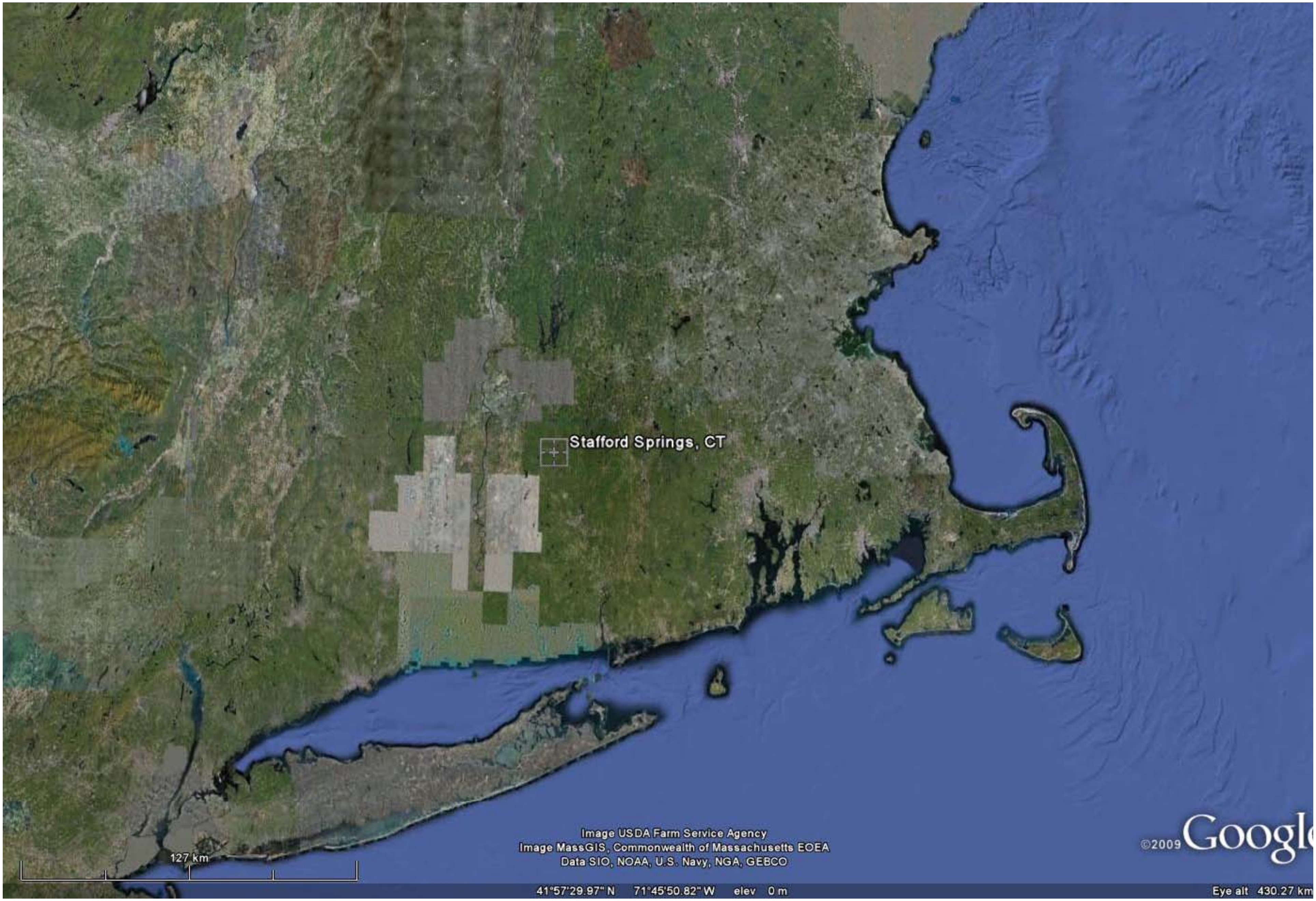
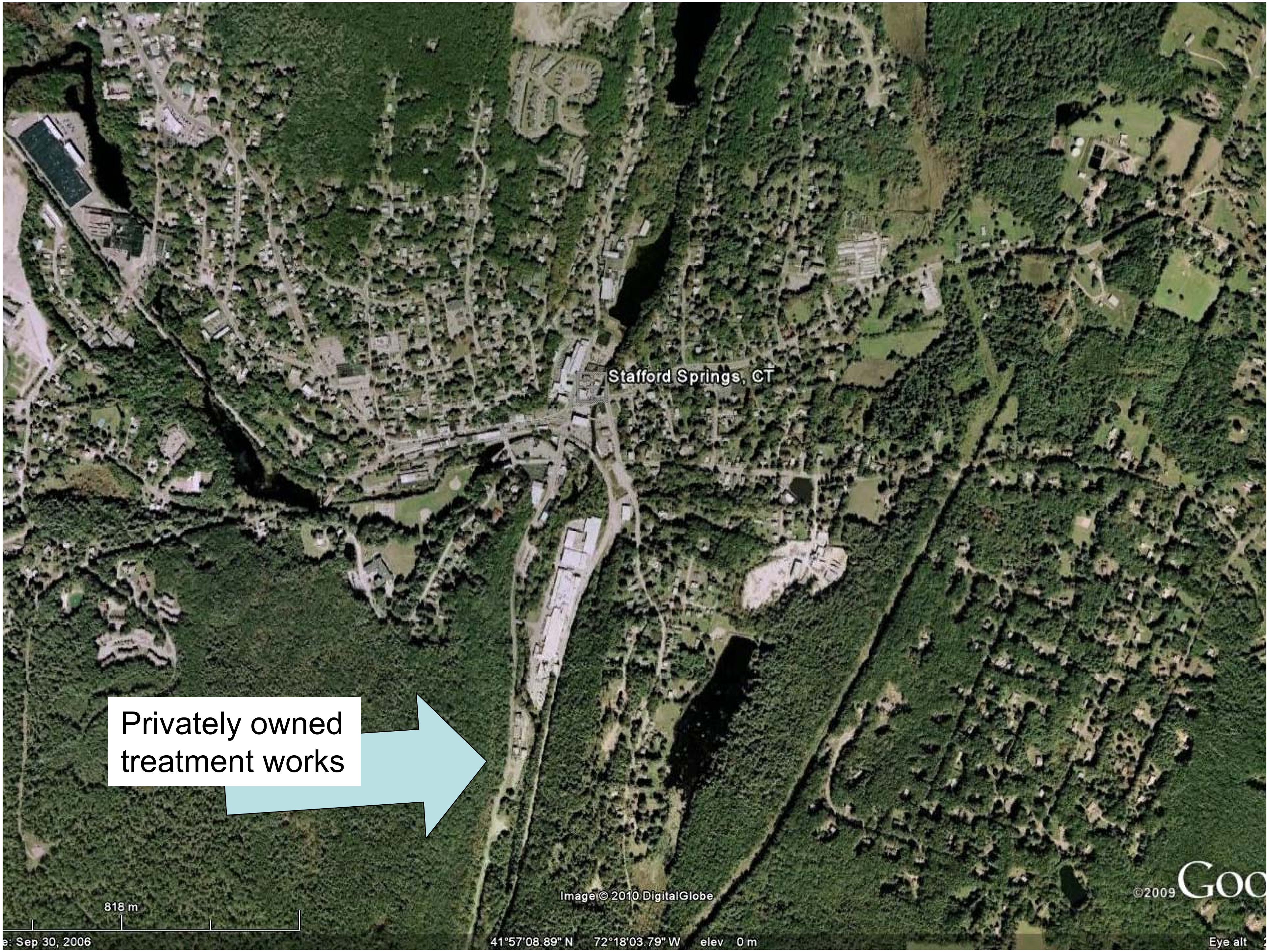
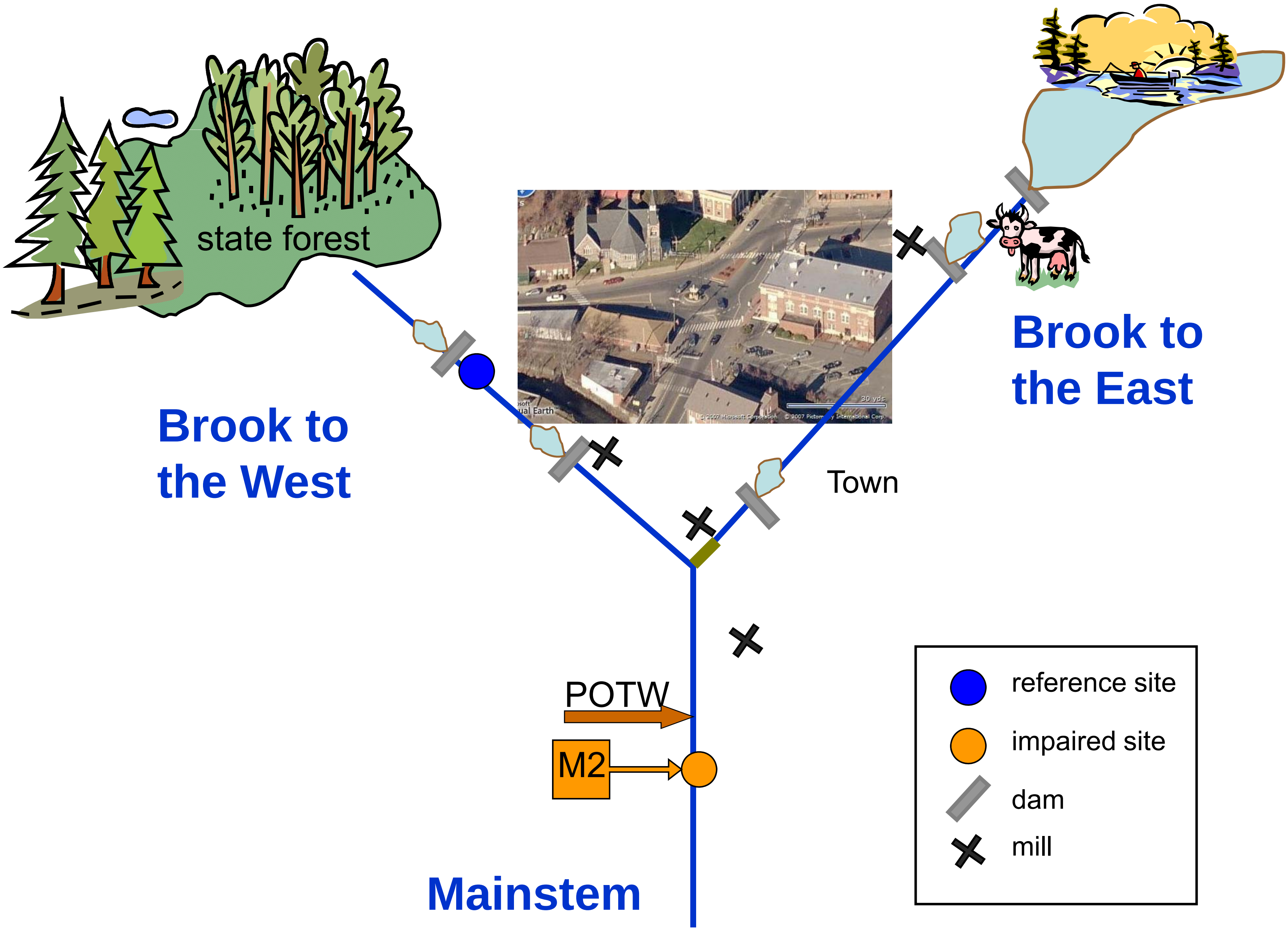
Willimantic River Application

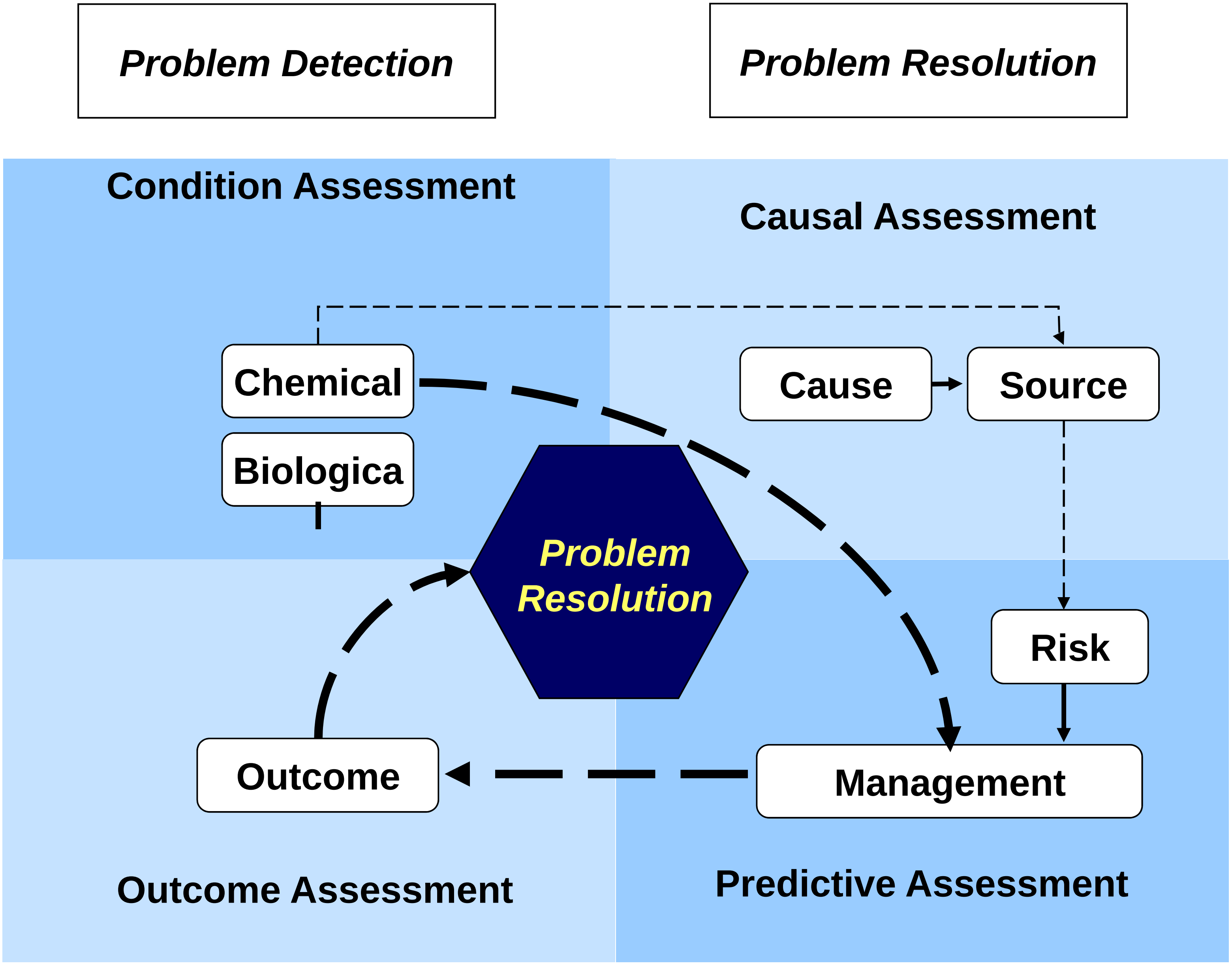

Stafford Springs, CT
127 km
Image USDA Farm Service Agency
Image MassGIS, Commonwealth of Massachusetts EOEA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
©2009 Google
41°57'29.97" N 71°45'50.82" W elev 0 m
Eye alt 430.27 km


Stafford Springs, CT
Privately owned
treatment works
Image © 2010 DigitalGlobe
©2009 Goo
818 m
e: Sep 30, 2006
41°57'08.89" N 72°18'03.79" W elev 0 m
Eye alt

