Utah's 2010 Integrated Report

Part 1: Methods for Assessing and Reporting the Condition of Lakes and Streams

October, 2010

Utah Department of Environmental Quality, Division of Water Quality

Disclaimer

This document provides information and methods used by Utah's Division of Water Quality (DWQ) to assess support of the designated uses that have been assigned to surface waters of the state. Given that assessment methods are constantly revised to reflect in concert with changes to standards and newly available science, every attempt will be made to update this document in a timely manner. However, DWQ does not guarantee that the current published assessment document reflects current assessment methods. Individuals interested in applying these methods should contact DWQ directly to ensure that the methods reflect current thinking. In addition, if anyone uses the methods in this guidance to assess water quality of Utah, they cannot directly state or imply that a river, stream, lake or reservoir is supporting or not supporting its designated uses. Only DWQ has the authority to make such determinations. However, DWQ always appreciates the submission of any data and information that can assist agency scientists in making the most accurate beneficial use assessments possible.

TABLE OF CONTENTS

OVERVIEW OF UTAH'S WATER QUALITY ASSESSMENT METHODS

INTRODUCTION

Clean Water Act (CWA) federal rules and regulations require Utah's Division of Water Quality (DWQ) to report the condition—or health— of all surface waters to Congress every other year. Known as the *Integrated Report* (IR), this report contains two key pieces of information. First, the report identifies waterbodies that are not meeting their designated uses. These waters are listed as impaired on the 303(d) list of this report (in reference to §303(d) of CWA), which subsequently requires that DWQ develops restoration plans to improve the condition of these waters. Second, the report summarizes the overall condition of Utah's surface waters, and estimates the relative importance of key water quality concerns (i.e., pollutants, habitat destruction) and sources of water quality problems. In addition to meeting federal legal requirements (CWA §305(b)), these broad statewide summaries help DWQ and the US Environmental Protection Agency (EPA) prioritize resource needs.

> The *Integrated Report* combines the 305(b) report on current water quality conditions with the 303(d) list of impaired waters.

This guidance manual summarizes the methods that the DWQ follows when assessing whether water quality is sufficient to support the designated uses assigned to Utah's surface waters. In particular, these methods describe how chemical and biological data are compared against Utah water quality standards (UAC R317-2) to identify impaired waters. These methods are often revised in response to new information or to improve their legal or scientific defensibility. In all cases, the aim of assessment methods is to balance the potential for false positive conclusions (conclusion of a degraded use when it is actually supported) and false negative conclusions (failure to identify a degraded use), while remaining consistent with federal regulations and guidance (e.g., EPA 2006). Comments on how these methods can be modified to more effectively meet these goals are appreciated.

DESIGNATED USES AND WATER QUALITY STANDARDS

The central objective of the Clean Water Act (CWA) is to, "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (CWA §101 (a)). To meet this objective, the CWA and associated regulations develop the concept of "designated uses". In essence, designated uses describe key aspects of waters that should be maintained to ensure that all surface waters provide important services to humans and other organisms. The creation of use classes allows different waterbodies (i.e., river segments, lakes) to be classified into similar classes (groups), which can then be used to develop numeric criteria that describe pollutant concentrations that must not be exceeded to ensure protection of the use class. Under Federal Regulations each State is required to establish uses classes, which can include as many classes as are needed to ensure protection; however, at a minimum the classes must ensure protection of aquatic life and recreation uses for all surface waters (40CFR 131.10(a)).

DWQ has designated uses to the rivers, streams, lakes and reservoirs of Utah. Utah's designated uses include: domestic use sources, recreation uses, aquatic life uses, and agricultural uses (Table 1), and are defined for specific waterbodies throughout Utah in UAC R317-2-6. Specific use designations (Class 5) were recently established different ecosystems associated with Great Salt Lake to assist with the development of additional numeric criteria for this ecosystem. As the narrative descriptions elucidate, the each of the designated uses—and associated subclasses—actually protects numerous activities (i.e., recreation, agricultural) or organisms (i.e., aquatic life, Great Salt Lake). In practice, numeric criteria are intended to ensure protection of the most sensitive of these activities or organisms.

Table 1. Designated uses protected under Utah's clean water act. Column 1 depicts uses codes. Numbers in use codes differentiate major uses classes: 1 = drinking water, 2= recreation, 3 = aquatic life, 4= agriculture and 5= Great Salt Lake. Letters in use codes indicate subclasses of uses, each with different associated numeric criteria. Use descriptions provide a narrative to describe each use as described in UAC R317-2-6. Emphasis (bold/italic text) indicates the names commonly used to describe uses in this document and elsewhere.

Use	Use Description
1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of ***Drinking Water***.
2A	Protected for ***primary contact recreation*** such as swimming.
2B	Protected for ***secondary contact recreation*** such as boating, wading, or similar uses.
3A	Protected for ***cold water*** species of game fish and other cold water ***aquatic life***, including the necessary aquatic organisms in their food chain.
3B	Protected for ***warm water*** species of game fish and other warm water ***aquatic life***, including the necessary aquatic organisms in their food chain.
3C	Protected for ***nongame*** fish and other ***aquatic life***, including he necessary aquatic organisms in their food chain.
3D	Protected ***for waterfowl, shore birds*** and other ***water-oriented wildlife*** not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain.
3E	***Severely habitat-limited waters***. Narrative standards will be applied to protect these waters for aquatic wildlife.
4	Protected for ***agricultural uses*** including irrigation of crops and stock watering.
5A	***Great Salt Lake Gilbert Bay***. Protected for infrequent primary and secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including their necessary food chain.
5B	***Great Salt Lake Gunnison Bay***. (see 5A)
5C	***Great Salt Lake Bear River Bay***. (see 5A)
5D	***Great Salt Lake Farmington Bay***. (see 5A)
5E	***Great Salt Lake Transitional Waters.*** (see 5A)

ASSESSMENT UNITS (AUS)

DWQ segments waters into relatively homogenous units called Assessment Units (AUs). The physical, chemical, or biological conditions of the waters within an AU are more similar to each other than to the conditions in adjacent AUs. Segments that have any different beneficial uses than an adjacent segment are always classified as different AUs. A stream may be divided into several AUs even when beneficial uses are the same because of for instance, different total dissolved solids concentrations when the stream crosses the Mancos Shale. Factors such as flow, channel morphology, substrate, riparian condition, adjoining land uses, confluence with other waterbodies, and potential sources of pollutant loading are considered when delineating AUs (USEPA, 2006). AUs for streams and rivers are established for defined stream segments or watersheds (see *Assessment Unit Delineation and Identification*), whereas lakes or reservoirs are typically considered to be a single and distinct AU.

ASSESSMENT METHODS

Pursuant to CWA requirements, DWQ has developed water quality standards, including narrative and numeric criteria, to help ensure that the designated uses are supported. The methods in this document describe how DWQ compares site-specific analytical data to these standards to assess whether waterbodies are meeting their designated uses. In general, chemical analytical results assess support in the context of numeric criteria, whereas biological data assess support against narrative criteria. For each AU, available chemical data are compared against the specific uses and criteria assigned to the waterbody. If two criteria exist for two different uses assigned to the AU, then the more protective criterion is used to make assessments.

The threat to designated uses posed by various water quality stressors depends upon the stressor itself and the specific designated use. This document describes how results obtained from water samples, including: conventional parameters (i.e., pH, dissolved oxygen), toxic pollutants, and bacteriological data are compared to the water quality standards (R317-2). A separate section of the document is used to describe assessment procedures for phosphorous, because while numeric criteria do not currently exist for nutrients, DWQ acknowledges that human-caused eutrophication can threaten designated uses and should be considered when making assessment decisions.

While some of these methods are directly applicable to lakes and reservoirs, others are not, because water chemistry data naturally differ with lake depth, which must be accounted for when interpreting lake and reservoir data. Also, monitoring data differ significantly among streams/rivers and lakes/reservoirs. For instance, while lakes and reservoirs are sampled less frequently, they are frequently sampled at multiple collections and monitoring protocols specify collecting additional data elements to provide more accurate designated uses assessments for these waters. Given these differences, a separate section of these methods describes a separate process for assessing support of the designated uses assigned to lakes and reservoirs.

Finally, biological assessment methods are also described. These relatively new assessment procedures quantify—with empirical models— the extent to which human-caused activities have altered the biological composition of streams and rivers. These biological assessments are then used to assess support of aquatic life designated uses. These assessments represent an objective interpretation of aquatic life uses based upon Utah's narrative criteria. Because both biological and chemical data are used to assess aquatic life use support, this section also describes how both sources of information are used to make final assessment decisions.

THE OVERALL ASSESSMENT PROCESS

Creating the IR is a multi-year process that requires careful coordination of many staff within DWQ, our external sister State and Federal agencies, and other interested stakeholders (Figures 1 and 2). In particular, federal regulations (40 CFR 130.7(b)(5)) require DWQ to examine all existing and readily available data when making assessment decisions, which includes consideration of data collected by DWQ and others. As a result, procedures have been developed for formally requesting and directly seeking data collected by other scientists that can be used to inform IR assessment decisions. These data must be obtained in sufficient time to DWQ to compile and organize the information to facilitate subsequent analysis. In addition, sufficient time must be provided for adequate review of the assessments within DWQ and then with our outside stakeholders. Overall the process identifies interim deadlines to help ensure that the report is submitted to EPA for approval by April of even years. DWQ continually strives to meet these interim target dates; however they are sometimes missed due to unforeseen circumstances. Interested stakeholders are encouraged to contact DWQ discuss status of current IR work. Similarly, informal comments outside of formal comment periods are encouraged, because many concerns can be addressed before the formal report is finalized.

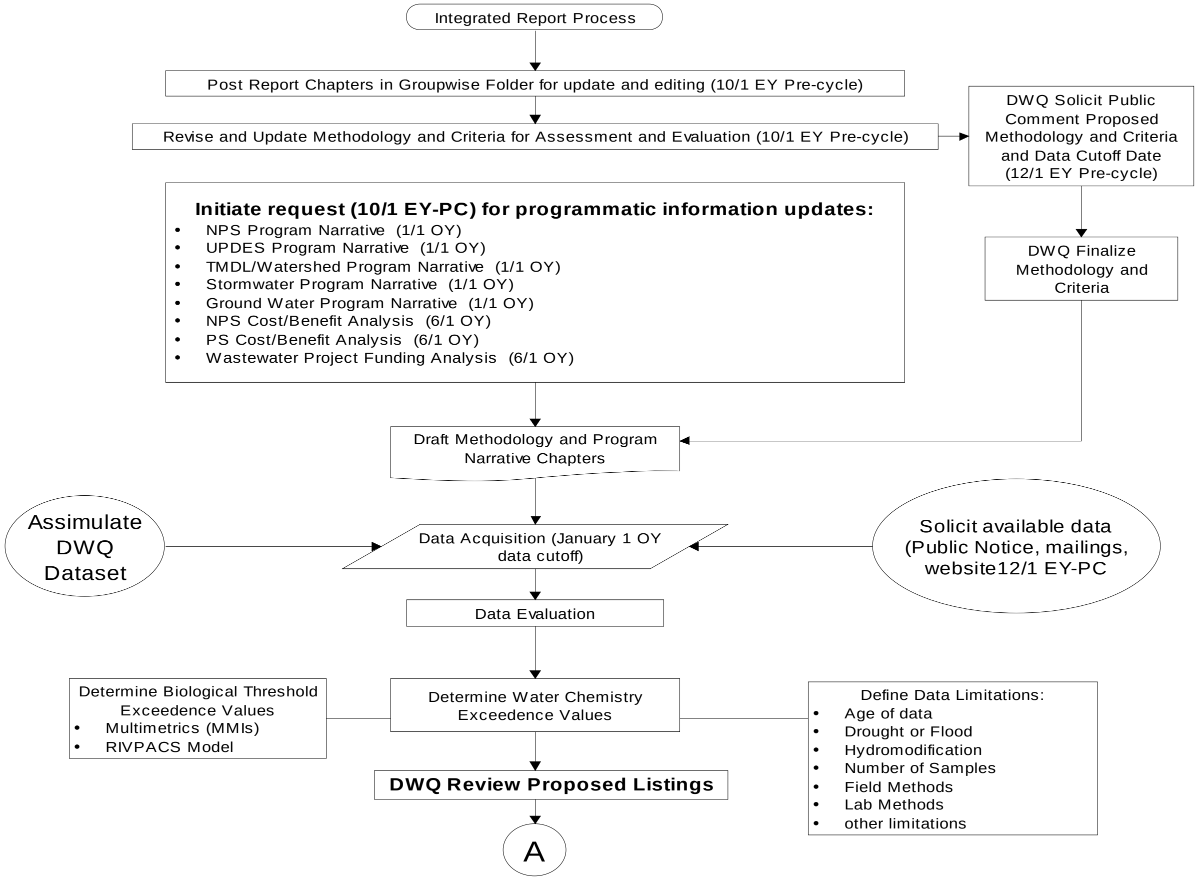

Figure 1. Flow chart illustrating the overall assessment process used by DWQ to determine if water quality is sufficient to support the designated uses of Utah's surface waters.

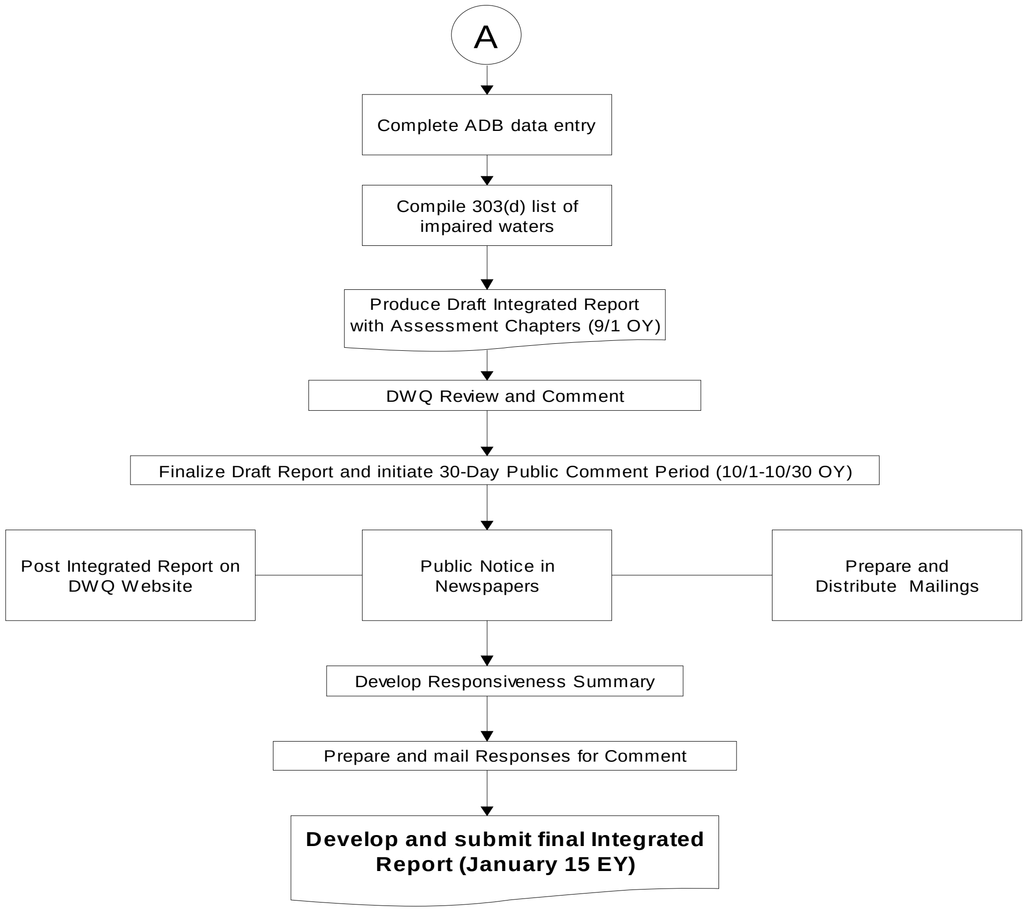

Figure 2. Flow chart illustrating the overall assessment process used by DWQ to determine if water quality is sufficient to support the designated uses of Utah's surface waters.

DATA REQUIREMENTS AND CONSIDERATIONS

INTRODUCTION

Pursuant to EPA's guidance and regulations (40 CFR 130.7(b)(5)), DWQ actively pursues all water quality information and data to assist with making informed impairment decisions. DWQ encourages the submission of any data, reports, or water quality observations that can help us make more informed decisions. Chemical samples collected following rigorous field and laboratory methods can often be directly combined with those collected by DWQ. Even completely subjective water quality observations (e.g., fish kills, algal blooms) often help agency scientists interpret more-quantitative data.

All water quality data submitted to DWQ are used to help make more informed assessment decisions, but different sources of information are interpreted differently in the context of assessing support of designated uses. Some of the questions that are asked about outside data sources to determine the weight that they should carry in making assessment decisions include:

- How frequently were the samples collected? When were the samples collected?
- Where were the samples collected? Is the location representative of the Assessment unit?
- Were rigorous field and laboratory methods followed? Are these methods comparable to those followed by DWQ or our federal cooperators?
- What Quality Assurance/Quality Control (QA/QC) procedures were followed? Were QA/QC results and procedures documented? What is the precision and accuracy of water quality data?
- Were sufficient metadata collected to allow DWQ to interpret the information in an assessment context?

Answers to these questions help DWQ determine how different data sources and information are used to make designated use assessment decisions. All readily available sources of data and information are reviewed when making assessment decisions. Data submitted that was collected following rigorous, well-documented, QA/QC procedures will be directly analyzed as if the information was collected by DWQ. Other sources of information, may not be directly used for an assessment decision, but will still be used to augment other assessment analyses.

This section of Utah's assessment methods summarizes how different types of data and information are used by DWQ for assessment purposes. First, the types of data used to make assessment decisions is discussed, along with considerations specific to these information sources. Second, minimum quality assurance requirements are discussed.

Many scientific investigations collect similar types of data. However, the specific QA/QC procedures followed when collecting and analyzing data frequently differs among studies for many reasons. Different studies require varying degrees of accuracy and precision or entirely unique methods, depending on the questions being investigated. DWQ does not require that outside data be collected following identical methods. Yet, the methods that were followed must be sufficiently documented so that DWQ can ascertain the precision and accuracy of the information. Also, DWQ must have sufficient information to interpret the data in an appropriate spatial and temporal context.

For outside entities interesting in submitting data for use in developing the IR, recommendations are described for data submission. These recommendations include data elements (metadata) that should be submitted to DWQ along with datasets or reports. DWQ acknowledges that it may not be possible to obtain all of the elements described in this document when submitting water quality information. In such cases, DWQ encourages stakeholders to submit whatever information is readily available. Some submissions may lack sufficient information to directly augment assessment analyses; however the information will still be used qualitatively as DWQ weighs all of the information available to make a final determination of beneficial use support.

TYPES OF DATA USED TO MAKE ASSESSMENT DECISIONS

Many types of data are used to make assessment decisions, including: chemical data, biological & habitat data, and technical reports/manuscripts. Each source of information is used differently to inform assessment decisions, and requires unique suite of QA/QC considerations. This section summarizes some of these unique considerations.

Chemical Data

The majority of assessment decisions are based upon chemical data, in part because these data are most easily linked to numeric criteria. DWQ uses different assessment methods for toxicant and conventional (non-toxic) chemical data. In addition, different assessment methods are followed when using chemical data to assess streams & rivers than are used for lakes and reservoirs. Generally speaking, it is much easier to combine chemical data from multiple data sources than other types of information, because field and laboratory methods are less variable and often better documented. However, chemical datasets are also highly spatially and temporally variable, which can complicate interpretation of the information, which must be accounted for when assessing support of designated uses.

