Biological and Hydrological Assessment of the Middle Vernon Creek Watershed

Prepared for:

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Re: Project 8-203; Middle Vernon Creek Stream Restoration Project

This Biological and Hydrological Assessment of the Middle Vernon Creek Watershed report is part of Habitat Conservation Trust Fund Project 8-203, Middle Vernon Creek Stream Restoration Project. The extent of the assessments in this report has been limited by available information, time and budget.

This report is considered to be a working document, part of an iterative planning process implemented by the Oceola Fish and Game Club. Modifications to the conclusions and recommendations are anticipated as new information is collected and knowledge gained.

The principal authors of this report are: Lorne Davies, P.Geo., Geostream Environmental Consulting, (250) 765-7444; and Dwight Shanner, R.P. Bio., Columbia Environmental Consulting Ltd., (250) 404-4229.

Sincerely,

Lorne Davies, P.Geo. Dwight Shanner, R.P.Bio.

Executive Summary

Wood Lake is one of the few remaining low elevation lakes in the Okanagan where kokanee fishing can still take place. To maintain this important sports fishery the Oceola Fish and Game Club (OFGC) has been working over the last 15 years to protect, restore, and enhance Middle Vernon Creek, the principal creek used by the Wood Lake kokanee population for spawning.

The number of kokanee spawners in Middle Vernon Creek has averaged approximately 7300 over the last 13 years, ranging from a high of 19,845 in 1999 to a low of 512 in 1990. The OFGC started a hatchery program in 1989. There were 7,152 kokanee spawners in 2002 and 5,003 in 2001.

The amount of water available for instream users (aquatic biota) or the off-stream users (irrigation) in Middle Vernon Creek is the main issue of concern. This was highlighted in the summer of 2002 when the creek went dry for a few days.

The Habitat Conservation Trust Fund (HCTF) provided funding for this hydrological and biological assessment of Middle Vernon Creek. The objectives of the report were to identify and prioritize actions that can be taken to increase flows for fish, assess the resident fisheries population in Middle Vernon Creek and to develop a framework for working with all water users in the watershed. This report is part of an on going iterative watershed-based planning process initiated by the OFGC.

The amount of water flowing in Middle Vernon Creek varies greatly from year to year. Factors that influence the amount of water flowing in the creek include the natural variability of the snowpack (and resultant stream flow), the amount of and timing of water released from Swalwell Lake reservoir, the amount of water removed from the creek for domestic and irrigation uses, the amount of surface water flowing into the ground to recharge the groundwater, and evaporation from Ellison Lake.

At present there are multiple proposed or on going planning initiatives taking place in the Middle Vernon Creek watershed. These include those initiated by the OFGC, BC Ministry of Water, Land and Air Protection, and the Lake Country Watershed Roundtable. The Oceola Fish and Game Club wants to complete a watershed based process and does not want to be constrained by mandates of individual government departments or jurisdictional boundaries that may prevent a holistic watershed approach.

A planning matrix has been developed to guide the Oceola Fish and Game Club. The main objectives are to identify linkages, incorporate more specific planning processes (such as Water Use Plans and Watershed-based Fish Sustainability Planning), reduce duplication, and to build on the overall iterative watershed-based planning process. The planning matrix is based on the seven themes of watershed management (education and awareness, partnerships and coordination, monitoring and research, planning and prioritization, funding and technical assistance, implementation, and evaluation) and water-related management policies/issues (instream flow requirements, reservoir

management, water resource planning committee, geomorphology, groundwater connectivity and land use).

Discussions with watershed stakeholders and members of the community have identified a lack of readily available and accurate information on stream flows in the watershed or on the amount of water diverted from the creeks for domestic and irrigation use. The Oceola Fish and Game Club is proposing to use HCTF funding to establish stream flow monitoring stations on Upper Vernon Creek and Middle Vernon Creek. This will help quantify the amount of water diverted from the creek for domestic and irrigation users, the amount of water recharging the groundwater and the amount of water for fish in Upper Vernon Creek and Middle Vernon Creek.

Sensitive Habitat Inventory Mapping (SHIM) was used to gather fish habitat information on 5.7 km of Middle Vernon Creek, between Wood Lake and Beaver Lake Road. Twenty-four distinct stream segments were identified: 47% of the creek was classified as natural, 30% as modified and 23% as channelized. In general the creek was in good shape but there is a need to reduce the amount of bank erosion, increase the number of pools and add more large woody debris.

Three species of sport fish populations, kokanee, rainbow trout, and mountain whitefish, have been documented in 1970s historical data and anecdotal information as present in Middle Vernon Creek. Field investigations found prickly sculpin, peamouth chub, largescale sucker, redside shiner, yellow perch, northern pike minnow and common carp populations in the creek.

The Oceola Fish and Game Club is also looking to use some of the proposed HCTF funding to expand on its landowner contact program. The focus would be on addressing the concerns identified through the SHIM survey. This included unauthorized withdrawals of water from the creek and a lack of screening on some water intakes.

Education and awareness, one of the watershed themes, has been an integral part of the projects completed by the Oceola Fish and Game Club and will continue to be so. The OCFG is looking to build on these initiatives with the Lake Country Watershed Roundtable, the District of Lake Country and the Ministry of Water, Land and Air Protection.

Acknowledgements

The authors (Lorne Davies and Dwight Shanner) would like to thank the Oceola Fish and Game Club for the opportunity to conduct this **Biological and Hydrological Watershed Assessment**. In particular we would like to thank Ron Taylor for the considerable volunteer time that he has given for monitoring this project. Funding for the project was provided through the Habitat Conservation Trust Fund British Columbia.

The authors would like to thank the Central Okanagan Regional District for their data collection and mapping services. Todd Cashin and Brent Magnan were instrumental for the completion of the Sensitive Habitat Inventory Mapping (SHIM).

Steve Matthews and Phil Epp from the BC Ministry of Water, Land, and Air Protection in Penticton also gave insightful comments. Oceola Fish and Game Club members provided local knowledge and comments. Comments were also received from members of the Lake Country Watershed Roundtable and the District of Lake Country staff. In addition, a thank you goes to all other stakeholders who provided information regarding historical and current biological and hydrological information.

A special thanks goes to Graham Martens, who assisted in the biological assessment, preparing this report, and editing.

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1.0 INTRODUCTION

The Oceola Fish and Game Club (OFGC) received funding from the Habitat Conservation Trust Fund (HCTF) to complete a biological and hydrological assessment of Middle Vernon Creek (in conjunction with stream restoration works).

The OFGC has been working to protect and enhance the local kokanee habitat over the last 15 years. Middle Vernon Creek supports approximately 80% of the kokanee production for Wood Lake, a very popular low elevation fishing lake between Kelowna and Vernon. Kokanee escapements in Middle (and Upper) Vernon Creeks have ranged from 512 to 19,845 over the past 13 years.

The most critical limiting factor for aquatic habitat in Middle Vernon Creek at present is the lack of water in the creek during critical low flow periods. There was minimal water flowing in sections of Middle Vernon Creek in August 2002.

The objectives of this report are to:

- Identify and prioritize actions that can be taken to increase flows for aquatic habitat in Middle Vernon Creek, particularly during critical low flow periods;
- Assess the resident fisheries population, determine high value habitat for kokanee production, record and evaluate the current fish habitat within Middle Vernon Creek;
- Develop a framework for working with all water users in the watershed to provide sufficient flows for aquatic habitat; and
- Continue the on-going iterative watershed-based planning process initiated by the OFGC.

The biological project objectives were met by gathering historical kokanee spawner counts, completing Sensitive Habitat Inventory Mapping (SHIM), and sub-sampling habitat units using electrofishing for species diversity and density.

A biological inventory was undertaken within Middle Vernon Creek to quantify existing habitat units, compare habitat utilized by Wood Lake kokanee spawners and determine the current fish species diversity and densities. It should be noted that this fisheries survey represents a snapshot in time, which records species information within a very limited time frame and should not be used as a complete record of species diversity or a population estimate.

SHIM was used to quantitatively and qualitatively measure fish habitat for approximately 5.7 km of Middle Vernon Creek. SHIM is a community-based approach to mapping aquatic habitats and their riparian areas, primarily for settlement areas of British Columbia. SHIM provides reliable, current, and spatially accurate information about local fish and wildlife habitats. SHIM is a 1:5,000 scale inventory and mapping project that was watershed based, building on existing local and senior government information. SHIM was developed by Fisheries and Oceans Canada, the British Columbia Ministry of Water, Lands and Air Protection, along with many municipalities and non-government groups as partners in fisheries inventory and information systems in BC.

Habitat units were quantified by SHIM and the sub-sampled data was used to determine fish species composition, densities, biomass, and total biomass within the creek. Habitat units were characterized as natural, moderately impacted, and channelized sections of stream. Population sub-sampling was located in watershed restoration sites (pre-treatment), best natural habitat units, moderately impacted habitat units, and highly impacted habitat units.

2.0 METHODOLOGY

2.1 Hydrology

At present there are several hydrology-related planning processes that have been completed, are being undertaken and are being proposed in the Middle Vernon Creek watershed. To help reduce duplication and streamline some of the aspects a planning matrix has been developed *[Table 3, page 22]*. This matrix is based on:

- The seven themes of watershed management: education and awareness; partnerships and coordination; monitoring and research; planning and prioritization; funding and technical assistance; implementation; and evaluation (USEPA 2001). This framework was used in the ***Middle Vernon Creek – Water Management Plan*** report (Geostream 2002);
- The policies of the Instream Flow Council (IFC), an organization that represents the interests of state fish and wildlife management agencies in the United States and provincial and territorial agencies in Canada dedicated to improving the effectiveness of their instream flow programs. The policies include:
    - Process development – establish a process for quantifying instream flow needs that allows the provincial fisheries agency to identify or approve study needs, study design, data analysis and flow implementation.
    - Reservoir Management – review and/or develop (if necessary) strategies for water releases (and sediment management). This could include development of plans to implement water use restrictions during drought periods to protect essential instream flows.
    - Water Resource Planning – Community lead, watershed based planning process that includes recognition of instream flows as an essential water use.

- Channel Morphology – physical parameters impacting on low flows (such as aggradation resulting in sub-surface flow and infilling of pools).
- Groundwater Connectivity (Management) - recognizes the connectivity between surface flows and groundwater; and the managing of groundwater withdrawals to avoid negative impacts.
- Land Use - recognize the effects of land use practices on natural drainage patterns (surface and sub-surface).

The IFC principles for riverine resource stewardship are also being used as a broad outline to guide the Oceola Fish and Game Club for the on-going watershed planning process. The principles are:

1. Recognize and promote provincial stewardship responsibility (MWLAP) as the basis for an advocacy role in conserving riverine resources for the use and enjoyment of present and future generations.
2. Recognize the limitations and opportunities imposed by legal and institutional factors. Work within them and through appropriate channels to expand them.
3. Always search for opportunities to maintain or restore natural ecosystem functions and processes in any increment.
4. Involve the public by providing information and seeking their input to develop a successful instream flow program and quantify the appropriate instream flow strategies.
5. Use an interdisciplinary approach to quantify instream flow needs that address the five riverine components (hydrology, biology, geomorphology, water quality, and connectivity).
6. Seek to maintain or restore the seasonal pattern of the intra-annual (magnitude, duration, timing, rate of change) and inter-annual variability (frequency) to maintain or restore the natural ecological function of riverine resources.
7. Follow a systematic, problem-solving process to address specific water management applications within the context of riverine resource management goals.
8. Use assessment tools and strategies appropriate to the unique needs of each instream flow situation.
9. Document the rationale behind decisions to address, or not address, any of the eight ecosystem resource management components in developing instream flow prescriptions.
10. Use monitoring or adaptive management to address uncertainty and learn from experience in appropriate settings.

The proposed planning matrix is to integrate the multiple planning processes. For example, the Water Use Planning process will be used to develop a set of operating rules for the control structures (dams) in the watershed; the Watershed-based Fish Sustainability Planning guidebook maybe used by the Lake Country Watershed Roundtable; the Official Community Plan for the District of Lake Country guides local development; and the Land and Resource Management Plan guides development on the Crown land portion of the watershed.

An iterative, adaptive watershed-based planning process is being utilized. Watershed components or resources are not assessed in isolation – the linkages (to other components and resources) are taken into consideration. Goals and objectives are also re-assessed as new information is collected and knowledge gained.

2.2 Biology

The objectives of this assessment were to estimate the fish utilization within Middle Vernon Creek and evaluate the habitat presently available for fish. This was completed by, utilization of historical data to show adfluvial fish populations (fish that live in lakes and spawn in streams), completion of a resident fish population inventory, and utilization of Sensitive Habitat Inventory Mapping (SHIM) to record and evaluate fish habitat.

2.2.1 Fish Population Estimates

Backpack electrofishing by conducting three-pass depletion was used to estimate the size of fish populations in varying habitat types within Middle Vernon Creek. The principle behind this method is that if a section of stream to be sampled repeatedly and the fish captured are removed, each sampling pass should remove fewer fish. By extrapolating the decreasing number of fish to zero, the total population can be estimated.

Fish sampling was conducted when flows were at seasonal low. In the case of Middle Vernon Creek, all sampling was completed on August 20-23, 2002 when stream flows were extremely low. Changes in discharge can affect habitat quality and quantity, and can alter surface area at a sampling site. Therefore, to enable the calculation of the total biomass of Middle Vernon Creek and record habitat conditions, Sensitive Habitat Inventory Mapping (SHIM) was completed.

Calculation of a surface area (length x mean width) permits fish population data to be expressed in a standardized format. Thus, population and biomass estimates can be converted to densities (number of fish per sample area) and standing crops (total weight of fish per 100 square meters). Densities and standing crops were calculated for each species present at the sites, and for different age groups within a species.

2.2.2 Field Method

Closed site electrofishing (100 m^2) was undertaken within run and pool habitat areas of 4 stream section types within the study area. The stream types were identified as:

- Most natural;
- Partially impacted;
- Urban setting on both banks; and
- Agricultural on both banks.

Although some riffle existed within the creek, the low gradient and the low stream flows created a consistent run habitat where the surface tension of the water was not broken even when flowing over rocks. It was estimated from sampling that the maximum amount of riffle habitat was approximately 6%. This area was not a significantly different portion of sampling area and was included within the run type habitat sampling. The SHIM database allows for identification of run habitat and riffle/pool habitat. Run was used to characterize this type of habitat.

Each measured section of stream was electrofished in an upstream direction. The individual carrying the electrofisher worked slowly keeping the probes about one meter apart. Electrofishing was completed paying particular attention to deeper areas with cover where fish might be hiding. Fish were held in separate buckets for each of the three electrofishing passes. After the third pass fish were sampled and then returned to the stream. Field data taken from the Fish Collection form and Individual Fish Data included:

- Site number and location;
- Habitat type (pool, run);
- Habitat impact type (natural, channelized, agricultural and urban impact);
- Channel wetted width;
- Channel survey length;
- Electrofishing pass number;
- Fish species caught;
- Individual fish length; and
- Individual and/or batch fish weight.

2.2.3 Biomass calculations using Microfish 3.0 software

Field data was entered into an excel spreadsheet for data manipulation. Microfish requires the total number of fish captured by species and electrofishing pass to be entered and then provides estimates of the total population within your sampling section. However, two assumptions must be made for this estimate to be valid. First, the removal effort must have a high enough catchability. That is, there must be sufficient removal with each pass to actually reduce the population enough so that fewer fish will be caught on the next pass. A minimum of about 50% of the total population has to be removed with each pass. This means that the removal method has to be adequate for the habitat. Using backpack electrofishing on small streams, the established rule is to use one backpack unit for each 3 m of stream width with the further condition that no spot in the section should be deeper than 1 m. The second assumption that must be met for the estimate to be valid is that there should be no movement of fish into or out of the sample section during or between passes. This was done by the use of stop (block) nets, placed upstream and downstream of the sample site.

When an irregular or non-descending removal pattern occurred, for example 24, 37, 26 occurring in passes 1, 2 and 3 respectively, Microfish terminates the run at a population estimate of five times the total catch and indicates the results should be considered unreliable. In these cases, we simply choose to represent the total estimated population as the total catch found during the survey. In addition, where only two or three fish of a particular species were caught in one or two of the three electrofishing passes we also determined this to be the total population for that particular survey site.

Having the total estimated population for each species, the data was broken down by total catch of either juvenile or adult. The batch weight’s taken for juveniles fish, for example, were averaged over the entire juvenile population. This was also done for the adult population. The distinction between juvenile and adult were made from both personal observations in the field and from historical data (Scott and Crossman 1973) dependent on the species and the current information available. A total biomass for each species could then be determined for each site. The biomass for each site was then extrapolated over 100 m^2 of wetted habitat type (wetted width x survey length) to ensure that all the sites could be compared equally.

To provide comparison of species diversity and densities between the habitat impact types (urban, agricultural, channelized and natural) habitat types found within each category were added together. For example, the total biomass for an agricultural impacted pool habitat was added to the total biomass of an agricultural run site. The SHIM survey data was used to determine the total pool or run area based on wetted width and stream length. The weighted biomass was then used to calculate over the entire agricultural impacted sections found using the SHIM database.

To determine the total biomass of each species within the surveyed sections of Middle Vernon Creek each habitat type was multiplied by the total biomass per species found within a representative 100 m^2 section of habitat. Therefore, those species and densities found within a representative 100 m^2 section of channelized run habitat were extrapolated over the total channelized run sections identified with the SHIM survey. For example if for every 100 m^2 of wetted channelized run habitat surveyed approximately 1.25 kg of prickly sculpins were found. Therefore, the calculated total biomass of 61 kg of prickly sculpins would be found within the 4,886 m^2 of channelized run habitat available within Middle Vernon Creek.

2.2.4 Kokanee Spawner Habitat Evaluation

Potential available kokanee spawning habitat was assessed during the SHIM survey. Indicators of low, moderate and high spawning habitat were based on the percent of suitable gravel available (2 mm – 64 mm), gravel compaction, and percent silt and fines found within each Sub-reach surveyed *[Table 1]*. Compaction at the time of the survey was found to range between low and moderate. No segments were rated as high compaction. Therefore, no segments were removed from potential spawning area calculations. Due to the low flow during sampling, water depth and velocity over spawning gravels would not have been useful data for quantifying spawning habitat. These measures would be useful during a late September assessment when flows are at more suitable levels for kokanee spawners.

The overall spawning habitat area available was based on the channel width and segment length surveyed; wetted width was not used for this evaluation, as extreme low flows such as those encountered at the time of the survey may not be a factor each year. Pool length and riffle length was also removed from the total available length.

Table 1. Criteria Used to Evaluate Low, Moderate and High Kokanee Spawning Habitat

Percent Suitable Gravels	Percent Fines and Silts	Spawning Habitat Rating
<40%	>40%	Low
40% -70%	<40%	Moderate
>70%	<30%	High

2.3 Sensitive Habitat Inventory Mapping

SHIM was completed using the standards identified by the methods manual that can be found at http://www.shim.bc.ca. The manual identifies the main steps to SHIM as:

- Gather existing information (digital files, etc.);
- Prepare field equipment and ensure GPS standards can be met;
- Collect SHIM data in field with Trimble GPS;
- Differentially correct data;
- Export raw GPS data to ArcView for processing;
- Link jpg images taken in the field with ArcView Shapefiles; and
- Post process SHIM data to ensure data accuracy.

Some additional information was gathered during field data collection. The stream segments were identified within the field to as natural, modified, and channelized based on the riparian bandwidth, the plant community and the degree of modifications made to the stream band were evaluated when assigning a characteristic. The minimum bandwidth was 4 m on both stream banks where a section could be called natural. This designation would require that the plant community was natural and forested and not a modified herb/grass community with exotic species. The designation as natural would also require the degree of human modifications to the stream bank was minimal and isolated. For example, a 2 m section of rip-rap within 100 m of natural banks would have been classified as natural.

A measure of the number of pieces of large woody debris (LWD) was completed within each segment. LWD was classified as a piece of wood greater than 3 m in length and greater than 0.1 m diameter. Each pool was measured individually also to evaluate the total pool area as well as quantify the pool, riffle, and run area of the stream. The stream area was utilized in determining the biomass of resident fish populations based on wetted width and section length. Field data observations were also recorded for potential kokanee spawning habitat and the area was used in conjunction with the bed material evaluations to determine spawning carrying capacity for kokanee. During data gathering, water intakes and outlets were catalogued was well as the fish screening material used at each intake.

3.0 BACKGROUND

3.1 Hydrology

The Middle Vernon Creek watershed is located in the Central Okanagan valley between Vernon and Kelowna. The watershed drains westerly off the Thompson Plateau, into the valley bottom and then drains north into Wood Lake. Middle Vernon Creek is located between Wood Lake and Ellison (Duck) Lake, and Upper Vernon Creek is located between Ellison Lake and Swalwell (Beaver) Lake.

The Middle Vernon Creek watershed consists of three main sections – upper, middle and lower areas. Three distinctive areas correspond to the changes in slope on the hypsometric curve *[Appendix A – Figure A1]*. Twenty percent of the watershed is below 600 m (lower watershed area); 25% of the watershed is between 500 m and 1300 m (middle watershed area); and 55% of the watershed is above 1300 m (upper watershed area).

Generalized hydrographs of the three watershed areas *[Appendix A – Figures A2, A3 and A4]* illustrate the main hydrologic components found in each section of the watershed.

Climate information is available from Environment Canada (Atmospheric Environment Service) weather stations located within or near the Middle Vernon Creek watershed. They include stations at Winfield, Kelowna Airport, Joe Rich Creek and McCulloch Lake. The provincial government operates the Mission Creek snow pillow station to the east of the watershed.

Based on the regional Environment Canada weather stations, the average annual total precipitation for the region ranges from around 400 mm in the valley bottom to over 700 mm in the upper watershed area *[Appendix A – Table A1 and Figure A5]*. Snowfall makes up approximately 25% of the total precipitation in the valley bottom and over 50% in the upper watershed area.

The annual snow pack in the upper watershed is quite variable, as evident by the April 1 snow pack data for the Postill Lake and Oyama Lake snow course stations *[Appendix A – Figure A6]*.

There has been increases in both temperature and precipitation in the Okanagan valley over the last 100 years (Cohen and Kulkarni 2001). There is a decadal scale variability within this trend - dryer conditions were present between 1950 and the late 1970s, and wetter conditions were present in the 1980s. In general, precipitation in the future is expected to increase during the fall and winter and decrease slightly during the summer.

The national Water Survey of Canada (WSC) program has collected surface water data at thirteen historic WSC hydrometric stations in the Middle Vernon Creek watershed *[Appendix A – Table A2]*. Stream flow data for a low flow year, medium flow year and high flow year for Middle Vernon Creek and Upper Vernon Creek were plotted *[Appendix A – Figures A8, A9 and A10]* to illustrate the variability in flows that occur in this watershed.

3.2 Biology

There have not been any historical evaluations of Middle Vernon Creek aquatic habitat or population studies. The Canada – British Columbia Basin Agreement completed a study (Koshinsky 1972) that reported on data collected in 1969 for some tributary streams. Middle Vernon Creek had "probable" rainbow trout spawning with no migration or juveniles documented and kokanee spawning/migration were listed as present. Lake studies have been completed on Ellison Lake, Wood Lake, and Swalwell Lake as well as a channel assessment procedure on Upper Vernon Creek for a forest company. The only fish stock assessment on Middle Vernon Creek has been annual kokanee spawner counts completed by the Ministry of Water, Land and Air Protection.

