4 Nutrients

Excessive nitrogen and phosphorus loadings to watersheds impact water quality by stimulating the growth of algae and aquatic plants which may result in depletion of dissolved oxygen, shifts in pH, degradation of habitat, impairment of drinking water sources, and in some cases harmful algal blooms. Eutrophication is a term commonly used to describe situations with excessive growth of algae and plants. According to the EPA, nearly every State has nutrient related pollution with impacts in over 80 estuaries/bays, and thousands of rivers, streams, and lakes.

In Idaho, nutrient related impairment listings and total maximum daily loads have emphasized phosphorus control for a number of key waterbodies. These include Cascade Reservoir, American Falls Reservoir, Swan Falls and C.J. Strike Reservoirs, Spokane River, Mid-Snake River and others in the Magic Valley area, Snake River Hells Canyon, Boise River, Big Wood River, Portneuf River, and others. In Idaho, phosphorus has been the nutrient historically targeted for TMDLs because eutrophication problems in Idaho related to nitrogen have not been identified to date. In some states both phosphorus and nitrogen have been or are being targeted. In some of these the reason for nitrogen control relates to eutrophication and/or dead zone impacts in estuaries and coastal waters such as Chesapeake Bay and the Gulf of Mexico, or because the state has determined that both nitrogen and phosphorus limit algae growth (e.g., Montana). Idaho is somewhat unique in that our rivers do not flow to estuarine or coastal waters (e.g., Columbia River basin) that are considered impaired by eutrophic conditions. In addition, the downstream states of Oregon and Washington have also been primarily focused on phosphorus for eutrophication control for rivers in the Columbia basin. This chapter includes information and discussion about both phosphorus and nitrogen because nutrient limitation or co-limitation will likely need to be determined on a case-by-case basis and nitrogen could become of greater concern in the future in some receiving waters.

4.1 Summary of Recommendations

<to be written>

4.2 Characterize the Receiving Water

Nutrient loadings from both point and nonpoint sources contribute to water quality impairments in waterways. Nutrients are of concern because at high concentrations, they can result in excessive and nuisance biological growth, such as algae, which may potentially lead to low dissolved oxygen conditions and the overall impairment of the receiving water. Point source discharges from wastewater treatment plants can be a significant source of nitrogen and phosphorus in watersheds. Nonpoint sources may contribute substantial amounts of nutrients from land use activities such as agriculture, forestry, and urban/suburban development.

4.2.1 Ambient Monitoring

Water quality monitoring for potential use in establishing nutrient TMDLs that may lead to nutrient discharge limitations should be developed specifically for the watershed objectives and adequate to support the water quality modeling used to establish wasteload allocations.

Targeted nutrient levels in lakes, streams, and estuaries can be very low concentrations that are challenging to meet with treatment of point sources and application of best management practices (BMPs) to nonpoint sources. The resulting nutrient control requirements may require very large capital investments and be expensive to operate. Therefore, credible and reliable monitoring data upon which to base potentially expensive decisions is essential.

Water quality monitoring may range from short-term and limited data collection to complex undertakings. If the data will be used for decision making and modeling, then the data must be collected and analyzed under standards and protocols that demonstrate the data are of high quality, relevant, and credible to the study. This is particularly important for water quality model applications representing the dynamics between wastewater effluent and receiving water conditions.

There is a continuum of approaches for effluent and receiving waterbody monitoring, including the breadth of duration and number of constituents analyzed. Typical constituents include:

- Flow.
- Temperature.
- pH.
- Dissolved oxygen.
- Total nitrogen.
- Total dissolved nitrogen/total inorganic nitrogen.
- Total kjledahl nitrogen.
- Nitrate.
- Nitrite.
- Total ammonia.
- Urea.
- Total phosphorus.
- Total dissolved phosphorus.
- Total and dissolved inorganic phosphorus.
- Dissolved silica.
- Biochemical oxygen demand (BOD).
- Carbonaceous Biochemical oxygen demand (CBOD).
- Total organic carbon (TOC)

The sample types may be grab samples or composite as determined in the quality assurance plan for the monitoring program. The duration of the monitoring program may be a few days or extend to years. The frequency may be random or designed to capture different types of events, such as irrigation versus non-irrigation seasons, wet and dry seasons, or high and low flow periods.

4.2.2 Nutrient Speciation

Nitrogen and phosphorus can be subdivided into compounds. Nitrogen compounds are represented as organic nitrogen, ammonia, nitrate, and nitrite. Phosphorus compounds are represented as organic phosphorus and dissolved phosphorus. These compounds may be further defined as labile or refractory. Some of these compounds, including ammonia and nitrite/nitrate can be both plant nutrients and toxic to aquatic species.

