Data-driven Planning for TMDL Effectiveness Monitoring & Statistical Test Selection for Analysis of Monitoring Data

Sponsored by EPA Region 10

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Overview of Presentation

- Recommended steps for developing a TMDL effectiveness monitoring plan.
- Data-driven planning for TMDL effectiveness monitoring.
- Data exploration methods for selecting statistical tests for analyzing TMDL effectiveness monitoring data.
- Demonstration of Excel-based TMDL effectiveness monitoring planning tool.

Data-driven Planning for TMDL Effectiveness Monitoring & Statistical Test Selection for Analysis of Monitoring Data

TMDL EFFECTIVENESS MONITORING PLANNING

“Effectiveness Monitoring”

- The process of measuring improvements in the water quality of a water body.
- Not to be confused with BMP effectiveness, which measures the success or effectiveness of the BMPs themselves.
- The primary goal of TMDL effectiveness monitoring is to identify water quality improvements (or lack thereof) that result from TMDL implementation.

Need for Effectiveness Monitoring

- Provides a quantitative measure of progress towards attainment with WQS.
- Allows for demonstration of incremental improvements in water quality.
- Supports adaptive management approach to implementation and restoration.
- Provides data for use in making SP-12 and WQ-10 determinations.
- Provides documentation of water quality improvements, which can be used to communicate results and justify the need for funding to support water programs.

Recommended Steps for TMDL Effectiveness Monitoring Planning

1. Review existing data and information.
2. Select monitoring sites, parameters, and study design.
3. Estimate sample size.
4. Develop TMDL effectiveness monitoring plan.

Review Existing Data and Information

- Begin with a thorough review of all available information that may direct the process.
- Existing data and information will provide an understanding of:
  - Historical and current water quality conditions.
  - TMDL implementation activities.
- Involve stakeholders early.

Select Monitoring Sites, Parameters, and Study Design

- Design effectiveness monitoring projects at the watershed scale.
  - Specific project scale should be decided upon using information on the number and extent of impaired or threatened waters, project resources, and project partners.
- Watershed scale effectiveness monitoring:
  - Pour point method
  - Distributed sampling method

Site Selection Approach: Pour Point Method

Site Selection Approach: Distributed Sampling Method

Site Selection

- Locate monitoring sites where TMDL implementation is expected to have discernible water quality effects.
- Examples include sites on impaired/degraded water bodies that are downstream of:
  - WWTFs with new or revised WLAs.
  - Discontinued illicit discharges.
  - NPS that are managed through BMPs.
  - Stream channel restoration projects.
  - Improved onsite wastewater management or expansion of sanitary sewer service.
  - Other TMDL-specific pollution control measures.
- Evaluate any potential existing monitoring network or sites.

Parameters

- At a minimum, monitor the pollutants for which the TMDL was developed.
- If resources allow, monitor for stressor and/or response variables, which provide additional information about the condition of a water body.
- If resources allow, monitor parameters that may be covariates to the primary pollutants of interest.
  - Stream flow is a common covariate for pollutants in streams and rivers.

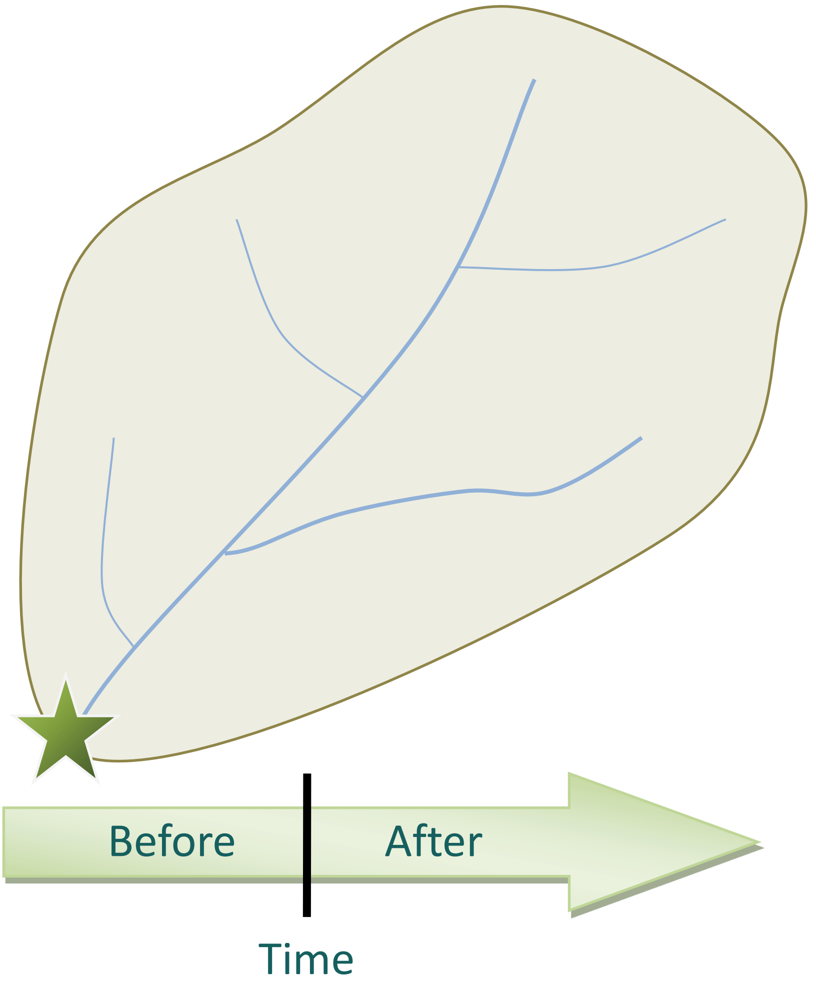
Study Design

- Outlines how water quality improvements will be demonstrated.
- Critical to ensuring the collection of the specific data needed to answer the study questions/goals.
- Selection is dependent on many factors, including:
  - Types of TMDL implementation actions.
  - Implementation schedule.
  - Availability and quality of previously collected data
  - Resources.
  - Existence of suitable reference sites.

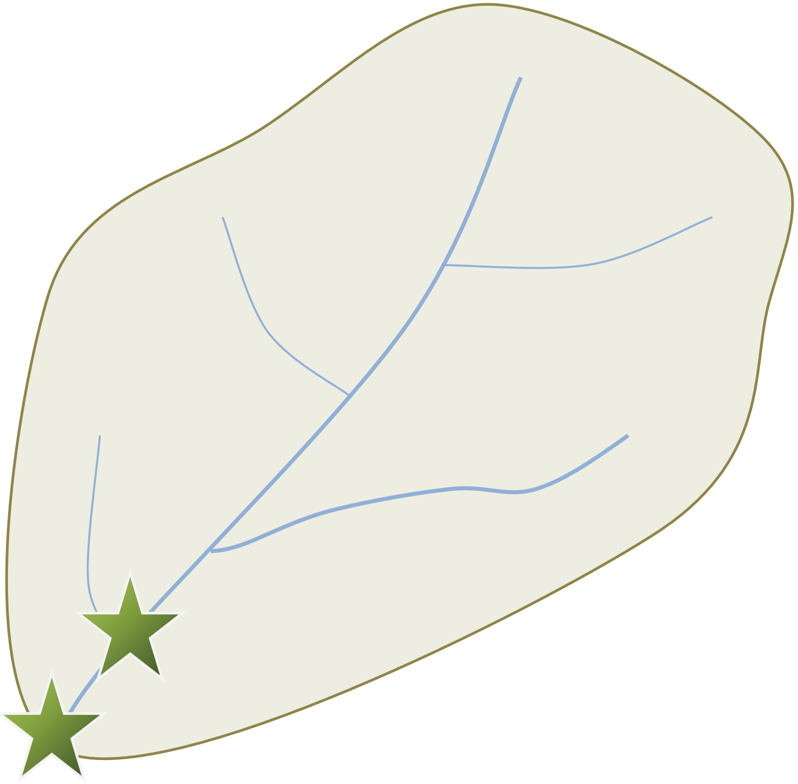
Study Design (cont.)

- Potential study designs for TMDL effectiveness monitoring include:
  - Before & After
  - Upstream/downstream
  - Paired watersheds
  - Trend monitoring

