Analysis of Multiyear Benefit Window on Dredge Location Selection

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US Army Corps of Engineers
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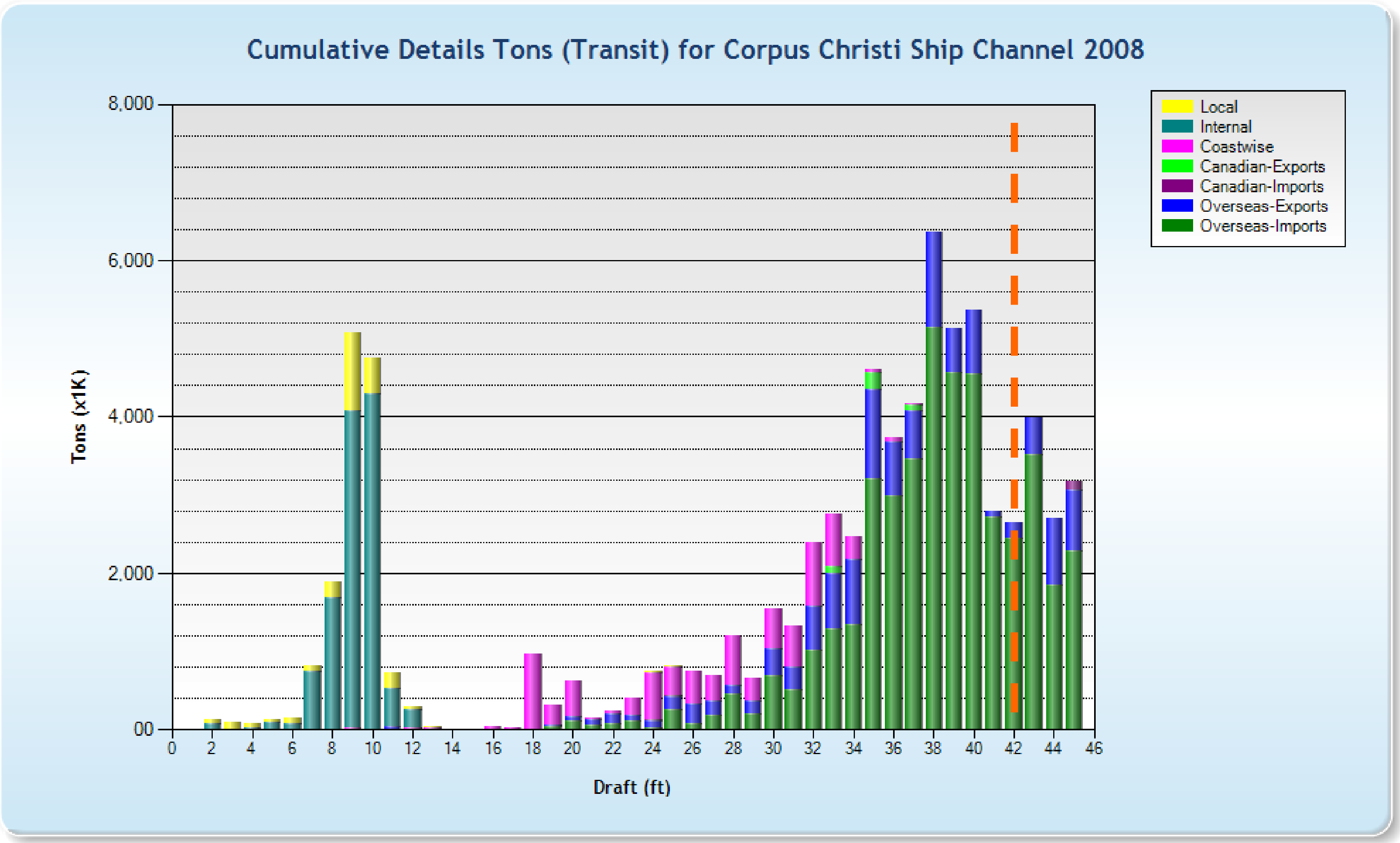
Limited O&M Funding

- **Fiscal constraints force the Corps to make difficult decisions concerning allocation of limited Operations and Maintenance (O&M) funds**

- **We investigate how to optimize limited resources to maximize value to the nation --- in this case measured by tonnage disrupted by shoaling**

- **Specifically, we aim to examine how forecasting efforts can improve efficiency**

