LOTT
Wastewater
Resource Management
Plan

August 2000

Budd Inlet Scientific Study: An Overview of Findings

The LOTT Partners – Lacey, Olympia, Tumwater, and Thurston County – have invested over $3 million in an 18-month long scientific study of Budd Inlet. The results helped show to what extent Budd Inlet could be relied upon for continued and/or expanded discharge of the community's treated wastewater flows in the future. If environmentally acceptable, additional winter discharge could offer a comparatively low cost way to gain reserve capacity as LOTT moves toward new wastewater recycling options. The scientific study final report was published in August 1998, and findings are also summarized in LOTT's Wastewater Resource Management Plan.

What's Inside?

Summary of Study Findings

The Budd Inlet Scientific Study is designed to answer several questions which are key to LOTT's Wastewater Resource Management Plan. The following presents a capsule summary of some answers offered by the study:

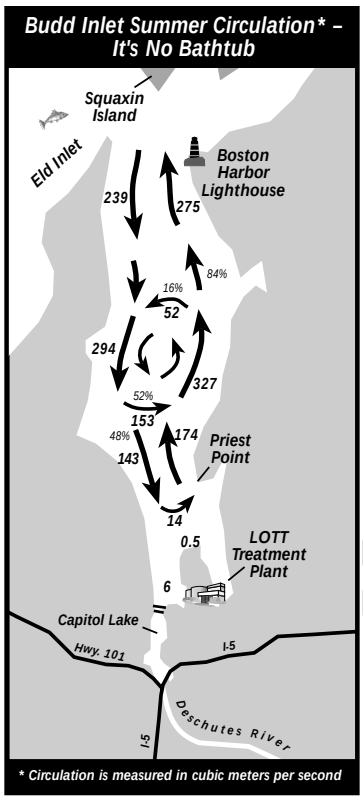
- Initial modeling results confirm that increased winter LOTT discharge won't harm Budd Inlet. Dissolved oxygen levels and other key water quality factors will remain largely unchanged.
- Circulation in Budd Inlet is much stronger than previously understood.
- Circulation is good in both winter and summer months – it takes just 8 to 12 days to replace the entire water volume in Budd Inlet.

- The low return of drift cards from Eld and Totten Inlets indicates LOTT discharges have little impact on shellfish harvest.
- Most of the fecal coliform bacteria in Budd Inlet – 93% – comes from two sources: Capitol Lake/Deschutes River and Moxlie Creek. LOTT's treatment plant adds less than 1%.
- Low dissolved oxygen (DO) levels in Budd Inlet occur in summer and early fall months only, are lowest near Capitol Lake and in East Bay, and are linked to plankton growth cycles and weaker tides.
- Water quality is much better in winter months, with DO levels well above State standards.
- LOTT is a very small contributor to winter nutrient levels in the Inlet. Another local source of nutrients – Capitol Lake/Deschutes River – is more prominent. Puget Sound is the dominant source.
- LOTT's earlier investment in nitrogen removal technology is paying off. Nutrient levels in Budd Inlet are reduced from historical levels.
- Organic material reaching the sediment decays rapidly; released nutrients are not stored long enough to carry over into sensitive summer months.

Budd Inlet's "Bathtub Theory" is Down the Drain

Scientists using the latest sonar technology were able to compile the first clear picture of marine circulation in Budd Inlet. The circulation patterns divide Budd Inlet roughly in half. Along the western shore, water flows into the Inlet from Puget Sound. Here, the water is colder, faster moving, more saline (saltier) and cleaner. Circulation patterns along the eastern shore carry water out of the Inlet. There is also a gyre in the central Inlet where the marine waters swirl (see diagram).

