CAD Pit Design and Long-Term Risks for Contaminated Dredged Material at Piaçaguera Canal, Brazil

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Dredging and Disposal Plan for the Navigational Channel

- Hopper dredge, about 30 days of dredging and placement
- Various placement methods investigated in short-term risk study
- Contained aquatic disposal (CAD) in excavated pits within navigation channel by hopper bottom dump

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Project Location

- Situated in the inner Santos estuary of Brazil, an area of high sedimentation and precipitation
- Navigation channel of Piaçaguera Canal serving the private Cubatão Harbor in the State of Sao Paulo, Brazil
  - 5.4 km long (2.4 km to be dredged)
  - 100 m wide
  - 13 m deep

Acknowledgements

- Work performed by The US Army Engineer Research and Development Center (ERDC), under a Cooperative Research and Development Agreement (CRADA) with Fundação de Estudos e Pesquisas Aquáticas (FUNDESPA), a contractor for Companhia Siderurgica Paulista (COSIPA)
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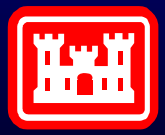
  - Guilherme Lotufo (EL)

ERDC Study Objectives

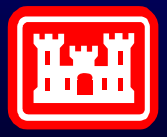
- Generate the best estimate of storage requirements for use in sizing the confined aquatic disposal (CAD) cells
- CAD pit must have sufficient volume for
  - Retention for settling
  - Densification for storage
  - Adequate clearance from erosive forces to reduce losses from contaminated dredged material
  - Adequate clearance from erosive forces to ensure cap stability
- Reduce the uncertainty of the prediction by using two methods of testing and analysis

Approach

- Laboratory testing
- Design modeling for short-term sizing
- Evaluation of long-term performance and risk management



Laboratory Testing for Short-Term Sizing Evaluation



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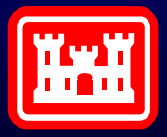
Settling for Short-Term Placement Volume

- Standard Column Settling Tests
  - Flocculent settling test for TSS in water column as a function of time
  - Zone settling test for area / flow rate constraint
  - Compression settling test for storage needs



Standard Settling Tests

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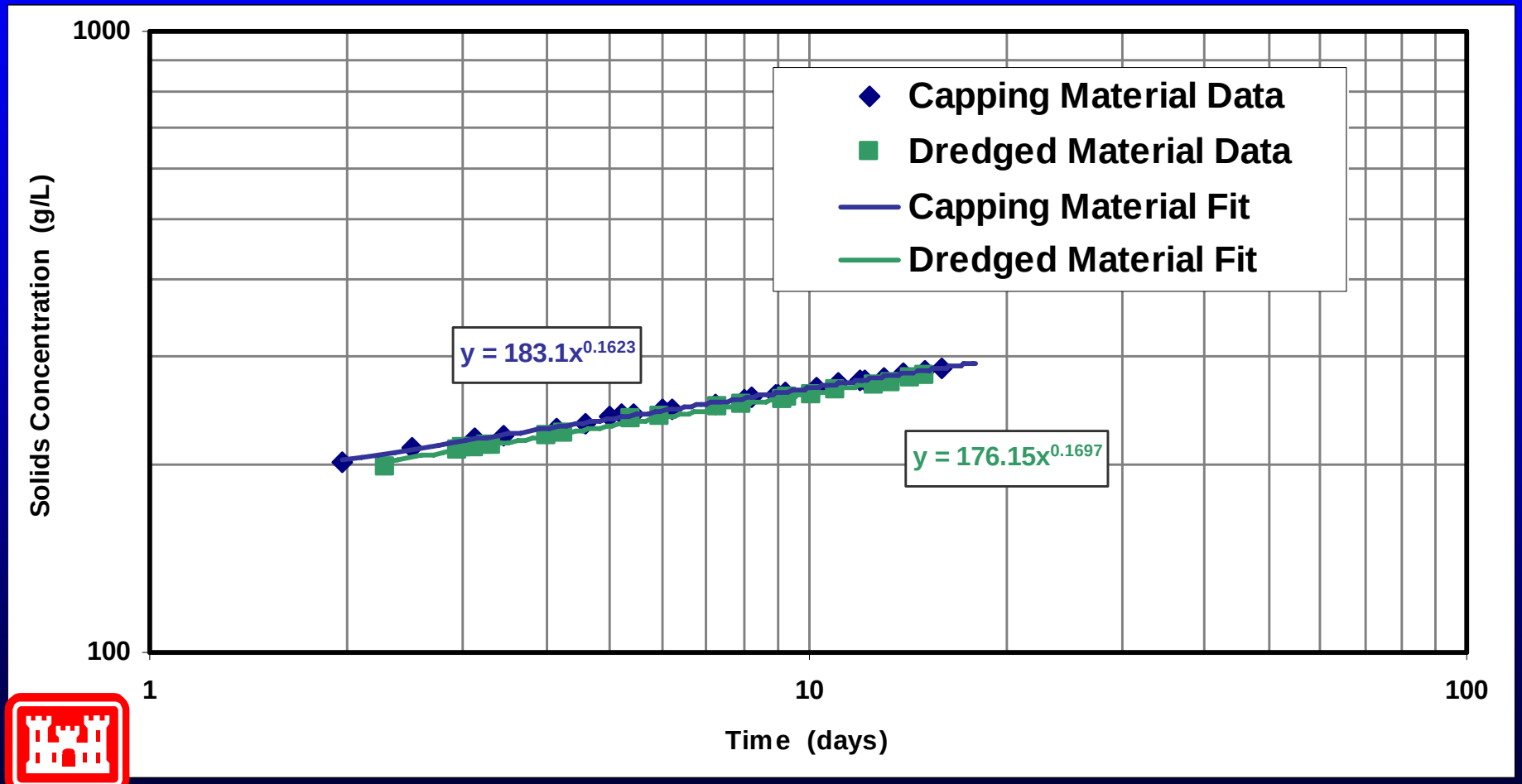
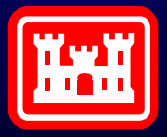
Standard Settling Results



