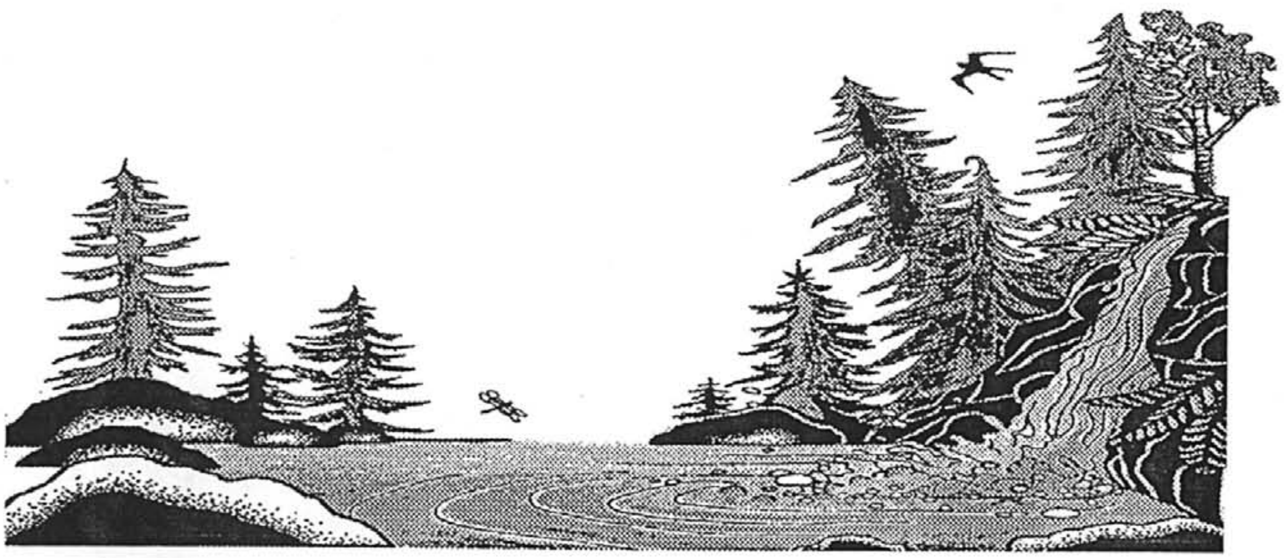
State of the Tsolum River



April 1999

State of the Tsolum River

A comprehensive report on work completed by the Tsolum River Task Force

April 1997 – March 1999

Edited and Compiled by
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ACKNOWLEDGEMENTS

Many groups and individuals have devoted years of service to caring for the Tsolum River. The TRTF would like to thank everyone who has assisted us in our efforts to restore the Tsolum River Watershed to historic levels of health and productivity, and to recognize these participants for their exceptional contributions:

Groups and Individuals

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Report Contributors

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SECTION 1

SUMMARY

SECTION 1. SUMMARY

Executive Summary

In the summer of 1997, the TRTF received funding from the Department of Fisheries and Oceans (DFO) for the Tsolum River Restoration Project.
The objectives of the project were to:

1. Assess salmon habitat and to identify factors which were limiting salmon production in the Tsolum River.
2. Complete a hydrological assessment to supplement existing information on water supply and diversions.
3. Conduct a water-monitoring program that would support and supplement existing water monitoring programs.
4. Undertake demonstration projects in fish habitat restoration and water storage.
5. Prepare action plans to achieve progress toward these deliverables.

Though acid mine drainage was recognized as a major factor contributing to the decline of salmon stocks, the Tsolum River Restoration Project funding mandate did not allocate funds specifically for minesite remediation. The TRTF was instructed by DFO to seek funding from other sources to reduce copper pollution in the Tsolum River to below the 7 parts per billion (ppb) level recommended by the Ministry of Environment Lands and Parks (Deniseger and Pommen, 1995).

The TRTF formed six work groups to address the problems of the watershed. Representatives from each work group formed a Steering Committee. In turn, the Steering Committee advised the Comox Valley Project Watershed Society Directors, and then after October 1999, the Tsolum River Restoration Society Directors on project progress. Appendices A through D detail the organizational structure, achievements, Member Groups and a Summary of Project Funders. In the past 18 months, the TRTF has achieved all project objectives and taken on additional projects such as assisting DFO with enhancement and adult assessment programs.

Public awareness of environmental problems within the watershed has been raised, and other funding agencies have joined DFO in supporting TRTF efforts to restore the Tsolum River. Though much has been achieved, there is still much to be done to protect salmon from loss of habitat and declining water quality.

An action plan has been developed to address the copper pollution leaching from the Mt. Washington Mine site. This plan was developed by community, government, and industry representatives participating in the Acid Mine Drainage Work Group. If government and industry can cooperate to provide the substantial funding necessary to complete this project, copper concentrations in the Tsolum River will be reduced to levels that will allow salmon populations to recover to historical levels.

HISTORY

The Tsolum...From a river of abundance to a river in decline

In his book "Land of Plenty, a History of the Comox District" (1987) local historian Dick Isenor states that when the first European settlers arrived in the Comox Valley in 1862, they were taken by canoe above the confluence of the Puntledge and Courtenay Rivers to a river known as the Tzo-o-oom (quiet waters) by the natives. The lowlands in this area were known for abundant easily harvested berries, fish and deer. As European settlers pre-empted the land and developed farms, this river later became known as the Tsolum, which now flows through the agricultural heartland of the Comox Valley.

Streambed degradation

Scouring and dredging of the Tsolum River spawning beds were the price paid for the development of settlements in the Comox Valley. As logging activity began along the Tsolum in the 1880s, trees were felled into the river and loggers attempted to float them downstream to the mills. The winding Tsolum often caught the logs, and jammed them on bars and in shallows before they could reach the mill (Isenor et al, 1987).

Further habitat degradation occurred in the 1940s when gravel was dredged from the spawning beds of the lower Tsolum River for the construction of the runway at CFB

Comox. This removal of spawning gravel reduced the available spawning habitat in the lower river.

The community that developed around the river withdrew water for domestic and agricultural supplies, increasing the problem of low summer flows in the river.

<u>Fisheries resources decline</u>

In the 1950's, runs of 100,000 pink salmon (*Oncorhynchus gorbuscha*) and 7,500 coho (*O. kisutch*) were counted spawning each year in this system (Walker & MacLeod (Ed), 1970). Cutthroat trout (*O.clarkii*) and chum salmon (*O. keta*) were plentiful in the lower river, and steelhead salmon (*O. mykiss*) in the 17 to 23 pound range were being caught by anglers (Brandt, 1997).

As clearcut logging activity intensified in the 1950s, the maximum flows in the lower Tsolum River were reported by the Water Survey Branch of Canada to be double what they had been in 1916.

Changes in the watershed caused increased siltation that smothered salmon redds and reduced the amount of invertebrate life which the young salmon relied on for their food supply, in the river. At times of low flow, the water was very warm and low in dissolved oxygen. This stressed the returning adults, and led to the decline in salmon abundance.

<u>Pink salmon die before spawning</u>

In 1951, Percy Wickett of the Department of Fisheries (PBS, 1951) documented the death of thousands of pink salmon stranded in the lower Tsolum River. In an effort to control the pink salmon migration upstream the Fisheries Department constructed a fence below Rees Bridge in the lower river. The idea was to keep the salmon out of the river until flows improved. This fence was subject to flood damage as the fall rains came, and many salmon died trapped behind the structure (Carwithen, 1998).

Mining in the upper watershed

In 1964, Mt. Washington Copper Ltd. and the Cumberland Mining Company opened a 13 ha. open pit copper mine which operated for two years before going into receivership in 1966. The mill site continued operations until 1967. The pyrite ore and sulphidic waste rock left exposed to water and air at the surface of the minesite began generating sulphuric acid that leached dissolved copper into Pyrrhotite, McKay and Murex Creeks. These tributaries to the Tsolum River carried the toxic copper leachate onto the spawning and rearing grounds of in the lower Tsolum River mainstem.

In 1979, Esso Resources Ltd. tested an acid treatment for leaching copper from the remaining ore at the site. As part of the process sulphuric acid and *Ferrobacillis oxidans* (an acid generating bacterium) was injected into the ore (Deniseger and Pommen, 1995). This process speeded up the release of copper from the minesite. The deadly effect of this copper was not discovered until 1985 when water samples were taken, and the dissolved copper levels were shown to be well above the 7 parts per billion dissolved copper limits established as water quality guidelines by the Ministry of Environment Lands & Parks.

Acid mine drainage leaching from an abandoned copper mine at Mt. Washington has been cited as a major factor in the decline of salmonid stocks in the Tsolum River, however low summer flows and habitat loss due to development and logging have also contributed to the loss. To reclaim the Tsolum River a whole watershed approach which drew together government expertise and local knowledge was needed.

From 1985 to 1997, the Comox Valley Chapter of the Steelhead Society of B.C., through its Tsolum River Enhancement Committee, took on reclaiming of the abandoned minesite and enhancement of the Tsolum River as its principle mandate. Through letters, TV and radio interviews, and working with the Federal and Provincial ministries, the Society brought community attention to the mine problem and assisted in bringing about a partial remediation of the minesite.

The economy of the Comox Valley has suffered through the loss of this resource. Once renowned for its steelhead population, the Tsolum River is now closed to all fishing. Though the cost of mine reclamation may be high, the cost of doing nothing is much higher.

Local surveys have estimated that each year two million dollars are lost to the economy of the Comox Valley because of damage to the fisheries resources of the Tsolum River. Over the last 30 years, this means that $60 million dollars of lost opportunity to the economy of British Columbia.

Creation of the Tsolum River Task Force

The TRTF grew out of many years of dedicated work by citizens concerned about water and watersheds of the Comox Valley. In 1992, DFO's Salmonid Enhancement Task Group, the Comox Valley Environmental Council and other local organizers held the "Water Lifestream of the Comox Valley" forum to discuss the health of local watersheds and other water related issues. The result of this forum was the production of the report titled " Water- Lifestream of the Comox Valley" (1993), which raised community awareness of watershed issues.

The Comox Valley Watershed Assembly is a local forum that convenes monthly to discuss watershed issues. At these meetings focus groups are formed to discuss concerns presented to the Assembly, and to develop solutions to these problems. The Assembly has been very effective for bringing watershed issues to the public and instrumental in the formation of many watershed stewardship groups. In 1995, the "Tsolum Team" was formed at a Watershed Assembly meeting and in 1997, the "Healing the Tsolum" workshop was attended by over 200 local residents. At a meeting the following day, the TRTF was formed with the goal of restoring the Tsolum River to historic levels of health and productivity.

The TRTF took its message to the Provincial Minister of Employment and Investment (Mines and Energy), the Honourable Dan Miller, and to the Minister of the Environment, the Honourable Cathy McGregor to request funding and support for the TRTF's efforts to clean up the problem of minesite pollution, address the problem of low summer water flows in the river and restore fisheries habitat throughout the watershed. In response to this call for action, the Ministers directed the TRTF to apply to Fisheries Renewal B.C. and the Environment Youth Team for assistance with this task.

In the spring of 1997, funding was received from DFO for the Tsolum River Restoration Project to be administered by the Comox Valley Project Watershed Society, with the supervision of the project under the control of the Steering Committee of the TRTF.

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Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Environment Canada, Ottawa

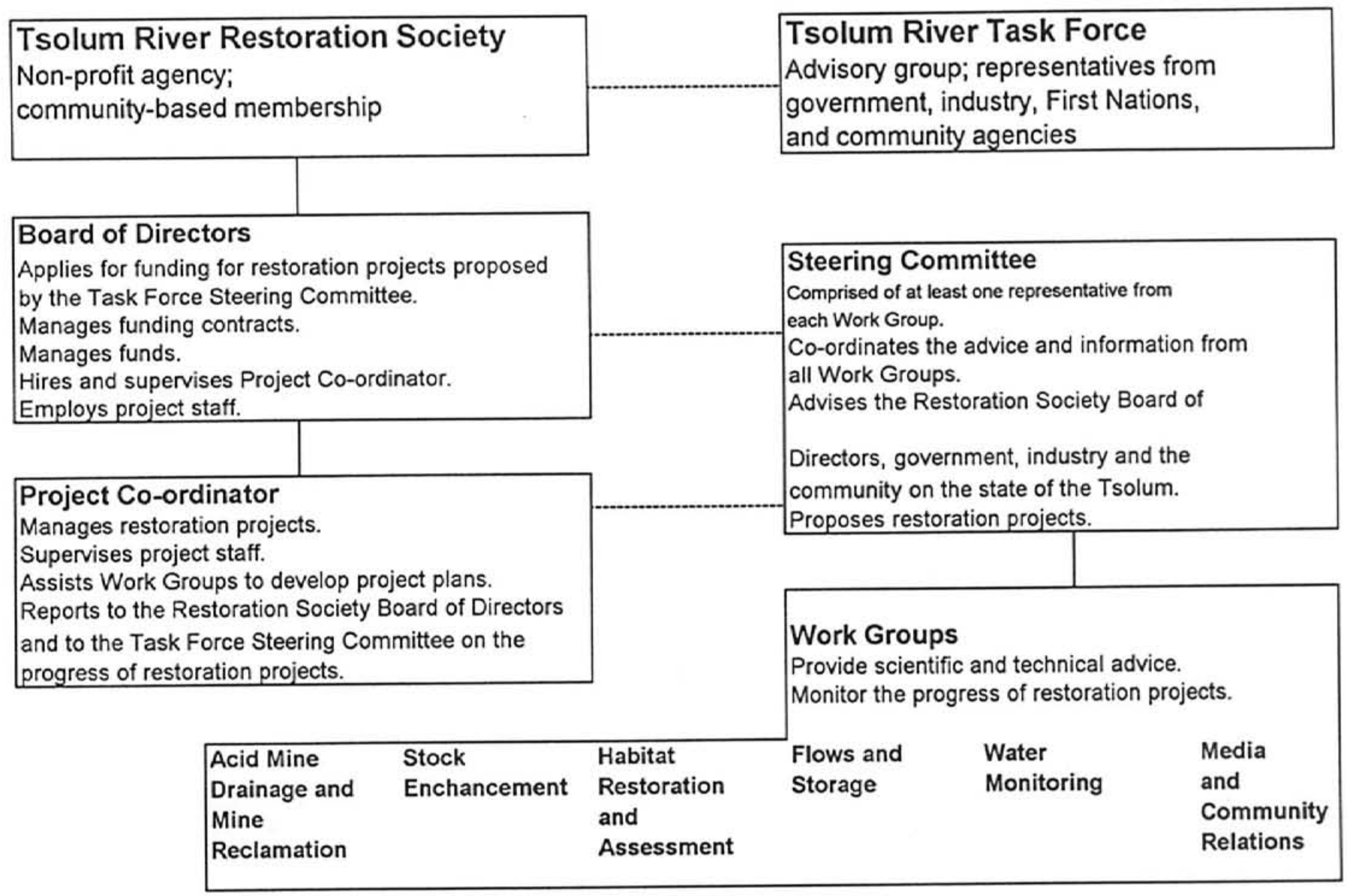
SECTION 1, APPENDIX A

Organizational Structure

Appendix A

Organizational Structure

March 1999



SECTION 1, APPENDIX B

TRTF Achievements

TRTF Achievements

Since its creation in the spring of 1997, the TRTF has achieved a wide variety of results including:

Delegation Visits Victoria

A TRTF delegation, including MLA Evelyn Gillespie met with provincial Minister of Mines, Honourable Dan Miller and Minister of the Environment, Honourable Cathy McGregor, to call for action on restoring the Tsolum River on July 22, 1997.

Funding Secured, Coordination & Administration Established

A proposal presented to the Department of Fisheries and Oceans (DFO) resulted in a collaborative agreement between Project Watershed, and DFO to fund the Tsolum River Restoration Project. On April 1, 1997 DFO committed funds to a two-year Tsolum River Restoration Project. Project Watershed received funds in July 1997 and by September, a full time Project Coordinator, and a part time Project Administrator were contracted to serve the TRTF.

Terms of Reference and Work Plans Developed

In September 1997, Terms of Reference for the TRTF were adopted by the Steering Committee. Six work groups were formed to address limitations to salmonid production in the watershed. Project plans were developed for each work group.

Tsolum River Streamkeeper Group Established

In November of 1997, Project Watershed provided Streamkeepers training to interested local residents, and the Tsolum River Streamkeepers group was formed. These community volunteers are actively working with the TRTF to protect fish habitat in the Tsolum River watershed.

Tsolum River Mapping Project Phase 1 and 2

The TRTF partnered with DFO and the Community Fisheries Development Centre to conduct a mapping project in the Tsolum River watershed. One supervisor and three fishers in transition were trained in the DFO "Sensitive Habitat Inventory and Mapping" methodology. By March 1998, protocols for landowner contact were in place and, 16.72 km of mapping was been completed. This program also identified wintering habitat for coho and steelhead in Tsolum River tributaries, and restoration project opportunities.

Lower Copper Loadings Detected in Water Samples

Water samples taken in the spring of 1998 indicated a 50% reduction in copper loadings entering the Tsolum River. More sampling is needed, as no cause has yet been determined for the lower copper levels.

Remediation Options Examined in Engineering Report

In April 1998, the Ministry of Energy Mines and Resources and the Ministry of Environment, Lands and Parks and Environment Canada commissioned a report by Levelton Engineering to examine reclamation options for the abandoned Mt. Washington copper mine.

Tsolum & Puntledge Declared B.C.'s Most Endangered Rivers

In May 1998, the Outdoor Recreation Council responded to a community petition and declared the Tsolum and Puntledge Rivers to be B.C.'s most endangered rivers. Provincial radio coverage and national television coverage highlighted TRTF efforts.

TRTF Joins with Community Partners: Mapping Phase 3

B.C. Hydro funded the "Community Partners Project" which employed one supervisor and three young people to work on environmental projects in the Comox Valley. This crew mapped barriers to salmon migration in the Tsolum River mainstem. The crew also participated in community events, and assisted with restoration projects.

Environmental Youth Team Interns Join the TRTF

In July 1998, the Ministry of Environment, Lands and Parks "Youth Options BC" program funded two Environment Youth Team (E Team) intern positions. These E Team members were trained as Streamkeepers by Project Watershed. The E Team interns Monitored temperature and dissolved oxygen throughout the watershed and compiled flow data for TRTF studies. They also raised community awareness of TRTF work by building and displaying a watershed model at 2 community events.

Eight Stream Restoration Projects Completed

During the summer of 1998, eight stream restoration projects were completed. These projects included: construction on refuge ponds, stream complexing, riparian planting, construction of riparian rafts and stream bank stabilization.

Water Storage Capacity is Increased

The leaking rock weir at the outflow of Wolf Lake was repaired in a cooperative effort between Puntledge Hatchery, DFO engineers, TimberWest and the TRTF during the summer of 1998. Water storage capacity of the lake was increased by 575 acre-feet providing more water for farms and fish during pink salmon migration.

Coho Refuge Pond Water Quality Pilot Study Completed

Refuge ponds in tributaries to the Tsolum River are essential habitat for fry and adult salmon. During the summer and fall of 1998, temperature and dissolved oxygen levels were monitored in nine refuge ponds. The study revealed that salmon were surviving under less than optimum water quality conditions. A proposal was developed to improve water quality and improve salmon survival.

TRTF Cooperates with DFO to Enumerate Spawning Stocks

In the fall of 1998 the TRTF participated with DFO to enumerate pink and coho salmon returning to the watershed. Several hundred adult coho pink and chum salmon were observed spawning. The TRTF produced maps of critical spawning habitat.

Formation of the Tsolum River Restoration Society

In October 1999, the Tsolum River Restoration Society (TRRS) formed to assume responsibility for the administration of the Tsolum River Restoration Project. The collaborative agreement between DFO and Project Watershed was transferred to the TRRS.

FsRBC Funds Mapping Phase 4

Fisheries Renewal BC (FsRBC) provided funding for stream mapping in the Headquarters and Dove Creek Watersheds

Community Based Siltwatch Program Established

In response to local concern for stream water quality, the TRTF used Fisheries Renewal B.C. funding to develop a community based siltwatch program. Volunteers participated with the TRTF to collect water samples and identify sources of point source erosion in Headquarters and Dove Creeks.

Landowners Assist TRTF to Protect Coho Habitat

Restoration work continues with the construction of riparian rafts for refuge pond habitat, and a continuation of streambank stabilization work. Funding proposals have been submitted to Fisheries Renewal B.C. and DFO's Habitat Restoration and Salmon Enhancement Program for work to be undertaken after April 1999.

Pink Salmon Enhancement Program Re-established

The TRTF Enhancement Work Group worked with Puntledge Hatchery and scientists from the Pacific Biological Station to complete a small-scale enhancement project at the Headquarters Creek Hatchery. Bioassay studies undertaken in the spring of 1999 will provide direction for future enhancement programs.

AMD Action Plan Produced

Canadian Pacific Railway, TimberWest and Better Resources, owners of the Mt. Washington Mine site, are working with the TRTF to develop an action plan for minesite reclamation. The Action Plan is a work in progress that is available on line:

http://www.netcolony.com/members/wildwolf/actionplan.

Community Events, Presentations and Education Programs

Since 1997, TRTF staff and volunteers have given 14 public presentations, and written 20 press releases that achieved local, provincial and national media coverage for the project. The TRTF has also encouraged college and university students to participate with the TRTF in field projects and to investigate the environmental problems of the watershed in their course work. Students from UBC, UVic, Excel Career College and North Island College have all completed projects with the guidance of the TRTF.

Sustained by the Efforts and Energy of its Volunteers

The TRTF has made considerable progress in addressing the causes of problems affecting the Tsolum River. Though much work is completed, much more work remains to be done. It is essential that the momentum generated, and the expertise that has been brought together continues to be supported to complete this important task.

We believe that our goal of restoring the Tsolum River to health and productivity is being achieved though our community oriented whole watershed approach.

SECTION 1, APPENDIX C

TRTF Member Groups

Tsolum River Task Force

Restoring the Tsolum River to historic levels of health and productivity

The TRTF is composed of representatives from the following groups:

Elected Representatives:
- M.P. John Duncan
- M.L.A. Evelyn Gillespie
- Comox Strathcona Regional District Area C Director Rod Nichol

First Nations:
- Kwakiutl Territorial Fisheries Commission

Government Agencies:
- Department of Fisheries and Oceans
- Environment Canada
- Ministry of Environment, Lands and Parks
- Ministry of Employment and Investment - Energy and Minerals Division

Fishing Industry
- Pacific Trollers Association

Forest Industry
- International Woodworkers of America
- TimberWest

Local Representatives
- Comox Valley Naturalists Society
- Comox Valley Watershed Assembly
- Courtenay Fish and Game Club
- Comox Valley Project Watershed Society
- Farmers Institute
- Merville Area Residents and Ratepayers Association
- Oyster River Watershed Management Committee
- Steelhead Society, Tsolum River Enhancement Committee

Mining Industry
- Better Resources Ltd.
- Canadian Pacific Railway
- North Island Exploration
- Westmin Resources

SECTION 1, APPENDIX D

TRTF Funding Agencies

Funding Agencies

The TRTF is grateful for the support that it received from the following funders:

- Dept. of Fisheries & Oceans, Habitat Restoration and Salmon Enhancement Program
- Environment Canada
- Fisheries Renewal B.C.
- Ministry of Energy and Mines
- Ministry of Environment, Lands and Parks
- Youth Options BC, Environment Youth Team
- Regional District of Comox-Strathcona Area C Director, Rod Nichol
- B.C. Hydro Opportunities for Youth
- Comox Valley Commercial Fishermen

SECTION 2

PROJECT AND WATERSHED DESCRIPTION

SECTION 2. PROJECT AND WATERSHED DESCRIPTION

Characterization of the Watershed

The Tsolum River is a low gradient stream that flows parallel to the coastal plain of Vancouver Island for approximately 30 km from its headwaters near Mt. Washington to the lower Comox Valley where it joins the Puntledge River. The river is unusual, as it does not have any impassible barriers on its mainstem. This 258 km^2 watershed is fed by several small lakes, and supported historical runs of pink, coho and steelhead and cutthroat trout which have steadily declined since the late 1950's. Some of the fish populations are now near extinction levels despite intensive enhancement efforts to raise coho and pink salmon at the DFO Tsolum River Facility.

There are six major, and dozens of minor, tributaries to the Tsolum River. The main tributaries in the lower watershed are Portuguese Creek, Dove Creek, and Headquarters Creek. Murex Creek, McKay Creek and Pyrrhotite Creeks are located in the upper watershed, draining the abandoned open pit copper mine previously operated by Mt. Washington Copper Co. (see Appendix A).

Land Use in the Tsolum River Watershed

The Tsolum River watershed is influenced by urban development, agriculture, logging, and the abandoned mine. Residential and agricultural development is in the lower watershed, mainly downstream from Headquarters Creek. Pasture for dairy and beef cattle border portions of the lower Tsolum River. Second pass forest harvesting occurs in the upper reaches of the watershed. An extensive portion of the upper watershed is owned by TimberWest Forest Limited, a forest harvesting and manufacturing company. Comox First Nation's Indian Reserve (IR) # 2 is located at the Tsolum River confluence with the Puntledge River.

The project identified five main land use regions within the watershed as shown in Appendix A. They include lowland agricultural, rural residential, suburban residential, forested upper slopes and the upper watershed and wetlands.

1) Lowland agricultural

This region extends from the confluence of the Tsolum and Puntledge Rivers to the confluence of the Tsolum River with Dove Creek. Land use in the region is predominantly agricultural. The area surrounding Lower Portuguese Creek and Dove Creek is also included in this classification.

The Tsolum River watershed has been a major centre of agricultural activity since the 1870s when settlers began developing farms in this region. Agriculture is a major economic activity in the Comox Valley and many farmers are very supportive of fish habitat restoration efforts. Most of this land is in large parcels, which simplifies landowner contact. In many areas the lack of riparian vegetation along the streambanks causes streambank instability and erosion.

Main issues that were addressed by the TRTF in this region included streambank erosion; lack of riparian vegetation; limiting cattle moving across streambeds; improving fish habitat in drainage ditches; and water use for irrigation and domestic purposes.

2) Rural residential

This area includes the Tsolum River mainstem from Dove Creek to the Tsolum River Oxbow. This is also the predominant land use along the upper reaches of Portuguese and Dove Creeks, as well as lower Headquarters Creek.

Land parcels in this area are smaller than the agricultural lowlands, generally several acres per parcel. There is less land clearing and more riparian vegetation. The increased number of properties in this area required that more time be devoted to landowner contact in order to gain permission to access this area for mapping and restoration work.

In this region, the TRTF concentrated upon increasing landowner awareness of how upstream activities affects salmon habitat; on the lack of refuge habitat and improvement of water quality in existing refuge ponds; on low summer flows and lack of summer rearing habitat in tributaries; on the importance of protecting wetlands from development and also conducted mapping and fish habitat assessment in small streams.

3) Suburban residential

In upper Finlay Creek there are many suburban residential lots under 1 acre. Fish habitat and mapping studies are more labour intensive because of the increased effort needed to contact every landowner bordering streams in this area before data collection begins. Development pressure is high, and use of water and chemicals to maintain lawns and gardens as well as run off from paved surfaces impact the small streams in this area.

Main issues addressed in this region include landowner awareness of how upstream activities affects salmon habitat; increasing developers' awareness of the importance of wetlands and "ditch" habitat; and conducting fish habitat assessment to locate areas of critical spawning and rearing habitat. In addition, fish safe yard care methods should be publicized. This should include information on reducing water use, maintaining riparian vegetation, and limiting the use of chemical garden and lawn fertilizers. A further need was identified for a campaign to raise landowner awareness of how paving changes the hydrology of a watershed, as well as mapping paved surfaces in this region of the watershed.

4) Forested upper slopes

The gradient is steeper here and forestry is the predominant land use. TimberWest Ltd. is the largest landowner in the forested upper slopes. Wolf Lake is an important reservoir in this area that supplies water to the lower Tsolum River during times of low flow.

The forest companies control access of volunteers and TRTF personnel in this area. In areas where active logging is occurring, access may be dangerous, and radio contact is necessary to assure crew safety. Keys are needed to access roads closed by locked gates.

The Vancouver Island Highway project is also impacting fisheries resources in this region. A community based Siltwatch program has begun to monitor stream siltation.

Main Issues addressed by TRTF in this region include obtaining landowner permission for access to these lands; maintenance of riparian zones which protect fish habitat; and effects of highway construction which may change drainage patterns and cause siltation and streambank erosion.

5) Upper watershed and wetlands

This area includes the many lakes and wetlands which are important to maintaining water flow and water quality. It also includes several higher gradient tributaries to the Tsolum River as well as the mine site.

Protection of humic acid rich wetlands is crucial to reducing copper toxicity in the Tsolum River. Draining or development of these areas would reduce the watershed's natural ability to detoxify copper contamination, and would lower the acceptable dissolved copper concentration necessary for fish health. Access to this area of the watershed is difficult due to active logging and snow which covers the mine site and upper watershed from November to June. During this time access is only possible by air, or snowmobile. During other times of the year, a four-wheel drive is preferred for travel off of the main logging roads.

In this part of the watershed, the TRTF addressed several concerns including the copper leaching from the abandoned Mt. Washington mine site. Presently levels of dissolved copper are above recommended water quality objectives and must be reduced to less than seven parts per billion to maintain fish health. There is no electricity at the mine site which necessitates the use of battery powered monitoring equipment.

The TRTF also identified a need for a wetlands survey to be completed with water quality testing completed to determine where reservoirs of humic acid rich water are located. A culvert mapping and assessment survey should also be completed to determine if culverts in this area are a barrier to fish passage.

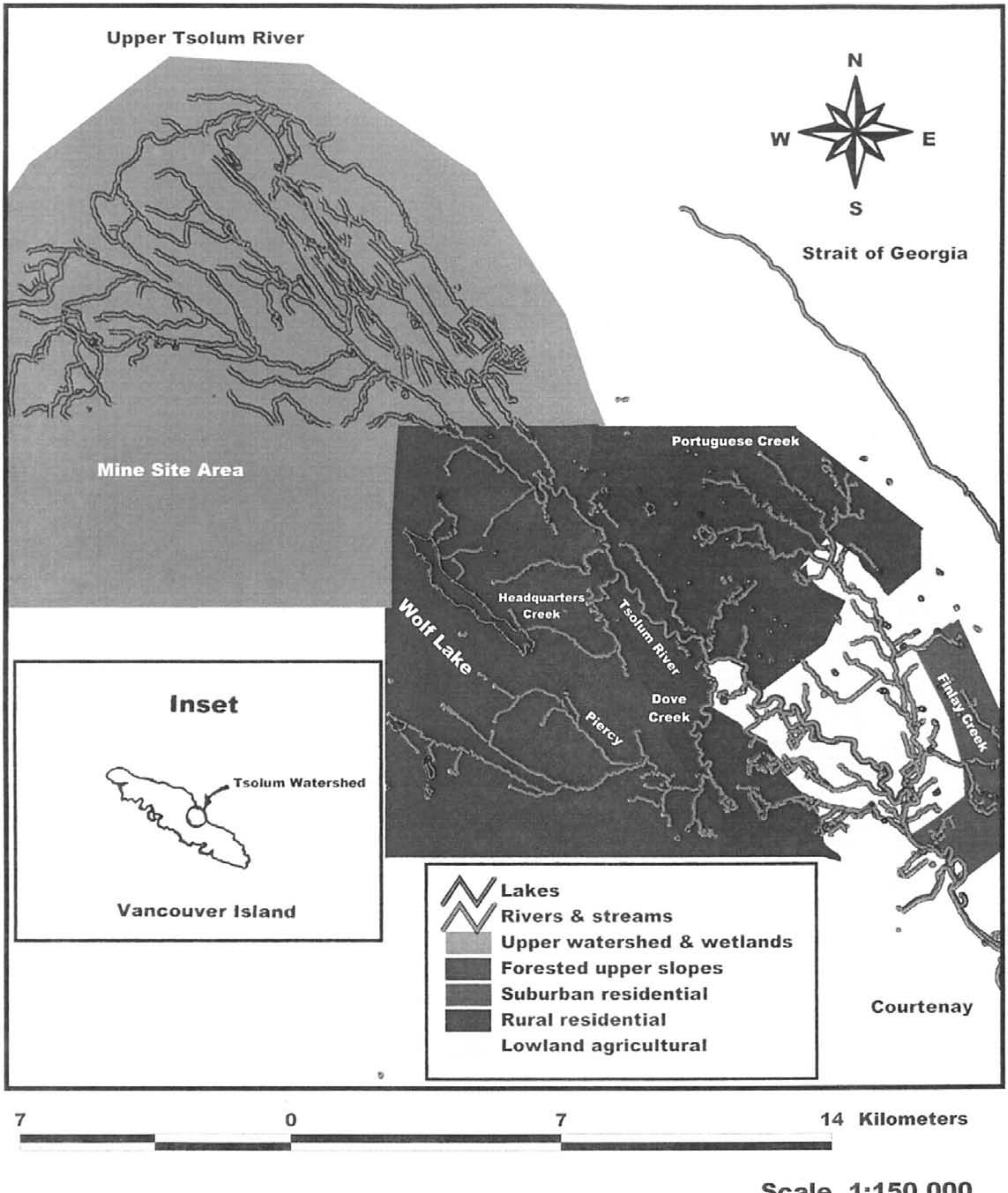
Water Use in the Tsolum River Watershed

The Tsolum River is a source of water for domestic and agricultural use. There are 14 registered domestic and 24 irrigation licenses on the Tsolum River. Water flows are very low between July and October. Low water flows and water temperatures in excess of 20°C during this time of year have been cited as being one of the major factors contributing to the decline of pink salmon populations.

SECTION 2, APPENDIX A

Tsolum Watershed Land Use Map

Tsolum Watershed Land Use



Created by Joanne Ellefson, March 19, 1999, for the Tsolum River Task Force.

