Guidance for Evaluating Emerging Stormwater Treatment Technologies

Technology Assessment Protocol – Ecology (TAPE)

January 2008 Revision

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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

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Prepared by:

Washington State Department of Ecology
Water Quality Program

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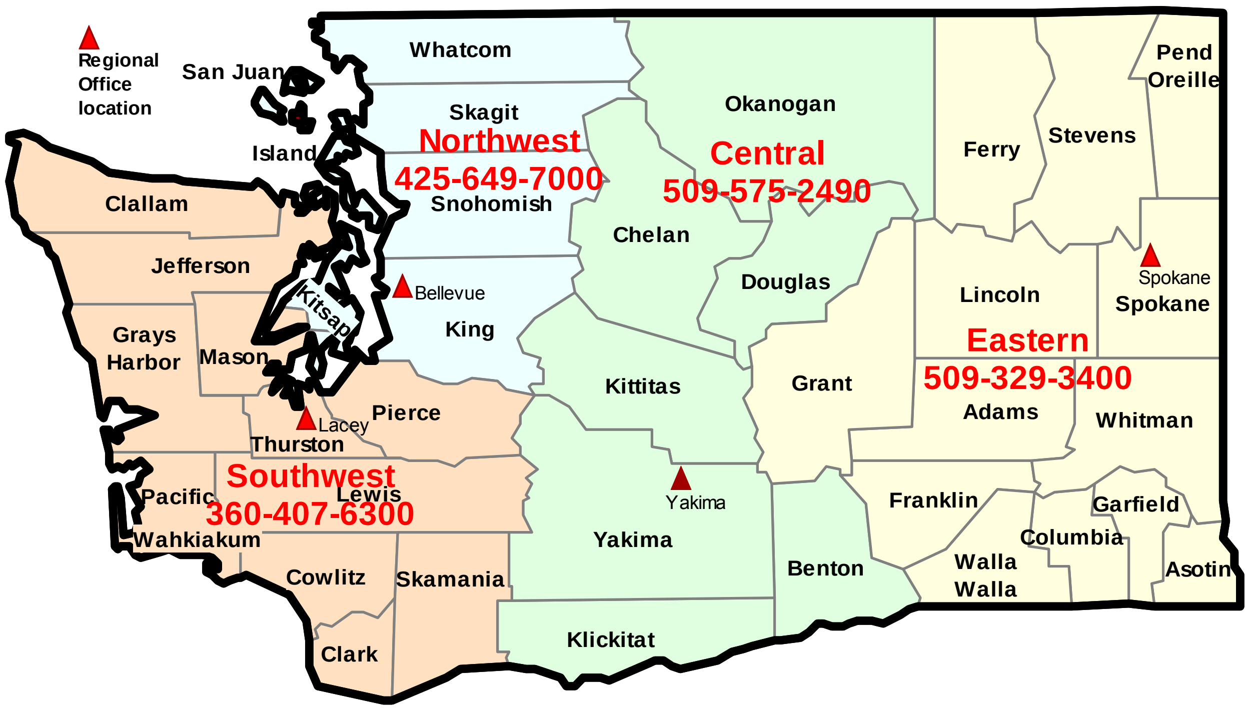

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Acknowledgment

Ecology developed this guidance document with the considerable assistance of a Technical Review Committee (TRC). Ecology appreciates efforts of the committee members and their willingness to share their expertise. Members included:

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Introduction

The Washington State Department of Ecology (Ecology) *Stormwater Management Manual for Western Washington* (SWMMWW) (Ecology 2005) and *Stormwater Management Manual for Eastern Washington* (SWMMEW) (Ecology 2004) include design criteria and performance goals for stormwater treatment facilities. The design criteria and performance goals ensure treatment facilities meet the treatment goals for new development, redevelopment, and retrofit situations. These Ecology manuals can be found online at http://www.ecy.wa.gov/programs/wq/stormwater/index.html.

Volume V, Chapter 12 of the SWMMWW and Chapter 5, Section 12 of the SWMMEW discuss emerging treatment technologies. The stormwater manuals do not provide criteria for the selection and sizing of emerging technologies because the technologies and the knowledge base are rapidly evolving. To provide local governments with guidance on permitting emerging treatment technologies, Ecology established the Technical Review Committee to evaluate and recommend new treatment technologies for addition to the list of technologies deemed to be all known, available, and reasonable methods of prevention, control, and treatment (AKART).

Purpose of This Guidance Document

This guidance defines a testing protocol and process for evaluating and reporting on the performance and appropriate uses of emerging stormwater treatment technologies. By obtaining accurate and relevant data, Ecology and the Technical Review Committee (TRC) can assess performance claims. Portions of this document may also be used to reevaluate the effectiveness of public domain best management practices (BMPs), possibly resulting in changes to the design standards for these practices in the stormwater management manuals. Local governments statewide can use the emerging technology use level designations posted on Ecology's website where applicable, depending on local conditions.

Applicability

This testing protocol is designed for short detention, flow-based BMPs and may not be suitable for all stormwater treatment practices. A proponent[1] may request a preliminary meeting with the TRC and Ecology to discuss which portions of the Technology Assessment Protocol – Ecology (TAPE) would apply for the technology and suggest other testing methods applicable to the technology.

Ecology's TAPE Program is not intended for conducting research on experimental devices. Ecology will not consider an application for a pilot use level designation (PULD), conditional use level designation (CULD), or a general use level designation (GULD) unless the application includes sufficient performance data that clearly demonstrate acceptable feasibility and the likelihood that it will achieve desired performance levels at actual full-scale field conditions.

[1] Proponent refers to the person(s) who are promoting the project through the TAPE process. This can be the manufacturer, the product vendor, the consultant, etc.

Roles and Responsibilities

Technical Review Committee (TRC)

The TRC includes representatives from Ecology and eastern and western Washington local governments.

The TRC:

- Assists Ecology in reviewing all submittals.
- Provides recommendations and assessments to Ecology of the appropriate emerging technology use level designations for posting at Ecology's website.
- Meets, as needed, to review new information and revise/update the TAPE.
- Interacts with Ecology staff to assess how well the TAPE process satisfies Ecology's stormwater treatment BMP selection objectives.

Ecology

Ecology facilitates the TAPE review process and:

- Participates in TRC activities.
- Grants use level designations.
- Approves extensions and changes made to use level designations.
- Provides oversight and analysis of all submittals to ensure consistency with Ecology's most recent western and eastern Washington stormwater manuals.
- Posts relevant information on the Ecology website.

Proponent of the technology

The proponent:

- Prepares the use level designation application.*
- Prepares the quality assurance project plan (QAPP).*
- Prepares the technology evaluation report (TER).*
- Provides information to interested parties. (The information that is available will be included in the use level designation documentation.)
- Informs Ecology of any changes in production, manufacturer standing, key personnel, etc.

*Ecology strongly encourages proponents to retain a consultant or an experienced agency professional (third party) to oversee preparation of all documentation.

Ecology *requires* independent third party work for all reports that contain field data regardless of where these data were collected. All proponents that submit conditional use level designation applications or general use level applications must have third party consultation. Independent third party consultation must begin at the onset of the field program. Ecology encourages proponents to involve an independent third party at the onset of laboratory testing as well.

At a minimum, an independent professional *must*:

- Complete the data validation report verifying that monitoring was conducted in accordance with the approved protocol and the approved QAPP.
- Prepare a TER summary that includes a test results summary and conclusions and compares these with the supplier's performance claims.
- Provide a recommendation of the appropriate technology use level.
- Provide additional testing recommendations, if needed.

Parties that do not have a direct financial interest in the outcome of testing a treatment device (e.g., public agencies' testing of public domain treatment facilities) are not required to obtain an independent third party review.

Cost consideration in conducting the verification program

The financial burden for completing a development program, including the laboratory and field testing, lies with the proponent of the emerging technology. Neither Ecology nor the TRC will provide funding for this work.

Ecology recognizes the need to minimize the cost of implementing a verification program. To the extent applicable, the following list provides ways to minimize cost yet provide sufficient verification data:

- For pilot use level and conditional use level designation applications, a proponent may submit data collected using protocols other than the TAPE, such as Environmental Technology Verification (ETV), Environmental Technology Evaluation Center (EvTEC), and Technology Acceptance and Reciprocity Partnership (TARP). Data must be consistent with the expectations of the TAPE process. A proponent cannot obtain a general use level designation by submitting data exclusively collected using protocols other than the TAPE.
- Use laboratory and controlled field testing to the maximum extent practical and justifiable.
- Carefully select field test sites so that evaluations based on the TAPE will be efficiently conducted and the results can be applied elsewhere, consistent with other protocols.
- Carefully prepare the QAPP to minimize the need to conduct additional sampling.
- Periodically evaluate the results to check for statistical significance and acceptability. For example, the number of sampling events required by this protocol ranges from 12 to 35. Proponents would therefore be prudent to review the data after 12 sample events have been analyzed to see if they are sufficient.
- For determination of statistical significance, consider pooling of data from several sites per application or for several applications, if justified. Data from more than one site can be combined (pooled) to meet the 12-35 sample event criterion provided that the tributary drainages are from similar land uses and the pollutant concentration variability is reasonably comparable. Data collected from different sized treatment systems must be normalized to reflect the size difference using flow data for this normalization.
- Submit interim status reports to Ecology and the TRC and request a sufficiency opinion.
- Propose/implement other cost saving measures based on the best professional judgment (BPJ) of the project professionals.

Ecology-Specified Treatment Performance Goals

Ecology's stormwater manuals specify basic, enhanced, phosphorus, and oil treatment goals, as stated below. Ecology provides details on these performance goals in Volume V, Chapter 3, of the SWMMWW and Chapter 5, Section 1 of the SWMMEW. Proponents claiming pollutant removal effectiveness should demonstrate that the treatment performance goals are achieved. The performance goals depend on whether the technology is a stand-alone facility or part of a treatment train. As part of a treatment train, the proponent should evaluate the performance of the entire treatment train and its components. In addition, Ecology will evaluate "factors other than treatment performance" to determine the emerging technology's appropriate use(s) (see Appendix B).

Performance goals apply to the water quality design flow rate and apply on an average annual basis to the entire annual discharge volume (treated plus bypassed). The incremental portion of runoff in excess of the water quality design flow rate can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. The local government may require that treatment facilities engage a bypass at flow rates higher than the water quality design flow rate, as long as the reduction in pollutant loading exceeds that achieved with initiating bypass at the water quality design flow rate. All performance goals apply to stormwater typically found in Pacific Northwest maritime climates, where long duration, low intensity storms predominate and stormwater contains mostly silt-sized particles.

There are several categories of solids in stormwater. These include total suspended solids, suspended solids concentration, total dissolved solids, and gross solids. For treatment performance goals, Ecology defines total suspended solids as all particles smaller than 500 microns in diameter.

Basic treatment

Ecology's basic treatment menu facility choices should achieve 80% removal of total suspended solids for influent concentrations ranging from 100 to 200 mg/L. For influent concentrations greater than 200 mg/L, a higher removal efficiency is appropriate. For influent concentrations less than 100 mg/L, the facilities should achieve an effluent goal of 20 mg/L total suspended solids.

Enhanced treatment (SWMMWW) or metals treatment (SWMMEW)

The enhanced menu facility choices should provide a higher rate of removal of dissolved metals than most basic treatment facilities. The performance goal for enhanced treatment assumes that the facility treats stormwater with dissolved copper ranging from 0.003 to 0.02 mg/L, and dissolved zinc ranging from 0.02 to 0.3 mg/L. Influent dissolved metals data must be in this range to obtain a use level designation. Data collected for an "enhanced" BMP should demonstrate significantly higher removal rates than basic treatment facilities. Data available on basic treatment BMP dissolved metals removal (e.g., from vendors or the ASCE National Stormwater BMP Database) can help determine if the device demonstrates significantly higher removal rates. Enhanced treatment facilities must achieve basic treatment goals in addition to enhanced treatment goals.

Phosphorus treatment

The phosphorus menu facility choices should achieve a goal of 50% total phosphorus removal for a range of influent total phosphorus (TP) of 0.1 to 0.5 mg/L. The phosphorus menu facility choices must achieve basic treatment goals in addition to phosphorus removal.

