TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE STATE OF COLORADO NATURAL RESOURCES CONSERVATION SERVICE

Water Quality Technical Note No. 7 **January, 2012**

To: All Colorado Area, Field and SCD Offices

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Water Quality Indicator Tools

Purpose and Scope

This technical note provides information on water quality indicator tools that are available for use by Natural Resources Conservation Service (NRCS) field office and partner personnel. These tools are designed to be used in conjunction with the Field Office Technical Guide (FOTG), Section II, Quality Criteria. These tools can be used to indicate and document whether a Conservation Management System (CMS) meet the water quality criteria at the Resource management System (RMS) level per the national Planning Procedures Handbook (NPPH, Amendment 4, March, 2003). A CMS combines individual conservation practices into a system that, when installed, prevents degradation of water quality and permits sustained use of available natural resources.

Indicators provide a measure for or describe a current, past, or future resource condition. Indicators only estimate resource conditions, so their use must be combined with professional judgment and common sense. The tools presented also provide a general background on the pollutant processes for different water quality parameters. The intent of this information is to educate and remind conservation planners of the resource concerns related to water quality.

Policies and Regulations

Clean water is essential to sustain life. Given the importance of water quality, the large quantity of policies and regulations in place are not surprising. Federal legislation addressing water quality dates back to the Rivers and harbors Act of 1899, which prohibited disposal of waste materials on the banks of waterways. The Federal Water pollution Control Act amendments of 1972, known as the Clean Water Act (CWA), set an interim goal commonly referred to as “fishable/swimmable” waters. The specific CWA objective is restore and maintain the chemical, physical, and biological integrity of the Nation’s waters. Most current water quality policies and regulations emanate from the CWA. Appendix A contains a table summarizing most of the pertinent Agency policy, as well as Federal and State regulations.

NRCS policy (GM 460-401) is simply “to promote the improvement, protection, restoration, and maintenance of surface and ground water for beneficial uses.”

To accomplish this, NRCS will:

- Provide assistance toward the prevention and correction of water quality problems;

- Ensure activities are in accordance with State defined water quality standards, Total Maximum Daily Loads (TMDL), uses, and priorities;
- Coordinate activities with federal, state, and local agencies and entities to protect water quality and to promote technology development and transfer;
- Create a public understanding of water quality concerns;
- Support data collection, technology development, and research needed to assess water quality resource concerns and the effectiveness of Best Management Practices (BMP); and
- Train Agency personnel in water quality concepts.

FOTG, Section III, Quality Criteria for all water quality resource concerns can be summarized into "meeting state water quality standards."

Principles of Water Quality

Water quality is defined by the capability of the water to support one or more designated beneficial uses. Beneficial uses include domestic water supply, livestock watering, irrigation, aquatic life, water contact recreation, navigation, aesthetics, in-stream flows, and other uses. A water quality problem exists when the beneficial or intended use of that waterbody is impaired. Water quality is usually measured using physical, chemical, or biological parameters. Some common parameters include bacteria, dissolved oxygen (DO), nutrients, pH, sedimentation, conductivity, turbidity, temperature, and concentration of toxic materials. Water quality can also be measured in terms of riparian/aquatic habitat condition, or from macroinvertabrate, fish, larval, or algal populations. Water quantity is linked to water quality, and often plays an important role by influencing a receiving waterbody's assimilative capacity and ability to support aquatic life.

When working with a water quality problem potentially resulting from agricultural activities:

(a) The pollutant or stressor causing the problem must be identified,
(b) The cause and effect relationship between the pollutant or stressor and the water quality effect must be determined,
(c) The source and pathway of the pollutant must be described, and
(d) Appropriate control practices must be selected and applied.

A stressor is any condition caused by management activities. For example, a reduction of streamside shading can result in elevated water temperatures that adversely affect aquatic habitat communities.

The pollution process is comprised of three components: availability, detachment, and transport. Availability is the presence and amount of a contaminant available to the system. Detachment is the process by which the material is mobilized in the environment. Transport is the pathway by which the pollutant leaves an agricultural area and is carried to a receiving waterbody. Control of most pollutants can be assessed in terms of the capacity to impact one or more of these processes. For example, Integrated Pest Management (IPM) limits the amount of chemical pesticides used or serves to reduce the availability of the potential contaminant. Erosion control practices assist in controlling detachment of soil particles and subsequent sedimentation. Filter strips or buffers intercept the transport of sediments to a receiving waterbody.

Some water quality concerns like stream temperature, riparian habitat, and stream flow cause direct impacts to the stream. An understanding of basic riparian habitat management, hydrology, and geomorphological principles is necessary to determine appropriate solutions to these types of non-chemical water quality problems.

