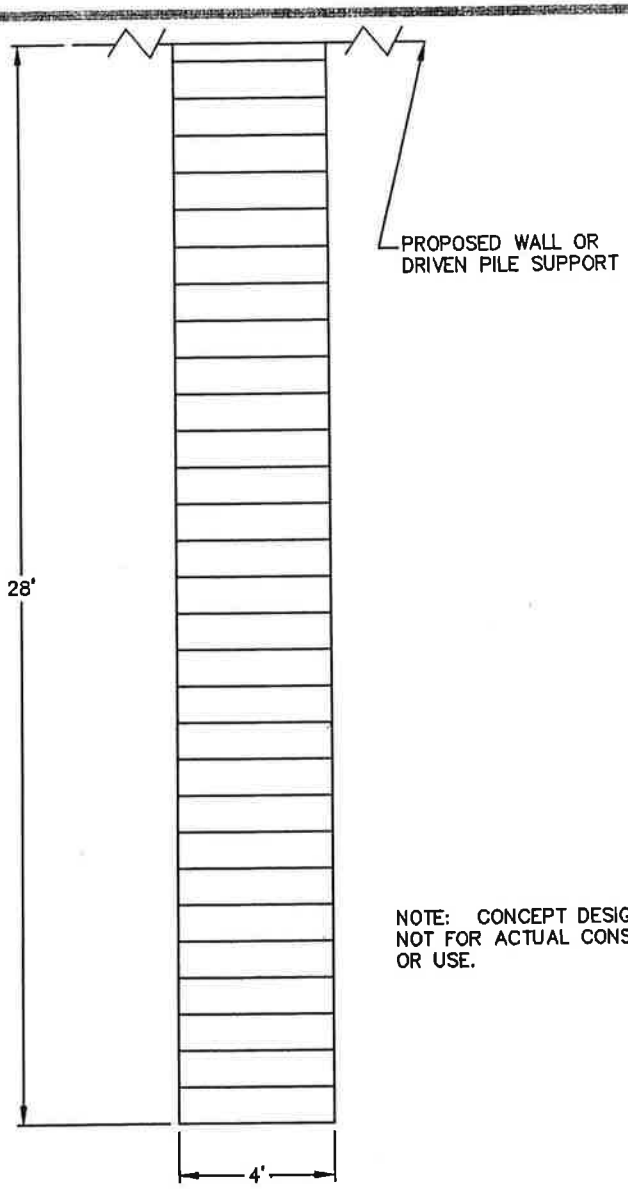
However, after discussion with Pete Nix, this number still seems low. Therefore, use a 50% increase over standard cost:

($25/ft)(1.5) = $37.50/ft

say $38/ft

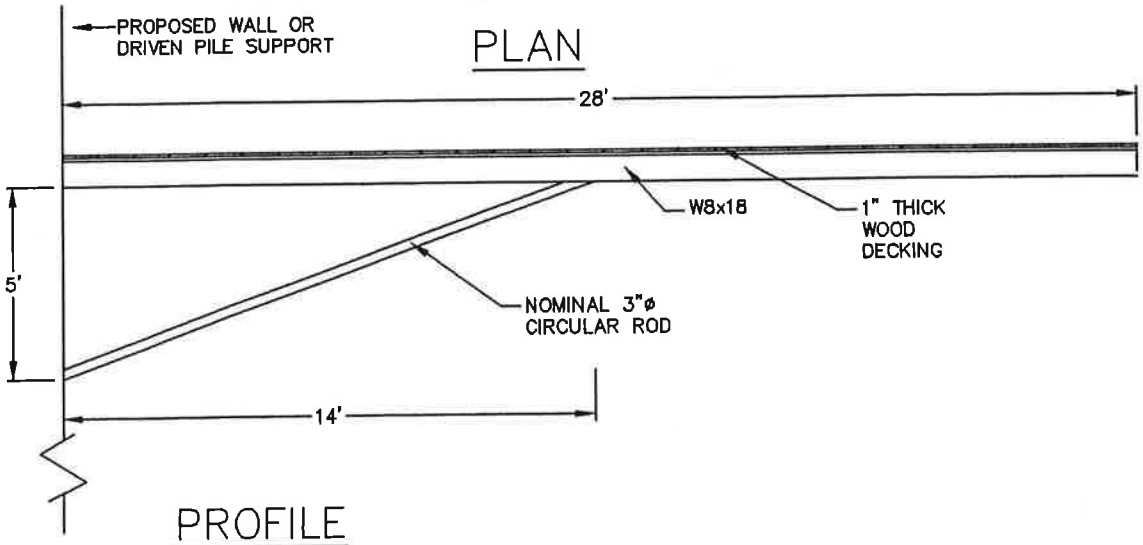
APPENDIX VI

Boat Dock Design



NOTE: CONCEPT DESIGN ONLY.
NOT FOR ACTUAL CONSTRUCTION
OR USE.

PLAN



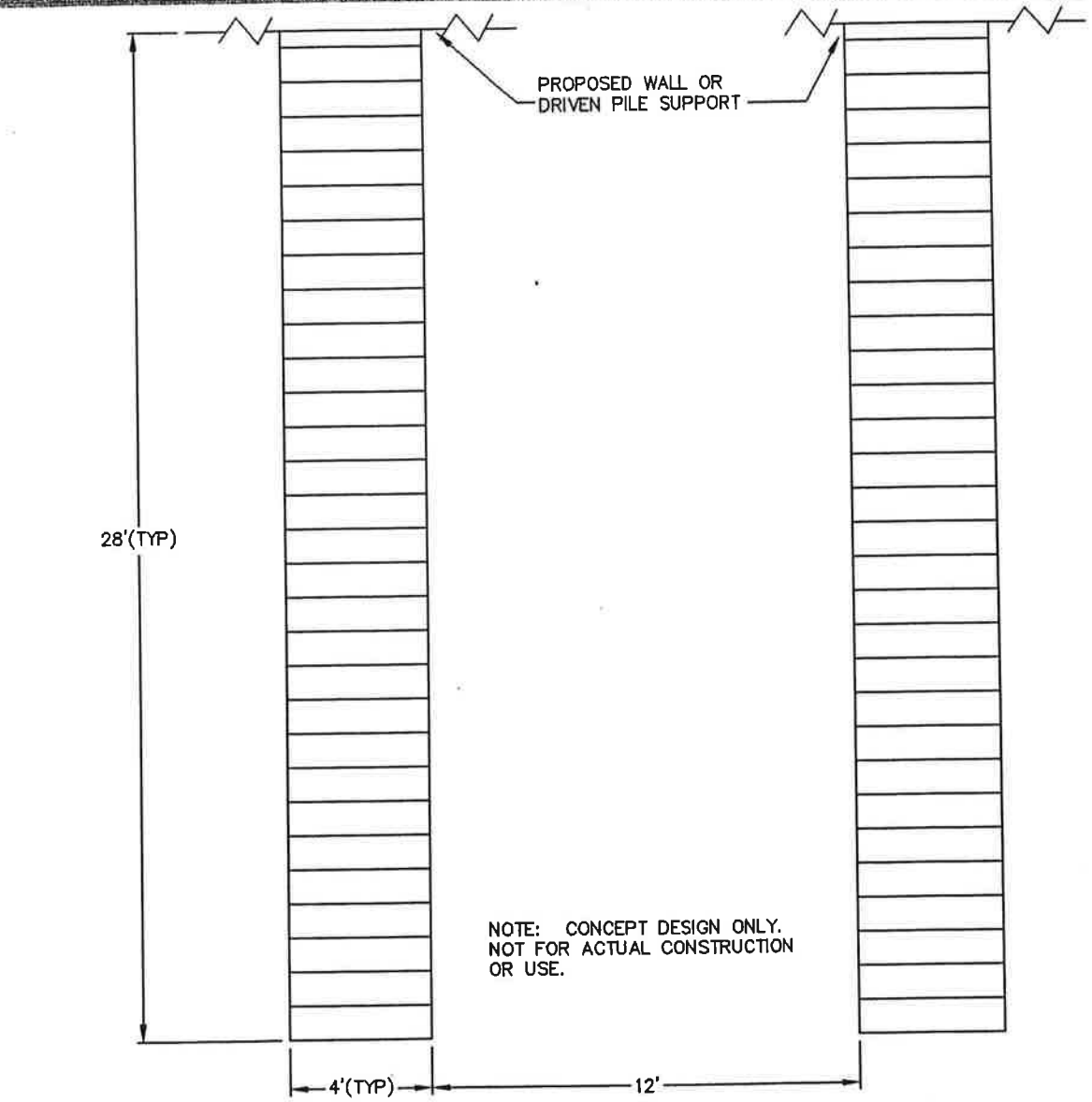
PROFILE

DLZ

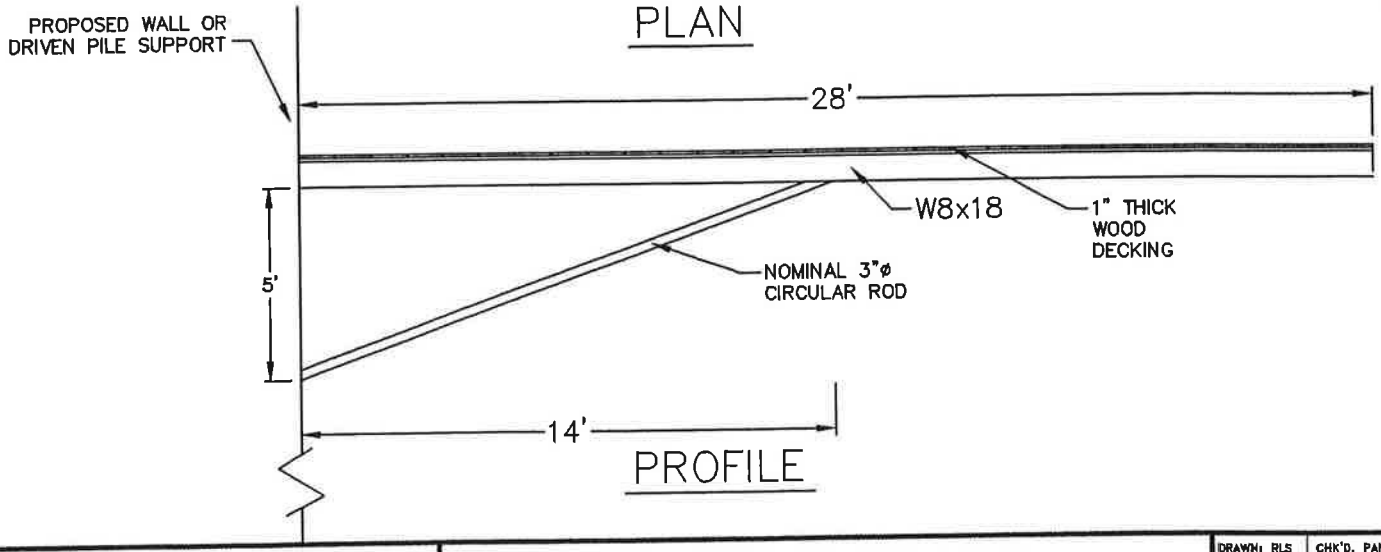
BUCKEYE LAKE STATE PARK
DAM EVALUATION

OPTION 1: SINGLE BOAT DOCK
WITHOUT BOAT LIFT

DRAWN: RLS	CHK'D. PAN
DESIGNED: PAN	APPRV'D: -
DATE: MAY 1, 2002	
SCALE:	1"=5'
PROJECT NUMBER	
0121-3074.00	



PLAN



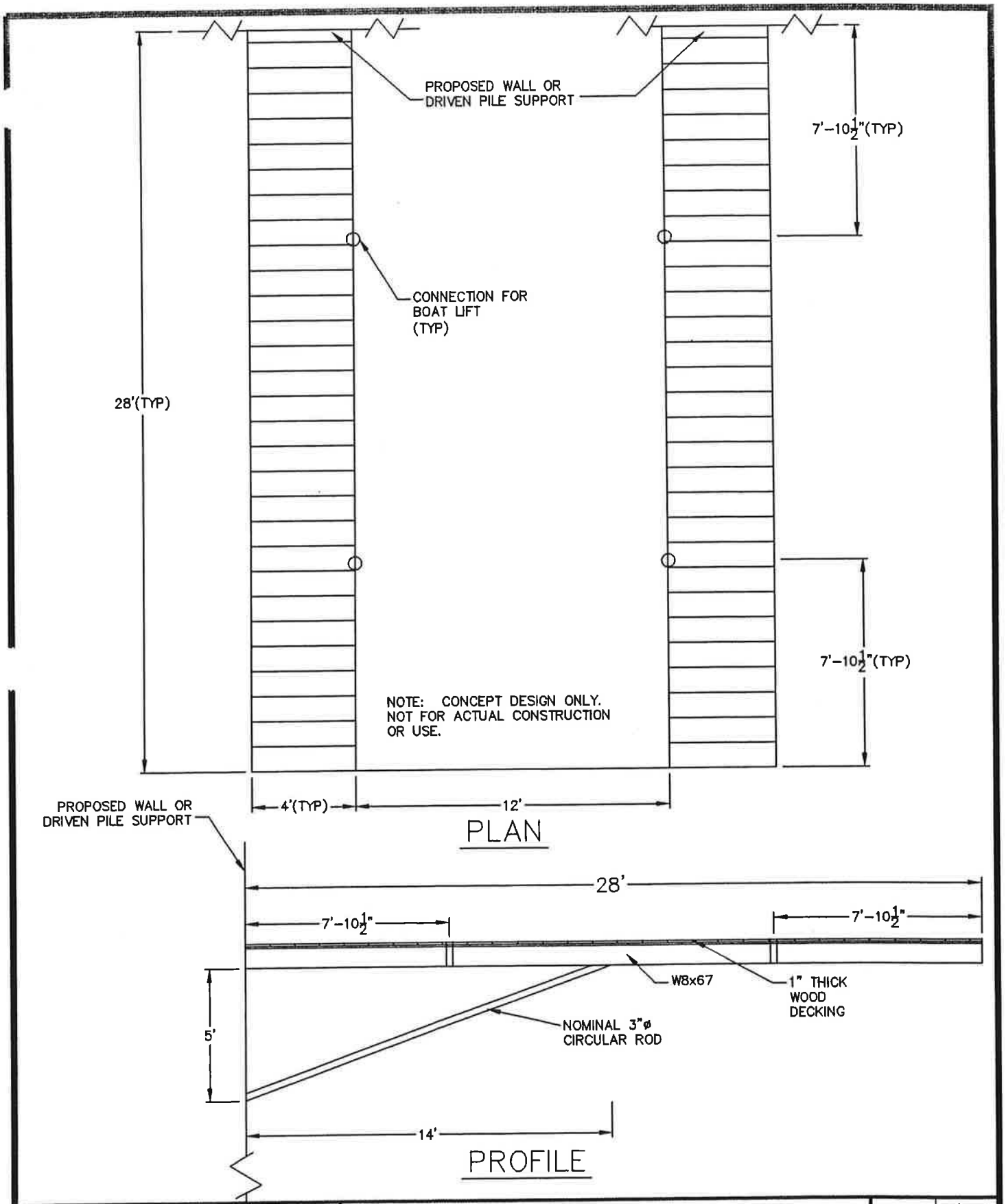
PROFILE

DLZ

BUCKEYE LAKE STATE PARK
DAM EVALUATION

OPTION 2: DOUBLE BOAT DOCK
WITHOUT BOAT LIFT

DRAWN: RLS	CHK'D. PAN
DESIGNED: PAN	APPRV'D: –
DATE: MAY 1, 2002	
SCALE:	1"=5'
PROJECT NUMBER	
0121-3074.00	



DLZ

BUCKEYE LAKE STATE PARK
DAM EVALUATION

OPTION 3: DOUBLE BOAT DOCK WITH BOAT LIFT
FOR 8000lb BOAT

DRAWN: RLS	CHK'D. PAN
DESIGNED: PAN	APPRV'D: –
DATE: MAY 1, 2002	
SCALE:	1"=5'
PROJECT NUMBER	
0121-3074.00	

Concept Design – Boat Docks

BOAT DOCK DESIGN

**** Denotes design reference used:** *Manual of Steel Construction, Allowable Stress Design*

Boat Dock Information

x = width of boat dock = *4.00* ft
L = length of boat dock = *28.00* ft

n = horizontal distance between post and rod = L/2 = 14.00 ft
o = vertical distance between beam and rod = *5.00* ft

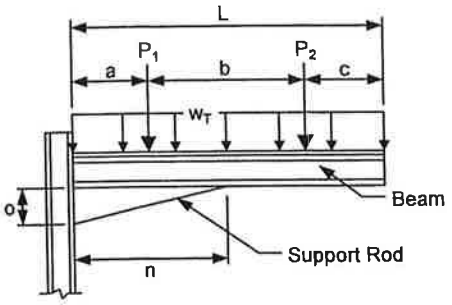
t_W = thickness of boat dock wood = *1.00* in
w_W = unit weight of boat dock wood = *50.00* lb/ft^3

w_{LL} = live load on boat dock = *30.00* lb/ft^2

$w_T = (w_W)*(0.5*x*(t_W/12)) + (w_{LL})*(0.5*x)$ = 68.33 lb/ft

a = *7.88* ft
b = *12.25* ft
c = 7.88 ft

P_1 = boat lift load = *0.00* lb
P_2 = boat lift load = 0.00 lb



Boat Dock Loads and Dimensions

Boat Dock Support Rod Design

select type of circular rod ('Standard Weight,' 'Extra Strong,' or 'Double-Extra Strong'): *Standard Weight* O.K.
select nominal diameter of circular rod (from 'CIRCULAR PIPE' sheet): *3* O.K.

Properties for Selected Circular Rod Section

d_n = nominal diameter = 3 in
d_o = outside diameter = 3.500 in
d_i = inside diameter = 3.068 in
t = wall thickness = 0.216 in
w = weight (plain ends) = 7.58 lb/ft

A_X = cross sectional area = 2.230 in^2
I = moment of inertia = 3.020 in^4
S = section modulus = 1.720 in^3
r = radius of gyration = 1.160 in
schedule no. = 40

selected steel ('A53 Grade B' or 'A501'): *A53 Grade B* O.K.
f_y = yield stress of selected steel = 35 ksi **[Table 3, pg. 1-92]

Cross Section Check for Support Rod

Flexure

d_o/t = 16.20 < $3300/f_y$ = 94.29 **[Table B5.1, pg. 5-36]
(SECTION IS COMPACT)

f_b = allowable stress = $0.66*f_y$ = 23.10 ksi **[F3.1., pg. 5-48]
M_{max} = maximum bending moment from STAAD output = *5.333* kip-in
S_{min} = minimum section modulus = M_{max}/f_b = 0.231 in^3
S = provided section modulus = 1.720 in^3 O.K.

Shear

f_v = allowable shear stress = $0.40*f_y$ = 14 ksi **[F4., pg. 5-49]
V_{max} = maximum shear from STAAD output = *0.081* kip
$A_{v,min}$ = minimum shear area = $(V_{max}*1000)/f_v$ = 0.006 in^2
A_X = provided shear area of the selected section = 2.230 in^2 O.K.

Boat Dock Beam Design

selected beam section (from "Manual of Steel Construction, Allowable Stress Design"): ***W 8x18***

Properties for Selected Beam Section

A = area =	*5.26*	in^2	w = nominal weight =	*18.00*	lb per ft of beam
d = depth =	*8.14*	in	r_T = radius of gyration =	*1.390*	in
t_w = web thickness =	*0.230*	in	I_{X-X} = moment of inertia about axis X-X =	*61.90*	in^4
b_f = flange width =	*5.250*	in	S_{X-X} = section modulus about axis X-X =	*15.20*	in^3
t_f = flange thickness =	*0.330*	in	I_{Y-Y} = moment of inertia about axis Y-Y =	*7.97*	in^4

selected steel: A36
f_y = yield stress of selected steel = 36 ksi
E = modulus of elasticity of selected steel = 29 $x10^6$ psi

Cross Section Check for Beam

Flexure

$b_f/(2*t_f)$ = 7.95 < $65/f_y^{0.5}$ = 10.83 **[B5.1. and Table B5.1, pgs. 5-35 and 5-36]
d/t_w = 35.39 < $640/f_y^{0.5}$ = 106.67 **[B5.1. and Table B5.1, pgs. 5-35 and 5-36]
(SECTION IS COMPACT)

$L_{c1} = (76*(b_f/12))/(f_y)^{0.5}$ = 5.54 ft **[F1.1., pg. 5-45]
$L_{c2} = 20{,}000/[((d/A_f)*f_y)/12]$ = 9.85 ft **[F1.1., pg. 5-45]
$L_c = \min(L_{c1}, L_{c2})$ = 5.54 ft **[F1.1., pg. 5-45]
L_b = unsupported length = 14.00 ft L(b) > L(c), CONTINUE WITH ANALYSIS

A_f = area of the compression flange = b_f*t_f = 1.73 in^2 **[F1.3., pg. 5-47]
C_b = *1.00* **[F1.3., pg. 5-47]
$L_b/r_T = (L_b*12)/r_T$ = 120.86
$[(102x10^3*C_b)/f_y]^{0.5}$ = 53.23 **[F1.3., pgs. 5-46 and 5-47]
$[(510x10^3*C_b)/f_y]^{0.5}$ = 119.02 **[F1.3., pgs. 5-46 and 5-47]
(L/r(t) > [(510x10^3*C(b))/f(y)]^0.5)

f(b1)' = [(170*10^3)*C(b)]/[L(b)/r(T)]^2 = 11.64 ksi **[F1.3., pgs. 5-46 and 5-47]
f(b)' = max{f(b1)', 0.6*f(y)} = 21.60 ksi **[F1.3., pgs. 5-46 and 5-47]
f(b)" = [(12x10^3)*C(b)]/[((L(b)*12)*d)/A(f)] = 15.20 ksi **[F1.3., pgs. 5-46 and 5-47]
f(b,max) = 0.6*f(y) = 21.60 ksi **[F1.3., pgs. 5-46 and 5-47]
f_b = allowable stress = min{max{f(b)', f(b)"}, f(b,max)} = 21.60 ksi **[F1.3., pgs. 5-46 and 5-47]

M_{max} = maximum bending moment from STAAD output = *101.363* kip-in
$S_{min,f}$ = minimum section modulus = M_{max}/f_b = 4.69 in^3
S_{X-X} = provided section modulus = 15.20 in^3 O.K.

