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Dungeness River and Matriotti Creek Fecal Coliform Bacteria Total Maximum Daily Load Study

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Dungeness River and Matriotti Creek Fecal Coliform Bacteria Total Maximum Daily Load Study

by
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Abstract

The Washington State Department of Ecology (Ecology) conducted a total maximum daily load (TMDL) study for fecal coliform bacteria in Matriotti Creek, the lower Dungeness River, and tributaries to Dungeness Bay. Due to nonpoint pollution sources, fecal coliform levels were not meeting freshwater quality standards in Matriotti Creek and not meeting marine water quality standards in Dungeness Bay.

Ecology, the Jamestown S'Klallam Tribe, and Clallam County staff sampled 35 to 40 stream sites from November 1999 through October 2000. Study results confirmed violations of water quality standards for fecal coliform in Matriotti Creek and Dungeness Bay, Meadowbrook and Cooper creeks, and Golden Sands Slough.

To help locate sources of bacterial pollution, sample sites were chosen to bracket possible pollution sources or specific land uses. Paired t-tests were used to determine stream segments or tributaries where loading sources occurred. Bacterial loading information was used to prioritize bacterial pollution control actions for the Dungeness River and tributaries in the study area.

To protect shellfish harvesting use in Dungeness Bay, the TMDL evaluation proposes a stringent fecal coliform bacteria target for the Dungeness River of a geometric mean of 13 fecal coliform (fc)/100mL and a 90^{th} percentile not to exceed 43 fc/100mL. This represents a 9% reduction in fecal coliform for the mouth of the Dungeness River. Tributaries to Dungeness Bay should meet the current Class AA freshwater standard of a geometric mean of 50 fc/100mL and a 90^{th} percentile of 100 fc/100 mL. This would mean reductions in fecal coliform of 59% for Meadowbrook Creek (mouth), 28% for Cooper Creek, and 82% for Golden Sands Slough.

To meet the TMDL target in the Dungeness River, the fecal coliform bacteria concentrations for Matriotti and Hurd creeks need to have a geometric mean of 60 fc/100mL and a 90^{th} percentile not to exceed 170 fc/100mL. To meet the target levels, a 78% bacterial loading reduction is required in Matriotti Creek. Hurd Creek currently meets the recommended TMDL target concentrations.

A separate TMDL study being conducted for Dungeness Bay will be completed in 2003.

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Executive Summary

The Washington State Department of Ecology (Ecology) conducted field surveys to support a total maximum daily load (TMDL) evaluation of the lower Dungeness River basin in 1999-2000. Ecology, the Jamestown S'Klallam Tribe, and Clallam County staff sampled water quality at sites on the Dungeness River, Matriotti Creek, Hurd Creek, Meadowbrook Creek and Slough, Golden Sands Slough, Cooper Creek, and irrigation ditches. They also sampled marine water in Dungeness Bay.

The purpose of the TMDL was to evaluate fecal coliform bacteria contamination in the freshwater areas of the lower Dungeness River basin. Contamination is from a variety of small sources (nonpoint sources) in the watershed.

Due to increasing concern about bacteria levels in Dungeness Bay, a separate TMDL study is currently being conducted on the bay. The bay TMDL will examine whether the fecal coliform load allocations for the tributaries to Dungeness Bay established in this TMDL study need to be adjusted to protect the shellfish harvesting in the bay. Because this Dungeness River study used the conservative assumption that water at the mouths of the Dungeness River and tributaries must meet shellfish protection criteria, no significant adjustments are expected to be needed.

Data from the field survey showed that the lower Dungeness River, Matriotti Creek, and tributaries to the bay need to reduce fecal coliform bacteria levels to protect the public from pathogens in freshwater, and to protect marine water and shellfish harvesting use in Dungeness Bay. Ecology recommends a geometric mean fecal coliform bacteria (fc) target of 13 fc/100 mL and a 90th percentile of 43 fc/100 mL for the Dungeness River at river mile (RM) 0.1. The bacteria target needed for the Dungeness River is lower, because the river has a large impact on the bay. The Dungeness River contributes a large volume of water and therefore can contribute more loading to Dungeness Bay, even when bacteria concentrations are fairly low. A 9% reduction in fecal coliform bacteria is needed at the mouth of the Dungeness River (RM 0.1) to meet the recommended target concentrations (Table 1).

In order to meet this target for the Dungeness River, Matriotti and Hurd creeks must meet a target of a geometric mean bacteria value of 60 fc/100 mL and a 90th percentile of 170 fc/100mL. The fecal coliform bacteria standard for these creeks was based on what levels need to be to meet the target bacteria levels set for Dungeness River. Hurd Creek meets these target values, but Matriotti Creek bacteria concentrations need to be reduced by 78% (Table 1).

Other tributaries to outer Dungeness Bay should meet their current bacterial standard (as described in the Water Quality Standards for Surface Waters of the State of Washington) of a geometric mean of 50 fc/100 mL and a 90th percentile of 100 fc/100 mL. Bacterial reductions for the tributaries are presented in Table 1.

Table 1. Fecal coliform bacteria target concentrations and reductions for lower Dungeness River sites.

Site	Bacterial target		Annual bacterial reduction needed
	Geometric mean	90th percentile	
Dungeness River at mouth (RM 0.1)	≤ 13 fc/100mL	≤ 43 fc/100mL	9%
Dungeness River between RM 0.3-0.1	≤ 13 fc/100mL	≤ 43 fc/100mL	2%
Matriotti Creek	≤ 60 fc/100mL	≤ 170 fc/100mL	78%
Hurd Creek	≤ 60 fc/100mL	≤ 170 fc/100mL	None
Irrigation return at Dungeness River RM 1.0	≤ 60 fc/100mL	≤ 170 fc/100mL	29%
Meadowbrook Creek and Slough	≤ 50 fc/100mL	≤ 100 fc/100mL	59%
Golden Sands Slough	≤ 50 fc/100mL	≤ 100 fc/100mL	82%
Cooper Creek	≤ 50 fc/100mL	≤ 100 fc/100mL	28%

To assist in prioritizing actions to control fecal coliform pollution in the lower Dungeness basin, areas were ranked by average loading. Priority areas for source control actions and further investigation are as follows, with highest priority actions first:

- Matriotti Creek between creek mile 0.7-0.3. Best management practices to control fecal coliform and sediment are needed in this area. Matriotti Creek is the highest ranked loading source during the irrigation season.
- Dungeness River between river mile 0.3 and 0.1. This reach was the highest ranked loading source during the wet season and is in close proximity to the shellfish beds. In addition, the possibility of human sources of bacterial contamination are of special public health concern.
- Dungeness River between river mile 3.2-0.8 and 0.1-0.0. Both areas need further investigation of sources during the irrigation season. Possible sources between RM 3.2-0.8 include other surface water inputs or land-use practices along this reach.
- Lotzgesell Creek, a tributary to Matriotti Creek. Continue monitoring water quality to evaluate improvements due to best management practices installed on this creek.
- Matriotti between creek mile 3.2-1.9. Investigate possible sources in this stretch, including failing on-site sewage systems, irrigation tailwater returns, and animal access.
- Mudd Creek, a tributary to Matriotti Creek. Investigate sources. Some source identification and corrections have occurred in this drainage, including elimination of an irrigation return with high bacteria levels. Other possible sources include failing on-site sewage systems along Mudd Creek.
- *Meadowbrook Creek, Meadowbrook Slough, and Golden Sands Slough.* Implement source control actions as mentioned in the body of the report.
- Continue water quality monitoring of selected sites to determine the effectiveness of source control actions.

Introduction

Background

In 1996 Matriotti Creek, a tributary to the Dungeness River, was placed on Washington State's 303(d) list of impaired waters because of fecal coliform bacteria violations. This list, required by section 303(d) of the federal Clean Water Act, is a set of waterbodies that are not meeting water quality standards.

The Washington State Department of Ecology (Ecology) is required by the Clean Water Act to conduct a total maximum daily load (TMDL) evaluation for waterbodies on the 303(d) list. The evaluation begins with a water quality technical study. The technical study determines the capacity of the waterbody to absorb pollutants and still meet water quality standards. The study also evaluates the likely sources of those pollutants and the amount pollutant sources need to be reduced to reach that capacity. The technical study will become the basis for water quality based controls. 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.

The Washington State Department of Health (DOH) reported increasing levels of fecal coliform bacteria in Dungeness Bay near the mouth of the Dungeness River in 1997 (DOH, 1998). In response to the water quality problems in the bay, in November 1997 the Jamestown S'Klallam Tribe began conducting water quality monitoring of tributaries adjacent to the bay. The Tribe hoped to find a definitive source that would explain the water quality problems. Unfortunately, no one bacterial source was identified; a number of areas and tributaries were not meeting water quality standards for fecal coliform. The Tribe, working in cooperation with Clallam County, expanded the monitoring program to include more sites and additional tributaries of the Dungeness River. It became evident that poor water quality in the bay was due to a number of pollution sources in the basin. In 1998 Ecology provided technical assistance to the monitoring effort and then agreed to conduct a TMDL on Matriotti Creek and other freshwater tributaries in the lower Dungeness watershed.

In cooperation with the Jamestown S'Klallam Tribe and Clallam County, Ecology began a year of monitoring in November 1999 in the lower Dungeness River basin. In January 2001, Ecology published a preliminary Dungeness River/Matriotti Creek report that presented data collected during those surveys, including laboratory and field water quality data and flow data from instantaneous flow measurements (Sargeant, 2001). A summary of the quality assurance and quality control analysis of the data was also provided.

During the freshwater TMDL water quality study, fecal coliform levels in the bay continued to increase. High fecal coliform levels in Dungeness Bay caused a reclassification by DOH of 300 acres from *Approved* to *Prohibited* for shellfish harvest in 2000. Fecal coliform levels in the bay continued to increase, causing an additional 100 acre closure in 2001. Due to increasing concerns about the water quality in the bay and the possibility of marine sources the Tribe sponsored a circulation study of the bay. Sampling for Phase One of this study was conducted in

2000-2001. Phase One results were published in August 2001 (Rensel and Smayda). Currently sampling for Phase Two of the circulation study is underway, and a final report will be completed in 2003. Ecology will prepare a Dungeness Bay TMDL based on the findings of the final circulation study report. The Dungeness Bay TMDL will make recommendations on fecal coliform load allocations to Dungeness Bay.

This TMDL report includes a technical analysis to determine the load capacity for fecal coliform, allocation of pollutant loads for various sources, and identification of the location of freshwater fecal coliform sources. This report will be used by the state, Tribe, local governments, and stakeholders to develop a water cleanup plan for the management of fecal coliform nonpoint source pollution in Matriotti Creek and the lower Dungeness River basin. This TMDL report will be part of the water cleanup plan and will be submitted to the U.S. Environmental Protection Agency (EPA) for approval, in accordance with section 303(d) of the Clean Water Act.

Problem Description

Since 1991 bacterial contamination in Matriotti Creek has been documented as a water quality problem through monitoring efforts by Clallam Conservation District and Clallam County (Clallam County, 1993). Matriotti Creek has been on Washington's 303(d) list since 1996 for not meeting water quality standards for fecal coliform. Fecal coliform is an indicator of the presence of possible harmful pathogens (e.g., bacteria and viruses) associated with human and animal waste. There are no point sources or regulated stormwater discharges to surface water in the study area. Nonpoint pollution is the source of fecal coliform problems in the basin.

Since 1997 Dungeness Bay has been experiencing increases in fecal coliform bacteria (DOH, 1998). During 2000 and 2001, portions of Dungeness Bay were reclassified by DOH from *Approved* to *Prohibited* for commercial shellfish harvest (Figure 1). The shellfish area was downgraded, because fecal coliform levels in the bay did not meet National Shellfish Program Sanitation Requirements for water quality in commercial shellfish harvesting areas and approved recreation harvesting areas.

Water Quality Standards and Beneficial Uses

Appendix A lists the water quality criteria for marine classification AA, and freshwater classifications A and AA. To determine if the fresh or marine standard applies, the following criteria are used for fecal coliform: the freshwater criteria shall be applied at any point where 95% of the vertically averaged daily maximum salinity values are less than or equal to 10 parts per thousand or greater (Chapter 173-201A Washington Administrative Code).

Dungeness Bay is marine water class AA. The bay supports recreational harvests of salmon and bottomfish, as well as important salt marsh habitat and eelgrass beds for brant, fish, crab and other shellfish. Oysters, hardshell clams, butter clams, and horse clams are harvested commercially and recreationally in Dungeness Bay, for a total of 1,183 acres of certified shellfish beds (PSCRBT,

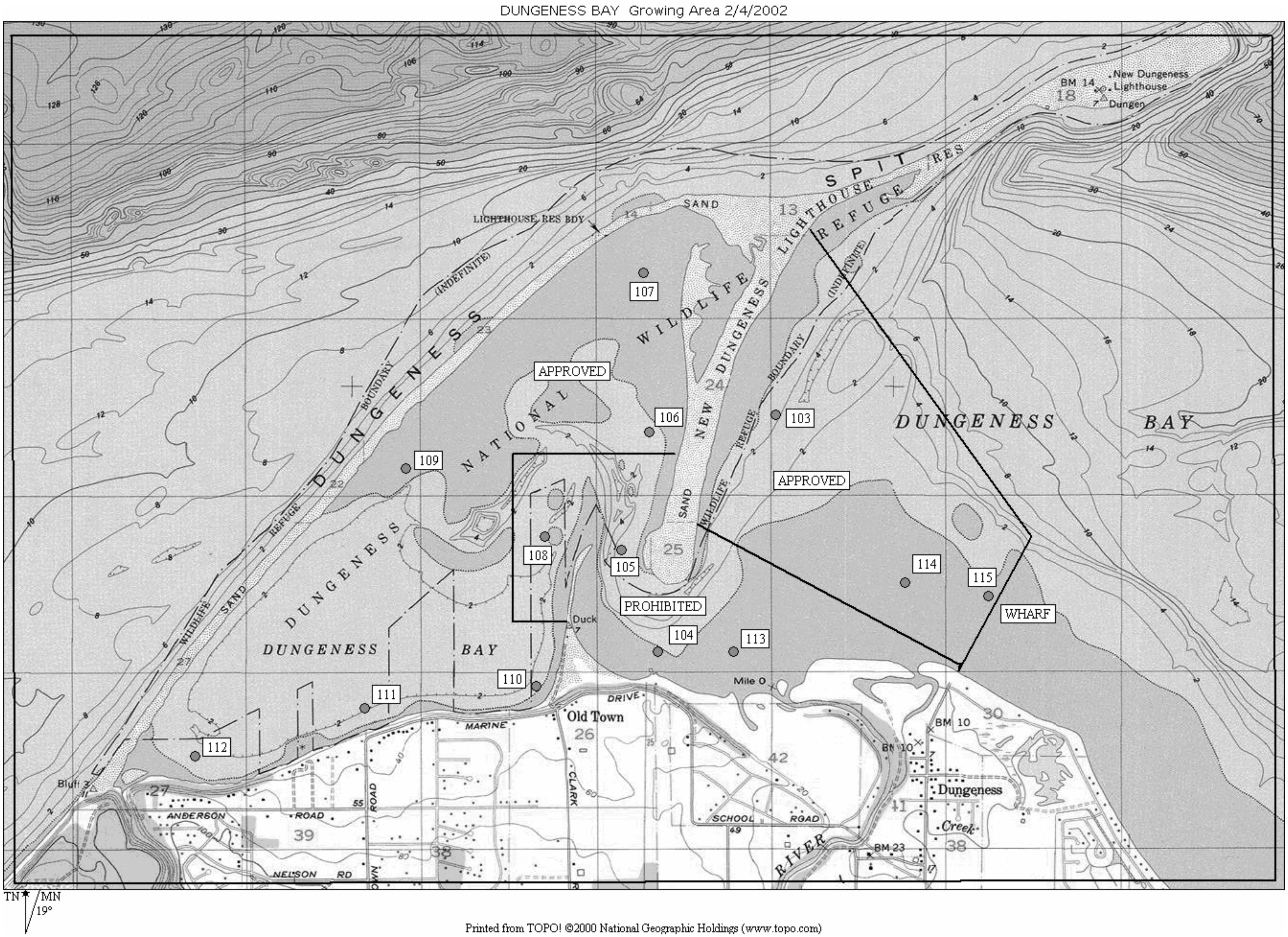

Figure 1. Washington State Department of Health Marine Monitoring Stations in Dungeness Bay.

1991). Dungeness crabs are also harvested commercially and recreationally in the bay. Other land uses 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 always harvested fish and shellfish from Dungeness Bay for food, trade, and cultural ceremonies. In addition to subsistence harvest in the bay, the Tribe currently harvests clams commercially. They also own and operate a commercial oyster and clam farm in Dungeness Bay (Muench, 1999).

The Dungeness River from the mouth to Canyon Creek (river mile 10.8) is Class A freshwater by special designation (Chapter 173-201A WAC). The Dungeness River supports fisheries such as chinook, coho, pink, and chum salmon, summer and winter-run steelhead, cutthroat and rainbow trout, and char. The river is a source and conveyance for irrigation water for crops and stock watering. Recreational uses include swimming, boating, fishing, and aesthetic enjoyment.

Hurd Creek and Matriotti Creek tributaries to the Dungeness River are Class A freshwater. Hurd Creek is used for irrigation water conveyance, and water is withdrawn from the creek for a fish hatchery. Hurd Creek is used by a variety of fish including coho, chum, steelhead, cutthroat trout, and Dolly Varden. Matriotti Creek is used for irrigation water conveyance, agricultural irrigation, and stock watering. Fisheries use in the creek includes coho and chum.

Meadowbrook and Cooper creeks, Golden Sands Slough, and other tributaries to Dungeness Bay are classified AA freshwater. In accordance with water quality standards, all unclassified surface waters that are tributaries to Class AA waters (Dungeness Bay) are Class AA. The irrigation systems source of water is the Dungeness River (Class A), so irrigation ditches are also classified A freshwater. Beneficial uses of Meadowbrook Creek and Slough include irrigation, wildlife, and fisheries such as coho and chum.

Project Objectives

The overall goals of the TMDL project are to characterize fecal coliform pollution and develop an implementation plan to reduce this pollution in order to protect beneficial uses. This technical report focuses on characterizing fecal coliform pollution in the study area and setting loading limits. The development of an implementation plan will be the next step of the TMDL process. Objectives of the technical study were to:

- Characterize fecal coliform bacteria concentrations and identify areas of major bacterial loading sources along Matriotti, Meadowbrook, and Hurd creeks and the lower Dungeness River.
- Determine maximum acceptable fecal coliform loads and concentrations allowable at the mouth of the Dungeness River to meet marine standards at DOH station 113.
- Determine maximum acceptable fecal coliform loads and concentrations in Matriotti Creek to meet the TMDL targets in the Dungeness River.
- Determine the percent reduction in bacteria concentrations necessary to meet the above targets.