Settling for Post-Placement Volume

- Incrementally Filled Tall Column Settling Test
  - Simulate 38 days of filling
  - Simulate storage for a deep CAD pit
  - Examine entrainment effects



Tall Column Settling Test

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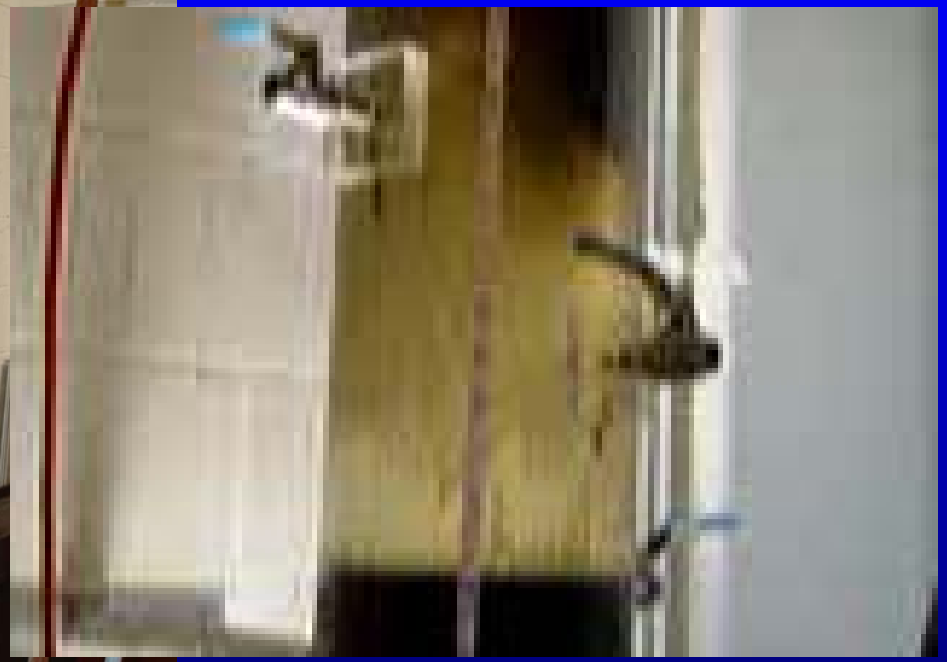
Tall Column Settling Test



Double Click

Water remains black (TSS up to about 10 g/L) for three hours per meter of settling height. Then, TSS of 30 to 150 mg/L.

