Chapter 5
Nitrate TMDL for Zollner Creek

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INTRODUCTION

Zollner Creek is listed on the 2004/2006 303(d) list as water quality limited year-round for nitrate nitrogen (nitrate). Required total maximum daily load (TMDL) components from OAR 340-042-0040 are listed in Table 5 - 1.

Table 5 - 1: Components of the Zollner Creek Nitrate TMDL.

Name & Location of Waterbodies OAR 340-042-0040(4)(a)	Zollner Creek within the Molalla-Pudding Subbasin, Butte Creek 5th field Hydrologic Unit Code 1709000902.
Pollutant Identification OAR 340-042-0040(4)(b)	*<u>Pollutant</u>:* Nitrate
Water Quality Standards and Beneficial Use Identification OAR 340-042-0040(4)(c) OAR 340-041-0033(1) OAR 340-041-0033(2)	OAR 340, Division 41 provides numeric and narrative toxics criteria: (1) Narrative Criteria: Toxic substances may not be introduced above natural background levels in the waters of the State in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety or welfare, aquatic life, wildlife or other designated beneficial uses. (2) Numeric Criteria: Levels of toxic substances may not exceed the criteria listed in Table 20 which were based on criteria established by EPA and published in Quality Criteria for Water (1986), unless otherwise noted. The criterion for both water and fish ingestion as well as drinking water is 10 mg/L. *Beneficial Uses*: Public and private domestic water supply are the most sensitive beneficial uses to nitrate pollution in the Molalla-Pudding Subbasin.
TMDL Loading Capacity OAR 340-042-0040(4)(d) **Excess Load OAR 340-042-0040(4)(e)** **Sources or Source Categories OAR 340-042-0040(4)(f)**	*<u>Loading Capacity:</u>* The loading capacity is expressed as a load that allows compliance with water quality criterion (10 mg/L) under all flow conditions. <u>Excess Load:</u> The difference between the actual pollutant load and the loading capacity of a waterbody. Excess load was calculated for five flow intervals across all flow conditions. Current pollutant load was estimated by the 90th percentile of nitrate load measured in all samples collected within a flow interval. Sources include natural sources, fertilizers, septic systems, confined animal feeding operations (CAFOs), animal waste, road runoff, and runoff from residential and agricultural land use. Industrial sources of nitrate are not present in the Zollner Creek watershed.
Wasteload Allocations OAR 340-042-0040(4)(g) **Load Alloacations OAR 340-042-0040(4)(h)**	*<u>Wasteload Allocations (Point Sources)</u>*: There are no point sources permitted in the Zollner Creek watershed. This TMDL does not assign any wasteload allocations. *<u>Load Allocations (Nonpoint Sources)</u>*: Load allocations are expressed as kilograms/day based on the flow in Zollner Creek. Load allocations apply to all non-point source sectors. Load Allocation = 10 mg/L N * Q * 2.45 * 0.9, where Q = Zollner Creek flow in cubic feet/second, 2.45 is a conversion factor, and 0.9 accounts for a 10% margin of safety.
Seasonal Variation OAR 340-042-0040(4)(j) *CWA §303(d)(1)*	In Zollner Creek, nitrate violations occur throughout the year and under all observed flow conditions, although higher concentrations occur during winter months. The load allocation of this TMDL applies year-round and allows Zollner Creek to meet water quality standards during all seasons.
Margins of Safety OAR 340-042-0040(4)(i) *CWA §303(d)(1)*	*<u>Margins of Safety</u>* A 10% margin of safety is applied to the load allocations.
Reserve Capacity OAR 340-042-0040(4)(k)	DEQ does not allocate to reserve capacity in this TMDL. Future point sources will be required to meet water quality criteria at the edge of a defined mixing zone. Additional non point source contribution, such as from land development, may not cause total loading to exceed the loading capacity.
Standards Attainment & Reasonable Assurance OAR 340-042-0040(4)(l)&(j)	<u>The Water Quality Management Plan</u> provides the framework of management strategies to attain and maintain water quality standards. The framework is designed to work with detailed plans and analyses provided in sector-specific or source-specific implementation plans.

NAME AND LOCATION OF WATERBODIES

The location of Zollner Creek is pictured in Figure 5 - 1. Zollner Creek, from the mouth to river mile 7.8, was first placed on the 2002 303(d) list based on 7 out of 21 samples with nitrate concentrations exceeding 10 mg/L. This listing carried over to the 2004/2006 303(d) list.

Zollner Creek is a tributary to the Pudding River. Compared to other streams in the Willamette Valley, including other agricultural basins with fertilizer applications, Bonn, et al. (1995) found the Pudding River to have higher nitrate concentrations. They found that nitrate concentrations exhibited seasonality, with highest concentrations in the winter – perhaps due to increased runoff, shorter groundwater flow paths, or decreased uptake by algae. The Pudding River sites, however, did not display the seasonal relationship between nitrate and total reduced nitrogen (ammonia and other forms of reduced nitrogen) observed in other Willamette basins. Rinella and Janet (1998) found that the waste water treatment plant (WWTP), located at approximately river mile 21 on the Pudding River, exerted more influence on summer nitrate concentrations than during months of higher stream flow. Summer concentrations of nitrate at the Pudding River site downstream of the WWTP increased, a characteristic not observed at other sampling locations in the basin.