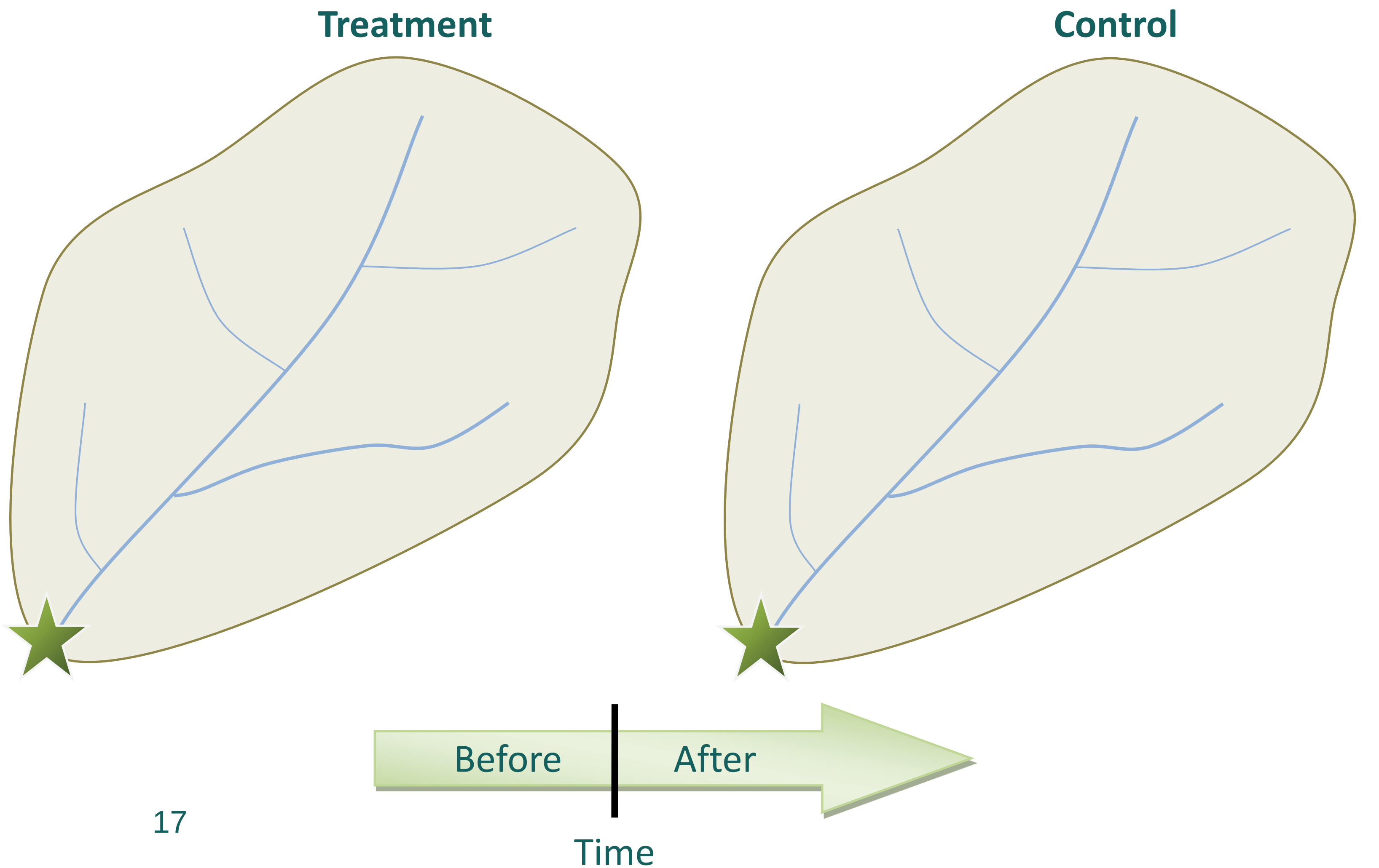
Study Design: Before/After Study



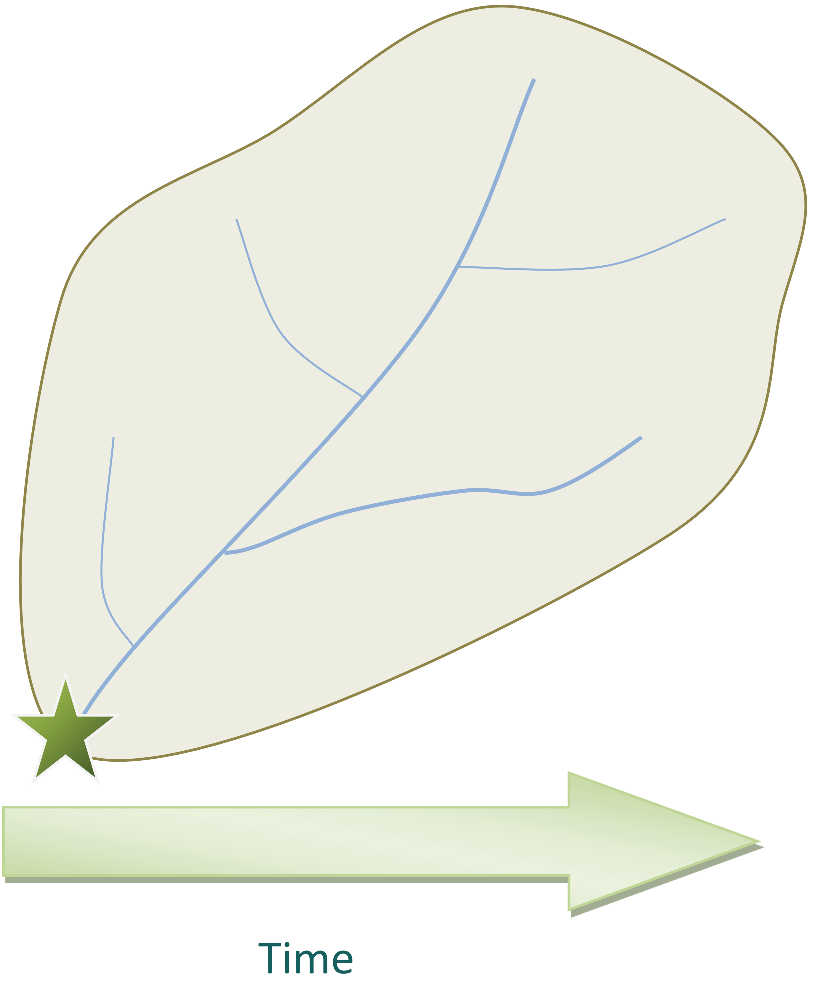
Study Design: Upstream/Downstream Study



Study Design:
Paired Watersheds Study



Study Design: Trend Monitoring



Estimate Sample Size

- Water quality data are often collected without considering the number of samples needed to demonstrate statistically significant changes.
- Objective and informed sample size decisions can be made using a statistical method know as power analysis.
- Power analysis uses information from pilot data to determine the optimal number of samples needed to identify statistically significant changes or trends.

Develop TMDL Effectiveness Monitoring Plan

- Steps for planning a TMDL effectiveness monitoring project:
  1. Review existing data and information.
  2. Select monitoring sites, parameters, and study design.
  3. Estimate sample size.
  4. Develop TMDL effectiveness monitoring plan.

Develop TMDL Effectiveness Monitoring Plan (cont.)

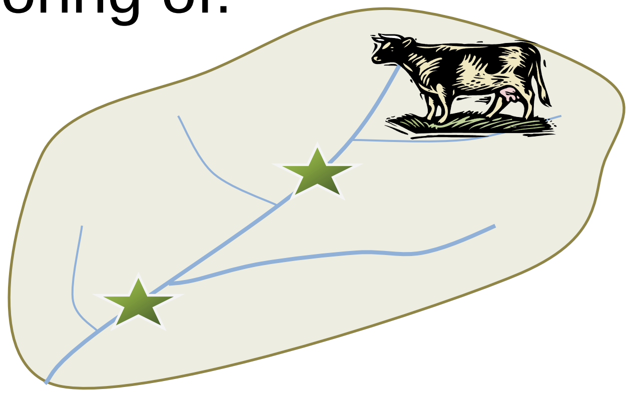
- The planning document should include:
  - Relevant background information.
  - Project goals and objectives.
  - Where and when monitoring will occur.
  - List of parameters to be monitored.
  - Preliminary discussion of intended data analysis methods, including selected level of significance.
- The TMDL effectiveness monitoring plan can be incorporated into a QAPP.

Data-driven Planning for TMDL Effectiveness Monitoring & Statistical Test Selection for Analysis of Monitoring Data

DATA-DRIVEN PLANNING

Common Example of post-TMDL Monitoring

- Ambient monitoring reveals that the Fox Run Watershed is impaired for total phosphorus.
- TMDL developed for total phosphorus.
- Post-TMDL monitoring completed through the routine monthly ambient monitoring of:
  - TP
  - TN
  - TSS
  - E. Coli
  - DO, conductivity, pH, Temp, Turbidity



Explore Pilot Data

- Pilot data are previously collected data
  - Ambient monitoring program
  - TMDL data
  - Special studies
- Helps to informs sample size estimation (power analysis)
- Informs selection of parameters to monitor for (correlation analysis)

Power Analysis

$\beta \approx \text{MDC} \times \alpha \times \sqrt{n}/\sigma$

Where:

β=power

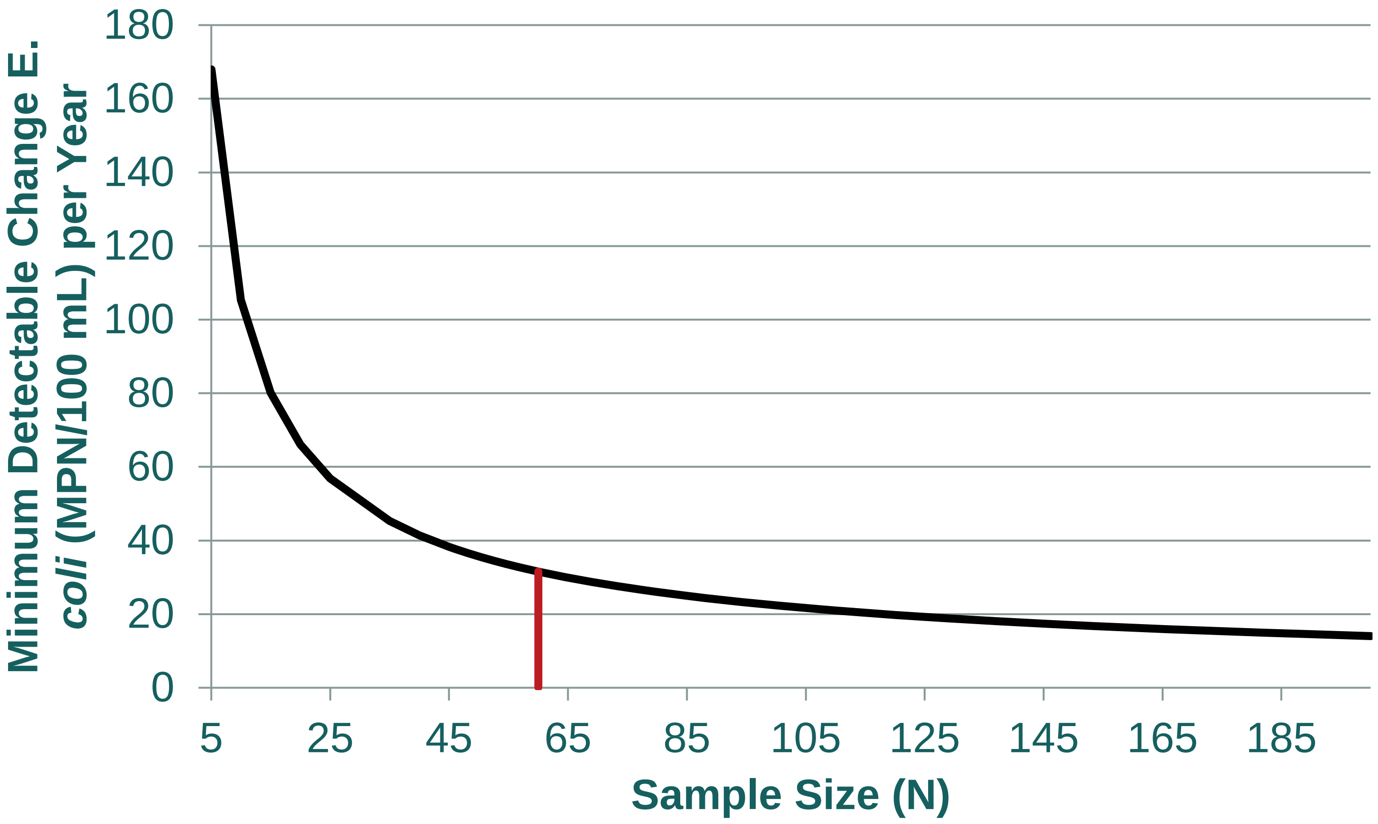
MDC=minimum detectable change

α=significance

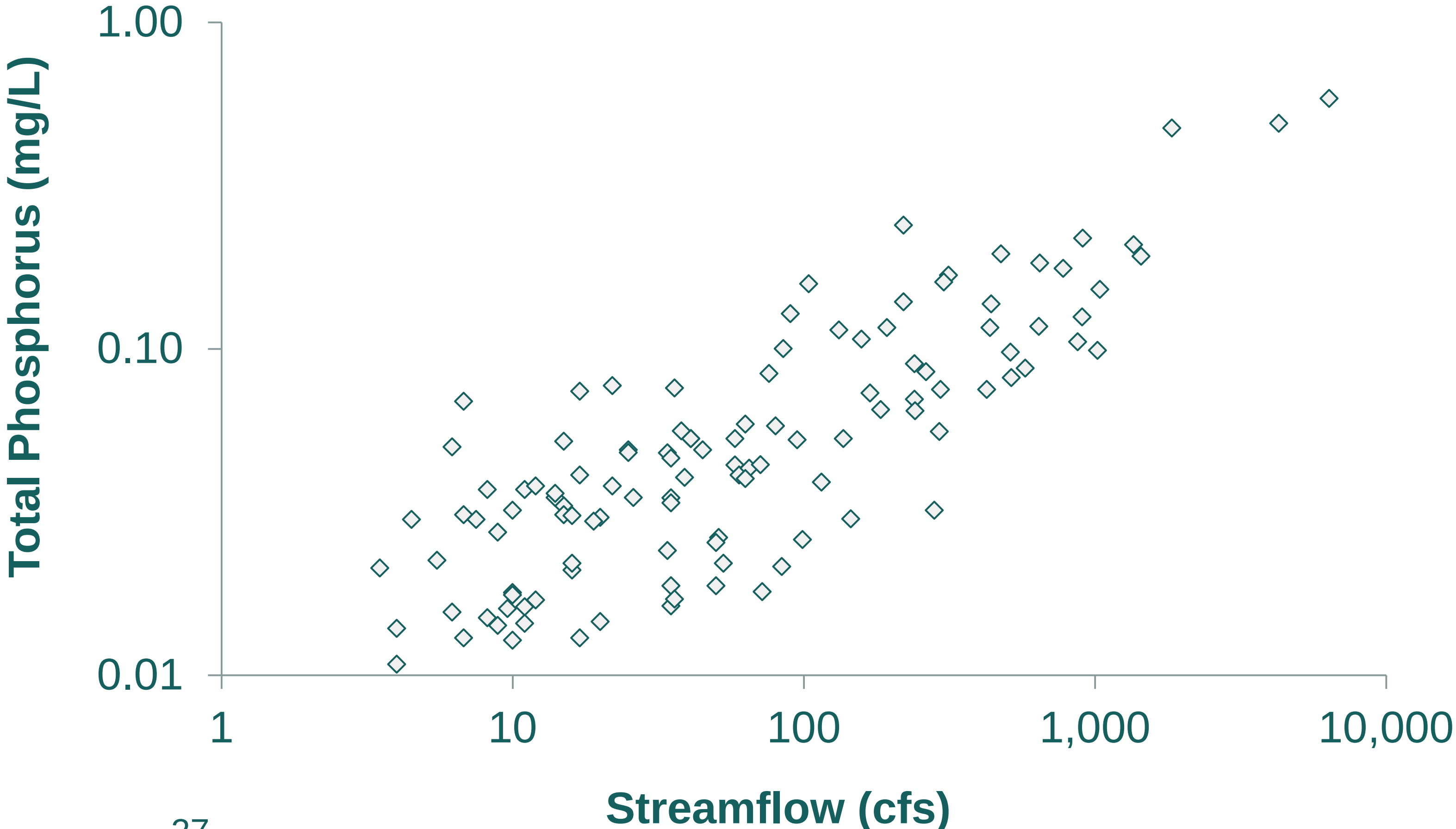
n=sample size

σ=standard deviation (variability)

