INTRODUCTION TO PORT DESIGN

Importance of Ports to Alaska

Table 1. Freight Shipments To, From, and Within Alaska: 1998, 2010, and 2020

ALASKA	Tons (millions)			Value (billions $)		
	1998	2010	2020	1998	2010	2020
State Total	78	83	103	60	125	222
By Mode						
Air	0.7	1.3	1.9	38	90	167
Highway	10	16	21	8	17	28
Other[a]	1.7	2.8	3.4	0.3	0.7	1.1
Rail[b]	NA	NA	NA	NA	NA	NA
Water	66	63	77	13	17	26
By Destination/Market						
Domestic	71	72	89	35	72	119
International	7	11	14	24	53	103

Note: Modal numbers may not add to totals due to rounding. NA = Not Available

[a] The "Other" category includes international shipments that moved via pipeline or by an unspecified mode.

[b] FAF does not include rail data for Alaska. The Alaska Railroad Corporation reports 7.8 million tons, valued at $65 million, were shipped in 1998. It forecast that 11 million tons, valued at $95 million, will be shipped in 2020.

Port – Definition

- **A location for transfer of cargo between ships and shore.**
- **A port normally includes docks, uplands and infrastructure necessary for commercial activity.**

Small Boat Harbor - Definition

- A location for permanent or temporary moorage of small unattended vessels.
- Moorings normally consist of floating docks protected by a breakwater.
- Vessel size in small boat harbors generally vary from about 18 foot skiffs up to about 150 foot commercial fishing boats.

Example Port – Anchorage, Ak.

Example Port
Long Beach, Ca.

Port Characteristics

- Normally Accommodates vessels ranging from about 150 feet to over 900 feet.
- Dock structures are generally fixed (not floating) and vessels are attended at all times. (Note: Areas of high tidal ranges require constant attention to mooring lines or use self tensioning winches).
- Port Design includes Dock structures, uplands, and associated infrastructure.
- May or may not include a protective Breakwater.

PIER

- Good for Access to Deep Water
- Vessels Can Be Moored on Two or More Sides
- Limited Weight Capacity (pile supported)
- Limited Working Space
- Commonly Used for Fuel Transfer & Light Cargo

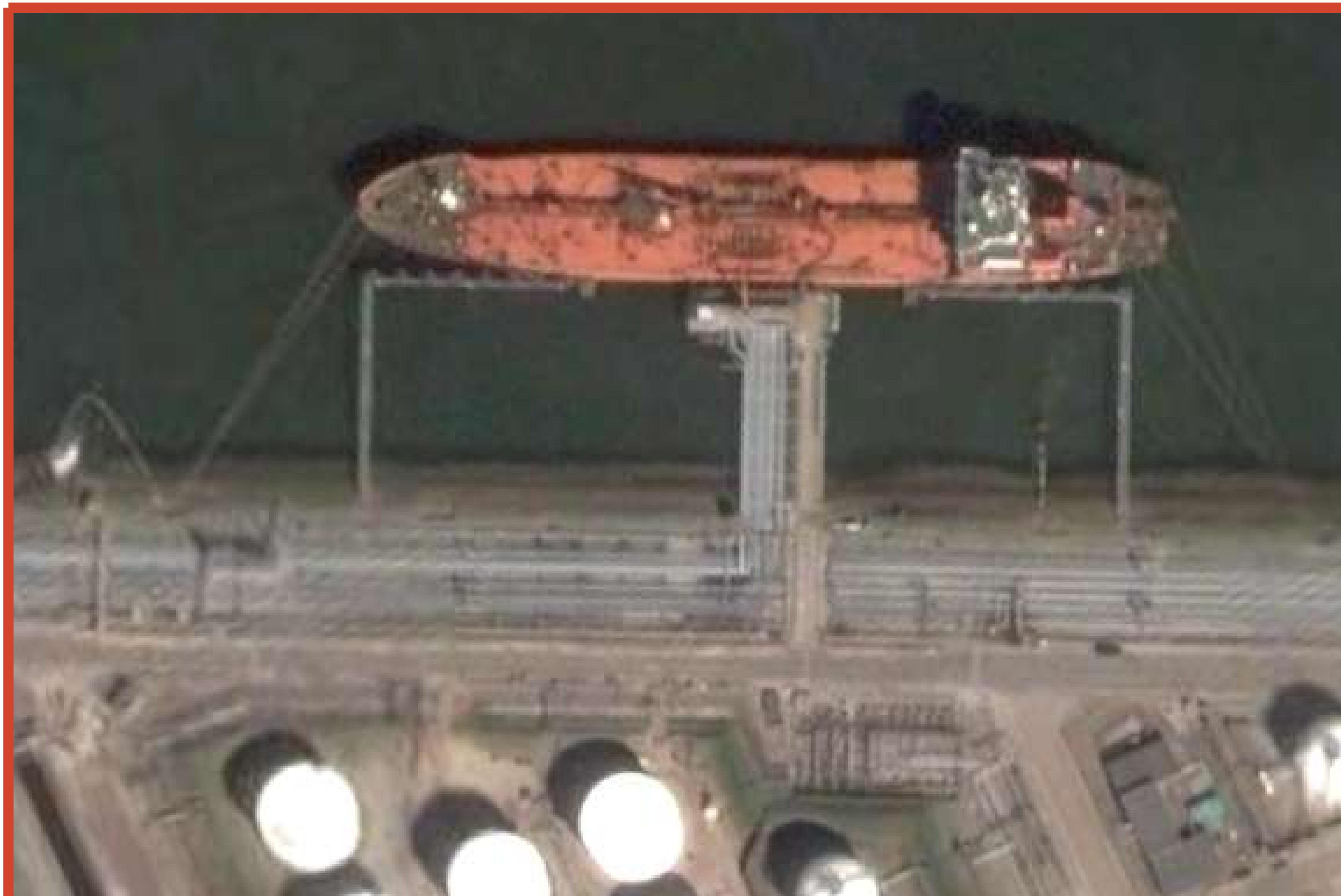
WHARF

- Moorage Parallel to Shore. Docking on Only One Side
- More Robust Than Piers. Good for Heavy Duty Transfer of Cargo – (E.G. Containers)
- Normally Constructed Close to Shore Where Depths Increase Rapidly

Combined Pier/Wharf Port of Anchorage

Combined Pier/Wharf
Port of Anchorage

Fuel Transfer
Port of Rotterdam



Design Considerations

Physical Site Conditions

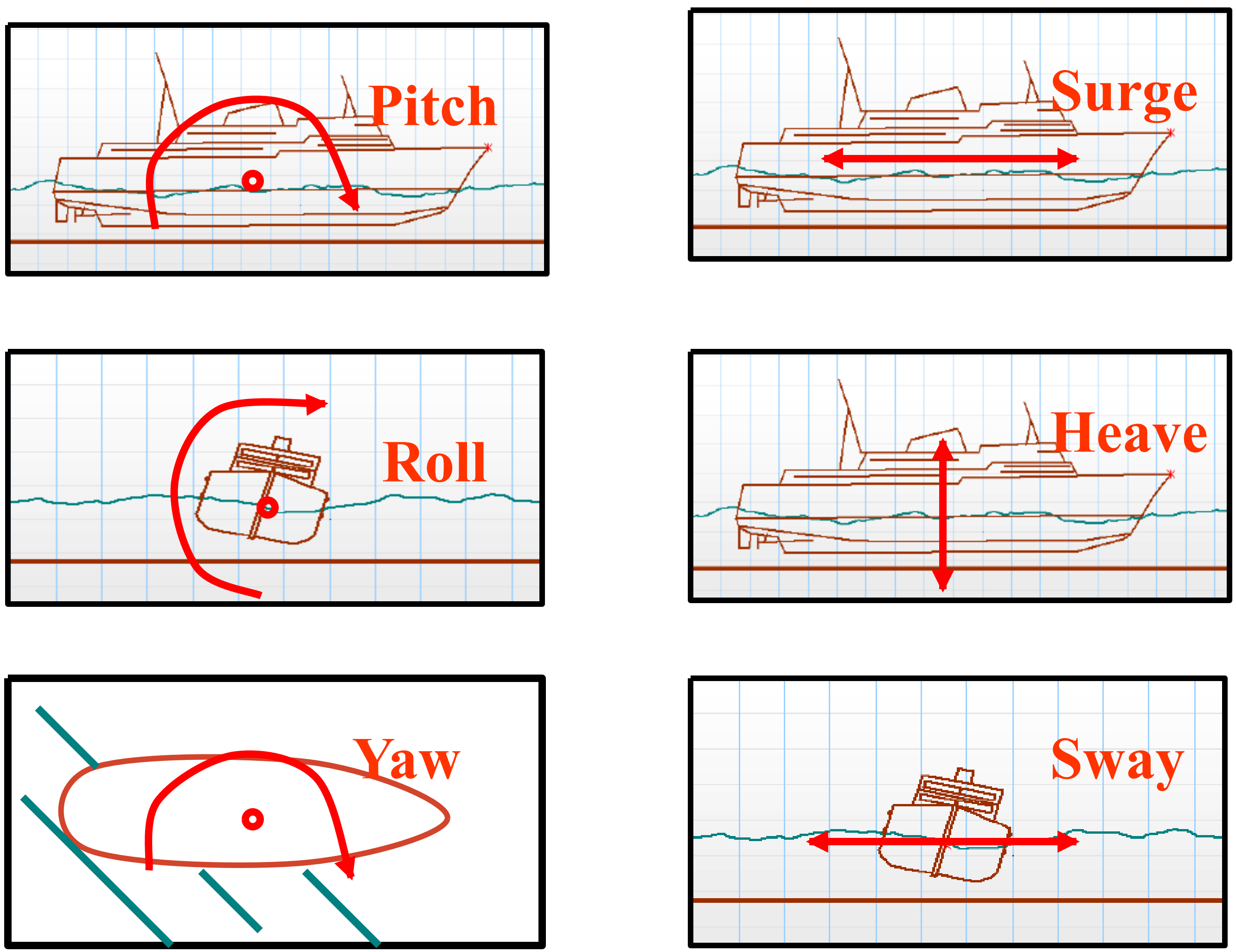
- Winds
- Waves
- Currents
- Ice
- Sedimentation
- Soils (foundations)
- Water Depths
- Available Uplands
- Access
- Environmental Impacts
- Other