SECTION 3

VOLUNTEERS AND COMMUNITY INVOLVEMENT

SECTION 3. VOLUNTEERS AND COMMUNITY INVOLVEMENT

Introduction

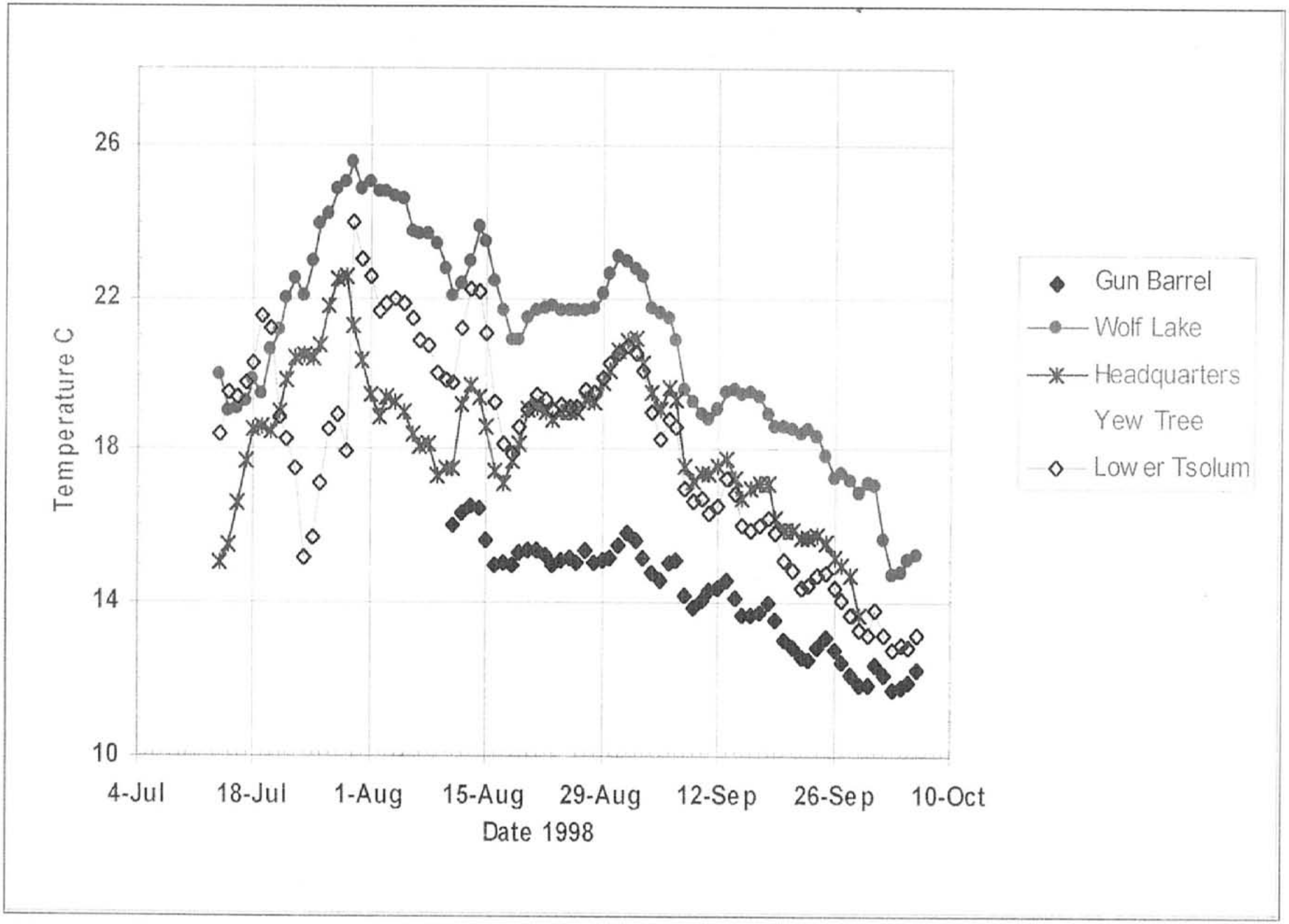
Community support is essential to the TRTF's efforts to restore the health and productivity of the watershed. The Streamkeeper Coordinator works with volunteers to assist them in preserving habitat, and communicates their concerns to TRTF work groups and other regulatory agencies.

In their roles as custodians of the river, Streamkeepers provide continuous informal monitoring of changes occurring in the Tsolum River and its tributaries. These changes may be the result of the highway construction, timber harvesting, previous mining activities in the upper watershed, or the loss of riparian vegetation due to development on private land. Their local knowledge is invaluable to planners, conservation officers, and habitat technicians who must evaluate referrals and enforce fish habitat regulations.

The Role of the Streamkeeper Coordinator

The Streamkeeper Coordinator is employed by the TRTF on a part time basis for one day per week. Though employed part time, the coordinator works a flexible schedule, returning calls in the evening and attending weekend events. The coordinator needs a wide variety of skills encompassing technical expertise and good communication and interpersonal skills. Streamkeeper Coordinators act as facilitators and guides, providing technical expertise and working alongside volunteers in the field (Appendix A).

Streamkeeper Coordinators train volunteers to complete surveys and gather data necessary for planning restoration projects. By providing project support for Streamkeepers, the TRTF supports community efforts, and benefits from community participation in restoring the river. The TRTF also provides equipment and training when requested by volunteers.



26
22
18
14
10
Temperature C
4-Jul
18-Jul
1-Aug
15-Aug
29-Aug
12-Sep
26-Sep
10-Oct
Date 1998
Gun Barrel
Wolf Lake
Headquarters
Yew Tree
Lower Tsolum

Siltwatch

In response to concerns about a decline in water quality due to logging and road construction, the TRTF trained Streamkeepers in water sampling techniques, and initiated a community Siltwatch program.

Raising Community Awareness

To raise community awareness about the decline in fisheries resources in the Tsolum River watershed, the TRTF encouraged volunteer involvement in the following events.

- A watershed model was constructed by the TRTF and displayed at community events to demonstrate problems existing in the Tsolum Watershed. This model and the accompanying photoboard display provided a graphic representation that was viewed by hundreds of people attending these events.

- Press releases announced meetings and the discussed the need for volunteer labour. Articles such as "Salmon Spotters needed on the Tsolum River", published in the local newspapers, invited public participation in TRTF projects.

- In November 1998, a photography contest called "Seasons of the Tsolum River" was held. This contest drew attention to the Tsolum River, its beauty, the people of the Tsolum area, and the status of the Tsolum River as an endangered river. Local merchants donated prizes that were awarded to the winners in four categories.

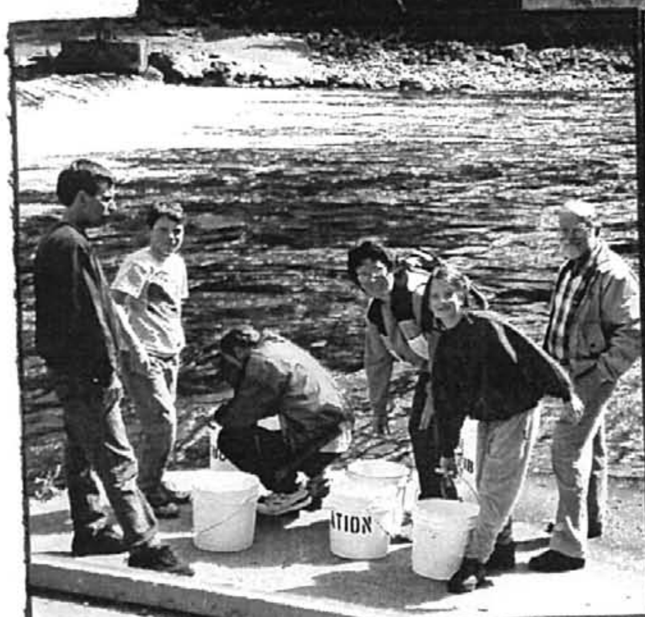
The Value of the Community Connection

By providing funding for the Streamkeeper Coordinator, the community and the TRTF benefit from volunteer energy and experience. This valuable program also supports DFO field personnel in their efforts to protect the river, and encourages neighbour-to-neighbour contact. This network results in habitat protection and care for the resource at the community level.

SECTION 3. APPENDIX A

Streamkeepers Wall of Fame
and
Streamkeepers at Work

Streamkeepers Wall of Fame



Streamkeepers at Work

A model of the Tsolum River watershed was presented at community events.

Between 1997 and 1999 Streamkeepers contributed over 1500 hours of volunteer work to protect and restore the Tsolum River Watershed.

SECTION 4

MEDIA AND PUBLIC EVENTS

SECTION 4. MEDIA AND PUBLIC EVENTS

Introduction

The Tsolum River Task Force formed as the result of a public meeting attended by over 200 people in the spring of 1997. During its inception, the TRTF recognized the importance of community involvement and support for its initiatives. The Media and Community Awareness work group was created to promote the TRTF's mandate, to raise public awareness of the problems endangering the Tsolum River watershed, and encourage community participation.

Community events, public meetings and presentations to special interest groups provided the TRTF with opportunities to discuss watershed issues, inform people about projects underway and to listen to community concerns. Between 1997 and 1999, the TRTF actively participated in numerous community events. These events included: BC Rivers Day 1997 and 1998, EarthFest'98, the 1998 Comox Valley Fall Fair, the 1998 Fish and Game Club Outdoor Show, the 1998 World Community Film Festival Bazaar and the 1998 Mountainaire Avian Rescue Open House. TRTF members also made several presentations to schools and community groups. The support that the TRTF received from the agricultural community and from volunteers was vital to the success of its projects.

The media work group's goal was to raise awareness of the habitat degradation in the Tsolum River through local and provincial media reports. The group's efforts were rewarded with significant coverage by local media. A CBC Radio special report, CBC Television News and CHEK Television News features, as well as in a Victoria Times Colonist newspaper article also provided provincial media coverage.

Public Events

Tsolum Spirit Park Rivers Day event was organized to celebrate the 17th BC Rivers Day on September 28, 1997. This provincial event, sponsored by the Outdoor Recreation Council of BC, is held annually on the third Sunday of September. Over 50 people participated in walks and talks about the river and/or watched Streamkeepers' demonstrations. The TRTF celebrated BC Rivers Day 1998, by participating with Department of Fisheries and Oceans staff at an open house held at the Puntledge River Hatchery.

A photoboard display, created by the media group, was viewed by 100 visitors to the January 1998, World Community Film Festival Bazaar held at the Florence Filberg Centre. The display and representatives were also present at the May 1998, Courtenay Fish and Game Club Outdoor Show and the 1998 Mountainaire Avian Rescue Open House in April 1998.

The TRTF exhibited a display at EarthFest'98, held in Courtenay on August 22-23, 1998. This very successful event attracted 1500 people, giving them the opportunity to walk through the TRTF gazebo and view the popular scale model of the Tsolum River watershed. Three weeks later, September 12-13, this exhibit promoted the TRTF at the annual Comox Valley Exhibition Association's 1998 Fall Fair.

To further raise the profile of the endangered Tsolum River, the TRTF sponsored a photo contest in November 1998. TRTF members judged more than fifty photographs in four categories: People and the River, the Endangered Tsolum, the Scenic Tsolum, and Fish and Fishing. Winners were announced in January 1999 and received prizes donated by four local businesses.

The TRTF facilitated publicly open general meetings in November 1997, as well as in February, June and November 1998. At these meetings the TRTF received public input on its achievements and project plans. Approximately forty people attended each meeting to view presentations and photoboard displays, and to participate in discussions on project progress.

Presentations were also made at several community group meetings. Mapping and water sampling techniques were presented to a Vancouver Island Highway Project meeting of Concerned Citizens held on November 1997 at Marsland House. A slide show and discussion of flow control on the Tsolum River were held at the February 1998 Farmers' Institute meeting at Dove Creek Hall. The TRTF also delivered a presentation to 75 members of the Courtenay Fish and Game Club at their annual general meeting held in May 1998. In January 1999, 20 Excel Career College students were introduced to GPS techniques being used by the TRTF in watershed mapping studies. Students at Tsolum School Careers Day, held in February 1999, saw a presentation titled "Working to Save the River".

Recognizing the valuable service of its volunteers, the TRTF co-hosted a Volunteer Appreciation Day at Marsland House with the Comox Valley Project Watershed Society and the Citizen's Action on Recycling and the Environment (CARE) group in April 1998. Fifty volunteers were treated to four workshops, lunch and the opportunity to meet other volunteers.

Endangered Rivers Campaign

A community campaign organized by the TRTF to publicize the decline of fisheries resources in the Tsolum River resulted in the Outdoor Recreation Council of BC (ORC) placing the Tsolum and Puntledge River at the top of the "BC's most endangered rivers" list in 1998. This list is designed to raise public awareness about threatened BC rivers, and to make regulators aware of watersheds in need of rehabilitation.

Print Media

The media work group produced many press releases to publicize the work of the project. Local newspapers actively supported the project by publishing photos and stories documenting the project's progress. (See Appendix A).

The *Comox Valley Echo* and *Comox Valley Record* newspapers published numerous articles covering TRTF issues and activities. For example, the Tsolum River's past, present and future; acid mine drainage issues; and TRTF efforts to obtain funding were featured. Articles also publicized BC Rivers' Day events, the activities of Tsolum Streamkeepers, the Environmental Youth Team's willow wattling project, the Endangered Rivers List campaign, and the Tsolum River photo contest.

Provincial exposure to acid mine drainage issues was provided by the Victoria *Times Colonist* July 4, 1998, issue describing lobbying by the Sierra Legal Defense Fund. Locally, the monthly *Mt. Washington Ridgeline* highlighted strategies for cleaning up acid mine drainage following the release of an engineering study in its June 25, 1998, issue. *The Voice*'s August 1998 issue described in detail the construction of the watershed model being built for the EarthFest exhibit.

Radio

On May 19-21, 1998, CBC Radio (British Columbia) aired a series of special reports and discussions on the future of the west coast fishery. This *Almanac* series, titled *No Fish No Future,* was capped by a special two hour provincial broadcast on May 22 from Campbell River that included a live interview with Kathy Campbell, TRTF project coordinator. An audiotape of the broadcast is archived.

Television

Both CBC TV (Vancouver) and CHEK TV (Victoria) supplied provincial television coverage. CHEK TV News broadcast stream bank stabilization efforts by the Environmental Youth Team's willow wattling project in June 1998. In October 1998, the CBC's Broadcast One news program featured a story about acid mine drainage, which included an interview with TRTF representative, Father Charles Brandt. Videotapes of these television features are available.

Web Page

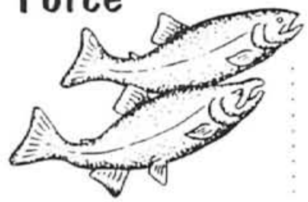
Worldwide use of the Internet by computer users continues to increase monthly and the TRTF is developing a website to bring information about the Tsolum River and the restoration project to a larger audience. This site will include feature articles and background information on the work of the Tsolum River Task Force and Tsolum River Restoration Society. It will encourage an exchange of information between community groups and other professionals about stream restoration techniques being used in the Tsolum River watershed.

Links to associated websites will bring visitors in touch with information about training and volunteering opportunities offered by the TRTF, other community stewardship groups or government agencies. Volunteers have offered to maintain the page after its creation.

SECTION 4. APPENDIX A

Media Coverage

The Tsolum River Task Force

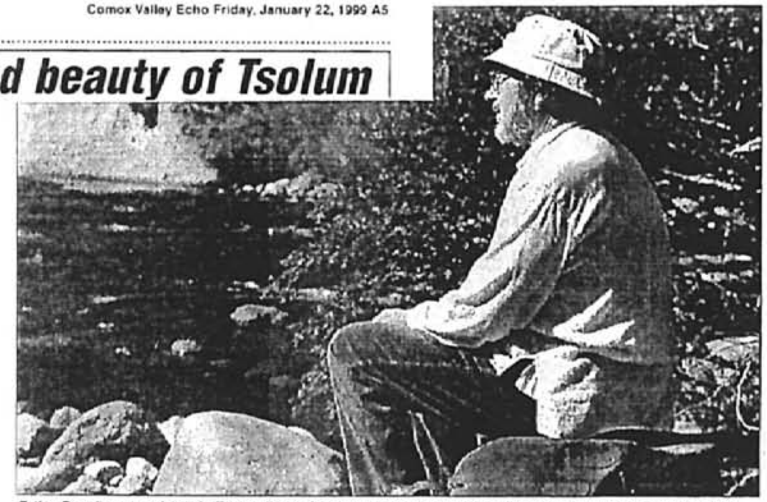


News

Comox Valley Echo Friday, January 22, 1999 A5

Photo contest highlighted beauty of Tsolum

This snowy scene, captured by Bill Peters and Shirley Ward, was voted the winner of the Tsolum River Task Force's Beauty of the Tsolum category



Father Brandt contemplates the Tsolum River - its glorious past, its death as a fish stream, and hopes for the future

Reclaiming a River

News

Comox Valley Echo Friday, March 20, 1998 A

'Amazing' salmon find in stream

❑ Tributary to troubled Tsolum yields steelhead

Environmental Youth Team program helps rivers - and workers

WILLOW WATTLE

❑ An old technique being used in effort to restore Tsolum watershed

Celebrate BC Rivers' Day at Tsolum Spirit Park

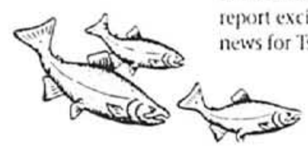
Celebrate the Spirit of the Tsolum on Rivers' Day this Sunday, September 28, 1 p.m. to 4 p.m., Tsolum Spirit Park.

B.C. Rivers Day is a special day reserved for us to reflect upon the greatness of our rivers, and to get out and celebrate their beauty. Join us at Tsolum Spirit Park on Tsolum River Road 1 p.m. to 4 p.m. Sunday, September 28. Walk the park trails, and see streamkeeper skills demonstrations, and learn more about how you can get involved in working on the challenges which face the Tsolum.

Rain or shine, rivers re beautiful in any weather, so don't wait, get out and enjoy it while you can. For more information call Cathy Campbell 337-2079.

200 pink salmon spotted

❑ Fish watchers report exciting news for Tsolum



Endangered status for Tsolum

MEDIA

Photos and Articles:
Comox Valley Echo

Appendix A - List of Media Coverage

Electronic Media

CBC Radio

No Fish No Future -- Vancouver Almanac Program, May 22, 1998

CBC TV

Acid Mine Drainage -- Evening News, October 1998.

CHEK TV

Environmental Youth Team willow wattling -- Evening News, June 1998.

Print Media

Comox Valley Echo

Celebrate BC Rivers' Day at Tsolum Spirit Park Friday, September 26, 1997.

Reclaiming a River Friday, September 26, 1997.

Endangered status for Tsolum
Community asked to join campaign for river's inclusion on list Friday, October 10, 1997.

Streamkeepers needed to work on Tsolum River Friday, November 7, 1997.

A River runs through it ... Rivers: the lifeblood of our Valley
Tuesday, February 10, 1998.

Tsolum River group anxious for funds - Fisheries Renewal process going slow
Tuesday, February 24, 1998.

'Amazing' salmon find in stream - Tributary to troubled Tsolum yields steelhead
Friday, March 20, 1998.

Willow Wattle - An old technique being used in effort to restore Tsolum watershed
Tuesday, March 31, 1998.

Salmon spotters needed on the Tsolum River Looking for Answers on the Missing Pinks
Tuesday, September 29, 1998

Photo contest highlighted beauty of Tsolum Friday, January 22, 1999.

Comox Valley Record

TRTF asks Fisheries program for acid-mine help
Friday, September 26, 1997.

Streamkeepers meet
Friday, November 7, 1997.

Chums released - New life for Tsolum
Friday, November 14, 1997.

Salmonids found - New Hope for Tsolum River
Wednesday, March 25, 1998.

Mt. Washington Ridgeline

Strategies for acid mine revealed following study
June 25, 1998.

The Voice

Solar power gets its moment in the sun
August 1998

Times Colonist

Sierra puts Heat on Old BC Mines with Appeal to NAFTA Watchdog
Saturday, July 4, 1998.

SECTION 4. APPENDIX B

List of Media Contacts

Appendix B - List of Media Contacts

Newspaper

Campbell River Mirror / North Island Weekender	#104- 250 Dogwood St., Campbell River, BC Mail: Box 459, Campbell River, BC, V9W 5C1 Office: (250) 287-9227 Fax: (250) 287-3238
Comox Valley Echo	407-D Fifth St., Courtenay, BC, V9N 1J7 Office: (250) 334-4722 Fax: (250) 334-3172 E-mail: echo@mars.ark.com
Comox Valley Record	765 McPhee Ave., Courtenay, BC Mail: Box 3729, Courtenay, BC, V9N 7P1 Office: (250) 338-5811 Fax: (250) 338-5568 Newsroom e-mail: cvrnews@island.net
Courier - Islander (Saturday!)	1040 Cedar St., Campbell River, BC Mail: Box 310, Campbell River, BC, V9W 5B5 Office: (250) 287-7464 Fax: (250) 287-8891 Newsroom e-mail: islander@cr.island.net
Mt. Washington Ridgeline	Paul Galinski Mail: Box 772, Campbell River, BC, V9W 6J3 Phone/Fax: (250) 923-0428
The Vancouver Sun / The Province	200 Granville St., Site. #1, Vancouver, BC, V6C 3N3 General Switchboard: (604) 605-2000 General Fax: (604) 605-2308
The Voice	719 6th St., Courtenay, BC, V9N 1M8 Office: (250) 334-3464 Fax: (250) 339-2210 E-mail: dbt@mars.ark.com
Times Colonist	2621 Douglas St., Victoria, BC Mail: Box 300, Victoria, BC, V8W 2N4 Office: (250) 380-5211 Fax: (250) 380-5353 E-mail: edit@victoriatimescolonist.com

Radio

CBC Radio Show	Karen Tankard or Lorna Haber - Vancouver Almanac E-mail: almanac@mindlink.bc.ca Mail: CBC Vancouver, Box 4600, Vancouver, BC, V6B 4A2 Switchboard: (604) 662-6000

CFCP 1440 AM	1625 McPhee Ave., Courtenay, BC, V9N 3A6 Office: (250) 334-2421 Fax: (250) 334-1977
CFWB 1490 AM	909 Ironwood Rd., Campbell River, BC, V9W 3E5 Office: (250) 287-7106 Fax: (250) 287-7170
CKLR 97.3 FM (*The Eagle*)	801-B 29th St., Courtenay, BC, V9N 7N3 Office: (250) 703-2200 Fax: (250) 703-9611

Television

CBC Television	Mail: CBC Vancouver, Box 4600, Vancouver, BC, V6B 4A2 Switchboard: (604) 662-6000 E-mail: talkback@vancouver.cbc.ca
CHEK Television	Jonathan Bartlett - North Island News Bureau (250) 337-0026 Victoria office: 1 888 389-6460

SECTION 4. APPENDIX C

Informational Pamphlet

Restoring the Tsolum River

Once productive . . . now endangered...

Forty years ago, 100,000 pink salmon returned each year to spawn in the Tsolum River.

In 1997, there were none.

Salmon and trout in the Tsolum River are now nearly extinct.

Most Endangered Rivers in B.C. **-** Tsolum/Puntledge Rivers topped the list in 1998

What happened to the . . . Tsolum River?

Human actions have led to low summer water flows, siltation of spawning beds, and eroding stream banks.

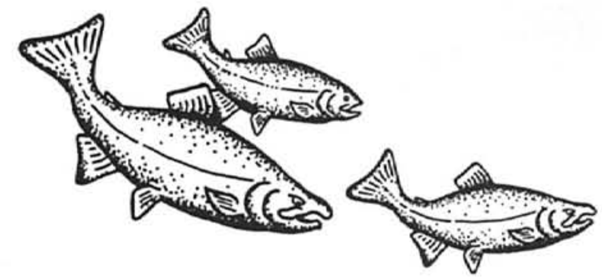
An abandoned mine on Mount Washington is leaching toxic levels of copper into the river.

For the past 30 years, we have had a poisoned, dying river running through the heart of our community.

More than. . . economic loss...

The Comox Valley loses $2 million a year in fisheries value due to the condition of the Tsolum River. Over the past 30 years, we have lost $60 million.

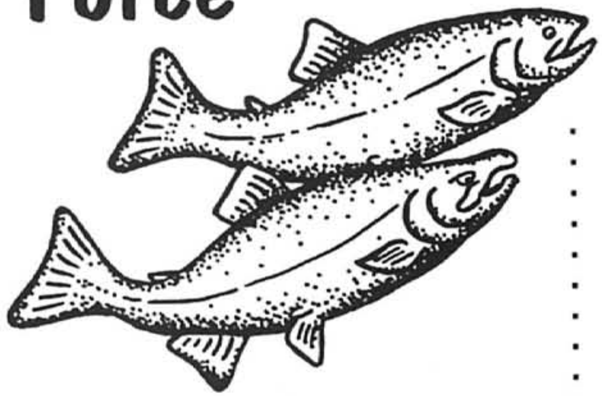
We are also losing an important part of our natural heritage.



The Tsloum . . . can be saved by...

- controlling toxic copper, which must be reduced by 95 percent for fish to survive
- maintaining flows above 15 cubic feet per second during times of low flow
- restoring fish habitat, and enhancing stocks of salmon and trout.

The Tsolum River Task Force



Working for change...

In the spring of 1997, the Tsolum River Task Force was formed. This action group is made up of local citizens, politicians, First Nations, and representatives from the federal and provincial governments and the mining and logging industries.

Our goal is to restore the Tsolum River to historic levels of health and productivity, and to bring salmon and trout back to the Tsolum River.

6 work groups...

- acid mine restoration
- habitat restoration
- water flows and storage
- water quality monitoring
- stock enhancement
- media and public information

Streamkeepers

are active in the Tsolum River watershed...

People volunteer as streamkeepers to take care of the streams running through their neighbourhoods.

Streamkeeper activities include fish habitat surveys; streamside fencing; water quality surveys; community awareness; stream channel improvement.

Do you want to help take care of your part of the Tsolum?

information...

The Tsolum River Task Force
337-5077 (phone and fax)
tsolum@mars.ark.com

Kathy Campbell, Project Coordinator
337-0005 (phone) 337-0045 (fax)
kathycam@mars.ark.com

Tsolum River Task Force initiatives are funded by...

- Department of Fisheries and Oceans
- Regional District of Comox-Strathcon
- Environment Canada
- Ministry of Environment, Lands and Parks
- Ministry of Energy and Mines
- BC Hydro Youth Options

and are sustained by the efforts and energy of its members.

SECTION 5

ACID MINE DRAINAGE

SECTION 5. ACID MINE DRAINAGE

Introduction

In the late 1950's, pink and coho salmon escapements in the Tsolum River started to decline. Despite enhancement efforts initiated by DFO at Headquarters Creek (a tributary of the Tsolum River) in 1968, fewer salmon returned to the river each year. By 1985, coho salmon runs numbering 7500 in 1957, were reduced to 800 while only 1000 pink salmon returned from runs that historically numbered over 75,000 (Deniseger et al 1995). Enhancement techniques that were successful in many other river systems were not working in the Tsolum River.

Federal and provincial investigations into the cause of the run declines began. Water samples revealed that copper concentrations in the mainstem of the Tsolum River were very high during the spring and fall. Researchers focused on the abandoned open-pit copper mine that operated on Mt. Washington from 1964 to 1967. Kangasniemi and Erickson (1986) stated that the failure of the Headquarters Creek salmon enhancement efforts resulted from unacceptably high dissolved copper concentrations in the Tsolum River. The high copper concentrations came from dissolved copper leaching from the old mine site, located on the east slope of Mt. Washington (Appendix A).

The now defunct Mt. Washington Copper Co. Ltd. and Cumberland Mining Co. Ltd. jointly operated two main pits at an elevation of approximately 1300 metres (Sierra Legal Defence Fund, 1998). Drainage from the south pit flows into the McKay Creek watershed. The north pit drains into the Pyrrhotite Creek watershed. The mined ore, chalcopyrite, was trucked 5 km south and 400 m lower to a crushing and concentrating mill on Murex Creek. The mill tailings were transferred via pipeline to a pond draining primarily into Wolf Lake. Of these four potential acid generating sites, to date only the north pit has been identified as a serious problem, while the other three sites are minor contributors of copper.

The term 'acid generating' refers to the production of sulphuric acid, which lowers the pH of surface and ground water. Copper and iron are found as sulphides in chalcopyrite. When this ore is exposed to oxygen rich water, the sulphide oxidises to sulphate, the iron oxidises to iron oxide and/or hydroxide, and sulphuric acid is released. Copper and other metals (aluminium, arsenic, iron, and zinc) dissolve in water at the reduced pH and leach into the Tsolum River headwaters. Drainage of this type from mine sites is called 'acid mine drainage' or AMD. This process, when naturally occurring or from non-mine disturbances, is known as 'acid rock drainage' or ARD.

The Effect of Copper on Salmon

There is little doubt that copper concentrations found in the Tsolum River cause damage to salmon. Salmonid studies reported by Deniseger et al (1995) indicate soluble copper concentrations in the Tsolum River must be reduced to below 7 micrograms/L to allow recovery of the salmon fishery. To achieve this result, approximately 95% of the mine discharge would require elimination or treatment when dilution by clean water in the lower watershed is lowest flow levels. Peak toxicity occurs during the spring freshet, when there is rapidly melting snow and little rainfall at lower elevations to dilute the copper dissolved in the runoff water. A secondary peak of toxicity exists during autumn, as coho salmon are entering the river. Dissolved copper levels are thought to cause adult salmon to avoid spawning in the Tsolum River mainstem. Salmon smolts migrating to the estuary are weakened or killed as high copper levels interfere with their ability to adapt to salt water. The effects of copper contained in sediments upon spawning salmon or incubating eggs are not well known. Despite evidence of mechanical transport of copper to 18 km from the minesite, the sediment-bound copper in the lower watershed appears to be highly stable such that the copper-rich sediments are unlikely to become a secondary source of dissolved copper (Deniseger and Kwong, 1996)

Evidence indicates that copper damages salmon by interfering with liver function, allowing other more toxic materials such as cadmium to cause further damage. In-stream bioassay studies have shown that salmon held in the Tsolum River die when dissolved copper concentrations are elevated by snowmelt or heavy rain at the minesite (Deniseger et al 1995). These results can be duplicated in the laboratory, where an LD-

50 indicating the concentration of copper lethal to 50% of a sample of salmon is calculated.

Remediation Work from 1987 to 1992

A 1987 report by Steffen Robertson and Kirsten (BC) Inc. (SRK) documented a number of measures to eliminate or reduce copper concentrations in the Tsolum River. This report recommended consolidation of the acid producing mine waste rock, into a single pile on the northeast side of the north pit. They further recommended covering the pile with 1 to 1.5 metres of high silt glacial till. An additional impermeable membrane could be sandwiched within the till cover. As well, SRK recommended site monitoring for three years, to assess the effectiveness of the till cover. The report suggested covering the pit and perhaps the waste dump, if the pit also proved to be acid generating.

During 1988 and 1989, the north pit waste rock was consolidated and covered with one metre of the glacial till. It later became apparent that the north pit waste rock was not the only source of *AMD*. Evidently, there is porosity in the bedrock and/or fractures in the bedrock. A combination of these geological features and movement of localized water table levels has contributed to the acid leaching in the north pit proper.

Various measures were implemented during 1989 to 1992 (Galbraith, 1993). These measures included diversion of ground and surface water, covering suspected 'hot' spots with concrete and asphalt impregnated textiles, and in situ neutralization with lime ($CaCO_3$ and $Ca(OH)_2$). Most of these procedures involved movement of potentially acid generating material around the site.

Site monitoring also continued. Unfortunately, as a result of the additional measures, the effectiveness of the till cover is unclear. The provincial government spent approximately $1.5 million dollars in attempts to control AMD by capping the mine waste and ditching the surface water at the mine site. Despite these efforts, high copper concentrations continue to limit fish production in the Tsolum River (Brandt 1997).

Remediation Options

Source control and water treatments are two basic options for reducing copper concentrations to acceptable levels.

Source control

Source control involves halting the acid generating reaction, or preventing the reaction products from entering fish bearing streams. Oxidative leaching can be slowed or stopped by preventing oxygen from contacting the copper ore. One method employs underwater submersion of the ore, tailings or waste. Oxygen, having a maximum solubility in water of 15 mg/L, is removed by biological action in deep water. Opportunities for convective re-oxygenation are limited. This method, used successfully at the Island Copper Mine near Port Hardy, is not suitable for the Mt. Washington site because of the elevation and the topography of the minesite.

Source control can also be achieved by inhibiting the entry of water to the mineralized zones, thereby limiting the extent of leaching and the mobility of leached products. The Mt. Washington mine site receives approximately 1.6 m or precipitation annually, 0.7 meters falling as snow, and 0.7 m as rainfall (Levelton 1998). Diverting the water entering the north pit by improving the diversion ditch, located uphill from the north pit, may reduce the contact between groundwater and the AMD generating material. The efficiency of the present diversion ditch could be improved by deepening the ditch and lining the bottom and sides of the ditch with an impermeable material. A multi-layer cover could then be placed over the entire north pit (including the pit floor and the waste rock material).

The design suggested by Haug 1998 includes a water impermeable layer of fine-grained material such as bentonite or fly ash (a by-product of pulp and paper manufacturing). The purpose of this layer is to exclude water and oxygen from coming in contact with the AMD. A second layer of soil will be placed on top of the impermeable layer and vegetation will be planted on top of the soil to protect the soil from erosion. This would reduce peak flows at critical times and decrease the copper leaching from the site.

Water treatment

Treatment of contaminated water involves removal of the copper cation. Anions, such as sulphide, carbonate or hydroxide, will combine with the cation to form insoluble salts. These insoluble salts can be removed from water by precipitation or filtration methods. Wetlands have the ability to naturally filter metals from water and neutralize AMD. Copper is initially removed from the water by the wetland vegetation. The vegetation dies, sinks to the bottom of the wetland and decays. The decomposition process removes oxygen, whereby sulphate is reduced to sulphide, which immobilizes the copper (Golder 1997). This natural phenomenon is limited to large wetlands experiencing low flows, relatively mild temperatures and acidity. It is not known if there is sufficient wetland area in the upper Tsolum River watershed to handle the very high peak copper loads which occur in the spring and fall.

Bioreactors utilizing a "bisulphide process" remove copper and zinc from leachate by using sulphate-reducing bacteria to reduce sulphate to sulphide. An optimum environment for the bacteria is provided when the pH within the reactor is >5 and the temperature is maintained at 30°C – 40°C Water channelled through the reactors brings metals in contact with the bacteria. . The bacteria are fed with hot gasses containing CO_2. The bacteria consume the organic material, producing carbonates as a by-product of the reaction. As the carbonates raise the pH, metals are precipitated out of solution as stable metal sulphides (Levelton 1998). Further research is needed to determine if bioreactors offer a cost effective solution to reducing the copper loadings draining from the Mt. Washington mine.

Full-scale industrial treatment facilities which employing rigorously controlled neutralization systems are available, but are expensive to construct and operate. Long term operational funding would be required, and the sludge produced as a by-product of this process may endanger aquatic plants and animals downstream of the minesite. The heavy snow pack (over 10 meters in 1999) and lack of hydro power at the site may make it necessary for any treatment plant to be constructed at a lower elevation with the acid drainage being carried by pipeline down to the treatment plant (Golder 1997b).

Combination treatment options

Combined treatment systems involves in situ neutralization and wetland enhancement, with or without neutralization.

Control of upstream surface water flow should be added to source control and treatment options. Under certain conditions (e.g. low flow rates downstream), it may be advantageous to capture and store contaminated water for release when flow rates increase downstream. Smaller treatment plants may also be feasible if peak flows were stored and released more slowly, in effect, buffering the flow rates.

Generally, source control solutions are felt to be 'permanent'. They will, however, require time to be effective and will probably be expensive, $4 to $10 million. Treatment solutions, meanwhile, require the ongoing expenses of materials, energy, sludge disposal. An evaluation of options and costs is being considered by the Acid Mine Drainage Work Group in the preparation of the AMD Action Plan.

TRTF Action Plan

Work on the mine problem since 1992 has, for the most part, been limited to monitoring strategic sites in the watershed and evaluating the options. Two local delegations lobbied provincial cabinet ministers for action on the mine. The first delegation met in 1995 with then Mines Minister, the Honourable Anne Edwards. In 1997, a second meeting was held with Mines Minister, the Honourable Dan Miller and Environment Minister, the Honourable Cathy McGregor. The Ministers suggested that funds would be forthcoming only after an action plan could assure the government that further work would be successful in lowering copper levels in the river.

Since March 1997, the Tsolum River Task Force's AMD work group has been seeking to provide solid answers for the Ministers. The work group began by examining two treatment options. One option involves the feasibility of piping the concentrated mine run off to a site more accessible year round (Golder Associates, 1997b). The other involves the feasibility of passive/active wetland options (Golder Associates, 1997a).

The draft Action Plan produced by the work group outlines their present position with regard to minesite remediation (see Appendix B). The Action Plan will form the basis of the TRTF remediation proposal. This draft plan is a work in progress, intended to provoke discussion within the work group. It is subject to revision and the author of the site welcomes ideas that would improve the plan (Ferguson 1998).

