

Beta-1

(<http://cloudfish.chesapeakebay.net:3838/vico/>)

Scenario Optimization Tool for CAST (the time-averaged Phase 6 watershed model)

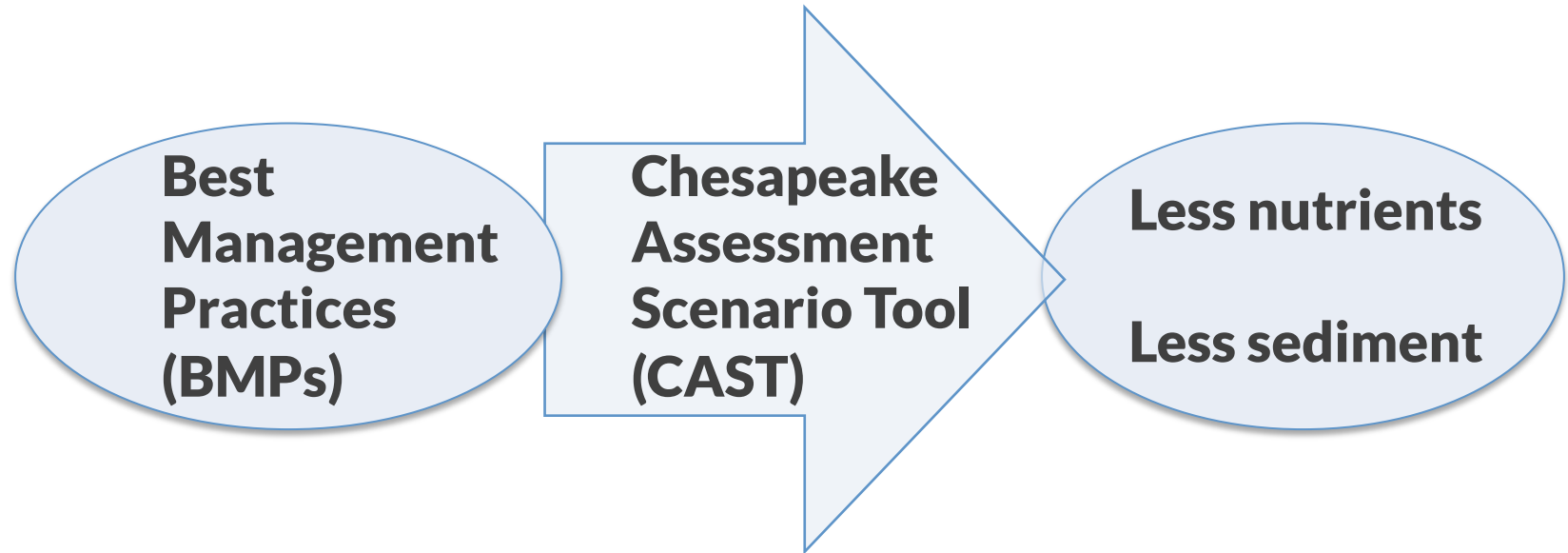
08 April 2019

Water Quality Goal Implementation Team (WQGIT) Meeting

Daniel Kaufman, Kevin Asplen, and the CBPO Modeling Team

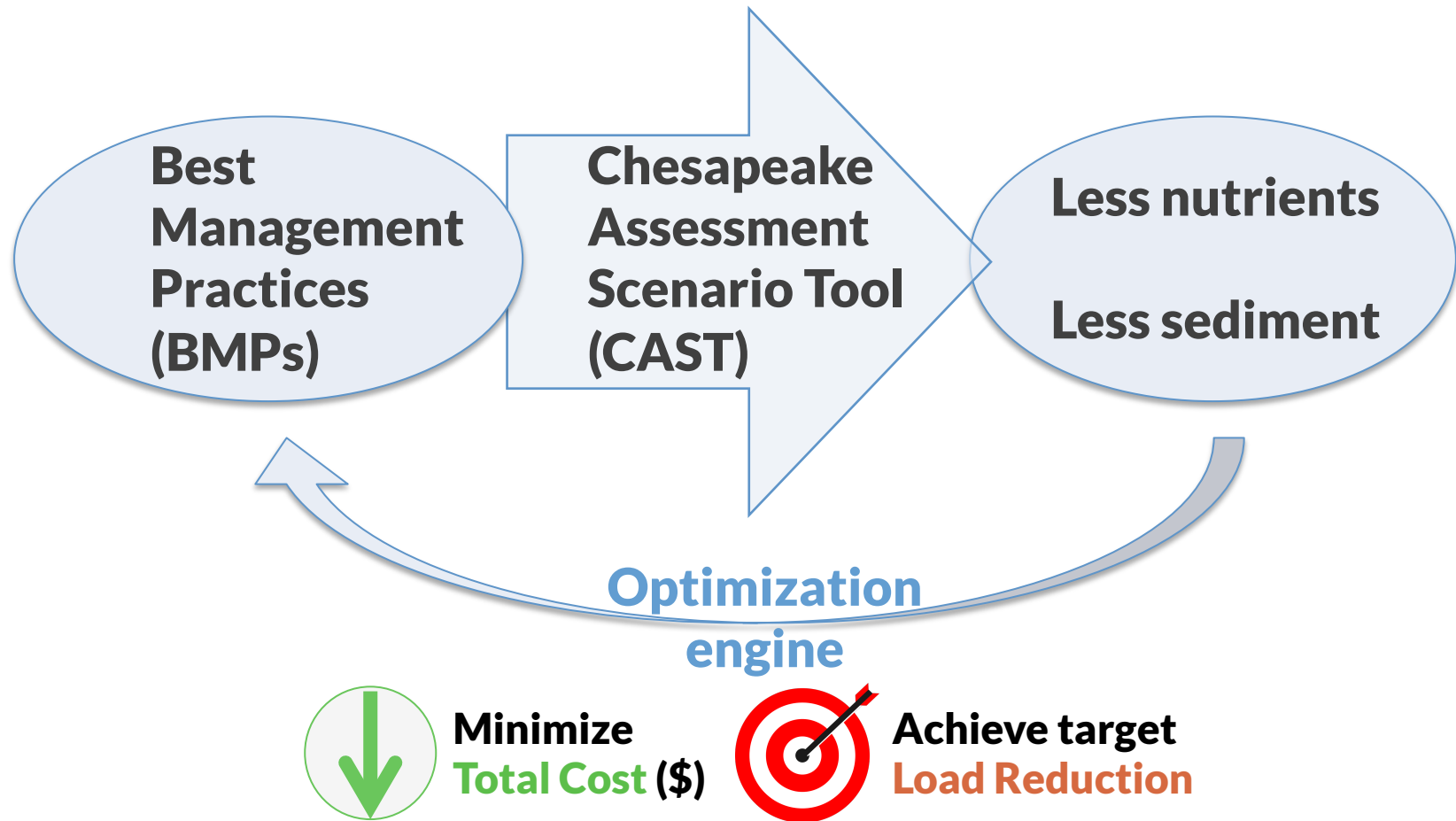
Project Goal: Investigate, develop, test, and implement an optimization system for the Chesapeake Assessment Scenario Tool (CAST) that will facilitate identification of more cost-effective and otherwise optimal approaches to pollutant load reduction for CBP partners.

