Mid-Yakima River Basin Bacteria

Total Maximum Daily Load

Water Quality Improvement Report - DRAFT

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Cover photo: Wide Hollow Creek in Randall Park, Yakima, WA

Project Codes and 1996 303(d) Water-body ID Numbers

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Water Quality Improvement Report

by

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Abstract

The mid-Yakima River basin is located in the south-central portion of Washington State (State) surrounding and including the cities of Union Gap and Yakima. The *Mid-Yakima River Basin Bacteria Total Maximum Daily Load* (TMDL) project area encompasses over 338 square miles and contains three sub-basins: Cowiche Creek, Moxee Drain and Wide Hollow Creek. The TMDL addresses thirty-four 303(d) listings for excessive fecal coliform bacteria (FCB) contained in the State's 2012 Water Quality Assessment (WQA). Excessive FCB pollution in local water bodies represents a significant health risk for human beings.

The greatest FCB pollution throughout the TMDL project area occurs during the agricultural irrigation season (April 15 through October 15). However, a few sites require substantial reductions in FCB pollution year-round in order to meet State water quality standards (WQS). Therefore, the critical condition for this TMDL is considered year-round, with an emphasis on the irrigation season. During the irrigation season, the FCB pollution needs to be reduced by approximately 46% in the Cowiche Creek sub-basin, 45% in the Moxee Drain sub-basin, and 62% in the Wide Hollow Creek sub-basin.

The majority of FCB pollution within the TMDL project area is associated with irrigation. However, six sites within the Moxee Drain sub-basin and four sites within the Wide Hollow Creek sub-basin were found to have very high FCB concentrations throughout the entire year. This suggests a predominance of either point sources or pseudo-point sources (non-point sources that have characteristics of point sources) unrelated to irrigation.

The TMDL project area contains several municipal separate storm sewer systems (MS4s). The municipalities operating most of those MS4s (Yakima County, city of Union Gap, and city of Yakima) are principal to the success of the TMDL. However, MS4 permits are also held by the Yakima Valley Community College (YVCC) and the Washington Department of Transportation (WSDOT). These latter entities are also stakeholders in the TMDL project.

Stormwater events were sampled only in the Wide Hollow Creek sub-basin because it has the most complicated stormwater collection system of all water bodies in this study. During the irrigation season, stormwater accounted for the greatest FCB concentrations found throughout the entire TMDL project area.

The percentages of *E. coli* and *Klebsiella* compared to FCB in individual water samples during the irrigation season averaged 63.8% and 1.45%, respectively. The respective non-irrigation season percentages were 66.7% and 0.62%. None of the Wasteload Allocations (WLAs) or Load Allocations (LAs) in this water quality improvement report (WQIR) was adjusted due to the percentage of *E. coli* or *Klebsiella*, as they are all assumed to be pathogenic.

This WQIR outlines some specific actions required of stakeholders in order to achieve compliance with State WQS by 2024. A more detailed water quality improvement plan (WQIP) will be completed within one year from U.S. Environmental Protection Agency (USEPA) approval of the TMDL.

Executive Summary

Introduction

In 2008, the Washington State Department of Ecology (Ecology) determined that fourteen surface waters in the Mid-Yakima River Basin have fecal coliform bacteria (FCB) levels greater than Washington State (State) allows in its water quality standards (WQS) for surface waters (Chapter 173-201A WAC). A total maximum daily load (TMDL) study is required for those water bodies. This report uses the results of a study (*Mid-Yakima River Basin Fecal Coliform Bacteria Total Maximum Daily Load: Water Quality Study Findings*), published in September 2012, in order to develop (1) appropriate target reductions for bacteria pollution, and (2) an implementation plan that lays out roles and responsibilities for the cleanup process.

Why did we develop a total maximum daily load (TMDL)?

The federal Clean Water Act (CWA) requires that a TMDL be developed for each of the water bodies on the 303(d) list. The 303(d) list is a list of water bodies, which the CWA requires states to prepare, that do not meet their WQS. Each TMDL water quality improvement report (WQIR) identifies pollution problems in the applicable watershed, and then specifies how much pollution needs to be reduced or eliminated to achieve clean water. The WQIR will be submitted to the U.S. Environmental Protection Agency (USEPA) for approval. Once approved Ecology with the assistance of local governments, agencies, and the community, will develop a water quality implementation plan (WQIP) that describes actions to control the pollution and monitor the effectiveness of the water quality improvement activities.

Watershed description

The Mid-Yakima River Basin Bacteria TMDL project area (338.5 square miles) is located in the central portion of the State and is completely within Yakima County. Yakima and Union Gap are the largest cities in the project area. Smaller communities include Moxee, Tieton and Cowiche, which were served by two Publicly-Owned Treatment Works (POTWs), though only the sewage treatment plant at Cowiche is still presently discharging effluent. The city of Moxee Publicly Owned Treatment Works (POTW) now discharges its effluent to the city of Yakima Regional POTW, which is outside the boundaries of the TMDL project area.

The TMDL project area is composed of three sub-basins: (1) the Cowiche Creek sub-basin (in Water Resource Inventory Area (WRIA) 38); (2) the Moxee Drain sub-basin (in WRIA 37); and (3) the Wide Hollow Creek sub-basin (in WRIA 37). Figure 1 presents the boundaries of the TMDL project area as well as its sub-basins. Mid-Yakima River Basin water bodies that were not within the project area include those that are entirely, or partially, located on the Yakama Nation tribal lands, such as Ahtanum Creek. Ahtanum Creek is the northern border of the Yakama Nation tribal lands and its sub-basin is contiguous to, and located to the south of, the Wide Hollow Creek sub-basin.

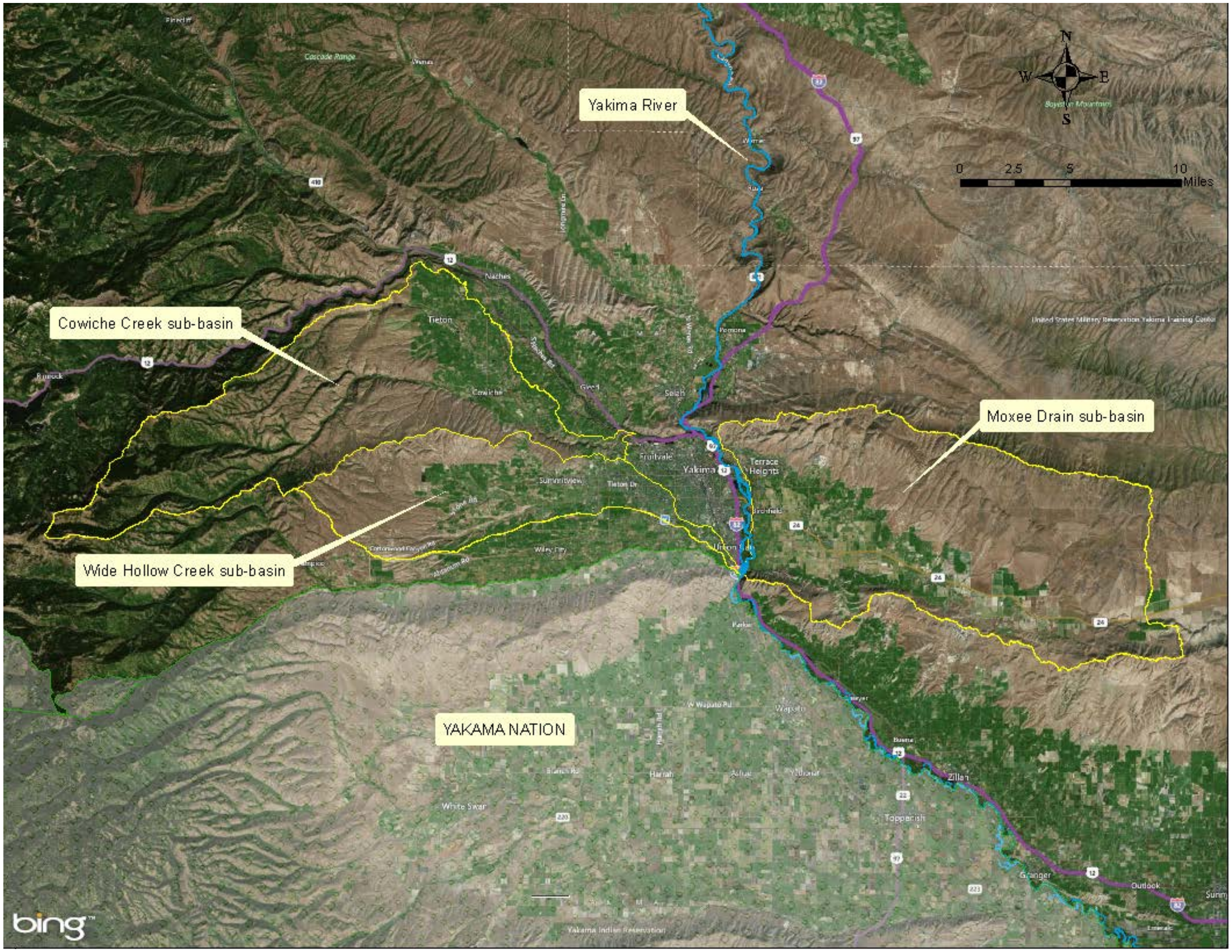

Figure 1: Boundary of TMDL project area and sub-basins.

The population within the *Mid-Yakima River Basin Bacteria TMDL* project area has been growing rapidly over the last thirty years. As a result, the project area is now a unique checkerboard of land uses including industrial, urban, transportation, residential, orchard, irrigated cropland, non-commercial farm, forest, and range applications. FCB pollution is an increasing problem in local surface waters due to a combination of both non-point sources and point sources.

The *critical condition* for the TMDL is the entire calendar year because bacteria pollution at some sites throughout the project area exceeds State WQS year-round. However, the summer (dry) season has significantly greater FCB concentrations than the winter (wet) season. This counter-intuitive seasonal variation is the result of local surface water having their greatest flows during the summer. The greater flows are caused by return flows from the intensive use of irrigation.

The summer also has the greatest potential for human contact (hikers, hunters, adventurous children) with local water bodies. Therefore, the majority of surface waters within the TMDL project area must be protected for *primary contact recreation* FCB criteria found in Chapter 173-201A WAC. However, there are a few surface waters located within the north-west portion of the Cowiche Creek sub-basin that are within the boundary of the Wenatchee National Forest (WNF). These latter surface waters must be protected for *extraordinary primary contact recreation* FCB criteria found in Chapter 173-201A WAC.

The goal of the *Mid-Yakima River Basin Bacteria TMDL* project is to bring all water bodies within its project area into compliance with State WQS for FCB. Doing so will allow for the public's incidental wading and swimming activities during the summer, with minimal chance of sickness.

What needs to be done in this watershed?

The 2012 water quality assessment (WQA) for the State identified thirty-three 303(d) listings for excessive FCB pollution throughout the *Mid-Yakima River Basin Bacteria TMDL* project area. Historical and present sampling determined that the greatest bacteria pollution occurs during the agricultural irrigation season of April 15 through October 15. During that season, all of the TMDL project area's water bodies exceed State water quality FCB criteria. This indicates that they are impaired for the designated use of primary contact recreation at that time. Primary contact recreation undoubtedly occurs during the hot summer months, especially by young children who are the most vulnerable to diseases associated with fecal contaminated surface waters.

During the irrigation season, FCB concentrations exceeded State WQS by approximately 49%, 48% and 77% in the Cowiche Creek, Moxee Drain and Wide Hollow Creek sub-basins respectively. Snowmelt, stormwater and irrigation drainage are suspected of being the predominant transport mechanisms of FCB pollution within the sub-basins due to bacteria-laden runoff. At a few sites, excessive FCB concentrations occur year-round, which may represent point source discharges or illicit sanitary connections. Additional amounts of FCB pollution are most likely due to re-suspension and re-growth of bacteria.

Various entities are participating in implementation of the *Mid-Yakima River Basin Bacteria TMDL*. However, Yakima County (County) has established itself as the lead agency for the Regional Stormwater Policy Group (RSPG), which controls 25.3 mi^2 (7.5%) of the entire TMDL project area. The RSPG jurisdictional area contains all but two of the potential point sources within the TMDL project area. As such, the County and the RSPG will have pivotal roles in the development of the TMDL.

For point and non-point sources of FCB pollution, this WQIR calculated site-specific geometric mean (geomean) and statistical threshold value (STV) target reductions that must be met in order to comply with State WQS. The USEPA, in its *2012 Recreational Water Quality Criteria* (EPA 820-F-12-058), prefers that both geomeans and STVs be utilized to analyze compliance with primary contact recreation bacteria criteria. The geomean is a measure of “long-term” compliance, while the STV is a measure of “short-term” compliance. Both values are used in the *Mid-Yakima River Basin Bacteria TMDL* to measure compliance with State WQS.

In the referenced document, USEPA stated that *the STV ... is a value that should not be exceeded by more than 10 percent of the samples used to calculate the geomean*. This wording is analogous to the corresponding State WQS language in WAC 173-201A-200(2)(b), which defines the secondary bacteria criterion as a value that is exceeded by *not more than 10 percent of all samples ... obtained for calculating the geometric mean*. In addition, State regulations specify that the STV criterion must be the largest value in any data set of less than 10 values. This WQIR calculated all STVs for data sets of 10 values and greater, according to the nonparametric Hazen method described in Appendix C.

For each non-point monitoring site, this WQIR presents the seasonal geomean and STV target reduction *load allocations* (LAs) that are needed to meet the respective site-specific numerical LAs (State’s WQS). Point source site-specific geomean and STV target reduction *wasteload allocations* (WLAs) are also presented. All % target reductions in this WQIR refer to the percentage of FCB concentrations which must be decreased in order to meet the State WQS.

All of the known point sources within the TMDL project area that have the potential to discharge significant amounts of FCB pollution and their WLAs are presented in Table 1. The Cowiche Sewer District POTW is presently meeting its WLAs. All new (after the date of TMDL approval by the USEPA) point sources of FCB pollution within the TMDL project area will be assigned WLAs equivalent to a geomean of 25 cfu/100mL, and a STV of 50 cfu/100mL. For National Pollutant Discharge Elimination System (NPDES) permitting, the STV WLA shall be interpreted as the Maximum Weekly limitation. The geomean WLA shall be interpreted as the Average Monthly limitation.

The stringent WLAs for new point sources represent FCB concentrations that are characteristically achievable with ultraviolet (UV) disinfection technology. This situation complies with the State’s requirement to implement *all known, available, and reasonable* *methods of prevention, control, and treatment* (AKART) for new sources. The stringent WLAs for new point sources also create an implicit amount of "reserve capacity" for future dischargers.

The seasonal MS4 stormwater WLAs presented in Table 1 were calculated by combining all MS4 samples per season into a single data set. This was done because there were insufficient samples collected at the individual MS4 sites that would have otherwise allowed site-specific WLAs to be calculated. The USEPA directs agencies to combine MS4 sampling data into one data set, when necessary. The respective seasonal WLAs were then allocated to all of the MS4s within the TMDL project area.

The LAs for non-point sources during the irrigation and non-irrigation seasons are presented in Table 2 (Cowiche Creek sub-basin), Table 3 (Moxee Drain sub-basin), and Tables 4 and 5 (Wide Hollow Creek sub-basin). The percent target reduction LAs represent the total percentage of FCB pollution reduction that a specific site must achieve in order to comply with its respective geomean or STV FCB criterion as given in the State's WQS for surface waters. A 0 percent target reduction implies that the site is already in compliance with the respective FCB criterion.

The *Mid-Yakima River Basin Bacteria TMDL* determined that the greatest FCB concentrations throughout all three sub-basins occur during the summer agricultural irrigation season (April 15 through October 15). However, some sites have FCB concentrations in excess of State WQS throughout the year. The TMDL's stakeholders and other interested parties should first strive to comply with the irrigation season allocations and then subsequently strive to comply with the non-irrigation season allocations, if still excessive.

The FCB pollution sources during the two seasons may be different (human and animal). Additionally, 243 pathogens in livestock manure are known as zoonotic agents (including *E. coli*) that can be transmitted from animals to humans (Guselle and Olson, 2004). Thus, substantial health risks are associated with humans recreating in livestock manure-impacted waters. In fact, the USEPA's *2012 Recreational Water Quality Criteria* recommends that TMDLs do not try to account for human and nonhuman sources of fecal contamination, as *the methods necessary to distinguish between human and nonhuman fecal sources, with the appropriate level of confidence, are still under development* (USEPA 820-F-12-058).

Why this matters

High FCB pollution within the various surface waters of the *Mid-Yakima River Basin Bacteria TMDL* project area does not allow for safe primary contact recreation by the general public. All surface waters need to comply with State WQS to ensure the general public's quality of life, as well as to ensure sustainable local and regional economic development. The TMDL will specifically reduce FCB pollution within the Cowiche Creek, Moxee Drain and Wide Hollow Creek sub-basins.

Table 1: Seasonal WLAs for NPDES sources within the TMDL project area.

Site ID	NPDES Permit #	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	WLA (cfu/100mL)	% Target Reduction (concentration)	WLA (cfu/100mL)	% Target Reduction (concentration)	WLA (cfu/100mL)	% Target Reduction (concentration)	WLA (cfu/100mL)
Cowiche Sewer District	WA-005239-6	0	50[1]	0	100[2]	0	50[1]	0	100[2]
City of Union Gap	WAR046010	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
City of Yakima	WAR046013	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
Eakin Fruit	WAG435031	NSD	50[1]	NSD	100[2]	NSD	50[1]	NSD	100[2]
Roy Farms	WAG435221	NSD	50[1]	NSD	100[2]	NSD	50[1]	NSD	100[2]
Yakima County	WAR046014	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
Yakima Valley Community College	WAR046201	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
WSDOT	WAR043000	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]

[1] This WLA equals the Maximum Weekly effluent limitation in an NPDES permit

[2] This WLA equals the Average Monthly effluent limitation in an NPDES permit

NSD = no sampling data was collected and no value could be estimated.

Yellow cells indicate that the discharge is in compliance with respective State water quality FCB criterion.

Table 2: Seasonal LAs in Cowiche Creek sub-basin.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
38-FC-1	45115	0	100	0	200	8.7	100	51.0	200
38-FC-1.25	8319	0	100	0	200	39.5	100	81.8	200
38-FC-1.5		0	100	63.0	200	44.7	100	49.1	200
38-FC-2	46633 & 8327	0	100	79.8	200	58.2	100	81.4	200
38-FC-2.5	46346 & 8326	0	100	0	200	38.8	100	86.7	200
38-FC-3 / 38-FC-3.5	8323	0	100	0	200	0	100	16.3	200
38-FC-4		0	100	0	200	0	100	0	200
38-FC-6	8322	0	100	0	200	37.0	100	71.0	200
38-FC-7		0	100	0	200	0	100	0	200
38-IS-7		NSD	100	NSD	200	88.0	100	75.9	200
38-IS-7.5		(0)	100	(80.5)	200	76.0	100	67.2	200
38-IS-7.6		(0)	100	(50.7)	200	0	100	54.5	200
38-IS-8	45886	NSD	100	NSD	200	59.3	100	68.3	200
38-IS-8.5		NSD	100	NSD	200	39.2	100	80.0	200

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with respective the State water quality FCB criterion.
Values in parentheses are estimates based on best professional judgment.

Table 3: Seasonal LAs in Moxee Drain sub-basin.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
37-FM-1	45717	0	100	30.6	200	49.6	100	61.7	200
37-FM-3	45122	43.0	100	66.7	200	62.0	100	65.6	200
37-FM-3.5	46355	71.1	100	61.5	200	63.6	100	81.8	200
37-FM-3.6	45703	60.3	100	77.5	200	84.2	100	94.4	200
37-FM-4 / 37-IS-2	46548 & 46673	0	100	0	200	50.2	100	77.5	200
37-FM-5 / 37-IS-1	45114	94.9	100	98.0	200	92.6	100	94.2	200
37-FM-5.5		(53.9)	100	(73.0)	200	58.3	100	37.5	200
37-FM-7 / 37-IS-3	45313	0	100	0	200	0	100	37.1	200
37-FM-8	46167	0	100	0	200	8.1	100	48.1	200
37-FM-9		0	100	0	200	0	100	31.7	200
37-FM-9.5		0	100	0	200	NSD	100	NSD	200
37-FM-10	46168	39.5	100	88.8	200	62.2	100	63.0	200
37-IS-0		NSD	100	NSD	200	27.0	100	0	200
37-IS-1.5		NSD	100	NSD	200	37.0	100	71.4	200
37-IS-4		NSD	100	NSD	200	0	100	20.0	200
37-IS-4.5		NSD	100	NSD	200	0	100	20.0	200
37-IS-4.6		NSD	100	NSD	200	55.8	100	79.4	200
37-IS-5		NSD	100	NSD	200	0	100	0	200
DeVries Family Farm Dairy (AFO)		NSD	0	NSD	0	NSD	0	NSD	0

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with the respective State water quality FCB criterion.
Values in parentheses are estimates based on best professional judgment.

Table 4: Seasonal LAs for mainstem Wide Hollow Creek.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
37-FW-0 / 37-SS-1	8306	4.6	100	22.8	200	74.1	100	89.6	200
37-FW-0B		0	100	0	200	98.6	100	98.0	200
37-FW-1 / 37-SS-5	6717	0	100	5.2	200	66.4	100	85.0	200
37-FW-1B		0	100	0	200	0	100	0	200
37-FW-1C		0	100	0	200	92.7	100	98.0	200
37-FW-2B		64.2	100	69.2	200	0	100	0	200
37-FW-3 / 37-FW-3B		0	100	20.0	200	65.9	100	72.0	200
37-FW-4 / 37-SS-7		0	100	0	200	58.8	100	71.3	200
37-FW-5	6718	20.3	100	51.7	200	69.2	100	92.4	200
37-FW-6 / 37-FW-6B		0	100	0	200	69.8	100	92.1	200
37-SS-11	16804	42.8	100	83.1	200	87.9	100	98.0	200
37-SS-12		0	100	0	200	58.2	100	88.0	200
37-FW-8 / 37-SS-14	45081	0	100	71.7	200	48.6	100	74.4	200
37-IS-16B		0	100	0	200	0	100	0	200
37-SS-15	46645	NSD	100	NSD	200	98.3	100	96.7	200
37-FW-12 / 37-SS-16	45161	0	100	0	200	27.8	100	95.0	200
37-FW-15 / 37-SS-17		0	100	0	200	96.3	100	92.6	200
37-FW-18		0	100	0	200	(78.7)	100	(91.1)	200

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with the respective State water quality FCB criterion.
Values in parentheses are estimates based on best professional judgment.

Table 5: Seasonal LAs for tributaries to Wide Hollow Creek.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
37-FW-2	45541	0	100	0	200	54.6	100	86.0	200
37-FW-13 / 37-SS-18	45210	0	100	0	200	75.5	100	97.5	200
37-FW-14	46164	0	100	25.9	200	89.2	100	93.2	200
37-FW-16		0	100	73.5	200	NSD	100	NSD	200
37-FW-17		0	100	0	200	NSD	100	NSD	200
37-IS-10		NSD	100	NSD	200	0	100	37.5	200
37-IS-13		0	100	0	200	0	100	98.5	200
37-IS-15	45219	98.5	100	98.0	200	97.9	100	96.7	200
37-IS-16	45875	0	100	0	200	44.5	100	87.1	200
37-IS-17		64.3	100	28.6	200	75.3	100	98.0	200
37-IS-17.5 / 37-SS-9	45753 & 46628	32.0	100	93.3	200	92.4	100	92.7	200
37-IS-18 / 37-IS-18B		71.4	100	42.9	200	66.7	100	72.6	200
37-IS-19 / 37-SS-48		0	100	0	200	21.7	100	95.0	200
37-IS-20 / 37-SS-38		0	100	0	200	35.1	100	65.5	200
37-IS-20A		NSD	100	NSD	200	0	100	0	200
37-IS-20B		NSD	100	NSD	200	0	100	0	200
37-IS-12 / 37-IS-12B		0	100	0	200	0	100	0	200
37-SS-11B		0	100	0	200	0	100	0	200
37-IS-23		0	100	0	200	77.6	100	98.0	200
37-SS-13 / 37-SS-13B	45869	NSD	100	NSD	200	95.2	100	97.8	200

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with the respective State water quality FCB criterion.

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What is a Total Maximum Daily Load (TMDL)

A TMDL is a numerical value representing the highest pollutant load a surface water body can receive and still meet State of Washington (State) water quality standards (WQS). Any amount of pollution over of the total maximum daily load (TMDL) level needs to be reduced or eliminated in order to achieve clean water.

Federal Clean Water Act requirements

The Clean Water Act (CWA) established a process to identify and clean up polluted waters. The CWA requires each state to have its own WQS designed to protect, restore, and preserve water quality. WQS consist of: (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) criteria, usually numeric criteria, to achieve those uses.

The Water Quality Assessment and the 303(d) List

Every two years, states are required to prepare a list of water bodies that do not meet applicable WQS. This list is called the CWA 303(d) list. In the State, this list is part of the Water Quality Assessment (WQA) process. Further information is available at Ecology's Water Quality Assessment website (www.ecy.wa.gov/programs/wq/303d/).

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, State, and federal governments, tribes, industries, and citizen monitoring groups. All data in the WQA are reviewed to ensure that they were collected using appropriate scientific protocol before they are used to develop the assessment. The WQA divides water bodies into five categories. Those not meeting State WQS are given a Category 5 designation, which collectively becomes the 303(d) list.

Category 1 – Meets standards for parameter(s) for which it has been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data or insufficient data available.

Category 4 – Polluted waters that do not require a TMDL because they:

- *4a*. – Have an approved TMDL.
- *4b*. – Have a pollution control program in place that should solve the problem.
- *4c*. – Are impaired by a non-pollutant such as low water flow, dams, or culverts.

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the State. The CWA requires that a TMDL be developed for each of the water bodies on the 303(d) list. Each TMDL identifies pollution problems in its watershed and specifies how much pollution needs to be reduced or eliminated to achieve clean water. That analysis comprises the *water quality improvement report* (WQIR). A draft WQIR will be made available at a future public meeting and a 30-day public comment period will be started at the same time, prior to publishing the document. Ecology will address the received public comments and submit the final draft of the WQIR to the USEPA for approval. After approval, the WQIR will be published.

Once approved Ecology, with the assistance of local governments, tribes, agencies, and the community, will then develop a strategy control for reducing or eliminating pollution sources and achieving clean water as well as a monitoring plan to assess the effectiveness of the water quality improvement activities. That development results in a *water quality implementation plan* (WQIP).

Who should participate in this TMDL process?

Nonpoint source pollutant targets have been set in this WQIR and are presented in Tables 2 through 4. Because nonpoint pollution comes from diffuse sources, all upstream watershed areas have the potential to affect downstream water quality. Therefore, all potential non-point sources in the watershed must use the appropriate *best management practices* (BMPs) to reduce impacts to water quality. The *Mid-Yakima River Basin Bacteria TMDL* project area is shown in Figure 1. Known nonpoint sources of fecal coliform bacteria (FCB) pollution in the project area include on-site septic systems, wildlife, livestock, stormwater drainage and irrigation drainage.

Similarly, all point source dischargers in the watershed must also comply with their respective targets established by this WQIR in Table 1. The presently known potential point sources of FCB pollution within the TMDL project area's surface waters include the Washington Department of Transportation (WSDOT), the Cowiche Sewer District POTW, the cities of Union Gap and Yakima (Phase 2 MS4 stormwater), Yakima County (Phase 2 MS4 stormwater), and the Yakima Valley Community College (Phase 2 MS4 stormwater).

Elements the Clean Water Act requires in a TMDL

Loading capacity, allocations, seasonal variation, margin of safety, and reserve capacity

A water-body's *loading capacity* is the amount of a given pollutant that a water body can receive and still meet State WQS. The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with the WQS.

The portion of the receiving water's loading capacity assigned to a particular source is a *wasteload* or *load* allocation. If the pollutant comes from a discrete (point) source subject to a National Pollutant Discharge Elimination System (NPDES) permit, such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation (WLA)*. If the pollutant comes from diffuse (nonpoint) sources not subject to an NPDES permit, such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation (LA)*.

The TMDL must also consider *seasonal variations* and include a *margin of safety (MOS)* that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A *reserve capacity* for future pollutant sources is sometimes included as well. Therefore, a TMDL is the sum of the WLAs, LAs, MOS, and any reserve capacity. The TMDL numeric value must be equal to or less than the loading capacity.

Other appropriate measure

When it is difficult to measure a pollutant allocation in terms of load, another appropriate measure may be used to provide more meaningful and measurable pollutant loading targets. USEPA regulations [40 CFR 130.2(i)] allow *other appropriate measures* in a TMDL such as mass per time, toxicity, and concentration. For FCB, the typical measure of loading (mass per unit-of-time) is difficult to compare to the State WQS bacteria criteria. Therefore, the *Mid-Yakima River Basin Bacteria TMDL* will utilize concentration (cfu/100mL) as a more appropriate measurement of bacteria pollution. The use of the concentration will also allow all of the involved entities to easily determine their compliance with the TMDL's calculated LAs and WLAs.

Compliance with the *primary contact recreation* FCB criteria contained in the State WQS consists of two values: a primary geometric mean (geomean) criterion, and a secondary Statistical Threshold Value (STV) criterion. Both values are measured in terms of bacterial concentration (cfu/100mL). Compliance with the criteria is required by State WQS and is assumed to protect the designated uses of primary contact recreation and extraordinary primary contact recreation, which is the goal of the *Mid-Yakima River Basin Bacteria TMDL.*

Implementation target

Presently, MS4 entities may utilize an implementation target of *flow per unit of impervious surface* in lieu of a purely FCB concentration for compliance with their applicable WLAs contained in the TMDL. However, the municipal separate storm sewer system's (MS4) owner must request in writing the use of this implementation target, or any other alternative target that does not directly measure FCB concentrations. The same numerical percent target reduction WLA will apply to the implementation target. Requests for using an implementation target must be approved by Ecology prior to its use for compliance with the *Mid-Yakima River Basin Bacteria TMDL*.

Why Ecology Conducted a TMDL Study in this Watershed

Background

Ecology is conducting the *Mid-Yakima River Basin Bacteria* TMDL project because Cowiche Creek, North Fork (N.F.) Cowiche Creek, South Fork (S.F.) Cowiche Creek, Moxee Drain, and Wide Hollow Creek have all been on the State's 303(d) list for excessive concentrations of FCB since 1996. Other surface waters were added to the 303(d) list in subsequent years. The 2012 WQA determined that there were thirty-three 303(d) listings for excessive FCB pollution within the TMDL project area.

The *Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load* (Joy, 2005) was the guiding document for the 2004-2006 data collected for the study. An *Addendum to Qualify Assurance Project Plan: 2010 Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Ross, 2012) was developed for the collection of the 2010 data. An *Addendum to Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Carroll, 2014) was developed for the collection of the 2014 data.

Impairments addressed by this TMDL

The main beneficial uses to be protected by the *Mid-Yakima River Basin Bacteria TMDL* are *primary contact recreation* and *extraordinary primary contact recreation*. These uses will be protected by decreasing the concentrations of FCB to levels below the applicable criteria in the State WQS in the water bodies located within the TMDL project area.

The State's 2012 WQA determined that a total of thirty-three 303(d) listings in fourteen surface water bodies within the TMDL project area contain FCB concentrations in excess of the State WQS (Table 6 and Figure 2). Four of those listings were also present in the 1996 303(d) list.

The State's proposed 2014 WQA includes a significant change in delineating water bodies. That change went from using a Range/Township/Section-based delineation to the National Hydrology Dataset (NHD) delineation in order to estimate the extent, or reach, of the individual listings. In Table 6 there were nine listings in the 2012 WQA that disappeared from the proposed 2014 WQA because they merged into other listings.

There are thirty-three 303(d) listings within the TMDL project area pertaining to other parameters, but this WQIR does not address them. Table 7 presents all of the 2012 non-addressed 303(d) listings within the TMDL project area.

Table 6: TMDL project area water bodies on the 2012 303(d) list for FCB.

Water-body Name	Township/ Range/ Section	NHD Reach Code	1996 WQA	2012 WQA	Listing ID
Congdon Canal	13N-17E-25	17030003003299	No	Yes	45875
Cottonwood Cr.	13N-17E-25	17030003013826	No	Yes	45210
Cottonwood Cr.	13N-17E-25	17030003013826	No	Yes	46164
Cowiche Cr.	13N-17E-11	17030002000408	No	Yes	8319
Cowiche Cr.	13N-17E-11	17030002001536	No	Yes	45886
Cowiche Cr.	13N-18E-9	17030002000408	No	Yes	45115
Cowiche Cr., N.F.	13N-17E-3	17030002000409	No	Yes	8323
Cowiche Cr., N.F.	14N-17E-18	17030002000412	Yes	Yes	8322
Cowiche Cr., S.F.	13N-17E-3	17030002003034	No	Yes	8327
Cowiche Cr., S.F.	13N-17E-4	17030002003034	No	Yes	46633
Cowiche Cr., S.F.	14N-16E-35	17030002000425	Yes	Yes	8326
Cowiche Cr., S.F.	14N-16E-36	17030002000425	No	Yes	46346
DID #11	12N-19E-2	17030003004013	No	Yes	45114
DID #11	12N-19E-3	17030003004010	No	Yes	45703
East Spring Cr.	12N-19E-8	17030003007802	No	Yes	45541
Hubbard Canal	12N-19E-2	17030003003845	No	Yes	46548
Hubbard Canal	13N-19E-27	17030003003845	No	Yes	46673
Moxee Canal	12N-19E-2	17030003000772	No	Yes	45313
Moxee Drain	12N-19E-3	17030003000775	No	Yes	46355
Moxee Drain	12N-19E-9	17030003000799	Yes	Yes	45122
Moxee Drain	12N-19E-11	17030003013377	No	Yes	46167
Moxee Drain	12N-20E-9	17030003013773	No	Yes	46168
Moxee Slough	12N-19E-9	17030003007920	No	Yes	45717
Randall Park Pond	13N-18E-27	17030003015930	No	Yes	46628
Shaw Creek	13N-18E-30	17030003007184	No	Yes	45869
Wide Hollow Cr.	13N-18E-29	not mappable	No	Yes	45081
Wide Hollow Cr.	13N-18E-36	17030003000812	No	Yes	45219
Wide Hollow Cr.	12N-19E-8	17030003000812	No	Yes	8306
Wide Hollow Cr.	12N-19E-7	17030003000812	Yes	Yes	6717
Wide Hollow Cr.	13N-17E-25	17030003007003	No	Yes	45161
Wide Hollow Cr.	13N-18E-27	17030003000812	No	Yes	16804
Wide Hollow Cr.	13N-18E-30	17030003000812	No	Yes	46645
Wide Hollow Cr.	13N-18E-35	17030003000812	No	Yes	6718

Unlisted but impaired for FCB TMDL project area water bodies.

Water-body Name	Township/ Range/ Section	NHD Reach Code	1996 WQA	2012 WQA	Proposed 2014 WQA Listing ID
DID #24	13N-18E-36	not mappable	No	No	74270
DID #40	13N-18E-27	not mappable	No	No	74271
Unnamed Ditch (Tributary to Moxee Drain)	12N 19E 11	not mappable	No	No	74276
Randall Park Pond Outlet	13N-18E-27	17030003015930	No	Cat 2[1]	45753

[1] This listing will move from Category 2 on the 2012 assessment to Category 5 on the proposed 2014 assessment once it is approved by USEPA.

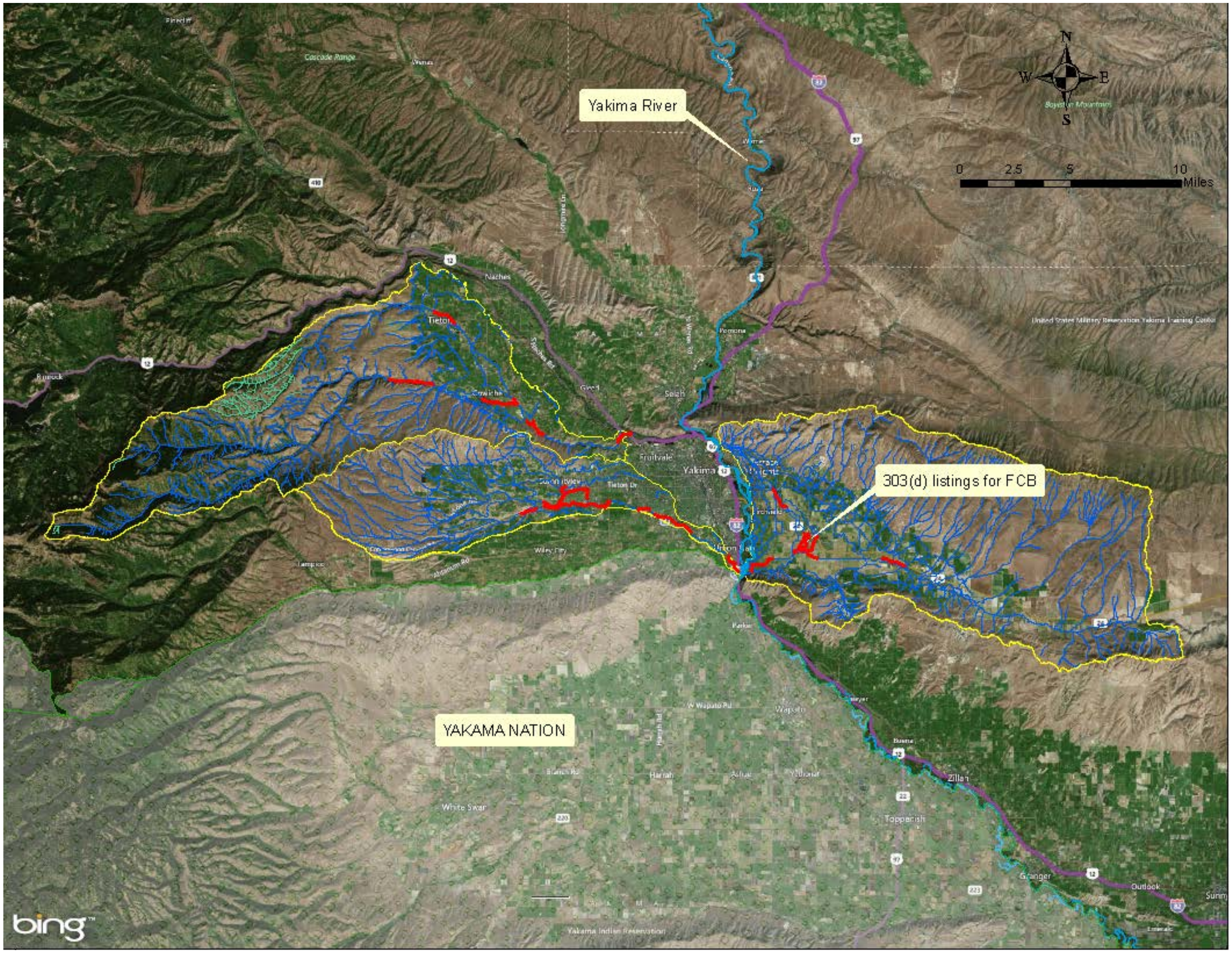

Figure 2: FCB 303(d)-listed segments within TMDL project area.

Table 7: 2012 WQA 303(d) listings within TMDL project area, but not addressed.

Water-body Name	Listing ID	Parameter	NHD Reach Code
Blue Slough	7378	Chlorpyrifos	17030003013826
Blue Slough	7377	4,4'-DDD	17030003013826
Blue Slough	7376	4,4'-DDE	17030003013826
Blue Slough	7380	DDT	17030003013826
Cottonwood Cr.	47395	Dissolved Oxygen	17030003013826
Cowiche Cr.	47386	Dissolved Oxygen	17030002000408
Cowiche Cr.	17214	4,4'-DDE	17030002000408
Cowiche Cr.	52833	PCB	17030002000408
Cowiche Cr.	11214	pH	17030002000408
Cowiche Cr.	50698	pH	17030002000408
Cowiche Cr., S.F.	47404	Dissolved Oxygen	17030003003034
Cowiche Cr., S.F.	47405	Dissolved Oxygen	17030002000425
East Spring Creek	66747	Temperature	17030003007831
Hubbard Canal	50665	pH	17030003003945
Moxee Drain	7373	DDT	17030003000799
Moxee Drain	7374	Dieldrin	17030003000799
Moxee Drain	7375	Endosulfan	17030003000799
Moxee Drain	16101	pH	17030003000799
Moxee Drain	50675	pH	17030003007892
Moxee Drain	50669	pH	17030003013377
Moxee Drain	50670	pH	17030003013605
Moxee Drain	16091	Temperature	17030003000799
Moxee Drain	48209	Temperature	17030003013773
Unnamed Ditch (Tributary to Moxee Ditch)	50688	pH	17030003000772
Wide Hollow Cr.	8849	4,4'-DDD	17030003000812
Wide Hollow Cr.	8848	4,4'-DDE	17030003000812
Wide Hollow Cr.	8855	DDT	17030003000812
Wide Hollow Cr.	8856	Dieldrin	17030003000812
Wide Hollow Cr.	47370	Dissolved Oxygen	17030003007003
Wide Hollow Cr.	11173	Dissolved Oxygen	17030003000812
Wide Hollow Cr.	8857	Endosulfan	17030003000812
Wide Hollow Cr.	11174	pH	17030003000812
Wide Hollow Cr.	8307	Temperature	17030003000812

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Water Quality Standards and Numeric Targets

The majority of the water bodies within the *Mid-Yakima River Basin Bacteria TMDL* project area are categorized by the State WQS for the designated use of *primary contact recreation*. The only exceptions are the upstream reaches of some water bodies located within the Wenatchee National Forest (WNF) in the northwest portion of the Cowiche Creek sub-basin (i.e. Weddle Canyon Creek and North Fork Cowiche Canyon). Those exceptional reaches are categorized for the more-stringent designated use of *extraordinary primary contact recreation*. No sampling sites for the TMDL project were located within the extraordinary primary contact recreation reaches, thus no LAs were calculated for those reaches. Both designated uses will be protected by decreasing the concentration of the FCB pollution in the water bodies within the TMDL project area until the State's FCB criteria are met.

An important goal of the CWA is to protect and restore waters for swimming. Thus, all of the water bodies within the *Mid-Yakima River Basin Bacteria TMDL* project area must comply with WAC 173-201A-200(2)(b) which establishes specific water quality FCB criteria for surface waters with designated uses of *extraordinary primary contact recreation* and *primary contact recreation*. Table 8 presents the applicable FCB criteria for the water bodies within the TMDL project area.

Table 8: Applicable State water quality FCB criteria.

Designated Use	Narrative Criteria	Numerical Criteria	
		Geomean	STV
Extraordinary Primary Contact Recreation	Concentrations must not exceed a geometric mean value of 50 colonies/100mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 cfu/100mL.	50 cfu/100mL	100 cfu/100mL
Primary Contact Recreation	Concentrations must not exceed a geometric mean value of 100 colonies/100mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 cfu/100mL.	100 cfu/100mL	200 cfu/100mL

The term *primary contact recreation* is intended for water bodies where a person would have direct contact with water and submergence or exposure is likely to include the eyes, ears, nose, throat, and/or urogenital openings. Since children are the most sensitive group for waterborne pathogens, even shallow waters with public access warrant primary contact protection.

The term *extraordinary primary contact recreation* is applicable for water bodies that need more stringent protection, such as those within national forests and other sensitive areas. As none of these latter reaches of water bodies have yet been identified as "impaired", the LAs and WLAs contained in this WQIR are only targeting the restoration of the reaches of water bodies categorized for primary contact recreation.

Figure 3 presents the designated uses of surface waters within the TMDL project area.

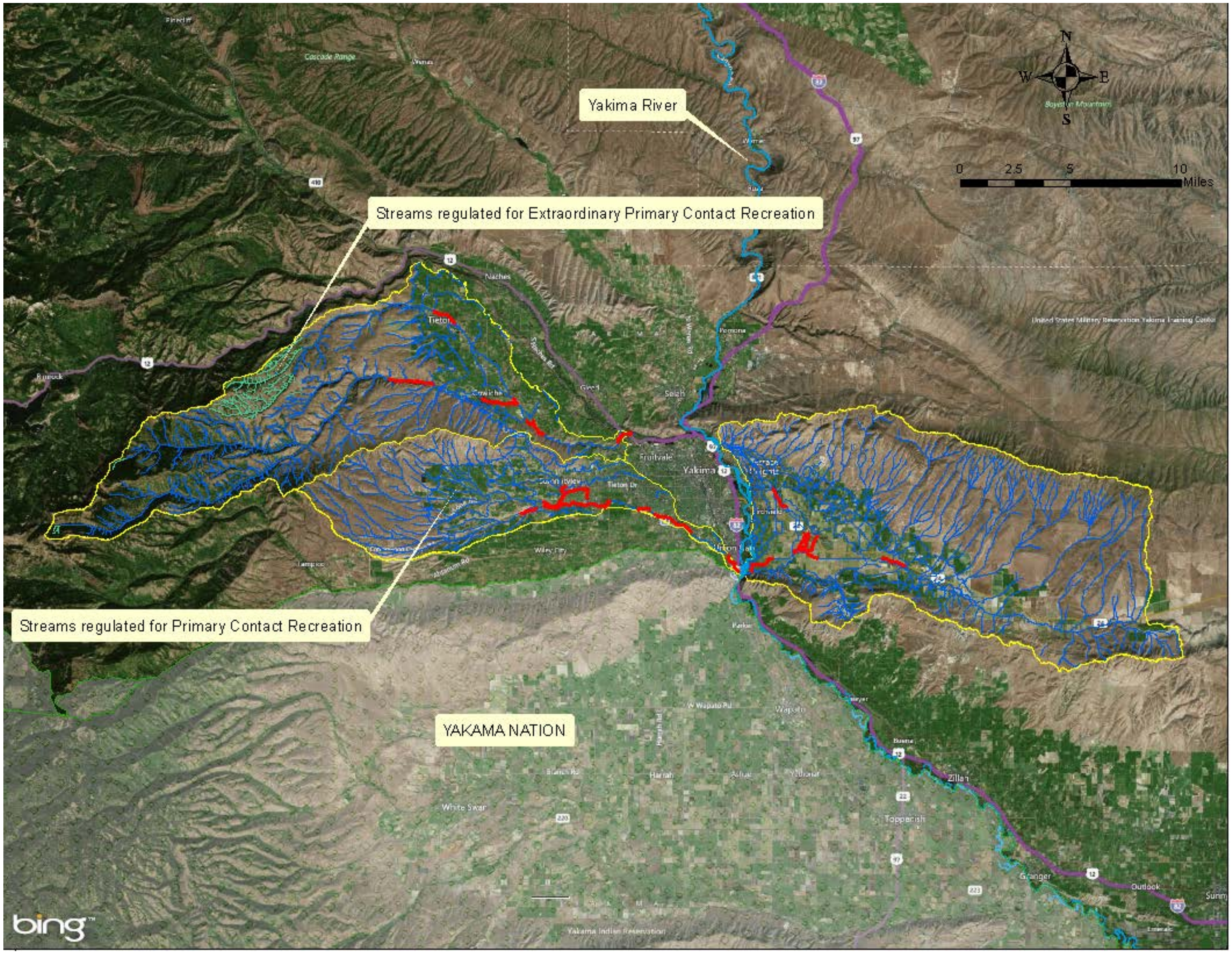

Figure 3: Designated uses of surface waters within TMDL project area.

Many reaches of the water bodies within the TMDL project area are accessible by the public for contact recreation. The Yakima Health District (YHD) has no recorded public drinking water intakes or official public bathing beaches within the TMDL project area. However, informal swimming and wading, especially by children, have been known to occur throughout the TMDL project area during the hot summer months. Young children are the most vulnerable segment of human populations to disease from fecal-contaminated surface waters and must be protected.

State water quality FCB criteria are based on a pre-determined risk of illness to humans that have contact with surface waters. They are designed to allow seven or fewer illnesses out of every 1,000 people engaged in primary contact recreational activities. Once the FCB concentrations reach the numeric loading capacity of a water body, human activities that would increase the concentrations further are prohibited. If the FCB criteria are already exceeded, as is the case with 14 water bodies within the TMDL project area, the State requires that actions be taken to reduce human activities discharging FCB and return to compliance with State WQS. If natural background levels of FCB cause the WQS to be exceeded, no additional measurable allowance will be given to human sources.

Pollutant Addressed by this TMDL

FCB is the only water quality pollutant addressed by the *Mid-Yakima River Basin Bacteria TMDL*. The presence of FCB in surface waters does not necessarily mean that pathogenic bacteria are also present. However, an excessive amount of FCB does indicate a statistically significant greater health risk for human beings having recreational contact with the surface water. There are numerous waterborne enteric pathogens known to be related to the feces of warm-blooded animals and zoonotic in nature. Due to the diversity and unpredictability of individual pathogens, water quality testing for each and every individual pathogen would be very time-consuming, technically intensive, and prohibitively costly. Fortunately, testing for the surrogate bacterial group known as FCB or its largest sub-group known as *Escherichia coli* (*E. coli*) is much easier, less expensive, and has been utilized for the past 100 years.

While the specific level of illness rates caused by animal versus human sources has never been quantified, it has been scientifically established that warm-blooded animals (particularly livestock) are a common source of serious waterborne zoonotic illness for humans. FCB concentrations have been found to correlate significantly to concentrations of several other bacteria, viruses and protozoan parasites. Therefore, irrespective of the source, all FCB are considered by the TMDL as potentially pathogenic to humans.

Potential sources of FCB pollution

Multiple potential sources of FCB pollution exist within the *Mid-Yakima River Basin Bacteria TMDL* project area. They include, to varying degrees, the following: wildlife, livestock, failing septic systems, illicit sanitary discharges, stormwater, irrigation return drainage, and wastewater treatment plant (POTW) effluent. Because there are similar health risks when comparing fecal wastes from animal and human hosts, USEPA has not developed separate national criteria for non-human sources.

The historical bacteria data presented in this WQIR demonstrated that the period of greatest FCB pollution occurs in conjunction with the area's irrigation season (April 15 through October 15). Ecology previously determined that elevated FCB pollution in parts of the lower-Yakima River basin (Granger Drain and Sulphur Creek Wasteway sub-basins) also correlated with the irrigation season (Bohn, 2001).

Potential point sources of FCB pollution

FCB is a parameter contained in the effluent discharged from all publicly-owned treatment works (POTWs). The TMDL project area included two such facilities: Moxee City POTW and Cowiche Sewer District POTW. However, all POTWs are required to disinfect their effluent and should be discharging minimal FCB during the entire year. The Cowiche Sewer District POTW is presently the only active POTW within the TMDL project area. The Moxee City POTW terminated discharging effluent to Drainage Improvement Districts (DID) #11 in 2008. Therefore, this WQIR will only contain WLAs for the Cowiche Sewer District POTW.

Additional point sources of FCB pollution are the Phase II municipal separate storm sewer systems (MS4) operated by the city of Yakima (9.3 square miles covered), the city of Union Gap (1.5 square miles covered), and Yakima County (14.4 square miles covered). Stormwater drainage typically contains surprisingly high FCB concentrations due to diverse causes, from illicit sanitary connections to roosting birds on bridges and roofs. Although the TMDL project area has limited total annual rainfall, it can still have severe flooding caused by short-term episodes of stormwater (Figure 4).

Figure 4: Results of large storm event in city of Yakima.

Several potential point sources of FCB pollution are located within the TMDL project area and are presented in Table 9.

Table 9: Potential point sources of FCB pollution within TMDL project area.

Permit Holder	Receiving Water	Permit Type	NPDES Permit #
Cowiche Sewer District	N.F. Cowiche Creek	POTW[1]	WA-005239-6
City of Union Gap	Wide Hollow Creek	Phase II[2]	WAR046010
City of Yakima	Wide Hollow Creek	Phase II[2]	WAR046013
Eakin Fruit	Moxee Drain	Fresh Fruit Packing	WAG435031
Roy Farms	Wide Hollow Creek	Fresh Fruit Packing	WAG435221
Yakima County	All surface waters in urbanized areas	Phase II[2]	WAR046014
YVCC	Wide Hollow Creek	Phase II[2]	WAR046201
WSDOT	All surface waters in urbanized areas	Phase II[3]	WAR043000

1 POTW = NPDES Individual Permit for Municipal POTW
2 Phase II = NPDES General Permit for Eastern Washington Phase II Municipal Stormwater
3 Phase II = NPDES General Permit for Municipal Stormwater for Washington State Department of Transportation

While the Mid-Yakima River Basin contains only two fresh fruit packing facilities (Eakin Fruit and Roy Farms) that are permitted to discharge process wastewater to local surface waters, several facilities discharge stormwater.

The Del Monte Foods #125 facility discharged stormwater into the city of Yakima's MS4 system prior to 2015. The FCB sampling data collected at that facility was incorporated into the combined data set for calculating WLAs for the MS4s within the TMDL project area.

The WSDOT highways and facilities are required to be covered under an MS4 permit (e.g. U.S. Highways 97 and U.S. Highway 12, Interstate 82, and State Route 24). There is a WSDOT Road Maintenance Facility in the city of Union Gap near the confluence of East Spring Creek with Wide Hollow Creek, just prior to the confluence with the Yakima River. Continued compliance with their stormwater general permit inside the Phase II boundary within the TMDL project area is assumed adequate to prevent excessive FCB concentrations being discharged into local surface waters.

A large-scale potential point source of FCB pollution is the Devries Family Farm dairy (presently categorized as an Animal Feeding Operation[1]) located in the upper reach of the Moxee Drain sub-basin (Figure 5). During construction of the dairy, the intermittent Moxee Creek was permanently channeled around the immediate south side of the livestock holding pens. The facility is prohibited by federal and State regulations from having any discharge to surface waters. However, Moxee Creek flows through the downstream manure application sites and is, therefore, highly susceptible to receiving FCB pollution.

The *Mid-Yakima River Basin Bacteria TMDL* will require monthly upstream and downstream water quality sampling in Moxee Creek, outside of the dairy's property lines, in order to determine if the facility is discharging FCB pollution to surface waters (and thus changing its category to Concentrated Animal Feeding Operation[2]).

1 An animal feeding operation (AFO) has no known discharges to surface waters of the State.
2 A confined animal feeding operation (CAFO) has known discharges to surface waters of the State.

Figure 5: DeVries Dairy in Moxee Drain sub-basin.

Potential non-point sources of FCB pollution

Due to a minimal number of point sources, Ecology suspects that the largest contributors of FCB pollution within the *Mid-Yakima River Basin Bacteria TMDL* project area are nonpoint sources. The nonpoint sources include wildlife, stormwater, and agricultural irrigation return drainage. In addition, there are pseudo-point source discharges, such as illicit sanitary connections, that discharge FCB bacteria directly into surface waters or stormwater systems.

Elk, deer, beaver, waterfowl, and other wildlife in headwater areas that are devoid of human activity can typically represent natural background bacteria concentrations. However, it is rare to find situations where the natural wildlife density causes FCB pollution to exceed the State WQS. Anthropogenic activities can sometimes artificially increase wildlife densities, such as the winter elk feeding station within the Cowiche Unit of the Oak Creek Wildlife Area.

A historically well-documented nonpoint site of excessive FCB pollution exists in the Wide Hollow Creek sub-basin: Randall Park pond (Figure 6). Randall Park is a 40-acre public park within the limits of the city of Yakima, and its pond has been utilized by the public as a feeding area for its large resident population of waterfowl. The pond is fed by a portion of the flow in DID #40 and was previously suspected by Kendra (1988) as being a large FCB reservoir due to the year-round waterfowl population.

Figure 6: Randall Park pond in the city of Yakima.

Livestock grazing increases the density of animals and thus increases the amount of manure deposition. Free access of cattle to streams allows manure to reach the water and has caused up to 36-fold increases in *E. coli* in downstream water samples compared to upstream water samples (Schumacher 2003; Vidon et al. 2008; Wilkes et al. 2009). Chin (2010) determined that livestock density better correlates to FCB pollution in surface waters than does the total number of animals in a watershed.

Animal feeding operations (AFOs) maximize the density of cattle and thus produce manure at high rates. The TMDL project area contains numerous small AFOs as well as one large AFO. Surface runoff from irrigation and stormwater events has resulted in FCB entering a tributary of the Yakima River (Bohn, 2001). *E. coli* contamination of ground water has been documented downgradient from an unlined cattle manure lagoon (Withers et al. 1998). Tile drainage under manure application fields provides a route for bacteria in ground water to reach surface waters (Haack and Duris 2008; USEPA 2005c). Manure entry into a tile drainage may occur through preferential transport via macropores, wormholes, and root channels (Jamieson et al. 2002, USEPA 2004), which bypasses the filtering effect of the soil matrix (Rosen 2000).

Resuspension as a potential FCB source

FCB bacteria are known to settle out of the water column and deposit in the bottom sediments of water bodies, where they sometimes can live and reproduce. Early on, Savage (1905) concluded that mud samples yielded more bacteriological evidence of fecal pollution than the overlying water column. The settling is due to the affinity of bacteria cells to adhere to suspended solids in the water column, which settle out during base-flow periods. In 1971, Van Donsel and Geldreich noted that concentrations of sediment FCB were 100-1,000 times greater than those in the water column. Jolley (2005) determined that stream bottom sediments under normal conditions contain up to 10,000 times more FCB than the actual water column.

Settled FCB bacteria can be resuspended into the water column after sediment disturbance. Grimes (1975) attributed increased levels of FCB to dredging of in the Mississippi River. Pettibone et al. (1996) found that the movement of lake-going ships increases bacteria levels 2-11 times due to sediment resuspension. An et al. (2002) found a direct relationship between the amount of gasoline sold at lake marinas (which correlates to sediment disturbance by boating activity) and the amount of *E. coli* in the water column. More obvious is when livestock ford/cross streams, Davies-Colley et al. (2004) found bacterial increases in relation to the associated sediment disturbance.

Besides anthropogenic physical disturbance of sediments and the water column, a natural increase in stream flows and bacterial resuspension occurs during storm events. Jamieson et al. (2005) and Cervantes (2012) found that resuspension rates increase proportionally as water flow increases due to greater shear forces caused by increased water velocities.

No estimations of the amount of resuspended FCB were made for the *Mid-Yakima River Bacteria TMDL* and the TMDL's allocations were, therefore, not adjusted for resuspension.

Regrowth as a potential FCB source

FCB have typically been considered to die-out completely some time after being introduced into surface waters. The die-off has been described as following a first-order kinetic decay model where the decay rate is based upon a multitude of environmental factors including predation, temperature, solar radiation, and water chemistry. However, some studies (Avery et al., 2008; Hellweger et al., 2009; Bucci et al., 2011) have described FCB populations as biphasic in nature, and later have a substantial increase (regrowth) of mutated surface water-adapted *E. coli*. Several strains of *E. coli* have been shown to grow in sterilized lake water (Vital et al., 2008). Encapsulated *E. coli* strains were responsible for bloom events in two lakes, indicating their capability of replication in surface water (Power et al., 2005). Walk et al. (2007) determined that 23% of the examined *E. coli* strains showed an adaptive advantage in the secondary habitat (surface waters). Bucci et al. (2011) found that surface water adaptation is heritable and consistent with the "Growth Advantage in Stationary Phase" (GASP) mutation phenotype.

No estimations of the amount of re-growth FCB were made for the *Mid-Yakima River Bacteria TMDL* and the TMDL's allocations were, therefore, not adjusted for re-growth.

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Watershed Description

Geographic setting

The mid-Yakima River basin is located in the south-central portion of the State with the Yakima River splitting the basin into eastern and western portions. The *Mid-Yakima River Basin Bacteria TMDL* project area encompasses approximately 338.5 square miles. It contains three sub-basins (Cowiche Creek, Moxee Drain and Wide Hollow Creek). Figure 7 shows the location of the TMDL project area within the State.

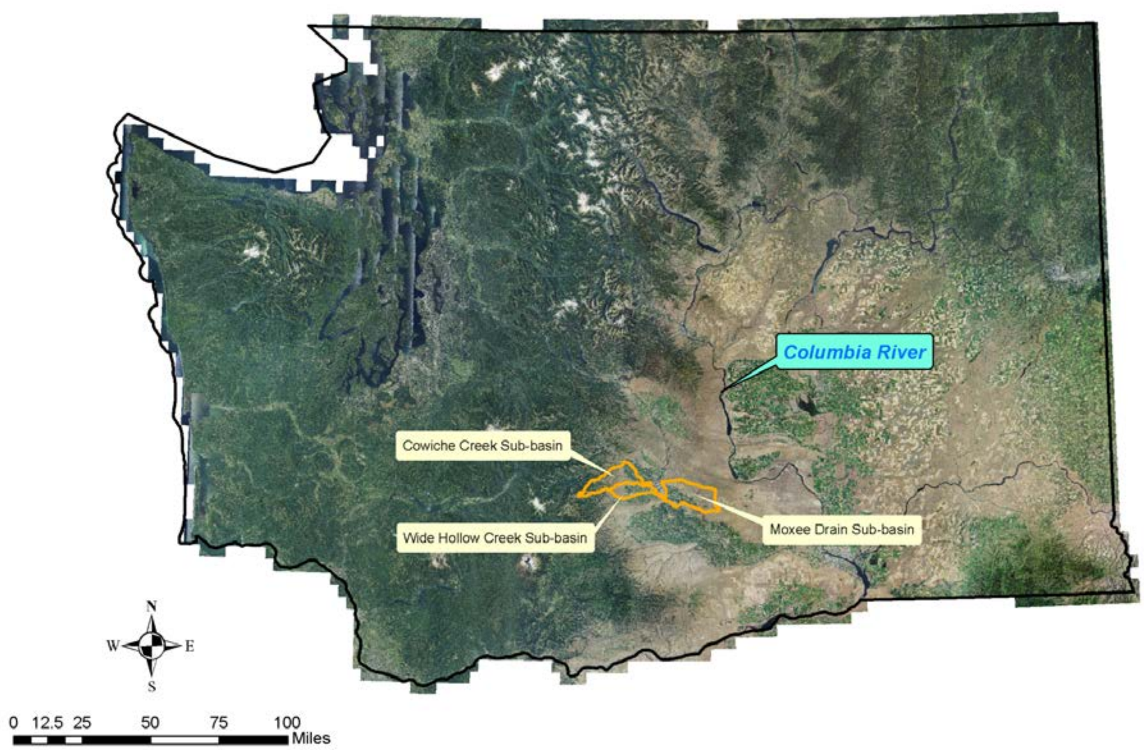

Figure 7: Location of TMDL project area within State.

A fourth contiguous sub-basin, Ahtanum Creek sub-basin, is located in the southwest portion of the mid-Yakima River basin. Even though Ahtanum Creek has been 303(d)-listed for FCB since 1996, it was not included in this TMDL because this creek serves as the northern boundary of the Yakama Nation reservation.

In the June 9, 1855 treaty with the United States Government, the Yakama's fishing rights are specifically tied to local waters: *The exclusive right of taking fish in all the streams, where running through or bordering said reservation....* Since the final boundaries of the Yakama Nation are still at issue in the courts, any TMDL that affects those waters may be more contentious than under normal circumstances. A future bacteria TMDL will be developed for only the Ahtanum Creek watershed, once the boundary issues have been resolved.

The TMDL project area occupies land within WRIAs 37 (Lower Yakima River) and 38 (Naches River), which is located within both the Eastern Cascades Ecoregion and the Columbia Basin Ecoregion. The Eastern Cascades Ecoregion receives an annual average precipitation of 20 inches; whereas, the Columbia Basin Ecoregion receives an annual average precipitation of 5 inches. The majority of the natural precipitation within the TMDL project area occurs during the fall, winter, and spring in the form of both rain and snow (Figure 8).

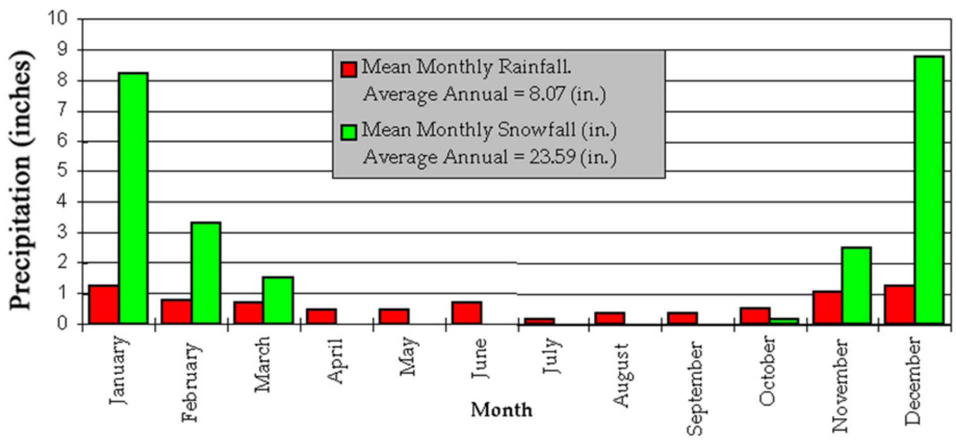

Figure 8: Mean monthly precipitation at city of Yakima.

The mid-Yakima River basin has a semi-arid climate with westerly prevailing winds. Average winter air temperatures range from 20-40 °F with occasional lows below 0 °F (-25 °F is lowest recorded). Average summer air temperatures range from 80-90 °F with occasional highs above 100 °F (110 °F is highest recorded). The entire basin has an average of 300 days of sunshine each year, with an agricultural growing season of 195 days. Figure 9 presents the average annual precipitation amounts within the *Mid-Yakima River Basin Bacteria TMDL* project area.

Generally, the valley floors of the sub-basins gently slope towards the Yakima River. There are few perennial tributary streams; however, several irrigation and drainage canals (Figure 10) are present that convey diverted Naches River and Yakima River water to irrigated lands. There are six Drainage Improvement Districts (DIDs) within the TMDL project area (Figure 11) and are all operated and maintained by Yakima County. The quality of downstream surface waters is degraded by the input of pollutants delivered by upstream runoff (overland and subsurface) and irrigation return flows. FCB pollution is one of those pollutants.

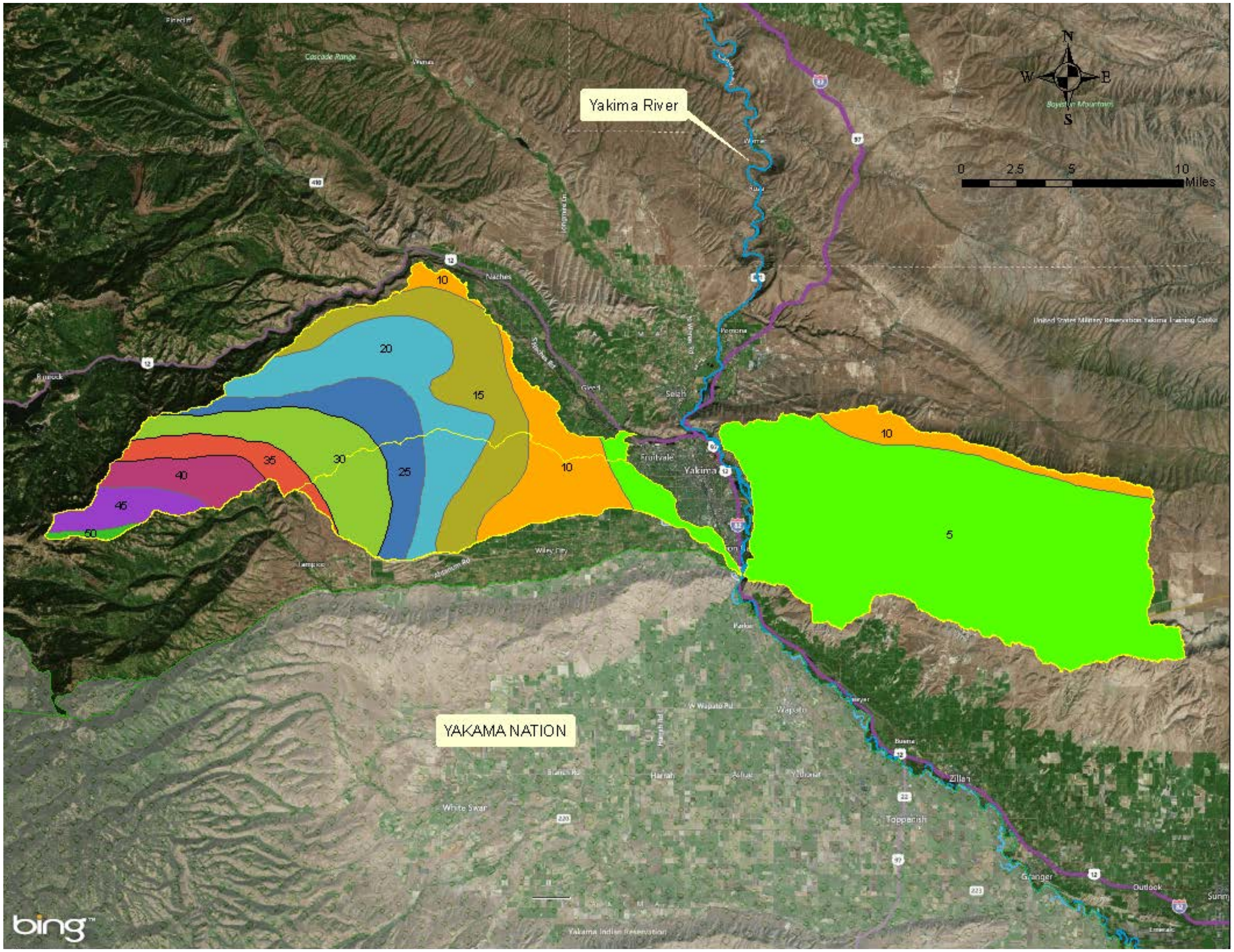

Figure 9: Average annual precipitation (inches) within TMDL project area.

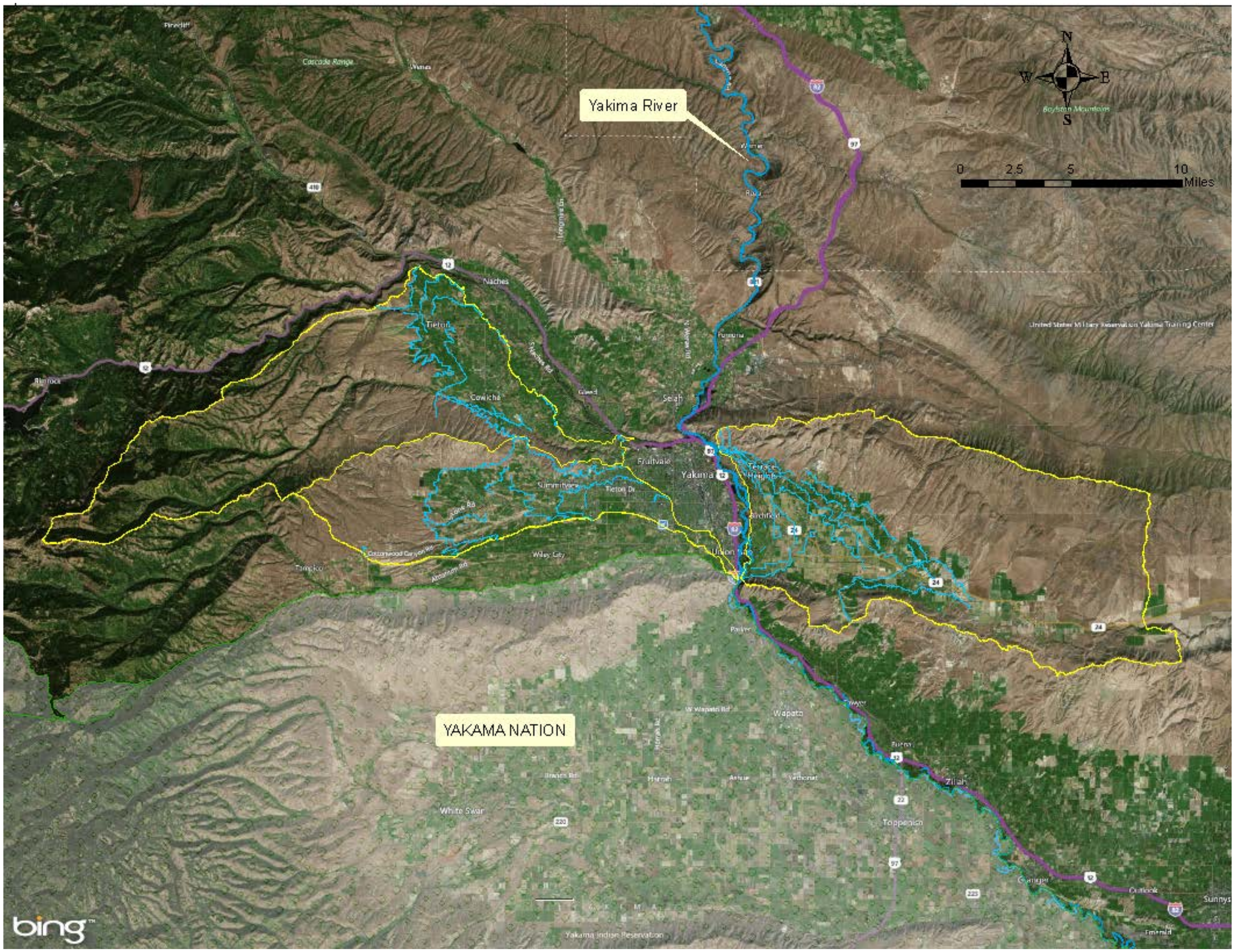

Figure 10: Irrigation and drainage canals within the TMDL project area.

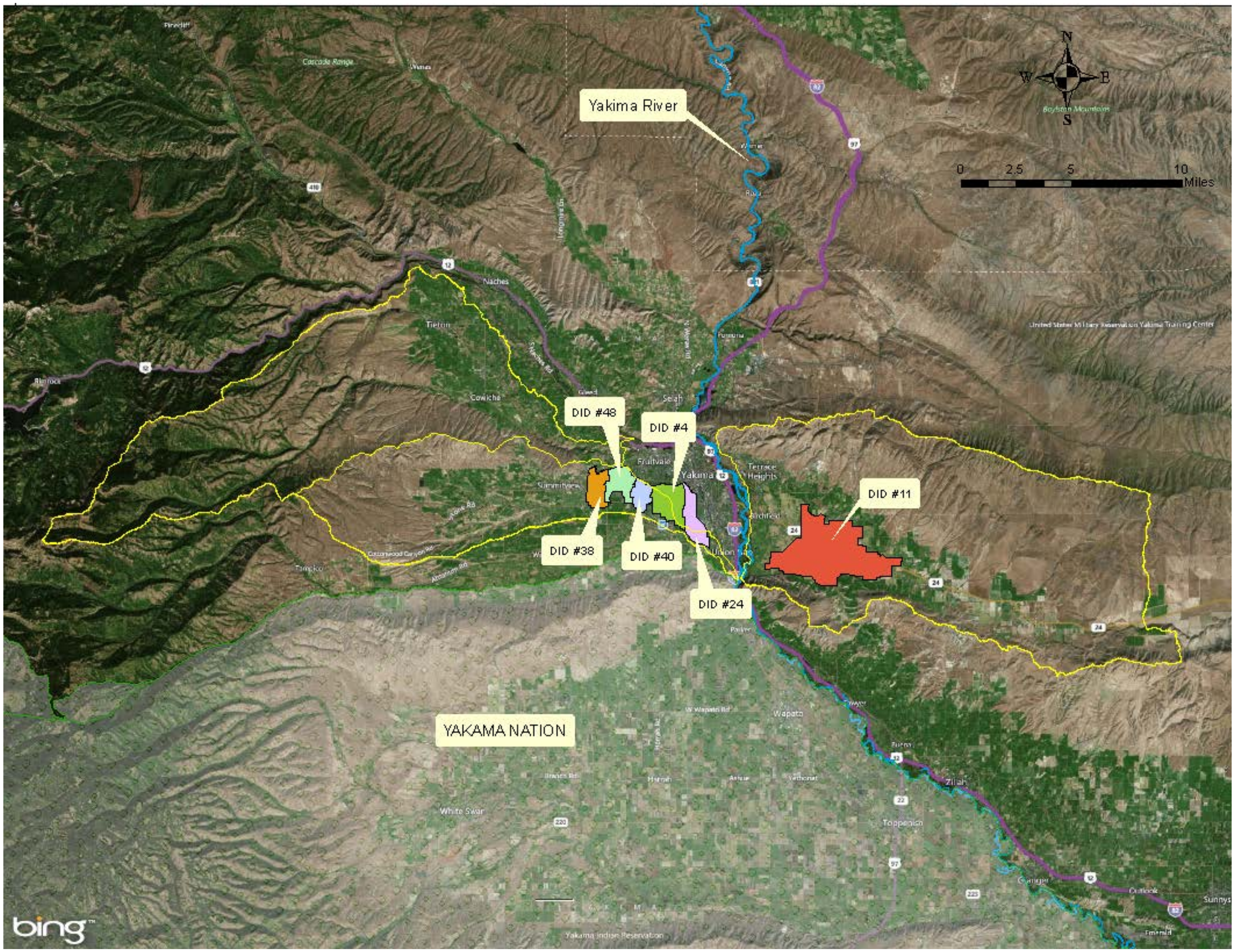

Figure 11: DIDs operated and managed by Yakima County within the TMDL project area.

In terms of plant communities, all three sub-basins are located within the boundaries of the historical shrub-steppe area of eastern Washington. Shrub-steppe (Figure 12) refers to the dominant vegetation of this ecosystem: *shrubs* (i.e. sagebrush, hopsage, greasewood, and bitterbrush); and *steppe,* or perennial bunchgrasses (i.e. bluebunch wheatgrass, needle-and-thread, Indian ricegrass, and Sandberg's bluegrass.

Figure 12: Shrub-steppe vegetation. (courtesy of WDFW)

It is estimated that about 12% of the State's historical shrub-steppe ecosystem remains, of which less than 1% is in pristine condition. In 2011, the Washington State Department of Fish and Wildlife (WDFW) stated that: *Shrub-steppe is one of Washington's most richly diverse habitats and home to some species found nowhere else in the State. Because of this and because a large portion of Washington's shrub-steppe has been disturbed or lost, shrub-steppe was added to our list of Priority Habitats and Species.*

The *Mid-Yakima River Basin Bacteria TMDL* project area contains at least 25 fish species, including chinook salmon, coho salmon, steelhead, brook trout, brown trout, bull trout, cutthroat trout, rainbow trout, and mountain whitefish.

Figure 13 presents the land-uses within the boundary of the TMDL. The largest land-use in the basin is the category of agriculture (53.9% = 182.5 square miles). The next two largest land-uses are "open space" (13.9% = 47.0 square miles), which is predominantly rangeland in the northeast corner of the Moxee Sub-basin, followed by public forests (9.1% = 30.8 square miles). The city of Yakima (102,848 pop.) is the geographical and urban center of the mid-Yakima River basin.

The TMDL project area also includes the following smaller urban areas: Cowiche (428 pop.), Moxee (4,144 pop.), Tieton (1,368 pop.), Terrace Heights (6,937 pop.), and Union Gap (6,855 pop.). The combined UGA population of all urban areas is approximately 123,000 persons and has increased by 40,000 between the years 1990 and 2010. Such increase has resulted in a substantial conversion of land previously dedicated to farms, orchard, and rangeland to residential use.

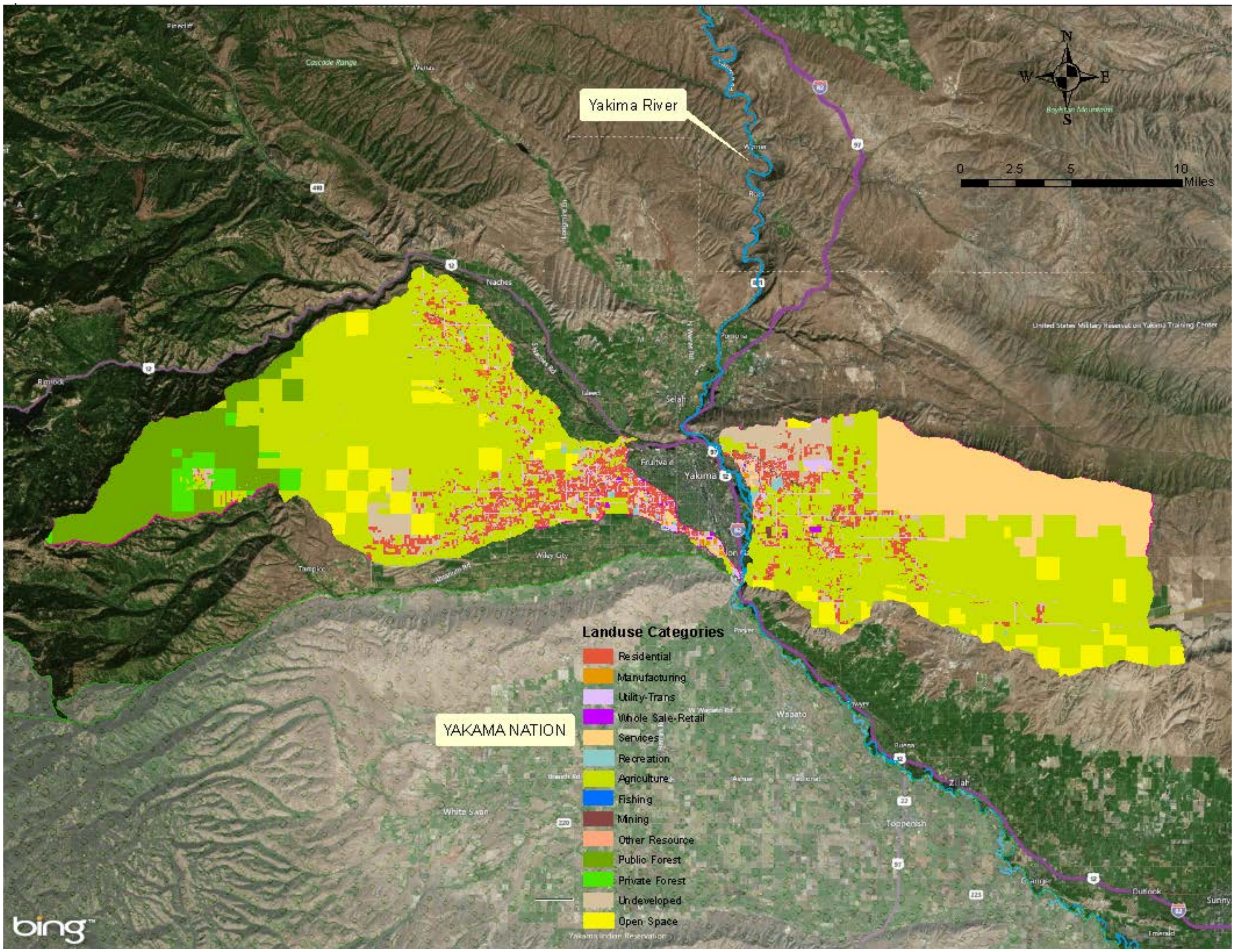

Figure 13: Land uses within TMDL project area.

Cowiche Creek sub-basin

The Cowiche Creek sub-basin (in WRIA 38) is a 115 square mile watershed located northwest of the city of Yakima. The sub-basin is bounded by Naches Heights along the east and northeast, by Divide Ridge to the northwest, and by Cowiche Mountain (Figure 14) to the south.

Figure 14: Cowiche Mountain. *Photo by David Hagen***.**

The sub-basin's principal surface waters are the N.F. Cowiche Creek, S.F. Cowiche Creek, and Cowiche Creek. N.F. Cowiche Creek originates from various highland springs on the southeast slope of Divide Ridge. S.F. Cowiche Creek originates from various springs along the east slope of Divide Ridge (Dome Peak and Strobach Mountain). Cowiche Creek (Figure 15) begins at the confluence of the N.F. and S.F. Cowiche Creeks and ultimately discharges into the Naches River at RM 2.7. The sub-basin's average annual precipitation is 14.3 inches.

Figure 15: Cowiche Creek.

The upper portions of the N.F. Cowiche Creek and the S.F. Cowiche Creek are forested. In fact, the upstream portions of North Fork, above the intersection of Hatton Road and NF-642, are located within the WNF. Also with the WNF are the upper portions of Weddle Canyon Creek, above the intersection of N.F. Cowiche Creek Road and NF-639.

The middle part of the S.F. Cowiche Creek is rangeland, while the lower portions of the North and South Forks are agricultural, containing orchards and vineyards being the primary crops. At the lower end of the sub-basin, Cowiche Creek flows through the narrow Cowiche Canyon. The developed areas around Tieton, Cowiche, and near the downstream mouth of the Cowiche Canyon, on the northwestern boundary of the city of Yakima, only occupy 6% of the sub-basin's area.

Early fish stockings of Cowiche Creek consisted of 2,000 fingerling rainbow trout in 1904 (US Dept. of Commerce, 1905), 2,000 fingerling brook trout in 1909 (US Bureau of Fisheries, 1910), and eastern trout in 1934-1941. In 1909, the S.F. of Cowiche Creek also had 1,500 fingerling brook trout planted (US Bureau of Fisheries, 1910). Recent fishing has relied only on wild populations. Steelhead, coho, and spring chinook salmon have all historically spawned in Cowiche Creek. In 2002, the Yakama Nation reported capturing 1 bull trout, approx. 6 inches in length in the S.F. Cowiche Creek. In 2009, the Yakama Nation Fisheries coho program started using a mobile acclimatization facility to introduce up to 10,000 coho smolts a year to the Cowiche watershed.

A U.S. Bureau of Fisheries survey was made of Cowiche Creek on August 1, 1936 (McIntosh et al., 1990). According to that survey, the stream was approximately seven miles long with nine irrigation diversions, each without headgates or protective devices. The same survey reported that:

> *The Cowiche watershed is very narrow from the mouth to the confluence of the North Fork. From a point approximately three miles above the mouth to the town of Weikel, a distance of two miles, the valley sides become very steep forming a small box canyon which is rarely over 200' in width. The hillsides of the entire valley are barren except for a sparse growth of sagebrush and grass.*
>
> *There are nine irrigation diversions on the Cowiche below the confluence of the North Fork. During low water periods the stream bed is practically dry in various areas. The total diversion is 8.43 cfs ... which at times during the summer is only available by the picking up of waste water from irrigation projects in the upper valley. In fact, the source of most of the supply of water in the main stream is the small seepage gain from swamps and waste water, and from ditches such as the Tieton and Congdon Canals diverting from the Naches River system.*

The same 1936 survey describer the N.F. Cowiche Creek as 18 miles long. The lower portion is *usually dry during the summer*, while the upper portion *is utilized as part of the Tieton canal and any water that might be in the creek becomes merely an addition to the canal's flow.* In the same survey, the S.F. Cowiche Creek length was reported as 25 miles and was *too small to warrant a detailed survey. Five diversions divert 5.5 cfs, but even this amount of water is lacking during the drier seasons.*

Moxee Drain sub-basin

The Moxee Drain sub-basin (in WRIA 37) is a 136 square mile watershed located east of the Yakima River and the city of Yakima. The sub-basin is bounded on the north by the Yakima Ridge and on the south by the Rattlesnake Hills (Figure 16).

Figure 16: Rattlesnake Hills. *Photo by childfreelifeadventures.com*.

The Moxee Drain (Figure 17) actually begins as an intermittent natural water body, Moxee Creek, in the far eastern portion of the Moxee Valley. It discharges into Blue Slough, which also collects drainage from Moxee Slough, which in turn discharges into the Yakima River at RM 107.5. As the stream flows westward down the valley toward the Yakima River, it parallels State Highway 24 and, at RM 8.6, begins to collect irrigation drainage (during the summer irrigation season) from adjacent agricultural lands. The sub-basin's average annual precipitation is 8.3 inches.

Figure 17: Moxee Drain.

The Moxee Drain is the lower portion of a natural drainage (Moxee Creek) that was systematically dredged and channelized to increase its capacity to transport massive amounts of irrigation return flows during the summer. The Moxee Drain officially begins at RM 8.6, where Moxee Creek crosses underneath the large concrete Roza Canal, immediately north of the intersection of Desmarais Road and Beane Road.

Most of the upper sub-basin is rangeland. The lower sub-basin is predominantly agricultural, with the primary crops being hops, tree fruit, hay, and fruit crops. Residential development of agricultural land has been occurring in recent years all around the city of Moxee. The urban and residential land-uses comprise approximately 2% of the sub-basin's area.

No known salmonids have been documented in the drain, although the USGS collected several small largescale suckers during their pesticide in fish tissue studies conducted throughout the Yakima River Basin in the 1980s and 1990s.

A little known fact is that just prior to its confluence with the Yakima River, the Moxee Drain passes along the north side of a 14-acre floating sphagnum bog, Moxee Bog. This is the only known example of an arid setting quaking bog within the United States, and it supports a colony of a rare butterfly: the silver-bordered fritillary, *Boloria selene*, (Figure 18). The Nature Conservancy purchased the property in the early 1960s and it essentially became the first butterfly preserve in the United States.

Figure 18: *Boloria selene*.

Wide Hollow Creek sub-basin

The Wide Hollow Creek sub-basin (in WRIA 37) is a 78 square-mile watershed located southwest of the city of Yakima. The 21.7-mile long natural water body begins on the south flanks of Cowiche Mountain and Pine Mountain (Figure 19).

Figure 19: Pine Mountain. *Photo by YARMLS*.

The sub-basin's principal surface water is Wide Hollow Creek (Figure 20). The stream flows along the southern edge of the cities of Union Gap and Yakima. Its major tributaries include: Cottonwood Creek (15.3 m^2), Shaw Creek (11.0 m^2), and East Spring Creek.

Figure 20. Wide Hollow Creek.

The sub-basin's average annual precipitation is 14.4 inches. The upper watershed hydrology is driven by snowmelt runoff, and peak runoff usually occurs in early May but may last until June or early July (Yakima County, 2010).

The middle and lower watersheds utilize irrigation water imported from the Naches and Tieton rivers (Ecology, 2013). East of 48th Avenue, there are inputs from several large springs as well as several DID drains (#4, #13, #24, #38, #40 and #48) which maintain a fairly stable year-round base-flow of approximately 7 cfs. All of the DID drains within the TMDL project area are operated and maintained by Yakima County.

Large amounts of irrigation water were historically needed to flush the "alkalinity" out of the soil profile so that agriculture could be profitable. This resulted in a high water table, which led to the construction of numerous artificial drainage networks leading to creeks. However, with the expansion of the urban areas, many of these systems are now located in cities and now serve a greater function as a conveyance for urban stormwater. Recent investigations by Yakima County (2010) have shown that 95% of DID flows are stormwater, as farmland irrigation has effectively ceased with urban expansion.

The sub-basin has been severely altered by man. The introduction of the Congdon Ditch (1906) brought Naches River water into the upper watershed and caused major realignments of the Wide Hollow Creek channel. Shaw Creek is a small stream, which has been altered into a roadside ditch as it approaches Wide Hollow Creek. East Spring Creek, in Union Gap, is a side channel of the Yakima River, which has been cut off from the Yakima River by the construction of I-82. Cottonwood Creek (the largest tributary to Wide Hollow Creek) has intermittent flow, with numerous springs and some return flow during the irrigation season.

The upper portion of the Wide Hollow Creek sub-basin is mainly rangeland, some of which is managed by the DNR. The lower portion of the sub-basin is composed of orchards, livestock pastures, residential subdivisions, and light industrial land uses up to the boundary of the city of Union Gap. The West Valley area of the sub-basin, downstream of the confluence with Cottonwood Creek, has experienced rapid urbanization due to several annexations by the city of Yakima. The sub-basin has the largest percentage of urban land use (28%) of the three sub-basins that comprise the TMDL project area.

The earliest verified fish stocking to Wide Hollow Creek was with 2,000 fingerling black-spotted trout (an early name for cutthroat trout) in 1903 (US Commission of Fish and Fisheries, 1905). About 2,000 fingerling brook trout were stocked in 1909 (US Bureau of Fisheries, 1910). Historically, it was also stocked with rainbow trout and brown trout, which have subsequently reproduced naturally. Redside shiners are the predominant species in the upstream reaches, while speckled dace and largescale suckers dominate the lower reaches. Wide Hollow Creek supports spring and fall chinook rearing, coho, summer steelhead, and mountain whitefish.

East Spring Creek has been documented to contain spring chinook and coho salmon, rainbow trout, native minnows, largescale suckers, and stickleback (WDFW unpublished data, 2006).

The stream ultimately enters into the Yakima River at RM 107.4 after passing through the city of Union Gap, crossing under Interstate 82, and then being joined by East Spring Creek (RM 0.5) from the north. Wide Hollow Creek was also mistakenly known as *Wide Hollar Creek* during several federal fish stocking programs in the early 1900s.

Wide Hollow Creek was originally known as Wide Hollow Slough and, when flowing, discharged into Ahtanum Creek. With the advent of white settlers, its channel was moved to supply irrigation water to lands between Ahtanum Creek and the Yakima River. In 1871, the Schanno brothers made an attempt to irrigate their land around Yakima City (presently known as Union Gap) from " a branch of Ahtanum Creek" (AKA: Wide Hollow Creek), but the creek's flow only lasted as long as snowmelt occurred (USGS, 1916). They enlarged the ditch in 1872 to bring a larger volume of irrigation water from Ahtanum Creek. Due to the increased volume of irrigation return flow, Wide Hollow Creek was subsequently able to continue flowing during the summer and thus was able to supply waterpower to the area's first flourmill (Barker Brothers) at Yakima City (Union Gap), near its outfall into the Yakima River.

Hydrological history and characteristics

Catholic Missionaries arrived to the mid-Yakima River basin in 1847 from Fort Walla Walla, at the request of Yakama Chief Kamiakin, and soon after established the Saint Joseph Mission on Ahtanum Creek in 1852. They were the first non-Indians to use irrigation within the *Mid-Yakima River Basin Bacteria TMDL* project area, as a few Yakamas had already been irrigating small plots of land and growing potatoes, corn, and peas from seed obtained from the Hudson's Bay Company at Fort Vancouver (Wriglesworth, 2010) prior to the missionaries' arrival.

By August of 1905, fifty-five different private irrigation canal companies had over-appropriated the entire flow of the Yakima River. In 1905, the newly created federal United States Bureau of Reclamation (USBR) launched the huge Yakima Project to provide a consistent supply of irrigation water throughout the entire Yakima Valley, including the TMDL project area.

The Yakima River basin is the leading agricultural region in the State. Agriculture is the primary consumptive user of surface water in the basin. During the hot arid summers, agricultural return flows become a large source of downstream surface water flow. Approximately 80% or more of the Yakima River flow downstream of Parker is composed of irrigation return flows and operational spills from diversions (USBR, 2002).

The three principal surface waters within the TMDL project area (Cowiche Creek, Moxee Drain and Wide Hollow Creek) have seasonal hydrologic flows that are influenced by agricultural irrigation drainage, e.g. high summer irrigation return flows and low winter natural base flows (Figure 21) which was presented by Tarbutton (2012). All of their maximum stream flows occur within the period of April through September. The seasonal hydrologic variation is greatest in the Moxee Drain and smallest in Wide Hollow Creek, which probably reflects their respective amounts of irrigated acreage.

Site-specific irrigation return flows are highly variable because they depend on water availability, the water needs of specific crops, and operational management of the irrigation network. Site-specific pollutants are dependent on crop type, irrigation method, and the amount and type of fertilizer used. When animal manure is used as a fertilizer or deposited directly by livestock, the irrigation return flows will most likely contain FCB concentrations higher than natural background conditions.

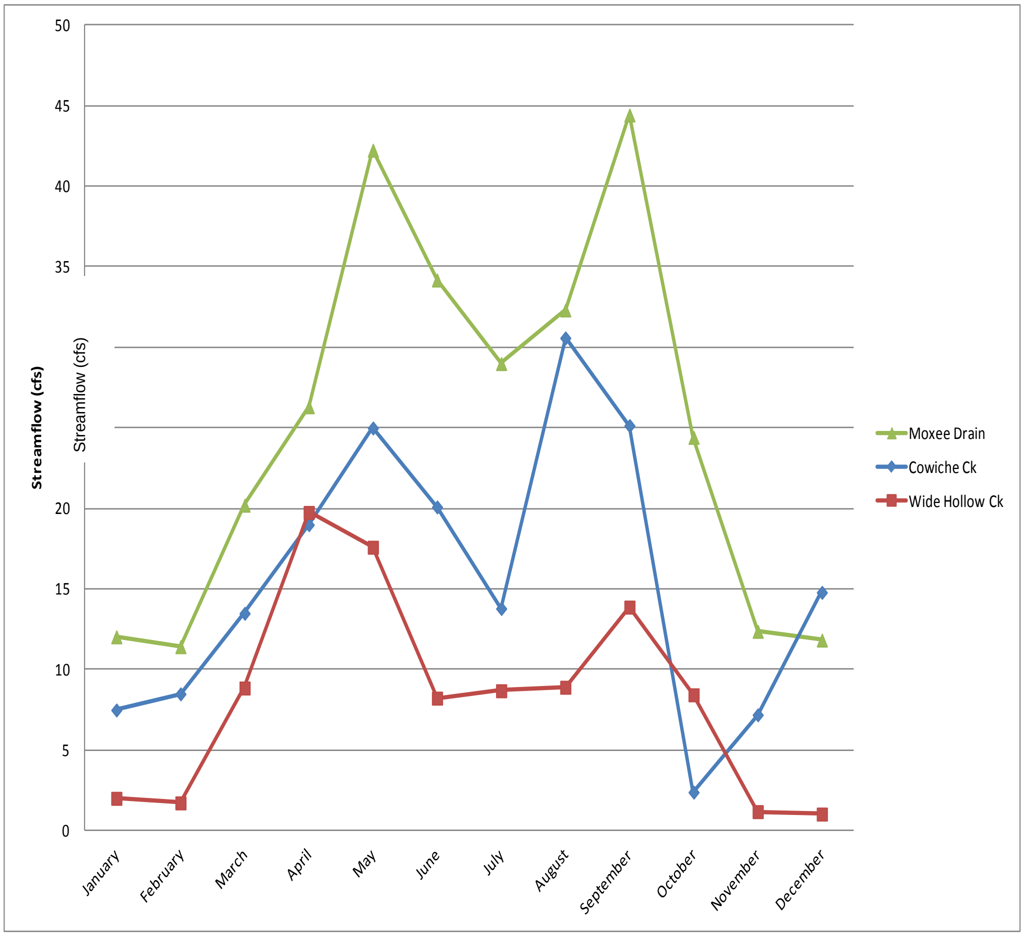

Figure 21: Historical mean monthly streamflows illustrating the hydrologic characteristics associated with agriculture irrigation and drainage operations within TMDL project area.

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TMDL Goal and Objectives

Study goal

The goal of the *Mid-Yakima River Basin Bacteria TMDL* is to meet the State water quality FCB criteria, as established in WAC 173-201A-200(2)(b), in all of the following water bodies and their tributaries within the TMDL project area: Cowiche Creek, Moxee Drain, and Wide Hollow Creek.

Study objectives

A *Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Joy, 2005) was approved in January 2005 to gather the 2004-2006 data utilized in this WQIR. An *Addendum to Quality Assurance Project Plan: 2010 Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Ross, 2012) was published for the collection of 2010 additional data. A second *Addendum to Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Carroll, 2014) was published for the collection of the 2014 additional data.

The principal objectives of the *Mid-Yakima River Basin Bacteria TMDL* are to:

- Determine the critical condition for FCB pollution and the respective loading capacities for all of the 303(d)-listed surface waters within the TMDL project area.
- Calculate the load and wasteload allocations necessary to meet State water quality FCB criteria for all known and suspected point sources and identified non-point sampling sites.
- Determine the percentages of *E. coli* and *Klebsiella* for better source identification and pollution elimination.
- Determine the greatest sources or locations of FCB pollution.
- Include a summary implementation plan that outlines the interested entities and their applicable schedule of BMP implementation.

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TMDL Study Design

Quality control

Data collection and quality

The *Mid-Yakima River Basin Bacteria TMDL* was originally known as the *Yakima Area Creeks Fecal Coliform TMDL* and had three *Quality Assurance Project Plans* (QAPPs) that were published separately for the 2004-2006, 2010, and 2014 sampling surveys. The 2004-2006 QAPP was entitled *Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Joy, 2005). The 2012 QAPP was titled *Addendum to Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Ross, 2012). The 2014 QAPP was titled *Addendum to Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Carroll, 2014).

Field data collection study methods were described in each QAPP. Ecology's Manchester Environmental Laboratory (MEL) conducted all laboratory analyses. Laboratory data were generated according to laboratory quality assurance/quality control (QA/QC) procedures (MEL, 2005; MEL, 2008). Measurement quality objectives (MQOs) were consistent with the current Ecology precision targets (Mathieu, 2006).

Table 10 presents the laboratory analysis methodologies, and data quality objectives used for the TMDL. Field sampling and measurement protocols follow those listed in the Watershed Assessment Section protocols manual.

Table 10: Study analysis methodologies with precision targets and reporting limits.

Analysis	Method	Reporting Limit	Precision MQO (% RSD)	Duplicate MQO (%RSD)
FCB – MF	SM 9222D	1 cfu/100mL	> 50% and > 90%[1]	40
E. coli - MF	USEPA 1103.1 (mTEC2)	1 cfu/100mL	> 50% and > 90%[1]	40
%*Klebsiella*[2]	Manchester SOP	0%	> 50% and > 90%[1]	40
Total Suspended Solids	SM 2540D	1 mg/L	15	20

[1] Two-tiered: 50% of replicates ≤ 20% RSD; 90% of replicates ≤ 50% RSD.
[2] Excludes results where one value is 0% and one value is higher; the statistical method of evaluation is not suitable
[3] The arcsine of each %*Klebsiella* value was used to calculate RPD

Analytical laboratory precision was determined separately to account for its contribution to overall variability. Precision for total suspended solids (TSS) was determined by calculating an average relative standard deviation (%RSD) of lab-split results. About 10% of the TSS samples were analyzed as laboratory split samples. Precision for FCB was determined by conducting a frequency analysis for %RSD values of lab-split pairs below 20% RSD and 50% RSD. For FCB samples, about 20% were analyzed as split samples.

The RSD was first calculated by dividing the standard deviation by the mean of the laboratory replicate measurements and multiplied by 100 for the %RSD. A higher %RSD is expected for values that are close to their reporting limits. For example: the %RSD for replicate samples with results of 1 and 2 is 47%, whereas the %RSD for replicate results of 100 and 101 is 0.7%, with each having a difference of 1.

Field replicate samples (side-by-side duplicates) were collected for at least 10% of the total number of general chemistry samples and at least 20% of the total number of microbiology samples in order to assess total precision (i.e., total variation) for field samples.

As was done for the lab precision evaluation, two tiers were also evaluated for total precision: field-replicate results less than five times the reporting limit and field-replicate results equal to, or more than five times, the reporting limit for TSS. For FCB, *E. coli*, and %*Klebsiella*, the two tiers evaluated were: 50% of replicates < 20% RSD and 90% of replicates < 50% RSD. %RSD was calculated for each parameter using field replicate results greater then reporting limits.

Data verification and validation

Laboratory-generated data reduction, review, and reporting used the procedures outlined in the *MEL User's Manual*. Laboratory results were checked for missing and/or improbable data. Variability in laboratory duplicates were quantified using the procedures outlined in the *MEL User's Manual*. The data was also verified and validated.

In February 2008, Ecology published all of the 2004-06 sampling data in the *Data Summary Report: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Mathieu and Joy, 2008). The 2010 and 2014 sampling data were not published prior to this WQIR. All laboratory and field data collected for the TMDL were loaded into Ecology's Environmental Information Management (EIM) database. These data are available online from the Ecology website at: www.ecy.wa.gov/eim/. Several query options are available. The study identification (study ID) designation is "YUTTMDL," and the study name is *Yakima Urban Tributaries Fecal Coliform TMDL*.

Sampling locations

The sampling design utilized a total of 83 sampling sites to characterize FCB concentrations throughout the Cowiche Creek, Moxee Drain and Wide Hollow Creek sub-basins that comprise the *Mid-Yakima River Basin Bacteria TMDL* project area. In addition to FCB, other parameters such as flow were measured whenever possible.

Table 11 and Figure 22 present the sampling site locations within the Cowiche Creek sub-basin. Table 12 and Figure 23 present the sampling site locations within the Moxee Drain sub-basin. Tables 13 and 14, and Figure 24 present the sampling sites within the Wide Hollow Creek sub-basin.

Table 11: Locations of Cowiche Creek sub-basin sampling sites.

Site ID	Corresponding 303(d) Listings	Site Description	Latitude	Longitude
38-FC-1	45115	Cowiche Cr. @ Powerhouse Rd.	46.6272	-120.5812
38-FC-1.25	8319	Cowiche Cr. @ the end of Cowiche Creek Rd.	46.6221	-120.6137
38-FC-1.5	45886	Cowiche Cr. @ Zimmerman Rd.	46.6361	-120.6667
38-FC-2	46633 & 8327	S.F. Cowiche Cr. @ Pioneer Way.	46.6471	-120.6842
38-FC-2.5	46346 & 8326	S.F. Cowiche Cr. @ WDFW bridge.	46.6606	-120.7689
38-FC-3	8323	N.F. Cowiche Cr. @ Mahoney Rd.	46.6475	-120.6822
38-FC-3.5		N.F. Cowiche Cr. @ Thompson Rd. (replacement site)	46.6577	-120.6921
38-FC-4		S.F. Cowiche Cr. @ Cowiche Mill Rd. (proposed background site)	46.6649	-120.8229
38-FC-6	8322	N.F. Cowiche Cr. @ Rozenkranz Rd.	46.7093	-120.7672
38-FC-7		N.F. Cowiche Cr. @ French Rd. (proposed background site)	46.7110	-120.8047
38-FC-WWE		Cowiche Regional POTW effluent @ UV chamber.	46.6749	-120.7042
38-FC-WWR		Cowiche Regional POTW effluent after wetland treatment	46.6735	-120.7028
38-IS-7		Loop return to N.F. Cowiche Cr. off Thompson Rd.	46.6584	-120.6821
38-IS-7.5		S.F. Cowiche Cr. @ Summitview Rd.	46.6484	-120.7015
38-IS-7.6		S.F. Cowiche Cr. @ Pioneer Way.	46.6540	-120.7203
38-IS-8		Side branch return to Cowiche Cr. @ Weikel Rd.	46.6334	-120.6675
38-IS-8.5		Irrigation return to S.F. Cowiche Cr. @ FC-2.	46.6471	-120.6843

Table 12: Locations of Moxee Drain sub-basin sampling sites.

Site ID	Corresponding 303(d) Listings	Site Description	Latitude	Longitude
37-FM-1	45717	Moxee Drain near mouth off Thorp Rd.	46.5378	-120.4587
37-FM-3	45122	Moxee Drain @ Birchfield Rd.	46.5458	-120.4383
37-FM-3.5	46355	Moxee Drain just below DID #11.	46.5505	-120.4176
37-FM-3.6	45703	DID #11 @ mouth.	46.5507	-120.4175
37-FM-4 / 37-IS-2	46548 & 46673	Hubbard Canal @ Bell Rd.	46.5570	-120.4104
37-FM-5 / 37-IS-1	45114	DID #11 @ Bell Rd.	46.5568	-120.4064
37-FM-5.5		DID #11 @ Beaudry Rd. (proposed background site)	46.5617	-120.4040
37-FM-7 / 37-IS-3	45313	Irrigation ditch to Moxee Drain @ Beaudry Rd.	46.5510	-120.4042
37-FM-8	46167	Moxee Drain @ Beauchene Rd.	46.5489	-120.4041
37-FM-9		Moxee Drain @ Walters Rd.	46.5459	-120.3561
37-FM-9.5		Irrigation ditch to Moxee Drain @ Walters Rd.	46.5460	-120.3562
37-FM-10	46168	Moxee Drain @ Beane Rd. (proposed background site)	46.5408	-120.3134
37-FM-WWE		Moxee City POTW effluent @ UV chamber.	46.5623	-120.4024
37-FM-WWO		Moxee City POTW effluent discharged to DID #11.	46.5567	-120.4064
37-IS-0		Irrigation return to Moxee Drain near 37-FM-1.	46.5380	-120.4561
37-IS-1.5		Irrigation outfall to DID #11 @ 37-FM-5.	46.5568	-120.4064
37-IS-4		Irrigation outfall to Moxee Drain @ Walters Rd.	46.5460	-120.3567
37-IS-4.5		Irrigation outfall to Moxee Drain @ 37-FM-8.	46.5488	-120.4042
37-IS-4.6		North irrigation outfall to Moxee Drain @ 37-FM-8.	46.5489	-120.4041
37-IS-5		Outfall from Roza Canal to Moxee Drain.	46.5404	-120.3127

Table 13: Locations of Wide Hollow Creek mainstem sampling sites.

Site ID	Corresponding 303(d) Listings	Site Description	Latitude	Longitude
37-FW-0 / 37-SS-1	8306	Wide Hollow Cr. @ Union Gap Public Works.	46.5429	-120.4752
37-FW-0B		Wide Hollow Cr. downstream of East Spring Cr.	46.5440	-120.4739
37-FW-1 / 37-SS-5	6717	Wide Hollow Cr. @ manhole in Main St. in Union Gap.	46.5436	-120.4759
37-FW-1B		Wide Hollow Cr. @ White St. in Union Gap	46.5496	-120.4806
37-FW-1C		Wide Hollow Cr. @ Fines Diversion	46.5524	-120.4916
37-FW-2B		Wide Hollow Cr. @ grist mill in Union Gap	46.5436	-120.4752
37-FW-3		Wide Hollow Cr. @ 3rd Ave. just downstream of DID #24 outfall	46.5587	-120.5090
37-FW-3B		Wide Hollow Cr. upstream of 3rd Ave. bridge. (replacement site)	46.5595	-120.5099
37-FW-4 / 37-SS-7		Wide Hollow Cr. @ 16th Ave. (Union Gap/Yakima boundary)	46.5685	-120.5305
37-FW-5	6718	Wide Hollow Cr. @ gas station just north of airport.	46.5739	-120.5477
37-FW-6B		Wide Hollow Cr. @ 40th Ave. (replacement site)	46.5786	-120.5656
37-FW-6	16804	Wide Hollow Cr. @ 44th Ave. (Randall Park boundary)	46.5782	-120.5676
37-SS-11		Wide Hollow Cr. @ 48th Ave. (Randall Park boundary)	46.5791	-120.5723
37-IS-16B		Wide Hollow Cr. downstream of Congdon Canal	46.5805	-120.6412
37-SS-12		Wide Hollow Cr. @ 64th Ave.	46.5834	-120.5940
37-FW-8 / 37-SS-14	45081	Wide Hollow Cr. @ 80th Ave. (Yakima city limits)	46.5813	-120.6146
37-SS-15	46645	Wide Hollow Cr. @ 91st Ave. & Wide Hollow Rd.	46.5822	-120.6295
37-FW-12 / 37-SS-16	45161	Wide Hollow Cr. @ Dazet Rd.	46.5798	-120.6464
37-FW-15 / 37-SS-17		Wide Hollow Cr. @ Wide Hollow Rd.	46.5838	-120.6674
37-FW-18		Wide Hollow Cr. @ Stone Rd. (proposed background site)	46.5749	-120.7411

Table 14: Locations of Wide Hollow Creek tributary sampling sites.

