Draft
Spokane County
Critical Aquifer Recharge Areas Review
Technical Memorandum #3

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Table of Contents

Introduction **1**

Study Objectives and Approach 1

Overview **2**

Constituents of Concern **3**

Sanitary Wastewater Loads **3**

Scenarios – Sanitary Wastewater Loads to Soils 4

Wastewater Loading to Groundwater **5**

Mixing of Wastewater and Groundwater 6

Scenarios –Wastewater Loads to Groundwater 8

Allowable Wastewater Loads to Groundwater 10

Next Steps **12**

References **13**

List of Tables

Table 1. Scenarios – Sanitary Wastewater Loads To Soils 4
Table 2. Scenarios – Sanitary Wastewater Loads to Groundwater 10

List of Figures

Figure 1. Process Flow for On-Site Non-Residential Wastewater 2
Figure 2. Schematic of Mixing Zone 6
Figure 3. Allowable Wastewater Nitrogen Loading for 2 mg/L Point of Compliance Increase 11
Figure 4. Allowable Wastewater Nitrogen Flow and Concentration for a Mixing Zone Width of 100 ft, Upgradient Concentration of 0 mg/L at 2 mg/L Downgradient Increase 12

Attachments

Attachment A – Maximum Hydraulic Loading Rate
Attachment B – Nitrate Balance Spreadsheet
Attachment C – Hydraulic Conductivity Values

Acronyms

C	carbon
CARA	critical aquifer recharge area
CT DEP	Connecticut Department of Environmental Protection
gpd	gallons per day
HDR	HDR Engineering, Inc.
IDEQ	Idaho Department of Environmental Quality
lbs/yr	pounds per year
MDEQ	Montana Department of Environmental Quality
mg/L	milligrams per liter
N	nitrogen
N-P	nutrient-pathogen
O	oxygen
POC	point of compliance
SCC	Spokane County Code
TMDL	total maximum daily load
UGA	urban growth area
WDOE	Washington Department of Ecology
WDOH	Washington Department of Health

Introduction

Study Objectives and Approach

The objective of this study is to review, and if necessary, recommend updates to the critical aquifer recharge area (CARA) wastewater disposal standards for non-residential uses and activities outside the urban growth areas (UGA) boundary (Spokane County Code (SCC) 11.20.075). HDR Engineering, Inc. (HDR) is working with Spokane County to review the current standard and to evaluate the need for standard revisions. An important component of this project is stakeholder participation, which includes a series of meetings and document review. Stakeholder engagement is being supported by Sarah Hubbard-Gray of Hubbard Gray Consulting.

This study involves an assessment of non-residential sanitary wastewater loadings to soils (typically through septic system drainfield) that are protective of groundwater in susceptible aquifer areas outside the UGA boundary. Understanding loadings that are protective of groundwater in this sensitive area allows for recommendations for revised standards. In addition, surface water protection associated with groundwater-to-surface-water discharge will be considered in this analysis. Acceptable constituent loadings to soil that lead to loadings to groundwater are dependent upon several factors, including wastewater constituent type, soil hydraulic and adsorption properties, groundwater properties, surface water properties, hydraulic loadings, and effluent attenuation factors.

To meet project objectives, the following tasks are being conducted:

a. Define area of study.
b. Define non-residential uses.
c. Define non-residential sanitary wastewater characteristics.
d. Define environmental/resource properties for the area of study.
e. Define groundwater quality criteria.
f. Analyze the aquifer mixing zone.
g. Determine soil loadings.
h. Determine sanitary wastewater loadings.
i. Develop a predictive model.

Four technical memoranda (drafts and finals) are being developed during the study that describe the above listed tasks and findings, along with supporting documentation:

i. Technical Memorandum # 1 – Introduction of regulations and description of current standards and summary of tasks a through d (listed above).
ii. Technical Memorandum # 2 – Documentation for task e.
iii. Technical Memorandum # 3 – Documentation for tasks f through h.
iv. Technical Memorandum # 4 – Documentation for task i.

This document, *Technical Memorandum #3*, presents the following information:

- Description of sanitary wastewater loads to soils and groundwater.
- Description and examples of aquifer mixing model and parameters.

Overview

Figure 1 provides a general flow process diagram for sanitary wastewater entering an on-site treatment system from a non-residential use. For this system, sanitary wastewater (influent) is discharged from a non-residential facility (influent wastewater) and enters into an on-site treatment system (commonly a septic tank) where it receives primary biological treatment. This treatment involves the digestion of wastewater into liquid, fats and grease, and insoluble particles. The fine insoluble particles settle to the bottom of the septic tank forming sludge. Greases and fats float to the top forming a scum layer. The liquid (effluent) flows through the outlet pipe into the drainfield piping and then into the soil. Once in the soil system, some constituents in the effluent can undergo secondary biological and chemical interactions (treatment). For example, organic nitrogen can undergo biological mineralization and nitrification processes (microbial process of converting organic nitrogen to ammonium and then to nitrate) and phosphorus can be adsorbed by soil clays. The hydraulic loading of the drainfield effluent to soils typically exceeds the ability of the soil to retain this water, thus the effluent, with its dissolved constituents (leachate), can move by gravity downward through the soil system and enter the groundwater system.

In order to assess non-residential on-site wastewater disposal standards under CARA, it is necessary to evaluate the following steps:

1. Influent wastewater loading to the treatment system (septic tank).
2. Effluent wastewater loading to the drainfield.
3. Leachate moving into and through the soil system after discharge from the drainfield.
4. Leachate loading into the groundwater.
5. Groundwater to surface water (only for some constituents, and only where there is a groundwater to surface water pathway)

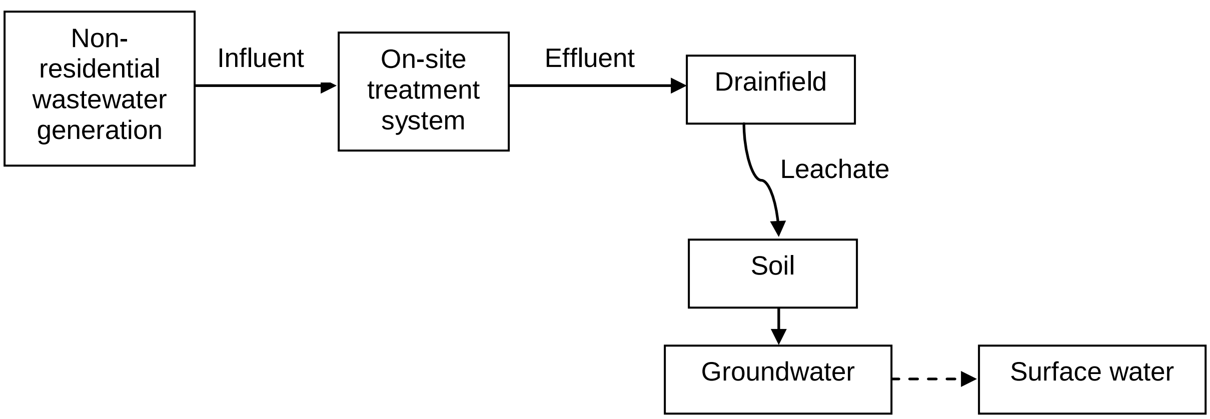

Figure 1. Process Flow for On-Site Non-Residential Wastewater

Constituents of Concern

The constituents of concern in non-residential sanitary wastewater are described in technical memoranda #1 and #2. The CARA evaluation is considering nitrate and phosphorus as the primary constituents of concern.