Nutrient speciation is an important consideration in monitoring programs and an area of potential confusion in vocabulary and laboratory analysis, especially at low concentration levels. Tables 4-1 and 4-2 present a comparison of commonly used terminology in wastewater effluent monitoring and ambient receiving water quality monitoring and modeling (Clark 2016b). Similar terms commonly used in water quality monitoring and modeling are shown in the tables in the un-shaded cells (red italics text). For N, the terms generally align and are fairly synonymous. For P, the terminology varies. These tables demonstrate the need for translation between the water quality terminology and the wastewater vocabulary used for nutrients. Recognizing these differences promotes more effective communication about nutrient management issues by offering synonymous terminology for all stakeholders to use.

Not all of the information to define nutrient species is available from conventional laboratory analysis. For N, a majority of the fractions may be analyzed in the laboratory with the remaining fractions calculated from the analyzed values, or estimated. Estimations may be necessary for the labile and refractory fractions. For P, a minority of the fractions may be analyzed in the laboratory with the remaining fractions calculated from the analyzed values, or estimated. Therefore, monitoring recommendations for wastewater effluent and ambient receiving waters are generally to analyze for as many of the nutrient species fractions as possible with standard methods to provide the most information for the calculation or estimation of the remaining fractions.

Table 4-1. Wastewater Terminology for Nitrogen Species.

<table>
<tr><td></td><td colspan="7">Total N (TN)</td></tr>
<tr><td></td><td colspan="5">Total Soluble N (TSN)</td><td colspan="2">Total Particulate N (TpN)</td></tr>
<tr><td></td><td>Ammonia (NH_3) + Ammonium (NH_4)</td><td>Nitrate (NO_3)</td><td>Nitrite (NO_2)</td><td colspan="2">Soluble Organic N (SON)</td><td colspan="2">Particulate Organic N (pON)</td></tr>
<tr><td>Modeling Terminolog</td><td>Ammonia + Ammonium</td><td>Nitrate</td><td>Nitrite</td><td>Dissolved Organic Nitrogen Labile</td><td>Dissolved Organic Nitrogen Refractory</td><td>Particulate Organic Nitrogen Labile</td><td>Particulate Organic Nitrogen Refractory</td></tr>
<tr><td></td><td>Total Ammonical N (TAN)</td><td colspan="2">Total Oxidized N (NO_x)</td><td colspan="4"></td></tr>
<tr><td></td><td colspan="3">Total Inorganic N (TIN)</td><td colspan="4">Total Organic N (TON)</td></tr>
</table>

Table 4-2. Wastewater Terminology for Phosphorus Species.

<table>
<tr><td></td><td colspan="6">Total Phosphorus (TP)</td></tr>
<tr><td></td><td colspan="3">Total Soluble P (TSP)</td><td colspan="3">Total Particulate P (TpP)</td></tr>
<tr><td></td><td>Soluble Reactive P (SRP)</td><td colspan="2">Soluble Non-reactive P (SNRP)</td><td>Particulate Reactive P (pRP)</td><td colspan="2">Particulate Non-reactive P (pNRP)</td></tr>
<tr><td>Modeling Terminolog</td><td>Phosphate</td><td colspan="2">Dissolved Organic Phosphorus

Labile and Refractory</td><td>Particulate Organic Phosphate Labile</td><td colspan="2">Particulate Organic Phosphate Refractory</td></tr>
<tr><td></td><td>Soluble Reactive P (SRP)</td><td>Soluble Acid Hydrolyzable P (SAHP)</td><td>Soluble Organic P (SOP)</td><td>Particulate Reactive P (pRP)</td><td>Particulate Acid Hydrolyzable P (pAHP)</td><td>Particulate Organic P (pOP)</td></tr>
</table>

4.2.2.1 SUITABILITY FOR PERMITTING CONSIDERATIONS

The adequacy of water quality monitoring data for use in permitting should correspond to and complement the level of decisions to be made with the resulting management scenarios. For example, nutrient speciation and bioavailability can be expected to be an important factor under the following circumstances:

- A receiving waterbody with low nutrient concentration targets.
- Management scenarios where nutrient reductions are planned, especially those approaching the limits of treatment technology.

A different approach should be taken when very low nutrient concentrations become more important and there is a need to understand refractory compounds. For refractory compounds, the methods of analysis are more complex and may use newly evolving methods (Brett 2015)(Li 2013)(Sedlak 2003).

4.2.2.2 CURRENT IMPAIRMENT V. FUTURE CONDITIONS

The availability and interpretation of data to characterize nutrient speciation and bioavailable and refractory organic compounds in ambient waters, as well as wastewater effluent and nonpoint sources, is important to the characterization of impaired conditions. Site specific water quality monitoring data for effluent and receiving waters provides data applicable at a given location under current conditions. It is important to also consider that future managed conditions will alter nutrient speciation and the relative contribution of point and nonpoint source loadings.

