Water Quality Reuse Classification Tool   **Stacia McCoy**

The objective of the water quality reuse classification tool described in this document is to facilitate decision making regarding human water uses. Because not all water uses require the same level of quality, more efficient water use can be achieved by coupling processes that produce lower quality effluent to processes with minimum quality influent requirements. If effluent water can be used directly in another process, the result is significant treatment energy and cost savings. Moreover, even if minimal treatment is needed to make a process effluent usable in another sector, this coupling will decrease costs in comparison to full-scale wastewater treatment.

Water reuse is clearly beneficial, but a water quality classification tool is needed to help utilities, industries, and governments establish combinations that will yield more efficient water use. Such a water quality classification tool, shown in Table 1, has been designed. The water use categories have been arranged in order with applications requiring the highest water quality at the top and processes requiring the lowest quality water at the bottom. Using this table, utility managers, industrial operators, and government officials can determine whether a process effluent is acceptable as an influent for another water use. With this tool as a guide, decision makers can suggest pairings of sector processes and evaluate their feasibility for a specific region. This tool encourages the formation of relationships between sectors with a net benefit of increased efficiency of water use and decreased water treatment costs.

For any parties interested in water reuse, the first question to ask is: "Is the water clean?" This is a simple question with a simple answer. It depends. Unlike other environmental challenges, such as climate change, water quality is a regional issue and water quality can vary widely between different locations within the same region. Thus, to determine whether the water is clean enough, one needs to know its water quality and its intended use. Considering that only 3% of global water resources is freshwater and only 1% is easily accessible in surface water and ground water (Addams et al., 2009), freshwater is a finite resource that should be used sustainably. The 2030 Water Resources Group predicts, assuming no efficiency gains, that global water requirements will increase from 4,500 billion m^3 to 6,900 billion by 2030 resulting in a 40% deficit of accessible, reliable water supply (Addams et al., 2009). One approach for closing the water demand-supply gap is to increase water use productivity through reuse applications (Addams et al., 2009). Water reuse is possible because not all uses require the same level of quality. Certain uses, such as irrigation, manufacturing, and sanitation (i.e. sewage flow) do not require high quality water (Nobel and Allen, 2000). Then, what quality is acceptable for a particular use? In order to reuse water efficiently, it is necessary to establish minimum water quality requirements for a particular application. Several national and international organizations have attempted to map water quality characteristics to prescribed applications, but most attempts have resulted in guidelines as opposed to enforceable standards.

Most water reuse guideline development begins with broad classifications of water reuse, such as urban, industrial, agricultural, environmental and recreational, groundwater recharge, and augmentation of potable supplies (USEPA and USAID, 2004) as defined by U.S. government agencies. Other country's water classifications, such as surface water classifications for China, are broader and only include four quality levels: non-usable; agriculture and irrigation; low-grade, industrial usage, and qualified for potable usage (Addams et al., 2009). Some government agencies are more focused on water use categories with significant ecological or human health

risks, such as aquatic life, fish consumption, recreation, and water supply (PADEP, 2010). For the purposes of this study, we have considered a broad, but not comprehensive, list of water reuse applications, which include agricultural irrigation (non-processed food crops), agricultural irrigation (processed food and non-food crops), aquaculture, construction, environmental, livestock, industrial (once-through cooling), industrial (re-circulating cooling), direct potable, indirect potable, recreational (boating and fishing), recreational (swimming), and urban residential. Although in particular cases ecological health is considered, the primary concern driving the minimum influent water quality requirements for different water reuses is human health risk.