The historical information shows multiple species present in Wood, Ellison, and Swalwell lakes and therefore stream use by the species is expected based on the life cycle requirements. A list of species identified within each lake and Middle Vernon Creek is shown in Appendix B – Table 1. Although multiple species of non-game fish are listed, three game fish were found. Kokanee, rainbow trout and mountain whitefish have been captured from gill netting. Only one record of a lake trout is shown in FISS data and according to S. Matthews (MWLAP, Penticton) this record may be unreliable. Kokanee are confirmed in Wood Lake that utilize Middle Vernon Creek for spawning while rainbow trout are suspected.

The gross spawning area for kokanee and rainbow trout in streams was quantified as 5965 m^2 (Koshinsky et al. 1973) for Wood Lake. The carrying capacity of kokanee spawners was also estimated to be 802,000 for stream and lake spawners whereby all spawning potential habitat was estimated based on shore spawners. The actual Middle Vernon stream escapement was 500 kokanee spawners at the time of the assessment and shore spawners were enumerated to be 3300 spawners (Koshinsky et al. 1973). Wood Lake was judged to be under-utilized based on this estimation.

Rainbow trout were recorded in Wood Lake and Swalwell Lake, but not identified as present in Ellison Lake until 1995 (Fisheries Information Summary System 2003). Wood Lake carrying capacity was estimated to have an escapement production of 119 spawners that would utilize habitat from Middle Vernon Creek and Winfield Creek (Koshinsky et al. 1973). Rainbow trout were not captured in gill netting in 1971 and 1972 (Koshinsky et al. 1973). However, FISS shows observation records in the database and lake sized fish were observed in upper

Vernon Creek in 2002 (Brent Magnan, pers. comm.). Swalwell Lake and small lakes tributary to Swalwell Lake have wild populations of rainbow trout. Swalwell Lake is also utilized by the Summerland Provincial Hatchery for harvesting rainbow trout eggs.

3.3 Watershed Planning

A summarization of the activities and concerns of the Oceola Fish and Game Club in regards to kokanee over the last fifteen years are as follows:

- 1987 - Club became involved in enhancing kokanee habitat in Winfield Creek and Middle Vernon Creek.
- 1988/89 - Applied for and received funding from HCF to enhance Winfield Creek for kokanee.
- 1988/89 – Manufactured incubator and installed to incubate kokanee eggs. This was done on the Winfield Creek Wildlife Preserve property that the club currently has a 30 year lease on.
- 1990 to present - Club has received permits from the provincial government to collect kokanee eggs (one year the Club did not receive the permit in time to collect eggs). The Club has looked after the collection of eggs for the past decade and has incubated up to 70,000 eggs.
- 1989 to present - Provincial government has paid for the enumeration of kokanee spawners.
- 1990 to present - Club has removed debris from the creeks every few years.
- 1999 – Club sought funding from Fisheries Renewal BC to do creek restoration, bank stabilization and riparian enhancement. Club was requested to complete an action plan.
- 2000 – Middle Vernon Creek and Winfield Creek: Stewardship Action Plan report by Geostream Environmental Consulting.
- 2000 to present – member Lake Country Watershed Roundtable.
- 2000 to 2003 – completed stream restoration projects (Fisheries Renewal BC and HCTF funding).
- 2001 – Club received funding from Fisheries Renewal BC to complete Middle Vernon Creek – Water Management Plan report by Geostream Environmental Consulting. In-kind support received from Water Planning Section, Ministry of Environment, Lands and Parks, Kamloops. However, lost partnership due to government re-organization. Club advised to work with the Lake Country Watershed Roundtable as conduit for public involvement.
- Currently the Ministry of Water Land and Air Protection has begun a creek assessment project on Middle Vernon Creek and has hired a

consultant to decide on the amount of water the fish require. The club believes that the project should be broader and look at the watershed and all the factors that influence the water for fish. The club has asked for funding in its 2003 HCTF request to do this.

- Since the HCTF project request was sent in, the local mayor is talking about forming a committee to look at watershed management. The club will have concerns that it may be a political process and not rely on input from all stakeholders.
- The club believes that all of these processes should be working together for the same end and is prepared to be very involved.

The Lake Country Watershed Roundtable meetings have had minimal attendance by government personnel to date. This can partially be attributed to reductions in provincial fisheries staff and government re-organization. There has also been a lack of continuity with MWLAP representation from different departments and even different cities. This has resulted in a lack of communication and partnership building between the local community (concerned about watershed issues) and government.

There has also been some general skepticism from the community at large on the ability of government to protect aquatic habitat. For example, there is the perception of double standards of having to keep cows out of the creek to protect fish but there is no problem if the creek goes dry.

4.0 RESULTS OF ASSESSMENT

4.1 Instream Flow Requirements

Stream flow data provides valuable information on the amount of surface water available for in-stream (aquatic habitat) and out-of-stream (irrigation and domestic) users. The national Water Survey of Canada (WSC) program has collected surface water data at several historic WSC hydrometric stations in the Middle Vernon Creek watershed *[Appendix A – Table A2]*.

The BC Ministry of Water, Land and Air Protection have allocated funding to estimate the natural hydrograph and review water supply/demand in the Middle Vernon Creek watershed (Upper Vernon Creek and Middle Vernon Creek) in order to develop realistic conservation fish flow requirements.

Review of the Kalamalka-Wood Lake Basin Water Resource Management Study (1974) has identified some areas of concern.

- Lake evaporation data was based on pan evaporation measurements at three AES climate stations. It should be noted that Environment Canada states that their evaporation data refers to the calculated lake evaporation occurring from a small natural open water-body having negligible heat storage and very little heat transfer at its bottom and sides. It represents the water loss from ponds and small reservoirs but not from lakes that have large heat storage capacities (Environment Canada 2003).

- There were concerns regarding the accuracy of the water withdrawal information collected by the District of Lake Country on Upper Vernon Creek. The 1974 report stated, "The district meter recorded a diversion of 4,464 acre-feet during 1972. However, this reading is inconsistent with the quantity of water required to nourish crops on the total acreage irrigated in the district. For the purposes of this chapter, it was assumed that the district diverted the full irrigation allotment of 6,550 acre-feet" (page 44).
- The 1974 report identified Clark Creek as a natural drainage area; however, local residents have stated that when water levels in the Oyama Lake reservoir are high water flows into Clark Creek.

The District of Lake Country currently records water levels on Upper Vernon Creek at their water intake twice daily. They use a baseline flow of 1080 usgpm (US gallons per minute, equivalent to 0.068 m^3/s or a monthly discharge of 147 acre-feet per month) to provide water for water licences and aquatic habitat between the Intake Dam on Upper Vernon Creek and Ellison Lake (District of Lake Country 2002b). The data collected is of limited value because of the potentially large differences that may occur between individual staff gauge readings and the averaging of continuous, recorded data.

The District of Lake Country is currently entering manually recorded water level information (1998 to present) into a spreadsheet. This information is required to better understand the current relationship between total precipitation, reservoir levels and resultant stream discharges from the upper watershed area.

Stream discharge data was collected by WSC on Middle Vernon Creek at the inlet to Wood Lake until 1987. The mean annual discharge (MAD) (not including any adjustments for upstream water diversions and water withdrawals) for Vernon Creek near the inlet of Wood Lake from 1970 to 1986 was 0.493 m^3/s. The average 7-day low flow for this period was below 5% MAD in 5 out of 17 years (Geostream 2000). The installation of a water recording station on Middle Vernon Creek would provide the current stream flows for adfluvial and resident fish species.

Any collection of stream flow data or water level information should follow provincial standards and protocols. These are outlined in the Manual of Standard Operating Procedures for Hydrometric Stations in British Columbia, prepared by the Ministry of Environment, Lands and Parks, Resource Inventory Branch.

It is evident that there are insufficient flows for all water users in the watershed in some years. The annual discharge for the Vernon Creek at Outlet to Swalwell

Lake hydrometric station *[Appendix A – Figure A7]* was less than 9000 acre-feet 33% of the time between 1969 and 1995, less than the licenced demand for approximately 10,000 acre-feet of water. Water from Swalwell Lake is also required for the recharging of the Ellison Lake to Wood Lake aquifer. In addition, there are the instream flow requirements for aquatic habitat.

To better assess the consequences of on-going human activities in the watershed current stream flow data is required to evaluate the present hydrologic variability and change, particularly in ecologically relevant terms. Parameters, such as those summarized below in Table 2, can be used to explain biological and geomorphic changes or to assess the magnitude or rate of human-induced changes.

Table 2. Potential Hydrologic Parameters for Analyses
(Adapted from Richter 1999)

Group	Regime Characteristics	Stream flow Parameters	Examples of Ecosystem Influences
Magnitude of Monthly Discharge Values	Magnitude Timing	1. Mean discharge for each calendar year	1. Habitat availability for aquatic organisms 2. Influences water temperature, oxygen levels and photosynthesis in water column
Magnitude and Duration of Annual Extreme Discharge Conditions	Magnitude Duration	1. Annual maximum and minimum one-day means 2. Annual maximum and minimum 7-day means 3. Number of zero flow days 4. 7-day minimum flow divided by mean flow for year	1. Structuring of river channel morphology and physical habitat conditions 2. Duration of stressful conditions such as low oxygen in aquatic environments
Timing of Annual Extreme Discharge Conditions	Timing	1. Julian days of each annual one-day maximum and minimum discharge	1. Spawning cues for migratory fish 2. Out migration cues for adfluvial fry and juveniles
Frequency and Duration of High/Low Flow Pulses	Magnitude Frequency Duration	1. Number of high pulses each year. 2. Number of low pulses each year.	1. Availability of floodplain habitats for aquatic organisms 2. Influences bedload transport and duration of substrate disturbance

There are also instream and off-stream flow requirements for Middle Vernon Creek. Water licence demand on Middle Vernon Creek is 440 acre-feet, or an average daily discharge of 0.034 m^3/s (from April 1 to September 30). Several unauthorized water intakes were also identified along the creek. Stream flow monitoring is required to evaluate any management initiatives undertaken to reduce the off-stream extraction of water in this creek.

Middle Vernon Creek has potential barriers to fish passage as well during low flow conditions. The Oceola Fish and Game Club had to install a plywood fishway on a concrete irrigation dam in 2002 to facilitate the passage of spawning Kokanee over the structure *[Appendix A – Photo 2]*. More detailed investigations are required to determine the feasibility of removing or modifying the structure.

4.2 Reservoir Management

The Winfield and Okanagan Centre Water System uses the upper watershed area of the Middle Vernon Creek watershed to supply water to the District of Lake Country for domestic and irrigation uses. The dam at the outlet of Swalwell Lake regulates the water flow from the upper watershed area. Water releases are controlled by a low level sluice gate located at the outlet of Swalwell Lake.

The storage capacity in the upper watershed area is 12,045 acre-feet or 14,857,500 m^3 (1 acre-foot = 1233.5 m^3): Crooked Lake and Deer Lake – 2,460 acre-feet; Swalwell Lake – 9,585 acre-feet. The licenced water demand for off-stream use (irrigation and domestic users) is approximately 10,000 acre-feet. That leaves approximately 2,000 acre-feet of storage for instream use (aquatic habitat) and to be retained for any potential subsequent dry years.

The 2001/2002 snowpack for the Postill Lake and Oyama Lake snow course stations was about average while the snowpack for the Mission Creek snow pillow station was above average. This would seem to indicate that there would be enough water for downstream water users (including aquatic habitat). However, this was not the case. This indicates that the amount of rainfall in the late spring and early summer is a very important factor to consider with the release schedule of water from the upper watershed area reservoirs. During a dry year there is also a corresponding higher off-stream water demand (for irrigation and domestic users).

A review of the current water release schedule from the Swalwell Lake reservoir, particularly in regards to flow requirements for downstream aquatic habitat, is one potential management option. This would involve more detailed analyses of the relationship between precipitation data (snowfall and rainfall) and reservoir levels. The District of Lake Country is currently in the process of summarizing their reservoir level information (data was collected by Water Survey of Canada from 1970 to 1998). Precipitation data for the watershed could be extrapolated from the Mission Creek snow pillow station. The data has been summarized into daily values, however, no summarization or assessment of data has taken place.

The summarization of water level information and regional climate data would be useful tools for any public education and awareness program. This information could also be used to develop a reservoir management decision calendar that indicates the timing of selected planning processes (such as flow releases for fish and/or irrigation) and operational issues (such as filling of the reservoirs).
There have been significant alterations to the modified hydrologic regime in the Middle Vernon Creek watershed over the last ten years. They include the elimination of diversions from Okanagan Lake; removal of the diversion ditch from Upper Vernon Creek; groundwater level changes at the Hiram Walker distillery site; and alterations to stream flow paths on the lower watershed area. Installation of water level recording stations (such as at the historic WSC sites) would allow a better understanding of the current hydrologic regime and help to prioritize action items to mitigate potential adverse impacts to aquatic habitat.
It is anticipated that the MWLAP contract will identify the need for collection of current stream flow data as one of the priority items to be addressed.

4.3 Water Resource Planning

Two water resource planning initiatives are required for the Middle Vernon Creek watershed: one for the entire watershed; and one for the lower watershed area around Middle Vernon Creek. The watershed scale initiative would deal with such issues as water diversions and withdrawals; the establishment of flow requirements for fish; and the overall management of water in the watershed. The concerns along Middle Vernon Creek would primarily deal with individual landowners or subwatershed areas.

Water diversions and withdrawals for the Middle Vernon Creek watershed include: Okanagan Lake (Hiram Walker pumping station); water licencees; unauthorized surface water withdrawals; groundwater wells (particularly shallow wells located adjacent to a water course); and Oyama Lake (high reservoir levels results in water flowing into Clark Creek).

It is proposed that the Oceola Fish and Game Club be the lead for an overall water resource planning initiative. This is partially to reflect the new direction being taken by MWLAP where “the ministry will emphasize shared stewardship by encouraging others to accept a greater role in environmental stewardship, and facilitating community initiatives to protect and restore their local environment” (MWLAP 2002). Issues and concerns identified by the local community include: land use around the upper reservoirs; aquifer protection; groundwater management; proprietary water rights on Middle Vernon Creek versus Upper Vernon Creek; water requirements for agriculture; water pricing; and reservoir management.

There is general support in principal for the watershed level committee, as indicated by one-on-one meetings/discussions with the following watershed stakeholders: the Oceola Fish and Game Club, District of Lake Country, Eldorado

Ranch, Ministry of Water, Land and Air Protection, Lands and Water BC Inc., and water licencees along Middle Vernon Creek. Other potential committee participants have also been identified; this includes the Okanagan Indian Band.

The preliminary consultation process initiated by the provincial government between the two key licensees (Eldorado Ranch and the District of Lake Country), the Oceola Fish and Game Club and the MWLAP is considered to be a component of the overall water resource planning initiative. The provincial government will be required to take a leadership role for any formal planning initiative such as the Water Use Planning process.

Support has been obtained from potential technical advisors (“experts” in technical issues found in the watershed). Personnel contacted include professors from Okanagan University College and government personnel. They will be used to help evaluate technical needs; translate technical jargon; and help determine technical solutions when necessary.

To address some of the concerns as outlined in Section 3.3 a working protocol should be developed to:

- Determine and record the ground rules, decision-making processes and conflict resolution procedures;
- Define the roles and responsibilities of committee members;
- Establish communication and information exchange protocols (for example some information may be the property of the licensee holder and is not to be released to the general public);
- Identify goals and objectives;
- Prioritize action items and activities that should be undertaken; and
- Establish a monitoring plan.

The decision-making process should be based on collaborative co-management and utilize a decision-making criteria where potential solutions can be ranked (based on selected criteria such as cost/benefit effectiveness, technical feasibility, political feasibility, acceptability, timeliness, and ease of implementation).

Monitoring is considered an integral part of the planning process. Quantitative stream flow data will be needed as a tool to guide the planning committee through the evaluation process.

The Water Resource Planning Initiative for Middle Vernon Creek would focus on reducing the potential conflicts between off-stream (irrigation and domestic) and instream (aquatic habitat) water uses. During critical low flow periods all or most of the water flowing in the creek is from adjacent tributaries and springs. As outlined in the 2002 Geostream report, subwatershed water management plans should be developed for the identified subwatershed areas. The primary focus of the plans will be to establish an education and awareness program to reduce activities that are having an adverse impact on stream flow. This program has already been informally initiated in conjunction with the on-going stream restoration projects.

Existing information about private landowners along Middle Vernon Creek should be summarized and consolidated into a database. This could include: private landowners along the creek, private landowners known by the Oceola Fish and Game Club, identification of persons withdrawing water from the creek (the SHIM survey identified over 30 surface withdrawal points on Middle Vernon Creek between Wood Lake and Beaver Lake Road, some unauthorized), and other water use activity (such as watering of livestock). Confidentiality procedures will have to be established to address such issues as potential unauthorized withdrawals.

4.4 Channel Morphology

At present Middle Vernon Creek has a moderately aggraded channel morphology that has resulted in a reduction of optimal fish habitat for the stream. This has probably resulted in higher stream flow requirements for aquatic habitat, particularly during low flow periods. Refuge areas for fish (deep pools) may be the limiting factor for some species when water temperatures are high. Some spawning areas may also require higher flows to be utilized as the stream bed has been elevated and/or widened, requiring greater flow to accommodate sub-surface flow and/or maintain required water depths.

The rate of sediment input into Middle Vernon Creek has been reduced through the stream channel restoration projects completed over the last three years. The SHIM survey identified 230 m of stream bank stabilized by the restoration projects and 400 m of eroding stream bank still existing. The stream banks stabilized to date primarily consisted of easily erodible fine-textured material. It is anticipated that pool densities and spawning areas will increase over time as the excessive amounts of sediment are flushed out of Middle Vernon Creek. More detailed investigations of the remaining 400 m of eroding stream bank are required to assess their potential adverse impact on the stream channel.

The completion of the SHIM survey of Middle Vernon Creek between Beaver Lake Road and Ellison Lake will provide a baseline of information in which to monitor the density of pools and amounts of spawning area in the creek.

Field investigations were undertaken in August 2002 to assess the potential adverse impacts that the channel morphology was having on stream flow during low flow conditions.

The upstream end of Middle Vernon Creek was assessed when there was minimal flow (~ 6 L/s) coming from Ellison Lake. There is an accumulation of fine-textured material in the upstream 100 m of the creek. The outlet of Ellison Lake maybe aggrading with this material, reducing the amount of water entering the creek during low flow periods.

Additional water may be available for Middle Vernon Creek if the stream bed elevation can be reduced with the removal of some sediment or the scouring of a low flow channel with the placement of LWD. More detailed investigations (such as surveying the longitudinal profile) are required to assess the feasibility of this option.

Stream flow in Middle Vernon Creek went sub-surface above the Beaver Lake Road crossing for approximately 100 m (August 2002). This build-up of sediment can probably be reduced with the stabilization of upstream eroding banks. This would subsequently result in the sediment being flushed out and a reduction in sub-surface flow.

The Beaver Lake Road culvert is also perched and some of the flow is going underneath the culvert. This may be a factor in the dewatering of the creek upstream of the culvert. One potential solution would be to backwater the culvert with the use of a riffle or other structure at the outlet. This would raise the flow profile in the bed upstream and potentially prevent the existing dewatering effect. However, detailed engineering drawings and calculations are required as there are houses quite close to the creek downstream.

Most of the flow in Middle Vernon Creek being discharged from the culvert under Beaver Lake Road appears to come from a tributary on the upstream side. Tributaries and springs along Middle Vernon Creek supply most of the water to the creek during low flow periods, particularly when no water flows from Ellison Lake. More detailed investigations are required to quantify the inputs (and water withdrawals) on Middle Vernon Creek during low flow periods.

4.5 Groundwater Connectivity

Streams interact with groundwater in three basic ways: streams gain water from inflow of groundwater through the streambed; they lose water to groundwater by outflow through the streambed; or they do both, gaining in some reaches and losing in others (Winter et al. 1998).

Upper Vernon Creek and Middle Vernon Creek each have their own unique regime of surface water and groundwater interaction. The lower half of Upper Vernon Creek provides a significant volume of water to the aquifer (groundwater recharge) located between Ellison and Wood lakes. Middle Vernon Creek receives a significant amount of its water from groundwater sources, particularly during low flow periods.

The 1974 water resource management study collected detailed stream flow data on Upper Vernon Creek for 20 months (December 1971 to July 1973). Some of the findings were deemed to be tentative as they are based on a relatively short period of observation. To better understand and quantify the amount of surface water lost to groundwater recharge additional stream flow data should be collected.

The SHIM survey carried out on Middle Vernon Creek also identified the location of some of the surface (tributary channels) and sub-surface (springs) water sources. The protection of these water sources would be one of the objectives carried out in conjunction with the proposed resource planning initiative for landowners along Middle Vernon Creek.

Effective water management requires a clear understanding of the linkages between groundwater and surface water.

4.6 Land Use

The lower watershed area, between Ellison Lake and Wood Lake, is the primary source of water for Middle Vernon Creek during critical low flow periods. Changes to the natural flow patterns (surface and sub-surface) and land use (agriculture and urban development) in some catchment areas appears to have resulted in a reduction of water reaching the creek during low flow periods. For example, Richards Brook (a small tributary) can no longer be utilized for irrigation or supply surface water to Middle Vernon Creek. More detailed assessments of land use (and associated changes to natural drainage patterns) within individual catchment areas are required to more fully assess any potential adverse impacts associated with land use.

One of the management objectives for the watershed should be to quantify the water requirements for sustainable agriculture (this would include defining what sustainable means) and to set targets for urban use. The 9,000 acre-feet of licenced demand for agriculture has been greater than the annual runoff in some years. It is anticipated that the proposed water resource planning committee will discuss and prioritize water conservation measures and management options for drought periods.

The consolidation of various mapping initiatives would be one of the main objectives in addressing potential land use impacts to low flows in Middle Vernon Creek. For example, the Okanagan-Kootenay Sterile Insect Release program has mapped tree fruit acreages and the mainstem of Middle Vernon Creek has been mapped using the Sensitive Habitat Inventory Mapping program.

4.7 Hydrology Action Plan

The main objective of this section is to outline a proposed plan of action. The components identified have been integrated with the seven themes of watershed management to consolidate the overall planning framework *[Table 3]*. All of the components and themes are linked and inter-related. The action items listed below are subject to change and/or modification as new information is collected, other reports completed and discussions by various watershed stakeholder groups.

The Oceola Fish and Game Club requires technical assistance from consultant(s) and government agencies to initiate the formation of an all encompassing water resource planning committee. The objective is to build off of the initiatives that have already been completed in the watershed. These include the October 2002 watershed tour and the May 2002 watershed workshop.

The first proposed actions would be to:

- Send an official letter of invitation with accompanying questions to the watershed stakeholders (as identified by the stakeholders listed in Section 4.3). It is anticipated that additional stakeholders will be identified; and
- Develop a draft working protocol for the group, partially based on the information provided by stakeholders;
- Hold a committee meeting to finalize the working protocol;
- Send an information letter to all water licencees, in partnership with Lands and Water BC Inc.

The second priority action items would be to secure more flows for aquatic habitat along Middle Vernon Creek. This will require:

- Re-establishment of the historic Water Survey of Canada hydrometric station on Middle Vernon Creek.
- The completion of Sensitive Habitat Inventory Mapping of Middle Vernon Creek and additional biomass sampling for new mapping sections (in progress);
- The development of a database on existing information and landowners along Middle Vernon Creek; and
- Working with private landowners to reduce unauthorized water withdrawals form Middle Vernon Creek.