Estimate Sample Size



Correlation Analyses



Select Parameters

	Chloride	Conductivity	TN	TP	TSS	Turbidity
Chloride	**1**	**0.88**	**0.62**	0.31	0.26	**0.31**
Conductivity	**0.88**	**1**	**0.74**	0.18	0.3	**0.32**
TN	**0.62**	**0.74**	**1**	0.28	0.34	**0.36**
TP	0.31	0.18	0.28	**1**	**0.52**	**0.56**
TSS	0.26	0.3	0.34	**0.52**	**1**	**0.88**
Turbidity	**0.31**	**0.32**	**0.36**	**0.56**	**0.88**	**1**

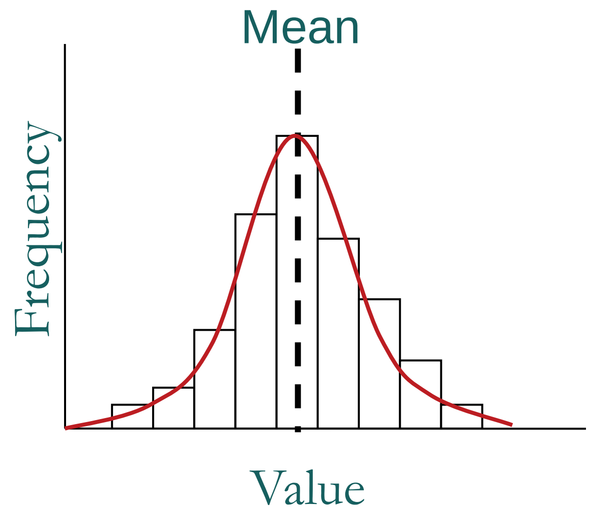
Data-driven Planning for TMDL Effectiveness Monitoring &
Statistical Test Selection for Analysis of Monitoring Data

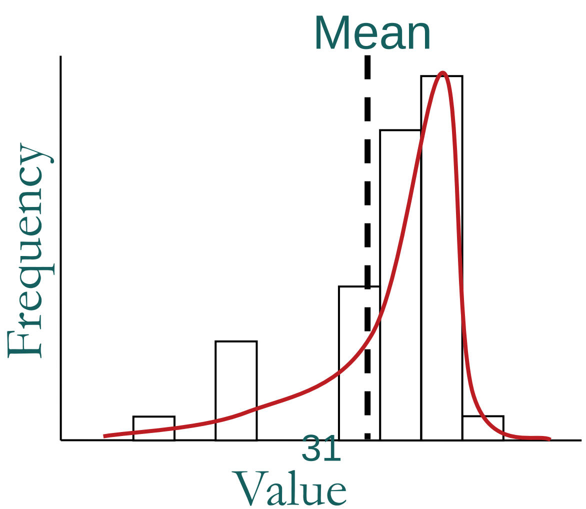
SELECTING STATISTICAL TESTS FOR ANALYZING EFFECTIVENESS MONITORING DATA

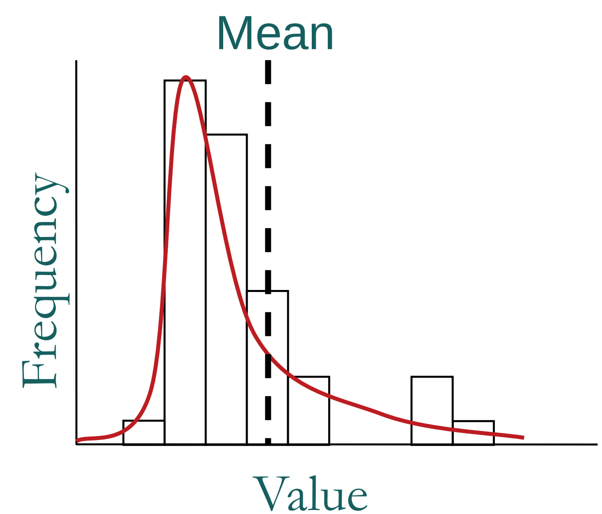
Common Types of Statistical Tests

- Parametric: Assumes the data are normally distributed. Examples include:
  - t-Test
  - Multiple linear regression
- Nonparametric: Makes no assumption about data distribution. Examples include:
  - Signed rank test
  - Mann-Kendall test for trend