Motivation for Optimization Tool



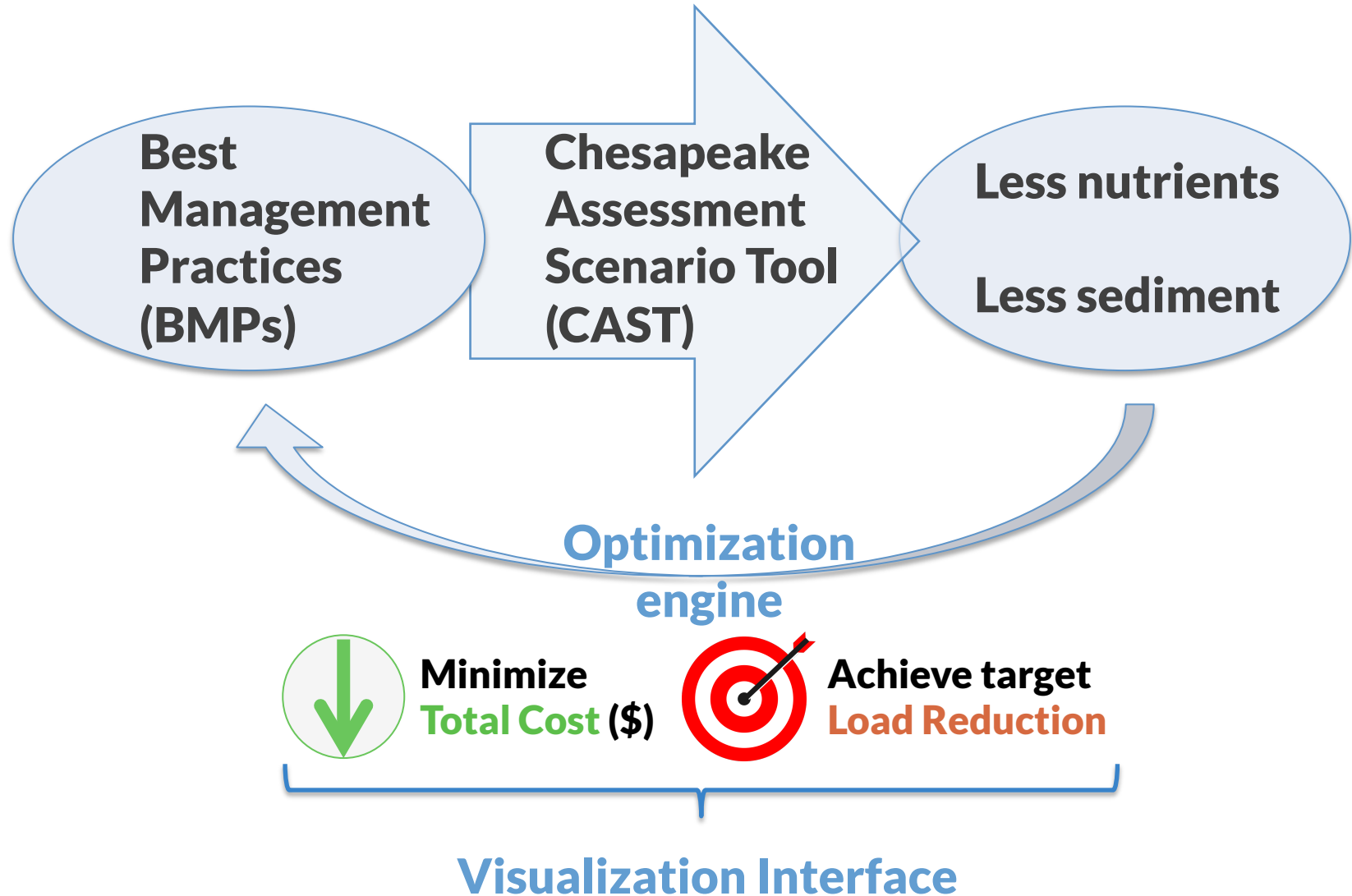
Would like to find low-cost BMP strategies, but not feasible to exhaustively try potential scenarios

Optimization engine



Beta version using only efficiency BMPs

to provide utility & gather feedback.



Beta-1 optimization tool

1

Overview

2

Features and Components

3

Future Developments

Optimization Engine

- Runs on the CBP cloud
- Optimization model built on-the-fly for a particular geography, objective, constraints
- Optimization Solutions (39,400) for:
 - 197 counties
 - 4 objective/constraint combinations
 - 50 constraint levels

Online Visualization Interface

- Runs on the CBP cloud
- Presents views of:
 - objective space (cost vs. load)
 - decision space (BMP acres, summed)
- Can interactively explore the BMPs implemented to achieve certain cost & load

Visualization Interface for Chesapeake Optimization (VICO) (Beta-1 Version)

Developed by the Chesapeake Bay Program Office in collaboration with the
Chesapeake Research Consortium

<http://cloudfish.chesapeakebay.net:3838/vico/>

Selection:

This page constructs two graphic images for answering questions about how best to allocate a county's resources among Best Management Practices (BMPs) to achieve targets for cost and load reduction:

1. The first graphic illustrates potential tradeoffs between cost and percentage reduction in loads (either Nitrogen or Phosphorus).
2. Upon clicking a point in the first graphic, a second graphic presents BMPs and implementation acres for achieving the cost and load reductions for that point.

Geography:

Calvert, MD

Objective and Main Constraint (for Given Range):

Minimize Cost for Target N Load Reduction (1% to 50%)

Selection: County

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Geography:

Calvert, MD

Objective and Main Constraint

Minimize Cost for Target N Load

Geography:

Calvert, MD

New Castle, DE

Sussex, DE

MD

Allegany, MD

Anne Arundel, MD

Baltimore, MD

Calvert, MD

Calvert, MD

Selection: Objective

This page constructs two graphic images for answering questions about how best to allocate a county's resources among Best Management Practices (BMPs) to achieve targets for cost and load reduction:

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Geography:

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Objective and Main Constraint

Minimize Cost for Target N Load Reduction

Geography:

Calvert, MD

Objective and Main Constraint (for Given Range):

Minimize Cost for Target N Load Reduction (1% to 50%)

Minimize Cost for Target N Load Reduction (1% to 50%)

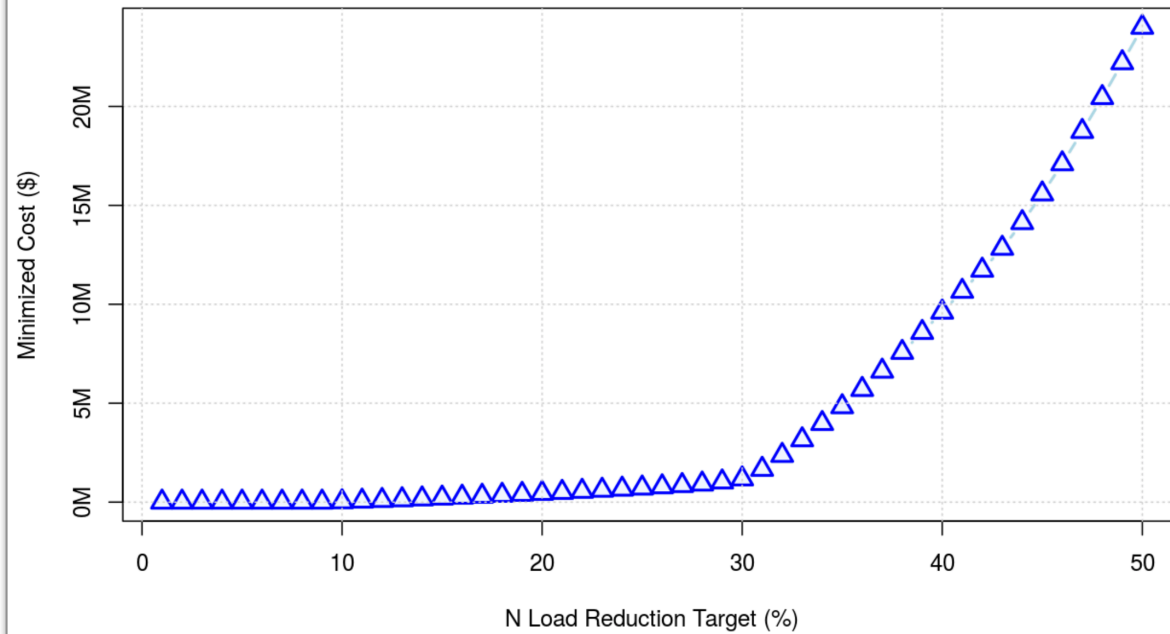
Minimize Cost for Target P Load Reduction (1% to 50%)

Maximize N Load Reduction for Target Cost (\$100K to \$5M)

Maximize P Load Reduction for Target Cost (\$100K to \$5M)

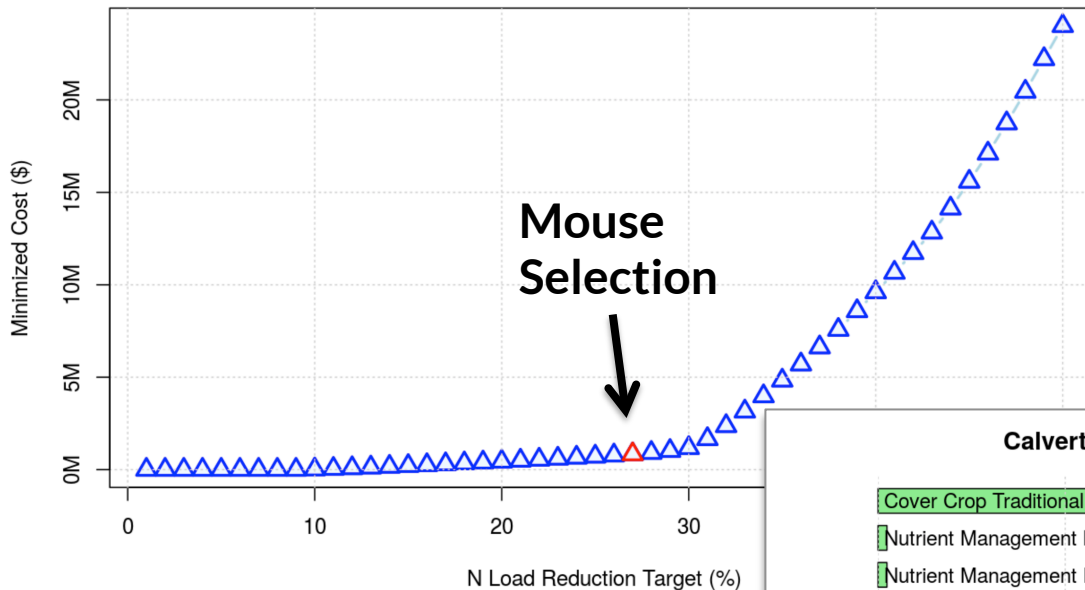
Cost vs. Load Tradeoff Curve

Calvert, MD: Minimized Cost for Target N Load Reduction (1% to 50%)