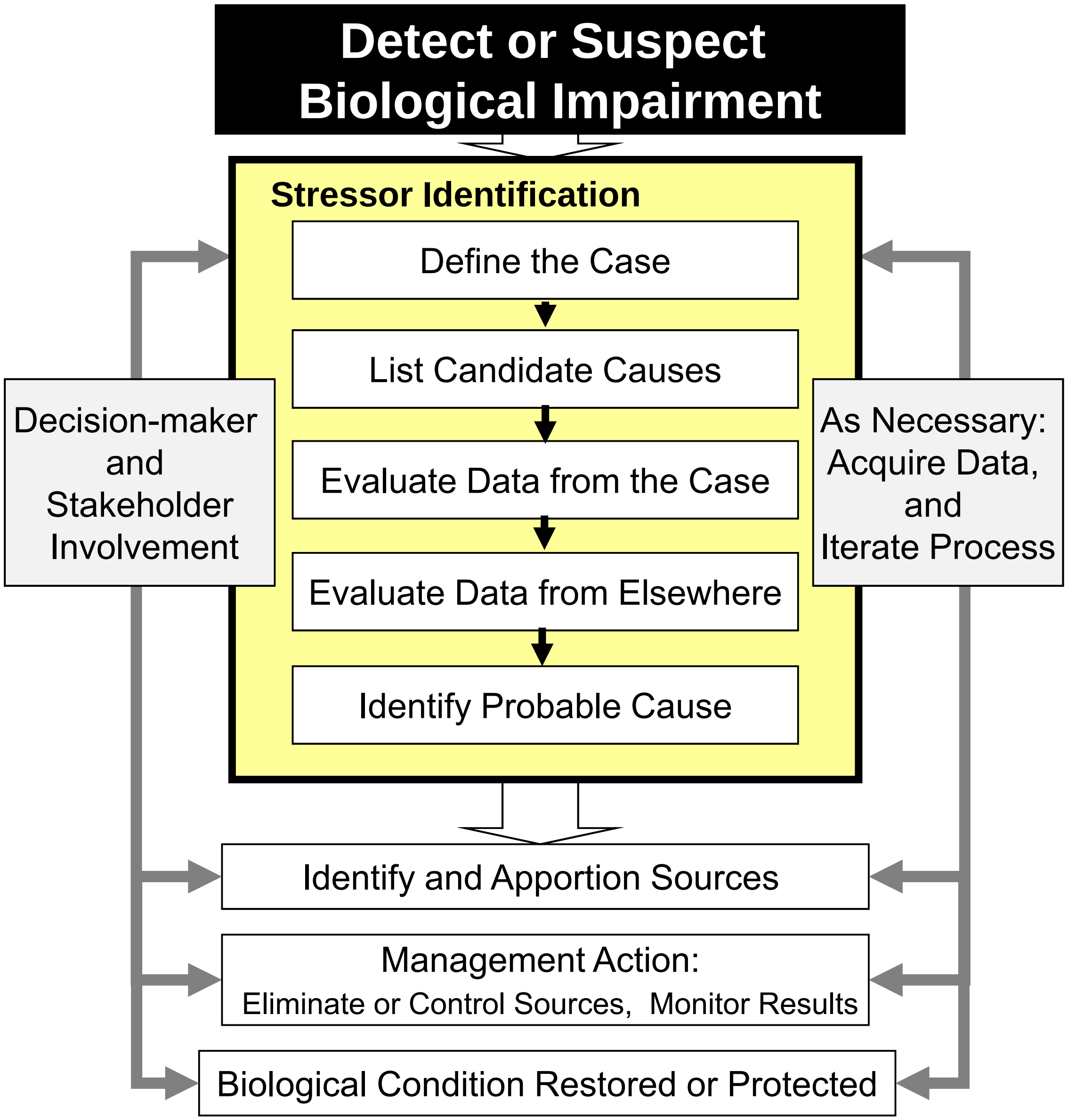

state forest
Brook to the West
Brook to the East
Town
POTW
M2
Mainstem
reference site
impaired site
dam
mill

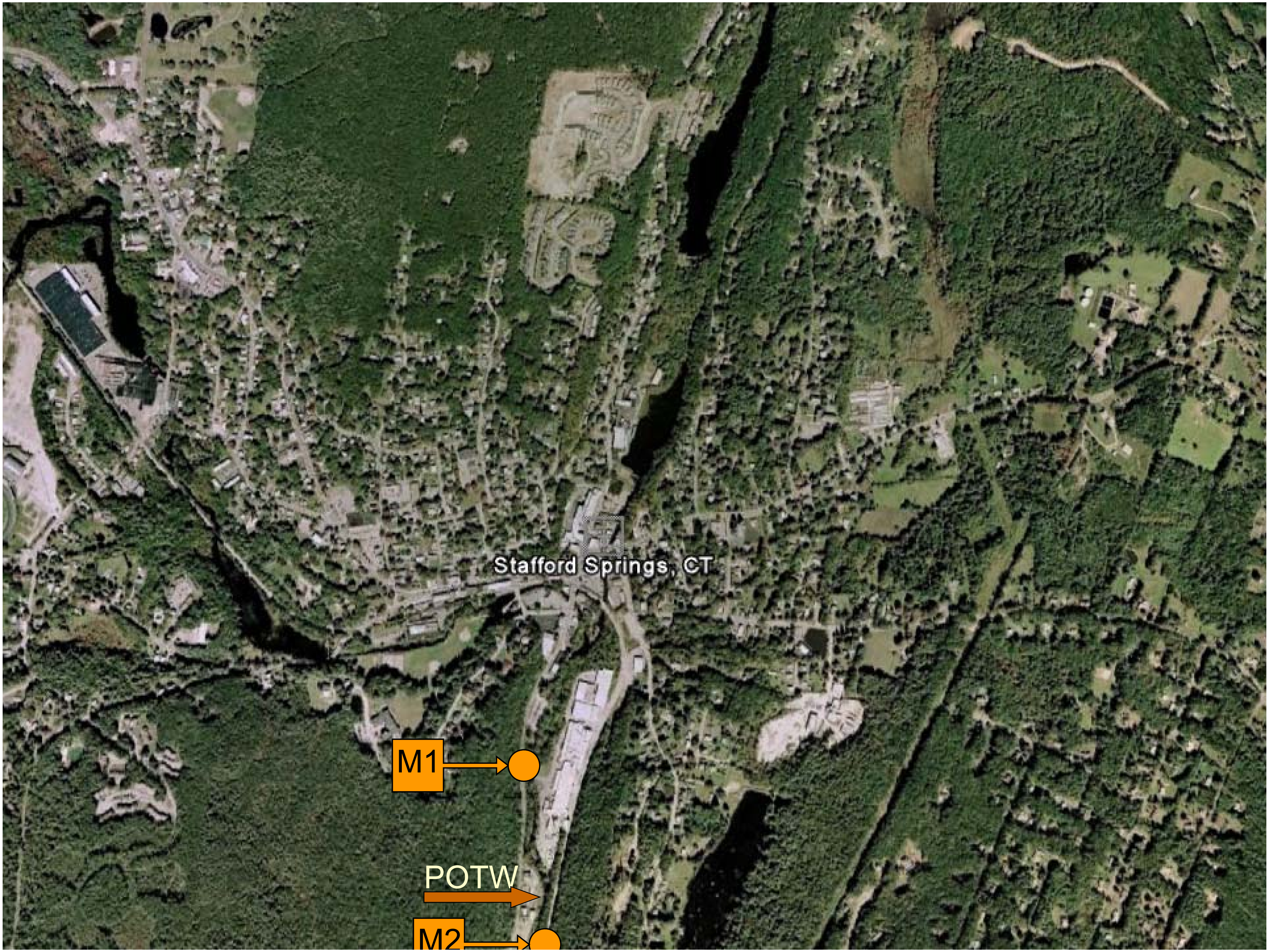
Based on chemical reports from POTW, CT DEP placed the segment of the river below the POTW on the 303d list of impaired waters.

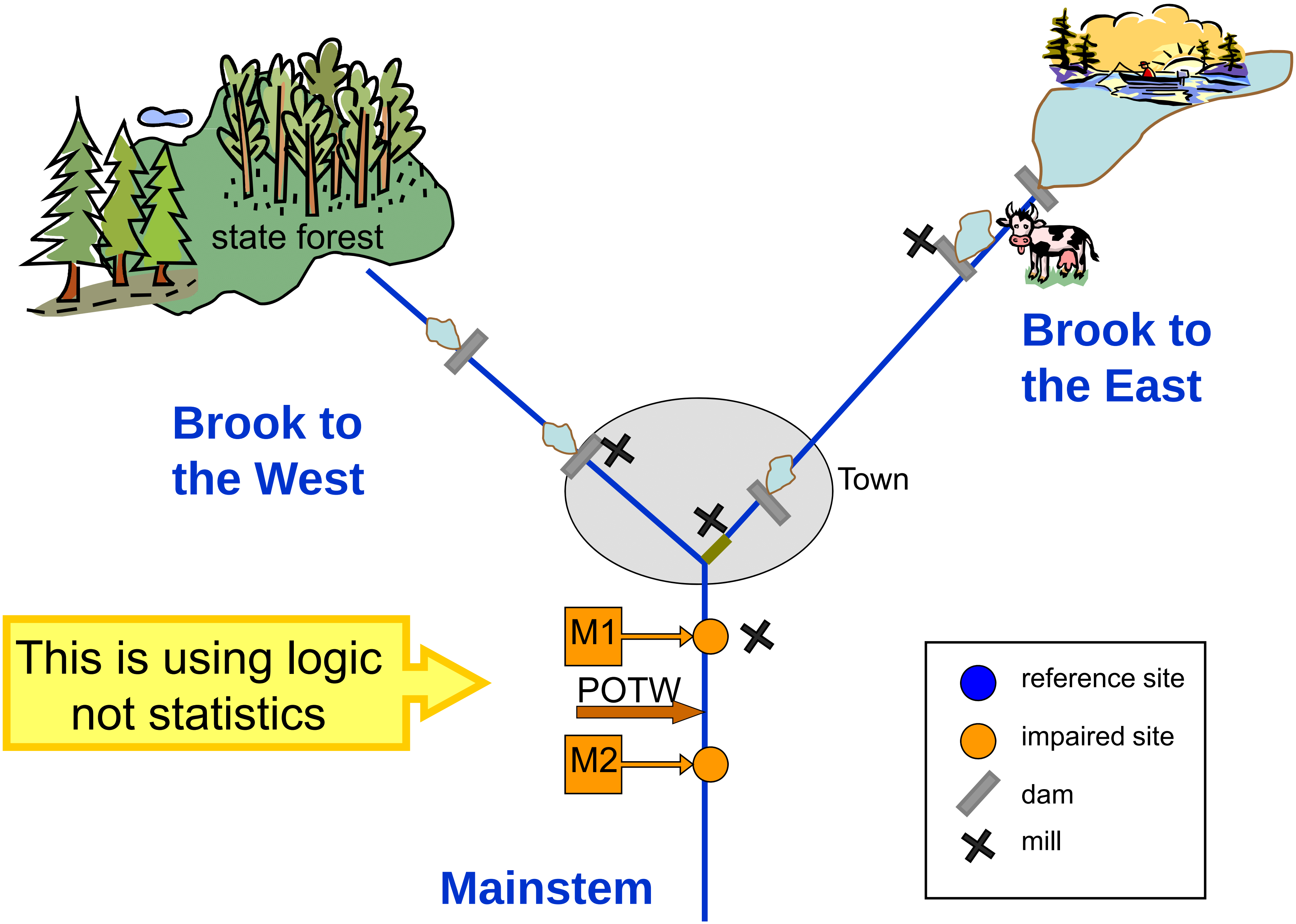
This is a chemical water quality condition assessment.



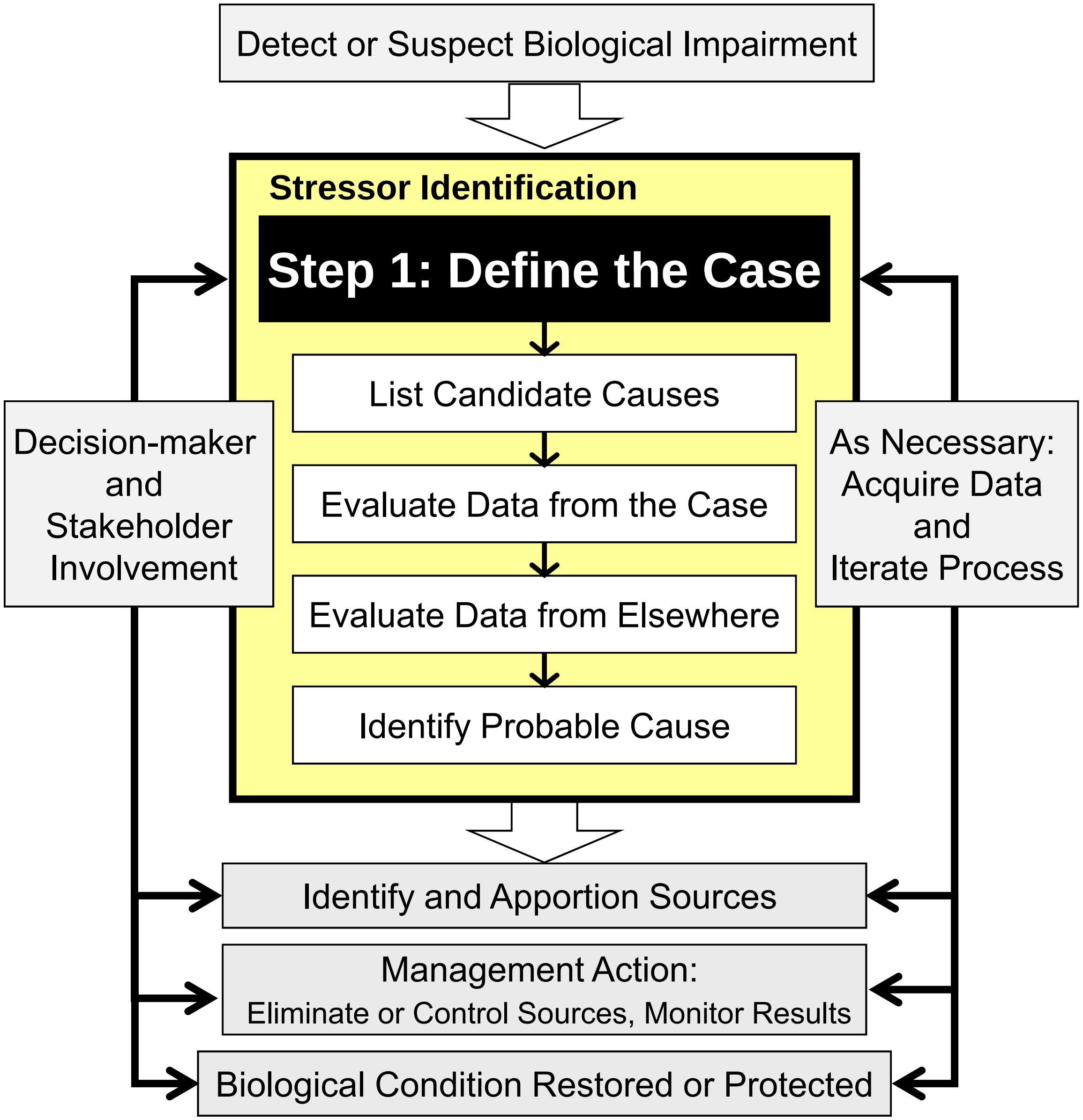
Problem Detection
Problem Resolution
Condition Assessment
Causal Assessment
Chemical
Biologica
Cause
Source
Problem Resolution
Risk
Outcome
Management
Outcome Assessment
Predictive Assessment


Detect or Suspect
Biological Impairment
Stressor Identification
Define the Case
List Candidate Causes
Evaluate Data from the Case
Evaluate Data from Elsewhere
Identify Probable Cause
Decision-maker
and
Stakeholder
Involvement
As Necessary:
Acquire Data,
and
Iterate Process
Identify and Apportion Sources
Management Action:
Eliminate or Control Sources, Monitor Results
Biological Condition Restored or Protected


