Beta-1

Scenario Optimization Tool for CAST

(the time-averaged Phase 6 watershed model)

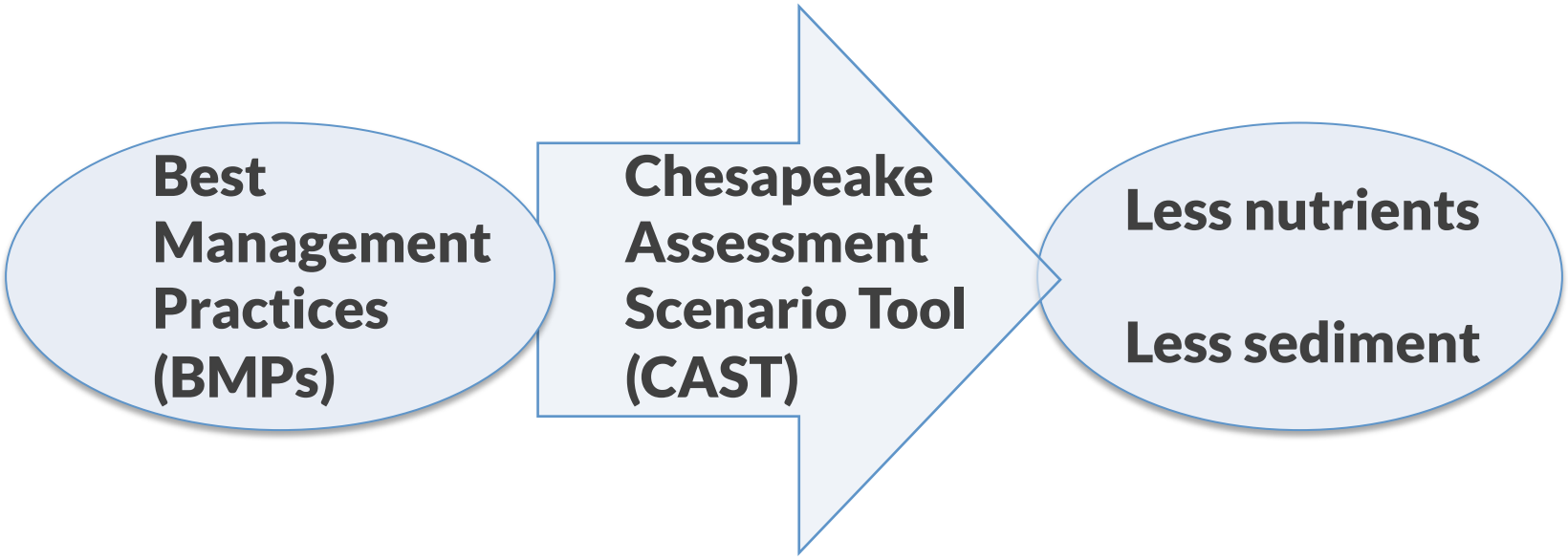
03 April 2019

Modeling Workgroup Quarterly Review

Daniel Kaufman, Kevin Asplen, and the CBPO Modeling Team

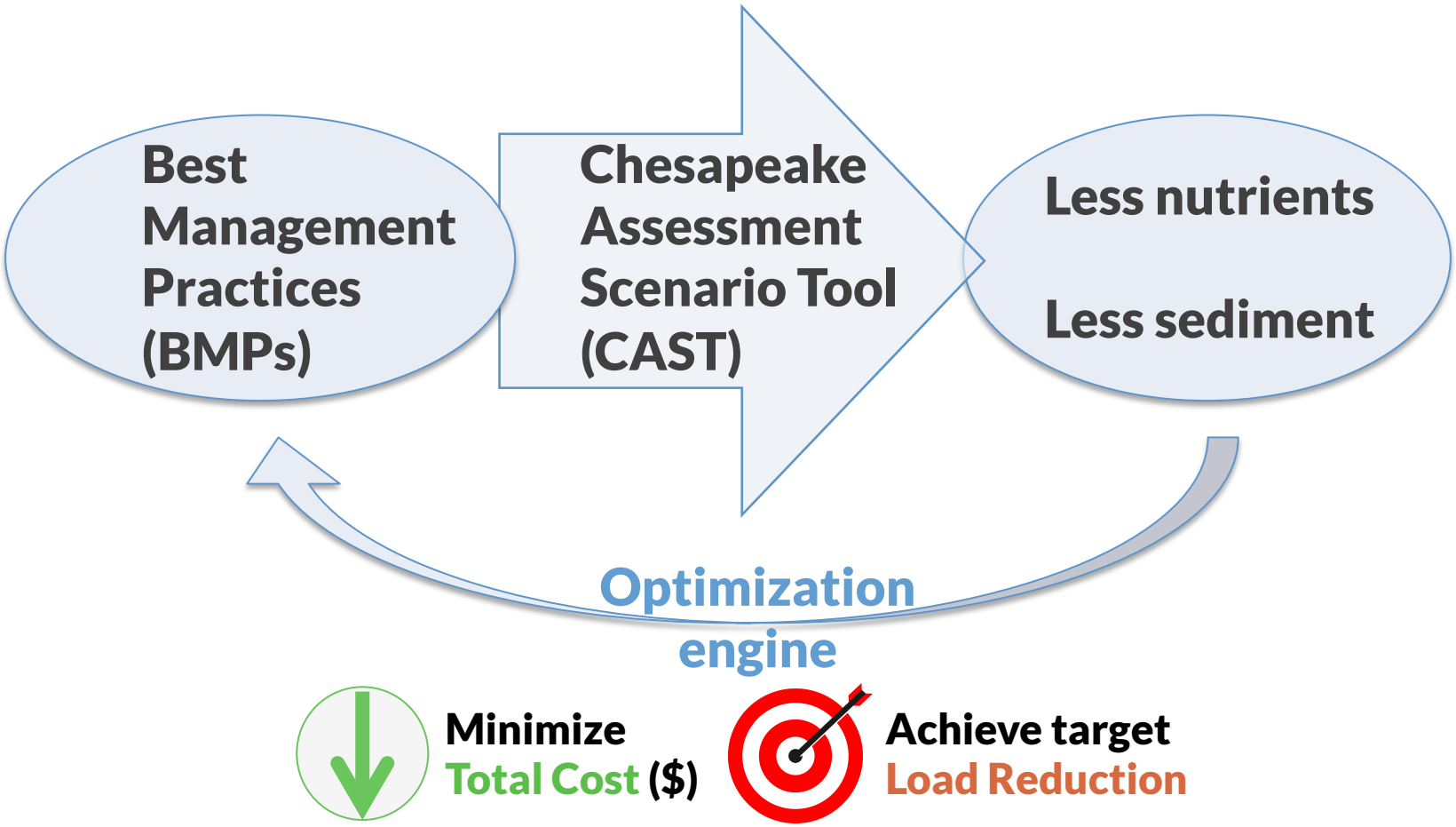
Project Goal: Investigate, develop, test, and implement an optimization system for the Chesapeake Assessment Scenario Tool (CAST) that will facilitate identification of more cost-effective and otherwise optimal approaches to pollutant load reduction for CBP partners.

Motivation for Optimization Tool

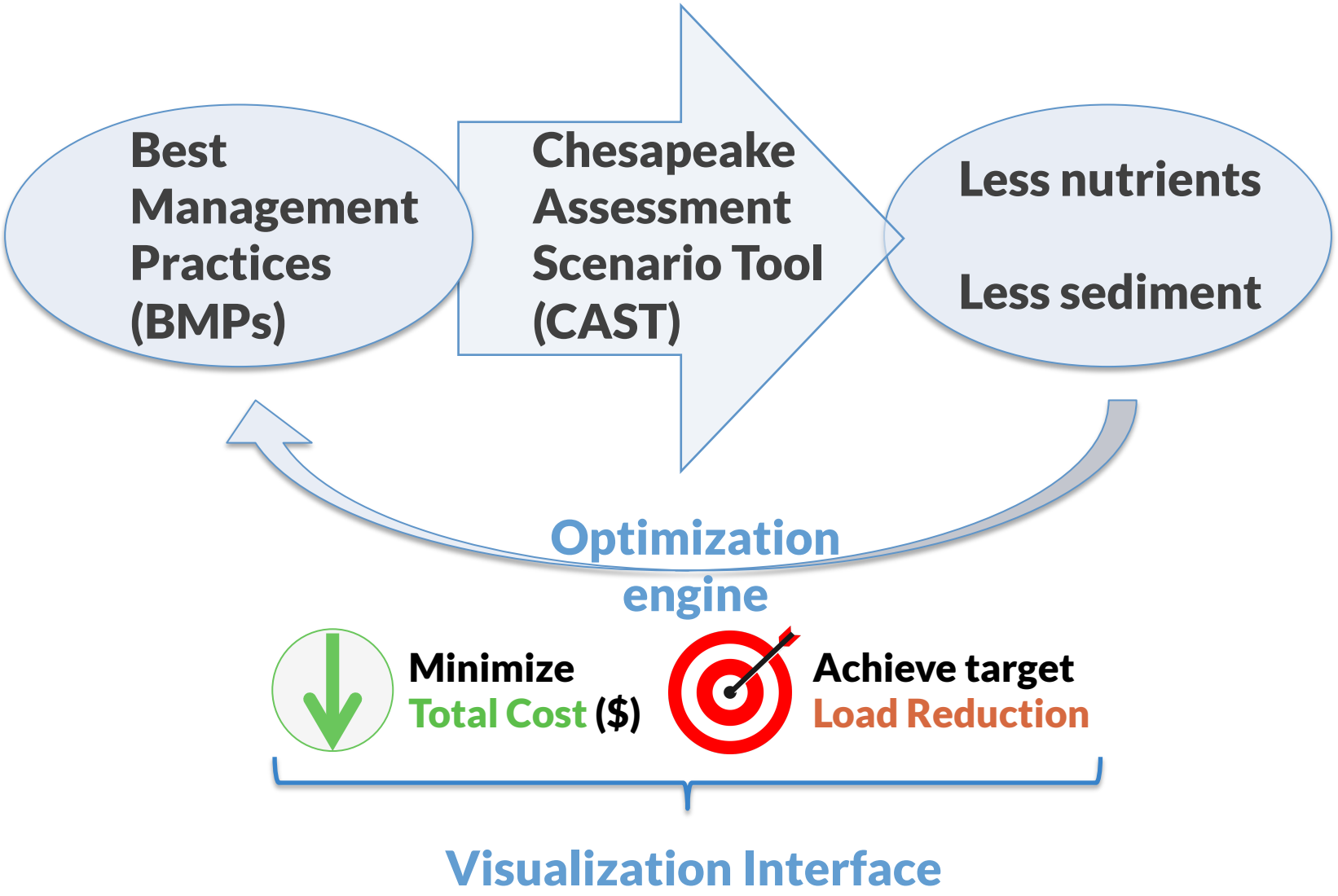


Would like to find low-cost BMP strategies, but not feasible to exhaustively try potential scenarios

Optimization engine



Beta version using only efficiency BMPs
to *provide utility & gather feedback.*



Overview of beta-1 tool

- Features
- Components
- Future developments

Optimization Engine

- Runs on the CBP cloud
- Builds optimization model on-the-fly for a particular geography, objective, constraints
- Optimization Solutions for:
  - 197 counties
  - 4 objective/constraint combinations
  - 50 constraint levels

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/

Visualization Interface (VICO)

- 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

Selection:

This page contructs 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.

