Nutrient-Pathogen Evaluation Program for On-Site Wastewater Treatment Systems

Idaho Department of Environmental Quality
in Coordination with the Central District Health Department

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Introduction

The Idaho Department of Environmental Quality (DEQ) requires all applicants for large soil absorption systems (LSAS) to conduct a site investigation using the services of a hydrogeologist or a soil scientist (IDAPA 58.01.03.013.01; http://www2.state.id.us/adm/adminrules/rules/IDAPA58/58INDEX.HTM). Applicants for central septic systems (CSS) may also be required to conduct a site investigation under the permit application requirement section of these rules (IDAPA 58.01.03.005.04). In addition, The Central District Health Department (CDHD) requires property developers to investigate potential impacts to ground water and surface water from on-site wastewater treatment systems.

These investigations must include a comprehensive, scientifically based evaluation of soils, geologic conditions, and water resources in and around the area of the proposed development, CSS, or LSAS. For approval of the on-site wastewater treatment systems, the site investigation (recently termed "nutrient-pathogen (N-P) evaluation") must conclude that the effluent from the treatment systems will not adversely impact the waters of the state.

This document is intended to provide guidance to those required to perform N-P evaluations either under a district health department's Land Development Program or DEQ's oversight of CSS and LSAS. Currently, CDHD is the most active district health department in the N-P Evaluation Program, but other district health departments may adopt this, or similar guidance, as needed for their Land Development Programs.

Applicability

DEQ requires N-P evaluations for all LSAS and those CSS that are located in nitrate priority areas or in areas of "sensitive resource" aquifers (e.g., Spokane Valley-Rathdrum Prairie aquifer) as described in Idaho's Ground Water Quality Rule (IDAPA 58.01.11.300). Figure 1 is a map of the ranked nitrate priority areas. Nitrate priority areas are ranked in order of most significant ground water quality degradation due to nitrate contamination. Nitrate priority area designations are based on a compilation of the available ground water quality data in Idaho and were set by the state's Ground Water Monitoring Technical Committee.

LSAS are those projects in which the proposed wastewater generation rates exceed 2,500 gallons per day (gpd). CSS are systems that receive wastewater in volumes exceeding 2,500 gpd or any system that receives wastewater from more than two (2) dwellings/buildings that are under separate ownership.