The third priority action item would be the development of an education and awareness program of the Swalwell Lake reservoir release schedule in partnership with the District of Lake Country. Downstream water users want a better understanding of why the creek went dry in 2002. This could include the development of a reservoir management decision calendar.

Table 3. Proposed Hydrology Planning Matrix for the Middle Vernon Creek Watershed

	Education and Awareness	Partnerships and Coordination	Monitoring and Research	Planning and Prioritization	Funding and Technical Assistance	Implementation	Evaluation
Instream Flow Requirements	Through LCWR	OFGC; MWLAP	1. Detailed data analyses 2. Stream flow monitoring	1. Upper Vernon Creek 2. Middle Vernon Creek	MWLAP; HCTF; OFGC; District of Lake Country	1. MWLAP report 2. Proposed HCTF project	Indicators – stream flow
Reservoir Management	District of Lake Country	OFGC; MWLAP; District of Lake Country	1. Inflow forecasting 2. Release schedule	1. Swalwell Lake 2. Ellison Lake	District of Lake Country; OUC	1. Detailed Hydrologic Assessment 2. Monitoring 3. MWLAP report	
Water Resource Planning	Through OFGC and LCWR	OFGC; MWLAP; LWBC; District of Lake Country; water users		1. Middle Vernon Creek 2. Upper Vernon Creek	HCTF; OFGC	1. Community lead planning process	Monitoring – stream flow
Geomorphology	OFGC	Private landowners; OFGC	1. Aggradation 2. Sediment transport	1. Middle Vernon Creek 2. Upper Vernon Creek	HCTF; OFGC	1. Bank stabilization – private land (on-going)	Monitoring reports
Groundwater Connectivity	OUC; LCWR	OFGC; OUC	1. Surface water - groundwater interaction	1. Middle Vernon Creek - floodplain 2. Upper Vernon Creek - aquifer	HCTF; OUC; MWLAP	1. Middle Vernon Creek 2. Upper Vernon Creek	Monitoring – stream flow
Land Use	District of Lake Country	OFGC; District of Lake Country		1. Lower watershed 2. Middle watershed 3. Upper watershed	District of Lake Country	1. SHIM – Middle Vernon Creek	

LCWR – Lake Country Watershed Roundtable; OFGC – Oceola Fish and Game Club; MWLAP – Ministry of Water, Land and Air Protection; LWBC – Lands and Water BC Inc.

The fourth priority action items would be the quantification of flows into and out of Ellison Lake and an assessment of potential mitigation measures. This would include:

- Installation of stream flow monitoring stations. Top priority would be the re-establishment of historic Water Survey of Canada hydrometric stations, such as at the intake structure;
- Assessment of sediment build-up at the outlet of Ellison Lake and upstream end of Middle Vernon Creek;
- Feasibility study for the construction of a water control structure at the outlet of Ellison Lake;
- Feasibility study for water diversion along the old Day/McCarthy ditch (water diversion from Upper Vernon Creek).
- Feasibility of servicing a greater component of Lake Country water from the Okanagan Lake supply system.

The other priority action items would be to:

- Quantify the water requirements for agriculture. This would require the consolidation of various mapping initiatives that have been carried out in the lower watershed area.
- Summarization of groundwater withdrawals, particularly on the floodplain. This may identify potential adverse impacts such as a reduction in the volume of groundwater recharge to Middle Vernon Creek.

All the action items incorporate the seven themes of watershed management. The development of each of the themes is part of the overall iterative planning process.

Education and awareness is an important component of this report. The primary purpose of the figures, tables and photos in the appendices is for public presentations, such as to the Oceola Fish and Game Club.

Most of the components have identified a need for the monitoring of stream flows. The information will allow proper evaluation of the actions undertaken and provide some information for potential research projects (such as the interaction between groundwater and surface water).

Planning and prioritization has been based on the relative importance between low flows in Middle Vernon Creek and the source of water. Each of the watershed areas in the Middle Vernon Creek watershed (upper, middle and lower) can be assessed individually or as a whole.

The Oceola Fish and Game Club is continually seeking out new sources of funding and technical assistance for its Middle Vernon Creek stream restoration project. New potential funding sources should be identified through the water resource planning committee if matching funds and/or in-kind support can be secured. The requirements for technical assistance will be assessed on a project-by-project basis; preliminary discussions have taken place with Okanagan University College.

The implementation of these proposed initiatives will be partially dependent on the available time and resources of the various partners and the acquisition of funding. The Oceola Fish and Game Club has applied for funding from the Habitat Conservation Trust Fund to implement components of this action plan in the 2003/04 fiscal year.

Evaluations will be based on the completion of proposed action items; stream flow monitoring results; and future biological assessments.

4.8 Biological requirement for Water Flows

As discussed earlier, low water flows within streams have multiple adverse impacts on aquatic organisms within streams *[see Section 4.1, Table 2, Examples of Ecosystem Influences]*. This year in particular (2002) Middle Vernon Creek had no flow for 3-5 days in early to mid-August, just prior to biological sampling *[Appendix B - Figure 14]*. This extreme in flow pattern likely caused the death of fish, particularly species more sensitive to high heat and low oxygen like rainbow trout and mountain whitefish. The period of no flow may explain why these two species were not captured during sampling.

If low flows in September are similar to those observed at the time of sampling in August 2002, then approximately 31% of the existing habitat would not be available to kokanee spawners. During biological sampling and SHIM data gathering the flow within Middle Vernon Creek was estimated to be from 0.010 m^3/s to 0.020 m^3/s which is near the minimum low flow recorded at the WSC hydrometric station. The wetted and channel measurements were taken to determine the available habitat for aquatic organisms and potential habitat available, respectively. Calculations from SHIM data estimate the available high and moderate value spawning habitat during low flows to be 21,894 m^2 and the potential habitat was found to be 31,855 m^2 *[see Table 1, Habitat Criteria]*.

Existing reservoir releases should be evaluated. The goal of the releases should be to make available the amount of water required for different life stages of the key species of fish in the watershed. For example, kokanee spawn in the fall and low flows would impact spawning area and habitat quality while egg incubation requires enough flow until the end of April. Rainbow trout spawn around the spring freshet time period and no flow constraints are known. Mountain whitefish are fall spawners, low flow regimes could potentially affect this species during extreme low flows, and habitat selection for velocity, water depth, and temperature over spawning gravels may be a limiting factor.

Based on SHIM data, it was found that there were more water intakes than registered users and many of the intakes did not have proper fish screens on the intakes. During SHIM data gathering, water intake information collected included their location, the fish screening material used on the intake and the size of the water intake pipe. The use of these intakes can have a significant impact on water flow especially at low flow periods. The unauthorized intakes should be removed and fish screens should be installed (where required) through landowner consultation and stewardship initiatives.

4.9 Resident Fish Population

To determine the total biomass of each species within the surveyed sections of Middle Vernon Creek each species was weighted by habitat type and extrapolated over the entire available habitat of that type *[Appendix B – Figures B1 to B7]*. Therefore, those species and densities found within a representative 100 m^2 section of channelized pool habitat were extrapolated over the total channelized pool habitat identified within the SHIM survey. It should be noted that this fisheries survey represents a point in time sample, which simply records species diversity and densities within a very limited time frame and should not be taken as a final species count or population estimate *[Table 4]*.

Table 4. Total Biomass per species at the time of sampling (Aug. 20-23, 2002) within the surveyed sections of Middle Vernon Creek (21,894m^2 wetted habitat)

Species	Natural Habitat (10,863m^2)	Channelized Habitat (4,886m^2)	Modified Habitat (6,145m^2)	Total Biomass (kg)
Prickly Sculpin	24.23	22.0	4.2	50.4
Peamouth Chub	9.94	0.0	0.4	10.3
Largescale Sucker	6.3	0.3	0.6	7.2
Redside Shiner	0.13	0.0	1.0	1.1
Yellow Perch	0.02	0.0	0.1	0.1
Northern Pikeminnow	3.13	0.0	0.0	3.13
Common Carp	0.0	0.0	0.2	0.2

Prickly sculpins dominate the total biomass for all fish species caught within Middle Vernon Creek. However, it should be noted that two large common carp were observed during electrofishing and an additional 40 carp throughout the length of the SHIM survey. An estimate of the carp weight would be 2 kg each. These fish were not included in the overall biomass of Middle Vernon Creek. However, the estimated biomass would be 84 kg.

It is interesting to note that prickly sculpins were found to have a similar biomass within both the natural and channelized section of stream especially given that the channelized section represents only 45% of habitat available compared to the natural section. The higher biomass within the channelized section is likely due to the presence of preferred habitat by sculpins, in the form of cobbles and boulders from both bank stabilizing riprap and broken gabions depositing cobbles within the stream as well as low water flows (Scott and Crossman 1973) provided in the channelized section.

The highest diversity of fish species found (6) was located within the natural pool section of stream. The second highest (5) species was found within the modified urban run habitat however, this may have been due to the abundance of modified run habitat within Middle Vernon Creek and the crews ability to sample a full 100 m^2 compared to a natural pool area of only 56 m^2. The channelized section had the lowest species diversity with only three species found.

Redside shiners were ranked fourth of five in overall total biomass. However, they were by far the most abundant fish species caught during electrofishing surveys. Their low biomass is only attributed to their small average size of 29 mm in length (1+ age) and 0.4 g weights.

Overall only one sport-fish (yellow perch) was captured within Middle Vernon Creek at the time of the survey. It was highly likely that this was directly related to the low flow conditions and high temperature found at the time of sampling. During a fish salvage in 2001 on Middle Vernon Creek there were over 200 yellow perch found stranded in a shallow warm water pool. The yellow perch population within Middle Vernon Creek is likely higher than was found on the days of sampling.

4.10 Kokanee Spawner Population

Spawning kokanee counts have been completed by MWLAP since 1990 for Middle Vernon Creek. The enumeration areas are divided into 4 sections that do not correlate to biological Sub-reach breaks but are consistent over the past 12 years. The kokanee spawner use by enumeration area (A, B, C, and D) has been graphed to show the kokanee spawner densities within each area. A cumulative graph of each section shows the total spawning kokanee population for each year broken down by enumeration area *[Appendix B – Figures B8 to B12]*. The spawner population has ranged from 512 to 19,845 over the past 13 years for the area counted.

Kokanee spawner counts of Middle Vernon Creek by Northcote et al. (1972) found 500 spawning kokanee. This count may include the entire length of Middle Vernon Creek but is far lower than recent counts. The area from Beaver Lake Road to Ellison Lake has been counted since 1997 by MWLAP and the count represented about 8% of the total spawner population. Enumeration of this section should be continued to evaluate the use by kokanee spawners and to determine more accurately Wood Lake kokanee escapement.

The total available spawning habitat for the sections of Middle Vernon Creek surveyed were estimated at 23,600 m^2 using the same methodology as Koshinsky et al. (1973). In general terms Sub-reaches 1, 2 and 3 were considered moderate spawning habitat while Sub-reach 4 was rated moderate to high. Sub-reach 5 was low to moderate with Sub-reach 6 rated low.

Based on the available potential spawning habitat, and using Tredger's (1987) proposed 7 kokanee/m^2 as optimum, an estimated 82,000 kokanee spawners could be supported within the surveyed sections of Middle Vernon Creek if all spawning habitat was made available. However, using a more conservative estimate of 0.426 kokanee spawners/m^2 (Koshinsky et al.1973) the available habitat could support approximately 55,000 spawners within the same area. This estimate may still be high as kokanee are not expected to utilize all potential habitat even though only the moderate and high quality habitat was selected *[see Table 1]*.

The potential spawning area was calculated based on the amount of Middle Vernon Creek that was completed by SHIM. The SHIM survey was not carried out on the section of stream from Beaver Lake Road to Ellison Lake or on Upper Vernon Creek downstream of the concrete spillway. The SHIM procedure should be completed on these areas and for Winfield Creek to determine the total habitat available for Wood Lake fish species to spawn.

4.11 Rainbow Trout

No rainbow trout were captured during the biological sampling of Middle Vernon Creek. This may have been due to the low flow and high water temperatures at the time of sampling. There is also a small population of rainbow trout identified within Wood Lake as indicated by Northcote et al. (1972) when a comparison of gill netting from 1935 and 1971 showed no rainbow trout captured in gill netting. Rainbow trout have been captured by several Oceola Club members and within Middle Vernon Creek. Rainbow trout have been observed moving downstream from Upper Vernon Creek near Ellison Lake that likely come from the Swalwell Lake population or a resident population within Upper Vernon Creek.

Koshinsky et al. (1973) calculated the numbers of trout fry, which can be accommodated in Wood Lake estimated on the basis of morphometry and total dissolved solids according to the stocking formula, utilized for the same purpose for the Okanagan headwater lakes. The estimated fry production was 3,600 fry and therefore means that 119 adult spawners would be using Middle Vernon Creek. Recent observations in 2002 indicate that rainbow trout adfluvial fish have been seen in Upper Vernon Creek. Biological surveying for fish species and densities earlier in the summer, prior to low flows, may prove useful to ensure rainbow trout utilization of Middle Vernon Creek.

4.12 Fish Habitat

An evaluation of the general habitat conditions was completed using SHIM data *[Appendix C]*. Many of the additional elements gathered during SHIM and the standard elements proved valuable for habitat analysis. Comparisons to other streams or biological norms were used to give perspective to the reader.

4.12.1 Stream Morphology

Pools form a critical fish habitat component within a natural stream system providing resting areas, cover and both inlet and outlet spawning habitat. Pool/riffle ratio can be used as an indicator of the overall health of a stream. Rosgen (1995) examined interior natural streams and found a typical pool/riffle ratio of 1:7-9. Hogan (1986) also evaluated natural streams with gradients ranging from 1% to 5% and found a pool/riffle ratio of 1:4-6.

During surveys within Middle Vernon Creek the average pool/riffle ratio was calculated to be very low (1:25) *[Appendix B - Figures B13 to B15]*. This is approximately 3 to 6 times lower than the expected average for interior streams.

4.12.2 Large Woody Debris

Large woody debris (LWD) is considered any large piece of relatively stable woody material having a diameter of greater than 10 cm and a length greater than 3 m that intrudes into the stream channel. In general terms, LWD is an important influence on stream channel morphology in streams less than 8% in gradient and not wider than 30 m bankfull width. In addition to the SHIM survey, technicians were asked to count the abundance of LWD within Middle Vernon Creek.

Peterson (1992) found that small-unmanaged streams were likely to contain between 18 and 61 pieces of LWD per 100 linear meters while streams with an average channel width of 5 m to 10 m would contain between 40 to 80 pieces per 100 linear meters. The results of our survey indicate a general lack of LWD found within the system *[Appendix B - Figure B16]*. Sub-reach 4 contained the highest amount of LWD per 100 m section at 6.2 pieces while Sub-reach 3 was the lowest at 1.6 pieces. The higher number of pieces found within Sub-reach 4, almost double the average, are likely the result of HCTF restoration activities already undertaken within Middle Vernon Creek.

4.12.3 Riparian Condition

Twenty-four distinct stream segments were identified within the SHIM survey of Middle Vernon Creek. The 24 segments of stream were broken into three channel types in an attempt to describe the current channel and riparian condition. Habitat types were identified as natural, modified and channelized. Nine (9) of the 24 segments were noted as natural with only minimal disturbances for a combined wetted area of 10,863 m^2. Eight (8) of the stream segments were identified as modified, which included such disturbances as the removal of riparian vegetation from both agricultural land and private property and bank stabilization with cobbles or rip-rap. This habitat type made up 6,145 m^2. The remaining six (6) segments were made up of channelized habitat that included extensive retaining walls in urban settings accounting for 4,886 m^2 of stream. One (1) segment, identified as off-channel oxbow habitat, was not included within the survey results.

Middle Vernon Creek has approximately half the length surveyed as natural habitat with a further 25% in semi natural condition. The bulk of this habitat was found within Sub-reach 4. It was also found that the highest density of kokanee spawners was found within enumeration area C and correlates to Sub-reach 4. The highest value spawning area evaluated by SHIM was also located within Sub-reach 4 and had an overall rating as moderate to high value.

Restoration works completed by the Oceola Fish and Game Club through HCTF funding have been focused within Sub-reach 4 and should continue within this high value area. It is also important to remember that access to this sub-reach must not be restricted by water flow, water quality to this sub-reach should be maintained or improved, sediment aggradations should be prevented, and habitat conditions throughout the creek also affect the highest value sections.

5.0 CONCLUSIONS

1. **Historical data and anecdotal information from the 1970s has documented the presence of kokanee, rainbow trout and mountain whitefish in Middle Vernon Creek.**

2. **The low flows observed in Middle Vernon Creek can be attributed to the cumulative impacts associated with several factors.**
   They include:
   - The natural variability of climatic conditions – the summer of 2002 was extremely dry;
   - Reservoir management – storage is primarily for agriculture and domestic use;
   - Excessive water use for agriculture and domestic purposes (licenced demand can exceed annual runoff);
   - Groundwater recharge on Upper Vernon Creek;
   - Sediment build-up in Middle Vernon Creek upstream of Beaver Lake Road;
   - Alteration of natural drainage paths (surface and sub-surface) in the lower watershed area (between Ellison Lake and Wood Lake).
   - Groundwater withdrawals in the lower watershed area; and
   - Unlicenced water withdrawals along Middle Vernon Creek.

3. **More detailed investigations and monitoring is required to quantify the expected natural flow and the flow reductions associated with the various activities listed above.**
   - The BC Ministry of Water, Land and Air Protection have allocated funding to estimate the natural hydrograph and review water supply/demand in the Middle Vernon Creek watershed (Upper Vernon Creek and Middle Vernon Creek) in order to develop realistic conservation fish flow requirements.

4. **Flows for aquatic habitat during critical low flow periods can be increased through the implementation of the following (subject to change and/or modifications as new information is collected, other reports completed and discussions take place):**
   - Establishment of linkages between the various on-going and proposed water-related planning processes being undertaken in the watershed. This would include the creation of an overall water resource planning committee, lead by the Oceola Fish and Game Club, to reduce duplication of effort and to identify any potential streamlining opportunities;
   - Completion of an information database for landowners along Middle Vernon Creek (including summarization of relevant SHIM information) and

subsequent consultation with landowners to address potential adverse activities;

- Development of a reservoir management decision calendar in partnership with the District of Lake Country;
- Installation of stream flow monitoring stations on Middle Vernon Creek and Upper Vernon Creek (with subsequent feasibility studies for potential mitigation projects);
- Quantification of water requirements for sustainable agriculture; and
- Summarization of groundwater withdrawals in the lower watershed area.

5. **A biology assessment and completion of a Sensitive Habitat Inventory Mapping survey was undertaken on Middle Vernon Creek between Wood Lake and Beaver Lake Road. Funding limited the assessment to this section of creek and under low flow conditions.**

6. **The SHIM survey has quantified the length of stream bank stabilized (200 m of easily erodible, fine-textured material) and the length of existing eroding stream bank (400 m). A more detailed assessment is required to quantify the volumes of material currently entering the stream. Stream restoration activities in 2002 resulted in approximately 100 pieces of large woody debris being placed within Middle Vernon Creek. The SHIM survey recorded 6.2 pieces of LWD per 100 m of stream within sub-reach 4, most of which can be attributed to the restoration activities.**
   - The Sensitive Habitat Inventory Mapping survey information can be used to help prioritize future proposed stream restoration efforts.

6.0 RECOMMENDATIONS

1. **Establish linkages between the various on-going and proposed water-related planning processes being undertaken in the watershed with the creation of an overall water resource planning committee lead by the Oceola Fish and Game Club. The objectives would be to reduce duplication of effort and to identify any potential streamlining opportunities.**

   The first proposed actions would be to:

   - Send an official letter of invitation with accompanying questions to the watershed stakeholders (as identified by the stakeholders listed in Section 4.3). It is anticipated that additional stakeholders will be identified; and
   - Develop a draft working protocol for the group, partially based on the information provided by stakeholders;
   - Hold a committee meeting to finalize the working protocol;
   - Send an information letter to all water licencees, in partnership with Lands and Water BC Inc.

2. **Proposed Habitat Conservation Trust Funding for 2003/04 should be used to complete the second priority action items identified in order to secure more flows for aquatic habitat along Middle Vernon Creek. This will include:**

   - Re-establishment of the historic Water Survey of Canada hydrometric station on Middle Vernon Creek;
   - The development of a database on existing information and landowners along Middle Vernon Creek;
   - Stop unauthorized water withdrawals along Middle Vernon Creek, ensure fish screening on water intakes comply with fisheries standards, and no electrical discharges come from water intakes that damage or kill aquatic organisms; and
   - Integrate water management issue resolution along Middle Vernon Creek with stream restoration projects. Emphasis will be on bank stabilization through LWD additions and creations of pool habitat while reducing run habitat.

3. **Proposed Habitat Conservation Trust Funding for 2003/04 should be used to establish stream flow monitoring stations on Upper Vernon Creek to quantify:**

   - **Current stream flows for aquatic habitat;**
   - **Major surface water withdrawals; and**
   - **Groundwater recharge rates.**

   The prioritization and number of hydrometric stations installed will be dependent on available funding, the results of concurrent reports, and feedback from watershed stakeholders. At present it is recommended that historical WSC stations be re-established.

Work will include data management and maintenance agreements with watershed stakeholders. Efforts will be made to acquire additional funds and/or in-kind support from the water resource planning committee members for the proposed action plan.

4. **It is recommended that an education and awareness program for the Swalwell Lake reservoir release schedule be developed in partnership with the District of Lake Country. This could include the development of a reservoir management decision calendar.**

5. **Complete biological and habitat assessments for un-mapped sections of the Middle Vernon Creek watershed. This would include:**
   - SHIM surveying of tributaries to Middle Vernon Creek, Middle Vernon Creek from Beaver Lake Road to Ellison Lake and on Upper Vernon Creek downstream of the concrete spillway.
   - Sampling at various stream discharges on: Middle Vernon Creek between Beaver Lake Road and Ellison Lake; tributary channels to Middle Vernon Creek; and on the downstream portion of Upper Vernon Creek (particularly the section utilized by Kokanee).
   - Re-sampling of fish populations Middle Vernon Creek between Wood Lake and Beaver Lake Road at higher stream discharges.
   - Re-sampling at the stream restoration project sites to determine effectiveness.