Stafford Springs, CT
M1
POTW
M2



This is using logic not statistics


Detect or Suspect Biological Impairment
Stressor Identification
Step 1: Define the Case
List Candidate Causes
Evaluate Data from the Case
Evaluate Data from Elsewhere
Identify Probable Cause
Decision-maker and Stakeholder Involvement
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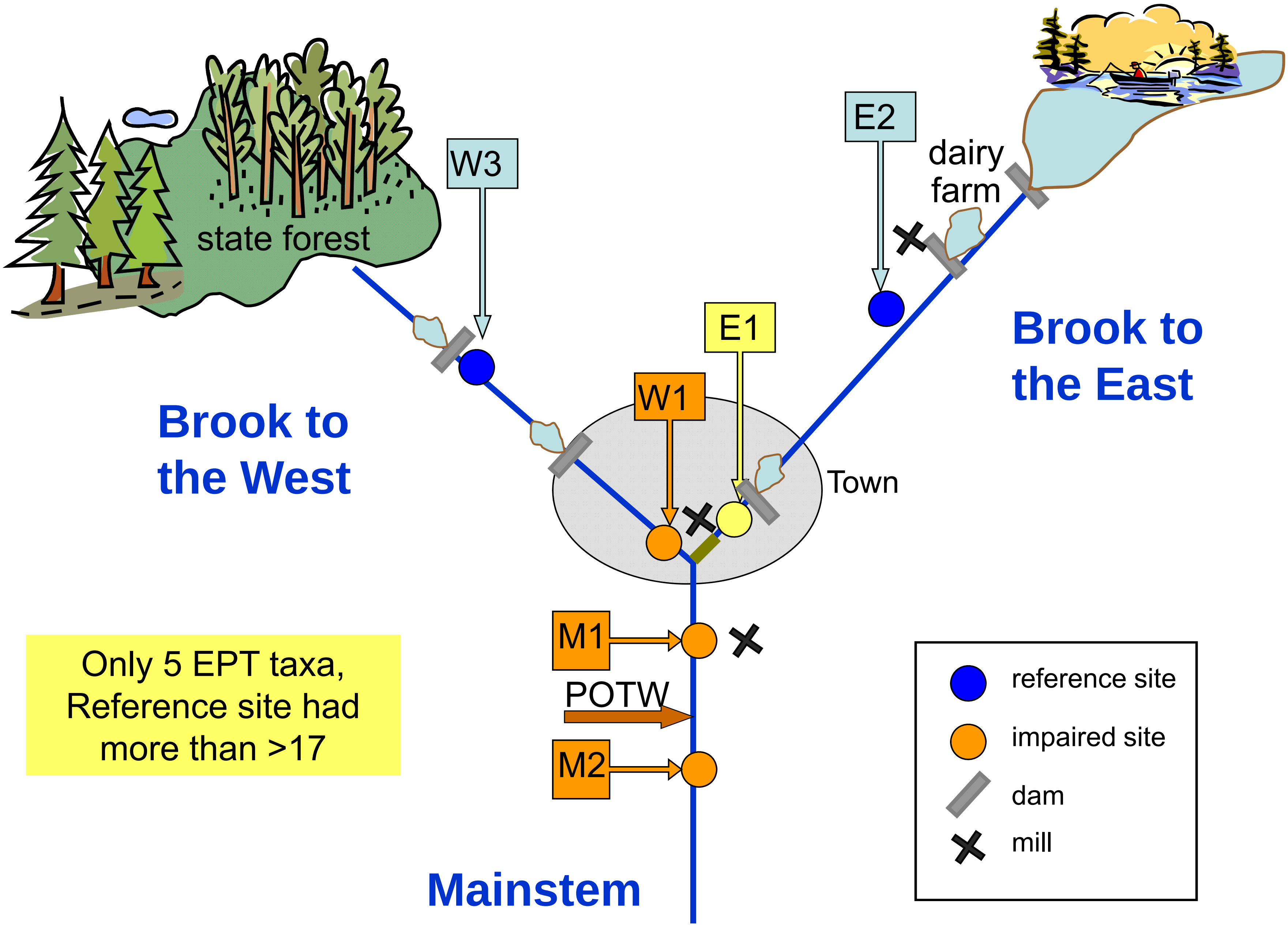
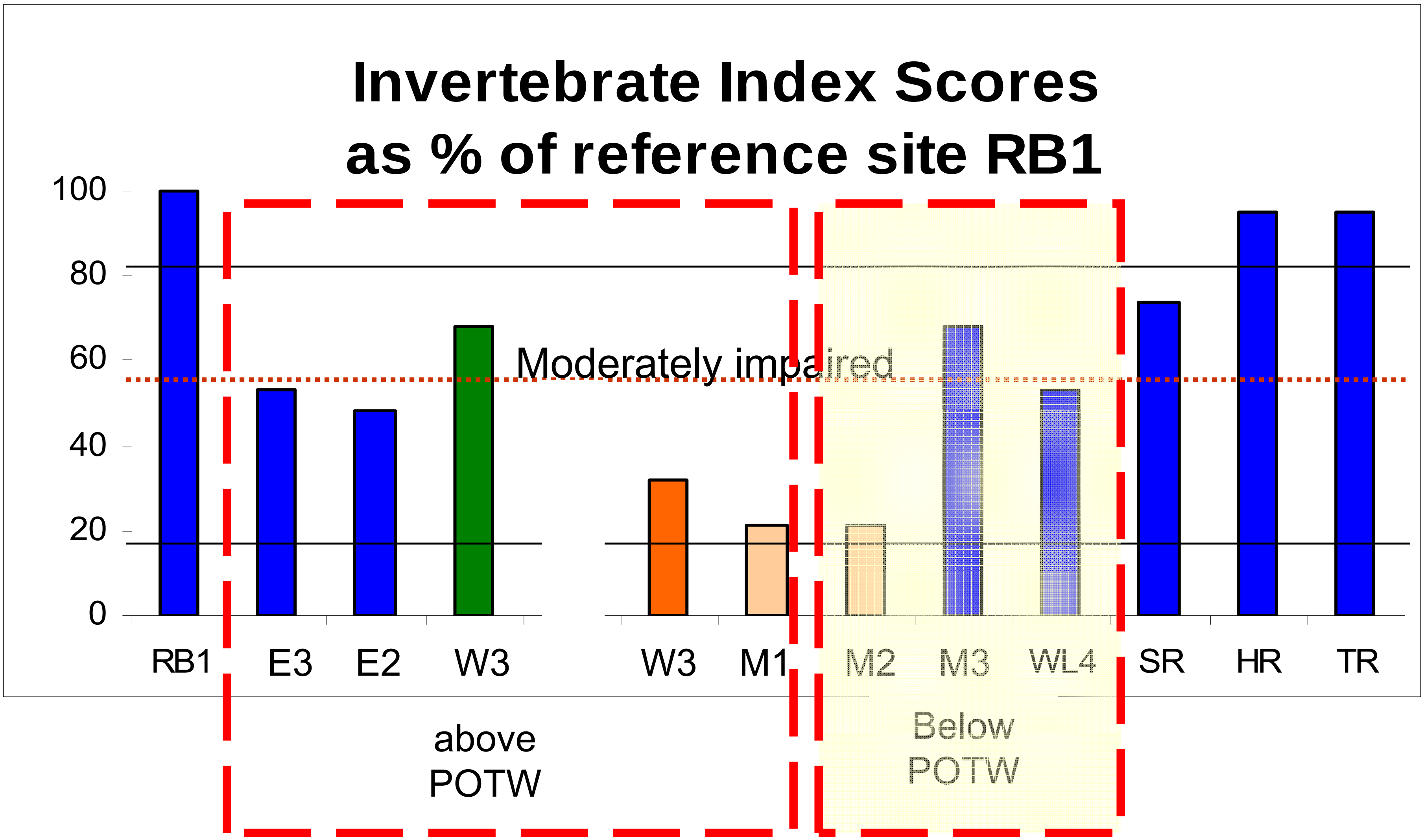
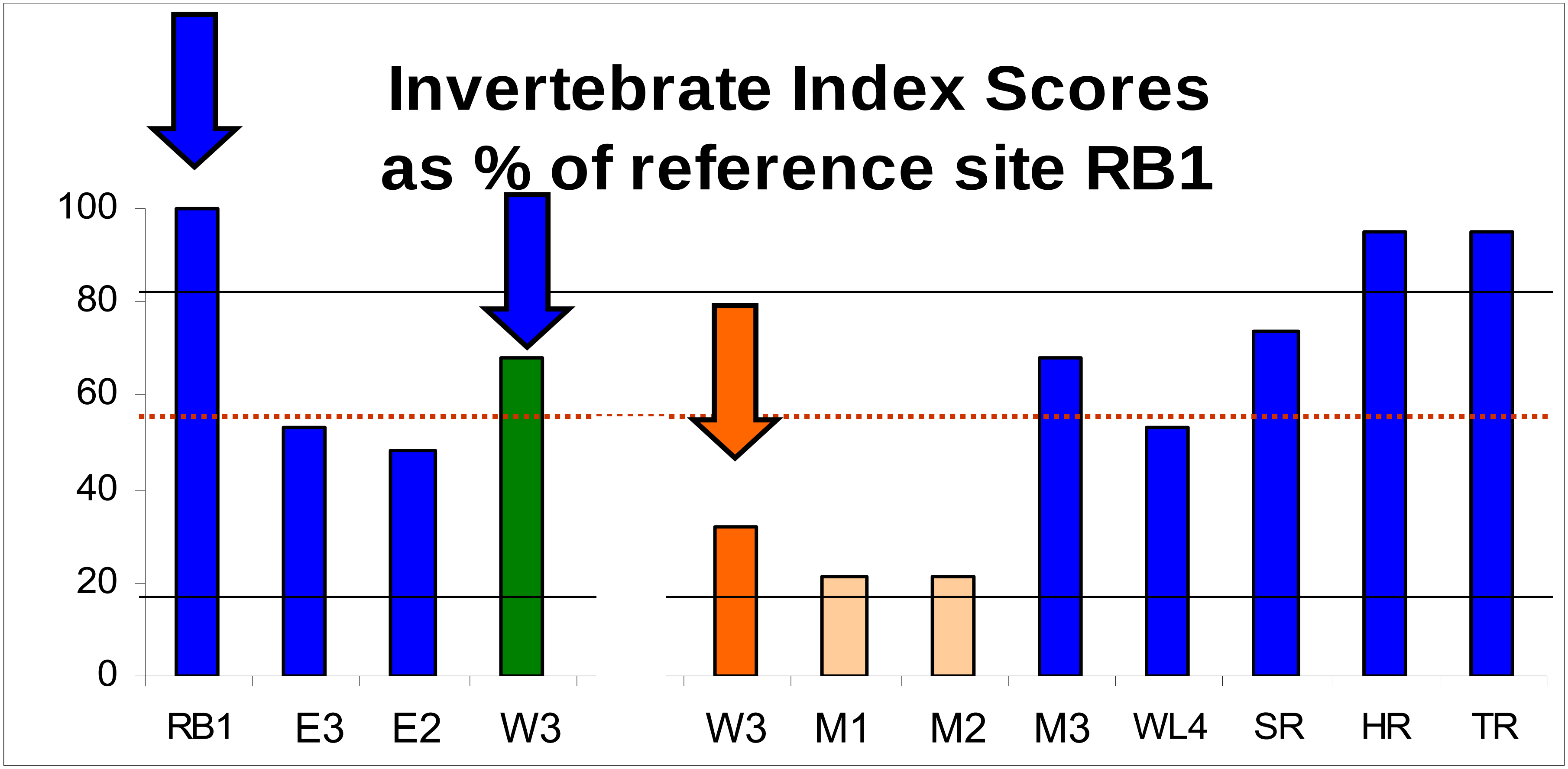


Only 5 EPT taxa,
Reference site had
more than >17

Define the Biological Impairment



Define the Biological Impairment

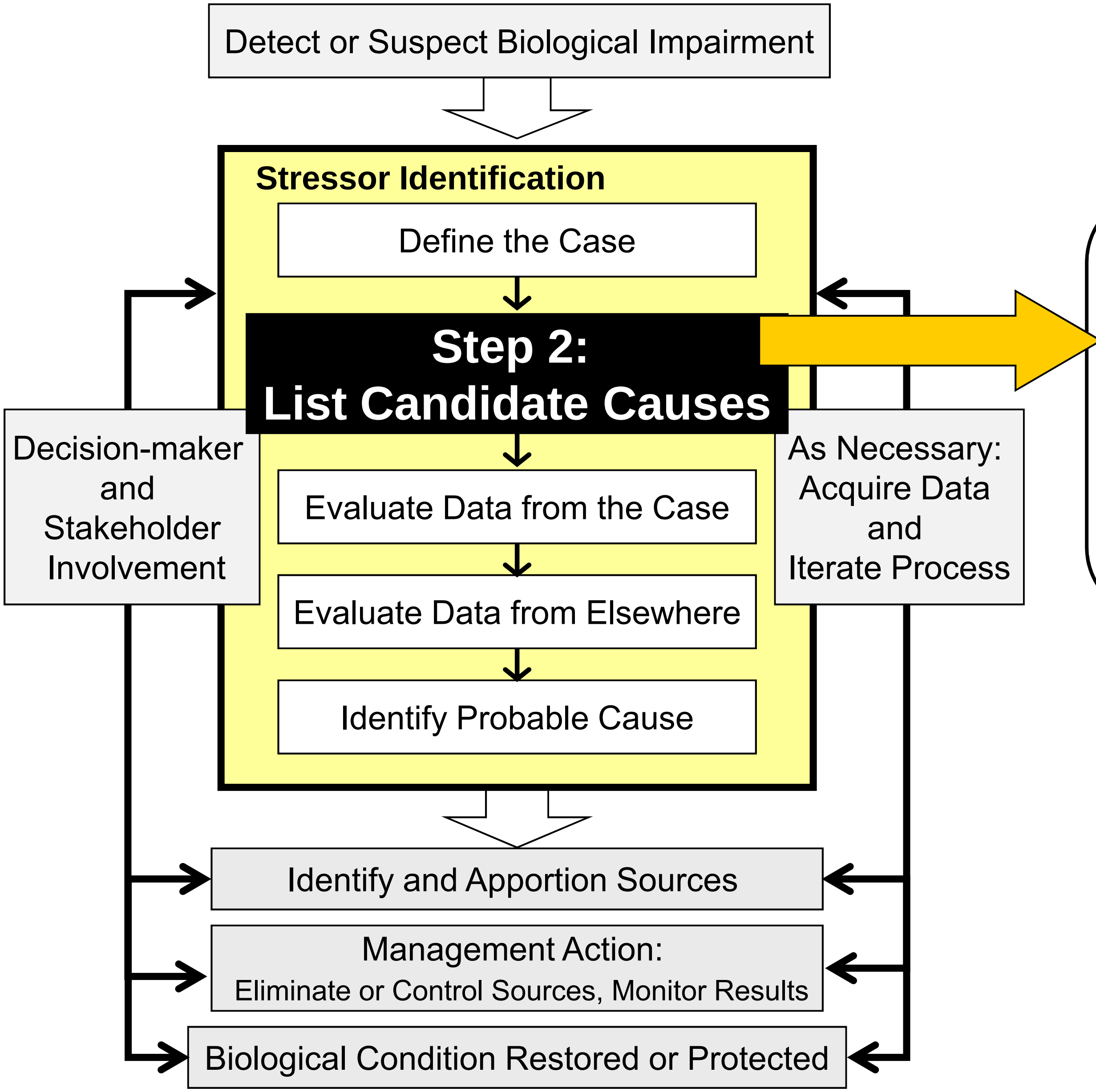


above
POTW

Below
POTW

Define the Biological Impairment

Effect	W3	W1	Change
Number of EPT Taxa	17	5	Decrease



- Gather information on potential sources, stressors, and exposures
- Develop a conceptual model
- Engage stakeholders

U.S. ENVIRONMENTAL PROTECTION AGENCY

Causal Analysis/Diagnosis Decision Information System (CADDIS)

Recent Additions | Contact Us   Search: GO

You are here: EPA Home » CADDIS » Candidate Causes » Common Candidate Causes

- **CADDIS Home**
- **Basic Information**
- **Frequently Asked Questions**
- **Step-by-Step Guide**
  - **Step 1: Define the Case**
  - **Step 2: List Candidate Causes**
  - **Step 3: Evaluate Data from the Case**
  - **Step 4: Evaluate Data from Elsewhere**
  - **Step 5: Identify Probable Cause**
  - **Summary Table of Scores**
  - **Summary Tables of Types of Evidence**
- **Examples**
- **Candidate Causes**
- **Analyzing Data**
- **Information Sources**
  - **Related Links**
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Candidate Causes

Common Candidate Causes | Interactive Conceptual Models

Common Candidate Causes

- CC.1. Metals
- CC.2. Sediments
- CC.3. Nutrients
- CC.4. Dissolved Oxygen
- CC.5. Temperature
- CC.6. Ionic Strength
- CC.7. Flow Alteration
- CC.8. Unspecified Toxic Chemicals

Candidate causes are stressors that could be responsible for causing the biological impairment that you are investigating. The pages in this section review basic information on several commonly encountered causes as identified in the navigation box on the right. We also refer readers to aquatic ecology text books such as Allan (1995), Dodds (2002) and Wetzel (2001). The stressors we discuss here appear frequently on U.S. EPA's 303(d) list of impaired water bodies. We plan to include material for more candidate causes in the future. In particular, we plan to add a module on physical habitat structure. So, please contact us with suggestions for additions.