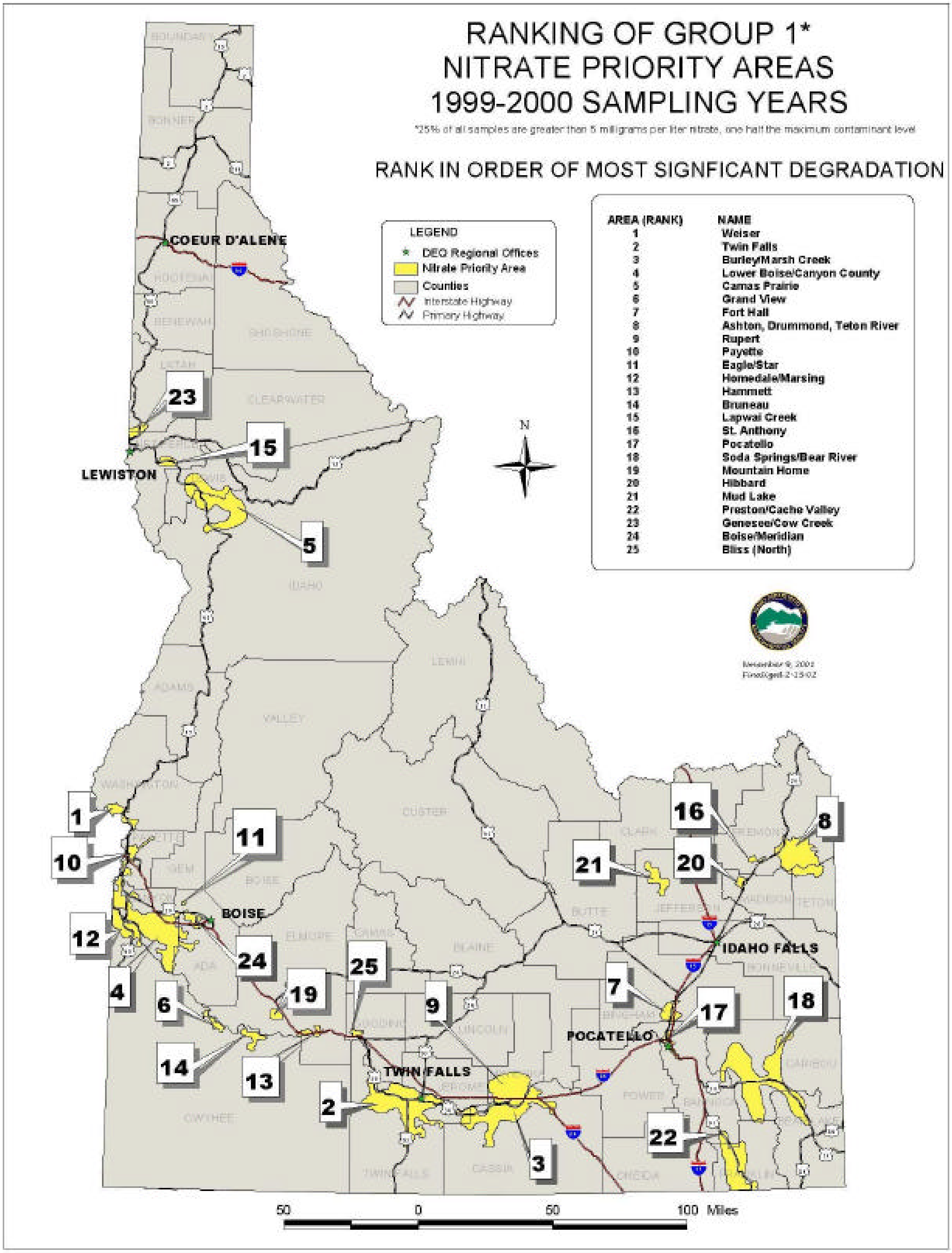

Figure 1. Nitrate Priority Areas.

The CDHD requires N-P evaluations for the following types of developments when on-site wastewater treatment systems are proposed and the development is to be built in an "area of concern:"

- Subdivisions involving five or more lots.

- Commercial facilities generating 600 gallons or more of wastewater per day.

An "area of concern" is defined as:

- An area or region where nutrient and/or pathogen contamination exists and has the potential to create a health risk, or

- An area where the soil depth is shallow or there exists a predominance of gravel or other coarse-grained sediment, a shallow depth to ground water (10 feet or less), or fractured bedrock (10 feet or less below land surface).

CDHD will not require an N-P evaluation for lot splits of original parcels of land on record as of 1984.

The district health departments or DEQ may also require a Level 1 or a Level 2 N-P evaluation (see Tables 1 and 2) on parcels of land where unusual conditions or circumstances give rise to concern about surface or ground water quality. In addition, the district health departments or DEQ may require suitable alternative on-site wastewater treatment system designs to better protect surface or ground water quality, and may consider application of such designs in lieu of performing a Level 2 N-P evaluation.

Whether an N-P evaluation is performed or not, all developments using on-site wastewater treatment systems are subject to the rules governing on-site wastewater treatment systems (IDAPA 58.01.03) and the associated *Technical Guidance Manual for Individual and Subsurface Sewage Disposal Systems* (http://www2.state.id.us/deq/waste/tgm_sewage.htm).

Program Objectives

N-P evaluations are designed to: (1) locate an appropriate number of on-site wastewater treatment systems on a given parcel of land and (2) to direct the placement of the individual on-site wastewater treatment systems in a way that will not significantly degrade the quality of ground water or surface water resources. The objectives are in agreement with the Ground Water Quality Rule (see IDAPA 58.01.11.006).

N-P evaluations must be performed by a qualified party with experience in subsurface resource evaluation practices. The work is typically performed by environmental consultants with backgrounds in geology, hydrogeology, soil science, geochemistry, or related engineering disciplines. The evaluation relates the predicted nutrient and pathogen movement in the subsurface to the type of on-site wastewater treatment system proposed, and the soil, geologic, and hydrologic conditions existing at the site. The professional performing the evaluation must certify that the results and any recommendations on design or placement of on-site wastewater treatment systems satisfy the approval criteria.

Approval Criteria

An approved N-P evaluation must demonstrate that the proposed on-site wastewater treatment system(s) will not degrade ground water or surface water quality beyond existing "background levels" (i.e., the development cannot cause concentrations of nutrients or pathogens in ground water or surface water that exceed those concentrations that exist at the site prior to the development).

As a practical application of this policy, DEQ usually considers the fate of nitrate discharged to the subsurface. Nitrate is often the limiting factor in determining appropriate lot sizes and on-site wastewater treatment system design and placement because it is the most mobile constituent of concern in domestic wastewater and has an impact on public health when the maximum contaminant level (MCL) is exceeded (nitrate-N >10.0 milligrams per liter (mg/l). Note that throughout this document, references to nitrate concentration infer nitrate measured as nitrogen (often reported by laboratories as NO_3 as N).

The evaluation of pathogen fate in the N-P process is accomplished by characterizing soil and geologic conditions to a level that enables the N-P professional to verify that pathogens will be attenuated in the subsurface before impacting surface or ground water. It is not anticipated that pathogen transport modeling can be done with enough certainty to be useful. Selected references on pathogen fate and transport are provided in Appendix 2.

DEQ considers an increase of 1.0 mg/l nitrate, or less, predicted to occur at the compliance boundary as demonstrating a negligible impact. The compliance boundary is defined as one, or any combination of, the following:

- Individual lot boundaries when non-centralized water supply wells are used (e.g., a single on-site wastewater treatment system cannot cause nitrate concentrations to increase more than 1.0 mg/l above pre-development levels as measured at the downgradient lot boundary when neighboring lots contain individual water supply wells).

- Downgradient boundary of the overall subdivision or development when a centralized, or community, water system is used (e.g., nitrate concentrations cannot increase more than 1.0 mg/l above pre-development levels as a result of the combined effect of all on-site wastewater treatment systems as measured at the outermost boundary of the development when the development is served by a centralized water system).