Oil treatment

The oil control menu facility choices should achieve the goals of no ongoing or recurring visible sheen, and a daily average total petroleum hydrocarbon concentration no greater than 10 mg/L, and a maximum of 15 mg/L for a discrete (grab) sample.

Pretreatment applications

The pretreatment menu generally applies to:

- Project sites using infiltration treatment.
- Treatment systems where pretreatment is needed to assure and extend performance of the downstream basic or enhanced treatment facilities.

The pretreatment menu facility choices should achieve 50% removal of total suspended solids for influent concentrations ranging from 100 to 200 mg/L. For influent concentrations less than 100 mg/l, the facilities should achieve an effluent quality of 50 mg/l total suspended solids.

Emerging Technology Designated Use Levels

The TRC and Ecology will evaluate the application report and determine a use level designation for each technology. The TRC will provide a draft use level designation document for proponent feedback prior to forwarding the use level designation to Ecology. Ecology will then review the TRC's recommendations and publish appropriate determinations on its website. Technologies that have not obtained a use level designation will not be posted on the website.

The TRC bases use level designations on the quality and quantity of performance data that the proponent supplies. Devices that have pilot and conditional use level designations require field testing to completely verify the technology's performance claims and obtain a general use level designation. To obtain a general use level designation devices must be field tested at a site that is representative of the Pacific Northwest. Typical weather must be characterized by low intensity, long duration storms and stormwater must contain mostly silt-sized particles. The easiest way to do this is pick a site located in the Pacific Northwest but if this is not a viable option, sites outside of the Pacific Northwest will be considered. For general use level designation, a quality assurance project plan must be submitted to Ecology and approved before testing can begin at any site. For proposed sites outside the Pacific Northwest, the proponent must prove that the site will represent conditions commonly found in the Pacific Northwest. Providing storm intensity information and particle size distribution data from the proposed site will help assess site representativeness.

Device owners do not need to remove devices that have pilot or conditional use level designations if field testing indicates that the device did not perform as expected. The owner may need to retrofit the site or add additional treatment BMPs in order to attain the level of treatment required for the area. Because local installation and testing provide useful information, Ecology encourages local jurisdictions, industrial/ commercial establishments, and consultants to pursue use of technologies with pilot and conditional use level designations.

Pilot use level designation

For emerging technologies with limited performance data, the pilot use level designation (PULD) allows limited use to enable field testing. PULDs may be given based solely on laboratory performance data. Pilot use level designations apply for a specified time period only. During this time period, the proponent must complete all field testing and submit a TER to Ecology and the TRC. Ecology will limit the number of installations to five during the pilot use level period.

Local governments may allow PULD technologies to be installed *provided* the proponent agrees to conduct additional field testing based on the TAPE at *all* installations in Washington state to obtain a general use level designation (GULD). Proponents must notify Ecology of each site and submit a site specific QAPP for review and approval before testing can begin. Proponents must conduct field testing at a minimum of one site indicative of or located in the Pacific Northwest[2] to obtain a GULD.

Local governments covered by a municipal stormwater NPDES permit must notify Ecology in writing when a PULD technology is proposed (use form in Appendix C). Ecology encourages other jurisdictions to notify Ecology headquarters when a PULD technology is proposed. Ecology also encourages all local governments to require vendors to provide a performance guarantee stating that PULD facilities will be upgraded as necessary, to the maximum extent practical, to meet Ecology performance goals.

Conditional use level designation

The TRC established the conditional use level designation (CULD) for emerging technologies that have a considerable amount of performance data but the data were not collected per the TAPE protocol. The TRC may recommend a CULD based on field data collected by a protocol that is reasonably consistent but does not necessarily fully meet the TAPE protocol. The field data must meet the statistical goals set out in the TAPE guidelines (Appendix D). Laboratory data may be used to supplement field data. Conditional use level designations apply for a specified time period only. During this time period, the proponent must complete all field testing and submit a TER to Ecology and the TRC. Ecology will limit the number of installations to ten during the CULD period. Proponents must notify Ecology of all sites that to be located in Washington. This notification requirement only applies during the CULD period. Proponents must complete field testing at a minimum of one site indicative of or located in the Pacific Northwest[2] to obtain a general use level designation.

General use level designation

The general use level designation (GULD) confers a general acceptance for the treatment device. Technologies with a GULD may be used anywhere in Washington, subject to Ecology conditions. Ecology plans to include GULD technologies in future stormwater manual updates.

[2] Pacific Northwest refers to locations in Washington, Oregon, Northern California, or British Columbia with rainfall distributions typical of a Pacific Northwest maritime climate, where long duration, low intensity storms predominate and stormwater contains mostly silt-sized particles.

Technology Assessment Protocol-Ecology (TAPE)

Objectives of the test protocol

The objectives of this protocol are to characterize, with a reasonable level of statistical confidence, an emerging technology's effectiveness in removing pollutants from stormwater runoff and to compare test results with proponent's claims. The test protocol also assesses technologies with respect to other factors such as maintenance, reliability; and longevity (see Appendix B).

Use level designation steps

The technology performance evaluation process consists of the following elements:

1. Preliminary testing of the product by the proponent.
2. Use level application submission to Ecology and TRC for review.
3. Denial or approval of a use level designation by Ecology.
4. Quality Assurance Project Plan submittal by proponent and approval by Ecology and the TRC.
5. Testing at a site indicative of the Pacific Northwest.
6. Submission of a Technical Evaluation Report to Ecology and the TRC.
7. Denial or approval of a general use level designation by Ecology.

Use level designation timeline

For technologies that receive a PULD or CULD, the designation will expire 30 months following PULD issuance. This allows for 6 months for TRC TER review. After the review, Ecology will issue a GULD, revoke the use level designation, or allow an extension.

Technologies that receive a GULD have no expiration date. Use level designations may be updated by Ecology at any time. Ecology will always discuss the update with the proponent prior to publication of any changes to the use level designation.

Proponents requiring extensions on use level designation components (QAPPs, TERs) must submit a request to Ecology at least 2 weeks before the due date. Ecology will grant extensions only if the proponent shows that progress is being made toward completing required components.

Use level designation application

Proponents must complete some testing to obtain relevant data before submitting a use level designation application so Ecology and the TRC can determine which use level designation to grant a technology. The reporting section gives a more detailed description of the requirements for use level designation applications and technology evaluation reports.

At a minimum, a **pilot use level designation** application *must include*:

- A cover letter.

- A detailed technology description.
- Description of system hydraulic capacity and performance.
- Field or laboratory data in support of the performance claims. These data may be collected by a protocol that is reasonably consistent but does not necessarily fully meet the TAPE protocol.
- A thorough analysis of the data with conclusions about system performance and any relevant statistical information.

At a minimum, a **conditional use level designation** application *must include*:

- A cover letter.
- A detailed technology description.
- Description of system hydraulic capacity and performance.
- Field data in support of the performance claims. These data may be collected by a protocol that is reasonably consistent but does not necessarily fully meet the TAPE protocol. Field data may be supplemented with laboratory data to reflect TAPE requirements.
- A thorough analysis of the data with conclusions on system performance.
- A statistical analysis as described in Appendix D.
- A third party review as described in the **Roles and Responsibilities** section of this guidance.

At a minimum, a **general use level designation** application *must include*:

- A cover letter.
- A Technical Evaluation Report (TER).
- A third party review as described in the **Roles and Responsibilities** section of this guidance.

Reporting

Use level designation applications should contain as many of the elements as possible from the following list. A GULD application (Technical Evaluation Report) requires all elements. A layout similar to that described below allows for an efficient review of the application.

For reports that obtain information from multiple test sites, proponents do not need to rewrite the cover letter, introduction, and technology description for each site. If using data from reports following other protocols, make sure data are consistent with that required in the TAPE in terms of storm and reporting criteria.

1. Cover letter

The cover letter should include:

- A description of the use level designation requested with an explanation of treatment type. For example, “we are requesting a pilot use level designation for basic treatment…”

- A brief performance claim for specific land use and identification of target pollutants. For example, "this device can remove 85% of total suspended solids from parking lots and residential streets…"
- The signature of a company representative.

2. Introduction

   The introduction should reiterate information included in the cover letter. It should include a description of the use level designation requested and include a performance claim.

3. Technology description

The technology description should include the elements listed below. The description should ensure that the reader can understand completely how the product works after reading this section.

- Detailed description of how the device works including its physical, chemical, and/or biological treatment functions. (Design drawings or photographs may be useful in this section.)
- Physical description of each treatment system component including:
  - Engineering plans/diagrams showing each of the functional components
  - Description of construction materials
  - Equipment dimensions
  - Description of each component's capacity
  - Explanation of site installation requirements (such as necessary soil characteristics, hydraulic grade requirements, depth to groundwater limitations, utility requirements)
- Description of any pretreatment requirements or recommendations.
- Detailed description of the sizing methodology.
- Expected treatment capabilities.
- Maintenance procedures.
- Description of bypass process.

4. Sampling procedures

This section should include descriptions of how data were obtained. It should describe:

- All procedures for obtaining data including a description of any deviations from this procedure.
- Equipment used to obtain data. (If the equipment is standard monitoring equipment, giving company name and model number is appropriate.)
- Quality assurance/quality control measures taken.
- Statistical goals used during monitoring.
- Detailed site information including a site map. This should include land cover type, land use activities location, site conditions, site elevations and slopes, location of sampling equipment, location of on-site stormwater collection system, and a description of any upstream BMPs.

- The method for sizing the device for the specific location.
- The specific device used (model number, size).
- The method used to calculate removal rates.
- Bypass conditions.
- Analytical methods used.
- Necessary maintenance needs including any devices necessary for maintenance performance. Include both preventative maintenance procedures to be implemented during the course of the field tests as well as long-term maintenance.

5. Data summaries

This section should include all summarized data for the site described in the sampling procedures section. The section should include:

- A summary table of the storm event data. This table should include the storm name, location, the storm depth (inches), the antecedent dry period (hours), the number of influent aliquots, the number of effluent aliquots, the storm duration, the influent volume of water, the volume of water bypassed for each storm event, and comparisons of data to storm event guidelines.
- Individual Storm Reports. These reports compare data and provide a detailed description of each storm event monitored in an easy to read format. Individual storm reports should include:

  General information
  - Storm name
  - Site location
  - Event date
  - System description (equipment model numbers, flowrate, etc.)
  - Date of last maintenance
  - Antecedent conditions

  Hydrological information
  - Total precipitation
  - Influent peak flow rate (gpm)
  - Effluent peak flow rate (gpm)
  - Bypass peak flow rate (gpm)
  - Total influent runoff volume (gallons)
  - Total effluent runoff volume (gallons)
  - Total bypass runoff volume (gallons)
  - An event hydrograph with axes of flow, time, and precipitation (time on x-axis, flow and precipitation on y-axes). Event hydrograph should include a graph of precipitation, influent flow, and effluent flow.

  Pollutant information
  - Number of influent aliquots
  - Number of effluent aliquots

- Parameters monitored
- Influent mean concentrations
- Effluent mean concentrations
- Removal efficiency (calculated per Appendix A)
- Reported detection limits

6. Maintenance information

This section should include any data available about maintenance. Ecology suggests you use a graphical representation of pollutant removal over time highlighting the times when and how maintenance was performed to verify maintenance cycles.

7. Statistical information

This section should include any information relevant to statistical goals such as determinations of coefficient of variance, confidence intervals, probability plots, and description of tests used. Good examples of statistical analysis reporting can be found at: http://www.bmpdatabase.org/

Note: The International Stormwater Database criteria do not meet all TAPE requirements. This link is solely intended to be a good example of statistical reporting.

8. Discussion

This section should include:

- A statistical data evaluation.
- An explanation of any deviations from sampling procedures.
- Information about anticipated performance in relation to climate, design storm, and/or site conditions.
- Information on recommended maintenance schedules, and identify any special disposal requirements.
- An explanation of poor performance.

9. Conclusions

Provide any conclusions based on the findings and summarize all performance claims in this section.

10. Appendices

This section should include all raw data such as any laboratory information, chain of custody forms, and resumes.