This draft document can be viewed on the Internet website at

http://www.netcolony.com/members/wildwolf/actionplan/APtoc.htm.

A list of references relating to AMD from the Mount Washington mine can be found in Appendix C.

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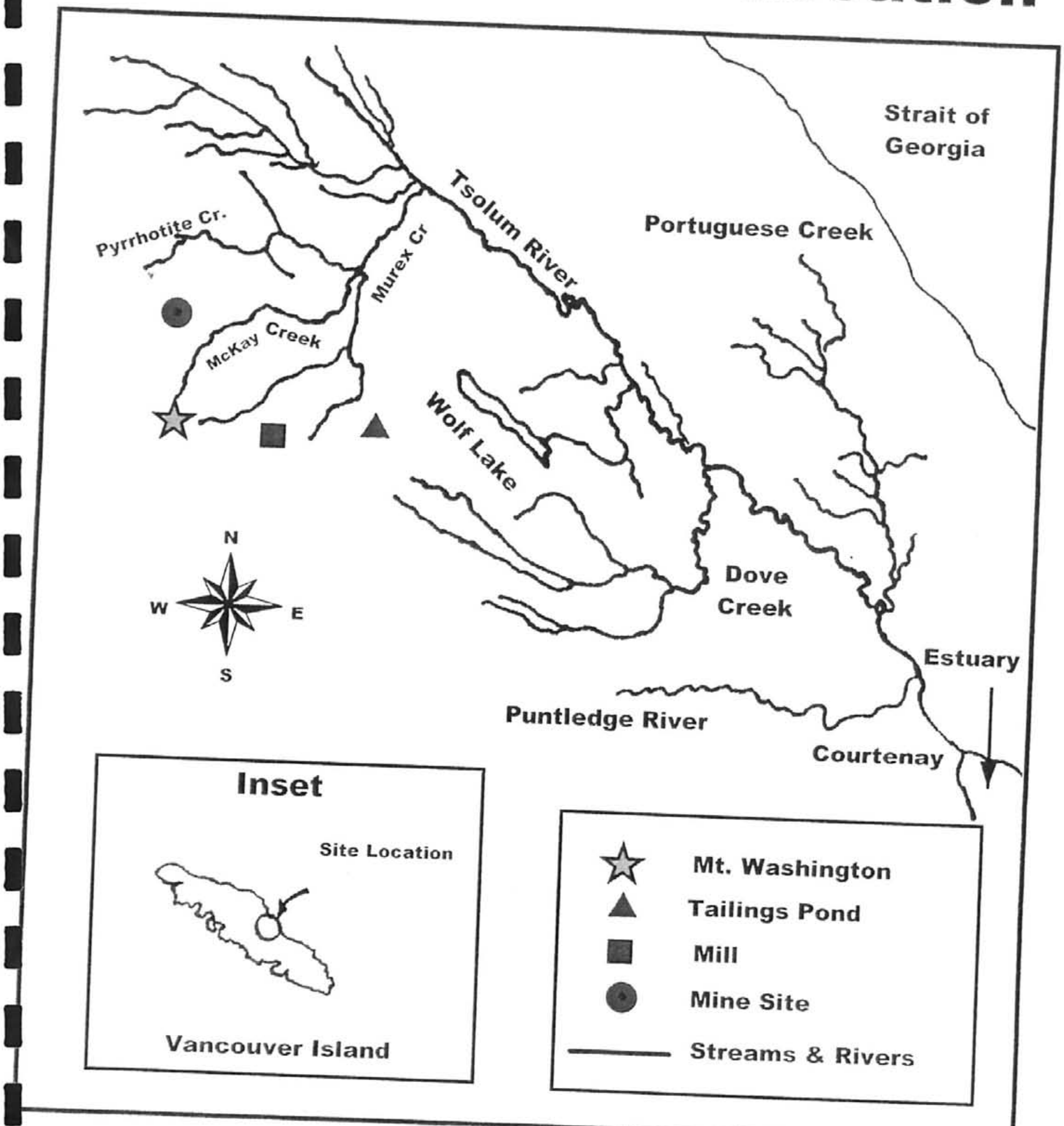
SECTION 5. APPENDIX A

Map of Mine Site

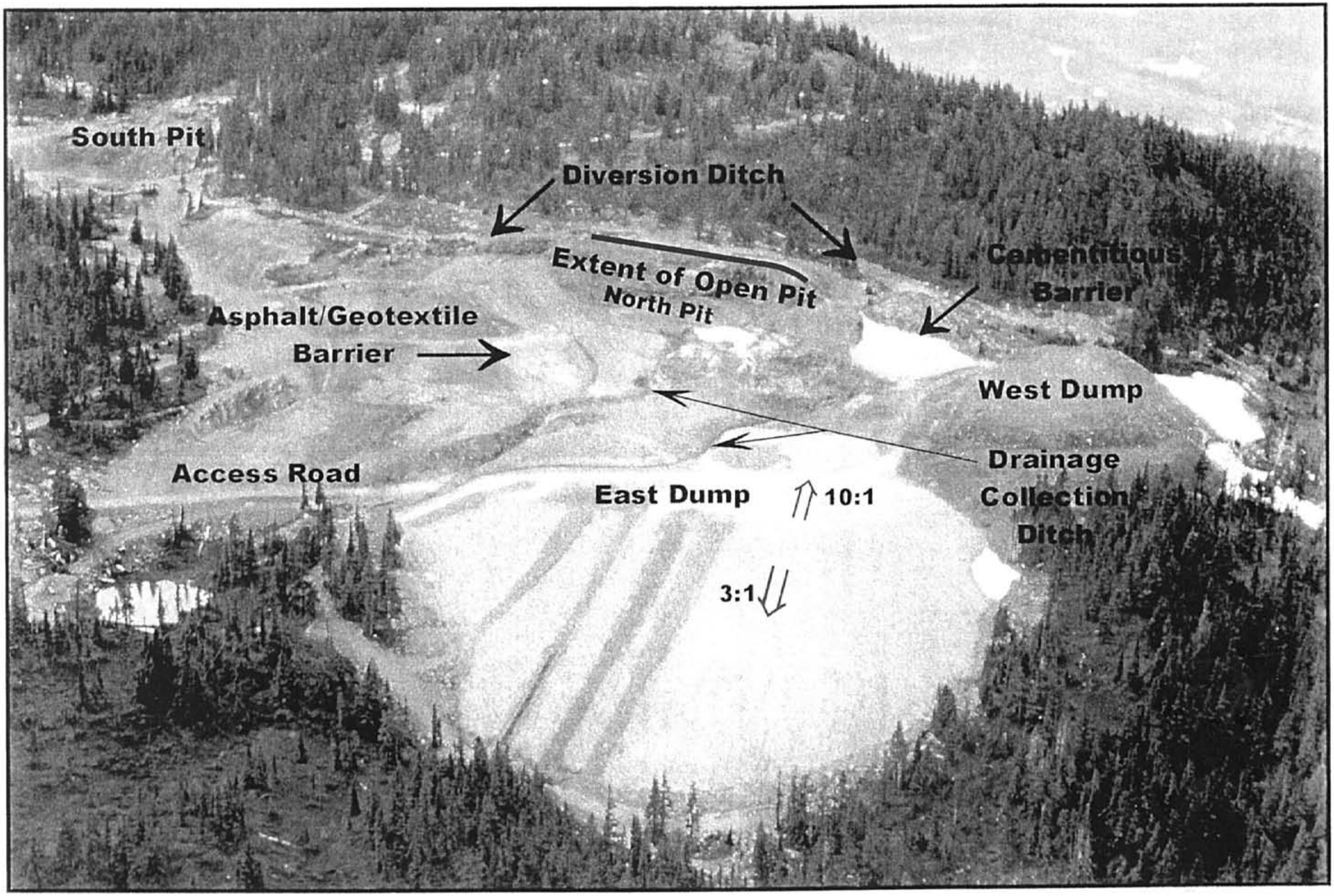
Tsolum River Watershed Showing Mine Site Location



Created by Joanne Ellefson, March 12, 1999, for the Tsolum River Task Force.

Scale unknown

Aerial Photograph of Mount Washington Site



SECTION 5. APPENDIX B

Outline of Draft Action Plan

Appendix B - Outline of draft Action Plan

For remediation of Acid Mine Drainage at the Mt. Washington Minesite

Action	When	Comment	Approximate Max. Cost
1. Finish Action Plan	February 1999	AMD work group	
2. Divert Uphill Water	Summer 1999		$0.5M - $1M
3. Seal off Pit Floor	Summer 1999	If necessary	$0M - $2M
4. Cover North Pit and Replant	Fall 1999		$2M - $3M
5. Enhance Wetlands	2003		$0M - $1M
6. Treatment Plant	2003	Only if necessary	$0 - $2M
7. Restore Salmon Habitat	1997 onward		$0.5 - $2M
8. Monitor	on-going		$1M
		TOTAL COSTS	$4M - $12M

SECTION 5. APPENDIX C

Bibliography from AMD Draft

Action Plan website.

Appendix C - Bibliography from AMD draft Action Plan website.

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SECTION 6

WATER MONITORING

SECTION 6. WATER MONITORING

Water monitoring programs undertaken by the TRTF addressed seasonal high water temperatures, elevated copper concentrations and high silt loads. These three factors were identified as the main limitations to salmon productivity in the Tsolum River.

Temperature Monitoring

In the summer of 1997 and 1998, water temperature data was collected from several sites in the Tsolum River watershed. The first objective of the study compared water temperature regimes in the Quinsam and Glendale Rivers with Tsolum River temperatures during pink salmon migration occurring in August and September.

A second objective assessed the influence of stream flow supplements on stream temperatures. This analysis was conducted in collaboration with the ongoing water flows and storage study. The results of this analysis are presented in the 1997-1998 Tsolum River stream flows and storage study summary report.

A third study objective evaluated and compared the temperature regime recorded at different locations in the Tsolum River watershed and developed a thermal profile for index sites at different locations in the watershed.

The final objective evaluated differences in stream temperatures for the contrasting years of 1997 - a very wet year, and 1998 - a very dry year.

The relationship between temperature and rate of development in pink salmon eggs incubated in the Tsolum River was previously reported by Heard (1991). This instream temperature study is complemented by an *in vitro* study of thermal effects on pink salmon egg survival underway at the Pacific Biological Station (*PBS*) in Nanaimo. The study will determine how high temperatures affect pink salmon egg survival.

Present pink salmon egg transplant programs utilize stocks from the Quinsam River near Campbell River. This river has cooler water due to the influence of groundwater entering the river from Cold Creek. Utilizing stocks from warmer systems such as the Glendale River in Knight Inlet may lead to greater pink salmon survival in the Tsolum River watershed. In 1971, pink salmon eggs were successfully transplanted from the Kakweiken River, Knight Inlet, to the Tsolum River (Bams, 1976).

Methodology

In 1997, temperature sites were monitored on the mainstem at the lower Tsolum River (site 1), the mid-Tsolum River (site 4) and at Headquarters Creek at the hatchery (site 5). In 1998, four additional sites were added to the temperature monitoring study in Portuguese Creek (site 2), Dove Creek (site 3). Appendix A shows their locations.

Two models of *Onset Computer Corporation* (*OCC*) miniature temperature data loggers: *StowAway*® *TidbiT*® and *Optic StowAway*® were used in the study (Appendix B). These single channel, waterproof, battery powered data loggers recorded temperatures every 15 minutes. The probes were protected by housings anchored to the shore. A companion device, the *Optic Shuttle*®, is used to download the digital data from the data loggers for export to a personal computer. *OCC BoxCar Pro* software is used to launch the data loggers and view and export temperature data files to other computer software.

The temperature data loggers were periodically calibrated (April 1996, May 1998 and December 1998). A constant temperature bath was used for calibrating the data loggers with testing occurring at four to five water bath temperatures ranging from 1.3 °C to 26.8 °C. At the time of writing of this report, calibrations for all units were not yet completed. Data reported here is therefore preliminary with calibrated data to be reported in a future report.

Figures C.1 and C.2 (Appendix C) relay the recording intervals for the seven different sites in the watershed, for 1997 and 1998, respectively. The data loggers located in Headquarters Creek (site 5) and at the Wolf Lake (site 6) outlet were operated year-round.

Data downloading occurred weekly at sites 1, 2, 3, 4 and 5, while data was downloaded biweekly at sites 6 (Wolf Lake) and 7 (upper Tsolum at the Gun barrel). Access to these more distant sites required coordination with TimberWest work crews.

Site Descriptions

Site 1. Lower Tsolum River

Mixed deciduous and coniferous riparian vegetation cover prevailed at the lower Tsolum River site. The data logger was attached to an old fish-counting fence in shallow water (12 to 15 cm summer depth) near the left bank, as viewed looking downstream.

Site 2. Portuguese Creek

The Portuguese Creek temperature logger was placed in a pool, of 1.2m maximum summer depth. With minimal summer flow, this pool became stagnant. The probe was attached to an overhanging tree root on the right bank, approximately 30 cm below the summer water surface level. Cattle fields border the stream on either side. Grass is the dominant riparian vegetation, interspersed with a few shrubs.

Site 3. Dove Creek

The Dove Creek temperature data logger site was located 100 m downstream of the Dove Creek Road crossing. This site is 25% covered by overhanging vegetation with mixed grass, deciduous shrubs and coniferous trees, with more shrubs present on the right bank. The data logger was attached to a tree root below an undercut bank in a pool (60 cm summer depth) near the right bank, suspended approximately 30 cm below the summer water surface level.

Site 4. Middle Tsolum River (Yew Tree)

The middle Tsolum River site, (also known as the Yew Tree) was located upstream of the confluence of the Tsolum River with Headquarters Creek. Both left and right banks of the river are densely vegetated and shrubs overhang the shallow pool where the logger was located. The logger was launched at a depth of about 18 cm in a pool with a summer water depth of 60 to 90 cm.

Site 5. Headquarters Creek

The average July to October 1998 stream depth at the Headquarters Creek temperature data logger site is 30 cm. This probe rests on a flat slab of hatchery raceway concrete on the left bank side. The right bank of the creek is covered with dense mixed riparian vegetation that provides some overhanging cover. There is no immediate riparian cover at the left bank.

Site 6. Outflow of Wolf Lake

As illustrated in Fig. B2 (Appendix B), the Wolf Lake temperature logger was located above the Wolf Lake dam on the right hand side of the outlet. This is where water flow from Wolf Lake to Headquarters Creek is measured. Vegetation is sparse and bedrock is the dominant stream substrate. The logger was kept 1 meter below the water surface.

Site 7. Upper Tsolum River (Gun barrel)

The most upstream Tsolum River data logger site was located at the Duncan Bay Main logging road crossing. Here the vertical bedrock at the right bank is 1.5 m high. Overhanging trees on both banks shade the large pool in which the logger was placed at a depth of 1.2 to 1.5 m.

Weather Station

An additional data logger was housed inside a weather station to record air temperature at Headquarters Creek Hatchery.

Results

1997 Temperature Data

Temperature data were collected at three sites in 1997: Headquarters Creek (March 7 to April 4, May 14 to November 18), mid-Tsolum River (August 22 to October 22), and lower Tsolum River (August 1 to October 20). Appendix C contains the graphed results.

Appendix C, Fig. C1 illustrates the 1997 mean daily temperatures for the three sites. Fig. C3 includes the daily mean, maximum and minimum temperatures for mid July to October. During the first half of August, site 1 (lower Tsolum R.) was warmer than site 5 (Headquarters Creek). In general, from August 22 to October 20, 1997, the daily mean temperatures are warmest at the site 5, followed by site 1 and site 4 (middle Tsolum R.). All three sites showed a similar pattern of temperature variation during the monitoring period. (Table C.1)

Data displayed in Appendix C, Fig. C3, shows that the differences in daily stream temperatures recorded in 1997.

1998 Temperature Data

Table C2 (Appendix C) summarizes maximum, minimum, and mean stream site temperatures for 1998 monthly records. The 1998 daily stream temperature records are graphically presented in Appendix C, Fig. C2, and C4 to C11.

The largest recorded daily temperature variations occurred over the summer period. Lowest temperature fluctuations were observed at site 6 (Wolf Lake) due to the moderating effect of the large volume of lake water. In order of the ascending range of daily temperature extremes the sites are: site 7 (upper Tsolum), site 1 (lower Tsolum), site 3 (Dove Creek), site 2 (Portuguese Creek), site 5 (Headquarters Creek) and site 4, (middle Tsolum). This variation is believed to be due to riparian vegetation differences and differences in probe location at the sites, however more temperature monitoring in needed to determine if these are consistent seasonal differences.

Appendix C, Fig. C2 illustrates average daily temperatures from May to August 1998. Over this period, site 7 (Upper Tsolum River (Gun barrel) continuously exhibited the lowest water temperatures, and site 6 (Wolf Lake) continuously exhibited the highest water temperatures. Table C2 summarizes the 1998 calculated mean monthly values for all sites.

As shown in Appendix C, Fig. C2, site 3 (Dove Creek), site 2 (Portuguese Creek) and site 7 (upper Tsolum R.) temperature logging began in August, 1998. Sites 3 and 7 continuously exhibited the lowest stream temperatures of all the sites. Temperatures recorded at site 7 are within the range recommended for rearing of coho salmon.

Figure C4 presents the subset of the average daily stream temperature data for the months of August and September. This is the time when pink salmon begin their migration into the Tsolum River. All sites show similar trends in temperature increases and decreases.

Comparison of 1997 and 1998 Stream Temperatures

Appendix C, Fig. C7, C8, and C11, compare the mean, maximum and minimum 1997 and 1998 daily summer stream temperatures at site 1 (lower Tsolum) site 4 (middle Tsolum) and site 5 (Headquarters Creek). Weather patterns during the summers of 1997 and 1998 were quite different, with 1997 being very wet, and 1998 being very dry. In 1998, temperatures are much higher than those reported in 1997. Temperatures remained above 20°C for several weeks during July and August 1998, and approached temperatures near lethal for salmonids (Sigma, 1983). Precipitation data for these two consecutive summers is presented in the Tsolum River stream Flows and Water storage report (Section 10).

Appendix C, Fig. C7 compares 1997 and 1998 summer (June 21 - September 22) stream temperatures for site 5 (Headquarters Creek). The warmest daily mean and maximum temperatures were recorded in 1998. In general, the monthly mean temperatures are greater during the summer of 1998.

Appendix C, Fig. C8 graphically presents 1997 and 1998 recorded mean, maximum and minimum daily stream temperature data for site 4 (middle Tsolum R.). For the period August 22 to September 7, 1998 mean daily temperatures are consistently warmer than in 1997. The 1998 daily minimum temperatures were greater than the 1997 daily maximums. Temperatures recorded during August at site 1 in the lower Tsolum River, are shown in Appendix C, Fig. C1.

Recommendations

1. Analysis of the 1997 and 1998 temperature data is ongoing. Data represented in this report is preliminary. In the final report, corrections must be applied to reflect correlated values.

2. More thorough temperature monitoring throughout the watershed is needed. Additional monitoring sites could include pools frequented by returning adults during the spawning season. In 1999 temperature data should be closely related to movements and spawning of adult pink salmon in the Tsolum River. This will require additional *StowAway® TidbiT®* temperature data loggers to key adult holding pools at typical holding depths.

3. It is recommended that a year-round accessible temperature index site be established.

4. Monitored stream temperatures indicate that temperatures in the upper watershed at site 7 (gun barrel) are suitable for year round coho rearing.

Copper Sampling

The abandoned open-pit copper mine near the summit of Mt. Washington is a source of acid mine drainage (AMD). The acid drainage flows into Pyrrhotite and McKay Creeks, which in turn flow into Murex Creek and the upper Tsolum River. Elevated concentrations of a number of metals are present in the AMD, but copper is the most toxic to fish.

Excluding copper, dilution and attenuation downstream of the mine reduces the concentrations of other metals to levels that normally meet the water quality criteria. Copper concentrations, however, not only exceed the water quality criteria and objectives, but are toxic to fish in the Tsolum River. It has been estimated that spring copper loadings must be reduced by 95% in order to meet water quality objectives for the protection of aquatic life in the Tsolum River. (Deniseger et al., 1995).

The majority of the acid mine drainage is carried by Pyrrhotite Creek, which enters Murex Creek, a principal tributary to the Tsolum River. Peak flows in the Tsolum River occur during the rainy winter months, while peak flows in Pyrrhotite Creek occur during spring snowmelt. During spring, Pyrrhotite Creek contributes significantly to the overall flow of the Tsolum River. The highest copper levels in the Tsolum River are found in samples taken from the Pyrrhotite Creek Branch 126 sample site during a four to six week period in May and June. This period corresponds to the timing of the outmigration of coho smolts. Short term pulses of copper associated with early fall storm events are also above recommended levels for maintaining fish health and may deter adult salmon from utilizing spawning grounds in the Tsolum River mainstem.

The purpose of the copper sampling program is to monitor water quality during critical periods. It will also provide a reference to assess the impact of measures taken to improve the acid mine drainage problem.

Methodology

In 1985, Pyrrhotite Creek at Branch 126 (P126) was established as a station to monitor the hydrology and water quality leaving the mine site. It quickly became apparent that the critical spring snowmelt (April to June) was responsible for approximately half the annual runoff and up to two-thirds of the annual copper loadings leaving the mine site. The monitoring site became a key indicator point to assess the success of the mine reclamation activity that was ongoing from 1987 to 1992.

Calculation of copper loadings involves collecting a large number of water quality samples in conjunction with a continuously operating hydrometric station. The Ministry of Environment, Lands, and Parks (MELP) operated the hydrometric station and maintained an intensive water sampling program from May 1986 through June 1990. Water level data were collected at a 90 degree, sharp-crested, v-notch weir using a recorder system (Deniseger et al., 1995). Daily discharge was estimated using the theoretical weir formula. The hydrometric station was discontinued during the summer of 1990 due to a funding shortage and a general consensus that the reclamation work was unsuccessful. Individual flow readings did continue using a staff gauge.

Environment Canada in cooperation with MELP and the TRTF, funded the re-establishment of the hydrometric station and monitoring program in 1997 so spring copper loadings for 1998 are available for comparison to earlier data.

Results

Spring copper loadings were remarkably consistent, ranging from 1512 to 1791 kg of copper, from 1986 through 1989. This is a reflection of both relatively consistent copper concentrations and a consistently high snowpack. Total water flows during spring freshet ranged from 295 to 330 dam^3 (1 dam^3= 1000 m^3 cubic meters), indicating similar snow melt and snowpack conditions from 1986 through 1989. The average monthly copper concentration during spring ranged from 3.6 to 7.55 mg/L from 1986 to 1989. In 1990, a low snowpack resulted in a relatively low discharge of 195 dam^3 and consequently lower spring loadings of 890 kg of copper. This was not indicative of improvements in the water quality leaving the site, but simply that less runoff was available to flush out the acid mine drainage.

The spring snowmelt in 1998 was comparable to those in the 1986 to 1989 period, as total flow was measured at 311 dam^3. Average monthly copper concentrations in 1998 were 3.5 mg/L in

April, 2.79 mg/L in May and 1.41 mg/L in June. These measurements are considerably lower than those of the late 1980's (Appendix D, Table D1). The spring copper loading for 1998 was calculated to be 701.2 kg of copper. This represents a significant decrease of 54 to 61% compared to 1986 to 1989 (Appendix D, Fig.D1). While the decrease in copper loadings observed in 1998 appear to be significant, the data must be viewed with caution.

Recommendations

1. While the decreased copper loadings observed in 1998 suggest that water quality has improved, levels of copper are still well above recommended levels for the fish health. It is essential to continue monitoring in 1999 to confirm whether the 1998 data represents a trend in lower copper loadings or a one-year anomaly. Further investigation at the mine site is needed to determine the causes of the observed decreased loadings. In addition to dissolved copper, Deniseger (1995) recommended monitoring for free copper, humic acid, and dissolved organic carbon to further develop the copper-organic complexing capacity relationship that was used to derive water quality objectives.

2. A quality assurance program including field blanks, field replicates, and reference samples is also recommended to ensure that high quality data are collected.

Bioassay Program

In March 1999, the TRTF, in cooperation with Puntledge Hatchery and the Pacific Biological Station, conducted a parallel series of experiments to monitor the lethal and sublethal effects of copper pollution on migrating pink salmon. In the field portion of the experiment, 96-hour bioassays were conducted with pink salmon held in aluminum boxes anchored instream at three different locations.

These sites were located at the Lower Tsolum River below Rees Bridge (BA site 1); Tsolum River mainstem at McEachren Bridge; downstream from the confluence of Headquarters Creek) (BA site 2); in Headquarters Creek at the Hatchery (BA site 3, control).

A laboratory study was also conducted using Tsolum River water and measured copper concentrations to test the sub-lethal effects of copper exposure on pink fry. Fish and water from Headquarters Creek and the Tsolum River were transported to the Pacific Biological Station in Nanaimo. Fry were first exposed to varying copper concentrations, then tested for saltwater tolerance using standard saltwater challenge methods. Copper concentrations were analyzed from both experiments by water samples transported to Northwest Labs in Vancouver. Results from these studies are available, but have not yet been collated.

Siltwatch

In response to community concern about increased stream siltation in the forested upper slope region of the watershed, a community based volunteer Siltwatch program was initiated by the TRTF. This program was designed to identify sources of erosion in Headquarters and Dove Creeks, and to identify the areas where restoration projects could be undertaken to reduce the silt load entering these streams.

The problem of increased siltation was most pronounced in the Headquarters Creek system. In 1995, pink salmon incubated at the Headquarters Creek hatchery emerged with 95% survival rate. In 1998, 40% of the one million pink salmon eggs incubated at this site died when a silt plume flowed into the hatchery from upper Headquarters creek, covering the eggs just prior to hatch. Changes in the watershed upstream of the hatchery due to logging and highway construction were cited as the reasons for the increased silt loadings.

The goal of the program is to inform landowners about streambank erosion from their property. The Task Force can then assist landowners with projects that will reduce erosion and instream siltation.

Methodology

Ten siltwatch sites were identified on orthophotos provided by DFO. The sites were chosen according to their accessibility, location of tributaries & the presence of unpaved roads. The outflow of Wolf Lake was chosen as a control site, indicative of water quality conditions at the source of Headquarters Creek. Timing was coordinated and pairs of volunteers were recruited and assigned to monitor the sites. After prolonged heavy rainfalls, volunteers collected water samples mid-stream, on the upstream side of bridges and mid-stream at sites where no bridges were located. When necessary, additional samples were taken after the initial survey to characterize the duration of the event.

A suspended solid sampling device was constructed to collect water throughout the entire water column. The sampler consisted of approximately 1.5 meters of 2" PVC pipe chamber with a flat flapper-valve on one end and cap and rope on the other.

The sample water was decanted into one liter plastic bottles and processed using standard methods of the Association of Official Analytical Chemists (AOAC) with a detection limit <1.0 ppm.

Results

The Siltwatch program is ongoing with initial results expected to be available in May 1999.

Recommendations for Siltwatch Program

Residents who live along the Tsolum River do constant informal monitoring. These volunteers should be trained to recognize siltation levels that are deleterious to fish health so they can alert DFO to problems. Fish culturists can then respond to clear the eggs of silt before major incubation losses occur.

The Task Force should work with the volunteers and landowners to isolate and restore areas that are contributing to silt load in the system. Projects should be monitored after completion to assure that they have been successful in improving water quality.

A sediment wedge should be tested against grab samples to see if this method offers a more cost-effective method of checking silt levels on an ongoing basis.

A serial water sampling device should be installed at the inflow of the Headquarters Creek keeper channels to protect future incubation programs.

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SECTION 6, APPENDIX A

Map of Tsolum River

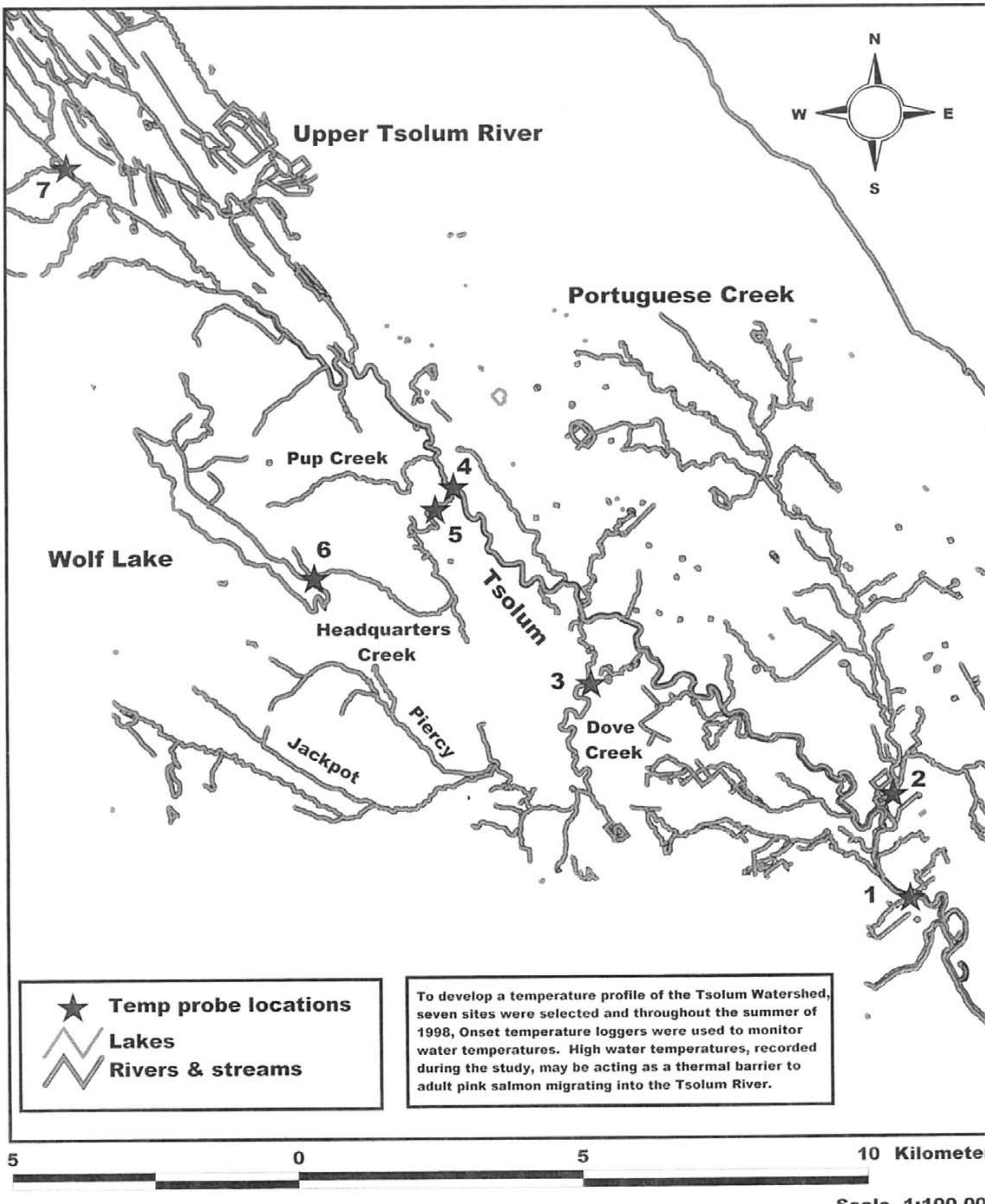
and

Table of Temperature probe locations

Tsolum River Temperature Probe Locations

Site Number	Name	Distance from Confleunce of Puntledge River (km)	UTM North	UTM East
1	Lower Tsolum	1.2	5507626	355403
2	Portuguese Creek	3.5	5509476	355114
3	Dove Creek	15.0	5511476	349829
4	Middle Tsolum (@ Yew Tree)	18.0	5514971	347420
5	Headquarters Creek	17.6	5514577	347100
6	Wolf Lake Outflow	23.0	5513356	344980
7	Upper Tsolum at Gunbarrel	28.5	5520672	340665

Tsolum River Temperature Probe Locations



Created by Joanne Ellefson, March 2, 1999, for the Tsolum River Task Force.

SECTION 6, APPENDIX B

Photos of temperature loggers and

monitoring sites.

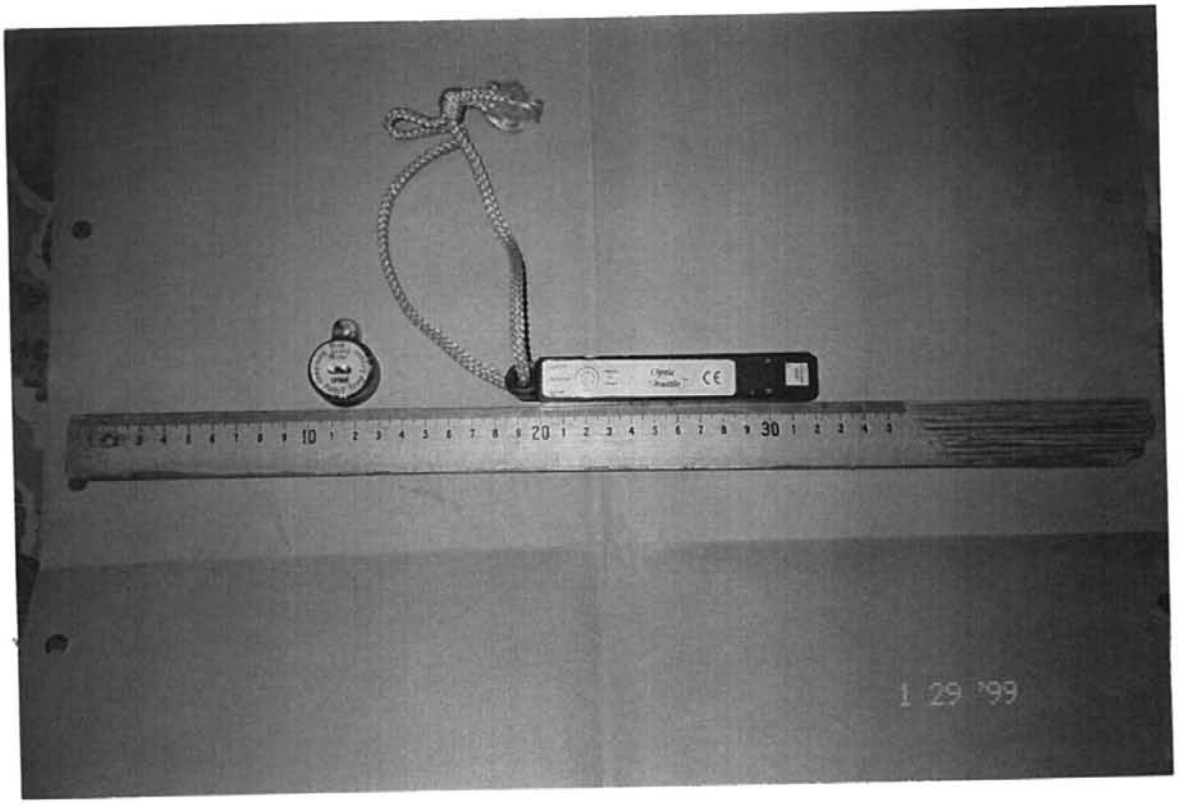


Figure B.1 Stream Temperature Data loggers: StowAway Tidbit® (left) and Optic Stowaway® (right).

Figure B.2 Wolf Lake Dam, a stream temperature monitoring site (summer 1998).