FOTG Planning Criteria

Planning criteria are quantitative or qualitative statements of a treatment level required to achieve a CMS for identified resource considerations for a particular land area. They are established in accordance with local, state, and federal programs and regulations in consideration of ecological, social, and economic effects. NRCS planning procedures suggest quality criteria be expressed using a target and an indicator. The term target value is used to express a desired future condition of a resource as measured by an indicator. Another way to looking at indicators is to think of a yardstick as the indicator and the target as a point on the yardstick. The following sections describe the FOTG Section III water quality resource concerns along with tools that can be used to evaluate water quality criteria. Included are descriptions for pesticides, nutrients, animal wastes, salinity, selenium, heavy metals, petroleum products, sediment and turbidity, dissolved oxygen, aquatic suitability, and temperature. NRCS and others have previously developed many of the referenced tools. Links to some of these tools are included in Appendix B. Useful websites relating to water quality are included in Appendix C.

These tools only provide estimates of resource conditions. They should always be used with professional judgment and common sense to deduce the status of water quality concerns. A deductive approach, aided by predictive tools, can be used to determine the appropriate treatment level for a particular water quality concern. Predictive tools alone cannot capture the variance in water quality concerns impacted by non-point sources. Cumulative impacts and individual characteristics of each waterbody limit the precision of predictive tools.

In areas with sensitive waterbodies and/or vulnerable aquifers, the planner should exercise additional care in the use and interpretation of tools to minimize risk to the environment and human health. Sensitive waters could include those listed as impaired (303(d) listed or included in the 305(b) report), harboring endangered or threatened species, sole source aquifers, or other waterbodies suffering from effects resulting from human impacts.

Suggested target levels to meet quality criteria are listed for indicator tools referenced in this technical note. The planner must still deduce if the suggested targets provide the appropriate level of water quality protection for site conditions being analyzed.

Pesticides

Pesticides, insecticides, herbicides, fungicides, miticides, nematicides, etc. are extensively used to control plant and animal pests and enhance agricultural productivity. Activities such as the storage, mixing, rinsing, and land application of these materials can potentially increase the risk of environmental pollution. Exposure to pesticides poses potential health risks to humans and the environment. Pesticides may harm the environment by eliminating or reducing desirable organisms and upsetting complicated ecosystem relationships. Toxic effects of pesticides are referred to as acute (immediate lethality or sublethal effects) or chronic (cumulative effects from long-term exposure).

Many physical, chemical, and biological parameters affect the potential environmental hazard for a given pesticide. Three pesticide properties are often used to describe the potential of a pesticide to contaminate water supplies: Solubility, Half-Life, and Adsorption. Solubility is a measure of a pesticide's ability to dissolve in water. Pesticides with a higher solubility have a greater potential to be lost in runoff or migrate into ground water. The persistence of a pesticide is measured as the time for one-half of the material to decompose (half-life). In some cases, the pesticide decomposition products may have a greater toxicity or half life than the parent compound. A pesticide's chemical properties, along with soil characteristics such as moisture, pH, organic matter, etc., determine the extent to which a pesticide is sorbed to soil particles. The sorption coefficient (K_{oc}) is a measure of the amount of material adsorbed by the soil. The higher the value for K_{oc}, the more tightly bound the material is to the soil particle. For example, dicamba salt has a low sorption coefficient (K_{oc} of 2) and benomyl has a high coefficient (K_{oc} of 1900). Consequently, dicamba salt is highly mobile compared to benomyl, which will be tightly bound to soil particles.

Availability of pesticides is best controlled through proper pest management that minimizes the use of specific pesticides through integrated pest management (IPM) techniques. IPM combines biological, cultural, and other alternatives to chemical control with the intent of limiting the use of pesticides. IPM includes activities such as:

- Scouting
- Forecasting pest outbreaks
- Introduction of beneficial insects
- Use of pest resistant crops, crop rotations, cultivation, and fertility management
- Alternating pesticide selection and application (timing, rate, and from)

Pesticide detachment and transport is governed by several factors:

- Pesticide properties (solubility, half-life, and adsorption)
- Soil characteristics (runoff, leaching, and erosion potential)
- Precipitation, temperature, and other climatic conditions

Evaluating and understanding these properties should assist the planner devise pest management alternatives that will help minimize potential negative impacts. Rate, form, method, and timing of a pesticide application all become important components. Supporting conservation practices that reduce erosion, runoff, and leaching reduce detachment of pesticides, while practices such as filter strips, buffers, sediment ponds, and grassed waterways can be used to interrupt the transport of pesticides.

Several tools exist that can be used to indicate whether pesticide use meets the FOTG Quality Criteria for field application to crops and pastureland, and for pesticide storage, handling, and disposal. The following table lists the tools, applicability to surface and groundwater concerns, RMS target level, and reference(s). The RMS target level simply indicates a low risk situation for a pesticide's use. A moderate or high risk rating does not necessarily mean a pesticide cannot be used, nor does a low or very low rating mean that indiscriminate application is appropriate. Observation of setting, climate, operator skill, and other factors combined with the planner's own professional judgment must be used to deduce if a particular pesticide represents a water quality hazard and what mitigating practices might be needed.

