US Army Corps of Engineers

Geotechnical Feasibility Report

Alaska Deep-Draft Arctic Port System

Seward Peninsula, AK, Alaska District, Pacific Ocean Division

February 2014

PN: #######

Status: DRAFT

DEPARTMENT OF THE ARMY
ALASKA DISTRICT, U.S. ARMY CORPS OF ENGINEERS
P.O. BOX 6898
JBER, AK 99506-0898

CEPOA-EN-G-GM February 2014

MEMORANDUM FOR

Civil Works Project Management (CEPOA-PM-C), Lorraine Cordova)

SUBJECT: Geotechnical Feasibility Report for Alaska Deep-Draft Arctic Port

This report was authorized and forwarded on to Geotechnical and Materials Section by the Civil Works Project Management Branch via the Project Manager, Lorraine Cordova.

Enclosed is the Geotechnical Feasibility Report for Alaska Deep-Draft Arctic Port. This Report evaluates five alternative options over three sites for preliminary design analysis to be used for identification of potential site uses and constraints on use and should not be used for final design. Three alternatives are for the Port of Nome, one for Point Spencer, and one for Cape Riley. Included with the report are seven figures including the Project Location and Vicinity Map, general site configurations, and other relevant illustrations.

Questions should be addressed to Robert Weakland at 907-753-2633 or John Rajek at 907-753-5695.

James Sauceda, P.E.
Chief, Geotechnical and Engineering Services
CEPOA-G

FOR
John Rajek, P.E.
Chief, Geotechnical and Materials Section
CEPOA-G-GM

Robert T. Weakland, P.E.
Civil Engineer
CEPOA-G-GM

Table of Contents

List of Figures and Tables

Figures

Tables

1.0 Introduction

This report documents the results of a geotechnical feasibility investigation performed to assist the selection process for adding select deep-draft arctic seaports along the west coastline of the Seward Peninsula, Alaska. The scope of the investigation was to obtain a historical perspective of the deep-draft port sites, identify geotechnical surface and subsurface conditions, and address geotechnical concerns relevant to the project. This report presents a summary of the findings based on historical documents, previous project reports, site observations, results of a field exploration and laboratory testing programs. This report also includes preliminary geotechnical engineering analysis and recommendations for breakwater structures and dredging.

Before final geotechnical recommendations for the design and construction of these proposed engineering systems discussed in this report, a more extensive exploration program and detailed engineering analysis are needed.

2.0 Project Description

The overall project description is to provide navigation improvements to support multiple maritime missions in the Arctic which includes Search and Rescue, Oil and Gas, Security, Cargo, Resource Export, Tourism, and emergency response. This would be accomplished by expanding, improving and/or upgrading existing ports by increasing their capacity to accommodate larger and more vessels of different lengths and drafts. This study is also considering building new ports at key location that would accommodate similar requirements. The end state of this project is to produce an efficient combination of all options available. The "*Alaska Deep-Draft Arctic Ports Navigation Feasibility Study, Tentatively Selected Plan SMART Planning Milestone*" is available upon request; see references for details. The considered locations are the Port of Nome, Point Spencer, and Cape Riley can be found on the Location and Vicinity Map; Figure 1. The focus of this Geotechnical Feasibility Report will be on these three locations and the design alternatives listed below.

2.1. Port of Nome Design Alternatives

Three design alternatives for the Port of Nome were evaluated to accommodate larger deep-draft vessels. Some deep-draft vessels that may use the port would include haul fuel barges, ice breakers, cargo barges, tankers, Coast Guard cutters, NOAA research vessels, landing crafts, and tugs. The first design alternative consisted of extending the existing causeway 2,150 feet and constructing two adjoining, 50-foot wide by 50-foot deep, concrete caisson docks; one 600-foot in length, the other 450-foot. The second design alternative consists of raising the current breakwater crest elevation from +14 feet mean lower low water (MLLW) to +25 feet MLLW.

The third design alternative is to dredge the outer channel and maneuvering area to -35 feet MLLW, and dredge between the existing causeway and main breakwater to -22 feet MLLW with an option of -35 feet MLLW. The general configuration and details of the three Nome design alternatives can be found on Figure 2.

2.2. Point Spencer Alternative

The design alternative for Point Spencer to accommodate large deep-draft vessels was evaluated. This alternative would involve new construction of a 1,800-foot causeway connecting to a 50-foot wide by 50-foot deep by a 1,000-foot long caisson dock. This would also require the dredging of a turning basin and entrance channel to -35 feet MLLW. The general configuration and details of this alternative can be found on Figure 5.

2.3. Cape Riley Alternative

The design alternative for Cape Riley to accommodate the necessary shallow draft mineral extraction vessels and lightering vessels was evaluated. This alternative would involve new construction of a 40-foot wide by 26-foot deep by a 250-foot long concrete caisson dock and a 200 by 360-foot staging area. This would also required the dredging of a 550-foot turning basin and 305-foot entrance channel, both to -12.5 feet MLLW. The Cape Riley alternative would also include a five and a half mile road connecting to the Nome/Teller Highway. The general configuration and details of this alternative can be found on Figure 7.

3.0 Previous Studies

Various geotechnical investigations have taken place in the vicinity of the Port of Nome. These investigations were performed by the U.S. Army Corps of Engineers and other agencies. All reports, maps, exploration logs, and lab data pertaining to these reports are available on request.

- Harding Lawson Associates. 1982 (May). “Soil Investigation, Port of Nome,” prepared for TAMS Engineers, 4791 Business Park Boulevard, Building H, Anchorage, Alaska 99503
- Woodward-Clyde Consultants. 1998 (Jan). “Nome Harbor Site Investigation Report,” prepared for city of Nome, 3501 Denali Street, Suite 101, Anchorage, Alaska 99503
- Alaska District, U.S. Army Corps of Engineers. 2004 (Jan). “Geotechnical Findings Report” prepared for the Nome Harbor Sheet Pile Replacement Project (072742)

- Alaska District, U.S. Army Corps of Engineers. 2006 (May). "Geotechnical Findings Report" prepared for the Nome Harbor Sheet Pile Replacement Project (NOM005)

No studies other than the U.S. Geological Survey investigations were available for the areas of Point Spencer and Cape Riley at the time of this feasibility study. All listed publications are available upon request.

4.0 Regional Geology

Nome is situated in low lands, with elevations under 1,000 feet, located in the southwest section of the Seward Peninsula in western Alaska. This area is along the southern coast of the peninsula and bordered to the north by highlands and rolling hills with summits from 1,000 to 3,000 feet. The Snake River, a result of confluence of local streams and drainage from the highlands, divides Nome as it enters Norton Sound at the harbor site. The dominant geologic features at the site are the result of episodes of Pleistocene glaciations and attendant sea level changes. The effects of the Snake River and offshore coastal processes have also contributed to the present geologic condition. The bedrock underlying the site consists of Paleozoic micaceous schists. The rock is overlain by Pleistocene glacial and marine deposits.