The Pudding River basin, including Zollner Creek, was also the subject of a chapter of Phase II of the Willamette River Basin Water Quality Study (E & S Environmental Chemistry, Inc. and Tetra Tech, Inc., 1995). They concluded that nitrate concentrations increase in surface water as early fall rains create an annual pulse of nitrate that has accumulated in soils. Nitrate concentrations then decline through the winter months because of dilution in higher surface water flows. They concluded that nitrate loading from Zollner Creek influences nitrate concentrations in the Pudding River, as does loading from groundwater. They also surmised that biological uptake of nutrients in the summer is partially responsible for lower nitrate concentrations in the summer months.

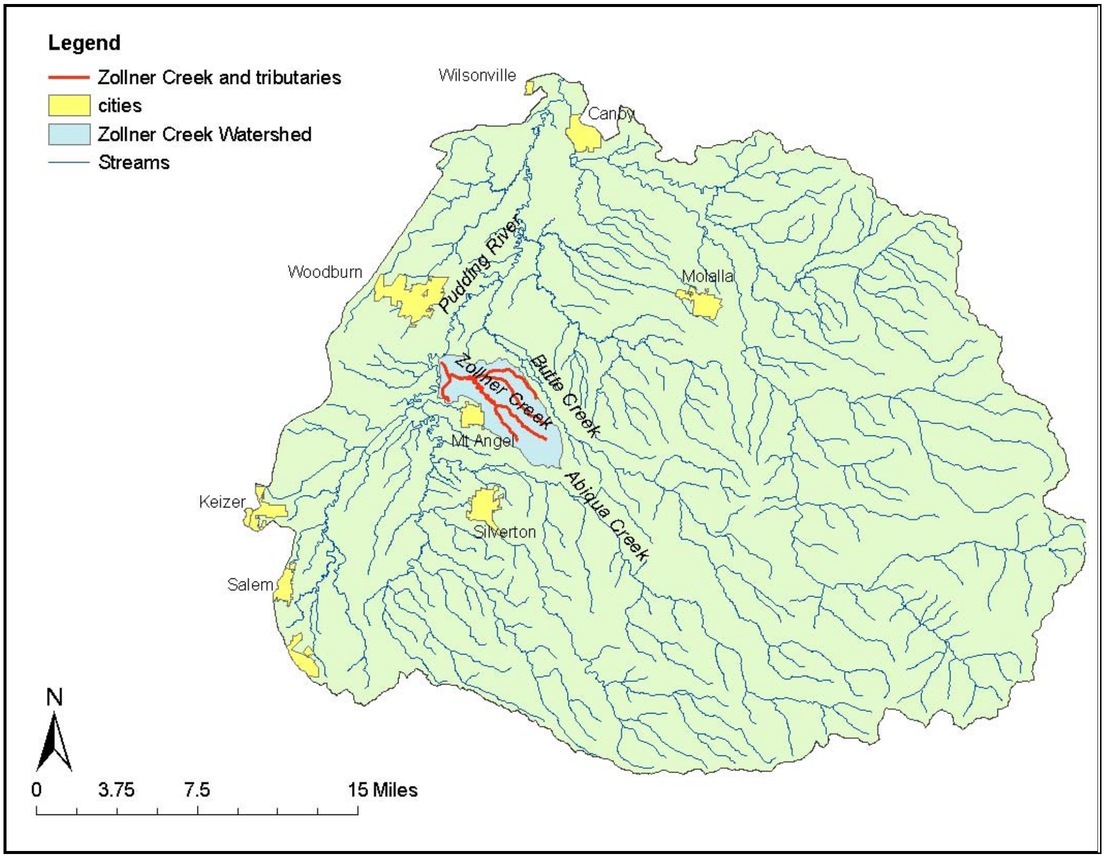

Figure 5 - 1: Location of Zollner Creek watershed in Molalla-Pudding Subbasin.

POLLUTANT IDENTIFICATION

The pollutant addressed in this TMDL is nitrate. Nitrate is a naturally occurring compound of nitrogen and oxygen. Nitrogen occurs in the air, living organisms and their waste. While nitrate and high organic nitrogen can occur in some geologic materials, human disturbance generally contributes to the concentration of that nitrate in groundwater (Hallberg and Keeney, 1993). Nitrate can also be manufactured for use in fertilizers, explosives, and food preservation. Throughout this chapter, nitrate concentrations will be reported as the molecular mass of nitrogen in the nitrate form, per volume of water. This is abbreviated as “mg/L NO_3-N.” The laboratory analyses that generated the USGS and DEQ data used in this report measured combined nitrite (NO_2-N) and nitrate (NO_3-N). Nitrite is unstable in oxygenated water and quickly converts to nitrate.