- Surface water bodies when subsurface conditions result in a hydraulic connection between impacted ground water and a surface water body within the boundary of the development. Phosphorus is usually the chemical of concern with respect to surface water quality. Direct coordination with the district health department and DEQ is necessary to design an appropriate N-P evaluation when surface water impacts are a concern.

Nutrient-Pathogen Evaluation Elements

Prior to performing an N-P evaluation, the project representative and N-P professional should meet with the DEQ (for LSAS or CSS projects) and/or the district health department (for individual on-site wastewater treatment systems) to discuss the elements and objectives of the N-P evaluation. The CDHD requires the project representative and N-P professional to submit a work plan (i.e., a scope of work) to CDHD for approval. The purpose of a meeting or work plan submittal is to ensure that unnecessary or inappropriate activities are not completed. Approval of a work plan, in many cases, has expedited the N-P evaluation approval process.

The general term “nutrient-pathogen evaluation” refers to a set of activities that includes the compilation of existing information, collection of site-specific information, and the completion of predictive contaminant fate and transport modeling for ground water. The district health departments or DEQ may allow an abbreviated N-P evaluation (termed “Level 1”) when site conditions or design factors warrant a review of preliminary information prior to determining the need for a more complete Level 2 N-P evaluation.

Level 1 N-P evaluations may be considered under the following circumstances:

- Proposed lot sizes are unusually large,
- Site conditions warrant a review of the “area of concern” designation, or
- A Level 2 N-P evaluation has been performed within ½ mile radius of the proposed development, and site and design conditions are sufficiently similar.

A nitrogen mass-balance spreadsheet with instructions (Microsoft Excel™), available from DEQ, is intended to help the N-P professional assess the expected nitrogen load from the development. This is a simplified screening tool used during the Level 1 evaluation to determine whether a more detailed Level 2 evaluation is needed. The mass-balance spreadsheet allows the N-P professional to adjust lot sizes, orientation with respect to ground water flow, and wastewater treatment options to minimize ground water impacts.

Table 1 and Table 2 summarize the minimum required elements for Level 1 and Level 2 N-P evaluations, respectively.

Table 1. Minimum Data Requirements for **Level 1** N-P Evaluations	Notes/Additional Guidance
▪ Well driller reports for wells within ½ mile radius of the project site	available at IDWR[1]
▪ Map showing the project with proposed lot configuration, property lines, on-site wastewater treatment systems, water supply wells, surface water features, and location of surrounding wells represented by wewelshdf well driller reports	generated by N-P professional or design engineer
▪ Information on the depth to ground water and ground water flow direction	available at IDWR
▪ Information on soil and surface geologic conditions at the site for evaluation of pathogen fate and nutrient migration	county soil surveys available through the NRCS[2] or test hole information available from the local district health department; geologic maps and products available through the IGS[3]
▪ Soil descriptions from test pits excavated at the site	generated by N-P professional and witnessed by the local district health department
▪ Ground water quality data in the vicinity of the project	Treasure Valley data available at DEQ[4] and USGS[5]; statewide data available from other DEQ regional offices and USGS
▪ Use nitrogen mass-balance spreadsheet to estimate impacts from the development	Use spreadsheet developed by DEQ

A Level 1 N-P evaluation may suffice if: (1) the results of the mass-balance spreadsheet indicate a nitrogen impact to ground water less than or equal to 1.0 mg/l nitrate, or (2) data demonstrate that site conditions do not warrant the “area of concern” designation.

[1] Idaho Department of Water Resources, 1301 N. Orchard, Boise (208) 327-7900; http://www.idwr.state.id.us/
[2] Natural Resources Conservation Service; this is a federal agency; contact district office in your area; http://www.nrcs.usda.gov/
[3] Idaho Geological Survey, Branch Office at Boise State University Math-Geology, Room 229, (208) 426-4002; http://www.idahogeology.org/default.htm
[4] Idaho Department of Environmental Quality, Boise Regional Office; contact Linda Boyle (208) 373-0550; http://www2.state.id.us/deq/
[5] United States Geological Survey, Water Resources Division, Idaho District; contact Deb Parliman (208) 387-1326; http://idaho.usgs.gov/

Table 2. Minimum Data Requirements for **Level 2** N-P Evaluations	Notes/Additional Guidance
▪ Fulfill all requirements in Table 1	see Table 1
▪ Install a minimum of three monitoring wells into the uppermost aquifer to: (1) determine existing site-specific background ground water quality, (2) establish site-specific ground water flow direction, and (3) establish site-specific aquifer hydraulic conductivity	performed by N-P professional; IDWR may require a drilling permit
▪ At a minimum, analyze water samples collected from on-site wells for pH, conductivity, temperature, chloride, sulfate, sodium, nitrate+nitrite, total Kjeldahl nitrogen (TKN), ammonia, ortho-phosphate, total organic carbon, total dissolved solids, and fecal coliform bacteria	generated by N-P professional
▪ ONLY for N-P evaluations with phosphorus considerations or for evaluating nutrient attenuation in the vadose or saturated zone, analyze soil samples (collected from pits or borings) for pH, moisture content, bulk density (calculate porosity), nitrate+nitrite, TKN, ammonia, ortho-phosphate, organic matter, and cation exchange capacity	OPTIONAL generated by N-P professional
▪ ONLY for N-P evaluations that consider nutrient attenuation in the vadose or saturated zone, analyze water samples for dissolved oxygen (or redox potential), dissolved organic carbon, nitrate+nitrite, TKN, and ammonia; describe stratigraphy and moisture content relationships in the soils between the bottom of the drainfield and the top of the water table; document any downgradient changes in aquifer characteristics conducive to denitrification, such as the existence of riparian zones, that are upgradient of proposed points of compliance	OPTIONAL generated by N-P professional
▪ Perform contaminant fate and transport modeling	generated by N-P professional; additional guidance follows