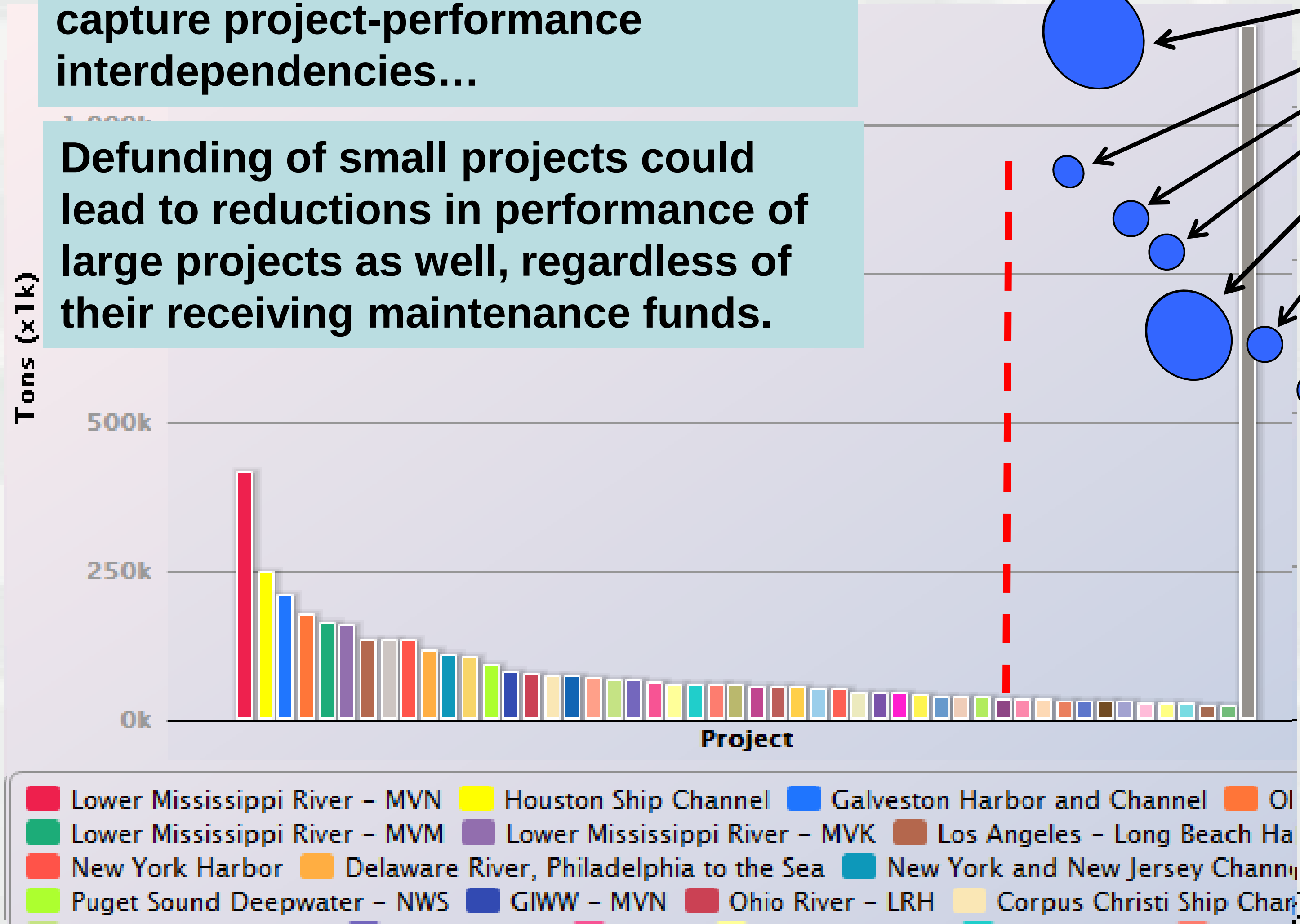
Focus on Shoal-vulnerable Cargo

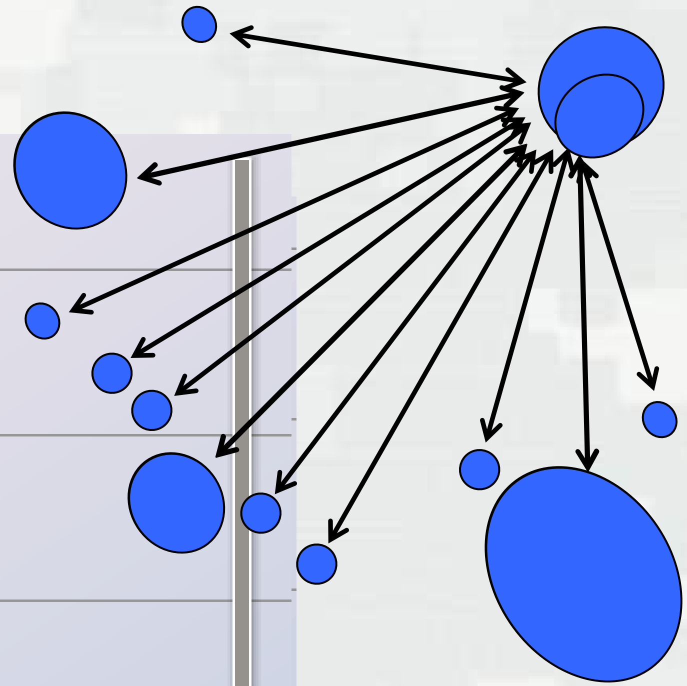


Project View versus System View

Rank-ordered project evaluation with cut-off line for funding often does not capture project-performance interdependencies…

Defunding of small projects could lead to reductions in performance of large projects as well, regardless of their receiving maintenance funds.





