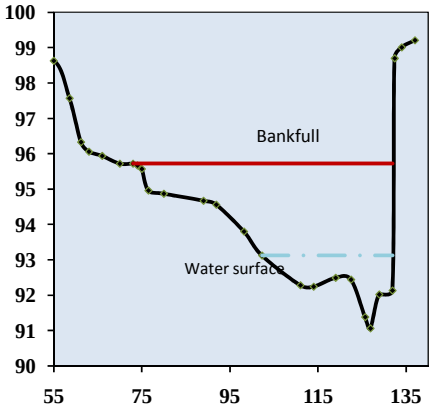
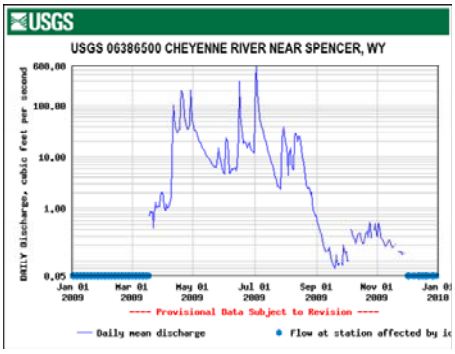
Surface Water Monitoring Strategy
2010-2019





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1.0 INTRODUCTION

1.1 Regulatory Framework

The Federal Water Pollution Control Act of 1948 was the first comprehensive statement of federal interest in clean water programs. In 1972, Congress passed the Federal Water Pollution Control Act (Public Law 92-500), also known as the Clean Water Act (CWA). The goal of the CWA was to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In 1977, an amendment was passed to establish the goal of protecting and managing waterbodies to insure "fishable and swimmable" conditions. The Act of 1972, the amendment of 1977, and subsequent amendments provide the basis for comprehensive water quality monitoring.

The United States Environmental Protection Agency (EPA) administers most clean water programs across the Nation. The Wyoming Department of Environmental Quality/Water Quality Division (WDEQ/WQD) implements the CWA in Wyoming, while EPA provides oversight and direction to State programs and certifies the fulfillment of CWA requirements in the State. Wyoming is responsible for assessing all waters of the State to determine if they support designated uses.

The WDEQ/WQD surface water monitoring program is responsible for collecting scientifically valid water quality monitoring data using established data collection methods and assessing those data in a consistent manner. The assessment methods (WDEQ/WQD 2001) provide guidance on using monitoring data to determine designated use support of a water body. Wyoming water quality standards are the rules concerning designated uses and the associated water quality criteria (WDEQ/WQD 2007). The Wyoming water quality standards consist of three parts: 1) surface water classes and associated uses, 2) numeric and narrative water quality criteria and 3) anti-degradation policy.

1.2 History of the Monitoring Program

Initiation of reference stream monitoring in 1992 marked the beginning of the WDEQ/WQD surface water monitoring program (hereinafter referred to as the Monitoring Program). The primary purpose of reference stream monitoring is to obtain benchmark chemical, physical, and biological data from least anthropogenic-impacted stream sites within each ecoregion of Wyoming. Data collected at reference sites is used to assess condition of other streams in the State and to develop and revise the Wyoming Stream Integrity Index and the Wyoming RIVPACS models, tools used to assess the biological integrity of Wyoming streams.

The 1997 Total Maximum Daily Load (TMDL) Work Plan committed the Monitoring Program to collect scientifically sound chemical, biological and physical monitoring data to determine designated use support for over 300 stream segments, lakes, and

reservoirs. As of 1996, many of these waterbodies had only anecdotal data suggesting that designated uses may not be fully supported. WDEQ committed to collect data from each waterbody within five years, followed by timely assessments of those data and where possible, determine designated use support. The large number of waterbodies requiring monitoring data to make use-support determinations within a period of five years necessitated a rapid screening approach.

The Beneficial Use Reconnaissance Project was implemented in 1998 to meet the needs of the 1997 TMDL work plan and essentially became the first monitoring strategy. Similar to EPA's Rapid Bioassessment Protocol (RBP), this project used a rapid screening approach to collect the monitoring data necessary to make designated use-support determinations. The Monitoring Program was therefore founded on RBP, monitoring protocols developed for reference streams and Wyoming's National Pollutant Discharge Elimination System (WYPDES) permitting and compliance program. These protocols were later updated and summarized in a document entitled Standard Operating Procedures for Sample Collection and Analysis (WDEQ 2004).

From 1998 to 2003, the Monitoring Program worked through the monitoring directive of the 1997 TMDL work plan using the RBP-like approach, and where possible made designated use-support determinations. Some designated use determinations proved to be more complex than originally anticipated, as many streams required a more intensive, multi-year assessment than what the RBP-approach entailed. This was particularly true when dealing with habitat degradation, stream channel instability and sediment pollution.

In 2004, a second monitoring strategy was implemented to guide the program for the subsequent five years (2004-2008). This strategy followed the recently published EPA guidance "Elements of a State Water Monitoring and Assessment Program (EPA 2003)." While the Monitoring Program already possessed most of the ten elements outlined, the EPA guidance was used as the template to build upon the 1997 TMDL work plan and incorporate multiple new approaches. Together, these elements led WDEQ toward a more complete, comprehensive monitoring program that addressed all waters of the State. In 2008, the strategy was amended to include the 2009 field season, which allowed time to transition into the new strategy developed for 2010.

1.3 Purpose of this Document

The purpose of this document is to outline the strategy WDEQ will use to address the requirements of the CWA over the next ten years (2010-2019). The document builds upon the previous strategy and continues to follow EPA guidance for developing State Water Monitoring and Assessment Programs.

2.0 MONITORING STRATEGY 2010-2019

2.1 Monitoring Guiding Principles

This strategy incorporates five guiding principles considered by the monitoring program to be essential for effective monitoring and necessary to meet goals and objectives.

Principle 1: Use a tiered monitoring approach consisting of core monitoring procedures at all probabilistic and regional reference sites and more intensive, stressor-specific monitoring procedures at a subset of pre-screened sites where designated use support is unknown or at reference sites to meet specific data needs.

The monitoring program will use core monitoring procedures to evaluate the water quality condition of a waterbody. If initial screening data suggests a potential problem exists, more intensive monitoring may be performed to verify the problem and to determine its cause(s) and source(s) (see Core and Supplemental Indicators). This tiered approach will result in the assessment of more waters each year and allow the monitoring program to focus limited resources on those waters with the most pressing needs.

Principle 2: Schedule data acquisition activities within the rotating basin monitoring schedule.

To the extent practical, monitoring projects will be coordinated to occur within a basin at the same time. This practice will minimize travel, increase efficiency and maximize the amount of work completed by a small staff with limited time and money.

Principle 3: Generate scientifically defensible monitoring data necessary for decision-making processes.

Each project in this strategy is founded on sound science and initiated to address specific objectives. Quality assurance and quality control procedures will be implemented to ensure data are of adequate precision and accuracy to support management decisions.

Principle 4: Manage and report water quality data in a manner that meets the needs of the primary user(s) while also addressing the needs of other potential users, to the extent possible.

The monitoring program is committed to data automation and management policies and procedures that ensure timely availability of easily accessible and manageable water quality data to monitoring program staff, other WDEQ staff, agencies, organizations and the general public. Reporting of data and associated analyses must have the scientific

rigor necessary for decision-making processes and a presentation that appeals to the wide array of other users.

Principle 5: Maximize the return on scarce monitoring resources by coordinating with other agencies and organizations.

The scarcity of resources necessary to adequately monitor and assess all Wyoming waters demands that the monitoring program work closely with other entities, both public and private, to ensure the broadest possible coverage of the State's surface water resources. The monitoring program will seek opportunities to collaborate with other organizations to plan and implement monitoring projects and minimize duplication of effort.

2.2 WDEQ Watershed Monitoring Program

2.2.1 Monitoring Program Objectives

The mission statement of WDEQ is to protect, conserve, and enhance the quality of Wyoming's environment. The overarching goal of the federal Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the Nations waters.

In support of this mission and goal, the monitoring program has established eleven monitoring objectives. To fully achieve every objective, additional staff and resources are required. In the event additional resources are unavailable, objectives have been prioritized as primary and secondary. Primary objectives apply to all waters of the State, whereas secondary objectives apply to select waters or specific data needs. Secondary objectives are further prioritized and will be addressed as time and resources allow, and when all primary objectives are satisfactorily achieved.

The following primary and secondary monitoring objectives have been established to meet the goals of this strategy.

Primary Objectives:

- Determine water quality standards attainment
- Identify impaired waters
- Identify causes and sources of water quality impairments
- Assess water quality status and trends at multiple scales
- Evaluate program effectiveness
- Respond to complaints and emergencies

Secondary Objectives (in priority order):

- Provide data and technical support to establish and revise water quality standards
- Provide data and technical support toward development and evaluation of Total Maximum Daily Loads (TMDLs)
- Provide data and technical support toward implementation and evaluation of non-point source (NPS) restoration projects
- Provide data and technical support toward development of Wyoming Pollutant Discharge Elimination System (WYPDES) program permits and policies

Successful accomplishment of the above primary objectives will result in a monitoring strategy that will generate information that can answer the following four basic questions:

- What is the overall quality of the waters in the State?
- To what extent is water quality changing over time?
- Where are the impaired waters in need of restoration and high quality waters in need of protection?
- How effective are State clean water programs?

2.2.2 Monitoring Design Summary

The WDEQ monitoring strategy for 2010-2019 involves continuing to collect the data required to make defensible determinations of designated use support. Intensive monitoring will occur on a few remaining high priority waters from the 1997 TMDL work plan, although the focus of the new strategy will be a rotating basin framework where probabilistic designs and targeted monitoring will be integrated. Within a five–year monitoring period for each basin, a probabilistic survey will be completed, the results of which will drive targeted monitoring on the highest priority waters with suspected impairments. Reference monitoring will also be focused within the basins under study, as will monitoring in support of secondary objectives, where time and resources allow.

The 2010-2019 monitoring strategy includes the following components in support of the primary monitoring objectives:

- Stream reference station monitoring
- Rotating basin probability surveys
- Rotating basin targeted monitoring
- 1997 TMDL work plan targeted monitoring priority waters
- Lake and reservoir monitoring
- Statewide probability survey

The following components support the secondary monitoring objectives and will be implemented as time and resources allow:

- Monitoring in support of nutrient criteria and other standards–related issues

- Monitoring in support of TMDL development and evaluation
- NPS program effectiveness monitoring
- Monitoring in support of WYPDES permits and policies

2.2.3 Monitoring Projects to Address Primary Objectives

Streams and Wadeable Rivers

Core and Supplemental Indicators

The monitoring program uses a suite of physical, chemical and biological indicators to assess stream and wadeable river water quality conditions and trends. The indicators can be divided into "core" and "supplemental" categories. Core indicators are used to assess water quality condition for projects that address primary monitoring objectives. Supplemental indicators are used in targeted designated use-support studies and are chosen based on the known or potential stressors. For projects designed to address secondary monitoring objectives, all indicators are chosen on a case-specific basis. Appendix A shows primary and secondary indicators, associated monitoring objectives, and applicable designated uses.