Shear

d/t_w = 35.39 < $380/f_y^{0.5}$ = 63.33 **[F4., pg. 5-49]
(O.K.)

f_v = allowable shear stress = $0.40*f_y$ = 14.40 ksi **[F4., pg. 5-49]
V_{max} = maximum shear from STAAD output = *1.216* kip
$A_{v,min}$ = minimum shear area = V_{max}/f_v = 0.08 in^2
A_v = provided shear area of the selected section = $d*t_w$ = 1.87 in^2 O.K.

Deflection

Δ_{all} = allowable deflection = *1.00* in
Δ_{max} = maximum deflection from STAAD output = *0.916* kip-in O.K.

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00	
	PROJECT	BUCKEYE LAKE	SHEET NO.	3	OF 3
	SUBJECT	BOAT DOCK DESIGN	COMPUTED BY	JAM	DATE 4/10/02
		SINGLE BOAT DOCK WITHOUT LIFTS	CHECKED BY	TKW	DATE 7-16-02

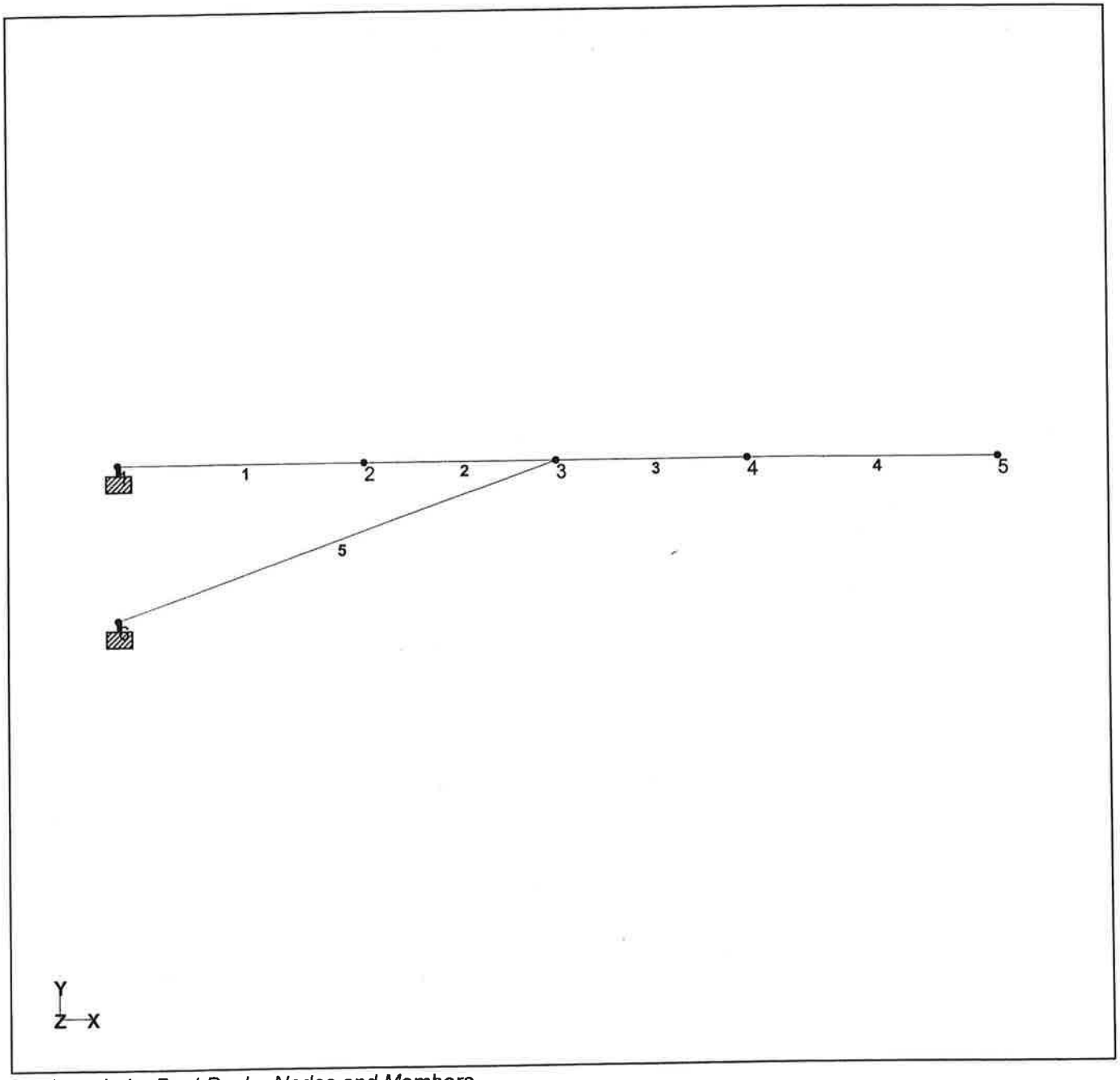
CIRCULAR PIPE

(information from "Manual of Steel Construction, Allowable Stress Design")

Nominal Diameter "d_n" [in]	Outside Diameter "d_o" [in]	Inside Diameter "d_i" [in]	Wall Thickness "t" [in]	Wt. (Plain Ends) "w" [lb/ft]	Cross Sec. Area "A_x" [in^2]	Mom. of Inertia "I" [in^4]	Section Modulus "S" [in^3]	Radius of Gyration "r" [in]	Schedule No.
				Standard Weight					
1/2	0.840	0.622	0.109	0.85	0.250	0.017	0.041	0.261	40
3/4	1.050	0.824	0.113	1.13	0.333	0.037	0.071	0.334	40
1	1.315	1.049	0.133	1.68	0.494	0.087	0.133	0.421	40
1 1/4	1.660	1.380	0.140	2.27	0.669	0.195	0.235	0.540	40
1 1/2	1.900	1.610	0.145	2.72	0.799	0.310	0.326	0.623	40
2	2.375	2.067	0.154	3.65	1.070	0.666	0.561	0.787	40
2 1/2	2.875	2.469	0.203	5.79	1.700	1.530	1.060	0.947	40
3	3.500	3.068	0.216	7.58	2.230	3.020	1.720	1.160	40
3 1/2	4.000	3.548	0.226	9.11	2.680	4.790	2.390	1.340	40
4	4.500	4.026	0.237	10.79	3.170	7.230	3.210	1.510	40
5	5.563	5.047	0.258	14.62	4.300	15.200	5.450	1.880	40
6	6.625	6.065	0.280	18.97	5.580	28.100	8.500	2.250	40
8	8.625	7.981	0.322	28.55	8.400	72.500	16.800	2.940	40
10	10.750	10.020	0.365	40.48	11.900	161.000	29.900	3.670	40
12	12.750	12.000	0.375	49.56	14.600	279.000	43.800	4.380	-
				Extra Strong					
1/2	0.840	0.546	0.147	1.09	0.320	0.020	0.048	0.250	80
3/4	1.050	0.742	0.154	1.47	0.433	0.045	0.085	0.321	80
1	1.315	0.957	0.179	2.17	0.639	0.106	0.161	0.407	80
1 1/4	1.660	1.278	0.191	3.00	0.881	0.242	0.291	0.524	80
1 1/2	1.900	1.500	0.200	3.63	1.070	0.391	0.412	0.605	80
2	2.375	1.939	0.218	5.02	1.480	0.868	0.731	0.766	80
2 1/2	2.875	2.323	0.276	7.66	2.250	1.920	1.340	0.924	80
3	3.500	2.900	0.300	10.25	3.020	3.890	2.230	1.140	80
3 1/2	4.000	3.364	0.318	12.50	3.680	6.280	3.140	1.310	80
4	4.500	3.826	0.337	14.98	4.410	9.610	4.270	1.480	80
5	5.563	4.813	0.375	20.78	6.110	20.700	7.430	1.840	80
6	6.625	5.761	0.432	28.57	8.400	40.500	12.200	2.190	80
8	8.625	7.625	0.500	43.39	12.800	106.000	24.500	2.880	80
10	10.750	9.750	0.500	54.74	16.100	212.000	39.400	3.630	60
12	12.750	11.750	0.500	65.42	19.200	362.000	56.700	4.330	-
				Double-Extra Strong					
2	2.375	1.503	0.436	9.03	2.660	1.310	1.100	0.703	-
2 1/2	2.875	1.771	0.552	13.69	4.030	2.870	2.000	0.844	-
3	3.500	2.300	0.600	18.58	5.470	5.990	3.420	1.050	-
4	4.500	3.152	0.674	27.54	8.100	15.300	6.790	1.370	-
5	5.563	4.063	0.750	38.55	11.300	33.600	12.100	1.720	-
6	6.625	4.897	0.864	53.16	15.600	66.300	20.000	2.060	-
8	8.625	6.875	0.875	72.42	21.300	162.000	37.600	2.760	-

Note: The listed sections are available in conformance with ASTM Specification A53 Grade B or A501. Other sections are made to these specifications. Consult with pipe manufacturers or distributors for availability.

DLZ OHIO, INC. Columbus, OH Software licensed to Demo User	Job No 0121-3074-00	Sheet No 1	Rev
	Part		
Job Title Buckeye Lake	Ref		
	By J. Miller	Date 06-May-02	Chd
Client Ohio Dept. of Natural Resources	File buck_dock.std	Date/Time 06-May-2002 09:16	



Buckeye Lake Boat Dock - Nodes and Members

✓TAA

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STAAD PLANE BUCKEYE LAKE BOAT DOCK
START JOB INFORMATION
JOB NAME Buckeye Lake
JOB CLIENT Ohio Dept. of Natural Resources
JOB NO 0121-3074-00
ENGINEER NAME J. Miller
ENGINEER DATE 06-May-02
END JOB INFORMATION
INPUT WIDTH 79
UNIT FEET POUND
JOINT COORDINATES
1 0 0 0; 2 7.88 0 0; 3 14 0 0; 4 20.13 0 0; 5 28 0 0; 6 0 -5 0;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 3 6;
UNIT INCHES POUND
MEMBER PROPERTY AMERICAN
1 TO 4 PRIS AX 5.26 IZ 61.90
5 PRIS AX 2.230 IZ 3.020
SUPPORTS
1 FIXED
6 FIXED
CONSTANTS
E STEEL MEMB 1 TO 5
DENSITY STEEL MEMB 1 TO 5
UNIT FEET POUND
LOAD 1 VERTICAL LOADS
SELFWEIGHT Y -1
MEMBER LOAD
1 TO 4 UNI GY -68.33
PERFORM ANALYSIS
PRINT ALL
PRINT ANALYSIS RESULTS
FINISH
```

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (ft)	Fx (kip)	Fy (kip)	Fz (kip)	Mx (kip-in)	My (kip-in)	Mz (kip-in)
Max Fx	3	1:VERTICAL LC	0.000	**0.000**	1.207	0.000	0.000	0.000	101.363
Min Fx	1	1:VERTICAL LC	0.000	**-7.024**	-0.009	0.000	0.000	0.000	-6.885
Max Fy	3	1:VERTICAL LC	0.000	0.000	**1.207**	0.000	0.000	0.000	101.363
Min Fy	2	1:VERTICAL LC	6.120	-7.024	**-1.216**	0.000	0.000	0.000	96.030
Max Fz	1	1:VERTICAL LC	0.000	-7.024	-0.009	**0.000**	0.000	0.000	-6.885
Min Fz	1	1:VERTICAL LC	0.000	-7.024	-0.009	**0.000**	0.000	0.000	-6.885
Max Mx	1	1:VERTICAL LC	0.000	-7.024	-0.009	0.000	**0.000**	0.000	-6.885
Min Mx	1	1:VERTICAL LC	0.000	-7.024	-0.009	0.000	**0.000**	0.000	-6.885
Max My	1	1:VERTICAL LC	0.000	-7.024	-0.009	0.000	0.000	**0.000**	-6.885
Min My	1	1:VERTICAL LC	0.000	-7.024	-0.009	0.000	0.000	**0.000**	-6.885
Max Mz	3	1:VERTICAL LC	0.000	0.000	1.207	0.000	0.000	0.000	**101.363**
Min Mz	1	1:VERTICAL LC	0.000	-7.024	-0.009	0.000	0.000	0.000	**-6.885**

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (ft)	Fx (kip)	Fy (kip)	Fz (kip)	Mx (kip-in)	My (kip-in)	Mz (kip-in)
Max Fx	5	1:VERTICAL LC	14.866	**7.467**	-0.025	0.000	0.000	0.000	0.362
Min Fx	5	1:VERTICAL LC	0.000	**7.429**	0.081	0.000	0.000	0.000	5.333
Max Fy	5	1:VERTICAL LC	0.000	7.429	**0.081**	0.000	0.000	0.000	5.333
Min Fy	5	1:VERTICAL LC	14.866	7.467	**-0.025**	0.000	0.000	0.000	0.362
Max Fz	5	1:VERTICAL LC	0.000	7.429	0.081	**0.000**	0.000	0.000	5.333
Min Fz	5	1:VERTICAL LC	0.000	7.429	0.081	**0.000**	0.000	0.000	5.333
Max Mx	5	1:VERTICAL LC	0.000	7.429	0.081	0.000	**0.000**	0.000	5.333
Min Mx	5	1:VERTICAL LC	0.000	7.429	0.081	0.000	**0.000**	0.000	5.333
Max My	5	1:VERTICAL LC	0.000	7.429	0.081	0.000	0.000	**0.000**	5.333
Min My	5	1:VERTICAL LC	0.000	7.429	0.081	0.000	0.000	**0.000**	5.333
Max Mz	5	1:VERTICAL LC	0.000	7.429	0.081	0.000	0.000	0.000	**5.333**
Min Mz	5	1:VERTICAL LC	11.893	7.460	-0.004	0.000	0.000	0.000	**-0.141**

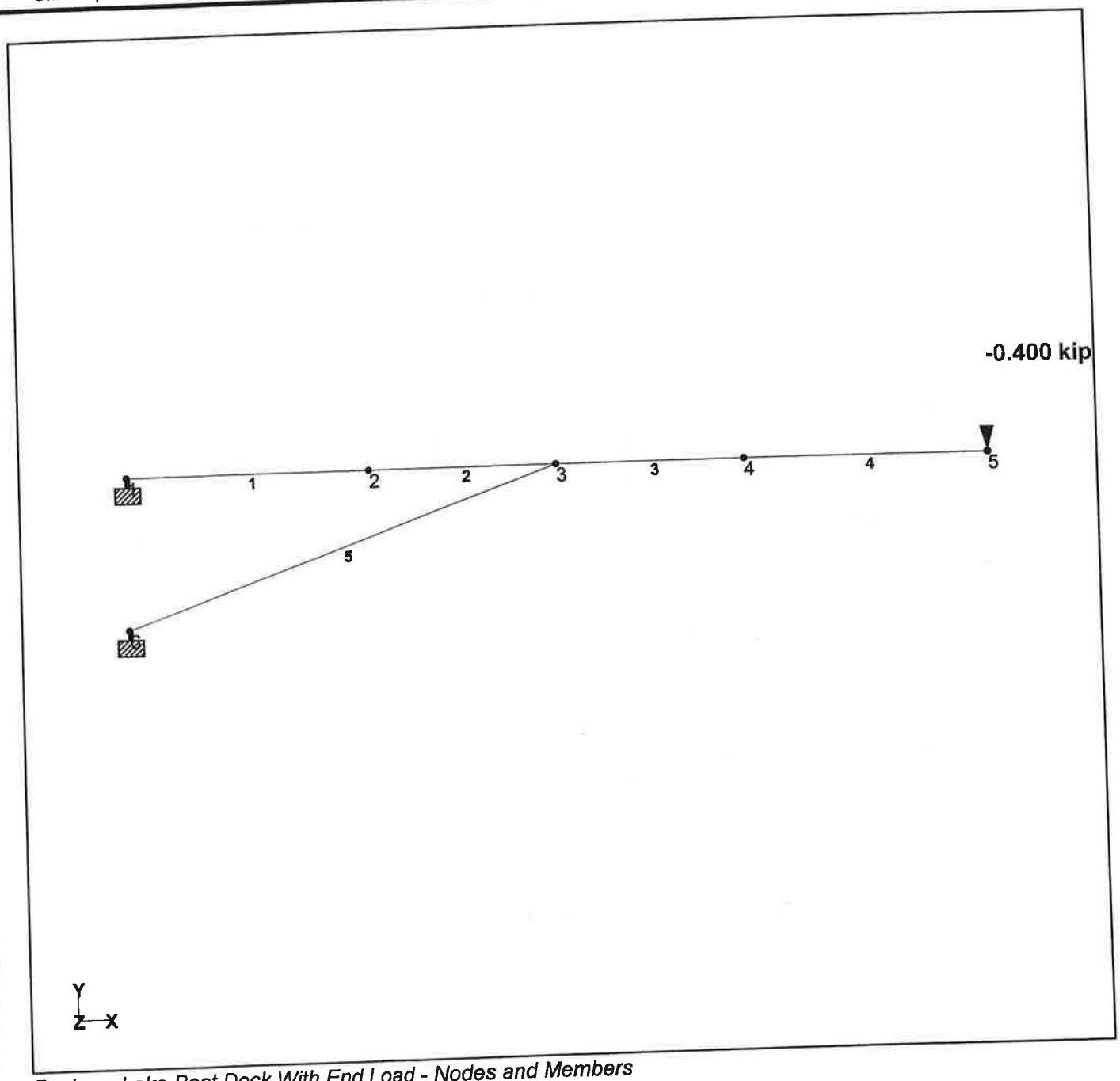
Node Displacements

Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
1	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
2	1:VERTICAL LC	0.004	0.003	0.000	0.005	0.00000	0.00000	-0.00022
3	1:VERTICAL LC	0.008	-0.083	0.000	0.083	0.00000	0.00000	-0.00259
4	1:VERTICAL LC	0.008	-0.386	0.000	0.386	0.00000	0.00000	-0.00519
5	1:VERTICAL LC	0.008	-0.916	0.000	0.916	0.00000	0.00000	-0.00575
6	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000

Reactions

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	FX (lb)	FY (lb)	FZ (lb)	MX (kip-ft)	MY (kip-ft)	MZ (kip-ft)
1	1:VERTICAL LC	-7.02E 3	-9.237	0.000	0.000	0.000	-0.574
6	1:VERTICAL LC	7.02E 3	2.54E 3	0.000	0.000	0.000	0.030

DLZ OHIO, INC. Columbus, OH Software licensed to DLZ Corporation	Job No 0121-3074-00	Sheet No 1	Rev
	Part		
Job Title Buckeye Lake	Ref		
	By J. Miller	Date 13-May-02	Chd
Client Ohio Dept. of Natural Resources	File buck_dock(end).std	Date/Time 13-May-2002 09:48	



Buckeye Lake Boat Dock With End Load - Nodes and Members

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STAAD PLANE BUCKEYE LAKE BOAT DOCK
START JOB INFORMATION
JOB NAME Buckeye Lake
JOB CLIENT Ohio Dept. of Natural Resources
JOB NO 0121-3074-00
ENGINEER NAME J. Miller
ENGINEER DATE 13-May-02
END JOB INFORMATION
INPUT WIDTH 79
UNIT FEET POUND
JOINT COORDINATES
1 0 0 0; 2 7.88 0 0; 3 14 0 0; 4 20.13 0 0; 5 28 0 0; 6 0 -5 0;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 3 6;
UNIT INCHES POUND
MEMBER PROPERTY AMERICAN
1 TO 4 PRIS AX 5.26 IZ 61.9
5 PRIS AX 2.23 IZ 3.02
SUPPORTS
1 FIXED
6 FIXED
CONSTANTS
E STEEL MEMB 1 TO 5
DENSITY STEEL MEMB 1 TO 5
UNIT FEET POUND
LOAD 1 VERTICAL LOADS
JOINT LOAD
5 FY -400
PERFORM ANALYSIS
PRINT ALL
PRINT ANALYSIS RESULTS
FINISH
```

✓ TRAA

Node Displacements

Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
1	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
2	1:VERTICAL LC	0.002	0.023	0.000	0.023	0.00000	0.00000	0.00003
3	1:VERTICAL LC	0.003	-0.032	0.000	0.032	0.00000	0.00000	-0.00179
4	1:VERTICAL LC	0.003	-0.250	0.000	0.250	0.00000	0.00000	-0.00394
5	1:VERTICAL LC	0.003	-0.684	0.000	0.684	0.00000	0.00000	-0.00493
6	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000

Reactions

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	FX (lb)	FY (lb)	FZ (lb)	MX (kip-ft)	MY (kip-ft)	MZ (kip-ft)
1	1:VERTICAL LC	-2.69E 3	-537.232	0.000	0.000	0.000	-2.171
6	1:VERTICAL LC	2.69E 3	937.232	0.000	0.000	0.000	-0.104

BOAT DOCK DESIGN

**** Denotes design reference used:** *Manual of Steel Construction, Allowable Stress Design*

Boat Dock Information

x = width of boat dock = *4.00* ft
L = length of boat dock = *28.00* ft

n = horizontal distance between post and rod = L/2 = 14.00 ft
o = vertical distance between beam and rod = *5.00* ft

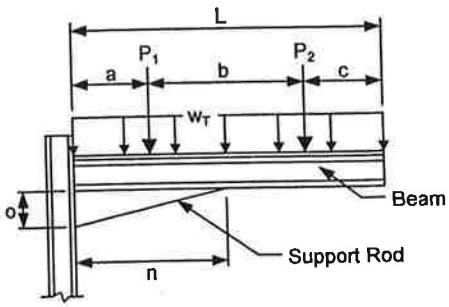
t_W = thickness of boat dock wood = *1.00* in
w_W = unit weight of boat dock wood = *50.00* lb/ft^3

w_{LL} = live load on boat dock = *30.00* lb/ft^2

$w_T = (w_W)*(0.5*x*(t_W/12)) + (w_{LL})*(0.5*x)$ = **68.33** **lb/ft**

a = *7.88* ft
b = *12.25* ft
c = 7.88 ft

P_1 = boat lift load = *2250.00* lb
P_2 = boat lift load = 2250.00 lb



Boat Dock Loads and Dimensions

Boat Dock Support Rod Design

select type of circular rod ('Standard Weight,' 'Extra Strong,' or 'Double-Extra Strong'): *Standard Weight* O.K.
select nominal diameter of circular rod (from 'CIRCULAR PIPE' sheet): *3* O.K.

