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Examples of Language in TMDLs and Plans that Implement TMDLs Regarding Evaluation of the Effects of Implementation

Part of *Evaluating the Water Quality Effects of TMDL Implementation*

This project is made possible through a cooperative agreement with the United States Environmental Protection Agency

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Methodology and Objective

In the fall of 2017, the Environmental Law Institute (ELI) disseminated a questionnaire about approaches to and experiences with evaluating the effectiveness of TMDL implementation. Staff from 39 states and the District of Columbia completed the questionnaire, and that information, especially references to particular TMDLs and plans for implementing TMDLs that contain details about effectiveness evaluation, provided the basis for this document. ELI staff found the referenced documents, searched through state repositories of TMDLs and TMDL implementation plans for additional examples, excerpted relevant language, and catalogued the contents.

The objective of this effort, and of this document, is to disseminate examples of how evaluating effectiveness has been covered in TMDLs and plans for implementing TMDLs, and to convey the breadth and depth of specifics regarding monitoring and the assessment of monitoring data – how, when, where, and by whom – that have been crafted. Some examples are unique in their state, while others are effectively boilerplate language. The examples are not intended to be comprehensive, nor are they intended to convey what that state includes in most TMDLs and related plans today. They are merely snapshots to inform others and spur innovation.

Alabama

TMDL for Cotaco Creek, fecal coliform

2008, General Statements

http://adem.alabama.gov/programs/water/wquality/tmdls/FinalCotacoCreekPathogensTMDL.pdf

5.0 Follow Up Monitoring

ADEM has adopted a basin approach to water quality management; an approach that divides Alabama's fourteen major river basins into five groups. Each year, ADEM's water quality resources are concentrated in one of the five basin groups. One goal is to continue to monitor §303(d) listed waters. Monitoring will help further characterize water quality conditions resulting from the implementation of best management practices in the watershed. This monitoring will occur in each basin according the schedule shown.

Table 5-1. 303(d) Follow Up Monitoring Schedule

River Basin Group	Year to be Monitored
Chattahoochee / Chipola / Choctawhatchee / Perdido-Escambia	2008
Tennessee	2009
Alabama / Coosa / Tallapoosa	2010
Escatawpa / Mobile / Lower Tombigbee / Upper Tombigbee	2011
Black Warrior / Cahaba	2012

TMDL for Little Tallapoosa River, E. coli

2017, General Statements

http://adem.alabama.gov/programs/water/wquality/tmdls/FinalLittleTallapoosaRiverPathogensTMDL.pdf

5.0 Follow up monitoring

ADEM has adopted a statewide approach to water quality management. Each year, ADEM's water quality resources are divided among multiple priorities statewide including §303(d) listed waterbodies, waterbodies with active TMDLs, and other waterbodies as determined by the Department. Monitoring will help further characterize water quality conditions resulting from the implementation of best management practices and load reductions in the watershed.

Alaska

TMDL for Granite Creek, Sediment and Turbidity

2002, Specific and Detailed

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjl24bEjf_yAhUhKVkFHUlKDUsQFnoECAIQAQ&url=https%3A%2F%2Fdec.alaska.gov%2Fmedia%2F18461%2Fgranitecreekfinal.pdf&usg=AOvVaw1TpGs-YTCxgkz61Nhl4oif

Sediment-related impacts on designated uses are often difficult to characterize. Given the uncertainties of estimating source loadings, and the fact that nonpoint sources are involved, a reasonable expectation is that a water quality monitoring plan will accompany the TMDL. Such a plan should be geared towards confirming the effectiveness of structural and operational BMPs in meeting water quality standards, verify source estimates, validate TMDL elements, and confirm that structural BMPS are put in place and maintained.

The Monitoring Plan for Granite Creek was formalized in October 2001. The Quality Assurance Project Plan for the Granite Creek Watershed Recovery Project and Total Maximum Daily Load (TMDL) Determinations was approved by ADEC in October 2001. The QAPP guided water quality data collection in fall 2001 and will guide future data collection. The QAPP sets the objectives and schedule for future monitoring in the watershed. Figures 4 and 5 show permanent monitoring stations established along the mainstem, North and South tributaries, and at the series of sediment retention ponds constructed in summer 2001. The location of stations is intended to assess individual source contributions as well as to document the integrated effects of all sources. Control stations are also included. Future, long-term monitoring will provide information that will:

- determine compliance with numeric in-stream TSS and turbidity targets
- verify the TSS-to-turbidity and TSS-to-flow relationships used in the TMDL
- access allowable sediment loads to Granite Creek
- assess effectiveness of operator BMPs in protecting water quality
- assess the degree of BMP implementation in the watershed
- detect and report significant changes in water quality and track water quality trends in the future
- restore/rehabilitate the watershed consistent with CBS lease requirements
- ensure collected data are of high quality and are used by the CBS and other agencies in managing lease operations in the watershed

The water quality monitoring parameters to be measured in the Granite Creek watershed are included in Table 10. Data Quality Objectives (DQOs) are included in the Appendix.

Sections B1.a and B1.b of the QAPP provide further details on monitoring site selection criteria and sampling parameters and collection frequency.

Stations for water quality monitoring are representative of the varied hydrologic, biological and physical/chemical conditions in the watershed as well as addressing several source activities. Accessibility to sampling sites was a major consideration. Representative stations are established on the main stem of Granite Creek (at the Halibut Point Road bridge site), a reference station prior to entering the gravel operation area, and both the north and south forks/tributaries to Granite Creek before they converge into the mainstem. Also, periodic sampling at selected settling ponds and drainage channels within the watershed are recommended using these criteria (Figure 5). Surface water quality will exclusively address sediments (settleable solids and total suspended solids), turbidity and flow. Confirming the mathematical relationship of turbidity -to-TSS for Granite Creek through further monitoring will allow for the use of turbidity alone as a cost-effective, surrogate means to evaluate compliance with sediment allocations.

Table 10: Water Quality Monitoring Checklist for the Granite Creek Watershed

WQ PARAMETER	GRANITE CREEK MAINSTEM	NORTH AND SOUTH FORKS	SETTLING PONDS AND CHANNELS
Primary measurements			
-sediments (settleable solids)	X	X	X
-total suspended solids (TSS)	X	X	X
-turbidity (water clarity)	X	X	X
-flow velocity and discharge rate[26]	X		
Additional measurements			
-petroleum hydrocarbons (oily visible sheen)	X	X	X
-suspended sediment concentration (SSC) [27]	X	X	X
-smolt counts(fry surveys)[28]	X	X	X

USGS and Forest Service hydrologists have assisted the water quality contractor in documenting Granite Creek flow rates, establishing permanent benchmarks at the Halibut Point Road bridge for determining long term stream discharge rates, and providing stream discharge data for Indian River for comparison with Granite Creek. As mentioned above, the USGS may provide information on the relationship of SCC-to-TSS at Indian River.

A future recommended monitoring task found in the Implementation Plan is to develop a stagedischarge curve for Granite Creek. This curve would allow for estimating flow based on stream elevation readings, allowing for quick and accurate flow estimates. Direct long- term stream elevation data from Granite Creek will be obtained from the permanent reference mark made at the Halibut Point Road bridge site in October 2001. This will allow for the eventual calculation of a stage discharge curve, where flow (cfs) can then be estimated directly from stream elevation. Stream elevation readings should be taken several times during all months of the year in concert with TSS and turbidity measurements. The result would lead to a more prescriptive TSS-flow relationship.

Given the tight schedule for development of the TMDL, water quality monitoring was envisioned to occur in two phases. During Phase 1, extending from October 1 through November 25, 2001, permanent stations were established on Granite Creek, staked for future reference, and monitored. These stations are selected to represent background conditions, integrate the downstream effects of all operations, and establish the relative contributions of sediment from each of the North Fork and South Forks of Granite Creek before they converge and enter the mainstem.

Longer-term monitoring will need to occur after the TMDL is approved to evaluate the effectiveness of sediment controls as well as to further refine the relationship of water quality to flow rate in Granite Creek.

Phase 2 monitoring will include periodic assessment of settling pond sediment and turbidity removal efficiency at two (2) upper creek stations and routine turbidity monitoring by CBS staff at the four permanent water quality stations (Figure 4) to evaluate compliance with water quality standards. Operator self-monitoring (checks for cloudy water) is encouraged to quickly detect and address short-term water quality problems. Same-day collection of simultaneous TSS and turbidity data will continue to occur at the Granite Creek bridge station. As mentioned above, simultaneous with the water quality data collection, Granite Creek flows/elevations will need further measurement at the Halibut Point Road/Granite Creek crossing to better establish a TSSflow relationship. Local CBS environmental staff will be available to read the height/elevations over an extended period and report that information to the USGS for use in refining the stage discharge curve for Granite Creek.

Both CBS contractors and CBS staff will also report narrative or anecdotal environmental observations in addition to conducting discrete grab sampling and will use photographs to document conditions. For example, photographic time series will be used to evaluate drainage modifications within the gravel lease sites and the success of using various operational and structural BMPs to reduce sediment and turbidity levels in Granite Creek.

Principal users of the data will be the CBS Public Works Department, the responsible party for lease operations in the upper Granite Creek basin. Data collected will also be provided to the ADEC using the format required in the current grant agreement. ADEC will enter data into the STORET database. The approved TMDL will be included on the ADEC website. The posting will provide Sitka residents and resource agencies a picture of what will be done to improve water quality conditions.

TMDL for Big Lake, Petroleum Hydrocarbons

2012, Specific but Brief
https://dec.alaska.gov/media/15862/biglake.pdf

7.5. Follow-up Monitoring

Follow up monitoring in Big Lake will be essential to assessing the progress and benefits of the Action Plan and other implementation actions. Repeat monitoring at the sampling sites and during the observed times of worst impairment (e.g., high use weekends) will be necessary to track water quality improvement. The water quality progress can be used to assess implementation actions and refine or enhance the action plan and related priorities as necessary. Repeat water quality data will also be necessary for identifying when Big Lake meets applicable water quality standards and can be removed from the state's impaired waters list. At least two years of data showing concentrations meeting water quality criteria will be necessary to delist the lake.

Arizona

TMDL for Boulder Creek, Arsenic, Copper and Zinc

2004, Specific but Brief
(http://www.azdeq.gov/sites/default/files/bill_williams_tmdl_boulder.pdf)

6 MONITORING

ADEQ intends to conduct follow-up monitoring five years after the approval of this TMDL. ADEQ continues to work in the area in support of the Alamo Lake mercury TMDL and possibly other metals TMDLs attributable to historic mining in the area. Once the Hillside Mine tailings piles are re-graded and capped, further monitoring will help assess the effectiveness of implemented remediation strategies.
[TMDL]

F. Monitoring Plan

Fish tissue will continue to be collected every few years to assess progress made in reducing the weighted trophic level fish tissue mercury for TL-4 and TL-3. ADEQ will work with AGFD to collect a broad spectrum of fish species and sizes. The ADEQ ambient lake monitoring program and/or the TMDL targeted monitoring program will continue to sample Alamo Lake every few years. In addition to monitoring mercury, ADEQ has scheduled a TMDL for low DO, high pH, and ammonia at Alamo Lake to begin in 2012.

TMDL for San Pedro River, E. Coli

2013, Specific and Detailed
http://www.azdeq.gov/sites/default/files/sanpedro_ecoli_tmdl.pdf

9.3 Time Frame and Future Monitoring

A.R.S. 49-234 mandates that a time frame be established for the implementation plan by which attainment of water quality standards is expected to be achieved. A three to five year time frame after the implementation of improvement measures is expected before significant improvements will become evident for Reach 15050203-001, assuming that measures to improve *E. coli* loading are implemented expeditiously. Effectiveness monitoring by ADEQ will commence five years after implementation measures are enacted.

For the purposes of implementation and effectiveness evaluations, stakeholders engaged in monitoring activities are encouraged to consider and evaluate monitoring results in terms of concentrations as stated in the Arizona water quality standards. As with permittees' monitoring under the MSGP and CGP, *E. coli* densities that meet Arizona's water quality concentration-based criteria will be considered consistent with the provisions governing the remainder of this TMDL. The assumption behind this provision relates to the close connection between loads and concentrations as outline in Section 3.0, with loads derived from concentrations. Waters meeting the concentration-based water quality standard are thus considered to be in compliance with associated load allocations, and these waters are not considered to be causing or contributing to actual or possible downstream impairments. The State's 2009 *E. coli* standard, with a single sample maximum value of 235 cfu/100 ml and a 30 day averaging period for a geomean value of 126 cfu/100 ml is in effect for assessment of results. ADEQ encourages stakeholders to comply if possible with the monitoring requirements of the geometric mean portion of the standard with its 30 day time frame, as this value gives the best overall view of the bacteriological water quality of the rivers over time. However, ADEQ recognizes that in meeting the requirements of the averaging period, particular difficulties are posed, with a narrow margin of sampling time discretion available to both establish a set of minimum size four with independence of all samples in the set (samples separated by at least a seven day interval) and to meet the time limit of 30 days for the complete collection of a set. ADEQ anticipates most monitoring results from stakeholders will be evaluated under the single sample maximum provision of the standard.

Where geomean assessment cannot be reasonably performed, it is recommended that sites be sampled for *E. coli* densities quarterly at a minimum in hydrologic conditions that represent all parts of the flow regime, including stormflow, snowmelt, and baseflow conditions. For interested stakeholders and other parties doing follow-up monitoring, ADEQ recommends the sites listed in Table 12 to best characterize subwatershed water quality conditions. Sites recommended have been considered for accessibility, suitability for project objectives, and other factors. Where private lands are involved, permission to access and sample from the landowner will be required.

ADEQ will review the status of the waterbody at least once every five years to determine if attainment of applicable surface water quality standards has been achieved. If attainment of applicable surface water quality standards has not been achieved, ADEQ will evaluate whether modification of this TMDL implementation plan is required (A.R.S. § 49-234).

Site	*ADEQ Designation*	*Arizona Associated Reach ID*	*Latitude/ Longitude (NAD27)*	*Representative USGS Site in Vicinity*	*Land Owner / Administrator*
San Pedro above confluence with Romero Wash	SPSPR001.54	15050203-001*	32° 58' 21.7", 110° 46' 03.2"	N.A.	ASARCO
San Pedro below Dodson Wash	SPSPR006.75	15050203-001	32° 55' 00.7" 110° 44' 03.9"	N.A.	Pinal County (access road ROW)
San Pedro below Aravaipa Creek confluence	SPSPR013.29	15050203-001	32° 50' 18.5" 110° 42' 56.7"	N.A.	Public
Aravaipa Creek above SPR confluence	SPARA000.28	15050203-004C	32° 50' 22" 110° 42' 37.9"	09473000 (upstream)	ADOT (Hwy 77 ROW)
Aravaipa Creek below Aravaipa Canyon Wilderness Boundary	SPARA010.19	15050203-004C	32° 53' 44" 110° 34' 04"	09473000 (downstream)	BLM
San Pedro at Hwy 77 Crossing, Mammoth	SPSPR022.15	15050203-003	32° 44' 33.2" 110° 38' 52.2"	09472050 (upstream)	ADOT (Hwy 77 ROW)

Table 12. Recommended Implementation Monitoring Sites

ADEQ will continue to monitor the San Pedro River and its tributaries, both as a routine part of its ambient monitoring program on a triennial basis, and for effectiveness evaluations of water quality improvement measures after water quality improvement measures have been implemented. The department will use load evaluation criteria presented in this TMDL document as opposed to the concentration-based criteria recommended to stakeholders to evaluate loading reductions and improvements in the impaired reaches and contributing subwatersheds where possible, as detailed in Section 8.2.2. As mentioned in Section 3.0, these two approaches are complementary, with loads being derived from concentrations. The more intricate nature of the loading analysis, however, makes it more suitable for application to the agency with personnel experienced in the determination, application, and interpretation of loading data in a load duration analysis.

TMDL for Watson Lake, Total Nitrogen, DO, pH & Total Phosphorus Targets

2015, Specific but Brief

http://www.azdeq.gov/sites/default/files/verderiver_watson_tmdl.pdf

9.4 Watershed Monitoring Strategy as Part of an Updated WIP

The ADEQ Watershed Protection Unit and Stormwater Permit Unit will work with stakeholders to develop a comprehensive and complimentary watershed monitoring strategy. Sample plans will follow ADEQ QAPP/SAP requirements and clearly state spatial and temporal monitoring objectives and reporting. ADEQ recognizes that permitted entities may have specific objectives that differ from non-permitted entities. Each monitoring entity will contribute a chapter to an appendix of the updated WIP, identifying site locations, sample parameters, collection methods, labs used, data reporting requirements, and quality assurance/quality control measures. It will be important to update the strategy on a regular basis so that source characterization and TMDL implementation are timely noted. The list of entities identified to date include:

- Prescott Creeks and volunteers (Nonpoint Source)
- Prescott College and volunteers (Nonpoint Source)
- Prescott National Forest (Nonpoint Source)
- State Lands (Nonpoint Source)
- YPIT (Nonpoint Source)
- Private entities TBD
- City of Prescott (MS4)
- Yavapai County (MS4)
- ADOT MS4 facilities

Florida

TMDL for Lower St. Johns River Basin Main Stem, Nutrients

2008, Specific and Very Detailed (Implementation Plan)
https://floridadep.gov/sites/default/files/adopted-lsjr-bmap.pdf

7.2 Water Quality Monitoring

The monitoring strategy addresses design, quality assurance (QA), and data management and interpretation that measure progress toward achieving the TMDLs. This approach also allows for evaluation and feedback that refines the monitoring strategy over time. The objectives of the monitoring strategy are:

- To assess the condition of the LSJR based on dissolved oxygen for the river's marine reach and chlorophyll *a* for the freshwater reach;
- To determine the compliance of domestic and industrial point sources with nitrogen and phosphorus load limits allocated in this BMAP and to track implementation of projects listed in this BMAP for urban nonpoint sources;
- To establish a continuing monitoring program for major tributaries to the LSJR that provides data for performing future water quality model simulations and assessments of nonpoint source loads; and
- To identify who will be tasked with the analysis, interpretation, and dissemination of monitoring information.

As technology changes and develops and information is obtained from the monitoring, the sampling techniques and station locations, described below, may change. However, the objectives of the monitoring must still be achieved. A more detailed discussion on the monitoring plan is included in a report entitled, "Compliance Assessment and Continuing Monitoring Plan Element" (Hendrickson 2008). The monitoring efforts described in this section will be coordinated, to the extent possible, with the monitoring to be conducted as part of the Lower St. Johns River tributaries fecal coliform TMDL.

7.2.1 Lower St. Johns River Target Compliance Monitoring

7.2.1.1 The Freshwater Reach Chlorophyll A Target

The monitoring for the freshwater section of the river is based on chlorophyll *a* with a target of "not to exceed 40 µg/L, as a WBID-wide average, for more than 40 consecutive days". The monitoring in the freshwater section will focus on the two "worst case" WBIDs: 2213L and 2213K, which are located on the reach of the river between Palatka and Tocoi (**Figure 8**).

A statistical power analysis was conducted to determine the optimum number of samples necessary to represent the daily mean chlorophyll *a* concentration with acceptable confidence. This analysis showed that 29 samples are needed to represent the daily mean within a chlorophyll *a* concentration of 5 µg/L. To keep costs reasonable at this monitoring intensity and build on existing ambient monitoring program stations, additional samples in each "worst case" WBID will be measured in the field by *in-vivo* fluorescence, with a subset of ten calibration samples collected in each event for laboratory spectrophotometric analysis. In addition, the USGS continuous water quality monitoring station at Federal Point will be instrumented with a chlorophyll sensor to track changes between biweekly events.

Monitoring will be conducted during the peak algal bloom months of April through October. The stations listed in **Table 33** will continue to be monitored as part of the SJRWMD's long term ambient monitoring program, with a complete laboratory analytical suite, including dissolved and total nutrients, major ions, trace metals, organic carbon, BOD, chlorophyll, and field measurements.

TABLE 33: LONG-TERM AMBIENT SAMPLING STATIONS IN THE FRESHWATER REACH AND RESPONSIBLE ENTITIES

Station Name	Location	Parameters Sampled	Frequency of Sampling	Responsible Entity
SJP	2213M	Std. parameters	Biweekly	SJRWMD
SJRCC	2213L	Std. parameters	Biweekly	SJRWMD
SJRCW	2213L	Std. parameters	Biweekly	SJRWMD
SJM37	2213K	Std. parameters	Biweekly	SJRWMD
SRP	2213K	Std. parameters	Biweekly	SJRWMD
SAVSCRAO	2213K	Std. parameters	Biweekly	SJRWMD
SJWSIL	2213J	Std. parameters	Biweekly	SJRWMD
SJSR16	2213I	Std. parameters	Biweekly	SJRWMD
SJRHBP	2213H	Std. parameters	Biweekly	SJRWMD
River Transect	2213K	Std. parameters + *In vivo* fluorescence	Biweekly (Apr-Oct)/At least 29 samples within WBID	Georgia Pacific
River Transect	2213L	Std. parameters + *In vivo* fluorescence	Biweekly (Apr-Oct)/At least 29 samples within WBID	Seminole Electric

Note: Transect points identify the intensive sampling locations that were used in the power analysis to determine sampling density. Water quality model grid overlain on the river will be used as the template to position monitoring sites.

FIGURE 8: SAMPLING PRIORITY AREA IN THE FRESHWATER REACH OF THE LSJR

7.2.1.2 The Marine Reach Dissolved Oxygen Target

The marine reach of the LSJR exhibits chronic low dissolved oxygen concentrations. This condition is the most pronounced in the narrow, deep section of the river's marine reach, from the Main Street Bridge in downtown Jacksonville to the Intracoastal Waterway. The greatest frequency of low concentrations is observed between river miles 5 to 11, corresponding to WBID 2213B. Because of the cyclical nature of dissolved oxygen (and the ancillary salinity, conductance, and temperature data), and the vertical and horizontal gradients that may be present, a fixed, multi-station, continuous monitoring program is proposed for WBID 2213B. Long-term ambient water quality monitoring within this reach, conducted by the City of Jacksonville and SJRWMD, will continue.

The continuous monitoring station locations have been selected to characterize the zones that tend to exhibit different oxygen patterns within the WBID: 1) the waters of the main channel and 2) the out-welling water of the Timucuan tide marsh north of Heckscher Drive. These locations, along with the long-term river ambient monitoring stations, are shown in **Figure 9**. **Table 34** describes the sites at which the continuous monitoring will occur. FDEP will provide the monitoring equipment for the two new monitoring stations, set up these new sites, and replace the equipment when necessary. JEA has agreed to provide the operations and maintenance for the two new stations.

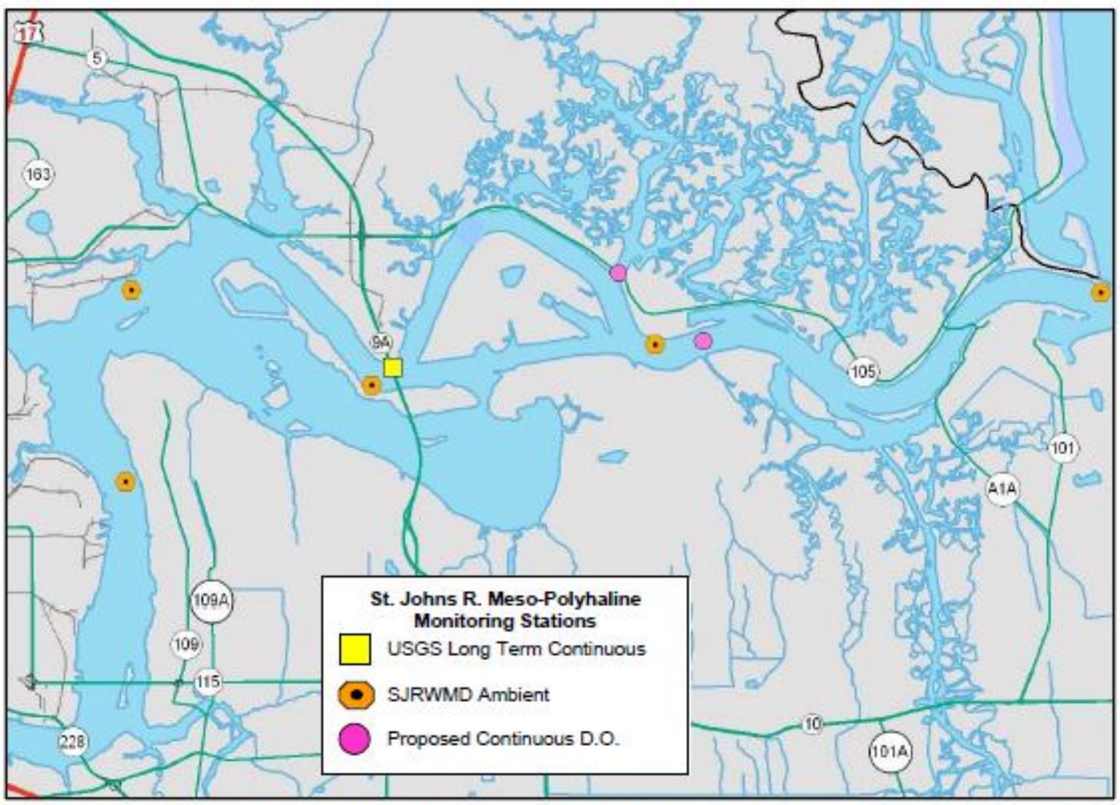

FIGURE 9: LONG-TERM AMBIENT AND PROPOSED AUTOMATED CONTINUOUS SAMPLING LOCATIONS IN THE MARINE REACH (WBID 2213B) OF THE LSJR

Table 34: Continuous Monitoring Stations in the Marine Reach and Responsible Entities

Station Name	Location	Parameters Sampled	Frequency of Sampling	Responsible Entity
Fulton Point	In channel between river miles 5 to 7	Dissolved oxygen, specific conductance, salinity, and water temperature at 2 vertical positions	Continuous every 15 minutes	FDEP (equipment and set up) and JEA (operation and maintenance)
Clapboard Creek	Heckscher Drive bridge piling	Dissolved oxygen, specific conductance, salinity, and water temperature at 1 vertical positions	Continuous every 15 minutes	FDEP (equipment and set up) and JEA (operation and maintenance)
SJR at Dames Point	Dames Point northern bridge fender	Dissolved oxygen, specific conductance, salinity, and water temperature at 2 vertical positions, with redundant instrumentation and real-time telemetry	Continuous every 15 minutes	USGS, funded by SJRWMD

7.2.2 Source Monitoring

The assessment of loads to the river from point and nonpoint sources is a critical component of the BMAP monitoring initiative. Wastewater point sources have permit requirements to verify explicitly through monitoring that load allocations are achieved. MS4s and urban and agricultural nonpoint sources also have allocations and expected load reductions, with compliance presumed through a demonstration of BMP implementation, rather than direct water quality monitoring. The recommended minimum constituent suite for monitoring for point sources and nonpoint sources is listed in **Table 35**. The water quality parameters are shown as core or supplemental indicators per EPA guidance for water quality monitoring plans. Core indicators can be "used routinely to assess attainment with applicable water quality standards" whereas supplemental indicators are used "to monitor when there is a reasonable expectation that a specific pollutant may be present in a watershed, when core indicators indicate impairment, or to support a special study such as screening for potential pollutants of concern (EPA 2003)."

Table 35: Indicators for Point and Nonpoint Source Monitoring to Assess Compliance with Allocations

Indicator	Required Reporting Limit*	Domestic Effluent	Industrial Effluent	Nonpoint Source/ Tributaries
Core Indicators				
Nitrate + Nitrite N	0.010 mg/L	X	X	X
Ammonia-N	0.010 mg/L	X	X	X
Total Kjeldahl Nitrogen	0.050 mg/L	X	X	X
Orthophosphate	0.005 mg/L	X	X	X
Total Phosphorus	0.010 mg/L	X	X	X
Color	10 pt-co		X	X
Sample Depth	0.1 m			X
TOC	0.2 mg/L	X	X	X
BOD	0.5 mg/L	X	X	X

Indicator	Required Reporting Limit*	Domestic Effluent	Industrial Effluent	Nonpoint Source/ Tributaries
Supplemental Indicators				
Chlorophyll *a*	0.5 µg/L		X	
Dissolved Oxygen	0.1 mg/L	X	X	X
Turbidity	0.2 ntu	X	X	X
Water Temperature	0.2 ºC		X	X
pH	0.1 unit		X	X
Specific Conductance	10 mmho/cm	X	X	X
Secchi Depth	2 cm			X
Total Depth	0.1 m			X

*In cases where the reporting unit is less than the method detection limit, value should be measured to these recommended levels and remarked with the STORET "T" code.
Note: Domestic waste effluents include wet-weather and APRICOT discharges, as well as continuous WWTF discharges for facilities greater than 0.2 mgd. Industrial effluents include pulp and paper, power plant, and demineralization concentrate.