Study Area

The Dungeness River, located in the northeast corner of the Olympic Peninsula, is the major freshwater tributary to Dungeness Bay. The river is 32 miles long and drains 172,517 acres. The upper two-thirds of the watershed are in the Olympic National Forest and Olympic National Park. The lower 13-mile stretch of river flows through mostly private land. The Dungeness River emerges through the foothills at about river mile (RM) 10 to the relatively flat Dungeness valley (Clallam County, 1993).

This study focuses on the Dungeness River and its tributaries below RM 3.2, below Woodcock/ Ward Road bridge (north of Highway 101). Major tributaries in this stretch include Matriotti and Hurd creeks. This study also includes tributaries to Dungeness Bay: Meadowbrook Creek and Cooper Creek that enter the bay to the east of the Dungeness River, as well as irrigation ditches. Figures 2 and 3 present a map of the study area and sampling sites.

The area climate is mild, because it lies in the rain shadow of the Olympic Mountains and close to the Strait of Juan de Fuca and the Pacific Ocean. Annual precipitation varies from 15 inches near Sequim to 80 inches at the headwaters of the Dungeness River (Clallam County, 1993). Average monthly precipitation for Sequim is presented in Table 2.

The Dungeness River typically has sharp peak flows in June from snow run-off events and another period of higher flows between November and February. Table 2 present average monthly flows for the Dungeness River at RM 11.0.

Table 2. Average monthly precipitation for Sequim, and average monthly flow discharge at Dungeness RM 11.0.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average rainfall in inches *	2.01	1.40	1.22	0.99	1.26	1.09	0.68	0.62	0.81	1.38	2.76	2.08
Average flow in cfs at Dungeness RM 11.0**	402	390	295	326	565	706	498	268	174	213	355	434

* period of record 1980-2000 (Western Regional Climate Center)
** period of record 1923-2000 (USGS)

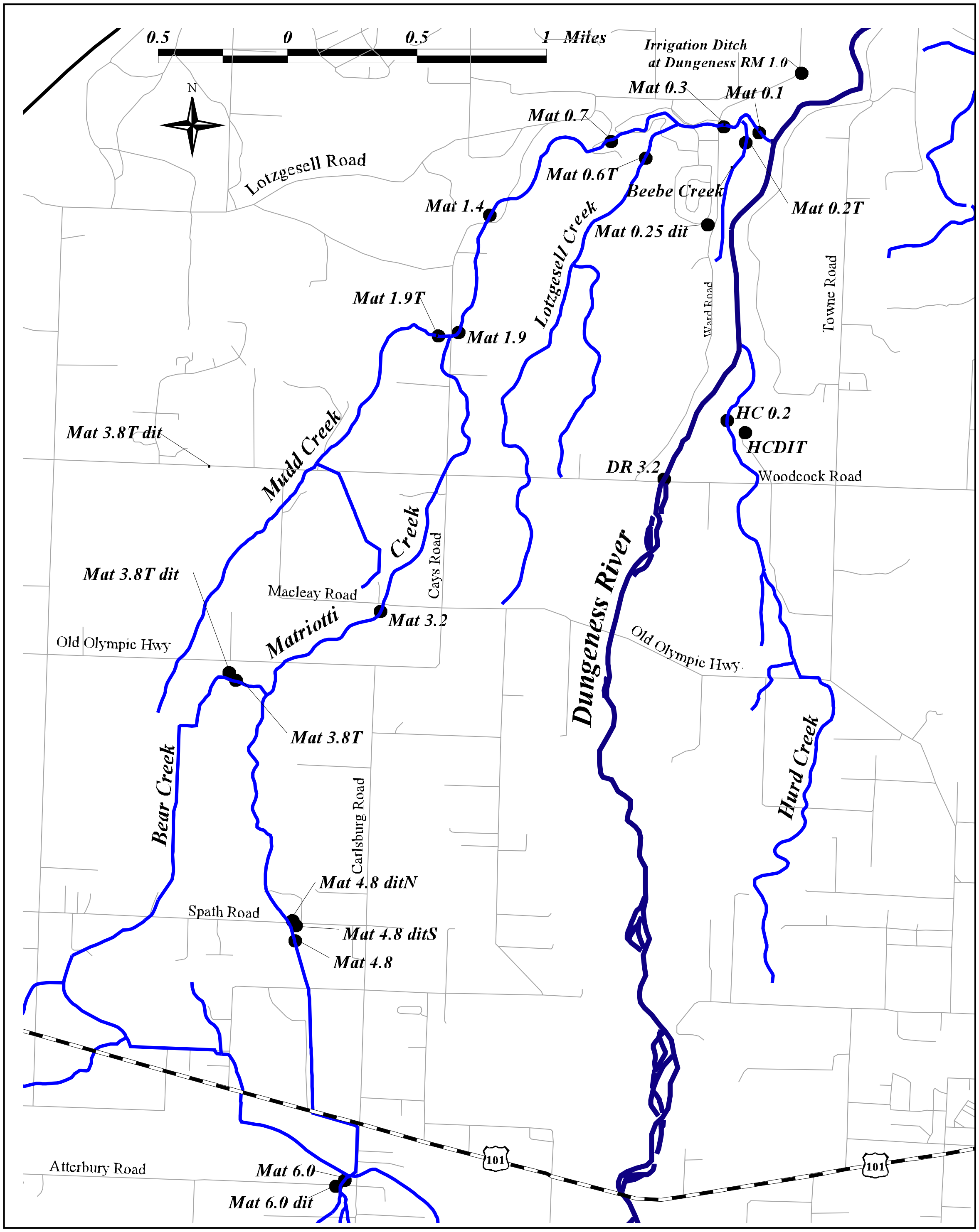

Figure 2. Dungeness River, Matriotti Creek, and Hurd Creek Water Quality Monitoring Sites.

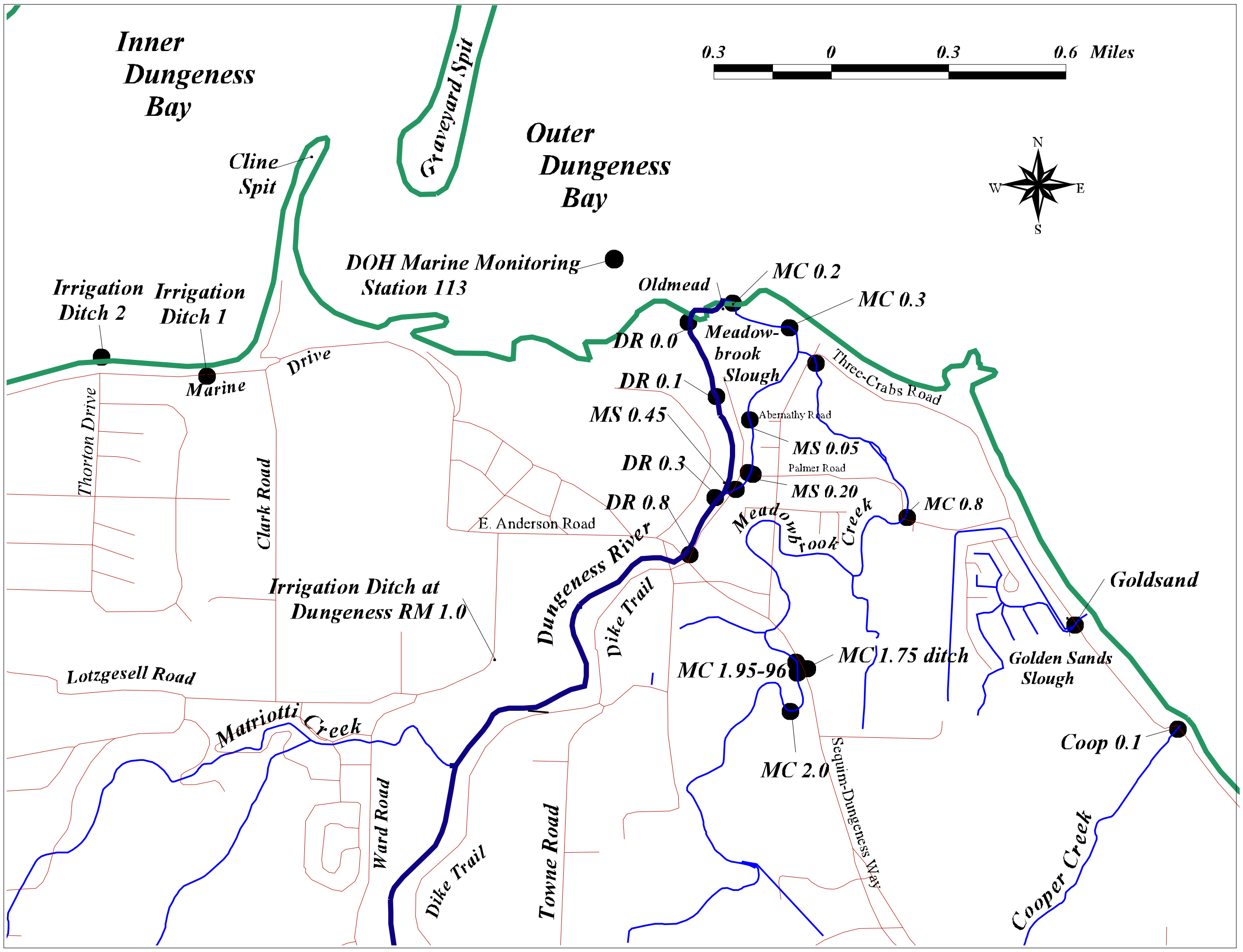

Figure 3. Dungeness River, Meadowbrook Creek, Cooper Creek, Golden Sands Slough, and Irrigation Ditch Water Quality Monitoring Sites.

Land Use

Land uses in the study area include residential, commercial, and agricultural. With increasing urbanization of the Sequim area, residential use is becoming a more predominant land use. Population in unincorporated Clallam County increased by 16% from 1990-2000, with most of the growth occurring in the eastern end of the Sequim-Dungeness valley (Wilson, 2002). While the city of Sequim is on a sewer system, residences and commercial establishments in the rural areas use on-site sewage treatment systems.

The study area contains an extensive irrigation system. All nine irrigation districts or companies are managed by the Dungeness River Agricultural Water Users Association. In the lower

Dungeness basin, there are 61.7 miles of irrigation ditches and 111 miles of laterals (Montgomery, 1999). Matriotti, Hurd, and Meadowbrook creeks are used as a conveyance for the irrigation system.

Descriptions of waterbodies in the study area and specific land uses that relate to potential sources of bacteria are described below:

1. Meadowbrook Creek and Slough

Meadowbrook Creek is located to the east of Dungeness River (Figure 2). The creek is approximately 3.0 miles long. An irrigation ditch flows into Meadowbrook Creek at creek mile (CM) 1.75. This ditch also receives irrigation tailwater return and stormwater from Sequim-Dungeness Way. Meadowbrook slough is a 0.5 mile slough entering Meadowbrook Creek at CM 0.25. The slough is fed with water from an outtake at Dungeness RM 0.3; a landowner on the Dungeness controls flow at the outtake. The slough widens and deepens before entering Meadowbrook Creek near the mouth. Since 1995 the mouth of Meadowbrook Creek has been migrating eastward. In 1995 it flowed into the Dungeness River just above the mouth; currently it flows into Dungeness Bay east of the Dungeness River.

Land use along Meadowbrook Creek includes a horse farm near the mouth, a wetland bird refuge, as well as agricultural, residential, and commercial activities in the community of Dungeness. Land use along Meadowbrook Slough includes residences and a private wildlife area near the mouth. All residences and commercial properties use on-site sewage treatment systems.

2. Cooper Creek, Golden Sands Slough, and Irrigation Ditches

Cooper Creek and Golden Sands Slough discharge into Dungeness Bay east of Meadowbrook Creek (Figure 2). Cooper Creek is a wetlands-fed creek, and the uplands are undeveloped. The downstream half of the creek has been straightened. The creek mouth is a tide gate installed in a bulkhead. In 1995 a small portion of the tide gate was removed to allow fish passage (Haring, 2000). There is residential development at the mouth of the creek and a fenced horse pasture along the west side of the creek.

Golden Sands Slough drains a series of man-made channels dug into wetlands behind the marine shoreline. The slough is fed by the wetlands, and there is a tide gate at the mouth of the slough. Water in the slough tends to be stagnant and saline. Along the canals a number of permanent homes were built that use on-site sewage treatment systems. The remainder of the lots are now restricted to recreational use only. Several of these lots are occupied year-round by recreational camper vehicles.

There are a few irrigation ditches that discharge to inner Dungeness Bay west of Cline spit; Irrigation Ditches 1 and 2 were sampled for this study (Figure 2). The irrigation tailwater entering the bay from two of these ditches was sampled. Water from these ditches originates from the Dungeness River and is used for agricultural purposes. During storm run-off events, these ditches also collect road and stormwater runoff.

3. Dungeness River

The Dungeness River below RM 3.2 is confined by levees along both banks, including a 3-mile long levee on the right bank and two smaller levees along the left bank (looking downstream). Tributaries below RM 3.2 include Matriotti and Hurd creeks. There is an irrigation tailwater return to the river at approximately RM 1.0, and an irrigation outtake at RM 0.3 that serves as the source of Meadowbrook Slough.

4. Hurd Creek

Hurd Creek is 1.0 mile in length and flows into the Dungeness River on the right bank at RM 2.7 (Figure 3). Hurd Creek starts as a spring and is augmented at times by tailwater from the irrigation system. Land use on the creek includes residences and a fish hatchery at CM 0.5. All homes in the area are served by on-site sewage treatment systems.

5. Matriotti Creek

Matriotti Creek is 9.3 miles long and drains 13.6 square miles (Figure 2). It enters the Dungeness River on the left bank (looking downstream) at RM 1.9. Land uses include residential, commercial, agricultural, and livestock use. A large exotic animal park, the Olympic Game Farm, is located near the mouth of Matriotti Creek. Matriotti Creek is used as a conveyance for the irrigation system. Irrigation water diverted from the Dungeness River enters Matriotti at CM 6.0 near Atterbury Road. Bear and Mudd creeks, which receive irrigation tailwater returns, enter Matriotti Creek at CM 3.8 and 1.95, respectively. There is an irrigation tailwater return ditch along Spath Road that discharges to Matriotti Creek at CM 4.8. At Matriotti CM 0.25, a drainage ditch that drains the area south of the Olympic Game Farm discharges to Matriotti Creek.

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Methods

Field and Laboratory Methods

The quality assurance project plan (Sargeant, 2000) and the Dungeness River/Matriotti Creek Total Maximum Daily Load Study Preliminary Data Results for November 1999 through October 2000 (Sargeant, 2001) describe procedures that were followed for collection and analysis of laboratory samples and for measurements made in the field. Sample site locations are shown in Figures 2 and 3. Site locations, sample timing, and field and laboratory sampling procedures are described in the preliminary data results report (Sargeant, 2001).

Streamflow Data

Continuous stream flow data were obtained for two sites in the project area, the Dungeness River at Schoolhouse Road bridge (Dungeness RM 0.8) and at the mouth of Matriotti Creek (Matriotti CM 0.1). The Dungeness River/Matriotti Creek Fecal Coliform Bacteria Total Maximum Daily Load Study Streamflow Summary report (Shedd, 2001) contains flow data for these sites. For all other sites several methods were used to determine flow discharge: instantaneous flow measurements, timed fill of a measured container, and flow estimate from the flow discharge-rating curve. Instantaneous flow results for these sites are available in the preliminary data report (Sargeant, 2001).

Data Analysis Methods

Field and laboratory data were compiled and organized using Excel® spreadsheet software. Water quality results from field and laboratory work were also entered into Ecology's Environmental Information Management database. Statistical calculations were made using either Excel® or SYSTAT® software.

The primary focus of this study is fecal coliform bacteria. Membrane filter (MF) method was used for data analysis throughout, unless otherwise noted. Field replicates and right and left bank (looking downstream) results for the Dungeness River were arithmetically averaged.

For comparison to standards, salinity levels were evaluated. Marine standards apply at salinities of 10 parts per thousand (ppt) or greater for fecal coliform bacteria, and at 1 ppt or greater for all other parameters. Appendix A describes the waterbody classification for each area in the study. To evaluate compliance, fecal coliform bacteria results were compared to standards for the entire year, the irrigation season (April through September), and the wet season (November through February). Only periods with at least five surveys of data were considered to contain sufficient data to evaluate compliance with standards.

Source Location Identification

Paired t-tests were used to compare water quality between upstream and downstream sites. Sites were evaluated for differences in fecal coliform concentration and loading, as well as turbidity, when data were available. A two-tailed test with a significance level of $\alpha = 0.05$ was used.

For the paired t-tests and graphs, when there was a measured tributary or ditch between sites, the upstream load and the incoming tributary or ditch load were summed to represent the expected load or load sum. This load sum was compared to the measured load downstream to determine if an unidentified source of loading was present. Variation in the load sum and the measured load could also be due to sampling errors in flow and bacteria measurements, temporal variance, fecal coliform die-off, and settling.

Flows were calculated using instantaneous flow measurements, rating curves (relating flow to staff gauge height), or a mathematical relationship to flow at a comparable site. Dungeness River flows were estimated using a continuous stream flow gauging station at the Schoolhouse Road bridge (Shedd, 2001). Flows for Ward Road bridge were estimated using downstream Schoolhouse Road bridge flows and subtracting flows from tributaries between the two sites. Dungeness flows downstream of Schoolhouse Road bridge were assumed to be equivalent to flows at Schoolhouse Road bridge. There are no known tributaries to the Dungeness River between the Schoolhouse Road bridge and the mouth.

No practical unit of loading is available for fecal coliform so, for the loading analyses, fecal coliform (fc) concentrations (# fc/100mL) were multiplied by the flow discharge in cubic feet per second (cfs) to obtain loading in # fc/100mL x cfs. Fecal coliform annual or seasonal loads were arithmetic means of the instantaneous loads in that time period to provide relative comparisons.

TMDL Analysis

The statistical rollback method (Ott, 1995) has been used by Ecology as a method for determining the necessary reduction for both the geometric mean value (GMV) and 90th percentile bacteria concentration (Joy, 2000; Seiders, 2001). In the case of the TMDL, 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 log-normal distributions, and the statistical rollback method could be applied to log-transformed values.

The rollback method uses 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 target 90th percentile are set to the corresponding water quality standard. The reduction needed for each target value to be reached is determined. The reduction factor (e.g., percent reduction) that allows both target values to be met is selected and applied to the known GMV and 90th percentile. The result is a revised target value for the GMV or the 90th percentile, depending upon which reduction factor was used. 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 standard. 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 (Seiders, 2001).