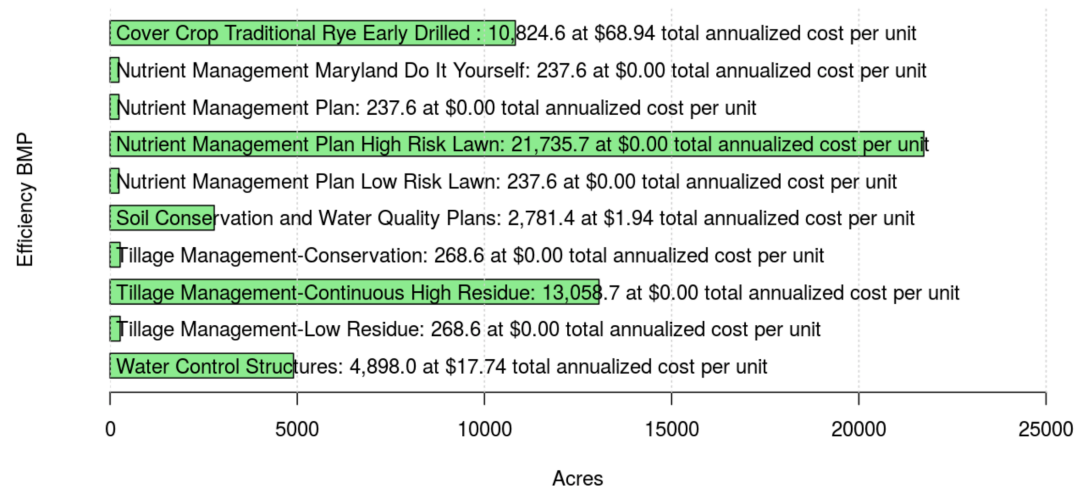
BMP acres to achieve load at cost

Calvert, MD: Minimized Cost for Target N Load Reduction (1% to 50%)



Click on [Graph Above](#) to Choose Load Reduction Lower Limit
 Selected = 27%, Corresponding Cost = \$838,597.78
 See [realization details below](#) for 27% load reduction

Calvert, MD: N Load Reduction >= 27%, Cost = \$838,597.78



VICO version Beta-1

(Visualization Interface for Chesapeake Optimization)

Visualization Interface for Chesapeake Optimization (VICO) (Beta-1 Version)

Developed by the Chesapeake Bay Program Office in collaboration with the Chesapeake Research Consortium.

The purpose of this optimization tool is to help identify strategies for minimizing costs and/or maximizing nutrient load reductions in CAST (Chesapeake Assessment Scenario Tool). This first Beta release has significant limitations and is intended for testing and gathering feedback. Future releases will improve the core engine and interface and provide additional features.

Please Note (along with disclaimer, additional considerations/limitations, and further details below):

- BMPs in CAST are of several different varieties, including Efficiencies, Land-Use Change, and Manure Transport. **This optimization tool is limited to Efficiency BMPs.** Greater load reductions can often be achieved in CAST utilizing non-efficiency BMPs, such as Buffers.
- This Beta version utilizes stored data for pre-solved optimization problems. Future releases covering more BMP types will solve optimization problems on demand in real time, often taking appreciably longer periods to generate results.

VICO version Beta-1

Considerations and Limitations

- This first Beta version is in the process of being tested and is not intended for use in Phase III WIP development because of potential defects and limitations, known and unknown.
- *BMPs in CAST are of several different varieties, including Efficiencies, Land-Use Change, and Manure Transport. **This optimization tool is limited to Efficiency BMPs.** Greater load reductions can often be achieved in CAST utilizing non-efficiency BMPs, such as Buffers.*
- *This **Beta version utilizes stored data for pre-solved optimization problems.** Future releases covering more BMP types will solve optimization problems on the fly, requiring more time to generate results.*
- This version includes "Planning BMPs." Consequently, some results here may not be available in CAST scenarios that are restricted to "Official BMPs" only.
- Geographic selection is limited to county-scale in the watershed.
- The assumed per-acre cost estimate of each BMP comes from the "watershed average" cost profile in CAST(<https://cast.chesapeakebay.net/Documentation/CostProfiles>). Future versions of this optimization tool will allow specification of your own cost profile, which is a feature available in CAST itself.
- Load sources in this optimization tool are restricted to non-federal land only. Load sources from other agencies or federal land are not included.
- Agriculture, Developed, and Natural sector load sources are included (excluding "Riparian Pasture Deposition" and "Stream Bed and Bank"). Wastewater and Septic sector loads are not included.
- Base loading values are restricted to 2010 No-Action values and were retrieved from CAST-2017d on 03/25/2019.

Features

VICO Version: Beta-1 - Visualiz

cloudfish.chesapeakebay.net:3838/vico/

Optimization tool is limited to Efficiency BMPs. Greater load reductions can often be achieved in C&D utilizing non-efficiency BMPs, such as Buffers.

- This Beta version utilizes stored data for pre-solved optimization problems. Future releases covering more BMP types will solve optimization problems on demand in real time, often taking appreciably longer periods to generate results.

This page constructs two graphic images for answering questions about how best to allocate a county's resources among Best Management Practices (BMPs) to achieve targets for cost and load reduction:

- The first graphic illustrates potential tradeoffs between cost and percentage reduction in loads (either Nitrogen or Phosphorus).
- Upon clicking a point in the first graphic, a second graphic presents BMPs and implementation acres for achieving the cost and load reductions for that point.

Geography:

Washington, DC

Waynesboro City, VA

Williamsburg City, VA

Winchester City, VA

WV

Berkeley, WV

Grant, WV

Hampshire, WV

Harper, WV

Objective and Main Constraint (for Given Range):

Minimize Cost for Target N Load Reduction (1% to 50%)

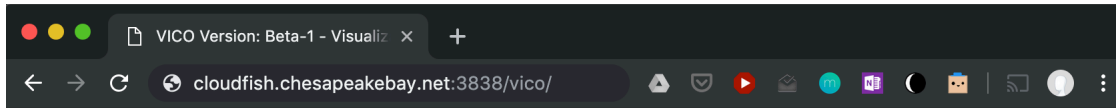
Washington, DC: Minimized Cost for Target N Load Reduction (1% to 50%)

| N Load Reduction Target (%) | Minimized Cost (\$) |
|-----------------------------|---------------------|
| 0 | 0.00 |
| 5 | 0.10 |
| 10 | 0.50 |
| 15 | 1.00 |
| 20 | 1.50 |
| 25 | 2.00 |
| 30 | 2.50 |
| 35 | 3.00 |
| 40 | 3.50 |
| 45 | 4.00 |
| 50 | 4.50 |

Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

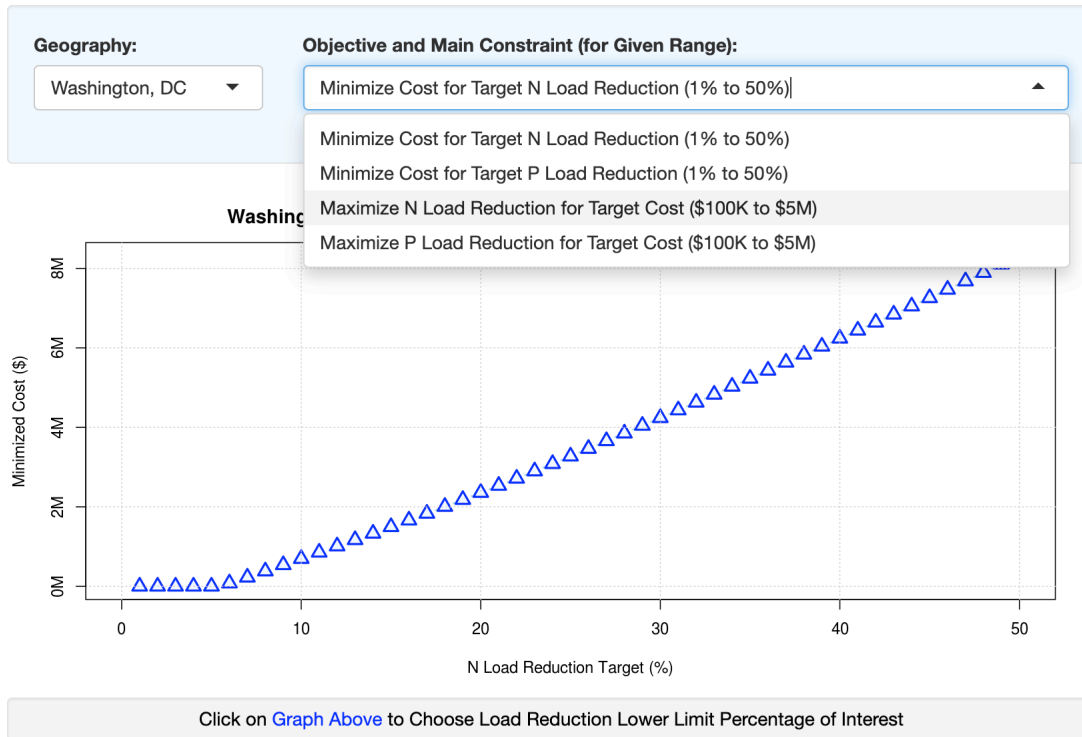
Disclaimer:

Features



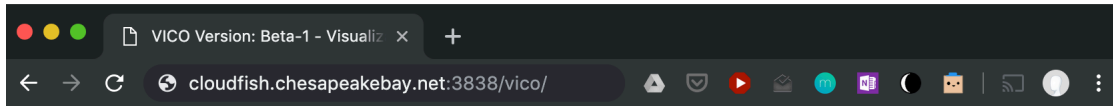
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Features



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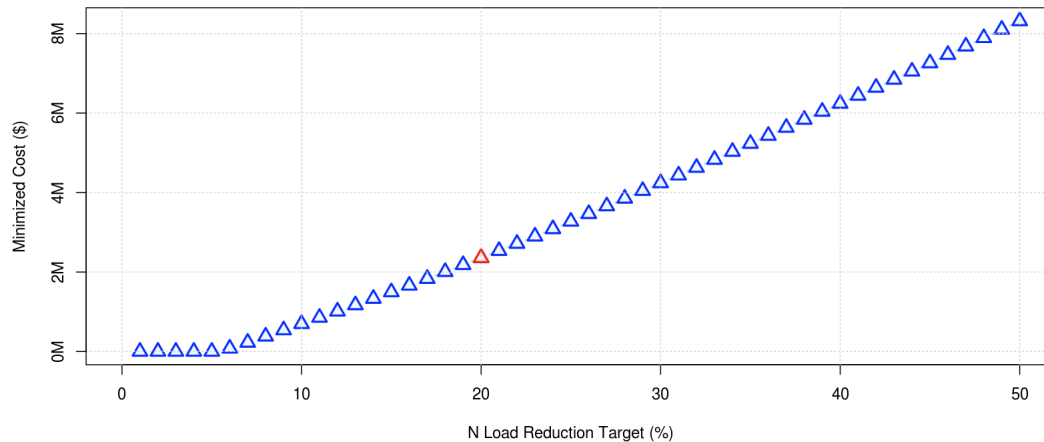
Geography:

Washington, DC

Objective and Main Constraint (for Given Range):

Minimize Cost for Target N Load Reduction (1% to 50%)

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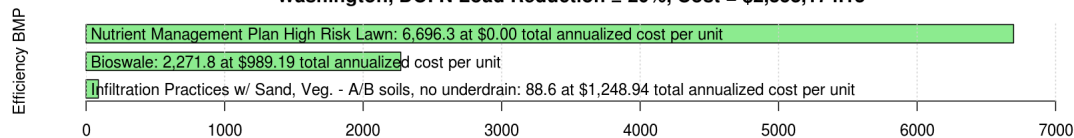


Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

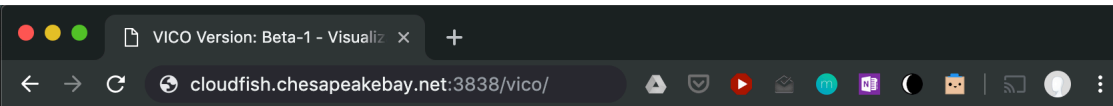
Selected = 20%, Corresponding Cost = \$2,358,174.13

See [realization details below](#) for 20% load reduction lower limit.

Washington, DC: N Load Reduction \geq 20%, Cost = \$2,358,174.13



Features



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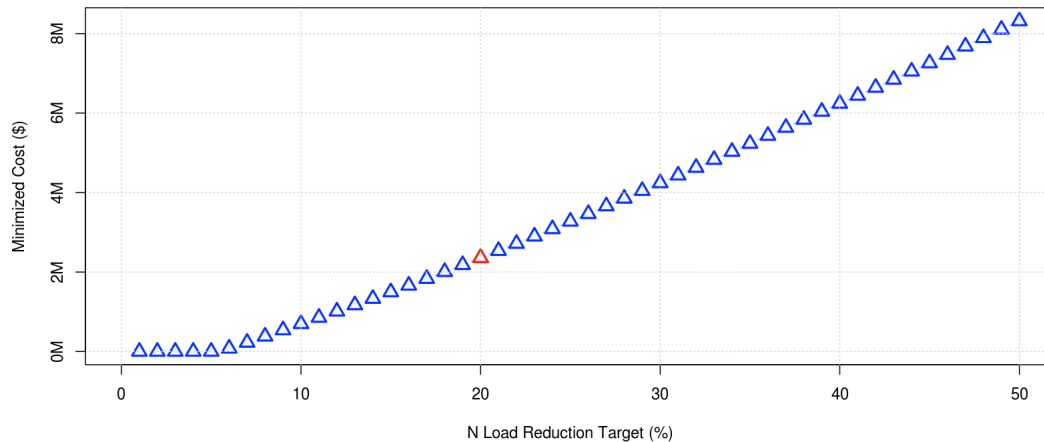
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Washington, DC

Objective and Main Constraint (for Given Range):

Minimize Cost for Target N Load Reduction (1% to 50%)

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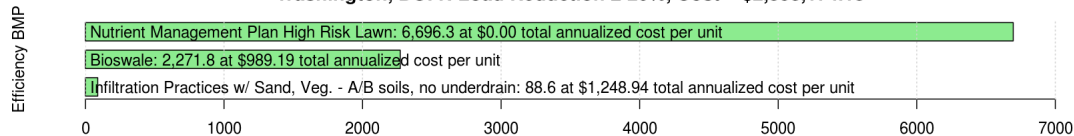


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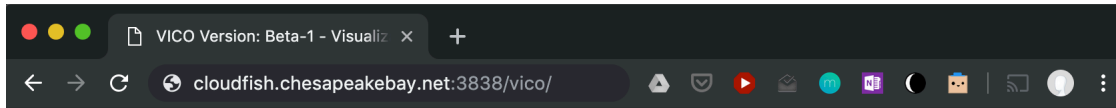
Selected = 20%, Corresponding Cost = \$2,358,174.13

See [realization details below](#) for 20% load reduction lower limit.

