American Association of Port Authorities

Alliance of the Ports of Canada, the Caribbean, Latin America and the United States

2017 Facilities Engineering Seminar
October 24-26, 2017

New Marine Container Terminal at Haifa

(Hamifratz Port)

Bill Paparis, Project Manager, D. P.E.

Preliminary Port Layout

Aerial View of Existing Port

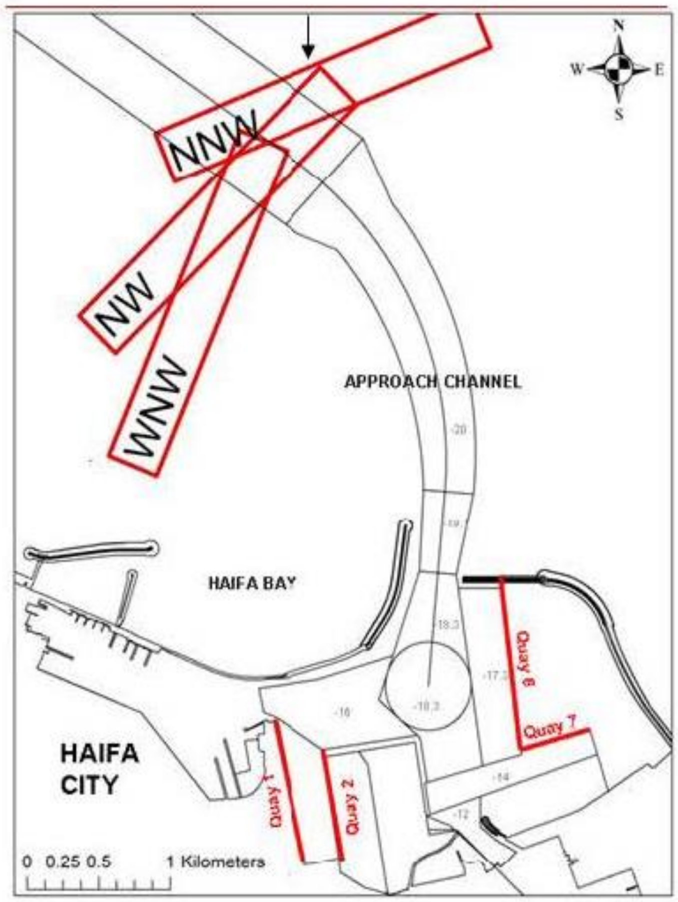
Major Issues

- Moderately high level of earthquake accelerations, and associated potential for liquefaction of hydraulic fill and breakwater/revetment foundations
- Site exposed to waves
- Difficulty in obtaining adequate quantities of suitable sand from dredging for reclamation
- Environmentally sensitive location

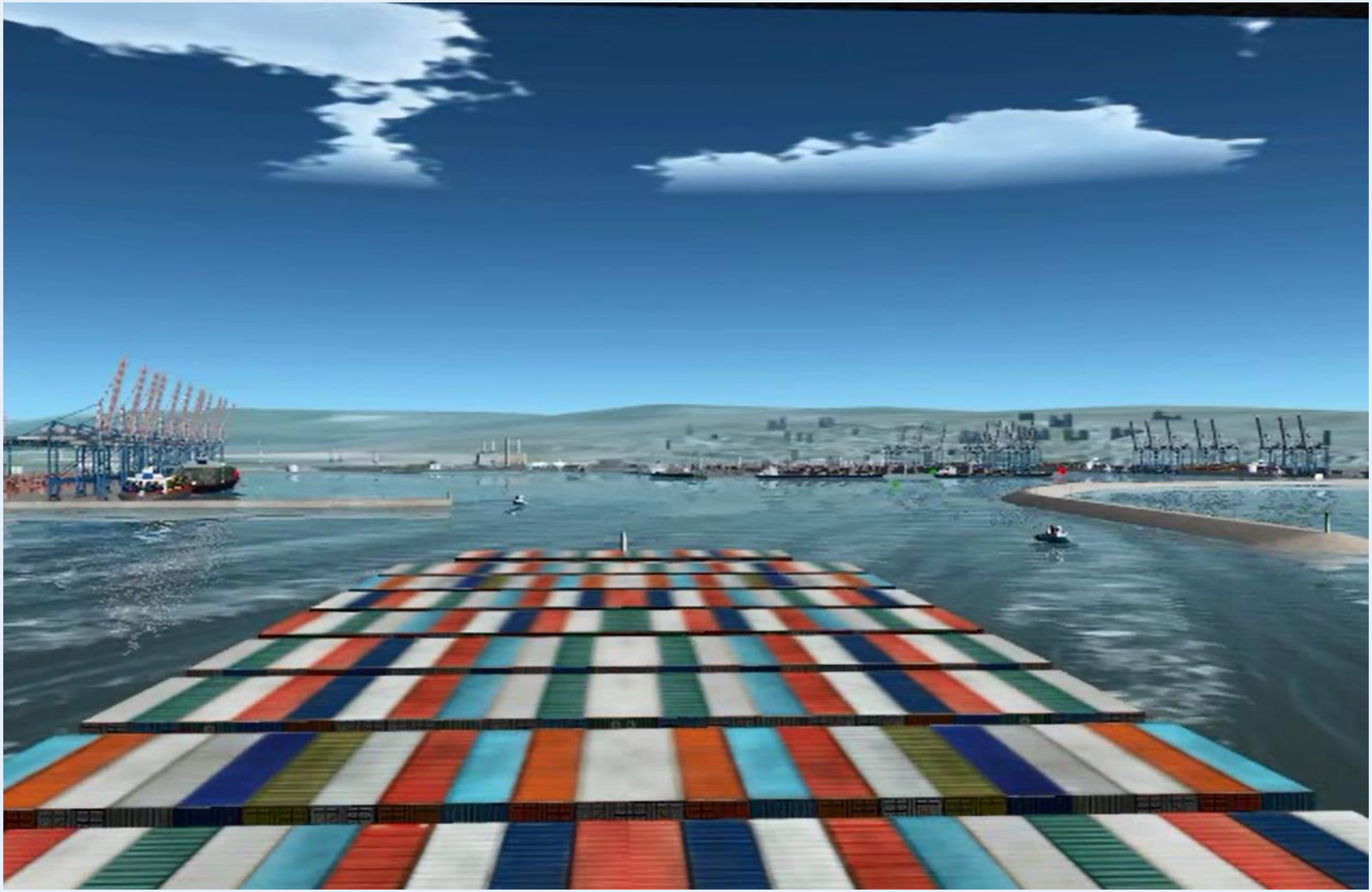
Maximum and Minimum Size Vessel Parameters

Parameter	Maximum Design Vessel (Quay 6)	Maximum Design Vessel (Quay 7)	Maximum Design Vessel (Quay 8)	Minimum Design Vessel
Vessel Type	Container Ship (Maersk EEE)	Container Ship (Post Panamax)	Container Ship (Panamax)	-
TEU Capacity	18,000	-	-	-
Deadweight Tonnage (dwt)	–	110,800	45,850	9,000
Length Overall (LOA), m	400	337	254	145
Beam, m	59.0	45.6	32.3	19.5
Loaded Draught, m	16.0	15.0	11.78	7.8
Loaded Displacement, tonnes	240,000	147,000	62,750	14,247

3D Model Testing of Port Layout



Real Time Navigation Simulation – Emma Maersk



Seismic Study

- Developed seismotectonic model taking into account regional tectonic setting, historical seismicity and mapped faults, including fault slip rates.
- Most important source is the Carmel Fault, located between 1.7 km and 2.9 km from the site.
- Model also includes the Dead Sea Transform Fault and Cyprus Trench, as well as more local sources such as the Levant Fault and the Gilboa Fault.
- Model was input into a computer program and Probabilistic Seismic Hazard Assessments were conducted for return periods of 72, 475, 975, and 2,475 years.

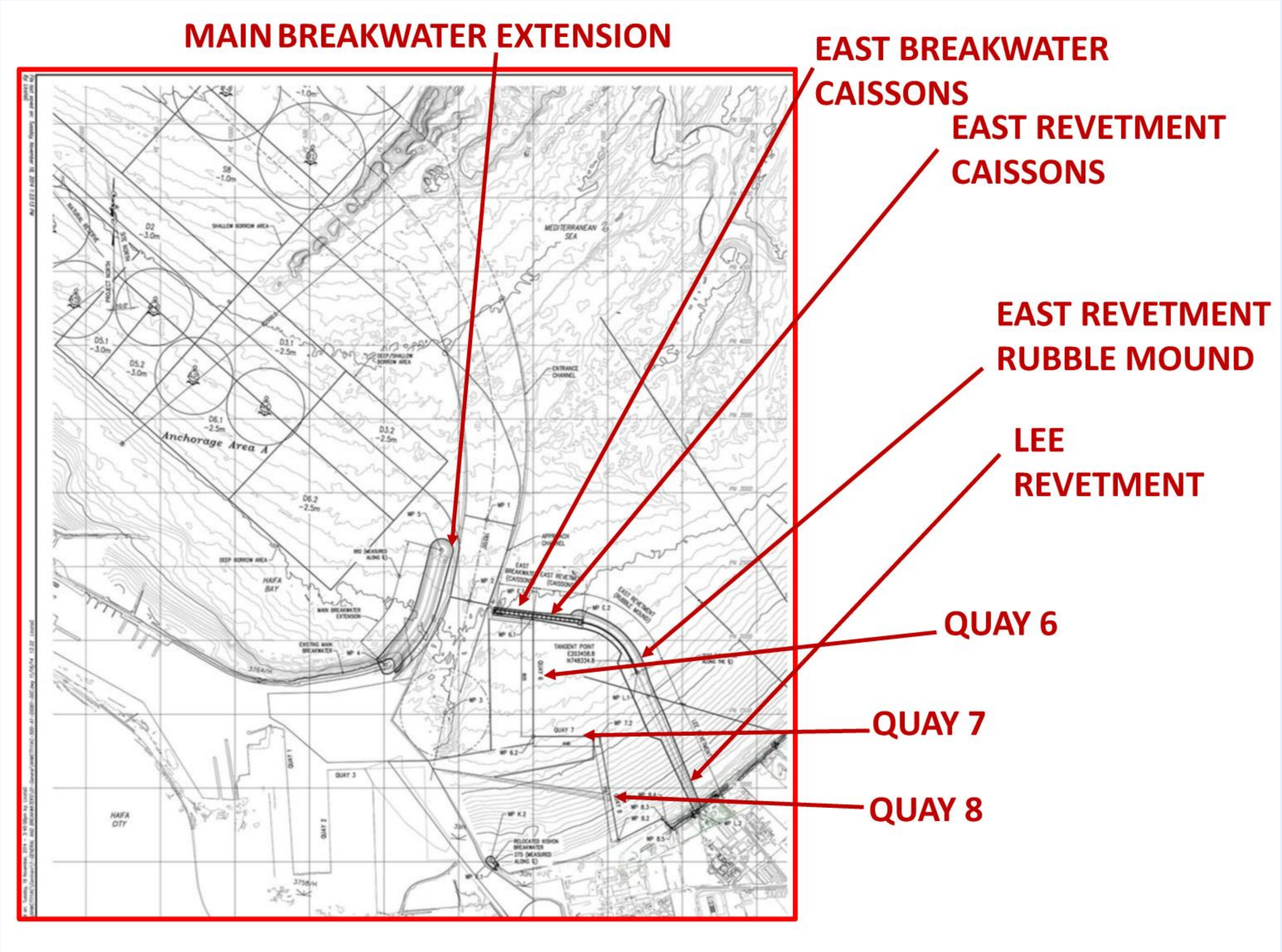
Three Levels of Seismic Design

- Contingency Level (10% Probability of Exceedance in 50 Years): Peak Ground Acceleration = 0.38 g (M=6.5-7.0)
- Operating Level (50% Probability of Exceedance in 50 Years): Peak Ground Acceleration = 0.12 g (M=4.5-5.0)
- Contingency Level for D&H Cargo (2% Probability of Exceedance in 50 Years): Peak Ground Acceleration = 0.86 g

