Dredging and Navigational Challenges

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AAPA American Association of Port Authorities
Alliance of the Ports of Canada, the Caribbean, Latin America and the United States

Executive Management Conference:
Leading Your Seaport to Prosperity

moffatt & nichol

Minimizing
Harbor and Channel Siltation

PIANC Working Group No. 43
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PRESENTATION TOPICS

- Why do We Dredge?
- Why Does Sedimentation Happen?
- Recent challenges and opportunities
- Strategies to reduce dredging
- Examples
- Conclusions

WHY DO WE DREDGE?

- To deepen waters for vessel access (new work dredging)
- To maintain depths subject to sedimentation (maintenance dredging)
- Dredged material can be managed by managing sedimentation
- Reducing sedimentation and need for dredging keeps sediment in the natural system

WHY DOES SEDIMENTATION HAPPEN?

- Sediment Movement and Tidal/Wave Conditions Are Balanced in Most Natural Systems
- Many Natural Systems Are Equilibrated and Free of Sedimentation or Scour
- Sedimentation Occurs When:
  - There Is Sediment (Mud, Silt or Sand) In The Water Column
  - Flow Velocities Are Not Strong Enough To Keep Sediment Moving (Usually a result of deepening for navigation/harbor development)

CHALLENGES AND OPPORTUNITIES

- Increases in vessel draft has resulted in continuous deepening of navigation channels and harbor basins
- Maintenance dredging volumes have increased dramatically.
- Conventional maintenance dredging (e.g., off-shore placement) is more a more difficult even for clean sediments.
- Upland disposal capacity limited
- Need to maintain sediment budget in sensitive systems: opportunity for innovative dredging approaches that Keep the Sediment in the System

HOW CAN WE MINIMIZE SEDIMENTATION/DREDGING?

- Build marine facilities in naturally deep water (i.e. Don't deepen)
- Otherwise, "simply":
  - **Keep Sediment Moving (KSM)**
  - **Keep Sediment Out (KSO)**
  - **Keep the Sediment Navigable (KSN)**

KSM IN FLOW-THRU HARBORS & CHANNELS

Possible strategies:

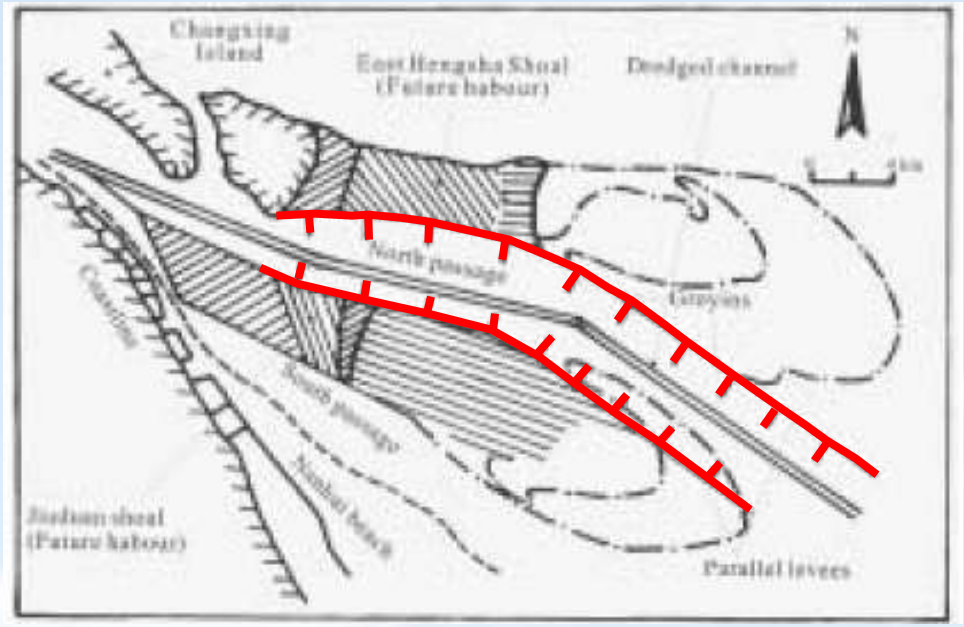
- Place harbor & channels within naturally deep water
- Increase velocity in deepened area by engineering works
  - ➢ Flow training structures that maintain velocities (Passive)
  - ➢ By flow augmentation with jets or water injection dredging (Active)

