SEDIMENTS AND SUBMARINES

INDIANA JONES AND ENVIRONMENTAL ENGINEERING

Danny Reible
Donovan Maddox Distinguished Engineering Chair
Texas Tech University

Austin American-Statesman

statesman.com

FINAL EDITION ▪ SATURDAY, JUNE 14, 2008 ▪ 75 CENTS

IN SPORTS | C1

ALL TIGER

WOODS IN HUNT AT U.S. OPEN

IN LIFE & ARTS | F1

CELEBRATING GARDEN ART

IN STATESMANCARS | D1

oddlove

AN AUSTIN MAN DIGS HIS CITROËN

IN NEWHOMES

SUN CITY'S HILL COUNTRY VIEWS

IN LIFE & ARTS IN PROMISELAND CHURCH FAMILY, A SON CARRIES ON HIS FATHER'S VISION F1

NORWAY ▪ ENVIRONMENT

Can UT prof neutralize Nazi sub threat?

Sunk in North Sea in 1945, U-864 still holds toxic payload

By Asher Price
AMERICAN-STATESMAN STAFF

Early in the final year of World War II, the German submarine U-864 was motoring through frigid waters just west of Norway on its way to Japan. The secret mission of the specially outfitted vessel: to deliver at least 60 tons of mercury to the Axis ally for use in explosives.

But the British military detected the sub's assignment through its code-breaking program and dispatched a submarine, the HMS Venturer, to intercept. U-864 and its cargo were sunk, and about 70 men were sent to their deaths.

Now, facing an environmental threat from the mercury, the Norwegians have turned to University of Texas environmental engineering professor Danny Reible to figure out a way to entomb the wreck.

For decades U-864 was more or less lost to the tides, a casualty 500 feet deep in a war littered with them.

About 60 years after the sub, split into at least two portions, sank to the ocean floor, the Norwegian navy located the wreck and found troubling signs that the steel canisters that contain the mercury are corroding, raising the possibility of an environmental disaster. Should the mercury escape it could contaminate fishing stocks in the region.

See **MERCURY**, A10

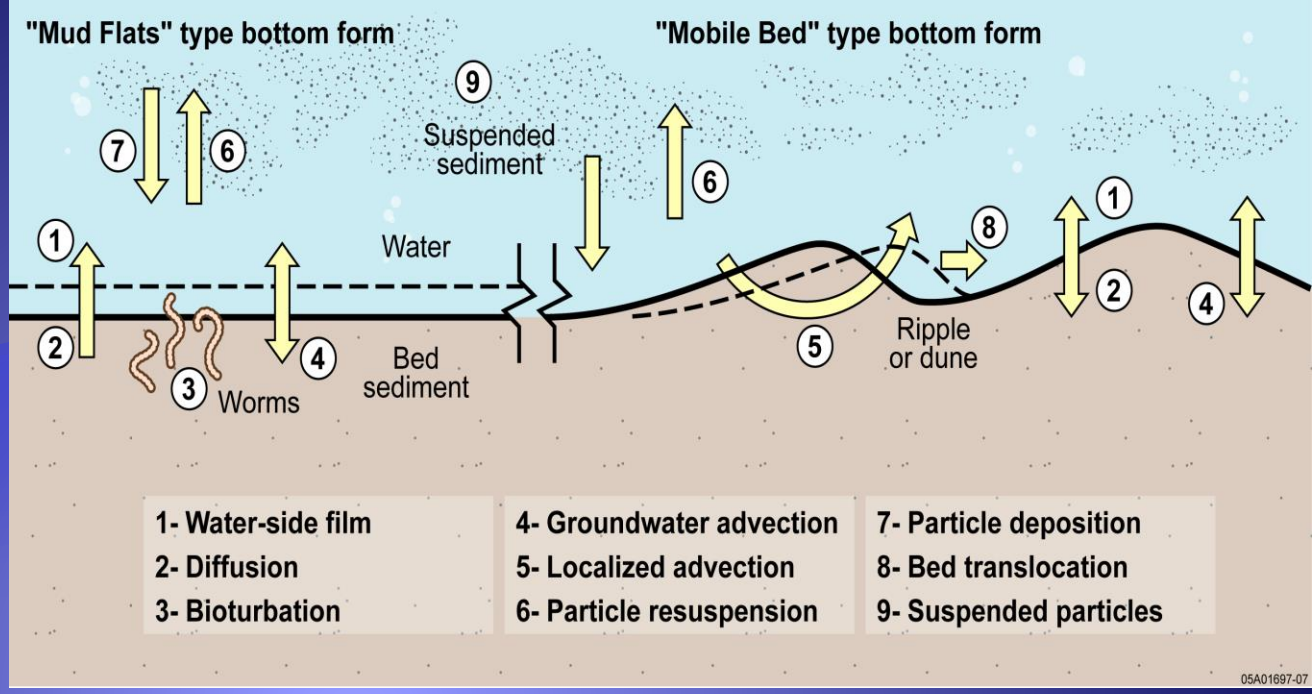
MIDWEST ▪ SEVERE WEATHER

Floods force 10,000 to flee

AUSTIN ▪ REPUBLIC OF TEXAS BIKER RALLY

Chrome on Congress

Reible Research



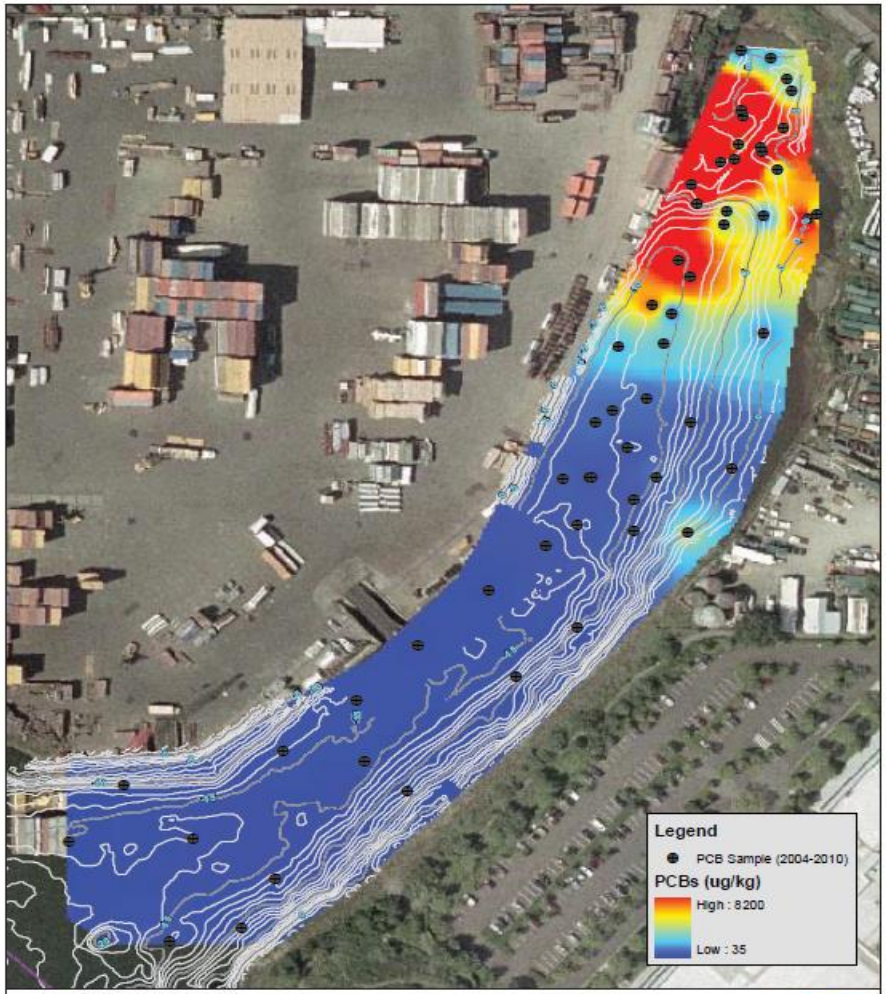
- How do assess the risks of contaminated sediments?
  - Should focus on what is or may be available to organisms- not bulk sediment concentration
  - Our efforts – understand sediment-water exchange processes and evaluate interstitial water concentration of contaminants as indicator of availability
- How do we manage those risks?
  - Our efforts focus on in-place remedies- sediment capping

Contaminated Sediments

What are they?

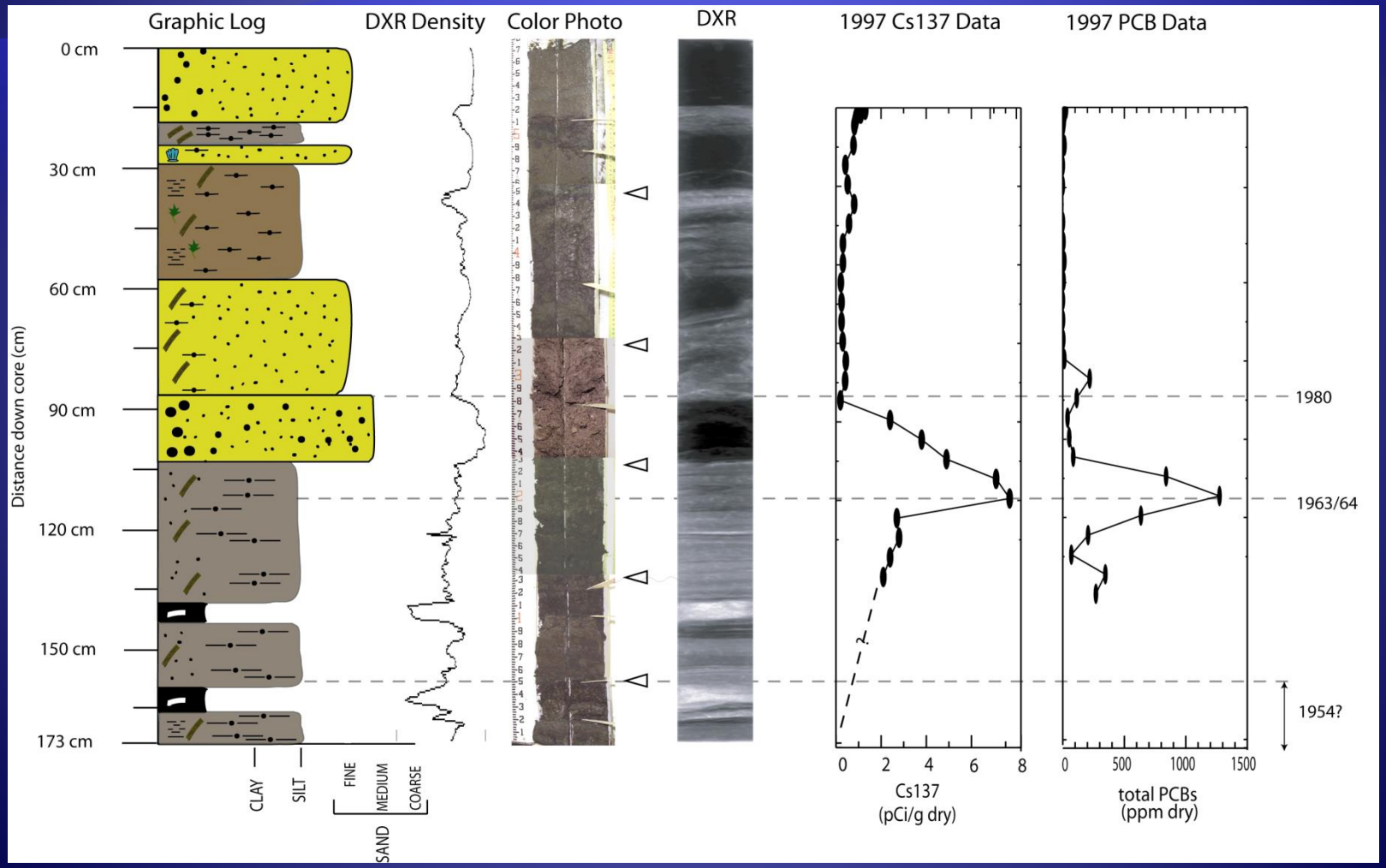
- Sediments are the ultimate "sink" for many contaminants
  - Polynuclear aromatic hydrocarbons (e.g. naphthalene, benzo[a]pyrene)
  - Polychlorinated biphenyls (PCBs, banned in 1970's but persistent)
  - Dioxin – similar to the PCBs
  - Metals (Cadmium, zinc, copper, lead, nickel and mercury)
  - **Refractory, sorbing contaminants**
- Historical sources largely controlled
  - Direct discharges to surface waters significantly reduced
  - Legacy of contaminated sediments an important source
  - Continuing sources, however, limit potential cleanup
    - Difficult to control point sources
    - CSO's – Combined sewer overflows
    - Runoff from contaminated sites