Rubble Mound Breakwater & Revetment Seismic Design Criteria

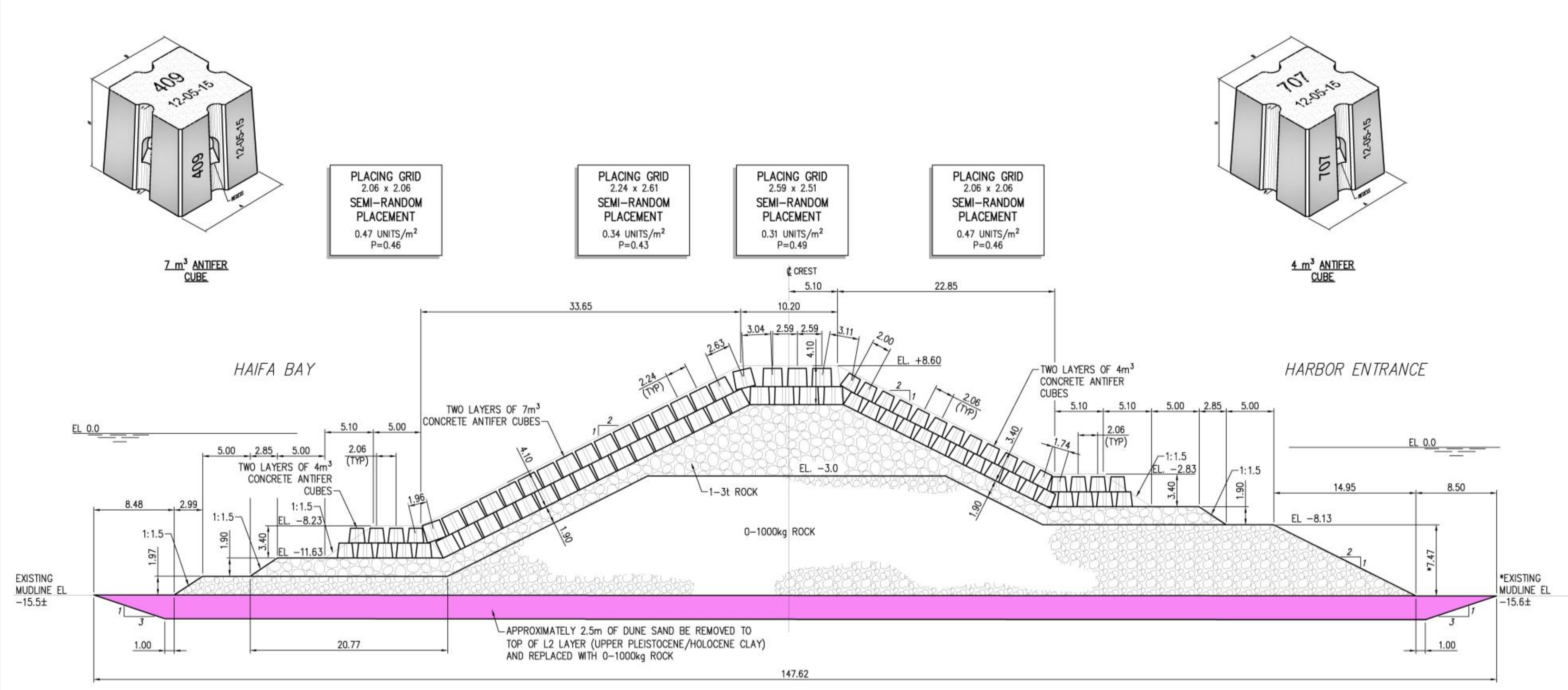
- Main Breakwater and Lee Breakwater were considered to be PIANC Grade A (primary) structures, so that minimal damage is expected in an OLE, while the damage in a CLE is controlled and repairable, and the structure is to remain serviceable
- For the CLE the stability of the structures was assessed in terms of the magnitude of the deformation
- Maximum permissible deformation under CLE ≈ 1.0 m
- Maximum side slopes were determined to be 1V to 2H

Final Port Layout

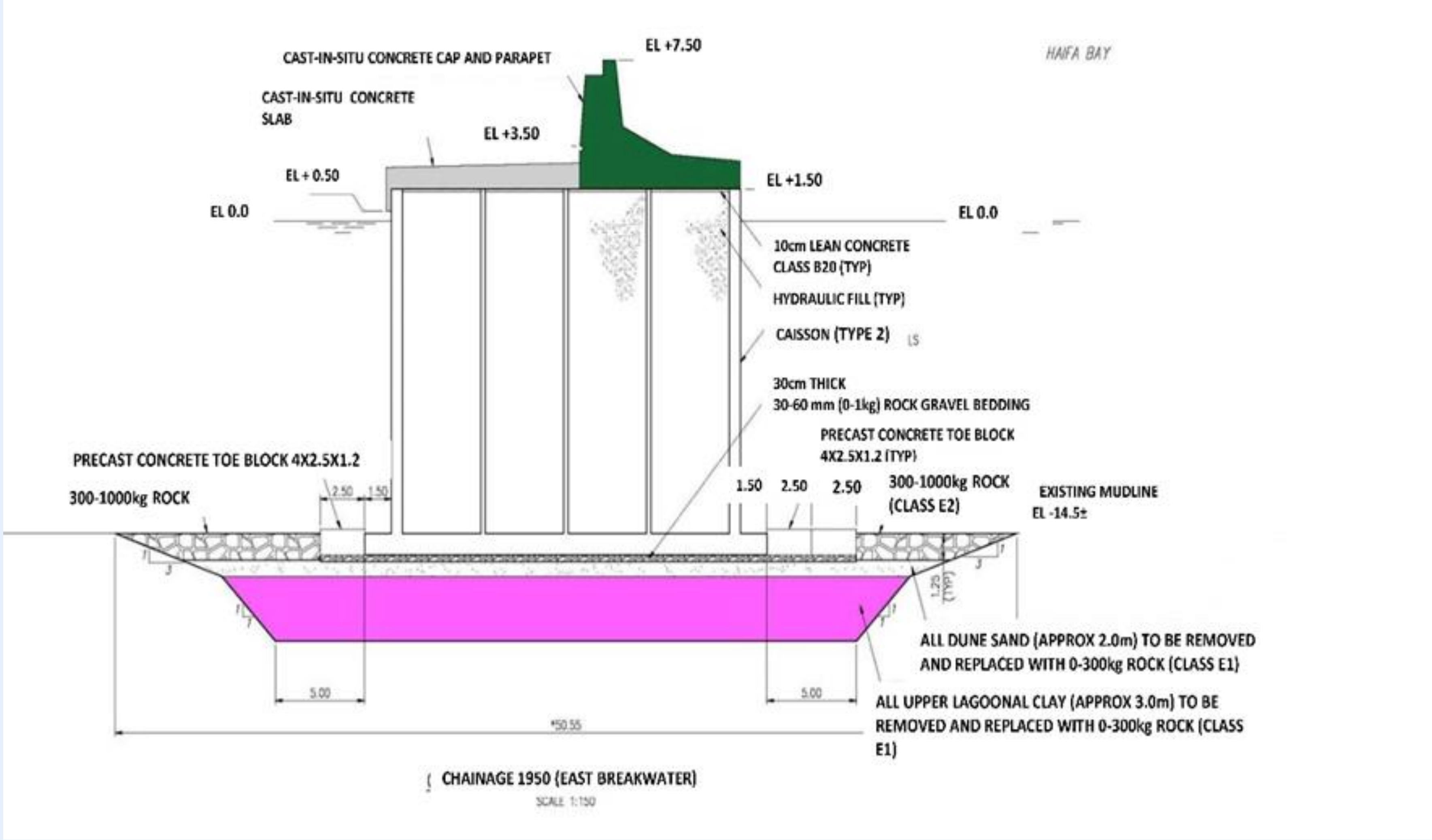


3D Physical Model Testing of Main Breakwater Extension

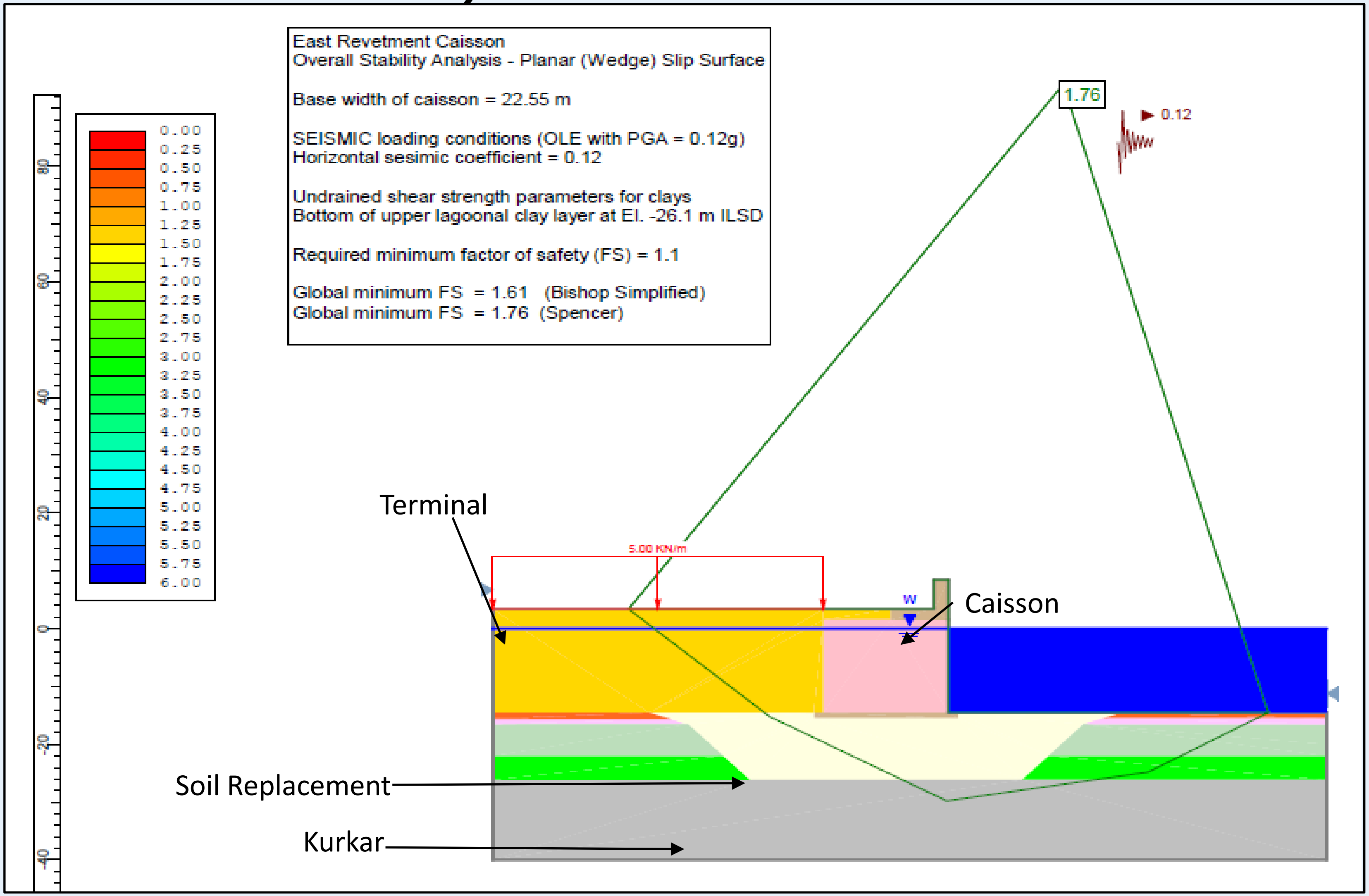
Typical Section Along Trunk of Main Breakwater Extension