Most of the currently available features in this module are relevant to Step 2: List Candidate Causes. If you already know the Stressor Identification (SI) process and have defined your case, you are ready to list candidate causes. If you are new to SI, we recommend that you review the entire SI process before proceeding.

The sections on "What to Consider When Determining if a Candidate Cause Should be Included" can help you:

Choose what to include in your list of candidate causes based on sources, site information, and observed biological effects,

Justify your choice to include some candidate causes and defer others,

Write your report by providing supporting text you can copy and modify to explain the source-to-impairment pathways for your site, and

Make useful site observations when you are in the field.

The "Ways to Measure" sections are useful for:

Local intranet

Listing advice for candidate causes

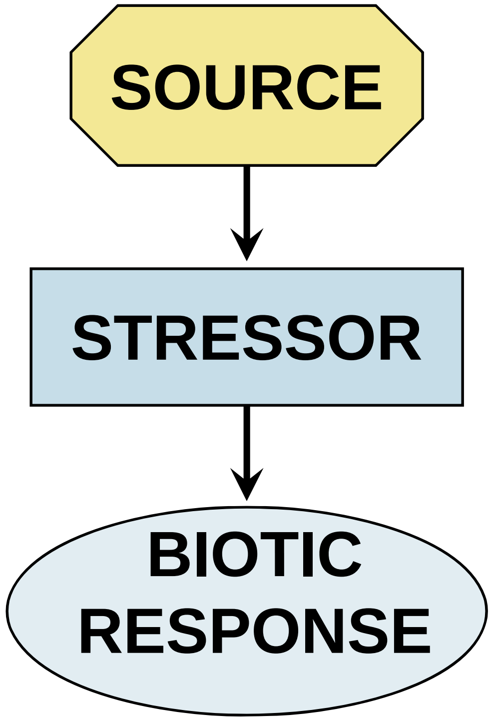
- 8 common candidate causes →
- Basic information:
  - Definition of candidate cause
  - Sources
  - Site evidence
  - Biological effects
  - When to exclude
  - How to measure
  - Recommended reviews
  - Generic conceptual model

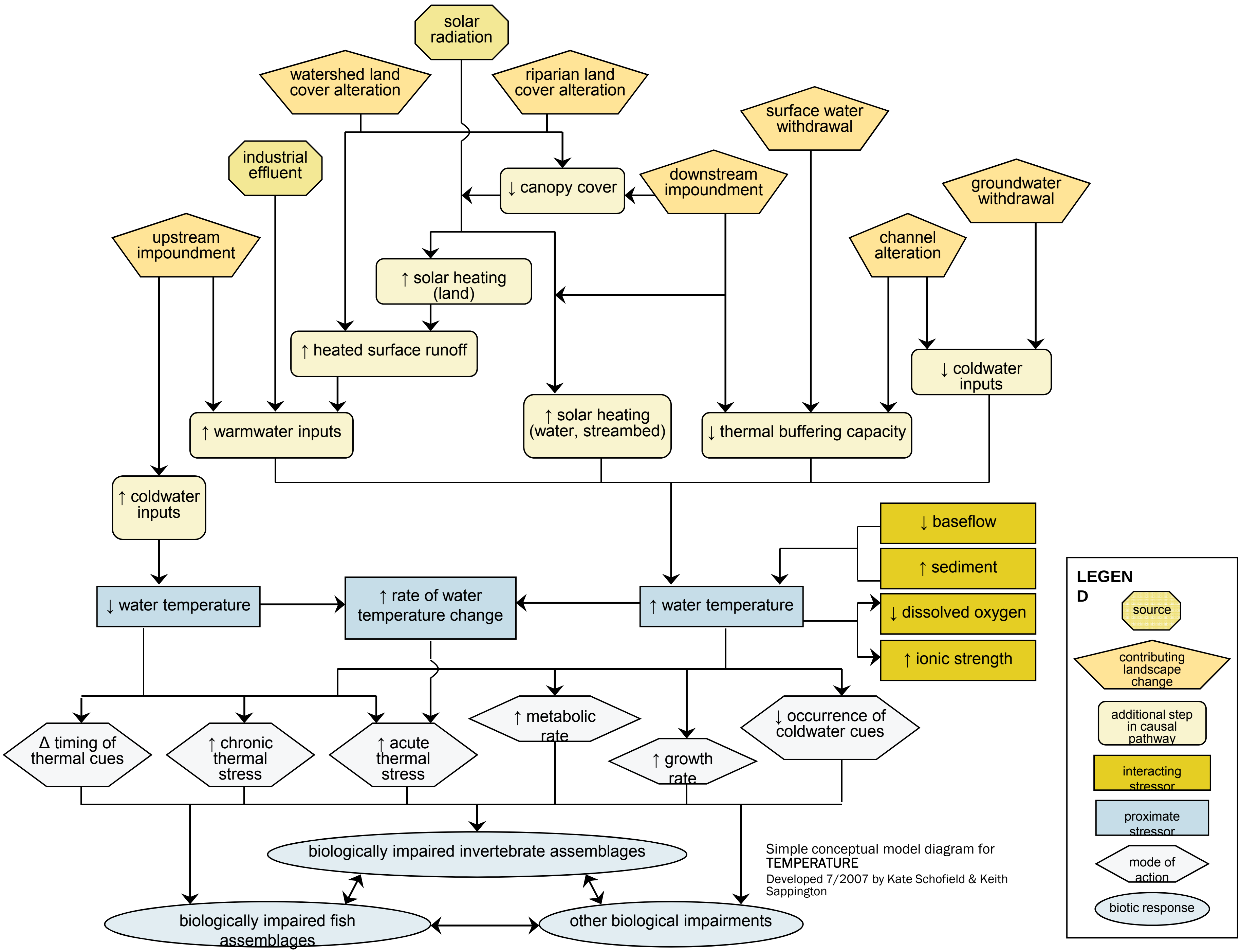
- **Metals**
- **Sediments**
- **Nutrients**
- **Dissolved oxygen**
- **Temperature**
- **Ionic strength**
- **Flow alteration**
- **Unspecified toxic chemicals**
- Ammonia
- Instream habitat
- pH
- Insecticides
- Herbicides

Developing a conceptual model

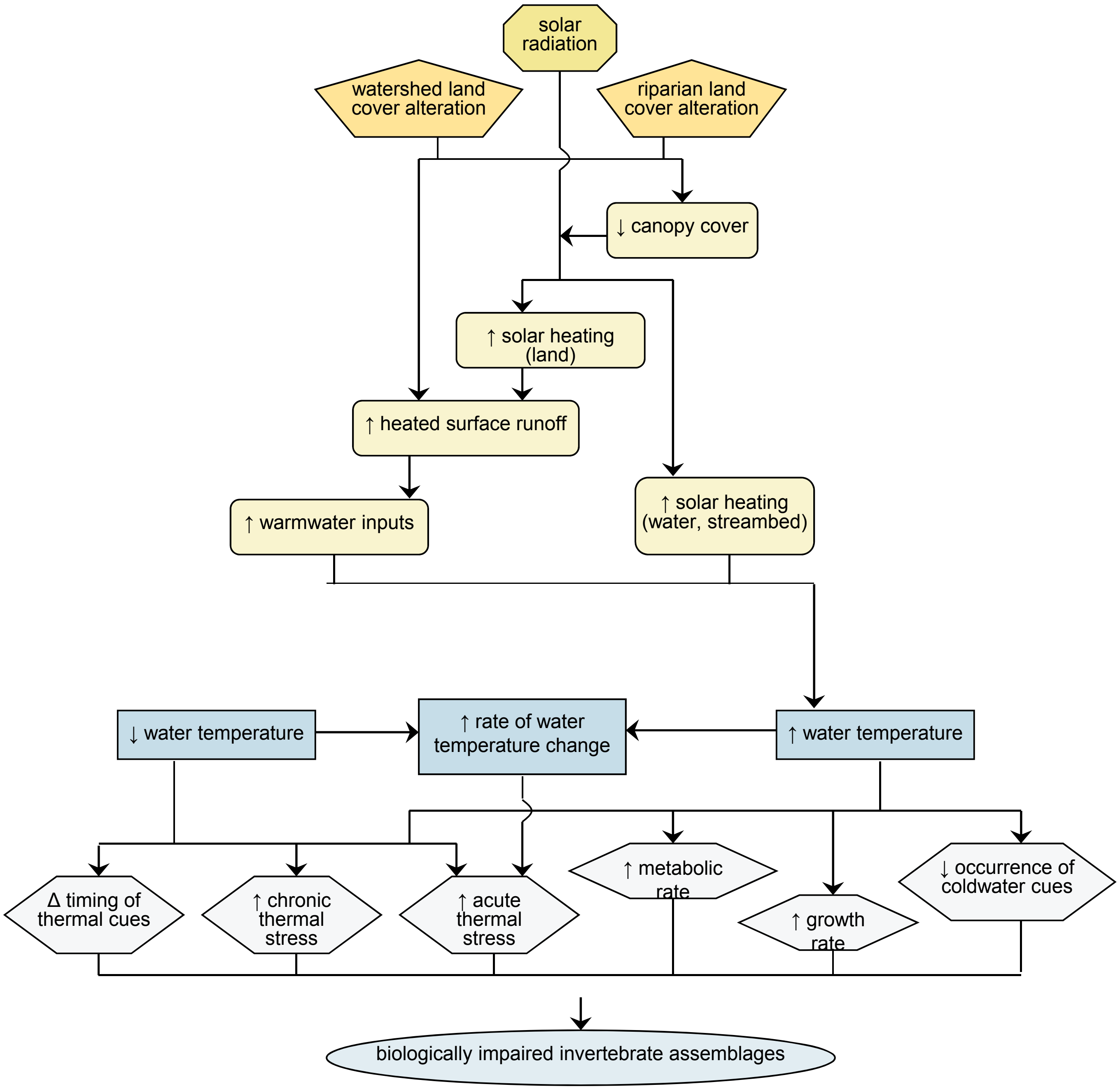
- What is it?
  - Diagram showing cause-effect linkages among sources, stressors, & biological effects

- Used for:
  - Initial brainstorming
  - Framework for analysis
  - Communication tool

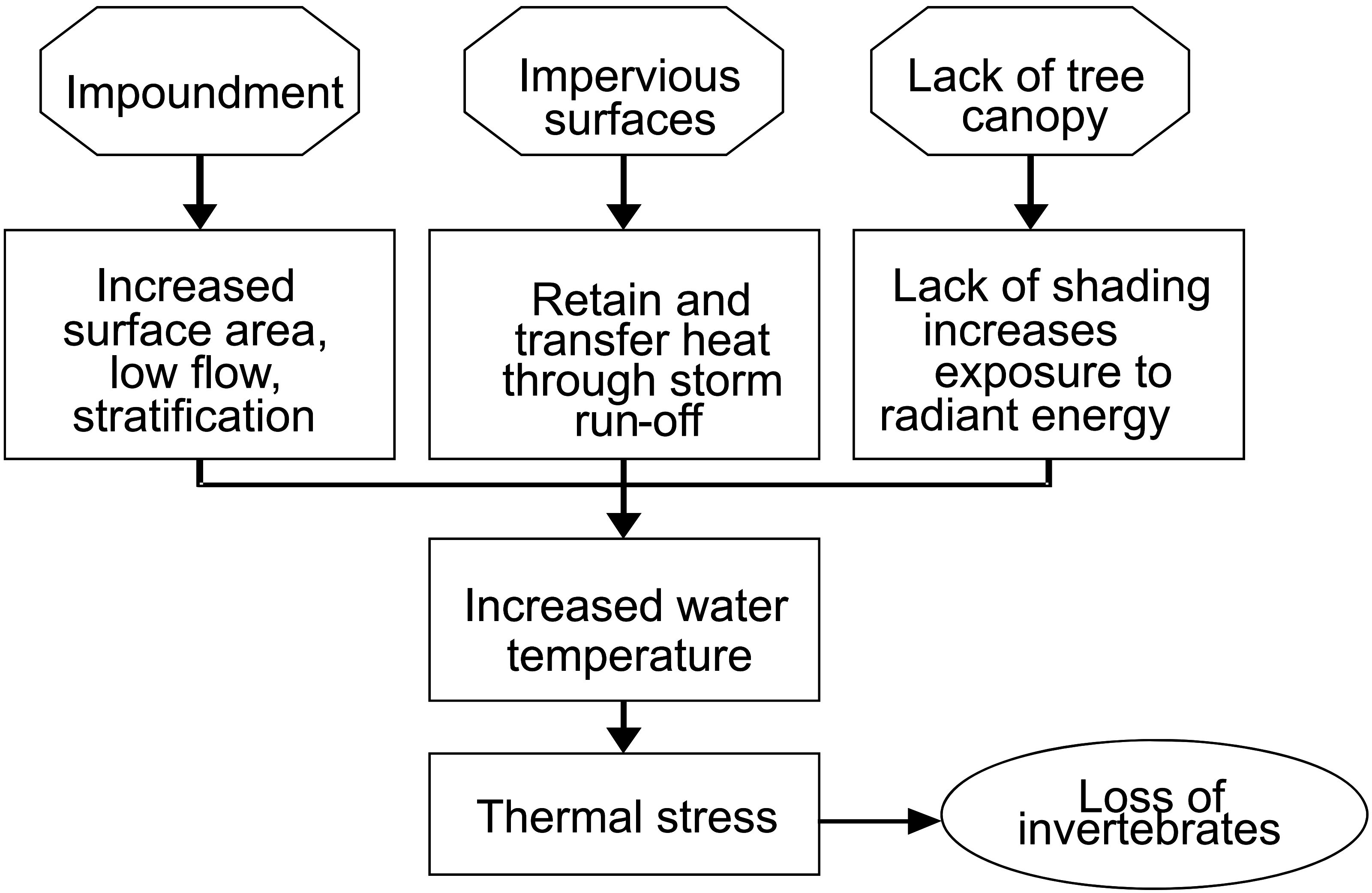




Simple conceptual model diagram for **TEMPERATURE**
Developed 7/2007 by Kate Schofield & Keith Sappington