7.2.2.1 Nonpoint Source Monitoring and Monitoring of Tributary Inputs

Because nonpoint sources come into the LSJR through many individual entry points including small streams, large tributaries, canals, ditches, groundwater seepage, and rainfall, it is not practical to monitor each individual nonpoint source. This monitoring plan instead focuses on measuring the loads from the major tributaries, along with monitoring of the main stem water quality itself, to estimate how nonpoint sources are changing. This water quality information can then be used to confirm the effects of the nonpoint source load reduction projects listed in **Appendix H** that will be tracked to ensure they are completed.

To provide water quality and load information for the majority of the flow entering the LSJR, monitoring should be continued or instituted on the stations listed in **Table 36**. Many of these stations are presently included in long-term ambient monitoring programs and several are associated with USGS discharge and continuous water quality monitoring. Monitoring performed at the stations listed in **Table 36** will characterize 88 percent of the calculated discharge entering the Lower St. Johns River.

Monitoring of the LSJR tributaries is designed to assess stormflow (shown as high-flow event in **Table 37**) and baseflow. Under the flow-weighted sampling protocol, baseflow and stormflow are considered as distinct water quality regimes. Because stormflow (the pulse in discharge associated with the immediate precipitation event, separated from baseflow through standard hydrologic analysis) typically represents from 60 to over 90 percent of annual runoff volume, its assessment is critical in the calculation of annual load. In the major tributary monitoring program, it is recommended that stormflow be assessed with grab sampling timed to capture runoff events, at an event frequency equivalent to that of baseflow sampling. Because baseflow is the prevailing state of tributary streamflow, it can typically be assessed with pre—scheduled, fixed interval monitoring programs. Conversely, stormflow collections must be executed during a relatively short interval following significant accumulation of precipitation. These intermittent collections should be targeted to occur within each of three predominant meteorological cycles that occur in a typical year: cool season events from November through mid-March; warmer, dry-season events from mid-March through mid-June; and wet, hot season events from mid-June through October. The goal is to collect two events per season per site, if possible. Sampling will continue on an annual basis until there are at least four data per season within a two year time period. This information on stormflow will be used to refine the loads entering the river from the tributaries in the modeling. Continuous water quality data collection is achieved with automated unattended equipment deployed in association with gauged discharge monitoring, and is typically comprised of measurements for DO, specific conductance, pH, temperature, and turbidity, and telecommunications equipment for real-time transmission of data. **Figure 10** identifies the watershed areas that are assessed under this tributary monitoring program.

TABLE 36: EXISTING AND RECOMMENDED LONG-TERM AMBIENT MONITORING STATIONS FOR THE TMDL

Station	Station ID	Discharge	Current Monitoring	Recommended Addition	Responsible Entity
Lake George Outlet	LG12	By difference	Biweekly sampling for chemistry; Automated Continuous for DO, WTEMP, SpCond at CM 4-5	No change	SJRWMD
Ocklawaha River Mouth	OCKLRM	Yes	Biweekly	No Change	SJRWMD
St. Johns R. at Buffalo Bluff	SRB	Yes	Biweekly sampling for chemistry; Automated Continuous for DO, WTEMP, SpCond	No Change	SJRWMD
Dunns Creek and Crescent Lake	DUNNSCRK	Yes	Biweekly	No Change	SJRWMD
Rice Creek at Hwy 17	RCB	Yes	Monthly Fixed Interval	See Table 37	SJRWMD
Peters Creek at C.R. 209	PTC	No	Monthly Fixed Interval	See Table 37	SJRWMD
Governors Cr. At S.R. 16	GC16	No	Monthly Fixed Interval	See Table 37	SJRWMD
North Fork Black Creek at Hwy. 21 Middleburg	NBC	Yes	Monthly Fixed Interval	See Table 37	SJRWMD
South Fork Black Creek C.R. 218 Middleburg	SBC	Yes	Monthly Fixed Interval	See Table 37	SJRWMD
Little Black Cr. at C.R. 220	Proposed station	No	None	Bi-Monthly Fixed Interval	JEA
Black Creek	BLC	Yes	Monthly Fixed Interval	Automated Continuous (DO, WTEMP, Turbidity, SpCond)	SJRWMD, CCUA
Ortega River at Collins Rd.	20030349	At Kirwin Rd.	Bi-monthly Fixed Interval; Continuous for DO, WTEMP, SpCond	See Table 37	SJRWMD
Cedar River Blanding Blvd.	20030083	At San Juan	Bi-monthly Fixed Interval	See Table 37	SJRWMD
Moncrief Creek	20030115	No	Bi-monthly fixed interval	No Change	SJRWMD
Ribault R.	RRLTR	No	None	Bi-Monthly Fixed Interval	JEA

Station	Station ID	Discharge	Current Monitoring	Recommended Addition	Responsible Entity
Pablo Creek at San Pablo Rd.	Proposed station	No	None	Bi-Monthly Fixed Interval	JEA
Arlington R. at University Blvd.	ARLRM	No		Bi-Monthly Fixed Interval	JEA
Julington Cr. at Old St. Augustine	Proposed station	No		Bi-Monthly Fixed Interval	JEA
Big Davis Creek at U.S. 1	LSJ099	Yes	Bi-monthly fixed interval	No Change	SJRWMD
Durbin Creek at Racetrack Road	LSJ087	No	Bi-monthly fixed interval	See Table 37	SJRWMD
Sixmile Creek	Proposed station	Yes	Monthly Fixed Interval	See Table 37	SJRWMD
Deep Creek	DCR	Yes	Monthly Fixed Interval; Continuous for DO, WTEMP, SpCond	See Table 37	SJRWMD
Dog Branch	DBR	No	Monthly Fixed Interval	See Table 37	SJRWMD
Hastings Drainage District	OHD	No	Monthly Fixed Interval	See Table 37	SJRWMD
Elkton Drainage District	OED	No	Monthly Fixed Interval	See Table 37	SJRWMD
Tocoi Creek	TOC	No	Monthly Fixed Interval	See Table 37	SJRWMD

TABLE 37: STORMFLOW SAMPLING FOR TMDL MODEL REFINEMENT

Station	Station ID	Recommended Addition	Responsible Entity
Rice Creek at Hwy 17	RCB	High-Flow Event Sampling, 2/season	SJRWMD
Peters Creek at C.R. 209	PTC	High-Flow Event Sampling, 2/season	CCUA
Governors Cr. At S.R. 16	GC16	High-Flow Event Sampling, 2/season	CCUA
North Fork Black Creek at Hwy. 21 Middleburg	NBC	High-Flow Event Sampling, 2/season	CCUA
South Fork Black Creek C.R. 218 Middleburg	SBC	High-Flow Event Sampling, 2/season	CCUA
Little Black Cr. at C.R. 220	Proposed station	High-Flow Event Sampling, 2/season	CCUA
Ortega River at Collins Rd.	20030349	High-Flow Event Sampling, 2/season	COJ
Cedar River Blanding Blvd.	20030083	High-Flow Event Sampling, 2/season	COJ
Ribault R.	RRLTR	High-Flow Event Sampling, 2/season	COJ
Pablo Creek at San Pablo Rd.	Proposed station	High-Flow Event Sampling, 2/season	COJ

Station	Station ID	Recommended Addition	Responsible Entity
Arlington R. at University Blvd.	ARLRM	High-Flow Event Sampling, 2/season	COJ
Julington Cr. at Old St. Augustine	Proposed station	High-Flow Event Sampling, 2/season	COJ
Durbin Creek at Racetrack Road	LSJ087	High-Flow Event Sampling, 2/season	COJ
Sixmile Creek	Proposed station	High-Flow Event Sampling, 2/season	To be determined*
Deep Creek	DCR	High-Flow Event Sampling, 2/season	To be determined*
Dog Branch	DBR	High-Flow Event Sampling, 2/season	To be determined*
Hastings Drainage District	OHD	High-Flow Event Sampling, 2/season	To be determined*
Elkton Drainage District	OED	High-Flow Event Sampling, 2/season	To be determined*
Tocoi Creek	TOC	High-Flow Event Sampling, 2/season	To be determined*

* High-flow event sampling will be conducted at these stations, if funding is available, to provide additional information for model refinement.

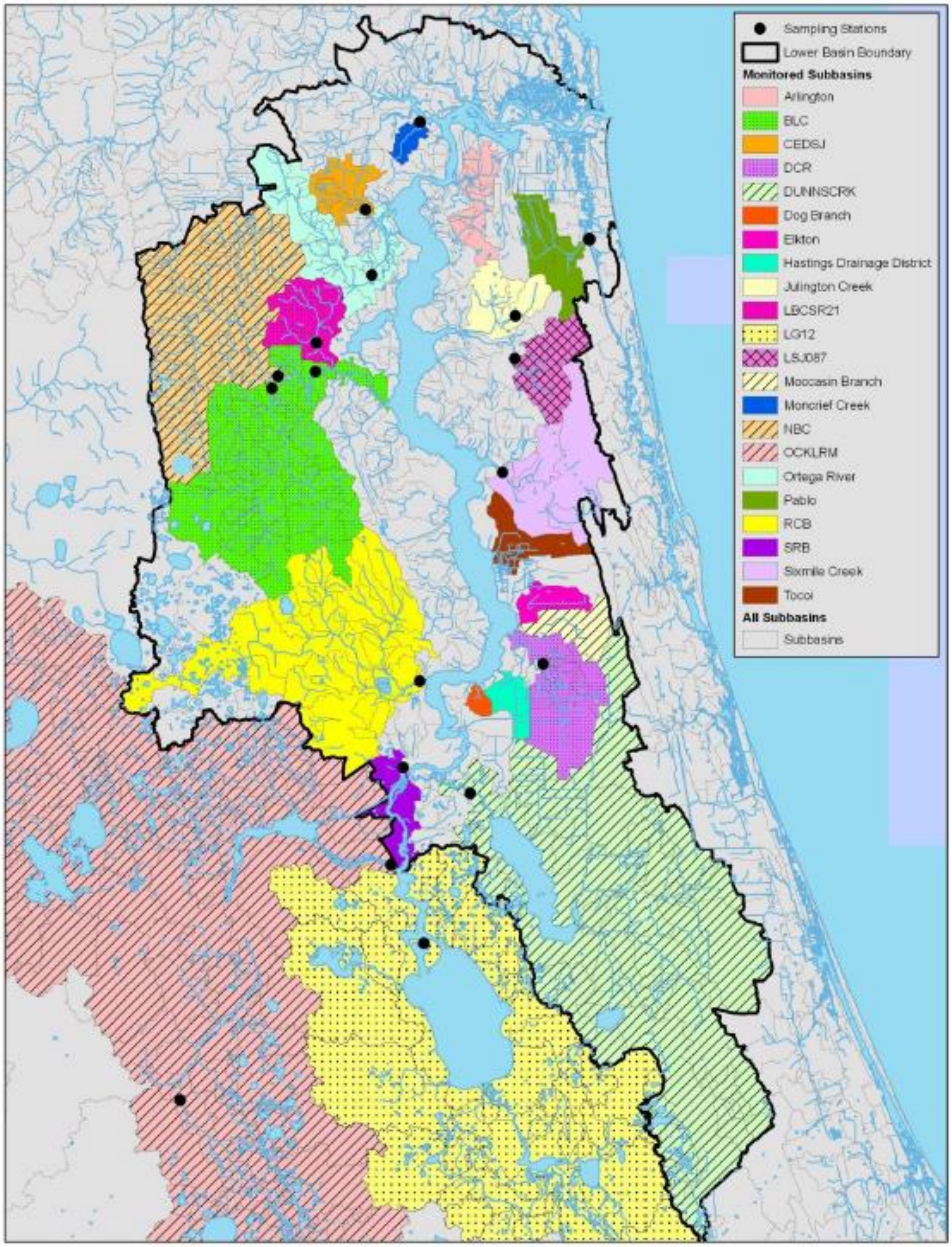

FIGURE 10: WATERSHED AREAS ASSESSED IN THE TRIBUTARY MONITORING PROGRAM

7.2.3 MONITORING RESPONSIBILITIES

Commitment for monitoring by the responsible entities is for two years of data collection (for both fixed interval and high-flow event monitoring). After the two years, the datasets will be evaluated to assess if sufficient data has been collected to reasonably determine loads and trends. If the data is not deemed to be sufficient by FDEP, the monitoring will continue for another year for subsequent evaluation. Annual evaluations will continue until sufficient data are available.

7.2.4 MAINTENANCE OF DATA

Data collected by the network will be loaded into the STORET database that is maintained by FDEP. Partners must meet QA requirements set by FDEP for STORET data. Additional interagency data comparisons and QA checks will be conducted as practical.

Observations of water quality conditions and trends will be reported to the Executive Committee and the public at least annually. Water quality data will be used to support the adaptive management process, assess projects, and identify the need for new actions. A more complete analysis of trends in progress towards achieving the water quality target will be made on a five-year basis, corresponding with FDEP's watershed management cycle.

TMDL for St. Lucie River and Estuary Basin, Nutrients and Dissolved Oxygen

2013, Specific and Detailed (Implementation Plan)
https://floridadep.gov/sites/default/files/stlucie-estuary-nutr-bmap.pdf

6.3 WATER QUALITY MONITORING

6.3.1 MONITORING OBJECTIVES

Focused objectives are critical for a monitoring strategy to provide the information needed to evaluate implementation success. The primary objective of the monitoring strategy for the St. Lucie River and Estuary is described below, and will be used to evaluate the success of the BMAP:
− ***Primary Objective*** *– Track trends in TN and TP loads in the major canals and tributaries, as well as the St. Lucie River and Estuary.*

6.3.2 MONITORING PARAMETERS, FREQUENCY, AND NETWORK

To achieve the objective above, the monitoring strategy focuses on the following suggested parameters:
− *TP.*
− *Orthophosphate as P.*
− *Nitrate/Nitrite as N.*
− *N, Ammonia.*
− *Total Kjeldahl Nitrogen.*
− *DO.*
− *BOD.*
− *Chlorophyll-a.*
− *pH.*
− *Temperature.*
− *Specific Conductance.*
− *Total Suspended Solids.*
− *Turbidity.*
− *Alkalinity.*

These parameters will be monitored at the sites listed in **Table 26**. However, it should be noted that not all parameters are measured at each of the sites. The monitoring network for this plan builds on existing efforts in the basin by the following entities:
− *North St. Lucie River WCD.*
− *Port St. Lucie.*
− *SFWMD.*
− *St. Lucie County.*
− *St. Lucie West Services District.*
− *U.S. Geological Survey (USGS).*

The stations included in the BMAP monitoring network are listed in **Table 26**. These stations are not specifically BMAP stations—i.e., they are designed for other purposes—but the data collected at these sites will be used to monitor the effectiveness of the BMAP. The water quality monitoring will be conducted in accordance with the frequencies below. The stations in the monitoring network are also shown in **Figure 7** through **Figure 9**.

Table 26: BMAP Monitoring Network

- = Empty cell/no data

Sampling Entity	Station ID	Station Name	Station Type	Frequency	Site Established
Hobe St. Lucie Conservancy District	Sample III	III	Grab	Annual	1974
Hobe St. Lucie Conservancy District	Sample 6	6	Grab	Annual	1974
Hobe St. Lucie Conservancy District	Sample 7	7	Grab	Annual	1974
Hobe St. Lucie Conservancy District	Sample 8	8	Grab	Annual	1974
North St. Lucie River WCD	1	Structure 23-1 Sager and Oleander	Grab	Quarterly	01/2011
North St. Lucie River WCD	2	North Fork St. Lucie River at Midway Road – White City Park pier	Grab	Quarterly	01/2011
North St. Lucie River WCD	3	Five Mile Creek at Edwards Road –Bridge at Kirby Loop Road	Grab	Quarterly	01/2011
North St. Lucie River WCD	6	South of Riser 40-1-2 NW corner Okeechobee Road and Kings Highway	Grab	Quarterly	01/2011
North St. Lucie River WCD	7	Structure 71-1-4 Ten Mile Creek & C-96 (bridge on Gordy Road)	Grab	Quarterly	01/2011
North St. Lucie River WCD	8	McCarty Road and Ten Mile Creek	Grab	Quarterly	01/2011
North St. Lucie River WCD	9	McCarty Road and Stetson Road	Grab	Quarterly	01/2011
Port St. Lucie	C-106	C-106	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	C-107	C-107	Grab	1 or 2 times/yr	06/2004
Port St. Lucie	C-108	C-108	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Sagamore WW	Sagamore WW	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Degan WW	Degan WW	Grab	1 or 2 times/yr	10/2004
Port St. Lucie	D-14	D-14	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	D-21	D-21	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Elcam In	Elcam In	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Elcam Spillway	Elcam Spillway	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Kingsway WW	Kingsway WW	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	A23	A23	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	A24	A24	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	A25	A25	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Burrow	Burrow	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	E8	E8	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Monterrey WW	Monterrey WW	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	U16-D016	U16-D016	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	H-16	H-16	Grab	1 or 2 times/yr	02/2004
Port St. Lucie	Blackwell Pump Station	Blackwell Pump Station	Grab	1 or 2 times/yr	02/2004

Sampling Entity	Station ID	Station Name	Station Type	Frequency	Site Established
Port St. Lucie	B-33	B-33	Grab	1 or 2 times/yr	03/2005
Port St. Lucie	B-95-3	B-95-3	Grab	1 or 2 times/yr	03/2005
SFWMD	C23S48	WQM	Grab	Weekly	01/1979
SFWMD	C23S48	WQM	Autosampler	Weekly	10/1996
SFWMD	C24S49	WQM	Grab	Weekly	01/1979
SFWMD	C24S49	WQM	Autosampler	Weekly	09/1997
SFWMD	C44S80	WQM	Grab	Weekly	01/1979
SFWMD	C44S80	WQM	Autosampler	Weekly	04/1999
SFWMD	G81	WQM	Grab	Biweekly	07/2012
SFWMD	GORDYRD	WQM	Grab	Weekly	08/1999
SFWMD	GORDYRD	WQM	Autosampler	Weekly	08/1999
SFWMD	SLT-1	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-10A	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-10B	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-11	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-17	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-19	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-21	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-22A	SLT	Grab	Biweekly	05/2012
SFWMD	SLT-26	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-29	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-2A	SLT	Grab	Biweekly	05/2013
SFWMD	SLT-3	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-30A	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-31	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-34A	SLT	Grab	Biweekly	05/2007
SFWMD	SLT-35	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-36	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-37A	SLT	Grab	Biweekly	01/2003
SFWMD	SLT-38	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-38A	SLT	Grab	Biweekly	05/2012
SFWMD	SLT-39	SLT	Grab	Biweekly	02/2003
SFWMD	SLT-4	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-40	SLT	Grab	Biweekly	01/2003
SFWMD	SLT-40A	SLT	Grab	Biweekly	05/2012
SFWMD	SLT-42B	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-44	SLT	Grab	Biweekly	05/2007
SFWMD	SLT-45	SLT	Grab	Biweekly	05/2013
SFWMD	SLT-5	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-6	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-7	SLT	Grab	Biweekly	11/2001
SFWMD	SLT-9	SLT	Grab	Biweekly	11/2001

Sampling Entity	Station ID	Station Name	Station Type	Frequency	Site Established
SFWMD	HR1	SE	Grab	Monthly	06/1994
SFWMD	SE 01	SE	Grab	Monthly	10/1990
SFWMD	SE 02	SE	Grab	Monthly	10/1990
SFWMD	SE 03	SE	Grab	Monthly	10/1990
SFWMD	SE 08B	SE	Grab	Monthly	12/2003
SFWMD	SE 09	SE	Grab	Monthly	10/1990
SFWMD	SE 11	SE	Grab	Monthly	06/1997
SFWMD	SE06B	SE	Grab	Monthly	10/1990
SFWMD	SE12B	SE	Grab	Monthly	07/2003
SFWMD	SE13B	SE	Grab	Monthly	07/2003
St. Lucie County	Platt's Creek Influent	Platt's Creek Influent	Grab	Triweekly	01/2008
St. Lucie County	Platt's Creek Effluent	Platt's Creek Effluent	Grab	Triweekly	01/2008
St. Lucie County	Indian River Estates Influent	Indian River Estates Influent	Grab	Triweekly	03/2009
St. Lucie County	Indian River Estates Effluent	Indian River Estates Effluent	Grab	Triweekly	03/2009
St. Lucie West Services District	Gate 7	7B	Outfall structure	-	08/2011
St. Lucie West Services District	Gate 8	7A	Outfall structure	-	08/2011
St. Lucie West Services District	Gate 6	6B	Outfall structure	-	08/2011
St. Lucie West Services District	Gate 4	4E	Outfall structure	-	08/2011
St. Lucie West Services District	Gate 3	3B	Outfall structure	-	08/2011
St. Lucie West Services District	Gate 2	2C	Outfall structure	-	08/2011
St. Lucie West Services District	Gate 1	1E	Outfall structure	-	08/2011
St. Lucie West Services District	Gate 5	5	Outfall structure	-	08/2011
USGS	2277100	St Lucie River at Speedy Point, Stuart, FL	Flow gage	Daily	08/1997
USGS	2277110	St Lucie River at A1A (Steele Point), Stuart, FL	Flow gage	Daily	08/1997
USGS	2276870	St Lucie Canal at Lake Okeechobee	Flow gage	Daily	03/1941
USGS	272524080221800	Five Mile Canal above S-29-1-4 near Ft Pierce	Flow gage	Daily	12/2002

