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

16-17 October 2018 – Modeling Workgroup Quarterly

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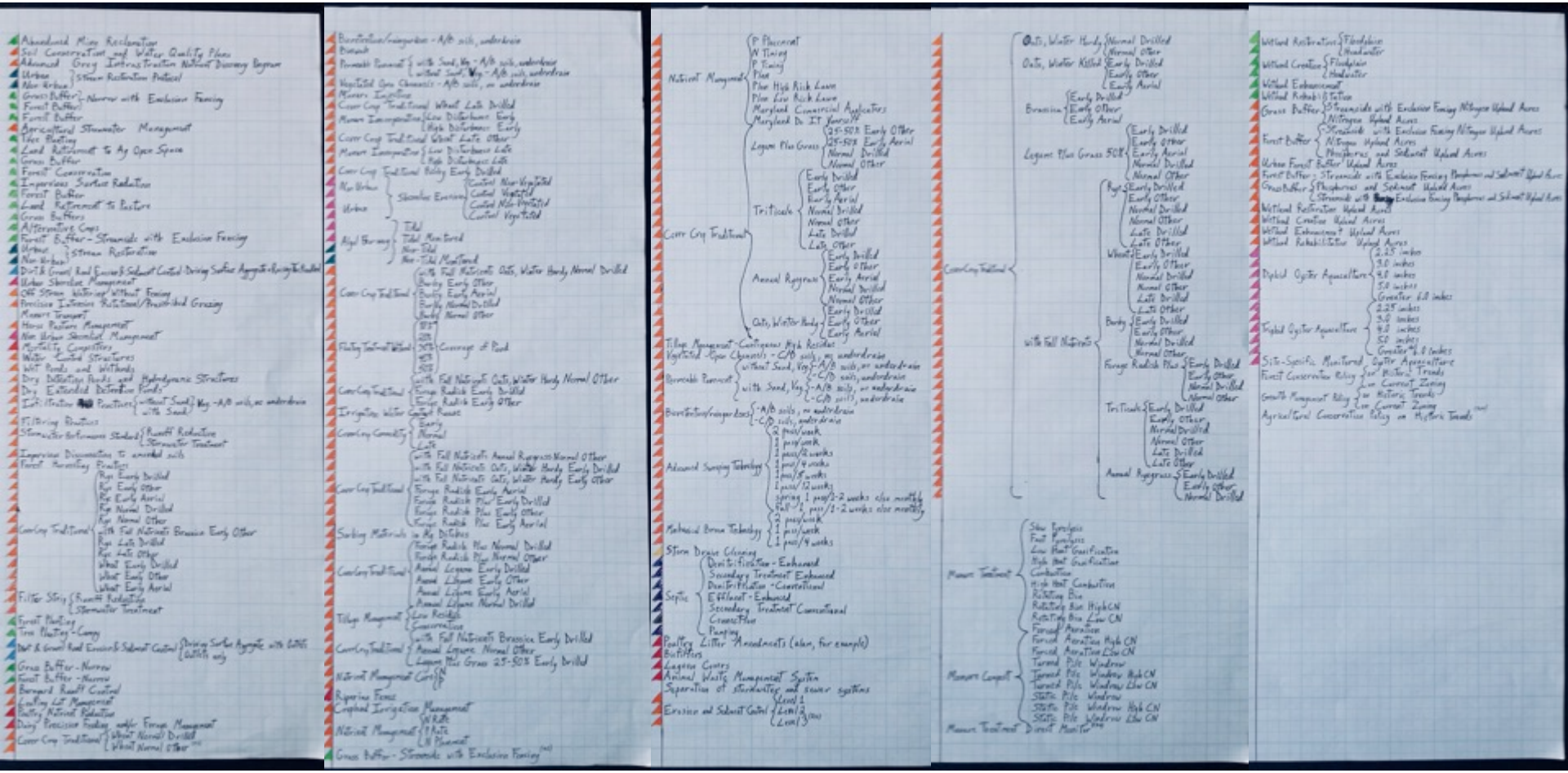
Project Goal: Investigate, develop, test, and implement an optimization system for the Chesapeake Assessment Scenario Tool (CAST) that will facilitate identification of more cost-effective and otherwise optimal approaches to pollutant load reduction for CBP partners.

Scenario Optimization System

Analyze potential BMP options and identify low-cost strategies

To help the Chesapeake Bay Program and its Partners restore the Bay and its watershed

Best Management Practices (BMPs) in CAST



Orange = Efficiency BMPs

Prototype methods

Two Model Versions

Minimize
(total cost)

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

Constrained by:
(Target load)

Maximize
(load reduction)

$$\%\,LoadReduction_{\substack{segment \\ \{pollutant\}}}$$

Constrained by:
(Cost bound)

Prototype methods

- Model code formulated with Pyomo[1]
  (algebraic modeling language library for python) developed by Sandia National Laboratories.

- Model instances solved using IPOPT[2]
  (interior point / barrier method solver) developed at Carnegie Mellon Univ. and available as part of the Computational Infrastructure for Operations Research (COIN-OR)

[1]Hart, William E., Carl D. Laird, Jean-Paul Watson, David L. Woodruff, Gabriel A. Hackebeil, Bethany L. Nicholson, and John D. Siirola. Pyomo – Optimization Modeling in Python. Second Edition. Vol. 67. Springer, 2017.
Hart, William E., Jean-Paul Watson, and David L. Woodruff. "Pyomo: modeling and solving mathematical programs in Python." Mathematical Programming Computation 3(3) (2011): 219-260.

[2]A. Wächter and L. T. Biegler,
On the Implementation of a Primal-Dual Interior Point Filter Line Search Algorithm for Large-Scale Nonlinear Programming, *Mathematical Programming* 106(1), pp. 25-57, 2006

Main takeaways from August optimization Advisory & Support Committee (ASC) meeting

Working prototype, using subset of BMPs, is well formulated:

- convexity and starting point analyses were useful
- and there are not any fatal flaws

Key elements to build on:

- larger geographic scales
- compare prototype results to 'optimal solutions' obtained by both CAST experts and other users

Merge long-term ideas with need to develop working prototype in 2019

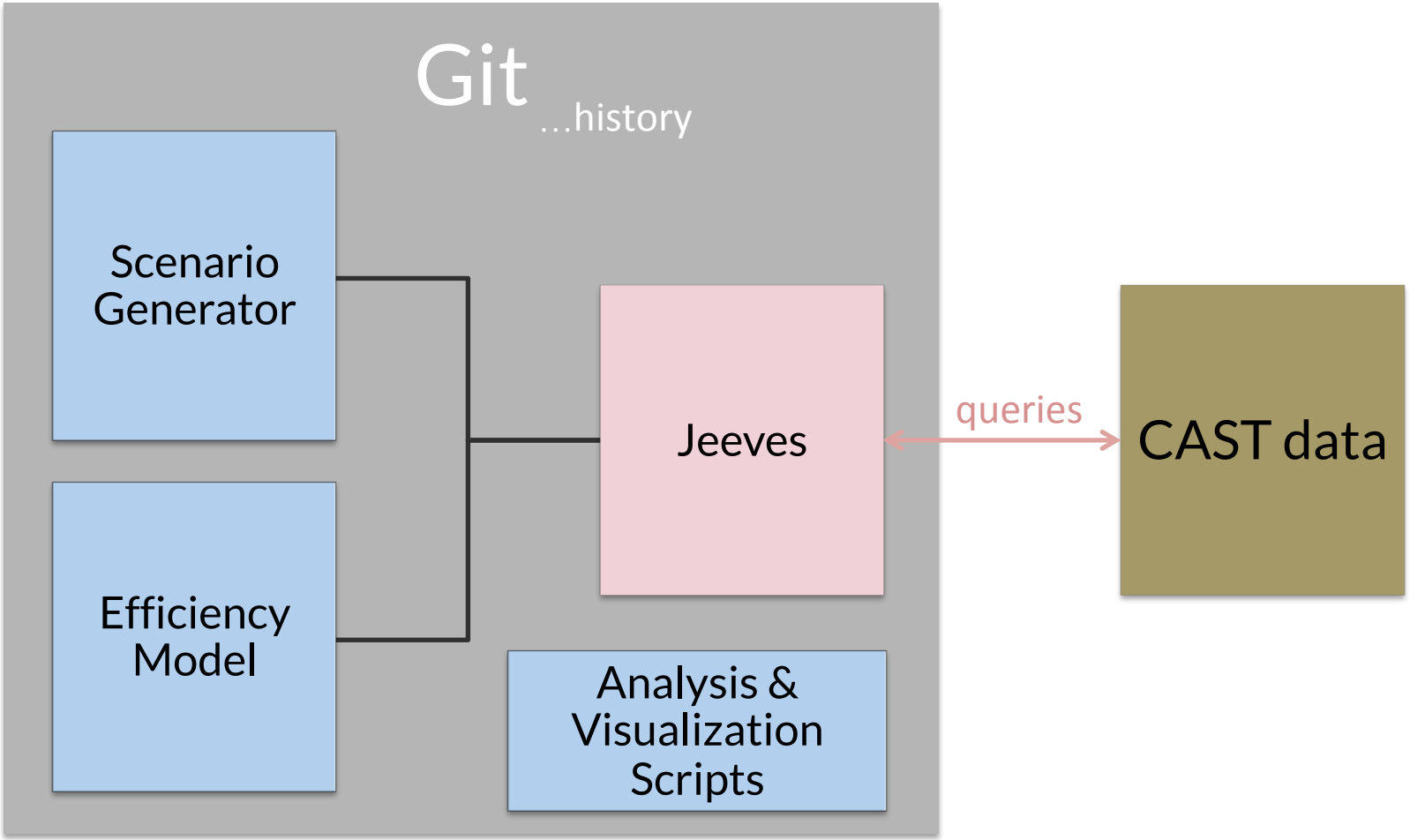
Utilize prototype to gather feedback and collaboratively build in features desired by users

- Actively engage users that have not been previously engaged
- Work with folks (could be you!) to construct and explore case studies

Outline

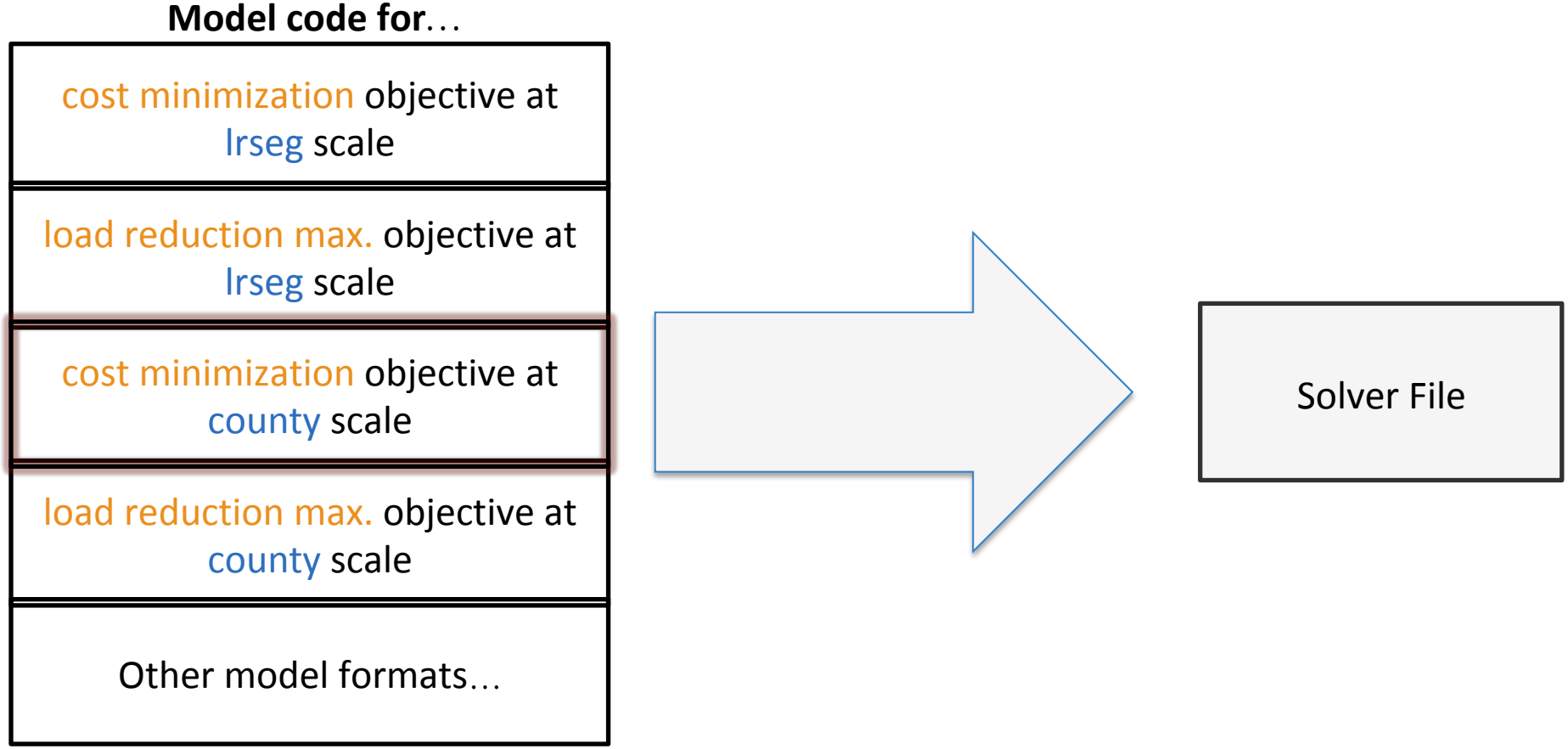
1. Prototype software updates
2. Example solutions
3. Next steps

Software update: 1 of 3
Structure



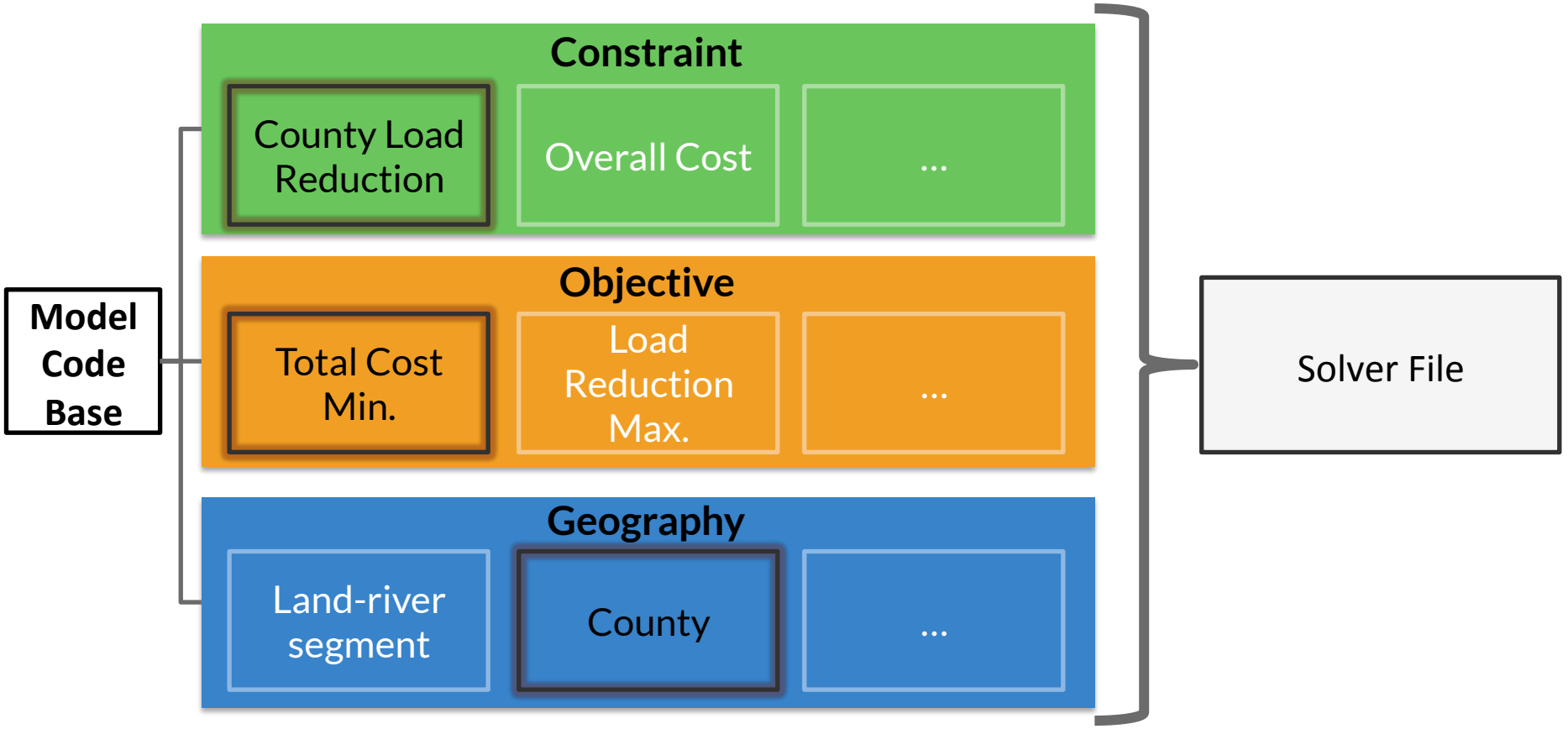
Merged separate code repositories into a single repository for coordinated source control

Software update: 2 of 3
Model Instantiation



Eliminated duplication for objective/geography combinations

Software update: 2 of 3
Model Instantiation



Eliminated duplication for objective/geography combinations

Software update: 3 of 3

Interface

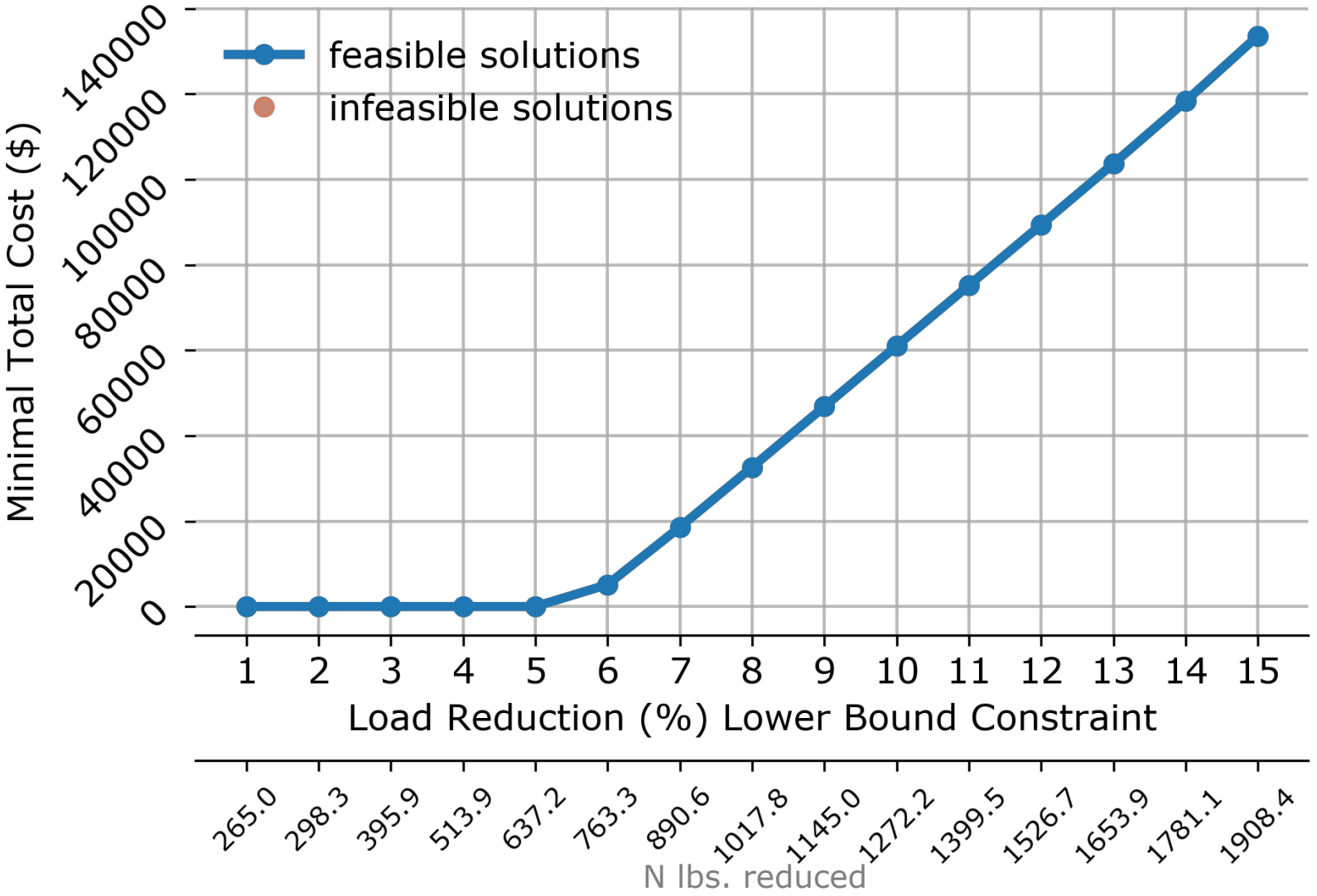
Simplify API and streamline model instantiation for test cases and analysis of solutions.

"A Study represents a series of one (or multiple) run(s), with different configurations."

```
# Example instantiation
s = Study(objectivetype='costmin',
          geoscale='county',
          geoentities=['Montgomery, MD'],
          baseconstraint=5)  # ≥ 5% N load reduction

# Example solving
solver_diagnostics, solution_csv, data, objective = s.go()
```

Objective:
Minimize Total Cost ($)



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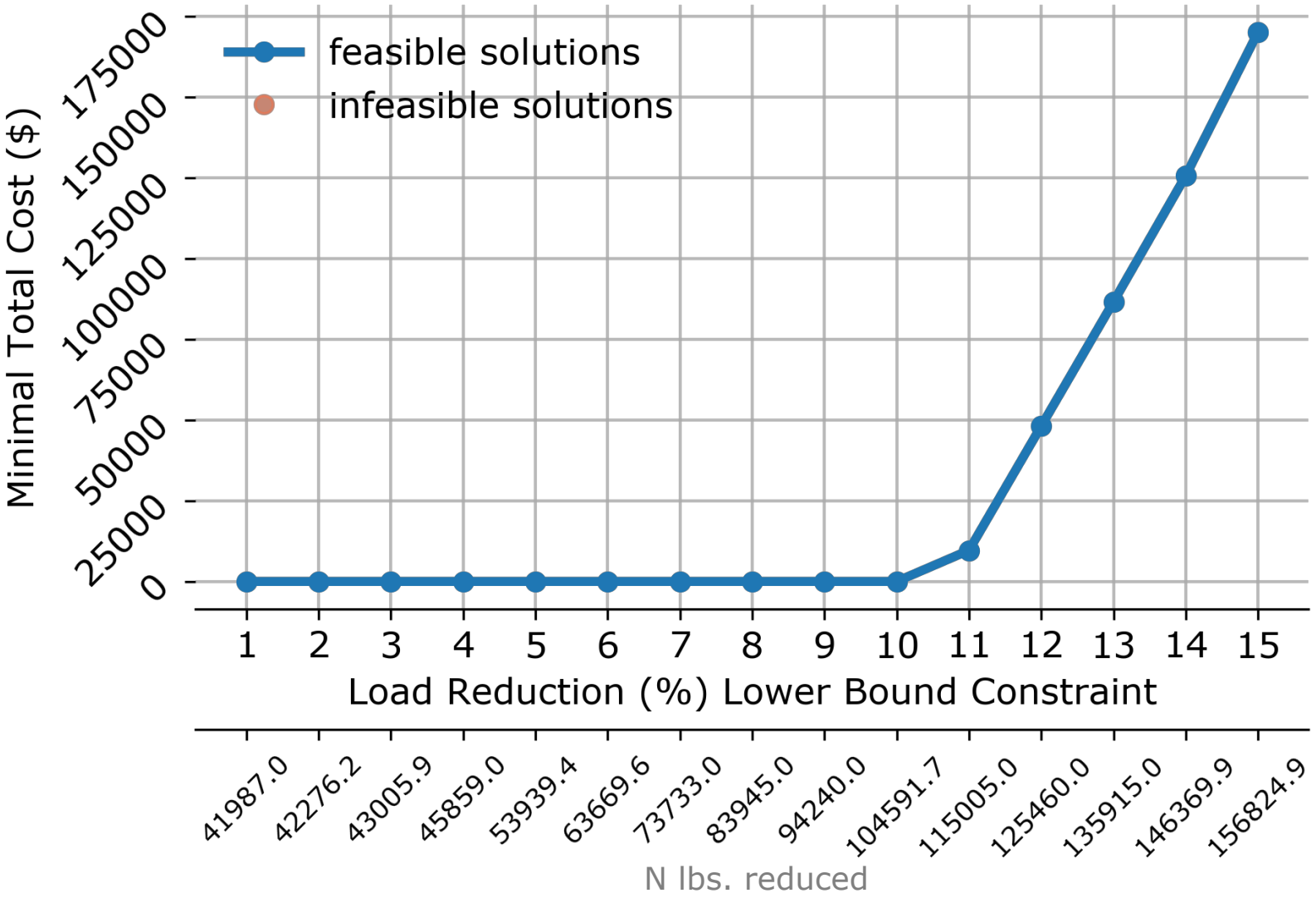

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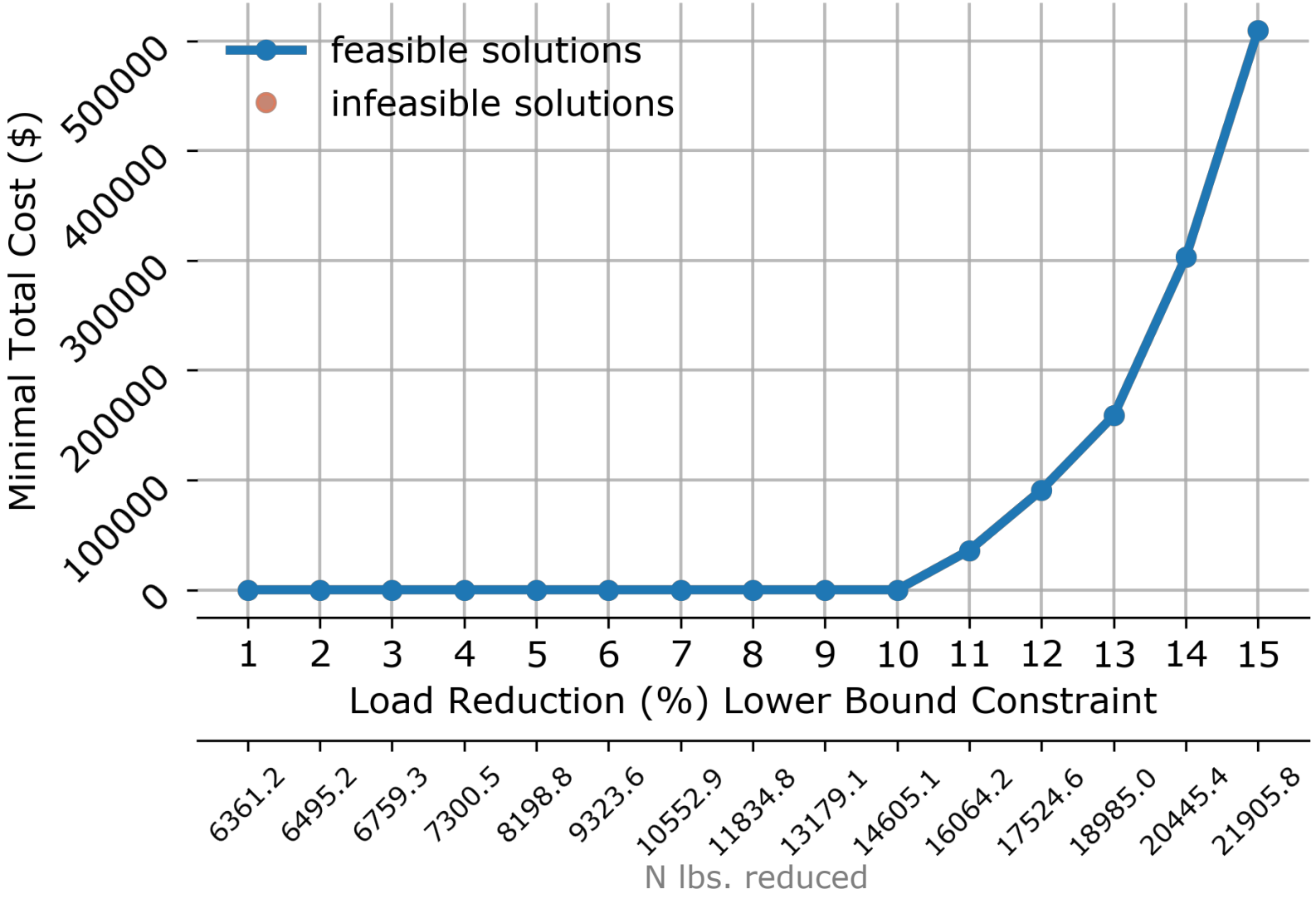

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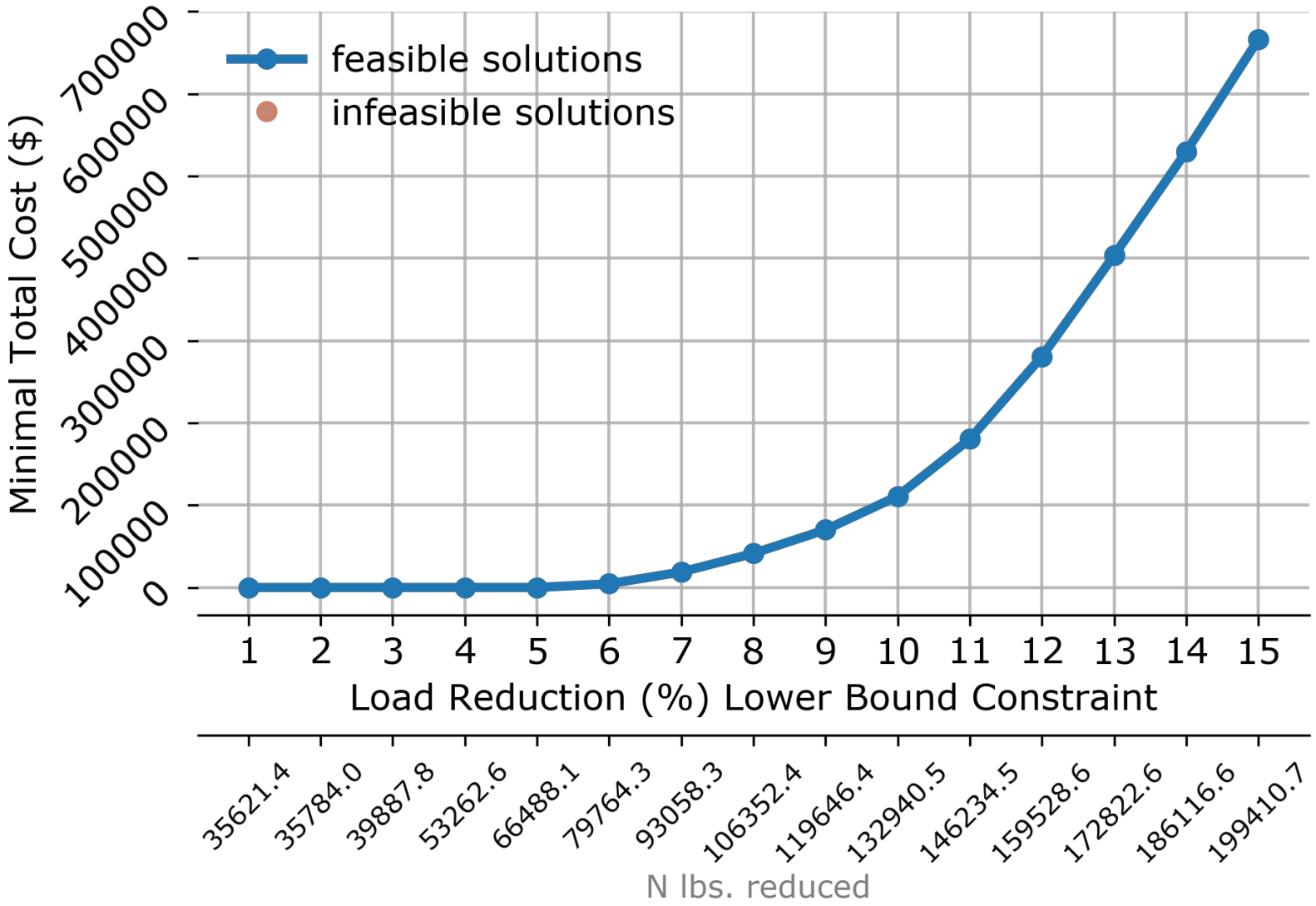

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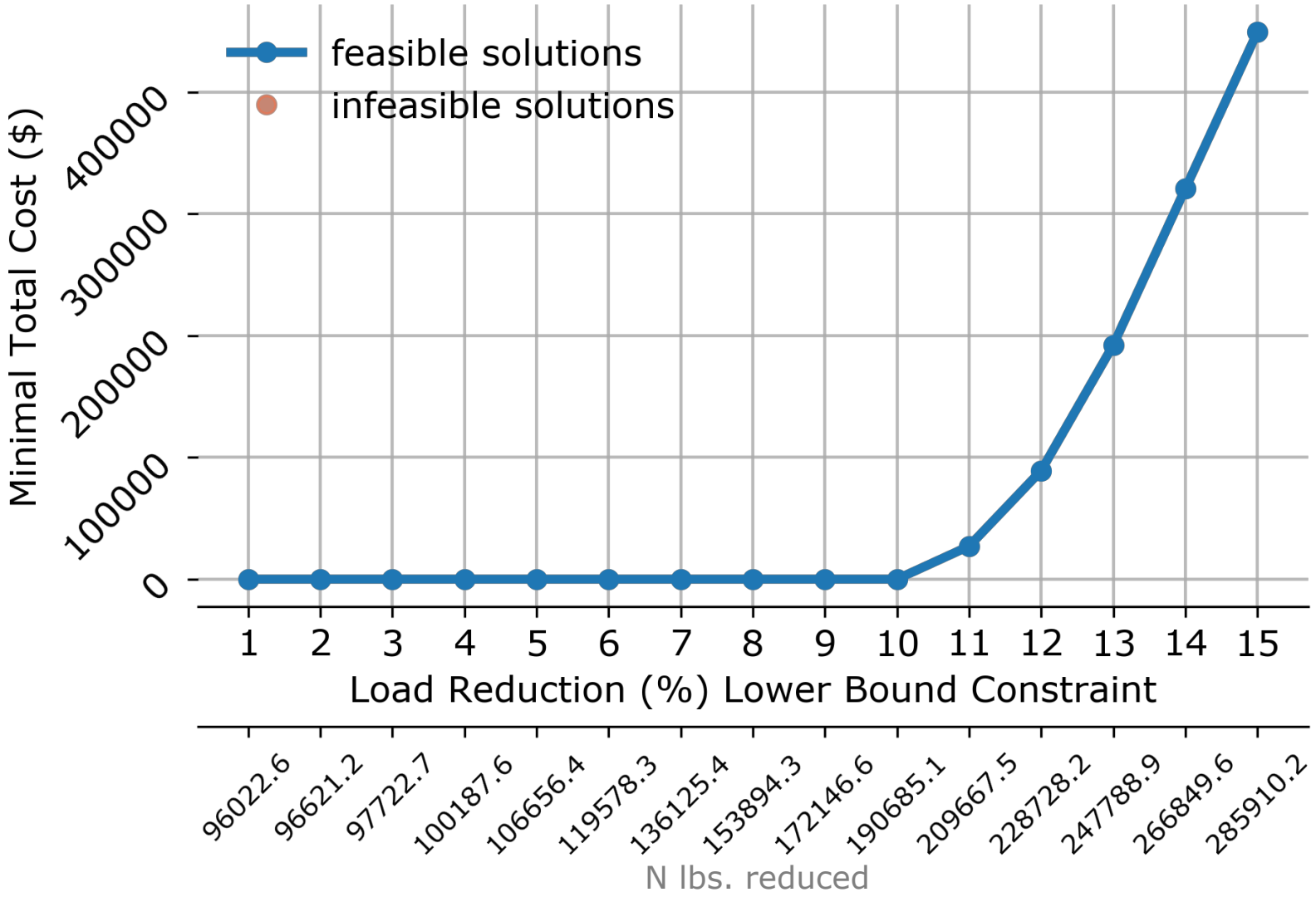

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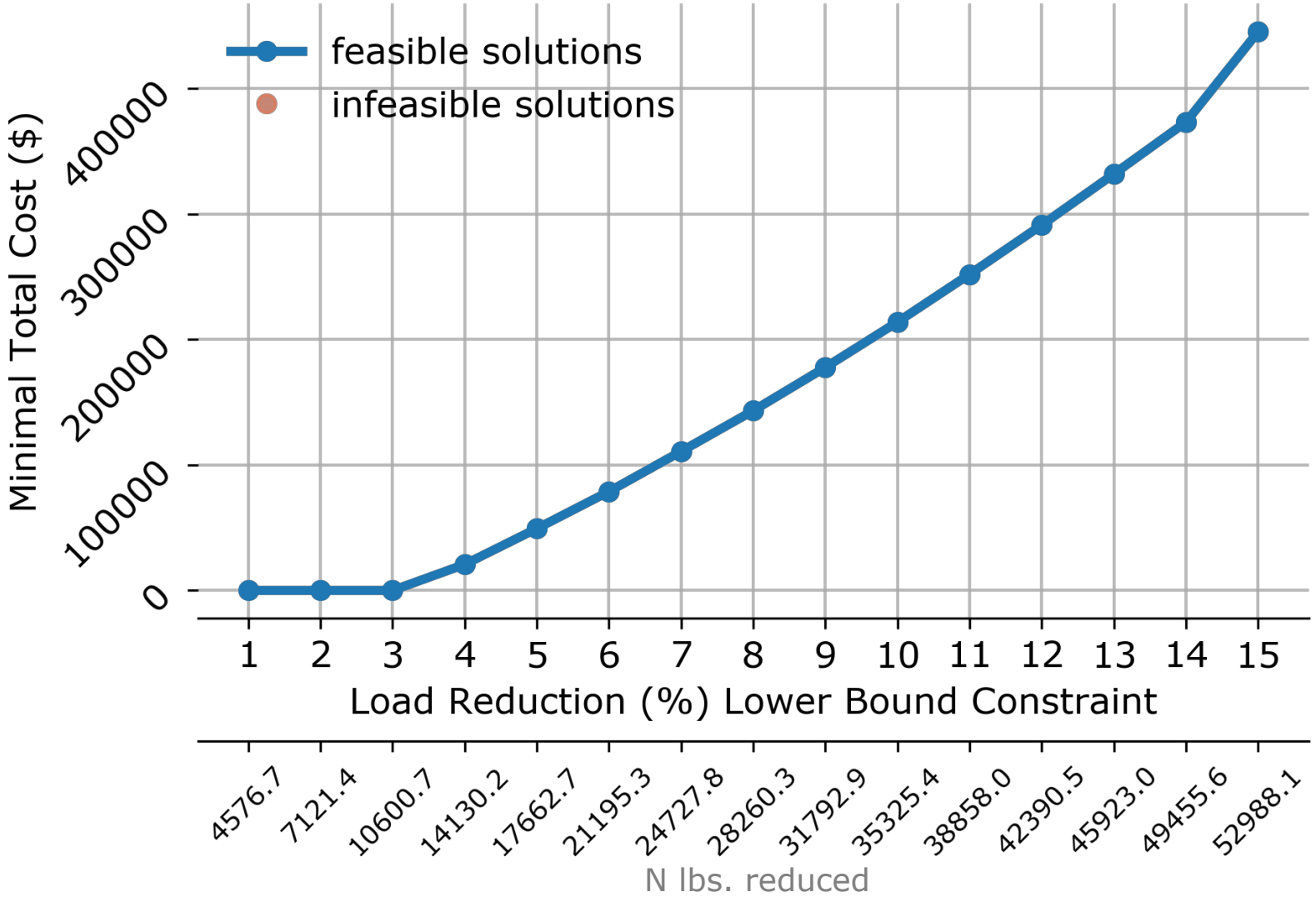

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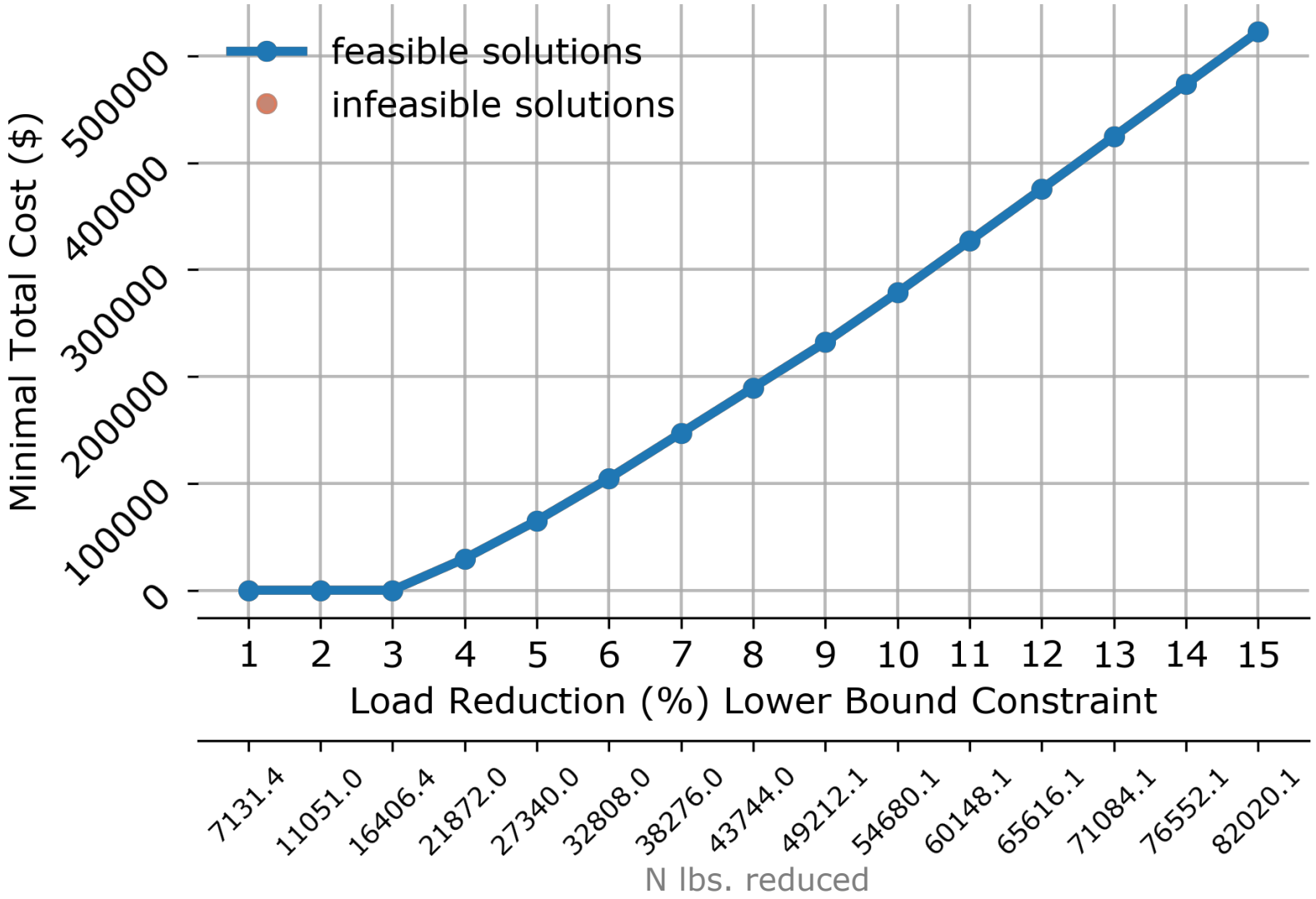

Current status

"Straw-arm" prototype
(Part of straw-man)

- Results are draft/preliminary, and subject to revision.
- Prototype is unlikely to be ready in time for Phase III WIP development.
- Beta version prototype will likely not include BMPs other than efficiencies. There are other BMPs, e.g. Buffers, that are important for reducing load.

Next steps

Efficiency BMP optimization model:

- Using oxygen damage units to consolidate N & P
- Ensuring robust solutions for more geographic regions
- Accounting for existing constraints, structural BMPs
- “John Henry” test

Feedback

Concurrent discovery for incorporating other BMPs

Will be shaped by feedback

Actively searching for ways to engage local decision makers at county and municipal scales for their guidance and feedback on prototype design.

Your area (county, sub-watershed) can be an early case study

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