Design Considerations
Structural

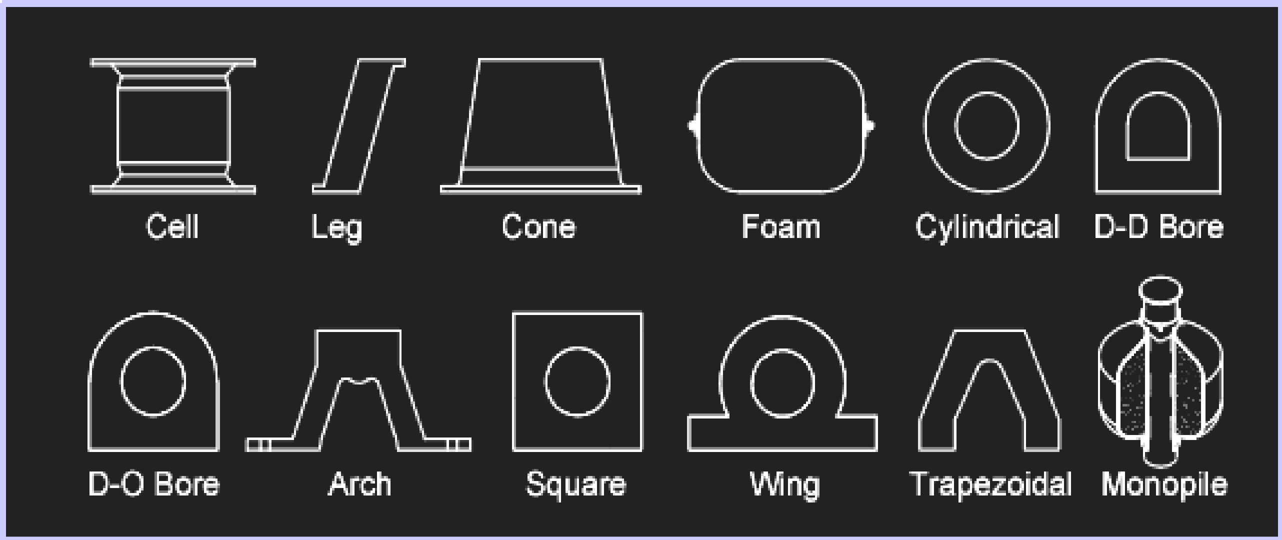
- **Size and displacement tonnage (weight) of ship . . . is there tug assist?**
- **What is the impact energy (fendering)**
- **What are the wind and current loads?**
- **Selection of materials (steel, concrete, wood?)**
- **Other**

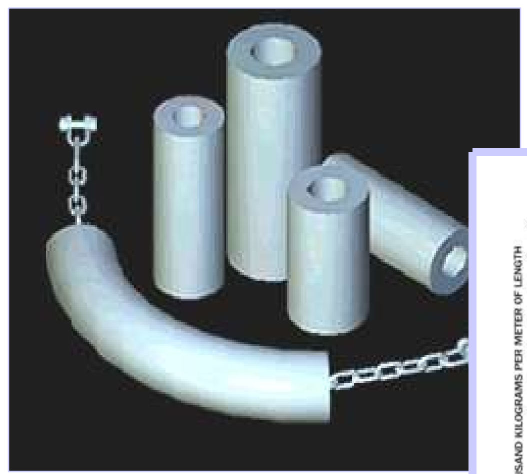
Six Degrees of Boat Motion

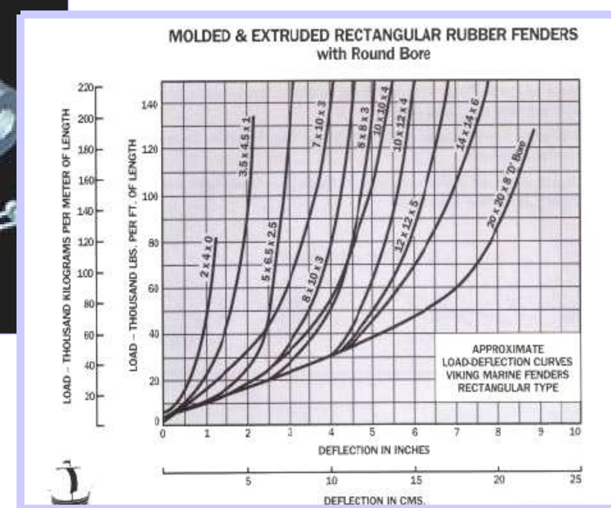
(3 rotation and 3 translation)



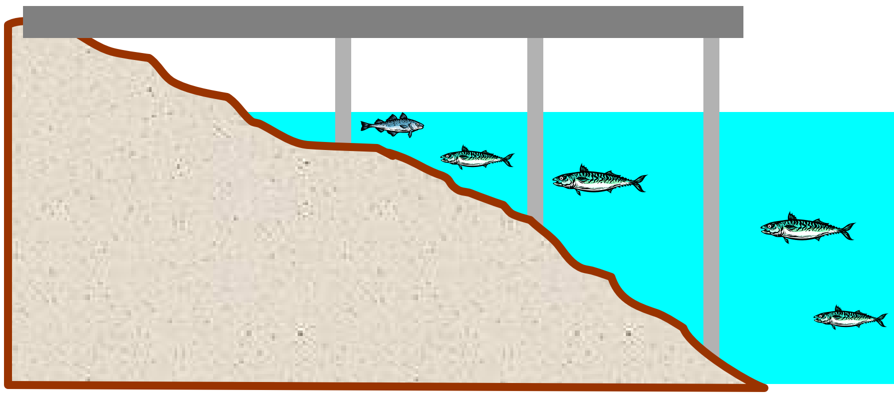
Fendering


Cell
Leg
Cone
Foam
Cylindrical
D-D Bore
D-O Bore
Arch
Square
Wing
Trapezoidal
Monopile




MOLDED & EXTRUDED RECTANGULAR RUBBER FENDERS
with Round Bore
LOAD – THOUSAND KILOGRAMS PER METER OF LENGTH
LOAD – THOUSAND LBS. PER FT. OF LENGTH
2 x 4 x 0
3.5 x 4.5 x 1
5 x 6.5 x 2.5
7 x 10 x 3
8 x 10 x 3
8 x 8 x 3
10 x 10 x 4
10 x 12 x 4
12 x 12 x 5
14 x 14 x 6
20 x 20 x 8 'D' Bore
APPROXIMATE
LOAD-DEFLECTION CURVES
VIKING MARINE FENDERS
RECTANGULAR TYPE
DEFLECTION IN INCHES
DEFLECTION IN CMS.

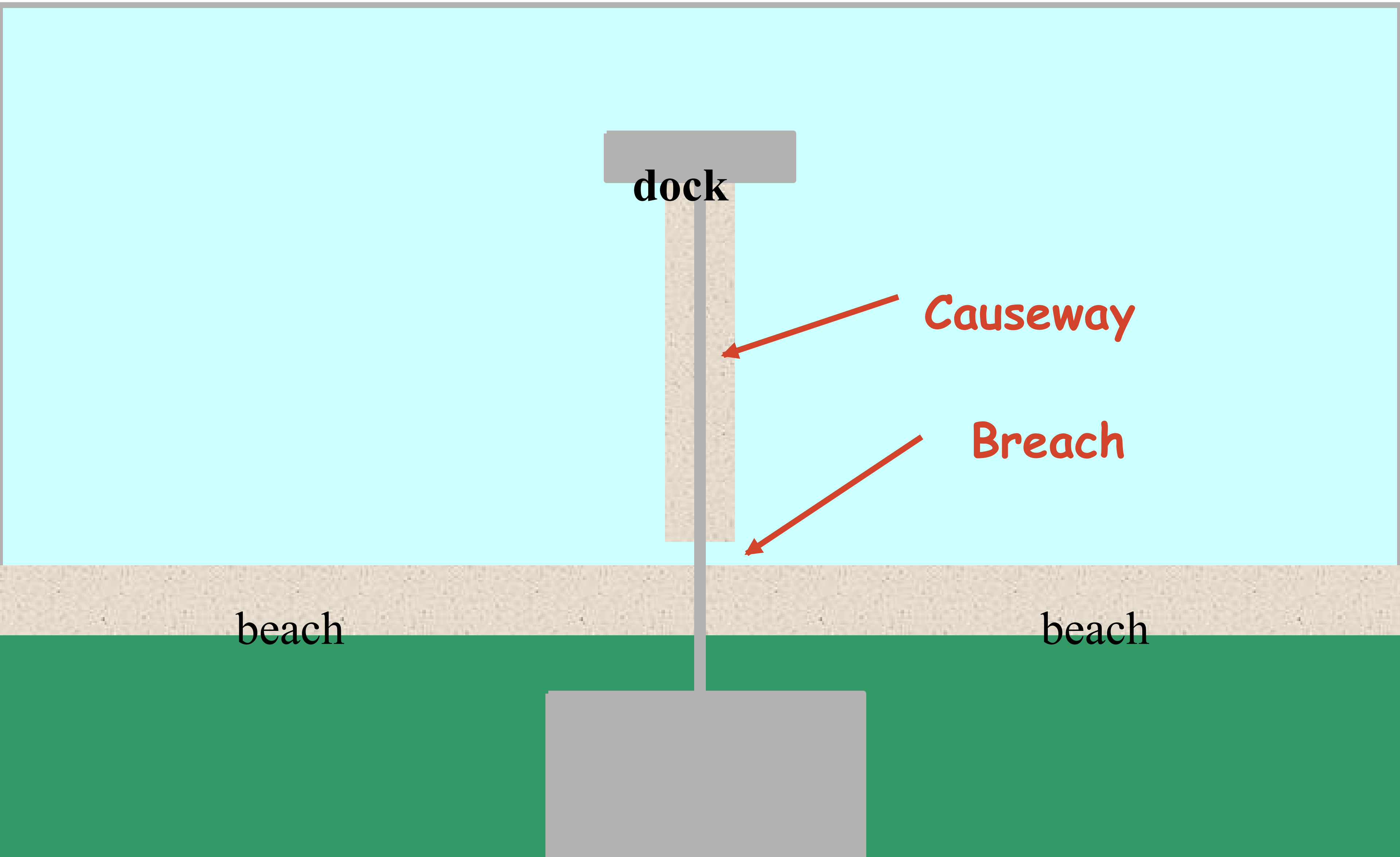
ENVIRONMENTAL
Dock Design & Fish Migration