4.3 Identify Applicable Water Quality Standards

Rules of the Department of Environmental Quality, IDAPA 58.01.02 “Water Quality Standards” include narrative surface water criteria that prohibit excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses. Narrative nutrient criteria require an interpretation to determine what level of nutrients constitute an impairment of beneficial uses. This generally requires an impairment listing and TMDL to define a wasteload allocation in order to form the basis for point source discharge permit limitations. Direct interpretations of narrative criteria have been discussed in some locations but have not been applied in Idaho.

4.3.1 No Numeric Nutrient Criteria in Idaho

The state of Idaho has not developed or implemented numeric nutrient criteria. The DEQ has not identified this as a priority and the status of potential numeric criteria process has been characterized as just starting for many years (DEQ 2007). A lack of data has been cited as one of the challenges for developing numeric nutrient criteria. In 2012, the DEQ initiated a review of procedures related to nutrients and proposed a project to monitor for effects of nutrients on surface waters in Idaho that was to be initiated in 2013 and potentially continue for additional years. This data may be useful for future numeric nutrient criteria development.

4.3.2 Idaho TMDLs and Nutrients

Most of the recently issued NPDES permits in Idaho that have included nutrient limits were based on TMDLs for specific waterbodies. In two watersheds, TMDLs were developed with the neighboring state that included WLAs for Idaho dischargers and that EPA used as the basis for NPDES permits; Washington Ecology for the Spokane River Dissolved Oxygen TMDL and Oregon DEQ and Idaho DEQ for the Snake River-Hells Canyon Dissolved Oxygen TMDL.

In Montana, the Clark Fork Voluntary Nutrient Reduction Program (VNRP) was approved by EPA Region 8 in 1998 as a functionally equivalent TMDL for the river to restore beneficial uses and eliminate nuisance algae growth in Montana streams and protect Pend Oreille Lake water quality in Idaho.

4.3.3 Pending TMDLs and No Net Increase

In some cases, no net increase policies have served as methods to control nutrient loadings when pending TMDLs have not yet been completed. No net increase goals may be achieved using methods such as pollutant trading, best management practices, and nutrient removal technologies. Elements of the no net increase include the selection of a baseline year, specific pollutant of concern, time period for the no net increase, and proposed loads such as season average with mass total.

4.4 Characterize the Effluent

Advanced levels of nutrient removal treatment impact effluent quality in multiple ways. First, effluent nitrogen and phosphorus concentrations are reduced. Second, nitrogen and phosphorus speciation is altered as a result of the advanced treatment processes. Third, the bioavailability of the remaining effluent nitrogen and phosphorus is reduced.

After advanced nutrient removal treatment, the remaining nitrogen and phosphorus in treatment plant discharges may not be removable with current treatment technology. Tables 4-1 and 4-2 identify the soluble dissolved organic nutrient fractions that cannot be removed in wastewater treatment by filtration, coagulation, or degradation. Nitrogen and phosphorus speciation is an important area of nutrient research, both in terms of biodegradability in wastewater treatment and bioavailability in the water environment.

Appropriate consideration should be given to effluent discharge permitting regarding emerging areas of advanced scientific understanding of the effect of advanced nutrient removal treatment on both nutrient speciation and bioavailability. At the boundaries of the current understanding of science is investigation of nitrogen and phosphorus remaining after advanced treatment that may not be removable with current treatment technology and may not be bioavailable in receiving waters. Nitrogen and phosphorus speciation are also important areas of nutrient research, both in terms of biodegradability in wastewater treatment and bioavailability in the water environment.

4.4.1 Wastewater Effluent Monitoring

Wastewater process monitoring and analysis is focused on the physical, chemical, and biological processes employed in treatment facilities. Refractory nutrient compounds are those that resist removal by treatment, pass through the process, and are present in the effluent discharge (Neethling 2013a,b,c)(Stensel 2016). Relevant timeframes in wastewater facilities are on the order of hours to days.

Refractory nutrient compounds that are not biodegradable in wastewater treatment facilities may become bioavailable in the natural environment. In receiving water monitoring and modeling analysis, refractory nutrient compounds are those that break down slowly as a result of natural processes that include biological and chemical degradation, solar, wind, and physical mechanisms. Relevant timeframes in the receiving water environment may range from days to months or years.

4.4.1.1 CURRENT IMPAIRMENT V. FUTURE CONDITIONS

Effluent characterization must include consideration of both current conditions, in order to be useful in interpreting current impairments, and future effluent characteristics to accurately represent future management scenarios with advanced nutrient removal treatment that alter speciation. Similar considerations for monitoring data apply to ambient water quality and nonpoint sources. Literature references may be useful in characterize potential future conditions.