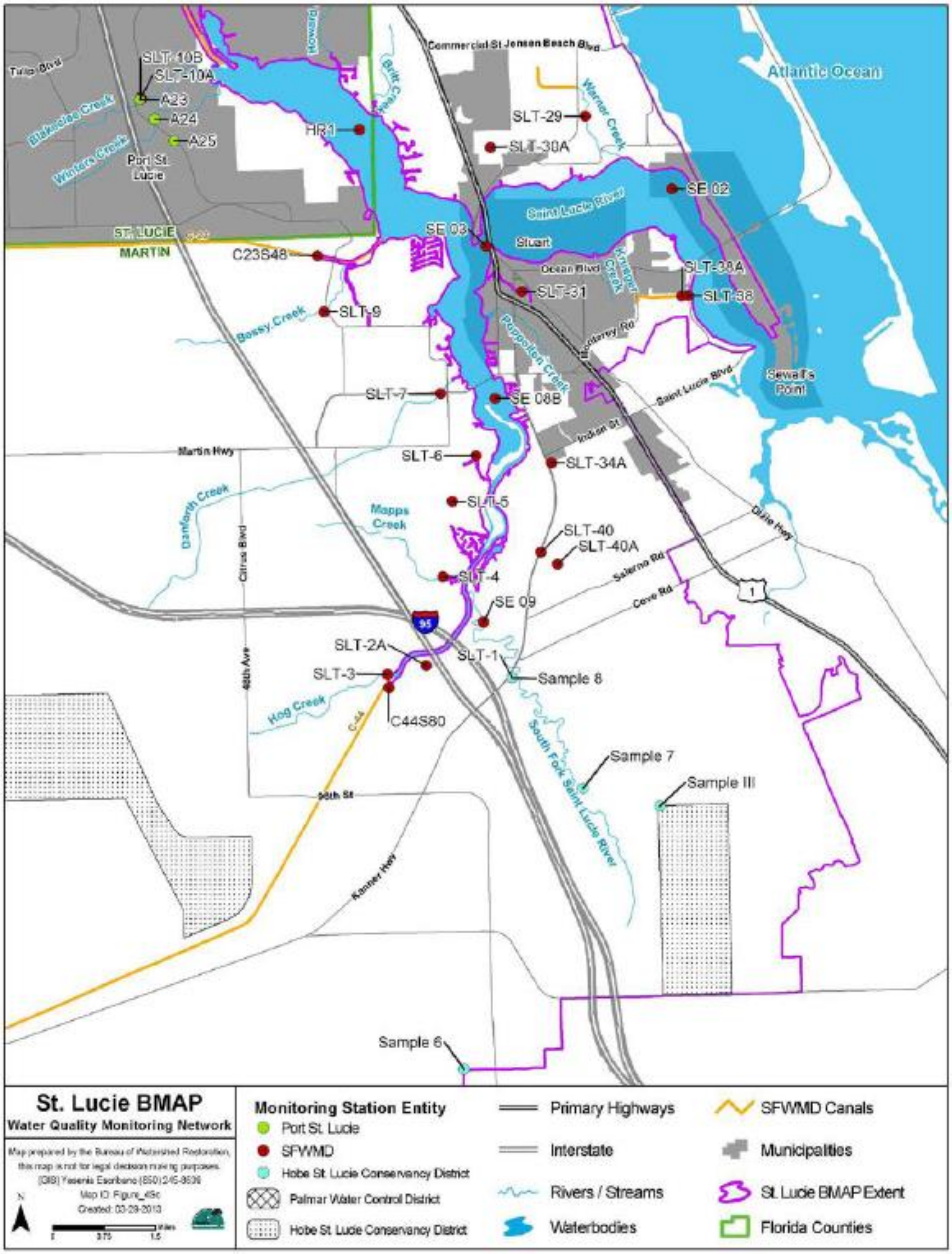

FIGURE 7: WATER QUALITY MONITORING NETWORK FOR THE SOUTHERN PART OF THE ST. LUCIE RIVER AND ESTUARY

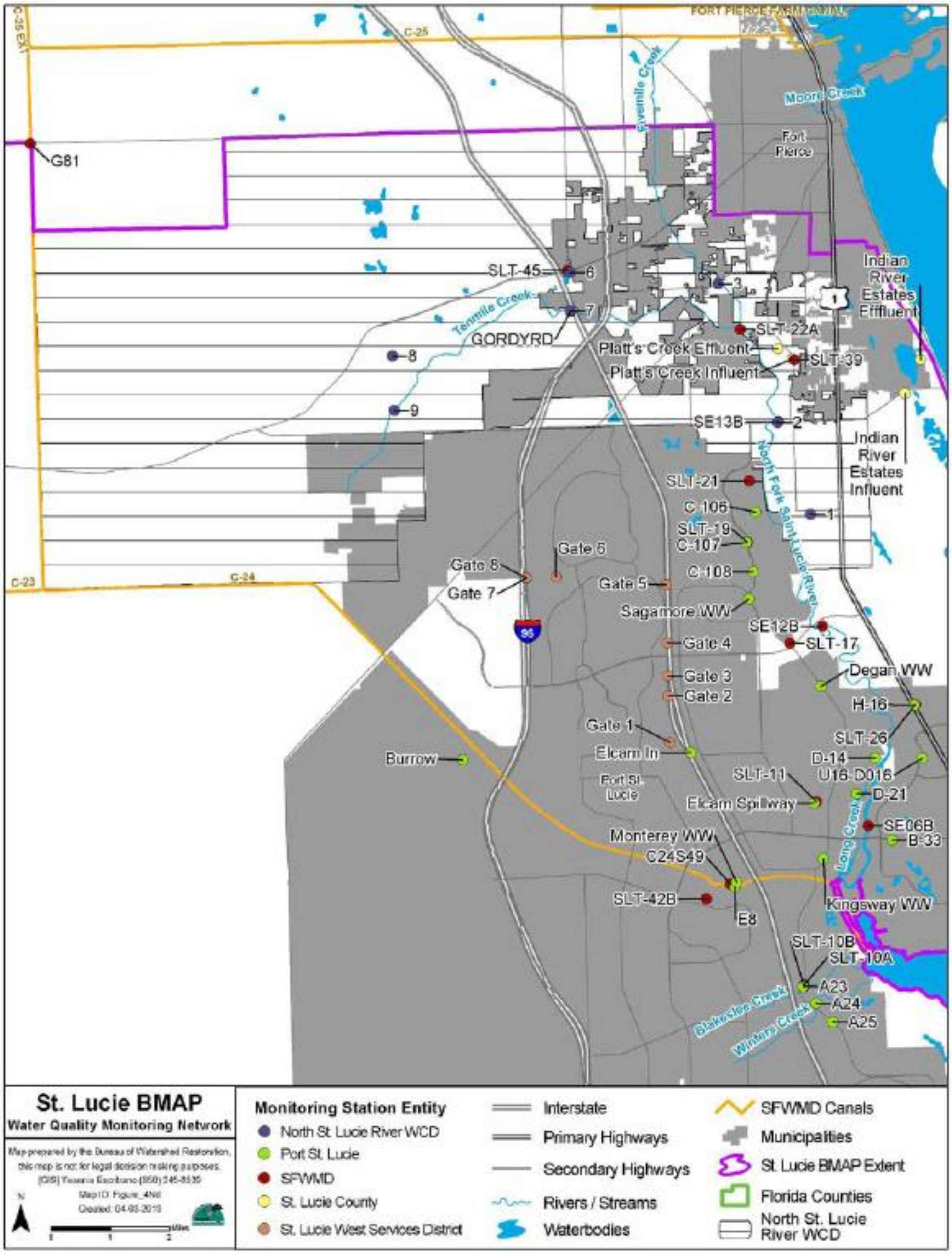

FIGURE 8: WATER QUALITY MONITORING NETWORK FOR THE NORTHERN PART OF THE ST. LUCIE RIVER AND ESTUARY

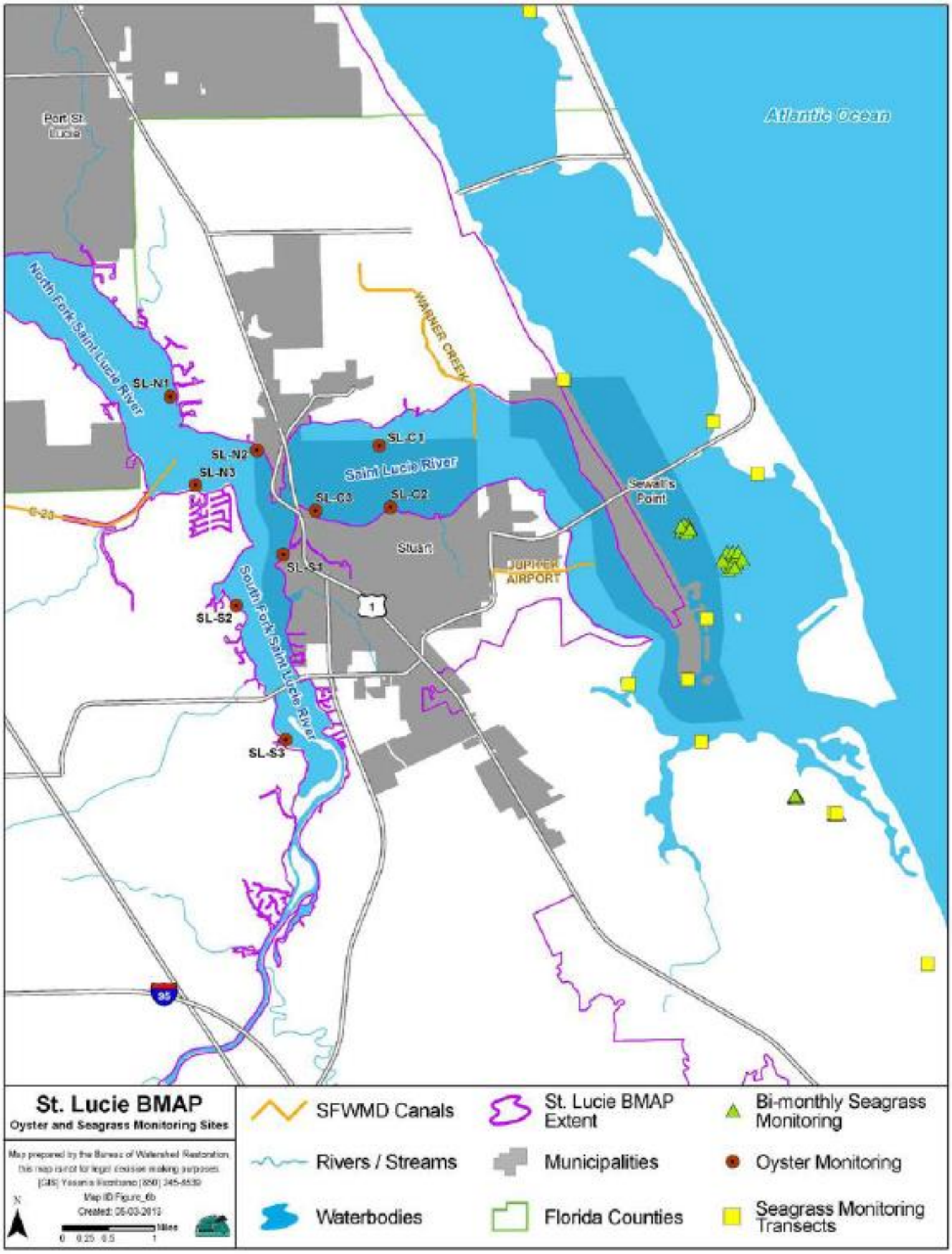

FIGURE 9: FLOW MONITORING NETWORK FOR THE ST. LUCIE RIVER AND ESTUARY

6.3.3 BIOLOGICAL MONITORING

In addition to the water quality parameters, the biological monitoring to assess the overall health of the St. Lucie River and Estuary is conducted. This monitoring includes evaluation of seagrass and oysters, as summarized in **Table 27** and shown in **Figure 10**. These stations are not specifically BMAP stations—i.e., they are designed for other purposes—but the data collected at these sites will be used to monitor the effectiveness of the BMAP.

TABLE 27: BIOLOGICAL MONITORING

Sampling Entity	Project	Number of Stations	Location	Frequency	Project Start Date
SFWMD	Seagrass Monitoring and Mapping	20	Transects in all lagoon segments	Semiannually	1994
SFWMD	Seagrass Monitoring and Mapping	Lagoonwide maps	Entire lagoon from St. Lucie Estuary upstream to Roosevelt Bridge (US 1)	Every 2 to 5 years	1986
SFWMD	Seagrass Monitoring and Mapping	10	IRL-S	Bimonthly (3 sites near St. Lucie Estuary monitored monthly)	2008
SFWMD	Oyster Monitoring and Mapping	9	St. Lucie Estuary	Semiannually	2005

6.3.4 Data Management and Assessment

The Florida STORET database serves as the primary repository of ambient water quality data for the state of Florida. The Department pulls water quality data used for impaired water evaluations and TMDL development directly from the STORET database. Ambient water quality data collected as part of the BMAP will be uploaded into STORET for long-term storage and availability. The Department and some local stakeholders currently upload water quality data into STORET. All BMAP data providers, with the exception of the SFWMD, have agreed to upload ambient water quality data to STORET at least once every six months, upon completion of the appropriate quality assurance/quality control (QA/QC) checks. The SFWMD uploads its data to DBHYDRO, and the Department can access this database for any BMAP evaluations.

Other data, such as biological and storm event, may also be collected, but the STORET database is not equipped to store these types of data. Stakeholders agree to provide these data to other BMAP partners on request and when appropriate for inclusion in BMAP data analyses and adaptive management evaluations.

The water quality data will be analyzed after four years of BMAP implementation to determine trends in water quality. A wide variety of statistical methods is available for trend analyses. The selection of an appropriate data analysis method depends on the frequency, spatial distribution, and period of record available from existing data. Specific statistical analyses were not identified during BMAP development; however, commonly accepted methods of data analysis will be used that are consistent with the TMDL model.

6.3.5 QA/QC

Stakeholders participating in the monitoring plan must collect water quality data in a manner consistent with the Department's standard operating procedures (SOPs) for QA/QC. The most current version of these procedures can be downloaded from http://www.dep.state.fl.us/water/sas/sop/sops.htm. For BMAP-related data analyses, entities should use National Environmental Laboratory Accreditation Conference (NELAC) National Environmental Laboratory Accreditation Program (NELAP)–certified laboratories (http://www.dep.state.fl.us/labs/cgi-bin/aams/index.asp) or other labs that meet the certification and other requirements outlined in the SOPs.

Georgia

TMDL for Flat Creek, Fecal Coliform

2004, General Statements (Implementation Plan)

https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/TMDLIP_FlatCreek_0313000108_Y2004.pdf

VII. MONITORING PLAN

The purposes of monitoring are to obtain more data, to determine the sources of pollution, to describe baseline conditions, and to evaluate the effects of management and activities on water quality. Describe any sampling activities or other surveys - active, planned or proposed - and their intended purpose. Reference the development and submission of a Sample Quality and Assurance Plan (SQAP) if monitoring for delisting purposes.

Table 6. MONITORING PLAN

PARAMETER(S) TO BE MONITORED	ORGANIZATION	STATUS (CURRENT, PROPOSED, PLANNED)	TIME FRAME START	END	PURPOSE (If for delisting, date of SQAP submission)
Fecal Coliform	City of Gainesville	Current;			Gainesville's Environmental Services Monitoring Program
Fecal Coliform	GA DNR - USGS	Current;	01/01/03	12/31/03	GA Water Quality Reports (305)

TMDL for Tennessee River Basin, Fecal Coliform

2009, General Statements

https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/EPD_Final_Tennessee_Fecal_TMDL_2009.pdf

6.1 Monitoring

Water quality monitoring is conducted at a number of locations across the State each year. The GA EPD has adopted a basin approach to water quality management that divides Georgia's major river basins into five groups. This approach provides for additional sampling work to be focused on one of the five basin groups each year and offers a five-year planning and assessment cycle. The Tennessee, Coosa, and Tallapoosa River Basins will again receive focused monitoring in 2011.

The TMDL Implementation Plan will outline an appropriate water quality monitoring program for the listed streams in the Tennessee River Basin. The monitoring program will be developed to help identify the various fecal coliform sources. The monitoring program may be used to verify the 303(d) stream segment listings. This will be especially valuable for those segments where no data, old data, or spill data resulted in the listing.

TMDL for Suwannee River Basin, Fecal Coliform

2016, General Statements

https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/Suwannee%20Fecal%20Coliform%20TMDL%20Report%20%5B2016%5D.pdf

6.1 Monitoring

Water quality monitoring is conducted at a number of locations across the State each year. Sampling is conducted statewide by EPD personnel in Atlanta, Brunswick, Cartersville, and Tifton. Additional monitoring sites are added as necessary.

In the case where a watershed-based plan has been developed for a listed stream segment, an appropriate water quality monitoring program will be outlined. The monitoring program will be developed to help identify the various fecal coliform sources. The monitoring program may be used to verify the 303(d) stream segment listings. This will be especially valuable for those segments where limited data resulted in the listing.

[TMDL]

7.4 Monitoring

EPD encourages local governments and municipalities to develop water quality monitoring programs. These programs can help pinpoint various fecal coliform sources, as well as verify the 303(d) stream segment listings. This will be particularly valuable for those segments where listing was based on limited data. In addition, regularly scheduled sampling will determine if there has been some improvement in the water quality of the listed stream segments. EPD is available to assist in providing technical guidance regarding the preparation of monitoring plans and Sampling Quality Assurance Plans (SQAP).

[Initial IP]

TMDL for Altamaha River Basin, Sediment

2017, General Statements

https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/EPD_Final_Altamaha_Biota_Impacted_TMDL_2017.pdf

6.1 Monitoring

GA EPD had previously adopted a basin approach to water quality management; an approach that divides Georgia's major river basins into five groups. This approach provides for additional sampling work to be focused on one of the five basin groups each year and offers a five-year planning and assessment cycle. GA EPD is in the process of reevaluating the effectiveness of the basin monitoring approach and comparing it to a more thorough statewide annual monitoring program. Currently, all river basins within the state are receiving some water quality monitoring each year. The locations include both previously assessed and unassessed waters.

[TMDL]

7.4 Monitoring

Monitoring of sediment through the measurement of total settable solids or TSS may be carried out through GA EPD's Adopt-A-Stream program. Additional opportunities for monitoring aquatic habitat through macro-invertebrate assessments may be available in the future. If it is determined through stakeholder involvement that either of these types of monitoring should take place, GA EPD will work with the entity that assumes responsibility for monitoring activities by providing the necessary training and taking the needed steps to establish a well-organized monitoring program.

[Implementation Plan]

Idaho

TMDL for Boise-Mores Creek Watershed Subbasin, Temperature/Unknown

2009, Specific but Brief

https://www2.deq.idaho.gov/admin/LEIA/api/document/download/11711

Monitoring Strategy

Sediment monitoring will be conducted using the DEQ-approved monitoring procedure at the time of sampling. It is optimal to revisit specific locations included in this subbasin assessment for stream bank erosion and depth fine measurements in order to measure change at each site. New sites may need to be added to fill data gaps or include representative reaches of each stream type and/or AU to account for variation throughout the watershed. It may be useful to collect bedload sediment data for trend analysis. Computer modeling of sediment load incorporates the entire watershed to account for sources outside of, but not necessarily contributing to, impaired AUs.

As indicated above, shade can be measured with a solar pathfinder at any time throughout the spring and summer on any stretch of creek to see if shade is increasing. After a period of ten years or more, aerial photo interpretation can be done to analyze solar loading to the entire stream as it was done for this TMDL. It is anticipated that as the riparian community develops, shade will increase and loadings will decrease toward PNV levels.

TMDL for Lower Salmon River & Hells Canyon Tributaries, Multiple Pollutants

2010, Specific but Brief

https://www2.deq.idaho.gov/admin/LEIA/api/document/download/12037

Monitoring Strategy

Idaho Code 39-3611 requires the Department of Environmental Quality to review and evaluate each Idaho TMDL, supporting assessment, implementation plan, and all available data periodically, at intervals no greater than five years. Such reviews are to be conducted using the Beneficial Use Reconnaissance Program protocol and the Water Body Assessment Guidance methodology to determine beneficial use attainability and status, and whether state water quality standards are being achieved.

Permanent control points for water quality monitoring should be established at the mouths of the tributaries and at the assessment unit boundaries. These would be used for long term monitoring to assess trends in cumulative pollutant loading identified by this TMDL. Beneficial use support status monitoring and assessment will be conducted within each assessment unit of the watershed and evaluated using the Water Body Assessment Guidance for compliance with Idaho state water quality standards.

Idaho Code 39-3621 requires designated agencies, in cooperation with the appropriate land management agency, to ensure best management practices are monitored for their effect on water quality. The monitoring results should be presented to the Department of Environmental Quality on a schedule agreed to between the designated agency and the Department. The designated management agency should report the effectiveness of the measures or practices implemented to the Department in the form of load reductions applicable to the TMDL.

Pollutant load reductions gained by the application of pollutant controls and best management practices will be monitored by the Department of Environmental Quality through reports provided by designated management agencies. Information reported will be compiled and tracked over time to determine measurable pollutant load reductions relative to the total maximum daily load allocations.

TMDL for American Falls Subbasin, Assessment and Loading Analysis

2012, Specific but Brief
https://www2.deq.idaho.gov/admin/LEIA/api/document/download/12942

5.3.4. Monitoring Strategy

DEQ will monitor BMP implementation through annual reports submitted as part of any implementation program. Due to constraints of money, time, and personnel, DEQ does not expect to directly monitor BMP effectiveness. Funding agencies should include monitoring as part of project funding requests. Tributary monitoring at the affected streams' confluences would help determine watershed BMP effectiveness.

DEQ is responsible for monitoring both mainstem and tributaries for compliance with TMDL allocations and progress toward supporting beneficial uses. The Beneficial Use Reconnaissance Program monitoring will help determine support of beneficial uses for cold water aquatic life, salmonid spawning, and contact recreation. Ambient water quality monitoring will be dependent on money, time, and personnel available to DEQ. Point sources will be monitored through their Discharge Monitoring Reports submitted monthly to DEQ.

TMDL for American Falls Subbasin, Implementation Plan for Agriculture

2014, Specific but Brief
https://www2.deq.idaho.gov/admin/LEIA/api/document/download/12943

Monitoring and Evaluation

Field Level

BMP effectiveness monitoring is part of the conservation planning process. The monitoring is conducted to determine how the BMP is installed, operated and maintained. Conservation planning establishes a benchmark for the resource concerns using several methods. The resources are inventoried and their condition is assessed with tools including but not limited to the following. RUSLE II and SISL are models used to predict sheet and rill erosion on non-irrigated and irrigated lands. The Alutin method, Imhoff Cones and direct volume measurements are used to measure sheet and rill, irrigation-induced and gully erosion. SVAP version 2 and SECI are indexes that are used to assess aquatic habitat and stream bank erosion. Stream channel cross sections and stream bank profile measurements are done to determine stream bank erosion and lateral recession rates. CAFO/AFO assessment is used to document problems with livestock feeding and waste storage areas.

After BMPs are installed, these same methods are applied to determine the effectiveness of the practice and the associated pollutant reduction. BMP effectiveness monitoring and field evaluations may be conducted by ISWCC and ISDA personnel. BMP effectiveness monitoring typically consists of a visual inspection and participant record keeping.

Watershed Level

The Idaho Department of Environmental Quality uses the Beneficial Use Reconnaissance Protocol (BURP) to collect and measure key water quality variables that aid in determining the beneficial use support status of Idaho's water bodies. In addition, DEQ conducts five-year TMDL reviews to update implementation and monitoring efforts.

Illinois

TMDL for Canton Lake Watershed, Phosphorus

2017, Specific and Detailed
https://www2.illinois.gov/epa/Documents/iepa/water-quality/watershed-management/tmdls/reports/canton-lake/final-tmdl-report.pdf

9.4 Monitoring Plan

The purpose of the monitoring plan for Canton Lake is to assess the overall effectiveness of implementing the BMPs outlined in this chapter. This can be accomplished by the continued monitoring of Canton Lake and its tributaries. Continued monitoring of the inflow tributaries is critical for following total phosphorus loading to Canton Lake as BMP measures are implemented. As discussed in the stage one report, the ISWS established several stations along the tributaries to Canton Lake, which were monitored for discharge, total phosphorus, and total suspended solids. These constituents were monitored on a weekly basis at two base tributary stations, and biweekly at three supplemental stations, but only between March, 2012 and October, 2012. In addition, sampling was conducted during high flow storm events. These are the only data available with which to directly calculate total phosphorus loading to Canton Lake. Additional discharge and water quality sampling should be conducted at these stations as BMP measures are implemented to document their effectiveness. At a minimum, routine samples should be collected quarterly, and 2 or more high flow events should sampled per year.

Estimating the effectiveness of the BMPs implemented in the watershed could be accomplished by monitoring before and after the BMP is incorporated into the watershed. For example, additional monitoring could be conducted on specific structural systems such as sediment control basins or riparian buffers. Inflow and outflow measurements could be conducted to determine site-specific TP removal efficiency.

The IEPA should also continue to monitor water quality at their three stations within Canton Lake. This should include measurements total and dissolved phosphorus, dissolved oxygen, and chlorophyll a, especially between April and October at a frequency of at least every few weeks. Additionally, at the deeper mid-lake (RDD-2), and near dam stations (RDD-1), both near-surface and near bottom samples should be analyzed, and profiles of dissolved oxygen and temperature collected, since both historical data and modeling simulations indicate that anoxic conditions can develop within Canton Lake under favorable conditions at depths greater than about 12 feet. Anoxic conditions promote internal phosphorus generation, which can help fuel algal production even as BMP measures are implemented and thus could mask their effectiveness.

Tracking the implementation of BMPs through these monitoring efforts can be used to address the following goals:
• Determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints
• Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts
• Measure the extent of voluntary implementation efforts

• Support work-load and costing analysis for assistance or regulatory programs
• Determine the extent to which management measures are properly maintained and operated

TMDL for Waverly Lake, phosphorus

2017, Specific and Very Detailed
https://www2.illinois.gov/epa/Documents/iepa/water-quality/watershed-management/watershed-based-planning/2017/waverly-lake-plan.pdf

15.0 Water Quality Monitoring Strategy

The purpose of the monitoring strategy for the Waverly Lake watershed is to utilize existing monitoring data (existing IEPA stations) and continue to monitor the condition and health of the lake and watershed in a consistent and on-going manner. In addition, the strategy seeks to add three watershed monitoring stations to isolate inflows from major lake tributaries, as well as Woods Creek where stream monitoring data is absent; monitoring data is only available within the lake.

The strategy allows for evaluation of the overall health of the watershed and its changes through time. Another key purpose is to assess the effectiveness of plan implementation projects, and their cumulative watershed-scale contribution towards achieving the goals and objectives of the plan. While programmatic monitoring tracks progress through achievement of actions, this section outlines a strategy to directly monitor the effectiveness of the actions.

Monitoring environmental criteria, as outlined in this strategy, is an effective way to measure progress toward meeting water quality objectives. One potential problem with in-stream indicators is the issue of isolating dependent variables. There are likely many variables influencing the monitoring results, so making conclusions with regard to one specific constituent should be done with caution. It should be noted, however, that the indicators are excellent for assessing overall changes in a watershed's condition.

Three IEPA monitoring stations exist within Waverly Lake (Table 51 and Figure 54). One additional site on Woods Creek and one on each of the two major tributaries noted in Figure 54 are also proposed to evaluate watershed and stream conditions and establish a baseline. Given the historical data currently available, it is recommended that monitoring continue at existing lake sites, ideally, under direction from the IEPA. The proposed monitoring categories and associated recommendations are summarized in Table 52. Monitoring activities should be coordinated with the IEPA and additional resources should be sought, such as the RiverWatch program through the National Great Rivers Research and Education Center (NGRREC) or through volunteers, as needed. Physical and biological data should be collected at the Woods Creek monitoring site to augment water quality information, since no biological data exists.

Due to the uncertainty in securing resources for edge-of-field monitoring to measure the effectiveness of BMPs, it is recommended that a more detailed monitoring plan be developed alongside future implementation actions, if funding permits.

Table 51 - Existing & Proposed Monitoring Sites & Description

Station ID	Site Description	Notes
SDC-1	Waverly Lake near dam	Existing IEPA monitoring site
SDC-2	Waverly Lake, approximately 1,700 ft North of dam	Existing IEPA monitoring site
SDC-3	Waverly Lake, approximately 275 ft North of boat launch on West side of lake	Existing IEPA monitoring site
ST-1	Woods Creek, approximately 1,100 ft upstream of Clevenger Rd	New monitoring site on Woods Creek
ST-2	Unnamed Tributary, approximately 100 ft upstream of Clevenger Rd	New tributary monitoring site
ST-3	Unnamed Tributary, approximately 1,700 ft West of N Lyons Rd	New tributary monitoring site

Table 52 - Summary of Monitoring Categories & Recommendations

Monitoring Category	Summary of Recommendations
Stream flow	Measure stream flow during every sample event, if conditions permit.
Ambient water quality	Utilize IEPA and local volunteers or City staff to execute regular monitoring for water quality at all stream and lake sites.
Physical & biologic assessment	Develop and execute stream monitoring for fish, macroinvertebrates, habitat, and channel morphology on Woods Creek.
BMP effectiveness	Monitor BMP effectiveness of specific practices or cluster of practices. Develop a detailed monitoring plan in combination with implementation activities.
Storm event runoff monitoring	Conduct monitoring during storm event at each stream site.
Trends in water quality	Establish baseline conditions for stream sites. Monitor/track changes and trends in lake water quality; continue to evaluate lake water quality parameters as IEPA data becomes available.

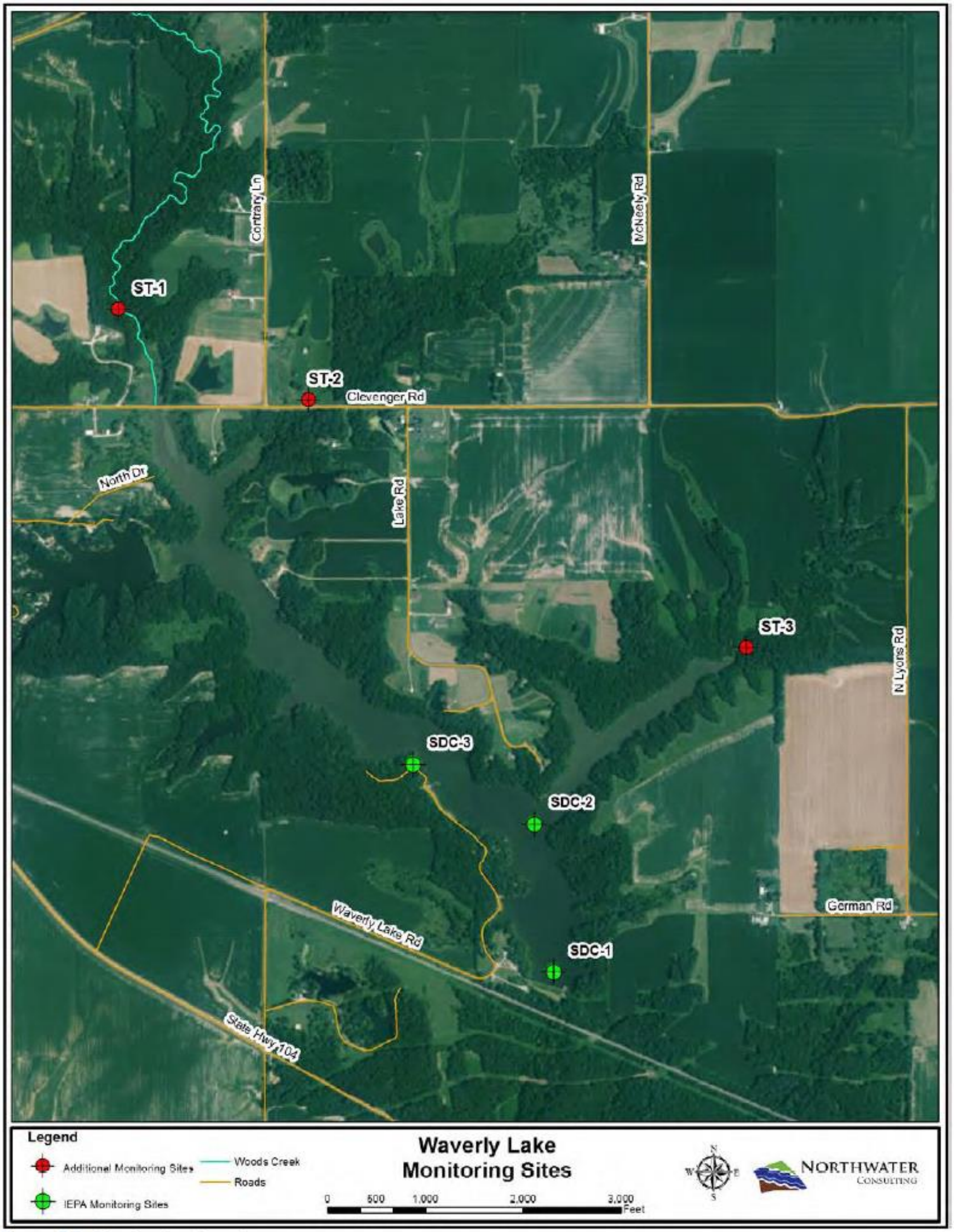

Figure 54 - Monitoring Locations

15.1 Water Quality Monitoring

Seasonal or monthly and storm-event water quality monitoring should be considered for all three additional stream monitoring stations in the watershed (Figure 54). Efforts should focus initially on collecting base-flow and storm-event data, followed by a regular sampling program. Regular monitoring should occur at a minimum of three times per year to capture seasonal variations in water quality; conduct storm event monitoring to supplement results. Monthly monitoring is preferred, if funding permits.

Table 53 includes the minimum parameters that should be considered for monitoring. Quantitative benchmarks that indicate impairment conditions are also illustrated in this table. The establishment of baseline conditions is important in order to evaluate trends and changes in water quality over time through implementation. Parameters, such as total phosphorus, total suspended sediment, and total nitrogen, should be analyzed considering flow volumes in order to make relative comparisons year to year, as concentrations of pollutants vary with flow volumes. The water quality monitoring results may also be used to calibrate the nonpoint source pollution load model and make revised annual loading estimates throughout implementation.

Table 53 - Baseline Water Quality Analysis Parameters

Analyte	Benchmark Indicators
Total Phosphorus	Less than 0.05 mg/l (IL standard)
Total Nitrogen	Less than 10 mg/L (based on IL Nitrate standard)
Total Suspended Sediment (TSS)	Less than 15 mg/L (based on AQI max value)
Turbidity	Less than 14 NTU (IL Lake Assessment Criteria)
Dissolved Oxygen	No less than 6.0 mg/l (IEPA standards)
Temperature	Less than 90° F (IEPA standards)
pH	Between 6.5 – 9.0 (IEPA standards)
Flow	--

15.2 Stream Bioassessment

Aquatic stream monitoring should be considered annually or at the maximum of 3- to 5-year increments. One station on Woods Creek is recommended. Table 54 shows the typical stream bioassessment techniques that can be applied to the monitoring program.