Excess nitrate in waterbodies can be responsible for eutrophication (e.g. excessive algal productivity), but nitrate is also addressed through criteria based on toxic effects. Nitrate levels above 10 mg/l may represent a serious health concern for infants and pregnant or nursing women. Nitrate, converted to nitrite in the body, can interfere with the ability of the blood to carry oxygen to vital tissues of the body in infants of six months old or younger. The result is called methemoglobinemia, or "blue baby syndrome." Preliminary studies suggest that excessive nitrate ingestion may be linked to gastric or bladder cancer, though that link is not firmly established. Nitrate’s toxic effects would come about through ingestion, rather than from other uses such as bathing, washing, or irrigation (OHD - DHS, 2001).

WATER QUALITY STANDARDS AND BENEFICIAL USE IDENTIFICATION

Water quality standards pertaining to nitrate are both narrative and numeric:

OAR 340-41-0033(1): Toxic substances may not be introduced above natural background levels in waters of the state in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare or aquatic life, wildlife, or other designated beneficial uses;

OAR 340-41-0033(2): Levels of toxic substances may not exceed the criteria listed in Table 20 which were based on criteria established by EPA and published in Quality Criteria for Water (1986), unless otherwise noted.

The Table 20 criteria for nitrate is 10 mg/L – N. The EPA has also set a maximum contaminant level for nitrate at 10 mg/L -N in public water supplies (Oregon DHS, 2001).

The beneficial uses impaired by nitrate toxicity, among all beneficial uses in the Molalla-Pudding Subbasin, are indicated in Table 5 - 2. The most sensitive beneficial use is domestic water supply. Fishing is indicated as a sensitive beneficial based on the human health criteria for Water and Fish Ingestion.

Table 5 - 2: Beneficial uses occurring in the Molalla-Pudding River Sub-Basin (OAR 340 – 41 – 0340). Toxics-sensitive beneficial uses are marked in gray.

Beneficial Use	***Occurring***	***Beneficial Use***	***Occurring***
Public Domestic Water Supply	✓	Salmonid Fish Spawning (Trout)	✓
Private Domestic Water Supply	✓	Salmonid Fish Rearing (Trout)	✓
Industrial Water Supply	✓	Resident Fish and Aquatic Life	✓
Irrigation	✓	Anadromous Fish Passage	✓
Livestock Watering	✓	Wildlife and Hunting	✓
Boating	✓	Fishing	✓
Hydro Power	✓	Water Contact Recreation	✓
Aesthetic Quality	✓	Commercial Navigation & Transportation	

SOURCES AND SOURCE CATEGORIES

Anthropogenic sources of nitrate include fertilizers, septic systems, animal feedlots, industrial wastes, food processing waste, and leachate from waste disposal in sanitary landfills. The Pudding River watershed contains both a landfill and a major waste water treatment plant, but neither of these sources are in the Zollner Creek watershed. Runoff of from highways and urban areas may also be nitrate sources. Mt. Angel is the only urban area in the Zollner Creek watershed and comprises only 1% of the watershed area.

Rinellla and Janet (1998) found that no nutrients were detected (<0.05 mg/L for nitrate-N) at a site in a 100% forested watershed (Molalla River at Wilhoit). Bonn (1995) found that two forested sites (Little Abiqua Creek near Scotts Mills and North Fork Silver Creek near Stayton) yielded nutrient concentrations ranging from <0.01 to 0.03 mg/L. These sites were not located in the Zollner Creek watershed but may be representative of natural nitrate concentrations in surface water in this subbasin.

Both groundwater and surface runoff may transport nitrates into Zollner Creek and nitrate concentrations in groundwater are discussed in the following section. Potential agricultural (e.g. fertilizers) and septic contributions are examined in more detail following the groundwater discussion.

NITRATES IN GROUNDWATER

Hinkle's (1997) analysis of groundwater in Willamette Basin alluvial aquifers found that concentrations of nitrate in groundwater downgradient from areas of irrigated agriculture exceeded those from areas downgradient of non irrigated agriculture. Wentz, et. al, (1998) report that nitrate in Willamette Basin alluvial groundwater relates to dissolved oxygen and the aquifer's permeability, and notes that groundwater nitrate concentrations likely reflect the land use practices at the time the water infiltrated through the soil, rather than the time the sample was collected.

DEQ reviewed groundwater nitrate data collected in the Molalla-Pudding subbasin to evaluate the relationship between nitrate concentrations in Zollner Creek and groundwater. DEQ reviewed groundwater data in DEQ, USGS, and the Oregon Department of Human Services, Health Division (OHD) Real Estate Transaction databases (Figure 5 - 2). The OHD data have not been quality assured and DEQ uses the data only for general comparison and to identify spatial patterns. Table 5 - 3 summarizes the nitrate concentrations measured in groundwater sample results compiled in the three databases.