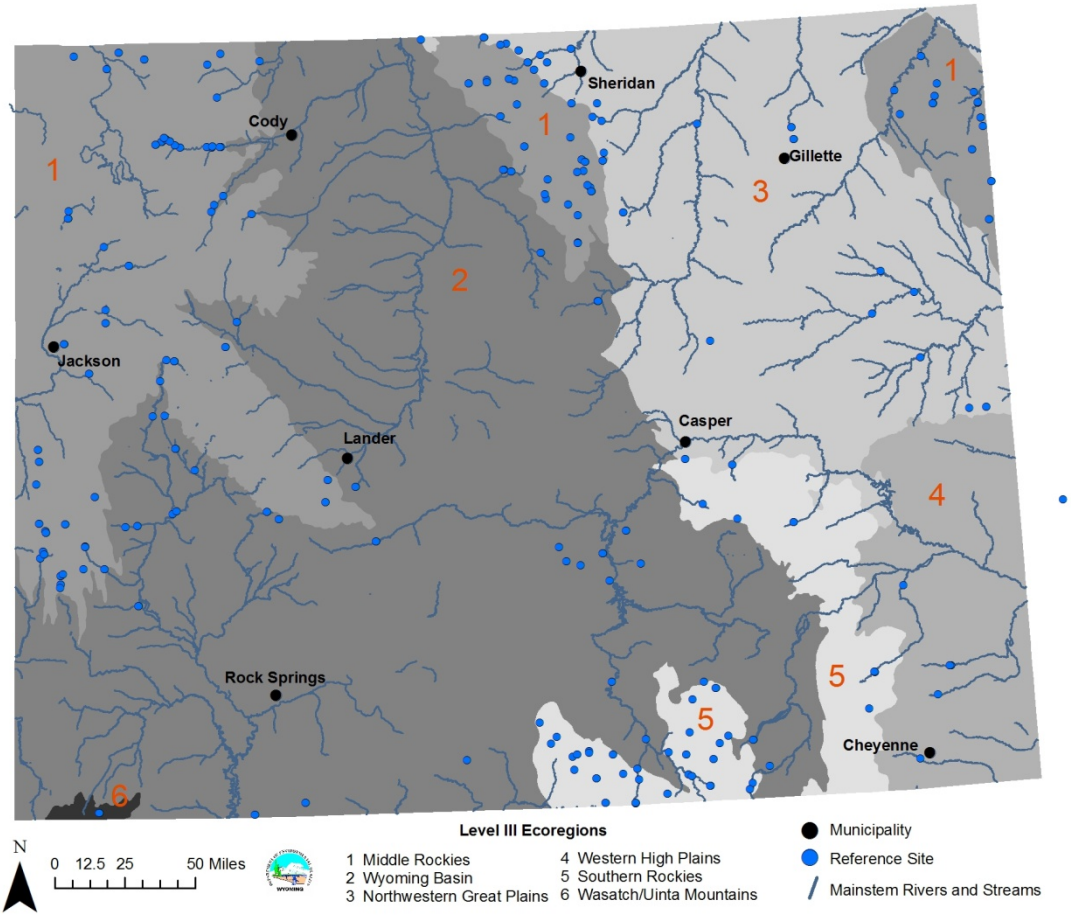
Reference Monitoring

Reference sites occur at stream locations that are minimally or least impacted by human activities within a geographic or ecological region, watershed, or area of interest; they do not necessarily represent pristine water quality or biological conditions. Reference condition (an aggregation of reference station data) is the baseline to which monitoring data from non-reference streams is compared. Reference condition represents realistic, attainable expectations for other streams and rivers. A significant departure from reference condition can therefore indicate impairment of designated uses. It is imperative that WDEQ possess a robust reference data set, both in space and time, which is reasonably representative of the natural biological, chemical, and physical nature of streams and rivers.To date, WDEQ has sampled over 200 reference sites distributed across six level III ecoregions (Chapman, et al. 2003) (Figure 1). Reference sites tend to occur in the mountainous regions of the State, leaving streams in the plains and inter-mountain basins, especially those of non-montane origin, under-represented. Therefore, the Monitoring Program will be opportunistic in identifying and monitoring additional reference sites as they are encountered, primarily during rotating basin probability surveys. Existing reference sites will be re-sampled periodically, and consistent with Monitoring Guiding Principle #2, by coordinating reference data collection with rotating basin probability surveys and targeted monitoring.

Reference stream data has been used to develop two tools for assessing aquatic life use support: the Wyoming Stream Integrity Index (WSII) and the Wyoming River InVertebrate Prediction And Classification System (WY RIVPACS). Channel dimension,

pattern, and profile data from reference sites is sometimes used in geomorphic departure analyses when channel stability and habitat condition are a concern. Water quality data from reference sites can be used to assist in interpretation of narrative water quality standards or parameters where numeric standards do not exist.

Figure 1. Reference sites and level III ecoregions of Wyoming.



Rotating Basin Probabilistic Survey

The rotating basin probabilistic survey serves as the primary method for assessing the current water quality condition of Wyoming's rivers and streams. This comprehensive approach best serves Wyoming's monitoring objectives and recognizes current and foreseeable levels of financial and staff resources. Data from a defined number of randomly selected river and stream locations distributed throughout each basin are used to make statistical inferences of the water quality condition within each basin. Because not all waters within a basin are directly sampled, a level of confidence or certainty for the estimate of water quality condition is determined, which reflects the

natural variability of conditions and level of sampling effort. Data generated by this approach not only allows WDEQ to estimate overall water quality condition for a basin but also identify waters of high quality and those where designated use-support may be limited.

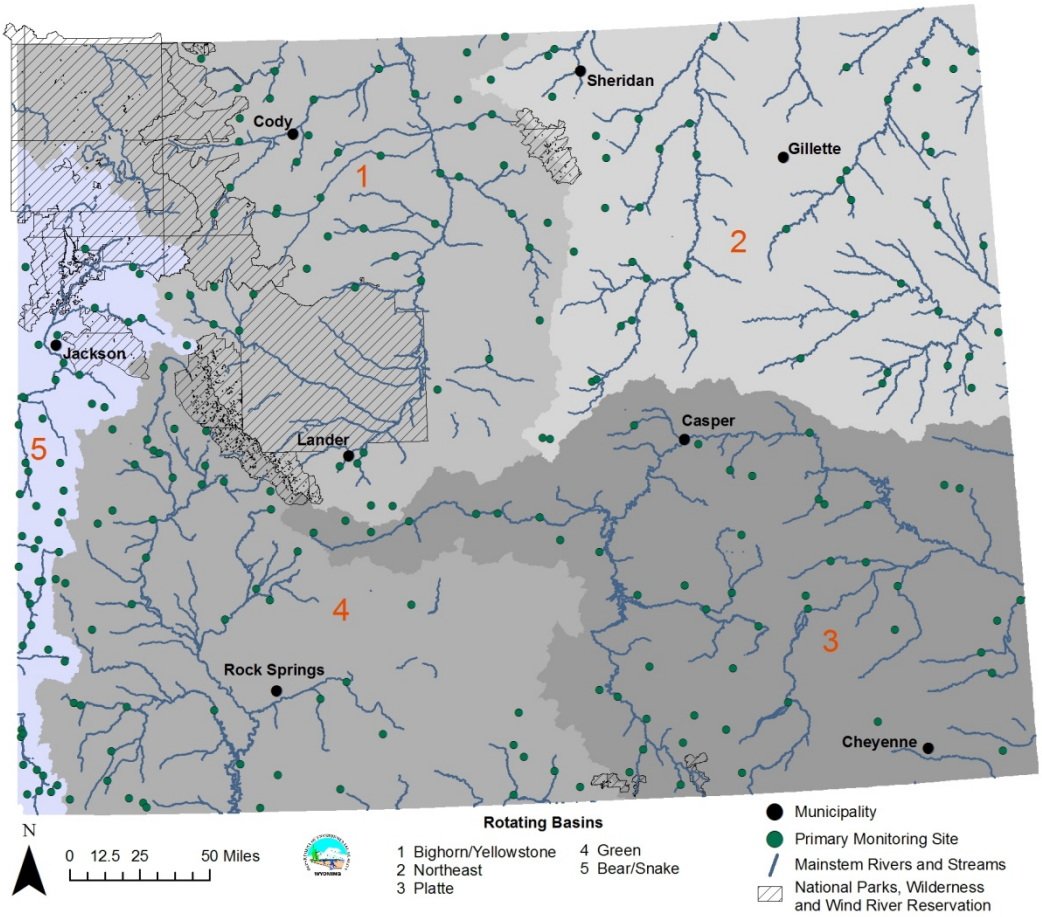
Wyoming's probabilistic rotating basin approach establishes an order of rotation and sampling year(s) among five 'superbasins' within the State, enhancing coordination efforts with other entities and program efficiency. The five 'superbasins' are delineated based on combinations of 6-digit Hydrologic Unit Codes (HUC) and geographical location (Figure 2). The five 'superbasins' and the associated HUC 6 basins they represent are:

- Bighorn/Yellowstone [Bighorn and Yellowstone Basins]
- Northeast [Belle Fourche, Cheyenne, Little Missouri, Powder and Tongue Basins]
- Platte [Niobrara, North Platte and South Platte Basins]
- Green [Great Divide, Green and Little Snake Basins]
- Bear/Snake [Bear and Snake Basins]

A total of 50 primary sites and their latitude and longitude coordinates are generated within each 'superbasin' by the EPA in Corvallis, Oregon using a stratified random survey design. The stratified random survey design selects sites on perennial, non-headwater (>1st Strahler order) rivers and streams that are not located in national parks, congressionally-designated wilderness areas and the Wind River Reservation. The design further stratifies site selection by HUC 8 clusters (four on average) within each 'superbasin', resulting in equal spatial allocation of the 50 primary sites among the HUC 8 clusters. Following the same design, a population of 100 oversample sites is generated for each 'superbasin'. Oversample sites are used as replacements when primary sites cannot be sampled due to access denial, dry channel, or other factors that make sampling impractical and non-representative of perennial rivers and streams within the 'superbasin'. Oversample sites generated for a HUC 8 cluster within a 'superbasin' are only used as replacements for primary sites within the same HUC 8 cluster to maintain representativeness and minimize logistical complexities of sampling.

The probabilistic rotating basin survey is based on a long-term repeat cycle for trend analysis, though only the first 10 years are incorporated into the current strategy (Table 1). All 50 sites within a 'superbasin' will be sampled in one year, followed by one year to compile, analyze and report the results. The summary report will prioritize recommendations for targeted monitoring to determine designated use support on waters with suspected impairments.

Figure 2. Primary probabilistic monitoring sites and associated superbasins.



Targeted monitoring will take place over two years followed by assessment reports. Monitoring for four of the five 'superbasins' is scheduled for completion during the current strategy, with the remaining 'superbasin' to be completed during the next 10 year strategy along with a repeat of the entire cycle to follow. Notable findings from each 'superbasin' report will also be documented in Wyoming's biannual Integrated Report beginning in 2014.

<u>Rotating Basin Targeted Monitoring</u>

Although data collected from the probabilistic rotating basin survey are sufficient to assess the condition of Wyoming's waters, these data are inadequate to identify the extent of suspected impairments on waters that may require TMDLs. Targeted monitoring is necessary to determine whether a water body supports its designated uses, and if not, to identify the pollutant(s) and source(s) responsible for the impairment. Waterbodies are prioritized for targeted monitoring based on findings from the probabilistic rotating basin survey. Prioritization will be based on consideration of several factors, including the magnitude and extent of the suspected impairment, types

of pollutants suspected to be responsible for the impairment, needs by other entities, human health risk, and influences to permitted point sources. It is anticipated that, within each 'superbasin', the top 2-4 ranking waters with suspected impairments based on narrative criteria will be selected for further targeted monitoring to assess designated use-support. This equates to targeted monitoring of 10-20 waters in one complete probabilistic rotating basin cycle. Targeted monitoring also may be completed on waters where numeric criteria were exceeded during the probabilistic survey, but data was not sufficient for a use-support determination. For example, if the single E. *coli* sample collected as part of the probabilistic survey exceeded the applicable single sample criterion and was considered to represent a potential significant human health risk, additional monitoring will be conducted to determine designated use support. Additional monitoring of private land sites is contingent on successful reacquisition of access from the applicable landowner(s).

Table 1 Implementation schedule for rotating basin probabilistic and targeted monitoring.

	Superbasin				
Year	BY	NE	GR	PL	SB
2010	Probabilistic Survey				TBD
2011		Probabilistic Survey			
2012	Targeted Monitoring				
2013	Targeted Monitoring	Targeted Monitoring			
2014	Targeted Reports	Targeted Monitoring			
2015		Targeted Reports	Probabilistic Survey		
2016				Probabilistic Survey	
2017			Targeted Monitoring		
2018			Targeted Monitoring	Targeted Monitoring	
2019			Targeted Reports	Targeted Monitoring	
2020				Targeted Reports	

BY= Bighorn/Yellowstone, NE= Northeast (Powder, Tongue, Cheyenne, Belle Fourche), GR= Green (Green, Great Divide, Little Snake), PL=North and South Platte, SB= Snake/Bear, TBD= Schedule to be determined at a later date

Targeted monitoring within a 'superbasin' will commence in year three of the five year

assessment period for that 'superbasin'. Average time for targeted monitoring on an individual water body is approximately two years. Depending on objectives and design, targeted monitoring may include extended measurement of spatial and temporal trends that requires longer than the two year average.