11. Third party review

For all submittals that contain field data, an independent professional third party must conduct the following elements:

- Complete the data validation report verifying that monitoring was conducted in accordance with the protocol and the QAPP.
- Prepare a data summary, including a test results summary and conclusions compared with the supplier's performance claims.
- Provide a recommendation of the appropriate technology use level.
- Provide additional testing recommendations, if needed.

Confidential information submitted by the applicant

Certain records or other information furnished to Ecology *may* be deemed confidential pursuant to RCW 43.21A.160. In order for such records or information to be considered confidential, the owner or operator of such technology must certify that the records or information relate to the processes of production unique to the owner or operator, or release to the public or to a competitor would adversely affect the competitive position of such owner or operator. The owner or operator must request that such records or information be made available only for the confidential use of Ecology. Upon receipt of such request, Ecology will consider the request, and, if deeming such records or information confidential would not be detrimental to the public interest and would otherwise be in accordance with Ecology's policies and purposes, may grant the request for confidentiality. Owners/operators may request return of material if Ecology denies the request for confidentiality. At a minimum, requests for confidentiality require a one month review.

To make a request for confidentiality clearly mark only those pages that contain confidential material with the words "confidential." Include a letter of explanation as to why these pages are confidential. Ecology will send notice granting or denying the confidentiality request.

Requesting/revising use level designations

Proponents seeking a technology use level designation by Ecology should mail their submittal to the following address:

TAPE Coordinator
Washington State Department of Ecology
Water Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

Send initial submittals to both the TRC chair and the TAPE Protocol Coordinator. They will review the applications for completeness. After initial review, send complete applications to the entire TRC. Proponents may obtain TRC contact information by contacting the TAPE Coordinator whose information can be found on the Emerging Technologies website: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html. Submittals can be mailed in paper format, on a CD, or sent electronically.

At a minimum, both initial and TRC review require a one month review period.

Ecology may amend a technology's use level designation at any time. Ecology will notify the proponent in the event of a change.

Granting a use level designation

Ecology grants a use level designation based on the information submitted and best professional judgment. Submitting the appropriate amount of data does not guarantee that Ecology will grant a use level designation. Ecology bases decisions on system performance and other factors including maintenance, operation, integrity, etc. (See Appendix B). Technologies not granted a GULD or CULD will automatically be considered for a CULD or PULD, respectively.

Quality assurance project plan (QAPP)

Proponents need to carefully plan and execute monitoring programs. *After* obtaining a PULD or CULD and *before* initiating testing at a site indicative of or located in the the Pacific Northwest for obtaining a GULD, the proponent must prepare and submit a quality assurance project plan (QAPP) for Ecology and TRC review and approval. QAPPs must be approved for each field test site proposed. Devices with a PULD must test at all proposed sites in Washington State.

The proponent must submit a QAPP that meets the TAPE's GULD requirements within **six months** of receiving a **PULD**.

The proponent must submit a QAPP that meets TAPE requirements either **with the CULD application** or within **six months** of receiving a CULD.

Failure to submit the QAPP within 6 months of receiving a PULD or CULD, or failing to demonstrate satisfactory progress during the testing period, will result in a suspension or cancellation of the PULD/CULD on the Ecology website. A suspension limits the installations to one in Washington State during the suspension period. Ecology will remove the suspension when the proponent finds a field site and receives approval for the QAPP. A cancellation requires the proponent to resubmit for use level designation. During use level suspension Ecology encourages local governments to allow installation of the device at a site, provided the applicant receives Ecology approval to test at the site.

The QAPP must specify the procedures to be followed to ensure the validity of the test results and conclusions. A person with good understanding of analytical methods should develop the QAPP in consultation with the analytical laboratory. The QAPP author should understand field sampling and data validation procedures. (Note: Refer to Role and Responsibilities section for additional guidance).

Ecology's QAPP guidance, Guidelines for Preparing Quality Assurance Project Plan for Environmental Studies (Publication #04-03-030) can be downloaded at: http://www.ecy.wa.gov/biblio/0403030.html. The QAPP guidelines include the following basic elements:

- Title page with approvals
- Table of contents and distribution list
- Background information and information about the technology to be tested
- Project description
- Organization and schedule
- Method quality objectives, including statistical goals
- Sampling process design
- Sampling procedures

- Measurement procedures
- Quality control
- Data management procedures
- Audits and reports
- Data verification and validation
- Data quality assessment
- Interim progress report(s) during the testing program (if applicable)

QAPP organization and approval schedule

The QAPP must specify the name, address, and contact information for each organization and individual participating in the performance testing. The QAPP must:

- Include project manager, test site owner/manager, field personnel, consultant oversight participants, and analytical laboratory that will perform the sample analyses.
- Identify who will perform the third-party evaluation.
- Identify each study participant's roles and responsibilities and provide key personnel resumes.
- Provide a schedule documenting when the equipment will be installed, the expected field testing start date, projected field sampling completion, and final project report submittal.

Ecology and the TRC will review and approve the QAPP prior to the start of field testing. Ecology recommends that before sampling begins, the proponent should allocate time for initial startup and testing of the treatment system and monitoring equipment. Proponents should allow up to three months for QAPP review and approval.

Sampling design considerations

This section describes test procedures for evaluating the stormwater treatment technologies.

Facility sizing

Although field testing must be performed at a site indicative of or located in the Pacific Northwest for GULD, which does not include sites in eastern Washington, sizing for facilities in eastern Washington is included for reference.

Western Washington:

Base sizing of the test facility to meet applicable performance goals at the design flow rate coinciding with treating at least 91% of the runoff volume, using an Ecology-approved continuous simulation model such as Ecology Western Washington Hydrology Model or MGS Flood.

Eastern Washington:
Each agency or local government should specify which of the following methods will be used to size facilities preceding detention ponds. If the jurisdiction has not identified a preferred method, the default method is Method 1.

Method 1: The runoff flow rate predicted for the proposed development condition from the short-duration storm with a 6-month return frequency.

Method 2: The runoff flow rate predicted for the proposed development condition from the SCS Type II 24-hour storm with a 6-month return frequency,

Method 3: The runoff flow rate for the proposed development condition calculated by the Rational Method using the 2-year Mean Recurrence Interval (see Chapter 4.7 of the SWMMEW). This method may be used *only* to design facilities based on instantaneous peak flow rates.

For both eastern and western Washington, base sizing for runoff facilities sited downstream of detention facilities on the full 2-year release rate of the detention facility.

Test site characterization

Select field test sites consistent with the technology's intended applications and geographical location. Sites must provide influent concentrations typical of stormwater for those land use types. Include the following information about the test site:

- Field test site catchment area, tributary land uses, (roadway, commercial, high-use site, residential, industrial, etc.) and amount of impervious cover.
- Description of potential pollutant sources in the catchment area (e.g., parking lots, roofs, landscaped areas, sediment sources, exterior storage, or process areas).
- Baseline stormwater quality information to characterize conditions at the site. For sites that have already been developed, Ecology recommends that the vendor collect baseline data to determine whether site conditions and runoff quality are conducive to performance testing.
- Site map showing catchment area, drainage system layout, and treatment device and sampling equipment locations.
- Catchment flow rates (i.e., water quality design flow, 2-year, 10-year, and 100-year peak flow rates) at 15-minute and 1-hour time steps as provided by an approved continuous runoff model.
- Make, model, and capacity of the treatment device.
- Location and description of the closest receiving water body.
- Description of bypass flow rates and/or flow splitter designs necessary to accommodate the treatment technology.
- Description of pretreatment system, if required by site conditions or technology operation.
- Description of any known adverse site conditions such as climate, tidal influence, high groundwater, rainfall pattern, steep slopes, erosion, high spill potential, illicit connections to stormwater catchment areas, and industrial runoff.

Ecology allows flow controlled field test sites , for example, the I-5 Lake Union Ship Canal Bridge site in Washington State. The field test site uses actual stormwater but controls the flows through the devices with gates and valves. Sampling plans will differ from these sites as compared to other field sites.

Number of test sites

Ecology requires field testing for a GULD. Devices that receive a PULD or a CULD must complete field testing at a minimum of one site indicative of or located in the Pacific Northwest. Sites should reflect the technology's intended applications. Samples should be collected over a range of rainfall intensities encountered during the year. For a GULD, collect samples over one and a half maintenance cycles to verify maintenance requirements and show how performance changes over time. For expected maintenance cycles greater than two years, the proponent must agree to conduct long term testing to show how performance decreases over time. In this case, the proponent may obtain a GULD with provisions for future testing.

Number of stormwater samples

Base the number of sample events on statistical significance (see Appendix D for a complete description). At a minimum, 12 sampling events are needed for statistically significant performance data. Regardless of statistical significance, 35 sample events is the maximum sampling effort required for this protocol. In this case, Ecology may grant a GULD based on statistically less significant performance data. The number of sample events required will vary with each field site and application. This requirement applies to flow-weighted and discrete flowrate (including design flowrate) composite sampling. Data from more than one site can be combined (pooled) to meet the 12-35 events criterion if the tributary drainages are from similar land uses and the pollutant concentration variability is reasonably comparable. In order to assess performance on an annual average basis, proponents should collect samples over a range of rainfall intensities.

Storm event guidelines

Ecology established the following storm event guidelines to assist in developing the sampling plan. If all the storm event guidelines are met, runoff produced will likely contain pollutant concentrations within an acceptable range.

Feature	Explanation	Guidelines
Minimum storm depth	Total rainfall amount during the sampling event	0.15 inches
Storm start/end (antecedent dry-period)	Defines the storm event's beginning and end as designated by minimum time interval without significant rainfall	6 hours minimum with less than 0.04 inches of rain
Minimum storm duration	Shortest acceptable runoff duration	1 hour
Minimum storm intensity	Lowest intensity that qualifies as a rainfall event.	None, as long as above guidelines are met[1]

[1] Average intensities should exceed 0.03 inches per hour of at least half the sampled storms.

Stormwater field sampling procedures

This section describes field sampling procedures necessary to ensure the quality and representativeness of the collected samples. This section presents discussions on sampling methodology (e.g., discrete versus composite sampling), flow monitoring, target pollutant selection, sample handling and preservation, and field QA/QC.

Sampling methods

Collect samples using automatic samplers, except for chemical constituents that require manual grab samples. Use Teflon or Teflon-lined tubing if samples will be analyzed for organic contaminants. To use automatic sampling equipment for insoluble TPH/oil, a determination is needed that any TPH/oil adherence to the sampling equipment is accounted for and meets QA/QC objectives. This determination requires support with appropriate data. The responsible project professional should certify that the sampling equipment and its location would likely achieve the desired sample representativeness, aliquots, frequency, and compositing at the desired influent/effluent flow conditions.

Note: Tygon or Teflon tubing may be used for sampling conventional parameters and metals.

Ecology identified the following three sampling methods for evaluating whether new treatment technologies will meet the Ecology stormwater treatment goals:

1. Automatic flow-weighted composite sampling. Collect samples over the storm event duration and composite them in proportion to flow. This sampling method generates an event mean concentration and can be used to determine whether the treatment technology meets Ecology's pollutant removal goals on an average annual basis. For this method, samples should be collected over the entire runoff period. As a guideline, at least 10 aliquots should be composited, covering at least 75% of each storm's total runoff volume. The greater the number of aliquots and storm coverage, the greater the confidence that the samples represent the event mean concentration for the entire storm. This technique is appropriate for short detention flow-through devices where effluent flows are controlled by the function of the device.

2. **Discrete flow composite sampling**. For this method, program the sampler to collect discrete flow-weighted samples. Combine samples representing relatively constant inflow periods (e.g., less than 20% variation from the median flow) to assess performance under specific flow conditions. The monitoring approach must also address the effect of lag time within the device that would affect the comparability of influent and effluent samples paired for purposes of evaluating a particular flow rate. One way to achieve this is to set the flow pacing so that each discrete sample bottle fills when the total runoff volume passing the sampler is equal to 8 times the treatment unit's detention volume. Other ways to account for lag time may also be considered.

