Analyzing Data to Characterize Your Watershed

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Steps in the Watershed Planning and Implementation Process

• Characterize the Watershed
• Identify causes and sources of pollution that need to be controlled
• Estimate pollutant loads

• Incorporation of the nine minimum elements

• Finalize Goals and Identify Solutions
• Identify critical areas
• Develop management measures to achieve goals

• Design an Implementation Program
• Develop implementation schedule
• Develop interim milestones for track implementation of management measures
• Develop approach to measure progress toward meeting watershed goals
• Develop monitoring component
• Develop information/education component
• Develop evaluation process
• Assign responsibility for reviewing and revising the plan

Water quality info & analysis

• Water quality goals
  - Designated uses, WQ criteria
  - Restoration and protection goals
  - Flooding, aesthetics, others???
• Monitoring and assessment result
  - Desktop data mining, local monitoring results
  - 1D impaired & threatened waters
• Key pollutants / stressors
  - Check 303(d); local monitoring/assessment
• Pollutant sources
  - From 303(d) or other assessment
• Current loads
  - Estimate, model, or otherwise quantify

Types of Data for Watershed Characterization

• Physical and Natural Features
  - Watershed boundaries
  - Hydrology
  - Topography
  - Soils
  - Climate
  - Habitat
  - Wildlife
• Land Use and Population Characteristics
  - Land use and land cover
  - Existing management practices
  - Demographics
• Waterbody Conditions
  - Water quality standards
  - 305(b) report
  - 303(d) list
  - TMDL reports
  - Source Water Protection Areas
• Pollutant Sources
  - Point sources
  - Nonpoint sources
• Waterbody Monitoring Data
  - Water quality data
  - Flow data
  - Biological data

E. Br. Coon Creek at Armada Center Rd.
Load Duration Curve (2004 Monitoring Data)
Site: EBC2

How can we estimate loads?

What is a “load?”

• Maybe measured by weight:
  - Kilograms per day
  - Pounds per week
  - Tons per month

• Maybe not:
  - Concentration-based expression of the “load” (e.g., milligrams per liter)
    • mg/L x L/day = mg/day (C = m/v)
  - # of miles of streambank needing stabilization or vegetation
  - # of AFOs requiring nutrient plans
  - % of urban area to be ‘perforated’

Existing loads come from lots of places.
Existing loads come from:

- **Point-source discharges (NPDES facilities)**
  - Info is available on the discharges (DMRs, etc.)
  - Some are steady-flow, others are precip-driven
- **Nonpoint sources (polluted runoff)**
  - All are (mostly) precip-driven
  - Calculating the “wash-off, runoff” load is tough
  - Literature values can be used to estimate
  - Modeling gets you closer...do you need it?
- **Air / atmospheric deposition**
  - Can be significant in some locations

Identification of causes & sources

- **What “pollutants” are you dealing with?**
  - Chemical or other stressors or causes of impairment
- **How big is the problem for each?**
- **How do you know?**
  - Did you “measure” them?
  - Did you estimate? How?
- **Where are they coming from?**
  - Can you put the info on a map?
- **Can you estimate the % from each source?**

Data-driven Approaches

- **Estimate source loads using:**
  - Monitoring data
    - Periodic water quality concentrations and flow gauging data
    - Facility discharge monitoring reports
  - Literature
    - Loading rates, often by landuse (e.g., lbs/acre/year)
    - Typical facility concentrations and flow

Is a Data-driven Approach Appropriate?

- **Monitoring data**
  - Does it represent most conditions that occur (low flow, storms, etc.)?
  - Are spatial and source variability well-represented?
  - Have all parameters of interest been monitored?
  - Is there a clear path to a management strategy?