Table 54 - Stream Bioassessment Metrics

Monitoring	Definition	Benchmark Indicators
Fish Index of Biologic Integrity (fIBI)[1]	Index based on presence and populations of non-native and native fish species and their tolerance to degraded stream conditions.	**No Impairment** ($\geq$41) – good resource quality and fully supporting aquatic life **Moderate Impairment** (<41 and >20) – fair resource quality and not supporting aquatic life **Severe Impairment** ($\leq$20) – poor resource quality and not supporting aquatic life
Macroinvertebrate Index of Biologic	Index indicative of stream quality based on the macroinvertebrate species and populations.	**No Impairment** ($\geq$41.8) – good resource quality and fully supporting aquatic life

Monitoring	Definition	Benchmark Indicators
Integrity (mIBI)[1]		**Moderate Impairment** (<41.8 and >20.9) – fair resource quality and not supporting aquatic life **Severe Impairment** ($\leq$20.9) – poor resource quality and not supporting aquatic life
Qualitative Habitat Evaluation Index (QHEI)[2]	Index indicative of habitat quality that incorporates substrate, in-stream cover, channel morphology, riparian zone, bank erosion and riffle/pool condition.	**Excellent** (>70) **Good** (55-69) **Fair** (43-54) **Poor** (30-42) **Very Poor** (<30)
Channel Morphology	Establish fixed cross-section and longitudinal profile of channel along a 1,500-foot-long fixed reach. Monitor regularly to assess changes in channel.	Entrenchment ratio Width/depth ratio bankfull Bed material Cross-sectional area Water slope

1 – From: IEPA Illinois Integrated Water Quality Report and Section 303(d) List, 2016; Guidelines for using Biological Information
2 – From: State of Ohio Environmental Protection Agency Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)

Upper Fox River - Chain O' Lakes Watershed TMDL, Phosphorus and Fecal Coliform

2020, General Statements
https://www2.illinois.gov/epa/topics/water-quality/watershed-management/tmdls/Documents/Upper%20Fox%20River-Chain%20O%27%20Lakes%20TMDL_Approved%20Final%20Report_062320.pdf

3.11.2 Monitoring Plan

The purpose of the monitoring plan for the Upper Fox River/Chain O'Lakes watershed is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the monitoring programs designed to:

- Track implementation of BMPs in the watershed by quantifying executed BMPs, such as linear feet of bank stabilization, acres of porous pavement, number of restored wetlands, etc.
- Estimate effectiveness of BMPs by monitoring pollutant-load reductions downgradient of BMPs.
- Further monitor point source discharges in the watershed throughout the duration of the permit to ensure the facilities remain in compliance.
- Continued monitoring of impaired stream segments and tributaries by Illinois EPA, Lake County Health Department, and/or other entities.
- Monitoring of storm-based high flow events by IEPA or volunteer organizations.
- Low flow monitoring of total phosphorus, DO, TSS, and fecal coliform in impaired streams and lakes

Tracking the implementation of management measures can be used to:

- Determine the extent to which management measures and practices have been implemented compared to action needed to meet the TMDL endpoints
- Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts
- Measure the extent of voluntary implementation efforts
- Support work-load and costing analysis for assistance or regulatory programs
- Determine the extent to which management measures are properly maintained and operated

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems such as a sediment control basin. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency.

In addition to the ALMP discussed, Illinois EPA conducts Intensive Basin Surveys every 5 years. Additionally, select ambient sites are monitored nine times a year. The Lake County Health Department (LCHD) Lakes Management Unit monitors each lake in their purview on a regular and rotating basis and assessment reports are produced for each lake every two to nine years. Continuation of these monitoring programs will result in ongoing assessment of lake and stream.

Iowa

TMDL for Duck Creek, E. Coli

2011, Specific and Very Detailed
https://www.iowadnr.gov/Portals/idnr/uploads/water/watershed/tmdl/files/final/duck10tmdl.pdf?ver=2011-12-20-105922-747

6. Future Monitoring

Water quality monitoring is critical for assessing the status of water resources and historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of BMPs implemented in the watershed and document the status of the waterbody in terms of achieving Total Maximum Daily Loads (TMDLs).

Future monitoring in the Duck Creek watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (IDNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program that provides training to interested volunteers. This program is called IOWATER, and more information can be found at the program website: http://www.iowater.net/Default.htm.

It is important that volunteer-based monitoring efforts include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here: http://www.iowadnr.com/water/standards/files/chapter61.pdf. Failure to prepare an approved QAPP will prevent data from being used to assess a waterbody's status on the state's 303(d) list – the list that assesses waterbodies and their designated uses as impaired.

The Scott County Snapshot Data, collected by the Partners of Scott County Watersheds through the IOWATER program, is an example of successful volunteer-led collection of data. Future monitoring efforts such as this are encouraged, as is the collection of more detailed data such as event sampling and continuous monitoring as described in the following sections. Care should be taken to ensure that any future data collected by volunteers satisfies Iowa's Credible Data Law.

6.1. Monitoring Plan to Track TMDL Effectiveness

Given current resources and funding, future water quality data collection in the Duck Creek watershed to assess water quality trends and compliance with water quality standards (WQS) will be limited. Unless there is local interest in collecting additional water quality data, it will be difficult to implement a watershed management plan and document TMDL effectiveness and water quality improvement. At a minimum, the Scott County Snapshot data should continue to be collected. However, Snapshot data alone is likely not enough to meet the needs of local stakeholders whose goal is to significantly improve water quality in Duck Creek.

6.2. Idealized Plan for Future Watershed Projects

An idealized plan will include, at a minimum, weekly flow and water quality monitoring similar to monitoring conducted by UHL and the Partners of Scott County Watershed in 2008. This monitoring data was sufficient for development of load duration curves (LDCs), and enabled the development of TMDLs and investigation of bacteria loads under varying flow conditions. However, these data were not sufficient to answer many questions about the exact nature of bacteria loads. Additional weekly flow and bacteria sampling will allow for development of more robust LDCs, and will help track changes in water quality as BMPs are implemented from year to year. More detailed monitoring data will be required to develop a successful watershed management plan and document water quality improvement. An “idealized” monitoring plan is outlined in Table 6-1. It is only through the interest and action of local stakeholders that funding and resources needed to acquire this data will become available.

The monitoring plan components in Table 6-1 are prioritized, with the highest priority data listed first. Data obtained through this idealized monitoring plan would better document the specific sources of existing bacteria loads and significantly reduce the level of uncertainty associated with load estimation and water quality trend analysis.

Table 6-1. Idealized monitoring plan for Duck Creek watershed.

Parameter(s)	Sampling Interval	Sampling Duration	Location(s)
E. coli and flow	Weekly snapshot	Throughout recreation season (ongoing)	DC-16, DC-10, DC-12, PC-2, GC-4, SC-1A, and [1] UC-1
[2] Microbial source tracking (MST)	Snapshot	At least two sampling events within recreation season. Consider one during high flow and one during low flow.	DC-16, DC-12, selected tributaries and/or stormwater outfalls
E. coli and flow (event sampling)	15-60 minutes	Throughout rising and falling limbs of hydrograph during at least two runoff events within recreation season.	DC-16, DC-12, selected tributaries, tile drains, and stormwater outfalls
E. coli and flow (dry weather sampling)	Snapshot	At least twice during low flow conditions within recreation season.	Selected stormwater outfalls in Davenport and Bettendorf
Biological monitoring (FIBI and BMIBI)	Snapshot	At least once during dry weather within recreation season.	DC-16 and DC-10 or DC-12

[1] UC-1 is a new location near the outlet of Unnamed Creek (1) as described in the 2008 UAA. This segment is designated as secondary contact recreation (Class A2). However, it drains to a Class A3 segment of Duck Creek and would likely need to meet A3 criteria. Existing water quality in this reach should be assessed, and ultimately, a TMDL may be required.

[2] There are several different types of MST. Selection should be researched and based on feasibility, cost, and advantage/disadvantages of each method. If budget does not allow for true MST methods, fluorometry or caffeine detection could be utilized in conjunction with *E. coli* sampling to document human sources of wastewater.

There are several different types of microbial source tracking (MST) methods, but all have a similar objective – to match microbes present in a waterbody to microbes from specific animal sources. Using information derived from MST, water quality decision makers would better understand the importance of different bacteria sources and select/design effective strategies to reduce bacteria in the stream. The source inventories developed using the SWAT model are useful for these purposes, but are approximations and have high degrees of uncertainty. MST would help determine the impact that distinct sources, such as humans, hogs, cattle, pets, deer, waterfowl, and other wildlife might have on water quality. If MST is not affordable or feasible, the use of a fluorometer to detect the presence of detergents and/or sampling for caffeine may be substituted. Detection of detergents or caffeine would indicate the presence of human bacteria sources. Fluorometry and caffeine analysis may not be useful in subbasins where WWTFs or private onsite wastewater treatment systems are located, because residual amounts of caffeine and/or detergents would be expected.

Event sampling for *E. coli* and flow at 15 to 60 minute intervals using an ISCO or other automated sampling device will help evaluate the distribution of bacteria loads throughout a storm. This will assist stakeholders in the selection and design of BMPs by revealing the relative importance of loads contributed to the stream by the first flush, the peak of the storm, and the hours shortly after the storm peak. Additionally, event sampling will help quantify loads associated with a particular size/frequency of runoff event.

Dry weather sampling should be conducted to evaluate the possibility of illicit sanitary sewer connections to the storm sewer system. If sustained flows with high bacteria concentrations are observed during extremely dry periods, it is likely that illicit connections may be present. Use of MST, fluorometry, or caffeine analysis in conjunction with dry weather flow sampling may be desirable.

Some of the features of Duck Creek suggest that it may be impaired by other pollutants in addition to bacteria. The stream is extensively channelized, and in some reaches significant incision can be observed. Urban streams often lack the physical, chemical, and biological qualities needed to support a diverse array of aquatic organisms. Biological monitoring to assess the diversity and population of fish and invertebrate communities would indicate the presence or absence of a healthy ecosystem, and could lead to the detection of additional pollutants detrimental to water quality. If other pollutant levels are elevated, it would be most efficient and beneficial to address them in the development of a locally-led watershed management plan that typically follows a WQIP, rather than waiting for impacts to worsen. Biological monitoring would be a first step in helping to identify other potential pollutants in Duck Creek. However, it is unrelated to the existing impairment, and would not be eligible for 319 funding.

Figure 6-1 illustrates the primary water quality monitoring locations in the Duck Creek watershed listed in Table 6-1. A new monitoring location is recommended near the confluence of Unnamed Creek (1) and Duck Creek just downstream from site DC-16. This location is labeled UC-1. The Unnamed Creek (1) was designated for secondary contact (Class A2) recreation in the 2008 UAA. However, no water quality data was available for this reach for TMDL development. Flow and water quality data is needed at this location to establish a baseline and to allow for future development of a TMDL, if needed.

Monitoring plans should be continually evaluated. Adjustment of parameters, sampling intervals, and/or monitoring locations should be based on newly discovered or suspected pollutant sources, BMP placement/installation, and other dynamic factors. The IDNR Watershed Improvement Section can provide technical support to locally led efforts in collecting and analyzing further water quality and flow data in the Duck Creek watershed.

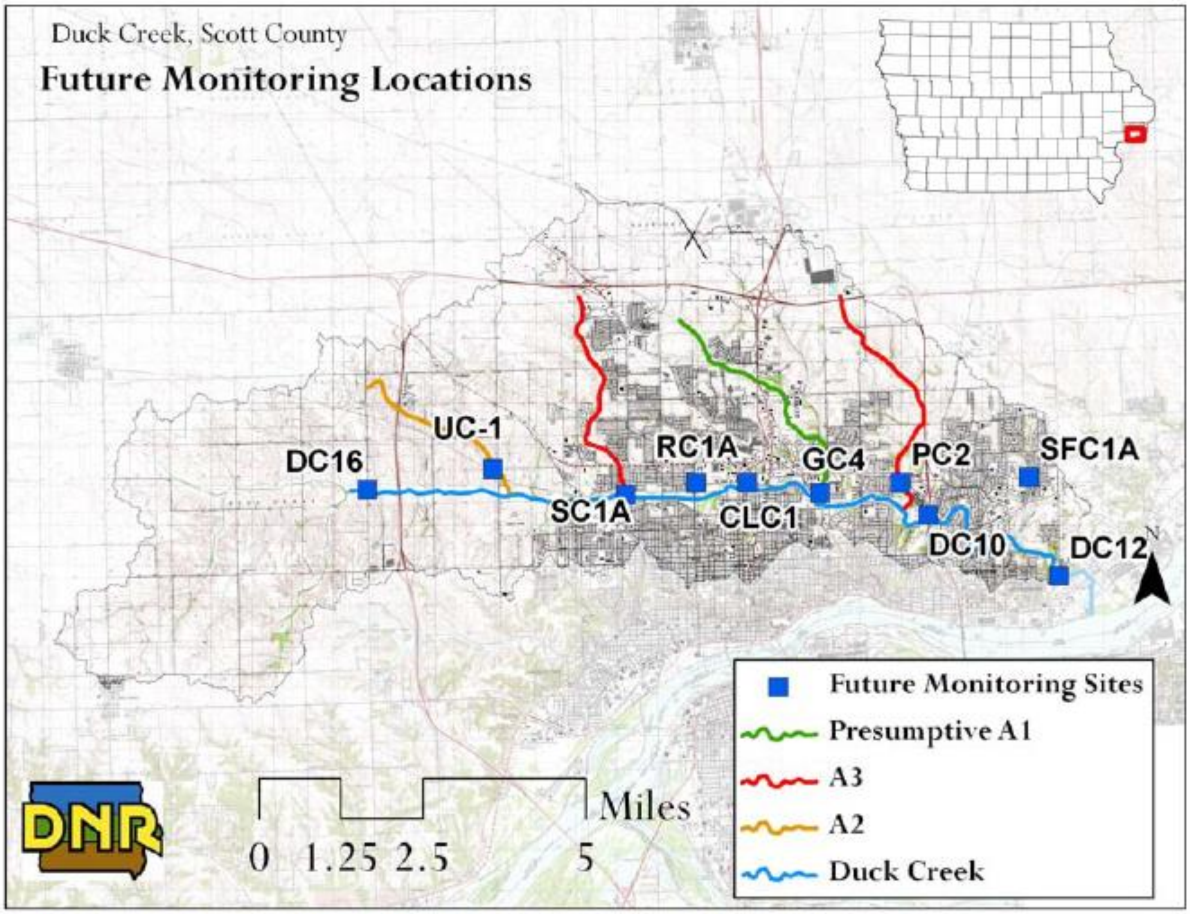

Figure 6-1. Recommended locations for future monitoring

TMDL for Little River Lake, Turbidity

2014, Specific and Very Detailed
https://www.iowadnr.gov/Portals/idnr/uploads/water/watershed/tmdl/files/final/littleriverlake.pdf?ver=2014-04-03-125520-813

5. Future Monitoring

Water quality monitoring is critical for assessing the current status of water resources as well as historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of best management practice (BMP) implementation and to document attainment of total maximum daily loads (TMDLs) and water quality standards (WQS).

Future monitoring in the Little River Lake watershed can be agency-led, volunteer-based, or both. The Iowa Department of Natural Resources (DNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program, called IOWATER, that provides training to interested volunteers. More information can be found at the program web site: http://www.iowater.net/Default.htm

Volunteer-based monitoring efforts should include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here: http://search.legis.state.ia.us/NXT/gateway.dll/ar/iac/5670___environmental%20protection%20commission%20__5b567__5d/0610___chapter%2061%20water%20quality%20standards/_c_5670_0610.xml?f=templates$fn=default.htm.

Failure to prepare an approved QAPP will prevent data collected from being used to evaluate waterbody in the 305(b) Integrated Report – the biannual assessment of water quality in the state, and the 303(d) list – the list that identifies impaired waterbodies.

5.1. Routine Monitoring for Water Quality Assessment

Data collection in Little River Lake to assess water quality trends and compliance with water quality standards (WQS) will include monitoring conducted as part of the DNR Ambient Lake Monitoring Program. This is the same source of data used to develop the TMDL. The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 137 of Iowa's lakes are being sampled as part of this program, including Little River Lake. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured.

Sampling parameters are reported in Table 5-1. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day. While the ambient monitoring program can be used to identify trends in lake water quality, it does not lend itself to calculation of watershed loads, identification of individual pollutant sources, or the evaluation of BMP implementation.

Table 5-1. Ambient Lake Monitoring Program water quality parameters.

Chemical	Physical	Biological
• Total Phosphorus (TP) • Soluble Reactive Phosphorus (SRP) • Total Nitrogen (TN) • Total Kjeldahl Nitrogen (TKN) • Ammonia • Un-ionized Ammonia • Nitrate + Nitrite Nitrogen • Alkalinity • pH • Silica • Total Organic Carbon • Total Dissolved Solids • Dissolved Organic Carbon	• Secchi Depth • Temperature • Dissolved Oxygen (DO) • Turbidity • Total Suspended Solids (TSS) • Total Fixed Suspended Solids • Total Volatile Suspended Solids • Specific Conductivity • Lake Depth • Thermocline Depth	• Chlorophyll a • Phytoplankton (mass and composition) • Zooplankton (mass and composition)

5.2. Other Planned Monitoring

As part of the existing watershed plan developed for the Little River Watershed Group by the Iowa Rural Water Association (IRWA), additional monitoring will be conducted annually "for as long as funds are available" (IRWA, 2010). Monitoring locations are illustrated in Figure 5-1, and include monthly grab samples at 3 tributary locations (#1, #2, and #3) and 3 in-lake locations (#4, #5, and #6). Some limited data has been collected at these sites since 2008. In addition to regularly-scheduled grab samples, the plan calls for collection of grab samples during 3 rainfall events each year. The plan does not include flow monitoring or collection of continuous data using automated samplers.

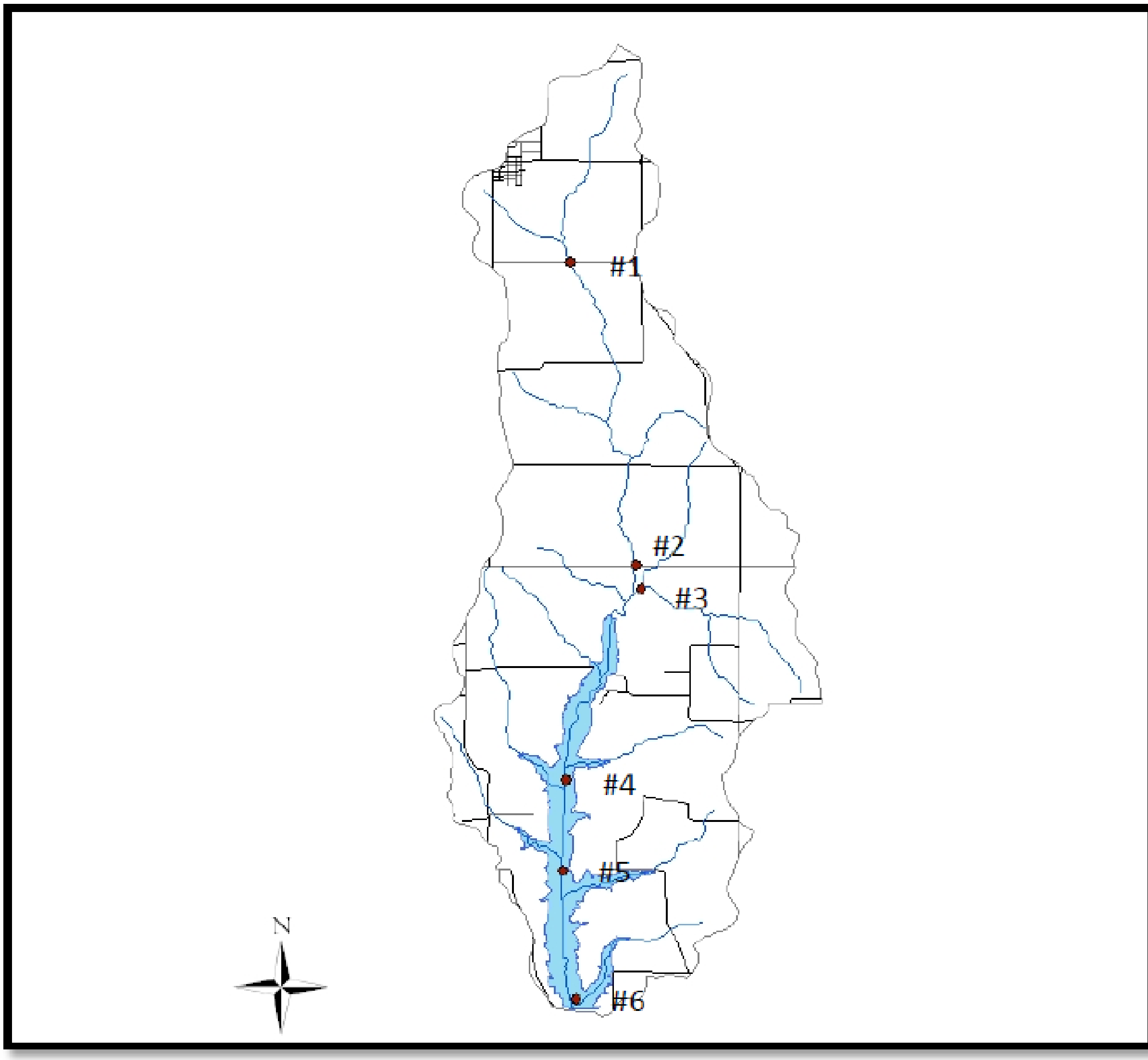

Figure 5-1. Monitoring locations in the existing watershed plan (IRWA, 2010).

Tributary monitoring outlined in the 2010 watershed plan will provide helpful anecdotal information, may reveal acute concerns (e.g., if nutrient spikes are detected), and should provide a good estimate of background water quality during low to normal flow conditions in the watershed. Monitoring at 3 in-lake locations may be helpful in detecting differences in water quality throughout the lake. However, at least 3 samples would be needed each growing season for at least four years, and the samples at all 3 locations must be collected on the same day. The in-lake data collection should be coordinated with the ambient monitoring program to avoid redundant sample collection and maximization of data. Several years of data at three locations in the lake (#4, #5, and #6 in Figure 5-1) could help determine the behavior (i.e., settling and dispersion) of sediment and phosphorus as water travels from the north end of the lake to the outlet. This may facilitate future modeling efforts and provide greater understanding of lake dynamics.

Even with several years of grab sample data collected as proposed in the 2010 plan, it may not be possible to detect changes in water quality, calculate phosphorus loads, or quantify reductions in loads resulting from implementation of BMPs. Samples will not be collected frequently enough, the total number of samples at each site will not be adequate for meaningful statistical analysis, and the lack of flow data makes calculation of pollutant loads impossible.

5.3. Expanded Monitoring for Detailed Analysis

If the goal of monitoring is to evaluate spatial and temporal trends and differences in water quality, then an expanded and more intensive monitoring program will be needed. Table 5-2 outlines potential parameters, required intervals (frequency), duration of data collection, and potential locations. It is unlikely that available funding will allow collection of all data included in Table 5-2, so the purpose/uses of each data type are also included to help stakeholders identify and prioritize data needs. Potential locations for each type of monitoring are illustrated in Figure 5-2.

Table 5-2. Expanded monitoring plan.

Parameter(s)	Intervals	Duration	[1]Locations	Purpose
Routine grab sampling: flow, sediment, P, and N	Every 1-4 weeks	Apr – Oct	1-3 Tributary Sites	Provides low to normal flow (i.e., background) concentrations.
Continuous: flow	15-60 minute	Apr – Oct	1-3 Tributary Sites, Lake Outlet	Model calibration and pollutant load calculation.
Runoff event: flow, sediment, P, and N	Continuous flow and event composite water quality	5-10 events between Apr – Oct	1-3 Tributary Sites	Model calibration and pollutant load calculation. Provides understanding of watershed dynamics.
[2]Depth-integrated sediment sampling	In conjunction with routine grab sampling and event sampling	Apr-Oct	1-3 Tributary Sites	Reveals sediment and phosphorus transport characteristics and correlations between TSS and actual sediment. May be necessary for accurate sediment and TP load calculation
In-lake grabs (ambient parameters)	Every 2 weeks	Apr-Oct	In-lake sites (e.g., LRL 4, LRL 6)	Increases statistical significance and increases spatial resolution.

[1]Final location of monitoring sites should be based BMP placement, landowner permission, access/installation feasibility, and available funding.
[2]Depth-integrated sampling should be conducted with runoff event sampling and with routine grab sampling. After several data points are collected, observed correlations between DI sediment and TSS may allow for reduced frequency of DI sampling.

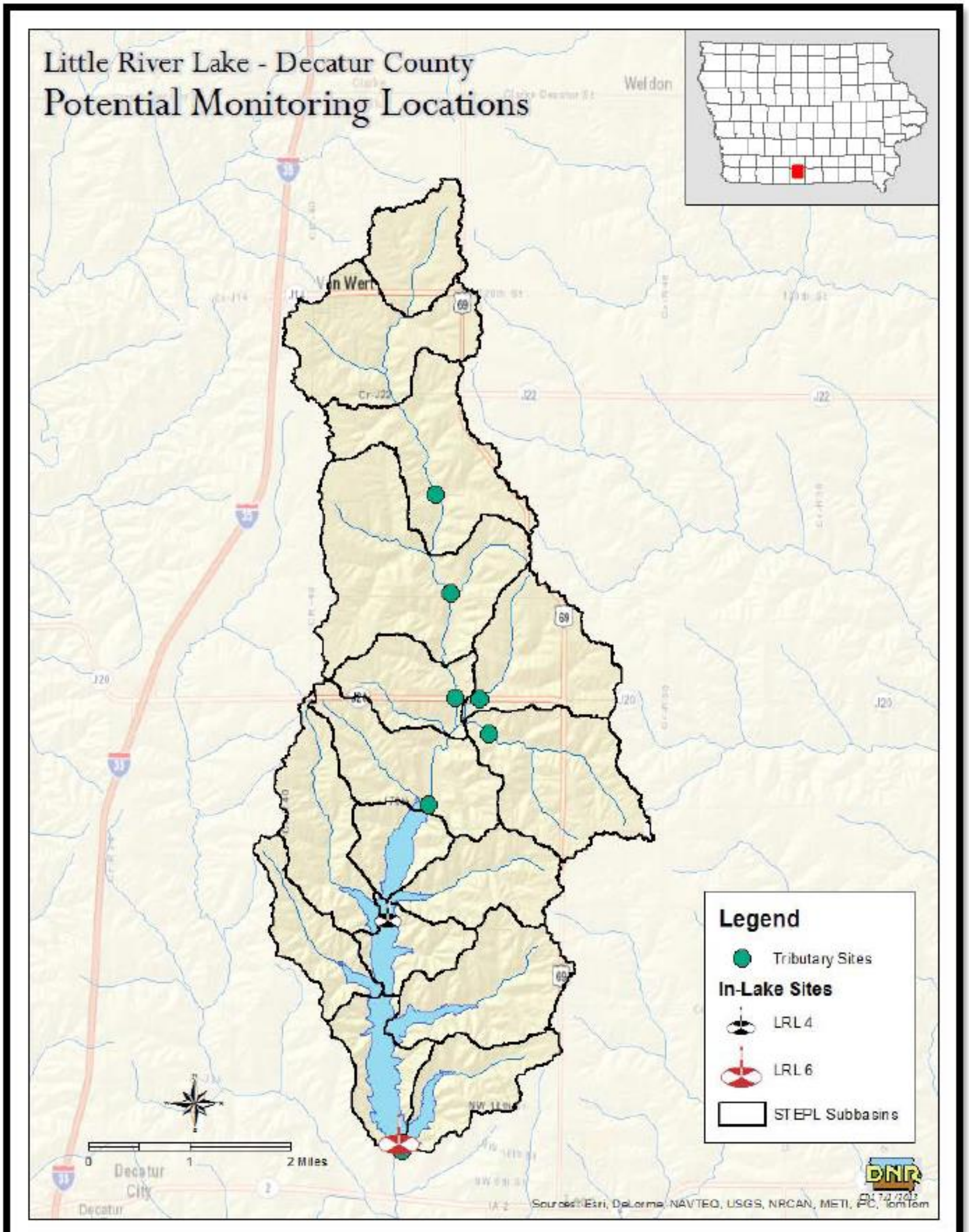

Figure 5-2. Potential monitoring locations.

This expanded monitoring information would improve statistical analysis for evaluating changes and/or trends in water quality over time. Additionally, more detailed data could be used to improve/develop watershed and water quality models for simulation of implementation scenarios and prediction of water quality response. Monitoring parameters and locations should be continually evaluated. Adjustment of parameters and/or locations should be based on BMP placement, newly discovered or suspected pollution sources, and other dynamic factors. The DNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Little River Lake watershed.

TMDL for Rathbun Lake, Turbidity

2017, Specific and Very Detailed
https://attains.epa.gov/attains-public/api/documents/actions/21IOWA/IA7001/138250

5. Future Monitoring

Monitoring is critical for assessing the current status of water quality as well as historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of best management practice (BMP) implementation and to document attainment of total maximum daily loads (TMDLs) and progress towards water quality standards (WQS).

Past monitoring efforts in the Rathbun Lake and its watershed are described in detail in Appendix C of this Water Quality Improvement Plan (WQIP). Future monitoring will depend on continued financial resources, commitment, and collaboration of local partners such as the Rathbun Land & Water Alliance (RLWA), the Iowa Department of Natural Resources (DNR), and the U.S. Army Corps of Engineers (USACE). Ideally, monitoring efforts should include an approved Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). Failure to prepare an approved QAPP will prevent data collected from being used to evaluate waterbody in the 305(b) Integrated Report – the biannual assessment of water quality in the state, and the 303(d) list – the list that identifies impaired waterbodies.