This method is suitable and necessary for flow-through devices (e.g., minimal hydraulic residence time at design flow). Proponents can use this method to determine whether the treatment technology achieves Ecology's pollutant removal goals at the design hydraulic loading rate. For this method, collect samples over a flow range that includes the manufacturer's recommended treatment system design flow rate. Sample other flow ranges to characterize the efficiencies of the device over a reasonable range of hydraulic loading rates. Distribute samples over a range of flow rates from 50-150% of the device's design loading rate. This technique is necessary for devices where the influent and effluent flowrate are nearly equal because the system does not control the effluent flowrate (e.g., swirl separators). This technique is required to verify how the device functions at varying flow rates.

3. Combination method. For flow-through devices, proponents can use a combination of the above two methods to evaluate both Ecology treatment goals. For the combination method, collect discrete flow composite samples as allowed during a single storm event and process for analysis. Composite the remaining bottles in the sampler into a single flow-weighted composite sample to capture the entire runoff event for analysis. Mathematically combine the results from the discrete flow composite samples and the single flow-weight composite sample to determine the overall event mean concentration.

The above sampling techniques are not appropriate for long detention BMPs (e.g., wet ponds). Ecology is currently working on a sampling method that applies to long detention BMPs.

Sampling locations

Provide a site map showing all monitoring/sampling station locations and identify the equipment to be installed at each site. To accurately measure system performance, samples must be collected from both the inlet to and outlet from the treatment system. Sample the influent to the treatment technology as close as possible to the treatment device inlet. Samples should represent the total runoff from the catchment area and should not include debris and particles greater than 500 microns in diameter (see Appendix F). To ensure that samples represent site conditions, design the test site so that influent samples can be collected from a pipe that conveys the total influent to the unit. To avoid skewing influent pollutant concentrations, sample the influent at a location unaffected by accumulated or stored pollutants in, or adjacent to, the treatment device.

Sample the effluent at a location that represents the treated effluent. If bypass occurs, measure bypass flows and calculate bypass loadings using the pollutant concentrations measured at the influent station. In addition, be aware that the settleable or floating solids, and their related bound pollutants, may become stratified across the flow column in the absence of adequate mixing. Collect samples at a location where the stormwater flow is well-mixed.

Sampler installation, operation, and maintenance

Provide a detailed sampling equipment description (make and model) as well as equipment installation, operation, and maintenance procedures. Discuss sampler installation (e.g., suction tube intake location relative to flow conditions at all sampling locations, field equipment security and protection), automatic sampler programming (e.g., composite versus discrete sampling, proposed sampling triggers and flow pacing scheme), and equipment maintenance procedures. Install and maintain samplers in accordance with manufacturer's recommendations. Indicate any deviations from manufacturer's recommendations. Provide a sampling equipment maintenance schedule. When developing the field plan, pay particular attention to managing the equipment power supply to minimize the potential for equipment failure during a sampling event.

Flow monitoring

Measure and record flow into and out of the treatment device on a continuous basis over the sampling event duration. The appropriate flow measurement method depends on the nature of the test site and the conveyance system. Depth-measurement devices and area/velocity measurement devices are commonly used flow measurement equipment. For offline systems or those with bypasses, measure flow at the bypass as well as at the inlet and outlet. Describe the flow monitoring equipment (manufacturer and model number), maintenance frequency and methods, and expected flow conditions (e.g., gravity flow or pressure flow) at the test site. For offline flow, describe the flow splitter that will be used and specify the bypass flow set point. Identify site conditions, such as tidal influence or backwater conditions that could affect sample collection or flow measurement accuracy. Ecology recommends that sampling/monitoring sites be established at locations where gravity flow conditions exist, because obtaining accurate flow measurements with existing flow measuring equipment under backwater conditions is difficult. Flow should be logged at a 15-minute or shorter interval, depending on site conditions.

Rainfall monitoring

Measure and record rainfall at 15-minute intervals or less during each storm event from a representative site. Indicate the type of rain gauge used (e.g., an automatic recording electronic rain gauge, such as a tipping bucket connected to a data logger, that records rainfall in 0.01 inch increments), provide a map showing the rain gauge location in relation to the test site, and describe rain gauge inspection and calibration procedures and schedule. Install and calibrate equipment in accordance with manufacturer's instructions. At a minimum, inspect the rain gauge after each storm and if necessary, maintain it. In addition, calibrate the gauge at least twice during the field test period. If the onsite rainfall monitoring equipment fails during a storm sampling event, use data from the next-closest, representative monitoring station to determine whether the event meets the defined storm guidelines. Clearly identify any deviations in the TER report. Nearby third party rain gauges may be used only in the event of individual rain gauge failure and only for the period of failure. If third party rain gauges are used to fill in data gaps, establish a regression relationship between site and third party gauges and use the regression equation to adjust the third party data to represent site rainfall when needed.

Target pollutants

Base pollutant analyte selection on the proponent's performance claims and product literature. The proponent should tailor the sampling regime to support the desired treatment level (basic, enhanced, phosphorus, oil, or pretreatment). The performance claims may be evaluated in relation to one or more of the parameters listed in the table below. Unless otherwise specified, analyze the parameters listed in the table at both the inlet and outlet sampling stations. See Appendix E for a detailed listing of chemical analyses, methods, and reporting limits.

Treatment level	Required parameters	Optional but recommended parameters
Basic and pretreatment	TSS, PSD[a], pH (lab)	SSC, TVSS, TP, PSD[b], total and dissolved Cu and Zn, NWTPH-Dx, deicing salts[d]
Phosphorus	TSS, PSD[a], pH (lab), TP, orthophosphate	SSC, TVSS, PSD[b]
Enhanced	TSS, PSD[a], pH (lab), hardness, total and dissolved Cu and Zn	SSC, TVSS, PSD[b], total and dissolved Cd and Pb, NWTPH-Dx[c], toxicity testing
Oil	NWTPH-Dx[c], Visible sheen	PSD[b], NWTPH-Gx[c]

[a] Influent station.
[b] Effluent station.
[c] Grab sample only.
[d] Roadway deicer, such as sodium and calcium chloride, should be included; if the deicer can significantly impact the performance of the device or it is a target pollutant.

Sampling for TSS

This protocol defines TSS as matter suspended in stormwater, excluding litter, debris, and other gross solids exceeding 500 microns in diameter (larger than medium-sized sand). Conceptually this definition is consistent with the Standard Methods 2540D approach, which excludes large particles if their inclusion is not desired.

To determine percent TSS reduction, the samples must represent the vertical cross section (be a well-mixed or homogeneous sample) of the sampled water at the influent and the effluent of the device. Select the sampling location and place and size the sampler tubing with care to ensure the desired representativeness of the sample and the stormwater stream. The influent sample must represent only particles that are smaller than 500 microns to be considered as a stand-alone treatment device. The sampling and analysis procedure for determining the particle size fraction below 500 microns can include sieve, such as US Standard #35 sieve, and instrumental analyses. The site professional should select the method using best professional judgment.

In this protocol, Ecology applies the TSS removal performance criterion at a discrete short timeframe for the low residence time treatment devices. This short-term performance criterion is necessary for sizing and for performance verification, but is not intended to be a measurement of compliance. Event and seasonal means are needed to confirm the sizing of long residence time devices and to provide useful data on the performance of the short residence time devices. Ultimately, achievement of Ecology's performance goals applies on an average annual basis to the entire annual discharge volume (treated plus bypassed).

Particle size distribution (PSD)

To meet the TSS removal goals, treatment technologies must be capable of removing TSS across the size fraction range typically found in urban runoff. In the Pacific Northwest, field data show most TSS particles are silt sized particles. PSD data can also provide information regarding solids transport during a storm.

To ensure a representative site and to size the treatment device, analyze TSS and PSD prior to installing the treatment device. Include this information in the QAPP. Proponents may use literature and manufacturer data for sizing, as justified by the project professional. Compare the PSD results of this test program with the PSD used in sizing the treatment device to confirm the design basis of the device.

Of the analytical procedures available, the Coulter Counter (Model 3) and the laser-diffraction method provide sufficient sensitivity to measure smaller particles, although other methods may be available that can attain sufficiently sensitive results. Proponents may use sieves to quantify the particulate fraction beyond the range of the instruments. Due to the potential differences in precision among analytical procedures (Webb, 2000), use the same analytical apparatus and procedure for each evaluation test program. A PSD analytical procedure recommended by the TRC using laser diffraction instrumentation and sieve analysis is attached (Appendix F). Refer to Pitt (2002) for a comprehensive discussion on PSD in stormwater runoff.

Accumulated sediment sampling procedures

Measure the sediment accumulation rate to help demonstrate facility performance and design a maintenance plan. Practical measurement methods would suffice, such as measuring sediment depth immediately before sediment cleaning and following test completion. Analyze sediment samples for PSD. Depending on desired treatment level, consider analyzing for the following constituents:

- Percent total solids
- Grain size; (See Appendix E)
- Total volatile solids
- NWTPH-Dx
- Total cadmium, copper, lead, and zinc
- Total phosphorus

Use several grab samples (at least four) collected from various locations within the treatment system to create a composite sample. This will ensure that the sample represents the total sediment volume in the treatment system. For QA/QC purposes, collect a field duplicate sample (see following section on field QA/QC). Keep the sediment sample at 4^{O}C during transport and storage prior to analysis. If possible, remove and weigh (or otherwise quantify) the sediment deposited in the system. Quantify or otherwise document gross solids (debris, litter, and other particles exceeding 500 microns in diameter). Use volumetric sediment measurements and analyses to help determine maintenance requirements, calculate a TSS mass balance, and determine if the sediment quality and quantity are typical for the application.

Field quality assurance and quality control (QA/QC)

The field QA/QC section describes the measures that the proponent will employ to ensure the representativeness, comparability, and quality of field samples. Field QA/QC should include the elements listed below:

Equipment decontamination

Describe how sampling equipment (sampler head and suction tubing) will be decontaminated between sampling events to prevent sample cross-contamination. Replace the suction tubing at least once during the test period and more frequently for highly contaminated runoff.

Quality control samples

Include the following QC samples in the QAPP:

Equipment rinsate blanks. Collect equipment rinsate blanks to verify the adequacy of the decontamination process. This verifies that the equipment is not a source of sample contamination. Collect equipment rinsate blanks by passing reagent-grade water through clean equipment and collecting samples for chemical analyses. Analyze these samples as regular samples with all appropriate quality control performed.

Collect equipment rinsate blanks at the inlet monitoring station where stormwater is expected to contain the highest contaminant concentrations. However, if the inlet station is difficult to access (e.g., confined space entry required), proponents may collect the rinsate blank from the outlet station. At a minimum, collect two separate rinsate blanks during the initial equipment startup and testing and at least one additional blank midway through the sampling program. Collect more frequent blank samples if site conditions warrant (e.g., following an event with unusually high contaminant concentrations).

Describe the equipment rinsate blank collection procedure in the QAPP. Include a description of the location and number of samples that will be collected, sample collection and processing procedures, and sample documentation (e.g., length of time that sampler was in place prior to collecting the blank, volume of stormwater that passed through the sample prior to cleaning the equipment). At a minimum, collect rinsate blanks after decontaminating the equipment according to the procedures specified in the QAPP after at least one storm event has been sampled (to “contaminate” the equipment). The stormwater sample should represent a volume of stormwater that will be collected during a typical sampling event.

Ecology (2004) recommends that the equipment rinsate blanks are at a “not detected” level. If they are not, then they will have to be taken into account in determining whether the Measurement Quality Objectives (MQOs) have been met. In the QAPP, describe corrective actions that the proponent will take (e.g., modifying decontamination procedures, replacing suction tubing) if contamination is found in the blank.

Field duplicate samples. A field duplicate is a second independent sample collected at the same location. Field duplicates are primarily used to assess the variation attributable to sample collection procedure and sample matrix effects. Include a description of techniques used to collect duplicate samples and specify the collection frequency in the QAPP. At a minimum, collect 10% field duplicate samples.

Sample preservation and handling

Preserve samples in accordance with Ecology (2005) methods, US EPA-approved methods (EPA 1983), or Standard Methods (APHA, AWWA, WEF 2005). Provide preservation during sample collection, as well as during transport. Describe how the automatic samplers will be cooled to maintain low temperatures throughout the sample collection period.