Load Estimates – Monitoring Data

- In simplest terms...
  \[ \text{load} = \text{flow} \times \text{concentration} \]
- **Load duration curves**
  - Flow-based presentation
- **Statistical techniques**
  - Relationships between flow and concentration to “fill in the blanks” when data aren’t available
  - Examples include:
    - Regression approach
    - FLUX
**Load Duration Curves**

- Rank daily flow and generate flow duration curve
- Multiply water quality concentrations by corresponding flow values

![Flow Duration Curve Diagram]

**Load Estimates - Literature**

- Landuse-specific loading rates (typically annual)
- Multiply loading rate by area:
  \[
  \text{load}_a = (\text{area}_{a1} \times \text{loading rate}_{a1}) + (\text{area}_{a2} \times \text{loading rate}_{a2}) + ...
  \]
- Generally for landuse or watershed-wide analysis
- Many sources: Lin (2004); Beaulac and Reckhow (1982), etc.
- Use with caution (need correct representation for your local watershed)
  - Pollution sources
  - Climate
  - Soils

**Example Load Estimation Based on Literature Values**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Load Estimation Method</th>
<th>Literature Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>Observed Flow Exceedence at KAIN18</td>
<td>Lin (2004)</td>
</tr>
<tr>
<td>COD</td>
<td>Calculated Flow Exceedence at KAIN18</td>
<td>Beaulac and Reckhow (1982)</td>
</tr>
</tbody>
</table>

**Limitations of Data-driven Approaches**

- Monitoring data
  - Reflect current/historical conditions (limited use for future predictions)
  - Insight limited by extent of data (usually water quality data)
    - Often not source-specific
    - May reflect a small range of flow conditions
- Literature
  - Not reflective of local conditions
  - Wide variation among literature
  - Often a “static” value (e.g., annual)

**Key Points:**

- Many tools are available to quantify pollutant loads
- Approach depends on intended use of predictions
- Simplest approaches are data-driven
- Watershed modeling is more complex and time-consuming
  - Provides more insight into spatial and temporal characteristics
  - Useful for future predictions and evaluation of management options
- **One size doesn’t fit all!**
Load assessment is an ongoing learning process—iterative & creative!

Identify Opportunities for Implementation
- Impervious analysis
- Political constraints and priorities
- Physical constraints
- Environmental constraints

Identify candidate practices

Quantifying Load Reductions to Meet Objectives
- Sources of load quantification data
  - Watershed modeling/load quantification results (previously described), TMDL reports, etc.
  - Source and spatial targets for implementation

Identify Optimal Solution
Example of BMP-DSS Multiple Run Output

Quantify BMP Options at a Subwatershed or Watershed Scale
- Goals
  - Quantify selected BMP strategies (i.e., individual BMPs or BMP pairings)
  - Watershed scale
  - Local scale
  - Compare potential load reductions to target
  - Determine optimal strategy considering environmental benefits and $$
- Available Tools
  - Spreadsheet tools
  - Watershed/site-scale models
Prioritizing/targeting BMPs

• Importance of waterbody
  - Drinking water source, recreational resource
• Magnitude of impairment(s)
  - Level of effort needed, public interest/attention
• Existing loads (stressors & sources)
  - Magnitude, spatial variation, clustering
• Ability of BMPs to reduce loads
  - Sure thing, or a shot in the dark?
• Feasibility of implementation
  - Willing partners? Public support?
• Additional benefits
  - Recreational enhancements, demonstration

What Tool Should I Select?

• Has a model already been used for load quantification?
• What scale is important?
• Is an annual load reduction estimate sufficient?
• Should individual storms be evaluated?

• Spreadsheet tools
  - Normally good for annual/overall reductions
  - Usually at a watershed scale – sometimes at the site scale
• Watershed models
  - Allow for continuous/long-term simulation
  - Often can be used for storm evaluation
  - Ability to function at all scales - site and watershed

Flashiness Index

Even without pollutant load data, can be used to quantify hydrologic impacts of watershed change on hydrologic regime and to evaluate efforts to restore natural flow regimes

Examples

• Minimize the total volume of surface water runoff that flows from any specific site during and following development, in order to replicate pre-development hydrology to the maximum extent practicable

• Achieve average annual 85% Total Suspended Solids (TSS) removal for the developed area of a site. Areas designated as open space that are not developed do not require stormwater treatment. All sites must employ Low Impact Development (LID) practices to control and treat runoff from the first inch of

Clinton River Watershed Site Evaluation Tool

• Evaluate potential benefits of BMPs at the site development scale
• Inputs
  - Site characteristics
  - BMP characteristics
• Outputs
  - Peak discharge
  - Annual runoff
  - Pollutant Loads

Why a Site Evaluation Tool?