USGS and DEQ data did not include any groundwater samples from the vicinity of Zollner Creek. Several of the DEQ groundwater samples were collected at or near the Woodburn (Marion County) Landfill or in locations at risk from nitrate contamination. The depth of the wells associated with the landfill ranged from less than five to 66 feet. The depth of wells not associated with the landfill was not recorded. The median and maximum of nitrate concentrations measured in groundwater collected from wells associated with the landfill exceeds those statistics from other wells. Still, groundwater samples collected by DEQ from 6 of 35 wells not associated with the landfill yielded nitrate concentrations exceeding 3 mg/L.[1]

At four of their 16 sampling locations, USGS collected samples with measured nitrate concentrations exceeding 3 mg/L. Most wells sampled were less than 80 feet deep. The median of the USGS-measured nitrate concentrations exceeded the median of the DEQ non-landfill nitrate concentrations, which may be explained in part by a smaller data set or sampling from different aquifers.

Three OHD-sampled wells are in the vicinity of Zollner Creek. The concentrations from these three OHD samples are non detectable (either <0.1 or <0.5 mg/L), 9.9 mg/L and 3.4 mg/L. The database does not list depths for the two wells with nitrate detections, but the well with a non-detectable nitrate concentration is 220 feet deep.

The groundwater data indicate certain areas in the subbasin where nitrate concentrations may exceed several mg/L, but do not indicate ubiquitous nitrate concentrations over 1 mg/L. The two measured nitrate concentrations in the vicinity of Zollner Creek are not sufficient to infer a widespread groundwater nitrate source in the Zollner Creek watershed, but do not contradict a potential relationship between groundwater and surface water nitrate in this area.

[1] Concentrations of up to 3 mg/L in water are generally considered safe to drink and naturally occurring. DEQ Fact Sheet, Sept. 2002, found at this location: http://www.deq.state.or.us/wq/pubs/factsheets/groundwater/nitratedw.pdf

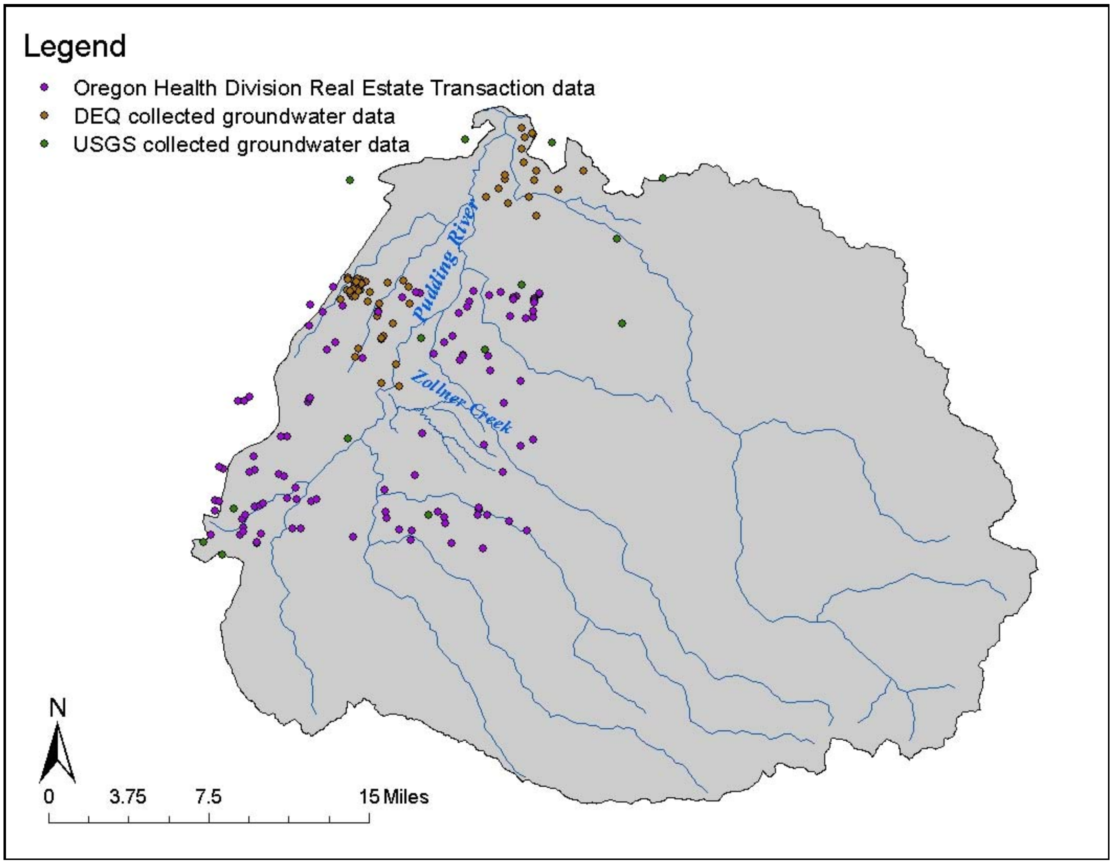

Figure 5 - 2: Locations of groundwater samples collected by DEQ, OHD, and USGS analyzed for nitrate in the Molalla-Pudding Subbasin.
DEQ data was collected between 1982 and 2004. Most of the USGS data were collected during summer months in 1993, with two data points from 1973 and 1996. The OHD data was collected between 1989 and 2002.