Quality Assurance and Quality Control Results

A complete discussion of the quality assurance and quality control results is included in the preliminary data results report (Sargeant, 2001).

Water Quality Results

Water Quality Monitoring Results

The Ecology study data were presented in the preliminary data report (Sargeant, 2001). The report contains a flow measurement error for Matriotti CM 4.8. Flow discharge for April 24, 2000 is reported as 0.38 cfs, but it was 0.83 cfs. This report is available on-line at http://www.ecy.wa.gov/biblio/0103002.html

Compliance with Standards

Sample results were compared to the applicable marine or freshwater quality standard. Parameters with applicable water quality standards include fecal coliform bacteria, turbidity at some sites, dissolved oxygen, temperature, pH, and ammonia-nitrogen.

All sites met state water quality standards for ammonia-nitrogen. Compliance with water quality standards for temperature, pH, dissolved oxygen, turbidity, and fecal coliform are described in Appendix B.

Loading Analysis and TMDL

Scope of TMDL Study

This TMDL addresses fecal coliform bacteria in Matriotti Creek, including both creek water segments that were included on the 1996 and 1998 303(d) list. Table 3 lists these segments as well as segments found to be impaired but not currently listed.

Table 3. Waterbodies impaired for fecal coliform bacteria in the Dungeness River and Matriotti Creek TMDL study.

Waterbody	Township, Range, Section	New Waterbody ID Number	Old Waterbody ID Number
Waterbodies on the 1996 and 1998 303(d) list			
Matriotti Creek	30N 04W 03	AZ071Y	WA-18-1012
Matriotti Creek	31N 04W 35	AZ071Y	WA-18-1012
Impaired waterbodies addressed in this TMDL but not currently on the 303(d) list			
Matriotti Creek	30N 04W 22	AZ071Y	WA-18-1012
Matriotti Creek	30N 04W 10	AZ071Y	WA-18-1012
Matriotti Creek	30N 04W 02	AZ071Y	WA-18-1012
Matriotti Creek	31N 04W 35	AZ071Y	WA-18-1012
Matriotti Creek	31N 04W 36	AZ071Y	WA-18-1012
Mudd Creek (tributary to Matriotti Creek)	30N 04W 03	No ID number available	
Lotzgesell Creek (tributary to Matriotti Creek)	30N 04W 35	No ID number available	
Meadowbrook Creek	31N 03W 31	No ID number available	
Meadowbrook Creek	31N 03W 30	No ID number available	
Meadowbrook Creek	31N 04W 41	No ID number available	
Golden Sands Slough	31N 03W 31	No ID number available	
Cooper Creek	31N 03W 32	No ID number available	

The Dungeness and Matriotti Creek TMDL also addresses fecal coliform in six other segments of Matriotti Creek, two tributaries to Matriotti Creek, and two segments of Meadowbrook Creek, Cooper Creek, and Golden Sands Slough (Table 3). It was determined during development of the TMDL that these waterbodies were not meeting water quality standards for fecal coliform and had not previously been included on the Washington 303(d) list. The information contained in this TMDL demonstrates that these non-listed waters are, in fact, water quality limited segments that are impaired and in need of a TMDL.

Seasonal Variation and Critical Conditions

Seasonal patterns in fecal coliform concentration and loading data were evaluated for all sites annually and seasonally. Results of this review are presented in Appendix C. The results showed that for most sites higher fecal coliform concentrations are present during the irrigation season (April through September). Fecal coliform loading was also higher during the irrigation season for a majority of the tributaries and the Dungeness River above RM 0.8. Fecal coliform concentrations for the Dungeness River at RM 0.1 (the site nearest the mouth) are higher during the irrigation season; however, fecal coliform loading is fairly consistent throughout the year, with a slight increase during the wet season.

In a review of the Dungeness Bay marine data, Rensel and Smayda (2001) found higher fecal coliform concentrations in the fall and winter season. Higher survival of fecal coliform in the bay is to be expected during late fall and winter, because two primary factors that increase fecal coliform die off (water temperature and light) are reduced at that time, probably allowing for relatively longer survival in waters of the inner bay (EPA, 2001; Bowie, 1985).

The beneficial use with the most restrictive fecal coliform criteria is shellfish harvesting in Dungeness Bay. The TMDL targets and fecal coliform reductions for the Dungeness River and tributaries need to be protective of all downstream beneficial uses. A large portion of the bay is closed to shellfish harvesting because water quality does not meet the National Shellfish Sanitation Program criteria. The water quality in the harvesting area must have a geometric mean value of no more than 14 most probable number (MPN)/100mL, with an estimated 90^{th} percentile value less than 43 MPN/100mL.

To protect downstream water quality and beneficial uses in Dungeness Bay, the Dungeness and Matriotti TMDL must encompass the entire year, and address the possibility of bacteria contamination from several potential sources with different delivery and transport mechanisms.

TMDL Development

Tributaries to Dungeness Bay

Fecal Coliform Load Balance

Figure 4 shows that, of all the freshwater sources to the inner and outer bay that were sampled, the Dungeness River contributes the vast majority of fecal coliform loading. Table 4 summarizes average annual values for flow, fecal coliform concentrations, and fecal loads for freshwater tributaries (including Dungeness River) to the inner and outer Dungeness Bay.

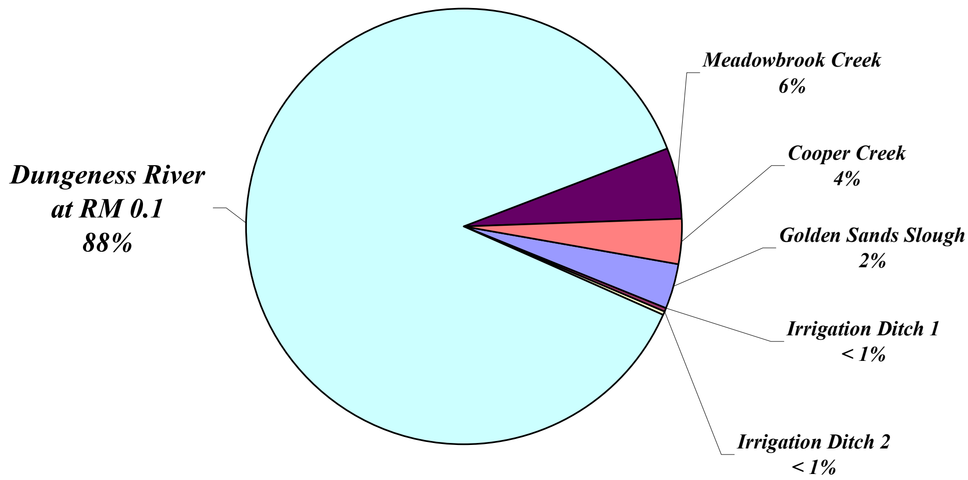

Figure 4. Relative Annual Contributions of Fecal Coliform Loading to Inner and Outer Dungeness Bay (1999-2000).

Table 4. Instantaneous mean daily values for fecal coliform concentration, flow, fecal coliform loading, and relative contributions of flow and fecal coliform loading to inner and outer Dungeness Bay.

Site	Mean FC (#fc/100mL)	Mean Flow (cfs)	Mean FC Load (#fc/100mL x cfs)	Freshwater Flow to Bay (%)	Freshwater FC Load to Bay (%)
Dungeness River RM 0.1	21	413	7589	97	88
Meadowbrook Creek CM 0.2	108	6	484	1.4	6
Cooper Creek	63	5	299	1.2	4
Golden Sands Slough	187	1	187	0.2	2
Irrigation Ditch 1	55	< 1	18	0.0	0
Irrigation Ditch 2	113	< 1	2	0.0	0

Mean fecal coliform load is an average of all the fecal coliform loading values. Loading values are calculated by multiplying the instantaneous flow x fecal coliform concentration. Mean fecal coliform concentration is an average of all fecal coliform concentrations (arithmetic mean), just as the mean flow is an average of all flow measurements obtained. Thus the mean fecal coliform concentration multiplied by the mean flow may not be equivalent to the mean fecal coliform load in the table.

Fecal Coliform Load Allocation

Currently sampling is being conducted for the Dungeness Bay TMDL, and a report is expected to be completed in early 2003. The Dungeness Bay TMDL will examine whether the fecal coliform load allocations for the tributaries to Dungeness Bay established in this report need to be adjusted to protect the shellfish harvesting in the bay. Because this study used the conservative assumption that water at the mouths of Dungeness River and tributaries in the study area must meet shellfish protection criteria, no significant adjustments are expected to be needed.

To determine fecal coliform concentrations that are protective of beneficial uses in the bay, concentrations for Dungeness RM 0.1 and Department of Health (DOH) marine station 113 were compared (Figure 2). Both stations were sampled for 13 of the 18 TMDL surveys. A non-parametric paired Wilcoxon signed rank test was used to determine if data from the station at Dungeness RM 0.1 and DOH station 113 had significantly different fecal coliform concentrations. Results showed fecal coliform levels at the two sites were not significantly different. However, the DOH station had a slightly higher geometric mean fecal coliform concentration than the Dungeness RM 0.1 station, with geometric mean values of 22 and 14 fc/100mL, respectively. This may be because the marine samples were analyzed by the DOH laboratory in Seattle using the MPN method of fecal coliform analysis, while the freshwater samples were analyzed by Ecology's Manchester Environmental Laboratory using the MF method. Different laboratories and methods could account for the slightly different results.

Since November 2000, the Jamestown S'Klallam Tribe has continued sampling for fecal coliform at most of the TMDL sites including Dungeness RM 0.1 and DOH marine station 113. The fecal coliform data obtained by the tribe used the fecal coliform MF method with the exception of four sample events where MPN was used to obtain fecal coliform concentrations at the DOH 113 site. To further test the hypothesis that fecal coliform concentration at Dungeness RM 0.1 and DOH station 113 were essentially the same, the tribal data set (n=11) and the Ecology data set (n=13) were combined and a paired t-test was used to determine if the two sites were significantly different. There was also no significant difference in fecal coliform concentrations between the two sites using the larger data set (n=24). The DOH station again had a slightly higher geometric mean that Dungeness RM 0.1, with geometric mean values of 13 and 11 fc/100mL, respectively.

The Dungeness RM 0.1 and DOH marine station 113 are in close proximity (0.4 miles) and did not significantly differ in fecal coliform concentrations during this study. Therefore, to provide adequate protection to the shellfish area, the TMDL target fecal coliform concentration set for the mouth of the Dungeness River needs to be set equivalent to the same fecal coliform standard as the bay (Class A marine fecal coliform standard). While the Dungeness River station at RM 3.2 met this standard, the downstream stations did not. Reductions in Dungeness River fecal coliform concentrations are needed downstream of RM 3.2. Recommended fecal coliform TMDL targets for the Dungeness River are included in Table 5.

Meadowbrook and Cooper creeks and Golden Sands Slough must meet their current classification, Class AA freshwater, and the irrigation ditches to the bay must meet Class A freshwater standards. Because the Dungeness River is the major fecal coliform loading contributor to the bay, the current standards for other tributaries and ditches to the bay are considered adequate. In addition, the Rensel and Smayda (2001) report concluded that spring and summer marine water circulation in

Table 5. Recommended fecal coliform TMDL load allocations and target concentrations for tributaries to Dungeness Bay.

Site	Study FC GMV* (#fc/100mL)	Study FC 90^{th} %tile (#fc/100mL)	Target FC GMV (#fc/100mL)	Target FC 90^{th} %tile (#fc/100mL)	Required Change (%)	Target FC Load Allocation (conc x flow)
Dungeness River RM 0.1	15	47	13	43	-9	6812
Meadowbrook Creek CM 0.2	33	243	14	100	-59	200
Cooper Creek	49	140	35	100	-28	214
Golden Sands Slough	109	565	19	100	-82	33
Irrigation Ditch 1	150	273	100	182	-33	12
Irrigation Ditch 2	153	1281	24	200	-84	< 1
Total						7271

* Geometric Mean Value

nearshore areas east of the Dungeness River mouth, such as Three Crabs Beach area, is generally southeasterly, away from the inner bay. Accordingly, freshwater flows from streams, seeps, or on-site sewage treatment systems in those areas would likely have less impact to inner Dungeness Bay. The exception to this would be during some winter periods when strong easterly or southeasterly winds and neap tides occur, which could enhance movement of shallow nearshore outer bay waters toward or into inner Dungeness Bay (Rensel, 2002).

The statistical rollback method (Ott, 1995) was used to determine the percent fecal coliform reduction necessary at each site to meet the desired concentration reduction targets recommended above. Table 5 describes the target fecal coliform geometric mean values and 90^{th} percentile values for each site. The target values were used to determine loading reductions described in Table 5.

Dungeness River

In the previous section, the TMDL target for the mouth of the Dungeness River (RM 0.1) was established as *GMV 13 fc/100mL and a 90^{th} percentile of 43 fc/100mL* (Table 5) to protect shellfish harvesting in the bay. This section evaluates fecal coliform loading to the Dungeness River. It establishes TMDL targets for contributors to the river, so that the TMDL target is met at the mouth. The analysis proceeds from downstream to upstream.

Fecal Coliform Load Balance

Figures 5 and 6 present Dungeness River fecal coliform loading results for the wet and irrigation seasons. Annually and seasonally loading from the mouth of Matriotti Creek is the largest contributor of fecal coliform.

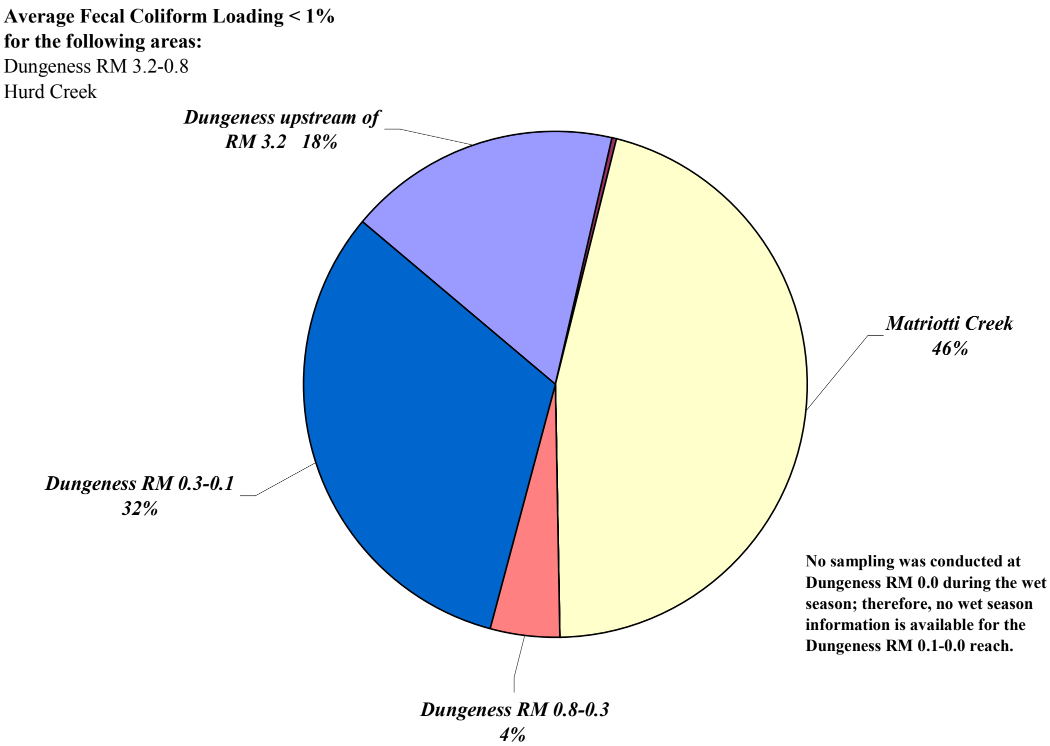

Figure 5. Relative Contributions of Fecal Coliform Loading to the Dungeness River, Wet Season (November 1999 - February 2000).

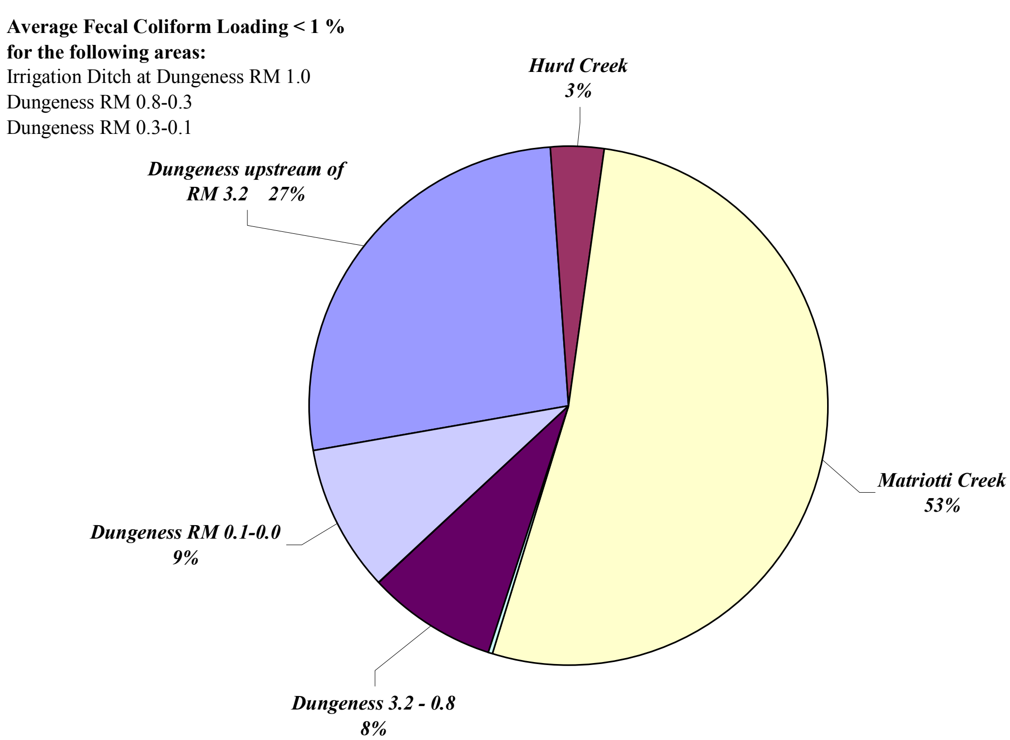

Figure 6. Relative Contributions of Fecal Coliform Loading to the Dungeness River, Irrigation Season (April-September 2000)

For the load balance, the Dungeness River was divided into three reaches:

Reach	Tributaries entering the river in this reach (sampled in this study)
RM 0.1 to 0.3	None
RM 0.3 to 0.8	None
RM 0.8 to 3.2	Matriotti and Hurd creeks and one irrigation ditch at Dungeness RM 1.0

Fecal coliform loads and concentrations at the downstream end of each reach were compared to measured loads and concentrations coming into the reach (both upstream and tributaries). The difference between input and output was termed the "residual". If the residual is positive, a source of bacteria in that reach is indicated. If the residual is negative, bacteria die-off or settling is indicated. Table 6 summarizes annual average values for flow, fecal coliform concentrations, and fecal coliform loads for tributaries to the Dungeness River.