5.1. Basic Monitoring for Water Quality Assessment

Without continued support from local partners, future data collection in Rathbun Lake will likely be limited to in-lake grab samples at RA-7, RA-8, RA-3, and RA-25 (Figure 5-1). The DNR will continue to collect data at RA-3 as part of the ambient monitoring program, and USACE will continue to collect grab samples at the other three locations (barring unforeseen changes in funding / resources). These data will be utilized primarily to assess water quality trends in the lake, compliance / exceedance of water quality standards (WQS), and will be used for 303(d) listing and delisting purposes.

Sampling parameters will includes those listed in Tables C-11 through C-14 of Section C.4 and water column profile data illustrated in Figures C-3 through C-6 of Section C.5. The DNR ambient monitoring includes at least three sampling events every summer between Memorial Day and Labor Day. USACE in-lake data will be collected once a month from April through September. While the DNR and USACE in-lake grab sampling can be used to identify long-term trends in water quality, it does not lend itself to assessment of short-term trends or phenomena (such as resuspension or mixing), calculation of watershed loads, identification of individual pollutant sources, or the evaluation of BMP implementation.

5.2. Recommended Watershed Monitoring for Tracking Loads

If the goal of monitoring is to evaluate spatial and temporal trends in sediment and phosphorus exports to the lake from the watershed and the impacts of BMP implementation on water quality, continued watershed / tributary monitoring, in addition to basic in-lake monitoring, is recommended. Pre-TMDL monitoring included regularly-scheduled grab sampling and automated, event-based monitoring at four locations in the watershed: RA-15 on the Chariton River, RA-41 on Wolf Creek, RA-12 on the South Fork Chariton (at USGS gaging station 06903700), and RA-39 on Jackson Creek (Figure 5-1). Since 2014, event-based monitoring has continued at RA-12 and at the USGS gaging station 06903400 located immediately downstream of the confluence of Wolf Creek (RA-41) and the Chariton River (RA-15). Flow, event-based, and occasional grab sampling at RA-12 and RA-45 on an on-going basis will allow reasonable estimates of annual (and perhaps monthly) sediment and TP loads entering the lake from the watershed, and will allow watershed and lake managers to relate spatial and temporal trends in watershed loads to observed water quality in the lake. However, this recommended monitoring lacks the resolution necessary to quantify the impacts of watershed / water quality improvement practices implemented in priority areas (at either the subwatershed or field scale).

5.3. Potential Expanded Monitoring for Assessing Implementation

If the evaluation of spatial patterns of sediment and phosphorus transport and / or the impacts of BMP adoption on sediment and nutrient loss is desired, then an expanded watershed monitoring plan that includes higher resolution of data collection is recommended. This monitoring should include collection of flow, grab samples, and potentially event-based samples at smaller scales than past and present watershed monitoring. At a minimum, water quality parameters should include sediment and TP, but collection of dissolved phosphorus and nitrogen-related data may also be of interest to stakeholders, even though they are not causing the current impairments.

To assess the impact of BMP implementation in RLWA planning subbasins, the type of monitoring at RA-12 could be conducted at several small subwatershed outlets. Additionally, a paired watershed sampling approach could be taken that collects similar data at two locations: (i) the outlet of a subwatershed with relatively little implementation (i.e., the control subwatershed) and (ii) the outlet of a subwatershed with a high degree of implementation. Targeted monitoring of this nature would either provide confidence that implementation efforts are improving water quality, or supply evidence that practices are not having the desired effect and that implementation strategies need refinement / adaptation. If more information about the performance of individual practices is desired, edge-of-field scale monitoring could be conducted, as well as inflow / outflow monitoring of structural BMPs.

5.4. Potential Expanded Monitoring for Advanced In-Lake Assessment

Although the historical in-lake grab sampling is adequate for assessing long-term, average conditions in four areas of the lake, it cannot be utilized to explain the dynamic nature of water quality based on weather phenomena, seasonal trends, or internal processes (i.e., mixing, resuspension, and anoxia). To provide insight into the short-term behavior of the lake, more advanced in-lake monitoring would be necessary. This could include higher frequency of grab samples, deployment of continuous data loggers, and evaluation of the hypolimnion and sediment-water interface at the bottom of the lake.

To determine what type of additional data collect may be desired and warranted, lake and watershed stakeholders need to develop a list of goals and objective and ask themselves what current questions cannot be answered with existing information. Table 5-1 provides a summary of varies types of monitoring, listed in order of most basic to most complex / detailed (within each location).

Table 5-1. Potential monitoring and data collection.

Location / Scale	Type	Parameters	Purpose(s)
In-Lake	Monthly grab samples	Historical DNR and USACE parameters (Appendix C)	Detect in-lake WQ trends and evaluate impairment status.
	Weekly to biweekly grab samples throughout the year	Same as above	Evaluate short-term trends and potential impacts of weather events, seasons, etc. Potentially useful for more advanced in-lake modeling.
	Continuous data loggers	Temperature, DO, pH, and Chl-a	Evaluate the diurnal nature of algal blooms. Potentially useful for evaluation of internal/mixing dynamics. Potentially useful for more advanced in-lake modeling.
Watershed (vary spatial scale with needs / goals)	Monthly or semi-monthly grab samples	Flow, sediment, phosphorus[1]	Detect changes in baseflow concentrations. Helpful for development of load estimates.
	Runoff events with automated samplers [2]	Flow, sediment, phosphorus[1]	Essential for development of load estimates. Potentially useful for watershed model refinement.
Edge of Field	Runoff events with automated samplers	Flow, sediment, phosphorus[1]	Calculate pollutant loads and improvement after BMP implementation; especially useful in a paired field/catchment study.
BMP Inflow / Outflow	Grab samples or event samples	Flow, sediment, phosphorus[1]	Evaluate the pollutant removal associated with specific BMPs or BMP types.

[1] Sediment and TP are most relevant to current impairments. Other parameters (e.g., nitrogen, atrazine, etc.) could be added for developing baseline information for potential/future issues.
[2] Event-based sampling is more important for estimating sediment and TP loads, which cause the current impairments. Therefore, this should be given priority over grab samples.

Kansas

TMDL for Cheney Lake, Eutrophication

2016, Specific but Brief

Monitoring Plan for TMDL(s) Under a Phased Approach

The TMDL identifies a monitoring plan that describes the additional data to be collected to determine if the load reductions required by the TMDL lead to attainment of water quality standards, and a schedule for considering revisions to the TMDL(s) (where a phased approach is used) [40 CFR § 130.7]. If this is a revised TMDL document, monitoring to support the revision will be documented in this section. Although the EPA does not approve the monitoring plan submitted by the state, the EPA acknowledges the state's efforts. The EPA understands that the state may use the monitoring plan to gauge the effectiveness of the TMDLs and determine if future revisions are necessary or appropriate to meet applicable water quality standards.

The KDHE will continue its summer seasonal, every three year sampling schedule in order to assess the trophic state of Cheney Lake. This monitoring schedule was used after establishing the original, 2000 TMDL document, and to support the development of the revised TMDL document. Monitoring occurred between 2001 and 2014 as outlined above in the Water Quality Standards Attainment section of this document. Based on the sampling results, the 303(d) listing will be evaluated in 2026. Should impairment status continue, the Phase II of this TMDL will commence and more intensive sampling will be conducted over the period 2026-2036 to assess progress in this implementation.

To evaluate load reductions to Cheney Lake from the North Fork Ninnescah River, future sample concentrations with their corresponding flow values will be plotted against the baseline curve for total phosphorus (Figure 33 of the TMDL document) and total nitrogen (Figure 34 of the TMDL document) and assessed for signals of improvement with more points below the regression curve indicating improvement in nutrient loading to the lake.

TMDL for Middle Kansas River, Ogden to Lecompton, Total Phosphorus

2017, Specific but Brief

https://www.kdhe.ks.gov/DocumentCenter/View/14055/Middle-Kansas-River-PDF

6. MONITORING

Future stream chemistry sampling will continue at SC260, SC259 and SC257 with sestonic chlorophyll *a* monitoring occurring at SC260 and SC257. Monitoring of tributary levels of TP for streams with existing KDHE monitoring stations will continue. Monitoring of TP should be a condition of the MS4 permits within the TMDL watershed.

Macroinvertebrate sampling will continue in the Kansas River at Wamego (SB260) and in the Kansas River at Lecompton (SB257). Macroinvertebrate sampling will also continue in the Kansas River above and below Topeka at SB371 and SB272, respectively, and possibly at other accessible locations in the river. If the biological endpoints are achieved over 2023-2027 at SB260, SB371, SB372 and SB257, the conditions descried by the narrative nutrient criteria will be viewed as attained and the Kansas River at Wamego (SC260), Willard (SC259) and Lecompton (SC257) will be moved to Category 2 on the 2028-303(d) list.

Once the water quality standards are attained, the adjusted ambient phosphorus concentrations in the Kansas River at Wamego (SC260), Willard (SC259) and Lecompton (SC257) will be the basis for establishing numeric phosphorus criteria through the triennial water quality standards process to protect the restored biological and chemical integrity of the reaches of the Middle Kansas River.

Massachusetts

TMDL for French Basin Lakes, Phosphorus

2002, Specific but Brief
https://www.mass.gov/doc/final-tmdls-of-phosphorus-for-selected-french-basin-lakes/download

Monitoring

Monitoring by DEP will be continued on a regular basis according to the five-year watershed cycle. Baseline surveys on the lake should include Secchi disk transparency, nutrient analyses, temperature and oxygen profiles and aquatic vegetation maps of distribution and density. At that time the strategy for reducing plant cover and reducing total phosphorus concentrations can be re-evaluated and the TMDL modified, if necessary. Additional monitoring by volunteer groups is encouraged.

Three Bays Watershed TMDL, Pathogens

2009, Specific but Brief
https://www.mass.gov/doc/final-bacteria-tmdl-report-for-the-three-bays-system/download

7.0 Monitoring

Long term monitoring at established ambient sampling stations will be important to assess the effectiveness of efforts to reduce bacteria and determine if water quality standards are being attained. The Massachusetts Division of Marine Fisheries has a well established and effective shellfish monitoring program that provides quality assured data which can be used to assess water quality standards attainment. Each growing area must have a complete sanitary survey every twelve years, a triennial evaluation every three years and an annual review in order to maintain a shellfish harvesting classification. The National Shellfish Sanitation Program established minimum requirements for sanitary surveys, triennial evaluations, annual reviews and annual fecal coliform water quality monitoring including the identification of specific sources and the assessment of the effectiveness of controls and attainment of standards.

Efforts by groups to monitor on a frequent basis as was demonstrated by the Three Bays Preservation, Inc. should continue. MassDEP will work with any and all such groups to ensure all data are compatible and comparable. The DMF data in combination with the Three Bays Preservation, Inc. data will be used to evaluate progress and will serve as a baseline to evaluate future controls resulting from implementation activities.

TMDL for Upper/Middle Charles River, Nutrients

2011, Specific but Brief

https://www.mass.gov/doc/final-tmdl-for-nutrients-in-the-uppermiddle-charles-river-0/download

7.3.1 Ongoing Monitoring

Water quality and flow monitoring programs in the Upper/Middle Charles River should be continued in order to assess progress towards and success of obtaining the TMDL's water quality goals. This monitoring is necessary to determine whether water quality goals are met through the implementation of the activities. Pilot projects should include water quality monitoring to determine their effectiveness at removing phosphorus. Instream monitoring programs should be designed to capture spatial, seasonal and climatic variability. In the Upper/Middle Charles River, periodic vegetative surveys should be conducted to determine the impacts of phosphorus reduction on biomass in critical reaches.

Wild Harbor Estuarine System TMDL, Nitrogen

2017, Specific and Detailed

https://www.epa.gov/sites/default/files/2018-10/documents/wild-harbor-tn-tmdl-report.pdf

Monitoring Plan MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that implementation will be conducted through an iterative process where adjustments may be needed in the future. The two forms of monitoring include: 1) tracking implementation progress as approved in the town CWMP plan (as appropriate); and 2) monitoring ambient water quality conditions, including but not limited to, the sentinel station identified in the MEP Technical Report.

If necessary to achieve the TMDL, the CWMP will evaluate various options to achieve the goals set out in the TMDL and Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by MassDEP, tracking progress on the agreed-upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality, MassDEP believes that an ambient monitoring program, much reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL load values are not fixed, the target threshold N concentrations at the sentinel stations are. Through discussions amongst the MEP it is generally agreed that existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes.

Although more specific details need to be developed on a case by case basis, MassDEP's current thinking is that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. Detailed monitoring plans will be included in appropriate groundwater discharge permits or watershed permits. Continued water quality monitoring of the sentinel stations in each of the estuaries is recommended, but not required prior to implementation of nitrogen removal plans. However, some current background monitoring data will be needed prior to implementing remedial actions and will be discussed during the pre-permitting process. Monitoring of sentinel stations monthly or bi-monthly between May and September should be anticipated.

In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations as a result of restoration efforts.

The MEP will continue working with the watershed communities to develop and refine monitoring plans that remain consistent with the goals of the TMDL. Through the adaptive management approach ongoing monitoring will be conducted and will indicate if water quality standards are being met. If this does not occur other management activities would have to be identified and considered to reach to goals outlined in this TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

Draft TMDL for the South Coastal Watershed, Pathogens

Specific but Brief

https://www.mass.gov/doc/draft-pathogen-tmdl-for-the-south-coastal-watershed-in-spreadsheet/download

8.0 Monitoring Plan

The long term monitoring plan for the South Coastal watershed includes several components:

1. continue with the current monitoring of the South Coastal watershed (local watershed conservation organizations, local governments, DMF),
2. continue with MADEP watershed five-year cycle monitoring,
3. monitor areas within the watershed where data are lacking or absent to determine if the waterbody meets the use criteria,
4. monitor areas where BMPs and other control strategies have been implemented or discharges have been removed to assess the effectiveness of the modification or elimination,
5. assemble data collected by each monitoring entity to formulate a concise report where the basin is assessed as a whole and an evaluation of BMPs can be made, and
6. add/remove/modify BMPs as needed based on monitoring results.

The monitoring plan is an ever-changing document that requires flexibility to add, change or delete sampling locations, sampling frequency, methods and analysis. At the minimum, all monitoring should be conducted with a focus on:

- capturing water quality conditions under varied weather conditions;
- establishing sampling locations in an effort to pin-point sources;
- researching new and proven technologies for separating human from animal bacteria sources; and
- assessing efficacy of BMPs.

Minnesota

TMDL for Lower Wild Rice River, Turbidity

2009, Specific but Brief
https://www.pca.state.mn.us/sites/default/files/wq-iw5-03e.pdf

Monitoring Plan

There are several monitoring activities occurring in the Wild Rice River watershed and many are planned to continue into the future. Some of these monitoring activities include the Red River Basin's River Watch, the United States Geological Survey flow monitoring and sediment analysis study, and the MPCA's Milestone and condition monitoring. These existing monitoring activities will be used to track progress towards the achievement of the TMDL for the Lower Wild Rice River. A detailed monitoring plan, which will include monitoring site locations, sampling schedules and responsible parties, will be developed as part of the forthcoming implementation plan referenced in the next section of this report.

TMDL for Knife River Watershed, Turbidity

2010, Specific but Brief
https://www.pca.state.mn.us/sites/default/files/wq-iw10-01e.pdf

7.0 Monitoring and Research Plan

An important step in the implementation process will be on-going monitoring of flow, turbidity, TSS, and transparency in the river to determine if the conditions are changing and determine the effectiveness of reduction strategies. Partners in this process will include: citizen stream monitors, the MPCA, the South St. Louis SWCD, the MN DNR, and the USGS. Funding for monitoring is a critical issue that needs to be addressed. Key monitoring requirements and objectives include:

- Maintaining the USGS flow monitoring station on the Knife River.
- Reestablishing water quality monitoring at the Fish Trap site or the USGS gage site.
- Ensure that all implementation activities, whether they occur through local, state, or federal programs, or other means, are tracked using a reporting database such as the BWSR E-link system. This will be crucial for gauging general implementation progress.
- Continue to promote and expand citizen stream monitoring in the Knife River watershed.
- Coordinate with the University of Minnesota and MPCA in conducting research on soil erosion and sediment delivery processes and the effectiveness of particular BMPs. Apply results of sediment "fingerprinting" and other research that will be completed as part of the Lake Superior Streams Sediment Project.
- Maintain all monitoring activities for a period of no less than 10 years, and preferably on a permanent basis.

TMDL for Pioneer-Sarah Creek Subwatershed, E. coli

2017, Specific and Detailed
https://www.pca.state.mn.us/sites/default/files/wq-iw8-55e.pdf

7. Monitoring Plan

Progress on TMDL implementation will be measured through regular periodic monitoring of water quality and tracking of the BMPs completed. This will be accomplished through the combined efforts of the organizations receiving LAs as well as the cooperating agencies (notably the PSCWMC, MPCA, and Three Rivers Park District). The Intensive Watershed Monitoring (IWM) program conducted by the MPCA is expected to provide a large-scale, longer-term picture of the degree to which conditions are changing in the Pioneer-Sarah Creek Subwatershed. Monitoring by the MPCA under this program was last conducted in 2007 and 2008 in the North Fork Crow Watershed and 2012 and 2013 in the South Fork Crow Watershed, and is expected to be undertaken again in 2017 and 2018, and 2022 and 2023 respectively as part of the 10-year monitoring cycle. As part of the Third Generation Watershed Management Plan, the Commission adopted and funded a rotating sampling program for streams and lakes designed in part to monitor progress in implementing the TMDL. A summary of the monitoring program to assess implementation progress is presented below.

7.1 Lake Monitoring

Spurzem Lake, Half Moon Lake, North Whaletail Lake and South Whaletail Lake will continue to be monitored by the Commission in partnership with Three Rivers Park District at least every two years because of their visibility and priority as public resources. Peter Lake and Ardmore Lake will be monitored at least once every three years by the Commission in partnership with Three Rivers Park District as access and resources are available, either through volunteers or under contract with professional staff. Lakes are generally monitored for Chl-*a*, TP, and Secchi disk transparency. The Commission has also regularly participated in the Metropolitan Council's Citizen Assisted Lake Monitoring Program (CAMP) since 2005. CAMP volunteers monitor surface water conditions and chemistry. They also judge the appearance of the lake, its odor, and its suitability for recreation. Aquatic plant surveys should will be conducted on each lake at approximately three to five year intervals by the Commission in partnership with Three Rivers Park District. In-lake monitoring will continue as implementation activities are undertaken across the respective watersheds. The DNR will continue to conduct fish surveys on lakes with public access (currently Spurzem Lake, Half Moon, and North Whaletail Lake) as allowed by their regular schedule. Currently, fish surveys are conducted approximately every five years.

7.2 Stream Monitoring

The Commission will continue to annually monitor flow and water quality at baseline sites on Sarah Creek and on Pioneer Creek, and at one additional site in the watershed per year on a rotating basis, so that each site is monitored every two to three years. These rotating sites include Dance Hall Creek, Loretto Creek, and Spurzem Creek. In addition, the Commission may periodically undertake special stream monitoring on other tributaries where necessary, for example to measure progress toward meeting a TMDL, calibrate models or refine source assessments.

7.3 Tracking of Best Management Practices

As part of their NPDES General Stormwater Permit, cities that are MS4s must annually track and report to the MPCA the number, type, location, and load reduction benefits of constructed BMPs (such as detention basins, filtration and infiltration basins, and swales) undertaken to achieve TMDL wasteload reductions. The PSCWMC will review member communities' annual reports to keep abreast of progress toward achieving the TMDLs. The Commission will also request that all its member cities track LA reduction BMPs and other WRAPS-related activities, and report them periodically so that the Commission can summarize this information annually and have it available for agencies and interested members of the public.

Missouri

TMDL for Village Creek, Inorganic Sediment and Lead

2009, Specific but Brief
https://dnr.mo.gov/document-search/village-creek-lead-sediment-total-maximum-daily-load

7. Monitoring Plan for TMDLs Developed Under Phased Approach

Sediment monitoring was completed for Village Creek in May 2008. The department has not yet scheduled other monitoring for this water body. However, the department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by the Missouri Department of Conservation under its Resource Assessment and Monitoring (RAM) Program. This program randomly samples streams across Missouri on a five to six year rotating schedule. Should additional water quality data be collected for the Village Creek watershed, these data will be evaluated in light of this TMDL.

TMDL for Hinkson Creek, Storm Water Runoff

2011, Specific but Brief
https://www.helpthehinkson.org/documents/mo_hinkson_creek_tmdl_final.pdf

10. Monitoring Plans

There are several monitoring efforts planned in the Hinkson Creek watershed for TMDL implementation and assessment purposes. One of the milestones of the Hinkson Creek Watershed Restoration Plan is to monitor the performance of storm water treatment structures and verify their effectiveness. The Storm Water Management Plan for the MS4 permit in the watershed will also require monitoring and other actions necessary to implement the requirements of the TMDL once the TMDL is effective. Additionally, a grant to monitor the hydrology of Hinkson Creek was recently initiated (See Appendix E).

In the first phase of implementation of the TMDL, EPA recommends assessment of the biocommunity to be conducted. In addition, MDNR intends to conduct a follow-up bioassessment of Hinkson Creek, including collection of water quality data, once substantial implementation of the TMDL has occurred, typically three to five years. Chloride data will also continue to be collected by volunteer water quality monitors to determine trends in chloride concentrations in Hinkson Creek.

TMDL for Mussel Fork, Pathogens

2017, General Statements

https://dnr.mo.gov/document-search/mussel-fork-pathogen-total-maximum-daily-load

12. Monitoring Plans

Post-TMDL monitoring is often scheduled and carried out by the department approximately three years after the approval of the TMDL or in a reasonable time period following completion of permit compliance schedules and the application of new effluent limits. The department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. In addition, certain quality-assured data collected by universities, municipalities, private companies and volunteer groups may potentially be considered for monitoring water quality following TMDL implementation. Determinations of water quality standards attainment or continued impairment of the water bodies subject to this TMDL will be completed by the department as part of its biennial water quality assessments for required Clean Water Act 305(b) and 303(d) reporting.

Montana

TMDL for Swan Lake Watershed

2004, Specific and Very Detailed
http://deq.mt.gov/Portals/112/Water/WQPB/TMDL/PDF/SwanLake/C10-TMDL-01a.pdf

10.1.3 Project Effectiveness Monitoring

An additional type of implementation monitoring involves efforts to assess the effectiveness of specific restoration or water quality improvement activities. All water quality projects should have some form of monitoring to assess overall effectiveness. In some situations, the monitoring can provide feedback for future projects or feedback on maintenance requirements. This monitoring can take on many forms, and can be as simple as before and after photos.

10.2 Monitoring and Assessment Recommendations

The additional assessment and watershed characterization monitoring has several potential roles. This type of monitoring can provide:

- additional information on land uses and impacts to aquatic life and pollutant loading throughout the watershed;
- information for making beneficial use support determinations in streams not yet evaluated where land management activities indicate a potential impairment;
- an improved understanding of reference or baseline conditions for evaluating beneficial use support and setting target conditions; and
- an improved understanding of the aquatic life and other beneficial uses to be protected.

This type of monitoring is broken into two priority categories of high and medium, although future stakeholder input and evaluation of new information could impact subsequent prioritization of these projects and activities.

10.2.1 High Priority Monitoring and Assessment Recommendations

Below is a list of the higher priority monitoring and assessment recommendations. These are in addition to the implementation monitoring recommendations in Section 10.1, which area all high priority monitoring activities. Many of these high priority monitoring recommendations are related to the additional target conditions defined in Section 7.4.

1) A near-shore algae investigation to address Additional Target Condition #1 is a very high priority to better define potential impacts associated with septic systems and increased growth in the vicinity of Swan Lake.
2) Efforts should be made to identify and eventually remediate undesirable fish passage barriers consistent with the goals of Additional Target Condition #2. A fish passage limitation can prevent a stream from ever being at a “full support” condition for cold-water fish.
3) The FWP monitoring of bull trout spawning redds and documentation of the results should continue. Additional monitoring and reporting on juvenile bull trout as well as

other native fish such as cutthroat trout is also recommended. Although not specifically used for target conditions, this fishery information along with other information within the watershed can help link watershed conditions to beneficial use support impacts.

4) Because beneficial use support decisions and potential future target development are typically based on local reference conditions, continued identification and monitoring of reference streams is recommended. Existing Forest Service data on potential reference reaches and other waterbodies in the watershed should be organized into a database and GIS format to assist with this effort.
5) Monitoring impacts from fires and significant flood events, in areas with and without land management activities, is suggested to help define pollutant loading and other potential impacts to streams under varying conditions.
6) The FWP should continue with their McNeil Core sampling program.
7) An assessment of channel conditions, percent fines, riparian health, macroinvertebrate communities, and/or other geomorphic indicators that can be linked to cold-water fish and aquatic life use support should be pursued for:
   - the whole length of the Swan River to help determine existing conditions and help track potential future impacts to this important waterbody;
   - streams where there are or have been indicators of potential impairment conditions such as substantial increases in development or other land use impact indicators, with focus on bounded alluvial valley stream segments consistent with Additional Target Condition #3; and
   - streams where significant development is planned to provide baseline information to help analyze the impacts of the development, again with focus on bounded alluvial valley stream segments as appropriate.

10.2.2 Medium Priority Monitoring and Assessment Recommendations

The following list of monitoring activities and projects are considered medium priority at this time, but could be considered higher priority depending on further stakeholder planning and subsequent priority determinations. Many of these recommendations could end up being a higher priority if DO or nutrient conditions became worse in Swan Lake.

1) Modeling could be done to better estimate nutrient loads from septic systems, especially in the vicinity to Swan Lake, and to also estimate potential load increases from future development. Any such efforts should take into consideration any documented near shore nutrient impairment concerns. If near shore impairments are identified, then this could become a high priority.
2) Craig Spencer’s (1991b) sediment cores from Swan Lake as well as two other lakes provided evidence that increased timber harvest and/or road construction increased the rate of sediment deposition in each lake. Additional cores could be taken from Swan Lake and from an additional control lake if one can be identified. It would be especially interesting to determine if the rate of sediment deposition in Swan Lake has decreased since 1990 as a result of BMP implementation. It may also be worthwhile to determine the extent of submerged logs in the lake bottom as part of this study or as part of a separate study.

3) A study of the mixing dynamics of the lake could be completed with an emphasis placed on determining the extent to which the deep-water basins are hydraulically isolated from the rest of the lake.
4) Efforts could be pursued to better understand the loading impacts that the wetlands along the south basin have on Swan Lake water quality.
5) Temperature monitoring in tributaries could be pursued to providing a better understanding of temperature conditions and also provide baseline data to evaluate future land use impacts.
6) Lindbergh, Cygnet and Holland Lakes should be monitored to provide baseline information concerning nutrients levels and document any existing impacts to beneficial uses. This is especially important for these two waterbodies given the threat posed by increasing development, specifically around Lindbergh Lake. Some of these lakes may be monitored during 2004 as part of a statewide lake monitoring project that DEQ is sponsoring.

TMDL for Bonita, Superior Metals

2013, Specific and Very Detailed
http://deq.mt.gov/Portals/112/Water/WQPB/TMDL/PDF/Bonita_Superior/C02-TMDL-03a.pdf

7.0 MONITORING FOR EFFECTIVENESS

The monitoring framework discussed in this section is an important component of watershed restoration, a requirement of TMDL development under Montana's TMDL law, and the foundation of the adaptive management approach to water quality improvement. An implicit margin-of-safety has been incorporated into the TMDLs developed in this document. Although loading and load allocations are calculated from the most recent data, the calculations are only estimate of a more complex seasonal loading system. The margin of safety is intended to offset the effect of this uncertainty, but complications related to the strength and volume of pollutant sources often become apparent only after restoration activities have begun. Monitoring during restoration can determine whether TMDL targets are being met, whether all significant sources have been identified, and whether attainment of TMDL targets is feasible in light of new information about pollutant strength and sources. Data from long-term monitoring provides technical justification for modifying restoration strategies, targets, or allocations schemes.

Rather than a fixed monitoring program with assigned responsibilities, the initial monitoring framework presented here allows for future adjustment to refine monitoring needs to field conditions. The recommendations are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans that measure the effects of water quality restoration practices. Funding for future monitoring is uncertain and can vary with economic and political changes. Monitoring priorities depend on restoration progress, stakeholder priorities, and funding availability.

The objectives for future monitoring in the Bonita – Superior project area include:

- tracking restoration activities and evaluating the effectiveness of individual and cumulative restoration activities

- baseline and impairment status monitoring to assess attainment of water quality targets and identify long-term trends in water quality, and
- refining the source assessments. Each of these objectives is discussed below.

