Critical Aquifer Recharge Areas Review

Sanitary Wastewater Loading to Groundwater

CARA Review Committee Meeting 2
December 12, 2012

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Presentation Outline

- Constituents of concern
- Mixing zone approach
- Examples and application
- Next steps

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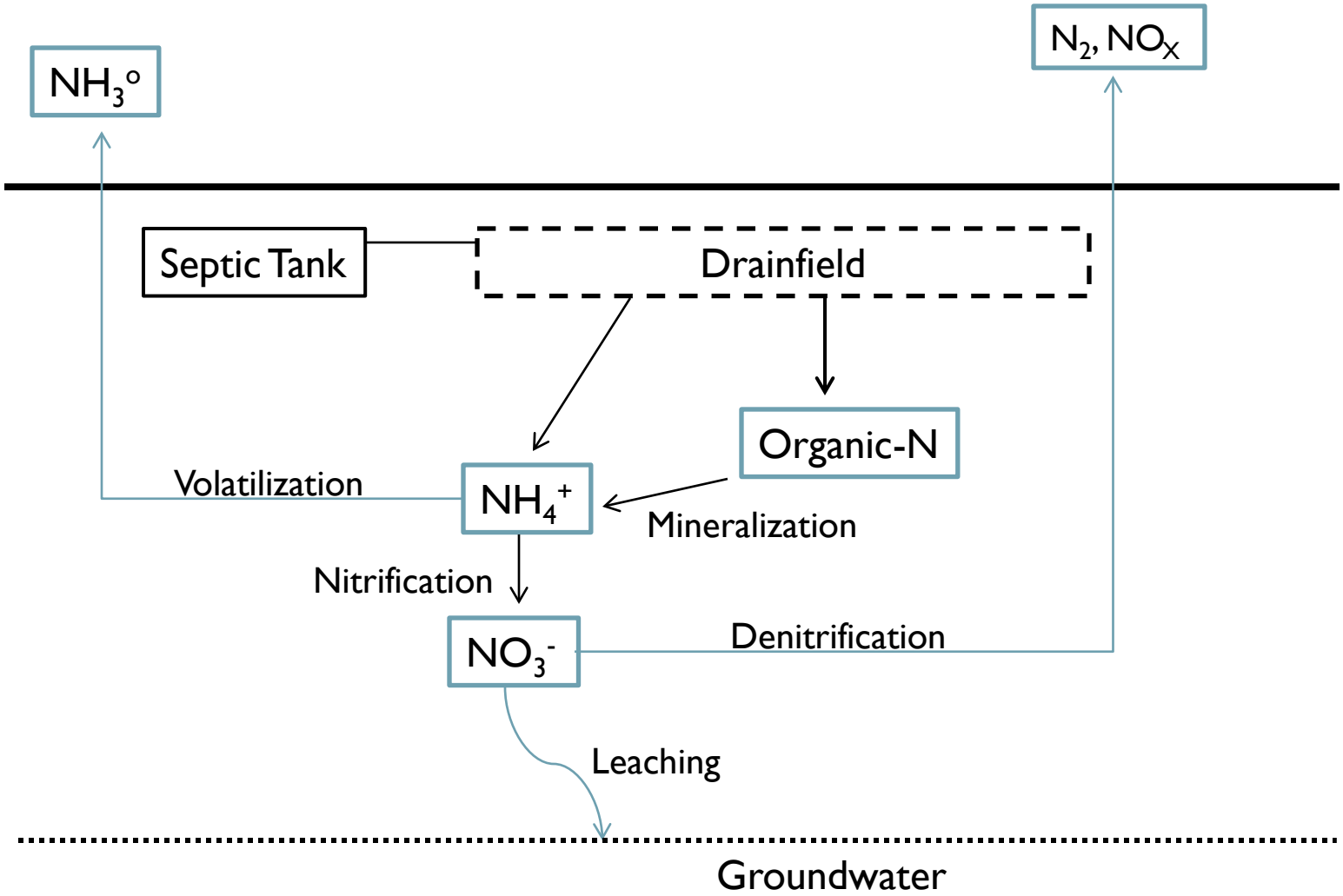
Constituents of Concern

- Focus nitrate and phosphorus
- Nitrate is "primary contaminant"
- Phosphorus surface water issue
  Total Maximum Daily Load (TMDL)
- Chlorides, sulfates, coliform
- Toxics – Critical Material Standards
- Trace organics – not regulated