Provide a table in the QAPP that lists sample container material, sample preservation, and holding time limits for the analyzed pollutants. See Ecology (2005) for sample container selection, preservation requirements, and target pollutant holding time limits. Obtain pre-cleaned sample bottles directly from the analytical laboratory. If the proponent proposes to obtain bottles from another source, provide a detailed bottle-cleaning procedure. Also, describe procedures that will be employed to label and track samples from collection through delivery to the analytical laboratory. Provide a sample chain of custody form in the QAPP.

Samples collected as discrete flow composites may need to be manually composited following the sampling event. If samples will be manually composited, describe compositing procedures to prevent sample cross-contamination. Certain parameters (e.g., NWTPH-Gx) cannot be composited and must be collected as grab samples. Describe how these samples will be collected and at what intervals they will be collected during the storm event.

Equipment calibration

Describe the field equipment calibration schedule and methods, including automatic samplers, flow monitors, and rainfall monitors. Because the accuracy of the flow meters is very important, the site professional – in accordance with manufacturer's recommendations – should carefully conduct and record the calibration.

Recordkeeping

Maintain a field logbook to record any relevant information noted at the collection time or during site visits. Include notations about any activities or issues that could affect the sample quality (e.g., sample integrity, test site alterations, maintenance activities, and improperly functioning equipment). At a minimum, the field notebook should include the date and time, field staff names, weather conditions, number of samples collected, sample description and label information, field measurements, field QC sample identification, and sampling equipment condition. Record measurements of sediment accumulation. In particular, note any conditions in the tributary basin that could affect sample quality (e.g., construction activities, reported spills, other pollutant sources). Provide a sample field data form in the QAPP.

Method quality objectives (MQOs)

MQOs establish consistent methods and procedures to be followed during sampling and analyses. MQOs help ensure that the data quality will be adequate to verify a technology. The MQOs explain: 1) how the data are affected by systematic errors (bias) and 2) the precision of collected/analyzed data. This section should discuss the following elements:

- Bias: Describe the bias measurement methodology and include the bias calculation. Include a table listing each analyte, with an appropriate range for control limits, acceptable spike and surrogate percent recovery ranges (if appropriate), and performance evaluations and/or confidence intervals for certified reference materials (when appropriate). Include a table specifying the frequency and type of quality control to be performed with each batch of samples to be analyzed. The table indicates which analytes will be spiked and which surrogates will be used in the table. Discuss what precautions the proponent will take to reduce bias due to sample collection procedures (including location and seasonal or other time-related concerns), sample transport, and sample storage (e.g., how will samples be kept cold during and after collection). Discuss other bias sources such as calibrations, reagent quality, method blanks, interference effects, dilutions, and field equipment contamination (equipment rinsate blanks).

- Matrix Spikes and Matrix Spike Duplicates (MS/MSDs): Perform MS/MSDs for all organic compounds. For metals, perform at least two separate pairs of MS/MSDs per year on samples specifically from this project. Perform QC on no less than 10% of the analyzed samples. Include one of each type of quality control (QC) procedures specified for small batches (less than 20 samples).

Treat contamination in method blank samples as follows:

- For all samples with contaminants, the sample concentration must be at least five times the method blank concentration in order for the result to be considered valid.
- Reporting limits listed in Appendix E should be met. In some cases, a laboratory may need to reduce laboratory contamination sources to meet the reporting limits.
- Precision: Describe the measurement methodology and include the formula for calculating precision. Include a table indicating the acceptable Percent Relative Standard Deviation (RSD) for laboratory splits, and MS/MSDs. Also, include a table indicating the frequency as well as type of quality control to be performed on each batch of analyzed samples. Perform laboratory splits (laboratory duplicates), field duplicates (important for sediment and grab samples), and MSDs with each batch.

Full-scale laboratory studies

Laboratory testing may precede or augment but cannot entirely replace field testing. Ecology requires field testing at a site indicative of or located in the Pacific Northwest to obtain a GULD. Laboratory data are useful because data can be collected under controlled conditions, in considerably less time than field tests, and under easily modified design conditions.

Conduct laboratory testing to demonstrate pollutant removal at peak design flow rates. The vendor should provide detailed test facility descriptions (photos, illustrations, process/flow diagrams), including all relevant factors such as treatment and hydraulic design flow and loading rates on a unit basis (e.g., gallons per minute per square foot), dead storage/detention volumes, inspection protocols to determine when maintenance is needed, maintenance performed during testing, and media type/quantity/thickness. If a less than full-scale setup is tested in the laboratory, such as single cartridge testing, describe the ratios to the full-scale device (sump capacity, flow paths, material differences, etc.).

Conduct laboratory tests under the following conditions:

- Constant flow rates of 50, 75, 100, and 150%, plus or minus 10%, of the manufacturer's facility design hydraulic loading rate or design hydraulic velocity rate.
- For TSS removal testing, the TSS added to laboratory water should approximate "typical" runoff PSDs for the treatment application (land use). Proponents must use U.S. Silica Sil-Co-Sil 106 ground silica (see Appendix G) to represent a typical PSD. Proponents may use OK-110 to represent a typical PSD for testing treatment technologies that fall under the pretreatment category.

- At a minimum, complete two tests each at 100 and 200 mg/L TSS influent concentration range. Ecology strongly encourages testing at lower influent concentrations as well.
- As a guideline, basic treatment devices should be able to remove at least 80% of Sil-Co-Sil 106 particles at the water quality design flowrate and pretreatment devices should be able to remove at least 80% of OK-110 particles at the water quality design flowrate.

Do not clean filters or settling chambers between tests, unless required under vendor's normal maintenance schedule. Comply with testing and reporting protocols described above.

Proponents must test the facility's maximum hydraulic loading rate to check for TSS resuspension and washout (negative removal efficiency). Conduct this test with the facility's treatment capability fully utilized (that is, at the time maintenance would be normally be performed, such as when the sediment settling area is full or filter media is saturated). Determine the flowrate where washout begins and provide for bypassing flows exceeding this flowrate in design guidelines.

Proponents may also analyze for other parameters during laboratory testing. The proponent should consult with the TRC on testing methods prior to initiating work.

Laboratory quality assurance procedures

Laboratories performing stormwater sample analysis must be certified by a national or state agency regulating laboratory certification or accreditation programs. For test sites located within Washington State, complete all laboratory work at a Washington-accredited laboratory. For a list of accredited labs go to: http://www.ecy.wa.gov/programs/eap/lab-accreditation.html Report results in the TER or use level designation application. Include a table with the following:

- Analyte.
- Sample matrix.
- Laboratory performing the analysis.
- Number of samples.
- Analytical method (include preparation procedures as well as specific methods especially when multiple options are listed in a method).
- Reporting limits for each given analytical method (include the associated units).

On each laboratory sheet include the sampling date, the preservation date if applicable, the extraction date, the analysis date, and whether the sample is a QC sample. Provide a table that shows how laboratory numbers correspond to each site.

When performing composite sampling, the chain-of-custody form must include a column for entering the time and date that the last aliquot is collected. The analytical laboratory needs this information to determine if a holding time has been exceeded.

Laboratory quality control

In the QC section, describe the laboratory's data quality assurance summary package requirements including the case narrative. QC samples are used to evaluate data quality. Quality control should describe laboratory control samples, method blanks, matrix spike/matrix spike duplicates (MS/MSDs), duplicates, surrogates, laboratory splits (lab duplicates), and reference samples such as performance evaluations (PE) or certified reference materials (CRM) when applicable.

Provide a table listing all QC samples being performed. Include the number and type of QC analyses that will be performed for each batch of samples. Perform QC on no less than 10% of the samples being analyzed. Include at least one of each QC procedure specified per batch for small batches.

QC results may indicate problems with the data. Additional procedures may be necessary to correct problems. Corrective actions might include re-calibrations, re-analyses of samples, need to re-sample, need for additional samples, or qualifying results.

Data management procedures

Include a quality assurance summary with a detailed case narrative that discusses problems with the analyses, corrective actions if applicable, deviations from analytical methods, QC results, and a complete definitions list for each qualifier used. Specify field/laboratory electronic data transfer protocols (state the percent of data that will undergo QC review) and describe corrective procedures. Corrections to data entries should include initials of the person making the correction and the date corrected. Indicate where and how the data will be stored.

Data review, verification, and validation

Include descriptions of how samples were handled and collected in all reports. Review all data to determine whether all sampling guidelines were met. Include information on QA/QC procedures. Analyze all data for statistical significance. Consider factors such as confidence level, power curves, and regression equations in the statistical analysis. Guidance on appropriate statistics can be found in Appendix D and other related reports (Pitt, 2002 & Burton and Pitt, 2001.)

Technical evaluation report (TER)

After completing field testing at a site indicative of or located in the Pacific Northwest, submit a TER to Ecology. The TER supports the technologies' ability to obtain a GULD. If Ecology accepts the TER, Ecology will grant a GULD for the technology and will add it to future stormwater management manuals.

Proponents with a **PULD** or **CULD** have a maximum of **24 months** to implement the QAPP and submit the TER.

At a minimum, the TER must contain the following information:

- Performance data from a minimum of one test site indicative of or located in the Pacific Northwest.
- A statement of the QAPP objectives including the vendor's performance claims for specific land uses and applications in western and eastern Washington.
- All deliverables specified in the QAPP.
- A thorough description of the technology, including sizing methodology, flow diagrams and appropriate illustrations.

- All relevant performance test results, statistical analyses, factors other than performance, and operating and maintenance activities including all the information requested in any prior PULD or CULD. A discussion of results obtained during each storm is required.
- Any available non-standard data (data not collected per the TAPE, such as laboratory testing, out-of-state testing not indicative of the Pacific Northwest, or field performance testing with real storms not meeting protocol guidelines).
- Conclusions and recommendations including the technology's development level, recommended operating and maintenance (O&M) procedures and frequency, pretreatment requirements, and use limitations.
- Capital and projected annual costs, including O&M costs.
- An executive summary.
- Recommended information to be posted at Ecology's website.
- Additional testing recommendations, if needed.
- A third-party review.

The reporting section of this protocol gives a more detailed description of the required elements of a TER. All elements of the reporting section are required in the TER.

References

APHA, AWWA, WEF. 2005. *Standard Methods for the Examination of Water and Wastewater*, 21th Edition. American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, DC.

APWA. 1999. *Protocol for the Acceptance of Unapproved Stormwater Treatment Technologies for Use in the Puget Sound Watershed*, prepared by the APWA Task Committee for American Public Works Association, Washington Chapter, Stormwater Managers Committee, WA.

Burton, G.A. Jr. and R. Pitt. 2001. *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*. CRC Press, Inc., Boca Raton, FL.

Ecology. 2004. *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies,* No. 01-03-003. Washington State Department of Ecology, Olympia, WA.

Ecology, 2005. *Manchester Environmental Laboratory Lab Users Manual, Eighth Edition*, Washington State Department of Ecology, Olympia, WA

Ecology. 2005. *Stormwater Management Manual for Western Washington*, Washington State Department of Ecology, Olympia, WA.

Ecology, 2004. *Stormwater Management Manual for Eastern Washington* , Washington State Department of Ecology, Olympia, WA

Ecology. 1997. *Analytical Methods for Petroleum Hydrocarbons*. No. ECY 97-602. Washington State Department of Ecology, Toxics Cleanup Program and Environmental Laboratory, Olympia, WA.

EvTEC. 2000. *EvTEC Evaluation Plan for Ultra-urban Stormwater Technologies*. prepared for Washington State Department of Transportation by the Environmental Technology Evaluation Center (EvTEC), Washington, DC, and David Evans and Associates, Inc., Bellevue, WA.

Pitt, Robert, 2002. "Review of WA State Department of Ecology Protocol for Evaluating Stormwater Controls"

Strecker, E.W., M.M Quigley, B.R. Urbonas, J.E. Jones, and J.K. Clary. 2001. *Determining Urban Stormwater BMP Effectiveness*. Journal of Water Resources Planning and Management, Volume 127. No. 3, pp. 144-149.

U.S. EPA, November 1997. *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls*, EPA 841-B-96-004, U. S. Environmental Protection Agency, Nonpoint Source Control Branch, Washington, D.C.

U.S. EPA. 1995. *EPA Clean Water Act Section 403 Report to Congress, NPDES Permitting Program*, EPA 842-R-94-001. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1983. *Methods for Chemical Analysis of Water and Wastes*. EPA-600/4-79-020. Environmental Monitoring and Support Laboratory, Cincinnati, OH.