Washington, DC: N Load Reduction \geq 20%, Cost = \$2,358,174.13



Features

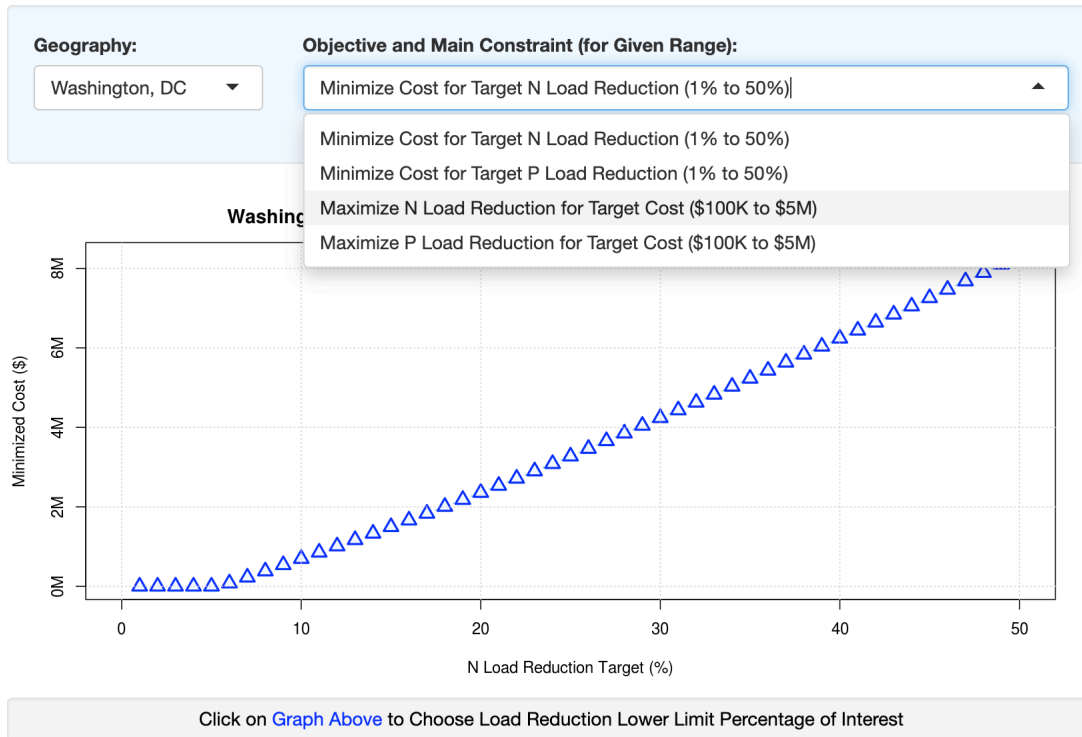


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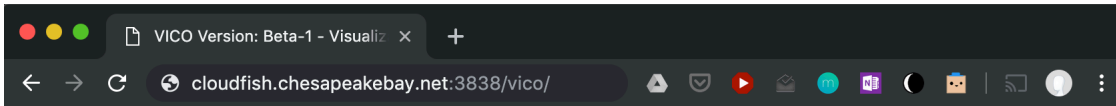
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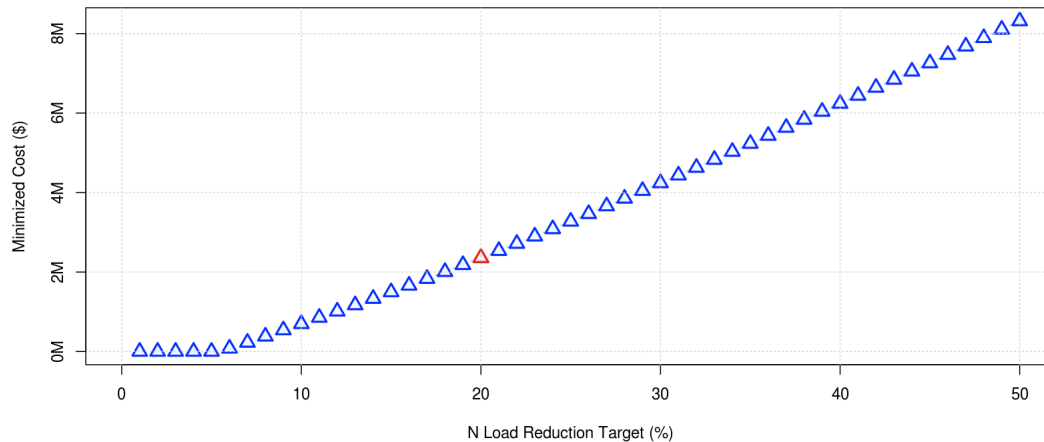
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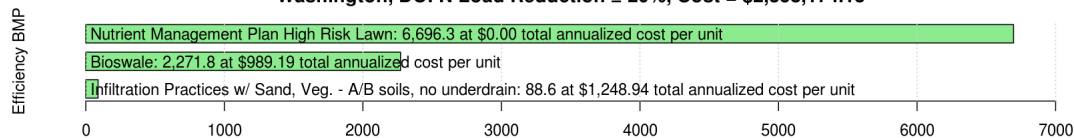


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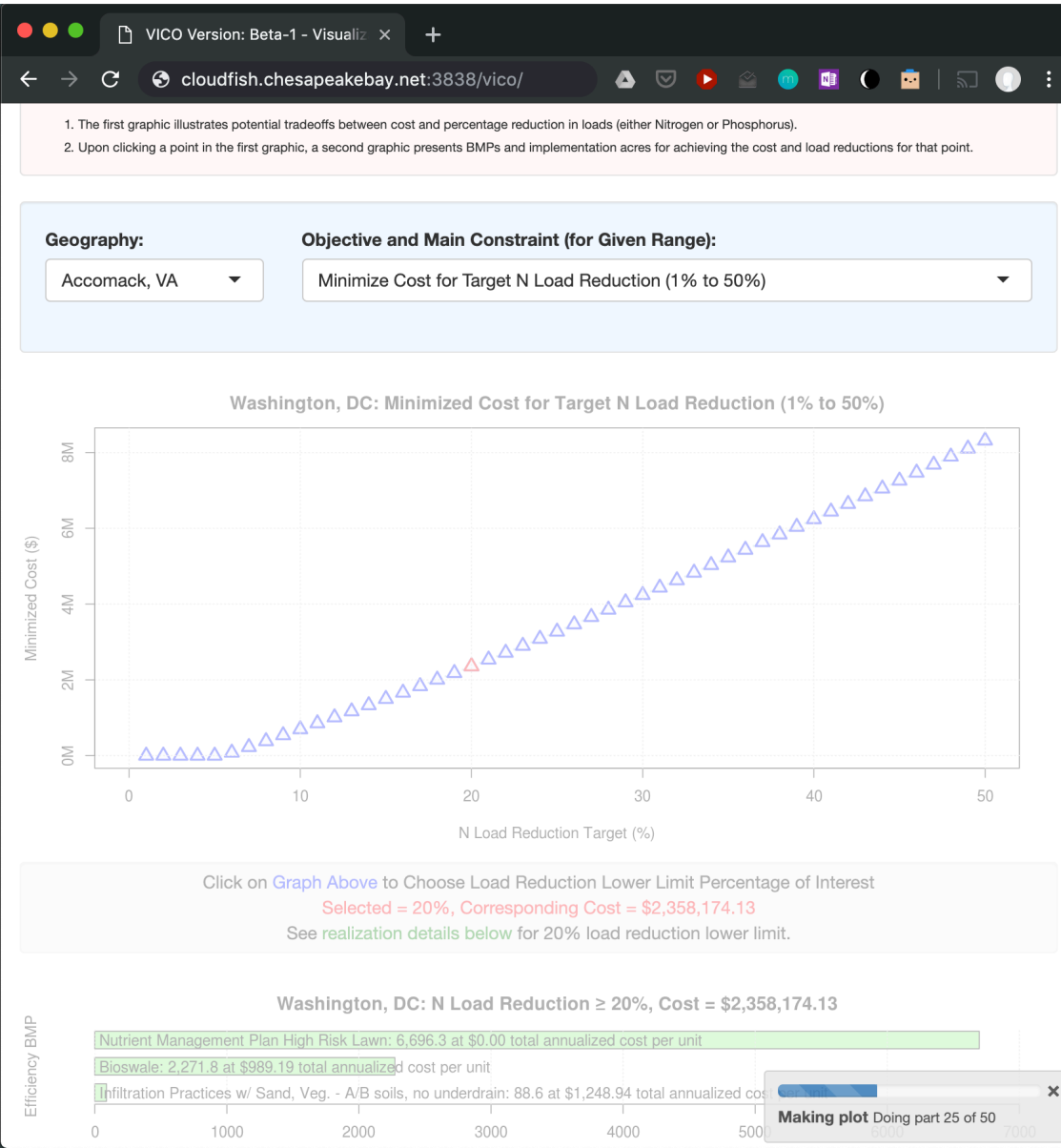
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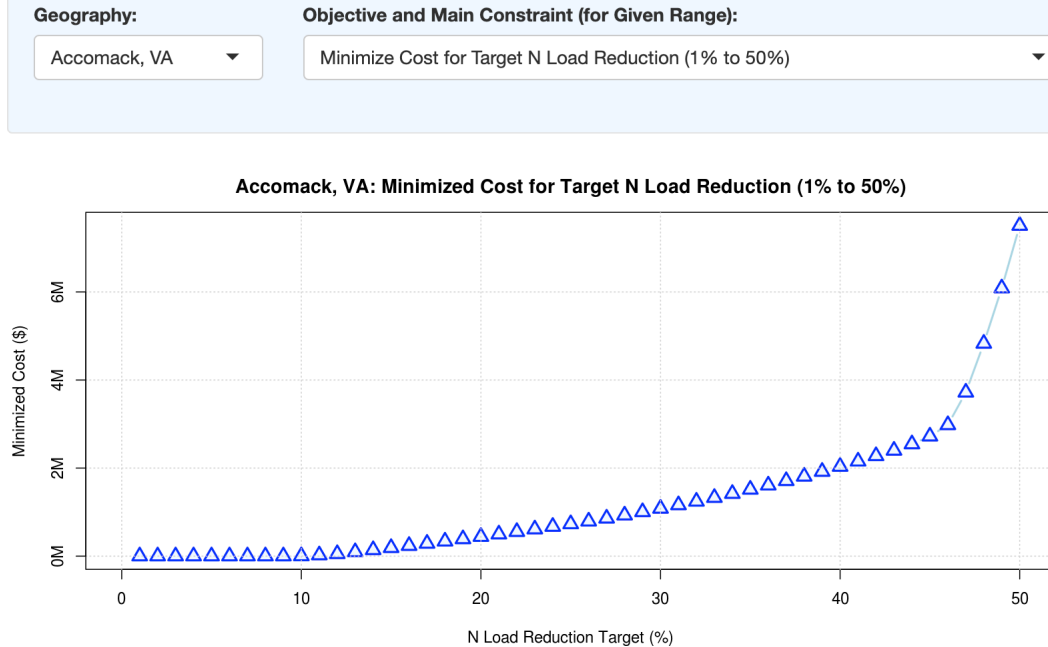
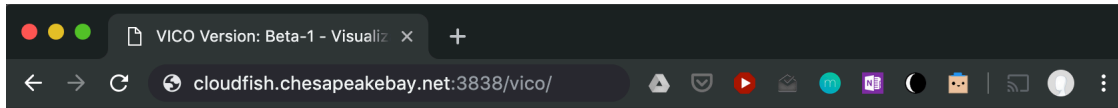
Washington, DC: N Load Reduction \geq 20%, Cost = \$2,358,174.13