• Evaluate flow and water quality impact of proposed residential and commercial development
• Identify most cost-effective suite of BMPs
• Support decision-making activities
  - Tool used in combination with other data/information to make final management decisions at the site scale
  - Promote consistency
• Help with Phase 2 reporting requirements
**Example**

Areal Loading Rates

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Design</th>
<th>Design</th>
<th>Target</th>
<th>Meets Goal?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Landscape</td>
<td>without BMPs</td>
<td>with BMPs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Nitrogen (lb/ac/yr)</td>
<td>0.66</td>
<td>9.56</td>
<td>7.17</td>
<td>6.00</td>
<td>No</td>
</tr>
<tr>
<td>Total Phosphorus (lb/ac/yr)</td>
<td>0.11</td>
<td>1.53</td>
<td>0.92</td>
<td>1.33</td>
<td>Yes</td>
</tr>
<tr>
<td>Sediment (ton/ac/yr)</td>
<td>0.011</td>
<td>0.123</td>
<td>0.181</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Site is located in Urban Residential Nutrient Zone
TN loading rate is higher than the buy-down range of 3.6 to 6 lb/ac/yr

Key Points in Quantifying BMP Performance:

- Quantifying potential impacts from BMPs is critical to watershed planning
  - Provides a guide toward achieving load reduction goal
  - Informs selection of a management strategy
- Spreadsheet and modeling tools are available
  - Spreadsheet tools
    - Most useful for watershed-scale analysis
    - Operate on a large time step
  - Watershed/site-scale models
    - Useful for local scale, as well as watershed-scale
    - Can operate on a short time-step (including individual storms)
    - Provide a key first step for engineering design
- **Again, one size doesn’t fit all!**

**Examples of Different Scenarios to Meet the Same Load Target**

<table>
<thead>
<tr>
<th>Source</th>
<th>Existing Phosphorus Loading (kg)</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Load Reduction</td>
<td>Allowable Load (kg)</td>
<td>% Load Reduction</td>
</tr>
<tr>
<td>Roads</td>
<td>79.36</td>
<td>26</td>
<td>58</td>
</tr>
<tr>
<td>Pasture/hay</td>
<td>21</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Cropland</td>
<td>219</td>
<td>26</td>
<td>102</td>
</tr>
<tr>
<td>Forest</td>
<td>97</td>
<td>26</td>
<td>72</td>
</tr>
<tr>
<td>Livestock</td>
<td>7</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Residential</td>
<td>6</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Groundwater</td>
<td>111</td>
<td>26</td>
<td>85</td>
</tr>
<tr>
<td>Total</td>
<td>539</td>
<td>26</td>
<td>400</td>
</tr>
</tbody>
</table>
Typical monitoring program measures water quality at a relatively few points in time, then "connects the dots". Note: Total annual load is assumed to be the area under the curve.

However:
If storm events aren't measured, the actual load may be much larger.

Many monitoring schemes miss daily variation as well. Blue dots are typical late afternoon measurements of dissolved oxygen. In many productive systems, however, DO drops to very low values at night.

Upstream/downstream monitoring demonstrates impact of BMP very effectively.

But... will upstream/downstream monitoring capture all impacts?
Findings: BMP implementations improved overall stream physical habitat conditions. However:

Spring Creek (with relatively large amounts of BMPs in both upland and riparian):
- improved habitat, temps and fisheries

Joos-Eagle (with very few BMPs installed):
- No change in fish or thermal regime
- habitat only improved in localized areas.

RESULTS

- Cooler water temperatures in pools and deeper runs
- Reduced width-depth ratios compared to unrestored reaches
- Rainbow trout numbers increased in restored reaches, while constant or decreasing in unrestored and control reaches

Findings:

- Fisheries improvement thru riparian bmps alone will only work if the watershed is already in good shape, or if upland bmps are installed.
- A minimum of 30-50% bmp implementation at a watershed scale may be necessary
The reports also utilize monitoring data collected by DWQ. In this example, response was measured as a change in the slope of the TP/discharge relationship.

Statistics is a vital part of any study design as it is usually the tool used to answer the question.