After identifying water reuse applications, it is necessary to identify criteria for defining water quality limits. Just as different countries focused on different water uses, different international agencies have used different methodological approaches to develop water reuse guidelines. For example, the USEPA water reuse guidelines are based on an inventory of state water reuse standards, primarily water quality requirements, treatment processes or both, and recommended for use by states that have not yet drafted regulations (USEPA and USAID, 2004). The United Kingdom Technical Advisory Group on the Water Framework Directive (UKTAG) developed water quality standards based on statistical associations between chemical parameters, such as dissolved oxygen, pH, and phosphorus, and surface water ecological status classifications of High, Good, Moderate, Poor, and Bad (UKTAG, 2008). With a target status of Good, water quality conditions associated with High/Good status were identified and standards set to protect most sensitive biological organism. Finally, the Australian government used a risk-management framework as opposed to post-treatment water quality testing to develop water reuse guidelines. Using a risk-based approach, three Australian government agencies: 1) identified human or environmental health hazards; 2) estimated hazard risk based on likelihood and consequences; 3) identified preventative measures to control risk; 4) established monitoring to check efficacy of preventative measures; and 5) instituted verification procedures to maintain steady water quality (NRMMC et al., 2006). All three approaches yield water quality parameter requirements. After considering the different methods and reviewing the recommended water quality limits in the United States, United Kingdom, and Australia, the most relevant water quality parameters with respect to the water reuse applications and their water quality classifications, Good, Moderate, and Poor, shown in Tables 1 and 2, were selected.

For this study, water quality parameters were considered individually as compared to an aggregated measure, such as a water quality index, because the importance or weighting of the parameters will vary depending on the intended water reuse. A notable expert elicitation yielded a water quality index that included the following parameters (ordered by largest weighting factor): dissolved oxygen (DO), fecal coliform, pH, BOD_5 (5-day biochemical oxygen demand), temperature, total phosphate, nitrates, turbidity, and total solids (TS), for assessing overall stream quality (Brown et al., 1970). The survey participants, which included regulatory officials, public utility managers, consulting engineers, and academics, concluded that the resulting index was good for general water quality, but many respondents expressed concerns about an overall water quality evaluation in comparison to classifying water for a particular use (Brown et al., 1970). Another study also used a weighted combination of parameters to specify an objective water quality index and extended its influence by assigning values to water uses. The index scale ranged from 0, representing worst possible water quality, to 10, representing the best possible water quality, with the categories of potable, swimmable, fishable, and boatable assigned to index values (Vaughan, 1986). Potable use required water quality greater than 9.5, safe for

swimming greater than 7, safe for fishing greater than 5, and safe for boating greater than 2.5 (Vaughan, 1986). This study succeeded in mapping an overall water quality index to specific uses, but it lacked the flexibility in parameter values needed to efficiently use reclaimed water resources. The five water quality parameters: fecal coliforms, dissolved oxygen, BOD_5, turbidity, and pH, included in this index can only be ranked from good to poor quality corresponding to potable to boatable water compared to individual consideration of parameters based on relevance to particularly water reuse.

A qualitative characterization of the minimum influent requirements of selected water quality parameters for selected potential water reuses has been developed and is shown in Table 1. As stated previously, the water reuse applications include agricultural irrigation (non-processed food crops), agricultural irrigation (processed food and non-food crops), aquaculture, construction, environmental, livestock, industrial (once-through cooling), industrial (re-circulating cooling), direct potable, indirect potable, recreational (boating and fishing), recreational (swimming), and urban residential. This list is not exhaustive, but it serves as a good starting point based on water reuse guidelines developed by international environmental organizations (NRMMC et al., 2006; UKTAG, 2008; USEPA and USAID, 2004).

The list of water quality parameters is also not comprehensive, but includes the following: fecal coliforms, DO, BOD_5, total dissolved solids (TDS), total suspended solids (TSS), turbidity, pH, temperature, chlorine residual, nitrate, and phosphate, which are important for the water reuses being considered. Reading across a particular row in Table 1 gives the minimum influent requirements for a specific reuse. The qualitative rating scale dictates that the parameter needs to be at a Good, Moderate, or Poor level of relative quality. Naturally, the relative level of quality depends on the parameter being considered. For example, fecal coliforms are an indicator of fecal contamination; thus, a low concentration of fecal coliforms is qualified as "Good" from a human health risk perspective. Consequently, Good quality water with respect to fecal coliforms is necessary for direct potable, aquaculture, and urban residential where there is consumption or direct contact, which increases the health risk for individuals or animals exposed to contaminated waters. In contrast, dissolved oxygen is a measure of the percentage of oxygen saturation at a specific temperature and pressure, so a Good quality level equates to high dissolved oxygen percentage because more oxygen translates to greater organism diversity and increased ecosystem health. For each reuse application, the water quality parameters were classified as Good, Moderate, or Poor, based on literature and recommended guidelines from USEPA, World Health Organization (WHO), Natural Resource Management Ministerial Council (NRMMC), Environment Protection and Heritage Council (EPHC), and Australian Health Ministers Conference (AHMC) (NRMMC et al., 2006; UKTAG, 2008; USEPA and USAID, 2004; WHO, 1989).