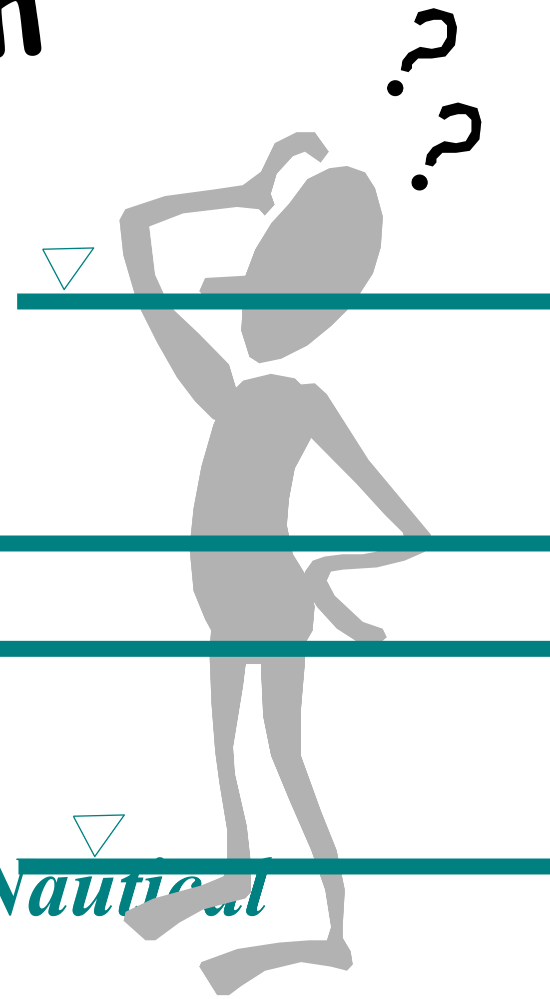
Pile supported docks are normally preferred for fish migration; however there may be concern for shading

There is concern that vertical faced docks force juvenile salmon into deep water. Sometimes this can be mitigated by hanging material from dock face.

ENVIRONMENTAL
Dock design & Fish migration



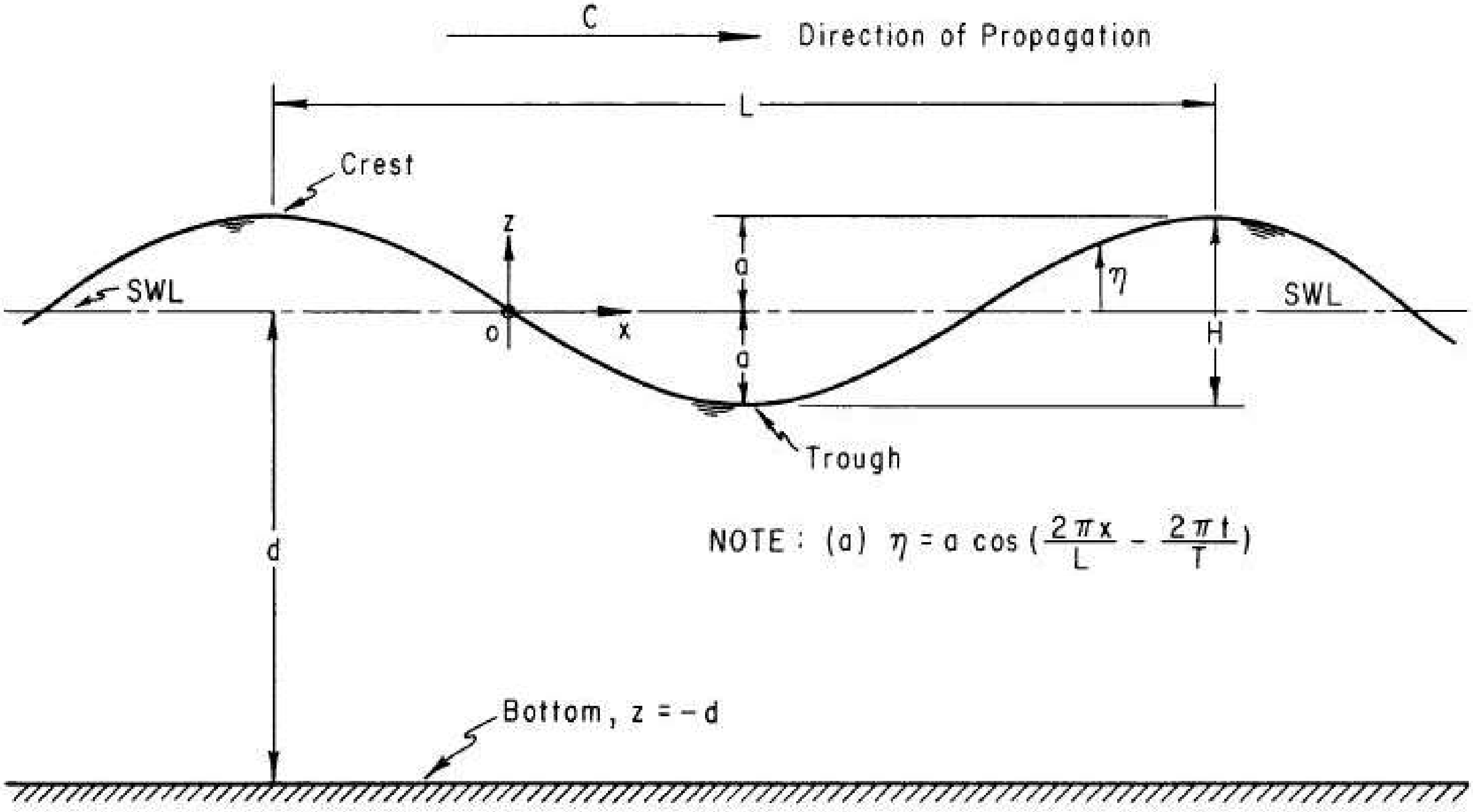
Vertical Datum



- **MHW** ***(Nautical Chart Uplands)***
- **NGVD** ***(Highways ?)***
- **MSL** ***(Airports ?)***
- **MLLW** ***(Harbors, Marine and Nautical Chart Soundings)***