Site ID	Corresponding 303(d) Listings	Site Description	Latitude	Longitude
37-FW-2	45541	East Spring Cr. @ Union Gap Public Works.	46.5427	-120.4715
37-FW-13 / 37-SS-18	45210	Cottonwood Cr. @ Dazet Rd. (bridge #440)	46.5792	-120.6464
37-FW-14	46164	Cottonwood Cr. @ Moore Rd. (proposed background site)	46.5778	-120.6675
37-FW-16		Tributary #1 @ Stone Rd. near school. (proposed background site)	46.5873	-120.7095
37-FW-17		Tributary #2 @ Stone Rd. (proposed background site)	46.5832	-120.7149
37-IS-10		Drain @ 4th St. and Pine St. in Union Gap.	46.5519	-120.4802
37-IS-12 / 37-IS-12B		DID #24 outfall on Lateral L1 @ 3rd Ave.	46.5588	-120.5096
37-IS-13		DID #24 outfall on Lateral L2 @ Pioneer Lane	46.5639	-120.5159
37-IS-15	45219	DID #4 outfall behind Gardner's Nursery	46.5677	-120.5228
37-IS-16	45875	Congdon Canal east of 101st Ave.	46.5824	-120.6417
37-IS-17		DID #40 outfall @ 38th Ave. and Logan Ave.	46.5799	-120.5592
37-IS-17.5 / 37-SS-9	46628	Randall Park Pond outlet @ 44th Ave.	46.5800	-120.5673
37-IS-18		DID #48 into ditch @ Viola Ave. & 48th Ave.	46.5821	-120.5726
37-IS-18B		DID #48 behind 48th Ave. (replacement site)	46.5846	-120.5733
37-IS-19 / 37-SS-48		DID #48 outfall @ 64th Ave.	46.5833	-120.5939
37-IS-20 / 37-SS-38		DID #38 outfall @ 64th Ave.	46.5833	-120.5939
37-IS-20A		Naches & Cowiche Canal @ 12th Ave.	45.5681	-120.5287
37-IS-20B		Naches & Cowiche Canal @ 32th Ave.	46.5753	-120.5515
37-IS-21		City stormwater outfall west of RR tracks. (MS4)	46.5501	-120.4840
37-IS-22		City stormwater outfall under Ahtanum Bridge. (MS4)	46.5578	-120.5031
37-IS-23		Spring Creek Irrigation District inflow	46.5635	-120.5202
37-SS-2		City stormwater outfall at east end of Ahtanum Rd. (MS4)	46.5570	-120.4714
37-SS-4		Storm drain for Del Monte Foods 125, south of main building.	46.5982	-120.5054
37-SS-6		City stormwater outfall at 3rd Ave. (MS4)	46.5589	-120.5097
37-SS-8		City storm drain @ end of 34th Ave. (MS4)	46.5769	-120.5542
37-SS-11B		Spring @ Randall Park downstream of 48th Ave. and Wide Hollow Cr.	46.5800	-120.5673
37-SS-13	45869	Shaw Cr. west of 80th Ave., north of Nob Hill.	46.5868	-120.6150
37-SS-13B		Shaw Cr. @ Wide Hollow Rd & 80th Ave. (replacement site)	46.5820	-120.6145

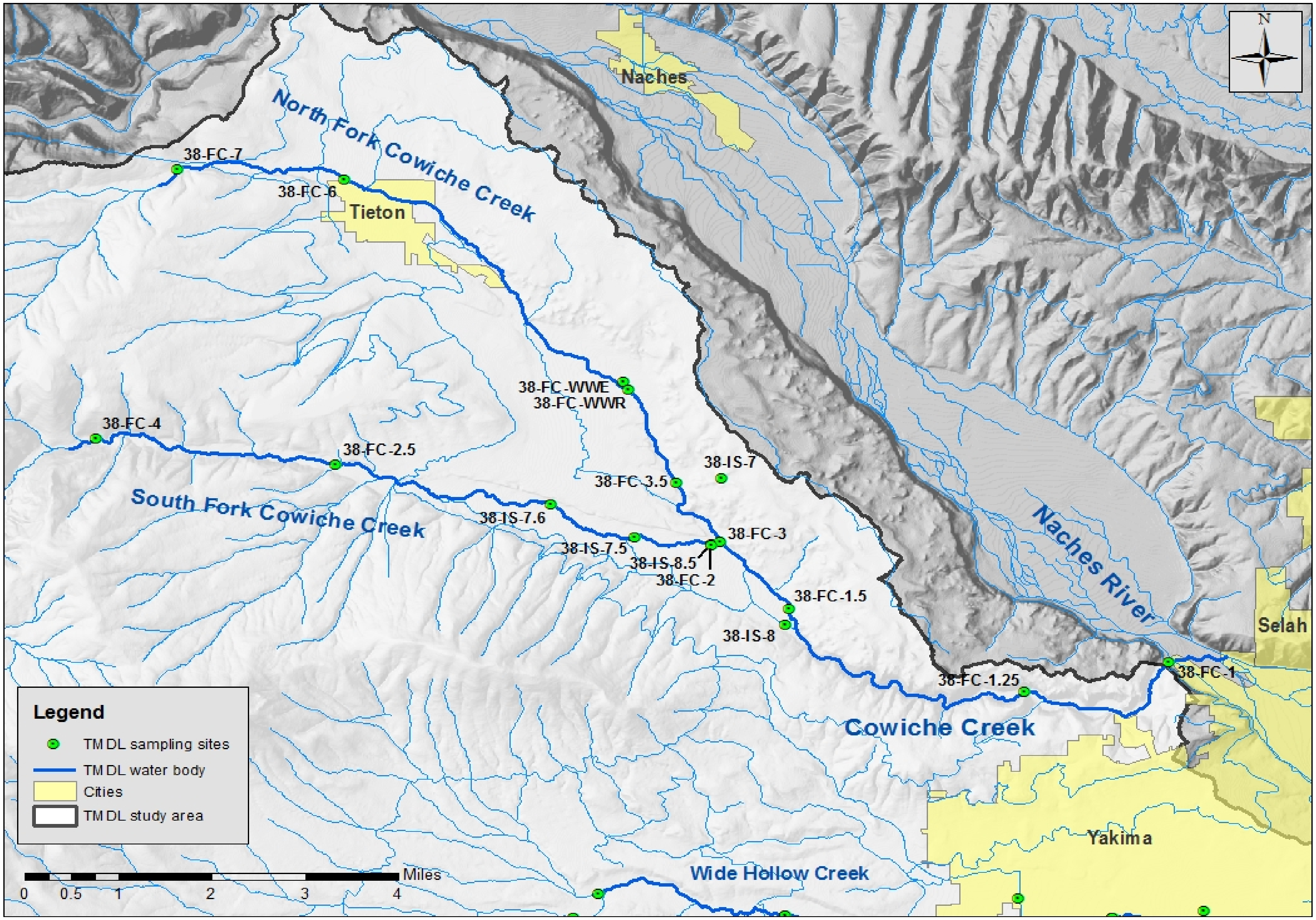

Figure 22: Map of Cowiche Creek sub-basin sampling sites.

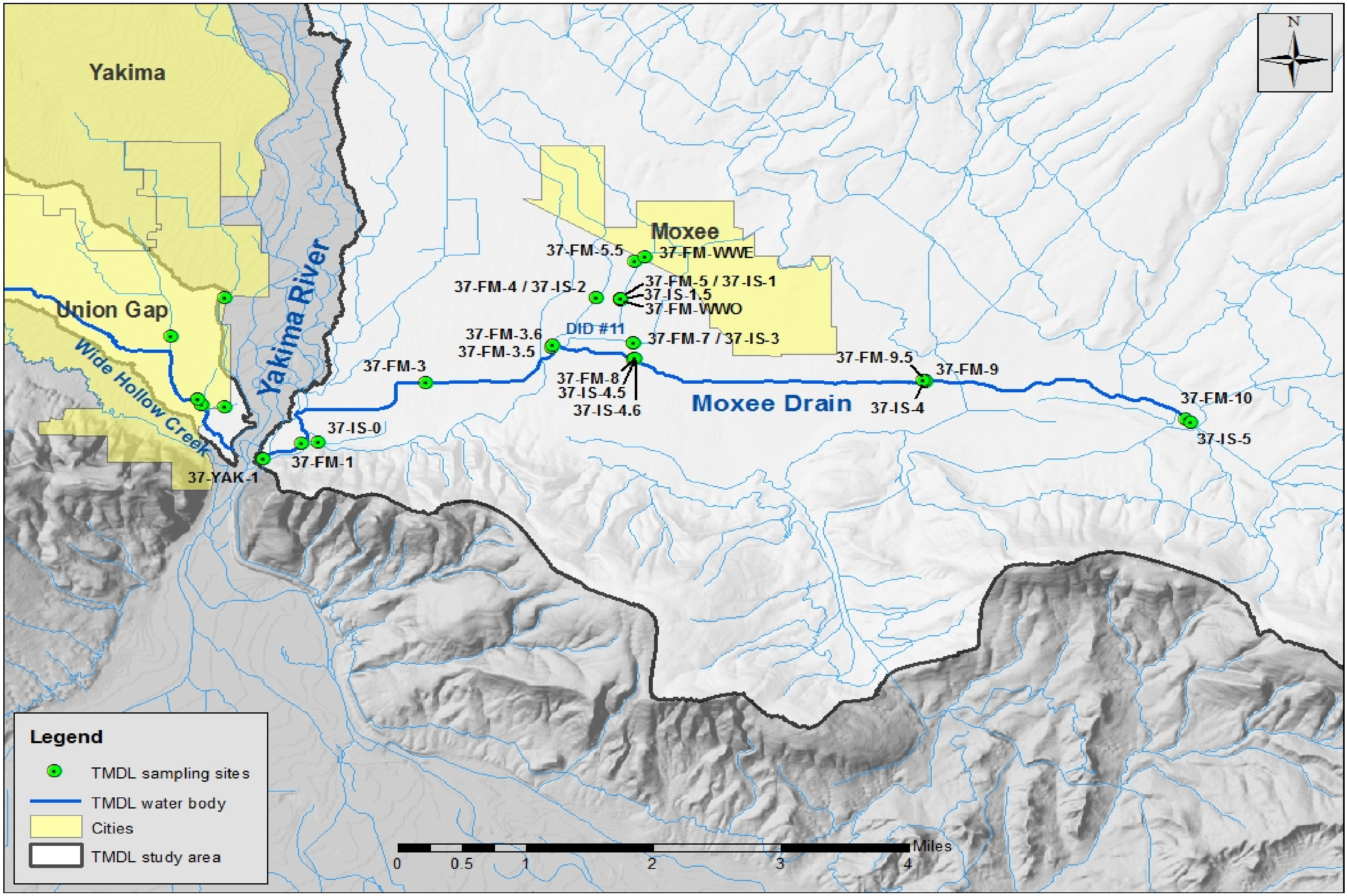

Figure 23: Map of Moxee Drain sub-basin sampling sites.

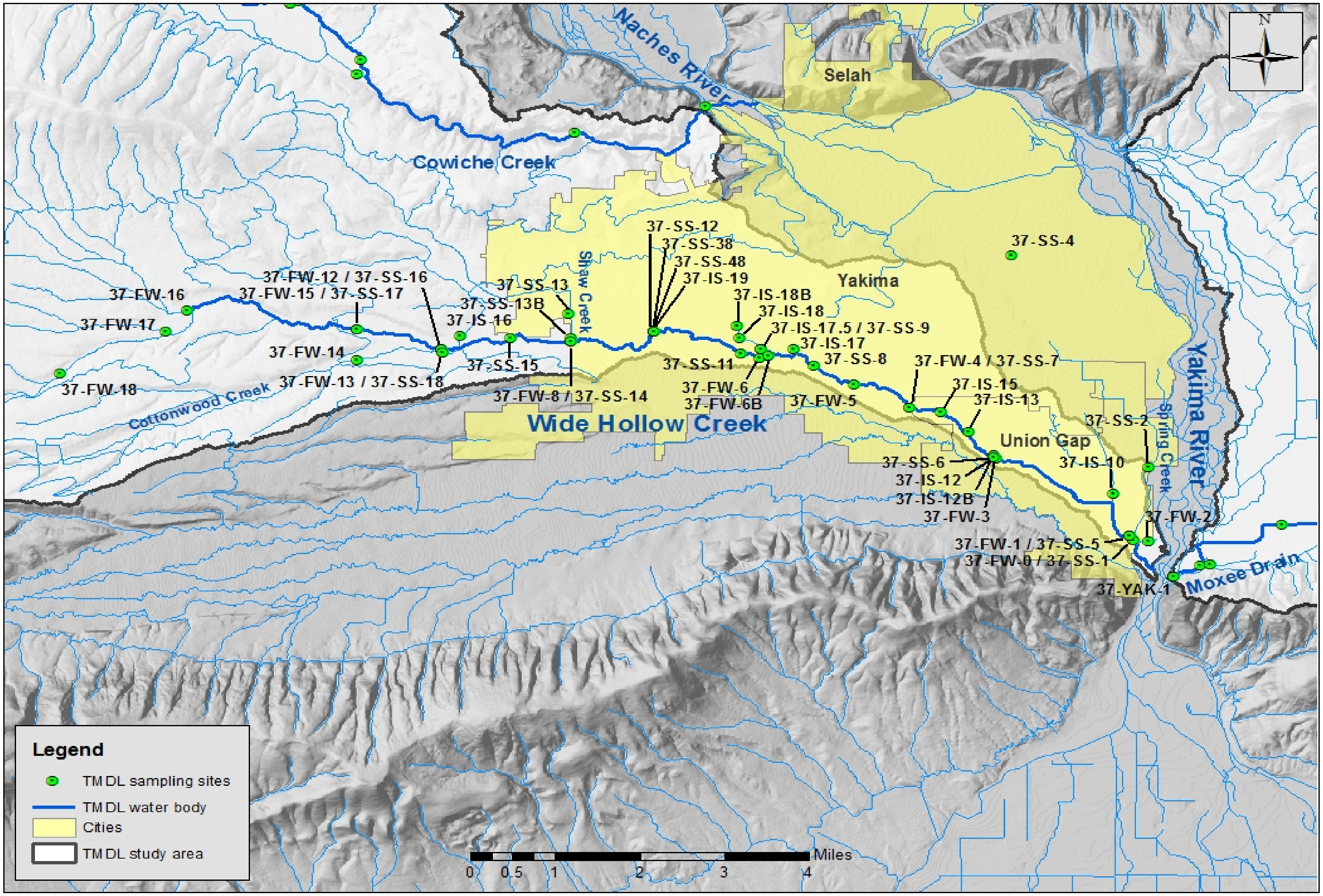

Figure 24: Map of Wide Hollow Creek sub-basin sampling sites.

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Historical Data Review

Water quality sampling performed by the United States Geological Survey (USGS) in 1988 (Embrey, 1992) documented numerous violations of State water quality FCB criteria within the TMDL project area, resulting in their inclusion on the State's 303(d) list of impaired waters. Additional data was collected by the Yakama Nation in 1995 and by Ecology in 1987-2004.

Bacteria concentration values are typically distributed in a lognormal fashion, similar to other parameters such as TSS and turbidity. In the following tables the geometric mean (geomean) is the statistical measure of the average value of a data set of sampled values. It is a measure of *long-term* compliance (USEPA, 2011). The STV is an approximation of the 90th percentile statistic and thus a measure of the *short-term* compliance (USEPA, 2011).

The FCB geomean value is compared to the applicable primary contact recreation FCB criterion specified in WAC 173-201A-200(2)(b). The STV is compared to the secondary FCB criterion specified in WAC 173-201A-200(2)(b) as the narrative: *not more than 10 percent of all values obtained for calculating the geometric mean value*.

The terms *primary* and *secondary*, as they relate to the FCB criteria, do not indicate that one or the other is more important. Both criteria are similarly important and need to be used together in order to provide a more accurate picture of the overall health of a water body

Yakama Nation

Table 15 presents the seasonal FCB statistics for bacteria data collected by the Yakama Nation Natural Resource Division at five sites in the Cowiche Creek sub-basin from January through November, 1995 (Palmer, 1996).

Table 15: 1995 seasonal FCB statistics for Cowiche Creek sub-basin.

Sampling Site Location	Non-Irrigation		Irrigation Season	
	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
N.F. Cowiche Cr. near city of Tieton	25	374	96	181
N.F. Cowiche Cr. near mouth	72	176	621	1,956
S.F. Cowiche Cr. at Cowiche Wildlife Area	10	42	64	124
S.F. Cowiche Cr. near mouth	38	187	246	1,983
Cowiche Cr. in Cowiche Canyon	58	361	747	1,879

[1] Cells shaded in this column represent values that exceed State WQS.

During the 1995 irrigation season, three (60%) of the five sampling sites contained FCB in excess of water quality FCB criteria. Only two (40%) of the sampling sites exceeded those same criteria during the non-irrigation season. Interestingly, the Cowiche Wildlife Area on the S.F. Cowiche Creek was the only site that complied with State WQS during both seasons. This suggests that anthropogenic management (feeding stations) of elk does not appear to increase FCB concentrations in excess of the State WQS, even during the irrigation season.

Washington State Department of Ecology

In 1974, Ecology collected one sample along Wide Hollow Creek, which was published in 1985 (Molenaar, D.). Additionally, Kendra (1988) published a report that contained several bacteria samples in the Wide Hollow Creek sub-basin during July 1987. Table 16 presents the irrigation season FCB statistics obtained for that data.

Table 16: 1974 and 1987 irrigation season FCB statistics for Wide Hollow Creek sub-basin.

Sampling Site Location	Irrigation Season	
	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
Wide Hollow Cr. at Main St. in Union Gap (RM 0.9)	376	610
Municipal stormwater at Pine St.	1,296	1,400
Wide Hollow Cr. at Goodman Rd. in Union Gap (RM 2.8) (1974)	12,260	28,000
Wide Hollow Cr. at 3rd Ave. in Union Gap (RM 3.2)	512	560
Wide Hollow Cr. at Pioneer St. in Union Gap (RM 3.7)	653	710
DID #24 at Pioneer St. on northeast side of bridge	180	180
Wide Hollow Cr. at 10th Ave. (RM 4.0)	479	560
Wide Hollow Cr. at 12th Ave. (RM 4.3)	268	300
Wide Hollow Cr. at 16th Ave. (RM 4.6)	265	270
Wide Hollow Cr. at 24th Ave. (RM 5.3)	413	560
DID #40 (Randall Park Pond) outflow	2,400	2,400
Wide Hollow Cr. at 48th Ave. (RM 7.2)	280	280
Municipal stormwater pipe at 48th Ave.	2,149	2,200
DID #38 at 64th Ave. on north side of creek	66	66
Wide Hollow Cr. at 72nd Ave. (RM 9.2)	82	100
Cottonwood Cr. at Dazet Rd.	53	53
Wide Hollow Cr. at Dazet Rd. (RM 11.5)	300	300
Wide Hollow Cr. at Wide Hollow Rd. (RM 13.7)	160	160

[1] Cells shaded in this column represent values that exceed State WQS.

During the 1974 and 1987 irrigation season sampling, fifteen (83.3%) of the eighteen sites contained FCB in excess of water quality FCB criteria. The general downstream trend was an increase in FCB concentrations attributed to the cumulative effect of increasing streamside livestock pasturing. Major tributary sources of FCB were stormwater and the Randall Park pond effluent.

From October 2000 through September 2002, Ecology collected several water quality samples from both Cowiche Creek at Zimmerman Road (38G120) and Wide Hollow Creek at Randall Park pond outlet (37E120). Twelve samples were collected from each site during both the historical irrigation (April 15 through October 15) and non-irrigation seasons. The seasonal FCB statistics for that data is presented in Table 17.

Nine of the twenty-four (37.5%) Cowiche Creek samples were found to be in excess of the State water quality STV criterion of 200 cfu/100mL. Seventeen of the twenty-four (70.8%) Wide Hollow Creek samples were found to be in excess of that same criterion.

Table 17: 2000-2002 seasonal FCB statistics for Cowiche Creek and Wide Hollow Creek.

Sampling Site Location	Non-Irrigation		Irrigation Season	
	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
Cowiche Creek	27.2	100	688.8	3,240
Wide Hollow Creek	333.5	2,610	724.1	5,710

[1] Cells shaded in this column represent values that exceed State WQS.

During the irrigation season, a Kolmogorov-Smirnov (non-parametric statistical test) analysis determined that both the Cowiche Creek and Wide Hollow Creek sites contained equivalent (K-S = 0.61, $p = 0.847$) FCB pollution. However, during the non-irrigation season, Wide Hollow Creek site contained significantly greater (K-S = 2.25, $p < 0.001$) FCB pollution.

The Wide Hollow Creek sub-basin contains more urban area and less forested lands than the Cowiche Creek sub-basin, which may account for the non-irrigation season difference. Various studies have found that surface water FCB concentrations are greater adjacent to downstream urban areas than adjacent to upstream forested areas. A similar conclusion was reached by Embrey (1992) for a study of bacteria pollution within the entire Yakima River basin.

It should be noted that the seasonal FCB concentrations obtained from Wide Hollow Creek were not significantly different (K-S = 0.82; $p = 0.532$), whereas, the Cowiche Creek seasonal FCB concentrations were significantly different (K-S = 2.25; $p < 0.001$). This suggests that the predominant FCB sources discharging into Wide Hollow Creek are not related to irrigation.

U.S. Geological Survey

The USGS (Embrey, 1992) reviewed July 1988 bacteria data collected in the Moxee Drain and Wide Hollow Creek to define long-term trends and to identify, describe, and explain the major factors affecting water quality. The USGS conducted additional bacteria sampling in 1999 and 2000 (Morace and McKenzie, 2002). Table 18 presents the 1988-2000 FCB data for the Moxee Drain and Wide Hollow Creek.

Table 18: 1988-2000 seasonal FCB statistics for Moxee Drain and Wide Hollow Creek.

Sampling Site Location	Non-Irrigation		Irrigation Season	
	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
Moxee Drain at Walters Rd. (1988)	-	-	590	590
Moxee Drain at Birchfield Rd.	120	120	1,297	2,900
Moxee Drain at Beane Rd.	23	23	960	960
Moxee Drain at Postma Rd.	24	53	114	1,500
Moxee Drain at Thorp Rd. (1988)	-	-	1,418	1,800
Wide Hollow Cr. at Union Gap (1988)	-	-	1,520	2,100
Wide Hollow Cr. at Union Gap	-	-	600	600

[1] Cells shaded in this column represent values that exceed State WQS.

All (100%) of the sampling sites in both the Moxee Drain and Wide Hollow Creek exceeded State WQS during the irrigation season. During the non-irrigation season, only one (33.3%) of the three sites actually sampled exceeded water quality FCB criteria. The bacteria increase was thought to be related to the greater land surface area having runoff during the irrigation season.

Yakima County

The greatest *E. coli* concentrations were all found in the several DID water bodies under the control of Yakima County. Because they are located within the county's MS4 stormwater jurisdiction, the county is responsible for ensuring that all of those water bodies (#4, #11, #13, #24, #38, #40, and #48) comply with State WQS throughout their entire lengths. Yakima County collected water quality samples for *E. coli* analysis from various sites in the Wide Hollow Creek sub-basin during the 2003 irrigation season (Table 19).

Table 19: 2003 irrigation season *E. coli* statistics for Wide Hollow Creek sub-basin.

Sampling Site Location	Irrigation Season	
	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
Cowiche Cr. (mouth) at dirt road off SR12 past 40th Ave.	28.3	>200
DID #4 outfall into Wide Hollow Cr. at manhole behind Gardner Nursery.	1,051.2	2,420
DID #24 outfall L2 into Wide Hollow Cr. at MH16 N. of Pioneer & W. of Cornell	72.4	345
DID #24 outfall L1 into Wide Hollow Cr. at MH1 on 3rd Ave. N. of Ahtanum Rd.	13.4	2,400
DID #38 outfall into Wide Hollow Cr. at NW corner of bridge on 64th Ave.	54.9	1,990
DID #40 outfall into Wide Hollow Cr. SE corner of Logan Ave. & 38th Ave.	80.8	1,200
DID #48 outfall into Wide Hollow Cr. at NW corner of bridge on 64th Ave.	70	70
East Spring Cr. at Freeway Ave. in Union Gap manhole.	122.3	152
Moxee Drain at Thorp Rd.	107.4	222
Shaw Cr. at 80th Ave. & Wide Hollow Rd.	68	68
Tieton Canal at Wide Hollow Rd. & 96th Ave.	35.5	>200
Union Gap Ditch at old mill on Main St. in Union Gap.	326.9	411
Wide Hollow Cr. (upstream) at West Valley park of 80th Ave.	22	>200
Wide Hollow Cr. (downstream) at N. side off of ramp 1-82 to Union Gap.	113.1	272

[1] Cells shaded in this column represent values that exceed State WQS.
[2] MPN is considered by this WQIR to be numerically equivalent to "cfu/100mL".

TMDL Study Results

Ecology published the *Data Summary Report: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Mathieu and Joy, 2008), which summarized the water quality data collected during the 2005 irrigation year (December 2004 - March 2006). Additional data, published in this report, was collected from the 2010 irrigation year (June – December, 2010) and again during the 2014 irrigation year (March – June, 2014).

All laboratory and field data have been placed into Ecology's EIM database. The data are available online from the Ecology website at: http://www.ecy.wa.gov/eim/. The study ID code is YUTTMDL, and the study name is *Yakima Urban Tributaries Fecal Coliform TMDL*. The TMDL project was renamed the *Mid-Yakima River Basin Bacteria TMDL* in 2011 in order to provide continuity with other bacteria TMDL projects within the Yakima River Basin.

Quality assurance results

Data collected for the *Mid-Yakima River Basin Bacteria TMDL* met the standards for credible data required by State law (RCW 90.48.585) and Ecology's WQP Policy 1-11. Data collection and analysis followed standard data QA/QC procedures. Because all QA/QC objectives were met, all of the 2005, 2010 and 2014 irrigation years' sampling data are credible, representative and appropriate for use in the development of the TMDL.

Laboratory QA/QC for samples

Ecology's Manchester Environmental Laboratory (MEL) conducted all laboratory analyses. Laboratory data were generated according to laboratory QA/QC procedures (MEL, 2006). MEL prepared and submitted QA memos to Ecology for each sampling survey. Each memo summarized the QC procedures and results for sample transport and storage, sample holding times, and instrument calibration. All samples were received in good condition and were properly preserved, as necessary. Some samples exceeded their maximum 24-hour holding time. A Student T analysis determined that no significant difference ($t = 0.304$, $p = 0.764$) existed after a holding time of 24 hours and 48 hours. Therefore, no data was censored for this WQIR due to exceedance of holding times.

Precision

Analytical precision was determined by calculating a pooled relative standard deviation (%RSD) of laboratory-split results. About 20% of the bacteria samples were analyzed as split samples. The %RSD is calculated by dividing the standard deviation by the mean of the replicate measurements and then multiplied by 100. For example: the %RSD for replicate samples with values of "1" and "2" is 47%, whereas the %RSD for replicate samples with values of "100" and "101" is 0.7%. This is a large range, although each of the situations has a difference of 1 between analysis values. The analytical precision results for the *Mid-Yakima River Basin Bacteria TMDL* are presented in Table 20.

Table 20: Analytical precision results.

Parameter	Reporting Limit	Target Precision	% of replicates ≤20% RSD or Average % RSD for replicates ≤5x reporting limit	% of replicates ≤20% RSD or Average % RSD for replicates ≤5x reporting limit
FCB – MF	1 cfu/100mL	>50% and >90%	60.9	92.2
E. coli - MF	1 cfu/100mL	>50% and >90%	65.2	92.4
%*Klebsiella*	0%	>50% and >90%	59.0	79.5
TSS	1 mg/L	<15% RSD	10.5	4.3

Because higher %RSD is expected near the reporting limit, two tiers were evaluated: "50% of replicates ≤20% RSD" and "90% of replicates ≤50% RSD". Both tiers were compared to the target precision objectives for all parameters. The only parameter that did not meet its analytical precision objectives was %*Klebsiella*; however, this is irrelevant as %*Klebsiella* data was not used in calculating the WLAs and LAs contained in this WQIR.

Field replicate samples were collected for at least 20% of the total number of microbiology samples in order to assess total precision (i.e., total variation) for field samples. As was done for evaluation of laboratory precision, the same two tiers were also evaluated for total precision. Total precision results for the TMDL project are presented in Table 21.

Table 21: Total precision results.

Parameter	Reporting Limit	Target Precision	% of replicates ≤20% RSD or Average % RSD for replicates ≤5x reporting limit	% of replicates ≤20% RSD or Average % RSD for replicates ≤5x reporting limit
FCB – MF	1 cfu/100mL	>50% and >90%	61.5	90.2
E. coli - MF	1 cfu/100mL	>50% and >90%	60.4	97.9
%*Klebsiella*	0%	>50% and >90%	71.4	82.1
TSS	1 mg/L	<15% RSD	18.1	9.7

The precision for field replicates was higher than laboratory precision because total precision is the sum of both field and analytical precisions. Only those field replicates that were collected within five minutes of each other were averaged for this WQIR. Due to the potential for high bacterial temporal variability, if more than five minutes passed between replicate samples, then the greatest FCB concentration value was used in the calculation of WLAs, LAs and target reductions.

Conclusion

All of the bacteria data collected by Ecology for the *Mid-Yakima River Basin Bacteria TMDL* met their respective data quality objectives. There was higher variability than predicted associated with %*Klebsiella* data. However, it was deemed irrelevant to the conclusions of this WQIR since the final LAs and WLAs were not adjusted for *%Klebsiella* in samples. Based on the QA/QC review, all of the bacteria data collected during the 2005, 2010 and 2014 agriculture year sampling surveys are of good quality, properly qualified, and acceptable for use in a TMDL project.

FCB sampling results

Bacterial concentration data sets derived from water quality samples are not normally distributed. In order to conduct valid parametric statistical analyses, such data must first be converted in order to achieve a normal distribution. Successful conversion may also require the censoring of outlying data, which could be numerous due to non-normal distributed data, such as bacteria. The censoring of any amount of water quality data should be viewed with caution. In order to eliminate the problems associated with data conversion and outliers, nonparametric statistical analysis methods are utilized.

This WQIR utilizes the nonparametric Kolmogorov-Smirnov (K-S) statistical analysis for comparing two data sets. For comparison of more than two data sets, this WQIR utilizes the nonparametric Kruskal-Wallis (K-W) statistical analysis. The confidence level for both statistical tests was selected as 90% ($p = 0.10$). Thus, the probability of obtaining identical independent data sets from a single population would occur less than ten times in every hundred sampling events.

FCB sampling was conducted for the *Mid-Yakima Basin Bacteria TMDL* during the 2005, 2010 and 2014 irrigation years. The 2014 survey was only conducted in the Wide Hollow Creek sub-basin, whereas the others were conducted throughout the entire project area. Each irrigation year sampling covered both the historical irrigation season (April 15 – October 15) and the corresponding historical non-irrigation season (October 16 – April 14). The specific dates of the sampling surveys are presented in Table 22 along with their irrigation year and season classifications.

FCB samples were typically collected only once or twice per month. Although it is preferable to use only a 30-day period of sampling data for statistical analyses, this short time-frame usually does not allow sufficient time to collect large amounts of data. The larger the data set, the greater the accuracy of the subsequent statistical analyses. Thus, the USEPA allows longer periods to be utilized if they do not mask water quality criteria violations. Analysis of the entire data set indicated no masking of the FCB pollution problems.

Experience with other TMDLs has indicated that if high bacteria concentrations are seen year-round, then that pollution is probably associated with point sources (or quasi-point sources) rather than nonpoint sources. Quasi-point sources are those that are federally classified as non-point sources, but that actually have several characteristics of point sources (i.e. can be traced to specific discharge outfalls or connections).

Table 22: Sampling survey dates for 2005, 2010, and 2014 irrigation years.

2005	2010	2014
December 6, 2004	June 14-15, 2010	March 4-5, 2014
December 13-15, 2004	June 29-30, 2010	March 25-26, 2014
January 10-12, 2005	July 13-14, 2010	April 29-30, 2014
February 7-9, 2005	July 27, 2010	June 3-4, 2014
March 7-9, 2005	August 11, 2010	
April 4-5, 2005	August 24, 2010	
April 18-20, 2005	September 14-15, 2010	
May 2-3, 2005	September 20-21, 2010	
May 9-10, 2005	September 27, 2010	
May 23-24, 2005	October 4-5, 2010	
June 13-14, 2005	October 18-20, 2010	
June 27-28, 2005	November 2-3, 2010	
July 11-12, 2005	November 15, 2010	
July 25-27, 2005	December 1, 2010	
August 8-9, 2005		
August 22-24, 2005		
September 12-14, 2005		
September 26-27, 2005		
October 3-5, 2005		
October 17-18, 2005		
November 6-7, 2005		
November 28-30, 2005		
December 5-7, 2005		
January 10-11, 2006		
February 28, 2006		
March 5, 2006		

Cells colored green represent irrigation season samples.
Cells colored brown represent non-irrigation season samples.

Temporal analyses

This TMDL project conducted a series of nonparametric statistical analyses to determine if any temporal differences exist with the FCB concentration data that was collected during three widely-separated (in time) sampling surveys. The bacteria data was analyzed on:

- A calendar month basis to determine if the FCB concentrations during any months (or groups of months) are significantly different from the other months (or groups of months.

- An irrigation/non-irrigation season basis to determine if a significant difference in FCB concentrations exists between the seasons.

Calendar month basis

Ecology analyzed 934 FCB concentration values collected during the 2005, 2010 and 2014 irrigation years on a calendar month basis. Table 23 presents the calendar month FCB statistics of that combined data.

Table 23: Calendar month FCB statistics.

Calendar Month	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
January	55	70.5	520
February	27	23.1	115
March	96	20.8	224
April	86	39.0	420
May	66	253.4	4,270
June	99	256.7	1,360
July	91	258.8	1,160
August	92	243.1	1,100
September	87	192.1	1,580
October	88	131.1	940
November	63	89.1	606
December	84	35.1	286

[1] Cells shaded in this column represent values that exceed State WQS.

The greatest bacteria pollution occurs during the calendar months of May through October, which corresponds to the historical irrigation season of mid-April through mid-October.

Irrigation/non-irrigation season basis

Ecology analyzed the same 934 FCB concentration values according to the irrigation and non-irrigation seasons. Table 24 presents the seasonal FCB statistics of that combined data.

Table 24: Seasonal FCB statistics.

Period of Sampling	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
Irrigation season	531	185.5	1,550
Non-irrigation season	403	46.3	454

[1] Cells shaded in this column represent values that exceed State WQS.

The irrigation season FCB concentrations were significantly greater (K-S = 5.74; p = <0.001) than those of the non-irrigation season. The greater bacterial concentrations during the irrigation season support the findings of several previous investigators.

Spatial analyses

Cowiche Creek Sub-basin

Both the N.F. Cowiche Creek and the S.F. Cowiche Creek were sampled from their respective headwaters to their confluence. Cowiche Creek was sampled from the confluence of the N.F. Cowiche Creek and the S.F. Cowiche Creek to the mainstem's confluence with the Naches River.

North Fork Cowiche Creek

The N.F. Cowiche Creek was sampled from its proposed background site, located upstream of French Canyon Reservoir (38-FC-7) to Thompson Rd. (38-FC-3/38-FC-3.5) near its confluence with the S.F. Cowiche Creek. Sampling occurred at three mainstem sites and two tributary sites. Table 25 presents the seasonal FCB statistics of the N.F. Cowiche Creek data.

Table 25: Seasonal FCB statistics for N.F. Cowiche Creek.

Site ID[1]	Non-irrigation Season			Irrigation Season		
	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)
38-FC-7	2	6.4	41	0	(41.4)[4]	(72)[4]
38-FC-6	3	16.6	108	3	158.7	690
38-FC-WWR	11	153.7	1,094	12	136.0	2,145
38-IS-7	0	NSD[3]	NSD[3]	1	830.0	830
38-FC-3 / 38-FC-3.5	11	14.8	128	12	88.8	239

[1] Cells shaded in this column represent tributaries.
[2] Cells shaded in this column represent values that exceed State WQS.
[3] NSD means no sampling data was collected and no value could be estimated.
[4] Mainstem value in parentheses is estimated as equal to same percent difference determined from the combined data at the next two downstream sites found during the opposite season.

A K-S analysis found significantly greater (K-S = 1.88, p = 0.002) FCB pollution during the irrigation season. During the irrigation season, all of the four (100.0%) sampling sites exceeded water quality FCB criteria, whereas, only one of four (25.0%) sampling sites during the non-irrigation season exceeded those same criteria.

The FCB concentrations, both actual and estimated, at 38-FC-7 (Figure 26) complied with State water quality FCB criteria throughout the entire year, which supports its proposed use as representative of background conditions. Note that the area upstream (west) of the site is not developed, which probably accounts for the minimal FCB concentrations.

Cowiche Regional POTW

During the 2005 irrigation year, the Cowiche Regional POTW effluent was monitored just after the ultraviolet (UV) disinfection chamber (38-FC-WWE) and again after the wetland treatment (38-FC-WWR), prior to discharging into the N.F. Cowiche Creek. Table 26 presents the seasonal FCB statistics of the data pertaining to the Cowiche Regional POTW.

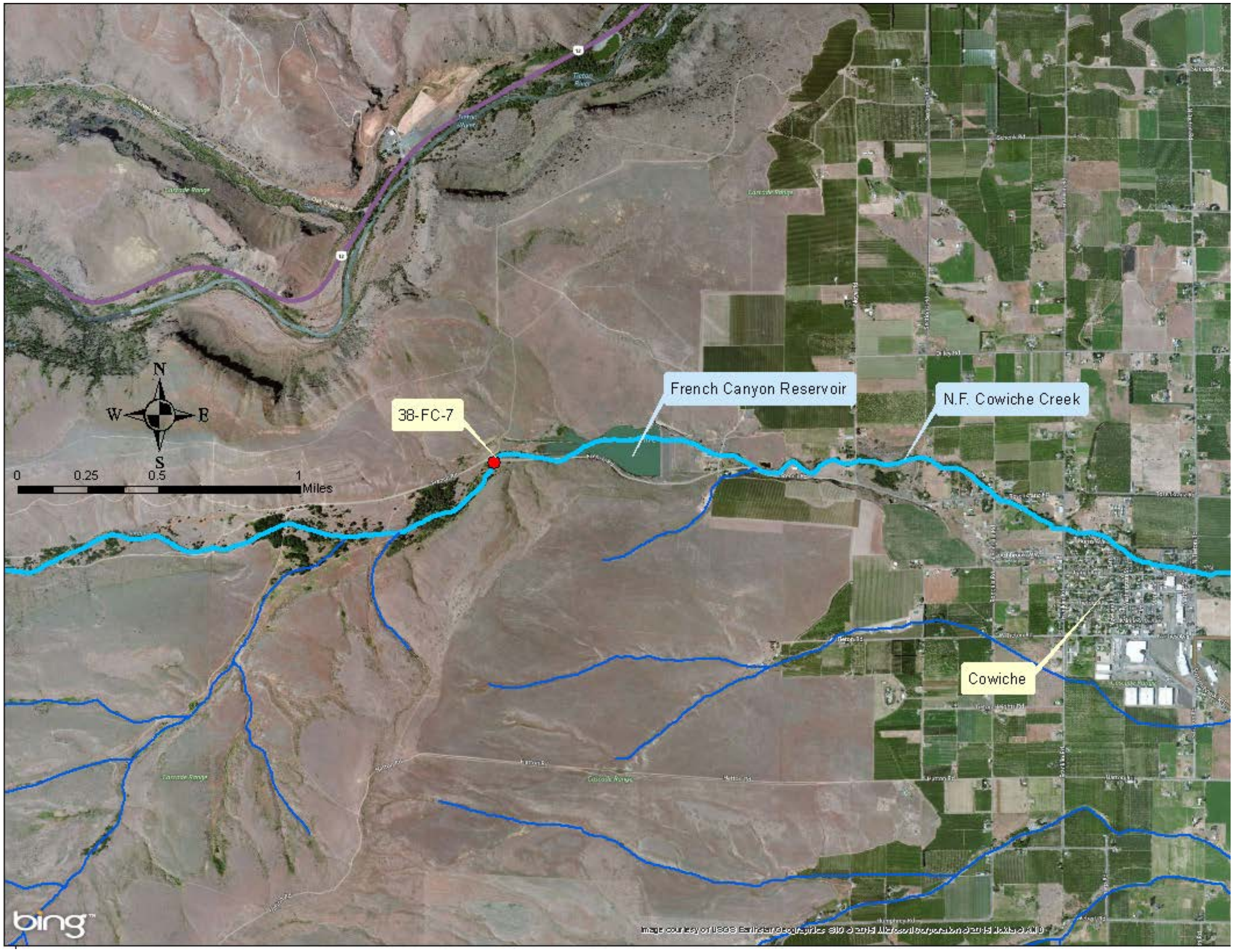

Figure 25: Location of N.F. Cowiche Creek proposed background site.

Table 26: 2005 seasonal FCB statistics for Cowiche Regional POTW effluent.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
38-FC-WWE	11	77.5	1,536	12	66.4	560
38-FC-WWR	11	153.7	1,094	12	136.0	2,145

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *no significant difference* (K-S = 0.53; p = 0.945) between the seasonal FCB concentrations, which is a consistent characteristic of a point source. The excessive FCB concentrations in the POTW effluent triggered Ecology's issuance of a Notice of Violation (NOV) for process control problems that occurred throughout 2005 and 2006. Ecology and the city of Cowiche subsequently corrected those problems.

Table 27 presents the seasonal FCB statistics for the POTW obtained from submitted Discharge Monitoring Reports (DMRs) from August 2012 to May 2014.

Table 27: 2012–2014 seasonal FCB statistics for Cowiche Regional POTW effluent from DMRs.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean (cfu/100mL)	STV (cfu/100mL)	N	Geomean (cfu/100mL)	STV (cfu/100mL)
38-FC-WWE_{DMR}	42	17.9	27	42	18.2	30

A K-S analysis found *no significant difference* (K-S = 0.92, p = 0.368) between the seasonal FCB concentrations during 2012-2014. It should be also noted that the POTW is now considered to be operating normally because it is in compliance with its NPDES permit's FCB limitations.

Table 28 presents the seasonal FCB statistics obtained from the POTW's effluent just after UV chamber as obtained from its 2012-2014 DMRs and previous sampling data.

Table 28: Comparison of seasonal FCB statistics for Cowiche Regional POTW effluent.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
38-FC-WWE	11	77.5	1,536	12	66.4	560
38-FC-WWE_{DMR}	42	17.9	27	42	18.2	30

[1] Cells shaded in this column represent values that exceed State WQS.

During the non-irrigation and irrigation seasons, K-S analyses found *significantly greater* (K-S = 2.57; p < 0.001; K-S = 2.17; p < 0.001, respectively) FCB pollution during the previous sampling data (38-FC-WWE). This suggests that the problems with the POTW effluent has returned to normal and is now in compliance with its NPDES permit FCB limitations on a year-round basis.

South Fork Cowiche Creek

The S.F. Cowiche Creek was sampled from its proposed background site at Cowiche Mill Rd. (38-FC-4) to Pioneer Rd. (38-FC-2) near its confluence with the N.F. Cowiche Creek. Sampling occurred at five mainstem sites and one tributary site. Table 29 presents the seasonal FCB statistics of the S.F. Cowiche Creek data.

Table 29: Seasonal FCB statistics for S.F. Cowiche Creek.

Site ID[1]	Non-irrigation Season			Irrigation Season		
	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)
38-FC-4	10	7.6	32.5	11	25.0	119
38-FC-2.5	6	14.6	48	7	163.4	1,500
38-IS-7.5	0	(77.6)[4]	(1,026)[4]	2	417.0	610
38-IS-7.6	0	(13.3)[5]	(406)[5]	3	87.5	440
38-IS-8.5	0	NSD[3]	NSD[3]	3	164.4	1,000
38-FC-2	11	36.4	992	12	239.2	1,073

[1] Cells shaded in this column represent tributaries.
[2] Cells shaded in this column represent values that exceed State WQS.
[3] NSD means no sampling data were collected and no value could be estimated.
[4] Mainstem value in parentheses is estimated as equal to same percent difference determined from the combined data at the next two downstream sites found during the opposite season.
[5] Mainstem value in parentheses is estimated as equal to same percent difference determined from the data at the next downstream site found during the opposite season.

A K-S analysis found *significantly greater* (K-S = 2.20, $p < 0.001$) FCB pollution during the irrigation season. Five of the six (83.3%) sampling sites exceeded State WQS during the irrigation season, whereas three of the five (60.0%) sites actually sampled during the non-irrigation season were expected to have exceeded water quality FCB criteria.

The FCB concentrations at 38-FC-4 (Figure 26) complied with State water quality FCB criteria throughout the entire year which supports its proposed use as representative of background conditions. Note that the area upstream (west) of the site is not developed, which probably accounts for the minimal FCB concentrations.

Cowiche Creek

Cowiche Creek was sampled from the confluence of its north and south forks at Thompson Rd. (38-FC-3/38-FC-3.5) and Pioneer Rd. (38-FC-2), respectively, to Powerhouse Rd. (38-FC-1) near its confluence with the Naches River. Sampling occurred at three mainstem sites and three tributary sites. Table 30 presents the seasonal FCB statistics of the Cowiche Creek data.

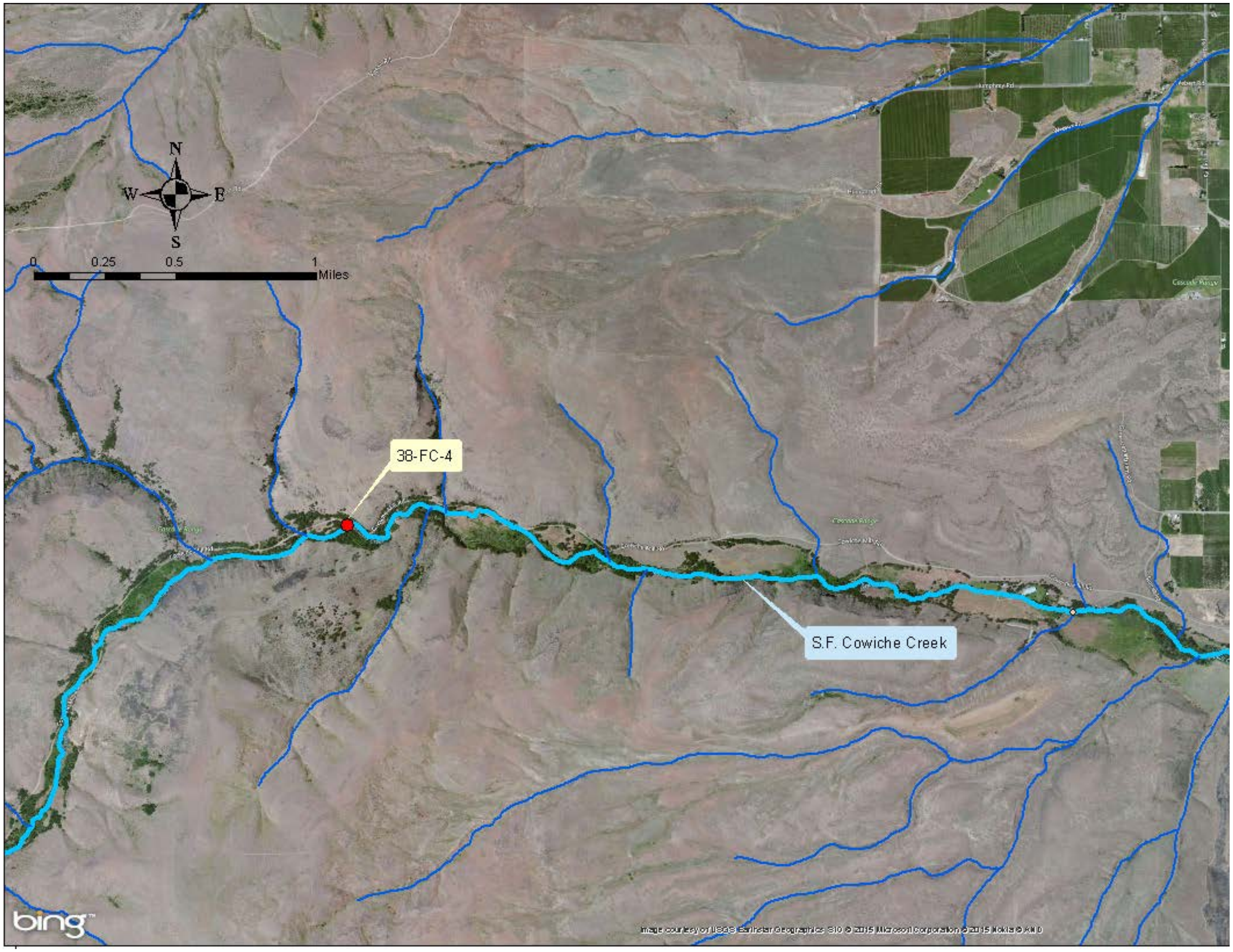

Figure 26: Location of S.F. Cowiche Creek proposed background site.

Table 30: Seasonal FCB statistics for Cowiche Creek.

Site ID[1]	Non-irrigation Season			Irrigation Season		
	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)
38-FC-2	11	36.4	992	12	239.2	1,073
38-FC-3 / 38-FC-3.5	11	14.8	128	12	88.8	239
38-FC-1.5	10	38.6	541	12	180.8	393
38-IS-8	0	NSD[3]	NSD[3]	4	246.0	630
38-FC-1.25	3	39.0	130	9	165.2	1,100
38-FC-1	15	12.3	75	21	109.6	408

[1] Cells shaded in this column represent tributaries.
[2] Cells shaded in this column represent values that exceed State WQS.
[3] NSD means no sampling data was collected and no value could be estimated.

A K-S analysis found *significantly greater* (K-S = 3.51, $p < 0.001$) FCB pollution during the irrigation season. All of the six (100%) sampling sites had FCB concentrations in excess of water quality FCB criteria during the irrigation season, whereas, only two of the five (40%) sites actually sampled during the non-irrigation season exceeded those same criteria.

Moxee Drain Sub-basin

The sampled sites in the sub-basin were on the Moxee Drain, DID #11, Moxee POTW effluent, Hubbard Canal, and Roza Canal. Moxee Creek, which is the headwaters of the Moxee Drain, was not sampled. Moxee Creek is an ephemeral stream and typically flows only during the spring runoff of snowmelt, as well as during the occasional large storm event.

Moxee Drain

The Moxee Drain was sampled from its proposed background site at Beane Rd. (37-FM-10) to Thorp Rd. (37-FM-1) near its confluence with Blue Slough, which discharges into the Yakima River. Sampling occurred at six mainstem sites and eight tributary sites. Table 31 presents the seasonal FCB statistics of the Moxee Drain data.

A K-S analysis found *significantly greater* (K-S = 3.08, $p < 0.001$) FCB pollution during the irrigation season. During the irrigation season, twelve of the 13 (92.3%) sites actually sampled had FCB pollution in excess of water quality FCB criteria; whereas, only five of the 9 (55.6%) sites actually sampled during the non-irrigation season exceeded those same criteria.

The greatest mainstem FCB concentrations in the Moxee Drain sub-basin were found at site 37-FM-3.5 which is located just downstream of its confluence with its major tributary (DID #11), where the greatest sub-basin FCB concentrations occur. The year-round excessive FCB concentrations found along that tributary suggests the occurrence of a point source or quasi-point source of pollution that needs to be investigated.

Table 31: Seasonal FCB statistics for Moxee Drain.

Site ID[1]	Non-irrigation Season			Irrigation Season		
	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)
37-FM-10	11	165.3	1,778	20	264.3	540
37-IS-5	0	NSD[3]	NSD[3]	4	11.4	17
37-FM-9	11	12.1	64	12	87.4	293
37-FM-9.5	1	16.0	16	0	NSD[3]	NSD[3]
37-IS-4	0	NSD[3]	NSD[3]	4	27.8	250
37-FM-8	12	32.5	136	12	108.9	385
37-IS-4.6	0	NSD[3]	NSD[3]	4	226.2	970
37-IS-4.5	0	NSD[3]	NSD[3]	4	69.1	250
37-FM-7 / 37-IS-3	2	18.2	22	12	97.1	318
37-FM-3.6	6	252.0	890	6	634.3	3,600
37-FM-3.5	6	345.5	520	6	274.9	1,100
37-FM-3	15	175.3	600	21	263.2	582
37-IS-0	0	NSD[3]	NSD[3]	4	137.0	180
37-FM-1	13	70.9	288	21	198.3	522

[1] Cells shaded in this column represent tributaries.
[2] Cells shaded in this column represent values that exceed State WQS.
[3] NSD means no sampling data was collected and no value could be estimated.

The excessive FCB pollution at 37-FM-10 (Figure 27) throughout the entire year does not support its proposed use as representative of background conditions. Note the substantial agricultural development upstream (east) of 37-FM-10 and the large dairy that exists still further upstream along Moxee Creek streambed. Another sampling site should be located further upstream for representing background conditions.

DID #11

DID #11 was sampled from its proposed background site at Beaudry Road (37-FM-5.5) to its mouth (37-FM-3.6) at the Moxee Drain. Sampling occurred at three mainstem sites and three tributary sites. Table 32 presents the seasonal FCB statistics of the DID #11 data.

Table 32: Seasonal FCB statistics for DID #11.

Site ID[1]	Non-irrigation Season			Irrigation Season		
	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)
37-FM-5.5	0	(217.1)[4]	(740)[4]	2	240.0	320
37-FM-5 / 37-IS-1	11	1,962.3	10,220	12	1,353.9	3,450
37-IS-1.5	0	NSD[3]	NSD[3]	4	158.6	700
37-FM-WWO	11	9.5	110	12	12.0	25
37-FM-4 / 37-IS-2	1	36.0	36	12	201.0	887
37-FM-3.6	6	252.0	890	6	634.3	3,600

[1] Cells shaded in this column represent tributaries.
[2] Cells shaded in this column represent values that exceed State WQS.
[3] NSD means no sampling data was collected and no value could be estimated.
[4]... Mainstem value in parentheses is estimated as equal to same percent difference determined from the data at the next downstream site found during the opposite season.

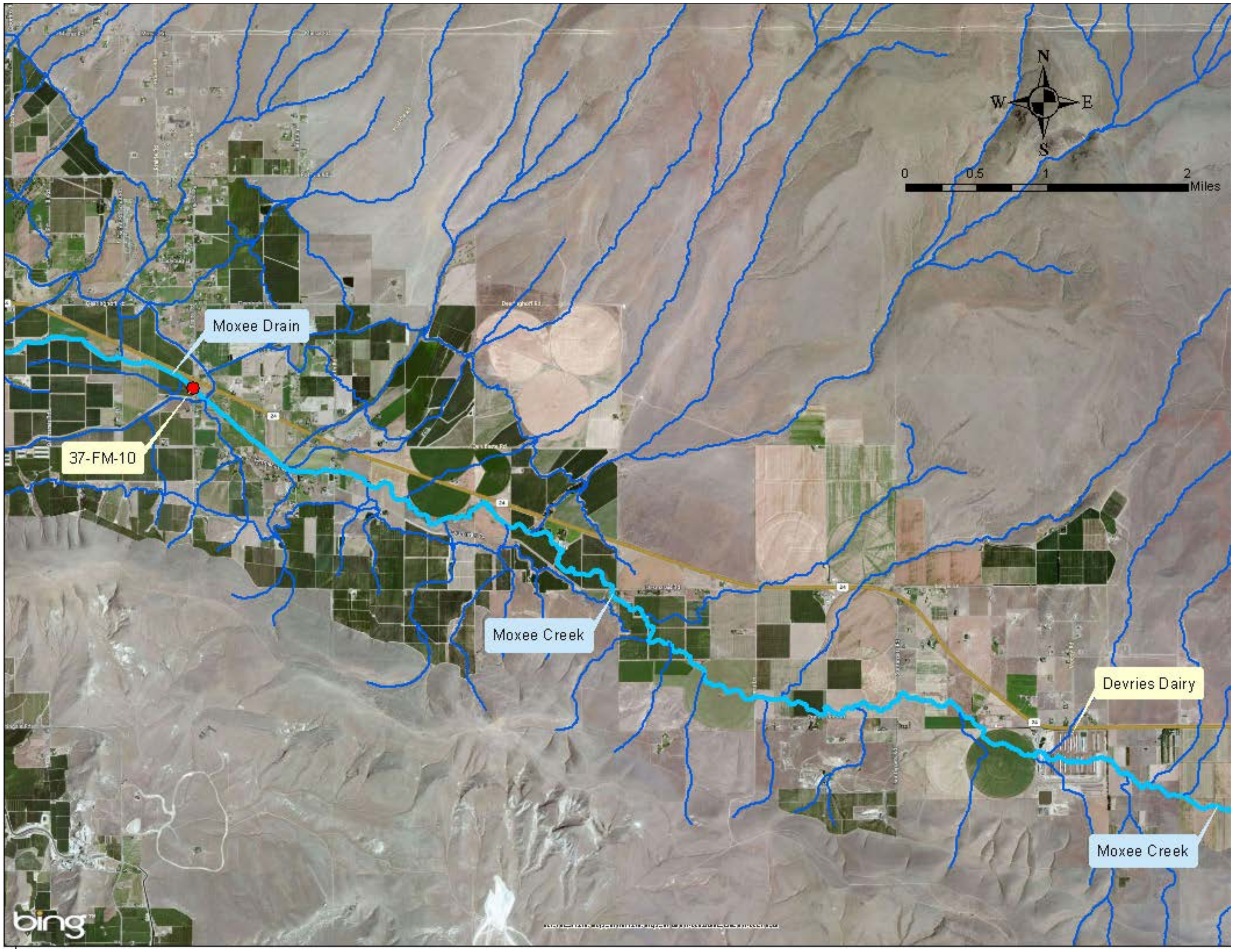

Figure 27: Location of Moxee Drain proposed background site.

A K-S analysis found *no significant difference* (K-S = 0.75; p = 0.630) between the seasonal FCB concentrations, which suggests that the primary source(s) of FCB pollution in DID #11 are unrelated to irrigation drainage. During the irrigation season, five of the six (83.3%) sampling sites had FCB concentrations in excess of State WQS. However, only two (50%) of the four sites actually sampled during the non-irrigation season had FCB pollution in excess of water quality FCB criteria.

The excessive FCB pollution, both actual and estimated, at 37-FM-5.5 (Figure 28) throughout the entire year does not support its proposed use as representative of background conditions. In fact, it suggests that the predominant source of FCB pollution may be a point source. Due to the location of DID #11(upper extent of the drainage), it should be considered improbable that any sampling site can ever be found that will represent background conditions.

Moxee City POTW

Sampling was conducted at the two Moxee City POTW effluent sites: after the ultraviolet disinfection chamber (37-FM-WWE) and at the effluent outfall (37-FM-WWO) to DID #11. Table 33 presents the seasonal FCB statistics of the Moxee City POTW data.

Table 33: Seasonal FCB statistics for Moxee City POTW effluent.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean (cfu/100mL)	STV (cfu/100mL)	N	Geomean (cfu/100mL)	STV (cfu/100mL)
37-FM-WWE	10	2.2	29	12	1.9	14
37-FM-WWO	11	9.5	110	12	12.0	25

A K-S analysis found *significantly greater* (K-S = 1.29, p = 0.077) FCB concentrations in the POTW effluent discharged into DID #11. However, neither (0%) of the sites exceeded water quality FCB criteria during either season.

The POTW sampling sites were removed from the WLA tables contained in this WQIR as the effluent is now discharged to the city of Yakima POTW sanitary sewer. The facility is no longer a point source discharger.

Hubbard Canal

During the 2005 irrigation year, the Hubbard Canal was sampled only at Bell Rd. (37-FM-4/37-IS-2). Table 34 presents the seasonal FCB statistics of the Hubbard Canal data.

Table 34: Seasonal FCB statistics for Hubbard Canal.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-FM-4 / 37-IS-2	1	36.0	36	12	201.0	887

[1] Cells shaded in this column represent values that exceed State WQS.

Figure 28: Location of DID #11 proposed background site.

The only site sampled on the Hubbard Canal determined that only during the irrigation season were FCB concentrations found to be in excess of the State water quality FCB criteria. This suggests that irrigation return flows are being discharged into the canal at some point upstream. Since only one sample was collected during the non-irrigation season, no valid statistical analysis could be performed.

Roza Canal

During the 2005 irrigation year, the Roza Canal was sampled only at its outfall to the Moxee Drain (37-IS-5). Table 35 presents the seasonal FCB statistics of the Roza Canal data.

Table 35: Seasonal FCB statistics for Roza Canal.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean (cfu/100mL)	STV (cfu/100mL)	N	Geomean (cfu/100mL)	STV (cfu/100mL)
37-IS-5	0	NSD[1]	NSD[1]	3	11.4	17

[1] NSD means no sampling data was collected and no value could be estimated.

The only site sampled on the Roza Canal determined that FCB concentrations were in compliance with the water quality FCB criteria. Since the canal is dry during the non-irrigation season, no samples could be collected.

Wide Hollow Creek Sub-basin

Wide Hollow Creek was sampled from its proposed background site at Stone Road (37-FW-18) to downstream of its confluence with East Spring Creek (37-FW-0B) near its confluence with the Yakima River. Sampling occurred at thirteen mainstem sites and sixteen tributary sites along Wide Hollow Creek. The sampled tributaries were: headwaters tributary #1, headwaters tributary #2, Cottonwood Creek, Shaw Creek, Congdon Canal, DID #4, DID #24, DID #38, DID #40, DID #48, Randall Park pond, East Spring Creek, and the Naches & Cowiche Canal.

Table 36 presents the seasonal FCB statistics of the Wide Hollow Creek data.

A K-S analysis found *significantly greater* (K-S = 5.42, $p < 0.001$) FCB pollution during the irrigation season. During the irrigation season, 22 of the 32 (84%) sites actually sampled exceeded State WQS; whereas, only 10 of the 32 (38%) sites actually sampled during the non-irrigation season exceeded State WQS.

No irrigation season sampling was conducted at three proposed background sites (37-FW-16, 37-FW-17, and 37-FW-18). However, estimation was possible for the mainstem site (37-FW-18). The estimated geomeans and STVs were calculated using the same percent difference as that found with the combined data from the next two downstream mainstem sites, as found during the opposite season.

Table 36: Seasonal FCB statistics for Wide Hollow Creek.

Site ID[1]	Non-irrigation Season			Irrigation Season		
	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)	N	Geomean[2] (cfu/100mL)	STV[2] (cfu/100mL)
37-FW-18	2	17.3	23	0	(469.8)[4]	(2,244)[4]
37-FW-17	2	8.4	71	0	NSD[3]	NSD[3]
37-FW-16	2	77.7	755	0	NSD[3]	NSD[3]
37-FW-15 / 37-SS-17	2	15.7	35	1	2,700.0	2,700
37-SS-15	0	(493.4)	(165)	1	6,000.0	6,000
37-FW-12 / 37-SS-16	8	6.6	47	6	264.3	4,000
37-FW-13 / 37-SS-18	11	6.7	137	8	404.4	10,000
37-IS-16	2	27.3	187	7	177.2	1,550
37-IS-16B	2	39.2	110	2	64.0	70
37-FW-8 / 37-SS-14	18	35.2	707	24	218.9	798
37-SS-13 / 37-SS-13B	0	NSD[3]	NSD[3]	2	2,079.4	9,200
37-SS-12	5	19.4	100	12	239.1	1,661
37-IS-20 / 37-SS-38	4	14.4	160	3	154.0	580
37-IS-19 / 37-SS-48	2	12.2	15	7	156.9	4,000
37-SS-11	4	174.8	1,187	3	829.1	10,000
37-IS-23	2	46.9	110	2	447.2	10,000
37-IS-17.5 / 37-SS-9	6	147.0	3,000	15	795.5	2,200
37-FW-6 / 37-FW-6B	17	54.3	144	22	312.6	713
37-SS-11B	2	1.0	1	2	4.8	23
37-IS-17	1	280	280	7	404.5	10,000
37-FW-5	14	125.5	414	14	357.4	4,260
37-FW-4 / 37-SS-7	18	35.3	117	24	255.5	981
37-IS-15	2	6,557.4	10,000	2	4,837.4	13,000
37-IS-13	3	1.0	1	5	139.2	690
37-IS-12 / 37-IS-12B	3	1.0	1	6	2.9	190
37-FW-3 / 37-FW-3B	5	60.7	250	11	293.0	714
37-IS-10	0	NSD[3]	NSD[3]	5	5.0	320
37-FW-1 / 37-SS-5	14	49.6	211	13	338.8	1,950
37-FW-1B	2	6.2	11	2	66.1	125
37-FW-1C	2	16.9	17	2	1,378.4	10,000
37-FW-2B	2	279.3	650	2	81.2	110
37-FW-0 / 37-SS-1	16	104.8	259	22	340.4	1,085
37-FW-2	15	50.4	140	14	220.1	1,423
37-FW-0B	2	63.7	133	2	7,130.9	10,000

1 Cells shaded in this column represent tributaries.
2 Cells shaded in this column represent values that exceed State WQS.
3 NSD means no sampling data was collected and no value could be estimated.
4... Mainstem value in parentheses is estimated as equal to same percent difference determined from the combined data at the next two downstream sites found during the opposite season.

The excessive FCB pollution estimated at 37-FW-18 (Figure 29), during the irrigation season does not support its proposed use as representative of background conditions. Although somewhat remote, the site is still just downstream (east) of 11 residences and small reservoir. Another sampling site should be located further upstream for representing background conditions.

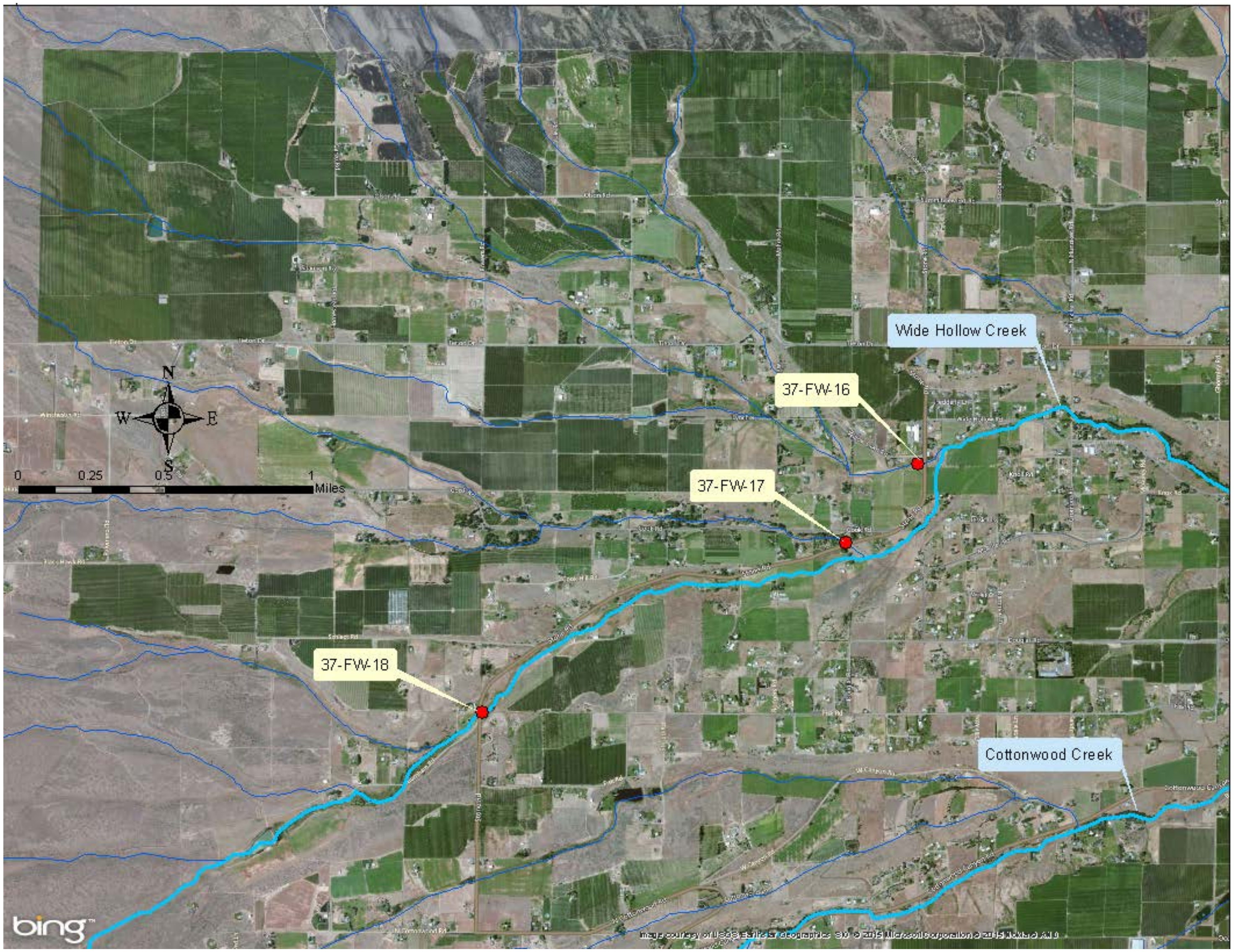

Figure 29: Locations of Wide Hollow Creek proposed background sites.

The actual FCB concentrations found at both 37-FW-16 and 37-FW-17 (Figure 30), during the non-irrigation season, do not comply with the State water quality FCB criteria. Thus, they do support those sites as representative of background conditions. Different sampling sites should be located further upstream for representing background conditions.

The mainstem Wide Hollow Creek site with the greatest FCB pollution is 37-FW-OB (downstream of confluence with Spring Creek). The tributaries with the greatest FCB pollution were Randall Park Pond effluent (37-IS-17.5/37-SS-9) and DID #4, behind Gardner's Nursery (37-IS-15).

Cottonwood Creek

Cottonwood Creek was sampled at its proposed background site at Moore Rd. (37-FW-14) and at Dazet Rd. (37-FW-13) near its mouth on Wide Hollow Creek. Table 37 presents the seasonal FCB statistics of the Cottonwood Creek data.

Table 37: Seasonal FCB statistics for Cottonwood Creek.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-FW-14	7	22.1	270	3	928.6	2,950
37-FW-13 / 37-SS-18	11	6.7	137	8	408.7	8,000

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *significantly greater* (K-S = 1.77, $p < 0.01$) FCB pollution during the irrigation season, when both (100%) Cowiche Creek sampling sites had FCB concentrations in excess of State WQS. During the non-irrigation season, only one of the two sites (50%) had excessive FCB concentrations.

The excessive year-round FCB pollution at 37-FW-14 (Figure 30) does not support its proposed use as representative of background conditions. Note the large area of agriculture development located upstream (south-west) of the sampling site. Another sampling should be located further upstream for representing background conditions.

Shaw Creek

Shaw Creek was only sampled at 80th Ave. (37-SS-13/37-SS-13B) north of Nob Hill Blvd. Nursery. Table 38 presents the seasonal FCB statistics of the Shaw Creek data.

Table 38: Seasonal FCB statistics for Shaw Creek.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-SS-13 / 37-SS-13B	0	NSD[2]	NSD[2]	2	2,079.4	9,200

[1] Cells shaded in this column represent values that exceed State WQS.
[2] NSD means no sampling data was collected and no value could be estimated.

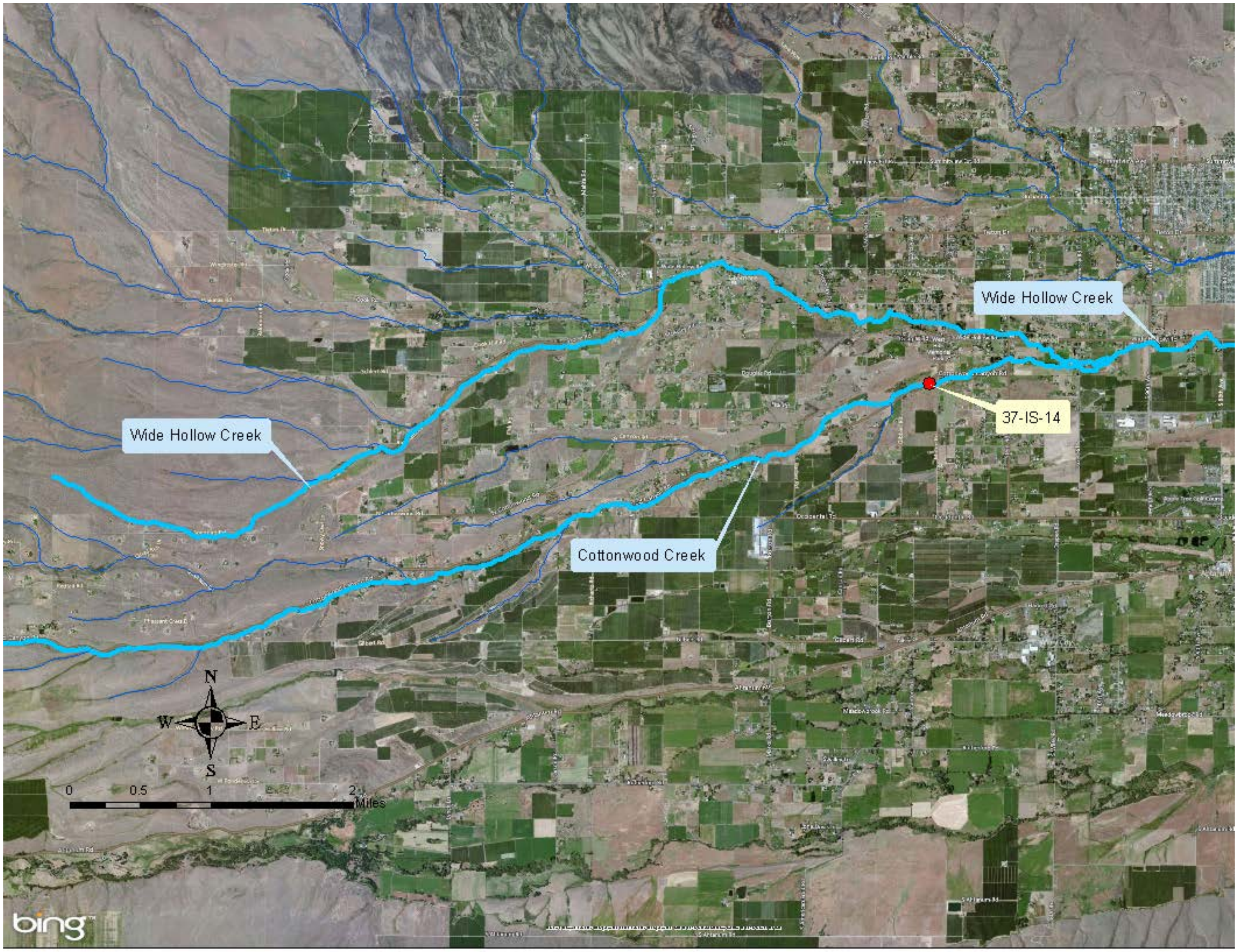

Figure 30: Location of Cottonwood Creek proposed background site.

No statistical analysis of the seasonal FCB concentrations could be determined, because no sampling data was collected during the non-irrigation season. The excessive bacteria concentrations during the irrigation season suggest the presence of point sources or pseudo-point sources of pollution.

DID #4

DID #4 was only sampled at its outfall into Wide Hollow Creek behind Gardner's Nursery (37-IS-15). Table 39 presents the seasonal FCB statistics of the DID #4 data.

Table 39: Seasonal FCB statistics for DID #4.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-IS-15	2	6,557.4	10,000	2	4,837.4	13,000

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *no significant difference* (K-S = 0.50; p = 0.964) between the seasonal FCB concentrations. During both seasons, the site exceeded the water quality FCB criteria. These facts suggest the presence of multiple point sources or pseudo-point sources of bacteria pollution.

DID #24

DID #24 was sampled at its Lateral L1 outfall at 3rd Ave. (37-IS-12/37-IS-12B) and at its Lateral L2 outfall at Pioneer Lane (37-IS-13). Table 40 presents the seasonal FCB statistics of the DID #24 data.

Table 40: Seasonal FCB statistics for DID #24.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-IS-12 / 37-IS-12B	3	1.0	1	6	2.9	190
37-IS-13	3	1.0	1	5	64.6	690

[1] Cells shaded in this column represent values that exceed State WQS.

DID #38

DID #38 was only sampled at its outfall near 64th Ave. (37-IS-20/37-SS-38). Table 41 presents the seasonal FCB statistics of the DID #38 data.

Table 41: Seasonal FCB statistics for DID #38.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-IS-20 / 37-SS-38	4	14.4	160	3	154.0	580

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *no significant difference* (K-S = 0.29; p = 0.982) between FCB concentrations during the irrigation and non-irrigation seasons. The site exceeded the water quality FCB criteria only during the irrigation season.

DID #40

DID #40 was only sampled at its outfall near 38th Ave. and Logan Ave. (37-IS-17). Table 42 presents the seasonal FCB statistics of the DID #40 data.

Table 42: Seasonal FCB statistics for DID #40.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-IS-17	1	280.0	280	7	404.5	10,000

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis could not be performed between seasons because of limited sampling data, although the FCB concentrations during the irrigation season appear to be greater than during the non-irrigation season. Both sites (100%) exceeded water quality FCB criteria on a year-round basis.

DID #48

DID #48 was sampled at Viola and 48th Ave. (37-IS-18/37-IS-18B) and at the large blue culvert under the 64th Ave. bridge (37-IS-19/37-SS-48). Table 43 presents the seasonal FCB statistics of the DID #48 data.

Table 43: Seasonal FCB statistics for DID #48.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-IS-18 / 37-IS18B	1	350.0	350	4	300.7	730
37-IS-19 / 37-SS-48	2	12.2	15	7	127.7	4,000

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *no significant difference* (K-S = 0.87; p = 0.438) between the FCB concentrations during the irrigation and non-irrigation seasons. During the irrigation season, both (100%) sites exceeded water quality FCB criteria. During the non-irrigation season, only one (50%) of the sites exceeded those same criteria.

Randall Park pond

During the 2005 and 2010 irrigation years, Randall Park pond was sampled at its influent (37-IS-18/37-IS-18B) and effluent (37-IS-17.5/37-SS-9). Table 44 presents the seasonal FCB statistics of the Randall Park pond data.

Table 44: Seasonal FCB statistics for Randall Park pond.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-IS-18 / 37-IS18B	1	350.0	350	4	300.7	730
37-IS-17.5 / 37-SS-9	6	147.0	3,000	15	1,316.2	2,750

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *no significant difference* (K-S = 1.03; p = 0.237) between the FCB concentrations during the irrigation and non-irrigation seasons. All (100%) sites exceeded water quality FCB criteria during both the irrigation and non-irrigation seasons.

The year-round excessive FCB pollution at both sites suggests the predominance of point source or pseudo-point source pollution. In order to determine if the pond was increasing in FCB pollution within the pond itself (internal increase); a comparison was made of the pond's combined year-round influent vs. effluent data. Table 45 presents the FCB statistics of that data.

Table 45: FCB statistics for Randall Park pond.

Site ID	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
Influent	5	309.9	730
Effluent	21	703.6	2,850

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis of the pond's influent and effluent found *significantly greater* (K-S = 1.34; p = 0.055) FCB concentrations year-round in the pond's effluent. This indicates that a significant amount of the FCB pollution discharged by the pond is being added internally.

The source of the internal FCB increase is most likely the resident population of waterfowl. Since they are concentrated due to anthropogenic causes, i.e. public feeding, they are not considered as natural background. This gives substantial support for minimizing the numbers of resident waterfowl living at the pond.

East Spring Creek

East Spring Creek is a 1.65-mile long side-channel of the Yakima River, originating at RM 110.5. It receives additional flow from spring waters that emerge from the shallow aquifer beneath the city of Union Gap. It is also known as Spring Creek 2, Chambers Creek, and as the "Chandler Branch of Spring Creek" in other documents. Despite its surrounding urban environment, the creek excellent water quality.

East Spring Creek was sampled during the 2005 irrigation year near the city of Union Gap Public Works facility (37-FW-2). Table 46 presents the seasonal FCB statistics of the East Spring Creek data.

Table 46: Seasonal FCB statistics for East Spring Creek.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-FW-2	15	50.4	140	14	220.1	1,423

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *significantly greater* (K-S = 1.40; p = 0.039) FCB concentrations during the irrigation season, when the site exceeded both water quality FCB criteria. During the non-irrigation season, the site complied with those same criteria.

Naches & Cowiche Canal

During the 2014 irrigation year, the Naches & Cowiche Canal was sampled at 12th Ave. (37-IS-20A) and at 32nd Ave. (37-IS-20B). Table 47 presents the seasonal FCB statistics of the Naches & Cowiche Canal data.

Table 47: Seasonal FCB statistics for Naches & Cowiche Canal.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean (cfu/100mL)	STV (cfu/100mL)	N	Geomean (cfu/100mL)	STV (cfu/100mL)
37-IS-20A	0	NSD[1]	NSD[1]	2	41.8	50
37-IS-20B	0	NSD[1]	NSD[1]	2	15.8	20

[1] NSD means no sampling data was collected and no value could be estimated.

The canal is only in operation during the irrigation season and, therefore, no K-S analysis could be performed comparing seasons. All (100%) sites during the irrigation season, however, did comply with the State water quality FCB criteria. It is assumed that during the non-irrigation season, if there was water flowing, the FCB concentrations would be less than the irrigation season FCB concentrations.

Congdon Canal

During the 2014 irrigation year, the Congdon Canal was sampled east of 101st Ave. (37-IS-16) during the non-irrigation season. The site was also sampled during the 2005, 2010 and 2014 irrigation years in order to obtain data during the irrigation season. Table 48 presents the seasonal FCB statistics of the Congdon Canal data.

Table 48: Seasonal FCB statistics for Congdon Canal.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
37-IS-16	2	27.3	187	7	180.0	1,550

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *no significant difference* (K-S = 0.62; p = 0.832) between the FCB concentrations during the irrigation and non-irrigation seasons. The site exceeded water quality FCB criteria during the irrigation, but not during the non-irrigation season.

MS4 drainage

Six stormwater drainage sampling sites were utilized by Ecology to reflect MS4 drainage FCB pollution: 37-SS-2 (east end of Ahtanum Rd.), 37-SS-6 (end of 3rd Ave.), 37-SS-8 (end of 34th Ave.), 37-IS-21 (west-side of railroad tracks), 37-IS-22 (Ahtanum bridge west of Goodman Road), and 37-SS-4 (Del Monte Foods #125 stormwater outfall). All sites were located in the Wide Hollow Creek sub-basin. Table 49 presents the seasonal FCB statistics of the MS4 data.

Table 49: Seasonal FCB statistics for MS4 drainage.

Site ID	Non-irrigation Season			Irrigation Season		
	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)	N	Geomean[1] (cfu/100mL)	STV[1] (cfu/100mL)
All sites combined	6	48.6	1,800	7	482.8	8,200

[1] Cells shaded in this column represent values that exceed State WQS.

A K-S analysis found *significantly greater* (K-S = 1.34; p = 0.056) FCB concentrations during the irrigation season. This suggests that irrigation water is entering the MS4 stormwater systems, either in the form of return flows or higher ground water levels.

When limited sampling data has been collected which prohibits site-specific MS4 WLAs from being assigned, the USEPA has directed agencies to base such WLAs on the combined (aggregated) MS4 data. In the case of this TMDL project, Ecology collected limited site-specific data and, therefore, the MS4 WLAs were calculated on aggregated data per season.

Escherichia coli sampling results

E. coli bacteria are a subset of FCB, and their concentrations typically mimic each other. Due to this hierarchy, *E. coli* concentrations in water samples should theoretically always be less than those samples' respective FCB concentrations. However, bacterial analyses of water samples are notorious for producing highly variable results. The USEPA concurred with this fact by stating in its *Ambient Water Quality Criteria for Bacteria – 1986* (EPA440/5-84-002) that "bacterial enumeration techniques are imprecise".

Temporal analysis

Ecology has previously reported that in most State watersheds, *E. coli* accounts for approximately 90-99% of the FCB (Hicks, 2002). For the *Mid-Yakima River Basin Bacteria TMDL*, Ecology analyzed 226 water samples during the 2005 and 2010 irrigation years for both *E. coli* and FCB.

Figure 31 presents the linear correlation between the log-normalized *E. coli* and FCB concentrations.

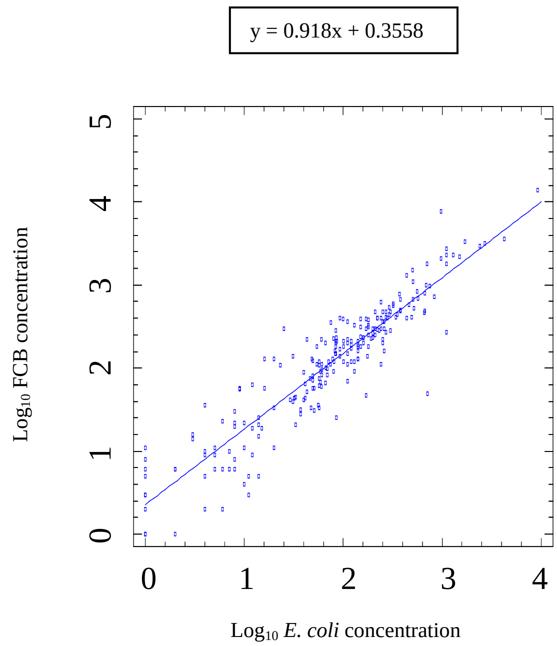

Figure 31: Log$_{10}$ FCB concentration vs. log$_{10}$ *E. coli* concentration.

The linear correlation was highly significant ($p < 0.001$) and very strong ($r = 0.93$). Approximately 86.5% of the variability in *E. coli* is explained by the presence of FCB. Based on the high correlation, this WQIR will assume that *E. coli* and FCB concentration data are equivalent and interchangeable for comparison purposes.

The same data were also used to calculate corresponding %*E. coli* values, where *"%E. coli"* represents the percentage of *E. coli* bacteria found in an FCB sample. The resultant values were found to be logarithmically distributed. Therefore, the geomean of those values represents their *average* condition. Table 50 presents the calendar month geomean %*E. coli* values that were found throughout the TMDL project area.

A K-W analysis found a *significant difference* (K-W = 27.7, p = 0.0036) between the monthly %*E. coli* values. The same values then were analyzed comparing the seasons. A K-S analysis found *significantly greater* (K-S = 1.86, p = 0.0020) %*E. coli* concentrations during the non-irrigation season. The geomean %*E. coli* concentrations during the non-irrigation and irrigation seasons were 66.7% and 63.8%, respectively.

Table 50: Calendar month %*E. coli* statistics.

Calendar Month[1]	N	Geomean %*E. coli* value
January	17	84.5
February	9	32.8
March	8	66.4
April	16	57.8
May	15	74.4
June	24	73.3
July	27	60.0
August	26	57.9
September	20	73.7
October	20	48.8
November	15	44.9
December	29	94.7

[1] Cells shaded in this column represent the irrigation seas

Spatial analysis

Table 51 presents the geomean of the %*E. coli* values that were found within the three sub-basins of the TMDL project area.

Table 51: Sub-basin %*E. coli* statistics.

Sub-basin	N	Geomean %*E. coli* value
Cowiche Creek	73	72.8
Moxee Drain	60	65.7
Wide Hollow Creek	93	58.1

A K-W analysis found *significantly less* (K-W = 8.04, p = 0.018) %*E. coli* in the Wide Hollow Creek sub-basin. The reason for this difference is not known, but may be linked a comparatively smaller percentage of "agricultural" acreage than either of the other two sub-basins. Since the highly agricultural Moxee Drain sub-basin receives several land applications of manure and/or biosolids, its %*E. coli* values would be expected to be high. The high %*E. coli* values found in the Cowiche Creek sub-basin were unexpected.

Klebsiella sampling results

Ecology analyzed 122 samples for *%Klebsiella* (the percentage of *Klebsiella* bacteria in an FCB sample) that were collected throughout the *Mid-Yakima River Basin Bacteria TMDL* project area during the 2005 and 2010 irrigation years. *Klebsiella* are a known interference in the laboratory analysis of FCB. When present, they can cause false positive readings for FCB, which results in higher values than what is actually present. *Klebsiella* occurrence is known to be very site specific.

Temporal analyses

For the *Mid-Yakima River Basin Bacteria TMDL*, Ecology analyzed 122 water samples during the 2004, 2005, 2006 for both *Klebsiella* and FCB.

Figure 32 presents the linear correlation between the log-normalized *Klebsiella* and FCB concentrations.

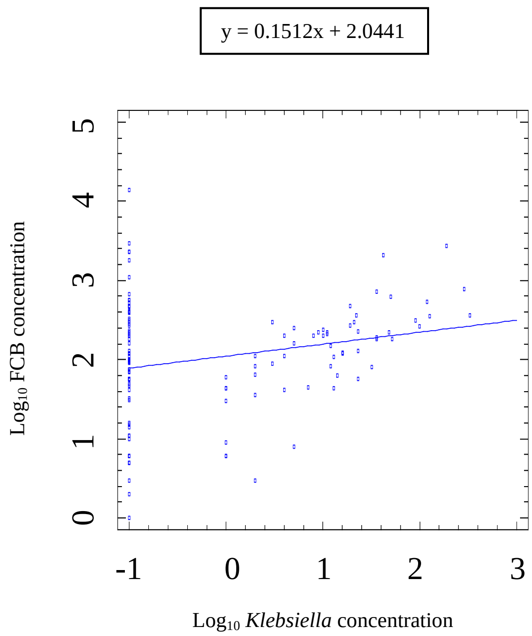

Figure 32: Log$_{10}$ FCB concentration vs. Log$_{10}$ *Klebsiella* concentration.

The linear correlation was highly significant ($p = 0.0097$) but very weak ($r = 0.23$). According to the correlation, only 5.3% of the variability in *Klebsiella* is explained by the presence of FCB. The same data were also utilized to calculate corresponding *%Klebsiella* values. The resultant values were found to be logarithmically distributed. Therefore, the geomean of those values represents their *average* condition.

The linear correlation was highly significant ($p = 0.0097$) but very weak ($r = 0.23$). According to the correlation, only 5.3% of the variability in *Klebsiella* is explained by the presence of FCB. The same data were also utilized to calculate corresponding *%Klebsiella* values. The resultant values were found to be logarithmically distributed. Therefore, the geomean of those values better represents their *average* condition.

Table 52 presents the calendar month geomean %*Klebsiella* values found throughout the TMDL project area.

Table 52: Calendar month %*Klebsiella* statistics.

Calendar Month[1]	N	Geomean %*Klebsiella* value
January	13	0.54
February	6	0.30
March	5	0.36
April	11	0.25
May	10	0.23
June	13	0.26
July	13	1.57
August	11	4.00
September	7	13.53
October	9	1.70
November	6	2.43
December	18	0.54

[1] Cells shaded in this column represent the irrigation season

A K-W analysis found a *significant difference* (K-W = 30.37, p = 0.0014) between the monthly %*Klebsiella* values. The same values were then analyzed comparing the seasons. A K-S analysis found *significantly greater* (K-S = 2.96, p < 0.001) %*Klebsiella* concentrations during the irrigation season. The geomean %*Klebsiella* concentrations during the non-irrigation and irrigation seasons were 0.62% and 1.45%, respectively.

Spatial analyses

Table 53 presents the geomean %*Klebsiella* values found within the three sub-basins of the TMDL project area.

Table 53: Sub-basin %*Klebsiella* statistics.

Sub-basin	N	Geomean %*Klebsiella* Value
Cowiche Creek	25	0.34
Moxee Drain	30	1.00
Wide Hollow Creek	43	1.01

A K-W analysis found *no significant difference* (K-W = 4.40; p = 0.111) between the sub-basin %*Klebsiella* values.

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Discussion and Conclusions

Klebsiella pollution

The genus *Klebsiella*, in the family *Enterobacteriaceae,* was named by Trevisan (1885) to honor the German microbiologist Edwin Klebs (1834-1913). Friedländer (1882) described a bacterium from the lungs of a patient who had died of pneumonia and named the organism *Klebsiella pneumoniae*. *Klebsiella* species are common residents in the intestines of humans and animals and cause infections only when the host is weakened (hospitalization).

Marcal et al. (2009) stated that *Klebsiella* species are very common in nature, and Podshun et al. (2001) determined that 53% of surface water samples were positive for *Klebsiella pneumonia*, which is the most common species. During FCB analyses of water quality samples, *Klebsiella* species cause "false positives" as they do not necessarily represent fecal contamination. This is especially true for samples of pulp and paper mill effluents (Caplenas et al., 1984). Ecology (Hicks, 2002) indicated that environmental *Klebsiella* species were harmless and their enumeration could possibly overstate health risks. This idea has changed due to recent studies.

Early researchers stated that environmental populations of *Klebsiella pneumoniae* may constitute a reservoir of pathogenic bacteria (Brown and Seidler, 1973; Bagley and Seidler, 1977). Later researchers have shown that *Klebsiella pneumoniae* from clinical and environmental settings are identical taxonomically and genetically, and have similar virulence (Knittel, 1975; Struve and Krogfelt, 2004).

In fact, *Klebsiella pneumoniae* was the first bacteria to be identified as a superbug (resistant to antibiotics). It has been identified in a large number of environmentally-caused infections (Pods**c**hun et al., 2000; Podshun et al., 2001; S.S. Long, 2009) including: (1) severe pancreatitis in 2003; (2) cellulitis and lymphangitis in 2010; (3) cholangitis complicated with septic shock in 2011; (4) necrotizing fasciitis (flesh-eating bacteria) in 2012; and (5) pyogenic liver abscesses since the 1980s. In 2013, the Centers for Disease Control and Prevention (CDC) listed *Klebsiella* as an urgent threat to public health requiring immediate and aggressive action.

The %*Klebsiella* values collected throughout the *Mid-Yakima River Basin Bacteria TMDL* project area typically accounted for less than 1% of the FCB concentrations. No significant spatial difference was found between %*Klebsiella* values among the sub-basins. However, on a temporal scale, %*Klebsiella* values were significantly greater during the irrigation season. This greater irrigation season prevalence of the bacteria may be related to either increased surface runoff volumes or increased water temperatures. Coincidentally, other researchers have determined that infections by *Klebsiella pneumoniae* increase during the summer (Anderson et al., 2008).

Due to the minimal occurrence of *Klebsiella* throughout the TMDL project area, and the fact that it is considered potentially pathogenic to humans, no WLAs or LAs contained in this WQIR were adjusted in response to *%Klebsiella* values obtained from the project area's water quality samples.

Escherichia coli pollution

In 1885, Theodor Escherich discovered *Bacillus* coli (*B. coli*), which he suggested was the predominant organism in the colon of infants. In 1892, Schardinger proposed that the species could be used as an indication of fecal pollution in water. Winslow and Walker (1907) documented that *B. coli* was indeed the principal FCB species in infant feces. The species was later renamed *Escherichia coli* (*E. coli*) by Castellani and Chalmers (1919).

E. coli (Figure 33) is present in all warm-blooded animal digestive tracts, although it is significantly less abundant in wildlife than in livestock (Langholz and Jay-Russell, 2013). The bacteria are located primarily in the large intestine and reside in the mucus layer that covers the epithelial cells throughout the tracts. Ruminants release as high as 10 million *E. coli* cells per gram of fecal matter.

Figure 33: *E. coli* bacteria. (courtesy of CDC website)

Previously, *E. coli* were thought to only be able to live within a host. It is now known, however, that the bacteria can survive and reproduce outside of a host in "secondary habitats" such as surface waters, sediment, and beaches (van Elsas et al., 2003; Walk et al., 2007). Hottes et al. (2013), Brennan et al. (2010), Doyle et al. (2006), Farrell and Finkel (2003), and Zambrano et al. (1993) found that *E. coli* can mutate rapidly and thrive in hostile environments, even surviving dry-fermentation processing used in the production of salami (Tilden et al., 1996). Now, it is even estimated that one half of all *E. coli* bacteria living at any time, exist outside of their warm-blooded hosts (Besser et al., 2011).

Due to their size and electrical properties, *E. coli* bacteria are able to migrate through soil much more rapidly than parasites like Cryptosporidium and Giardia (Robertson and Edberg, 1997). In addition, they can leach through the top layers of the soil for more than two months after the application of manure (Gagliardi and Karns, 2000).

Water bodies contaminated with animal fecal matter pose a serious health risk to humans because of the substantial potential of zoonotic infections (communicable from animals to humans). In fact, more than 60% of human infectious diseases, including *E. coli*, are caused by pathogens shared with animals (Karesh et al., 2012). Although most (>95%) *E. coli* strains are nonpathogenic, the few pathogenic strains (collectively known herein as EcO157) have gained notoriety in recent years. The Centers for Disease Control and Prevention (CDC) now estimates that 73,000 cases of EcO157 occur each year in the United States. The majority of these cases have been traced to contamination by animal manure.

Historically, in 1968 through 1970, various outbreaks of enteric disease (colibacillosis) among swine occurred in Canada and the United States. They were attributed to a new unclassified *E. coli* bacterium. The next year (1971) serological advances permitted the identification of EcO157 in several additional cases of porcine colibacillosis. Up to this time there were no known human cases identified to EcO157.

The first infection by EcO157 in the United States occurred in 1975 (Naval Biosciences Laboratory, Oakland, CA) where recombinant genetic experiments were being conducted on *E. coli*. Coincidentally, later investigators noted that "*in the summer of 1975 ... the Naval Biosciences Laboratory tested E. coli [host-vector distribution] systems in a series of simulated accidental spills in the laboratory*." (Congress of the United States, 1981) That first infection was not immediately identified as EcO157. However in 1983, the CDC matched the stored bacteria strain from this first known infection to bacteria strains isolated from later outbreaks.

EcO157 was recognized as a human enteric pathogen in 1982 due to 25 cases in Oregon and 18 cases in Michigan related to undercooked hamburger. Another outbreak also occurred in Sacramento, California that year, but was not linked to EcO157 until several years later (Rogers et al., 1986). In 1987, Washington was the first state in the nation to mandate public health reporting of outbreaks of Ec0157. In 1993, EcO157 became a widely-accepted pathogen due to a large outbreak of >700 people (501 persons in the State) which was associated with undercooked hamburger. In 1994, EcO157 reporting became mandatory throughout the nation.

EcO157 is now a prominent cause of both epidemic and sporadic gastroenteritis in the United States. Infection can lead to hemolytic uremic syndrome (HUS), a devastating and sometimes fatal complication characterized by microangiopathic hemolytic anemia, thrombocytopenia, and renal failure. In population studies, age-specific attack rates for HUS have been highest among children younger than 5 years. From 1982 to 2002 there were 350 outbreaks of EcO157 throughout the United States; however, only 14 were associated with recreation activities in lakes or ponds (Rangel et al., 2005).

Recreation in surface waters has resulted in outbreaks in Illinois (1995), Missouri (1997), Minnesota (1998), Connecticut (1999), and again in Minnesota (2005). Washington State's first water body-associated outbreak of EcO157 occurred in Battle Ground Lake (1999) and affected 37 children < 15 years old, including three that had to have kidney dialysis treatment for HUS. The infection route was accidental ingestion of lake water. Bruce et al. (2003) later determined that a diaper was rinsed in the shallow children's swimming area. The lake's swimming area was closed for two years after the outbreak. Usually overlooked is the fact that *E. coli* is up to 38 times more abundant in upper 20 cm of beach sand than in the water column at freshwater beaches (Alm et al., 2003).

Young children (< 5 years) are highly susceptible to infection from EcO157. The bacteria species also has a very low infectious dose of 10-100 cfu/100mL (Kolling and Matthews, 2001). Because of these facts, the *Mid-Yakima River Basin Bacteria TMDL* must assume that all *E. coli* are potentially pathogenic. There was no attempt by this project to differentiate or quantify pathogenic from non-pathogenic *E. coli*. Therefore, no WLAs or LAs contained in this WQIR were adjusted in response to the %*E. coli* bacteria in water quality samples.

The topic of *E. coli* was succinctly summarized early on by Nataro and Kaper (1998) as follows: *Our perspective on intestinal E. coli has undergone a remarkable transformation in recent decades and undoubtedly will continue to evolve. Once dismissed as a harmless inhabitant of the intestinal tract, E. coli is now seen as a pathogenic species with remarkable versatility in its ability to mutate and cause disease in humans and animals.*

The *Mid-Yakima River Basin Bacteria TMDL* determined watershed-wide geomean %*E. coli* values of 66.7% and 63.8% for the non-irrigation and irrigation seasons, respectively. The slightly lower %*E. coli* value during the irrigation season may be related to a study by McLain et al. (2011) that found *E. coli* false positive identification rates inversely related to water temperature.

The Cowiche Creek, Moxee Drain, and Wide Hollow Creek sub-basins had average %*E. coli* values of 72.8%, 65.7%, and 58.1%, respectively. The latter sub-basin has a comparatively much smaller percentage of agricultural acreage than the other two sub-basins, which may account for the difference. Since the highly agricultural Moxee Drain sub-basin receives extensive land applications of manure and/or biosolids, its %*E. coli* values were expected to be high. Unexpectedly, the highest %*E. coli* values were found in the Cowiche Creek sub-basin. The sources of bacteria in this sub-basin are not known.

An upcoming source of worldwide concern is antibiotic resistance in bacteria. *E. coli* rates of resistance to antibiotics have been increasing since the 1950s (Tadesse et al., 2012). That study found a significant increasing trend for resistance with *E. coli* strains obtained from livestock when compared to strains obtained from humans. The livestock strains were commonly resistant to 11 of the 15 antibiotics tested, with tetracycline resistance being the most common (70% of *E. coli*). This is not surprising because the drug has been widely used in therapy and to promote feed efficiency in livestock since its approval in 1949.

Note that 30-90% of veterinary antibiotics are excreted after administration to livestock and thus present a direct route for environmental contamination (Karesh et al., 2012). Once excreted, these antibiotics can enter surface and groundwater from manure-applied lands (Kumar at al., 2005). Steele et al. (2005) also found antibiotic (ampicillin) resistant *E. coli* in 53% of the isolates collected from seabirds at wildlife rehabilitation centers along the Pacific coast of Washington State and California. Since antibiotics point to anthropogenic activities, this suggests that wild birds are able to transport *E. coli* bacteria from anthropogenic sources.

Fecal coliform pollution

The presence of the numerous individual species of pathogenic bacteria in surface water is sporadic, highly variable, and not easily analyzed in the laboratory. Fortunately, testing for the relatively non-pathogenic indicator bacteria group known as FCB has been historically used as a surrogate for the presence of pathogenic bacteria. Testing for FCB is known to reasonably reflect the presence of the numerous pathogenic bacteria.

In the 1950s, the U.S. Public Health Service determined that gastrointestinal illness rates increased when total coliform bacteria concentrations exceeded 2,300 cfu/100mL in surface waters. However, FCB are more reliable indicators of fecal contamination because total coliform bacteria include various non-fecal bacteria species. Therefore, in 1968, the U.S. Department of the Interior's National Technical Advisory Committee determined that 2,300 total coliforms was equivalent to 400 cfu/100mL of FCB. Applying a safety factor of 0.5 achieved a geomean WQS of 200 cfu/100mL, for *no risk* of illness in recreational waters was expected.

The State calculated even more stringent FCB criteria by applying an additional safety factor of 0.5, which resulted in the present geomean criterion of 100 cfu/100mL for primary contact recreational waters. That criterion is applicable to all of the water bodies that were sampled within the TMDL project area. In fact, that criterion is applicable to approximately 99% of the water bodies within the project area. The few exceptions are located in the northwest corner of the project area, within the Wenatchee National Forest (WNF), which have a more stringent FCB geomean criterion of 50 cfu/100mL that is reserved for extraordinary primary contact recreational waters. These latter water bodies were not sampled for *Mid-Yakima River Basin Bacteria TMDL*.

All surface waters within the TMDL project area must comply with the State's WQS. Stormwater runoff and irrigation drainage are known to transport large quantities of FCB downstream and degrade water quality (Lubliner et al., 2006). Wyer et al. (1996) and Jolley et al. (2008) found that even short pulses of stormwater discharge can significantly increase the bacteria concentrations in downstream receiving waters. In the lower Yakima River basin, irrigation drainage has been shown to act as a transport mechanism for FCB pollution (Bohn, 2001). Pathogen and indicator microorganism concentrations in stormwater and irrigation drainage have been positively correlated to turbidity (Bradford and Schijven, 2002; Schijven et al., 2004) and phosphorus (Dao et al., 2008).

It should be noted that FCB concentrations were measured in Battle Ground Lake, Washington, two days (August 26) before the 1999 outbreak of EcO157 was identified (discussed in the previous section) soon after two children were reported becoming ill after swimming in the lake. The FCB concentrations were found to be 18 cfu/100mL and 93 cfu/100mL (Bruce et al., 2003). Although those concentrations were in compliance with the State's FCB criteria for primary contact recreation, the public was definitely not protected against infection by EcO157.

Kolling and Matthews (2001) stated that the infectious dose of EcO157 in surface waters is extremely low (10-100 cfu/100 mL). This low infectious dose was not included into the prior calculations of the State's water quality FCB criteria. Recently, Limayem and Martin (2014) concluded that *[antibiotic] resistant microbes in surface waters ... increase the probability of infection by 10-fold on exposed human populations.* The sources of the antibiotic resistant bacteria were described as being connected with livestock and their wastewaters.

It should also be noted that the State's WQS do not differentiate between human and animal bacteria sources, or between pathogenic and non-pathogenic FCB. This view is supported by Cooley et al. (2007) who determined that high numbers of nonpathogenic bacteria in surface waters are often accompanied by an increased likelihood of pathogenic species.

Temporal analyses

The greatest FCB pollution throughout the *Mid-Yakima River Basin Bacteria TMDL* project area occurs during the months of May through October. These months correspond to the area's historical agricultural irrigation season. Various studies in other watersheds have made similar findings (Kendra, 1988; Embrey, 1992; USEPA, 2000; Bohn, 2001; Morace and McKenzie, 2002; Characklis et al., 2005; Fries et al., 2006; Krometis et al., 2007).

Some sites within the TMDL project area were found to have excessive FCB concentrations throughout the entire year. Because of that, their sources of FCB pollution are assumed to be from either point sources or quasi-point sources and unrelated to irrigation drainage. Those specific sites are: (1) Cowiche Regional POTW effluent, (2) Moxee City POTW effluent, (3) Randall Park Pond discharge into Wide Hollow Creek, (4) DID #11 discharges into Moxee Drain, and (5) DID #48 flows.

The agricultural irrigation season also corresponds to the period of highest annual stream flows due to irrigation returns. In addition to transporting FCB pollution, high flows and high velocities can re-suspend FCB that have previously settled into stream sediments (USEPA, 1985; Chapra, 1997; Rifai and Jensen, 2002). Francey et al. (2005) found that total rainfall energy expended during a storm event coincided significantly with bacteria concentrations in streams. This TMDL project did not measure the amount of re-suspended FCB, and no WLAs or LAs were adjusted for re-suspended bacteria.

It is interesting to note that in the Wide Hollow Creek sub-basin the geomean and STV concentrations of FCB peaked rapidly after a storm event began, and then decreased 73% and 67%, respectively, within 24 hours. After 24 additional hours, another 22% reduction occurred and FCB concentrations reached pre-storm levels. The Wide Hollow Creek sub-basin is the only sub-basin that was sampled regarding stormwater.

Spatial analyses

Cowiche Creek sub-basin

100% of the N.F. Cowiche Creek sampling sites did not meet State WQS for FCB, with 60% of the FCB loading attributed to the Cowiche Regional POTW (38-FC-WWR) outfall. The excessive FCB concentrations associated with the POTW effluent were attributed to process upsets that occurred in 2005 and 2006. Ecology has determined that normal operating conditions at the POTW have since resumed as it is now meeting its WLA target reductions. The stream's proposed background site 38-FC-7 (at French Rd) was estimated to comply with State WQS for FCB throughout the entire year.

About 80% of the S.F. Cowiche Creek sampling sites exceeded State FCB criteria, with 62% of FCB loading in the S.F. Cowiche Creek attributed to sources downstream of the Summitview-Cowiche Rd. The stream's proposed background site 38-FC-4 was found to be in compliance with State WQS for FCB throughout the entire year. This finding is especially important since the site also represents bacteria pollution from the Cowiche Unit of the Oak Creek Wildlife Area.

All of the mainstem Cowiche Creek sampling sites exceeded State WQS for FCB. Tarbutton (2012) calculated that 75% of the FCB loading to Cowiche Creek is derived from the S.F. Cowiche Creek, while the rest is derived from the N.F. Cowiche Creek.

Moxee Drain sub-basin

83% of the mainstem Moxee Drain sampling sites did not comply with State WQS for FCB. The greatest FCB mainstem concentrations were found at the downstream site 37-FM-3 (at Birchfield Rd.) and at the farthest upstream site 37-FM-10 (at Beane Rd.). Having a large amount of FCB pollution at the downstream end of Moxee Drain is reasonable, as bacteria concentrations typically increase going downstream. However, the large amount of bacteria pollution at the upstream end of Moxee Drain is of concern. DeVries Dairy is located approximately 12 miles upstream from sampling site 37-FM-10 and should be monitored for potential FCB discharges.

About 75% of the tributary sampling sites had FCB concentrations in excess of State WQS for FCB. The greatest FCB concentrations were found at the mouth of DID #11 just prior to its confluence with the Moxee Drain. Approximately 72% of the FCB loading to the Moxee Drain is derived from DID #11. In addition, 87% of the FCB load in DID #11 was from upstream of tributary sites 37-FM-5/37-IS-1 (Bell Rd.) and 37-FM-WWO (POTW outfall).

None of the DID #11 sites met State WQS for FCB. The FCB pollution was year-round. This situation suggests that the predominant source(s) of FCB in DID #11 are not associated with irrigation drainage. In fact, the greatest FCB concentrations were located just downstream of a mobile home park. The mobile home park is presented in the center of Figure 34. DID #11 (red-dashed line) flows in a south-westerly direction, from sampling sites #1 to #7, and directly underneath the mobile home park.

During August and September of 2006, Ecology conducted sampling to determine the locations of bacteria hotspots along DID #11. A K-S analysis found a significant (K-S = 2.683; $p < 0.01$) increase in FCB concentrations between sampling sites #4 and #5. Ecology suspected that the FCB pollution increase underneath the Country Mobile Estates (CME) property was probably due to failing on-site septic systems (OSSS), as no other possible sources are located nearby.

The USEPA (Region 10 Office) joined the investigation in 2007. Ecology collected additional samples from the same sampling sites in Figure 16 during June and July of that same year. The samples were analyzed using the Bacteroides Polymerase Chain Reaction (PCR) methodology. The investigation (USEPA Project Code: WOO-064A) revealed that all samples from sampling sites #1 through #4 were negative for human bacteroides, but all downstream samples (#5 through #7) were positive.

Ecology concluded that substantial input of human-associated FCB into DID #11 occurred between sampling sites #4 and #5. In August 2009, CME received an Administrative Order from Ecology to cease and desist in discharging FCB. CME completed OSS upgrades in October 2009, according to the YHD. Additional sampling should be conducted throughout the duration of the *Mid-Yakima River Basin Bacteria TMDL* in order to determine if the mobile home park continues to be a significant source of FCB pollution.

Figure 34: DID #11 sampling sites.

Wide Hollow Creek sub-basin

During the irrigation season, 79% of the mainstem sites exceeded State water quality FCB criteria. However, during the non-irrigation season, only 43% exceeded those same criteria. During the irrigation season, 86% of the tributary sites exceeded State water quality FCB criteria, while only 29% exceeded those same criteria during the non-irrigation season.

The mainstem site with the greatest FCB pollution during the irrigation season was just downstream of the confluence with East Spring Creek (37-FW-0B). Since this is the last downstream sampling site, it is logical to expect that the greatest FCB pollution is located there.

The tributary sites with the greatest FCB pollution during the irrigation season were Shaw Creek (37-SS-13/37-SS-13B), Randall Park Pond outlet (37-SS-17.5/37-SS-9), and DID #4 behind Gardner's Nursery (37-IS-15). Interestingly, the two latter sites had very high FCB concentrations throughout the entire year. Waterfowl are suspected of being responsible for the increase of FCB pollution in Randall Park Pond. In March 2009, Yakima County conducted smoke testing of all connections to DID #4, which was spurred by high FCB concentrations. Illicit sewer connections were discovered at two homes (Figure 35), a hospital, and one school.

Figure 35: Illicit connection smoke testing.

None of the four originally proposed background condition sites (37-FW-14, 37-FW-16, 37-FW-17, and 37-FW-18) in the Wide Hollow Creek sub-basin complied with State FCB criteria. This probably is due to substantial agricultural and residential development in their upstream areas, as evidenced in Figures 29 and 30.

The only tributaries in compliance with State water quality FCB criteria during the irrigation season were a spring near Randall Park (37-SS-11B), and the DID #24 Lateral L1 outfall at 3rd Ave. in Union Gap (37-IS-12/37-IS-12B). It is interesting to note that the nearby DID #24 Lateral L2 outfall at Pioneer Lane (37-IS-13) had significantly higher FCB concentrations.

Information provided by Yakima County has shown that the two laterals are completely independent of each other (Figure 36), with L1 transporting only groundwater and L2 transporting both stormwater and groundwater. Stormwater is the only known difference in type of liquid transported by the laterals and it is, therefore, suspected of transporting the high FCB concentrations. However, neither of the laterals was sampled during or just after storm events. Since the higher FCB concentrations occurred during the irrigation season, it is now suspected that substantial irrigation return flow also enters Lateral L2, but not Lateral L1.

MS4 stormwater drainage

Six sampling sites were chosen to reflect the FCB content of MS4 stormwater drainage: 37-SS-2, 37-SS-6, 37-SS-8, 37-IS-21, 37-IS-22 and 37-SS-4. There was significantly less FCB pollution during the non-irrigation season than during the irrigation season (geomean concentrations were 53.9 and 167.4, respectively). Each season's WLAs were calculated after combining together all sampling data from all the MS4 sampling sites. In general, MS4 WLAs are less stringent than those for other point sources simply because a discharging facility is required to comply with AKART, whereas stormwater runoff is not.

Numerous DID irrigation return ditches have existed within the TMDL project area since the early 1900s. They were constructed to lower the water table and drain surface runoff caused by intensive irrigation. As urbanization encroached upon agricultural lands, many of the original boards operating those DIDs dissolved and reverted to Yakima County for management, operation, and maintenance. The county now operates and maintains several DIDs that are located within the project area (#4, #11, #13, #24, #38, #40 and #48). DIDs #7, #12, #16 and #28 are still operated by boards.

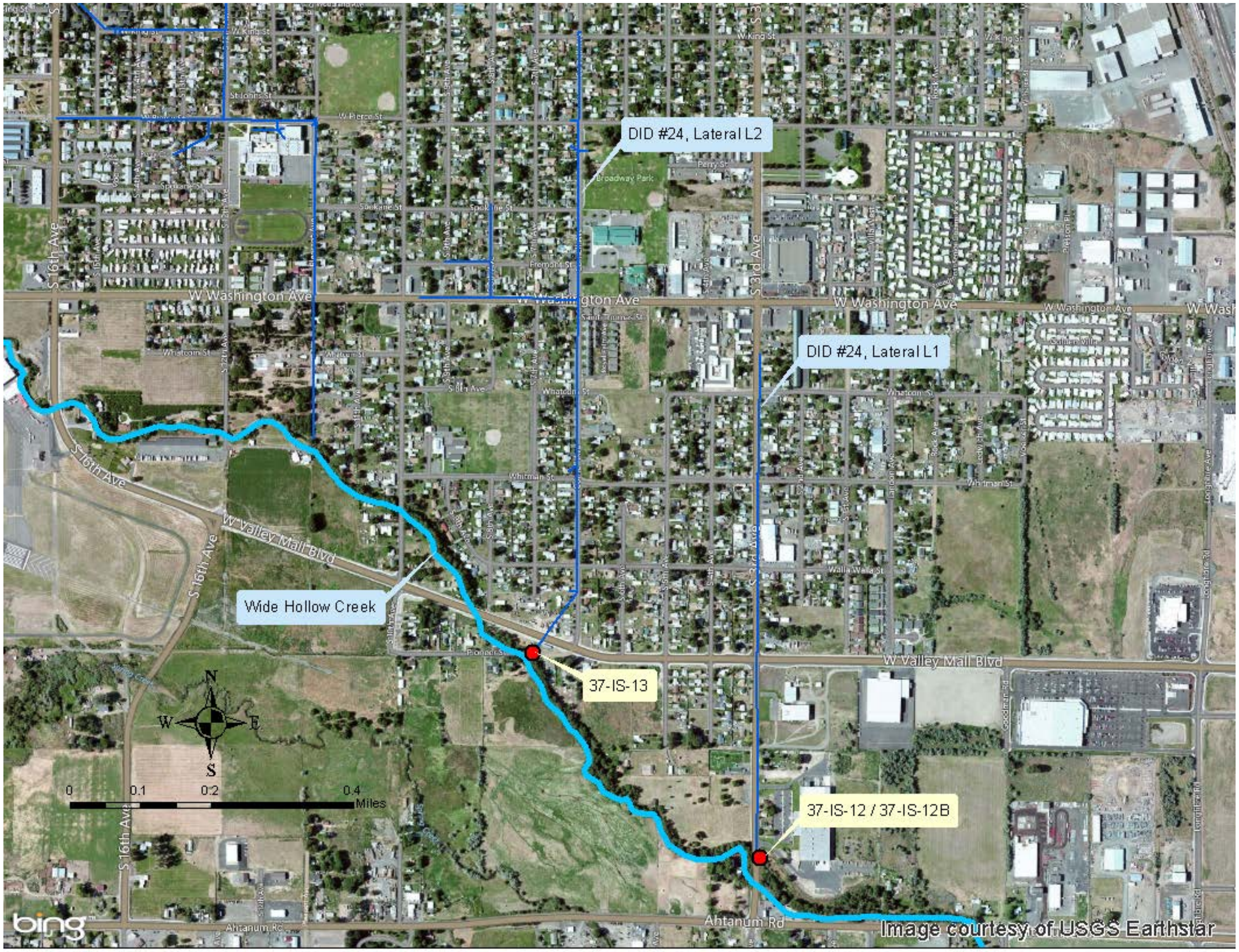

Figure 36: Outfall locations for Lateral L1 and Lateral L2 of the DID #24 system.

TMDL Analysis

Although most wasteload allocations (WLAs) and load allocations (LAs) are developed as pollutant loads (pollutant concentration multiplied by stream flow), this approach does not work well for bacteria studies. An allocation of FCB pollution in terms of loading is awkward and challenging to understand, as well as useless for implementation purposes. Therefore, this water quality improvement report (WQIR) uses the appropriate alternative measure of concentration for the *Mid-Yakima River Basin Bacteria TMDL*. Such an approach is allowed by USEPA regulations, and has proven successful in prior bacteria TMDLs in the State. It also allows the public to easily determine compliance with the numerical FCB criteria contained in the State WQS.

This section of the WQIR discusses the WLAs and LAs for various sites within the Cowiche Creek, Moxee Drain and Wide Hollow Creek sub-basins. They were calculated for both the irrigation and non-irrigation seasons based on the FCB concentrations collected by Ecology during the 2004-2006, 2010 and 2014 surveys. The irrigation season WLAs and LAs are more stringent than the corresponding allocations calculated for the non-irrigation season. Thus, the irrigation season is considered to be the critical condition for the TMDL.

The following formulas were utilized to calculate the FCB statistics and WLAs/LAs presented in this WQIR:

- The geomean of each data set was calculated using an Excel® spreadsheet, which is compared to the primary numerical FCB criterion stipulated in WAC 173-201A-200(2)(b).

- The STV of each data set was calculated using the Hazen method (Appendix C), which is compared to the secondary narrative FCB criterion that represents "no more than 10% of samples", which is stipulated in WAC 173-201A-200(2)(b).

- Each sampling site and potential point source are required to comply with specific LAs and WLAs, respectively, that were calculated by this WQIR.

- By the end of year 4 of the 10-year *Mid-Yakima River Basin Fecal Coliform Bacteria TMDL*, 50% of the percent target reduction at each site should be reached. By the end of year 8 of the 10-year TMDL, 90% of the percent target reduction at each site should be reached. At the end of the irrigation season of year 10, all percent target reductions should be met.

Loading capacity

The loading capacity of a water body is the maximum amount of a pollutant it can receive from point and non-point sources and still comply with State WQS. For the *Mid-Yakima River Basin Bacteria TMDL,* it is assumed that if the individual tributaries and various segments (reaches) of Cowiche Creek, Moxee Drain and Wide Hollow Creek were to comply with State WQS, then the entire mainstem of those same water bodies will also comply with State WQS.

Compliance with WQS

The State FCB criteria for all sampling sites within the TMDL project area are: (1) a maximum geomean concentration of 100 cfu/100mL, and (2) a maximum STV concentration of 200 cfu/100mL. The WLA and LA percent reductions presented in this WQIR indicate the proportion that the respective sampling site's FCB concentrations are out of compliance with the above State FCB criteria. Sites already in compliance with those same criteria received a percent target reduction of zero (0).

Although no TMDL project area sampling sites are presently located within the reaches of the Cowiche Creek sub-basin regulated by extraordinary primary contact recreation, it is possible that future sampling will occur and show bacteria impairment. In that case, those reaches (i.e. Weddle Canyon Creek and N.F. Cowiche Creek) must comply with: (1) a maximum geomean concentration of 50 cfu/100mL, and (2) a maximum STV concentration of 100 cfu/100mL.

Seasonal variation

The FCB pollution throughout the *Mid-Yakima River Basin Bacteria TMDL* project area is greatest during the months of May through November. This period corresponds to the area's agricultural irrigation season (April 15 through October 15), when the project area's streams also have their greatest flows. Consequently, irrigation returns are suspected of being the principal transport mechanism of FCB to the surface waters within the TMDL project area.

Load and wasteload allocations

The *Mid-Yakima River Basin Bacteria TMDL* determined that primary contact recreation within nearly all water bodies within the project area are impaired by excessive FCB pollution. In order to comply with State WQS, this WQIR assigns LAs for non-point sources and WLAs for point sources. The LAs presented in this WQIR reflect the percentage of FCB pollution that needs to be reduced during each season in order to comply with State WQS.

The TMDL will first require compliance with the irrigation season LAs as they are the most stringent. It is hypothesized that many of the BMPs implemented for that season's FCB pollution will also result in decreased FCB pollution during the non-irrigation season. This WQIR expresses LAs and WLAs in terms of bacterial concentration and as percent target reductions. Such LAs and WLAs can be quickly and easily compared to the concentration-based FCB criteria contained in the State WQS.

The LA and WLA percent target reductions in the tables below were calculated using the following formulas:

Geomean % target reduction = [(observed geomean – 100 cfu/100mL) / observed geomean] x 100

STV % target reduction = [(observed STV – 200 cfu/100mL) / observed STV] x 100

Wasteload allocations

Table 54 presents the seasonal geomean and STV WLAs for all presently identified point sources of FCB pollution within the *Mid-Yakima River Basin Bacteria TMDL* project area. There is one publicly-owned treatment works (POTW) and numerous MS4 outfalls within the TMDL project area. The city of Yakima, city of Union Gap, Yakima County, and the Washington Department of Transportation (WSDOT) operate and maintain the TMDL project area's numerous MS4 discharges.

Yakima County is responsible for operating and maintaining several Drainage Improvement Districts (DIDs) water bodies throughout the Moxee Drain and Wide Hollow Creek sub-basins (DIDs #4, #11, #13, #24, #38, #40, and #48). All seasonal MS4 WLAs are identical because the seasonal FCB concentration data was combined together in order to calculate those WLAs. Otherwise, there would have been insufficient MS4 sampling data to site-specific WLAs.

The MS4s may comply with their WLAs by reducing FCB concentrations or by utilizing an implementation target. Such target could be reducing *flow volume per area of impervious surface*, or an alternative target. However, the MS4 entity must request and obtain, from Ecology, approval to use any implementation target prior to the end of 24 months after the TMDL has been approved by the USEPA. All implementation target requests must be approved, in writing, by Ecology. When requesting the use of an implementation target for FCB, the requester must specifically show, to Ecology's satisfaction, the correlation between FCB concentrations and the implementation target. This will allow both Ecology and the MS4 to gauge compliance with their WLAs contained in this WQIR.

Likewise, all point source dischargers to the MS4s must have written permission to discharge issued by the entity having jurisdiction for stormwater collection systems receiving those discharges. An MS4 is responsible for non-compliance with State WQS caused by discharges into its stormwater collection system. In other words, if polluted stormwater from an industrial or construction site is causing the MS4's discharge to exceed TMDL FCB limitations, then the MS4 must require the upstream discharger to implement appropriate BMPs or terminate those discharges. All BMPs implemented within the TMDL project area must be adequate and properly operated and maintained year-round. This is especially important for the sites that have year-round high-concentration FCB pollution, such as Randall Park Pond, DID #11, and DID #48.

Table 54: Seasonal WLAs for NPDES sources within the TMDL project area.

Site ID	NPDES Permit #	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	WLA (cfu/100mL)	% Target Reduction (concentration)	WLA (cfu/100mL)	% Target Reduction (concentration)	WLA (cfu/100mL)	% Target Reduction (concentration)	WLA (cfu/100mL)
Cowiche Sewer District	WA-005239-6	0	50[1]	0	100[2]	0	50[1]	0	100[2]
City of Union Gap	WAR046010	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
City of Yakima	WAR046013	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
Eakin Fruit	WAG435031	NSD	50[1]	NSD	100[2]	NSD	50[1]	NSD	100[2]
Roy Farms	WAG435221	NSD	50[1]	NSD	100[2]	NSD	50[1]	NSD	100[2]
Yakima County	WAR046014	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
Yakima Valley Community College	WAR046201	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]
WSDOT	WAR043000	0	100[1]	88.9	200[2]	79.3	100[1]	97.6	200[2]

[1] This WLA equals the Maximum Weekly effluent limitation in an NPDES permit
[2] This WLA equals the Average Monthly effluent limitation in an NPDES permit
NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the discharge is in compliance with respective State water quality FCB criterion.

Load allocations

LAs apply to nonpoint sources of FCB and will be addressed through the implementation of best management practices (BMPs). All such sources must comply with primary contact recreation FCB criteria. All LAs must be completely met at the end of year 10 of the *Mid-Yakima River Basin Bacteria TMDL*.

Table 55 presents the seasonal geomean and STV LAs for the sampling sites within the Cowiche Creek sub-basin.

Table 56 presents the seasonal geomean and STV LAs for the sampling sites within the Moxee Drain sub-basin.

Tables 57 and 58 present the seasonal geomean and STV LAs for the mainstem and tributaries sampling sites within the Wide Hollow Creek sub-basin.

Reserve capacity for future growth

The *Mid-Yakima River Basin Bacteria TMDL* contains a small amount of reserve capacity for future growth based on the fact that all new point sources will be required to comply with more stringent WLAs than existing point sources. The WLAs for new point sources are: a geomean WLA of 25 cfu/100mL, and an STV WLA of 50 cfu/100mL. These are twice as stringent as the WLAs for existing point sources, which are: a geomean WLA of 50 cfu/100mL, and an STV WLA of 100 cfu/100mL.

The stringent WLAs are reflective of the State requirement to implement AKART prior to discharging. AKART for bacteria in discharges has been determined to be disinfection by UV radiation and typically results in FCB concentrations below 10 cfu/100mL.

A substantial amount of additional reserve capacity, comes from the fact that all new non-point sources must ensure immediate compliance with the State's FCB criteria for *primary contact recreation*, except for those that discharge into surface waters within the WNF and their tributaries. The latter dischargers must immediately comply with the State's FCB criteria for *extraordinary primary contact recreation*.

Table 55: Seasonal LAs in Cowiche Creek sub-basin.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
38-FC-1	45115	0	100	0	200	8.7	100	51.0	200
38-FC-1.25	8319	0	100	0	200	39.5	100	81.8	200
38-FC-1.5		0	100	63.0	200	44.7	100	49.1	200
38-FC-2	46633 & 8327	0	100	79.8	200	58.2	100	81.4	200
38-FC-2.5	46346 & 8326	0	100	0	200	38.8	100	86.7	200
38-FC-3 / 38-FC-3.5	8323	0	100	0	200	0	100	16.3	200
38-FC-4		0	100	0	200	0	100	0	200
38-FC-6	8322	0	100	0	200	37.0	100	71.0	200
38-FC-7		0	100	0	200	0	100	0	200
38-IS-7		NSD	100	NSD	200	88.0	100	75.9	200
38-IS-7.5		(0)	100	(80.5)	200	76.0	100	67.2	200
38-IS-7.6		(0)	100	(50.7)	200	0	100	54.5	200
38-IS-8	45886	NSD	100	NSD	200	59.3	100	68.3	200
38-IS-8.5		NSD	100	NSD	200	39.2	100	80.0	200

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with respective the State water quality FCB criterion.
Values in parentheses are estimates based on best professional judgment.

Table 56: Seasonal LAs in Moxee Drain sub-basin.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
37-FM-1	45717	0	100	30.6	200	49.6	100	61.7	200
37-FM-3	45122	43.0	100	66.7	200	62.0	100	65.6	200
37-FM-3.5	46355	71.1	100	61.5	200	63.6	100	81.8	200
37-FM-3.6	45703	60.3	100	77.5	200	84.2	100	94.4	200
37-FM-4 / 37-IS-2	46548 & 46673	0	100	0	200	50.2	100	77.5	200
37-FM-5 / 37-IS-1	45114	94.9	100	98.0	200	92.6	100	94.2	200
37-FM-5.5		(53.9)	100	(73.0)	200	58.3	100	37.5	200
37-FM-7 / 37-IS-3	45313	0	100	0	200	0	100	37.1	200
37-FM-8	46167	0	100	0	200	8.1	100	48.1	200
37-FM-9		0	100	0	200	0	100	31.7	200
37-FM-9.5		0	100	0	200	NSD	100	NSD	200
37-FM-10	46168	39.5	100	88.8	200	62.2	100	63.0	200
37-IS-0		NSD	100	NSD	200	27.0	100	0	200
37-IS-1.5		NSD	100	NSD	200	37.0	100	71.4	200
37-IS-4		NSD	100	NSD	200	0	100	20.0	200
37-IS-4.5		NSD	100	NSD	200	0	100	20.0	200
37-IS-4.6		NSD	100	NSD	200	55.8	100	79.4	200
37-IS-5		NSD	100	NSD	200	0	100	0	200
DeVries Family Farm Dairy (AFO)		NSD	0	NSD	0	NSD	0	NSD	0

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with the respective State water quality FCB criterion.
Values in parentheses are estimates based on best professional judgment.

Table 57: Seasonal LAs for mainstem Wide Hollow Creek.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
37-FW-0 / 37-SS-1	8306	4.6	100	22.8	200	74.1	100	89.6	200
37-FW-0B		0	100	0	200	98.6	100	98.0	200
37-FW-1 / 37-SS-5	6717	0	100	5.2	200	66.4	100	85.0	200
37-FW-1B		0	100	0	200	0	100	0	200
37-FW-1C		0	100	0	200	92.7	100	98.0	200
37-FW-2B		64.2	100	69.2	200	0	100	0	200
37-FW-3 / 37-FW-3B		0	100	20.0	200	65.9	100	72.0	200
37-FW-4 / 37-SS-7		0	100	0	200	58.8	100	71.3	200
37-FW-5	6718	20.3	100	51.7	200	69.2	100	92.4	200
37-FW-6 / 37-FW-6B		0	100	0	200	69.8	100	92.1	200
37-SS-11	16804	42.8	100	83.1	200	87.9	100	98.0	200
37-SS-12		0	100	0	200	58.2	100	88.0	200
37-FW-8 / 37-SS-14	45081	0	100	71.7	200	48.6	100	74.4	200
37-IS-16B		0	100	0	200	0	100	0	200
37-SS-15	46645	NSD	100	NSD	200	98.3	100	96.7	200
37-FW-12 / 37-SS-16	45161	0	100	0	200	27.8	100	95.0	200
37-FW-15 / 37-SS-17		0	100	0	200	96.3	100	92.6	200
37-FW-18		0	100	0	200	(78.7)	100	(91.1)	200

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with the respective State water quality FCB criterion.
Values in parentheses are estimates based on best professional judgment.

Table 58: Seasonal LAs for tributaries to Wide Hollow Creek.

Site ID	Corresponding 303(d) Listings	Non-irrigation Season				Irrigation Season			
		Geomean		STV		Geomean		STV	
		% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)	% Target Reduction (concentration)	LA (cfu/100mL)
37-FW-2	45541	0	100	0	200	54.6	100	86.0	200
37-FW-13 / 37-SS-18	45210	0	100	0	200	75.5	100	97.5	200
37-FW-14	46164	0	100	25.9	200	89.2	100	93.2	200
37-FW-16		0	100	73.5	200	NSD	100	NSD	200
37-FW-17		0	100	0	200	NSD	100	NSD	200
37-IS-10		NSD	100	NSD	200	0	100	37.5	200
37-IS-13		0	100	0	200	0	100	98.5	200
37-IS-15	45219	98.5	100	98.0	200	97.9	100	96.7	200
37-IS-16	45875	0	100	0	200	44.5	100	87.1	200
37-IS-17		64.3	100	28.6	200	75.3	100	98.0	200
37-IS-17.5 / 37-SS-9	45753 & 46628	32.0	100	93.3	200	92.4	100	92.7	200
37-IS-18 / 37-IS-18B		71.4	100	42.9	200	66.7	100	72.6	200
37-IS-19 / 37-SS-48		0	100	0	200	21.7	100	95.0	200
37-IS-20 / 37-SS-38		0	100	0	200	35.1	100	65.5	200
37-IS-20A		NSD	100	NSD	200	0	100	0	200
37-IS-20B		NSD	100	NSD	200	0	100	0	200
37-IS-12 / 37-IS-12B		0	100	0	200	0	100	0	200
37-SS-11B		0	100	0	200	0	100	0	200
37-IS-23		0	100	0	200	77.6	100	98.0	200
37-SS-13 / 37-SS-13B	45869	NSD	100	NSD	200	95.2	100	97.8	200

NSD = no sampling data was collected and no value could be estimated.
Yellow cells indicate that the site is in compliance with the respective State water quality FCB criterion.

Margin of Safety

A substantial amount of implicit "margin of safety" (MOS) has been established by the *Mid-Yakima River Basin Bacteria TMDL* to account for scientific uncertainty associated with TMDL targets. The MOS for the TMDL includes several conservative assumptions, such as:

- The WLAs for existing point sources, other than MS4 stormwater, are based on the more stringent *extraordinary primary contact recreation* FCB criteria of a geomean = 50 cfu/100mL; STV = 100 cfu/100mL. This results in substantial MOS because the typical State FCB criteria applicable throughout the majority of the TMDL project are numerically twice as large (*primary contact recreation* criteria). The implication on point sources should be minimal as they are already required by State regulations to install AKART (UV disinfection) if they discharge significant amounts of bacteria.

- The LAs and WLAs are based on a combination of both storm event and fixed-site bacteria sampling data. The inclusion of a few numerically large FCB concentrations from storm events results in the calculation of WLAs and LAs that are more conservative than those based solely on non-storm event data. This results in substantial MOS.

- Whenever bacteria sampling was not conducted at a mainstem site, during either the non-irrigation or irrigation season, the respective LAs for that site were assumed to be equal to the same percent difference found during the opposite season at the next two downstream mainstem sites. This is a very conservative assumption since upstream sites typically have less bacteria pollution than downstream sites. This results in substantial MOS.

- All *Klebsiella* and *E. coli* bacteria are considered pathogenic to humans, even though some may not be. The bacteria data utilized to calculate the WLAs and LAs contained in this WQIR were, therefore, not reduced to account for non-pathogenic bacteria. This results in a small amount of MOS for *Klebsiella* and a large amount of MOS for *E. coli*.

- Whenever multiple FCB samples were collected within a consecutive 48-hour period, only the largest data value obtained therein was utilized in WLA and LA calculations. This was done so as to not exaggerate their value, since samples were typically collected monthly or bi-monthly. Using only the largest value results in a more conservative data set, than if averaging the multiple samples, and a small amount of MOS.

- If five minutes or more elapsed between the collections of replicate field samples, then each sample was considered separate and unique. If less than five minutes elapsed, then the results from both samples were averaged in order to obtain a single value. This results in a more conservative data set and a small amount of MOS.

- All bacteria concentrations described by the laboratory as "0" were replaced by the value "1 cfu/100mL" prior to calculating WLAs and LAs. This results in a more conservative set of bacteria data and substantial MOS.

- All bacteria concentrations described by the laboratory as “TNTC” were replaced by the value “10,000 cfu/100mL” prior to calculating WLAs and LAs. This numerical replacement procedure follows Ecology protocol established by the agency’s laboratory directives for the statistical analysis of bacteria data. This results in a more conservative set of bacteria data and substantial MOS.

- The WLAs and LAs contained in this WQIR were not reduced to account for resuspension of bacteria during storm events, which undoubtedly occur during episodes of increased stream flows. This results in a more conservative data set and substantial MOS.

- The WLAs and LAs contained in this WQIR were not reduced to account for regrowth of bacteria, which may occur in the riparian environment or in MS4 systems. This results in a more conservative data set and substantial MOS.

Reasonable Assurance

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint sources) for a water body. Both point and non-point sources of FCB pollution exist within the *Mid-Yakima River Basin Bacteria TMDL* project area. Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of the TMDL are met.

While Ecology is authorized under Chapter 90.48 RCW to impose strict requirements or issue enforcement actions to achieve compliance with State WQS, it is the goal of all TMDL participants to achieve clean water through cooperative efforts. The goal of this TMDL project is to assure that the waters within the project area comply with State water quality FCB criteria by the end of the 2024 irrigation season.

At year four, six and eight of this TMDL project, Ecology will make adaptive management decisions that will be based on effectiveness monitoring data. The adaptive management process will determine if the State WQS will be met on schedule, or if adjustments will need to be made. If necessary, adjustments will be made to implementation activities and methods, but not to the compliance schedule. If reaching the TMDL goal does not appear to be on schedule, then increased implementation of BMPs or implementing different BMPs should begin as soon as possible.

There is considerable interest and local involvement toward resolving the water quality bacteria pollution problems within the TMDL project area. Numerous organizations and agencies are already engaged in stream restoration and source correction actions that will help reduce FCB pollution. This assumes that those activities are continued and maintained. Ecology believes that the past implementation of the activities specified in the following list add to the reasonable assurance that the TMDL will comply with State water quality FCB criteria by the end of the 2024 irrigation season:

- Yakima County and the cities of Union Gap and Yakima established a Regional Stormwater Policy Group (RSPG) in 2005 to deal with stormwater issues within their respective MS4 stormwater jurisdictions (Figure 37).

- Ecology issued individual Phase 2 MS4 stormwater permits to all RSPG members in February 2007.

- An interlocal agreement (ILA) was signed between the RSPG members in July 2007 and again in September 2009. (The city of Yakima later withdrew from the agreement on April 2, 2014).

- Extensions of the ILA were signed in November 2009, in June 2011, and in February 2012.

- In March 2009, the city of Yakima conducted extensive smoke testing that discovered several illicit sanitary connections in its MS4. These were later corrected.

- All RSPG members are presently in compliance with the requirements of the Eastern Washington Phase 2 Municipal Stormwater NPDES Permit that became effective on February 16, 2007.

- In February 2012, Yakima County submitted to Ecology a complete map of all MS4 stormwater outfalls within the RSPG jurisdiction.

- The Yakima Health District has worked with Ecology and the Country Mobile Estates property owner to repair the failing OSSS that are located within that site (located in the Moxee Drain sub-basin) and which have polluted DID #11 with high concentrations of FCB for several years.

- The city of Moxee POTW has completely eliminated its discharge of effluent to DID #11 (Moxee Drain sub-basin). The effluent is now discharged to the city of Yakima Regional POTW for treatment.

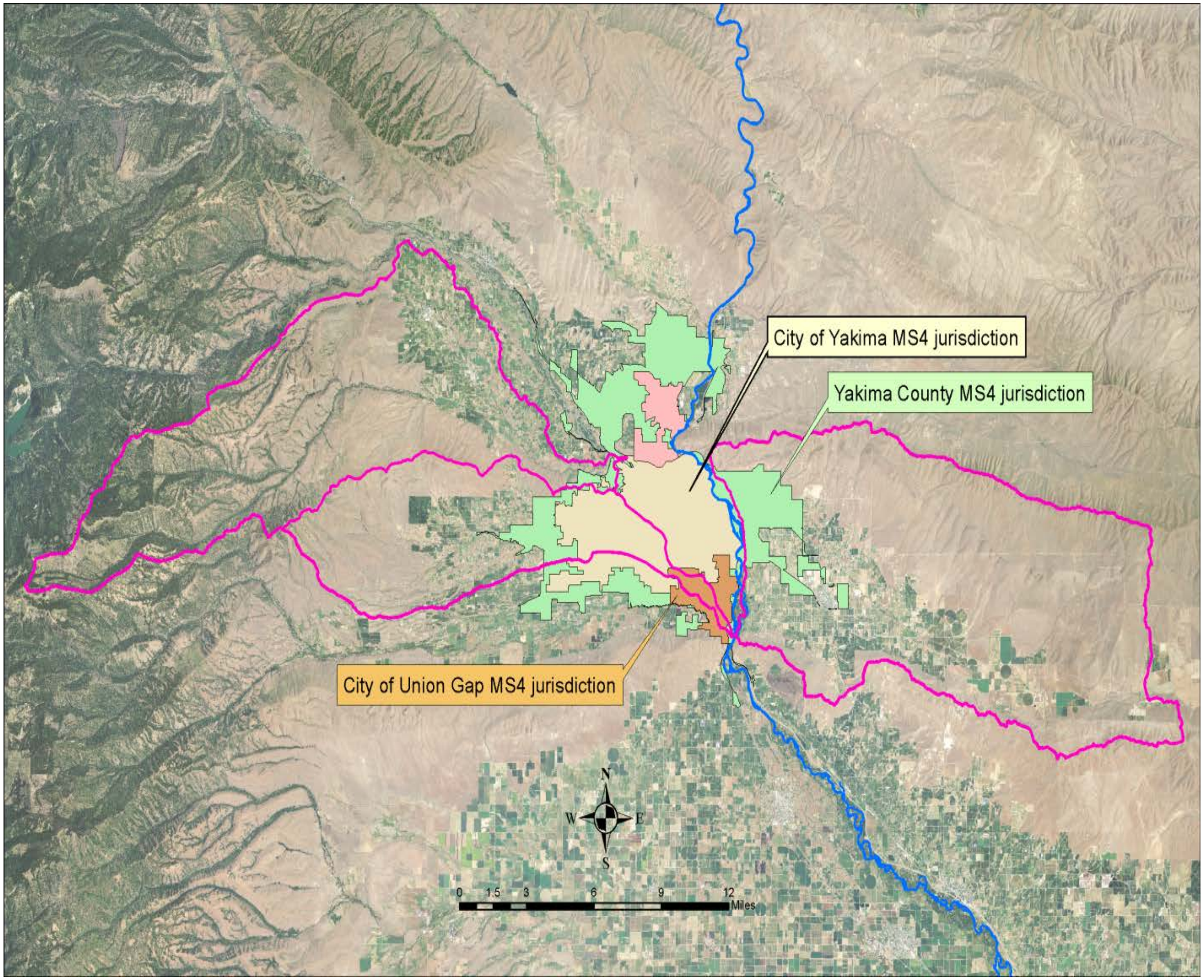

Figure 37: Boundaries of MS4 stormwater jurisdictions.

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Implementation Strategy

Introduction

This implementation strategy describes what will be done to improve water quality. It explains the roles and authorities of cleanup partners (those organizations with jurisdiction, authority, or direct responsibility for cleanup), along with the programs or other means through which they will address these water quality issues. It prioritizes specific actions planned to improve water quality and achieve State WQS.

After the USEPA approves this TMDL report, interested and responsible parties work together to develop a detailed *water quality implementation plan (WQIP)*. The WQIP describes how fecal coliform bacteria (FCB) pollutant concentrations will be reduced to meet State WQS. The goal of the *Mid-Yakima River Basin Bacteria TMDL* is to meet the WQS by the end of the 2024 irrigation season in all of the water bodies within the Cowiche Creek, the Moxee Drain and the Wide Hollow Creek sub-basins.

Who needs to participate in implementation?

A variety of entities are required to participate in implementation activities related to this TMDL project. The major cleanup partners include, but are not limited to, the following:

- Yakima County is the lead agency of the RSPG. It has jurisdiction over several Phase 2 for municipal separate storm sewer systems (MS4) stormwater areas, and also operates and maintains all of the DID ditches within the TMDL project area.

- The Yakima Health District (YHD) is responsible for addressing failing on-site septic systems (OSSS) throughout the TMDL project area.

- The city of Yakima and the city of Union Gap have MS4 stormwater discharges in the Wide Hollow Creek sub-basin.

- The Cowiche Regional publicly owned treatment works (POTW) discharges effluent in the Cowiche Creek sub-basin.

- The WA Department of Fish and Wildlife (WDFW) is responsible for FCB pollution runoff from feeding areas where wildlife is concentrated.

- The Washington State Department of Transportation (WSDOT) is responsible for MS4 stormwater discharges from its maintenance facility in the city of Union Gap, as well as from State highways throughout the TMDL project area.

- All fresh fruit packing facilities have stormwater discharges, and some even have process wastewater discharges to surface waters within the TMDL project area.

- Private landowners within the TMDL project area are responsible for their direct discharges, OSSS, and stormwater discharges. Those landowners who operate animal feeding operations or manure application sites should be especially aware of preventing irrigation and stormwater drainage from manure-contaminated areas.

- The WDFW needs to be aware of possible FCB pollution adjacent to its Cowiche Unit of the Oak Creek Wildlife Area (RM 4.2 to 7.7). The agency needs to maintain adequate berming of all wildlife feeding areas to prevent the runoff of contaminated stormwater.

What needs to be done?

BMPs to achieve compliance with this TMDL

The greatest reduction of FCB pollution in surface waters throughout the TMDL project area is expected to occur from implementing BMPs and AKART that will: (1) reduce irrigation and stormwater drainage flows, (2) prevent turbid runoff from reaching receiving water bodies, and (3) eliminate surface water disturbance mechanisms.

Table 59 presents a variety of BMPs that can be utilized to reduce FCB pollution delivered by urban stormwater drainage.

Table 59: Urban stormwater BMPs for reducing FCB pollution.

Type of BMP	Description of Activity
Impervious surface reduction	Promotes infiltration and reduces drainage volumes.
Maintenance	Includes: routine removal of street debris (street sweeping), management of animal (both domestic and wild) wastes, improved landscape maintenance, and structures (grit chambers) to retain coarser materials.
Sediment control	Includes: mulch or geotextiles to filter drainage, structural barriers (e.g., check dams and berms) and silt curtains to trap and retain suspended material.
Retention/detention systems	Use ponds, bio-retention, and subterranean chambers to: store stormwater runoff, reduce erosion and minimize soil loss. Stored water is subsequently released or allowed to infiltrate.
Infiltration systems	Use of vegetated basins, trenches, or on-site dry swales to increase infiltration.
Constructed wetlands	Create wetlands to retain suspended material, while providing wildlife habitat and aesthetic value. Wetlands can often be incorporated into community landscape improvement efforts.
Infiltration systems	Includes: grassed filter strips, mechanical devices (sand filter chambers, underground filter cascades), and other landscape designs for removing suspended material.

Concerning the large "resident" population of waterfowl in the Randall Park pond, a robust public education campaign should be implemented to educate citizens on how their actions can affect water quality. It should include signage (Figure 38) to discourage waterfowl feeding. Local ordinances may also be enacted and enforced to discourage these activities.

Figure 38: Example of waterfowl signage.

Table 60 presents a variety of techniques to improve BMP efficiency that reduce FCB pollution in urban stormwater drainage.

Table 60: Techniques to improve efficiency of urban stormwater BMPs.

BMP Improvement Technique
Create high light conditions in the water column of ponds and wetlands. For example, storage should be provided in a series of separate, interconnected, and shallow cells.
Provide at 2-5 days of retention/detention time to promote greater settling. Alternatively, engineers could size BMPs based on a smaller minimum design particle (i.e. 15 microns).
Design inlet and outlet structures of BMPs to prevent bottom sediments from being re-suspended and exported.
Reduce turf and open water areas around ponds to prevent the establishment of a resident waterfowl population, which can become a significant FCB source.
Add shallow benches and wetland areas to ponds to enhance the plankton community and, therefore, increase predation of FCB.
Disconnect rooftop gutter system from discharging to a municipal sewer system and connect to an on-site infiltration systems.
If filtering practices are used, employ finer-grained media in the filter bed with a small diameter (i.e. 15 microns), or at least provide a finer-grained layer at mid-depth in the filter profile. The typical “concrete-grade” sand used in most sand filters may be too coarse-grained to reduce FCB concentrations unless the treatment duration is extended for 40 hours or more.
Remove trapped sediments from filter pretreatment chambers on a more frequent basis during the irrigation season. In addition, “dry” pretreatment chambers may be more desirable since FCB-laden sediment would be subject to both sunlight and desiccation. In general, sand filters should be physically oriented to provide maximum solar exposure.
Consider infiltration systems as a priority. Given sufficient pretreatment and soil filtering depth and duration, these BMPs have the potential to achieve bacterial removal rates comparable to functioning OSSS.
Conveyance systems should be lined, and either self-cleaning or cleaned annually to remove sediment deposition.
An ideal stream buffer should be composed of two lateral zones: a depression area that leads to an infiltration system. The depression is designed to capture and store drainage during small storm events and to by-pass large drainage amounts directly into the infiltration system (i.e. zero discharge situation).
Most OSSS have an average design life-span of 20 years. All older OSSS should be inspected to ensure whether rehabilitation or replacement is necessary.
Develop rated charts for key stormwater discharge points. Rated charts will show a relationship between stormwater volume, area of impervious surface, discharge volume and FCB concentrations.

BMPs for agricultural operations that will achieve compliance with this TMDL

Agricultural operations shall not create any discharges of pollutants to state waters (90.48 RCW). Table 61 presents recommended BMPs that can be utilized to prevent FCB pollution delivered by agricultural irrigation and stormwater drainage. Persons engaged in agricultural operations who implement and maintain the recommended BMPs will be presumed to be in compliance with the TMDL and State Water Pollution Control Act (90.48 RCW). If an agricultural operation is applying all recommended BMPs and a violation of water quality criteria remains, the operator may be required to modify existing practices or apply further water pollution control measures, selected or approved by the department, to achieve compliance with water quality criteria. Alternative BMPs may be used if they provide equivalent protection to the set of BMPs listed in Table 61.

