RETURN TO SER AR INDEX

ASSESSMENT OF BLASTING IMPACTS TO THE NEW BEDFORD-FAIRHAVEN HURRICANE BARRIER NEW BEDFORD MARINE COMMERCE TERMINAL NEW BEDFORD, MASSACHUSETTS

PREPARED FOR:
Apex Companies, LLC
Boston, Massachusetts

PREPARED BY:
GZA GeoEnvironmental, Inc.
Providence, Rhode Island

October, 2012
File No. 33734.03

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SDMS Doc ID 523875

GZA
GeoEnvironmental, Inc.

Engineers and Scientists

October 5, 2012
File No. 33734.03

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Mr. Chet Myers
Apex Companies, LLC
184 High Street, Suite 502
Boston, Massachusetts 02110

Re: Assessment of Blasting Impacts to the New Bedford-Fairhaven Hurricane Barrier
New Bedford Marine Commerce Terminal
New Bedford, Massachusetts

Dear Mr. Meyers:

GZA GeoEnvironmental, Inc. (GZA) is pleased to provide you with this geotechnical letter report pertaining to proposed blasting in the vicinity of the New Bedford-Fairhaven Hurricane Barrier. This report was prepared in accordance with our proposal dated September 4, 2012. The primary objective of this letter report is to present our assessment of blasting induced ground vibrations and its effects on the global stability of the existing New Bedford-Fairhaven Hurricane Barrier for the proposed New Bedford Marine Commerce Terminal project. This report is subject to the Limitations presented in Appendix A.

BACKGROUND

The New Bedford-Fairhaven hurricane barrier spans across New Bedford Harbor between New Bedford and Fairhaven, Massachusetts, and is located immediately south of Palmer Island. The barrier was constructed in the 1960's as part of a flood control infrastructure program. It is generally comprised of an earth fill embankment consisting of layered armor stone, filter stone, and earth fill layers. There is an access roadway that extends the length of the barrier positioned on the harbor side of the embankment. Two gated conduits were incorporated into the barrier which, under normal operating conditions, allows water to easily flow from one side of the barrier to the other during tidal fluctuations. A gated navigation channel is also located on the eastern side of the barrier.

This hurricane barrier is located immediately south of the proposed New Bedford Marine Commerce Terminal project (see Figure 1, Locus Plan). The project involves the development of a waterfront parcel into an all purpose marine terminal having specific applications to the offshore wind industry. The development will include the construction of a cellular cofferdam bulkhead and near-shore dredging along the cofferdam bulkhead to

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facilitate berthing of larger vessels. The proposed bulkhead and limits of dredging are shown in Figure 2 (Apex Figure P-2.6).

In 2011, the U.S. Army Corps of Engineers (USACE) requested a global stability analysis of the hurricane barrier which addressed the potential impacts to the barrier due to the proposed dredge elevations. GZA completed a report addressing this request, titled "Global Stability Analysis, New Bedford-Fairhaven Hurricane Barrier, New Bedford Marine Commerce Terminal, New Bedford, Massachusetts" dated November 23, 2011.

Recently, USACE requested that the stability of the hurricane barrier be re-assessed considering vibrations resulting from any proposed blasting activities. Blasting of shallow bedrock may be allowed at the site in order to meet the proposed dredge elevations.

REVIEW OF EXISTING DOCUMENTATION

Original USACE drawings were provided to GZA by Apex Companies, LLC (Apex). The following drawings were used to develop a cross section of the hurricane barrier for this analysis. These drawings are included in Appendix B.

- "New Bedford-Fairhaven Barrier, General Plan", April 1962
- "New Bedford-Fairhaven Barrier, Harbor Barrier and Dike, Plan and Profile No. 2", 1962
- "New Bedford-Fairhaven Barrier, Harbor Barrier and Dike, Typical Sections No. 1", 1962
- "New Bedford-Fairhaven Barrier, Parking Area, New Bedford", 1962

All current project elevations reference the Mean Lower Low Water (MLLW) datum; however, all of the original USACE drawings and accompanying subsurface information reference the Mean Sea Level (MSL) Datum, which was assumed to be NGVD 1929. These elevations were converted to MLLW using the following information provided by Apex: MLLW = NGVD 1929 + 1.52 ft.

The subsurface boring logs used to generate a design cross section included recent test boring logs by Apex and original USACE borings. The logs and the location plans are included in Appendix C.

In the immediate vicinity of the hurricane barrier (Dredge Area 1), shallow dredging to approximate elevation -14 feet referenced to the Mean Lower Low Water (MLLW) datum is proposed. The dredge areas are shown in Figure 2 (Apex Figure P-2.6). According to Apex, it is possible that in the future, this area could be dredged to elevation -20 feet. In review of the subsurface data provided by Apex, it is likely that bedrock excavation will not be required in Dredge Area 1. However, based on the available subsurface data, bedrock excavation may be required in Dredge Areas 2 and 3. Based on the subsurface

data, bedrock elevations range between approximately -25 and -30 feet MLLW indicating that between approximately 2 and 7 feet of bedrock may need to be removed to meet the proposed dredge elevations. It is possible that blasting will be allowed during construction to remove the bedrock. The distance between the toe of the hurricane barrier and proposed blasting activities at the lower dredge elevation would be approximately 450 feet.

FACTOR OF SAFETY

The literature was reviewed for an acceptable factor of safety for the hurricane barrier under these seismic conditions. The United States Army Corps of Engineers (USACE) Slope Stability Engineering Manual EM 1110-2-1902 dated October 31, 2003 was reviewed. Minimum required factors of safety for new and earth and rock-fill dams were given, but no guidance was given for seismic loading conditions. The manual referred to a USACE Engineering Circular "Dynamic Analysis of Embankment Dams" which was still in preparation at the time of publication. A search of the USACE manuals and guidance documents did not produce the reference. The USACE Engineering Report "Recommended Guidelines for Safety Inspection of Dams", ER 1110-2-106, dated September 26, 1979 (also republished in July 1, 2011, as 33 CFR Ch II, Section 222.6 National Program for Inspection of Non-Federal Dams, Appendix D) recommended a factor of safety of 1.0 for an embankment dam under earthquake or seismic loading. GZA also reviewed the textbook "Soil Strength and Slope Stability" by J. Michael Duncan and Stephen G. Wright published in 2005. In a section devoted to seismic slope stability, the authors recommended a factor of safety of 1.0 or 1.15 for pseudostatic analyses such as those used in this report. The reference also indicated that a certain level of deformation due to seismic events was generally acceptable, and that deformation on the order of 3 feet was tolerable for a dam.

The USACE Design Memorandum No. 5 on the New Bedford Hurricane Barrier titled "Embankments and Foundations for the New Bedford, Fairhaven and Acushnet Hurricane Protection Project, New Bedford, Massachusetts" dated November 3, 1961 was also reviewed. The USACE conducted slope stability analyses of critical portions of the hurricane barrier during the original design of the barrier. The calculated factors of safety of 1.19 and 1.36 (during construction), and 1.33 (after construction) were considered adequate. Seismic conditions were not considered in the original design. Based on the review of the available information, and a range of recommended factors of safety of 1.0 to 1.15, an acceptable factor of safety of 1.15 for seismic conditions was used for these analyses.

SLOPE STABILITY

GZA used the computer model of the hurricane barrier previously established for the global stability analysis using the Slope/w 2007 program. The cross section of the hurricane barrier analyzed is shown on Figure P-2.6 (Appendix B). A dredge elevation in the vicinity of the hurricane barrier of -20 feet MLLW was used in the analysis based on

the possible proposed future dredging depths. It is GZA's understanding, that although the design plans currently call for a dredge depth of -14 feet, a lower dredge depth of -20 may be considered in the future.

The effects of seismic forces such as from blasting or earthquakes are commonly modeled in slope stability analyses by applying an inertial force to the slope, which is referred to as a pseudostatic analysis. GZA conducted a pseudostatic analysis for this study and applied various seismic forces to the slope to determine the effect of the seismic forces on the stability of the hurricane barrier. The forces were applied in vertical and horizontal directions, and failure of both the ocean side and land side of the embankment was considered. A horizontal seismic force of 0.079g was determined to be the maximum force that would result in an acceptable factor of safety on the slope stability. The results of the slope stability analysis are shown in Figures 3 through 6.

CONTROL OF BLAST INDUCED VIBRATIONS

The maximum allowable seismic force was related to proposed blasting forces using a relationship incorporating weight of the charge per delay and distance from the structure. GZA then determined the maximum charge weights that can be used during construction as a function of distance from the hurricane barrier. This approach is described in more detail in the following sections.

Typically, construction vibrations are measured in terms of peak particle velocity having units of inches-per-second (ips) measured some distance from the blast site by portable seismographs. At a minimum, seismographs measure and report particle velocities in three mutually perpendicular directions: lateral, transverse, and vertical. The following equation can be used to convert between peak particle velocity and acceleration, given the assumption that the motion is sinusoidal.

$$PPV = \frac{GA}{2\pi F}$$

Where,
PPV = peak particle velocity, in/sec
G = gravitational constant = 386.1 in/sec^2
A= acceleration coefficient, units of g
F = Frequency, Hz

This relationship between acceleration and peak particle velocity was used to generate blasting criteria using the acceleration from the pseudostatic analysis. The following formula, as published in the 1971 U.S. Bureau of Mines Bulletin 656, "Blast Vibrations and Structures", relates charge weight, distance, and particle velocity.

$$PPV = H\left[\frac{D}{\sqrt{W}}\right]^{\beta}$$

Where,
D = distance, feet
W = weight of charge per delay, lbs
B = slope factor
H = peak particle velocity intercept, in/sec, at a value of $D/(W)^{0.5} = 1$

The Bureau of Mines Bulletin reports that vibrations levels are independent of the delay interval, and that the maximum charge weight per delay should be considered in analyzing their effects. For the development of blasting criteria, conservative values for the parameters H and β were used. Data published in the Bulletin collected from blasting at various sites across the country was analyzed by GZA. Typical values of H were found to vary between 20 to 50. A conservative value of 100 was used for these recommendations. The value of β was reported to vary approximately between -1.1 and -1.6 (Bureau of Mines 1971 and Wiss 1981). A conservative value of -1.6 was used for these recommendations. The values of β and H are generally site specific and should be verified and adjusted during a blasting test program, which is described in more detail in later sections of this report.

Based on these assumed values, GZA estimated the maximum allowable charge weights as a function of distance from the hurricane barrier. The frequency content of a blast is highly variable. Blasting frequencies are generally higher than earthquakes and other construction induced vibrations. A conservative range of frequency of the blast was chosen to be 60 Hz to 90 Hz based on typical values for blasting (Wiss 1981). In addition, for an additional factor of safety, GZA recommends that the levels of charge weight be reduced to 90% of the maximum, for the allowable charge weights shown in Table 1. If the frequency content of the blast vibrations is measured to be considerably different at the site than those assumed, then the maximum charge weights should be adjusted accordingly.

