SMC CLEAN LID/GI Monitoring Protocol

This document outlines the process of data collection for a specific LID or green infrastructure project. It provides project management information, specific project information (meta data) to be collected, monitoring plan review recommendations, specific details on the data acquisition process including monitoring equipment, site set-up guidance, monitoring parameters for hydrology and water quality, and describes the intended use of the data collected. As much as possible, sample collection and analysis methods are standardized for comparability. However, do to different study needs, the recommended sampling frequency and schedule may vary substantially. Consequently, sampling schedules are included for three identified project types: Basic BMP Performance Verification; BMP Performance over Time, and Special BMP Studies (Tables 1, 2, and 3).

Basic BMP Performance Verification—for new BMP installations:

- To establish that the implemented BMP provides the hydrologic and pollutant reduction benefits as expected based on its design and application.
- To fulfill effectiveness assessment requirements for grant-funded BMPs;
- To support quantitative BMP effectiveness inputs to watershed management plans and impacts on receiving water quality;
- To support regional studies of bioretention BMP performance (such as the SMC CLEAN Project).

BMP Performance over Time:

- To evaluate the lifespan of bioretention media or otherwise predict major maintenance needs (e.g., media replacement) for common bioretention installations;
- To evaluate the performance implications of plant conditions and maintenance;
- To support cost-benefit evaluations.

Special BMP Studies:

- Proof-of-concept to evaluate new bioretention soil media types, new designs, or unique BMP arrangements;
- To evaluate the performance impacts of specific factors such as plant palette; construction practices; rainfall characteristics, or other;
- To evaluate pollutant fate and transport.

This data collection protocol is designed to ensure that monitoring data are adequate to evaluate the effectiveness of the aggregate of LID BMPs and are collected in a consistent manner to ensure that data from different LID BMP installations will be comparable. Improved understanding of the hydrologic and water quality benefits of LID BMPs will improve efforts to modify LID designs, specifications, and maintenance measures to optimize performance. Many individual LID BMPs should be monitored throughout all regional watersheds. Collectively, such data can be used to determine how effectively each class of LID BMPs reduce runoff volume and maintain or restore pre-project hydrologic parameters; how effectively they reduce pollutant loads and concentrations in runoff; what maintenance is required to ensure BMP performance over time; and what is the typical lifespan of bioretention media. Monitoring data collected, depending on the protocol options selected, will support evaluations of LID performance for individual projects, for multiple projects at small and large scales, and for various LID design approaches and implementation conditions. For example, monitoring for Basic BMP Verification or proof-of-concept studies for new designs or new bioretention media should be designed to stand alone since conclusions must be drawn from a single (or very few) installations.

This protocol is an integral part of a comprehensive project evaluation process. The process requires a complete project description and implementation records; stated objectives and management questions; a monitoring/sampling protocol; laboratory test methods, analytical procedures, and QA/QC procedures; data evaluation methods; and reporting specifications. The LID/GI monitoring is part of an iterative process as identified in Figure 1 on the following page. The effectiveness evaluation should be scaled to the scope and life expectancy of the project. Most LID BMPs are expected to function effectively for 10 – 20 years or longer if adequately maintained. If possible, prior to investing in full water quality monitoring, perform visual monitoring of at least one storm to identify any functional defects that may need to be corrected. A comprehensive evaluation will include documentation and evaluation of maintenance and performance over the life of the project BMP.

Pre-Monitoring Check

Before monitoring is scheduled to commence the basic functionality of the BMP must be checked. This Pre-Monitoring Check should verify:

- BMP built and sized per design;
- Preferred Construction Practices were used to minimize soil compaction or contamination;
- Correct BSM Materials used and installed correctly;
- Correct Elevations to ensure functionality;
- Inlet and Outlet in good condition
- Hydraulic Connectivity between BMP and inlet/outlet conveyance

Contributing Area Condition Evaluation

The condition of the area contributing runoff to the BMP must be evaluated periodically to verify the size of the area, the land use and use intensity, and the surface cover condition.