Nutrients, Organics, and Pathogens

Nutrients are defined as any organic or inorganic substances that promote plant or animal growth. Organics include animal wastes and other biosolids. Animal wastes can contribute nutrients, organic matter, and pathogens to receiving waters. Nitrogen and phosphorus are the two major nutrients from agriculture that can degrade water quality. When these nutrients are introduced into a stream, lake, or other receiving estuary at high rates, aquatic plant productivity may be increased dramatically by the process of eutrophication. Eutrophication has many negative side effects on aquatic ecosystems. Increased growth of algae and aquatic weeds can degrade water quality, reduce dissolved oxygen levels, cause wide pH fluctuations, and interfere with use of the water for fisheries, recreation, industry, agricultural, and domestic uses. Toxins produced by the explosive growth of some algae and dinoflagellates can pose serious health threats to humans, livestock, and wildlife. Elevated levels of nitrate (> 10 ppm nitrate nitrogen) in drinking water reduce the oxygen carrying capacity of blood, which is potentially dangerous to infants (blue baby syndrome). Organic matter includes a family of compounds containing carbon. Excessive concentration of organic matter in surface water results in an increase in turbidity and oxygen consumption. In ground water, organics have been found to cause foul odors and tastes. Pathogens associated with animal wastes can transmit diseases to humans and livestock.

Nitrogen is naturally present in soils, but additional nitrogen is often added to increase crop production. Nitrogen is taken up by the plants in the form of nitrate and ammonium ions. The nitrogen cycle is complex, and due to these complexities, it is difficult to account for all sources and sinks for nitrogen in the environment. Some typical processes that nitrogen undergoes are:

- Mineralization: Conversion of organic N to ammonium (NH_4^+)
- Nitrification: Conversion of ammonium (NH_4^+) to nitrate ($NO3^-$) through microbial processes
- Denitrification: Conversion of nitrate ($NO3^-$) to atmospheric nitrogen (N_2) or N_2O
- Volitization: Loss of ammonia (NH_3) to the atmosphere in a gaseous form
- Immobilization: Uptake of nitrogen by soil microbes
- Plant consumption: Uptake of NO_3^- and NH_4^+ by plants
- Leaching and Runoff: Translocation of negatively charged nitrate by surface runoff or deep percolation
- Erosion: Positively charged ammonium ions tend to bind to soil particles and translocate due to erosive forces

Commercial fertilizers applied in the form of nitrate and ammonium is readily available to plants but is also susceptible to loss through leaching, runoff, and erosion. Adding nitrification inhibitors to ammonium fertilizers slows down the microbial conversion rate to nitrate, which helps reduce loss to in surface runoff and leaching. Urea based fertilizers and animal wastes convert to ammonia, which is subject to volitization losses unless incorporated into the soil (converted to NH_4^+ and sorbed to soil particles). A portion of animal wastes contains more stable organic N that must slowly go through mineralization and nitrification before it is available for plant uptake. Consequently, not all of the N from animal wastes is converted to plant available forms the year that the waste is applied to the field. Ammonia, if delivered directly to water bodies, can be very toxic to fish and aquatic invertebrates and can deplete the water of dissolved oxygen. Gas losses from denitrification and volitization may contribute to greenhouse gas concerns and air quality problems.

Phosphorus (P) is one of the key essential elements for plant growth. Fertilization of crops comprises the largest proportion of P used in agriculture. Phosphorus plays several important roles in plant growth, the primary one being the storage and transfer of energy through the plant. Excess phosphorus in water bodies promotes eutrophication.

Only a small percentage of phosphorus in the environment is readily available for use by living organisms. Organophosphate ions ($H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}) or dissolved P are the forms that are readily soluble in water and available use by biological systems. The majority of inorganic phosphorus in the environment is sorbed to iron, aluminum, and manganese oxides or to clay particles. Organic phosphorus is mostly held in soil organic matter. The portion of phosphorus in the soil that is subject to change is referred to as the labile fraction. The equilibrium between the labile and dissolved P is dependent on the biological and chemical characteristics of the soil or water body. Phosphorus is very insoluble in both acidic and alkaline soils, and is most soluble in soils with a neutral pH (6.0 to 7.5). Most P is moved into runoff from agricultural fields by dissolution and erosion. Although generally considered a less important mechanism than surface runoff, P leaching followed by shallow lateral subsurface flow can contribute dissolved P to surface waters, especially if a high water table is present. Soils with large macropores would also facilitate dissolved P loss. This mechanism becomes more important in soils with large accumulations of P that saturate surface sorption capacity leading to downward and lateral movement of

P. Phosphorus applications (commercial fertilizers or animal wastes) beyond this threshold increase the opportunity for loss of dissolved P. Animal wastes have proportionally more phosphorus than nitrogen compared to plant requirements, resulting in the buildup of excess phosphorus if wastes are applied at agronomic rates for nitrogen.