Much of the regulatory focus for groundwater protection from on-site treatment systems has been on nitrate. This compound is very mobile in soil and groundwater systems, is at relatively high concentrations in effluent (e.g., typically in the 40 to 60 milligrams per liter [mg/L] range compared to a groundwater quality standard of 10 mg/L), and is a “primary contaminant” under the groundwater quality standards. Nitrate is a “primary contaminant” due to its biological affects (EPA 1980; Lee et.al, 2005).

Phosphorus was selected as an important constituent to analyze due to the total maximum daily load (TMDL) for the Spokane River, which sets phosphorus allocations (WDOE 2010). While the design and permitting of on-site septic systems has historically focused on nitrates and pathogens, more recently, phosphorus loads have been identified as an important contributor to eutrophication of sensitive waters. There is evidence that phosphorus from on-site septic systems affects groundwater and surface water (HDR 2007). Studies have shown drainfields have a hydraulic connection to groundwater and under some conditions can release a phosphorus load; therefore, there is increasing recognition and concern about phosphorus leaching from on-site septic systems reaching surface waters (DDNR 2006; IDEQ 2006; MDEQ, 2009; Dillon, et.al, 1986). These concerns are based on findings showing on-site septic systems to be major contributors of phosphorus loads to surface waters (Doyle, et.al, 2005; McCray, et.al, 2005; McCray, et.al, 2000; TSWQC 2005).

The focus of this technical memorandum is nitrate, as this is the most common groundwater pollutant associated with on-site treatment systems. Phosphorus will be covered under separate cover. The need for evaluating other constituents will be considered once protocols are established for nitrate and phosphorus.

Sanitary Wastewater Loads

Non-residential sanitary wastewater is described in *Technical Memorandum #1*. Sanitary wastewater generally means wastewater such as associated with personal hygiene, food preparation, or cleaning. (See *Technical Memorandum #1* for regulatory definition). For Spokane County, a wide variety of services (e.g., schools) and retail (e.g., restaurants) fall into the non-residential wastewater category. Wastewater generating activities in some non-residential establishments are similar to those of residential dwellings. For example, a retail store may have restrooms, a small kitchen, and employee showers, and would generate similar wastewater characteristics as a dwelling. A restaurant would generate a waste stream dominated by dishwashing activities and food waste, and would have a waste stream of greater volumes and solids loading compared to a typical single-family dwelling. A church’s waste stream would be expected to generate low solids loading (dominated by urine) compared to a typical residential waste stream.

Load is the mass of the constituent in the water and is calculated as the wastewater flow multiplied by the wastewater concentration. This calculation in typical units is shown in **Equation 1**.

$$Load\left(\frac{lbs}{yr}\right) = Flow(gpd) \times Concentration(\frac{mg}{L}) \times 3.875(\frac{L}{gal}) \times \frac{1}{453{,}592.37}(\frac{lb}{mg}) \times 365(\frac{day}{yr})$$

Equation 1. Load Equation

The quality and quantity of treated wastewater load to soils (leachate) are dependent on the following parameters:

- Type of facility or use (e.g., non-residential: restaurant, school, supermarket).
- Treatment type (e.g., conventional septic tank and drainfield or advanced treatment).
- Flow rate (based on type of facility).
- Constituent type (e.g., nitrogen, phosphorus).
- Concentration (based on the treatment type).
- Duration (e.g., constant or periods of high flows and concentrations).
- Frequency (e.g., occasional, daily, or weekly periods of high flows and concentrations).

Scenarios – Sanitary Wastewater Loads to Soils

Several scenarios of sanitary wastewater loads to soils are provided in **Table 1**. (Refer to *Technical Memorandum #1* for discussion of characteristic flows and concentrations.) The first scenario is for residential sanitary wastewater loads, since this is the most common use of on-site treatment systems, and there is an extensive database on residential wastewater characteristics. The other scenarios are examples of non-residential uses. The scenarios show the range in hydraulic and nitrogen loads resulting from various flows and concentrations.

Table 1. Scenarios – Sanitary Wastewater Loads To Soils

Facility or Use[1]	Flow (gpd)	Nitrate	
		Concentration (mg/L)	Load (lbs/yr)
Residential (3 people)	300[2]	45[3]	42
Restaurant (30 seats at 50 gpd each)	1,500[2]	40[4]	187
School (935 students at 16 gpd each)	15,000[2]	90[4]	4,210
Supermarket (50,000 ft^2 at 200 gpd per 1,000 ft^2)	10,000[2]	60[4]	1,871

[1]See *Technical Memorandum #1* for more detail on sanitary wastewater characteristics
[2]WDOE 2008
[3]IDEQ 2002
[4]CT DEP 2006
gpd=gallons per day
mg/L = milligrams per liter
lbs/yr = pounds per year

For evaluation purposes, total nitrogen (organic nitrogen, ammonium, and nitrate) in effluent discharged to a drainfield is assumed to convert to nitrate. Once in the soil system, nitrate can undergo several fates:

- Denitrification - Under low oxygen conditions (anoxic), nitrate can serve as an electron donor for microbial decomposition of organic matter (C). This reaction is expressed:

$$5C + 4NO_3^- + 2H_2O \longrightarrow 2N_2 + 4HCO_3 + CO_2$$

Nitrogen gas (N_2) is lost to the atmosphere. Soils beneath drainfields are subject to alternating aerobic and anaerobic conditions, and therefore, nitrate can undergo denitrification. The amount of denitrification is difficult to quantify and depends on several variables, including soil carbon, soil moisture, soil temperature, and soil pH. In general, a coarse, well-drained soil will have less denitrification than a fine, poorly-drained soil. The Washington State Department of Health (WDOH) recommends a default denitrification rate of 10 percent as part of their Level 1 Nitrate Balance model (WDOH 2011). The Idaho Department of Environmental Quality (IDEQ), on the other hand, assumes no denitrification as part of their nutrient-pathogen (N-P) study guidelines for evaluating of on-site drainage systems (IDEQ 2012).

- Plant Uptake – Plant roots can uptake nitrate as a macronutrient. Generally, drainfields are of sufficient depth (3 feet [WAC specifies a layer of between six and twenty-four inches of cover material and the infiltrative surface may not be deeper than three feet below the finished grade, except under special conditions approved by the local health officer]) that the quantity of nitrate plant uptake is a small percentage of the nitrate loading to soils and is typically ignored when evaluating nitrate leaching to groundwater from on-site treatment systems (IDEQ 2012; WDOH 2011).
- Leaching – As an anion (negatively charge), nitrate is not adsorbed to the negatively charged soil particles and is highly mobile in soil and groundwater systems.

The on-site sewage systems rules and regulations limit the maximum flow rate or hydraulic loading to the soil based on the soil type. “Loading rates equal to or less than those in Table VIII (**Attachment A**) applied to the infiltrative surface of the soil dispersal component or the finest textured soil within the vertical separation selected by the designer, whichever has the finest texture” (WDOH 2007). Flows rates shown below are based on nitrate loadings that are protective of groundwater; however, in practice the soil type and soil hydraulic loading must be reviewed and could be a limiting factor.