Table 1. Allowable Charge Weight per Delay as a Function of Distance from Hurricane Barrier.

Distance from Hurricane Barrier (ft)	**60 to 90 Hz**
	Charge Weight per delay (lbs)
350	8.9
400	11.7
450	14.8
500	18.2

550	22.1
600	26.2
700	35.7
800	46.7
900	59.1
1000	72.9
1100	88.2
1200	105.0

It is GZA's opinion that if the blast levels are kept below these recommended levels, the stability of the hurricane barrier will not be adversely affected, and that negligible settlement of the barrier will result due to blasting activities.

PROJECT BLAST TESTING PROGRAM

GZA recommends that a test blast program be performed in the field by the contractor to verify the input parameters used in these analyses, including the blasting frequencies.

The test blast program should consist of performing small test blasts and measuring particle velocity with distance from the blast with various seismographs. The test blasts should be located a significant distance away from the hurricane barrier. Portable seismographs capable of measuring peak particle velocity in three mutually perpendicular directions and frequency are recommended for this work.

A site specific graph of scaled distance versus peak particle velocity should be generated on a log-log plot as shown in Figure 7. The scaled distance is the distance in feet from the blast divided by the square root of W (weight of charge per delay, lbs). The data from the test program should be analyzed by fitting a best-fit regression line to provide the site specific values of velocity intercept (H) and slope factor (β) as defined previously. The frequency of the blast vibrations will also be reviewed and compared to the assumed values.

These site-specific values can then be used to determining the final allowable blasting criteria for production blasting at the site. Vibration monitoring is also recommended during the production blasting.

CONCLUSIONS AND RECOMMENDATIONS

The dredging phases of the New Bedford Marine Commerce Terminal Project will require the removal of approximately 2 to 7 feet of bedrock to meet the proposed dredge elevations at a distance of approximately 450 feet away from the toe of hurricane barrier. Since

blasting to remove the bedrock is being considered, GZA conducted an analysis to assess the effect of the vibrations on the hurricane barrier.

GZA evaluated the levels of seismic vibrations that the hurricane barrier can tolerate. These limits were related to proposed blasting operations on the site by an established relationship from the U. S. Bureau of Mines. GZA recommends limiting the charge weights to 90% of the limiting values as an initial blasting criterion. The recommended charge weights per delay are given in Table 1 of this report. These recommended values were based on conservative parameter values. A test blast program is recommended in order to verify the design parameters for site-specific values. It is GZA's opinion that if these recommendations are followed, vibration levels can be controlled to within safe limits for the hurricane barrier and surrounding structures.

CONTRACT DOCUMENT REVIEW AND CONSTRUCTION SERVICES

GZA would welcome the opportunity to be retained to revise the plans and specifications in accordance with these recommendations. GZA can also provide services that could include vibration monitoring during the blast testing program and production blasting, reduction of the vibration data, preparation of ground calibration parameters, and preparation of final production blasting criteria.

We trust that this report addresses the current geotechnical issues of this project. Please do not hesitate to contact the undersigned with any questions or comments.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

Diane Baxter, Ph.D.
Senior Project Manager

Thomas E. Billups, P. E.
Consultant/Reviewer

David R. Carchedi, Ph.D.
Senior Principal

DYB/DRC:jm

REFERENCES:

Duncan, J. M. and Wright, S. G., "Soil Strength and Slope Stability", John Wiley & Sons, Inc., New Jersey, 2005.

Nicholls, H. R., Johnson, C. F., and Duvall, W. I., "Blasting Vibrations and Their Effects on Structures", United States Bureau of Mines, Bulletin 656, 1971.
United States Army Corps of Engineers, "Slope Stability Engineering Manual", EM 1110-2-1902, October 31, 2003.

United States Army Corps of Engineers, "Recommended Guidelines for Safety Inspection of Dams", ER 1110-2-106, September 26, 1979. (Also republished as 33 CFR Ch II, Section 222.6, "National Program for Inspection of Non-Federal Dams", Appendix D, July 1, 2011).

United States Army Corps of Engineers, "Design Memorandum No. 5 - Embankments and Foundations for the New Bedford, Fairhaven and Acushnet Hurricane Protection Project, New Bedford, Massachusetts", November 3, 1961.

Wiss, J. F., "Construction Vibrations: State of the Art", *Journal of the Geotechnical Engineering Division*, Proceedings of the American Society of Civil Engineers, ASCE, Vol. 107, No. GT2, February, 1981, pp. 167-181.

Attachments:
Figure 1. Locus Plan
Figure 2. Bottom of Dredge Plan
Figure 3. Slope Stability Run 1
Figure 4. Slope Stability Run 2
Figure 5. Slope Stability Run 3
Figure 6. Slope Stability Run 4
Figure 7. Test Blast Figure
Appendix A: Limitations
Appendix B: Original USACE Drawings
Appendix C: Subsurface Boring Logs

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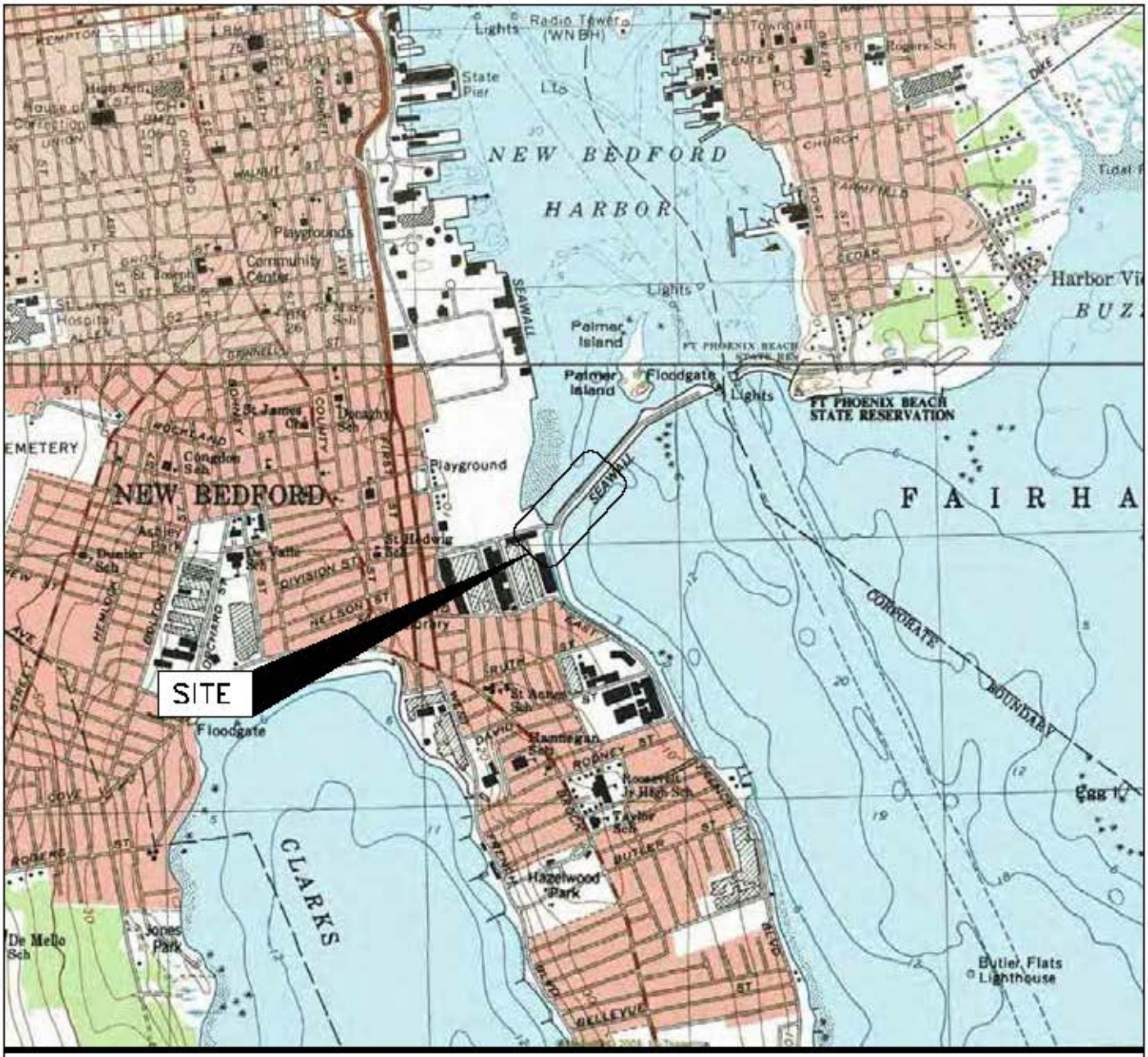
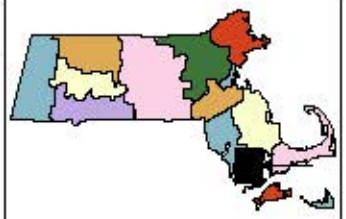
FIGURES



APPROXIMATE SCALE IN FEET

0' 1000' 2000' 4000'

N W E S



MASSACHUSETTS

QUADRANGLE LOCATION

SOURCE:

BASE MAP FROM THE FOLLOWING USGS QUADRANGLE MAP:
NEW BEDFORD SOUTH, MASSACHUSETTS (1977)

DIGITAL TOPOGRAPHIC MAPS PROVIDED MY MAPTECH, INC.

CONTOUR ELEVATIONS REFERENCE NGVD 29,
CONTOURS ARE SHOWN IN FEET AT 10 FOOT INTERVALS

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NEW BEDFORD SOUTH TERMINAL NEW BEDFORD , MASSACHUSETTS	PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: APEX COMPANIES, LLC
HURRICANE BARRIER SLOPE STABILITY	PROJ MGR: DYB DESIGNED BY: JJM DATE: SEPT. 2011	REVIEWED BY: DRC DRAWN BY: MEA PROJECT NO. 33734.00	CHECKED BY: JJM SCALE: AS NOTED REVISION NO. 0
			FIGURE 1 SHEET NO. 1 OF