Legacy of Contaminated Sediment



Duwamish Waterway
Seattle WA

Legacy of Contaminated Sediments Grasse River, New York



Courtesy AnchorQEA/Alcoa Inc

Contaminated Sediments

Why are they so important?

- Lack of disposal options is a major impediment to harbor development
  - 95% of shipping trade passes through dredged ports
  - Dredging leads to resuspension, release of contaminants
  - NIMBY limits disposal of dredged sediment
- Significant impediment to unrestricted usage of waterways
  - Fish advisories throughout great lakes and other areas
- Widespread problem
  - Of 21,000 national sediment sampling stations (1996 survey)
  - 26% exhibit potential of adverse effects
  - Additional 49% exhibiting intermediate probability of adverse effects
  - About 30% of superfund sites involve contaminated sediments

Contaminated Sediments

Why are they so difficult?

- Sources often difficult to identify and control
- Sediments often reside in highly variable, dynamic systems
  - Tides, wave action, high flow events, propwash all contribute to uncertainty
- Large volume of sediment
  - Often greater than 1,000,000 m^3
  - Average Superfund site ex situ treatment - <30,000 m^3
- Large amounts of water
  - Dredged solids content often in range of 1-10%
- Often marginal contamination with incomplete exposure pathways and uncertain risks
- Mercury
  - Widely distributed
  - Cannot be degraded (although can be present in bioavailable forms)
  - Complex biogeochemical processes

Background

Mercury Contamination

WARNING!

Nearly all fish and seafood contain some amount of mercury and related compounds, chemicals known to the State of California to cause cancer, and birth defects or other reproductive harm. Certain fish contain higher levels than others.

Pregnant and nursing women, women who may become pregnant, and young children should not eat the following fish:

SWORDFISH · SHARK · KING MACKEREL · TILEFISH

They should also limit their consumption of other fish, including tuna.

Fish and seafood can be an important source of nutrients and an important part of a balanced diet. However, the federal Food and Drug Administration advises pregnant and nursing women, women who may become pregnant, and children to limit their weekly consumption of fish.

The California Department of Health Services recommends that these individuals:

- Eat a variety of different types of fish;
- Eat smaller fish rather than older, larger fish;
- Begin following these guidelines one year before becoming pregnant.

Fish that tend to have little or no mercury include shrimp and scallops. Mercury levels in tuna vary. Tuna steaks and canned albacore tuna have higher levels of mercury than canned light tuna.

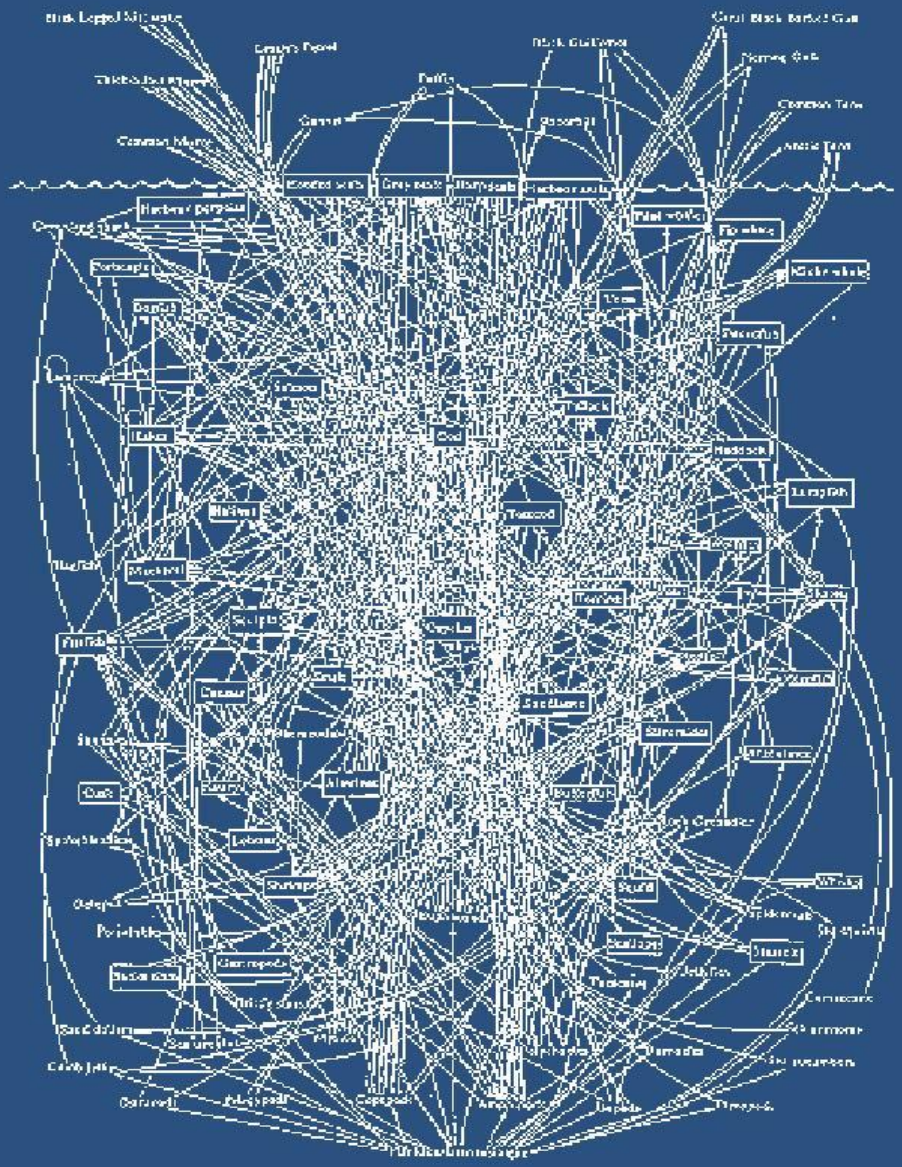
For more information about the risks of mercury in fish and about the levels in various types of fish consult the following websites:

U.S. Food and Drug Administration ("FDA") **www.cfsan.fda.gov**
U.S. Environmental Protection Agency **www.epa.gov/ost/fish**