Wastewater Loading to Groundwater

The sanitary wastewater load discharged from the drainfield moves through the soil and into the groundwater (assuming no restrictive layers that would prohibit movement to groundwater). Groundwater flows predominantly in a horizontal direction. The vertical column of leachate moving down through the soil column intersects the horizontal flow of groundwater at the water table where the leachate mixes with the groundwater. Nitrate in the leachate mixes with nitrate in the upgradient groundwater resulting in the downgradient nitrogen concentration. This concentration of nitrogen is informative because the water quality standard is concentration-based. The groundwater quality criterion for nitrate-N in groundwater is 10 mg/L. While the criterion is 10 mg/L, the Water Quality Standard for Ground Water of the State of Washington (Chapter 173-200 WAC) does not simply allow wastewater loadings to groundwater up to the criterion, rather the antidegradation policy must also be taken into account when assessing loadings to groundwater (see *Technical Memorandum #2* for discussion).

As presented in Technical Memorandum #2 an increase of greater than 2.0 mg/L nitrate-N in groundwater above background is defined as being acceptable and meeting the groundwater quality standard requirements. However, WDOH’s policy restricts increases in the groundwater nitrate concentration above 5.0 mg/L. This value is consistent with EPA’s safe drinking water policies. “A threshold value of 5 mg/L was chosen because this value represents half of EPA’s maximum contaminant level set to protect against blue baby syndrome” (EPA 2012a). Along with EPA’s technical factsheet on nitrate/nitrite that indicates 5 mg/L is a critical trigger (EPA 2012b). In Washington, the nitrate action level for drinking water standards is 5 mg/L which triggers additional sampling.

In practice, when the groundwater concentration is less than or equal to 3.0 mg/L then a 2.0 mg/L increase is possible, when the groundwater concentration is between 3.0 and 5.0 mg/L then an increase between 0 and 2.0 mg/L is allowed that results in downgradient (point of compliance) groundwater concentration of no more than 5.0 mg/L. When the upgradient groundwater concentration is greater than 5.0 mg/L then a minimal increase in nitrate-N such as 0.1 mg/L is used.

Movement of the leachate through the groundwater is related to multiple parameters. Understanding these parameters is important to characterizing the sanitary wastewater load. Parameters that have an effect on the wastewater load to groundwater include:

- Flow rate of wastewater (based on the type of facility).
- Constituent type (e.g., nitrogen, phosphorus).
- Concentration of constituents in wastewater (based on the treatment type).
- Flow rate of the groundwater (based on hydrogeology).
- Concentration of the constituent groundwater (upgradient).
- Geology (e.g., fine or coarse materials).
- Hydraulic conductivity (describes how readily the water moves through the geology).
- Hydraulic gradient (describes the force moving water between locations).
- Mixing zone depth (the depth from the water table where the constituent initially mixes).
- Orientation of the drainfield to groundwater flow direction (intersection of the water moving in the soil column (vertically) with the groundwater movement (horizontally)).
- Sorption (e.g., adsorption, chemical precipitation, desorption, and dissolution).

Mixing of Wastewater and Groundwater

The Level 1 Nitrate Balance was developed by WDOH as an approach to evaluating wastewater loading into groundwater (WDOH 2011). This approach has also been used by the Washington Department of Ecology (WDOE). The change in nitrate groundwater concentration from a septic drainfield can be demonstrated "by using a simple mixing equation" (WDOE 2005). As the leachate moves from the soil into the groundwater, it mixes with the upgradient groundwater. A schematic of the mixing zone is shown in **Figure 2**.

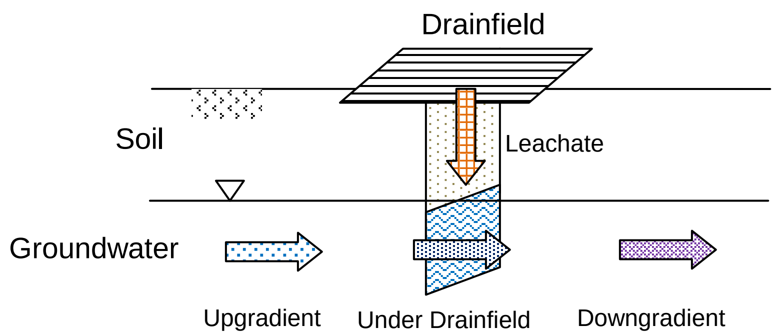

Figure 2. Schematic of Mixing Zone

A mixing analysis is a mathematical equation representing a volume-weighted average of two concentrations. The analysis represents the results of a volume of water with a constituent concentration added, or mixed, with a second different volume of water with a different constituent concentration. The result is a new constituent concentration for the sum of the volumes of water. This is shown in **Equation 2**.

$$\text{Concentration}_{\text{New}} = \frac{\text{Volume}_1 \times \text{Concentration}_1 + \text{Volume}_2 \times \text{Concentration}_2}{\text{Volume}_1 + \text{Volume}_2}$$

Equation 2. Mixing Equation

In **Equation 2**, Volume 1 and Concentration 1 represent the groundwater upgradient (groundwater flow upstream or before passing under a drainfield). Volume 2 and Concentration 2 represent the wastewater from a septic drainfield. Mixing these two flows represents the groundwater downgradient (point of compliance). This is shown in the conceptual diagram of groundwater and a septic system in **Figure 2**.

Additional variables may be added that describe aquifer and wastewater characteristics. Examples of this include the WDOH nitrate balance spreadsheet (WDOH 2012) and the IDEQ nitrogen mass balance spreadsheet (IDEQ 2012). The WDOH spreadsheet includes variables for the aquifer, wastewater, recharge, and two points of compliance, under the drainfield and at the property line (**Attachment B**). (The points of compliance are described in *Technical Memorandum #2*. The alternative point of compliance at the property line includes some dilution by recharge from infiltrating precipitation. Using the point of compliance as under the drainfield (consistent with the groundwater quality standards and does not include recharge), then the mixing equation is as shown in **Equation 3**. In **Equation 3** the width of the drainfield perpendicular to groundwater flow is used for the mixing zone and not the width of the parcel perpendicular to groundwater flow.

$$\text{Concentration}_{\text{Downgradient}} = \frac{\text{K} \times \text{i} \times \text{b} \times \text{W} \times \text{Concentration}_{\text{Upgradient}} + (\text{Volume}_{\text{Wastewater}} \times \text{Concentration}_{\text{Wastewater}}) \times \text{Factor}}{\text{K} \times \text{i} \times \text{b} \times \text{W} + \text{Volume}_{\text{Wastewater}}}$$

Where:

K = Aquifer hydraulic conductivity.
i = Aquifer hydraulic gradient.
b = Mixing zone thickness.
W = Width of mixing zone perpendicular to groundwater flow for the drainfield.
Factor = Attenuation factor such as for denitrification, degradation, or sorption.

