Designing and Implementing Effective Monitoring - Element I (Handbook; Chapter 12.6)

Element i — “A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.”

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Why Monitor?
Measurable progress is critical to ensuring continued support of your watershed project, and progress is best and most meaningfully measured using water quality data relevant to identified problems in the water body.

Ultimate goal is to protect and restore water bodies for their intended uses.

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Steps of a successful monitoring plan:
1. Define specific data quality objectives
2. Know approximate budget and personnel constraints
3. Review existing data
4. Determine sample locations, sampling procedures and frequency, variables to monitor and analytic techniques (i.e., develop a monitoring design plan)
5. Initiate and continue monitoring program
6. Prepare regular reports and recommendations
7. Modify and adjust monitoring as needed

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Step 1. Define Specific Data Quality Objectives
- Analyze long-term trends
- Document changes in management and pollutant source activities
- Measure performance of specific management practices
- Fill data gaps in watershed characterization (e.g., suspected hotspots)
- Track compliance and enforcement in point sources
- Provide data for educating and informing stakeholder
Step 2. Know Budget and Personnel Constraints
- Monitoring can be very expensive (e.g., wet-weather monitoring, streamflow gauges, etc.)
- Monitoring can require specialized skills of personnel and their availability when needed (routine monitoring vs. wet-weather monitoring demands on personnel)

Step 3. Review Existing Data
- Is good streamflow data available (e.g., USGS streamflow recording station)?
- What is the nature of the water quality data (e.g., temporal and spatial density)?
- What do the data show?
- Can existing data be used to characterize pre-management conditions?

Step 4. Develop a Monitoring Design Plan
- What questions are we trying to answer?
- What assessment techniques will be used?
- What statistical power and precision is needed?
- Can we control for the effects of weather and other sources of variation?
- What are our constraints (financial, personnel, time, etc.)?
- Will our design allow us to attribute changes in water quality to the implementation program?

Financial and Personnel Constraints Always Exist!
- Coordination with other monitoring programs (SWQM, CRP, etc.) if possible.
- Is there a role for volunteer monitoring in your project? (Texas Stream Team, River Systems Institute, Texas State Univ.)

Past Experiences Indicate:
- Obtaining adequate pre-treatment or pre-implementation water quality data is often a problem. And this problem is not easily overcome without delaying implementation efforts.

Common Statistical Designs for Monitoring
- Before and After (Time Trends or Time Series Analysis) Uncorrected for Meteorological Variables
- Before and After Time Trends Corrected for Streamflows
- Above and Below (Upstream – Downstream) with Before and After
- Paired Watershed Study Design.
Before and After (Time Trends or Time Series Analysis)

- Monitor one or more sites over time.
- Advantage: Easiest to conduct with limited resources.
- Disadvantage: Sensitivity is low, difficult to attribute changes to land treatment measures, long monitoring period needed.
- By adding streamflow measurements, the disadvantages may be partially overcome.

Before & After Time Trends Corrected for Streamflow

An Example: TCEQ Sponsored Project Through §319(h) Grant Assessing TMDL Activities

Methods for Trend Analysis

Two Datasets – Monthly Grab & Loading

- Adjust data for highest reporting limit
- Check for seasonal influences
- Flow adjust (LOWESS regression)
- Evaluate residuals for trend (nonparametric Kendall’s tau)

Trends in Phosphorus

(Volume-Weighted Storm & Grab Samples)

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Period</th>
<th>SRP</th>
<th>Total P</th>
</tr>
</thead>
<tbody>
<tr>
<td>BO020</td>
<td>Above Stephenville</td>
<td>1997-2005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BO040</td>
<td>Below Stephenville</td>
<td>1994-2005</td>
<td></td>
<td></td>
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<td>BO070</td>
<td>Near Hico</td>
<td>1993-2006</td>
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<tr>
<td>BO059</td>
<td>Near Grifton</td>
<td>1996-2006</td>
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<tr>
<td>BO095</td>
<td>Near Valley Mills</td>
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</table>

Major Tributary Sites:

GC100  Green Creek  1993-2006  ▼  ▼
NC060  Nells Creek  1996-2006  ▼  ▼

Long-term Trend Analysis: Annual box and whisker plots of monthly routine PO4-P grab data for station 11963 (BO040). Data natural log transformed and flow-adjusted.

