Publication No. 86-e06

WA-17-0050

Sources of Water Quality Problems in Sequim Bay Watersheds

by

Timothy A. Determan
Water Quality Investigations Section

October 1986

Washington State Department of Ecology
Olympia WA 98504-6811

TABLE OF CONTENTS

ABSTRACT

A summertime water quality survey was done on streams, irrigation ditches, and a wastewater treatment plant (WTP) in Sequim Bay watershed. Bell Creek contributed 90 percent of the watershed fecal coliform load. Jimmycomelately and Johnson Creeks contributed 8 and 2 percent, respectively. Fecal coliform load from the remaining streams and the WTP were negligible. The three segments farthest downstream in the Bell Creek drainage (mostly cattle pasture) generated the greatest loads. This survey provides a baseline only. Further winter rain-event work is needed.

INTRODUCTION

A debate has emerged within the Sequim Bay community about the relative importance of several fecal coliform sources in the Sequim Bay region. The sources include: Sequim City wastewater treatment plant (WTP); waste from grazing animals along creeks and irrigation ditches; and increasing urbanization of the area. In light of the issues, the Southwest Regional Office (SWRO) of the Department of Ecology (Ecology) and others have requested information to develop policies to protect Sequim Bay's beneficial uses, including shellfish resources. In response, Ecology's Water Quality Investigations Section conducted a survey on June 30 and July 1, 1986. The objectives of the survey were to:

1. Determine pollutant loads: at points of irrigation return flow or land-use boundaries within Bell Creek and Johnson Creek drainages; at the mouth of each stream that enters Sequim Bay; and at the Sequim WTP.

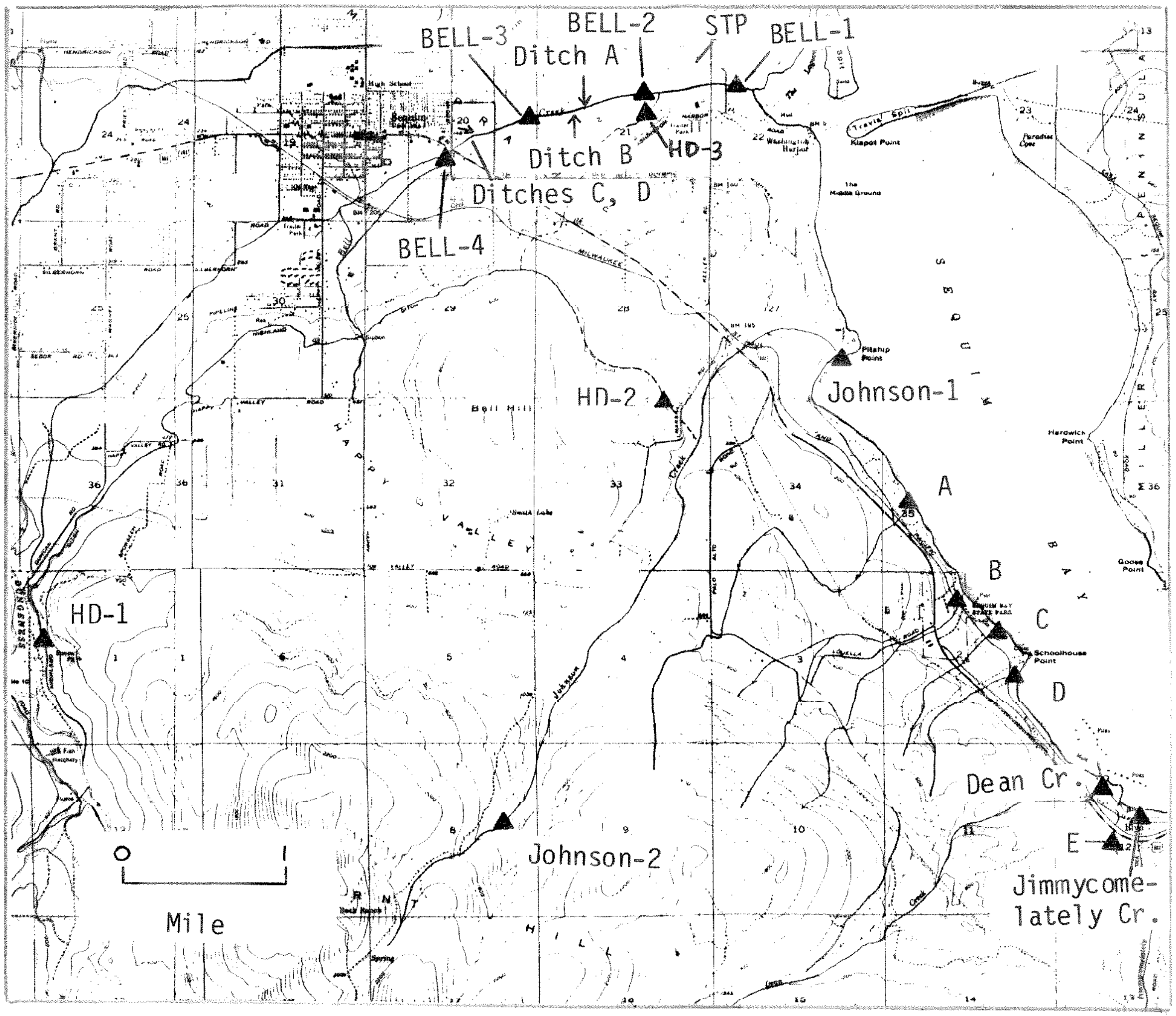
2. Rank these pollutant loads during summer low-precipitation conditions.