Based on suggested upper limits of 200 and 1000 fecal coliforms per 100 ml for limited exposure uses (USEPA 2004, WHO 1989), such as restricted irrigation, industrial, and environmental reuse, Moderate quality for fecal coliforms was defined as 100 – 1000 CFU/ml. Given the no detectable fecal coliform limits advised for direct contact or consumptive activities (USEPA 2004), such as urban residential, non-processed crop irrigation, and indirect potable reuse, Good quality was defined as 0 – 100 CFU/ml. Consequently, Poor quality includes waters with fecal coliforms concentrations greater than 1000 CFU/ml.

As previously discussed, dissolved oxygen is important for ecological health; thus, greater dissolved oxygen yields higher quality water with respect to this parameter. Dissolved oxygen concentration varies with temperature and pressure, so it is more appropriate to set value

ranges with respect to saturation percentage. Because high dissolved oxygen supports a healthy, diverse ecosystem, greater than 75% oxygen saturation is Good quality, 50-75% is Moderate quality, and less than 50% is Poor quality (UKTAG, 2008). At low oxygen levels, sensitive organisms cannot survive and the freshwater system can become imbalanced as algae and anaerobic organisms take over (Mitchell et al. 2000).

Biochemical oxygen demand is the amount of oxygen consumed by microorganisms during aerobic oxidation of organic materials. Specifically, the BOD_5 refers to the oxygen used by microorganisms over 5 days. Industrial discharge, agricultural runoff, and wastewater treatment plant effluent can contribute to high organic matter concentrations in the water resulting in high BOD_5 values. High BOD_5 is not ideal in freshwater environments because it indicates a high organic pollutant load as well as high aerobic microbial activity, which may deplete oxygen necessary to sustain a healthy, diverse ecosystem (Mitchell et al. 2000).

Total dissolved solids (TDS) is a measure of dissolved solid particles, including calcium, bicarbonate, chloride, nitrogen, and phosphorus, that cannot be filtered from the water. Similarly, total suspended solids (TSS) is a measure of solid particles, including plant material, soil, and sewage, that can be separated from the water by filtration. Turbidity is a measure of clarity or how well light can be transmitted through the water column. Turbidity increases as the suspended solids concentration increases giving the water a cloudy appearance. Turbidity and TSS are directly related, such that an increase in total suspended solids yields an increase in turbidity. For most direct contact or consumptive water uses, low TSS or turbidity is considered Good quality because it suggests there is a lower concentration of contaminated materials (Mitchell et al. 2000) and it is practically important for applications that require piping or spraying. The TSS Good, Moderate, and Poor quality levels are defined as $0 - 5$, $5 - 30$, and greater than 30 mg/L. Similarly, the turbidity quality levels are $0 - 10$, $10 - 100$, and greater than 100 NTU. Although some concentration of dissolved elements and ions is necessary to sustain life, low TDS (or conductivity) is considered increased quality water with respect to this parameter. The TDS Good, Moderate, and Poor quality levels are less than 100, $100 - 500$, and greater than 500 mg/L, respectively.