or call the FDA toll-free at **1-888-SAFEFOOD 1-888-723-3366).**

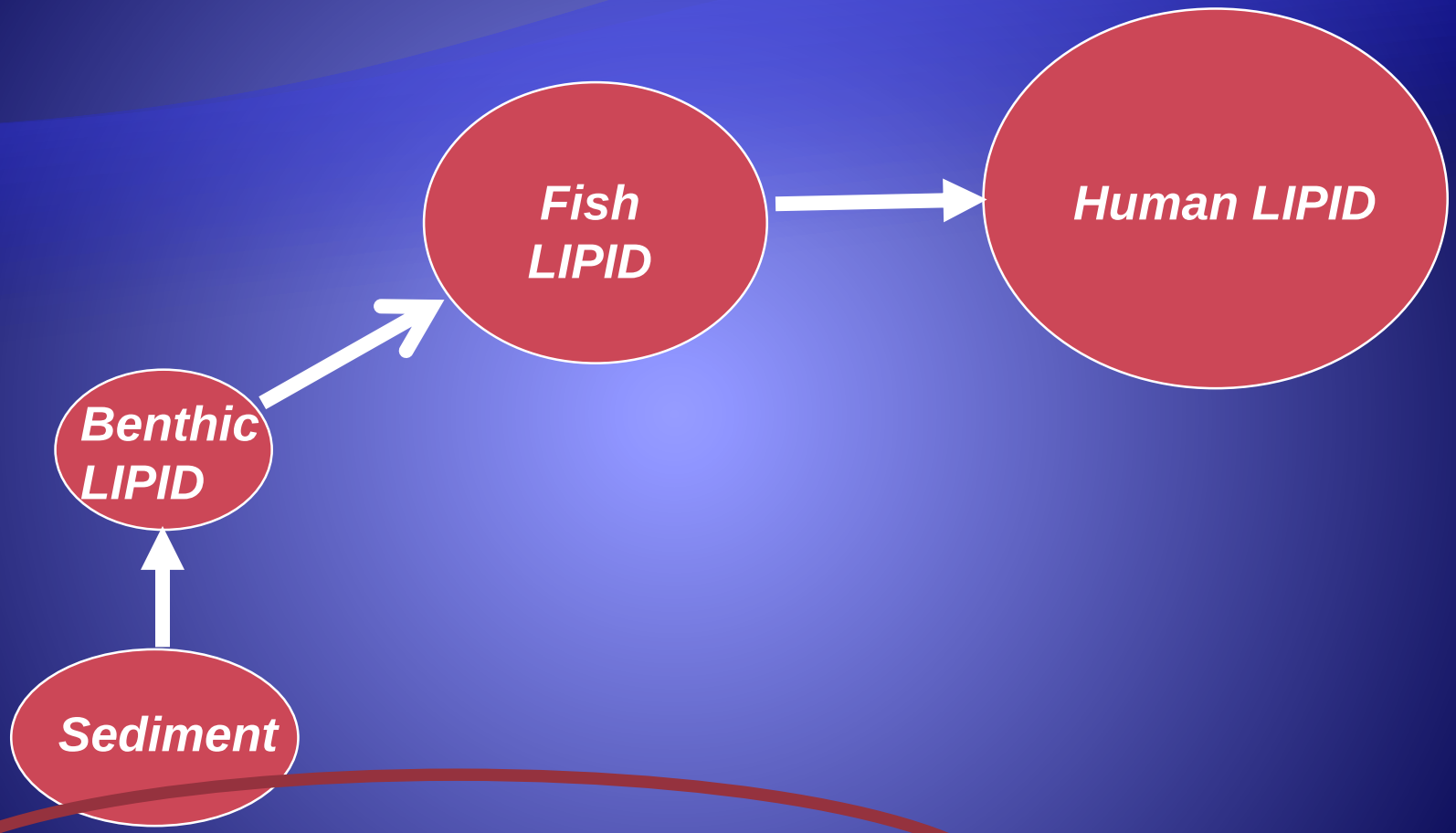
Bioaccumulation in the Food Web

Northwest Atlantic Food Web



Mercury → Methyl Mercury → Benthic Org. → Fish → Humans

Chemist/Engineer's View of a Food Web

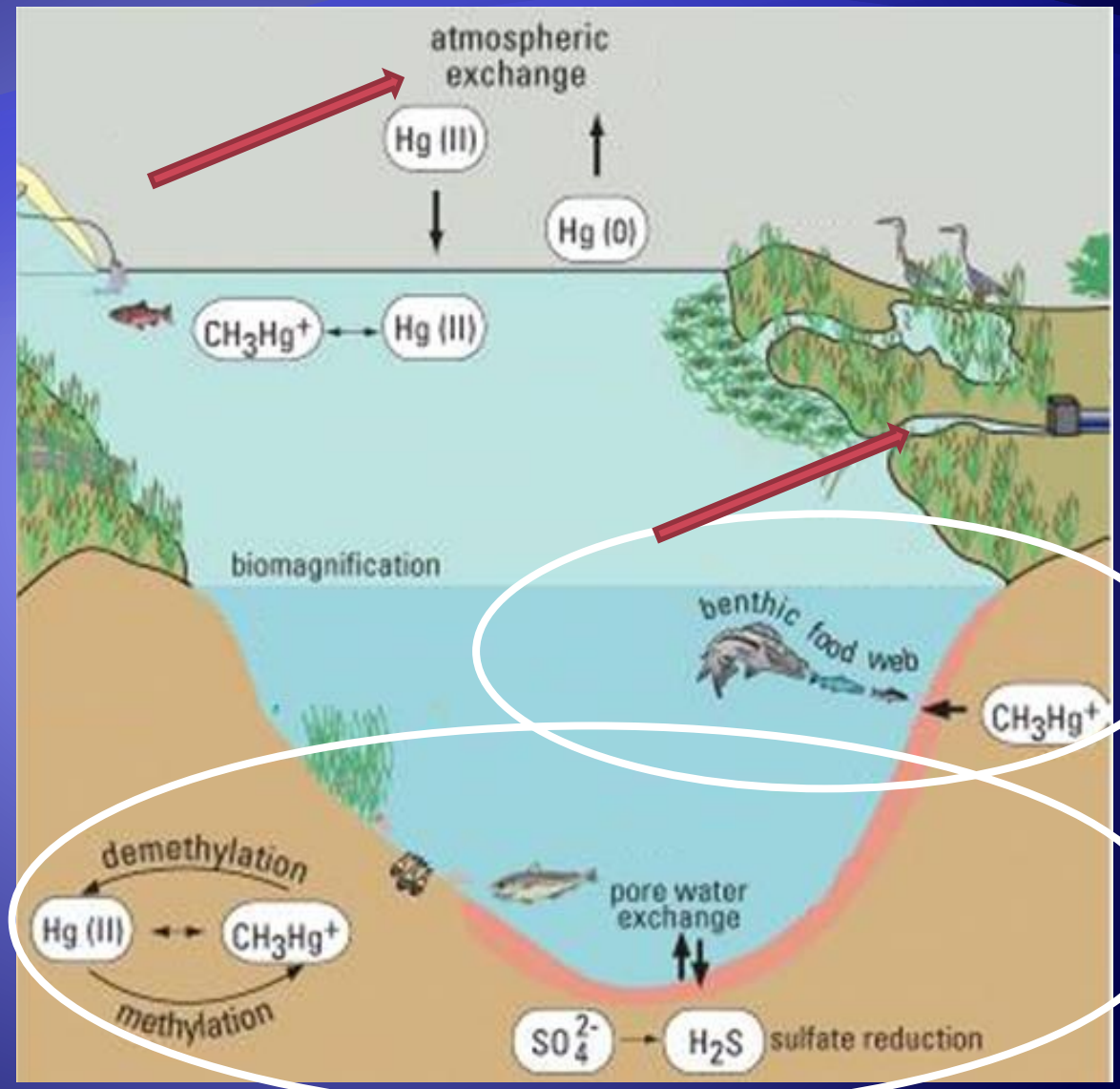


Mercury → Methyl Mercury → Benthic Org. → Fish → Humans

Background

Mercury in Fish

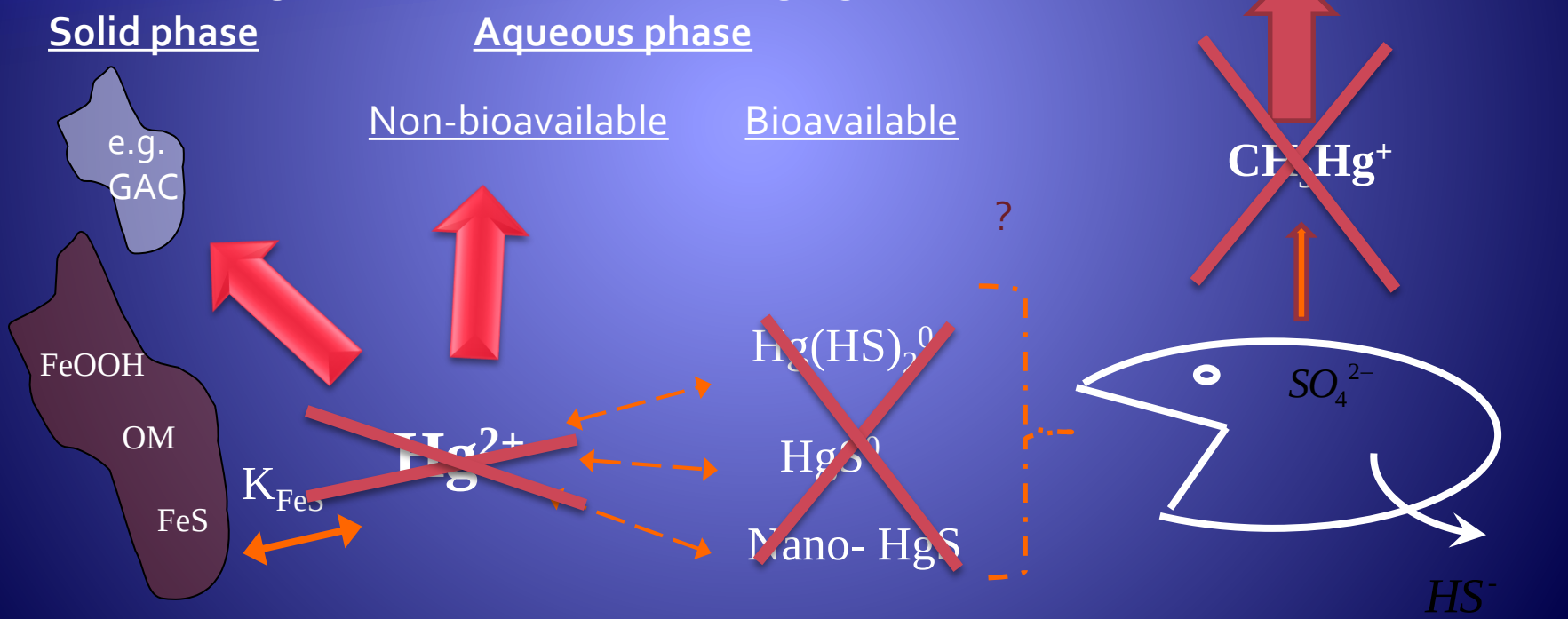
1. Mercury source & movement to sediments
2. Mercury availability
3. Conducive Hg speciation
4. Conducive biogeochemistry
5. Food web transfer



Alpers, C.N. et al., USGS, 2005-3014

Conceptual model – Amendments (Task3)

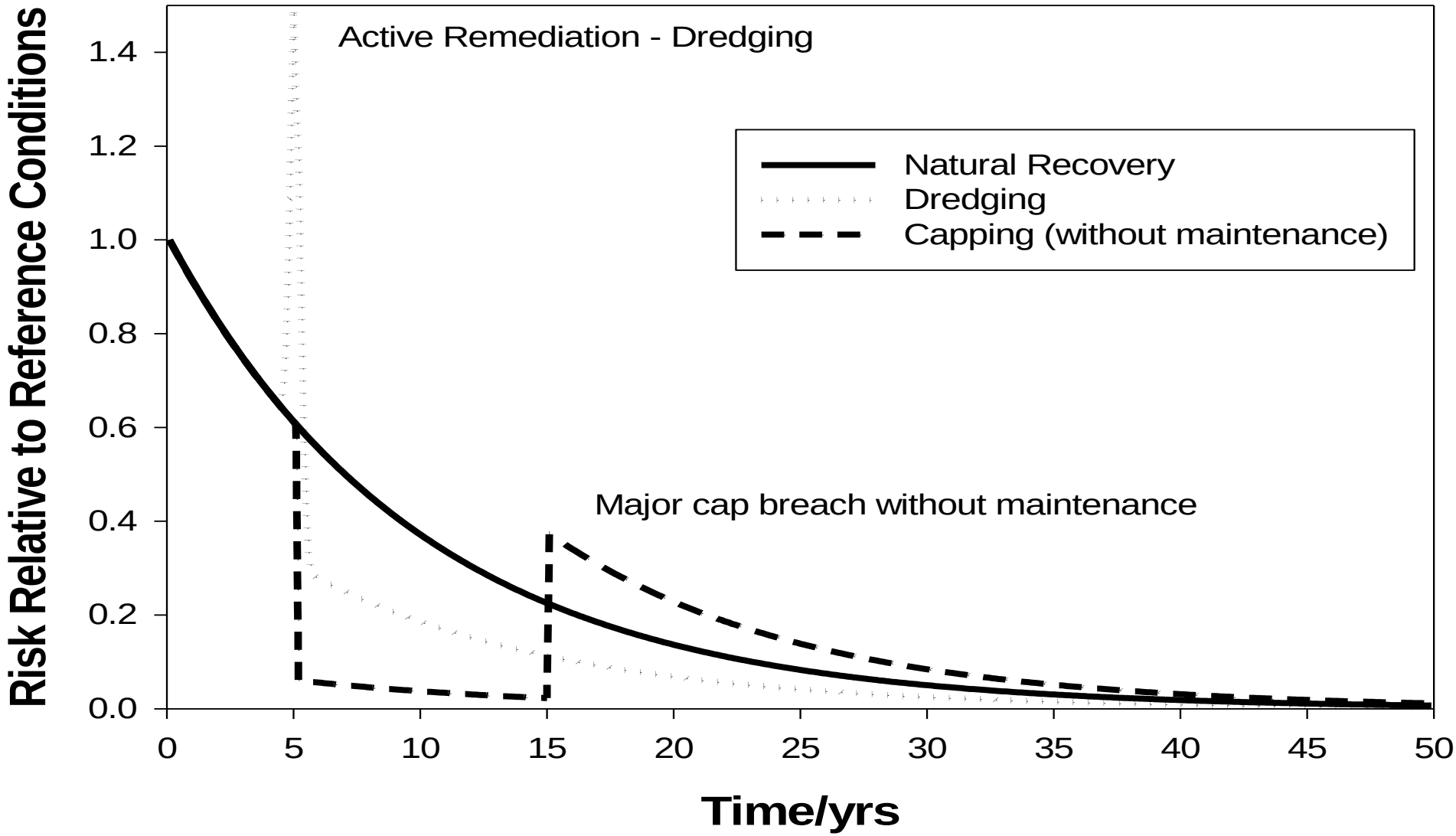
- To reduce Hg in food
  - control aqueous speciation –reduce bioavailability
  - sorbing amendments-reduce available Hg
  - isolate from biologically active zone- capping
  - Remove Hg from environment- dredging??



