# Real-Time Distribution System Water Quality Monitoring

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# System Background

- System Capacity – 50 MGD
- Customers – City of Ann Arbor Citizens,
  Ann Arbor & Scio Townships
- Population Served ~ 120,000
- Distribution System

# Project Goals

- Operations – On-line monitoring to detect degradation of water quality from natural causes such as high water age, biofilm, nitrification, etc.
- Security – On-line water quality monitoring to protect population from distribution system contamination threats
- Response Plan – Address water quality concerns efficaciously

# Project Activities

- Technology Assessment
- Instrument/Parameter Selection
- Monitoring Location Selection
- Instrument pilot testing
- Preliminary design development
- Response Plan
- Installation

# Project Activities

- Technology Assessment
  - Field visits
  - Utility surveys
- Instrument/Parameter Selection
- Monitoring Location Selection
- Instrument pilot testing
- Preliminary design development

# Field Visits Goals

- Gather information on types and performance of on-line monitors
- Visit monitor installations and discuss site evaluation issues
- Review emerging technologies
- Gather researcher equipment insights

# Field Visits

- Cincinnati EPA Pipe loop lab
- Cincinnati Water Works
- YSI
- ORSANCO

# EPA Pipe Loop System

# EPA Monitor Testing

# Utility Surveys

- Phone and written survey
  - Five utilities with experience in on-line monitoring
- Monitoring focus:
  - Most utilities use online monitoring for water quality reasons
  - Security is the new focus

# Surveys: Parameters Being Monitored

- Chlorine (free)
- pH
- Conductivity
- TDX
- Temperature
- TOC
- Organics
- UV254
- Nitrate
- Biomonitoring

- Standard instruments on panels
- Solids state probes on panels
- Probes with flow through cells
- In pipe installations still under development

# Surveys: Maintenance Requirements

- Every 1-3 weeks typical maintenance/ calibration interval
- Reagentless devices preferred
- Some utilities contract with instrument manufacturer for maintenance
- Utility staff involvement is key

# Surveys: Issues Identified

- Data collection a concern
  - Data overload common
  - How is the data reviewed/used
  - Alarm conditions can overwhelm operators
- Response protocols often not developed

# What did we learn?

- TOC (or UV) & chlorine are the most useful parameters

# What did we learn? (cont'd)

- Security monitoring not well developed or standardized
- Utility practices still being developed
- Utility staff involvement critical to success
- Regular maintenance required

# Project Activities

- Technology Assessment
- Instrument/Parameter Selection
- Monitoring Location Selection
- Instrument pilot testing
- Preliminary design development

# Considered Monitoring for

- Chemical
- Biological
- Radiological

# Candidate Parameters

| Parameter | Contaminant Monitoring | Water Quality Monitoring |
|---|---|---|
| Conductivity | X | |
| ORP | X | |
| DO | X | X |
| TOC or UV | X | |
| Ammonia | X | X |
| Chloride | X | X |
| Combined Chlorine | X | X |
| Turbidity | | X |
| Nitrite | | X |
| HPC or ATP | X | X |
| Biomonitoring | X | |
| VOCs by GC | X | |

# Instrument & Site Characteristics

| Characteristic | Instrument | Site/location |
|---|---|---|
| No reagents | X | |
| Low maintenance | X | X |
| Cost – Min O&M | X | X |
| Stable/repeatable | X | |
| Sensitivity | X | |
| Broad spectrum | X | |
| Durability | X | X |
| Ease of use | X | |
| No false pos/neg | X | |

# Instrument & Site Characteristics

| Characteristic | Instrument | Site/location |
|---|---|---|
| HVAC, electrical, communications | X | X |
| Power quality | | X |
| No confined spaces | | X |
| Avoid roadway and hazardous location | | X |
| Redundancy | | X |
| Waste disposal | X | X |
| Trend data on site with alarm | X | |
| Not proprietary | X | |
| Recovery | X | |

# Select Instruments

- UV S::can
- Multi parameter sondes
- Reagent less total chlorine
- Panel instruments do not need pilot testing as well established track record
- Radiation monitors literature only

# Project Activities

- Technology Assessment
- Instrument/Parameter Selection
- Monitoring Location Selection
  - Threat assessment modeling
  - Water quality impact modeling
  - Operations staff experience
  - Field location review
  - Regret analysis
- Instrument pilot testing
- Preliminary design development

# Location of Monitors

- Security issues
  - Can occur in almost any area of system
  - Maximize population coverage
  - Detect changes rapidly
  - Broad spectrum monitoring needed
  - Use historical info to understand monitoring data
- Water quality issues
  - Areas of high water age
  - Population coverage not key
  - Detect changes in small area of system
  - Use historical data
  - Specific parameters indicate problems

# Potential Monitoring Locations

- Utilized utility staff experience
- Sites short-listed:
  - Tanks & reservoirs
  - Entry points to customers
  - Flow splits & water quality zones
  - Source water
- Reviewed site constraints

# Modeling: Optimizing Locations

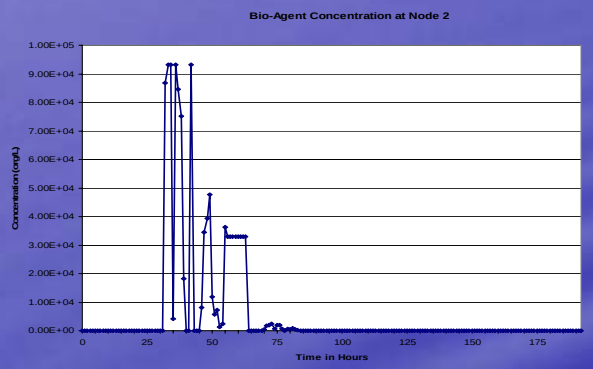
- EPA TEVA – Security focused modeling system to assess impacts of alternative monitoring locations
- PipelineNet – Water quality focused review of factors identifying high priority locations
- Expert input – Staff input on other factors making a site feasible