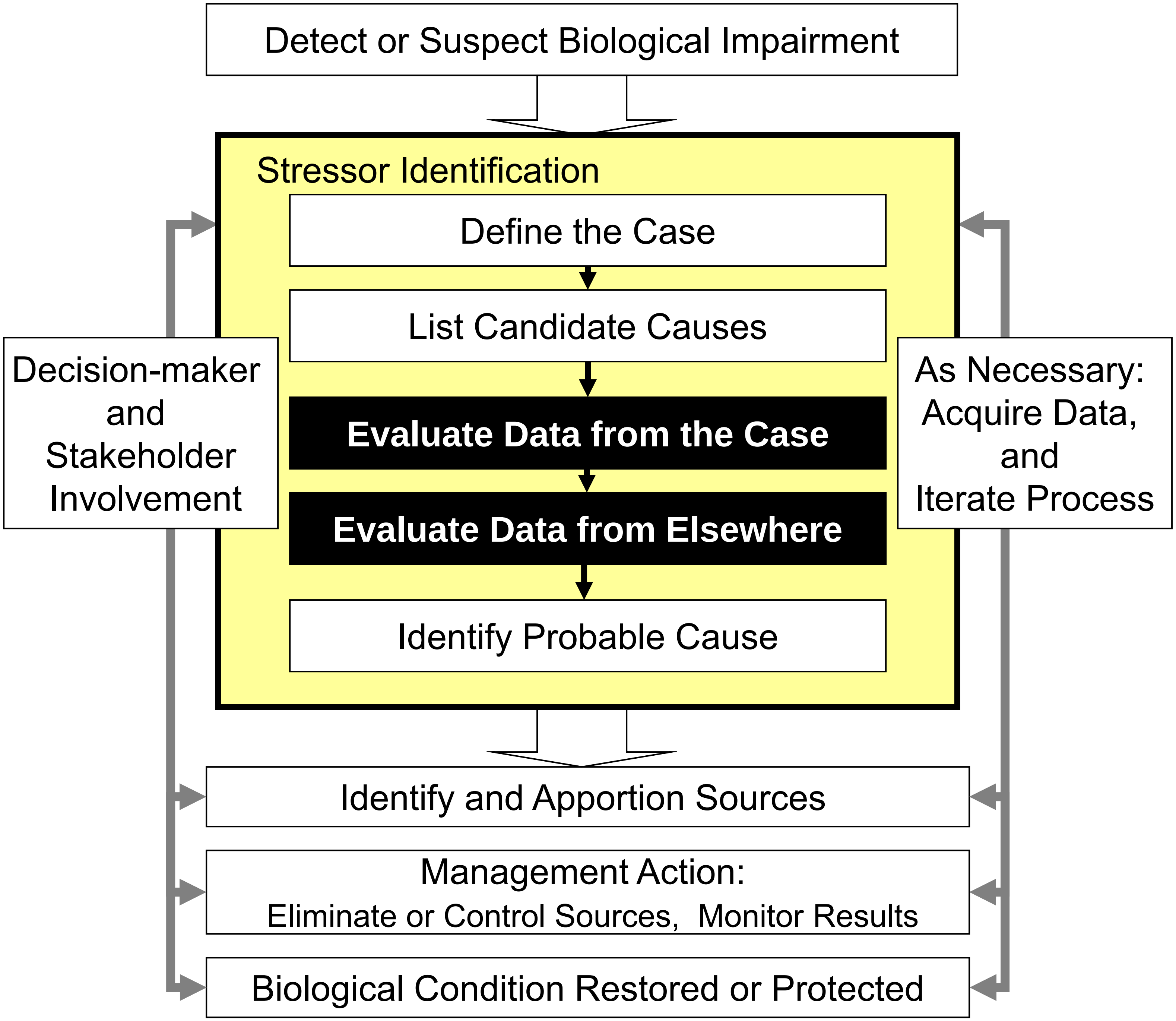

solar radiation
watershed land cover alteration
riparian land cover alteration
↓ canopy cover
↑ solar heating (land)
↑ heated surface runoff
↑ warmwater inputs
↑ solar heating (water, streambed)
↓ water temperature
↑ rate of water temperature change
↑ water temperature
Δ timing of thermal cues
↑ chronic thermal stress
↑ acute thermal stress
↑ metabolic rate
↑ growth rate
↓ occurrence of coldwater cues
biologically impaired invertebrate assemblages

Conceptual Model for Temperature



Candidate Causes for Willimantic

- Metals
- Ammonia
- Low Dissolved Oxygen
- Elevated water temperature
- Altered flow regime
- Altered food resources
- Embedded substrate
- Altered habitat
- Toxic mixture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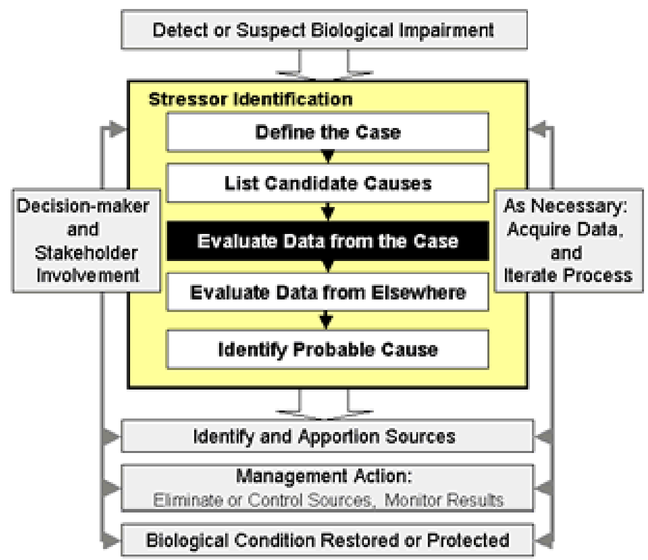
Step 3: Evaluate Data from the Case

3.1. Overview | 3.2. In-Depth Look | 3.3. Results and Next Steps

In Step 3, you assemble and analyze data from the case at hand, with two goals in mind:

- To develop consistent and credible evidence that allows you to confidently eliminate very improbable causes, or to use symptoms to refute or diagnose a cause, and
- To begin building the body of evidence for those candidate causes that cannot be eliminated or diagnosed, which will be used in Step 5 to identify the most probable causes.



Analyses conducted during this step combine measures of the biological response (e.g., trout abundance or invertebrate taxonomic richness) with direct measures of proximate stressors (e.g., toxicant concentrations or percent embeddedness values), or measures of other steps linking sources, candidate causes, and biological effects. For example, if low levels of dissolved oxygen (DO) constitute the candidate cause, data from the case may include actual dissolved oxygen measurements at the impaired and reference sites; evidence that organisms intolerant of low DO have declined at the impaired site; and/or measurements of increased organic matter (one potential step in the causal pathway) at the impaired site.

Data from the case can be used to address the following questions:

Questions that frequently can be addressed:

- Do the candidate cause and the effect occur in the same location?
- Is there a complete series of events linking the source to the causal agent?
- Does the magnitude of the effect increase with the magnitude of exposure to the causal agent?

Step 3: Evaluate Data from the Case

3.1. Overview | **3.2. In-Depth Look** | 3.3. Results and Next Steps

Causal analyses often begin with an examination of data from the case at hand. For example, a field biologist might observe that effects occur when a particular candidate cause is present, but do not occur when it is absent. Such associations provide the core of information used for characterizing causes. We recommend that associations from the case be evaluated first, because they can be powerful enough to eliminate candidate causes from further consideration.

Associations derived from other cases or biological knowledge cannot be used to refute a candidate cause, but can provide useful supplemental information for comparing strength of evidence. For example, a common assessment method compares ambient chemical concentrations with concentrations causing effects in laboratory studies; however, this type of evidence has substantial uncertainties associated with the type of laboratory organisms, extrapolation from lab to field, and so on. This and other types of evidence that bring in data from outside of the case are described in Step 4.

Links to Types of Evidence that Use Data from the Case

[-] Types of Evidence that Use Data from the Case

Back to Evaluate Data from the Case: In-Depth Look

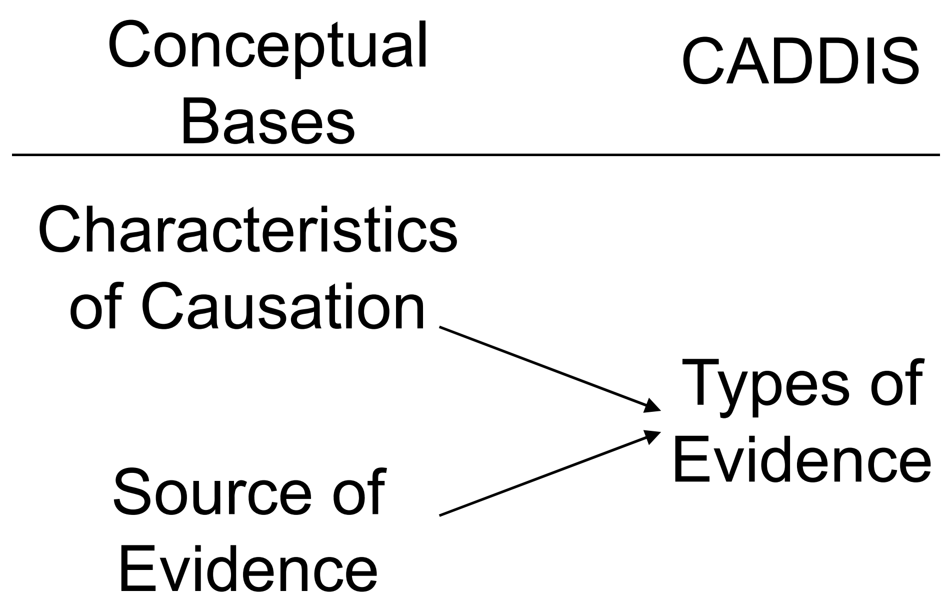
Assembling the Data

In Step 1, the biological impairment was defined and measurements were assembled that could be used to generate evidence to support or weaken a causal linkage in the causal pathway. In Step 2, candidate causes are selected for the analysis that occurs in Step 3and 4. In Step 3, the evidence is developed. The strongest type of evidence either supports the relationship between a candidate cause (a proximate stressor) and the biological impairment. However, other parts of the causal pathway can also be analyzed and provide evidence. More detail is provided in Data Sources which discusses data from the case and Organizing Data along Causal Pathways which lists the types of measurements that might be used to develop evidence.

We recommend developing a table that clearly shows the measurements that are available, and how they relate to each candidate cause (example tables of measurements). For evaluating uncertainty and data quality, additional tables should show the number and type of samples and provide references for the methods.

Definition

Types of evidence are categories of relationships that provide logically distinct ways to support, weaken, or refute the case for a candidate cause.


Conceptual Bases
CADDIS
Characteristics of Causation
Source of Evidence
Types of Evidence

Why so many types of evidence?

- Helps make sure that potential sources of evidence are not overlooked
- The label associated with a particular piece of evidence is not important – just make sure you don’t double count

Use **all available types of evidence** to make an inferential assessment

Types of evidence using data from the case

- ***Spatial/temporal co-occurrence***
- Evidence of exposure or biological mechanism
- ***Causal pathway***
- ***Stressor-response relationships from the field***
- Manipulation of exposure
- Laboratory tests of site media
- Temporal sequence

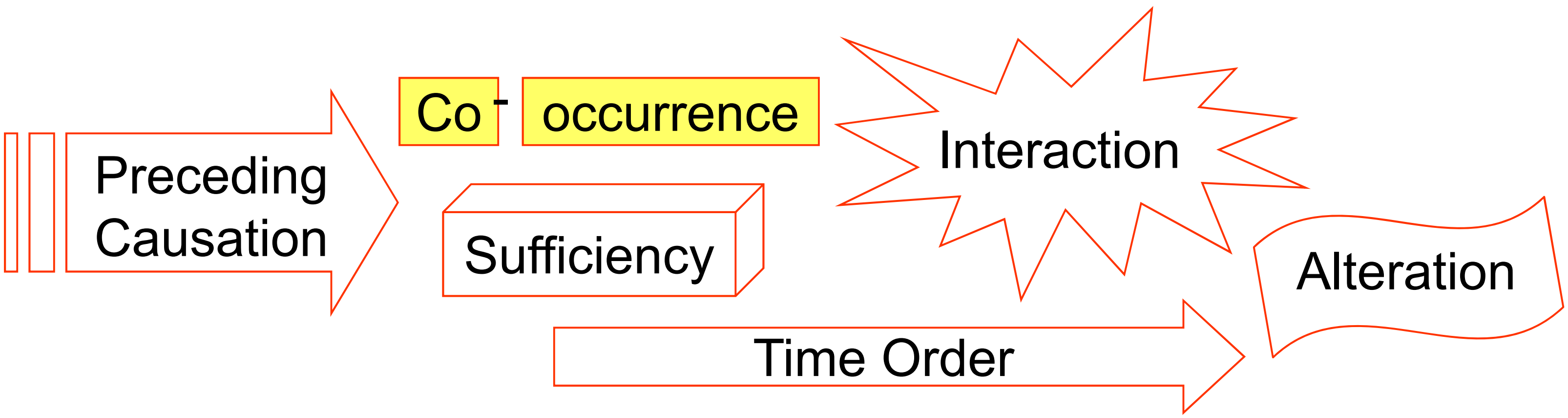
Types of evidence using data from elsewhere

- ***Stressor-response relationships from other field studies***
- ***Stressor-response relationships from laboratory studies***
- Stressor-response relationships from ecological simulation models
- Mechanistically plausible cause
- Manipulation of exposure at other sites
- Analogous stressors
- Verified predictions
- Symptoms

Blue bold italics indicates commonly available types of evidence

Characteristics of Causation

Modified from Hill's Criteria

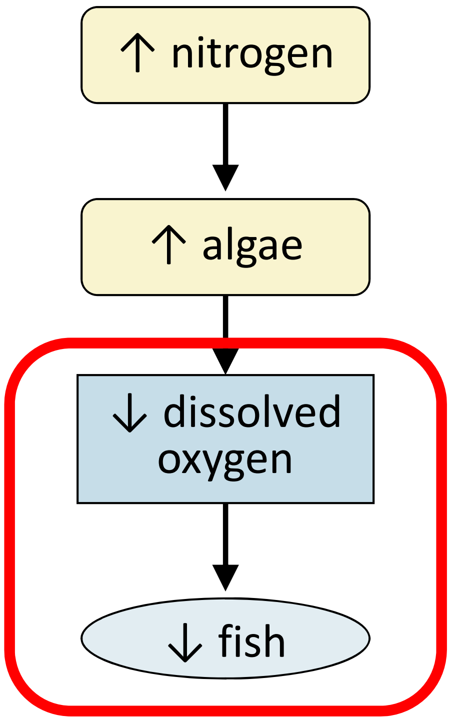


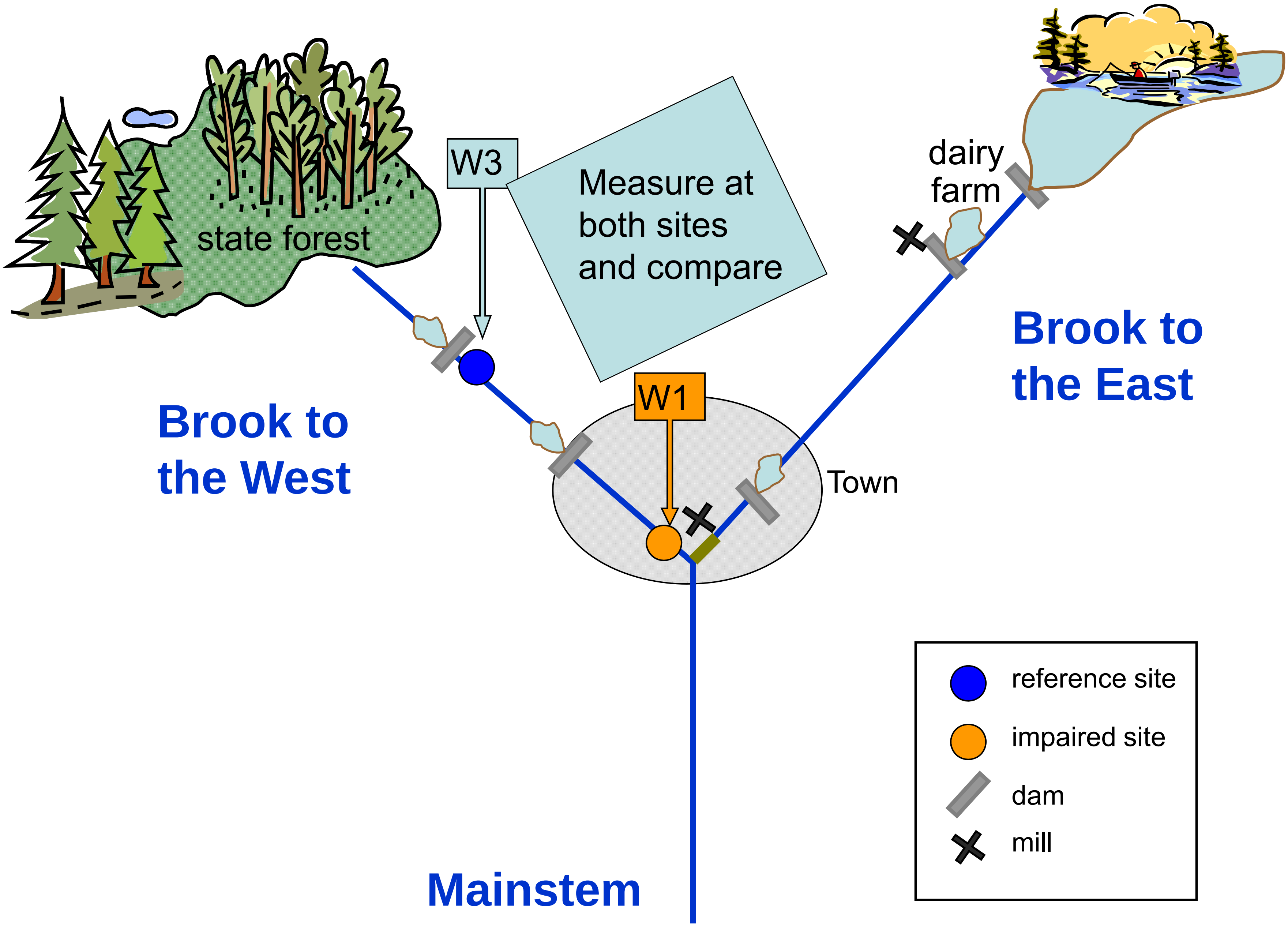
Co-occurrence	The cause co-occurs with the unaffected entity in space and time