Always Show Datum on Plan Sheets

Wave Terminology



Distribution of Ocean Wave Energy

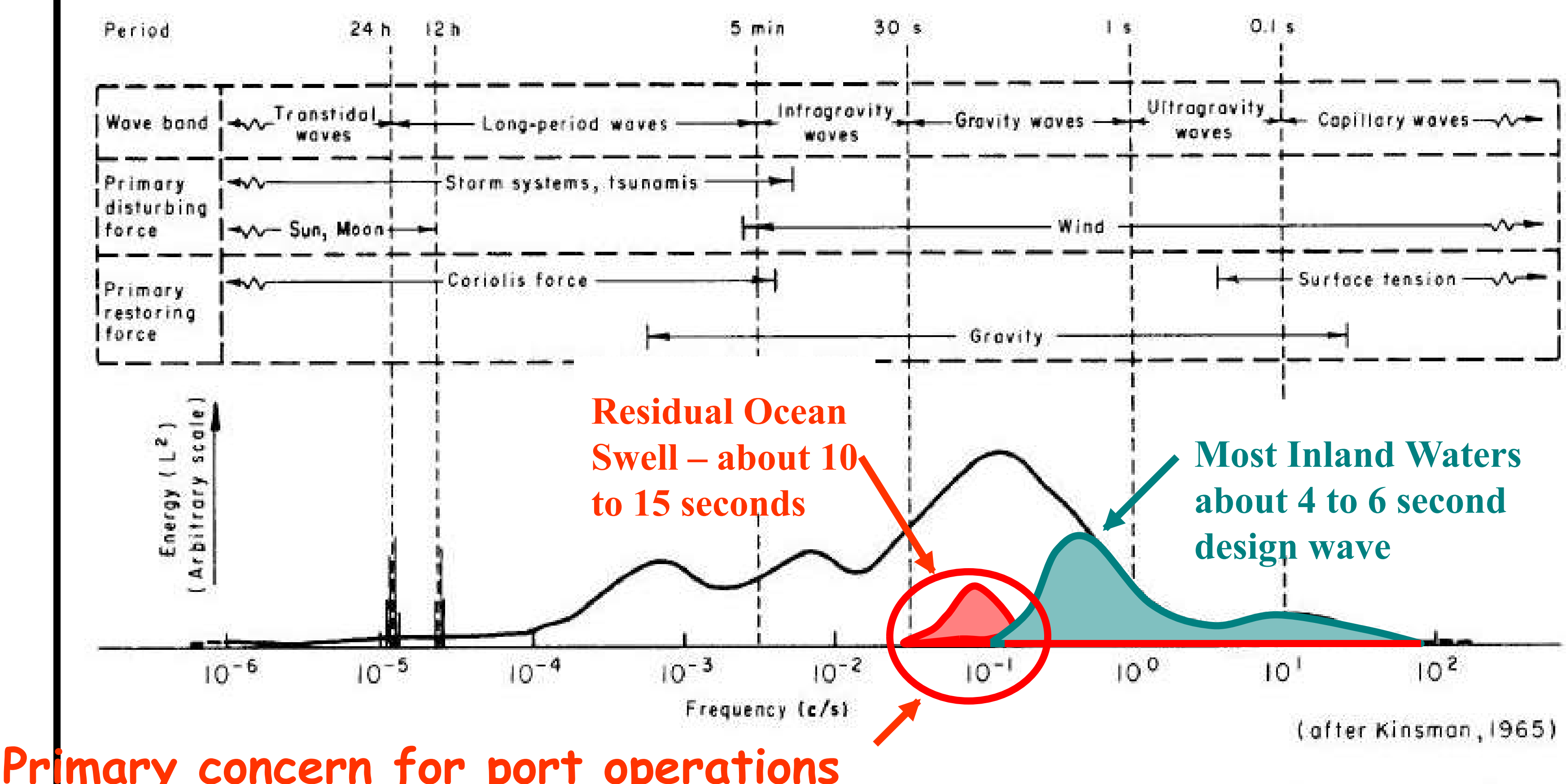


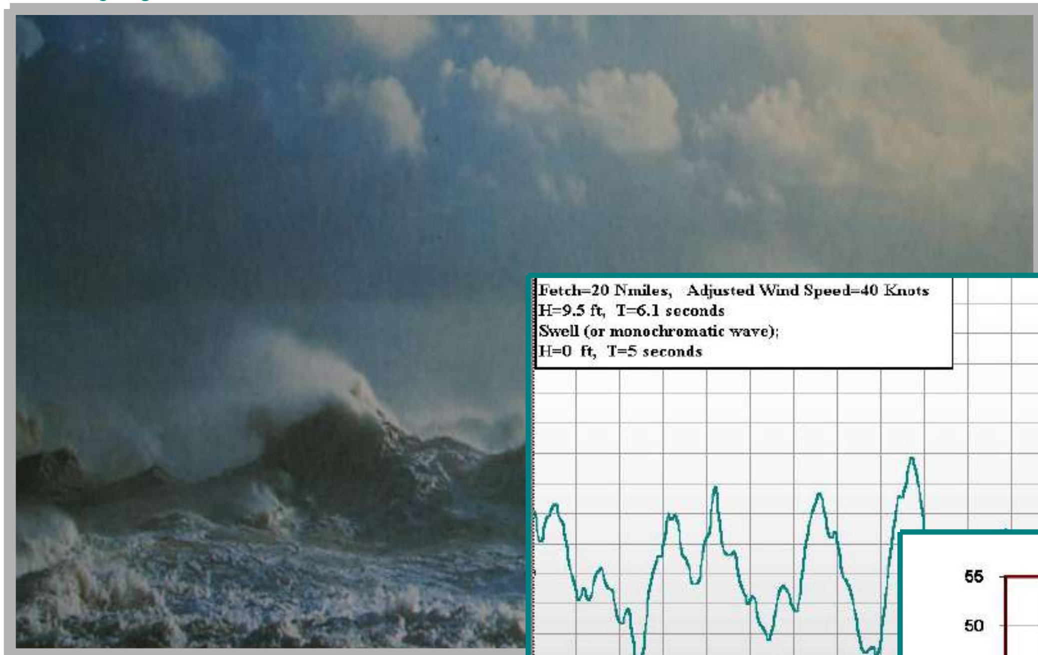
Figure 2-1. Approximate distribution of ocean surface wave energy illustrating the classification of surface waves by wave band, primary disturbing force, and primary restoring force.

Sea State as most engineers design it

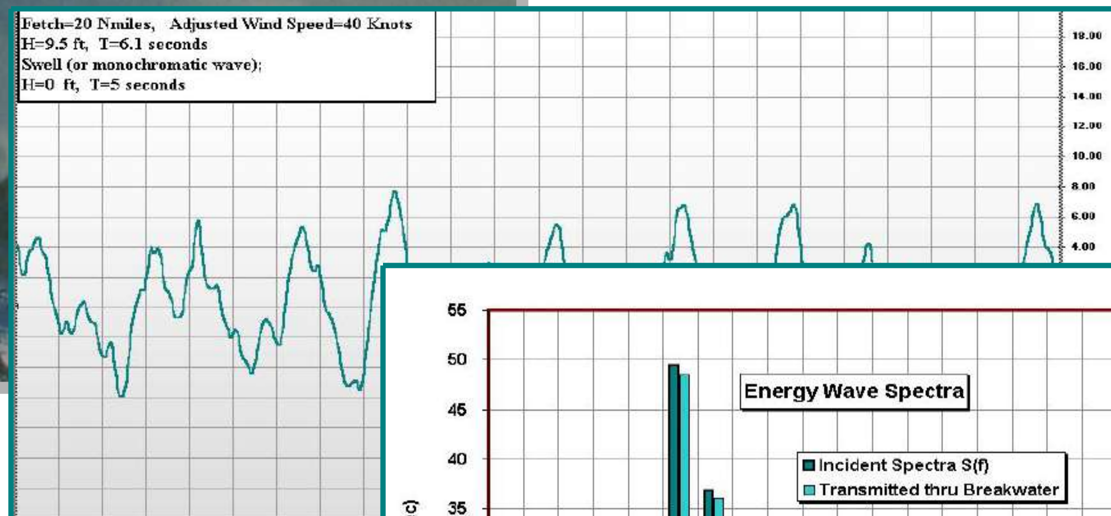
Typical Sea State

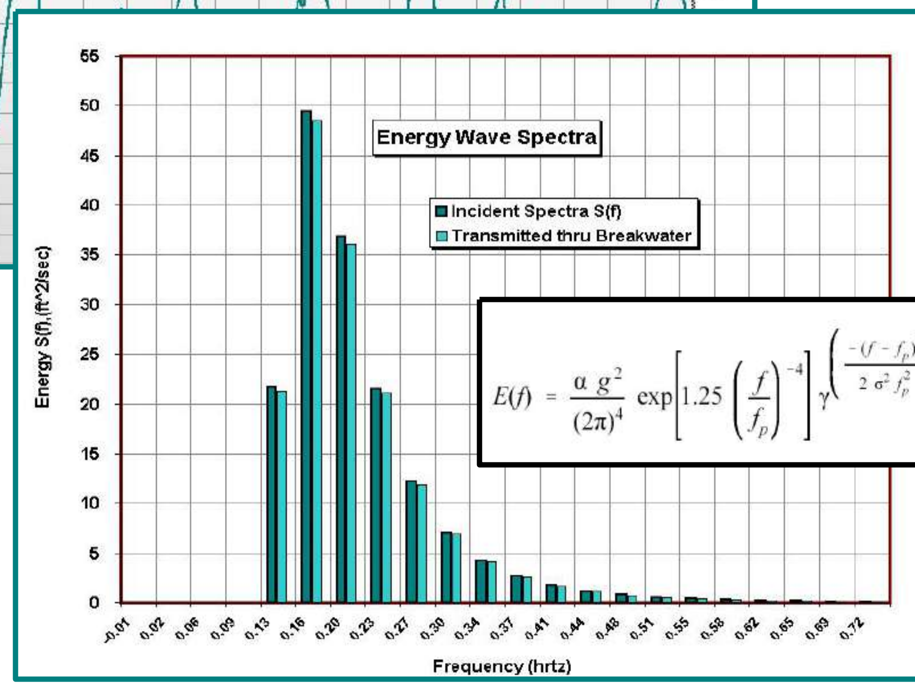
What tools can we use to describe it numerically ??