7.1 Restoration Effectiveness Monitoring

Monitoring should occur before and after restoration projects are implemented to tracks the degree and rate of recovery of the aquatic system. Effectiveness monitoring should address a targeted set of pollutants for each project. Each monitoring project should begin with compiled information on source locations, spatial extent, surface ownership, remediation design, and the location and nature of BMP applications elsewhere in the watershed.

The Linton Mine section of Cramer Creek was restored in the early 2000s and this effort appears to have been largely successful. Future monitoring should be planned to track lead concentrations in Cramer Creek. A monitoring program should also track aluminum concentrations, with attention to any soil and land conservation BMPs that may be implemented to meet the sediment TMDL that will be developed for Cramer Creek (as part of a separated project and document).

DEQ recommends additional monitoring of copper concentrations in Wallace Creek. The copper impairment determination was based on the detected concentration exceeding the chronic aquatic life standard in greater than 10% of the samples, however the sample population was small (9 samples). Future reassessment based on a larger sample population may conclude that copper is no longer an impairment cause to Wallace Creek.

The remediation and restoration activities in Flat Creek related to the Iron Mountain Mill OU2 site will include post-restoration monitoring. This should be a collaborative project, incorporating EPA, USFS, DEQ Federal Superfund Bureau and DEQ Water Quality Planning Bureau.

BMP effectiveness in reducing metals loading can best be evaluated by comparisons of water sample analysis results with metals targets. Also, photo documentation of BMP-affected source reductions is appropriate in cases where significant lag time may occur between BMP application and water quality improvement.

DEQ will conduct a TMDL Implementation Evaluation (TIE) within a watershed to determine whether monitoring results document sufficient in water quality improvement. The TIE process consists of compiling recent data, conducting additional monitoring when needed, completing target comparisons, summarizing the applied BMPs, determining the degree of TMDL achievement, and identifying water quality trends post-dating TMDL development.

If the TIE results indicate the TMDL is being achieved, the waterbody is recommended for a formal reassessment of its use-support status. If TMDLs are not being met, DEQ evaluates the recent progress toward restoring water quality and the effectiveness of land, soil, and water conservation practices in place in the watershed. The evaluation determines whether the solution requires improved BMP application, more time for currently effective BMPs to work, or reevaluating the feasibility of meeting standards with complete BMP application.

7.2 Baseline and Impairment Status Monitoring

In addition to tracking BMP effectiveness, monitoring locations should, in many cases, be distributed to provide adequate knowledge of water quality conditions and loading sources throughout the drainage. These additions to the dataset can be used during the TIE. Since DEQ is the lead agency for evaluating use impairment, the data types and collection methodologies should be compatible with DEQ assessment methods. Other agencies or entities collecting water quality and aquatic life data are encouraged to provide compatible information wherever possible. Guidance for monitoring water quality for metal pollutants is helpful for ensuring that the data quality is adequate as a basis for standards comparisons, impairment evaluations, and trend detection.

7.3 Source Assessment Refinement

The level of detail of the source assessment allows allocations to broad source categories and geographic areas. Additional monitoring may be helpful to better partition pollutant loading at mine sites with multiple sources. The needed refinements may require more seasonally stratified sampling or a more detailed field reconnaissance and follow-up sampling to better locate stream segments representing background loading.

In Cramer Creek, the inability to distinguish background aluminum loading from human-caused aluminum loading led to use of a broad composite allocation. In Wallace Creek, further sampling would allow better delineation of copper sources between potential abandoned / inactive mining sources. [TMDL]

TMDL for Bitterroot Watershed, Nutrients, Metals, and Temperature

2014, Specific and Very Detailed
http://deq.mt.gov/Portals/112/Water/WQPB/TMDL/PDF/Bitterroot/C05-TMDL-04a.pdf

10.0 Monitoring Strategy and Adaptive Management

10.1 Monitoring Purpose

The monitoring strategies discussed in this section are an important component of watershed restoration, and a requirement of total maximum daily load (TMDL) implementation under the Montana Water Quality Act (Montana Code Annotated (MCA) 75-5-703(7)), and the foundation of the adaptive management approach. Water quality targets and allocations presented in this document are based on available data at the time of analysis. The scale of the watershed analysis, coupled with constraints on time and resources, often result in necessary compromises that include estimations, extrapolation, and a level of uncertainty in TMDLs. The margin of safety (MOS) (**Section 4.4**) is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities, the amount of reduction of instream pollutants (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long-term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate.

The monitoring strategy presented in this section provides a starting point for the development of more detailed planning efforts regarding monitoring needs; it does not assign monitoring responsibility. Monitoring recommendations provided are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet the water quality improvement goals outlined in this document. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on funding opportunities and stakeholder priorities for restoration. Once restoration measures have been implemented for a waterbody with an approved TMDL and given time to take effect, Department of Environmental Quality (DEQ) will conduct a formal evaluation of the waterbody's impairment status and determine whether TMDL targets and water quality standards are being met.

10.2 Adaptive Management and Uncertainty

In accordance with the Montana Water Quality Act (Montana Code Annotated (MCA) 75-5-703 (7) and (9)), DEQ is required to assess the waters for which TMDLs have been completed and restoration measures, or best management practices (BMPs), have been applied to determine whether compliance with water quality standards has been attained. This aligns with an adaptive management approach that is incorporated into DEQ's assessment and water quality impairment determination process.

Adaptive management as discussed throughout this document is a systematic approach for improving resource management by learning from management outcomes, and allows for flexible decision making. There is an inherent amount of uncertainty involved in the TMDL process, including: establishing water quality targets, calculating existing pollutant loads and necessary load allocations, and determining effects of BMP implementation. Use of an adaptive management approach based on continued monitoring of project implementation helps manage resource commitments and achieve success in meeting the water quality standards and supporting all water quality beneficial uses. This approach further allows for adjustments to restoration goals, TMDLs, and/or allocations, as necessary.

For an in-depth look at the adaptive management approach, view the U.S. Department of the Interior's (DOI) technical guide and description of the process at: http://www.doi.gov/archive/initiatives/AdaptiveManagement/. DOI includes **Figure 10-1** below in their technical guide as a visual explanation of the iterative process of adaptive management (Williams and Shapiro, 2009).

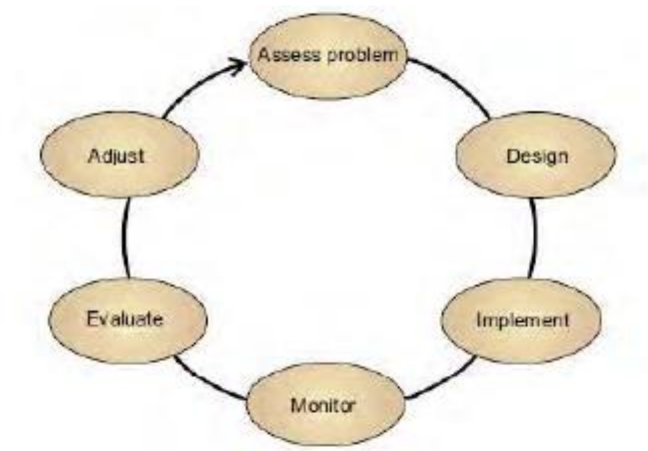

Figure 10-1. Diagram of the adaptive management process

10.3 Future Monitoring Guidance

The objectives for future monitoring in the Bitterroot Watershed Project Area include:

- Strengthen the spatial understanding of sources for future restoration work, which will also improve source assessment analysis for future TMDL review
- Gather additional data to supplement target analysis, better characterize existing conditions, and improve or refine assumptions made in TMDL development
- Gather consistent information among agencies and watershed groups that is comparable to the established water quality targets and allow for common threads in discussion and analysis
- Expand the understanding of streams and nonpoint source pollutant loading throughout the Bitterroot Watershed Project Area beyond those where TMDLs have been developed and address issues
- Track restoration projects as they are implemented and assess their effectiveness

10.3.1 Strengthening Source Assessment

In the Bitterroot Watershed Project Area, the identification of pollutant sources was conducted largely through tours of the watershed, assessments of aerial photographs, the incorporation of geographic information system information, reviewing and analyzing available data, and the review of published scientific studies. In many cases, assumptions were made based on known watershed conditions and extrapolated throughout the project area. As a result, the level of detail often does not provide specific areas on which to focus restoration efforts, only broad source categories to reduce pollutant loads from each of the discussed streams and subwatersheds. Strategies for strengthening source assessments for each of the pollutant categories are outlined below.

Nutrients

- A better understanding of nutrient concentrations in groundwater (as well as the sources) and the spatial variability of groundwater with high nutrient concentrations
- A better understanding of cattle grazing practices and the number of animals grazed in the Bitterroot Watershed Project Area

- A more detailed understanding of nutrient contributions from historical and current mining within the watershed
- A better understanding of septic system contributions to nutrient loads in the nutrient impaired streams
- A review of land management practices specific to subwatersheds of concern to determine where the greatest potential for improvement can occur for the major land use categories
- Additional sampling in streams that have limited data

Metals

- Review data collected by the Lolo Wastewater Treatment Plant (WWTP) as required by the new National Pollutant Discharge Elimination System (NPDES) permit to confirm Environmental Protection Agency's (EPA) 2013 samples are representative of the plant's typical effluent and verify the facility is an insignificant source of lead
- Conduct additional investigations into abandoned mines in the lower Bitterroot River basin to confirm the assumption in this document that lead loading from these sites in fact minimal
- Research further through investigative site visits and groundwater, surface water and soil sampling, the Billingsley Placer Mine, the three historic waste disposal sites near Missoula, and underground gasoline storage tanks to better determine any potential influence they have on the Bitterroot River
- Streambed sediment sampling should also bracket known automobile rip rap sections to verify cars are not contributing to the metals impairment and support the conclusions drawn from the existing US Fish and Wildlife Service (USFWS) soil samples
- Collect soil and bedrock samples in the Lick Creek basin to analyze for aluminum content. Special attention should be paid to the known mineral lick outcrop upstream of EPA sample site C05LICKT01 and any similar mineralized locations. This work will help refine the aluminum contribution from background sources

Temperature

- Field surveys to better identify and characterize riparian area conditions and potential for improvement
- Identification of possible areas for improvement in shading along major tributaries, particularly where riparian vegetation is dominated by grasses due to present and historical land use
- Collection of flow measurements at all temperature monitoring locations during the time of data collection
- Investigation of groundwater influence on instream temperatures, and relationships between groundwater availability and water use in the Mill Creek watershed and the entire Bitterroot Watershed Project Area
- Assessment of irrigation practices and other water use in Mill Creek watershed and Bitterroot Watershed Project Area and potential for improvements in water use that would result in increased instream flows
- Use of additional collected data to evaluate and refine the temperature targets

10.3.2 Increasing Available Data

While the Bitterroot Watershed Project Area has undergone remediation and restoration activities, data are still often limited depending on the stream and pollutant of interest. Infrequent sampling events at a small number of sampling sites may provide some indication of overall water quality and habitat condition. However, regularly scheduled sampling at consistent locations, under a variety of seasonal conditions is the best way to assess overall stream health and monitor change.

Temperature

Temperature investigation for Mill Creek watersheds included seven data loggers, deployed throughout the stream and selected tributaries in summer of 2013. Increasing the number of data logger locations and the number of years of data, including collection of associated flow data, would improve our understanding of instream temperature changes and better identify influencing factors on those changes. Collecting additional stream temperature data in sections with the most significant temperature changes and/or largest spatial gaps between loggers will also help refine the characterization of temperature conditions in Mill Creek. In addition, since shade is a major focus of the allocations, a more detailed assessment of existing riparian conditions and identification of areas for passive and active restoration of riparian vegetation on Mill Creek and its major tributaries is recommended.

Nutrients

Although extensive nutrient data were collected to assist with TMDL development, as conditions change in the respective watersheds with changes in management practices and/or land use, continued monitoring of impaired systems is warranted. When watershed scale monitoring is conducted to assist with future impairment determinations, particular attention should be given to collecting additional nutrient data on impaired streams. Future sampling should also include algal sampling for chlorophyll-*a* and AFDM. Additionally, macroinvertebrates are part of a second tier assessment if nutrient and/or algae concentrations do not clearly indicate impairment and therefore should be collected. Data collection that includes water quality, algal, and macroinvertebrate samples ensures that all aspects of nutrients and their effects on aquatic life can be evaluated.

There are several specific data collection efforts that would better delineate some of the nutrient sources addressed in **Section 5.0**, which include:

- Because there was limited flow data, additional nutrient sampling and flow measurements on all of the impaired streams may help identify whether there are low or high flow issues regarding nutrient loading to further help with source assessment.
- Targeted sampling of Threemile Creek tributaries included in the Wheelbarrow Creek drainage. In the McDowell and Rokosch (2005) report, the Wheelbarrow Creek drainage, which includes Wheelbarrow Creek, Grayhorse Creek, and Spring Gulch, was identified as having important nutrient loads originating in this drainage. These streams were not captured by the DEQ monitoring.
- Because two assessment units (AUs) on the Bitterroot River were previously listed as nutrient impaired, local interests should be concerned with maintaining the unimpaired water quality status and continue monitoring the river and tributaries to ensure the current status is not changing. Continued monitoring will help identify new nonpoint sources and identify impacts, especially from expanding population growth and residential development. In addition, the Bitterroot River is a major tributary to the Clark Fork River, which has a Voluntary Nutrient Reduction Program, so periodic monitoring is encouraged to ensure that nutrient targets are met.
- Targeted sampling in the Upper Rye Creek watershed to determine if total phosphorus (TP) concentrations are decreasing as the watershed recovers from forest fires. The unnamed creek

above the crossing of Moonshine Connection Road with Rye Creek saw a large pulse of TP, so a targeted sampling at various flow regimes may provide further information.

- Targeted sampling of Threemile Creek above the Lee Metcalf National Wildlife Refuge to determine nutrient loads coming into the system. In addition, targeted water quality sampling on the Bitterroot River downstream of this wetland area to see if there is potential influence on nutrient concentrations.
- Additional monitoring in the headwaters of the Bitterroot watershed to collect more reference data to enhance the existing data set and refine natural background concentrations of phosphorus in the watershed. TP in the watershed may be underestimated since the value is based on median concentration values from reference sites in each ecoregion under ideal conditions. Elevated TP concentrations (above target for the Middle Rockies Ecoregion) were found in the upper reaches of the Threemile and Lick watersheds where there was limited human influence.
- Additional monitoring to determine the scope and magnitude of loading from inter-basin transfers of irrigation water. This is especially pertinent to those creeks where inter-basin transfers were identified including: Ambrose, Lick and Threemile Creeks.

Metals

The concepts and assumptions presented in this TMDL are based on the best information available at the time this document was produced. As with any environmental investigation, there are data gaps and portions of the analysis that could be improved upon with the collection of additional data and further study. The information listed below, if available in the future, should be incorporated into the adaptive management approach detailed in **Section 10.2** and can be used to refine source assessments, strengthen or update impairment status determinations, and recognize trends in water quality. DEQ recommends the following actions to improve our understanding of metals-related concerns in the Bitterroot River:

- Conduct additional watershed-wide investigations extending into the upper Bitterroot River segments to determine the influence of the 2000 wildfires and better understand whether the declining trend in metals concentrations is a result of sediment-bound metals issues being resolved passively as contaminates are flushed through the system.
- Conduct synoptic sampling at multiple sites along the lower Bitterroot River segment. The current dataset consists of a sufficient number of water quality samples collected largely from one site (USGS 12352500), however, no paired samples are available from which to draw loading patterns within the segment. Additional synoptic samples would clarify the geographic extent of the lead impairment, potentially highlight source areas where BMP implementation would be most effective, and conclude whether or not the river has assimilative capacity above the Lolo WWTP.
- Collect streambed sediment samples throughout the segment and compare against National Oceanographic and Atmospheric Administration probable effects levels (PEL) values. Only two sediment samples are currently available for the lower Bitterroot River segment and they were collected 15 year ago. New sediment information would help DEQ determine if the high flow water quality exceedance are a consequence of elevated lead concentrations in streambed sediments getting resuspended in the water column. Streambed sediment sampling should also impairment and support the conclusions drawn from the existing USFWS soil samples.

- Review data collected by the Lolo WWTP as required by the new NPDES permit to confirm EPA's 2013 samples are representative of the plant's typical effluent and verify the facility is an insignificant source of lead.
- Collect additional dissolved aluminum water quality samples. The current dataset consists of only three samples. While the existing samples meet targets, DEQ considers eight samples to be the minimum dataset required to make assessment determinations (Drygas, 2012).
- Collect additional copper water quality samples. The current dataset is sufficiently robust (i.e., 63 samples), however, four aquatic life target exceedances have been observed. Following DEQ's assessment methodology outlined in **Section 7.4.3**, copper is not impairing aquatic life beneficial uses because the exceedance rate is <10%. Future investigations should continue to monitor the impairment status of copper.
- Conduct additional water quality sampling during low flow time periods. In order to address seasonality, DEQ prefers roughly 66% of the samples are representative of low flow conditions (Drygas, 2012). The existing lead dataset collected during low flow conditions represents only 42% of the dataset.
- Conduct additional investigations into abandoned mines in the lower Bitterroot River basin to confirm the assumption in this document that lead loading from these sites is in fact minimal.
- Research further through investigative site visits and groundwater, surface water and soil sampling, the Billingsley Placer Mine, the three historic waste disposal sites near Missoula, and underground gasoline storage tanks to better determine any potential influence they have on the Bitterroot River.
- Conduct additional investigations into the potential for lead loading from road material throughout the watershed that may have originated from contaminated tailings at the Curlew Mine.

DEQ recommends the following actions to improve our understanding of metals-related concerns in Lick Creek:

- Collect soil and bedrock samples in the Lick Creek basin to analyze for aluminum content. Special attention should be paid to the known mineral lick outcrop upstream of EPA sample site C05LICKT01 and any similar mineralized locations. This work will help refine the aluminum contribution from background sources.
- Collect additional iron and lead water quality samples. The existing datasets for these pollutants had aquatic life exceedances but they were not listed as impairing water quality because the exceedance rate was <10%. These iron and lead exceedances were collected during high flow conditions when suspended sediment was elevated, therefore the sources of iron and lead may be controlled through the implementation of the Lick Creek sediment TMDL established in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a).
- Research further the validity of adopting 87 µg/L as the aluminum chronic aquatic life target for waters with pH <6.5 as documented in **Section 7.4.2.1**.

10.3.3 Consistent Data Collection and Methodologies

Data has been collected throughout the Bitterroot Watershed Project Area for many years and by many different agencies and entities; however, the type and quality of information is often variable. Wherever possible, it is recommended that the type of data and methodologies used to collect and analyze the information be consistent so as to allow for comparison to TMDL targets and track progress toward meeting TMDL goals.

DEQ is the lead agency for developing and conducting impairment status monitoring; however, other agencies or entities may work closely with DEQ to provide compatible data. Water quality impairment determinations are made by DEQ, but data collected by other sources can be used in the impairment determination process. The information in this section provides general guidance for future impairment status monitoring and effectiveness tracking. Future monitoring efforts should consult DEQ on updated monitoring protocols. Improved communication between agencies and stakeholders will further improve accurate and efficient data collection. The development of a DEQ approved Sampling Analysis Plan (SAP) and a Quality Assurance Protection Plan (QAPP) will ensure that the data collected meets DEQ standards for data quality.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect water quality beneficial uses in a manner consistent with Montana's water quality standards. Other regulatory programs with water quality protection responsibilities may impose additional requirements to ensure full compliance with all appropriate local, state, and federal laws. For example, reclamation of a mining related source of metals under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA) typically requires source-specific sampling requirements, which cannot be defined at this time, to determine the extent of and the risk posed by contamination, and to evaluate the success of specific remedial actions.

Nutrients

For those watershed groups and/or government agencies that monitor water quality, it is recommended that the same analytical procedures and reporting limits are used so that water quality data may be compared to TMDL targets (**Table 10-1**). In addition, stream discharge should be measured at time of sampling.

Table 10-1. DEQ Nutrient Monitoring Parameter Requirements

Parameter*	Preferred method	Alternate method	Required reporting limit (ppb)	Holding time (days)	Bottle	Preservative
Total Persulfate Nitrogen (TPN)	A4500-NC	A4500-N B	40	28	250mL HDPE	≤6°C (7d HT); Freeze (28d HT)
Total Phosphorus as P	EPA-365.1	A4500-P F	3			H2S04, ≤6°C of Freeze
Nitrate-Nitrite as N	EPA-353.2	A4500-N03 F	10			
Chlorophyll-*a* &	A 10200 H	n/a	n/a	21(pH≥ 7)/ASAP	Filter	Freeze
Ash-Free Dry Weight	A 10300 C(5)	n/a	n/a			
Periphyton	PERI-1/PERI-1mod	n/a	n/a	n/a	50 cm^3 centrifuge tube	Formalin (40% formaldehyde solution)
Macroinvertebrates	EMAP	n/a	n/a	n/a	1L Acid-washed HDPE	Ethanol

*Preferred analytical methods and required reporting limits may change in the future (e.g., become more stringent); consult with DEQ prior to any monitoring effort in order to ensure you use the most current methods.

Metals

Metals monitoring should include analysis of a suite of total recoverable metals (e.g., As, Cu, Cd, Pb, Zn), sediment samples, hardness, pH, discharge, and total suspended solids (TSS). **Table 10-2** identifies the current DEQ metals sampling methodologies and reporting limits for the standard metals suite (water and sediment)(Drygas, 2012).

Table 10-2. DEQ Metals Monitoring Parameter Requirements

Parameter*	Preferred Method	Alternate Method	Req. Report Limit ug/L	Holding Time Days	Bottle	Preservative
Water Sample - Physical Parameters and Calculated Results						
Total Hardness as $CaCO_3$	A2340 B (Calc)		1000			
Total Suspended Solids	A2540D		4000	7	1000 ml HDPE/500 mlHDPE	≤6oC
Water Sample - Dissolved Metals (0.45 um filtered)						
Aluminum	EPA 200.7	EPA 200.8	9	180	250 ml HDPE	Filt 0.45 um, HNO_3
Water Sample - Total Recoverable Metals						
Total Recoverable Metals Digestion	EPA 200.2	APHA3030F (b)	N/A	180	500 ml HDPE/ 250 ml HDPE	HNO_3
Arsenic	EPA 200.8		1			
Cadmium	EPA 200.8		0.03			
Calcium	EPA 200.7		1000			
Chromium	EPA 200.8	EPA 200.7	1			
Copper	EPA 200.8	EPA 200.7	1			
Iron	EPA 200.7		20			
Lead	EPA 200.8		0.3			
Magnesium	EPA 200.7		1000			
Potassium	EPA 200.7		1000			
Selenium	EPA 200.8		1			
Silver	EPA 200.8	EPA 200.7/200.9	0.2			
Sodium	EPA 200.7		1000			
Zinc	EPA 200.7	EPA 200.8	8			
Antimony	EPA 200.8		0.5			
Barium	EPA 200.7	EPA 200.8	3			
Beryllium	EPA 200.7	EPA 200.8	0.8			
Boron	EPA 200.7	EPA 200.8	10			
Manganese	EPA 200.7	EPA 200.8	5			
Nickel	EPA 200.7	EPA 200.8	2			
Thallium	EPA 200.8		0.2			
Uranium, Natural	EPA 200.8		0.2			

Table 10-2. DEQ Metals Monitoring Parameter Requirements

Parameter	Preferred Method	Alternate Method	Req. Report Limit mg/kg (dry weight)	Holding Time Days	Bottle	Preservative
Sediment Sample - Total Recoverable Metals						
Total Recoverable Metals Digestion	EPA 200.2		N/A	180	2000 ml HDPE Widemouth	
Arsenic	EPA 200.8	EPA 200.9	1			
Cadmium	EPA 200.8	EPA 200.9	0.2			
Chromium	EPA 200.8	EPA 200.7	9			
Copper	EPA 200.8	EPA 200.7	15			
Iron	EPA 200.7	EPA 200.7	10			
Lead	EPA 200.8	EPA 200.9	5			
Zinc	EPA 200.7	EPA 200.7	20			
Sediment Sample - Total Metals						
Mercury	EPA 7471B		0.05	28	2000 ml HDPE Widemouth	

*Preferred analytical methods and required reporting limits may change in the future (e.g., become more stringent); consult with DEQ prior to any monitoring effort in order to ensure you use the most current methods

Temperature

It is important that temperature data are collected in consistent locations and using consistent methods. Data loggers should be deployed at the same locations through the years to accurately represent the site-specific conditions over time, and recorded temperatures should at a minimum represent the hottest part of the summer when aquatic life is most sensitive to warmer temperatures. Data loggers should be deployed in the same manner at each location and during each sampling event, and follow a consistent process for calibration and installation. Any modeling that is used should refer to previous modeling efforts (such as the QUAL2K analysis used in this document) for consistency in model development to ensure comparability. In addition, flow measurements should also be conducted using consistent locations and methodology.

10.3.4 Effectiveness Monitoring for Restoration Activities

As restoration activities are implemented, monitoring is valuable to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. Monitoring can help attribute water quality improvements to restoration activities and ensure that restoration activities are functioning effectively. Restoration projects will often require additional maintenance after initial implementation to ensure functionality. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is often also a long-term process. An efficiently executed long-term monitoring effort is an essential component to any restoration effort.

Due to the natural high variability in water quality conditions, trends in water quality are difficult to define and even more difficult to relate directly to restoration or other changes in management. Improvements in water quality or aquatic habitat from restoration activities will most likely be evident in fine sediment deposition and channel substrate embeddedness, changes in channel cumulative width/depths, improvements in bank stability and riparian habitat, increases in instream flow, and changes in communities and distribution of fish and other bio-indicators. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budget and time constraints.

As restoration activities begin throughout the project area, pre and post monitoring to understand the change that follows implementation will be necessary to track the effectiveness of specific projects. Monitoring activities should be selected such that they directly investigate those subjects that the project is intended to effect, and when possible, linked to targets and allocations in the TMDL.

10.3.5 Watershed Wide Analyses

Recommendations for monitoring in the Bitterroot Watershed Project Area should not be confined to only those streams addressed within this document. The water quality targets presented in this document are applicable to all streams in the watershed, and the absence of a stream from the state's impaired waters list does not necessarily imply that the stream fully supports all beneficial uses. Furthermore, as conditions change over time and land management changes, consistent data collection methods throughout the watershed will allow resource professionals to identify problems as they occur, and to track improvements over time.
[TMDL & IP]

TMDL for Sheep Creek, E. coli

2017, Specific and Detailed
http://deq.mt.gov/Portals/112/Water/WQPB/TMDL/PDF/SheepCreek/M10-TMDL-01a.pdf

6.1 IMPROVEMENT AND MONITORING STRATEGY OVERVIEW

The strategy includes general measures for reducing loads from identified nonpoint sources of *E. coli* as well as approaches to further evaluate *E. coli* conditions in the Sheep Creek watershed. Effective monitoring is integral for evaluating conservation practices and provides a foundation of an adaptive management approach. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities, pollutant load reductions and status of TMDL target attainment. This strategy can also help determine if all significant sources have been identified. Data from long-term monitoring also provides technical justification to modify restoration strategies, targets, or allocations if appropriate.
…
DEQ's water quality sampling for *E. coli* was distributed spatially along Sheep Creek in order to delineate pathogen sources. Samples were collected over the course of one summer field season. The level of detail of the source assessment for this project resulted in allocations to broad source categories. Therefore, additional monitoring may be helpful to better partition pollutant loading in areas with multiple sources. The following monitoring would help improve the understanding of *E. coli* loading in Sheep Creek:

- Additional monitoring of *E. coli* for all of Sheep Creek, to span multiple field seasons.
- Additional sampling on Sheep Creek including locations upstream of sampling site 1F (**Figure 5-2**). Preferably one around the area of Deadman Creek, and one just downstream of the concentrated residential area.

- Additional monitoring of *E. coli* for the tributaries of the Sheep Creek where there is significant impacts from grazing to riparian areas. Additional monitoring will yield a better understanding of the *E. coli* sources located throughout the watershed.
- Monitoring during both high and low flow conditions. As *E. coli* exceedances occurred during a summer storm event more concerted sampling efforts could be made to collect samples during this type of events.

Below is information that could help strengthen the source assessment and help guide monitoring activities.

- Thorough analysis of the number of septic systems in the watershed, their proximity to surface water and their state of repair.
- A better understanding of waste management relative to campgrounds and other recreational activities.
- A more detailed understanding of grazing and manure management practices within the watershed.

6.7 CONSISTENT DATA COLLECTION AND METHODOLOGIES

For those stakeholders that monitor water quality, it is recommended that the same analytical methods, procedures and reporting limits are used in order that *E. coli* data be comparable to TMDL targets (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014). It is important to note that *E. coli* sampling can be complicated by the 6-hour holding time restriction (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014, Section 2.1.4). In addition, stream discharge should be measured at time of sampling.