pH is a measure of the acidity or alkalinity of a solution. Most organisms can survive within a fairly narrow range of pH $6 - 9$ (slightly acidic to slightly alkaline). Water reuses that involve direct exposure to animals or plants, such as aquaculture or agricultural irrigation, require pH values fairly close to neutral in order to prevent deleterious effects on ecosystem health. The Good, Moderate, and Poor classifications for pH are $6.5 - 8.5$, $5.0 - 6.5$, and $2.0 - 5.0/8.5 - 12.0$, respectively. Temperature also has an effect on aquatic life, thus, similar to pH, water uses with direct impacts on freshwater ecosystems, such as aquaculture or recreational impoundments, require limited temperature ranges. Many aquatic species, such as freshwater fish, need specific conditions for healthy growth and reproduction, but these temperature ranges vary depending on the species. For example, the maximum weekly average temperature for growth of sockeye salmon and largemouth bass is 18°C and 32°C, respectively, representing a wide spread of ideal temperatures (Brungs et al. 1977). The Good quality range for temperature was selected to represent the ideal conditions for the majority of fish species, but it is important to investigate the requirements of ecosystem organisms influenced by reclaimed water.

Chlorine is commonly used to disinfect water and wastewater, but it can have detrimental effects on organisms if concentrations are too high. In addition to its strong oxidant properties, chlorine can react with natural organic matter to form carcinogenic disinfection byproducts (DBPs). On the contrary, it is an effective disinfectant that inactivates pathogens protecting

consumers from waterborne disease. Clearly, there is a tradeoff between a low and a high chlorine concentration. For reuse applications, it is assumed that Good quality is less than 1.0 mg/L free chlorine, which is sufficient for human health protection and produces minimal DBP concentrations. Moderate and Poor quality is defined as 1.0 – 2.0 and greater than 2.0 mg/L free chlorine, respectively.

The final parameters, nitrate and phosphate, are primarily a concern for reclaimed water applications that directly affect aquatic organisms, such as recreational fishing or stream augmentation. The two main sources of nitrate are agricultural runoff containing fertilizers and inadvertent sewage effluent. Nitrate is necessary for plant growth; thus, high concentrations can lead to uncontrolled algal growth, consumption of dissolved oxygen, and loss of organism diversity (Mitchell et al. 2000). To maintain sufficient dissolved oxygen concentrations that will promote ecosystem health and diversity, Good nitrate quality corresponds to less than 1.0 mg/L concentration. Moderate or Poor quality corresponds to 1.0 – 5.0 or greater than 5.0 mg/L of nitrate. Phosphate is also a plant growth nutrient. Excess phosphate, found in sewage, fertilizers, or industrial wastes, entering water bodies can cause eutrophication and, consequently, loss of species diversity due to depleted oxygen reserves (Mitchell et al. 2000). Similar to nitrate, the Good, Moderate, and Poor quality levels are defined as less than 1.0, 1.0 – 5.0, and greater than 5.0 mg/L phosphate.

The water reuse applications have been placed in order, from top to bottom, with the application requiring the highest quality water at the top. Aquaculture has the most stringent minimum quality requirements with all selected parameters needing a high level of relative quality. Considering that fish must survive and grow in the water for this particular reuse, it is important that critical parameters for biological life, including dissolved oxygen, BOD_5, pH, temperature, and chlorine residual be at Good quality levels. In addition, to prevent disease and clogging of gills in fish, the water should contain low levels of fecal coliforms and be Good quality with respect to total dissolved solids, total suspended solids, and turbidity. Finally, elevated nitrate and phosphate concentrations may promote algal growth and depletion of dissolved oxygen necessary for fish survival. Drinking or direct potable water reuse also has stringent minimum quality requirements because of human health risks associated with consumption. To reduce waterborne disease-causing agents and organic chemical contaminants, Good quality for fecal coliforms, TDS and BOD_5 is needed. Further, suspended particles that can harbor pathogens or chemical contaminants should also be present at low concentrations, thus the water should be Good quality for TSS and turbidity. Since drinking water does not (directly) influence biological life, Moderate quality is acceptable for dissolved oxygen, pH, temperature, and chlorine residual. Good quality levels for nitrate and phosphate are needed to reduce organism growth on treatment filters and within distribution system pipes.