The guidance provided in Table 1 and Table 2 is not a substitute for the experience and judgement required on the part of the N-P professional. Other types of information may be warranted due to the unique characteristics of a project. Also, data sources not listed may provide more useful information relative to a particular project.

Nutrient Predictive Modeling

Ground water flow and contaminant transport modeling is used in N-P evaluations as a tool to predict the impact of the proposed development on ground water quality. Surface water quality may also need to be considered if ground water discharges to nearby drains or creeks.

In most cases, it is assumed that nitrate will be the contaminant that dictates the necessary lot configuration, lot size, and on-site wastewater treatment system placement. Nitrate is the most mobile constituent of concern in domestic wastewater and is used as a surrogate for other constituents in the modeling effort. Other elements of the N-P evaluation (e.g., soil analyses) need to address the adequacy of pathogen and phosphorus attenuation.

It is imperative that the modeler develop a realistic site conceptual model by: (1) collecting adequate information on the subsurface geologic structure and aquifer properties and (2) considering factors such as the influence of nearby surface water bodies or pumping wells. In simplified modeling scenarios, it is inherent that assumptions and professional judgement will be used. When the need arises, use conservative assumptions to predict "worst-case" conditions. Also provide clear justification for any assumptions used.

Nutrient Modeling Parameters

The model must simulate all sources of contaminant input simultaneously (i.e., multiple contaminant source locations corresponding to the proposed on-site wastewater treatment system locations and development configuration). This will ensure that interactions between adjacent contaminant source locations are assessed (e.g., additive effects from drainfields aligned along a common flow path or the joining of adjacent contaminant plumes due to dispersion).

Below are some basic modeling requirements that must be met and default assumptions that must be made, unless a variance is provided by the district health department or DEQ:

1. Model non-reactive chemical transport to conservatively simulate nitrate migration. Contaminant transport simulations should project plume migration at time periods of 5, 10, and 20 years after on-site wastewater treatment system use begins.

2. Areally distributed recharge to the aquifer is typically not considered. If the project developer or N-P professional wants to consider the effects of recharge from precipitation or irrigation, the nutrient load associated with the recharge must also be investigated and included in the model.

3. Ground water flow direction: determined at the site by the installation of at least three monitoring wells constructed in the uppermost aquifer. An accurate elevation survey must be performed to establish the relative elevation of the monitoring wells.

4. Hydraulic conductivity: determined at the site by aquifer pumping tests, slug tests, or by use of an empirical formula based on grain-size distribution analysis. In some cases, samples collected from site borings may be submitted for laboratory analysis of hydraulic conductivity. Another acceptable and potentially useful means of estimating hydraulic conductivity (for fine-grained sediments) is through the use of quasi-empirical models such as Rosetta (U.S. Salinity Laboratory, USDA-ARS, 1999)[6]. Slug tests should be performed on multiple wells, specified in an approved work plan, to represent site-wide conditions. Grain-size analyses should be

[6] U.S. Department of Agriculture-Agricultural Research Service Salinity Laboratory. 1999. Rosetta (computer model authored by Marcel Schapp) available for download at http://www.ussl.ars.usda.gov/MODELS/rosetta/rosetta.htm#Abstract

performed on samples collected from the uppermost aquifer at multiple well locations.

The default empirical formula using grain-size distribution analysis is provided by Alyamani and Sen (1993)[7]:

$$K = 1300[I_0 + 0.025(d_{50} - d_{10})]^2$$

K = hydraulic conductivity (m/day); I_0 = graphical horizontal axis intercept provided in the cited method (mm); d_{50} and d_{10} = 50% and 10% passing grain sizes on standard grain-size distribution curves, respectively (mm).

5. Aquifer thickness: determined by an analysis of on-site boring logs and well driller reports for nearby wells.

6. Background concentrations of nitrate (or other constituents listed in Table 2, such as ortho-phosphate, when required): determined by sampling on-site monitoring wells and by considering existing regional nitrate data.

7. Contaminant source introduction: the conservative approach calls for introduction of the total volume of septic tank effluent within the upper 15 feet of the aquifer. One hundred percent conversion of all nitrogen forms to nitrate at the water table is assumed. Typically, no consideration is given to nitrogen attenuation during transport through the vadose zone, although such an analysis could be proposed to the district health department or DEQ for approval. Default values of wastewater volume and nitrogen concentration are 300 gallons per day (four-bedroom home) and 45 mg/l nitrogen for each drainfield, respectively. Adjustments to nitrate input concentrations may be considered for systems utilizing enhanced nutrient treatment, or where other site-specific factors (e.g., geochemical conditions resulting in de-nitrification) warrant adjustment.