Biological and Habitat Data

Biological and habitat data can be useful sources of information when interpreting aquatic life beneficial use support. However, both field and laboratory methods for these data are less standardized than they are for chemistry data. Differences among protocols complicate directly incorporating biological and habitat data obtained from different sources. As a result, it is often more useful for DWQ to receive summary data and information that interprets biological or habitat information in the context of aquatic life use support. In such cases, it is particularly important that ancillary information is supplied that describes how the data were collected and details of subsequent analyses. The scientific rigor employed to obtain information that describe the physical and biological integrity of waters varies extensively; DWQ will apply varying weights to information submitted based on the confidence we have with collection and analytical techniques, and our confidence that the data are representative of watershed conditions.

Manuscripts and Reports

Reports, articles from refereed journals, and other scientific publications are evaluated for applicability to water quality standards, both numeric and narrative. Sometimes these studies are difficult to interpret in an assessment context. In other cases, the results and conclusions are contrary to other sources of data and information. These difficulties are not surprising because these studies are almost never conducted with the aim of assessing support of water quality standards. Nonetheless, all of these investigations provide insight into how various biological and biogeochemical processes influence the designated uses of Utah's aquatic ecosystems. In the end, DWQ makes formal impairment decisions based on the overall weight of evidence derived from all sources of data and information, which includes research conducted to address indirectly related scientific questions.

QUALITY ASSURANCE CONSIDERATIONS

DWQ has established numerous quality assurance procedures. These procedures include Quality Assurance Project Plans (QAPPs) that document data accuracy objectives and define protocols for the storage and delivery of analytical results and the associated Quality Assurance/Quality Control (QA/QC) data. In addition, field and laboratory methods (Standard Operating Procedures (SOPs)) have been established that describe specific procedures to be followed when collecting and analyzing data. Whenever possible, all established a method conforms to standard practices and procedures. Details of these procedures are available elsewhere. This section provides a summary of several key QA/QC considerations that DWQ uses when evaluating data to be used to make designated use support decisions.

Are the data representative of the AU being assessed?

Assessments are predicated on the assumption that samples capture representative conditions of watersheds or entire lakes and reservoirs—established AUs. Efforts are made to ensure that the sample location provides a representative sample. For instance, samples used for assessing the effects of a point source discharge are generally not collected directly from the effluent, but from the receiving water outside of the mixing zone. In some situations, data sources suggest that AU boundaries are inappropriate, in which case the AU boundaries are adjusted to ensure as appropriate (see *AU Delineation Procedures* below).

Are the data representative of current conditions?

Designated uses assessments should reflect current conditions. Assessments are generally based on data collected within the most recent five years. For the 2010 IR, the most recent data generally considered was collected by December 31, 2008. Data collected 5-10 years ago were occasionally used for assessment purposes, if supporting documentation or information indicate that significant changes in hydrology or land use have not occurred since the samples were collected. Data older than 10 years are not used to determine beneficial use support.

Were appropriate laboratory methods used to obtain analytical results?

All water quality samples should be analyzed in a State or EPA certified laboratory or in a USGS approved laboratory. If the samples are analyzed in a non-certified laboratory or with a nonstandard method, a Quality Assurance Project Plan (QAPP) should accompany the data, which should include the QA/QC data used in quality control checks within the laboratory. These data should include quality assurance data such as results from field blanks, duplicate samples, spiked samples and samples with a known concentration for each of the parameters submitted to DWQ. A citation of the method used to analyze the samples should be included to assist DWQ in evaluating the data. If the method was developed by the laboratory, the method validation documentation should be submitted along with the data for evaluation.

The following documents provide procedures for the standard methods used to make water quality assessments:

1. *Standard Methods for the Examination of Water and Wastewater*

2. *EPA Methods for Chemical Analysis of Water and Wastes*

3. ASTM Standards, Part 31, Water

4. *EPA Biological Field and Laboratory Methods*

5. Code of Federal Regulations, Title 40, Part 2

6. Other Methods - EPA approved or as determined by DWQ

Unlike for chemistry, standard laboratory methods do not generally exist for habitat and biological data. Nonetheless, laboratory techniques can bias water quality interpretations. For instance, inferences of macroinvertebrate collections differ depending on the intensity of subsampling and the typical level of taxonomic resolution to which individuals are identified. There are numerous laboratory methods for processing biological data, all of which are acceptable provided that data are internally consistent. Detailed QA/QC documents for processing biological samples have been developed by DWQ or our contractors, which can be provided upon request.

SUBMISSION OF DATA FROM OUTSIDE SOURCES

Early in the process of developing the IR, DWQ formally and informally requests data and information from as many sources as possible. In many cases, DWQ has worked with outside partners for many years, and have developed routine processes for sharing data. These partnerships are symbiotic, helping both DWQ and our partners make more informed management decisions. This section of these methods was written as a guide for others interested in submitting data and information for use in making IR assessment decisions.

For the most part, field collections following standard State or Federal field procedures, coupled with chemical analyses done in a state- or federally-certified lab, are of sufficient quality to allow standard beneficial use analyses. For instance DWQ routinely obtains and analyzes data collected and processed by the United States Geological Survey (USGS) and local municipalities. Data quality procedures for these programs are well-documented and DWQ has already conducted the work necessary to ensure sample comparability. Data collected by other outside entities that have not previously collaborated with DWQ is evaluated on a case-by-case basis to determine how it will be used to make beneficial use support decisions. This section of the report discusses how DWQ solicits data and information, how “outside” data sources are evaluated, how data of varying quality is used to make assessment decisions, and recommendations for submission of data to ensure that it is used to the greatest extent possible.

> DWQ routinely obtains data from numerous outside partners including: USGS, USFS, BLM, NPS, Davis Co, Salt Lake Co, Salt Lake City, and others.

Public Notification

Each IR cycle DWQ makes a formal public notification—through newspaper ads, website postings, and e-mail list servers—requesting data and information that can be used to inform designated use assessments. Whenever possible, the aim of DWQ is to obtain all data and information with sufficient time to compile all data by April of odd years. This allows staff sufficient time to compile and interpret the information, obtain clarification where necessary, to ensure that outside information sources are used to the greatest extent possible for IR assessments. Following each public notice, interested stakeholders will have a minimum of 30-days to submit water quality information to DWQ.

External Data Submission

Whenever possible, all datasets should be submitted electronically, either as spreadsheets or as comma-delimited text files. Each dataset is unique and DWQ will work with interested stakeholders on formatting issues to ensure that the datasets are as compatible as possible to those used by DWQ for IR assessment analyses. Direct communication with outside investigators is necessary to ensure that outside data sources are properly interpreted. However, DWQ requests that electronic data submissions also be accompanied with sufficient metadata to provide documented spatial, temporal, and analytical context to the information.   Guidance on desired metadata elements is available and was made public in conjunction with the external data request. The following list provides a few examples of metadata that are crucial for interpreting water quality data:

- The latitude and longitude, and datum, of the monitoring site.
- The date and time when the sample was collected.
- The type of waterbody (i.e., river, stream, reservoir).
- The type of sample represented by the data (i.e. grab sample, composite, profile).
- Detection and reporting limits
- Units of measurement used, (e.g., mg/L, ppb)

Considerations for the use of External Data

Data are sometimes submitted to DWQ with the expectation that it will be analyzed, following the assessment methods outlined in this document, to make assessment decisions. However, in some cases DWQ does not receive sufficient information to interpret these data to make assessment decisions. In other cases, QA/QA procedures are questionable or are poorly documented. All data used to make assessment decisions, whether collected by DWQ or anyone else, is screened following similar procedures (Figures 3 and 4). Data that fail to pass these screens and are not used direct analytical assessments. In such cases, the data are summarized and used to augment other data sources, in a weight of evidence approach, to make assessment decisions.

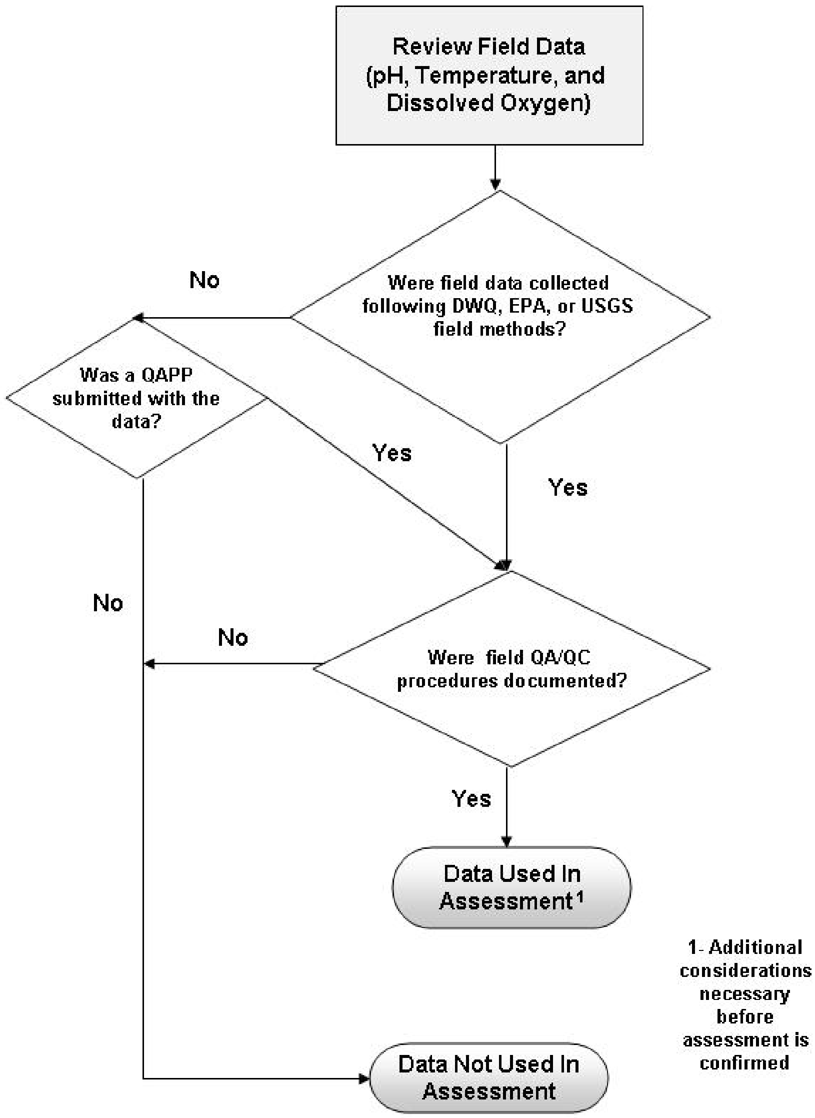

Figure 3. An outline of The process that DWQ follows when determining if field-based datasets, by themselves, are of sufficient quality for making assessment decisions. Datasets that fail QA/QC objectives are summarized and used to augment other sources of data and information available for each AU.

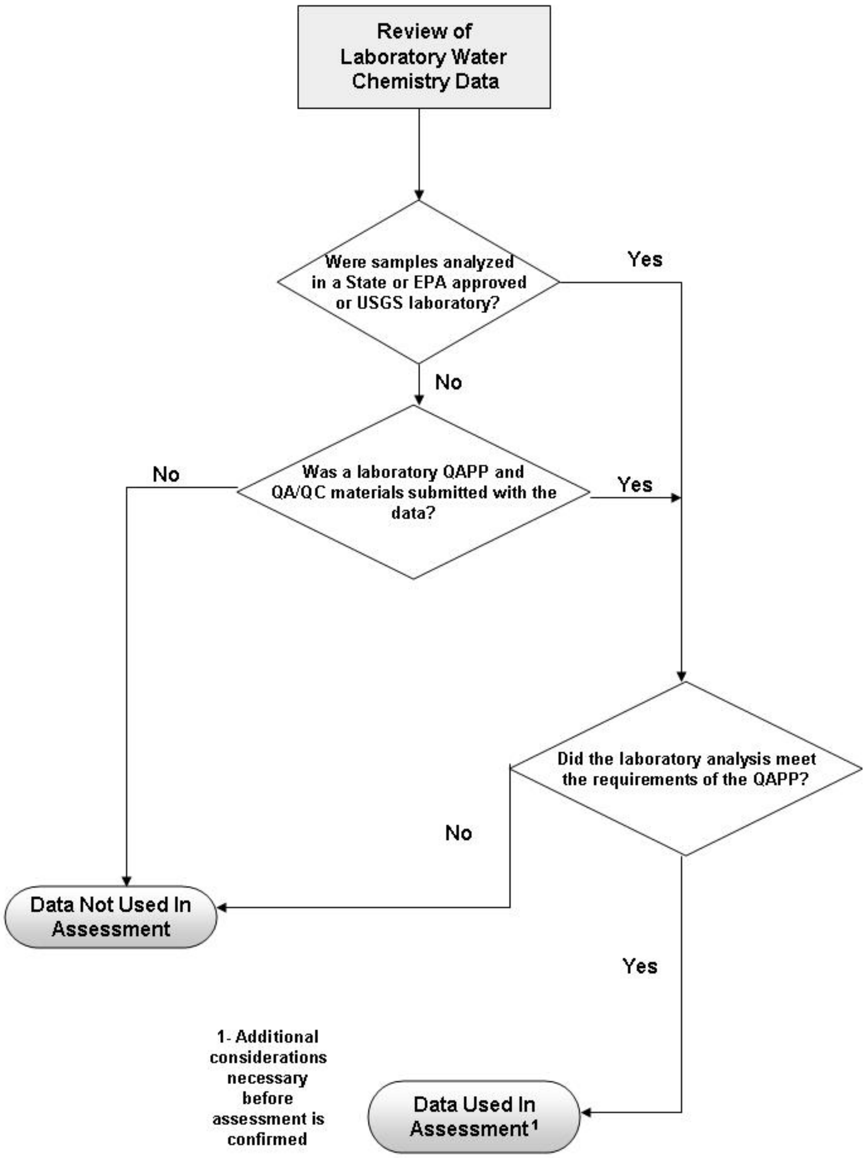

Figure 4. An example of the process that DWQ follows when determining if chemistry datasets, by themselves, are of sufficient quality for making assessment decisions. For datasets that fail QA/QC objectives[1], DWQ will work directly with researchers, on a case-by-case basis to evaluate data comparability and data quality.

ASSESSMENT UNIT DELINEATIONS

INTRODUCTION

DWQ's goal is to assess Utah's streams and lakes on a watershed scale. However, for pragmatic reasons the watersheds are further subdivided into Assessment Units (AUs) for assessment. Discrete AUs DWQ designated decision units on which beneficial use attainments are determined. Lakes and reservoirs are usually delineated as individual AUs and the size is reported in acres. Rivers and streams are delineated by specific river, river or stream reach, or several stream reaches in sub-watersheds. When using sub-watersheds to delineate stream AUs, the new USGS 5th (10-digit) and 6th (12-digit) level watershed units for Utah are used to delineate the AUs. These watershed units allow for the aggregation of stream reaches into individual AUs that are of similar size and have similar physical, chemical, and ecological characteristics. The 5th and 6th hydrological units were developed by individuals representing state and federal agencies, and have been certified by the Natural Resource Conservation Service.

These broad guidelines develop a starting point with AUs, which are subsequently screened further, using GIS- and field-derived data, to determine if these watersheds other characteristics (i.e., major changes in surrounding vegetation, hydrologic diversions) warrant further dividing the AU into smaller watersheds. This section of the document outlines the methods that DWQ follows when delineating AUs.

> Assessment results apply to Assessment Units (AUs), which are defined stream segments , lakes , or reservoirs with similar chemical and physical conditions

GUIDELINES FOR DELINEATING STREAM AND RIVER ASSESSMENT UNITS (AUS)

When delineating river and stream AUs, DWQ followed the guidelines listed below and consistently adheres to the first two guideline statements.

- The AU is within an eight-digit USGS hydrologic unit (HUC).
- Each river and stream in an AU has the same designated beneficial use classifications. For instance, if a stream segment has designated uses classes 1C, 2B and 3A, whereas an adjacent segment has classes 2B and 3B, then the watershed would have at least two AUs.
- Large rivers, such as the Green River, Colorado River and portions of other large rivers (Bear River, Weber River, etc), were delineated into "linear" or "ribbon" AUs. For these rivers AU boundaries were established at the point of entry of major tributaries, or at other significant hydrologic boundaries (i.e., dams).
- AUs for smaller rivers and streams were delineated primarily using the 5th and 6th level hydrologic units.
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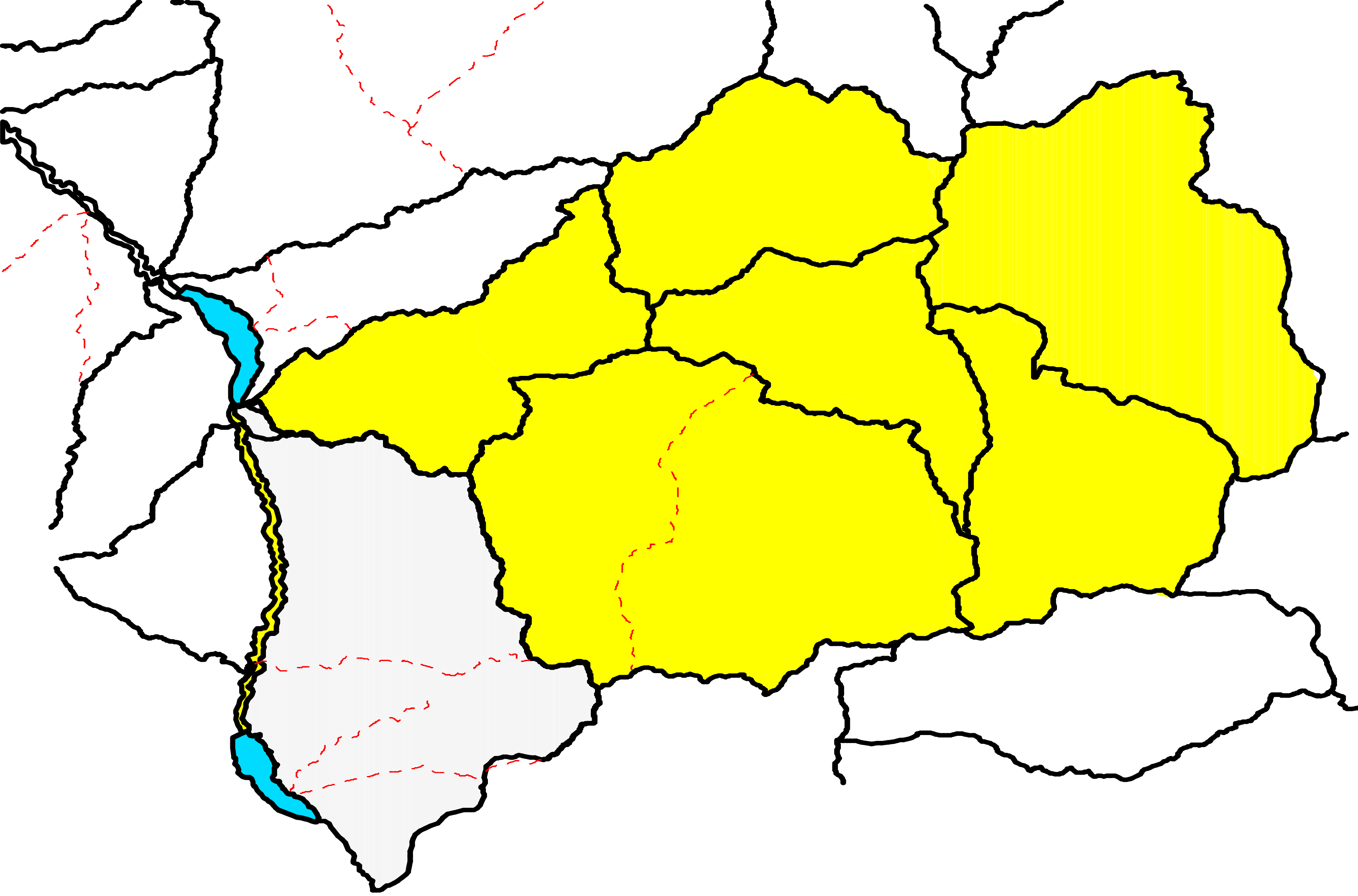


Figure 5. An example of the spatial extent of Asssessment Units (AUs) developed for the upper Weber River watershed**.** Each of the polygons delineated by black borders represents a separate AU. Note that in most cases the AUs are catchments, whereas the AU for the section of stream beween the reservoirs is a stream segment due to the the local hydrologic influence of these reservoirs on the river.

- Some AUs are split to smaller segments that those established for 5th or 6th level watersheds if changes within the AU are observed, such as: hydrology (i.e., entry of tributary streams, changes in stream power), stream size, geology/soils, vegetation, or human land-use.
- With the exception of Great Salt Lake, lakes and reservoirs are currently considered a single AU.

All AUs have been geo-referenced (indexed) to the National Hydrologic Database using a reach-indexing tool that provides the capability of using GIS techniques to display information and data for each AU (e.g., Figure 5). Beneficial use classifications and assessments for individual AUs can be mapped or displayed to provide visual representation of assessment results. Individual stream AUs were assigned a unique identification code for indexing which includes the 8-digit hydrological unit (HUC) number with the prefix UT and followed by a 3-digit code to identify each unique AU in a HUC. Lake and reservoir AUs were identified by adding the prefix UT-L- to the 8-digit HUC follow by a 3-digit code.

CHANGES TO ASSESSMENT UNITS

With each IR cycle established AUs are refined based upon DWQs continually expanding knowledge of the ambient conditions of Utah's streams and rivers.   Whenever DWQ changes AU boundaries, DWQ documents the rationale for making these changes and submits this information as part of the IR to EPA for approval.

REPORTING ASSESSMENT RESULTS

INTRODUCTION

Beginning in 2002, EPA recommends five categories for reporting results of designated use assessments. The five categories were developed by EPA to provide a clearer summary of a state's water quality status and to assist in developing management actions to protect and restore waters of a state to meet Utah's water quality standards and support its designated uses. Utah summarizes assessment results using these five categories, along with state-derived subcategories for internal tracking and planning purposes.

DESIGNATED USE ASSESSMENT: CATEGORICAL RESULTS

EPA assessment reporting categories for assessment results were developed to improve national consistency among States and to avoid conveying to stakeholders that water quality is not better—or worse—than it actually is. However, there are overlaps among assessment categories that may be confusing to stakeholders. First, AUs are assessed independently for each of their designated uses, and assessment results are reported accordingly. As a result, several different assessment results—one for each use—are possible for a single AU. Second, assessment result reporting Categories 1 and 2 summarize assessment results across all uses, whereas Categories 3-5 summarize results independently for each use. Finally, it is possible that designated use exceeds numeric criteria for more than one pollutant and TMDLs are pollutant-specific. Hence, assessment reporting Categories 4 and 5, which track impaired waters, are both pollutant-specific. The following definitions provide details of the meaning of each reporting category (see also Figure 6):

Category 1: All designated uses are attained.

AUs assessments are reported as Category 1 if all beneficial uses have been assessed against ≥1 numeric criterion ***and*** each uses was found to be fully supporting all uses.

Category 2: Some of the designated uses are attained, but there is insufficient data to determine beneficial use support for the remaining designated uses.

AUs assessments are reported as Category 2 if some but not all designated uses have been evaluated, ***yet*** those uses that have been assessed were found to be supporting designated uses.

Category 3: Insufficient data to make a determination, or lakes and reservoirs that show indication of impairment for a single monitoring cycle.

For each designated use, assessments are reported as Category 3 if some data and information are available to evaluate ≥1 of an AUs designated uses, ***yet*** available data are insufficient to make a conclusive assessment determination. Inconclusive decisions result from datasets that fail to meet Data Quality Objectives (DQOs) that DWQ has established for making IR assessment decisions. Examples of situations where AUs are reported as Category 3 include: datasets with an insufficient number of samples were available for analysis, situations where contradictory conclusions from multiple data sources, or situations where QA/QC procedures were improper or poorly documented.

By reporting an AU as Category 3—versus simply reporting the AU as not assessed—DWQ is making a commitment to prioritize future monitoring to make a final assessment determination. In part due to this intrinsic commitment to prioritize monitoring, DWQ uses three Category 3 sub-categories for planning purposes, which are defined as follows:

- **<u>Category 3A</u>**: Assessment Units are listed in Category 3A if there is assessment insufficient data and information to make an assessment, or in some cases, multiple datasets reveal inconsistent and conflicting information.

- **<u>Category 3B</u>**: Lakes and reservoirs that have been assessed as not supporting a beneficial use for one monitoring cycle are included in Category 3B. If a lake or reservoir is assessed as impaired for two consecutive monitoring cycles it is listed on the 303(d) list.

- **<u>Category 3C</u>**: This category is currently used for Great Salt Lake (Designated Use Class 5). Assessment of this ecosystem with traditional approaches is complicated by the current lack of numeric criteria, with the exception of a selenium standard applicable to bird eggs. Also, the lake is naturally hypersaline, so traditional assessment methods are not appropriate. DWQ is working toward developing both numeric criteria and assessment methods for this ecosystem. In the interim, the Integrated Report will include an Appendix that summarizes progress that was made in the most recent 2-year reporting cycle.

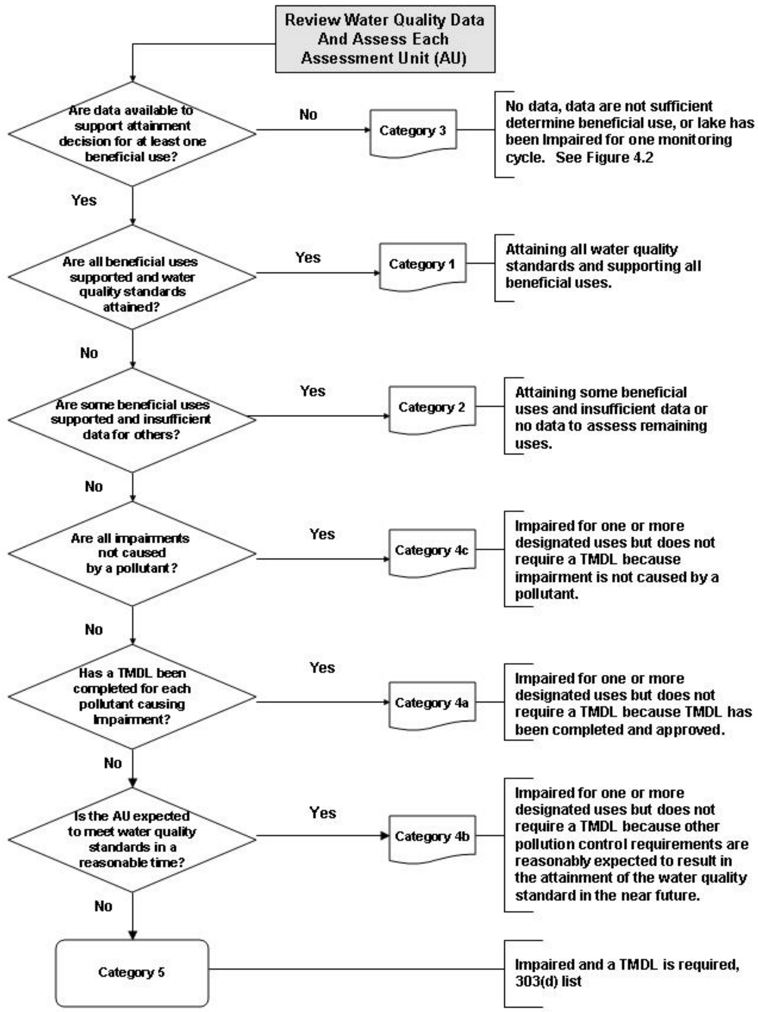


Figure 6. A broad description of the process that DWQ follows to determine the final assessment results and the associated assessment classification.

Category 4: Impaired for one or more designated uses, but does not require development of a TMDL.

For each designated use, AUs are reported as Category 4 if water quality remains insufficient to support the designated use, yet a TMDL is not required.

- **Category 4A: TMDL has been completed for any pollutant.**

Assessment Units are listed in this sub-category when any TMDL(s) has been developed and approved by EPA, that when implemented, are expected to result in full support of the water quality standards or support the designated designated uses. Where more than one pollutant is associated with the impairment of an AU, the AU and the parameters which have an approved TMDL are listed in this category. If it has other pollutants that need a TMDL, it is also listed in Category 5. Therefore, an AU can be listed in Category 4A and 5.

- **Category 4B: Other pollution control requirements are reasonably expected to result in attainment of the water quality standard in the near future.**

  Consistent with the regulation under 40 CFR, 130.7(b)(I) (ii), and (iii), AUs are listed in this subcategory where other pollution control requirements (e.g., best management practices required by local, state, or federal authority are stringent enough to meet any water quality standard or support any beneficial use applicable to such waters.

- **Category 4C: The impairment is not caused by a pollutant.**

  Assessment units are listed in this subcategory if the impairment is not caused by a pollutant (e.g., habitat alteration, hydromodification).

Category 5: The concentration of a pollutant—or several pollutants—exceeds numeric water quality criteria, or quantitative biological assessments indicate that the biological designated uses are not supported (narrative water quality standards are violated).

Waters reported as Category 5 are impaired, which means that they are not meeting their designated uses. The list of Category 5 waters if sometimes called the "303(d) list" if reference to this section of the CWA, which among other things, requires States to identify impaired waters. There are several sources of data and information that are used when making impairment decisions. First, chemical assessments evaluate designated use support for an AU by comparing pollutant concentrations against numeric criteria that have been established to protect the use. A designated use of an AU is reported as Category 5 if any of the following apply:

- The concentration of any pollutant exceeds—as defined by the methods described in this document—a numeric water quality criterion.
- Quantitative biological assessment results for streams and rivers are statistically different than the reference site conditions.
- Weight of evidence assessments for lakes and reservoirs indicate that designated uses are not being supported.

The specific methods used by DWQ to make any of the above conclusions are documented in detail throughout the remaining sections of this document.

EXCEPTIONS BASED UPON UNUSUAL HYDROLOGIC OR CLIMATIC CONDITIONS

Severe or extreme natural conditions, such as a drought, can be considered during the beneficial use assessment. During severe to extreme drought conditions, streams can have temperatures greater than the standard but are rare in occurrence if the normal hydrological regime occurs. In this case, DWQ reserves the right to identify these waters, but not list the AU on the 303(d) list. A rationale for not listing will be provided whenever this occurs. The AU will be assessed again when normal flow conditions return. For example, during the extreme drought in southern Utah, the Paria River was listed as not being assessed because the stream dried up during several months of the year and samples could not be collected.

CRITERIA FOR REMOVING AN AU FROM THE 303(D) LIST (CATEGORY 5)

There are various reasons for removing an AU from the 303(d) list (Category 5 waters). Any AU can be removed from the 303(d) list based upon the criteria listed below. Once a decision is made the pollutant is removed from the 303(d) list. The AU is listed in the assessment category that results because of the delisting, e.g., an assessment unit is moved to Category 4A if a TMDL has been completed and approved by EPA. As a result of a delisting, an AU could be placed in multiple assessment categories.

The following list provides circumstances where it may be appropriate to move an AU that was assessed as impaired (Category 5) in a previous IR to another assessment result:

1. The AU was placed on list due to error in assessment or because an AU was listed incorrectly in place of another AU or any other error not based on water quality assessment.

2. The most recent data assessment indicates that the AU is now meeting Utah water quality standard or is supporting the designated beneficial use support for all of its designated designated uses that were assessed.

3. A total maximum daily load analysis (TMDL) for any pollutant(s) has been completed and approved by EPA. The approved TMDL and the pollutant(s), is automatically moved to Category 4A. Any pollutant(s) remaining on the 303(d) list for which a TMDL has not been completed and approved for that AU will remain on the 303(d) list (Category 5A). Therefore, an AU may be listed in both Categories 4A and 5A.

4. An existing AU delineation has changed**:**

(1) An AU has been changed by dividing it into several assessment units.

(2) The AU boundaries have been changed and it is now a part of a different AU or portions of the AU are included in newly defined assessment units.

5. A change in the method(s) of determining beneficial use support. The methodology change may cause the assessment to result in all of the designated uses being assessed as fully supported.

6. A change in State water quality standards or pollution indicator values may change assessment to fully supporting all designated uses that have sufficient data to be assessed.

7. A determination that insufficient amounts of data were collected to place the AU on the list originally, e.g., too few samples collected to make a reliable determination of beneficial use support.

8. Utah exercises discretion in using data or information that goes beyond the criteria listed above in determining whether to de-list an AU and can include other types of information and best professional judgment.

All changes from Category 5 to any other assessment category are subject to EPA approval. The rationale for removing any AU from Category 5 (303(d) list) is documented in a “Request for Removal” table that accompanies the IR.

WATER CHEMISTRY ASSESSMENTS OF STREAMS AND RIVERS

INTRODUCTION

For each AU, DWQ compiles and screens all available water quality data to obtain a final list of parameters that can be coupled to any of the numeric criteria assigned to all designated uses within the AU. Each of these parameters is then evaluated, one-by-one, against the most protective criterion assigned to any of the AU's designated uses (Figure 7). Each designated use is considered to be fully supported (Category 2) once any of its associated numeric criteria is found to be meeting it numeric criteria. Similarly, once any parameter is found to exceed its numeric criteria—following the methods outlined in this section—the designated use is considered to be not meeting the applicable designated use(s) for that parameter, and the AU will be listed as impaired (303(d) list).

Given that AUs are assigned numerous uses—both within and among designated use classes—it is not uncommon for an AU to have numerous numeric criteria for a single chemical parameter. If this occurs within a use class, for instance in a situation where a site is assigned numerous aquatic life uses, then DWQ evaluates the WQ data against the most protective criterion to make assessment decisions for that use. If a parameter has criteria assigned to different designated use classes, for instance ammonia criteria for drinking water and aquatic life uses, then the criteria are evaluated independently to determine designated use support of all uses. These independent evaluations mean that if a site is found to be degraded based on the most restrictive criterion among designated uses, then all of the designated uses with criteria associated with the parameter are considered impaired.

> Generally a minimum of 5 samples are required to make as assessment based on toxic criteria, whereas at least 10 samples are required for conventional (non-toxic) criteria

This section provides the methods that DWQ follows for interpreting designated use support from chemical analytical results. Assessment procedures are described for both conventional and toxic parameters.

SAMPLE SIZE REQUIREMENT

As a general rule, DWQ requires at least 10 samples (conventional parameters) or 5 samples (toxic parameters), collected from an AU within the most recent five years, to make an assessment of designated use support. AUs with fewer than 10 samples are considered "not assessed" for the applicable designated use, unless data quality objectives are met for another parameter associated with that use. This rule helps ensure that assessment decisions are not made from data collected during anomalous conditions (i.e., storm events) that may not be representative of the actual threat to associated designated uses. However, because DWQ considers all existing and readily available data when making assessments, smaller numbers of samples are sometimes used, along with other sources of data and information, to make impairment decisions. In the end, any observation that numeric criteria have been exceeded—however limited—will be used to either conclude impairment or prioritize the AU for immediate follow-up monitoring to obtain the data necessary to make conclusive assessment decisions.

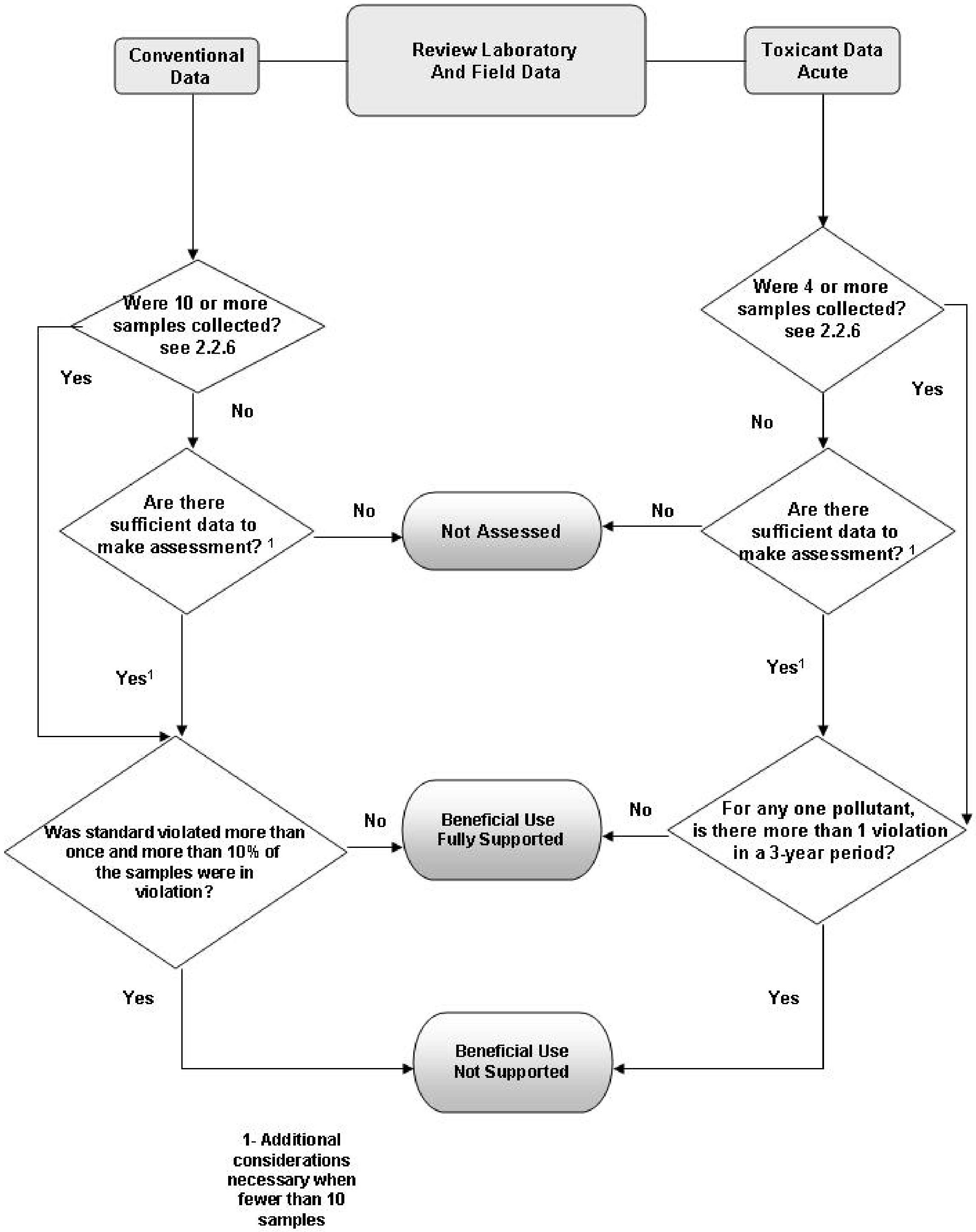


Figure 7. This flow chart depicts the overall assessment process for conventional and toxic (toxicant) water quality parameters. Additional details can be found in later figures and text.

CONVENTIONAL PARAMETERS

Conventional measures of chemical condition (Table 2) have high temporal variation—daily, seasonally, and yearly. Also these parameters are not acutely toxic and tend to degrade designated uses via exposure over relatively long time periods. To avoid over-interpretation of outliers when interpreting designated use support, DWQ follows the "10% rule" (UAC R317-2-7.1), which allows ≤10% of samples within an AU to exceed numeric criteria before it would be considered impaired (Figure 7).

The following rules generally apply for evaluations of conventional chemical parameters to determine support of applicable general uses:

> **Beneficial Use Supported-** For each parameter, if ≥10 samples are available for an AU within the most recent 5-years, then the AU is considered to be supporting its designated use(s) if <10% of the samples exceed the numeric criterion.
>
> **Beneficial Not Supported-** For each parameter, if ≥10 samples are available for an AU within the most recent 5-years, then the AU is considered to be impaired—not supporting its designated uses—if ≥10% of the samples exceed the numeric criterion.

While these rules apply in most circumstances, AUs are sometimes listed with fewer than 10 samples if other lines of evidence suggest degradation of applicable designated uses.

Table 2. Conventional parameters and associated designated uses as identified for assessment purposes (UAC R317-2-7.1). The notes field provides important considerations for interpretation of assessment results.

Parameters	Designated Uses	Notes
Dissolved Oxygen (DO)	Aquatic Life	Numerous recurrence intervals are listed. Minimum and 30-day averages are used for assessments based on grab samples.
Maximum Temperature	Aquatic Life (3A, 3B, 3C)	Many site-specific standards have been generated, which are used for assessment purposes.
pH	Domestic (1C) Recreation (2A, 2B) Aquatic Life (3A, 3B, 3C, 3D) Agriculture (4)	Criteria are identical across uses.
E. coli	Domestic (1C) Recreation (2A, 2B)	Recreation uses have more protective criteria than domestic.
Total Dissolved Solids (TDS)	Agriculture (4)	Many site-specific standards have been generated, which are used for assessment purposes.

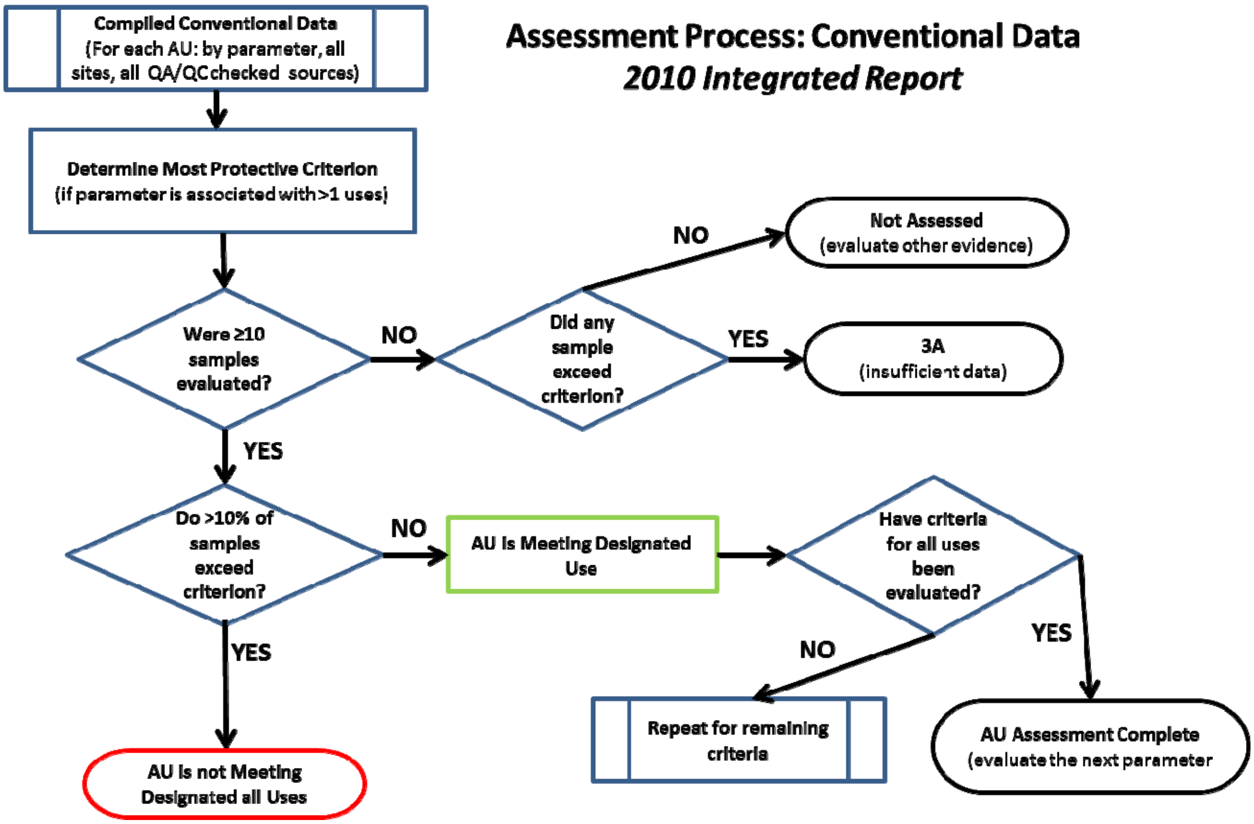


Figure 7. This flowchart depicts DWQ's process for assessing designated use support from conventional water quality parameters, which is followed parameter-by-parameters for each AU. The assessment process begins following a compilation of all available data that meets data quality objectives. Typically, a minimum of ten samples collected from an AU during the most recent 5-years are required. Assessments from small sample sizes typically result in a conclusion of not assessed, however if there is an indication potential water quality concerns, then DWQ will prioritize the AU for future sampling (3A listing). AUs are generally considered to be meeting their designated uses if <10% of conventional data samples are below applicable numeric criteria, and impaired otherwise.

TOXIC PARAMETERS

Assessment procedures for toxicants are more conservative than conventional parameters: sample size requirements are relaxed, AUs are considered degraded with ≥1 criterion violation, and two separate assessment procedures are followed for determination of aquatic life use support. These conservative elements are necessary to ensure protection of designated uses for a few reasons. First, many toxic substances accumulate in the tissue of aquatic organisms, becoming increasingly toxic with prolonged exposure to high pollutant concentrations. Similarly, many toxic substances biomagnify, increasing in tissue concentration from lower to higher trophic levels. Finally, high concentrations of many of these substances can lead to the direct mortality of many species at numerous life stages, so catching problems early is necessary to prevent catastrophic ecological impacts.

At first glance, assessment methods based on toxic criteria appear complex (Figure X). However, the process is easier to interpret in light of a few key distinctions. First, two slightly different approaches are to assess drinking water (Class 1) and Aquatic Life (Class 3) uses with toxic parameter data. This distinction exists primarily because aquatic life uses are protected with both acute and chronic standards, whereas drinking water uses are protected with a single criterion. For aquatic life AU assessments based on < 10 samples, a multiplier of 1.75 is applied to develop a chronic screening criterion. For instance, a site if a site had a chronic (4-day average) arsenic criterion of

150 mg/l, a criterion of 262.5 mg/l would actually be evaluated at an AU with few than 10 samples. Similarly, all Class 1 waters are also protected for aquatic life uses, which generally have more conservative criteria because aquatic biota are continually exposed to toxic pollutants in their environment. As a result, an AU that fails to support Class 3 uses is often also impaired for Class 1 uses. A final potential area of confusion is the minimum number of samples that are required to make an assessment. In general, ≥4 samples are required to conclude full support of uses, whereas any number of samples can be used to declare impairment.

Beyond the nuances discussed above, assessments using toxic parameters are similar for both Class 3 and Class 1 waters.

> **Beneficial Use Supported-** For each toxic parameter, the AU is considered to support all applicable uses if ≤1samples exceeds the criterion, provided that ≥4 samples were processed within the most recent 3-years.
>
> **Beneficial Not Supported-** For each toxic parameter, the AU is considered impaired if >1 samples exceeds the criterion, or the chronic screening values applicable to aquatic life uses.

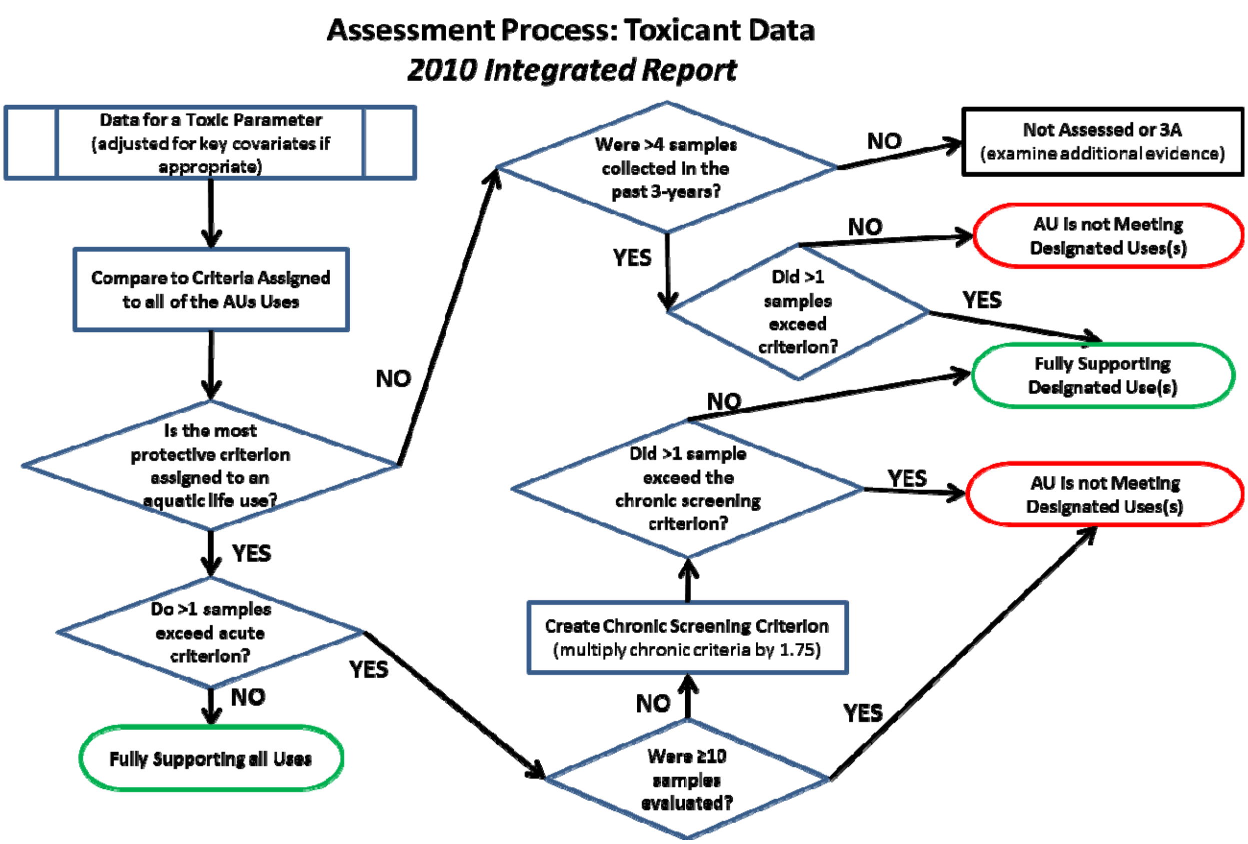


Figure 8. Utah's assessment process for toxic substances, which have criteria associated with aquatic life (Category 3) and domestic (Category 2) designated uses. For domestic uses at least four samples are required to make an assessment, whereas aquatic life use assessments can be made with fewer samples. Aquatic life designated uses are evaluated with both acute and chronic criteria. In the case of sites with <10 samples, the chronic criterion is multiplied by 1.75 before conducting assessments. Generally speaking, an AU is considered impaired if greater than one sample, collected in the most recent 5-years, exceeds the criterion or screening value.

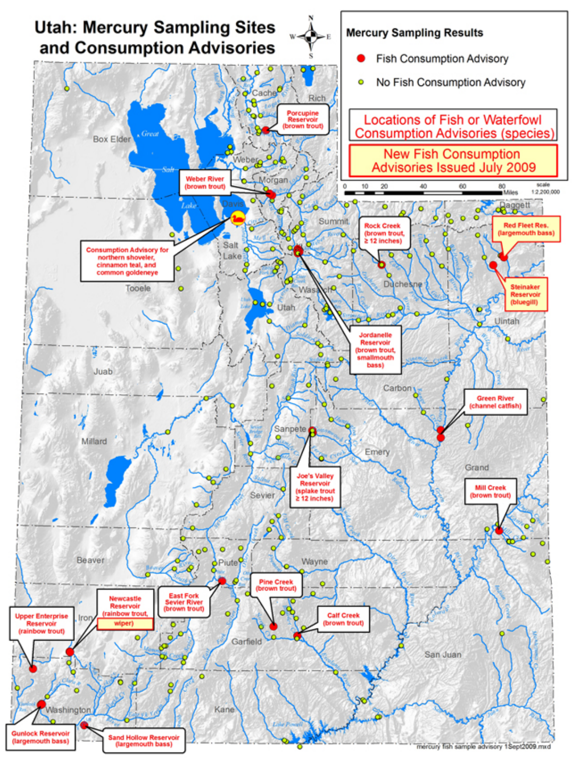
ADDITIONAL CONSIDERATIONS

Drinking Water Closures

If Utah's Division of Drinking Water—or other local municipality—issues an advisory or closure for a surface drinking water source, then DWQ will assess the site as impaired for 1C uses, unless data can be shown to show that the problem has been solved.

Fish Kills

DWQ requests information on reported fish kills from Utah's Division of Wildlife Resources (DWR) and other stakeholders. These data are used in concert with water quality data to make final assessment decisions. For instance, sites that would generally not be assessed due to small sample sizes may be list as impaired if fish kills have also been observed at the waterbody.



advisories at sites where high mercury concentrations are observed in animal tissue. This map depicts waters that currently have consumption advisories for fish (red dots) or birds (yellow dot). For additional information please see: http://www.fishadvisories.utah.gov/.

Beneficial Use Assessment Based on Tissue Consumption Health Advisories

Human health consumption advisories are issued by the Utah State Department of Health (UDOH), in conjunction with DWQ, the Division of Wildlife Resources (DWR) and local health departments. DWQ and the UDOH developed a sampling protocol based upon statistical analyses to determine how many fish are required to be collected to use in an advisory. The statistical parameters are as follows:

- The probability of a Type I error is set at 10%. A type I error is when the average concentration in fish is concluded to be greater than screening level when the actual average concentration is equal to, or lower than the screening level.
- The probability of at Type II error is set at 20%. A type II error is when the average concentration in fish is concluded to be equal to, or less than the screening level when the actual average concentration actually exceeds the screening level by more than the minimum detectable difference (see next bullet).
- The minimum detectable difference was set at 0.15 mg/kg. For instance, for mercury health advisories, the screening levels for consumption advisories are 0.3 mg/kg, so under the minimum

conditions described above, the average concentration would have to be 0.45 mg/kg before the desired level of confidence in the results is achieved.

If the required confidence is not achieved, additional samples are required. Type I and Type II errors are inversely proportional when the number of sample and minimum detectable difference are held constant. For instance, to achieve a reduction in the Type II error probability would require a corresponding acceptance of an increase in the Type I error probability. If the average contaminant concentrations in fish are greater than 0.45 mg/kg, then both Type I and Type II error probabilities are reduced.

Mercury

The current approach for making assessments of aquatic life use support from mercury consumption advisories is different for advisories based on birds than for those based on fish (Figure 9). Fish are constant residents of the waterbodies where that are collected, whereas waterfowl migrate across large areas. As a result, it is difficult to directly tie higher waterfowl tissues directly to an AU.

Currently health advisories are issued if the mercury concentration in fish tissue 0.3 ppm (0.3 mg/kg wet weight, or 0.3 µg/g). This concentration is recommended by EPA but is less than the United States Food and Drug Administration (FDA) value of 1.0 mg/kg. The FDA set the consumption concentration at 1.0 mg/kg, which correlates to the water column mercury concentration of 0.012 ug/l in previous studies by EPA. (EPA, 1985). Utah's water quality standard for mercury is 0.012 ug/l as a 4-day average. Therefore, the corresponding fish tissue concentration of 1.0 mg/kg is used for assessment.

Beneficial Use Supported – No fish consumption advisories for mercury or the fish tissue mercury concentration is less than or equal to (≤) 1.0 mg/kg.

Beneficial Not Supported - Fish consumption advisory for mercury is in place and fish tissue mercury concentration is greater than (>) 1.0 mg/kg.

DWQ will evaluate the applicability of waterfowl consumption advisories for beneficial use assessments independently for each waterbody. The first step is to link the contaminants in waterfowl tissue to the waterbody being assessed but a specific methodology has not been established. Only waterfowl collected from GSL currently have consumption advisories and the methodology for assessing mercury in GSL is presented in Part 2 of the 2010 IR.

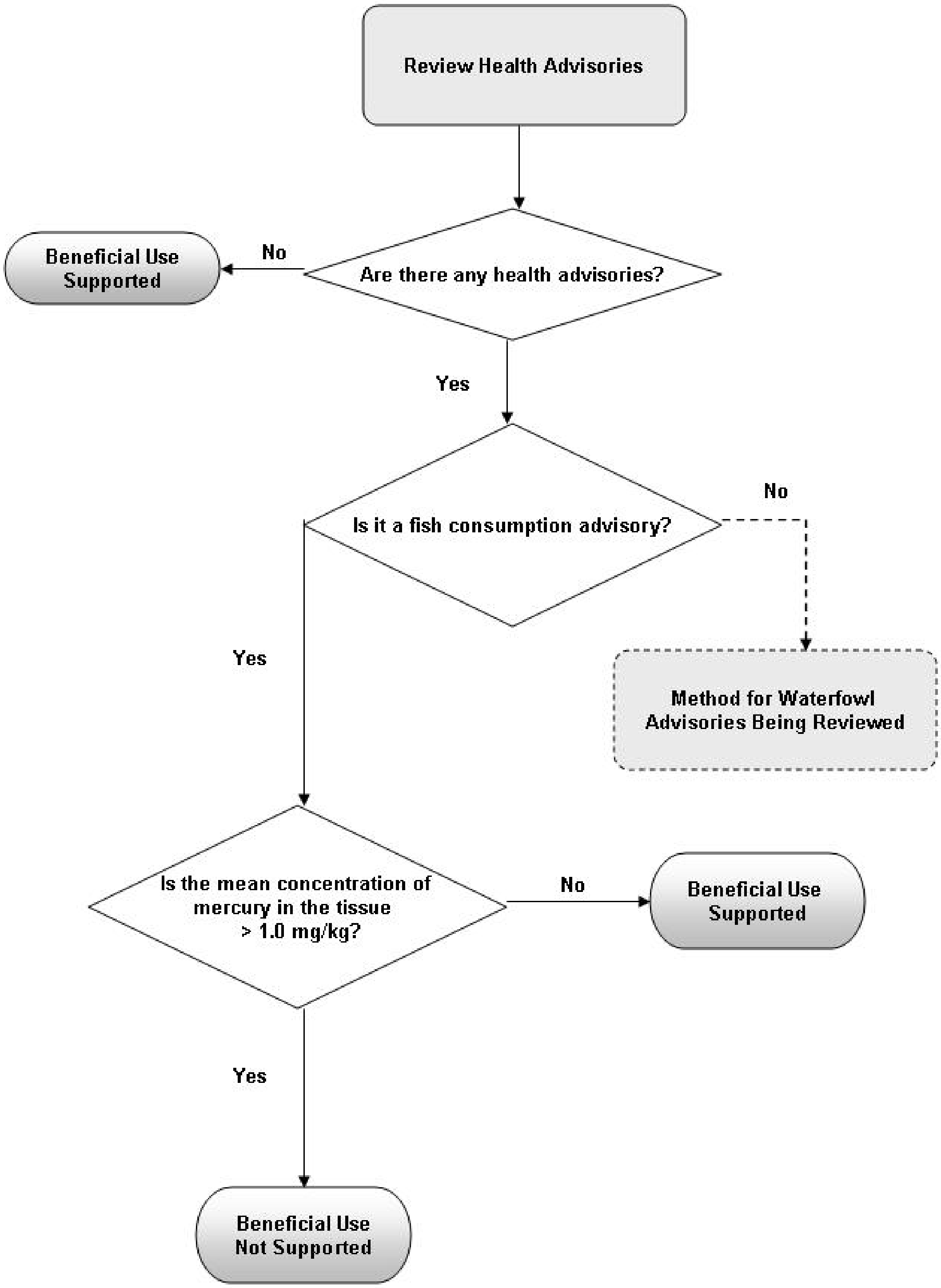


Figure 9. Methods used to determine support of aquatic life based on consumption health advisories for mercury.

Total Phosphorus Evaluations

Total phosphorus (TP) does not directly adversely affect aquatic life, but as a nutrient it can stimulate growth of aquatic algae and emergent plants. Nuisance blooms of algae and other aquatic plants can have an effect on the amount of dissolved oxygen (DO) and habitat that fish and macroinvertebrates occupy. During the day, production exceeds respiration and algae and aquatic plants produce a net increase in DO concentrations. At night, the cycle is reversed because primary production ceases, whereas respiration from all aquatic organisms—including plants, algae, fish and microbes—continues to consume oxygen. When nutrient concentrations are excessively high, daytime production of plants, algae and microbes is too high resulting in nighttime respiration rates that cause anoxia, which results in stressful conditions to stream biota.

DWQ is currently developing numeric nutrient criteria. In the interim, DWQ has developed a screening technique to determine if an AU needs further study to determine whether total phosphorus is degrading aquatic life uses. AUs that exceed these TP screening criteria are identified and placed on a list of waters that need further evaluation, unless the AU is currently part of an ongoing or completed Total Maximum Daily Load analysis (TMDL) for total phosphorus.

Additional evaluations of AUs with high TP can be conducted in many ways. At a minimum, these AUs may be evaluated by doing a DO diurnal study to determine if DO concentrations are low enough, over a long enough time period, to cause impairment to the designated aquatic life uses. Also, biological assessments are conducted on high TP waters to quantify the extent of biologically degradation that may be attributable to eutrophication.

Figure 10. The pictures depict examples of algal growth in Utah streams. Excessive algae growth sometimes occurs in waters with high nutrient concentrations, which can harm aquatic life or recreation uses. The top image show filamentous algae blooms that can sometimes harm beneficial uses. The bottom panel depicts *Nostoc*, which is another form of algae that indicates that nitrogen is more limiting than phosphorous.

The assessment methodology to determine the need for further studies based on the potential impact of total phosphorus is listed below.

Assessment Unit Needs Further Evaluation –The mean concentration of the total phosphorus exceeds 0.06 mg/L AND more than ten percent (>10%) of the samples exceed the total phosphorus indicator value of 0.05 mg/L.

Assessment Unit Does Not Need Further Evaluation – The mean concentration of total phosphorus does not exceed 0.06 mg/L OR less than 10% of the samples exceed the total phosphorus indicator value of 0.05 mg/L.

BIOLOGICAL ASSESSMENTS OF RIVERS AND STREAMS

Introduction

Utah's biological beneficial uses require the protection of fish (e.g., cold- or warm-water species) and the organisms upon which they depend. In the past, DWQ has assessed these beneficial uses via water chemistry sampling and associated standards that assume to protect aquatic organisms. However, DWQ has developed an empirical model that directly assesses attainment of biological beneficial uses by quantifying the 'health' of macroinvertebrate assemblages. Measuring biological communities directly has the advantage that it integrates the combined effects of all pollutants which allows a direct examination of how pollutants are interacting to affect the condition of a stream ecosystem. (Karr, 1981). Moreover, because aquatic macroinvertebrates spend the majority of their life in aqueous environments, they are capable of integrating the effects of stressors over time providing a measure of past, transient conditions (Karr and Dudley, 1981).

Biological assessments are often conducted by comparing the biological assemblage *observed* at a site with the *expected* biological assemblage in the absence of human-caused disturbance. Ideally, these comparisons are made using historical data to measure changes to the current biological community. However, in most cases historical data are not available. As a result, biological conditions representing an absence of human-caused stress are typically set using reference sites as controls, or benchmarks, to establish the biological condition expected in the absence of human-caused disturbance. The biological integrity of sites can be evaluated by comparing the biological composition observed at a site against a subset of physically similar reference sites. Collectively, such comparisons are referred to as biological assessments.

In aquatic biological assessments, reference sites are selected to represent the best available condition for streams with similar physical and geographical characteristics (see Hughes et al 1986, Suplee et al. 1995, and the Western Center for Monitoring and Assessment of Freshwater Ecosystems website http://www.cnr.usu.edu/wmc for more details). When reference sites are selected for water quality programs, conditions vary regionally depending upon adjacent historical landuse. For example, reference sites in Utah mountains are generally more pristine than in valleys. As a result, biological benchmarks are higher in areas of the State that receive less man-made disturbance than those with more disturbances.

A numeric index is a useful tool that quantifies the biological integrity, or biological beneficial use of stream and river segments. Data obtained from biological collections are complex with hundreds of species found throughout Utah that vary both spatially and temporally. Similarly, the physical template upon which biota depends also varies considerably across streams. A robust index of biological integrity should simultaneously account for naturally occurring physical and biological variability and summarize these conditions with a single, easily interpretable number.

RIVER INVERTEBRATE PREDICTION AND CLASSIFICATION SYSTEM (RIVPACS) MODELS

DWQ employs the RIVPACS (River Invertebrate Prediction and Classification System) model approach (Wright 1995) to quantify biological integrity. RIVPACS is a classification of freshwater sites based on macroinvertebrate fauna that was first derived in 1977. In the early 1970's scientists and water managers recognized a need to understand the links between the ecology of running waters and macroinvertebrate communities. This began some of the very early biological assessment work in Europe. A four-year project was initiated to create a biological classification of unpolluted running waters in Great Britain based on the macroinvertebrate fauna (Furse et al., 1984, Wright 1995, Clarke et al., 1996, Moss et al., 1999). Over the past 30 years, equivalent RIVPACS models have been developed for aquatic ecosystems throughout the world including Australia (Metzeling et al., 2002, Marchant and Hehir, 2002, Davies et al., 2000) and Indonesia (Sudaryanti et al., 2001). In the United States scientists have developed RIVPACS models to assess the biological integrity of the country's aquatic habitats (Hawkins et al., 2000, Hawkins and Carlisle, 2001). Recently, many western states have adapted the RIVPACS model to determine beneficial uses of aquatic life in the rivers of State's such as Colorado (Paul et al., 2005), Montana (Feldman, 2006, Jessup et al., 2006) and Wyoming (Hargett et al., 2005).

RIVPACS-based methods for conducting biological assessments were initially developed in Great Britain (Wright, 1995) and have subsequently been used in numerous biological assessment programs worldwide. To quantify biological condition, RIVPACS models compare the list of taxa (the lowest practical taxonomic resolution to which taxonomic groups are identified) that are observed (O) at a site to the list of taxa expected (E) in the absence of human-caused stress. Predictions of E are obtained empirically from reference sites that together are assumed to encompass the range of ecological variability observed among streams in the region where the model was developed. In practice, these data are expressed as the ratio O/E, the index of biological integrity.

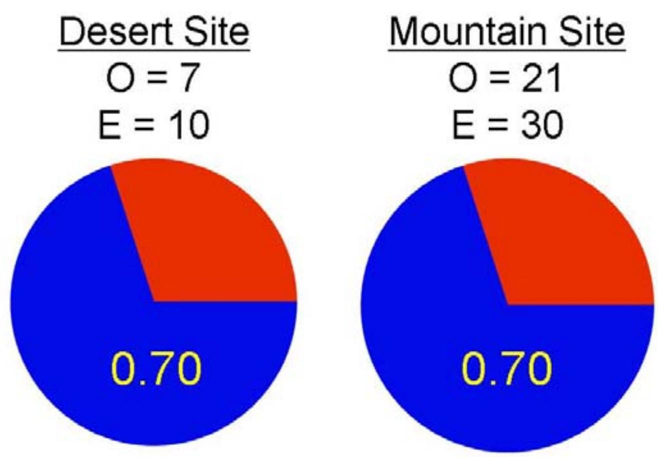


Figure 11. A hypothetical example of observed/expected (O/E) as a standardization of biological assessments in different natural environments using numbers benthic macroinvertebrate taxa. In the desert site, 7 taxa were observed (O) from an expected number (based on reference) of 10 taxa (E). Thus, the O/E score was .70 or a loss of 30% of the taxa expected at the site.

Interpretation of RIVPACS models requires an understanding of the O/E ratio. In essence, O/E quantifies loss of biodiversity. It is not a measure of raw taxa richness since O is constrained to include only those taxa that the model predicted to occur at a site. The fact that O/E only measures losses of native taxa is an important distinction because the stream ecological template changes in response to human-caused disturbance and taxa richness can actually increase as conditions become more advantageous to taxa that are more tolerant of the degraded condition. Despite the mathematical complexities of model development, O/E is easily interpreted as it simply represents the extent to which taxa have become locally extinct as a result of human activities. For example, an O/E ratio of 0.40 implies that, on average, 60% of the taxa have become locally extinct as a result of human-caused alterations to the stream.

O/E has some very useful properties as an index of biological condition. First, it has an intuitive biological meaning. Species diversity is considered the ecological capital on which ecosystem processes depend; thus, O/E can be easily interpreted by researchers, managers, policy-makers, and the public. Second, O/E is universally spatial which allows direct and meaningful comparison throughout the state (Figure 11). This is particularly important for Utah where streams vary considerably from high-altitude mountain environments to the arid desert regions of the state. Third, its derivation and interpretation does not require knowledge of stressors in the region; it is simply a biological measuring tool. Finally, the value of O/E provides a quantitative measure of biological condition.

MODEL CONSTRUCTION AND PERFORMANCE

Construction of a RIVPACS model for Utah began in 2002 which involved developing and evaluating dozens of models. Details of model development procedures can be found elsewhere (Wright et al. 1993, Wright 1995, Clarke et al., 1996, Moss et al. 1999, http://cnr.usu.edu/wmc/htm/predictive-models/predictive-models-primer, http://www.epa.gov/wed/pages/models/rivpacs/rivpacs.htm). Here a brief summary is provided so Utah's model results and subsequent assessments are better understood.

Table 11. Final predictor variables used in model construction.

General Category	Description
Geology	Weighted average percent calcium content of rocks in the watershed.
Geographical	Mean watershed elevation (meters) from National Elevation Dataset.
Geographical	Watershed area in square kilometers.
Weather	Watershed average of the mean day of year (1-365) of the last freeze derived from the PRISM data.
Weather	Watershed average of the annual minimum of the predicted mean monthly precipitation (mm) derived from the PRISM data. for the sampling site.
Weather	Watershed average of the annual mean of the predicted mean monthly air temperature (tenths of degree Celsius) derived from PRISM data.

As mentioned in the introduction, predictions of E are obtained empirically from reference site collections made throughout Utah. Reference sites are selected using experienced DWQ scientists who identified sites that represented the reference conditions in different biogeographical settings throughout Utah. The initial list of candidate reference sites is independently ranked by different scientists familiar with the streams. Only reference sites with a consensus representing best available conditions are used in model development. Subsequent reference sites are added using scores from reference scoring metrics developed during site visits and averaging with independent rankings from field scientists.

Some of the calculations involved in obtaining E are complex. A heuristic description of the steps involved in predicting E provides some context of the assessment methodology. The first step in model development is to classify reference sites into groups of sites with similar taxonomic composition using a cluster analysis. Next, models are developed based on watershed descriptors (i.e., climatic setting, soil characteristics, stream size) to generate equations that predict the probability of a new site falling within each group of reference sites. These equations account for environmental heterogeneity and ensure that when a new site is assessed, it is compared against ecologically similar reference sites. When a new site is assessed, predictions of group membership are then coupled to the distributions of taxa across groups of reference sites to estimate the probability of capturing ($P_{c)}$ each taxon from the regional pool of all taxa found across all reference sites. E is then calculated as the sum of all taxa P_cs that had a greater than 50% chance of occurring at a site given the site's specific environmental characteristics.

The accuracy and precision of RIVPACS models depend in part on the ability of the models to discriminate among groups of biologically similar reference sites. An extensive list of 78 Geographic Information System (GIS)-based watershed descriptors is evaluated as potential predictor variables in models that predict the probability of membership within biological groups for sites not used in model construction. GIS-based predictor variables, such as soils, meteorology, and geography, instead of field-derived descriptors, are evaluated for a couple of reasons. First, GIS-based descriptors are unlikely to be influenced by human disturbance and are therefore unlikely to bias estimates of expected conditions (Hawkins, 2004). Second, these predictors are easily obtained for any site which allows inclusion of additional macroinvertebrate samples collected by others. Various subsets of potential predictors are evaluated in an iterative, analytical process that explores different combinations of predictors able to explain the biological variability among reference sites. The final analysis selected 6 variables that resulted in the most precisely predictive model (Table 11).

The RIVPACS model used for the 2010 assessments is nearly as accurate and precise as the 2008 model. If the model was perfectly accurate and precise, the O/E score for all reference sites would equal 1. Instead, reference O/E values are typically spread in a roughly normal distribution centered on 1 (Wright, 1995). Model precision is often expressed as the standard deviation (SD) of reference O/E values with lower SDs indicating higher model precision. The RIVPACS model used for the *2010 Integrated Report* assessments had a SD of 0.17 which is within the range of 'accepted' water quality models. The average reference O/E score for the current model is 1.03 which means that the model is slightly biased to generate higher O/E values than expected (Figure 12). The accuracy of the model is evaluated by examining the distribution of reference O/E scores in different environmental settings and revealed reference O/E values as not biased by stream size, elevation, or ecoregion.

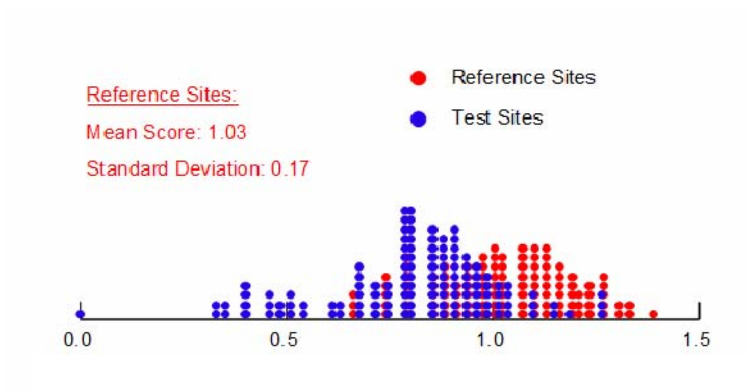


Figure 12. Distribution of reference- and test-site O/E scores. As expected, sites that were not previously classified in reference condition had O/E values lower than 1, indicating local extinctions resulting from human-caused perturbations to these stream ecosystems. Conversely, the reference sites showed a roughly normal distribution centered 1 indicating that the model was globally accurate.

ASSESSING BIOLOGICAL BENEFICIAL USE SUPPORT

Utah does not currently have numeric biological criteria. However, model outputs are used to guide assessments under the narrative standards of the Utah Clean Water Act (R317-2). To make the narrative assessments as rigorous as possible, a systematic procedure was devised to use the RIVPACS model O/E values to determine aquatic life beneficial use support (Figure 13). The goal of this assessment process is to characterize each Assessment Unit (AU) as *Fully Supporting* or *Not Supporting* aquatic life beneficial uses.

Utah currently assesses watersheds based on established Assessment Units (AUs). While many AUs contain a single biological collection site, some AUs contain multiple sites. In such instances, DWQ staff examine available data to determine if multiple sites within an AU score similarly. When comparisons suggest that sites within an AU are ecologically similar, O/E scores from all sites within an AU are averaged for assessment purposes provided that conclusions of biological condition are similar. If O/E scores differ appreciably among multiple sites within an AU, then DWQ will investigate possible explanations for such discrepancies. If DWQ finds multiple sites within an AU from different environmental settings AUs are subdivided into smaller watershed units whenever clear boundaries can be identified (e.g., political/landuse boundaries, tributary confluence). Additionally, if only one site is sampled within an AU, it is examined whether it is an appropriate representation of the AU.

To translate the O/E values into assessment categories it is necessary to devise impairment thresholds, or O/E scores that indicate whether or not a site is meeting biological beneficial uses (Table 3). For these assessments,

Table 3. Beneficial use support determination for O/E values obtained from different sample sizes.

Sample Size	O/E Threshold	Use Determination	Comments
≥ 3 samples collected over 3 years	Mean O/E score ≥ 0.83	Fully Supporting	Threshold based on 10% Type I error rate (10th Percentile)
≥ 3 samples collected over 3 years	Mean O/E score < 0.83	Not supporting	Threshold based on 10% Type I error rate (10th Percentile)
< 3 samples	Mean O/E score ≥0.78 – 0.83	Category 3A (insufficient data)	Lower Threshold based on 5% Type I error rate (5th Percentile)
< 3 samples	Mean O/E score <0.78	Not supporting	Threshold based on 5% Type I error rate (5th Percentile)

DWQ calculates thresholds based on one sample as outlined by Lester Yuan (EPA, pers. comm.). Yuan's process defines thresholds based upon accepted false positive rates rather than simply assigning thresholds based on percentiles of the distribution. Sampling variability within site "measurement error" is derived from average standard deviation of reference sites that had repeated site visits. The variance of all samples is derived from the standard deviation of the RIVPACS model. In addition, to account for measurement error of test samples, measurement error is subtracted at some targeted probability of being different from reference sites (false positive rate). However, the question is: should a 5% or 10% false positive rate be acceptable, while considering that a lower false positive rate also increases a false negative rate? It is a balance described later when considering sample strength (Table 3).

Essentially, the data used for the 2010 assessment calculates the threshold based on 5th Percentile at 5% false positive rate at 0.78 while the 10th Percentile at 10% false positive rate is 0.83. These thresholds will provide the bounds according to sample strength. At least 3 yearly samples are preferred for assessments because O/E scores can vary from year-to-year and assessments are based on average conditions. Assessments based on the average condition of ≥ 3 samples reduces the probability of making an error of biological beneficial use support as a result of an unusual sampling event (i.e., following a flash flood, improperly preserved sample). These errors can be costly to DWQ by increasing staff time and resources conducting follow-up assessments on misclassified AUs. Conversely, AUs not meeting these thresholds will be assessed as non-supporting or required for follow-up sampling if additional information is needed. Assessments of > 3 samples with average O/E scores ≥ 0.83 have low (10%) probability of being misclassified as 'non-support'. Alternatively, assessments with < 3 samples with an average O/E score < 0.78 have 5% probability of being misclassified as 'non-support'. The low Type-I error probability gives confidence that the AU is indeed not supporting the designated beneficial uses even if only one applicable sample were collected. Assessments with < 3 samples that have a mean O/E score ≥ 0.78 and < 0.83 will be placed in impairment category 3A, which indicates that there is insufficient data to make an assessment. All sites listed as 3A will be given a high priority for future biological monitoring.

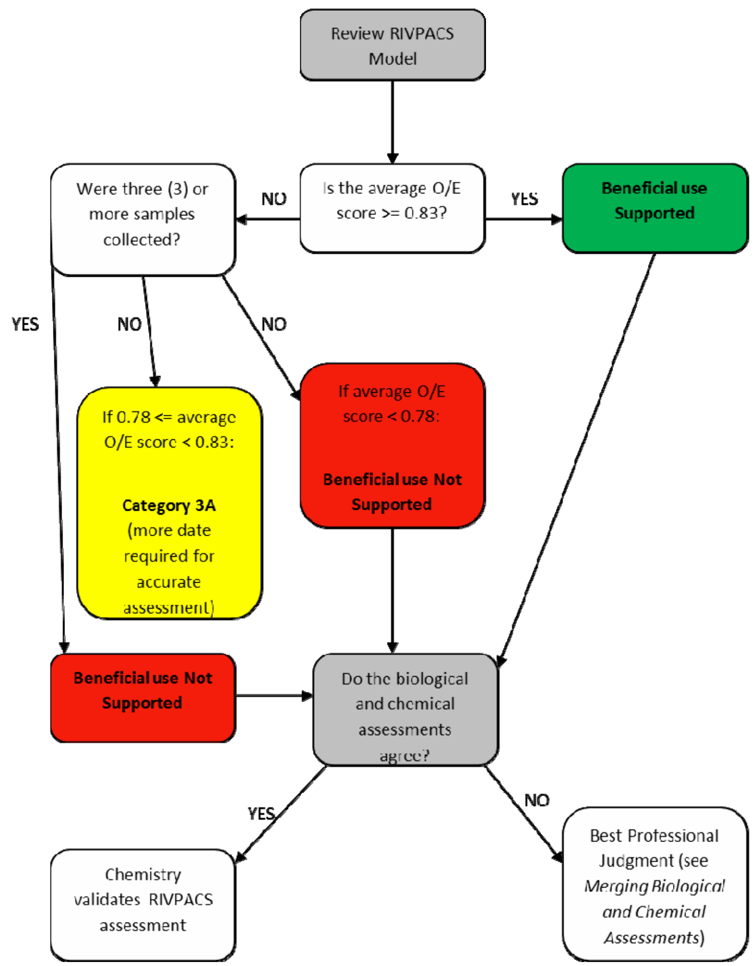


Figure 13. Flow diagram depicting the decision tree for making biological assessment decisions.

MERGING BIOLOGICAL AND CHEMICAL ASSESSMENTS

For years, DWQ has assessed biological beneficial use attainment with water chemistry standards that are assumed to be protective of stream biota. Before making final decisions about biological beneficial use support, a comparison is made between impairment assessments obtained from stream biota with those obtained from stream chemistry. The primary goal behind these evaluations is to further limit both false positive and false negative assessments beyond what is considered in the biological assessment. There are four potentially confounding factors that warrant a more careful scrutiny of incongruous biological and chemical assessments. These factors are summarized in a Best Professional Judgment (BPJ) framework (Figure 14) wherein disagreements between chemistry and biology assessments are objectively and systematically evaluated on a case-by-case basis.

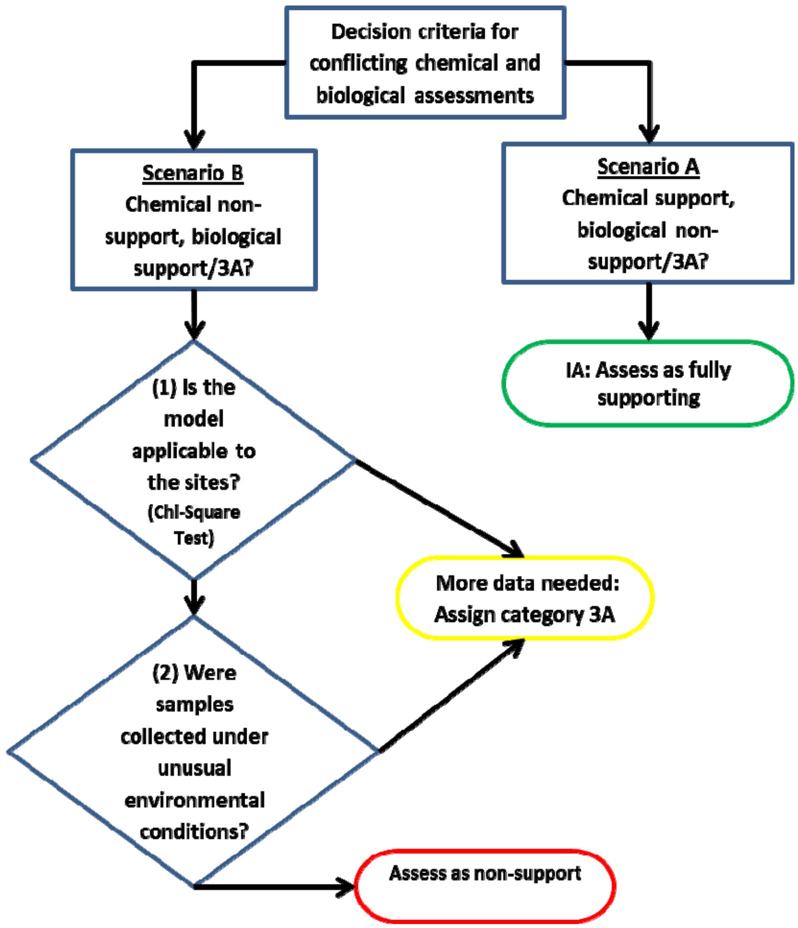


Figure 14. A diagram that describes the process that DWQ follows to reconcile disagreements among chemical and biological assessments

These judgment decisions are based in part on EPA's "Consolidated Assessment and Listing Methodology" (CALM) guidance published in 2002. The guidance provides a framework to weigh multiple types of data used for waterbody assessment. Specifically, the guidance refers to the policy of independent applicability (IA) which stresses that if any one type of applicable data indicates water quality standards are not supported the waterbody shall be identified impaired. Finally, if an AU results in a 3A listing for either biological or chemical assessment, the assessment type with sufficient data to determine the listing will be used. For example, if the biological data of an AU indicates Full Support while chemical data indicates 3A, the AU will be listed as Full Support. The decision framework rectifying situations where chemical and biological data suggest different conclusions about overall water quality is discussed in this section.

SCENARIO A: CHEMICALLY SUPPORTS, BIOLOGICALLY NONSUPPORT/3A

Under this scenario, the AU is meeting water quality standards according to chemical criteria. However, the biological assessment indicates there is impairment or not enough information to make a confident decision (i.e., more data is needed). A few more questions need to be answered before deciding the appropriate method for the final assessment decision:

1. Is the model applicable to the site? One of the fundamental assumptions of RIVPACS models is that the suite of reference sites used in model construction encompasses the range of environmental conditions observed in the sites that are to be assessed. All sites are evaluated using a Chi-square test to determine whether this assumption is met before a final assessment is made. In instances where model results fall significantly outside of the distribution (i.e., fail the test), the biological assessment is null and therefore the chemical assessment takes precedence.

2. Were the chemical or biological samples collected during unusual environmental conditions? Conclusions of impairment can potentially be biased when samples are collected during unusual environmental conditions. For instance, both biological composition and chemical criteria are known to be altered by drought and data collected under these conditions may be suspect. Similarly, the composition of stream assemblages is known to be altered by flash floods and samples collected following these events are suspect. In these situations, the biological data is not indicative of average conditions and the chemical assessment will be used. Alternatively, if the biological samples were collected under average conditions, the biological assessment shall take precedence.

SCENARIO B: CHEMICALLY NONSUPPORT, BIOLOGICALLY SUPPORTING/3A

Under this scenario, the AU is NOT meeting water quality standards according to chemical criteria. However, the biological assessment indicates that the biological beneficial use is fully supported. Under this scenario, due to IA, the results of the chemical assessment shall take precedence.

ASSESSMENTS WITH MICROBIAL (E. COLI) INDICATORS

INTRODUCTION

The World Health Organization (WHO) reports that 80% of all sicknesses can be attributed to inadequate water supplies and poor sanitation. To ensure the protection of public health, routine monitoring and assessment programs are needed. For Utah's bacteriological monitoring program, surface waters will routinely be monitored for pathogens that originate from fecal pollution from both human and animal waste. It is not feasible to monitor all pathogens in water, but by analyzing indicator organisms, i.e., *Escherichia coli (E. coli)*, the overall potential health risks from water exposure can be quantified.

Using indicator organisms as a means of assessing pathogens' presence in surface waters has been adopted by WHO, US EPA, and the European Union. *E. coli* are the most abundant coliform bacteria present in human or animal intestines numbering up to 1000 million individuals per gram of feces. They are the only true fecal coliform bacteria in that their presence can be exclusively attributed to a fecal origin. *E. coli* are not the only pathogenic organisms that present a potential health threat in surface waters; however, the concentration of *E. coli* is strongly correlated with other pathogenic species, and more importantly, to sickness rates in people exposed to contaminated water. The presence of *E. coli* in water is a strong indication of recent sewage or animal waste contamination. Fecal contamination sources are not just limited to raw sewage. Other fecal sources include: grazing pasture, confined feedlots, wildlife, or dog parks. These bacteria may be washed into surface waters during precipitation events such as rainfall or snow melts. When these waters are consumed without proper treatment or used recreationally, they can pose a threat to human health.

E. coli standards and associated assessment methods are relatively new for Utah. A stakeholder group has been formed to help inform the public of immediate health concerns. (www.ecoli.utah.gov)

DWQ recently modified Utah's water quality standards to include numeric *E. coli* criteria (UAC R317-2-6). All surface waters in Utah are assigned *E. coli* numeric criteria to protect recreation uses, and some of these waters have also been assigned numeric criteria to protect domestic (drinking water) uses. Recreation use classes are further divided into two subclasses: frequent primary contact (e.g., swimming, water skiing) recreation uses (Class 2A), or recreation activities (e.g., fishing, hunting) that result in infrequent primary contact and secondary contact with waters (Class 2B). In each case, E. coli criteria have been established for As a result of these newly established criteria, DWQ—in cooperation with our volunteer cooperators—has been implementing an aggressive monitoring program to collect *E. coli* data to assess these uses. The 2010 *Integrated Report* represents the first formal evaluation data collected though this newly developed program. DWQ anticipates that this program will be modified as the program develops.

REGULATORY BACKGROUND

Beneficial Use Classifications

All rivers, streams, and irrigation canals and ditches within Utah are designated—explicitly or implicitly—as Class 2B waters, protected for infrequent primary contact and secondary contact recreation such as boating, wading, or similar uses. Some lakes and reservoirs have also been designated as Class 2A, waters protected for primary contact recreation such as swimming and water skiing. These beneficial apply to all lakes and reservoirs greater than 20 acres (*see* R317-2-13.12). All lakes and reservoirs not designated in the standards as 2A are designated as Class 2B waters by default. Lakes or reservoirs not listed in the standards are assigned uses by default to the classification(s) of their tributary streams. Some of these waters are also protected as domestic water sources (Class 1C).

E. coli Numeric Criteria

Two *E. coli numeric* criteria, with different frequency and recurrence intervals, have been developed to protect both Class 3 and Class 1C designated uses as follows:

> Class 3A: A maximum (not to exceed) concentration of 126 (Most Probably Number) MPN per 100 ml or a 5-sample geometric mean of 126 MPN.
>
> Class 3B & Class 1C: A maximum (not to exceed) concentration of 206 (Most Probably Number) MPN per 100 ml or a 5-sample geometric mean of 668 MPN.

Recreation Period

In order to evaluate recreation (Class 2) uses, *E. coli* sampling will be conducted in the 'recreational period' (May through September). This time period is of greatest risk because this is when the majority of recreation occurs on Utah's waters. In addition, this period also coincides with higher *E. coli* concentrations due to warmer water temperatures, which increases the growth and reproduction rates of these organisms.

The summer index period may not adequately protect recreation uses of southern-Utah waterbodies, where sometimes have relatively high water temperatures throughout the year. As additional data are available DWQ will reevaluate—on a site-by-site basis—the index period for southern Utah waters. In the interim, the statewide summer index period will be used for assessment purposes.

ASSESSMENT METHODS

EPA's *Implementation Guidance for Ambient Water Quality Criteria for Bacteria* (2004) states that the monitoring and assessment methods must match the numeric standards set for *E. coli*. This guidance document also provides considerations for interpreting bacteriological criteria when assessing support of recreation (2A/2B) and drinking water (1C) uses, yet it still provides some flexibility by providing a range of approaches to accommodate different monitoring strategies and environmental settings. These assessment procedures were developed to be congruous with both federal guidance and Utah's *E. coli* criteria. DWQ's assessment methods based on these recommendations and aim to ensure protection of recreation and drinking water uses, while simultaneously considering the need to balance false positive (erroneous conclusion of impairment, Type I error) and false negative (missing an impairment, Type II error) assessments.

In general, the likelihood of becoming ill when recreating in waters increases with increasingly high *E. coli* concentrations. Hence, these assessment methods consider the magnitude of exceedance (difference between the sample and the numeric criterion). In addition, *E. coli* concentrations in freshwater ecosystems vary extensively, both spatially and temporally, which also must be taken into account when interpreting bacteriological data, because data collected from a single sample may not reflected the likelihood of becoming ill from recreating in contaminated waters.

The overarching goal of this assessment approach is to define criteria that ensure protection of recreation and drinking water uses, while simultaneously considering both false positive (erroneous conclusion of impairment, Type I error) and false negative (missing an impairment, Type II error) assessments. The following rules discuss how these criteria are interpreted for varying numbers of samples collected during the 5-year period prior to making assessment decisions. AUs that fail to meet any of these criteria will generally be listed as failing to meet recreation—or drinking water— designated uses on Utah's 303(d) list of impaired waters; however, exceptions may be made to these rules if a single collection event represents an outlier that biases results:

- **Rule 1**: For each AU with >10 samples in any recreation season, all 5-sample rolling geometric means of samples collected from May 1st through September 30th should not exceed either 126 MPN/100ml for 2A waters or 206 MPN/100ml for 1C/2B waters.

- **Rule 2**: For each AU with >5 samples in any recreation season, no more than 10% of samples collected from May 1st through September 30th should exceed 409 MPN/100ml for 2A waters or 668 MPN/100ml for 1C/2B waters throughout the most recent three years.

- **Rule 3**: AUs with ≤4 samples in any recreation season will not be assessed for support of recreation uses. These sites will be prioritized for future sampling, particularly if limited data suggest a potential problem exists in the waterbody.

Analytical Methods

Before making any assessment decision, DWQ first compiles information about any beach closures or health advisories, and all existing and available *E. coli* data collected from Utah's waters during the three most recent recreation seasons (May 1st through September 30th). These data are summarized, by Assessment Unit (AU), as follows:

- **Closures or Health Advisories:** A tally of the lake or reservoir closures issued for the waterbody during each recreation season.

- **Single Samples**: A tally and percent of the number of samples collected over the most recent five years that are greater than the maximum—not to exceed—*E. coli* criterion.

- **Rolling Geometric Means**: A tally of the number of times that 5- sample rolling geometric means exceeds the E. coli applicable 5-sample, 30-day criterion. For these purposes, rolling geometric means are calculated by ordering all samples by date and then calculating a series of moving 5-sample geometric means, starting with the first 5 samples, then samples 2-6, then 3-7 samples, etc. for all samples within each recreation season. In some situations, very frequent samples (>1/day) are collected in response to health advisories or beach closures, in such situations the geometric mean of these samples is used to represent a single collection event to avoid overweighing a single spike in high *E. coli* concentrations when assessing support of designated uses.

ASSESSMENT OF RECREATION AND DRINKING WATER USES WITH E. COLI DATA

Based on the summary of all *E. coli* data and information, an Assessment Unit will be assessed as not meeting its designated recreation uses if any one of the following decision rules apply (see also Figure 15):

- **Rule 1**: A lake or reservoir that has ≥3 posted health advisories or beach closures during any recreation season shall be considered impaired—not supporting recreation uses. In many cases, sites will also be designated as impaired following the other assessment rules; however, because health advisory rules are conservative—by using the 5-sample, 30-day geometric mean criteria without the 10% exceedance exception— this rule captures sites with repeated moderately high *E. coli* concerns. While this rule is not explicitly required by Utah's water quality standards UDWQ believes that it is consistent with the intent of recreation use protections.

- **Rule 2:** Any AU where >10% of samples are greater than the designated not to exceed criterion shall be considered impaired. AUs are not assessed with this rule unless the analysis is based on ≥5 collection events, which should be collected during a single recreation season for Class 2 designated uses.

- **Rule 3:** Any of the 5-sample rolling geometric mean calculations exceed the 30-day, 5-sample geometric mean criterion assigned to waters within the AU, provided that ≥10 samples were collected in the AU during any of the 5 recreation seasons evaluated. However, this rule shall not be used to make assessments if the results are biased from a single, atypical outlier.

The outcome from these impairment rules are subsequently used to place each AU with any *E. coli* data or information into 303(d) beneficial use support categories as follows:

- **Insufficient Data or Information (Category 3A)**: Sites with ≤4 collection events in all seasons evaluated, provided that impairment is not suggested by the first impairment rule (≥3 health advisories); OR impairment Rule 3 (rolling geometric means) is violated, but violations are based on a single, anomalous spike in *E. coli*—a statistical outlier. All 3A sites will be prioritized for future monitoring, particularly when this assessment is based on the influence of statistical outliers.

- **Fully Supporting (Category 1 or 2)**: There is no evidence of impairment from any of the three impairment rules and there exists at least five collection events exist for the AU for at least one recreation season over the most recent five years..

- **Not Supporting (Category 5)**: An AU is considered to be impaired— not meeting its designated uses—if any of the impairment rules suggest that problems with *E. coli* represent a threat to human health.

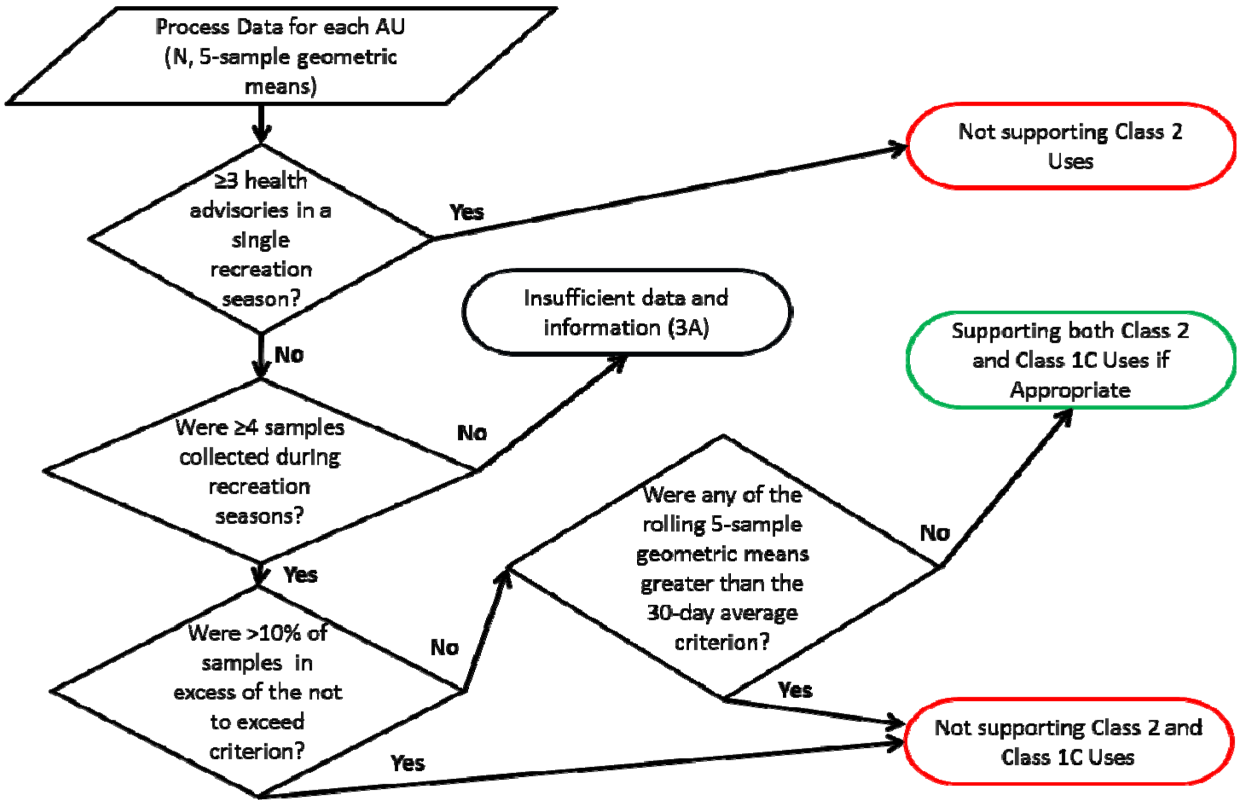


Figure 15. Decision Rules to determine if an Assessment Unit is meeting Class 1 C Drinking Water and Class 2 Recreational Beneficial Uses.

LAKE AND RESERVOIR ASSESSMENT METHODS

INTRODUCTION

Lakes and reservoirs are defined as waters of Utah which are protected by beneficial use designations. Each lake and reservoir has been designated as an Assessment Unit (AU) for purposes of assessment. The terms lake, reservoir and assessment unit are used interchangeably in this chapter.

Section R317-2-14 contains the standards established for both toxics and conventional parameters including total dissolved solids. Lakes and reservoirs greater than 20 acres are listed along with their beneficial use classifications. Lakes or reservoirs not specifically listed in Section R317-2-13.12 are assigned designated uses by default to the classification(s) of their tributary stream(s).

DWQ is currently reviewing the assessment methods for lakes and anticipates that the methodology will undergo significant changes for the 2012 IR. Some of the contemplated changes identified by DEQ, EPA, and other reviewers are suggestions to improve the current methodology and address potential deficiencies. These changes are identified in the relevant portions of the following text.

GREAT SALT LAKE

Great Salt Lake (GSL) is divided into five assessment units (UAC R317-2-5). With the exception of a selenium standard for the Gilbert Bay assessment unit, no numeric standards are available for any of the assessment units. Progress made on the proposed assessment methodology, as yet incomplete, is presented in Appendix A of the 2010 IR. In the absence of numeric standards, the designated uses of GSL are assessed with the Narrative Standard (UAC R317-2-7.2).

RESERVOIR AND LAKE ASSESSMENTS

When DWQ started to monitor lakes and reservoirs, 132 lakes based on size and public interest were selected to make lake and reservoir assessments for the Integrated Report, i.e., 305(b) Report and 303(d) List of Impaired Waters. These lakes and reservoirs account for 93% of the water surface acres in Utah. The lakes were divided into two groups, one group being sampled during even years; and the other group during the odd years. Monitoring for each lake and reservoir is done twice each year. The first set of samples is typically collected starting about June 1st and the second set is collected starting about August 1st.

DWQ is transitioning to a watershed-intensive approach where routine sampling will be focused in a watershed with more intensive sampling. High priority lakes and reservoirs, *e.g.*, TMDL or special projects, will continue to be sampled in other watersheds. The TMDL and special studies lakes and reservoirs are monitored four times during the monitoring season. The 2010 assessment is based on data collected from 2007 and 2008.

Water column profile data are collected at the surface and at every meter of the water column depth, and is completed when the probe is 1 meter above the bottom. All water chemistry samples, except dissolved metals and algal samples, are collected at the surface, one meter above the thermocline, one meter below the thermocline, and near the bottom. The dissolved metals sample is collected 1 meter above the bottom at the deepest site on the lake or reservoir. The algal sample is collected as a composite sample from 3 times the depth of the secchi disc reading to the surface. The algal sample is collected once at the deepest monitoring site on the lake or reservoir.

The assessment of reservoirs and lakes consists of three tiers:

- **Tier I assessment** is the preliminary determination of support status based on conventional parameters, such as Dissolved Oxygen (DO), temperature, pH, toxicants, etc.
- **Tier II assessment** looks further into the weighted evidence criteria (trophic state index TSI, fish kills, and blue-green algal dominance) using best professional judgment. The Tier I preliminary support status may be modified through an evaluation of the TSI, winter DO conditions with reported fish kills, and the presence of significant blue-green algal populations in the phytoplankton community. The Tier II evaluation could adjust the preliminary support status ranking if at least two of the three criteria indicate a different support status.
- **Tier III assessment** is the final evaluation based on cyclic nature of the data. Any change of designated use support status requires two consecutive assessment cycles of equivalent support status.

TIER I ASSESSMENTS

Total Dissolved Solids

Data collected on individual Assessment Units (AU) from all monitoring sites are used to determine the beneficial use support based on total dissolved solids (TDS). If TDS data is unavailable but conductivity data is available, the conductivity is used to estimate TDS (http://pubs.usgs.gov/tm/2006/tm1D3/pdf/TM1D3.pdf). An exceedance using conductivity as a surrogate will result in a Category 3A listing and the lake will targeted for TDS sampling.

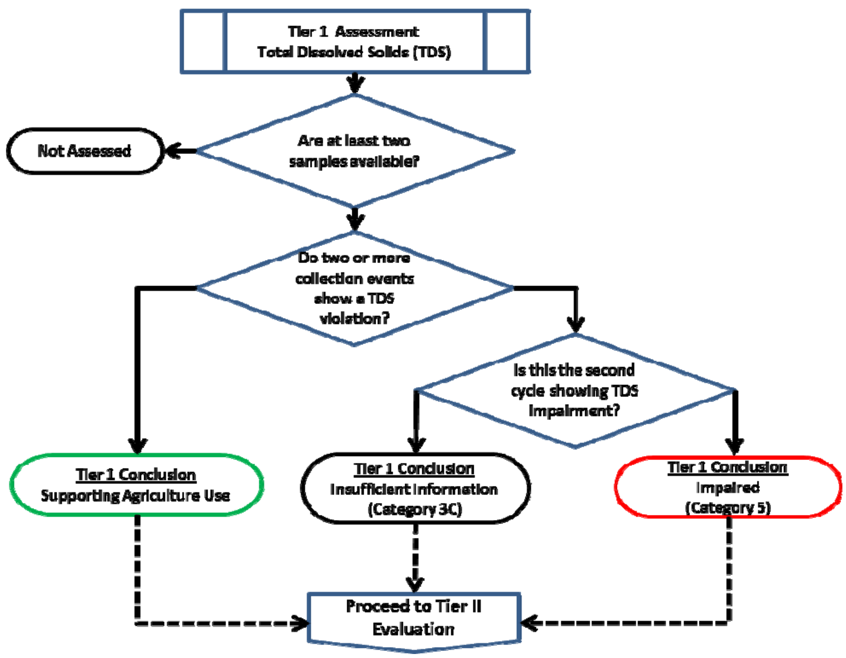


Figure 16. The assessment process that DWQ follows to determine support of a lake's designated agricultural uses with TDS data.

The following rules are used to determine whether a lake or reservoir is supporting its agricultural designated uses (see also Figure 16):

Beneficial Use Supported – The beneficial use is supported if the standard is exceeded not more than one time (≤ 1) in two consecutive monitoring cycles, e.g., 2002 and 2004 for even-numbered years, or 2001 and 2003 for odd-numbered years.

Beneficial Use Not Supported – The beneficial use is not supported if the TDS standard is exceeded two or more times (≥ 2) in two consecutive monitoring cycles.

Assessments Using Lake Profile Data: pH, Temperature and Dissolved Oxygen

Lake and Reservoir monitoring routinely involves collecting pH, temperature, and Dissolved Oxygen (DO) measurements at one meter intervals through the water column—from surface to the lake bottom. These water column measurements are compared against Utah water quality standards to assess beneficial use support (Figure 17). If more than one site is sampled in a lake, the profile measurements collected at the deepest site are used for assessment calculations, unless there is sufficient reason to use the profile data from other locations on the lake or reservoir.

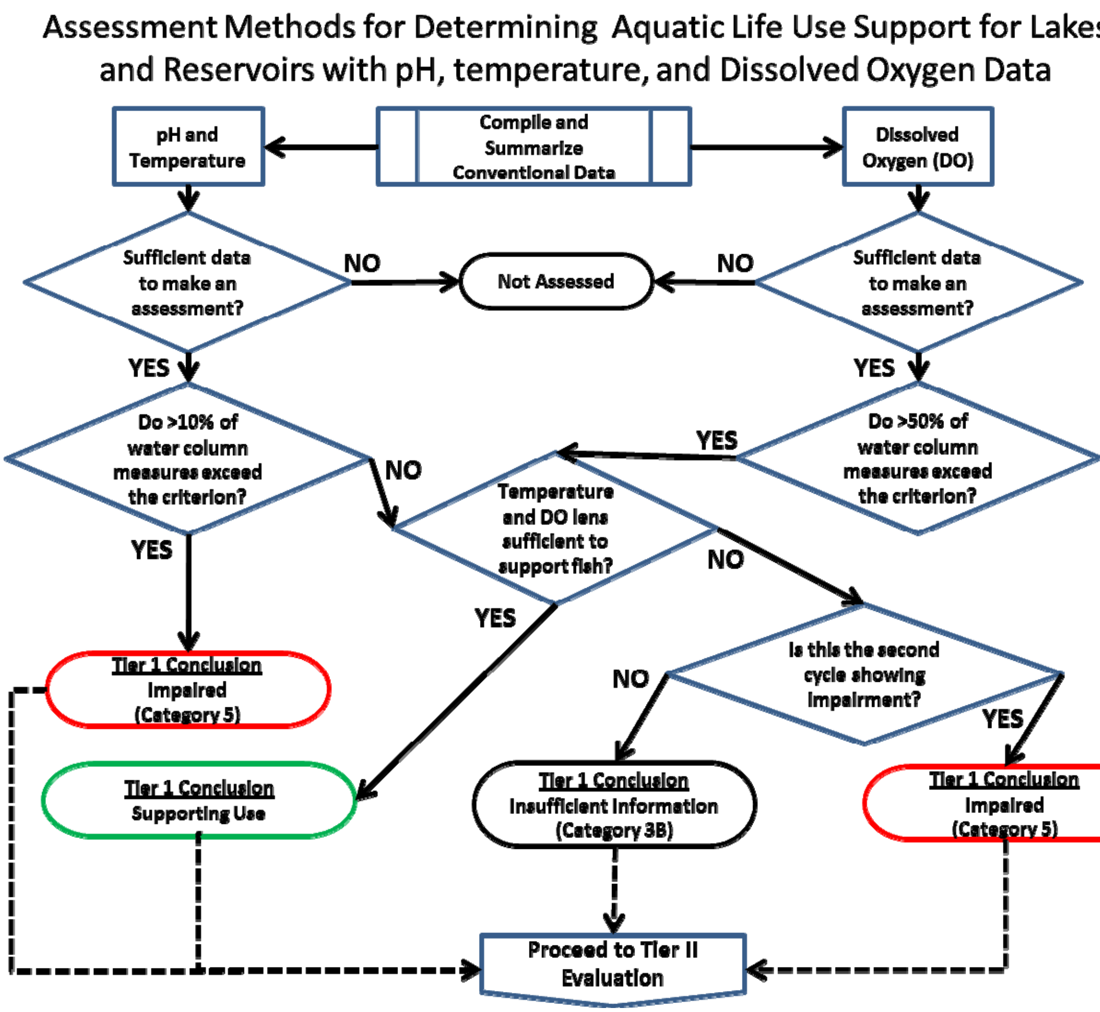


Figure 17. This flowchart depicts the process that DWQ follows when using conventional (non-toxic) parameters to assess Utah's lakes. In the case of temperature and Dissolved Oxygen (DO) a second test follows the primary water quality screen to evaluate whether fish have sufficient habitat by looking at the area of the water column that fails to meet both DO and temperature criteria. In all cases, these assessments are followed by a second, Tier II, assessment process.

pH Data

Two pH criteria, maximum and minimum, are used to assess support of designated uses as follows:

> **Beneficial Use Supported –** The beneficial use is supported if the number of violations are less than or equal to 10 percent (≤10%) of the measurements (e.g., Figure 18, Panel A).
>
> **Beneficial Use Not Supported –** The beneficial use is not supported if more than 10 percent (>10%) of the measurements violate the pH standard (e.g., Figure 18, Panel B).

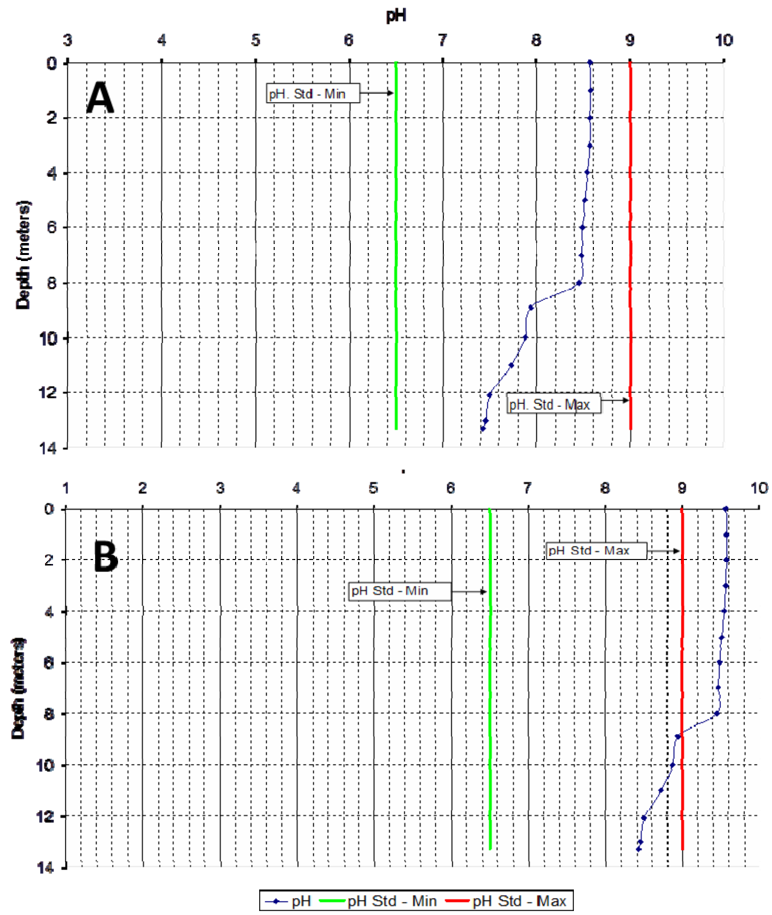


Figure 18. Plots of pH measurements (blue dots) against reservoir depth for two reservoirs as an example of assessment procedures. Two pH criteria are depicted, a minimum criterion of 6.5 (green line) and a maximum criterion of 9 (red line). Panel A (top) provides an example of a reservoir meeting its designated use because all of the pH measures are between the two pH criteria. Panel B (bottom) provides an example of an impaired reservoir because >10% of the pH measures are higher than the maximum pH criterion.

Temperature Data

The criteria for assessing the beneficial use support for lakes and reservoirs using temperature data is based upon profile data collected at the surface and then at one meter intervals. Data collected from the deepest site during the spring through fall monitoring periods are used to calculate the percentage of violations for each sampling date. For a lake or reservoir to be placed on the 303(d) list, the temperature standard must be exceeded in two consecutive monitoring cycles, e.g., in the 2002 and 2004 monitoring cycles the temperature was exceeded in more than 10 percent (> 10 %) of the measurements from any individual sampling event.

Beneficial Use Fully Supported – The beneficial use is supported if the number of violations are less than or equal to 10 percent (≤10%) of the measurements (see Figure 19, Panel A).

Beneficial Use Not supported – The beneficial use is not supported if more than 10 percent (>10%) of the measurements violate the temperature standard (see Figure 19, Panel B).

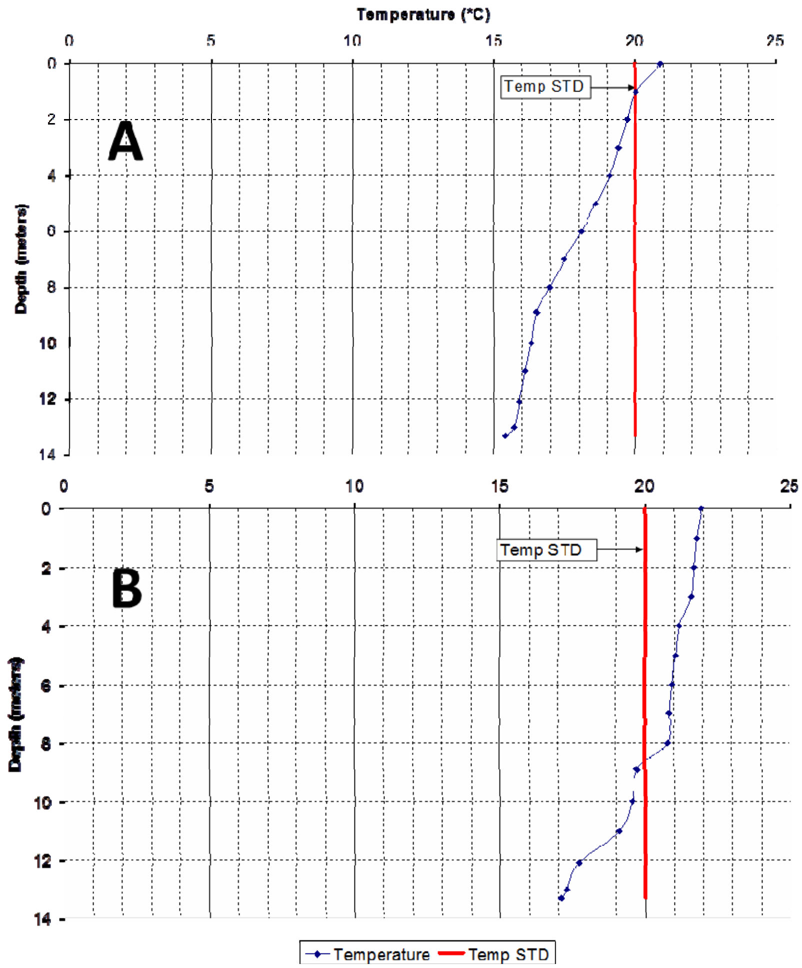


Figure 19. Plots of temperature measurements (blue dots) against reservoir depth for two reservoirs to provide an example of assessment procedures. The red line illustrates a temperature criterion of 20°C—Class 3A designated use. Panel A (top) illustrates a reservoir meeting its designated use because <10% of the temperature measures are greater than the criterion, whereas Panel B (bottom) illustrates an impaired reservoir because >10% of temperature measures exceed the criterion.

Dissolved Oxygen Data

The dissolved oxygen (DO) assessment uses the DO standard of 4.0 mg/L for Class 3A waters and 3.0 mg/L for Class 3B waters (see R317-2-14). State standards account for the fact that anoxic or low dissolved oxygen (DO) conditions may exist in the bottom of deep reservoirs. Therefore, a fully supporting status is assigned for DO when all the measurements are above the applicable DO standard for the upper 50% of the entire water column depth at the deepest site for each lake.

Some lakes are shallow and an anoxic zone may not be formed. DWQ will not use the 50% depth criteria for lakes that do not thermally stratify. In these cases, DWQ uses the entire water column to assess DO. See Figure 20 for examples of beneficial use supported and not supported. The methodology for assessing DO is being reevaluated for the 2012 IR to clarify that the methodology is consistent with the numeric standards in R317-2-14.

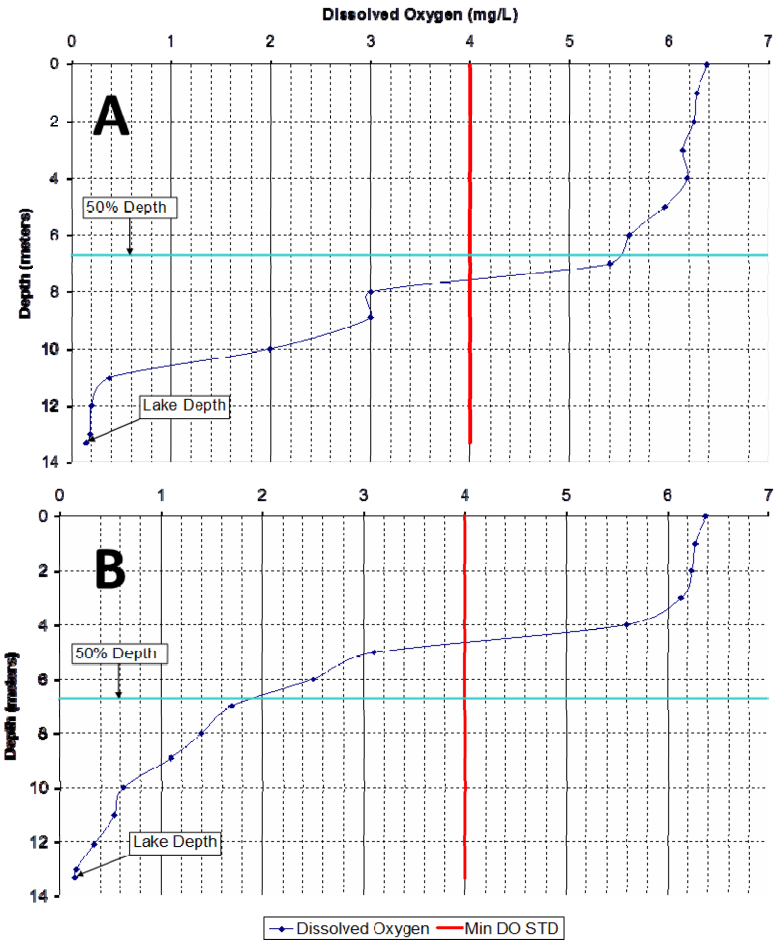


Figure 20. Plots of Dissolve Oxygen (DO) measurements (dark blue dots) against reservoir depth for two thermally stratified reservoirs, to provide an example of assessment procedures. The red line illustrates a DO criterion of 4 mg/l—Class 3A designated use. The red line illustrates the ½ of reservoir depth. Panel A (top) illustrates a reservoir meeting its designated use because DO concentrations are greater than the criterion for >50% of the water column, whereas Panel B (bottom) illustrates an impaired reservoir because DO concentrations were lower than the criterion in >50% of the water column.

Beneficial Use Supported – For stratified lakes, the beneficial use is supported if the oxygen concentrations are greater than the dissolved oxygen standard for the upper 50% of the water column depth (see Figure 20, Panel A). For non-stratified lakes, the beneficial use is supported if at least 90% (≥ 90%) of the oxygen measurements are greater than the dissolved oxygen standard for the entire water column depth.

Beneficial Use Not Supported – For stratified lakes, the beneficial use is not supported if the dissolved oxygen concentrations are not greater than the dissolved oxygen standard for the upper 50% of the water column (see Figure 20, Panel B). For non-stratified lakes, the beneficial use is not supported if more than 10% (> 10%) of the oxygen measurements are below the dissolved oxygen standard for the entire water column depth.

Assessments Based on Dissolved Oxygen Concentration and Temperature Above The Thermocline

If the temperature profile indicates that the habitat is reduced by high temperatures at or near the surface, an assessment of the thickness of the lens is made to determine if there is sufficient habitat for the fishery. If the data indicates insufficient habitat for fishery, the lake or reservoir shall be listed. This assessment is largely based upon best professional judgment because of the variability in the size and depth of the lake or reservoir. In the case of reservoirs that are subject to human controlled operations, drawdown is taken into consideration. Drawdown can change from year to year based upon the spring runoff and how full they were at the end of the previous irrigation season or how much water was needed for culinary purposes. Figure 21 provides an example of supporting and not supporting the beneficial use based on the DO and temperature data above the thermocline. The rationale for a conclusion of fully supporting based on the existence of a lens will be clearly documented.

Beneficial Use Supported – Sufficient habitat for fish based on DO and temperature above the thermocline.

Beneficial Use Not Supported – Insufficient habitat for fish based on DO and temperature above the thermocline.

Toxicants: Dissolved Metals, Ammonia and Gross Alpha Data

To obtain toxicant data, one sample is collected near the bottom of the lake at the deepest point in the lake or reservoir. These samples are obtained at the deepest point because this area generally has the highest dissolved metal, ammonia, and gross alpha concentrations. If the concentration of these pollutants exceeds the standard, DWQ will return to the site to conduct follow-up sampling. In some cases this may occur the following year.

Beneficial Use Supported – The beneficial use is supported if there are less than two (< 2) exceedances of the chronic or acute standard.

Beneficial Use Not Supported – The beneficial use is not supported if concentration exceeds the chronic or acute standard two or more (≥ 2) times.

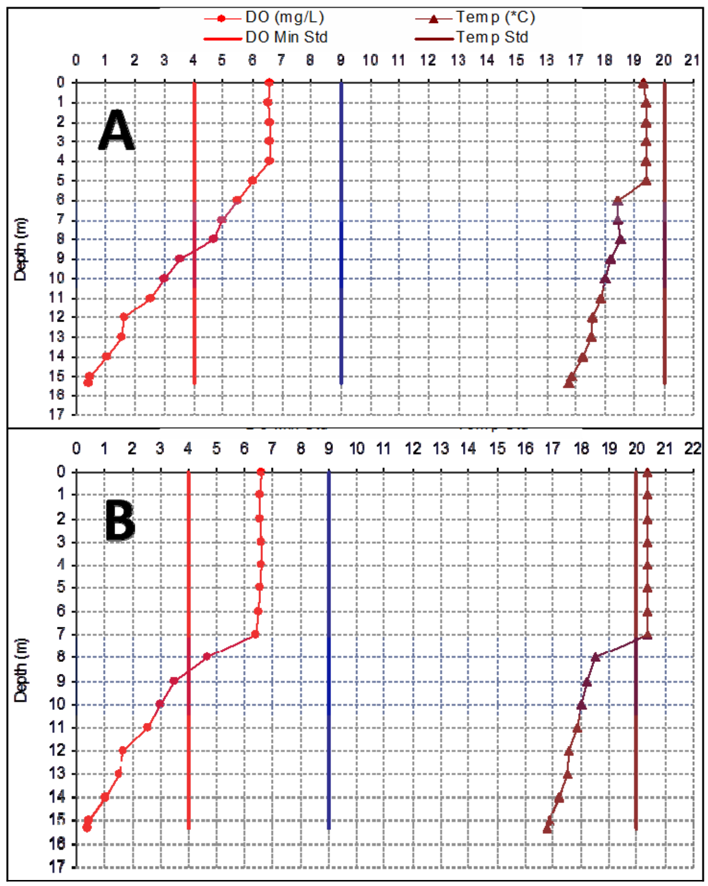


Figure 21. These images illustrate the concept of ecological lens, which is a zone where both Dissolved Oxygen (DO) and temperature are suitable for fish. The reservoir depicted on the top (Panel A) would be considered supporting because the lens where both temperature and DO violate water quality criteria is small. Conversely, the reservoir on the bottom would be considered impaired due to the large are of unsuitable conditions for fish.

Weighted Evidence Criteria

The weighted evidence criteria consist of the following three data types. These evaluations are based to a large extent on best professional judgment, but efforts are made to be as consistent as possible (Figure X).

- There is an increasing TSI trend over a long-term period or a TSI greater than 50.
- There are winter fish kills or low winter dissolved oxygen when it is measured.
- There is a dominance of green algae or cyanobacteria.

Carlson's Trophic State Index

The Carlson's Trophic State Index (TSI) is calculated using secchi disk transparency, total phosphorus, and chlorophyll-*a*. TSI value ranges from 0 to 100 with increasing values indicating a more eutrophic condition, as follows (see also Table X):

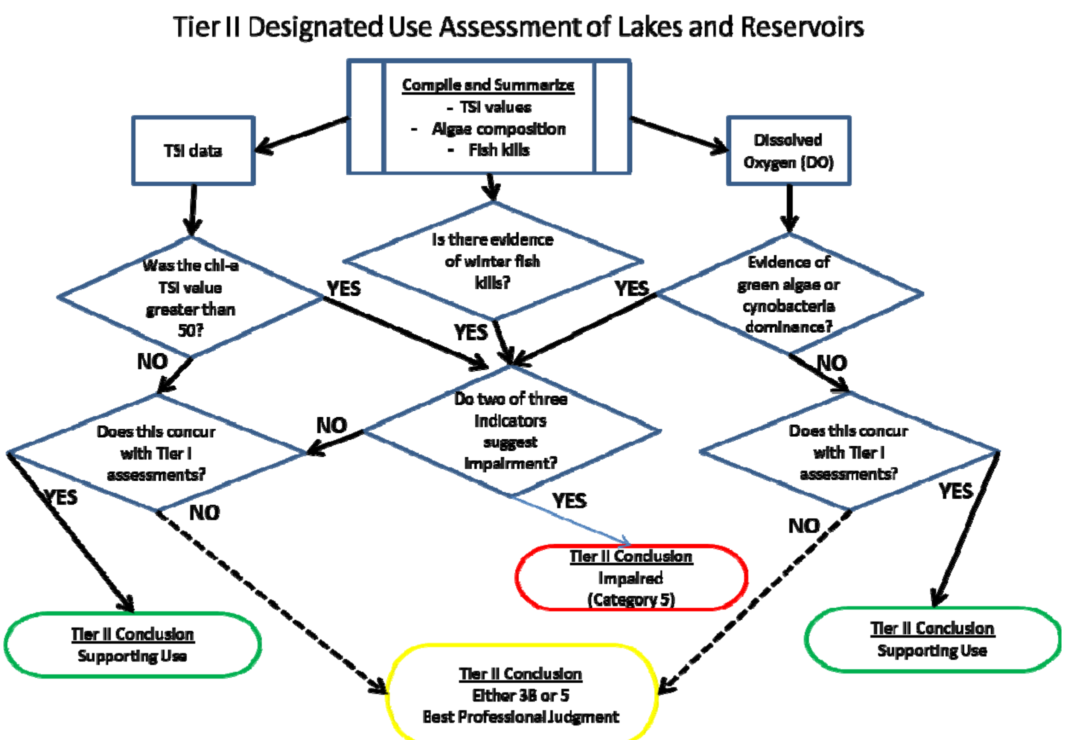


Figure 22. A flow chart that describes the Tier II assessment process for lakes and reservoirs. These assessments allow DWQ to use key lines of evidence in making assessments that would be ignored by exclusively focusing on chemical water quality parameters.

Carlson's TSI estimates are calculated using the following equations:

Trophic status based on secchi disk (TS-SD):

TSI-SD = 60 - 14.41 ln (SD),
where SD = Secchi disk transparency in meters.

Trophic status based on total phosphorus (TSI-TP):

TSI-TP = 14.20 ln (TP) + 4.15,
where TP = Total phosphorus concentration in µg/L.

Trophic status based on chlorophyll-a (TSI-Chl-a):

TSI-Chl-a = 9.81 ln (Chl-a) + 30.60,
where TC = Chlorophyll-a concentrations in µg/L. The abbreviation “ln” indicates the natural logarithm .

Once calculated, these independent TSI indicators can be used to interpret how various factors interact to influence lake production (Table 4). In each case, each TSI value can also be used to generalize the overall trophic state of the lake or reservoir as follows:

TSI Index value < 40 - Oligotrophic
TSI Index value 40 to 50 - Mesotrophic
TSI Index value 51 to 70 - Eutrophic
TSI Index value > 70 – Hypereutrophic

Table 4. Conditions likely limiting production derived from interpretations of the relationships among the three Trophic State Index (TSI) calculations: chlorophyll-*a* (Chl-a), secchi disc water clarity (SD), and total phosphorous (TP) (USEPA, 2000).

Relationship Between TSIs	Conditions Limiting Algae Production
TSI (Chl-a) = TSI(SD) = TSI(TP)	Algae conditions dominate light attenuation
TSI(Chl-a) > TSI(SD)	Large particulates, such as Aphanizomenon flakes, dominate
TSI(TP) = TSI(SD) > TSI (Chl-a)	Nonalgal particulates or color dominate light attenuation
TSI(SD) = TSI (Chl-a) > TSI(TP)	Phosphorus limits algal biomass (TN/TP ratio greater than 33:1)
TSI(TP) > TSI (Chl-a) = TSI(SD)	Zooplankton grazing, nitrogen, or some factor other than phosphorus

limits algal biomass

TSI's were calculated independently for each indicator (e.g., secchi disk and total phosphorus) but were not averaged. The previous methodology was to calculate an average TSI using all of the measures. Per Carlson (1997), the most reliable indicator of trophic status is chlorophyll-a (TSI-Chla), followed by Secchi disk (TSI-SD), and total phosphorus (TSI-TP). In some lakes, the TSIs for each index are similar. For other lakes, large differences may be observed.

For this reporting cycle, the average TSI (May through September) for each measure is reported. Large discrepancies between TSIs can be suggestive of specific lake conditions that may provide additional context for interpreting the TSI.

Tier II Assessment Using Fish Kill Observations

Most lake monitoring data occurs in summer months, yet winter fish kills can result from poor water quality, which is an important line of evidence that a lake or reservoir is not meeting its designated uses. To obtain this information DWQ contacts regional biologists within the Division of Wildlife to obtain fish kill records. Reliable winter fish kill data are not available for most lakes and reservoirs. As a result, the lack of fish kill observations generally cannot be used to infer support of aquatic life uses. However, reported fish kills are a compelling source of corroborating information that a like or reservoir is not supporting its aquatic life uses.

Tier II Assessment Using Blue-Green Algae Abundance

DWQ routinely samples to evaluate the composition and relative abundance of algae and cyanobacteria. These data are used as an additional line of evidence to determine if a lake or reservoir is impaired due to human-caused eutrophication.

Phytoplankton (algal) data are used in the Tier II assessment process, because they reflect nutrient abundance and nutrient ratios. Although there is seasonal variability, diatoms dominate lakes that have relatively low nutrient concentrations and have nitrogen:phosphorus ratios that are typical of natural aquatic ecosystems (16:1 respectively). Lakes that meet these conditions are classified as oligotrophic (meaning low food or nutrients). An observation that a lake or reservoir has diverse and abundant diatoms relative to other algae or cyanobacteria taxa is used as a line of evidence that the waterbody is supporting its designated uses.

On the other end of the scale, nutrient loading often leads to an imbalance of nutrients. In freshwater lakes, excess phosphorus is the most common problem. Such lakes are classified as eutrophic or even hypereutrophic (meaning true or high food or nutrients, respectively). This high and imbalanced nutrient ratio favors another group of algae known as cyanobacteria (sometimes called blue-green algae). This group is unusual in that it can "fix" or convert atmospheric nitrogen to biologically available organic forms. This can allow explosive growth of the algal biomass, which may coat the surface of lakes or wetlands with algal films unless the nutrient ratio in the algal cells once again approaches 16:1. Excessive growth of cyanobacteria can lead to taste and odor problems, which increases drinking water treatments costs. Some species of cyanobacteria produce substances—cyanotoxins—that are toxic to people and animals. Finally, excessive cyanobacteria growth can result in DO conditions that are deleterious to fish. Although daytime dissolved oxygen may be very high in lakes with high cyanobacteria concentrations, evening oxygen depletion from respiration and biodegradation of cyanobacteria cells sometimes causes DO concentrations to fall below values needed to support aquatic life. For these reasons, high concentrations of cyanobacteria are used as a line of evidence that the lake or reservoir is not meeting its designated uses.

Tier III Assessments: Inconsistent year-to-year water quality observations

Lakes or reservoirs are identified as being cyclic if they are assessed as not supporting in the during one assessment cycle but they are monitored and then assessed as fully supporting during the next assessment cycle. If the assessment is the reverse of the above, the lake or reservoir is cyclic also. In general, if an AU is assessed as not supporting the aquatic beneficial use designation on a consistent basis, it is listed on the 303(d) list. Lakes that fluctuate between fully supporting and not supporting the beneficial use over several cycles are not automatically listed on the 303(d) list. They are first placed in Utah's Category 3B. In order to be listed on the 303(d) list, lakes or reservoirs that exhibit this cyclic characteristic must be assessed as impaired for two consecutive assessment cycles.

Previous IRs did not discuss the use of overwhelming evidence criteria when, for instance, the severity of an exceedance may result in a Category 5 listing after only one cycle of not supporting. The overwhelming evidence criterion may be applied when the minimum number of samples is unavailable or when a standard is exceeded for only one reporting cycle. DWQ is currently defining guidelines for when the overwhelming evidence criterion applies and anticipates applying the guidelines for the 2012 IR.

The following decision rules apply when making a Tier III assessment, which nearly always determines the final lake and reservoir decision recorded in the *Integrated Report*:

Assessment Result

> **Beneficial Use Supported -** To be assessed as supporting, these lakes must be assessed as supporting for two consecutive assessment cycles.
>
> **Beneficial Use Not Supported -** To be assessed as not supporting, these lakes must be assessed as not supporting for two consecutive assessment cycles.
>
> **Insufficient Data and Information** – Unless overwhelming evidence suggests otherwise, lakes or reservoirs with a single assessment (new sampling locations), or those with conflicting assessment results between the two most recent assessment cycles, are assessed as Category 3B (insufficient data and information).

Whenever possible, DWQ will prioritize lakes and reservoirs for subsequent monitoring so that conclusive beneficial use assessments can be made.

FUTURE REVISIONS

DWQ has developed these assessments methods over numerous years and while they represent a rigorous process—with numerous checks and balances—areas for improvement will always remain. Stakeholders interested in water quality assessments are encouraged to make suggestions on how these methods can be improved at any time. All suggestions submitted to DWQ will be considered, whether or not the IR is under formal review. This section describes several revisions that are already in varying stages of development.

RESTRUCTURING ASSESSMENT METHODS TO BETTER ACCOMMODATE SITE-SPECIFIC DATA

DWQ has recently restructured its monitoring program to improve both efficiency and effectiveness (see http://www.waterquality.utah.gov/Monitoring/index_update.htm), which is requiring DWQ to rethink its assessment approaches to accommodate available data sources. This plan essentially involves conducting two tiers of monitoring with each of 6 rotating watersheds. In the first tier, data are collected at 50 randomly selected sites within in each major watershed. These data will allow statistical inference to all waters of the state, and will allow DWQ to assess all surface waters. Assessing all surface waters meets an important Clean Water Act goal, but more importantly it will provide DWQ with unbiased estimated of water quality concerns and will help to prioritize future monitoring, assessment, and restoration efforts. Site identified through Tier I monitoring as having water quality concerns will be sampled more intensively—both spatially and temporally—with Tier II monitoring to better understand water quality concerns. New assessment approaches will need to accommodate site-specific information. While these analyses will be more intrinsically complex, they will greatly improve our understanding of the magnitude and extent of impairments, and will facilitate a much better understanding of the causes and sources of water quality impairments. DWQ anticipates that these new methods will be developed over the next two years and plans to include these methods in the 2012 *Integrated Report*.

ACCOMMODATING HIGH FREQUENCY DO AND TEMPERATURE DATA

Traditionally, water quality assessments were based on "grab" samples that capture conditions at a single point in time. Such collection efforts complicate the interpretation of parameters like temperature and DO, which exhibit wide daily fluctuations. However, technology is improving and DWQ increasingly has data from deployed instruments that quantifies water quality parameters at a high frequency (e.g., every 15 minutes) for several days or weeks. DWQ is working on developing assessment methods that help us better interpret water quality data from these more accurate data sources.

DEVELOPMENT OF WETLAND ASSESSMENT TECHNIQUES

DWQ is in the process of developing procedures that will ultimately provide quantitative information about the support of the designated uses assigned to wetlands. The initial focus will be on wetlands associated with Great Salt Lake, but DWQ hopes to ultimately expand these tools statewide. EPA recently awarded DWQ a grant that will greatly facilitate the continuation of this critical work.

DEVELOPMENT OF TECHNIQUES TO QUANTIFY THE EFFECTS OF ANTHROPOGENIC EUTROPHICATION

Numerous studies have shown excessive nutrients to be among the most important, largely unaddressed, water quality pollutants. DWQ is actively developing programs to help address these concerns in Utah. Part of these efforts involve the development of monitoring and assessment techniques that will allow DWQ to directly quantify some of the deleterious effects that nutrients sometimes cause to aquatic ecosystems.

REVISIONS TO LAKE AND RESERVOIR ASSESSMENT METHODS

Under most conditions, the current assessment methods for lakes and reservoirs work well. However, DWQ is increasingly encountering situations where reservoirs show impairments during late summer conditions due entirely to low lake levels. While it is certainly important to convey the negative ecological consequences associated with these conditions, these scenarios present significant problems for DWQ because solutions to these problems are not within our regulatory authority. Moreover, many of these reservoirs were constructed primarily to assist with water distribution, which is certainly a critical use that is not currently accounted for in our water quality standards. DWQ is currently exploring options on how to address these scenarios so that we can focus our limited resources on water quality problems that have practical solutions.

EXPANSION OF UTAH'S BIOLOGICAL ASSESSMENT PROGRAM

Utah's biological assessment program remains in its infancy, but it is rapidly expanding. More and more DWQ and our collaborators are finding these data to be extremely useful in identifying and understanding areas with water quality problems. Over the next several years, DWQ hopes to develop biological assessment models that will allow us to interpret the composition of benthic algae in an assessment context. DWQ is also actively pursuing analytical methods that will translate composition measures into indicators of specific pollutants.

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