The survey was carried out in consultation with Ecology's Shorelands Division and the Clallam County Health Department. (The health department is currently applying for a grant from Ecology to study contamination in the Sequim Bay watershed.)

Sequim Bay is classified as AA marine water (WAC 173-201-085[21]) (Ecology, 1982). Clam, oyster, and mussel rearing, spawning, and harvesting are included in the list of beneficial uses to be protected by this classification. Tributary streams and creeks also are classed as AA (WAC 173-201-070[6]-General Classifications).

At present, most of Sequim Bay's eastern shore and that south of Sequim Bay State Park are certified by the Department of Social and Health Services (DSHS) Shellfish Sanitation Program for the direct harvest of shellfish (Kennedy, 1984). Commercial harvesting of oysters, clams, and geoducks have occurred along the entire eastern shoreline, at Middle Ground (south of the bay entrance), and along the southwest shore at Schoolhouse Point and Blyn (Saunders, 1984) (Figure 1). The shoreline between Sequim Bay entrance and Pitship Point (John Wayne Marina) and the Middle Ground are presently closed to commercial harvest due to the risk of waste dumping from boats (J. Lilja, Shellfish Protection Program). A similar closure is in effect for the shoreline fronting Sequim Bay State Park.

Kennedy (1984) conducted a survey of the Sequim Bay shoreline. Soils on Sequim Bay's western shore have highly variable absorption abilities. Southern soils are in general, poorly drained. As a result, most of the streams are located in the western and southern portions of the watershed. The best drained soils are found on the east side. The lack of year-round surface drainage and only one intermittent stream (USGS map, Sequim quadrangle) reflects these conditions. All streams except Bell Creek drain lightly developed subbasins.