Point Spencer is predominantly surficial deposits. These deposits are described as undivided frost-rived (ice-moved) rubble on slopes and broad low ridges. This area is a glacial moraine and has glacially deposited sand, gravel, and boulders; fluvial gravel and sand; marine and fluvial terrace deposits; and wetlands.

Cape Riley is in the middle of Grantley Harbor fault zone. This zone is weakly metamorphosed metasedi-mentary rocks with stronger deformational fabrics than those in the western Seward Peninsula, but weaker deformational fabrics than found in the Nome Complex. Primary sedimentary features are locally preserved. The small area around Cape Riley consists of intercalated grayish-green metasiltstone to medium-grained metasandstone, in layers one half inch to three feet thick, grayish-green to silver phyllite and silty phyllite, and dark gray to black phyllitic shale. Percentage of these lithologies varies throughout the outcrop belt but metasiltstone and/or metasandstone generally predominate. Some coarser grained layers appear to be graded, contain parallel laminae, and/or show local cut-and-fill structures; shaly rip-up clasts as much as an inch and a half long occur at several localities. Metasandstone and metasiltstone layers have a semi schistose texture and consist mainly of quartz, calcite, and quartz-white mica aggregates in a matrix of white mica and chlorite; lesser clast types include feldspar, dolomite, and allanite.

5.0 Site Conditions

5.1.Port of Nome

Seven test borings are in the vicinity of the proposed project footprint. These were conducted in 1982 by Harding Lawson Associates for the existing causeway. The profile fence diagram can be found in Figure 3. Most of surface soil is disturbed by construction, dredging and mining. This surface soil is composed of a medium dense to dense Holocene stratum of silty sand and gravel and ranges from two to 15 feet in thickness. Beneath this Holocene stratum there are three Pleistocene strata; glacial till, marine sand and silt, and glacial rubble over bedrock. The 1982 exploration reports a medium to very dense layer of glacial till 20 to 30 feet in thickness over the top of the dense to very dense grey marine sand and silt. Where encountered, the marine layer was found to be five to ten feet thick. Very dense rubble and bedrock were found below the marine layer. The bedrock was cored, profiled, and classified beneath the existing causeway during the 1982 exploration. The bedrock was classified as dark colored weathered micaceous Schist. The center of the channel has been dredged from -12 to -22 feet MLLW into the glacial till. Some difficulty was experience dredging to the greater depths. Previous explorations indicate the outer channel and maneuvering area has virtually the same soil material lithology; although, a slightly thicker surface deposits (Holocene) was found. A more thorough subsurface geotechnical investigation is required to better classify the subsurface conditions.

5.2.Point Spencer and Cape Riley

No subsurface investigations or reports were available in the vicinity of Point Spencer and Cape Riley for this study. Hence, very little is known about the subsurface of these two sites. Based on U.S. Geological Survey bedrock geologic maps, the surface and subsurface is similar to Nome. Both are expected areas of glacial till shown to be overlain with out-washed surface silts and sands. Bedrock can be expected near the shore at the Cape Riley site two to five feet below the existing ground surface. A thorough subsurface geotechnical investigation will need to be performed to classify the subsurface conditions and to delineate the bedrock.

6.0 Preliminary Engineering Analysis and Recommendations

6.1. Assumptions

Engineering properties for the Port Nome site were assumed using previous Nome investigation reports. Engineering properties for the Point Spencer and Cape Riley sites were conservative assumed values based on similar soils and engineering judgment. All values shown in Table 1 are for preliminary engineering analysis and should not be used for final design.

6.1.1. Estimated Properties of Armor Stone

For estimating purposes we have assumed a porosity (n) value of 40 percent for all of the in-place large stone products for all three sites. The specific gravity of the stone from the Cape Nome Quarry is 2.65 (Quarry Stone Test Data, Cape Nome Quarry, Nome Alaska, 5 February 1987). These test results are available upon request. To calculate the estimated dry unit weight of in-place large stone the following relationship was used between specific gravity, porosity, and the unit weight of water: $\gamma_d = G_s(1-n)\gamma_w$

γ_d = Estimated Dry Unit Weight (lbs/ft^3)
G_s = Relative Density (Specific Gravity), (BSSD)
n = Porosity (assumed 40 percent) (USACE Shore Protection Manual)
γ_w = Unit Weight of water $\left(62.4\frac{\text{lb}}{\text{ft}^3}\right)$

$\gamma_d = 2.65(1-.40)62.4\frac{lb}{ft^3} = 99.2\frac{lb}{ft^3} \approx 100\frac{lb}{ft^3}$ to be conservative.

6.1.2. Estimated Properties of the Constructed Fill

The designs for these three sites are very similar. The constructed fill in the three designs call for Classified and Unclassified Fill under the Armor Rock layers. Classified Fill is the bulk of the fill used. For a conservative analysis, classified fill was used in all preliminary analysis. The engineering properties for the classified fill were estimated using Cornell University's Manual on Estimating Soil Properties. Effective unit weight was used in all calculations for soils below the modeled water level. Likewise, total unit weight was used above.

6.1.3. Estimated Properties of the Insitu Soils

The seven test borings from the 1982 Harding Lawson Associates Soil Investigation from the initial Nome Harbor Investigation shows the engineering properties of the subsurface soils improve the deeper the material. The location of these test borings are shown on Figure 2. A profile fence diagram constructed from these boring is shown on Figure 3. The coarse grained surface layer can be up to 15 feet thick; therefore, the engineering properties of this layer is used for all preliminary analysis of the subsurface insitu soil for all three sites.

Table 1. Assumed engineering properties for Nome, Point Spencer and Cape Riley.

Material	Dry Unit Weight (pcf)	Phi (˚)	Effective Unit Weight (pcf)
Stone Armor	100	-	56
Constructed Fill	127	37	64
Insitu soil unit	115	32	42
Assume Density of Seawater	-	-	64

All soils are considered non cohesive.

6.2. Preliminary Analysis

The following analysis was completed referencing EM 1110-2-2100, *Stability Analysis of Concrete Structures*; EM 1110-2-2502, *Retaining and Flood Walls*; EM 111-2-1100 Part VI, *Introduction to Coastal Project Element Design*, EM 1110-1-1905, *Bearing Capacity of Soils*, and EM 1110-2-1902, *Engineering and Design – Slope Stability*. The design criteria can be found in Table 2. The critical cases for all design features were evaluated. The Simplified Bishop Method was used to determine all the slope stability analysis performed in this section. The analysis was performed using a spreadsheet and hand calculations. A more in-depth computer model should be developed using further soil investigations and a computer analysis (Spenser method) should be conducted for final design.

Table 2. Design criteria for project features.