Table 5 - 3: Summary of groundwater nitrate concentrations, NO_3-N.
DEQ data includes duplicates collected from some locations. *OHD data has not been quality assured and are used only for general comparison. In order to calculate the median, results qualified as "less than" or "estimated" were entered as the method reporting limit or the estimate, respectively.

Source	Number of Samples		Median (mg/L)	Min (mg/L)	Max (mg/L)
DEQ – all	518	121 qualified	0.04	<0.02	24
DEQ – non-landfill	46	18 qualified	0.02	<0.02	18
USGS	16	7 qualified	0.23	0.005	19
OHD*	121	37 qualified	0.5	<0.05	16.8

SEPTIC SYSTEMS

The Zollner Creek watershed contains approximately 200 residential septic systems [Matt Knundson, Marion County, personal communication]. A generalized estimate of worst-case potential nitrate loading from the septic systems can be represented as follows:

L = Q * P * C = 12 kg/day

L = kg per day of potential nitrate loading to Zollner Creek
Q = 48 gallons per day is average septic tank effluent discharge per person (Bounds, 1997)
P = 800 persons utilizing home septic systems (200 tax lots * 4 people average per lot)
C = 85 mg/L inorganic and organic nitrogen: upper end of measured concentration range for septic effluent (Bounds, 1997; Townsend, 1997).

Conversion factor: 3.78 x10E-6 gallons to liters, mg to kg

While aging septic systems may be contributing nitrate loading to Zollner Creek, the estimate above is a worst-case scenario because it does not account for any uptake of nitrogen between the septic system and the stream. If septic effluent were a significant portion of the nitrate loading to Zollner Creek, one would expect higher nitrate concentrations in the summer months when stream flows are lower. Seasonal analysis, described in a following section of this chapter, does not reveal such a pattern. Rather, nitrate concentrations in Zollner Creek are lowest in the summer months.

AGRICULTURAL SOURCES

Nitrate contamination of surface water may result from direct deposition of animal waste in streams or from runoff containing animal waste. There are approximately 10 confined animal feeding operations (CAFOs) in the Zollner Creek watershed. Part of normal CAFO facility operation is to manage the accumulated manure. The facilities are regulated as point sources under a general NPDES permit issued by ODEQ and administered by Oregon Department of Agriculture (ODA). Under the terms of these permits, no discharge is allowed from areas of animal confinement, manure management or storage. DEQ is not aware of any Notices of Noncompliance issued to CAFOs in the Zollner Creek watershed. Animal and manure management at smaller, non-CAFO facilities may contribute to excessive nitrate concentrations in Zollner Creek.

The results of storm sampling (E & S Environmental Chemistry, Inc. and Tetra Tech, Inc., 1995) indicate Zollner Creek has a high ammonium concentration relative to other forms of nitrogen (nitrate, and total Kheldhal nitrogen -- organic nitrogen plus ammonia). During an October storm, both ammonium and nitrate increased rapidly, with nitrate continuing to increase during the falling limb of the hydrograph. They interpret these characteristics and a strong relationship between TKN and ammonium in Zollner Creek as being consistent with a major source of organic waste, such as manure.

While the exact contribution of each source of nitrate is unknown, it is generally accepted that application of manufactured fertilizers can result in groundwater contamination in vulnerable hydrogeologic settings (Follet, Keeney, and Cruse, 1991). Hinkle (1997) cites Alexander and Smith (1990) in presenting how nitrogen fertilization rates have increased in the Willamette Valley since 1945.

Feaga and Selker (2004) performed a study of nitrate leaching below row (vegetable) crops in Lane County. Vegetables, they claim, are inefficient at using nitrogen fertilizer because of shallow rooting depth and large distances between plants. They cite that 30 – 70% of applied nitrogen is removed during harvest, the remainder potentially being released to air, soils, and water. For their study, between 200 and 250 lb/N acre was applied to the subject fields. Water was collected in sampling devices installed below the plants' root zone. In most vegetable test fields, the nitrate leached below the root zone exceeded 10 mg/L, with highest concentrations measured July through November.

They estimated that mass leaching ranged from approximately 40 to 150 lb N/acre for the vegetable fields.