Scientists had assumed that summertime conditions in the Inlet resemble a bathtub, with little movement of water. The facts show that the flushing rate for Budd Inlet is much faster than most other inlets in Puget Sound. It takes just 8 to 12 days to replace the entire water volume in Budd Inlet. Circulation is about 30% stronger in the rainy months, when more freshwater flows into the Inlet. But since the main water source that flushes Budd Inlet has been found to be tidal pumping, circulation is good during both winter and summer months (see box).



Flushing Rates – Puget Sound Water Bodies

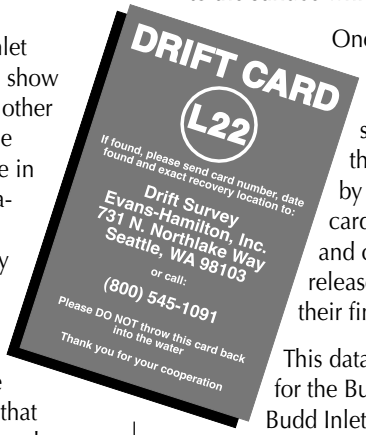
Water Body	Flushing Time (days)
Port Ludlow	1
Budd Inlet	**8-12**
Main Basin	20
Entire Puget Sound*	90
Southern Puget Sound	120
Dabob Bay	~700

* Includes: Admiralty Inlet, Hood Canal, Deception Pass, Tacoma Narrows, Nisqually Reach, and Dana Passage

Beachcombers Contribute to Budd Inlet Study

One unique approach used for the Budd Inlet Scientific Study involved South Puget Sound area beachcombers and other citizens in the actual collection of important data.

The gauges that oceanographers use to measure marine currents must be anchored at depths greater than 30 feet, to avoid ships' keels and propellers. That leaves a "blind spot" in the currents that flow closer to the surface which can't be captured by the scientists' meters.



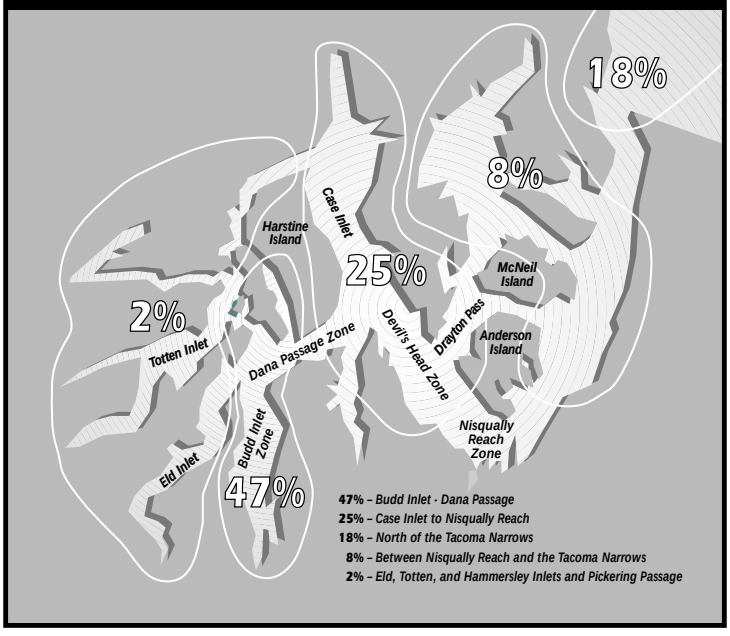
One method used to find the direction of these surface currents is to drop "drift cards" into the water at fixed locations and intervals. These small wooden cards float on the water surface, then are later collected and reported or returned by beachcombers, boaters and others. The drift cards are brightly colored to make them easy to spot, and coded to reveal the time and location of their release. A telephone number lets beachcombers report their findings by phone.

This data collecting technique has proven highly effective for the Budd Inlet Study. Of the 9,000 cards dropped into Budd Inlet, over 4,600 have been reported/returned. Cards were found as far away as Alaska. This return rate – 51% – is the highest in history for any Puget Sound study (see diagram below for survey results).