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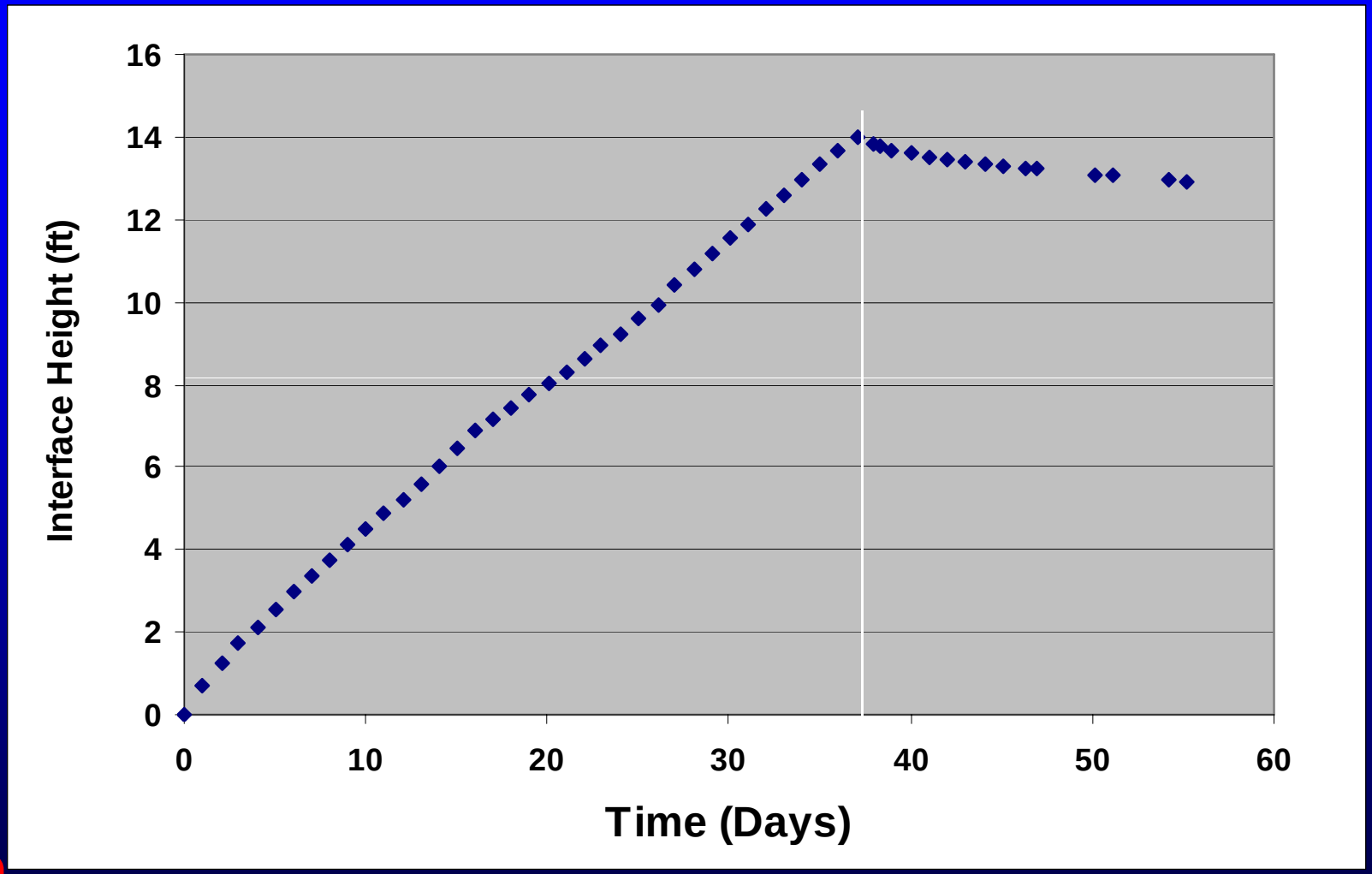
Height of Fill



Added 1 ft of 120 g/L slurry each day for 38 days.

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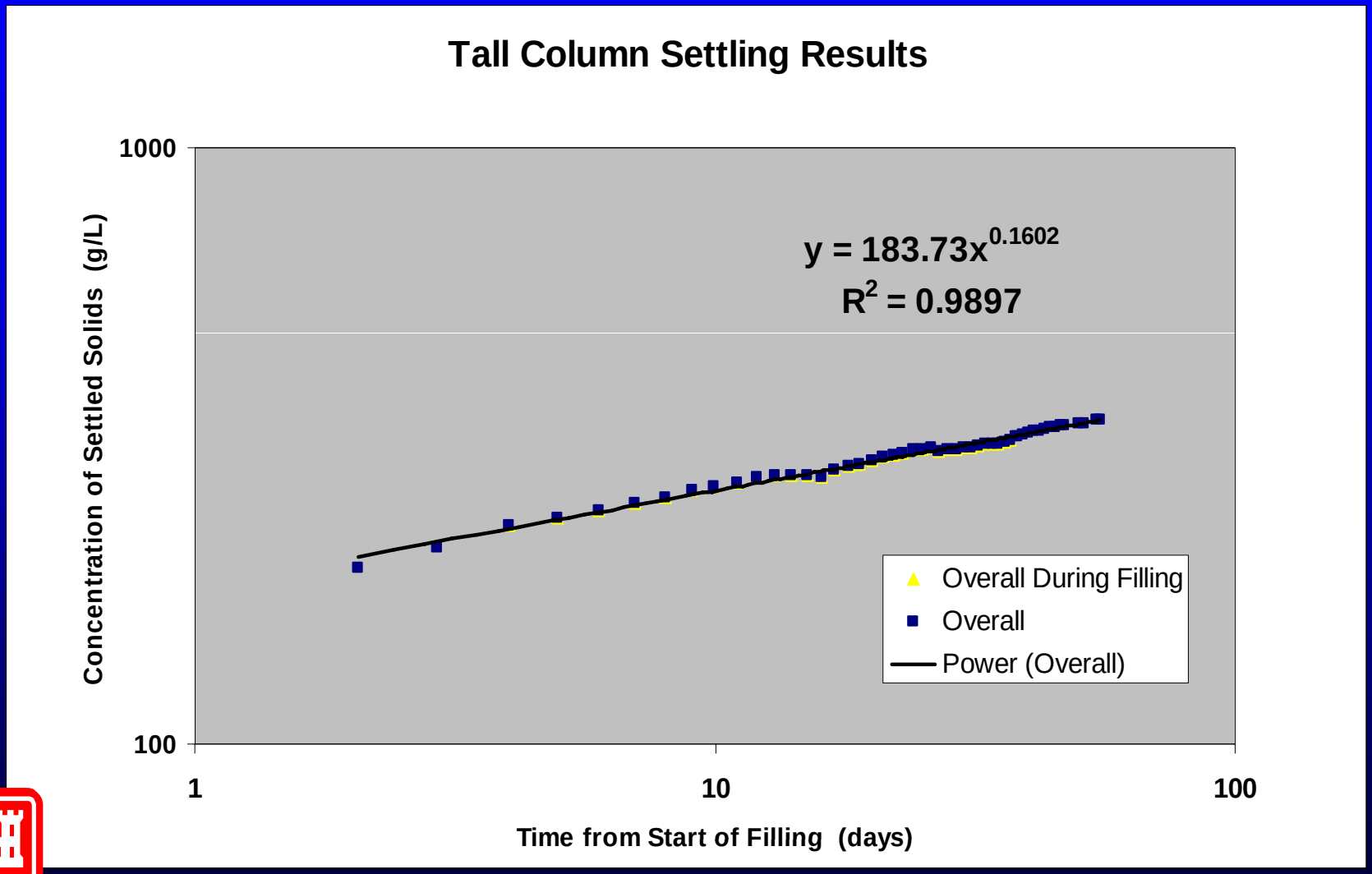
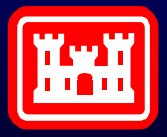
Storage Concentration