Land use in the Zollner Creek watershed is 98% agriculture, with about 1% forestry, and 1% urban (E&S Environmental Chemistry and Tetra Tech, Inc., 1995). Previous studies have found that Zollner Creek nitrate concentrations significantly exceed concentrations at other locations in the basin as well as other streams dominated by agricultural uses (Rinella and Janet, 1998; Wentz, et al., 1998). Rinella and Janet (1998) analyzed surface water nitrate data from several sites in the Molalla-Pudding basin, collected over a range of flow conditions. Noting high nitrate concentrations in the late fall that decrease steadily through the winter, they concluded that first rains flushed nitrates stored in the soils and the concentration decreased as stored nitrates decreased. From a synoptic study during an April storm (Pudding River at 3,000 cfs), they also concluded that nutrient concentrations in surface water correlated with the percentage of the basin that was in agricultural use (also reported in Wentz, et al., 1998).

Because of the documented relationship between groundwater nitrate contamination and fertilizer use (Follett, et al, 1991; Hallberg and Keeney, 1993; Feaga and Selker, 1994), DEQ compiled information about current fertilization practices in the watershed to better understand current potential loading. The information DEQ compiled is detailed in the remainder of this section.

Grass seed is one of the major crops grown in the Zollner Creek watershed. Grass grown for seed has higher fertilization rates than hay or pasture (Young[2]). Grass growers have practices to minimize the need for fertilization such as leaving straw on fields following harvest and planting nitrogen-fixing cover crops (Oregon Seed Council[3]). Agricultural producers grow a variety of other crops in the Zollner Creek Watershed. Table 5 - 4 (E&S Environmental Chemistry and Tetra Tech, Inc., 1995) lists the percent of the watershed cultivated for different kinds of crops or used for other purposes.

Current recommended fertilization practices can provide estimates of application rates above which nitrate may not be utilized by the plants and may accumulate in soil. Table 5 – 5 summarizes generalized information about fertilizers used on different kinds of crops grown in the Zollner Creek watershed. DEQ was unable to obtain estimates for fertilization rates for row crops, hops, and pasture.

Table 5 - 4: Land use and crop types in the Zollner Creek watershed.
Source: E&S Environmental Chemistry and TetraTech (1995): Percent based on review and digitization of 1993 aerial photographs at 1:24,000 scale.

Land Use	Hectare	Percent
Developed	106	2.7
Grass/wheat	1361	34.6
Nursery	72	1.8
Pasture	203	5.1
Row Crop	1621	41.1
Orchards	25	0.6
Hops	303	7.7
Livestock	31	0.8
Livestock lagoons	1	>0.1

[2] Young, William C. III, Grass Seed Production in Oregon. Oregon State University Extension. http://cropandsoil.oregonstate.edu/seed-ext/Pub/or_prod.html.

[3] Oregon Seed Council. Grass Seed Production and the Environment. http://forages.oregonstate.edu/organizations/seed/osc/brochures/production-environment/index.html#fertility

Table 5 - 5: General fertilization practices for crops grown in the Zollner Creek watershed.
Sources: Silberstein T., Owen J., Regan, R., McReynolds, B., Oregon State University Extension, 2007, personal communication; Young, et al., 1999.

Crop	Recommended Rate lb N/acre	Type	Season of application
Grass seed: Perennial rye	135 – 180	Urea, ammonium sulfate	February – April Fall (~20 – 30% of spring application)
Grass seed: fescue	50 – 70	Urea, ammonium sulfate	February – April Fall (~20 – 30% of spring application)
Christmas trees	100 – 150	Urea, ammonium nitrate, ammonium sulfate, calcium nitrate	September - October
Nursery: containers		Controlled release, e.g. Osmocote, Apex	When plants repotted; liquid feed with irrigation in summer
Nursery: field crops	50 – 200	Urea, ammonium nitrate, ammonium sulfate, calcium nitrate	Mostly spring – early summer. Fewer summer/fall applications

LOADING CAPACITY

The loading capacity of a waterbody is the an accepted rate of pollutant that still allows water quality standard compliance. For purposes of determining this nitrate TMDL, loading capacity for Zollner Creek is the load under which the criterion (10 mg/L NO_3-N) is not exceeded under any flow condition. The loading capacity can be represented by a load duration curve (Figure 5 - 3) or the following equation:

LC (kg/day) = 10 mg/L NO_3-N * Q * 2.45

where Q = stream discharge in cubic ft/second
2.45 is a conversion factor
LC = loading capacity

Table 5 - 6 indicates the loading that Zollner Creek could accept at different flows and still meet the water quality standard.