Typical East Breakwater Cross Section



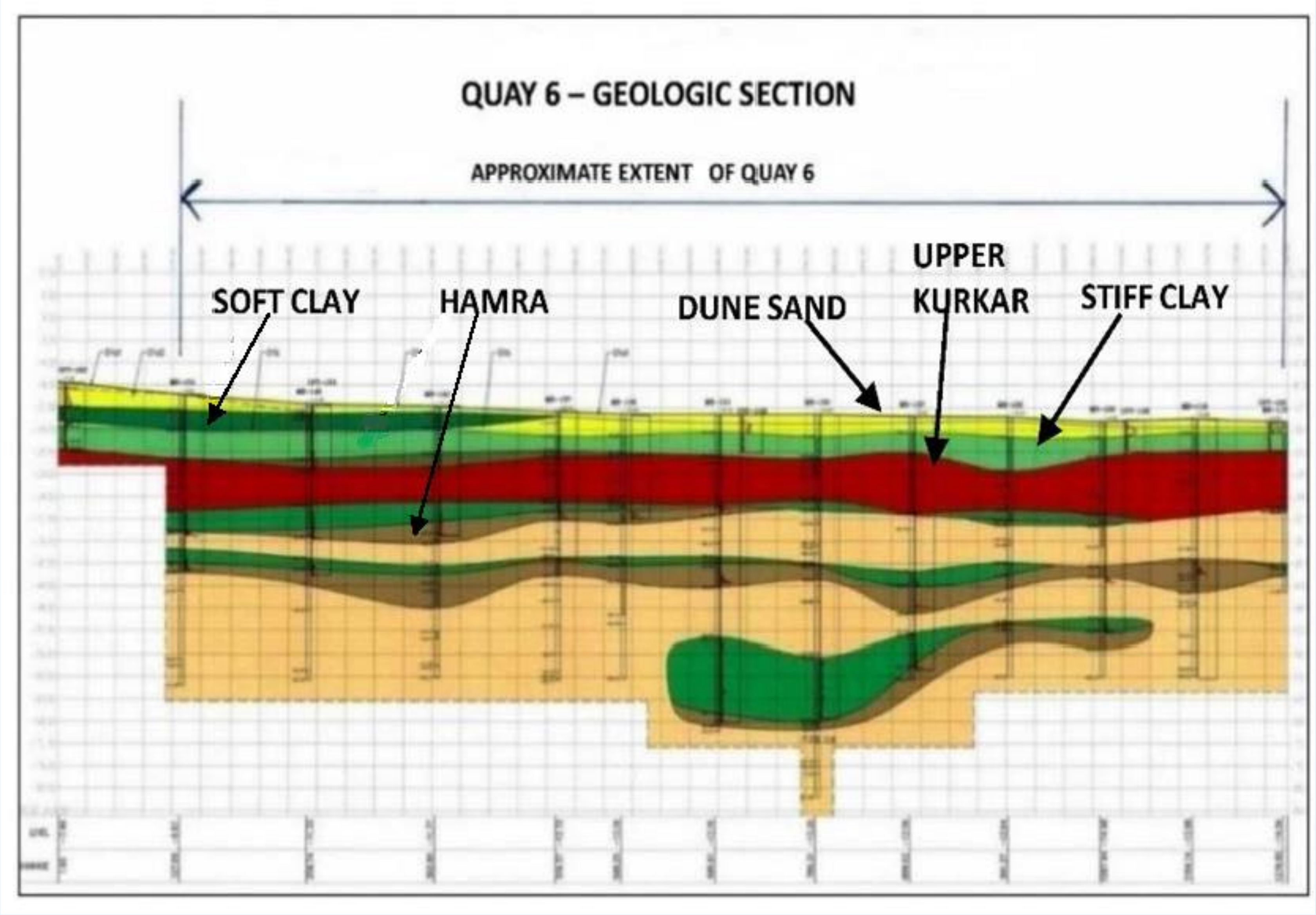
Seismic OLE Slope Stability Analysis of East Revetment Caisson – 9.6 m Clay Removal



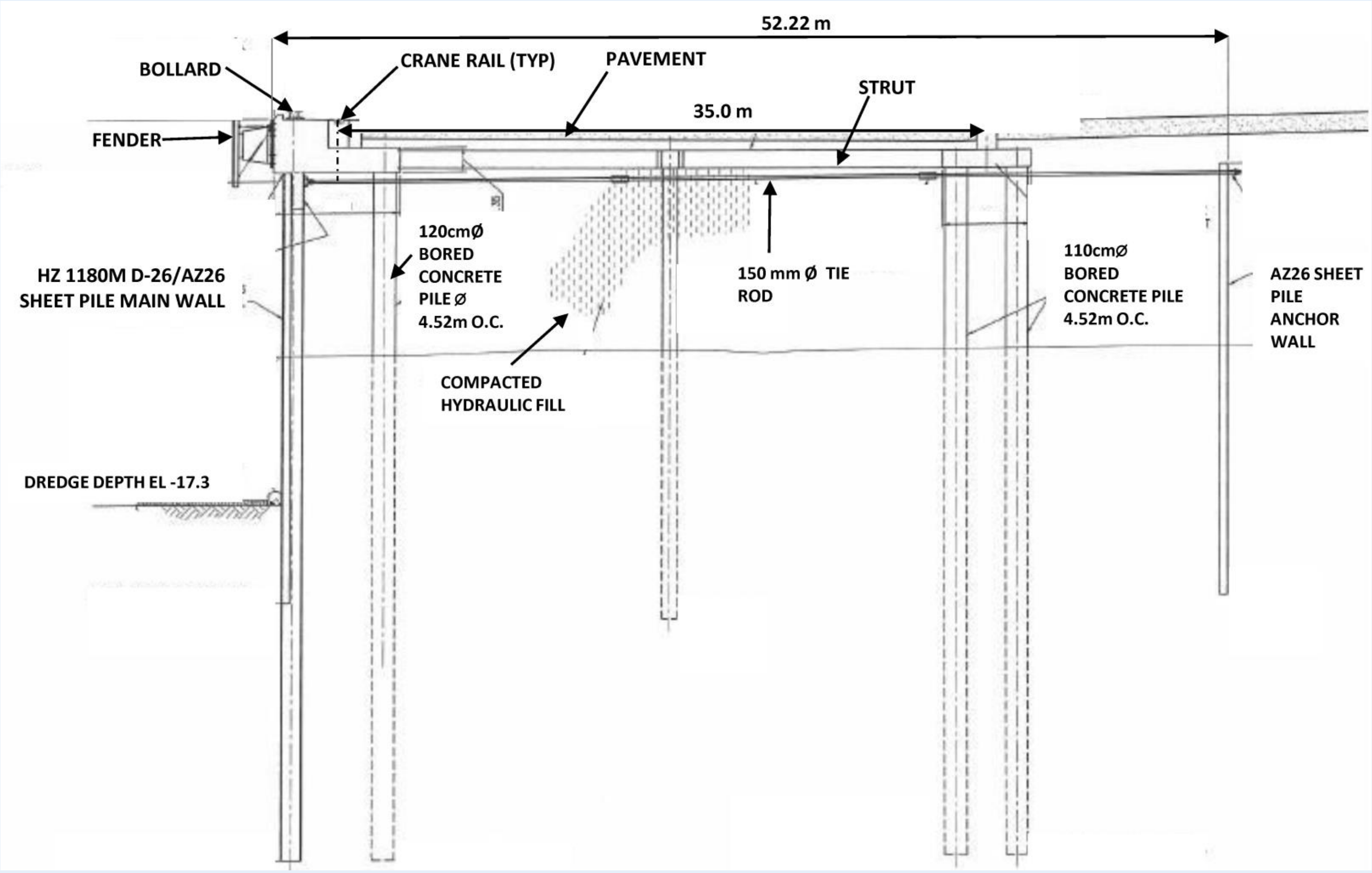
Seismic (CLE) Displacements of East Revetment Caisson

Displacements from FLAC Analyses for the CLE Condition		Allowable Displacements As Defined in PIANC Document	
Displacements at the End of Earthquake Shaking	Magnitude of Displacements (Approx.)	Degree II Damage Level (for CLE Condition)	Degree I Damage Level (for OLE Condition)
Horizontal Displacement at Caisson Seaward Face	15 cm - 20 cm	30 cm to 90 cm	30 cm
Settlement at Caisson Toe	12 cm	N/A	N/A
Settlement at Caisson Heel	2 cm	N/A	N/A
Titling of Caisson Seaward Facing	0.25 degree	3 to 5 degree	Less than 3 degree
Horizontal Displacement of Backfill Directly Behind Caisson	10 cm	N/A	N/A
Settlement of Backfill Directly Behind Caisson	30 cm	N/A	Less than 30 to 70 cm