U.S. EPA. 1983-NURP Study, *Results of the Nationwide Urban Runoff Program*, Volume 1. U.S. Environmental Protection Agency, Washington, D.C.

Webb, Paul A., August 15, 2000; Micromeritics internal document, http://www.micromeritics.com/

Wentworth, C.K. 1922. “A scale of grade and class terms for sediments.” Journal of Geology. 30:377-392.

Appendix A: Treatment Efficiency Calculation Methods

Calculate several efficiencies, as applicable. Consider lag time and steady-state conditions to calculate loads or concentrations of effluents that represent the same hydraulic mass as the influent. State the applicable performance standard on the table or graph.

For technologies sized for long residence times (hours versus minutes), the proponent must consider cumulative performance of several storms – wet season or annual time periods. For short residence times (several minutes), Ecology recommends event mean comparisons. For discrete short-time step residence times (few minutes), the proponent should consider lag times for influent/effluent comparisons.

Method #1: Individual storm reduction in pollutant concentration.
The reduction in pollutant concentration during each individual storm calculated as:

$$\frac{100[A-B]}{A}$$

Where: A = flow-weighted influent concentration B = flow-weighted effluent concentration

Method #2: Aggregate pollutant loading reduction.
Calculate the aggregate pollutant loading removal for all storms sampled as follows:

$$\frac{100[A-B]}{A}$$

Where: A = (Storm 1 influent concentration) * (Storm 1 volume) + (Storm 2 influent concentration) * (Storm 2 volume) +… (Storm N influent concentration) * (Storm N volume)

B = (Storm 1 Effluent concentration) * (Storm 1volume) + (Storm 2 effluent concentration) +…(Storm N effluent concentration) * (Storm N volume)

Concentrations are flow-weighted and flow = average storm flow or total storm volume

Method #3: Individual storm reduction in pollutant loading.

$$\frac{100[A-B]}{A}$$

Where: A = (Storm 1 influent concentration) * (Storm 1 volume)
B = (Storm 1 effluent concentration) * (Storm 1 volume)

Method #4:

Method #4 applies to partial-storm data (EvTEC approach), comparing influent and effluent discrete flow composites for relatively steady-state flow periods within storms to evaluate removal efficiency versus flow rate. Contact EvTEC at evtec@cerf.org for more information. Show graphically how pollutant removal efficiencies decline from the initial "clean" to ultimate "maintenance needed" condition. This information can assess robustness and estimate the nature and cost of maintenance.

Appendix B: Factors Other Than Treatment Performance

Local government staff should also evaluate relevant factors such as those given below, along with the facility's verified pollutant removal performance. Given the limited experience with emerging technologies, this is an arena where "best professional judgment" based on the "weight of the evidence" is appropriate.

Include any of the relevant following elements and report them in the TER.

Technology description

Describe the treatment technology including process diagrams, primary equipment drawings, sketches, etc. Include details on the relevant treatment mechanisms such as:

Mechanism	Measurement
Anion exchange (dissolved nutrients)	Each medium's anion exchange capacity.
Cation exchange(dissolved metals)	Each medium's cation exchange capacity.
Adsorption (dissolved nutrients or metals)	Each target pollutant's adsorption isotherms (capturing typical range of stormwater pollutant concentrations).
Adsorption (hydrocarbons)	Each medium's percent organic matter or organic carbon (mass/mass).
Absorption (hydrocarbons)	Capacity (pollutant mass absorbed per mass and absorbent type).
Vortexing separation	Flow versus removal efficiency versus grain size and density.
Filtration	Filter media grain size distribution, clean media hydraulic conductivity, hydraulic conductivity versus sediment loading (provide sediment grain size distribution and dry density used in analysis), provide typical and maximum operational hydraulic gradient.
Biological	Describe target pollutant's specific degradation mechanisms and estimated half-life versus temperature, provide estimated stormwater contact time (or detention time) for design flow, and provide target pollutant's estimated treatment efficiency versus flow rate.
Settling	Detention time, length to width ratio, hydraulic loading rate for design flow, removal efficiency versus flow rate, particle size distribution, and specific gravity for each system type or size.

Applications

- Provide the applications the manufacturer recommends for the technology (e.g., land uses such as roadways, high-use sites, commercial, industrial, residential runoff areas). Give the rationale for the recommendations.
- List the pretreatment requirements.

- Provide a list of the facilities that are installed in the United States. Include location, land use, and size of each facility. Provide at least three references with names and telephone numbers.

Site characteristics

Describe whether the following site characteristics or safety considerations favor or limit the technology's use: climate, rainfall pattern, steep slopes, high groundwater, seepage/baseflows, tidal action, soil type, proximity to wells, septic systems and buildings, facility depth limits for access and safety, hazardous materials spill risk, driving head requirements, and power availability. Describe how the factors affect the technology.

Design criteria for sizing

Provide the following design criteria:

- Pollutant removal at design flow and for representative stormwater characteristics.
- Design hydraulics (design flow, by-pass flow, hydraulic grade line, scour velocities, etc.).
- Design residence time, vertical/horizontal velocities, etc.
- Stormwater constituent limitations (pollutants and other constituents), including fouling factors.
- Specific media flow rate (design velocity).
- Media head loss curves.
- Minimum media contact time and minimum thickness.
- Estimate system/system components design life before major overhaul.
- Media specifications ensuring adequate media quality at all times. A physical/chemical and impurity specifications list should be provided.

Construction

Describe the following:

- The role the proponent takes in design and construction.
- Technology installation requirements including length of time to install.
- Provisions for factors such as structural integrity, water tightness, and buoyancy.
- Types of problems that can occur/have occurred in designing and installing the technology.
- Methods for diagnosing and correcting potential problems and person responsible to diagnose and correct problems.
- Impacts to the technology's effectiveness if problems are not corrected.
- Technology availability (e.g., where do the major components come from and how much lead time is needed).

Costs

- Provide capital and annual maintenance costs: base the cost analysis on the test results.
- Indicate approximate annualized system capital/operating costs for all system models on a “design cfs *treated* basis” (not per cfs hydraulic capacity), or a dollar per TSS removed basis, using typical stormwater TSS concentrations (see earlier footnote).
- Estimate the useful facility life before needing replacement.

Operation and maintenance

For a typical installation with typical stormwater, discuss each of the following:

- How inspections are performed and their frequency.
- How to forecast when maintenance will be needed, i.e., what is the "trigger" for determining maintenance needs. Provide rationale for the maintenance triggers.
- How maintenance is performed.
- Maintenance area accessibility by people and equipment. List special equipment or methods needed for access and identify any confined space entry areas.
- Estimated maintenance frequency and basis for this estimated maintenance frequency.
- Maintenance equipment and materials required.
- Maintenance service contract availability. Include cost information about mobilization, equipment rental, mileage, solids/spent media disposal, etc.
- How solids/spent media are classified (waste type) and disposed.
- Whether the technology can be damaged due to delayed maintenance, and if so, tell how is it restored.
- The number of years the manufacturer has been in business. If vendor goes out of business or product model changes, describe how/where the facility owner will find needed parts, materials, and service.

Reliability

- Assuming the technology is designed and installed correctly, list factors that can cause it not to perform as designed.
- Describe any circumstances where the technology can add, transform, or release accumulated pollutants.
- Does the filter medium decompose or is it subject to slime/bacteria growth?
- Is the technology sensitive to heavy or fine sediment loadings—is pretreatment required?
- How is underperformance diagnosed and treated?
- What is the warranty?
- What initial/ongoing user support is provided? Does the vendor charge for support?

Other factors

Discuss whether the technology provides benefits or presents challenges in other potentially relevant areas, such as groundwater recharge, thermal effects on surface waters, habitat creation, aesthetics, vectors, safety, community acceptance, recreational use, and efficacy on redevelopment sites.

Appendix C: Pilot Level Technologies Notice of Intent Form

Treatment Facility Vendor Information

Company: ____

Street address: ____

City: ____________________________ State: ________________ Zip code: ________

Phone/fax: ____

Email and company web addresses: ____

____

Facility name and size: ____

Development level designation sought: ____

Target pollutants: ____

Project Information

Project name: ____

Street address: ____

City: _____________________

Local agency with Jurisdiction: ____

Project Type: ____

Desired installation date: _____________________

Facility discharge receiving water: ____

Describe proposed testing plan (number storms, parameters, test period, who will do work, etc.):

____

____

____

Local Government Certification and Acceptance

Signature: ____ Date: ________________

Name and title: ____

WASHINGTON DEPARTMENT OF ECOLOGY

PILOT USE LEVEL TECHNOLOGIES NOTICE OF INTENT FORM

Background Information

Local governments with a National Pollutant Discharge Elimination System (NPDES) permit must submit this Notice of Intent Form to Ecology and receive Ecology's approval prior to installing a pilot-designated technology (except in retrofit situations). All other jurisdictions are encouraged to notify Ecology when a pilot use level designation (PULD) technology is proposed.

Local governments may allow PULD technologies to be installed *provided that* the proponent agrees to conduct additional field testing based on the TAPE at *all* installations to obtain a general use level designation (GULD). Field testing must be completed at a minimum of one site indicative of or in the Pacific Northwest* to obtain a general use level designation.

* Pacific Northwest refers to locations in Washington, Oregon, Northern California, or British Columbia with rainfall distributions typical of a Pacific Northwest maritime climate, where long duration, low intensity storms predominate and stormwater contains mostly silt sized particles. Technologies granted a pilot use level designation will be limited to five installations at locations where their use is intended during the pilot use level period.

Submit completed forms to TAPE Coordinator, Washington State Department of Ecology, Water Quality Program, P.O. Box 47600, Olympia, WA 98504-7600. Please allow 30 days for response.

Appendix D: Statistical Considerations

By Robert Pitt, P.E., Ph.D.

Background

It is important to specify a statistical goal for acceptance or rejection of the evaluation analyses. It is also important that the experimental design consider conservative goals for confidence and power to enable sufficient data to be collected and that the actual significance level of the results be presented. Stormwater practices that provide relatively low treatment efficiencies are much more difficult to evaluate successfully than more effective controls (if one is trying to show that influent and effluent concentrations are statistically different). However, these less-effective devices may still be used for pretreatment.

Analytical QA/QC procedures theoretically result in very high levels of confidence (at the 99% level), but sampling rarely reaches this pristine level. In characterization studies, it is rare to be able to collect sufficient samples to reduce the errors associated with the median concentrations to less than 25%. A 1% level of error would be unheard of and impossible to obtain. Traditional goals of 95% confidence and 80% power are usually suitable for experimental design, and it is traditional to accept a probability result of 0.05, or less, during analyses for a significant result. It may be suitable and reasonable to accept a level of 0.10 as being significant for many types of tests. The following statistical test probability levels are suggested for different outcomes:

Recommended statistical approach

The following statistical approach is recommended:

1. Designs of paired experiments (using local coefficient of variance (COV) values and expected level of control): 90 to 95% confidence (α= 0.05 to 0.1) and 75 to 80% power (β= 0.2 to 0.25).

2. Acceptance levels for statistical tests:

   - Basic treatment (80% TSS reductions): $P \leq 0.05$ that influent does not equal effluent.
   - Enhanced treatment (moderate reductions in dissolved heavy metal concentrations): $P \leq 0.10$ that influent does not equal effluent.
   - Phosphorus treatment (50% reductions in TP): $P \leq 0.10$ that influent does not equal effluent.
   - Oil treatment (no sheen, etc.): $P \leq 0.10$ that influent does not equal effluent.
   - Pretreatment (lesser levels of performance than above): to be considered in conjunction with other treatment train components.