Properties for Selected Circular Rod Section

d_n = nominal diameter = 3 in
d_o = outside diameter = 3.500 in
d_i = inside diameter = 3.068 in
t = wall thickness = 0.216 in
w = weight (plain ends) = 7.58 lb/ft

A_X = cross sectional area = 2.230 in^2
I = moment of inertia = 3.020 in^4
S = section modulus = 1.720 in^3
r = radius of gyration = 1.160 in
schedule no. = 40

selected steel ('A53 Grade B' or 'A501'): *A53 Grade B* O.K.
f_y = yield stress of selected steel = 35 ksi **[Table 3, pg. 1-92]

Cross Section Check for Support Rod

Flexure

d_o/t = 16.20 < $3300/f_y$ = 94.29 **[Table B5.1, pg. 5-36]
(SECTION IS COMPACT)

f_b = allowable stress = $0.66*f_y$ = 23.10 ksi **[F3.1., pg. 5-48]
M_{max} = maximum bending moment from STAAD output = *4.468* kip-in
S_{min} = minimum section modulus = M_{max}/f_b = 0.193 in^3
S = provided section modulus = 1.720 in^3 O.K.

Shear

f_v = allowable shear stress = $0.40*f_y$ = 14 ksi **[F4., pg. 5-49]
V_{max} = maximum shear from STAAD output = *0.068* kip
$A_{v,min}$ = minimum shear area = $(V_{max}*1000)/f_v$ = 0.005 in^2
A_X = provided shear area of the selected section = 2.230 in^2 O.K.

Boat Dock Beam Design

selected beam section (from "Manual of Steel Construction, Allowable Stress Design"): ***W 8x67***

Properties for Selected Beam Section

A = area =	*19.70*	in^2	w = nominal weight =	*67.00*	lb per ft of beam
d = depth =	*9.00*	in	r_T = radius of gyration =	*2.280*	in
t_w = web thickness =	*0.570*	in	I_{X-X} = moment of inertia about axis X-X =	*272.00*	in^4
b_f = flange width =	*8.280*	in	S_{X-X} = section modulus about axis X-X =	*60.40*	in^3
t_f = flange thickness =	*0.935*	in	I_{Y-Y} = moment of inertia about axis Y-Y =	*88.60*	in^4

selected steel: A36
f_y = yield stress of selected steel = 36 ksi
E = modulus of elasticity of selected steel = 29 $x10^6$ psi

Cross Section Check for Beam

Flexure

$b_f/(2*t_f)$ = 4.43 < $65/f_y^{0.5}$ = 10.83 **[B5.1. and Table B5.1, pgs. 5-35 and 5-36]
d/t_w = 15.79 < $640/f_y^{0.5}$ = 106.67 **[B5.1. and Table B5.1, pgs. 5-35 and 5-36]
(SECTION IS COMPACT)

$L_{c1} = (76*(b_f/12))/(f_y)^{0.5}$ = 8.74 ft **[F1.1., pg. 5-45]
$L_{c2} = 20{,}000/[((d/A_f)*f_y)/12]$ = 39.82 ft **[F1.1., pg. 5-45]
$L_c = \min(L_{c1}, L_{c2})$ = 8.74 ft **[F1.1., pg. 5-45]
L_b = unsupported length = 14.00 ft L(b) > L(c), CONTINUE WITH ANALYSIS

A_f = area of the compression flange = b_f*t_f = 7.74 in^2 **[F1.3., pg. 5-47]
C_b = *1.00* **[F1.3., pg. 5-47]
$L_b/r_T = (L_b*12)/r_T$ = 73.68
$[(102x10^3*C_b)/f_y]^{0.5}$ = 53.23 **[F1.3., pgs. 5-46 and 5-47]
$[(510x10^3*C_b)/f_y]^{0.5}$ = 119.02 **[F1.3., pgs. 5-46 and 5-47]
([(102x10^3*C(b))/f(y)]^0.5 <= L(b)/r(t) <= [(510x10^3*C(b))/f(y)]^0.5)

f(b1)' = [((2/3)-[(f(y)*(L(b)/r(T))^2]/[(1530*10^3)*C(b)])*f(y)] = 19.40 ksi **[F1.3., pgs. 5-46 and 5-47]
f(b)' = max{f(b1)', 0.6*f(y)} = 21.60 ksi **[F1.3., pgs. 5-46 and 5-47]
f(b)" = [(12x10^3)*C(b)]/[((L(b)*12)*d)/A(f)] = 61.44 ksi **[F1.3., pgs. 5-46 and 5-47]
f(b,max) = 0.6*f(y) = 21.60 ksi **[F1.3., pgs. 5-46 and 5-47]
f_b = allowable stress = min{max{f(b)', f(b)"}, f(b,max)} = 21.60 ksi **[F1.3., pgs. 5-46 and 5-47]

M_{max} = maximum bending moment from STAAD output = *324.542* kip-in
$S_{min,f}$ = minimum section modulus = M_{max}/f_b = 15.03 in^3
S_{X-X} = provided section modulus = 60.40 in^3 O.K.

Shear

d/t_w = 15.79 < $380/f_y^{0.5}$ = 63.33 **[F4., pg. 5-49]
(O.K.)

f_v = allowable shear stress = $0.40*f_y$ = 14.40 ksi **[F4., pg. 5-49]
V_{max} = maximum shear from STAAD output = *4.143* kip
$A_{v,min}$ = minimum shear area = V_{max}/f_v = 0.29 in^2
A_v = provided shear area of the selected section = $d*t_w$ = 5.13 in^2 O.K.

Deflection

Δ_{all} = allowable deflection = *1.00* in
Δ_{max} = maximum deflection from STAAD output = *0.978* kip-in O.K.

DLZ	CLIENT	OHIO DEPT. OF NATURAL RESOURCES	PROJECT NO.	0121-3074-00	
	PROJECT	BUCKEYE LAKE	SHEET NO.	3	OF 3
	SUBJECT	BOAT DOCK DESIGN	COMPUTED BY	JAM	DATE 4/10/02
		SINGLE BOAT DOCK WITH LIFTS	CHECKED BY	TRW	DATE 7-16-02

CIRCULAR PIPE

(information from "Manual of Steel Construction, Allowable Stress Design")

Nominal Diameter "d_n" [in]	Outside Diameter "d_o" [in]	Inside Diameter "d_i" [in]	Wall Thickness "t" [in]	Wt. (Plain Ends) "w" [lb/ft]	Cross Sec. Area "A_x" [in^2]	Mom. of Inertia "I" [in^4]	Section Modulus "S" [in^3]	Radius of Gyration "r" [in]	Schedule No.
				Standard Weight					
1/2	0.840	0.622	0.109	0.85	0.250	0.017	0.041	0.261	40
3/4	1.050	0.824	0.113	1.13	0.333	0.037	0.071	0.334	40
1	1.315	1.049	0.133	1.68	0.494	0.087	0.133	0.421	40
1 1/4	1.660	1.380	0.140	2.27	0.669	0.195	0.235	0.540	40
1 1/2	1.900	1.610	0.145	2.72	0.799	0.310	0.326	0.623	40
2	2.375	2.067	0.154	3.65	1.070	0.666	0.561	0.787	40
2 1/2	2.875	2.469	0.203	5.79	1.700	1.530	1.060	0.947	40
3	3.500	3.068	0.216	7.58	2.230	3.020	1.720	1.160	40
3 1/2	4.000	3.548	0.226	9.11	2.680	4.790	2.390	1.340	40
4	4.500	4.026	0.237	10.79	3.170	7.230	3.210	1.510	40
5	5.563	5.047	0.258	14.62	4.300	15.200	5.450	1.880	40
6	6.625	6.065	0.280	18.97	5.580	28.100	8.500	2.250	40
8	8.625	7.981	0.322	28.55	8.400	72.500	16.800	2.940	40
10	10.750	10.020	0.365	40.48	11.900	161.000	29.900	3.670	40
12	12.750	12.000	0.375	49.56	14.600	279.000	43.800	4.380	-
				Extra Strong					
1/2	0.840	0.546	0.147	1.09	0.320	0.020	0.048	0.250	80
3/4	1.050	0.742	0.154	1.47	0.433	0.045	0.085	0.321	80
1	1.315	0.957	0.179	2.17	0.639	0.106	0.161	0.407	80
1 1/4	1.660	1.278	0.191	3.00	0.881	0.242	0.291	0.524	80
1 1/2	1.900	1.500	0.200	3.63	1.070	0.391	0.412	0.605	80
2	2.375	1.939	0.218	5.02	1.480	0.868	0.731	0.766	80
2 1/2	2.875	2.323	0.276	7.66	2.250	1.920	1.340	0.924	80
3	3.500	2.900	0.300	10.25	3.020	3.890	2.230	1.140	80
3 1/2	4.000	3.364	0.318	12.50	3.680	6.280	3.140	1.310	80
4	4.500	3.826	0.337	14.98	4.410	9.610	4.270	1.480	80
5	5.563	4.813	0.375	20.78	6.110	20.700	7.430	1.840	80
6	6.625	5.761	0.432	28.57	8.400	40.500	12.200	2.190	80
8	8.625	7.625	0.500	43.39	12.800	106.000	24.500	2.880	80
10	10.750	9.750	0.500	54.74	16.100	212.000	39.400	3.630	60
12	12.750	11.750	0.500	65.42	19.200	362.000	56.700	4.330	-
				Double-Extra Strong					
2	2.375	1.503	0.436	9.03	2.660	1.310	1.100	0.703	-
2 1/2	2.875	1.771	0.552	13.69	4.030	2.870	2.000	0.844	-
3	3.500	2.300	0.600	18.58	5.470	5.990	3.420	1.050	-
4	4.500	3.152	0.674	27.54	8.100	15.300	6.790	1.370	-
5	5.563	4.063	0.750	38.55	11.300	33.600	12.100	1.720	-
6	6.625	4.897	0.864	53.16	15.600	66.300	20.000	2.060	-
8	8.625	6.875	0.875	72.42	21.300	162.000	37.600	2.760	-

Note: The listed sections are available in conformance with ASTM Specification A53 Grade B or A501. Other sections are made to these specifications. Consult with pipe manufacturers or distributors for availability.

DLZ OHIO, INC. **Columbus, OH** Software licensed to Demo User	Job No **0121-3074-00**	Sheet No **1**	Rev
	Part		
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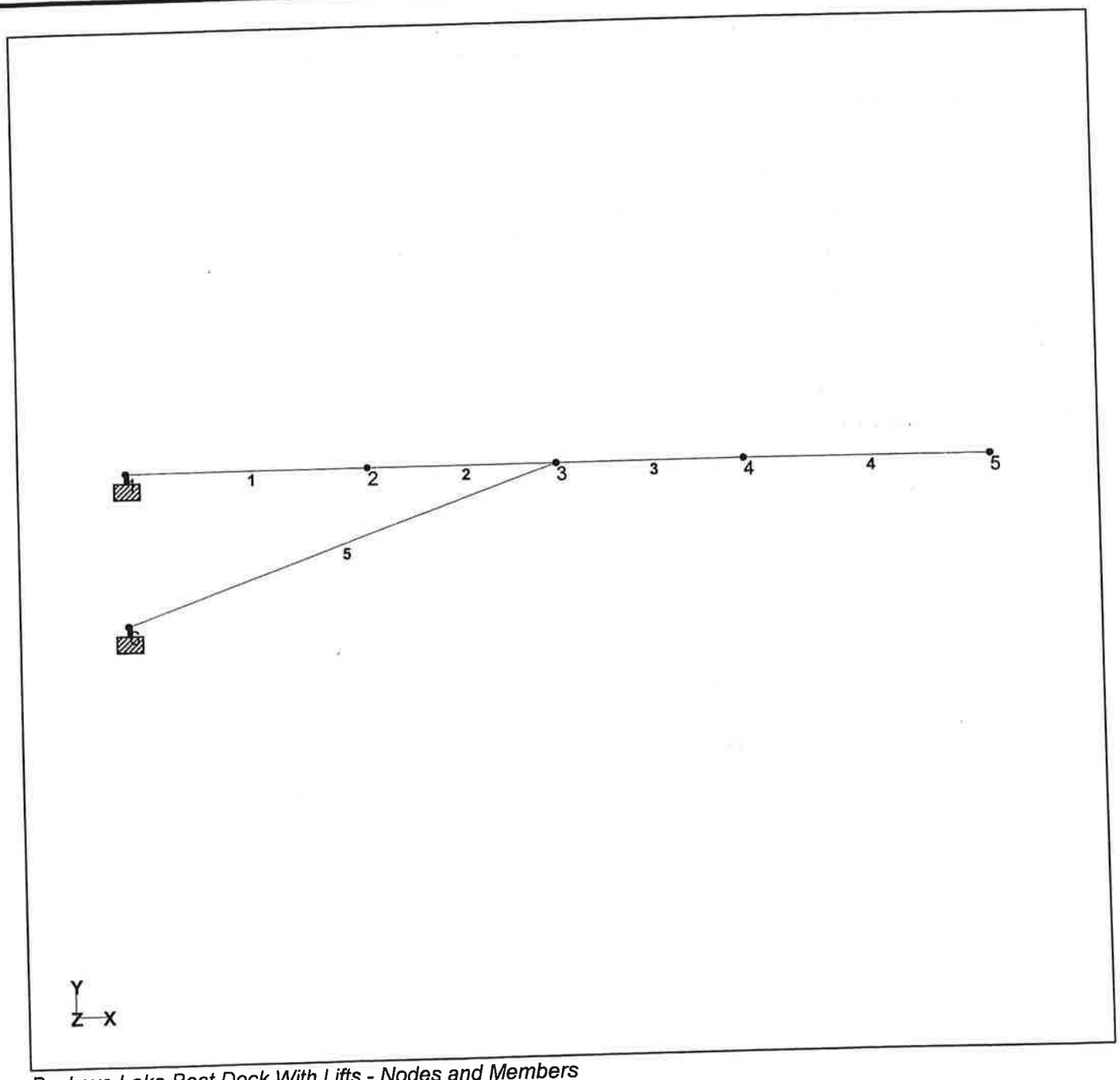
	By J. Miller	Date 06-May-02	Chd
Client Ohio Dept. of Natural Resources	File buck_dock&lifts.std	Date/Time 06-May-2002 08:51	



Buckeye Lake Boat Dock With Lifts - Nodes and Members

✓ TAA

```
STAAD PLANE BUCKEYE LAKE BOAT DOCK
START JOB INFORMATION
JOB NAME Buckeye Lake
JOB CLIENT Ohio Dept. of Natural Resources
JOB NO 0121-3074-00
ENGINEER NAME J. Miller
ENGINEER DATE 06-May-02
END JOB INFORMATION
INPUT WIDTH 79
UNIT FEET POUND
JOINT COORDINATES
1 0 0 0; 2 7.88 0 0; 3 14 0 0; 4 20.13 0 0; 5 28 0 0; 6 0 -5 0;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 3 6;
UNIT INCHES POUND
MEMBER PROPERTY AMERICAN
1 TO 4 PRIS AX 19.70 IZ 272.00
5 PRIS AX 2.230 IZ 3.020
SUPPORTS
1 FIXED
6 FIXED
CONSTANTS
E STEEL MEMB 1 TO 5
DENSITY STEEL MEMB 1 TO 5
UNIT FEET POUND
LOAD 1 VERTICAL LOADS
SELFWEIGHT Y -1
MEMBER LOAD
1 TO 4 UNI GY -68.33
JOINT LOAD
2 4 FY -2250
PERFORM ANALYSIS
PRINT ALL
PRINT ANALYSIS RESULTS
FINISH
```

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

	Beam	L/C	d (ft)	Axial Fx (kip)	Shear Fy (kip)	Shear Fz (kip)	Torsion Mx (kip-in)	Bending My (kip-in)	Bending Mz (kip-in)
Max Fx	3	1:VERTICAL LO	0.000	**0.000**	4.143	0.000	0.000	0.000	324.542
Min Fx	1	1:VERTICAL LO	0.000	**-21.379**	0.724	0.000	0.000	0.000	117.382
Max Fy	3	1:VERTICAL LO	0.000	0.000	**4.143**	0.000	0.000	0.000	324.542
Min Fy	2	1:VERTICAL LO	6.120	-21.379	**-3.420**	0.000	0.000	0.000	320.074
Max Fz	1	1:VERTICAL LO	0.000	-21.379	0.724	**0.000**	0.000	0.000	117.382
Min Fz	1	1:VERTICAL LO	0.000	-21.379	0.724	**0.000**	0.000	0.000	117.382
Max Mx	1	1:VERTICAL LO	0.000	-21.379	0.724	0.000	**0.000**	0.000	117.382
Min Mx	1	1:VERTICAL LO	0.000	-21.379	0.724	0.000	**0.000**	0.000	117.382
Max My	1	1:VERTICAL LO	0.000	-21.379	0.724	0.000	0.000	**0.000**	117.382
Min My	1	1:VERTICAL LO	0.000	-21.379	0.724	0.000	0.000	**0.000**	117.382
Max Mz	3	1:VERTICAL LO	0.000	0.000	4.143	0.000	0.000	0.000	**324.542**
Min Mz	4	1:VERTICAL LO	7.870	0.000	-0.000	0.000	0.000	0.000	**-0.000**