The final tally shows that only 2% of the drift cards were returned from Eld and Totten Inlets. This finding suggests there would be little impact on shellfish harvest if LOTT increased its discharges into Budd Inlet.

Thanks, beachcombers, for contributing to the study!

Drift Card Distribution – Final Tally
October 1996 – December 1997



The low return of drift cards from Eld and Totten Inlets indicates LOTT discharges have little impact on shellfish harvest.

Study Pinpoints Bacteria Sources

The study explored possible sources of bacterial contamination in Budd Inlet. The presence of fecal coliform was monitored to find the extent and origins of human-caused bacteria. Samples were taken at every freshwater source, and also at the outfalls for LOTT and other sewage treatment plants.

This year-round investigation revealed that nearly all of the fecal coliform bacteria in Budd Inlet – 93% – comes from just two sources. Capitol Lake/Deschutes River contributes 50% of the bacteria; and Moxlie Creek adds 43%. LOTT's treatment plant contributes less than 1%.

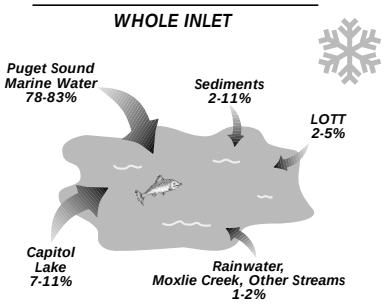
Follow the Nutrients

One major goal of the Budd Inlet Scientific Study was to carefully track all of the various sources of nitrogen that enter Budd Inlet – including discharges from LOTT's plant.

In summer months, nitrogen can act like fertilizer, speeding up algae growth in marine waters. As algae blooms die at the end of this growth cycle, the levels of dissolved oxygen in Budd Inlet can plummet, harming fish habitat.

Studies now confirm that LOTT is a very small contributor to winter nutrient (nitrogen) levels in Budd Inlet. LOTT's discharges add only 2 to 5% of the total nitrogen in winter months. Other sources are more prominent, with Puget Sound itself contributing 78 to 83% of the nitrogen (see chart).

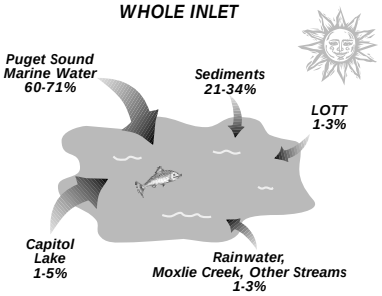
The Study Shows that LOTT is a Small Contributor to Winter Nutrient (Nitrogen*) Levels in Budd Inlet



* Dissolved Inorganic Nitrogen

In summer months, LOTT's contributions are even smaller. Under current permit requirements, the LOTT treatment plant operates biological nitrogen removal processes during the summer, virtually eliminating treatment plant nitrogen discharges. Thus, LOTT contributes only 1 to 3% of Budd Inlet's total nitrogen in dry weather months.

Nitrogen Removal at Treatment Plant Ensures LOTT's Contributions to Budd Inlet are Even Smaller in Summer



Dissolved Oxygen Impacted by Plankton Growth

There have been concerns for many years about water quality in Budd Inlet. In summer months, the Inlet has low dissolved oxygen (DO), which harms fish habitat. This condition is caused by algae growth and decay, and other factors.

The recent study results confirm the existence of low DO conditions in summer months, with the lowest levels found next to Capitol Lake.

The strong relationship between low DO levels and plankton growth cycles is also confirmed by the Budd Inlet Study. Plankton growth is much faster in months having more sunlight, with intense blooms in spring and summer months. The lowest DO levels in Budd Inlet occur as these growth cycles end, when decaying plankton consumes the dissolved oxygen.

Winter conditions in Budd Inlet are much better than in summer months. Dissolved oxygen levels in winter are good – 7 to 8 milligrams (mg) per liter (L) – well above the State standard of 5 mg/L. Circulation in the Inlet speeds up with increased rainfall, and algae growth is limited in winter by the lack of sunlight.