Spatial/temporal co-occurrence

Issues & recommendations:

- Simple comparison – is exposure to proximate stressor greater where/when impairment occurs?
- Don’t consider whether magnitude of stressor is sufficient
  - Magnitude considered under “Stressor-response relationships from elsewhere”
- Consider uncertainty & variability in data set, but don’t rely on statistical tests
- Use only measurements of proximate stressor
  - Other measurements are considered under “Causal pathway”





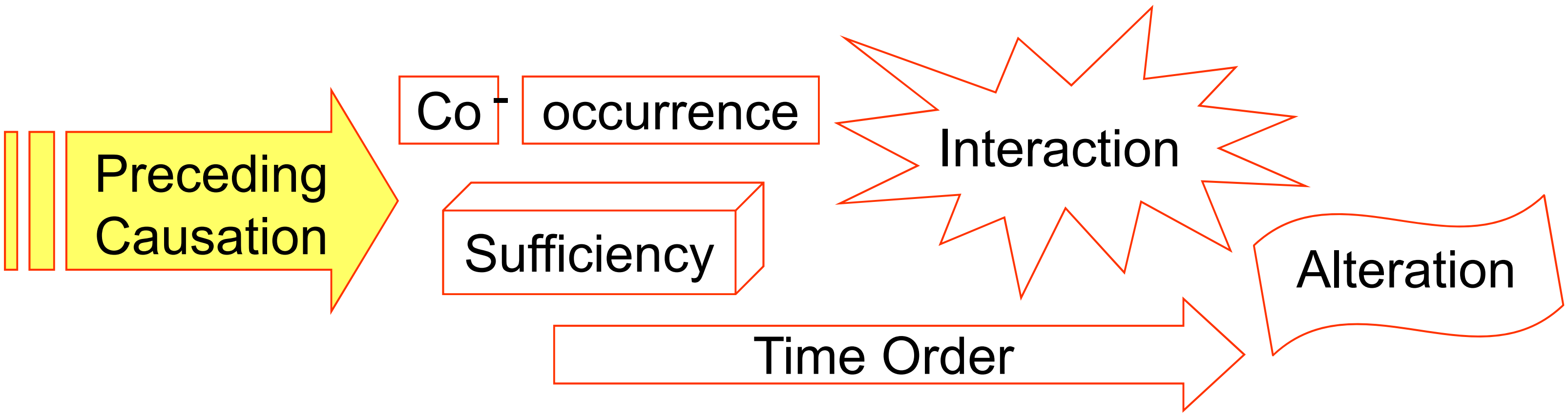
state forest
W3
Measure at both sites and compare
dairy farm
Brook to the East
Brook to the West
W1
Town
Mainstem
reference site
impaired site
dam
mill

Spatial/Temporal Co-Occurrence

Candidate Cause	Measurement	Upstream reference	Watershed reference	Impaired site		Adverse change compared to references	
1. Toxics	Total Metals and Ammonia (mg/L)	MR1	RB1	MR3		MR1	RB1
	Al	0.080	0.037	0.101		**Yes**	**Yes**
	Cd	0	0	0		No	No
	Cr	0	0	0.005		**Yes**	**Yes**
	Cu	0.004	0.004	0.005		**Yes**	**Yes**
	Fe	0.395	0.208	0.695		**Yes**	**Yes**
	Ni	0	0.001	0		No	No
	Pb	0.001	0	0.001		No	**Yes**
	Zn	0.006	0.004	0.011		**Yes**	**Yes**
	NH_3	0.1	0.1	0.1		No	No

Spatial/Temporal Co-Occurrence

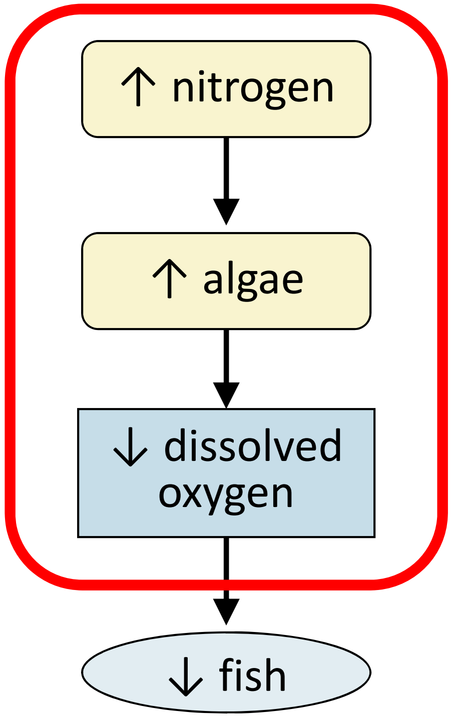
Spatial co-occurrence							
Candidate Cause	**Measurement**	**Upstream reference**	**Watershed reference**	**Impaired site**		**Advance change compared to references**	
2: High Flow	No Evidence						
		MR1	RB1	MR3		MR1	RB1
3: Embeddedness	% Silt Covered Substrate	0-25%	0-25%	50-75%		**Yes**	**Yes**
4: Low Dissolved Oxygen	Minimum Dissolved Oxygen (mg/L)	7.32[b]	10.17[b]	8.91[b]		No	Yes
5: Temperature Stress	Maximum Temperature	22.56°C[b]	17.28°C[a]	23.41°C[b]		**Yes**	**Yes**
6: Altered food resource	No Measurements						



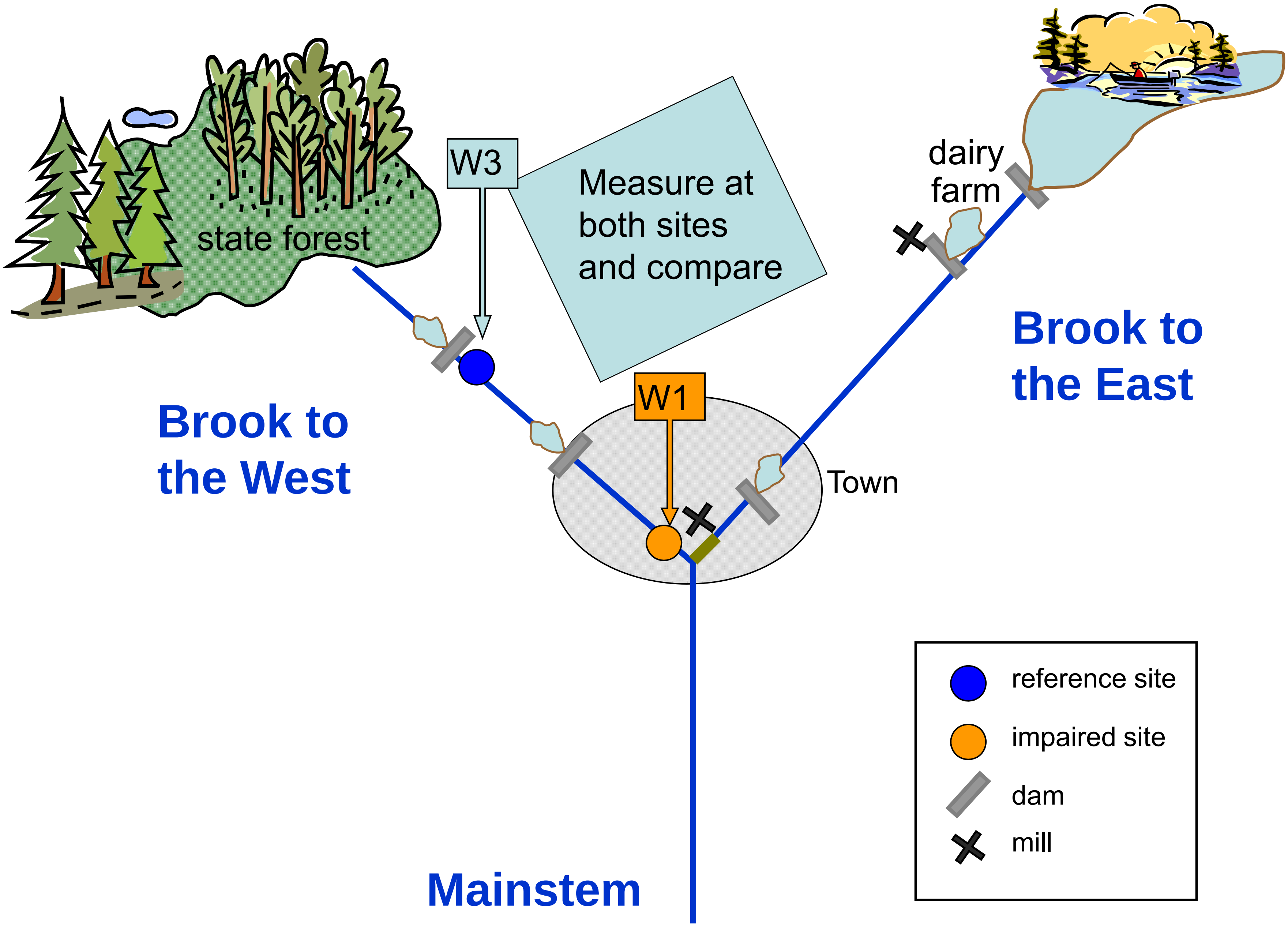
Preceding causation	Each causal relationship is a result of a larger web of cause and effect relationships

Causal pathway

Issues & recommendations:

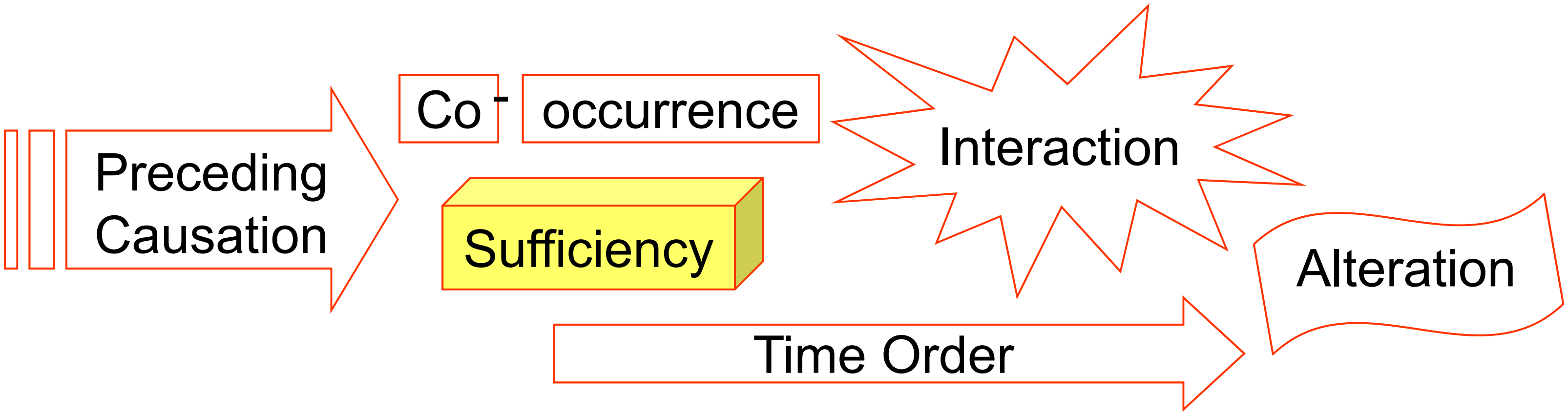


- Similar to spatial co-occurrence, but uses data from entire causal chain
- When in doubt, assume a step exists
- Evidence of missing step is powerful; evidence of many intermediate steps increases confidence
- May be able to eliminate one pathway but not eliminate all pathways
- Don't double-count evidence with spatial co-occurrence

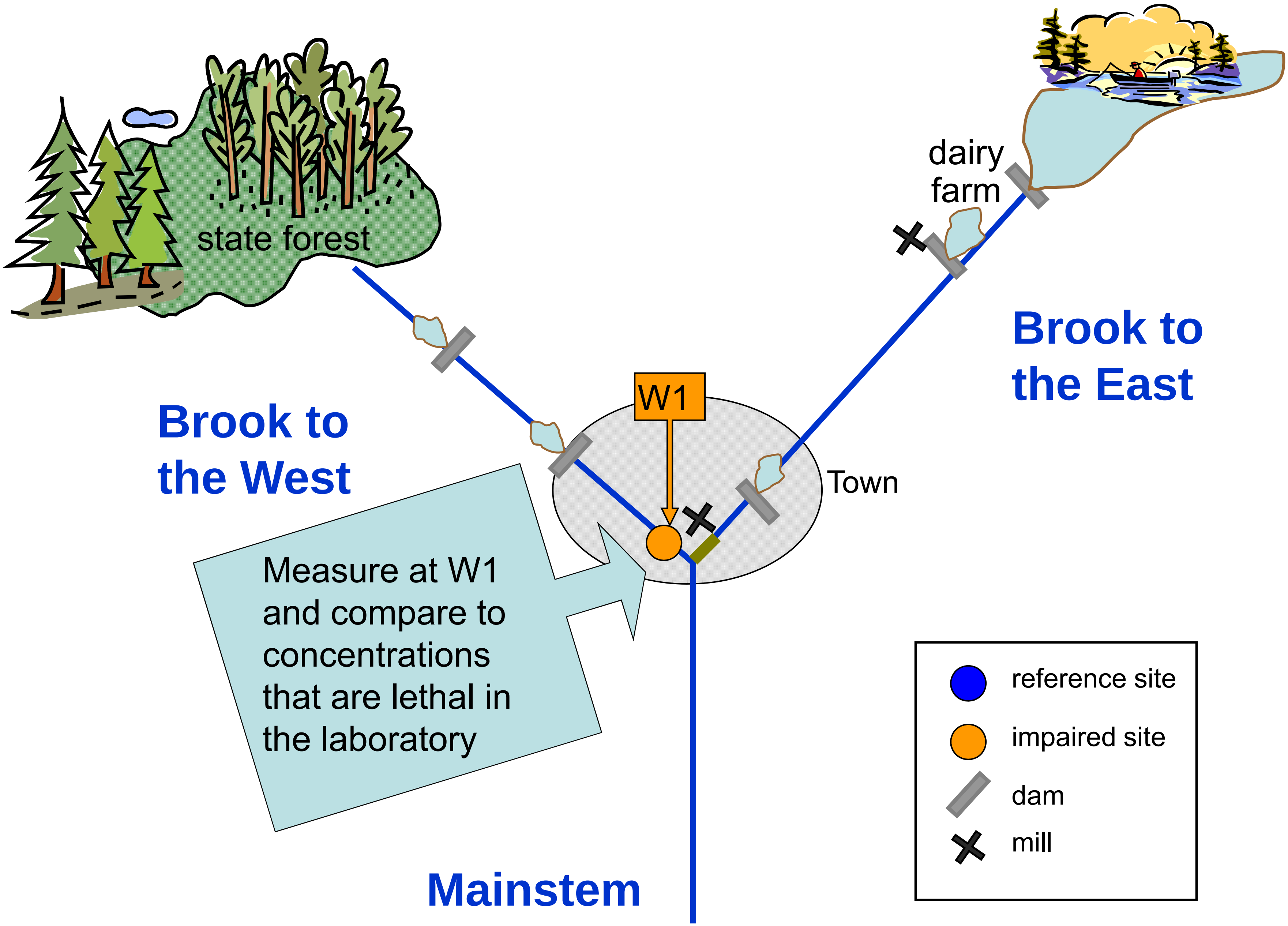

state forest
W3
Measure at both sites and compare
dairy farm
Brook to the East
Brook to the West
W1
Town
Mainstem
reference site
impaired site
dam
mill

Example: Causal pathway for Temperature

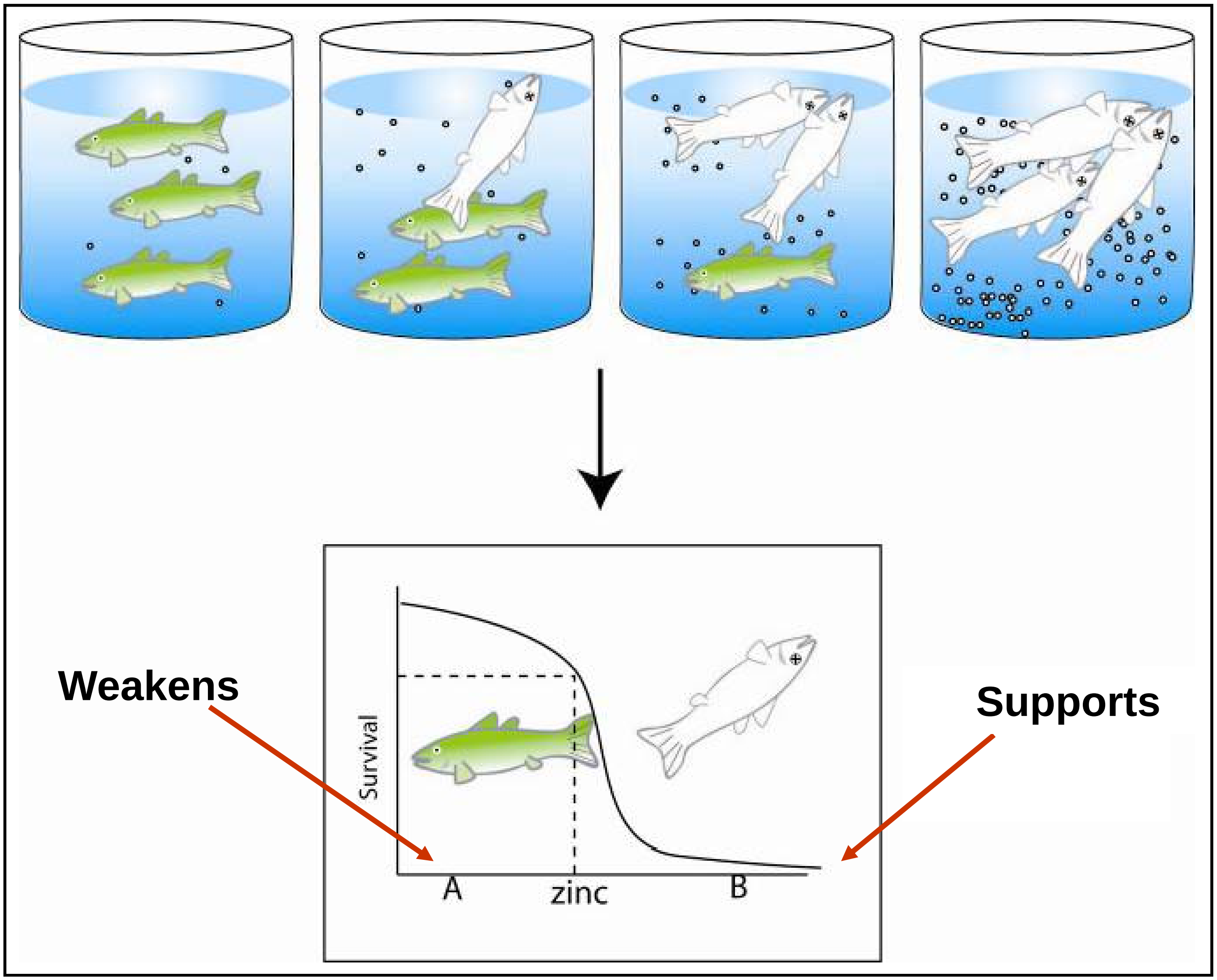
Data	Upstream Reference MR2	Watershed Reference RB1	Impaired Site MR3	Pathway Supported Compared To Both References
Impoundment	present	absent	present	No
Tree Canopy	Moderate	High	Low	**Yes**
Stormwater Outfalls	Some	No	More	**Yes**
% Impervious Surface	Low	Low	Moderate	**Yes**



Sufficiency	The intensity, frequency, and duration of the cause are adequate and the entity is susceptible to produce the type and magnitude of the effect


state forest
dairy
farm
Brook to
the East
W1
Brook to
the West
Town
Measure at W1
and compare to
concentrations
that are lethal in
the laboratory
reference site
impaired site
dam
mill
Mainstem

Stressor-response relationships from the lab



Example: stressor-response from lab studies

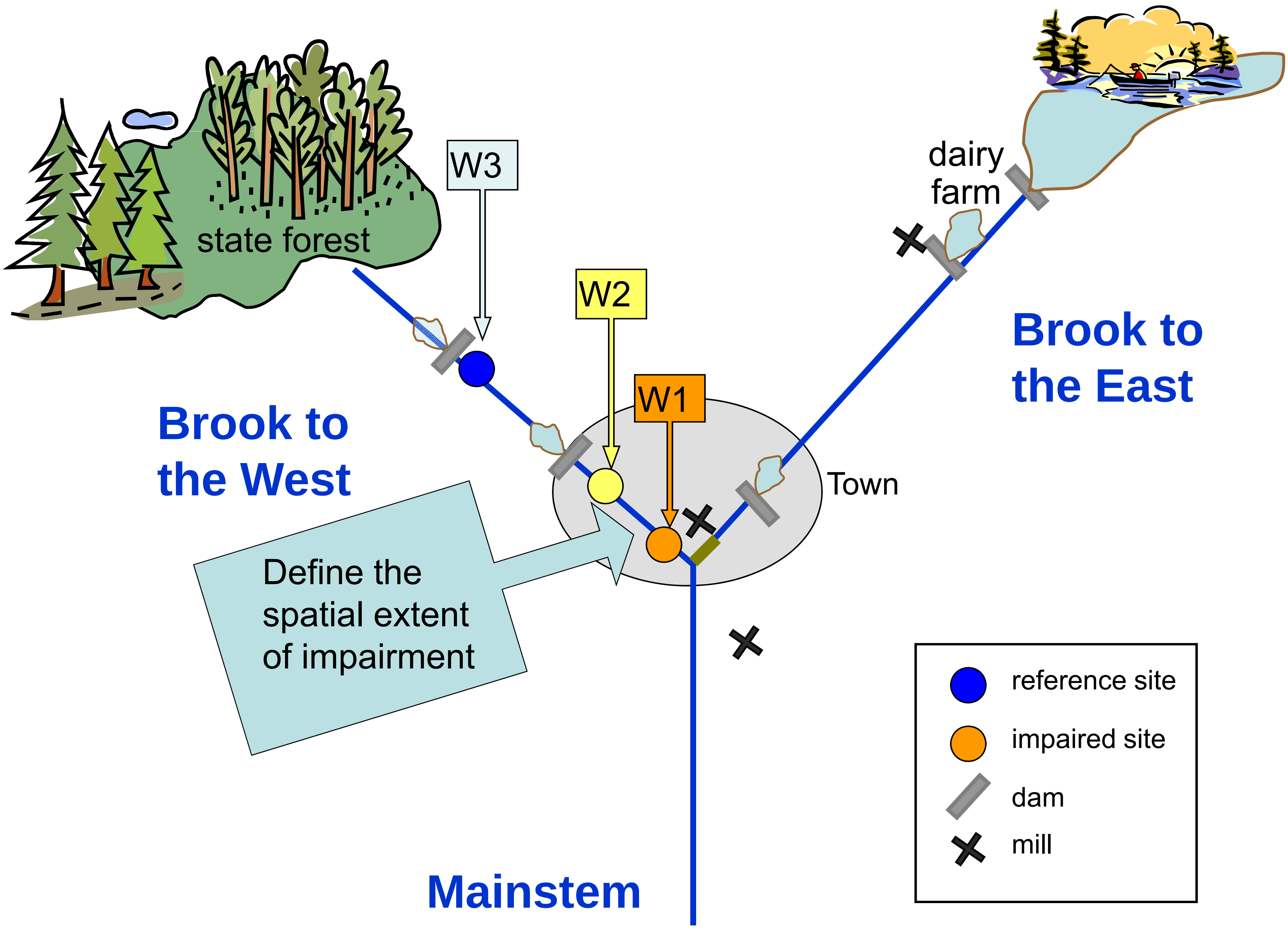
	CT Values (ug/L)	Daphnids (ug/L)	Test EC20	MR1	Exceeded at MR1?	MR3	Exceeded at MR3?
Al	None1	1900	540	82.2	No	107	No
Cd	0.62	0.15	0.75	0.4	Yes	0.5	Yes
Cr	100	<44	0.5	0.2	No	2	Yes
Cu	4.8	0.23	0.205	2.2	Yes	2.5	Yes
Fe	None1	4380	-	522.8	No	532	No
Ni	88	<5	45	0.2	No	0.3	No
Pb	1.2	12.3	-	0	No	0.8	No
Zn	58.2	46.73	-	6.5	No	8.6	No
NH3	1430-2470	630		120	No	100	No

Example: stressor-response from lab studies

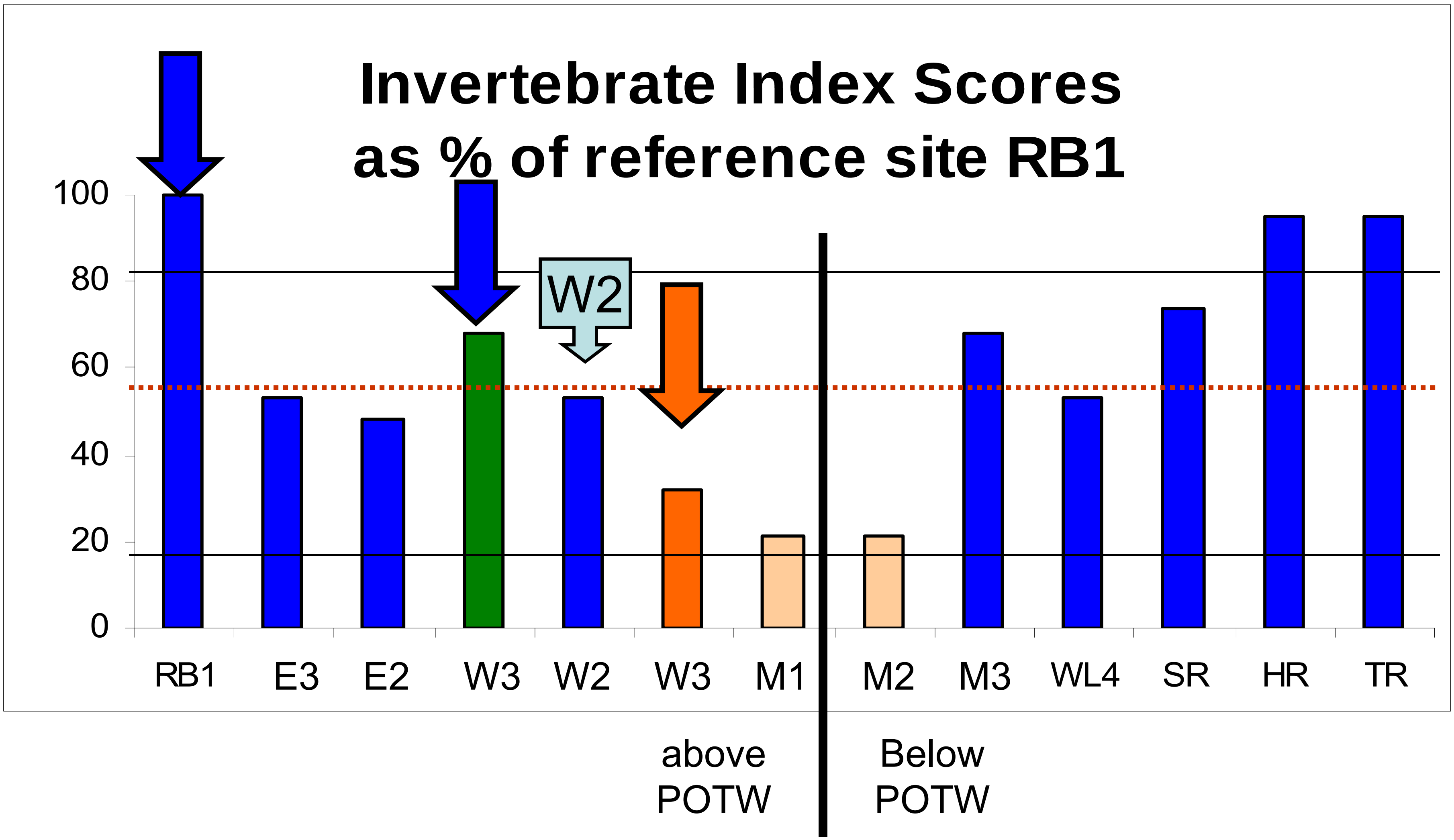
	CT Values (ug/L)	Daphnids (ug/L)	Test EC20	MR1	Exceeded at MR1?	MR3	Exceeded at MR3?
Cr	100	<44	**0.5**	0.2	No	**2.0**	**Yes**
Ni	88	<5	**45**	0.2	No	**0.3**	**No**

Example: stressor-response from lab studies

Plausible Stressor Response Evaluated by Sum of Partial Toxicity Based on Benchmarks for Test EC_{20} Values and Daphnids Lowest Chronic Values and Mean Ambient Concentrations from 1999–2000								
	Test EC_{20} (µg/L)	MR1 Reference	MR3 Impaired	WL1 Impaired	Lowest Chronic Value (µg/L)	MR1 Reference	MR3 Impaired	WL1 Impaired
Al	540	0.043	0.198	0.215	1900	0.043	0.056	0.061
Cd	0.75	0.533	0.667	0.667	0.15	2.667	3.333	3.333
Cr	0.5	0.400	4.000	3.400	<44	0.005	0.045	0.039
Cu	0.205	10.732	12.195	13.171	0.23	9.565	10.870	11.739
Fe	-	***0.119***	***0.121***	***0.109***	4380	0.119	0.121	0.109
Ni	45	0.004	0.007	0.007	<5	0.040	0.060	0.060
Pb	-	***0.000***	***0.065***	***0.146***	12.3	0.000	0.065	0.146
Zn	-	***0.139***	***0.184***	***0.154***	46.73	0.139	0.184	0.154
Total		***11.971***	***17.437***	***17.868***		12.578	14.735	15.642


state forest
W3
W2
W1
dairy
farm
Brook to
the East
Brook to
the West
Town
Define the
spatial extent
of impairment
reference site
impaired site
dam
mill
Mainstem

Define the Biological Impairment

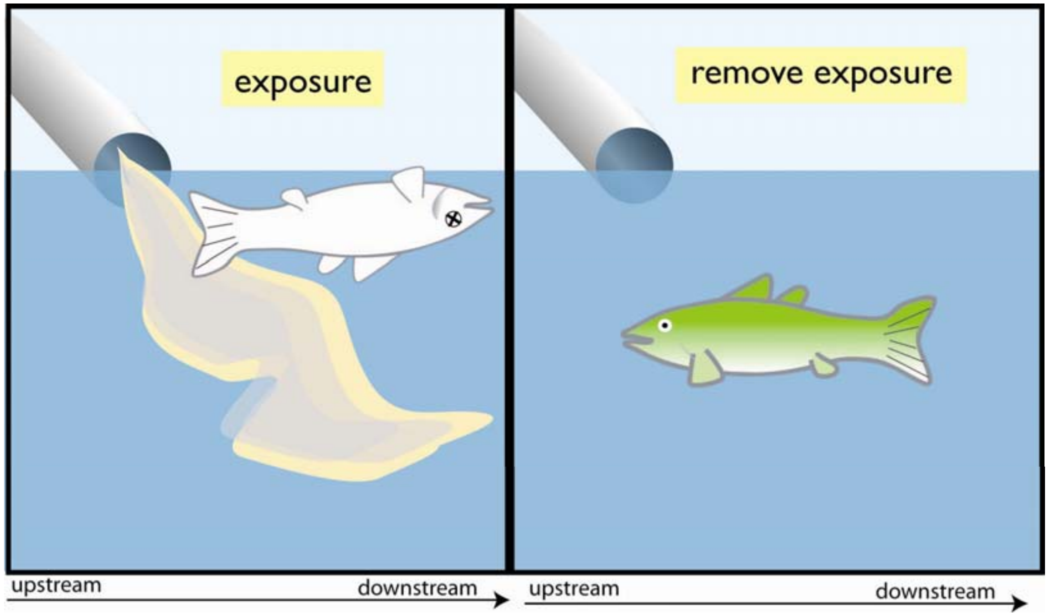


Define the Biological Impairment

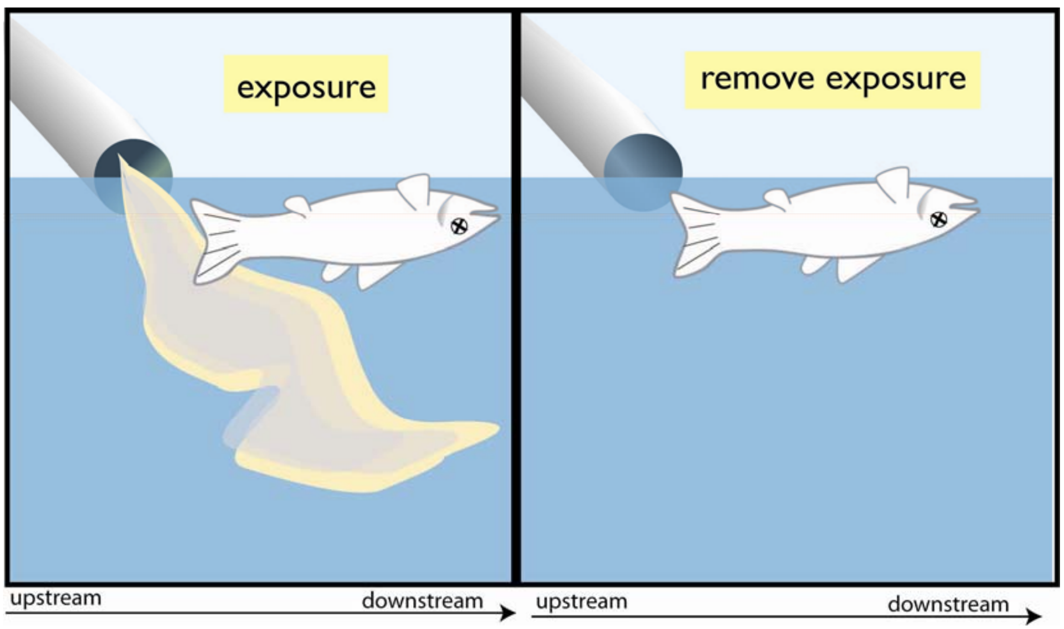
Effect	W2	W1	Change
Number of EPT Taxa	13	5	Decrease


Illicit discharge observed
upstream from impairment

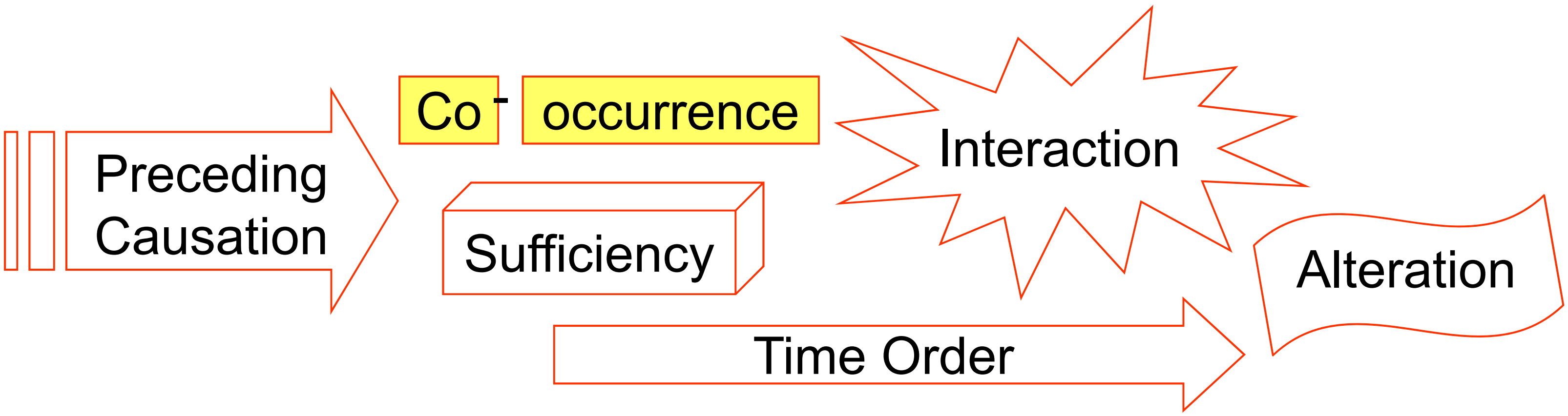
Manipulation of Exposure



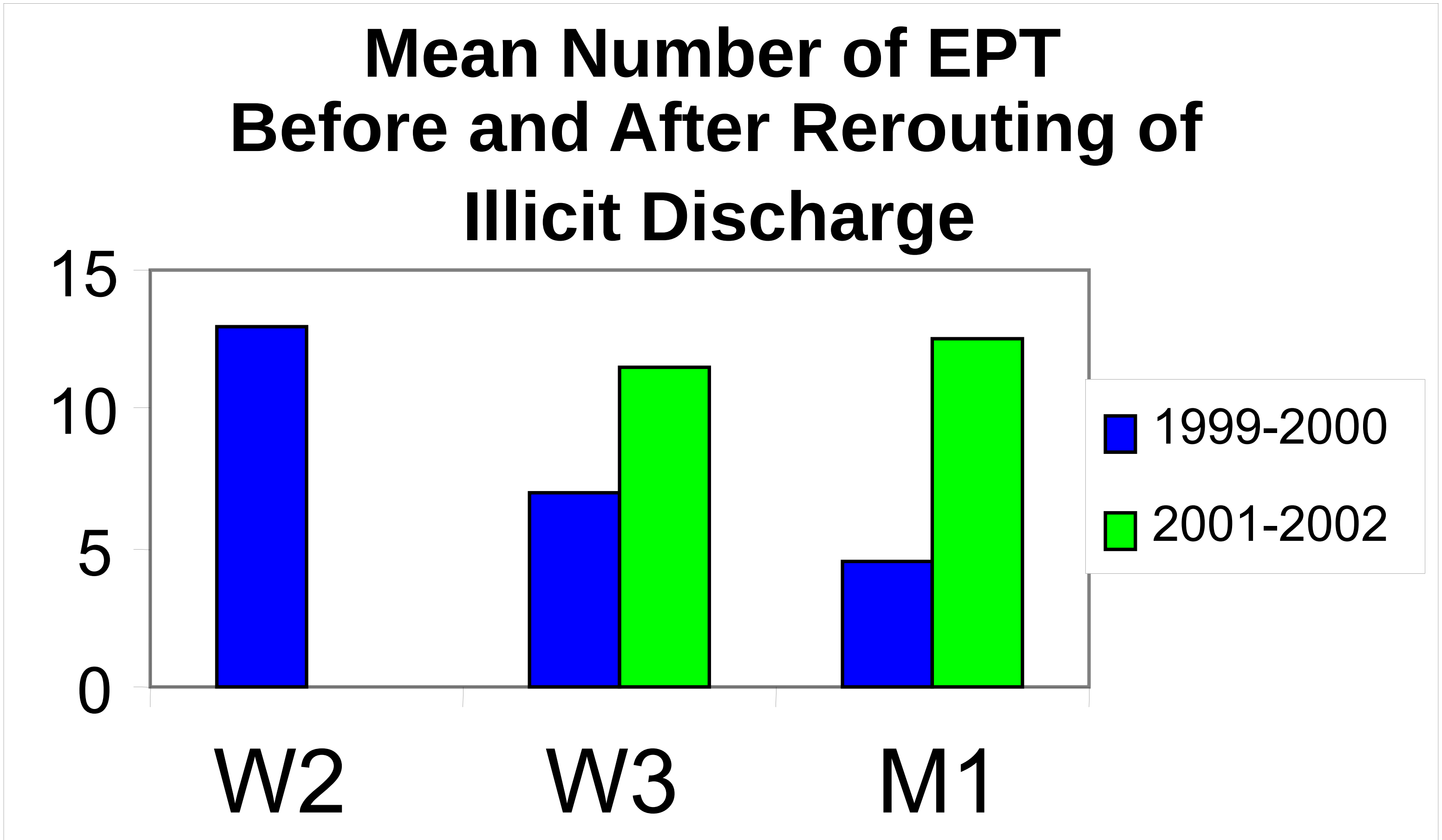
Supports



Weakens


Preceding Causation
Co - occurrence
Sufficiency
Interaction
Alteration
Time Order

Manipulation of Exposure



How we identify probable causes

- Eliminate when you can
- Diagnose when you can
- Otherwise, analyze **strength of evidence**

HOW?

Apply a **scoring system** to the available evidence under each type of evidence

The scoring system

R	refutes	
D	diagnoses	
+++	convincingly supports	(or weakens - - -)
++	strongly supports	(or weakens - -)
+	somewhat supports	(or weakens -)
0	neither supports nor weakens	
NE	no evidence	

Willimantic case study		Metals	NH_3	Flow	Silt	Low DO	Temp	Food	Episodic Mix
Types of Evidence that Use Data from the Case									
Preceding Causation	Causal Pathway		-	+	-	-	+	-	+
	Verified Predictions								+ + +
Co-Occurrence	Spatial/Temporal Co-Occurrence	+	-		+	- - -	+		+
	Manipulation of Exposure								+ + +
Sufficiency	Stressor-Response from the Field/Case	+	-		-	+	+		
Alteration	Evidence of Biological Mechanism	+	+	+	-	+	+	-	+
Types of Evidence that Use Data from Elsewhere									
Sufficiency	Stressor-Response from Other Field	- -	+						
	Stressor-Response from Laboratory	+ +	-			-	+		
Evaluating Multiple Types of Evidence									
Consistency of Evidence		-	-	-	-	-	+	-	+ + +

What could we have used here? WET test. TIE.

Scoring of spatial/temporal co-occurrence

+	The effect occurs where or when the candidate cause occurs, OR the effect does not occur where or when the candidate cause does not occur.
0	It is uncertain whether the candidate cause and the effect co-occur.
- - -	The effect does not occur where or when the candidate cause occurs, OR the effect occurs where or when the candidate cause does not occur.
R	The effect does not occur where or when the candidate cause occurs, OR the effect occurs where or when the candidate cause does not occur, AND the evidence is indisputable.

Scoring of laboratory tests of site media

+++	Laboratory tests with site media show clear biological effects that are closely related to the observed impairment.
+	Laboratory tests with site media show ambiguous effects, OR clear effects that are not closely related to the observed impairment.
0	Laboratory tests with site media show uncertain effects.
-	Laboratory tests with site media show no toxic effects that can be related to the observed impairment.

Qualities of Evidence and Descriptors

Relevance to effect
- From the case
- From other similar situations

Nature of the association
- quantitative
- qualitative

Logical implication
- negative
- positive

Directness of cause
- proximate cause
- sources & intermediate causal connections

Strength of association
- strong relationships and large range
- weak relationships and small range

Independence of association
- independent
- confounded

Specificity
- Effect due to only one cause

Effect due to multiple causes

Quantity of information
- many data
- few data

Quality of information
- good study
- poor study

Recap

- Strongly recommend using a formal method with scoring process
- Evidence from the case is usually the most relevant and therefore the stronger evidence
- Evidence for all candidate causes are developed
- Screening assessment are helpful for finding definitve evidence

Combining stressors

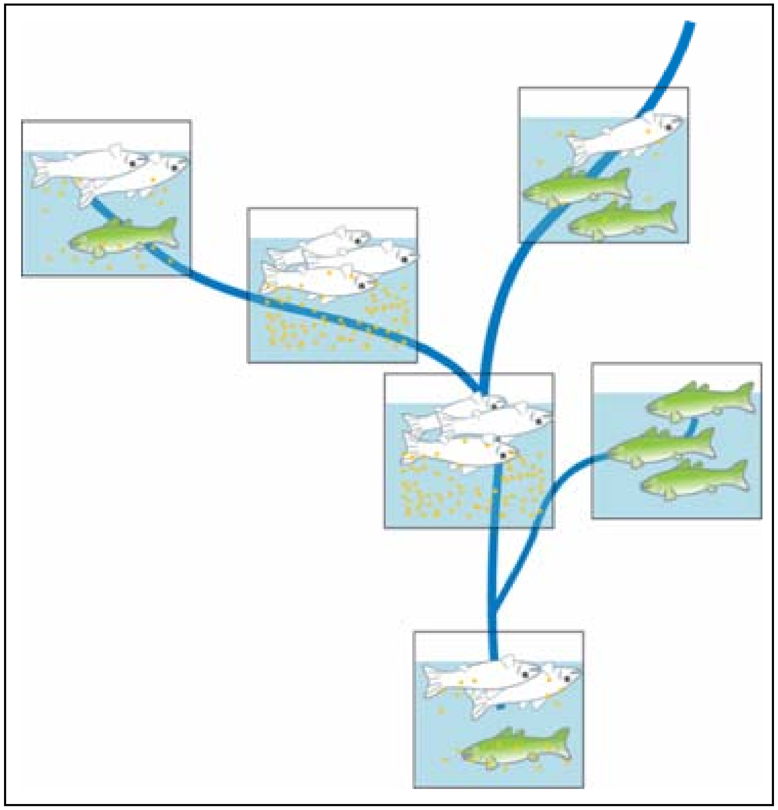
- Strategies
  - Combine if they share causal pathways, modes of action, sources & routes of exposure, or if they interact
  - Re-aggregate stressors that have been unnecessarily disaggregated
  - Identify independently acting stressors that cause the same effect
  - Define effects more specifically

- Warnings
  - Avoid combining causes without an underlying model
  - Avoid broad candidate cause definitions
  - Don't lose independent effects of individual causes

Stressor-response relationships from the field

Issues & recommendations:

- Evaluate direction & strength of relationship
  - Look at r & r^2
  - Look at sign
- Be wary of statistical tests
- Beware of confounders
- Works best if sites are contiguous



Stressor-response relationships from other field studies

The benefits…

- Relevant data often available
- Can use for stressors not usually tested in lab

…and the potential drawbacks…

- Co-varying stressors
- Influence of biotic interactions
- Site equivalence (e.g., in terms of ecoregion, gradient)
- Measurement & sampling design equivalence
- Extent of stressor gradient
- Analytical issues (e.g., wedge plots)

Stressor-response relationships from laboratory studies

The benefits…

- Confident relationship is causal, because exposures controlled, randomized & replicated

…and the potential drawbacks…

- Need to extrapolate to your response of interest
- Lab conditions may not represent field exposures
- Stressor variables usually tested singly
- Organisms tested in isolation (no biotic interactions)
- Use criteria values with caution, as they are intended to be protective & may not be effects-based

Stressor-response caveats

- Response for which you have data will probably not be response of interest
  - in lab, test organisms usually differ
  - in field, species differ across regions (EPT ≠ EPT)
- Test system will differ from system of interest
  - lab to field extrapolations
  - differing covariates mean that regional stressor-response curves may not have predictive value for your site
- Water quality criteria correspond to protective levels, so difficult to interpret exceedances

Scoring of stressor-response from other field studies

++	The stressor-response relationship in the case agrees quantitatively with stressor-response relationships from other field studies.
+	The stressor-response relationship in the case agrees qualitatively with stressor-response relationships from other field studies.
0	Agreement between the stressor-response relationship in the case and stressor-response relationships from other field studies is ambiguous.
-	The stressor-response relationship in the case does not agree with stressor-response relationships from other field studies.
- -	There are large quantitative differences or clear qualitative differences between the stressor-response relationship in the case and the stressor-response relationships from other field studies.

Scoring consistency & credibility

Consistency of Evidence	All available types of evidence support the case for the candidate cause.	+ + +
	All available types of evidence weaken the case for the candidate cause.	- - -
	All available types of evidence support the case for the candidate cause, but few types are available.	+
	All available types of evidence weaken the case for the candidate cause, but few types are available.	-
	The evidence is ambiguous or inadequate.	0
	Some available types of evidence support and some weaken the case for the candidate cause.	-
Explanation of the Evidence	There is a credible explanation for any negative inconsistencies or ambiguities in an otherwise positive body of evidence that could make the body of evidence consistently supporting.	+ +
	There is no explanation for the inconsistencies or ambiguities in the evidence.	0
	There is a credible explanation for any positive inconsistencies or ambiguities in an otherwise negative body of evidence that could make the body of evidence consistently weakening.	-