Algorithm Formulation

- Multiple Depths

4 Dredging Options

4 Shoaling Options

11 Total Depths

Algorithm Formulation

- Multiple Depths
- Multiple Costs

Cost to dredge 1-4 Feet

Mob/Demob Costs included

Algorithm Formulation

- Multiple Depths
- Multiple Costs
- Multiple Tonnages

Entire path must be dredged

Tonnage passes at "shallowest" point on path

Algorithm Formulation

- Multiple Depths
- Multiple Costs
- Multiple Tonnages
- Multi-Year

The end state (depth at each port) of a simulation is the starting point for the next year

(20 year simulation)

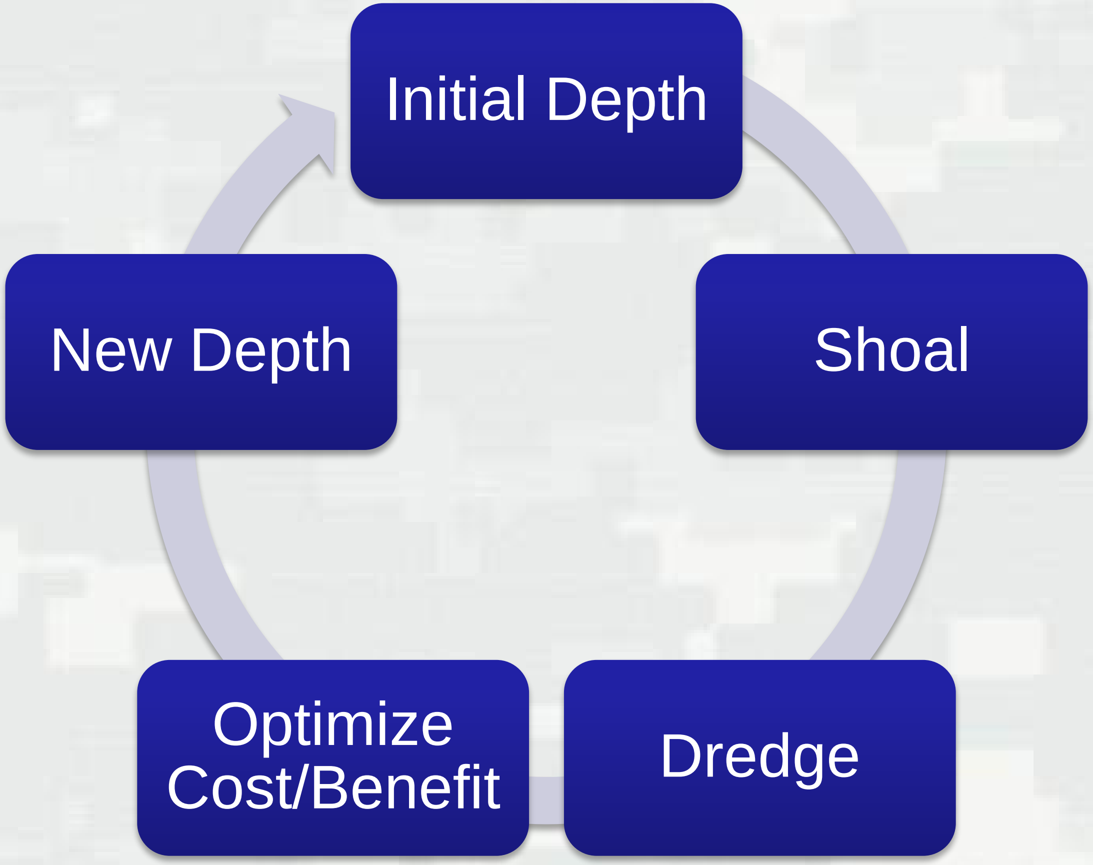
Algorithm Formulation

- Multiple Depths
- Multiple Costs
- Multiple Tonnages
- Multi-Year
- Shoaling

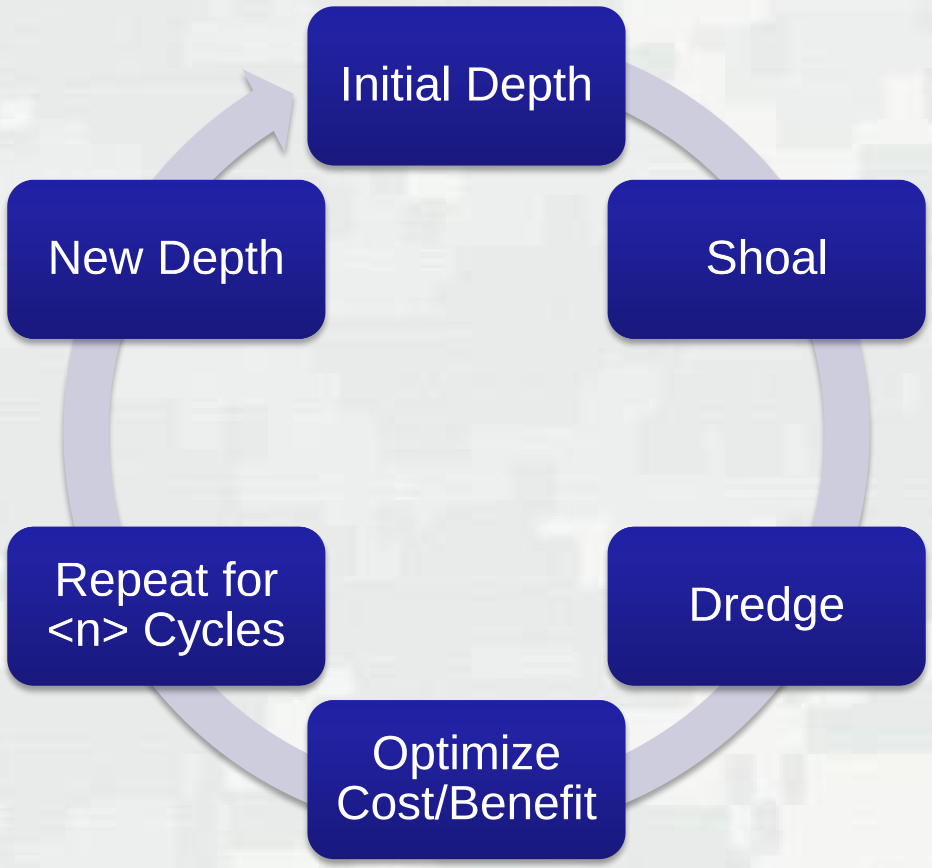
At the start of each “year”, each channel shoals at a rate dependent on:

- Current Depth
- Previous Year Dredging

Basic Algorithm



Expansion of Algorithm



Solving the System

- Use Genetic Algorithm (pyevolve) to optimize dredging decision
- For a system with 783 unique ports and 39,418 routes, it takes ~ 20-40 minutes to optimize one "year"
- 10^{11} possibilities *each year!*