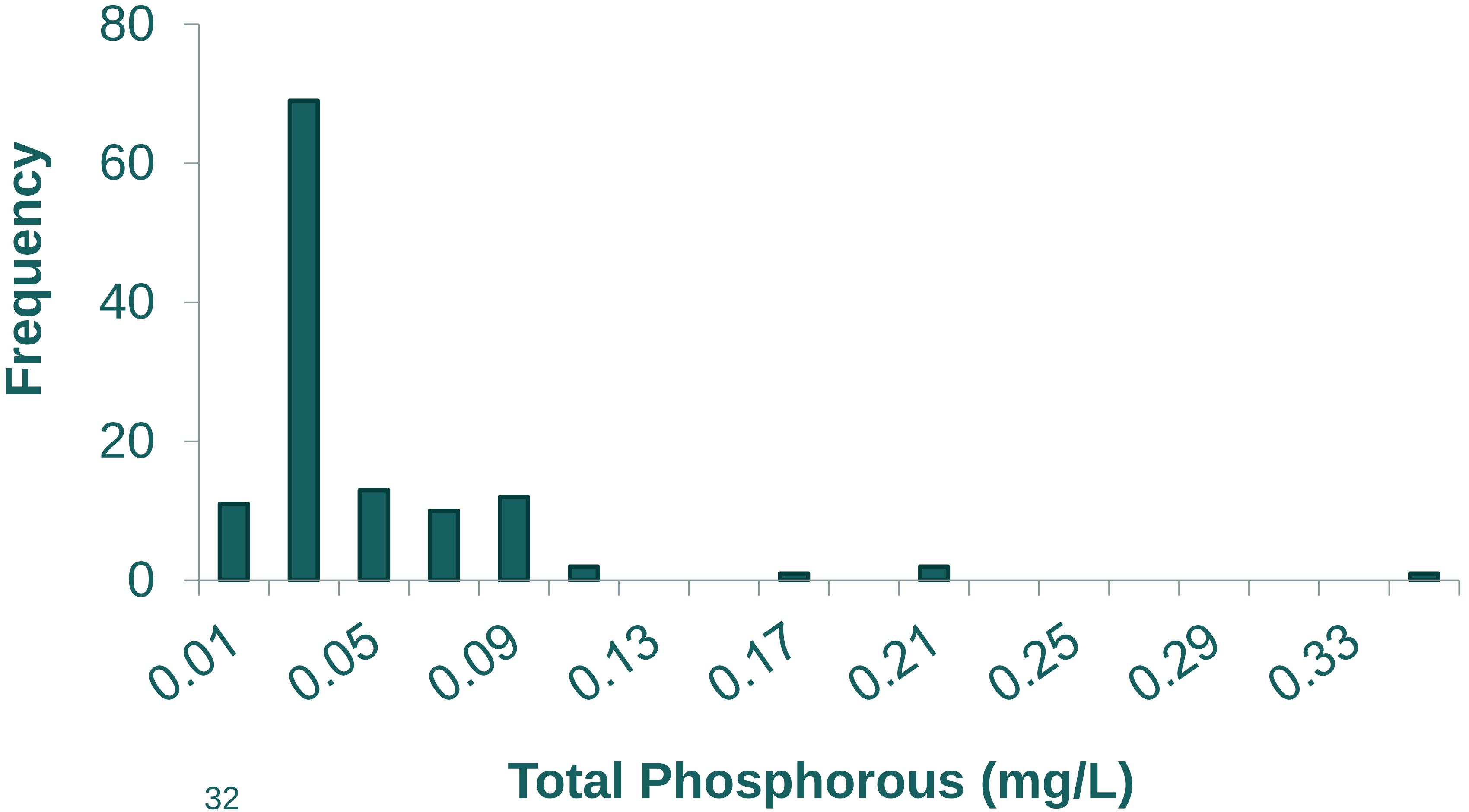
Data Distributions



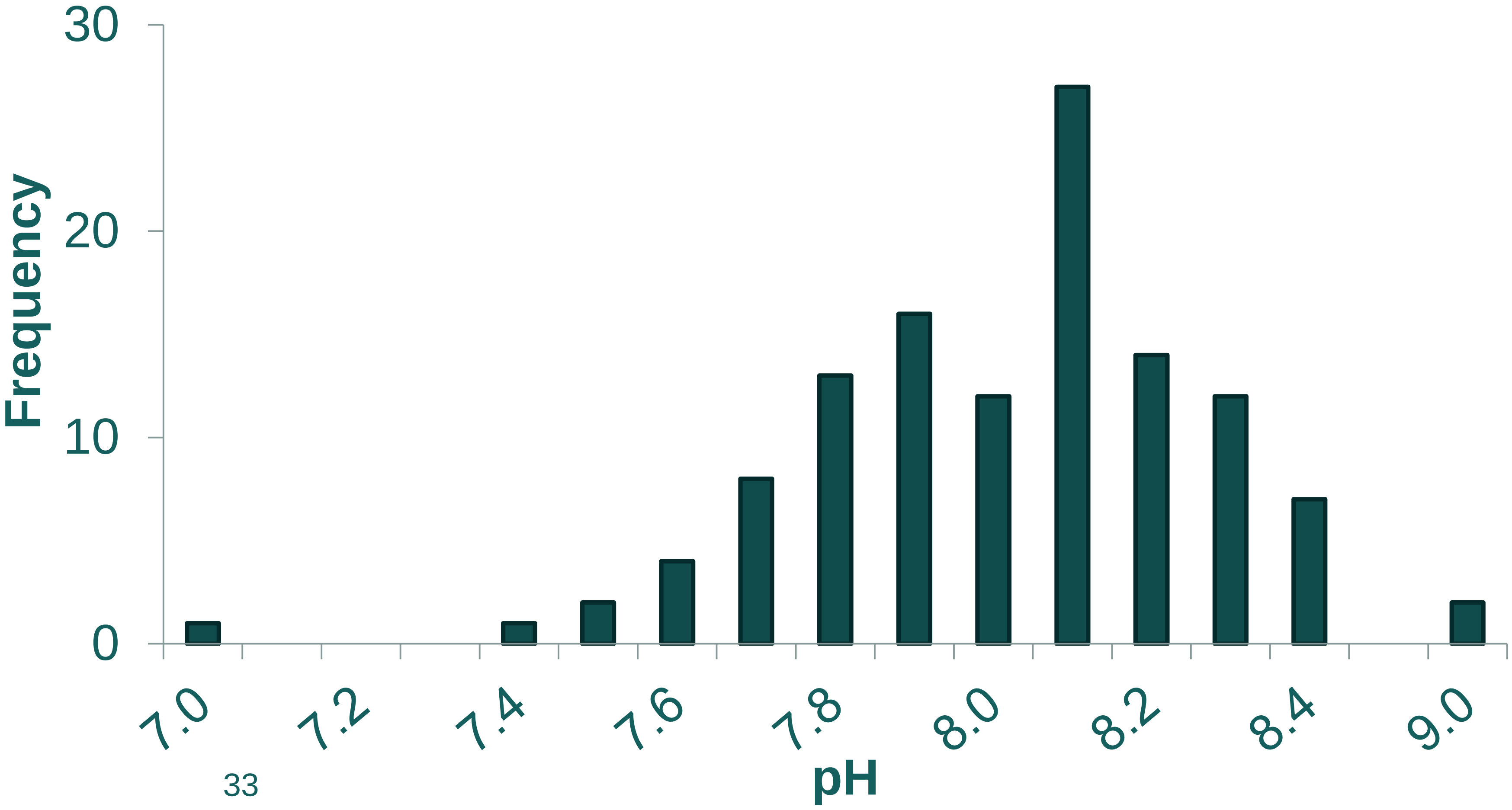




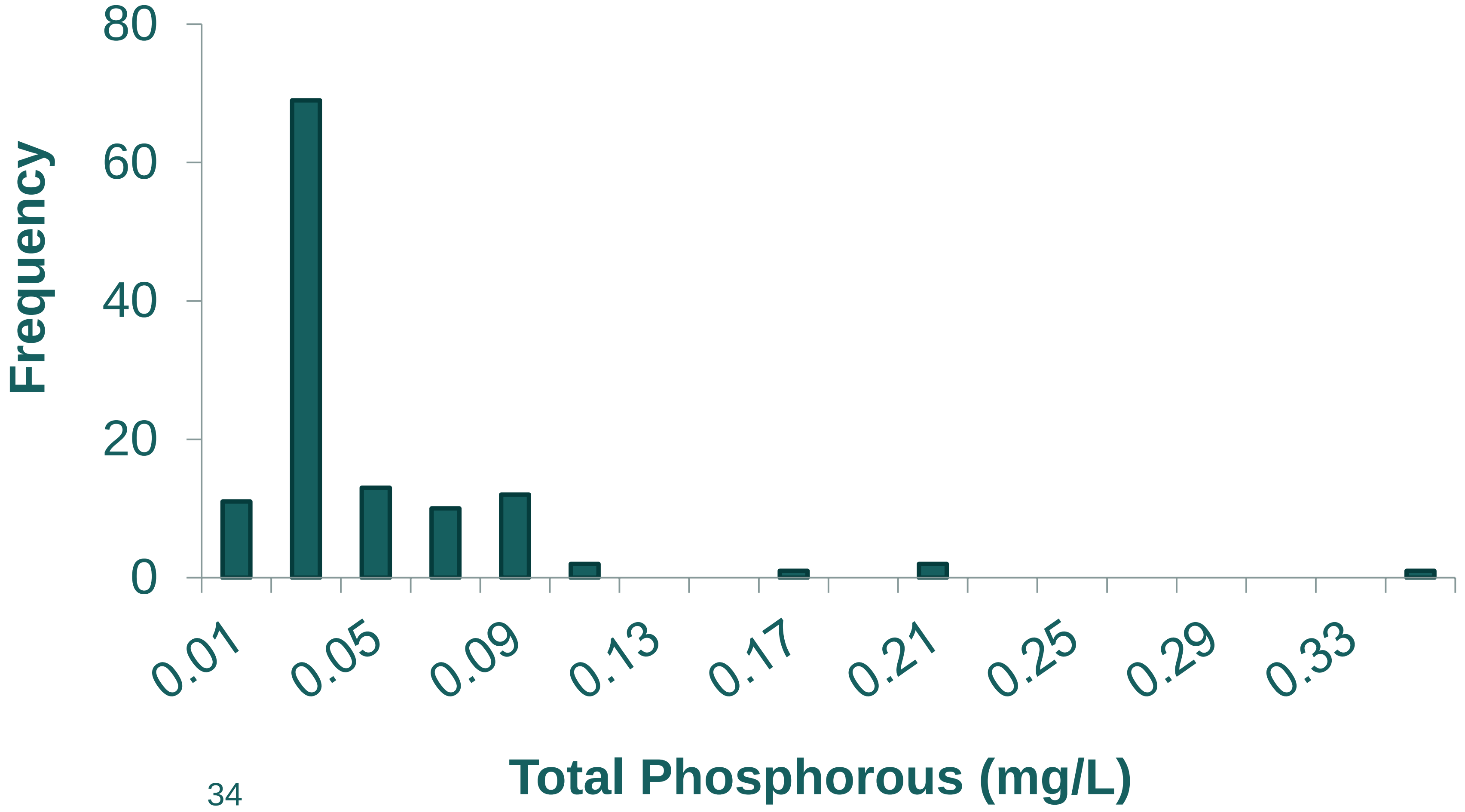
Histograms


Frequency
80
60
40
20
0
0.01
0.05
0.09
0.13
0.17
0.21
0.25
0.29
0.33
Total Phosphorous (mg/L)

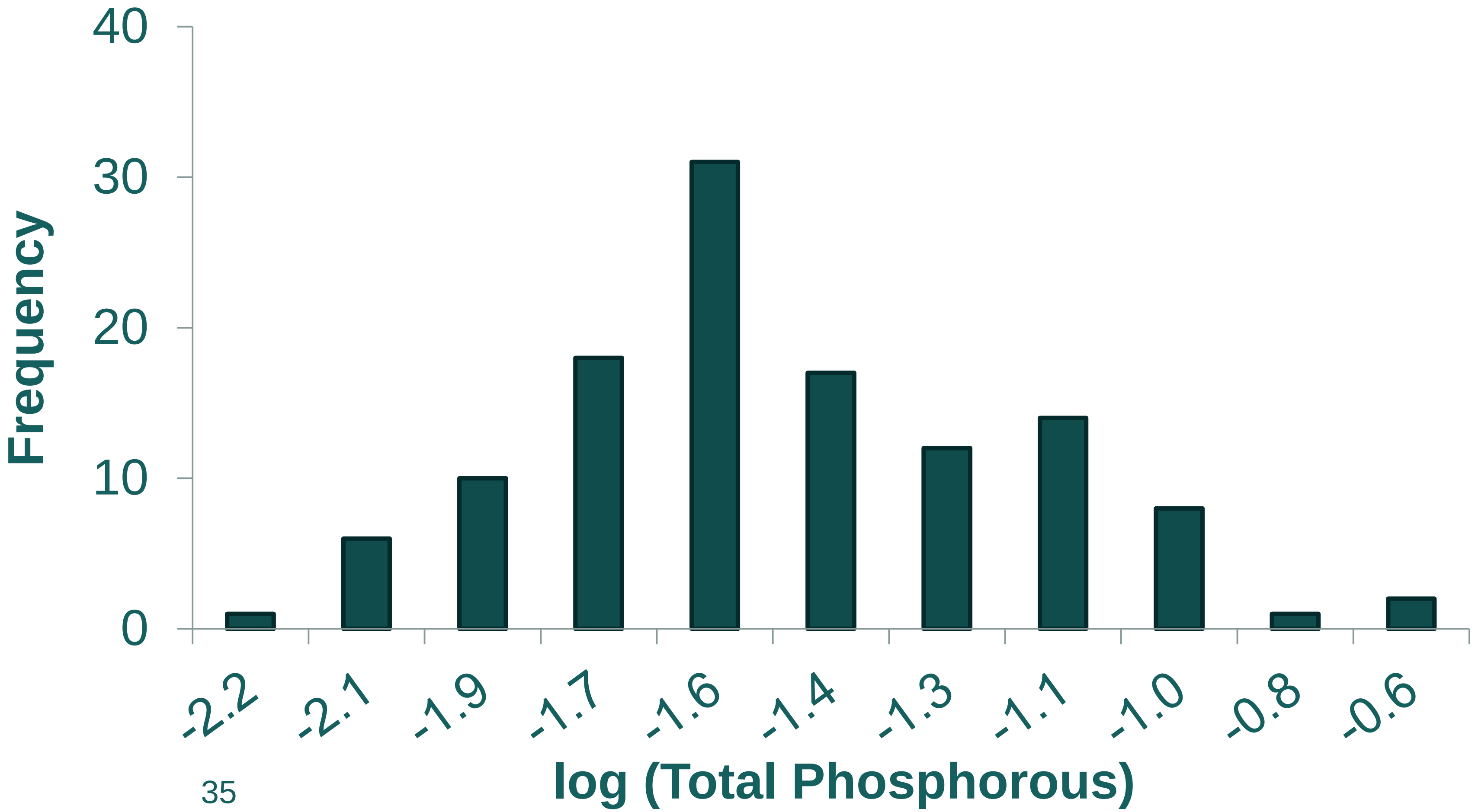
Histograms (cont.)



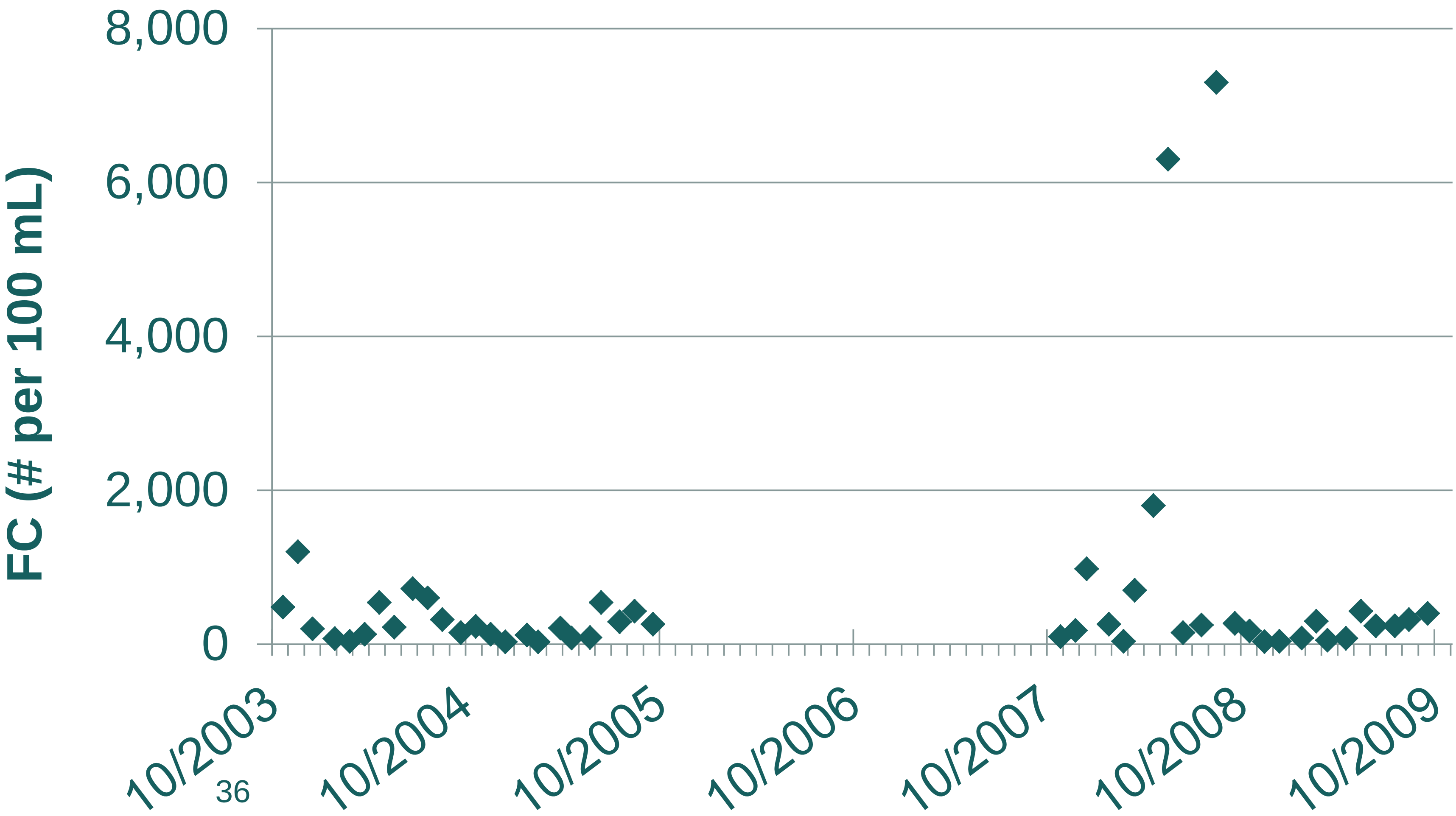
Data Transformations



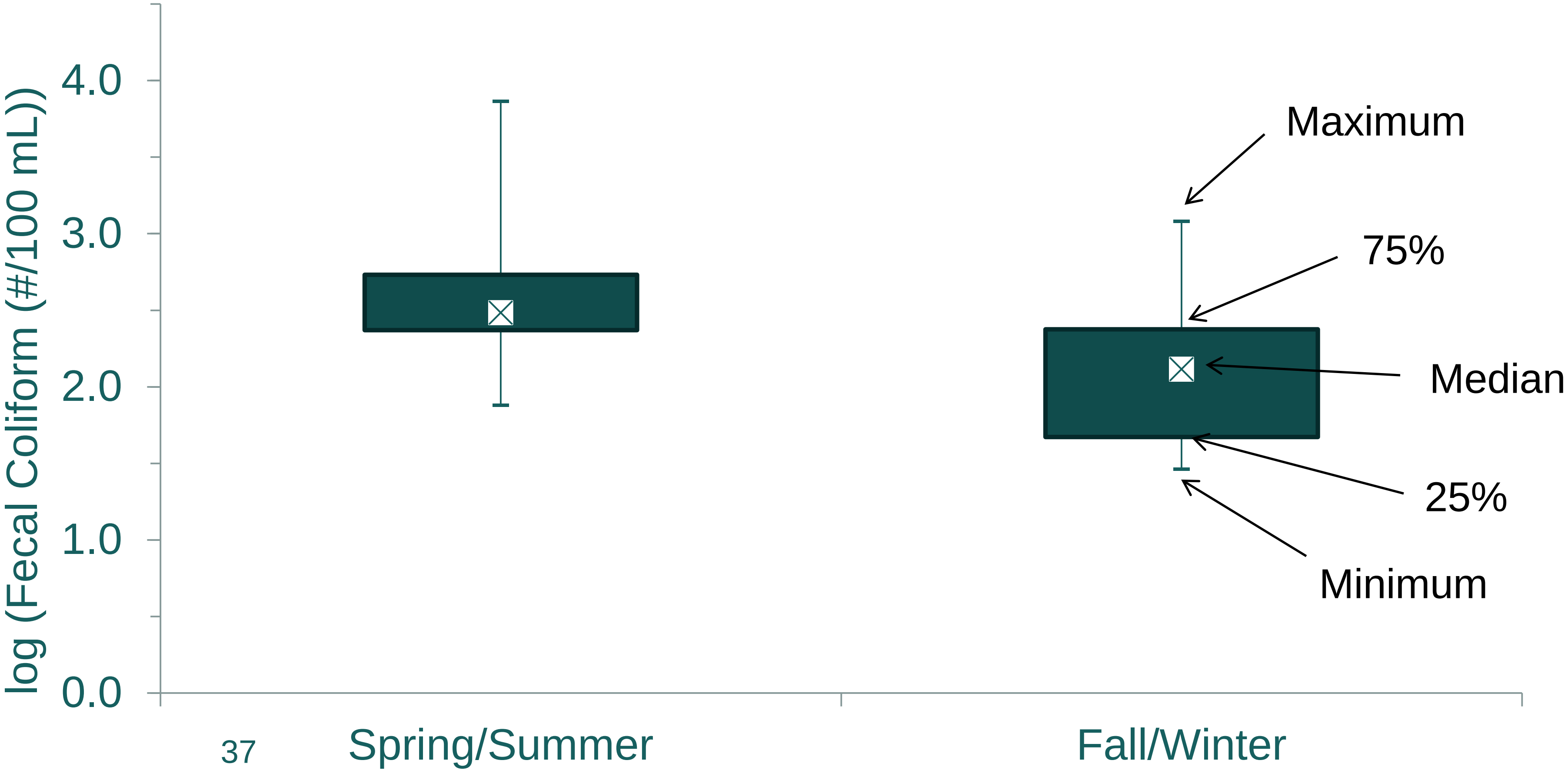
Data Transformations (cont.)