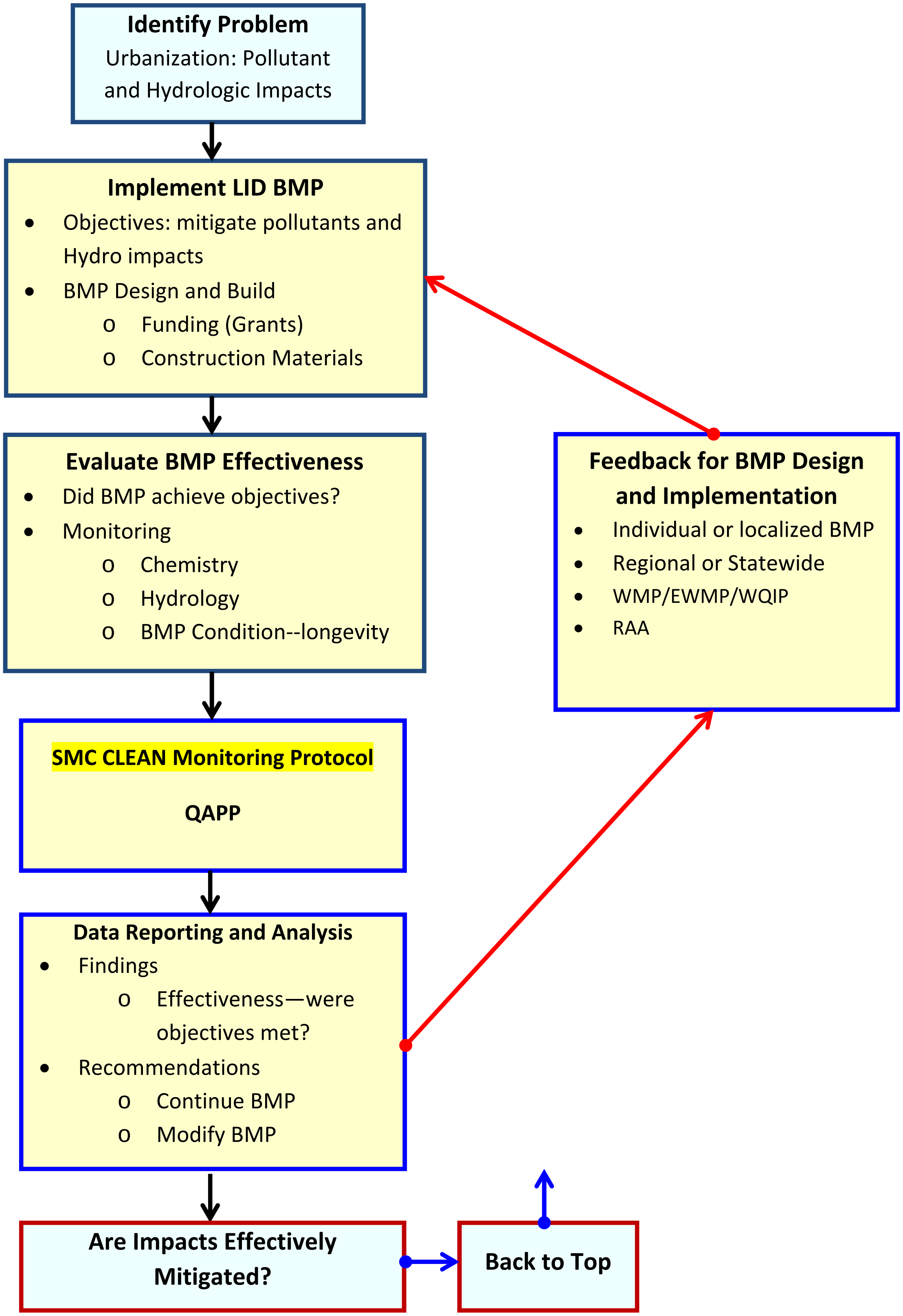
Plant Condition Assessment

The condition of the plants in the bioretention BMP must be periodically evaluated and documented, including consideration of the following parameters:

- Planted per Design
    - Plant type
    - Placement/spacing
- % Cover
- Irrigation system observations
- Maturity
    - Plant establishment date
- No Plants by Design

Maintenance Condition Tracking: Specific protocol to be developed

Figure 1: Iterative Process & LID/GI Monitoring



Monitoring/Sampling Frequency Options

<table>
<tr><th colspan="3">Table 1: Basic BMP Performance Verification</th></tr>
<tr><th>Year 1</th><th>Year 2</th><th>Year 3</th></tr>
<tr><td>Pre-monitoring check</td><td rowspan="3">3 events; early, mid, late season:
• Influent, effluent, hydrology
• Contributing area observations
• Plant condition observations
• Maintenance condition tracking</td><td rowspan="2">1 event:
• Influent, effluent, hydrology
• Contributing area observations
• Plant condition observations
• Maintenance condition tracking</td></tr>
<tr><td>2 events; early and mid/late season:
• influent samples;
• hydrology;
• contributing area observations;</td></tr>
<tr><td>Monthly plant condition observations</td><td>2 additional events required if significant BMP changes occur:
• Influent, effluent, hydrology
• Visual monitoring of contributing area
• Plant condition observations</td></tr>
</table>

<table>
<tr><th colspan="4">Table 2: BMP Performance over Time</th></tr>
<tr><th>Year 1</th><th>Year 2</th><th>Year 3 - 10[1]</th><th>Year 11 - 20[1]</th></tr>
<tr>
<td>Pre-monitoring check</td>
<td rowspan="2">3 events; early, mid, late season:
• Influent, effluent, hydrology
• Contributing area observations;
• Plant condition observations
• Maintenance condition tracking</td>
<td rowspan="2">2 events; early and mid/late season:
• Influent, effluent, hydrology
• Contributing area observations;
• Plant condition observations
• Maintenance condition tracking</td>
<td rowspan="2">2 events; early and mid/late season:
• Influent, effluent, hydrology
• Contributing area observations;
• Visual hydrologic function verification
• Plant condition observations
• Maintenance condition tracking</td>
</tr>
<tr>
<td rowspan="2">2 events; early and mid/late season:
• influent samples;
• hydrology;
• Contributing area observations;</td>
</tr>
<tr>
<td rowspan="4">3 events required after significant BMP changes occur:
• Influent, effluent, hydrology
• Contributing area observations;
• Plant condition observations
• Maintenance condition tracking</td>
<td>3 events required after significant BMP changes occur:
• Influent, effluent, hydrology
• Contributing area observations;
• Plant condition observations
• Maintenance condition tracking</td>
<td>2 events required after significant BMP changes occur:
• Influent, effluent, hydrology
• Contributing area observations;
• Plant condition observations
• Maintenance condition tracking</td>
</tr>
<tr>
<td>Monthly plant condition observations</td>
<td>[1]Evaluate data after year 5 and confirm or revise sampling frequency.</td>
<td>[1]Evaluate data after year 10 and confirm or revise sampling frequency.</td>
</tr>
<tr>
<td>First event after plant establishment:
• Influent, effluent, hydrology
• Contributing area observations
• Plant condition observations</td>
<td colspan="2" rowspan="2">Evaluate and revise schedule in response to any significant changes to BMP, major plant or structural failure, change, or replacement;

Evaluate and revise schedule with any significant changes in contributing area condition.</td>
</tr>
<tr>
<td rowspan="2">Maintenance condition tracking
(develop protocol with CWH)</td>
</tr>
<tr>
<td colspan="3">Older, established BMPs can begin monitoring using the Year 2 schedule.</td>
</tr>
</table>

<table>
<tr><th colspan="4">Table 3: Special BMP Studies</th></tr>
<tr><th>Year 1</th><th>Year 2</th><th>Year 3</th><th>Beyond Year 3</th></tr>
<tr><td>Pre-monitoring check</td><td rowspan="3">3 events; early, mid, late season:
• Influent, effluent, hydrology
• Soil moisture
• Contributing area observations
• Maintenance condition tracking
• Monthly plant condition observations</td><td rowspan="2">3 events; early, mid, late season:
• Influent, effluent, hydrology
• Soil moisture
• Contributing area observations
• Maintenance condition tracking
• Monthly plant condition observations</td><td rowspan="3">Evaluate study objectives and existing data; confirm or revise sampling frequency.