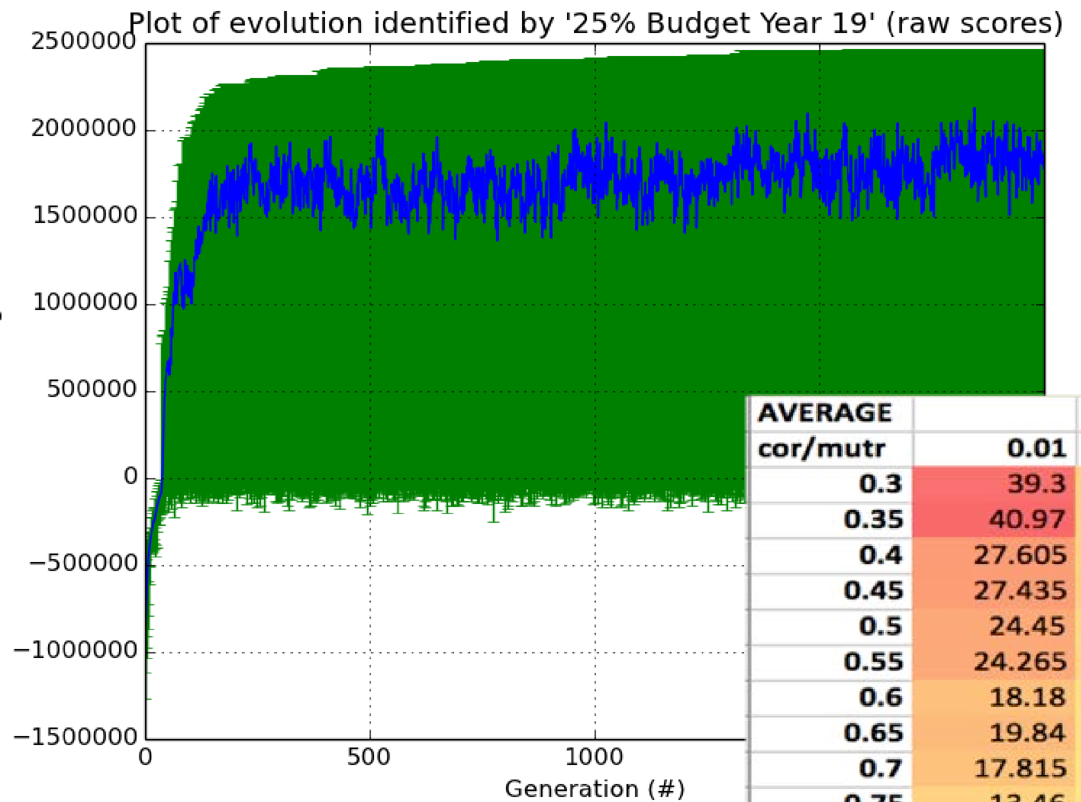
Multi-Year Challenges

- “Butterfly Effect” is challenging for optimization
- Signal to Noise masks feasible solutions
- Determine ratios for future benefits vs. current
- 10^{11} possibilities *each year!* Exponentially more for multiple years!

Genetic Algorithm (GA)

- No sense of a traditional "downhill" for an optimizer to follow
- Must explore the space "randomly"
- GA allows us to "efficiently" explore space
  - Main constraint is time
- Local minima for multi-year are a hazard