A variety of both core and supplemental chemical, physical and biological indicators are collected for all targeted water monitoring (Appendix A). These indicators are used to not only identify the presence and extent of impairment but also the pollutants causing the impairment. Core and supplemental indicators are compared to specific water quality standards that have been established in Wyoming to protect surface waters for certain designated uses. The Wyoming water quality standards for surface waters specify minimum numeric and narrative criteria that waters must meet to support their assigned designated uses. Other specific indicators may also be used given the circumstances of the suspected impairment and type(s) of pollutants investigated for an individual waterbody.

Targeted monitoring typically involves watershed-scale sampling designed to isolate sources of pollution and the extent of impairment. Designs for targeted monitoring vary and are dependent on the specific objectives, type(s) of pollutants causing the suspected impairment in addition to the magnitude, extent and duration of the problem. Targeted monitoring designs can range from site-specific to regional and paired-watershed based comparisons. For example, for waterbodies where a paired-watershed or regional comparison design may be inappropriate or limited, the targeted monitoring design may include establishment of a site-specific biological and/or geomorphic 'reference' or control that represents the best attainable condition for that waterbody. Departure from the control site will be evaluated using core and supplemental indicators to determine designated use support.

Data will be assessed based on the methodology used for investigating the particular pollutants and impairments in conjunction with WDEQ's method for determining water quality condition of surface waters (WDEQ 2008b). Data, analyses, results and conclusions from each targeted monitoring project will be compiled into an assessment report with determinations of designated use-support. The assessment report is generally completed one to two years after the last year of monitoring on the targeted water. Designated use-support determinations from all assessment reports on targeted waters are subsequently incorporated into Wyoming's biennial Integrated Report. Partial or non-support designated use determinations on targeted waters and other pertinent information will be evaluated according to Wyoming's assessment methodology (WDEQ, 2009b) prior to placement of the targeted water on Wyoming's 303(d) list of impaired waters that require development of a TMDL.

Other Targeted Monitoring

Since 1998, the Monitoring Program has been implementing targeted monitoring for

making designated use-support determinations on over 300 waterbodies that were part of the original monitoring directive set forth in the 1997 TMDL work plan. As stated previously, designated use determinations proved to be more complex than originally anticipated, and many streams required more intensive, multi-year assessments than what the original RBP-approach entailed. As a result, the original directive was integrated into the 2004-2009 monitoring strategy to provide sufficient time to gather the necessary data for designated use-support determinations where possible. As of 2009, the Monitoring Program had sampled, at least once, all of the original 300 waterbodies that were sampleable and accessible. Of the sampled waterbodies, designated use determinations had been made or were expected to be made on two-thirds. Targeted monitoring for some of the remaining one-third to determine designated use-support was still ongoing in 2010 and is expected to conclude by 2015. Targeted monitoring and designated use support determinations will be limited to only the highest priority remaining waterbodies, thus designated use determinations will not be made on some of the waterbodies from the 1997 TMDL work plan. Priority for additional targeted monitoring and/or designated use support determinations is based on a variety of factors, including but not limited to the likelihood that an actual impairment exists, the ability to separate natural from anthropogenic factors in a designated use support determination, the magnitude and extent of a suspected impairment, types of pollutants suspected to be responsible for the impairment and potential human health risk. The design, data analysis, assessment and reporting of these remaining priority targeted waters is essentially equivalent to what was described for targeted monitoring derived from the probabilistic rotating basin survey. By 2015, the original 1997 TMDL workplan directive will be considered complete.

WDEQ may conduct targeted monitoring projects that result from currently unforeseen citizen complaints, interests of other agencies or emerging water quality issues. Because each issue is unique, monitoring plans to assess each issue also are unique. Sampling locations, frequency, indicators and analysis techniques will depend on the needs of the specific project. For that reason, details on targeted monitoring projects that result from these unforeseen circumstances are not discussed here.

Statewide Probabilistic Survey

WDEQ is required by the CWA to report biennially on the quality of the State's waters, including percentages of stream miles that support or do not fully support their designated uses. Reference monitoring and targeted monitoring in support of the 1997 TMDL work plan was not representative of the State as a whole and could not be extrapolated beyond the specific length of stream being monitored.

In 2004, to address the need to monitor all streams of the State, the monitoring program implemented a statewide probabilistic survey. It is a simple randomized design that excludes National Parks, wilderness areas, the Wind River Reservation and first order streams from the target population. Between 2004 and 2007, 64 sites were sampled to

represent water quality conditions across Wyoming. In 2008, a second statewide survey was implemented which will conclude in 2011. A similar number of sites will be sampled from the same targeted population as in the first survey. The incorporation of probability surveys into the monitoring strategy has enabled WDEQ, over time and at various scales, to better estimate statewide water quality condition, as well as determine trends in water quality condition. After conclusion of the second statewide survey in 2011, the data from both surveys will be presented in a summary report and the 2014 Integrated Report. Completion of the second statewide probabilistic survey will assist in tracking temporal trends in statewide water quality condition as well as validate results of the first statewide survey. After 2011, statewide probabilistic surveys will be phased out because the rotating basin probability survey will achieve the same goal of assessing State water quality.

Lakes and Reservoirs

Core and Supplemental Indicators

Core indicators used to assess lakes and reservoirs are shown in Appendix A. Currently, there are no supplemental indicators being used. The lake and reservoir program consists of only the large reservoir program described below.

Large Reservoir Monitoring

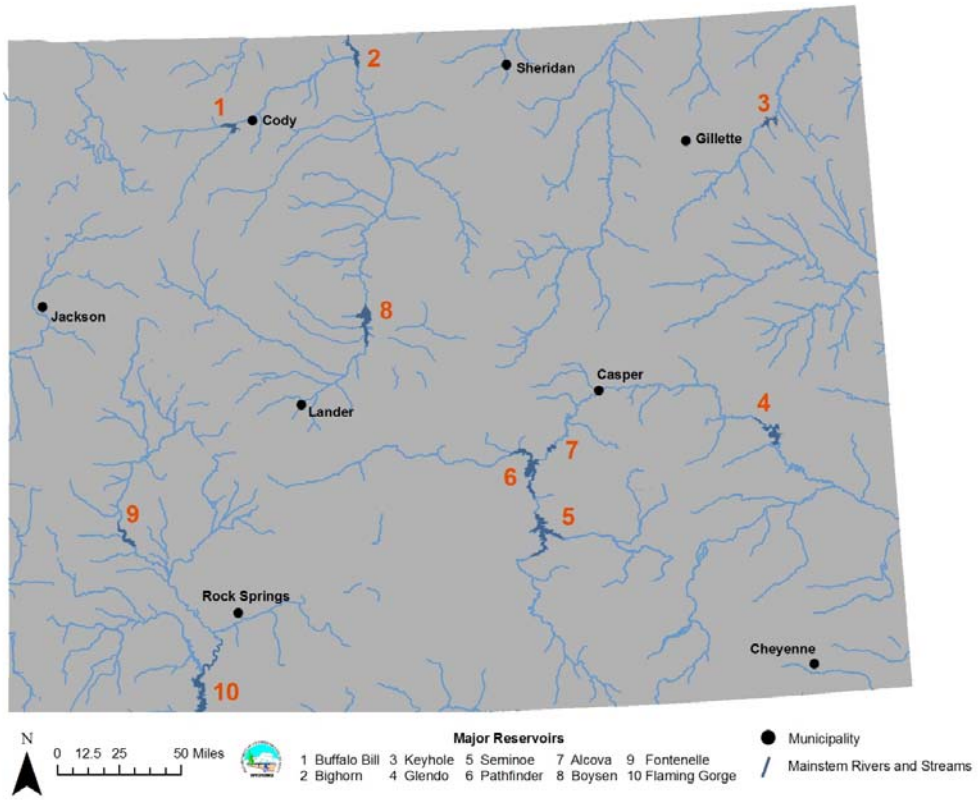
Lake and reservoir monitoring was initiated because several lakes and reservoirs were part of the monitoring directive of the 1997 TMDL work plan. The two large reservoirs from the work plan, Keyhole and Boysen, could not be assessed with one sampling event. The need for additional data for these reservoirs, combined with the CWA directive of assessing all waters, led to development of a sampling program for ten of the largest reservoirs in the State. The current strategy is to sample each of the ten large reservoirs for three consecutive years, followed by three years without any sampling (Table 2, Figure 3). After completion of two, three-year sampling events for each reservoir, an assessment of water quality condition and designated use support is completed. If the assessment identifies potential water quality issues, sampling will continue with focus on identifying trends in water quality over time using core indicators. If no potential water quality issues are identified, sampling frequency may be revised appropriately. The large reservoir monitoring strategy does not follow the rotating basin approach used for streams.

Table 2 - Schedule for sampling the 10 major reservoirs, 2010-2019.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Keyhole	x				x[1]	x[1]	x[1]			
Boysen	x				x[1]	x[1]	x[1]			
Glendo	x	x	x				x[1]	x[1]	x[1]	
Seminoe		x	x	X				x[1]	x[1]	x[1]
Pathfinder		x	x	X				x[1]	x[1]	x[1]
Alcova		x	x	X				x[1]	x[1]	x[1]
Bighorn				X	x	x				
Fontenelle	x				x	x	x			
Buffalo Bill				X	x	x				
Flaming Gorge							x	x	x	

x[1] Third 3-yr monitoring period.

Figure 3. Reservoirs sampled as part of the large reservoir sampling program



Integration with other Lake/Reservoir Monitoring Programs

WDEQ will consider integration of other lake/reservoir monitoring objectives such as the EPA National Lake Assessment into this and future strategies to help address CWA goals. Integration of such projects may result in revisions to the lake and reservoir schedule presented in Table 2.

National Lakes Assessment (NLA) field work conducted in 2007 sampled 20 lakes in Wyoming. Twenty lakes is not sufficient for a statistically valid statewide estimate of lake condition, though this, and future, NLA data may be useful for identifying lakes that may not fully support their designated uses and therefore require targeted monitoring. This approach aligns with the rotating basin probabilistic and targeted monitoring approach for streams and wadeable rivers previously described in this document. It is unclear at this time if sufficient resources exist to prioritize and assess lakes screened using NLA data. The feasibility of this approach will be evaluated in 2015, after one five-year rotating basin assessment has been completed.

The National Lakes Assessment is scheduled to be repeated in 2012. Wyoming has the option of partnering with EPA by adding additional lakes to the survey to develop a statistically valid estimate of statewide lake condition, similar to that described for streams and wadeable rivers previously described in this document. Currently, WDEQ does not have the staff or financial resources to support the additional lake sampling. If funding were available, WDEQ would consider contracting out the additional sampling. Information on the National Lake Assessment can be found at http://www.epa.gov/lakessurvey/.

Description of Monitoring Projects to Address Secondary Objectives

Monitoring in Support of Water Quality Standards

Water quality standards are the foundation of the water quality-based pollution control program mandated by the CWA. Water quality standards define the goals for a water body by designating its known and attainable uses (recreation, aquatic life, drinking water, agriculture, etc.), setting criteria to protect those uses and establishing anti-degradation provisions.

The CWA requires States to review their standards a minimum of once every three years and revise them if appropriate. Updates may be needed, for example, due to changes in water quality conditions or water body uses or new scientific information on the effects of pollutants in the environment.

One foreseeable revision to Wyoming's water quality standards involves development of numeric nutrient criteria. Wyoming has developed a nutrient criteria development plan

(WDEQ 2008a), reviewed lake and reservoir nutrient criteria related literature (WDEQ 2009) and produced a data needs analysis and associated sampling and analysis plan (WDEQ 2009) to guide acquisition and analysis of data to support nutrient criteria development.

The monitoring program has and will continue to acquire the data necessary to support development of numeric nutrient criteria for Wyoming. Nutrient and related data is being collected at all reference and probabilistic sites and select targeted sites, but no projects that focus specifically on nutrients are scheduled at this time. Nutrient data from reference sites are especially important as it defines background or attainable conditions on which numeric criteria can be based. In the future, the monitoring program may conduct focused data acquisition projects to fill specific data needs, or conduct stressor-response or other effects-based studies to determine critical thresholds in nutrient concentrations where support of designated uses is compromised.