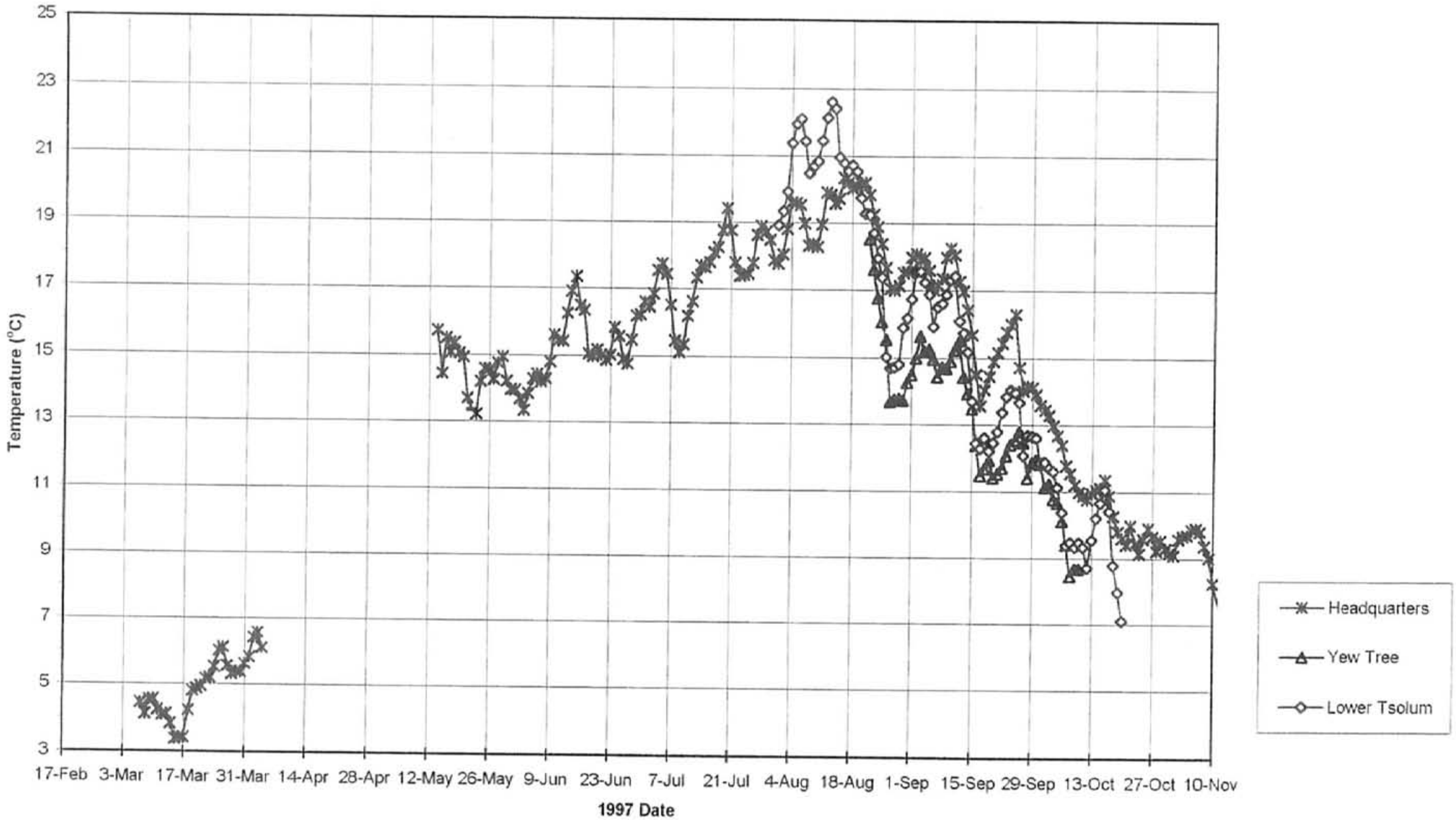


Figure C.1. Mean Daily Stream Temperatures, 1997 Tsolum River Temperature Study.

1997 Temperature Summary of the Tsolum River Watershed

		Temperature (°C)								
		March	April	May	June	July	August	September	October	November
Headquarters	Max	6.95		17.25	18.86	21.14	21.97	19.18	13.93	10.50
	Mean	4.74		14.55	15.20	17.51	18.95	16.11	10.81	8.29
	Min	2.88		11.91	13.77	14.55	16.13	13.00	8.50	5.86
Middle Tsolum (Yew Tree)	Max						18.97	16.88	12.17	
	Mean						15.39	13.41	9.18	
	Min						13.11	10.47	5.81	
Lower Tsolum	Max						23.73	19.74	12.44	
	Mean						19.46	14.71	10.01	
	Min						13.83	11.05	6.54	

Table C.1.

SECTION 6, APPENDIX C.

Graphs and Tables of temperature data

Figures and Tables

Figures

1998 Temperature Summary of the Tsolum River Watershed

		Temperature (^0C)								
		March	April	May	June	July	August	September	October	November
Gun Barrel	Max						17.35			
	Mean						15.41			
	Min						14.02			
Wolf Lake	Max			16.83	21.38	26.16	25.47			
	Mean			15.06	19.05	21.59	22.71			
	Min			14.14	16.36	18.77	20.23			
Headquarters Creek	Max	8.19	15.18	17.57	21.64	24.52	22.36	22.03		
	Mean	6.23	8.89	13.51	16.21	18.69	18.79	18.54		
	Min	3.51	5.54	9.74	12.69	14.39	15.72	15.57		
Middle Tsolum	Max			12.68	19.17	22.97	22.62	20.3		
(Yew Tree)	Mean			9.6	12.92	16.67	18.38	17.58		
	Min			7.42	8.96	12.68	15.17	14.86		
Dove Creek	Max						22.03	20.38		
	Mean						17.47	16.86		
	Min						14.62	13.84		
Portuguese Creek	Max						23.28	23.62		
	Mean						20.80	18.75		
	Min						18.36	14.54		
Lower Tsolum	Max			24.27	23.07	24.27	23.92	21.41	14.36	
	Mean			12.69	16.49	19.5	20.24	16.36	11.43	
	Min			8.48	11.27	13.74	17.04	12.34	6.94	
Weather Station	Max							23.66	19.18	10.36
(Air Temperature)	Mean							12.71	8.41	6.25
	Min							4.61	0.17	-1.13

Table C.2.

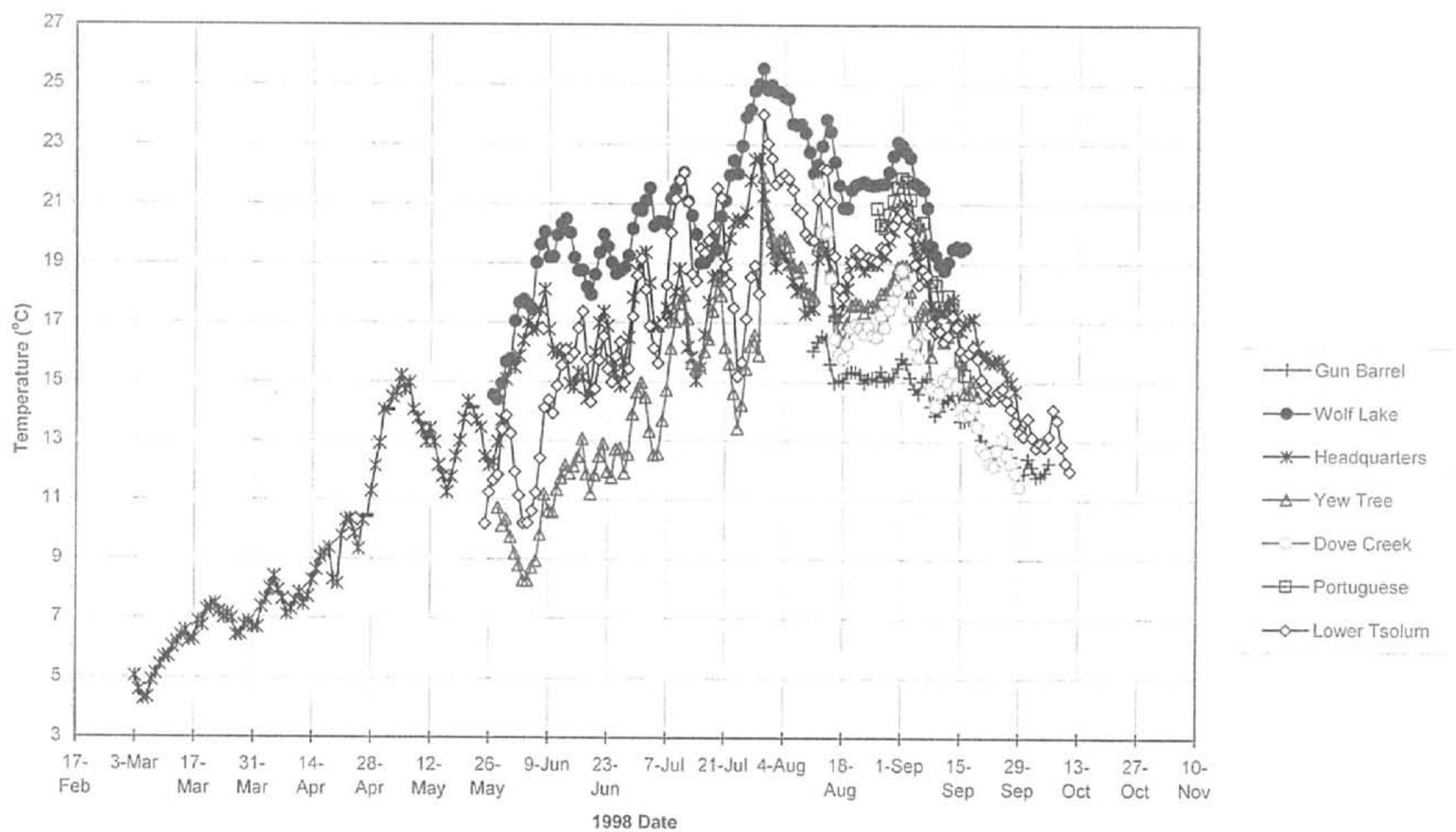


Figure C.2. Mean Daily Stream Temperatures, 1998 Tsolum River Temperature Study.

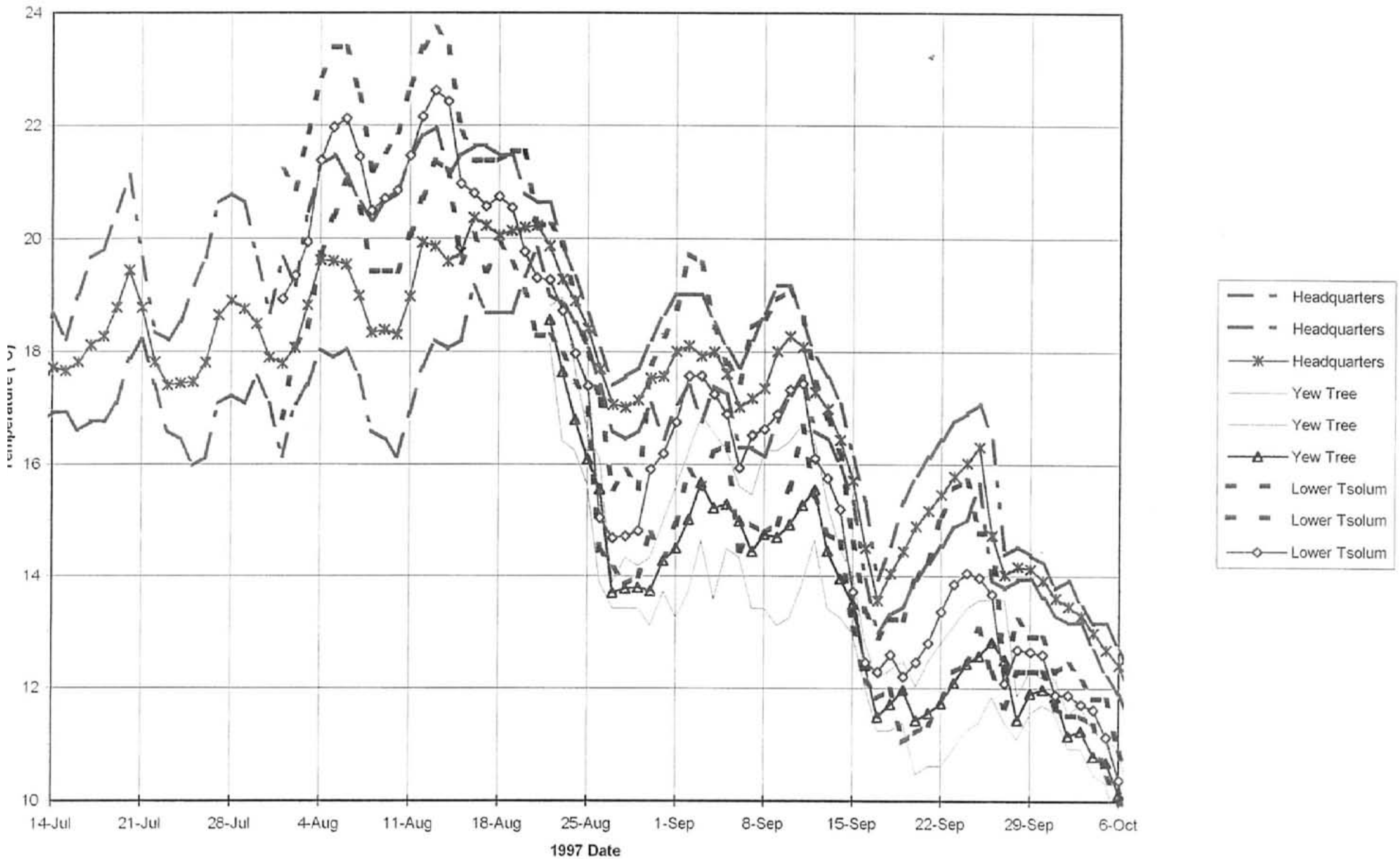
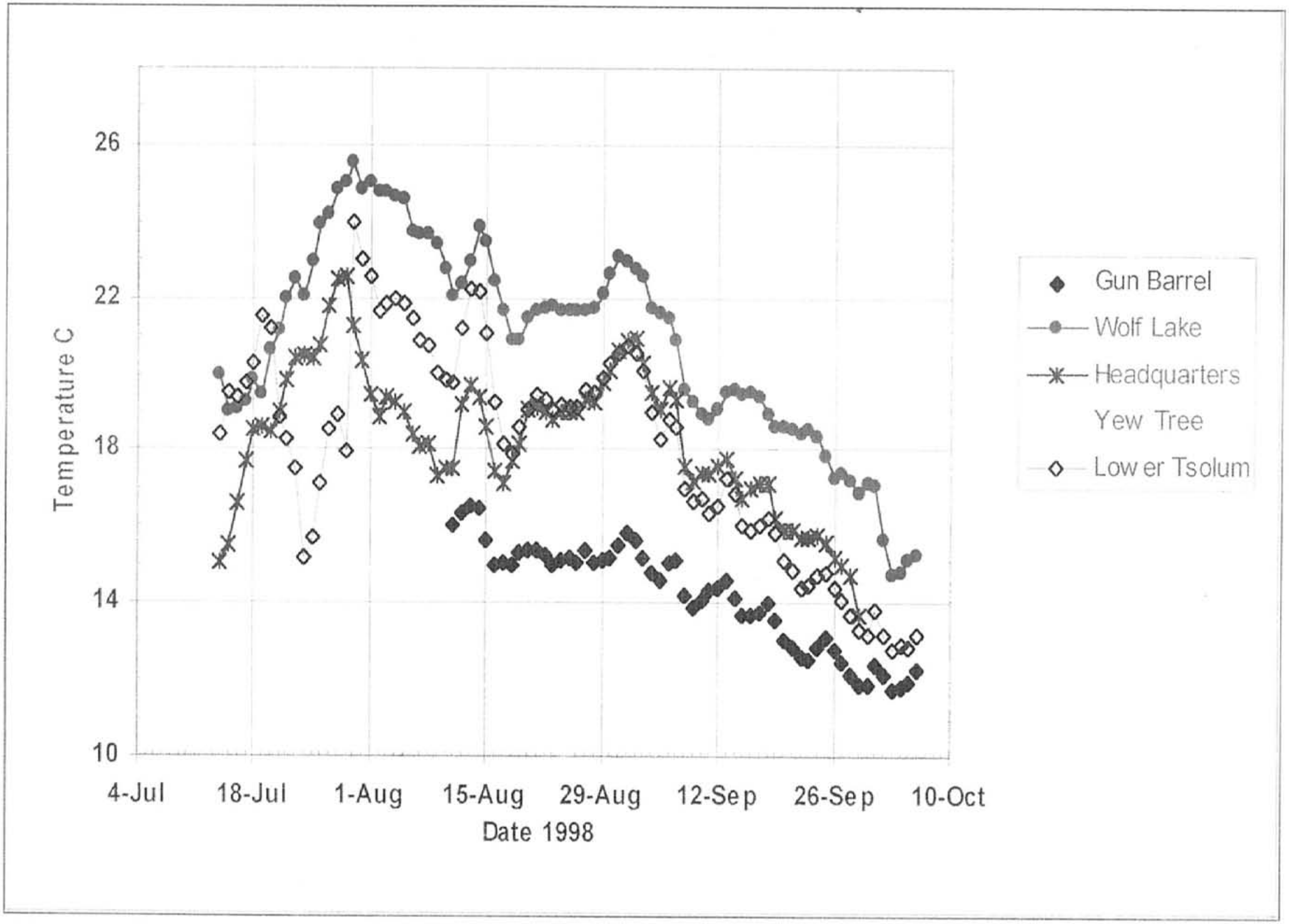


Figure C.3. Mean, Maximum and Minimum 1997 Daily Stream Temperatures for Headquarters Creek, Mid Tsolum River (Yew Tree) and Lower Tsolum River Sites.



Temperature C
26
22
18
14
10
4-Jul
18-Jul
1-Aug
15-Aug
29-Aug
12-Sep
26-Sep
10-Oct
Date 1998
Gun Barrel
Wolf Lake
Headquarters
Yew Tree
Lower Tsolum

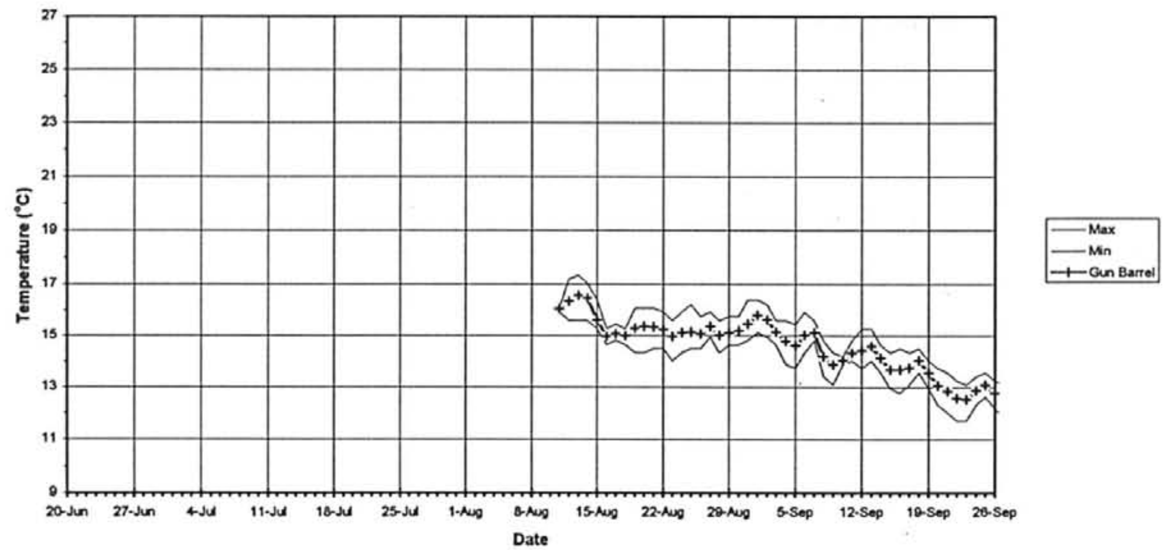


Figure C.5. Mean, Maximum and Minimum 1998 Daily Summer Stream Temperatures for Upper Tsolum River (Gun Barrel) Site.

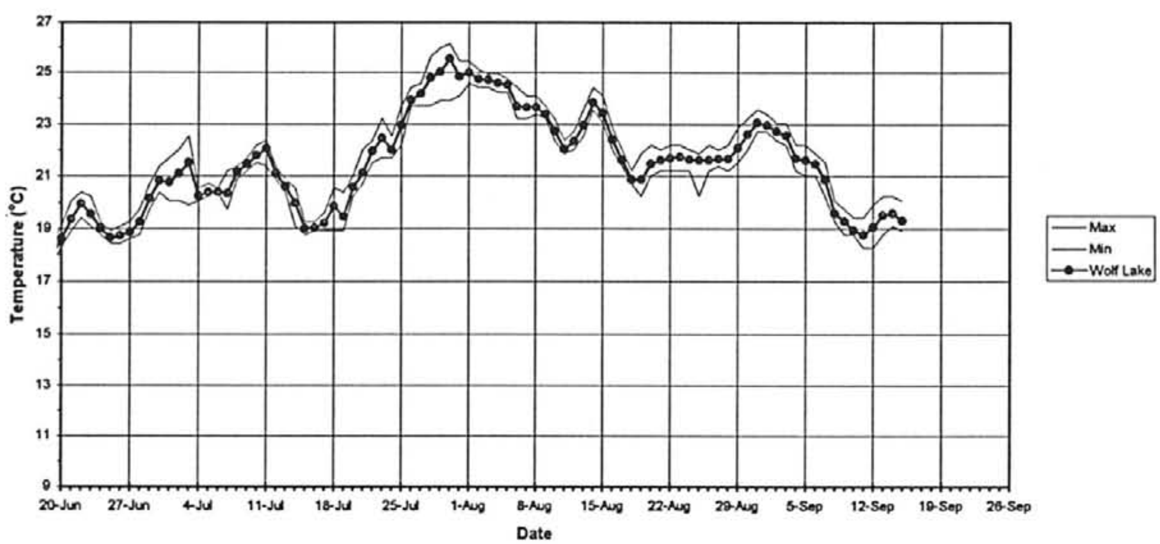


Figure C.6. Mean, Maximum and Minimum 1998 Daily Summer Stream Temperatures for Wolf Lake Dam Site.

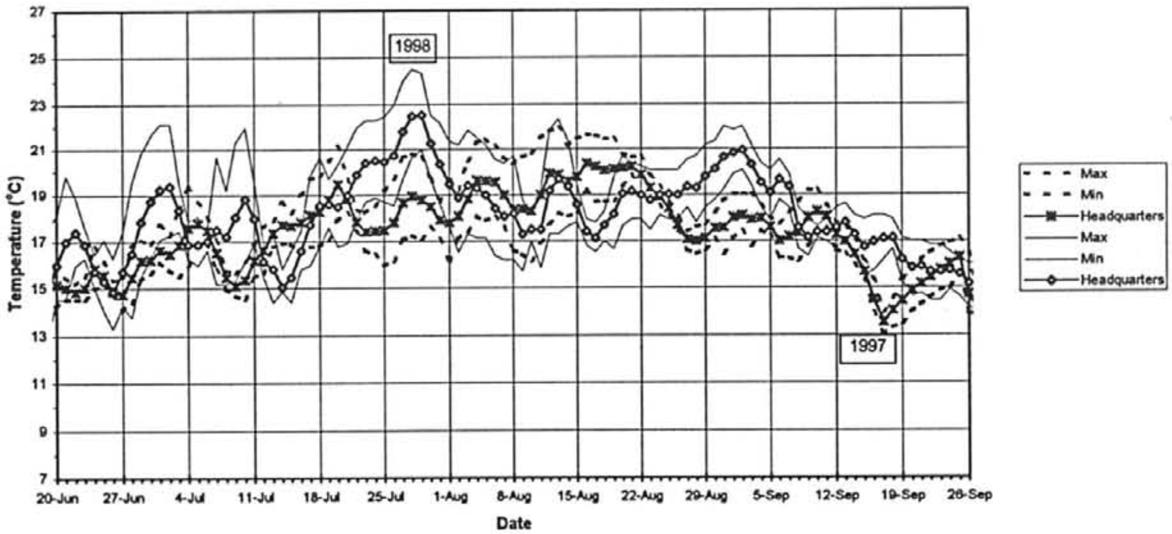


Figure C.7. Mean, Maximum and Minimum 1997 and 1998 Daily Summer Stream Temperatures for Headquarters Creek Site.

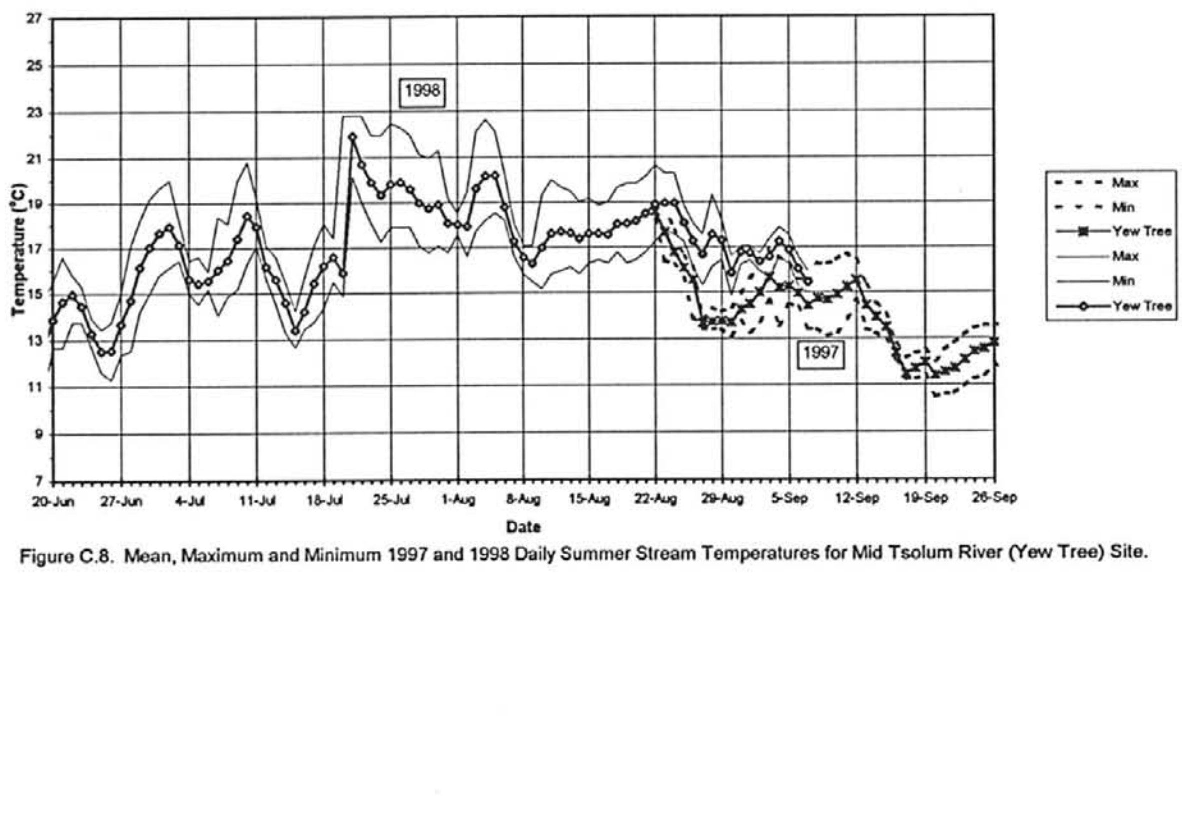


Figure C.8. Mean, Maximum and Minimum 1997 and 1998 Daily Summer Stream Temperatures for Mid Tsolum River (Yew Tree) Site.

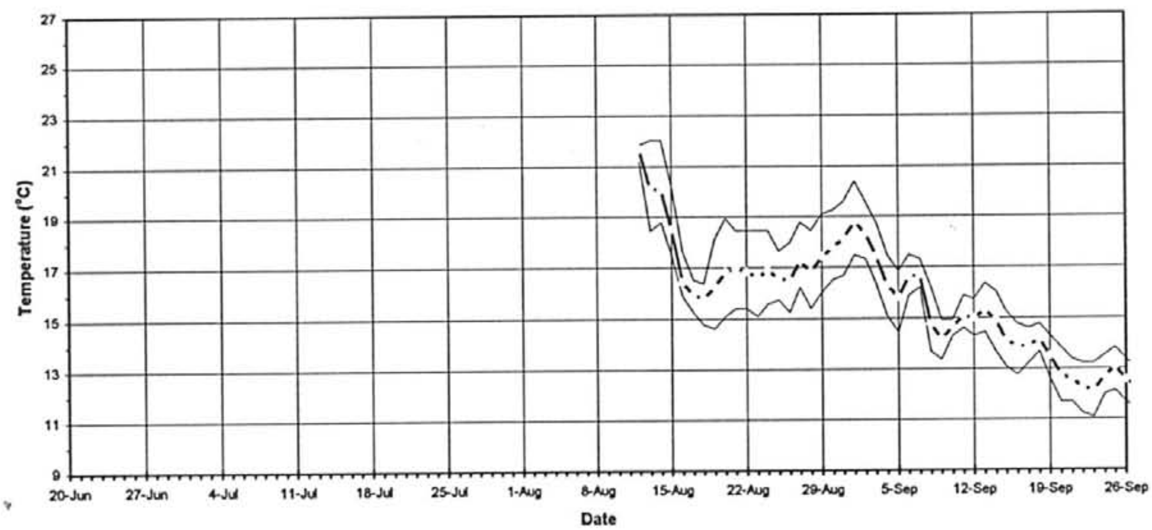


Figure C.9. Mean, Maximum and Minimum 1998 Daily Summer Stream Temperatures for Dove Creek Site.

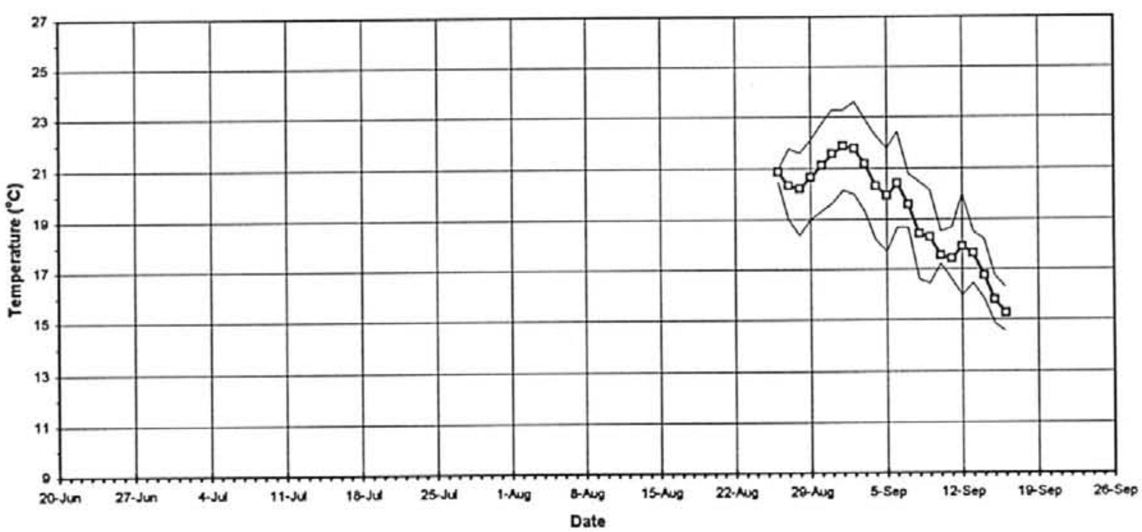


Figure C.10. Mean, Maximum and Minimum 1998 Daily Summer Stream Temperatures for Portuguese Creek Site.

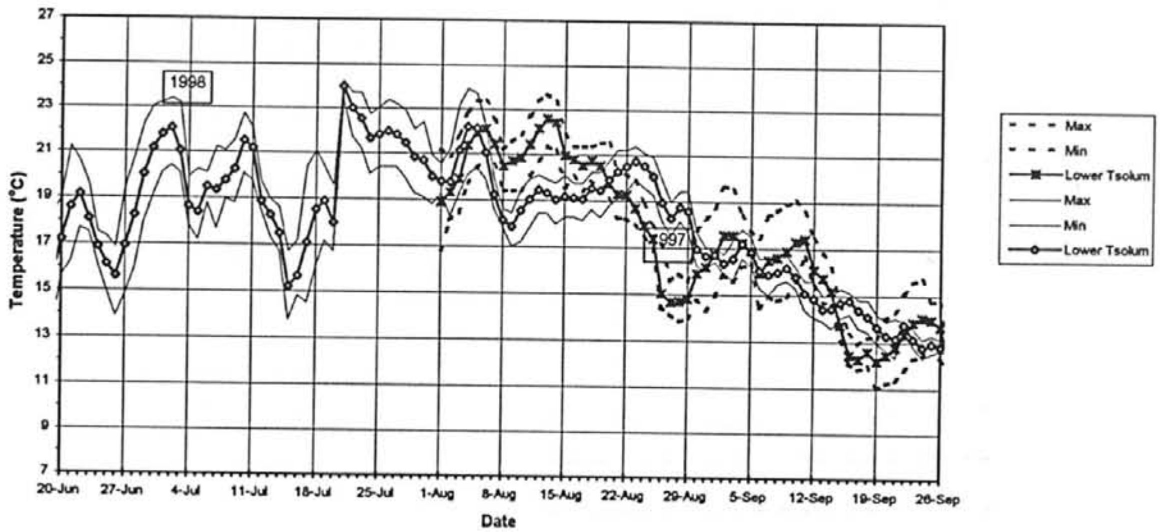
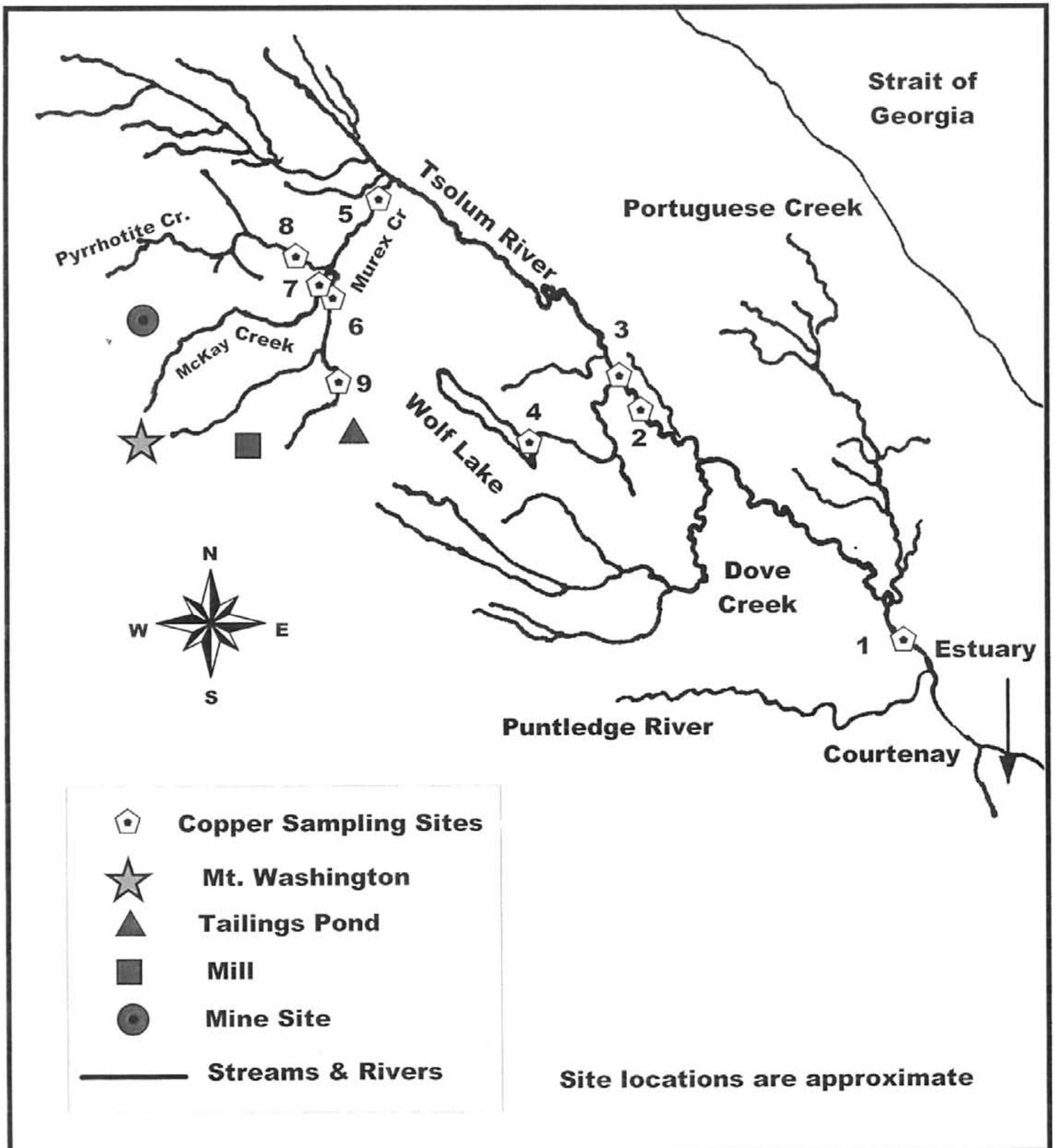


Figure C.11. Mean, Maximum and Minimum 1997 and 1998 Daily Summer Stream Temperatures for Lower Tsolum River Site.