Managing Risks of Sediments What are the Options?

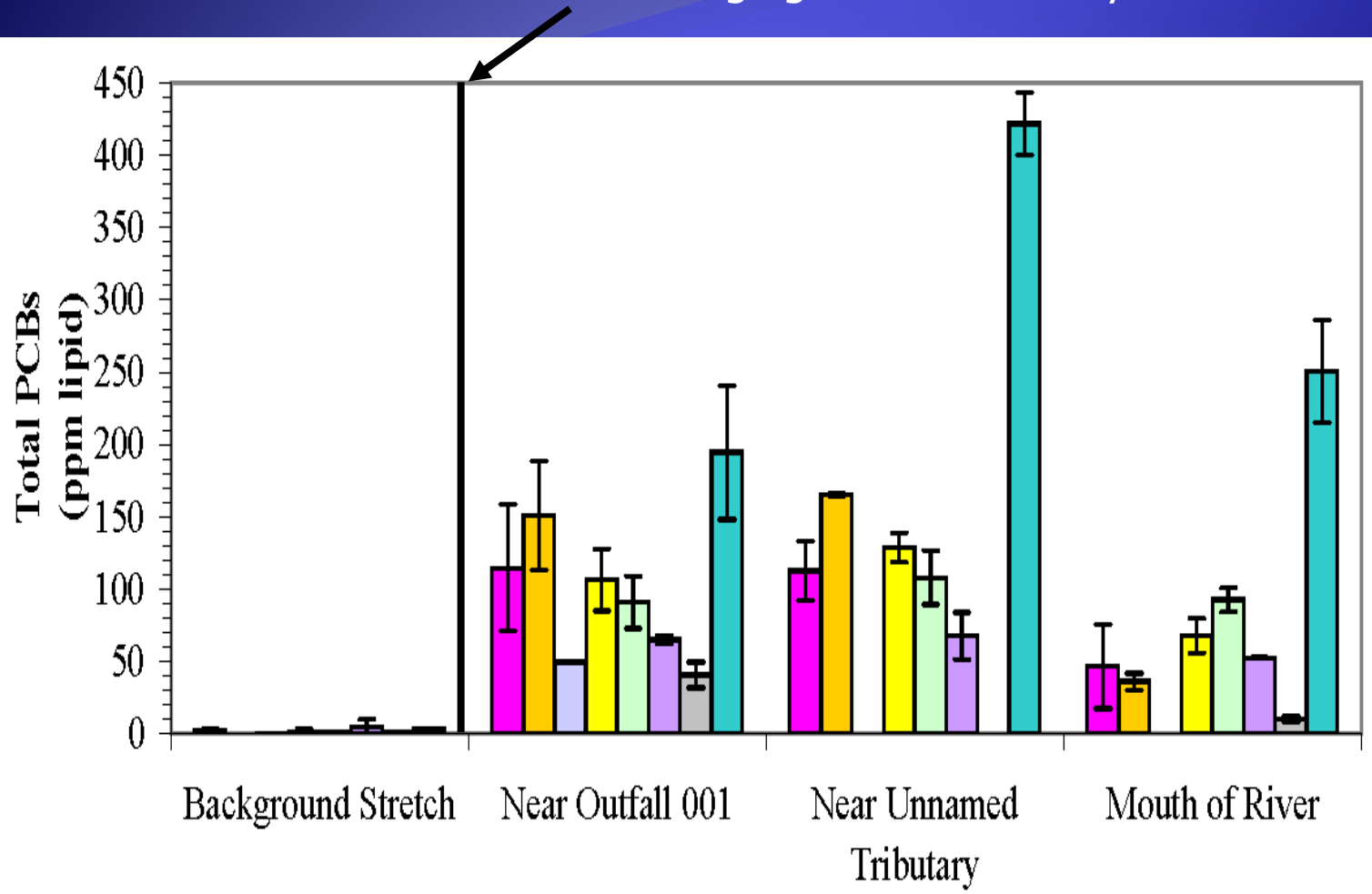
- Monitored Natural Recovery
  - Part of all remedies
  - May be an integral part of active remediation
- Dredging
  - Need to recognize impacts and limitations
  - Triggers a variety of onshore activities
- Capping
  - Clean sediment/sand layer over contaminated sediment
  - Can be rapidly implemented with minimal impact
  - Need to assess long-term protectiveness

Response to Remedial Approaches



Is Dredging a Good Idea?

Dredging conducted early 2005 near outfall 001

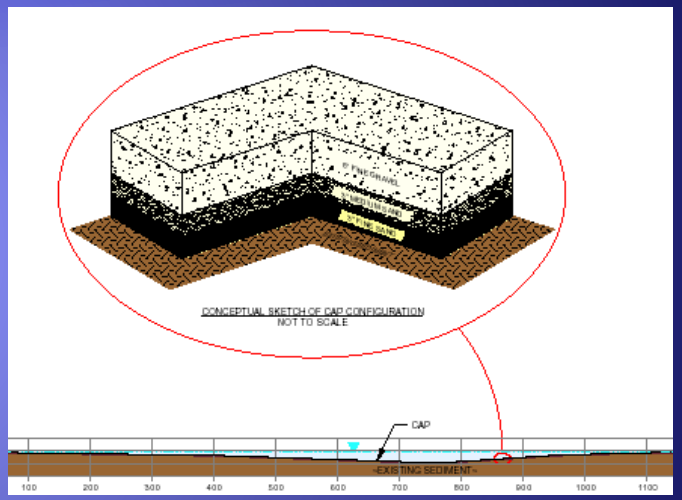


NRC, 2007

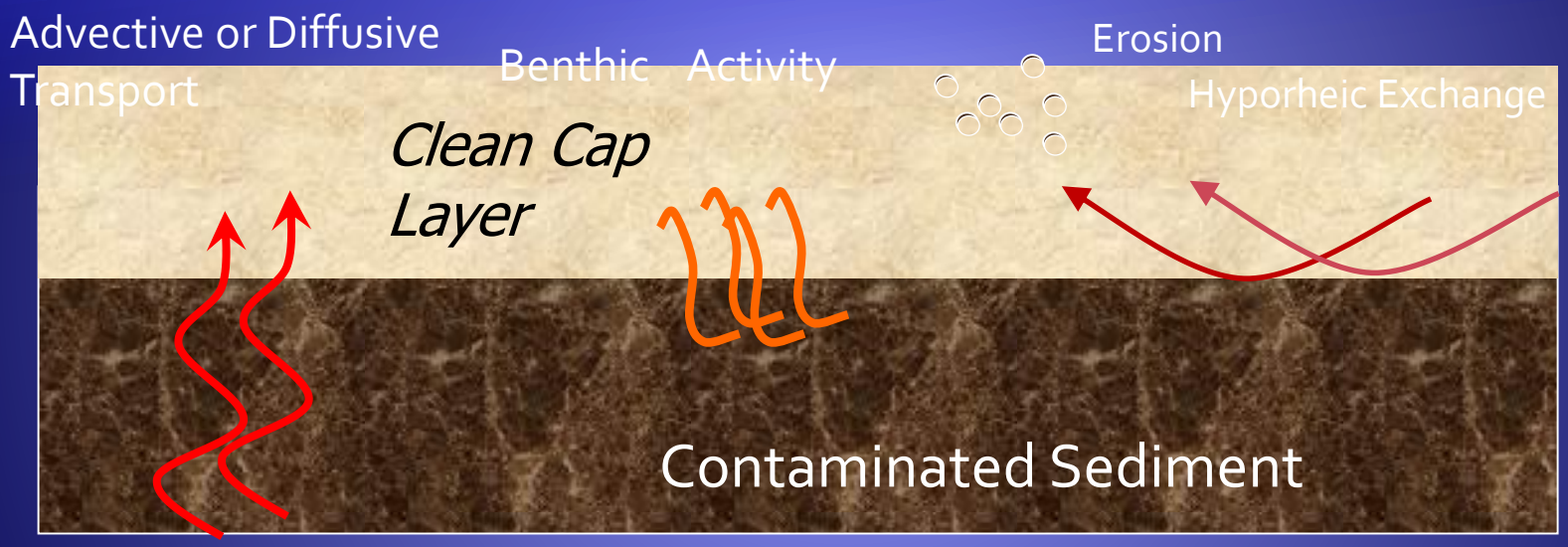
1998 1999 2000 2001 2002 2003 2004 2005

Sediment In-situ Capping/Entombment

- Reduce risk by:
  - Stabilizing sediments
  - Physically isolating sediment contaminants from benthos
  - Reducing contaminant flux to benthos and water column
- Sand surprisingly effective for strongly solid associated contaminants
- "Amended caps" for other situations



Objective of Capping: Physical Containment



Austin American-Statesman

statesman.com

FINAL EDITION ▪ SATURDAY, JUNE 14, 2008 ▪ 75 CENTS

IN SPORTS | C1

ALL TIGER

WOODS IN HUNT AT U.S. OPEN

IN LIFE & ARTS | F1

CELEBRATING GARDEN ART

IN STATESMANCARS | D1

oddlove

AN AUSTIN MAN DIGS HIS CITROËN

IN NEWHOMES

SUN CITY'S HILL COUNTRY VIEWS

IN LIFE & ARTS IN PROMISELAND CHURCH FAMILY, A SON CARRIES ON HIS FATHER'S VISION F1

NORWAY ▪ ENVIRONMENT

Can UT prof neutralize Nazi sub threat?

Sunk in North Sea in 1945, U-864 still holds toxic payload

By Asher Price
AMERICAN-STATESMAN STAFF

Early in the final year of World War II, the German submarine U-864 was motoring through frigid waters just west of Norway on its way to Japan. The secret mission of the specially outfitted vessel: to deliver at least 60 tons of mercury to the Axis ally for use in explosives.

But the British military detected the sub's assignment through its code-breaking program and dispatched a submarine, the HMS Venturer, to intercept. U-864 and its cargo were sunk, and about 70 men were sent to their deaths.

Now, facing an environmental threat from the mercury, the Norwegians have turned to University of Texas environmental engineering professor Danny Reible to figure out a way to entomb the wreck.

For decades U-864 was more or less lost to the tides, a casualty 500 feet deep in a war littered with them.

About 60 years after the sub, split into at least two portions, sank to the ocean floor, the Norwegian navy located the wreck and found troubling signs that the steel canisters that contain the mercury are corroding, raising the possibility of an environmental disaster. Should the mercury escape it could contaminate fishing stocks in the region.