Availability of nutrients is best controlled through proper nutrient management practices to prevent surface flow or water infiltrating into the soil from coming into contact with nutrients. Timely incorporation of manure, sludge, or fertilizers below the soil surface can reduce excess nutrients in runoff. If the nutrients cannot be incorporated, they should be spread on fields with close growing crops or crop residue to control runoff and erosion. Prevention of nutrient contamination of groundwater can also be accomplished by use of nutrient forms that are not easily detached such as low solubility or slow release fertilizers. Nutrient applications can be applied in split applications to be available in the amounts and in the timeframes that the crops need them. Supporting practices such as filter strips, buffers, sediment ponds, and grassed waterways can be used to interrupt the transport of nutrients. Cover crops can be used to utilize excess nutrients. Deep-rooted crops within a rotation can recycle nutrients that have moved below the rooting zone of more shallow-rooted crops.

Animal wastes are potential sources of approximately 150 diseases. Numerous factors influence the nature and amount of disease producing organisms that reach surface or groundwater. Some of these are climate, soil types, depth to water table, infiltration rates, topography, animal types, and presence of disease-causing organisms. When livestock wastes are applied on dry, sunny days, harmful bacteria die off quite rapidly. Manure applied on cool, rainy days to soils that are saturated can yield high concentrations of pathogens in runoff. Pathogens are carried with surface runoff and subsurface flows to receiving waters. For quality criteria purposes, it generally can be assumed that if animal manures are properly managed as nutrients that pathogens will also be controlled.

Salinity

The natural weathering process of soil and geologic materials produces salts. They are present in varying degrees in all soils, and in both surface and ground water. High salt concentrations are more likely to occur in semiarid regions and in regions where evapotranspiration rates exceed precipitation. The salt content of water is usually expressed as the Total Dissolved Solids (TDS) concentration in units of milligrams per liter (mg/l), or in units of conductivity with units of decisiemens/meter (dS/M).

Salt loading associated with agriculture occurs through deep percolation or when return flows (surface or subsurface) concentrate salts through evapotranspiration. Loading of salts can also occur with the application of animal or other organic wastes, fertilizers, and some pesticides.

Salinity can be problematic for crop and forage production if the salt concentration in the soil or in the applied irrigation water exceeds the tolerance threshold for the crops being grown. Salt accumulations break down the soil structure, reducing infiltration and increasing water stress on the crop, as well as having potentially toxic effects to the crops being grown. Elevated salt concentrations in streams and lakes can also harm freshwater flora and fauna. TDS concentrations of up to 2000 mg/l can be tolerated by humans. Livestock can tolerate somewhat higher levels. State standards for drinking water limit TDS to 500 mg/l, or approximately 0.7 dS/M. Salts can also cause excessive corrosion of equipment, and is especially problematic with some irrigation system hardware and materials.

Salts are composed of anions, typically chloride, nitrate, sulfate, carbonate, and bicarbonate, combined with cations, typically sodium, calcium, magnesium, and potassium, though many other chemical combinations are possible. Many salts are highly soluble in water and readily move with runoff or through leaching. Salinity control, again usually of greatest concern in semiarid and arid regions, can be achieved through proper irrigation water management, coupled with proper nutrient management. Salinity control is complicated due to the fact that excessive leaching fractions can create problems downstream or in the aquifer, but insufficient leaching can cause salt accumulations in the soil that affect crop health and productivity, and can damage soil structure.

Electrical conductivity (EC) can be used as an indication of salt concentration; however, the potential concentrations of other ions in solution must be considered. EC is measured in either dS/M or in terms of millimhos per centimeter, where mhos are the inverse of electrical resistance in ohms ($1/\Omega$) and are indicated by an inverted ohm symbol. Conductivity measurements are taken or normalized to a temperature of 25C. These measurements indicate how easily an electric current may be passed through water over a fixed distance. An approximate relationship between EC and TDS is that 650 ppm TDS $\approx$ 1.0 dS/M EC.

Electrical conductivity can be used as an indicator of excessive salinity or TDS. For drinking water, EC should be less than 0.7 dS/M. Taste can be used as a rough indicator in lieu of testing for TDS in drinking water. This should only be attempted if the water is from a known potable source. For most crops and freshwater aquatic plants, EC should be less than >3.0 dS/M to meet quality criteria. Salt tolerances for specific crops can be found at the National Salinity Lab website: http://www.ars.usda.gov/Services/docs.htm?docid=8908.

Heavy Metals

Heavy metals represent another category of pollutants. Heavy metals are present in the earth's crust, and some are needed in trace amounts in order to support life processes. Heavy metals can become concentrated in soils and water by agricultural and other activities to the extent that they become toxic to organisms. Some of the common heavy metal trace elements of concern include aluminum, boron, copper, lead, selenium, mercury, nickel, zinc, arsenic, chromium, cadmium, and molybdenum. Not all elements classified as heavy metals are metallic elements in the strict chemical sense, but can be generally treated as such. Boron and arsenic are chemically classified as metalloids, and selenium is chemically a nonmetal, with the environmental chemistry of these elements reflecting these differing classifications.