Typical Sea State – How It's Quantified



Typical Wave Record (Time Series)



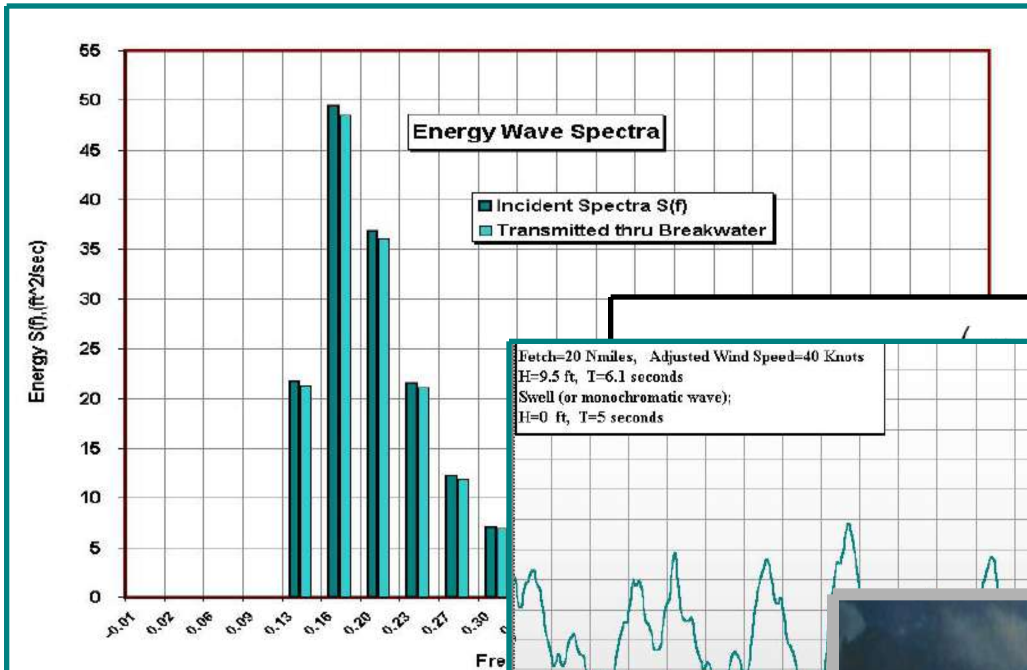


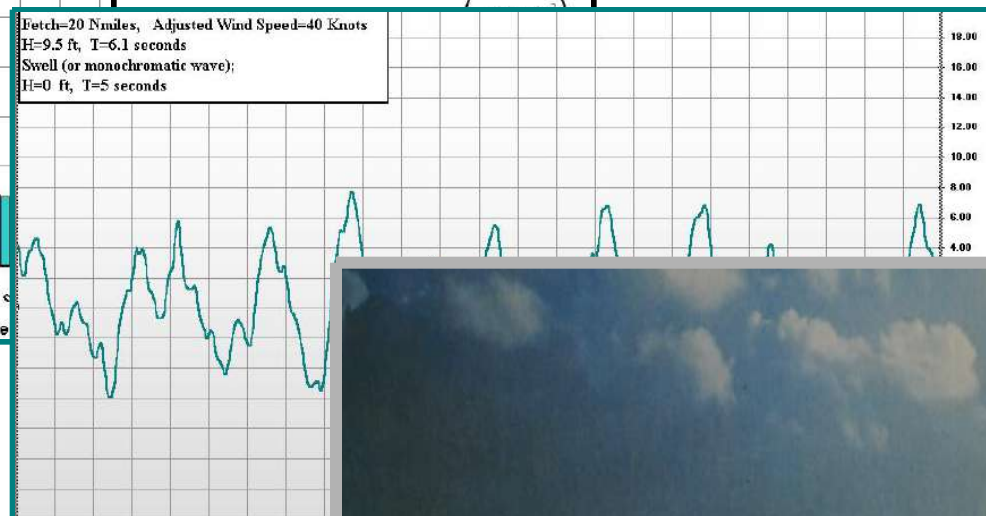
$$E(f) = \frac{\alpha\, g^2}{(2\pi)^4}\, \exp\left[1.25\left(\frac{f}{f_p}\right)^{-4}\right] \gamma^{\left(\frac{-(f-f_p)^2}{2\,\sigma^2 f_p^2}\right)}$$

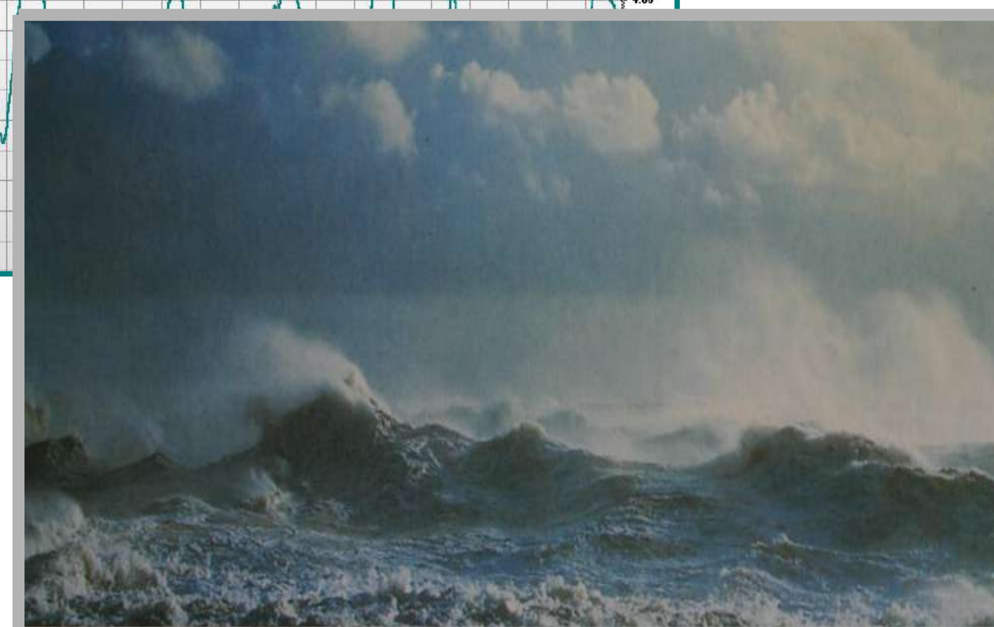
Use Fast Fourier Transform (FFT) to get Frequency Spectra

"Similar to earthquake design for Bridges"

In Design we go backwards







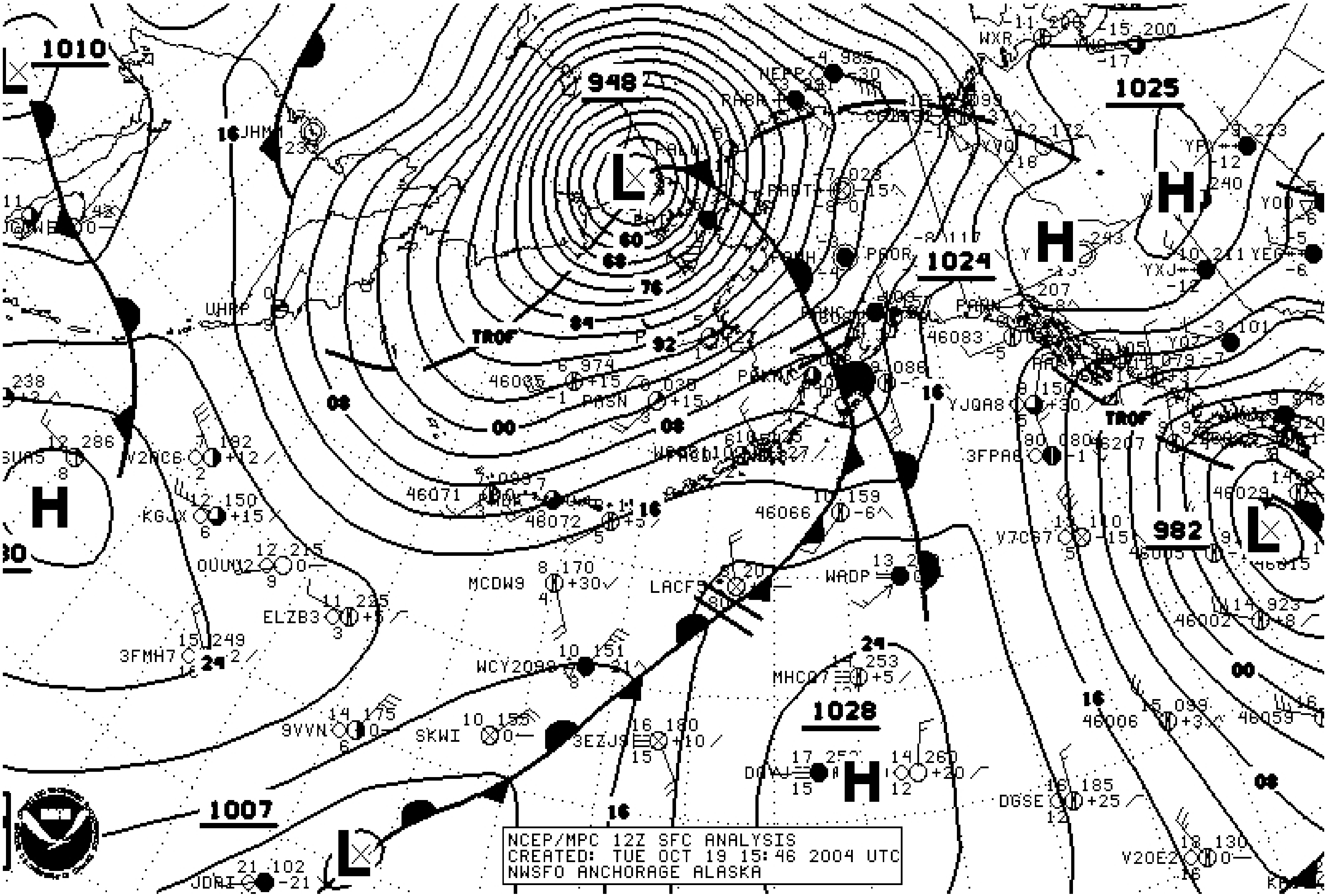
Starting with a Spectral Model

(Usually JONSWAP or SMB)