See **MERCURY**, A10

MIDWEST ▪ SEVERE WEATHER

Floods force 10,000 to flee

AUSTIN ▪ REPUBLIC OF TEXAS BIKER RALLY

Chrome on Congress

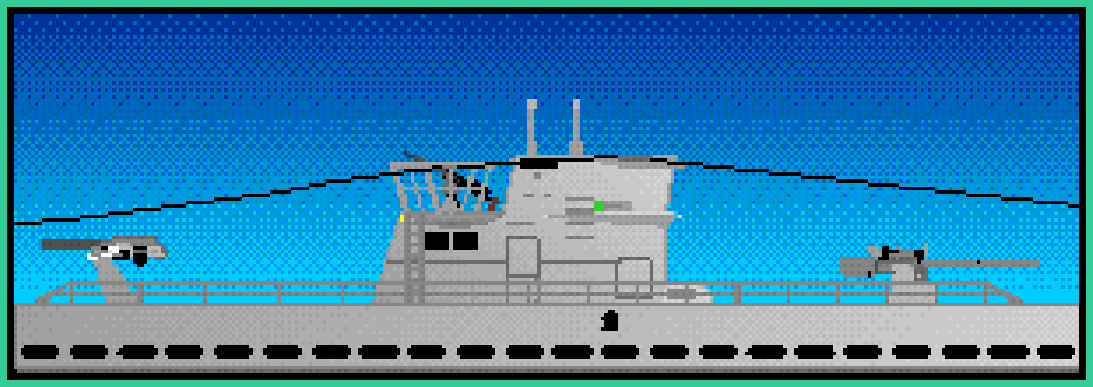
Unterseeboot -864 (U-864)

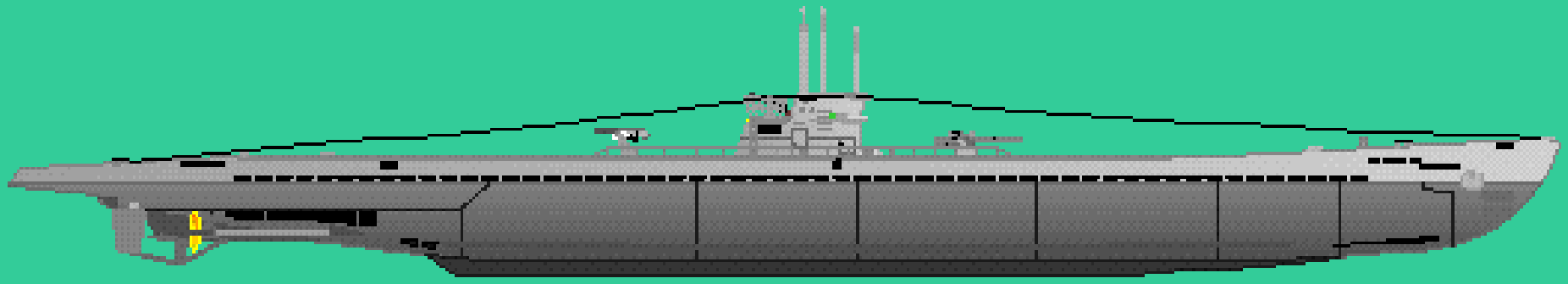
- U-864
  - Commander: Korvkpt. Ralf-Reimar Wolfram
  - Commissioned 9 Dec 1943
  - Used for training throughout most of 1944
- Assigned to Operation Caesar late fall 1944
  - Transferring military technology and supplies to Japan
  - Cargo of U-864
    - 65 tons of elemental mercury
    - Jet engine components from Me-262
    - V-2 missile guidance systems
    - German and Japanese scientists and engineers
- Plans intercepted by code breakers at Bletchley Park
- HMS Venturer sent to intercept

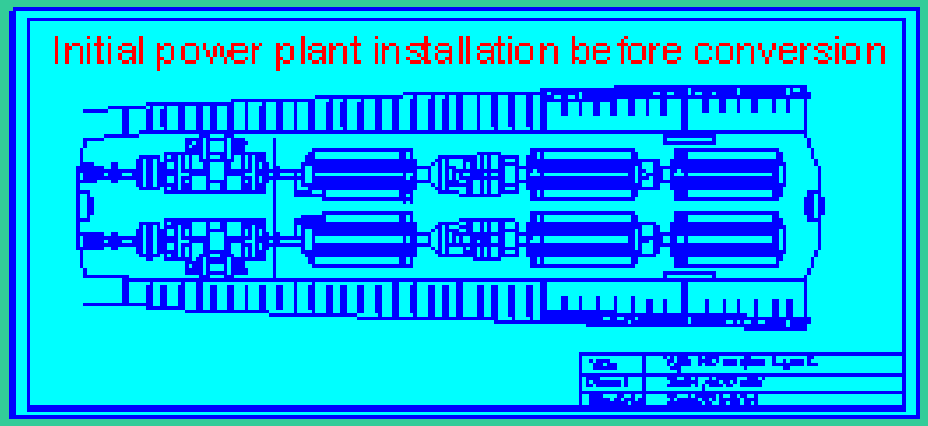
Source:en.wikipedia.org

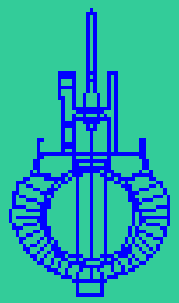
U-864

TYPE IXD









Source: www. Uboat.net

Source:militaryhistory.about.com

Venturer vs U-864

- Venturer
  - Royal Navy V Class
  - 545 tons, 206 ft in length
  - 3" gun, 8 torpedoes (4 bow tubes)
  - 13 knots (surface) 9 knots (submerged)
  - Crew of 37
- U-864
  - German IXD class
  - 1616 tons, 287 ft in length
  - 105 mm (~4")/45 mm (~2"), 24 torpedoes (4 bow, 2 stern)
  - 19.2 knots (surface) , 6.9 knots (submerged)
  - Crew of 73 (including scientists for transport to Japan)

The Last Voyage of U-864


Source: www.ww2incolor.com

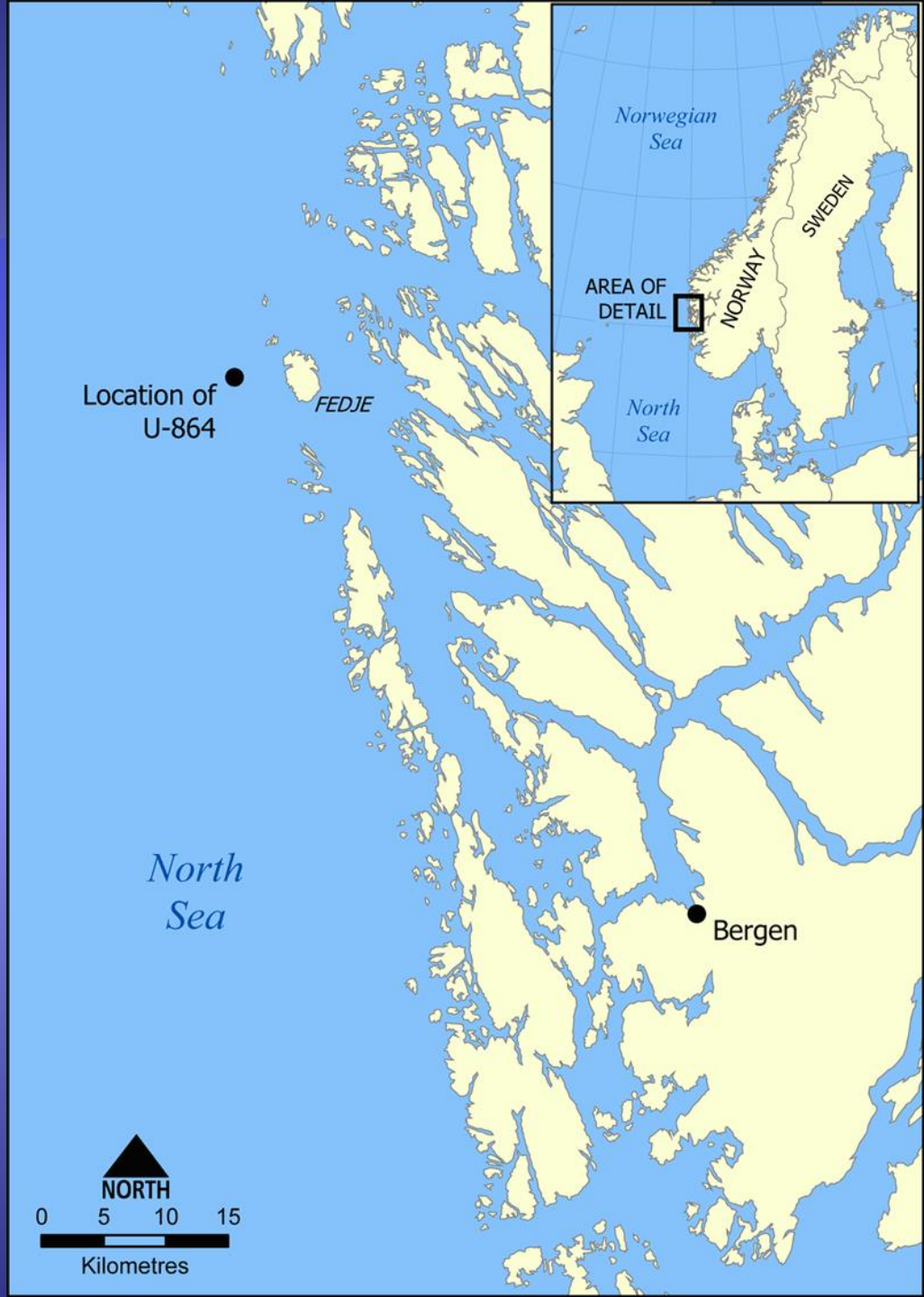
- U-864 runs aground January 1945 and routed to Bergen for repairs
- Delayed by RAF bombing on 12 January
- Cleared area by 6 February but had to turn back with engine problems
- Escort arranged for 10 February but periscope seen by Venturer on 9 February
- Venturer follows to sink upon surfacing but ultimately fires 4 torpedoes in 3-D firing solution to avoid U-864 escape
- 4th torpedo strikes U-864 more than 3 minutes after firing
- Only instance of submarine sinking another submarine while both submerged