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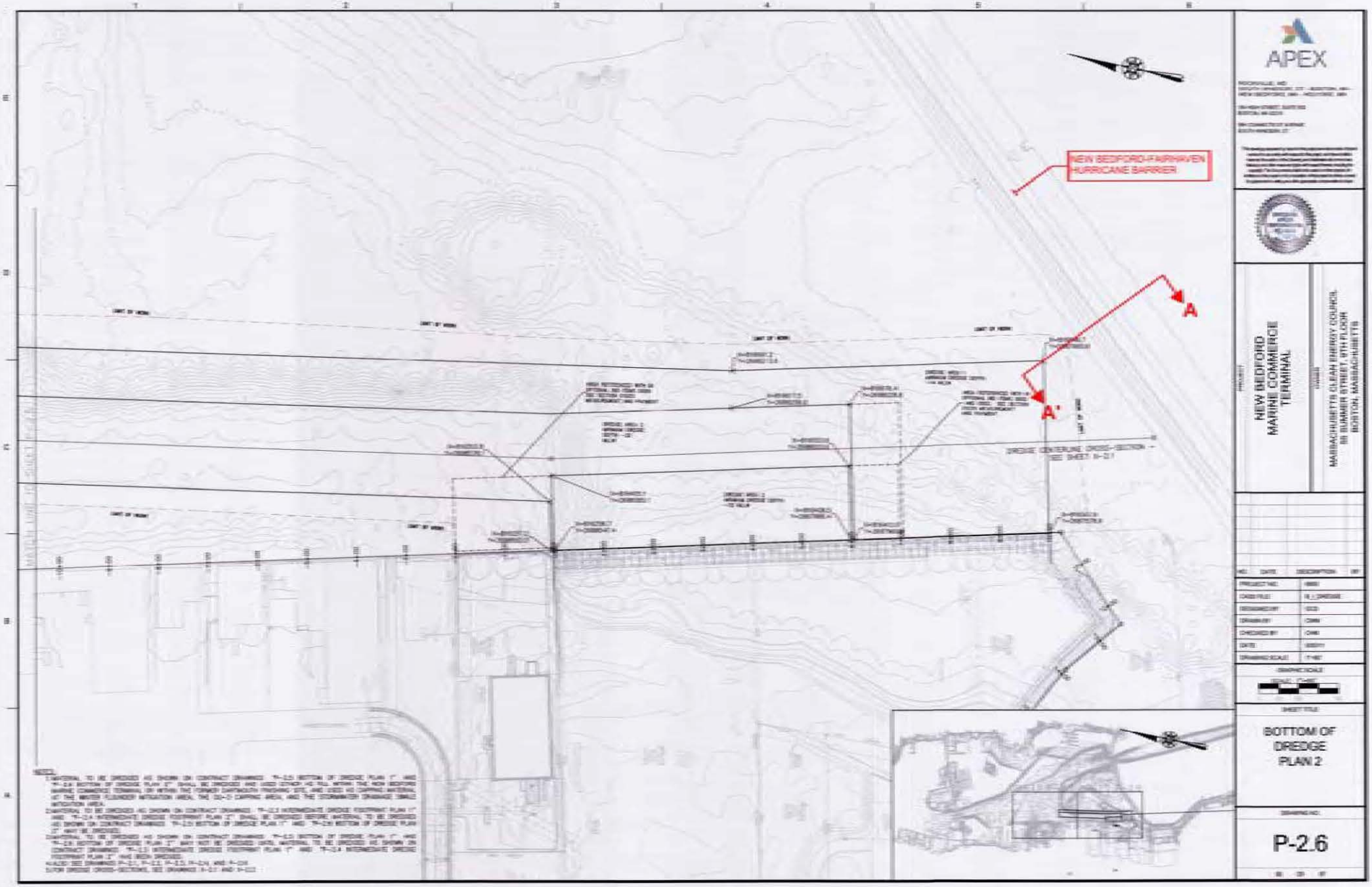