FLOW-THROUGH HARBORS

Newark Bay, NJ

Wilmington, DE

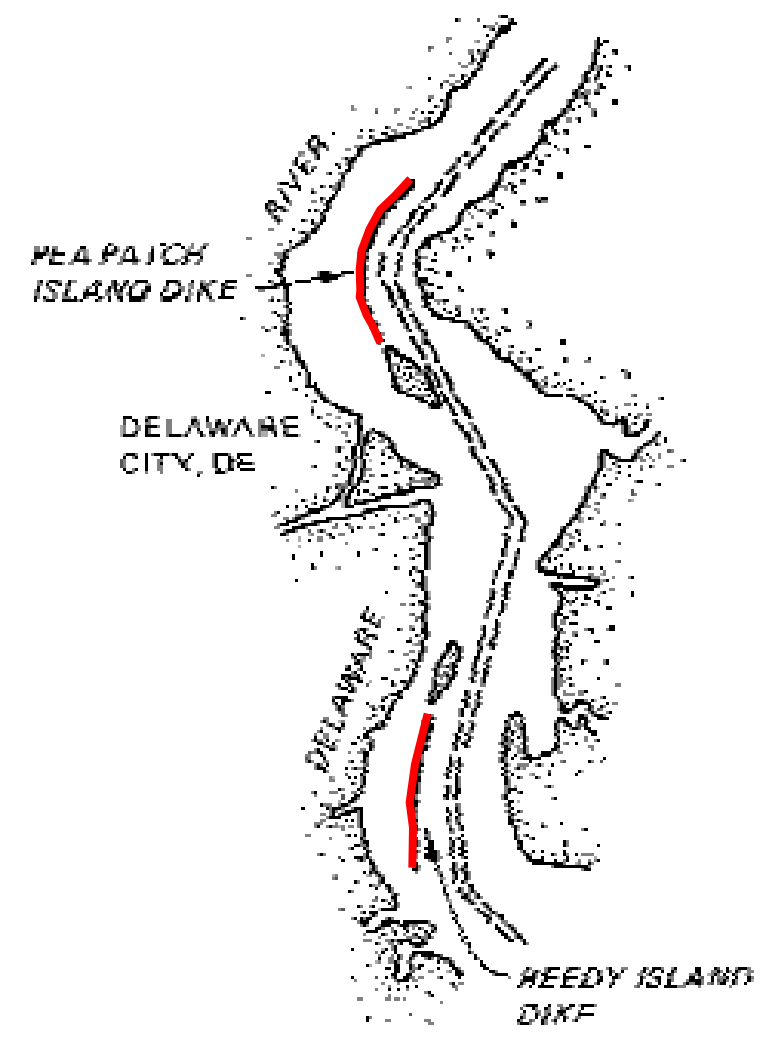
KSM- FLOW TRAINING STRUCTURES MAINTAIN VELOCITY IN A DEEPENED AREA



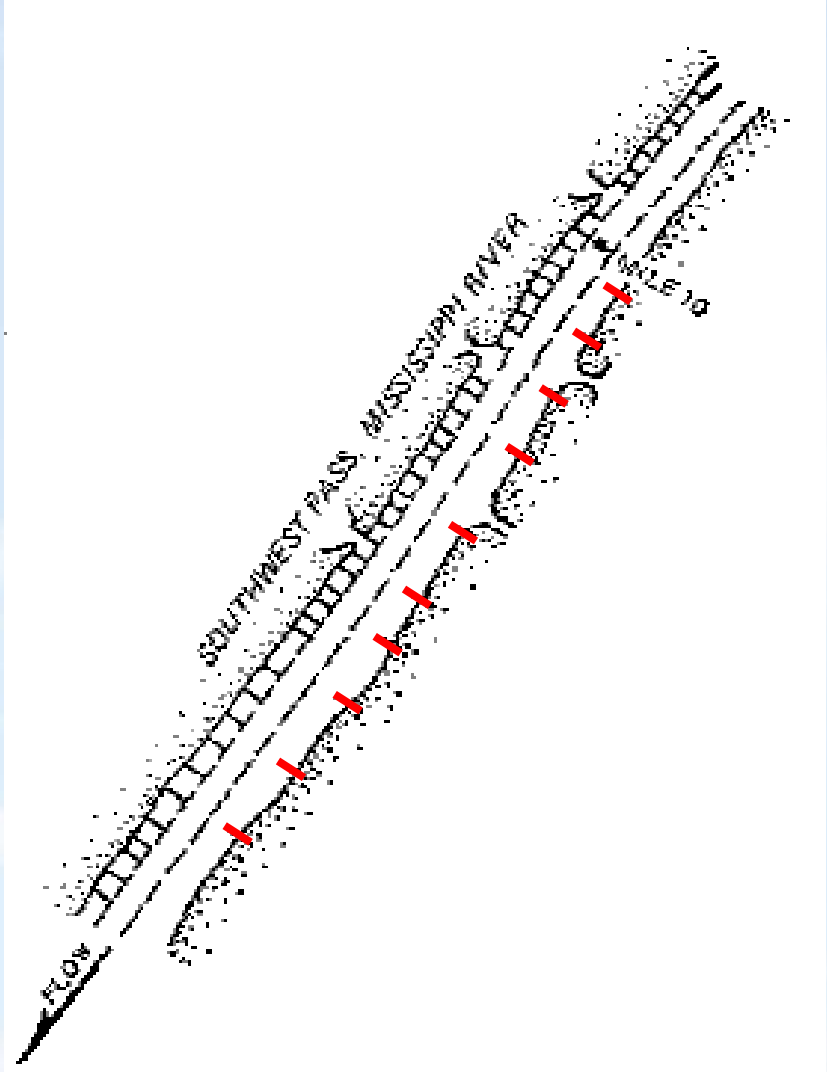
Yangtze River, China

Shooters Island, NY

KSM- FLOW TRAINING STRUCTURES



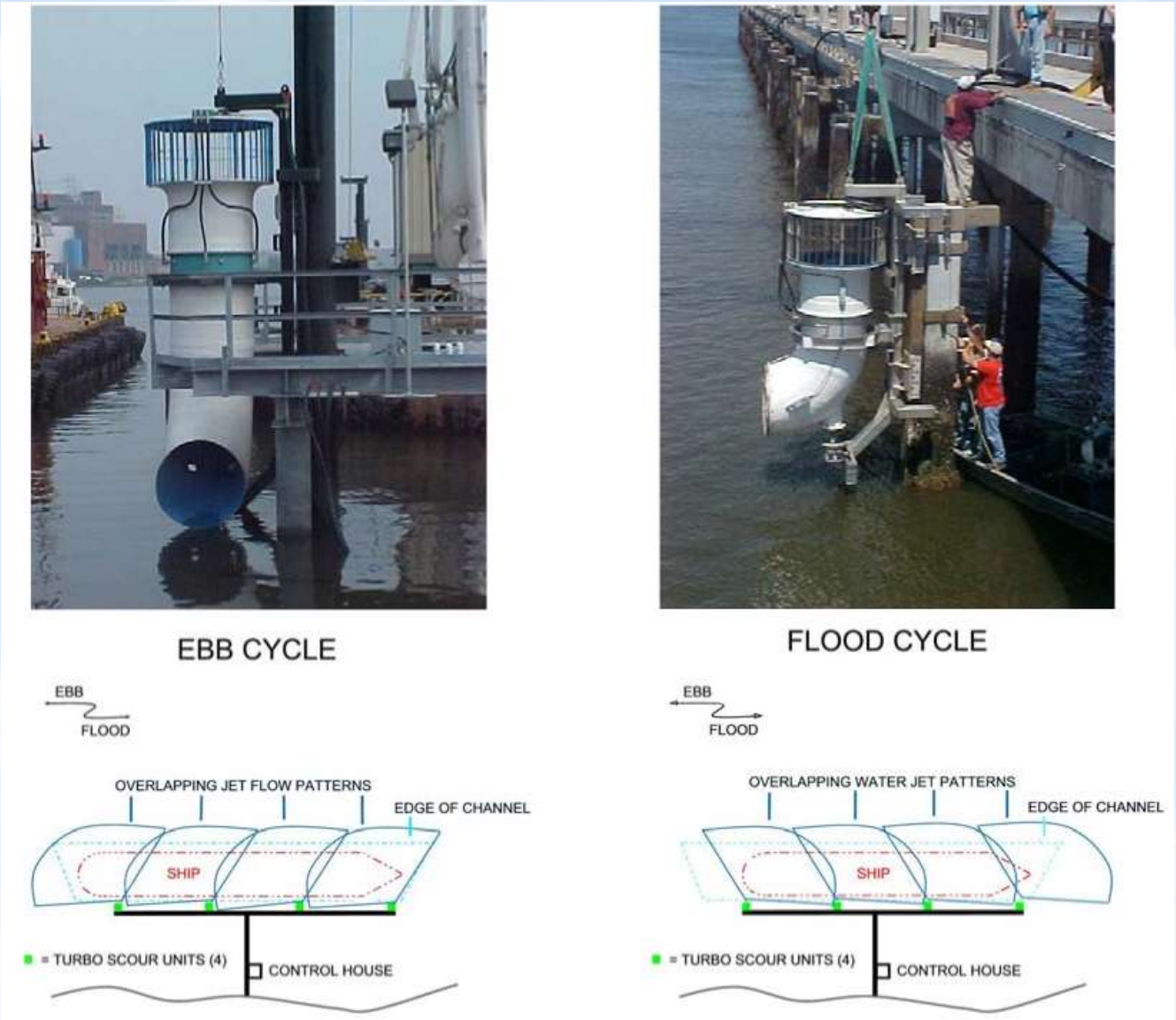
Delaware Bay



Mississippi River

KSM- FLOW AUGMENTATION WITH SCOUR JETS

KSM- FLOW AUGMENTATION WITH PROPELLER JETS



Propeller Jet System, Scour Systems

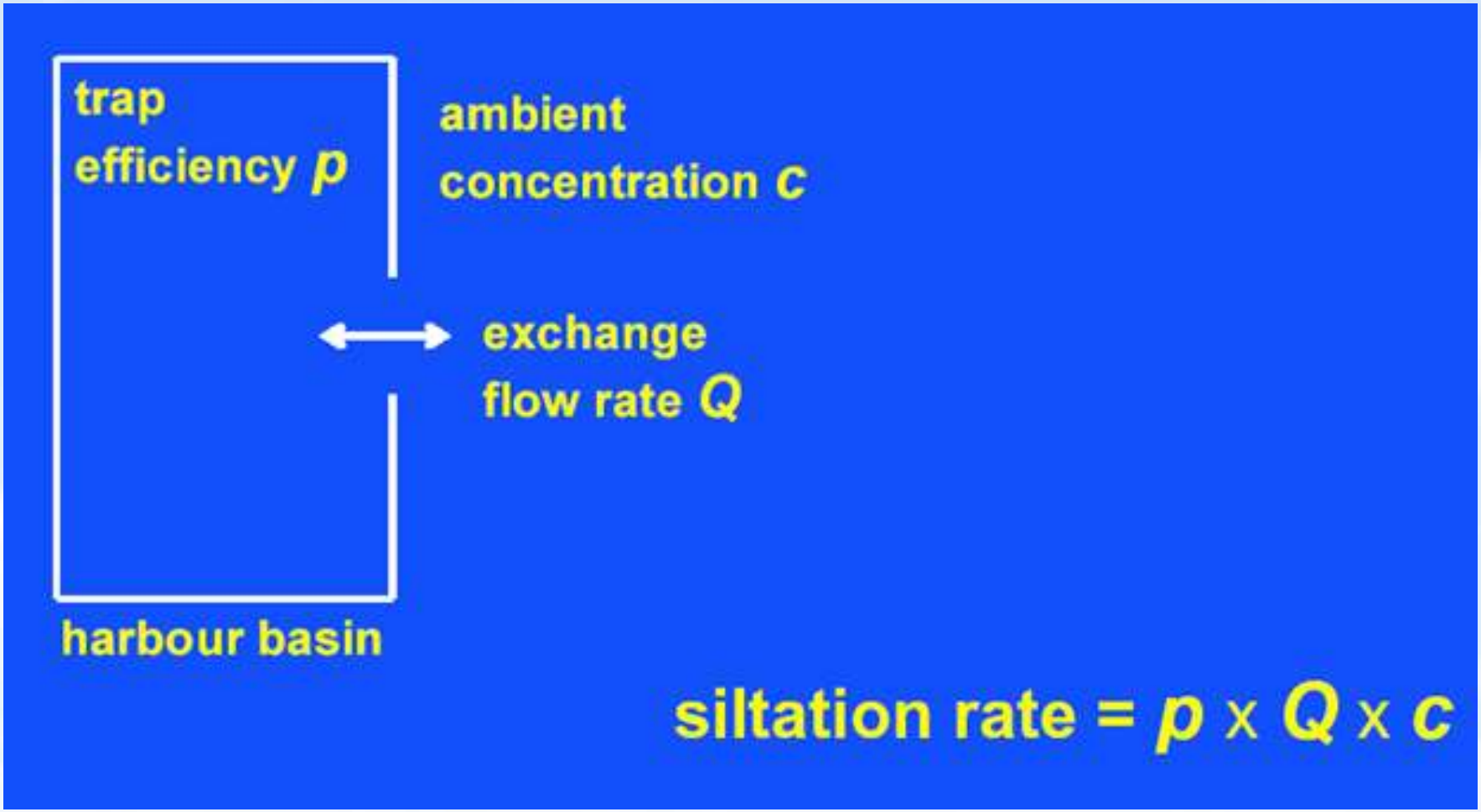
KSM- PROPELLOR/SCOUR JETS

- Systems Have Been Installed:
  - King's Bay, GA
  - Savannah, NC
  - Linden, NJ
  - Gray's Harbor
- Each installation has eliminated dredging
- Best-suited for berthing areas
- System keeps sediment in the natural system