Nitrogen Cycle Drainfields



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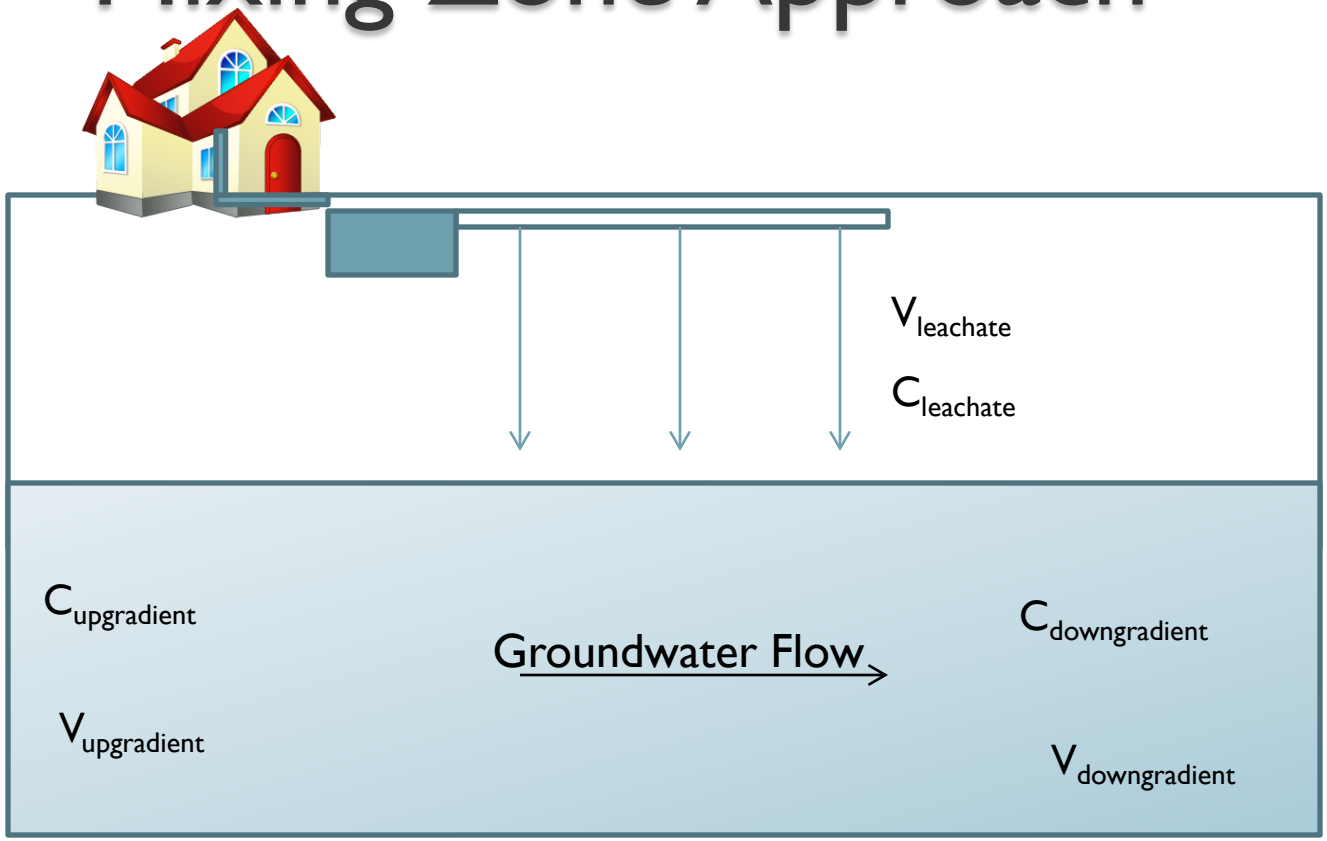
Mixing Zone Approach



C = concentration
V = volume

$$C_{downgradient} = \frac{(C_{upgradient} \times V_{upgradient}) + (C_{leachate} \times V_{leachate})}{(V_{upgradient} + V_{leachate})}$$