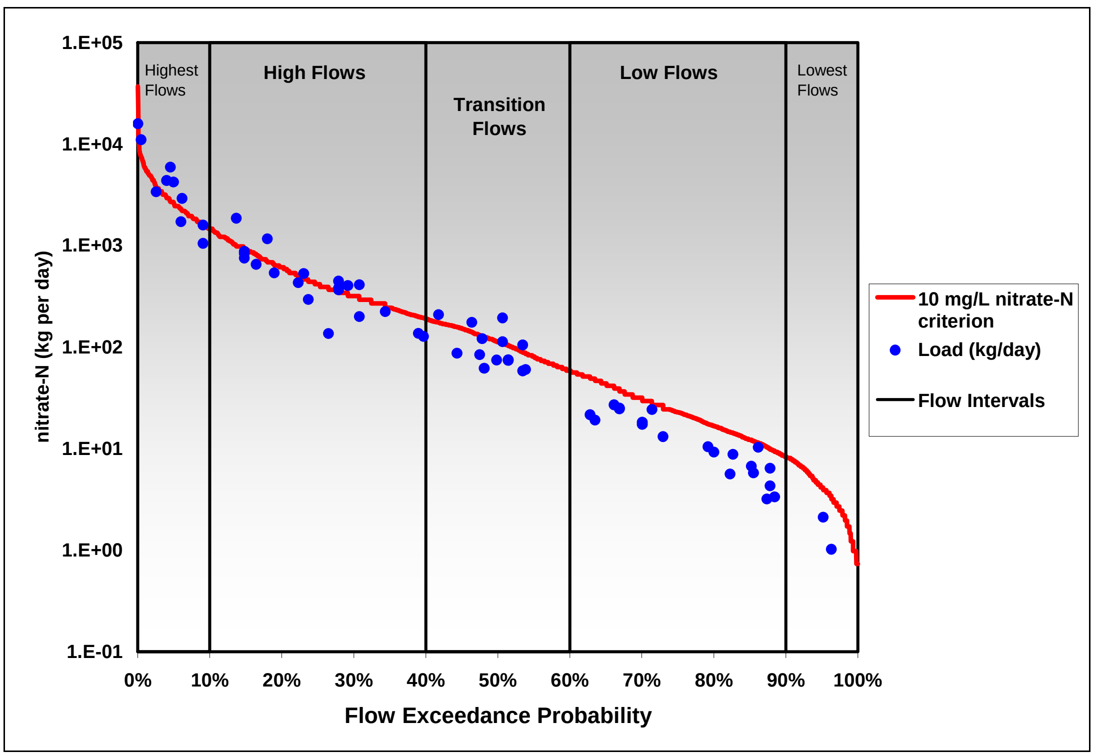

Figure 5 - 3: Loading capacity of Zollner Creek for nitrate based on 10 mg/L NO_3-N criterion.

Table 5 - 6: Loading capacity at different stream flows in Zollner Creek.

Flow (cfs)	Flow Exceedance Probability	Load to meet criterion of 10 mg/L (kilograms per day)
0.17	95%	4.16
0.93	75%	22.8
4.6	50%	113
17	25%	416
108	5%	2,646

EXCESS LOAD

Excess load is the difference between the current pollutant load to a waterbody and the loading capacity of that waterbody. Current nitrate load was estimated by calculating the 90th percentile of the load within each flow interval – a more conservative estimate than using the median. DEQ conservatively represented the loading capacity for each flow interval by the loading capacity at highest exceedance probability in each flow interval. The difference between the loading capacity and the estimated current pollutant load is an explicit excess load.

Table 5 - 7: Excess Load of nitrate in Zollner Creek.

NO_3-N (kg/day)	**Highest Flows** 0 - 10% Exceedance Probability	**High Flows** 10 - 40% Exceedance Probability	**Transitional Flows** 40 - 60% Exceedance Probability	**Low Flows** 60 – 90% Exceedance Probability	**Lowest Flows** 90 - 100% Exceedance Probability
Current Load	11,498	904	188	25	2.0
Loading Capacity	1468	191	59	8	1.2
Excess Load	10.030	713	129	17	0.8

ALLOCATIONS

WASTELOAD ALLOCATIONS

No point sources discharge in the Zollner Creek watershed and wasteload allocations were not calculated.

LOAD ALLOCATIONS

The load allocation for non-point sources in the Zollner Creek watershed is equivalent to the loading capacity minus a 10% margin of safety, calculated with the equation below: Specific load allocations were not identified for each non-point source but all sources are responsible for meeting the load allocation.

LA (kg/day) = 10 mg/L N * Q * 2.45 * 0.9

Where:
LA = load allocation in kg per day
10 mg/L NO_3-N = nitrate criterion
Q = instream flow in cubic feet per second
2.45 = conversion factor to kilograms per day

The load allocation is streamflow dependent. Table 5 - 8 shows, through a range of flows measured at Zollner Creek at Monitor McKee Road (river mile 0.3), the load allocation (LA) for background and nonpoint sources necessary to meet the instream loading capacity for nitrate. The load allocation takes into account a 10% margin of safety.

Table 5 - 8: Example Load Allocations in kilograms/day of nitrate-N in Zollner Creek at specific flows as measured at river mile 0.3.
Load allocation reflects a 10% Margin of Safety.

Flow (cfs)	Flow Exceedance Probability	Load allocation to non-point source (kilograms per day)
0.17	95%	3.7
0.93	75%	20.5
4.6	50%	102
17	25%	374
108	5%	2,382

SEASONAL VARIATION

The stream segment addressed in this TMDL is listed for nitrate year-round. Analysis of data collected between 1989 and 2006 indicates a statistically significantly lower median concentration from samples collected between July and September (refer to Appendix L). Lower summer concentrations probably result from hydrologic conditions (e.g. a deeper water table and low precipitation to flush nitrate out of the soil) and biologic conditions (e.g. algal uptake of nitrate), rather than different sources of nitrate with season. For that reason, the load allocation applies year-round to protect beneficial uses in all seasons and across all flow conditions.