HARBOR BASINS

Port Elizabeth Channel, NJ

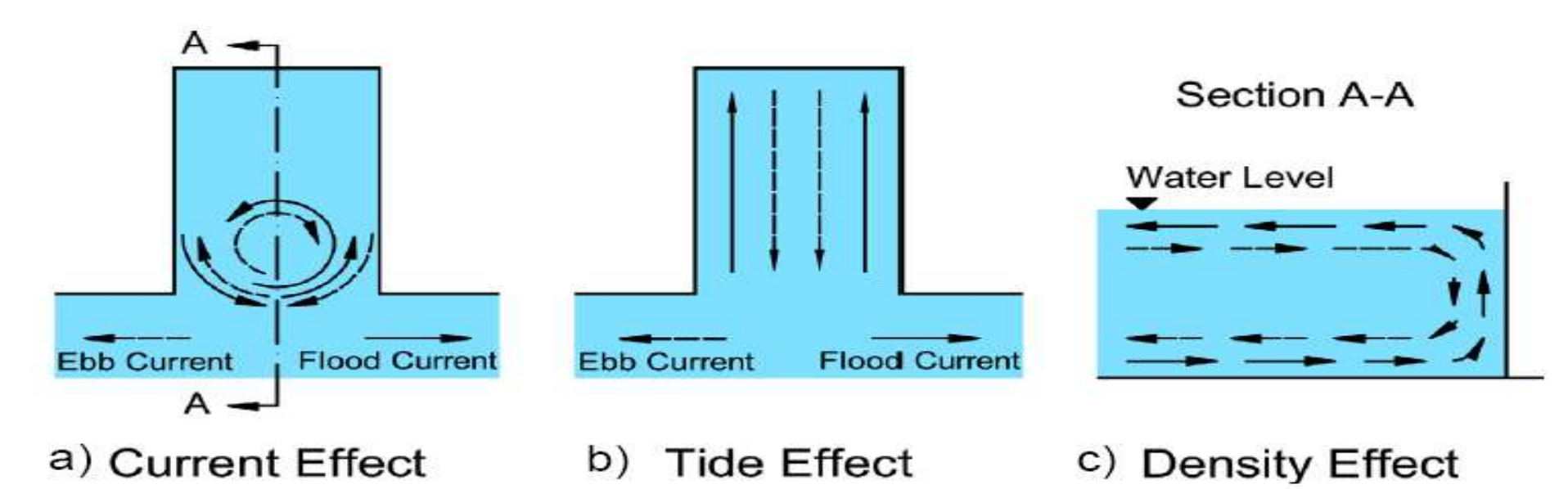
SEDIMENTATION IN BASIN HARBORS



FLOW PHENOMENA IN HARBOR BASINS

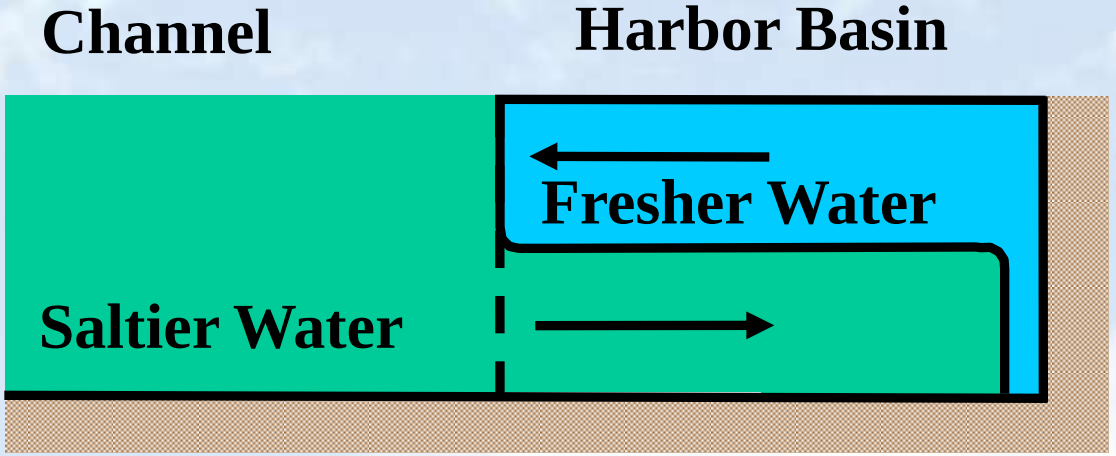
Q Depends on 3 Mechanisms:

- Horizontal Eddy Exchange (Can Be Reduced)
- Tidal Filling (Cannot Be Changed)
- Density Currents (Can Be Reduced)