# EPA TEVA Model Inputs

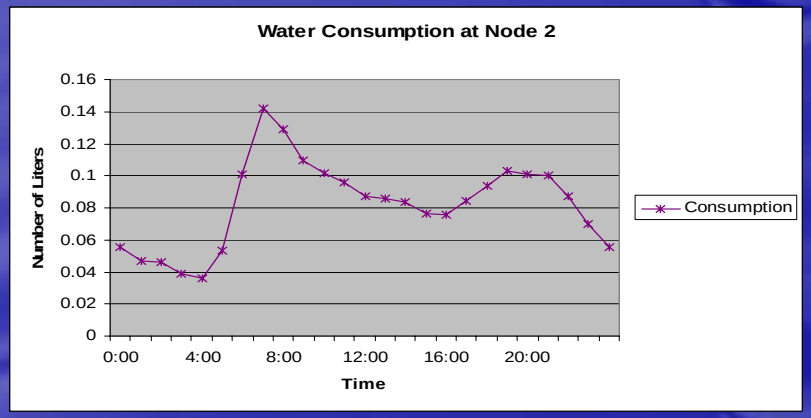
- Hypothetical contaminants – 2 types
- Contaminant volume and duration of release
- Release locations
- Population census based with modifications (e.g. students)
- Hydraulic analysis
- Sensitivity (latency, fatality rate)
- Water consumption – 2 liters/person/day
- Demand rates – low, winter average, summer average, peak day