Monitoring in Support of Total Maximum Daily Loads (TMDLs)

CWA section 303(d) requires States to identify and develop total maximum daily loads (TMDLs) for waters that are not supporting their assigned designated uses. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, with allocations of that amount to the pollutant's sources.

Although a primary goal of this strategy is to identify impaired waters that require a TMDL, the data used to identify impairment may not be adequate to develop the TMDL. Generally, a waterbody is deemed impaired if any narrative or numeric criteria are not achieved and/or designated uses are shown to be adversely affected by anthropogenic activities. A water body can be determined to not fully support a designated use based on more than one exceedance of a numeric criteria within a three year period, even if the data are not representative of all hydrologic and temporal conditions. Data requirements for a TMDL are often much more extensive than for an impairment decision. A TMDL must identify maximum loading allocations for a pollutant that, when implemented, provide reasonable assurance that applicable water quality standards will be attained over time across all hydrologic conditions. Included within a TMDL is an assessment of the pollutant problem and impacts to designated uses, development of numeric targets that interpret and apply the water quality standard(s), an assessment of the pollutant sources and estimation of loading capacity and associated load allocations, including a margin of safety, to meet the water quality standard(s).

Currently, most TMDLs in Wyoming are being developed by private contractors hired by WDEQ, using existing data. In cases where the existing data is inadequate, private contractors or TMDL program staff may collect the necessary data. If however, the pace of TMDL development surpasses TMDL staff time and funding, assistance from the monitoring program may be required. Although not exclusive, the types of analysis and monitoring that have been needed to date and will likely be needed in the future include

projects like evaluating unprocessed monitoring data from third parties; creating more robust data sets for parameters such as sediment, nutrients, metals, and temperature; setting and maintaining continuous monitoring equipment and data loggers; conducting effectiveness monitoring once an implementation portion of the TMDL is started; meeting and coordinating field operations with stakeholders and landowners; and/or managing and conveying data to the public.

Nonpoint Source Project or TMDL Effectiveness Monitoring

Effectiveness monitoring is a fundamental component of non-point source (NPS) projects and TMDL implementation because it is used to determine whether goals and objectives are being achieved. For example, effectiveness monitoring for NPS projects are used to determine whether best management practices (BMPs), as designed and implemented, are effective in meeting management goals and objectives. TMDL implementation effectiveness monitoring measures to what extent the waterbody has improved since the TMDL was implemented and whether it has been brought into compliance with State water quality standards. In general, the benefits of NPS and TMDL effectiveness monitoring include:

- a measure of progress toward achieving restoration goals (i.e. how much watershed restoration has been achieved, how much more effort is required);
- more efficient allocation of funding and optimization in planning and decision-making (i.e. identifying recommendations or restoration activities that worked, which restoration activity achieved the most success for the money spent); and
- technical feedback to refine the initial TMDL model, BMPs, non-point source plans and permits.

As with TMDL monitoring, effectiveness monitoring for NPS projects and TMDL implementation will likely be accomplished through a joint effort between TMDL, NPS and monitoring staff. As a secondary objective of this strategy, the monitoring program will assist with effectiveness monitoring when primary objectives are at a satisfactory level of attainment. Because this strategy employs some new, untested projects and it is unknown precisely how much time monitoring staff will be able to allocate to effectiveness monitoring, it is likely that a combined effort between the NPS, TMDL and monitoring programs will be needed to accomplish effectiveness monitoring objectives. At a minimum, monitoring program seasonal staff will be available to assist NPS and TMDL staff.

Because each NPS project or TMDL implementation plan is unique, each monitoring plan will also be unique. Sampling locations, frequency, indicators, and analysis techniques will depend on the needs of the specific TMDL or NPS project. For that reason, details on effectiveness monitoring designs are not discussed here.

WYPDES Program Permits and Policies

Discharge of wastewater effluent to Wyoming surface waters requires a surface water discharge permit issued by the WDEQ/WQD's Wyoming Pollutant Discharge Elimination System (WYPDES) program. The WYPDES permit sets effluent limits for the wastewater effluent to ensure that water quality standards are achieved in the receiving water. The WYPDES program benefits from and occasionally requests collection of ambient water quality data to: characterize upstream and downstream conditions of the receiving water for issuance or renewal of permits, support permit development such as establishing effluent limits, support non-degradation reviews, delineate mixing zones, support development of WYPDES policies for permit development and compliance and support inspections or enforcement actions for permitted facilities. The WYPDES program can utilize the Monitoring Program for these requests.

Similar to TMDL and NPS monitoring objectives, it is anticipated that monitoring for WYPDES program permits and policies will be accomplished through a joint effort between WYPDES and Monitoring Program staff. As a secondary objective of this strategy, monitoring for WYPDES program permits and policies by the Monitoring Program will occur when all primary objectives of this strategy are at a satisfactory level of attainment and time and resources are available.

2.2.4 Quality Assurance

Evaluating and documenting the quality, consistency and reliability of monitoring data are essential components to support the primary and secondary objectives of this and future monitoring strategies.

To ensure that monitoring data are of a known and documented quality, the WDEQ/WQD has developed and implemented an EPA approved Quality Assurance Project Plan (QAPP) (WDEQ 2000). The QAPP documents planning, implementation, assessment procedures and quality assurance and quality control objectives to ensure that all data and information collected are sufficient for their intended purposes. Wyoming's QAPP was originally developed to address the objectives of the 1997 TMDL work plan. It is recognized that some modifications to the existing QAPP are needed in the future to more accurately reflect the evolution of the Monitoring Program and other water quality monitoring objectives performed on behalf of the EPA. Modification of the QAPP has been identified as a goal to be accomplished within three years.

Standard operating procedures (SOPs) (WDEQ 2004) exist for most field and laboratory operations implemented by the Monitoring Program. These SOPs are revised as needed to reflect changes in methodologies used by the Monitoring Program to satisfy objectives of the Monitoring Strategy. Some more newly adopted methodologies do not yet have an SOP developed. Development of new and revised SOPs is a goal to be

accomplished within three years. Training in new methodologies, information and equipment to help achieve the objectives of the Monitoring Strategy are periodically made available to all Monitoring Program staff.

A flowchart depicting the Monitoring Program QA process is shown in Figure 4.

2.2.5 Data Management

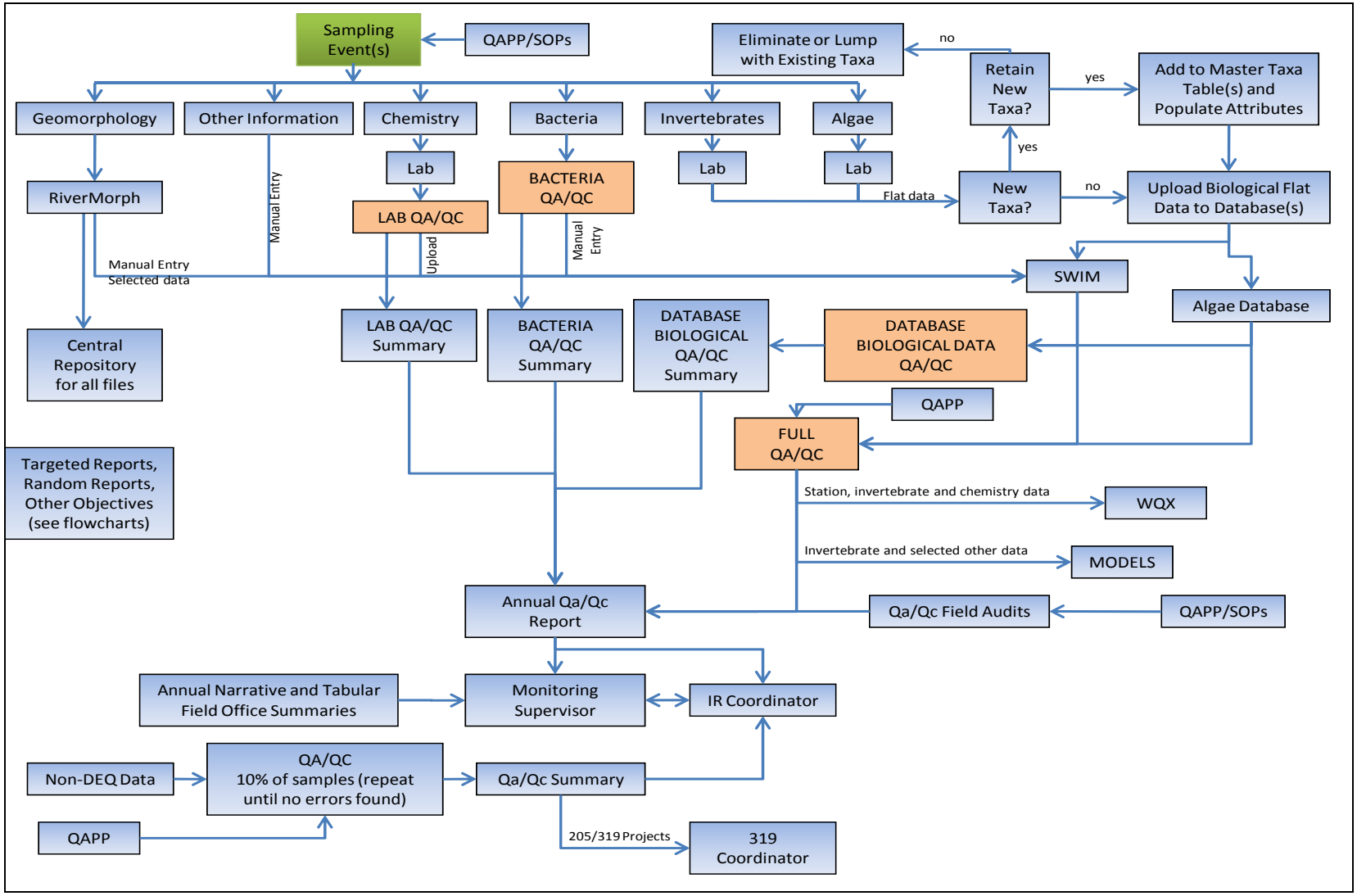
Water quality data collected by the Monitoring Program are populated with applicable qualifiers and comments into one or more electronic databases for storage and dissemination. The Access database known as Ecological Data Application System (EDAS) has been used as the primary data storage and dissemination tool by the Monitoring Program since 1999. With the integration of EDAS in 1999, the Monitoring Program also adopted EPA's STORET software followed later by SIM (STORET Import Module). This allowed the Monitoring Program to efficiently migrate data stored in EDAS to the EPA STORET website for public distribution.

To increase efficiency and handle the Monitoring Program's growing database, EDAS was converted in 2004 to a centralized SQL server database with a customized Access front-end tool to provide full querying functionality.

In 2007, the EPA initiated a shift away from STORET to the adoption of the Water Quality Exchange (WQX). Using Extensible Markup Language (XML), WQX better facilitates the submission and exchange of water quality data between the EPA and its partners over the internet. As of September 2009, STORET is no longer supported by the EPA.

To increase the efficiency of entry and migration of data from EDAS to WQX via XML documents, the Monitoring Program utilized an EPA Exchange Network Grant to upgrade the front-end of EDAS in 2008 and 2009. Prior to and concurrent with this upgrade, WDEQ led an effort to centralize the agency's various databases into the Enterprise System. The upgraded EDAS was incorporated into the Enterprise System as part of the Exchange Network Grant, although query functionality, table access and further enhancements are still being addressed. SWIM (Surface Water Information Management), as it will be known, eventually will house all water quality data collected by the Monitoring Program and will improve relational integrity, tabular updates and access, query functionality and the ability to automatically upload electronic laboratory results. As of May 2010, WDEQ was developing a Scope of Work and Request for Proposals for completion of the migration to SWM from EDAS. The RFP was scheduled for release on July 1, 2010, with services expected to be commenced during the Fall of 2010, and completion in Spring 2011.

Figure 4. Flow chart for QA/QC process.