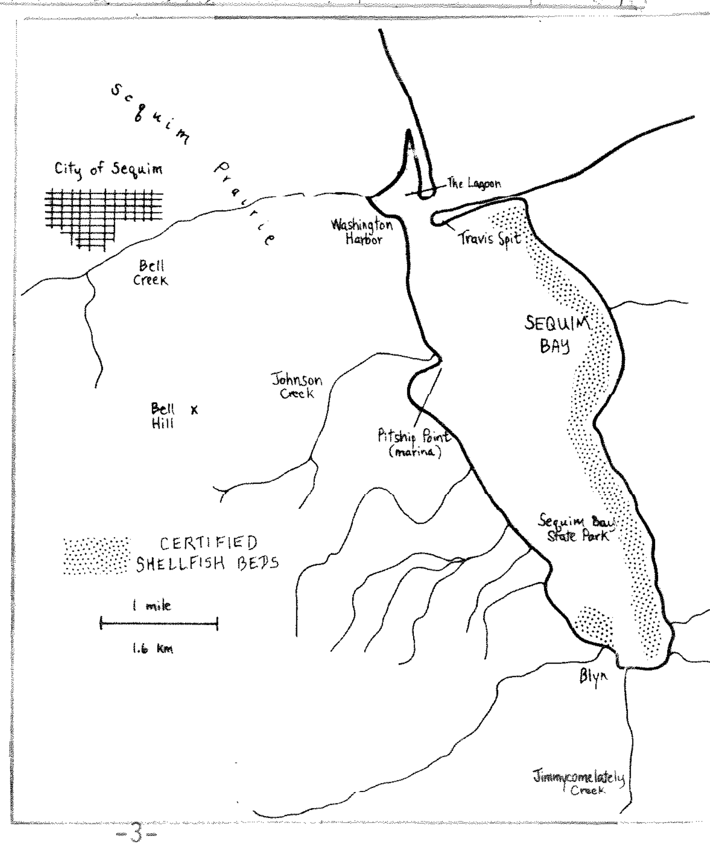


Figure 1. Sequim Bay drainage areas sampled on June 30 - July 1, 1986. (Adapted from USGS topographic map, Sequim Quadrangle and Saunders, 1984.)

Bell Creek flows through the town of Sequim. It collects irrigation return flows from farms and canals on Sequim Prairie. Flows are highly variable, with seasonal maxima during the summer (D. Carter and W. Bergstrom, Ecology SWRO, personal communication). The summertime maxima are due to irrigation return flow from the north branch of the Highland Ditch that enters Bell Creek about 0.5 mile upstream from the mouth.

The Highland Ditch serves one of several irrigation districts on the Sequim Prairie. The ditch splits into a north branch that leads to Bell Creek and a south branch that leads to Johnson Creek (W. Bergstrom, Ecology SWRO, personal communication; Drost 1983).

Past studies have not addressed the effects of stormwater runoff. Rain-generated flow from roads and city streets can carry significant contamination. This is especially true if sewers or septic system drainfields "leak" into the storm drain system. Because of the dryness at the time of the survey, it is doubtful that this was an important contamination factor.

Johnson Creek enters Sequim Bay at Pitship Point. The stream mouth is physically separated from John Wayne Marina to the north by a massive riprap breakwater. The creek receives irrigation return flow from the south branch of the Highland Ditch (D. Carter, Ecology SWRO, personal communication). The drainage is sparsely settled; however an approved residential development at Bell Hill is predicted to grow to about 480 lots. The development will be sewered, but residents near the Highland Ditch south branch have voiced concern about the effects of the development on water quality (Jimmycomelately Gazette, July 27, 1983).

Determan (1986) analyzed bacteriological data from Sequim Bay collected since 1977. Relatively high bacteriological concentrations in shellfish occurred near the mouth of the bay (Washington Harbor), with decreasing concentrations to the south and east. To date, contamination has been confined largely to the western shore. Both Bell Creek and the Sequim WTP enter marine waters near Washington Harbor. The fecal coliform load from Bell Creek was estimated to be over 500 times higher than that from the Sequim WTP. Kennedy (1984) identified a large dairy farm near the mouth of Bell Creek as the major agricultural source. Mr. Gary Smith, owner of the dairy farm, recently installed a manure storage lagoon. The lagoon lies about 100 meters from the south bank of Bell Creek.

METHODS

Sampling sites were located at several points along Bell and Johnson Creeks and at the mouths of the remaining flowing streams (Figure 1). The sites were selected as a result of a streamwalk survey conducted by the author and Nancy Kmet (Ecology SWRO) on June 4, 1985. Notes from the survey are included with sampling site descriptions in the appendix.

Physical and chemical parameters measured at each sampling station, methods of analysis, and applicable water quality standards (Ecology, 1982) are shown in Table 1. Fecal coliform samples from Sequim WTP were taken in sterilized bottles containing sodium thiosulfate.

Samples were taken in the Bell and Johnson Creeks drainages on June 30. Duplicates were collected in most cases in order to account for an expected high degree of variation. Single samples only were taken from the remaining stations on July 1.

Dissolved oxygen and temperature data were used with a computer program, DOSAT, to calculate the percent saturation of oxygen at each site.