Time Series Plots

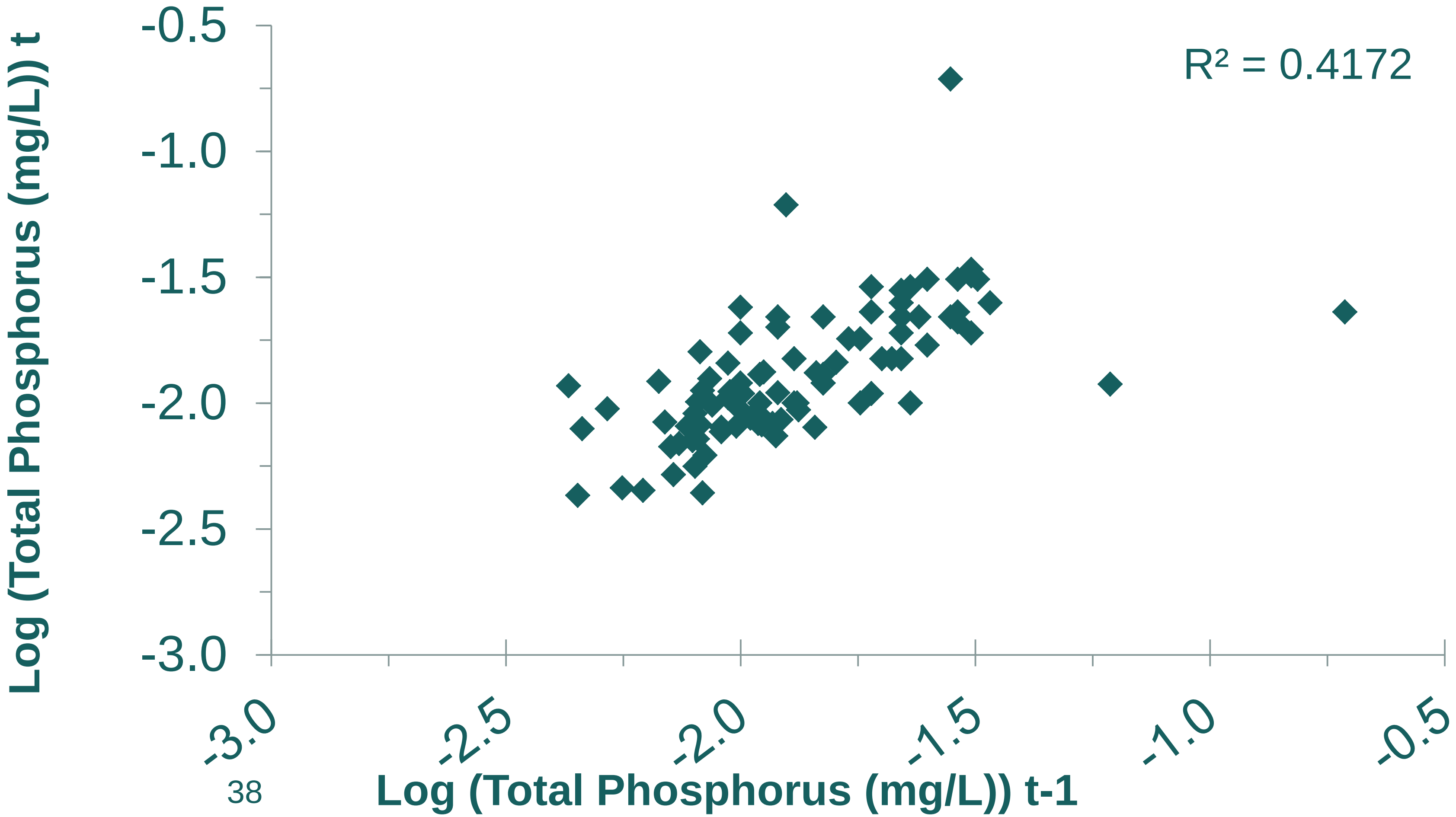


Boxplots



log (Fecal Coliform (#/100 mL))
4.0
3.0
2.0
1.0
0.0
Spring/Summer
Fall/Winter
Maximum
75%
Median
25%
Minimum

Autocorrelation & Lag Plots



Censored Data

Date	Fecal Coliform (#/100 mL)
1/13/2012	345
2/1/2012	280
2/29/2012	>2,400
3/17/2012	279
4/2/2012	240

Substituting >2,400 with the value of 2,400 gives a calculated mean of 709

If that value were really 10,000, the mean would be 2,229

Selecting an Appropriate Test

- Objectives
- Study Design
- Characteristics of our data:
  - Normal distribution
  - Outliers
  - Censored data points
  - Seasonality
  - Autocorrelation
  - Missing data

Selecting an Appropriate Test (cont.)

- Study Objective: Compare two independent data groups
- Relevant Study Designs:
  - Before/after;
  - Upstream/downstream
- Parametric test: Two sample t-test
- Nonparametric test: Rank sum test

Selecting an Appropriate Test (cont.)

- Study Objective: Compare data groups with matched pairs
- Relevant Study Designs
  - Paired watersheds;
  - Upstream/downstream
- Parametric test: Paired t-test
- Nonparametric test: Signed rank test

Selecting an Appropriate Test (cont.)

- Study Objective: Compare two data groups while adjusting for covariates
- Relevant Study Designs: Paired watersheds
- Parametric test: Analysis of covariance (ANCOVA)

Selecting an Appropriate Test (cont.)

- Study Objective: Evaluate the relationship between one data group and time (without seasonality)
- Relevant Study Designs: Trend monitoring
- Parametric test: Linear regression
- Nonparametric test: Mann-Kendall test

Selecting an Appropriate Test (cont.)

- Study Objective: Evaluate the relationship between one data group and time (with seasonality)
- Relevant Study Designs: Trend Monitoring
- Parametric test: Linear regression with seasonal term
- Nonparametric test: Seasonal Kendall test

Selecting an Appropriate Test (cont.)

- Study Objective: Evaluate the relationship between one data group, time, and other variables (without seasonality)
- Relevant Study Designs: Trend Monitoring
- Parametric test: Multiple linear regression
- Nonparametric test: Mann-Kendall test with LOWESS (“locally weighted scatterplot smoothing”)

Selecting an Appropriate Test (cont.)

- Study Objective: – Evaluate the relationship between one data group, time, and other variables (with seasonality)
- Relevant Study Designs: Trend monitoring
- Parametric test: Multiple linear regression with seasonal term
- Nonparametric test: Seasonal Kendall test with LOWESS

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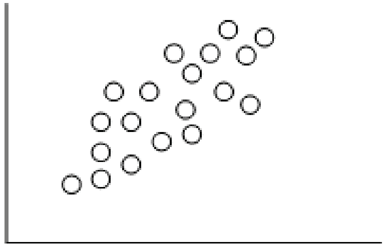
DEMO OF TMDL EFFECTIVENESS MONITORING PLANNING TOOL

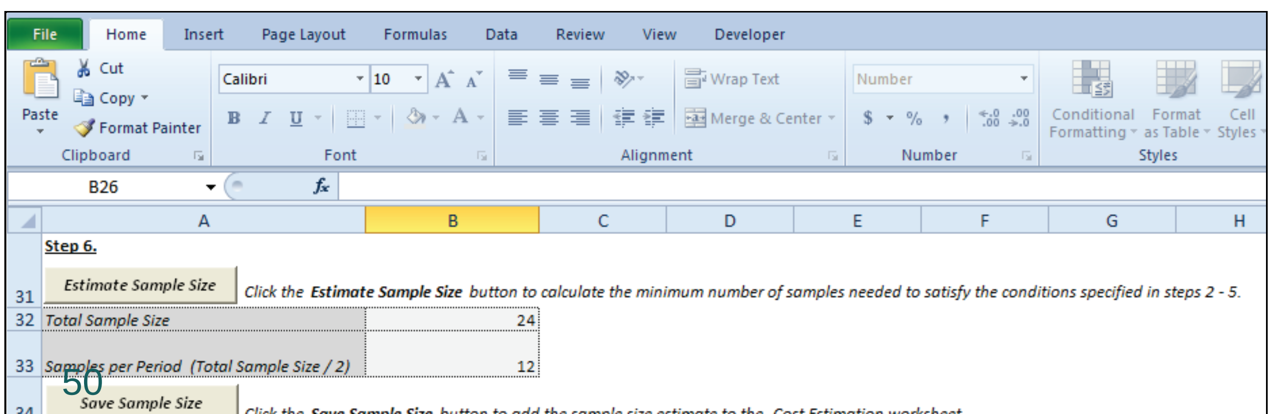
Data Exploration Software

- Spreadsheet software (Excel)
  - Simple user-interface
  - Limited analysis options
- Statistical packages
  - Open source (R) or proprietary (SAS)
  - Steep learning curve
- Web-based tools



A Customized Tool

- TMDL Effectiveness Monitoring Planning Tool (EMTool.xlsm)
  - Excel-based
  - Enhances basic Excel features with VBA code
- Objective: Facilitate ***data-driven*** planning.
  - Create exploratory plots
  - Estimate sample size using power analysis
  - Estimate monitoring costs

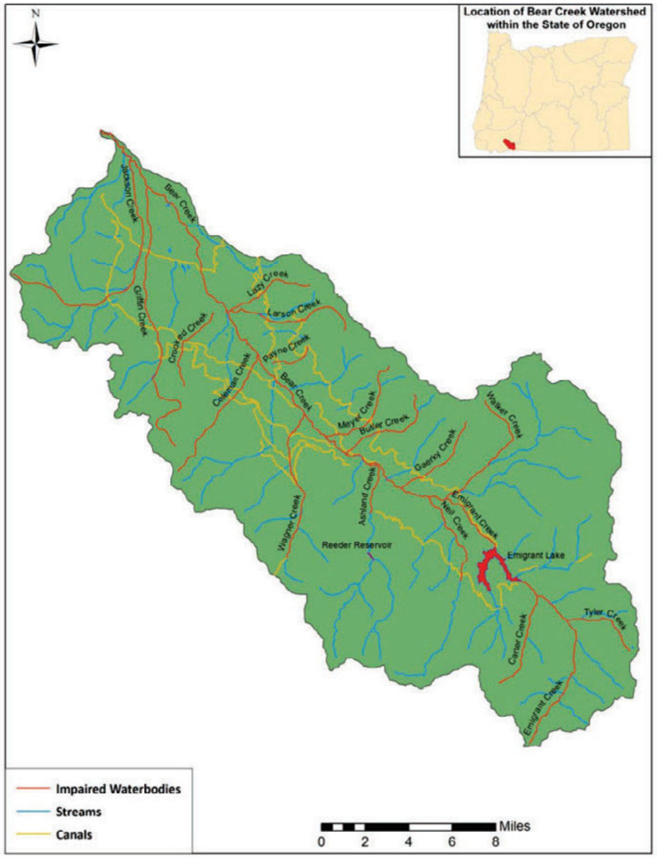


Data Exploration Checklist

- Inputs:
  - Pollutants of concern
  - Pollution control types & implementation schedule
  - Monitoring locations
  - Study design
  - Water quality targets
- Outputs:
  - Covariates
  - Sample frequency, timing, and size
    - Project costs
  - Statistical methods

Example Dataset: Bacteria in Bear Creek, OR

- TMDLs for Bear Creek & tributaries (1992 & 2007):
  - Ammonia
  - BOD
  - Total phosphorus
  - Sediment
  - Bacteria
  - Temperature
- 2008-2009 summer *E. coli* concentrations at the watershed outlet.