6. **Seek additional sources of funds and/or partnership development to address other resource-based issues identified. This would include the quantification of water for agriculture in the watershed and urban development initiatives to reduce water consumption.**

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APPENDIX A

Hydrology
Figures, Tables and Photos

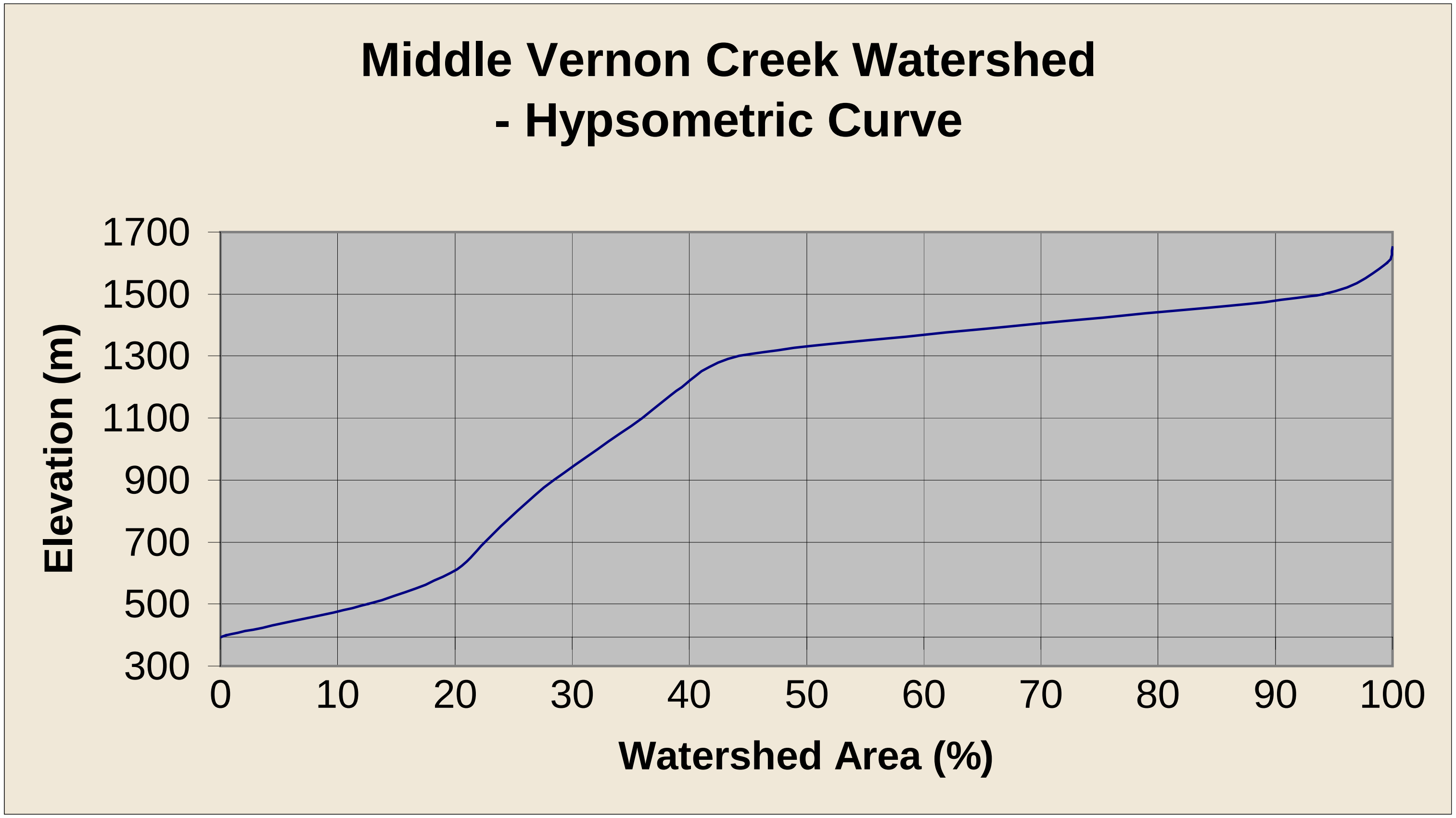

Figure A1. Hypsometric Curve for the Middle Vernon Creek Watershed.

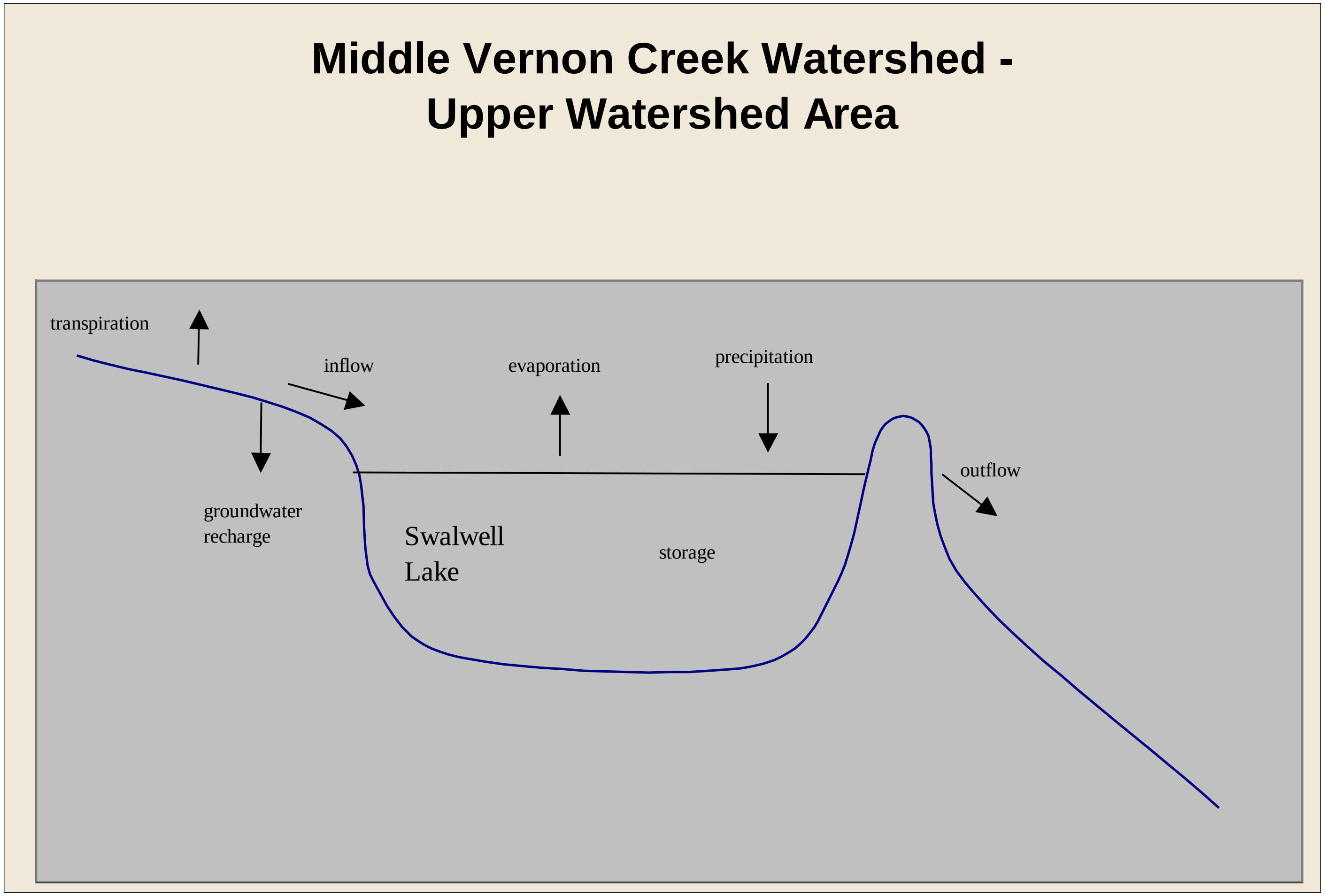

Figure A2. Generalized hydrologic cycle for the upper watershed area of the Middle Vernon Creek watershed.

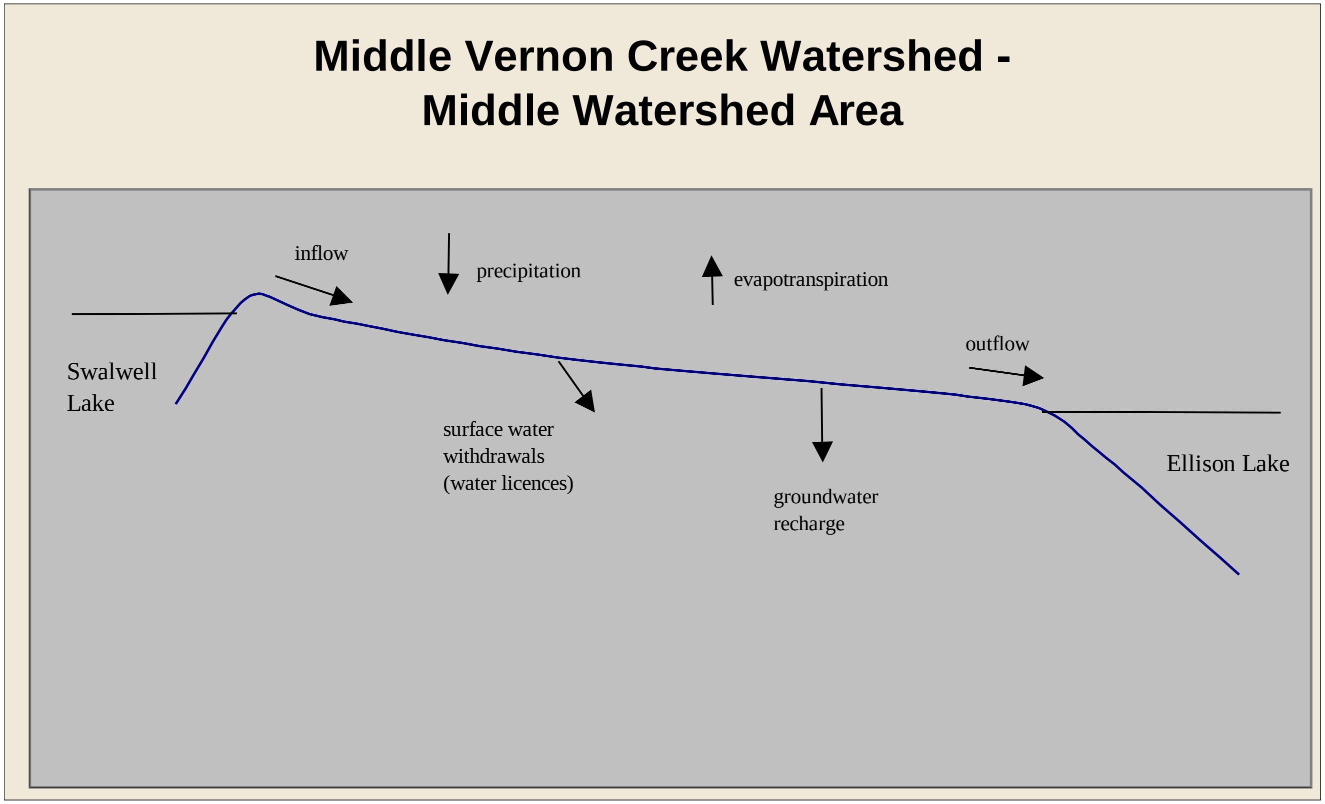

Figure A3. Generalized hydrologic cycle for the middle watershed area (Upper Vernon Creek) of the Middle Vernon Creek watershed.

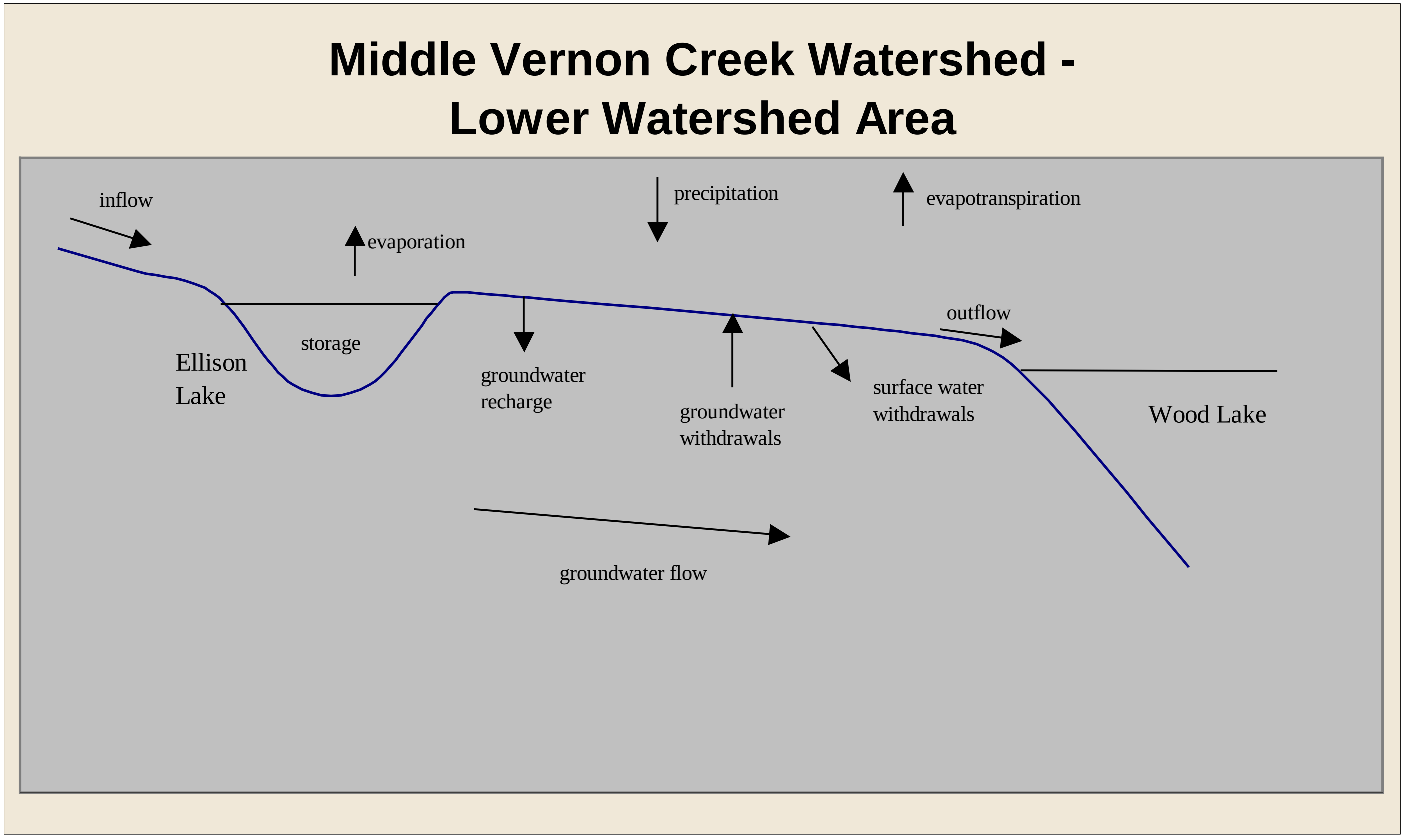

Figure A4. Generalized hydrologic cycle for the lower watershed area of the Middle Vernon Creek watershed.

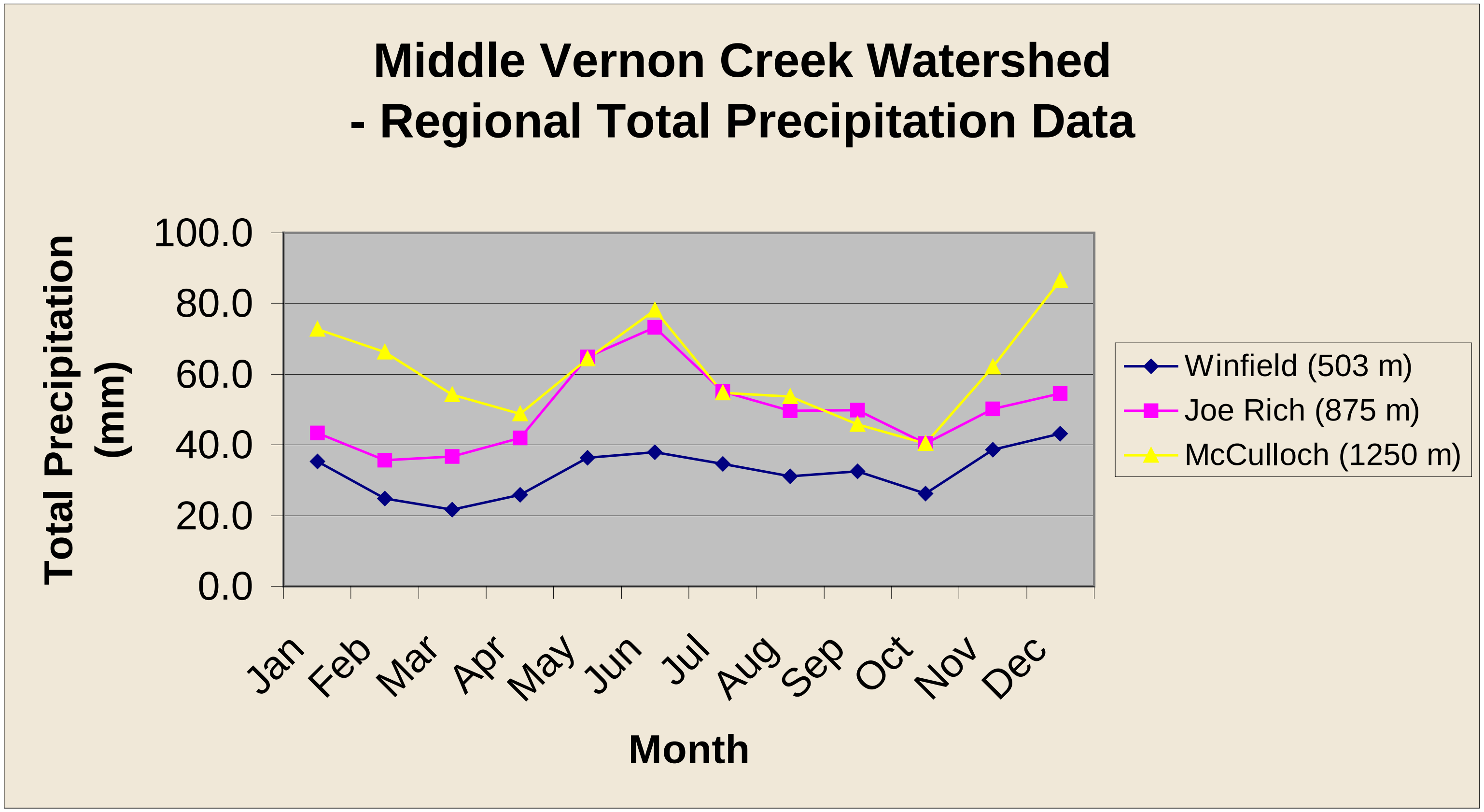

Figure A5. Regional mean monthly total precipitation data for the Middle Vernon Creek watershed.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Winfield (503 m)													
Rainfall	5.4	9.2	16.4	25.3	36.4	37.9	34.6	31.1	32.5	25.4	21.8	8.7	284.7
Snowfall	30	15.7	5.2	0.5	0	0	0	0	0	0.8	16.9	34.4	103.5
Precipitation	35.4	24.9	21.6	25.8	36.4	37.9	34.6	31.1	32.5	26.2	38.7	43.1	388.2
Joe Rich (875 m)													
Rainfall	6.2	8.8	22.1	36.7	64.5	73.2	55.0	49.6	49.8	36.0	21.4	8.3	431.6
Snowfall	37.0	27.0	14.7	5.3	0.4	0.0	0.1	0.0	0.1	4.3	28.8	46.2	163.9
Precipitation	43.2	35.8	36.8	42.0	64.9	73.2	55.1	49.6	49.9	40.3	50.2	54.5	595.5
McCulloch (1250 m)													
Rainfall	2.3	3.3	7.5	27.1	57.0	77.6	53.8	53.7	45.2	25.1	8.6	2.1	363.3
Snowfall	70.5	62.9	46.7	21.6	7.4	0.6	0.9	0.0	0.7	15.3	53.5	84.5	364.6
Precipitation	72.8	66.2	54.2	48.7	64.4	78.2	54.7	53.7	45.9	40.4	62.1	86.6	727.9

Table A1. Regional mean monthly precipitation data for the Middle Vernon Creek watershed.

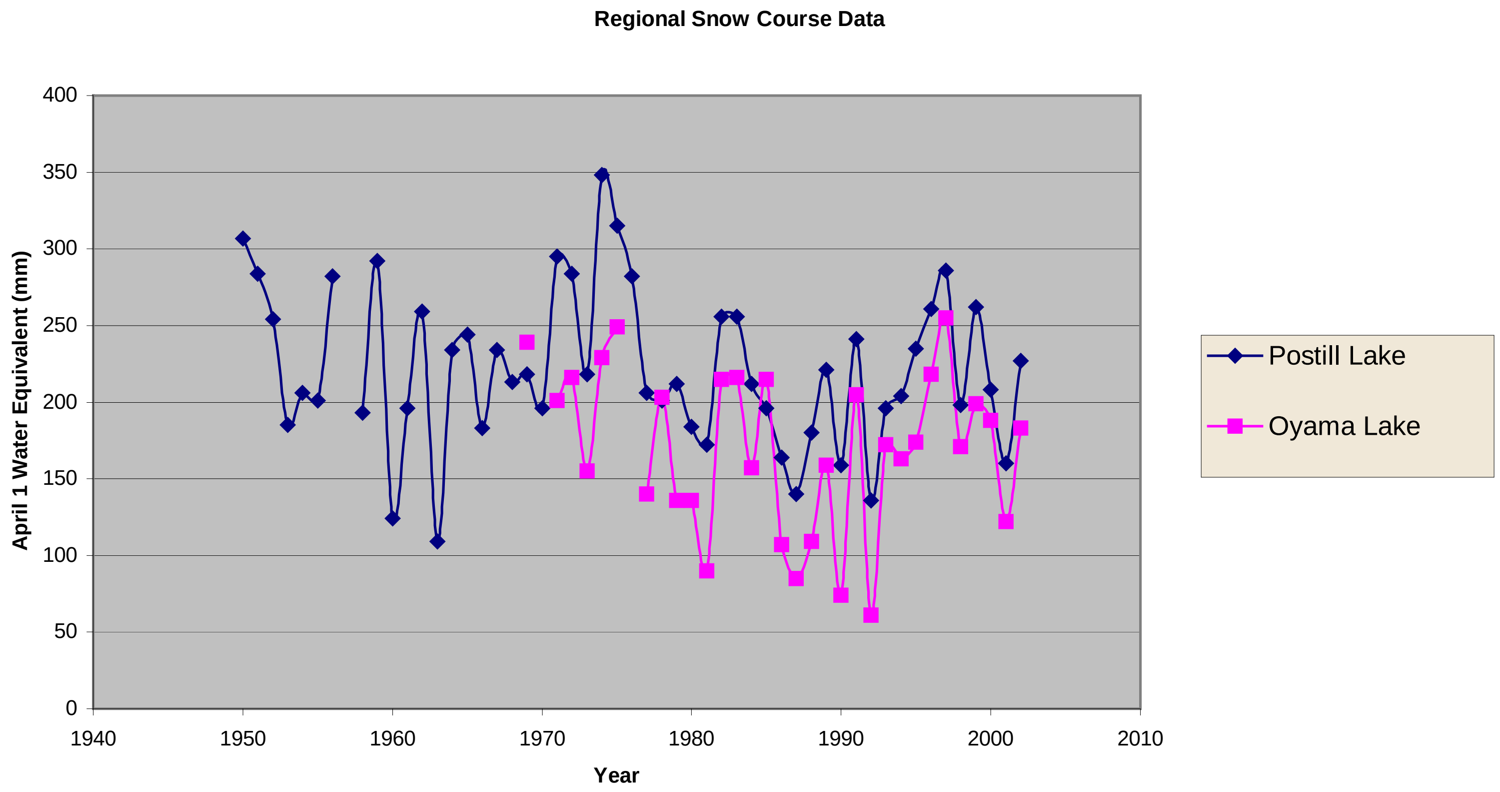

Figure A6. Regional snow course data for the Middle Vernon Creek watershed.