Equation 3. WDOH Mixing Equation at Point of Compliance

Alternatively, for the alternative point of compliance, at the property line, which also includes recharge, the mixing equation is as shown in **Equation 4**.

$$\text{Concentration}_{\text{Downgradient}} = \frac{K \times i \times b \times W \times \text{Conc.}_{\text{Up}} + (\text{Volume}_{\text{WW}} \times \text{Conc.}_{\text{WW}}) \times \text{Factor} + \text{Area} \times \text{Recharge} \times \text{Conc.}_{\text{Rain}} \times \text{Factor}}{K \times i \times b \times W + \text{Volume}_{\text{Wastewater}} + \text{Area} \times \text{Recharge}}$$

Where:

K = Aquifer hydraulic conductivity.
i = Aquifer hydraulic gradient.
b = Mixing zone thickness.
W = Width of mixing zone perpendicular to groundwater flow for the drainfield.
Conc. = Concentration
WW = Wastewater
Area = Area from drainfield to the property boundary in direction of groundwater
Recharge = Recharge rate of precipitation
Factor = Attenuation factor such as for denitrification, degradation, or sorption.

Equation 4. WDOH Mixing Equation at Alternative Point of Compliance

For the constituents of concern, nitrate is assumed to have a factor for soil denitrification of 0.1. WDOH recommends a default mixing zone depth of 20 feet and a hydraulic gradient of 0.01, if unknown (WDOH 2011).

Hydraulic conductivity is an important parameter. Multiple studies and sources of information exist on hydraulic conductivity for aquifers in Spokane County (**Attachment C**). Aquifer hydraulic conductivity was reviewed as part of the SHADI/CARA process and mapped for Spokane County (Spokane County, unknown). (SHADI is an abbreviation for five environmental characteristics to assess aquifer susceptibility: soil media, hydraulic conductivity, annual recharge, depth to ground water, and importance of the vadose zone).

Scenarios –Wastewater Loads to Groundwater

Setting the hydraulic gradient to 0.01 feet/foot (ft/ft) and mixing zone thickness to 20 feet (WDOH default values) the wastewater load can be calculated for a range of hydraulic conductivities and mixing zone widths (drainfield widths perpendicular to groundwater flow). An example calculation using **Equation 3** is presented in **Box 1**. In this example, a hydraulic conductivity of 50 feet/day (ft/day) was used and an assumed upgradient nitrate-N concentration of 1.0 mg/L. The width of mixing zone is 100 feet (width of drainfield) and the soil denitrification at 0.1. With a leaching loading of 200 gpd, the resulting change in nitrate concentration is 1.0 mg/L (downgradient of 2.0 mg/L and upgradient of 1.0 mg/L). This scenario shows that for these conditions the downgradient increase in nitrate is less than the 2 mg/L allowable increase in nitrate-N. Reducing the hydraulic conductivity to 10 ft/day, the resulting change in nitrate concentration is 4.7 mg/L (downgradient of 5.7 mg/L and upgradient of 1.0 mg/L). This scenario shows that for these conditions, the downgradient increase in nitrate is more than the 2 mg/L allowable increase.

Scenarios are provided to demonstrate select facilities with characteristic values to calculate the estimated wastewater loads to groundwater (**Tables 1** and **2**). The first scenario is for residential since this is the most common use of on-site septic systems and more references exist. The other scenarios are examples of non-residential uses. The scenarios show the range in concentrations for the sanitary wastewater loads to soils.

Box 1: Example Calculation

Scenario 1
K = 50 ft/day
i = 0.01 ft/ft
b = 20 ft
W = 100 ft
Concentration upgradient = 1 mg/L
Wastewater flow = 200 gpd
Wastewater concentration = 45 mg/L

$$\text{Concentration}_{\text{Downgradient}} =$$

$$\frac{50\,\frac{\text{ft}}{\text{day}} \times 0.01 \times 20\text{ft} \times 100\text{ft} \times 7.48052\,\frac{\text{gpd}}{\text{cfs}} \times 1\,\frac{\text{mg}}{\text{L}} + \left(200\text{gpd} \times 45\,\frac{\text{mg}}{\text{L}}\right) \times (1 - 0.1)}{50\,\frac{\text{ft}}{\text{day}} \times 0.01 \times 20\text{ft} \times 100\text{ft} \times 7.48052\,\frac{\text{gpd}}{\text{cfs}} + 200\text{gpd}}$$

= 2.0 mg/L

Scenario 2
Same inputs except
K = 10 ft/day

$$\text{Concentration}_{\text{Downgradient}} =$$

$$\frac{10\,\frac{\text{ft}}{\text{day}} \times 0.01 \times 20\text{ft} \times 100\text{ft} \times 7.48052\,\frac{\text{gpd}}{\text{cfs}} \times 1\,\frac{\text{mg}}{\text{L}} + \left(200\text{gpd} \times 45\,\frac{\text{mg}}{\text{L}}\right) \times (1 - 0.1)}{10\,\frac{\text{ft}}{\text{day}} \times 0.01 \times 20\text{ft} \times 100\text{ft} \times 7.48052\,\frac{\text{gpd}}{\text{cfs}} + 200\text{gpd}}$$

= 5.7 mg/L

Table 2. Scenarios – Sanitary Wastewater Loads to Groundwater

Facility or Use	Flow (gpd)	Hydraulic Conductivity (ft/day)	Nitrogen			
			Upgradient Concentration (mg/L)	Leachate Concentration (mg/L)	Downgradient Concentration (mg/L) POC	Downgradient Concentration (mg/L) Alt.
Residential	300	100	2	45	2.8	2.5
		500			2.2	2.1
Restaurant	1,500	100	2	40	5.1	4.6
		500			2.7	2.6
School	15,000	100	2	90	41.5	39.3
		500			15.2	14.9
Supermarket	10,000	100	2	80	30.0	28.1
		500			10.3	10.0

POC = point of compliance
Alt. = alternative point of compliance
Soil denitrification = 0.1
Mixing zone thickness = 20 ft
Width of mixing zone = 100 ft
Distance to property line = 2,500 ft
Hydraulic gradient = 0.01 ft/ft

Allowable Wastewater Loads to Groundwater

As described in *Technical Memorandum #2*, a nitrate concentration increase of 2 mg/L at the point of compliance (with a trigger point at 5 mg/L) is defined as meeting the groundwater quality standards (WDOH 2011). **Equation 3** can be re-arranged to solve for the allowable wastewater concentration based on an allowable point of compliance increase of 2 mg/L. The wastewater flow and concentration can then be used to calculate the wastewater load. **Equation 5** shows the mixing equation solved for the wastewater load.

$$\text{Concentration}_{\text{Wastewater}} =$$

$$\frac{7.48052\ \text{K} \times \text{i} \times \text{b} \times \text{W} \times (\text{Conc.}_{\text{Downgradient}} - \text{Conc.}_{\text{Upgradient}} + (\text{Volume}_{\text{Wastewater}} \times \text{Conc.}_{\text{Downgradient}}\,)}{0.9\ \text{Volume}_{\text{Wastewater}}}$$

Where:

K = Aquifer hydraulic conductivity (ft/day).
i = Aquifer hydraulic gradient (ft/ft).
b = Mixing zone thickness (ft), this is the width of the drainfield perpendicular to groundwater flow.
W = Width of mixing zone perpendicular to groundwater flow for the drainfield (ft).
Factor = Denitrification (0.1).
Volume of Wastewater (gpd).
Concentration of nitrate-N (mg/L).