The use of loads provides a means of making quantitative comparisons among streams and stream segments. Fecal coliform loads were calculated using Kittrell (1969):

FC load (FC per sec) = [FC] x Q x 284.7
where: [FC] = fecal coliform count (number per 100 mL)
and: Q = stream flow in cubic feet per second (cfs)

Loads for nutrients and total suspended solids were calculated from equations in IHD-WHO (1978):

Load (Kg/day) = [material] x Q x f
where: [material] = material concentration (mg/L)
and: Q = stream flow (cubic feet per sec)
and: f = conversion constant 2.4465

Table 1. Physical and chemical parameters measured in Sequim Bay watershed, June 30 - July 1, 1986.

Parameter	Method	Reason for Sampling	Water Quality Standard (Class AA Freshwaters)
Fecal Coliform Bacteria in Water (FC/100 mL)	Membrane Filter (MF) APHA (1985)	Indicator of presence of intestinal wastes from humans and other animals.	Not to exceed a geometric mean of 50 FC per 100 mL, with not more than 10 percent of samples to exceed 100 FC/100 mL.
Temperature (°C) (°C)	Thermometer	Used with oxygen to determine percent saturation. Temperature also affects gas solubility and rates of biological processes.	Not to exceed 16.0°C due to human activities. When natural conditions exceed 16°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C.
Dissolved Oxygen (mg/L)	Winkler titration (azide modification) EPA (1979) APHA (1985)	Elevated, relatively constant oxygen levels are essential for stable aquatic communities. Highly variable levels downflow from a source may be indicative of an organic load in excess of the ability of the system to assimilate it.	Shall exceed 9.5 mg/L.
Nutrients (mg/L) NO_3-N + NO_2-N; NH_3-N; T-PO_4-P	EPA (1979); APHA (1985)	Inorganic nutrients are readily available for assimilation by algae and other aquatic plants. Excessive levels with abundant light may lead to massive algae production at the expense of other plants and animals. Ammonia (NH_3-N) is an immediate byproduct of the breakdown of urine and therefore may be useful to trace animal wastes in water.	No current state standard.
pH (S.U.)	Orion Model 399A pH meter	pH affects the carbonic acid-carbon dioxide balance in water. pH also affects the activity of un-ionized ammonia, sulfide, and metals.	Shall be within the range of 6.5 to 8.5, with man caused variation within a range of less than 0.2 unit.
Total Suspended Solids or Total Non-filterable Residue (mg/L)	EPA (1979); APHA (1985)	Measures water column transparency and light availability, and is an estimate of suspended material in water column. Sufficient light is essential to aquatic plant growth. Excessive suspended material may stress plants and animals by light reduction or smothering.	No standard.
Specific Conductivity (umhos/cm)	Beckman Model RB-5 "Solubridge" Conductivity Meter	Can be used as a tracer to estimate the quantity of pollutants in freshwaters from sources such as septic tanks, stormwater, etc.	No standard.
Turbidity (NTU)	Hach Turbidimeter	Measures water column transparency and light availability, and is an estimate of suspended material in water column. Turbidity is a function of the quantity and light scattering characteristics of the suspended material. Sufficient light is essential to aquatic plant growth. Excessive suspended material may stress plants and animals by light reduction or smothering.	Not to exceed 5 NTU over background if background is 50 NTU or less, or have more than a 10 percent increase in turbidity when background turbidity is more than 50 NTU.
Stream Flows (cfs)	Marsh-McBirney flow meter (Buchanan & Somers, 1969) or bucket & stopwatch)	Used with FC to calculate fecal coliform loads using the method of Kittrell (1969).	Not applicable.

RESULTS AND DISCUSSION

Table 2 shows water quality results from all sources discharging into Sequim Bay. The three major streams; Bell, Johnson, and Jimmycomelately account for nearly 95 percent of the surface water entering Sequim Bay from all sources including the WTP.

In the Bell Creek drainage, fecal coliform levels exceeded the water quality standards at every point except at the Highland Ditch diversion (HD-1). Concentrations near the mouth were highest. Active cattle grazing was evident in Bell Creek's lower stretch, whereas vacant fields or urban use characterized the upper sites. Jimmycomelately Creek and Johnson Creek mouth (Johnson-1) also exceeded the fecal coliform standard. The Johnson-1 concentration was not much different from the Highland Ditch tributary upstream. One of the six minor streams (Stream D at Schoolhouse Point) also had high levels (possibly due to the influence of what appeared to be a single residence in the drainage about 20 feet above the backshore line).