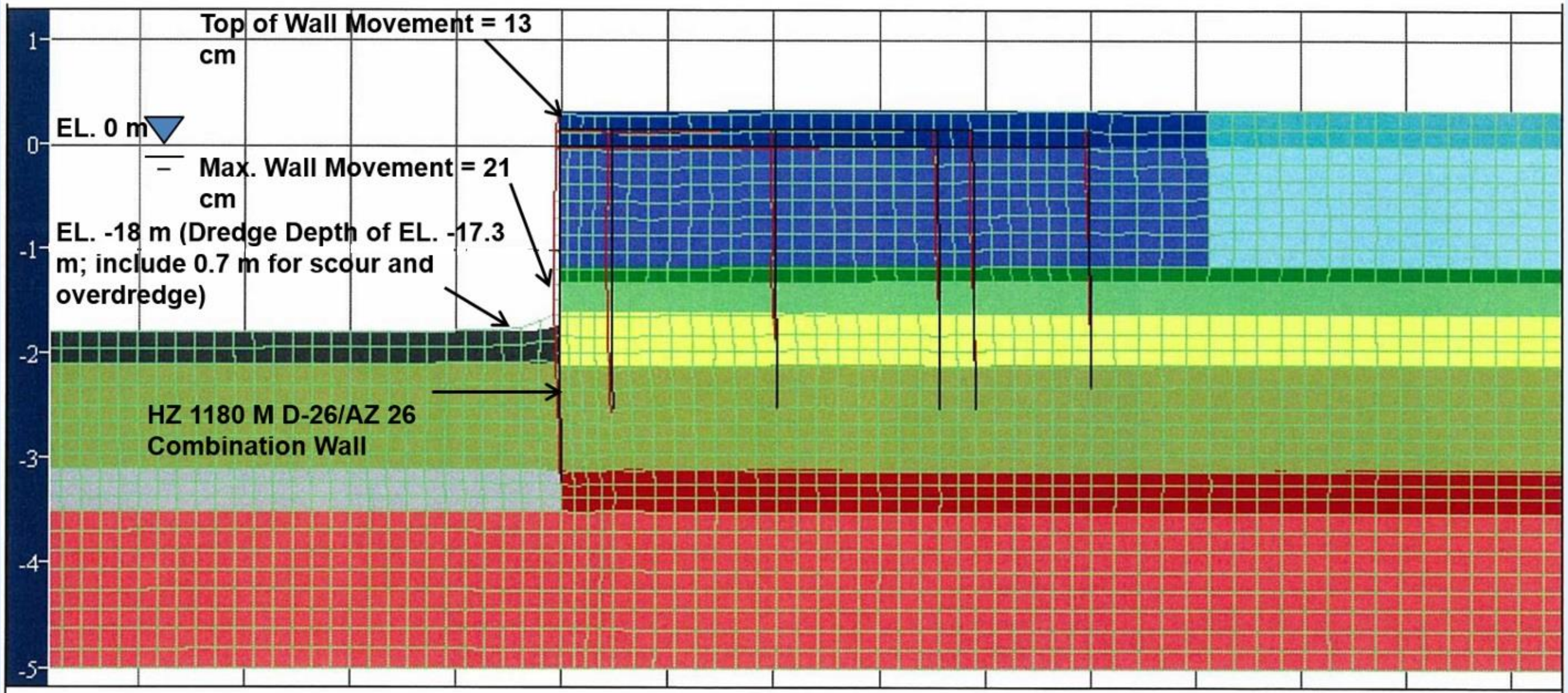
Geological Profile Along Quay 6



Quay 6 Typical Cross Section

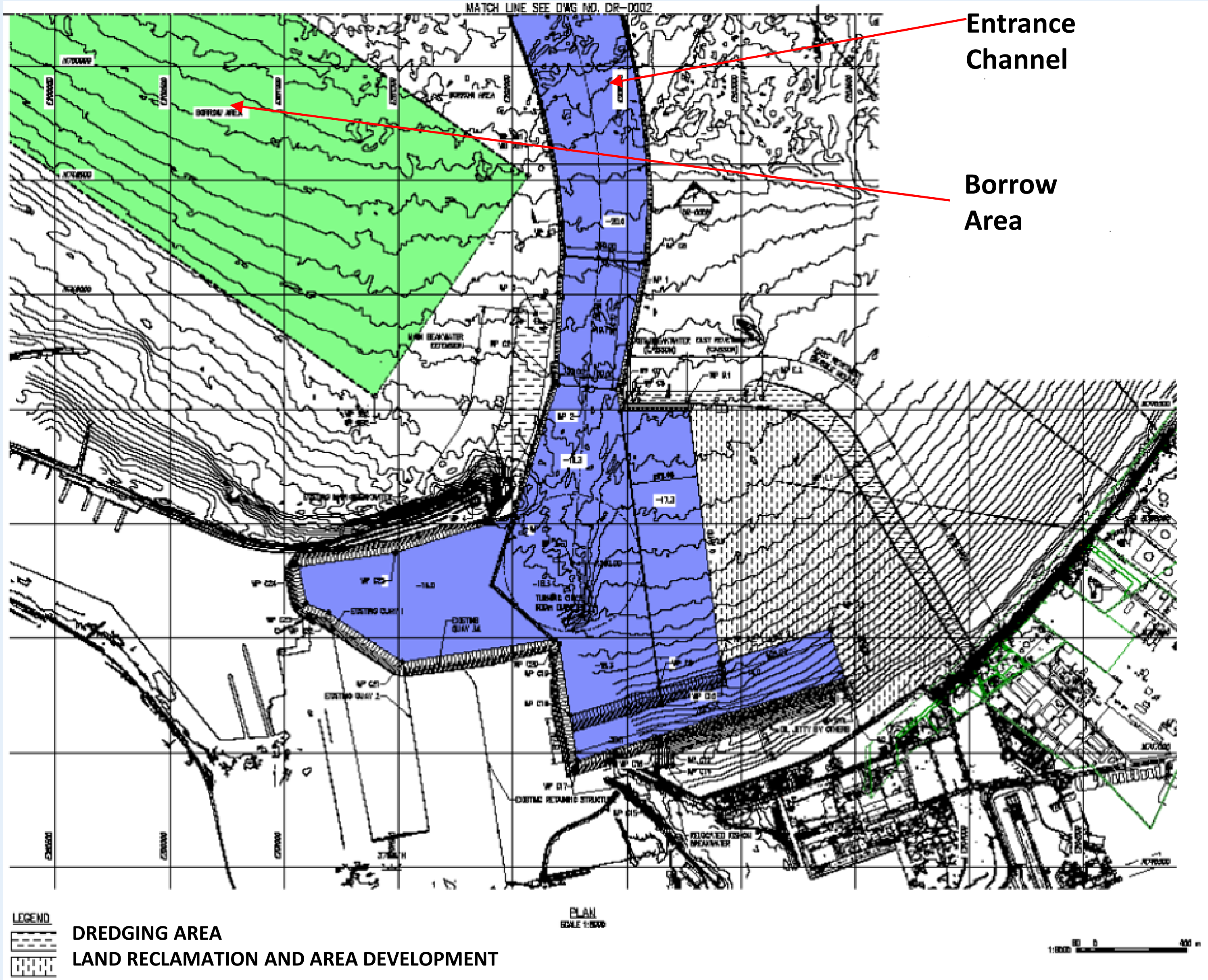


Lateral Motion of Piles and Soil Mass at Quay 6 Due to Shaking



Notes:
(1) The black lines represent the pre-earthquake locations of the piles, bulkhead, and deadman; and the red lines represent their post-earthquake locations.
(2) The green lines represent the deformed soil mesh.

Dredging Plan - Harbor



Dredging Evaluation for EIA

- Evaluated preferred 70% (full) loading scenario and it was determined to be unacceptable from an environmental standpoint due to high levels of spillage
- Developed dredging plans for 45% parallel loading scenario and these were used to evaluate acceptability from environmental standpoint
- Based on this, loading of dredgers will have to be limited so as not to exceed environmental thresholds, thus resulting in higher fines content for reclamation fill

Ground Improvement (GI)

LEGEND

TYPE 1 – GI	VIBROFLOTATION WITH STONE COLUMN TEST AREA
TYPE 2 – GI	VIBROCOMPACTION OR VIBROFLOTATION WITH STONE COLUMN TEST AREA
TYPE 3 – GI	VIBROFLOTATION WITH STONE COLUMN TEST AREA

GRAPHIC SCALES
CHECK BEFORE USE
IF SHEET IS LESS THAN 594mm X 841mm IT IS A REDUCED PRINT. SCALE ACCORDINGLY

Construction of Lee Revetment

Casting of Concrete Caisson

Completed Concrete Caisson

Driving Main Sheet Pile Wall at Quay 6

AAPA

Ground Improvement

Construction of Main Breakwater Extension

Construction of Main BW Extension Roundhead

View of Quay 7, Quay 6, and Reclamation Area

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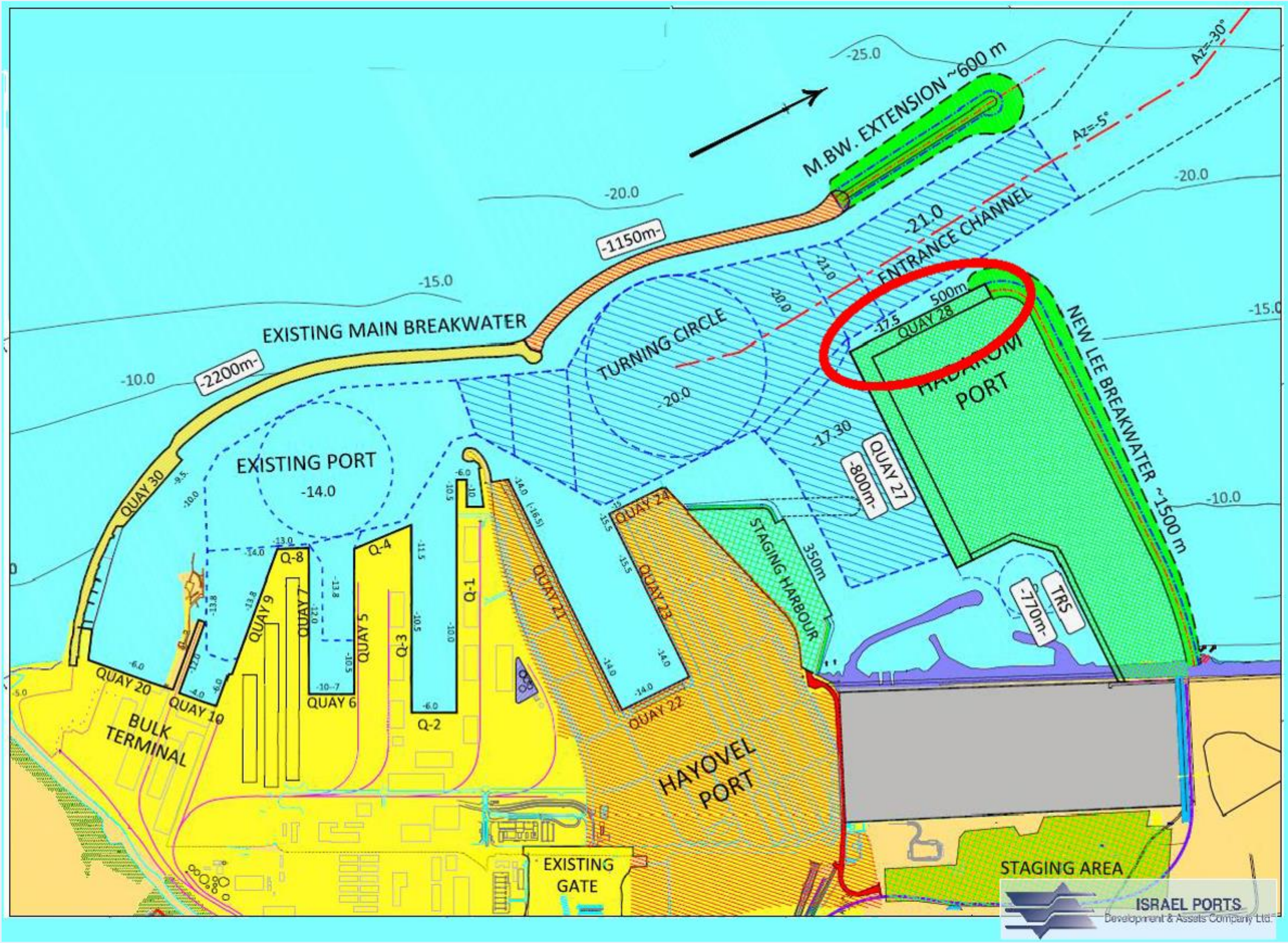
New Marine Container Terminal at Ashdod

(Hadarom Port)

Bill Paparis, Project Manager, D. P.E.

Port Layout



EXISTING MAIN BREAKWATER
-2200m-
-1150m-
M.BW. EXTENSION ~600 m
ENTRANCE CHANNEL
-21.0
TURNING CIRCLE
-20.0
EXISTING PORT
-14.0
QUAY 28
500m
HADAROM PORT
NEW LEE BREAKWATER ~1500 m
QUAY 27
-800m-
-17.30
STAGING HARBOUR
350m
TRS
-770m-
QUAY 30
QUAY 20
QUAY 10
BULK TERMINAL
Q-8
QUAY 9
QUAY 7
QUAY 5
QUAY 6
Q-4
Q-3
Q-2
Q-1
QUAY 21
QUAY 24
QUAY 23
QUAY 22
HAYOVEL PORT
EXISTING GATE
STAGING AREA
-25.0
-20.0
-15.0
-10.0
Az=-5°
Az=-30°
ISRAEL PORTS
Development & Assets Company Ltd.