SECTION 6, APPENDIX D.

Tsolum River Watershed
Copper Sampling Sites



Created by Joanne Ellefson, March 12, 1999, for the Tsolum River Task Force.

Scale unknown

Table D1. Comparison of Copper Loadings Recorded at Branch 126 between 1986 and 1998.

Month - Year	Total Flow (dam^3)	Average Copper Concentration (mg/L)	Monthly Copper Loadings (kg)
May - 1986	150.5	7.55	1076
Jun - 1986	108.6	4.87	503
Apr - 1987	34.5	6.25	212
May - 1987	148.8	4.7	789
Jun - 1987	146.3	3.26	511
Apr - 1988	65.5	5.34	393
May - 1988	139.4	5.89	885
Jun - 1988	115.2	4.37	513
Apr - 1989	64.8	5.01	347
May - 1989	141.9	5.38	835
Jun - 1989	87.8	3.6	355
Apr - 1998	27	3.5	98.9
May - 1998	141	2.79	403.7
Jun - 1998	143	1.41	198.6

Figure D.2 Average Copper Concentration at Pyrrhotite Creek @ B126

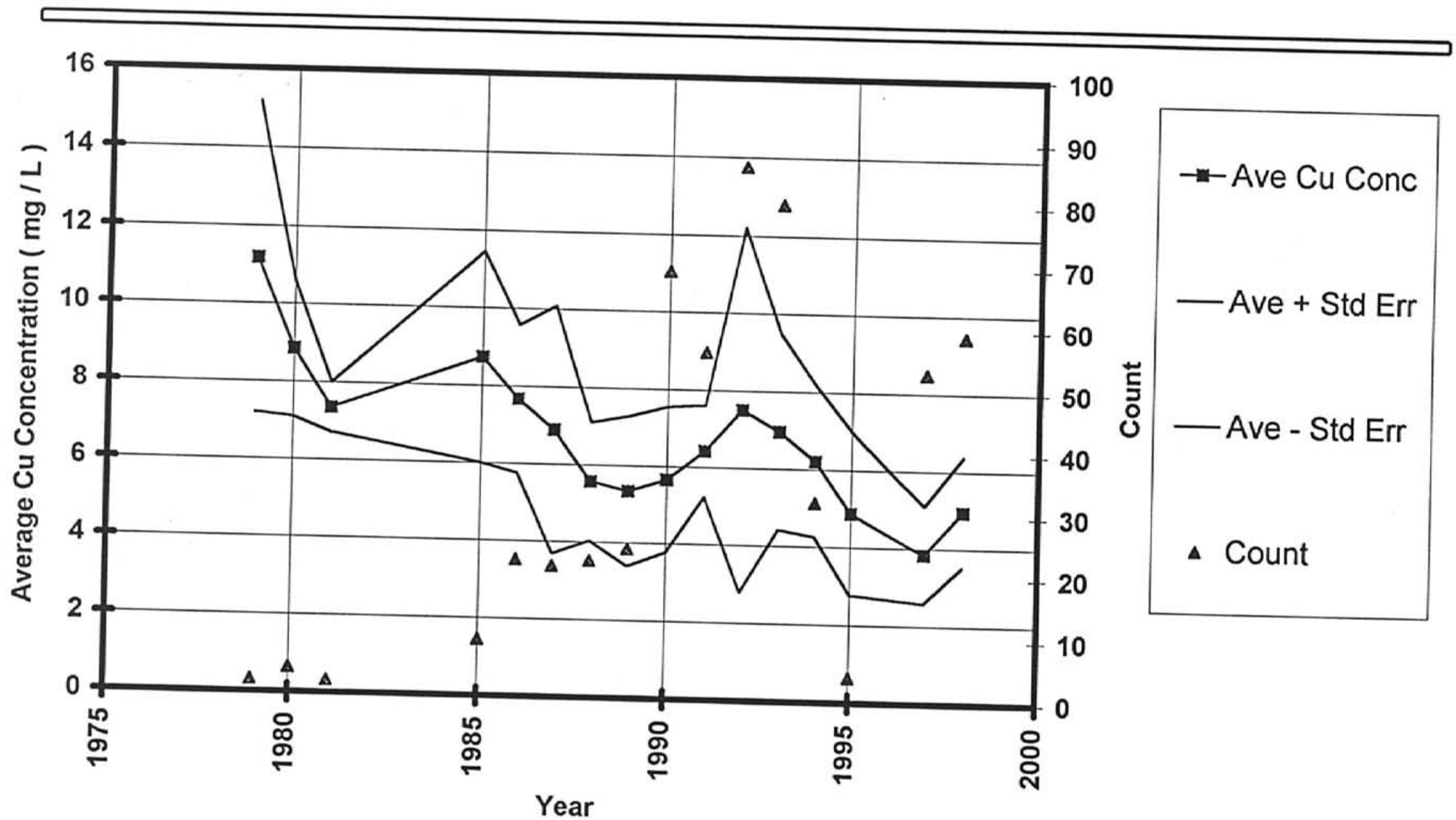


Figure 2. Yearly average copper concentration at Pyrrhotite Creek/ Branch 126 sampling station.

SECTION 7

FISH HABITAT MAPPING PROGRAM

SECTION 7. FISH HABITAT MAPPING PROGRAMS

Introduction

The Tsolum River watershed covers an area of 258 km^2. Land adjacent to the river and its tributaries is utilized for forestry, rural and suburban settlement and lowland agriculture. Many of the most critical areas for fish habitat are small streams that were not well defined on the 1:50,000 National Topographic Series (NTS) or the 1:20,000 Terrain Resource Inventory Mapping (TRIM) map series.

Methodology

In 1997, the Department of Fisheries and Oceans (DFO), and the Ministry of Environment Lands and Parks (MELP), in partnership with the Pacific Streamkeepers Federation, developed the Sensitive Habitat Inventory Mapping (SHIM) methodology for land use planning in coastal urban watersheds (Mason et al 1998). The purpose of this program was to provide updated information for the Regional District of Comox-Strathcona Environmentally Sensitive Areas Atlas, to identify opportunities for habitat restoration projects, and to establish fish presence in areas of unknown fish habitat. This information will be used to assist planners, landowners and fisheries personnel in protecting fish habitat (Appendix A).

The Tsolum River Task Force employed the SHIM methodology in modified and unmodified versions, on four mapping projects undertaken between 1997 and 1999. High water mapping surveys were conducted in the tributaries during the winter and spring seasons. Summer low water surveys were conducted in the mainstem to identify obstructions to adult migration.

Materials and Equipment

Orthophoto maps (1:5,000 to 1:36,000 scale) were provided to the TRTF by DFO's Habitat Enhancement Branch. Field equipment was purchased by the TRTF and the Community Fisheries Development Centre (CFDC), or borrowed from other watershed groups.

DFO also provided computer software and technical support for processing the mapping data. Data collected by the crews was entered into Access and Excel spreadsheets, then submitted to Project Watershed's Watershed Inventory Program. Watershed Inventory technicians from this program used the data to produce maps in GIS ArcView Format. This information was forwarded to DFO and was subsequently included in the second edition (June 1998) of the of Comox-Strathcona Habitat Atlas (DFO, RDCS 1998).

Mapping Programs

Four field programs were completed in the Tsolum River watershed during 1998 and 1999.

Program 1. Tributary mapping, lower Tsolum R. watershed

The CFDC partnered with DFO and the TRTF to employ a crew of 3 full time mapping technicians, and one part time crew supervisor in February, 1998. They were trained in the SHIM methodology, developed landowner contacts and completed the mapping of 11.71 km of fish habitat.

Program 2. Additional tributary mapping, lower Tsolum R. watershed

A second mapping program was funded and a crew of 2 mapping technicians and a part time supervisor were redeployed during March and April, 1998. The crew mapped an additional 5.01 km and catalogued data into the Streamkeeper's database and Excel spreadsheets.

During the first and second field programs, mapping was restricted to the tributaries because water flow in the river was too high for the crew to work safely in the Tsolum River mainstem. A program of fish trapping using Gee traps baited with sardines or salmon roe was also undertaken. Trapping revealed coho and steelhead utilizing previously unidentified winter rearing habitat.

Program 3. Identification of barriers to salmon migration

The TRTF worked with other fisheries and environmental groups in the Community Partners Program to complete low water mapping in the Tsolum River mainstem and in Headquarters Creek. Funding for the program was provided by B.C. Hydro Opportunities for Youth.

The crew traversed the Tsolum River mainstem from the confluence with the Puntledge River to the confluence with Headquarters Creek. GPS data was collected for major stream features such as the location of large woody debris, holding pools, intake pipes, areas of significant erosion or riverbank modification and gravel beds, which may be obstructions to salmon migration at low water. Data was also collected on migration barriers and stream features in Headquarters Creek, and on tributaries which were dry during August 1998 (Appendix B).

The crew also conducted mapping surveys in tributaries to Dove Creek that were within the area to be impacted by the construction of the Vancouver Island Inland Highway.

This data was used to develop maps for TRTF project planning.

Program 4. Mapping in the Dove Creek and Headquarters Creek watersheds

Project four received support from government agencies, companies, educational institutions and community groups. In January 1999, Fisheries Renewal B.C. provided funding for a SHIM mapping program to be conducted in Dove Creek and Headquarters Creek. Both watersheds were undergoing significant changes in their drainages due to logging activity and highway construction.

Field work involved the TRTF mapping crew assisted by Excel Career College GPS/GIS mapping technology students. The college also provided GPS equipment and computer software for differentially correcting GPS data. Students and TRTF map technicians cooperated in producing a data dictionary for the Trimble Geoexplorer GPS unit and assisted in the production of files used for GIS ArcView maps.

Additional GPS units were loaned to the project by the Little River Enhancement Society and DFO. DFO and ESRI Canada provided software support. TimberWest Ltd. provided maps and permission to access their property. Approximately 30 km of mapping was completed in project four.

The map crew was invited to attend a two day Resource Inventory Committee (RIC) training program on the use of the Pathfinder GPS units. This program was sponsored by the CFAC and Project Watershed.

This crew also collected information on sources of erosion that were contributing to silt loading in both watersheds. This information was used to develop a water sampling program for the Community Based Siltwatch Program that was also funded by Fisheries Renewal B.C.

Gee trapping studies were conducted with the information being provided to DFO for inclusion with habitat referral files.

Recommendations

1. There is a need for more SHIM mapping to be completed in the Tsolum River watershed. A strategic plan covering unmapped areas should be produced. Priority should be given to areas that will be impacted by highway construction, logging or development.

2. A study of wetlands should be completed in the upper watershed, as this area is threatened by development, and is very important to maintaining water quality in the Tsolum River.

3. Watershed mapping should also be completed in the middle and lower areas of the watershed. Many wetlands are located on private property and are threatened by development. Landowner awareness of the importance of wetland habitat should be promoted as part of future wetland mapping projects.

4. It is essential that a good relationship be maintained with landowners to assure that access to unmapped areas is not restricted. Landowners should be made aware of information collected in mapping surveys and encouraged to provide information on fish habitat on or near their properties.

5. Version 3 of the SHIM methodology recommended that a Garmin 12XI hand-held GPS unit with differential antennae be employed by map crews. This equipment was used in programs 1 – 3, but not on program 4. Tests conducted by DFO during January 1999 showed that the accuracy of these units was not sufficient for urban watershed mapping. Future projects should employ more accurate GPS equipment.

6. The Trimble Pathfinder is now being recommended for SHIM mapping programs. This equipment requires specialized training. The cost of the units are beyond the budget of most community projects and should be acquired as a shared purchase between projects or rented and operated by certified operators.

7. Cooperation with other groups facilitated the success of Project 4. It is recommended that community resources be pooled whenever possible and that participation of educational institutions be encouraged in TRTF projects.

8. Maps produced by the summer mapping survey would have benefited from the inclusion of a cadastral layer in the map. The TRTF should approach the Regional District of Comox-Strathcona for permission to use a "read only" copy of the cadastral information for the watershed.

9. The map crew spent considerable time and energy at the beginning of the program attempting to wire the Trimble Geoexplorer 2 GPS unit with a differential antenna. This was not possible, and it is recommended that other crews not attempt this.

10. This information should be used in the production of a watershed management plan for the Tsolum River watershed.

References

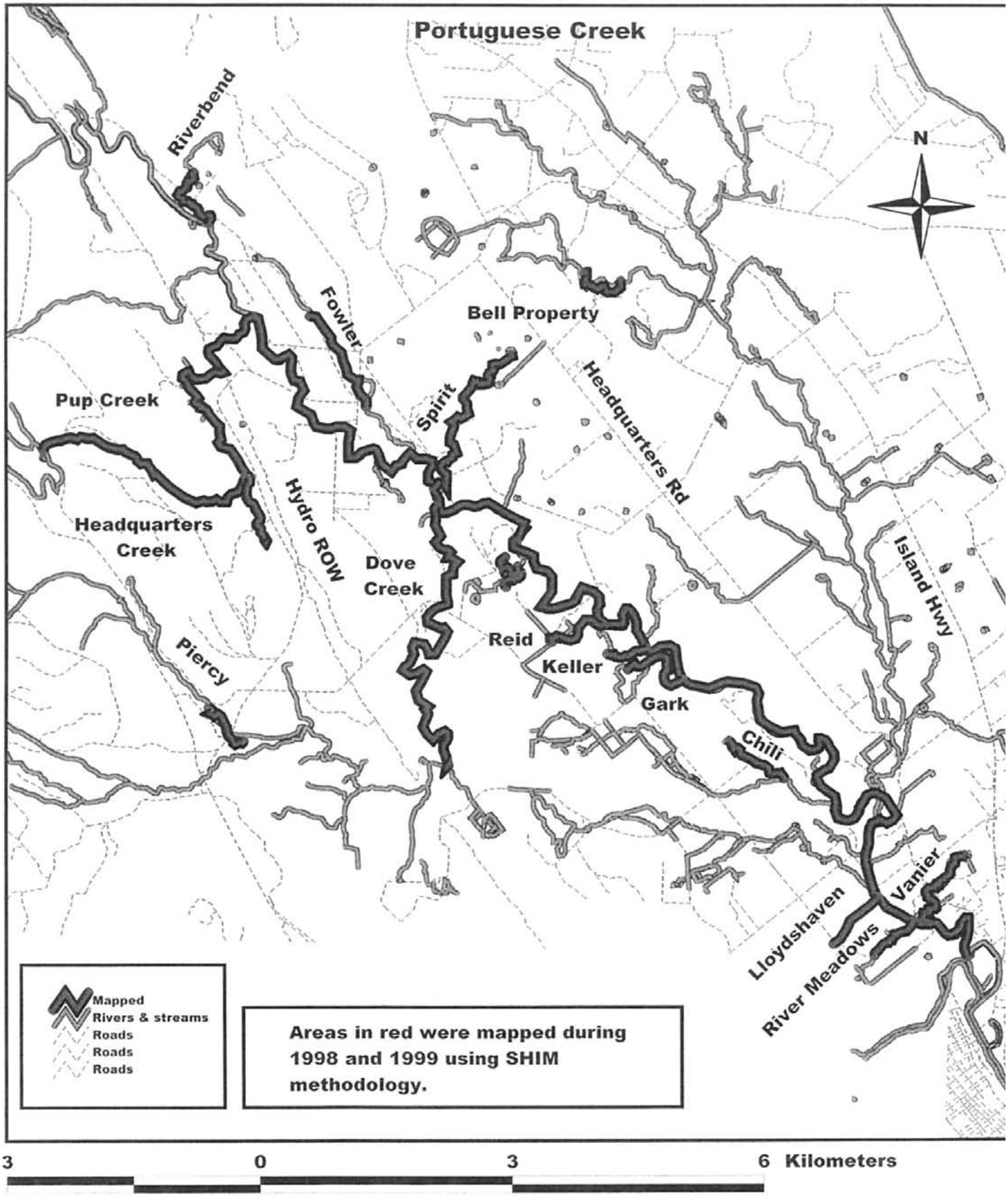
Mason, Brad. 1998. Stream Mapping Procedures for Land-Use Planning in Coastal Urban Watersheds. Habitat and Enhancement Branch, Department of Fisheries and Oceans. Vancouver, BC.

Department of Fisheries and Oceans, and Regional District of Comox-Strathcona 1998. Comox-Strathcona Sensitive Habitat Atlas. DFO, Vancouver,BC.

SECTION 7. APPENDIX A

Tsolum River Watershed
Areas Mapped by 1999

Tsolum Watershed Areas Mapped by 1999



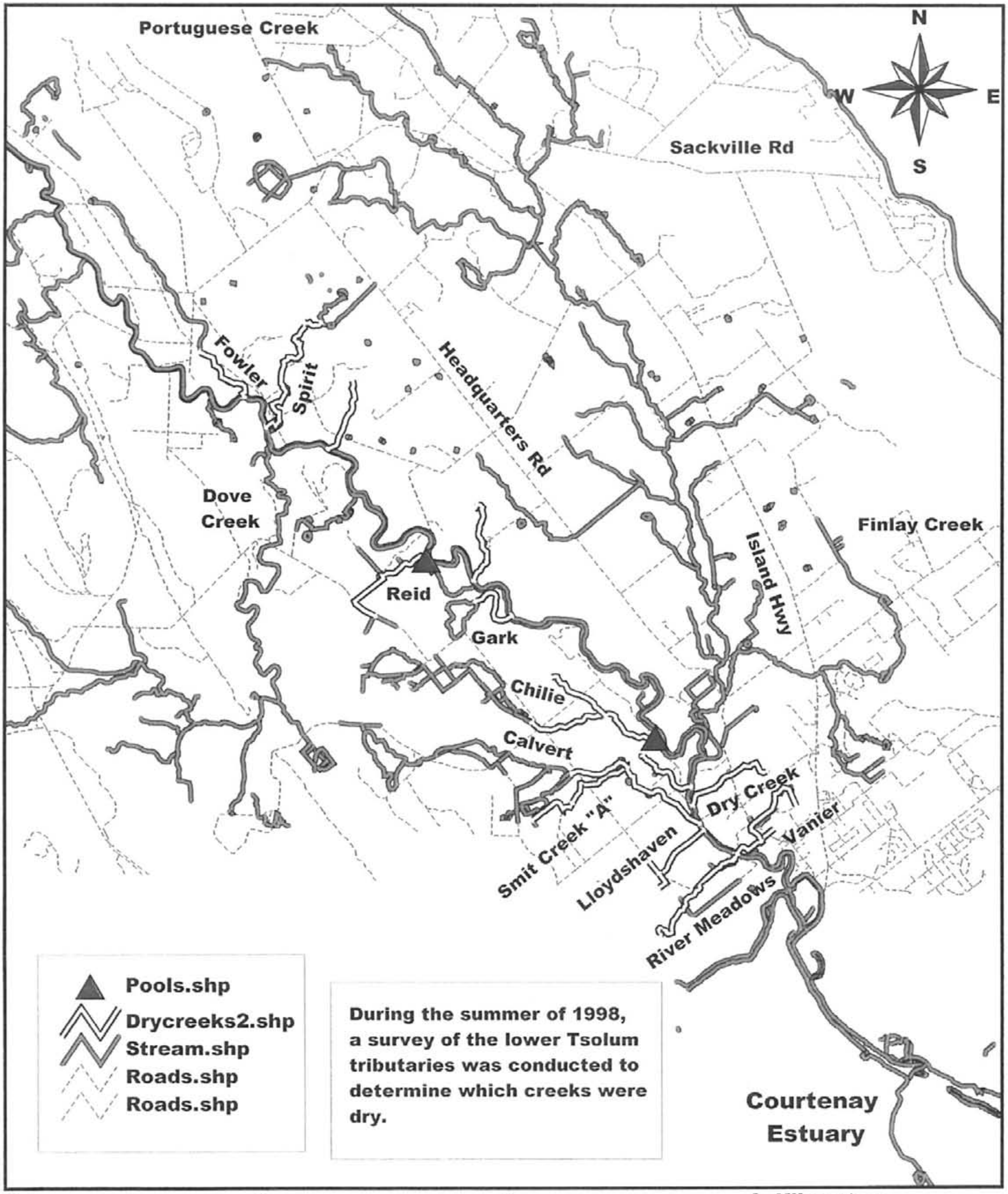
Scale 1:70,000

Created by Joanne Ellefson, March 16, 1999, for the Tsolum River Task Force.

SECTION 7. APPENDIX B

Tsolum Watershed Dry Creeks
August 1998

Tsolum River Dry Creeks



During the summer of 1998, a survey of the lower Tsolum tributaries was conducted to determine which creeks were dry.

Created by Joanne Ellefson, March 2, 1999, for the Tsolum River Task Force.

SECTION 8

REFUGE POND STUDIES

SECTION 8. REFUGE PONDS

Introduction

In the summer and fall of 1998, TRTF, Environmental Youth Team members worked with volunteers from the Portuguese Creek Watershed Stewards and a North Island College student to investigate water quality conditions and carrying capacities of nine ponds in the Portuguese Creek and Smit Creek - Forsythe Creek drainages.

The Portuguese Creek Watershed Stewards identified thirty-four ponds in the rural residential and lowland agricultural areas of the watershed (Appendix A). This habitat has become the critical link for survival of coho and trout stocks in tributaries to the Tsolum River. Over the last 80 years, land development has resulted in the ditching of many natural watercourses, reducing habitat complexity and eliminating natural pool habitat. Deep pools are important as rearing habitat for juvenile salmonids, and refuge habitat for migrating adults. Where no natural pools occur, constructed ponds offer the only shelter and cool water available to fish (Norm Sieffert, 1998).

Nine ponds in the Portuguese Creek and Dove Creek sub-basins were monitored for temperature and dissolved oxygen concentrations during the summer and fall of 1998.

There are two basic types of refuge ponds used by salmon and trout in these sub-basins. Instream ponds (Appendix B, Fig. B2) maintain a connection to the adjacent stream, while near-stream ponds (Appendix B. Fig. B1) have no water inflow or outflow during months with low stream flows. As the water level decreases in nearby streams, fry retreat into near-stream ponds where they live until water levels rise in the fall. In summer, water levels drop in these ponds due to evaporation, and rainwater is the only source of new water. Dissolved oxygen levels are controlled by photosynthetic activity in these ponds.

In-stream ponds have year round water flow that helps to maintain higher levels of dissolved oxygen in the pond. Flow rates may be reduced in dry periods as water levels decline in the streams that flow though them.

Methodology

A Lowrance differential receiver Garmin 12XL handheld Global Positioning System (GPS) was used to determine location of the ponds. GPS data was transferred to ArcView GIS format for inclusion in watershed maps. An OxyGuard MKII portable dissolved oxygen meter with temperature probe and a portable pH meter were used to monitor water quality. Baited Gee minnow traps, and a customized netting device known as the "Super Dave", were used to capture salmon and trout fry for length-weight sampling.

In the spring of 1998, the Little River Enhancement Society salvaged coho, chum and cutthroat trout fry, from various locations (Little River Enhancement Society, 1998). Fry salvaged in the Tsolum River watershed were relocated to the Tsolum River mainstem or to refuge ponds near their streams of origin. These salvaged fry added to the natural population of fish in the refuge ponds.

Water quality was sampled weekly in the nine index ponds from July 29 to September 21. Dissolved oxygen and water temperature were measured at three depths: surface, 0.5 m and 1.0 m. and ambient air temperature was also recorded. Measured physical dimensions and characterization are documented for five ponds by Raudzins, 1998.

Fish sampling occurred at five ponds in October 1998 using a 'Super Dave' trawl sampler. This is a netting device made of a light PVC box frame with one side open to capture fish as it is pulled through the pond. Bait is thrown into the pond to entice fish into the trawl's path and facilitate capture.

Site Descriptions

All ponds in the study area had an average surface area less than 100m^2. Depths in the ponds ranged from 1.7 m. to 3.0 m. The riparian cover density differs for each pond. Site descriptions are reported in Appendix C.

Results

Water quality data collected in all sampled ponds indicated conditions were below optimum levels for salmon survival, however fry condition recorded for the five sampled ponds showed that these fish were healthy and well fed. Multiple species (cutthroat trout, sticklebacks and coho salmon) were sampled from some ponds.

Results of the pond fish sampling carried out October 21, 1998 are summarized in Appendix D. Table D2 summarizes physical dimensions for five of the ponds, while Table D3 tabulates the quantities of juvenile salmonid species sampled at these ponds. Table D4 summarizes fry length and weight measurements. Water quality parameters are summarized in Table D1.

Discussion

Little is known about the refuge ponds in tributaries to the Tsolum River. In most cases no information exists on pond volume, temperature profiles or water quality. It is known that fish do survive in the ponds, and that without this habitat no fish would be able to remain in streams which dry up over the summer.

The main threats to fry survival in refuge ponds is believed to be poor water quality and predation. This predation may be from other fish in the pond or from terrestrial predators. Survival in refuge ponds may be increased if a greater understanding of pond carrying capacity was developed. This would require a survey of pond volume as well as regular monitoring of water quality. Monitoring diurnal patterns of temperature and dissolved oxygen would indicate which ponds have critical oxygen shortages.

This information would be useful to groups conducting fry salvage operations for determining which ponds offer suitable summer rearing habitat and have excess capacity. Ponds which require increased oxygenation, more shade or more refuge habitat could be enhanced to become better rearing and refuge areas for juvenile and adult salmon.

The condition index [wt (mg)/fork length $(mm)^3$] is an indicator of fish health. Optimum condition is reported with an index of approximately 1.0. In all cases, coho fry sampled from refuge ponds in October 1998 had condition indices $\geq$ 1 suggesting that pond carrying capacity had not been exceeded.

Recommendations

1. Recommendations for future Tsolum River watershed refuge pond initiatives include more extensive water quality testing, aeration, riparian planting, and in-pond habitat complexing. Water quality testing may help determine the suitability of other ponds in the watershed. Ponds found to have suitable water quality can be stocked with salvaged fry.

2. Fry sampling should be conducted in October when water temperatures are lower. It is important that samples be taken before water levels rise in the adjacent streams to ensure that fish sampled are summer residents, and not recent migrants from the adjacent stream.

3. Increasing pond dissolved oxygen levels is recommended for ponds 2, 29, and 30. Pond aeration may be accomplished with mechanical aerators, oxygen cylinders, and/or with oxygenating plants. Such plants may include the creeping underwater coontail (*Ceratophyllum demersum*) (Pettinger, 1996). For pond 29 and 30, diverting stream flow to the ponds may be another method for increasing pond dissolved oxygen levels.

4. More vegetated rafts are recommended to increase riparian cover. Earlier spring planting and initial plant maintenance will improve survival rates for plants surrounding the ponds. It is also advisable to protect this vegetation from deer by using fencing or vexar tubes.

5. Strategic placement of logs, stumps and boulders will increase the value of refuge habitat by providing cover and shade. Pond habitat complexing is recommended for ponds 18, 19, 20, 29 and 30.

References

Dobbs, Rahsaan. 1999. Tsolum River E-team crew member, Courtenay, BC. Personal Communication, January 1999.

Kuta, Christine. 1999. Tsolum River E-team crew member, Comox, BC. Personal Communication, January 1999.

Little River Enhancement Society. 1998. Smolt/Fry Salvage Report. Little River Enhancement Society, Courtenay, BC. 19 June, 1998.

Pettinger, April. 1996. Native Plants in the Coastal Garden – A Guide for Gardeners in British Columbia and the Pacific Northwest. Whitecap Books, Vancouver, BC.

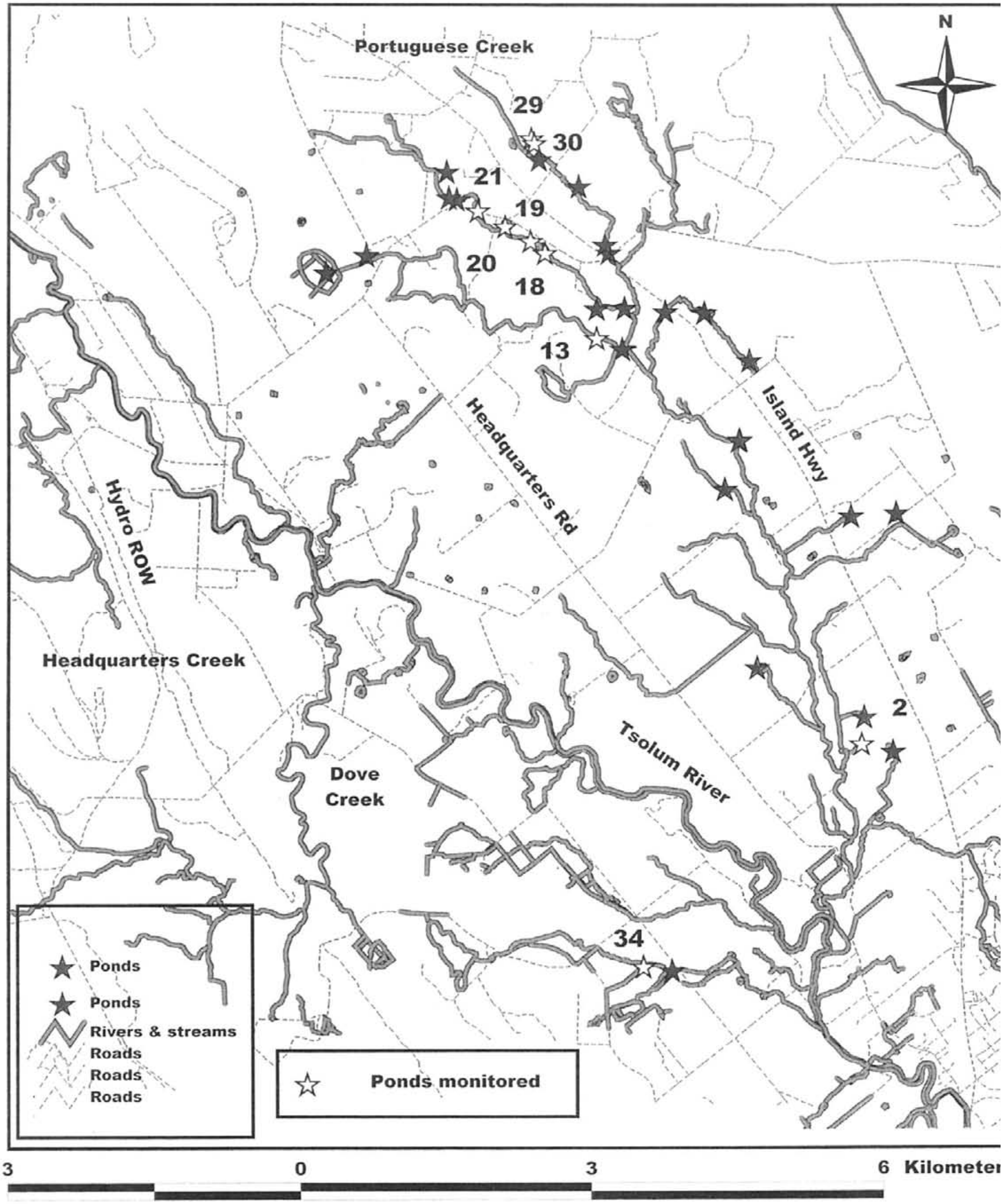
Raudzins, Ilze. 1998. A Biophysical Assessment of Five Salmon Summer Refuge Ponds in the Portuguese Creek Watershed. Renewal Resources 290 Course Project, Environmental Assessment Program, North Island College, Courtenay, December 7, 1998.

Sieffert, Norm. 1998. Resident and Streamkeeper, Courtenay, BC. Personal Communication, September 1998.

SECTION 8. APPENDIX A

Project map identifying pond locations

Tsolum Watershed Salmonid Refuge Ponds



Created by Joanne Ellefson, March 16, 1999, for the Tsolum River Task Force

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SECTION 8. APPENDIX B

Photographs of typical near-stream and in-stream ponds

Figure B.1 Near-Stream Refuge Pond, Poulton Road, Merville, B.C.

Figure B.2 In-Stream Refuge Pond, Merville Road, Merville, B.C.

SECTION 8. APPENDIX C

Refuge pond sites

Pond #	Stream Name	Pond Type	% Cover	Site Description	UTM North	UTM East	Address
2	Portuguese Cr.	Near- Stream	<50%	Subsurface aerator in operation which raises dissolved oxygen levels. The southwest corner of the pond is shaded by a golden willow (*Salix alba)* Aquatic plants occupy 50% of the pond volume. No salmonids observed.	5510992	355286	Sunnydale Golf Course
13	Portuguese Cr. Middle Branch	Near- Stream	>50%	Abundant mature 2nd growth fir and riparian vegetation surround this pond. Smallest pond in the study (3.5m wide, 2 m deep)	5515219	352563	Gunter Road
18	Portuguese Cr. Middle Branch	Near- Stream	>50%	Grass is predominant riparian vegetation No water flow through the pond until mid-Oct. No salmonids observed. Poor water quality. 17 m long by 5 meters wide shallow pond	5516104	352027	Poulton Road
19	Portuguese Cr. Middle Branch	In- Stream	<50%	Shallow pond max. depth aprox. 1 m 25 m long by 5 m wide	5516227	351887	Poulton Road
20	Portuguese Cr. Middle Branch	Near-Stream	<50%	Groundwater inflow circular pond with 12 m Diameter. Max 3 m depth Landowners feed fish in pond A small raft provides some shade and cover.	5516380	351616	Poulton Road
21	Portuguese Cr. Middle Branch	In-Stream	<50%	30 m x 7 m pond was deepened in 1994 No flow through the pond in September 1998 Landowner supplements pondwater with some groundwater during low flows.	5516545	351332	Merville Road
29	Portuguese Cr. East Branch	Near- Stream	>50%	Mixed forest provides constant shade 12m x 3 m dug in 1996 Steep 1m high banks at west end and at the north side Fruit flies supplement natural feed.	5517294	351882	N. Island Hwy.
30	Portuguese Cr.	Near- Stream	>50%	Well shaded in 2nd growth forest clearing 8m x 5m pond dug in 1996. Downstream of pond #29 Sept. 1998 organic oil on pond	5517247	351911	N. Island Hwy.
34	Smit Cr.	Near- Stream	<50%	Very little riparian vegetation One of the largest ponds stocked in 1998 by fry salvage	5508681	353048	Condensory Rd.