4.5 Regulatory Approach

Section 402 of the Clean Water Act (CWA) specifically required EPA to develop and implement the NPDES program. NPDES permits include effluent limitations for Publicly Owned Treatment Works (POTWs). The CWA authorizes the permit writer "to use his or her best professional judgment (BPJ) to establish case-by-case limitations" (EPA 2010). The permit writer is to use his or her knowledge of the industry, the specific discharge, and the receiving water, to develop effluent limitations specific to the facility. Thus, "the limitations and conditions in NPDES individual permits are unique to each permittee" (EPA 2010).

4.5.1 Nutrients Are Not Toxics

Much of the existing guidance to permit writers is based on EPA's Technical Support Document for Water Quality-based Toxics Control Basis (TSD) (EPA 1991). Nutrient impacts on water quality are distinctly different than the impact of toxics. Rather than directly impacting aquatic organisms in a harmful way, nutrients act as a stimulating growth factor, often on longer spatiotemporal scales than are typically seen for toxic compounds. It is important to note that when permit writer applies toxics control approaches to nutrients, the resulting effluent limits are likely to be unnecessarily low concentrations and perhaps lower than achievable with advanced nutrient removal treatment technology.

Toxics impact the physiology of aquatic organisms in a harmful way, often on short spatiotemporal scales. Consequently, the approach to permitting is overly conservative and restrictive to protect aquatic life and guidance (EPA 1991) guidance is based on conditions that would occur rarely, or never, and would result in permit limits more stringent than necessary:

> *"Traditional single-value or two-value steady-state WLA models calculate WLAs at critical conditions, which are usually combinations of worst-case assumptions of flow, effluent, and environmental effects. For example, a steady-state model for ammonia considers the maximum effluent discharge to occur on the day of lowest river flow, highest upstream concentration, highest pH, and highest temperature. Each condition by itself has a low probability of occurrence; the combination of conditions may rarely or never occur. Permit limits derived from a steady-state WLA model will be protective of water quality standards at the critical conditions and for all environmental conditions less than critical. However, such permit limits may be more stringent than necessary to meet the return frequency requirements of the water quality criterion for the pollutant of concern." (EPA, 1991)*

4.6 Evaluate the Need for WQBELs

The permit writer sets the effluent limitations after evaluating technology based effluent limits (TBELs) and water quality based effluent limits (WQBELs). There are no technology based effluent limits for nutrients nationally, and although some states have applied TBELs for nutrients under some circumstances, such as with water quality variances, this has not occurred in Idaho. WQBELs are meant to be protective of state water quality standards and incorporate wasteload allocations (WLAs) assigned in an approved TMDL for the receiving water. Since there are no numeric nutrient criteria in Idaho, traditional reasonable potential analysis (RPA) to calculate potential exceedence of standards is not applicable. Therefore, in Idaho, potential effluent nutrient limits are based upon the WLA from a TMDL.

4.6.1 Interpretation of TMDLs for Nutrient Permitting

The permit writer must prepare effluent limits that are consistent with the TMDL and translate the in-stream nutrient targets from the TMDL, expressed in terms of magnitude, duration, and frequency, into effluent limitations expressed in terms of magnitude and averaging period. Often, the applicable magnitude, duration, and frequency of the nutrient endpoints is not well defined in the TMDL. It is also important to note that discharge permit limits are not required to be an exact match with a TMDL, such as necessitating expression of permit limits as Maximum Daily Limits because the terminology TMDL includes the words "daily load."

4.6.2 Impracticable Determinations

Average weekly and monthly effluent limits are required for POTWs (40 CFR 122.45(d)), unless "impracticable". Impracticable determinations have been made in key watersheds, including in Idaho, where more suitable structures for nutrient permit limits were found to be appropriate. EPA found that annual nutrient permit limits were appropriate for the Chesapeake Bay, because is impracticable to express limits on a shorter time scale (Hanlon 2004). In an example pertaining to an individual municipal wastewater facility, EPA determined that for the City of Coeur d'Alene wastewater treatment plant (EPA 2014):

> *"it is impracticable to express the water quality-based effluent limits for TP, ammonia, and Carbonaceous Biochemical Oxygen Demand (CBOD) that are necessary to meet Washington's water quality criteria for dissolved oxygen as monthly average and weekly average limits…... The water quality-based effluent limits for total phosphorus (TP), ammonia and CBOD are expressed as seasonal average loading limits that are identical to the loads of TP simulated in the modeling."*

The result of this impracticable determination was that seasonal mass loading limits were used for the phosphorus, ammonia and CBOD discharges to the Spokane River.

