Component VIII
Water Quality Assessment

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INTRODUCTION

The term "water quality" includes the water column and the physical channel required to sustain aquatic life. The goal of the federal Clean Water Act, "*to protect and maintain the chemical, physical, and biological integrity of the nation's waters,*" establishes the importance of assessing both water quality and the habitat required for maintaining fish and other aquatic organisms. Although water quality potentially encompasses a wide range of topics, it is necessary in a watershed assessment to focus on critical issues and partition the evaluation into components.

The purpose of the Oregon watershed assessment manual is to complete a **screening-level** [1] assessment The screening level is used to flag obvious areas of water quality **impairment** in the watershed. This is accomplished by comparing selected measurements of water quality to evaluation **criteria**. A more rigorous approach would use detailed statistical assessments to evaluate seasonal fluctuations, to evaluate trends over time, or to evaluate the specific sources of pollution by using an upstream/downstream set of stations. Watershed councils will need to conduct detailed water quality studies to fill data gaps or investigate the sources of pollutants: see Appendix VIII-A and the Watershed Condition Evaluation and Monitoring components of this manual for examples and further discussion. The council should obtain the services of a water quality specialist for these kinds of projects. The Additional Resources section at the end of this component provides more resource information on finding help to conduct a water quality analysis.

Water quality is evaluated by comparing key indicators against evaluation criteria. Indicators are selected water quality measures that are representative of a pollution category. For example, total phosphorus is used as the single indicator for the effect of phosphorus as a plant nutrient in water. In a more detailed analysis, as may be required for a **Total Maximum Daily Load (TMDL) plan**, an analyst would evaluate the biological availability of the phosphorus by examining dissolved and other forms of phosphorus. The decision to pursue more detailed analysis will depend on the importance of the issue in the watershed and the potential costs of pollutant load reduction versus resource benefits.

Because water quality is such a broad topic, some aspects of water quality are addressed in other components. Fine sediments are evaluated in the Fish and Fish Habitat Assessment component; the source of sediment is addressed in the Sediment Sources component; the processes that affect temperature are addressed in the Riparian/Wetlands Assessment component (riparian continuity and shade), and in the Hydrology (low flows) and Water Use component. The Water Quality Assessment component addresses water quality issues that are not evaluated elsewhere in the manual: temperature, **dissolved oxygen**, **pH**, nutrients, bacteria, chemical contaminants, and **turbidity**.

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

Critical Questions

1. What are the designated **beneficial uses** of water for the **stream segment**?

   The beneficial uses of water, identified in the Oregon Water Quality Standards, provide the basis for selecting criteria used to assess water quality.

2. What are the water quality criteria that apply to the **stream reaches**?

   Water quality rules contain both narrative and numeric standards. Values for narrative standards may be based on local conditions and are derived from the literature. This assessment suggests default values for the narrative standards. These two sources of criteria are combined and used as "evaluation criteria" for the purposes of this assessment.

3. Are the stream reaches identified as water quality limited segments on the 303(d) list by the state?

   Stream reaches that are on the 303(d) list have already been targeted for development of **nonpoint source** management plans or TMDL plans by the state. The TMDL process has identified water quality issues that should be addressed in the assessment.

4. Are any stream reaches identified as high-quality waters or Outstanding Resource Waters?

   Designation as Outstanding Resource Water indicates a stream of high quality or important ecological value. These stream segments have already been identified as a high priority for protection.

5. Do water quality studies or evaluations indicate that water quality has been degraded or is limiting the beneficial uses?

   The water quality analysis will evaluate existing data for temperature, dissolved oxygen, pH, nutrients, bacteria, chemical contaminants, and turbidity.

Assumptions

- The assessment will focus on water quality parameters encountered most frequently as an issue in Oregon watersheds. These issues include temperature, dissolved oxygen, pH, nutrients, bacteria, turbidity, organic contaminants, and metal contaminants.

- Evaluation criteria are derived from the Oregon Water Quality Standards. Evaluation criteria are based on an interpretation of narrative and numeric standards in the Oregon Water Quality Standards. Where numerical criteria are not provided in the state standards, we have indicated **evaluation indicators** that are based on the literature. These evaluation criteria could be modified to fit watershed conditions based on local technical knowledge with concurrence from the Oregon Department of Environmental Quality (ODEQ).

- Sensitive beneficial uses such as **salmonid** fish serve as **surrogate measures** for other beneficial uses of water in characterization and assessment of water quality.

- The scope of parameters is limited to evaluation indicators or criteria that are representative of the type of pollution. For example, although there are many forms of phosphorus that can be measured, we use total phosphorus as the indicator for phosphorus enrichment.

- Organic contaminants are screened by tallying the number of "detections" above minimum detection levels. This does not constitute an evaluation of harm to beneficial uses; it simply serves as a screening tool. A more detailed evaluation of effects is required where organic contaminants are an issue or the number of detections indicate potential risk to beneficial uses.

- The limited list of metal contaminants (six) is based on their occurrence in Oregon as reported in the ODEQ Statewide Water Quality Status Reports.

- At decision points where one interprets water quality data, a conservative approach is taken. The screening-level assessment is designed to detect patterns of impairment. When combined with information from other components of the watershed assessment manual, these patterns help identify potential problem areas spatially within the watershed. More detailed evaluation may be needed before any restoration actions are undertaken.

Materials Needed

- Refined Land Use Map (from the Start-Up and Identification of Watershed Issues component)

- Watershed Base Map (from the Start-Up and Identification of Watershed Issues component)

- ODEQ Water Quality Standards for the basin

- ODEQ 303(d) list and decision matrix

- State reports on water quality (from ODEQ and Oregon Department of Fish and Wildlife [ODFW

- Land management reports (from US Forest Service [USFS], US Bureau of Land Management [BLM], and corporate landowners)

- Calculator

- Spreadsheet program (recommended) (e.g., Excel, Lotus, Quattro Pro)

Necessary Skills

Performing this assessment involves dealing with numeric data and averages. The analyst should be willing to perform basic math functions.