There is an equation for mixing septic leachate and groundwater

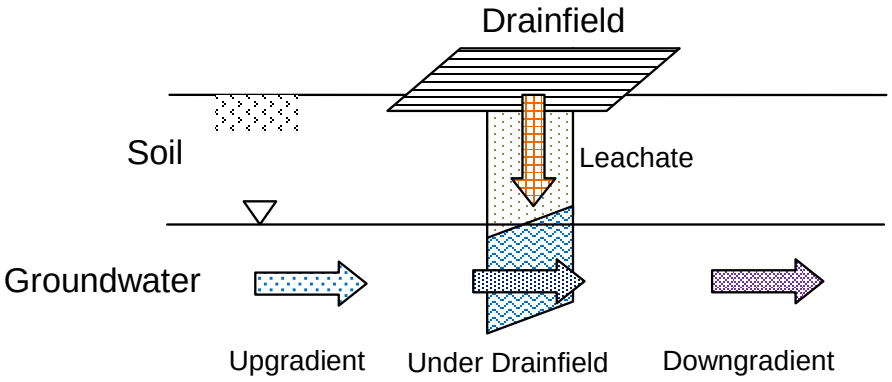
Use of Mixing Zone Approach by Agencies

- Agencies have developed regulations and tools based on the mixing zone equation
- Washington Department of Health
  - Large On-Site Sewage Systems (LOSS) Program
- Idaho Department of Environmental Quality
  - Nutrient-pathogen evaluations
- Montana Department of Environmental Quality
  - ARM 17.30.715(1)
  - How to perform a non-degradation analysis for subsurface wastewater treatment facilities

Agencies use Mixing Zone approach

Parameters to Assess Wastewater Loading to Groundwater

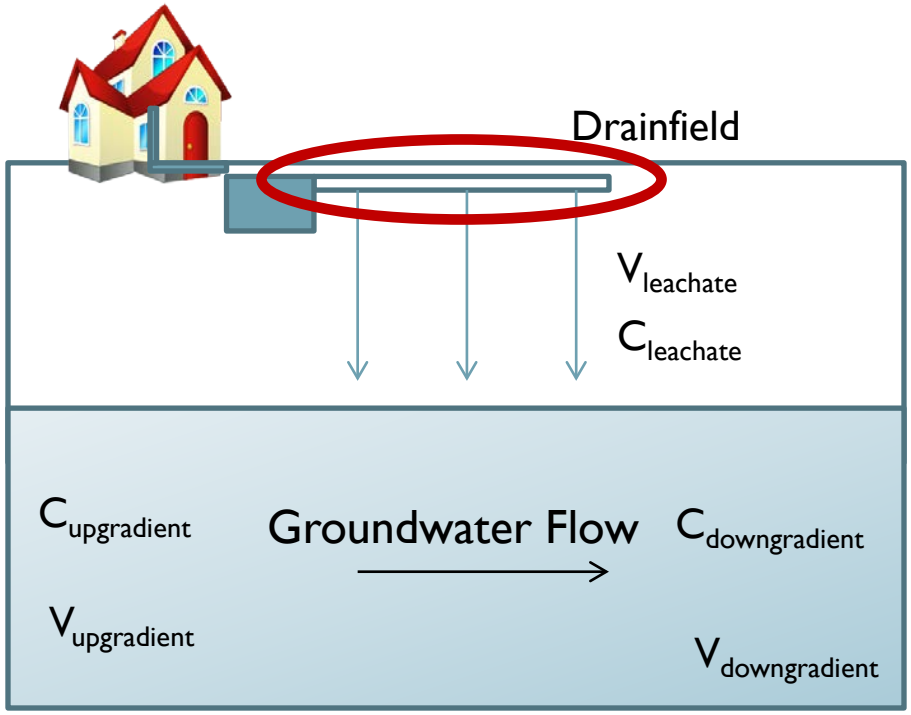
1. Flow rate of wastewater
2. Constituent type
3. Concentration of constituents in wastewater
4. Soil type
5. Flow rate of the groundwater
6. Concentration of the constituent groundwater
7. Geology
8. Hydraulic conductivity
9. Hydraulic gradient
10. Mixing zone depth
11. Orientation of the drainfield to groundwater flow direction
12. Sorption



Many parameters required

Drainfield Parameters

- Flow rate of wastewater
  - Based on the type of facility
- Constituent type
  - e.g., Nitrate
- Concentration of constituents in wastewater
  - Based on the type of facility and on the treatment type
- Mass (load) of constituent
  - Flow times concentration



Key parameters from on-site septic system are flow and concentration

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Example of Sanitary Wastewater Loads