Features



Features



Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

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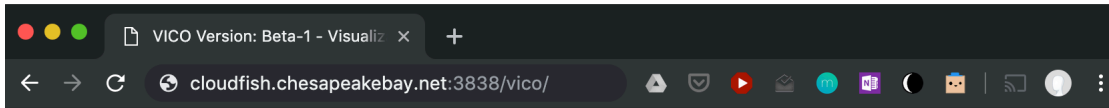
All users of VICO are advised to safeguard important data, to use caution, and not to rely in any way on correct functioning or performance of the beta release and/or accompanying materials. CBPO will not be liable for any loss (including direct, indirect, special, or consequential losses) suffered by any party as a result of the use of or inability to use the VICO web application, its software, or its content, even if CBPO has been advised of the possibility of such loss.

Should you encounter any bugs, glitches, lack of functionality, or other problems on the website, please let us know. We can be reached at e-mail address dkaufman@chesapeakebay.net. *Your help in this regard is greatly appreciated!*

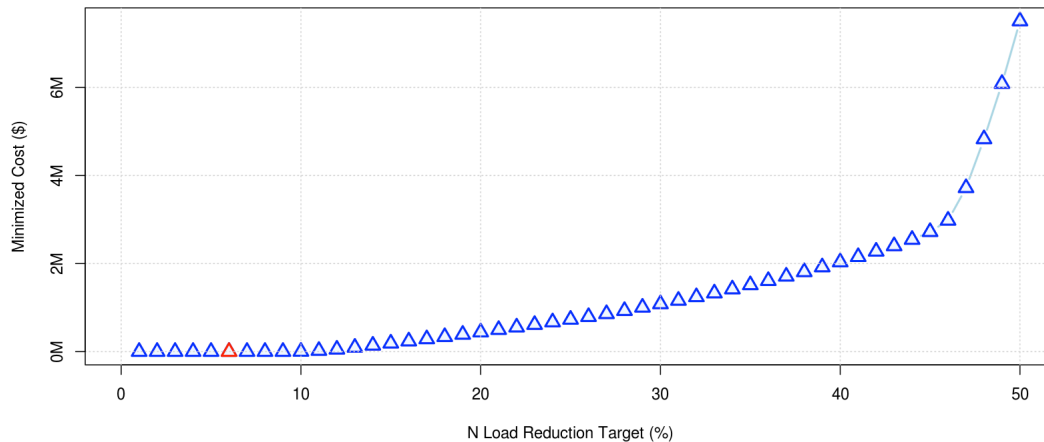
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Features



Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)

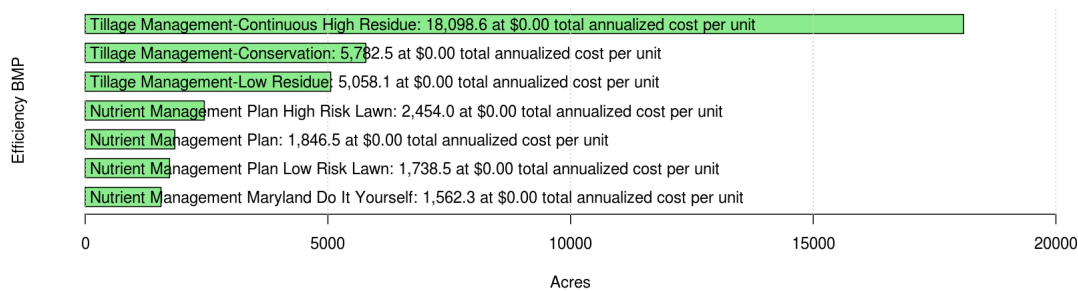


Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

Selected = 6%, Corresponding Cost = \$0.00

See [realization details below](#) for 6% load reduction lower limit.

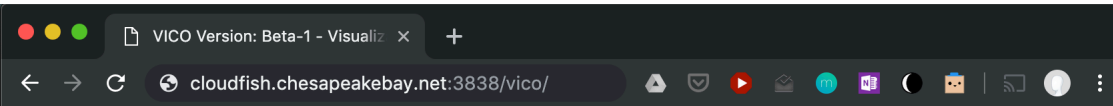
Accomack, VA: N Load Reduction \geq 6%, Cost = \$0.00



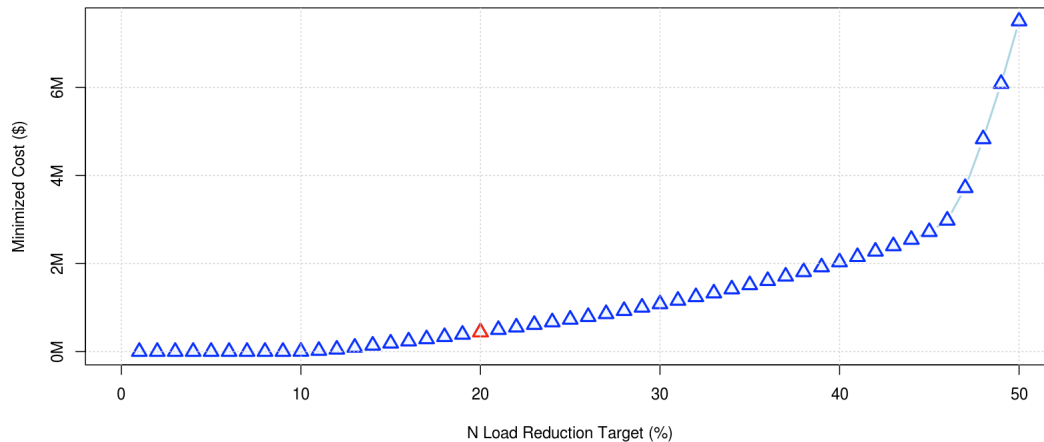
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Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)

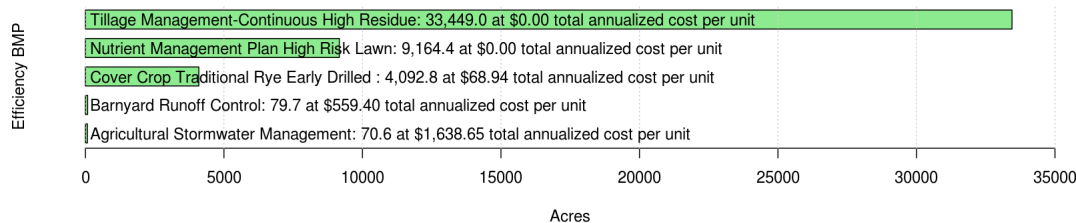


Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

Selected = 20%, Corresponding Cost = \$442,424.16

See [realization details below](#) for 20% load reduction lower limit.