# Predicting the Public Health Impacts of Contamination

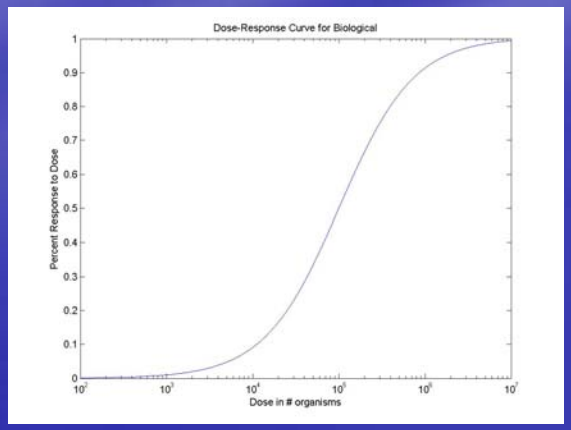
Contaminant Concentration



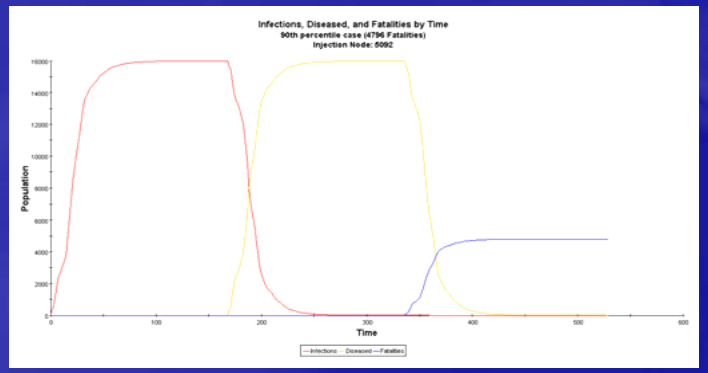

Water Usage Patterns




Dose-Response Data




Disease Transmission/Progression

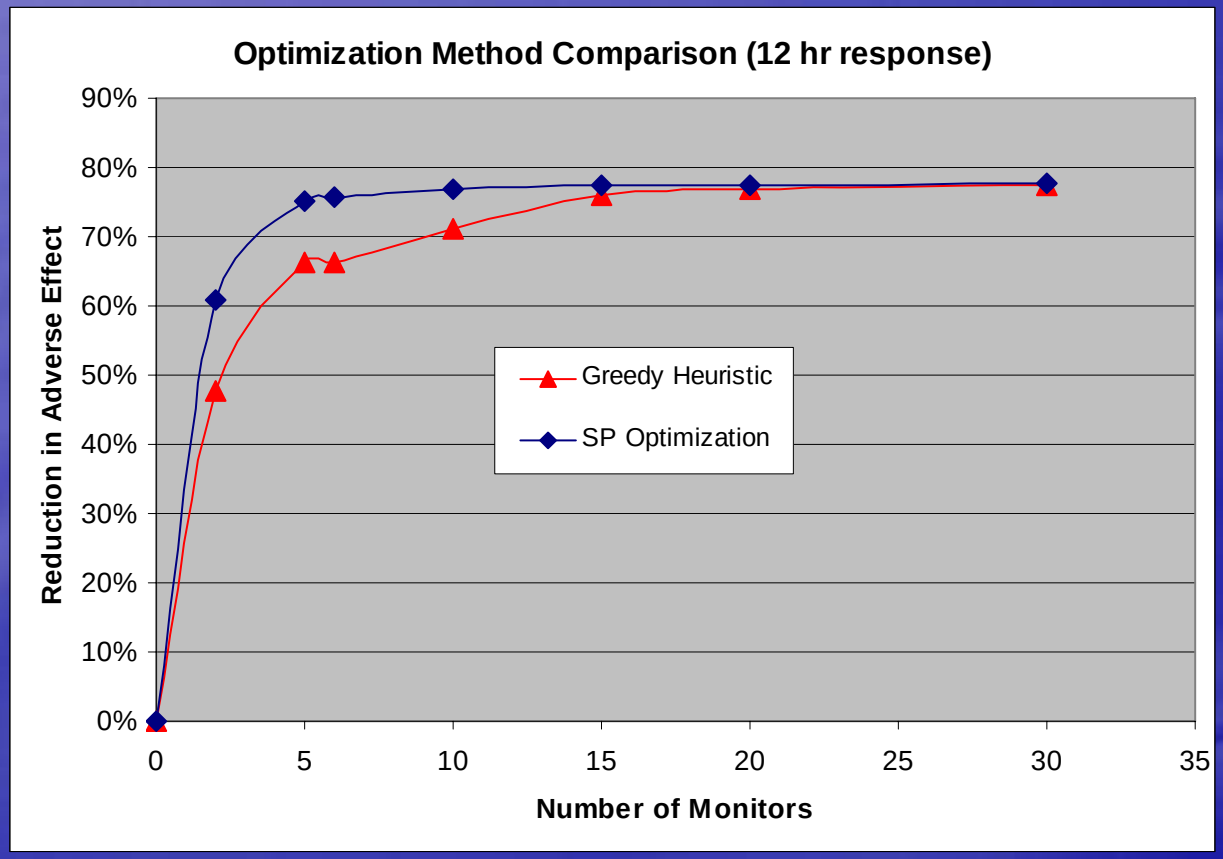



Monitoring Location: Threat Assessment

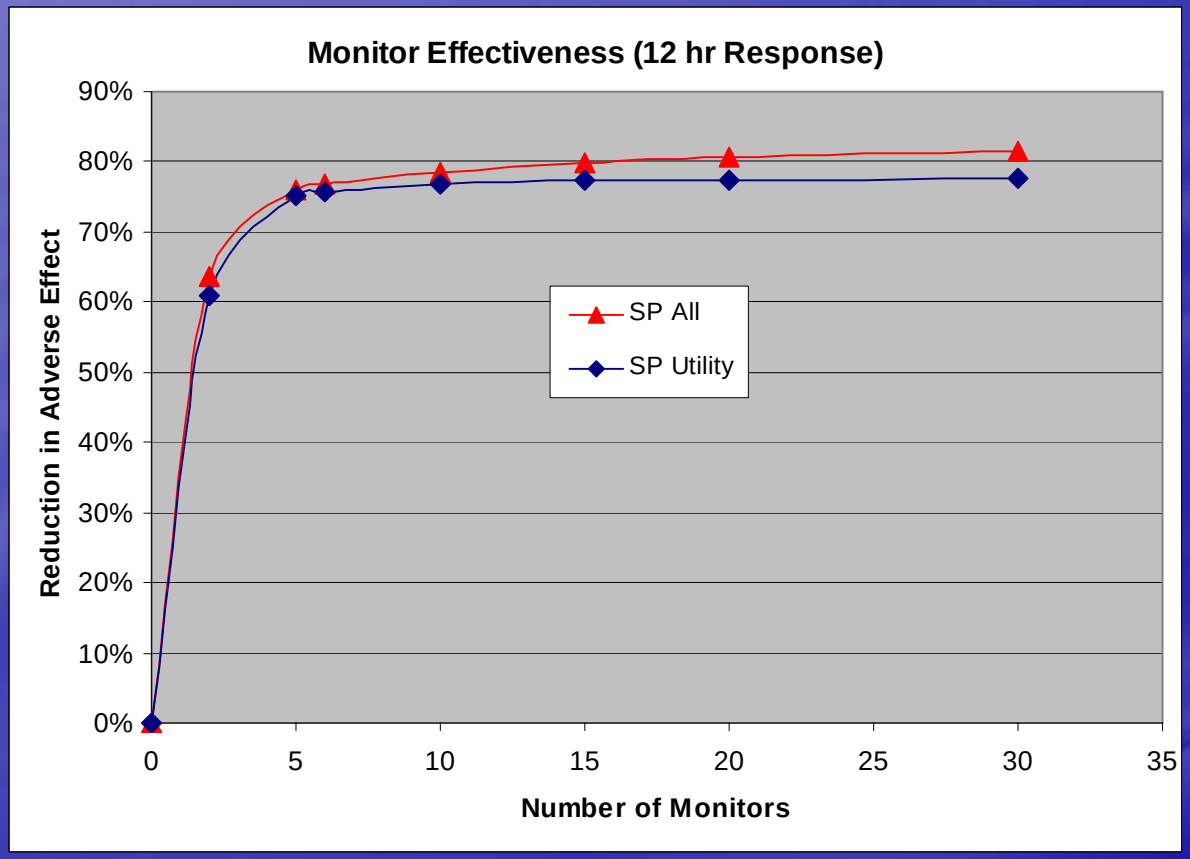
# EPA TEVA Output

- Evaluates health impacts
- Sensor placement design
  - Optimal/prioritized locations
  - Relative improvement for increasing numbers of monitor locations
  - Benefit versus number of monitors
  - Reviewed impact of response delay