GA Parameters



Extensive Testing

for multi-year

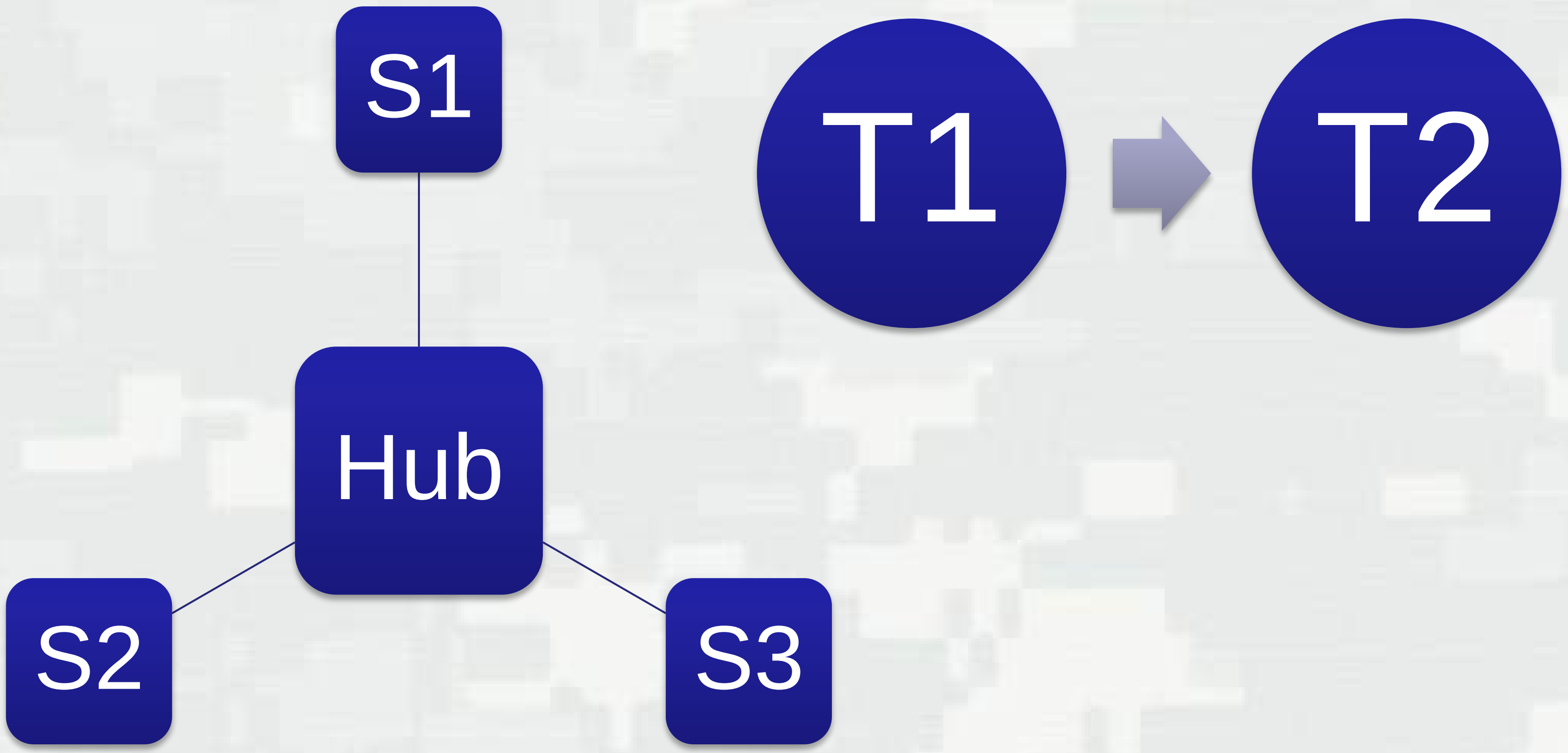
performance

AVERAGE					
cor/mutr	0.01	0.02	0.03	0.04	0.05
0.3	39.3	13.11	8.64	6.18	6.315
0.35	40.97	13.145	9.66	6.68	5.94
0.4	27.605	13.16	10.06	7.735	5.15
0.45	27.435	14.26	8	6.415	5.4
0.5	24.45	11.75	8.595	5.755	4.325
0.55	24.265	12.155	6.89	5.885	5.125
0.6	18.18	9.925	8.25	5.27	4.705
0.65	19.84	9.39	7.025	5.75	4.71
0.7	17.815	8.62	6.83	5.785	4.245
0.75	13.46	8.76	6.23	5.495	4.14
0.8	13.015	6.77	5.69	3.96	3.88
0.85	14.08	7.09	4.81	4.595	3.86
0.9	8.85	7.17	4.83	4.06	4.09
0.95	8.475	5.51	4.545	3.835	3.305
1	9.435	5.095	3.895	3.21	3.2

Sample Data

- 5 port system to test multi-year forecasting
- Limited Budget to shrink decision space
- Exploits single vs multi-year benefits

Sample System



Sample Data Results

1 Year

6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
4	3	2	1	0	0	0	0	0	0
4	3	2	1	0	0	0	0	0	0

In a 1-year Window, the algorithm only realizes the benefit of dredging the isolated pair. The hub-spoke system is not visited because the benefit cannot be realized in a single year operation.

Sample Data Results

1 Year

6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
4	3	2	1	0	0	0	0	0	0

2

5

With a two year window, the optimizer starts dredging the isolated pair, then begins to realize the benefit of the hub-spoke system. After benefits of the hub-spoke are realized, the isolated pair are abandoned.

Sample Data Results

1 Year

6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
4	3	2	1	0	0	0	0	0	0
4	3	2	1	0	0	0	0	0	0

The results are similar with a 5 year window to a 2-year. However, the 5 year forecast recognizes the value of deeply dredging a single location in the hub-spoke system.

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6

Sample Data Results

1 Year

6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6
4	3	2	1	0	0	0	0	0	0
4	3	2	1	0	0	0	0	0	0

2 Year

6	6	6	4	3	4	5	4	3	4
6	6	6	4	5	4	3	4	5	4
6	6	4	5	4	5	4	5	4	5
6	6	4	5	6	4	5	4	5	4
4	3	4	5	6	6	6	6	6	6
4	3	4	5	6	6	6	6	6	6

5 Year

6	6	6	6	4	4	5	4	3	4
6	6	6	6	4	2	3	2	3	3
6	6	6	6	6	6	4	5	6	3
6	6	6	2	3	4	3	4	3	4
4	3	2	3	4	5	6	6	6	6
4	3	2	3	4	5	6	6	6	6

