Design of a Dam Sediment Mitigation System to Aid Water Quality Restoration of the Chesapeake Bay

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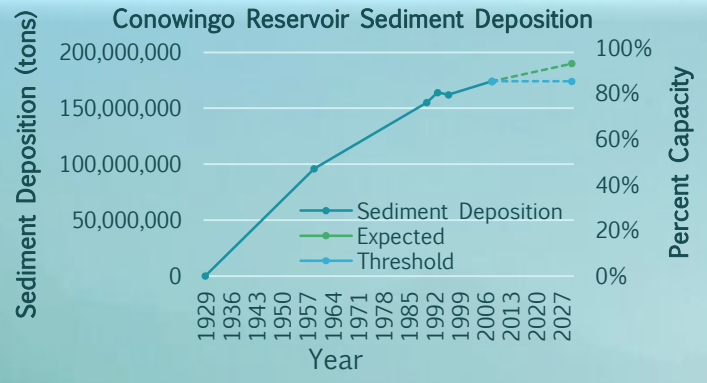
Context



- Major storms (>300,000cfs) cause scouring events
- Scouring events cause sediment plumes along Chesapeake Bay
- Sediment plumes cause large algae blooms which damages aquatic ecosystem health
- Scouring events occur due to sediment build-up at Conowingo Reservoir (area behind dam)
- Sediment scour exponentially increases as flow rate increases
- Max Recorded Flow Rates:
  1. (1972) Hurricane Agnes: 1,120,000 cubic ft. per second
  2. (2011) Tropical Storm Lee: 709,000 cubic ft. per second

Stakeholder Tension: Sediment needs to be managed. Dam owners do not want to take responsibility. Relicensing may result in payment for system.

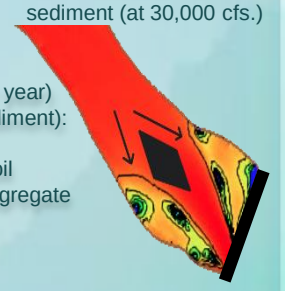
Need & Design Alternatives

Need to create a system to reduce the environmental impact of scouring events while facilitating current (Chesapeake Bay TMDL) ecological regulations.

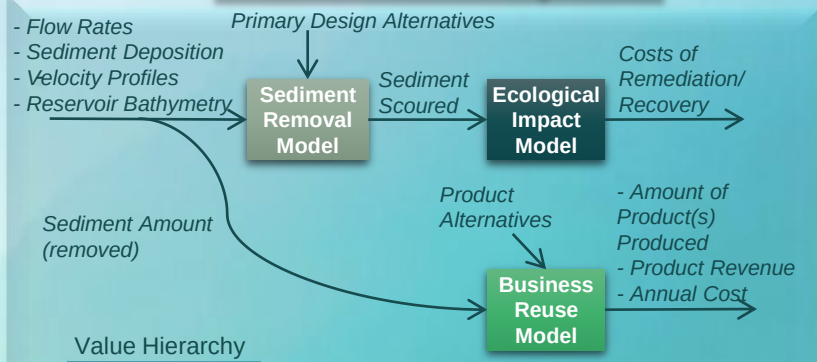
Alternatives

1. No mitigation (baseline)
   - Sediment continues accumulation at Conowingo Reservoir
2. Hydraulic Dredging
   - Mechanical removal of sediment via pipeline (1, 3, 5 million cubic yards per year)
   - Sub-alternatives (action taken with sediment):
     - Quarry (baseline)
     - Low-Temp Washing – Topsoil
     - Rotary Kiln – Lightweight Aggregate
     - Plasma Arc Vitrification –
       - Low Grade Tile
       - High Grade Tile
3. Dredging & Artificial Island
   - Island made using processed dredged sediment (after 2 years)
   - Flow velocity increases, Rouse number decreases around island (i.e. more sediment through dam at steady-state)
   - Same sub-alternatives above apply (after island construction)

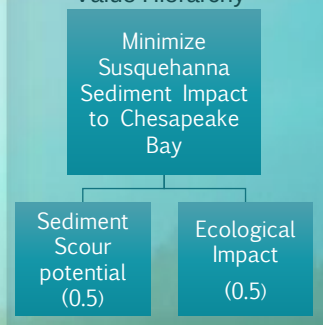
Rouse Number (particle fall velocity divided by bed shear stress) with artificial island location
Yellow-Blue is trapped sediment (at 30,000 cfs.)