Settling Results and Conclusions

- Sediment is primarily fine-grained high plastic and highly compressible silt/clay with about 20% sand.
- Hindered settling occurs above 160 g/L. Zone settling velocities are quite slow and pose concerns for sizing and potential losses of solids during placement.
- Settling properties of dredged material and capping material are very similar.
- Suspended solids concentration under quiescent settling are below 40 mg/L initially, below 20 mg/L in 1 day, and below 10 mg/L in 7 days.
- Tall column settling test provided very good data for storage needs.

Laboratory Long-Term Performance Evaluation



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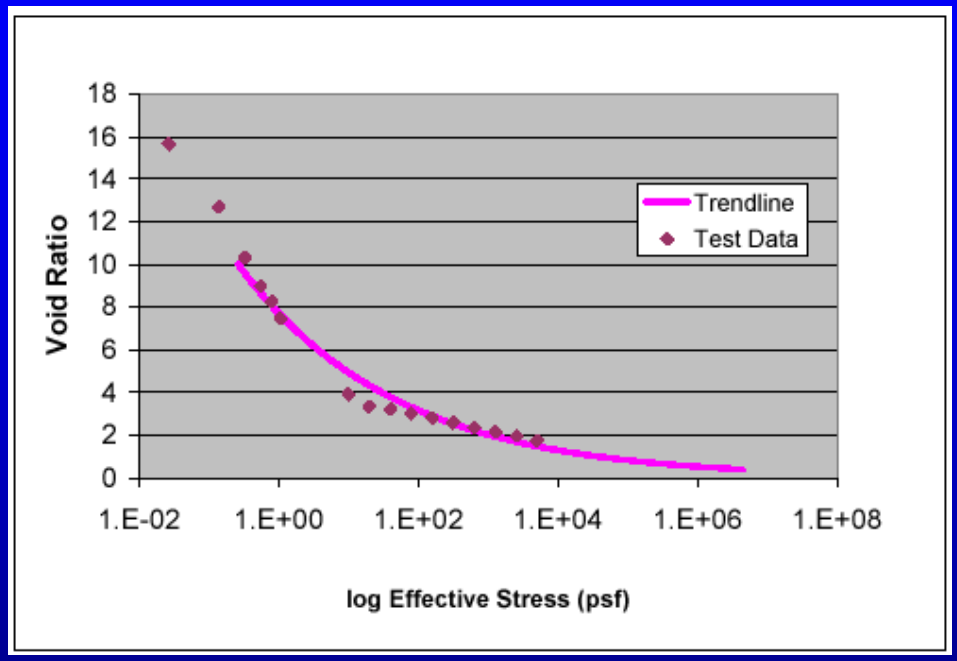
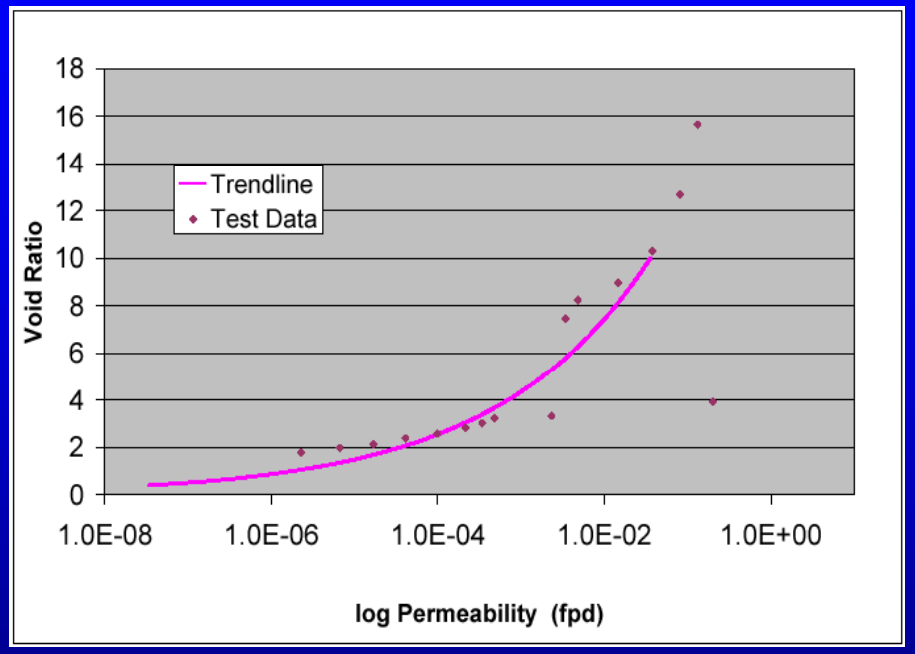
Consolidation Test Results