Design Feature	Source Publication	Safety Factor
Slope Stability	EM 1110-2-1902	1.5
Bearing Capacity	EM 1110-1-1905	3.0
Sliding	EM 1110-2-2100	1.5
Overturning	EM 1110-2-2100	Usual (100% of Base in Compression)

6.2.1. Port of Nome

The proposed Nome causeway extension with the concrete caissons and new proposed crest elevation for the existing breakwater have been analyzed for slope stability and the proposed caisson docks have been analyzed for global stability. The Simplified Bishop Method was used to determine the slope stability of the causeway and breakwater; geometry can be found on Figure 4. Using the assumptions in Table 1 and an embankment elevation of +13.5 feet MLLW, on a 2 horizontal to 1 vertical slope, a factor of safety against slope failure of the causeway was 2.0. Increasing the breakwater crest to an elevation of +25 feet MLLW and maintaining the same critical 1.5 horizontal to 1 vertical slope results in a computed factor of safety of 1.3. A more in-depth computer model and analysis should be conducted for design subsequent to further soils investigation.

The global stability to include bearing capacity, sliding and overturning was calculated for the concrete caisson dock for Nome. The internal stability is assumed to be accounted in the design of the caisson structure itself. The 600 by 50 by 50-foot caisson has a design embedment of two feet; this is ignored for conservative analysis. Rotational behavior is satisfactory due to all resultant applied forces with respect to the potential failure plane are in compression for this usual load condition. Further safety is ensured by the safety factor requirements for sliding and by the limits on allowable bearing stresses. From the design and performance of the existing Nome Causeway and Breakwater, settlement is the controlling limit state at an allowable bearing pressure of 5,000 pounds per square foot. Also note, this allowable bearing pressure is used for Point Spencer and Cape Riley's analysis. Using this value and the assumed values in table 1, the calculated bearing pressure was 3,630 pounds per square foot. The resulting bearing capacity factor of safety is 4.1. The factor of safety for sliding was calculated to be 3.5.

6.2.2. Point Spencer

The proposed Point Spencer causeway with the caisson dock has been analyzed for slope stability. The caisson dock has been analyzed for global stability. The Simplified Bishop Method was used to determine the slope stability of the causeway; geometry can be found on Figure 6. Using the assumptions in Table 1 and a causeway elevation of +13.5 feet MLLW, on a 1.5 horizontal to 1 vertical slope, a factor of safety against slope failure was 1.9. A more in-depth computer model and analysis should be conducted for design subsequent to further soils investigation. The maximum bearing pressure for the critical section of the purposed causeway is 3,100 pounds per square foot. The sub grade has an allowable bearing capacity of 5,000 pounds per square foot resulting in a bearing capacity factor of safety of 4.8.

The external global stability to include bearing capacity, sliding and overturning was calculated for the concrete caisson dock for Point Spencer. The internal stability is assumed to be accounted in the design of the caisson structure itself. Almost identical design as the Nome caisson, except for its length, the 1000 by 50 by 50-foot caisson also has a design embedment of two feet. This two-foot embedment was ignored for conservative analysis. Rotational behavior is satisfactory due to all the resultant applied forces with respect to the potential failure plane are in compression for this usual load condition. Further safety is ensured by the safety factor requirements for sliding and by the limits on allowable bearing stresses. Using the assumed values in Table 1 and an allowable bearing capacity of 5,000 pounds per square foot, the calculated bearing pressure of the caisson dock structure was 3,630 pounds per square foot resulting in a bearing capacity factor of safety of 4.1. The factor of safety for sliding is 3.5.

6.2.3. Cape Riley

The proposed Cape Riley breakwater has been analyzed for bearing pressure capacity and considered for slope stability. The caisson dock has been analyzed for global stability. The breakwater compared to the Point Spencer Breakwater has the same preliminary design and geometry; however, it has less relative height and less overall material, resulting in a less significant load on the insitu soils. Therefore, the factor of safety against slope failure is greater than Point Spencer’s 1.9. A more in-depth computer model and analysis should be conducted for design subsequent to further soils investigation. The maximum bearing pressure for the critical section of the purposed breakwater is 2,600 pounds per square foot; the sub grade has an allowable bearing capacity of 5,000 pounds per square foot resulting in a bearing capacity factor of safety of 5.8.

The external global stability to include bearing capacity, sliding and overturning was calculated for the concrete caisson dock at Cape Riley. The internal stability is assumed to be accounted in the design of the caisson structure itself. The 250 by 40 by 26-foot caisson has a design embedment of two feet. This two-foot embedment was ignored for conservative analysis. Rotational behavior is satisfactory due to all the resultant applied forces with respect to the potential failure plane are in compression for this usual load condition. Further safety is ensured by the safety factor requirements for sliding and by the limits on allowable bearing stresses. Using the assumed values in Table 1, the calculated bearing pressure is 1,600 pounds per square foot. The sub grade has an allowable bearing capacity of 5,000 pounds per square foot resulting in a bearing capacity factor of safety of 9.4. Factor of safety for sliding is 2.0.

6.3. Preliminary Engineering Recommendations

Preliminary engineering analysis shows the project sites are suitable for the construction of the proposed project options.

Recommendations presented in this section are meant as preliminary engineering recommendations for the elements outlined in this feasibility report. The zone of influence for settlement is two times the width of the caisson; for Nome and Point Spenser it is 100 feet and 52 feet for Cape Riley. Assuming the soil characteristics are the same as found in the 1982 Nome soil investigation, the subsurface soil is a coarse grained, medium dense non-cohesive soil, and becomes very dense to bedrock. Following these assumptions, we do not anticipate excessive settlement. By inspection of previous like construction in the vicinity of Nome, all settlement will be minimal and occur during construction. A more in-depth geotechnical investigation should be conducted and updated recommendation should be prepared in the event that this project is brought to 100 percent design.

The medium dense silty sand and gravel soils at all three site would allow a variety of excavation methods to be used. This includes excavators from barge or clam shell in which both of these methods have been successful in the Port of Nome. Some difficulty dredging was encountered in the area between the causeway and the main breakwater at a depth of approximately -20 feet MLLW near mid-channel in the glacial till. Clam shell dredging should be considered for dredging the deeper channel. Localized areas at Cape Riley, shallow bedrock may impede normal dredging. For these areas, blasting may be necessary.

A stable channel side slope should be no steeper than 3 horizontal to 1 vertical slope at an offset of no less than 25 feet from the toe of any breakwater or causeway. This offers protection against the breakwater or causeway failing the dredge slope. The worsted case at a 25-foot offset offers a factor of safety of 1.4 against slope failure. The medium dense silty sand and gravel soils at all three sites will not likely remain in place after construction. If cut slopes are steeper than 3 horizontal to 1 vertical slope, it is recommended to protect channel side slopes with armor rock.