Method of Analysis

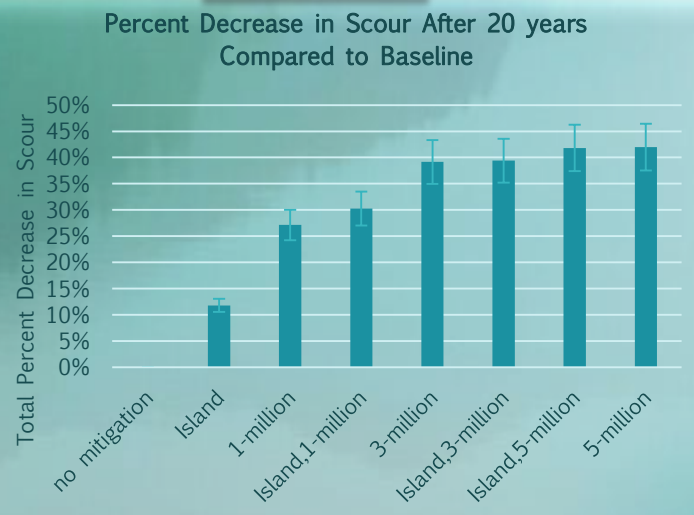


Value Hierarchy



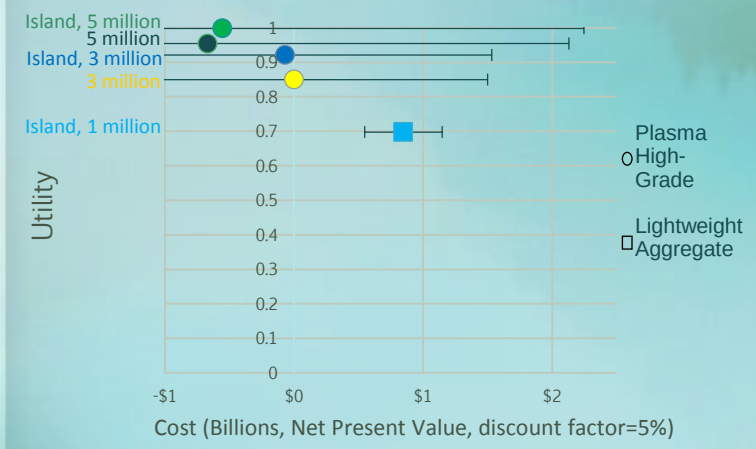
- Sediment Removal Model
  - Simulates reservoir activity after mitigation alternatives applied
- Ecological Impact Model
  - Simulates monetary value of Chesapeake Bay impact
- Business Reuse Model
  - Simulates cost of processing dredged sediment into products

Results



For every 1 million cubic yards dredged:
- 2% initial decrease in scour
- 0.4% decrease in scour after maximum dredging for 20 years.

Analysis



- Plasma high-grade is only alternative with a chance to turn a profit, but has high variability
- Lightweight aggregate does not have a chance to turn a profit, but has a low uncertainty

Recommendation

- **Best option**
  - Dredge 5 million cubic yards annually
  - Produce high-grade architectural tile for maximum product and profit potential
  - Further analysis on plasma gas arc vitrification is needed to solidify profitability.
- **Best (non-Plasma) option –**
  - Construct an artificial island* from sediment dredged
  - After island construction, dredge 1 million cubic yards annually
  - Produce lightweight aggregate.
  - This is the safest option, as it provides low uncertainty and beneficial reuse

Rank	Alternative Combo (Product, Mitigation)
1	Plasma - High-Grade Tile, 5 million
2	Plasma - High-Grade Tile, 5 million with Island
3	Plasma - High-Grade Tile, 3 million with Island
4	Plasma - High-Grade Tile, 3 million
5	Lightweight Aggregate, 1 million with Island

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