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Optimization Solvers for a Hydraulic Response to a Water Distribution System Contamination Event

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Homeland Security Research Program

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Outline

- Motivation
- Approach
- Results
- Summary

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Motivation

- Water distribution systems are vulnerable to intentional or accidental contamination through multiple points of access
- Numerous contaminants could be used to cause severe public health consequences and significant economic impacts
- Given the cost of treating and decontaminating a water distribution system, modeling tools can be used to determine the best flushing locations in order to maximize the benefit

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Approach

- Use two different optimization solvers to identify locations to flush contaminated water out of a water distribution network
  - Two network models
  - Two injection scenarios
- Examine solution quality and simulation runtimes

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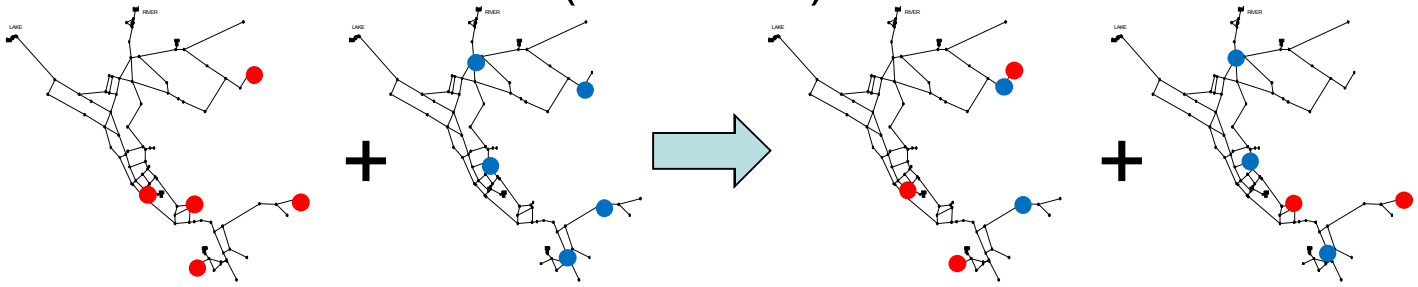
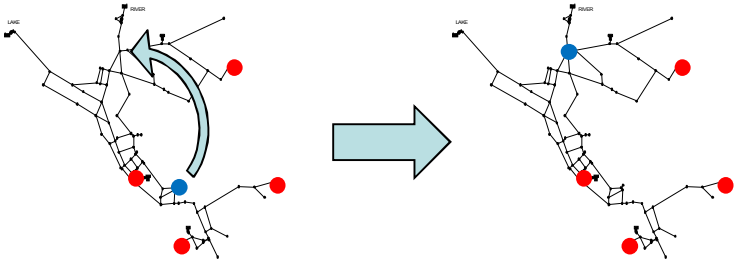
Evolutionary Algorithm (GA)

- Population-based stochastic global search
- "Randomly" perturb solutions
  - Solution recombination (crossover)



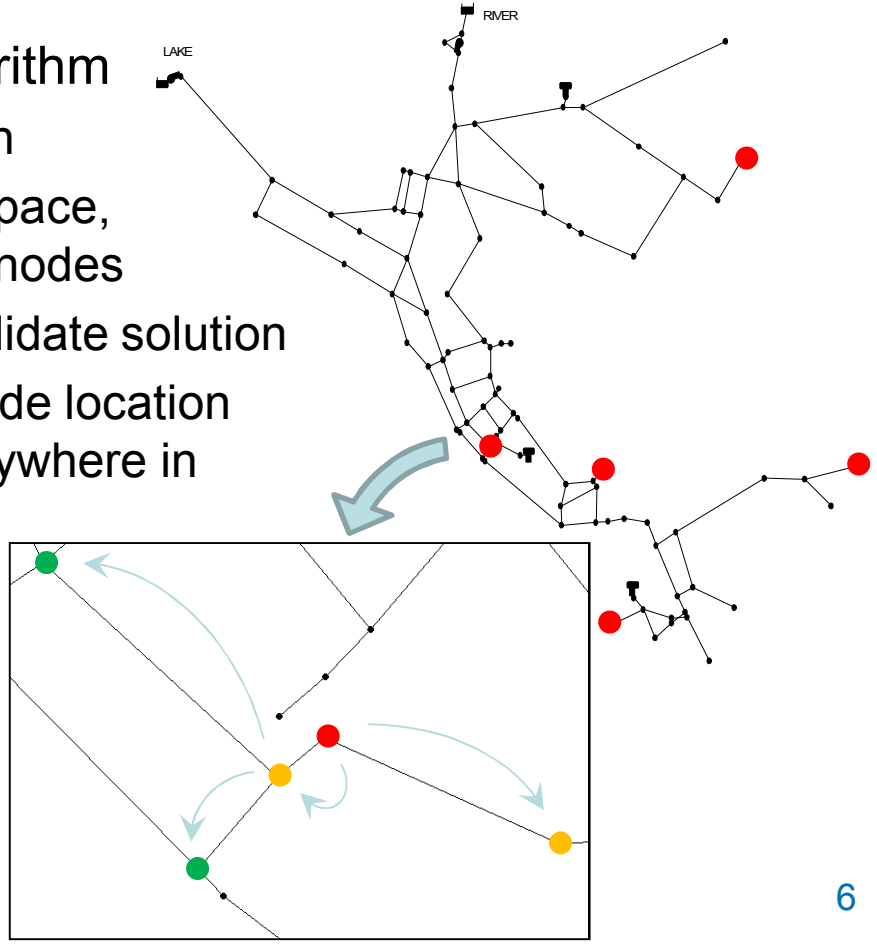
  - Solution mutation



- Termination criteria: effort (number of trial evaluations)

Network-constrained Local Search

- Derivative-free local search algorithm
  - Discrete analog to Pattern Search
  - Instead of moves in continuous space, allowable moves are to adjacent nodes
  - Provides local refinement of candidate solution
  - Valid moves include removing node location & placing any removed nodes anywhere in the network
    - In the absence of an initial solution, reduces to a greedy placement algorithm
  - Convergence occurs when no improving moves remain



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Hydraulic Response Characteristics

- Flushing rate – 800 gpm
- Flushing duration – 8 hours
- Response time delay – 0 hours
- Number of flushing locations – 1 to 10
- Impact measure – Population exposed (PE)