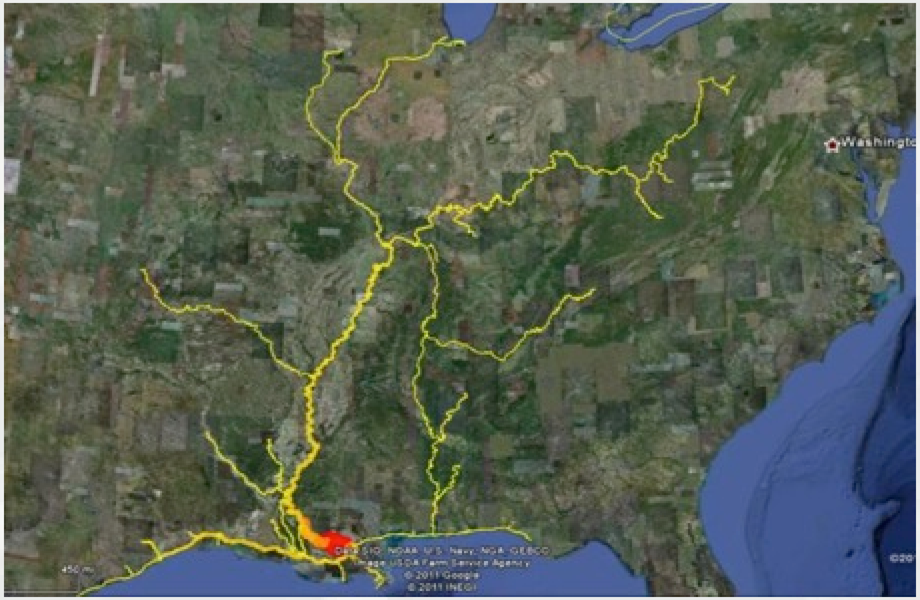
Waterborne Commerce Data

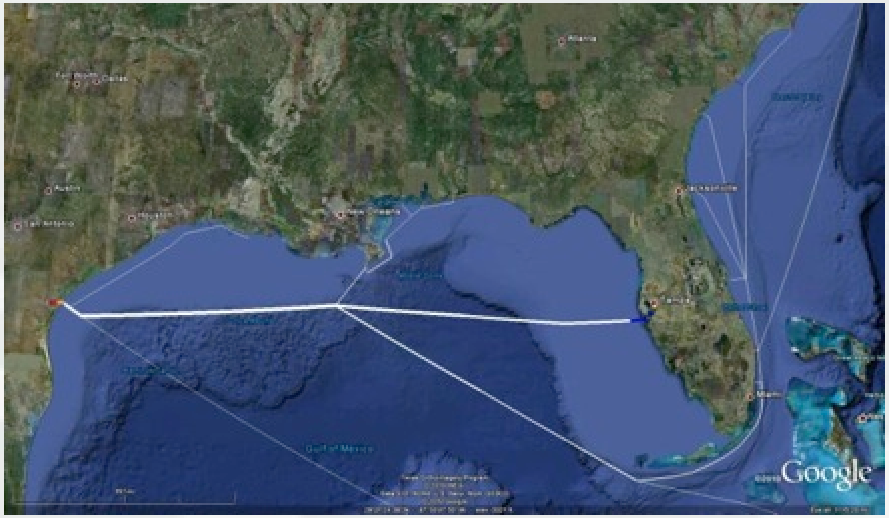
- The Corps' Waterborne Commerce Statistics Center (WCSC) collects and collates data from several sources concerning commercial use of US waterways.
  - ▸ Dock-level, origin-to-destination routing (Corps-use-only)
  - ▸ Includes tons, commodity types, vessel counts, drafts