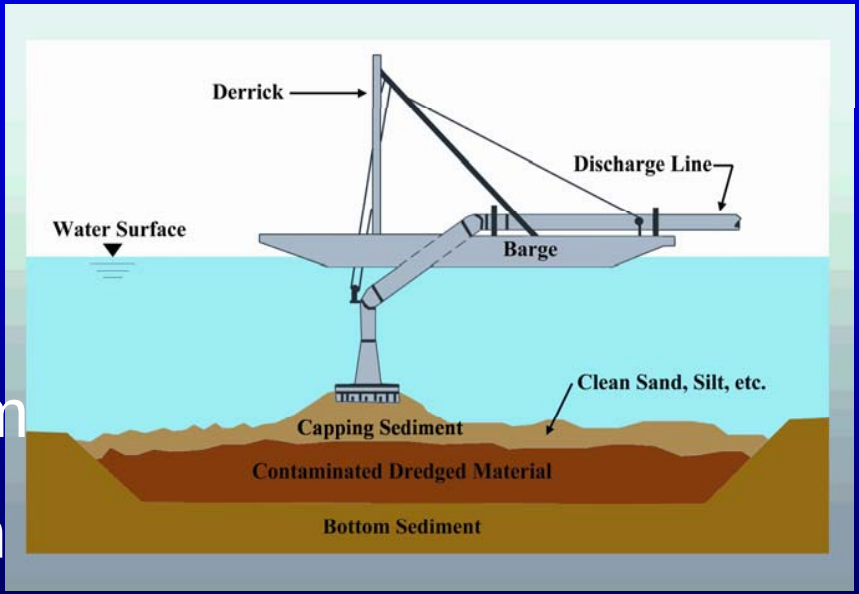
$e = 7.724\ P^{-0.1932}$

$K = 0.00000122\ e^{4.374}$

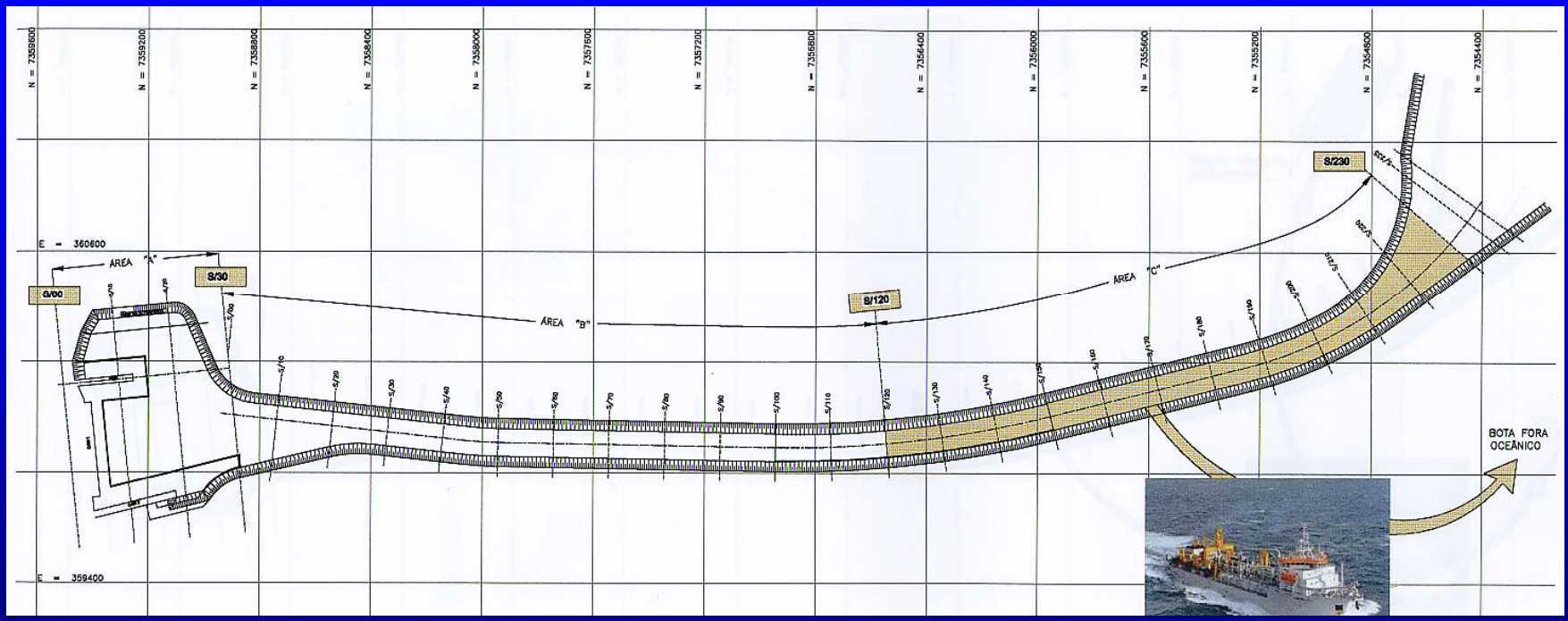
In situ Material: Gray Sandy Clay (CH); 22% Sand;
w = 144.5% (553 g/L)