7.0 References

U.S. Geological Survey. (2011). Bedrock Geologic Map of the Seward Peninsula Pamphlet and accompanying Maps (3131-1 and 2). N.p.: U.S. Department of the Interior.

U.S. Army Coastal Engineering Research Center. (1977). Shore Protection Manual (III ed., Vol. II, pp. 7-208-7-210). Washington DC: U.S. Government Printing Office.

U.S. Army Corps of Engineers. (1992). *EM 1110-1-1905, Engineering and Design BEARING CAPACITY OF SOILS*. Washington, D.C.: U.S. Department of the Army.

U.S. Army Corps of Engineers. (2002). *EM 1110-2-1100, Coastal Engineering Manual - Part V*. Washington, D.C.: U.S. Department of the Army.

U.S. Army Corps of Engineers. (2003). *1110-2-1902, Engineering and Design SLOPE STABILITY*. Washington, DC: U.S. Department of the Army.

U.S. Army Corps of Engineers. (1998). *EM 1110-2-2502, Engineering and Design RETAINING AND FLOOD WALLS*. Washington, D.C.: U.S. Department of the Army.

Cornell University. (1990). Chapter 2. In *Manual on Estimating Soil Properties for Foundation Designs*. Washington, D.C.: Electric Power Research Institute.

Harding Lawson Associates. (1982). *Soil Investigation Report for Port of Nome*. Anchorage, AK: TAMS Engineers.

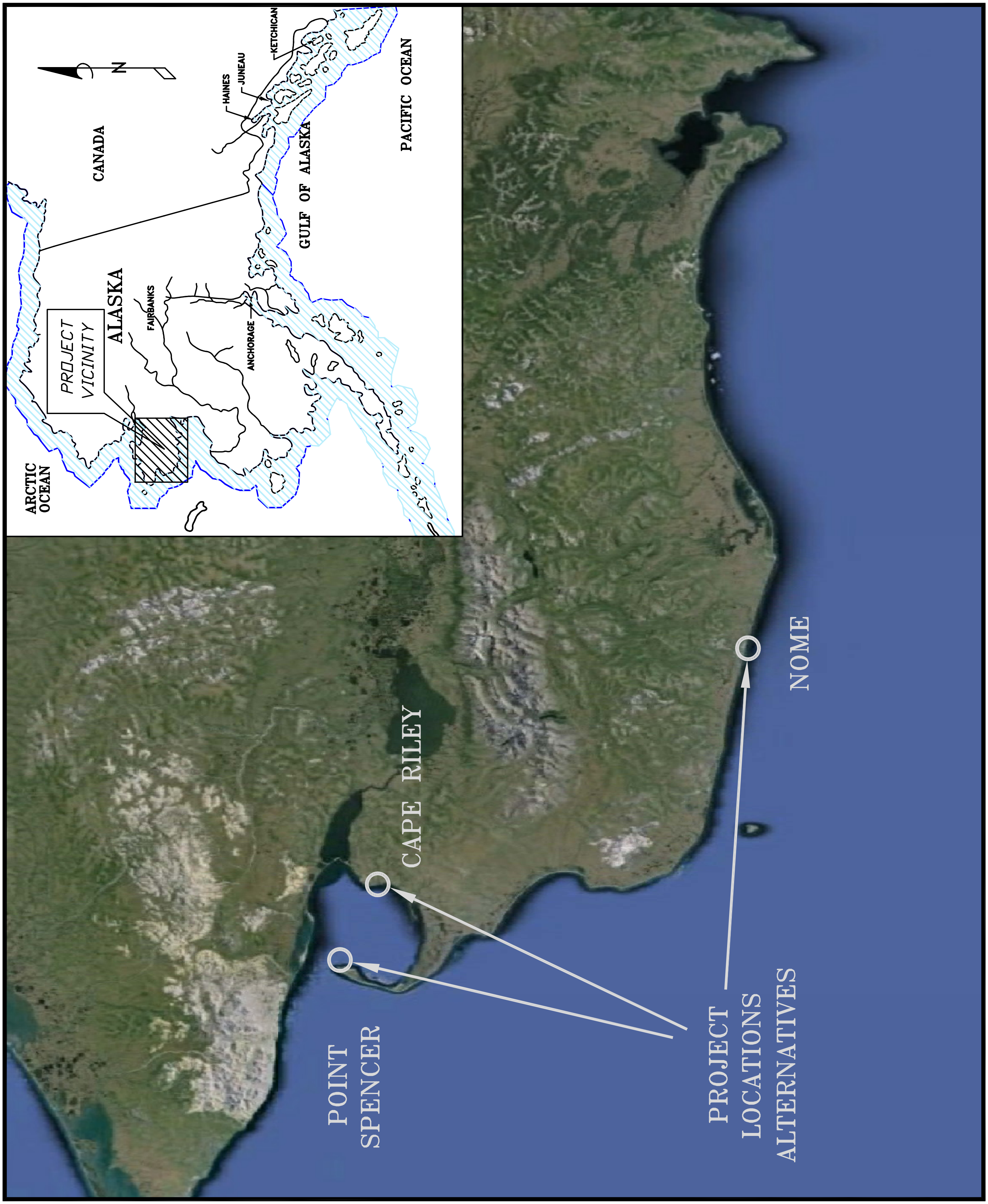
Woodward-Clyde Consultants. (n.d.). *Nome Harbor Site Investigation Report*. Anchorage, AK: City of Nome.

U.S. Army Corps of Engineers, Alaska District. (2004). *Geotechnical Findings Report for the Nome Harbor Sheet Pile Replacement Project (072742)*. Anchorage, AK: Geotechnical and Materials.

U.S. Army Corps of Engineers, Alaska District. (2006). *Geotechnical Findings Report for the Nome Harbor Sheet Pile Replacement Project (NOM005)*. Anchorage, AK: Geotechnical and Materials.

U.S. Army Corps of Engineers, Alaska District. (2013). Alaska Deep-Draft Arctic Ports Navigation Feasibility Study. In *Tentatively Selected Plan SMART Planning Milestone* (pp. 1-42).