Heavy metals and trace elements can accumulate from atmospheric deposition or as a result of pesticide residues, industrial and municipal wastes, drainages from abandoned mine sites, and from leaching of metal-bearing soils and geologic formations.

Quality criteria can only be considered met if an approved plan and permit has been obtained from the state. NRCS will not take the lead in providing clients with technical assistance to develop a biosolids management plan. A RMS may include a biosolids-based nutrient management component has a Colorado Department of Public Health and Environment (CDPHE) approved plan.

All biosolids applications in Colorado fall under ***5 CCR 1002-64***, Biosolids Regulation No. 64. The text of this regulation can be found at:
http://www.cdphe.state.co.us/regulations/wqccregs/100264wqccbiosolidsreg.pdf

A CDPHE approved plan is required by state regulation for each land application. These management plans are designed to protect the public health and environment. The plan includes a description of the metal content of the sludge, application site characteristics, list of management practices, and land use. Additional limitations control application rates, maximum accumulations of metals on individual sites, and the timing and use on fields used for food crops and grazing animals.

Management plans address:

- Biosolid composition
- Site and soil condition
- Protection of ground and surface water
- Protection of wells
- Crop rotations and/or vegetation
- Biosolids application rates
- Timing of biosolids application
- Application methods
- Public notification
- Odor management
- Required monitoring

Suspended Sediments and Turbidity

Sediment is organic or inorganic material that is in suspension, in transport, or that has already been moved and deposited away from its point of origin. Sediment is considered a pollutant when it concentrates to the point to which it degrades habitat suitability for organisms, and/or increases turbidity that in turn reduces light penetration and the process of photosynthesis. Turbidity is an expression of the clarity of water. Turbidity in water results from suspended matter such as clay, silt, colloidal materials, organic matter, or other materials that are dissolved or suspended in surface water. Suspended sediment and turbidity are not interchangeable measurements; however, they are different measurements of similar processes and have similar effects on the environment. Besides interfering with aquatic life, sediment deposition in water bodies causes reduced water storage capacity, safety hazards for swimming and boating, increased costs for water treatment, and reduced aesthetics.

Sediment is the result of erosion, and suspended sediment is the primary cause of increased turbidity in agricultural streams. Chemicals, such as some pesticides, phosphorus, and ammonium are transported with sediment in an adsorbed state. As a result, sediment is a carrier of many other pollutants to surface waters. Over time, changes to the aquatic environment can cause chemicals to be released from the sediment and contribute to eutrophic or toxic conditions.

Availability of sediment from crop and pastureland is best controlled through erosion control practices. Once soil particles are detached, practices that reduce the velocity of water flows so that particles are deposited prior to reaching surface waters are preferred. Examples of practices commonly used to control sediment delivery include residue management, terraces, filter strips and buffers, grassed waterways, irrigation water management, sediment control basins, and tailwater recovery systems.

Other major sources of sediment associated with agriculture stem from the erosion of streambanks, ditches, and other drainages. Changes in stream flow, channel morphology, and vegetative cover represent some of the contributing factors to bank instability. Grade stabilization structures, waterways, buffers, permanent vegetative cover, proper grazing use, bio-engineering practices, etc. are a few of the conservation practices that might be considered to control streambank erosion and the resultant sediment.

Quality criteria for soil erosion including sheet & rill, wind, concentrated flow, classic gully streambank, irrigation induced, soil mass movement, roadbanks, construction sites, or scour areas should be met in order to control sediment delivery to water bodies.

Physical measurements of either suspended sediment or turbidity are possible and are relatively inexpensive to conduct. Sampling for use as quality criteria is somewhat problematic. Suspended sediments and turbidity vary over space and time. Readings are often highest during or following a storm event, increasing with discharge, but can vary due to local turbulence and velocity of the water column. Impacts observed in a given water body may result from upstream sources from the point being evaluated. Water quality standards for turbidity and suspended solids are usually measured as a percentage change from a baseline condition. The baseline conditions vary from waterbody to waterbody and site to site.

Typically, there is a strong relationship between turbidity and suspended sediment. Generally, about 80% of the variability in suspended sediment concentrations can be explained by simultaneous turbidity measurements. Turbidity is measured in either Jackson turbidity units (JTU) or nephelometric turbidity units (NTU). NTU can be measured by photoelectric turbidimeters that accurately record lower levels of turbidity and are generally not affected by particle color. Secci disks are often used to measure turbidity in lakes.

For these reasons, it is suggested the planner use professional judgment in conjunction with tools like the **Stream Visualization Assessment Protocol, Version 2** to determine if quality criteria are being met. It is assumed that the quality criteria for Soil Erosion must be met in order to meet criteria for sediment. Physical measurements using Secci disks and inexpensive pocket turbidimeters would, over time, add to an individual's professional judgment. The planned conservation management system must overcome the site and management limitations that create excessive sedimentation and turbidity with practices that control erosion, reduce surface runoff, and/or filter sediment.