Piaçaguera Canal CAD Pits

- Multiple cells excavated from bottom of existing navigation channel
- 4H : 1V side slopes
- 100 m top width
- Maximum depth of 25 m
- Maximum fill height of 10 m
- Cap thickness of up to 2 m
- Want about 3 m clearance to sediment interface

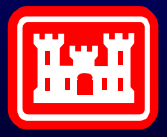


Location of CAD Cells



CAD cells will be placed in the lower dredging reach where the sediments are suitable for ocean disposal.

Modeling



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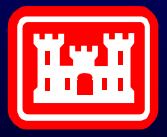
Implications for Sizing

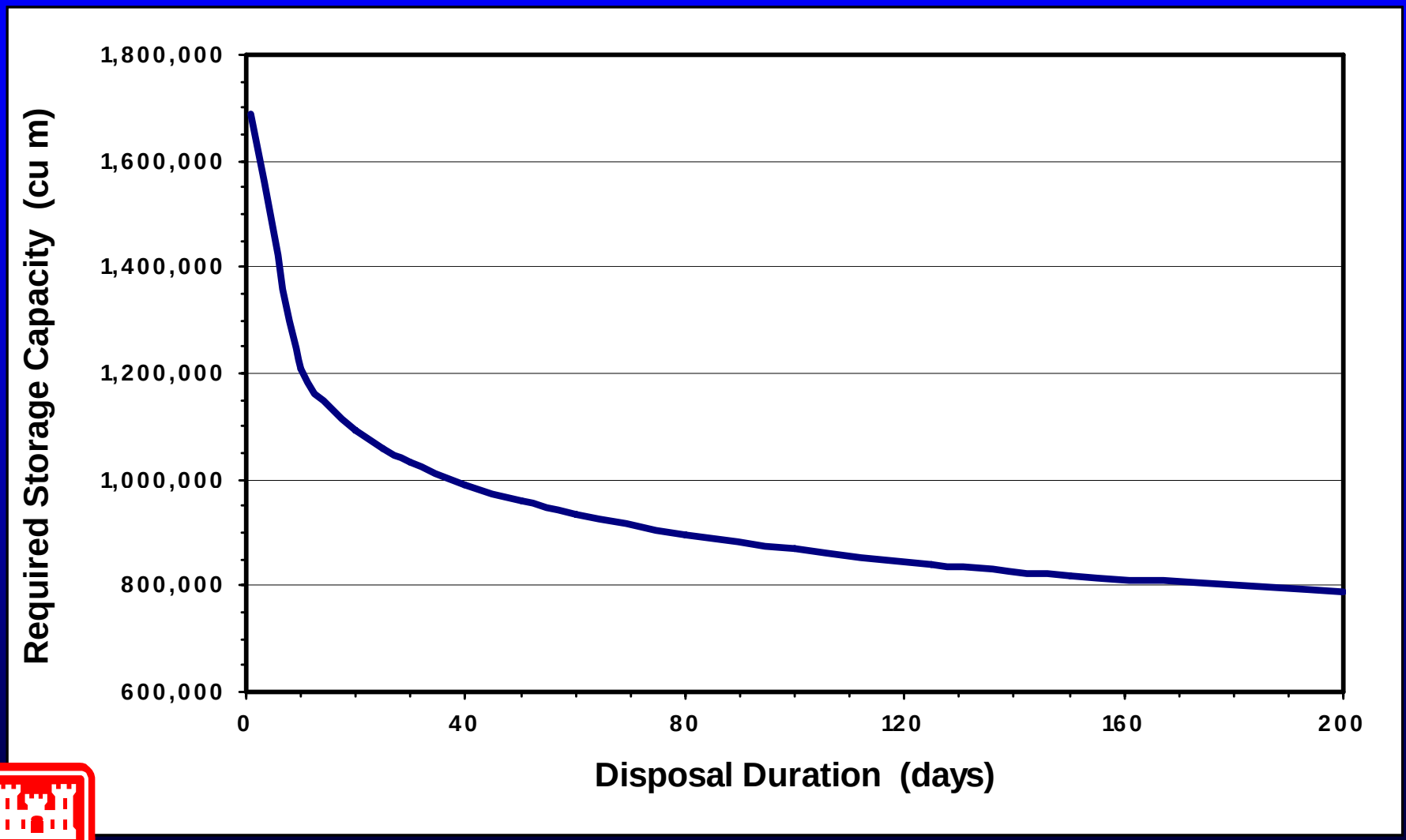
- **Settling (Short-Term Placement Volume)**
  - Modeling Using USACE SETTLE Model
    - Prediction of Settled Solids Concentration and Bulking
    - Prediction of Total Suspended Solids (TSS) Concentration at Disposal Site (20 to 30 mg/L after 12 to 24 hours of settling)
    - Predicts Slow Zone Settling Rate (about 0.5 m/day at 120 g/L). Typical Rates are 1 to 2 m/day.
    - Prediction of Minimum Cell Area (about 21 ha/m^3/s)
    - e.g., at Dredge Pump Rate of 0.5 m^3/s, minimum cell area is about 10 ha (0.1 sq km)