Equation 5. WDOH Mixing Equation

Using **Equation 5**, setting the hydraulic gradient to 0.01 ft/ft, mixing zone thickness to 20 feet

(WDOH default values), mixing zone width to 100 feet, upgradient concentration to 0 mg/L, and the downgradient concentration to 2 mg/L, the allowable wastewater load can be calculated for a range of hydraulic conductivities. The resulting allowable wastewater nitrogen loadings with an increase of 2 mg/L at the point of compliance are shown in **Figure 3**. For a known hydraulic conductivity, the corresponding nitrogen wastewater load that causes a 2 mg/L increase may be determined for the given conditions. For example, at a hydraulic conductivity of 3,000 ft/day, the wastewater flow is 3,110 gpd, while at a hydraulic conductivity of 5,000 ft/day the wastewater flow is 5,185 gpd. The mixing zone analysis indicates that at greater hydraulic conductivities, the allowable wastewater loading is larger because are a larger volume of water is able to mix with a larger discharge. In other words, **Figure 3** shows that as hydraulic conductivity increases, the allowable wastewater load also increases. The wastewater loads presented in Figure 3 are based on allowable nitrate loading to groundwater. The load is also restricted by the drainfield design and soil type (On-site Sewage Systems Chapter 246-272A WAC).

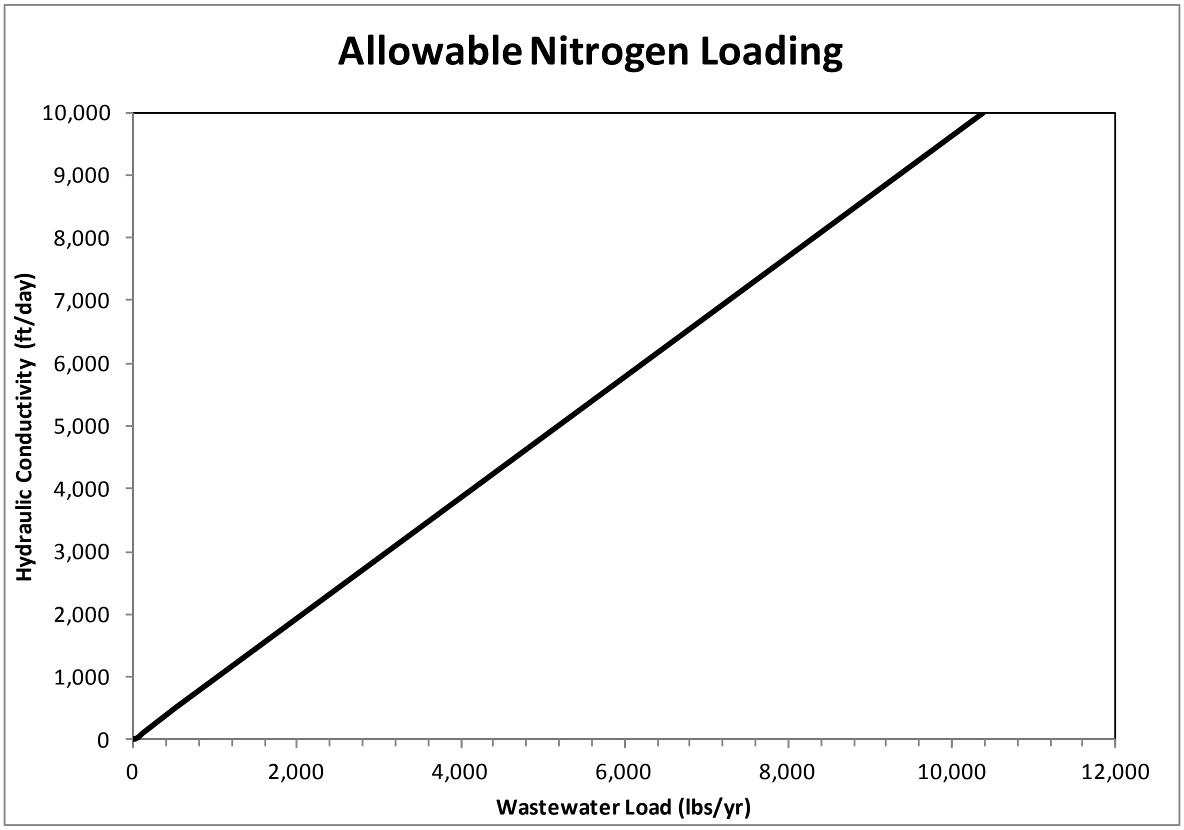

Figure 3. Allowable Wastewater Nitrogen Loading for 2 mg/L Point of Compliance Increase

The wastewater load in **Figure 3** is a function of the wastewater flow rate and wastewater concentration for a range of hydraulic conductivities. The resulting allowable wastewater flow and concentration for this mixing zone width and upgradient concentration of 0 mg/L with a compliance point increase of 2 mg/L are shown in **Figure 4**. The wastewater flow shown in **Figure 4** is a maximum of 3,500 gpd because discharges greater than 3,500 gpd are considered large on-site sewage systems (WDOE, 2012). The nitrate-N concentrations shown in **Figure 4** are a maximum of 100 mg/L to represent ranges that may be found in non-residential wastewater as documented in *Technical Memorandum #1*.

To provide an example using **Figure 4**, if a parcel was in an area with a hydraulic conductivity of 50 ft/day (yellow dash-dot line), and the estimated effluent nitrate-N concentration was 60 mg/L (vertical axis), then the allowable wastewater flow would be 285 gpd. If the effluent nitrate concentration could be treated and reduced to 45 mg/L, then the allowable wastewater flow would increase to 390 gpd. Generally, a reduction in the effluent nitrate concentration allows for greater wastewater flow. However, this relationship diminishes with decreasing hydraulic conductivities. In the example, if the parcel was in an area with a hydraulic conductivity of 0.1 ft/day (black solid line), and the estimated effluent nitrate concentration was 60 mg/L, there is not an allowable wastewater flow. Essentially, the effluent nitrate concentration is 2.5 mg/L regardless of the wastewater flow at a hydraulic conductivity of 0.1 ft/day. In other words, **Figure 4** shows that at larger hydraulic conductivities, meeting the allowable nitrogen loading is achievable with a combination of wastewater flows and concentrations, but at smaller hydraulic conductivities, meeting the allowable nitrogen loading requires low wastewater concentrations regardless of the wastewater flow.