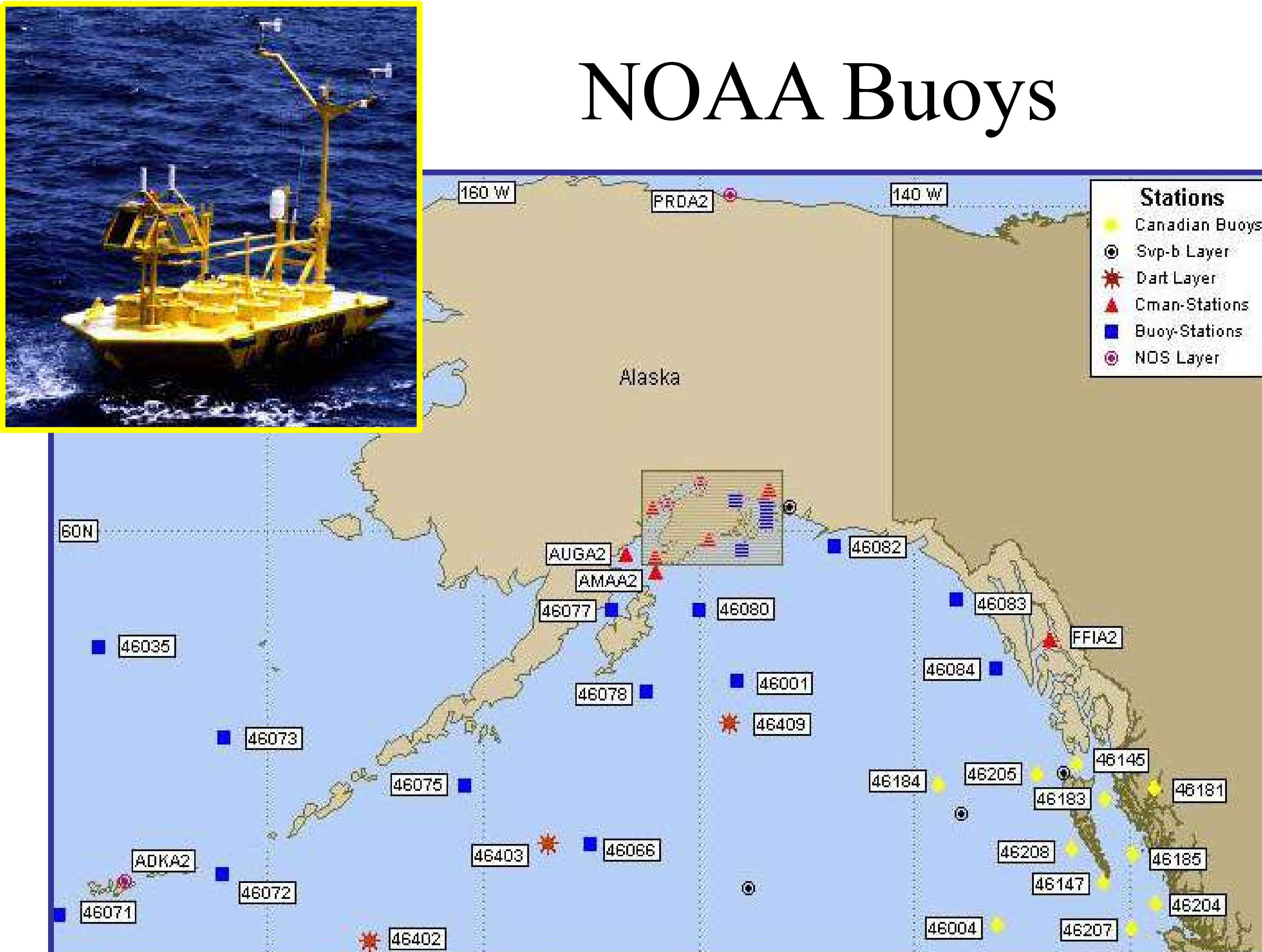
We Develop a Numerical Time Series

Representing a design Storm Event

METEOROLOGY



NOAA Buoys


160 W
PRDA2
140 W
Stations
Canadian Buoys
Svp-b Layer
Dart Layer
Cman-Stations
Buoy-Stations
NOS Layer
Alaska
60N
AUGA2
AMAA2
46082
46083
46077
46080
FFIA2
46035
46084
46001
46078
46409
46073
46145
46184
46205
46181
46075
46183
46208
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46403
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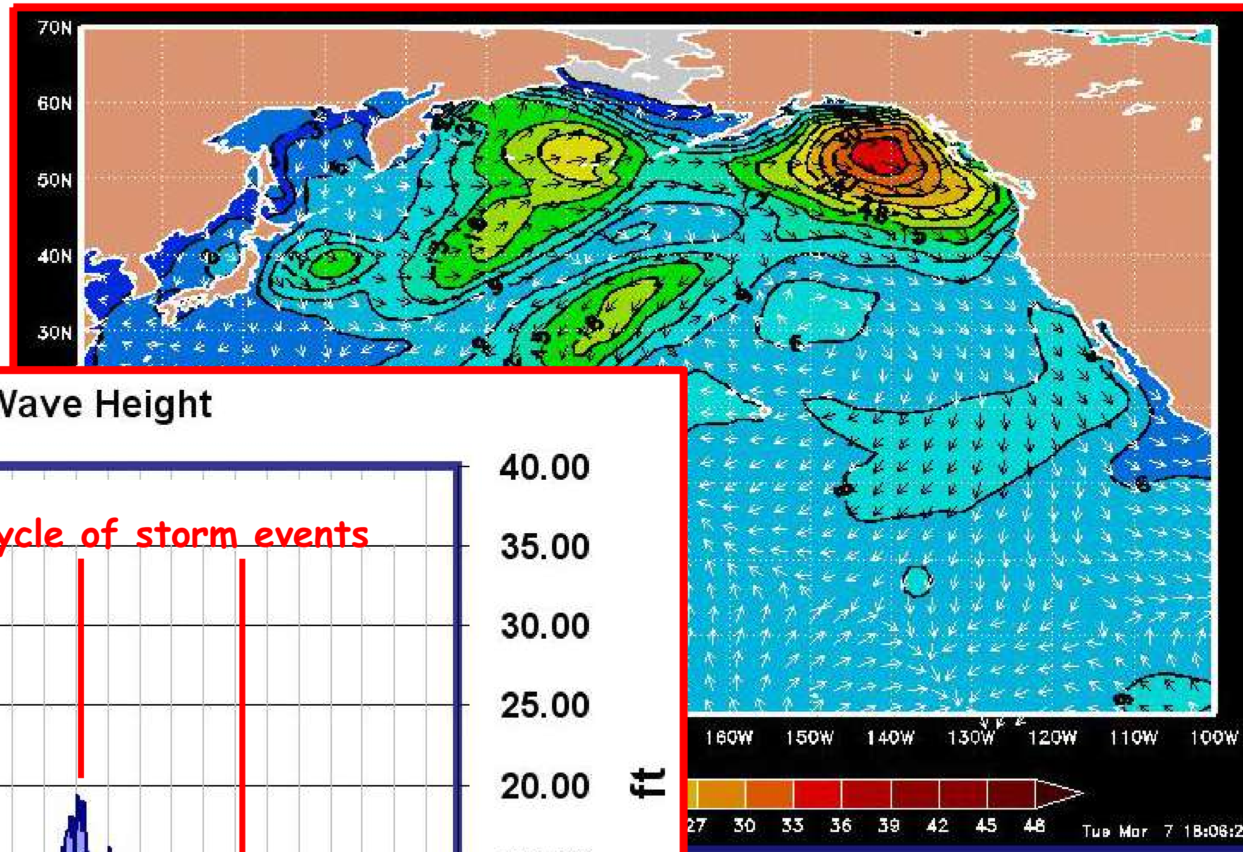
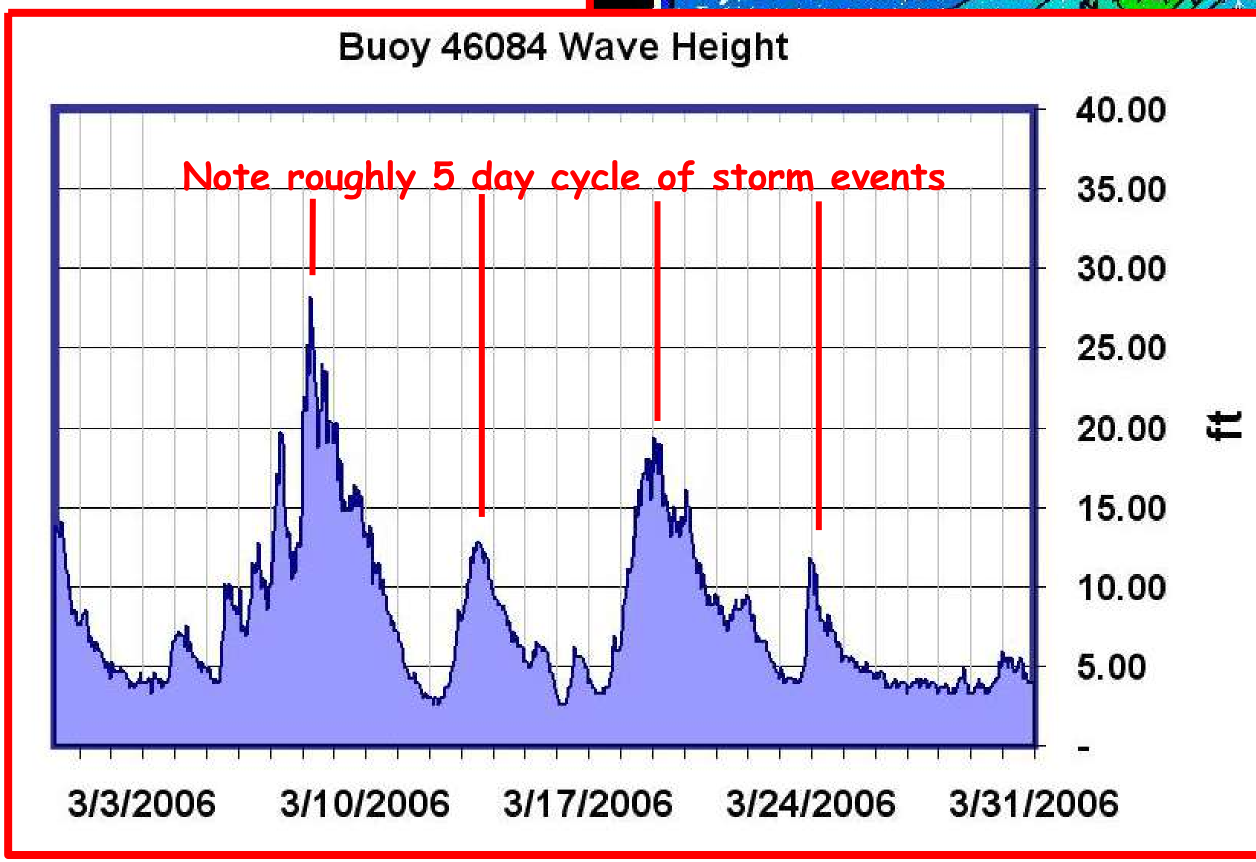
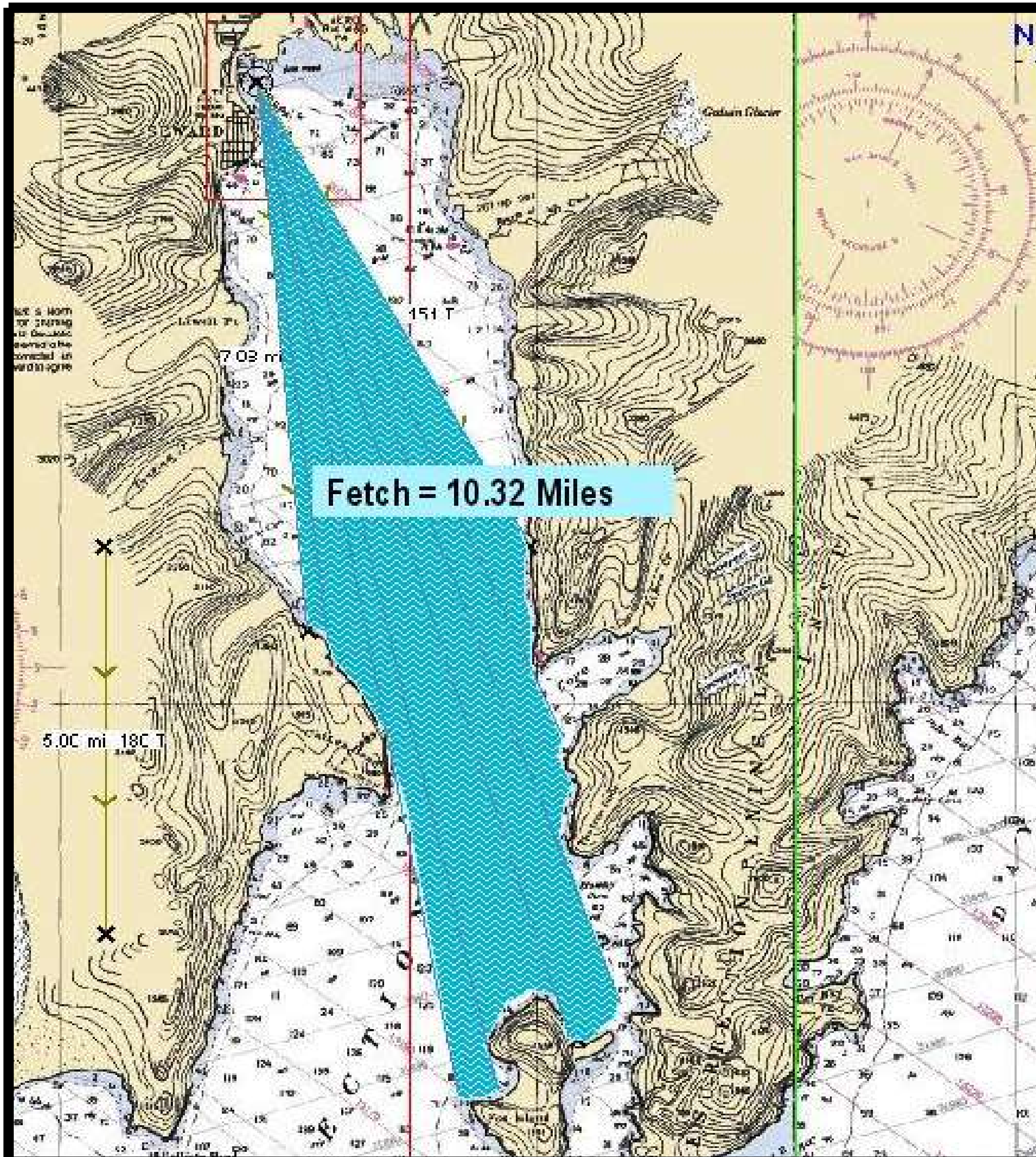
ADKA2
46147
46072
46204
46071
46004
46207
46402