60 Years Later

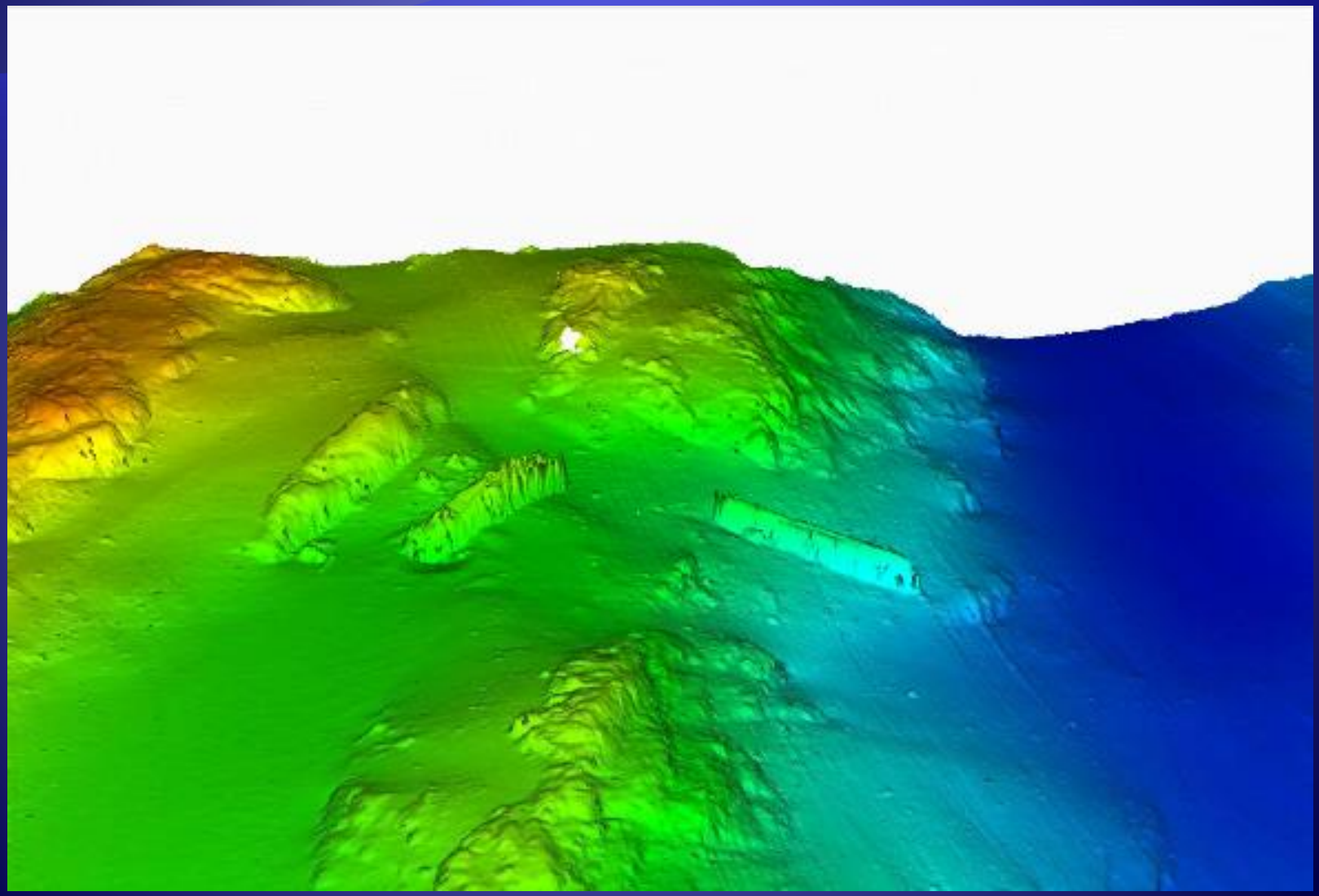
- Late 1990's- amateur historians and declassification of war documents leads to a renewed search for U-864
- Discovered by Norwegian Vessel Tyr in Spring 2003 in 150 m (~500 ft) of water after a nearly 5 year search