4.7 Determine Interim and Final WQBELs

Surface water nutrient discharges should receive special considerations in discharge permitting for distinction from other effluent parameters, in particular toxic parameters, upon which much of the existing EPA permit writer's guidance is based. Appropriate NPDES discharge permit structures for nutrients can be protective of surface water quality and also be based on long averaging periods, such as seasonal limits based on mean or median statistics. It is important that consideration be given to variability and reliability of effluent performance from advanced nutrient removal facilities because these technologies are highly effective in nutrient removal despite their inherent variability in effluent quality, particularly at low phosphorus and nitrogen concentrations.

4.7.1 Case-by-Case Analysis

Although receiving water quality requirements vary depending upon location and permit writers are to use their best professional judgment to establish case-by-case effluent limitations for water quality-based effluent limitations, it is important that permits be technically attainable and flexible. Permits should be attainable from the standpoint of treatment performance for successful compliance. Flexible in terms of fostering opportunities for effective effluent management, trading, water quality offsets, effluent recycling and reuse etc. to improve water quality and meet nutrient discharge limitations.

4.7.2 Avoiding Immaterial Compliance Issues

Appropriate NPDES permit structures for nutrients will avoid the creation of frameworks that result in compliance issues that are immaterial to surface water quality protection, such as maximum daily and maximum weekly limits, overly restrictive receiving water streamflow assumptions, and the assumption of extreme and improbable coincident events, such as statistical extremes occurring in both receiving waters and effluent discharge quality. Over specifying nutrient permit limits beyond the capabilities of treatment technology will not result in improved water quality, but may result in permit compliance issues for wastewater utilities.

4.7.3 Nutrient Permitting Considerations

There are unique considerations regarding nutrients that a permit writer and permittee may examine when drafting a new permit or renewing an existing permit. These considerations are a part of applying appropriate approaches in the development of effluent nutrient limits, including the following:

- Advanced nutrient removal treatment is costly and complex.
- Nutrients should be distinguished from toxics.
- Effluent nutrient concentrations vary even in the best nutrient removal facilities.
- A variety of nutrient discharge permit structures have been successful.
- Flexibility in permitting promotes reuse, recharge and restoration.

Point source permitted dischargers are the most highly regulated sources subject to nutrient control requirements resulting from numeric nutrient standards, total maximum daily loads, and water quality based permit limits. The costs for nutrient removal are substantial and vary widely depending upon existing treatment facilities and site specific circumstances. While high levels of nutrient removal can be achieved in advanced wastewater treatment, nutrient removal processes require additional energy, chemicals, maintenance materials, and labor, which increase the complexity of plant operations and costs. It is therefore important that effluent nutrient permitting requirements are attainable from a treatment technology standpoint and protective of receiving water quality.

It is also important that consideration be given to variability and reliability of effluent performance from advanced nutrient removal facilities, especially those operating at low or very low levels. Appropriate NPDES permitting methodologies will avoid compliance issues that are immaterial to surface water quality protection. Short-term limitations, such as maximum daily and maximum weekly, should not be imposed for nutrients. Technology performance statistics provide a science based approach to characterize feasible effluent limits within the capabilities of advanced nutrient removal treatment and also characterize the variability in effluent performance and reliability of treatment.

Nutrient discharge permits that are restrictive in ways unrelated to water quality protection because of the structure of the permit itself should be avoided. Unnecessarily restrictive permits do not enhance water quality protection, but may create circumstances that result in noncompliance. From a sustainability standpoint, little additional nutrient removal is accomplished approaching the limits of treatment technology, however there are other environmental impacts that result from the additional use of energy and chemicals, and from increased atmospheric emissions.

A wide variety of nutrient permit structures have been utilized across the country and flexibility is available for permit writers to prepare permits for successful compliance with attainable treatment technology. Nutrient permit structures that provide utilities with flexibility foster creative solutions to best meet overall water quality objectives, such as watershed permitting, shared loading capacity, and trading. Flexible permits can be developed to facilitate opportunities for effluent reuse, recharge, and restoration.

4.7.4 Nutrient Permit Structure

Emphasis in nutrient discharge permitting should focus on providing the greatest amount of flexibility possible in the structure of nutrient limits in order to preserve the opportunity for the most creative and economical approaches to managing nutrients. Traditional permit structures for publically owned treatment works generally include both monthly and weekly limits on both a concentration and mass basis. This may inadvertently eliminate the most effective watershed solutions to nutrient management by creating disincentives to wastewater dischargers to explore combinations of advanced wastewater treatment and other watershed management practices.