- Channel Portfolio Tool (CPT: https://www.cpt.usace.army.mil) provides means of querying this large database and analyzing waterway network flow patterns. Now available to all federal employees.

- Allows systems-based approaches to analyze benefit over entire route, not just at single location

MTS Freight Flows





The O-D flows within the WCSC data allow the Corps to evaluate navigation project interdependencies.

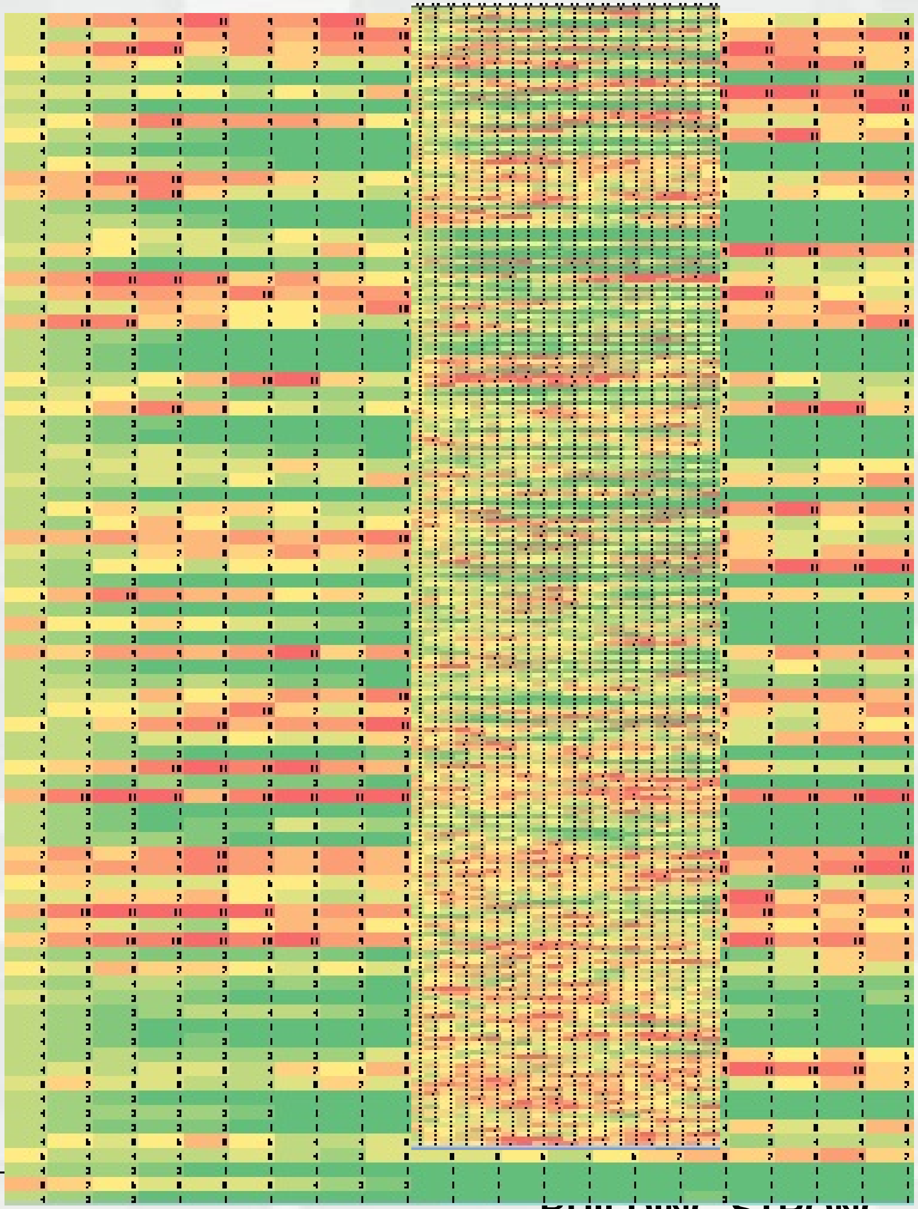
Evaluate entire route, not just one port