March 8 Storm in Gulf





Local Fetches



Estimating Wave Height & Period

Wave Height (H)

$$\frac{gH}{U_A^2} = 0.283 \tanh\left[0.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right] \tanh\left\{\frac{0.00565\left(\frac{gF}{U_A^2}\right)^{1/2}}{\tanh\left[0.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right]}\right\}$$

Wave Period (T)

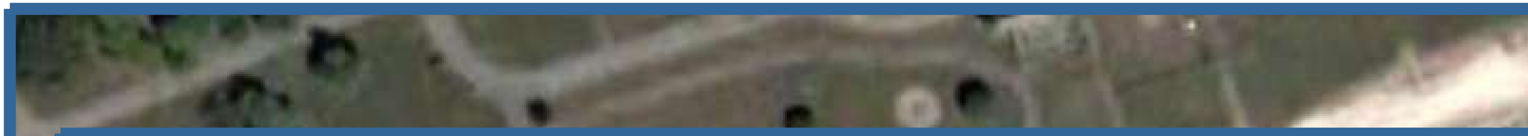
$$\frac{gT}{U_A} = 7.54 \tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right] \tanh\left\{\frac{0.0379\left(\frac{gF}{U_A^2}\right)^{1/3}}{\tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right]}\right\}$$

O Wind Stress Factor (U_A)
O Fetch (F)
O Water Depth (d)

Shallow Water Wave Transformation

- Refraction
- Diffraction
- Shoaling
- Reflection

Refraction & Diffraction



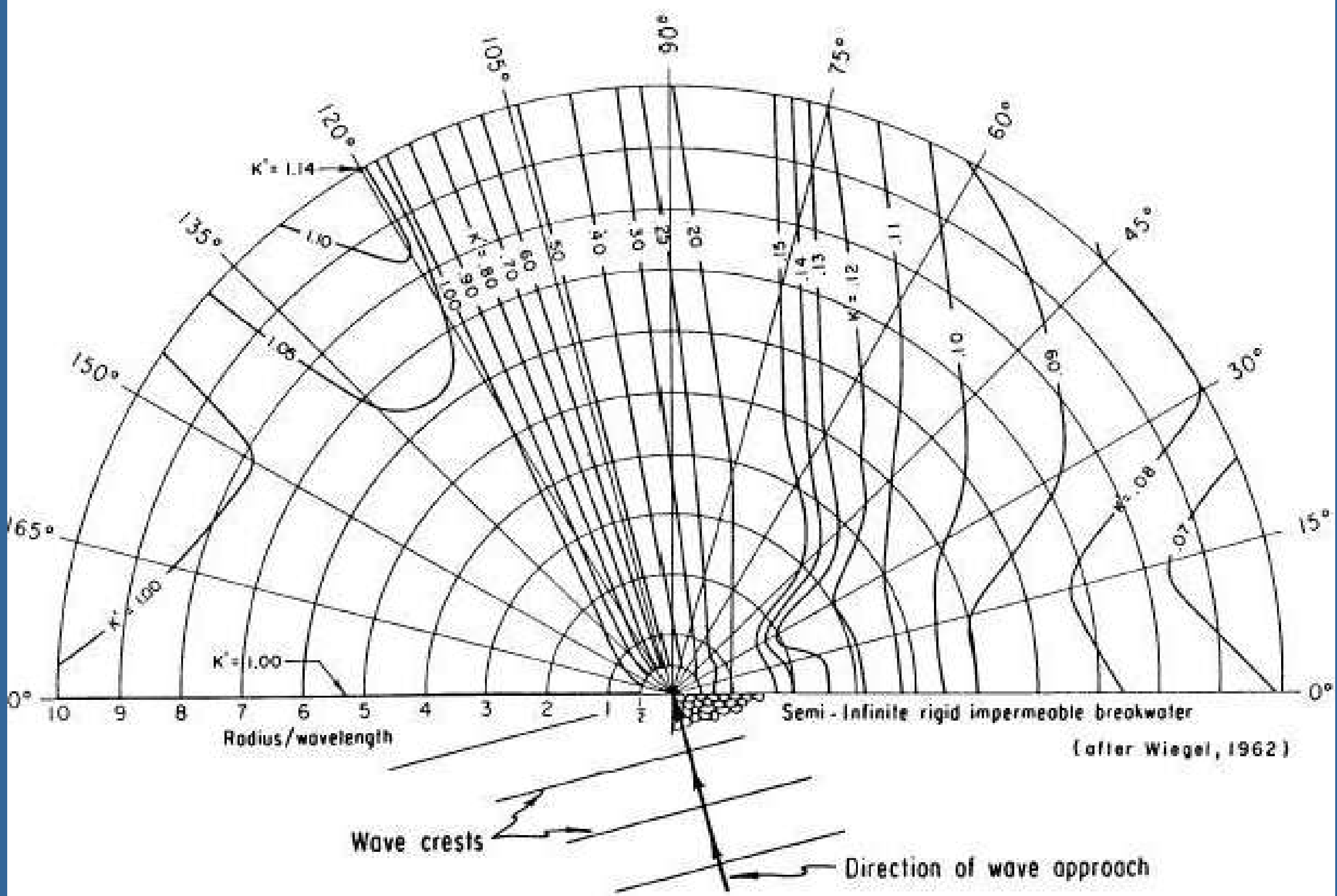


Figure 2-34. Wave diffraction diagram--105° wave angle.