Fecal Coliform Load Allocation

The loading capacity for Dungeness River and Matriotti Creek are set to meet the fecal coliform criteria set in the bay. Fecal coliform loading capacities are expressed as concentrations.

To determine load allocations, the loading analysis proceeded downstream to upstream, starting with the previously established TMDL target for the mouth of the Dungeness River of a geometric mean value 13 fc/100mL, and a 90th percentile not to exceed 43 fc/100mL.

For the lowermost reach, RM 0.1 to 0.3, average annual sampling results in Table 6 show that there was a slight increase in loading over the length of this reach (128 fc/100mL x cfs), representing about 2% of the total river loading. This residual indicates a source of bacteria not yet identified, that should be eliminated. Therefore, the target load for this residual is zero. (There should not be a net increase of loading over this short river reach with this large volume of water). Therefore, the previously identified TMDL target of a geometric mean value 13 fc/100mL, and a 90th percentile not to exceed 43 fc/100mL can be moved upstream to the bottom of the middle reach: RM 0.3 to 0.8.

Table 6. Mean daily values for fecal coliform concentrations, flow, loading and relative contributions of flow and fecal coliform loading for reaches of the Dungeness River.

	Inputs and Outputs (measured) and Residual	Mean FC (#fc/100mL)	Mean Flow (cfs)	Mean FC Load (#fc/100mL x cfs)	Flow Contribution to Reach (%)	FC Contribution to Reach (%)
Reach RM 0.1 to 0.3						
Input	Upstream end of reach (RM 0.3)	26	413	7461	100	98
Residual	Residual contributions	-	0	128	0	2
Output	Downstream end of reach (RM 0.1) *	21	413	7589		
Reach RM 0.3 to 0.8						
Input	Upstream end of reach (RM 0.8)	37	413	9493	100	100
Residual	Residual contributions	0	0	-2032	0	0
Output	Downstream end of reach (RM 0.3)	26	413	7461		
Reach RM 0.8 to 3.2						
Input	Upstream end of reach (RM 3.2)	13	390	3279	94	34
	Matriotti Creek	381	17	5972	4	62
	Hurd Creek	47	6	316	1	3
	Irrigation ditch at Dungeness RM 1.0	132	0.1	13	0	< 1
Residual	Residual contributions	0	0	-87	0	0
Output	Downstream end of reach (RM 0.8)	37	413	9493		

Mean fecal coliform load is an average of all fecal coliform loading values. Loading values are calculated by multiplying the instantaneous flow x fecal coliform concentration. Mean fecal coliform concentration is an average of all fecal coliform concentrations (arithmetic mean), just as the mean flow is an average of all flow measurements obtained. Thus the mean fecal coliform concentration multiplied by the mean flow may not be equivalent to the mean fecal coliform load in the table.

*No sampling was conducted at Dungeness RM 0.0 during the wet season; therefore, no wet season information is available for the Dungeness RM 0.1-0.0 reach, and it was not possible to calculate mean annual values for this reach.

The fecal coliform reductions needed for the sites within this reach are shown in Table 7 and Figure 7. Loading capacity (expressed as concentrations) for Dungeness River and the tributaries below Dungeness RM 3.2 are shown in Table 7. Fecal coliform load information is also presented. There are no point source permitted discharges in the study area; therefore, the waste load allocation is equivalent to 0.

Table 7. Recommended fecal coliform TMDL load allocations and target concentrations for the Dungeness River and tributaries.

Site	Study FC GMV* (#fc/100mL)	Study FC 90th Percentile (#fc/100mL)	Target FC GMV (#fc/100mL)	Target FC 90th Percentile (#fc/100mL)	Required Change (%)	FC Target Load Allocation (conc. x flow)
Dungeness RM 0.1	15	47	13	43	-9	6812
Residual – Reach RM 0.1 to 0.3			0	0	-2	0
Dungeness RM 0.3	13	61	9	43	-29	5288
Dungeness RM 0.8	17	81	9	43	-47	5059
Irrigation ditch at Dungeness RM 1.0	83	239	60	170	-29	24
Matriotti Creek	279	783	60	170	-78	1267
Hurd Creek	12	100	12	100	0	316
Dungeness RM 3.2	6	28	6	28	0	3279

* GMV=geometric mean value

The mass balance for the middle reach (RM 0.3 to 0.8) shows a net loss, or die-off, of bacteria through the reach. To be conservative and as a margin of safety, the TMDL target was assumed to stay the same through this reach. Therefore, the target geometric mean value of 13 fc/100mL and a 90th percentile not to exceed 43 fc/100mL would apply at the bottom of the uppermost reach, at RM 0.8. Table 7 shows a geometric mean value of 9 fc/100mL for Dungeness RM 0.3 and 0.8, because in applying roll-back analysis to sample distributions at these two sites, a 9 fc/100mL geometric mean value was needed to meet the 90th percentile of 43 fc/100mL.

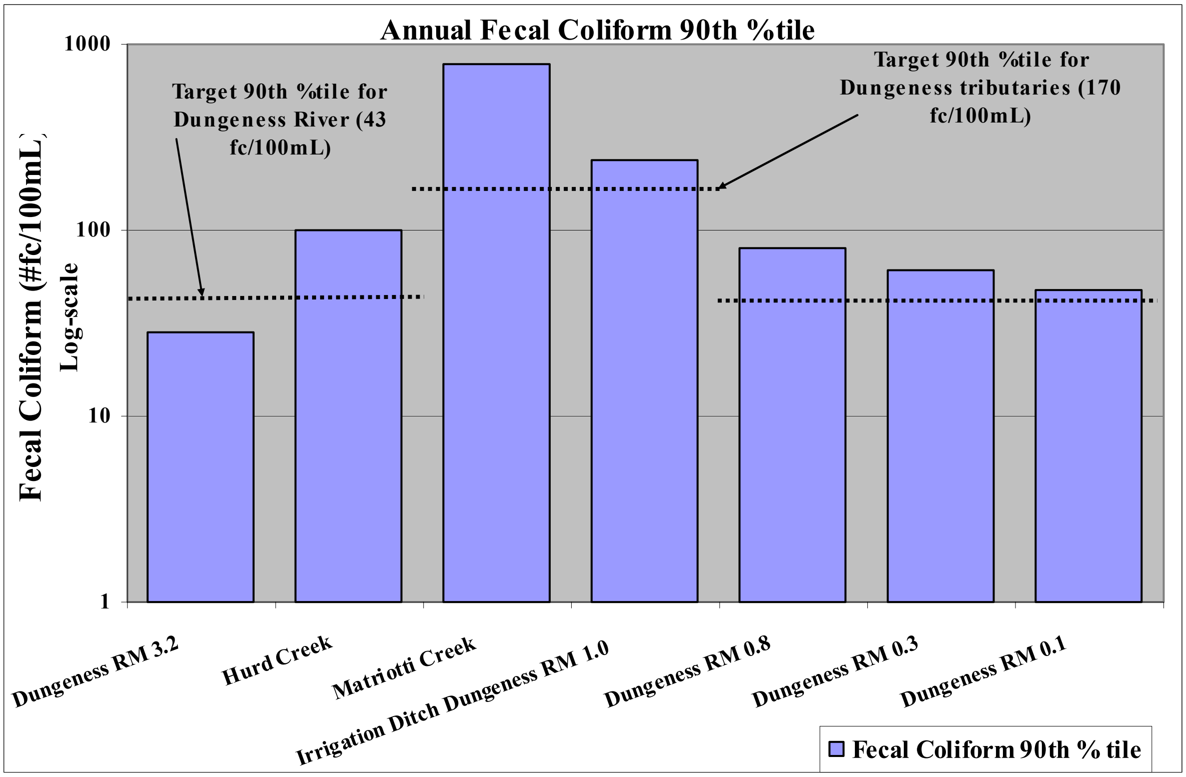

Figure 7. Dungeness River and Tributaries Fecal Coliform 90th Percentiles, and Target Fecal Coliform 90th Percentile Concentrations. (The 90th percentile is the limiting part of the fecal coliform standard for all areas in the graph).

The uppermost reach (RM 0.8 to 3.2) has contributions from Matriotti Creek, Hurd Creek, an irrigation ditch at Dungeness RM 1.0, and residual contributions. The necessary load reduction needed for the downstream end of this reach, at RM 0.8, is shown in Table 7. The next step is to determine the load reductions necessary for the three tributary loads, and any additional inputs to this reach, to meet the downstream target. The upstream boundary of this reach (Dungeness RM 3.2), with a geometric mean value of 6 fc/100mL and a 90th percentile of 28 fc/100 mL, does not require any load reduction, and the residual is negative for this reach. The remaining three inputs (Matriotti, Hurd, and irrigation ditch) need to be reduced to meet the downstream reach target.

There are many ways to allocate reductions among these three inputs. For equity, it was decided to set the target geometric means and 90th percentiles to be the same for all three. Following this approach, it was determined that a target geometric mean value of 60 fc/100mL and a 90th percentile of 170 fc/100 mL for Matriotti Creek and the irrigation ditch at Dungeness RM 1.0 was sufficient to meet the downstream target. For Hurd Creek, the current geometric mean value (12 fc/100mL) and 90th percentile already met this target and did not need to be further reduced. These load allocations are summarized in Table 7.

Location of Bacterial Sources

For the freshwater tributaries to the bay including the Dungeness River, paired t-tests and fecal coliform loading and concentration graphs were used to compare upstream and downstream sites to determine the location of fecal coliform sources.

1. Meadowbrook Creek and Meadowbrook Slough

Statistical Analysis

On Meadowbrook Creek and Slough, paired t-tests were used to compare upstream and downstream sites for differences in fecal coliform concentration, loading, and, where available, flow. There were no significant differences in fecal coliform concentration or loading for Meadowbrook Slough. For Meadowbrook Creek, the only significant difference was a decrease in fecal coliform concentration and an increase in flow between CM 1.95 and 0.8, which suggests dilution from a clean flow source such as groundwater.

Table 8 presents estimated fecal coliform loading results for three periods for Meadowbrook Creek and Slough. Figures 8 and 10 show fecal coliform loading for the wet season and irrigation season by site, and Figures 9 and 11 present geometric mean fecal coliform concentration by site for the same periods. Average fecal coliform loading estimates were obtained by averaging fecal coliform loading annually or seasonally. Negative loading values were used in the averaged results.

Table 8. Estimated fecal coliform loading contributions for Meadowbrook Creek and Meadowbrook Slough.*

Site	Annual Loading Average (#fc/100/mL x cfs) n=18	Wet Season Loading Average (#fc/100/mL x cfs) n=7	Irrigation Season Loading Average (#fc/100/mL x cfs) n=9
Meadowbrook Creek			
Upstream of CM 2.00	**	**	366
Upstream of CM 1.95	493	178	n/a
CM 2.00-1.95	**	**	185
CM 1.75T	26	13	38
CM 1.95-0.8	-156	-101	-149
CM 0.8-0.3	-92	20	-90
CM 0.3-0.2	215	432	144
Meadowbrook Slough			
Intake	20	< 1	39
CM 0.45-0.20 east tributary	3	< 1	7
CM 0.20 west tributary	46	10.1	52
At CM 0.2	69	10.8	98

* These data are determined by subtracting the load from the station above and tributaries from the station below, to determine the incremental gain or loss of fecal coliform load within each reach.
** Data are not available for this period.

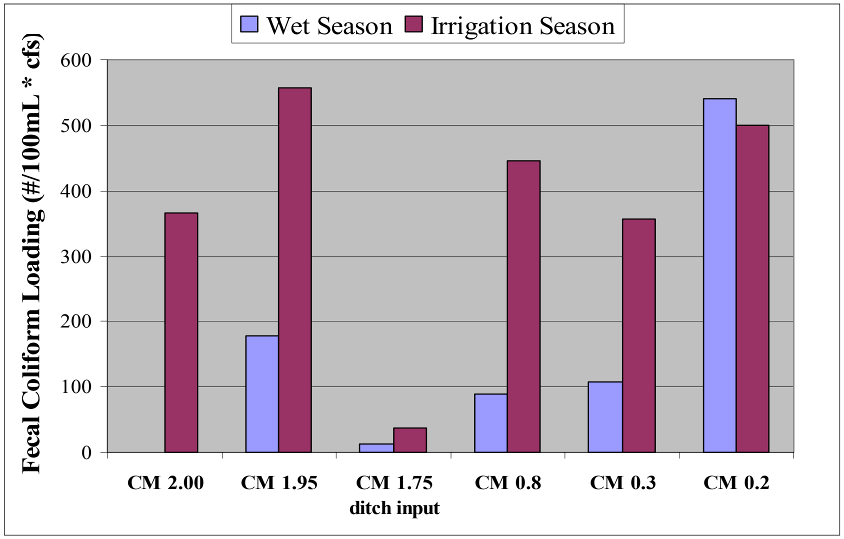

Figure 8. Meadowbrook Creek Fecal Coliform Loading.

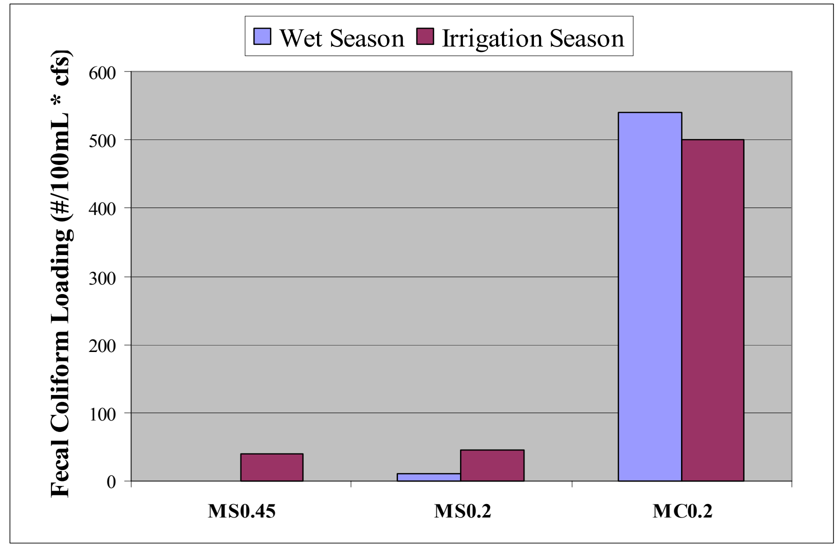

Figure 10. Meadowbrook Slough Fecal Coliform Loading.

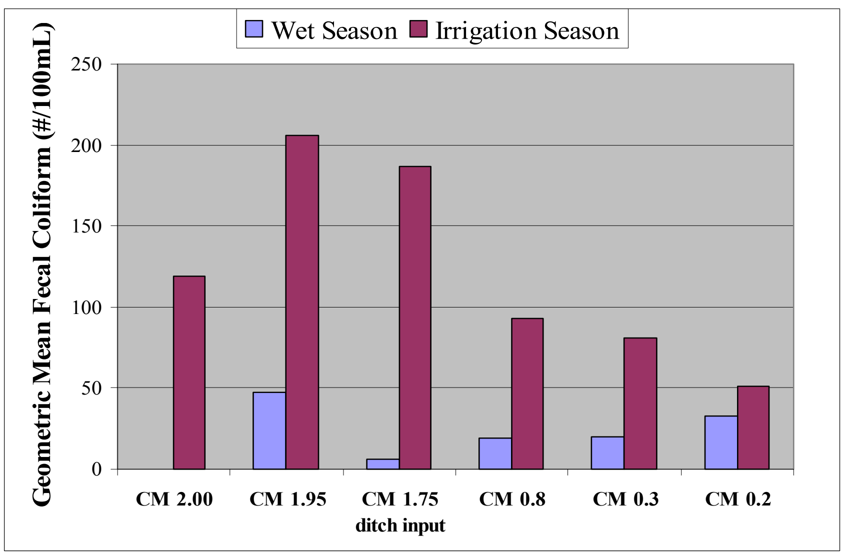

Figure 9. Meadowbrook Creek Fecal Coliform Concentrations.

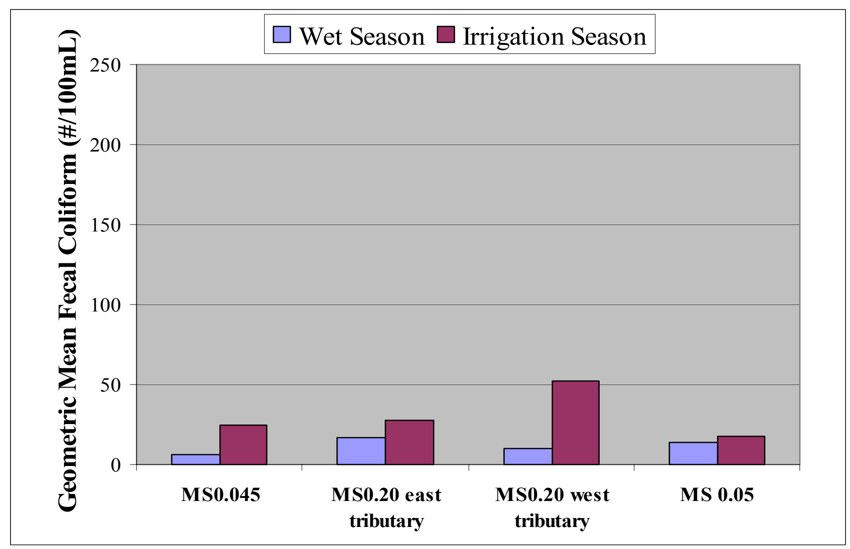

Figure 11. Meadowbrook Slough Fecal Coliform Concentrations.

Fecal Coliform Loading Results and Discussion

Meadowbrook Creek

For Meadowbrook Creek during the wet season, the second highest fecal coliform loading was upstream of CM 1.95 (Figure 8). Fecal coliform concentrations and loading decrease between CM 1.95 and 0.8, probably due to die-off or settling. A loading increase (not statistically significant) is seen between CM 0.8 and 0.3. The largest increase in loading is seen between CM 0.3 and 0.2 at the mouth. Meadowbrook Slough enters the creek between these two sample sites. Loading from the slough upstream of CM 0.20 does not account for this increase. Possible reasons for the increase in fecal coliform loading include sources on the slough downstream from CM 0.20 or sources from the marine environment.