Excel Tool - Pilot Data Worksheet

Pilot Data Worksheet - *Enter pilot data for the water quality parameters included in TMDL effectiveness monitoring.*

Step 1.

Define Water Quality Parameters - *Select a water quality parameter from the drop-down menu OR type the parameter name in the drop-down box. Enter up to ten parameters and measurement units for pilot data.*

Parameter 1:	E. Coli	*Measurement Units:*	MPN/100 mL
Parameter 2:	Streamflow	*Measurement Units:*	cfs
Parameter 3:		*Measurement Units:*	
Parameter 4:		*Measurement Units:*	
Parameter 5:		*Measurement Units:*	
Parameter 6:			
Parameter 7:			
Parameter 8:		*Measurement Units:*	
Parameter 9:		*Measurement Units:*	
Parameter 10:		*Measurement Units:*	

Ammonia
Chlorophyll a
Fecal Coliform
Macroinvertebrate
Nitrate/Nitrite
Periphtyon
Total Nitrogen
Total Organic Carbon

- ***Enter Parameter Names & Units***

Step 2.

Enter Pilot Data *- Enter sample dates and values in the appropriate column. Notes:*

-500 sample dates/values can be entered for each parameter.

-Do not leave cells empty to indicate missing data. If a sample date is specified, values must be entered for all parameters.

-If pasting data from another spreadsheet, select ***Values and Number Formats*** *from the* ***Paste Special*** *menu.*

-Enter a numeric season code (1-12) if seasonality will be explored. Up to 12 seasons can be defined.

-Separate project files should be created for parameters collected at varied frequencies/dates (e.g., monthly nitrate and weekly TSS).

-Users with continuous data may wish to enter daily mean values (or daily minimum/maximum/etc.).

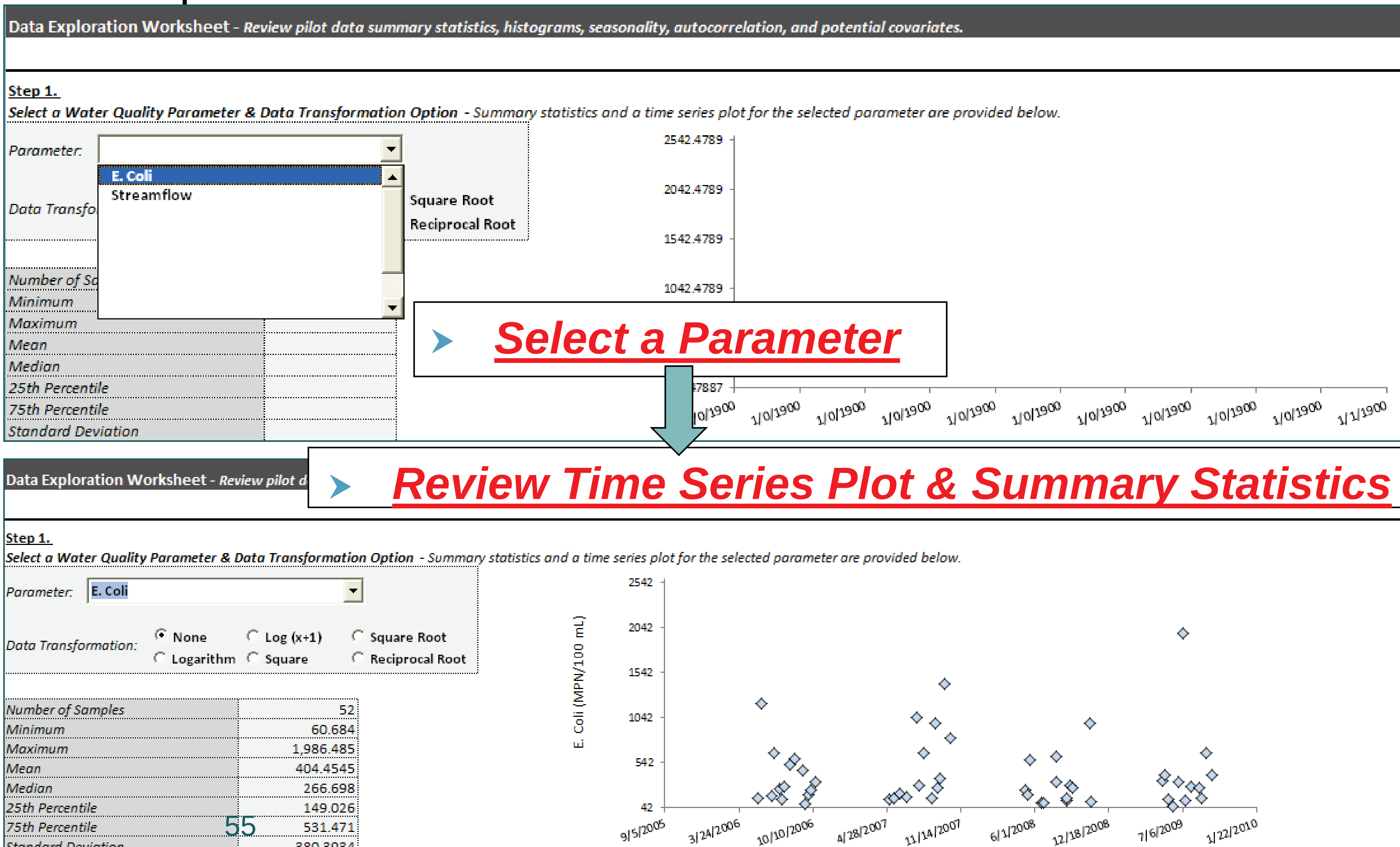
When finished, click on the Data Exploration worksheet tab to explore pilot data.

Sample Date	*Sample Season*	*E. Coli (MPN/100 mL)*	*Streamflow (cfs)*	*Parameter 3*	*Parameter 4*
5/15/2006	5	150	164		
5/24/2006	5	1203	216		
6/20/2006	6	179	65		
6/28/2006	6	649	38		
7/11/2006	7	248	33		
7/19/2006	7	139	34		
7/26/2006	7	272	31		
8/8/2006	8	517	53		
8/23/2006	8	579	41		
9/13/2006	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9/20/2006	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9/27/2006	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10/5/2006	10	236	58		
10/18/2006	10	328	48		
5/4/2007	5	133	212		
5/16/2007	5	146	36		
6/1/2007	6	196	30		
6/21/2007	6	162	27		
7/19/2007	7	1047	111		
7/25/2007	7	291	43		
8/6/2007	8	649	53		
8/27/2007	8	147	51		
9/6/2007	9	987	35		
9/11/2007	9	260	26		

Welcome | **Pilot Data** | Data Exploration | Sample Size | Cost Estimation

Enter Sample Dates, Seasons & Values

Excel Tool - Data Exploration Worksheet

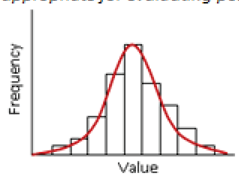


Excel Tool - Data Exploration Worksheet

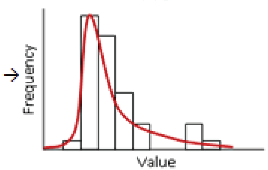
Step 2 .

Review the Histogram - *Does it take on the characteristic "bell" shape of normally-distributed data or appear highly-skewed? How does the skewness change when a data transformation is applied? If the data appear normally distributed, a parametric statistical test may be appropriate for evaluating post-TMDL water quality change.*

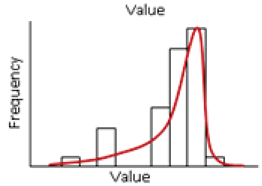
Histogram showing normal distribution →

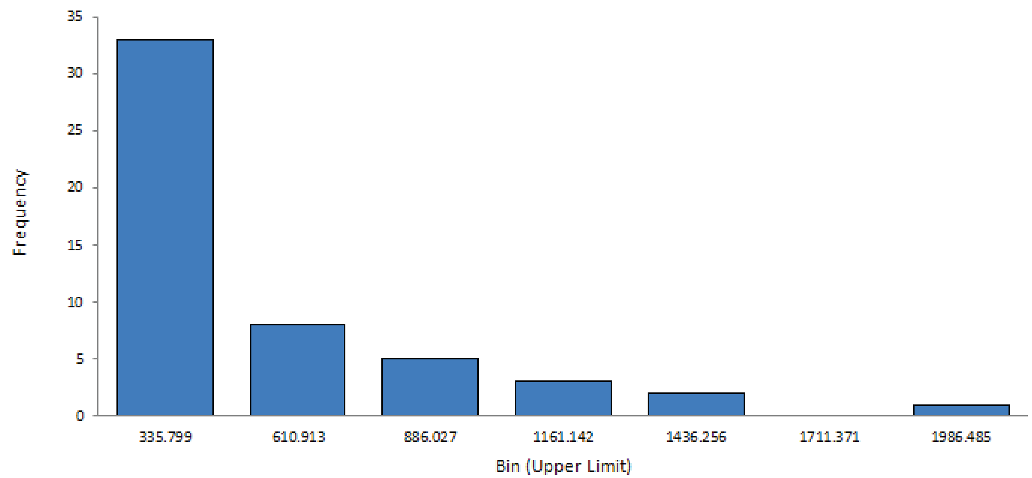


Histogram showing right-skewed distribution →



Histogram showing left-skewed distribution →





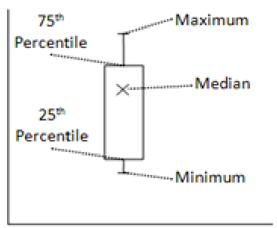
➤ ***Review Histogram***

Excel Tool - Data Exploration Worksheet

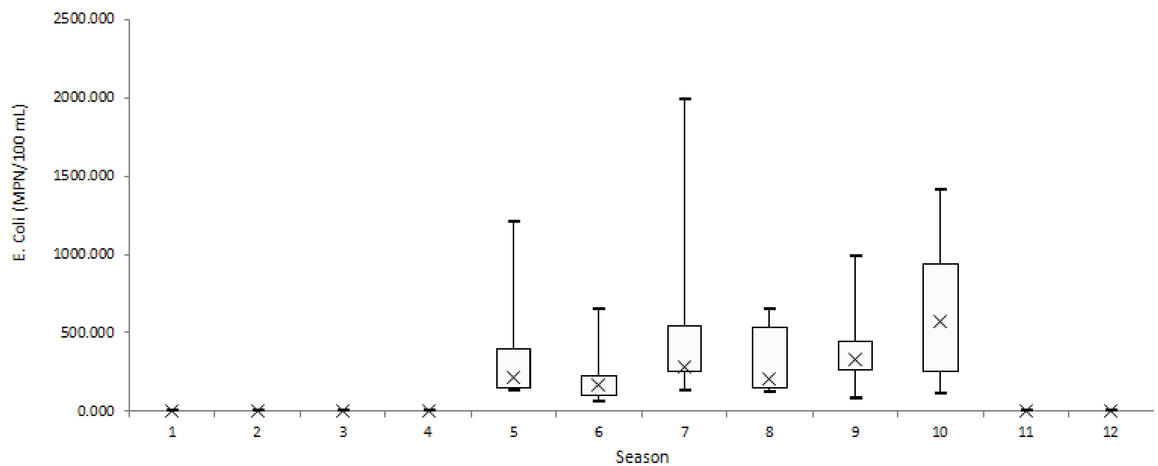
Step 3.

Review the Seasonal Boxplot *- Are observed values similar for each season or does the parameter display strong seasonality? If a strong seasonal pattern is evident, planners may wish to monitor and analyze single-season data only (e.g., the season with the highest risk for water quality impairment) or apply advanced statistical methods that account for the effects of seasonality on trend detection or comparisons of two data groups.*

The boxplot displays 5 key summary statistics for each season: the minimum, 25th percentile, median, 75th percentile, and maximum values:



Note that the seasonal boxplot will not be populated unless two or more numeric seasonal codes (1-12) are entered in the Pilot Data Worksheet (up to 12 seasons can be defined).