Dredging and Channel Design


The End

Small Boat Harbors

- A location for permanent or temporary moorage of small unattended vessels.
- Moorings normally consist of floating docks.
- The vessel size in harbors generally vary from about 18 foot skiffs up to about 150 foot commercial fishing boats.
- Larger boats are more often associated with ports and movement of cargo.

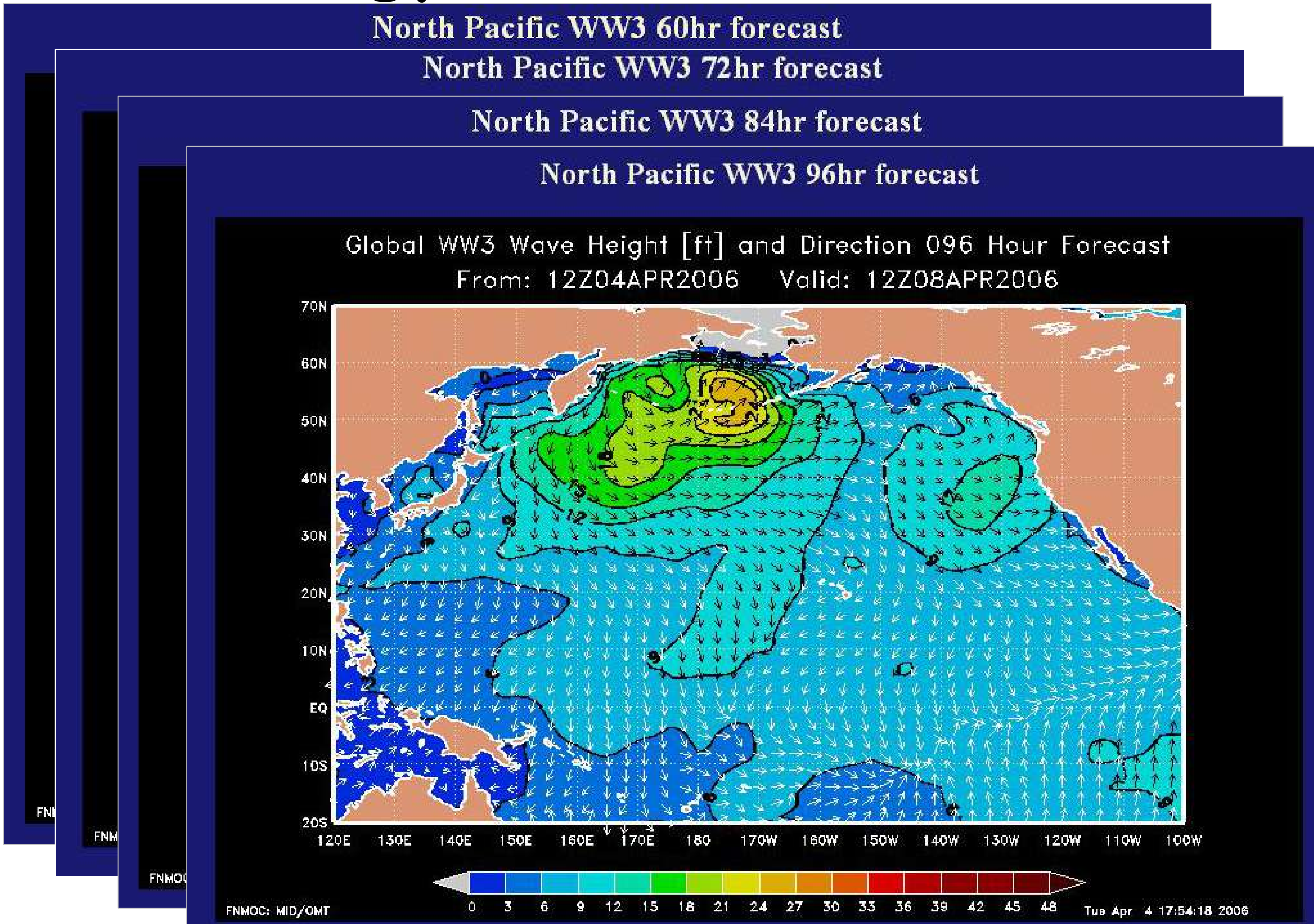
Linear Wave Theory

RELATIVE DEPTH	SHALLOW WATER $\frac{d}{L} < \frac{1}{25}$	TRANSITIONAL WATER $\frac{1}{25} < \frac{d}{L} < \frac{1}{2}$	DEEP WATER $\frac{d}{L} > \frac{1}{2}$
1. Wave profile	Same As →	$\eta = \frac{H}{2}\cos\left[\frac{2\pi x}{L} - \frac{2\pi t}{T}\right] = \frac{H}{2}\cos\theta$	← Same As
2. Wave celerity	$C = \frac{L}{T} = \sqrt{gd}$	$C = \frac{L}{T} = \frac{gT}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$	$C = C_o = \frac{L}{T} = \frac{gT}{2\pi}$
3. Wavelength	$L = T\sqrt{gd} = CT$	$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$	$L = L_o = \frac{gT^2}{2\pi} = C_o T$
4. Group velocity	$C_g = C = \sqrt{gd}$	$C_g = nC = \frac{1}{2}\left[1 + \frac{4\pi d/L}{\sinh(4\pi d/L)}\right] \cdot C$	$C_g = \frac{1}{2}C = \frac{gT}{4\pi}$
5. Water Particle Velocity (a) Horizontal	$u = \frac{H}{2}\sqrt{\frac{g}{d}}\cos\theta$	$u = \frac{H}{2}\frac{gT}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta$	$u = \frac{\pi H}{T} e^{\frac{2\pi z}{L}}\cos\theta$
(b) Vertical	$w = \frac{H\pi}{T}\left(1 + \frac{z}{d}\right)\sin\theta$	$w = \frac{H}{2}\frac{gT}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta$	$w = \frac{\pi H}{T} e^{\frac{2\pi z}{L}}\sin\theta$
6. Water Particle Accelerations (a) Horizontal	$a_x = \frac{H\pi}{T}\sqrt{\frac{g}{d}}\sin\theta$	$a_x = \frac{g\pi H}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta$	$a_x = 2H\left(\frac{\pi}{T}\right)^2 e^{\frac{2\pi z}{L}}\sin\theta$
(b) Vertical	$a_z = -2H\left(\frac{\pi}{T}\right)^2\left(1 + \frac{z}{d}\right)\cos\theta$	$a_z = -\frac{g\pi H}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta$	$a_z = -2H\left(\frac{\pi}{T}\right)^2 e^{\frac{2\pi z}{L}}\cos\theta$
7. Water Particle Displacements (a) Horizontal	$\xi = -\frac{HT}{4\pi}\sqrt{\frac{g}{d}}\sin\theta$	$\xi = -\frac{H}{2}\frac{\cosh[2\pi(z+d)/L]}{\sinh(2\pi d/L)}\sin\theta$	$\xi = -\frac{H}{2} e^{\frac{2\pi z}{L}}\sin\theta$
(b) Vertical	$\zeta = \frac{H}{2}\left(1 + \frac{z}{d}\right)\cos\theta$	$\zeta = \frac{H}{2}\frac{\sinh[2\pi(z+d)/L]}{\sinh(2\pi d/L)}\cos\theta$	$\zeta = \frac{H}{2} e^{\frac{2\pi z}{L}}\cos\theta$
8. Subsurface Pressure	$p = \rho g(\eta - z)$	$p = \rho g\eta\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)} - \rho g z$	$p = \rho g\eta e^{\frac{2\pi z}{L}} - \rho g z$

L=5.12 T^2

Fig. 2-6 84 SPM

Meteorology



https://www.fnmoc.navy.mil/PUBLIC/WAM/all_npac.htm

Common Equations for Port and Harbor Design

Wave Length (Deep Water): When depth(d) > L/2

$$L_0 = \frac{gT^2}{2\pi}$$

or

Deep

$$L_o = 5.12\, T^2 \text{ (feet)}$$

Wave Length : When depth(d) < L/2

$$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)$$

Requires Iterative Solution

However:

Shallow

$$L \approx \frac{gT^2}{2\pi}\sqrt{\tanh\left(\frac{4\pi^2}{T^2}\frac{d}{g}\right)} \approx L_o\sqrt{\tanh\left(\frac{2\pi d}{L_o}\right)}$$