Dissolved oxygen levels satisfied the water quality standard at all sites in the Bell Creek drainage except at the mouth and the Highland Ditch tributary to Bell Creek. It is possible that organic matter from animal waste or low-oxygen ground-water inflow may be factors at Bell Creek. Several of the minor streams violated the dissolved oxygen standard, particularly Dean Creek which discharged through several culverts below an access road to a small log sort yard. The cause of the low oxygen level was not determined.

In general, nutrient concentrations were not noteworthy. The nitrogen levels at the Sequim WTP did appear to be lower than expected and lower than many of the creeks. The low nitrogen concentrations at the WTP and a review of recent NPDES data suggest a high removal efficiency (M. Heffner, Ecology; Molly Adolfson, Brown and Caldwell, personal communication).

Table 3 ranks the pollutant loads from the several sources discharging into Sequim Bay or its vicinity during the survey. Bell Creek ranked first in nearly all categories. Bell Creek discharged 90 percent of the fecal coliform, 97 percent of the combined nitrate+nitrite, 80 percent of the ammonia, and 75 percent of the suspended matter.

Clearly, the major contributor of bacteria and solids to Bell Creek is the stretch between Bell-3 and Bell-2. Fecal loads from the Highland Ditch (HD-3) are also significant.

The load at Bell Creek mouth (Bell-1) was higher than the sum of the loads from sites Bell-2 and HD-3 for total suspended matter and each nutrient. A possible source of the nutrients may have been ground water. Also, several small pipes drain the adjacent pasture.

On the other hand, the net fecal coliform load from Bell Creek mouth was lower than the sum of HD-3 and Bell-2 loads. This may indicate that use of the new waste storage lagoon and present animal-keeping practices may have had a

Table 2. Water quality in Sequim Bay drainages in summer, 1986. (Results are means of two replicates unless otherwise indicated).

Station	Date	Time	Flow (cfs)	FC per 100 mL Sample 1	FC per 100 mL Sample 2	FC per 100 mL Geo. Mean	Nutrients NO_2+NO_3 (mg/L)	Nutrients NH_3 (mg/L)	Nutrients T-PO_4-P (mg/L)	Temp. (°C)	Cond. (umhos/cm)	pH (S.U.)	D.O. (mg/L)	(% sat.)	Turb. (NTU)	TSS (mg/L)
Bell Creek Drainage																
Bell-1 (mouth)	6/30	1500	5.1	2800	3800	3300*	1.4	0.04	0.11	15.5	250	7.4	9.3*	92.7	4	14
	7/01	0800	5.2	4000	3800	3900*	1.4	0.06	0.16	12.2	245	7.3	--	--	3	11
HD-3	6/30	1415	1.3[1]	4200	3300	3700*	0.51	0.03	0.10	15.9	225	7.4	8.1*	81.4	2	8
Bell-2	6/30	1400	3.2	8000	5750	6800*	0.98	0.04	0.10	13.5	230	7.5	10.0	95.5	5	10
Ditch A	6/04	1344	--	14	--	--	--	--	--	--	--	--	--	--	--	--
Bell-3	6/30	1240	0.8	70	100	84*	0.02	0.02	0.06	13.4	105	7.2	9.8	93.7	12	9
Bell-4	6/30	1210	1.1	80	100	89*	0.02	0.02	0.06	13.2	120	7.2	10.0	95.4	8	14
HD-1	6/30	1130	19[2]	<4	<4	4	0.01	0.01	0.01	9.7	95	7.4	11.1	98.4	1	2
Johnson Creek Drainage																
Johnson-1 (mouth)[3]	7/01	1030	2.4	204*	--	--	0.04	0.01	0.04	12.0	165	7.4	10.8	100.9	3	6
HD-2	6/30	1530	1.9	210	208	209*	0.01	0.01	0.02	11.6	100	7.2	10.6	98.2	2	4
Johnson-2 (headwater)	6/30	1520	NA[4]	4	<1	2	0.07	0.01	0.07	10.3	285	8.1	10.0	93.6	1	1
Jimmycomelately Creek[3]	7/01	1230	2.9	610*	--	--	0.04	0.01	0.03	12.4	200	7.7	10.4	102.0	<1	<1
Minor Streams																
A[3]	7/01	1040	0.03	29	--	--	0.25	0.01	0.08	12.0	410	7.8	9.2*	89.5	2	2
B (state park)[3]	7/01	1100	0.03	35	--	--	0.13	0.02	0.08	13.4	340	7.7	10.0	100.3	3	<1
C[3]	7/01	1120	0.02[5]	69	--	--	0.56	0.02	0.12	11.5	360	7.8	9.8	94.3	2	5
D (Schoolhouse Point)[3]	7/01	1130	0.04	260*	--	--	0.30	0.01	0.12	11.5	350	7.7	10.1	97.2	4	9
Dean Creek[3]	7/01	1220	0.03[5]	37	--	--	0.01	0.07	0.16	12.4	330[6]	7.0	5.8*	56.9	1	3
E[3,5]	6/04	1720	0.05	39	43	41	--	--	--	--	--	--	--	--	--	--
Sequim WTP[7]	7/01	0800	0.5[8]	16	21	18	0.01	0.04	5.6	16.9	370	6.9	--	--	1	2