   Nitrate source locations may be modeled as injection wells placed in the locations of the proposed drainfields or as area recharge over zones sized to represent the drainfield footprint. For grid-based models, the grid must be sized to represent the size of the individual nutrient sources (both for wells and areally distributed nitrate introduction).

8. Aquifer porosity: determined by a laboratory analysis of soil bulk density (to calculate porosity) from samples collected at the site, or from text book values for typical aquifer materials.

9. Dispersivity: dispersivity is shown to be scale-dependent (e.g., Xu and Eckstein, 1995)[8]. For purposes of N-P evaluations, the default value shall be 20 feet for longitudinal dispersivity and 0.8 feet for transverse (horizontal) and 0.08 feet for transverse (vertical) dispersivity. The longitudinal dispersivity value is based on

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[7] Alyamani, M.S. and Z. Sen. 1993. Determination of hydraulic conductivity from complete grain-size distribution curves. Ground Water. v. 31, no. 4, pp. 551-555.

[8] Xu, M. and Y. Eckstein. 1995. Use of weighted least-squares method in evaluation of the relationship between dispersivity and field scale. Ground Water. v. 33, no. 6, pp. 905-908.

analyses presented by Xu and Eckstein (1995) showing that longitudinal dispersivity may be represented by the formula:

$\alpha_L = 0.83 (\log_{10}L)^{2.414}$ where α_L is longitudinal dispersivity (in meters) and L (in meters) is the field scale, which can be interpreted to represent the estimated nitrate plume length.

N-P evaluations conducted in granular aquifer settings in southern Idaho since 1997 have provided estimates of nitrate plume lengths of 100 to 300 feet. However, a thorough review of scientific literature and numerical modeling simulations performed by DEQ suggest that these early N-P program nitrate transport simulations may have underestimated plume lengths due in part to the use of high dispersivity values. Much of the scientific literature documents the existence of long, narrow plumes (for conservative contaminants or tracers), reflecting low dispersivity values, especially in the transverse direction. References to many of the publications reviewed are found in Appendix 2 under the "Dispersion and Dispersivity" heading.

More realistic plume lengths (in coarse alluvial sediments) are probably in the range of 500 to several thousand feet. Considering the "high reliability" dispersivity estimates compiled by Gelhar et al. (1992)[9] and Xu and Eckstein's (1995) regression analysis, DEQ has chosen representative α_L , $\alpha_{TH,}$ α_{TV} values of 20, 0.8, and 0.08 feet, respectively.

Table 3 provides a summary of default modeling parameters. Alternative values may be warranted in some cases, but must be supported by site-specific data.

[9] Gelhar, L.W., C. Welty, and K.R. Rehfeldt. 1992. A critical review of data on field-scale dispersion in aquifers. Water Resources Research. v. 28, no. 7, pp. 1955-1974.

Table 3. Nutrient Modeling Default Parameters	
Parameter	Value or Description
Flow model	▪ steady-state simulation of uppermost aquifer
Solute transport model	▪ transport predictions at 5, 10, and 20 years in the future; simulate nitrate as non-reactive
Grid design (when applicable)	▪ refine ("customize") grid in the area of interest; cell sizes near drainfields must be small (e.g., 5 to 20 feet) ▪ size of adjacent cells in a "customized" or refined grid cannot increase or decrease by more than 1.5 times in any direction
Aquifer top/bottom elevations and model layers	▪ determined by review of well driller reports and existing scientific literature
Hydraulic conductivity	▪ determined by one or a combination of: (1) aquifer pumping tests; (2) slug tests in at least three wells; (3) grain-size analysis in conjunction with an empirical formula; (4) quasi-empirical modeling using Rosetta (U.S. Salinity Laboratory); or (5) laboratory analyses (i.e., permeameter procedures)
Gradient of uppermost ground water surface	▪ determined by water level measurements in monitoring wells and review of existing regional data
Effective porosity	▪ assume 0.20 to 0.35 for medium-sized granular materials ▪ assume 0.20 for fractured bedrock
Aquifer recharge	▪ assume no areally-distributed recharge; more complex scenarios considered on a site-specific basis
Dispersivity	▪ $\alpha_L = 0.83 (\log_{10} L)^{2.414}$ where α_L is longitudinal dispersivity (in meters) and L (in meters) is the field scale which can be interpreted to represent the estimated nitrate plume length; usually, this value should be about 6 meters or 20 feet ▪ assume α_{TH}(transverse-horizontal dispersivity) = 0.8 feet ▪ assume α_{TV} (transverse-vertical dispersivity) = 0.08 feet
Wastewater flow per drainfield	▪ 300 gal/day (assumes four bedroom home); see Technical Guidance Manual (pages 113-115) for other flow rates
Nitrate concentration in wastewater	▪ 45 mg/l[10,11] ; (assumes 100% conversion of all N forms to nitrate; nitrate measured as N)
Nitrate concentration for enhanced nutrient treatment systems	▪ 32 mg/l (assumes 30% nitrate reduction versus standard systems)

[10] Small Scale Waste Management Project, University of Wisconsin, Madison. 1978. Management of Small Waste Flows. EPA 600/2-78-173, NTIS Report PB 286 560, September 1978. 804 pp. Table A-113 Septic Tank Effluent Quality - Field Sites.