4.7.4.1 WATER QUALITY LINKAGES

The most appropriate nutrient discharge permits will be prepared based on an understanding of both receiving water quality requirements and the capabilities of advanced nutrient removal treatment. Where either is lacking, an investment may be necessary to determine the level of nutrient management required to meet water quality objectives and link that analysis with specific objectives for effluent quality. When the relationship between nutrient loadings and water quality responses is not well defined, it is advisable to avoid overly restrictive effluent limits at the outset, since they may later prove unnecessary to meeting actual receiving water needs when they eventually become better understood. Preserving an opportunity for adaptive management approaches to guide the process of nutrient management over time may improve water quality incrementally, without overly restrictive discharge permits that result in over investment in advanced treatment. Permits structured around no net increase in existing loadings, or simple seasonal or annual loading reductions, may provide a foundation for adaptive management.

Where the linkages with water quality requirements are less well defined, the following approaches are recommended:

- Establish a foundation for adaptive management whereby the impact of nutrient loadings on receiving water quality can be better understood over time.
- In cases where nutrient limitations are warranted, develop nutrient discharge permit limits based on no net increase in existing loadings.
    - If necessary, utilize technology based effluent limits at the basic biological nutrient removal level.
- Utilize compliance schedules in discharge permitting to provide the time necessary to develop a water quality based set of requirements for effluent limits linked with water quality response variables.

Where the linkages with water quality requirements are defined but overall watershed nutrient management and nonpoint source controls are uncertain, the following additional approaches are recommended:

- Incorporate the most basic level of nutrient limits possible in discharge permits to preserve the ability to optimize the combination of point and nonpoint source nutrient controls through adaptive management.

- When nonpoint source controls are uncertain, additional information should be gathered prior to considering point source controls.
- Utilize mass loading limits or technology based effluent limits at the basic biological nutrient removal level.

4.7.4.2 TECHNOLOGY PERFORMANCE STATISTICS

When the linkage between water quality requirements and nutrient loadings result in the need for advanced levels of nutrient removal treatment, technology performance statistics (TPS) provide a basis to define effluent performance and reliability. TPS describes the performance of a technology or process or facility under specific conditions (Bott 2011)(Neethling 2013a,b,c). In this approach, the treatment plant or technology performance is tied to the statistical rank to express the probability of achieving a certain performance. The TPS is determined from performance data and is linked to the operational conditions during which the data were collected (pilot, full scale, summer, winter, excess capacity available, SRT, etc.). The conditions must also include external factors that impact the technology, industrial loadings, seasonality, absence of recycle streams, etc.

Where the linkages with water quality requirements are not well defined, the following approaches are recommended:

- Consider whether technology performance statistics are warranted.

Where the linkages with water quality requirements are well defined, the following approaches are recommended:

- Utilize technology performance statistics to define effluent limits based on receiving water quality requirements in terms of effluent quality and reliability.
  - Where appropriate, utilize median statistics (50^{th} percentile) to define effluent quality such that inherent variability in treatment performance with advanced nutrient removal can be allowed.
  - Specify effluent limits in terms of average (50^{th}), 90^{th}, or 95^{th} percentile statistics depending upon the reliability of treatment required for receiving water conditions.
- Establish a foundation for adaptive management whereby the impact of nutrient loadings on receiving water quality can be better understood over time.

Where the linkages with water quality requirements are well defined but water quality based effluent limits result in technically infeasible nutrient limits, the following approaches are recommended:

- Utilize the following regulatory implementation tools and define a level of feasible effluent performance for interim operation:
  - Site specific nutrient criteria.
  - Compliance schedules.
  - Variances.
  - Use attainability analysis.

4.7.4.3 PREDICTIVE WATER QUALITY MODELS

When water quality models are available to simulate the water quality response to nutrient loadings, discharge permit scenarios can be simulated to develop the basis for the most flexible and sustainable permit structure possible. Water quality models are powerful tools that can provide significant insights into receiving water conditions and the impacts of wastewater discharges and other nutrient loading sources on water quality. A number of water quality models of varying complexity and capabilities are available for simulation of water quality. Many of these models include quantitative relationships between nutrients, site-specific water quality, and ecological response indicators (dissolved oxygen, pH, algae). Process based load-response models use mathematical representations that link nutrient loads to in situ water quality and/or ecological responses.