During the irrigation season, the major fecal coliform loading sources are upstream of CM 2.00, with increases in loading seen between CM 2.00 and 1.95 and again between CM 0.3 and 0.2 at the mouth. Figure 9 shows an increase in fecal coliform concentrations during the irrigation season between CM 2.00 and 1.95. Downstream of CM 1.95, the decreases in concentration are likely due to bacterial die-off and dilution.

Meadowbrook Slough

For Meadowbrook Slough, higher concentrations and loading are seen during the irrigation season (Figures 10 and 11). The slough's source of water, the Dungeness River, also has higher concentrations of fecal coliform during the irrigation season. The west tributary of the slough at CM 0.20 has elevated concentrations of fecal coliform during the irrigation season. The source of this tributary is a spring approximately 20 yards upstream from the sample site. Possible sources in this area include wildlife or domestic pets.

Recommendations

- Sources upstream of Meadowbrook Creek CM 2.00 should be investigated.
- A residential home with a pond is the only land use between CM 2.00 and 1.95. This site should be investigated for possible on-site sewage treatment system failure or a contributing land-use practice on the property.
- The increase in fecal coliform loading seen between Meadowbrook Creek 0.3 and 0.2 could be from on-site sewage treatment failures of homes along the slough downstream of Meadowbrook Slough CM 0.20 or from marine sources.

2. Cooper Creek, Golden Sands Slough, and Irrigation Ditches

Fecal Coliform Loading Results and Discussion

Fecal coliform loading values from the mouth of Cooper Creek, Golden Sands Slough, Irrigation Ditches 1 and 2, and the Dungeness River at RM 0.1 and RM 0.0 are estimated in Table 9. Average fecal coliform loading estimates were obtained by averaging fecal coliform loading annually or seasonally. Negative loading values were used in the averaged results.

Table 9. Estimated fecal coliform loading contributions for tributaries to inner and outer Dungeness Bay.

Site	Total Loading Average (conc. x flow)	Averaging Period
Cooper Creek	299	4/24/00-10/9/00 n=10
Golden Sands Slough	187*	12/7/99-10/9/00 n=14
Irrigation Ditch 1	39 **	6/6/00-10/9/00 n=6
Irrigation Ditch 2	4 ***	6/6/00-10/9/00 n=5
Dungeness River at RM 0.1	7589	11/16/99-10/9/00 n=18
Dungeness River at RM 0.0	8688	5/10/00-10/9/00 n=9

* Fecal coliform results were done by MPN analysis. Flow was conservatively estimated to be 1 cfs.
** Water in ditch 6 of 8 times sampled; average load for the irrigation season calculated by dividing sum of 6 loads by 8.
*** Water in ditch 5 of 8 times sampled; average load for the irrigations season calculated by dividing sum of 5 loads by 8.

For Cooper Creek and the irrigation ditches 1 and 2, sampling did not start until March 2000. For Golden Sands Slough, no flow data are available, so loading is estimated using a flow of 1 cfs for all estimates. Golden Sands Slough loading is calculated using fecal coliform most probable number (MPN) data. Table 9 also contains loading estimates for the Dungeness River for comparison. It is important to consider the averaging period when looking at loading estimates; many of the study sites tend to have higher loading values during the irrigation season.

Recommendations

- Upstream fecal coliform sources on Cooper Creek should be investigated by walking the creek and obtaining additional fecal coliform samples. Aerial photos indicate possible drainage ditch inputs upstream of the mouth (Ecology, 1994).

- Investigate waste treatment systems in Golden Sands development.

- Take action to eliminate irrigation ditch discharge to the bay (i.e., tight-lining ditch) or investigate possible source of bacterial contamination along the ditch length, with irrigation ditch 1 being the highest priority for action.

3. Dungeness River

Statistical Analysis

The results of the paired t-test analysis are presented in Appendix D. Paired t-tests showed significant increases from upstream to downstream in fecal coliform concentrations annually and during the irrigation season at Dungeness RM 0.8, and fecal coliform loading increased significantly during the wet season at RM 0.8.

In looking at annual, wet, and irrigation season data, there is a significant increase in turbidity at Dungeness RM 0.8. The average annual turbidity at RM 3.2 was 6.1 NTU, and at RM 0.8 was 7.5 NTU. Turbidity was higher during the wet season.

Fecal Coliform Loading

Figures 5 and 6 present Dungeness River fecal coliform loading results for the wet and irrigation seasons. Table 10 presents fecal coliform loading contributions on the Dungeness River, annually and seasonally.

Table 10. Estimated fecal coliform loading contributions for the Dungeness River.*

Site	Annual Loading Average (fc conc. x cfs)	Wet Season Loading Average (fc conc. x cfs)	Irrigation Season Loading Average (fc conc. x cfs)
Above RM 3.2	3279	1614	4211
RM 3.2-0.8	-87	-685	1266
Hurd Creek (mouth)	316	31	536
Matriotti Creek (mouth)	5972	4223	8268
Irrigation ditch at Dungeness RM 1.0	13	0	34
RM 0.8-0.3	-2032	406	-4061
RM 0.3-0.1	128	3063	-2801
RM 0.1-0.0	No information	No information	1445

* These data are determined by subtracting the load from the station above and tributaries from the station below to determine the incremental gain or loss of fecal coliform load within each reach.

Fecal Coliform Loading Results and Discussion

For Dungeness River below RM 3.2, the greatest fecal coliform loading source annually and seasonally is Matriotti Creek. During the wet season, the second largest source is fecal coliform loading from the river between Dungeness RM 0.3 and 0.1. This stretch of the river has no known tributaries. The west side of the river has a residential development on on-site sewage treatment systems. These on-site systems should be inspected during the wet season to determine if there are on-site system failures or run-off from residential activities.

Recommendations

- Take actions necessary to meet water quality standards in Matriotti Creek (see Matriotti Creek recommendations).
- Between Dungeness RM 0.3 and 0.1, on-site sewage treatment systems of homes located near the river should be inspected during the wet season to determine if there are system failures or run-off from residential activities. On-site system failures should be corrected immediately.

4. Hurd Creek

Fecal Coliform Loading

Figure 12 presents a comparison of Hurd Creek and Matriotti Creek fecal coliform loading for the year, wet season, and irrigation season. Higher levels of fecal coliform loading and concentrations are seen during the irrigation season.

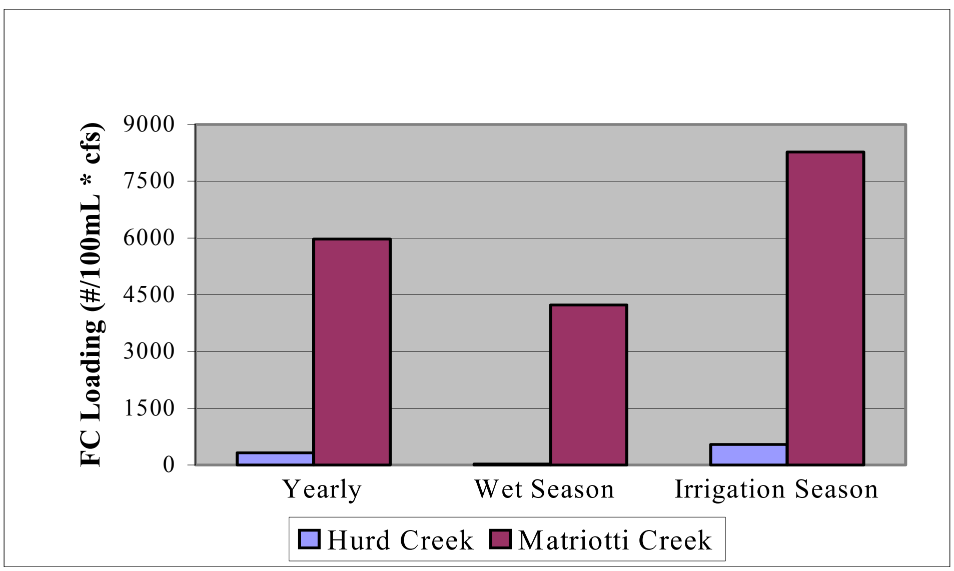

Figure 12. Average Fecal Coliform Loading from Hurd and Matriotti Creeks.

Results and Discussion

Hurd Creek did not appear to be a significant contributor of fecal coliform loading during most of the year, and fecal coliform levels met TMDL target concentrations. During the irrigation season, fecal coliform concentrations were higher than the wet season.

Recommendation

- Hurd Creek is a low priority for source control actions.

5. Matriotti Creek

Statistical Analysis

The results of the paired t-test analysis are presented in Appendix D. Paired t-tests showed significant increases from the upstream site in fecal coliform concentration at Matriotti CM 3.2 and 0.3. Significant increases in fecal coliform loading were seen at Matriotti CM 3.2, 1.9, and 0.3.

Paired t-tests were used to determine if there was a difference in turbidity between CM 0.7, 0.3, and 0.1 (n=7) for the sampling period June 19 through September 9, 2000. Turbidity did tend to increase between CM 0.7 to 0.3, though not significantly. There was a significant decrease in turbidity between CM 0.3 and 0.1.

Paired t-test Results and Discussion

Mat 6.0 and 4.8

Results show that fecal coliform concentrations decrease significantly from CM 6.0 to 4.8, but there was no significant change in the load. There was significant increase in flow between CM 6.0 and 4.8, so dilution could account for decreases seen in fecal coliform concentration.

Mat 4.8 and 3.2

A significant increase in fecal coliform concentrations, loading, and flow is seen from CM 4.8 to 3.2. Two irrigation ditches and Bear Creek empty into Matriotti Creek between these sites. Reach stream flow outputs were significantly higher than inputs. Fecal coliform output was also higher but to a less significant level (P=0.07). This means that inputs of bacterial loading may exist between CM 4.8 and 3.2. Most of this loading is from Bear Creek and the irrigation ditches, but there may also be some sources of fecal coliform loading along Matriotti Creek.

Mat 3.2 and 1.9

Fecal coliform loading and flows were significantly higher at CM 1.9. Mudd Creek enters Matriotti Creek just upstream of the station at CM 1.9. Significant increases in loading could be due to bacteria sources between CM 3.2 and 1.9, or Mudd Creek. Comparing the measured flow and the expected flow for CM 1.9, significantly higher measured flow levels are seen indicating water input between CM 3.2 and 1.9, with an annually mean increase in flow of 1.2 cfs between the sites.

Mat 1.9, 1.4, and 0.7

No significant differences in bacterial concentrations, loading, or flow are seen between CM 1.9 and 1.4 or between CM 1.4 and 0.7.

Mat 0.7 and 0.3

Significant increases in bacterial concentrations, loading, and flow are seen between CM 0.7 and 0.3. Lotzgesell Creek enters Matriotti Creek at CM 0.6. When reach outputs are compared to inputs, significant increases in fecal coliform loading are seen at Matriotti Creek 0.3, indicating a fecal coliform loading source within this reach over and above the contributions from Lotzgesell Creek.

Mat 0.3 and 0.1

Significantly higher fecal coliform concentrations are seen at the upstream site at CM 0.3. Significantly higher flows are seen at CM 0.1. There is no significant difference in fecal coliform loading between the sites. Beebe Creek and a drainage ditch enter Matriotti Creek between the two sample sites. In comparing the measured values seen at CM 0.1 to the values at CM 0.3, bacterial loading is higher at CM 0.3 but not significantly so, due to the short travel time for the 0.2 mile reach.

The most likely explanation for the decrease in fecal coliform concentration in this reach is dilution from a relatively clean source of water. Significant increases in flow mean there is a source of water input between the sites. This source evidently is fairly clean (low in bacteria), accounting for decreases in fecal coliform concentration. This water source could be surface or groundwater input.

Another possible contributing factor relates to the significant decrease in turbidity seen between CM 0.3 and 0.1. Turbidity indicates the amount of solids suspended in the water, whether mineral (e.g., soil particles) or organic (e.g., algae). Fecal coliform could adhere to suspended soil particles and settle out in the sediment in the lower reaches. Bacterial die-off likely accounts for a minor decrease, due to the short travel time for the reach.

Fecal Coliform Loading

Table 11 presents the estimated loading results for the year, wet season, and irrigation season. Figures 13 and 14 present the relative contribution of fecal coliform loading to Matriotti Creek during the wet and irrigation season.

Average fecal coliform loading estimates were obtained by averaging fecal coliform loading annually and seasonally. Negative loading values were used in the averaged results.

Table 11. Estimated fecal coliform loading contributions for Matriotti Creek.*

Reach/Tributary Description	Reach or Tributary	Annual Loading Average (fc conc. x flow)	Wet Season Loading (fc conc. x flow)	Irrigation Season Loading (fc conc. x flow)
Matriotti Creek upstream of Atterbury Rd	US CM 6.0	67	86	63
Ditch south of Atterbury Rd	CM 6.0 ditch	22	50	5
Matriotti Creek between Atterbury Rd and Spath Rd	CM 6.0-4.8	-24	-37	-16
Spath Rd south ditch	CM 4.8 south ditch	7	0	7
Spath Rd north ditch	CM 4.8 north ditch	159	28	221
Bear Creek near airport	CM 3.8 tributary	149	245	97
Matriotti Creek between Spath Rd and Macleay Rd	CM 4.8-3.2	118	-5	182
Mudd Creek at Cays Rd	CM 1.95 tributary	471	416	556
Matriotti Creek between Macleay Rd and Cays Rd	CM 3.2-1.9	494	316	790
Matriotti Creek between Cays Rd and Lamar Lane	CM 1.9-1.4	-15	60	-88
Matriotti Creek between Lamar Lane and Game farm western property boundary	CM 1.4-0.7	-269	-164	-429
Lotzgesell Creek upstream of Game farm	CM 0.6 tributary	623	1206	304
Matriotti Creek between Game farm western property boundary and Ward Rd	CM 0.7-0.3	5939	2265	8846
Drainage ditch at Game farm boundary south	CM 0.25 ditch	no data	no data	59
Beebe Creek near mouth	CM 0.2 tributary	397	60	420
Matriotti Creek between Ward Rd and mouth	CM 0.3-0.1	-2132	-280	-2743
At mouth of Matriotti Creek	Total load at CM 0.1	5972	4223	8268

* These data are determined by subtracting the load from the station above and tributaries from the station below, to calculate the incremental gain or loss of fecal coliform load within each reach.

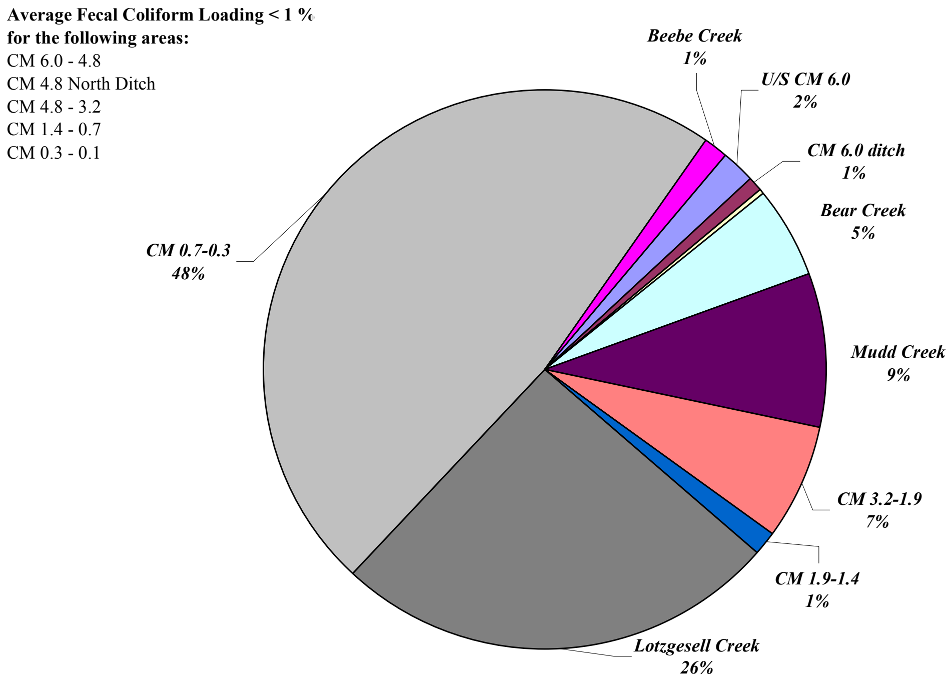

Figure 13. Relative Contributions of Fecal Coliform Loading to Matriotti Creek, Wet Season (November 1999 - February 2000).

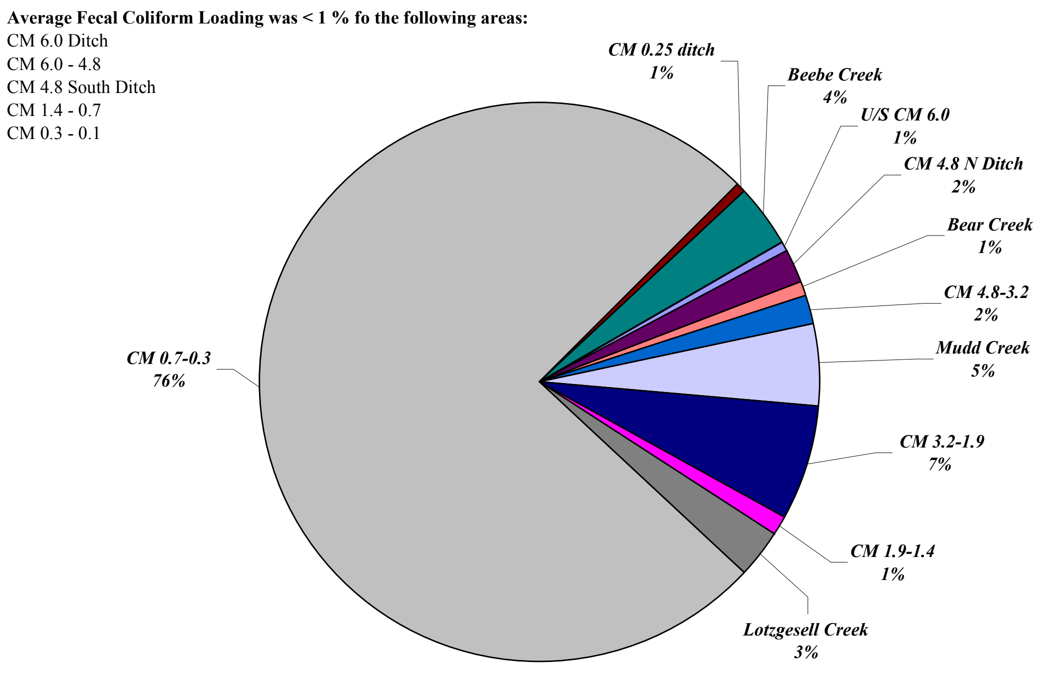

Figure 14. Relative Contributions of Fecal Coliform Loading to Matriotti Creek, Irrigation Season (April-September 2000).