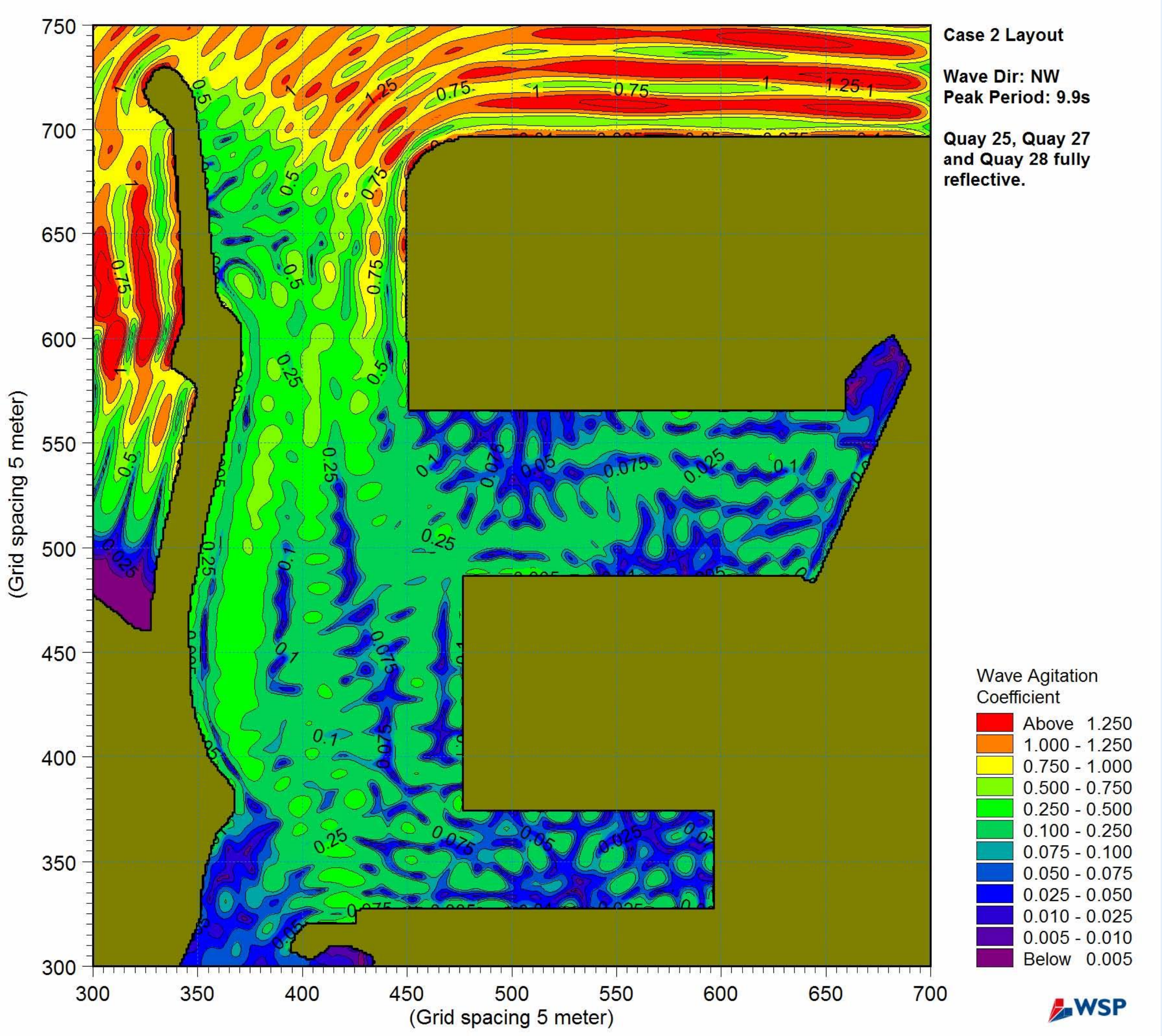
Major Issues

- Site directly exposed to high waves from Mediterranean Sea
- Moderate levels of earthquake accelerations, and associated potential for liquefaction of hydraulic fill and poor soils underlying breakwater foundations
- Potential settlement of reclamation area and breakwaters due to deep clay layers
- Concern over increased downtime in existing port due to construction staging

Maximum and Minimum Size Vessel Parameters

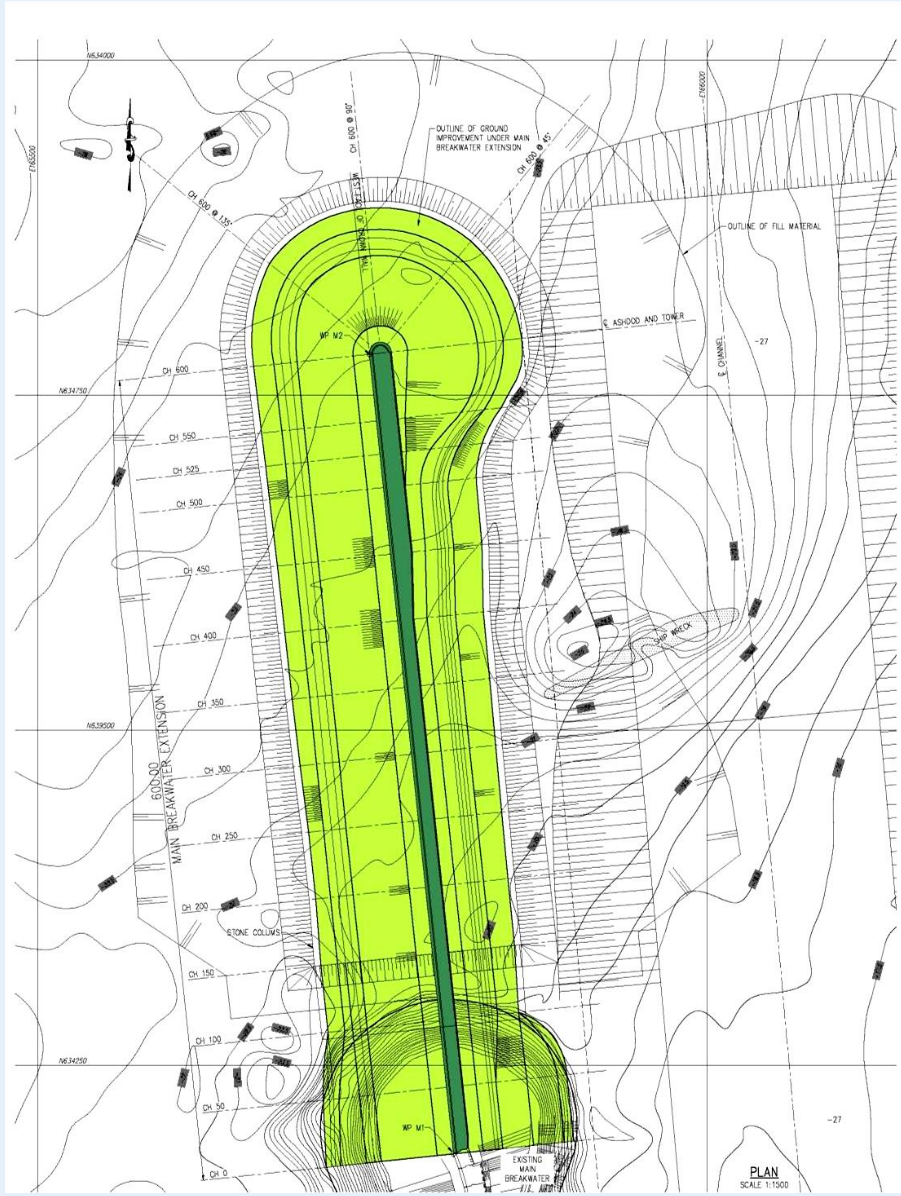
Parameter	Maximum Design Vessel (Quay 27)	Maximum Design Vessel (Quay 28)	Minimum Design Vessel
Vessel Type	Container Ship (Maersk EEE)	Container Ship (Panamax)	-
TEU Capacity	18,000	4,000	600
Loaded Displacement, tonnes	240,000	75,000	10,000
Length Overall (LOA), m	400	270	125
Beam, m	59.0	32.2	20
Loaded Draught, m	16.0	12.0	7.6

Wave Agitation Plot for North-West Wave Direction



Overview of the Ashdod Port Model in Large Area Basin (CHC, Canada)

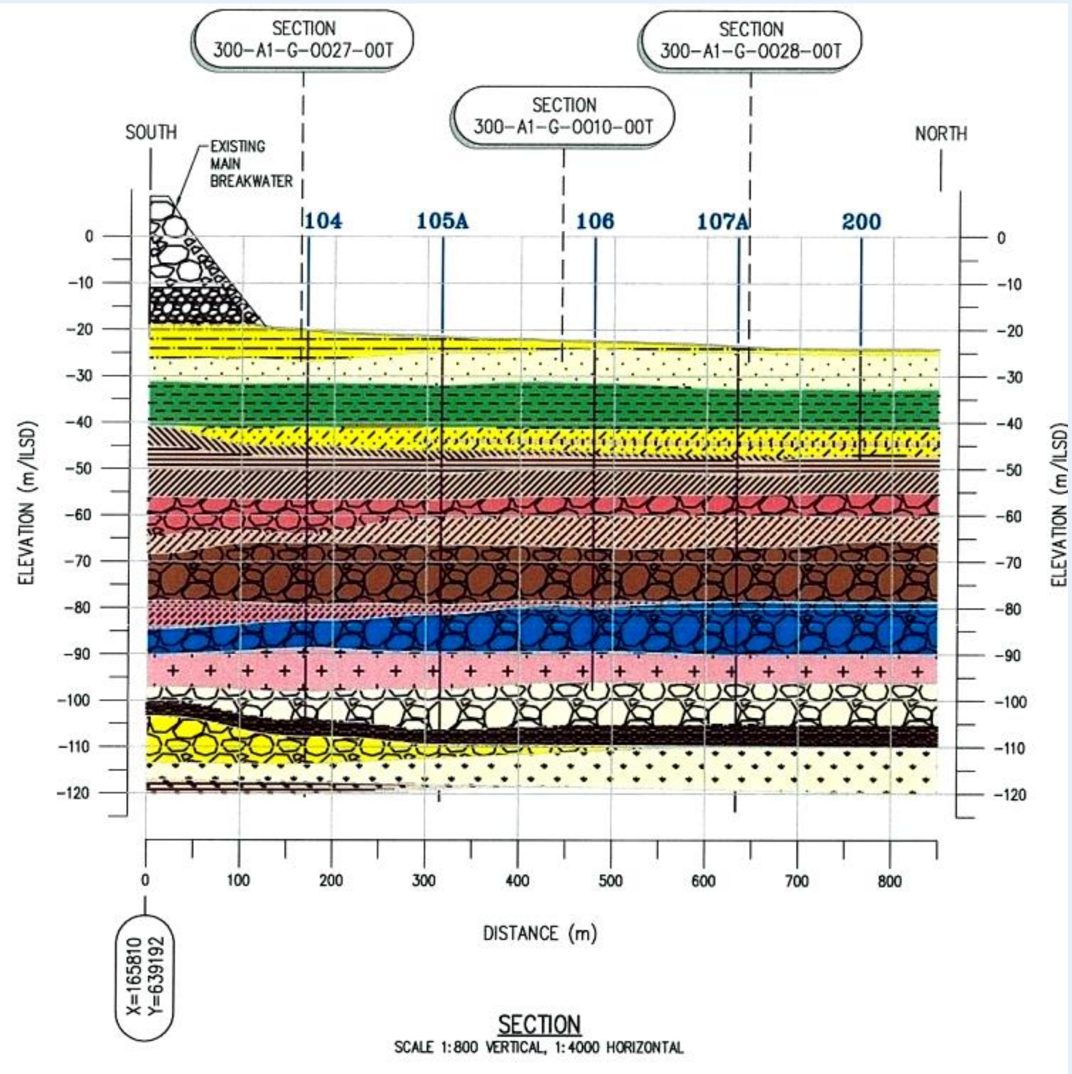
Plan of Main Breakwater Extension

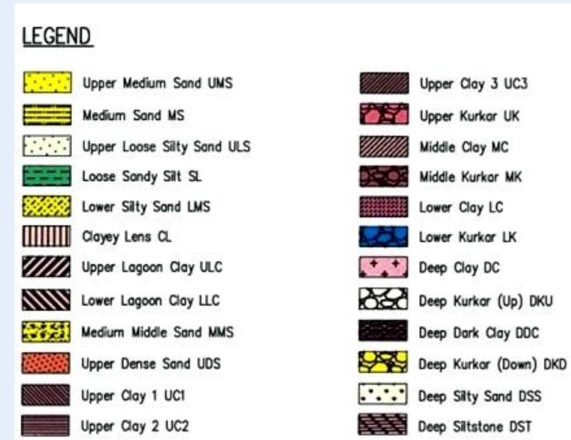


Main Design Issues for Main Breakwater Extension

- Maximum significant wave height of 8.3 m
- Anticipated long-term settlement
- Potential liquefaction of underlying soils

Geological Profile Along Main Breakwater Extension





NOTES

1. ALL UNITS IN METERS UNLESS OTHERWISE NOTED.
2. COORDINATE GRID BASED ON NEW ISRAEL GRID.
3. ALL ELEVATIONS BASED ON ISRAELI LAND SURVEY DATUM (ILSD).
4. THE CROSS SECTIONS ARE BASED ON INTERPOLATED DATA FROM THE SOIL INVESTIGATION BY GEMS (2009/2010). THE BOREHOLES ARE PROJECTED PERPENDICULAR TO THE SECTION.
5. THESE DRAWINGS ARE SHOWING INFORMATION AS GATHERED DURING THE SOIL INVESTIGATION BY GEMS (2009/2010). ALL SOIL INVESTIGATION RESULTS (PREVIOUS INVESTIGATIONS AS WELL) ARE AVAILABLE FOR THE CONTRACTOR'S REVIEW.