Final Products of the Water Quality Assessment

- Beneficial Uses and Water Quality Issues form (Form WQ-1) (Step 1 result)

- Summary of Percent **Exceedance** Criteria (Form WQ-2) (Step 4 result)
- Summary of Water Quality Impairment (Form WQ-3) (Step 5 result)
- Confidence Evaluation (Form WQ-4)

ASSESSMENT OVERVIEW

The water quality assessment is based on a process which identifies the beneficial uses that occur within the watershed, identifies the evaluation criteria which apply to these uses, and evaluates water quality conditions by comparison of existing data with these criteria. This conceptual framework is consistent with the guidelines established by the US Environmental Protection Agency (EPA) under authority of the federal Clean Water Act and the water quality programs of the ODEQ.

The assessment is completed in a step-wise procedure illustrated in Figure 1. The first three steps address the following questions: (1) What are the beneficial uses of concern? (2) What criteria apply? (3) What do we know about water quality conditions? In Steps 4 through 6, we compare current conditions to the evaluation criteria and determine if there is a water quality problem. Determining the potential cause of water quality decline is completed during the Watershed Condition Evaluation component when information from the other components are combined and synthesized.

Step 1: Identify Sensitive Beneficial Uses in the Watershed

The requirements for in-stream water quality are based on protection of recognized uses of water. The term "beneficial uses" is legally defined in the Oregon Water Quality Standards and refers to uses such as drinking water, aquatic life, swimming, and boating. In practice, the sensitive beneficial uses drive the evaluation of water quality and are the basis for establishing best management practices (Table 1).

The list of beneficial uses are found in the Oregon Water Quality Standards for the 19 hydrologic basins in Oregon. The official list of beneficial uses for a waterbody are determined by consulting the basin-specific list. In most waterbodies the sensitive beneficial uses shown in Table 1 apply, and these are the uses that should be carefully evaluated. Exceptions to these general assumptions can be identified by examining the basin tables in the Oregon Water Quality Rules (Oregon Administrative Rules 340.41). See the Water Quality Information Resources sidebar to find out how to identify beneficial uses in your watershed.

Table 1. Sensitive beneficial uses of water applicable to this assessment

Beneficial Uses
Aesthetic quality
Fishing
Domestic water supply
Resident fish and aquatic life
Salmonid fish rearing
Salmonid fish spawning
Water contact recreation

Aquatic species, particularly salmonid fish, are often considered the most sensitive beneficial uses in a watershed. Salmonid species—the pacific salmon, char, and whitefish—are adapted to cold-water, high-gradient habitats where temperatures are cool and dissolved oxygen is high. Salmonids have highly variable life histories (see Watershed Fundamentals component of this manual for a description of salmonid life histories), but display similarity in laying eggs in gravels and have **fry** and **juveniles** that rear close to where they hatch from the egg. These early life stages are particularly sensitive to changes in water quality.

At this step, also determine if the stream is on the 303(d) list and, if so, identify for which parameters the stream segment is listed. See the Water Quality Information Resources sidebar (next page) to find out where to get information on the 303(d) list. Also, the assessment team may already have obtained this information in the Start-Up and Identification of Watershed Issues component. If so, transfer the information to the Beneficial Uses and Water Quality Issues form (Form WQ-1), and pat yourself on the back for a job well done!

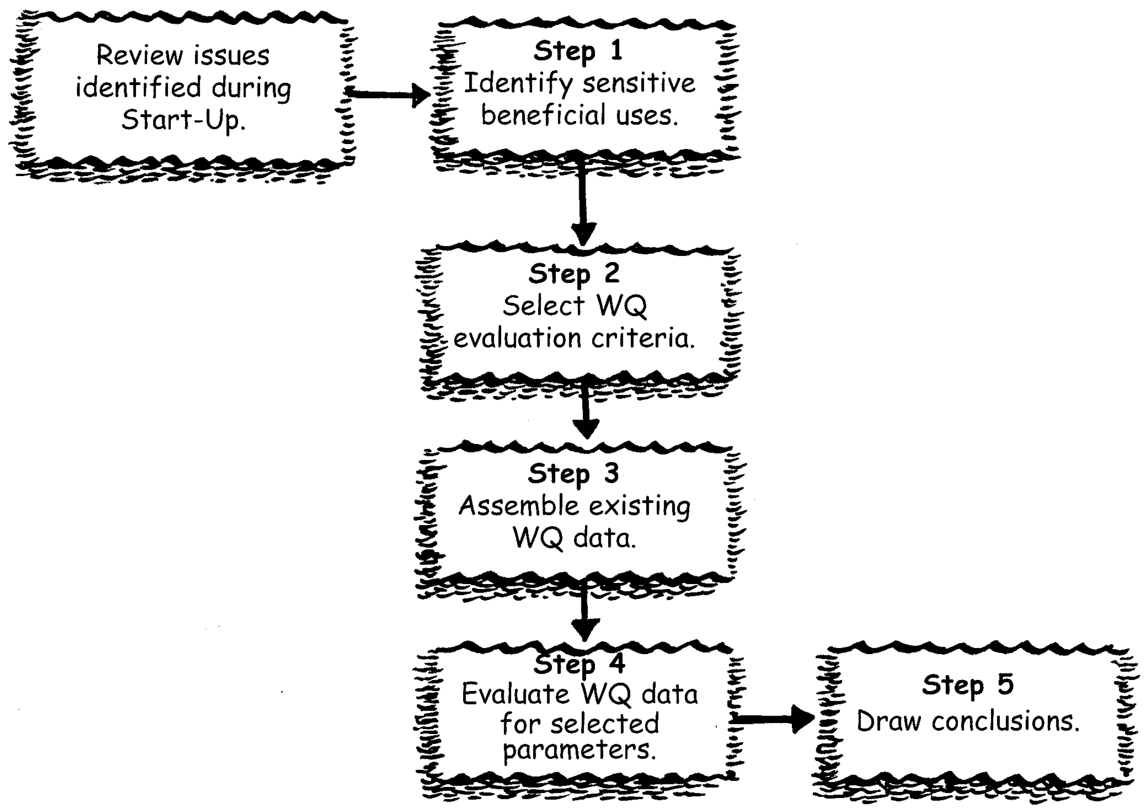

Figure 1. The water quality assessment is performed using a step-wise procedure that identifies the beneficial uses which occur within the watershed, identifies the evaluation criteria which apply to these uses, and evaluates water quality conditions by comparison of existing data with these criteria.