Model Output

Over 20 budget years, GA identifies solutions that balance:

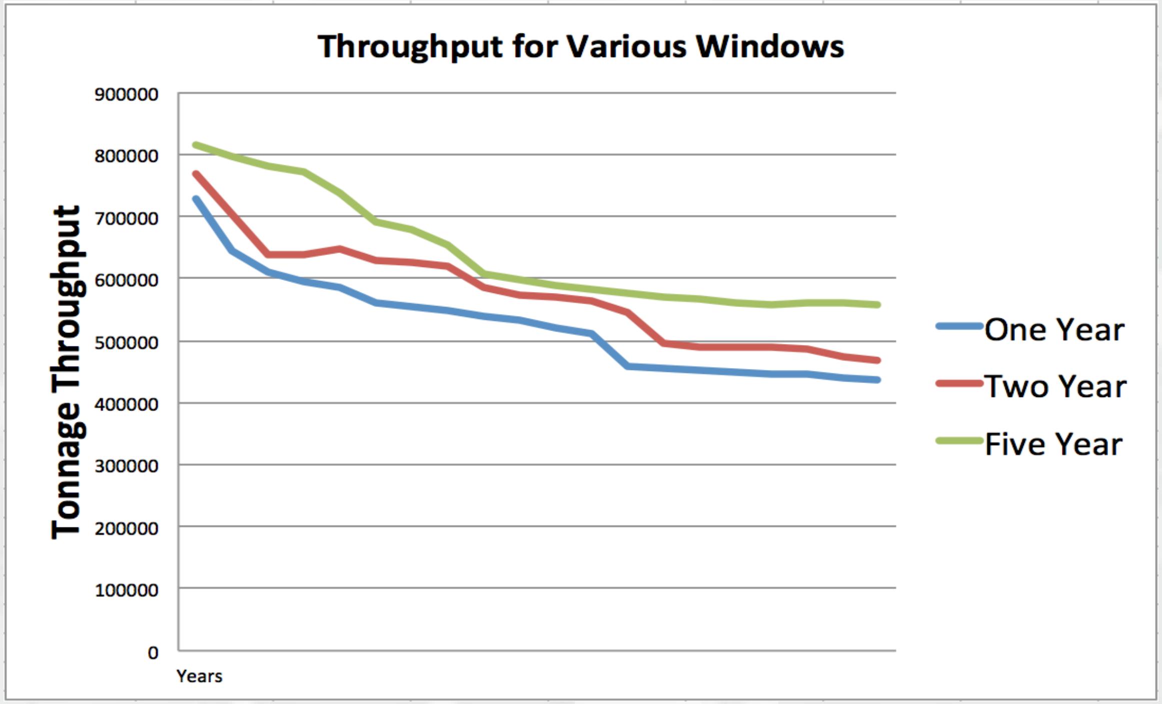
- maintaining some projects fully
- allowing others to mostly shoal in
- Cyclical maintenance strategies, with dredging only every few years

GA shows preference for projects with higher heuristic scores, e.g. dredging costs/tonnage



Not Quite…

The look-ahead seems to uniformly underperform single-year methods



Potential Explanations

- Foreign Cargo emphasizes key locations
- Random shoaling processes undermine forecasting
- Connectedness of data exposes otherwise hidden potential benefits
- Inappropriate weighting of future benefits