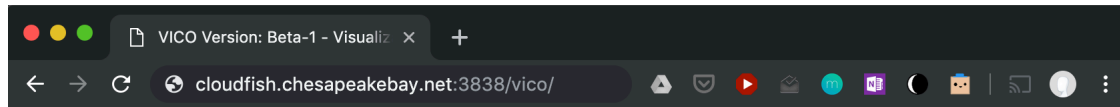
Accomack, VA: N Load Reduction \geq 20%, Cost = \$442,424.16



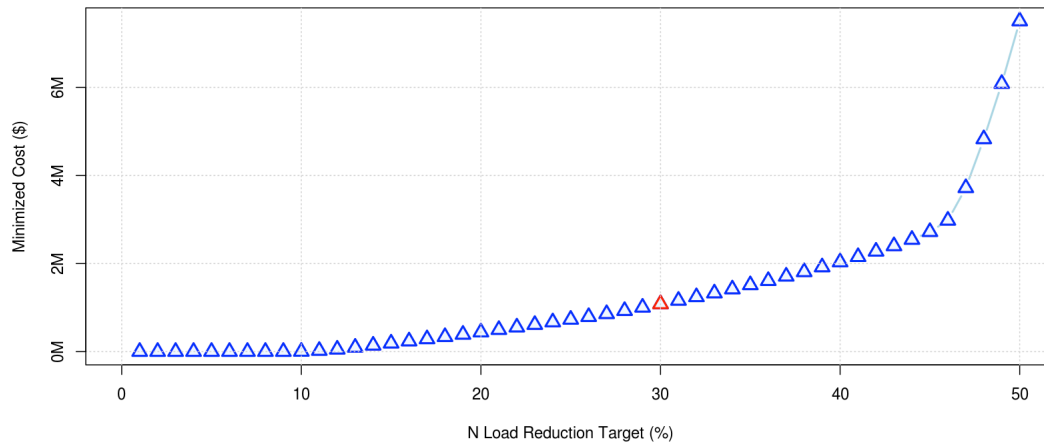
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Features



Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)

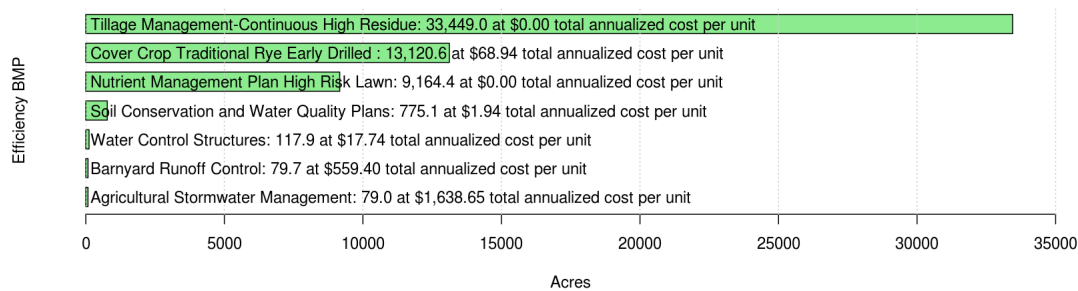


Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

Selected = 30%, Corresponding Cost = \$1,082,077.95

See [realization details below](#) for 30% load reduction lower limit.

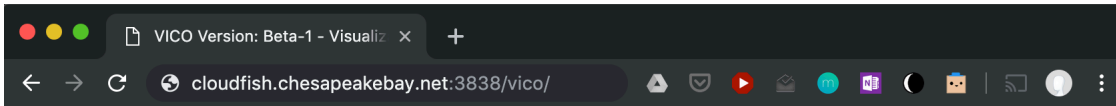
Accomack, VA: N Load Reduction \geq 30%, Cost = \$1,082,077.95



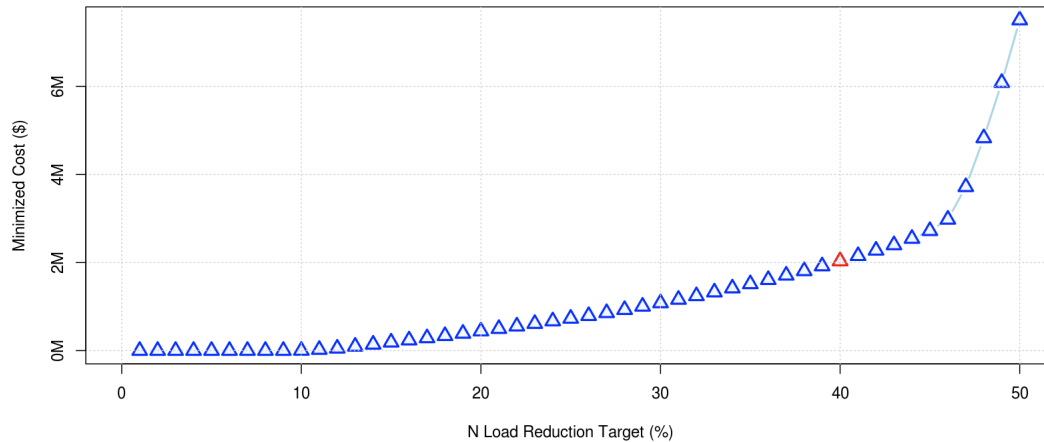
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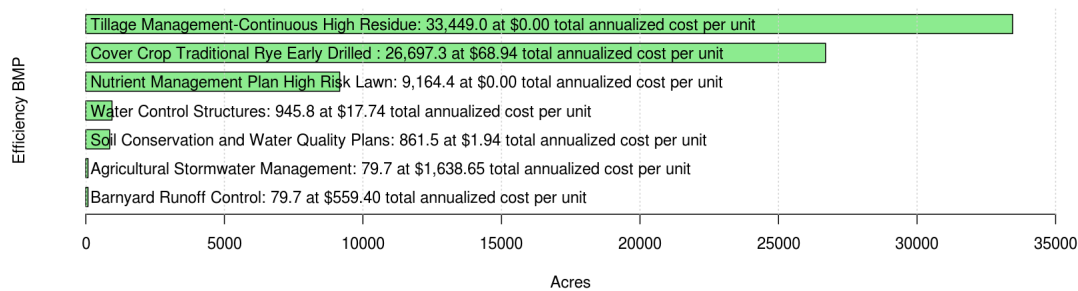


Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

Selected = 40%, Corresponding Cost = \$2,034,093.44

See [realization details below](#) for 40% load reduction lower limit.

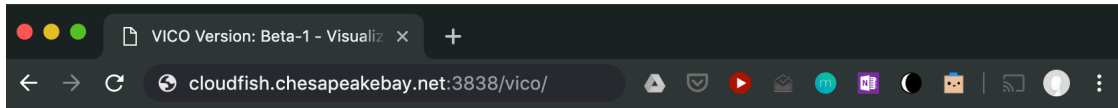
Accomack, VA: N Load Reduction \geq 40%, Cost = \$2,034,093.44



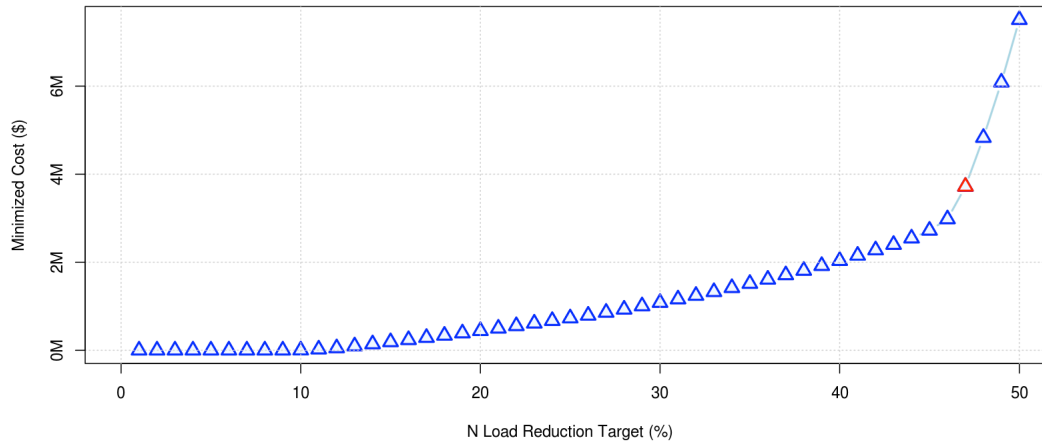
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Features



Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)



Click on [Graph Above](#) to Choose Load Reduction Lower Limit Percentage of Interest

Selected = 47%, Corresponding Cost = \$3,719,891.40

See [realization details below](#) for 47% load reduction lower limit.

