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DEPARTMENT OF
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Dungeness Bay
Fecal Coliform Bacteria
Total Maximum Daily Load Study

March 2004

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Dungeness Bay
Fecal Coliform Bacteria
Total Maximum Daily Load Study

by
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Environmental Assessment Program
Olympia, Washington 98504-7710

March 2004

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Table of Contents

Page

List of Figures and Tables ii

Abstract iii

Acknowledgements iv

Introduction 1

Study Area 3

Background 5

Dungeness Bay Circulation and Bathymetry 7

Water Quality Standards and Resource Impairments 9
- Washington State Water Quality Standards for Bacteria 9
- Washington State Department of Health Shellfish Harvesting Criteria 10

Water Quality Sampling Methods 11
- Seasonal Grouping for Dungeness Bay 12
- Laboratory Methods 13
- Water Quality Monitoring Results 13

Total Maximum Daily Load Analysis 19
- Seasonal Variation and Critical Conditions 19
- Technical Analysis and Modeling Approach 20
- Fecal Coliform Loading 21
- Load and Wasteload Allocations 25
- Fecal Coliform Loading Sources 29
- Margin of Safety 30
- TMDL Schedule, Actions, and Monitoring 31

References 35

Appendix: Compliance with Water Quality Standards for Fecal Coliform Bacteria

List of Figures and Tables

Page

Figures

Figure 1. Study zone sub-areas and sampling station locations..3

Figure 2. 2003 Department of Health Shellfish Harvesting Status of Dungeness Bay 5

Figure 3. Location of ditch outfalls to inner Dungeness Bay 12

Figure 4. Geometric mean fecal coliform concentrations in ditches discharging to Dungeness Bay, 2001-2002..16

Figure 5. 90th percentile fecal coliform concentrations in ditches discharging to Dungeness Bay, 2001-2002..16

Figure 6. Dungeness Bay fecal coliform loading (billions/day), calculated from concentration multiplied by flow, November - February 23

Tables

Table 1. Waterbodies not meeting water quality standards for fecal coliform bacteria in Dungeness Bay and tributaries, including ditches 6

Table 2. Washington State Water Quality Criteria for Fecal Coliform Bacteria and U.S. Department of Agriculture DOH Shellfish Harvesting Standard 9

Table 3. Description of marine study zones and list of sampling stations.......................11

Table 4. Description of freshwater sample sites 12

Table 5. Dungeness Bay annual summary statistics for fecal coliform surface and sub-surface sample areas, October 2001 - September 2002 17

Table 6. Annual and seasonal fecal coliform loading estimates for Dungeness RM 0.1, October 2001 - September 2002 20

Table 7. Annual water inflow and outflow to inner Dungeness Bay year, October 2001 - September 2002 21

Table 8. Dungeness Bay fecal coliform loading sources, November 2001 - February 2002..22

Table 9. Fecal coliform loading reductions necessary to meet water quality standards for Dungeness Bay marine sites and the Dungeness River during the critical period 25

Table 10. Fecal coliform concentrations, geometric mean, and 90th percentile for Dungeness RM 0.1 and sub-area 2 for coincident sample events.....................26

Table 11. Fecal coliform loading reductions to meet Class AA freshwater standards for the ditches, October 2001 - September 2002..27

Table 12. DOH fecal coliform concentrations for Dungeness Bay, October 2001 - September 2002..28

Abstract

The Washington State Department of Ecology prepared a total maximum daily load (TMDL) study for fecal coliform bacteria in Dungeness Bay and ditches to inner Dungeness Bay. The study summarizes information from a technical study of the bay conducted by Rensel Associates Aquatic Sciences Consultants.

From October 2001 through September 2002, Rensel sampled numerous sites in the inner and outer Dungeness Bay, the Dungeness River, and six ditches (irrigation and stormwater) to the inner bay. Sites were sampled for fecal coliform, salinity, and temperature. Surface and sub-surface samples were obtained under a variety of environmental conditions. Rensel also conducted circulation and reflux studies.

In order to meet the Class AA marine water quality standard of 14 fecal coliform (fc)/100 mL geometric mean and 43 fc/100 mL 90^{th} percentile, fecal coliform reductions of 41% for west inner Dungeness Bay and 65% for the convergence zone are required during the November – February critical period. A year-round 60% reduction in bacteria is required for Dungeness Bay near the mouth of the Dungeness River. Rensel's data confirm the TMDL bacteria target value set for the Dungeness River of 13 fc/100 mL geometric mean and 43 fc/100 mL 90^{th} percentile. Bacteria reductions needed in the ditches vary from 33 - 97% during the November – February critical period.

TMDL recommendations for Dungeness Bay include (1) practices to control pollution to irrigation and stormwater ditches and (2) monitoring during the non-irrigation season to determine the extent and location of fecal coliform pollution. For the Dungeness River, actions for reducing bacteria inputs include continuing to implement recommendations in the *Water Cleanup Plan for Bacteria in the Lower Dungeness Watershed* (Hempleman and Sargeant, 2002).

Acknowledgements

The author would like to thank the following people for their contribution to this study:

- Jack Rensel for all his work on Dungeness Bay including continued technical assistance, comments, and review of this TMDL study.

- Morris Clemmer, Hansi Hall, Chris Hempleman, Joe Holtrup, Mike Jeldness, Laurie Mann, Kim McKee, Don Melvin, Lyn Muench, Pam Sanguinetti, and Valerie Streeter for review and comments of this TMDL study.

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Introduction

The Washington State Department of Ecology (Ecology) is required by the federal Clean Water Act to conduct a total maximum daily load (TMDL) evaluation for waterbodies on the 303(d) list. The 303(d) list is a set of waterbodies that are not meeting water quality standards.

The TMDL evaluation begins with a water quality technical study. The technical study determines the loading capacity of the waterbody to absorb pollutants and still meet water quality standards. The loading capacity is allocated among load and wasteload sources.

- If pollution comes from diffuse (nonpoint) sources, that share of the load is called a load allocation.
- If the pollutant comes from a discrete (point) source, such as a wastewater treatment plant discharge, that facility's share of the loading capacity is called a wasteload allocation. There are no point source discharges and, therefore, no wasteload allocation in this project area.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or a waterbody's loading capacity. The sum of the load and wasteload allocations and the managing of safety must be equal to or less than the loading capacity of the system.

The study also evaluates the likely sources of those pollutants and the amount of pollutant sources that needs to be reduced to reach that capacity. The technical study becomes the basis for water quality based controls. In this case, the technical study for Dungeness Bay was conducted by a contractor to the Jamestown S'Klallam Tribe, Rensel Associates Aquatic Sciences Consultants.

This document recommends total maximum daily pollutant loads based on the results of the Rensel study. Ecology will work with other agencies and local citizens to identify best management practices and actions needed to control water pollution, based on the sources found in the study.

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Study Area

Dungeness Bay is located on the Olympic Peninsula near the eastern end of the Strait of Juan de Fuca. The bay is partly enclosed within a sand spit that extends 8.4 km eastward into the strait (Figure 1). The Dungeness River is the main freshwater tributary to Dungeness Bay. The river is the source of water to about 270 km of irrigation ditches; return flow from some of the irrigation ditches discharges back to the river near the mouth and directly to the inner bay (Rensel, 2003). During the non-irrigation season, the irrigation ditches also convey stormwater.

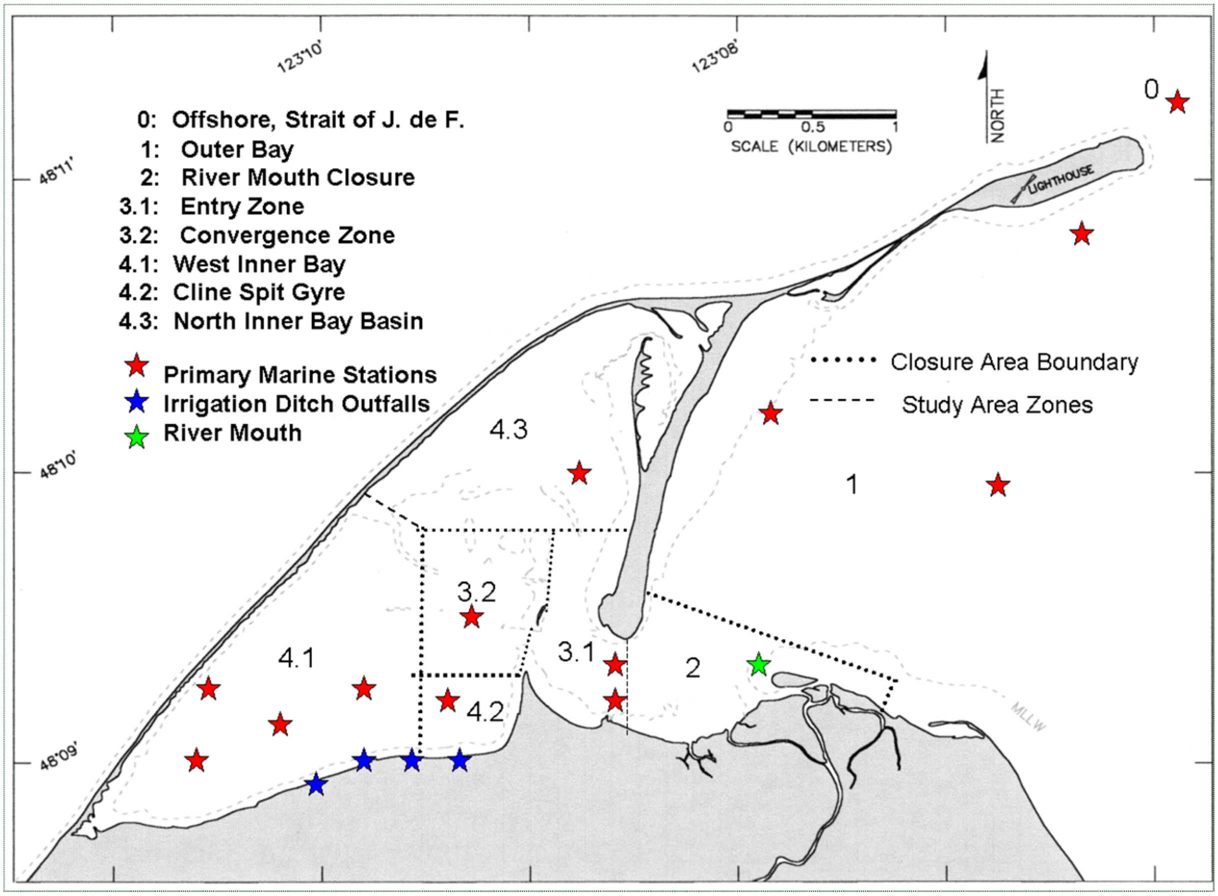

Figure 1. Study zone sub-areas and sampling station locations from Rensel (2003).

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Background

The Washington State Department of Health (DOH) reported increasing levels of fecal coliform bacteria in Dungeness Bay (Figure 2) near the mouth of the Dungeness River in 1997 (DOH, 1998). Since then bacteria levels have continued to increase, with higher levels occurring in inner Dungeness Bay as well. As a result, in 2000 DOH closed 300 acres near the mouth of the Dungeness River to shellfish harvest: stations 104, 105 and 113 (Figure 2). In 2001, 100 more acres in the vicinity of station 108 were added to the closure area. In 2003, DOH changed the classification of the inner bay to "conditionally approved" for shellfish harvest. This classification would require the “conditionally approved” portion of Dungeness Bay be closed to shellfish harvest each year from November 1 through January 31 (Melvin, 2003). The three stations near the mouth remain closed to shellfish harvest year-round, and an additional station (114) was added to the year-round closure.

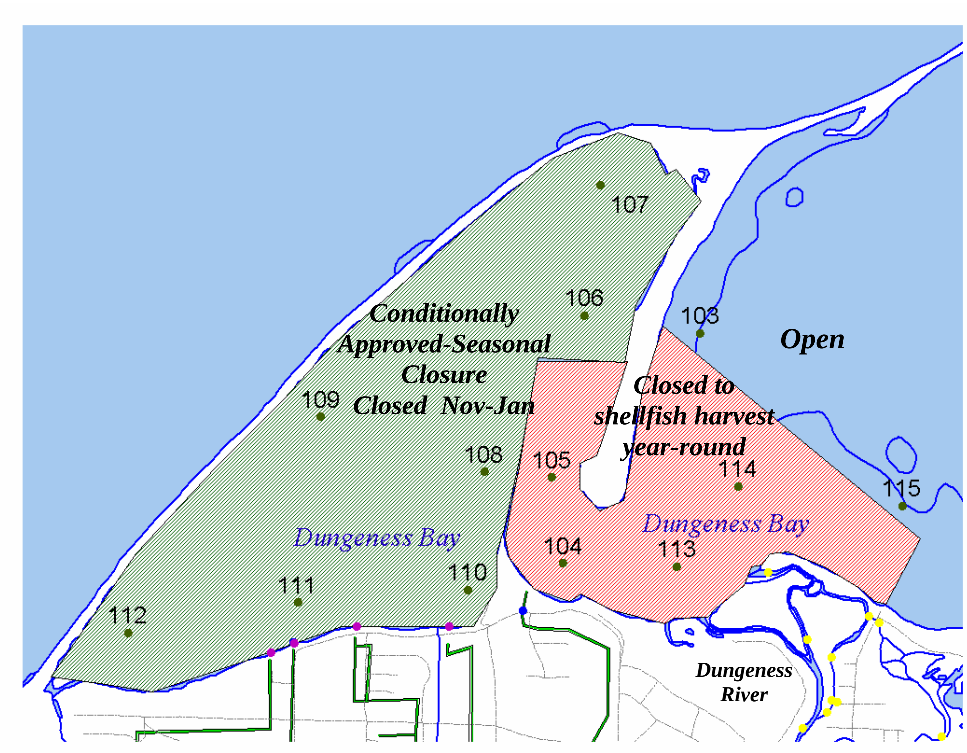

Figure 2. 2003 Department of Health Shellfish Harvesting Status of Dungeness Bay (Streeter, 2003).

In part due to concerns about high bacteria levels in Dungeness Bay, in 2002 Ecology completed a fecal coliform bacteria TMDL study of the Dungeness River, Matriotti Creek, and several tributaries that flow into the Dungeness Bay area. TMDL recommendations included a more stringent fecal coliform target for the Dungeness River and bacteria loading reductions for the tributaries to Dungeness Bay (Sargeant, 2002).

Due to increasing concerns about water quality in the bay and the possibility of marine sources, the Jamestown S'Klallam Tribe hired a consultant, J.E. Jack Rensel, Ph.D., of Rensel Associates Aquatic Sciences Consultants, to conduct a study of Dungeness Bay. Sampling for Phase One of the study focused on circulation patterns in the bay (Rensel and Smayda, 2001). Phase Two focused on collecting and providing information to be the technical basis for a Dungeness Bay TMDL study (Rensel, 2003).

This report summarizes information from Rensel's technical report to develop the TMDL for Dungeness Bay. This TMDL study addresses fecal coliform bacteria in inner and outer Dungeness Bay, the Dungeness River, and ditches to the inner bay.

Table 1 lists the two water quality areas that do not meet water quality standards. Neither of these areas was included on the 1998 303(d) list, but they are expected to be on the 2002 list.

Table 1. Waterbodies not meeting water quality standards for fecal coliform bacteria in Dungeness Bay and tributaries, including ditches to the inner bay.

Waterbody	Watercourse ID	Township, range, section	1998 303(d) List	Proposed for 2002 303(d) List
Dungeness Bay	390KRD	31N 04W 23, 24, 39, 41	No	Yes
Irrigation Ditches to Inner Bay	none	31N 04W 26, 27, 38, 39	No	Yes

Dungeness Bay Circulation and Bathymetry

In addition to conducting bacterial sampling, Rensel conducted several circulation, bathymetry, and reflux studies on Dungeness Bay. A full description of results can be found in Rensel (2003) and Rensel and Smayda (2001).

Rensel (2003) compared 2000 inner Dungeness Bay water volume to water volume in 1967. In 2000, inner Dungeness Bay appears to have 35% less volume than 1967 for depths below mean low tide (zero foot or meter datum). Intensive drogue surveys were used to determine the amount of ebb tide water leaving the inner bay and the amount of water that returns on the following flood tide (reflux).

Reflux was experimentally measured to be 45%. This value is much higher than many Puget Sound bays, but not surprising given the large area of outer Dungeness Bay. This means approximately 45% of the water leaving the inner bay returns back to the same area within a single tidal cycle. As explained in Rensel (2003), such a high reflux rate significantly slows the effective flushing of water from the inner bay and leads to conservation of water quality properties that differ significantly from those observed in the Strait of Juan de Fuca.

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Water Quality Standards and Resource Impairments

Applicable water quality criteria are the state standards for fecal coliform bacteria in fresh and marine waters. The resource impairment is shellfish rearing, spawning, and harvesting, under WAC 173-201A-030 (b) (iii). Commercial shellfish harvesting is subject to standards under the National Shellfish Sanitation Program administered by DOH. These standards are essentially the same as the state water quality standards for Class AA and A marine water. This study is based on the state water quality standards, but DOH shellfish standards also are included for completeness.

Washington State Water Quality Standards for Bacteria

Table 2 lists the water quality criteria for marine classification AA and freshwater classifications A and AA. Freshwater standards apply where 95% of the vertically-averaged daily maximum salinity values are less than or equal to 10 parts per thousand or greater; otherwise marine standards apply (Chapter 173-201A WAC).

Table 2. Washington State Water Quality Criteria for Fecal Coliform Bacteria (Ch. 173-201A WAC) and U.S. Department of Agriculture DOH Shellfish Harvesting Standard.

Fecal coliform bacteria	Class AA marine water	DOH shellfish harvesting standard	Class A fresh water	Class AA fresh water	TMDL target for Dungeness R. RM 3.2 to mouth (Sargeant, 2002)
Shall not exceed a geometric mean value of (number of colonies/100 mL)	14	14	100	50	13
With not more than 10% of samples exceeding (number of colonies/100 mL)	43	--	200	100	--
A 90th percentile not to exceed	--	43	--	--	43

Dungeness Bay is identified as a Class AA marine waterbody in WAC 173-201A-140 as part of the Strait of Juan de Fuca. The bay supports recreational harvest of salmon and bottom fish, and provides important salt marsh habitat and eelgrass beds for brant, fish, crab, and other shellfish. Dungeness crab, oysters, hardshell clams, butter clams, and horse clams are harvested commercially and recreationally in Dungeness Bay (PSCRBT, 1991). Other activities in the area include recreational waterfowl hunting, bird watching, nature study, hiking and beach combing, and commercial and recreational boat use.

The Jamestown S'Klallam Indians have harvested fish and shellfish from Dungeness Bay for food, trade, and cultural ceremonies for thousands of years. In addition to subsistence harvest in the bay, the tribe currently harvests clams commercially; they own and operate commercial oyster and clam farms in the bay (Muench, 1999).

The Dungeness River and Matriotti Creek TMDL established a bacteria target level for the mouth of the Dungeness River (river mile 0.1) of 13 fecal coliform (fc) per 100 mL geometric mean, and 43 fc/100 mL 90th percentile (Sargeant, 2002). Meadowbrook Creek and other tributaries to Dungeness Bay are Class AA freshwater. In accordance with the water quality standards, all surface waters that are tributaries to Class AA waters (Dungeness Bay) are Class AA, unless otherwise classified.

Classification of ditches to inner Dungeness Bay is not specifically designated in the water quality standards. While water for the irrigation ditch system is obtained from Class A freshwater (Dungeness River at approximately RM 6.0), the ditch irrigation water and stormwater discharge to Class AA waters (Dungeness Bay). In order to protect the beneficial use of shellfish harvesting in Dungeness Bay, irrigation ditches discharging to the bay should, at a minimum, meet Class AA freshwater standards for bacteria.

Washington State Department of Health Shellfish Harvesting Criteria

DOH applies guidelines for shellfish harvest set by the National Shellfish Sanitation Program (NSSP) in its classification program. Before an area is classified for shellfish harvest, DOH must collect 30 water samples for fecal coliform bacteria from each sampling station in the growing area. The samples must be collected under a variety of environmental conditions. Two statistics (geometric mean and 90th percentile) are calculated from the 30 water samples. These are compared to the NSSP Growing Area Criteria described below. Both water quality criteria must be met in order to meet NSSP requirements.

1. The geometric mean is not to exceed 14 MPN[1]/100 mL in water.
2. The 90th percentile is not to exceed 43 MPN[1]/100 mL of water (applied to areas where only nonpoint sources are present); or 10% of the results are not to exceed 43 MPN/100 mL of water (applied when one or more point sources of pollution are present).

In addition, DOH surveys the upland watershed and the marine shoreline to find and assess pollution sources. An area cannot be approved for harvest if the survey reveals significant pollution threats, even if water quality is good (Determan, 2003).

DOH uses the MPN method for fecal coliform laboratory analysis. Ecology may use either the MPN method or the membrane filter (MF) technique for laboratory analysis of fecal coliform samples. The data presented in this study are based on the MF technique.

[1] Most Probable Number. This represents a statistically-based estimate of the concentration of fecal coliform bacteria.

Water Quality Sampling Methods

The sampling period for the consultant's study is October 2001 - September 2002 (Rensel, 2003). The monitoring strategy involved sampling a variety of flood and ebb conditions, from average to extreme, and included surface and sub-surface sampling at 0.1 meter and 2/3 total water depth (from top of water column), respectively. Figure 1 and Table 3 describe locations of sub-area and fixed sampling stations in the marine environment. Some stations were primarily for characterizing fecal coliform and related conditions, while other stations were intended to provide information for the mass balance model (Rensel, 2003).

Table 3. Description of marine study zones and list of sampling stations from Rensel (2003).

Marine study area zones	Primary stations	Other stations	Purpose of primary station and notes
0 - Offshore	1	0	Reference area, Strait of Juan de Fuca
1 - Outer bay	2	3	Near lighthouse and center of bay routine stations. Others in main channel.
2 - River mouth	1	1	River mouth station moved with tide, channel station less frequently measured. North channel station representing marine water and a south channel station to verify river plume.
3.1 - Entry area	1	3	Stations in Cline Spit passage (west side of sub-area) and upstream to downstream stations near seal haul out area on Cline Spit Island.
3.2 - Convergence area	1	1	To west of Cline Spit Island in poorly flushed area. Name is derived from flood tide entering around both sides of Cline Spit Island.
4.1 - West inner bay	4	1	Multiple main stations in western area to cover a large area and possible variation.
4.2 - Cline Spit gyre	1	1	Persistent counterclockwise gyre in small area near boat ramp.
4.3 - North basin	1	1	Main station north and east of Cline Spit Island.

Figure 3 and Table 4 describe the locations of ditch sample stations. The ditches are part of the lower Cline irrigation system; however, only ditches 2, 4, and 5 are in irrigation use during the April 15 - September 15 period (Clemmer, 2003). The purpose of these stations was to quantify non-riverine freshwater bacteria loading impacts to Dungeness Bay.

A full description of methods, quality assurance/quality control programs, and water quality results can be found in Rensel (2003).

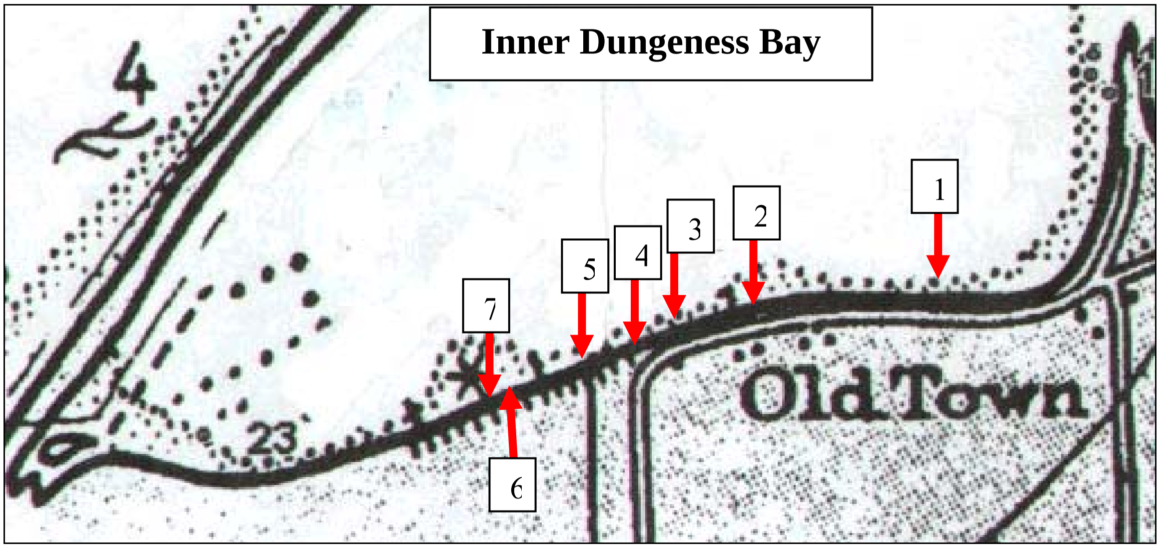

Figure 3. Location of ditch outfalls to inner Dungeness Bay (Rensel, 2003).

Table 4. Description of freshwater sample sites.

Station	Location
Dungeness River RM 0.1	Dungeness River at the Northern Conservation Farm
Ditch 1	Inner Bay at 48.1501499 N, 123.1560474 W
Ditch 2	Inner Bay at 48.1501379 N, 123.1615627 W
Ditch 3	Inner Bay at 48.1498313 N, 123.1640600 W
Ditch 4	Inner Bay at 48.1493384 N, 123.1652547 W
Ditch 5	Inner Bay at 48.1490078 N, 123.1668986 W
Ditch 7	Inner Bay at 48.1482684 N, 123.1696922 W

Note: Ditch 6 was not flowing during any sample events

Seasonal Grouping for Dungeness Bay

Rensel assigned seasonal periods, with river flow and fecal coliform concentration patterns being the primary consideration. Wildlife abundance patterns also were considered. The following seasons were established:

- Season 1: November through February
- Season 2: March through July
- Season 3: August through October

In comparison, the Dungeness River and Matriotti Creek TMDL (Sargeant, 2002) was based on year-round conditions with seasonal conditions being considered: irrigation season (April - September) and wet season (November - February). The year-round presence and variation of wildlife in the bay indicated the need for a different seasonal definition (Rensel, 2003).

Laboratory Methods

The membrane filter (MF) method was used in this study's laboratory analysis of fecal coliform. Both the MF and the most probable number (MPN) method are consistent with the state water quality standards for fecal coliform bacteria. DOH uses the MPN for fecal coliform laboratory analysis.

Membrane Filter and Most Probable Number Comparison

The MF method calls for samples of varying dilutions to be passed through a membrane filter. The membrane is then placed on an appropriate medium and incubated under specified conditions. Discrete bacteria colonies are counted after 24-48 hours, and the population density of the target bacteria is described as the number of colony-forming units (CFU) per 100 mL.

The MPN analysis is a statistical method based on the random dispersion (Poisson) of microorganisms per volume in a given sample. This test is performed as a multiple-tube fermentation test and is based on the presence or absence of gas formed in the tubes representing various dilutions (Metcalf and Eddy, 1991). The major advantage of this technique is that it will accept both clear and turbid samples, and it inherently allows the resuscitation and growth of injured bacteria (Borrego and Figueras, 1997).

The MF technique is more precise than MPN, but the MF test presents the limitation of its exclusive use for low turbidity waters with low concentrations of background microorganisms. The MPN results have a wider confidence interval than MF (less precise) and a positive statistical bias. Some researchers believe the MPN method is better at enumerating injured or stressed organisms (Joy, 2000). Because of the positive bias and better ability to enumerate stressed organisms, MPN may produce higher fecal coliform values than the MF method for the same actual concentrations.

Water Quality Monitoring Results

Water quality monitoring results are described in Rensel (2003) and summarized briefly below.

Compliance with Standards

Annual and seasonal geometric mean and 90th percentile fecal coliform results by sub-area are presented in the appendix of this report. Daily values for each sample area consist of an average of all fecal coliform data in a sub-area for a sample day, including surface and sub-surface samples. The seasonal geometric mean and 90th percentile were calculated from the daily fecal coliform value for the area. The geometric mean was calculated taking the antilog of the mean of the log-transformed data. The 90th percentile was calculated as the antilog of (the mean of the log-transformed data plus 1.28 times the standard deviation of the log-transformed data). The 90th percentile corresponds to a value for which 90% of the observations are expected to lie below it and 10% above. A daily value for an area better represents fecal coliform conditions for the area and day, while obtaining a geometric mean for an area may underestimate fecal coliform values for the area that day.

For Dungeness data, a minimum of five sample events was deemed necessary to determine compliance with standards. However, if fewer than five samples were available, but at least two samples exceeded the 90th-percentile part of the standard, the site was considered to not meet standards. Otherwise the sample size was deemed insufficient to make a compliance determination. The appendix, Compliance with Water Quality Standards for Fecal Coliform Bacteria, includes sample size for each site.

Annual and Seasonal Results

Dungeness Bay

Results for each sub-area in Dungeness Bay were compared to the Class AA marine water quality standard for fecal coliform.

- Sub-areas 0 and 1 (offshore and outer bay area) met water quality standards annually and seasonally. For these areas, both the geometric mean and 90^{th} percentile concentrations were very low, generally less than 10 cfu/100 mL.

- Sub-area 3.1 (entry zone to inner Dungeness Bay) met water quality standards annually and for all seasons.

- Sub-area 4.3 (north inner bay basin) met water quality standards annually and for all seasons, though limited data are available for August - October. For this area, geometric mean and 90^{th} percentile levels were generally low.

- Sub-area 4.1 (west inner bay) met water quality standards annually and for some seasons but did not meet standards during November - February. During this period, surface levels were generally good while the sub-surface samples had the highest bacteria levels.

  Higher sub-surface bacteria levels suggest a sediment or sub-surface reservoir of fecal coliform. Limited sediment sampling throughout the bay showed this area had very low levels of bacteria. Persistently higher sub-surface fecal coliform concentrations were probably related to increased bacteria survival due to darker and cooler winter conditions (Rensel, 2003).

- Sub-area 4.2 (Cline Spit gyre) had fecal coliform results similar to sub-area 4.1. This area met standards annually and for March - July. There were insufficient sample events to determine if this area met water quality standards during August - October and November - February. As with sub-area 4.1, surface levels were low while sub-surface bacteria levels were high from November - February.

- Sub-area 3.2 (convergence zone) did not meet water quality standards annually or for the August - October and November - February periods. For this area, bacteria levels tend to be higher in the sub-surface during November - February, possibly influenced by sub-areas 4.1 and 4.2 along the inner bay shoreline.

- Sub-area 2 (near the Dungeness River mouth) did not meet water quality standards annually or during March - July and August - October. During periods when standards were not met, sub-surface fecal coliform levels were much lower, while surface levels were higher and did not meet standards. Salinity levels were also much lower on the surface, indicating the influence of freshwater sources. Bacterial sources from the Dungeness River are likely the main contributor of fecal coliform to this area.

Dungeness River

Results for the Dungeness at river mile (RM) 0.1 were compared to the river TMDL target of 13 cfu/100 mL geometric mean and 43 cfu/100 mL 90^{th} percentile. The Dungeness River at RM 0.1 meets Class A freshwater standards for fecal coliform bacteria, but does not meet the TMDL target for fecal coliform bacteria annually or for any season. As with marine sub-area 2, the highest levels are seen during March - July and August - October.

Ditches to Inner Dungeness Bay

The ditches were compared to the Class AA freshwater standard for fecal coliform. The irrigation season begins in mid-April when water is diverted from the Dungeness River to the irrigation ditch system, and generally runs through mid-September; however, the ditches, including those used for irrigation, capture stormwater and associated pollutants year-round. To look at irrigation discharge, two periods were examined: the active irrigation season (April - September) when water is diverted, and the non-irrigation season (October - March). Six of the seven ditches to the inner bay were sampled. Ditch 6 was not flowing during any sample events.

Figures 4 and 5 present seasonal geometric mean and 90^{th} percentile fecal coliform concentrations. Based on monitoring results, fecal coliform concentrations in the ditches are higher during the non-irrigation period when the water stagnates or carries stormwater than when water is actively transferred for irrigation.

Ditches 1, 2, 3, 4, 5, and 7 did not meet Class AA freshwater quality standards for fecal coliform annually or for either of the two analysis periods: active irrigation (April - September) or non-irrigation (October - March). For ditches 1, 2, 4, and 7, non-irrigation season sampling was done. For these ditches, fecal coliform values were highest when the ditches carried stormwater rather than when the ditches transferred Dungeness River water.

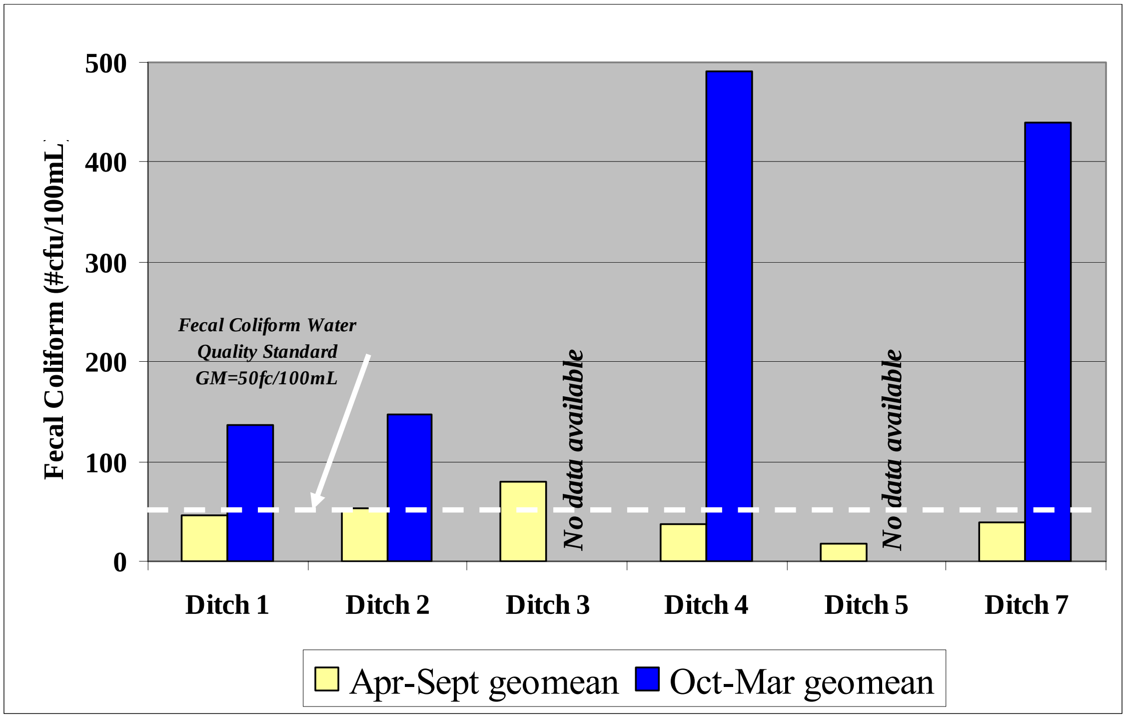

Figure 4. Geometric mean fecal coliform concentrations in ditches discharging to Dungeness Bay, 2001-2002. Seasons correspond to active (April-September) and inactive (October-March) irrigation, respectively.

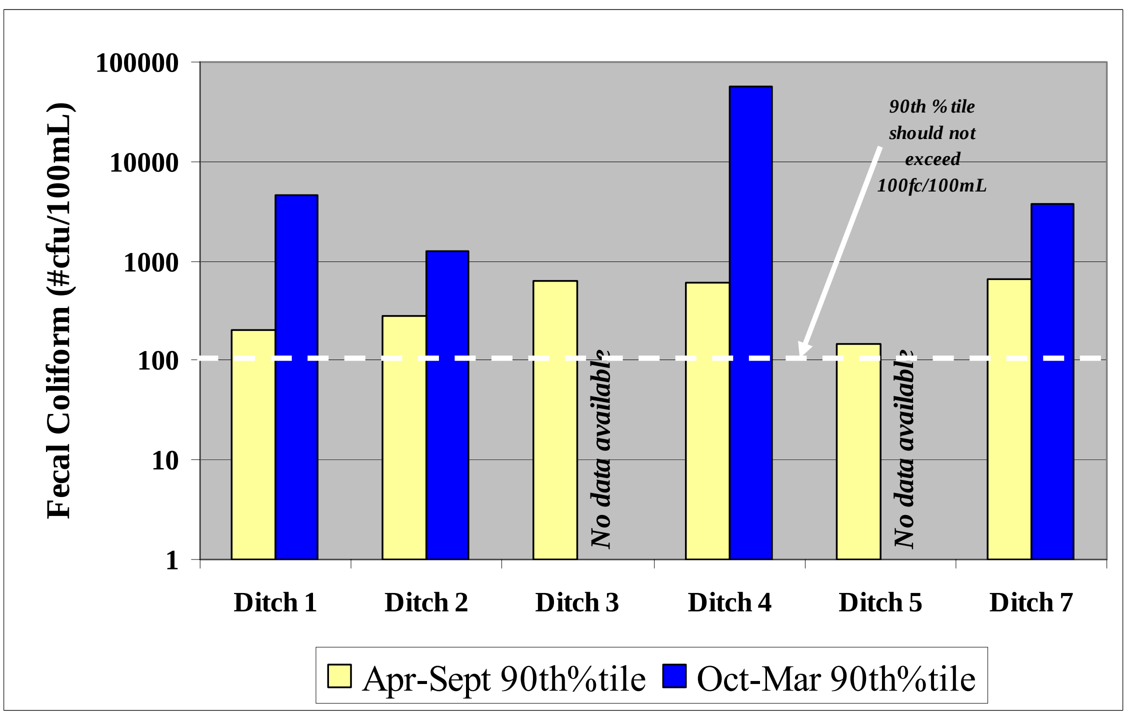

Figure 5. 90th percentile fecal coliform concentrations in ditches discharging to Dungeness Bay, 2001-2002. Seasons correspond to active (April-September) and inactive (October-March) irrigation, respectively.

Surface versus Sub-Surface Fecal Coliform Results for Dungeness Bay

Rensel (2003) analyzed surface and sub-surface sample results by area, depth, and season. Table 5 presents annual surface and sub-surface concentrations for each sub-area. For this analysis, fecal coliform results were partitioned into surface (≤ 0.1 meters) and sub-surface (> 0.1 meters). These results were averaged for the sample day over an area.

- Sub-areas 0 and 1: Fecal coliform levels and salinity were found to be similar.
- Sub-area 2: Data show fecal coliform levels inversely related to salinity for all three seasons.
- Sub-area 3.1: Surface waters had higher fecal coliform concentrations than sub-surface during November - February, but differences were minimal during other seasons.
- Sub-area 3.2: Slightly higher sub-surface fecal coliform concentrations were recorded during November - February.
- Sub-area 4.1: Elevated sub-surface fecal coliform concentrations were noted during November - February.
- Sub-area 4.3: Elevated sub-surface fecal coliform concentrations were seen annually.

Table 5. Dungeness Bay annual summary statistics for fecal coliform surface and sub-surface results by sub-area, October 2001 - September 2002.

Sub-area	Depth (meters)	Average salinity (ppt)	Number of samples	Geometric mean (#/100 mL)	90th percentile (#/100 mL)
0 - Off-shore	≤ 0.10	31.13	16	1	1
	> 0.10	31.33	16	1	2
1 - Outer bay	≤ 0.10	29.16	17	2	7
	> 0.10	31.14	17	2	16
2 - River mouth	≤ 0.10	10.99	17	**16**	**60**
	> 0.10	24.81	12	5	24
3.1 - Entry zone	≤ 0.10	26.63	17	4	30
	> 0.10	30.36	17	3	11
3.2 - Convergence zone	≤ 0.10	29.13	16	5	**45**
	> 0.10	30.43	16	5	35
4.1 - West inner bay	≤ 0.10	29.10	17	2	10
	> 0.10	30.39	17	6	42
4.2 - Cline Spit gyre	≤ 0.10	29.17	13	4	22
	> 0.10	30.35	12	3	22
4.3 - North inner bay	≤ 0.10	28.49	12	2	4
	> 0.10	30.62	12	3	9

Bold – values exceeded water quality standards

A non-parametric Wilcoxon paired sample test (two-tailed test with significance level of alpha=0.05) was used to confirm that statistically significantly higher levels of bacteria occur at the surface for sub-area 3.1. Sub-areas 4.1 and 4.3 had statistically significant higher sub-surface levels of bacteria.

In summary, surface fecal coliform levels are generally higher at sub-areas 2 and 3.1, the river mouth and entry zone. Sub-surface fecal coliform levels are generally higher at sub-area 4.1, the west inner bay, especially during November - February.

Total Maximum Daily Load Analysis

Seasonal Variation and Critical Conditions

Clean Water Act Section 303(d) (1) (C) requires that TMDLs "be established at a level necessary to implement the applicable water quality standards with seasonal variations…". The current water quality regulation also states that the determination of "TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters" [40CFR 130.7(c) (1)]. In Dungeness Bay, the time period and locations of elevated fecal coliform bacteria levels vary throughout the year. Therefore, critical conditions vary by season and location, and load allocations are established based on seasons to account for the variability.

Dungeness Bay

For inner Dungeness Bay:

- Sub-area 4.1 did not meet fecal coliform standards. The highest bacteria concentrations, particularly in sub-surface samples, were detected in November - February.
- Sub-area 3.2, the convergence zone, had highest bacteria levels from August - February.
- Sub-area 3.1, the entry zone, met fecal coliform standards. The highest bacteria levels occurred from August - February.
- Sub-area 2, near the Dungeness River mouth, did not meet standards annually or during March - July and August - October. The highest bacteria levels were detected in March - July.

In summary, the critical period for sub-areas 4.1 and 3.2 in the inner bay is November - February, while the critical period for sub-area 2 near the river mouth is March - October, when the highest bacteria concentrations occur.

Dungeness River

Dungeness River had the highest fecal coliform concentrations during March - October (Rensel, 2003). Fecal coliform loading results are presented in Table 6. To obtain seasonal and annual bacteria loading estimates for the river, daily stream flow data were obtained from Ecology's continuous stream flow gaging station at Dungeness RM 0.8 at Schoolhouse Road bridge (Ecology, 2003).

While fecal coliform concentrations are highest during March - October, loading was highest during November - July. The critical period for this site is year-round. This is consistent with Dungeness River and Matriotti Creek TMDL results where higher bacteria concentrations were seen during the irrigation season (April-September), and bacterial loading was consistent throughout the year, with a slight increase during the wet season.

Table 6. Annual and seasonal fecal coliform loading estimates for Dungeness RM 0.1, October 2001 - September 2002.

Time period	Number of sample events	Average flow discharge for sample period* (cfs)	Arithmetic mean FC concentration for sample period (cfu/100 mL)	FC loading (number of FC per day)
Annual	18	460	24	2.72×10^{11}
Nov - Feb	5	654	17	2.73×10^{11}
Mar - Jul	9	508	27	3.37×10^{11}
Aug - Oct	4	125	27	8.29×10^{10}

* Average flow obtained by averaging daily values for the sampling season.

Ditches to Inner Dungeness Bay

Rensel (2003) calculated fecal coliform loading for three periods: November - February, March - July, and August - October. Rensel found the highest loading from all irrigation ditches total to be during November - February, coinciding with the critical period for the southern inner Dungeness Bay sub-areas. The highest bacterial concentrations for the inner Dungeness Bay ditches were detected during the non-irrigation season of October - March.

Summary

The critical period for the inner bay and the ditches to the bay is November - February. The critical period for the Dungeness River and marine sites near the mouth of the river is the entire year.

Technical Analysis and Modeling Approach

The modeling approach uses the statistical rollback method to determine the load reduction necessary to achieve the fecal coliform water quality standard in Dungeness Bay and tributaries to the bay. The statistical rollback method (Ott, 1995) has been used by Ecology to determine the necessary reduction for both the geometric mean value (GMV) and 90th percentile bacteria concentration (Joy, 2000) to meet water quality standards. Compliance with the most restrictive of the dual fecal coliform criteria determines the bacteria reduction needed.

Fecal coliform sample results for each site in this study were found to follow lognormal distributions. The 90th percentile was calculated as the antilog of the mean of the log-transformed data plus 1.28 times the standard deviation of the log-transformed data.

The rollback method uses the statistical characteristics of a known data set to predict the statistical characteristics of a data set that would be collected after pollution controls have been implemented and maintained. In applying the rollback method, the target fecal coliform GMV and the target 90th percentile are set to the corresponding water quality standard. The reduction needed for each target value to be reached is determined. The rollback factor, $f_{rollback}$, is

$$f_{rollback} = \text{minimum } \{(\text{fecal coliform water quality standard GM/sample GMV}), (\text{fecal coliform water quality standard 10\% value not to exceed/sample } 90^{th} \text{ percentile})\}$$

The percent reduction ($f_{reduction}$) needed is

$$f_{reduction} = (1 - f_{rollback}) \times 100\%$$

which is the percent reduction that allows both GMV and 90th percentile target values to be met.

The result is a revised target value for the GMV or 90th percentile. In most cases, a reduction of the 90th percentile is needed, and application of this reduction factor to the study GMV yields a target GMV that is usually less (i.e., more restrictive) than the water quality criterion. The 90th percentile is used as an equivalent expression to the "no more than 10%" criterion found in the second part of the water quality standards for fecal coliform bacteria. The reduction factors and description of sources are included in this report under *Load and Wasteload Allocations*.

Fecal Coliform Loading

Fecal coliform concentrations are important to evaluate a waterbody's compliance with the water quality criteria. Fecal coliform loading calculations can provide a more comprehensive water quality analysis than fecal coliform concentrations. Loading is a function of both contaminant concentration (bacteria density) and discharge quantity. Loading analysis can reveal the presence of additional contaminant sources, dilution and dispersion characteristics, as well as transport mechanisms.

Inner Dungeness Bay Water Budget

Before a loading analysis can be performed, the routing and balance of water must be calculated for the bay. Rensel (2003) calculated a water budget for inner Dungeness Bay (Table 7) for the study year. Rensel found that 96% of inflow to the inner bay is marine water, which includes refluxed inner bay and river water. River inflow is the second major inflow at 4.1%. Direct precipitation, irrigation return flow, and direct stormwater inflow were all less than 0.1% of the total inflow.

Table 7. Annual water inflow and outflow to inner Dungeness Bay,
October 2001 - September 2002 (Rensel, 2003).

Water inflow – outflow and source	Volume (meter^3/year)	Fraction (%)
Inflow to the inner bay		
Marine water*	4,420,000,000	95.89
Dungeness River water	187,000,000	4.06
Direct precipitation	1,880,000	0.04
Direct irrigation flow	684,000	0.01
Total inflow	4,609,564,000	100
Outflow from the inner bay		
Tidal outflow	4,605.384,000	99.95
Evaporation	2,300,000	0.05
Total outflow	4,609,564,000	100

* Marine water includes refluxed inner bay water and refluxed river water not accounted for separately.

Inner Dungeness Bay Fecal Coliform Loading

The water balance data and fecal coliform sample results for the inner bay during the critical period (November - February) were used to estimate seasonal mean daily fecal coliform loads. Fecal coliform loading values for all sources except the Dungeness River are from Rensel (2003).

River loading values were calculated based on an arithmetic mean of 17fc/100 mL, a flow discharge of 654 cubic feet per second (18.5 meter^3/second). Rensel calculated that fecal coliform loading from the river contributes to inner bay loading during flood tide periods which occur on average 45% of the time. The river loading value was multiplied by 45% to obtain fecal coliform loading contribution to the inner bay from the river.

The outer bay loading value includes outer bay wildlife as well as reflux from the inner bay and river. Rensel (2003) cautions that some loading factors are not known with great accuracy, but there is enough information to reach first order conclusions regarding seasonal sources and sinks of fecal coliform.

Table 8 and Figure 6 present fecal coliform loading estimates for the inner bay critical period by source.

Table 8. Dungeness Bay estimated fecal coliform loading by source, November 2001 - February 2002.

Source	Load* (10^9 fc/day)	% known load	% total load	Flow (10^6 m^3/year)	% flow	% total load/ % total flow**
Dungeness River	122	11.2%	8.7%	187	4.065%	2.2
Outer Bay	606	55.4%	43.3%	4400	95.652%	0.5
Irrigation	28	2.6%	2.0%	0.68	0.015%	135
Groundwater	0	0.0%	0.0%	4.5	0.098%	0.0
Inner Bay Wildlife	337	30.8%	24.1%	0	N/A	N/A
Unknown	307		21.9%	0	N/A	N/A
Sum of known sources	1093	100.0%		4592		

* River load based on arithmetic mean fecal coliform concentration for November-February of 17fc/100 mL.
** A ratio greater than 1 indicates a source more concentrated than the average source to Dungeness Bay.

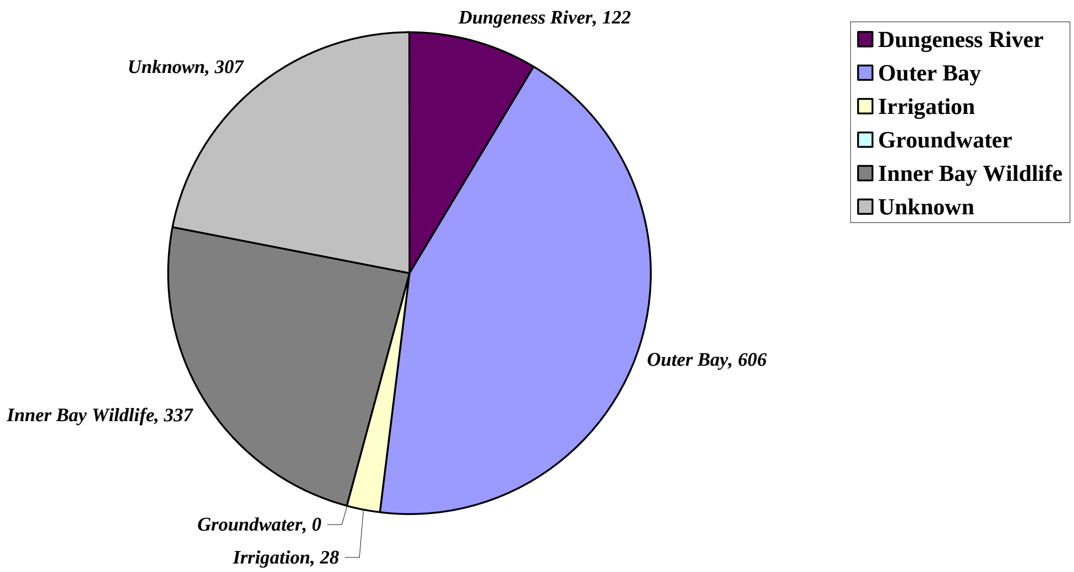

Figure 6. Dungeness Bay estimated fecal coliform loading by source (billions/day), calculated from concentration multiplied by flow, November - February.

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Load and Wasteload Allocations

Load Allocations

Load allocations are determined using the rollback method to determine reduction factors necessary to meet both parts of the water quality standard. In most cases, application of the rollback method yields a more stringent target for one part of the standard (GMV or 90th percentile) than the applicable water quality standard. For this study the target standard is the applicable water quality standard. If the 90th percentile is limiting, then the goal would be to meet the 90th percentile goal (e.g., 43 fc/100 mL in marine water). No goals would be set for the geometric mean since, with the implementation of target reductions, the already low geometric mean would only get better. Similarly, if the geometric mean is limiting (e.g., 14 fc/100 mL in marine water), the goal would be to achieve a geometric mean of 14 fc/100 mL with no goals for the already low 90th percentile.

Wasteload Allocation

There are no point source permitted discharges in the study area; therefore, the wasteload allocation is zero, and the entire load capacity is allocated to nonpoint sources and the margin of safety.

Dungeness Bay

The critical period for the inner bay is November - February. Table 9 summarizes the fecal coliform loading reduction factors necessary for the inner bay. The bacteria reductions are based on inner Dungeness Bay sub-areas meeting the Class AA marine standard.

Table 9. Fecal coliform loading reductions necessary to meet water quality standards for Dungeness Bay marine sites and the Dungeness River during the critical period.

Sub-area	Critical period or season	# of sample events in season	# of samples in season	Geo-mean	90th %tile	FC reduction needed to meet standards	Limiting criterion	Target value fc/100 mL
3.2 – Convergence zone	November-February	5	17	16	122	65%	90th percentile	43
4.1 – West inner bay	November-February	5	35	24	64	41%	Geometric mean	14
2 – River mouth	March-July	8	58	20	107	60%	90th percentile	43
Dungeness RM 0.1	March-July	9	33	13	80	46%	90th percentile	43

The critical period for Dungeness Bay sub-area 2 (river mouth) is year-round. Using the rollback method to determine bacteria reductions needed, the most stringent reductions required are during March - July. To ensure water quality is protected in the bay, the most stringent bacteria reductions will be required (see Table 9 for sub-area 2). It is assumed that if the bacteria reductions required during March - July are achieved, then water quality targets will be met year-round.

Dungeness River

As with marine sub-area 2, the critical period for the Dungeness River at RM 0.1 is year-round, but the most stringent reductions required are during March - July. To ensure water quality is protected in the bay, the most stringent bacteria reductions will be required (Table 9). It is assumed if the bacteria reductions required during March - July are achieved, then water quality targets will be met year-round.

The marine reductions needed at sub-area 2 are greater than reductions needed in the river (Table 9). There are two possible reasons for greater reductions necessary at sub-area 2 versus Dungeness RM 0.1:

1. Rensel (2003) observed large numbers of gulls congregating at the Dungeness River mouth during low-tide periods during the day, especially during the late spring and summer. He also conducted sampling above and below bird groups near the mouth of the Dungeness River. His results showed that seven of the nine sample events had significantly higher downstream than upstream fecal coliform geometric means, and two other days had results of approximately equal values (Rensel, 2003).

2. Another reason could be that sampling of both sites was not always done on the same day. Table 10 compares fecal coliform results for both sub-areas when they were sampled on the same day. For the seven dates compared, Dungeness RM 0.1 did not meet marine water quality standards for fecal coliform bacteria, while results from marine sub-area 2 did because of the April 15, 2002 results. These exceeded 43 cfu/100 mL, while the marine sub-area did not. Bacteria levels at Dungeness RM 0.1 strongly affect bacteria levels at marine sub-area 2.

Table 10. Fecal coliform concentrations (cfu/100 mL**)**, geometric mean, and 90th percentile for Dungeness RM 0.1 and sub-area 2 for coincident sample events.

Date	Dungeness RM 0.1	Marine sub-area 2 near river mouth
3/18/02	1	13
4/15/02	100	4
5/13/02	13	28
5/23/02	35	23
6/10/02	5	20
6/26/02	23	17
7/15/02	7	7
Geometric mean	12	13
90th percentile	81	33
Percent reduction	47%	0%
Limiting criterion	90th %tile	-
Target 90th percentile	43	-

Ditches to Inner Dungeness Bay

While the critical period for the ditches to the inner bay is November - February, bacteria reductions necessary for the ditches were calculated for the annual period due to lack of data for November - February. Reductions are based on the ditches meeting Class AA freshwater bacteria standards (Table 11). At a minimum, ditches should meet Class AA freshwater standards due to shellfish harvesting in Dungeness Bay which is Class AA marine.

Table 11. Fecal coliform loading reductions to meet Class AA freshwater standards for the ditches to the inner bay, October 2001 – September 2002.

Ditch number	Number of sample events	Geometric mean	90^{th} percentile	FC reduction necessary to meet standards	Limiting criterion	Target value fc/100 mL
1	16	69	702	86%	90^{th} %tile	100
2	7	111	805	88%	90^{th} %tile	100
3	5	80	622	84%	90^{th} %tile	100
4	14	78	2879	97%	90^{th} %tile	100
5	8	18	149	33%	90^{th} %tile	100
7	13	98	1874	95%	90^{th} %tile	100

Using Rensel's data, the total loading contribution for each ditch per sample day was calculated annually and for the October - March period. Annually the highest to lowest bacteria loading contributions to the bay is from ditches 7, 1 and 4 (same loading contribution), 2, 3, and 5. For November - March, the bacteria loading contributions ranked as follows: ditch 7, 4, 1, and 2. Ditches 3 and 5 had no measurable flow during the November - March sample period.

DOH sampling is typically conducted at high tide or near the end of a flood tide to access sites in the bay, and sampling targets conditions near beaches where shellfish stocks may occur. With this sampling regime, ditch outfalls will influence DOH sites that are close to inner Dungeness Bay beaches. Class AA marine bacteria standards are much more stringent than freshwater AA standards. If ditches to the inner bay meet standards eight years after TMDL approval but the south end of the bay (DOH stations 110, 111, 112) does not, then even more stringent target standards may be required for the ditches.

Comparison of DOH and TMDL Results

Rensel's study design selected sub-areas that best represented geographic and loading averages which tended to be mid-channel areas in some cases. DOH sampling is typically conducted at high tide or near the end of a flood tide to access sites in the bay by boat, and sampling targets conditions near beaches where shellfish stocks may occur. By collecting samples at high tide, the effects of the river and the ditches are exaggerated somewhat. The river water only enters the inner bay during high tide, and the ditch outfalls will influence DOH sites that are closer to inner Dungeness Bay beaches.

DOH results for this TMDL sampling period are presented in Table 12. DOH stations (Figure 2) are matched up with the sub-areas in Rensel's study (Figure 1). DOH uses the MPN method of fecal coliform analysis. Fecal coliform results using this method can be higher than the MF method (see previous section, *Membrane Filter and Most Probable Number Comparison*).

Table 12. DOH fecal coliform concentrations for Dungeness Bay, October 2001 - September 2002.

DOH station	103	104	106	108	110	111	112	109	113
Rensel sub-area	1	3.1	4.3	3.2	4.2	4.1			2
10/9/01	1.7	2.0	1.7	1.7	2.0	2.0	1.7	1.7	4.5
11/7/01	1.7	1.7	2.0	11	33	17	4.5	33	4.5
12/19/01	13	27	23	23	49	49	79	33	17
1/7/02	70	23	49	110	31	17	70	49	49
2/11/02	2.0	33	49	79	79	49	130	22	23
3/25/02	17	49	23	33	22	17	13	6.8	49
7/15/02	1.7	1.8	13	1.7	1.7	1.7	1.7	1.7	4.5
9/26/02	1.7	13	7.8	2.0	4.5	4.5	1.7	1.7	49
Geomean	5	10	12	12	14	11	11	9	16
90th %tile	31	61	65	109	94	59	122	60	37
% reduction needed based on DOH data	0%	29%	33%	60%	54%	27%	65%	28%	66%
% reduction needed based on TMDL results	meets standards	meets standards	meets standards	65%	insufficient data	41%			60%

In comparing TMDL reductions for the critical period to DOH reductions needed (yearly basis), results are similar. Bacteria reductions recommended in the TMDL will be protective of DOH shellfish harvesting use in the bay, without taking into consideration the differences in the two methods (MPN and MF).

Discussion of Load and Wasteload Allocation

Inner Dungeness Bay

Marine sub-area 4.1, the west inner bay, needs a 41% reduction in bacteria during the November - February period. Possible contaminant sources to this area include the ditches to the inner bay, inner bay wildlife, and the Dungeness River. Due to proximity, the ditches are the largest controllable source to this area, particularly given the DOH sampling strategy. The ditches need a 33-97% reduction in bacteria. It is likely that bacteria reductions in the ditches alone could achieve water quality standards in sub-area 4.1. Reductions in Dungeness River values may affect water quality in this area as well. Wildlife inputs are part of natural background levels and are not a controllable source.

Marine sub-area 3.2, the convergence zone, needs a 65% reduction in bacteria during the November - February period. This is an area of poor flushing. Possible contaminant sources to this area include the ditches, inner bay wildlife, and the Dungeness River. Reductions in bacteria from the Dungeness River and ditches are needed to meet water quality standards in this area. If sub-area 3.2 does not meet standards based on bacteria reductions in the Dungeness River and ditches, more stringent bacteria targets may be required. Wildlife is not a controllable source.

Outer Dungeness Bay

Marine sub-area 2, the Dungeness River mouth, needs a 60% reduction in bacteria during March - July. A 46% reduction in bacteria is needed at Dungeness RM 0.1 during this same period. Due to proximity, bacteria reductions in the Dungeness River will result in a substantial reduction at sub-area 2. It is likely that if Dungeness River target limits are met, then sub-area 2 will meet water quality standards if not a more stringent bacteria target may be required for the river.

Fecal Coliform Loading Sources

Inner Dungeness Bay

Rensel (2003) concluded that, except during winter, inner Dungeness Bay has fairly low fecal coliform levels. He noted that his conclusions do not match DOH results, and suggested differing results may be due to differences in sampling regime. Rensel's order of importance of fecal coliform loading sources, based on load magnitude, to the inner bay are as follows: marine water that includes Strait of Juan de Fuca water, reflux of inner bay and Dungeness River water, and part of the outer bay wildlife inputs; inner bay wild birds, especially ducks; Dungeness River discharge including gull contributions in the river plume; and irrigation and stormwater ditches that flow year-round.

The marine water has a geometric mean of 1 fc/100 mL and represents an important diluting effect. This ranking does not consider concentration. It is not feasible to eliminate fecal coliform from the marine water. The large marine loading contribution is due to large tidal volume multiplied by a small concentration of bacteria.

Portions of Dungeness Bay are within a national wildlife refuge and an important winter migration and feeding area for waterfowl. In his report, Rensel summarized some available data in regard to bird population dynamics in the region including data from the Audubon Society and the Dungeness National Wildlife Refuge, but population trend results were inconclusive for the entire (refuge and non-refuge) Dungeness area.

While birds are an important source of bacteria during the winter months, there is no conclusive evidence to show that overall numbers are increasing or decreasing in the study area. Wildlife contributions are considered natural, and controls are not appropriate. Human-related source controls are required to reduce inputs in order to meet water quality standards.

Ditches to the Bay

The ditch contribution to the inner bay was minimal in comparison to total Dungeness Bay loading sources, but it is important to note that the irrigation ditch system now conveys stormwater during the non-irrigation season and that the highest levels of bacteria were seen during this period. Rensel (2003) noted that ditches to the inner bay were a significant contributor to fecal coliform load during the winter, contributing more than 96% of their annual fecal coliform load at that time. In addition, the ditches discharge bacteria directly to the inner bay in close proximity to shellfish beds and DOH sampling sites.

In the past, sampling of the irrigation ditches has focused on the April - September period. For this study, four of the six ditches were sampled minimally during the non-irrigation period, October - March. On January 7, 2002 the highest bacteria levels were seen in the ditches; 0.60" of rain fell that day. Previous monitoring focused on the irrigation season and did not include storm event sampling; therefore, contributions are likely underestimated. The ditches may provide bacteria, especially during the non-irrigation months, to near-shore marine areas 4.1 and 4.2. These areas seem to have higher bacteria levels that coincide with the period of high bacteria in the ditches. However, this is also a period of increased bird use.

Possible sources of bacteria to the ditches include animal waste from animal-keeping operations (commercial and small non-commercial), pet waste, failing on-site sewage treatment systems, stormwater feeding into ditches, and wildlife. Sources of bacteria in stormwater include poor animal-keeping practices, pet waste, wildlife, and failing on-site sewage treatment systems.

Outer Dungeness Bay and Dungeness River

Rensel concluded that Dungeness River sources are the primary cause of frequent water quality violations at the river mouth and immediately adjacent marine water sub-areas. In spring and summer, the situation is exacerbated by congregations of gulls and other birds directly in the river mouth and along nearby shorelines at low, to moderately high, daylight tide.

Dungeness River does not meet TMDL target bacteria levels. A description of bacterial sources is included in the Dungeness River and Matriotti Creek TMDL Study (Sargeant, 2002).

Margin of Safety

A margin of safety to account for scientific uncertainty must be considered in TMDLs for load allocations to be protective. The margin of safety for this TMDL is implicit; it is contained within conservative assumptions used to develop the TMDL. Factors contributing to a margin of safety are:

- The rollback method assumes that the variance of the pre-management data set will be equivalent to the variance of the post-management data set. As pollution sources are managed, the occurrence of high fecal coliform values is likely to be less frequent, and thus reduces the variance and the 90^{th} percentile of the post-management condition.

- The lower the sample set used for the rollback calculation, the more stringent the reduction necessary. The lower sample size has greater variability in the data set, causing higher 90^{th} percentiles. A variable data set and a higher 90^{th} percentile meant greater reductions were needed. This is evident in the geometric mean that is necessary to achieve compliance with the 90^{th} percentile target.
- The simple mass-balance calculations for the Dungeness River and subsequent derivation of target values in freshwater assume no fecal coliform die-off. Mass-balance calculations for fecal coliform from Dungeness River to Dungeness Bay also disregarded die-off and dilution in the marine waters.

TMDL Schedule, Actions, and Monitoring

Schedule

The TMDL process allows an iterative approach to improving water quality when nonpoint sources predominate. However, Ecology is responsible for achieving compliance within a reasonable schedule. The compliance targets are calculated using the best available data, but the interpretation of the data is only an estimate of a complex ecological system. The margin of safety used to set the targets reflects some of the uncertainty in the interpretation, but other problems with the interpretation are not known until abatement actions are underway. Monitoring the effectiveness of the fecal coliform bacterial control measures and the rate of reduction in bacteria loads will provide additional data to adjust compliance targets and establish realistic compliance dates. Ecology must review these data at regular intervals, and targets or actions can be adjusted through the TMDL public process.

The compliance schedule will be part of Ecology's TMDL action plan. The plan will be drafted by Ecology's Southwest Regional Office and reviewed under the TMDL public process. The compliance schedule will be closely coordinated with the Sequim-Dungeness Clean Water Workgroup and local initiatives. The Workgroup assesses water quality problems and implements solutions. The group answers to the Clallam County Commissioners and the Dungeness River Management Team. A complete evaluation of monitoring data should occur within eight years to judge the effectiveness of the plan and the appropriateness of the TMDL targets.

Actions for Reducing Fecal Coliform Bacterial Source Impacts

In Dungeness Bay, a portion of bacteria loading is from wildlife sources such as birds and seals (Rensel, 2003). If there are no obvious human activities that increase wildlife numbers, wildlife is considered a natural contribution that will not be reduced. In Dungeness Bay, there are no obvious human activities that enhance wildlife numbers, so there is no justification for reducing wildlife sources. Additional monitoring of bird populations is recommended to better understand fecal coliform effects in the bay.

Reductions in human-related sources to Dungeness Bay are required to meet water quality standards. These sources are carried to the bay via the irrigation and roadside ditches and the

Dungeness River. Actions for reducing bacteria inputs include continuing to implement those recommended in the *Water Cleanup Plan for Bacteria in the Lower Dungeness Watershed* (Hempleman and Sargeant, 2002). Water clean-up actions in this plan are taken directly from the *Clean Water Strategy for Addressing Fecal Coliform in Dungeness Bay and Watershed* (Sequim-Dungeness Clean Water Workgroup, 2000).

Sources of bacterial pollution to the irrigation and roadside ditches are of concern because the highest levels of bacteria occur during November - February when the irrigation system is shut off. The purpose of the irrigation ditch system is to provide water for agricultural uses in the watershed during the dry season. Contaminated stormwater generated from urban and rural areas is a water quality concern in the irrigation ditches. Future residential, commercial, and redevelopment planning should take into consideration protecting water quality in the irrigation and roadside ditches. Stormwater best management practices should be implemented as appropriate.

Currently the ditches must meet the Class AA freshwater bacteria standard. If the ditches to inner Dungeness Bay meet Class AA freshwater bacteria standards as a part of the TMDL compliance schedule but the bay still does not meet standards, then even more stringent target standards may be required for the ditches.

Possible sources of bacteria to the ditches include animal waste from animal-keeping operations (commercial and small non-commercial), pet waste, failing on-site sewage treatment systems, stormwater feeding into ditches, and wildlife. Sources of bacteria in stormwater include poor animal-keeping practices, pet waste, wildlife, and failing on-site sewage treatment systems.

To protect water quality in Dungeness Bay, the Dungeness River, and the ditch systems, the following actions are recommended:

- Current efforts to pipe irrigation ditch water and eliminate irrigation tail water should continue.
- Animal-keeping operations (including non-commercial farms) should have animals fenced out of waterways, including the irrigation ditch system. An adequate buffer should be maintained between the waterway and fence.
- On-site sewage treatment systems, especially those located near waterways including ditches, should have regularly scheduled maintenance and inspection.
- Landowners should dispose of pet waste properly. Information on pet-waste disposal should be available to landowners in the area, as well as to the public at public access points to the bay and river.
- Additional monitoring of the Dungeness River and ditches to the inner bay, especially during the non-irrigation season, is needed to determine the location of bacteria sources and where corrections should occur. Monitoring should include a storm-event sampling component.
- Additional monitoring of bird populations is needed to better understand fecal coliform effects in the inner and outer bay. Gull populations at the mouth of the Dungeness River should be tracked to confirm that human activities are not contributing to gull populations at the mouth.

Monitoring

The Jamestown S'Klallam Tribe has been conducting follow-up monitoring and source identification monitoring in the freshwater tributaries to the study area. Monitoring for water temperature and fecal coliform bacteria is conducted monthly at most of the TMDL sites. DOH continues to monitor fecal coliform concentrations, salinity, and temperature in Dungeness Bay every other month.

To determine the success of fecal coliform control strategies, regular water quality monitoring is recommended. Recommended stations for continued monitoring include DOH marine sampling stations, the Dungeness River at RM 0.0, 0.1, 0.8, and 3.2, and inner bay ditch stations.

A complete evaluation of the TMDL follow-up monitoring data should be conducted in 2009, after five years of data have been collected. As of 2012, the bay should meet Class AA marine standards for fecal coliform bacteria, the river should meet the TMDL bacteria target, and the ditches should meet Class AA freshwater standards for fecal coliform bacteria.

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Appendix

Compliance with Water Quality Standards for Fecal Coliform Bacteria

Marine Sub-areas: Dungeness Bay

Sub-area and Monitoring Period	Number of Sample Events	Geometric Mean ≤ 14 fc/100 mL	90th Percentile ≤ 43 fc/100 mL	Meets Water Quality Standards		% Bacteria Reduction Needed to meet Standards.
				DOH	Ecology	
0: Offshore, Strait of Juan de Fuca						
Annual	16	1	1	Yes	Yes	0%
Nov-Feb	4	1	2	Yes	Yes	0%
Mar-Jul	8	1	1	Yes	Yes	0%
Aug-Oct	4	1	1	Yes	Yes	0%
1: Outer Bay						
Annual	17	3	7	Yes	Yes	0%
Nov-Feb	5	5	10	Yes	Yes	0%
Mar-Jul	8	3	6	Yes	Yes	0%
Aug-Oct	4	1	2	Yes	Yes	0%
2: River Mouth						
Annual	**17**	**15**	**60**	**No**	**No**	**28%**
Nov-Feb	5	8	21	Yes	Yes	0%
Mar-Jul	**8**	**20**	**107**	**No**	**No**	**60%**
Aug-Oct	**4**	**16**	**54**	**No**	**No**	**21%**
3.1: Entry Zone						
Annual	17	4	20	Yes	Yes	0%
Nov-Feb	5	8	33	Yes	Yes	0%
Mar-Jul	8	3	12	Yes	Yes	0%
Aug-Oct	4	3	28	Yes	Yes	0%
3.2: Convergence Zone						
Annual	**16**	**8**	**57**	**No**	**No**	**24%**
Nov-Feb	**5**	**16**	**122**	**No**	**No**	**65%**
Mar-Jul	7	7	16	Yes	Yes	0%
Aug-Oct	**4**	**4**	**91**	**No**	**No**	**53%**
4.1 West Inner Bay						
Annual	17	5	27	Yes	Yes	0%
Nov-Feb	**5**	**24**	**64**	**No**	**No**	**41%**
Mar-Jul	8	4	10	Yes	Yes	0%
Aug-Oct	4	1	1	Yes	Yes	0%
4.2: Cline Spit Gyre						
Annual	13	4	24	Yes	Yes	0%
Nov-Feb	3	14	Ins. data	Ins. data	Ins. Data	
Mar-Jul	7	3	20	Yes	Yes	0%
Aug-Oct	3	3	Ins. data	Ins. data	Ins. data	
4.3: North Inner Basin						
Annual	12	2	7	Yes	Yes	0%
Nov-Feb	4	6	12	Yes	Yes	0%
Mar-Jul	6	2	3	Yes	Yes	0%
Aug-Oct	2	2	Ins. data	Ins. data	Ins. data	

Bold – values do not meet water quality standards
Ins. Data - insufficient data were collected to determine if the site met water quality standards during the time period.

Freshwater Station: Dungeness River at RM 0.1

Station and Monitoring Period	Number of Sample Events	Geometric Mean ≤ 13 fc/100 mL	90^{th} Percentile ≤ 43 fc/100 mL	Meets Class A Freshwater Standards	Meets TMDL Target Limits	% Bacteria Reduction Needed to Meet TMDL Target Concentration Levels
Annual	18	16	60	Yes	No	29%
Nov-Feb	5	16	24	Yes	No	21%
Mar-Jul	9	13	80	Yes	No	46%
Aug-Oct	4	23	52	Yes	No	45%

Ditches to Inner Dungeness Bay

Station and Monitoring Period	Number of Sample Events	Geometric Mean ≤ 50 fc/100 mL	90^{th} Percentile ≤ 100 fc/100 mL	Meets Class AA Freshwater Standard*	% Bacteria Reduction Needed to Meet Standards.
Ditch 1					
Annual	16	69	702	No	86%
Apr-Sept	10	46	204	No	
Oct-Mar	6	137	4584	No	
Ditch 2					
Annual	7	111	805	No	88%
Apr-Sept	2	54	279	No	
Oct-Mar	5	147	1271	No	
Ditch 3					
Annual	5	80	622	No	84%
Apr-Sept	5	80	622	No	
Oct-Mar	No samples				
Ditch 4					
Annual	14	78	2879	No	97%
Apr-Sept	10	37	608	No	
Oct-Mar	4	491	57500	No	
Ditch 5					
Annual	8	18	149	No	33%
Apr-Sept	8	18	149	No	
Oct-Mar	No samples				
Ditch 7					
Annual	13	98	1874	No	95%
Apr-Sept	8	39	650	No	
Oct-Mar	5	440	3765	No	

* Washington State Class AA freshwater standard for fecal coliform bacteria:

Geometric mean (GM) not to exceed 50 fecal coliform/100 mL, and 10% of the samples used for calculating the GM not to exceed 100 fecal coliform/100 mL.