FIGURE 2 - BOTTOM OF DREDGE PLAN

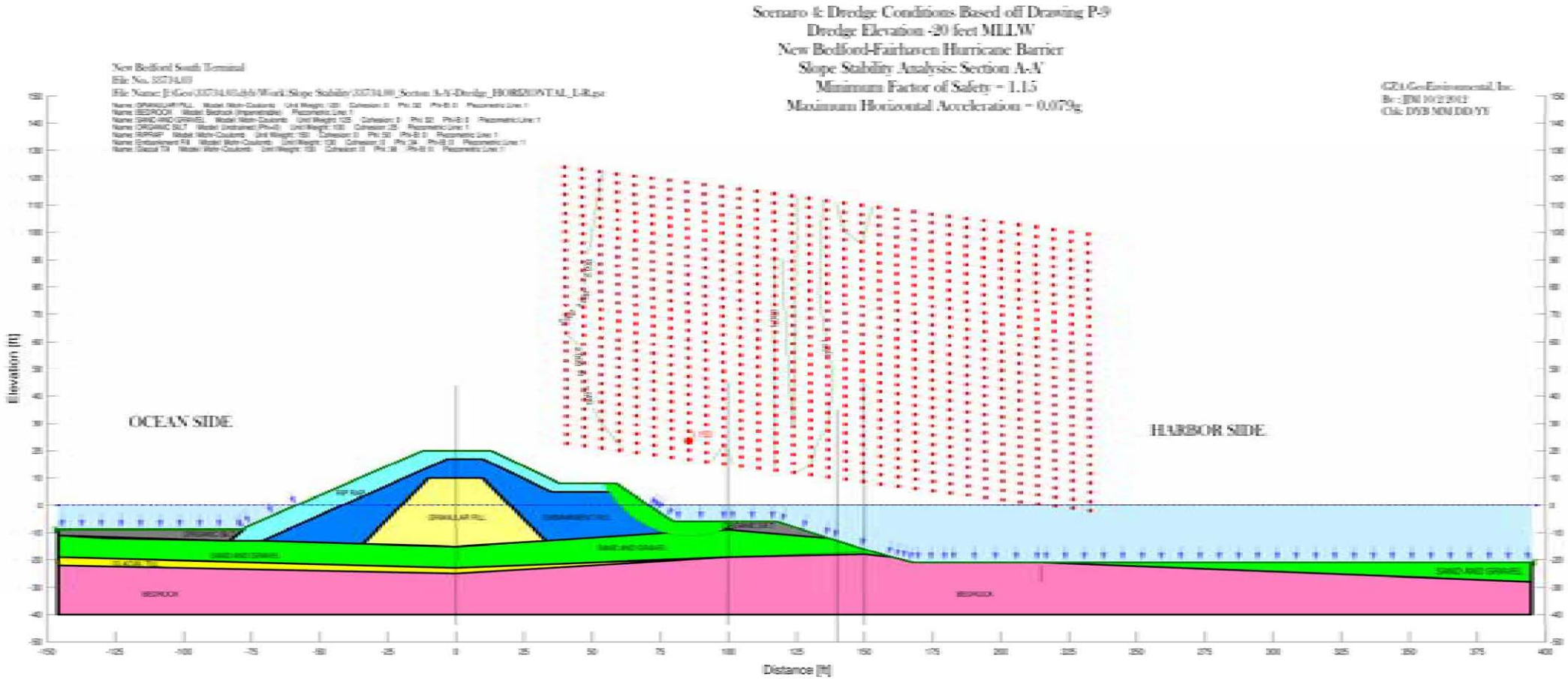


FIGURE 3 - SLOPE STABILITY RUN 1

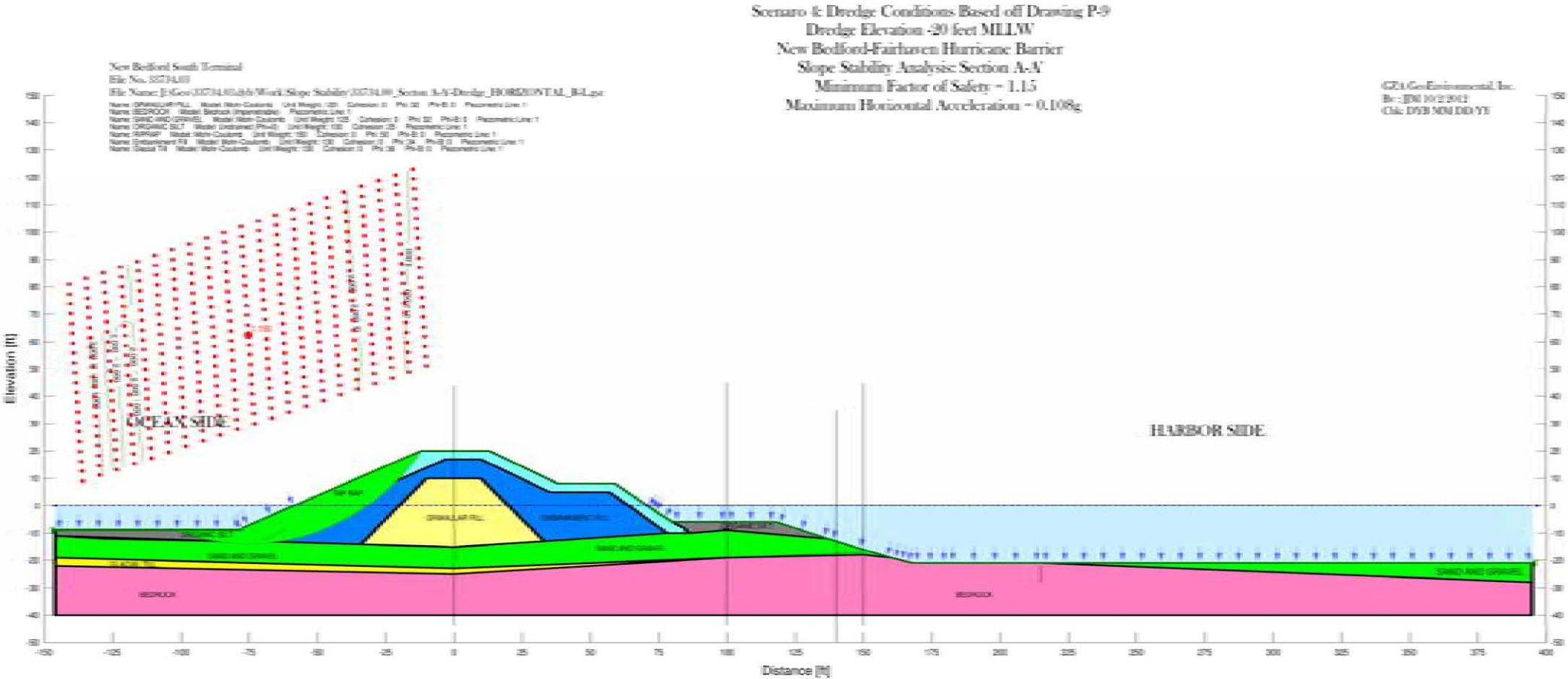


FIGURE 4 - SLOPE STABILITY RUN 2

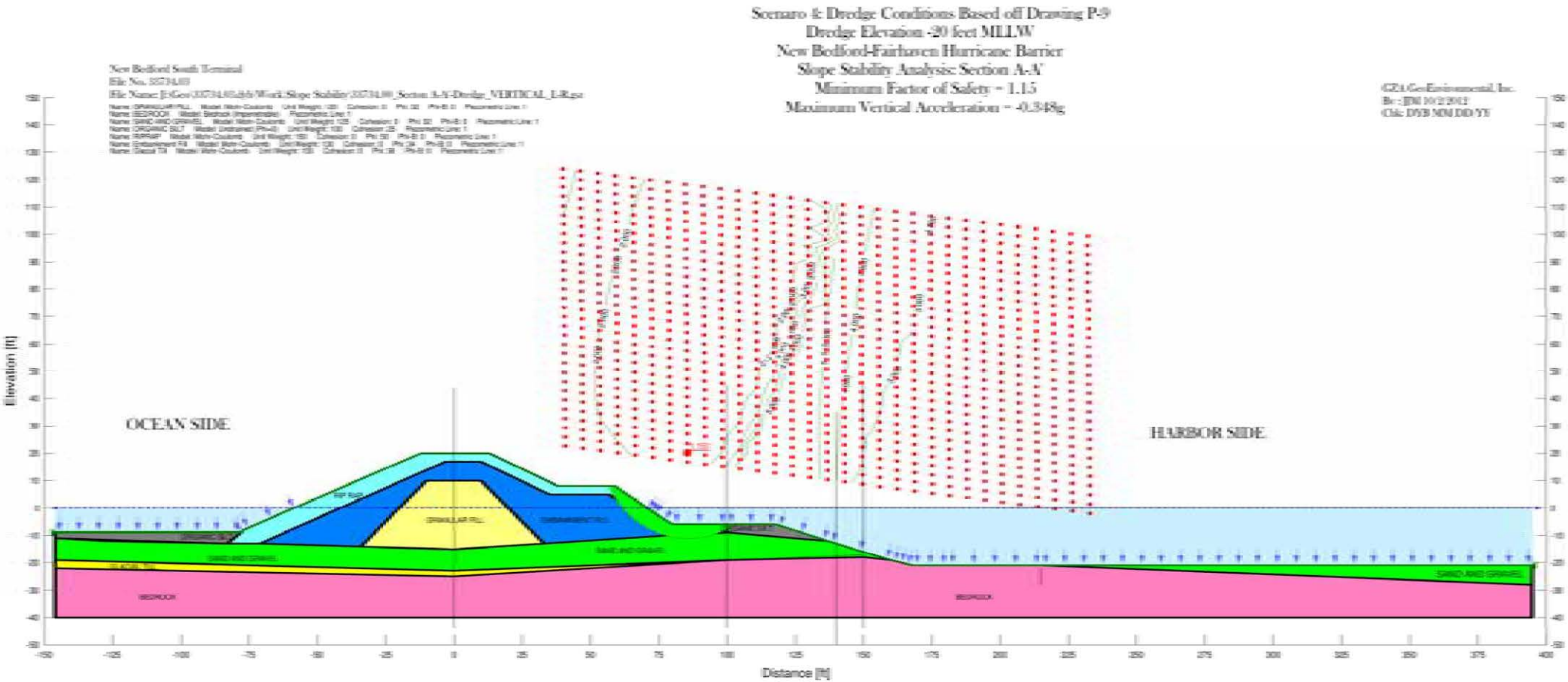


FIGURE 5 - SLOPE STABILITY RUN 3

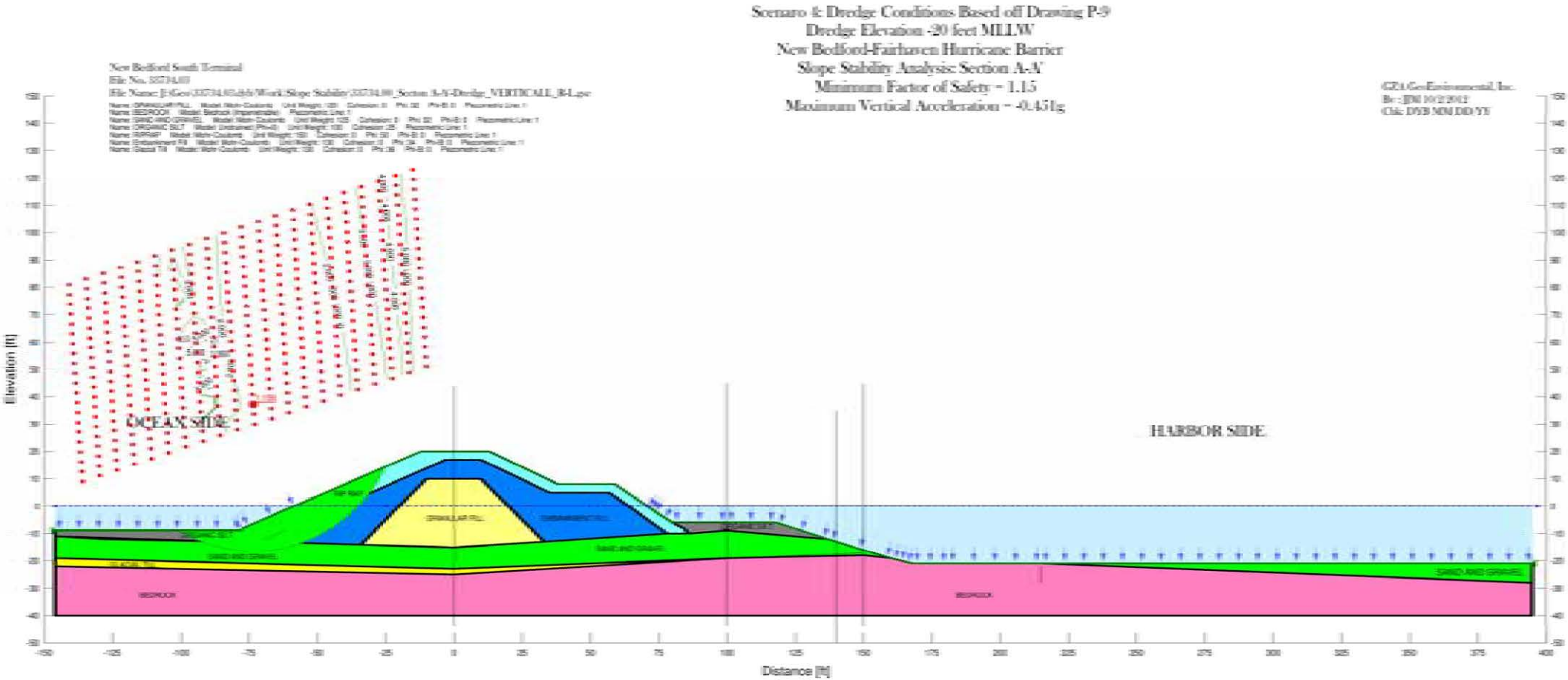


FIGURE 6 - SLOPE STABILITY RUN 4

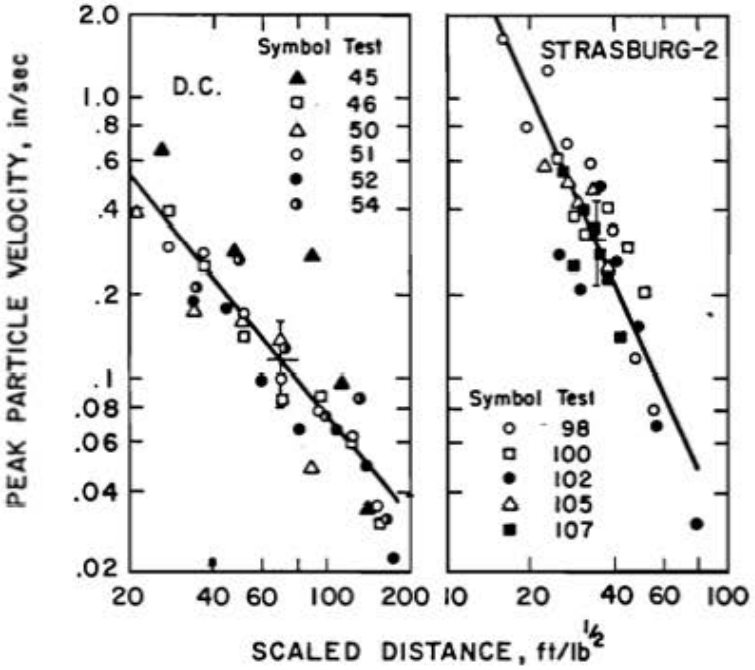


FIGURE 7

EXAMPLE OF SCALED DISTANCE VS.
PEAK PARTICLE VELOCITY
(BUREAU OF MINES, 1971)

APPENDIX A

LIMITATIONS

GEOTECHNICAL LIMITATIONS

Use of Report

1. GZA GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of our Client for the stated purpose(s) and location(s) identified in the Proposal for Services and/or Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not expressly identified in the agreement, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

Standard of Care

2. GZA's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in Proposal for Services and/or Report, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. If conditions other than those described in this report are found at the subject location(s), or the design has been altered in any way, GZA shall be so notified and afforded the opportunity to revise the report,as appropriate, to reflect the unanticipated changed conditions .

3. GZA's services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services, at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.

Subsurface Conditions

4. The generalized soil profile(s) provided in our Report are based on widely-spaced subsurface explorations and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs.

5. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein which were made available to GZA at the time of our evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

6. Water level readings have been made in test holes (as described in the Report) and monitoring wells at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. Fluctuations in the level of the groundwater however occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, the presence of subsurface utilities, and/or natural or artificially induced perturbations. The water table encountered in the course of the work may differ from that indicated in the Report.

7. GZA's services did not include an assessment of the presence of oil or hazardous materials at the property. Consequently, we did not consider the potential impacts (if any) that contaminants in soil or groundwater may have on construction activities, or the use of structures on the property.

8. Recommendations for foundation drainage, waterproofing, and moisture control address the conventional geotechnical engineering aspects of seepage control. These recommendations may not preclude an environment that allows the infestation of mold or other biological pollutants.