Expected sampling efforts to obtain these above goals are shown on the following table, based on observed Pacific Northwest stormwater monitoring results:

Table 1

Treatment Level	Standard		Minimum Number of Sample Events Needed: (confidence/power)		
		COV	**95/80**	**95/50**	**90/80**
Basic treatment	• 80% reductions for SS	0.55	6	2	5
Enhanced treatment	• (assume 50% reductions for dissolved heavy metals)	0.50	14	8	10
Phosphorus treatment	• 50% reductions for phosphorus	0.75	28	15	20

The experimental design process

The following needs to be considered during the experimental design process:

- It may be possible that the COV values for commercial and industrial land uses are higher than in the above calculations, and the corresponding sampling efforts would therefore be greater.
- It is relatively "easy" to measure large differences between influent and effluent conditions, while substantially greater effort is needed when the stormwater control device provides less treatment.
- The sampling effort procedures described in this report are applicable for normally distributed data. If the COV values of the concentrations are relatively low (about 0.4, or less), the corresponding distributions are close to normal distributions. As the COV values increase (as is likely), greater error will occur in these estimates. Therefore, these are only guidelines and it is suggested that the actual sampling effort be increased to cover the expected errors. It is also important that the confidence and power levels are calculated for the actual tests, in addition to the measured percentage reductions.
- If the minimum number of sample events is used to measure the effectiveness of a control practice for a specific treatment category, the result will be a "pass/fail" indication of meeting the treatment goal. If the actual treatment is less than the goal, it is not possible to determine what the actual level of treatment is at the same level of confidence and power. For this reason, it is suggested that the number of sample pairs exceed the minimum number listed for a specific goal category. The following table summarizes the sampling efforts needed for specific treatment goals and COV values, for 95% confidence and 80% power:

Table 2

Performance Level (% reductions)	COV = 0.3	COV = 0.5	COV = 0.75	COV = 1.0	COV = 1.25	COV = 1.50
95 %	<5	<5	8	15	25	30
80	<5	5	12	20	30	45
50	5	13	28	50	80	120
30	12	35	75	130	200	300

The average number of runoff producing rains in the Pacific Northwest is about 100 to 110 per year. If only half of the rains are monitored over an 8-month period, about 35 rains will be sampled. Under this situation, the level of performance that can be statistically established will be limited to:

Table 3

COV	Minimum performance levels that can be statistically quantified for a maximum of 35 paired tests (at 95% confidence and 80% power)
0.3	19 %
0.5	30 %
0.75	45 %
1.0	60 %
1.25	73 %
1.50	90 %

Acceptable maximum number of sampling events

It may not be possible to measure the performance of marginal stormwater control practices under typical conditions. The 50% performance goal for total phosphorus may be measurable for COV conditions of up to about 0.75, while the 80% basic goal for suspended solids may be measurable for COV conditions of up to about 1.25. These bracket the typical COV conditions for many situations. Again, it is important that the statistical significance of the measured pollutant reductions be reported in all cases (assuming a set level for power). Lower levels of confidence (and power) should be suitable for determining the performance levels of controls if they do not meet the higher performance level goals.

The following is recommended for a thorough evaluation:

- The necessary number of sample events must be calculated based on the local COV for the constituents of interest and using a confidence level of 95% and a power of 80% for basic treatment and using a confidence level of 90% and a power of 75% for enhanced, phosphorus, and oil treatment. (See Figure 2).
- In all cases, at least 12 sample events are required, in order to be reasonably certain of the actual COV and to be able to calculate good statistical relevance values.
- If uncontrollable factors hinder timely conclusions of the sampling effort, or if unusual conditions produce unusually high COV values, then a reasonable maximum sampling effort would be 35 sample events.
- In all cases, the statistical outcomes of the analyses need to be specifically noted, not just labeling a test as pass or fail.

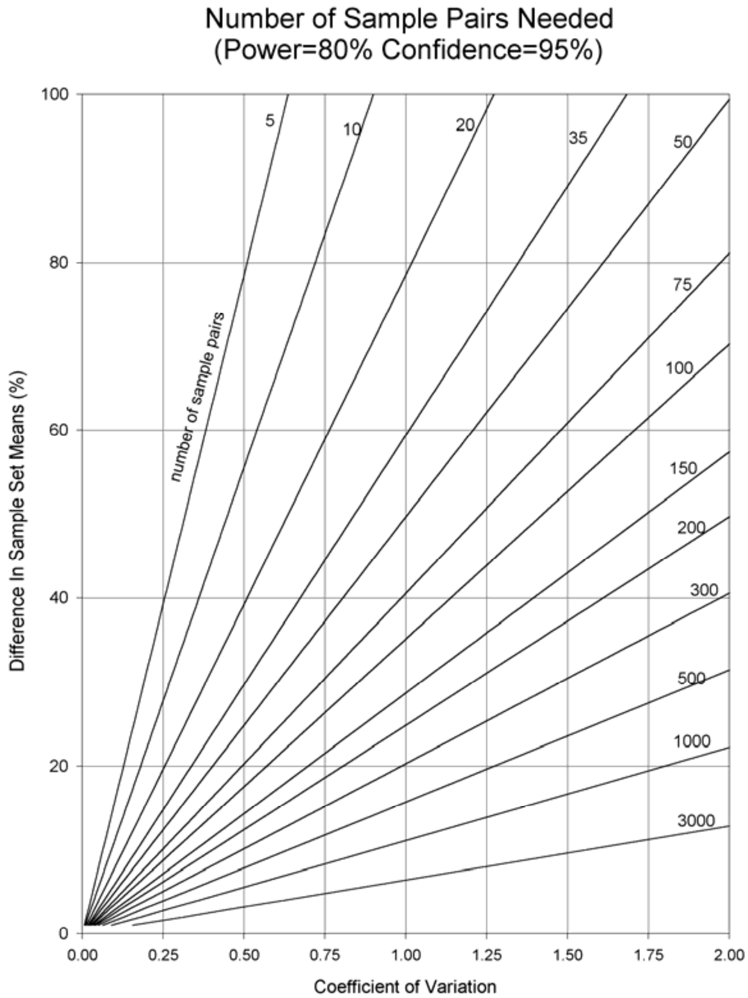

Figure 2. Sample Effort Needed for Paired Testing (Power of 80% and Confidence of 95%) (Pitt and Parmer 1996).

Null hypothesis- Type I and Type II Errors

The following table describes the relationships between confidence and power, and Type I and Type II errors:

Table 4

	Actual Situation:	
Statistical Decision:	**H_0 True**	**H_0 False**
Do not reject H_0	Confidence ($1-\alpha$)	Type II error (β)
Reject H_0	Type I error (α)	Power ($1-\beta$)

The confidence of a test is to correctly not reject the null hypothesis when it should not be rejected. Another way of stating this Null Hypothesis is, "There is a (1-alpha)(100) % confidence that the result represents a true condition." Similarly, the power of a test is to correctly reject the null hypothesis when the null hypothesis is in fact false and should be rejected. The Type I and Type II errors are when the rejection or acceptance actions are not correct. As noted previously, one way to control the probability of making an error is to increase the sample size. For a given level of α, increasing the sample size will decrease β, which increases the power of the test to detect that the null hypothesis is false. However, with any given sample size, increasing confidence necessarily must decrease power. **The only way to increase both objectives is to increase the sample size.**

The experimental designs and associated sampling efforts can be based on these calculations, especially if adjusted upwards to account for deviations in the assumptions. Statistical comparison tests need to be used and the actual test statistics (especially the P values) need to be reported, not just an indication that the null hypothesis was accepted, or rejected. In summary, the following needs to be considered:

- Careful and adequate experimental design must be an integral part of the test procedure in order to be comfortable with both the level of confidence and power of the outcome.
- The statistical tests must report probability of failure (actual calculated p value), not just if "accepted" or "rejected."

Data evaluation methodology

The following is a step-by-step procedure for conducting the statistical analysis:

1. Exploratory Data Analysis

In all cases, simple plots need to be presented to observe overall data characteristics. These plots should include probability plots and scatter plots. Grouped notched box and whisker plots are also useful to examine influent and effluent conditions. These plots must be presented along with statistical analyses to quantify the patterns observed.

2. Nonparametric Tests for Paired Data Observations

Nonparametric statistical tests may be a better choice than typical parametric tests. If the data conditions allow parametric tests (at least normally distributed data, for example), then the parametric tests usually have more statistical power. However, few environmental data meet parametric statistical test requirements. If a parametric test is improperly selected, then the calculated results can be very unreliable. **In most cases, nonparametric test alternatives are available and should be used unless the more restrictive test conditions can be met.**

Nonparametric tests also have certain requirements and these need to be considered. Generally, if the COV of a data set is less than about 0.4 (unlikely for most stormwater information, except for pH), it may be possible to use standard parametric tests. Alternately, it may be possible to transform the data (typically by using log transformations) so the data are normally distributed if parametric tests are desired. The following paragraphs summarize some of the more useful nonparametric tests for evaluating stormwater controls.

Nonparametric paired tests are probably the most useful statistical test procedure when conducting stormwater control evaluations. The sign test is the basic nonparametric test for paired data. It is simple to compute and has no requirements pertaining to data distributions. A few “not detected” observations can also be accommodated. Two sets of data are compared. The differences are used to assign a positive sign if the value in one data set is greater than the corresponding value in the other data set, or a negative sign is assigned if the one value is less than the corresponding value in the other data set. The number of positive signs are added and a statistical table is used to determine if the number of positive signs found is unusual for the number of data pairs examined.

The Mann-Whitney signed rank test has more power than the sign test, but it requires that the data distributions be symmetrical (but with no specific distribution type). Without logarithmic or other appropriate transformations, this requirement may be difficult to justify for water quality data. This test requires that the differences between the data pairs in the two data sets be calculated and ranked before checking with a special statistical table. In the simplest case for monitoring the effectiveness of treatment alternatives, comparisons can be made of inlet and outlet conditions to determine the level of pollutant removal and the statistical significance of the concentration differences.

Friedman’s test is an extension of the sign test for several related data groups. There are no data distribution requirements and the test can accommodate a moderate number of “non-detectable” values, but no missing values are allowed.

3. Regression Analyses

Regression analyses are very popular, but frequently misused. The use of the regression option in Microsoft Excel provides sufficient information for correct interpretation of the test results. Unfortunately, it is easy to place too much emphasis on the R^2 value when conducting a regression analysis, without first checking on the significance of the equation coefficients and ensuring that the regression assumptions have been met. An analysis of variance (ANOVA) should always be conducted along with a regression analysis to determine the statistical relevance of the resulting overall regression equation and equation terms. These are always more useful than the traditional R^2 value when determining the acceptability of an equation. It is possible to have a statistically significant and useful model, with a seemingly low R^2 value.

In order to obtain the best and most useful regression analysis results, Burton and Pitt (2002) presented the following steps:

- Formulate the objectives of the curve-fitting exercise.
- Prepare preliminary examinations of the data (most significantly, prepare scatter plots and probability plots of the data, plus correlation evaluations to examine independence between multiple parameters that may be included in the models).
- Identify alternative models from the literature that have been successfully applied for similar problems.
- Evaluate the data to ensure that regression is applicable and make suitable data transformations.
- Apply regression procedures to the selected alternative models.
- Evaluate the regression results by examining the coefficient of determination (R^2) and the results of the analysis of variance of the model (standard error analyses and p values for individual equation parameters and overall model).
- Conduct an analysis of the residuals (probability plot of residuals, plot of residuals against predicted model outcomes, and a plot of the residuals against the time sequence when the data were obtained). The probability plot should indicate a random distribution of the residuals, while the other plots should indicate an even (and hopefully narrow) band straight across the plot, centered along the 0 residual value. If these plots are incorrect, then the resulting model is likely faulty and should be reconsidered. Data transformations and additional model coefficients can be used to improve residual behavior).
- Evaluate the results and select the most appropriate model(s).
- If not satisfied, it may be necessary to examine alternative models, especially based on data patterns (through cluster analyses and principal component analyses) and re-examinations and modification of the theoretical basis of existing models.

4. Summary of Results

List all the results based on the exploratory and complete data analyses. Include the statistical determinations for alpha and beta errors, calculated p-values, COV, regression equations and other models plus associated residual analyses, and plot the power curve.

5. Summary of the Statistics Methodology Used

As indicated above, the basic steps in the recommended statistical methodology include:

- Proper and balanced experimental design considering project objectives and expected characteristics.
- Conducting initial experiments and initial data evaluations for quality control and general verification of methodology and experimental errors (do not make any major changes until sufficient data have been collected and evaluated to protect against premature experimental modifications).
- Conducting complete experiments.
- Exploratory data analysis and other basic statistical tests (comparison tests, regression analyses, etc.).