1:800 8 0 40 m
1:4000 40 0 200 m

GRAPHIC SCALES
CHECK BEFORE USE

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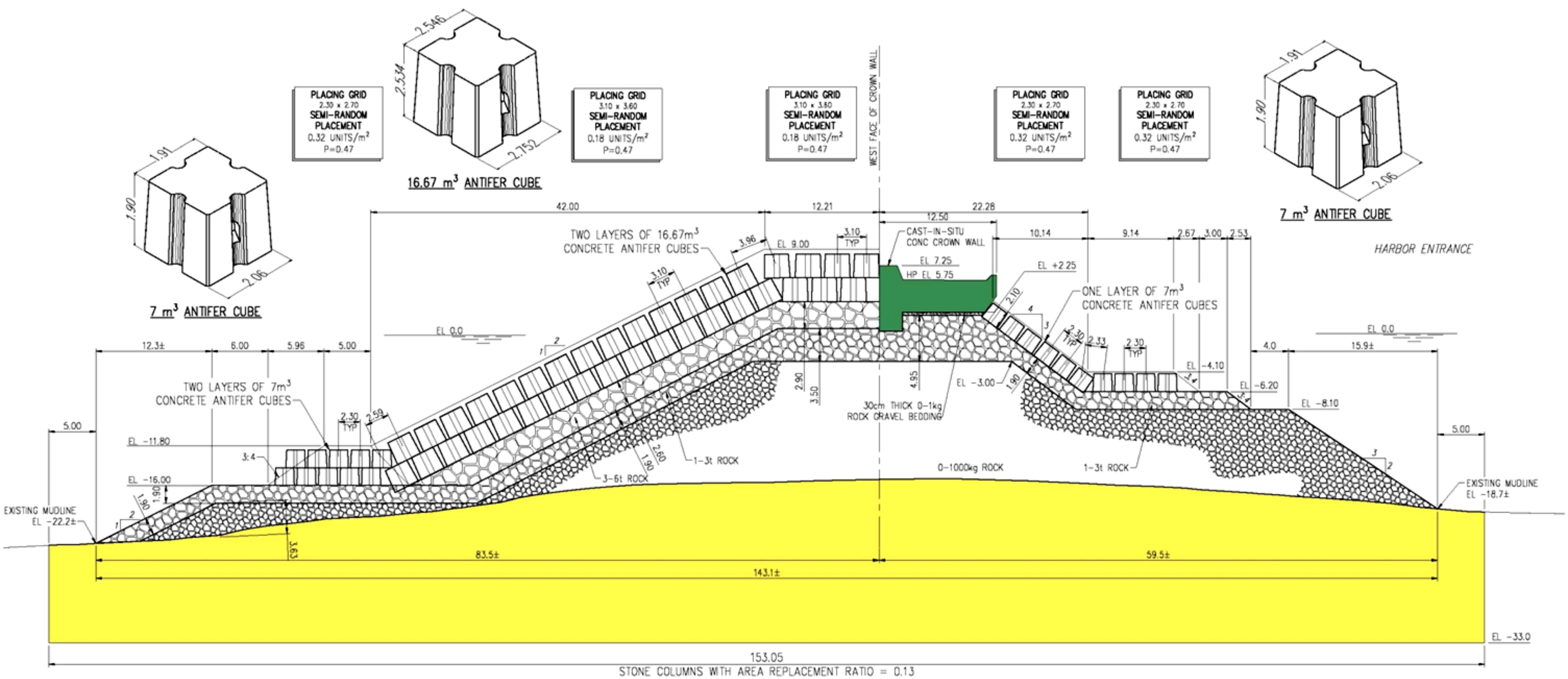
SCALE ACCORDINGLY

Liquefaction Assessment at Main Breakwater Extension

- Slope stability analyses were carried out for three loading conditions:(1) static; (2) pseudo static for contingency level earthquake conditions; and (3) post-seismic static loading using residual undrained shear strengths.
- The loose silty sand was determined to be liquefiable (based on a PGA = 0.12 g and M = 7.5), while the silt was determined to be susceptible to strength reduction.
- Further analyses were then carried out assuming that the silty sand is: (1) replaced; and (2) improved, and the maximum earthquake induced displacements were on the order of 60-80 cm, which is considered acceptable for this type of structure, as it can accommodate lateral deformation.
- Stone columns with an area replacement ratio of 13% were implemented to improve the silty sand.

Section of Main Breakwater Extension At Chainage 100



CHAINAGE 100

SCALE 1:250

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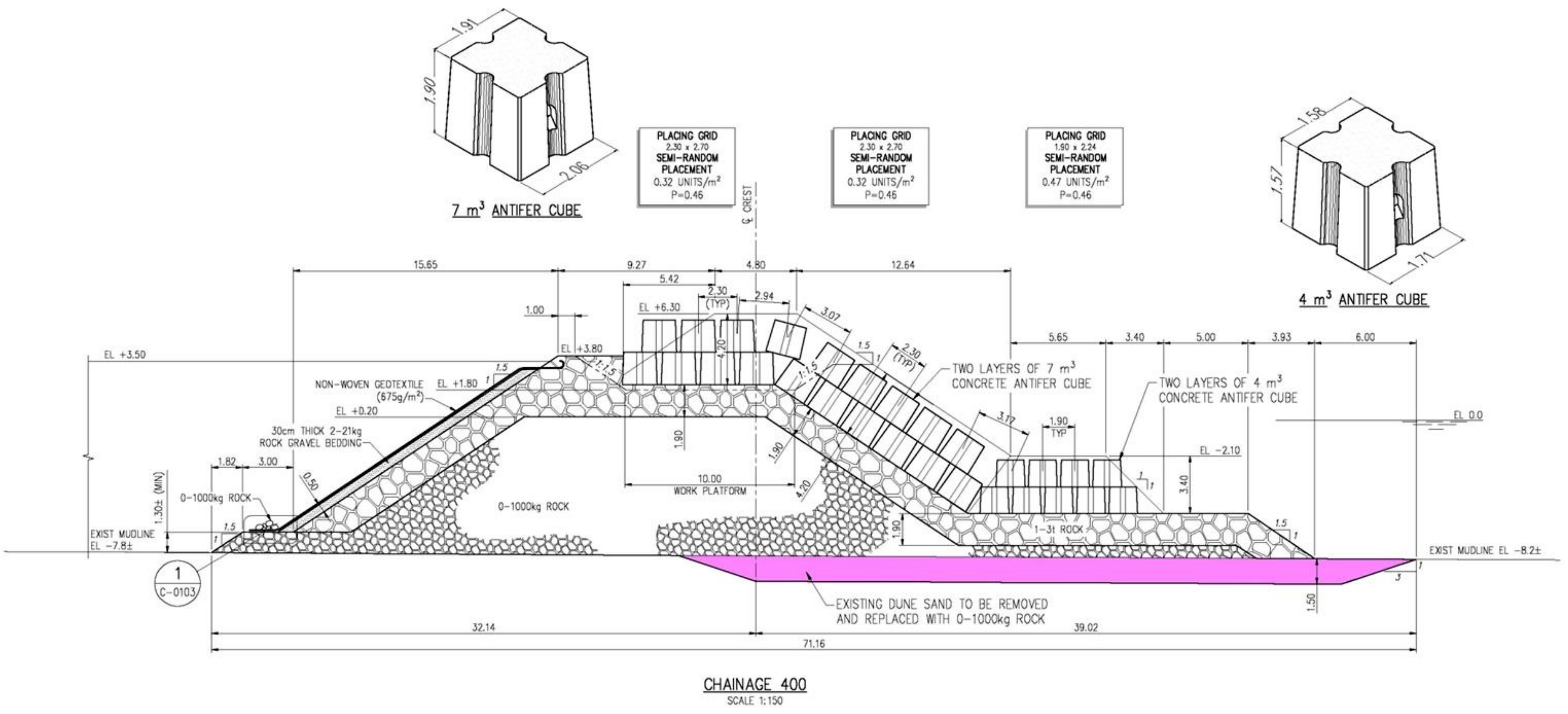
4. ANTIFER CUBES SHOWN ARE ILLUSTRATIVE. PLACING OF UNITS SHALL BE IN ACCORDANCE WITH SPECIFICATIONS.
5. FOR CROWN WALL DETAILS SEE DWG NOS. C-261 THRU C-0264.
6. FOR CONSTRUCTION TOLERANCES SEE DWG NO. C-.

2D Stability Testing of Main Breakwater Extension (H.R. Wallingford, UK)

3D Stability Testing of Lee Breakwater Roundhead (H.R. Wallingford, UK)

Section of Lee Breakwater at Chainage 400



NOTES

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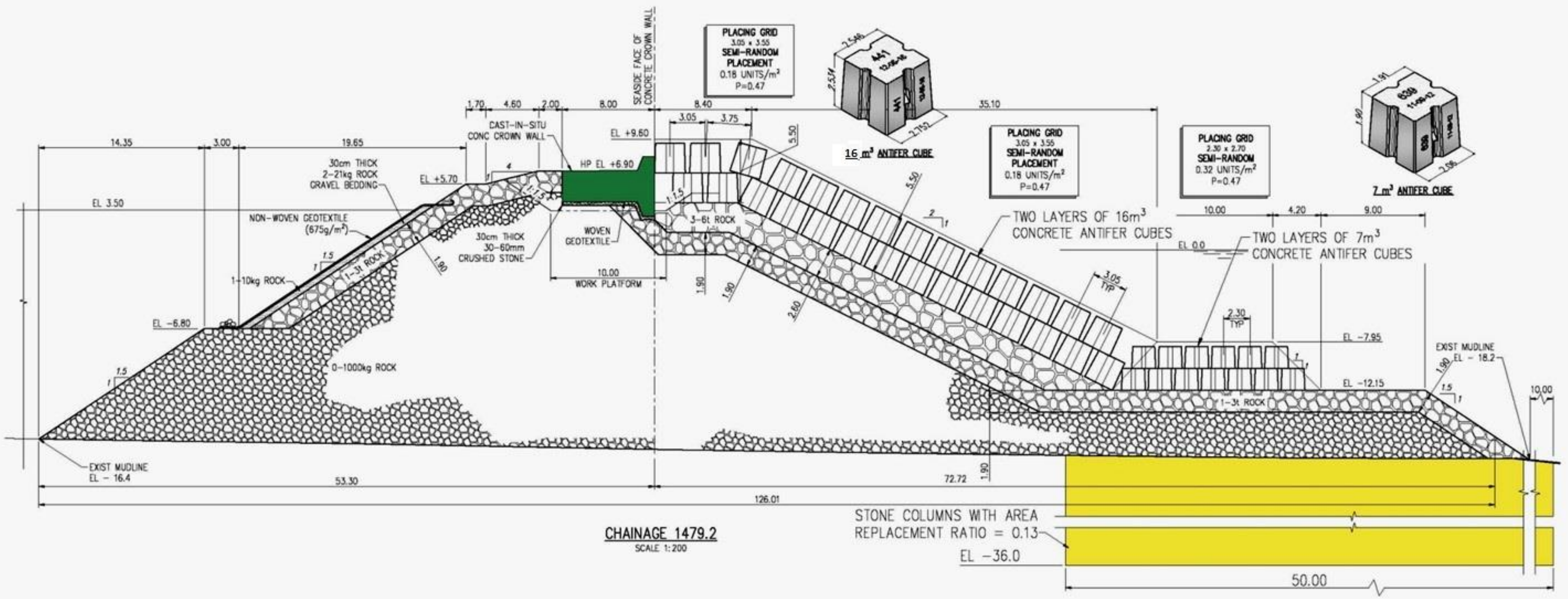
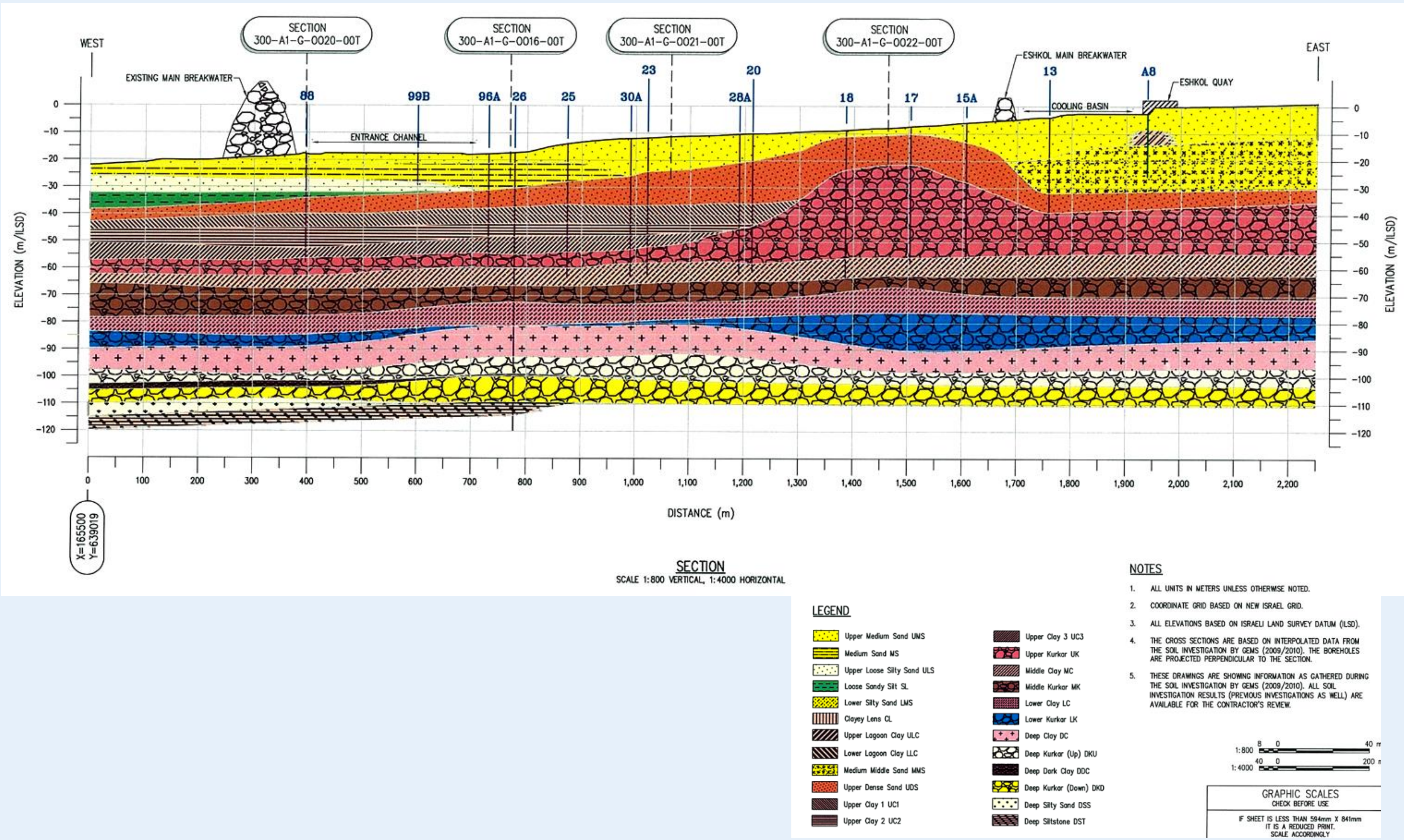
2. ALL ELEVATIONS BASED ON ISRAELI LAND SURVEY DATUM (ILSD).
3. ANTIFER CUBES SHOWN ARE ILLUSTRATIVE. PLACING OF UNITS SHALL BE IN ACCORDANCE WITH SPECIFICATIONS.
4. FOR CONSTRUCTION TOLERANCES SEE DWG NO. XYZ.