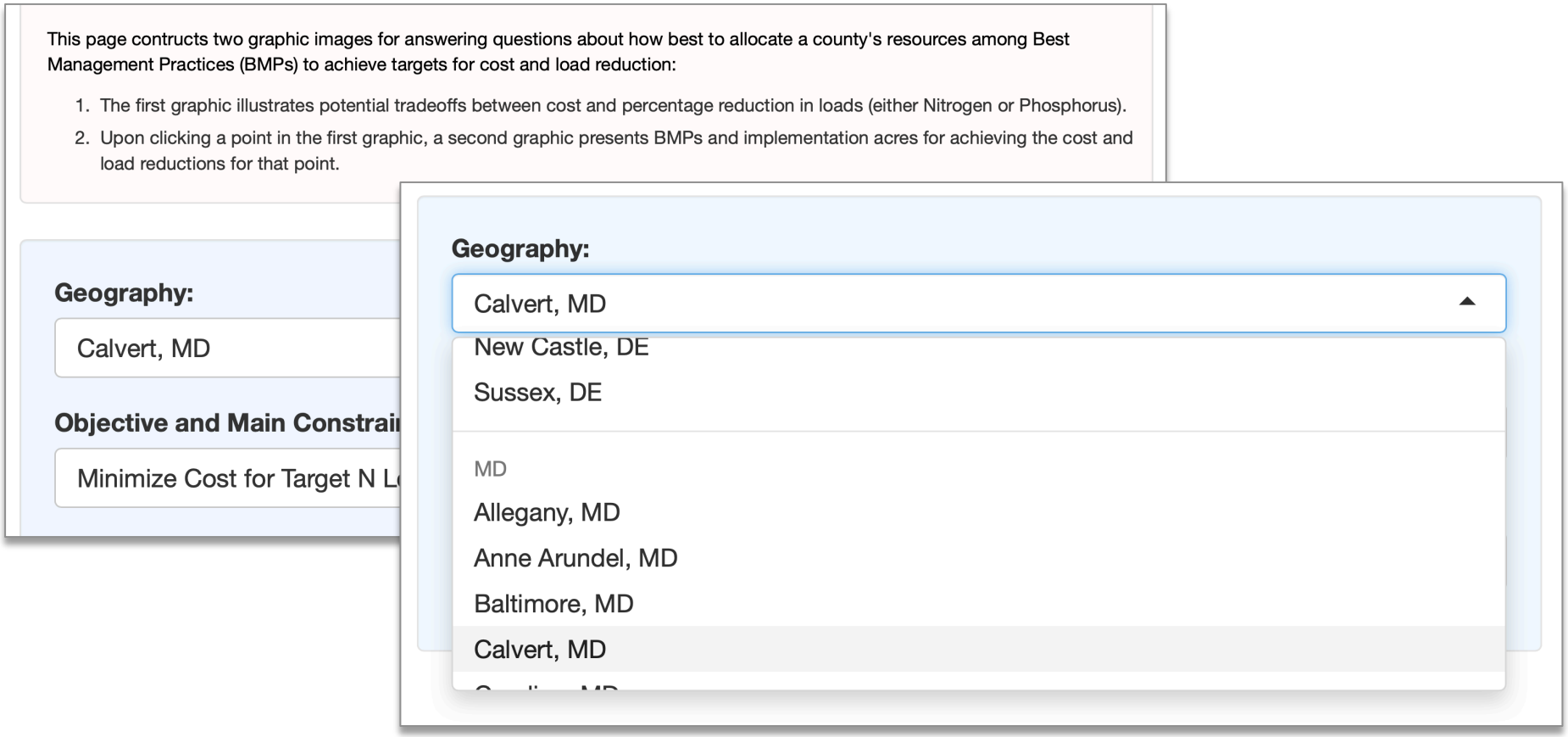
Geography:

Calvert, MD

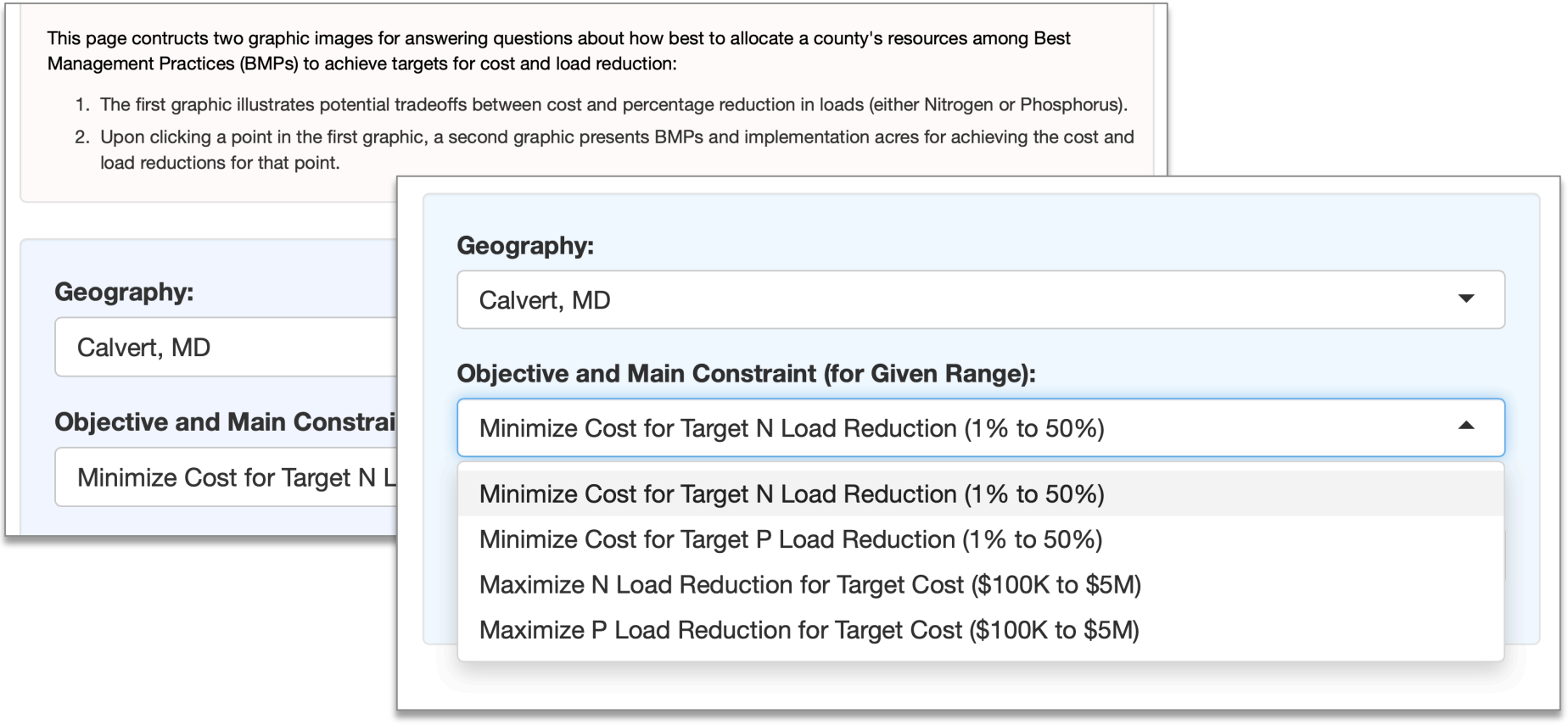
Objective and Main Constraint (for Given Range):