While much of the water quality data collected by the Monitoring Program is stored in the upgraded EDAS and eventually SWIM, the Rivermorph© software package is used for data storage and analysis of most quantitative physical data. Biological periphyton data are stored and disseminated in a separate Access database. These two packages will remain outside of SWIM, but are readily accessible to Monitoring Program staff and the public. In the future, periphyton data will be integrated into SWIM.

Future improvements include incorporation of tablet computers to streamline the data entry process, provide greater digital functionality in the field, create automated reports, improve digital quality assurance controls and expand the results submitted to the WQX. These data management enhancements will expedite the process between data collection and reporting, allowing flexibility to adapt to an evolving Monitoring Program.

Along with the Integrated Report, states are also required to submit a copy of the state's Assessment Database (ADB) and corresponding geographic information systems (GIS) layers to EPA by April 1st of even numbered years. Wyoming's ADB is a Microsoft Access Database that is used to manage the various metadata associated with each categorized surface water, or the waters for which use-support determinations have been made. Examples of metadata include water type, assessment unit name, location description and the causes and sources of impairments. These waters are also spatially indexed using the U.S. Geological Survey's National Hydrography Dataset (NHD) and GIS. By using a unique identifier for each categorized water, data from Wyoming's ADB can be joined to GIS attribute data tables. Ultimately, the Integrated Report, ADB and GIS layers for each state are combined and summarized by EPA and used for national reporting purposes.

2.2.6 Data Analysis, Assessment, and Reporting

WDEQ has developed a methodology for assessing the monitoring data and making decisions on designated use support (WDEQ 2008b). This document outlines the criteria and decision-making processes WDEQ uses to make determinations on the water quality condition of surface water of Wyoming. This document is available at http://deq.state.wy.us/wqd/watershed/Downloads/305b/Final%20Methodology.pdf. All data will be compared to State numeric and narrative water quality standards**.** Specific tools have been developed to assist evaluation of narrative aquatic life criteria. The Wyoming Stream Integrity Index (WSII) and the Wyoming RIVPACS predictive model are tools developed from the reference stream data that assist with interpretation of macroinvertebrate data. All are considered dynamic tools that will be refined periodically as more reference stream data is collected. For more information on the WSII see Hargett et al. (2005), and for RIVPACS information see Hargett et al. (2007).

WDEQ currently produces a variety of reports based on ongoing water quality monitoring programs outlined in this strategy (Table 3), some of which are required by

the CWA.

Table 3 - Reports developed by WDEQ to satisfy CWA requirements.

Report	Timeframe	Comments
305(b) Integrated Report	Biennial; written report in even numbered years; integrated with 303(d) list of waters requiring TMDLs	Serves as the primary assessment of statewide water quality conditions; 303(d) list consists of impaired waters not attaining water quality standards, pollutants causing impairments, and the priority ranking of waters requiring TMDL development
Monitoring Strategy	Written report every 5-10 years	First monitoring strategy covered 1998-2002; second strategy covered 2004-2009, third strategy covers 2010-2019
Annual Monitoring Work Plans	Annually, by March 15.	Describes monitoring activities planned for a given year, including objectives, projects, and specific waters
Assessment reports	Approximately one year after completion of a targeted monitoring project	Designated use support assessment for targeted monitoring projects
Rotating Basin Probabilistic Survey reports	Two years after completion of rotating basin probabilistic survey	Will summarize water quality within a superbasin and prioritize waters for additional targeted monitoring to determine designated use support

Section 305(b) of the federal Clean Water Act (CWA) requires that each state prepare and submit a biennial report to EPA by April 1st of even numbered years. The report must contain a description of the navigable waters of the State for the preceding year, including the extent to which current conditions allow for the "protection and propagation of a balanced population of shellfish, fish and wildlife, and allow recreational activities in and on the water". Section 305(b) also requires each State to report the water quality and reduction of pollutants that would be necessary to achieve designated use support. Specifically, each state is to identify waters not meeting the above conditions, recommend strategies to achieve these objectives and to estimate the environmental impacts, economic and social costs and benefits and the predicted timeline for project completion. Lastly, Section 305(b) requires that the sources and extent of non-point source pollution in each state be estimated, including a description of the current program(s) used to mitigate these pollutants, along with associated financial costs.

Section 303(d) of the CWA requires that states identify and list waters for which the effluent limits outlined in Section 301 are not effective in attaining designated uses. The CWA also requires that states develop a separate TMDL for each pollutant/segment combination on the 303(d) List. States are required to prioritize waters on the 303(d) List for TMDLs based on the severity of each pollutant/segment combination, or listing. TMDLs are to be completed on these impaired waters "to assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, and allow recreational activities in and on the water". Each state must submit a 303(d) List of impaired waters to EPA by April 1st of each even numbered year. EPA is required to review the 303(d) List within 30 days of submittal. Wyoming's Integrated 305(b) and 303(d) Report combines the requirements of sections 305(b) and 303(d) into a single document.

While the CWA gives States the primary responsibility for implementing programs to protect or restore water quality, including monitoring and assessment, CWA Section 106(e)(1) requires EPA to determine that a state is monitoring the quality of navigable waters, compiling and analyzing data on water quality and including it in the State's Integrated Report prior to the award of Section 106 grant funds. When assessing compliance with 106 (a)(1), EPA requires that States have a comprehensive monitoring strategy that serves its water quality management needs and addresses all State waters. This document, "Surface Water Monitoring Strategy 2010-2019" satisfies EPAs requirement for a strategy. On an annual basis, the monitoring program also publishes work plans that describe monitoring objectives, projects planned to address those objectives and lists specific waterbodies to be sampled.

Results of rotating basin probabilistic surveys will be presented in a summary report approximately two years after the initial year of sampling within the 'superbasin'. In addition, the summary report will provide prioritized recommendations for targeted monitoring to determine designated use-support on waters with suspected impairments within the 'superbasin' Notable findings from each 'superbasin' report will also be documented in Wyoming's biannual Integrated Report beginning in 2014.

The monitoring program also produces individual assessment reports for targeted monitoring projects. These reports present background information on the water of interest, data collection and analysis methods, the monitoring data, an analysis of the data, recommendations on status of designated use support, as well as any recommendations for future monitoring. These reports are available in hard copy from the Cheyenne WDEQ office**,** and electronically at
http://deq.state.wy.us/wqd/watershed/Downloads/Monitoring/MonitoringReports/WatershedReportsMap.htm

Flowcharts depicting the probabilistic and targeted assessment and reporting processes are shown in Figures 5 and 6.

2.2.8 Potential Future Monitoring Programs

Wetlands

Wetland monitoring is currently limited to a qualitative assessment of riparian wetland condition conducted as part of stream and river assessments because a large percentage of Wyoming wetlands are riverine in nature. Riparian condition assessments will continue at all probabilistic, reference, and selected targeted sites. Degraded riparian wetlands are identified through Wyoming's 303(d) list of impaired waters and ultimately addressed through the TMDL and NPS watershed planning processes, provided that the degraded condition can be associated with less than full support of a designated use using water quality standards.

The monitoring program is in the process of developing a Rapid Assessment Methodology (RAM) for riparian and non-riparian wetlands. The RAM may replace the current procedure for riparian wetlands, though will need to be fully tested and evaluated as a pilot project prior to full implementation. The uses of the RAM for non-riparian wetlands have not been fully explored, but a rotating basin, probabilistic design is being considered. After completion of one five-year rotating basin probability survey for streams, staff and funding resources will be evaluated to determine if implementation of a non-riparian wetland component is feasible.

Integration with other Wetland Monitoring Programs

WDEQ will consider integration of other wetland monitoring programs such as the EPA National Wetland Condition Assessment (NWCA) into this and future strategies to help address CWA goals.

An opportunity exists to use data from the NWCA to achieve CWA objectives at the State level. The field portion of the NWCA is scheduled for 2011, although the sample size will be inadequate to make a statistically valid estimate of wetland condition. Wyoming could partner with EPA to expand the NWCA to achieve a statistically valid estimate of wetland condition if the NWCA is repeated in 2016. If this option is pursued, it likely will be through the use of a contractor, with additional funding required to sample the additional sites necessary to achieve a statistically-valid survey. Information on the NWCA is available at http://www.epa.gov/owow/wetlands/survey/.

Figure 5. Flow chart for probabilistic assessments.

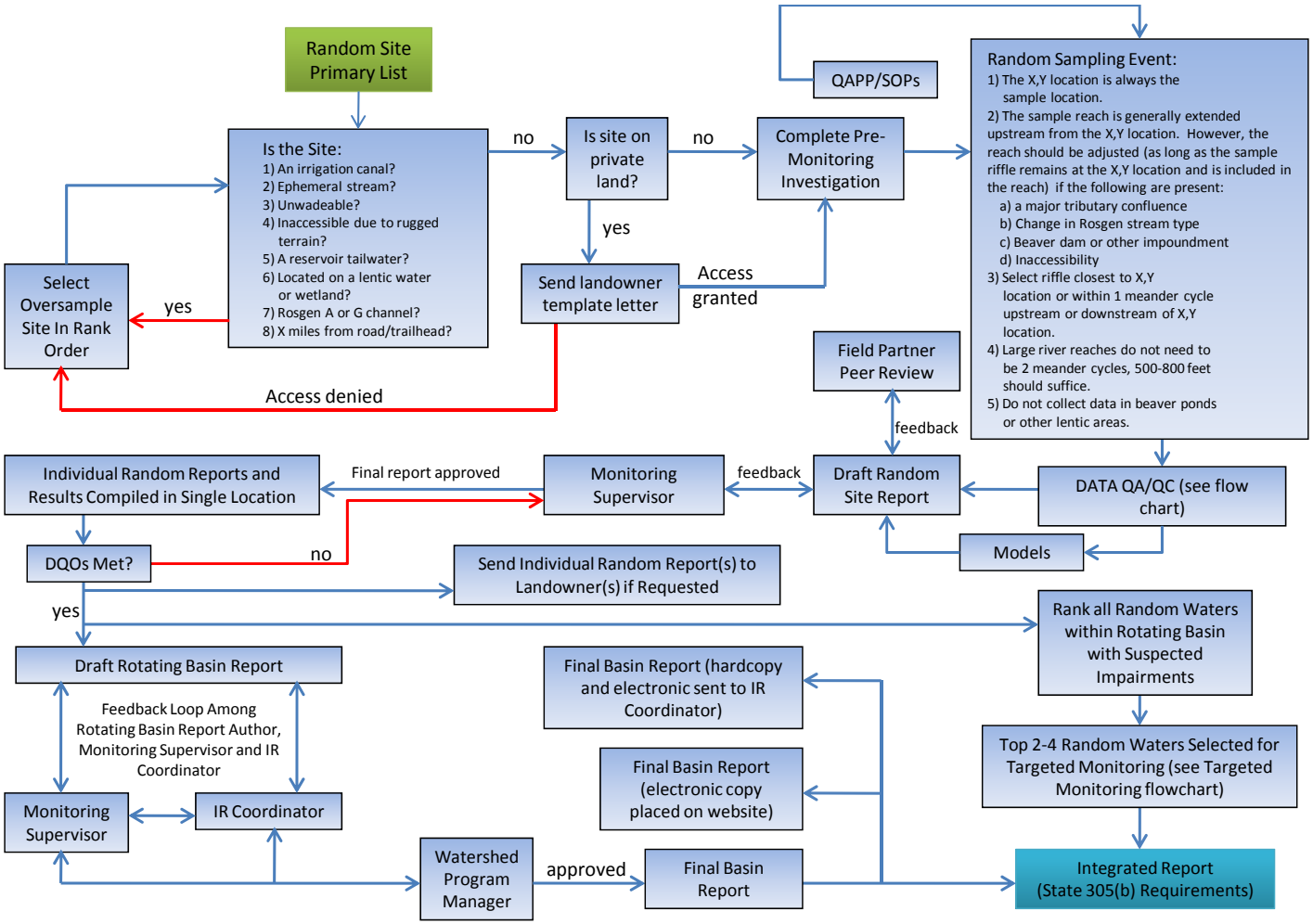
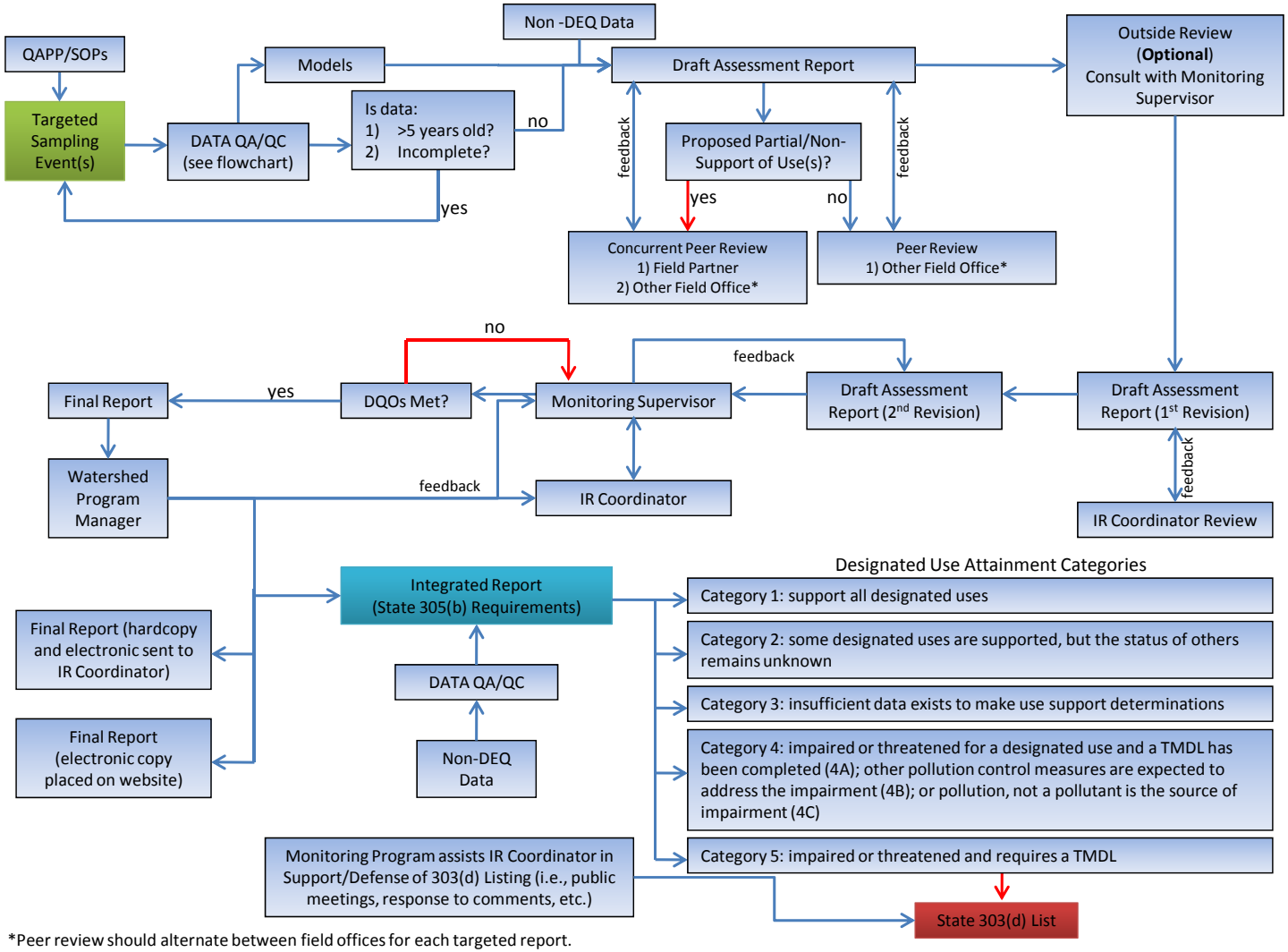