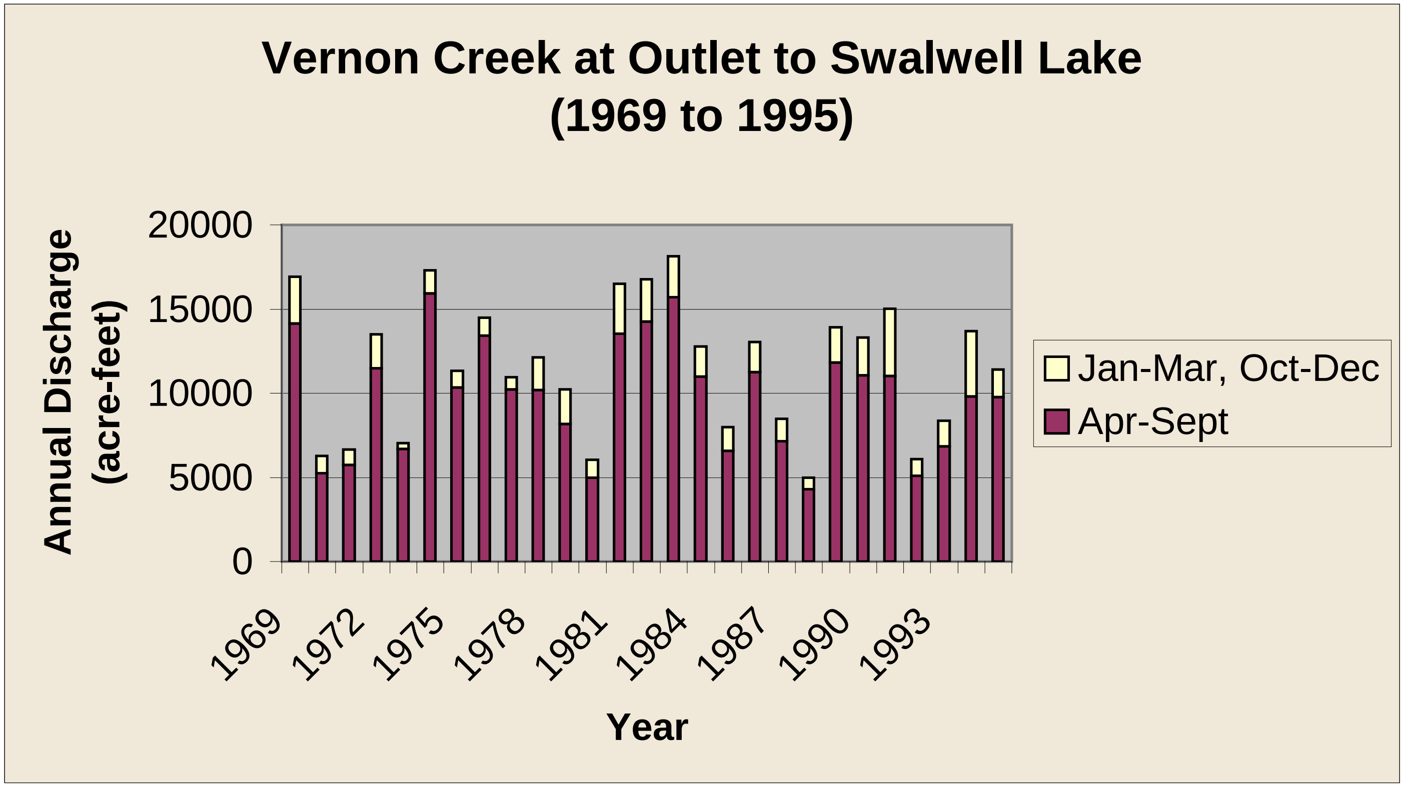

Figure A7. Annual discharges for Upper Vernon Creek at the outlet of Swalwell Lake.

Station No.	Station Name	Drainage Area (km^2)	Discharge Records
08NM062	Swalwell Lake Near Okanagan Centre		1926/28, 1970 – manual, stage, seasonal 1971/94 – manual, stage, continuous
08NM022	Vernon Creek at Outlet of Swalwell Lake	62.4	1921/30, 1945/46, 1960/64, 1965,1966/67 – manual, flow, seasonal 1969/98 – recording, flow, continuous
08NM175	Vernon Creek below Arda Dam	102	1972/79 – recording, flow, continuous
08NM043	Vernon Creek near Okanagan Centre	90.1	1919/22, 1926/30, 1960/63 – manual, flow, seasonal 1923/25 – manual, flow, misc.
08NM162	Vernon Creek at Inlet to Ellison Lake	127	1969/70 – manual, flow, misc. 1971 – manual, flow, seasonal 1972/74 – recording, flow, continuous
08NM067	Ellison Lake Near Winfield		1968/69, 1971, 1974/75 – recording, stage, seasonal 1970, 1972/73, 1976/80 – recording, stage, continuous
08NM182	Vernon Creek at Outlet of Ellison Lake	138	1971/74 – recording, flow, continuous
08NM008	Vernon Creek above Diversions	90.7	1919 – manual, flow, seasonal
08NM009	Vernon Creek at Inlet to Wood Lake	151	1919/21 – manual, flow, seasonal 1969/71 – manual, flow, continuous 1969/98 – recording, flow, continuous
08NM163	Crooked Lake at the Outlet		1970, 1973/74 – manual, flow, seasonal 1971/72, 1975/81 – manual, flow, continuous
08NM236	Vernon Creek Diversion to WOCID		1973/78 - recording, flow, continuous
08NM044	Vernon Creek Okanagan Centre Diversion		1919, 1922/31, 1960/63 – manual, flow, seasonal
08NM146	Clark Creek near Winfield		1968/82– recording, flow, continuous

Table A2. Summary of historical Water Survey of Canada hydrometric stations for the Middle Vernon Creek watershed.

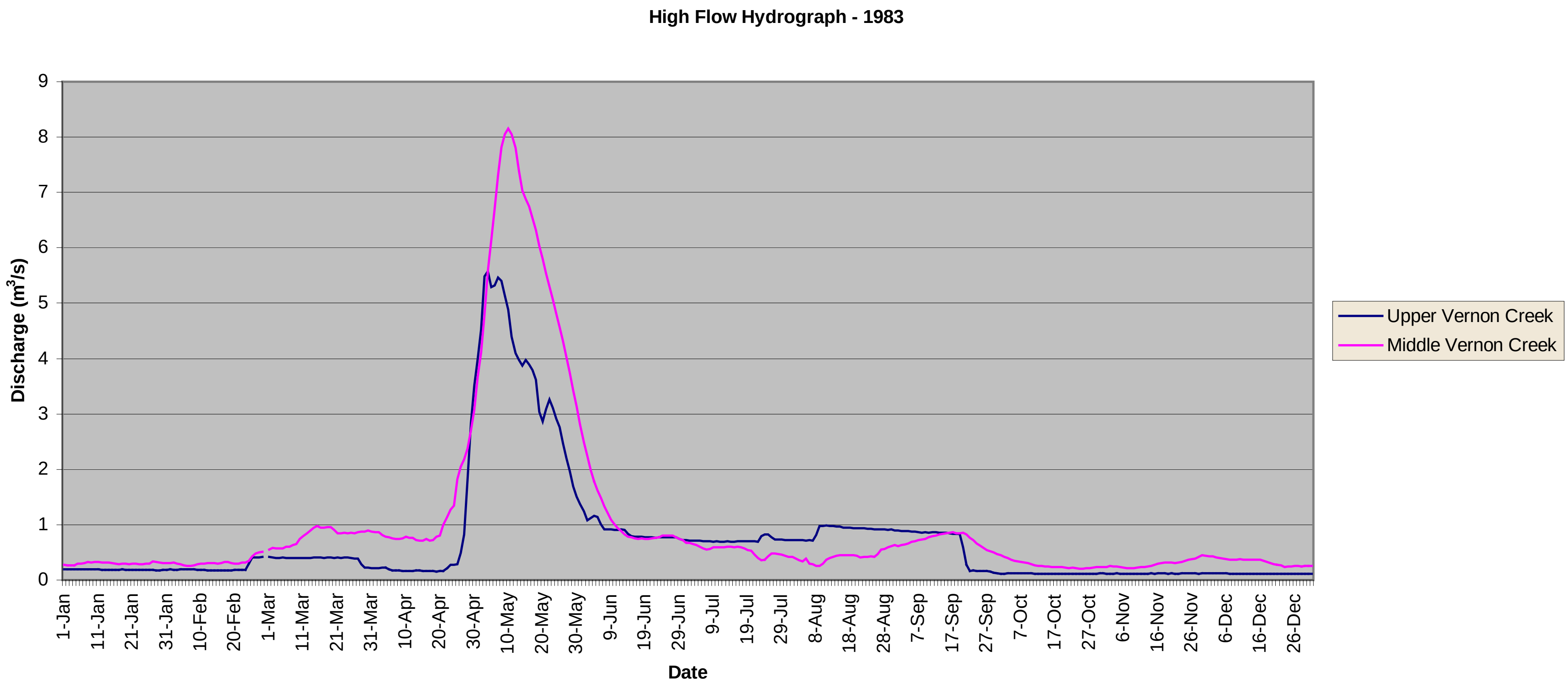

Figure A8. Hydrograph of high stream flow in Upper Vernon Creek and Middle Vernon Creek.

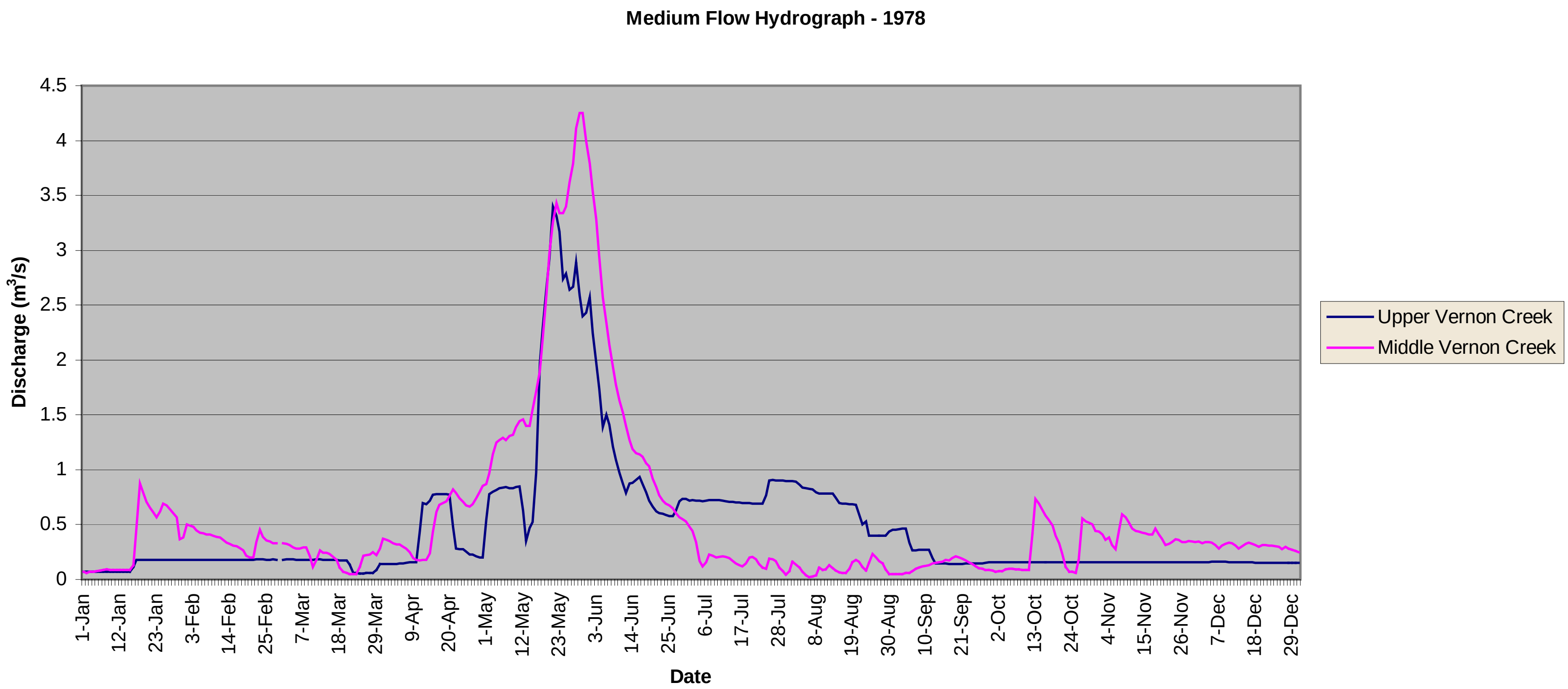

Figure A9. Hydrograph of medium stream flow in Upper Vernon Creek and Middle Vernon Creek.

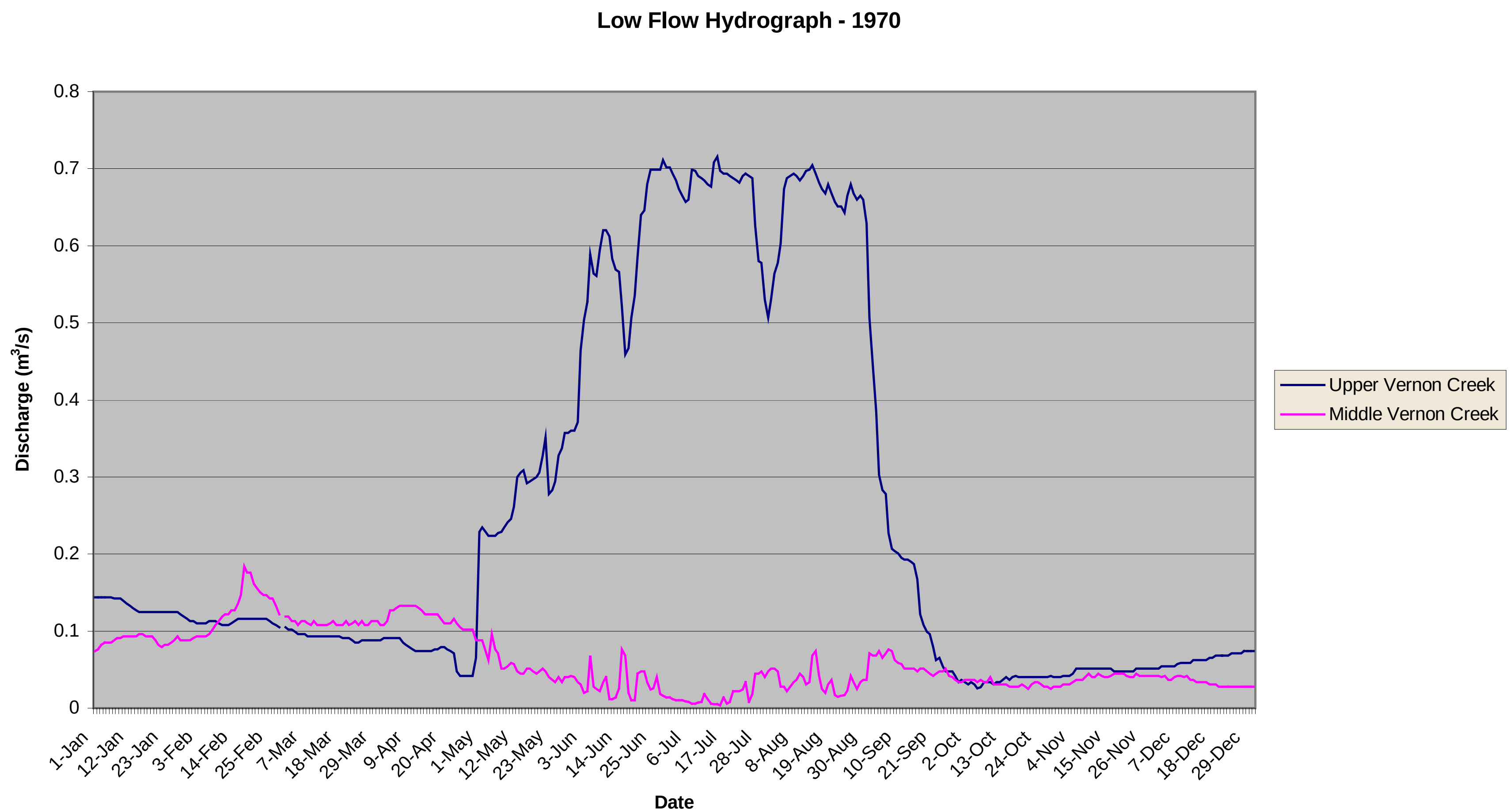

Figure A10. Hydrograph of low stream flow in Upper Vernon Creek and Middle Vernon Creek.

Photo 1. Spawning Kokanee in Middle Vernon Creek electrocuted by water intake. (Oct 4, 2002)

Photo 2. Fishway constructed by Oceola Fish and Game Club to facilitate passage for spawning Kokanee over irrigation dam. (Sept. 30, 2002)

APPENDIX B

Biology
Figures and Tables

Table B1. Species list for Swalwell, Ellison, and Wood Lakes from Historical Information. (Northcote et al. 1972, Columbia 2001/02 and FISS 2002)

Family	Common Name	Scientific Name	Wood Lake	Ellison Lake	Swalwell Lake	Middle Vernon Creek
Trout and Salmon	Kokanee	*Oncorhynchus nerka*	X			X
	Rainbow Trout	*Oncorhynchus mykiss*	X	X	X	X
	Lake Trout	*Salvelinus namaycush*	X			
Whitefishes	Mountain Whitefish	*Prosopium williamsoni*	X			
Suckers	Largescale Sucker	*Catostomus macrocheilus*	X	X		X
	Sucker					X
Minnows	Carp	*Catostomus catostomus*	X	X		X
	Redside Shiner	*Richardsonius balteatus*	X	X		X
	Northern Pikeminnow	*Ptychocheilus oregonensis*	X	X		X
	Peamouth Chub	*Mylocheilus caurinus*	X	X		X
Perches	Yellow Perch	*Perca fluviatilis*				X
Sculpins	Prickly Sculpin	Cottus asper	X		X	X
	Sculpins					X

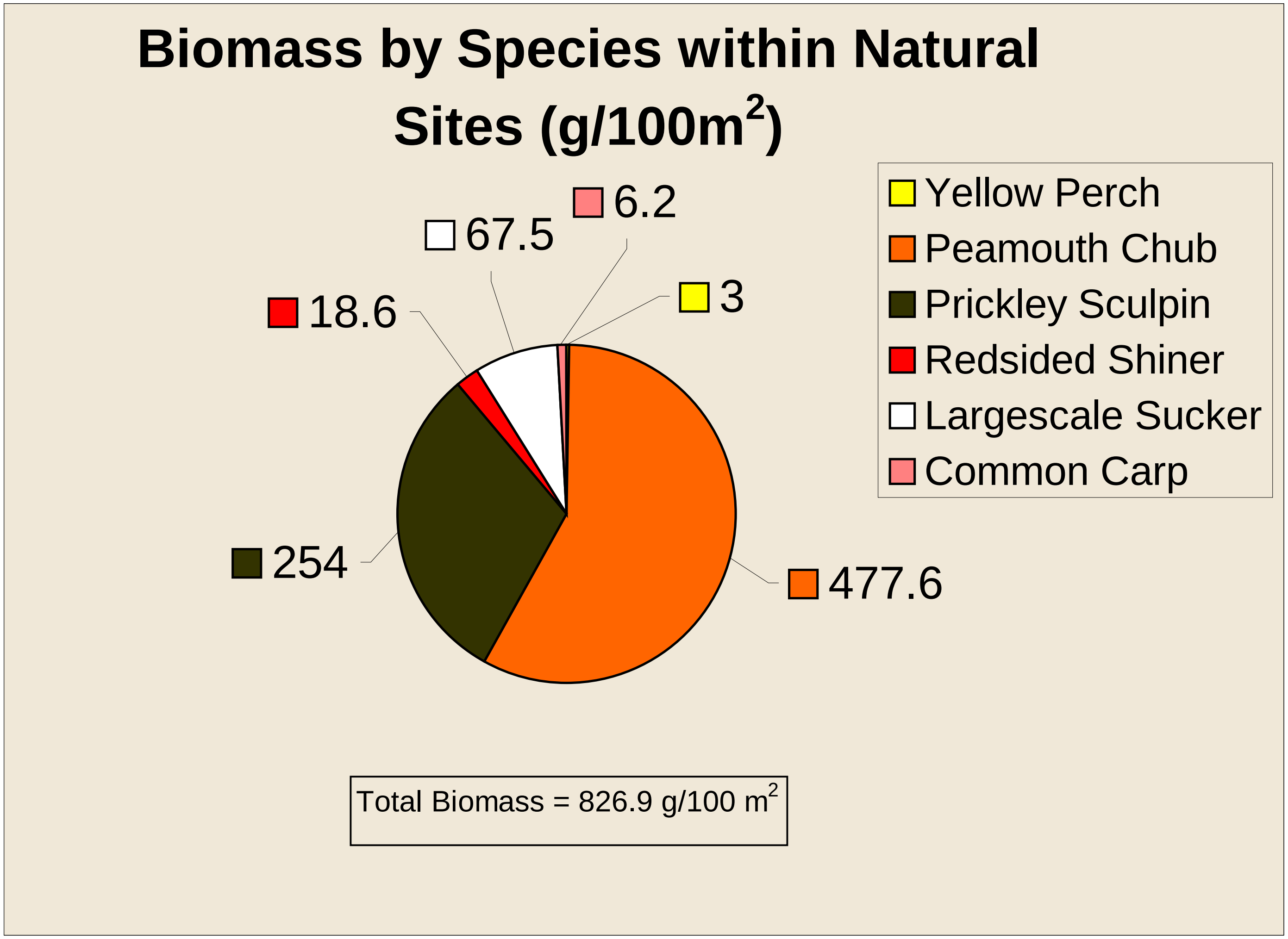

Figure B1. Biomass by species within Natural Sites of Middle Vernon Creek.