WATER QUALITY INFORMATION RESOURCES

Oregon Division of Environmental Quality Web Site
ODEQ home page: http://www.DEQ.state.or.us

Information on beneficial uses, water quality criteria, and 303(d) listings are available on the ODEQ Internet site. The information can be obtained by following the hypertext links starting with the ODEQ home page address listed above. Several pathways and the information found by following them are described in the following sections:

http://waterquality.deq.state.or.us/wq [Select "Water Quality Program Rules" from the menu.]

Beneficial Uses

The water quality rules are organized by river basins, which are shown in the Basin Index Map. Download the figure for the specific river basin which shows the stream segments located in the basin. Download the basin table which lists the beneficial uses in the basin.

Table 20 – Water Quality Criteria Summary

This table provides criteria for toxins such as pesticides and heavy metals. Download this table only if toxic chemicals are an issue in the basin.

Table 21 – Dissolved Oxygen Criteria

Download this table only where dissolved oxygen has been identified as a water quality issue in the basin and a more detailed analysis is required.

OAR 340 – Oregon Administrative Rules, Chapter 340

These rules provide the official list of water quality standards for the basin. This section is very lengthy and is generally not needed for the screening-level assessment. Refer to these rules only if there is question about the application of a specific water quality standard. Download a summary of the water quality criteria contained in the 303(d) list site.

http://waterquality.deq.state.or.us/wq [Select "Water Quality Limited Streams (303d)" from the menu.]

Listing Criteria for 1998 303(d) List

The listing criteria provide a summary of the Oregon Water Quality Standards. This list also provides the rationale for deciding what information is needed to place streams on the 303(d) list.

Oregon's Water Quality Limited Waterbodies - Section 303(d) List

This list shows the parameters, basis, and supporting data for including a waterbody on the stream segment. Query the list only for the specific stream segments of interest and download this information.

More 303(d) Information

The 303(d) List site contains additional information about water quality limited streams and TMDLs. Refer to this site for information on TMDL schedules, priorities, 303(d) database, fact sheets, guidance, and examples of TMDLs.

http://www.DEQ.state.or.us/lab/lab.htm

The ODEQ laboratory home page provides information on water quality and biological monitoring. The Water Quality Index basin summary provides a summary of types of pollution and their potential severity in the basin.

Phone Numbers
(800) 452-4011 ODEQ Public Information
(503) 229-5279 Water Quality Division
(503) 229 5983 ODEQ Laboratory regional water quality monitoring coordinators

Step 2: Identify Water Quality Criteria Applicable to the Sensitive Beneficial Uses

The Oregon Water Quality Standards are several hundred pages in length, so the brief summary of water quality criteria discussed here and listed in Table 2 should be used with caution. In general, the values summarized in the table apply to the majority of stream and river systems and are sufficient for the purposes of this assessment. The official state standards for the basin should be consulted where a key issue relative to water quality is under consideration.

Evaluation criteria are based on an interpretation of narrative and numeric standards in the Oregon Water Quality Standards. Where numerical criteria are not provided in the state standards, we have indicated evaluation indicators that are based on the literature. These are useful for evaluating water quality conditions, but do not have any regulatory standing.

Step 2 result: Highlight the criteria in Table 2 that are applicable to the watershed assessment. Note any modifications based on local water chemistry.

Table 2. Water quality criteria and evaluation indicators.

Water Quality Attribute	Evaluation Criteria		
Temperature	Criteria: Daily maximum of 64°F (7-day moving average)		
Dissolved Oxygen	Criteria: 8.0 ***mg/l***		
pH	Criteria: 6.5 to 8.5 units		
Nutrients	No statewide numeric criteria. See state standards for water quality criteria established in specific basins.		
Total Phosphorus	Indicator: 0.05 mg/l		
Total Nitrate	Indicator: 0.30 mg/l		
Bacteria	<u>Water-contact recreation (criteria)</u> 126 *E. coli*/100 ml (30-day log mean—minimum 5 samples) 406 *E. coli*/100 ml (no single sample can exceed the criteria) <u>Marine waters and estuarine shellfish growing area</u> 14 fecal coliform/100 ml (median) 43 fecal coliform /100 ml (not more than 10% of samples)		
Turbidity	Indicator: 50 NTU maximum above background		
Contaminants, Organic	Indicator: Above detection limits		
Contaminants, Metal	Chronic toxicity for freshwater aquatic life:		
	Hardness	100 mg/l	25 mg/l
	Arsenic	190.0 ***µg/l***	
	Cadmium	1.1 µg/l	0.4 µg/l
	Chromium (Hex)	11.0 µg/l	
	Copper	12.0 µg/l	3.6 µg/l
	Lead	3.2 µg/l	0.5 µg/l
	Mercury	0.012 µg/l	
	Zinc	47.0 µg/l	32.7 µg/l

Step 3: Assemble Existing Water Quality Information

Now that the potential pollutants, beneficial uses, and water quality criteria have been identified, you need to search for applicable information on water quality regarding your watershed.

Water quality information may be accessed in different forms—raw data, reports, and professional judgement. These sources of information all start with some form of data—the "raw material" of an assessment. This raw material must be processed in a technically sound manner. Water quality data is turned into information by comparing data against criteria or comparing data between collection sites.

Consider beginning your search with the following data sources:

- Raw data. Data in tabular format from agency or private-company files. Data is commonly stored on spreadsheet programs, such as Quattro Pro, Excel, or Lotus. Raw data is processed using the procedure described in Appendix VIII-B.

- Reports. The most common sources of information are state and federal agencies, such as ODEQ, ODFW, USFS, BLM, and the US Geological Survey (USGS). Studies are also completed by private corporations, universities, private contractors, and municipal water providers. In urban areas, local public works agencies may have collected water quality data. Reports should summarize water quality conditions in the Conclusion section. This information may be directly transferable to the Watershed Condition Evaluation component.