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

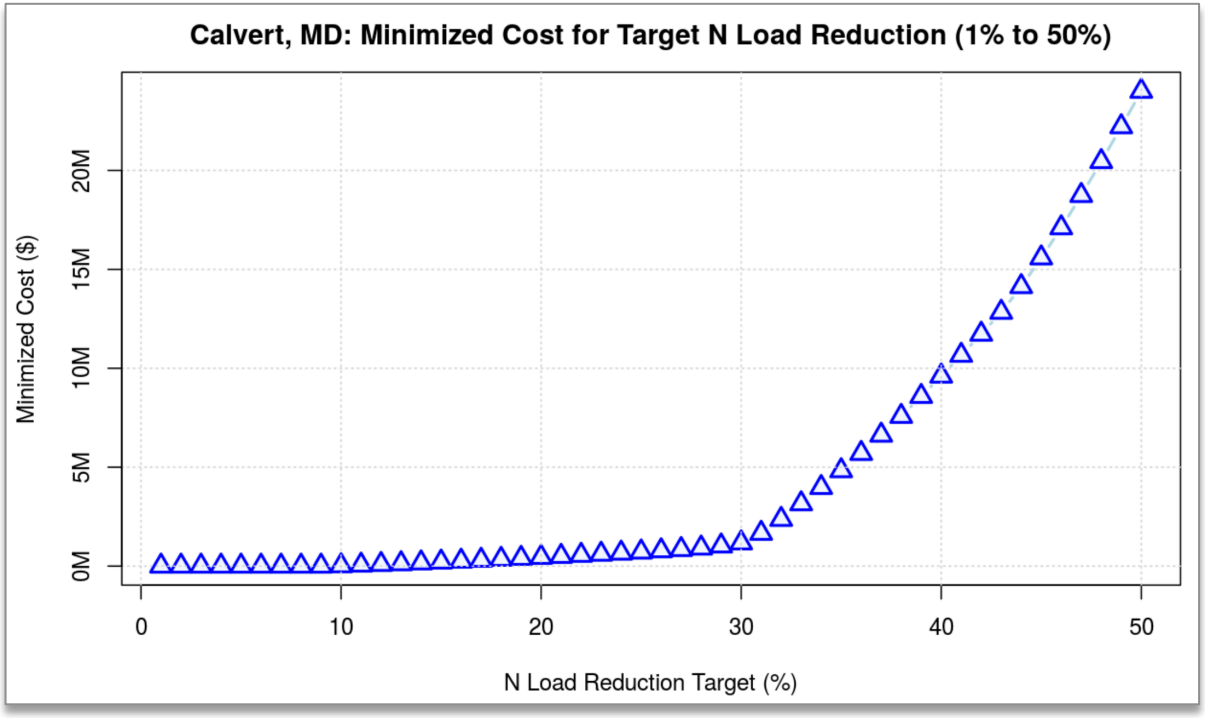
Selection: County



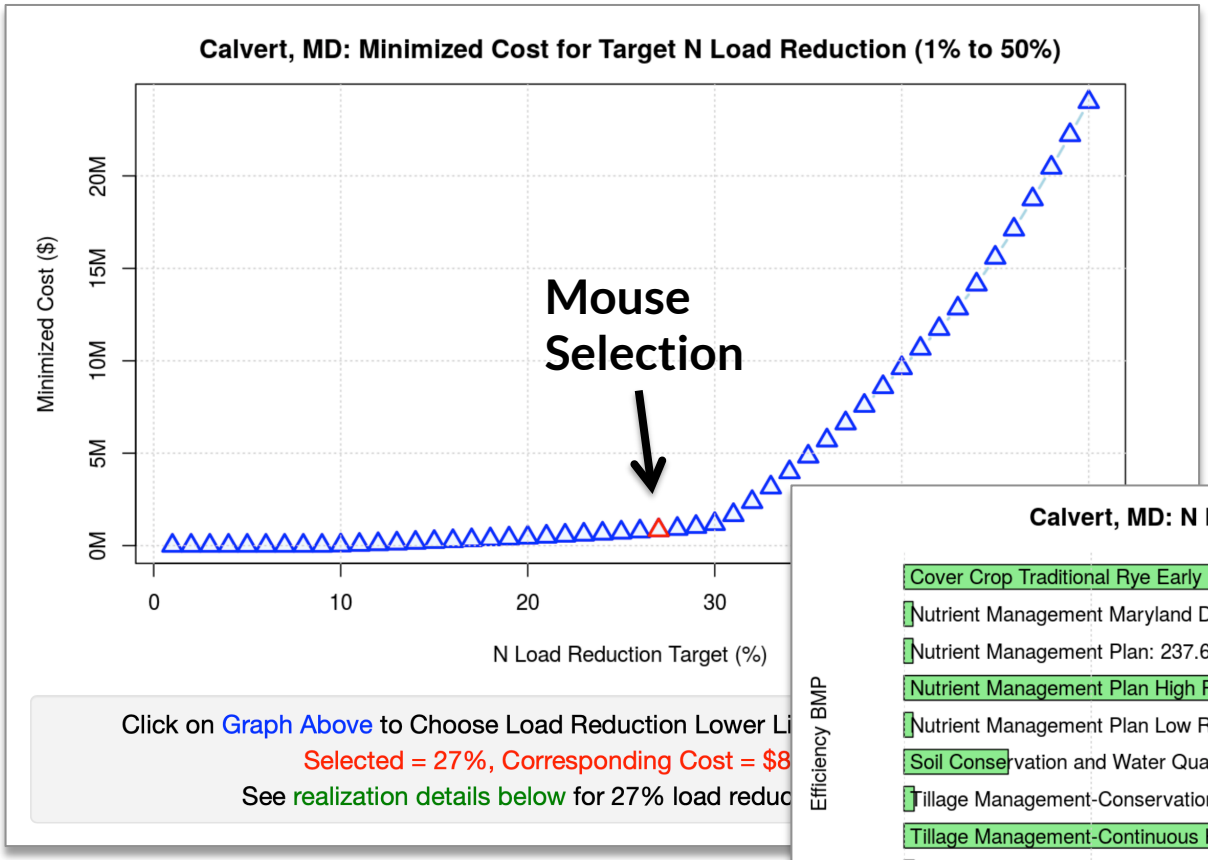
Selection: Objective

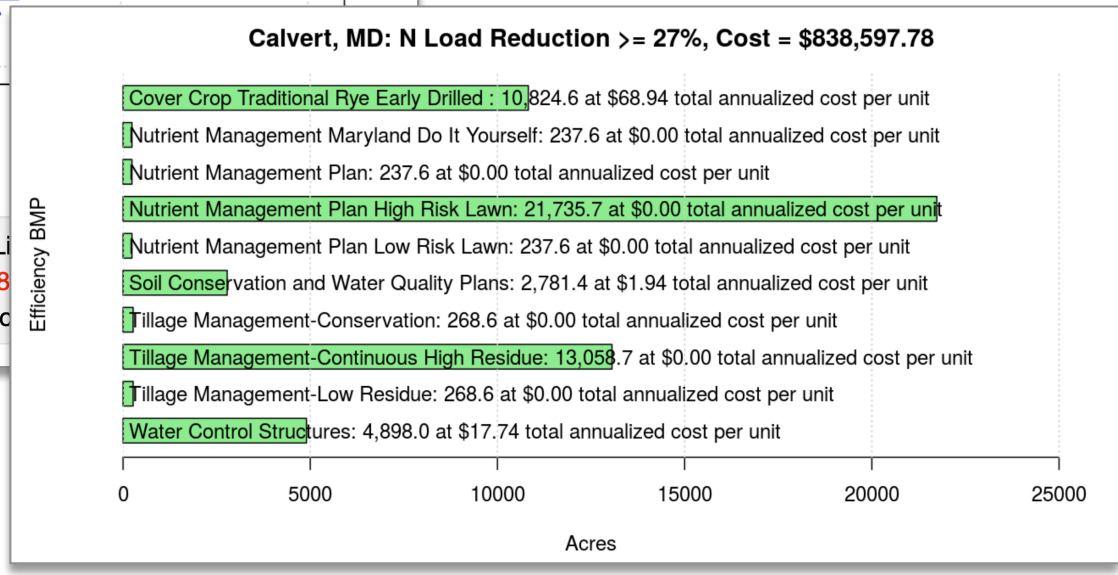


Cost vs. Load Tradeoff Curve



BMP acres to achieve load at cost





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):

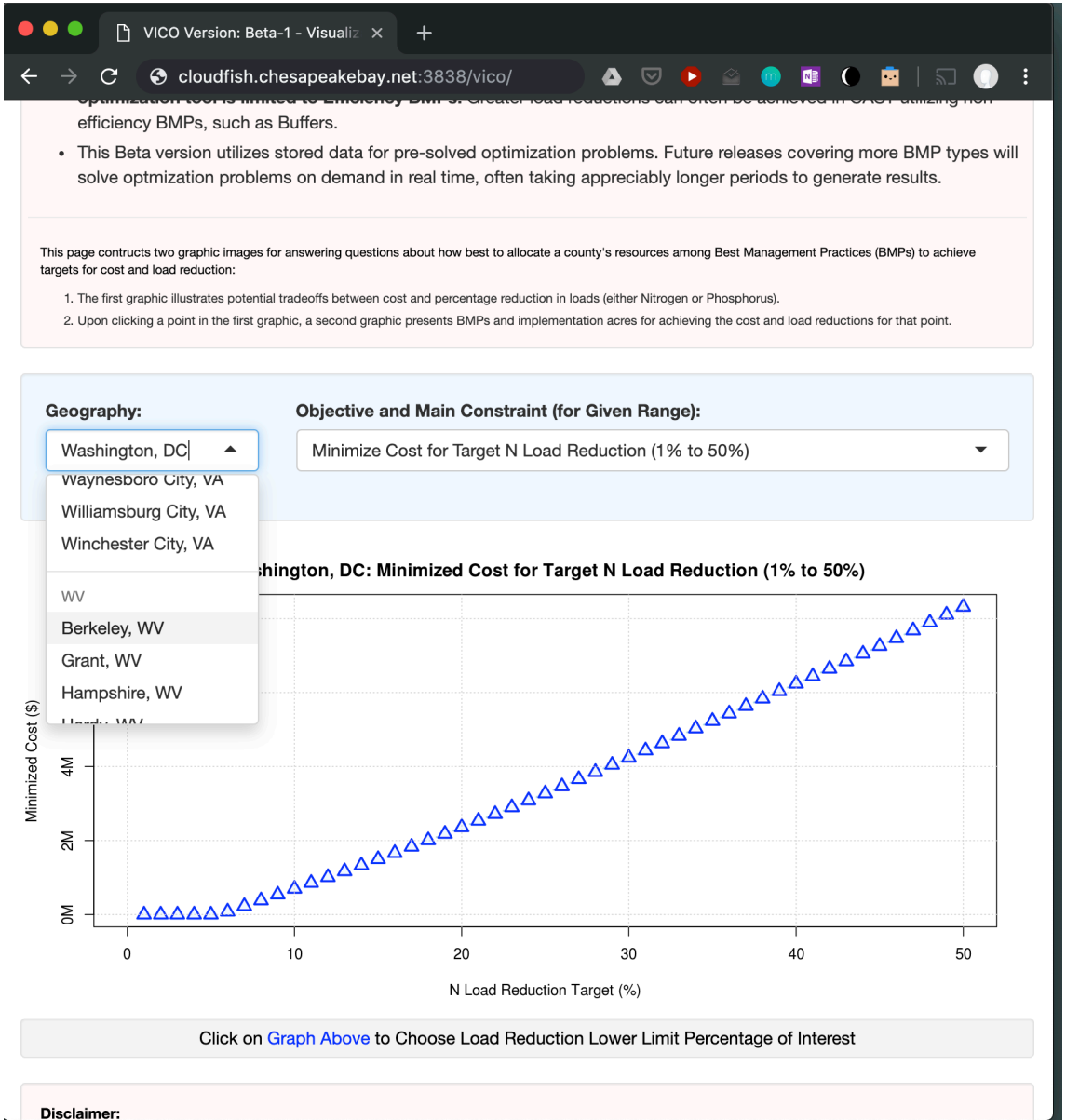
- BMPs in CAST are of several different varieties, including Efficiencies, Land-Use Change, and Manure Transport. **This optimization tool is limited to Efficiency BMPs.** Greater load reductions can often be achieved in CAST utilizing non-efficiency BMPs, such as Buffers.
- This Beta version utilizes stored data for pre-solved optimization problems. Future releases covering more BMP types will solve optmization 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 optmization 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/
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This page contructs 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:
Washington, DC
Objective and Main Constraint (for Given Range):
Minimize Cost for Target N Load Reduction (1% to 50%)
Waynesboro City, VA
Williamsburg City, VA
Winchester City, VA
WV
Berkeley, WV
Grant, WV
Hampshire, WV
shington, DC: Minimized Cost for Target N Load Reduction (1% to 50%)
Minimized Cost ($)
0M
2M
4M
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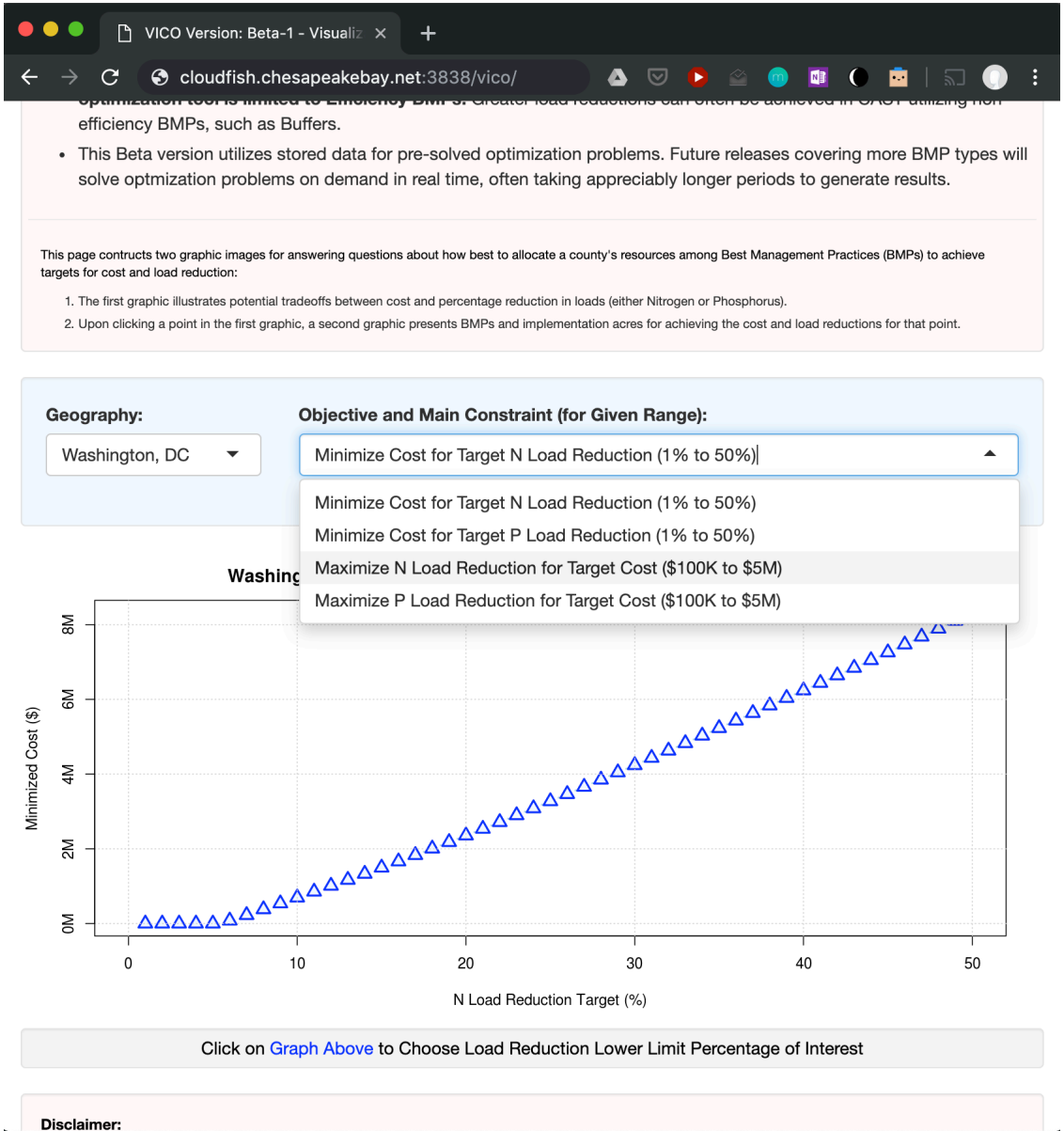
30
40
50
N Load Reduction Target (%)
Click on Graph Above to Choose Load Reduction Lower Limit Percentage of Interest
Disclaimer:

Features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Washington, DC
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 $5M)
Minimized Cost ($)
0M
2M
4M
6M
8M
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30
40
50
N Load Reduction Target (%)
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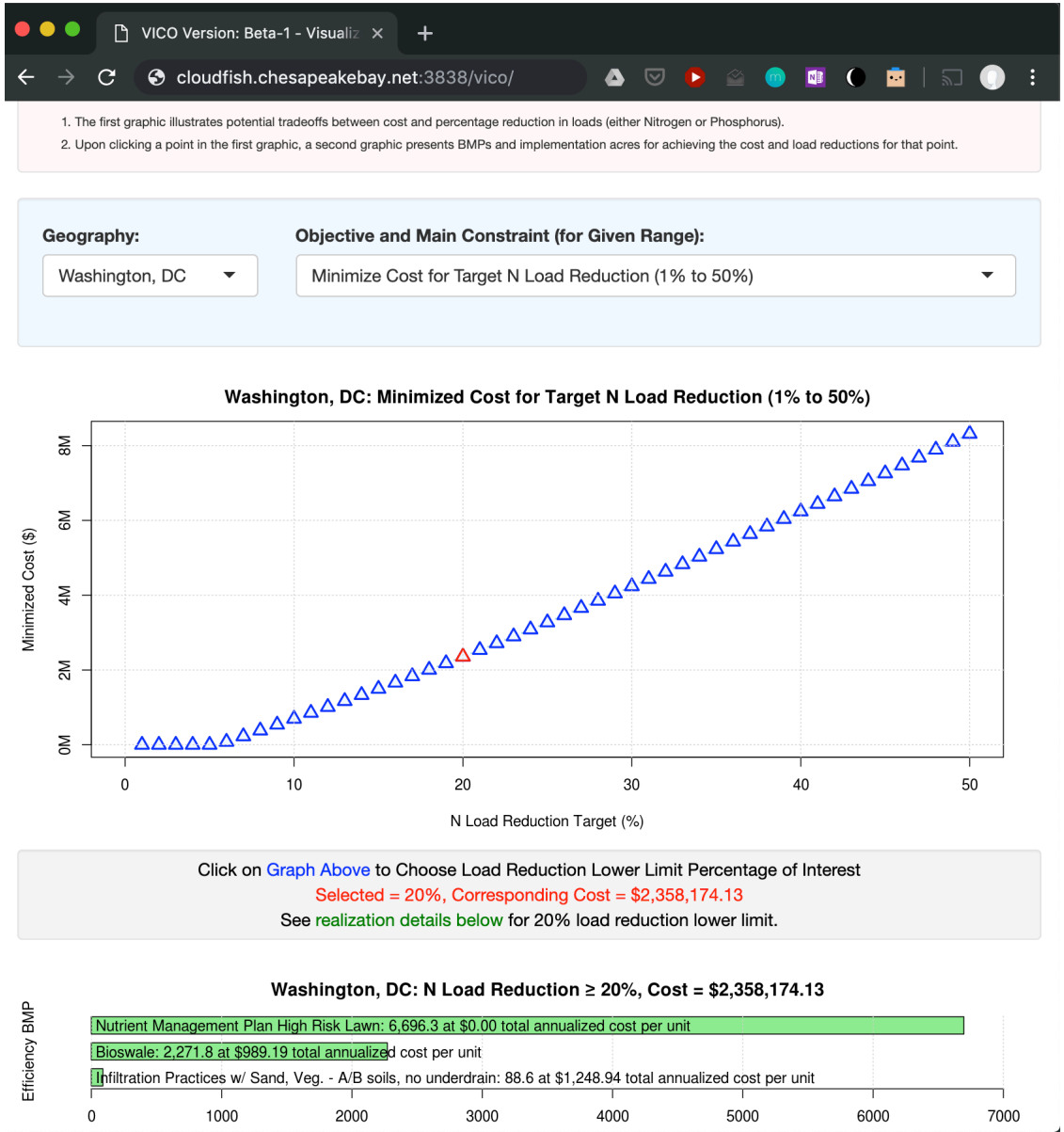
Disclaimer:

Features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Minimize Cost for Target N Load Reduction (1% to 50%)
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Minimized Cost ($)
0M
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4M
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N Load Reduction Target (%)
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 ≥ 20%, Cost = $2,358,174.13
Efficiency BMP
Nutrient Management Plan High Risk Lawn: 6,696.3 at $0.00 total annualized cost per unit
Bioswale: 2,271.8 at $989.19 total annualized cost per unit
Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain: 88.6 at $1,248.94 total annualized cost per unit
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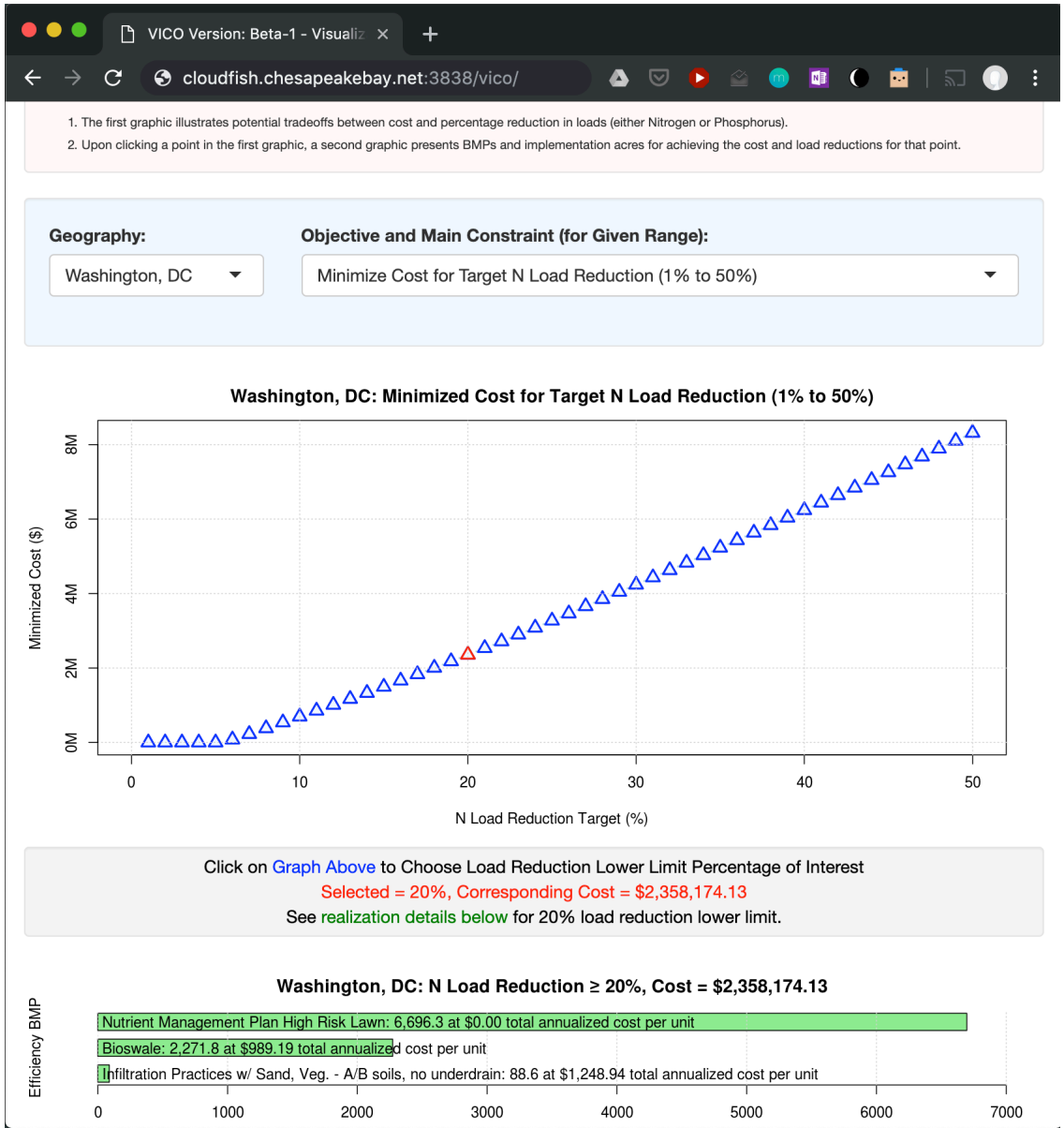
Features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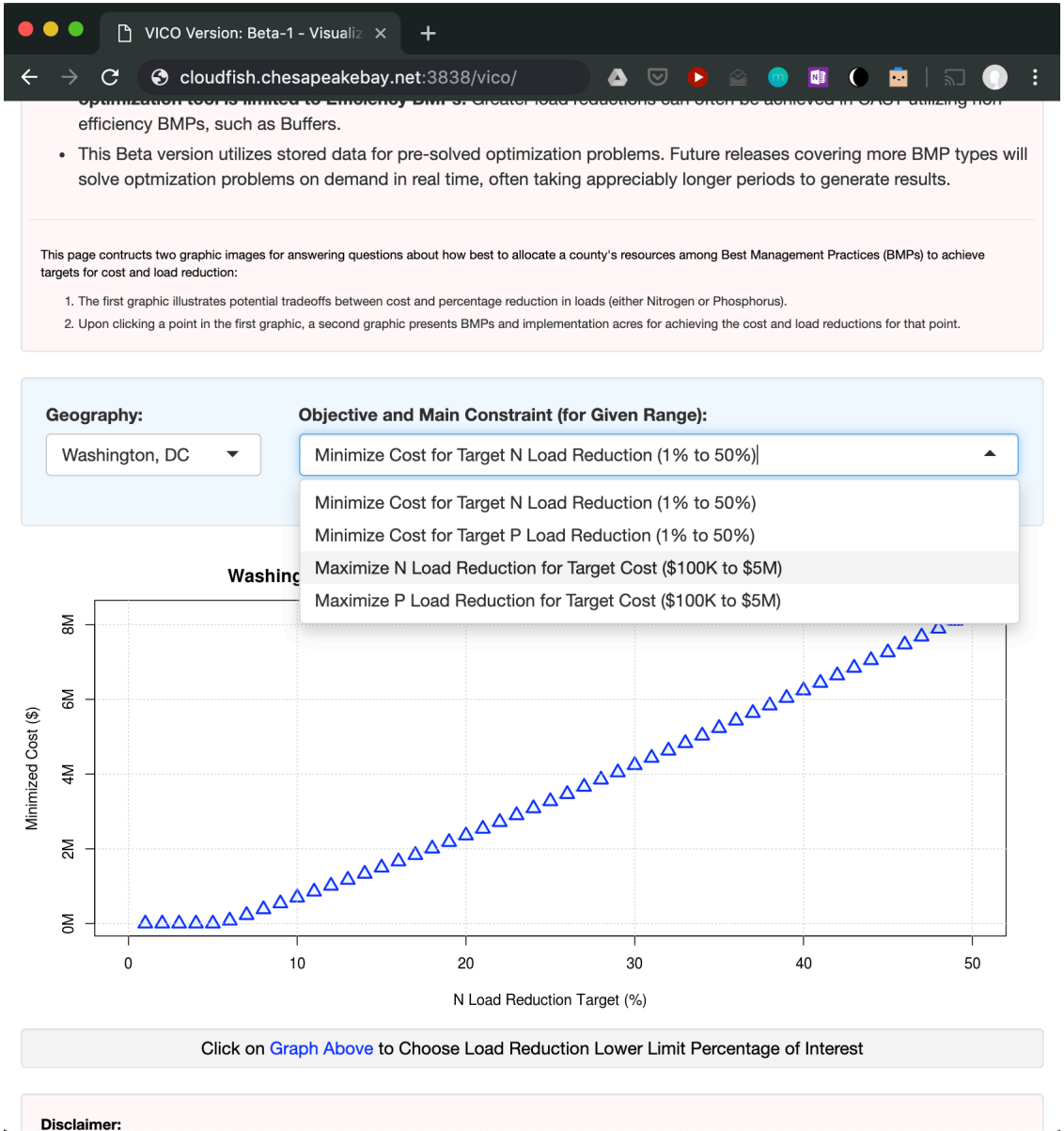
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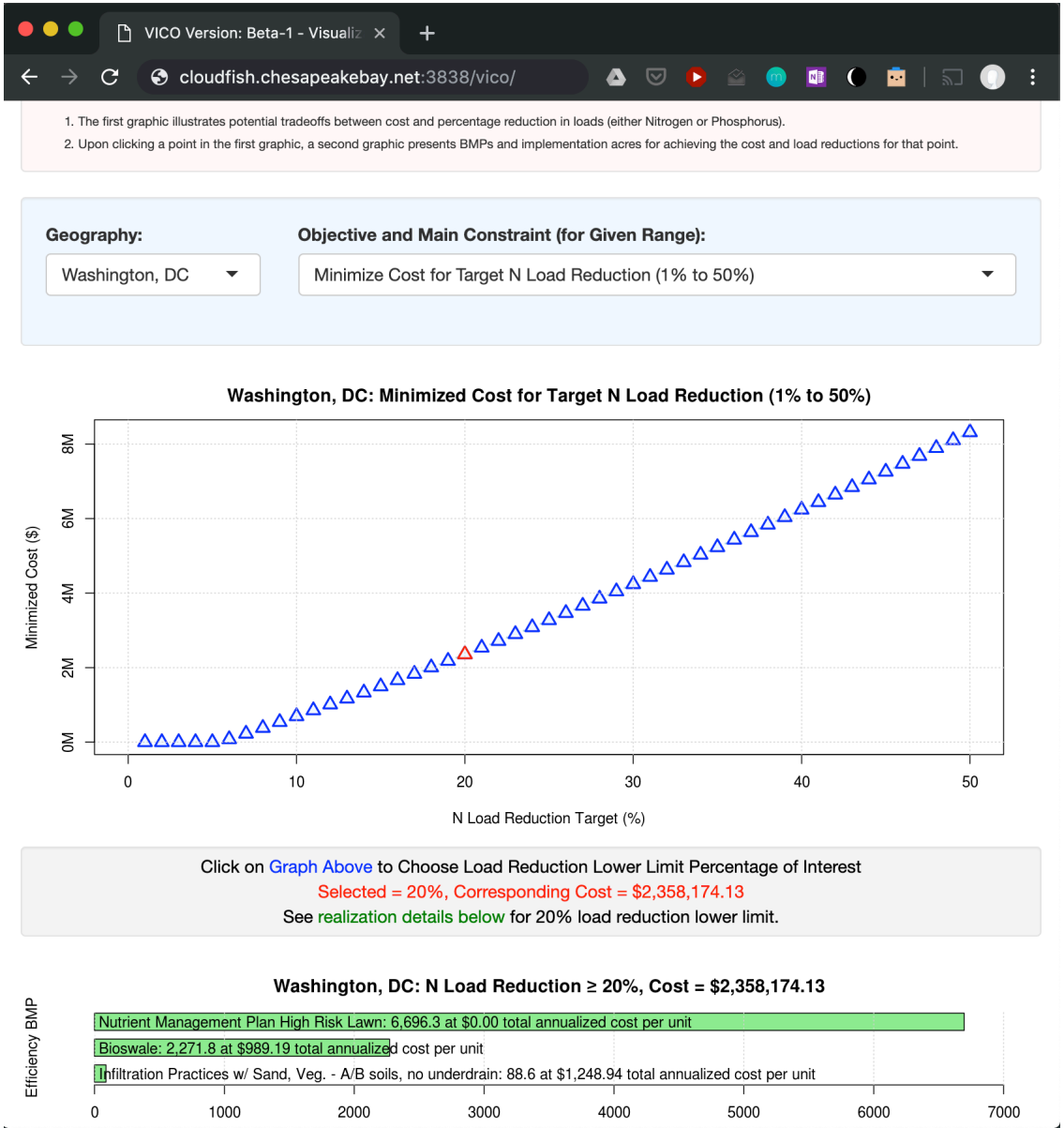
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Minimized Cost ($)
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N Load Reduction Target (%)
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Selected = 20%, Corresponding Cost = $2,358,174.13
See realization details below for 20% load reduction lower limit.
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Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain: 88.6 at $1,248.94 total annualized cost per unit
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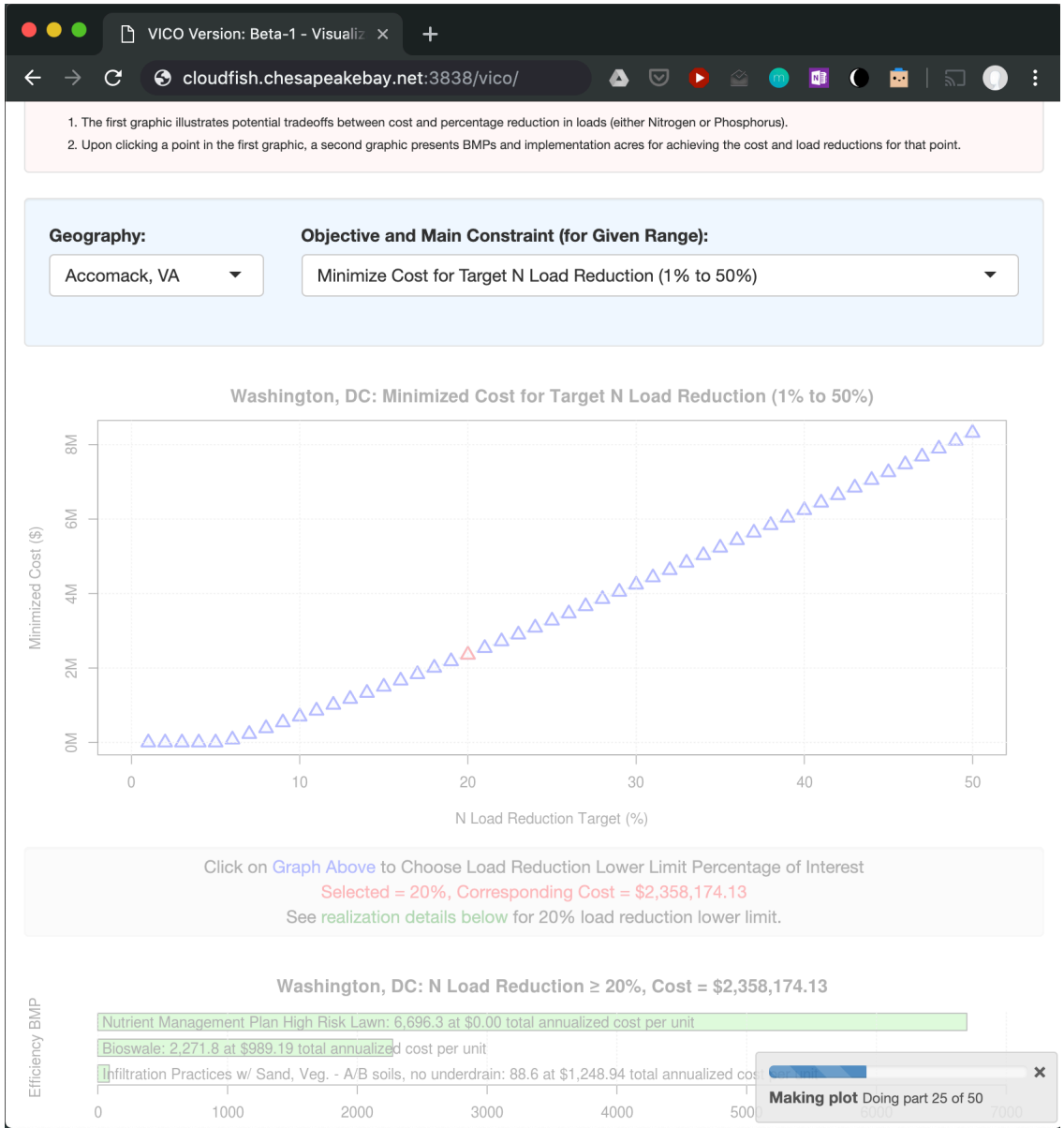
Features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Geography:
Accomack, VA
Objective and Main Constraint (for Given Range):
Minimize Cost for Target N Load Reduction (1% to 50%)
Washington, DC: Minimized Cost for Target N Load Reduction (1% to 50%)
Minimized Cost ($)
0M
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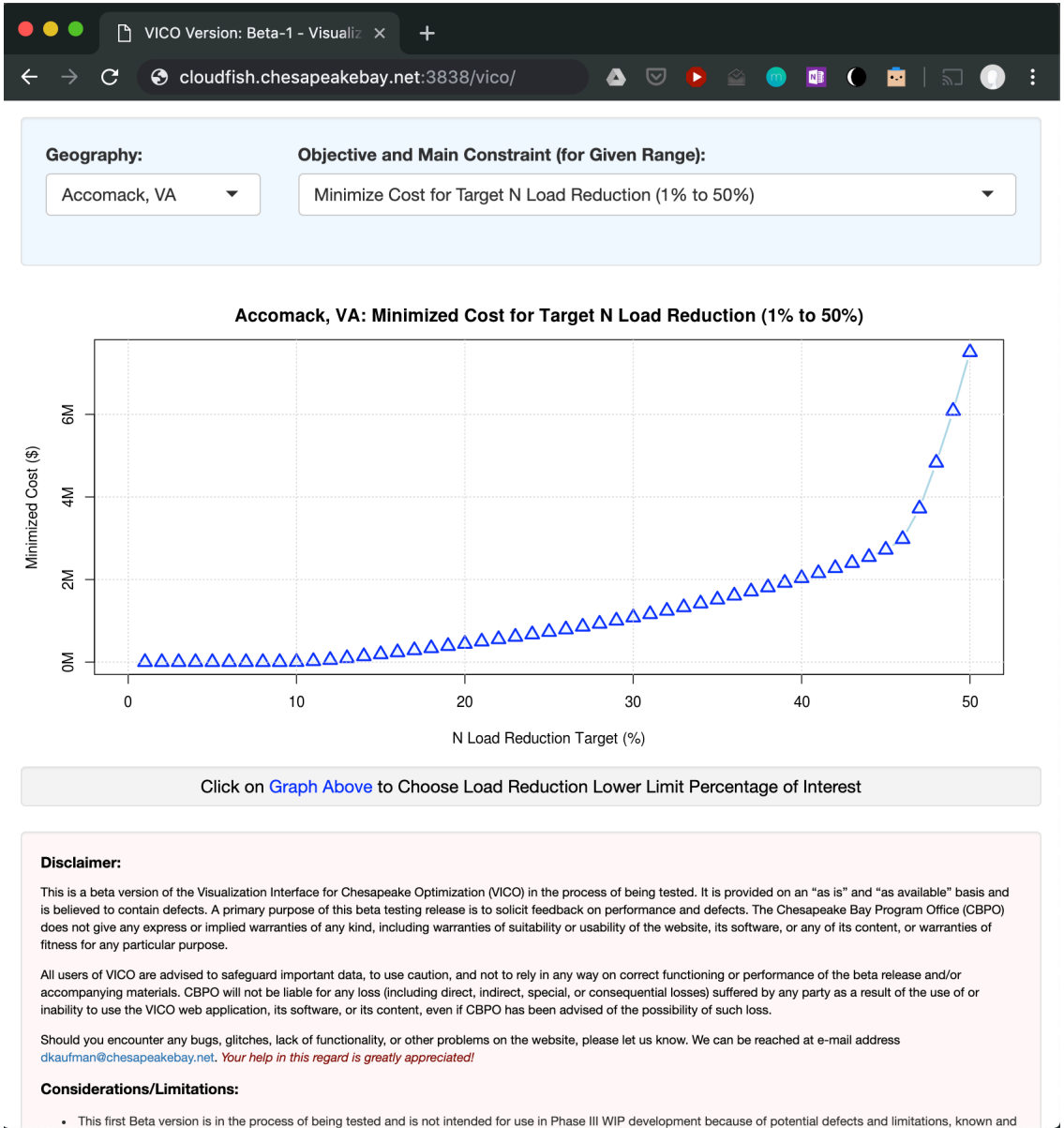
Making plot Doing part 25 of 50