The water quality criteria for sediment is assumed met by meeting the quality criteria for erosion. The **Stream Visualization Assessment Protocol, Version 2** or the **Water Quality Indicators Guide** provides additional visual descriptors to help indicate whether a given issue is sediment or turbidity related. Both waterbodies and farm fields should be evaluated. When no ditch, stream, lake, pond, or wetland lie in proximity to the fields being evaluated, the planner must use professional judgment to estimate the potential for turbid or sediment-laden runoff to reach surface waters.

Dissolved Oxygen

Dissolved Oxygen (DO) measures the amount of oxygen dissolved water. The amount of O_2 that can be dissolved in water is dependent on multiple factors, including water temperature, atmospheric pressure, and the surface area exposed to the atmosphere. The two primary sources of oxygen in waterbodies are atmospheric oxygen, and photosynthetic byproducts from aquatic plants. Oxygen sinks result from respiration and the biochemical O_2 demand of substances in the water. The holding capacity of O_2 is inversely proportional with water temperature. Increased temperature lowers the holding capacity of O_2 at saturation. Diurnal fluctuations in DO concentration result from photosynthesis in excess of respiration during the day, at night photosynthesis ceases, so respiration will act as an O_2 sink.
DO concentrations can also vary between the surface stream water and water flowing through alluvial material in the streambed. Oxygen replenishment to these intergravel waters comes primarily from the exchange of well-aerated surface waters with oxygen-impoverished intergravel waters. Low DO within the alluvial materials in the stream bed affects the survival of fish eggs and invertebrates. Clogging of gravel with fine sediment and organic matter is the primary concern affecting this exchange.

Dissolved oxygen is critical to the biological community and for the breakdown of organic matter. Maintaining DO concentrations at appropriate levels is essential for sustaining aquatic life populations. Varying the level of biological diversity in an aquatic community, such as fish, invertebrates, algae, and bacteria requires a different minimum level of DO for success.

Oxygen depletion in streams and lakes is usually associated with excessive temperature, heavy growth of aquatic plants, algal blooms, or high concentrations of organic matter and nutrients. Practices that control excess delivery of sediment, nutrients, and organics to surface waters, maintain or lower water temperature, and provide good reaeration and habitat are most effective in maintaining DO levels.

The quality criteria for nutrients, sediment and turbidity, and temperature should be used to indicate whether suitable dissolved oxygen levels exist for benchmark conditions and/or the planned conservation management system. Direct measurement of DO levels with inexpensive test kits and handheld probes may be used as an indicator if precautions are taken to account for seasonal and diurnal variability.

Aquatic Habitat and Temperature

Aquatic habitat is included as a water quality parameter because the suitability of an aquatic habitat to support aquatic life is an important parameter. Riparian habitat with sufficient shade and streams with an adequate width/depth ratio are the primary factors affecting water temperature. The primary source of heat energy delivered to the water column is solar energy striking the water column. When shaded, far less energy will be transferred to the water column. Shallow, wide streams provide more unit area for solar heating, and a greater opportunity to transfer heat to the stream bed as well as the water column. Hydro-geomorphic conditions that impact channel configuration and stream flow are other factors that impact the suitability of aquatic habitat and water temperatures.

Appendix A: Water Quality Policy, Rules, and Regulations Important to Agriculture

Policy, Rule, or Regulation	Reference	Summary
Federal – USDA NRCS		
USDA Nonpoint Source Water Quality Policy	Department Regulation 9500-7	Promote the improvement, protection, restoration, and maintenance of water quality to support beneficial uses
USDA Ground Water Quality Policy	Departmental Regulation 9500-8	Protect water users and the natural environment from exposure to harmful substances in ground water, enhance groundwater where appropriate
USDA NRCS Water Quality Policy	GM 460-401	Adhere to and support USDA Nonpoint Source Water Quality Policy by: Recognizing responsibilities of state and local governments Coordinating activities with conservation districts, private institutions, and other federal, state and local governments Emphasizing voluntary actions Supporting monitoring, research, and education
NRCS National Planning Policy	GM 180-409, GM 450-401, NPPH	The NRCS objective is the sound use and management of soil, water, air, plant, and animal resources. Social, cultural, and economic considerations are used to establish the level of natural resource protection obtainable and may constrain the resource