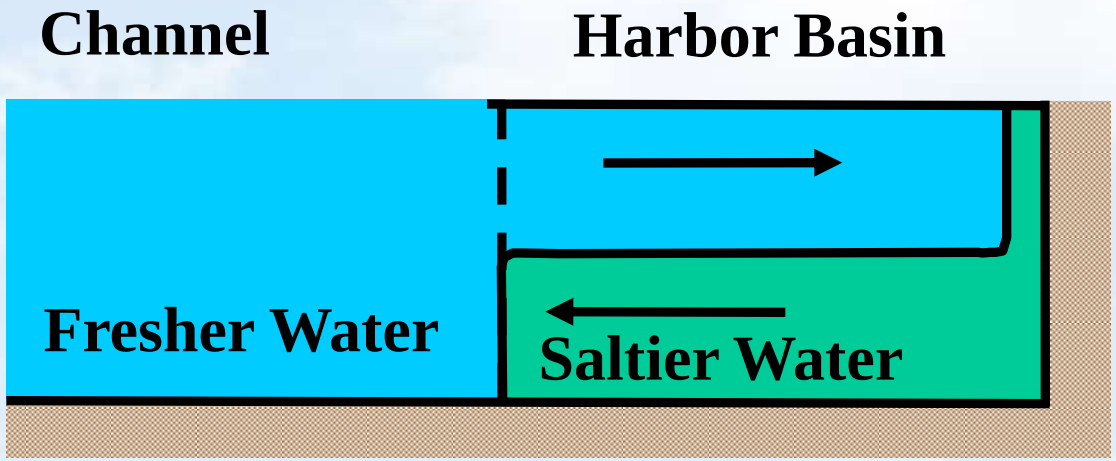


SALT/FRESH WATER DENSITY CURRENTS- HARBOR BASINS

Incoming Tide:
Brings Saltier/Heavier Water To Basin



Outgoing Tide:
Brings Fresher/Lighter Water To Basin



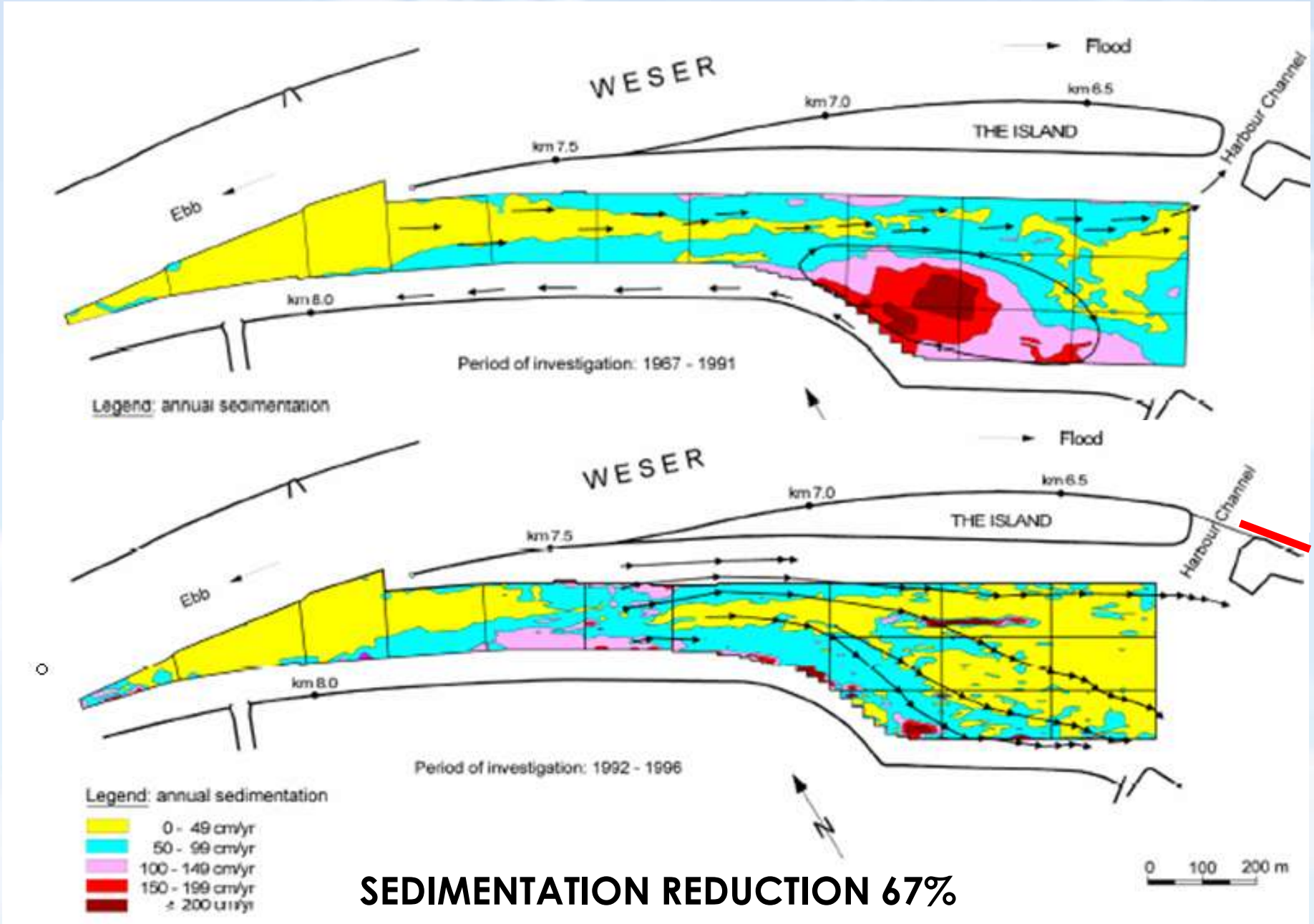
Even a small change in salinity (i.e., 1-2 ppt) can exchange a tremendous volume of water, more than tide or eddy Exchange!!

METHODS TO REDUCE FLOW EXCHANGE

- Narrow Entrance
- Use Only 1 Entrance
- Change Entrance Orientation
- Use Structures to Reduce Q
  - Pile Groin
  - Current Deflecting Wall (CDW)
  - Modified CDW For Density Currents