SECTION 8. APPENDIX D

1998 Pond Study Data

Table 1. Refuge pond water quality data

Table 2. Pond dimensions

Table 3. Fish sampling results

Table 4. Length/weight data

Table D1 Refuge Pond Water Quality Data

Pond #	Date	Time (pm)	O2 (mg/l) surf	O2 (mg/l) 1/2m	O2 (mg/l) 1m	Air Temp p.m.	Water Temp surf	Water Temp 1/2m	Water Temp 1m	pH
2	29-Jul-98	3:15	1			27.8	17.5			
	26-Aug-98	4:00	0.5			22.4	14.2			
	08-Sep-98	3:45	0.9			18.3	14			
	16-Sep-98	3:55	2.4			24	13.4			
13	29-Jul-98	4:30	8.3	7	5.6	24	27.1	24	23.2	
	26-Aug-98	2:30	6.7	5.7		20.4	21.1	18.2		
	01-Sep-98	2:25	7.2	5.4		21.1	20.6	18.7		
	08-Sep-98	1:50	7.1	5.1		18.1	16.8	15.5		
	13-Sep-98									
18	12-Aug-98	1:30	5.6	6.2		30.7	20.6	18.5		
	26-Aug-98	2:10	10.8	10.8	8.3	19.2	16.6	15.6	15.4	
	01-Sep-98	2:10	10.7	0.6	0.3	20.8	18.7	15.6	14.7	
	08-Sep-98	1:30	6.4	5.6		15.7	14.6	14.0		
	21-Sep-98	3:23	6.8	5.1	4.4	18.4	14.5	12.3	11.8	
19	29-Jul-98	1:45	7.4	6.7		23.7	21	18		
	26-Aug-98	1:58	7.6	8	8	25.4	21.1	15.9	15.3	
	01-Sep-98	1:59	6.7	6.8	6.8	28	18.5	17.2	16.4	
	08-Sep-98	1:05	6.6	6.6	6.6	19.3	14.3	13.8	13.7	
20	29-Jul-98	1:30	5.8	6.1		22.8	21.3	20.4		
	11-Aug-98	4:45	8.1	8.4		22.7	18.7	17.7		
	18-Aug-98	1:10	3.8	3.2		18	15.1	14.6		
	25-Aug-98	6:05	7	7.1		19.8	17.1	16.6		
	31-Aug-98	2:58	6.1	6.1		25	18.8	18.1		
	08-Sep-98	3:10	5.8	5.8		18.1	15.8	15.5		
	15-Sep-98	4:18	6.9	6.8		17.9	14.5	14.1		
	21-Sep-98	12:30	6.7	6.5		17.6	14	13		8.3
21	29-Jul-98	12:50	5.4	5		29.4	23.7	22.2		
	04-Aug-98	4:22	6.6	6.7		24.2	20.4	19.6		
	06-Aug-98	3:00	4.9	2.3	2.3	30.4	21.3	19.1	17.9	
	11-Aug-98	4:30	6.4	5.7	5.6	24.3	21.2	18.9	18.1	
	18-Aug-98	12:15	5.8	6	5.9	18.1	17.8	16.5	16	
	25-Aug-98	6:00	6.5	5.6		20.4	20.1	19		
	31-Aug-98	2:43	4.9	5.3	5	31	22.6	19.8	19.3	
	08-Sep-98	3:05	4.4	3.8	3.8	19.6	18.8	17.5	16.8	
	15-Sep-98	4:32	5.8	5.0	5.3	20.2	17.9	16.2	15.5	
	21-Sep-98	10:26	7.2	7.2	8.0	20.1	13.3	12.9	12.5	7.59
29	29-Jul-98	1:08	0.5	0.1			16.8	12.6		
	04-Aug-98	4:45	1.7	0.2		25	15	10.2		
	11-Aug-98	5:05	2.2	0.6		23.2	14.5	10.2		
	18-Aug-98	1:32	3.4	0.5	0.4	18.3	13.1	10.2	9.7	
	24-Aug-98	2:30	3	0.2		23.6	13.4	9.7		
	31-Aug-98	3:25	1.8	0.3		25.3	14.9	10.3		
	08-Sep-98	3:30	2.8	0.8	0.3	16.8	12.0	11.4	16.8	
	15-Sep-98	4:00	2.4	0.4		21.8	12.8	10.8		
	21-Sep-98	1:45	2.1	0.2	0.2	16.9	11.9	9.6	9.4	7.94

Table D1 *continued*. Pond water quality sampling data

Pond Number	Date	Time (pm)	O2 (mg/l) surf	O2 (mg/l) 1/2m	O2 (mg/l) 1m	Air Temp pm	Water Temp surf	Water Temp 1/2m	Water Temp 1m	pH
30	29-Jul-98	1:16	2.6	0.1	0.1	19.8	20.2	17.8	15.6	
	04-Aug-98	4:47	6.8	3.9		18.3	19.3	17		
	11-Aug-98	5:12	5.5	3.5	0.7	19.5	17.3	16.3	15.7	
	18-Aug-98	1:40	3.8	3.2		18	15.1	14.6		
	24-Aug-98	2:40	4.8	1.3		18.3	16.7	15.2		
	31-Aug-98	3:35	4	1.7		25.3	17.9	16.7		
	08-Sep-98	3:30	2.8	0.8	0.3	16.8	12.0	11.4	16.8	
	15-Sep-98	4:05	2.5	2.0		18.4	14.3	13.7		
	21-Sep-98	2:15	2.4	1.5		16.7	13.1	12.6		7.34
34	26-Aug-98	11:40	12.1	10.3	1.4	22.3	20	18.6	18.6	
	01-Sep-98	10:28	12.5	11.8	8.7	21.7	20.6	20.2	19.8	
	08-Sep-98	10:50	4.5	2.3		14.8	16.1	16.1		
	16-Sep-98	11:19	8.4	7.6		19.8	16.4	15.2		
	23-Sep-98	2:12	12.7	10.4		22.2	16.2	14		

Table D2. Pond Dimensions

	Pond #18	Pond #20	Pond #21	Pond #29	Pond #30
Surface area (m^2)	77	95	235	35	36
Volume (m^3)	44	102	210	22	26
Max. length (m)	17	12.8	31.5	12.1	8
Max. width (m)	6.5	12	13	3.2	5.0
Max. depth (m)	1.8	3.0	2.9	1.7	1.8

Table D3. Fish Sampling Results, Oct. 19, 1998

	Pond #18	Pond #20	Pond #21	Pond #29	Pond #30
Using 'Super-Dave':					
Number of coho	0	45	0	11	15
Number of cutthroat	0	0	0	0	2
Number of stickleback	2	4	2	0	0
Using Gee-traps:					
Number of coho	0	-	0	0	0
Number of cutthroat	0	-	0	0	0
Number of stickleback	1	-	0	0	0

Table D4. Length/Weight data, Oct. 19, 1998.

	Number Caught	Avg. Length (cm)	Avg. Wt. (g)	Condition Factor
Coho – pond #20	45	7.1	4.10	1.10
Coho – pond #29	11	7.1	4.02	1.05
Coho – pond #30	15	6.3	2.88	1.11
Cutthroat – pond #30	2	12.2	17.06	0.88

SECTION 9

RESTORATION PROJECTS

SECTION 9. SUMMARY OF RESTORATION PROJECTS

Preserving Tsolum River Salmon Habitat

In order to maintain salmon stocks in this watershed, it is essential that fish habitat be restored and preserved. In 1998 and 1999, eight habitat enhancement and restoration projects were completed by the Tsolum River Task Force, as shown in Appendix A.

These projects included:

- Digging in-stream and near-stream refuge ponds.
- Stabilizing stream banks by constructing tiers of willow wattles (Appendix B).
- Planting streamside riparian vegetation to provide shade, cover from predators, and filtering of runoff from upstream runoff (Appendix C).
- Complexing stream habitat by constructing rock weirs and placement of habitat logs to increase pool scouring.
- Hardening streambeds with gravel to allow cattle to cross streams without causing erosion of soft substrate.
- Constructing riparian rafts that provide shade, cover and increase the food supply of refuge ponds (Appendix D).
- Installing a culvert to improve access to habitat previously inaccessible at low water.
- Protecting side-channel habitat from erosion.

Planning of 1997 and 1998 Restoration Initiatives

Consultation with the Tsolum River Task Force Habitat Work Group began in October 1997. Priorities for in-stream projects were set and a work plan was developed for projects to be undertaken in 1998. On the advice of the Habitat work group, it was agreed that restoration work should begin in the tributaries that were not affected by the adverse effects of copper pollution leaching into the Tsolum River mainstem below Murex Creek. DFO Community advisor, Bryan Allen, and Norm Sieffert of the Portuguese Creek Watershed Stewards, also provided project advice.

In the spring and summer of 1998, mapping crews used the Sensitive Habitat Inventory and Mapping (SHIM) Methodology (Mason et al, 1998. Version 3.1), to map stream habitat, and identify opportunities for future restoration projects.

In the spring of 1998, the restoration crew worked with landowners to develop project plans. These plans were approved by the Habitat Work Group and by the appropriate government agencies before in-stream work began.

Restoration Projects

Plans for the following projects completed by TRTF in 1998 and 1999 are available in Chamberlain and Campbell 1999.

1) Streambank stabilization, Franklin property

The Franklin property was experiencing a lot of flooding and streambank erosion. To alleviate the flooding, sod and soil in the center of the channel were removed, and willow wattles were constructed to protect streambanks from erosion. This project was completed in four phases which are detailed in Appendix A, Table 1.

Tiered willow wattles were constructed along 10 m of streambank in April 1998. Willow stakes were also planted to stabilize the wattles and to provide cover on a low-lying area of the bank. Designs for wattle construction were modeled after designs presented in Polster, 1998. In July 1998, an island of sod which was restricting fish passage at low water was removed from the center of the channel. Once the island was removed, six more metres of willow wattling were completed. Streambanks were later replanted with riparian vegetation, which were tended by the landowner throughout the summer. A further 15 meters of willow wattles will be constructed to stabilization streambanks in March 1999.

2) Stream channel complexing, Finlay Creek

In 1994 and 1995, Comox Valley Project Watershed Society installed boulders and woody debris in Finlay Creek, a tributary to Portuguese Creek.

These structures were installed to combat siltation following the clearing of an upstream wetland property. The TRTF restoration crew revisited the sites in the third reach of the stream and determined that additional stream complexing was needed. In-stream structures that had been previously installed were stabilized to encourage pool development.

3) <u>Near-Stream Refuge Pond Construction, Bell property</u>

Water levels in Portuguese Creek rise quickly after a rainfall due to runoff entering the creek from surrounding residential and agricultural land. Water levels in the creek also drop to near zero during the months of July and August. With few wetlands to buffer changes in flow, fish in the creek must migrate to rearing habitat in other creeks, or survive in refuge ponds.

Many landowners have worked with the Portuguese Creek Watershed Stewards to develop refuge ponds on their properties. These ponds provide a dual service to salmon, offering summer refuge to coho and trout fry and providing shelter for adults returning to spawn in the system.

In the spring of 1998, the TRTF worked with a landowner and the Portuguese Creek Watershed Stewards to construct a near-stream pond on the Bell property adjacent to Gunter Road. The pond joined the creek at one site and was filled in the fall by high water. Stumps from trees removed during pond construction were placed back into the pond to provide cover for fish.

Riparian vegetation and grass seed was planted to stabilize sloping pond banks and to provide cover for the fish. In the fall of 1998, landowners observed adult coho holding in this pond prior to spawning. In the spring of 1999, a catamaran style riparian raft was installed in this pond.

4) <u>In-stream ponds and riparian raft construction, McWilliam's property</u>

Forsythe and Smit Creeks (tributaries to Dove Creek) run dry during the summer and offer little refuge to salmon because of lack of in-stream complexity. During November

1997, chum salmon were observed spawning in Forsythe Creek. In the spring of 1998, coho fry were salvaged from drying stream pools and transported to refuge ponds.

Groundwater in this area is in short supply and much of the water resource available is utilized for domestic and agricultural purposes. To provide refuge habitat, two in-stream refuge ponds were constructed, and a series of rock weirs were constructed in Smit Creek on the McWilliam property. In the fall of 1998, riparian vegetation was planted on the streambanks and around a previously constructed irrigation pond used as rearing habitat for salmonid fry.

To provide shade and cover for fry in this pond, two riparian rafts were constructed (Appendix D). The raft is anchored to the pond bottom and the vegetation on the raft provides cover and shade for the fish. Insects that land along the raft edges become a potential food source for the salmon fry when they drop off the raft into the pond. To maximize the effect, the rafts were constructed as small rectangles thereby providing the maximum edge area. Designs for riparian rafts can be obtained from the TRTF.

5) Heidema pond and stream reconstruction

The Portuguese Creek Watershed Stewards had reported large numbers of fry rearing in this branch of Portuguese Creek, and had cooperated with the landowner to construct two small off channel ponds that provide summer and winter refuge habitat for coho pre-smolts and trout fry.

A site assessment determined that a larger pond was needed, and that some channel reconstruction would alleviate flooding occurring on an adjacent property. This channel would provide easy access to the new pond. This area is used by coho spawners that rely on the ponds to provide refuge from predators during times of low flow.

The Portuguese Creek Watershed Stewards had established landowner contact, and were instrumental in assisting with project planning and design. To alleviate flooding on the adjacent property, a silt plug was removed and the stream was redirected into a more stable outflow channel.

After the pond and channel reconstruction was completed, riparian vegetation and grasses were planted to stabilize streambanks and pond sides.

6) Culvert installation at Gark Creek

Gark Creek is an ephemeral tributary to the Tsolum River. To enhance salmon habitat the owner of the property had installed a culvert in the creek. Unfortunately this culvert acts as a barrier at low water flows, and as the creek dried up salmon fry became trapped in pools below the culvert.

The original plan was to remove the culvert and install a bridge using donated timbers. When the timbers became unavailable; a second plan was developed by an engineering technician to design a culvert installation plan. In cooperation with DFO engineers the plan was approved, and the culvert was installed between August 19 and September 8, 1998. The landowners supported the project by offering a machine and operator to install the culvert. Root wads and boulders were donated by the Vancouver Island Highway Project. These were placed in the channel upstream of the culvert to provide cover for fry and adults. Riparian vegetation was planted along the sides of the creek to offer additional shade and cover.

7) Stream complexing and cattle crossing, Pistell property

Previous projects completed by the Portuguese Creek Watershed Stewards and Comox Valley Project Watershed's "Stewardship on the Farm" program brought this opportunity to the attention of the TRTF. Coho salmon had have been seen rearing in the middle branch of Portuguese Creek and in the pond downstream from the restoration site.

The stream channel had been degraded by years of cattle crossing and lacked riparian cover and large woody debris. Once fencing had been put in place to eliminate cattle, plans were prepared with reference to Fish Habitat Restoration Procedures (Slaney and Zaldokas,1997) and the Stream Enhancement Guide (Anon., 1980). Work began at the property on August 14 after landowner and government approvals had been received. The TRTF paid for the cost of the machine and materials used for the project while the landowner provided stumps for stream complexing, and a neighbour provided cedar logs for in-stream weirs.

Downstream from the weirs, a silt plug was removed and a small pool was excavated. Gravel was placed in the stream above the pool to provide cattle with access to an adjacent field. This project will be monitored for structure stability, and additional large woody debris will be added if necessary.

8) Side channel stabilization, Jorgensen property

The channel that borders the Jorgensen property (downstream of Dove Creek) is one of only two known side channels in the lower Tsolum River. In 1997, fall floods eroded the entrance to the channel, and the mainstem of the river threatened to erode the entire area.

Adjacent landowners approached the Task Force and DFO to arrange a site visit. A plan was developed, and following DFO approval the work began. Boulders and rootwads were placed to protect the outside of the channel. By the spring of 1999, some channel modification had occurred, but most of the channel habitat was still intact. The summer of 1998 was very long and dry, allowing an extension of the prescribed fisheries window. This seasonal variation meant that we were able to complete the project later in the season than would normally have been allowed.

Recommendations for Further Work

1. To continue with streambank stabilization, willow wattling should be completed in the eroding sections of lower Portuguese Creek. Erosion control is also needed on sections of Headquarters Creek above the hatchery and in areas which are being impacted by the Vancouver Island Highway project.
2. Many small streams would benefit from increasing the amount of riparian vegetation along the banks. This should be undertaken on agricultural land only after streamside fencing is in place.
3. The addition of spawning gravel and weir construction would benefit Portuguese Creek, Forsythe Creek and several other tributaries.
4. The addition of large woody debris (stream complexing) is needed in several small streams, such as Forsythe, and some of the tributaries to Dove Creek.
5. There is a shortage of summer and winter rearing habitat and refuge for spawners. Construction of more refuge ponds, and linking existing ponds into a network would improve salmon survival.
6. There is a need to provide additional shade and cover in some of the refuge ponds. Installation of riparian rafts in these areas would improve habitat quality.
7. Working with the agricultural community to test the effectiveness of riparian bridges for improving fish habitat in drainage ditches should be initiated. These bridges will provide cover for fish and improve winter rearing habitat without blocking the drainage capability of the ditches.
8. A culvert study should be undertaken to determine whether existing culverts are barriers to fish passage. Culverts that are limiting fish movement should be replaced or reinstalled.
9. A program of landowner contact and public awareness would greatly assist habitat restoration efforts. By informing landowners of the importance of maintaining streamside vegetation, we may reduce the need for stream rehabilitation.

References

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Polster D. 1998. Soil Bioengineering for Forest land Reclamation and Stabilization Prepared for British Columbia Ministry of Forests. Resource Tenure & Engineering Branch Engineering Section. BC Ministry of Forests. Victoria, BC.

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SECTION 9. APPENDIX A

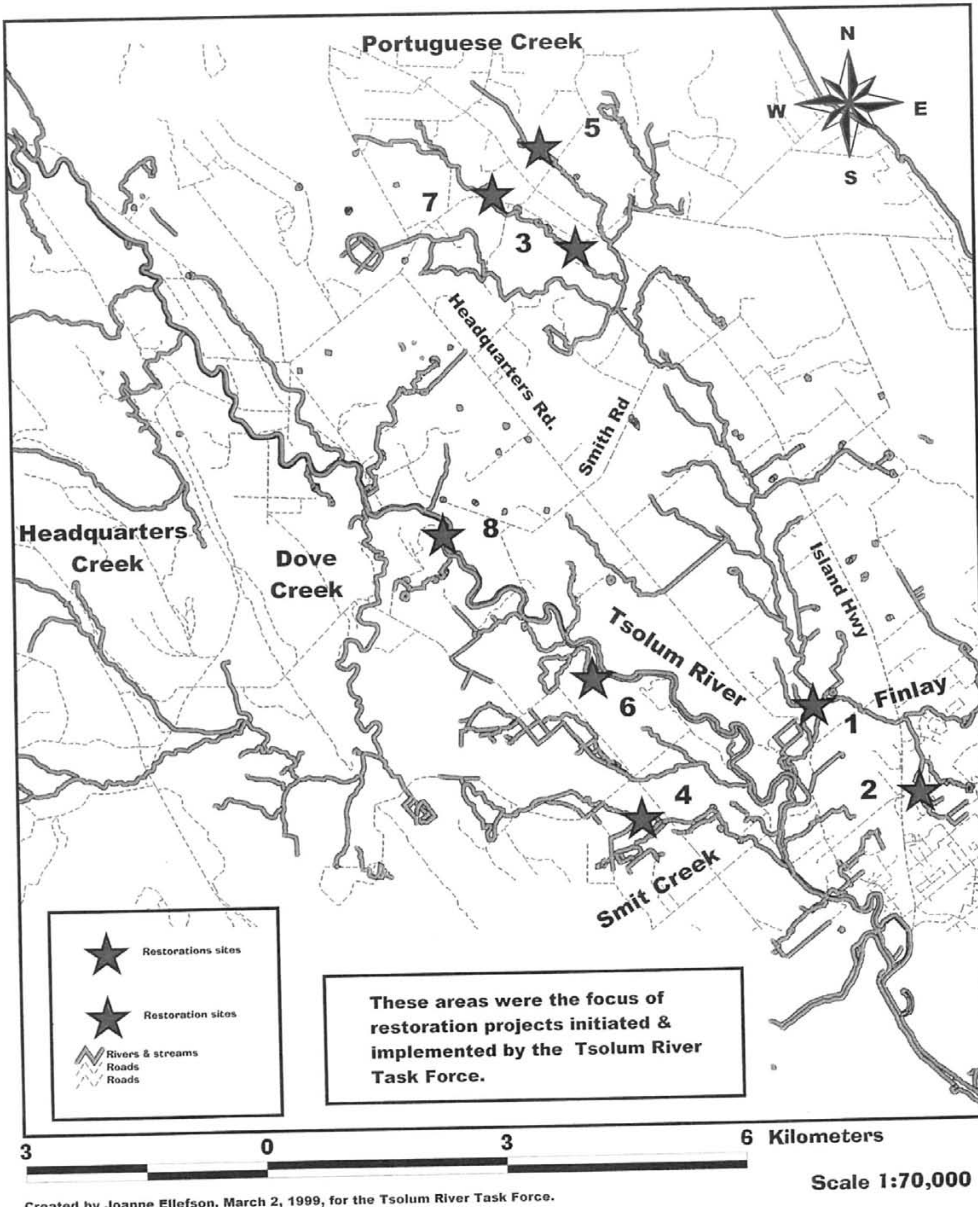
Map and Table of Restoration

Project Locations

Table 1. Completed Restoration Projects

	Project Title	Location	UTM Easting	UTM Northing	Date Begun	Date Completed
1a	Franklin Property Streambank Stabilization	Franklin Property Carwithen Rd. Lot 3 Sec 35 Comox Dist.	352362	5515924	March 25, 1998	April 29, 1999
1b	Franklin Property Channel Clearing	Franklin Property Carwithen Rd. Lot 3 Sec 35 Comox Dist.	352362	5515924	July 22, 1998	July 22, 1999
1c	Franklin Property Riparian Replanting	Franklin Property Carwithen Rd. Lot 3 Sec 35 Comox Dist.	352362	5515924	July 28, 1999	July 28, 1999[A]
1d	Franklin Property Streambank Stabilization	Franklin Property Carwithen Rd. Lot 3 Sec 35 Comox Dist.	352362	5515924	March 15, 1999 Est In Process	March 26, 1999
2	Stream Complexing Findlay Creek	Findlay Creek Reach 3 Between. Wentworth & Caledon Rd.	356536 upstream	5508966 upstream	July 18, 1998	July 22, 1998
3	Refuge Pond Construction Portuguese Creek	Bell Property, Gunter Rd. Merville DL 147 Comox District	352362	5515924	August 8, 1998	August 8, 1998
4a	McWilliam Pond Riparian Raft	McWilliam Property 3465 Burns Rd Section 73 Comox District	353066	5508690	July 22, 1999	July 22, 1999
4b	McWilliam Property Stream Complexing, Pond Construction	McWilliam Property 3465 Burns Rd Section 73 Comox District	353066	5508656	September 12, 1998	October 8, 1998
4c	McWilliam Property Refuge Pond LW Placement	McWilliam Property 3465 Burns Rd Section 73 Comox District	353066	5508656	October 30, 1999	October 30, 1999
5	Heidema Property Refuge Pond, and Stream Channel Reconstruction	Heidema Property 6850 N. Isl. Hwy	351928	5517195	August 17, 1998	August 31, 1998
6	Gark Property Culvert Installation Stream Complexing	Gark Property 4052 Dove Cr. Rd. Lot B DL 122 Comox District DD 34556-1	352483	5510479	August 19, 1998	September 8, 1998
7	Pistell Property Stream Complexing	Pistell Property 6669 N. Isl. Hwy.	351300 upstream	5516672 upstream	August 14, 1998	August 20, 1999
8	Jorgensen Property Sidechannel Armoring	Jorgensen Property, Todd Rd Site 463 C5, RR #4 Courtenay	Unkn	Unkn	October 15, 1998	October 22, 1998

Tsolum River Restoration Projects



Created by Joanne Ellefson, March 2, 1999, for the Tsolum River Task Force.

SECTION 9. APPENDIX B

Willow Wattling Photos

Figure B.1 Willow wattles constructed in Portuguese Creek July 1998.

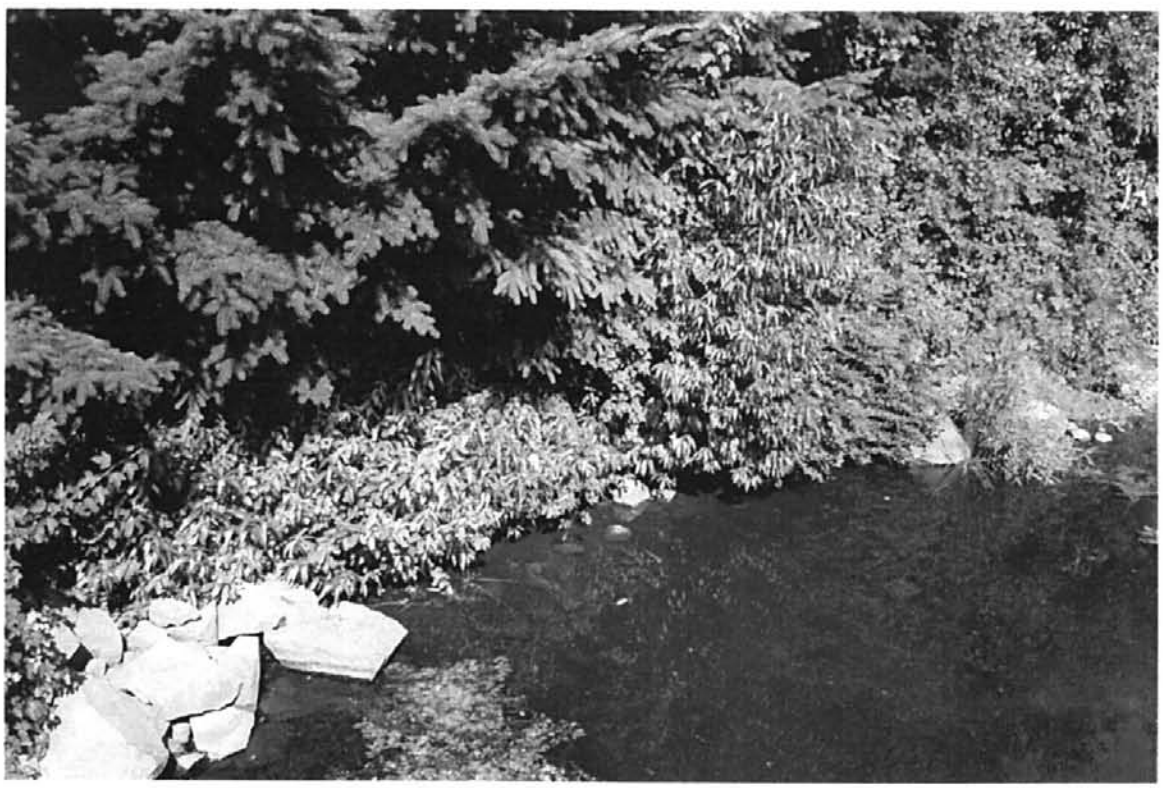


Figure B.2 Willow wattles at the same site in September 1998.

SECTION 9. APPENDIX C

List of Species Planted

Appendix C: Plants Used in Riparian Replanting Projects

COMMON NAME	SCIENTIFIC NAME
Red Alder	*Alnus rubra*
Red osier Dogwood	*Cornus stolonifera*
Black Hawthorne	*Crataegus douglasii*
Ocean Spray	*Holodiscus discolor*
Black Twinberry	*Lonicera involucrata*
Pacific Crabapple	*Malus fusca*
Pacific Ninebark	*Physocarpos capitatus*
Cascara	*Rhammus purshiana*
Nootka Rose	*Rosa nootkana*
Hooker's Willow	*Salix hookerania*
Sitka Willow	*Salix sitchensis*
Red Elderberry	*Sambucus racemosa*

SECTION 9. APPENDIX D

Photos of riparian rafts

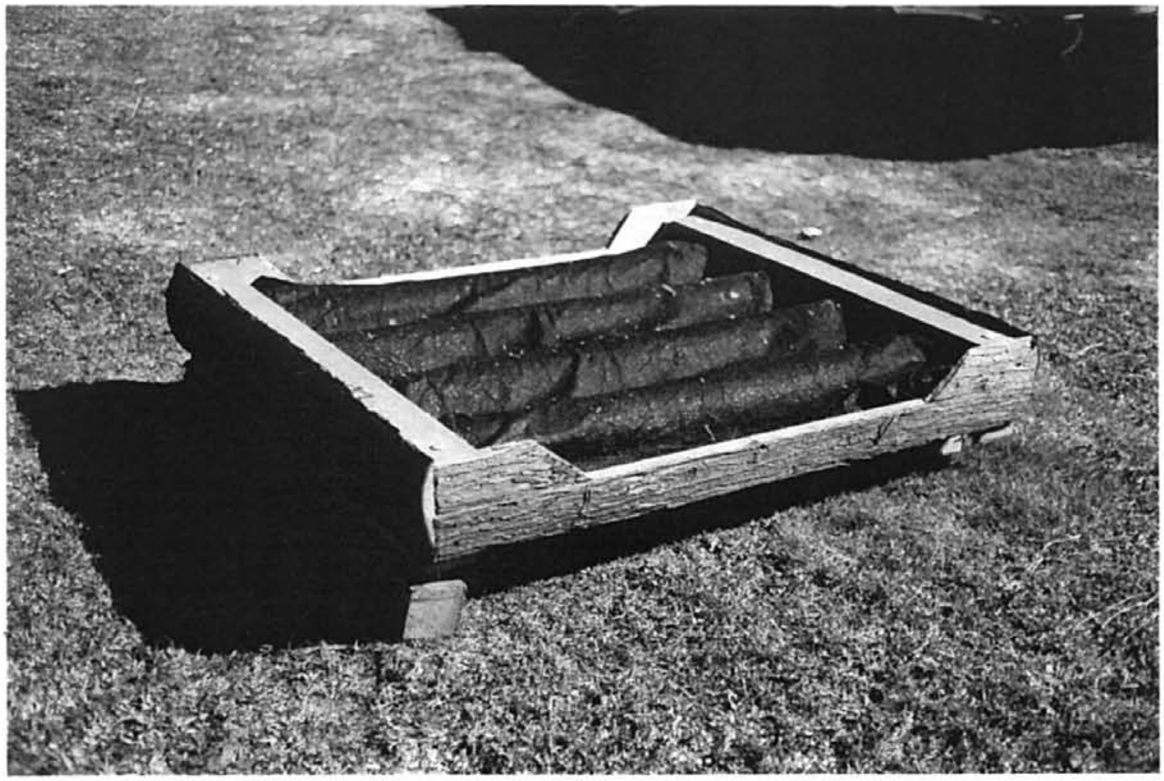


Figure D.1 Riparian rafts are built by piling soil on a floatation bed.

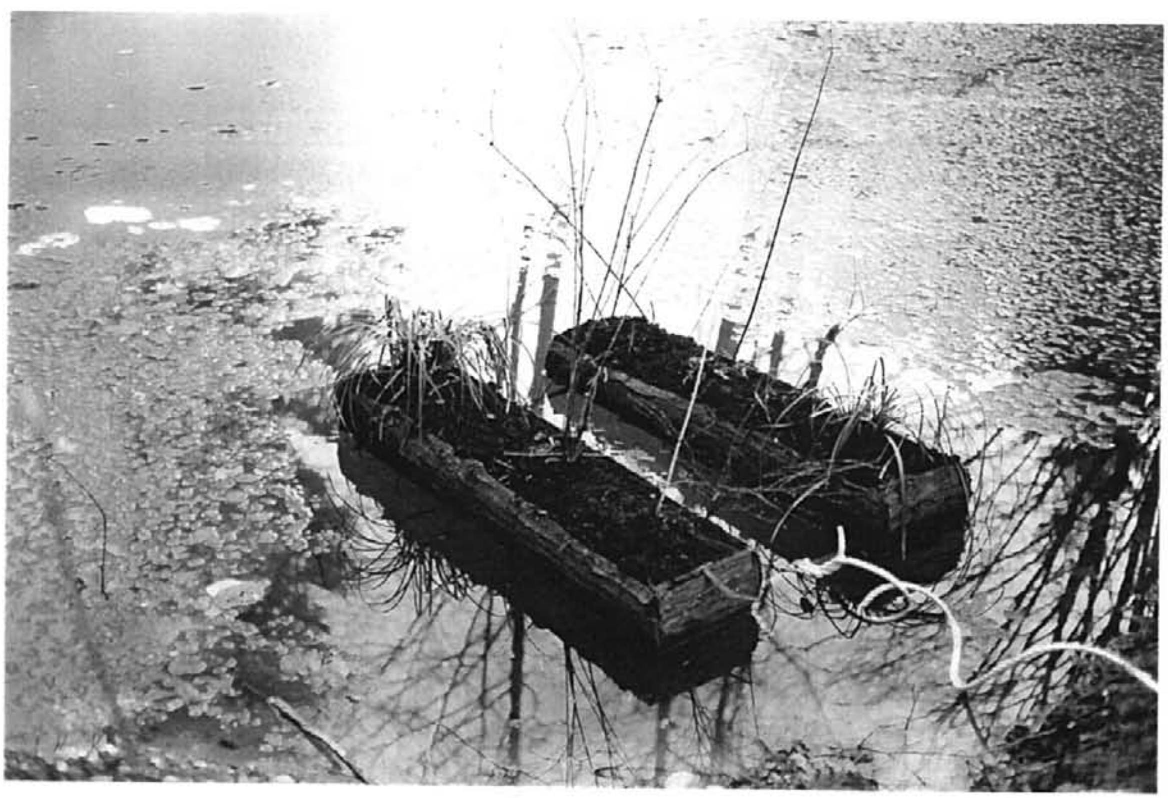


Figure D.2 The plants on the raft provide shade, cover and contribute pond nutrients.

SECTION 10

FLOWS AND STORAGE REPORT

SECTION 10. FLOWS AND STORAGE REPORT

Introduction

In 1964, DFO installed a concrete dam and control works at the Wolf Lake outlet to facilitate water storage and augment stream flow during times of low rainfall (Appendix A, Figure A.1). The 156 ha lake flows into Headquarters Creek, a main tributary of the Tsolum River (Walsh 1997). In 1997 and 1998, funds provided by the TRTF assisted DFO engineers in repairing a leaking rock weir located beside the dam. When lake levels were high water leaked through the weir into Headquarters Creek. This meant less water was available for controlled release when water was needed downstream in late summer. Controlled water releases from Wolf Lake normally occur between August 15 and September 30. This released water maintains flows in the lower river at or above 15 cfs (10% of mean annual discharge), the minimum acceptable flow for fish survival (B.C. Environment Ministry 1992).

The water released from Wolf Lake that travels down Headquarters Creek into the Tsolum River is used for fisheries enhancement and is removed for agricultural irrigation . Additional losses result from evaporation, deep percolation and ground water seepage into the floodplain. Of these losses, seepage is believed to be more significant (Associated Engineering Services Ltd. (AESL) 1976). In the summer of 1998, the TRTF installed five index wells for monitoring ground water seepage (Appendix A, Table and Figure A.1).

As pink salmon enter the Tsolum River in August or September they are confronted with high temperatures. Low water levels also expose gravel bars in the lower river that present barriers to adult migration (Table and Figure A.2). Increasing water flows through controlled releases provides more suitable conditions for adult migration and also benefits coho and trout fry rearing in the system. The increased flow also provides benefits for the agricultural industry which withdraws water from the Tsolum River for irrigation (Figure A.3) .

Methodology

Wolf Lake Weir and Dam

The Wolf Lake weir extends 23.5 m (Appendix B, Figures B.2 and B.3). DFO weir site assessments in 1997 and 1998 led to several recommended repairs (Busto, 1998). To reduce resistance and improve flow from the dam, an excavator removed debris from the outflow channel in August 1997.

While lake levels were low in August 1998, logs were removed from the weir by DFO staff. Steel mesh was placed over the weir to provide increased stability before the concrete cap was poured to cover the mesh. After capping the weir with concrete, void spaces in the weir were filled with a no-shrink grout.

At the Wolf Lake outlet, a 5' (1.53 m) wide slide gate at the base of a concrete dam allows release of lake water to Headquarters Creek. The dam slide gate is lifted by means of a worm gear. The length of exposed thread is an indicator of the distance the gate has been lifted. The gate overlaps the sill; therefore it must be lifted approximately 1 5/8" (4.1 cm) before water flows freely through the opening (Appendix C Table C.1).

The water flow through the gate depends on the size of the opening and on the head difference between the upstream (lake) and downstream sides of the dam (Appendix C Figure and Table C.2). At high lake levels water passes over a rock weir to enter the creek via a bypass channel.

Index Wells

In July 1998, the TRTF established five index wells within the Tsolum River floodplain (Appendix B, Figure 4). These wells were installed to measure the water table elevation at different distances from the river. This data, correlated with stream flow data, was to be used for predicting stream water losses by seepage.

The lower Tsolum River index wells, referred to as the Regional District of Comox-Strathcona (RDCS) wells, are located across the river from the WCS hydrometric station 08HB011 (200 m downstream of Rees Bridge). They are 15.5 m and 25.3 m from the top of the stream bank. These wells were constructed by driving well points approximately 5 m into the ground using a manual post pounder. The well points are 1¼" x 18" sand points with 80 mesh screens. Approximately 1.5 m of the well pipe is above ground level. This exposed pipe is painted with fluorescent paint for easy detection. In between measurements, a threaded cap is securely fastened on the top to prevent tampering (Appendix B, Figure B4).

The other three index wells, known as the Cubitt wells are located on private property near Tsolum River road between Dove Creek and Headquarters Creek. These wells are located 6.8 m, 14.1 m and 20.3 m from the riverbank. Installing these wells entailed drilling with a 6" hand auger, placing the well casing, backfilling the hole and tamping. These 3 m deep wells have a casing of 4" PVC sewer pipe. There were some difficulties encountered in choosing good sites for the wells and in well point installation.

The benchmark at the lower Tsolum River flow station is 5.51 m above mean sea level. This benchmark is also used for the flow station stage data. A differential level survey was conducted to measure the elevation of the top of the two wells relative to the benchmark. The level was proofed for accuracy before taking the measurements.

Well water depth measurements occurred weekly, from mid August to early September. Stage or depth is measured with a Geotechnical Instruments pocket dip meter, model dm1.1m. These measured values are related to the surveyed relative elevations.

Stream Flow Measurement

There are five Water Survey of Canada (WSC) hydrometric stations in the Tsolum River watershed. These are located at the lower Tsolum River, near Courtenay; Dove Creek, Headquarters Creek at the hatchery, in the Tsolum R. mainstem 500 m downstream of Murex Creek and on Pyrrhotite Creek at Branch 126. These stations have staff gauges and a data logger to continuously record stream depth or stage.

Records for the WSC flow station in the lower Tsolum River (08HB011) cover the periods 1914-1920, 1955-57, and 1964 on. This station is located approximately 14 km downstream of the Headquarters Creek hatchery, and is downstream of most pumping stations on the river. The stream level is recorded hourly. A preliminary stage to flow conversion table for the lower Tsolum River is presented in Appendix C Table and Figure C.3

The flow station on Headquarters Creek was established in June 1997 by WSC with support from DFO It is located at the Headquarters Creek hatchery approximately 6 km downstream from Wolf Lake.

Results

Wolf Lake Water Levels and Water Release

In 1997, the level of Wolf Lake dropped 34 cm (1.1'), from May 14 to August 14. This drop is attributed to leakage and overflow at the rock weir. Weir repairs are completed and it is anticipated that the lake level in August 1999 will be approximately 2.9 m (McLean, 1999). This represents an additional 71 ha-m (575 acre-ft) of stored lake water available to enhance downstream water levels.

On August 14, 1997 at 10:35 the gate at the dam was lifted to give an opening of approximately 2¼". At 12:00 this was decreased to an opening of 1$^{1}/_{16}$" (1.1 cm). It was opened to 2" (5 cm) on August 15 (15:40); 3" (7.6 cm) on August 18 (15:15); 4" on August 19 (15:43) and 5 inches on Sept 8 (11:30). Appendix C Table C.4, summarizes flow changes resulting from these releases. A stepped release pattern is used to avoid abrupt changes in downstream flow that could endanger swimmers.

On August 14, 1998 at approximately 09:30 the gate was opened to approximately 1" (2.5 cm). The gate was opened to 2" (5 cm) on August 17 (10:37); and 3" (7.6 cm) on August 19. A record of 1998 gate operation dates and the resultant flow in Headquarters Creek and the Tsolum River are presented in Appendix C,

Flows

Water released from Wolf Lake resulted in a corresponding flow increase in the Tsolum River. The flow records graphed in Appendix C illustrate this. Figure C2 shows flow in Headquarters Creek and the lower Tsolum River between August 12 and September 10, 1997. In 1997, flow in the Tsolum increased to 900 *cfs* on August 26, due to heavy rain. This value is off the scale presented in figure C2.

Stream water losses are determined using the hourly recorded flow data. This assumes negligible inputs from other Tsolum River tributaries. It is further assumed that the watershed water balance remains stable over several hours.

In 1997, there were minimal water losses. The negative loss values may be attributed to measurement error. During the 1997 Wolf Lake water releases, less than 20% of the water was lost. Expected losses due to evaporation, seepage and water withdrawals did not materialize. This may be due to rainfall in June and July, and the short dry period in August (Figure C4). This precipitation would result in a higher water table and lower summer irrigation requirements.

Calculated water losses for 1998 are as high as 64%. Comox airport summer precipitation data for 1998 reveals a dry summer, compared with 1997. Seepage losses are expected with the resulting lower water table. During hot dry weather, irrigation demands and evaporative water losses are higher. If the seepage losses from the river could be accurately measured and predicted, the timing and amount of the water release from Wolf Lake could be optimized for fish survival.

After the lake water is released, there is a time lag before the increased stream flow reaches the measurement stations at Headquarters Creek Hatchery (6 km downstream), and the lower Tsolum station (20 km downstream). Response time varies between three and six hours for the water to reach the hatchery, and between 11 and 31 hours for water to reach the lower Tsolum station. The time lag is shorter as water moves faster at higher flows.

There is no simple relationship between the flow released from Wolf Lake and water temperature in the lower Tsolum River. Although Wolf Lake was the warmest site monitored in this study, water released from the lake does not raise water temperatures downstream because the temperature of water released from the lake is modified as the water flowing downstream makes contact with the atmosphere. The decrease in mean daily water temperature of 4°C (Figure C.4) in the lower Tsolum River in mid August coincided with lake releases, but was actually due to a cooling trend in the weather. Mean daily air temperature at the Comox Airport dropped 9°C between August 13 and 16. This cooling trend preceded a few days of light rain and caused a drop in water temperature throughout the watershed.

Index Wells

The stage (depth) data for index wells in the lower Tsolum River, along with flow station stage, is presented in Figure C6. These results are inconclusive, and lead to several recommendations for future initiatives.

Recommendations

1. The lake is shallow (2 to 2.5 m) near the outlet into Headquarters Creek. If water were to be piped to the dam from the north end of the lake it would be possible to access cooler water from the deeper areas of the lake (39 m maximum depth). A temperature and depth study should be completed in 1999 to provide data on the lake's thermal profile.

2. Debris jamming at the Wolf Lake dam occurred in September 1998. To avoid re-occurrence, a boom and debris catcher should be placed at the lake outlet.

3. The climatic data referred to in this report is for the Comox airport weather station. It would be beneficial to continuously monitor rainfall within the Tsolum River watershed. A data logger monitored rainfall gauge is proposed.

4. Flow stations should be calibrated before water releases. This should take place in the first two weeks of August.

5. Consideration should be given to increasing downstream flows in the future. During the dry months of August and September 1998, there was no problem releasing enough water to maintain a 15 cfs flow rate.

6. The upstream Cubit wells are correlated with a stream flow station. A flow station should be installed near the well location.

7. More frequent measurement at additional points in the flood plain, are necessary to correlate lag time between river flows and ground water levels to predict seepage losses. Continuous monitoring of well water levels could be carried out with the use of electronic data loggers.

References

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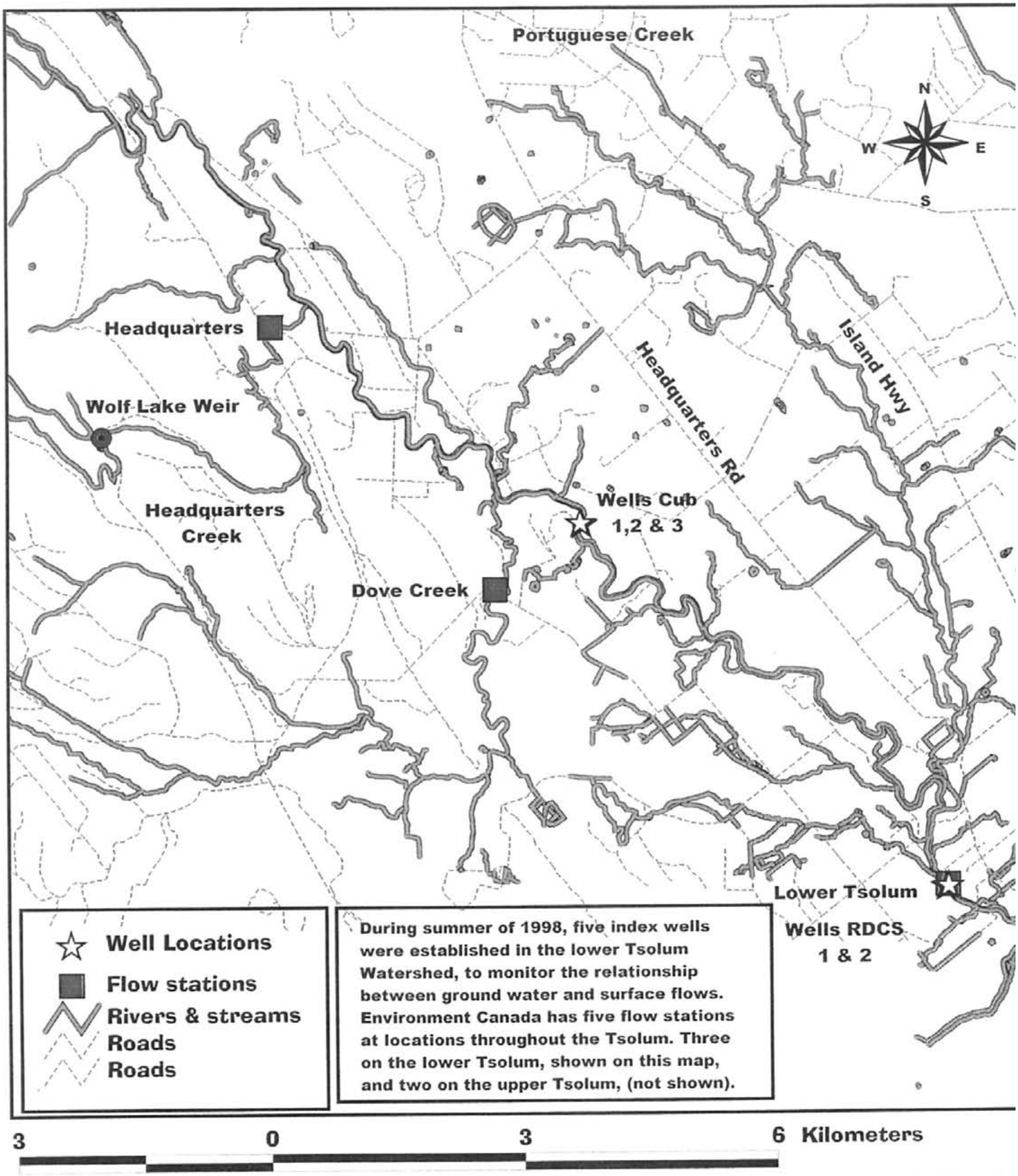
SECTION 10. APPENDIX A

Lower Tsolum River
Flow Station and Well Locations

Tsolum River Index Well Sites

Site	Location	UTM North	UTM East	Address
RDCS 1	Well located 50 m from edge of river	5507911	354985	Behind the RDCS fairground downstream of Rees Bridge
RDCS 2	Well located 75 m from edge of river	5507922	355019	Behind the RDCS fairground downstream of Rees Bridge
CUB 1	Well located 25 m from edge of river	5512310	350677	Cubitt-Morwood Property 6019 Tsolum River Road
CUB 2	Well located 75 m from edge of river	5512302	350688	Cubitt-Morwood Property 6019 Tsolum River Road
CUB 3	Well located 100m from edge of river	5512291	350700	Cubitt-Morwood Property 6019 Tsolum River Road

Lower Tsolum River
Flow Station & Well Locations



Scale 1:70,000

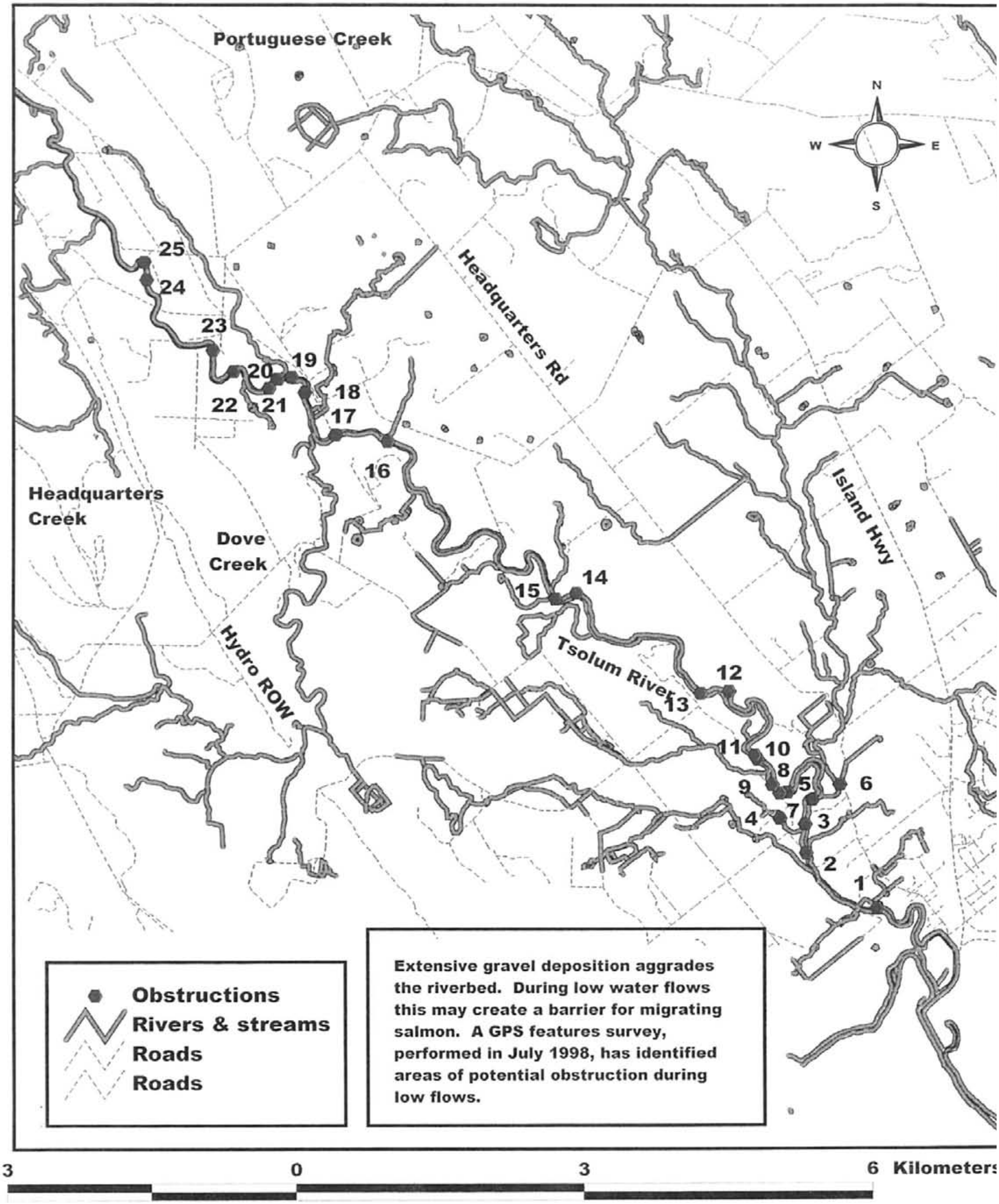
Created by Joanne Ellefson, March 2, 1999, for the Tsolum River Task Force.

Table A.2 Low Flow Obstructions, Tsolum River

Feature Number	Feature Type	Comment	UTM East	UTM North	Length	Height	Width	Depth
15	Other	Gravel bar possibly a barrier during low flows.	355538	5507627			12.00	0.15
24	Other	Potential gravel bar barrier at low flows.	354803	5508217				0.15
27	Other	Presently passable but may be a barrier during low flows.	354793	5508519	3.00	0.10	14.00	
33	Other	Top end of gravel wedge is a possible barrier during	354868	5508776	20.00		50.00	1.00
36	Other	Riffel,possible barrier at very low flow.	355158	5508938	17.00		1.70	0.15
47	Other	Braid .Left 50%, right 50%. Vegitated gravel ridge.	354612	5508858	65.00			
48	Other	Possible gravel barrier at the top end of the wedge.	354533	5508846			12.00	0.80
49	Other	Braid. right 70%, left 30%. Shallow gravel bar unvegi	354455	5508936	38.00	0.30		
51	Other	Braid Right 40%,left30%.shallow unvegitated gravel bar	354301	5509207	47.00			
52	Other	Gravel bar which may be a barrier during low flows.	354270	5509250		0.10	30.00	0.80
65	Other	Potential barrier at lowest flows.	354004	5509923		0.50	34.00	0.35
70	Other	This gravel bar has a change in gradient.	353713	5509904			34.00	35.00
81	Other	Cobble boulder bar, possible barrier during low flows.	352418	5510963	15.00		16.00	0.20
86	Other	Cobbel riffle, possible barrier at lowest flows.	352197	5510903	62.00		2.50	0.30
114	Side channel	Upper entrance filled with sand and gravel.	350447	5512566		0.60	4.50	
124	Obstruction		349909	5512635	43.00		24.00	0.15
131	Obstruction	Potential barrier from top of rearing pool until next	349587	5513082				0.15
133	Obstruction		349448	5513245	50.00		24.00	17.00
137	Obstruction	Cobble/boulder riffle, possible barrier at lowest flows.	349305	5513223	51.00		17.00	0.15
140	Obstruction	Possible barrier.	349214	5513126	3.00		18.00	0.12
144	Obstruction	Potential barrier.	348849	5513304	1.50		28.00	
148	Obstruction	Cobble/boulder riffle, possible barrier in low season.	348632	5513529	138.00		24.00	0.15
159	Obstruction	Gravel bar.	347948	5514270	2.00	0.05	26.00	
162	Obstruction	Possibly enhanced by humans.	347922	5514457	2.50		21.00	0.10

Data collected by B.C. Hydro Crew, Gord Bainbridge, Leah Brown, Jenifer Alton, Allison Garbut during the summer of 1998 on the Tsolum River. The SHIM survey methodology, was used to collect all data.

Tsolum River Low Flow Obstruction Sites

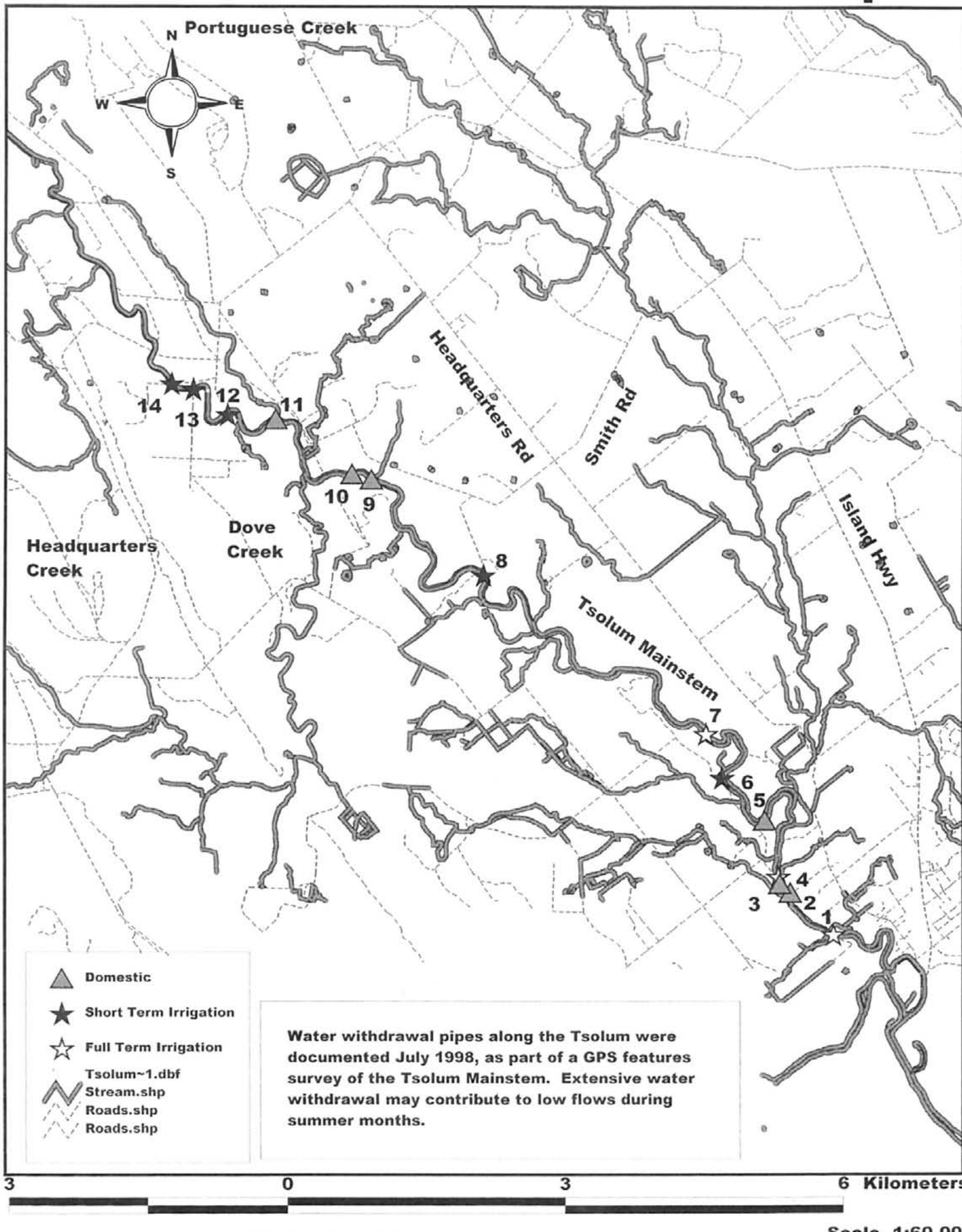


Extensive gravel deposition aggrades the riverbed. During low water flows this may create a barrier for migrating salmon. A GPS features survey, performed in July 1998, has identified areas of potential obstruction during low flows.

Scale 1:60,00

Created by Joanne Ellefson, March 2, 1999, for the Tsolum River Task Force.

Tsolum River Water Withdrawal Pipes



Water withdrawal pipes along the Tsolum were documented July 1998, as part of a GPS features survey of the Tsolum Mainstem. Extensive water withdrawal may contribute to low flows during summer months.

Created by Joanne Ellefson, March 2, 1999, for the Tsolum River Task Force

SECTION 10. APPENDIX B

Photographs of Wolf Lake dam and weir and index well site.

Figure B.1. Headquarters Creek, looking upstream to Wolf Lake Dam (summer 1998).

Figure B.2. Weir at Wolf Lake outlet, prior to weir repairs (summer 1998).

Figure B.3. Repairing weir at Wolf Lake outlet (summer 1998).

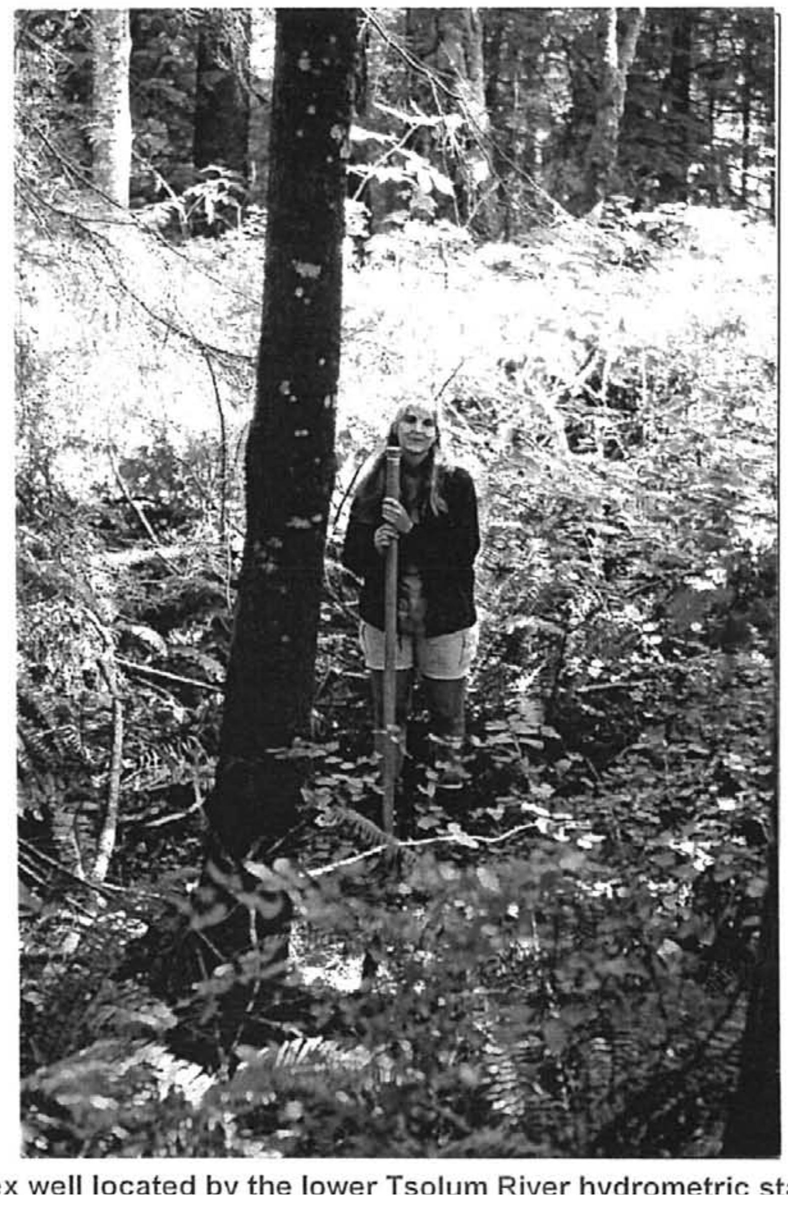


Figure B.4. Index well located by the lower Tsolum River hydrometric station (summer 1998).

SECTION 10. APPENDIX C

Graphed and tabulated stream flow and water storage data, 1997 and 1998

Table C.1. Water released from Wolf Lake, Flow Increases Downstream, and Delay between Release time and Flow Increase; 1997.

Release at	Change in Flow cfs						
Wolf Lake	Headquarters Cr.		Tsolum River		Loss	Loss	
Date Gate Opened	Increase	Delay hrs	Increase	Delay hrs	cfs	%	Comments
14-Aug-97 10:35	15.5	3.9					gate opened briefly
14-Aug-97 12:45	8.6	5.0	7.2	17.3	1.40	16.3	
15-Aug-97 15:40	3.7	3.1	4.1	17.9	-0.41	-11.0	
18-Aug-97 15:15	4.6	3.7	4.1	14.8	0.51	11.0	
19-Aug-97 15:43	5.2	3.0	6.0	13.3	-0.75	-14.4	rain in watershed
8-Sep-97 11:30	6.2	2.8	4.0	11.1	2.24	36.1	after large flood

Watershed was stable until rain on Aug 20. The August 19 release may have been influenced by rain in upper watershed. There was a flood in late August/early Sept -- conditions were not stable on Sept 8. Using 4 values(Aug 14 12:45 to August 19) the mean % loss was:

Mean % Loss 1997 0.5

(note: negative loss means flow created between HQ and lower Tsolum - probably due to measurement error)

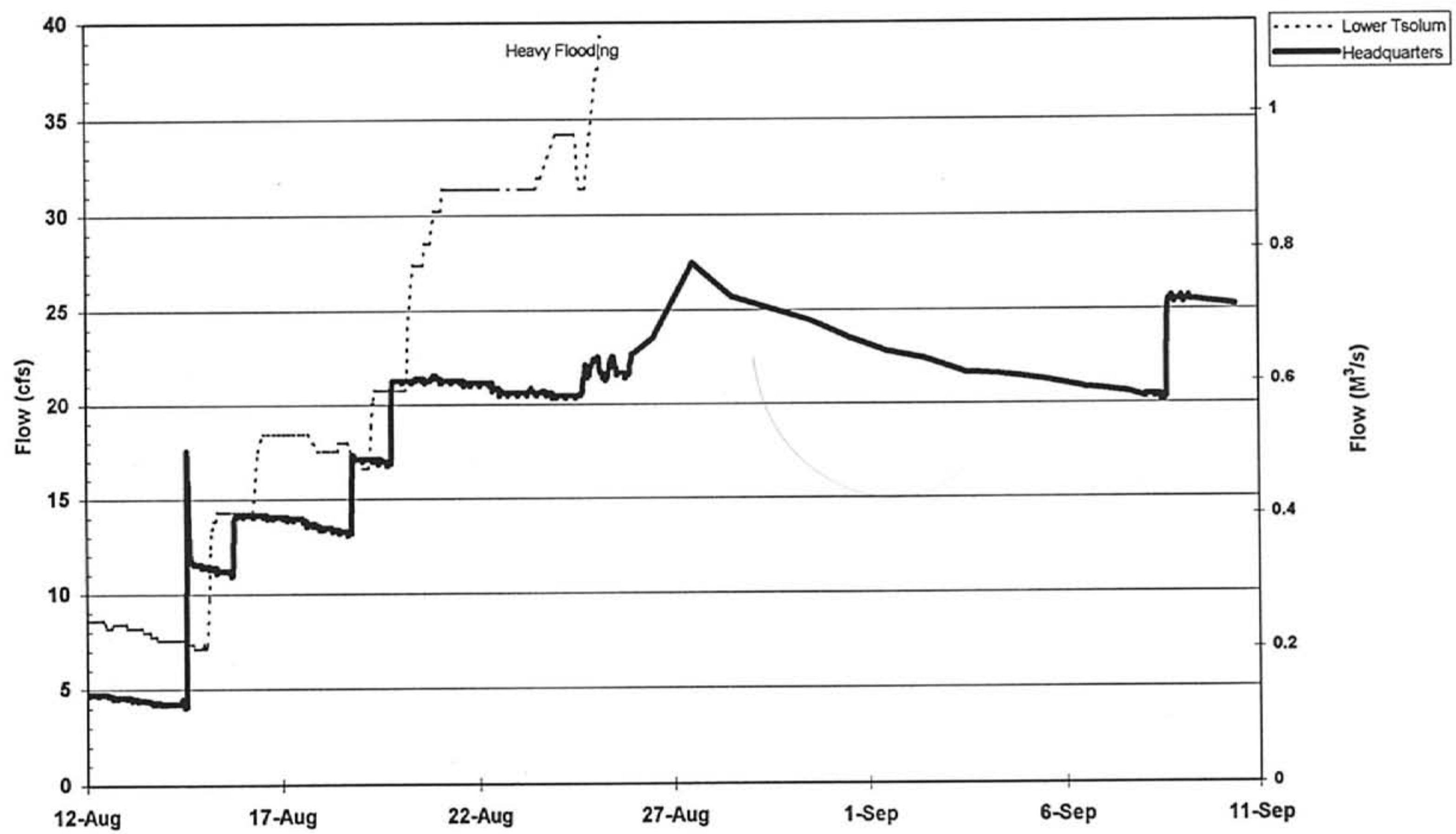


Figure C.1. Lower Tsolum River and Headquarters Creek Flow Curves for Summer 1997, Wet Year.

Table C.2. 1998 Water Stage to Flow Conversion Table for the Lower Tsolum River.

Gauge m	Flow m3/s	cfs
0.66	0.01	0.4
0.67	0.02	0.7
0.68	0.04	1.4
0.69	0.06	2.1
0.7	0.09	3.2
0.71	0.12	4.2
0.72	0.16	5.7
0.73	0.2	7.1
0.74	0.25	8.8
0.75	0.3	10.6
0.76	0.35	12.4
0.77	0.4	14.1
0.78	0.46	16.2
0.79	0.56	19.8
0.8	0.66	23.3

Table used to extrapolate flow from flow station stage value.
All data is preliminary.