- Professional judgement. Local specialists in hydrology, fisheries, water quality, and other professions that are familiar with a watershed can provide some useful insight into conditions. Although this professional expertise can provide valuable information, professional judgement is not a substitute for assessments based on data.

An inventory of available information should answer the following questions:

- Who collected the information?
- What data were collected?
- At which locations were the data collected?
- Was data analyzed?
- Was a report filed?
- Were conclusions made?

You also need to evaluate and record the applicability and reliability of available information. Criteria to consider when evaluating information includes:

1. How old is the information?

2. Have watershed conditions changed since the evaluation was completed?

3. Was the data coverage (over time and geographic extent) sufficient to assess conditions?

4. Is the information based on inventory methods (primarily observations) or on more rigorous studies (primarily measurements)?

Step 4: Evaluate Water Quality Conditions Using Available Data

This procedure is an initial data evaluation; more rigorous statistical procedures may be required to draw conclusions confidently from the data set. The analysis can be completed using a hand-held calculator; however, using spreadsheet software will help speed up data analysis and organize the information.

The same general procedure is used for each pollutant category. The procedure is illustrated in Appendix VIII-B using nutrients as an example. The purpose of the analysis is to:

1. Describe the existing condition of the stream under study.

2. Compare the existing condition to reference sites where available (upstream sites or adjacent watersheds).

3. Compare existing condition to water quality criteria.

Temperature

Cool water temperatures are a basic requirement for native salmon, trout, amphibians, and other aquatic life. Growth and reproduction are adversely affected when water temperature is outside of the range to which these organisms were adapted. There is continuous debate about the actual numerical values that should be used for setting the temperature criterion. This is because the temperature cycle varies daily and seasonally, and different life stages and species of fish exhibit different tolerances.

The following temperature criteria are established in the Oregon Water Quality Standards (OAR 340-41-[basin][2][b]) for the protection of resident fish and aquatic life, and salmonid spawning and rearing.

> Seven (7) day moving average of the daily maximum shall not exceed the following values unless specifically allowed under a Department-approved basin surface water temperature management plan:
>
> - 64°F (17.8°C);
> - 55°F (12.8°C) during times and in waters that support salmon spawning, egg incubation and fry emergence from the egg and from the gravels;
> - 50°F (10°C) in waters that support Oregon Bull Trout:
> - 68°F (20°C) in the Columbia River (mouth to river mile 309);
> - 68°F (20°C) in the Willamette River (mouth to river mile 50);

[except when air temperature during the warmest 7-day period of the year exceeds the 90th percentile of the 7-day average daily maximum air temperature calculated in a yearly series over the historical record]

Water Quality Limited Criteria: Rolling seven(7) day average of the daily maximum exceeds the appropriate standard listed above. In the cases where data was not collected in a manner to calculate the rolling seven (7) day average of the daily maximum, greater than 25 percent (and an minimum of at least two exceedances) of the samples exceed the appropriate standard based on multi-year monitoring programs that collect representative samples on separate days for the season of concern (typically summer) and time of day of concern (typically mid to late afternoon).

The screening-level assessment bypasses these complexities by using the daily maximum temperature of 64°F as the evaluation criterion. Because temperature is such an important water quality issue in Oregon, you may find it useful to complete a more exacting evaluation by calculating the 7-day moving average as described in the state standards. See Appendix VIII-A, which provides an example of a more detailed temperature analysis.

Action: For this level of assessment, tally the number of days that the maximum temperature exceeds 64°F. Follow the procedure described in Appendix VIII-B to summarize results, and record the result in the Summary of Percent Exceedance Criteria (Form WQ-2).

Dissolved Oxygen

Like temperature, high dissolved oxygen is characteristic of watersheds throughout the Pacific Northwest that support cold-water organisms such as native salmon and trout. These species are adapted to waters with high dissolved oxygen. Developing salmon and trout embryos are especially sensitive to dissolved oxygen. The Oregon Water Quality Standards, therefore, have specified higher dissolved oxygen for salmonid spawning. The standards also specify a standard for oxygen in the gravel when salmon and trout eggs are developing.

Oxygen is dissolved in running water in equilibrium with the atmosphere. The water temperature and pressure determine the percent oxygen saturation from the atmosphere. Oxygen solubility varies inversely with temperature, colder water containing a higher concentration of oxygen. Dissolved oxygen fluctuates on a daily cycle that is tied to the daily change in temperature and the photosynthesis and respiration of aquatic organisms. Dissolved oxygen generally reaches a high in the afternoon due to photosynthesis from algae, and a low at night, shortly before dawn, due to the uptake of oxygen by all the organisms in the stream, including algae.

The requirement for measuring dissolved oxygen appropriately is therefore very similar to temperature. Dissolved oxygen must be measured over a 24-hour period to be useful. Data based on single grab samples of oxygen are fairly useless in characterizing the actual oxygen levels that influence aquatic organisms. Devices for measuring dissolved oxygen over a daily cycle are more expensive and require more expertise than the simple temperature data loggers. For this reason, there are likely very few adequate existing data records for dissolved oxygen.

The Oregon Water Quality Standards contain a number of dissolved oxygen criteria. More restrictive criteria are specified for dissolved oxygen during the period that salmonid fish are spawning (11 mg/l). Also, the standards specify a dissolved oxygen concentration (8 mg/l) in the gravel used by spawning fish. Additional specific language addresses the difference between cold-water, cool-water, and warm-water fish.

For the purposes of the screening-level assessment, the evaluation criterion is set at a minimum of 8 mg/l in the water column for cold-water fish. Because the criterion is a minimum, tally the measurements found below the criterion.

Action: Use the criterion of 8 mg/l for dissolved oxygen. Follow the procedure described in Appendix VIII-B to summarize results and record the result in Form WQ-2. Where dissolved oxygen is identified as a critical issue in the watershed, consult the water quality standards for the specifics of the water quality standards.

pH

The pH is a measure of the hydrogen ion concentration of water. pH is measured in a logarithmic scale, with pH below 7 indicating acidic conditions and pH above 7 indicating alkaline conditions. pH of water is important in determining the chemical form and availability of nutrients and toxic chemicals. Measurement of pH is especially important in mining areas because there is potential for both generation of heavy metals and a decrease in pH. Metal ions shift to a more toxic form at lower pH values. The pH of waters varies naturally across Oregon due to the chemical composition of the rock type in the watershed and the amount of rainfall. Eastside basins generally will have more alkaline water than westside and coastal basins.