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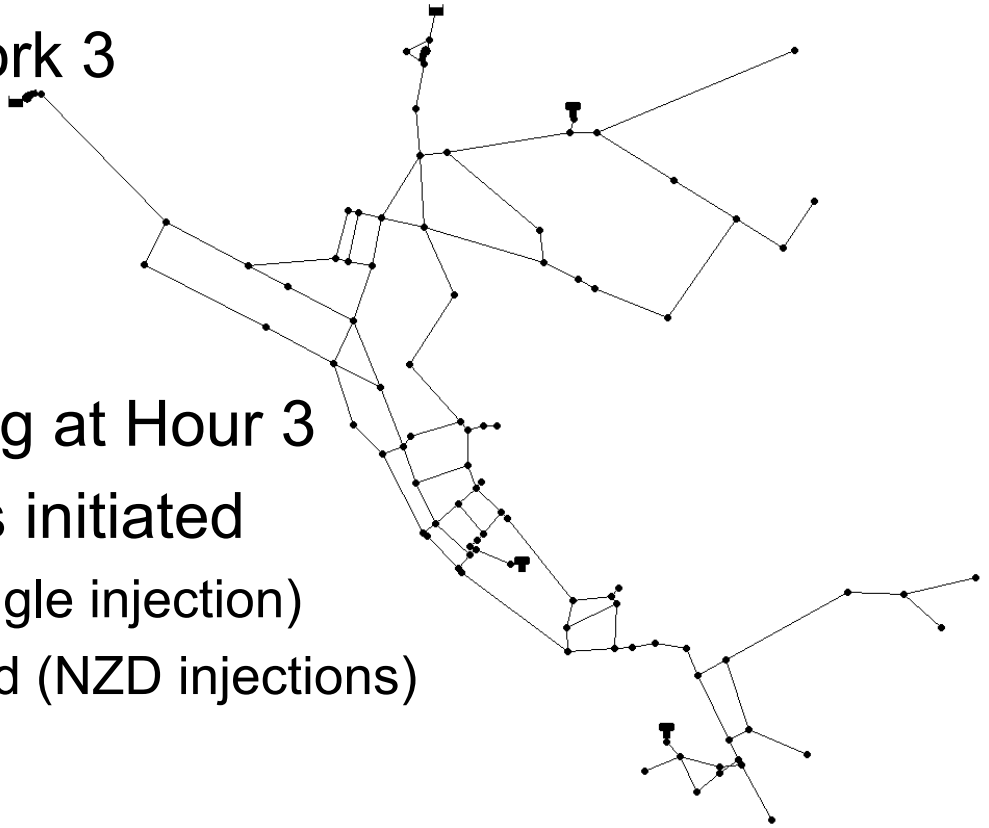
Example Network 1

- EPANET Example Network 3
- Injection node(s):
  - 101
  - NZD
- One hour injection starting at Hour 3
- With no response actions initiated
  - 10,392 people exposed (single injection)
  - Mean 4,420 people exposed (NZD injections)



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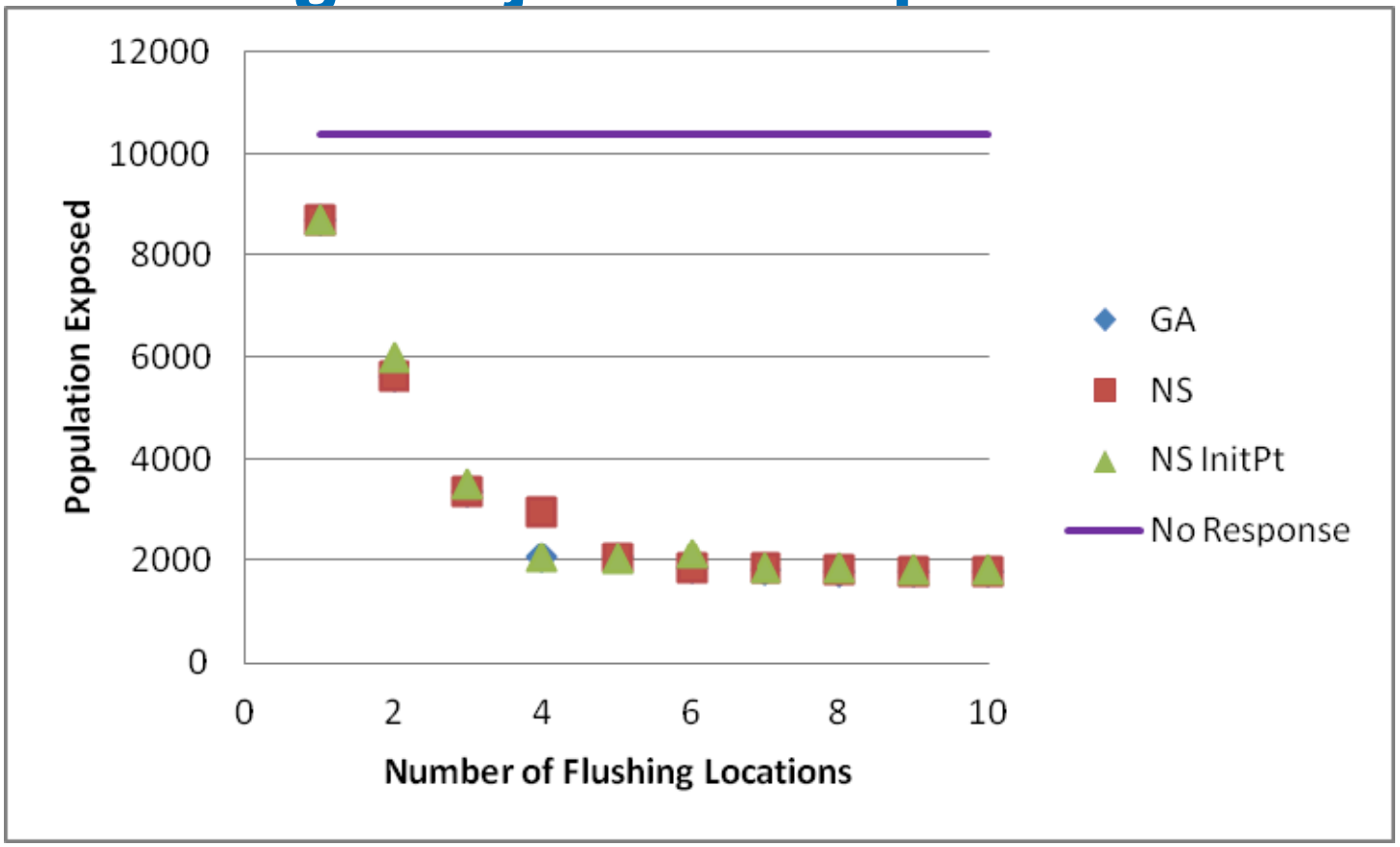
Net 1: Single Injection Impact Measure



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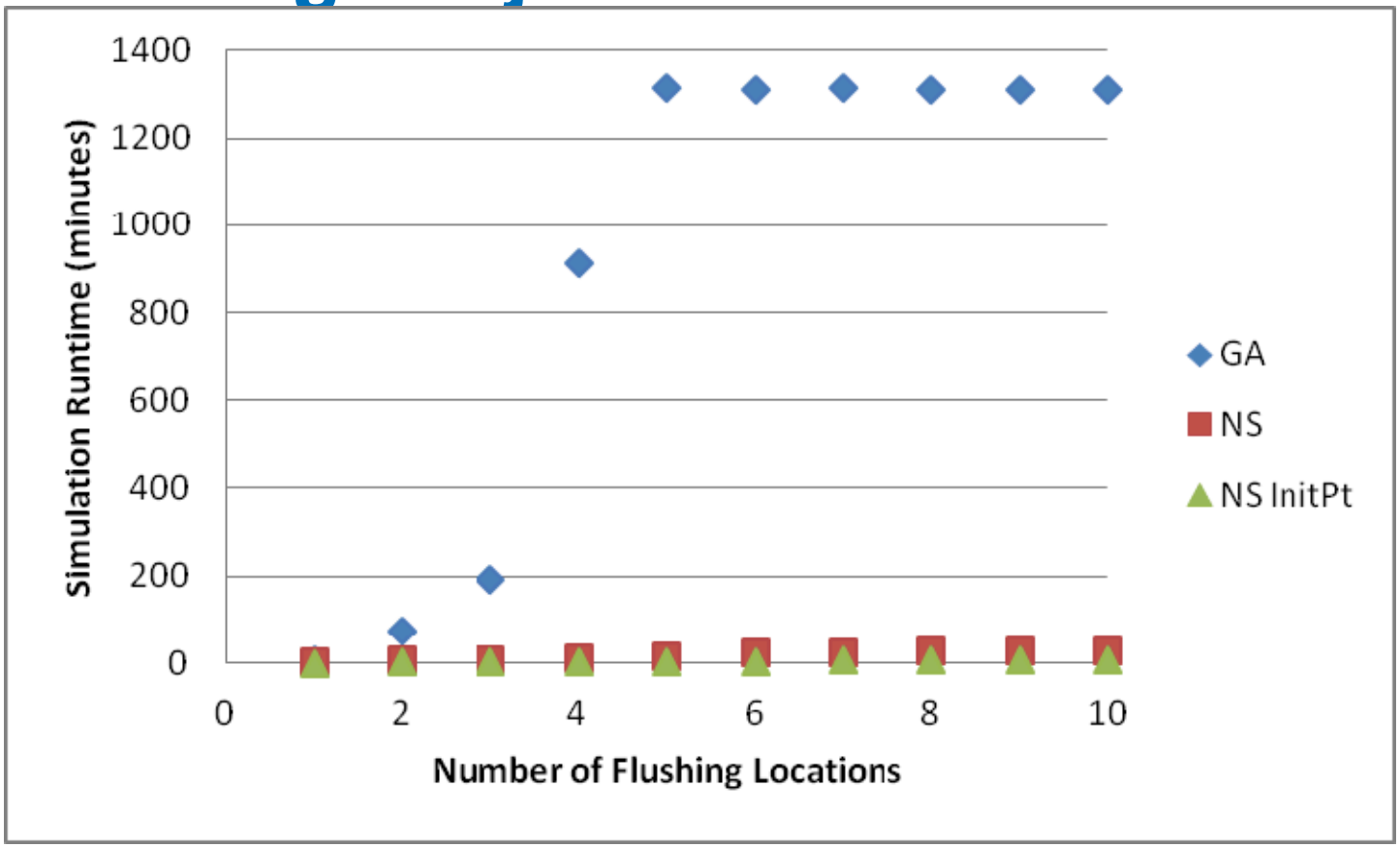
Net 1: Single Injection Runtime



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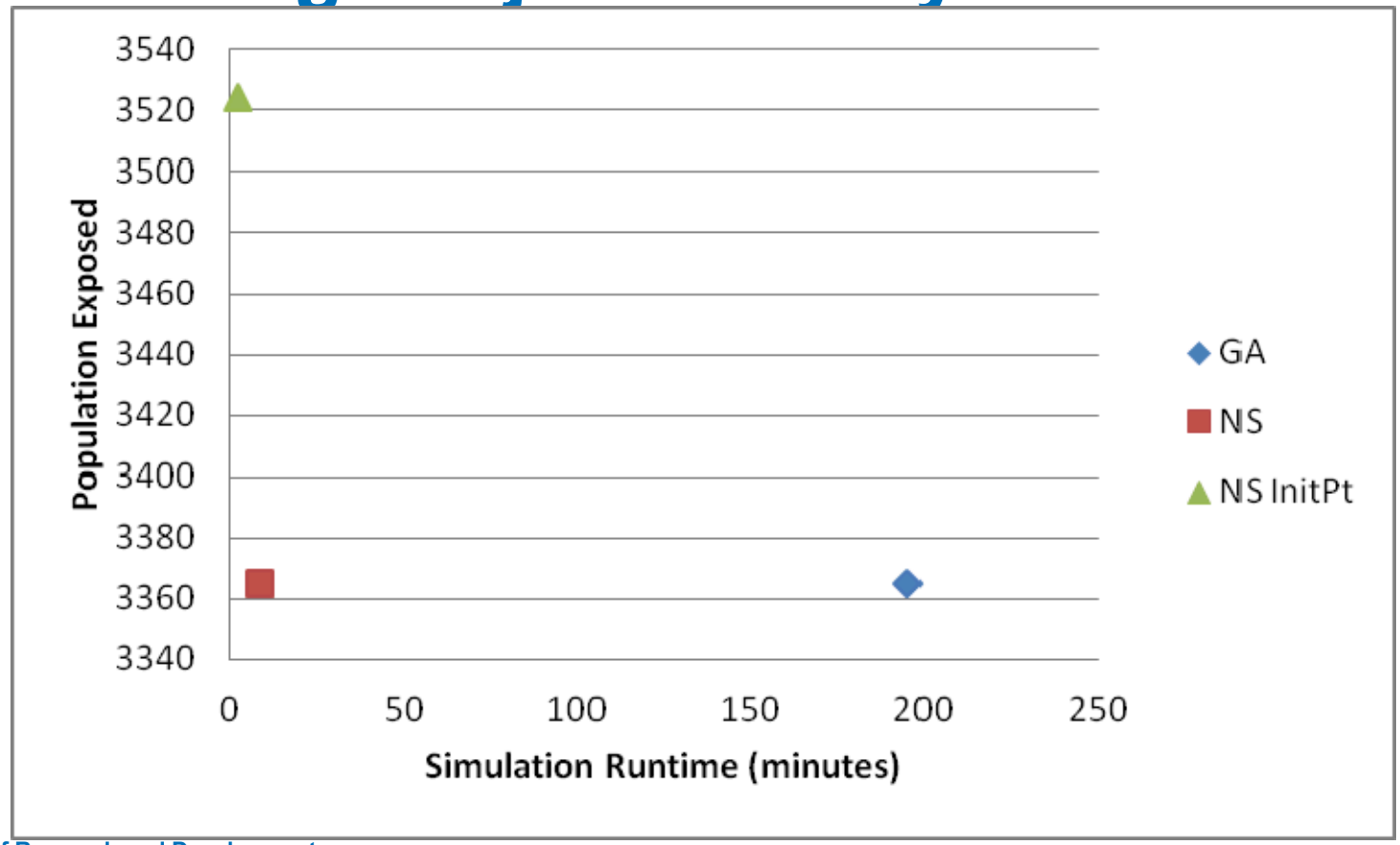
Net 1: Single Injection 3 Hydrants



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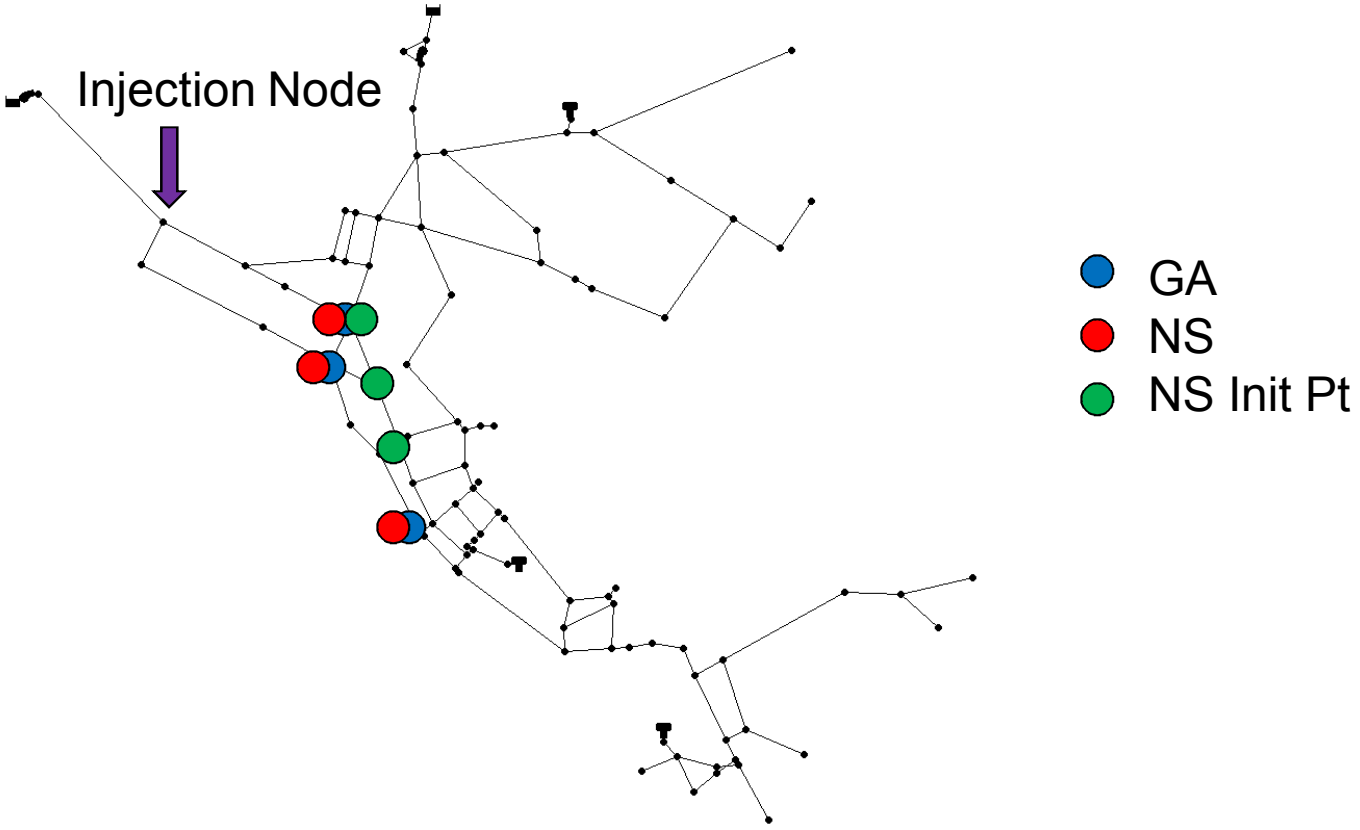
Net 1: Single Inject Flushing Locations



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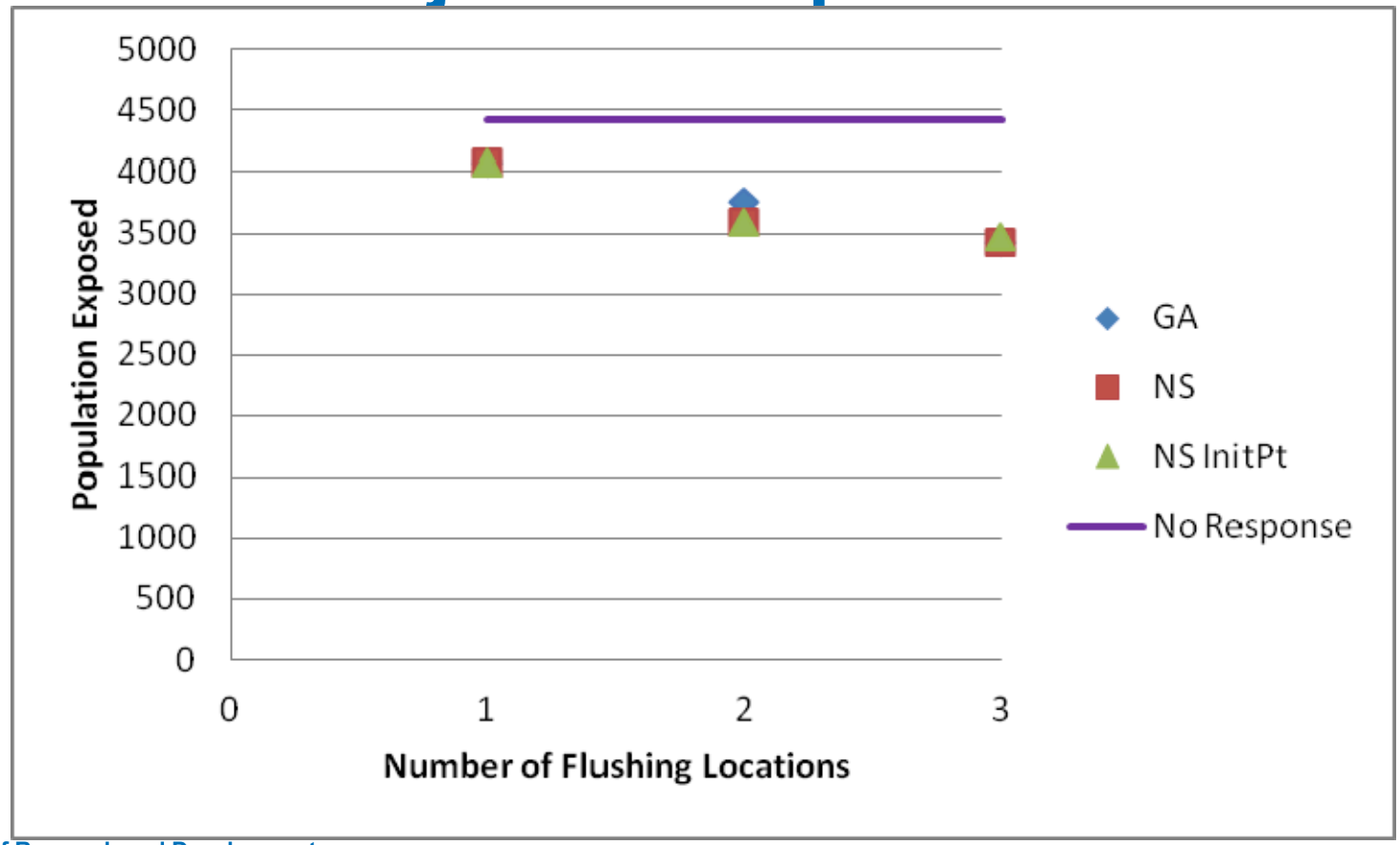
Net 1: NZD Injection Impact Measure



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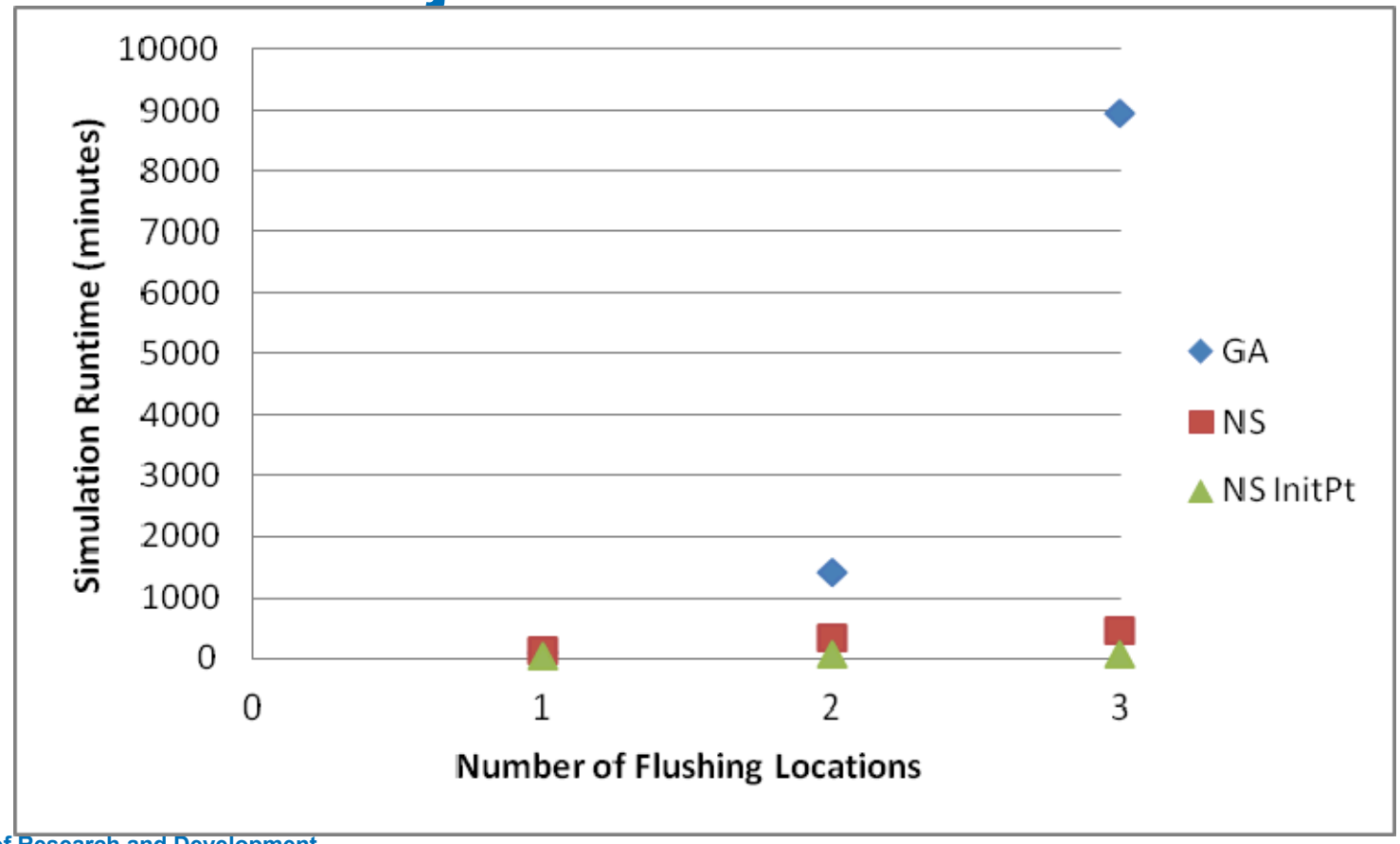
Net 1: NZD Injection Runtime



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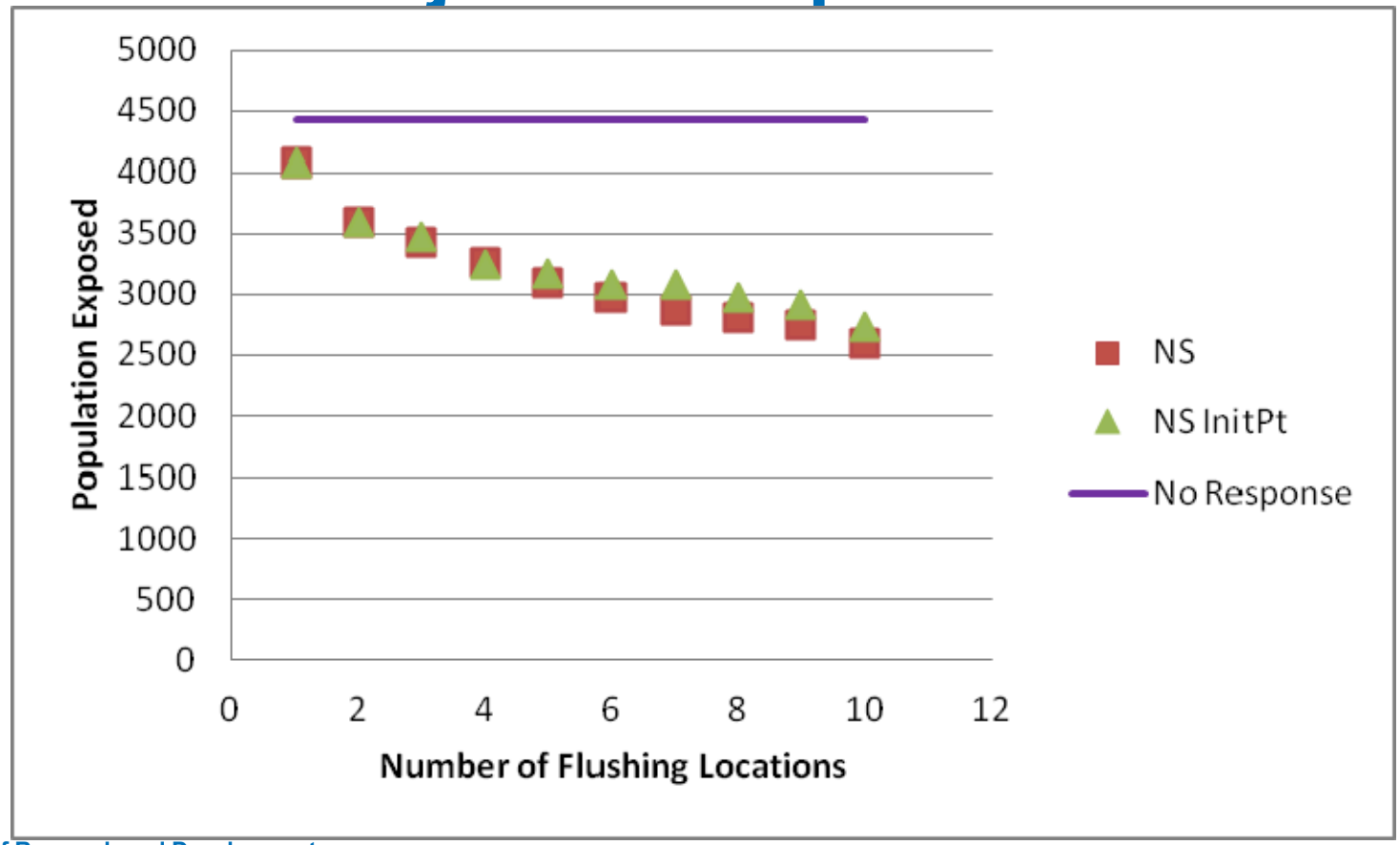

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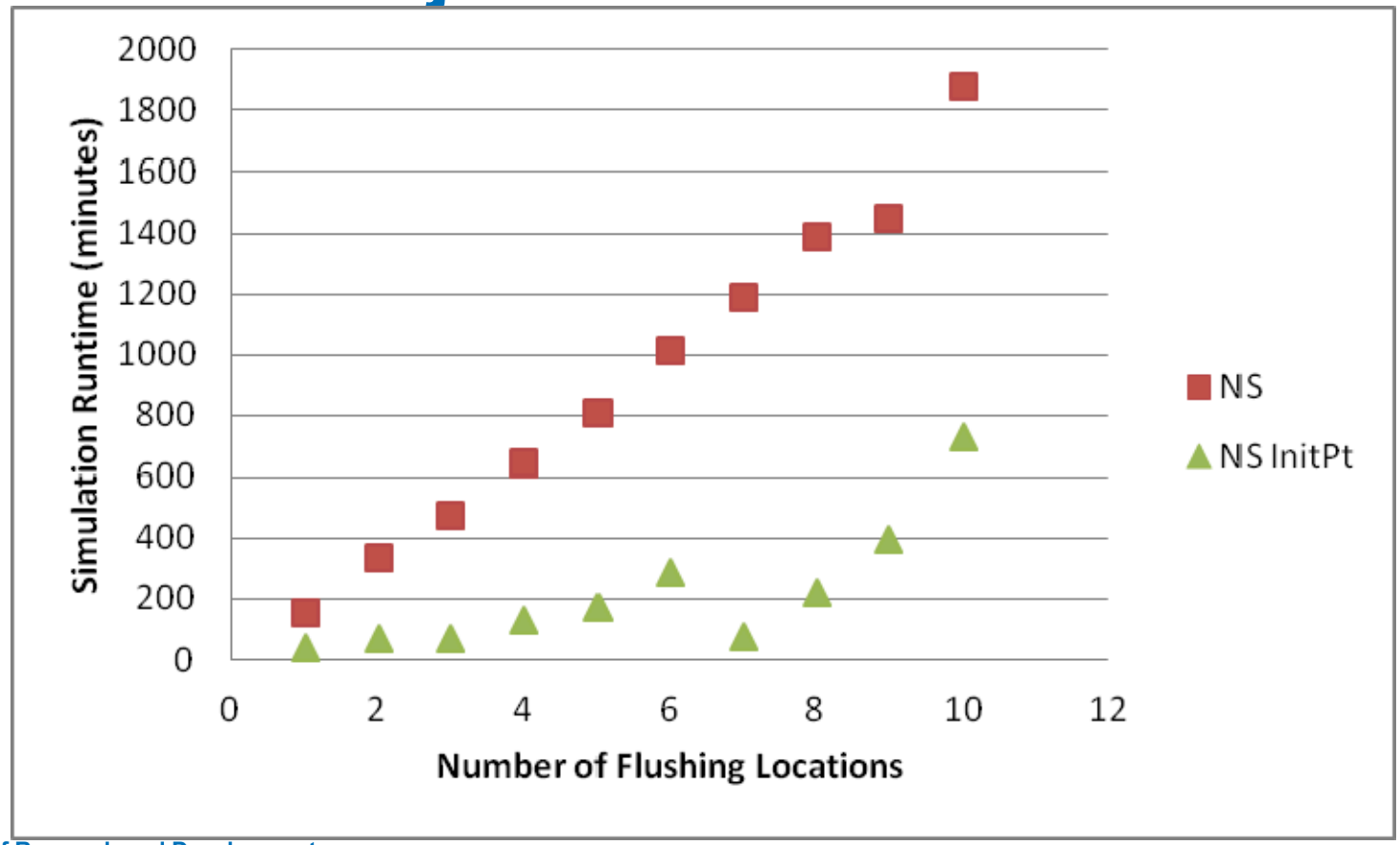
Net 1: NZD Injection Runtime



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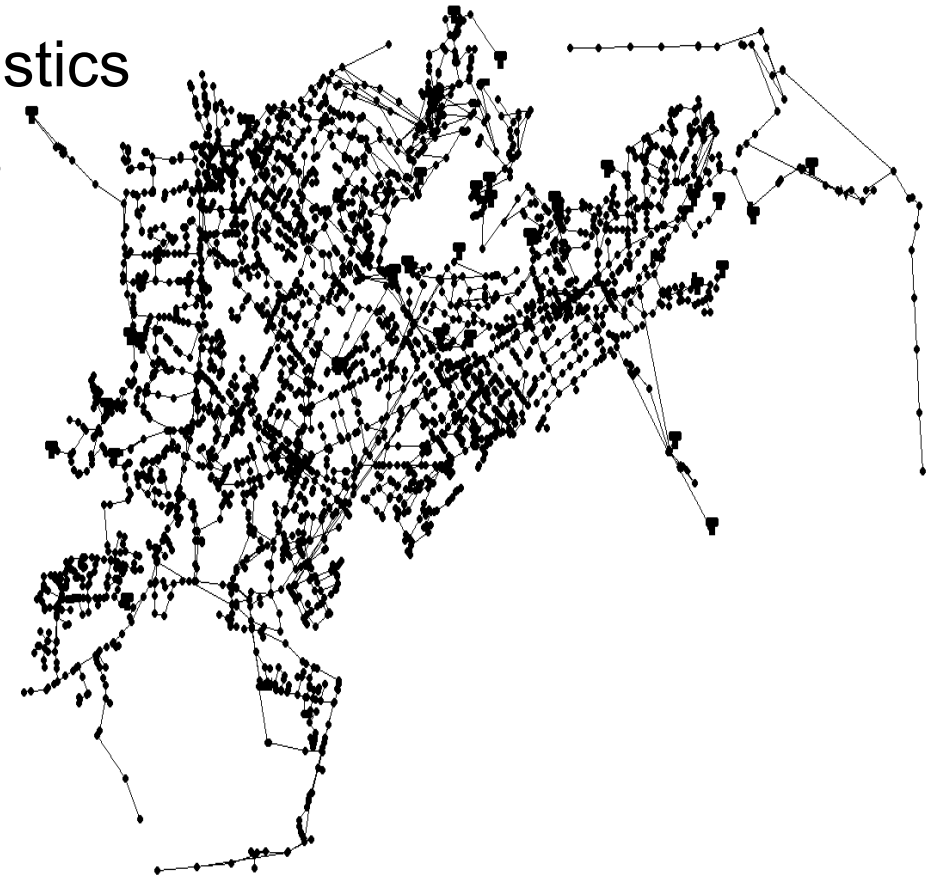
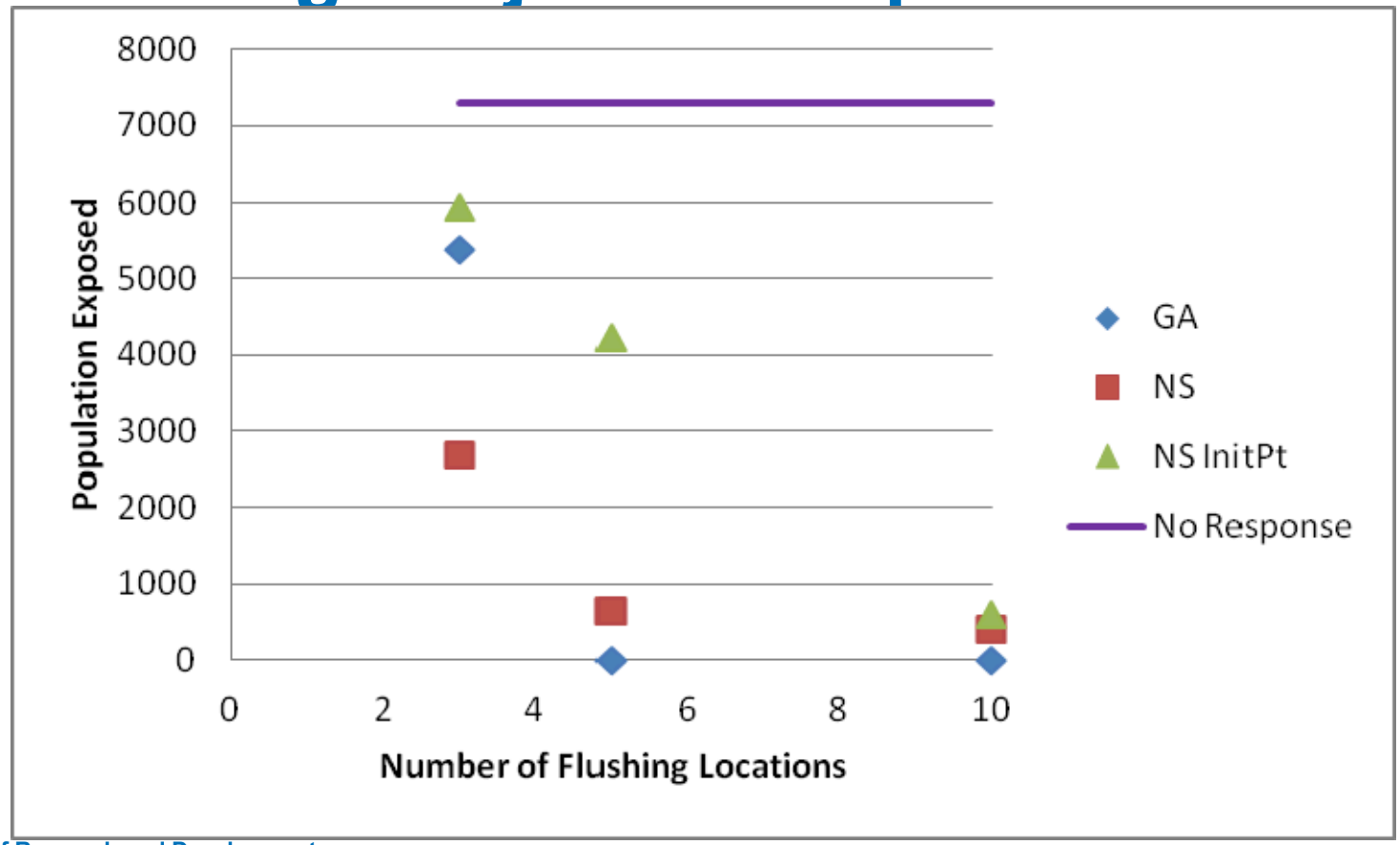
Example Network 2

- Injection node: JUNCTION-242
- Same injection characteristics
- With no response actions initiated
  - 7,297 people exposed



Net 2: Single Injection Impact Measure



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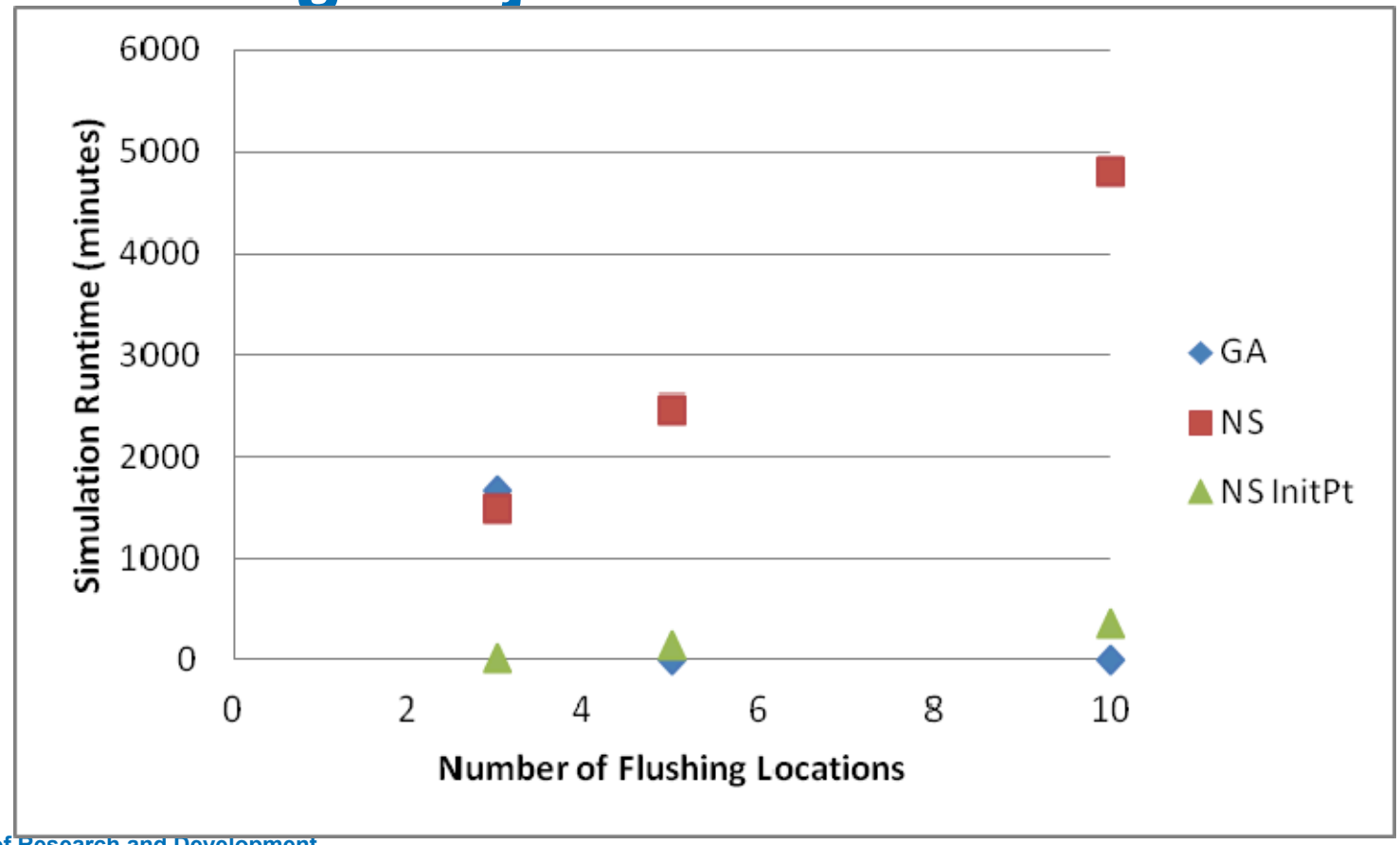
Net 2: Single Injection Runtime



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Conclusions and Future Work

Conclusions

- Network-constrained local search solver
  - Identified good quality solutions
  - Had shorter simulation runtimes

Future Work

- Continue study on Example Network 2 for NZD
- Develop approach to identify good initial starting points