		criteria used in formulating a RMS. Where regional, state, or local regulations establish more restrictive criteria, these must be used.
Pest Management Policy	National Agronomy Manual, Subpart C; GM 190-404, Secretary's Memo No. 1929	Sets the policy, procedures, and role NRCS should follow in all pest management activities. This includes promoting the use of integrated pest management methods.
Nutrient Management Policy	National Agronomy Manual, Subpart B	Sets policy, procedures, and role for NRCS technical assistance involving nutrient management and the utilization of organic byproducts including animal wastes.
Farm Bill 1985, 1990, 1996, 2003, 2008	P.L. 6124, 1990 FACTA	The Secretary shall develop guidance materials describing a process to assist agricultural producers in preparing and implementing on farm agricultural water quality management plans necessary to assist in complying with state and federal environmental laws.
Other Federal		
Clean Water Act of 1972 (CWA),	33 U.S.C. §1251 et seq. (1972)	Objective is to restore and maintain the physical, chemical, and biological integrity of the Nation's waters.
CWA, Section 303(c)		Requires states to set, review, revise, and enforce water quality standards to protect beneficial uses of water.
CWA, Section 303(d)		Requires states to identify waters that do not meet water quality standards at defined intervals.
CWA, Section 305(b)		Requires states to implement a water quality status assessment at defined intervals.
CWA, Section 319		Requires states to develop a state water quality management plan to control nonpoint pollution of the waters of the state. In addition, this section provides grant funds to implement the nonpoint source management plan.
CWA, Section 320		National Estuary Program, focuses on both point and nonpoint pollution in geographically targeted, high priority estuarine waters.
CWA, Section 401		State water quality certification required where federal actions may result in a discharge to state waters.
CWA, Section 404		Gives the U.S. Army Corps of Engineers the responsibility for regulating the placement of fill or dredge materials in the waters of the United States (404 permit).
CWA, Section 502		Defines confined animal feeding operations

		(CAFO) as point sources subject to National Pollution Discharge Elimination System (NPDES) permits.
Coastal Zone Management Act of 1972	16 U.S.C. 1455b	Protects the unique waters of coastal areas. Required states to develop coastal zone management plans.
Safe Drinking Water Act of 1974 (SDWA)	42 U.S.C. s/s 300fd, amended in 1990, 1996, PL 104-170	Objective is to protect public water systems by setting drinking water standards, establishing wellhead protection programs, sole source aquifers, source assessments, providing grant funds, and establishing state revolving funds.
Food Quality Protection Act	7 U.S.C. 136	Provides for stronger, health based safety standards for pesticide residues in foods. Calls for EPA and USDA to work on promoting integrated pest management.
Federal Insecticide, Fungicide, and Rodenticide Act of 1972 (FIFRA)	7 U.S.C. s/s 135 et seq.	Directs federal control of pesticides through labeling and registration, sale and distribution, applicator certification, worker protection standards, and safe disposal
Resource Conservation and Recovery Act (RCRA)	42 U.S.C. 6901	Regulates disposal of hazardous wastes including pesticides, and the construction, maintenance, and monitoring of underground storage tanks.
Use of Biosolids	40 CFR, Parts 403 and 503	General pretreatment standards and regulations for the use and disposal of sewer sludge.
State of Colorado		
Colorado Primary Drinking Water Regulations	5 CCR 1003-1	
Colorado Chemigation Act	5 CCR 1002-64, Biosolids Regulation No. 64	

Appendix B: Water Quality Indicator Tools

Pesticides

Indicator Tools	Surface/Ground Water	RMS Target Level	Information
WinPST	Both	Low or Very Low	
Water Quality Indicators Guide – Field Sheet 4b	Ground	Ratings of Good to Excellent	Water Quality Indicators Guide, Terrence Institute, 1717 K Street NW, Suite 801, Washington, DC 20006

Nutrients, Organics, and Pathogens

Indicator Tools	Surface/Ground Water	RMS Target Level	Information
Nitrogen Index	Both	Low or Medium Rating	Colorado Agronomy Technical Note #97
Phosphorus Index	Surface	Low or Medium Rating	Colorado Agronomy Technical Note No. 95
Leaching Index – Soil Rating for Nitrate and Soluble Nutrients	Ground	LI < 2	
Water Quality Indicators Guide – Field Sheet 3B	Surface	Ratings of Good to Excellent	Water Quality Indicators Guide, Terrence Institute, 1717 K Street NW, Suite 801, Washington, DC 20006
Water Quality Indicators Guide – Field Sheet $2B_1$	Surface	Ratings of Good to Excellent	Water Quality Indicators Guide, Terrence Institute, 1717 K Street NW, Suite 801, Washington, DC 20006
Water Quality Indicators Guide – Field Sheet $2B_2$	Surface	Ratings of Good to Excellent	Water Quality Indicators Guide, Terrence Institute, 1717 K Street NW, Suite 801, Washington, DC 20006
Stream Visualization Assessment Protocol 2 (SVAP-2), Element 8, Nutrient Enrichment	Surface	Rating of 6 or higher	National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3)

Salinity

Application	Indicator	RMS Target Level	Information
Drinking Water	No saline taste or measured TDS	TDS less than 500 mg/l or 0.7 dS/M	
Irrigation and surface waters	Measured TDS	Less than 3.0 dS/M or below the crop threshold tolerance level	
Flood and furrow irrigated acres	Water Quality Indicators Guide – Field Sheets 5A and $5B_1$	Ratings of Good to Excellent	Water Quality Indicators Guide, Terrence Institute, 1717 K Street NW, Suite 801, Washington, DC 20006
Riparian corridors	Stream Visualization Assessment Protocol 2 (SVAP-2),Element 16 – Salinity Scoring Matrix	Score of 5 or higher	National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3)