Table 61: Agricultural BMPs for preventing FCB pollution.

Name of BMP	Description of Activity
Livestock Practices	
Riparian Buffer	The riparian buffer must be a minimum of 35 feet wide from the top of the streambank measured horizontally, and include the reestablishment of streamside vegetation sufficient to filter out pollutants before they reach the stream, and stabilize stream banks. The buffer may need to be wider based site-specific characteristics. Further, the buffer width may need to be wider to mitigate pollutants and criteria not addressed by this TMDL. Ecology recommends that a 75-foot buffer be implemented on perennial waters (50 feet, if non-fish bearing perennial) to ensure compliance with State water quality standards.
Exclusion Fence	Exclusion fence must be used to prevent livestock access to the riparian buffer. Animals should also be excluded from flooded or seasonally inundated areas during periods of saturation. The use of hardened stream crossings should be used for all animal movement across the riparian zones.
Off-Stream Water Facility	Off-stream water facilities must to be set back a minimum of 100 feet from surface waters unless it can be demonstrated that there is no suitable site more than 100 feet from surface waters. In the latter case, Ecology must approve a design plan to prevent contamination of State waters.
Animal Confinement and Feeding Areas	Animal confinement and feeding areas must be set back a minimum of 100 feet from surface waters unless it can be demonstrated that there is no suitable site more than 100 feet from surface waters. In the latter case, Ecology must approve a design plan to prevent contamination of State waters. A 100-foot buffer must also be established around all surface inlets and vents to subsurface drainage that is located beneath and within the boundaries of the animal confinement and feeding areas. Animal confinement and feeding areas must be sited away from locations that will concentrate runoff or increase the potential for polluted runoff to reach surface water such as steep slopes, unstable or erodible soils, natural or constructed drainages, or topography that concentrates runoff. Confinement areas must be stabilized with compacted gravel or concrete to allow for manure collection and prevent erosion.
Dry Manure Management	Livestock manure must be collected, stored, composted and utilized in a manner that prevents contamination of State waters. Manure must be stored and composted in appropriately constructed waste management facilities. Waste management facilities must be set back a minimum of 100 feet from surface waters unless it can be demonstrated that there is no suitable site more than 100 feet from surface waters. In the latter case, Ecology must approve a design plan to prevent contamination of State waters. A 100-foot buffer must also be established around all surface inlets and vents to subsurface drainage that is located beneath and within the boundaries of the manure storage and composting areas. Waste storage facilities must be designed to provide adequate storage based on the volume of manure generated by the operation, be covered, and installed on an impermeable surface. Clean water must be diverted from waste storage facilities through the use of gutters, berms, roofs, or other means of conveyance to prevent contact with manure. Clean water must be diverted from confinement areas through the use of gutters, berms, roofs, or other means of conveyance to prevent contact with manure. All manure must be utilized in a manner that prevents contamination of State waters. Application of dry manure to fields must be consistent with the Nutrient Application BMPs listed below in the section labeled Cropland Practices.

Name of BMP	Description of Activity
Liquid Manure Management	Livestock manure must be collected, stored and utilized in a manner that prevents contamination of State waters. Liquid manure must be stored in appropriately designed and constructed waste storage lagoons. Waste storage lagoons must be set back a minimum of 100 feet from surface waters unless it can be demonstrated that there is no suitable site more than 100 feet from surface waters. In the latter case, Ecology must approve a design plan to prevent contamination of State waters. A waste storage lagoon must never be constructed directly above or within a 100-foot horizontal distance of any subsurface drainage pipe. This includes small-diameter tile in-field drainage, as well as large-diameter collector drains, that are completely covered over with soil. Waste storage lagoons must be designed to provide adequate storage based on the volume of manure generated by the operation, as well as for the local area's 25-year, 24-hour storm event volume. The lagoon volume must also include sufficient volume for an extra 4 months of manure production, as no wastewater application is allowed during the winter months. Waste storage lagoons must, at a minimum, consist of a single 60-mil HDPE geo-membrane liner installed over a 12-inch thick soil bed. Clean water must be diverted from waste storage facilities through the use of gutters, berms, roofs, or other means of conveyance to prevent contact with manure. All liquid manure must be utilized in a manner that prevents contamination of State waters. Application of liquid manure to fields must be consistent with the Nutrient Application BMPs listed below in the section labeled Cropland Practices.
Cropland Practices	
Riparian Buffer	The riparian buffer must be a minimum of 35 feet wide from the top of the streambank measured horizontally, and include the reestablishment of streamside vegetation sufficient to filter out pollutants before they reach the stream, and stabilize stream banks. The buffer may need to be wider based site-specific characteristics. Further, the buffer width may need to be wider to mitigate pollutants and criteria not addressed by this TMDL. Ecology recommends that a 75-foot buffer be implemented on perennial waters (50 feet, if non-fish bearing perennial) to ensure compliance with State water quality standards
Irrigation Water Management	Irrigation systems should apply the amount of water needed by the crop in a manner to limit waste, prevent surface losses of nutrient and soil, and prevent nutrient leaching. In no event should runoff occur when using any irrigation method. Rill irrigation should be eliminated.
Nutrient Application	No manure shall be applied within riparian buffers. All sources of nutrients should be accounted for when determining recommended application rates for crops. Nutrient applications should be based on soil testing by field. Nutrient applications rates shall be commensurate with crop removal and crop growth patterns, and consistent with university recommendations, standard agricultural practices or a nutrient management plan for the farm. To prevent surface or leaching losses, nutrient shall be applied to crops at times closest to plant uptake. Manure must not be applied between October 1 and March 1. Additionally, manure must not be applied to saturated, frozen or snow covered soils, in flood prone areas during seasons when flooding or inundation is likely, or within 48 hours of a forecasted precipitation event.
Sediment and Erosion Control	Cropland shall be cultivated in such a manner that minimizes soil and nutrient loss.

Summary Implementation Strategy

Table 62 presents a *summary implementation strategy* (SIS) of BMP activities that have been determined by Ecology to be necessary for locating and reducing sources of FCB pollution throughout the *Mid-Yakima River Basin Bacteria TMDL* project area. Specific activities are ordered by priority, with 1 being the highest priority and 3 being the lowest priority.

Table 62: Summary Implementation Strategy

Yakima County	Priority
Work with local land owners to identify FCB sources and provide technical assistance for eliminating those sources from drainage conveyances and local surface waters through landowner-driven, voluntary stewardship approaches.	1
Target outreach to landowners with livestock within the County's MS4 jurisdiction to implement BMPs that reduce FCB.	1
Comply with all requirements contained within the County's NPDES stormwater permit.	1
Focus BMP implementation on at least one mile of streamside property per year.	2
Implement applicable BMPs in order to meet WLAs established in this WQIR.	2
City of Yakima	
Comply with all requirements contained within the facility's NPDES stormwater permit.	1
Target outreach to land owners within City's jurisdiction to implement BMPs that reduce FCB.	1
Implement applicable BMPs in order to meet WLAs established in this WQIR.	2
City of Union Gap	
Comply with all requirements contained within the facility's NPDES stormwater permit.	1
Target outreach to land owners within City's jurisdiction to implement BMPs that reduce FCB.	1
Implement applicable BMPs in order to meet WLAs established in this WQIR.	2
Yakima Valley Community College	
Comply with all requirements contained within the facility's NPDES MS4 stormwater permit.	1
Implement applicable BMPs in order to meet WLAs established in this WQIR.	2
Fresh Fruit Packing Facilities	
Comply with all requirements within the Fresh Fruit Packing Industry NPDES General Permit.	1
Implement applicable BMPs in order to meet WLAs established in this WQIR.	2
If FCB are found in discharges at concentrations exceeding WLAs, then must implement disinfection.	3
WSDOT	
Comply with all requirements within the agency's NPDES municipal stormwater permit.	1
Implement applicable BMPs in order to meet WLAs established in this WQIR.	2
Ecology	
Complete the WQIP for the *Mid-Yakima River Basin Bacteria TMDL*.	1
Target outreach to landowners outside of the RSPG's jurisdiction to implement BMPs that reduce FCB leaving their properties.	1
Collect monthly water quality samples of Moxee Creek upstream and downstream of the Devries Family Farms dairy located in the upper Moxee Drain sub-basin throughout 2016 and 2017.	2
Seek funding to assist landowners within TMDL project area.	2
Take whatever actions are necessary in order to achieve compliance with State WQS.	3
Landowners with livestock	
Implement all Structural Practices BMPs that are listed in Table 53.	2

The BMP activities in Table 62 should not be considered all-inclusive. The items listed have been used in watershed FCB mitigation in the past. The wide array of activities allows the technical advisory workgroup (TAW) members to select those that will have the greatest ability to cause water quality improvement. As FCB dynamics are further examined and understood, the suggested BMP activities will be updated and reflected in the future WQIP.

The goal of the *Mid-Yakima River Basin Bacteria TMDL* is to meet State WQS. Doing so supports the designated uses of *primary contact recreation* and *extraordinary primary contact recreation*, and ultimately delisting the presently FCB impaired surface waters within the TMDL project area. It is important and legally necessary to utilize AKART to achieve the overall goal.

Measuring progress toward goals

This WQIR contains specific actions to be undertaken by the various involved entities associated with the *Mid-Yakima River Basin Bacteria TMDL*. It is recommended that all involved entities work together to allocate sufficient resources to ensure that all TMDL project area surface waters comply with State WQS for FCB by May 2027.

To track the progress of the TMDL, Ecology will assist local agencies in conducting a biennial review of water quality monitoring data and status reports from organizations responsible for achieving bacteria reductions. Each biennial review will include an open meeting format to encourage information sharing and will, at a minimum, address the following three questions:

(1) Does monitoring data indicate sufficient progress is being made toward meeting the interim and final target reductions?

(2) Is each involved entity fulfilling its implementation commitment as contained in this WQIR?

(3) If implementation is occurring on schedule but the interim target reductions are not being met, then what additional activities or alternative approaches will be implemented? This is called Adaptive Management.

Ecology will conduct the first biennial review of water quality data in 2019 (two years after TMDL commencement). It is acknowledged that future monitoring will probably be needed to identify all FCB sources and meet the TMDL's WLAs, LAs and target reductions. The success of the TMDL project will be assessed at each biennial review using the monitoring data collected from, at a minimum, the same sites that were initially sampled by Ecology as identified in the "Sampling Design" section of this WQIR. The participating entities may monitor additional sites as they deem necessary.

What is the schedule for achieving water quality standards?

Water quality monitoring shall begin in January 2017. All participating agencies are responsible for developing and implementing a water quality monitoring program within their respective jurisdictions. Ecology will work with the other involved entities to ensure monitoring of the remaining TMDL project area.

Bi-monthly (Level 1) monitoring will be required at each sampling site, during May through November of each year. Water quality data will be reviewed after each two years of monitoring at the biennial reviews. After the first two irrigation seasons following USEPA approval, if any sampling site does not show a significant (via K-S analysis) decrease from the corresponding original data utilized by this WQIR (2004-06 and 2010 surveys), then a weekly (Level 2) monitoring schedule shall commence with the next irrigation season. Once started, Level 2 monitoring shall continue each year until significant progress has been determined.

If at any time future monitoring indicates that a point source, not previously identified as a known FCB source, is discharging FCB pollution to a surface water, then Ecology will contact the applicable point source and require:

(1) Its participation in the TMDL project.

(2) The submittal of an NPDES permit application.

(3) If already under NPDES permit, to modify the permit to contain the WLAs applicable to the Cowiche Regional POTW as well as to begin Level 1 monitoring of its discharges.

Monitoring progress

A monitoring program for evaluating progress is an important component of any implementation strategy. Monitoring is needed to keep track of what activities have or have not been done, measure the success or failure of target pursuit actions, and evaluate improvements in water quality. Monitoring should also be done after WQS are achieved (compliance monitoring) to ensure that standards continue to be met.

Monitoring implementation actions and how they will be maintained

Compliance monitoring will be needed when WQS are believed to have been achieved.

Entities with enforcement authority are responsible for following up on any enforcement actions. Stormwater permittees and point-source permittees are responsible for meeting the requirements of their permits. Those conducting restoration projects or installing BMPs are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing.

The WQIP will describe the coordinated monitoring strategy.

Effectiveness Monitoring Plan

Effectiveness monitoring determines if the interim targets and State WQS have been met after the BMP activities described in this WQIR have been implemented and are functioning properly.

Effectiveness monitoring of TMDL projects is usually conducted by Ecology but may also be conducted by another entity, if pre-approved by Ecology.

Effectiveness monitoring of the TMDL project is conducted after several years once a TMDL has been approved by the USEPA. Effectiveness monitoring is distinct from the Level 1 and Level 2 monitoring described in the "What is the schedule for achieving water quality standards?" section of this WQIR.

Before effectiveness monitoring is performed, a quality assurance project plan (QAPP) must be prepared and approved by Ecology. The QAPP must follow Ecology guidelines (Lombard and Kirchmer, 2004), paying particular attention to consistency in sampling and analytical methods. Monitoring objectives should clearly be established to ensure that sampling results will meet those objectives. Monitoring personnel will consult with the *Mid-Yakima River Basin Bacteria TMDL* Ecology project manager to determine the critical areas of the monitoring and to verify sampling locations.

Effectiveness monitoring will compare the results from BMP activity implementation against attainment of State water quality FCB criteria, which is the ultimate goal of the TMDL. Ecology and the involved entities for the *Mid-Yakima River Basin Bacteria TMDL* will review all effectiveness monitoring data and use it to:

- Assess the effectiveness of the BMPs and other actions and how they are maintained.
- Determine the quality of water after BMP implementation and estimate when State water quality FCB criteria will be achieved.

Ecology and the TAW will be responsible for publishing all Effectiveness Monitoring Reports for the *Mid-Yakima River Basin Bacteria TMDL*. All of the entities with enforcement authority will be responsible for following up with enforcement actions, if needed, within their respective jurisdictions. All NPDES Permittees will be responsible for meeting the requirements of their individual permits. Participating entities implementing BMPs will be responsible for the adequate operation and maintenance of those BMPs during the entire year.

Adaptive management

Natural systems are complex and dynamic. The way a system will respond to human management activities is often unknown and can only be described as probabilities or possibilities. Adaptive management involves testing, monitoring, evaluating applied strategies, and incorporating new knowledge into management approaches that are based on scientific findings. In the case of TMDL projects, Ecology uses adaptive management to assess whether the BMP activities identified as necessary to resolve the FCB pollution problems are the correct ones and whether they are working.

As actions are implemented, the system will respond, and it will also change. Adaptive management allows actions to be more effective, and to try new strategies if evidence exists that a new approach could help achieve compliance with the *Mid-Yakima River Basin Bacteria TMDL*'s goal of compliance with State WQS.

Compliance with State WQS should be achieved by November 2024 through the use of interim and final targets that are described in both numerical LAs and WLAs, and as target reductions. Partners will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the implementation strategy as needed.

Ecology will use adaptive management when water monitoring data show that the TMDL targets are not being met or implementation activities are not producing the desired result. Figure 39 is a generalized feedback loop for TMDL adaptive management.

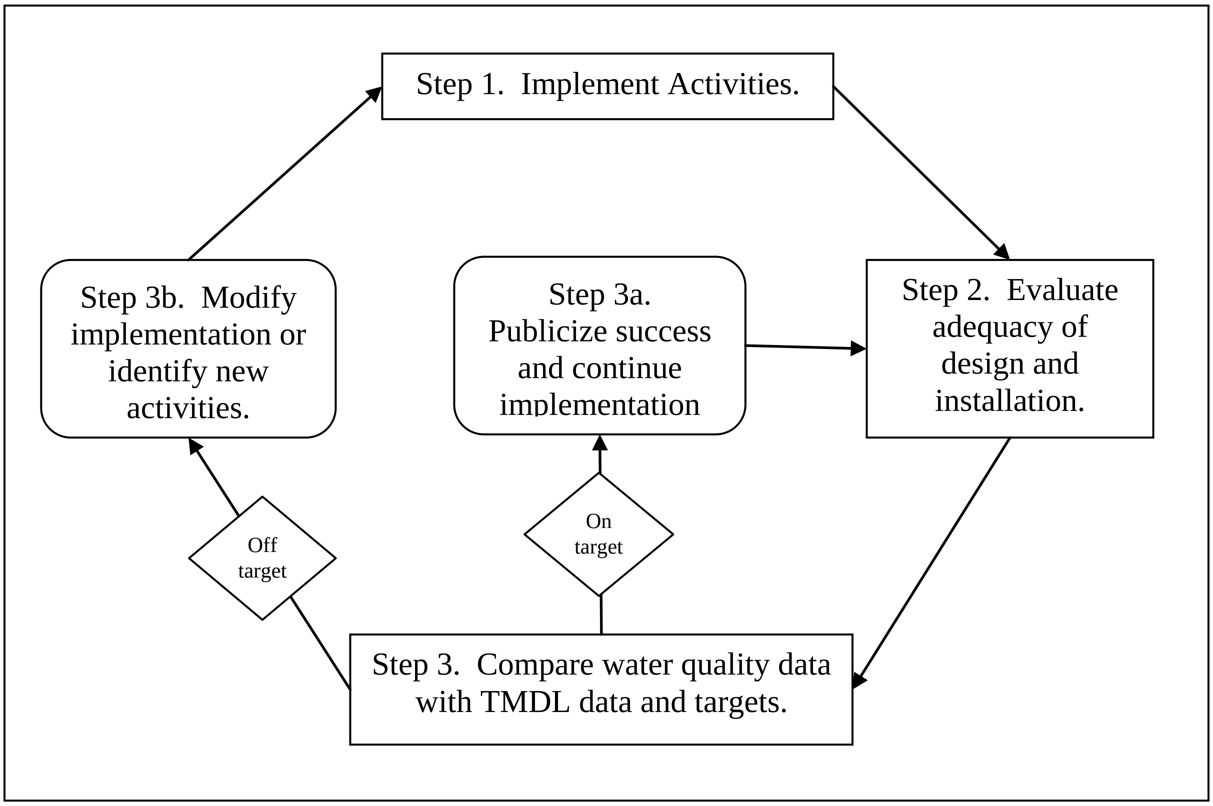

Figure 39: Feedback loop for determining need for adaptive management.

The basic steps in feedback loop are as follows:

Step 1. The BMP activities described in this WQIR are implemented.

Step 2. The BMP activities are evaluated for technical adequacy of design and installation.

Step 3. The effectiveness of the BMP activities is evaluated by assessing new monitoring data and comparing it to the data used to set the TMDL project targets.

Step 3a. If the TMDL's goals and objectives are achieved, the implementation efforts are considered adequate as designed, installed, and maintained. Project success and accomplishments should be publicized and reported to continue project implementation and increase public support.

Step 3b. If not, then BMP activities must be modified or new activities identified. The new or modified activities are then applied as in Step 1.

Ecology is authorized under Chapter 90.48 RCW to issue enforcement actions to achieve compliance with State WQS. However, it is the goal of the *Mid-Yakima River Basin Bacteria TMDL* process to achieve clean water primarily through voluntary control actions. Ecology will consider the issuance of notices of noncompliance, in accordance with the Regulatory Reform Act, whenever it deems them necessary to achieve the goals of the TMDL.

Entities with enforcement authority will be responsible for following-up on any enforcement actions within their jurisdictions. All NPDES permittees are responsible for meeting the requirements of their permits. Those conducting restoration projects or installing BMPs will be responsible for monitoring plant survival rates and maintenance of improvements, structures, and fencing.

Additional monitoring may be necessary to better isolate the bacteria pollution sources so that new BMPs can be designed and implemented to address all sources of bacteria within the TMDL project area. It is ultimately Ecology's responsibility to assure that BMP implementation is being actively pursued and that the State WQS are achieved.

Potential funding sources

Financial assistance for water quality improvement activities is available through Ecology's grant and loan programs, State salmon recovery and outdoor recreation grants, North Yakima Conservation District cost-share programs, Yakima County programs, and other sources (Table 63). Ecology will work with stakeholders to identify funding sources and prepare appropriate scopes of work to help implement the *Mid-Yakima River Basin Bacteria TMDL*.

Table 63: Potential funding sources for BMP implementation.

Sponsor	Fund	Uses
Department of Ecology, Water Quality Program	Centennial Clean Water Fund, Section 319, and State Revolving Fund www.ecy.wa.gov/programs/wq/funding	Facilities and water pollution control-related activities with priorities include: implementing water quality implementation plans (TMDLs); keeping pollution out of streams and aquifers; modernizing aging wastewater treatment facilities; reclaiming and reusing wastewater.
Department of Ecology, Shorelands, and Environmental Assistance Program	Coastal Zone Protection Fund Watershed Planning www.ecy.wa.gov/watershed/index.html	Limited grants for on the ground projects funded by penalty monies collected by the WQP.
State Conservation Commission	www.scc.wa.gov/index.php/contact/Conservation-Districts	Various environmental program grants.
State Public Works Board	Public Works Trust Fund www.pwb.wa.gov/Program_Information.asp	Provides financial assistance to local government and private water systems. It supports public works projects and encourages independence at the local level.
State Recreation and Conservation Funding Board	Recreation and Conservation Office www.rco.wa.gov/rcfb/grants.asp	Provides grants for habitat restoration, land acquisition and habitat assessment.
Office of Interagency Committee, Salmon Recovery Board	Salmon Recovery Funding Board www.iac.wa.gov/srfb/grants.asp	Provides grants for habitat restoration, land acquisition and habitat assessment.
Natural Resources Conservation Service	Emergency Watershed Protection www.nrcs.usda.gov/programs/ewp/index.html	NRCS purchases land vulnerable to flooding to ease flooding impacts.
Natural Resources Conservation Service	Wetland Reserve Program www.wa.nrcs.usda.gov/programs/wrp/wrp.html	Landowners may receive incentives to enhance wetlands in exchange for retiring marginal agricultural land.
Natural Resources Conservation Service	Conservation Programs www.nrcs.usda.gov/programs	To help landowners improve water quality and increase wildlife habitat.
Natural Resources Conservation Service	EQIP (Environmental Quality Incentive Program) www.nrcs.usda.gov/programs/eqip	Voluntary conservation program that promotes environmental quality as a compatible national goal; includes cost-share funds for farm BMPs.
Natural Resources Conservation Service	AWEP (Agriculture Water Enhancement Program) www.nrcs.usda.gov/programs/AWEP	Offers financial and technical assistance for enhancement activities that improve water quality on agricultural lands.
U.S. Environmental Protection Agency	Watershed Funding www.epa.gov/owow/funding.html	Provides tools, databases, and information on funding sources that can be used to protect watersheds.
North Yakima Conservation District	Federal Conservation Reserve Enhancement Program (CREP)	Provides conservation easements; cost-share for implementing agricultural/riparian BMPs.

Summary of public involvement methods

Appendix B contains a summary of all of the public involvement methods utilized in conjunction with the Mid-Yakima River Basin Bacteria TMDL.

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Appendices

Appendix A. Glossary, Acronyms, and Abbreviations

Glossary

303(d) List: Section 303(d) of the federal CWA requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited water bodies (ocean waters, estuaries, lakes, and streams) that fall short of State WQS and are not expected to improve within the next two years.

Basin: A large drainage area in which all land drains and water bodies flow toward a specific surface water at a lower elevation. It is analogous to a watershed.

Best management practices (BMPs): Physical, structural, or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act (CWA): A federal act passed in 1972, and subsequently revised, that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the act establishes the TMDL program.

Critical condition: The time period which exemplifies the scenario of environmental and pollutant loading conditions in the water body in which the level of pollution for the parameter of concern exceeds the State WQS. It can be seasonal, hourly, or some other period of time.

Designated uses: Those uses specified in Chapter 173-201A WAC (*Water Quality Standards for Surface Waters of the State of Washington*) for each water body or segment, regardless of whether or not the uses are currently attained.

Die-off: Reduction in FCB population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Existing uses: Those uses actually attained in fresh waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

Extraordinary primary contact: Waters requiring extraordinary protection against waterborne disease.

Fecal coliform bacteria (FCB): That portion of the coliform group of bacteria, which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2°C. FCB are "indicator" organisms that suggest the presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100mL).

Geometric mean: A mathematical value that is representative of "average" long-term pollution. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the calculation of an arithmetic mean. It is used for analysis of bacteria concentration data because that data is typically not normally distributed. The calculation is calculated by taking the antilogarithm of the arithmetic mean of the logarithms of the individual values. For this WQIR it was calculated by Microsoft® EXCEL software. It is also referred to as the "geomean".

Illicit connection: Any manmade conveyance that is connected to a MS4 without a permit, excluding roof drains and other similar type connections.

Illicit discharge: Any discharge to a MS4 that is not entirely composed of stormwater.

Irrigation drainage: That portion of applied irrigation water that does not naturally percolate deep into the ground or evaporate, but instead runs off the land surface to which it was applied. It also includes applied irrigation water that percolates into the root zone and is transported away through subsurface drainage.

Load allocation (LA): The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet State WQS.

Margin of safety (MOS): Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

Municipal separate storm sewer systems (MS4): A conveyance, or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by the State, county, city, town, district, association, or other public entity having jurisdiction over disposal of wastes, stormwater, or other wastes, including special districts under State Law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe, or a designated and approved management agency under section 208 of the CWA that discharges to waters of the United States; (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a POTW as defined at 40 CFR 122.2.

According to 40 CFR 122.26(b)(16)iii, small MS4s (population less than 100,000) includes systems similar to separate storm sewer systems in municipalities, such as; (1) military bases; (2) large hospitals; (3) prison complexes; and (4) highways and other thoroughfares. The term does not include separate storm sewers in very discrete areas such as individual buildings.

National Pollutant Discharge Elimination System (NPDES): National program for issuing and revising permits, as well as imposing and enforcing pretreatment requirements, under the CWA. The program regulates discharges from POTWs, commercial/industrial factories, and other facilities that discharge wastewater back into surface waters of the State.

Natural background levels: Levels of a pollution parameter representing the chemical, physical, and biological conditions that result from naturally-occurring wildlife, weather and other environmental processes.

Nonpoint source: Pollution that enters any waters of the State from any dispersed land-based or water-based activities, including, but not limited to, the following: (1) atmospheric deposition; (2) surface water runoff from agricultural lands, urban areas, or forest lands; (3) subsurface or underground sources; or (4) discharges from boats or marine vessels not otherwise regulated under the NPDES program. It is any source of water pollution that does not meet the legal definition of *point source* in section 502(14) of the CWA.

Parameter: A physical, chemical, or biological property whose values determine environmental characteristics of a water body.

Phase 2 stormwater permit: The second phase of stormwater regulation required under the federal CWA. This NPDES permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre. An urbanized area is automatically designated Phase II if the population is at least 50,000 and has an overall population density of at least 1,000 people per square mile based on the 2000 Census.

EPA regulations require Phase 2 entities to develop stormwater programs that address the following six minimum control measures: (1) public education and outreach; (2) public participation/involvement; (3) illicit discharge detection and elimination (IDDE); (4) construction site runoff control; (5) post-construction runoff control; and (6) pollution prevention/good housekeeping.

State regulations require Phase 2 entities to address the following three additional elements: (1) compliance with all applicable TMDL WLAs; (2) monitoring, reporting, and record keeping requirements; and (3) use, where feasible, low impact development (LID) techniques to control stormwater.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water and that are not specified as *non-point* in federal regulations. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than five acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the State. This includes change in temperature, taste, color, turbidity, radioactivity, or odor of the waters. This definition assumes that the changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence of any bodily orifice including, but not limited to, skin diving, swimming, and water skiing.

Reach: A specific portion or segment of a stream.

Riparian: Transitional zone between aquatic and upland areas. The riparian area has vegetation or other physical features reflecting permanent influence on surface water or subsurface water.

Statistical threshold value (STV): A mathematical value that is representative of worst-case, short-term pollution. It estimates the 90th percentile of a set of non-parametric data. For the *Mid-Yakima River Basin Bacteria TMDL*, the value is calculated by the non-parametric Hazen method (Appendix C).

Stormwater: That portion of natural precipitation that does not naturally percolate into the ground or evaporate, but instead runs off the surface onto which it was applied. It is typically associated with impervious surfaces (such as: pavement, sidewalks, parking lots, and roofs) and occurs during storm events and periods of snow melt. It may also be associated with hard, compacted or saturated naturally pervious surfaces such as lawns, pastures, playfields, and agricultural lands.

Surface waters of the State: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the boundaries of Washington State.

Total maximum daily load (TMDL): A TMDL can be either numeric or narrative in nature and both types are designed to protect a water body from exceeding State WQS. A numeric TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a MOS to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided. A narrative TMDL is the Water Quality Improvement Report (WQIR) that is prepared for bringing a water body listed on the State's 303(d) list on non-compliant water bodies back into compliance with State WQS.

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

Wasteload allocation (WLA): The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. WLAs constitute one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Zoonotic: A pathogen that can be passed from animals to humans and cause disease in the latter. Examples are: bubonic plague, Rocky Mountain spotted fever, and *E. coli* O157:H7.

Acronyms and abbreviations

BMP	Best management practice
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
FCB	Fecal coliform bacteria
LA	Load allocation
MOS	Margin of safety
MS4	Municipal separate storm sewer system
N.F.	North Fork
NPDES	National Pollutant Discharge Elimination System
OSSS	On-site septic systems
POTW	Publicly-Owned Treatment Works
RM	River mile
S.F.	South Fork
STV	Statistical threshold value
TAW	Technical advisory workgroup
TMDL	Total maximum daily load (water cleanup project)
TSS	Total suspended solids
USEPA	U.S. Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WLA	Wasteload allocation
WQIP	Water quality improvement plan
WQIR	Water quality improvement report
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation

Units of Measurement

°C	degrees centigrade
cfu	colony forming units
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mi^2	square mile
mL	milliliters

Appendix B. Record of Public Participation

Introduction

Public participation with all TMDLs is a requirement of the USEPA, prior to their approval of the TMDL. Ecology has always complied and acknowledges the absolute merit of such requirement. Public participation with the *Mid-Yakima River Basin Bacteria TMDL* is documented by the following information, which will be completed after the public comment period.

Summary of comments and responses

[xx]

List of public meetings

A public meeting on the draft WQIR was held on [XXX], 2015 at the Yakima Convention Center prior to its publishing. A 30-day comment period was started at the same time.

Outreach and announcements

Ecology distributed a news release on June 26, 2012 concerning the fecal bacteria pollution in the mid-Yakima River basin (Cowiche Creek, Wide Hollow Creek, and Moxee Drain). This re-introduced the general public to the basic problem and informed them of the TMDL's TAW reformation.

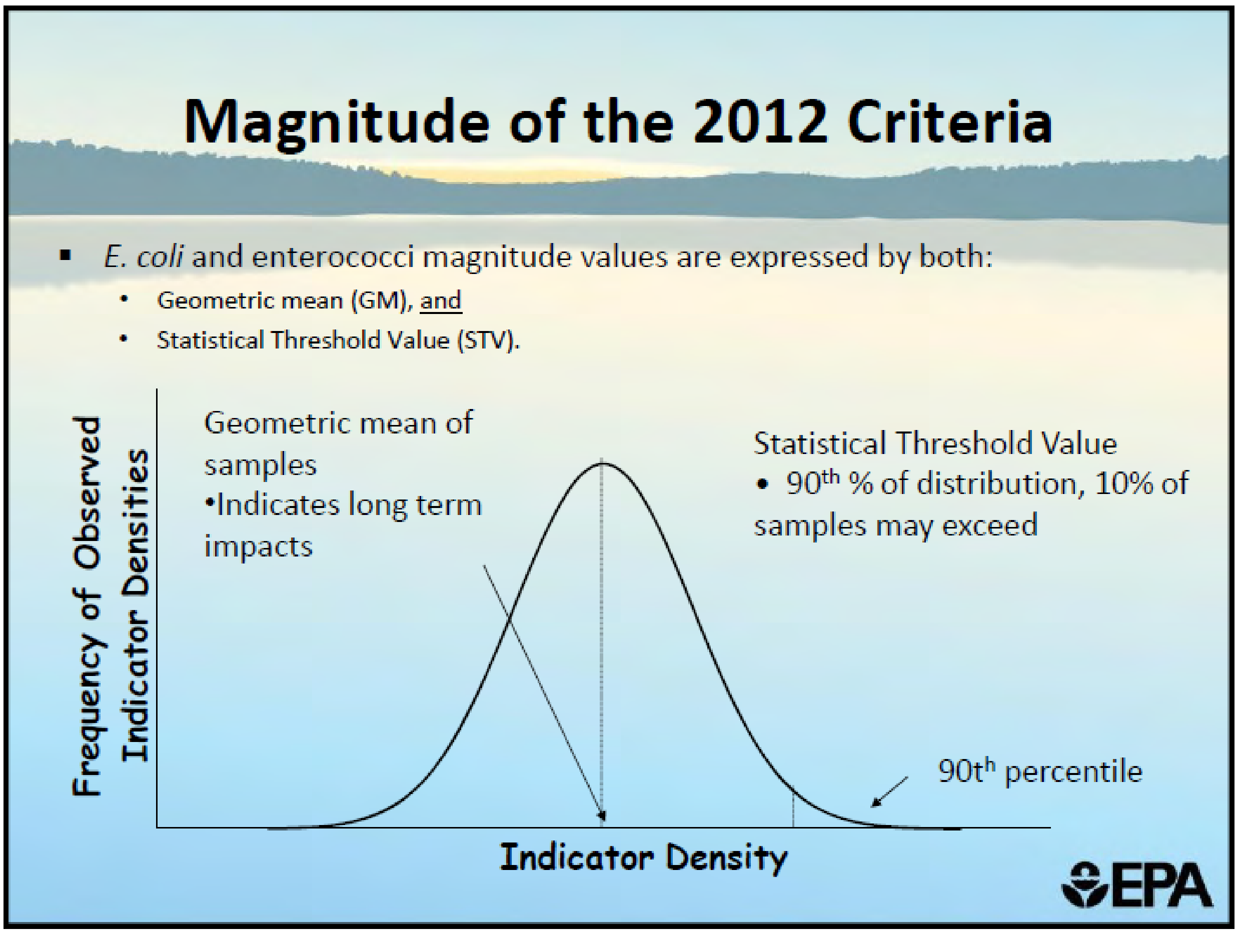
The Yakima Herald-Republic published on July 17, 2012 an article on bacteria pollution within the TMDL project area. The article was instigated by an Ecology news release regarding the *Mid-Yakima River Basin Bacteria TMDL*.

Ecology An advertisement was placed in the Yakima Herald-Republic on [XXX], 2015 regarding the public meeting and public comment period regarding the draft *Mid-Yakima River Basin Bacteria TMDL WQIR*. A final version of the WQIR, that includes responses to the public comments, will be submitted to USEPA for approval.

Appendix C. Hazen Method for Calculating STVs

Data set percentile calculations include various methods, both parametric and nonparametric. Ecology typically utilizes the EXCEL® spreadsheet to calculate a 90th percentile statistic for comparison to the State's secondary FCB criterion contained in the State's WQS. However, WAC 173-201A-200(2)(b) does not explicitly state that a 90th percentile must be utilized. State regulations contain only the following narrative: *with not more than 10% of all samples obtained for calculating the geometric mean value.*

The USEPA recently devised a new measurement that has a definition nearly identical to the above narrative. The measurement is called the Statistical Threshold Value (STV) and was first presented in the USEPA's 2012 Recreational Water Quality Criteria recommendations. The STV represents the 90th percentile of set of bacteria data and thus the short-term, worst-case scenario.



The use of a statistically-calculated STV has resulted in several “false-positive” and “false-negative” exceedances of the State’s WQS. Instances of both conditions were found upon review of the *Mid-Yakima River Basin Fecal Coliform Bacteria Total Maximum Daily Load: Water Quality Study Findings* that was published in September 2012.

Bacteria sampling data are typically log-normally distributed. It is often easier and more precise to use nonparametric methods for calculating an STV. The Hazen method is a nonparametric method that is the least-biased estimator of a statistical percentile (Hunter, 2002). In fact, USEPA Region 4 regularly uses the Hazen method in developing bacteria TMDLs

To coincide with the State’s WQS, the Hazen method should only be used when a data set contains 10 or more values. Data sets with less than 10 values must explicitly use their maximum values as the STV. Directions for using the Hazen method are as follows:

1. Rank all of the *n* values in a data set from lowest to highest.

2. Assign a Hazen Rank (HR) of “1” to the lowest value and proceed, in order, with the rest of the values in the data set.

3. Calculate the Hazen percentile applicable to each HR using the formula:
   (HR – 0.5)/(total number of data values in data set).

For example, a FCB concentration of 133 cfu/100 mL will be assigned a HR of 14 out of a total of 34 values. Its respective Hazen percentile is calculated as: (14 – 0.5) / 34; or, 0.40, which equals 40%. This implies that 40 percent of the time, the instream FCB concentration is less than 133 counts/100 mL.

The STV for any data set containing 10 or more values will be the ranked value corresponding to a Hazen percentile of 90%.

The use of the Hazen method for determining compliance with bacteria standards is widespread throughout the world and the United States. The European Bathing Directive determined that the Hazen method was the most appropriate method for calculating percentiles, since it results in a more conservative approach (more protective of bathers) for classifying water quality. The Governments of Argentina and New Zealand also utilize the Hazen method in their bacteria programs. California, Alaska and Florida (and others) also use the Hazen method for bacteria TMDLs.

Appendix D. Response to Public Comments

This appendix will be completed after the public comment period that is required prior to TMDL submittal to the USEPA.