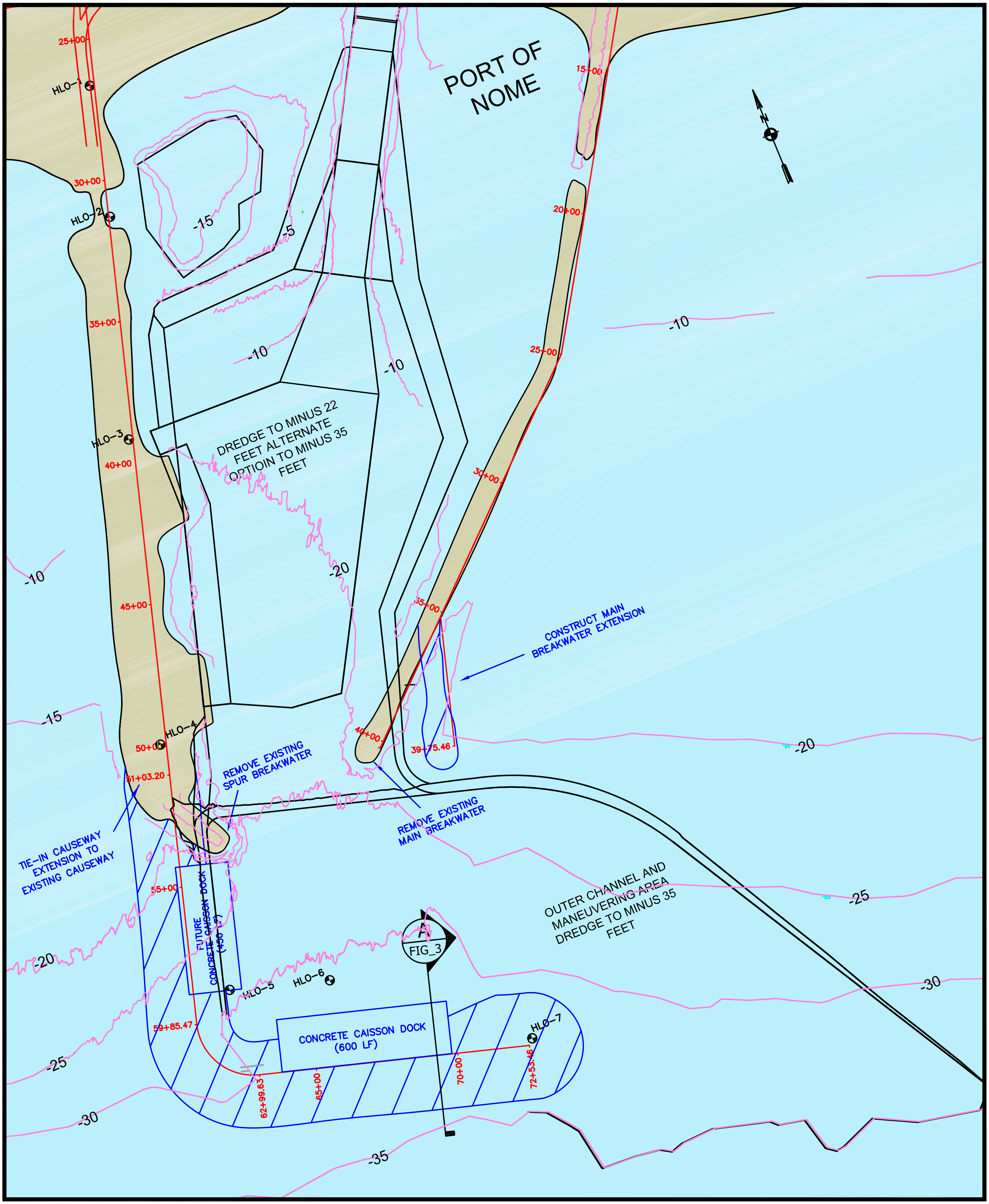
CORPS OF ENGINEERS U.S. ARMY



ALASKA DISTRICT
CORPS OF ENGINEERS
GEOTECHNICAL AND MATERIALS

DEEP-DRAFT ARCTIC PORTS
GEOTECHNICAL FEASIBILITY REPORT
LOCATION AND VICINITY MAP
SEWARD PENINSULA, ALASKA

SCALE: NTS
DATE: Feb 2014
DRAWN/RVW: RTW/JR
FIGURE 1

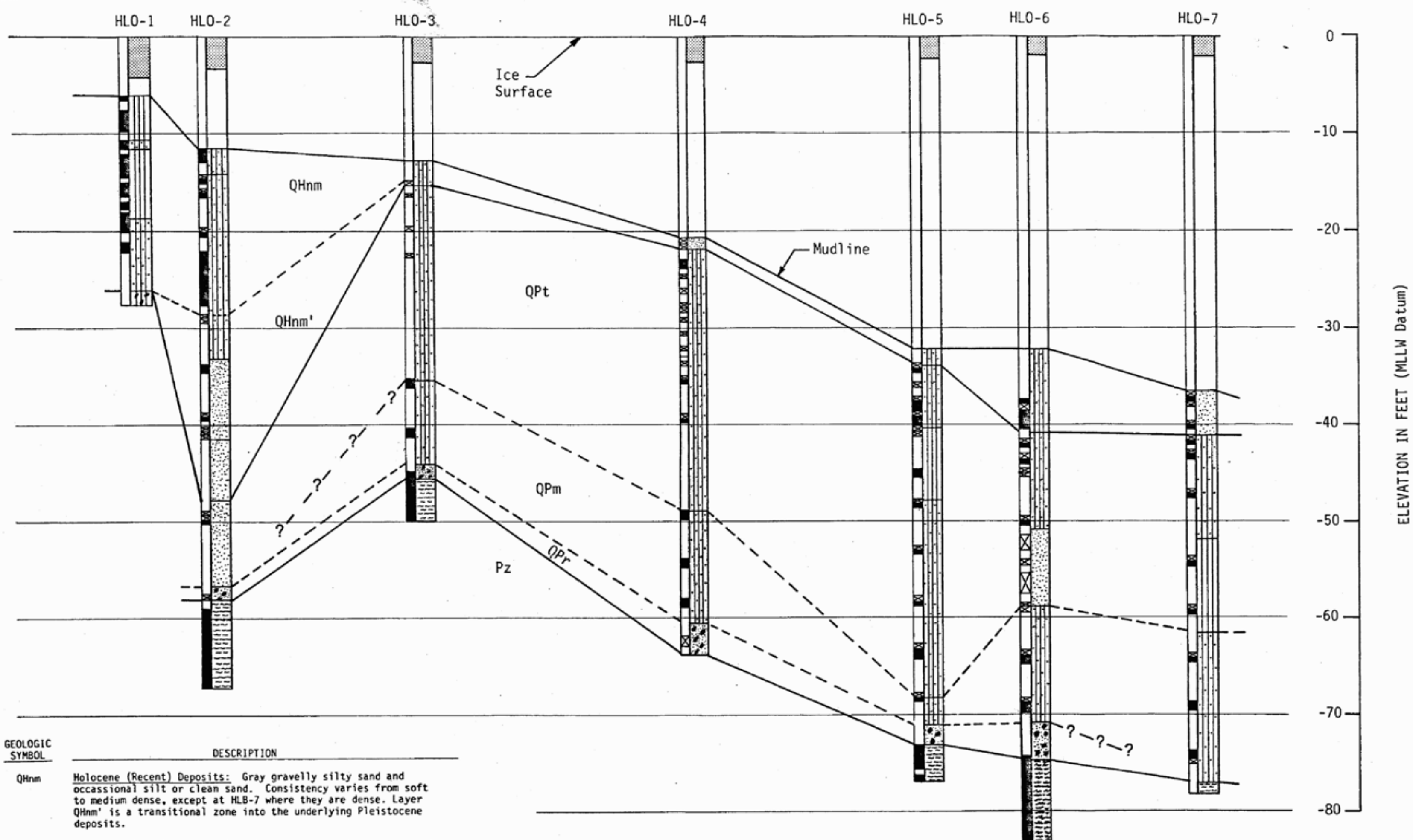


ALASKA DISTRICT
CORPS OF ENGINEERS
GEOTECHNICAL AND MATERIALS

DEEP-DRAFT ARCTIC PORTS
GEOTECHNICAL FEASIBILITY REPORT
NOME ALTERNATIVES
NOME, ALASKA

SCALE: NTS
DATE: FEB 2014
DRAWN/RVW: RTW/JR

FIGURE 2



GEOLOGIC SYMBOL	DESCRIPTION
QHnm	Holocene (Recent) Deposits: Gray gravelly silty sand and occassional silt or clean sand. Consistency varies from soft to medium dense, except at HLB-7 where they are dense. Layer QHnm' is a transitional zone into the underlying Pleistocene deposits.
QPt	Glacial Till: Gray gravelly silty sands and silt; occassional clean sand and silty gravel. Medium dense to very dense. Contains angular rock fragments (gravels).