Beam Force Detail Summary

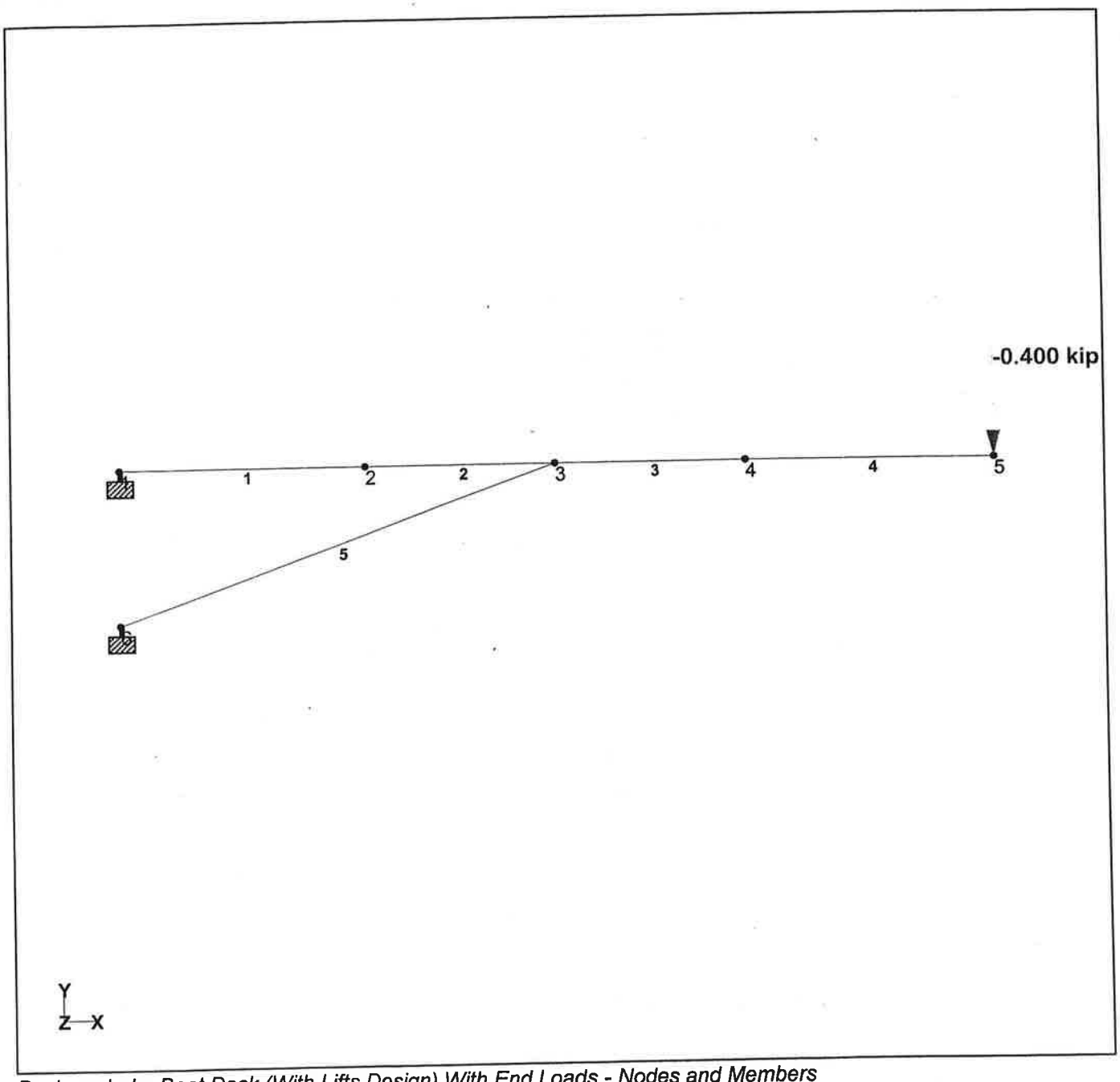
Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (ft)	Fx (kip)	Fy (kip)	Fz (kip)	Mx (kip-in)	My (kip-in)	Mz (kip-in)
Max Fx	5	1:VERTICAL LO	14.866	**22.715**	-0.038	0.000	0.000	0.000	1.732
Min Fx	5	1:VERTICAL LO	0.000	**22.677**	0.068	0.000	0.000	0.000	4.468
Max Fy	5	1:VERTICAL LO	0.000	22.677	**0.068**	0.000	0.000	0.000	4.468
Min Fy	5	1:VERTICAL LO	14.866	22.715	**-0.038**	0.000	0.000	0.000	1.732
Max Fz	5	1:VERTICAL LO	0.000	22.677	0.068	**0.000**	0.000	0.000	4.468
Min Fz	5	1:VERTICAL LO	0.000	22.677	0.068	**0.000**	0.000	0.000	4.468
Max Mx	5	1:VERTICAL LO	0.000	22.677	0.068	0.000	**0.000**	0.000	4.468
Min Mx	5	1:VERTICAL LO	0.000	22.677	0.068	0.000	**0.000**	0.000	4.468
Max My	5	1:VERTICAL LO	0.000	22.677	0.068	0.000	0.000	**0.000**	4.468
Min My	5	1:VERTICAL LO	0.000	22.677	0.068	0.000	0.000	**0.000**	4.468
Max Mz	5	1:VERTICAL LO	0.000	22.677	0.068	0.000	0.000	0.000	**4.468**
Min Mz	5	1:VERTICAL LO	8.920	22.700	0.005	0.000	0.000	0.000	**0.567**

Node Displacement Summary

	Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
Max X	3	1:VERTICAL LC	**0.006**	-0.204	0.000	0.204	0.00000	0.00000	-0.00310
Min X	1	1:VERTICAL LC	**0.000**	0.000	0.000	0.000	0.00000	0.00000	0.00000
Max Y	1	1:VERTICAL LC	0.000	**0.000**	0.000	0.000	0.00000	0.00000	0.00000
Min Y	5	1:VERTICAL LC	0.006	**-0.978**	0.000	0.978	0.00000	0.00000	-0.00500
Max Z	1	1:VERTICAL LC	0.000	0.000	**0.000**	0.000	0.00000	0.00000	0.00000
Min Z	1	1:VERTICAL LC	0.000	0.000	**0.000**	0.000	0.00000	0.00000	0.00000
Max rX	1	1:VERTICAL LC	0.000	0.000	0.000	0.000	**0.00000**	0.00000	0.00000
Min rX	1	1:VERTICAL LC	0.000	0.000	0.000	0.000	**0.00000**	0.00000	0.00000
Max rY	1	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	**0.00000**	0.00000
Min rY	1	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	**0.00000**	0.00000
Max rZ	1	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	0.00000	**0.00000**
Min rZ	5	1:VERTICAL LC	0.006	-0.978	0.000	0.978	0.00000	0.00000	**-0.00500**
Max Rst	5	1:VERTICAL LC	0.006	-0.978	0.000	**0.978**	0.00000	0.00000	-0.00500

DLZ OHIO, INC. Columbus, OH Software licensed to Demo User	Job No 0121-3074-00	Sheet No 1	Rev
	Part		
Job Title Buckeye Lake	Ref		
	By J. Miller	Date 06-May-02	Chd
Client Ohio Dept. of Natural Resources	File buck_dock&lifts(end).std	Date/Time 06-May-2002 09:30	



Buckeye Lake Boat Dock (With Lifts Design) With End Loads - Nodes and Members

```
TAAD PLANE BUCKEYE LAKE BOAT DOCK
TART JOB INFORMATION
OB NAME Buckeye Lake
OB CLIENT Ohio Dept. of Natural Resources
C  ) 0121-3074-00
N  ER NAME J. Miller
   EER DATE 07-May-02
   JOB INFORMATION
NPUT WIDTH 79
NIT FEET POUND
OINT COORDINATES
. 0 0 0; 2 7.88 0 0; 3 14 0 0; 4 20.13 0 0; 5 28 0 0; 6 0 -5 0;
EMBER INCIDENCES
. 1 2; 2 2 3; 3 3 4; 4 4 5; 5 3 6;
NIT INCHES POUND
EMBER PROPERTY AMERICAN
1 TO 4 PRIS AX 19.70 IZ 272.00
5 PRIS AX 2.230 IZ 3.020
SUPPORTS
1 FIXED
5 FIXED
CONSTANTS
E STEEL MEMB 1 TO 5
DENSITY STEEL MEMB 1 TO 5
UNIT FEET POUND
LOAD 1 VERTICAL LOADS
JOINT LOAD
5 FY -400
PERFORM ANALYSIS
PRINT ALL
PRINT ANALYSIS RESULTS
FINISH
```

✓ TAA

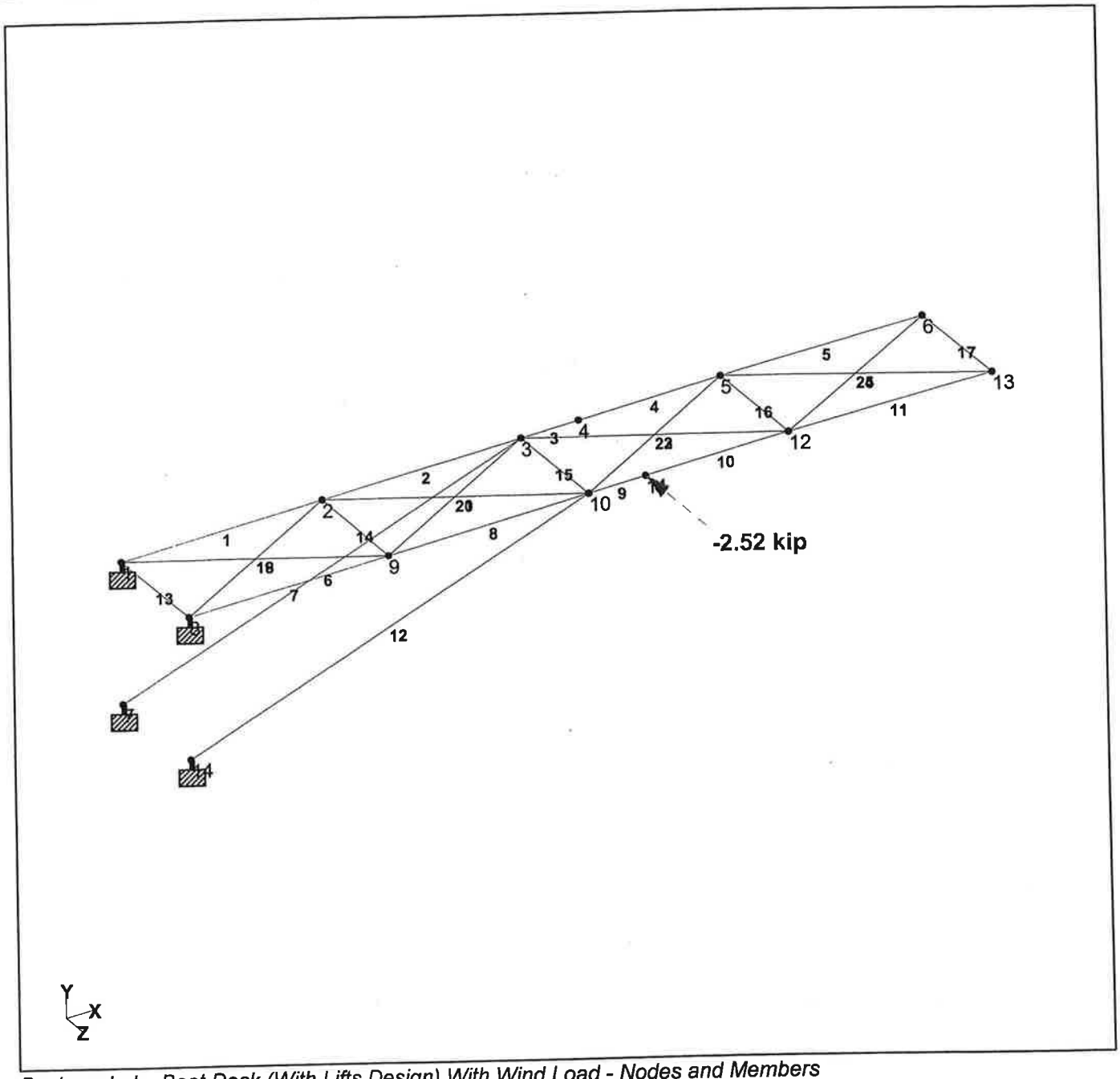
Node Displacements

Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
1	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
2	1:VERTICAL LC	0.000	-0.001	0.000	0.001	0.00000	0.00000	-0.00011
3	1:VERTICAL LC	0.001	-0.024	0.000	0.024	0.00000	0.00000	-0.00056
4	1:VERTICAL LC	0.001	-0.085	0.000	0.085	0.00000	0.00000	-0.00105
5	1:VERTICAL LC	0.001	-0.198	0.000	0.198	0.00000	0.00000	-0.00128
6	1:VERTICAL LC	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000

Reactions

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	FX (kip)	FY (kip)	FZ (kip)	MX (kip-in)	MY (kip-in)	MZ (kip-in)
1	1:VERTICAL LC	-2.468	-0.476	0.000	0.000	0.000	-13.516
6	1:VERTICAL LC	2.468	0.876	0.000	0.000	0.000	-0.184

DLZ OHIO, INC. Columbus, OH Software licensed to Demo User	Job No 0121-3074-00	Sheet No 1	Rev
	Part		
Job Title Buckeye Lake	Ref		
	By J. Miller	Date 06-May-02	Chd
Client Ohio Dept. of Natural Resources	File buck_dock&lifts(wind_r).s	Date/Time 06-May-2002 09:31	



Buckeye Lake Boat Dock (With Lifts Design) With Wind Load - Nodes and Members

```
STAAD SPACE BUCKEYE LAKE BOAT DOCK
START JOB INFORMATION
JOB NAME Buckeye Lake
JOB CLIENT Ohio Dept. of Natural Resources
JOB NO 0121-3074-00
ENGINEER NAME J. Miller
ENGINEER DATE 07-May-02
END JOB INFORMATION
INPUT WIDTH 79
UNIT FEET POUND
JOINT COORDINATES
1 0 0 0; 2 7 0 0; 3 14 0 0; 4 16 0 0; 5 21 0 0; 6 28 0 0; 7 0 -5 0; 8 0 0 4;
9 7 0 4; 10 14 0 4; 11 16 0 4; 12 21 0 4; 13 28 0 4; 14 0 -5 4;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 5 6; 6 3 7; 7 8 9; 8 9 10; 9 10 11; 10 11 12;
11 12 13; 12 10 14; 13 1 8; 14 2 9; 15 3 10; 16 5 12; 17 6 13; 18 1 9; 19 2 8;
20 2 10; 21 3 9; 22 3 12; 23 5 10; 24 5 13; 25 6 12;
UNIT INCHES POUND
MEMBER PROPERTY AMERICAN
1 TO 5 7 TO 11 PRIS AX 19.70 IZ 272.00 IY 88.60
6 12 TO 25 PRIS AX 2.230 IZ 3.020 IY 3.020
SUPPORTS
1 FIXED
7 FIXED
8 FIXED
14 FIXED
CONSTANTS
E STEEL MEMB 1 TO 25
DENSITY STEEL MEMB 1 TO 25
UNIT FEET POUND
LOAD 1 HORIZONTAL LOADS
JOINT LOAD
11 FZ -2520
PERFORM ANALYSIS
PRINT ALL
PRINT ANALYSIS RESULTS
FINISH
```

✓ THK

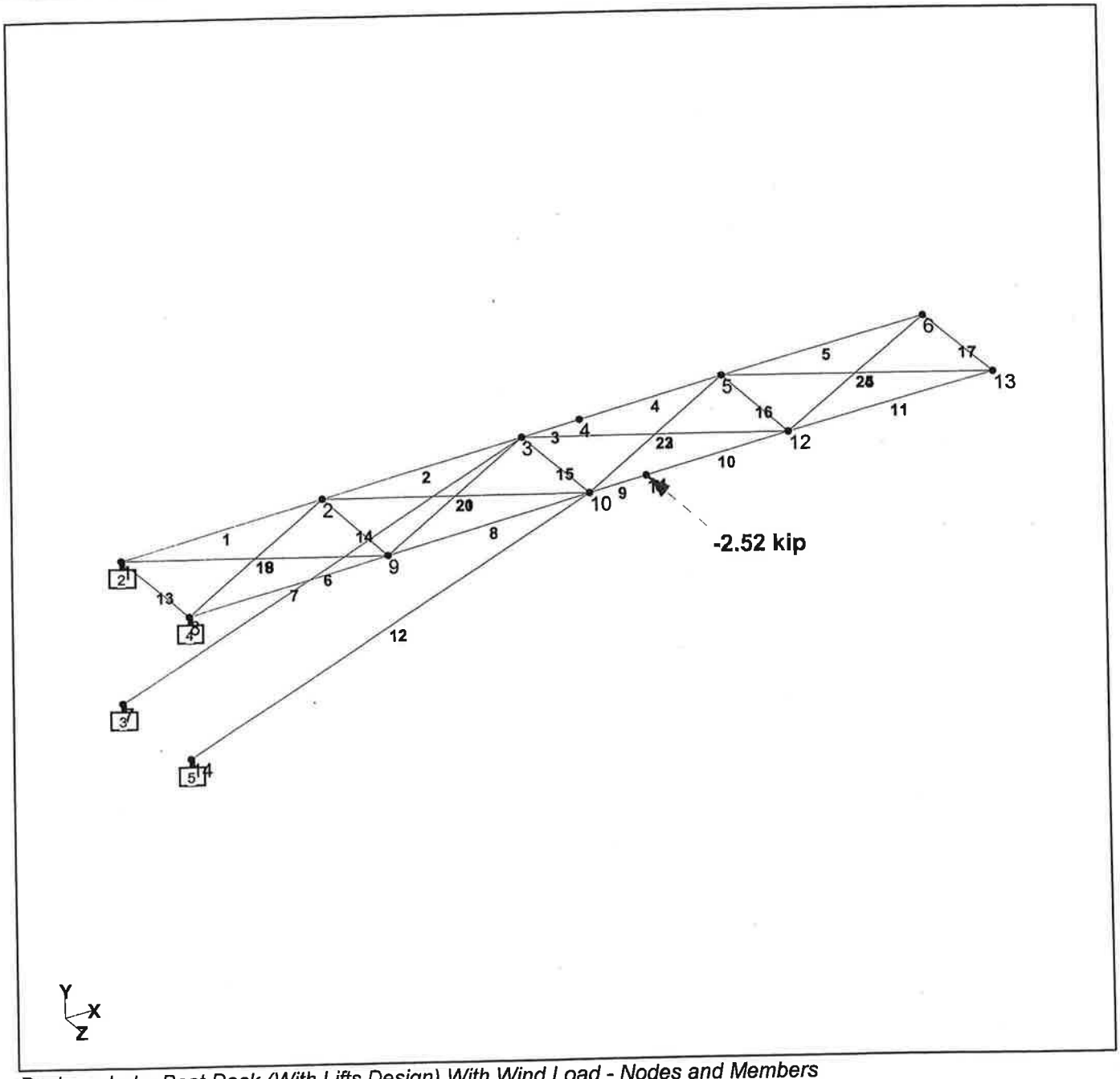
Node Displacements

Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
1	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
2	1:HORIZONTA	-0.001	0.001	-0.009	0.009	0.00005	0.00015	0.00003
3	1:HORIZONTA	-0.002	0.004	-0.021	0.022	0.00015	0.00012	0.00003
4	1:HORIZONTA	-0.002	0.004	-0.024	0.024	0.00000	0.00010	0.00003
5	1:HORIZONTA	-0.002	0.006	-0.029	0.030	0.00026	0.00007	0.00003
6	1:HORIZONTA	-0.002	0.008	-0.035	0.036	0.00034	0.00006	0.00002
7	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
8	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
9	1:HORIZONTA	0.001	-0.001	-0.009	0.009	0.00005	0.00012	-0.00003
10	1:HORIZONTA	0.002	-0.004	-0.022	0.022	0.00016	0.00027	-0.00003
11	1:HORIZONTA	0.002	-0.005	-0.028	0.029	0.00000	0.00021	-0.00003
12	1:HORIZONTA	0.002	-0.006	-0.029	0.030	0.00026	-0.00002	-0.00003
13	1:HORIZONTA	0.002	-0.008	-0.035	0.036	0.00034	0.00011	-0.00002
14	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000

Reactions

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	FX (kip)	FY (kip)	FZ (kip)	MX (kip-in)	MY (kip-in)	MZ (kip-in)
1	1:HORIZONTA	9.543	-0.028	1.220	0.008	-10.006	-3.550
7	1:HORIZONTA	0.081	0.029	0.003	0.096	-0.269	-0.038
8	1:HORIZONTA	-9.542	0.028	1.296	0.008	-11.493	3.588
14	1:HORIZONTA	-0.081	-0.029	0.001	0.054	-0.152	0.038

DLZ OHIO, INC. Columbus, OH Software licensed to Demo User	Job No 0121-3074-00	Sheet No 1	Rev
	Part		
Job Title Buckeye Lake	Ref		
	By J. Miller	Date 06-May-02	Chd
Client Ohio Dept. of Natural Resources	File buck_dock&lifts(wind_u).s	Date/Time 06-May-2002 09:32	



Buckeye Lake Boat Dock (With Lifts Design) With Wind Load - Nodes and Members

✓ TRA

```
STAAD SPACE BUCKEYE LAKE BOAT DOCK
START JOB INFORMATION
JOB NAME Buckeye Lake
JOB CLIENT Ohio Dept. of Natural Resources
JOB NO 0121-3074-00
ENGINEER NAME J. Miller
ENGINEER DATE 07-May-02
END JOB INFORMATION
INPUT WIDTH 79
UNIT FEET POUND
JOINT COORDINATES
1 0 0 0; 2 7 0 0; 3 14 0 0; 4 16 0 0; 5 21 0 0; 6 28 0 0; 7 0 -5 0; 8 0 0 4;
9 7 0 4; 10 14 0 4; 11 16 0 4; 12 21 0 4; 13 28 0 4; 14 0 -5 4;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 5 6; 6 3 7; 7 8 9; 8 9 10; 9 10 11; 10 11 12;
11 12 13; 12 10 14; 13 1 8; 14 2 9; 15 3 10; 16 5 12; 17 6 13; 18 1 9; 19 2 8;
20 2 10; 21 3 9; 22 3 12; 23 5 10; 24 5 13; 25 6 12;
UNIT INCHES POUND
MEMBER PROPERTY AMERICAN
1 TO 5 7 TO 11 PRIS AX 19.70 IZ 272.00 IY 88.60
6 12 TO 25 PRIS AX 2.230 IZ 3.020 IY 3.020
SUPPORTS
1 FIXED BUT MY
7 FIXED BUT MY
8 FIXED BUT MY
14 FIXED BUT MY
CONSTANTS
E STEEL MEMB 1 TO 25
DENSITY STEEL MEMB 1 TO 25
UNIT FEET POUND
LOAD 1 HORIZONTAL LOADS
JOINT LOAD
11 FZ -2520
PERFORM ANALYSIS
PRINT ALL
PRINT ANALYSIS RESULTS
FINISH
```