Features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Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)
Minimized Cost ($)
0M
2M
4M
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N Load Reduction Target (%)
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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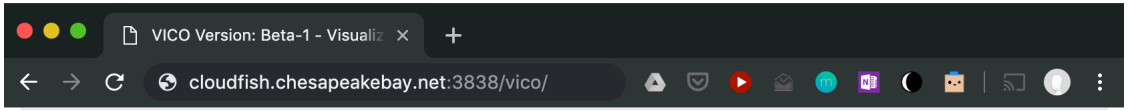
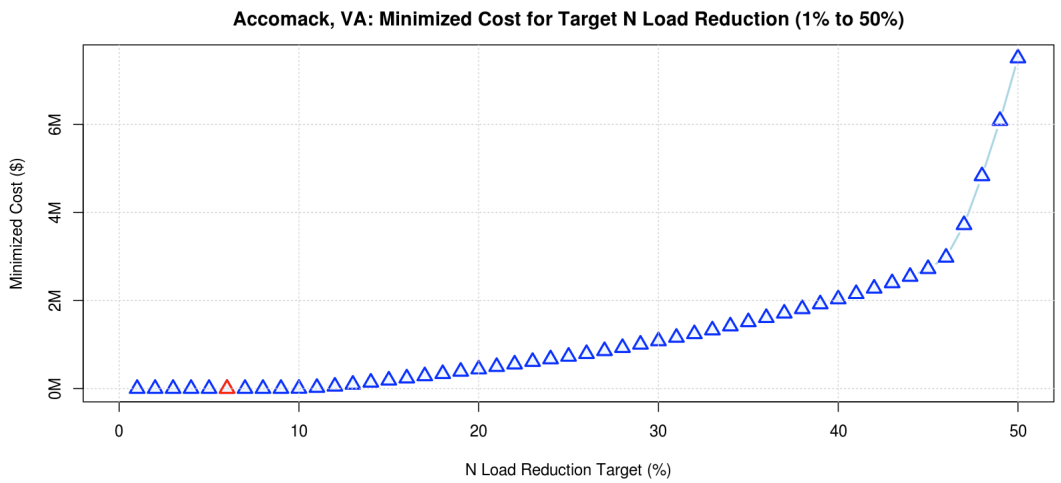
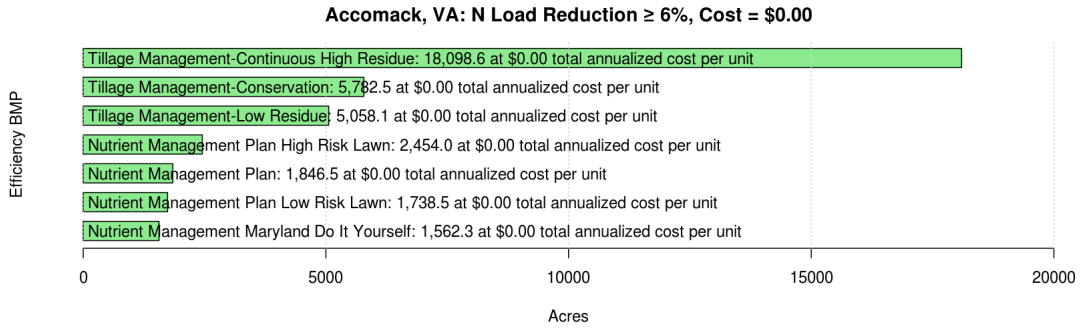




Click on Graph Above to Choose Load Reduction Lower Limit Percentage of Interest
Selected = 6%, Corresponding Cost = $0.00
See realization details below for 6% load reduction lower limit.



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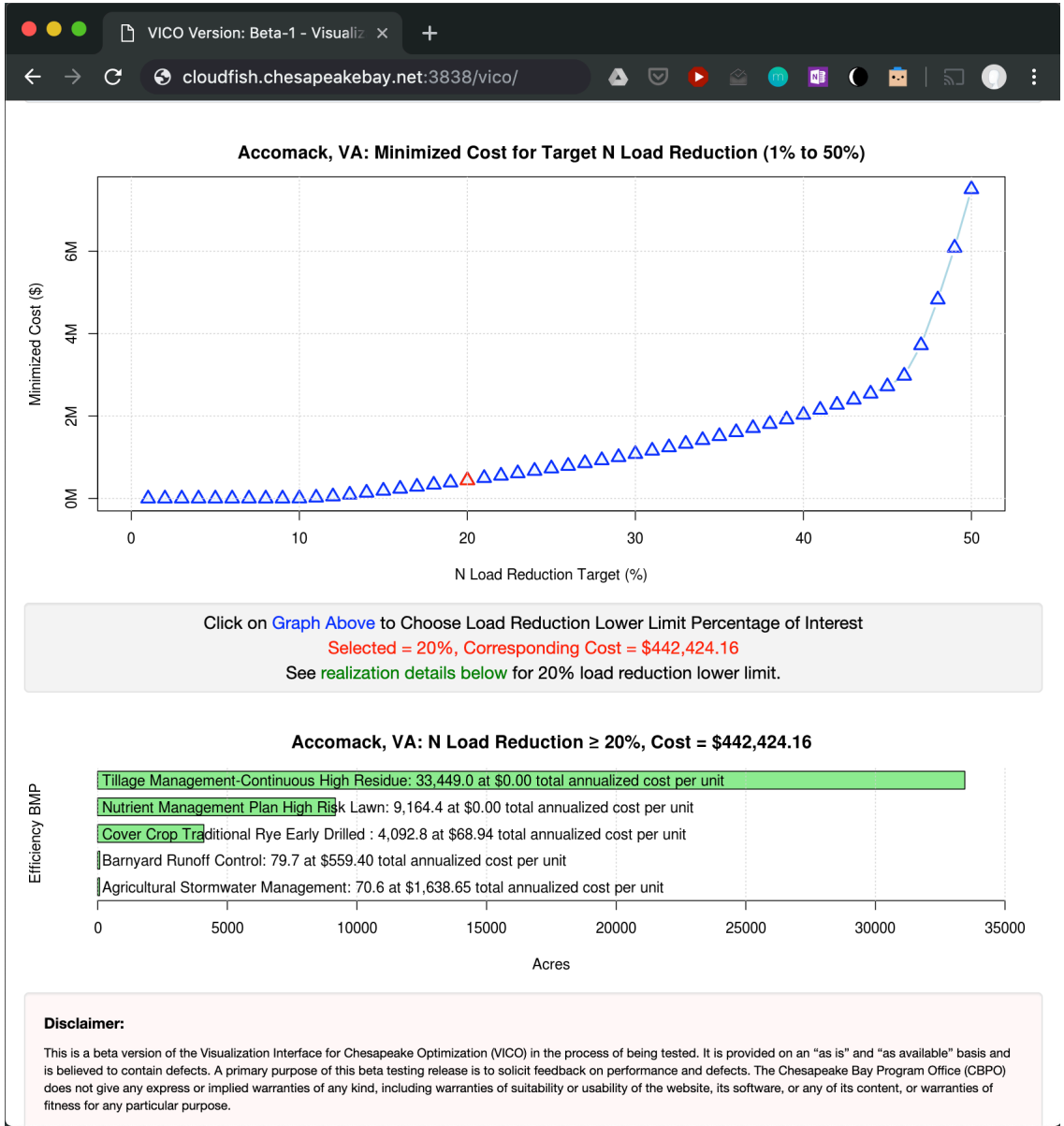
VICO Version: Beta-1 - Visualiz
cloudfish.chesapeakebay.net:3838/vico/
Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)
Minimized Cost ($)
0M
2M
4M
6M
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N Load Reduction Target (%)
Click on Graph Above to Choose Load Reduction Lower 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 ≥ 20%, Cost = $442,424.16
Efficiency BMP
Tillage Management-Continuous High Residue: 33,449.0 at $0.00 total annualized cost per unit
Nutrient Management Plan High Risk Lawn: 9,164.4 at $0.00 total annualized cost per unit
Cover Crop Traditional Rye Early Drilled : 4,092.8 at $68.94 total annualized cost per unit
Barnyard Runoff Control: 79.7 at $559.40 total annualized cost per unit
Agricultural Stormwater Management: 70.6 at $1,638.65 total annualized cost per unit
0
5000
10000
15000
20000
25000
30000
35000
Acres
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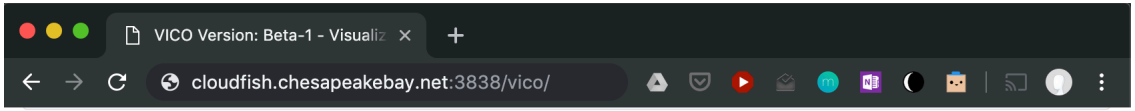
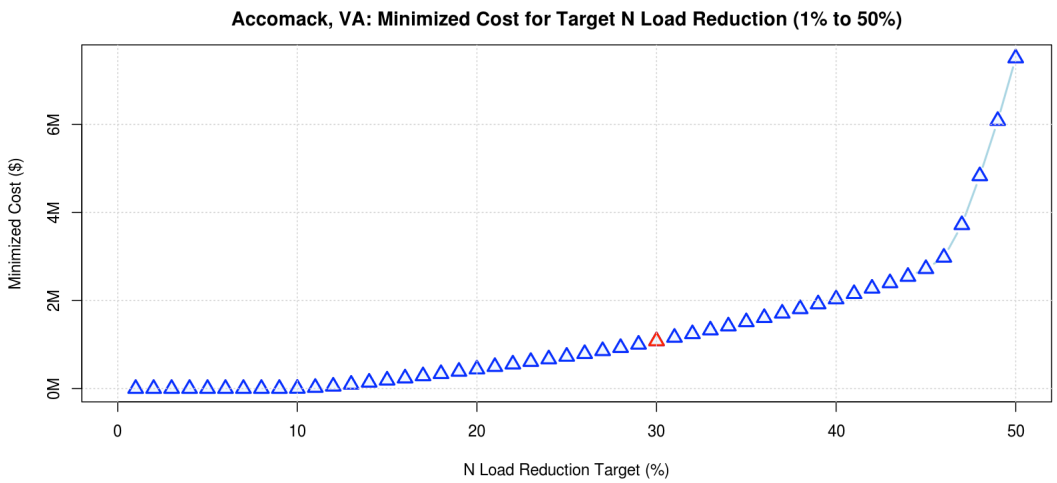
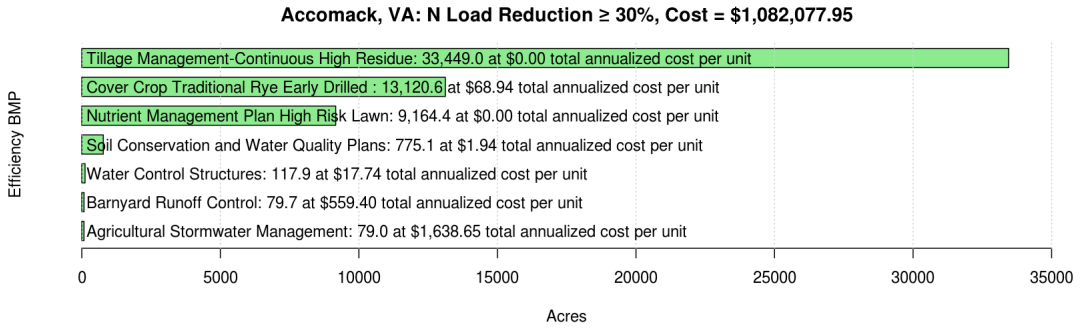
Features