QPm	Marine: Gray silty sand; fine grain; dense to very dense.
QPr	Glacial Rubble: Gray sandy gravel; very dense; silty to clean.
Pz	Bedrock: Micaceous shist; highly weathered at surface.

Harding Lawson Associates
Engineers, Geologists & Geophysicists

SUBSURFACE CROSS-SECTION

Port of Nome
Nome, Alaska

PLATE 3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	15,001,002.08	TJS	4/82		

ALASKA DISTRICT
CORPS OF ENGINEERS
GEOTECHNICAL AND MATERIALS

DEEP-DRAFT ARCTIC PORTS
GEOTECHNICAL FEASIBILITY REPORT
Profile Fence Diagram
NOME, ALASKA

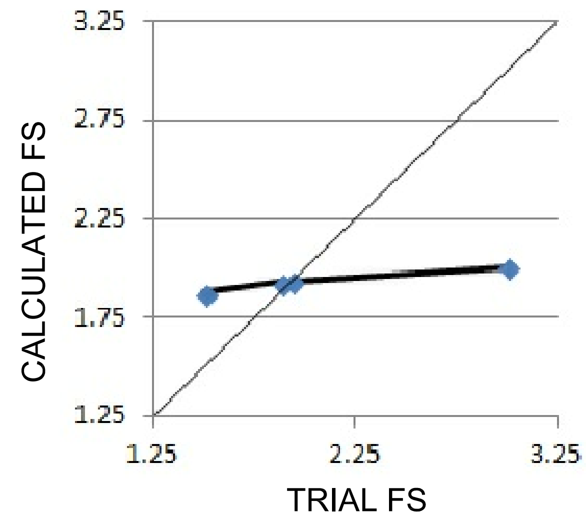
SCALE: NTS
DATE: Feb 2014
DRAWN/RVW: RTW/JR

FIGURE 3

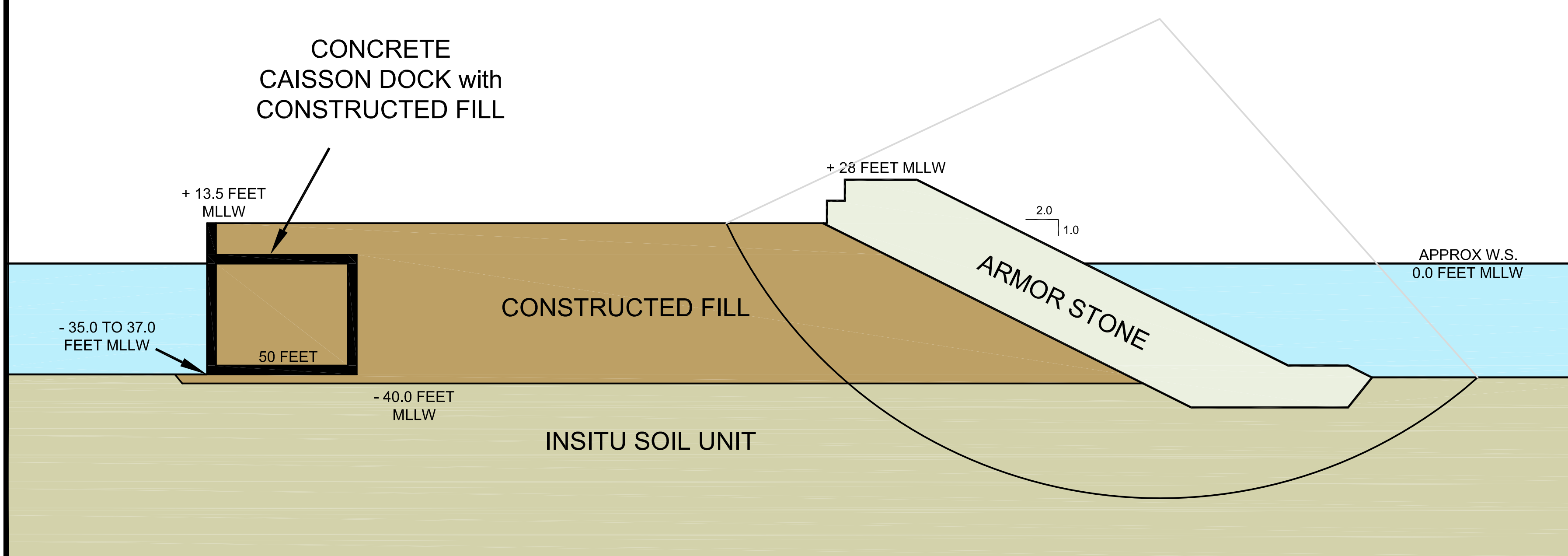
CORPS OF ENGINEERS
U.S. ARMY

This drawing was used to simplify the geometry of the causeway extension/concrete caisson dock sections for preliminary geotechnical design calculations for the Nome alternatives. This drawing should not be used for final designs. This drawing was used for both, the 450-foot and the 600-foot causeway/caisson sections.