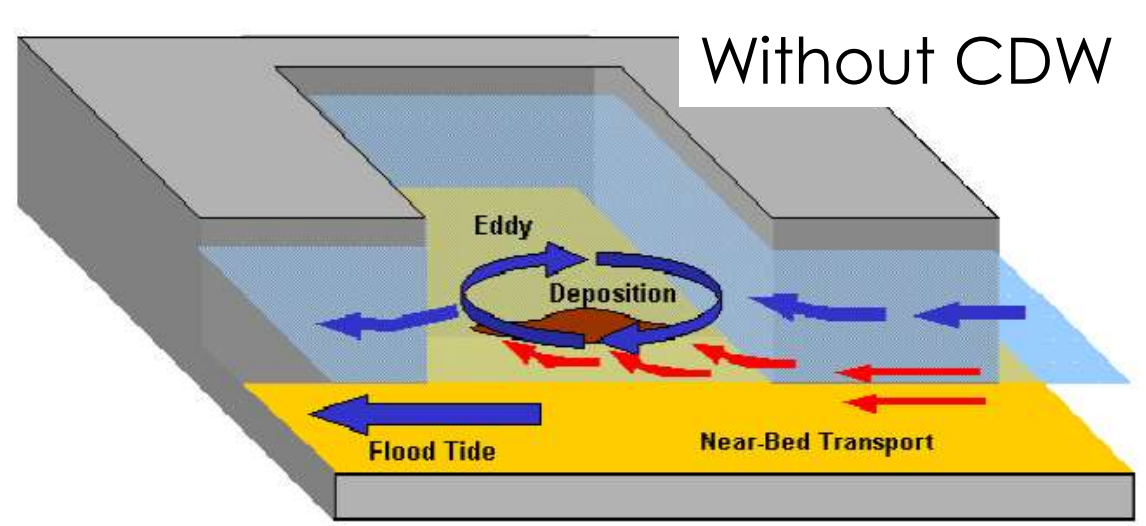
CLOSED SECOND ENTRANCE

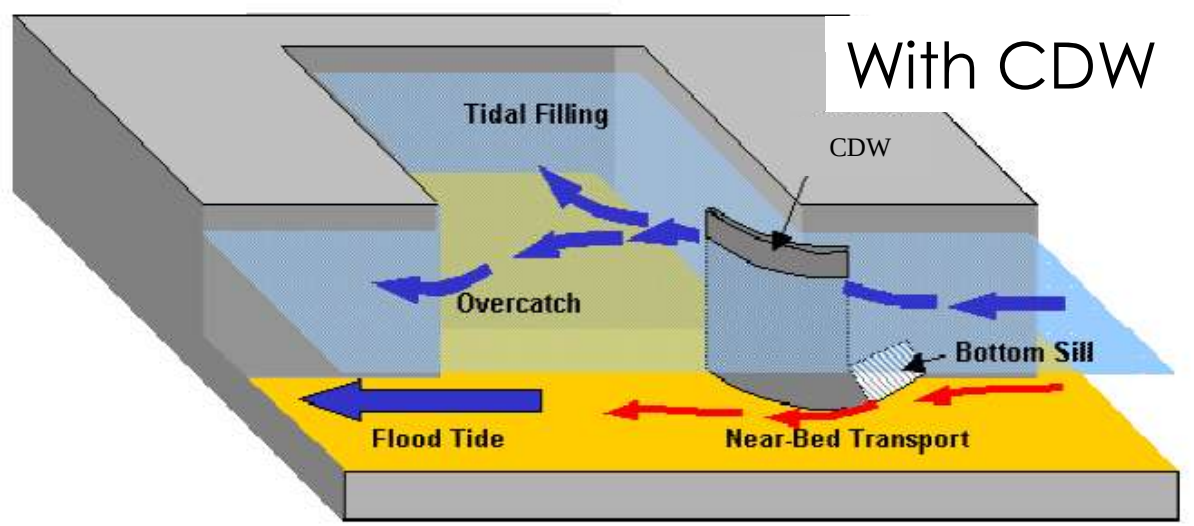
PORT OF BREMEN, GERMANY



SEDIMENTATION REDUCTION 67%

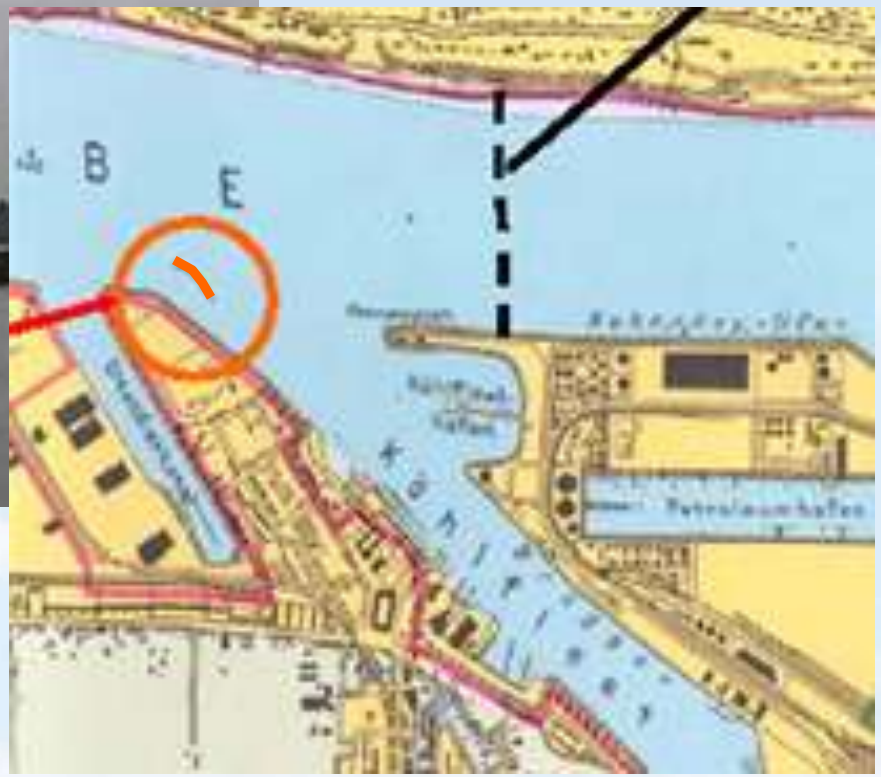
CURRENT DEFLECTING WALL- PRINCIPLES



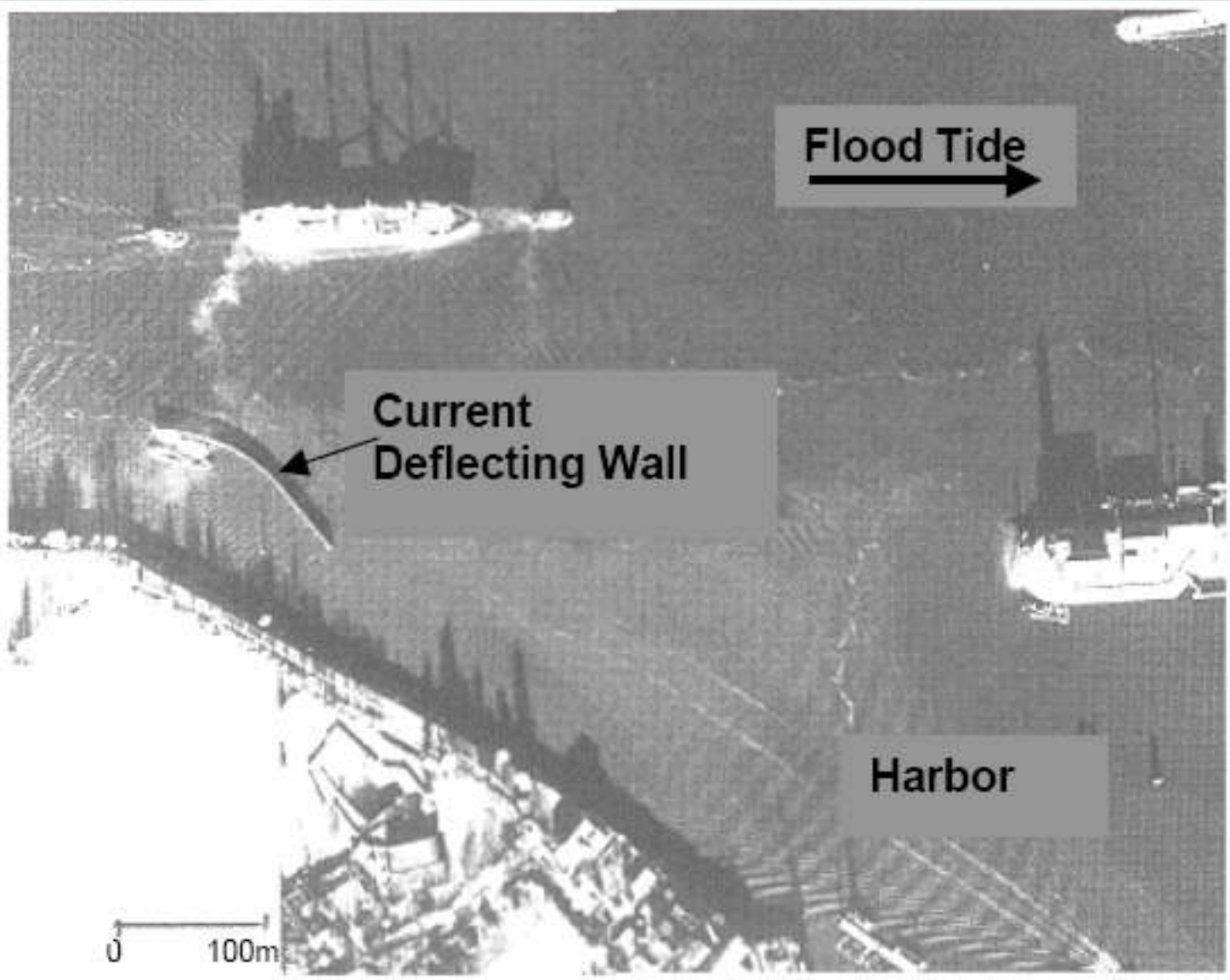


CURRENT DEFLECTING WALL- REDUCES f_h By 30%

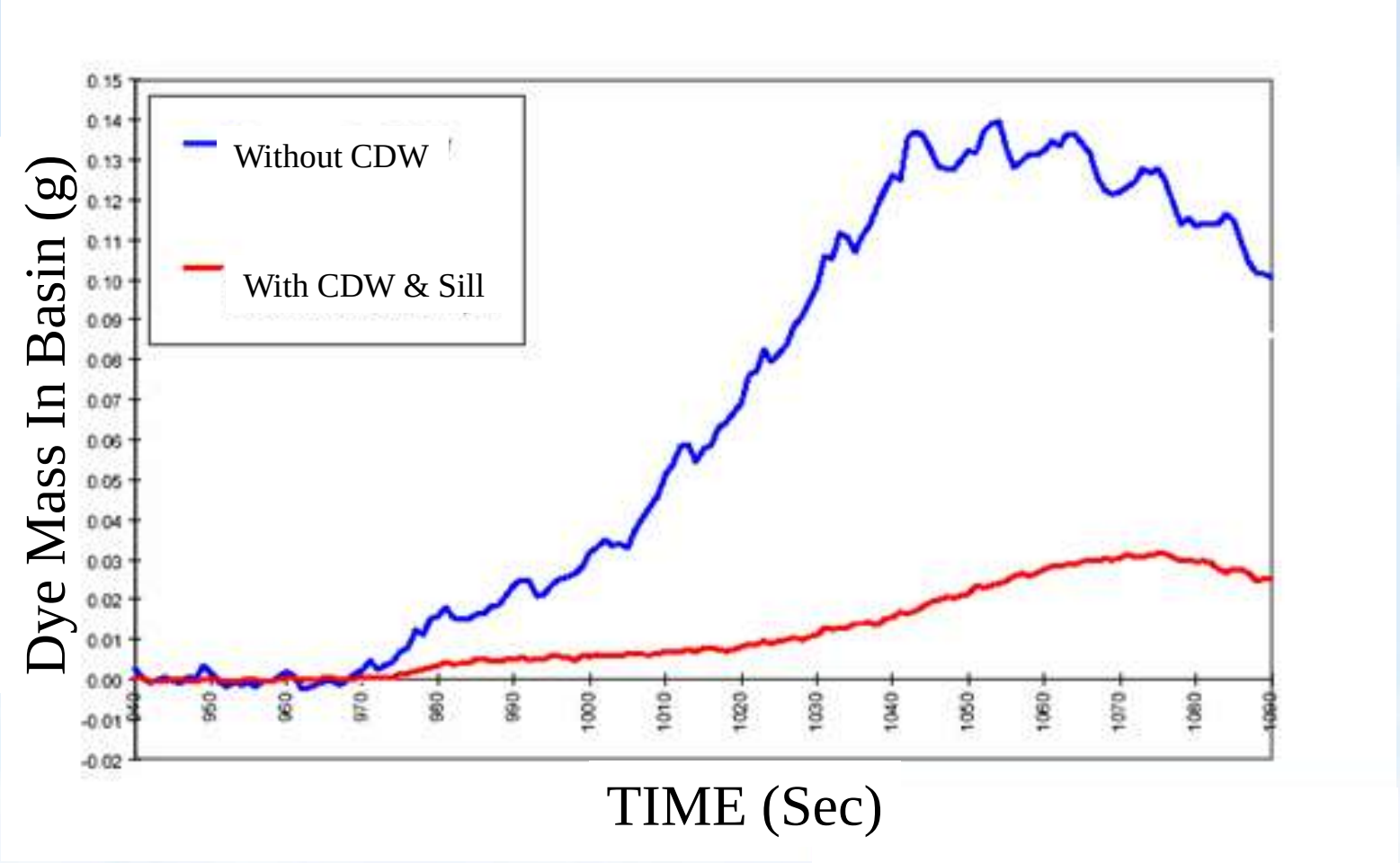
Kohlfleet Harbor Basin
Hamburg, Germany



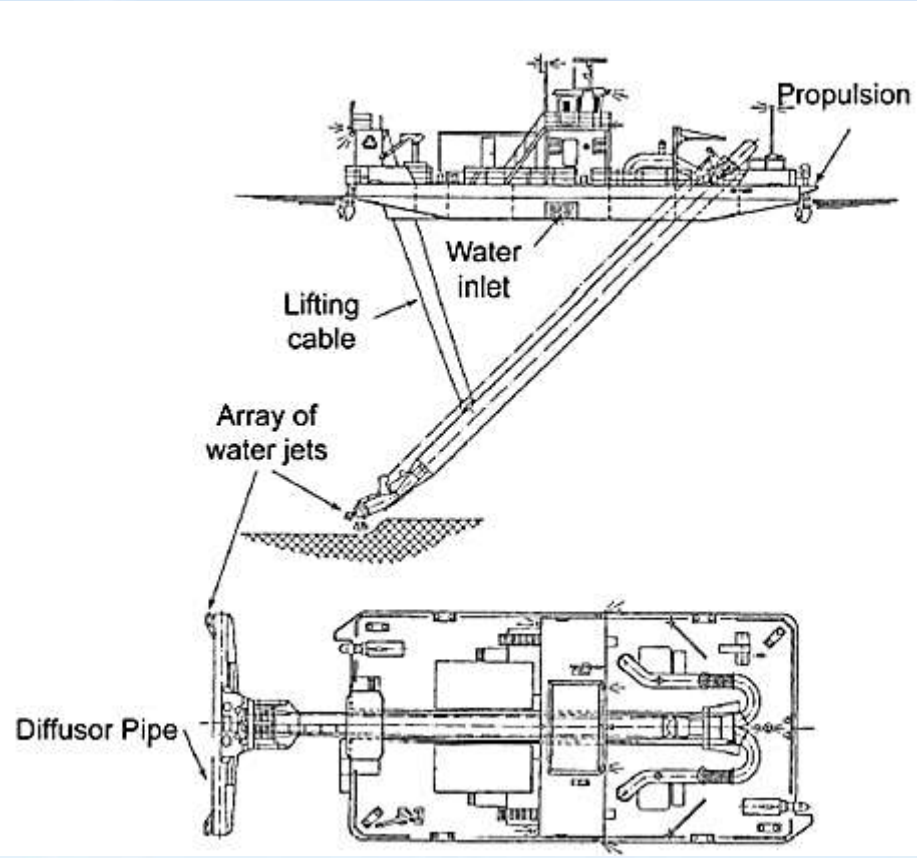
CURRENT DEFLECTING WALL- KOHLFLEET BASIN



CURRENT DEFLECTING WALL FOR DENSITY CURRENTS- PHYSICAL MODEL TESTS



KSM- FLOW AUGMENTATION WITH WATER INJECTION DREDGING (WID)



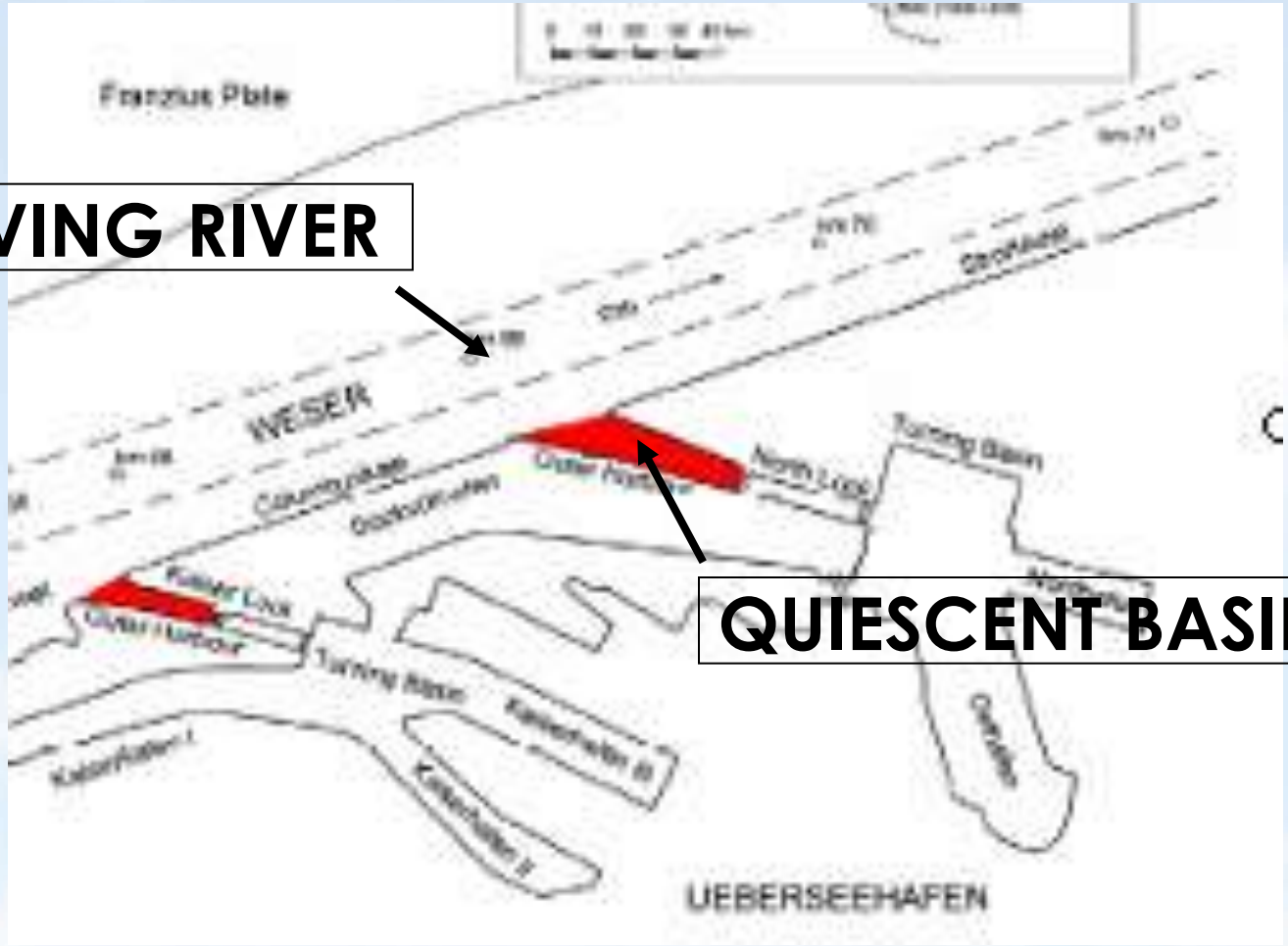
Water Injection Dredge (After van Oord)

KSM- WATER INJECTION DREDGING

- Mobilize Sediments Near the Bottom Under Low Pressure
- Used Extensively In Europe To Move Sediments From Quiescent Areas To Areas of High Velocities
- Sediment Is Lifted Only A Few Feet Off Bottom Creating Little Entrainment
- Can Be Used To Move Sediments Up to 1000m
- 2M m^3 are Managed This Way in Port of Hamburg
- Two possible WID strategies:
  - Strategy 1 (KSM): move shoaled sediment from one area to another
  - Strategy 2 (KSN): Loosen deposited/consolidated sediments to increase navigable depth

KSM- FLOW AUGMENTATION WITH WATER INJECTION DREDGING (WID)

FAST-MOVING RIVER



QUIESCENT BASIN

BREMERHAVEN, GERMANY

KSM- WID, PORT OF BREMERHAVEN, GERMANY

- Historical Sedimentation 350,000 m^3 per year
- WID Used For 11 Years
- WID reduced sedimentation rate to zero
- Eliminated need for upland placement
- Keeps Sediment In the System

WID in the USA (Weeks Marine)