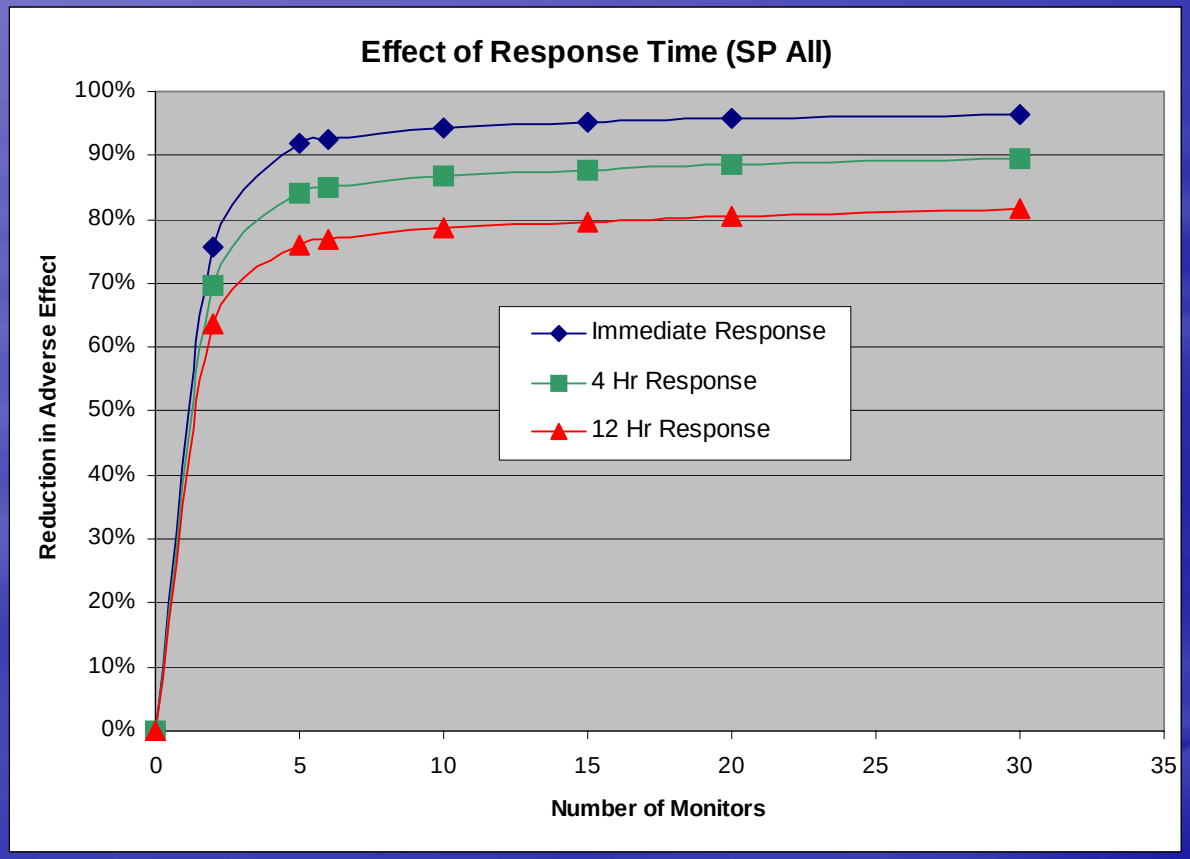
# TEVA Methodology Effectiveness



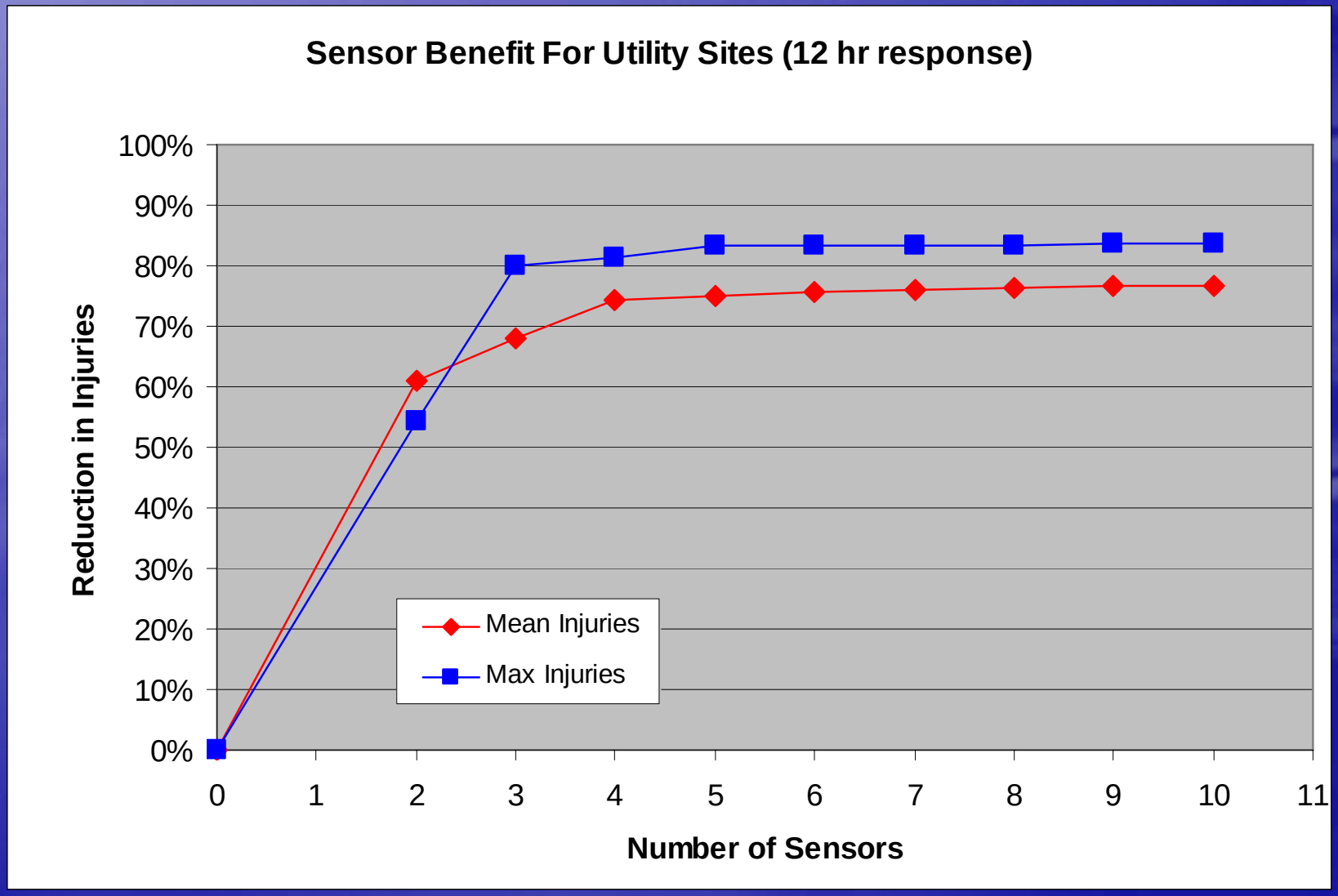
# Constraining Monitoring Locations



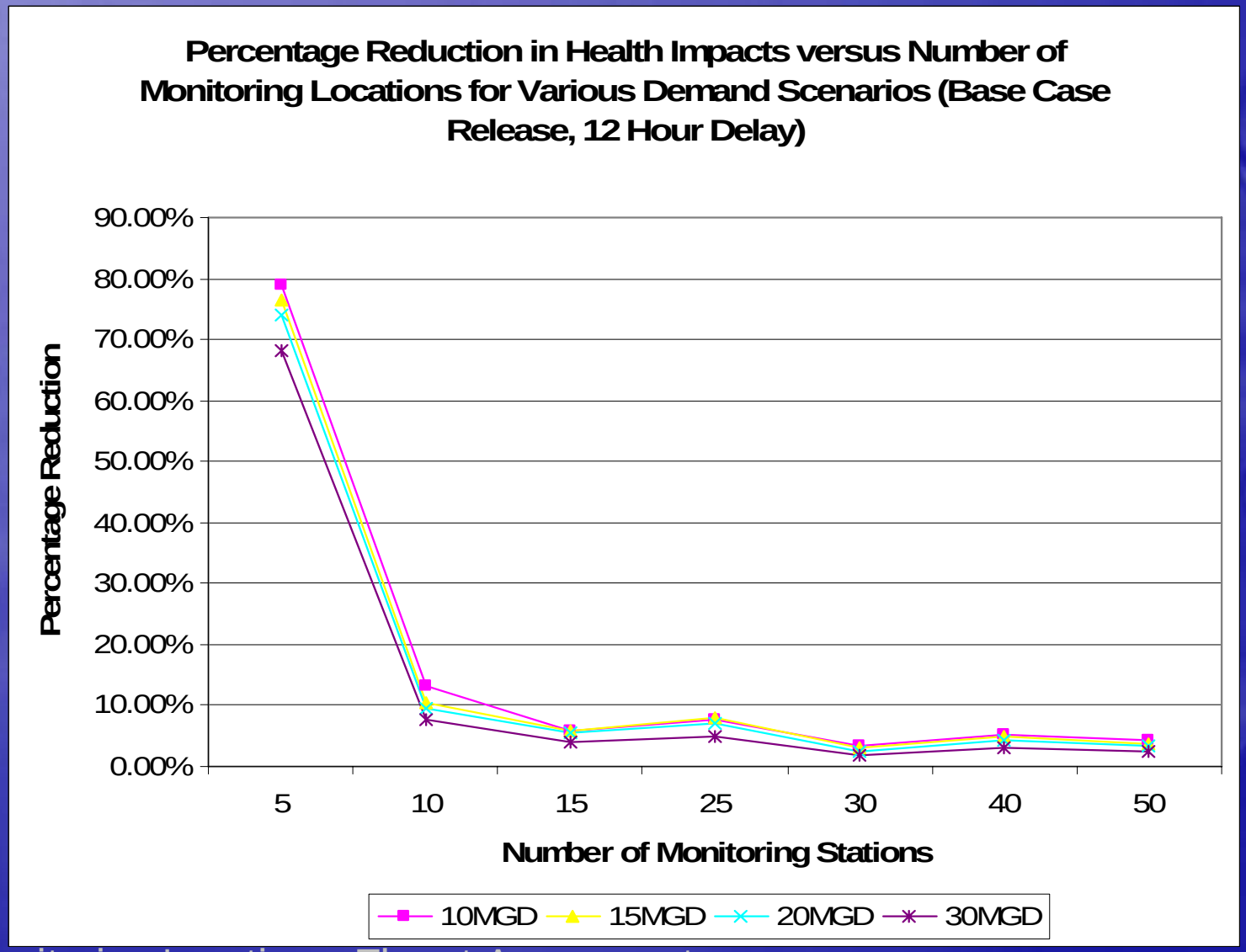
# Impact of Response Time



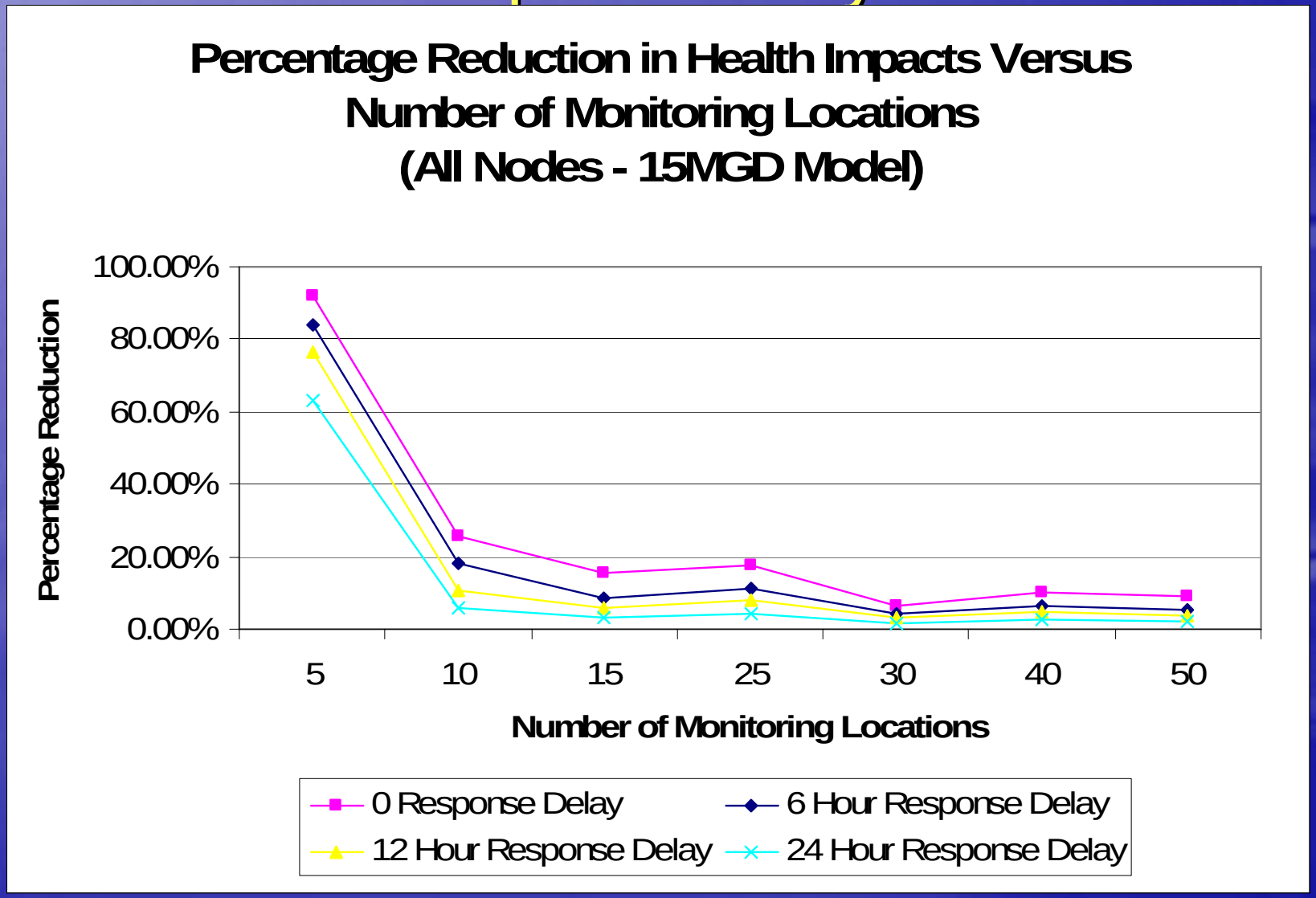
# Optimal Locations



# Demand Scenarios



# Response Delays



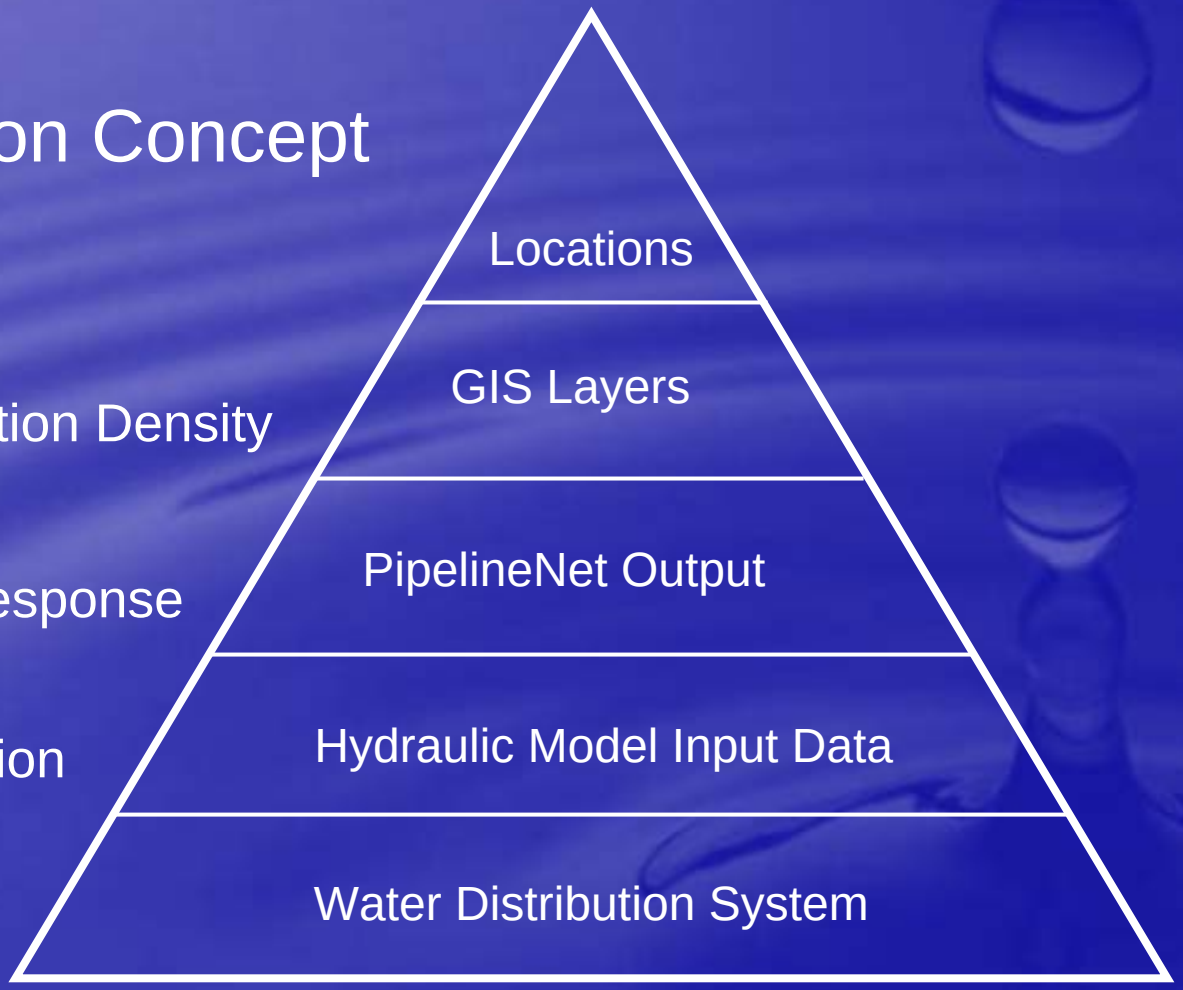
# PipelineNet Selection Process

Hierarchical Selection Concept

**Step 3**
Critical Facilities & Population Density

**Step 2**
Distribution System Response

**Step 1**
Source Prioritization




Monitoring Locations

# Ann Arbor PipelineNet Analysis

- Primary Analysis: Water quality objective
  - Eliminate dead end nodes with zero demands
  - Velocity, water age, pipe roughness
- Secondary Analysis: Security
  - Eliminate dead end nodes with zero demands
  - Flow, water age
  - Critical areas: schools and hospitals
- Base runs and sensitivity runs

# Distribution System Response

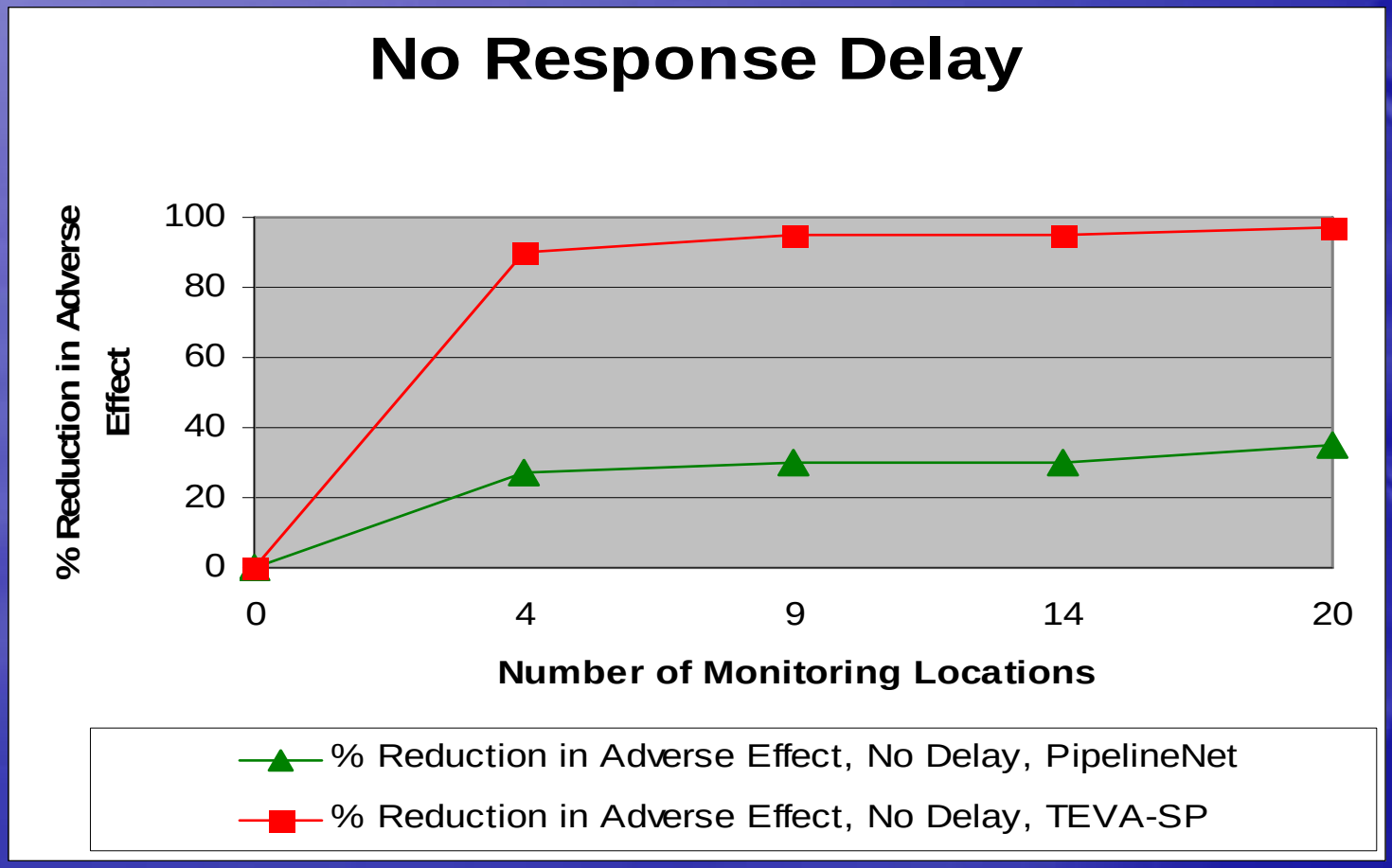
- Develop matrix of scores (10 is highest level of concern) based on outputs from PipelineNet
- User-defined breakpoints for scoring
- Defined by specific ranges (or equal quantiles)

| Parameter | PRIMARY ANALYSIS: WATER QUALITY OBJECTIVES SCORES BASED ON USER DEFINED RANGES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Velocity (fps) | >2 | <2 | <1 | <0.5 | <0.1 | <0.05 | <0.04 | <0.03 | <0.02 | < 0.01 |
| Age (hours) | <6 | <12 | <24 | <48 | <72 | <96 | <120 | <144 | <168 | >168 |
| Roughness | 125-200 | 105-114 | 95-104 | 85-94 | 75-84 | | | | | |

# PipelineNet Output

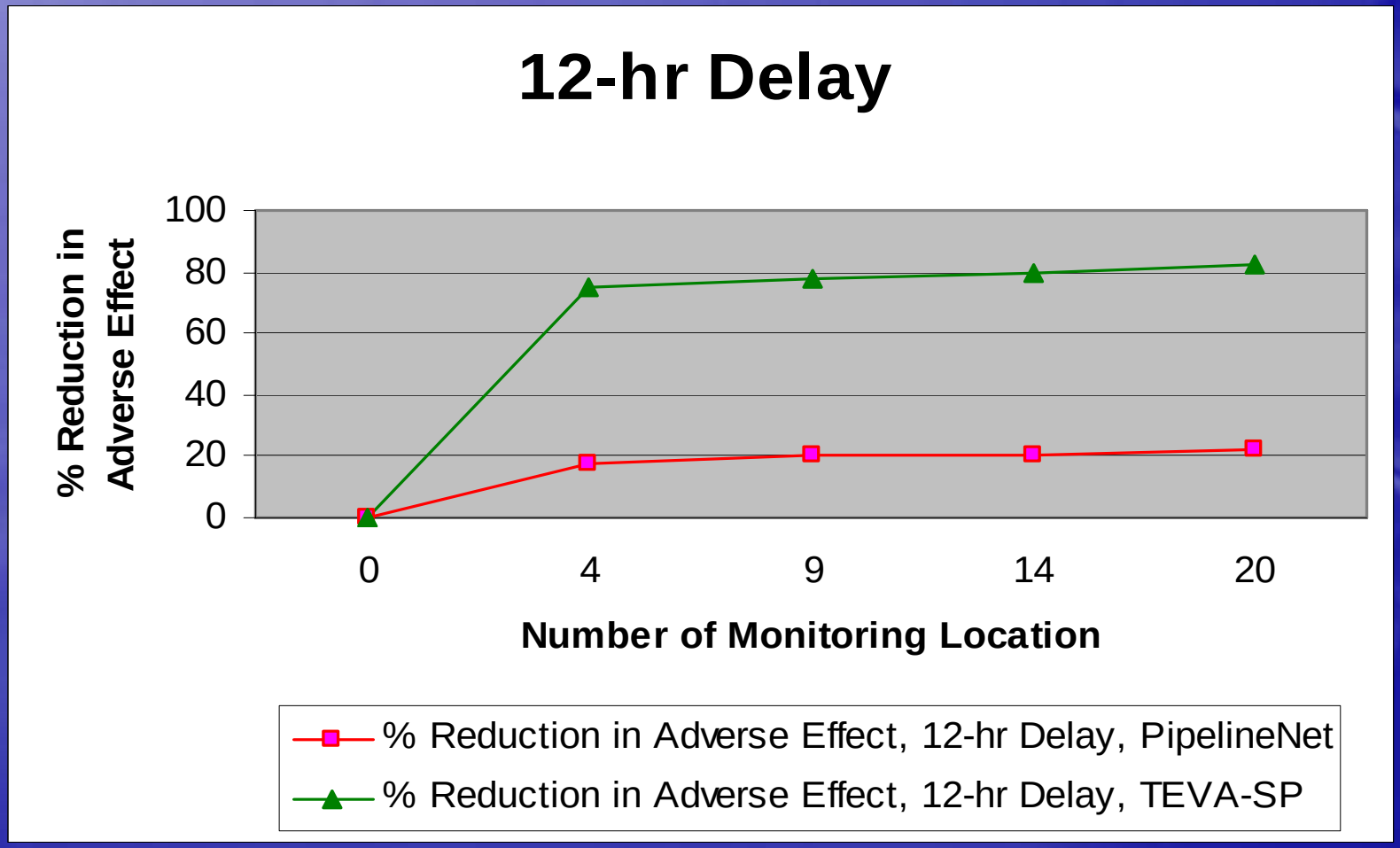
- Areas with high water age and low velocity
- No recommendation on numbers of monitors