Factor of Safety for slope stability was calculate using the Simplified Bishop Method with eight slices and three trials: FS = 2.0



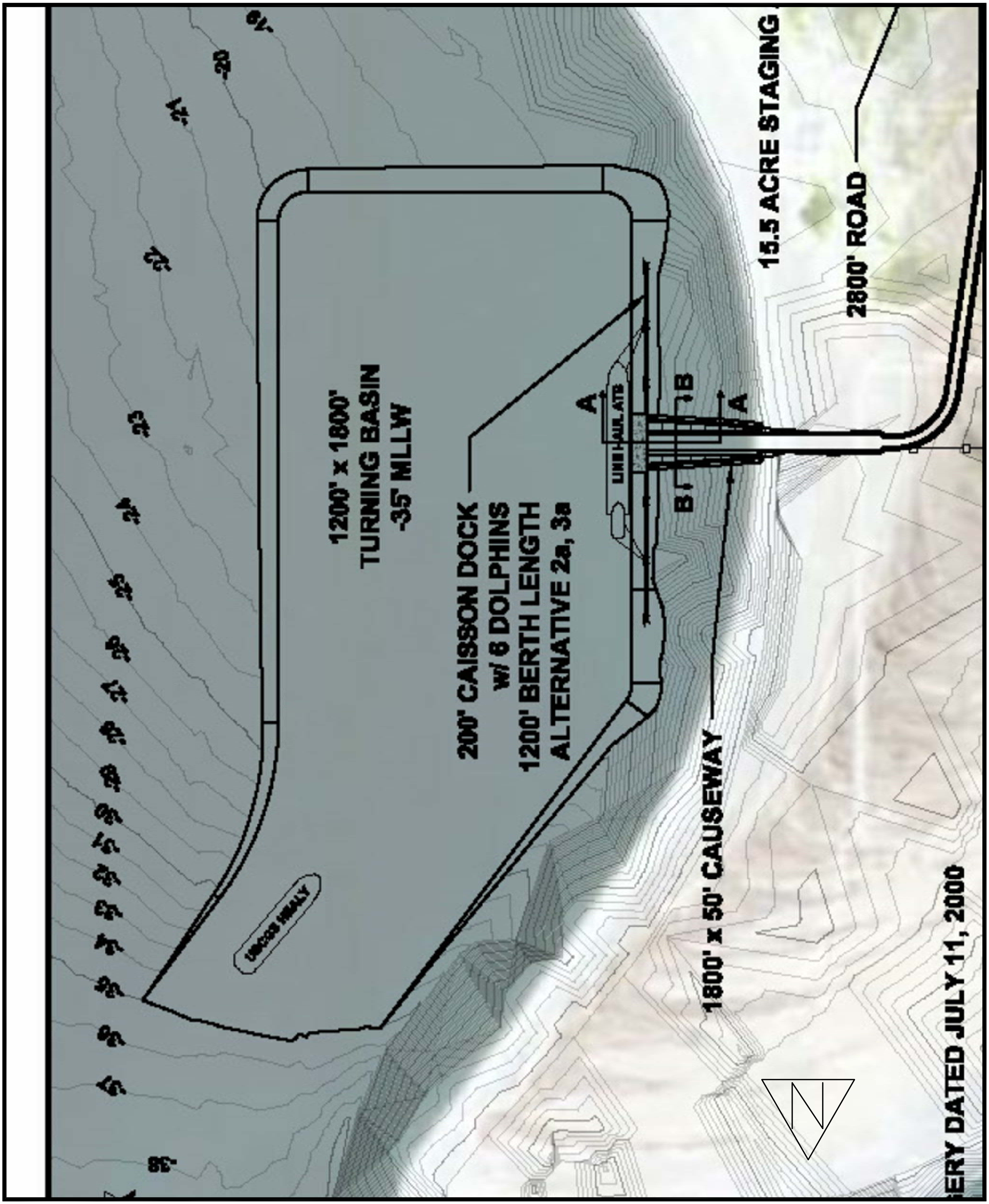
A TYPICAL SIMPLIFIED SECTION
SIMPLIFIED FOR CALCULATIONS



ALASKA DISTRICT
CORPS OF ENGINEERS
GEOTECHNICAL AND MATERIALS

DEEP-DRAFT ARCTIC PORTS
GEOTECHNICAL FEASIBILITY REPORT
NOME CAUSEWAY SECTION
NOME, ALASKA

SCALE: NTS
DATE: Feb 2014
DRAWN/RVW: RTW/JR
FIGURE 4



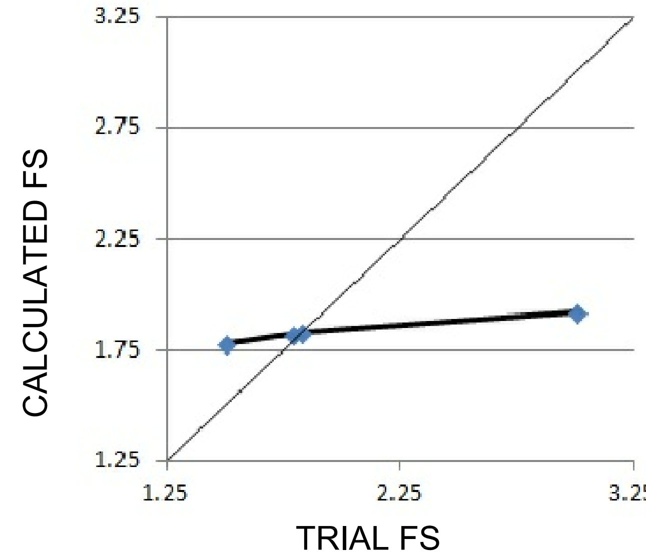
ALASKA DISTRICT
CORPS OF ENGINEERS
GEOTECHNICAL AND MATERIALS

DEEP-DRAFT ARCTIC PORTS
GEOTECHNICAL FEASIBILITY REPORT
POINT SPENCER ALTERNATIVE
POINT SPENCER, ALASKA

SCALE: NTS
DATE: FEB 2014
DRAWN/RVW: RTW/JR
FIGURE 5

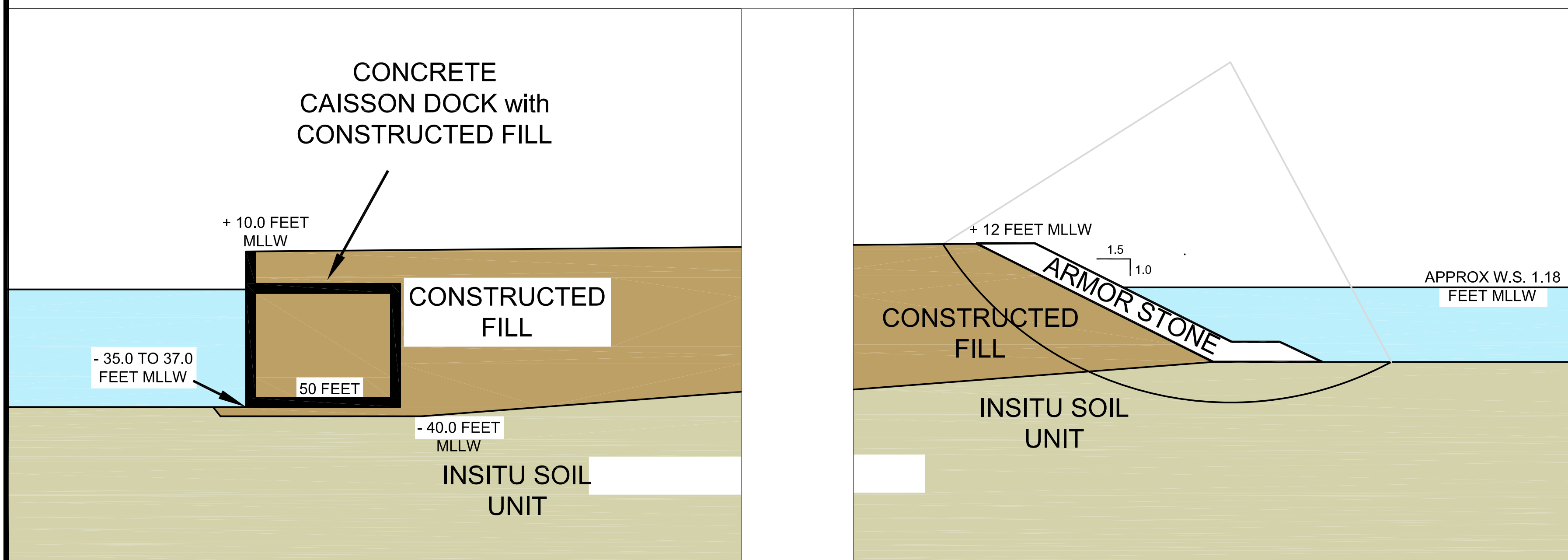