Private Dock Work

- Mississippi River
  - Grain Dock – Convent, LA
  - Refinery – Baton Rouge, LA
  - Refinery – Sunshine, LA
  - Grain Dock – Destrehan, LA
  - Chemical – Plaquemines, LA
  - Refinery – St. James, LA
  - Barge Dock - Jefferson, LA
  - Refinery – St. James, LA
  - Refinery – Jefferson, LA
  - Agricultural – Jefferson, LA
- Atchafalaya River
  - Refinery – Krotz Springs, LA

Federal Navigation

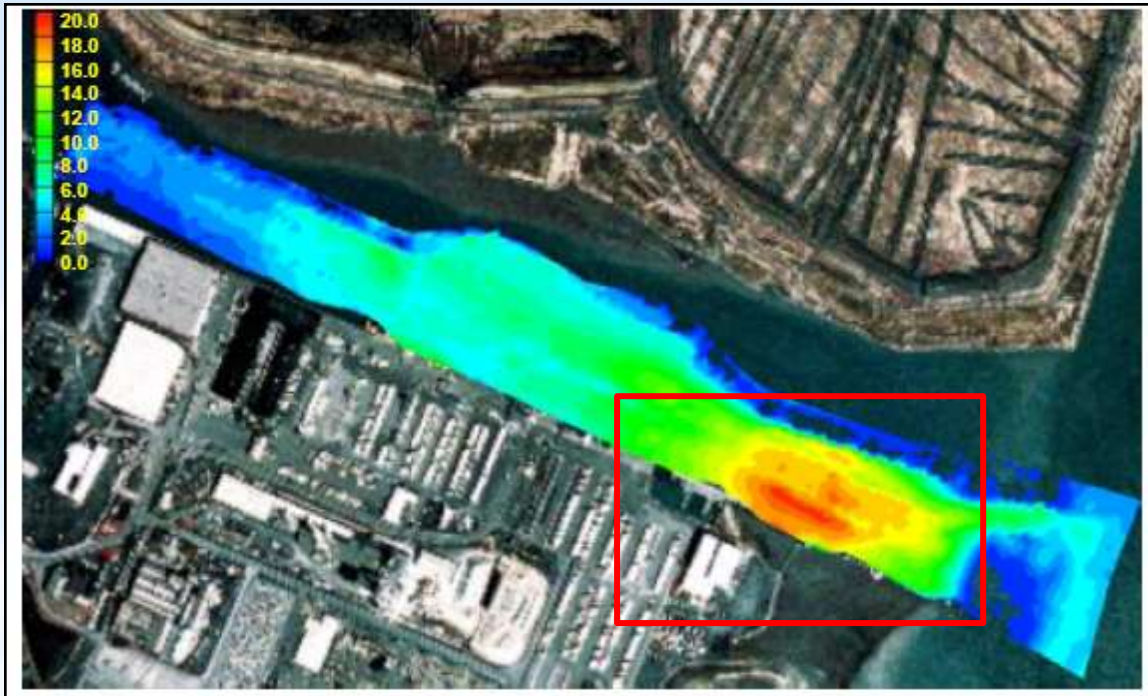
- New Orleans District
  - New Orleans Harbor
  - Michoud Canal
  - Miss. River Gulf Outlet
  - E & W Calumet Floodgates
  - Tiger Pass Channel
- Galveston District
  - Houston Ship Channel
  - Bayport Ship Channel
- Mobile District
  - Horn Island

500,000 m3 in 2009

Wilmington Harbor, DE

PROBLEM

- Shoaling caused by entrance eddy
- Localize sedimentation up to 20 ft per dredge cycle (6-9 months).
- Existing dredging ~500,000 cy/yr ($1.5M/yr).
- Nearby upland disposal site nearing capacity.
- Future dredging costs are expected to increase by 3 times ($5M/yr).



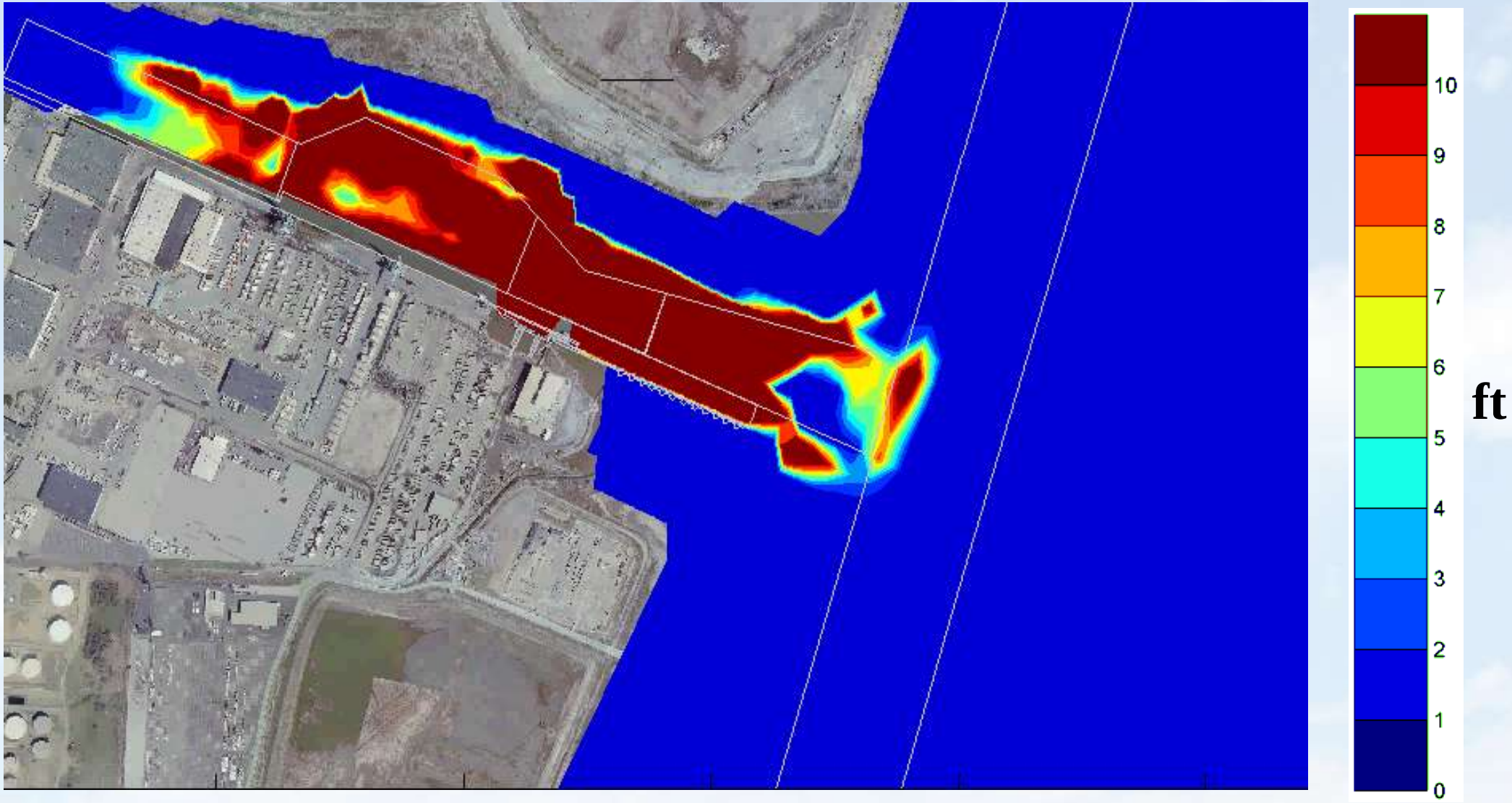
Surveyed Shoaling 2/17/97 to 10/15/97 (240 days)