*Water quality standards violation.

[1]Underestimated due to marshy conditions. Some water flowed through tall grass on either side of main channel.
[2]Flow taken from Drost (1983). In-stream flow not taken due to hazardous conditions.
[3]One sample set only.
[4]Streamflow very low. Technically difficult to measure.
[5]Flow estimated with bucket and stopwatch.
[6]Salinity = <3.64 ppt.
[7]Total residual chlorine = 0.6 mg/L.
[8]Taken from plant flow meter.

Table 3. Loads from sources draining into Sequim Bay and adjacent marine waters during summer, 1986.

Sources	Fecal Coliforms (FC/sec x 10^3)	Fecal Coliforms (% contrib.)	Nitrite + Nitrate (Kg/day)	Nitrite + Nitrate (% contrib.)	Ammonia (Kg/day)	Ammonia (% contrib.)	Total Phosphorus (Kg/day)	Total Phosphorus (% contrib.)	Total Susp. Solids (Kg/day)	Total Susp. Solids (% contrib.)
Bell Creek Drainage										
Bell Creek (mouth)[1]	5,282	89.0	17.6	96.9	0.6	75	1.7	18.9	158	77
HD-3	1,369	--	1.6	--	0.1	--	0.3	--	26	--
Bell-2	6,195	--	7.7	--	0.2	--	0.8	--	78	--
Bell-3	19	--	0.04	--	0.04	--	0.1	--	18	--
Bell-4	28	--	0.1	--	0.05	--	0.2	--	38	--
HD-1	22	--	0.5	--	0.5	--	0.5	--	93	--
Johnson Creek Drainage										
Johnson-1 (creek mouth)	139	2.3	0.2	1.1	0.06	7.5	0.2	2.2	35	17
HD-2	113	--	0.1	--	0.05	--	0.1	--	19	--
Johnson-2 (headwater)	--	--	--	--	--	--		--	--	--
Jimmycomelately Creek	504	8.5	0.3	1.6	0.1	12.5	0.2	2.2	7	3.4
Minor Streams										
A	0.3	--	0.02	--	0.00[2]	--	0.01	--	0.2	--
B (state park)	0.3	--	0.01	--	0.00[2]	--	0.01	--	0.1	--
C	0.4	--	0.03	--	0.00[2]	--	0.01	--	0.2	--
D (Schoolhouse Point)	3.0	--	0.03	--	0.00[2]	--	0.01	--	0.9	--
Dean Creek	0.3	--	0.00[2]	--	0.01	--	0.01	--	0.2	--
E	0.6	--	--	--	--	--	--	--	--	--
TOTAL	5	0.1	0.1	0.6	0.0[2]	0[2]	0.0[2]	0[2]	2	1.0
Sequim WTP	3	0[1]	0.0[2]	0[2]	0.0[2]	0[2]	6.9	76.7	3	1.5
GRAND TOTAL (mouths only)	5,933	100	18.2	100	0.8	100	9.0	100	205	100

[1]Mean of 6/30 and 7/1.
[2]Approximate.
[3]Creek mouths and WTP only.

positive effect in reducing fecal coliform contamination. Also, present stream conditions may promote fecal coliform die-off. The stream bed between Bell-2 tends to be wide and shallow with minimal shading from stream-bank vegetation. This would permit a high degree of solar disinfection.