This drawing was used to simplify the geometry of the breakwater/concrete caisson dock sections for preliminary geotechnical design calculations for the Point Spencer alternatives. This drawing should not be used for final designs.

Factor of Safety for slope stability was calculate using the Simplified Bishop Method with eight slices and three trials: FS = 1.9



A & B — TYPICAL SIMPLIFIED SECTION

SIMPLIFIED FOR CALCULATIONS

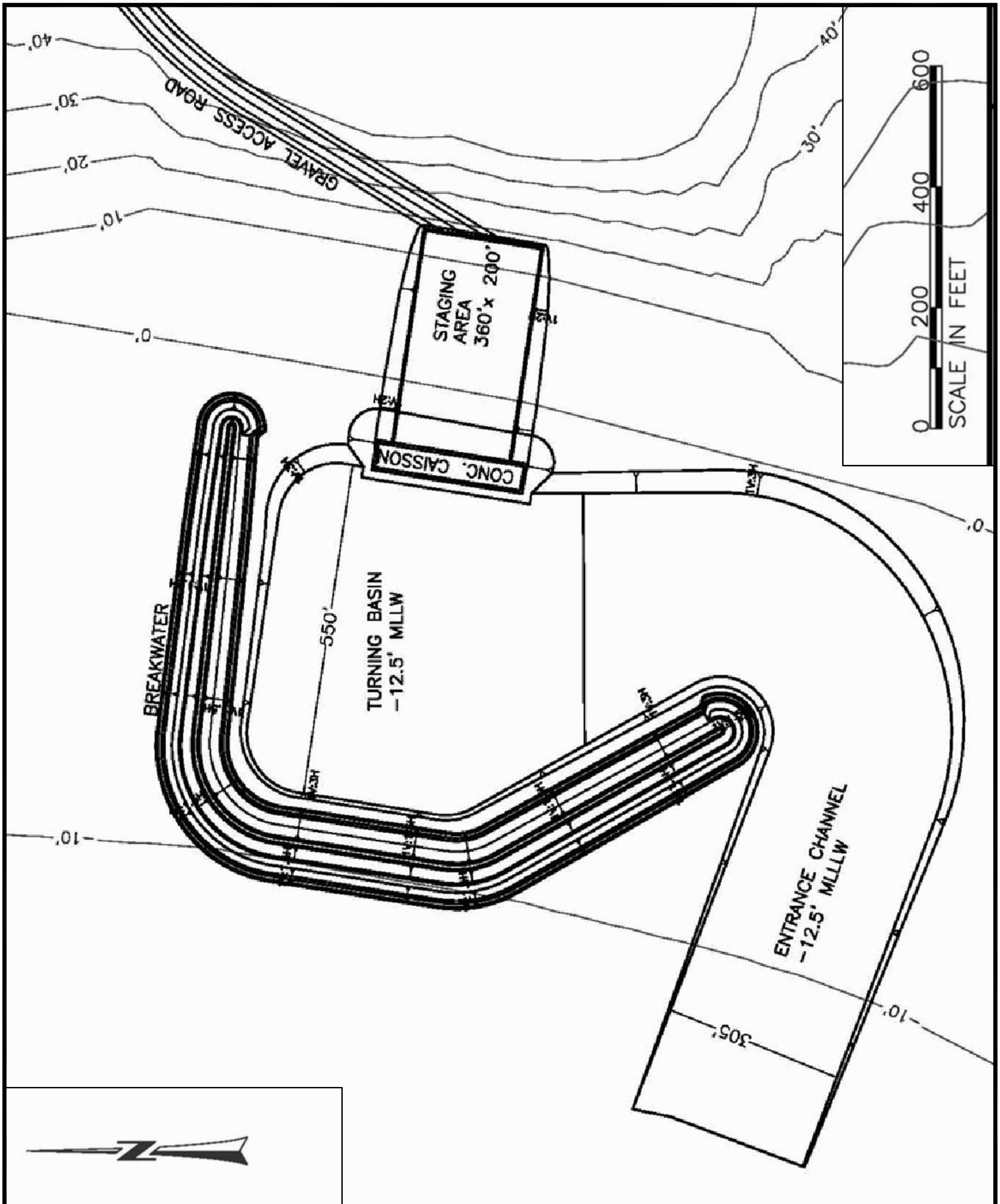


ALASKA DISTRICT
CORPS OF ENGINEERS
GEOTECHNICAL AND MATERIALS

DEEP-DRAFT ARCTIC PORTS
GEOTECHNICAL FEASIBILITY REPORT
POINT SPENCER SECTION
POINT SPENCER, ALASKA

SCALE: NTS
DATE: Feb 2014
DRAWN/RVW: RTW/JR

FIGURE 6



ALASKA DISTRICT
CORPS OF ENGINEERS
GEOTECHNICAL AND MATERIALS

DEEP-DRAFT ARCTIC PORTS
GEOTECHNICAL FEASIBILITY REPORT
CAPE RILEY ALTERNATIVE
CAPE RILEY, ALASKA

SCALE:	NTS
DATE:	FEB 2014
DRAWN/RVW:	RTW/JR

FIGURE 7