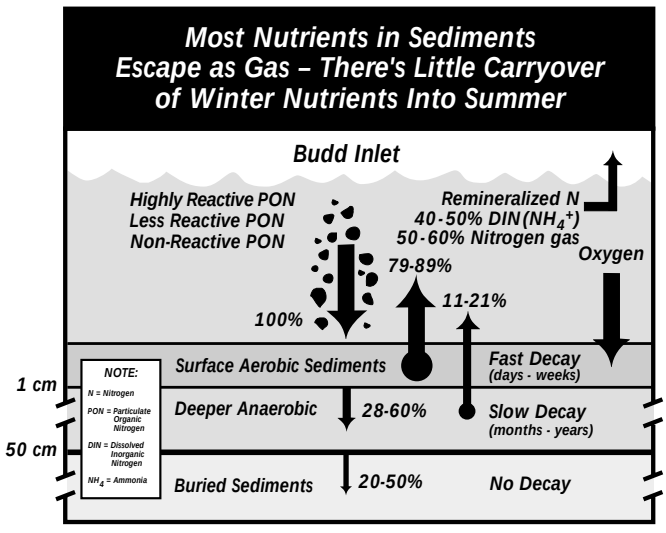
Sediments Don't Muddy the Waters

Some nutrients are trapped in sediments for a time, and can return later to the water column. Sources of the nutrients – called *particulate organic nitrogen* (PON) – include dying algae and plankton fecal matter.

Budd Inlet sediment studies involved extensive tests to find out what happens to these nutrients. The methodology included collecting deep and shallow sediment cores, sampling pore water (water trapped between sediment grains), measuring nutrient transport into and out of the sediments and installing sediment traps near the bottom of the Inlet.

Study findings demonstrate that the decay of algae and plankton occurs rapidly (2-4 weeks). Over half of the particulate nitrogen reaching the sediments is converted and returns directly to the atmosphere as nitrogen gas. This eliminates the potential to promote algae growth (see diagram below). As a result, there's little carryover of this nitrogen from winter into sensitive summer months.

Most Nutrients in Sediments Escape as Gas – There's Little Carryover of Winter Nutrients Into Summer



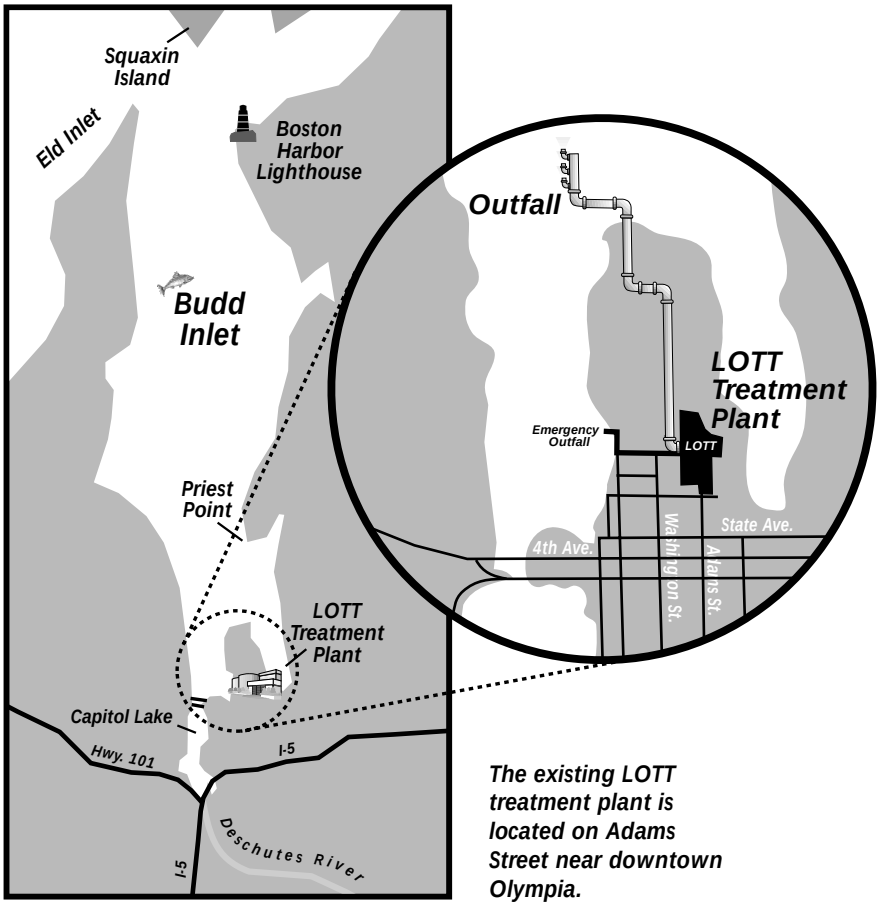
Scientific Information Collected for Budd Inlet Study