[11] USEPA, Office of Water Program Operations.1980. Design Manual: Onsite Wastewater Treatment and Disposal Systems. EPA 625/1-80-012, October 1980. 391 pp. Table 6-1 Summary of Effluent Data From Various Septic Tank Studies.

Nutrient Modeling Parameter Variances

Consideration of more realistic nutrient fate and transport phenomena may provide benefits to the project developer. However, additional data collection and model development is required. Justification for performing more complex modeling or using parameters that deviate from the default values or requirements will be necessary. The developer and the N-P professional should assess the costs and benefits associated with more complex modeling.

Two areas in particular offer the potential to perform more complex modeling with potential benefits to the developer: (1) consideration of attenuation of nitrogen in the vadose zone or in the saturated zone, and (2) areally-distributed recharge, including nutrients carried by the recharge water. The additional soil testing requirements associated with vadose zone attenuation are described in Table 2. Other project-specific requirements must be discussed with DEQ or the district health department prior to implementation.

Attenuation of nitrogen in the vadose and saturated zones, other than by dilution or dispersion, occurs primarily through the process of denitrification. During denitrification, nitrogen in nitrate form, acting as an electron acceptor, is reduced through a series of microbial-mediated reactions to nitrous oxide (N_2O) or nitrogen gas (N_2). The conditions that are necessary for the complete series of reactions to occur include:

- Adequate temperature; while rates of denitrification increase as temperature increases, it has been found that isolates of denitrifying microbial populations were capable of growth and activity at temperatures as low as 39 degrees Fahrenheit (Gamble et al., 1977)[12].

- Reducing conditions; the presence of anaerobic conditions is critical to successful denitrification. In aquifers this is indicated by dissolved oxygen concentrations below about 0.5 mg/l. In soils, areas of high moisture content, greater than 60 to 80 percent of saturation, are typically associated with poor aeration, low oxygen content, and measurable rates of denitrification. These areas of high saturation may occur as a result of layering of materials of differing permeability such as found in perched water areas. In the case of soils, the reducing conditions must be present for a sufficient period of time along with the other factors described (adequate temperature and carbon) in order for denitrification to be significant.

  For denitrification to occur in these zones of reduced aeration, it is assumed that the wastewater has encountered a prior aerated zone that would permit the transformation of ammonium nitrogen to nitrate.

- Carbon source; the availability of sufficient, readily mineralizable carbon that can be used as an energy source by microbes is the most critical limitation to denitrification typically identified in field studies associated with on-site wastewater nitrogen

[12] Gamble, T.N., M.R. Betlach, and J.M. Tiedje. 1977. Numerically dominant denitrifying bacteria from world soils. Applied Environmental Microbiology. vol. 33. pp. 926-939.

impacts (DeSimone and Howes, 1998)[13]. This type of organic carbon is often found naturally in soils and aquifers consisting of heterogeneous, layered deposits of fine and coarse-textured materials such as in riparian zones. It can be leached from organic-rich surface soil horizons or it can be provided by the wastewater itself (although much of this carbon is often depleted via transformations in the septic tank and drainfield). A rule of thumb regarding microbial denitrification is that if the nitrate concentration exceeds the organic carbon concentration in ground water the amount of carbon is insufficient to denitrify the nitrate (Korom, 1992)[14].

- Adequate microbial populations; this is usually not a limiting factor in evaluating the potential for denitrification to occur.

Rates of denitrification in both soils and ground water have been shown to vary substantially, both spatially and temporally. In agricultural soils it is generally assumed that 15 to 20 percent of applied fertilizer, on average, is lost to denitrification (Myrold, 1991). Studies of denitrification associated with on-site wastewater treatment systems have found that losses range from 0 to 35 percent (Ritter and Eastburn, 1985). In ground water, for coarse-textured alluvial aquifers, daily losses via denitrification in field studies ranged from <1 to 24 percent of initial nitrate concentrations with an average of about 7 percent (Korom, 1992; DeSimone and Howes, 1998).

Incorporation of the attenuation mechanism of denitrification into an N-P evaluation will require: (1) sufficient site-specific documentation regarding the presence of the conditions described above to provide confidence that denitrification may be operational, (2) a description of how denitrification is implemented in the model that will be used, (3) the associated model input requirements, and (4) justification for the input values chosen.

Model Boundary Conditions

It is generally desirable to confine the model domain with real physical boundaries, such as impermeable geologic contacts or hydraulically connected surface water features.[15] Impermeable geologic contacts can be represented as no-flow boundaries. Surface water features are often represented as constant head or constant flux boundaries.