• Evaluate and revise schedule in response to any significant changes to BMP, major plant or structural failure, change, or replacement.

• Evaluate and revise schedule with any significant changes in contributing area condition.</td></tr>
<tr><td>2 events; early and mid/late season:
• influent samples;
• Hydrology;
• Soil moisture;
• Contributing area observations;

In addition:
For studies requiring pollutant removal data to evaluate performance of bioretention soil media:
• Collect effluent samples;
For studies where pollutant removal is determined by volume of retention;
• Ensure flow monitoring equipment is functional prior to each event</td></tr>
<tr><td>Monthly plant condition observations</td><td>2 additional events required if significant BMP changes occur:
• Influent, effluent, hydrology
• Soil moisture
• Contributing area observations
• Monthly plant condition observations</td></tr>
</table>

Integration of Monitoring into LID BMP Design

LID BMPs are inherently challenging to monitor due to their design as part of the landscape. There conveyance features are more subtle and distributed when compared to conventional BMPs which have defined inlet and outlet structures. Therefore, monitoring approaches should be considered and monitoring features should be integrated as part of the BMP design. LID BMP designs should be modified based on the type of monitoring that will be performed.

Project Description and Implementation

- Site drawings – Design plans, specifications, As-builts
- Design storm, drainage area size, and sizing calculations
- Drainage area land uses and percentages
- Historic site information
- Native soils information (including analysis of all inorganics measured in the water quality protocol), geotechnical report, infiltration tests
- Engineered soil matrix information, soil matrix source
- Plant information/list, plant source
- Mulch information/source
- Construction records, contractor information
- Maintenance protocols
- Maintenance records, maintenance contractor information
- Inspection records
- Data tracking protocols
- Data access information
- Data reporting protocols
- Other information being collected for each site and why it is being collected.

Monitoring Plan Review and Reporting

LID project monitoring plans should be consistent with the requirements of the agency requesting/requiring project monitoring and should be reviewed before being implemented. Some projects may have a monitoring plan review requirement imposed by the jurisdiction where the project has been implemented or by a regulatory agency (i.e. SWRCB) for a grant funded project or as part of a 401 Water Quality Certification or other regulatory requirement. For projects in the geographic scope of the SMC, projects can submit their LID monitoring plan to the SMC CLEAN project for review.

Monitoring data should be reported as specified by the jurisdiction approving the project and per applicable regulatory reporting requirements (e.g. CEDEN/SWAMP). For LID BMP projects in the geographic region of the SMC, LID monitoring and meta data will be submitted to the SMC CLEAN Data Submittal Tool.

Required Monitoring Equipment

Some or all of the following equipment will be required:

- data logger (a remote electronic measurement recorder)
- autosampler(s) with sample bottles and required accessories
- rain gauge
- weir(s) or flume(s)
- bubbler or pressure transducer
- area velocity meter or impeller
- Field meter (e.g. pH, EC, turbidity, DO) if available
- Soil moisture sensors (optional)

Measurements

Monitoring will include these measurements:

- Rainfall depth
- Temperature (?)
- Flow Rate[1]
    - Water level/depth
    - Flow velocity
    - Area-velocity
- Pollutant Concentration
- Soil Moisture (optional)

Site Setup

Develop BMP configuration schematic including:

- Contributing drainage area(s)
- Influent sampling point(s)
- Underdrain/effluent sampling point (s)
- Overflow/bypass sampling point(s)

Flow rate of water into and/or out of the selected LID BMP and pollutant concentration should be measured during runoff events at each point:

- Inflow
- Overflow
- Underdrain
- Bypass
- Vadose zone or within the bioretention soil media or gravel reservoir (optional)

[1] See flow monitoring guidance: http://www.openchannelflow.com/blog/isco-releases-7th-edition-of-its-flow-measurement-handbook

If all inlet/outlet points cannot be monitored, representative sites should be selected that allow for scaling or modeling of the entire BMP. Monitoring of flow from the underdrain (if present) and overflow/bypass is preferred to monitoring of the overflow/bypass alone.