It appeared the size of the herd in the lower Bell Creek segment was lower than observed by Kennedy (1984). It is possible that the herd(s) were dispersed. Fecal coliform loading to the lower segment may thus be more important during winter if adjacent animal densities increase.

In Johnson Creek, the fecal coliform load at HD-2 is over 80 percent of that at Johnson-1. The Highland Ditch branch appears to be an important summertime component of water quality and quantity in Johnson Creek.

The city of Sequim WTP ranked first as a source of total phosphorus loads. However, it's role as a source for fecal coliform was negligible. Loads from the small streams were essentially zero.

CONCLUSIONS

- The two most significant sources of fecal coliform loads are in the Bell Creek drainage; the segment of Bell Creek between North Rhodefer Road and the confluence with Highland Ditch and Highland Ditch itself.

- The source for Bell Creek loads appears to be direct creek access by grazing animals.

- The Highland Ditch appears to be the major summertime contributor of water and contamination to Johnson Creek.

- Bell Creek is by far the greatest contributor of fecal coliform to Sequim Bay. Jimmycomelately Creek and Johnson Creek follow. Neither the STP nor the minor creeks appear to be significant summertime contributors of fecal coliform.

- It is important that specific sources within Bell and Johnson Creeks be identified and controlled in order to restore and protect the present beneficial uses of Washington Harbor and Pitship Point as recognized in the Water Quality Standards. These include swimming and recreational clamming which go on despite the present DSHS decertified status.
  It also is important to encourage land-use practices that will protect water and shellfish quality in all of Sequim Bay in the face of future accelerated watershed development.

RECOMMENDATIONS

- o The results of this survey are applicable to summertime low-precipitation conditions only. They do not reflect the effects of stormwater runoff or the effects of seasonal changes in animal-keeping practices. An intensive effort should be made to conduct surveys during winter, particularly during periods of heavy rainfall when runoff from pastures, roadways, and urban areas would be likely to have the greatest effect.
- o Detailed searches for sources should be carried out along Bell Creek between North Rhodefer Road and Highland Ditch; both branches of Highland Ditch; and Jimmycomelately Creek. These searches should be carried out during an appropriate period of saturated soils.
- o This report cites the possibility of a failed septic system above Stream D at Schoolhouse Point. This and others mentioned in Kennedy (1984) should be inspected while studies are on-going.

REFERENCES

American Public Health Association, 1985. Standard Methods for the Examination of Water and Wastewater. 16th Ed., Washington, DC. 1268 pp.

Buchanan, T.J. and W.P. Somers, 1969. Discharge measurements at gaging stations. In: Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3: Applications of Hydraulics. U.S. Gov't. Printing Ofc., Washington, DC. 65 pp.

Determan, T.A., 1986. Analysis of shellfish and water quality from Sequim Bay, Washington. Washington Dept. of Ecol., Olympia, WA. 31 pp.

Drost, B.W., 1983. Impact of Changes in Land Use on the Ground-Water System in the Sequim-Dungeness Peninsula, Clallam County, Washington. Water Resources Investigations Report 83-4094. U.S. Geological Survey, Dept. of the Interior, Tacoma, WA. 61 pp.

Ecology, Washington Dept. of, 1982. Water quality standards for waters of the state of Washington. Chapter 173-201 WAC.

EPA (Environmental Protection Agency), 1976. Quality Criteria for Water. U.S. Gov't. Printing Ofc., Washington, DC. 256 pp.

EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. Cincinnati, OH. 460 pp.

IHD-WHO, 1978. Water quality surveys. UNESCO/WHO, United Kingdom. 350 pp.

Kennedy, J., 1984. Shoreline Survey of Sequim Bay, Clallam County. DSHS Shellfish Sanitation Progam, Olympia, WA. 4 pp.

Kittrell, F.W., 1969. A Practical Guide to Water Quality Studies of Streams. U.S. Dept. of Interior/FWPCA CWR-5. Washington, DC. 135 pp.

Saunders, R.S., 1984. Shellfish Protection Strategy. Washington Dept. of Ecol., Olympia, WA. 38 pp.