Nutrient predictive modeling is usually performed on a local scale and the distance to such permanent features may prohibit their use as external model boundaries. In most cases, artificial boundaries (sometimes called “hydraulic” boundaries) must be designated by the modeler. Hydraulic boundaries can be no-flow boundaries represented by streamlines (lines perpendicular to equipotential lines) or boundaries with known hydraulic head (constant head boundaries) represented by equipotential lines. These features are less desirable model boundaries than real physical features because they are not permanent and can change with time. Hydraulic boundaries must

[13] DeSimone, L.A. and B.L. Howes. 1998. Nitrogen transport and transformations in a shallow aquifer receiving wastewater discharge: A mass balance approach. Water Resources Research. vol. 34, no. 2, pp. 271-285.
[14] Korom, S.F. 1992. Natural denitrification in the saturated zone: A review. Water Resources Research. vol. 28, no. 6, pp. 1657-1668.
[15] For an overview of modeling, including model boundaries, see (1) Kresic, N. 1997. Quantitative Solutions in Hydrogeology and Groundwater Modeling. Lewis Publishers, Boca Raton, 461 p. or (2) Anderson, M.P. and W.W. Woessner. 1992. Applied Groundwater Modeling, Simulation of Flow and Advective Transport, Academic Press, New York, 381 p.

be set far enough from the area of interest (i.e., the drainfield locations) so that they do not influence the flow pattern resulting from the introduction of wastewater from the drainfields.

Surface water features found in the model domain, such as agricultural drains, canals, springs, streams, rivers, lakes and reservoirs must be considered. These features may represent a source of recharge or a point of discharge to the aquifer, or their water quality may be adversely impacted by the development. Surface water features hydraulically connected to an underlying aquifer can be represented as a constant head, constant flux, or variable flux boundary.

In all cases, it is necessary to base boundary condition selections on the physical and hydraulic characteristics of the project location, and to document why the boundary conditions were chosen. Flux boundaries must be as realistic as possible even if they are adjusted during model calibration. Data from regional or local water budget assessments are often necessary to assign reasonable flux boundaries.

Assessing Model Uncertainty

N-P modeling is typically performed in a “predictive” mode without the benefit of being able to directly measure the development’s impact to ground water or surface water. Therefore, formal calibration of the contaminant fate and transport model component is usually not possible. However, the output from the flow component of the model (i.e., modeled heads) must be compared with on-site and regional ground water elevations to assess the accuracy of the model.

The N-P evaluation report must include a discussion about the accuracy of the flow component and about any other parameters (flow or contaminant transport) that are particularly sensitive. Several model runs that include a range of input parameters may be warranted when the uncertainty about the value of key parameters is high. Remember that modeling predictions should err on the side of conservatism (i.e., “worst-case” scenarios need to be taken into account in the development design).

Reporting

A thorough presentation of compiled historical data and the data collected from the project site shall be submitted in a written report along with a completed N-P Project Summary and Checklist (Appendix 3). The report shall include a professional’s interpretation and certification of the findings as well as recommendations for design or the need for further site evaluation. All interpretations need to be well supported by the N-P evaluation data. A suggested outline for an N-P evaluation report follows:

> <u>Title</u>: Include a project name and specify whether the information represents a “Level 1” or “Level 2” N-P evaluation.
>
> 1.0 <u>Introduction</u>: list the name of the project, project location, legal description and current land uses; also discuss the intended site use and development design; anticipated wastewater characteristics; geographic, geologic, and hydrologic setting and water well inventory.

2.0 Field Investigation: describe the installation of borings, soil test pits, and monitoring wells; discuss the protocol used in sampling (all media involved), aquifer hydraulic conductivity testing, pathogen fate assessment, and contaminant fate and transport modeling for ground water; include documentation supporting assumptions made during model development.

3.0 Results: Discuss soil conditions; ground water elevation and flow characteristics; background water quality; hydraulic conductivity; nutrient-pathogen fate issues; model results; model uncertainty.

4.0 Conclusions: summarize the key elements of the evaluation.

5.0 Recommendations: provide recommendations for development layout; on-site wastewater treatment system design; water supply and well construction; and the need for further evaluation activities.

The presentation of recommendations on the part of the N-P professional constitutes certification that: (1) the data adequately support the recommendations and, (2) that interpretations based on the data are accurate and represent sound, unbiased professional judgement.

Monitoring

Currently, neither the health districts nor DEQ requires post-development ground water monitoring except in instances involving LSAS or CSS (see IDAPA 58.01.03.013; http://www2.state.id.us/adm/adminrules/rules/IDAPA58/58INDEX.HTM). However, periodic sample collection from ground water monitoring wells installed as part of the N-P evaluation is recommended.

It is recommended that samples be collected at least twice per year (usually during times that represent low water table and high water table conditions) and analyzed for nitrate+nitrite, TKN, chloride, sodium, and coliform density (total and fecal coliform and fecal streptococcus) bacteria. Evaluation of the monitoring results is the only way to assess the validity of the predictive modeling. Anomalous or unexpected monitoring results should be discussed with the district health department and DEQ in order to formulate an appropriate remedy.

Conclusions

These guidelines provide a reasonable approach to typical N-P evaluation scenarios. They should be used in conjunction with sound scientific reasoning and judgement. Projects presenting unusual problems or issues should be discussed ahead of time with DEQ or the district health department. N-P evaluations are performed as part of the requirements for the Individual/Subsurface Sewage Disposal Rules (IDAPA 58.01.03) and the Ground Water Quality Rule (IDAPA 58.01.11).