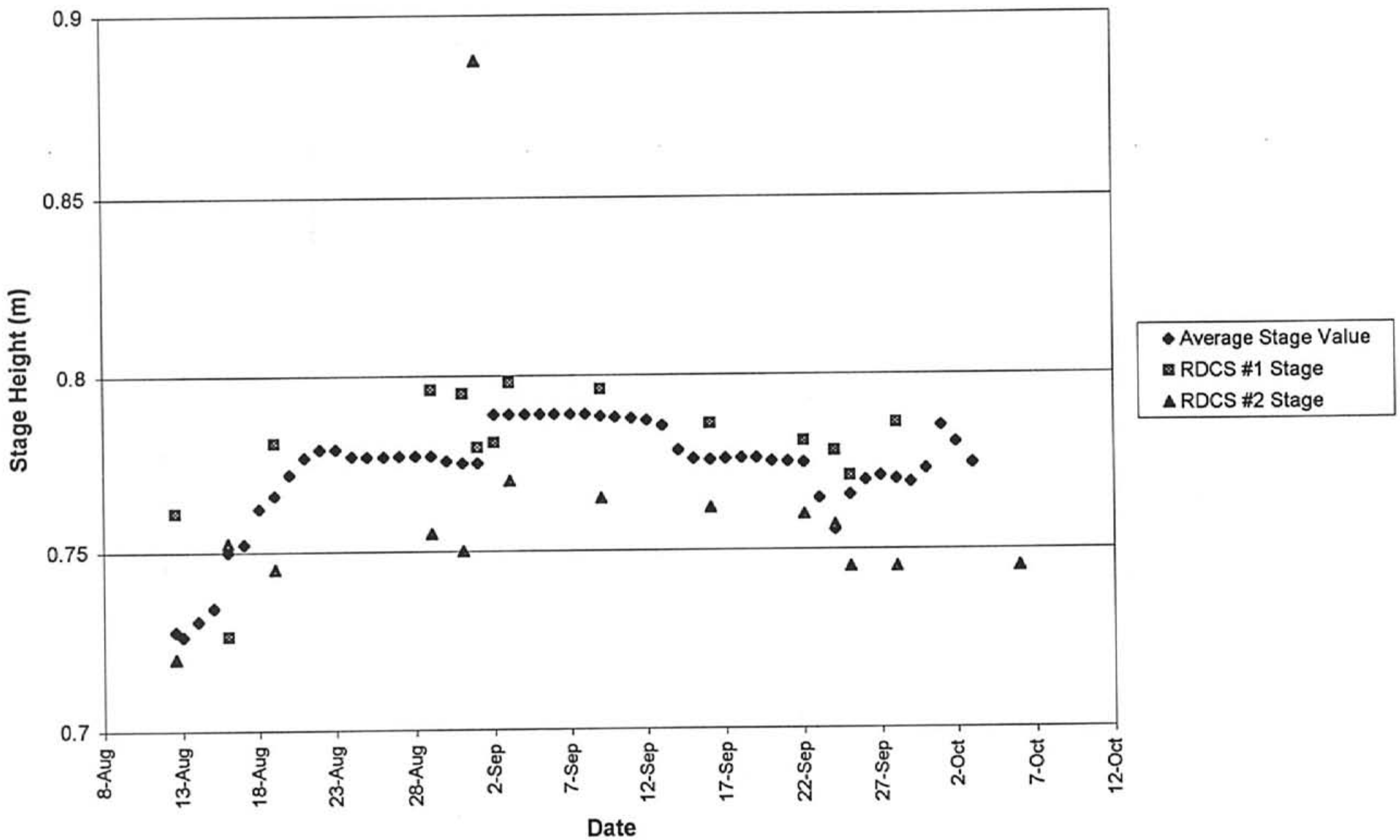


Figure C.2. Water Stage Data for the Lower Tsolum River Hydrometric Station and Index Wells.

Table C.3. 1998 Water Stage to Flow Conversion Table for the Lower Tsolum River.

Model -- Table Curve 2D

Q = a + bx^c; r^2 = 0.999

a = -2.83343

b = 1.14682

c = 8.414782

		Measured Values		Model
Date	Gauge m	Flow cms	Flow cfs	model cfs
2-Jun-98	1.24	0.116	4.1	4.2
12-Aug-97	1.261	0.146	5.15	5.2
18-Aug-98	1.348		12.8	11.3
28-May-97	1.352	0.328	11.6	11.7
29-Jul-97	1.353	0.318	11.2	11.8
15-Aug-97	1.362	0.345	12.2	12.6
18-Aug-97	1.386	0.423	14.9	15.0
20-Aug-98	1.393	0.419	14.8	15.8
19-Aug-97	1.42	0.572	20.2	19.1
20-Aug-97	1.456	0.688	24.28	24.2
10-Sep-97	1.486	0.821	28.99	29.3
30-Apr-97	1.665	2.29	80.9	80.9

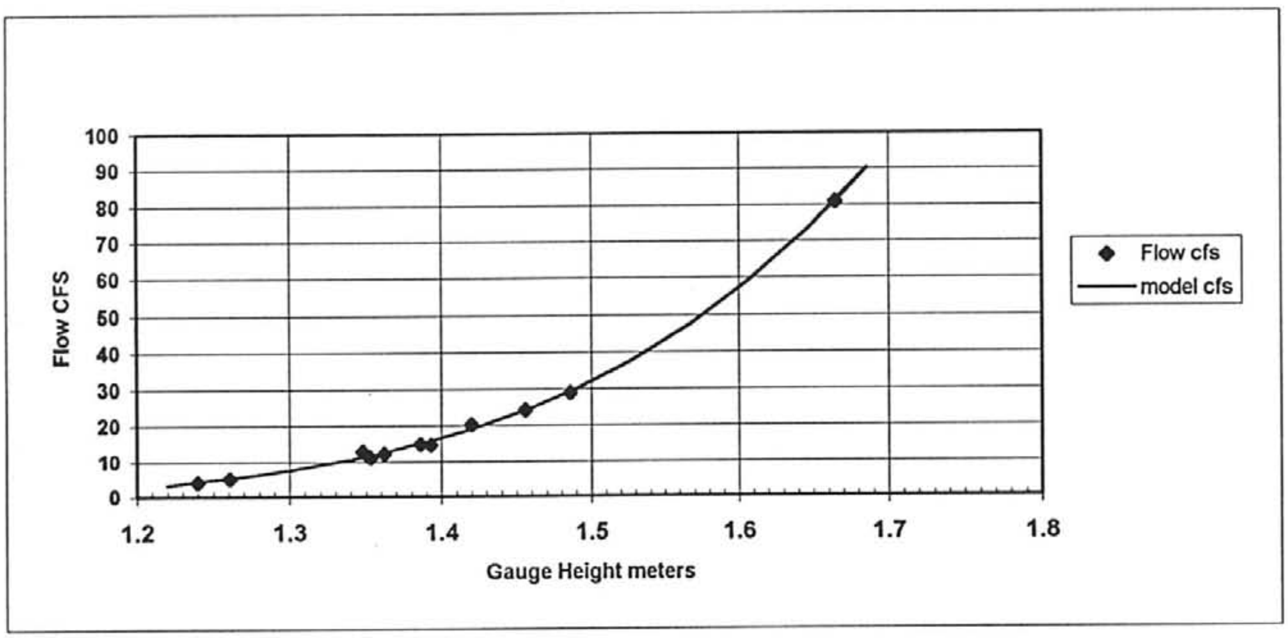


Figure C.3. Headquarters Creek Flow Calibration Curve, October 1998

Table C.4. Water released from Wolf Lake, Flow Increases Downstream, and Delay between Release time and Flow Increase; 1997.

Release at	Change in Flow cfs						
Wolf Lake	Headquarters Cr.		Tsolum River		Loss	Loss	
Date Gate Opened	Increase	Delay hrs	Increase	Delay hrs	cfs	%	Comments
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15-Aug-97 15:40	3.7	3.1	4.1	17.9	-0.41	-11.0	
18-Aug-97 15:15	4.6	3.7	4.1	14.8	0.51	11.0	
19-Aug-97 15:43	5.2	3.0	6.0	13.3	-0.75	-14.4	rain in watershed
8-Sep-97 11:30	6.2	2.8	4.0	11.1	2.24	36.1	after large flood

Watershed was stable until rain on Aug 20. The August 19 release may have been influenced by rain in upper watershed. There was a flood in late August/early Sept -- conditions were not stable on Sept 8. Using 4 values(Aug 14 12:45 to August 19) the mean % loss was:

Mean % Loss 1997 0.5

(note: negative loss means flow created between HQ and lower Tsolum - probably due to measurement error)

SECTION 11

ENHANCEMENT

Introduction

Historically the Tsolum River supported large numbers of pink and coho salmon, steelhead and anadromous cutthroat trout. The decline of pink salmon in the 1960's led to pink salmon stock enhancement initiatives. Current pink salmon enhancement projects in the Tsolum River watershed are the initiative of the Tsolum River Task Force (TRTF), in collaboration with Human Resources Development Canada (HRDC), and the Department of Fisheries and Oceans (DFO), Habitat Restoration and Salmon Enhancement Program.

Appendix A illustrates recorded escapement trends for Tsolum River coho salmon, pink salmon (even and odd year runs), and chum salmon. Appendix B, Table 1 summarizes the escapement records for these species, while Appendix B, Table 2 summarizes steelhead harvest analysis results.

Recorded coho salmon escapement numbers declined continuously from the late 1960's to the present (Appendix A, Figure A1). These coho escapements range from highs of 15,000 in the 1950's and early 1960's, down to 0 in 1994.

The odd year Tsolum River pink cycle collapsed in 1969. By the mid-seventies, with stocking efforts, both odd and even year pink escapements increased to approximately 10,000 fish (Appendix A, Figure A2). In the 1980's, the pink escapement numbers again declined to well below 1,000 fish.). Tsolum River chum salmon escapement records fluctuated significantly from the 1950's to the present with escapements ranging from 1 to 11,000 (Appendix A, Figure A3).

1968 to 1997 Enhancement Initiatives

Since 1968, efforts took place to supplement collapsed wild salmon stocks in the Tsolum River watershed. Appendix B, Table 1 summarizes Tsolum River salmonid enhancement efforts. DFO efforts to restore pink salmon and coho salmon stocks in the Tsolum watershed met with poor returns. This led to consideration of two limiting environmental problems - water quality and inadequate flows.

Present initiatives address problems of poor water quality and low summer flows in the Tsolum River watershed. Poor water quality is primarily attributed to the acid mine drainage from the abandoned copper mine near the summit of Mount Washington. Results from three bioassay studies support the theory that the acid mine drainage is adversely affecting Tsolum watershed fish populations (Deniseger et al., 1995).

In some years, low flows occurring in August and September resulted in high mortalities of migrating adult salmon (Walker and MacLeod, 1970). For example, in September 1951, extreme drought conditions trapped migrating pinks that entered the Tsolum River on the high tide. In response, DFO erected a temporary barrier near the outlet of the Tsolum River (PBS, 1951). This prevented more fish from entering the stream, subsequently becoming stranded and dying from lack of oxygen.

In 1964, DFO installed a concrete dam and control works at the outlet of Wolf Lake. This facilitates water storage and stream flow augmentation during low flows. Wolf Lake sources Headquarters Creek, a main tributary of the Tsolum River.

After the construction of the Wolf Lake flow control structure, efforts to enhance of pink, coho, cutthroat and steelhead populations began. In 1968, DFO established a hatchery on Headquarters Creek near its confluence with the Tsolum River. Poor salmon returns led to closure of the hatchery operation in 1984.

In 1968, DFO began a hatchery research program at Headquarters Creek. Incubation techniques were evaluated using gravel boxes built on Headquarters Creek (Bams and Crabtree, 1976). This program continued in 1970 and 1972 (Bams, 1979). Between 1968 and 1973, over 165,000 fry were annually released to Headquarters Creek from these gravel boxes (Appendix C, Table 1). In 1971, pink eggs were transported from Kakweiken River, a mainland stream that flows into Thompson Sound, Knight Inlet (Bams, 1976). Over half of these eggs were fertilized with sperm from Tsolum River males, and incubated in gravel boxes.

In 1978, the BC Fish and Wildlife Branch stocked Wolf Lake with 7,000 juvenile cutthroat trout (Bond, Circa 1978). Annual fish sampling is conducted in the lake (Peterson, 1999). The seined cutthroat are counted, sized, and sexed, and stomach contents are analyzed.

Headquarters Creek pink enhancement initiatives resumed in 1979. This resulted in 52,000 fry being released to the Tsolum River in the spring of 1980. In the fall of 1980, an enhancement effort began with the collection of over 1.2 million eggs. Egg incubation took place in gravel boxes or in keeper channels. The unfed pink fry were released to the Tsolum and Puntledge Rivers in the spring of 1981. Some fry were also reared in sea pens at the Courtenay River estuary. Releasing these fish at a larger size served to increase their ocean survival.

In 1983, the BC Ministry of the Environment stocked Headquarters Creek with juvenile steelhead and cutthroat trout (Stanton, 1999). This stock production occurred at the Puntledge River hatchery. The stock tagging and release took place at the smolt stage.

From 1984 to 1990, the Puntledge hatchery stocked several lakes in the upper Tsolum River watershed with coho fingerlings. These stocking sites included Little Lost Lake, Lost Lake, Helldiver Lake, Constitution Creek and Blue Grouse Lake. Habitat surveys revealed suitable rearing habitat in these areas (Tinney, 1985). Coho smolts (> 20 g) were also released from the Headquarters Creek hatchery in 1986 and 1990. Seaward smolt migrations of these released fry occurred in the spring of 1985, 1986, 1987, 1990 and 1991 (Appendix C, Table 1).

In 1993-1994 and 1994-1995, Comox Valley Project Watershed Society oversaw the incubation of pink eggs at the Headquarters Creek hatchery. The initiative used 110,000 transported Quinsam hatchery eggs. A survival of 98% from the eyed stage was realized (Chamberlain, 1998).

1997 to 1999 Enhancement Initiatives

With limited enhancement success, salmon stock restoration efforts have been redirected to solving the water quality and stream flow problems in the watershed. Present salmon enhancement efforts for the Tsolum River are small scale. The introduced salmon contribute to the stream nutrient cycle and food chain. They also serve as indicators of the stream health. If flow and water quality problems are resolved, the system may again support healthy, large returns of adult salmonids.

In October 1998 a pink egg incubation channel was established at the Headquarters Creek hatchery by converting one of the three concrete hatchery raceways to a keeper channel. This keeper channel is for incubating salmon alevins. The conversion entailed gravel placement, screen placement, and construction of over-raceway covers (see Appendix E).

A gravity fed water intake system cleans the hatchery keeper channel intake screens. Ten 4' by 8' screens, made of beach seine netting, sit above the gravel. After hatching the alevins fall through the screens and distribute themselves in the gravel. They remain in the gravel until they absorb their yolk sacs. Flow serves to maintain a suitable amount of oxygen and other dissolved gases, and to help distribute the alevins evenly through the gravel.

On September 21, 1998, eggs and milt were taken from broodstock at Quinsam Hatchery in Campbell River. These eggs were incubated to the eyed stage, then transferred to Puntledge Hatchery. Eggs were picked and then placed in the Headquarters Creek keeper channel. Siltation caused the loss of approximately 40% of the eggs before hatching. The remainder of the eggs hatched in February and were released from the channel in March 1999.

In mid November 1998, DFO transported 3500 adult chum salmon from the Puntledge River to the Tsolum River system at the Farnham Road bridge and Dove Creek (Campbell, 1999). In addition to restocking, these chum clean the spawning gravel of excess silt as they dig redds. Their decomposing carcasses also release nutrients back into the system.

In the summer of 1998, ten summer rearing ponds in the Portuguese Creek drainage were monitored. Coho fry salvaged from various locations in the lower watershed were transported to these rearing ponds. Other 1998 small stream restoration projects included the creation of vegetated shade rafts for some of these ponds.

In 1997 and 1998, adult pink salmon enumerations were conducted in the Tsolum River watershed. Official pink escapement numbers indicate returns of 0 for 1997 and 550 for 1998. In addition, anecdotal reports for 1998 indicate coho returns of 200 for Portuguese Creek and 150 for Headquarters Creek (Rosenguard, 1998). Snorkel surveys were completed for several streams in the area (Peterson, 1999). The snorkel survey carried out in one section of Dove Creek documented 34 coho and numerous redds.

Recommendations

1. With the present Headquarters Creek hatchery pink salmon incubation setup, siltation caused a 40 % egg loss. To avoid this in the future, a silt-settling pond is proposed. The keeper channel could be relocated to the middle or third raceway. The first raceway could then become the settling pond.

2. Information on water quality results, recorded flows, and bioassay results must be periodically reviewed for refining salmon stock enhancement plans. Water quality and flow monitoring should continue.

3. Pink salmon migration and spawning time coincides with timing for the same events in the Quinsam River, a cold water system near Campbell River, and the Glendale River, a warmer system in Knight Inlet. More study is needed to determine if there would an advantage to using the warm water Glendale stock to restock the Tsolum River.

4. There is an apparent relation between stream flows and escapement numbers. For example, notably higher Tsolum (and Puntledge) pink escapements (20,000) occurred in 1991, a year when high stream flow rates followed a year of pink enhancement. It is recommended that trends between flows, enhancement and adult returns be examined more closely.

5. Several individuals familiar with the Puntledge River and Tsolum River watersheds suggested that current adult pink returns to the Tsolum River may be a 'spillover' of Puntledge River fish. A suitable method for discerning between Puntledge and Tsolum stocks could confirm this. In the early 1980's, pink fry released to Headquarters Creek were marked with half dorsal fin clips (McLean, 1985). This type of marking reduces fish survival and is not unique. Another method, such as thermal marking, may be more appropriate.

6. A survey of adult chum salmon in the system is recommended to determine if transplanted adult chum are competing with the returning pink adults. These results could help determine suitable adult chum transplant numbers and locations.

7. It is recommended that data from fish habitat assessments be correlated with sustainable fish numbers and species. This may identify possible future enhancement plans, for example transplanting adults to underutilized habitat in the watershed.

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SECTION 11, APPENDIX A

Semi-log graph presentations of Tsolum River coho, pink and chum salmon escapements (1950 to present).

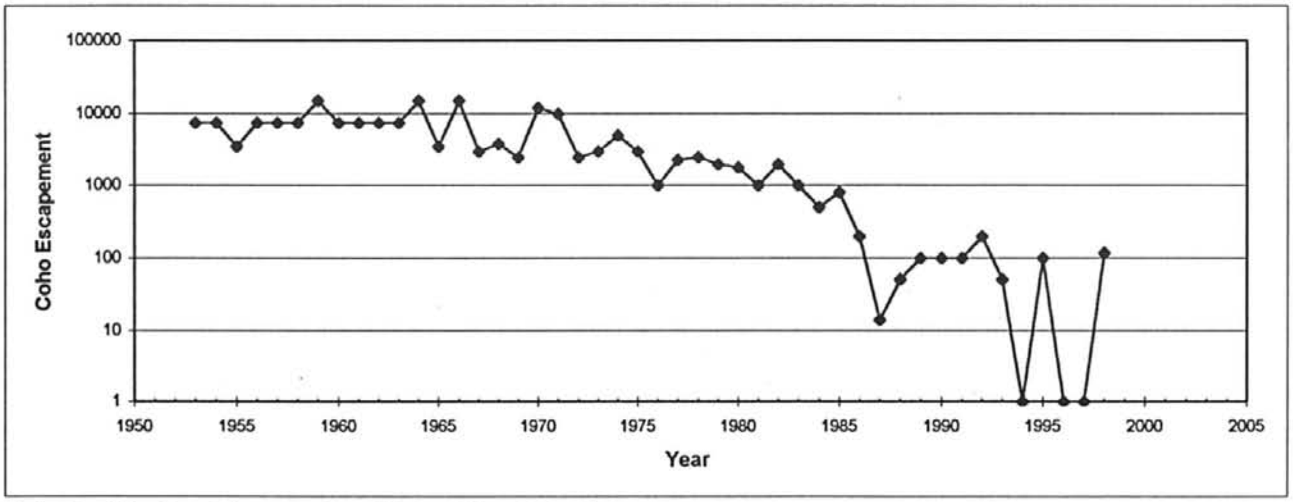


Figure A.1 Semi-log Graph Presentation of Tsolum River Coho Escapement Records. NB. 1 denotes 0 fish observed or escapement unknown.

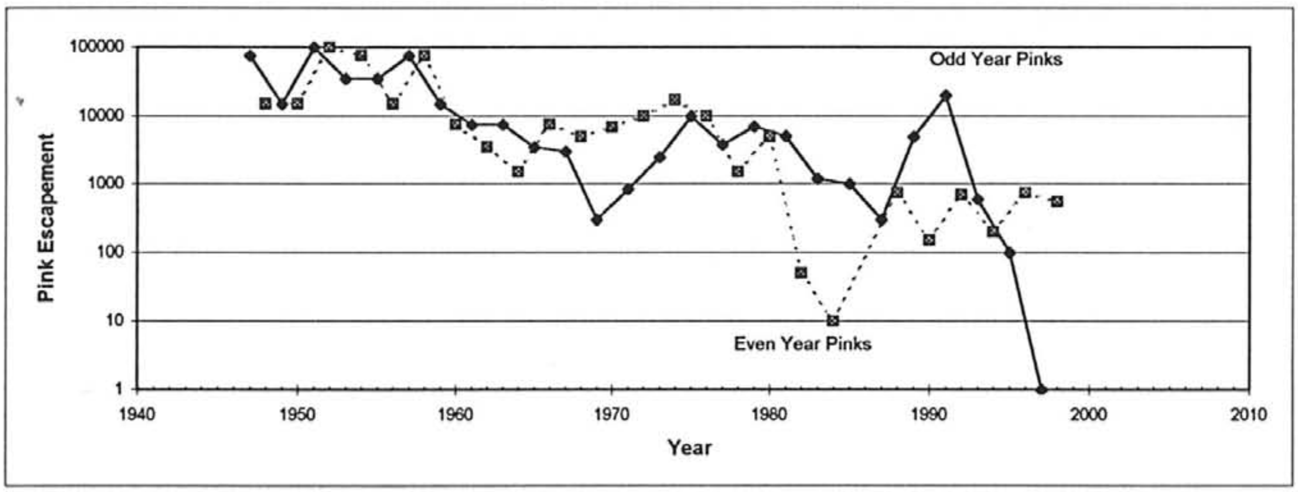


Figure A.2 Semi-log Graph Presentation of Tsolum River Pink Escapement Records. NB. 1 denotes 0 fish observed or escapement unknown.

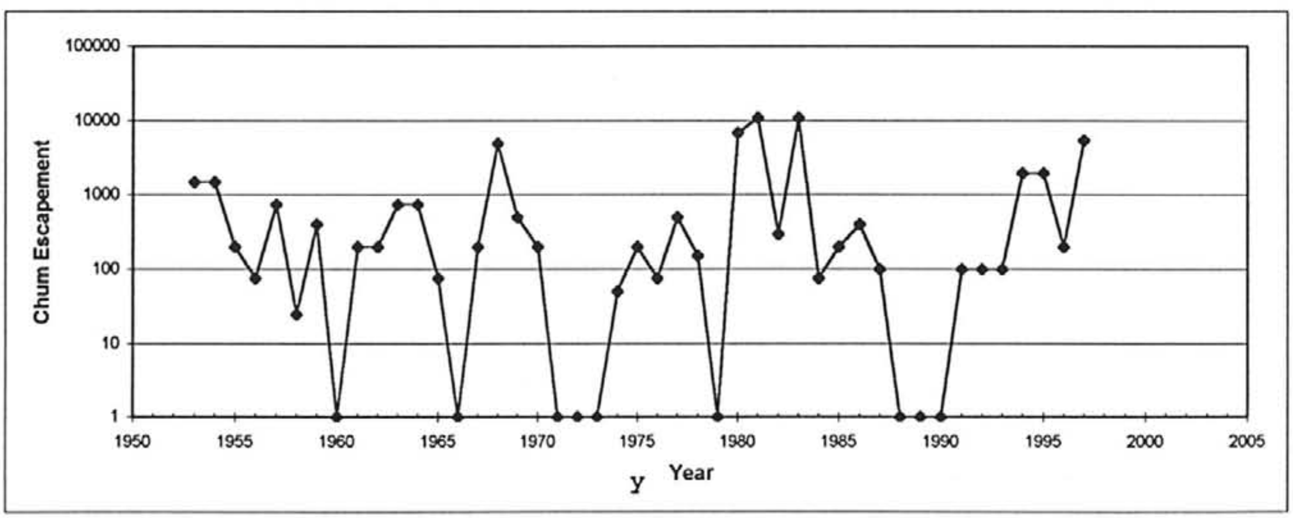


Figure A.3 Semi-log Graph Presentation of Tsolum River Chum Escapement Records. NB. 1 denotes 0 fish observed or escapement unknown.

SECTION 11, APPENDIX B
Historical Escapement Data

Table B.1 Historical Escapement Data

Tsolum River Salmon Escapements, 1953 to 1998
Watershed-code: 92-2800-010*

Year	Sockeye	Coho	Pink	Chum	Chinook
1953	0	7500	35000	1500	0
1954	0	7500	75000	1500	0
1955	0	3500	35000	200	0
1956	0	7500	15000	75	0
1957	0	7500	75000	750	0
1958	25	7500	75000	25	0
1959	0	15000	15000	400	0
1960	0	7500	7500	0	0
1961	0	7500	7500	200	0
1962	3	7500	3500	200	0
1963	0	7500	7500	750	0
1964	0	15000	1500	750	0
1965	25	3500	3500	75	0
1966	25	15000	7500	no	0
1967	25	3000	3000	200	0
1968	25	3800	5525	5000	0
1969	0	2500	300	500	0
1970	Unk	12000	6880	200	0
1971	Unk	10000	850	no	0
1972	Unk	2500	10000	no	0
1973	Unk	3000	2489	no	0
1974	0	5000	10100	50	0
1975	0	3000	10000	200	0
1976	Unk	1000	10000	75	no
1977	0	2300	3800	500	no
1978	0	2500	1500	150	0
1979	0	2000	7000	0	0
1980	10	1800	5000	7000	0
1981	0	1000	5095	11000	0
1982	0	2000	200	300	0
1983	0	1000	1200	11000	0
1984	0	500	10	75	0
1985	No	800	1000	200	no
1986	0	200	unk	400	unk
1987	0	14	300	100	0
1988	0	50	741	0	0
1989	Unk	100	5000	unk	unk
1990	Unk	100	150	unk	unk
1991	Unk	100	20,000	100	10
1992	Unk	200	700	100	unk
1993	Unk	50	600	100	unk
1994	Unk	0	200	2000	unk
1995	Unk	100**	100	2000 (200**)	unk
1996	Unk	Unk	750	200	unk
1997	Unk	1	0	5500	unk
1998	Unk	200***, 150††, 34†	550†††		unk

* old BC watershed code system
** Portuguese Cr. (DFO, 1995) † Dove Cr. (Peterson, 1999) †† Headquarters Cr. (DFO, 1998)
*** Portuguese Cr. (DFO, 1998) ††† Headquarters Cr. and Tsolum R. (TRTF, Rosengard, 1998)

Table 2. Tsolum River Angling Effort and steelhead Catch, 1967 to 1998

Source: BC Ministry of Environment, Lands and Parks, steelhead Harvest Analysis

License Year	Number of Anglers	Number of Days	Wild Kept	Wild Released	Total Wild	Hatchery Kept	Hatchery Released	Total Kept	Total Released	Total Catch
1967-1968	436	2,130	393	0	393	0	0	393	0	393
1968-1969	213	1,115	262	0	262	0	0	262	0	262
1969-1970	284	1,667	346	0	346	0	0	346	0	346
1970-1971	214	1,150	122	29	151	0	0	122	29	151
1971-1972	103	379	108	41	149	0	0	108	41	149
1972-1973	176	994	228	145	373	0	0	228	145	373
1973-1974	143	741	93	90	183	0	0	93	90	183
1974-1975	95	385	68	71	139	0	0	68	71	139
1975-1976	160	1,982	38	65	103	0	0	38	65	103
1976-1977	116	355	26	31	57	0	0	26	31	57
1977-1978	42	200	29	39	68	0	0	29	39	68
1978-1979	88	462	24	41	65	0	0	24	41	65
1979-1980	45	235	6	3	9	0	0	6	3	9
1980-1981	3	40	0	36	36	0	0	0	36	36
1981-1982	16	52	0	36	36	0	0	4	39	43
1983-1984	30	51	0	9	9	0	0	0	9	9
1984-1985	17	300	0	31	31	0	0	0	31	31
1985-1986	7	57	0	7	7	0	0	0	7	7
1986-1987	8	36	0	0	0	0	0	0	0	0
1987-1988	8	22	0	0	0	0	0	0	0	0
1988-1989	5	10	0	0	0	0	0	0	0	0
1990-1991	8	15	0	0	0	0	0	0	0	0
1992-1993	4	7	0	0	0	0	0	0	0	0
1993-1994	5	25	0	0	0	0	0	0	0	0
1994-1995	3	6	0	0	0	0	0	0	0	0
1995-1996	3	3	0	0	0	0	0	0	0	0
1997-1998	5	10	0	0	0	0	0	0	0	0

SECTION 11, APPENDIX C

Historical Enhancement Initiatives

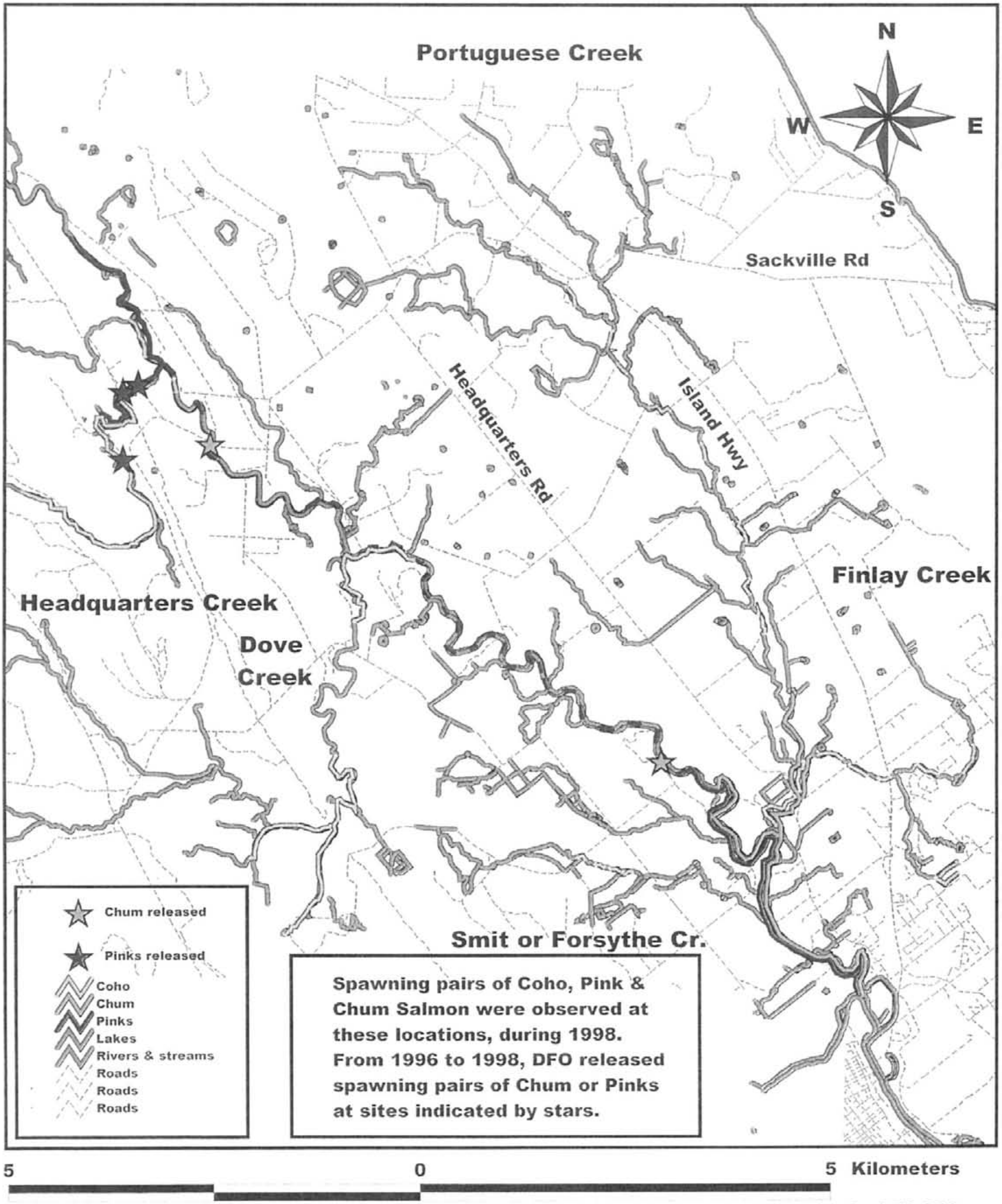
Table C.1 Summary of Salmonid Enhancement stocking Initiatives in the Tsolum River Watershed, 1968 to 1998.

Release Year	Species	Life stage	Stock	Location	Total	Contact or Reference
1968	pink	juvenile	Headquarters	Headquarters		Bams
1969	Chinook	juvenile	Big Qualicum	Tsolum	50,000	
1970	pink	juvenile	Headquarters	Headquarters		Bams
1971	pink	juvenile	Headquarters	Headquarters	264,800	Bams, 1973
1972	pink	juvenile	Tsolum-Kakweiken	Headquarters	117,220	Bams, 1976
			Kakweiken	Headquarters	114,500	Bams, 1976
1973	pink	juvenile	Headquarters	Headquarters	165,676	Bams, 1979
1978	ct	juvenile	?	Wolf Lake	7,000	Bond, Circa 1978
1980	pink	juvenile	Tsolum	Tsolum	51,547	Bill McLean, DFO
1981	pink	juvenile	Tsolum	Tsolum	668,317	
				Puntledge	125,822	
				sea pens in Courtenay R. estuary	93,299	
1982	pink	juvenile	Tsolum	Puntledge	571,459	
				sea pens in Courtenay R. estuary	142,494	
1983	anadromous ct	juvenile	Puntledge	Headquarters Cr.	950	Dave Stanton, MELP
					750	
1983	steelhead	juvenile	Puntledge	Headquarters Cr.	4,000	
					6,350	
1984	pink	juvenile	Puntledge	Headquarters Cr.	41,156	Bill McLean, DFO
1984	coho	juvenile	Puntledge	Little Lost Lake	70,854	Bill McLean DFO, Puntledge Hatchery
				Lost Lake	35,450	
				Helldiver Lake	148,330	
				Constitution Cr.	54,601	
				Blue Grouse L.	35,784	
1985	coho	juvenile	Puntledge	Little Lost Lake	71,114	
				Lost Lake	34,196	
				Helldiver Lake	126,482	
				Constitution Cr.	31,997	
				Blue Grouse L.	32,985	
1986	coho	juvenile	Tsolum	Headquarters C	53,542	
1986	coho	juvenile	Puntledge	Lost Lakes	89,212	
				Helldiver Lake	97,001	
				Constitution Cr.	19,756	
				Blue Grouse L.	40,056	
1987	pink	adult	Puntledge	Headquarters C	9,764	DFO, Puntledge Hatchery
				Tsolum R.	7,007	
1988	pink	adult	Puntledge	Headquarters C	2,741	
1989	pink	adult	Puntledge	Headquarters C	509	
1990	pink	adult	Puntledge	Headquarters C	3,705	
1990	coho	juvenile	Puntledge	Headquarters C	101,330	DFO, Puntledge Hatchery
				Lost Lakes	10,608	
				Blue Grouse L.	9,108	
1993	pink	juvenile	Puntledge	Headquarters C	816,000	Bill McLean, DFO
1994	pink	juvenile	Quinsam	Headquarters C	107,800	Bill McLean, DFO;
1995	pink	juvenile	Quinsam	Headquarters C	107,800	Don Chamberlain, Project Watershed
1996	pink	adult	Puntledge	Tsolum	5400	DFO, Puntledge hatchery
1997	pink	adult	Puntledge	Tsolum	2000	Pete Campbell, DFO
1998	chum	adult	Puntledge	Tsolum/Dove Cr.	3500	Pete Campbell, DFO
1999	pink	juvenile	Quinsam	Tsolum	(1 million eggs)	Pete Campbell, DFO

SECTION 11, Appendix D

Map Highlighting Adult Salmonid Distribution

Tsolum Watershed Spawning Locations



Created by Joanne Ellefson, March 2, 1999, for the Tsolum River Task Force