Facility or Use[1]	Flow (gpd)	Nitrate Concentration (mg/L)	Nitrate 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

Non-residential uses have a wide range of loads

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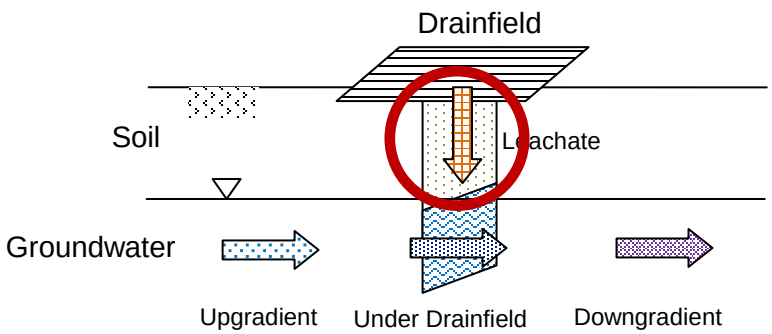
Soil Parameters

- Soil Type
  - Nitrate highly mobile
  - Essentially moves unchanged through the soil



There are no key soil parameters for nitrate mixing zone analysis

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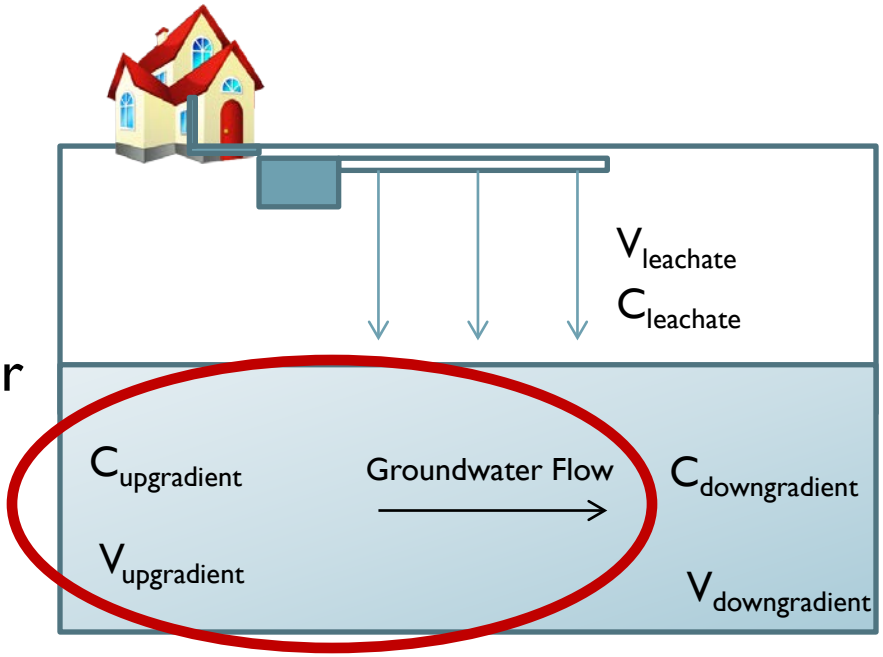
Groundwater Parameters

- Flow rate of the groundwater
  - Based on hydrogeology
- Concentration of the constituent groundwater
  - Upgradient
- Geology
  - e.g., fine or coarse grained materials



Key parameters from groundwater are flow* and concentration
*Flow requires aquifer parameters

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Aquifer Parameters

- Hydraulic conductivity (K)
  - How readily the water moves through the geology (ft/day)
- Hydraulic gradient (i)
  - The force moving water between locations (ft/ft)
- Mixing zone depth (b)
  - Depth from the water table where the constituent initially mixes (ft)
- Orientation of the drainfield to groundwater flow direction (W)
  - Intersection of the water moving in the soil column (vertically) with the groundwater movement (horizontally) (ft)