DEQ is the lead agency for developing and conducting impairment status monitoring; however, other agencies or entities may work with DEQ to provide compatible data. Water quality impairment determinations are made by DEQ, but data collected by other sources can be used in the impairment determination process and to help evaluate overall progress of restoration efforts.
[Implementation Plan]

TMDL for Mission and Aransas Rivers, Indicator Bacteria

2001 and 2003, Specific and Very Detailed (in watershed-based plan, which includes the TMDL Implementation Plan)
https://www.tceq.texas.gov/downloads/water-quality/tmdl/mission-aransas-rivers-recreational-76/76a-mission-aransas-iplan-approved.pdf

Management Measure 8

Reduce WWTF Contributions by Meeting Half of the Permitted Bacteria Limit

....

Monitoring Component

Monitoring for this management measure will occur at existing monitoring stations located downstream of the CCNs, during TCEQ CRP monitoring. Additional monitoring may be needed and should be developed under Management Measure 9 of this document.

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Table 26. Management Measure 8.0: Reduce WWTF Contributions by Meeting Half of the Permitted Bacteria Limit

Potential Load Reduction (In cfu/year Enterococcus)	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
Mission River Watershed – N/A Aransas River Watershed – 1.58 trillion cfu/year Enterococcus	**Technical Assistance** TCEQ, TEEX **Financial Assistance** TCEQ EDAP USDA RUS-WWD Loans and Grants EPA/TWDB CWSRF	City personal and elected officials will be educated on the reasons for voluntarily adopting reductions in effluent concentrations to half of permitted bacteria limits and how to treat wastewater efficiently and identify noncompliance.	**Year 1:** Evaluate the option of treating effluent to meet half of permitted bacteria limits. Pursue funding for education programs. **Year2 - 5:** If found feasible, effluent will be treated to meet half the permitted limit for bacteria. Education programs will be developed and delivered as funding allows.	Number of WWTFs that have voluntarily adopted reductions in effluent bacteria concentrations to half of the permitted	**Year 1:** Ability to meet half the permitted bacteria limits in treated effluent evaluated. Pursued grant opportunities and/or education programs. **Years 2 – 5:** Treated effluent limits not exceeding half permitted effluent limits for bacteria. Developed and delivered education programs.	TCEQ CRP and additional monitoring developed under Management Measure 9	City of Beeville City of Sinton Town of Woodsboro Town of Refugio City of Taft Pettus MUD Skidmore WSC St. Paul WSC Tynan WSC Town of Odem

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Management Measure 9

Coordinate and Expand Existing Water Quality Monitoring in the Watershed

Description

Expanding water quality monitoring in the watershed has been a primary goal of the Mission River and Aransas River watersheds stakeholder workgroups. Current quarterly monitoring is not sufficient to aid watershed managers in identifying and addressing water quality problems. An expanded monitoring network that collects data at strategic locations on a refined time scale will aid entities involved in the management of their watersheds, identifying where problem areas for bacteria loading may be and when they are most problematic.

Monitoring is needed in the watersheds to accomplish two primary goals:
1) Better define where the problem areas are in the watersheds
2) Monitor long-term trends in water quality prior to and post BMP implementation

Further evaluation of potential sources in the watersheds is also needed. Some in-formation exists across the watersheds regarding potential sources of pollution. A physical survey of the stream network in the watersheds should be conducted and paired with a GIS source survey to further understand potential sources of bacteria in the watersheds.

To fulfill these needs, stakeholders will work together to facilitate development of proposals that refine desired water quality monitoring goals, objectives, tasks, and expected outcomes of special monitoring and source assessment projects. Funding will be sought through various sources including, but not limited to, the TCEQ's and TSSWCB's NPS programs, as well as the TGLO CMP, to implement this measure.

A volunteer monitoring program should also be utilized to conduct supplemental monitoring in the watershed to help target future BMP implementation. Stake-holders will work with Texas State University's Texas Stream Team Program to promote volunteer monitoring in the TMDL watersheds, with the goal of reactivating the two, currently inactive, monitoring sites established on the Aransas River and to establish additional volunteer monitoring sites on the Mission and/or Aransas rivers.

The data produced through the monitoring projects will provide valuable information to state agencies and watershed stakeholders, aiding them in better managing local water resources and planning future improvements in water quality. All additional monitoring projects identified will be conducted contingent upon the receipt of funding targeted specifically for additional water quality monitoring.

Some stakeholders in the TMDL watersheds have expressed concerns over the declining population of dung beetles (Phanaeus vindex MacLachlan; Onthophagus gazella Fabricius), which are known to help break down fecal matter. Research should be conducted to better understand the population dynamics of dung beetles and potential methods of mitigating the impacts of human and invasive species on these insects in an effort to increase their populations. Possible introduction of additional dung beetles may be needed in some areas to reestablish depleted beetle populations. More information about dung beetles can be found at <https://in-sects.tamu.edu/fieldguide/bimg146.html>.

The overall purpose of this management measure is to develop a more refined understanding of the spatial and temporal dynamics of bacteria loading in the Mission River Tidal and Aransas River Tidal segments. The water quality impairments in the two segments are based on quarterly data collected at a total of three sampling locations (TCEQ stations 12943, 12947, and 12948). To accurately identify and address the sources of water quality impairments in the watershed, an intensified monitoring effort is needed.

Education Component

Educating stakeholders about ongoing monitoring and how to access monitoring results would be beneficial to stakeholders by allowing them to track water quality in the Mission and Aransas Rivers throughout the implementation process. Easily accessible websites containing monitoring results and other related information, such as land use, hydrology, soils, and other data and information would be a valuable planning and management tool for watershed stakeholders as well as natural resource managers and the public. A good example of a website which currently provides valuable data and information to a watershed stakeholder group in south Texas is the Arroyo Colorado Watershed Partnership website: <http://arroyocol-orado.org/map/>.

A watershed website for the Mission and Aransas Rivers would be a beneficial learning tool for stakeholders as monitoring results can be easily accessed and tracked within a number of contexts. Furthermore, stakeholders should be educated on the various types of monitoring, benefits of different monitoring frequencies, identification of sites, etc., so that an appropriate monitoring regime could be developed that would capture the effectiveness of TMDL implementation. Forums for stakeholder input could be provided by local entities such as the coordinated monitoring meetings hosted by the NRA. Finally, stakeholders should be engaged by learning through experience utilizing a voluntary monitoring program.

Priority Areas

Priority areas for this management measure will be identified by the stakeholders as data quality objectives are refined.

Responsible Parties and Funding

Responsible Parties

Nueces River Authority
The NRA will continue to monitor the Mission River and Aransas River watersheds under the state's CRP, as funding allows.

TCEQ
The TCEQ's CRP will continue to support monitoring of the Mission and Aransas River watersheds.

TCEQ
The TCEQ Region 14 Office will continue to support monitoring efforts in the watershed through their involvement in coordinated monitoring efforts.

Stakeholders will assist in determining and refining data and data quality objectives for future monitoring programs so that activities can be targeted in priority areas.

Technical Assistance
Texas Water Resources Institute (TWRI) will assist, as funding allows, in coordinating monitoring efforts in the watershed; TWRI will assist watershed stakeholders in the development of monitoring proposals, and will manage the monitoring projects to ensure that they are completed as described.

Nueces River Authority – The NRA can provide monitoring services through TCEQ's CRP or through grant-funded projects, as funding allows. The NRA can also provide technical assistance to other responsible parties.

TCEQ CRP can provide further technical assistance in determining monitoring frequency and locations.

Financial Assistance

TCEQ and TSSWCB – The state's NPS and State General Revenue funds may be used to fund monitoring efforts in addition to the ongoing CRP efforts.

GLO – The CMP may also be a source of funds to continue and to enhance monitoring efforts.

Table 27. Estimated Costs

Entity	Activities Needed	Estimated Costs
Stakeholders and Monitoring Entities	Additional data collection, assessment of monitoring data and research (proposals for refinement of water quality monitoring, source assessment, and dung beetle research projects)	$370,000
Stakeholders/Volunteers	Volunteer monitoring activities ($5,000 annually)	$25,000

Measureable Milestones

Measurable milestones for this management measure will consist of:

- Number of education meetings for stakeholders on various types of monitoring projects
- Developed website where data can be easily accessed
- Developed proposal for funding of monitoring projects
- Establishment of a volunteer monitoring program

Progress Indicators

Progress indicators for this management measure consist of:

- Year 1 – Hold stakeholder meetings to provide monitoring education and dis-cuss local monitoring objectives; establishment of data objectives for monitoring projects; submittal of a proposal for funding of monitoring pro-jects; development/enhancement of a website containing monitoring data and other watershed information; establishment of a volunteer monitoring pro-gram
- Years 2 - 5 – Development of QAPPs for monitoring projects; initiation and continuation of volunteer monitoring and assessment monitoring; analysis of monitoring results and continued monitoring education for stakeholders

Monitoring Component

Monitoring for this management measure will occur at existing TCEQ CRP stations; however, monitoring projects can be developed under this management measure that may identify additional monitoring sites as the need arises.

Implementation Schedule

Year 1

Responsible parties will, as funding allows:

- Establish data objectives for monitoring and submit a grant proposal for funding monitoring projects
- Develop a website containing water quality data and watershed information
- Promote volunteer monitoring

Years 2 – 5

Responsible parties will, as funding allows:

- Develop QAPPs for monitoring projects;
- Initiate and continue both targeted monitoring and volunteer monitoring; analyze monitoring results and continue monitoring education

Estimated Loading Reductions

Loading reductions from additional water quality monitoring cannot be quantified.

Table 28. Management Measure 9.0: Coordinate and Expand Existing Water Quality Monitoring in the Watershed

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
N/A	**Technical Assistance** TWRI TCEQ TSSWCB Local Stakeholders Nueces River Authority **Financial Assistance** TCEQ and TSSWCB – CWA Section319(h)NPS programs and State GR funds GLO – CMP TWRI	Educate stakeholders about ongoing water quality monitoring and how to access results; place results on a website that can be located easily and which contains multiple information components such as land use, hydrology, soils, historical water quality data, and other information of interest to stakeholders. Establish voluntary monitoring program	**Year 1** Establish data objectives for monitoring and submit a grant proposal for funding of monitoring projects; develop website containing data and other information; establish a volunteer monitoring program in the TMDL watersheds **Years 2 – 5** Develop QAPPs for monitoring projects; initiate and continue both volunteer monitoring and assessment monitoring; analyze monitoring results and continue monitoring education.	Educate stakeholders on various types of monitoring projects Develop a website where data can be easily accessed Develop a monitoring proposal for funding Establish a volunteer monitoring program	**Year 1:** Delivery of education programs about monitoring; establishment of data objectives for monitoring projects; submittal of a proposal for funding of monitoring projects; development of a website containing monitoring data and other watershed information; establishment of a volunteer monitoring program **Years 2 – 5:** Development of QAPPs for monitoring projects; initiation and continuation of both volunteer monitoring and assessment monitoring; analysis of monitoring results and continued education with monitoring results	TCEQ CRP and additional monitoring developed under Management Measure 9	Nueces River Authority TCEQ – Clean Rivers Program TCEQ – Regional Office TSSWCB Stakeholders

TMDL for Greater Trinity River Region, Bacteria

2013, Specific and Very Detailed (in watershed-based plan, which includes the TMDL Implementation Plan)
https://www.tceq.texas.gov/assets/public/waterquality/tmdl/66trinitybact/66C_TrinityI-PlanApproved.pdf

Monitoring Coordination Implementation Strategies

The Project area is home to approximately 365 miles of rivers and streams as defined by U.S. Census Bureau's TIGER/Line (Topologically Integrated Geographic Encoding and Referencing) data set (USCB, 2012). One hundred and fifty three of those miles are impaired by elevated *E. coli* levels*.* Understanding the condition of rivers and streams in the region through monitoring and analyzing monitoring data is critical for developing effective plans for maintaining, managing, and restoring the waterways.

There are several different surface water monitoring programs with data that help demonstrate the effectiveness of BMPs and other implementation strategies discussed in this I-Plan. One of the best known is the Clean Rivers Program (CRP). Established in 1991, the Texas Clean Rivers Program is a state fee-funded, non-regulatory program created to provide a framework and forum for managing water quality issues in a more holistic manner. The focus of the program is to work at the watershed level, within each river basin, by coordinating the efforts of diverse organizations. CRP is comprehensive — collecting samples region-wide, and should remain one of the primary sources of data for ambient water quality. This monitoring network includes dozens of sites and provides long-term data accredited through the National Environmental Laboratory Program (NELAP) for the evaluation of ambient conditions in the region's waterways. Monitoring sites are strategically chosen to give the greatest degree of coverage while also attempting to isolate individual waterways or their smaller units to allow for the accumulation of data with direct relevance to local conditions. Monitoring is conducted under a regional Quality Assurance Project Plan (QAPP) (TCEQ, 2012b).

The Regional Wet Weather Characterization Program (RWWCP) is a NCTCOG-coordinated program for Phase I MS4 regulated entities with stormwater permit requirements to monitor stormwater during wet weather (rainfall) events. NCTCOG assists local entities through a cooperative regional monitoring program designed to meet these requirements. The regional program includes the cities of Dallas, Fort Worth, Arlington, Garland, Irving, Plano, and Mesquite; the local districts of the Texas Department of Transportation (TxDOT); and the North Texas Tollway Authority (NTTA). Data is gathered quarterly, analyzed by a NELAP-accredited laboratory, and an annual report is provided to participants. The program operates in five-year terms in conjunction with the TPDES permit term.

Sampling resulting from an IDDE investigation can be useful in determining and eliminating some bacterial sources. An illicit discharge is any discharge to the MS4 not composed entirely of stormwater, except for discharges allowed under a TPDES permit. Non-stormwater discharges can originate from direct connections to the storm drain system from business or commercial establishments (illicit connections), or indirectly as improper surface discharges to the storm drain system.

Another potential source of information is effluent monitoring. Since 2010, new and renewed WWTF permits include an effluent monitoring requirement for *E. coli*. Currently required monitoring frequency is detailed in Table 6.

Texas Stream Team is a network of trained volunteers and supportive partners working to gather information about surface water quality in the state and ensure the information is publically available. Established in 1991, Texas Stream Team is administered through a cooperative partnership between Texas State University, TCEQ, and the EPA. For the purpose of this I-Plan, Stream Team volunteers are stakeholders in the Project area committed to helping fill gaps in monitoring data wherever possible.

The Coordination Committee encourages all feasible use of monitoring programs and the collective analysis of their respective data to help determine the efficacy of the implementation strategies within this I-Plan.

Implementation Strategy 6.0: Routine sampling

Stakeholders currently participating in voluntary or permit-required monitoring programs, such as CRP, RWWCP, and WWTF effluent monitoring, will continue routine sampling as feasible. For voluntary programs such as CRP, the routine sampling will occur at the monitoring stations detailed in the QAPP and as resources allow. To help determine the efficacy of implementation strategies, the Monitoring Coordination technical subcommittee will provide analysis of routine sampling results for the Coordination Committee. Figure 11 shows the CRP monitoring locations on impaired segments in the Project area, while Table 39 summarizes the implementation strategy for routine sampling.

Table 39. Implementation Strategy 6.0 Summary — Routine sampling

Targeted Source(s)	All potential sources
Estimated Potential Load Reduction	IS 6.0 will allow tracking and verification of bacteria load reductions and may result in a 2% reduction over 25 years
Technical and Financial Assistance Needed	Technical: some technical assistance may be necessary should entities new to monitoring wish to participate Financial: grants or existing funding as appropriate
Education Component	Some education of governing bodies may be necessary to start, maintain, or expand monitoring programs
Schedule of Implementation	As resources are available, the implementation of this activity will begin immediately and will continue for the entire implementation process
Interim, Measurable Milestone	Collective analysis of monitoring data
Progress Indicators	Number of results analyzed Ability to compare results to efficacy of BMPs
Monitoring Component	Monitoring Coordination technical subcommittee will report analytical results to NCTCOG
Responsible Entity	Monitoring Coordination technical subcommittee will collectively analyze data to determine efficacy of implementation strategies NCTCOG will compile results into a report for the Coordination Committee

Implementation Strategy 6.1: Monitoring coordination forum

A coordinated, regional approach to monitoring and data analysis is a key component of this implementation strategy. As resources are available, NCTCOG will facilitate a forum of monitoring participants, including those involved with CRP, RWWCP, IDDE, wastewater treatment effluent monitoring, and the Texas Stream Team. The schedule for forum meetings will be determined by forum participants, although meetings will take place at least annually. Table 40 details the strategies for the monitoring coordination forum.

6.1.1: Existing *E. coli* monitoring network evaluation

As part of the monitoring forum, the stakeholders will evaluate the existing *E. coli* monitoring network in the impaired subwatersheds and refine it based upon data gaps. Data considered may include CRP, RWWCP, IDDE monitoring, wastewater treatment facility effluent monitoring, and data collected by Texas Stream Team.

6.1.2: New source review for data

The monitoring forum will identify sources of data and existing monitoring which may not be appropriate for screening, for example monitoring data that are not collected under a QAPP or analyzed under a NELAP-accredited program, but that could be helpful in identifying bacteria sources.

6.1.3: Data assessment of overall trends for BMP efficacy

As monitoring results become available, the forum participants will evaluate CRP and RWWCP data to assess overall trends in water quality within the impaired water segments in the Greater Trinity River basin. These analyses may be used to determine efficacy of BMPs, overall improvement or degradation within the applicable sub-basins, and the potential need to implement additional BMPs. Data analysis results will be shared with the Coordination Committee annually.

6.1.4: Funding in relation to gaps in sampling data

Monitoring forum participants, including TRA, may work with TCEQ to address available funding in response to gaps in sampling data.

6.1.5: Reevaluating monitoring technologies for pilot projects and/or research partnerships

Monitoring forum participants will continue to reevaluate monitoring technologies, such as surrogate testing, no less than every five years for use in pilot projects or partnerships with researchers in local universities.

6.1.6: Evaluate need for online data consolidation and access

Accessing monitoring data online remains difficult for those without technical backgrounds in the monitoring field. Monitoring forum participants and the Coordination Committee will periodically evaluate the need for online data consolidation and access.

Table 40. Implementation Strategy 6.1 Summary — Monitoring coordination forum

Targeted Source(s)	All potential sources
Estimated Potential Load Reduction	IS 6.1 – 6.1.6 will allow tracking and verification of bacteria load reductions and may result in a 2% reduction over 25 years
Technical and Financial Assistance Needed	Technical: some technical assistance may be necessary should entities new to a given type of monitoring wish to participate Financial: grants or existing funding as appropriate
Education Component	Some internal education may be necessary for some forum participants on new or existing monitoring methods or programs
Schedule of Implementation	As resources are available, the implementation of this activity will begin immediately and will continue for the entire implementation process with forum meetings taking place annually at a minimum
Interim, Measurable Milestone	Existing *E. coli* monitoring networks evaluated New source review for data Data assessment of overall trends for BMP effectiveness Reevaluation of monitoring technologies Online data consolidation and access evaluation
Progress Indicators	Number of existing monitoring sites evaluated Number of data gaps identified Number of new non-traditional monitoring sources identified Number of data assessments (reports) in relation to BMP effectiveness Number of pilot projects evaluated
Monitoring Component	NCTCOG will collect results of evaluations, assessments, and other results from the Monitoring Coordination Forum
Responsible Entity	Monitoring Coordination Forum or Monitoring Coordination technical subcommittee will evaluate existing *E. coli* monitoring and new sources for data, reevaluate monitoring technologies, evaluate online data access, and assess data for BMP effectiveness NCTCOG will compile results into a report for the Coordination Committee

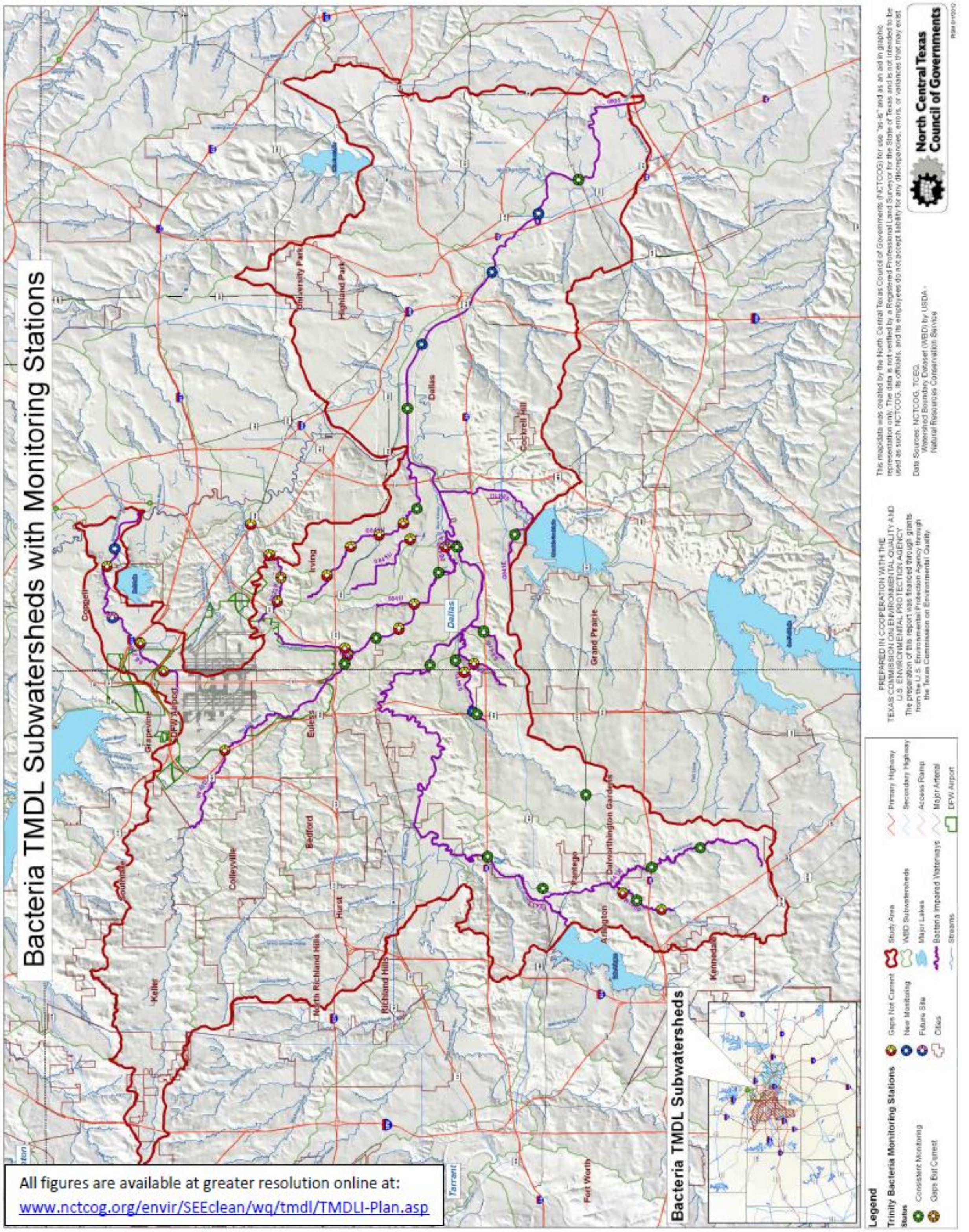
Implementation Strategy 6.2: Source identification and monitoring review

Accurate identification and quantification of *E. coli* sources in the project area is needed. Without this information it is difficult to accurately assess the impact of any one implementation strategy, or for that matter, the impact of any one source. As explained in Table 41, in 2018 the Coordination Committee will review monitoring techniques and determine whether it is appropriate, in terms of financial and technical viability, to request the TCEQ make changes in their monitoring with particular regard to source identification.

Table 41. Implementation Strategy 6.2 Summary — Source identification and monitoring review

Targeted Source(s)	Species-specific and/or human versus non-human contributors to bacteria loading
Estimated Potential Load Reduction	IS 6.2 may result in a 10% reduction over 25 years of calculated bacteria loading by allowing better identification and targeting of bacterial sources, with consequent reductions in loading
Technical and Financial Assistance Needed	Technical: assistance from experts in source identification may be necessary to assist Coordination Committee in decision-making Financial: new source identification methods may have different costs than known methods
Education Component	The Coordination Committee and TCEQ will need to be aware of technological and cost changes of source identification
Schedule of Implementation	In 2018 the Coordination Committee will review monitoring techniques and technologies to see if requesting source identification by TCEQ is appropriate
Interim, Measurable Milestone	New source identification methods and costs identified
Progress Indicators	Greater source identification results available to better target effectiveness of implementation strategies
Monitoring Component	Report to the Coordination Committee on new source identification availability and costs
Responsible Entity	Monitoring Coordination technical subcommittee will identify and evaluate new methods, techniques, and costs for source identification NCTCOG will prepare a report of the results from the technical subcommittee for the Coordination Committee The Coordination Committee will evaluate new methods and determine if a request to TCEQ for guidance or approval on the new method or type of test is warranted NCTCOG will coordinate dialogue between stakeholders and TCEQ to facilitate TCEQ consideration, and possible adoption or use of new source identification methods.

Figure 11. Monitoring Locations on Impaired Segments Map



All figures are available at greater resolution online at:
www.nctcog.org/envir/SEEclean/wq/tmdl/TMDLI-Plan.asp

Utah

Chalk Creek Watershed Coordinated Resource Management Plan, Coliform, Nitrates, Phosphate & Sediment

1994, Specific and Detailed
https://documents.deq.utah.gov/water-quality/watershed-protection/total-maximum-daily-loads/DWQ-2015-006571.pdf

Monitoring and Evaluation

Monitoring and evaluation will be used to document progress towards achieving improved water quality conditions as nonpoint source control programs are implemented. The effectiveness of BMPs and whether the objectives of the Chalk Creek Coordinated Resource Management Plan are being met will also be documented.

All data collection and water quality sampling will be conducted by the Department of Environmental Quality. Monitoring of riparian vegetation, stream geomorphology and fishery population/productivity and photo points will be collected by the NPS Interagency Monitoring Work Group.

Land use and BMP implementation tracking will be conducted by the Soil Conservation Service and Summit Soil Conservation District.

The Utah Division of Wildlife Resources is monitoring the fishery at selected sites. They are conducting shocking studies to determine species numbers and production (in pounds) of each species.

Monitoring sites are located at critical points along the course of Chalk Creek. Information obtained will help determine the trend of water quality at that site, and if the BMPts applied are effective.

Water quality parameters that are being monitored in Chalk Creek drainage include TSS, total phosphorous, total coliform, fecal coliform, total dissolved phosphorous, TKN, N02, NO3, NH3, oil and grease, water flows, fish habitat, geomorphic and vegetation.

The eight official monitoring sites established by the Utah Department of Environmental Quality (DEQ) are at the following locations:

- -Chalk Creek at US-189 crossing
- -Chalk Creek above confluence with South Fork
- -So. Fork Chalk Creek above confluence with Chalk Creek
- -Chalk Creek 4 miles east of Upton
- -Chalk Creek above confluence with East Fork
- -East Fork abovewconfluence with Chalk Creek
- -Chalk Creek at the Utah/Wyoming state line
- -Huff Creek above confluence with Chalk Creek

Specific monitoring procedures outlined by DEQ are found in the monitoring plan for the Chalk Creek Watershed.

Watershed Restoration Action Strategy for Lower Bear River

2002, Specific but Brief
https://documents.deq.utah.gov/water-quality/watershed-protection/total-maximum-daily-loads/DWQ-2002-001842.pdf

7.3 Recommended Monitoring Program

The main objective of a water quality investigation will be to document the water quality conditions above, at and below the current project location.

It is recommended that grab samples be obtained from the Bear River above and below Cutler Reservoir and at Corinne. Samples should also be collected in the Malad River, just upstream of the confluence with the Bear River. It is recommended that samples be collected quarterly, and follow the major hydrologic conditions including upper and lower basin runoff as well as summer and winter baseflow. Parameters will include nutrients (nitrogen and phosphorous), total suspended solids, dissolved oxygen and temperature. All sampling procedures should follow Standard Methods (APHA 1999).

TMDL for Little Cottonwood Creek, Dissolved Zinc

2002, Specific but Brief
https://documents.deq.utah.gov/water-quality/watershed-protection/total-maximum-daily-loads/DWQ-2015-006585.pdf

5.2 TMDL Monitoring Recommendations

A water-monitoring program needs to be conducted to further validate or define loading sources, and to monitor stream responses to implementation actions. The program will be designed to measure stream flows conditions over an entire year, encompassing both the spring-runoff period and the low flow period. At a minimum, dissolved zinc, hardness, and flow should be monitored at the target points (LCC below Howland, LCC below Wasatch, and LCC below Tanner Flat). Additional samples should also be collected from LCC above the Howland Tunnel, and from the Howland Tunnel and Wasatch Drain Tunnel discharge points (bypass and Snowbird cogenerations plant) to quantify these specific loads. Monitoring should be performed on a monthly basis to better quantify the variability between high and low flow periods. All monitoring activities should be coordinated between SLC Service Area No. 3, Snowbird, SLC, and UTDEQ to ensure that all conditions (e.g., discharge rates from the Wasatch Drain Tunnel) can be documented during data collection activities. The load allocations set forth in Section 4 of this report should be refined if warranted by the results of this additional monitoring.