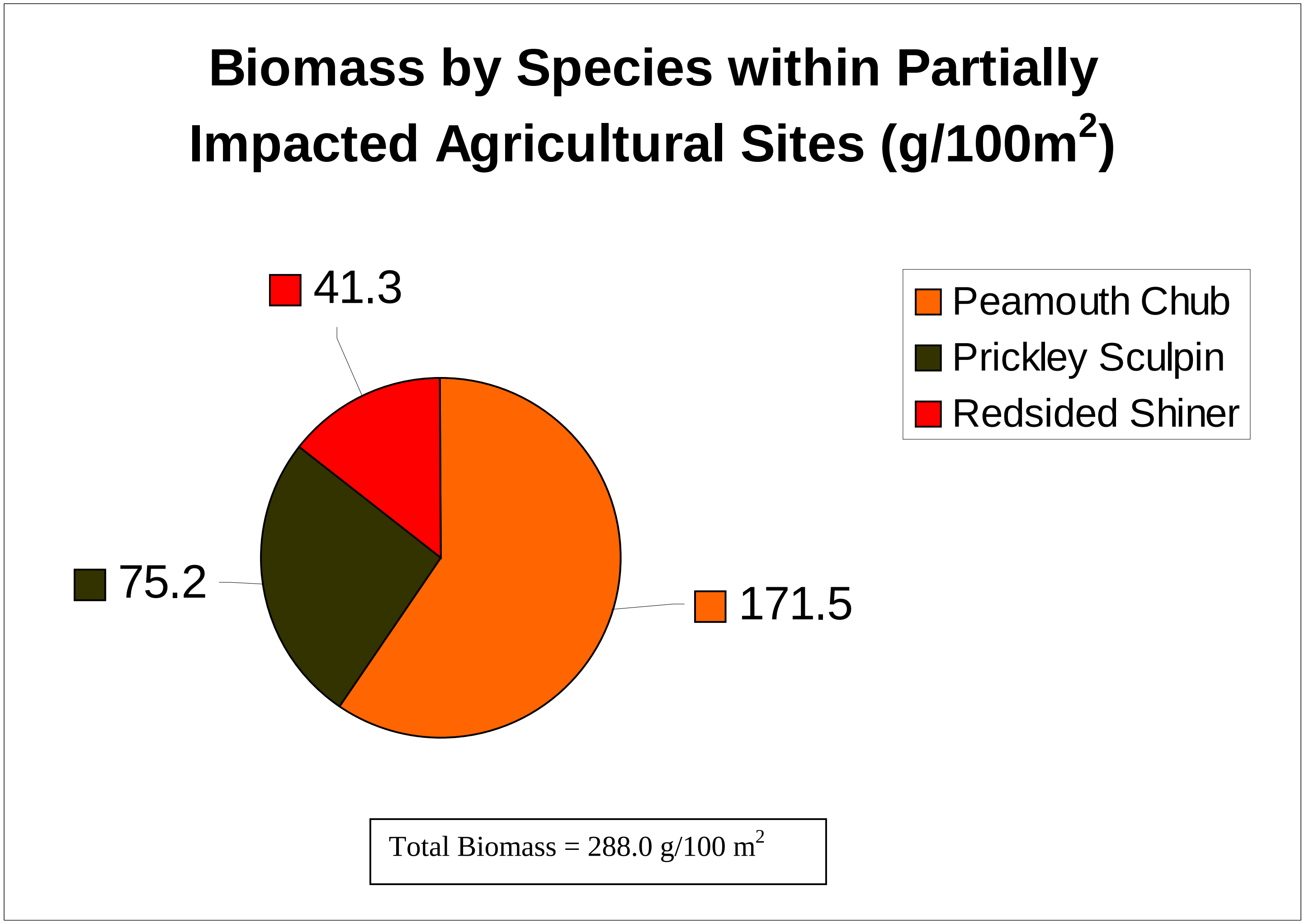

Figure B2. Biomass by species within Partially Impacted Agricultural Sections of Middle Vernon Creek.

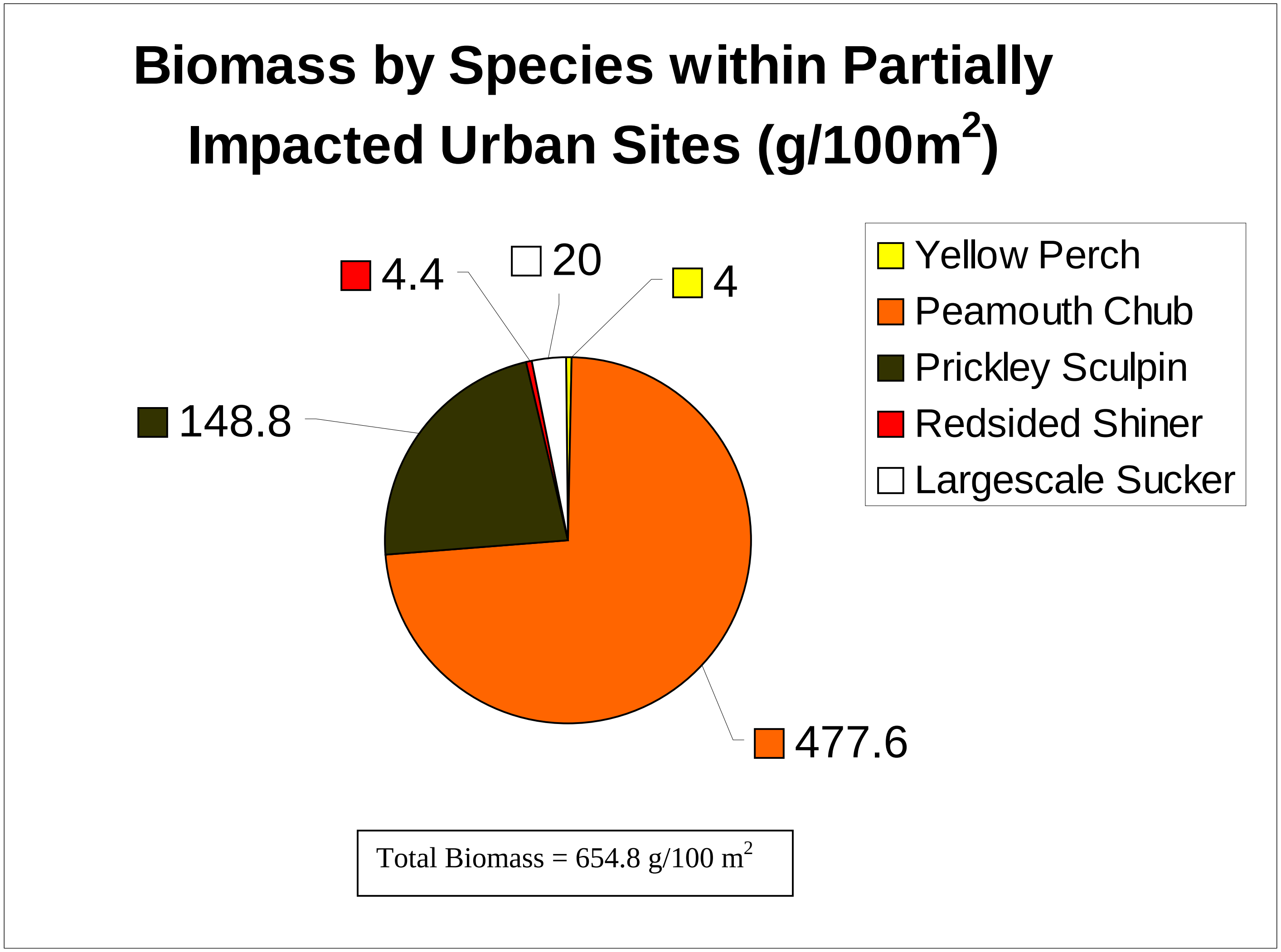

Figure B3. Biomass by species within Partially Impacted Urban Sections of Middle Vernon Creek.

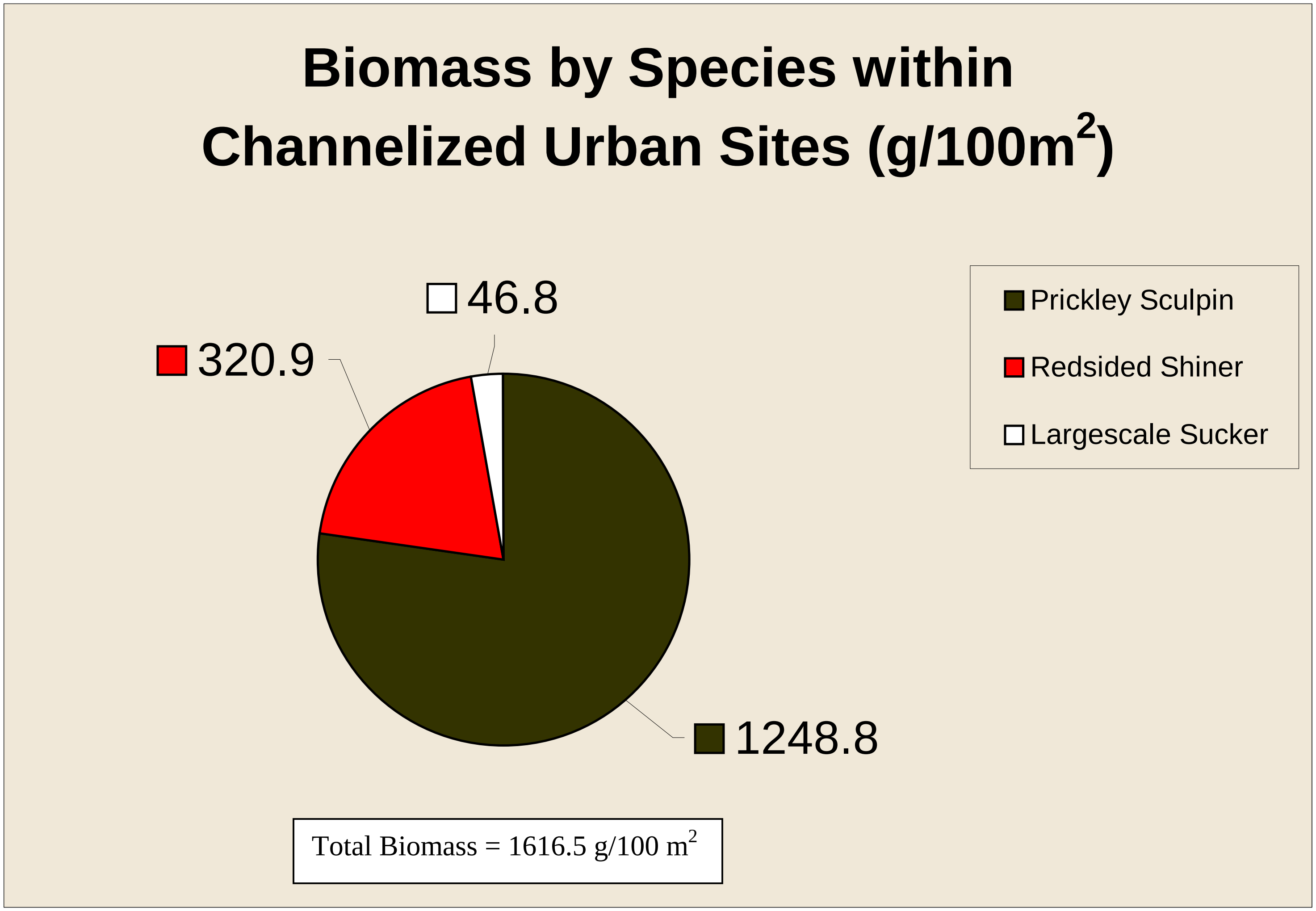

Figure B4. Biomass by species within Channelized Urban Sections of Middle Vernon Creek.

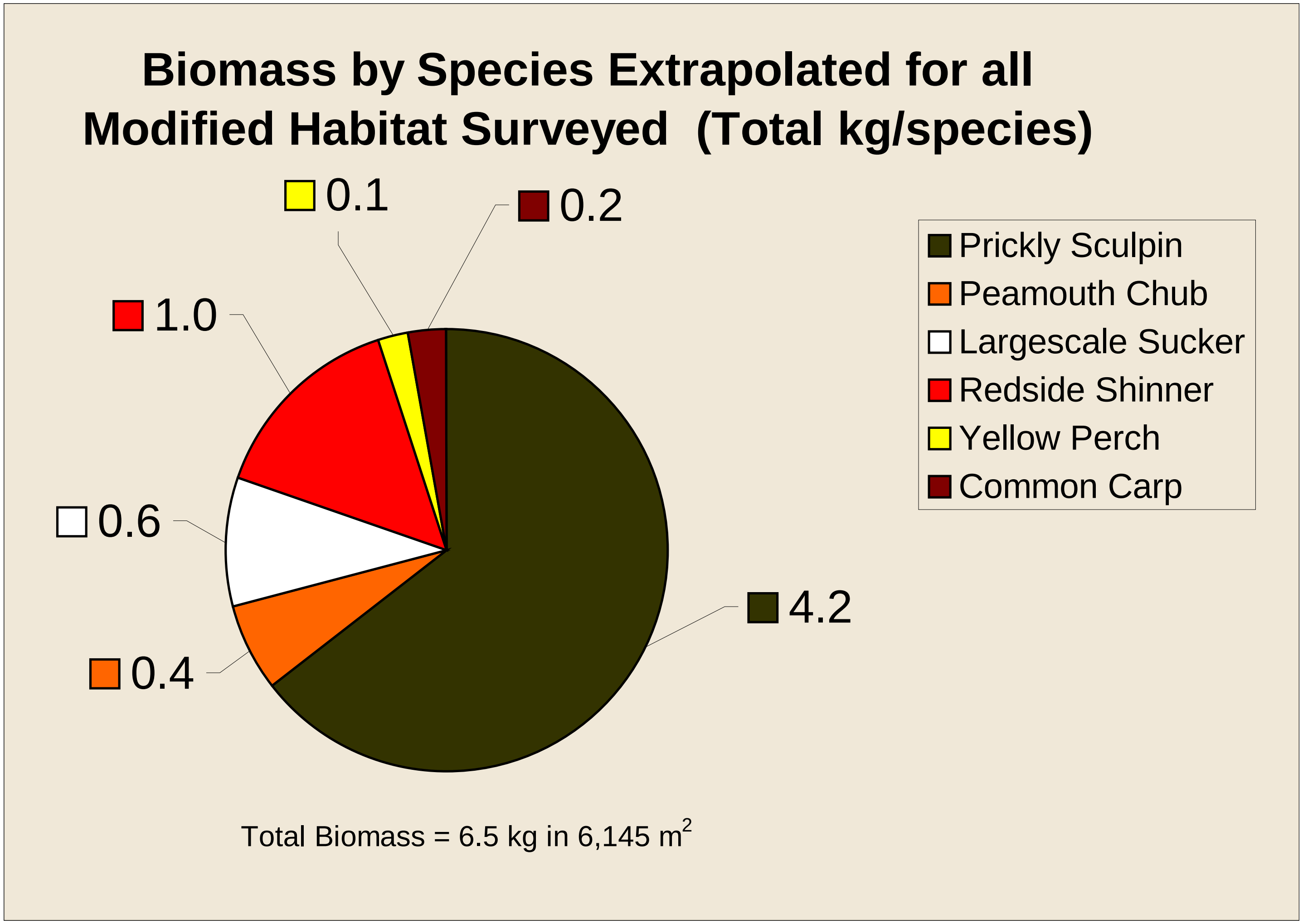

Figure B5. Biomass by species extrapolated for all Modified Habitat surveyed in Middle Vernon Creek.

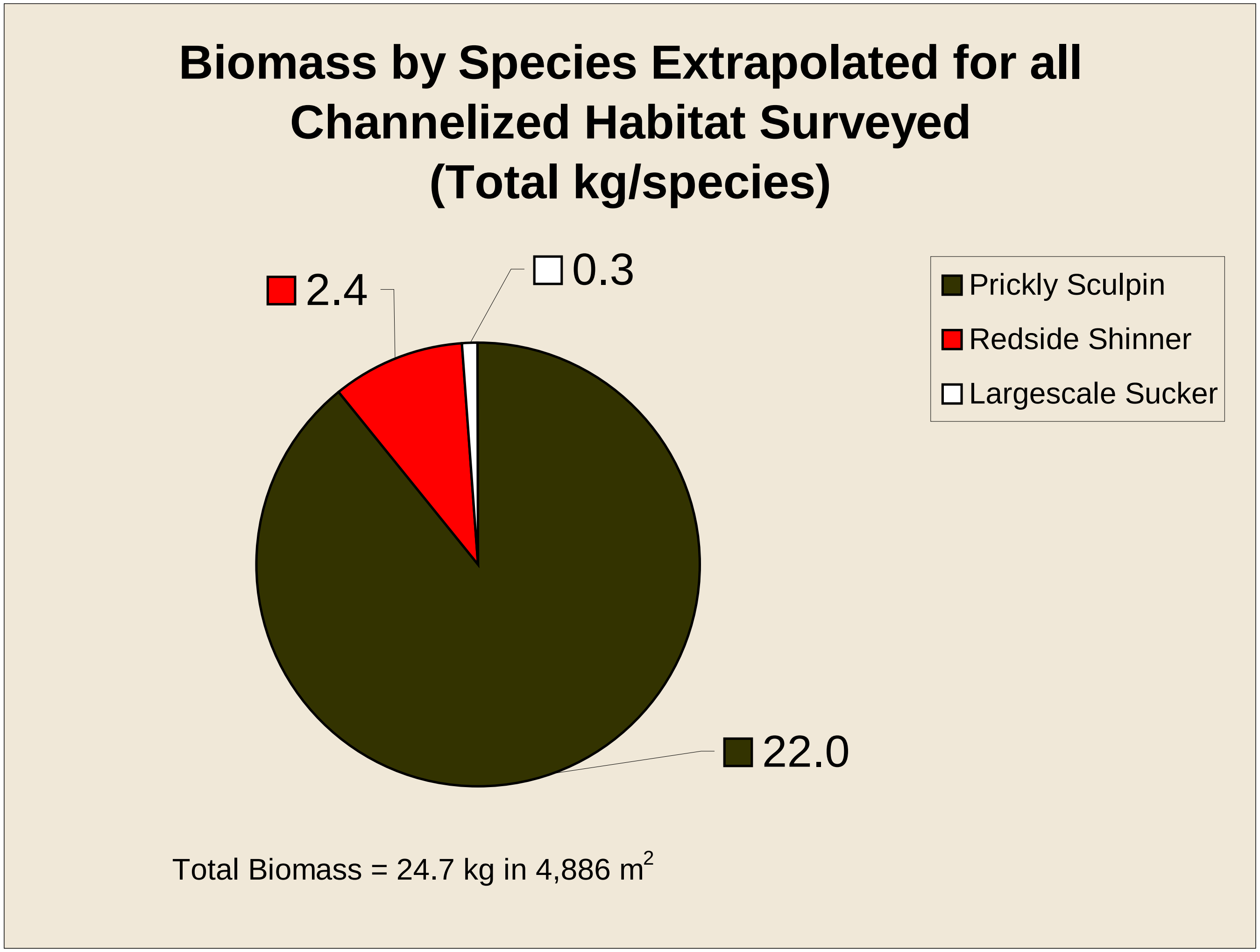

Figure B6. Biomass by species extrapolated for all Channelized Habitat surveyed in Middle Vernon Creek.

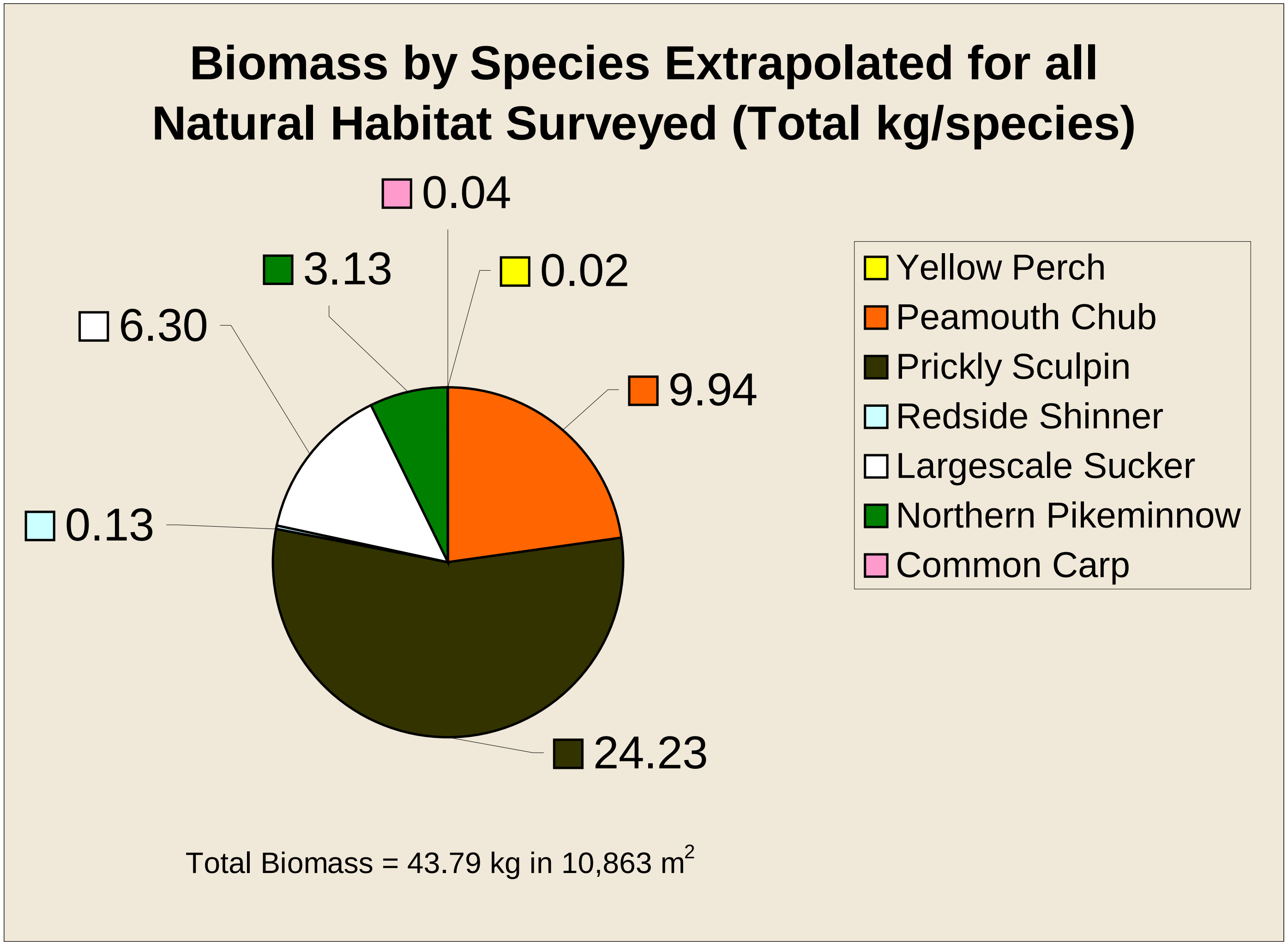

Figure B7. Biomass by species extrapolated for all Natural Habitat surveyed in Middle Vernon Creek.