Section at Roundhead of Lee Breakwater



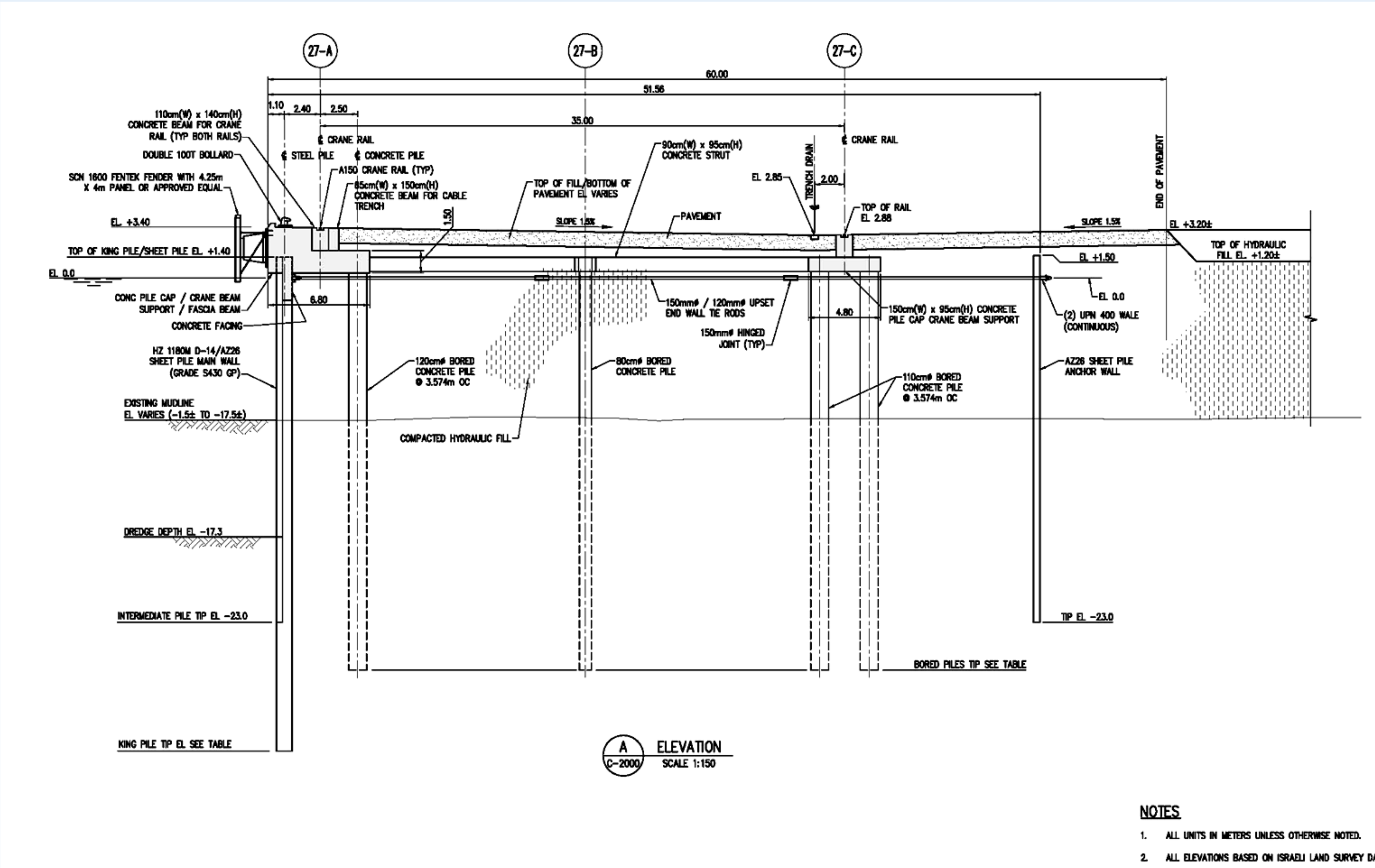
Geological Profile Along Quay 27



Quay 27 – Crane Loads

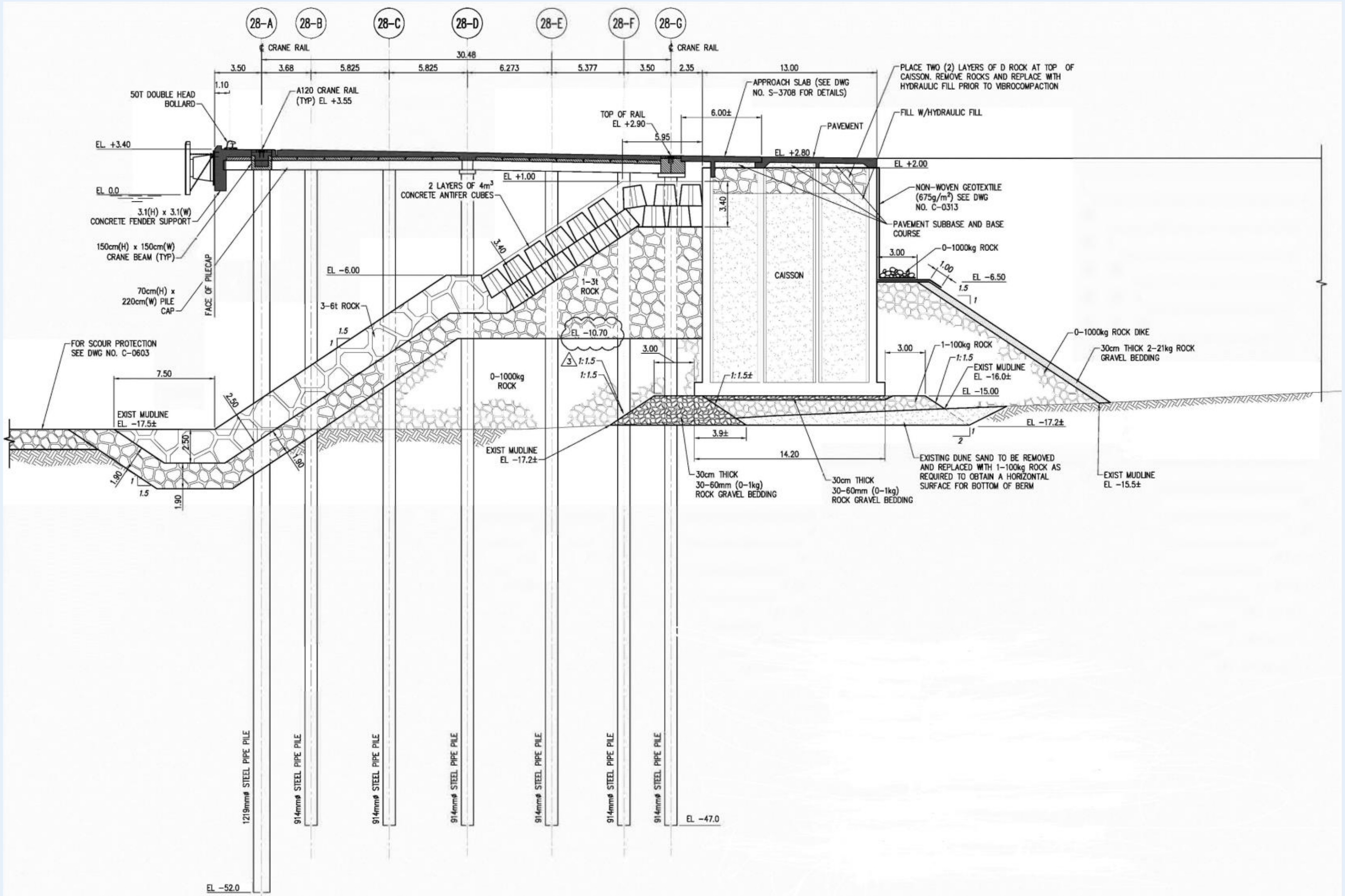
		Waterside	Landside
Maximum Wheel Load	tonnes/wheel	160	130
Maximum Load on Crane Beam	tonnes/m	130	110
Maximum Lateral Force on WS or LS Rail	tonnes	15% of Vertical Load	15% of Vertical Load
Anchor Pin Loads (Storm)	tonnes	200	200
Tie-Down Loads	tonnes/corner	220	220