Residential subdivisions and commercial developments include other potential sources of water pollutants. For example, storm water disposal structures and fertilization of lawns and other landscaped areas may introduce nitrate and other contaminants to the subsurface. N-P evaluations, at this point in time, do not address these other sources of contamination unless a more complex modeling project is performed (optional).

Any nutrient application to landscaped areas is assumed to be performed under best management practices to prevent ground water or surface water contamination. Nutrient budgets should be used to guide fertilizer application. It is especially important to consider existing nutrient concentrations in the soil and in the water supply before applying additional fertilizer. Storm water disposal features must be constructed using the State of Idaho *Catalog of Storm Water Best Management Practices* published by DEQ in June 1997 (see http://www2.state.id.us/deq/policies/pm98_3.htm).

American Society of Civil Engineers seepage/ground water modeling links
http://emrl.byu.edu/gicac/gw.html

Bacterial source tracking web pages
http://www.bsi.vt.edu/biol_4684/BST/BST.html

Central District Health Department Environmental Health Division
http://www.phd4.state.id.us/EnvironmentalHealth/

Environmental Modeling Systems, Inc. (GMS)
http://www.ems-i.com/

Idaho State Department of Agriculture water quality information
http://www.agri.state.id.us/agresource/gw/Water%20Resources%20TOC.htm

Idaho Department of Environmental Quality home page
http://www2.state.id.us/deq/

Idaho Department of Environmental Quality rules
http://www2.state.id.us/adm/adminrules/rules/IDAPA58/58INDEX.HTM

Idaho Department of Water Resources Snake River Resources Review study area
http://www.idwr.state.id.us/usbr/

Idaho Department of Water Resources technical information
http://www.idwr.state.id.us/planpol/

Idaho Geological Survey home page
http://www.idahogeology.org/

Idaho Technical Guidance Manual for Individual and Subsurface Sewage Disposal Systems
http://www2.state.id.us/deq/waste/tgm_sewage.htm

Idaho Water Update (outreach newsletter)
http://www.idahowaterupdate.com/

Isogeochem stable isotope resources
http://geology.uvm.edu/geowww/isogeochem.html

Leopold Center for Sustainable Agriculture at Iowa State University
http://www.leopold.iastate.edu/

Natural Resources Conservation Service science & technology
http://www.info.usda.gov/nrcs/SandT/

North Carolina on-site wastewater non-point source pollution program
http://www.deh.enr.state.nc.us/oww/nonpointsource/NPSseptic/npsseptic.htm

Oregon State University Hillslope and Watershed Hydrology Group
http://www.cof.orst.edu/cof/fe/watershd/h20fram5.html

State of Idaho access to state information
http://www.accessidaho.org/index.html

U.S. Department of Agriculture office information locator
http://offices.usda.gov/scripts/ndISAPI.dll/oip_public/USA_map

U.S. Department of Agriculture, Agricultural Research Service, Salinity Laboratory
http://www.ussl.ars.usda.gov/index000.htm

U.S. Environmental Protection Agency Center for Subsurface Modeling Support
http://www.epa.gov/ada/csmos.html

U.S. Environmental Protection Agency Office of Ground Water and Drinking Water
http://www.epa.gov/safewater/dwhealth.html

U.S. Geological Survey ground water information pages
http://water.usgs.gov/ogw/

U.S. Geological Survey Idaho District Office
http://idaho.usgs.gov/

U.S. Geological Survey national mapping information
http://mapping.usgs.gov/

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Appendix 3
N-P Project Summary and Checklist

General Project Information	
Project/Subdivision name:	
N-P Level (1 or 2):	
N-P Evaluation performed by:	
Date:	
Development area (acres):	
Number of lots:	
Range of lot sizes (acres):	
County:	

Level 1 (check elements included in report)		
Required Element	Included	Notes:
Well driller reports within ½ mile radius	☐	
Project map	☐	
Ground water depth and flow information	☐	
General soil and surface geologic information	☐	
Soil descriptions from on-site test pits/borings	☐	
Ground water quality information for vicinity	☐	
Mass-balance spreadsheet results	☐	

Level 2			
Parameter	N-P Default	Value Used	Comments/Justification
Monitoring wells installed	3 (minimum)		
Number of water quality samples collected	3 (minimum)		
Type of flow and transport model used:	site-specific		
Grid spacing	site-specific		
Aquifer top elevation (ft)	site-specific		
Aquifer bottom elevation (ft)	site-specific		
Hydraulic conductivity (ft/d)	site-specific		
Ground water gradient	site-specific		
Effective porosity: ▪ medium-sized sediment ▪ fractured rock	 0.20 to 0.35 0.20		
Dispersivity: ▪ α_L(ft) ▪ α_{TH}(ft) ▪ α_{TV}(ft)	 20 0.80 0.08		
Wastewater flow per drainfield (gal/day)	300		
Nitrate concentration per drainfield (mg/l as N)	45		
Nitrate source introduction: ▪ injection wells ▪ recharge from surface	 upper 15 ft of aquifer recharge area sized to match drainfields		
Complex Models (optional)			

Level 2			
Parameter	N-P Default	Value Used	Comments/Justification
Provide narrative description of additional modeling parameters for: ▪ models considering vadose zone or saturated zone attenuation ▪ areally-distributed recharge from irrigation and precipitation ▪ phosphorus modeling			