MARGINS OF SAFETY

The margin of safety in the TMDL is explicitly allocated. The load allocations have been reduced by 10 percent as a safety factor. There is also an implicit margin-of-safety in conservative assumptions made to calculate the loading capacity and excess load, and in the data itself. Reported nitrate concentrations are actually combined nitrite plus nitrate, converted to equivalents of nitrogen. In surface water, and oxygenated groundwater, nitrite is unstable and quickly converts to nitrate. Still, the actual nitrate concentrations on which the load allocation is based could be less than the reported nitrite+nitrate concentrations.

RESERVE CAPACITY

DEQ does not allocate to reserve capacity in this TMDL. Any future point sources would be required to meet water the quality criterion at the edge of a defined mixing zone. Any additional non point source could not cause nitrate loading to exceed the loading capacity.

ADDITIONAL CONSIDERATIONS

The nitrate load reduction necessary to meet this TMDL targets the nitrate criteria based on toxicity. The load allocation would not protect Zollner Creek from additional water quality violations associated with eutrophication such as pH and dissolved oxygen violations or excessive algae growth. A concentration of 10 mg/L nitrate-N exceeds in-stream nitrate-N concentrations from predominantly forested landscapes and EPA guidelines for nutrient criteria in the Willamette Valley (0.15 mg/L) (EPA, 2001) by more than an order of magnitude. Land managers should target a nitrate concentration in Zollner Creek lower than 10 mg/L to protect against other water quality violations.

REFERENCES

Bonn, Bernadine A., Hinkle, Stephen R., Wentz, Dennis A., and Uhrich, Mark A. 1995. Analysis of Nutrient and Ancillary Water-Quality Data for Surface and Ground Water of the Willamette Basin, Oregon, 1980 -90. U.S. Geological Survey, Water-Resources Investigations Report 95-4036.

Follett, R.F., Keeney, D.R., and Cruse, R.M. 1991. Managing Nitrogen for Groundwater Quality and Farm Profitability, Eds. Soil Science Society of America, Inc., Madison, WI.

Hallberg G.R. and Keeney, D. R. 1993. Nitrate, in Regional Groundwater Quality, Van Nostrand Reinhold, New York.

E&S Environmental Chemistry, Inc. and Tetra Tech, Inc. 1995. Willamette River Basin Water Quality Study, Phase II, Non-Point Source Pollution in the Pudding River Sub-Basin of the Willamette River, Draft Report. DEQ Contract No. 074-94.

Environmental Protection Agency. 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling. Second Ed. 475 pp.

Environmental Protection Agency. 1986. EPA Gold Book, Quality Criteria for Water.

Environmental Protection Agency. 2001. Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and tribal Nutrient Criteria, River and Streams in Ecoregion I, Willamette and Central Valleys, EPA 822-B-01-012.

Oregon Department of Human Services, Health Division, June 2001, Technical Bulletin Health Effects Information, Nitrate.

Oregon Seed Council. Grass Seed Production and the Environment. http://forages.oregonstate.edu/organizations/seed/osc/brochures/production-environment/index.html#fertility

Rinella, Frank A. and Janet, Mary L. 1998. Seasonal and Spatial Variability of Nutrients and Pesticides in Streams of the Willamette Basin, Oregon 1993 – 1995. U.S. Geological Survey, Water-Resources Investigations Report 97-4082-C.

Thomann, R.V., and Mueller, J.A. 1987. Principles of Surface Water Quality Modeling and Control, Harper Collins Publishers, Inc., 644 pp.

Wentz, Dennis A., Bonn, Bernadine A., Carpenter, Kurt D., Hinkle, Stephen R., Janet, Mary L., Rinella, Frank A., Uhrich, Mark A., Waite, Ian R., Laenen, Antonius, and Bencala, Kenneth E. 1998. Water Quality in the Willamette Basin, Oregon, 1991 – 95. U.S. Geological Survey Circular 1161.

Young, W.C. III, Gingrich, G.A., Silberstein, T.B., Griffith, S.M., Chastain, T.G. and Hart, J.M. 1999. Defining Optimum Nitrogen Fertilization Practices for Fine Fescue Seed Production Systems in the Willamette Valley.

Young, W.C, M. E. Mellbye, G.A. Gingrich, T.B. Silberstein, S.M. Griffith, T.G. Chastain and J.M., Hart. 1999. Defining Optimum Nitrogen Fertilization Practives for Perennial Ryegrass and Tall Fescue Seed Production Systems in the Willamette Valley.

Young, William C. III, Grass Seed Production in Oregon. Oregon State University Extension. http://cropandsoil.oregonstate.edu/seed-ext/Pub/or_prod.html.