Willingham, W.T., J.E. Colt, J.A. Fava, B.A. Hillaby, C.L. Ho, M. Katz, R.C. Russo, D.L. Swanson, and R.V. Thurston, 1979. Ammonia. In: A Review of the EPA Red Book: Quality Criteria for Water. Water Quality Section, American Fisheries Society, Bethesda, MD. 6-18 pp.

APPENDIX

Description of sampling sites used during a survey of Sequim Bay drainages done on June 30 and July 1, 1986 (refer to Figure 1). Notes include observations on Bell Creek obtained during a streamwalk survey done on June 4, 1986.

Location Description	Station Number	Land-Use Description
(Bell Creek Drainage)		
Downstream-side of Schmuck Road	Bell-1	
South side of Bear Creek 0.5 mile upstream from Bell-1. Source suspected to be Highland Ditch.	HD-3	Bottomland narrow (1500 feet), confined by ridges. Barn, runoff lagoon on south side of stream. Pastures moderately grazed. Animals on south side during survey.
Just upstream of HD-3.	Bell-2	
Just downstream from stretch of heavy thickets that block access to the creek from adjacent fields. (Ditch is 1 foot wide, very low flow, drains north bank. Fecal coliform samples were taken. See Table 2.)	Ditch A	Lowland widens. Few active pastures. These used for hay production or left fallow. Minimal grazing at creek edge. Thicket forest and uncut grass shade narrow, deep streambed. No nearby residences.
Just upstream from A-Ditch. It drains south bank. Roughly 1 foot wide. It also drains pasture. (Fecal coliform sample taken.)	Ditch B	
Downstream side of North Rhodefer Road.	Bell-3	Open fields, Lions Club, Carrie Blake Community Park. Residential, commercial development in upstream end. Sequim City commercial zone directly west of Bell-4. (Storm drainage possible during heavy rain in vicinity of Bell-4). Culverts, pipes, or built storm drain structures were not observed.
Shallow, diffuse flows draining field north of creek below residential tract. Located 1/4 mile downstream of Bell-4.	C,D-Ditches	
Just upstream of HW-101 at Brown Road (behind Taco Trio).	Bell-4	
Highland Ditch near diversion from Dungeness River.	HD-1	Narrow, steep-sided valley: forested uplands. Residents, small farms along stream bank.
(Johnson Creek Drainage)		
At Pitship Point just south of marina. Samples taken, flows measured at mid intertidal point during low tide.	Johnson-1	
On Marshall Road about 0.6 mile from Highway 101. Sampling site on west side of road. NOTE: confluence with Johnson Creek was not observed.	HD-2	Pitship Point, shoreline densely developed with marina, RV park, residences. Southwest of Highway 101, land sparsely developed with moderately sized farms, homes. Grazing pressure light to moderate. Upper drainage forested, some logging activities.
Marshall Road beyond paving; sample taken upstream of point where culvert goes under the road.	Johnson-3	
(Other Drainages)		
Sample site reached by walking upstream from Sequim Bay. Residence closest to the bay located on east bank about 200 meters from creek mouth.	Jimmycomelately Creek	Scattered houses, small farms, marshes in lower end; forested zones upstream with intensive logging.
Small flow spills over edge of rock face onto narrow beach. Sample taken at upper intertidal level.	Site A	Moderately dense housing along nearby shoreline. Forested above sampling site.
Samples taken near shoreline. Creek flows through state park north of boat ramp. Channel is a ravine with steep banks.	Site B	State park and low-density housing. Park served with sewage lagoon with uplands spray application of pond effluent on forest lands. Effluent production directly related to park usage.
Samples taken from natural spillway formed by erosion-resistant rock and tree roots about 20 meters landward and 3 meters above shoreline.	Site C	Land surrounding sample site forested. Use above this point unknown but drainage basin very small.
Samples taken at beach/backshore boundary south and west of spit at Schoolhouse Point.	Site D	One residence on bank above smaple site. Considerable forest. Use of rest of basin unknown, but basin area small
Samples taken downstream of culverts passing under access road to small log sort yard. Stream channel passes through salt marsh to bay.	Dean Creek	Land use in remaining basin unknown.
Samples taken on downstream edge of Highway 101 bridge.	Site E	Limited drainage area; marshy with scattered homes on the edge.