- The type of statistical method to be used is guided by your question and the design of your study.
- Statistics is a separate course in itself.
- It is the data assumptions inherent in statistical methods that drives the development of so many sampling strategies.
- Knowledge of statistics is required to address sample size estimates and determine the cost of science-related programs.
The issue of scale has been referred to as the central problem in ecology. There is no single correct scale at which to study something and the results you get are dependent on the scale you choose. A linear change in scale does not necessarily mean a linear change in the measured value. Scale dependent patterns can be complex and non-linear. How can you select the appropriate scale(s) for a study?

Power Analysis, Effect Size & Sample Size Estimation:

- Effect Size: The smallest detectable change.
- Variation: The amount of “noise” in the data.
- Confidence: Probability of not making a “false alarm” (Type 1 error).
- Power: Probability of not missing a significant change when it happens (Type 2 error).
- Sample Size: The amount of data you have.

Using Power Analysis, if you have estimates for any 4 of these things, you can solve for the 5th thing.

The Power Curve:

Preliminary & Sequential Sampling:

- Where do you get estimates for power analysis parameters?
  - Preliminary Sampling (i.e., pilot projects) occurs before the formal start of a study. This stage allows for testing of methods, evaluating effort, and for collecting power analysis parameters to pin down the strength of the proposed study.
  - Sequential Sampling (i.e., ongoing monitoring) occurs when data are analyzed during the data collection phase of a project. Sequential sampling, analysis, and evaluation makes the manager more familiar with the study and its data and promotes Adaptive Management.

Money is Always Tight:

- Study design should be carefully considered before any investment in monitoring is made.
- No amount of statistical hocus pocus will turn data collected from a bad design into useful information.
- Not all designs are complex and not all topics covered today will always be relevant, but some always will be (e.g., scale, disturbing variables - bias).
- Most study design problems groups face are common across the country. If you have a problem chances are someone has already thought about it.

Monitoring

Several major watershed monitoring projects have reported little or no improvement in water quality after extensive implementation of best management practices (BMPs) in the watershed:

- Uncooperative weather
- Improper selection of BMPs
- Mistakes in understanding of pollution sources
- Poor experimental design
- Lag time
VT NMP Project 1993 - 2001
Evaluate effectiveness of livestock exclusion, streambank protection, and riparian restoration in reducing runoff of nutrients, sediment, and bacteria from agricultural land to surface waters

RESULTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change</th>
<th>Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>[TP]</td>
<td>-15%</td>
<td>-800 kg/yr</td>
</tr>
<tr>
<td>[TKN]</td>
<td>-12%</td>
<td>-2200 kg/yr</td>
</tr>
<tr>
<td>[TSS]</td>
<td>-34%</td>
<td>-115,000 kg/yr</td>
</tr>
<tr>
<td>E. coli</td>
<td>-29%</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>-6%</td>
<td></td>
</tr>
<tr>
<td>TP load</td>
<td>-49%</td>
<td></td>
</tr>
<tr>
<td>TKN load</td>
<td>-38%</td>
<td></td>
</tr>
<tr>
<td>TSS load</td>
<td>-28%</td>
<td></td>
</tr>
</tbody>
</table>

Microinvertebrate IBI improved to meet biocriteria

OR Upper Grande Ronde NMP Project 1995 - 2003
Improve salmonid community through restoration of habitat and stream temperature regime
Document effectiveness of channel restoration on water temperature and salmonid community

Is a Model Necessary?
It depends what you want to know...

- What are the loads associated with individual sources?
- Where and when does impairment occur?
- Is a particular source or multiple sources generally causing the problem?
- Will management actions result in meeting water quality standards?
- Which combination of management actions will most effectively meet load targets?
- Will future conditions make impairments worse?
- How can future growth be managed to minimize adverse impacts?

Models are used in many areas...
- TMDLs, stormwater evaluation and design, permitting, hazardous waste remediation, dredging, coastal planning, watershed management and planning, air studies...
To model, or not to model . . .

• As these things increase:
  - Number of pollutants
  - Complexity of loads/stressors
  - Uncertainty regarding existing information
  - Expense involved in addressing problems
• The need for more sophisticated modeling also increases