Quay 27 – Typical Section

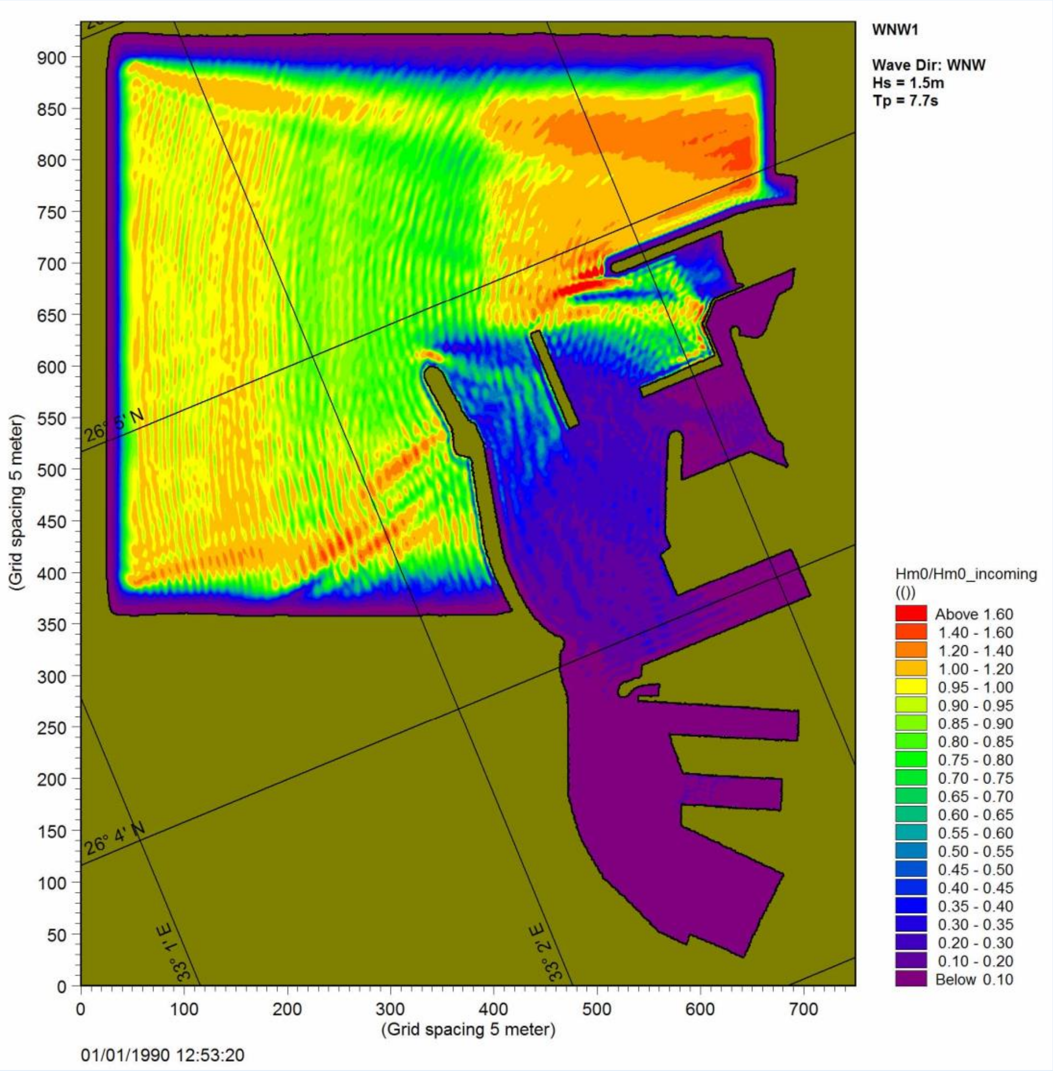


AAPA

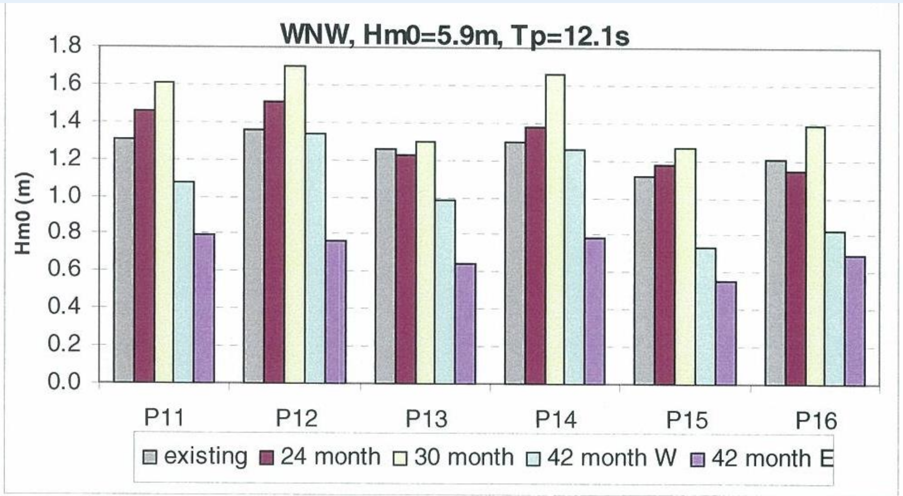
Quay 28 – Typical Section

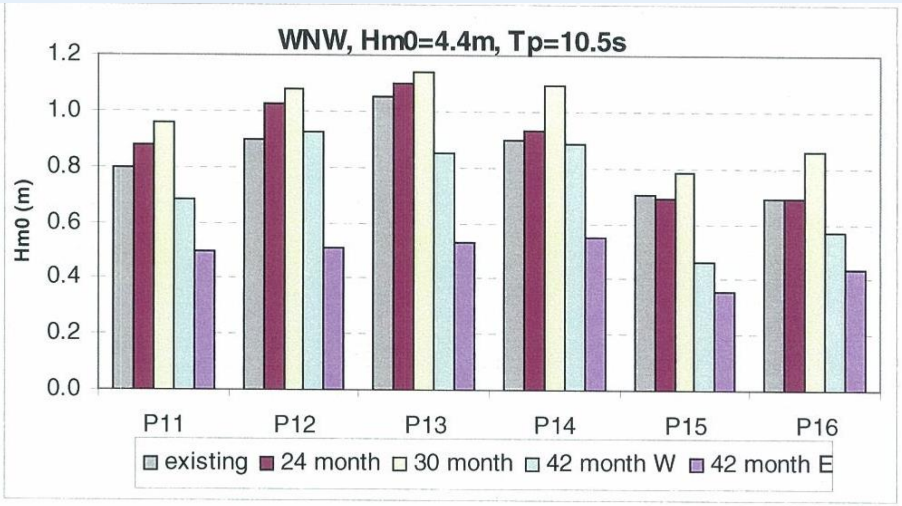


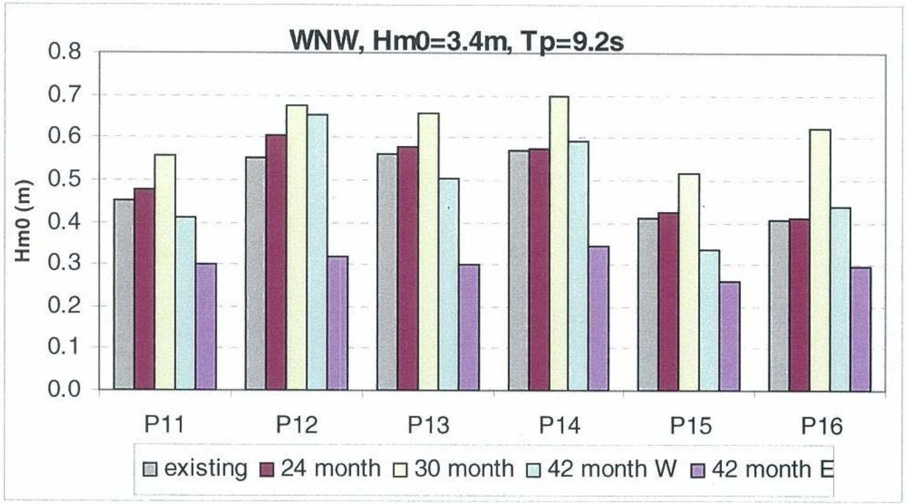
Instantaneous Steady State Wave Disturbance Plot for Construction Phase

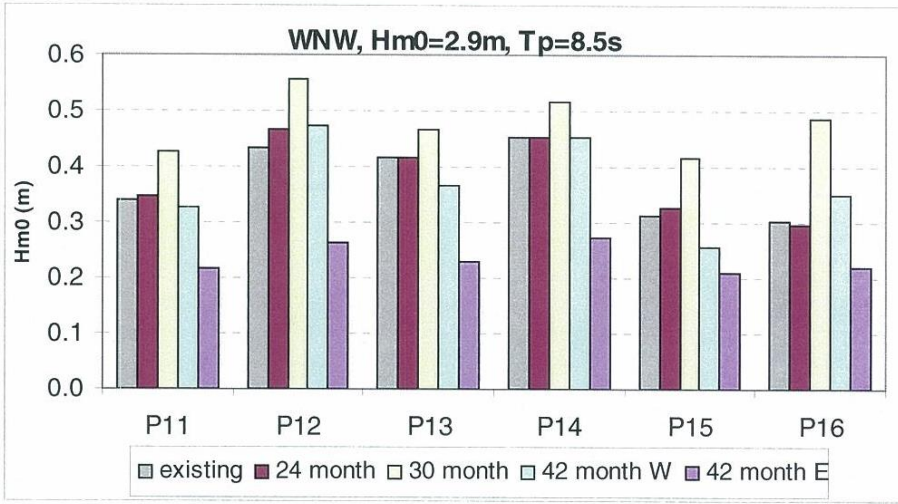


Wave Heights at Existing Quays 23, 22, and 21









Front View of Quay 28 Model Testing

Settlement of Reclamation Area

- Due to the questionable quality and uncertainty of the original geotechnical data, settlement calculations were based on the assumption that all clay layers were normally consolidated.
- Based on the original 2009/2010 boring logs, without any ground treatment, the maximum post-construction settlements at the western area of the site were estimated to be up to 70 cm.
- Analyses indicated that a wick drain program in combination with 2 m of surcharge would be effective in reducing the post-construction settlements to 35 cm or less.
- An additional geotechnical investigation was performed during construction to attempt to minimize the uncertainty.

General Subsurface Stratigraphy

Strata #	Strata LEGEND	Strata ID	
1		UMS	Upper Medium Sand
2		MS	Medium Sand
3		ULS	Upper Loose Sand
4		SL	Silt (not seen in the reclamation area)
5		UDS	Upper Dense Sand
6		UC UC1 / UC2 / UC3	Upper Clay
7		UK	Upper Kurkar
8		MC	Middle Clay
9		MK	Middle Kurkar
10		LC	Lower Clay
11		LK	Lower Kurkar
12		DC	Deep Clay
13		DKU	Deep Kurkar (Up)
14		DDC	Deep Dark Clay

Time-Dependent Settlement Parameters (Based on Additional Geotechnical Investigation)

Unit	γ' (kN/m^3)	PI	C_c	C_r	e_0	$C\alpha$	c_v (m^2/year)	OCR top to bot (PCPTs)	OCR top to bot (triaxial)
UC	9	30	0.295	0.045	0.898	0.004	1.5	2.9 to 1.5	2 to 1.6
MC	8	36	0.45	0.057	1.183	0.0054	0.75	1.6 to 1.2	1.3
LC	9.4	30	0.247	0.025	0.769	0.0036	1	2.1 to 1.3	1.5
DC	9.7	23	0.248	0.025	0.774	0.006	0.75	1.6 to 1.5	1.5

Key Post-Construction Settlement and Differential Settlement Values

Differential settlement between waterside and landside rails at Quay 27:

- 10 years after the completion of construction: 5.8 cm
- 20 years after the completion of construction: 7.4 cm
- 50 years after the completion of construction: 8.4 cm

Maximum settlement within the reclamation area:

- 10 years after the completion of construction: 15.4 cm
- 20 years after the completion of construction: 18.6 cm
- 50 years after the completion of construction: 22.2 cm

Lee Breakwater and Temporary Retaining Structure Construction

Lee Breakwater & Reclamation Area Construction

Quay 28 Construction

Quay 27 Construction

Quay 27 Construction

AAPA

Main Breakwater Extension Construction

Overall View Looking Northeast

Overall View Looking Southeast