$$V_{upgradient} = K \times i \times b \times W$$

Key parameters from aquifer are
hydraulic conductivity and orientation width

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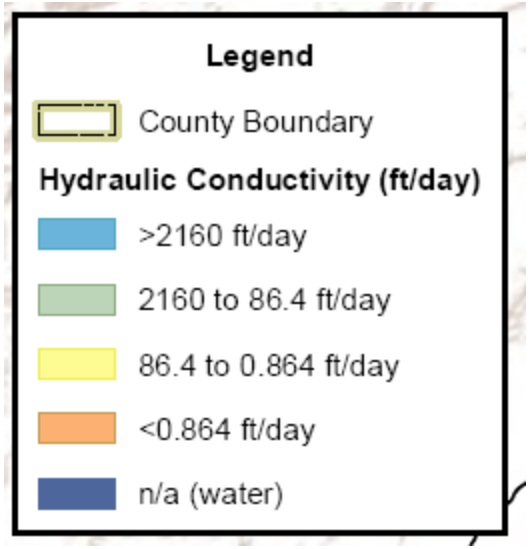
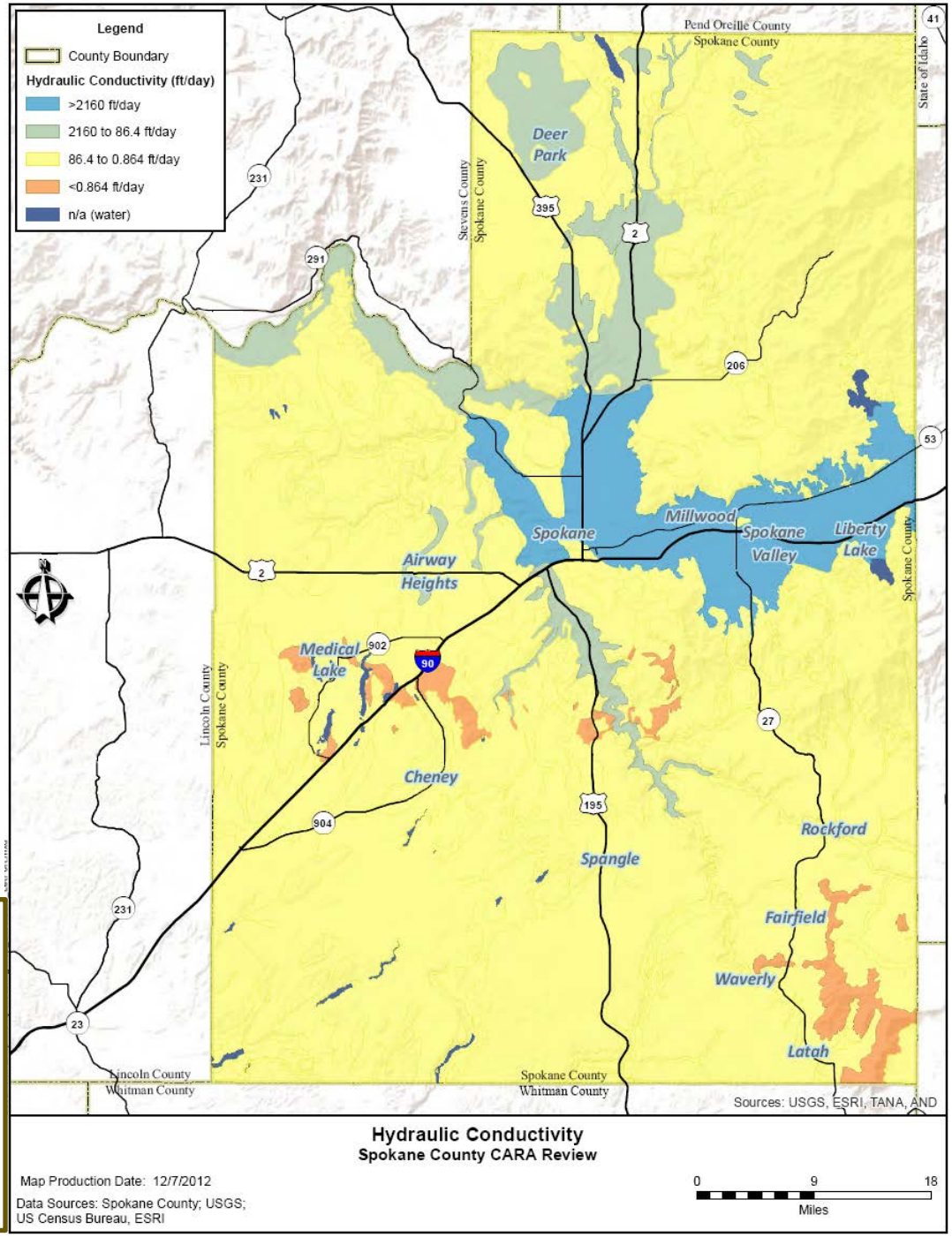
Hydraulic Conductivity Map