The Oregon Water Quality Standards specify the expected pH range for all the basins in Oregon. The pH criteria is generally 6.5 to 8.5 for westside basins, and 7.0 to 9.0 for eastside desert basins. It should be recognized that, like dissolved oxygen, pH also varies in streams naturally throughout the day due to the photosynthesis and respiration cycles of attached algae.

Action: To simplify the statewide screening-level assessment, use a pH range of 6.5 to 8.5. Follow the procedure described in Appendix VIII-B to summarize results and record the result in Form WQ-2. If the screening assessment shows values outside of this range, consult the specific basin standards.

Nutrients

Total phosphorus measures primarily phosphates in the water column and phosphorus in suspended organic material. **Total nitrate** (commonly measured as nitrite plus nitrate) provides a measure of the majority of nitrogen present in surface waters. Evaluation criteria are based on literature values that have been identified as causing excessive plant growth. Local watershed or basin-specific values should be used if they have been identified through a state-approved planning process.

Excess algae and aquatic plant growth can create a problem in slow-moving streams and rivers, and in still waters such as ponds and lakes. The excessive growth can result in low or no dissolved oxygen, can interfere with recreation, and with certain algae can produce chemicals that are toxic to livestock and wildlife. Phosphorus and nitrogen, the major growth-limiting nutrients in water, are the focus of the water quality evaluation. Although aquatic scientists measure nutrients in many forms, these are two primary chemical forms limit plant growth.

Action: Where TMDLs have not been established, use the evaluation criteria of 0.05 mg/l for total phosphorus and 0.30 mg/l for total nitrates. Follow the procedure described in Appendix VIII-B to summarize results and record the result in Form WQ-2.

Bacteria

Bacteria in the coliform group are used as indicators to test the sanitary quality of water for drinking, swimming, and shellfish culture. For the purpose of screening bacterial contamination, bacterial numbers can be compared to a single sample criterion: 406 **E. coli**/100 ml in fresh waters and 43 **fecal coliform**/100 ml in marine waters. This approach provides an appropriate red flag for bacterial contamination and maintains simplicity for the watershed assessment. Where bacterial data have been collected for a specific study (e.g., in public bathing beaches or below waste treatment facilities), the analysis and the conclusions should be available in agency reports.

Action: Follow the procedure described in Appendix VIII-B to evaluate bacterial numbers using the single sample criterion. Transfer the results to Form WQ-2.

Contaminants: Organic Compounds, Pesticides, and Metals

The term “contaminants” refers to chemicals that may cause toxicity in aquatic organisms. Organic compounds are man-made chemicals that are used for a variety of industrial purposes and as pesticides and herbicides. Because of the wide variety of organic chemicals it is not feasible to list the criterion for each chemical in a screening assessment. Establishing the “safe” level for these chemicals is the subject of continuing debate among scientists.

For organic compounds, the suggested assessment is to count the number of “detections” or “hits” in a data set that are above minimum detection levels. The detection level for these chemicals is usually reported in the parts per billion range, and the detection limit varies by compound. A high percentage of observed detections should be considered a red flag, and a more detailed evaluation of the data should be completed by a water quality specialist or toxicologist.

Criteria for metals are expressed as acute and chronic values. Chronic values are intended to protect the organism from sublethal effects such as physiological stress, growth inhibition, and decreased reproduction. Toxicity for most metals is based on the **hardness** of the receiving water, and therefore the regulatory criterion is expressed as a formula. To simplify the process, the chronic criterion for freshwater aquatic life is listed for only two hardness levels, 25 and 100 mg/l of hardness. As hardness decreases, the toxicity of the metal increases. Request assistance from the ODEQ in adapting the criteria to the local water chemistry conditions if hardness levels are outside of this range.

Action: For organic compounds, count the number of detections and express this count as a percentage of measurements taken. For metals, compare the values to the evaluation criteria in Table 2 and use the data analysis procedure described in Appendix VIII-B. Transfer the results of the assessment to Form WQ-2.

Turbidity/Suspended Sediment

Turbidity is a measure of the clarity of water. In most cases water is cloudy due to runoff of sediment, and therefore turbidity is a useful surrogate for measuring **suspended sediment**. Turbidity can also be caused by other sources of suspended material such as algae or fine materials from glaciers, so the assumed relationship to suspended sediment should be verified by checking with local experts. Suspended sediment can directly affect fish by damaging their gills and reducing the feeding ability of sight-feeding fish such as salmonids. Suspended sediment is a carrier for other pollutants (nutrients, pesticides, and bacteria) and is therefore a concern for water quality in general. In addition, suspended sediment interferes with recreational uses and the aesthetic quality of water. State tourism bureaus like to advertise the gin-clear mountain streams—those waters with low suspended sediment and turbidity.

Turbidity is measured optically by passing a light beam through a sample. With increased suspended material, less light passes through the sample and a higher turbidity value is recorded. The unit of measure, an **NTU** (nephelometric turbidity unit), is based on the original measurement device and has no direct meaning.

Turbidity varies naturally with the soil type in a landscape. The small particle sizes, silts and clays, will stay suspended for long periods and cause turbidity. Soils that break down into sand-size fractions will settle to the bottom and result in comparatively low turbidity values. Turbidity in a stream will increase naturally during storm and runoff events. This high variability makes it difficult to establish a simple, meaningful criterion.

The Oregon Water Quality Standards specify a criterion that compares an activity relative to background. This criterion is only useful in comparison to a specific pollutant source where paired samples have been collected; finding this information in routine data collections would be rare. For this assessment we recommend using an evaluation criteria of 50 NTU. Turbidity at this level interferes with sight-feeding of salmonids and therefore provides a direct indicator of biological effect. Turbidity at this level is not lethal to fish, but, it does provide a useful red flag for screening turbidity and suspended sediment.