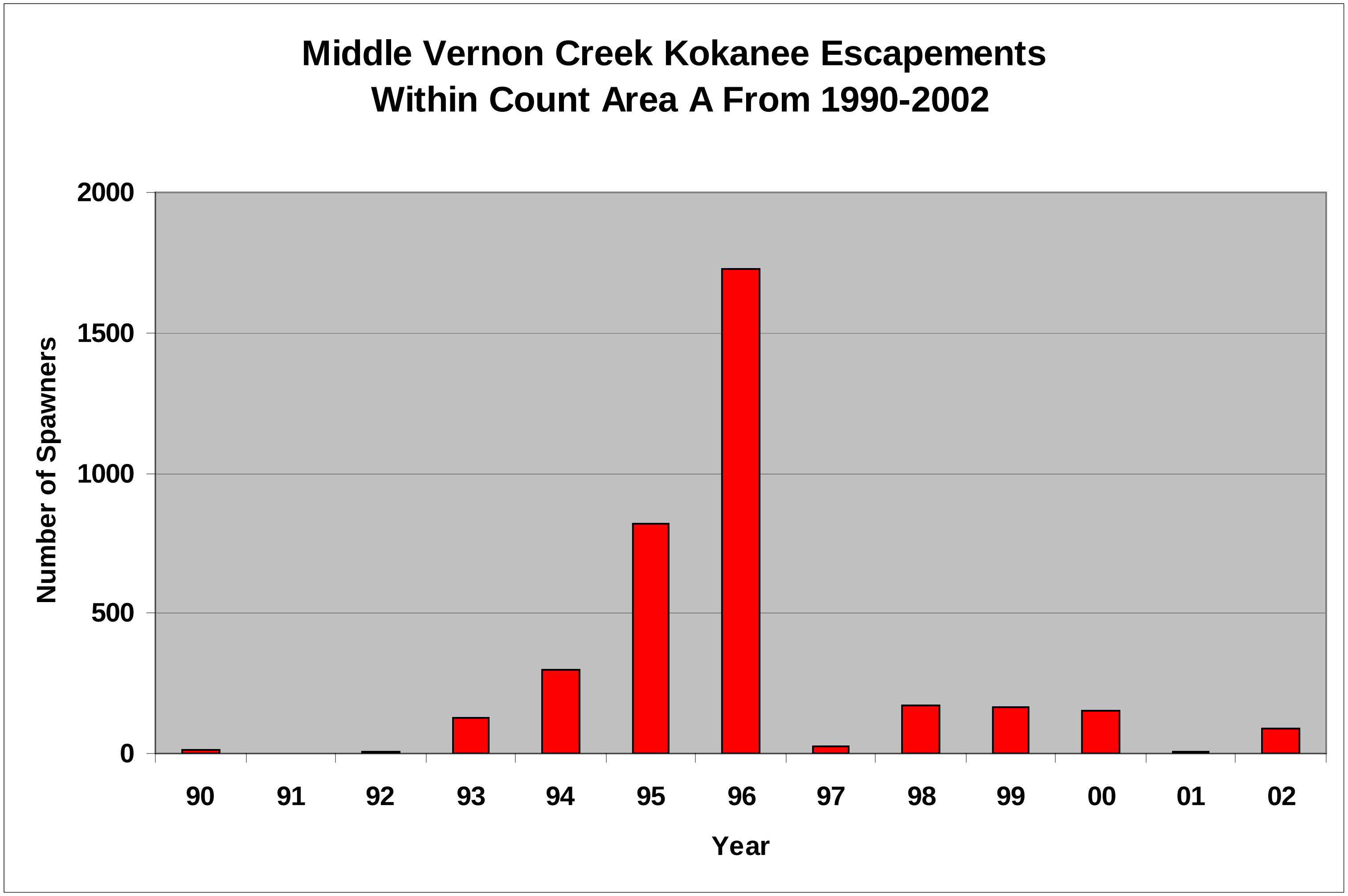

Figure B8. Kokanee Escapement within Count Area A of Middle Vernon Creek (MWLAP 2003).

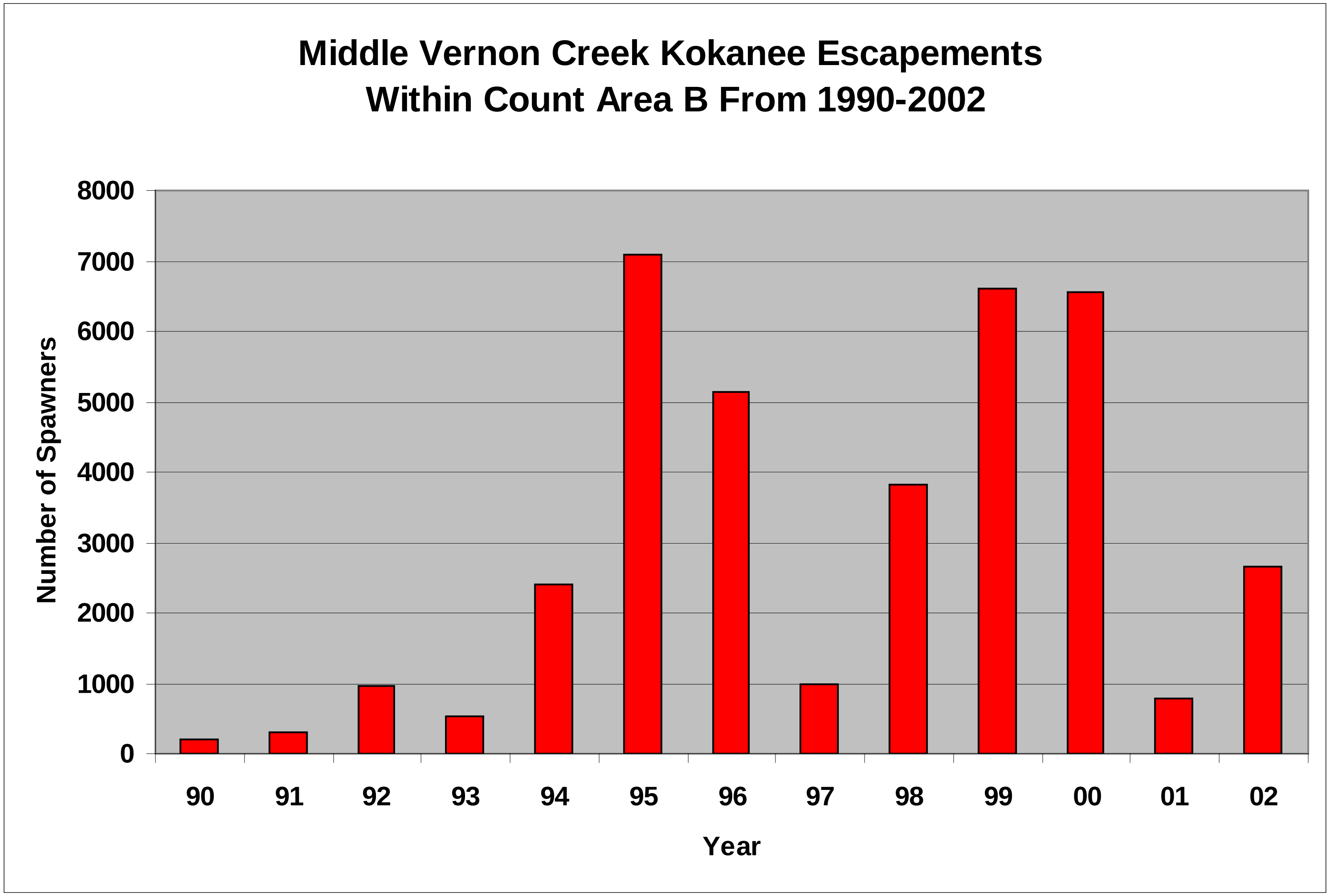

Figure B9. Kokanee Escapement within Count Area B of Middle Vernon Creek (MWLAP 2003).

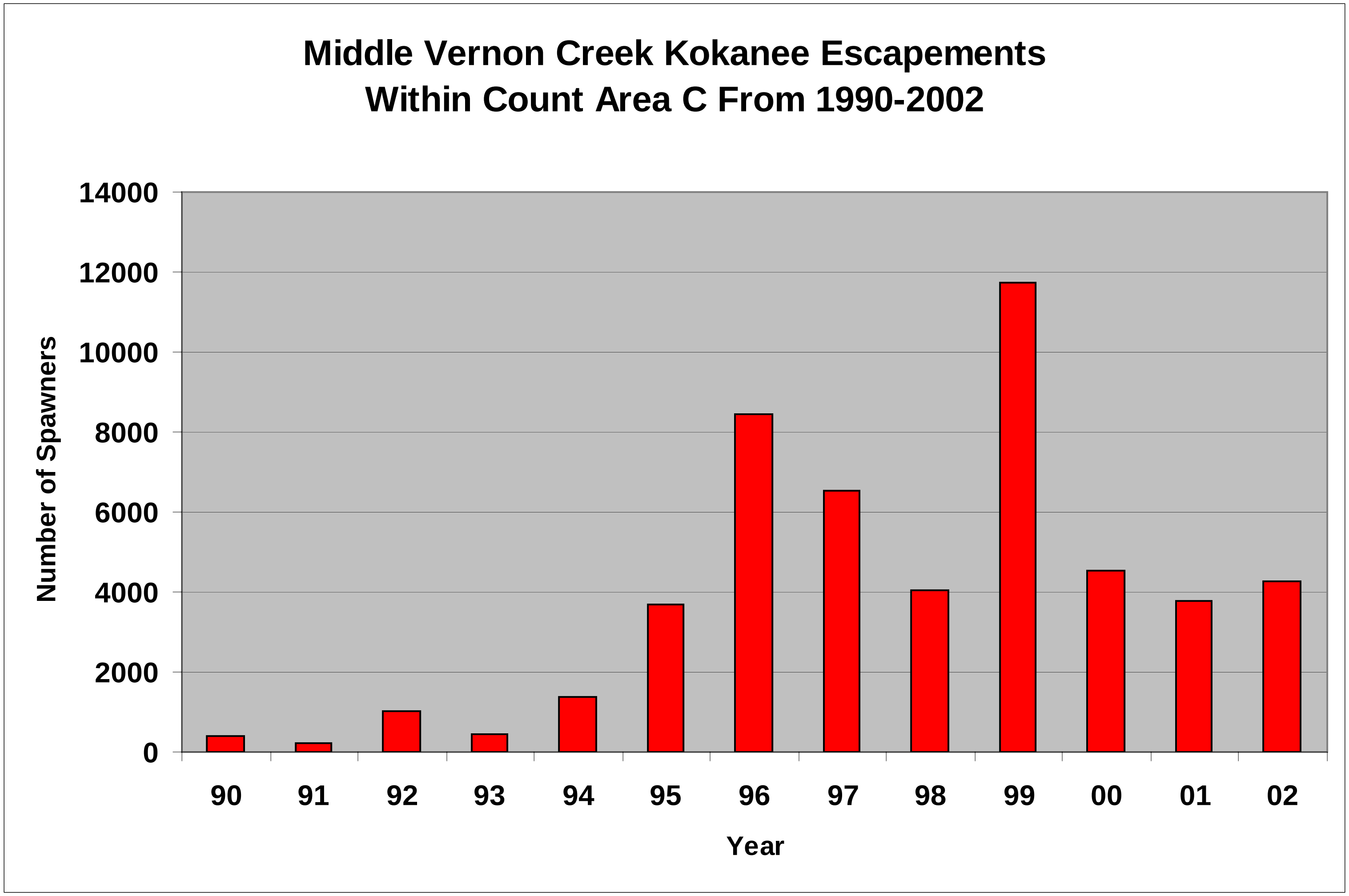

Figure B10. Kokanee Escapement within Count Area C of Middle Vernon Creek (MWLAP 2003).

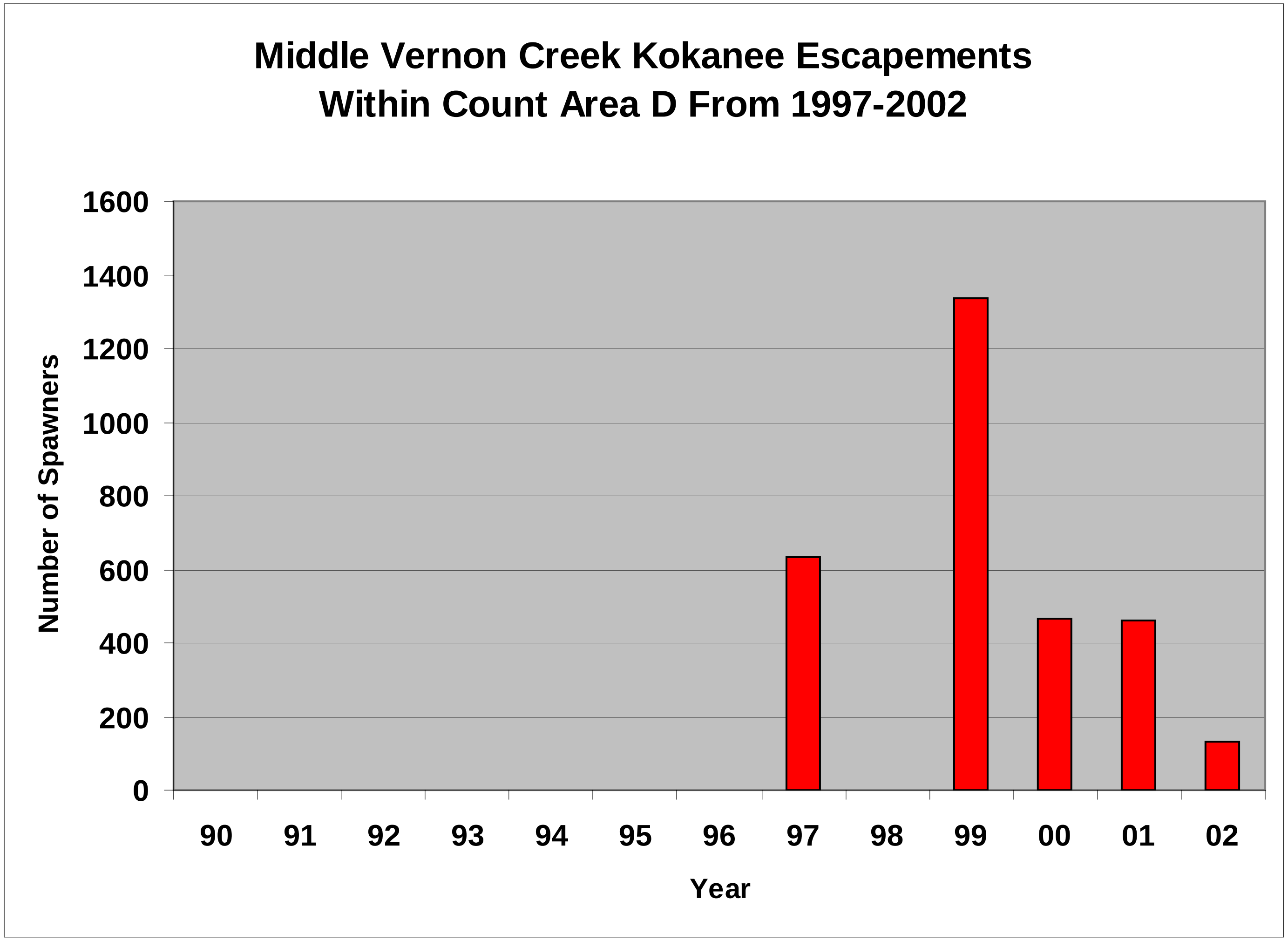

Figure B11. Kokanee Escapement within Count Area D of Middle Vernon Creek (MWLAP 2003).

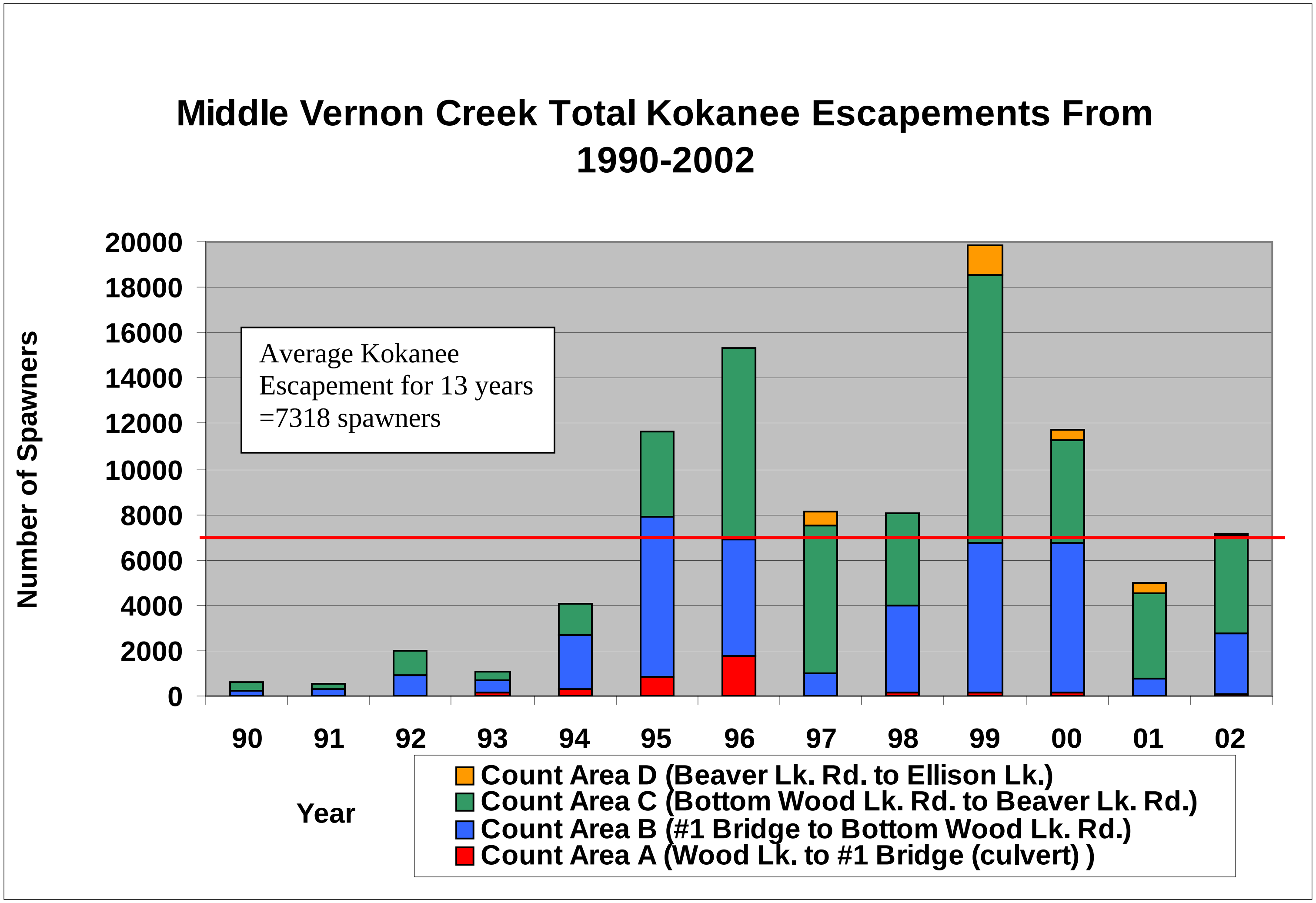

Figure B12. Total Kokanee Escapement of Middle Vernon Creek from 1990-2002 (MWLAP 2003).

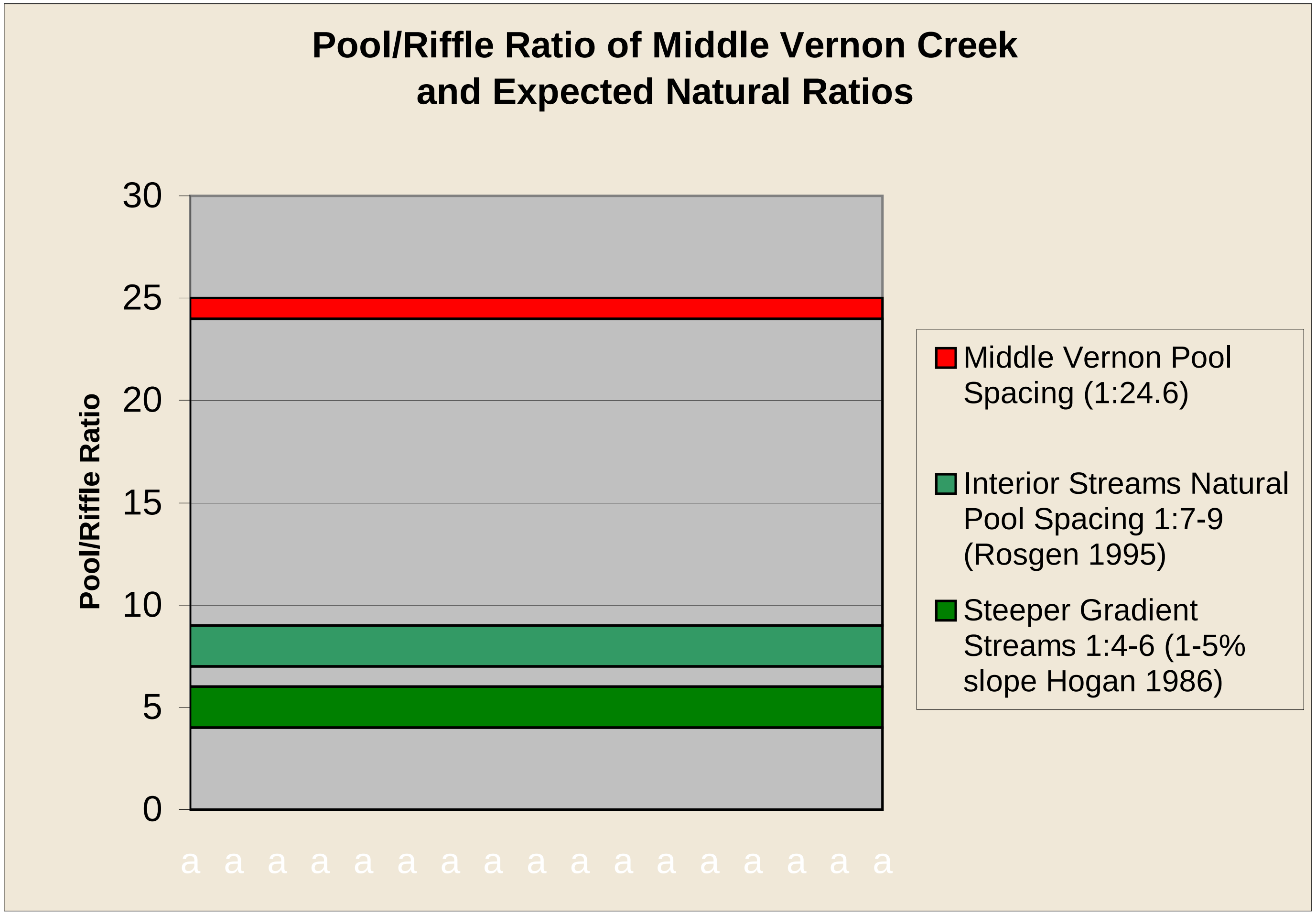

Figure B13. Pool/Riffle Ratio of Middle Vernon Creek and Expected Natural Ratios.

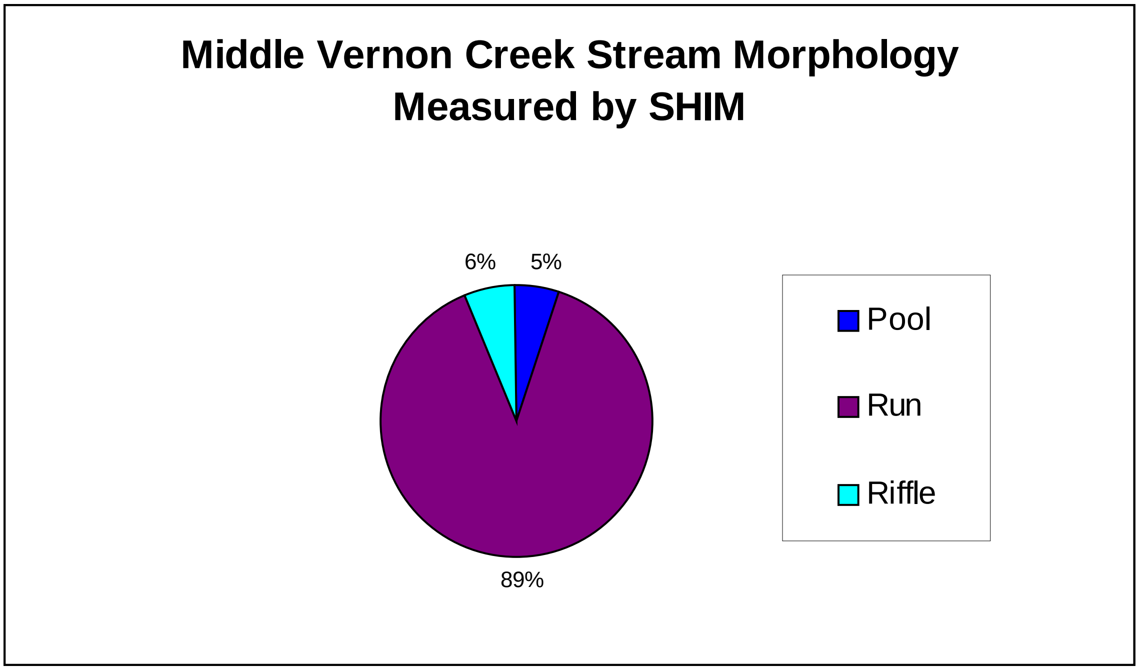

Figure B14. Middle Vernon Creek stream Morphology Measured by SHIM.