With completion of this scientific study, noted oceanographer Dr. Curtis Ebbesmeyer believes Budd Inlet is now "the most studied and best understood inlet in the Puget Sound".

Sampling activities conducted throughout the Inlet have been carefully timed to provide periodic "snapshots" of Budd Inlet ecology through the entire year, measuring conditions in both wet and dry seasons. Characteristics sampled and/or measured included:

- Tidal levels and currents
- Freshwater flows – from streams and Capitol Lake
- Wind speed and direction
- Temperature – air and water
- Bathymetry – water depth
- Water quality, especially:
  - Nutrients – including nitrogen, phosphorus and silicates
  - Fecal coliform
  - Biological oxygen demand (BOD)
- Phytoplankton population, species and behavior
- Zooplankton population, species and behavior
- Sediment properties
- Sunlight

Samples were also collected from many streams and creeks that flow into the Inlet: Mission Creek, Moxlie Creek/Indian Creek, Capitol Lake/Deschutes River and approximately eight other streams and creeks.



The existing LOTT treatment plant is located on Adams Street near downtown Olympia.

Budd Inlet – Comparing Wet vs. Dry Months

WINTER

Winter (wet) months are November through March

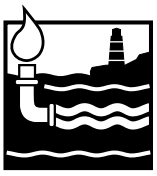
- DO (dissolved oxygen) levels in Budd Inlet meet or exceed State minimum standards – no harm to fish habitat
- Lack of sunlight limits algae growth
- Nutrients captured in sediments escape in a few weeks; do not carry over to affect DO levels in summer months
- Circulation of marine water is very strong; replaces the Inlet's water volume in about a week

SUMMER

Summer (dry) months are April through October

- LOTT operates nitrogen removal process, virtually eliminates treatment plant nitrogen discharges
- But low DO levels in Inner Sound still do not meet State standards – fish habitat harmed
- Algae blooms flourish, due to favorable environmental conditions – sunlight, temperature, nutrients. Cycle of algae die-off then worsens low DO conditions
- Annual drawdown of Capitol Lake adds more nutrients, further affects DO levels
- Circulation of marine water remains strong, with somewhat slower movement in the turning basin near Capitol Lake

Changes Needed to Discharge More in Budd Inlet



The LOTT plant today discharges treated wastewater to Budd Inlet through an existing outfall off the northwest end of the port peninsula (see map). Discharging more in Budd Inlet in the wintertime is one part of LOTT's long-range plan for managing the region's wastewater in the future. This involves continuing and increasing the permitted discharge of treated wastewater to Puget Sound through Budd Inlet in winter months.

LOTT must also renegotiate its existing discharge permit with the Washington State Department of Ecology.

Other actions which may be required to increase Budd Inlet discharges:

- modifying or moving the existing outfall or using a completely new outfall, or
- providing additional treatment to satisfy all applicable regulations and requirements.

Computer Model Helps Answer "What If" Questions

As a key piece of the scientific study, a computer model has been developed to simulate how the Budd Inlet environment responds to changing conditions. The model allows scientists to test the water quality implications of many possible changes to Budd Inlet – including increased LOTT wintertime discharges.

The computer model combines year-round data on tides, bathymetry, freshwater inflows, weather, water quality, and LOTT discharge rates and concentrations along with dozens of other factors.

The Budd Inlet model actually links two separate models: one that tracks water movement, and another focused on water quality. The model divides the entire inlet into cells, which measure 3 cubic meters in the shallower water, and 9 cubic meters in deeper water. This creates a three-dimensional picture of the entire inlet – a "virtual inlet."

When pooled, these data sources interact to give a more complete picture of how the Budd Inlet environment operates throughout the year.

The model will be useful not only for predicting the impact of LOTT discharges, but also the influences of many other factors, including Capitol Lake and changing weather conditions.

The model incorporates elements of a model first used in 1986 that resulted in LOTT's adding nitrogen removal to its wastewater treatment process. The original model was developed for the Department of Ecology by Chuck Boatman of Aura Nova Consultants, who also participated in the Budd Inlet Scientific Study modeling with Dr. John Edinger.

What's the Capitol Lake Connection?

The Budd Inlet Study's preliminary findings point to some links between Budd Inlet's water quality conditions and Capitol Lake. Today, Capitol Lake, with the flows it receives from the Deschutes River, is a major source of nutrients and fecal bacteria in the inlet.

In winter months, Capitol Lake/Deschutes River contributes 7 to 11% of the total nitrogen in the inlet, compared with 2 to 5% contributed by LOTT. The annual drawdown of Capitol Lake in summer months is also suspected to affect algae growth in Budd Inlet.

A separate study has been underway to evaluate options for future Capitol Lake management strategies. Options considered in an Environmental Impact Statement (EIS) include four freshwater management alternatives (including "no action,") and two estuarine (saltwater) alternatives. The intent is to develop a Capitol Lake Adaptive Management Plan. For more information on the Capitol Lake study, contact Steve Morrison, Thurston Regional Planning Council, at (360) 786-5480.

An Introduction to the Budd Inlet Science Team

The Budd Inlet Scientific Study team was coordinated by the engineering firm Brown and Caldwell. Team members included academic, governmental and private consulting representatives. The team was made up of marine scientists and modeling experts who offered significant expertise and knowledge related to Budd Inlet. Following is a list of the team's scientists and a brief description of their roles in the study:

Chuck Boatman, *Aura Nova Consultants*

Led development of the water quality model for the Budd Inlet Scientific Study.

Mr. Boatman, who passed away in December 1999, was a Marine Chemist and Geochemist with over 25 years of experience researching marine chemical and biological conditions. His expertise included computer modeling of marine chemical, sediment, and biological oceanographic conditions and was involved in the previous Budd Inlet nutrient model on which LOTT's present permit is based.

Jeffrey M. Cox, *Evans-Hamilton, Inc.*

Led marine water quality sampling and modeling investigations.

Mr. Cox is an oceanographer with 20 years experience conducting oceanographic studies related to understanding circulation and pollution transport within Puget Sound and other marine estuaries.

Allan Devol, Ph.D., Professor, *University of Washington*

Investigated molecular breakdown of oxygen and nutrients in Budd Inlet sediments.

Dr. Devol is a nationally recognized expert in sediment geochemistry and the exchange of substances between sediments and the overlying water.

Curtis C. Ebbesmeyer, Ph.D., *Evans-Hamilton, Inc.*

Analyzed marine circulation patterns and their effects on water quality.

Dr. Ebbesmeyer is an oceanographer with 30 years experience in developing conceptual models of the circulation of estuarine systems worldwide and of Puget Sound in particular.