Action: Compare turbidity values to the 50 NTU evaluation criteria using the procedure in Appendix VIII-B and transfer the results to Form WQ-2.

Step 5: Draw Inferences from the Water Quality Assessment

The data assessments completed in Step 4 result in a percentage of criteria exceedance. The next step is to make an inference about water quality conditions based on the assessment and summarize the information. Because water quality data are normally very limited, the forms are set up to record water quality by subwatershed rather than by **Channel Habitat Type** (CHT). If there is sufficient information to break the subwatershed into smaller units, then the segment breaks should be at transitions between CHTs.

Water quality varies seasonally as the watershed experiences the process of erosion and pollutant transport associated with rain and snowmelt events. Aquatic biota integrate the variability in water quality over time. If water quality conditions are unfavorable during critical periods then the population will either be reduced or eliminated from the waterbody. For this reason, it is not useful to evaluate water quality on an average annual condition; this would tend to mask the effect on the aquatic life. Instead, you need to consider how seasonal extremes or short-duration events effect the organisms living in the stream.

To capture this concept of seasonal effects, we suggest using a fairly conservative assessment of the data. However, the procedure provides some allowance for limited excursions above the criteria that may be attributed to natural variability and to which aquatic organisms are adapted. These factors are balanced by setting a low percentage of criteria exceedance (15%) as the criterion for impairment. Analysts should recognize that these are subjective breakpoints.

To apply the information from the Water Quality Assessment component to the Watershed Condition Evaluation component, summarize water quality using the last column (Summary of Miles Impaired) in Form WQ-3, Summary of Water Quality Impairment. If any water quality category is rated "Moderately Impaired" or "Impaired" (Table 3), the summary should be recorded as "Impaired." This approach is based on the concept of limiting factor: If one water quality factor is limiting the beneficial use, then this needs to be noted in Form WQ-3 so that the condition can be addressed in stream restoration.

Finally, the information is summarized by number of miles impaired. The number of miles each **water quality station** represents is evaluated based on the land use and stream course maps. A water quality station represents stream miles between stations. Where only one station is located at the mouth of the tributary, the distance represented by the station is a judgement call. If the land use is uniform within the subwatershed, then the station could be considered representative of the entire length. Where there is an obvious land use change, (e.g., from crop land to forest land), then that distance to the change in land use should be used.

ADDITIONAL RESOURCES

The Water Quality Assessment component describes a screening-level procedure that accomplishes the purpose of flagging potential problem areas in the watershed. In many situations, this cursory analysis may not be sufficient for making critical decisions about restoration projects, and additional data collection or data analysis may be desired. Information on more detailed analytical methods are maintained by state and federal agencies that have generally made an effort to provide this information via the Internet. The information detailed on the following pages provides links to more detailed analytical procedures and further reading on cause-and-effect relationships.

Table 3. Criteria for evaluating water quality impairment.

Percent Exceedance of Criteria	Impairment Category
(<15%)	**No Impairment** No or few exceedances of criteria.
(15-50%)	**Moderately Impaired** Criteria exceedance occurs on a regular basis.
(>50%)	**Impaired** Exceedance occurs a majority of the time.
Date lacking/insufficient	**Unknown**

EPA Publications

EPA publications can be ordered on the Internet (http://www.epa.gov/OWOW/info/PubList/comments.html) by filling in an on-line Publication Order Form. The order form requires the EPA document number. Publication requests can also be made by mail, fax, or phone (see NCEPI address below). EPA Region 10, Seattle, maintains a toll-free number (800-424-4372) for requesting documents that are available at the Seattle office. Most documents are available to the public at no cost.

NCEPI (National Center for Environmental Publications and Information)
11029 Kenwood Road, Building 5
Cincinnati, OH 45242
(800) 490-9198
Fax: (513) 489-8695

Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls, EPA 841-B-96-004 (EPA 1997) provides detailed guidance on developing nonpoint-source monitoring plans, biological monitoring, data analysis, quality assurance, and reporting. This publication replaces several other documents that were previously available from EPA, and is therefore a valuable desktop reference.

Environmental Indicators of Water Quality in the United States – Fact Sheet, EPA 841-F-96-001. (EPA 1996) describes in detail the set of core water environmental indicators used by EPA to track water quality progress. The document is useful as a more detailed introduction to understanding the indicators used in this assessment manual. It is also available on line at http://www.epa.gov/OW/indic.

Volunteer Stream Monitoring: A Methods Manual, EPA-841-B-97-003, EPA (1997) provides step-by-step methods for use by volunteer programs for monitoring biological health, water quality conditions, and habitat in wadeable streams. The document includes a chapter on watershed surveys. Similar manuals are available on volunteer monitoring for lakes and estuaries. See the Publications Order Form Internet address listed above.

BASINS (Better Assessment Science Integrating Point And Nonpoint Sources) (EPA 1998) is a software package that evaluates water quality at a watershed level using national databases, water quality and point-source loading, GIS data layers, and water quality models. BASINS uses GIS ArcView to integrate spatial information on the watershed with water quality data. This is a tool for the advanced watershed assessment with emphasis on pollutant load evaluation. BASINS is available for downloading at http://www.epa.gov/OST/BASINS.

Ecological Restoration: A Tool to Manage Stream Quality, EPA 841-F-95-007 (EPA 1996) provides a good explanation of the relationship between restoration techniques and water quality parameters– altered stream geomorphology, sedimentation, flow alteration, nuisance algal growth, dissolved oxygen, pH, and toxic elements. It includes a chapter on cost-effectiveness and case studies.

Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen (Carpenter et al. 1997) provides the scientific foundation for the nontechnical reader on phosphorus and nitrogen input, output, and transport processes in a watershed. This is one of a series of papers in the EPA Watershed Academy, an on-line information series, that provide basic technical information useful to watershed councils. You can download the publication at http://www.epa.gov/OWOW/watershed/wacademy/acad2000.html or order from NCEPI.

US Geological Survey

The USGS is a primary source for water quality and quantity data collection and analysis techniques. Reports can be requested via the addresses listed below. Current prices can be obtained when contacting Information Services.