Sizing

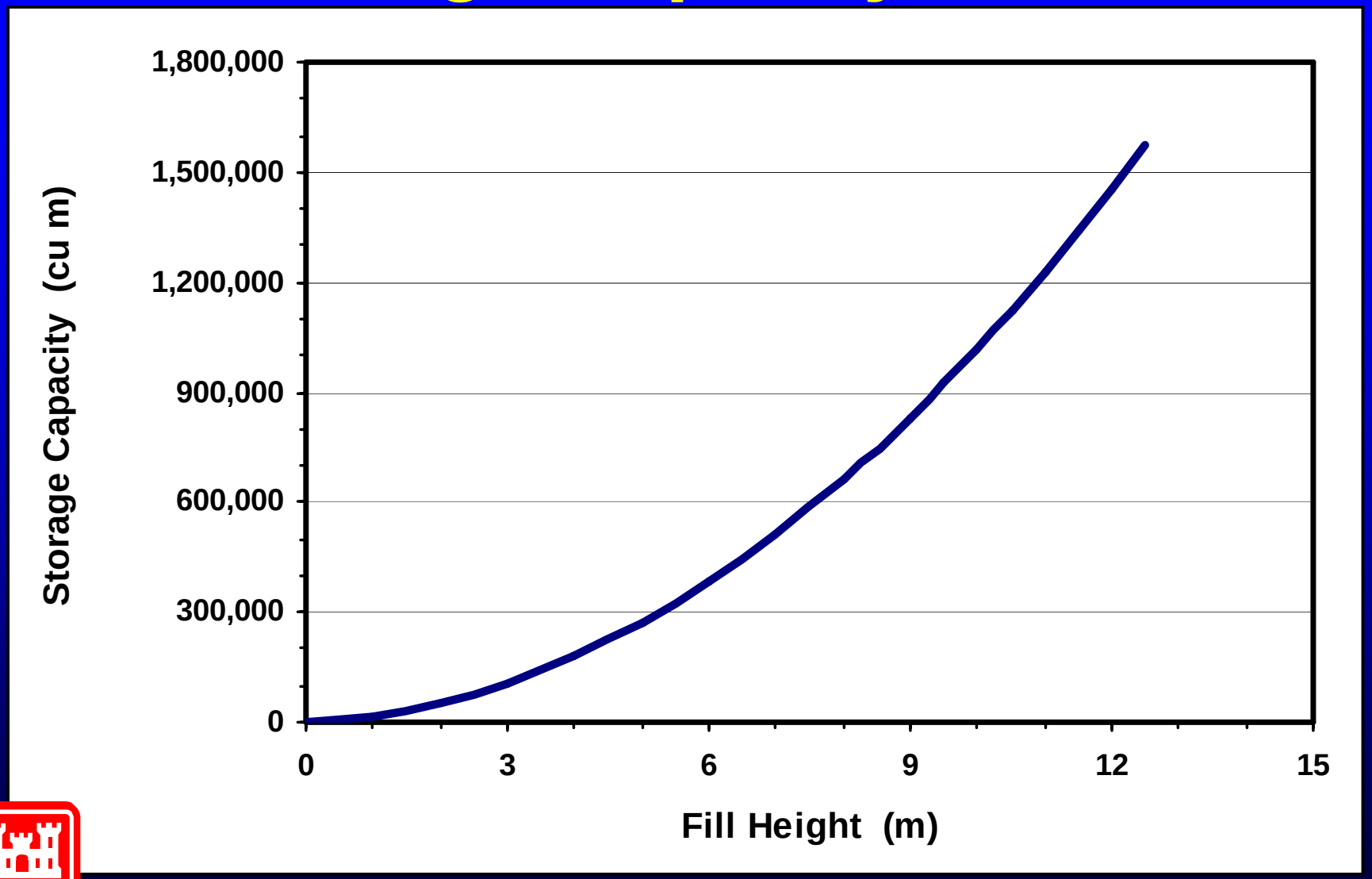
- Minimum cell area is about 200,000 sq m, given a width of 100 m, the minimum length of the CAD cell(s) is about 2 km
- If multiple cells are used, filling must cycle between cells
- Alternatives are to reduce the production rate by disposing only intermittently, to select a smaller dredge or to decrease slurry concentration