Source: www.history.navy.mil

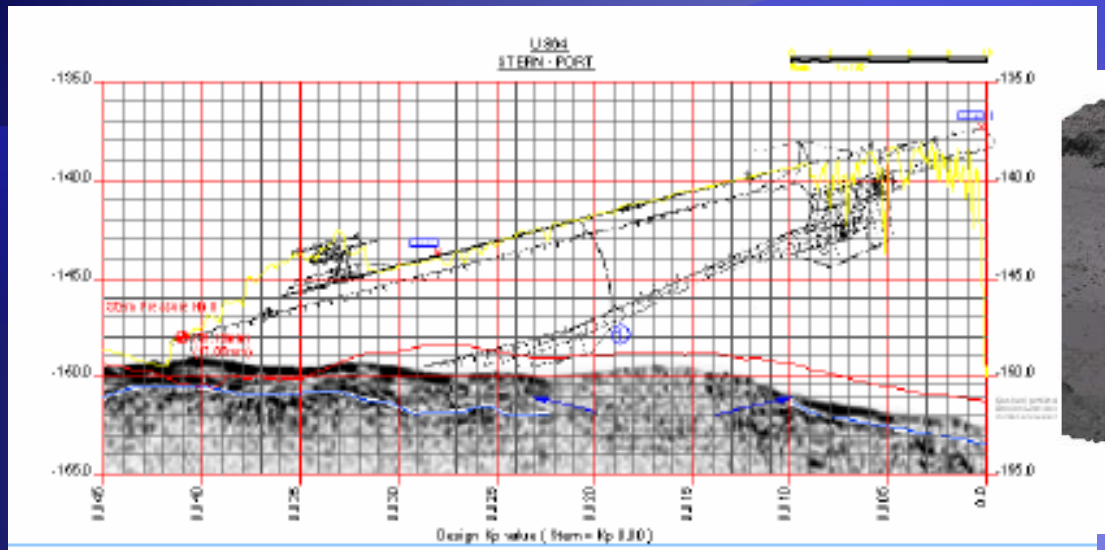
Location of U-864

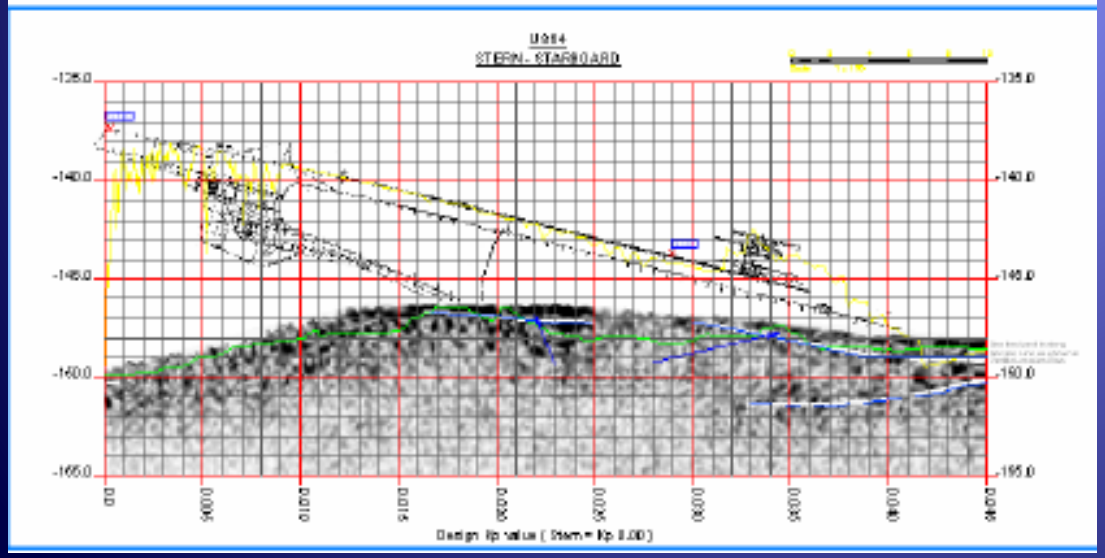


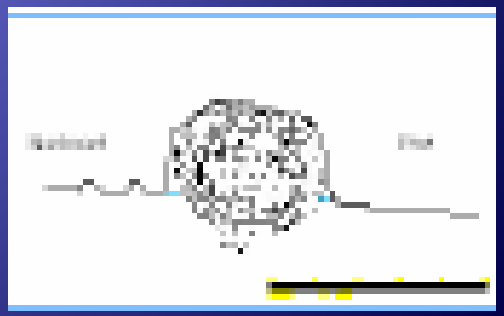
U-864 Resting on the Bottom



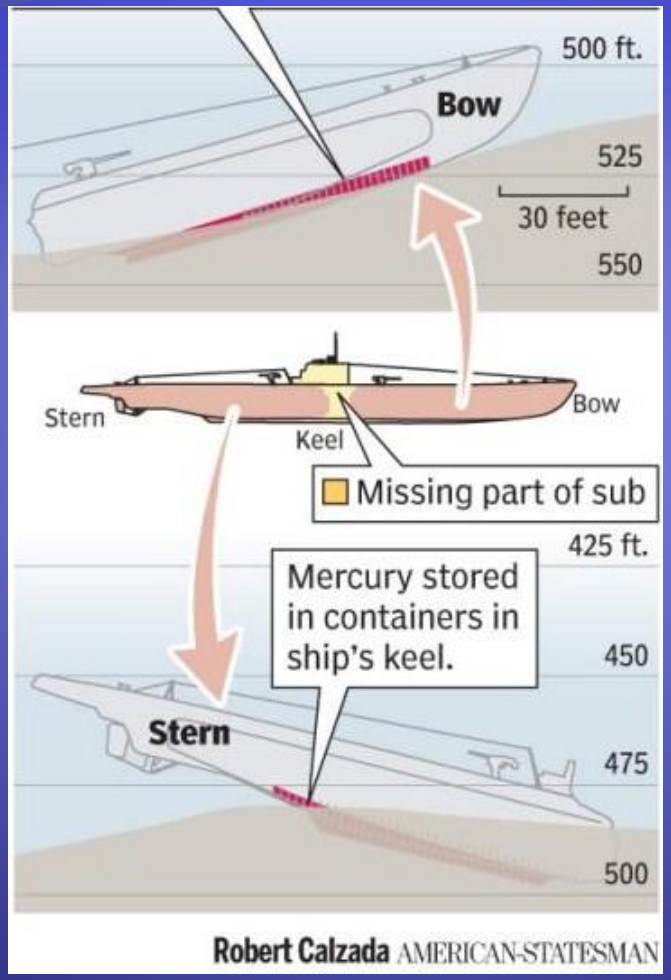
U-864 Resting on the Bottom







U-864 Mercury



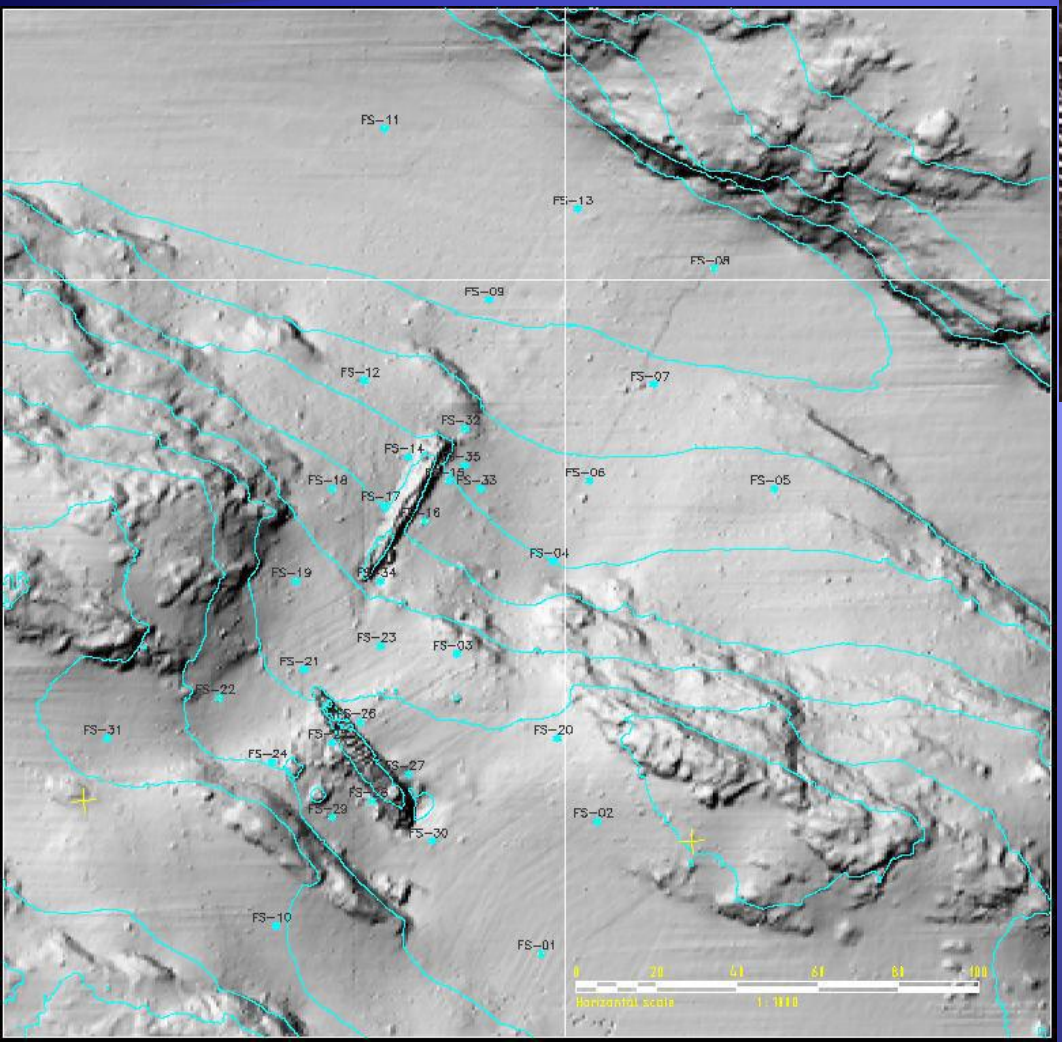
1,857 Mercury Canisters

Two Located

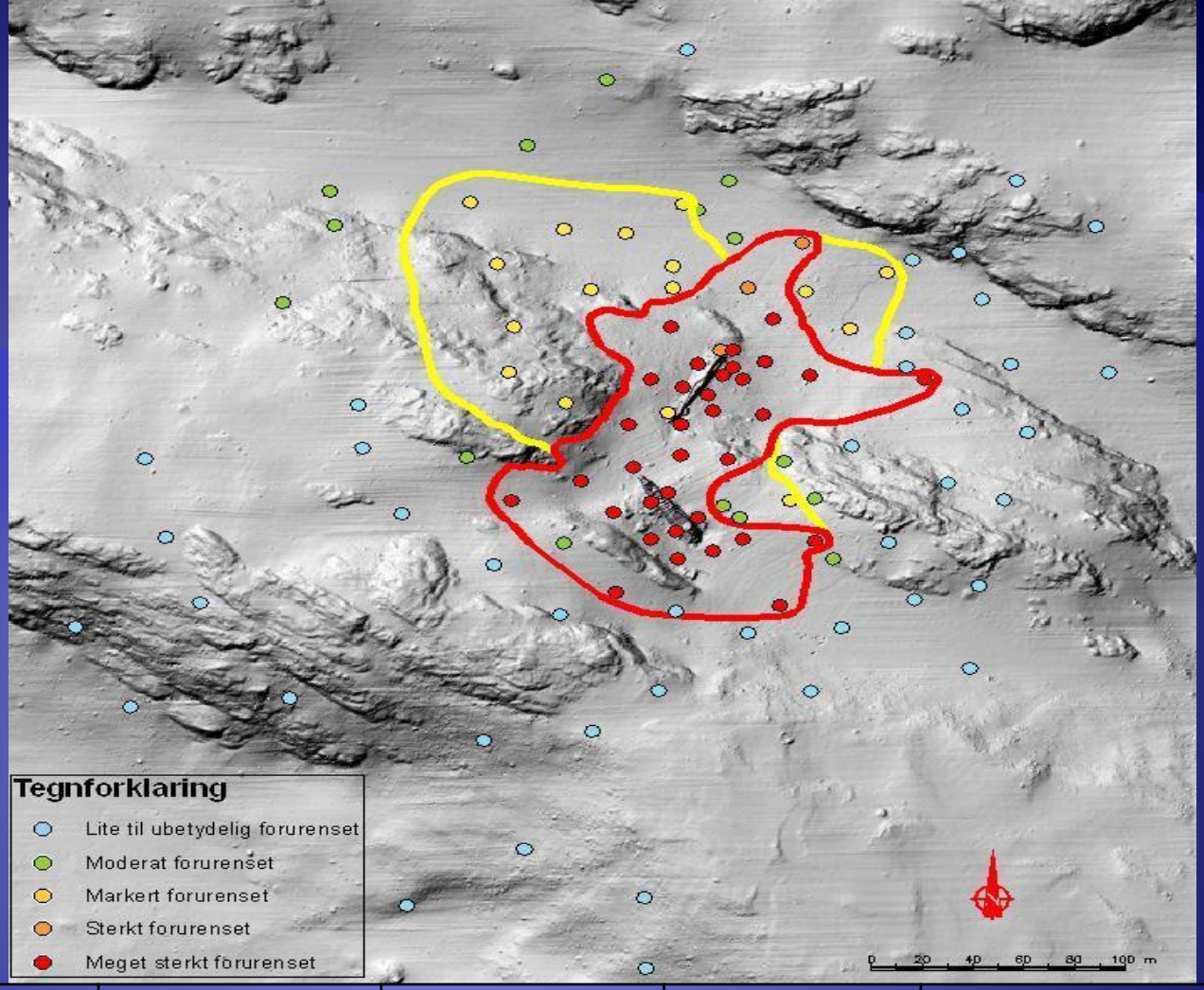
One Empty

One intact but initial 5 mm wall reduced to 1mm

Sediment Sampling



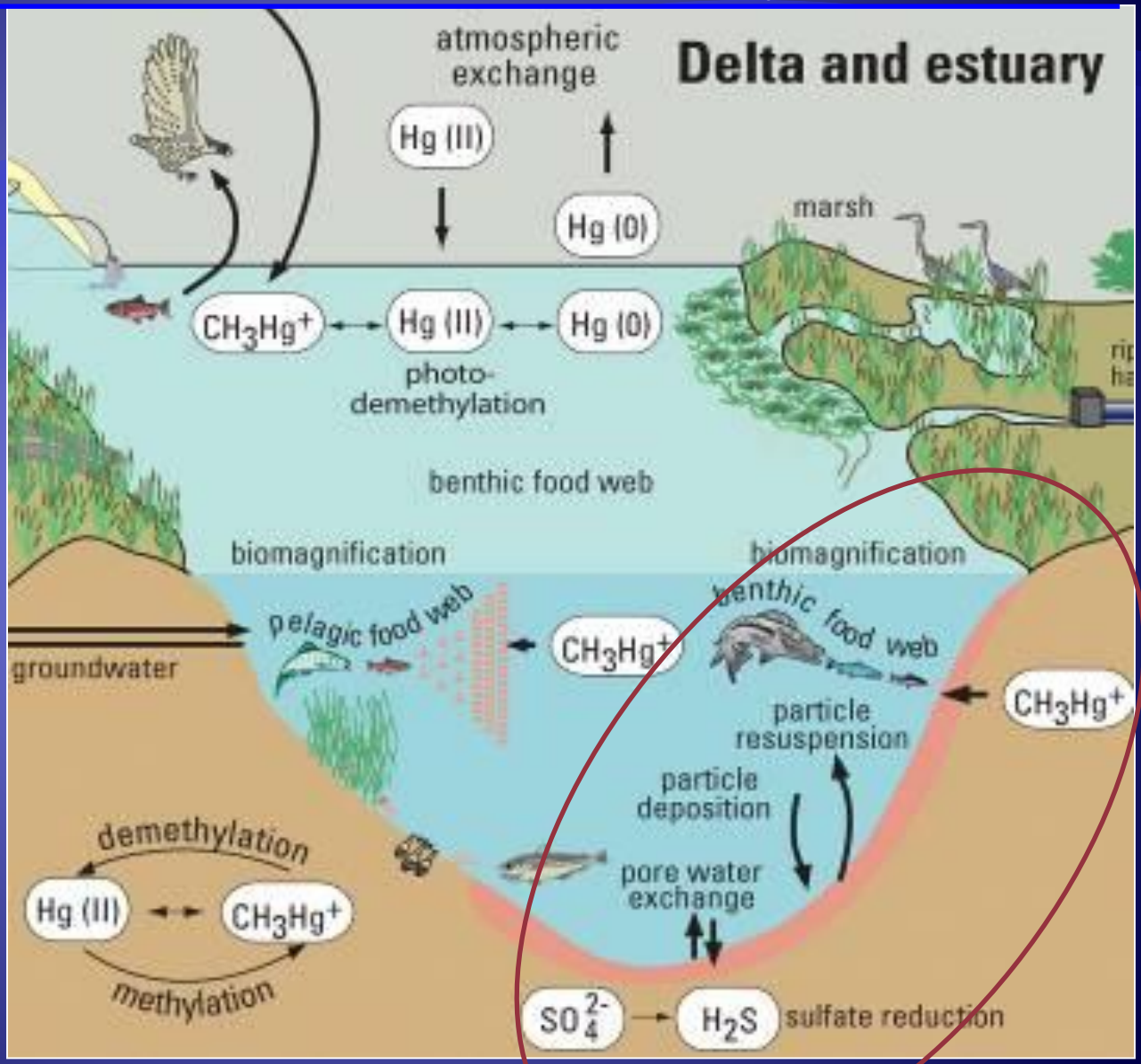
U-864 Sediment Mercury Levels



I Background	II Moderately polluted	III Significantly polluted	IV Severely polluted	V Extremely polluted	
<0.15 mg/kg	0.15-0.6 mg/kg	0.6-3 mg/kg	3-5 mg/kg	>5 mg/kg	Old guidelines (which the Figure is based on)
<0.15 mg/kg	0.15-0.63 mg/kg	0.63-0.86 mg/kg	0.86-1.6 mg/kg	>1.6 mg/kg	New guidelines (valid from February 2008)

Mercury in the Environment

Alpers, C.N. et al., USGS, 2005-3014



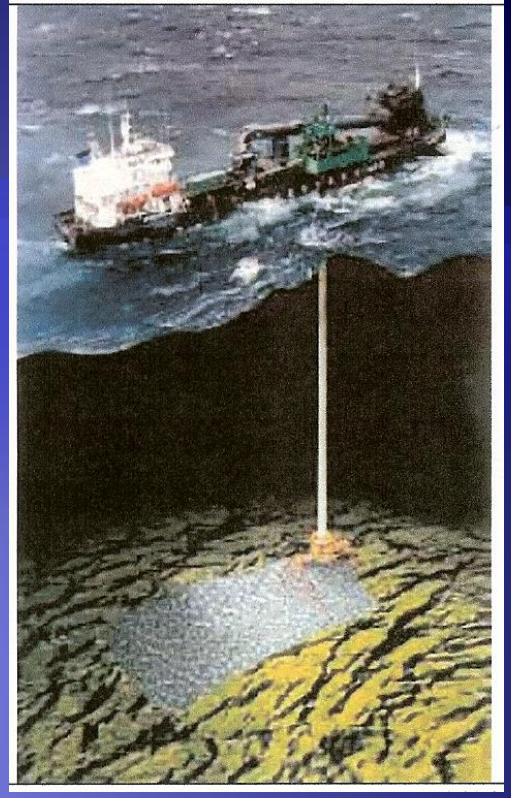
65 tons of mercury
Equivalent to enough
Mercury to contaminate
Norway's total fish catch
for 30 years