US Geological Survey
Branch of Information Services
Box 25286, Federal Center
Denver, CO 80225
(303) 202-4700
Fax: (303) 202-4693
http://wwworegon.wr.usgs.gov/pubs_dir/twri-list.html

The following three manuals are examples of the technical documents that are in the *Techniques of Water-Resources Investigation Series*. The manuals describe detailed procedures for collecting and analyzing data from surface- and groundwater for the advanced technical user.

- Wilde, F.D., and D.B. Radtke. 1998. Field Measurements. TWRI Book 9, Chapter A6.
- Myers, D.N., and F.D. Wilde. 1997. Biological Indicators. TWRI Book 9, Chapter A7.
- Britton, L. J., and P.E. Greeson. 1989. Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. TWRI Book 5, Chapter A4.

The USGS operates two national water quality networks. The Hydrologic Benchmark Network collects data on small, minimally disturbed watersheds, and provides information on water quality and quantity under natural conditions. The National Stream Quality Accounting Network tracks trends in water quality in larger watersheds. Nearby stations can be useful in understanding reference or benchmark conditions at the river basin scale. Refer to *Data From Selected USGS National Stream Water-Quality Monitoring Networks*; information available at http://wwwvares.er.usgs.gov/wqn96cd/

The Oregon Plan

This water quality analysis evaluates water quality based on existing data and reports. One of the potential outcomes of the analysis is that information is lacking on an important water quality issue. Watershed councils will likely wish to initiate a monitoring program to fill data gaps identified during the assessment.

Fortunately, a state interagency group has developed a guidebook (*Water Quality Monitoring Guide Book, Oregon Plan for Salmon and Watersheds* [Water Quality Monitoring Team 1998]) that will assist watershed councils in developing a monitoring program for water quality. The council should obtain a copy of the document and contact one of the mentors listed in the document for assistance in developing a monitoring plan. Also, refer to the Monitoring Plan component of this document for general guidance on developing a monitoring program.

REFERENCES

Boyd, M. and D. Sturdevant. 1998. The Scientific Basis for Oregon's Stream Temperature Standard: Common Questions and Straight Answers. Oregon Department of Environmental Quality, Water Quality Bureau, Portland.

Dissmeyer, G.E. 1994. Evaluating the Effectiveness of Forest Best Management Practices in Meeting Water Quality Goals or Standards. Misc. Publication 152. USDA Forest Service, Atlanta, Georgia.

EPA (US Environmental Protection Agency). 1997. Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls. US EPA, Nonpoint Source Control Branch, EPA/841-B-96-004. Washington, D.C. EPA. [Comprehensive technical guide for monitoring plans, data analysis, and quality assurance.]

Helsel, D.R., and R.M. Hirsh 1995. Statistical Methods in Water Resources. Studies in Environmental Science 49, Elsevier Science Publishing, New York. [Applied statistical methods for professional hydrologists.]

Hansen, R.N., H.M. Babcock, and E.H. Clark. 1988. Controlling Nonpoint Source Pollution: A Citizen's Handbook. Conservation Foundation, Washington, DC. [An overview of nonpoint source pollution, assessment, and management for the citizen.]

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluating Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, EPA 910/9-91-001, Region 10, Seattle, Washington.

GLOSSARY

beneficial uses: Uses of water specified in Oregon Water Quality Standards.

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, **channel pattern**, and **confinement**. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

criteria: Elements of Oregon Water Quality Standards expressed as concentrations or narrative statements representing a quality of water that supports a particular use.

dissolved oxygen: Oxygen present in water. Dissolved oxygen is absorbed by fish and other aquatic organisms through gills and membranes.

E. coli: The *Escherichia coli* bacterium is an indicator of human or animal feces.

evaluation indicator: A numerical value used to judge water quality impairment. The numerical value is based on the literature and is not a water quality standard.

exceedance: When a measure of water quality exceeds the criteria. The exceedance needs to be evaluated with respect to natural or human causes.

fecal coliform: Bacteria group used as an indicator of human or animal feces.

fry: The early life stage of salmon and trout after the yolk sac is absorbed.

hardness: A measure of the calcium and magnesium concentrations in water; used to select the appropriate criteria for heavy metals.

impairment: An interpretation of criteria exceedance which indicates that the beneficial use is harmed.

juvenile: The early life stage of salmon and trout, usually the first and second years.

nonpoint source: Sources of pollution from diffuse sources such as storm runoff from farming, logging, and roads.

NTU: nephelometric turbidity unit. A unit of turbidity measurement that is defined by its relationship to an original measurement method. Synonymous with JTU and FTU.

pH: A measure of the relative acidity or alkalinity of water.

salmonid: Fish of the family *Salmonidae*, including salmon, trout, char, whitefish, ciscoes, and grayling. Generally, the term refers mostly to salmon, trout, and char.

screening-level assessment: An initial evaluation of information using simplified methods.

stream reach: A section of stream possessing similar physical features such as gradient and confinement; usually the length of stream between two tributaries.

stream segment: Contiguous stream reaches that possess similar stream gradient and confinement, and which can be used for analysis.

surrogate measure: An indirect measure of a pollutant; for example, the use of turbidity to measure suspended sediment.

suspended sediment: Fine soil particles (e.g., silts and clays) that do not readily settle out. Compare to “fine sediment” – which is sand-sized particles that readily settle to the bottom of a stream and fill in the substrate.

Total Maximum Daily Load (TMDL) plan: A TMDL is a plan for pollutant reduction required under the authority of Section 303(d) of the Clean Water Act for waters designated as water quality limited. See the Start-Up component for further information.

total nitrate: A measurement form of nitrogen in surface- and groundwater that is composed of nitrate and nitrite.

total phosphorus: A commonly used measurement of phosphorus that includes most forms of phosphorus which are biologically available (or can be readily converted to available forms) to algae and aquatic plants.

turbidity: An optical measure of the murkiness of water. An indirect measure of the affect of suspended sediment in water.

mg/l: Milligrams per liter. Unit of chemical concentration that is essentially equivalent to parts per million (ppm).