County provided map as source for hydraulic conductivity value

Maps are a method to have input values vary for different areas or zones of the county

Mixing of Wastewater with Groundwater

- Wastewater
  - Volume
    - Non-residential use
  - Concentration
- Groundwater
  - Volume
    - Hydraulic conductivity
    - Hydraulic gradient
    - Mixing depth
    - Drainfield width
  - Concentration

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

Equation becomes more complicated when expanded to include other parameters

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Example Calculation

- Wastewater
  - Wastewater flow = 200 gpd
  - Wastewater nitrate-N concentration = 45 mg/L, 10% denitrification
- Groundwater
  - Hydraulic conductivity = 50 ft/day
  - Hydraulic gradient = 0.01 ft/ft
  - Mixing zone depth = 20 ft
  - Orientation width = 100 ft
  - Upgradient nitrate-N concentration = 1.0 mg/L

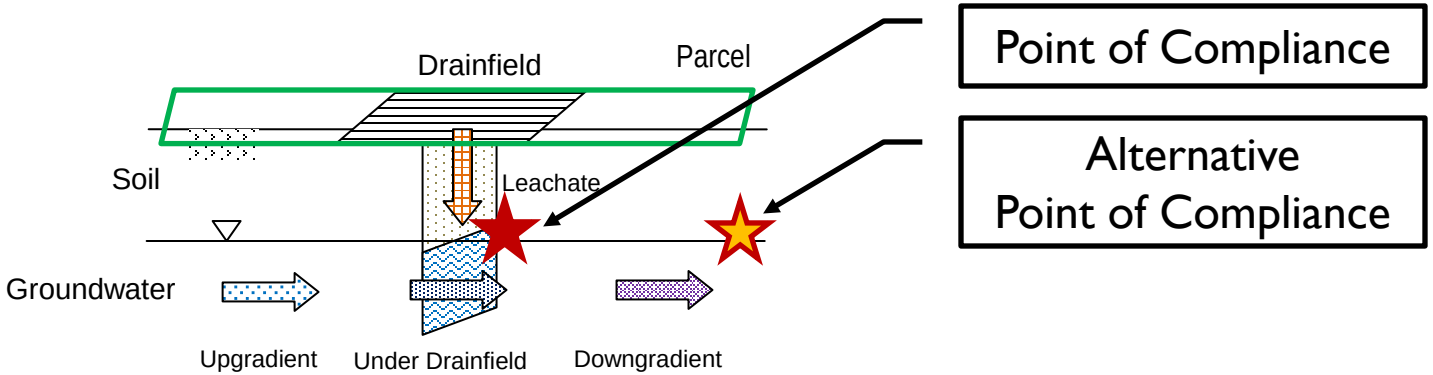
$$\text{Concentration}_{\text{Downgradient}} = 2.0 \text{ mg/L}$$

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

Example shows the many parameters
and the values may be either default or site specific

Point of Compliance

- Under the drainfield
- Edge of the property



Parcel size is:
- not included in equation for point of compliance under drainfield
- is partially included in equation for alternative point of compliance

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Example of Mixing Calculations

Facility or Use	Flow (gpd)	Hydraulic Conductivity (ft/day)	Nitrate Upgradient Conc. (mg/L)	Nitrate Effluent Conc. (mg/L)	Nitrate Down-gradient POC (mg/L)	Nitrate Down-gradient Alt. POC (mg/L)
Residential	300	100	2	45	2.8	2.5
		500			2.2	2.1
Restaurant	1,500	100		40	5.1	4.6
		500			2.7	2.6
School	15,000	100		90	41.5	39.3
		500			15.2	14.9
Supermarket	10,000	100		60	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

Non-residential uses have a wide range of downgradient concentrations

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Department of Health Mixing Analysis Spreadsheet