John Edinger, Ph.D., *Edinger Associates*

Assisted in developing and applying Budd Inlet computer model.

Dr. Edinger is recognized nationally for his work in numerical modeling of water quality and dynamics. He has approximately 30 years experience conducting analysis and modeling of water quality conditions influenced by hydrothermal, effluent, or other pollutant discharges to fresh and marine water systems.

Jan Newton, Ph.D., *Washington State Department of Ecology and Northeastern University*

Conducted primary measurements to describe role of nutrients, light and other factors on determining seasonal characteristics of algae growth in Budd Inlet.

Dr. Newton is a biological oceanographer with over eight years professional experience studying biological productivity in oceanic, coastal, and estuarine systems. She heads the Marine Waters Monitoring group for the Environmental Investigations and Laboratory Services at Ecology, and has taught for Northeastern University at Friday Harbor Laboratories for seven years.

Dale Norton, *Washington State Department of Ecology*

Principal scientist in charge of conducting sediment trap studies to determine nutrient and chlorophyll levels associated with settling particulate matter in the Inlet, as well as sediment accumulation and resuspension rates.

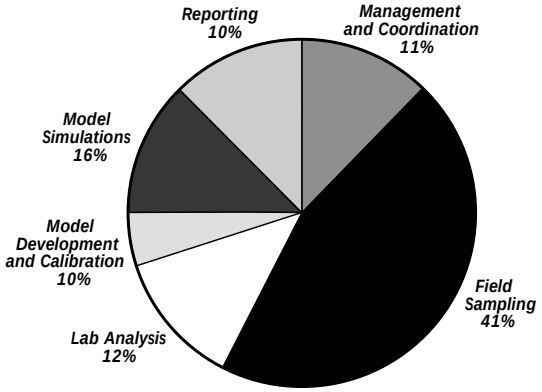
Mr. Norton has been with the Washington State Department of Ecology since 1980 serving as lead scientist on a variety of environmental research and monitoring programs.

Budd Inlet science team members from Department of Ecology and Evans-Hamilton staff measured hydraulic conditions, chlorophyll and nutrients in the Inlet for a full year.

Cost of the Study

LOTT has made a substantial investment in the Budd Inlet Scientific Study. The total budget for the study was approximately $3.15 million. The largest costs were for collecting samples year-round, and doing laboratory analysis to produce data. The comprehensive data provided the physical evidence necessary to calibrate the computer model of Budd Inlet, and demonstrate its ability to predict various environmental conditions.

Study Budget by Task



Agency Involvement in Budd Inlet Study

The Budd Inlet Scientific Study was planned and conducted in close coordination with:

- the Washington State Department of Ecology's Water Quality Program, and the Environmental Investigations and Laboratory Services Program; and
- the Washington State Department of Health Shellfish Program.

Ecology and Health agencies expect the Budd Inlet study to produce data needed to reach decisions about the possibilities for increased LOTT winter discharges. Ecology and LOTT have coordinated closely on the study, making corrections as needed, and meeting at frequent intervals, with periodic "peer review" by other scientists in related fields asked to critique study methods and results. Ecology was deeply involved in the sampling program, and directed the peer review. Other interested resource agencies and tribes have also been involved at all stages of the study.

Peer Review Gave Independent Look at Study Approach

To ensure the scientific integrity of the Budd Inlet Scientific Study, a peer review process was conducted and facilitated by Dr. Jan Newton, Washington State Department of Ecology and University of Washington Affiliate Assistant Professor. The purpose of this "peer review" was to first provide an independent and objective analysis of the study approach in order to identify "fatal flaws," and make recommendations to improve the study, then later to assist in analyzing the results.

For the Budd Inlet study, members of the peer review committee (see list below) were asked to review the study plan to identify any concerns. Their mission was to:

1. Raise serious concerns or flaws that would threaten the success of the study to address the questions LOTT is asking; and
2. Recommend refinements to the approach or measurements.