Compliance with Codes and Regulations

9. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

Cost Estimates

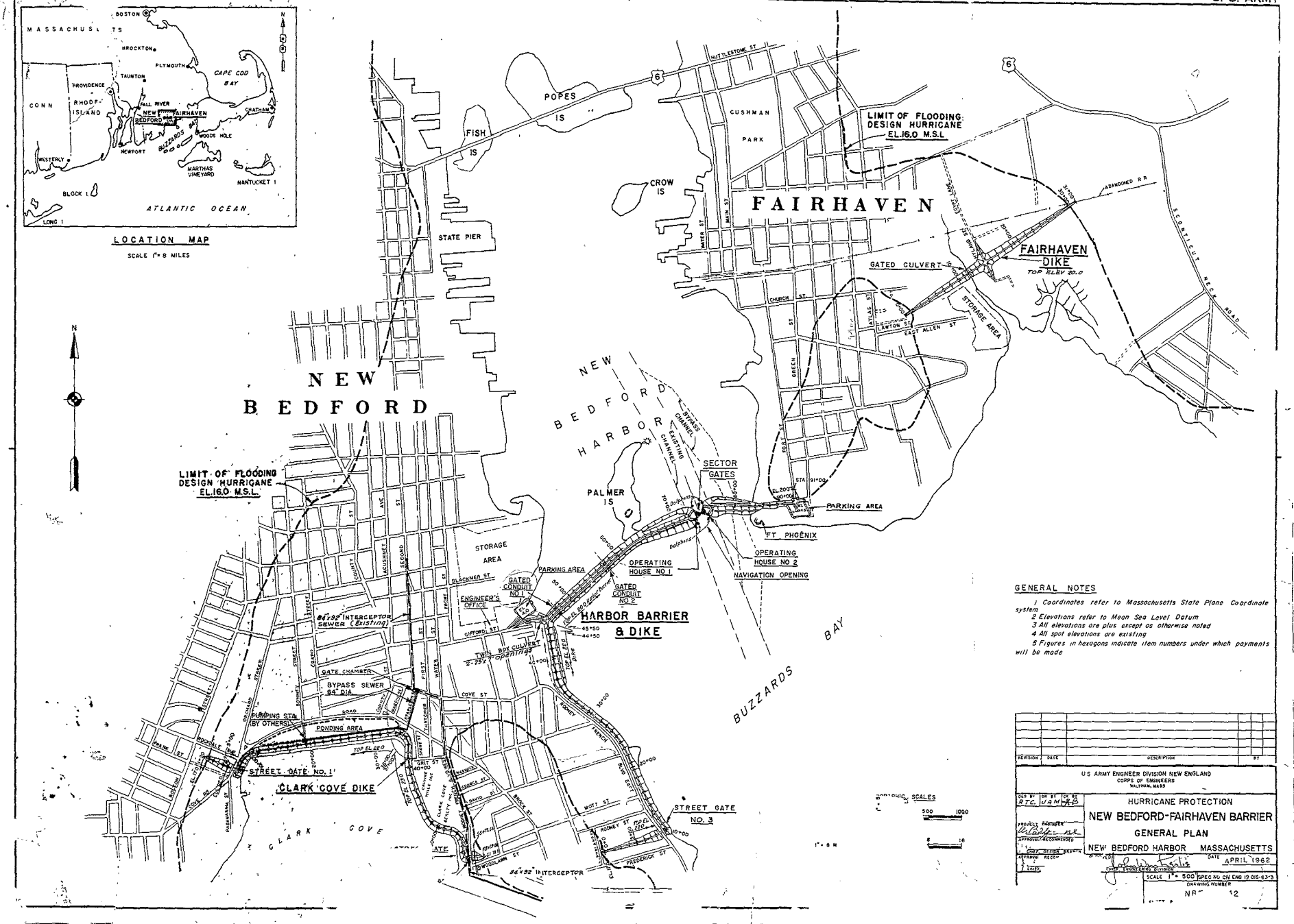
10. Unless otherwise stated, our cost estimates are only for comparative and general planning purposes. These estimates may involve approximate quantity evaluations. Note that these quantity estimates are not intended to be sufficiently accurate to develop construction bids, or to predict the actual cost of work addressed in this Report. Further, since we have no control over either when the work will take place or the labor and material costs required to plan and execute the anticipated work, our cost estimates were made by relying on our experience, the experience of others, and other sources of readily available information. Actual costs may vary over time and could be significantly more, or less, than stated in the Report.

Additional Services

11. GZA recommends that we be retained to provide services during any future: site observations, design, implementation activities, construction and/or property development/redevelopment. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.

APPENDIX B

ORIGINAL USACE DRAWINGS



GENERAL NOTES

1 Coordinates refer to Massachusetts State Plane Coordinate system
2 Elevations refer to Mean Sea Level Datum
3 All elevations are plus except as otherwise noted
4 All spot elevations are existing
5 Figures in hexagons indicate item numbers under which payments will be made

REVISION	DATE	DESCRIPTION	BY

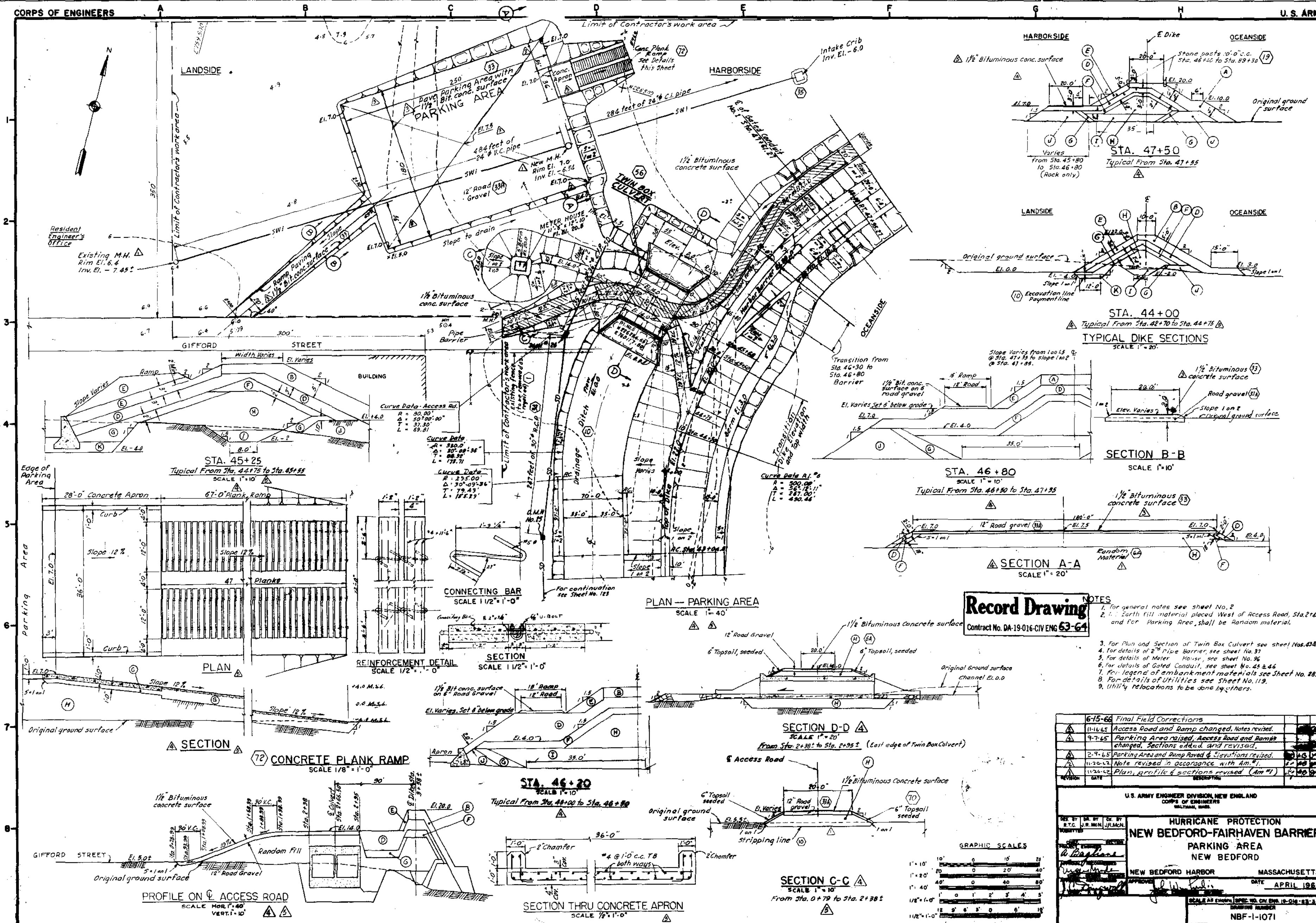
U S ARMY ENGINEER DIVISION NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY RTC DR BY JAM CK BY AB

HURRICANE PROTECTION
NEW BEDFORD-FAIRHAVEN BARRIER
GENERAL PLAN
NEW BEDFORD HARBOR MASSACHUSETTS

PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOM
CHIEF
CHIEF, ENGINEERING DIVISION

DATE APRIL 1962
SCALE 1" = 500
SPEC NO. CIV ENG 19 016-63-3
DRAWING NUMBER
NB 12



Record Drawing
Contract No. DA-19-016-CIV ENG 63-64

NOTES

1. For general notes see sheet No. 2
2. Earth fill material placed West of Access Road, Sta. 2+43 and for Parking Area, shall be Random material.
3. For Plan and Section of Twin Box Culvert see sheet Nos. 43 & 44
4. For details of 2"ϕ Pipe Barrier, see sheet No. 37
5. For details of Meter House, see sheet No. 96
6. For details of Gated Conduit, see sheet No. 45 & 46
7. For legend of embankment materials see Sheet No. 28.
8. For details of Utilities see Sheet No. 119.
9. Utility relocations to be done by others.

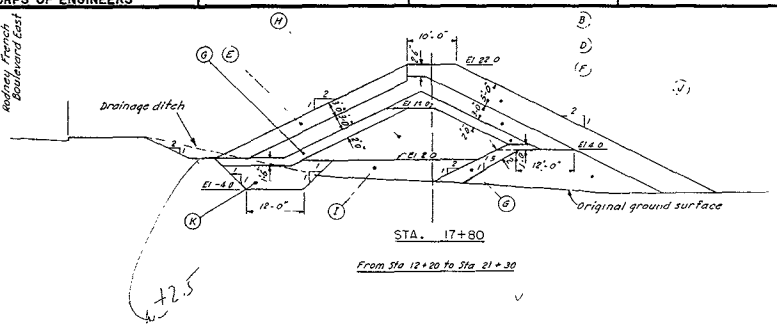
REVISION	DATE	DESCRIPTION
	6-15-66	Final Field Corrections
5	11-16-65	Access Road and Ramp changed. Notes revised.
4	9-7-65	Parking Area raised, Access Road and Ramps changed, Sections added and revised.
3	2-9-65	Parking Area and Ramp Paved & Elevations revised.
2	11-20-62	Note revised in accordance with Am. #1.
1	11-26-62	Plan, profile & sections revised (Am #1)

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY R.T.C. | DR. BY J.R.McN. | CK. BY J.R.McN.