Where water quality models are available to define the impact on receiving water beneficial uses in terms water quality response variables (dissolved oxygen, pH, algae, etc.), the following approaches are recommended:

- Utilize water quality models to simulate receiving water quality responses to define effluent limits in terms of effluent quality and reliability.
- Utilized water quality models to simulate effluent discharges in alternative ways such that the critical factors affecting the response variables can be better understood, such as extended period simulations.
- Combine water quality modeling and monitoring in adaptive management approaches whereby the impact of nutrient loadings on receiving water quality can be better understood over time in pursuit of optimal watershed nutrient management.
    - Consider the changes in receiving water quality that occur following the initial reduction of point source nutrient loadings, along with each successive reduction in both point and nonpoint source loadings.
    - Select effluent nutrient limits that provide proportionate improvements in receiving water quality.
- Pursue sustainable combinations of point source nutrient removal and nonpoint source watershed nutrient management.
    - Avoid overly restrictive effluent limits that do not provide a commensurate improvement in receiving water quality, but may result in excessive use of energy and chemicals, and over production of residual biosolids.

4.7.4.4 PROBABILISTIC ANALYSIS

Where there is recognition that variability exists in receiving water flows and water quality, consider the application of probabilistic approaches to define levels of effluent performance to meet performance objectives and at what frequency. Extremely low receiving water flow conditions are not likely to coincide with maximum effluent discharge conditions. Likewise, aquatic life and recreational beneficial uses would generally not be thought to be impaired if a single rock, pool or riffle, or even a short reach of river had benthic algae higher than a target value. Probabilistic analysis can provide a tool to analyze the frequency at which specific conditions may occur in receiving waters based on variability in both effluent and receiving water.

Effluent limits developed in the traditional deterministic approach are back calculated directly from an acceptable downstream mixed concentration condition based on the applicable water quality standard or wasteload allocation. Probabilistic calculations result in a distribution of downstream conditions that can be compared to either an allowable frequency of exceedance of the applicable standard, or a probabilistic representation of an acceptable downstream condition as a probability distribution rather than a single value. Development of effluent limits using a probabilistic approach will require calculation of the downstream conditions, followed by a comparison with the allowable frequency of exceedance. This may be followed by successive iterations with refined effluent flow and nutrient concentration values to converge on the effluent limits necessary to satisfy the downstream conditions.

Monte Carlo analysis is a method for using the full probability distributions for each of the parameters in the mass balance approach to develop effluent limits. A Monte Carlo simulation may be used to combine the effluent and receiving water flow and concentration data and calculate the probability distribution for the downstream mixed conditions. The Monte Carlo analysis results in the probability distribution of calculated in-stream concentrations, which can then be evaluated in comparison to the in-stream target concentration.

Probabilistic analysis is recommended in the following circumstances:

- Where there are conditions in which there is a high degree of variability in receiving water and effluent flows and/or concentrations.
- Extremes in receiving water low flow conditions, or high ambient concentrations, are short lived or infrequent.

4.8 Special Topics

Special topics which have an influence on nutrient discharge permitting include watershed permitting and trading, filtered and unfiltered effluent, anti-backsliding and the bioavailability of nitrogen and phosphorus.

4.8.1 Watershed Permitting and Water Quality Trading

Since nutrients are often a broad watershed scale issue in terms of water quality, consideration should be given to watershed permitting. Watershed permitting provides a structure that allows for collaboration among point source dischargers, nonpoint sources, and other stakeholders to achieve watershed nutrient management objectives. Individual discharge permit renewal schedules and other administrative factors may artificially constrain the opportunity to develop and implement watershed scale permits. Approaching nutrient management considerations from the watershed scale, as opposed to individual permits, may reveal the opportunity for watershed permits to result in effective collaborations.

A potentially attractive tool in developing effective watershed scale nutrient management plans is nutrient trading. It is important to structure discharge permit in a manner that avoids inadvertent disincentives to nutrient trading. Combinations of both effluent concentration and mass effluent limits for nutrients may constrain the development of trades, or increase the complexity in accounting for trades. Watershed permits formulated with trading in mind may facilitate the implementation of water quality trading.

Recommendations are as follows:

- Incorporate Idaho specific trading guidance on a state-wide basis (DEQ 2016) and watershed-specific trading frameworks such as the one for the Lower Boise Watershed (DEQ 2017).
- Structure NPDES discharge permits with long averaging periods linked to the specific waterbody response to nutrient enrichment, such as seasonal or annual limits based on long-term average values.
- Consider effluent limits based on the total loading for the compliance period (e.g., total pounds discharged on an annual or seasonal basis) to facilitate compliance and provide an opportunity for water quality offsets and trading.

4.8.2 Filtered and Unfiltered Flow Issues

Compliance with effluent phosphorus limits at very low concentration levels generally less than 0.250 to 0.50 mg/L requires the use of chemical coagulants and effluent filters. Effluent filter sizing is controlled by hydraulic loading rates and the peak flow routed to effluent filtration generally governs sizing. Since effluent filtration is an expensive tertiary process to capitalize and operate, it is desirable to avoid unnecessary oversizing of the effluent filters based on treating extreme peak flows that rarely occur. This is especially the case with microfiltration membranes, which can be very effective in producing very low effluent phosphorus, but have a narrow band of peak to average flow capabilities (approximately <1.5:1 on a maximum day flow basis). Consequently, if may be advantageous to design for a combination of filtered and unfiltered effluent to be produced during rare peak flow events to avoid oversizing of effluent filters, providing that effluent phosphorus limits can be attained. However, a complicating factor that potentially impacts this practice is the bypass provision included in NPDES permits.