Recreational use, specifically boating and fishing, requires water of a moderate quality, less stringent then drinking water because there is no consumption, but sufficient for ecosystem health and diversity. Since there is very little water contact during boating and fishing activities, there is lower risk of fecal contamination and coliform quality can be Poor. Although dissolved oxygen, BOD_5, total dissolved solids, and pH need to be Good quality for aquaculture, the minimum influent requirements may be relaxed to Moderate quality for recreational fishing. TSS, turbidity, temperature (Good quality is species-specific), and chlorine residual should be Good quality to support a healthy and productive fish population. In addition, to prevent algal blooms, which can deplete necessary oxygen and clog boating waterways, nitrate and phosphate levels should be at minimum (Good) levels.

Agricultural irrigation of either non-processed food or processed food/non-food crops has nearly identical water quality requirements. The fecal coliforms parameter is the only difference with Good quality and Moderate quality needed for non-processed food and processed food/non-food crops, respectively. Many processed foods undergo additional pasteurization or sterilization steps, so moderate fecal coliform levels will be inactivated during these processes. Moreover, non-food crops will not be consumed by humans, so the health risk is significantly decreased for these agricultural products. Total suspended solids, turbidity, and temperature should be Moderate quality to prevent clogging of spraying equipment and side effects to plants. Total dissolved solids, pH, and chlorine residual need to be Good quality to provide the plants with necessary growth nutrients and to maintain plant health. Assuming there is no direct influence on an aquatic habitat during irrigation, dissolved oxygen, BOD_5, nitrate, and phosphate can be Poor quality.

Reusing water for a recreational use, specifically swimming, requires Good quality for TSS, turbidity, and temperature in order that it may be aesthetically pleasing to swim. If focusing solely on needs of swimmers, not fish or plant life, Poor quality parameters include dissolved oxygen, chlorine residual, nitrate, and phosphate. Fecal coliforms and BOD_5 can be Moderate quality since health risk from fecally- or chemically-contaminated water is decreased for direct contact exposure compared to consumption. Lastly, TDS and pH should also be Moderate quality to reduce maintenance and skin irritation issues, respectively.

Environmental and urban residential require similar quality for the selected parameters, most likely due to similarities between wetland maintenance and lawn watering. TDS, TSS, turbidity, pH, and temperature only need be Moderate quality as animal life is a secondary consideration to plant life. However, these water uses require Good quality for chlorine residual because of ecosystem sensitivity to high disinfectant levels. Environmental and urban residential use requires Poor and Good quality for fecal coliforms, respectively. Wetlands and marshes naturally attenuate water; in fact, wetlands are sometimes used as tertiary treatment of wastewater (Verhoeven and Meuleman, 1999), so high levels of fecal coliforms are permissible. Conversely, urban residential uses, such as lawn watering, car washing, and toilet flushing, involve direct contact between water and humans, so, consequently, the water requires higher quality level for fecal coliforms. Ecosystem diversity and health is important for environmental uses, thus dissolved oxygen and BOD_5 should be at Good quality levels. Similarly, nitrate and phosphate should be controlled at Moderate concentrations to prevent dominance of algal species in the ecosystem. For an urban residential application, there is no direct influence on aquatic environments, so dissolved oxygen, BOD_5, nitrate, and phosphate may be Poor quality.

Indirect potable water use requires Good quality for fecal coliforms and Moderate quality for all other parameters. Since the water will be tapped as a drinking water source, the fecal contamination level should be minimal. Given the minimal influence on organism growth and survival for this water application, dissolved oxygen, BOD_5, chlorine residual, nitrate, and phosphate are not significant concerns, so Moderate quality is acceptable. TDS, TSS, turbidity, pH, and temperature have an effect on aesthetic quality of drinking water, so these should also be Moderate quality in order to reduce treatment processing and costs.