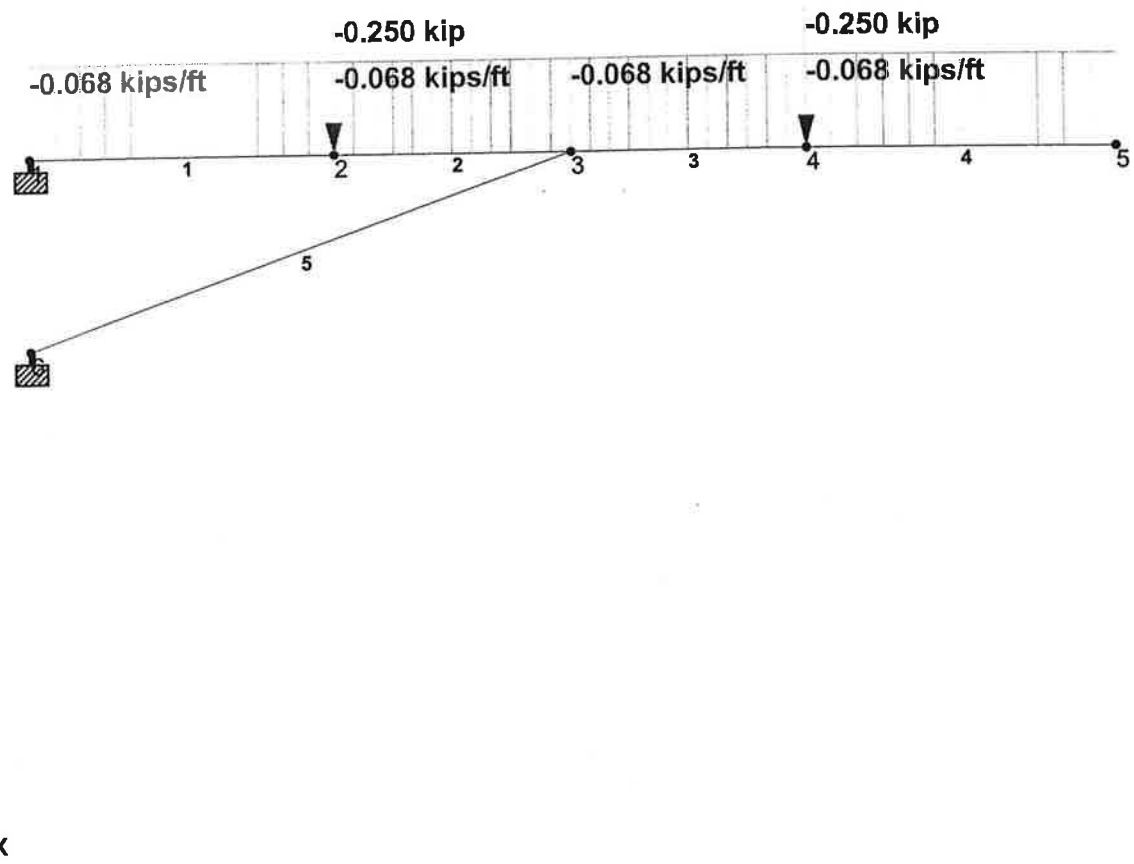
Node Displacements

Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
1	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00009	0.00000
2	1:HORIZONTA	-0.001	0.001	-0.010	0.010	0.00005	0.00014	0.00003
3	1:HORIZONTA	-0.002	0.004	-0.022	0.022	0.00016	0.00013	0.00003
4	1:HORIZONTA	-0.002	0.005	-0.025	0.025	0.00000	0.00011	0.00003
5	1:HORIZONTA	-0.002	0.006	-0.030	0.031	0.00026	0.00008	0.00003
6	1:HORIZONTA	-0.002	0.008	-0.036	0.037	0.00035	0.00007	0.00002
7	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00016	0.00000
8	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00011	0.00000
9	1:HORIZONTA	0.001	-0.001	-0.010	0.010	0.00005	0.00010	-0.00003
10	1:HORIZONTA	0.002	-0.004	-0.023	0.023	0.00017	0.00028	-0.00003
11	1:HORIZONTA	0.002	-0.005	-0.029	0.030	0.00000	0.00021	-0.00003
12	1:HORIZONTA	0.002	-0.006	-0.030	0.031	0.00026	-0.00002	-0.00003
13	1:HORIZONTA	0.002	-0.008	-0.036	0.037	0.00035	0.00011	-0.00003
14	1:HORIZONTA	0.000	0.000	0.000	0.000	0.00000	0.00009	0.00000

Reactions

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	FX (kip)	FY (kip)	FZ (kip)	MX (kip-in)	MY (kip-in)	MZ (kip-in)
1	1:HORIZONTA	10.002	-0.028	1.234	0.008	0.000	-3.625
7	1:HORIZONTA	0.078	0.028	0.000	0.000	0.000	-0.038
8	1:HORIZONTA	-10.001	0.028	1.287	0.008	0.000	3.664
14	1:HORIZONTA	-0.079	-0.028	-0.001	0.000	0.000	0.039

DLZ OHIO, INC. Columbus, OH Software licensed to DLZ Corporation	Job No 0121-3074-00	Sheet No 1	Rev
	Part		
Job Title Buckeye Lake	Ref		
	By J. Miller	Date 07-May-02	Chd
Client Ohio Dept. of Natural Resources	File buck_dock&lifts(-boat).std	Date/Time 07-May-2002 10:58	



Buckeye Lake Boat Dock With Lifts (No Boat) - Nodes and Members

```
STAAD PLANE BUCKEYE LAKE BOAT DOCK
START JOB INFORMATION
JOB NAME Buckeye Lake
JOB CLIENT Ohio Dept. of Natural Resources
JOB NO 0121-3074-00
E    EER NAME J. Miller
    EER DATE 07-May-02
    JOB INFORMATION
INPUT WIDTH 79
UNIT FEET POUND
JOINT COORDINATES
1 0 0 0; 2 7.88 0 0; 3 14 0 0; 4 20.13 0 0; 5 28 0 0; 6 0 -5 0;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 3 6;
UNIT INCHES POUND
MEMBER PROPERTY AMERICAN
1 TO 4 PRIS AX 19.7 IZ 272
5 PRIS AX 2.23 IZ 3.02
SUPPORTS
1 FIXED
6 FIXED
CONSTANTS
E STEEL MEMB 1 TO 5
DENSITY STEEL MEMB 1 TO 5
UNIT FEET POUND
LOAD 1 VERTICAL LOADS
SELFWEIGHT Y -1
MEMBER LOAD
1 TO 4 UNI GY -68.33
JOINT LOAD
2 4 FY -250
PERFORM ANALYSIS
PRINT ALL
PRINT ANALYSIS RESULTS
FINISH
```

Node Displacements

Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
1	1:VERTICAL LO	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
2	1:VERTICAL LO	0.002	-0.028	0.000	0.028	0.00000	0.00000	-0.00062
3	1:VERTICAL LO	0.003	-0.108	0.000	0.108	0.00000	0.00000	-0.00172
4	1:VERTICAL LO	0.003	-0.278	0.000	0.278	0.00000	0.00000	-0.00273
5	1:VERTICAL LO	0.003	-0.551	0.000	0.551	0.00000	0.00000	-0.00293
6	1:VERTICAL LO	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000

Reactions

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	FX (kip)	FY (kip)	FZ (kip)	MX (kip-in)	MY (kip-in)	MZ (kip-in)
1	1:VERTICAL LO	-11.295	0.319	0.000	0.000	0.000	50.348
6	1:VERTICAL LO	11.295	4.080	0.000	0.000	0.000	1.583

DLZ

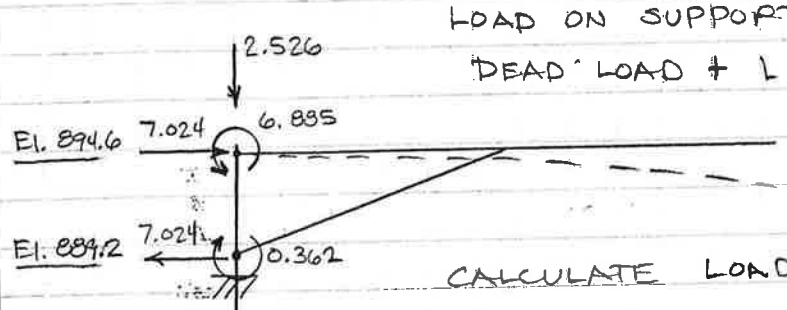
CLIENT: ODNR
PROJECT: Buckeye Lake
SUBJECT: Boat Dock w/o lift

PROJECT NO. 021-3074.00
SHEET NO. 1 OF 3
COMP. BY PAN DATE 5/13/02
CHECKED BY DAA DATE 7/19/02

LOAD CASE 1

LOAD ON SUPPORT PILE

DEAD LOAD + LIVE LOAD



$\Delta = 0.9''$ due to deflection of dock alone

CALCULATE LOADS ON PILE AT EL 888 ft

$\sum F_x = 0$

$\sum F_y = -2.526$ kip

$\circlearrowleft + \sum M_{888} = 6.885 - 0.362 - 7.024\,(5.4' \times 12'')$

$= -448.6$ k-in

DESIGN CRITERIA

1. $f_b \leq F_b$

$f_b = \frac{M}{S}$ $\quad F_b = 0.66\,F_y = 0.66\,(50\text{ ksi}) = 33\text{ ksi}$

$33\text{ ksi} = \frac{450\text{ k-in}}{S_{Reqd}}$ $\quad S_{Reqd} = 13.6\text{ in}^3$

Any standard HP section would work

2. slope < 1"/8 ft

$1''/8\text{ ft} \times 28\text{ ft} = 3.5''$

$3.5 - 0.9 = 2.6''$

$\frac{2.6''}{28\text{ ft}} \times \frac{1\text{ ft}}{12''} = 0.0077$

$\tan^{-1}(0.0077) = 0.44°$

0.0077 rad

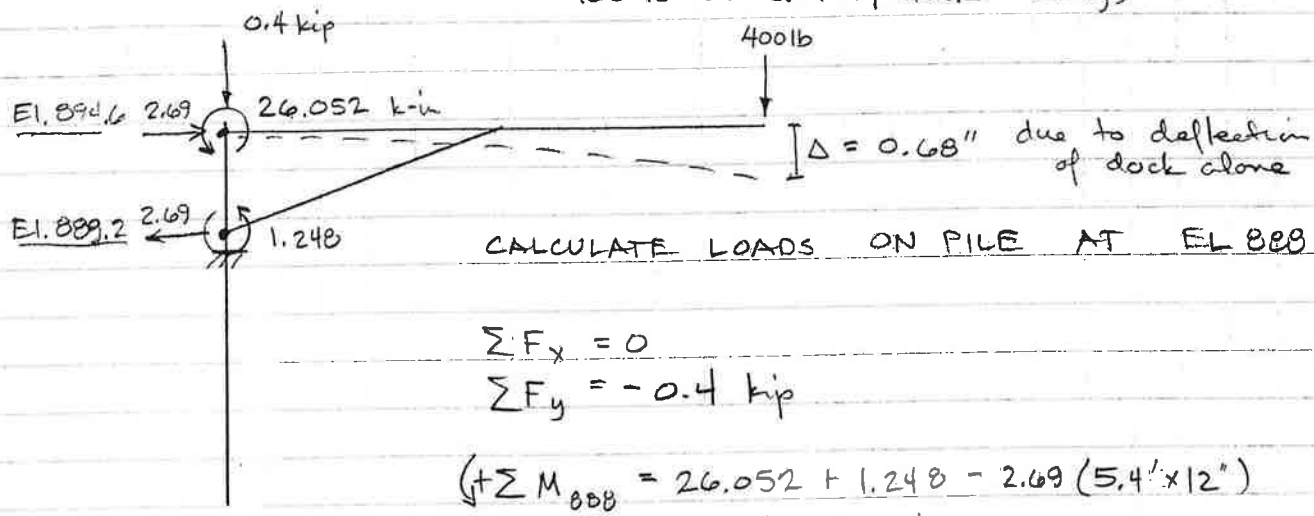
DLZ

CLIENT: ODNR
PROJECT: Buckeye Lake
SUBJECT: Boat Dock w/o lift

PROJECT NO. 0121-3074.00
SHEET NO. 2 OF 3
COMP. BY PAN DATE 5/13/02
CHECKED BY DAA DATE 7/19/02

LOADS ON SUPPORT PILE W/O LIFT — LOAD CASE 2

400 lb at end of dock (only)



CALCULATE LOADS ON PILE AT EL 888 ft

$\Sigma F_x = 0$

$\Sigma F_y = -0.4$ kip

$\circlearrowleft + \Sigma M_{888} = 26.052 + 1.248 - 2.69\,(5.4' \times 12'')$

$= -147.0$ kip-in

DESIGN CRITERIA

$\Delta < 4''$ at end of dock

$4'' - 0.68'' = 3.32''$

$\frac{3.32''}{28'} \times \frac{1'}{12''} = 0.0099$ rad

slope < 0.0099 rad

DLZ

CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Boat Dock w/o lift

PROJECT NO. 0121-3074.00
SHEET NO. 3 OF 3
COMP. BY PAN DATE 5/13/02
CHECKED BY DAA DATE 7/19/02

TRY

HP8 x 36

LC1 slope = 0.0154 > 0.0077 NG

HP 10 x 42

LC1 slope = 0.0090 > 0.0077 NG

HP 12 x 53

LC1 slope = 0.0057 < 0.0077 OK

$S = 66.8 \text{ in}^3$

$M_{MAX} = 449.3$ k-in @ 5.1 ft (El 882.9')

$f_b = \frac{449.3}{66.8} = 6.73$ ksi < 33 ksi OK

LC2 slope = 0.0016 < 0.0099 OK

USE HP 12 x 53 with pile tip at 873 (22' long)

==========

LPILE Plus for Windows, Version 4

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

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All Rights Reserved

==========

This program is licensed to:

Peter Narsavage
DLZ Ohio, Inc.

Path to file locations:	M:\proj\0121\3074.00\geot\Lpile\
Name of input data file:	Dock No Lift S5.lpd
Name of output file:	Dock No Lift S5.lpo
Name of plot output file:	Dock No Lift S5.lpp
Name of runtime file:	Dock No Lift S5.lpr

Time and Date of Analysis

Date: May 13, 2002 Time: 13:18:22

Problem Title

Buckeye Lake Dock - No Boat Lift

Program Options

Units Used in Computations - US Customary Units, inches, pounds

Basic Program Options:

Analysis Type 1:
- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:
- Only internally-generated p-y curves used in analysis
- Analysis does not use p-y multipliers (individual pile or shaft action only)
- Analysis assumes no shear resistance at pile tip
- Analysis includes automatic computation of pile-top deflection vs. pile embedment length
- No computation of foundation stiffness matrix elements
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments	=	100
- Deflection tolerance for closure	=	1.0000E-05 in
- Maximum number of iterations allowed	=	100
- Maximum allowable deflection	=	1.0000E+03 in

Printing Options:
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 180.00 in
Depth of ground surface below top of pile = 60.00 in
Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 2 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq.in	Modulus of Elasticity lbs/Sq.in
1	0.0000	12.05	393.0000	15.5000	29000000.00
2	180.0000	12.05	393.0000	15.5000	29000000.00

Soil and Rock Layering Information

The soil profile is modelled using 2 layers

Layer 1 is soft clay, p-y criteria by Matlock, 1970
Distance from top of pile to top of layer = 60.000 in
Distance from top of pile to bottom of layer = 84.000 in

Layer 2 is stiff clay with water-induced erosion
Distance from top of pile to top of layer = 84.000 in
Distance from top of pile to bottom of layer = 400.000 in
p-y subgrade modulus k for top of soil layer = 100.000 lbs/in**3
p-y subgrade modulus k for bottom of layer = 100.000 lbs/in**3

(Depth of lowest layer extends 220.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Distribution of effective unit weight of soil with depth
is defined using 4 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	60.00	.03910
2	84.00	.03910
3	84.00	.03910
4	400.00	.03910

Shear Strength of Soils

Distribution of shear strength parameters with depth
defined using 4 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k_rm	RQD %
1	60.000	3.47000	.00	------	------
2	84.000	3.47000	.00	------	------
3	84.000	5.21000	.00	------	------
4	400.000	5.21000	.00	------	------

Notes:

(1) Cohesion = uniaxial compressive strength for rock materials.
(2) Values of E50 are reported for clay strata.
(3) Default values will be generated for E50 when input values are 0.
(4) RQD and k_rm are reported only for weak rock strata.

Static loading criteria was used for computation of p-y curves

---

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load Case Number 1 Dead Load + Live Load

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Shear force at pile head = .000 lbs
Bending moment at pile head = 448600.000 in-lbs
Axial load at pile head = 2526.000 lbs

Non-zero moment at pile head for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Load Case Number 2 400 lb at end of dock

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Shear force at pile head = .000 lbs
Bending moment at pile head = 147000.000 in-lbs
Axial load at pile head = 400.000 lbs

Non-zero moment at pile head for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Computed Values of Load Distribution and Deflection
for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Specified shear force at pile head = .000 lbs
Specified bending moment at pile head = 448600.000 in-lbs
Specified axial load at pile head = 2526.000 lbs

Non-zero moment for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res p lbs/in
0.000	.404535	4.486E+05	-2.918E-08	-.005658	7037.5059	0.0000
1.800	.394413	4.486E+05	-2.953E-06	-.005588	7037.8977	0.0000
3.600	.384419	4.487E+05	1.362E-07	-.005517	7038.2846	0.0000
5.400	.374553	4.487E+05	3.774E-07	-.005446	7038.6665	0.0000
7.200	.364814	4.487E+05	4.626E-07	-.005375	7039.0435	0.0000
9.000	.355203	4.487E+05	3.174E-07	-.005304	7039.4155	0.0000
10.800	.345719	4.487E+05	1.930E-07	-.005233	7039.7826	0.0000
12.600	.336363	4.488E+05	1.235E-07	-.005162	7040.1448	0.0000
14.400	.327135	4.488E+05	8.881E-08	-.005091	7040.5020	0.0000
16.200	.318034	4.488E+05	1.469E-08	-.005021	7040.8543	0.0000
18.000	.309061	4.488E+05	-1.190E-07	-.004950	7041.2017	0.0000
19.800	.300215	4.489E+05	-1.697E-07	-.004879	7041.5441	0.0000
21.600	.291497	4.489E+05	-2.117E-07	-.004808	7041.8815	0.0000
23.400	.282906	4.489E+05	-1.566E-07	-.004737	7042.2141	0.0000
25.200	.274443	4.489E+05	-7.885E-08	-.004666	7042.5417	0.0000
27.000	.266108	4.489E+05	-5.275E-08	-.004595	7042.8643	0.0000

28.800	.257900	4.490E+05	-9.845E-08	-.004524	7043.1820	0.0000
30.600	.249820	4.490E+05	-1.819E-07	-.004453	7043.4948	0.0000
32.400	.241868	4.490E+05	-2.418E-07	-.004383	7043.8026	0.0000
34.200	.234043	4.490E+05	-3.526E-07	-.004312	7044.1055	0.0000
36.000	.226346	4.491E+05	-4.260E-07	-.004241	7044.4035	0.0000
37.800	.218777	4.491E+05	-5.363E-07	-.004170	7044.6965	0.0000
39.600	.211335	4.491E+05	-5.410E-07	-.004099	7044.9846	0.0000
41.400	.204021	4.491E+05	-5.688E-07	-.004028	7045.2677	0.0000
43.200	.196835	4.491E+05	-6.398E-07	-.003957	7045.5459	0.0000
45.000	.189776	4.491E+05	-5.574E-07	-.003886	7045.8191	0.0000
46.800	.182845	4.492E+05	-4.771E-07	-.003815	7046.0874	0.0000
48.600	.176042	4.492E+05	-4.736E-07	-.003744	7046.3507	0.0000
50.400	.169366	4.492E+05	-4.856E-07	-.003673	7046.6092	0.0000
52.200	.162818	4.492E+05	-4.248E-07	-.003602	7046.8626	0.0000
54.000	.156398	4.492E+05	-5.014E-07	-.003531	7047.1112	0.0000
55.800	.150105	4.492E+05	-5.998E-07	-.003460	7047.3547	0.0000
57.600	.143941	4.493E+05	-5.235E-07	-.003389	7047.5934	0.0000
59.400	.137904	4.493E+05	-5.095E-07	-.003318	7047.8271	0.0000
61.200	.131994	4.493E+05	-34.7384	-.003248	7048.0558	-38.5982
63.000	.126213	4.492E+05	-104.7617	-.003177	7046.3632	-39.2055
64.800	.120559	4.489E+05	-175.8419	-.003106	7042.7190	-39.7725
66.600	.115032	4.486E+05	-247.9061	-.003035	7037.0951	-40.2987
68.400	.109634	4.481E+05	-320.8799	-.002964	7029.4654	-40.7834
70.200	.104362	4.474E+05	-394.6882	-.002893	7019.8059	-41.2258
72.000	.099218	4.467E+05	-469.2543	-.002823	7008.0945	-41.6254
73.800	.094201	4.458E+05	-544.5004	-.002752	6994.3114	-41.9814
75.600	.089310	4.447E+05	-620.3472	-.002682	6978.4390	-42.2928
77.400	.084546	4.436E+05	-696.7137	-.002612	6960.4619	-42.5589
79.200	.079908	4.423E+05	-773.5175	-.002542	6940.3667	-42.7787
81.000	.075396	4.408E+05	-850.6742	-.002472	6918.1427	-42.9510
82.800	.071009	4.392E+05	-928.0975	-.002402	6893.7813	-43.0749
84.600	.066747	4.375E+05	-1187.3464	-.002333	6867.2763	-244.9795
86.400	.062609	4.350E+05	-1621.3664	-.002264	6828.6030	-237.2649
88.200	.058595	4.317E+05	-2041.4846	-.002196	6778.1444	-229.5332
90.000	.054704	4.276E+05	-2447.6671	-.002128	6716.2845	-221.7807
91.800	.050934	4.229E+05	-2839.8722	-.002061	6643.4082	-214.0027
93.600	.047285	4.174E+05	-3218.0488	-.001995	6559.9018	-206.1935
95.400	.043754	4.113E+05	-3582.1341	-.001929	6466.1530	-198.3458
97.200	.040340	4.046E+05	-3932.0509	-.001865	6362.5516	-190.4507
99.000	.037041	3.972E+05	-4267.7042	-.001801	6249.4897	-182.4974
100.800	.033855	3.892E+05	-4588.9770	-.001739	6127.3622	-174.4725
102.600	.030780	3.807E+05	-4895.7258	-.001678	5996.5677	-166.3595
104.400	.027813	3.716E+05	-5187.7735	-.001619	5857.5090	-158.1379
106.200	.024951	3.620E+05	-5464.9017	-.001561	5710.5945	-149.7823
108.000	.022192	3.519E+05	-5726.8397	-.001505	5556.2392	-141.2600
109.800	.019534	3.414E+05	-5973.2499	-.001450	5394.8663	-132.5292
111.600	.016972	3.304E+05	-6203.7075	-.001397	5226.9094	-123.5348
113.400	.014505	3.191E+05	-6417.6711	-.001346	5052.8152	-114.2024
115.200	.012128	3.074E+05	-6614.4380	-.001296	4873.0472	-104.4275
117.000	.009839	2.953E+05	-6793.0732	-.001249	4688.0909	-94.0561
118.800	.007633	2.829E+05	-6952.2853	-.001203	4498.4614	-82.8462
120.600	.005508	2.703E+05	-7082.9848	-.001159	4304.7153	-62.3755
122.400	.003460	2.574E+05	-7174.9460	-.001118	4107.8692	-39.8037
124.200	.001485	2.445E+05	-7226.3840	-.001078	3909.0441	-17.3496
126.000	-4.21E-04	2.314E+05	-7237.5067	-.001040	3709.3548	4.9910
127.800	-.002260	2.184E+05	-7208.5120	-.001005	3509.9107	27.2253
129.600	-.004038	2.055E+05	-7139.5828	-9.714E-04	3311.8160	49.3628
131.400	-.005757	1.927E+05	-7030.8822	-9.399E-04	3116.1700	71.4157
133.200	-.007422	1.802E+05	-6893.0867	-9.105E-04	2924.0677	81.6904
135.000	-.009035	1.679E+05	-6738.4460	-8.830E-04	2736.0195	90.1326
136.800	-.010601	1.559E+05	-6569.4601	-8.574E-04	2552.4446	97.6296
138.600	-.012122	1.443E+05	-6387.6335	-8.337E-04	2373.7154	104.3999
140.400	-.013602	1.329E+05	-6194.1422	-8.118E-04	2200.1682	110.5905
142.200	-.015044	1.220E+05	-5989.9349	-7.917E-04	2032.1105	116.3065
144.000	-.016452	1.114E+05	-5775.7953	-7.733E-04	1869.8262	121.6264
145.800	-.017828	1.012E+05	-5552.3819	-7.565E-04	1713.5795	126.6107
147.600	-.019175	91399.8509	-5320.2554	-7.413E-04	1563.6181	131.3077
149.400	-.020497	82039.4473	-5079.8978	-7.276E-04	1420.1753	135.7563
151.200	-.021795	73118.8351	-4831.7272	-7.153E-04	1283.4720	139.9888
153.000	-.023072	64651.7344	-4576.1082	-7.044E-04	1153.7186	144.0323
154.800	-.024331	56651.2517	-4313.3607	-6.949E-04	1031.1157	147.9094
156.600	-.025573	49129.9546	-4043.7666	-6.865E-04	915.8562	151.6397

158.400	-.026802	42099.9347	-3767.5750	-6.793E-04	808.1251	155.2399
160.200	-.028019	35572.8620	-3485.0069	-6.732E-04	708.1015	158.7247
162.000	-.029226	29560.0316	-3196.2588	-6.680E-04	615.9583	162.1065
163.800	-.030424	24072.4051	-2901.5062	-6.638E-04	531.8636	165.3964
165.600	-.031615	19120.6455	-2600.9061	-6.604E-04	455.9807	168.6038
167.400	-.032801	14715.1485	-2294.5992	-6.577E-04	388.4690	171.7371
169.200	-.033983	10866.0692	-1982.7126	-6.557E-04	329.4840	174.8035
171.000	-.035162	7583.3457	-1665.3611	-6.542E-04	279.1782	177.8093
172.800	-.036338	4876.7187	-1342.6490	-6.533E-04	237.7007	180.7597
174.600	-.037513	2755.7497	-1014.6719	-6.526E-04	205.1980	183.6593
176.400	-.038688	1229.8348	-681.5178	-6.523E-04	181.8143	186.5120
178.200	-.039862	308.2178	-343.2683	-6.522E-04	167.6910	189.3208
180.000	-.041036	0.0000	0.0000	-6.522E-04	162.9677	192.0884

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

Pile-head deflection	=	.40453450	in
Computed slope at pile head	=	-.00565843	
Maximum bending moment	=	449288.44	lbs-in
Maximum shear force	=	-7237.51	lbs
Depth of maximum bending moment	=	61.20	in
Depth of maximum shear force	=	126.00	in
Number of iterations	=	17	
Number of zero deflection points	=	1	

Computed Values of Load Distribution and Deflection
for Lateral Loading for Load Case Number 2

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Specified shear force at pile head = .000 lbs
Specified bending moment at pile head = 147000.000 in-lbs
Specified axial load at pile head = 400.000 lbs

Non-zero moment for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res p lbs/in
0.000	.102266	1.470E+05	-1.548E-08	-.001614	2278.4973	0.0000
1.800	.099381	1.470E+05	-4.827E-07	-.001591	2278.5150	0.0000
3.600	.096538	1.470E+05	1.741E-08	-.001568	2278.5324	0.0000
5.400	.093736	1.470E+05	-3.492E-08	-.001545	2278.5496	0.0000
7.200	.090976	1.470E+05	-7.123E-08	-.001522	2278.5665	0.0000
9.000	.088259	1.470E+05	-5.189E-08	-.001498	2278.5832	0.0000
10.800	.085583	1.470E+05	-5.076E-09	-.001475	2278.5996	0.0000
12.600	.082948	1.470E+05	-2.677E-08	-.001452	2278.6157	0.0000
14.400	.080356	1.470E+05	-5.022E-08	-.001429	2278.6316	0.0000
16.200	.077805	1.470E+05	-3.581E-08	-.001405	2278.6472	0.0000
18.000	.075296	1.470E+05	-9.308E-08	-.001382	2278.6626	0.0000
19.800	.072829	1.470E+05	-1.146E-07	-.001359	2278.6777	0.0000
21.600	.070404	1.470E+05	-6.073E-08	-.001336	2278.6926	0.0000
23.400	.068020	1.470E+05	-1.391E-08	-.001313	2278.7072	0.0000
25.200	.065679	1.470E+05	3.837E-08	-.001289	2278.7216	0.0000
27.000	.063379	1.470E+05	4.082E-08	-.001266	2278.7357	0.0000
28.800	.061120	1.470E+05	3.984E-08	-.001243	2278.7495	0.0000
30.600	.058904	1.470E+05	4.793E-08	-.001220	2278.7631	0.0000
32.400	.056730	1.470E+05	5.726E-08	-.001196	2278.7764	0.0000
34.200	.054597	1.470E+05	5.322E-08	-.001173	2278.7895	0.0000
36.000	.052506	1.470E+05	4.151E-08	-.001150	2278.8023	0.0000
37.800	.050457	1.470E+05	4.144E-08	-.001127	2278.8149	0.0000

39.600	.048449	1.470E+05	3.160E-08	-.001104	2278.8272	0.0000
41.400	.046484	1.470E+05	2.450E-08	-.001080	2278.8392	0.0000
43.200	.044560	1.470E+05	1.908E-08	-.001057	2278.8510	0.0000
45.000	.042678	1.470E+05	7.503E-09	-.001034	2278.8626	0.0000
46.800	.040838	1.470E+05	1.583E-08	-.001011	2278.8738	0.0000
48.600	.039040	1.470E+05	2.268E-08	-9.875E-04	2278.8849	0.0000
50.400	.037283	1.470E+05	4.055E-08	-9.643E-04	2278.8956	0.0000
52.200	.035568	1.470E+05	4.124E-08	-9.410E-04	2278.9061	0.0000
54.000	.033895	1.470E+05	5.763E-08	-9.178E-04	2278.9164	0.0000
55.800	.032264	1.470E+05	8.187E-08	-8.946E-04	2278.9264	0.0000
57.600	.030675	1.470E+05	7.899E-08	-8.714E-04	2278.9361	0.0000
59.400	.029127	1.470E+05	8.524E-08	-8.482E-04	2278.9456	0.0000
61.200	.027621	1.470E+05	-20.6241	-8.249E-04	2278.9548	-22.9157
63.000	.026157	1.470E+05	-62.1295	-8.017E-04	2277.8260	-23.2014
64.800	.024735	1.468E+05	-104.1230	-7.785E-04	2275.5450	-23.4580
66.600	.023354	1.466E+05	-146.5520	-7.554E-04	2272.0990	-23.6853
68.400	.022016	1.463E+05	-189.3632	-7.322E-04	2267.4767	-23.8827
70.200	.020718	1.459E+05	-232.5025	-7.092E-04	2261.6683	-24.0498
72.000	.019463	1.454E+05	-275.9150	-6.862E-04	2254.6656	-24.1862
73.800	.018248	1.449E+05	-319.5448	-6.632E-04	2246.4618	-24.2913
75.600	.017075	1.443E+05	-363.3351	-6.404E-04	2237.0516	-24.3646
77.400	.015943	1.436E+05	-407.2282	-6.177E-04	2226.4315	-24.4055
79.200	.014852	1.428E+05	-451.1651	-5.950E-04	2214.5993	-24.4133
81.000	.013801	1.420E+05	-495.0857	-5.725E-04	2201.5548	-24.3874
82.800	.012790	1.410E+05	-538.9285	-5.502E-04	2187.2991	-24.3269
84.600	.011820	1.400E+05	-642.9937	-5.280E-04	2171.8353	-91.3010
86.400	.010890	1.387E+05	-802.6310	-5.060E-04	2151.8381	-86.0738
88.200	.009999	1.372E+05	-952.8450	-4.842E-04	2127.5670	-80.8306
90.000	.009146	1.353E+05	-1093.6223	-4.627E-04	2099.2823	-75.5887
91.800	.008333	1.332E+05	-1224.9806	-4.415E-04	2067.2443	-70.3649
93.600	.007557	1.309E+05	-1346.9664	-4.206E-04	2031.7124	-65.1749
95.400	.006819	1.284E+05	-1459.6537	-4.001E-04	1992.9442	-60.0332
97.200	.006117	1.256E+05	-1563.1417	-3.801E-04	1951.1952	-54.9535
99.000	.005450	1.227E+05	-1657.5533	-3.605E-04	1906.7173	-49.9484
100.800	.004819	1.197E+05	-1743.0334	-3.413E-04	1859.7593	-45.0295
102.600	.004222	1.165E+05	-1819.7465	-3.227E-04	1810.5653	-40.2073
104.400	.003657	1.131E+05	-1887.8752	-3.046E-04	1759.3748	-35.4913
106.200	.003125	1.097E+05	-1947.6186	-2.870E-04	1706.4218	-30.8901
108.000	.002624	1.061E+05	-1999.1897	-2.699E-04	1651.9350	-26.4111
109.800	.002153	1.025E+05	-2042.8145	-2.534E-04	1596.1366	-22.0608
111.600	.001712	98759.7267	-2078.7295	-2.376E-04	1539.2427	-17.8447
113.400	.001298	94989.2705	-2107.1804	-2.223E-04	1481.4626	-13.7674
115.200	9.12E-04	91174.1973	-2128.4202	-2.076E-04	1422.9988	-9.8323
117.000	5.51E-04	87327.2568	-2142.7074	-1.935E-04	1364.0467	-6.0423
118.800	2.15E-04	83460.7293	-2150.3047	-1.800E-04	1304.7943	-2.3992
120.600	-9.68E-05	79586.4189	-2151.4774	-1.671E-04	1245.4228	1.0962
122.400	-3.86E-04	75715.6512	-2146.4916	-1.548E-04	1186.1055	4.4436
124.200	-6.54E-04	71859.2723	-2135.6129	-1.432E-04	1127.0087	7.6438
126.000	-9.02E-04	68027.6511	-2119.1053	-1.321E-04	1068.2913	10.6980
127.800	-.001130	64230.6837	-2097.2295	-1.217E-04	1010.1049	13.6084
129.600	-.001340	60477.8002	-2070.2419	-1.118E-04	952.5941	16.3778
131.400	-.001532	56777.9738	-2038.3935	-1.026E-04	895.8964	19.0094
133.200	-.001709	53139.7314	-2001.9285	-9.390E-05	840.1424	21.5073
135.000	-.001871	49571.1665	-1961.0836	-8.579E-05	785.4562	23.8759
136.800	-.002018	46079.9539	-1916.0871	-7.824E-05	731.9554	26.1202
138.600	-.002152	42673.3656	-1867.1577	-7.123E-05	679.7513	28.2457
140.400	-.002274	39358.2886	-1814.5043	-6.475E-05	628.9497	30.2581
142.200	-.002385	36141.2435	-1758.3247	-5.879E-05	579.6503	32.1636
144.000	-.002486	33028.4043	-1698.8056	-5.332E-05	531.9478	33.9687
145.800	-.002577	30025.6200	-1636.1218	-4.835E-05	485.9319	35.6800
147.600	-.002660	27138.4354	-1570.4358	-4.383E-05	441.6874	37.3045
149.400	-.002735	24372.1142	-1501.8976	-3.976E-05	399.2951	38.8491
151.200	-.002803	21731.6614	-1430.6443	-3.612E-05	358.8317	40.3212
153.000	-.002865	19221.8467	-1356.8003	-3.289E-05	320.3702	41.7277
154.800	-.002922	16847.2276	-1280.4770	-3.004E-05	283.9806	43.0760
156.600	-.002973	14612.1729	-1201.7727	-2.756E-05	249.7296	44.3732
158.400	-.003021	12520.8855	-1120.7733	-2.541E-05	217.6819	45.6262
160.200	-.003065	10577.4255	-1037.5521	-2.359E-05	187.8994	46.8419
162.000	-.003106	8785.7318	-952.1703	-2.206E-05	160.4428	48.0269
163.800	-.003144	7149.6443	-864.6772	-2.080E-05	135.3707	49.1876
165.600	-.003181	5672.9238	-775.1114	-1.979E-05	112.7408	50.3300
167.400	-.003215	4359.2717	-683.5007	-1.900E-05	92.6098	51.4597

169.200	-.003249	3212.3485	-589.8634	-1.840E-05	75.0339	52.5818
171.000	-.003282	2235.7901	-494.2087	-1.797E-05	60.0687	53.7011
172.800	-.003314	1433.2231	-396.7480	-1.768E-05	47.7698	54.5885
174.600	-.003345	807.5228	-298.2547	-1.750E-05	38.1813	54.8485
176.400	-.003377	359.5316	-199.2961	-1.741E-05	31.3161	55.1055
178.200	-.003408	90.0820	-99.8768	-1.737E-05	27.1869	55.3604
180.000	-.003439	0.0000	0.0000	-1.737E-05	25.8065	55.6139

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 2:

Pile-head deflection	=	.10226579	in
Computed slope at pile head	=	-.00161440	
Maximum bending moment	=	147029.86	lbs-in
Maximum shear force	=	-2151.48	lbs
Depth of maximum bending moment	=	61.20	in
Depth of maximum shear force	=	120.60	in
Number of iterations	=	8	
Number of zero deflection points	=	1	

Summary of Pile-head Response

Definition of symbols for pile-head boundary conditions:

y = pile-head displacment, in
M = pile-head moment, lbs-in
V = pile-head shear force, lbs
S = pile-head slope, radians
R = rotational stiffness of pile-head, in-lbs/rad

BC Type	Boundary Condition 1	Boundary Condition 2	Axial Load lbs	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V= 0.000	M= 4.49E+05	2526.0000	.4045	4.493E+05	-7237.5067
1	V= 0.000	M= 1.47E+05	400.0000	.1023	1.470E+05	-2151.4774

Pile-head Deflection vs. Pile Length

Boundary Condition Type 1, Shear and Moment

Shear	=	0.	lbs
Moment	=	448600.	in-lbs
Axial Load	=	2526.	lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
180.000	.40453450	449288.44	-7237.51
171.000	.48161164	449390.26	-8040.71
162.000	.60199648	449554.27	-8921.96
153.000	.96923159	450053.93	-10237.12
144.000	-144.77	448600.07	3848.27
135.000	-137.20	448599.84	3210.77
126.000	-137.19	448600.15	2923.64
117.000	-138.99	448600.44	2626.47

108.000	-142.18	448601.20	2388.78
99.000	-147.06	448602.14	2125.52

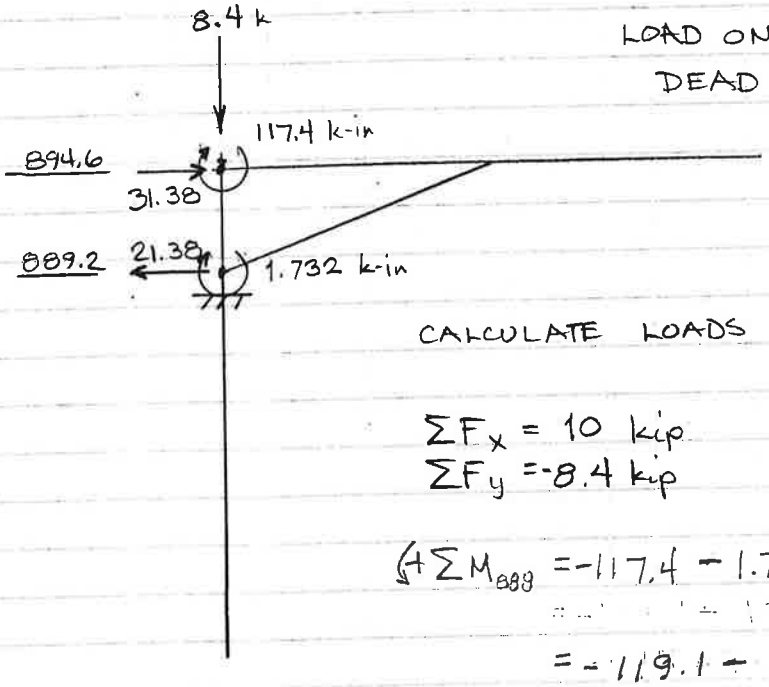
The analysis ended normally.

DLZ

CLIENT: ODNR
PROJECT: Buckeye Lake
SUBJECT: Boat Dock w/ lift

PROJECT NO. 0121-3074.00
SHEET NO. 1 OF 4
COMP. BY PAN DATE 5/13/02
CHECKED BY DAA DATE 7/19/02

LOAD CASE 1



LOAD ON SUPPORT PILE
DEAD LOAD + BOAT + WIND LOAD

CALCULATE LOADS AT EL 888.0

$\Sigma F_x = 10$ kip
$\Sigma F_y = -8.4$ kip

$\circlearrowleft + \Sigma M_{888} = -117.4 - 1.7 - 31.38 \times (94.6 - 88.0)12'' + 21.38 \times (89.2 - 88.0)\,12''$
$= -119.1 - 2485.3 + 307.9$
$= -2297$ kip-in

PILE GROUP EFFICIENCY

← 4' →
I I

$e = 0.64\left(\frac{s}{b}\right)^{0.34}$ for $\frac{s}{b} \leq 3.75$

$\frac{4}{b} = 3.75$

for 12" piles and smaller, $e = 1.0$
for 14" piles, $e = 0.64\left(\frac{48}{14}\right)^{0.34} = 0.97$ $b = 1.07' \simeq 12.8''$

Req'd section modulus, $f_b = \frac{M}{S}$

$F_b = 0.66\,F_y$
use $F_y = 50$ ksi
$F_b = 33$ ksi

$33 \text{ ksi} = \frac{2297 \text{ k-in}}{S}$

$S = 69.6 \text{ in}^3$

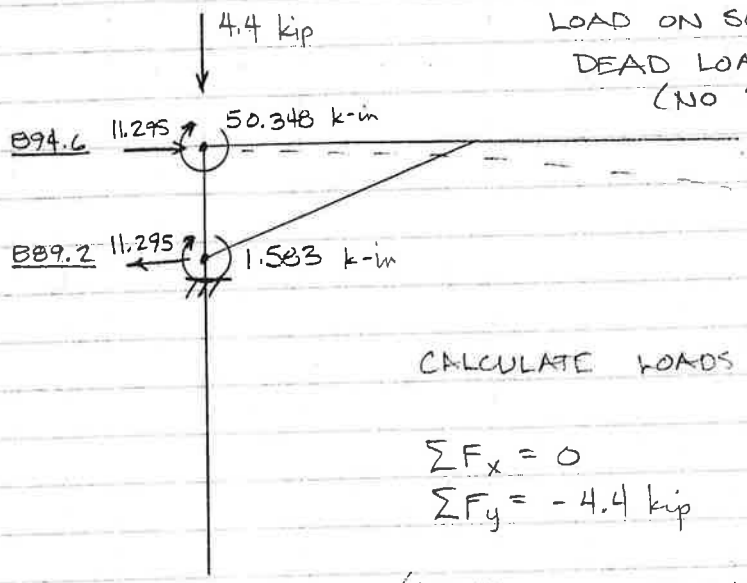
OPTIONS HP 12 × 63, 74, 84
HP 14 × 73, 89, 102
(HP 13 sizes have a limited availability)

DLZ

CLIENT: ODNR
PROJECT: Buckeye Lake
SUBJECT: Boat Dock w/ lift

PROJECT NO. 0121-3074.00
SHEET NO. 2 OF 4
COMP. BY PAN DATE 5/13/02
CHECKED BY PAA DATE 7/19/02

LOAD CASE 2



LOAD ON SUPPORT PILE
DEAD LOAD + LIVE LOAD
(NO BOAT)

$\Delta = 0.55''$ due to deflection of dock alone

CALCULATE LOADS AT EL 888.0

$\Sigma F_x = 0$
$\Sigma F_y = -4.4$ kip

$\circlearrowleft + \Sigma M_{888} = -50.348 - 1.583 - 11.295(94.6 - 89.2)12''$
$= -783.85$ k-in

DESIGN CRITERIA 1"/8 ft slope

$1''/8\text{ft} \times 28\text{ ft} = 3.5''$
$3.5 - 0.55 = 2.95''$
$\frac{2.95''}{28\text{ ft}} \times \frac{1\text{ ft}}{12''} = 0.0088$

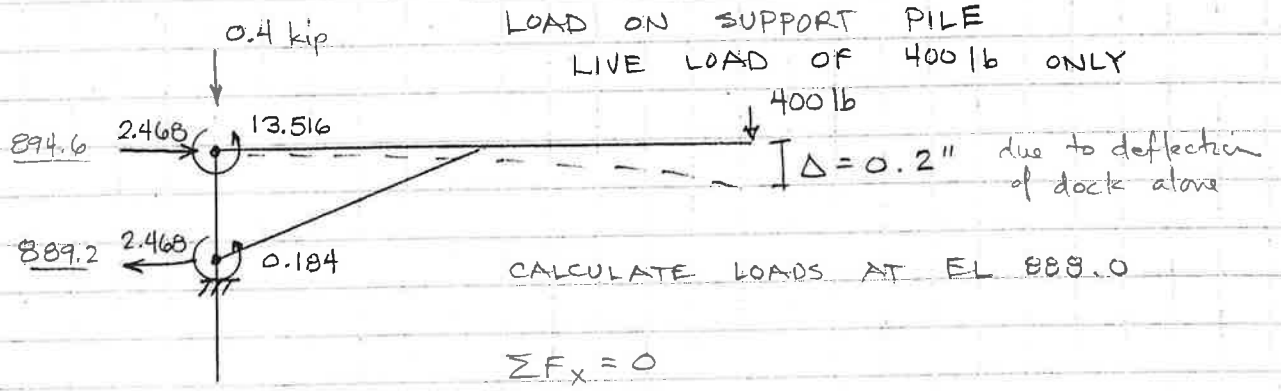
$\tan^{-1}(0.0088) = 0.5°$
0.0088 rad

DLZ

CLIENT: ODNR
PROJECT: Buckeye Lake
SUBJECT: Boat Dock w/ lift

PROJECT NO. 0121-3074.00
SHEET NO. 3 OF 4
COMP. BY PAN DATE 5/13/02
CHECKED BY DAA DATE 7/15/02

LOAD CASE 3



LOAD ON SUPPORT PILE
LIVE LOAD OF 400 lb ONLY

CALCULATE LOADS AT EL 889.0

$\Sigma F_x = 0$

$\Sigma F_y = -0.4$ kip

$\circlearrowleft + \Sigma M_{888} = 13.516 + 0.184 - 2.468(94.6 - 89.2)12''$
$= -146.23$ k-in

DESIGN CRITERIA
$\Delta < 4''$ at end of dock

$4'' - 0.2'' = 3.8''$

$\frac{3.8''}{28'} \times \frac{1'}{12''} = 0.011$ rad.

slope < 0.011 rad.

DLZ

CLIENT ODNR
PROJECT Buckeye Lake
SUBJECT Boat Dock w/ lift

PROJECT NO. 0121-3074.00
SHEET NO. 4 OF 4
COMP. BY PAN DATE 5/13/02
CHECKED BY DAA DATE 7/19/02

FOR SECTION 5 SOILS
HP 14 × 73
LPile results indicate M_{MAX} = 3200 kip-in @ 8¾ ft

$F_b = 0.66(50\text{ ksi}) = 33\text{ ksi}$

$S_{REQD} = \frac{3200}{33} = 97\text{ in}^3$ HP14×73 $S = 107\text{ in}^3$ OK

HP14×73 from L-Pile Sect. 5 soils, 25' below El 888

LOAD CASE 1
$M_{max} = 3200$ k-in

$f_b = \frac{3200}{107} = 29.9\text{ ksi} < 33\text{ ksi}$ OK

LOAD CASE 2
slope = 0.0052 rad < 0.0088 rad OK

LOAD CASE 3
slope = 0.00089 rad < 0.011 rad OK

USE HP14×73 with pile tip at El. 863 (32' long)

==========

LPILE Plus for Windows, Version 4

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

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==========

This program is licensed to:

Peter Narsavage
DLZ Ohio, Inc.

Path to file locations:	M:\proj\0121\3074.00\geot\Lpile\
Name of input data file:	Dock Boat Lift S5.lpd
Name of output file:	Dock Boat Lift S5.lpo
Name of plot output file:	Dock Boat Lift S5.lpp
Name of runtime file:	Dock Boat Lift S5.lpr

Time and Date of Analysis

Date: May 13, 2002 Time: 9:11: 3

Problem Title

Buckeye Lake Dock - With Boat Lift

Program Options

Units Used in Computations - US Customary Units, inches, pounds

Basic Program Options:

Analysis Type 1:
- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:
- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multiplers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis for fixed-length pile or shaft only
- No computation of foundation stiffness matrix elements
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments	=	100
- Deflection tolerance for closure	=	1.0000E-05 in
- Maximum number of iterations allowed	=	100
- Maximum allowable deflection	=	1.0000E+03 in

Printing Options:
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 300.00 in
Depth of ground surface below top of pile = 60.00 in
Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 2 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq.in	Modulus of Elasticity lbs/Sq.in
1	0.0000	14.59	729.0000	21.4000	29000000.00
2	300.0000	14.59	729.0000	21.4000	29000000.00

Soil and Rock Layering Information

The soil profile is modelled using 2 layers

Layer 1 is soft clay, p-y criteria by Matlock, 1970
Distance from top of pile to top of layer = 60.000 in
Distance from top of pile to bottom of layer = 84.000 in

Layer 2 is stiff clay with water-induced erosion
Distance from top of pile to top of layer = 84.000 in
Distance from top of pile to bottom of layer = 400.000 in
p-y subgrade modulus k for top of soil layer = 100.000 lbs/in**3
p-y subgrade modulus k for bottom of layer = 100.000 lbs/in**3

(Depth of lowest layer extends 100.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Distribution of effective unit weight of soil with depth
is defined using 4 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	60.00	.03910
2	84.00	.03910
3	84.00	.03910
4	400.00	.03910

Shear Strength of Soils

Distribution of shear strength parameters with depth
defined using 4 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k_rm	RQD %
1	60.000	3.47000	.00	------	------
2	84.000	3.47000	.00	------	------
3	84.000	5.21000	.00	------	------
4	400.000	5.21000	.00	------	------

Notes:

(1) Cohesion = uniaxial compressive strength for rock materials.

(2) Values of E50 are reported for clay strata.
(3) Default values will be generated for E50 when input values are 0.
(4) RQD and k_rm are reported only for weak rock strata.

Distribution of p-y multipliers with depth defined
using 2 points

Point No.	Depth X in	p-mult	y-mult
1	60.000	.9700	1.0000
2	400.000	.9700	1.0000

Static loading criteria was used for computation of p-y curves

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Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 3

Load Case Number 1 Dead Load + Live Load + Boat + wind

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Shear force at pile head = 10000.000 lbs
Bending moment at pile head = 2297000.000 in-lbs
Axial load at pile head = 8400.000 lbs

Non-zero moment at pile head for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Load Case Number 2 Dead Load + Live Load (no boat)

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Shear force at pile head = .000 lbs
Bending moment at pile head = 783850.000 in-lbs
Axial load at pile head = 4400.000 lbs

Non-zero moment at pile head for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Load Case Number 3 400 lb at end of dock

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Shear force at pile head = .000 lbs
Bending moment at pile head = 146230.000 in-lbs
Axial load at pile head = 400.000 lbs

Non-zero moment at pile head for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Computed Values of Load Distribution and Deflection
for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Specified shear force at pile head = 10000.000 lbs
Specified bending moment at pile head = 2297000.000 in-lbs
Specified axial load at pile head = 8400.000 lbs

Non-zero moment for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res p lbs/in
0.000	2.813	2.297E+06	10000.0000	-.027387	23370.4006	0.0000
3.000	2.731	2.328E+06	10000.0000	-.027059	23677.3664	0.0000
6.000	2.651	2.358E+06	10000.0000	-.026727	23984.2489	0.0000
9.000	2.571	2.389E+06	10000.0000	-.026390	24291.0471	0.0000
12.000	2.492	2.420E+06	10000.0000	-.026049	24597.7598	0.0000
15.000	2.415	2.450E+06	10000.0000	-.025703	24904.3860	0.0000
18.000	2.338	2.481E+06	10000.0000	-.025353	25210.9245	0.0000
21.000	2.262	2.512E+06	10000.0000	-.024999	25517.3743	0.0000
24.000	2.188	2.542E+06	10000.0000	-.024641	25823.7342	0.0000
27.000	2.115	2.573E+06	10000.0000	-.024278	26130.0031	0.0000
30.000	2.042	2.603E+06	10000.0000	-.023910	26436.1801	0.0000
33.000	1.971	2.634E+06	10000.0000	-.023539	26742.2639	0.0000
36.000	1.901	2.665E+06	10000.0000	-.023163	27048.2534	0.0000
39.000	1.832	2.695E+06	10000.0000	-.022783	27354.1477	0.0000
42.000	1.764	2.726E+06	10000.0000	-.022398	27659.9455	0.0000
45.000	1.698	2.756E+06	10000.0000	-.022009	27965.6458	0.0000
48.000	1.632	2.787E+06	10000.0000	-.021616	28271.2476	0.0000
51.000	1.568	2.817E+06	10000.0000	-.021218	28576.7496	0.0000
54.000	1.505	2.848E+06	10000.0000	-.020816	28882.1508	0.0000
57.000	1.443	2.879E+06	10000.0000	-.020410	29187.4502	0.0000
60.000	1.383	2.909E+06	9863.2920	-.019999	29492.6466	-91.1387
63.000	1.323	2.939E+06	9585.7252	-.019584	29789.5337	-93.9058
66.000	1.265	2.968E+06	9300.0559	-.019165	30077.8611	-96.5404
69.000	1.208	2.995E+06	9006.6845	-.018742	30357.3909	-99.0406
72.000	1.153	3.023E+06	8706.0163	-.018315	30627.8967	-101.4049
75.000	1.098	3.049E+06	8398.4618	-.017884	30889.1649	-103.6315
78.000	1.045	3.074E+06	8084.4365	-.017450	31140.9940	-105.7187
81.000	.993603	3.098E+06	7764.3611	-.017012	31383.1952	-107.6649
84.000	.943226	3.121E+06	7122.1803	-.016571	31615.5924	-320.4556
87.000	.894179	3.142E+06	6137.5753	-.016126	31819.0270	-335.9477
90.000	.846468	3.159E+06	5107.1277	-.015679	31992.1036	-351.0174
93.000	.800103	3.173E+06	4032.1082	-.015230	32133.4648	-365.6623
96.000	.755088	3.184E+06	2913.7939	-.014779	32241.7916	-379.8806
99.000	.711429	3.191E+06	1753.4670	-.014327	32315.8036	-393.6707
102.000	.669128	3.195E+06	552.4133	-.013874	32354.2589	-407.0318
105.000	.628188	3.195E+06	-688.0792	-.013420	32355.9544	-419.9632
108.000	.588607	3.192E+06	-1966.7215	-.012967	32319.7260	-432.4650
111.000	.550386	3.184E+06	-3276.6538	-.012515	32244.4482	-440.8231
114.000	.513520	3.173E+06	-4607.4527	-.012064	32129.3689	-446.3761
117.000	.478004	3.157E+06	-5952.3142	-.011614	31973.9884	-450.1982
120.000	.443833	3.137E+06	-7306.1016	-.011168	31777.9633	-452.3267
123.000	.410997	3.114E+06	-8663.7894	-.010724	31541.1025	-452.7986
126.000	.379487	3.086E+06	-10020.4629	-.010284	31263.3645	-451.6505
129.000	.349291	3.054E+06	-11371.3153	-.009849	30944.8537	-448.9178
132.000	.320395	3.018E+06	-12711.6426	-.009418	30585.8171	-444.6338
135.000	.292783	2.978E+06	-14036.8363	-.008992	30186.6418	-438.8287
138.000	.266440	2.935E+06	-15342.3722	-.008573	29747.8519	-431.5286
141.000	.241346	2.887E+06	-16623.7947	-.008160	29270.1060	-422.7531
144.000	.217481	2.835E+06	-17876.6941	-.007754	28754.1961	-412.5132
147.000	.194823	2.780E+06	-19096.6751	-.007355	28201.0459	-400.8074
150.000	.173348	2.721E+06	-20279.3094	-.006965	27611.7111	-387.6154
153.000	.153032	2.659E+06	-21420.0638	-.006583	26987.3817	-372.8875
156.000	.133847	2.593E+06	-22514.1781	-.006211	26329.3857	-356.5221
159.000	.115766	2.524E+06	-23556.4211	-.005848	25639.1991	-338.3066
162.000	.098760	2.452E+06	-24540.2899	-.005495	24918.4641	-317.6059
165.000	.082797	2.377E+06	-25453.5486	-.005152	24169.0471	-291.2333
168.000	.067846	2.299E+06	-26285.8458	-.004820	23393.3251	-263.6315
171.000	.053874	2.219E+06	-27033.6782	-.004500	22593.7858	-234.9234
174.000	.040847	2.137E+06	-27692.9013	-.004191	21773.0168	-204.5587
177.000	.028730	2.053E+06	-28257.0740	-.003893	20933.7548	-171.5564
180.000	.017487	1.968E+06	-28715.1757	-.003608	20078.9739	-133.8447
183.000	.007082	1.881E+06	-29043.7111	-.003335	19212.0725	-85.1789
186.000	-.002523	1.794E+06	-29104.9150	-.003074	18337.4350	44.3763
189.000	-.011363	1.707E+06	-28876.5217	-.002826	17466.7286	107.8860
192.000	-.019477	1.621E+06	-28502.8190	-.002590	16605.6742	141.2491
195.000	-.026901	1.536E+06	-28041.9434	-.002366	15757.2787	166.0013
198.000	-.033672	1.453E+06	-27514.3620	-.002154	14923.7734	185.7196
201.000	-.039824	1.371E+06	-26932.8213	-.001953	14106.9366	201.9743

204.000	-.045392	1.291E+06	-26306.4104	-.001764	13308.2347	215.6330
207.000	-.050410	1.213E+06	-25642.0993	-.001587	12528.9003	227.2411
210.000	-.054912	1.137E+06	-24945.4804	-.001420	11769.9812	237.1716
213.000	-.058930	1.064E+06	-24221.1800	-.001264	11032.3741	245.6954
216.000	-.062495	9.921E+05	-23473.1095	-.001118	10316.8492	253.0183
219.000	-.065638	9.228E+05	-22704.6288	-9.821E-04	9624.0682	259.3022
222.000	-.068388	8.559E+05	-21918.6582	-8.559E-04	8954.5994	264.6782
225.000	-.070773	7.914E+05	-21117.7583	-7.390E-04	8308.9292	269.2550
228.000	-.072822	7.292E+05	-20304.1895	-6.311E-04	7687.4720	273.1242
231.000	-.074560	6.696E+05	-19479.9563	-5.319E-04	7090.5783	276.3646
234.000	-.076013	6.124E+05	-18646.8423	-4.409E-04	6518.5419	279.0447
237.000	-.077205	5.577E+05	-17806.4379	-3.579E-04	5971.6064	281.2249
240.000	-.078160	5.056E+05	-16960.1621	-2.824E-04	5449.9697	282.9589
243.000	-.078900	4.560E+05	-16109.2814	-2.142E-04	4953.7901	284.2949
246.000	-.079446	4.089E+05	-15254.9247	-1.529E-04	4483.1894	285.2762
249.000	-.079817	3.644E+05	-14398.0964	-9.799E-05	4038.2578	285.9426
252.000	-.080034	3.225E+05	-13539.6875	-4.924E-05	3619.0567	286.3300
255.000	-.080113	2.832E+05	-12680.4851	-6.262E-06	3225.6227	286.4715
258.000	-.080071	2.465E+05	-11821.1817	3.132E-05	2857.9699	286.3974
261.000	-.079925	2.123E+05	-10962.3822	6.387E-05	2516.0928	286.1355
264.000	-.079688	1.807E+05	-10104.6117	9.175E-05	2199.9692	285.7115
267.000	-.079374	1.517E+05	-9248.3216	1.153E-04	1909.5619	285.1486
270.000	-.078996	1.252E+05	-8393.8960	1.350E-04	1644.8214	284.4684
273.000	-.078565	1.013E+05	-7541.6577	1.510E-04	1405.6874	283.6904
276.000	-.078090	79929.3183	-6691.8737	1.639E-04	1192.0907	282.8322
279.000	-.077581	61122.1691	-5844.7610	1.739E-04	1003.9547	281.9096
282.000	-.077046	44851.9876	-5000.4919	1.814E-04	841.1971	280.9365
285.000	-.076493	31110.0738	-4159.1996	1.868E-04	703.7308	279.9250
288.000	-.075926	19887.3742	-3320.9836	1.904E-04	591.4653	278.8856
291.000	-.075350	11174.5741	-2485.9151	1.926E-04	504.3074	277.8267
294.000	-.074770	4962.1745	-1654.0427	1.938E-04	442.1621	276.7549
297.000	-.074187	1240.5516	-825.3976	1.942E-04	404.9331	275.6751
300.000	-.073604	0.0000	0.0000	1.943E-04	392.5234	274.5900

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

Pile-head deflection	=	2.81288368	in
Computed slope at pile head	=	-.02738748	
Maximum bending moment	=	3195247.34	lbs-in
Maximum shear force	=	-29104.92	lbs
Depth of maximum bending moment	=	105.00	in
Depth of maximum shear force	=	186.00	in
Number of iterations	=	47	
Number of zero deflection points	=	1	

Computed Values of Load Distribution and Deflection
for Lateral Loading for Load Case Number 2

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Specified shear force at pile head = .000 lbs
Specified bending moment at pile head = 783850.000 in-lbs
Specified axial load at pile head = 4400.000 lbs

Non-zero moment for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res p lbs/in
0.000	.373605	7.839E+05	1.203E-09	-.005234	8046.7956	0.0000
3.000	.358071	7.839E+05	-3.522E-07	-.005123	8047.4793	0.0000

6.000	.342870	7.840E+05	9.099E-08	-.005011	8048.1484	0.0000
9.000	.328003	7.841E+05	2.267E-08	-.004900	8048.8028	0.0000
12.000	.313470	7.841E+05	3.712E-09	-.004789	8049.4424	0.0000
15.000	.299270	7.842E+05	8.150E-09	-.004677	8050.0674	0.0000
18.000	.285405	7.842E+05	-3.355E-08	-.004566	8050.6777	0.0000
21.000	.271873	7.843E+05	4.605E-09	-.004455	8051.2733	0.0000
24.000	.258675	7.844E+05	-3.397E-08	-.004344	8051.8542	0.0000
27.000	.245811	7.844E+05	-1.104E-07	-.004232	8052.4204	0.0000
30.000	.233281	7.845E+05	-1.096E-07	-.004121	8052.9719	0.0000
33.000	.221085	7.845E+05	-1.125E-07	-.004010	8053.5087	0.0000
36.000	.209223	7.846E+05	-1.346E-07	-.003898	8054.0309	0.0000
39.000	.197695	7.846E+05	-1.699E-07	-.003787	8054.5383	0.0000
42.000	.186501	7.847E+05	-2.014E-07	-.003676	8055.0310	0.0000
45.000	.175641	7.847E+05	-2.124E-07	-.003564	8055.5090	0.0000
48.000	.165115	7.848E+05	-2.296E-07	-.003453	8055.9723	0.0000
51.000	.154924	7.848E+05	-2.362E-07	-.003342	8056.4209	0.0000
54.000	.145066	7.849E+05	-2.590E-07	-.003230	8056.8547	0.0000
57.000	.135542	7.849E+05	-2.489E-07	-.003119	8057.2739	0.0000
60.000	.126353	7.849E+05	-61.5800	-.003007	8057.6784	-41.0534
63.000	.117498	7.846E+05	-186.0045	-.002896	8054.3721	-41.8963
66.000	.108976	7.839E+05	-312.8058	-.002785	8047.2791	-42.6380
69.000	.100789	7.828E+05	-441.6776	-.002674	8036.3328	-43.2766
72.000	.092934	7.813E+05	-572.3073	-.002563	8021.4755	-43.8099
75.000	.085413	7.794E+05	-704.3760	-.002452	8002.6593	-44.2358
78.000	.078223	7.772E+05	-837.5576	-.002341	7979.8460	-44.5519
81.000	.071364	7.745E+05	-971.5187	-.002231	7953.0070	-44.7555
84.000	.064835	7.714E+05	-1425.2311	-.002122	7922.1241	-257.7194
87.000	.058634	7.660E+05	-2179.4390	-.002013	7868.0241	-245.0858
90.000	.052759	7.584E+05	-2895.7939	-.001904	7791.8445	-232.4841
93.000	.047207	7.487E+05	-3574.3882	-.001798	7694.7199	-219.9122
96.000	.041974	7.370E+05	-4215.3043	-.001692	7577.7823	-207.3652
99.000	.037054	7.234E+05	-4818.6048	-.001589	7442.1617	-194.8351
102.000	.032442	7.081E+05	-5384.3207	-.001487	7288.9864	-182.3089
105.000	.028132	6.911E+05	-5912.4361	-.001388	7119.3844	-169.7680
108.000	.024116	6.727E+05	-6402.8661	-.001291	6934.4851	-157.1853
111.000	.020387	6.528E+05	-6855.4268	-.001197	6735.4216	-144.5219
114.000	.016935	6.316E+05	-7269.7923	-.001106	6523.3345	-131.7217
117.000	.013752	6.092E+05	-7645.4272	-.001018	6299.3765	-118.7016
120.000	.010829	5.857E+05	-7981.4801	-9.329E-04	6064.7203	-105.3336
123.000	.008155	5.613E+05	-8276.5948	-8.515E-04	5820.5699	-91.4095
126.000	.005720	5.361E+05	-8514.7020	-7.737E-04	5568.1792	-67.3286
129.000	.003513	5.102E+05	-8679.2518	-6.994E-04	5309.7169	-42.3714
132.000	.001523	4.840E+05	-8771.0286	-6.289E-04	5047.4302	-18.8131
135.000	-2.61E-04	4.576E+05	-8794.3016	-5.621E-04	4783.4408	3.2977
138.000	-.001850	4.313E+05	-8753.4651	-4.990E-04	4519.7396	23.9266
141.000	-.003255	4.051E+05	-8652.9974	-4.397E-04	4258.1845	43.0519
144.000	-.004488	3.794E+05	-8497.4241	-3.840E-04	4000.4978	60.6637
147.000	-.005559	3.541E+05	-8293.2449	-3.320E-04	3748.2657	75.4557
150.000	-.006480	3.296E+05	-8057.8625	-2.835E-04	3502.8202	81.4658
153.000	-.007260	3.058E+05	-7806.3149	-2.384E-04	3264.7030	86.2325
156.000	-.007910	2.828E+05	-7541.9490	-1.966E-04	3034.3436	90.0114
159.000	-.008440	2.606E+05	-7267.4661	-1.581E-04	2812.0828	92.9771
162.000	-.008858	2.392E+05	-6985.1157	-1.226E-04	2598.1879	95.2565
165.000	-.009175	2.187E+05	-6696.8118	-9.013E-05	2392.8645	96.9461
168.000	-.009399	1.990E+05	-6404.2096	-6.049E-05	2196.2651	98.1220
171.000	-.009538	1.802E+05	-6108.7575	-3.359E-05	2008.4961	98.8460
174.000	-.009601	1.623E+05	-5811.7345	-9.280E-06	1829.6229	99.1693
177.000	-.009594	1.454E+05	-5514.2781	1.255E-05	1659.6749	99.1350
180.000	-.009525	1.293E+05	-5217.4051	3.204E-05	1498.6494	98.7803
183.000	-.009402	1.141E+05	-4922.0281	4.930E-05	1346.5148	98.1376
186.000	-.009229	99726.3953	-4628.9689	6.447E-05	1203.2134	97.2352
189.000	-.009015	86276.1025	-4338.9687	7.767E-05	1068.6644	96.0983
192.000	-.008763	73690.5328	-4052.6971	8.902E-05	942.7655	94.7494
195.000	-.008481	61957.5697	-3770.7598	9.864E-05	825.3956	93.2088
198.000	-.008172	51063.3697	-3493.7046	1.067E-04	716.4163	91.4947
201.000	-.007841	40992.5264	-3222.0269	1.132E-04	615.6733	89.6237
204.000	-.007493	31728.2199	-2956.1750	1.184E-04	522.9985	87.6109
207.000	-.007131	23252.3517	-2696.5542	1.223E-04	438.2107	85.4697
210.000	-.006759	15545.6673	-2443.5308	1.250E-04	361.1175	83.2126
213.000	-.006381	8587.8669	-2197.4361	1.267E-04	291.5156	80.8506
216.000	-.005999	2357.7054	-1958.5700	1.275E-04	229.1926	78.3935
219.000	-.005616	-3166.9190	-1727.2046	1.274E-04	237.2875	75.8501

222.000	-.005234	-8008.8867	-1503.5878	1.266E-04	285.7238	73.2278
225.000	-.004856	-12191.7892	-1287.9470	1.252E-04	327.5672	70.5328
228.000	-.004483	-15739.8740	-1080.4931	1.232E-04	363.0602	67.7698
231.000	-.004117	-18678.0012	-881.4253	1.208E-04	392.4515	64.9421
234.000	-.003758	-21031.6144	-690.9353	1.180E-04	415.9957	62.0512
237.000	-.003409	-22826.7274	-509.2137	1.149E-04	433.9530	59.0965
240.000	-.003069	-24089.9290	-336.4567	1.115E-04	446.5894	56.0749
243.000	-.002740	-24848.4118	-172.8743	1.081E-04	454.1768	52.9801
246.000	-.002421	-25130.0275	-18.7015	1.045E-04	456.9939	49.8018
249.000	-.002112	-24963.3801	125.7875	1.010E-04	455.3269	46.5242
252.000	-.001815	-24377.9679	260.2597	9.745E-05	449.4708	43.1239
255.000	-.001528	-23404.3947	380.5970	9.406E-05	439.7317	37.1010
258.000	-.001251	-22096.8691	482.3479	9.083E-05	426.6519	30.7330
261.000	-9.83E-04	-20512.7053	565.1037	8.781E-05	410.8049	24.4376
264.000	-7.24E-04	-18708.5650	629.0691	8.503E-05	392.7573	18.2060
267.000	-4.73E-04	-16740.5356	674.4176	8.251E-05	373.0702	12.0263
270.000	-2.29E-04	-14664.2378	701.2830	8.029E-05	352.3001	5.8840
273.000	9.14E-06	-12534.9569	709.7521	7.836E-05	331.0000	-.2379
276.000	2.42E-04	-10407.7935	699.8588	7.673E-05	309.7211	-6.3577
279.000	4.70E-04	-8337.8296	671.5802	7.540E-05	289.0144	-12.4948
282.000	6.94E-04	-6380.3030	624.8344	7.435E-05	269.4324	-18.6691
285.000	9.16E-04	-4590.7860	559.4807	7.358E-05	251.5311	-24.9001
288.000	.001135	-3025.3613	475.3209	7.303E-05	235.8715	-31.2064
291.000	.001354	-1740.7889	372.6523	7.270E-05	223.0213	-37.2393
294.000	.001572	-791.3667	256.6094	7.252E-05	213.5239	-40.1226
297.000	.001789	-203.0467	132.2132	7.245E-05	207.6386	-42.8082
300.000	.002006	0.0000	0.0000	7.243E-05	205.6075	-45.3340

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 2:

Pile-head deflection	=	.37360501	in
Computed slope at pile head	=	-.00523377	
Maximum bending moment	=	784937.91	lbs-in
Maximum shear force	=	-8794.30	lbs
Depth of maximum bending moment	=	60.00	in
Depth of maximum shear force	=	135.00	in
Number of iterations	=	11	
Number of zero deflection points	=	2	

Computed Values of Load Distribution and Deflection
for Lateral Loading for Load Case Number 3

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Specified shear force at pile head	=	.000	lbs
Specified bending moment at pile head	=	146230.000	in-lbs
Specified axial load at pile head	=	400.000	lbs

Non-zero moment for this load case indicates the pile-head may rotate under the applied pile-head loading, but is not a free-head (zero moment)condition.

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res p lbs/in
0.000	.058236	1.462E+05	-1.080E-09	-8.913E-04	1481.4931	0.0000
3.000	.055593	1.462E+05	4.212E-08	-8.706E-04	1481.5036	0.0000
6.000	.053013	1.462E+05	-4.787E-09	-8.498E-04	1481.5140	0.0000
9.000	.050494	1.462E+05	-1.966E-09	-8.291E-04	1481.5240	0.0000
12.000	.048038	1.462E+05	5.718E-09	-8.083E-04	1481.5339	0.0000
15.000	.045644	1.462E+05	1.685E-08	-7.876E-04	1481.5434	0.0000
18.000	.043313	1.462E+05	2.186E-08	-7.668E-04	1481.5528	0.0000
21.000	.041043	1.462E+05	2.205E-08	-7.461E-04	1481.5619	0.0000

24.000	.038836	1.462E+05	1.873E-08	-7.253E-04	1481.5707	0.0000
27.000	.036691	1.462E+05	1.864E-08	-7.046E-04	1481.5793	0.0000
30.000	.034609	1.462E+05	1.492E-08	-6.838E-04	1481.5876	0.0000
33.000	.032588	1.462E+05	1.159E-08	-6.631E-04	1481.5957	0.0000
36.000	.030630	1.462E+05	2.491E-08	-6.423E-04	1481.6035	0.0000
39.000	.028734	1.462E+05	3.172E-08	-6.216E-04	1481.6111	0.0000
42.000	.026901	1.462E+05	2.654E-08	-6.008E-04	1481.6184	0.0000
45.000	.025129	1.462E+05	2.425E-08	-5.801E-04	1481.6255	0.0000
48.000	.023420	1.462E+05	2.752E-08	-5.593E-04	1481.6324	0.0000
51.000	.021774	1.462E+05	3.221E-08	-5.386E-04	1481.6390	0.0000
54.000	.020189	1.462E+05	3.283E-08	-5.178E-04	1481.6453	0.0000
57.000	.018667	1.462E+05	3.205E-08	-4.971E-04	1481.6514	0.0000
60.000	.017207	1.462E+05	-31.6835	-4.763E-04	1481.6572	-21.1223
63.000	.015809	1.461E+05	-95.5712	-4.556E-04	1479.7612	-21.4695
66.000	.014473	1.457E+05	-160.4085	-4.349E-04	1475.9319	-21.7553
69.000	.013200	1.451E+05	-226.0089	-4.142E-04	1470.1438	-21.9783
72.000	.011988	1.443E+05	-292.1821	-3.937E-04	1462.3767	-22.1371
75.000	.010838	1.433E+05	-358.7325	-3.733E-04	1452.6163	-22.2299
78.000	.009748	1.422E+05	-425.4595	-3.530E-04	1440.8543	-22.2548
81.000	.008719	1.408E+05	-492.1564	-3.330E-04	1427.0885	-22.2098
84.000	.007750	1.392E+05	-614.9604	-3.131E-04	1411.3228	-59.6596
87.000	.006841	1.371E+05	-786.4222	-2.935E-04	1390.1857	-54.6483
90.000	.005990	1.345E+05	-942.7809	-2.742E-04	1364.1283	-49.5908
93.000	.005196	1.314E+05	-1083.9602	-2.553E-04	1333.6060	-44.5287
96.000	.004457	1.280E+05	-1210.0038	-2.369E-04	1299.0746	-39.5003
99.000	.003774	1.242E+05	-1321.0660	-2.190E-04	1260.9866	-34.5411
102.000	.003143	1.201E+05	-1417.4027	-2.017E-04	1219.7887	-29.6834
105.000	.002564	1.157E+05	-1499.3619	-1.850E-04	1175.9181	-24.9561
108.000	.002033	1.111E+05	-1567.3740	-1.689E-04	1129.8005	-20.3853
111.000	.001550	1.063E+05	-1621.9424	-1.535E-04	1081.8475	-15.9936
114.000	.001112	1.013E+05	-1663.6340	-1.387E-04	1032.4543	-11.8008
117.000	7.18E-04	96297.6709	-1693.0702	-1.247E-04	981.9985	-7.8233
120.000	3.64E-04	91183.3970	-1710.9175	-1.114E-04	930.8383	-4.0749
123.000	4.93E-05	86032.4336	-1717.8792	-9.884E-05	879.3110	-.5663
126.000	-2.29E-04	80876.3590	-1714.6870	-8.700E-05	827.7325	2.6944
129.000	-4.73E-04	75744.5206	-1702.0927	-7.589E-05	776.3965	5.7018
132.000	-6.84E-04	70663.9850	-1680.8611	-6.550E-05	725.5738	8.4526
135.000	-8.66E-04	65659.5109	-1651.7629	-5.583E-05	675.5119	10.9462
138.000	-.001019	60753.5414	-1615.5679	-4.686E-05	626.4353	13.1838
141.000	-.001147	55966.2159	-1573.0391	-3.858E-05	578.5457	15.1687
144.000	-.001251	51315.3992	-1524.9274	-3.097E-05	532.0216	16.9058
147.000	-.001333	46816.7260	-1471.9662	-2.400E-05	487.0194	18.4017
150.000	-.001395	42483.6599	-1414.8673	-1.767E-05	443.6739	19.6642
153.000	-.001439	38327.5646	-1354.3170	-1.193E-05	402.0987	20.7026
156.000	-.001466	34357.7866	-1290.9724	-6.776E-06	362.3873	21.5271
159.000	-.001479	30581.7465	-1225.4589	-2.168E-06	324.6139	22.1486
162.000	-.001479	27005.0386	-1158.3675	1.918E-06	288.8346	22.5790
165.000	-.001468	23631.5371	-1090.2532	5.511E-06	255.0880	22.8305
168.000	-.001446	20463.5064	-1021.6334	8.639E-06	223.3968	22.9160
171.000	-.001416	17501.7162	-952.9869	1.133E-05	193.7688	22.8483
174.000	-.001378	14745.5580	-884.7534	1.362E-05	166.1977	22.6406
177.000	-.001334	12193.1630	-817.3334	1.553E-05	140.6650	22.3060
180.000	-.001285	9841.5203	-751.0880	1.710E-05	117.1405	21.8575
183.000	-.001232	7686.5940	-686.3398	1.834E-05	95.5839	21.3079
186.000	-.001175	5723.4377	-623.3733	1.929E-05	75.9456	20.6697
189.000	-.001116	3946.3078	-562.4364	1.998E-05	58.1682	19.9549
192.000	-.001055	2348.7714	-503.7412	2.042E-05	42.1874	19.1752
195.000	-9.93E-04	923.8114	-447.4659	2.066E-05	27.9329	18.3417
198.000	-9.31E-04	-336.0739	-393.7563	2.070E-05	22.0535	17.4648
201.000	-8.69E-04	-1438.7759	-342.7274	2.057E-05	33.0843	16.5545
204.000	-8.08E-04	-2392.4876	-294.4659	2.030E-05	42.6247	15.6199
207.000	-7.47E-04	-3205.6198	-249.0317	1.990E-05	50.7588	14.6696
210.000	-6.88E-04	-3886.7253	-206.4604	1.940E-05	57.5722	13.7113
213.000	-6.31E-04	-4444.4287	-166.7654	1.881E-05	63.1511	12.7521
216.000	-5.75E-04	-4887.3626	-129.9398	1.815E-05	67.5820	11.7983
219.000	-5.22E-04	-5224.1111	-95.9592	1.743E-05	70.9506	10.8555
222.000	-4.71E-04	-5463.1597	-64.7834	1.667E-05	73.3419	9.9284
225.000	-4.22E-04	-5612.8513	-36.3587	1.588E-05	74.8394	9.0214
228.000	-3.76E-04	-5681.3498	-10.6202	1.508E-05	75.5246	8.1376
231.000	-3.32E-04	-5676.6088	12.5061	1.428E-05	75.4771	7.2799
234.000	-2.90E-04	-5606.3476	33.1015	1.348E-05	74.7743	6.4504
237.000	-2.51E-04	-5478.0321	51.2527	1.269E-05	73.4907	5.6504

240.000	-2.14E-04	-5298.8620	67.0495	1.193E-05	71.6984	4.8808
243.000	-1.79E-04	-5075.7638	80.5836	1.119E-05	69.4666	4.1419
246.000	-1.47E-04	-4815.3875	91.9466	1.049E-05	66.8620	3.4334
249.000	-1.16E-04	-4524.1095	101.2287	9.825E-06	63.9482	2.7546
252.000	-8.77E-05	-4208.0390	108.5171	9.206E-06	60.7864	2.1043
255.000	-6.10E-05	-3873.0289	113.8950	8.632E-06	57.4352	1.4809
258.000	-3.59E-05	-3524.6896	117.4402	8.107E-06	53.9506	.8825
261.000	-1.23E-05	-3168.4072	119.2242	7.633E-06	50.3865	.3068
264.000	9.89E-06	-2809.3629	119.3114	7.208E-06	46.7949	-.2487
267.000	3.09E-05	-2452.5563	117.7583	6.835E-06	43.2256	-.7867
270.000	5.09E-05	-2102.8294	114.6133	6.512E-06	39.7271	-1.3100
273.000	7.00E-05	-1764.8923	109.9157	6.237E-06	36.3466	-1.8217
276.000	8.83E-05	-1443.3502	103.6961	6.010E-06	33.1300	-2.3247
279.000	1.06E-04	-1142.7302	95.9759	5.826E-06	30.1228	-2.8220
282.000	1.23E-04	-867.5085	86.7680	5.684E-06	27.3696	-3.3166
285.000	1.40E-04	-622.1361	76.0763	5.578E-06	24.9151	-3.8111
288.000	1.57E-04	-411.0639	63.8973	5.505E-06	22.8036	-4.3082
291.000	1.73E-04	-238.7657	50.2197	5.459E-06	21.0801	-4.8101
294.000	1.89E-04	-109.7585	35.0265	5.434E-06	19.7896	-5.3187
297.000	2.06E-04	-28.6196	18.2953	5.424E-06	18.9779	-5.8355
300.000	2.22E-04	0.0000	0.0000	5.422E-06	18.6916	-6.3614

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 3:

Pile-head deflection	=	.05823624	in
Computed slope at pile head	=	-.00089134	
Maximum bending moment	=	146246.41	lbs-in
Maximum shear force	=	-1717.88	lbs
Depth of maximum bending moment	=	60.00	in
Depth of maximum shear force	=	123.00	in
Number of iterations	=	7	
Number of zero deflection points	=	2	

Summary of Pile-head Response

Definition of symbols for pile-head boundary conditions:

y = pile-head displacment, in
M = pile-head moment, lbs-in
V = pile-head shear force, lbs
S = pile-head slope, radians
R = rotational stiffness of pile-head, in-lbs/rad

BC Type	Boundary Condition 1	Boundary Condition 2	Axial Load lbs	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V= 10000.000	M= 2.30E+06	8400.0000	2.8129	3.195E+06	-29104.9150
1	V= 0.000	M= 7.84E+05	4400.0000	.3736	7.849E+05	-8794.3016
1	V= 0.000	M= 1.46E+05	400.0000	.058236	1.462E+05	-1717.8792

The analysis ended normally.

Quantities and Cost Estimate – Boat Docks

DLZ

CLIENT OHIO DEPT. OF NAT. RESOURCES
PROJECT BUCKEYE LAKE
SUBJECT BOAT DOCK COST ESTIMATE

PROJECT NO. 0121-3074-00
SHEET NO. 1 OF 1
COMPUTED BY JAM DATE 5/6/02
CHECKED BY TMG DATE 7-16-02

SINGLE BOAT DOCK				
ITEM	UNIT COST	QUANT.	UNITS	TOTAL COST
W 8x18 BEAMS	$6	56	FT	$336
3" DIA. SCH. 40 PIPE	$2	114	FT	$228
1" THICK TREATED LUMBER	$2	112	SQ FT	$224
LABOR	$1,200	1	LUMP	$1,200
SINGLE BOAT DOCK TOTAL COST =				$1,988

DOUBLE BOAT DOCK				
ITEM	UNIT COST	QUANT.	UNITS	TOTAL COST
W 8x18 BEAMS	$6	112	FT	$672
3" DIA. SCH. 40 PIPE	$2	228	FT	$457
1" THICK TREATED LUMBER	$2	224	SQ FT	$448
LABOR	$1,200	2	LUMP	$2,400
DOUBLE BOAT DOCK TOTAL COST =				$3,977

DOUBLE BOAT DOCK WITH LIFT				
ITEM	UNIT COST	QUANT.	UNITS	TOTAL COST
W 8x67 BEAMS	$22	112	FT	$2,438
3" DIA. SCH. 40 PIPE	$2	228	FT	$457
1" THICK TREATED LUMBER	$2	224	SQ FT	$448
BOAT LIFT & LABOR	$12,000	1	LUMP	$12,000
DOUBLE BOAT DOCK WITH LIFT TOTAL COST =				$15,343

SINGLE BOAT DOCK - BEAMS

N = NUMBER OF BEAMS PER DOCK = 2
L = LENGTH OF BEAM = 28.00 FT
TOTAL LENGTH PER DOCK = N*L = 56.00 FT

SINGLE BOAT DOCK - PIPE

TOTAL LENGTH PER DOCK = 114.22 FT

SINGLE BOAT DOCK - LUMBER

W = WIDTH OF DOCK = 4.00 FT
L = LENGTH OF DOCK = 28.00 FT
TOTAL AREA PER DOCK = W*L = 112.00 SQ FT

DLZ			
CLIENT	OHIO DEPT. OF NAT. RESOURCES	PROJECT NO.	0121-3074-00
PROJECT	BUCKEYE LAKE	SHEET NO.	1 OF 1
SUBJECT	BOAT DOCK COST ESTIMATE PRICES	COMPUTED BY	JAM DATE 5/6/02
		CHECKED BY	TAW DATE 7-16-02

Prices from: Columbus Pipe and Equipment (444-7871)
Date: 5/6/02

Material	Size	Quoted Price*	Unit Price	Rounded Unit Price
W Beam	W 8x18	$115/20'	$5.75	$6
W Beam	W 8x67	$1306/60'	$21.77	$22
Sch. 40 Pipe	3" Dia.	$40.95/21'	$1.95	$2

** Note: Price includes delivery to Buckeye Lake*