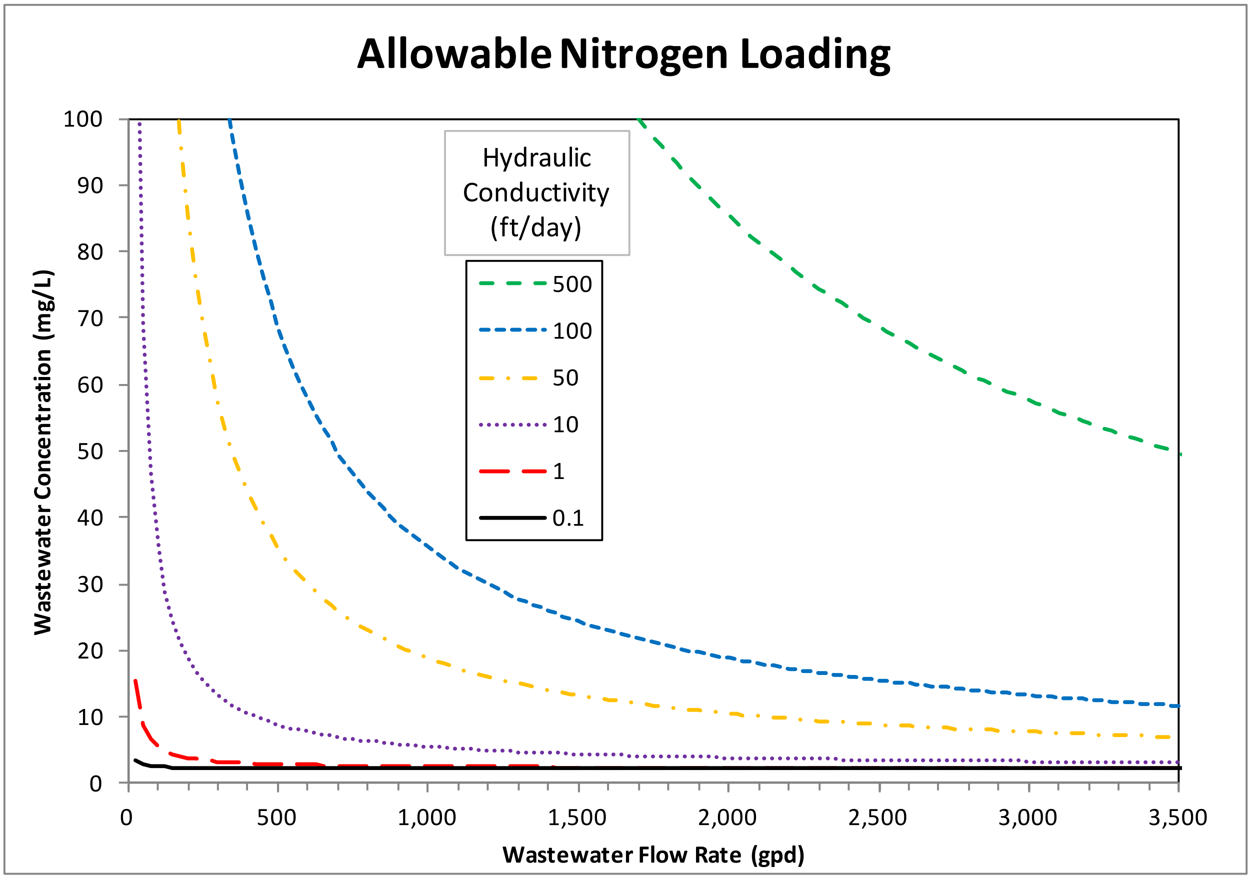

Figure 4. Allowable Wastewater Nitrogen Flow and Concentration for a Mixing Zone Width of 100 ft, Upgradient Concentration of 0 mg/L at 2 mg/L Downgradient Increase

Next Steps

The objective of *Technical Memorandum #3* is to describe and evaluate the "mixing" of nitrate present in non-residential sanitary wastewater with the environment. Information on wastewater and nitrogen as they move and interact through the environment was discussed. A draft of this technical memorandum will be presented to the CARA review committee for input. In addition, the project team will meet with the committee to discuss the technical memorandum and future study activities. The information presented in this memorandum, as well as input provided by the committee, will be used to support an evaluation of non-residential sanitary wastewater constituent loadings to soils that are protective of groundwater in CARA outside the UGA.

References

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Attachment A

TABLE VIII
Maximum Hydraulic Loading Rate[1]

Soil Type	Soil Textural Classification Description	Loading Rate for Residential Effluent Using Gravity or Pressure Distribution (gal./sq.ft./day)
1	Gravelly and very gravelly coarse sands, all extremely gravelly soils excluding soil types 5 and 6, all soil types with greater than or equal to 90-percent rock fragments.	1.0
2	Coarse sands.	1.0
3	Medium sands, loamy coarse sands, loamy medium sands.	0.8
4	Fine sands, loamy fine sands, sandy loams, loams.	0.6
5	Very fine sands, loamy very fine sands; or silt loams, sandy clay loams, clay loams and silty clay loams with a moderate structure or strong structure (excluding a platy structure).	0.4
6	Other silt loams, sandy clay loams, clay loams, silty clay loams.	0.2
7	Sandy clay, clay, silty clay and strongly cemented firm soils, soil with a moderate or strong platy structure, any soil with a massive structure, any soil with appreciable amounts of expanding clays.	Not suitable

[1] On-Site Sewage Systems Chapter 246-72A WAC

Attachment B

WASHINGTON DEPARTMENT OF HEALTH					
LEVEL 1 NITRATE BALANCE FOR LARGE ON-SITE SEWAGE SYSTEM					
Project name:					
Address, city and county:					
Completed by (name and title):					
Date:					
Input Values	**Factor**	**Units**	**Values**	Instructions	**Information Source**
Nitrate concentration in precipitation	N_R	mg/l as N	0.24	Default	
Total nitrogen concentration in wastewater	N_W	mg/l	60	Default - residential strength	
Soil denitrification	d	unitless	0.1	Default	
Aquifer thickness	b	ft	20	Default or aquifer thickness if known	
Drainfield area	A_D	ft^2		Primary drainfield area	
Distance from drainfield to property boundary	D_{pb}	ft	0	Measure in direction of GW flow	
Aquifer width	W_A	ft		Perpendicular to GW flow	
Aquifer hydraulic conductivity	K	ft/day		Measured or literature value	
Hydraulic gradient	i	ft/ft		If unknown, use 0.010	
Recharge	R	in/yr		Recharge will be a % of ppt	
Nitrate concentration of upgradient ground water	N_B	mg/l		Prefer sampling data	
Wastewater volume	V_W	gpd		Design flows or measured volume	
Output Values					
Groundwater nitrate value	N_{GW}	mg/l as N		Point of Compliance (POC)	
Groundwater nitrate value	$N_{GW\ ALT}$	mg/l as N		Alternative POC	
DOH 337-070					Revised: July 2012

Attachment C

Table 2. SHADI Ratings for Hydraulic Conductivity		
Relative Ranking	**Hydraulic Conductivity (ft/day)**	**SHADI Rating**
High	> 2,160	10
Medium High	86.4 to 2,160	8
Medium	21.6 to 86.4	6
Medium Low	0.864 to 21.6	4
Low	< 0.864	2

Source: (Spokane County, unknown)

Table 5. Aquifer properties estimated from multiple well aquifer tests in the West Plains Study Area

Data Source	Test Locality	Aquifer	Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)	Storativity (dimensionless)
Engineering and Geologic Resources Inc. (1993)	Graham Road Landfill	Wanapum	6.08	na	na
			1.96	na	na
			12.1	na	na
			11.9	na	na
Halliburton NUS Environmental Corporation (1993)	Fairchild AFB	Wanapum	0.33	16.7	0.0000177
			0.42	20.9	0.00016
			0.18	4.8	0.00055
Geologic Analysis and Consulting Services (1994)	Sec. 33, T26N,R42E	Basement[1]	na	38.4	0.0006161

na = data not available

[1] Well screened in the Latah Formation at the basement rock contact.