WASHINGTON DEPARTMENT OF HEALTH

LEVEL 1 NITRATE BALANCE FOR LARGE ON-SITE SEWAGE SYSTEM

Using WDOH spreadsheet as analysis foundation provides consistency

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

Application

Implementation Mechanism	CARA Study
Anti-degradation	Upgradient nitrate-N ≤3.0 mg/L; then allow a 2.0 mg/L increase at point of compliance Upgradient nitrate >3.0 to ≤5.0 mg/L; then allow an increase up to 5.0 mg/L at point of compliance Upgradient nitrate-N > 5.0 mg/Land ≤10.0 mg/L ; then allow a 0.1 mg/L increase at point of compliance Upgradient nitrate-N > 10.0 mg/L; then no measureable increase allowed
AKART	On-site sewage treatment systems meet AKART by being permitted and meeting the design requirements outlined in Chapter 246-272A WAC – *On-Site Sewage Systems* and Chapter 246-272C WAC – *On-Site Sewage System Tanks Regulations*
Standards	The on-site treatment system shall not result in groundwater nitrate-N exceeding 10 mg/L (in addition the anti-degradation policy and AKART must be met)
Point of Compliance	Point of compliance is directly downgradient of the drainfield, but alternative would be end of property

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Draft Spokane County Spreadsheet

Modified WDOH spreadsheet for analysis
Open Excel file for details

Input Values	Sign	Units	Values	Instructions
Aquifer hydraulic conductivity	**K**	**ft/day**	**260**	**Measured or literature value**
Hydraulic gradient	**i**	**ft/ft**	**0.010**	**Use data or default of 0.010**
Mixing zone thickness	**b**	**ft**	**20**	**Default or aquifer thickness if less**
Drainfield effective width	**W_A**	**ft**	**100**	**Perpendicular to GW flow**
Nitrate concentration of upgradient ground water	**N_B**	**mg/l**	**2**	**Use sampling data from wells**
Wastewater volume	**V_W**	**gpd**	**1,500**	**Design flows or measured volume**
Total nitrogen concentration in wastewater	**N_W**	**mg/l**	**60**	**Use default value or justify other**
Soil denitrification	**d**	**unitless**	**0.1**	**Default of 0.1 or justify other**
Drainfield area	**A_D**	**ft^2**	**2,000**	**Primary drainfield area**
Distance from drainfield to property boundary	**D_{pb}**	**ft**	**2,500**	**Measure in direction of GW flow**
Nitrate concentration in precipitation	**N_R**	**mg/l as N**	**0.24**	**Use default value**
Recharge	**R**	**in/yr**	**4**	**Use 4 or documented source**
Allowable hydraulic loading rate	**H_R**	**gal/ft^2/day**	**0.8**	**Based on soil type**
Calculations				
Volume of recharge over drainfield	V_R	gpd	14	A_D * R * conversion
Area between drainfield & property boundary	A_{RD}	ft^2	250,000	W_A * D_{pb}
Volume of infiltration from drainfield area	V_i	gpd	1,514	$V_W + V_R$
Volume of discharge downgradient	V_{RD}	gpd	1,708	R * A_{RD} * conversion
Total volume of recharge	V_T	gpd	1,722	$V_R + V_{RD}$
Aquifer discharge	Q	gpd	38,899	K * i * b * W_A * conversion
Total Nitrogen concentration from drainfield area	N_i	mg/l as N	53.51	$((V_R * N_R + V_W * N_W) * (1 - d)) / (V_R + V_W)$
Downgradient ground water nitrogen concentration	N_{GW}	mg/l as N	3.93	$(Q * N_B + V_i * N_i) / (Q + V_i)$
Downgradient ground water nitrogen concentration	N_B	mg/l as N	3.78	$((V_i+Q)*N_{GW} + V_{RD}.N_R*(1-d)) / (V_i+V_{RD}+Q)$
Hydraulic loading	D_H	gal/ft^2/day	0.8	V_W / A_D
Output Values				
Groundwater nitrate value	**N_{GW}**	**mg/l as N**	**3.93**	**Point of Compliance (POC)**
Groundwater nitrate value	**$N_{GW\ ALT}$**	**mg/l as N**	**3.78**	**Alternative POC**
Assessment				
Increase in groundwater nitrate value	POC	mg/l as N	1.93	**Point of Compliance (POC)**
Increase in groundwater nitrate value	POC_{ALT}	mg/l as N	1.78	**Alternative POC**
Are nitrate criteria met at the POC?		Yes/No	Yes	If No, review input values
Are nitrate criteria met at the alternative POC?		Yes/No	Yes	If No, review input values
Is the hydraulic loading criteria met?		Yes/No	Yes	If No, review input values