Figure 6. Flow chart for the targeted assessments.



*Peer review should alternate between field offices for each targeted report.

2.3 Interagency Cooperative Monitoring

2.3.1 USGS Ambient Network

WDEQ has worked cooperatively with the USGS since the 1970s on water quality monitoring of fixed stations around the State. Today, most of these stations are located on larger rivers and co-located with USGS stream gaging stations. Currently, the USGS ambient network includes 19 water quality monitoring stations and one stream gage station (Figure 4). Parameters vary by site and sampling frequency is most often quarterly (Table 4). Data is available from the USGS National Water Information System (NWIS) database accessible through the Wyoming Water Science Center website http://waterdata.usgs.gov/wy/nwis/qw/.These stations are used for surveillance of water quality trends, identification of emerging water quality issues, evaluation of impacts downstream of reservoirs, the Wyoming 305(b) report, 303(d) list of impaired waters and development of WYPDES permits.

2.3.2 USGS CBM Network

WDEQ has worked cooperatively with the USGS since 2000 on water quality monitoring at fixed stations in areas of the State where active coalbed methane (CBM) and other natural gas development is occurring. Most fixed stations are located in the Powder River Basin (PRB), although several are located in south-central and southwest Wyoming. Most fixed stations are located on streams where effluent is discharged under the authority of the WYPDES program, with some placed on larger receiving streams that integrate numerous affected tributaries or multiple direct discharges of treated or untreated effluent. Data is used for development of WYPDES permits and policies and to evaluate attainment of water quality standards and designated uses.

Currently, the CBM network includes 44 water quality monitoring stations (Figure 4). Parameters vary by site and sampling frequency is typically monthly (Table 5). Several stations also include stream gages and continuous conductivity and water temperature monitors. Data is available from the NWIS database accessible through the Wyoming Water Science Center website (http://waterdata.usgs.gov/wy/nwis/qw/). Several publications have been written using the data and can be accessed through the website.

Figure 7. WDEQ-USGS cooperative monitoring sites included in the Ambient and CBM networks.

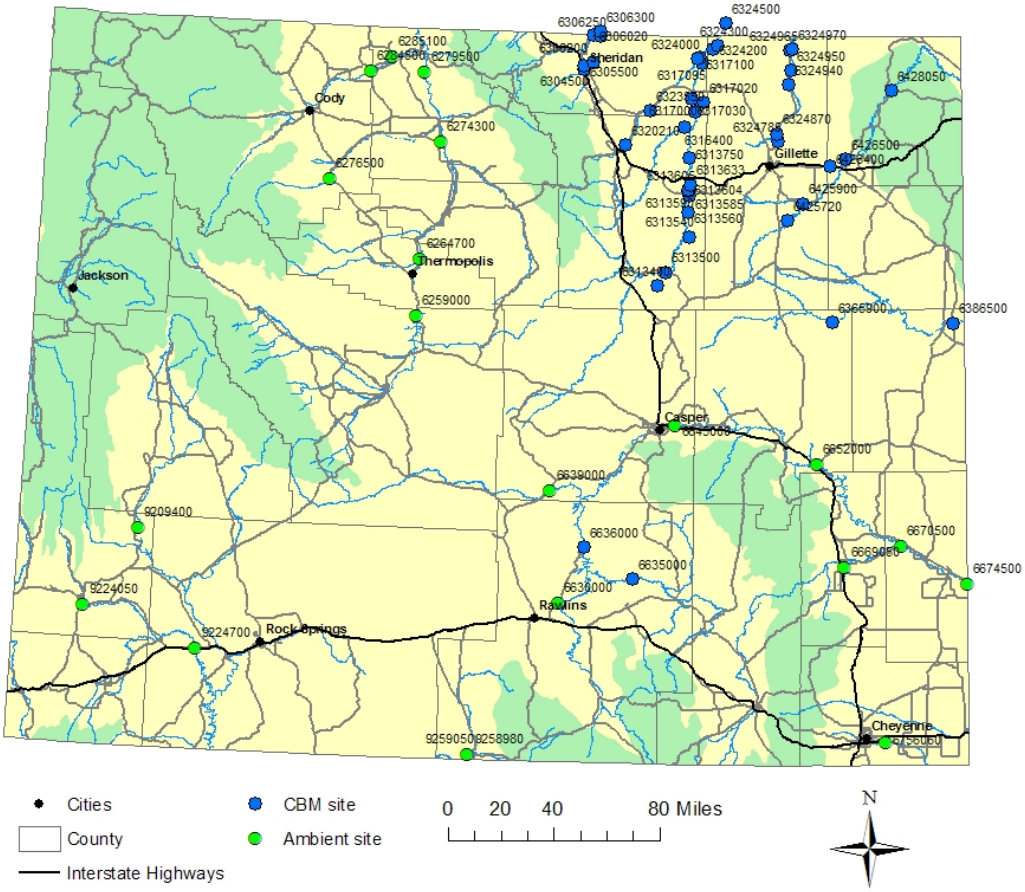


Table 4 – WDEQ-USGS Cooperative water resources program – ambient network, 2008-2010.

USGS Station Identifier	Station Name	Parameters	Sampling Frequency
06264700	Bighorn R at Lucerne	Bacteria, Nutrients, Sediment	4/yr
06274300	Bighorn R at Basin	Bacteria, Nutrients, Sediment	4/yr
06276500	Greybull R at Meeteetse	Bacteria, Nutrients, Sediment	4/yr
06279500	Bighorn R at Kane	Bacteria, Nutrients, Sediment	4/yr
06284500	Bitter Cr nr Garland	Bacteria, Nutrients	4/yr
06285100	Shoshone R nr Lovell	Bacteria, Nutrients, Sediment	4/yr
06630000	N Platte R ab Seminoe Rsvr nr Sinclair	Bacteria, Nutrients, Sediment	4/yr
06639000	Sweetwater R nr Alcova	Major Anions and Cations, Nutrients, Sediment	4/yr
06645000	N Platte R bel Casper	Bacteria, Nutrients, Major anions and cations, Trace elements	4/yr
06652000	N Platte R at Orin	Bacteria, Nutrients, Sediment	4/yr
06669050	Wheatland Cr bel Wheatland	Bacteria, Nutrients	4/yr
06670500	Laramie R at Fort Laramie	Bacteria, Nutrients, Sediment	4/yr
06674500	N Platte R at WY-NE State Line	Bacteria, Nutrients, Sediment	4/yr
06756060	Crow Cr nr Archer	Bacteria, Nutrients, Major anions and cations, Trace elements	4/yr
09224050	Hams Fork nr Diamondville	Bacteria, Nutrients, Major anions and cations, Trace elements	4/yr
09224700	Blacks Fork nr Little America	Bacteria, Nutrients, Sediment	4/yr
09259050	Little Snake R bel Baggs	Major anions and cations, Sediment	4/yr
06259000	Wind R bel Boysen Rsvr	Bacteria, Nutrients, Sediment, CBM[1]	12/yr
09209400	Green R nr La Barge	Sediment, CBM[1]	12/yr

[1] Major anions and cations, selected filtered trace elements, whole water recoverable arsenic

Table 5 – WDEQ-USGS Cooperative water resources program – CBM network, 2008-2010.

USGS Station Identifier	Station Name	Parameters	Sampling frequency	Gaging station	Continuous EC and temperature
06299980	Tongue R at Monarch WY *	CBM	12/yr	X	
06304500	Little Goose Cr at Sheridan	CBM	12/yr		
06305500	Goose Cr bel Sheridan	CBM	12/yr		
06306020	Tongue R bel Youngs Cr nr Acme WY	CBM, filtered Se, filtered Hg	12/yr		
06306200	Prairie Dog Cr at Wakely Siding nr Sheridan	CBM	12/yr	X	
06306250	Prairie Dog Cr nr Acme WY *	CBM	12/yr	X	
06313400	Salt Cr nr Sussex	CBM, filtered Se	12/yr		
06313500	Powder R at Sussex	CBM, filtered Se	24/yr	X	X
06313590	Powder R ab Burger Draw nr Buffalo	CBM	12/yr	X	
06313605	Powder R bel Burger Draw nr Buffalo	CBM	12/yr		
06316400	Crazy Woman Cr at Upper Station nr Arvada	CBM	24/yr	X	X
06317000	Powder R at Arvada	CBM, Nutrients	24/yr		
06320210	Clear Cr ab Kumor Draw nr Buffalo	CBM	12/yr		
06324000	Clear Cr nr Arvada	CBM	24/yr	X	X
06324970	Little Powder R ab Dry Cr nr Weston	CBM, Nutrients, Sediment	12/yr		
06369500	Cheyenne R nr Dull Center	CBM	12/yr	X	
06386500	Cheyenne R nr Spencer	CBM	12/yr		
06425900	Caballo Cr at mouth nr Piney	CBM, Nutrients	12/yr		
06426400	Donkey Cr nr Moorcroft	CBM	12/yr		
06426500	Belle Fourche R bel Moorcroft	CBM, Nutrients	12/yr		
06428050	Belle Fourche R bel Hulett	CBM	12/yr		
06635000	Medicine Bow R ab Seminoe Res nr Hanna	CBM, Nutrients, Sediment	12/yr		
06636000	N Platte R ab Pathfinder Res	CBM, Sediment	12/yr		
09258980	Muddy Cr bel Young Draw nr Baggs	CBM, Sediment	12/yr		
06313540	Willow Cr nr mouth nr Sussex	Major cations	12/yr		
06313560	Pumpkin Cr nr mouth nr Sussex	Major cations	12/yr		
06313585	Beaver Cr at mouth nr Sussex	Major cations	12/yr		
06313604	Burger Draw at mouth nr Buffalo	Major cations	12/yr		
06313633	Van Houten Draw at mouth nr Buffalo	Major cations	12/yr		
06313750	Barber Cr at mouth nr Buffalo	Major cations	12/yr		
06316900	Cottonwood Cr at mouth nr Arvada	Major cations	12/yr		
06317030	Wild Horse Cr at mouth at Arvada	Major cations	12/yr		
06317095	Spotted Horse Cr at mouth nr Arvada	Major cations	12/yr		
06317100	Powder R ab Clear Cr nr Arvada	Major cations	12/yr		
06323550	Clear Cr ab Double Crossing Cr nr Clearmont	Major cations	12/yr		
06324200	L X Bar Cr at mouth nr Moorhead MT	Major cations	12/yr		
06324300	S A Cr at mouth nr Moorhead MT	Major cations	12/yr		
06324785	Dry Fk Little Powder R at mouth nr Gillette	Major cations	12/yr		
06324870	Rawhide Cr at mouth nr Gillette	Major cations	12/yr		
06324940	Horse Cr at mouth nr Weston	Major cations	12/yr		
06324950	Little Powder R bel Elk Cr nr Weston	Major cations	12/yr		
06324965	Olmstead Cr at mouth nr Weston	Major cations	12/yr		
06425720	Belle Fourche R bel Rattlesnake Cr nr Piney	Major cations	12/yr		

CBM=Major anions and cations, selected filtered trace elements, whole water recoverable arsenic

2.3.3 Powder River Interagency Workgroup

The Powder River Basin (PRB) is a geologic structural basin that contains extensive natural gas resources associated with regional coal deposits located beneath millions of acres of private and public land in southeastern Montana and northeastern Wyoming. The PRB Interagency Working Group (IWG) was established in June 2003 to identify, discuss and find solutions to issues of common concern to government agencies involved in permitting and monitoring coal bed natural gas development. The PRB IWG is composed of managers and technical staff from local, State, tribal and federal government agencies with land management, conservation or regulatory responsibilities in the PRB, as well as agencies like the U.S. Geological Survey (USGS) that provide technical support.

The mission of the PRB IWG is to: (1) provide for environmentally sound energy development, (2) develop coordinated and complementary best management practices, guidelines and programs related to CBM activities to conserve and protect resources, (3) monitor the impact of CBM activities and assess the effectiveness of mitigating measures, (4) develop and integrate the databases and scientific studies needed for effective resource management and planning, and to make that information readily available, and (5) promote compatibility in the application of each agency's mission.

In order to more effectively address the technical issues presented by CBM development, Task Groups staffed by technical specialists from the member agencies were formed. The Task Groups include Air, Aquatic Life, Water Quality and Wildlife. WDEQ monitoring program personnel are active members of the Aquatic Life and Water Quality Task Groups (ATG and WTG). These groups have developed and implemented large scale water quality and aquatic wildlife monitoring programs. Funding is from a variety of sources and includes substantial contributions of State funds and federal grant allocations by WDEQ. Future support of the ATG and WTG is a high priority for WDEQ.

Aquatics Task Group

Objectives of the Aquatics Task Group (ATG) are to (1) develop aquatic habitat and species monitoring plans for watersheds with current or anticipated Coal Bed Natural Gas (CBNG) development and (2) make recommendations to PRB IWG regarding measures to avoid or minimize effects of CBNG development on aquatic species. If preventing substantial development effects is not possible, the task group will identify measures to mitigate the effects of CBM development and recommend methods to assess their effectiveness.

The ATG developed a sampling plan that describes monitoring of aquatic biota and habitat for drainage basins with current and anticipated CBNG development. The objectives of this monitoring plan are to (1) establish data on current conditions for

aquatic biota and their habitat and (2) determine existing and potential effects of CBNG discharge waters on aquatic life. Although it is too late to establish a true baseline of pre-CBNG development conditions in many areas, the current condition of aquatic communities and habitat can be assessed. The ATG has supplemented field monitoring with various remote sensing data to characterize and map aquatic habitat, riparian disturbances and invasive plants.

Sampling to assess the current condition of aquatic communities was conducted in 2005 through 2008 by the USGS in cooperation with the BLM, Montana DEQ, Montana Fish, Wildlife, and Parks, EPA, Wyoming DEQ and Wyoming Game and Fish Department. A total of 47 sites were sampled over the four years of study, though not all sites were sampled every year. The scope of work varied according to the river system, available funding, and the interests of the cooperators from Wyoming and Montana. More detail on the ATG sampling plan can be found at: http://pubs.usgs.gov/fs/2006/3047/pdf/fs2006-3047.pdf. An interpretive report for the 2005-06 monitoring was completed in 2009 (Peterson et al. 2009: available at http://pubs.usgs.gov/sir/2009/5023). A second interpretive report covering all four years of monitoring will be published in 2010.

Water Task Group

An objective of the Water Task Group (WTG) is to develop and implement water quality monitoring plans for surface water and ground water at local and regional scales. This monitoring will help agencies make more informed decisions regarding CBNG permitting and allow for dissemination of information to the public. The surface water monitoring plan is a sampling network composed of sites where PRB IWG member agencies have been conducting monitoring. The CBM network contains 37 sites in Wyoming and two sites in Montana that support the WTG monitoring plan. Sampling sites are located on mainstems and selected tributaries in each watershed. Sampling frequencies vary with stream type and constituent class. The constituent classes being monitored are shown below. A more detailed summary is available at http://pubs.usgs.gov/fs/2005/3137/.

- Streamflow and field measurements of pH, dissolved oxygen, specific conductance, and temperature
- Major ions: dissolved calcium, magnesium, potassium, sodium, alkalinity, chloride, fluoride, sulfate, and silica; dissolved solids; and sodium-adsorption ratio
- Nutrients: total and dissolved nitrogen and phosphorus species
- Trace elements (primary): total and dissolved aluminum, arsenic, barium, beryllium, iron, manganese, and selenium
- Trace elements (secondary): total and dissolved cadmium, copper, chromium, lead, nickel, and zinc.
- Suspended sediment

2.3.4 Bear River Interagency Workgroup

The original Bear River Compact of 1958, and the Amended Bear River Compact of 1980, in conjunction with the Bylaws of the Bear River Compact Commission and the laws of the States of Wyoming, Idaho, and Utah, establishes the framework under which the waters of the Bear River are divided was established by the US Congress. This framework regulates how the waters of the Bear River are distributed to water users in Wyoming, Idaho, and Utah as the River. Out of the Commission grew the Water Quality Committee whose members are the heads of each State's water quality program. The Committee has directed TMDL efforts as well as successfully nominated the Tri-State Bear River Basin for an EPA Watershed Initiative Program grant which recently ended. Water quality improvement efforts directed by the Committee continue in all three states.

2.3.5 U.S. Forest Service

WDEQ and the U.S. Forest Service have agreed upon a Memorandum of Understanding (MOU) that emphasizes the need for a cooperative working environment for the two agencies. The MOU outlines the roles and responsibilities of each agency in implementing the NPS Program, water quality and Best Management Practice (BMP) effectiveness monitoring and Use Attainability Analyses. Several National Forests are conducting BMP reviews and have been submitting results to WDEQ for review and potential inclusion in the basin description information of the Integrated Report.

2.3.6 Wyoming Game and Fish Department

The Wyoming Game and Fish Department (WGFD) and WDEQ sometimes have similar objectives. In recent years, there has been greater emphasis on cooperation between the two agencies on water quality issues. Staff from both agencies has worked together on a number of monitoring projects, including projects on the Shoshone River and Brooks Lake. WGFD have assisted with TMDL development efforts by providing data and expertise to WDEQ staff. WDEQ staff has assisted WGFD with fisheries surveys on the Powder River and other streams. WDEQ will continue to seek out opportunities to pair with WGFD to achieve common goals and reduce duplication of effort.

2.3.7 Wyoming Conservation Districts

Wyoming's Conservation Districts lead local level watershed planning and implementation activities. Legislative appropriations, local mill levies, 604(b) and 319 grants from WDEQ provide funding for Districts to address water quality issues in their local communities. In the past, WDEQ has assisted Districts with training, sampling and analysis plan design, QA/QC and data interpretation. Common water resource related projects conducted by Districts include water quality assessments, watershed planning efforts, and watershed improvement programs. Watershed improvement programs

include improvements to Animal Feeding Operations (AFOs) and septic systems, stock water development projects, riparian buffer projects, stream channel restoration projects and others. Currently, many Districts cooperate with WDEQ on development of TMDLs and lead local level BMP implementation on impaired streams.

2.4 Programmatic Evaluation

2.4.1 Performance Partnership Agreement

The performance partnership agreement (PPA), developed annually, outlines the commitments of the Wyoming Department of Environmental Quality to receive funding under a variety of grants administered by EPA Region 8. The PPA documents the commitments of EPA and the state for implementation of several federal environmental programs, including those required by the Clean Water Act for water quality monitoring and assessment. As part of the PPA, the EPA provides feedback to the State on its management of CWA programs.

2.4.2 Internal Evaluation

Continual informal evaluations occur through feedback from staff, the public, and other agencies to monitoring program and higher-level WDEQ management. Resultant adjustments may occur to project-level resource allocation within the monitoring program during the course of the current ten-year strategy, but overall, the scope and central objectives of the program are expected to remain the same until the next strategy is developed for 2020 and beyond.

Internal evaluations have identified eleven goals for improvement over the next ten years. These goals are listed below, with an approximate implementation schedule shown in Table 5.

1. Increase spatial reference site coverage to improve existing multi-metric index and predictive model for assessing biological condition and facilitate development of other bioassessment tools; Refine existing multi-metric index and predictive model using newer data
2. Explore development of periphyton models;
3. Develop a wetland rapid assessment methodology (RAM) and evaluate how the RAM may be integrated into probabilistic rotating basin and targeted monitoring;
4. Evaluate existing methods and design for lake and reservoir assessment;
5. Continue to improve cooperation with other local, state, and federal land and water management agencies
6. Continue to strengthen nutrient criteria database
7. Develop regional curves to improve ability to assess physical habitat degradation, plan and design stream restoration activities, and assess effectiveness of restoration
8. Update the Quality Assurance Project Plan

9. Develop SOPs for new methodologies; update existing SOPs where needed

10. Incorporate an integrated effectiveness monitoring program to evaluate success and needed changes to Section 319 grant projects, watershed plans, TMDL implementations plans and associated programmatic decisions and direction.
11. Conduct monitoring as needed to develop water quality standards, fill assessment gaps when developing TMDLs, and prioritizing monies on Section 319 projects.

2.5 General Support and Infrastructure Planning

Currently, the Monitoring Program has six full time field staff, one part time QA officer, one full time monitoring supervisor, and 1-3 seasonal employees during some years. These staff are not only responsible for implementing the monitoring strategy, but also 401 certification, complaint/spill response, non-point source project management, data entry, QA.QC, and community outreach. It is anticipated that this level of staff support is adequate to achieve the primary monitoring objectives described in this strategy, provided that current lake and wetland monitoring is not expanded. At a minimum, two additional staff is needed to achieve the improvement goals and fully address all resource types. Secondary objectives currently are addressed through a combination of staff support from the Monitoring, TMDL, and NPS programs, and contractor support. It is difficult to determine the level of additional staff support needed to fully achieve the secondary monitoring objectives. Additional funding for contractors may be beneficial and partly offset the need for staff, though funding alone will not be adequate. Increased staffing levels must be approved by the Administrator, Director, Governor and the Legislature. Increased funding does not necessarily result in approval for additional staff. Further, additional funding for contractors, while beneficial, also requires that existing staff take time away from current duties in order to develop requests for proposals, scopes of work, and manage the contracts.

Table 6. Approximate implementation schedule for programmatic improvement goals.

Goal	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Improve reference site coverage	Continuous process										
Refine RIVPACS and WSII		WSII	RIVPACS				WSII	RIVPACS			
Explore use of periphyton models				Research	Development and implementation?						
Wetland RAM development											
Evaluate reservoir design and methods	Complete second three year cycle										
Improved interagency coordination	Continuous process										
Monitoring for nutrient criteria	Continuous process			Proposed criteria development							
Regional curve development	Central/Western Mts		Additional region(s) possible								
Refine QAPP			Update					Update			
Develop/refine SOPs		Update	Additional new or revised SOPs as needed								
Effectiveness Monitoring	Analysis	Phase-in	Variable effort dependent upon needs and available resources								
Monitoring for TMDLs and standards	Variable effort dependent upon needs and available resources										

3.0 REFERENCES CITED

Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B. 1999. Rapid BIoassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Chapman, S.S., Bryce, S.A., Omernik, J.M., Despain, D.G., Zumberge, J.R., and M. Conrad. 2003. Ecoregions of Wyoming (color poster with map, descriptive text, summary tables, and photographs): Reston, VA: U.S. Geological Survey (map scale: 1: 1,400,000).

Hargett, E.G., and ZumBerge. J.R. 2006. Redevelopment of the Wyoming Stream Integrity Index for assessing the biological condition of wadeable streams in Wyoming. Wyoming Department of Environmental Quality, Cheyenne, WY

Hargett, E.G., ZumBerge, J.R., and Hawkins, C.P. 2005. Development of a RIVPACS model for wadeable streams of Wyoming. Wyoming Department of Environmental Quality, Cheyenne, WY

Hargett, E.G., ZumBerge, J.R., Hawkins, C.P., and Olson, J.R. 2007. Development of a RIVPACS-type predictive model for bioassessment of wadeable streams in Wyoming, *Ecological Indicators* 7(2007), p. 807-826.

Peterson, D.A., Wright, P.R., Edwards, G.P., Hargett, E.H., Feldman, D.L., ZumBerge, J.R., and Dey, P. 2009. Ecological assessment of streams in the Powder River Structural Basin, Wyoming and Montana, 2005-06: U.S. Geological Survey Scientific Investigations Report 2009-5023, 139 p.

Rosgen, D.L. 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology, Fort Collins, CO.

USBLM. 1998. Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. Technical Reference 1737-15, United States Department of the Interior; Bureau of Land Management; Denver, CO

USEPA, 2003. Elements of a state water monitoring and assessment program. United States Environmental Protection Agency, Washington, D.C.

WDEQ 2000. Quality assurance project plan for Beneficial Use Reconnaissance Project water quality monitoring. Wyoming Department of Environmental Quality, Cheyenne, WY.

WDEQ 2004. Manual of standard operating procedures for sample collection and analysis. Wyoming Department of Environmental Quality, Cheyenne, WY.

WDEQ 2007. Wyoming water quality rules and regulations, Chapter 1: Surface water quality standards. Wyoming Department of Environmental Quality, Cheyenne, WY

WDEQ 2008a. Wyoming nutrient criteria development plan. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, Wyoming.

WDEQ. 2008b. Wyoming's method for determining water quality condition of surface waters and TMDL prioritization criteria for 303(d) listed waters. Wyoming Department of Environmental Quality, Cheyenne, WY.

WDEQ 2009. Summary of scientific literature relevant to Wyoming lake/reservoir nutrient criteria. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, WY.

WDEQ 2009b. Wyoming nutrient criteria sampling and analysis plan, Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, WY.

Appendix A - Core and Supplemental Indicators Used to Assess Wyoming Water Quality

				Primary Objectives					Secondary Objectives				
Indicator	**Indicator**	**Chapter 1 criteria type (section)**	**Interpretive tools for narrative criteria**	**Reference**	**Rotating-Basin Probability Survey**	**Targeted**	**Statewide Probability Survey**	**Lakes & Reservoirs**	**Nutrient criteria development**	**TMDLs**	**NPS**	**Designated use(s)**	**Other applications**
Biological													
Benthic Macroinvertebrates	C	Narrative (32)	Reference stream data, WSII[a], RIVPACS[b], metrics, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X		X	X	X	Aquatic Life[1]	Potential response variable for deriving numeric nutrient criteria
Periphyton	C	Narrative (32)	Reference stream data, metrics, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X		X	X	X	Aquatic Life[1]	Potential response variable for deriving numeric nutrient criteria
Fish	S	Narrative (32)	Reference stream data, regional IBIs, metrics, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment			X		X		X	X	Fisheries	Chapter 1 classification
Fish tissue	S	Numeric, Narrative (18)	Scientific literature, regional guidance, professional judgment			X		X		X	X	Fish consumption	
Chlorophyll α (periphyton)	C	Narrative (28)	Reference stream data, paired-watershed, upstream,/downstream approach, scientific literature, regional guidance, professional judgment.	X	X	X	X		X	X	X	Aquatic Life[1]	Potential numeric criteria
Chlorophyll α (planktonic)	C	Narrative (28)	Scientific literature, regional guidance, trophic state indices, professional judgment.					X	X	X	X	Aquatic Life[1]	Potential numeric criteria
E. coli bacteria	C	Numeric		X	X	X	X	X		X	X	Recreation	
Qualitative biosurvey	C	Narrative (17, 28, 32)	Reference stream data, paired-watershed, upstream,/downstream approach, USEPA RBP Manual[c], professional judgment	X	X	X	X	X		X	X	Aquatic Life[1]	

Chemical													
Dissolved oxygen	C	Numeric, Narrative (24)		X	X	X	X	X		X	X	Aquatic Life[1] Fisheries	
Conductivity	C	Narrative (32)		X	X	X	X	X		X	X	Aquatic Life[1]	Surrogate for total dissolved solids, guidance limits for agricultural use
Total sulfates	C	Narrative (32)		X	X	X	X			X	X	Aquatic Life[1]	Guidance limits for agricultural use
Total chlorides	C	Numeric		X	X	X	X			X	X	Aquatic Life[1]	
pH	C	Numeric, Narrative (26)		X	X	X	X	X	X	X	X	Aquatic Life[1]	pH-dependent numeric criteria
Ammonia-N	C / S	Numeric, Narrative (21)				X		X		X	X	Fisheries	
Nitrate-nitrogen	C	Numeric, Narrative (32)	Reference stream data, paired-watershed, upstream,/downstream approach, scientific literature, regional guidance, trophic state indices (lakes & reservoirs), professional judgment.	X	X	X	X	X	X	X	X	Aquatic Life[1] Drinking water	Potential additional numeric criteria
Total phosphorus	C	Narrative (32)	Reference stream data, scientific literature, paired-watershed, upstream,/downstream approach , regional guidance, trophic state indices (lakes & reservoirs), professional judgment.	X	X	X	X	X	X	X	X	Aquatic Life[1]	Potential numeric criteria
Total nitrogen	C	Narrative (32)	Reference stream data, scientific literature, paired-watershed, upstream,/downstream approach, regional guidance, trophic state indices (lakes & reservoirs), professional judgment.	X	X	X	X	X	X	X	X	Aquatic Life[1]	Potential numeric criteria
Total Kjeldahl nitrogen	C	Narrative (32)	Reference stream data, scientific literature, paired-watershed, upstream,/downstream approach, regional guidance, trophic state indices (lakes & reservoirs), professional judgment.	X	X	X	X	X	X	X	X	Aquatic Life[1]	Potential numeric criteria
Alkalinity	C			X	X	X	X	X		X	X		RIVPACS predictor variable

Hardness	S			X		X		X		X	X		Hardness-dependent numeric criteria
Priority and non-priority pollutants (Chapter 1)	S	Numeric, Narrative (21, 32)				X		X		X	X	Aquatic Life[1] Drinking water Fish consumption	
Color, odor, sheen	C	Narrative (17, 29)		X	X	X	X	X		X	X	Aquatic Life[1] Drinking water Fish consumption	
Other constituents	S	Narrative				X		X		X	X		
Physical													
Water temperature	C	Numeric, Narrative (25)	Reference stream data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X	X		X	X	Aquatic Life[1] Fisheries	Chapter 1 classification
Turbidity	C	Numeric, Narrative (16, 23)		X	X	X	X		X	X	X	Fisheries Drinking water	Potential response variable for deriving numeric nutrient criteria
Total suspended solids	C	Narrative (16)	Reference stream data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X		X	X	X	Aquatic Life[1]	
Flow	C	Narrative (11)	Calculation of 7Q10, regional guidance	X	X	X	X			X	X		Exemptions for numeric criteria during low flow
Secchi depth	C	Narrative (16)	Scientific literature, regional guidance, trophic state indices, professional judgment.					X		X	X	Aquatic Life[1] Fisheries	Potential response variable for deriving numeric nutrient criteria
Riffle substrate	C	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X			X	X	Aquatic Life[1]	RIVPACS predictor variable
Riffle embeddedness	S	Narrative (15, 32)	Reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X			X	X	Aquatic Life[1]	
Reachwide substrate	C	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X			X	X	Aquatic Life[1]	Rosgen classification

Reach slope	C		WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X			X	X		Rosgen classification
Cross-section profile(s)	C	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X			X	X	Aquatic Life[1]	Rosgen classification
Bed feature delineation	C			X	X	X	X			X	X		Used for reachwide substrate indicator
Longitudinal profile	S	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment			X				X	X	Aquatic Life[1]	
Sinuosity	C		WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment	X	X	X	X			X	X		Rosgen classification
Bank erosion profile(s)	S	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment			X				X	X	Aquatic Life[1]	
Bank Erosion Hazard Index / Near Bank Stress	S	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment			X				X	X	Aquatic Life[1]	
Bar sample(s)	S	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment			X				X	X	Aquatic Life[1]	
River Stability Prediction Survey	S	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment			X				X	X	Aquatic Life[1]	
Scour chain(s)	S	Narrative (15, 32)	WARSSS[d] methodology, reference reach data, paired-watershed, upstream,/downstream approach, scientific literature, professional judgment			X				X	X	Aquatic Life[1]	

Bank stability and cover	C	Narrative (15, 32)		X	X	X	X			X	X	Aquatic Life[1]	
Pool quality	C	Narrative (15, 32)	Reference stream data, paired-watershed, upstream,/downstream approach, USEPA RBP Manual[c], professional judgment	X	X	X	X			X	X	Fisheries	
Qualitative riparian vegetative structure and human influence survey	C	Narrative (15, 32)	Reference stream data, paired-watershed, upstream,/downstream approach, professional judgment	X	X	X	X			X	X	Aquatic Life[1]	
Qualitative stream and riparian condition survey	C	Narrative (15, 32)	Reference stream data, paired-watershed, upstream,/downstream approach, USBLM PFC[e] methodology, professional judgment	X	X	X	X			X	X	Aquatic Life[1]	
Qualitative reach and watershed characterization	C			X	X	X	X			X	X		Reference designation
Shoreline habitat characterization	C	Narrative (15, 32)	Regional guidance, professional judgment					X		X	X	Fisheries	
Other constituents or methods	S					X		X		X	X		

C = Core Indicator, S = Supplemental Indicator.
[1]Often used as surrogate for other uses such as fisheries, agriculture, industry, and wildlife (WDEQ 2007)
[a] Hargett and Zumberge (2006)
[b] Hargett et al. (2007 and 2005)
[c] Barbour et al. (1999)
[d] Rosgen (2006)
[e] USBLM (1998)