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.



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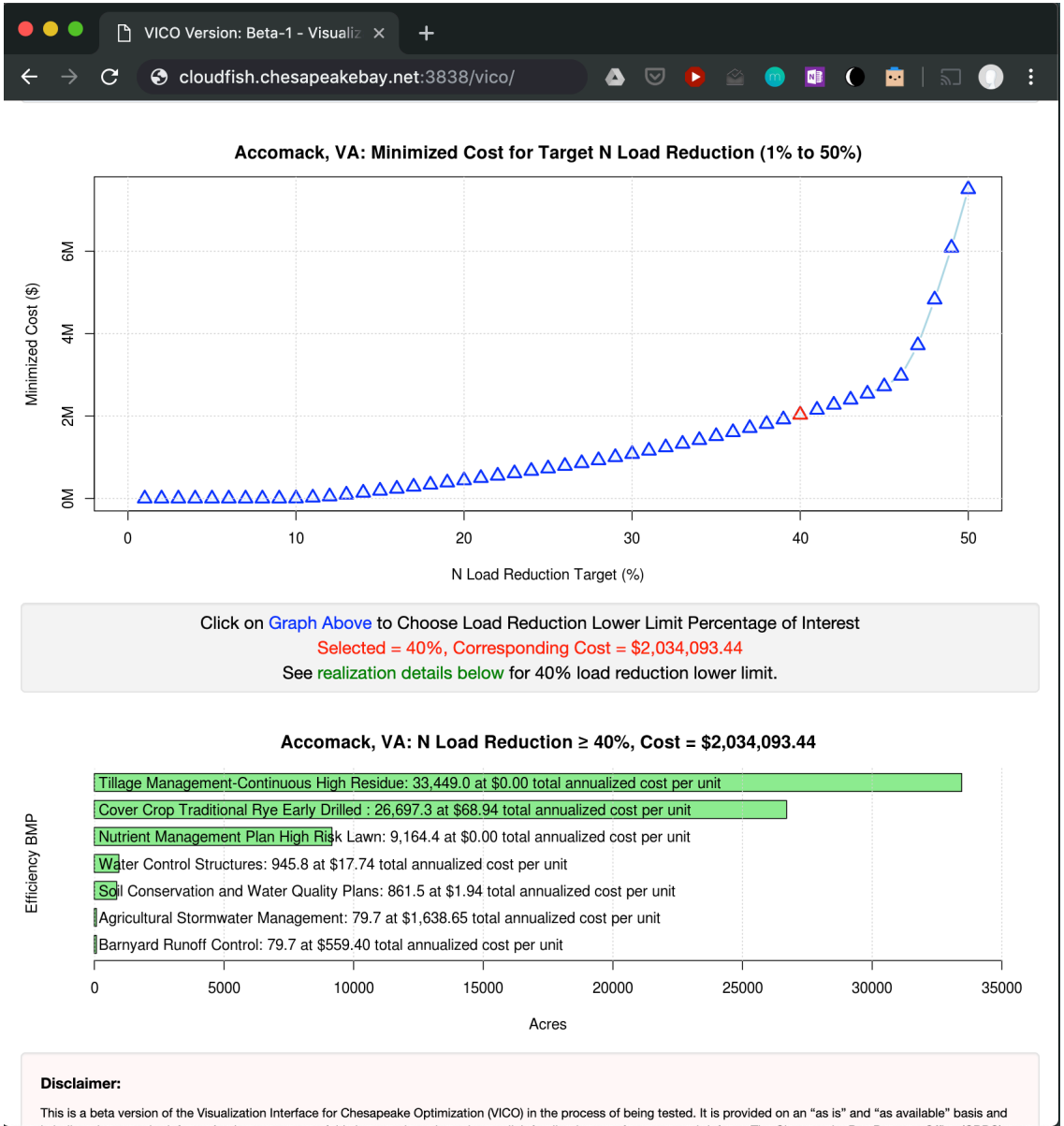
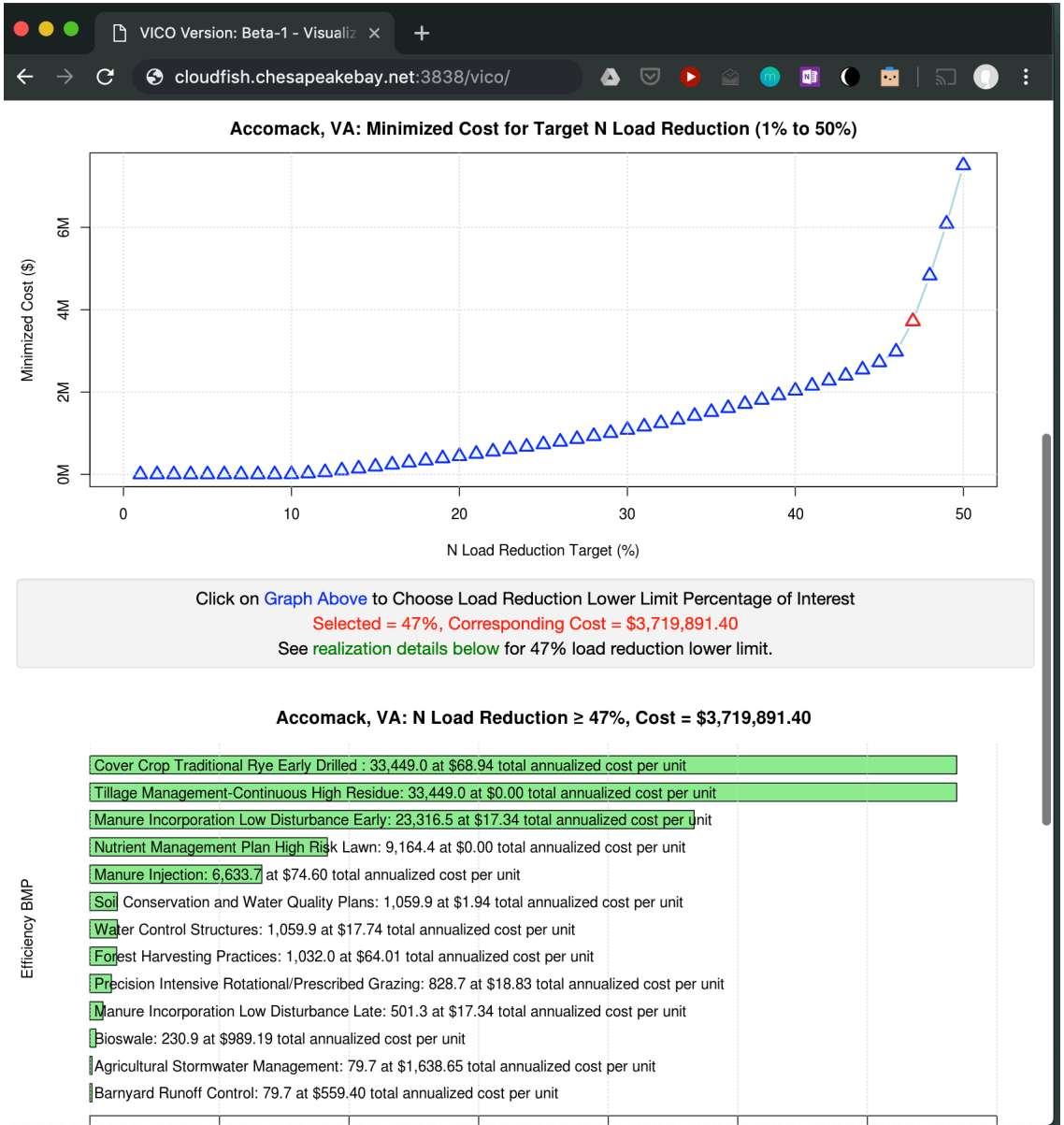

VICO Version: Beta-1 - Visualiz
cloudfish.chesapeakebay.net:3838/vico/
Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)
Minimized Cost ($)
0M
2M
4M
6M
0
10
20
30
40
50
N Load Reduction Target (%)
Click on Graph Above to Choose Load Reduction Lower Limit Percentage of Interest
Selected = 40%, Corresponding Cost = $2,034,093.44
See realization details below for 40% load reduction lower limit.
Accomack, VA: N Load Reduction ≥ 40%, Cost = $2,034,093.44
Efficiency BMP
Tillage Management-Continuous High Residue: 33,449.0 at $0.00 total annualized cost per unit
Cover Crop Traditional Rye Early Drilled : 26,697.3 at $68.94 total annualized cost per unit
Nutrient Management Plan High Risk Lawn: 9,164.4 at $0.00 total annualized cost per unit
Water Control Structures: 945.8 at $17.74 total annualized cost per unit
Soil Conservation and Water Quality Plans: 861.5 at $1.94 total annualized cost per unit
Agricultural Stormwater Management: 79.7 at $1,638.65 total annualized cost per unit
Barnyard Runoff Control: 79.7 at $559.40 total annualized cost per unit
0
5000
10000
15000
20000
25000
30000
35000
Acres
Disclaimer:
This is a beta version of the Visualization Interface for Chesapeake Optimization (VICO) in the process of being tested. It is provided on an “as is” and “as available” basis and

Features


VICO Version: Beta-1 - Visualiz
cloudfish.chesapeakebay.net:3838/vico/
Accomack, VA: Minimized Cost for Target N Load Reduction (1% to 50%)
Minimized Cost ($)
0M
2M
4M
6M
0
10
20
30
40
50
N Load Reduction Target (%)
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 ≥ 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
Barnyard Runoff Control: 79.7 at $559.40 total annualized cost per unit

Efficiency BMPs include:

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

Rain Gardens

Methods

Nonlinear Optimization Model

Minimize
(total cost)

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

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)

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

Constrained by:
(Target load)

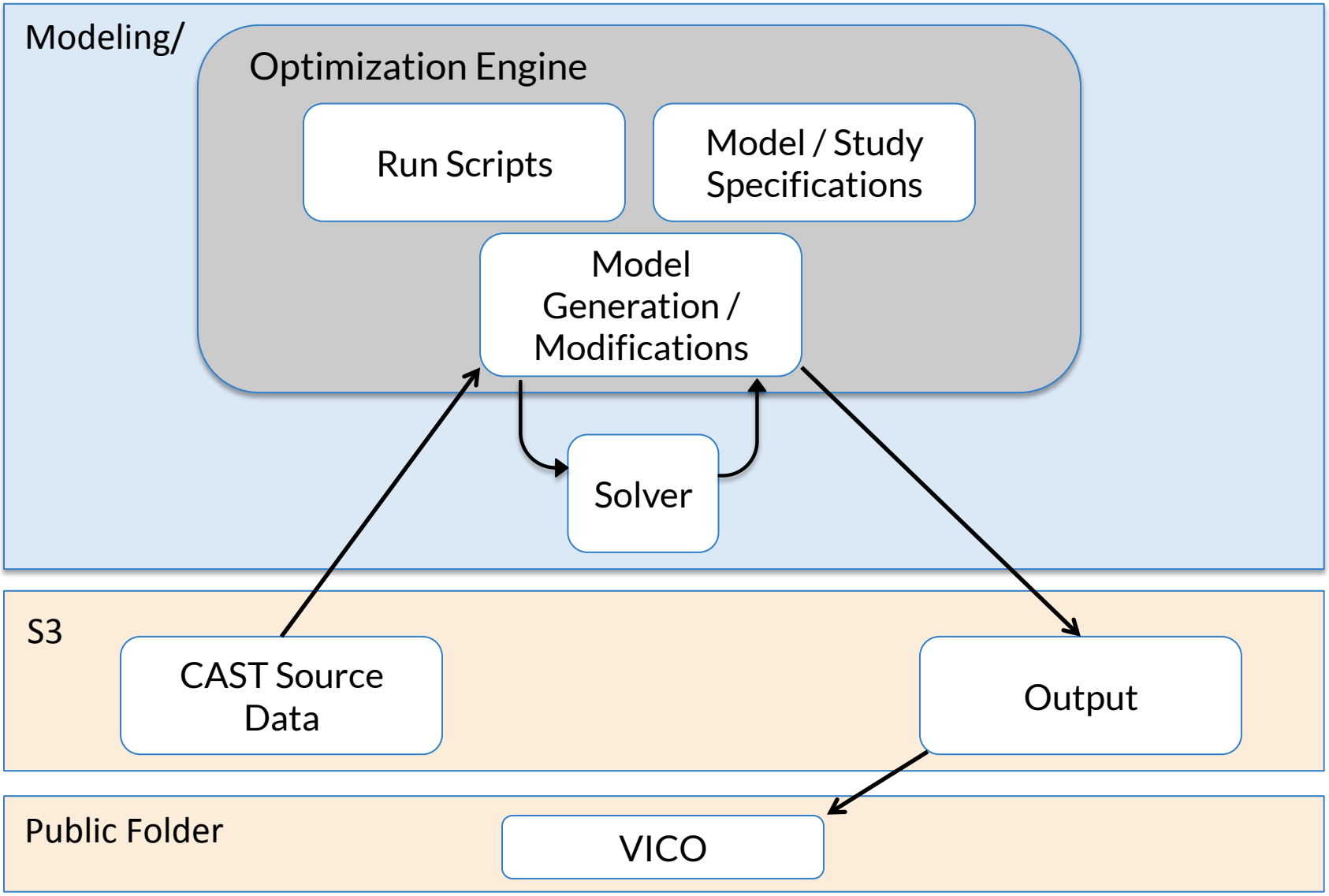
Code formulated with **Pyomo**

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

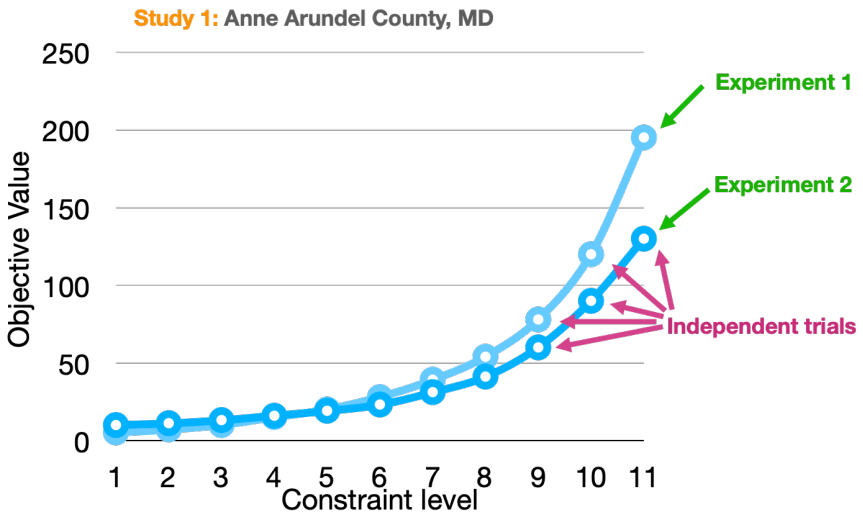
Instances solved using **IPOPT**

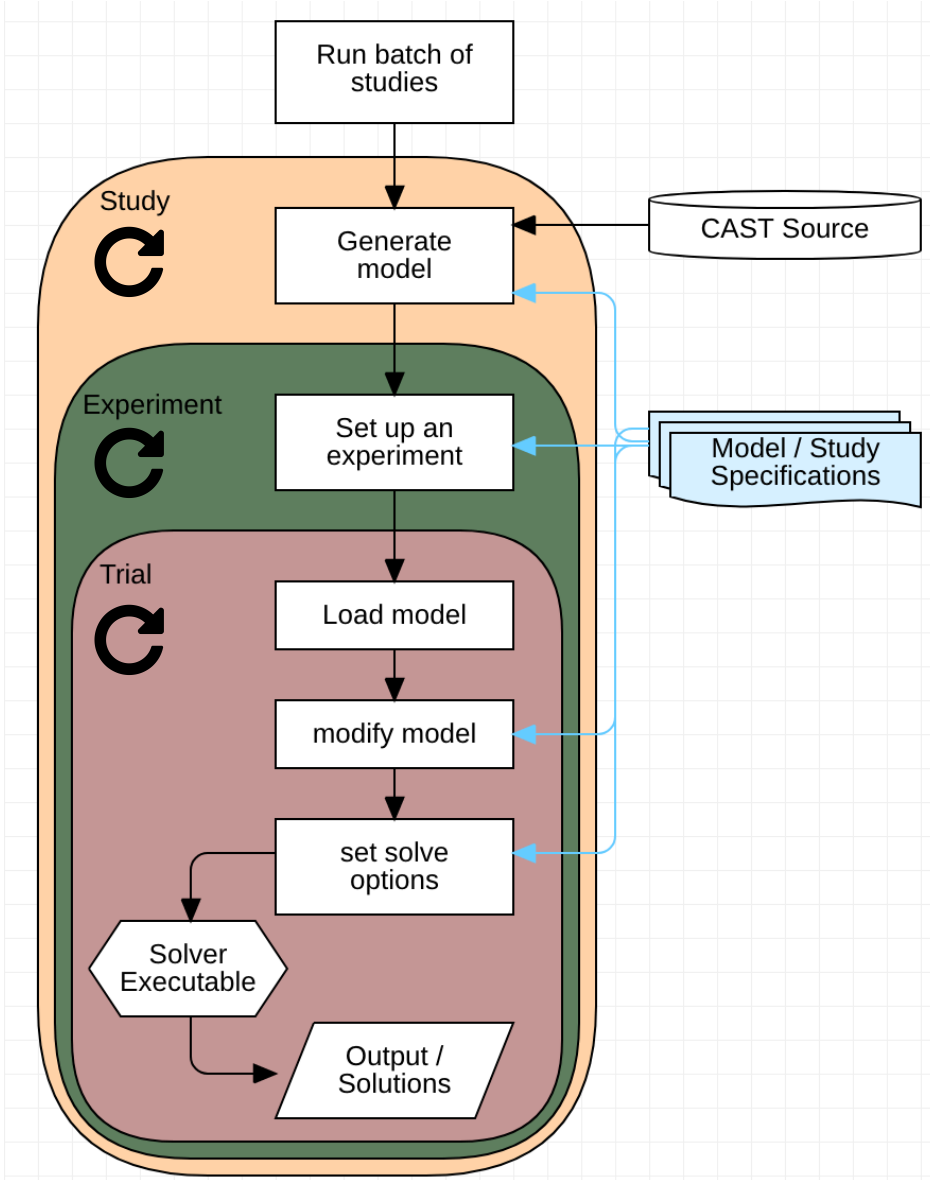
(interior point / barrier method solver) developed at Carnegie Mellon Univ. and available as part of the Computational Infrastructure for Operations Research (COIN-OR)

Current version components



High-level Components





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/

Email me (Danny) at: dkaufman@chesapeakebay.net