Federal regulations prohibit bypassing, which is defined as the intentional diversion of waste streams from any portion of a treatment facility. There are mandatory bypass prohibitions included in all NPDES permits. The NPDES regulations also state that the prohibition of bypass applies even where the permittee does not violate permit limitations during the bypass. However, bypasses for essential equipment maintenance may be allowed if effluent limitations are not exceeded.

Nationally, blending has been a controversial issue because of unresolved peak wet weather flow policies. Blending is a common practice at many wastewater facilities during peak flow events when some portion of the primary effluent flow is routed around the secondary treatment process to combine and satisfy secondary requirements. However, this is blending to meet technology based secondary treatment limits for BOD and total suspended solids, which is entirely different from a tertiary process combining filtered and unfiltered effluent for phosphorus control, which far exceeds secondary treatment standards. Nevertheless, the bypass provisions of NPDES permits are worded so strongly that the issue of whether or not combining filtered and unfiltered effluent to meet phosphorus limits results in a potential compliance issue is unclear.

4.8.3 Anti-Backsliding and Permitting

Anti-backsliding refers to statutory and regulatory provisions that prohibit the renewal, reissuance, or modification of an existing NPDES permit that contains effluent limitations, permit conditions, or standards less stringent than those established in the previous permit (EPA, 2010b). When a permit writer determines that effluent limits for a pollutant in permit renewal, or that any of the permit limitations are less stringent than the previous permit, an anti-backsliding analysis must take place. Exceptions do exist where less stringent limitations are acceptable, but the determination of applicability requires careful examination of both statutory and regulatory provisions.

Anti-backsliding may become a factor in the renewal of NPDES permits with nutrient limits when historical effluent performance exceeds that required by an existing permit, or when receiving water quality studies, such as TMDLs, are incomplete and lead to uncertainty about the need for future effluent limits. In these cases, effluent limits may have been established base on historical performance levels that cannot be maintained in the future. This circumstance has led to a reluctance on the part of wastewater utilities to explore optimization of existing treatment processes for nutrient removal because demonstrating an ability to reduce effluent nutrient levels might result in expectations to continue that performance. This is especially of concern in situations where under-loaded wastewater facilities operating at less than full design loadings use available treatment reactor capacity to pursue nutrient removal processes. Later, as flows and loads increase to the originally intended design capacity, it may not be possible to sustain the nutrient removal process explored earlier.

Permit writers should avoid creation of NPDES permits with limits that may unintentionally lead to future anti-backsliding issues unnecessarily. Other methods should be utilized to preserve flexibility for dischargers to make near-term nutrient reductions that are beneficial to water quality without creating anti-backsliding jeopardy by using alternative means, such as further monitoring requirements, compliance schedule requirements, and interim limits.

4.8.4 Bioavailability

Understanding changes in nutrient speciation and bioavailability that occur in advanced nutrient removal treatment is important because effluent concentrations are not only reduced, but the nature of the remaining nitrogen and phosphorus that is discharged is fundamentally changed. Effluent concentrations are reduced, nutrient speciation is altered, and the bioavailability of the remaining nutrients is reduced because the most advanced biological nutrient removal processes will remove most, if not all, of the bioavailable species. This is important to understand for discharge permitting, as well as watershed management, because the nutrients that remain in the effluent from advanced treatment facilities will not impact receiving waters in the same way as secondary effluent.

Research and monitoring data have shown that as treatment facilities remove nutrients to lower concentrations, especially at the limits of treatment technology, the remaining nutrients in the effluent discharged to the receiving water are generally classified as slowly bioavailable. Further reducing the slowly bioavailable nutrients remaining in the effluent may not provide significant benefits to the water quality of the receiving water. The high cost of treatment and the lack of potential benefit to the receiving water make nitrogen and phosphorus speciation an important area of nutrient research, both in terms of biodegradability in wastewater treatment and bioavailability in the water environment.

The translation of TMDL wasteload allocations to NDPES permits limits can vary significantly depending upon the characterization of nutrients in the effluent and how the effluent is represented in water quality modeling. The more sophisticated water quality models have the capability, as currently structured, to accept input describing nutrient speciation and bioavailability providing that monitoring data is available to accurately characterize effluent and receiving waters.

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