Current Sediment Contamination

- Observations only account for 3-15 tons of 60 tons believed to be in the submarine
- Where is the remainder?
  - Dispersed at time of sinking?
  - Dispersed subsequent to sinking?
  - ***Retained within keel of submarine?***
- Remote vehicles to confirm but withdrawn when sediment showed instability

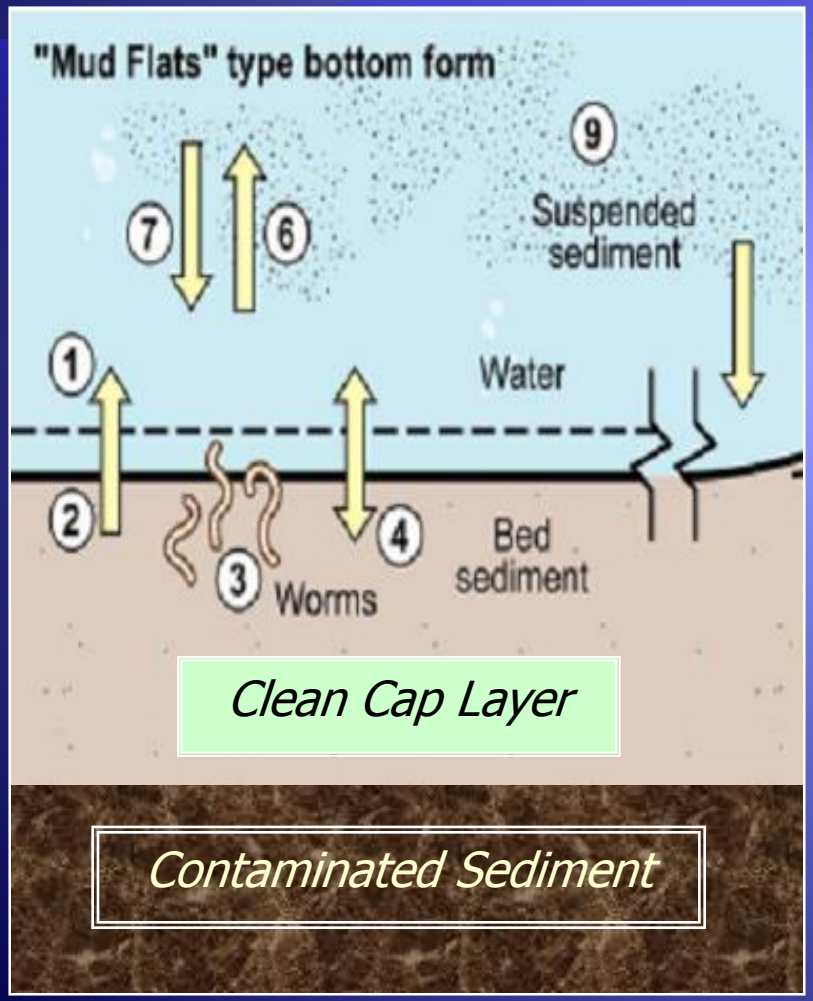
Options

- Salvage submarine?
  - Can submarine be raised intact without loss of mercury?
  - 60 + years of corrosion- ability to support its own weight?
- Entomb submarine?
  - Material selection?
  - Ability to place and retain with confidence?
  - Long term effectiveness?
  - Potential for encouraging mercury methylation?



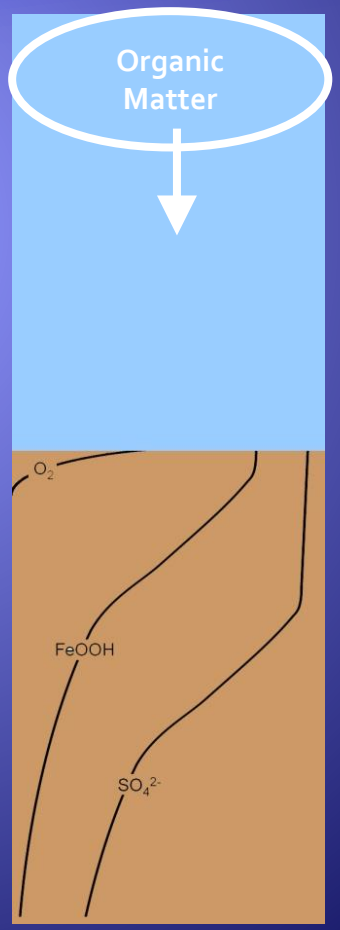
Effects of Capping

Physical Sequestration

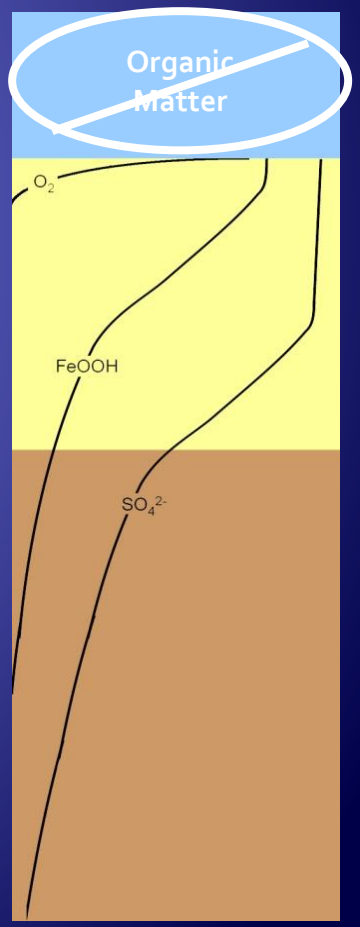


Biogeochemical Changes

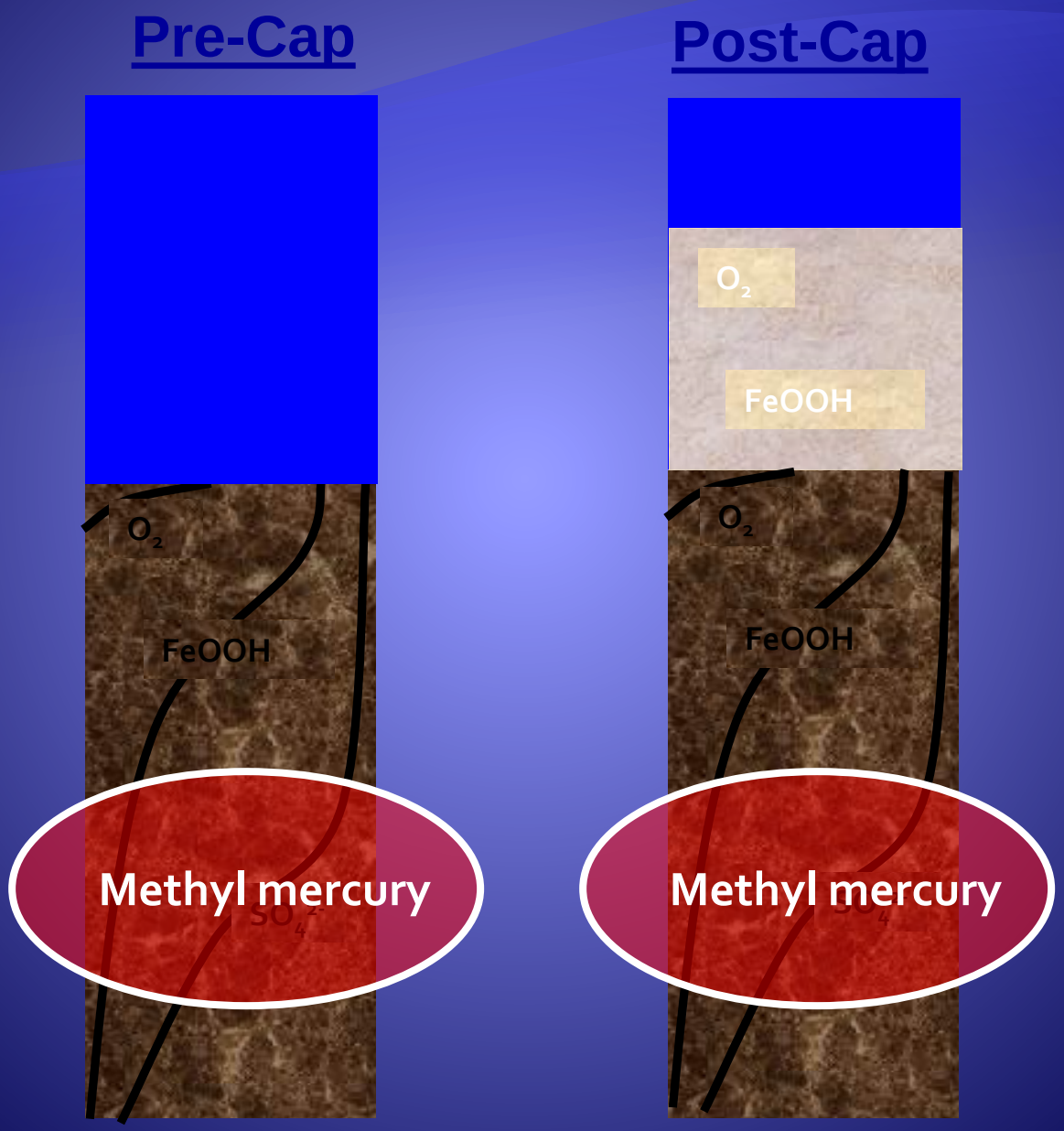
Pre-Cap



Post-Cap



Conceptual Model



Will capping increase methylation?

- Observed a ~50% increase in MeHg in test sediments (Lavaca Bay), but what about North Sea sediments?
  - Similar sulfur/sulfide concentrations but less organic matter which drives microbial activity causing sulfate reduction
- Can mercury and methyl mercury retention be guaranteed in perpetuity?
  - Perpetuity difficult to predict but increased methylation modest and expected to remain buried below cap
  - Mercury mobility low and can be further reduced through amendments
- **Capping/Entombment Feasible!**

Evaluation of Alternatives

- Teams of experts evaluated all approaches/factors
  - Entombment/capping
  - Salvage
  - Submarine corrosion
  - Geotechnical considerations on sea bottom
- Recommendation for burial/capping in place to Norwegian Coastal Authority – Fall 2008
- Spring 2009 – Exploration of removal

Plans - 2009

- Salvage submarine and remove contents
  - Driven by fishing /environmental community concerns
  - Public perception- "Just remove it"
- Approach
  - Grappler structure to place submarine pieces on a platform and the platform raised to the surface and placed on submerged barge
  - Originally planned for summer 2010
- Likely need to remediate contaminated sediment remaining
  - Dredging
  - Capping

Current Status

- Salvage decision "tabled"
  - Cost, liability and feasibility concerns
  - Reassessment of decision currently ongoing
  - More detailed evaluation of other options ongoing
- Prognosis?
  - Likely some sediment removal where possible
  - Entombment of remainder including submarine