Figure provided by USACE Philadelphia

Modeling Approach – WID

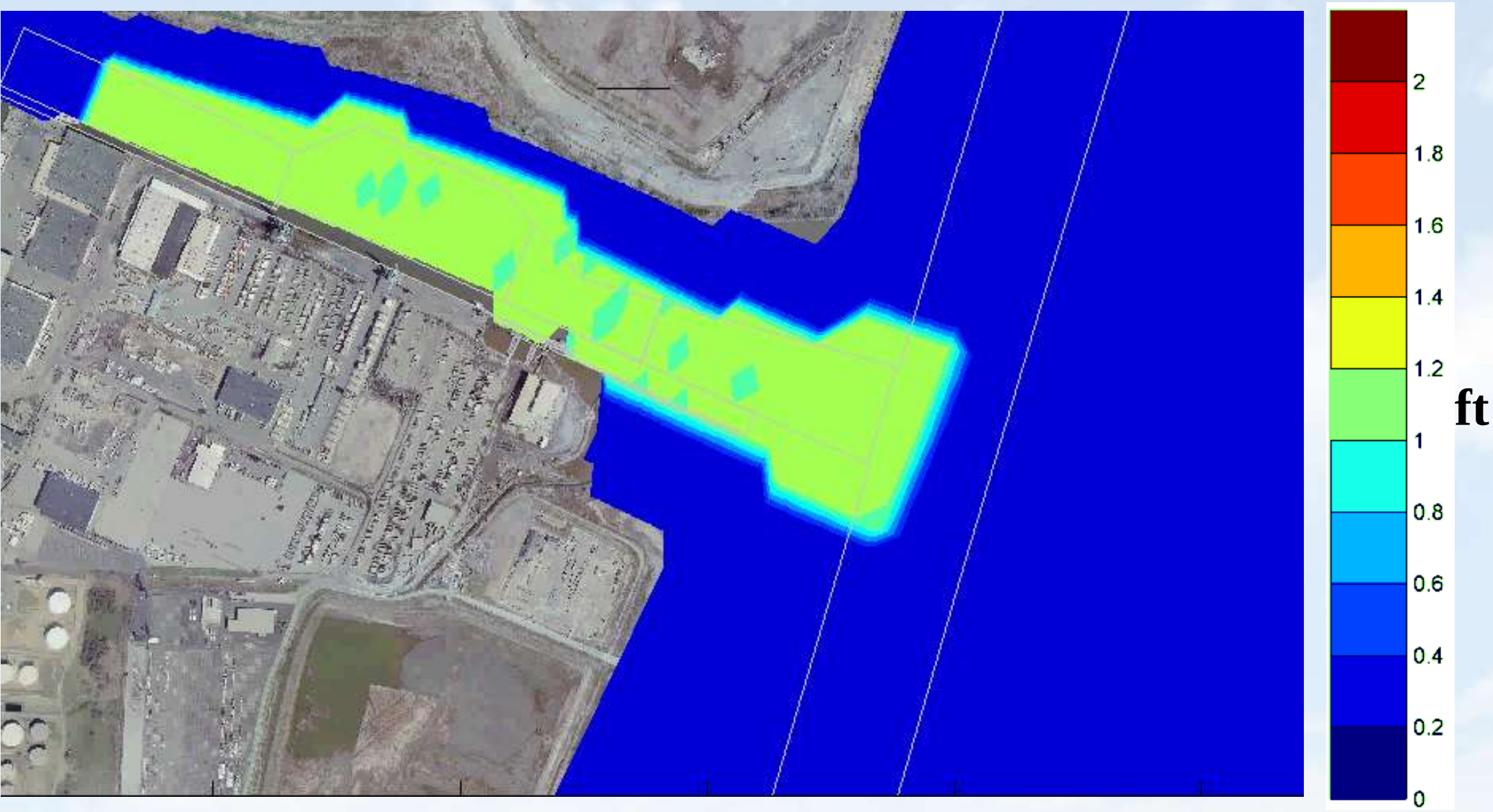
- Fluid mud model couples a mud and suspension layer
- Fluid mud is treated more like a dense fluid (Bingham plastic fluid)
- Simulates entrainment of mud into the suspension layer
- Dredge movement not simulated, bed layer was fluidized instantly
- Purpose was to model sediment fate

Model Results – Case 1 (Entire Bed)



Fluid Mud Layer Thickness (ft)

Model Results – Case 2 (1 ft of Bed)

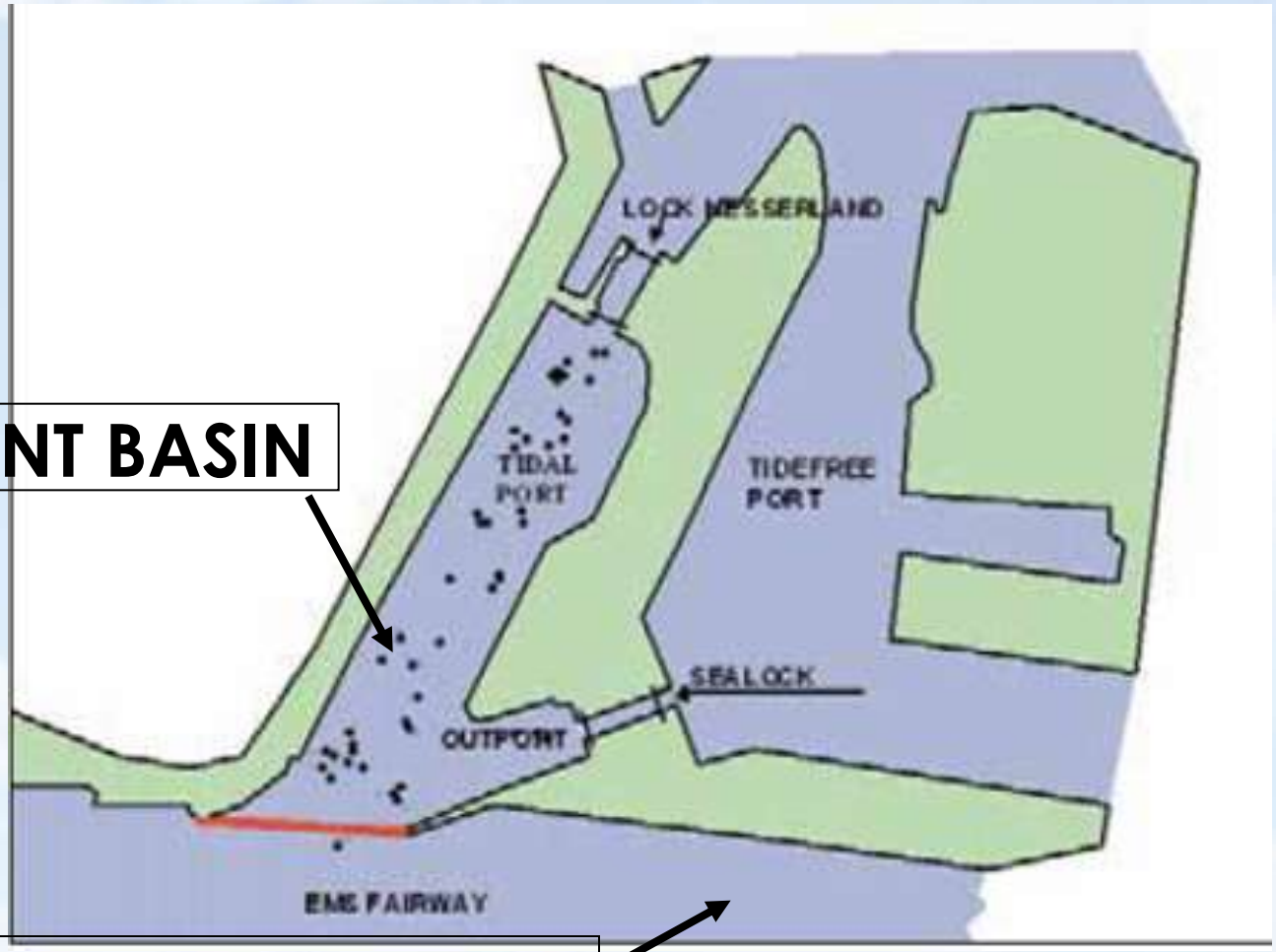


Fluid Mud Layer Thickness (ft)

Cost Summary–WID at Wilmington Harbor

	Mob/Demob ($)	Operation of WID ($/hr)	Standby of WID ($/hr)	Annual Total Cost ($)
Existing Practice	-	-	-	5,215,000
WID	250,000	1,200	800	2,986,00

KSN-PORT OF EMDEN, GERMANY



QUIESCENT BASIN

FAST-MOVING RIVER

In-Situ Treatment, PORT OF EMDEN, GERMANY

- Harbor area fronting lock subject to 2.5M cubic meters per year (deposited upland and/or offshore)
- The deposit starts as fluid mud & eventually consolidates into mud
- IST consists of removing sediment from the bottom into a dredge hopper, exposing it to oxygen (oxygenating it), and then depositing it back on the bottom
- Sediment is not removed or suspended above bottom
- Ships sail right thru the fluid mud!
- IST, performed every 3 months, eliminated the need for dredging

CONCLUSIONS

- Dredged material can be managed thru sedimentation management
- There are a number of strategies including relatively new ones (e.g., WID, KSN) proven in Europe
- These strategies keep sediment in the system
- These systems can be very cost-effective and are equally applicable to large and small harbors