If possible, projects should collect hydrologic and water quality data at the proposed BMP location before the BMP is installed. These projects should characterize the pre-BMP drainage area, instrument the location with flow rate measurement devices and autosamplers, collect flow-weighted composite samples, and analyze water samples for the same parameters to ensure comparability to samples collected after the BMP is installed.

Each sampling point for the LID BMP should be instrumented with a data logger, autosampler, and flow measurement devices. Tubing lines should be properly secured to the sampling location and protected within PVC conduit stretching from the sampler to the sample location to avoid damage to the lines. At the sampling location, tubing lines should be secured to the bottom of the flow pathway directly upstream of a metering weir (where possible). The weir will create sufficient head for an accurate water level measurement which can be used to calculate flow over the weir as well as provide a reservoir of storm water for collection through the autosampler tubing inlet strainer during lower flow periods of the hydrograph. If no weir is present, install the tubing lines to ensure that stormwater flow will not dislodge the equipment. Equipment checks should be conducted to ensure no blockages or tears will prevent proper measurements. The bubbler line should be secured, but allow bubbles to form at a continuous rate (1 bubble/sec) and sampling tubing lines lengths should be programmed to allow for proper head clearance, flushing time, and run time to collect samples. One rain gauge should be installed per BMP location to accurately measure the rainfall that occurs on the BMP drainage area. The preferable rain gauge is a tipping bucket gauge that interfaces directly with the data logger to allow direct comparison to flow data.

All sampling equipment should be placed in lockable security enclosures to deter theft and vandalism. Tubing lines and data cables should be protected with a PVC conduit from the elements and vandalism.

<u>Event Mobilization</u>

Prior to mobilization for a sampling event, weather/storm events should be tracked using multiple weather sources such as NOAA National Weather Service and Accuweather to estimate the event rainfall amount and arrival time of the storm event. Rainfall estimates should equal at least the project specific threshold to ensure adequate runoff to sample (0.25 inches suggested over 24 hrs.), and for effluent sampling, the antecedent dry period should be sufficient so that the BMP has completely drained water from previous rain events.

When event conditions are met, the sampling team should conduct a pre-event site visit to ensure the site is prepared for monitoring and the equipment remains properly installed, and begin sampling preparation procedures.

<u>Sampler Programming</u>

Composite samples

Minimum: collect a single volume-adjusted composite sample at the inlet and outlet/overflow which will represent the event mean concentration for the storm event.

Enhanced: collect a composite sample representing the “first flush” or rising limb of the hydrograph, and a composite sample representing the remaining flow for the event at the inlet and outlet/overflow.

Time-based

Based on the duration of the forecasted storm event autosamplers should be programmed to sample for up to 24 hrs. to provide a composite sample to represent the event mean concentration for the event. For a 24-hr. storm, tiered programming is recommended; where the first 12 discrete auto samples are collected every 30 minutes and the final 12 samples are collected at 1.5 hrs. For a storm event shorter than 24 hours the program should be appropriately scaled so that at least 75% of the storm is sampled.

Volume-based

Alternatively, autosamplers can be programmed for volume-weighted sampling by triggering samples based on a user-defined volume-to-sample quantity. In this case, a good estimate of flow rate and shape/timing of the hydrograph are needed. Adjustments are usually required based on experience from initial storm events. Underestimation of runoff will result in collection of additional samples and increased sample pacing which can backlog the autosampler tubing rinse/purge routine; backlogged samples then become time-weighted. Overestimation of runoff will result in collection of fewer samples and reduced representation of the event. Estimation of storm volumes and hydrographs can be improved by observing the monitoring site and instrumentation during the sampling event and adjusting pacing if needed. Hydrologic response of the BMP contributing area can also be better understood by monitoring and evaluating rainfall and flow only during storm event(s) prior to initiation of water quality sampling.