µg/l: Micrograms per liter. Unit of chemical concentration that is essentially equivalent to parts per billion (ppb).

water quality station: A designated location on a stream at which water samples are collected

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Appendix VIII-A
Watershed Characterization of Temperature—Umpqua Basin

Appendix VIII-B
Data Assessment

DATA ASSESSMENT

1. List the data by collection date.

2. Rank the data from the lowest to the highest number.

3. Calculate summary statistics and compare to water quality criteria.

4. Compare stations where appropriate and interpret results.

Example: Total Phosphorus (µg/l)
Situation: This data is based on a real example that illustrates the value of comparing stations. An allotment is grazed by cattle in a section of an industrial private forest. Grazing is season-long within the allotment, but is restricted in an adjacent subwatershed. Data from Stream A within the grazing allotment is compared to Stream B, where forestry is the predominant land use.

1. *Data are listed by collection date.*

Date	Stream A	Stream B
Mar 10	24	45
Apr 11	37	51
Apr 24	30	47
May 08	34	51
May 24	23	32
Jun 08	24	43
Jul 05	30	76
Aug 01	32	74
Sep 12	37	78
Oct 10	31	52

2. *Data are ranked in order form lowest to highest.*

Stream A	Stream B
23	32
24	43
24	45
30	47
30	51
31	51
32	52
34	74
37	76
37	78

3. *Calculate summary statistics and compare to water quality criteria.*

Number: The count of data points.

Minimum: The lowest data point in the list.

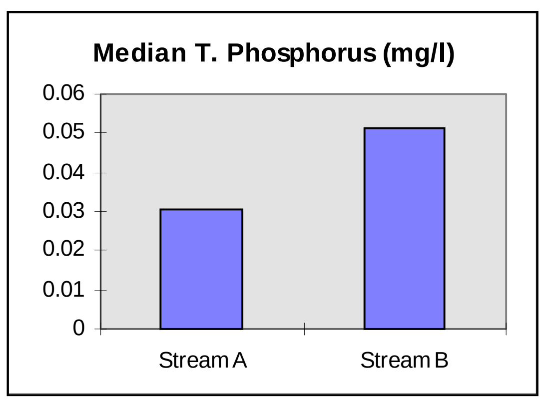
Maximum: The highest data point in the list.

Median: The middle number in the ranked list. In this example, the median for Stream A is between the 5th and 6th number in the list - between 30 and 31 - the median is therefore 30.5.

The evaluation criteria for total phosphorus is 0.05 mg/l or 50 µg/l. The number of data points that exceed 50 µg/l are counted and the percent of exceedance is calculated. E,g., six values exceeded 50 in Stream B; therefore, the percent exceedance is equal to 6 out of 10, or 60 percent.

Statistic	Stream A	Stream B
Number	10	10
Min	23	32
Max	37	78
Median	30.5	51
Number (> 50)	0	6
% exceedance	0	60

A bar chart of the median values provides a visual illustration of the results.



Appendix VIII-C
Blank Forms

Form WQ-1: Beneficial Uses and Water Quality Issues

Watershed:____

Analyst's Name:____

Beneficial Uses in Watershed:______________________________________

Beneficial Uses	Check Uses that Apply
Aesthetic quality	
Fishing	
Domestic water supply	
Resident fish and aquatic Life	
Salmonid fish rearing	
Salmonid fish spawning	
Water contact recreation	
Other (list)	
Other (list)	

303(d) Stream Segment: (Y / N) _____

Parameters	303(d) List	Details from 303(d) List
Temperature		(e.g., summer)
Dissolved oxygen		(e.g., salmonid spawning)
pH		
Nutrients		(e.g., phosphorus summer)
Bacteria		
Toxics		(e.g., tissue pesticides)
Turbidity/suspended sediment		
Habitat modification		Refer to Fish and Fish Habitat component
Flow modification		Refer to Hydrology and Water Use component

Form WQ-2: Summary of Percent Exceedance Criteria

Subwatershed:____

Analyst's Name:____

Percent Exceedance of Water Quality Evaluation Criteria:

Monitoring Site	Temp.	Dissolved Oxygen	pH	Nutrients	Bacteria	Turbidity	Toxics
(Example) Hill Creek #1	no data	0 %	0 %	60%	50%	no data	no data

Form WQ-3: Summary of Water Quality Impairment

Subwatershed:____

Analyst:____

Analyst's rating of confidence in water quality assessment (from Form WQ-4)__________

____

____

____

Fill in the columns as None, Moderately Impaired, Impaired, or Unknown.

Monitoring Site	Temp.	Dissolved Oxygen	pH	Nutrients	Bacteria	Turbidity	Summary of Miles Impaired*
(Example) Hill Creek #1 4.5 miles	Unknown	None	None	Impaired	Mod. Impaired	Unknown	Impaired 4.5 miles

* Summary of Miles Impaired: If any box is rated as Moderately Impaired or Impaired, the Summary is rated as Impaired. Miles in columns are not additive.

Form WQ-4: Confidence Evaluation

Watershed:____

Analyst's Name:____

Analyst's Experience / Expertise____

____

____

Note: Where the availability or quality of information varies by subwatershed, fill out a separate form for each subwatershed.

Use the following table to summarize your confidence in the conclusions about water quality conditions.

Category	Potential issue?[1] (Yes, No, Unsure)	Information sufficient?[2] (Yes, No, Unsure)	Confidence in conclusions?[3] (High, Moderate, Low)
Temperature			
Dissolved Oxygen			
pH			
Nutrients			
Bacteria			
Toxics – Organic			
Toxics – Metals			
Turbidity			
Overall Evaluation			

1 Potential issue? Answer this question based on the Start-Up and Identification of Watershed Issues component.

2 Information sufficient? Evaluate data or conclusions of reports by considering the following questions.

- a) How old, or how applicable, is the information to the current watershed condition?
- b) Have watershed conditions changed in a significant way since the data was collected?
- c) Was the data coverage (over time and geographic extent) sufficient to assess conditions?
- d) Is the information based on observations or on more rigorous studies (primarily measurement)?

3 Confidence in conclusions? This conclusion is based on the analyst's opinion regarding the sufficiency of the information and the analyst's confidence in completing the evaluation.

Recommendations for additional water quality monitoring: