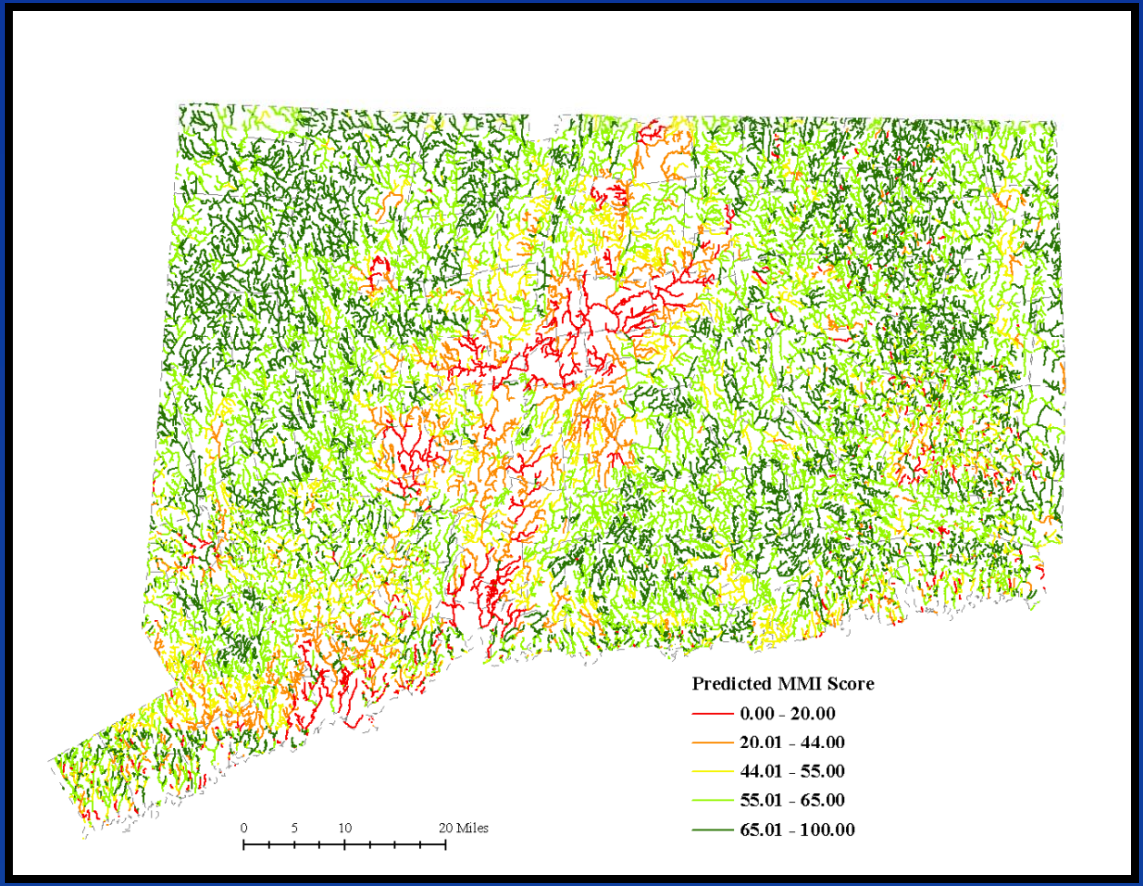
# Modeling Macroinvertebrate Multi-metric Index Scores in Connecticut's Rivers and Streams Using Landscape Variables -An Approach to Support Restoration Goals and Anti-degradation Policy

*2010 National Monitoring Conference*




Chris Bellucci, Mary Becker and Mike Beauchene

# MMI Model at 50,000 feet

ID High Quality Waters

Guide Future Sampling Effort

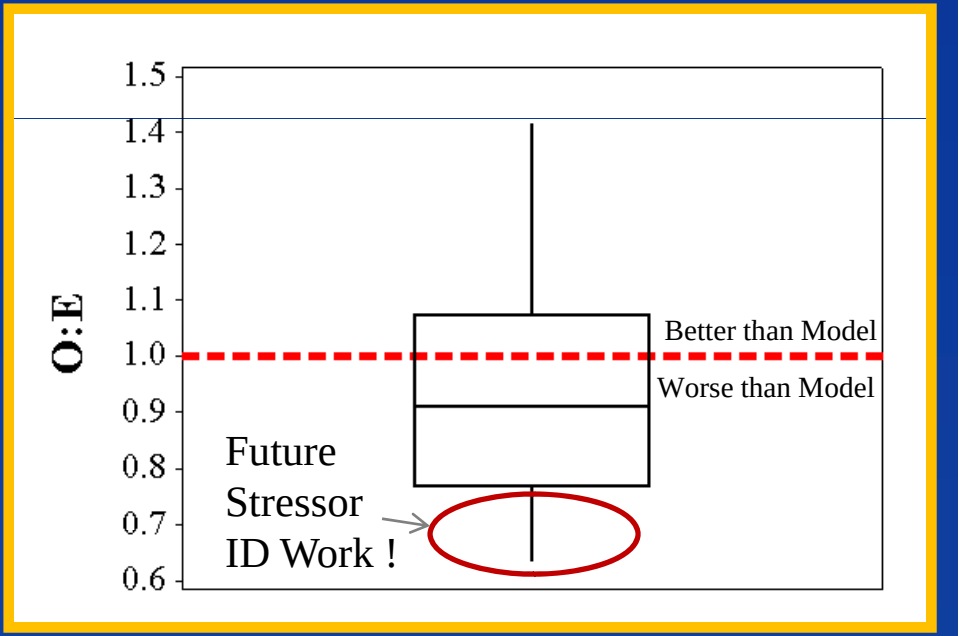
Anti-deg Tiers

Tier 1

Tier 2 = HQ Water

Tier 3- ONRW

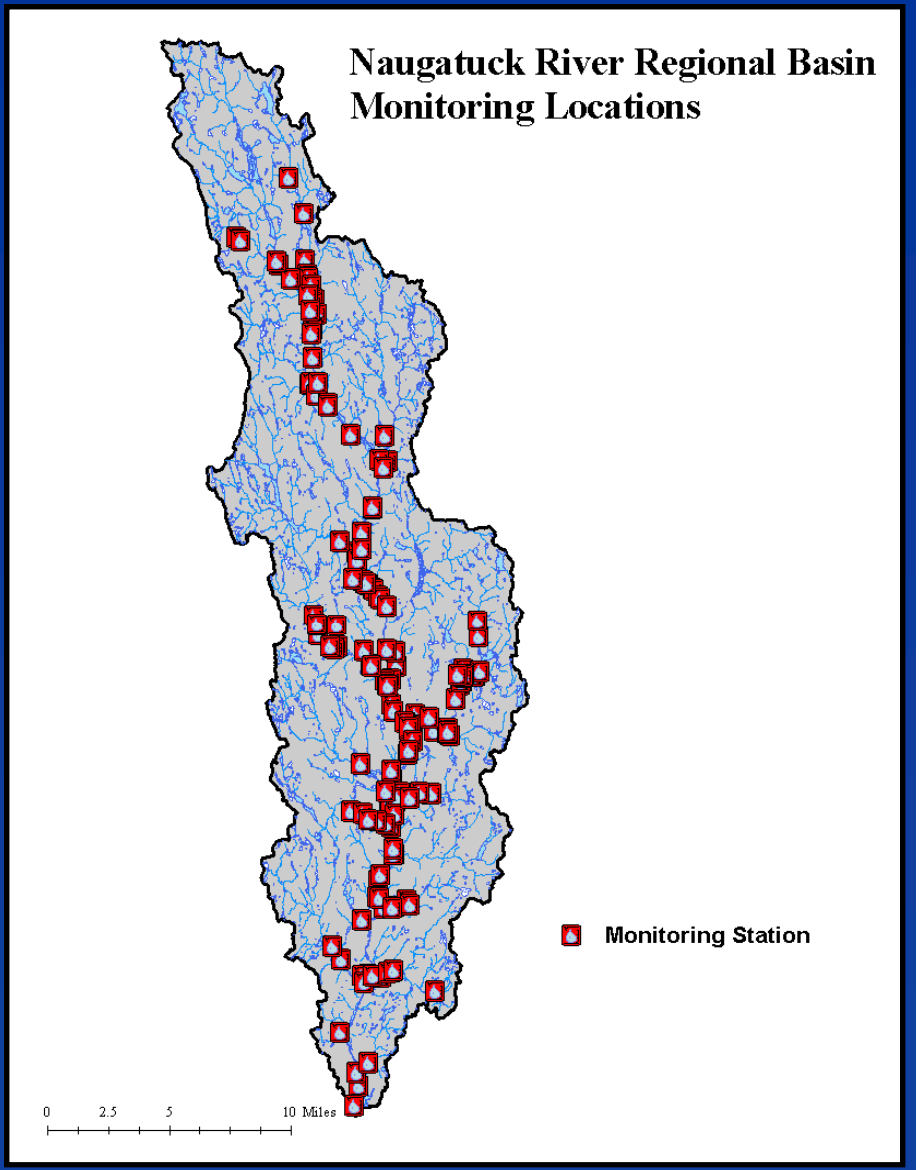
Highest Quality



# Tools to Support Water Quality Management

## Targeted Monitoring

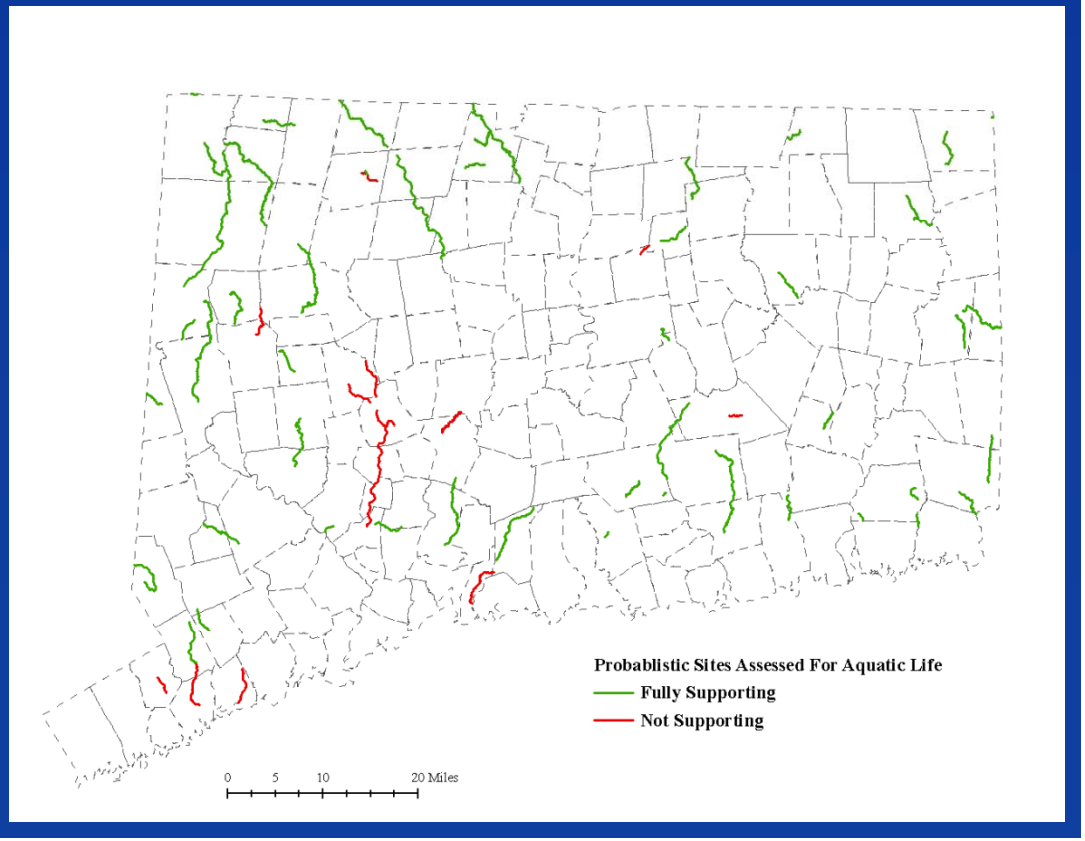
- Assess WQS Attainment
- Measure localized trends
- Identify sources of pollutants specific to waters
- Support development of local management measures (TMDLs, NPDES permits, NPS BMPs)



# Tools to Support Water Quality Management

## Statistical Monitoring

- Estimate proportion of all waters supporting water quality goals
- Measure overall State-wide water quality trends
- Support development of new water quality standards
- Prioritize targeted monitoring



# Tools to Support Water Quality Management

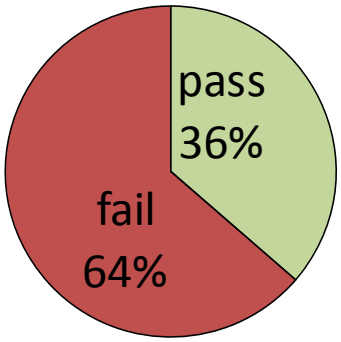
## Project Plan (Dunbar's Challenge)

Can you establish a methodology to predict the expected biological condition at an unmonitored sites utilizing geospatial analysis of readily available watershed data?

## YES WE CAN!! Using Macroinvertebrate Data…

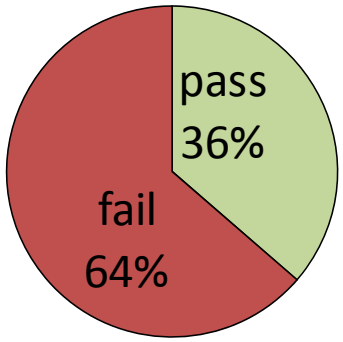
**Model Predicted Assessment**

**Model Validation Data Set**




**Actual Assessment**

**Model Validation Data Set**

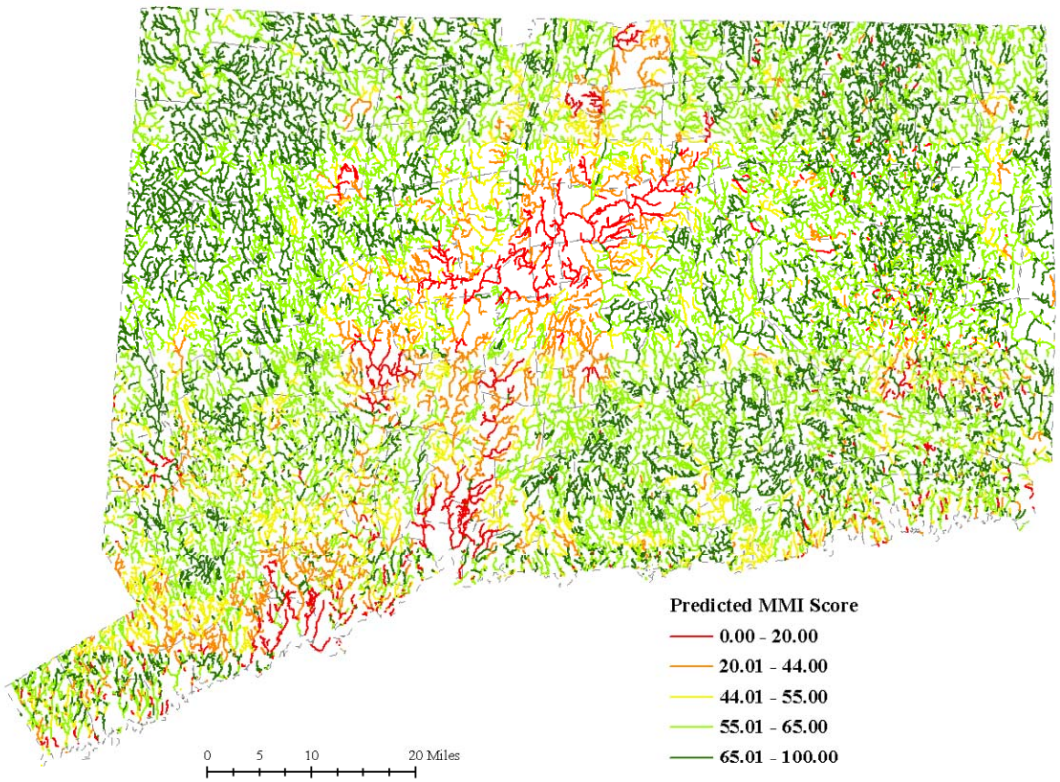



N = 66 Sites

# Tools to Support Water Quality Management

## Modeling and landscape analysis

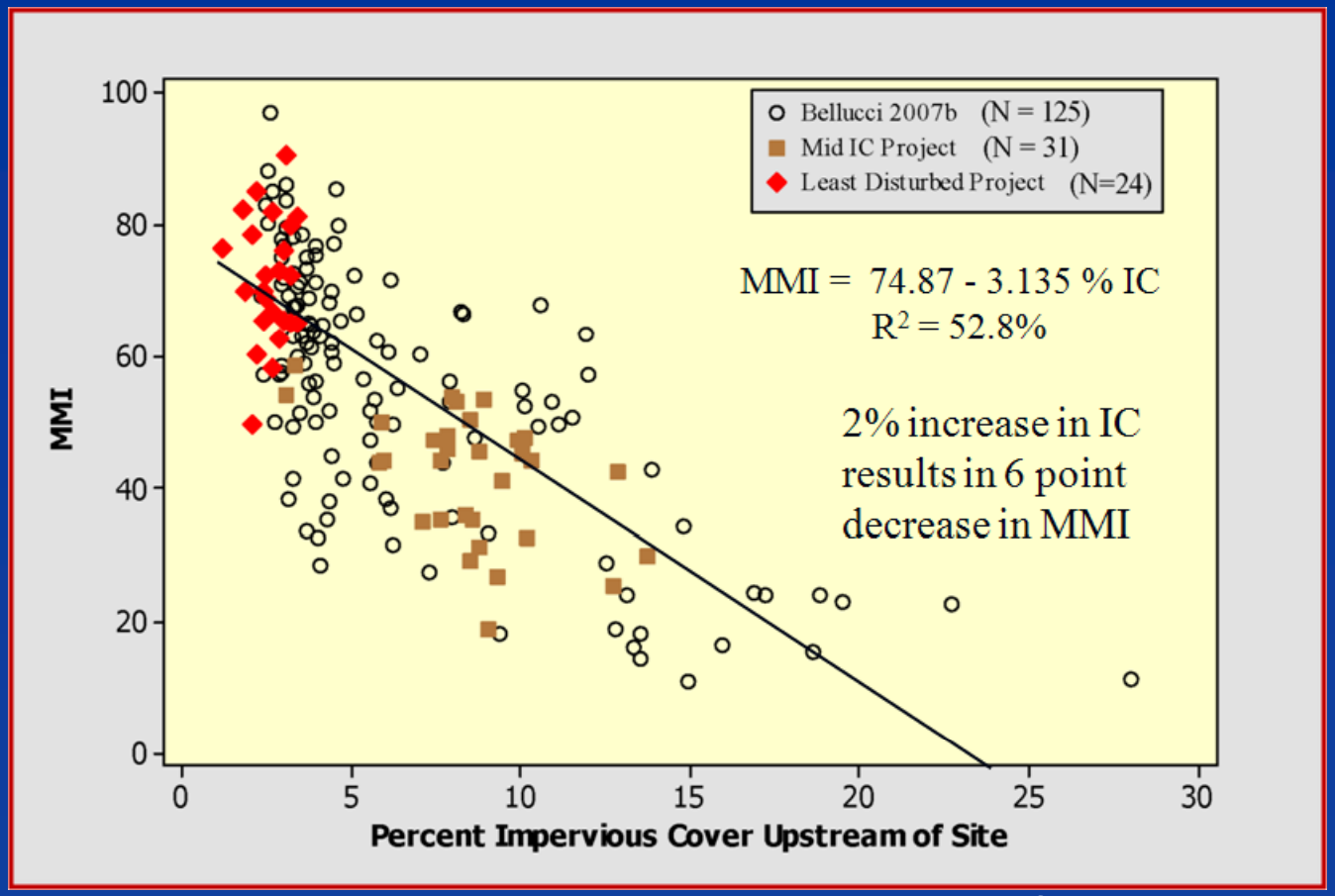
- Predict localized expected water quality condition and trends where we don't have monitoring data
- Prioritize targeted monitoring for Stressor – ID
- Support development of local management measures (TMDLs, NPDES permits, NPS BMPs)
- Implement Anti-Deg State-wide



# Prior Research

## Modeling and landscape analysis: Impervious Cover

- Negative relationship between MMI and increasing total percent impervious cover
- Support development of local management measures (TMDLs, NPS BMPs)
- Prioritize targeted monitoring for TMDLs

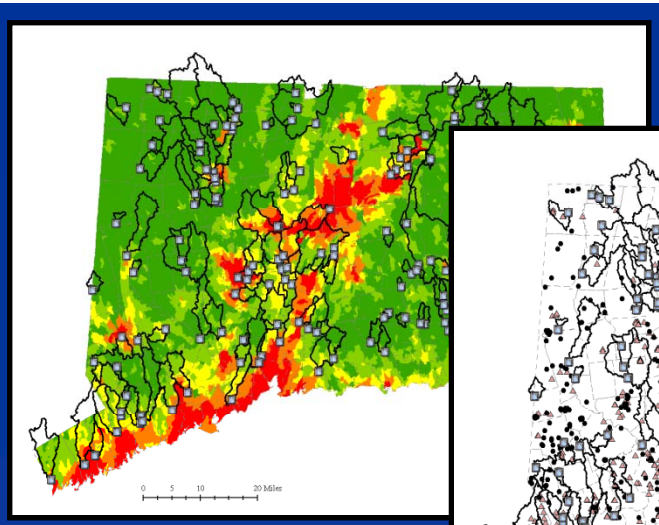


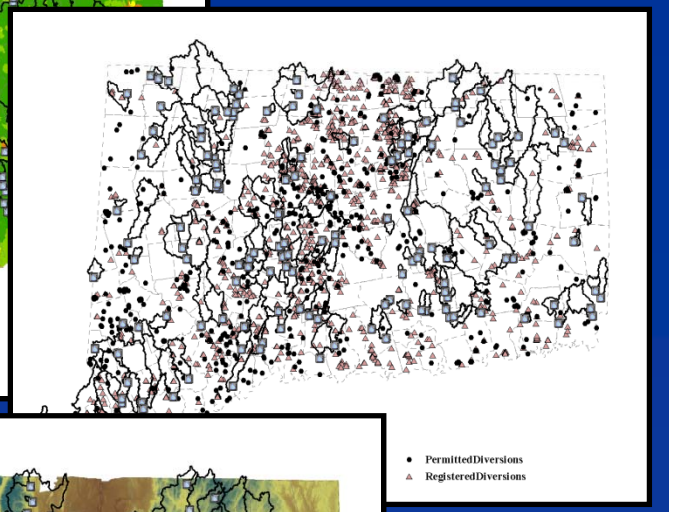

MMI = Multimetric Index. An index used for defining levels of restoration goals and aquatic life protection criteria (Gerritsen & Jessup, 2007). Calibrated in CT for macroinvertebrate communities.

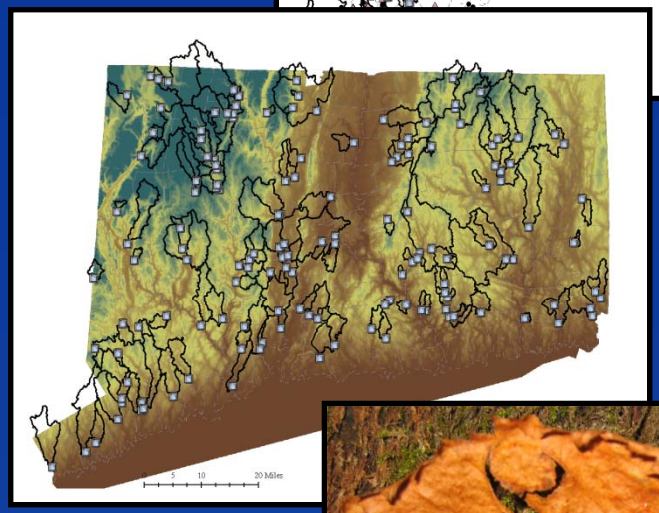
# Project Plan

## Modeling and landscape analysis: Expected Biological Condition

- Expand impervious cover work by including other factors that potentially effect the biological condition
- Establish a methodology to predict the expected biological condition at an unmonitored site utilizing geospatial analysis of readily available drainage basin data

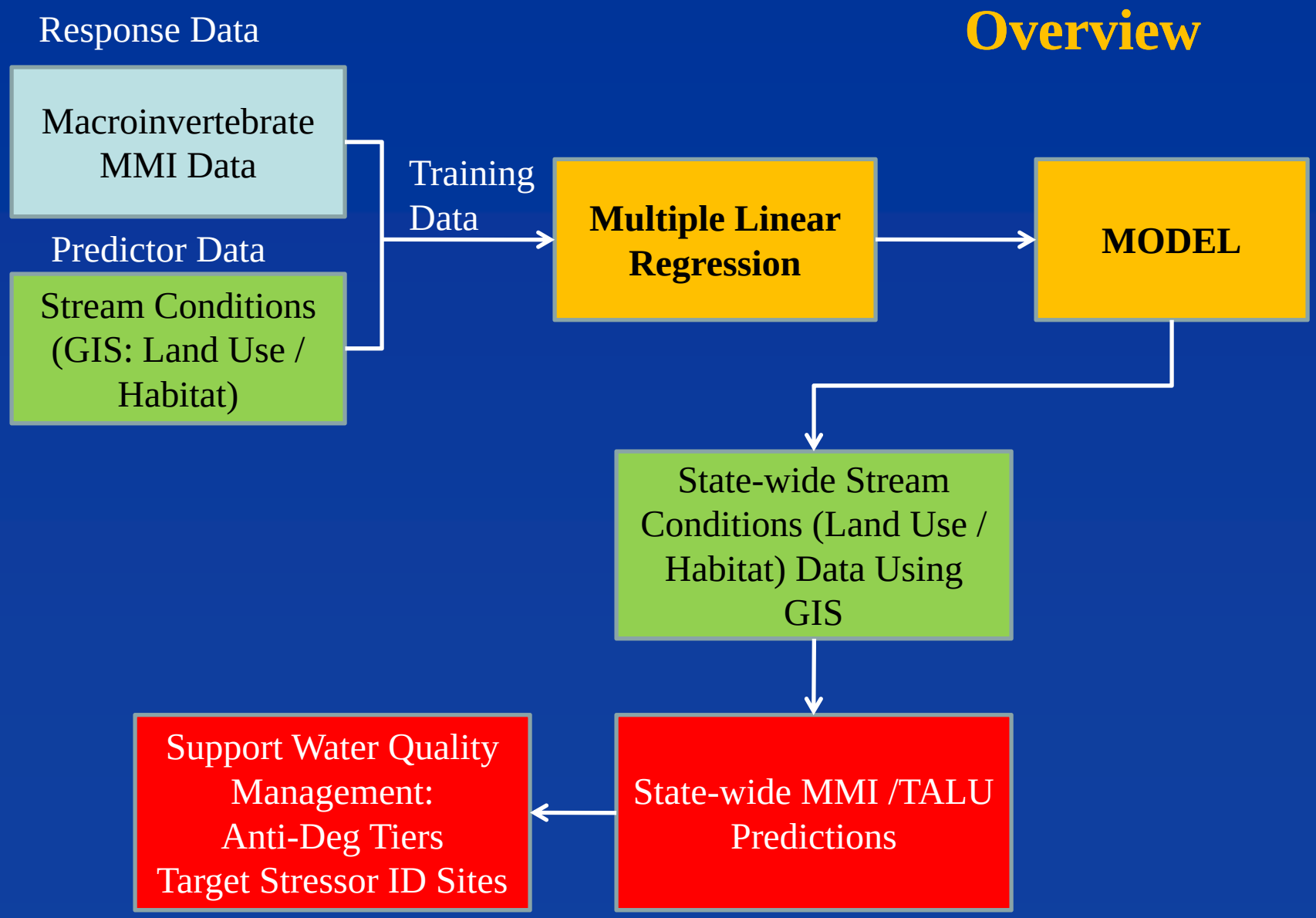


# Methodology

## Overview



# Methodology

## Site Selection

Started with 266 sites – Ended with 153 sites for Model Calibration

- Recent data only 2002-2004, 2006-2007
- Constant sampling effort – all 2 $m^2$ kick net samples

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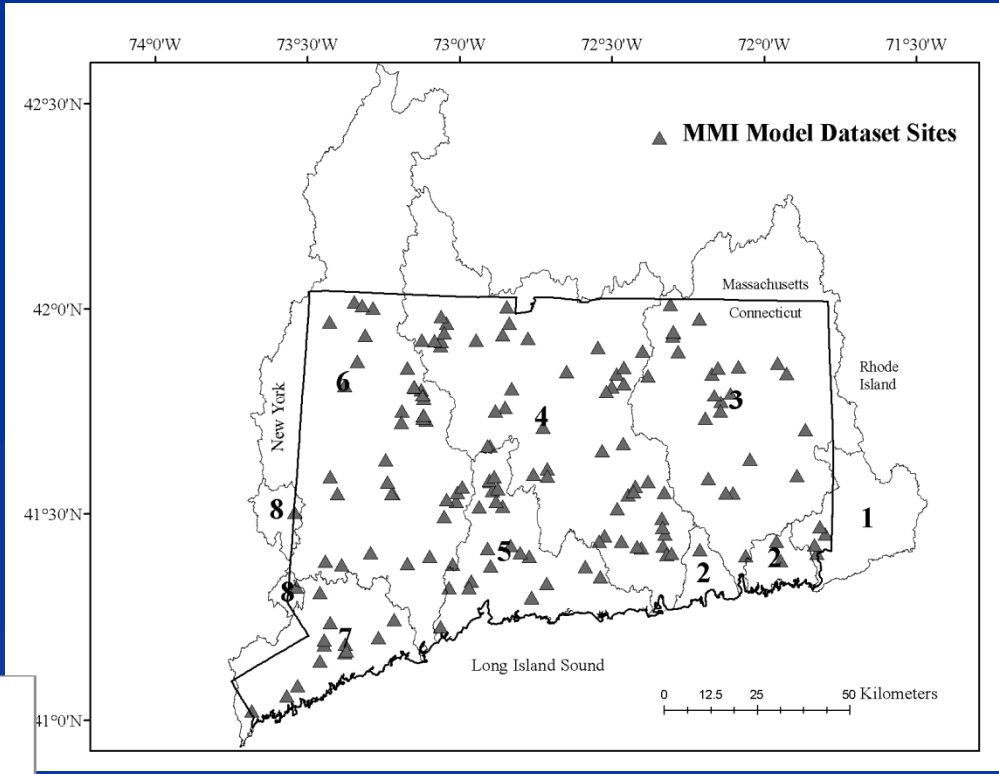
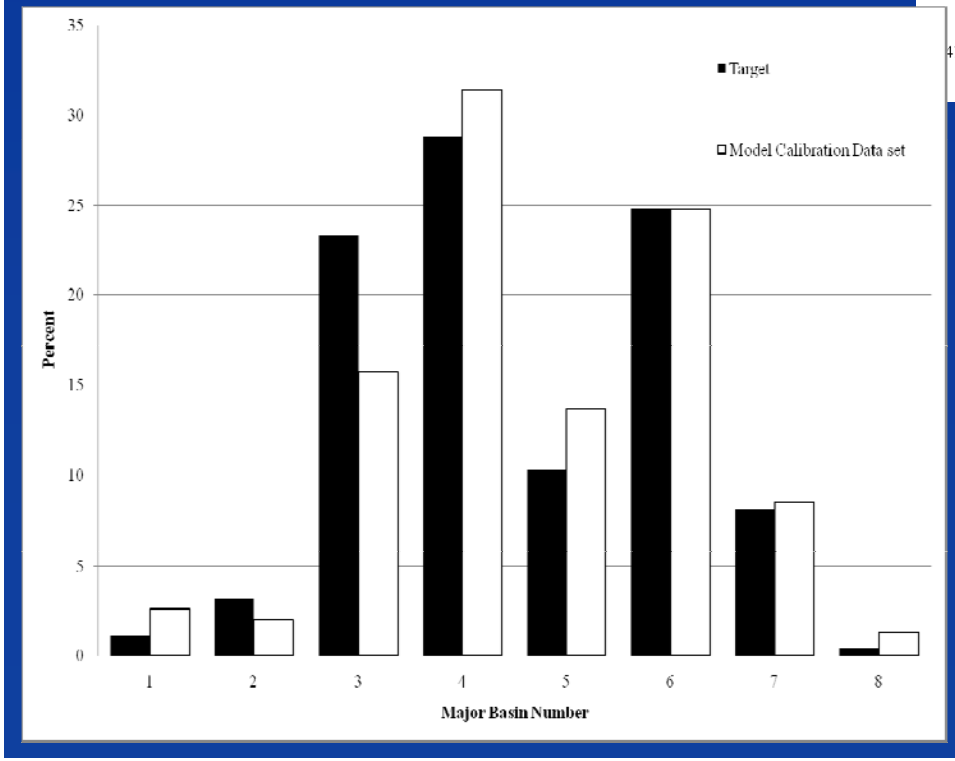
- Site could only be in data set only once
- Only 1 MMI answer per site (average MMI)
- Watersheds > 60% in State of CT
- Watersheds < 100 square miles
- Eliminated anomalous sites by BPJ (desiccation, spill investigations etc)
- Weighted sites in each major basin proportional to area

# Methodology

## Site Selection

- Weighed the data set by the proportion of surface area in each CT major basin
- Randomly selected sites in each major

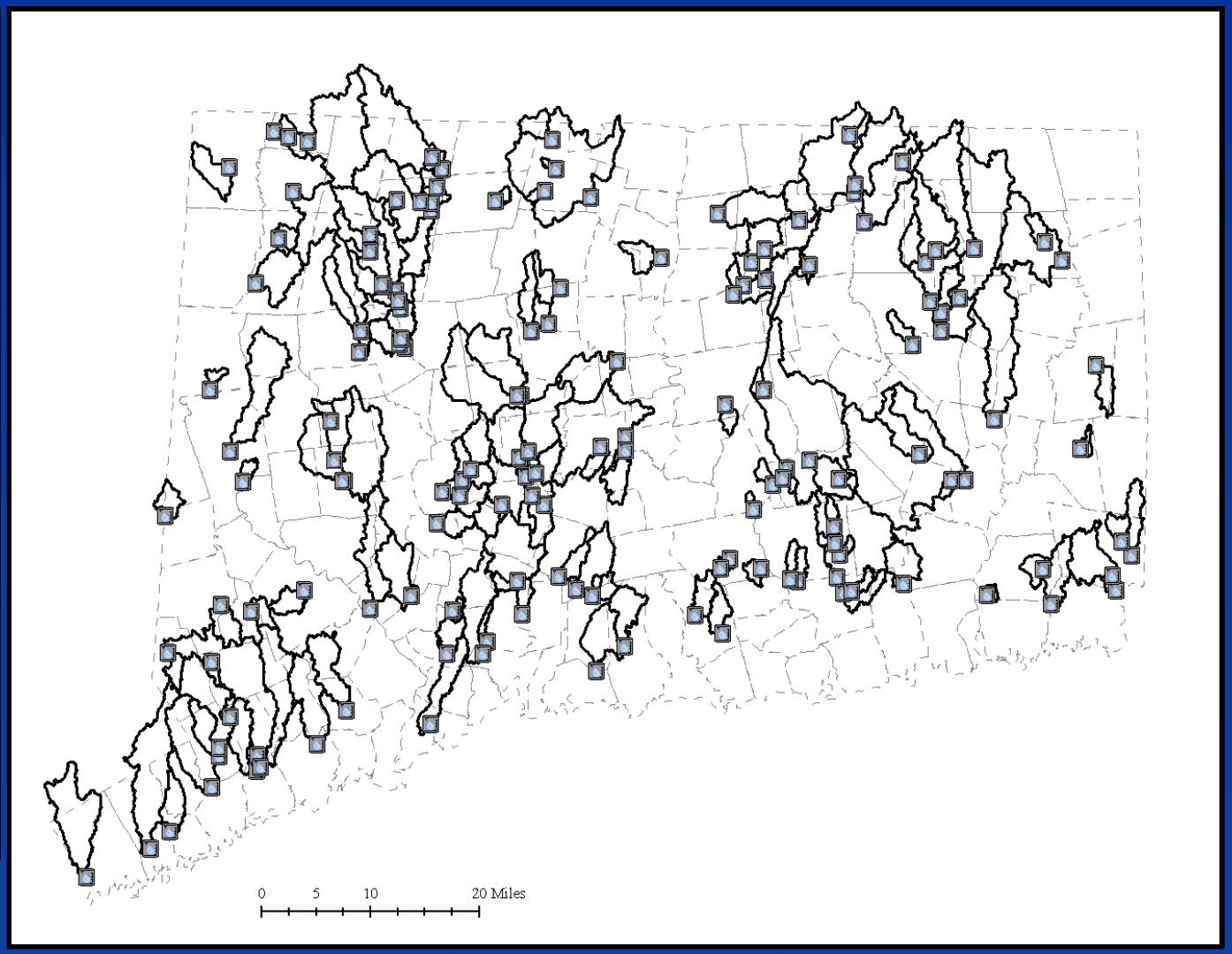


# Methodology

## Landscape Variable Selection

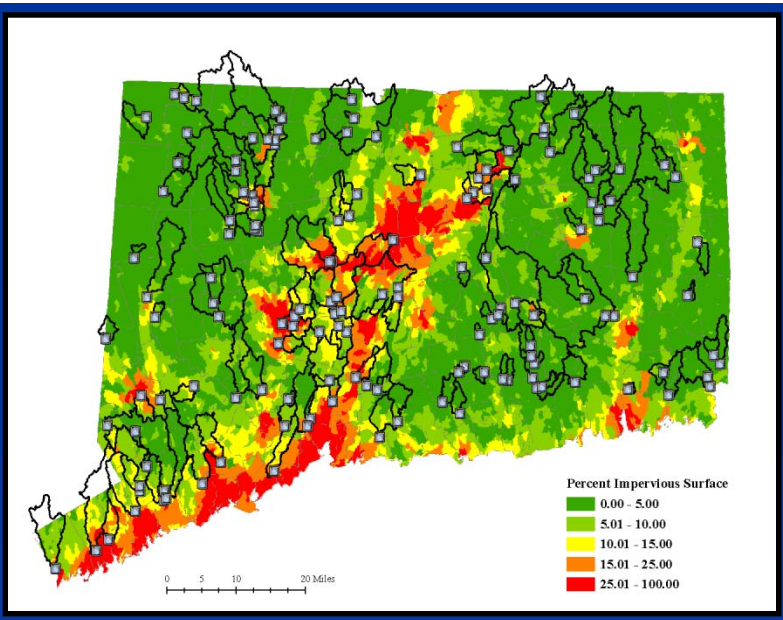
- Delineated drainage basin from stream site using ArcHydro Batch Global Watershed Delineation
- Assembled best available and geospatial datasets relevant to the biological condition of water resources



# Methodology

## 43 Landscape Variables

*Land Use/Land Cover*
Human Population Density (number/sq mile)
Agriculture (percent)
Utility Right of Way (percent)
Barren (percent)
Tidal Wetland (percent)
Non-Forested Wetland (percent)
Coniferous Forest (percent)
Deciduous Forest (percent)
Turf and Grass (percent)
Developed (percent)
Water (percent)
Lake Area (percent)
Forested Wetland (percent)
Farm Density (number/sq mile)
Edge Forest (percent)
Interior Forest (percent)
Patch Forest (percent)
Perforated Forest (percent)
Sewer Service Area (Percent)
**Impervious Cover (percent)**




*Physical*
**Drainage Area (sq miles)**
Stream Density (number/sq mile)
Average Elevation (ft)
Maximum Drainage Elevation (ft)
Sampling Site Elevation (ft)
Minimum Drainage Elevation (ft)
Stream Order at Sampling Site
Stratified Drift (percent)
Till (percent)

*Habitat Fragmentation*
Road Crossing density (number/square mile)
Major Road Crossings (percent)
Large Dam Density (number/sq mile)

# Methodology

## 43 Landscape Variables (Continued)

*Water Quality/Quantity*

Permitted Diversion Density (number/sq mile)

**Average Diversion Amount, July-Oct (MGD/square mile)**

Maximum Permitted Diversion Amount (MGD/ square mile)

Registered Diversion Density

(Number per square mile)

7Q10 (cfsm)

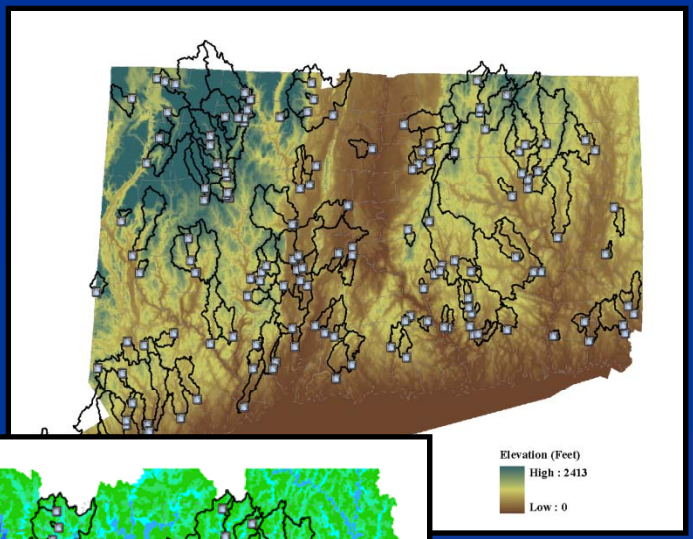
Average Diversion Amount Withdrawal During July-Oct, Divided By Basin 7Q10

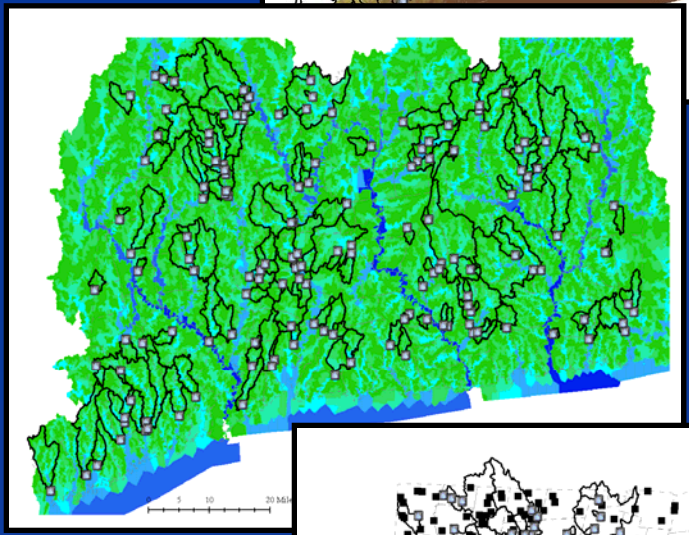
Maximum Permitted Diversion Amount Divided By 7Q10

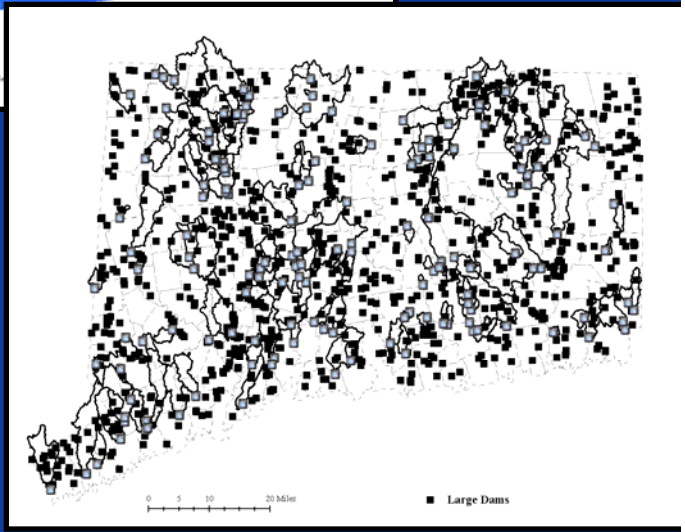
Maximum Registered Diversion Amount Divided By 7Q10

Average Sewage Treatment Plant Flow (MGD/square mile)

Average Sewage Treatment Plant Flow Divided By 7Q10





# Methodology

## Reduce Landscape Variables By Eliminating Redundant Variables

- Checked Statistical Assumptions and Transformed Variables
- Eliminated Highly Correlated Variables
- Used Ordination Techniques To Identify Most Important Variables to Predict MMI and Reduce Dataset
- Developed a Multiple Linear Regression Equation to Predict MMI from Landscape Variables

# Methodology

| Model | Variables |
|---|---|
| 1 | Percent IC |
| 2 | Percent IC; Basin Area |
| 3 | Percent IC; Basin Area; Summer Regulated Diversion Withdrawals / Drainage Area |

Multiple Linear Regression Model

***Final Regression Equation: Model 3 Based on Validation Dataset***

$$MMI = 89.931 - 40.805(\text{Log IC}) - 9.044\,(\text{Log Area}) - 1.240\,(\text{Diversion})$$

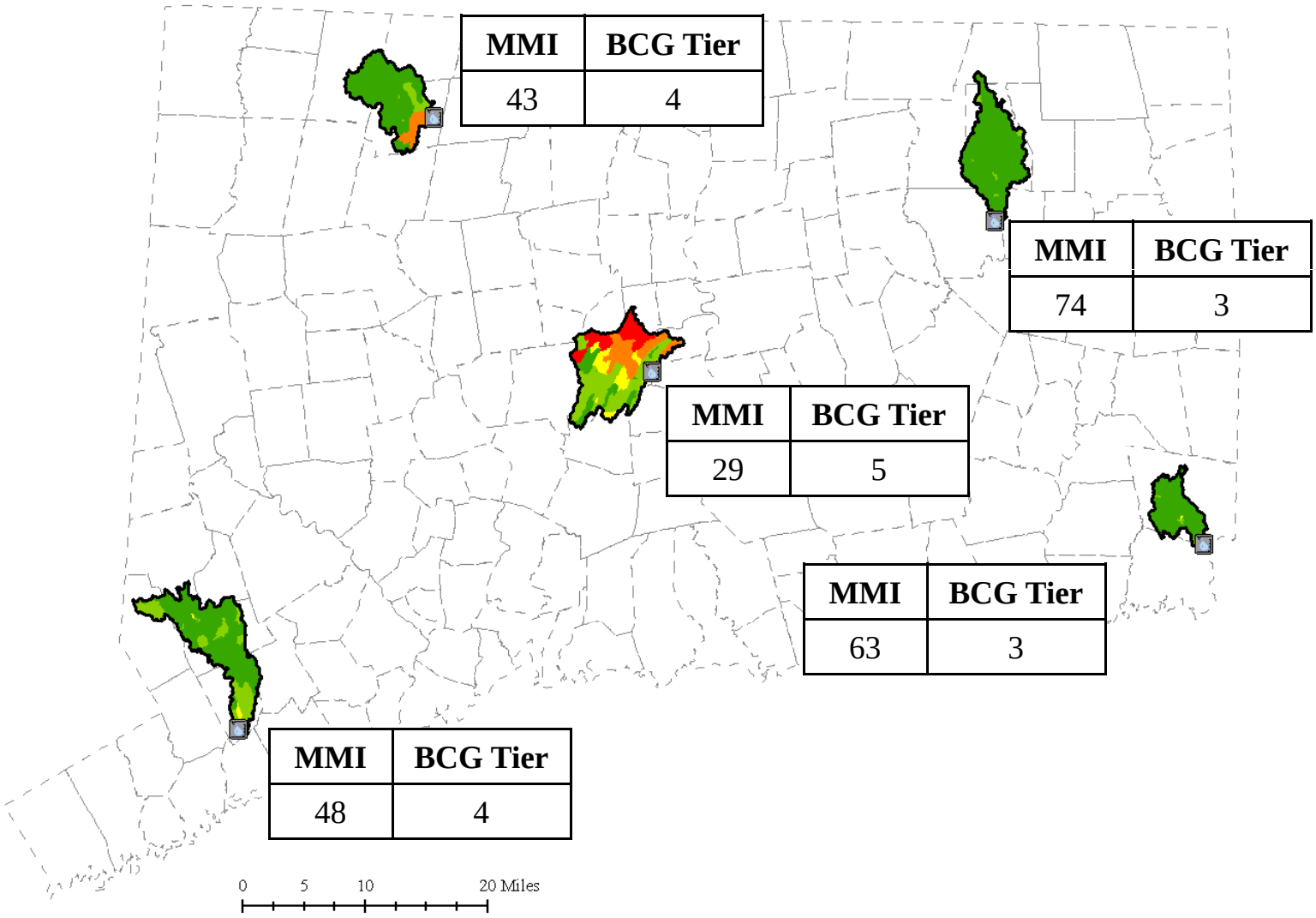
**Model Summary(d)**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change | |
| 1 | 0.701 | 0.491 | 0.488 | 12.72 | 0.491 | 145.782 | 1 | 151 | 0.000 | |
| 2 | 0.768 | 0.590 | 0.585 | 11.46 | 0.099 | 36.137 | 1 | 150 | 0.000 | |
| 3 | 0.778 | 0.606 | 0.598 | 11.28 | 0.016 | 5.935 | 1 | 149 | 0.016 | 2.188 |

a. Predictors: (Constant), LogIC
b. Predictors: (Constant), LogIC, LogArea2MI
c. Predictors: (Constant), LogIC, LogArea2MI, Loglowflowreg2mi
d. Dependent Variable: AvgOfMMI

# Methodology

Predict Biological Indicator Scores Based on Landscape Variables




| MMI | BCG Tier |
|---|---|
| 43 | 4 |

| MMI | BCG Tier |
|---|---|
| 74 | 3 |

| MMI | BCG Tier |
|---|---|
| 29 | 5 |

| MMI | BCG Tier |
|---|---|
| 63 | 3 |

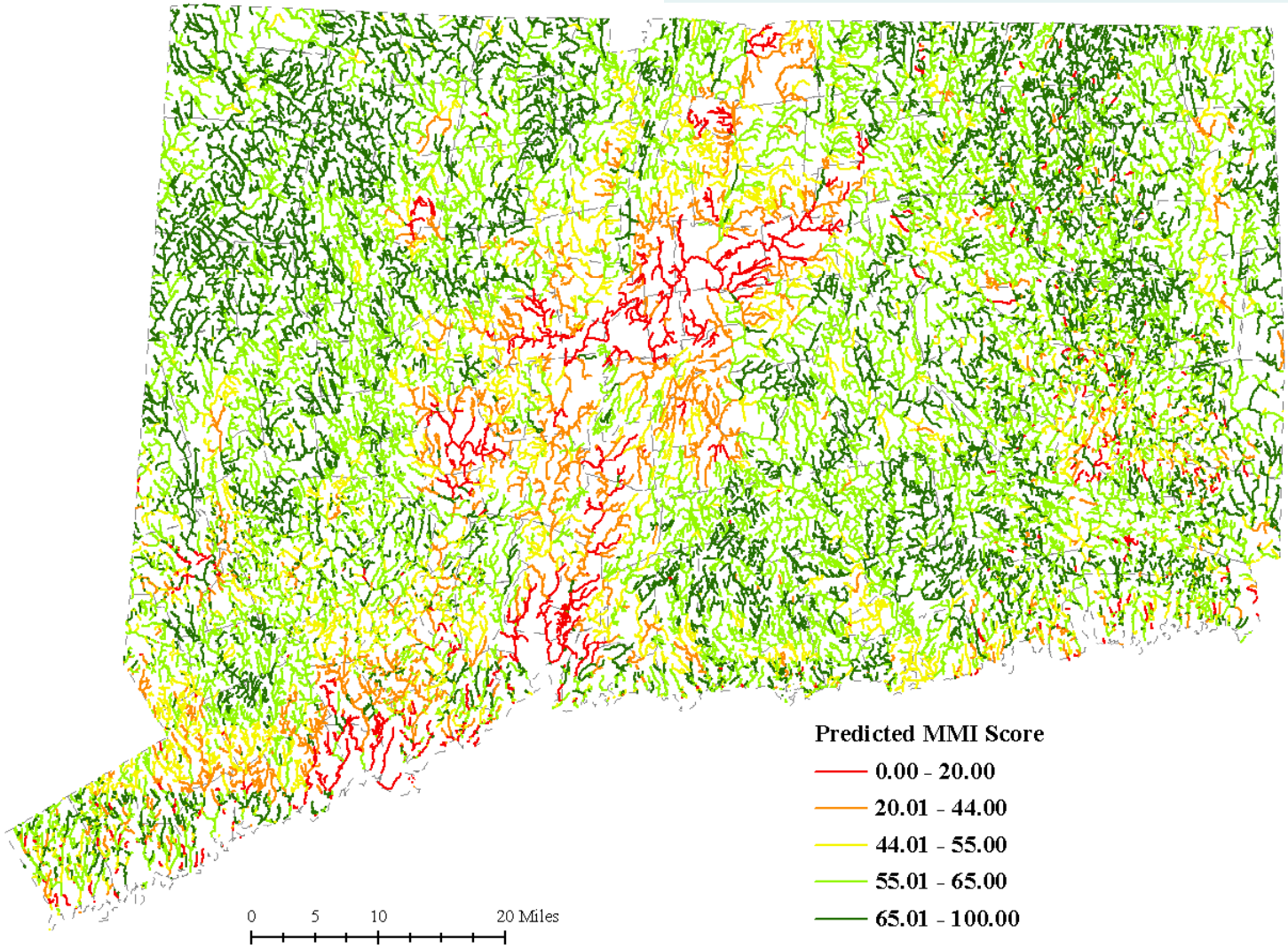
| MMI | BCG Tier |
|---|---|
| 48 | 4 |

# Methodology

## Predict Biological Indicator Scores Based on Landscape Variables

**~1200 Stream Miles Assessed For Aquatic Life**

**~10,800 Stream Miles Unassessed For Aquatic Life**



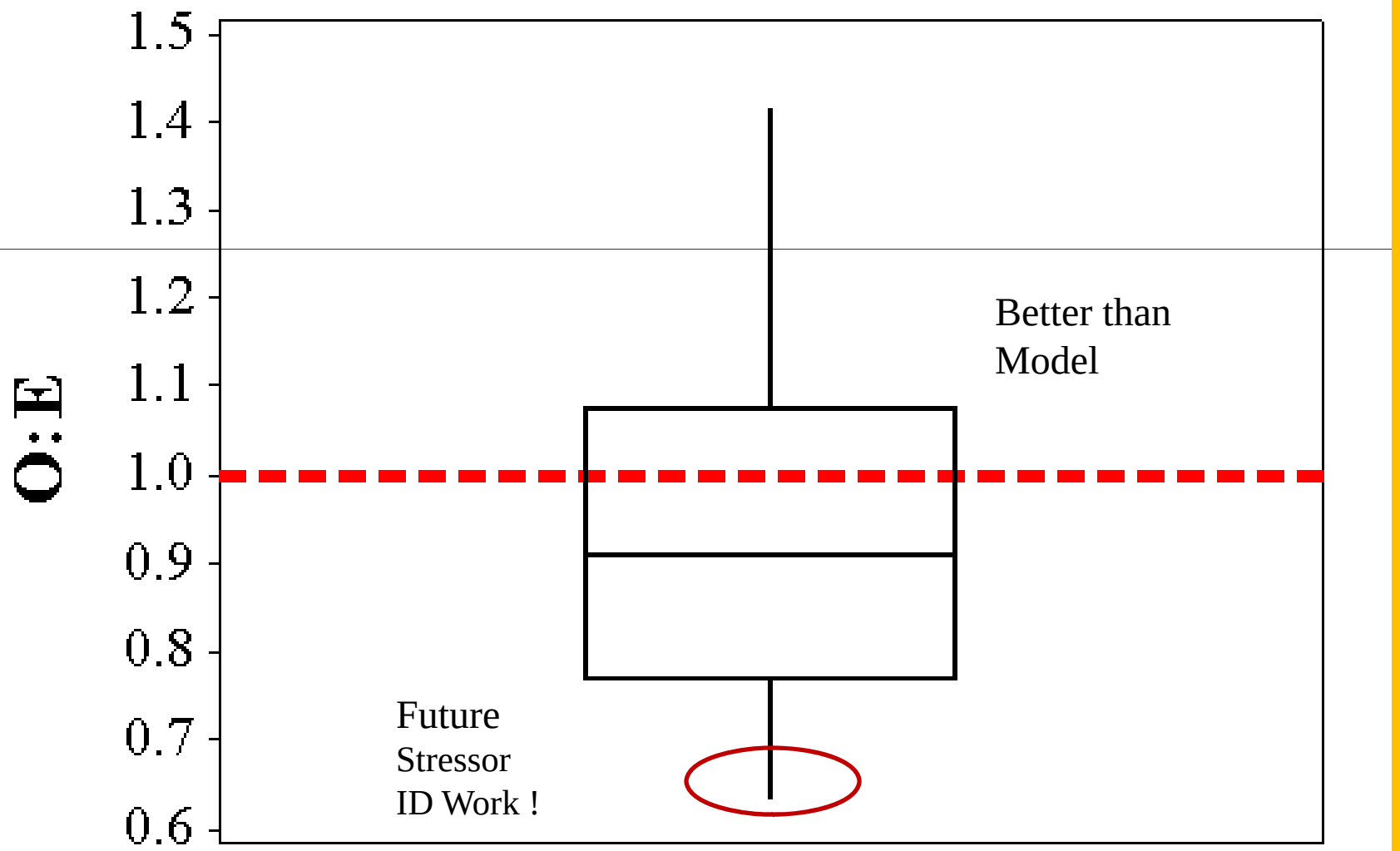
# Tools to Support Water Quality Management

## Optimizing Resources

| Situation | Policy Choices |
|---|---|
| No Monitoring Data | Model used as guidance for decisions until monitoring confirms |
| Monitoring Data > Previous sample or Model | Find out Why?<br>Improve model |
| Monitoring Data = Previous sample or Model | Ok |
| Monitoring Data < Previous sample or Model | Find Out Why?<br>Develop and Prioritize List for Stressor Identification Study |

# Tools to Support Water Quality Management

## Prioritizing Future Work



# Tools to Support Water Quality Management

## Prioritizing Future Work

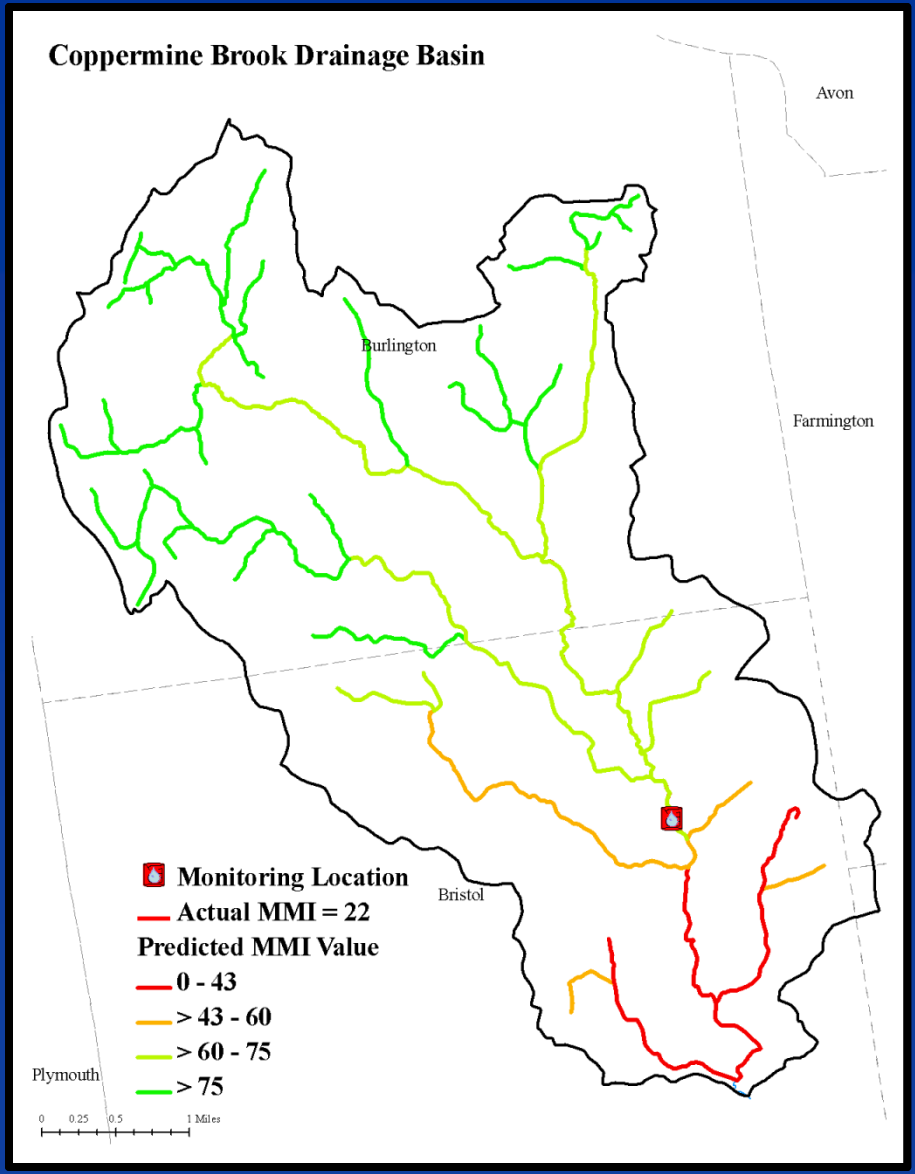
| Assessment Now | Previously Monitored or Model Predicted | Delta MMI | % Change |
|---|---|---|---|
| **List of Sites to Investigate for Stressor ID Study** | | | |
| 52 | 90 | -38 | -42 |
| 50 | 80 | -30 | -38 |
| 50 | 75 | -25 | -33 |
| 65 | 75 | -10 | -13 |
| 63 | 64 | -1 | -2 |
| 73 | 74 | -1 | -1 |
| 50 | 50 | 0 | 0 |
| 73 | 70 | 3 | 4 |
| **Impaired Water List** | | | |
| 35 | 36 | -1 | **303d** |
| 30 | 30 | 0 | **303d** |

- Produce a list ranked by % change in MMI that the DEP would use to prioritize Stressor ID Studies.

# Tools to Support Water Quality Management

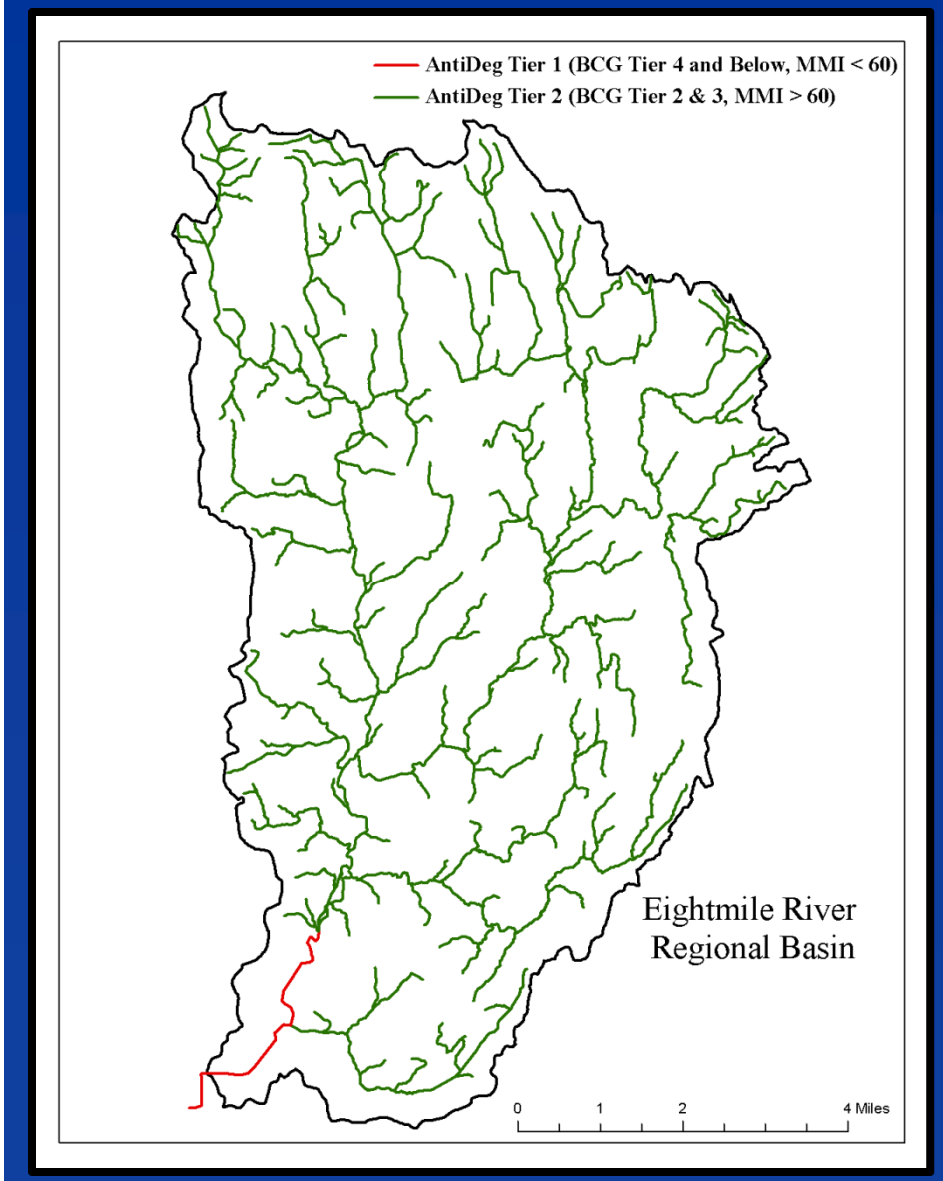
## Prioritizing Future Work

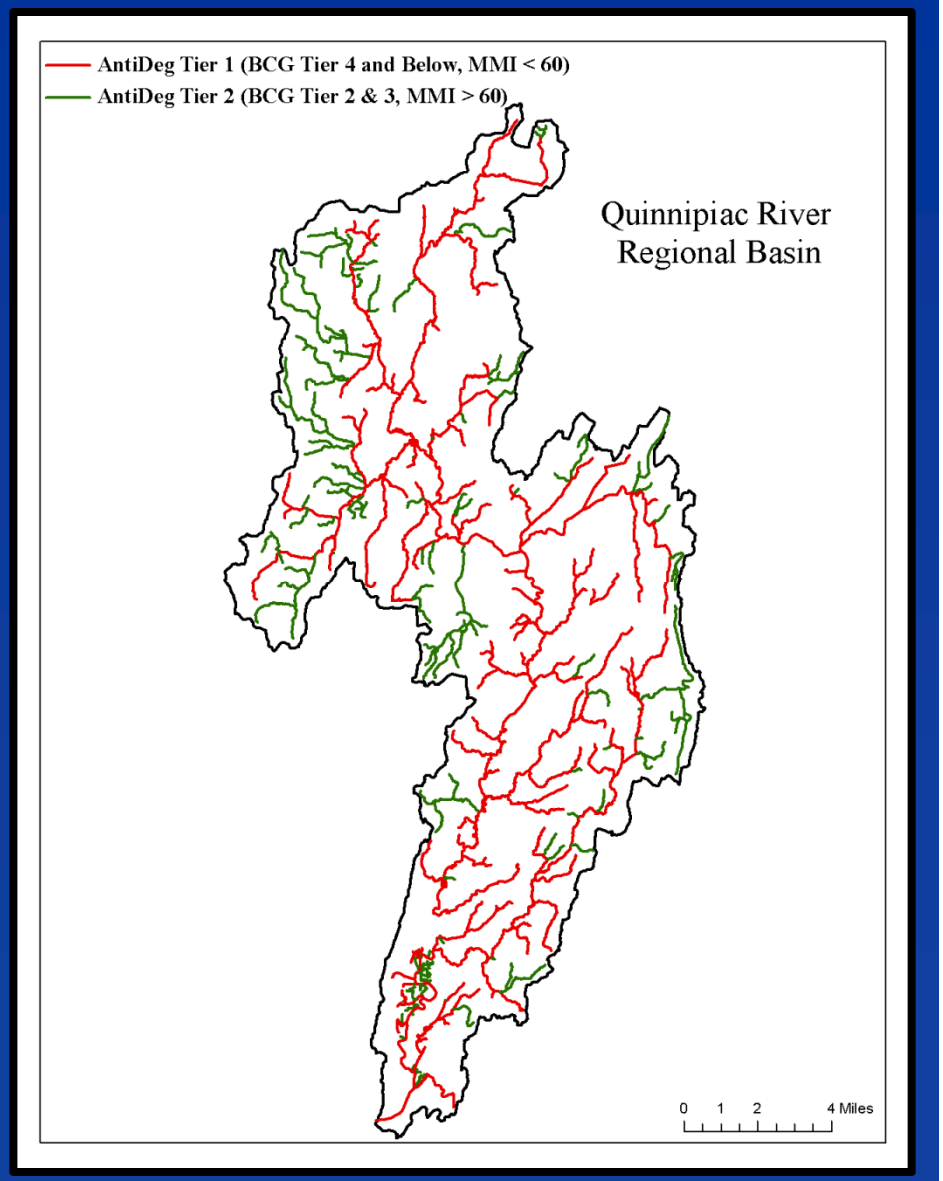
- Identify waterbody segments that disagree with the model and figure out why
- Predict changes water quality trends
- Prioritize targeted monitoring for stressor identification studies
- Support development of local management measures (TMDLs, NPDES permits, NPS BMPs)



# Tools to Support Water Quality Management

## Informing Anti-Deg Policies



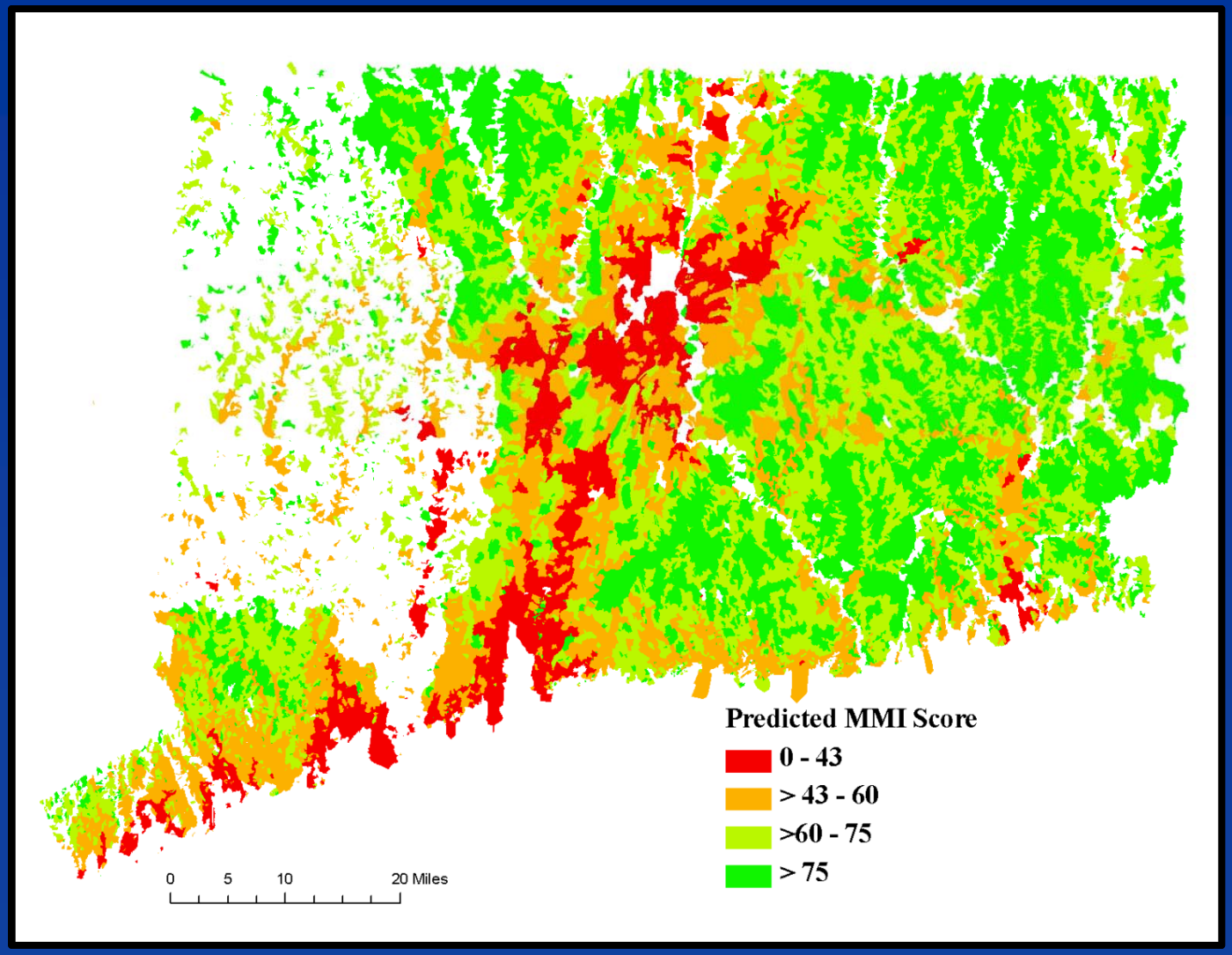



# Tools to Support Water Quality Management

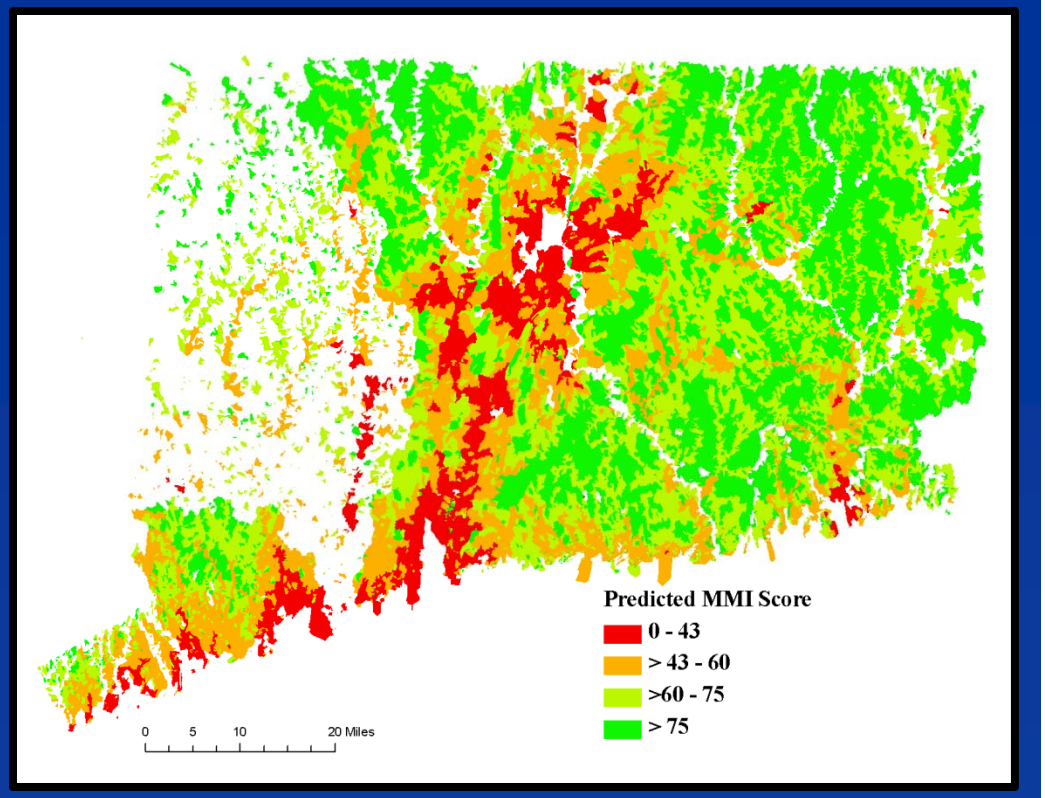
## Next Steps: Extend Model Statewide

*Delineate Watersheds For Over 36,000 Catchments*

- Afford better protection to high quality waters
- Provide intermediate goals for mixed landuse waters
- Provide recovery potential goals for urban rivers



# Questions?

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