Suspended Sediments and Turbidity

Indicator Tool	RMS Target Level	Information
Stream Visualization Assessment Protocol 2 (SVAP-2), Element 7, Nutrient Enrichment	Score of 8 or higher	National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3)
FOTG Planning Criteria for Erosion	Meets Quality Criteria	FOTG Section III

Dissolved Oxygen

Indicator Tool	RMS Target Level	Information
Stream Visualization Assessment Protocol 2 (SVAP-2), Element 9, Manure or Human Waste Presence	Score of 9 or higher	National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3)
Direct Measurement	Meets State water quality criteria	
FOTG Quality Criteria for Nutrients, Sediment and Turbidity, Aquatic Habitat, and Temperature	Meets Quality Criteria	FOTG Section III

Aquatic Habitat and Temperature

Indicator Tool	RMS Target Level	Information
Stream Visualization Assessment Protocol 2 (SVAP-2)	Overall score of 7.5 or higher	National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3), national Water and Climate Center Technical Note No. 12
Stream Visualization Assessment Protocol 2 (SVAP-2), Element 13, Aquatic Invertebrate Habitat	Score of 6 or higher	National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3)
Stream Visualization Assessment Protocol 2 (SVAP-2), Element 14, Aquatic Invertebrate Community	Score of 8 or higher	National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3)

Appendix C: Selected Useful Water Quality Websites

References for water quality policies, rules, and regulations are listed in the following tables. Most USDA/NRCS policies can be found in the General Manual or other official agency guidelines.

The following websites can be queried to locate federal and state rules, policies, and regulations:

Federal and International Websites:

Natural Resources Conservation Service
http://www.nrcs.usda.gov/wps/portal/nrcs/home

Water Quality Information Center
http://wqic.nal.usda.gov/nal_display/index.php?info_center=7&tax_level=1

Environmental Protection Agency
http://www.epa.gov

United States Geological Survey
http://water.usgs.gov/owq/

United States Fish and Wildlife Service
http://www.fws.gov/contaminants/Issues/WaterQuality.cfm

United States Forest Service
http://www.fs.fed.us/

Bureau of Reclamation
http://www.usbr.gov/

Bureau of Land Management – Colorado Water Law Summary
http://www.blm.gov/nstc/WaterLaws/colorado2.html

Government Printing Office Access
http://www.gpoaccess.gov/cfr/

World Health Organization
http://www.who.int/water_sanitation_health/dwq/en/

United Nations – Water for Life
http://www.un.org/waterforlifedecade/quality.shtml

Colorado River Salinity Control Forum
http://www.coloradoriversalinity.org/

State Websites:

Colorado Department of Public Health and Environment
http://www.cdphe.state.co.us/

Water Quality Control Division
http://www.cdphe.state.co.us/op/wqcc/

Colorado Division of Water Resources
http://water.state.co.us/Home/Pages/default.aspx

Colorado Nonpoint Source Alliance
http://npscolorado.com/

Colorado Water Quality Monitoring Council
http://www.coloradowaterquality.org/

References

"*Agricultural Chemicals Management*", NRCS, National Water and Climate Center, Oct. 1996.
"*Water Quality Field Guide*", USDA/SCS SCS-TP-160, March, 1998.
"*Water Quality Field Guide*", Terrene Institute, Washington D.C., January, 1996.
"*Managing Nitrogen for Groundwater Quality and Farm Profitability*", Soil Science Society of America, Inc., 1991.
"*A Procedure to Estimate the Response of Aquatic System Changes in Phosphorus and Nitrogen Inputs*", NRCS, National Water and Climate Center, January, 1998.
"*Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska*", Environmental Protection Agency, Water Division, EPA/910/9-91-001. May, 1991.
"*Irrigation Management Practices to Protect Ground Water and Surface Water*". Washington State University, April, 1995.
"*Animal Waste Management Handbook*", SCS, 210-AWMFH, April, 1992.
"*Stream Visualization Assessment Protocol 2*", National Biology Handbook, Subpart B, Part 614 (190-VI-NBH, Amend. 3), National Water and Climate Center Technical Note No. 12
Sullivan, Dan (1996) "*Managing Municipal Biosolids as a Resource*", Oregon State University
Waskom, R. and Kallenberger, J. (2009) "Graywater Reuse and Rainwater Harvesting" Colorado State University Extension Service Fact Sheet no 6.702. http://www.ext.colostate.edu/pubs/natres/06702.html
Kendall, P. (2010) "Drinking water quality and health" Colorado State University Extension Service Fact Sheet no 9.307. http://www.ext.colostate.edu/pubs/foodnut/09307.html