# Reduction in Adverse Effect TEVA-SP vs PipelineNet




Monitoring Locations: Threat Assessment

# Reduction in Adverse Effect TEVA-SP vs PipelineNet

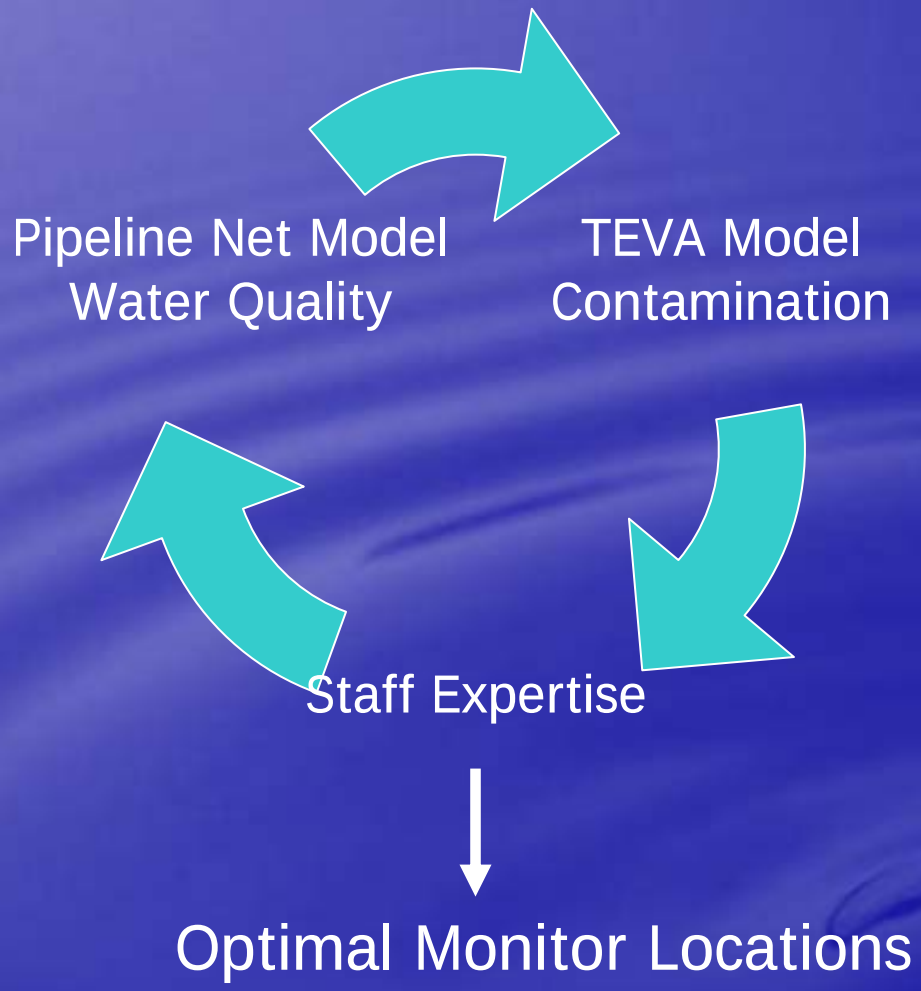



Monitoring Locations: Threat Assessment

# Expert Input

- Practical constraints on monitor location using staff knowledge & experience
  - Do the model outputs seem reasonable
  - Any areas the modeling missed?

# Optimal Locations



# Project Activities

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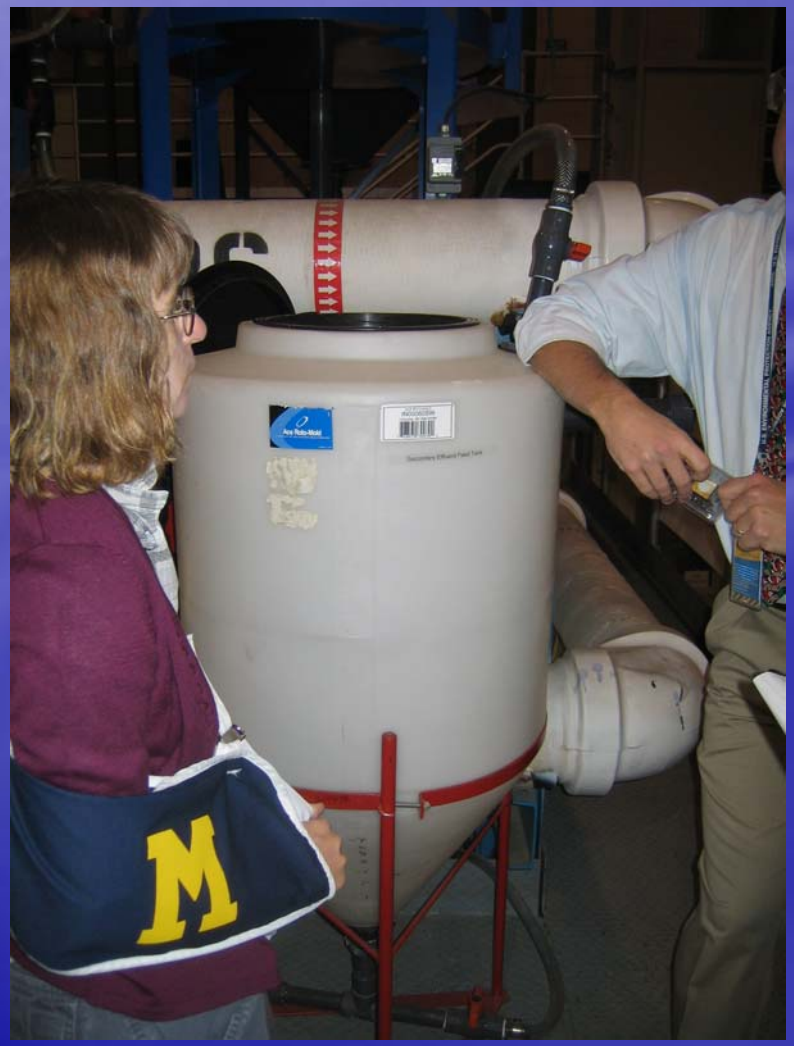
# Pilot Testing to be Performed on Selected Instruments



# Conclusions

- Modeling useful to prioritize monitoring sites
- TEVA modeling methodology provides most benefit for security threats
- Relatively small number of monitors can provide contaminant event warning for public health protection
- PipelineNet is useful in assessing optimal locations for water quality monitoring
- Contaminant monitoring and water quality monitoring have little overlap

# Conclusions (continued)

- Parameters selected may be utility specific, but TOC and chlorine are the most promising
- Need a plan for data management/review
- Development of response plan for use of information is important
- Staff involvement is critical to success

# Next Steps

- Pilot selected instruments and parameters
- Preliminary design phase
- Design expandable system
- Implement and test system
- Develop Response Plan

# Thank You