Fecal Coliform Loading Results and Discussion

To assess the greatest sources of loading on Matriotti Creek, the top five loading sites were determined for the irrigation season, wet season, and the whole data set. Table 12 presents the rank and loading for the five greatest loading sources annually, and during the irrigation and wet seasons.

Table 12. Ranking of fecal coliform loading sources for Matriotti Creek by season.

Rank	Annual	FC Load (fc conc. x flow)	Irrigation Season	FC Load (fc conc. x flow)	Wet Season	FC Load (fc conc. x flow)
1	CM 0.7-0.3 (not including Lotzgesell Creek	5939	CM 0.7-0.3	8846	CM 0.7-0.3	2265
2	Lotzgesell Creek	623	CM 3.2-1.9	790	Lotzgesell Creek	1206
3	CM 3.2-1.9	494	Mudd Creek	556	Mudd Creek	416
4	Mudd Creek	471	Beebe Creek	420	CM 3.2-1.9	316
5	Beebe Creek	397	Lotzgesell Creek	304	Bear Creek	245

The highest fecal coliform loading to Matriotti Creek occurs in the reach between CM 0.7 and 0.3. This reach has the highest loading rates annually, and during the wet and irrigation seasons, with the highest loading during the irrigation season. The Clallam Conservation District is currently working with the landowner at the Olympic Game Farm to install best management practices (BMPs) to control bacterial pollution.

Lotzgesell Creek had the second highest loading levels annually and during the wet season, with the higher loading during the wet season. BMPs to control fecal coliform pollution were installed on Lotzgesell Creek and at Matriotti CM 0.9-0.7 in late 1999 and early 2000. Improvements in irrigation season water quality may be due to installation of these BMPs. The Jamestown S'Klallam Tribe continues monitoring of this area to determine if BMPs are effective.

The reach between Matriotti CM 3.2 and 1.9 ranked high annually, as well as during the wet and irrigation season. Mudd Creek, a tributary to Matriotti Creek at CM 1.95, also ranked high consistently.

Beebe Creek met water quality standards during the year and during both seasonal periods. However, during the irrigation season Beebe Creek was the fourth highest source of loading to Matriotti Creek. During the wet season, the fecal coliform geometric mean value was 8 fc/100mL; during the irrigation season, the geometric mean value was 88 fc/100mL. A non-parametric Mann-Whitney statistical test was used to determine if there was a significant difference between the wet and irrigation season fecal coliform concentration and loading levels in Beebe Creek (two-tailed test with a significance level of $\alpha = 0.05$). Test results showed that fecal coliform concentrations and loading are significantly different during the wet and irrigation seasons, with higher levels during the irrigation season. Animals with access to Beebe Creek were observed during the irrigation season.

Bear Creek ranked fifth during the wet season, but Bear Creek meets water quality standards during all periods. Higher loading at this site is due to higher water volume during the wet season.

Recommendations

- Best management practices (BMPs) to control animal waste should be implemented at the Olympic Game Farm between Matriotti CM 0.7 and 0.3. Additional monitoring should be conducted, especially during the irrigation season, to determine if these practices are effective.

- Monitoring should continue on Lotzgesell Creek to determine if the recently installed BMPs are effective in controlling bacterial loading.

- Sources of fecal coliform bacteria on Mudd Creek should be investigated. Possible sources include failing on-site sewage treatment systems, irrigation return, and stormwater. In early 2001 an irrigation tailwater ditch return to Mudd Creek with high fecal coliform loading values was eliminated. However, 2001 post-TMDL sampling continues to show that Mudd Creek is a source of bacteria to Matriotti Creek.

- Sources of fecal coliform between Matriotti CM 3.2 and 1.9 should be investigated. There are higher levels of fecal coliform loading during the irrigation season. Increases in water input are noted along this stretch as well. Sources could include irrigation return, animal access to the creek, failing on-site sewage treatment systems, or stormwater.

- BMPs, including animal exclusion, should be implemented on Beebe Creek.

Margin of Safety

A margin of safety to account for scientific uncertainty must be considered in the TMDLs in order for load allocations to remain 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 simple mass balance calculations and subsequent derivation of target values in freshwater assumed no fecal coliform die-off. Mass-balance calculation for fecal coliform from Dungeness River to Dungeness Bay also disregarded die-off and dilution in the marine waters.

- 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 90^{th} percentile of the post-management condition.

- The smaller 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.

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 reasonably short 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 bacteria control measures and the rate of reduction in bacteria loads will provide additional data to adjust compliance targets, and to establish realistic compliance dates. Ecology must review these data at regular intervals, and targets or actions can be adjusted through the TMDL 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 schedule should be closely coordinated with the Sequim-Dungeness Clean Water Workgroup and other local initiatives. The Clean Water Workgroup's mission is to oversee implementation of the Dungeness Bay and Watershed Clean Water Strategy. Secondly, the Workgroup was established to provide technical and policy advice on a broad range of water resource activities. The Workgroup reports to both the Board of Clallam County Commissioners and the Dungeness River Management Team. If stability in the local programs is assured, a complete evaluation of monitoring data should occur within five years to judge the effectiveness of the plan and the appropriateness of the TMDL targets.

Actions for Reducing Bacterial Source Impacts

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

- To protect water quality, animal access to open waterways, including irrigation and drainage ditch systems, should be restricted. Adequate vegetated buffers should be maintained along waterways.

- On-site sewage treatment systems, especially those with a clear potential for impacting surface water quality, should be inspected and tested for functionality. A program of regularly scheduled on-site sewage treatment system inspections and maintenance should also be implemented, as part of a long-term surface and groundwater protection effort.

- The purpose of the irrigation ditch system is to provide water for agricultural uses in the watershed. These ditches also convey stormwater and may pick up contamination from failing on-site sewage treatment systems. Many irrigation ditches are fenced or piped; these efforts should continue in an effort to protect and improve water quality. Contaminated stormwater generated from increasing development could be of increasing water quality concern in the irrigation ditches. Impervious surfaces (roads, driveways, rooftops) carry untreated stormwater previously absorbed by soil and vegetation. Future residential planning and development should take into consideration the protection of water quality, and stormwater best management practices should be implemented.

- Landowners should dispose of pet waste properly. Information on pet-waste disposal should be available to landowners in the area and to the public, particularly at public access points to the bay and river.

In 1999 and 2000 during the TMDL technical study, a Shellfish Closure Response Plan was being developed by the Sequim-Dungeness Clean Water Workgroup (formerly the Shellfish Closure Response Group). When a shellfish closure occurs, local government must form a Shellfish Closure Response District and develop a Shellfish Closure Response Plan. This plan defines actions necessary to control bacterial pollution and to reopen the shellfish beds.

The Shellfish Closure Response Plan for Dungeness Bay was developed using historical water quality data and the preliminary TMDL data. The data were used to determine areas of focus for bacterial source control recommendations. Elements of the Shellfish Closure Response Plan, entitled *Clean Water Strategy for Addressing Fecal Coliform in Dungeness Bay and Watershed*, will be integrated into Ecology's Water Cleanup Plan for the TMDL. Actions included in the *Clean Water Strategy* (Sequim-Dungeness Clean Water Workgroup, 2000), as per TMDL findings, are pollution source identification and remediation activities, public outreach, and a plan for long-term water quality protection.

Monitoring

Since TMDL monitoring concluded in October 2000, the Jamestown S'Klallam Tribe has been conducting follow-up monitoring as well as monitoring to further define sources in the study area. Monitoring is conducted monthly at most of the TMDL sites for water temperature, fecal coliform, and flow discharge. Source identification monitoring has occurred between Matriotti CM 0.7 and 0.3 to further delineate sources in this reach. In addition, the Stream Keepers of Clallam County sponsor citizen volunteer monitoring on selected irrigation ditches in the study area. The volunteers measure fecal coliform concentrations at irrigation ditch sites on a monthly basis. The Washington State Department of Health (DOH) continues to monitor fecal coliform concentrations, salinity, and temperature in Dungeness Bay every other month.

Continued water quality monitoring is needed to determine compliance with the fecal coliform target limits and to help evaluate the effectiveness of pollution management actions. Monitoring should be based on a 12-month period. Water quality monitoring for fecal coliform near the mouth of the Dungeness River, Matriotti, Meadowbrook, and Cooper creeks, and Golden Sands Slough is needed to determine compliance with water quality standards and the TMDL targets.

Should fecal coliform targets not be met, additional monitoring at other sites may be needed to determine sources of fecal coliform loading.

A complete evaluation of the TMDL follow-up monitoring data should be conducted in 2006, after five years of data have been collected. Evaluation should include data from the Tribe's follow-up monitoring, DOH data, data collected from citizen monitoring of irrigation ditches, and Ecology's Ambient Monitoring data on the Dungeness River.

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Summary Conclusions and Recommendations

Total Maximum Daily Load

- Class A freshwater quality criteria in the lower Dungeness River basin are inadequate to protect the bacterial quality of the marine water in Dungeness Bay. The Dungeness River at RM 3.2 and downstream must have fecal coliform bacteria levels that meet Class A marine water quality criteria to protect the marine waters and their beneficial uses. This criterion is:

  A geometric mean value of 13 fc/100mL and a 90^{th} percentile not to exceed 43 fc/100mL.

- To meet Class A marine water quality criteria in the Dungeness River, tributaries below RM 3.2 must meet the following fecal coliform target criteria:

  A geometric mean value of 60 fc/100mL and a 90^{th} percentile not to exceed 170 fc/100mL.

- Fecal coliform reductions are needed in the Dungeness River below RM 3.2 and the tributaries to meet these recommended targets. The most practical fecal coliform reductions at this time, to be protective of shellfish harvesting use in the bay, are as follows:
  - Matriotti Creek — 78%
  - Hurd Creek — no reduction
  - Irrigation ditch at Dungeness RM 1.0 — 29%
  - Dungeness River RM 0.3-0.1 — 2%

- To protect water quality in Meadowbrook and Cooper creeks and Golden Sands Slough, as well as marine uses in Dungeness Bay, fecal coliform levels in these tributaries to the bay must meet Class AA freshwater fecal coliform criteria. This criterion is:

  A geometric mean value of 50 fc/100mL and a 90^{th} percentile not to exceed 100 fc/100mL.

- Fecal coliform reductions are needed on Meadowbrook and Cooper creeks, Golden Sands Slough, and irrigation ditches to meet the appropriate water quality standard (fresh or marine). Fecal coliform reductions needed are as follows:
  - Meadowbrook Creek and Slough — 59%
  - Cooper Creek — 28%
  - Golden Sands Slough — 82%

Bacterial Source Attenuation and Monitoring

To assist in prioritizing actions to control fecal coliform bacteria pollution in the lower Dungeness River basin, areas were ranked by average seasonal loading. This ranking is included in Appendix E. Areas needing source control actions and further investigation are as follows, with highest priority actions first:

1. Matriotti Creek between CM 0.7 - 0.3.

   Best management practices (BMPs) to control fecal coliform and sediment are needed in this area. Matriotti Creek was the highest ranked loading source during the irrigation season.

2. Dungeness River between RM 0.3 - 0.1.

   BMPs to control fecal coliform and sediment are needed in this area. This reach was the highest ranked loading source during the wet season and is in close proximity to the shellfish beds. In addition, the possibility of human sources of bacterial contamination is of public health concern.

3. Dungeness River between RM 3.2 - 0.8 and between RM 0.1 - 0.0.

   Both areas need further investigation of sources during the irrigation season. Possible sources between RM 3.2 - 0.8 include other surface water inputs or land-use practices along this reach. Possible sources between RM 0.1 - 0.0 should be investigated, even though contamination could include tidally induced back-flow of the river.

4. Lotzgesell Creek.

   Continue monitoring water quality to evaluate any improvements from BMP activities on this creek.

5. Matriotti Creek between CM 3.2 - 1.9.

   Investigate possible sources in this stretch, including failing on-site sewage systems, irrigation tailwater returns, and animal access.

6. Mudd Creek, a tributary to Matriotti Creek.

   Investigate sources. Some source identification and corrections have occurred in this drainage, including water quality monitoring of irrigation ditches and elimination of an irrigation return with high bacteria levels. Other possible sources include failing on-site sewage systems along Mudd Creek.

7. Meadowbrook Creek, Meadowbrook Slough, and Golden Sands Slough.

   Implement source control actions as described on pages 28 to 30 of this report.

8. Continue monitoring to determine the effectiveness of source control actions.

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Appendices

Appendix A

Water Quality Standards

Waterbody classifications in the study area include Class A and AA, freshwater and marine. Table A-1 describes the applicable water quality standards for each waterbody in the study area. For comparison of data to water quality standards, salinity levels were evaluated.

To determine if the fresh or marine standard applies, the following criteria are used for fecal coliform: the freshwater criteria shall be applied at any point where 95% of the vertically averaged daily maximum salinity values are less than or equal to 10 parts per thousand or greater (Chapter 173-201A Washington Administrative Code). All salinity data for each site during each survey were averaged to determine whether marine or freshwater standards applied to that site.

Table A-1. Classification for waterbodies included in this study

Waterbody	Classification
Lower Dungeness River	Class A freshwater
Hurd Creek	Class A freshwater
Matriotti Creek	Class A freshwater
Meadowbrook Creek	Class AA freshwater
Meadowbrook Creek at mouth	Class AA marine for all parameters except FC. FC Class AA freshwater.
Meadowbrook Slough	Class AA freshwater
Meadowbrook Slough near mouth	Class AA marine for all parameters except FC. FC Class AA freshwater.
Cooper Creek	Class AA marine for all parameters except FC. FC Class AA freshwater.
Golden Sands Slough	Class AA marine for all parameters
Irrigation ditches to Dungeness Bay	Class A freshwater
Dungeness Bay	Class AA marine water

The Washington State Water Quality Criteria for parameters used in this study are described in Table A-2

Table A-2. Washington State Water Quality Criteria for Selected Parameters (Ch. 173-201A WAC)

Parameter	Class AA (Extraordinary)		Class A (Excellent)	
	Fresh	Marine	Fresh	Marine
Fecal Coliform Bacteria				
Shall not exceed a geometric mean value of (number of colonies/100 mL):	50	14	100	14
With not more than 10% of samples exceeding (number of colonies/100 mL):	100	43	200	43
Dissolved Oxygen				
Shall exceed (mg/L):	9.5	7.0 *	8.0	6.0 *
Temperature				
Shall not exceed, due to human activities (°C): (When natural conditions exceed this value, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C.)	16.0 **	13.0 **	18.0 **	16.0 **
pH				
Shall be within the range of (pH units):	6.5 - 8.5	7.0 - 8.5	6.5 - 8.5	7.0 - 8.5
Human-caused variation shall be within the range of less than (pH units):	0.2		0.5	
Turbidity				
When background turbidity is 50 NTU or less, shall not exceed background turbidity by (NTU):	5		5	
When background turbidity is more than 50 NTU, shall not have more than an increase of:	10%		10%	
Aesthetics				
Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.				
Ammonia				
Ammonia criteria are dependent on the temperature and pH of the water.				

* When natural conditions, such as upwelling occur, causing the dissolved oxygen to be depressed near or below this value, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L.

** Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C.

Appendix B

Compliance with Water Quality Standards

To evaluate compliance with water quality standards, duplicate field and laboratory samples were averaged for all parameters. Instantaneous measurements for dissolved oxygen and temperature were compared to standards. To evaluate fecal coliform bacteria, compliance with the standards results for the entire year were compared to standards and results for the irrigation season (April through September) and wet season (November through February). At some sites fecal coliform MPN and MF analysis was conducted. These data sets are evaluated separately. Only periods with at least five surveys of data were considered to contain sufficient data to evaluate compliance with standards.

In the Dungeness watershed, pH values tend to be higher than in most western Washington streams. The Dungeness River drains a large mass of true basalt, which was submerged in the ocean at some point; this may account for higher pH (Freudenthal, 2002). During the summer, when a majority of surface flow is from groundwater, higher pH is seen because of contact with the basalt. Lower pH is seen in winter or spring when most of the flow of the river is from overland flow (snowmelt or rainwater). Weather in Sequim is generally dry, with infrequent rain events.

Dungeness River - Class A Freshwater

Dungeness River survey results met state water quality standards for ammonia-nitrogen, temperature, dissolved oxygen, and turbidity. There were a few isolated pH readings that exceeded water quality standards. These sites are listed in Table B1.

Table B1. Dungeness River sites not meeting pH standards.

Station name	Site code	Date	pH	pH standard
Dungeness River at Ward Road bridge (RB)	DR3.2RB	12/7/99	8.6	6.5-8.5 SU
Dungeness River at Ward Road bridge (LB)	DR3.2LB	7/6/00	8.7	6.5-8.5 SU
Dungeness River at mouth	DR 0.0	7/6/00	8.6	6.5-8.5 SU

Table B2 describes compliance with fecal coliform water quality standards during the three periods. All of the Dungeness River sites, except the Dungeness River at Schoolhouse Road bridge, met fecal coliform water quality standards during all three periods. During the irrigation season, this site did not meet fecal coliform water quality standards.

Marine water quality standards and Washington State Department of Health (DOH) standards for shellfish areas are much more stringent than freshwater standards. The DOH standard is as follows: the fecal coliform geometric mean should not exceed 14 organisms/100 mL and the estimate of the 90^{th} percentile should not be greater than 43 organisms/100 mL. Because this study is focused on bacteria impacts to shellfish beds, Dungeness River results were also compared to the DOH standard. This standard does not currently apply to the Dungeness River. Results are described in Table B3. The upstream site at Ward Road bridge met the stringent DOH standard, while the sites downstream did not.

Table B2. Dungeness River compliance with Class A Freshwater fecal coliform water quality standards at monitoring sites.

	Annual Results November 1999 - October 2000			Wet Season Results November 1999 - February 2000			Irrigation Season Results April - September 2000		
Site*	Geometric mean below 100cfu/100 mL	10% or less of all samples exceed 200cfu/100 mL	Meets water quality standards	Geometric mean below 100cfu/100mL	10% or less of all samples exceed 200cfu/100 mL	Meets water quality standards	Geometric mean below 100cfu/100 mL	10% or less of all samples exceed 200cfu/100 mL	Meets water quality standards
DR 3.2	6	0 of 18 > 200	Yes	2	0 of 7 > 200	Yes	10	0 of 9 > 200	Yes
DR 0.8	17	1 of 18 > 200	Yes	7	0 of 7 > 200	Yes	35	1 of 9 > 200♦	No
DR 0.3	13	0 of 18 > 200	Yes	6	0 of 7 > 200	Yes	25	0 of 9 > 200	Yes
DR 0.1	15	0 of 18 > 200	Yes	9	0 of 7 > 200	Yes	18	0 of 9 > 200	Yes
DR 0.0	24	0 of 9 > 200	Yes	No wet season samples			25	0 of 8 > 200	Yes

* Site locations are shown in Figure 1.
♦ One sample exceedance does not cause a waterbody to be placed on the 303d list.