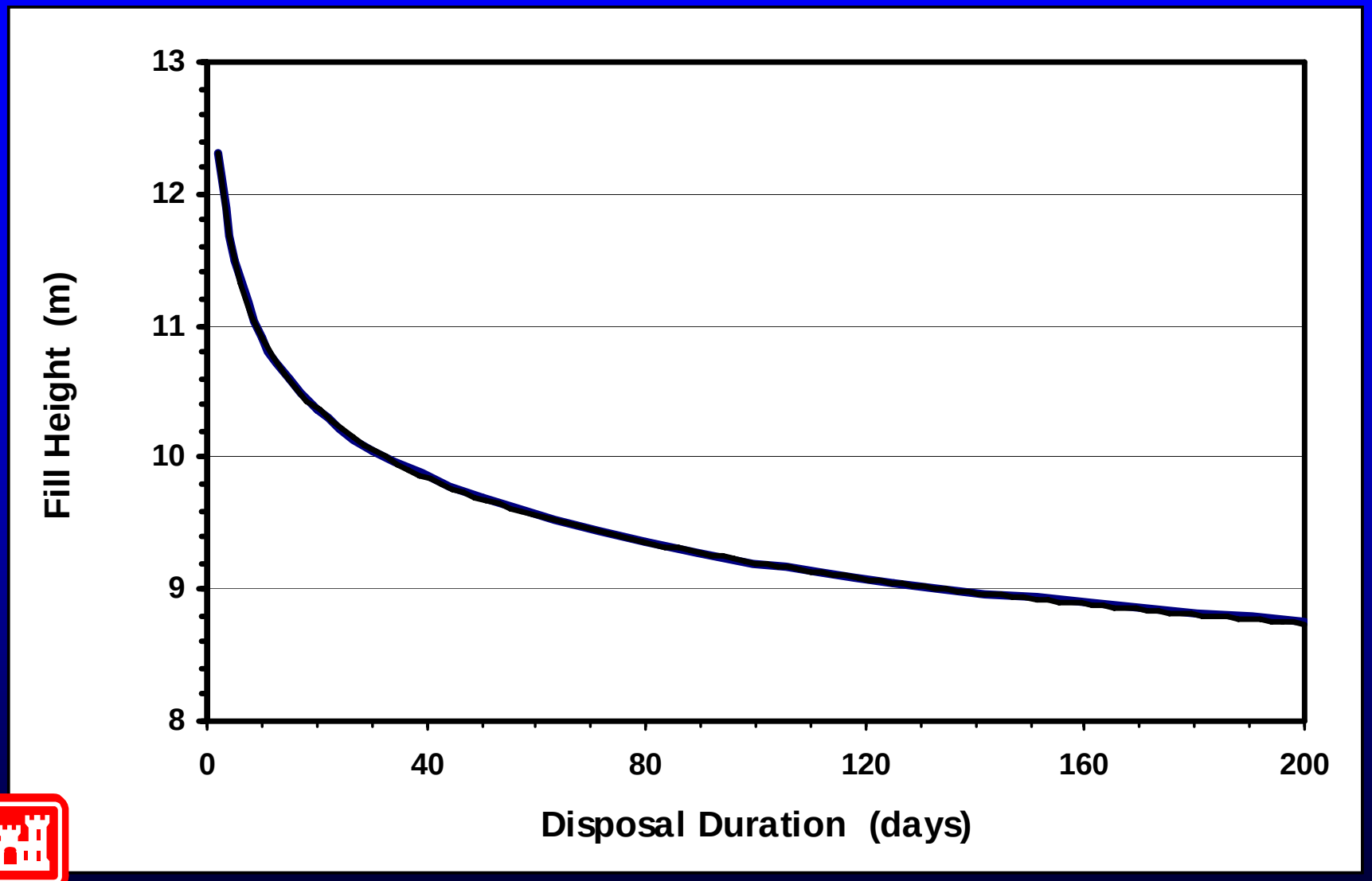
Required Storage Capacity



Storage Capacity Curve



Filling Curve



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Implications for Sizing

- **Consolidation (Long-Term Placement Volume)**
  - Modeling Using USACE PSDDF Model
    - Short-term sizing needs controlled by permeability
    - Permeability measurements in consolidation testing lacks precision and accuracy needed for predicting short-term sizing needs
    - Permeability data can be calibrated using tall column settling test results for mid- and long-term predictions
    - Relatively small adjustments required for calibration
    - Long-term volume will be about half of volume immediately after placement

Preliminary CAD Cell Design Conclusions

- Preliminary CAD cell design just meets area requirements
- Storage capacity provides 2 to 2.5 m of clearance for ship props, settling, and capping, about 0.5 m to 1 m less than expected
- Stretching disposal period would improve capacity

Testing Conclusions

- Tall column compression settling test provide the best basis for sizing deep CAD cells
- Tall column predicts greater compression settling as expected due to 5 times greater material thickness
- Permeability data in the consolidation modeling needed to be decreased by 50 percent to match tall column results
- Consolidation test data is imprecise for permeability due to rapid changes in short sample

Long-Term Risk

- Long term performance improved by consolidation, thereby increasing clearance for cap and providing for natural infilling of acceptable material
- Based on short-term risk evaluation, in the long-term,
  - Cap is reworked and mixed, but not lost
  - Mixing does not occur to a depth that compromises isolation of contaminated sediment
- Short-term risk can be improved by controls

Controls

- Mechanical dredging and disposal would increase density of disposed material
  - Increased density would reduce TSS losses to water column due to less entrainment of water and greater settling rates
  - Increased density would reduce erosional losses
  - Increased density would reduce storage needs and CAD pit size

Controls

- Disposed at the bottom of the CAD cell
- Limit the height of dredged material fill
  - Slow rate of disposal; extend period of disposal
  - Increase size of CAD cell
  - Limit quantity of dredged material