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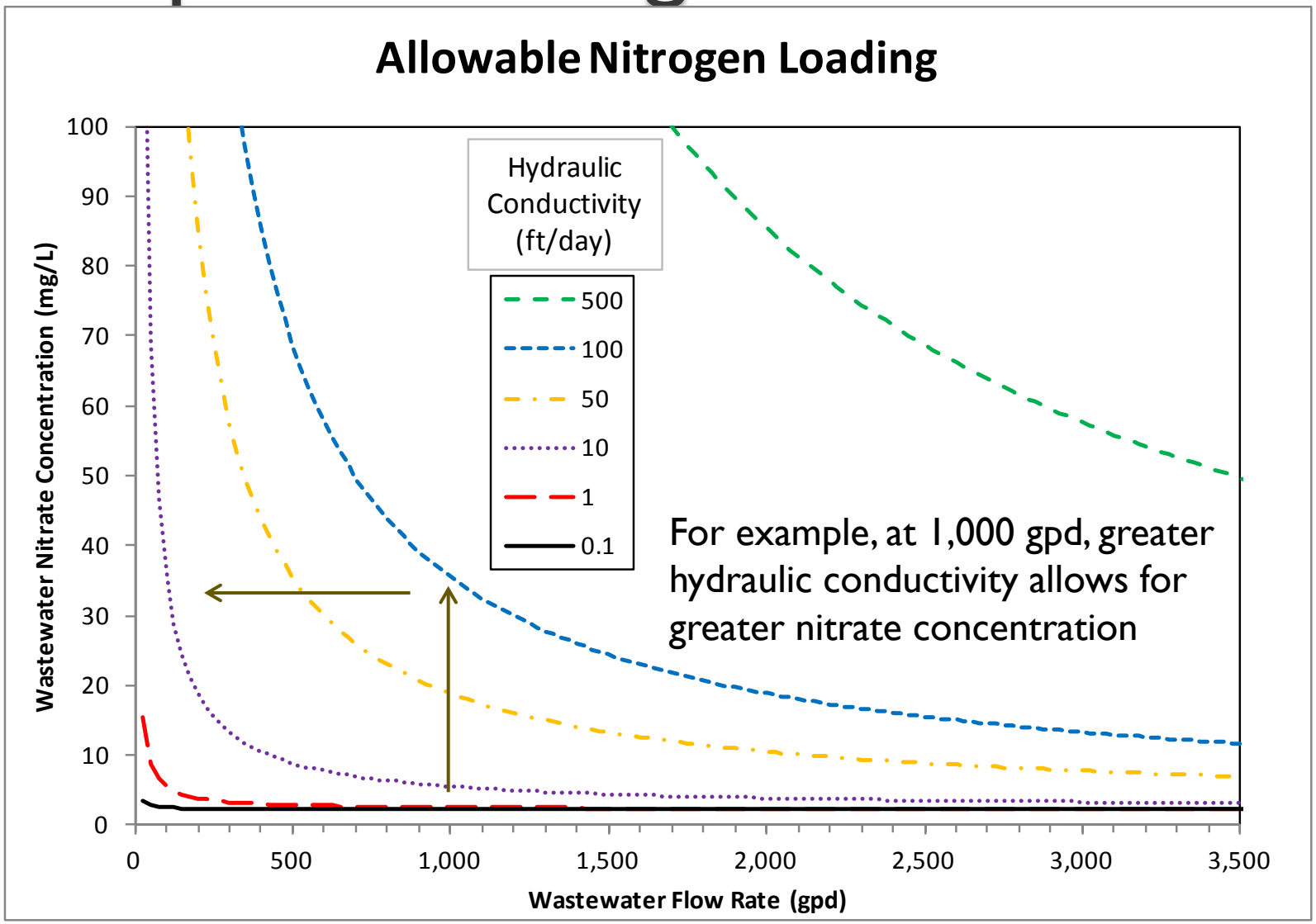
Graph of Loading Combinations



Wastewater nitrogen flow and concentration for mixing zone width of 100 ft, upgradient concentration of 0 mg/L at 2 mg/L downgradient increase

Summary

- Focus on nitrate loadings (Technical Memorandum #3)
- Phosphorus analysis presented in separate future technical memorandum
- Nitrate -mixing zone approach adapted from WDOH and consistent with nearby states (Montana and Idaho)
- Spreadsheet developed that allows for determination of nitrogen loadings that are protective of groundwater

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Next Steps

- Seek input from review committee on Technical Memoranda #2 and #3
- Continue to develop phosphorus technical approach and memorandum
- Evaluate options for implementing into standard
- Develop tools and recommendations

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Comments?

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