Microwatershed Sampling Sites: TSSWCB 319 Project
### Before & After Analysis EMC

<table>
<thead>
<tr>
<th>Site</th>
<th>Cows /ha</th>
<th>Manure Hauled (kg/cow/ha)</th>
<th>Location</th>
<th>PO₄-P</th>
<th>Total P</th>
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<tr>
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<td>North Fork</td>
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<td>South Fork</td>
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</table>

**Manure Hauled Through 2006**

### Above and Below (Upstream – Downstream) Design

- Sampling a flowing system over time above and below potential sources.
- Advantage: Accounts for upstream inputs.
- Disadvantage: Sensitivity can be low (especially if upstream inputs are significant); requires twice as many sites as Before & After Design.
- By adding streamflow measurements, the disadvantages may be partially overcome.

### Paired Watershed Study Design

<table>
<thead>
<tr>
<th>Period</th>
<th>Control Watershed</th>
<th>Treatment Watershed</th>
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<tbody>
<tr>
<td>Calibration</td>
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<tr>
<td>Treatment</td>
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<td>BMP</td>
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Source: EPA. 1993. 841-F-93-009
Pre- and post-BMP phosphorus loadings from bermudagrass plots

Scaling Issues

Edge of Field (acres)
- 100% Waste Application Fields
  - PO4-P: 4.0 mg/L

Microwatershed (hundreds of acres)
- 45% Waste Application Fields
  - PO4-P: 2.4 mg/L

Major Subwatershed (tens of thousands of acres)
- 7% Waste Application Fields
  - PO4-P: 0.20 mg/L

Entire Watershed (hundred thousand acres)
- 3% Waste Application Fields
  - PO4-P: 0.02 mg/L

Examples of Implications of Sampling Frequency

Revisiting Assessment of Current Conditions
(North Bosque River)

Subsample monthly chlorophyll-a data
(June 1993 – May 1998):
- Bimonthly (2 schemes)
- Quarterly (3 schemes)

Bosque River Watershed Sites

Upper North Bosque River Chlorophyll-a Assessment (>25%, concern)
North Bosque River (All Sites)
Chlorophyll-a Assessment
(<25%, not supporting)

Monthly
Bi-Monthly-A
Bi-Monthly-B
Quarterly-A
Quarterly-B
Quarterly-C

Comparison of Average Annual SRP from Different Sampling Schemes - Site BO040
Biweekly / Two-Monthly / Six-Quarterly

Comparison of Average Annual SRP from Different Sampling Schemes - Site BO090
Biweekly / Two-Monthly / Six-Quarterly

Location, location, location
Where to sample?
Steps 5-7. Implement Your Monitoring Design Plan & Build in an Evaluation Process

- Initiate and continue monitoring program.
- Prepare regular reports and recommendations. (don’t wait until the end of your project to look at the data thoroughly)
- Modify and adjust monitoring as needed.
Documented Changes in Management Activities: An Example

- New solid waste fields
- New irrigation fields
- Deep plow fields
- Only apply commercial nitrogen
- Application rate based on soil test phosphorus
- Filter strips

Fill Data Gaps in Watershed Characterization: An Example

Goose Branch Microwatershed Soil Test P

Provide Data for Educating and Informing Stakeholders
Provide Data to Understand Complex Systems

Identify Targets for Nutrients/Aquatic Plants
Data & Studies for use in Process
a. Periphytometer deployment in streams (Marty Matlock, TAMU)
b. Algal assay Lake Waco (Owen Lind, Baylor)
c. Fish survey (TIAER)
d. Benthic Macroinvertebrate (mainly upper watershed, TIAER)
e. Water quality data, Lake Waco and watershed (TIAER)

Matlock Periphytometer Treatment Array

Stream Bioassay Sites
Summary of Stream Bioassay Results: 1997-1998

<table>
<thead>
<tr>
<th>Site</th>
<th>P-limited</th>
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<th>Co-limited</th>
<th>Other</th>
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Percent 32 11 11 47 100

Thank You

Questions?