Accomack, VA: N Load Reduction \geq 47%, Cost = \$3,719,891.40

Efficiency BMP

| | | |
|---|----------|--|
| Cover Crop Traditional Rye Early Drilled | 33,449.0 | at \$68.94 total annualized cost per unit |
| Tillage Management-Continuous High Residue | 33,449.0 | at \$0.00 total annualized cost per unit |
| Manure Incorporation Low Disturbance Early | 23,316.5 | at \$17.34 total annualized cost per unit |
| Nutrient Management Plan High Risk Lawn | 9,164.4 | at \$0.00 total annualized cost per unit |
| Manure Injection | 6,633.7 | at \$74.60 total annualized cost per unit |
| Soil Conservation and Water Quality Plans | 1,059.9 | at \$1.94 total annualized cost per unit |
| Water Control Structures | 1,059.9 | at \$17.74 total annualized cost per unit |
| Forest Harvesting Practices | 1,032.0 | at \$64.01 total annualized cost per unit |
| Precision Intensive Rotational/Prescribed Grazing | 828.7 | at \$18.83 total annualized cost per unit |
| Manure Incorporation Low Disturbance Late | 501.3 | at \$17.34 total annualized cost per unit |
| Bioswale | 230.9 | at \$989.19 total annualized cost per unit |
| Agricultural Stormwater Management | 79.7 | at \$1,638.65 total annualized cost per unit |
| Barryard Runoff Control | 79.7 | at \$559.40 total annualized cost per unit |

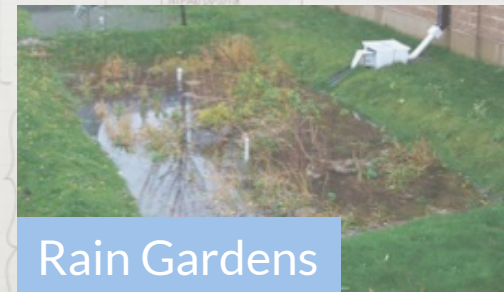
Best Management Practices (BMPs) in CAST

[illegible]

Orange = Efficiency BMPs

Efficiency BMPs include:

- Cover crops
- Conservation tillage
- Urban Nutrient management
- Bio-retention



Methods

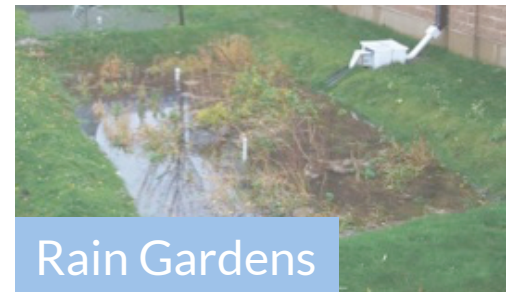
Nonlinear Optimization Model

Minimize
(total cost)



$$\sum_{\substack{\text{Segments} \\ \text{BMPs} \\ \text{LoadSources}}} (\text{cost} * \text{BMP acres})$$

Constrained by:
(Target load)



CAST data used for acres available, BMP efficiencies & costs, base loading, load sources, etc.

Methods

Nonlinear Optimization Model

Minimize
(total cost)



$$\sum_{\substack{\text{Segments} \\ \text{BMPs} \\ \text{LoadSources}}} (\text{cost} * \text{BMPacres})$$

Constrained by:
(Target load)

Code formulated with **Pyomo**

(algebraic modeling language library for python) developed by Sandia National Laboratories

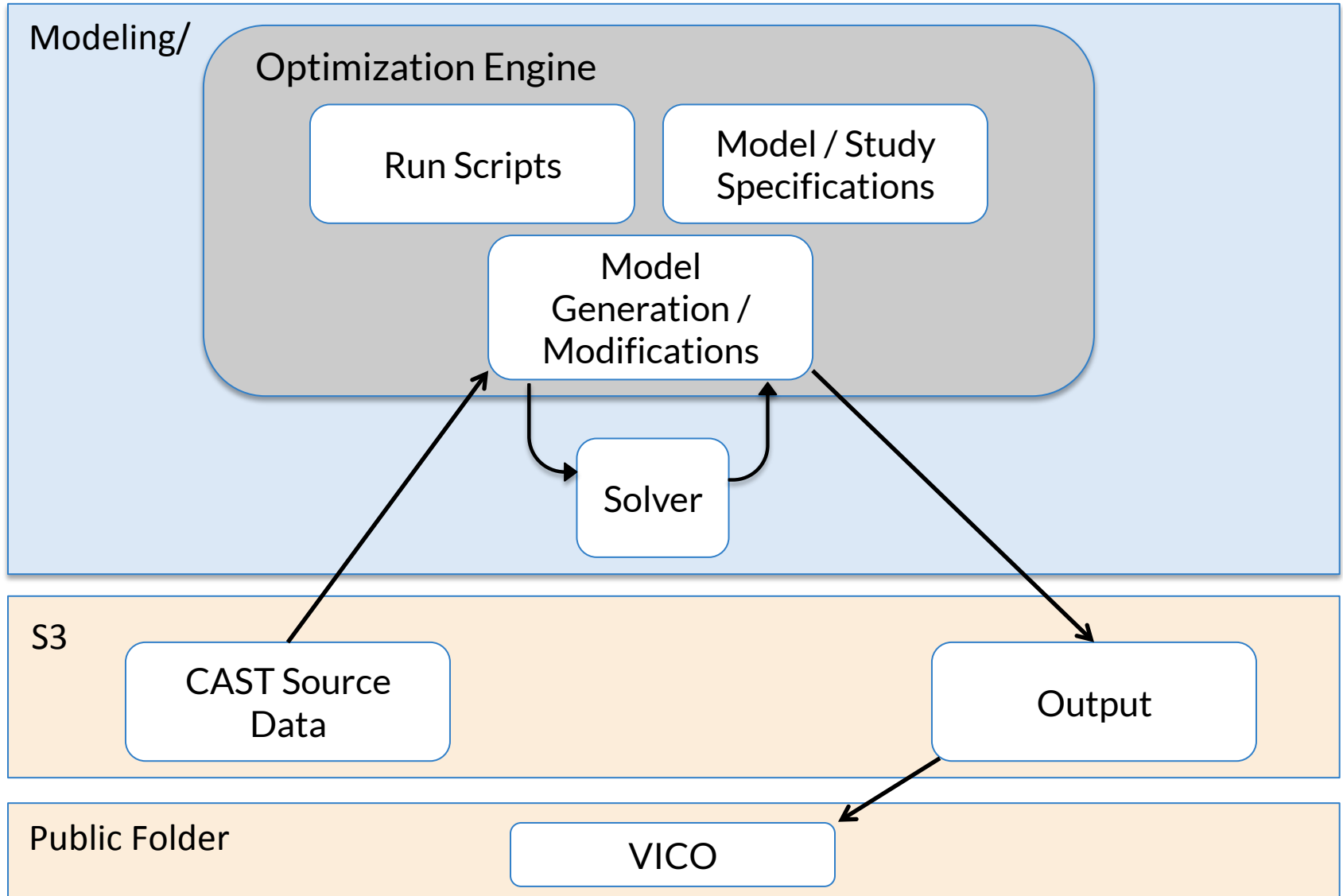


Instances solved using **IPOPT**

(interior point / barrier method solver) developed at Carnegie Mellon Univ. and available as part of the Computational Infrastructure for Operations Research (COIN-OR)



Current version components



Dependencies & Credits

- **Overall**

Amazon Web Services, Bitbucket, Git, GitLab, Jenkins, Slurm

- **Core Engine**

AmplPy, Cloudpickle, IPOPT, NumPy, Pandas, Pyomo, Python

- **Web Interface**

R, NotePad++, Shiny

Summary

- VICO Interface
 - for viewing county-scale results of an optimization model for "efficiency BMPs" (which are a subset of all the BMPs in CAST [<http://cast.chesapeakebay.net/>])
 - pulls optimization results for each county in the watershed (197), for 4 different objective/constraint combinations, and for 50 different constraint levels (39,400 runs).
 - You can explore coarse tradeoffs between cost and load reduction for any county, and then click a point to view the BMP acres needed to achieve that target
- Limited to efficiency BMPs, pre-solved solutions, and uses a 2010 'No-Action' baseline right now, so it's a long way from optimizing all BMPs, for all geographic scales, and for any constraints, but it represents an important development step
- The hope is that VICO will help us gather useful feedback for moving forward towards the larger goals, such as including more of the complex BMPs in CAST, running on-the-fly with configurable constraints, different load baseline years, etc.

Much more work to be done!

Improving VICO beta-1

- In response to feedback
- To eliminate known limitations
- Ideas from all the feedback already

Working towards inclusion of additional, complex, BMPs

- Plan for technical report to detail specific challenges (narratively & mathematically), and to suggest approach(es), by first quarter of next year.
- In collaboration with Advisory and Support Committee and Dr. Skipper

Will be shaped by feedback

VICO Beta-1 is a first step

<http://cloudfish.chesapeakebay.net:3838/vico/>

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