Peer Review Committee

Members of the peer review committee are national authorities in their scientific fields.

Scientific Field	*Peer Review Members*
Physical Oceanography	Parker MacCready, University of Washington Hal Mofjeld, National Oceanic and Atmospheric Administration Ed Laws, University of Hawaii*
Plankton Ecology	Paul Harrison, University of British Columbia
Chemical Oceanography	John Hedges, University of Washington
Microbial Oceanography	David Kirchman, University of Delaware John Baross, University of Washington
Harmful Algae	Rita Horner, University of Washington*
Biological Oceanography with Wastewater Treatment Plant Expertise	Chris D'Elia, University of Maryland Randy Shuman, King County Department of Natural Resources
Benthic Ecology	Jack Word, Batelle*
Fisheries	Robert Donnelly, University of Washington
Modeling	Winston Lung, University of Virginia Ray Walton, WEST Consultants Tom Cole, US Army Corps of Engineers

* Written comments only

The peer review panelists met to discuss the Scientific Study at a workshop held in March, 1997 at the University of Washington. The workshop included participants from federal, state and local agencies, academia, and scientific consulting firms. The workshop was open to the public and was well attended by faculty members, students, a tribal representative, and other interested parties.

The peer review committee members found no fatal flaws with the study approach. However, they did suggest several modifications to the study plan which affected the water quality modeling approach. Another recommendation of the peer review was to better understand the role and availability of forms of carbon in the Budd Inlet environment. Consequently, additional samples have been included in the study.

As the study concluded, the peer review committee members reviewed the study report and continued to offer recommendations to the study team.

Additional samples were collected in response to the peer review committee's recommendation to further explore the role of carbon in Budd Inlet.

Does the Budd Inlet Study Conform to Public Values?

The scientific study of Budd Inlet addresses key public values which guide LOTT's planning. These values were drawn from citizen surveys conducted early in the planning:

- **Maximize utilization of LOTT's existing treatment capacity** – LOTT's existing wastewater treatment plant is currently permitted by the Department of Ecology to discharge up to an average of 22 million gallons per day (mgd) of treated wastewater into Budd Inlet during the wettest month of the year. LOTT's consultant team has determined that the treatment plant can actually handle up to 30 mgd.
- **Control facilities costs –** The value of that extra 8 mgd in already-built capacity **could save $40 million,** compared with the cost to build an equivalent amount of new treatment capacity.
- **Use treated wastewater as a resource –** Increased wintertime discharges to Budd Inlet will serve as reserve capacity to help facilitate LOTT's transition to wastewater recycling.

What Happens Next?

The results of the Budd Inlet Scientific Study contributed important information for the Supplemental Environmental Impact Statement (SEIS) prepared for LOTT's Plan.

The Budd Inlet Scientific Study findings have been submitted for review by the Washington State Department of Ecology, Department of Health and other interested agencies. Ecology must decide on LOTT's request to increase permit limits for wintertime discharges to Budd Inlet from LOTT's existing treatment plant.

Ecology has participated in the study from the outset. At Ecology, teams of scientists will independently review and confirm the data before LOTT's permit request can be considered. A final decision is expected in late 2000.

Where is the Study Available?

Copies of the complete printed study are available for review at local public and college libraries; Washington State Library; the LOTT Wastewater Treatment Plant and the LOTT Alliance Office.

Copies of the Budd Inlet Scientific Study or its summary are available from the LOTT Office in the following formats:

- Complete Study, printed 2-volume set (cost of duplication, about $200 per set)
- Overview of Findings, 8-page summary (free)

For More Information

To find out more about LOTT's long-term plan for managing the region's wastewater, or for more copies of this summary of the Budd Inlet Scientific Study findings contact Lisa Dennis-Perez or Karla Fowler – telephone (360) 664-2333, fax (360) 664-2336, email at karlafowler@lottcleanwater.org.

LOTT Wastewater Alliance

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