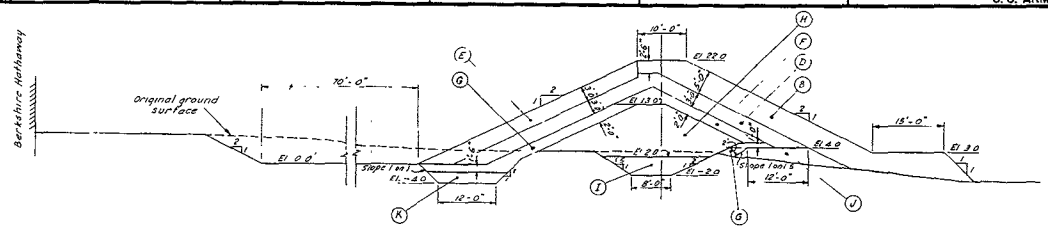
HURRICANE PROTECTION
NEW BEDFORD-FAIRHAVEN BARRIER
PARKING AREA
NEW BEDFORD
NEW BEDFORD HARBOR — MASSACHUSETTS
DATE APRIL 1962
SCALE AS SHOWN | SPEC. NO. CIV. ENG. 19-016-63-3
DRAWING NUMBER NBF-1-1071
SHEET 41

CORPS OF ENGINEERS — U.S. ARMY



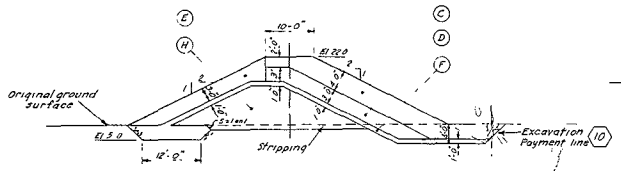
STA. 17+80

From Sta 12+20 to Sta 21+30



STA. 39+75

From Sta 36+70 to Sta 46+30
Transition occurs between Sta. 36+50 & Sta 36+70
Top elevation changes between Sta 44+50 and Sta 45+50

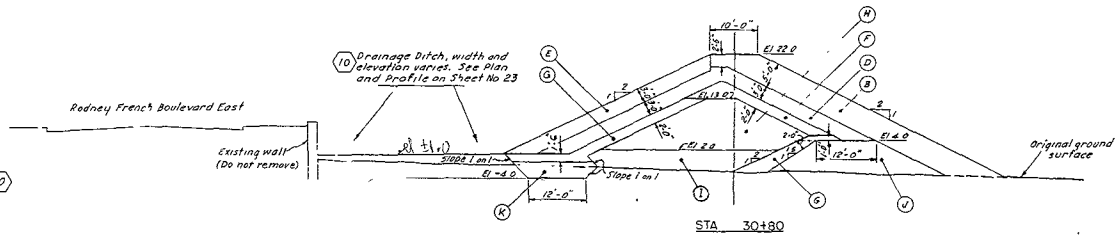


LANDSIDE — OCEANSIDE

STA. 8+60

From Sta 7+20 to Sta. 8+78± (Street Gate No 3)

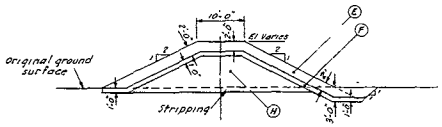
Transition occurs between Sta. 7+00 and Sta 7+20



LANDSIDE — OCEANSIDE

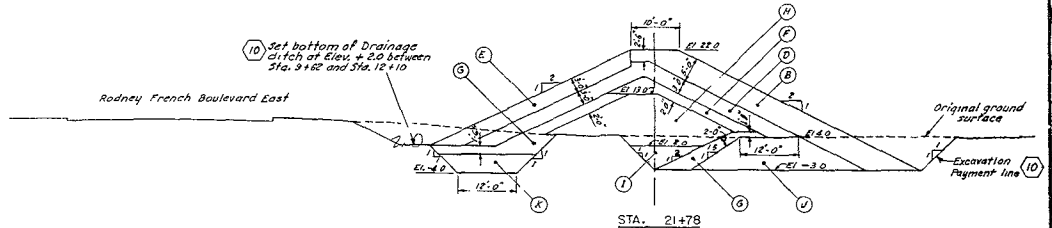
STA 30+80

From Sta. 22+50 to Sta 36+50



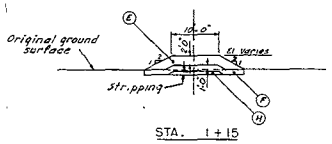
STA 4+55

From Sta. 1+80 to Sta. 7+00



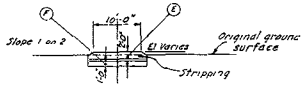
STA. 21+78

From Sta 10+00± (St Gate No 3) to Sta 12+20 & From Sta. 21+30 to Sta. 28+50



STA. 1+15

From Sta 0+50 to Sta. 1+80



STA. 0+25

From Sta -0+68 ± to Sta. 0+50

NOTES

1. For general notes see sheet No 2
2. Within the foundation area of the Dike, remove all exposed boulders, cobbles and stones above low water, and surface and buried grains, wattle, masonry, concrete structures and timbers. Remove all existing riprap and bedding and strip area as directed by the Contracting Officer
3. For location of Sections see sheet Nos. 23, 24 and 41
4. Surfaces of tops and ocean side berms of barrier and dikes and of tops of ramps shall be chinked
5. The barrier and dike between Sta 36+70 and Sta 50+00 above El 4.0 shall not be constructed untill after a period of 60 days after completion below El 4.0
6. For details of Street Gate No 3, see sheet No 63 thru 70
7. For details of access Ramps see Sheet Nos 36 and 41

LEGEND

MATERIAL DESIGNATION	TYPE OF MATERIAL	PAY ITEM NUMBERS
(A)	Armor Stone, 4.5 to 27.5 tons	20
(B)	Armor Stone, 3.0 to 2.0 tons	19
(C)	Armor Stone, 2.0 to 1.0 tons	18
(D)	Bedding Stone	22
(E)	Protection Stone.	23
(F)	Gravel bedding	15
(G)	Filter material	16
(H)	Compacted Earth fill	6,6A,10
(I)	Dumped Earth fill	6,7A,10
(J)	Rock fill	21
(K)	Drainage Trench Material.	17
(W)	Waste Material, dumped	10

TYPICAL SECTIONS

SCALE: 1" = 10'

GRAPHIC SCALE

1" = 1'-0" 10 0 10 20

REVISION	DATE	DESCRIPTION

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY RTC | DR BY RTC | CK BY

SUBMITTED

CHIEF, DESIGN SECTION

CHIEF, ENGINEERING DIVISION

CHIEF, PLANNING DIVISION

HURRICANE PROTECTION
NEW BEDFORD-FAIRHAVEN BARRIER
HARBOR BARRIER AND DIKE
TYPICAL SECTIONS NO. 1

NEW BEDFORD HARBOR — MASSACHUSETTS

APPROVED — DATE APRIL 1962

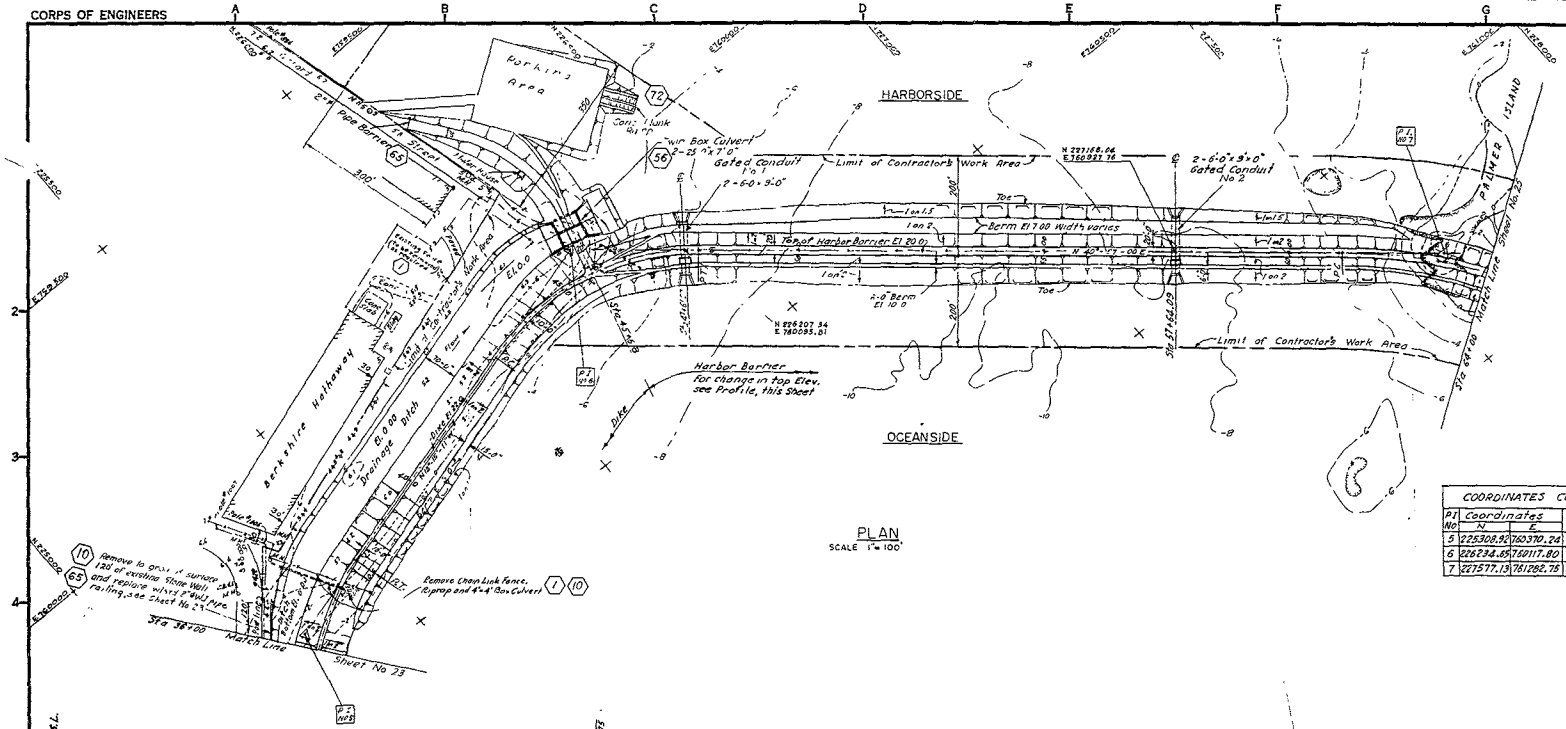
CHIEF, ENGINEER DIVISION

SCALE: 1"=10' — SPEC. NO. CIV ENG.19-016-63-3

DRAWING NUMBER NBF-1-1056

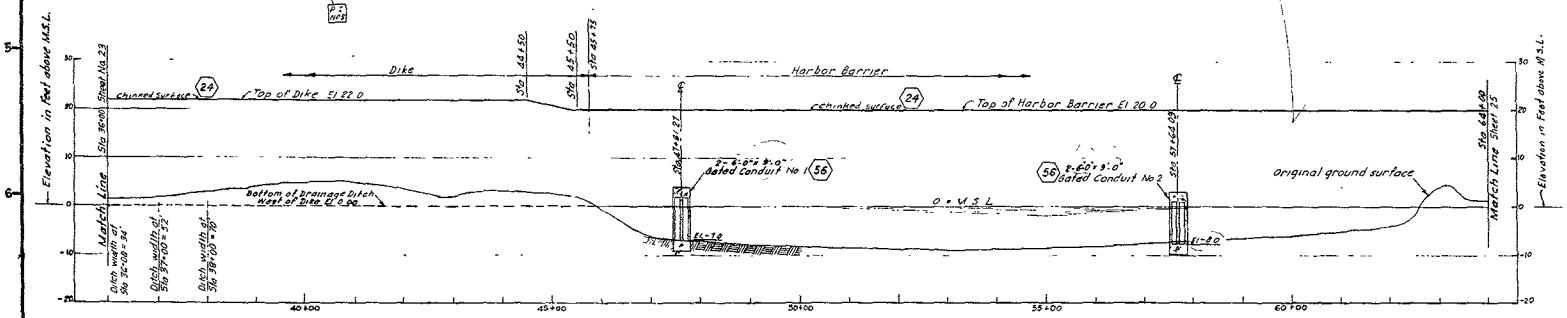
SHEET 28

CORPS OF ENGINEERS U. S. ARMY



PLAN
SCALE 1" = 100'