Table B3. Dungeness River compliance with Department of Health shellfish growing area standards.

	Annual Results November 1999 - October 2000			
Site	Number of samples	Geometric mean not > 14/100 mL	Estimated 90th percentile not > 43/100mL	Meets DOH shellfish area standards
DR 3.2	18	6	27	Yes
DR 0.8	18	17	81	No
DR 0.3	18	13	61	No
DR 0.1	18	15	48	No
DR 0.0	9	24	59	No

Meadowbrook Creek and Meadowbrook Slough

Meadowbrook Creek and Slough met state water quality standards for ammonia-nitrogen. Sites on Meadowbrook Creek and Slough that did not meet water quality standards for temperature, pH, or dissolved oxygen are described in Table B4.

Table B4. Meadowbrook Creek and Slough sites not meeting temperature, pH, or dissolved oxygen standards.

Sites not meeting temperature standards				
Station name	Site code	Date	Temp.	Temp. standard
Meadowbrook Creek irrigation ditch	MC 1.75T	6/19/00 7/6/00	18.3° C 18.6° C	≤ 18.0°C
Meadowbrook Creek (mouth)	MC 0.2	6/19/00 7/6/00 7/17/00 8/9/00 9/19/00	16.7° C 14.2° C 14.8° C 15.5° C 17.1° C	≤ 13.0°C
Meadowbrook Creek remnant channel	OLDMEAD	7/17/00 9/19/00	17.4° C 14.7° C	≤ 13.0°C
Meadowbrook Slough near Abernathy Road	MS 0.05	6/19/00 7/6/00 7/17/00 8/9/00	14.6° C 13.6° C 14.9° C 14.7° C 13.8° C	≤ 13.0°C
Sites not meeting pH standards				
Station name	Site code	Date	pH	pH standard
Meadowbrook Creek irrigation ditch	MC 1.75T	7/6/00	8.9	6.5-8.5 SU
Meadowbrook Creek at Pettit Farm	MC 0.8	10/9/00	6.3	6.5-8.5 SU
Meadowbrook Creek at Three Crabs Road	MC 0.3	12/7/99 10/9/00	5.9 5.9	6.5-8.5 SU
Meadowbrook Creek at mouth	MC 0.2	11/16/99 12/7/99 10/9/00	6.8 6.7 5.9	7.0-8.5 SU
Meadowbrook Slough	MS 0.45	10/9/00	6.4	6.5-8.5 SU
Meadowbrook Slough at Palmer Road (east tributary)	MS 0.02R	10/9/00	6.2	6.5-8.5 SU
Meadowbrook Slough at Palmer Road (west tributary)	MS 0.02L	10/9/00	6.2	6.5-8.5 SU
Meadowbrook Slough near Abernathy Road	MS 0.05	11/16/99 10/9/00	6.0 6.7	7.0-8.5 SU

(Table B4 continued on next page)

Table B4 (cont.). Meadowbrook Creek and Slough sites not meeting temperature, pH, or dissolved oxygen standards.

Sites not meeting dissolved oxygen standards				
Station name	Site code	Date	D.O.	D.O. standard
Meadowbrook Creek CM 2.0	MC 2.0	6/19/00 7/17/00 8/9/00 8/29/00 9/19/00	8.7 8.8 8.4 8.6 7.8	> 9.0 mg/L
Meadowbrook Creek west of Sequim Dungeness Way	MC 1.9	5/10/00 7/17/00 8/9/00 8/29/00 9/19/00	8.8 8.5 7.3 7.8 7.9	> 9.0 mg/L
Meadowbrook Creek at Pettit Farm	MC 0.8	5/10/00 6/19/00 7/17/00 8/9/00 8/29/00 9/19/00	9.0 7.9 7.5 8.2 7.1 6.4	> 9.0 mg/L
Meadowbrook Creek at Three Crabs Road	MC 0.3	7/6/00 7/17/00 8/9/00 8/29/00 9/19/00	9.1 7.2 8.6 7.2 6.7	> 9.0 mg/L
Meadowbrook Creek at mouth	MC 0.2	7/6/00 7/17/00 8/29/00	6.6 5.5 6.6	> 7.0 mg/L
Meadowbrook Slough at Palmer Road Confluence of tributaries	MS 0.20 MS 0.20	7/17/00 8/29/00	7.3 3.6	> 9.0 mg/L
Meadowbrook Slough near Abernathy Road	MS 0.05	7/17/00	3.6	> 7.0 mg/L

Table B5 describes Meadowbrook Creek and Slough compliance with fecal coliform water quality standards during the three periods. Meadowbrook Creek sites at CM 0.8 and 0.3 met water quality standards during the wet season. The only site to consistently meet standards on Meadowbrook Slough was the site just downstream of the Dungeness River diversion.

Table B5. Meadowbrook Creek and Slough compliance with fecal coliform water quality standards at monitoring sites.

	Annual Results November 1999 - October 2000			Wet Season Results November 1999 - February 2000			Irrigation Season Results April - September 2000		
Meadowbrook Creek									
Site*	Geometric mean below 50cfu/100 mL	10% or less of all samples exceed 100cfu/100 mL	Meets water quality standards	Geometric mean below 50cfu/100 mL	10% or less of all samples exceed 100cfu/100 mL	Meets water quality standards	Geometric mean below 50cfu/100 mL	10% or less of all samples exceed 100cfu/100 mL	Meets water quality standards
MC 2.0	162	5 of 9 > 100	No	No wet season samples			119	4 of 8 > 100	No
MC 1.9	124	12 of 18 > 100	No	47	2 of 7 > 100	No	206	8 of 9 > 100	No
MC 0.8	55	5 of 18 > 100	No	19	0 of 7 > 100	Yes	93	4 of 9 > 100	No
MC 0.3	41	5 of 18 > 100	No	20	0 of 7 > 100	Yes	81	4 of 9 > 100	No
MC 0.2	33	4 of 18 > 100	No	33	1 of 9 > 100	No	51	3 of 9 > 100	No
Site*	Geometric mean below 100cfu/100 mL	10% or < of all samples for calculating the GM exceed 200cfu/100 mL	Meets water quality standards	Geometric mean below 100cfu/100 mL	10% or < of all samples for calculating the GM exceed 200cfu/100 mL	Meets water quality standards	Geometric mean below 100cfu/100 mL	10% or < of all samples for calculating the GM exceed 200cfu/100 mL	Meets water quality standards
MC 1.7 ditch	58	5 of 16 > 200	No	6	1 of 6 > 200	No	187	3 of 9 > 200	No
Meadowbrook Slough									
Site*	Geometric mean below 50cfu/100 mL	10% or less of all samples exceed 100cfu/100 mL	Meets water quality standards	Geometric mean below 50cfu/100 mL	10% or less of all samples exceed 100cfu/100 mL	Meets water quality standards	Geometric mean below 50cfu/100 mL	10% or less of all samples exceed 100cfu/100 mL	Meets water quality standards
MS 0.45	13	0 of 18 > 100	Yes	6	0 of 7 > 100	Yes	25	0 of 9 > 100	Yes
MS 0.20 east tributary	20	1 of 18 > 100	Yes	17	1 of 7 > 100	No	28	0 of 9 > 100	Yes
MS 0.20 west tributary	33	6 of 18 > 100	No	10	1 of 7 > 100	No	53	4 of 9 > 100	No
MS 0.05	16	3 of 18 > 100	No	14	0 of 7 > 100	Yes	18	2 of 9 > 100	Yes

* Site locations are shown in Figure 1.

Sites not meeting water quality standards according to this table do not automatically get placed on Ecology's 303(d) list. Listing criteria are currently being revised; draft guidance is available on Ecology's web site under Water Quality Program. Generally one sample exceedance is not sufficient for 303(d) listing.

Cooper Creek, Golden Sands Slough, and Irrigation Ditches

Cooper Creek and Golden Sands Slough discharge to Dungeness Bay and are Class AA waterbodies. Due to salinity, the Cooper Creek site is classified marine for all parameters except fecal coliform. Golden Sands Slough is marine classification for all parameters including fecal coliform. The irrigation ditches are Class A freshwater, because the source of water is the Dungeness River.

Cooper Creek met standards for dissolved oxygen. The irrigation ditch near 182 Marine Drive Road met temperature standards. None of the sites met fecal coliform standards. Sites not meeting pH and temperature standards are listed in Table B6.

Table B6. Sites not meeting temperature or pH standard.

Sites not meeting temperature standards				
Station name	Site code	Date	Temp	Temp standard
Cooper Creek	Coop 0.1	7/17/00 8/9/00	14.4 13.5	≤ 13.0°C
Golden Sands Slough	Goldsand	4/24/00 6/6/00 7/6/00 7/17/00 8/9/00 9/19/00 10/9/00	16.2 16.0 15.7 20.0 20.5 15.7 13.3	≤ 13.0°C
Irrigation ditch, 495 Marine Road	Irr1	7/6/00	19.8	≤ 18.0°C
Sites not meeting pH standards				
Station name	Site code	Date	pH	pH standard
Cooper Creek	Coop 0.1	10/9/00	6.5	7.0-8.5 SU

None of the sites met water quality standards for fecal coliform. For Golden Sands Slough, standards were compared to fecal coliform most probable number (MPN) results. Table B7 describes water quality results in comparison to the fecal coliform standard.

Table B7. Cooper Creek, Golden Sands Slough, and irrigation ditch compliance with fecal coliform water quality standards at monitoring sites.

Site	Number of samples	Geometric mean not > 50/100 mL	10% or less of all samples exceed 100cfu/100 mL	Meets WQ standards
Cooper Creek	n=10 (3/00 - 10/00)	49	2 of 10 > 100	No
Site	Number of samples	Geometric mean not > 14/100 mL	10% or less of all samples exceed 43 cfu/100 mL	Meets WQ standards
Golden Sands ditch	n=14 (12/99 - 10/00)	109	11 of 14 > 43	No
Site	Number of samples	Geometric mean not > 100/100 mL	10% or less of all samples exceed 200cfu/100 mL	Meets WQ standards
Irrigation ditch 2	n=5 (6/00 - 10/00)	153	2 of 5 > 200	No
Irrigation ditch 1	n=6 (6/00 - 10/00)	150	1 of 6 > 200	No

Sites not meeting water quality standards according to this table do not automatically get placed on Ecology's 303(d) list. Listing criteria are currently being revised; draft guidance is available on Ecology's web site, http://www.ecy.wa.gov/programs/wq/303d/index.html. Generally one sample exceedance is not sufficient for 303(d) listing.

Matriotti Creek - Class A Freshwater

Matriotti Creek survey results met state water quality standards for ammonia-nitrogen and temperature. There were a few isolated pH readings and dissolved oxygen measurements that did not meet water quality standards. These sites are listed in Table B8.

Table B8. Matriotti Creek sites not meeting pH or dissolved oxygen standards.

Sites not meeting pH standards				
Station name	Site code	Date	pH	pH standard
Matriotti Creek at Atterbury Rd.	MAT6.0	8/9/00	8.8	6.5-8.5 SU
Matriotti Creek at Cays Rd.	MAT1.9	7/6/00	6.4	6.5-8.5 SU
Matriotti Creek at mouth	MAT0.1	5/10/00	8.6	6.5-8.5 SU
Sites not meeting dissolved oxygen standards				
Station name	Site code	Date	D.O.	D.O. standard
Matriotti Creek tributary Mudd Cr.	MAT3.8T	9/19/00	7.6	> 8.0 mg/L
Matriotti Creek at Cays Rd.	MAT1.9	8/9/00	7.5	> 8.0 mg/L

At the beginning of the study, only two sites on Matriotti Creek were sampled for turbidity: the uppermost site at CM 6.0 and the mouth at CM 0.1. These sites cannot be compared to the water quality standard for turbidity, because there is no suitable background site. During the later part of the study from June 19 through September 9, 2000, turbidity sampling was added at two downstream sites: CM 0.7 and 0.3. A violation in the turbidity standard was seen on October 9, 2000, when turbidity increased 12 NTU from CM 0.7 to 0.3.

Table B9 presents a comparison of all sites to the fecal coliform standard. Only a few sites met fecal coliform water quality standards for all three periods, as listed below:

- Matriotti Creek at Spath Road.
- A ditch to Bear Creek tributary to Matriotti Creek.
- Beebe Creek tributary to Matriotti Creek.

Table B9. Matriotti Creek compliance with fecal coliform standard.

	Yearly Results November 1999 - October 2000			Wet Season Results November 1999 - February 2000			Irrigation Season Results April - September 2000		
Site*	Geometric mean below 100cfu/100 mL	10% or less of all samples exceed 200cfu/100 mL	Meets water quality standards	Geometric mean below 100cfu/100 mL	10% or less of all samples exceed 200cfu/100 mL	Meets water quality standards	Geometric mean below 100cfu/100 mL	10% or less of all samples exceed 200cfu/100 mL	Meets water quality standards
Mat 6.0 ditch	18	2 of 18 > 200	No	22	1 of 7 > 200	No	23	1 of 9 > 200	No
Mat 6.0	52	4 of 18 > 200	No	21	0 of 7 > 200	Yes	131	4 of 9 > 200	No
Mat 4.8	21	0 of 18 > 200	Yes	13	0 of 7 > 200	Yes	42	0 of 9 > 200	Yes
Mat 4.8 S ditch	Water in ditch during irrigation season only.						295	2 of 4 > 200	No
Mat 4.8 N ditch	162	7 of 13 > 200	No	43	1 of 3 > 200		408	6 of 9 > 200	No
Mat 3.8 tributary Bear Creek	30	1 of 18 > 200	Yes	22	0 of 7 > 200	Yes	48	1 of 9 > 200	No
Mat 3.8 tributary ditch	19	0 of 8 > 200	Yes	21	0 of 7 > 200	Yes	No water in ditch during irrigation season.		
Mat 3.2	75	6 of 18 > 200	No	30	0 of 7 > 200	Yes	158	5 of 9 > 200	No
Mat 1.9 tributary Mudd Creek	239	11 of 18 > 200	No	87	2 of 7 > 200	No	406	7 of 9 > 200	No
Mat 1.9	124	7 of 18 > 200	No	59	1 of 7 > 200	No	244	5 of 9 > 200	No
Mat 1.4	129	5 of 18 > 200	No	63	1 of 7 > 200	No	227	4 of 9 > 200	No
Mat 0.7	115	7 of 18 > 200	No	51	2 of 7 > 200	No	213	4 of 9 > 200	No
Mat 0.6 tributary Lotzgesell Creek	42	2 of 18 > 200	No	47	1 of 7 > 200	No	50	1 of 9 > 200	No
Mat 0.3	599	14 of 18 > 200	No	279	4 of 7 > 200	No	1119	9 of 9 > 200	No
Mat 0.25 ditch	231	6 of 10 > 200	No	Samples obtained from April - October 2000			203	5 of 9 > 200	No
Mat 0.2 tributary Beebe Creek	40	1 of 17 > 200	Yes	8	0 of 6 > 200	Yes	88	0 of 9 > 200	Yes
Mat 0.1	279	11 of 18 > 200	No	149	1 of 7 > 200	No	510	9 of 9 > 200	No

* Site locations are shown in Figure 1.

Hurd Creek - Class A Freshwater

Hurd Creek survey results met state water quality standards for ammonia-nitrogen, pH, temperature, and dissolved oxygen. Water quality standards for fecal coliform were met during the wet season and annually. Table B10 describes Hurd Creek compliance with the fecal coliform standard.

Table B10. Hurd Creek compliance with fecal coliform standard.

	Geometric mean below 100cfu/100 mL	10% or less of all samples exceed 200cfu/100 mL	Meets water quality standards
Annual Results November 1999 - October 2000	12	1 of 18 > 200	Yes
Wet Season Results November 1999 - February 2000	4	0 of 7 > 200	Yes
Irrigation Season Results April - September 2000	33	1 of 9 > 200	No

Appendix C

Seasonal Patterns in Fecal Coliform

Dungeness Bay

Pie charts showing the seasonal relative load contribution to Dungeness Bay are presented in Figures C1 and C2. Loading from Cooper Creek and the irrigation ditches to Dungeness Bay were included in the irrigation season loading graphs, but not the wet season graph. Data were not collected for Cooper Creek during the wet season and the irrigation ditches to the bay, and only a partial data set was available for Golden Sands during the wet season. It is assumed the irrigation ditches do not contain much water during the non-irrigation season.

The charts show that, of all the freshwater sources sampled, the mouth of the Dungeness River contributes the vast majority of freshwater fecal coliform loading during both the wet and irrigation seasons.

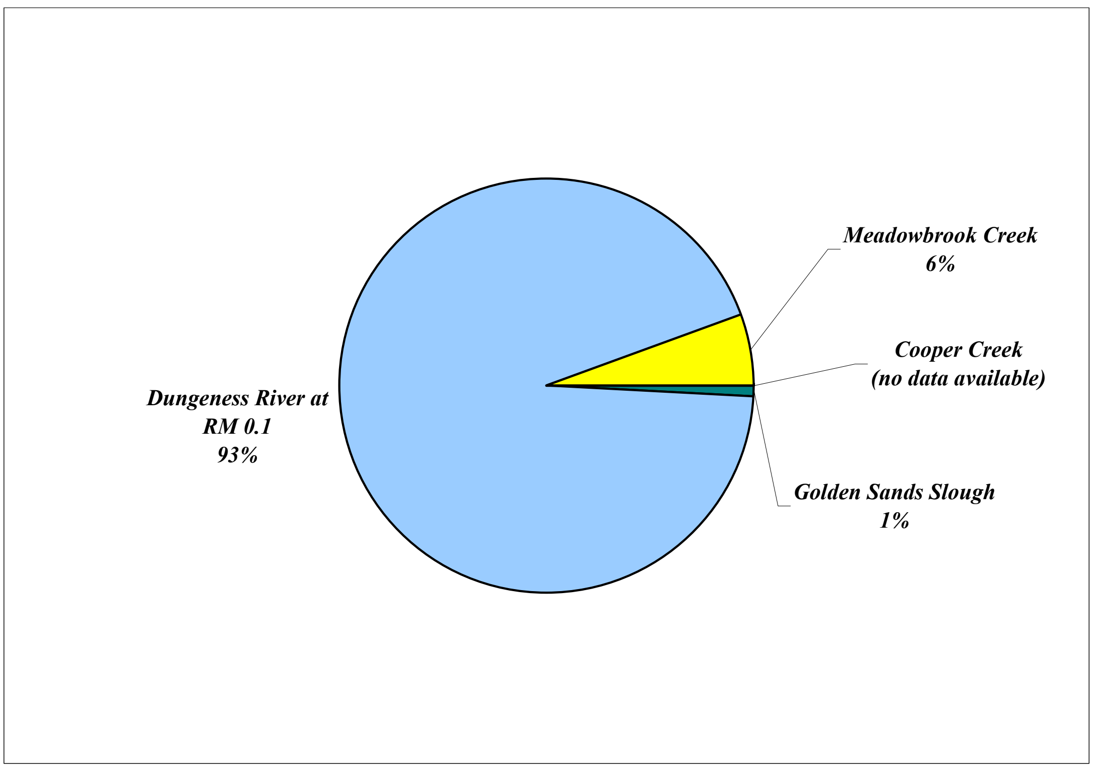

Figure C1. Relative Contributions of Fecal Coliform Loading, Dungeness Bay Wet Season (November 1999-February 2000).