	Season 1	Season 2	Season 3	Season 4	Season 5	Season 6	Season 7	Season 8	Season 9	Season 10	Season 11	Season 12
25th Percentile					147.262	102.500	254.109	146.652	259.693	259.031		
Minimum					133.403	60.684	125.888	118.592	82.265	112.572		
Median					214.954	170.284	283.302	205.604	328.309	572.290		
Maximum					1203.396	648.721	1986.485	648.721	987.216	1413.760		
75th Percentile					394.062	228.150	541.063	532.672	448.338	939.298		

➤ ***Review Seasonal Boxplot***

Excel Tool - Data Exploration Worksheet

Step 4.

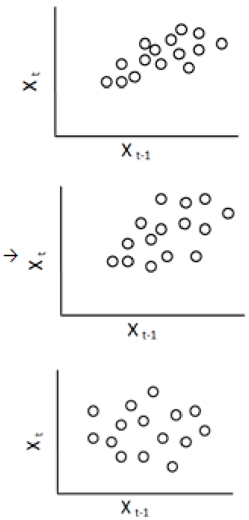
Review the Lag Plot - *Does the parameter display lag-1 autocorrelation (correlation between observed values and observations lagged by one sampling interval)? The presence of strong lag-1 autocorrelation is noteworthy since the assumption of independent/random samples included in many statistical tests is violated. Autocorrelated data require the use of specialized statistical tests for evaluating TMDL effectiveness.*

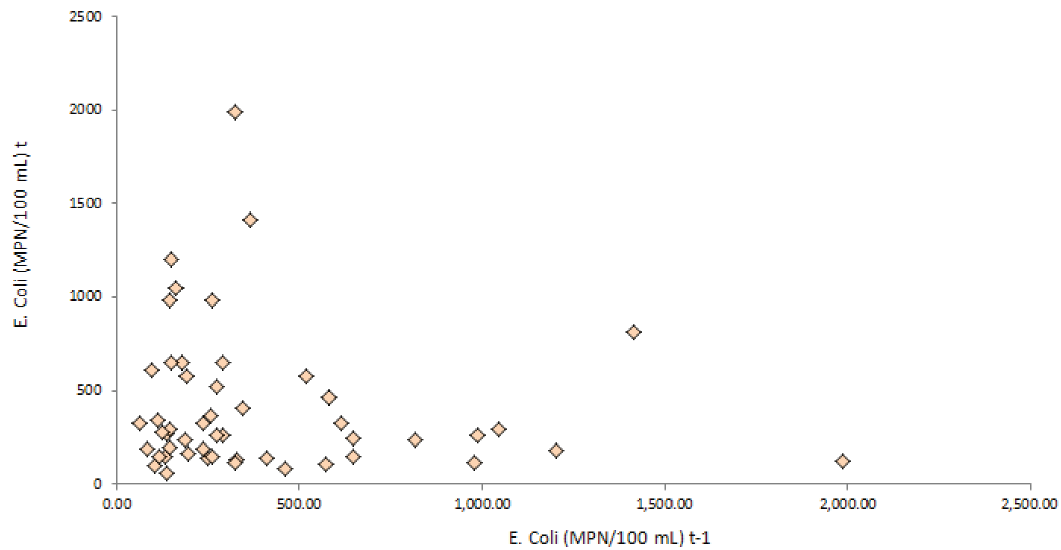
The lag plot displays observed values on the y-axis and lagged values on the x-axis. Note that the lag plot is valid for parameters sampled at regular intervals only (e.g., monthly or weekly) with complete data records.

Lag plot showing strong autocorrelation →

Lag plot showing moderate autocorrelation →

Lag plot showing weak autocorrelation →





➤ **Review Lag Plot**

Excel Tool - Data Exploration Worksheet

Step 5.

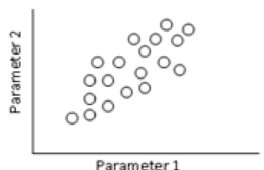
Explore Covariates *- Review the scatterplot and correlation statistics between parameters. Does the scatterplot appear random or do the parameters "vary together"? The addition of covariates in monitoring and statistical analysis can increase the detectability of water quality changes.*

Covariate: Streamflow

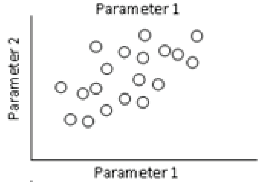
Covariate Transformation: (•) None ( ) Log (x+1) ( ) Square Root ( ) Logarithm ( ) Square ( ) Reciprocal Root

Correlation Coefficient (R)	0.08
Coefficient of Determination (R^2)	0.01

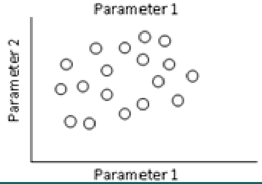
Scatterplot showing strong correlation →

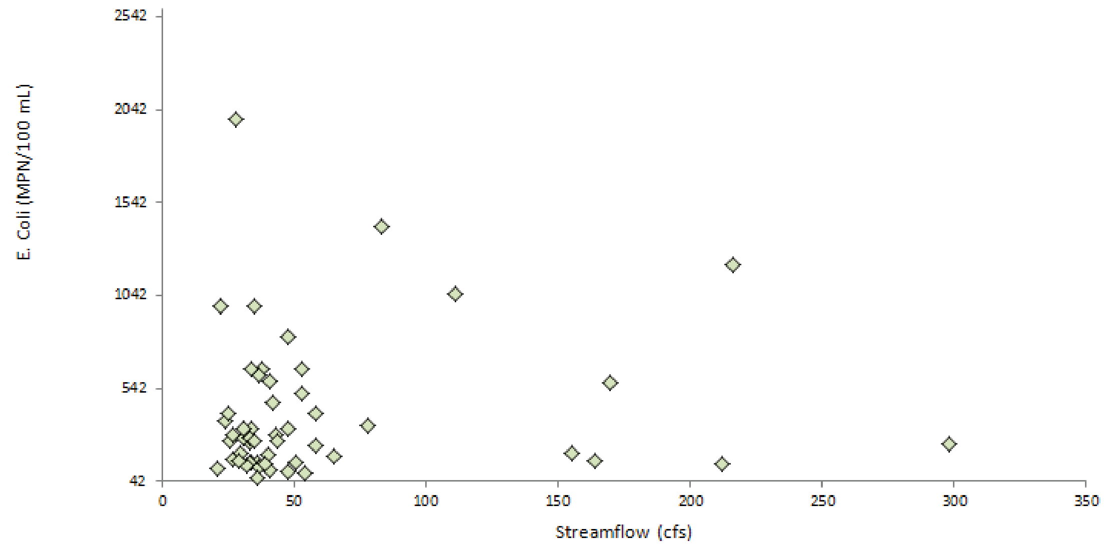


Scatterplot showing moderate correlation →



Scatterplot showing weak correlation →





➤ **Explore Covariates**

Excel Tool - Data Exploration Worksheet

Data Exploration Worksheet - *Review pilot data summary statistics, histograms, seasonality, autocorrelation, and potential covariates.*

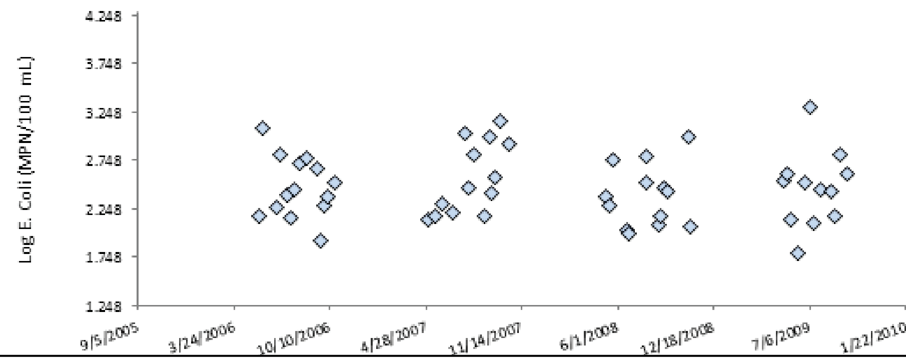
Step 1.

Select a Water Quality Parameter & Data Transformation Option *- Summary statistics and a time series plot for the selected parameter are provided below.*

Parameter: E. Coli

Data Transformation: ○ None ○ Log (x+1) ○ Square Root ◉ Logarithm ○ Square ○ Reciprocal Root

Number of Samples	52
Minimum	1.783
Maximum	3.298
Mean	2.4637
Median	2.426
25th Percentile	2.173
75th Percentile	2.725
Standard Deviation	0.3452



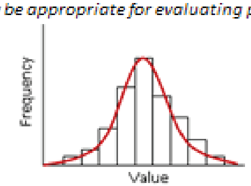
Explore Data Transformation Options

Step 2.

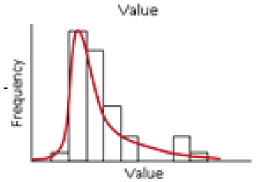
Review the Histogram *- Does it take on the characteristic "bell" shape of normally-distri*

distributed, a parametric statistical test may be appropriate for evaluating post-TMDL

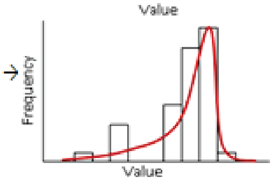
Histogram showing normal distribution →

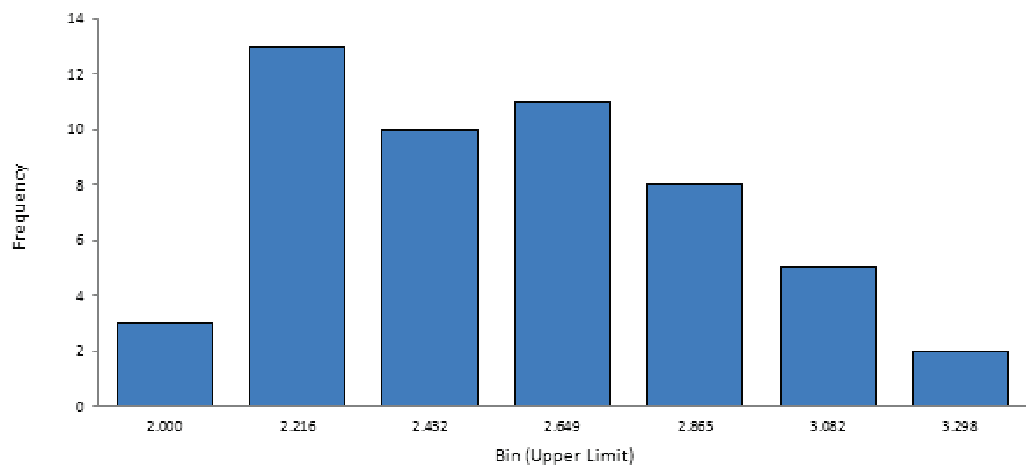


Histogram showing right-skewed distribution →



Histogram showing left-skewed distribution →

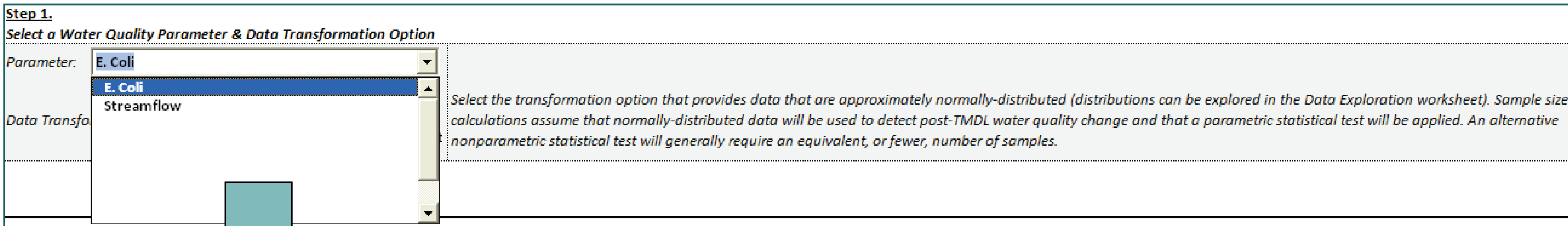




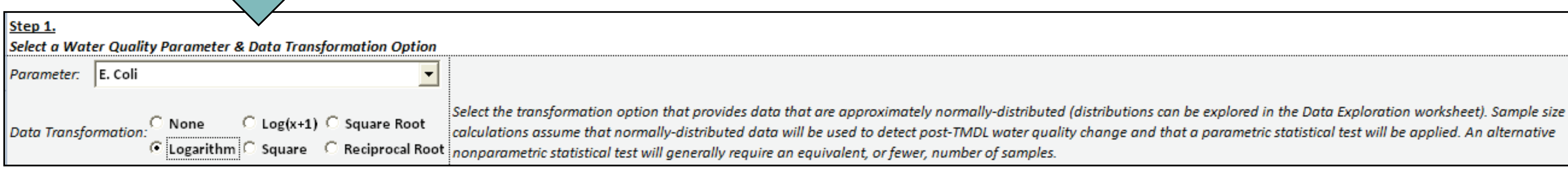
Excel Tool - Sample Size Worksheet

- How many samples are needed to detect a statistically significant water quality change?
- Depends on:
  - Statistical test applied
  - Confidence level
  - Statistical power
  - Data variability
  - Minimum detectable change