Source: (West Plains – Wanapum Hydraulic Conductivity, unknown)

Aquifer type & Location	K category	SHADI rating	Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/sec)	Estimate thick (ft)	Source
Crystalline basement/Latah contact at West Plains	mL	2	1.9	0.00044444	20	Geologic Consulting (Deobald)
Grande Ronde of Columbia Plateau	H to L	2 to 10	0.0050 to 2,592			Whiteman
Wanapum of the Columbia Plateau	H to L	2 to 10	0.0070 to 5,270			Whiteman
Wanapum of West Plains	mL to L	2 to 4	0.18 to 12			Deobald
Wanapum of Five Mile	mL	4	1.4 to 2.5	0.0016 to 0.0022	75 to 100	Olson
Basalt/Landslide at Colbert LF	mL to L	2 to 4	0.70 to 1.0			Landau
Lower sand & gravel at Colbert LF	mH	8	104 to 138 164 to 233			Landau, Colbert
Upper sand & gravel at Colbert LF	mH	8	527 to 639			Landau, Colbert
Deer Park upper sand & gravel				722 to 270,000		CH2M Hill
Hangman Valley (Buchanan)	mH	8	1,702			Buchanan
Marshall valley sand	mH	8	501 & 256			Waquar
Upper basalt Marshall valley	L	2	< 0.050			Waquar
Lower basalt in Marshall valley	L	2	< 0.0033			Waquar
Precambrian Rock (Ybr) in Marshall valley	L	2	< 0.00033			Waquar
Central Well in Hillyard Trough	H	10	5,011 to 5,184			CH2M Hill
Qes Eaglewood	mL	4	2.6 to 20			Landau
Qfc Eaglewood near Mead	mH to M	6 to 8	21 to 320			Landau
Palouse	mL	4	1.0 to 5.0			Whiteman
Qfg Along Little Spokane River	H to mH	8 to 10	864 to 2,592	2 to 6	200	Vaccaro & Bolke
Basalt at Deer Park	mL	4	5.0	0.00058		Anderson

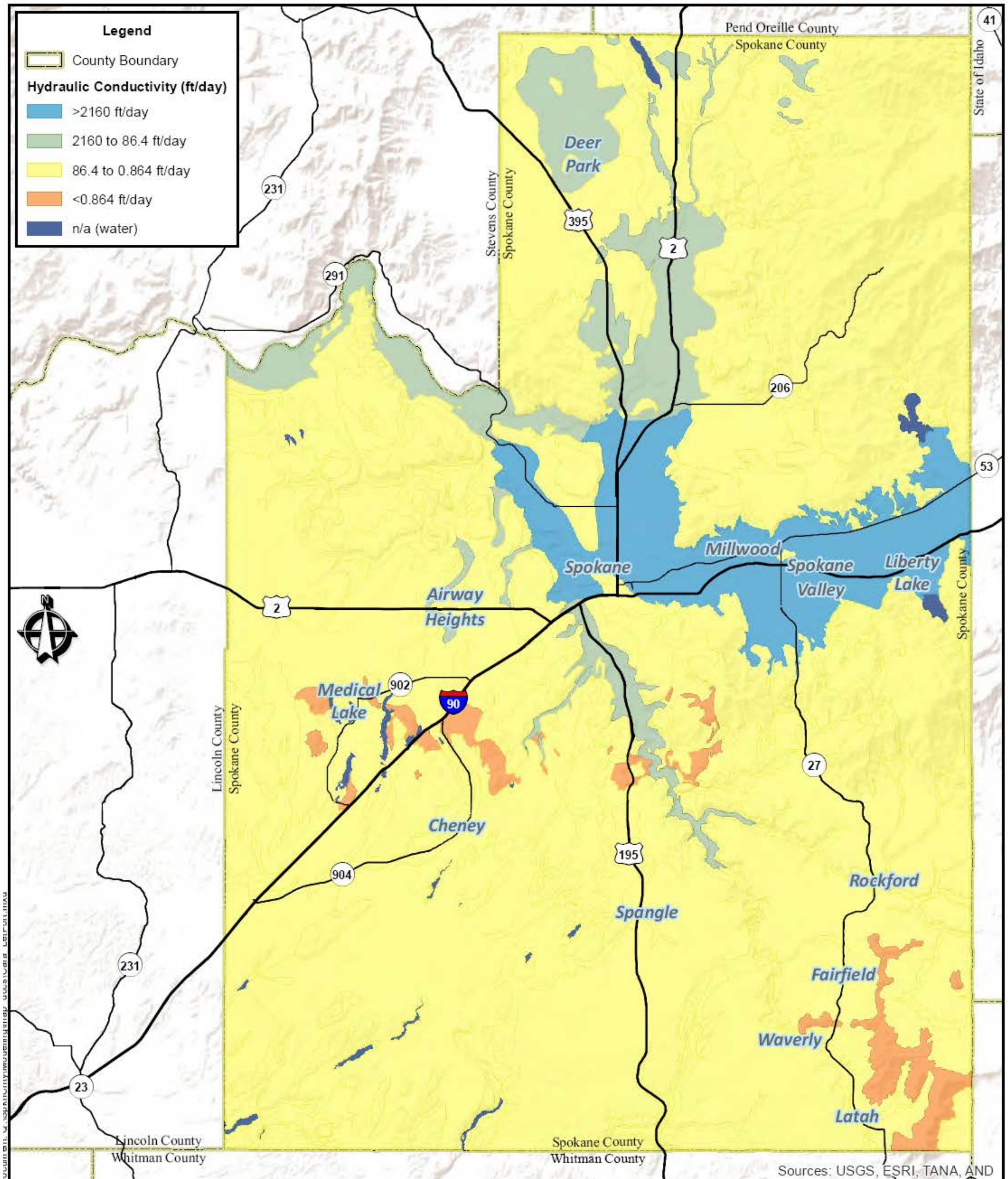
Aquifer type & Location	K category	SHADI rating	Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/sec)	Estimate thick (ft)	Source
Basalt under Steam Plant site	L	2	0.068			Landau, RI
Basalt in S. Spokane County	mH to L	2 to 8	0.38 to 147	0.00022 to 0.404	50 to 230	Olson etc
Latah under Steam Plant	L	2	0.00085 to 0.057			Landau, RI
Sand and interbedded silt below the Steam Plant	mH to mL	4 to 8	2.9 to 950			Landau, RI
Fractured metamorphic and igneous rocks	M to L	2 to 6	52 to 0.000069			Anderson & Woessner
Unfractured metamorphic and igneous rocks	L	2	0.00086 or less			Anderson & Woessner
Fractured Shale	L	2	0.00052 to 0.0000086			Anderson & Woessner
Unfractured shale	L	2	< 0.0000086			Anderson & Woessner
Fractured metamorphic and igneous rocks	mH to L	2 to 8	285 to 0.0029			Freeze & Cherry
Unfractured metamorphic and igneous rocks	L	2	0.000029 to 0.000000029			Freeze & Cherry
silt, sandy silts, clayey sands, till	L	2	0.29 to 0.0029			Fetter
silty sands, fine sand	M to L	2 to 6	29 to 0.029			Fetter
well-sorted sands, glacial outwash	mH to mL	4	285 to 2.9			Fetter
Peat	L	2	< 0.029			Emerick et al
Metamorphic rocks in Spokane County are more deeply weathered than igneous rocks					<5 ft for igneous	Water Resouces Study
Weathered zone under Peone Prairie					14 to 151 ft, ave. 70 ft	Boleneus and Derkey
In & surrounding Fivemile & rock of Walk in the Wild Zoo	M to mL	4 to 6	86 to 0.86			Bolke & Vaccaro,1981