General setup

The autosampler should be programmed to conduct a triple rinse of the line, take a 1-liter water sample, and then purge the line.

The auto sampler/bubbler should be programmed to trigger sample collection based on a minimum flow/water level when water begins to overflow the weir. This can be done by setting a zero water level at ambient atmospheric pressures and setting the trigger to be the elevation of the top of the weir. Sample bottles should be then loaded into the auto sampler and iced for sample preservation prior to setting the sampler to standby.

Finally, all field meters should be calibrated/checked per manufacturer’s instructions for in-situ instructions.

Grab Samples

Grab sampling may be required to collect samples for a specific parameter such as oil and grease or bacteria. Such grab samples should be collected during the estimated peak of a storm event in an area with representative flow. Collect water grab samples using a clean HDPE bottle. Once bottled, water samples are to be put on ice for rapid cooling to reduce biological activity. See USEPA *Industrial Stormwater Monitoring and Sampling Guide* (EPA-832-B-09-003; 2009) for grab sampling procedure.

If the use of autosamplers is not feasible, collect a composite sample by collecting 1-L grab samples using a time-based approach (e.g. 1 grab sample every 30 minutes for first 6 hours and 1 sample every 1.5 hours for remaining storm event duration) scaled to the project site and size of the storm event. Discrete samples are then combined in a single vessel to create the composite, or they can be composited by the laboratory.

Use field meter to measure temperature, pH, EC, DO, turbidity and other parameters at selected times during the storm event.

Sample Collection

Multiple trips to collect or retrieve the composite / grab samples may be required to ensure hold times are met (sampling collection times should be calculated based on the final sample of the composite). Composite samples for the rising, peak, and declining limbs of the hydrograph should be composited together in a clean vessel and homogenized prior to subsampling into containers for sample analysis. Personnel should wear disposable gloves to prevent sample contamination. One subsample should be used to collect in-situ measurements such as temperature, conductivity, pH, and dissolved oxygen.

Laboratory Preparation

Transport samples to a safe, dry, and clean area for preparation to ship to a contract laboratory for processing. Alternatively subsamples for dissolved species can be filtered using a 0.45 micron filter in the field where possible using a syringe filter. Samples requiring acid preservation should then have their pH adjusted to <2 as required.

Prepare Chain of Custody (COC) and field sheets for accurate documentation of the collection and processing of samples.

Laboratory Guidance

Common parameters that the contract laboratory should test for are listed below with their typical units and reporting limits from the 2015 Surface Water Ambient Monitoring Program:

Parameter	Analysis Method	Common Units	Target Detection Limit
	Conventional		
pH	SM 4500-H+	s.u.	N/A
Conductivity	SM 2510	µS/cm	2.5
Turbidity	EPA 180.1	NTU	1
Total Suspended Solids (TSS)	SM 2540-B	mg/L	2.0
Total Hardness	SM 2340-B	mg/L	1
	Bacteria		
Fecal Coliform	SM 9221-E	MPN/100 mL	2
Enterococcus	EPA 9000-1600	Colonies/100 mL	1
	Nutrients		
Total Phosphorus	SM 4500 – P E	mg/L	0.5
Total Kjeldahl Nitrogen	SM 4500-N	mg/L	0.5
	Metals – Total & Dissolved		
Cadmium	EPA 200.8(m)	µg/L	0.03
Copper	EPA 200.8(m)	µg/L	0.10
Lead	EPA 200.8(m)	µg/L	2
Zinc	EPA 200.8(m)	µg/L	0.70
	Organics		
Pesticides	EPA 625(m)	µg/L	0.005 - 0.2
	Hydrocarbons		
Total Petroleum Hydrocarbons (TPH)	EPA 625(m)	mg/L	0.5