Macroinvertebrate populations will also be sampled on an annual basis as an additional gauge to stream response to implementation actions. Monitoring sites will be set up along the creek to match those sites that have been monitored historically. These same monitoring sites will also be evaluated for microhabitat during annual sampling, so that macroinvertebrate data can be developed that is consistent in both location and time.

A monitoring plan addressing the above recommendations, including funding and individual responsibilities, will be developed cooperatively by the members of the Little Cottonwood Canyon Watershed Group.

TMDL for Brough, Red Fleet, and Steinaker Reservoirs, Dissolved Oxygen

2008, Specific but Brief

https://documents.deq.utah.gov/water-quality/watershed-protection/total-maximum-daily-loads/DWQ-2018-013730.pdf

5.5 Monitoring

Under the Division's lake and reservoir assessment program these waterbodies and their tributaries will be sampled twice every other year. The objectives of this monitoring plan will be to determine existing water quality conditions, evaluate water quality trends, and establish achievable water quality goals through the development of tiered aquatic life uses. The purpose of this monitoring plan will be to provide productivity data including lake transparency values, phosphorus concentrations and chlorophyll-a levels and other chemical and physical parameters including dissolved oxygen, temperature, and pH.

Brough Reservoir will be sampled during even years (2008, 2010, etc.) at two locations on the reservoir (Storet Sites 5932430 and 5932440) and at the tributary site, Canal above Brough Reservoir (Storet Site 5932450). Steinaker and Red Fleet Reservoirs will be sampled during odd years (2009, 2011, etc.) at two locations on Steinaker Reservoir (Storet Sites 4937550 and 4937570) and at three locations on Red Fleet Reservoir (Storet Sites 5937650, 5937660, and 5937730). The tributary sampling location for Steinaker Reservoir is Steinaker Ditch above Steinaker Reservoir (Storet Site 4937520) and the tributary sampling location for Red Fleet Reservoir is Big Brush Creek above Red Fleet Reservoir (Storet Site 4937860).

TMDL for Colorado River Watershed, Selenium

2014, Specific but Brief

https://documents.deq.utah.gov/water-quality/watershed-protection/total-maximum-daily-loads/DWQ-2015-006573.pdf

9.0 Future Monitoring

Long-term monitoring of water quality will be conducted at the four locations used in this study, and will be used to evaluate the effects of BMPs, as well as progress toward meeting water quality goals and supporting beneficial uses.

The water quality monitoring stations used in this TMDL are all located on the main stem of the Colorado River. Data from these stations may include storm flows and runoff events captured during routine monitoring visits; however storm flows are not specifically targeted. Additionally, a large portion of the watershed is drained by dry washes that only flow after storm events. Pollutant loads generated from storm events in these drainages are not captured by the current water quality monitoring strategy.

TMDL for Upper Nine Mile Creek Watershed, Temperature

2017, Specific but Brief

https://documents.deq.utah.gov/water-quality/watershed-protection/total-maximum-daily-loads/DWQ-2017-002713.pdf

9.0 Future Monitoring

Long-term monitoring of water quality including both grab and high frequency data should be conducted throughout the watershed to evaluate the effects of BMPs and any progress toward meeting the water quality goals and supporting beneficial uses. Continued monitoring will allow for the periodic reevaluation of the implementation strategies and goals defined in this TMDL document. Should projects designed to reduce temperature fail to show reductions after 7 years following substantive implementation, UDWQ will explore developing site specific temperature criteria that better represent attainable conditions. Future monitoring efforts should include:

- Characterization of irrigation return flows
- Photo documentation to compare changes in geomorphology, streambanks, riparian conditions, flow levels, and shade
- Aerial photo analysis to monitor the overall health of the riparian corridor and composition of riparian vegetation
- Biological monitoring should include both macroinvertebrate, fishery, and beaver communities
- Deployment of high frequency monitoring probes to measure both temperature and flows especially in the Upper Nine Mile Creek where flow data is lacking
- Continue baseline water quality sampling at critical locations: Minnie Maud above Confluence of Nine Mile Creek, Argyle Creek above Confluence Nine Mile Creek, Nine Mile Creek at Cottonwood Glen, and new additional site of Nine Mile Creek below Confluence of Argyle Creek

Virginia

Guidance for Implementation Plans

2017

https://www.deq.virginia.gov/home/showpublisheddocument/6849/637511609521170000

8.3.2 Water Quality Monitoring Plan

An appropriate monitoring plan documents the schedule for and location of water quality monitoring, organization(s) responsible for monitoring, and monitoring procedure(s). If possible, monitoring should be conducted at the same sites used during TMDL development to evaluate changes in water quality once BMPs have been implemented. Also, monitoring should be conducted where needed to assess the effectiveness of targeted aggregated efforts.

Virginia's Water Quality Monitoring Strategy states that for bacteria TMDLs, *E. coli* will be the parameter of concern in freshwater streams, Enterococcus in saltwater, and fecal coliform in shellfish-growing areas. For benthic TMDLs, the assessment should focus on biological monitoring. Implementation monitoring will generally be the same as that done in TMDL development. However, modifications may be made to reflect the needs of the IP. DEQ staff will determine sites, frequency, and duration of implementation monitoring.

Planning an effective monitoring strategy during TMDL Implementation Plan development

There are many things to consider when monitoring the success of implementation and measuring water quality milestones. These may include

- identifying sources of monitoring data - see above text for more information on potential sources
- matching parameters to be monitored with impairment. For a bacterial impairment, water quality analysis should include the appropriate bacteria indicator, e.g., *E. coli* enumerations. For a general standard (benthic) impairment, water quality analysis should include biological monitoring or monitoring of other related indicators that measure reductions in pollutant loadings achieved by BMP implementation (e.g., measuring turbidity or bank stability to assess sediment reduction).
- setting a timeline for achieving water quality milestones

TMDL for Ash Camp Creek

Specific but Brief

Tracking BMPs Implementation and Water Quality Monitoring

Agricultural BMPs will be tracked through the Virginia Agricultural Cost-Share Program. Urban/residential BMPs will be tracked in cooperation with the Southside SWCD and Charlotte County Erosion and Sediment Control Program.

Improvements in water quality will be determined in both impaired watersheds through monitoring conducted by the DEQ's biological monitoring program. The monitoring data include physical parameters (temperature, dissolved oxygen, pH and conductivity) and a host of benthic communities – aquatic habitat and micro-invertebrates. Based on the Stream Condition Index, DEQ determines the aquatic health of a water body. Biological sampling at the DEQ stations (Table 14) will be performed at least every other year in spring and fall seasons. These stations are shown in Figures 1 and 3 for Ash Camp Creek and Twittys Creek watersheds, respectively. The samples will be collected and evaluated by DEQ using established biological monitoring protocols. Monitoring will continue to ensure data update and to evaluate the effectiveness of the implementation actions.

Table 14. DEQ's water quality monitoring stations in Ash Camp Creek and Twittys Creek watersheds.

Station ID	Stream name	Location	Monitoring
4AACC002.60	Ash Camp Creek	Upstream side of Route 654 bridge	Biological
4AACC004.87	Ash Camp Creek	Upstream side of Conservation Road bridge (private)	Biological
4ATWT003.36	Twittys Creek	Downstream of Route 642	Biological
4ATWT006.40	Twittys Creek	Upstream of Drake Branch on Route 47	Biological

TMDL for Beaver Creek Watershed, Contaminant

Specific and Detailed

DEQ MONITORING

Virginia's 1997 Water Quality Monitoring, Information and Restoration Act requires that TMDL implementation plans include measurable goals and milestones for attaining water quality standards. Implicit in those milestones is the requirement of a method to measure progress. Implementation progress will be evaluated through water quality monitoring conducted by VADEQ and any citizen monitoring support that may develop as implementation progresses. VADEQ presently has 15 Beaver Creek and Little Creek monitoring locations that will be monitored continually or on a rotational schedule.

VADEQ will continually monitor two locations, State and 8th Street, in the Beaver Creek watershed and at Paty Lumber State Street in the Little Creek Watershed. The Beaver Creek Station is the most downstream station in the Virginia portion of the stream, 6CBEV015.27. Both stations will be sampled monthly beginning in January 2007 for the following twelve months. The following parameters will be collected at the 6CBEV015.27 monitoring station: *E.coli* bacteria, temperature, dissolved oxygen, pH, specific conductance, total nitrogen, total phosphorus, total solids, and total suspended solids. The following parameters will be monitored at the 6CLTL000.26 station: temperature, dissolved oxygen, pH, conductivity and *E. coli*. Benthic macroinvertebrate sampling will occur in the spring and fall at 6CBEV023.99.

At the time of the development of the Beaver Creek TMDL, fecal coliform was the indicator species for Virginia's bacteria water quality standard. In 2003, Virginia began the transition to an *E. coli* water quality standard. *E. coli* is a subset of fecal bacteria that has been shown to have a stronger correlation to gastrointestinal illness than fecal coliform. Assessment of implementation progress will rely on results of the *E. coli* sampling. At the end of 2007, a data review will determine whether monitoring will continue, the frequency adjusted, or postponed for a monitoring cycle.

In addition to DEQ's monitoring, there is interest from John S. Battle High School, Virginia Highlands Community College, and Emory and Henry College to assist in the water quality monitoring plan for Beaver Creek and Little Creek Watersheds. Citizen monitoring is a great screening tool for feedback on a stream and to determine if the stream is better or worse. There is a strong possibility for volunteer manpower for biological monitoring in Beaver Creek and Little Creek Watersheds. Funding will need to be acquired to fund monitoring equipment for citizens.

TMDL for Piankatank River, Contaminant

Specific and Detailed

Monitoring

Improvements in water quality and implementation progress will ultimately be determined through monitoring conducted by VDH-DSS at the established bacteriological monitoring stations in accordance with its shellfish monitoring program. DEQ will continue to use data from these monitoring stations and related ambient monitoring stations to evaluate improvements in the bacterial community and the effectiveness of TMDL implementation in attainment of the general water quality standard. VDH-DSS water quality monitoring data can be accessed using the agency's GIS Data Viewing tool which uses Google Earth at: http://www.vdh.state.va.us/EnvironmentalHealth/Shellfish/documents/ShellfishSanitation.kml. (also see Figures 1-3)

Additional monitoring may be conducted by citizen monitors to better identify bacteria source "hot spots" and the effectiveness of implementation actions. Citizen monitors will use Coliscan Easygel to perform monthly monitoring of *Escherichia coli (E. coli)* bacteria. Through comparison studies performed by DEQ, Coliscan has proven to be a good screening tool in estimating *E. coli* density. In addition, Coliscan Easygel is about 1/10th the cost of typical laboratory monitoring, allowing for testing additional sample sites in a watershed to identify potential *E. coli* "hot spots". Although fecal *Enterococcus* and fecal coliform are the correct bacteria indicators for salt or brackish water, the citizen provided Coliscan *E. coli* data may be used to gauge the success of implementation in reducing the amount of fecal bacteria entering the streams. This citizen provided data cannot be used for the purpose of delisting the streams based on observed improvements. Some possible groups to conduct such monitoring in the area were mentioned during the working group sessions, both for hotspot and BMP effectiveness monitoring.

Washington

Effectiveness Monitoring Reports

https://fortress.wa.gov/ecy/publications/UIPages/PublicationList.aspx?IndexTypeName=Topic&NameValue=Effectiveness+Monitoring+for+Water+Quality+Improvement+Projects+(TMDLs)&DocumentTypeName=Publication

TMDL for Lower Okanogan River Basin, DDT and PCBs

2004, Specific but Brief
https://fortress.wa.gov/ecy/publications/documents/0410043.pdf

Monitoring Strategy

The persistent natures of DDT and PCBs in the environment truly make them a legacy of past practices. While these toxic compounds continue to persist in the environment their effective levels are reduced over time through degradation and by natural attenuation through dilution and capping. The natural processes resulting in the lower exposure of aquatic life to the contaminants will play a major role in the success of this TMDL. Monitoring fish tissue concentrations of these contaminants will be the most effective means to judge the progress of environmental improvement.

Analytical testing results for fish tissue sampling for the 2003 TMDL Technical Assessment report show DDT and PCB values that appear to be substantially lower than the fish tissue samples that were taken in the period of 1984 – 1995. Unfortunately, there is insufficient data from 1985-1995 to determine if this apparent reduction of contamination in fish tissue is truly significant. The fish tissue data from the 2003 Technical Assessment report will serve as the baseline data to judge progress of environmental improvement. Repeating the fish tissue sampling efforts on a regular cycle of 5 years is recommended for the tracking of effective water quality improvements.

TMDL for Upper Chehalis River, Fecal Coliform

2004, Specific and Detailed
https://fortress.wa.gov/ecy/publications/documents/0410041.pdf

Monitoring Strategy Recommendations

The Upper Chehalis River watershed consists of many segments, tributaries, and sub-tributaries that do not meet Washington State water quality standards for fecal coliform bacteria. Target load reductions established in this report should help focus and prioritize cleanup strategies in impaired segments. The following recommendations are made to help in this effort.

• Use the highest reduction targets to prioritize where resources should be invested first.

• Begin implementation of best management practices (BMPs) first at the most upstream segment, tributary, or sub-tributary. Monitoring should follow wherever BMPs are implemented.

• As the segment, tributary, or sub-tributary with the worst problem is brought into compliance with water quality standards, the monitoring effort should be moved to a less severe area where the next set of BMPs would be implemented.

• Basic BMPs such as fencing and riparian buffer zones to keep cattle out of rivers and streams should be required throughout the watershed. Also, failing on-site sewage treatment systems within the watershed need to be replaced to improve the long-term health of the watershed.

Ongoing monitoring of water quality trends and activity implementation is essential in order to:

• Show where water quality is improving
• Help locate sources of pollution
• Help indicate effectiveness of cleanup activities
• Document achievement of compliance with state water quality standards

In addition to monitoring segments that have recommended target reductions, other segments are recommended for monitoring (Table 21). These segments have limited data that show potential exceedances of the water quality standards.

Table 21. Segments with limited data and recommended for further monitoring.

*Chehalis River	RM 74.6 (below Dillenbaugh Creek)
Waterbody	Monitoring Location
Chehalis River	RM 106.3
Coal Creek	RM 0.87 (at National Avenue)
Elk Creek	RM 0.5 (near Doty)
NF Lincoln Creek	RM 0.8 (at Lincoln Creek Road)
SF Lincoln Creek	RM 1.4 (at Lincoln Creek Road)
NF Newaukum River	RM 0.3 (at Forest)
SF Newaukum River	RM 0.2 (at Forest)

* The proposed 2002 listing is being changed from Category 5 to Category 2 due to insufficient data.

Water quality monitoring plans will continue to be implemented in different parts of the watershed. Ecology is developing a comprehensive monitoring plan to help focus and coordinate the monitoring being planned by various parties in the Chehalis Basin. These include those with direct responsibility for implementing the TMDL, as well as those who serve in a coordinating role such as the Chehalis Basin Partnership (CBP) and a water quality committee of the CBP.

Ecology’s comprehensive monitoring plan is due for completion during the summer of 2004. The plan will identify the parties doing sampling as well as what, where, when, how, and why. The plan is intended to serve as a Quality Assurance Project Plan that can guide the monitoring work either individually or collectively by different parties throughout the basin. The monitoring plan will be one outcome of a Detailed Implementation (cleanup) Plan for the Chehalis basin.

This TMDL study used the most current monitoring data available. While some data were from last year (2003), others were from previous years. Land-use changes since the sampling took place may have resulted in changes in pollution levels. Implementation of a monitoring strategy should provide a more accurate picture of current water quality conditions in the basin. Ongoing monitoring will help prioritize areas and strategies for cleanup**.**

If ambient monitoring data show that progress towards targets is not occurring, compliance water quality monitoring will occur. Compliance monitoring will be designed to verify preliminary data and then identify the specific sources of fecal coliform bacteria. Sampling over time will be adjusted to locate the sources by narrowing the geographic area where contamination is occurring.

A new sampling site in the Upper Chehalis River was added to Ecology's ambient monitoring program in October 2001. This station at Prather Road will be in place at least through 2004.

Ecology, and EPA with use of their 319 nonpoint water quality protection grants, will continue to support monitoring work by others throughout the basin:

- The Chehalis River Council will continue their Upper Chehalis sampling through 2004.
- Grant funding is expected to supplement monitoring by conservation districts and local volunteer groups.
- A water quality education and monitoring project operated by Educational Service District 113 and the Chehalis Basin Education Consortium will continue to involve 4th through 12th grade and community college students. By testing chemical and biological parameters, the students will learn scientific methods and develop a better understanding and appreciation for their watershed.

Data provided by non-Ecology sources will have positive informational value to help document progress being made to meet the TMDL targets. Results also will help to refine and adapt water cleanup strategies of the TMDL.

TMDL for Lower Yakima River, Suspended Sediment

2006, Specific and Detailed

https://fortress.wa.gov/ecy/publications/documents/0603014.pdf,
https://fortress.wa.gov/ecy/publications/documents/9810202.pdf

LOWER YAKIMA RIVER SUSPENDED SEDIMENT TMDL

Monitoring Strategy

Monitoring is a required component of the TMDL process. Monitoring allows direct evidence of target compliance or control measure effectiveness. It also can provide the data necessary to modify or adjust targets in specific situations. The TMDL schedule contains elements requiring monitoring for both compliance, and target re-evaluation and development

Turbidity and TSS monitoring will be necessary to check progress with the turbidity criterion compliance along the main stem Yakima River. Compliance monitoring requires establishing a background turbidity site, and at least one compliance check point at the Kiona gage at Benton City (RM 29.9). Ecology proposes establishment of three more sites to ensure turbidity compliance within the reach: 1) the abandoned Parker railroad trestle below the Sunnyside Dam (RM 103.7); 2) a site between the mouths of Granger Drain and Toppenish Creek (approximately RM 81); and 3) Euclid bridge (RM 55). Any mainstem monitoring at sites on or bordering the Yakama Reservation will be carried on in cooperation with the Yakama Nation. Full scale monitoring as outlined in this plan will be initiated in the two years preceding the five-year target date. Until that time, ambient monitoring by Ecology on the mainstem will proceed on a monthly basis. Background turbidity and TSS will be measured at 2 sites, at Harrison Bridge on the Yakima River (RM 121.2) and at Ramblers Park Bridge on the Naches River (RM 3.7). From data gathered at these sites the theoretical mixed TSS and turbidity will be calculated. Monthly ambient monitoring has already been initiated at these sites.

The TMDL monitoring and evaluation concluded that most TSS effects from irrigated agriculture are observed by Yakima mainstem RM 29.9, the Kiona gage at Benton City. However, West Richland at Van Giesen bridge (RM 8.4) could be an alternative compliance site since it would place controls on the entire lower main stem except for the Kennewick Irrigation District return via the Amon Wasteway (RM 2.1). Sampling will be expanded or moved to West Richland as progress is made upstream of Benton City. Data will be used to ensure that water quality improvements are transferred downstream by the year 2007. Amon Wasteway will be evaluated and will be monitored as part of the assessment. If it is considered a significant TSS input, it will be placed under the same reduction schedule as the returns and tributaries upstream.

Drains and tributaries will be monitored at locations used for the TMDL evaluation unless more appropriate sites are chosen. To the extent possible, tributaries and drains will be sampled for TSS and turbidity at the same time as main stem sites. Continuous discharge monitoring stations will be established at the water quality monitoring sites or instantaneous discharge measurements will be obtained at the time samples are collected.

Monitoring will be conducted every two weeks during the irrigation season (*i.e.*, usually between March 20 and October 20). This will normally provide 15 data points per site to calculate 90th percentile values for control and compliance checks. Sampling order should follow upstream to downstream. Sample timing will be roughly synchronized with discrete blocks of water by evaluating gage data or calculating river time of travel (Hubbard *et al.*, 1982).

A depth integrating sampler will be employed for sampling at main stem sites at three or more points along the cross-section. Sulphur Creek, Spring Creek, Granger Drain and Moxee Drain will also be sampled at multiple points along the site cross-section. The smaller drains require only one depth integrated grab sample. A ratio turbidimeter will be used to continue to check the TSS to turbidity relationship.

Pesticide samples will be collected in conjunction with turbidity and TSS samples, especially in the priority drains and tributaries as turbidity and TSS levels are reduced. Main stem sample collection will continue as well. Historically, the peak concentrations of DDT and other organochlorine pesticides occur in June and July, so samples will be collected at that time. Analytical quantification limits must be at or below the chronic aquatic life criteria for the DDT metabolites and dieldrin.

Monitoring of organophosphorus pesticides detected in the TMDL "Evaluation Report" will continue to document any further water quality problems related to their use. Sampling periods will occur during periods of application to crops.

Of the several drainages in the Lower Yakima Basin within the jurisdiction of the State of Washington, four of these, Moxee Drain, Granger Drain, Sulphur Creek and Snipes/Spring Creek are major contributors of suspended sediment to the lower Yakima River. At several sites in each of these drainages one or more public entities, other than Ecology, is conducting regular water quality monitoring for a number of parameters, including suspended solids and turbidity. North Yakima, South Yakima and Benton Conservation Districts and the Roza/Sunnyside Valley Irrigation District Joint Board of Control are conducting monitoring, currently funded under local support, Centennial Clean Water Fund and 319 Clean Water Fund grants. Monitoring resources need to be coordinated so that data collected by other agencies and groups are useful to the TMDL effort and vice versa. Ecology will support efforts to coordinate monitoring, and be a key participant in developing data quality standards, data storage and exchanges, geographical information system (GIS) coverages, and cooperative monitoring agreements.

The North Yakima Conservation District includes the areas drained by Moxee Drain. NYCD has been sampling for turbidity and sediment at several sites in the drain since 1994. This monitoring project is in conjunction with the NYCD's ongoing project to educate growers and facilitate the conversion of furrow irrigated lands to drip or sprinkler. The monitoring program is funded through a Centennial Clean Water Grant and is budgeted through the irrigation season of 1999. (see Appendix 1, Moxee Watershed Plan and Assessment)

South Yakima Conservation District is conducting a sampling and monitoring program at 18 sites in the Sulphur Creek Drainage and 2 additional sites in the Giffin Lake Drainage. This project has been underway since 1997 and is funded through December 1999 under a 319 Clean Water Fund grant. The purpose of the project is to monitor reductions in sediment and nutrient transport in the return drains as irrigation conversion progresses. SYCD is facilitating demonstration projects in this drainage which emphasize alternatives to furrow irrigation. Partnering with SYCD, the Natural Resource Conservation Service is providing cost share money as incentives for farmers to switch from furrow irrigation techniques.

Benton Conservation District is continuing its monitoring program at 6 sites on Spring and Snipes Creeks for several parameters, including suspended sediment and turbidity. This monitoring is the continuation of a project originally funded and undertaken to track sediment loads associated with furrow irrigation and measure improvements attributable to changes in irrigation practices.

Roza-SVID Board Joint of Control (BOJC) has undertaken a monitoring program in the Granger Drain, Sulphur Creek and Spring/Snipes Creek drainages. Twenty-seven sites are being monitored on a biweekly or monthly basis for several parameters including flow, turbidity and TSS. This is an ongoing project initiated in 1997. Also, BOJC is working with the Bureau of Reclamation and Ecology to establish a permanent monitoring site with building and instrumentation near the mouth of Granger Drain. When completed, this will provide continual monitoring and data collection for a number of parameters. (See Appendix 7, BOJC)

TMDL for Upper Naches River and Cowiche Creek, Temperature

2010, Specific and Detailed

https://fortress.wa.gov/ecy/publications/documents/1010068.pdf

What is the schedule for achieving water quality standards?

The goal of this TMDL is to reduce water temperature mainly by increasing system potential shade and reducing stream width. Similar shade increase is required on federal, state, and private lands. Trees will need many years to grow and produce the shade required by this TMDL. Therefore, the water temperature standard should be met 80 years after the completion of the water quality implementation plan, or 2091. All implementation actions required to achieve shade targets must be installed by 2021.

Monitoring progress

Assessing progress in meeting the goals of this water quality improvement report requires

- Monitoring the rate of implementation.
- Ensuring that it continues on schedule.
- Conducting water quality monitoring at key locations in the upper Naches River and Cowiche Creek watersheds.

Ecology conducts effectiveness monitoring. However, because of the time involved in getting riparian planting projects underway and achieving some height of the vegetation for effective shading, Ecology does not expect to schedule effectiveness monitoring in the near future. Ecology will begin monitor the pace of implementation when this TMDL is approved by EPA.

Entities with enforcement authority are responsible for following up on any enforcement actions. Stormwater permittees and point source permittees are responsible for meeting the requirements of their permits. Those conducting restoration projects or installing BMPs are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing.

Monitoring and assessment are considered critical to generating understanding and support for improving creek health among landowners living in each creek watershed. The plan may consider a variety of monitoring approaches and assessment methods, because some provide better feedback and will generate more interest among the public. River and creek health can be defined in a variety of ways, and could include measurements of:

- Stream width-to-depth ratios taken and compared to the data presented in the water quality study findings (Brock 2008).
- Vegetation height and survival rates, which can be assessed in newly established riparian areas.
- Sediment on the stream bottom (bed load and/or embeddedness), which can be taken before and after projects.
- Riparian photo points, which can be established and aerial photos can be taken. Ecology recommends photo points because they show changes over time.
- Stream temperature, which can also be used to show progress. However, unless there has been a considerable change in stream flow or stream restoration work, lower temperatures may be difficult to detect.

- Biological indicators, such as an increase in the number of steelhead and bull trout in a given stream reach. This could also be a redd count.

Adaptive management

Natural systems are complex and dynamic. The way a system will respond to human management activities is often unknown and can only be described as probabilities or possibilities. Adaptive management involves testing, monitoring, evaluating applied strategies, and incorporating new knowledge into management approaches that are based on scientific findings. In the case of TMDLs, Ecology uses adaptive management to assess whether the actions identified as necessary to solve the identified pollution problems are the correct ones and whether they are working. As we implement these actions, the system will respond and will also change. Adaptive management allows us to fine-tune our actions to make them more effective, and to try new strategies if we have evidence that a new approach could help us to achieve compliance.

Implementation targets will be set to achieve compliance with the load allocations in this TMDL. Partners will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the implementation strategy as needed.

Ecology will use adaptive management when visual assessment of implementation shows that the TMDL is not being implemented, or when water monitoring data show that the TMDL targets are not being met or implementation activities are not producing the desired result. A feedback loop (Figure 9) consisting of the following steps will be implemented:

Step 1. The activities in the water quality implementation plan are put into practice.

Step 2. Programs and BMPs are evaluated for technical adequacy of design and installation.

Step 3. The effectiveness of the activities is evaluated by assessing new monitoring data and comparing it to the data used to set the TMDL targets.

> Step 3a. If the goals and objectives are achieved, the implementation efforts are adequate as designed, installed, and maintained. Project success and accomplishments should be publicized and reported to continue project implementation and increase public support.
>
> Step 3b. If not, then BMPs and the implementation plan will be modified or new actions identified. The new or modified activities are then applied as in Step 1.

It is ultimately Ecology’s responsibility to assure that implementation is being actively pursued and water standards are achieved.

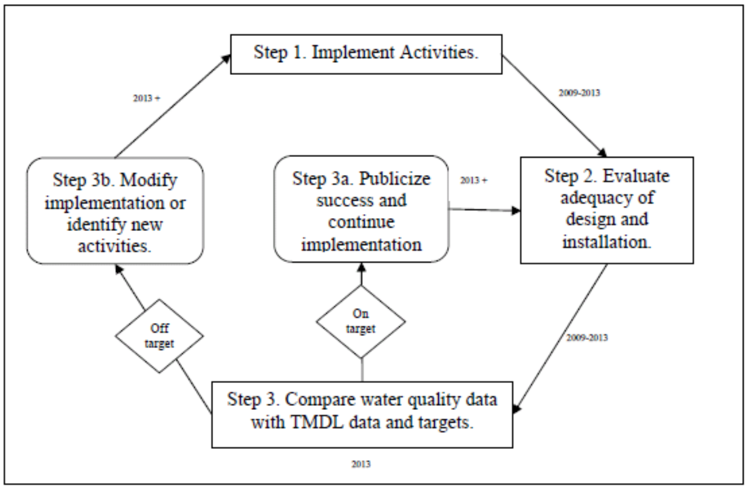


Figure 9. Feedback loop for determining need for adaptive management.