COORDINATES			CURVE DATA - STATIONS OF BASE LINE				FOR DIKE AND HARBOR BARRIER	
PI No	Coordinates N	Coordinates E	R	Δ	T	L	P.C. Sta	P.T. Sta.
5	225308.92	760370.24	500.00'	41°-15'-49"	188.25'	360.10'	34+40.43	38+00.53'
6	226234.85	759117.80	500.00'	56°-12'-11"	267.00'	490.46'	43+04.81'	47+95.27'
7	227577.13	761282.75	1000.00'	22°-40'-59"	200.57	395.18'	61+05.16'	65+01.05'



PROFILE ON ℄ OF DIKE AND HARBOR BARRIER
SCALES HOR. 1" = 100'
VERT. 1" = 10

NOTES

1. For general notes see sheet No. 2
2. For Plan and Details of Parking Area see sheet No 41
3. For Details of Twin Box Culvert see sheet Nos 43 and 44
4. For Details of Gated Conduit No. 1 and 2 see sheet Nos 45 thru 48
5. For Typical Sections of Dike and Harbor Barrier see sheet Nos 28 and 29
6. For existing and new utility details see sheet Nos 122-135 incl
7. For details of 2" Pipe Barrier see sheet No 37
8. Utilities are shown on sheet Nos 122-135 incl
9. Utility relocations to be done by others
10. For details of 2" ϕ W.I. pipe railing see Sheet No 86

GRAPHIC SCALES
SCALE 1" = 10'
SCALE 1" = 100'

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY R T C | DR BY J A M | CK. BY K.B.
SUBMITTED
CHIEF, SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED
CHIEF, F & S BRANCH
APPROVED
CHIEF, ENGINEERING DIVISION

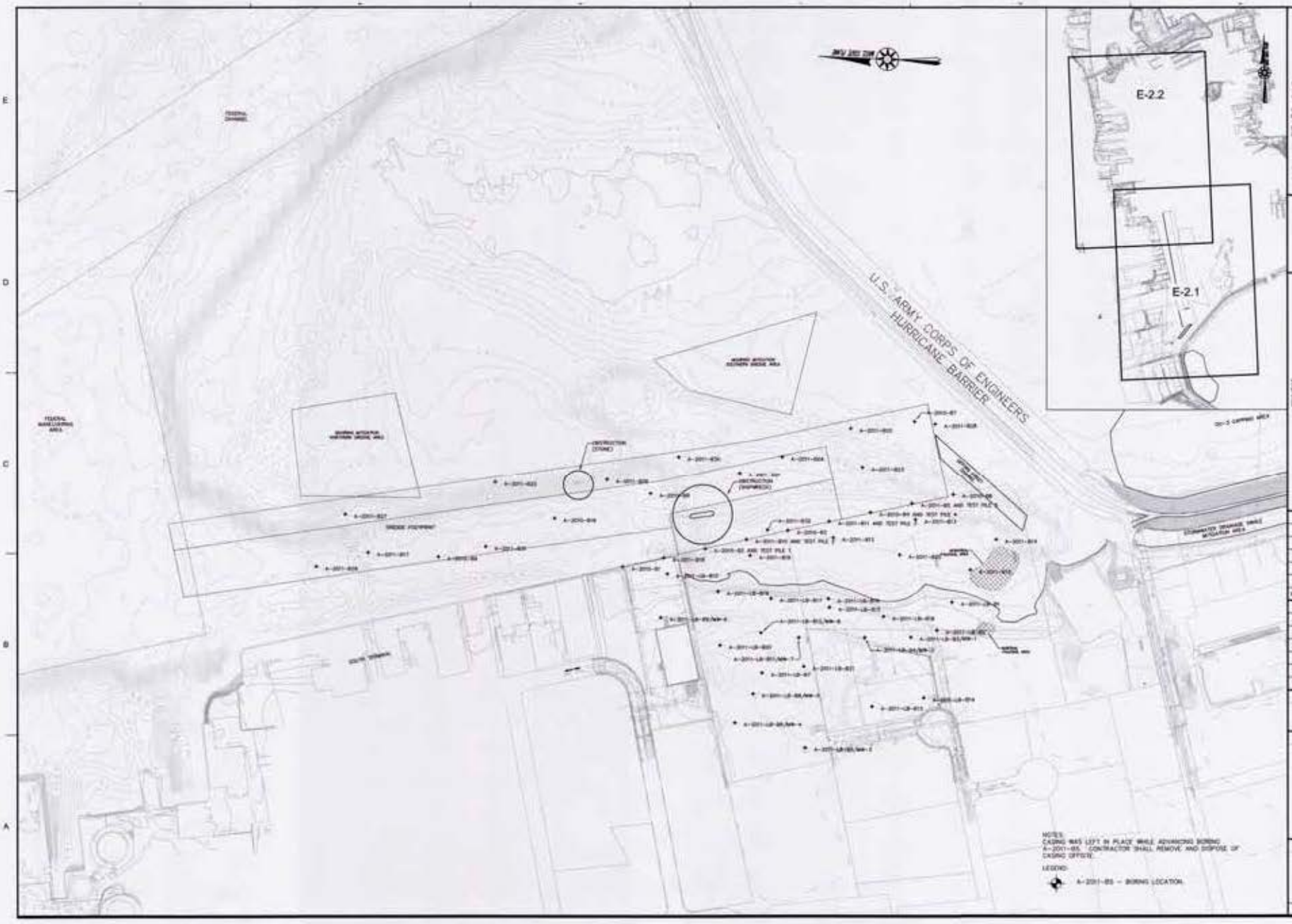
HURRICANE PROTECTION
NEW BEDFORD-FAIRHAVEN BARRIER
HARBOR BARRIER AND DIKE
PLAN AND PROFILE NO 2
NEW BEDFORD HARBOR MASSACHUSETTS

DATE APRIL 1962

SCALE AS SHOWN SPEC. NO. CIV. ENG.-19-018-62-36
DRAWING NUMBER NBF-1-1054
SHEET 24

APPENDIX C

SUBSURFACE EXPLORATION LOGS



APEX

ROCKVILLE, MD
SOUTH WINDSOR, CT - BOSTON, MA
NEW BEDFORD, MA - HOLYOKE, MA

PROJECT
NEW BEDFORD
MARINE COMMERCE
TERMINAL

OWNER
MASSACHUSETTS CLEAN ENERGY CENTER
55 SUMMER STREET, 9TH FLOOR
BOSTON, MASSACHUSETTS

NO.	DATE	DESCRIPTION	BY
2	06/08/12	BORING NO. UPDATE	DMM
0	03/08/12	EX. COND. UPDATE	DMM
1	12/23/11	FOR CONSTRUCTION	DMM

PROJECT NO.	[illegible]
CADD FILE	[illegible]
DESIGNED BY	GCD
DRAWN BY	GCD
CHECKED BY	DMM
DATE	08/04/2011
DRAWING SCALE	1"=150'

GRAPHIC SCALE
SCALE: 1"=150'
0 75 150 300

SHEET TITLE
EXISTING CONDITIONS DREDGE FOOTPRINT SHEET 1

DRAWING NO.
E-2.1

SE OF BY

BORING LOG

Date: 9/24/2010
Time: 12:15 PM

Project:	Phase IV Dredging	Project No: 6690.005	X: 816781.1
Location:	South Terminal Expansion		Y: 2687710.6
Elevation at mudline:	-5.5	Datum: MLLW	
Casing Type: Steel		Boring Depth: -28.0' MLLW	Boring No: A-2010-B7
Casing Diameter:	4"	Drill Rig: CME 45	
Drill Co:	NH Boring	Method: Drill and Wash	Sheet: 1 of 1
Driller:	Todd Pentacost	Log By: GAD	

Depth below mudline (ft)	RQD	Penetration/ Recovery	Blows per 6" / Drill Min. per Foot	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%	Elevation (MLLW)
2		24" 12"	WOR,6,8,8	0-1' Black, organic SILT 1'-2' Olive Grey, fine to medium SAND, some shell hash, trace silt	-7.5
4		24" 12"	9/11/12/16	Olive Grey, fine to medium SAND, some shell hash, trace silt	-9.5
6		24" 12"	7/5/7/5	4'-4.5' Olive Grey, fine to medium SAND, some shell hash, trace silt 4.5'-6' Greenish grey, fine SAND and SILT	-11.5
8		24" 17"	15/23/100-5"	6'-7' Olive Grey, fine to medium SAND, some shell hash, trace silt 7'-7.4' Olive grey, fine SAND and SILT	-13.5
10		24" 24"	18/14/12/17	8'-8.5' Greenish grey, fine to medium SAND and fine angular GRAVEL 8.5'-9.5' Light grey, fine to medium SAND, some coarse SAND 9.5'-10' Greenish grey, fine SAND and SILT	-15.5
12		24" 24"	15/18/24/58	10'-11.5' Greenish grey, fine SAND and SILT, trace fine angular gravel 11.5'-12' Olive grey, medium to coarse SAND, trace rock fragments at tip.	-17.5
12.5				Drove casing to refusal, cleaned hole, and began core run at -18.0 MLLW	-18
17.5	88%	60" 56"	11/10/12/15/12	Rock Core #1: -18.5to -23.5 MLLW - Highly to moderately fractured grey and pink Granitic Gneiss	-23
22.5	61%	60" 40"	8/8/7/8/9	Rock Core #2: -23.5 to -28.5 MLLW - Highly to moderately fractured grey and pink Granitic Gneiss	-28

Comments: Core run was completed at less revolutions per minute than recommended by core barrel manufacturer, drill time is not a good indicator of rock competency.

Notes:
1). Numbers in "Depth below mudline (ft)" column represent the depth below mudline of the bottom of the respective split-spoon, core run, or drill tool advancement.
2). Numbers in "Elevation (MLLW)" column represent the elevation of the bottom of the respective split-spoon, core run, or drill tool advancement.

BORING LOG

Date: 3/17/2011
Time: 1:00 PM

Project:	Phase IV Dredging	Project No: 6690.008	X: 816606
Location:	South Terminal Expansion		Y: 2687892
Elevation at mudline:	-10.65	Datum: MLLW	
Casing Type: Steel		Boring Depth: -38.65' MLLW	Boring No: A-2011-B23
Casing Diameter:	4"	Drill Rig: CME 45	
Drill Co:	NH Boring	Method: Drill and Wash	Sheet: 1 of 1
Driller:	Norman Stuttard	Log By: GCD	

Depth below mudline (ft)	RQD	Penetration/ Recovery	Blows per 6" / Drill Min. per Foot	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%	Elevation (MLLW)
2		24" 8"	WOR, WOR, WOR, WOR	Top 4": Black, organic SILT. Last 4": Dark gray, fine to medium SAND and SILT, trace shell hash.	-12.65
7		24" 12"	13,13,17,21	Light gray, fine to coarse SAND.	-17.65
10		0" 0"	100/2"	No recovery.	-20.55
18.25				Obstruction encountered at -23.4 MLLW. Advanced roller bit through a series of obstructions, believed to be either a series of boulders or rock fragments to -28.85 MLLW.	-28.85
18.25		0" 0"	100/0"	No recovery.	-28.85
18.25				Cleaned hole and began core run at -28.85 MLLW.	-28.85
23	65%	4.8' 4.55'	8,9,9,10,11	Rock Core #1: -28.85 to -33.65 MLLW 0.0'-4.8' Intensely to moderately fractured pink grey GRANITE.	-33.65
28	85%	5' 5'	8,8,7,9,9	Rock Core #2: -33.65 to -38.65 MLLW 0.0'-5.0' Moderately fractured pink grey granitic GNEISS.	-38.65

Comments:

Notes:
1). Numbers in "Depth below mudline (ft)" column represent the depth below mudline of the bottom of the respective split-spoon, core run, or drill tool advancement.
2). Numbers in "Elevation (MLLW)" column represent the elevation of the bottom of the respective split-spoon, core run, or drill tool advancement.