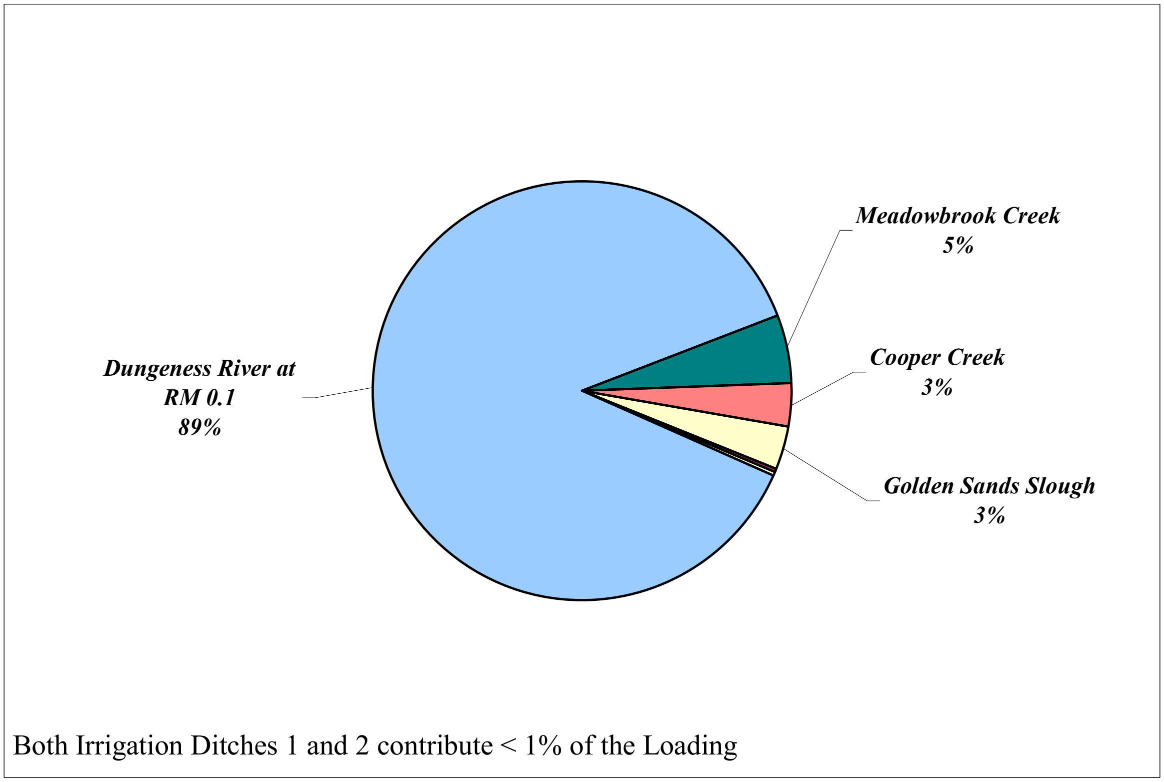

Figure C2. Relative Contributions of Fecal Coliform Loading, Dungeness Bay Irrigation Season (April-September 2000).

Figures C3 and C4 present geometric mean fecal coliform concentrations and fecal coliform loading for the Dungeness River sites and the mouths of the major tributaries. The results showed that for most sites higher fecal coliform concentrations are present during the irrigation season. For a majority of the tributaries and the Dungeness River above RM 0.8, higher loading is seen during the irrigation season. During the wet season, fecal coliform loading levels for the Dungeness River increase from RM 0.8 downstream. Fecal coliform loading at RM 0.1, the site nearest the mouth, is fairly consistent throughout the year with a slight increase during the wet season. This is consistent with the findings of Rensel and Smayda (2001) where, in a review of the marine data, higher fecal coliform concentrations were seen in the fall and winter season.

To protect water quality and beneficial uses in Dungeness Bay, the critical period for the TMDL study is the entire year.

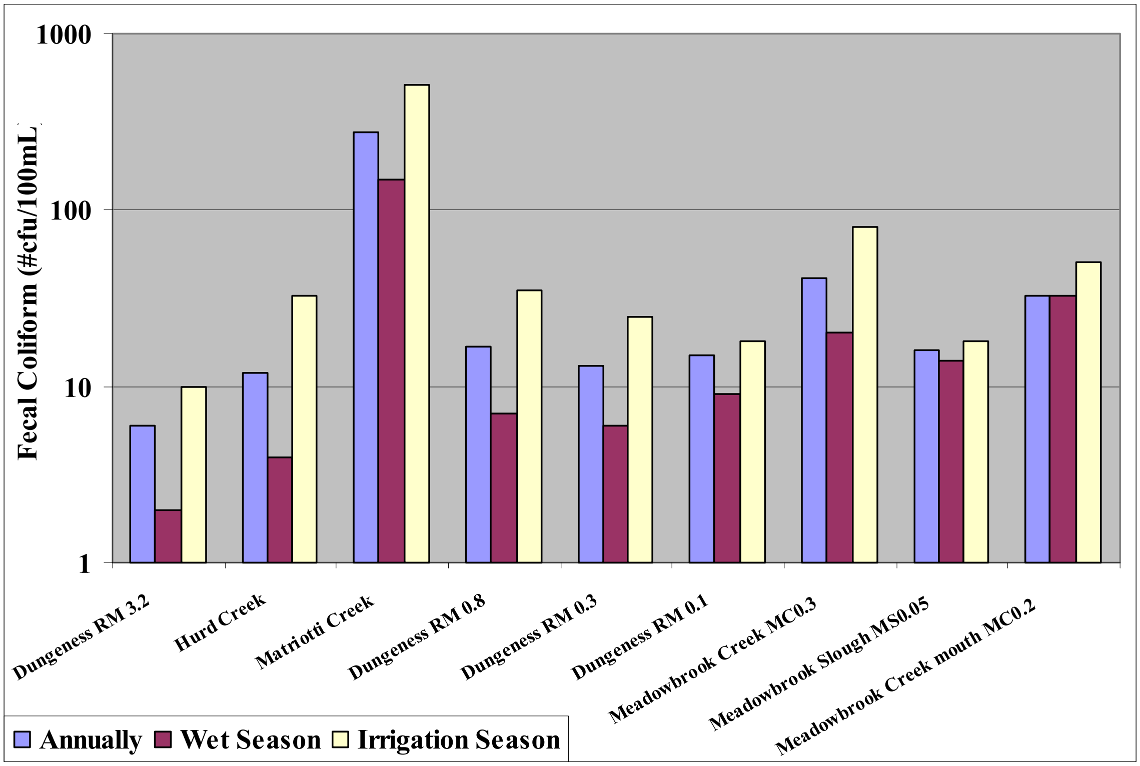

Figure C3. 1999-2000 Lower Dungeness Geometric Mean Fecal Coliform Concentrations.

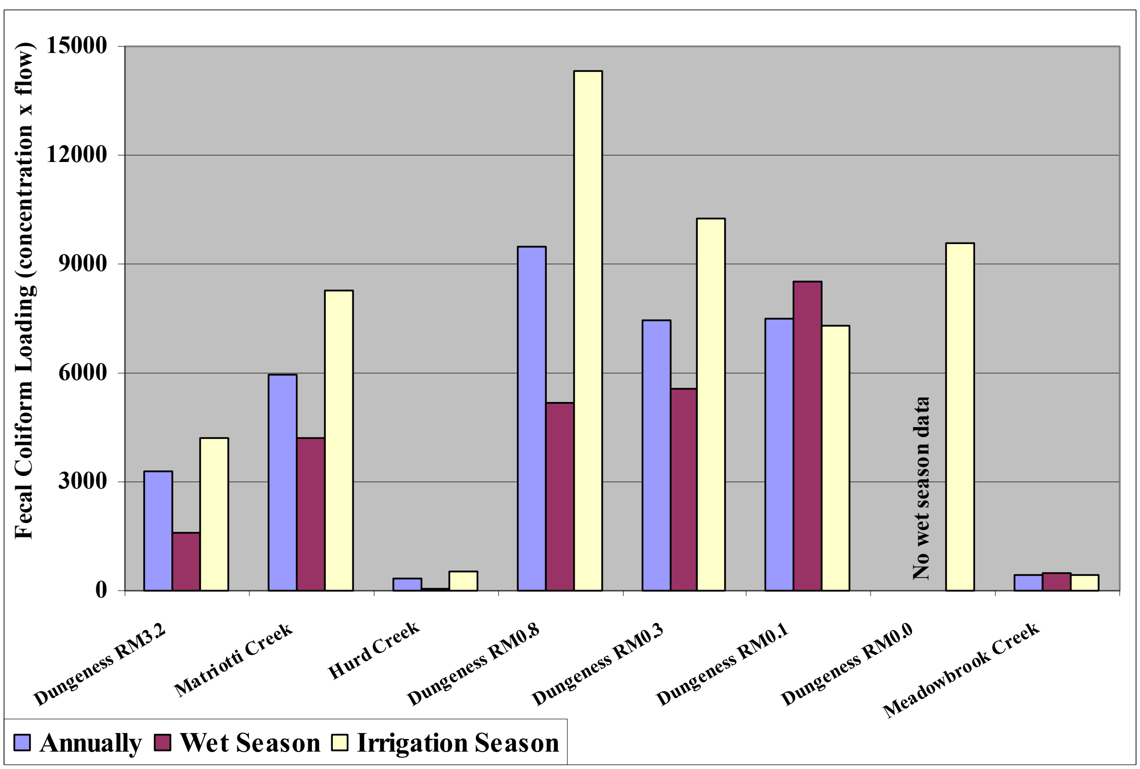

Figure C4. 1999-2000 Lower Dungeness Average Fecal Coliform Loading.

Appendix D

Results of Paired t-test

Paired t-tests were used to compare water quality between upstream and downstream sites. Sites were evaluated for differences in fecal coliform concentration and loading, and turbidity when data were available. A two-tailed test with a significance level of $\alpha = 0.05$ was used.

Dungeness River

Paired t-tests were used to compare water quality at sites on the Dungeness River. Table D1 describes the results of the paired t-tests for fecal coliform concentration and loading. Significant differences between sites are italicized in the table.

Table D1. Dungeness River results of paired t-test for fecal coliform concentration and loading. (P(T<=t) two-tailed.)

	Annual Results (n=18)	Wet Season (n=7)	Irrigation Season (n=9)
Fecal coliform concentration			
RM 3.2 and 0.8	*0.01 (RM 0.8 higher)*	0.11 (RM 0.8 higher)	*0.02 (RM 0.8 higher)*
RM 0.8 and 0.3	0.13 (RM 0.8 higher)	0.51 (RM 0.3 higher)	0.13 (RM 0.8 higher)
RM 0.3 and 0.1	1.00	0.11 (RM 0.1 higher)	0.29 (RM 0.3 higher)
RM 0.1 and 0.0			0.20 (RM 0.0 higher)
Fecal coliform loading			
RM 3.2 and 0.8	0.10 (RM 0.8 higher)	*0.04 (RM 0.8 higher)*	0.09 (RM 0.8 higher)
RM 0.8 and 0.3	0.17 (RM 0.8 higher)	0.80	0.23 (RM 0.8 higher)
RM 0.3 and 0.1	0.37 (RM 0.3 higher)	0.08 (RM 0.1 higher)	0.08 (RM 0.3 higher)
RM 0.1 and 0.0			0.38 (RM 0.0 higher)

Matriotti Creek

Table D2 presents Matriotti Creek results of the paired t-tests for fecal coliform concentration and loading, and flow discharge. Significant differences between sites are italicized in the table. Where there were measured tributaries or a ditch between sites, the measured fecal coliform loading and flows were compared to the expected sum of loading and flow.

Table D2. Matriotti Creek results of the paired t-test for fecal coliform concentration, loading, and flow discharge. (P(T<=t) two-tailed)

Matriotti Creek sites	Fecal coliform concentration	Fecal coliform loading	Flow discharge
Mat 6.0 and Mat 4.8	*0.03 (Mat 6.0 higher)*	0.25	*0.02 (Mat 4.8 higher)*
Mat 4.8 and Mat 3.2	*0.01 (Mat 3.2 higher)*	*0.00 (Mat 3.2 load higher)*	*0.00 (Mat 3.2 higher)*
Sum and Measured Mat 3.2	-	0.07 (measured load higher)	*0.00 (measured higher)*
Mat 3.2 and Mat 1.9	0.29	*0.05 (Mat 1.9 load higher)*	*0.00 (Mat 1.9 higher)*
Sum and Measured Mat 1.9	-	0.25	*0.00 (measured higher)*
Mat 1.9 and Mat 1.4	0.74	0.96	0.07 (Mat 1.9 higher)
Mat 1.4 and Mat 0.7	0.58	0.20	0.21
Mat 0.7 and Mat 0.3	*0.00 (Mat 0.3 higher)*	*0.00 (Mat 0.3 load higher)*	*0.00 (Mat 0.3 flow higher)*
Sum and Measured Mat 0.3	-	*0.00 (measured load higher)*	0.18
Mat 0.3 and Mat 0.1	*0.00 (Mat 0.3 higher)*	0.11	*0.00 (Mat 0.1 flow higher)*
Sum and Measured Mat 0.1	-	0.07 (summed load higher)	*0.00 (Mat 0.1 flow higher)*

Appendix E

Ranking of Fecal Coliform Loading Sources by Season

Table E1 presents the average wet and irrigation season fecal coliform loading results by tributary or river/creek stretch, with the highest loading contributions first. Average fecal coliform loading estimates were obtained by averaging fecal coliform loading for the wet and irrigation season. Negative loading values were used to calculate averaging loads.

In determining the importance of the fecal coliform source to the bay, it is important to remember that sources closest to the bay have the greatest effect. The greater the distance from the source, the more bacterial die-off must be taken into consideration. In determining bacterial impacts to the bay, it is important to consider that Rensel and Smayda (2001) found that in the DOH database for Dungeness Bay marine sampling, seasonal concentrations of fecal coliform were lower during spring and summer and higher during fall and winter. So, wet season fecal coliform loading sources to the bay are an important consideration. The table below describes instantaneous average fecal coliform loading values and does not take into account die-off of bacteria.

Table E1. Ranking of Fecal Coliform Loading Sources by Season.

	Reach or Tributary	Wet Season Loading (conc x flow)	Reach or Tributary	Irrigation Season (conc x flow)
1	DR RM 0.3-0.1	2950	MAT CM 0.7-0.3	8846
2	MAT CM 0.7-0.3	2265	Upstream DR RM 3.2 *	4211
3	Upstream DR RM 3.2 *	1614	DR RM 0.1-0.0	1445
4	MAT 0.6T Lotzgesell Creek	1206	DR RM 3.2-0.8	1266
5	MC CM 0.3-0.2	432	MAT CM 3.2-1.9	790
6	MAT 1.95T Mudd Creek	416	MAT 1.95T Mudd Creek	556
7	DR RM 0.8-0.3	389	MAT 0.2T Beebe Creek	420
8	MAT CM 3.2-1.9	316	Upstream MC1.95	366
9	MAT3.8T Bear Creek	245	MAT 0.6T Lotzgesell Creek	304
10	Upstream MC1.95 or 2.0	178	Cooper Creek	289
11	Upstream MAT6.0	86	Golden Sands Slough	272
12	Golden Sands Slough	68	MAT 4.8 N Ditch	221
13	MAT CM 1.9-1.4	60	MAT CM 4.8-3.2	182
14	MAT 0.2T Beebe Creek	60	MC CM 0.3-0.2	144
15	MAT6.0 Ditch	50	MAT CM 1.9-1.4	133

* Represents fecal coliform loading from the entire Dungeness River watershed (a drainage area of 197 miles); as such, it should represent the highest loading of all the sites because it drains such a large area.

Table E1 (cont). Ranking of Fecal Coliform Loading Sources by Season.

	Reach or Tributary	Wet Season Loading (conc x flow)	Reach or Tributary	Irrigation Season (conc x flow)
16	MC CM 0.8-0.3	20	MAT3.8T Bear Creek	97
17	MC1.75T	13	Upstream MAT 6.0	64
18	MAT4.8 North Ditch	12	MAT 0.25 Ditch	62
19	MS 0.20 west tributary	10	MS 0.20 west tributary	52
20	MS CM 0.45-0.20 east tributary	0.5	MS 0.45	39
21	MS 0.45	0.3	Irrigation Ditch 1	39
22	Irrigation Ditch 1	Aver no load	MC CM 1.75T	38
23	Irrigation Ditch 2	Aver no load	LOTZRDIT DR Irrigation Ditch	34
24	MAT CM 6.0-4.8	Aver no load	MS CM 0.45-0.20	7
25	MAT4.8 South Ditch	Aver no load	MAT 6.0 Ditch	5
26	MAT CM 4.8-3.2	Aver no load	Irrigation Ditch 2	4
27	MAT CM 1.4-0.7	Aver no load	MAT 4.8 South Ditch	3
28	MAT CM 0.3-0.1	Aver no load	MAT CM 6.0-4.8	Aver no load
29	MC CM 1.95-0.8	Aver no load	MAT CM 1.4-0.7	Aver no load
30	DR RM 3.2-0.8	Aver no load	MAT CM 0.3-0.1	Aver no load
31	LOTZRDIT DR Irrigation Ditch	Aver no load	MC CM 1.95-0.8	Aver no load
	DR RM 0.1-0.0	unknown	MC CM 0.8-0.3	Aver no load
	Cooper Creek	unknown	DR RM 0.8-0.3	Aver no load
	MatCM 0.25 Ditch	unknown	DR RM 0.3-0.1	Aver no load
	RM 0.1-0.0	unknown		