The minimum influent quality needed for industrial water reuse depends on the type of cooling tower, once-through or re-circulating. For thermoelectric generation plants with once-through cooling towers, water is cycled through the heat exchanger before being discharged to a local water body. In power plants using re-circulating cooling, water is cycled multiple times resulting in significant loss of water via evaporation. Once-through cooling requires significant

withdrawals with minimal consumption while re-circulating cooling has decreased withdrawals and increased water consumption. Consequently, once-through cooling has a greater influence on aquatic ecosystems to which it is discharged. Considering this influence, fecal coliforms, dissolved oxygen, BOD_5, TDS, TSS, turbidity, pH, temperature, nitrate, and phosphate should be Moderate quality to maintain health of aquatic organisms. There may be a high concentration of chlorine or Poor quality as disinfected water will prevent biofouling of heat exchange media, which is a significant concern in cooling towers. In re-circulating cooling towers, TDS, TSS, turbidity, and pH should also be Moderate quality to reduce potential problems of corrosion and scaling. Similarly, fecal coliforms should be Moderate quality and chlorine concentration may be high to prevent biofouling in these towers (Vidic and Dzombak, 2009). Since re-circulating towers do not exert direct influence on aquatic ecosystems, dissolved oxygen, BOD_5, temperature, nitrate, and phosphate may be Poor quality.

The final water reuse categories, livestock and construction, have identical minimum influent for all selected parameters, except fecal coliforms. Water use for livestock operations requires Good quality for fecal coliforms, so that they animals do not become ill from contact with or consumption of contaminated water. Conversely, water used in construction activities, such as dust control, has minimal exposure to humans and, thus, a higher public health risk is acceptable. Because of the use of spraying and washing apparatus in both activities, it is recommended that TSS, turbidity, and pH be of Moderate quality to reduce clogging of equipment. Similar to the re-circulating cooling tower, aquatic plants and animals will not typically come in contact with this water allowing for Poor quality ratings for dissolved oxygen, BOD_5, TDS, temperature, chlorine residual, nitrate, and phosphate.

Having established relative water quality rankings for thirteen water reuse applications, the next step is to apply this rubric in a life cycle assessment (LCA) to improve the valuation of water quality degradation in different processes. LCAs have typically evaluated the impacts of manufacturing processes on water quantity. Few studies have examined water quality and fewer still have attempted to incorporate water quality metrics into LCAs. While water quantity use is important given the limited global freshwater supply, it is equally important, if not more so, to determine the quality and how that quality level dictates potential human water reuses. Some of the most important activities for water reuse potential are those with large withdrawal and small consumptive values, such as thermoelectric power generation. Moreover, it is also critical to identify activities that have great potential for receiving large volumes of lower quality water, such as irrigation. Efficient coupling of processes that produce and processes that require large volumes of water could yield significant decreases in water treatment costs. In addition, a relative quality ranking system, such as Table 1, is valuable for identifying applications where a process effluent quality meets the minimum influent requirements for another water use. The development of a method to connect water quality characteristics with human water reuses is an important contribution to life cycle assessments and water resource management. Such a water quality reuse classification tool will enable location-specific analyses and evaluation of degraded water impacts in LCAs as opposed to just environmental release inventories.

As a demonstration of this water quality reuse classification tool, example effluent water has been compared to the minimum water quality parameters listed in the table to determine if this discharged water can be used directly or with minimal treatment in another application. Prior to using the tool, water quality data for the sample water, a secondary-treated wastewater treatment plant effluent, was collected for as many of the relevant parameters as possible. Wastewater effluent was chosen as an example because of its availability and close proximity to

urban areas, which typically contain other water use applications. In Table 3, the quantitative values and relative quality ranking are shown for the following parameters: fecal coliforms, TDS, TSS, pH, temperature, chlorine residual, nitrate, and phosphate. All quantitative values, excluding pH, temperature, and chlorine residual, were taken from the secondary effluent data of a Phoenix, Arizona wastewater treatment plant reported in Chapter 2 of the EPA Guidelines for Water Reuse. Because pH, temperature, and chlorine residual were not reported for this effluent, these parameters were based on typical secondary-treated effluent values presented in Vidic and Dzombak.

  Based on the defined parameter ranges for relative quality rankings, the sample effluent has Poor quality with respect to fecal coliforms, TDS, and phosphate; Moderate quality for TSS and temperature; and Good quality for pH, chlorine residual, and nitrate. Comparison with the water quality reuse classification tool suggests that this secondary effluent could be directly used for construction activities, such as dust control, concrete mixing, etc. The tool also suggests that this effluent could be used for recreational (boating and fishing) or environmental purposes, if the phosphate and TDS quality were improved through additional treatment. Depending on treatment costs, it may be more cost-effective to improve the relative quality of fecal coliforms and TDS by decreasing their concentrations. Specific treatment to improve the water quality with respect to fecal coliforms and TDS would make the water usable in agricultural irrigation (non-processed food crops), agricultural irrigation (processed food and non-food crops), recreational (swimming), urban residential, and industrial (re-circulating cooling). With this table as a guide, utility managers, industrial operators, and policy makers can visually identify and evaluate water reuse options based on specific needs and constraints of their communities. This tool serves as a good starting point for recommending water reuse actions, but all decisions should be supported by location-specific analysis that examines the cost, required treatment, and feasibility of such recommendations.

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Table 1. Water Reuse Categories with Associated Quality Rankings for Selected Parameters.

Types of Reuse	Water Quality Parameters										
	Fecal coliform (CFU/100ml)	Dissolved Oxygen (% saturation)	BOD_5 (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)	pH	Temp (ºC)	Cl_2 residual (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
Aquaculture	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Drinking - Direct Potable	Good	Moderate	Good	Good	Good	Good	Moderate	Good	Moderate	Good	Good
Recreational - Boating & Fishing	Poor	Moderate	Moderate	Moderate	Good	Good	Moderate	Good	Good	Good	Good
Agricultural Irrigation, Non-processed Food Crops	Good	Poor	Poor	Good	Moderate	Moderate	Good	Moderate	Good	Poor	Poor
Agricultural Irrigation, Processed Food and Non-food Crops	Moderate	Poor	Poor	Good	Moderate	Moderate	Good	Moderate	Good	Poor	Poor
Recreational - Swimming	Moderate	Poor	Moderate	Moderate	Good	Good	Moderate	Good	Poor	Poor	Poor
Environmental - wetlands, marshes, stream augmentation	Poor	Good	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Moderate	Moderate
Urban Residential - toilet flushing, car washing, water lawn	Good	Poor	Poor	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Poor	Poor
Indirect Potable	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Industrial, Once-through cooling	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Poor	Moderate	Moderate
Industrial, Recirculating cooling towers	Moderate	Poor	Poor	Moderate	Moderate	Moderate	Moderate	Poor	Poor	Poor	Poor
Livestock - drinking & washing equipment	Good	Poor	Poor	Poor	Moderate	Moderate	Moderate	Poor	Poor	Poor	Poor
Construction	Poor	Poor	Poor	Poor	Moderate	Moderate	Moderate	Poor	Poor	Poor	Poor

Table 2. Recommended Ranges for Qualitative Rankings of Water Quality Parameters.

Parameter	Good	Moderate	Poor
Fecal coliform (CFU/100ml)	0 - 100	100 - 1000	> 1000
Dissolved Oxygen (% saturation)	> 75%	50 - 75%	< 50%
BOD_5 (mg/L)	0 - 3.0	3.0 - 6.0	> 6
Total Dissolved Solids (mg/L)	< 100	100 - 500	> 500
Total Suspended Solids (mg/L)	0 - 5.0	5.0 - 30.0	> 30.0
Turbidity (NTU)	0 -10	10 -100	> 100
pH	6.5 - 8.5	5.0 - 6.5	2.0 - 5.0; 8.5 - 12
Temp (°C)	5 - 20ºC	20 - 35ºC	> 35ºC, < 5ºC
Cl_2 residual (mg/L)	< 1.0	1.0 - 2.0	> 2.0
Nitrate (mg/L)	< 1.0	1.0 - 5.0	> 5.0
Phosphate (mg/L)	< 1.0	1.0 - 5.0	> 5.0

Table 3. Water Quality for Example Secondary Treated Wastewater Effluent.

	Fecal coliform (CFU/100 ml)	Dissolved Oxygen (% sat)	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	pH	Temp (C)	Cl$_2$ residual (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
Quantitative Value	3500		750	11		~ 7.0	~ 20	~ 0.5	0.5	5.5
Relative Quality Ranking	Poor		Poor	Moderate		Good	Moderate	Good	Good	Poor