Excel Tool - Sample Size Worksheet



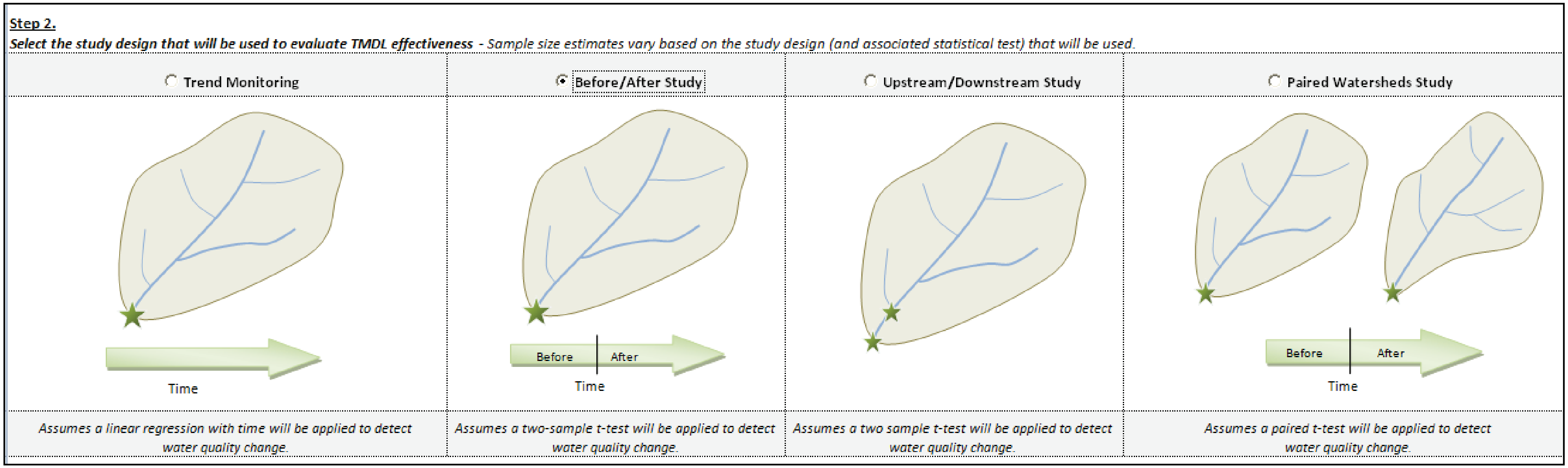
- ***Select a Parameter & Data Transformation Option***



- ***Key Assumption: A Parametric Statistical Test Will be Applied***

Excel Tool - Sample Size Worksheet

- Sample size depends on:
  1) Statistical test applied



- **Select Study Design**

Excel Tool - Sample Size Worksheet

- Sample size depends on:
  2) Statistical power
  3) Confidence level

Step 3.
***Enter Desired Power and Confidence Level** - Sample size increases with increased statistical power and confidence level.*

Statistical Power	0.80	*Statistical power is the probability (0 to 1) that a water quality change will be detected given that a change has actually occurred. The minimum recommended value is 0.8.*
Confidence Level	0.90	*The confidence level is the probability (0 to 1) that a water quality change that is detected has actually occurred. The minimum recommended value is 0.9.*

- ***Enter Statistical Power & Confidence Level***

  4) Data variability

Step 4.
***Estimate Data Variability (Standard Deviation)** - Sample size increases with increased data variability.*

Standard Deviation (from pilot data)	0.345	*The standard deviation of the selected parameter is calculated from data entered in the Pilot Data worksheet. If a transformation was applied in Step 1, the standard deviation of the transformed dataset is used for estimating sample size and is displayed here.*

- ***Review Standard Deviation***

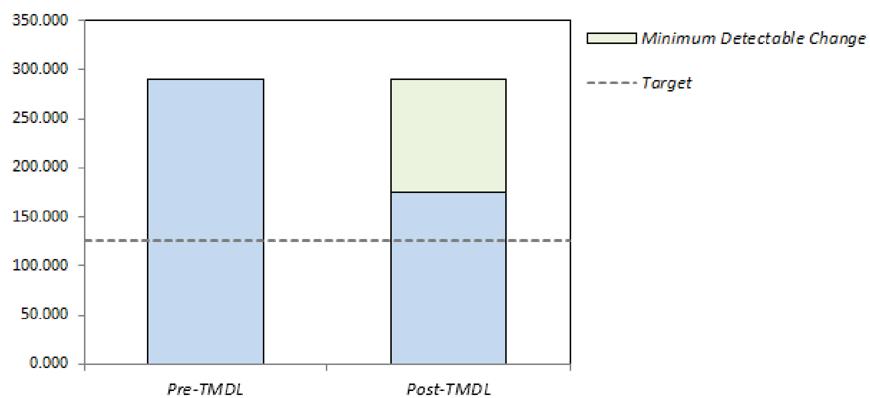
Excel Tool - Sample Size Worksheet

- Sample size depends on:
  5) Minimum detectable change

Step 5.

Enter Minimum Detectable Change - *Water quality changes less than the minimum detectable change cannot be detected with statistical significance. Sample size increases with decreased minimum detectable change.*

Pre-TMDL Mean (from pilot data)	290.902 MPN/100 mL	*The mean of the selected parameter is calculated from data entered in the Pilot Data worksheet. If a transformation is applied, the mean of transformed values is displayed in untransformed units.*
Change Type & Direction	◉ Percent ○ Absolute ◉ Decrease ○ Increase	*The minimum detectable change can be entered as a percent change (e.g., a 10% decrease) or absolute change (e.g., a 0.1 mg/L decrease).*
Minimum Detectable Change	40.000 %	*Enter the desired minimum detectable change as a percent change or absolute change in untransformed units.*
Water Quality Target	126.000 MPN/100 mL	*Enter the water quality target. This value is for display purposes and is not used in sample size calculations.*



The plot on the left displays three factors to take into account when selecting a minimum detectable change value:

1) The pre-TMDL condition (displayed here as the pre-TMDL mean);
2) The expected post-TMDL condition (displayed here as the pre-TMDL mean minus the minimum detectable change); and
3) The post-TMDL target.

Users may wish to designate the minimum detectable change as the change needed to achieve the water quality target (the difference between the pre-TMDL mean and the target). However, incremental changes which are less than this difference will not be detected as statistically significant. If a goal of the monitoring study is to identify incremental changes (i.e., the target is not expected to be met during the study period), a smaller minimum detectable change value should be entered.

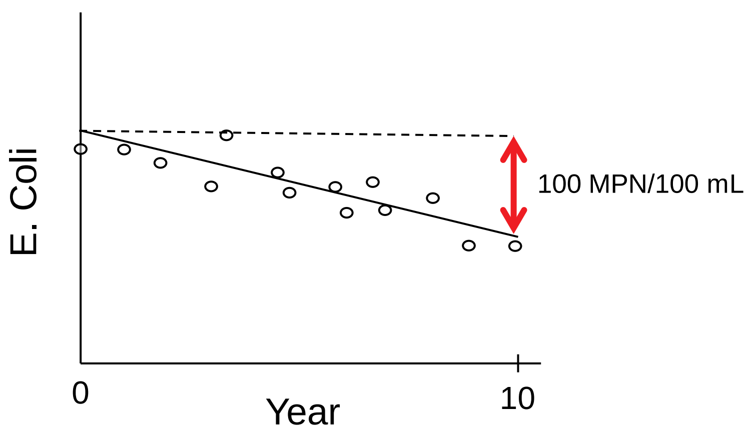
- ***Enter Minimum Detectable Change***

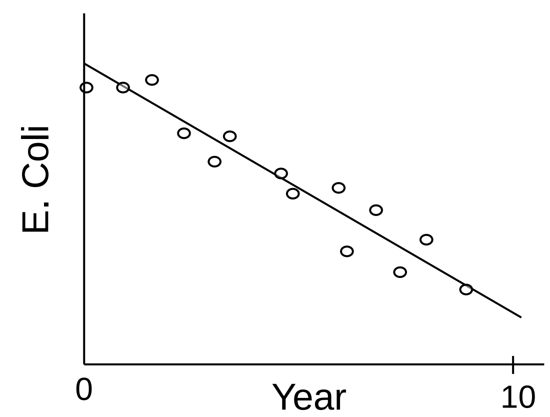
Excel Tool - Sample Size Worksheet

Step 5.

Enter Minimum Detectable Change *- Water quality changes less than the minimum detectable change cannot be detected with statistical significance. Sample size increases with decreased minimum detectable change.*

Pre-TMDL Mean (from pilot data)	290.902 MPN/100 mL	*The mean of the selected parameter is calculated from data entered in the Pilot Data worksheet. If a transformation is applied, the mean of transformed values is displayed in untransformed units.*
Change Type & Direction	○ Percent ◉ Absolute ◉ Decrease ○ Increase	*The minimum detectable change can be entered as a percent change (e.g., a 10% decrease) or absolute change (e.g., a 0.1 mg/L decrease).*
Minimum Detectable Change	100.000 MPN/100 mL	*Enter the desired minimum detectable change as a percent change or absolute change in untransformed units.*
Minimum Length of Time	10 years	*Enter the desired minimum length of time for detecting a statistically significant trend.*





➤ ***Enter Minimum Detectable Change***

Excel Tool - Sample Size Worksheet

Step 6.

Estimate Sample Size — Click the **Estimate Sample Size** button to calculate the minimum number of samples needed to satisfy the conditions specified in steps 2 - 5.

Total Sample Size	62
Samples per Period (Total Sample Size / 2)	31

Save Sample Size — Click the **Save Sample Size** button to add the sample size estimate to the Cost Estimation worksheet.

Before moving on, please note that this power analaysis includes several assumptions:
- *Data are normally distributed.*
- *An unpaired or paired t-test, or linear regression with time, will be used to evaluate water quality changes.*
- *Pilot data are representative of TMDL effectiveness monitoring data.*
- *Samples are independent/random (not autocorrelated).*

If these assumptions are not met, sample size estimates will be skewed and should be viewed as general approximations only.

- ***Estimate Sample Size***

Step 6.

Estimate Sample Size — Click the **Estimate Sample Size** button to calculate the minimum number of samples needed to satisfy the conditions specified in steps 2 - 5.

Total Sample Size	246
Samples per Year (Total Sample Size / Number of Years)	25

Save Sample Size — Click the **Save Sample Size** button to add the sample size estimate to the Cost Estimation worksheet.

Before moving on, please note that this power analaysis includes several assumptions:
- *Data are normally distributed.*
- *An unpaired or paired t-test, or linear regression with time, will be used to evaluate water quality changes.*
- *Pilot data are representative of TMDL effectiveness monitoring data.*
- *Samples are independent/random (not autocorrelated).*

If these assumptions are not met, sample size estimates will be skewed and should be viewed as general approximations only.

Excel Tool – Cost Estimation Worksheet

- Use information gained from data exploration to estimate project costs:
  - Lab/equipment
  - Labor/personnel
  - Travel
  - QAPP development
  - Data analysis

Cost Estimation Worksheet - *Complete steps one through eight to estimate project costs. Required input is displayed in GREEN cells.*

Step 1.
Enter Project Length - *This should only include years in which data collection will occur. Project length can be estimated from sample size estimates on the Sample Size worksheet.*

Number of Years	10

Step 2.
Estimate Lab Analysis Costs - *Enter the cost per sample, number of samples per site over the project length, and number of sites. Sample size requirements can be estimated on the Sample Size worksheet.*

Parameter	*Cost per Sample*	*Number of Samples per Site*	*Number of Sites*	*Cost*
Parameter 1 - E. Coli	$ 25	246	1	$ 6,150
Parameter 2 - Streamflow				$ -
Parameter 3 -				$ -
Parameter 4 -				$ -
Parameter 5 -				$ -
Parameter 6 -				$ -
Parameter 7 -				$ -
Parameter 8 -				$ -
Parameter 9 -				$ -
Parameter 10 -				$ -
Total	----	----	----	$ 6,150
Total per Year	----	----	----	$ 615

- Adjust monitoring decisions to maximize available resources

Question & Answer

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