BORING LOG

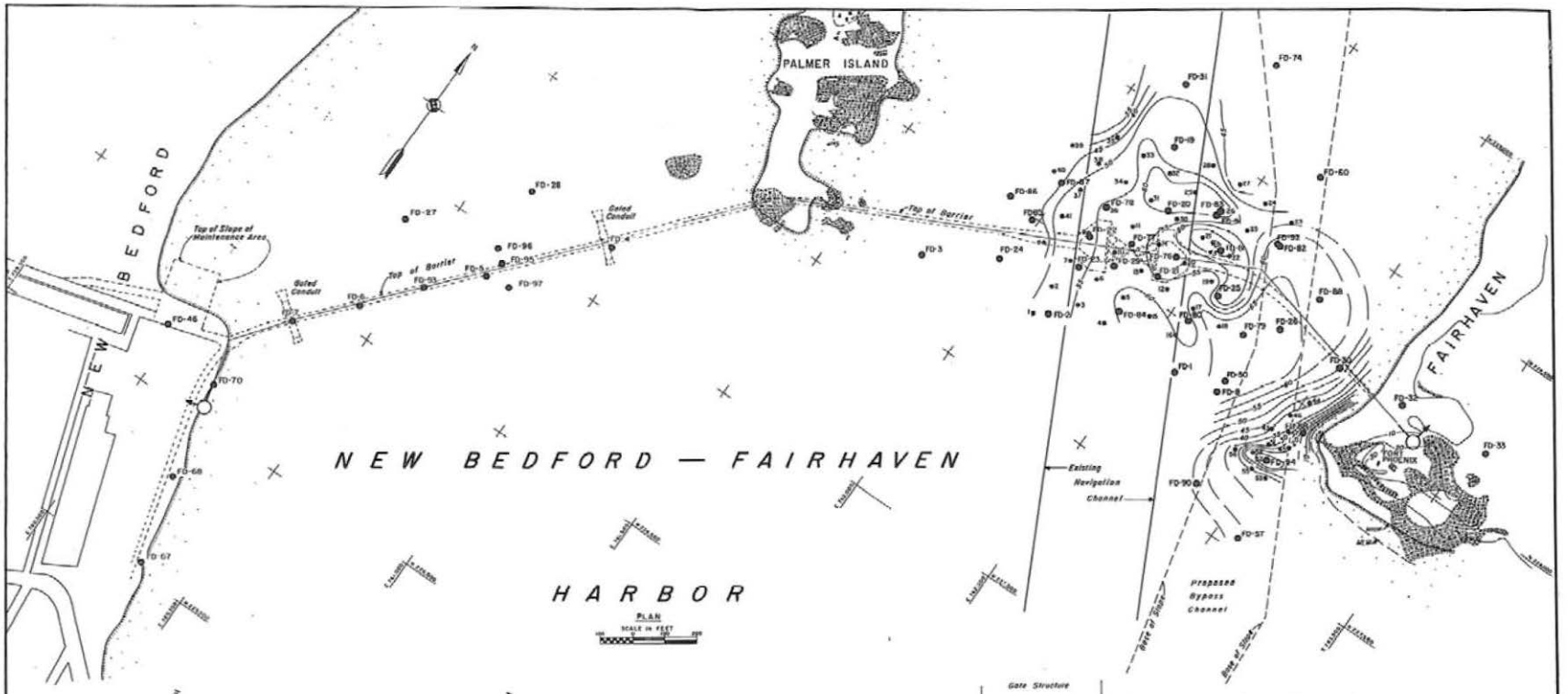
Date: 3/28/2011
Time: 9:29 AM

Project:	Phase IV Dredging	Project No: 6690.008	X: 816775
Location	South Terminal Expansion		Y: 2687636
Elevation at mudline:	-5.2	Datum: MLLW	
Casing Type: Steel		Boring Depth: -24.0' MLLW	Boring No: A-2011-B28
Casing Diameter:	4"	Drill Rig: CME 45	
Drill Co:	NH Boring	Method: Drill and Wash	Sheet: 1 of 1
Driller:	Norman Stuttard	Log By: GCD	

Depth below mudline (ft)	RQD	Penetration/ Recovery	Blows per 6" / Drill Min. per Foot	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%	Elevation (MLLW)
2		24" 14"	WOR, WOR, WOR, WOR	Black, organic SILT, trace fine to coarse sand, trace shell hash.	-7.2
4		24" 16"	10,6,10,12	Grey, fine to medium SAND, little shell hash.	-9.2
6		24" 16"	9,12,11,13	Tan to grey, very fine SAND, trace inorganic silt.	-11.2
8		24" 7"	10,18,17,18	Grey, fine SAND, little inorganic silt, little medium to coarse sand, trace gravel.	-13.2
10		24" 9"	10,20,29,32	Grey fine SAND, little silt, trace coarse gravel.	-15.2
12		24" 12"	20,27,29,43	Grey fine to coarse SAND, little silt, little fine to coarse gravel.	-17.2
13		12" 6"	24,37, 100/0"	Grey, fine to coarse SAND, little silt, little fine to coarse gravel.	-18.2
14.3				Encountered obstruction at -19.5 MLLW. Cleaned hole and began core run.	-19.5
18.8	36%	4.5' 4.5'	5,4,5,5	Rock Core #1: -19.5 to -24.0 MLLW - Intensely to moderately fractured pink grey granitic GNEISS.	-24.0

Comments: Intervals 0-2, 2-4. and 4-6 Sampled using a 3" diameter split spoon sampler, all of the other intervals were sampled using a standard 2" diameter split-spoon.

Notes: 1). Numbers in "Depth below mudline (ft)" column represent the depth below mudline of the bottom of the respective split-spoon, core run, or drill tool advancement.
2). Numbers in "Elevation (MLLW)" column represent the elevation of the bottom of the respective split-spoon, core run, or drill tool advancement.



GEOLOGIC SECTION - HARBOR ALIGNMENT
(LOOKING NORTH)

LEGEND

- FD-8 Foundation Test Boring
- 22 Foundation Test Probing
- Bedrock Outcrop
- Marsh

Location and Orientation of Geologic Section

NOTES

Geologic units in the harbor represent assumed bedrock surface referred to Mean Sea Level.

Coordinates refer to the Massachusetts Grid System.

FD-91 and FD-92 are undisturbed sample borings.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

HURRICANE PROTECTION

NEW BEDFORD - FAIRHAVEN

PLAN OF HARBOR EXPLORATIONS AND GEOLOGIC SECTION

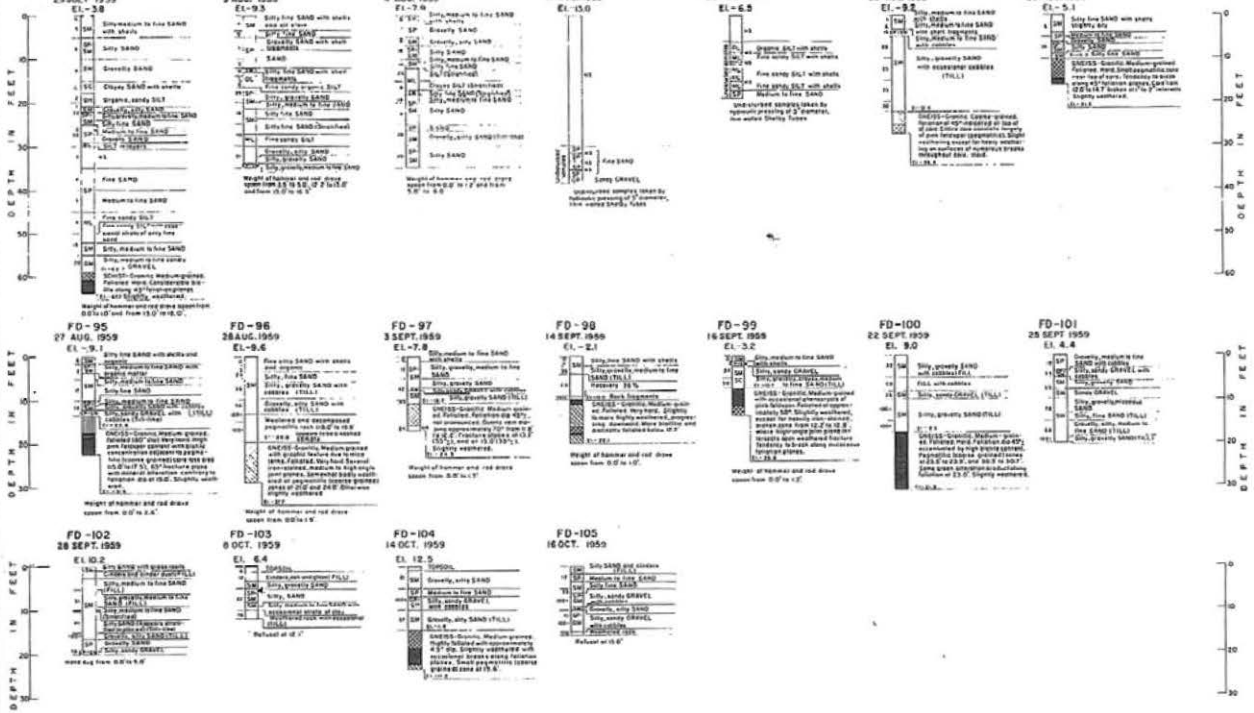
NEW BEDFORD HARBOR MASSACHUSETTS

DATE FEB 1960

SCALE AS SHOWN | DEPT. NO. ENG.-15-806-
DRAWING NUMBER

SHEET 3 OF 11

PLATE 3



NOTES

Locations of subsurface explorations are shown on Plate 2

Legend for graphic logs appears on Plate 5

Subsurface water levels in the explorations may be subject to tidal fluctuation.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

HURRICANE PROTECTION

NEW BEDFORD - FAIRHAVEN

RECORD OF FOUNDATION EXPLORATIONS NO. 4

NEW BEDFORD HARBOR MASSACHUSETTS

DATE FEB 1960

SCALE

SHEET 8 OF 11