- Additional statistical tests to investigate other data features (trends, complex interactions, etc.).
- Preparing project report, including recommendations.

Appendix E: Laboratory Methods

Table C-1: Recommended analytical procedures in stormwater.

Parameter	Analyte (or surrogate)	Method (in water)	Reporting Limit[a, b]
Conventional parameters	Total suspended solids	SM 2540D	1.0 mg/L
	Total dissolved solids	SM 2540C	1.0 mg/L
	Settleable solids	SM 2540F	1.0 mg/L
	Total Volatile Solids	EPA Method 160.4	1.0 mg/L
	Suspended Sediment Concentration	ASTM Method D3977-97	1.0 mg/L*
	Particle size distribution	Coulter Counter or Laser diffraction, or comparable method	NA
	Grain-size	Ecology method sieve and pipette (PSEP 1997), or comparable method	NA
	pH	EPA Method 150.1 or SM 4500H^+	0.2 units
	Hardness as $CaCO_3$	EPA Method 130.1 or SM 2340B	1.0 mg/L*
Nutrients	Total phosphorus	EPA Method 365.3 or SM 4500-P E	0.001 mg/L
	Orthophosphate	EPA Method 365.3	0.003 mg/L
	Total kjeldahl nitrogen	EPA Method 351.2	1.0 mg/L
	Nitrate-Nitrite	EPA Method 353.2 or SM 4500 -$NO3^-$ F	0.01 mg/L
Metals	Total recoverable zinc	EPA Method 200.8 (ICP/MS)	5.0 µg/L
	Dissolved zinc	EPA Method 200.8 (ICP/MS)	1.0 µg/L
	Total recoverable lead	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Dissolved lead	EPA Method 200.8 (ICP/MS)	0.02 µg/L
	Total recoverable copper	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Dissolved copper	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Total recoverable cadmium	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Dissolved cadmium	EPA Method 200.8 (ICP/MS)	0.02 µg/L
Petroleum hydrocarbons	NWTPH-Dx	Ecology, 1997, (Publication No. 97-602) or EPA SW-846 method 8015B	0.1 mg/L
	NWTPH-Gx	Ecology, 1997, (Publication No. 97-602)	0.12 mg/L
Toxicity	*Daphnia pulex*	EPA Method 600/4-90/027F (acute)	NA
	Ceriodaphnia dubia	EPA Method 600/4-90/027F (acute)	NA

[a] Reporting limits established as per Manchester Environmental Laboratory Users Manual (Ecology, 2005). Reporting limits for your lab should be the same or below those given in the table.
[b] All results below reporting limits should also be reported and identified as such. These results may be used in the statistical evaluations.
*Reporting limits are based on similar methods because Manchester Lab does not conduct particular method.

NA – Not applicable
SM – Standard Methods
ICP/MS – Inductively Coupled Plasma/Mass Spectrometer

Table C-2: Recommended analytical procedures in sediment.

Parameter	Analyte (or surrogate)	Method (in Sediment)	Reporting Limit[a, b]
Grain-size	Total solids Total Volatile Solids Grain-size	EPA Method 160.3 or SM 2540B EPA Method 160.4 or SM 2540E Ecology Method Sieve and Pipet (PSEP 1997) or ASTM F312-97	NA 0.1%
Metals	Total recoverable zinc	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) or EPA Method 200.7 (ICP)	5.0 mg/Kg
	Total recoverable lead	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS)	0.1 mg/Kg
	Total recoverable copper	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS)	0.1 mg/Kg
	Total recoverable cadmium	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS)	0.1 mg/Kg
Petroleum hydrocarbons	NWTPH-Dx	Ecology, 1997 (Publication No. 97-602) or EPA SW-846 method 8015B	25.0-100.0 mg/Kg
Toxicity	*Daphnia pulex* *Ceriodaphnia dubia*	EPA Method 600/4-90/027F (acute) EPA Method 600/4-90/027F (acute)	NA NA

[a] Reporting limits established as per Manchester Environmental Laboratory Users Manual (Ecology, 2005). Reporting limits may vary with each lab. Reporting limits for your lab should be the same or below those given in the table.
[b] All results below reporting limits shall also be reported and identified as such. These results may be used in the statistical evaluations.
NA – Not applicable
SM – Standard Methods
PSEP – Puget Sound Estuary Program
ICP/MS – Inductively Coupled Plasma/Mass Spectrometry

Appendix F: Particle Size Distribution

Wet sieve protocol and mass measurement
(Recommended by the TRC Subcommittee)

The intent of providing this protocol is to allow more analytical flexibility for vendors while setting reasonable expectations in terms of results. The purpose of requiring Particle Size Distribution (PSD) analysis in the TAPE protocols is to collect consistent information on particle size that will aid in evaluating system performance. PSD measurements will provide a frame of reference for comparing variability in performance between storms and between different sites. These measurements are an important tool with which to assess performance because performance is likely to be affected by particle size. For example, it is likely that performance will drop with a substantial increase in fine soil particles. Conversely, it is anticipated that performance will be high with sandy sediments.

This protocol is intended for use with the laser diffraction Particle Size Distribution (PSD) analysis. Laser diffraction methods are effective for particles smaller than 250 µm. Therefore, particles greater than 250 µm must be removed with a sieve prior to PSD analysis. These large-sized particles will be analyzed separately to determine the total mass of particulates greater than 250 µm. This protocol functions as a supplement to the existing protocols provided by the manufacturers of laser diffraction instruments such that the larger-sized particles in the sample can also be measured.

The mass measurement for the larger-sized particles will also separate out particles between 499 to 250 µm in order to be consistent with the *Guidance for Evaluating Emerging Stormwater Treatment Technologies* definition of TSS (total suspended particles <500 µm).

NOTE: The Technical Review Committee (TRC) recognizes the fact that applying a mathematical constant for density would provide a rough estimate of mass. However, there is concern that the potential error associated with the results due to different soil types and structure might be large.

Wet Sieving and Mass Measurement for Laser Diffraction Analysis

Wet sieving

Sample Collection/Handling

Samples should be collected in HDPE or Teflon containers and held at 4°C during the collection process. If organic compounds are being collected, the sample containers should be glass or Teflon.

Preservation/holding time

Samples should be stored at 4°C and must be analyzed within 7 days (EPA, 1998). Samples may not be frozen or dried prior to analysis, as either process may change the particle size distribution.

Sonication

Do not sonicate samples prior to analysis to preserve particle integrity and representativeness. Laboratories using laser diffraction will have to be notified not to sonicate these samples at any time during the analysis. It is recommended that this request also be written on the chain-of-custody form that the analytical laboratory receives in order to assure that sonication is omitted.

Laboratory Procedures

Equipment

__ 2 Liters of stormwater sample water (total sample required for analysis (ASTM D 3977))
__ Drying oven (90°C ±2 degrees)
__ Analytical balance (0.01 mg accuracy)
__ Desiccator (large enough diameter to accommodate sieve)
__ Standard sieves - larger than 2" diameter may be desirable
__ 500 µm (Tyler 32, US Standard 35)
__ 250 µm (Tyler 60, US Standard 60)
__ Beakers - plastic (HDPE)
__ Funnel (HDPE - Large enough diameter to accommodate sieve)
__ Wash bottle
__ Pre-measured reagent-grade water

Sample processing

- Dry 250 µm and 500 µm mesh sieves in a drying oven to a constant weight at 90 ± 2°C.
- Cool the sieves to room temperature in a desiccator.
- Weigh each sieve to the nearest 0.01 mg.
- Record the initial weight of each dry sieve.
- Measure the volume of sample water and record.
- Pour the sample through a nested sieve stack (the 500 µm sieve should be on the top and the sieve stack should be stabilized in a funnel and the funnel should be resting above/inside a collection beaker).

- Use some of the pre-measured reagent-grade water in wash bottle to thoroughly rinse all soil particles from sample container so that all soil particles are rinsed through the sieve.
- Thoroughly rinse the soil particles in the sieve using a pre-measured volume of reagent-grade water.
- The particles that pass through the sieve stack will be analyzed by laser diffraction Particle Size Distribution (PSD) analysis using the manufacturers recommended protocols (with the exception of no sonication).
- Particles retained on the sieve (>250 µm) will not be analyzed with the laser diffraction PSD.
- Dry each sieve (500 µm and 250 µm) with the material it retained in a drying oven to a constant weight at 90 ± 2°C. The drying temperature should be less than 100°C to prevent boiling and potential loss of sample (PSEP, 1986).
- Cool the samples to room temperature in a desiccator.
- Weigh the cooled sample with each sieve to the nearest 0.01 mg.
- Subtract initial dry weight of each sieve from final dry weight of the sample and sieve together.
- Record weight of particles/debris separately for each size fraction (> 500 µm and 499 - 250 µm).
- Document the dominant types of particles/debris found in this each size fraction.

Laser diffraction (PSD)

PSD results are reported in ml/L for each particle size range. Particle size gradations should match the Wentworth grade scale (Wentworth, 1922).

Mass Measurement

Equipment

__ Glass filter - 0.45 µm (pore size) glass fiber filter disk (Standard Method D 3977) (larger diameter sized filter is preferable)

__ Drying oven (90°C ±2 degrees)

__ Analytical balance (0.01 mg accuracy)

__ Wash bottle

__ Reagent-grade water

Procedure

- Dry glass filter in drying oven at 90 ± 2°C to a constant weight.
- Cool the glass filter to room temperature in a desiccator.
- Weigh the 0.45 µm glass filter to the nearest 0.01mg.
- Record the initial weight of the glass filter.
- Slowly pour the laser diffraction sample water (after analysis) through the previously weighed 0.45 µm glass filter and discard the water.
- Use reagent-grade water in wash bottle to rinse particles adhering to the analysis container onto glass filter
- Dry glass filter with particles in a drying oven at 90 ± 2°C to a constant weight.
- Cool the glass filter and dried particles to room temperature in a desiccator.
- Weigh the glass filter and particles to the nearest 0.01mg.

- Subtract the initial glass filter weight from the final glass filter and particle sample weight.
- Record the final sample weight for particles <250 µm in size.

Quality Assurance

Dried samples should be cooled in a desiccator and held there until they are weighed. If a desiccator is not used, the particles will accumulate ambient moisture and the sample weight will be overestimated. A color-indicating desiccant is recommended so that spent desiccant can be detected easily. Also, the seal on the desiccator should be checked periodically, and, if necessary, the ground glass rims should be greased or the "O" rings should be replaced.

Handle sieves with clean gloves to avoid adding oils or other products that could increase the weight. The weighing room should not have fluctuating temperatures or changing humidity. Any conditions that could affect results such as doors opening and closing should be minimized as much as possible.

After the initial weight of the sieve is measured, the sieve should be kept covered and dust free. Duplicate samples should be analyzed on 10% of the samples for both wet sieving and mass measurements.

Reporting

Visual observations should be made on all wet sieved fractions and recorded. For example if the very coarse sand fraction (2,000-1,000 µm) is composed primarily of beauty bark, or cigarette butts, or other organic debris this should be noted. An option might also be for a Professional Geologist to record the geological composition of the sediment as well.

References

ASTM. 1997. *Standard test methods for determining sediment concentration in water samples*. Method D 3977. American Society for Testing and Materials, Philadelphia, PA.

PSEP. 1986. *Recommended Protocols for measuring conventional sediment variables in Puget Sound*. Prepared by Tetra Tech, Inc. for U.S. Environmental Protection Agency and Puget Sound Water Quality Authority. Tetra Tech Inc., Bellevue, WA.

U. S. EPA. 1998. Analysis of total suspended solids by EPA Method 160.2. Region 9, Revision 1. SOP 462. 12 pp

Wentworth, C.K. 1922. “A scale of grade and class terms for clastic sediments.” *Journal of Geology.* 30:377-392

Appendix G: Product Data from U.S. Silica

Sil-Co-Sil 106 is a readily available ground silica product, manufactured by U.S. Silica Corporation. Information on this product is available at:

http://www.u-s-silica.com/PDS/Mill%20Creek/MiCSCS1062000.PDF

http://www.u-s-silica.com/PDS/Mill%20Creek/MiCOK1102002.PDF