Source: (Spokane County, unknown)

Hydrogeologic Unit	Aquifer Area	Locality	Well	Saturated Thickness (ft)	Pump Rate / Well Yield (gpm)	Specific Capacity (gpm/ft)	Transmissivity (ft2/day)	Hydraulic Conductivity (ft/day)	Storage	Porosity (%)	Linear Velocity (ft/day)	Source
Alluvium				0 - 40	5 - 600							Cline, 1969.
Flood Sand & Gravel	SVRP							0.1 - 10,000	0.1 - 0.2	10 - 20	30.00	Spokane County, 2001 Draft
Flood Sand & Gravel	Deer Park		TW-1	45	90		722	16				EMCON, 1992.
Flood Sand & Gravel	Deer Park		TW-2	50	106		6,685 - 20,055	134 - 401				EMCON, 1992.
Flood Sand & Gravel	Little Spokane River	Colbert Landfill					10,000 - 12,000	530 - 640	0.2		3.5 - 6.4	Landau, 1991. Boese & Buchanan, 1996.
Flood Sand & Gravel	SVRP	N Spokane, Francis & Market	N Spokane ID #3	200	800	198	100,000 - 700,000	500 - 3,500				CH2MHill, 2000
Flood Sand & Gravel	SVRP	Kaiser Trentwood - Central Spokane Valley	OH-EW-1	175	1,065		160,000 - 350,000	650 - 1,400				Hart Crowser, 1994 cited in CH2MHill, 1998
Flood Sand & Gravel	SVRP	Hillyard						864	0.10 - 0.15			Bolke & Vaccaro, 1981
Flood Sand & Gravel	SVRP	Valley, Sullivan & Broadway	Vera #2-1	400	2,500		380,000	950				CH2MHill, 2000
Flood Sand & Gravel	SVRP	Below Spokane Falls	Northside Landfill					1,200 - 2,100				CH2MHill, 1998
Flood Sand & Gravel	SVRP	Kaiser Mead North - North Hillyard Trough	Well No. 6					1,100 - 2,500				Hart Crowser, 1980 cited in CH2MHill, 1998
Flood Sand & Gravel	SVRP	Whitworth - North Hillyard Trough	7G2					1,100 - 2,500				Hart Crowser, 1980 cited in CH2MHill, 1998
Flood Sand & Gravel	SVRP	North Hillyard Trough					4,320 - 172,800		0.05 - 0.15			Boese & Buchanan, 1996.
Flood Sand & Gravel	SVRP	Hillyard					130,000					Drost & Seitz, 1978.
Flood Sand & Gravel	SVRP	Hillyard		160			400,000	2,500		30	47.00	Drost & Seitz, 1978.
Flood Sand & Gravel	Little Spokane River	West WRIA 55					172,800 - 518,400					Boese & Buchanan, 1996.
Flood Sand & Gravel	SVRP	Central Hillyard Trough	Central Well No. 2	250 - 300	8,225	1,443	630,000 - 750,000	2,500				CH2MHill, 1998
Flood Sand & Gravel	SVRP	Downtown Spokane						2,592	0.10 - 0.15			Bolke & Vaccaro, 1981
Flood Sand & Gravel	SVRP	Idaho Road & Wellesley	CID #11A	400	3,400	1,889	800,000 - 1,700,000	2,000 - 4,200				CH2MHill, 2000
Flood Sand & Gravel	SVRP	South Hillyard Trough	Nevada Well	400	18,200	2,563	1,300,000	3,000				CH2MHill, 1998
Flood Sand & Gravel	SVRP	Central Spokane Valley						4,320	0.15 - 0.20			Bolke & Vaccaro, 1981
Flood Sand & Gravel	SVRP	State Line to Pines Knoll						6,048	0.15 - 0.20			Bolke & Vaccaro, 1981
Flood Sand & Gravel	Deer Park		Olsen (west)	44	620		267,400	6,077	0.001			EMCON, 1992.
Flood Sand & Gravel	SVRP	Valley, nr Barker & Mission	CID #4B	450	1,975	2,821	1,900,000 - 2,500,000	4,200 - 6,200				CH2MHill, 2000
Flood Sand & Gravel	SVRP	State Line		280			3,400,000	12,000		25	64.00	Drost & Seitz, 1978.
Flood Sand & Gravel	SVRP	State Line					11,000,000					Drost & Seitz, 1978.
Flood Sand & Gravel				0 - 700	600 - 20,000							Cline, 1969.
Lower Flood Sand & Gravel	Little Spokane River	Colbert Landfill	CP-E1		200		10,000 - 14,000	100 - 140	0.16	30	0.30	Landau, 1991. Boese & Buchanan, 1996.
Lower Flood Sand & Gravel	Little Spokane River	Colbert Landfill	CP-W1		220		30,000 - 40,000	170 - 230	0.0004	30	0.60	Landau, 1991. Boese & Buchanan, 1996.
Glacial Lake Deposits	Deer Park			0 - 300	5 - 600							Cline, 1969.
Grande Ronde Basalt	Columbia Plateau							0.005 - 2,522				Boese & Buchanan, 1996.
Wanapum Basalt	Columbia Plateau							0.007 - 5,244				Boese & Buchanan, 1996.
Wanapum Basalt	West Plains							0.18 - 12.1				Boese & Buchanan, 1996.

Hydrogeologic Unit	Aquifer Area	Locality	Well	Saturated Thickness (ft)	Pump Rate / Well Yield (gpm)	Specific Capacity (gpm/ft)	Transmissivity (ft2/day)	Hydraulic Conductivity (ft/day)	Storage	Porosity (%)	Linear Velocity (ft/day)	Source
Basalt	Little Spokane River	Colbert Landfill	CP-E2				25	0.7 - 1.0	0.01	10	0.40	Landau, 1991. Boese & Buchanan, 1996.
Basalt	Five Mile Prairie	Five Mile Prairie		80		0.5 - 1	134 - 267	1.7 - 3.3	0.0025			Olson, 1979
Basalt	Deer Park	City of Deer park	DP-5		350							EMCON, 1992.
Basalt					< 35							Cline, 1969.
Wanapum Basalt	Five Mile Prairie						134.8 - 192.5					Boese & Buchanan, 1996.
Latah					< 35							Cline, 1969.
Basement					< 35							Cline, 1969.
Basement	West Plains						38					Boese & Buchanan, 1996.
Basalt & Basement	Five Mile Prairie	N. Five Mile Prairie						1 - 86	< 0.05			Olson, 1979

Source: (WRIA 55-57 Compilation of Aquifer Properties, unknown)



Hydraulic Conductivity
Spokane County CARA Review

Map Production Date: 12/7/2012

Data Sources: Spokane County; USGS; US Census Bureau, ESRI

0 9 18 Miles