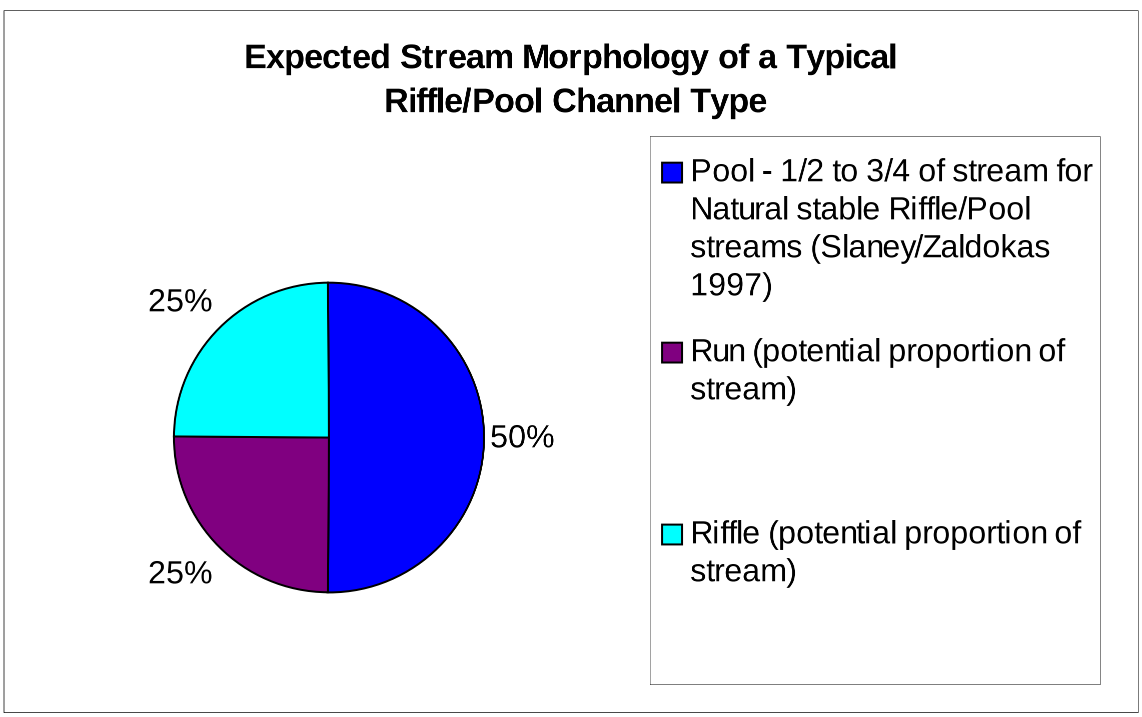

Figure B15. Expected Stream Morphology of Middle Vernon Creek for a Typical Riffle/Pool Channel Type.

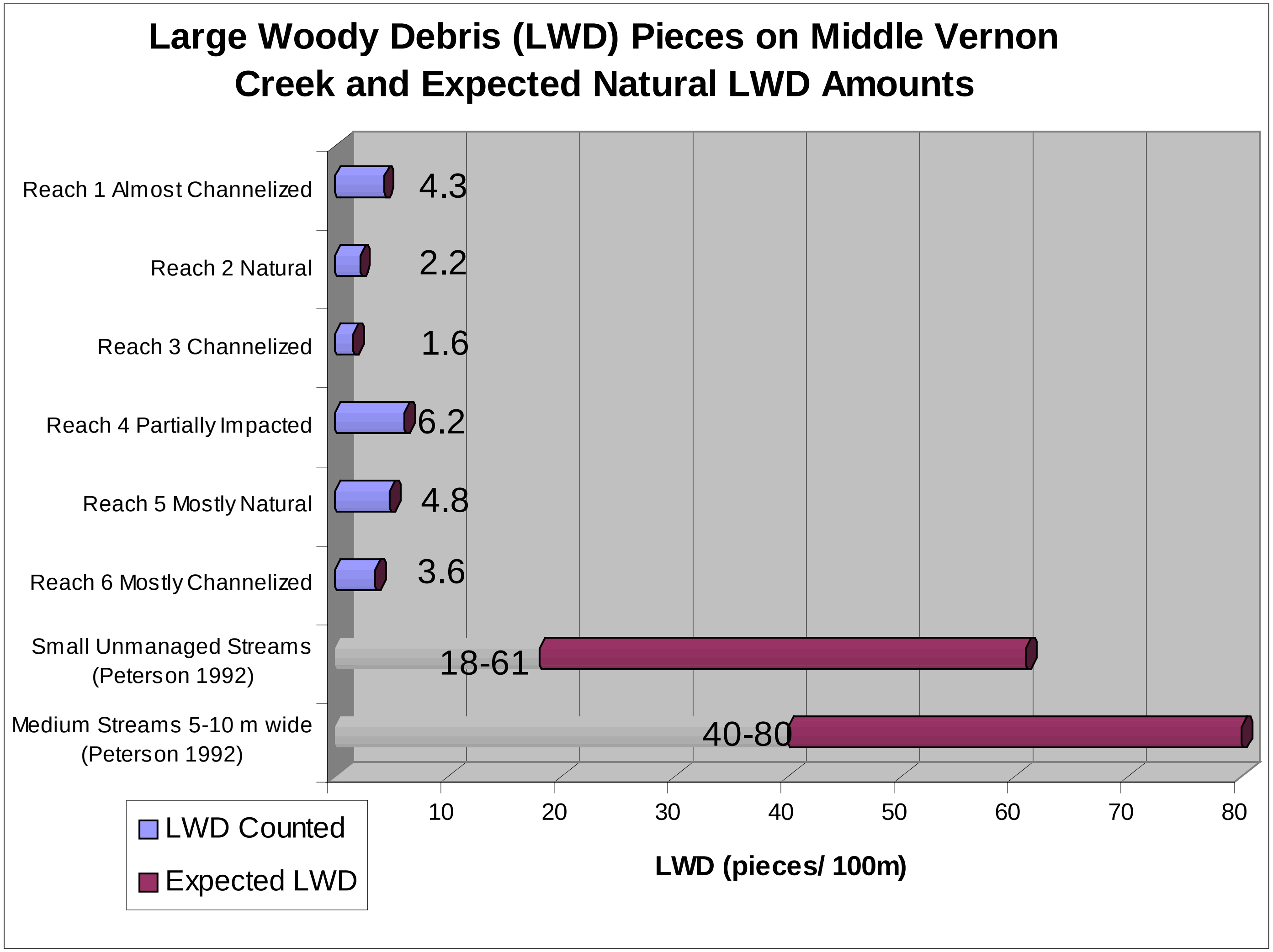

Figure B16. Large Woody Debris Pieces on Middle Vernon Creek and Expected natural LWD Amounts.

Table B17. Raw data from electrofishing sites in Middle Vernon Creek (20-23/08/2002)

SHIM Site	EF Pass #	Species*	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight	SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight
1	1	CAS	40	3			5	1	CAS	44	2		
1	1	CAS	66	3			5	1	CAS	105	22		
1	1	CAS	69	3			5	2	CAS	39	2		
1	1	CAS	70	3			5	2	CAS	41	2		
1	1	CAS	70	3			5	2	CAS	41	2		
1	1	CAS	71	3			5	2	CAS	50	3		
1	1	CAS	74	4			5	2	CAS	50	3		
1	1	CAS	74	4			5	3	CAS	39	2		
1	1	CAS	80	7			5	3	CAS	45	2		
1	1	CAS	80	8			5	3	CAS	48	3		
1	1	CAS	82	4			5	3	CAS	49	3		
1	1	CAS	82	6			6	1	CAS	22	1		
1	1	CAS	82	5			6	1	CAS	26	1		
1	1	CAS	85	7			6	1	CAS	30	1		
1	1	CAS	85	6			6	1	CAS	31	1		
1	1	CAS	90	8			6	1	CAS	31	1		
1	1	CAS	90	7			6	1	CAS	32	1		
1	1	CAS	90	7			6	1	CAS	32	1		
1	1	CAS	90	7			6	1	CAS	32	1		
1	1	CAS	92	9			6	1	CAS	33	1		
1	1	CAS	95	10			6	1	CAS	34	1		
1	1	CAS	104	14			6	1	CAS	34	1		
1	1	RSC	100	11			6	1	CAS	34	1		
1	1	RSC	105	8			6	1	CAS	34	1		
1	1	RSC	107	13			6	1	CAS	34	1		
1	1	RSC	107	11			6	1	CAS	35	1		
1	2	CAS	70	4			6	1	CAS	35	1		
1	2	CAS	75	4			6	1	CAS	35	1		
1	2	CAS	78	5			6	1	CAS	36	1		
1	2	CAS	82	6			6	1	CAS	36	1		
1	2	CAS	85	7			6	1	CAS	36	1		
1	2	CAS	87	11			6	1	CAS	37	1		
1	2	CAS	91	8			6	1	CAS	37	1		
1	2	CAS	103	13			6	1	CAS	38	2		
1	2	CAS	106	13			6	1	CAS	38	2		
1	2	CAS	112	21			6	1	CAS	38	2		
1	2	CAS	126	28			6	1	CAS	38	2		
1	2	CAS	128	28			6	1	CAS	38	2		
1	2	CAS	.	.			6	1	CAS	38	2		
1	2	RSC	95	7			6	1	CAS	38	2		
1	2	RSC	95	8			6	1	CAS	38	2		
1	2	RSC	105	11			6	1	CAS	38	2		
1	2	RSC	108	14			6	1	CAS	38	2		
1	2	RSC	110	12			6	1	CAS	38	2		
1	2	CSU	135	26			6	1	CAS	38	2		
1	3	CAS	28	2			6	1	CAS	38	2		
1	3	CAS	36	3			6	1	CAS	38	2		
1	3	CAS	39	3			6	1	CAS	38	2		
1	3	CAS	45	3			6	1	CAS	38	2		
1	3	CAS	56	3			6	1	CAS	38	2		
1	3	CAS	60	3			6	1	CAS	38	2		
1	3	CAS	71	3			6	1	CAS	40	2		
1	3	CAS	72	3			6	1	CAS	41	2		

* CAS=prickly sculpin, RSC=redside shiner, CSU=largescale sucker, YP=yellow perch, PCC=Peamouth chub, NSC=northern pikeminnow, CC=common carp

SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight	SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight
1	3	CAS	78	5			6	1	CAS	41	2		
1	3	CAS	74	4			6	1	CAS	41	2		
1	3	CAS	82	6			6	1	CAS	41	2		
1	3	CAS	83	6			6	1	CAS	41	2		
1	3	CAS	84	6			6	1	CAS	41	2		
1	3	CAS	85	7			6	1	CAS	41	2		
1	3	CAS	86	7			6	1	CAS	41	2		
1	3	CAS	86	7			6	1	CAS	42	2		
1	3	CAS	87	8			6	1	CAS	42	2		
1	3	CAS	87	8			6	1	CAS	42	2		
1	3	CAS	89	8			6	1	CAS	42	2		
1	3	CAS	91	8			6	1	CAS	42	2		
1	3	CAS	96	10			6	1	CAS	42	2		
1	3	CAS	112	21			6	1	CAS	42	2		
1	3	CAS	113	21			6	1	CAS	42	2		
1	3	CAS	123	21			6	1	CAS	42	2		
1	3	RSC	78	6			6	1	CAS	42	2		
1	3	RSC	97	8			6	1	CAS	42	2		
1	3	RSC	98	8			6	1	CAS	43	2		
2	1	CAS	24	1			6	1	CAS	43	1		
2	1	CAS	27	1			6	1	CAS	43	2		
2	1	CAS	27	1			6	1	CAS	44	2		
2	1	CAS	28	1			6	1	CAS	44	2		
2	1	CAS	29	1			6	1	CAS	44	2		
2	1	CAS	29	1			6	1	CAS	44	2		
2	1	CAS	29	1			6	1	CAS	44	2		
2	1	CAS	29	1			6	1	CAS	44	2		
2	1	CAS	29	1			6	1	CAS	44	2		
2	1	CAS	29	1			6	1	CAS	44	2		
2	1	CAS	29	1			6	1	CAS	44	2		
2	1	CAS	31	1			6	1	CAS	44	2		
2	1	CAS	31	1			6	1	CAS	44	2		
2	1	CAS	31	1			6	1	CAS	44	2		
2	1	CAS	31	1			6	1	CAS	44	2		
2	1	CAS	31	1			6	1	CAS	45	2		
2	1	CAS	31	1			6	1	CAS	45	2		
2	1	CAS	32	1			6	1	CAS	46	2		
2	1	CAS	32	1			6	1	CAS	46	2		
2	1	CAS	32	1			6	1	CAS	46	2		
2	1	CAS	32	1			6	1	CAS	48	3		
2	1	CAS	33	1			6	1	CAS	48	3		
2	1	CAS	33	1			6	1	CAS	48	3		
2	1	CAS	34	1			6	1	CAS	52	3		
2	1	CAS	34	1			6	1	CAS	52	3		
2	1	CAS	35	1			6	1	CAS	54	3		
2	1	CAS	35	1			6	1	YP	64	6		
2	1	CAS	35	1			6	1	RSC	21	0.4		
2	1	CAS	35	1			6	1	RSC	23	0.4		
2	1	CAS	35	1			6	1	RSC	30	0.4		
2	1	CAS	35	1			6	1	RSC	31	0.4		
2	1	CAS	36	1			6	1	RSC	33	0.4		
2	1	CAS	36	1			6	1	RSC	34	0.4		
2	1	CAS	36	1			6	1	RSC	36	0.4		
2	1	CAS	36	1			6	1	CSU	46	.		
2	1	CAS	37	1			6	2	CAS	.	.	16	16
2	1	CAS	37	1			6	2	RSC	32	0.4		
2	1	CAS	37	1			6	2	RSC	32	0.4		
2	1	CAS	38	2			6	2	RSC	32	0.4		

SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight	SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight
2	1	CAS	38	2			6	2	RSC	32	0.4		
2	1	CAS	39	2			6	2	CSU	35	.		
2	1	CAS	39	2			6	2	CSU	42	.		
2	1	CAS	39	2			6	2	CSU	45	.		
2	1	CAS	39	2			6	3	CAS	32	1		
2	1	CAS	39	2			6	3	CAS	32	1		
2	1	CAS	40	2			6	3	CAS	32	1		
2	1	CAS	40	2			6	3	CAS	32	1		
2	1	CAS	41	2			6	3	CAS	55	3		
2	1	CAS	42	2			6	3	CAS	55	3		
2	1	CAS	43	2			6	3	CAS	55	3		
2	1	CAS	47	2			6	3	CAS	55	3		
2	1	CAS	76	5			6	3	CAS	135	26		
2	1	CAS	85	6			6	3	CC	55	.		
2	1	CAS	93	9			7	1	RSC	16	0.4		
2	1	CAS	136	38			7	1	RSC	18	0.4		
2	1	RSC	20	0.4			7	1	RSC	20	0.4		
2	1	RSC	21	0.4			7	1	RSC	21	0.4		
2	2	CAS	26	1			7	1	RSC	21	0.4		
2	2	CAS	27	1			7	1	RSC	21	0.4		
2	2	CAS	28	1			7	1	RSC	21	0.4		
2	2	CAS	28	1			7	1	RSC	22	0.4		
2	2	CAS	28	1			7	1	RSC	23	0.4		
2	2	CAS	28	1			7	1	RSC	24	0.4		
2	2	CAS	29	1			7	1	RSC	25	0.4		
2	2	CAS	29	1			7	1	RSC	27	0.4		
2	2	CAS	30	1			7	1	RSC	27	0.4		
2	2	CAS	30	1			7	1	RSC	27	0.4		
2	2	CAS	30	1			7	1	RSC	28	0.4		
2	2	CAS	32	1			7	1	RSC	28	0.4		
2	2	CAS	32	1			7	1	RSC	29	0.4		
2	2	CAS	32	1			7	1	RSC	29	0.4		
2	2	CAS	32	1			7	1	RSC	29	0.4		
2	2	CAS	32	1			7	1	RSC	29	0.4		
2	2	CAS	33	1			7	1	RSC	30	0.4		
2	2	CAS	33	1			7	1	RSC	30	0.4		
2	2	CAS	34	1			7	1	RSC	31	0.4		
2	2	CAS	34	1			7	1	RSC	33	0.4		
2	2	CAS	34	1			7	1	PCC	234	130		
2	2	CAS	34	1			7	1	PCC	246	142		
2	2	CAS	34	1			7	2	CAS	34	1		
2	2	CAS	35	1			7	2	CAS	42	2		
2	2	CAS	35	1			7	2	CAS	46	2		
2	2	CAS	35	1			7	2	RSC	22	0.4		
2	2	CAS	35	1			7	2	RSC	23	0.4		
2	2	CAS	35	1			7	2	RSC	27	0.4		
2	2	CAS	36	1			7	2	RSC	28	0.4		
2	2	CAS	36	1			7	2	CC	62	2		
2	2	CAS	36	1			7	3	CAS	32	1		
2	2	CAS	36	1			7	3	CAS	34	1		
2	2	CAS	37	1			7	3	CAS	34	1		
2	2	CAS	37	1			7	3	CAS	43	2		
2	2	CAS	37	1			7	3	CAS	49	2		
2	2	CAS	38	2			7	3	RSC	19	0.4		
2	2	CAS	38	2			7	3	RSC	22	0.4		
2	2	CAS	38	2			7	3	RSC	29	0.4		
2	2	CAS	38	2			7	3	CSU	44	2		
2	2	CAS	38	2			7	3	CSU	45	2		

SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight
2	2	CAS	38	2		
2	2	CAS	38	2		
2	2	CAS	39	2		
2	2	CAS	40	2		
2	2	CAS	42	2		
2	2	CAS	42	2		
2	2	CAS	42	2		
2	2	CAS	43	2		
2	2	CAS	43	2		
2	2	CAS	43	2		
2	2	CAS	44	2		
2	2	CAS	44	2		
2	2	CAS	45	2		
2	2	CAS	46	2		
2	2	CAS	52	2		
2	2	CAS	68	3		
2	3	CAS	24	1		
2	3	CAS	26	1		
2	3	CAS	26	1		
2	3	CAS	26	1		
2	3	CAS	27	1		
2	3	CAS	27	1		
2	3	CAS	28	1		
2	3	CAS	29	1		
2	3	CAS	29	1		
2	3	CAS	29	1		
2	3	CAS	31	1		
2	3	CAS	31	1		
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2	3	CAS	32	1		
2	3	CAS	32	1		
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2	3	CAS	40	2		
2	3	CAS	41	2		
2	3	CAS	41	2		
2	3	CAS	41	2		
2	3	RSC	15	0.4		
2	3	RSC	22	0.4		
2	3	RSC	26	0.4		
3	1	RSC	21	0.4		
3	1	RSC	22	0.4		
3	1	RSC	23	0.4		
3	1	PCC	223	110		
3	2	RSC	23	0.4		

SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight
8	1	CAS	31	1		
8	1	CAS	32	1		
8	1	CAS	33	1		
8	1	CAS	33	1		
8	1	CAS	33	1		
8	1	CAS	33	1		
8	1	CAS	33	1		
8	1	CAS	34	1		
8	1	CAS	34	1		
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8	1	CAS	35	1		
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8	1	CAS	49	3		
8	1	CAS	50	3		
8	1	CAS	52	3		
8	1	CAS	107	15		
8	1	CAS	112	21		
8	1	PCC	66	5		
8	1	PCC	95	18		

SHIM Site	EF Pass #	Species	Length (mm)	Weight	# of Fish in Group	Group Weight	SHIM Site	EF Pass #	Species	Length (mm)	Weight (grams)	# of Fish in Group	Group Weight
3	2	RSC	24	0.4			8	1	PCC	136	42		
3	2	RSC	24	0.4			8	1	CSU	124	24		
3	3	RSC	24	0.4			8	1	CC	47	6		
4	1	CAS	49	3			8	1	NSC	146	30		
4	1	CAS	112	70			8	2	CAS	27	1		
4	1	RSC	19	0.4			8	2	CAS	32	1		
4	1	RSC	21	0.4			8	2	CAS	32	1		
4	1	RSC	21	0.4			8	2	CAS	32	1		
4	1	RSC	21	0.4			8	2	CAS	34	1		
4	1	RSC	21	0.4			8	2	CAS	34	1		
4	1	RSC	21	0.4			8	2	CAS	35	1		
4	1	RSC	22	0.4			8	2	CAS	35	1		
4	1	RSC	23	0.4			8	2	CAS	36	1		
4	1	RSC	23	0.4			8	2	CAS	36	1		
4	1	RSC	23	0.4			8	2	CAS	37	1		
4	1	RSC	24	0.4			8	2	CAS	40	2		
4	1	RSC	24	0.4			8	2	CAS	41	2		
4	1	RSC	24	0.4			8	2	CAS	42	2		
4	1	RSC	24	0.4			8	2	CAS	42	2		
4	1	RSC	25	0.4			8	2	CAS	43	2		
4	1	RSC	25	0.4			8	2	CAS	44	2		
4	1	RSC	25	0.4			8	2	CAS	46	2		
4	1	RSC	25	0.4			8	2	CAS	48	2		
4	1	RSC	25	0.4			8	2	CAS	48	2		
4	1	RSC	26	0.4			8	2	CAS	52	2		
4	1	RSC	26	0.4			8	2	CAS	82	5		
4	1	RSC	26	0.4			8	2	CSU	140	28		
4	1	RSC	26	0.4			8	3	CAS	24	1		
4	1	RSC	27	0.4			8	3	CAS	27	1		
4	1	RSC	27	0.4			8	3	CAS	30	1		
4	1	RSC	27	0.4			8	3	CAS	32	1		
4	1	RSC	28	0.4			8	3	CAS	32	1		
4	1	RSC	28	0.4			8	3	CAS	32	1		
4	1	RSC	29	0.4			8	3	CAS	34	1		
4	1	RSC	29	0.4			8	3	CAS	35	1		
4	1	RSC	31	0.4			8	3	CAS	36	1		
4	1	RSC	.	.	9	4	8	3	CAS	37	1		
4	1	PCC	39	1			8	3	CAS	37	1		
4	2	RSC	18	0.4			8	3	CAS	38	2		
4	2	RSC	18	0.4			8	3	CAS	39	2		
4	2	RSC	21	0.4			8	3	CAS	41	2		
4	2	RSC	22	0.4			8	3	CAS	42	2		
4	2	RSC	23	0.4			8	3	CAS	42	2		
4	2	RSC	24	0.4			8	3	CAS	45	2		
4	2	RSC	26	0.4			8	3	PCC	36	1		
4	2	RSC	27	0.4			8	3	PCC	49	2		
4	2	RSC	27	0.4									
4	2	RSC	33	0.4									
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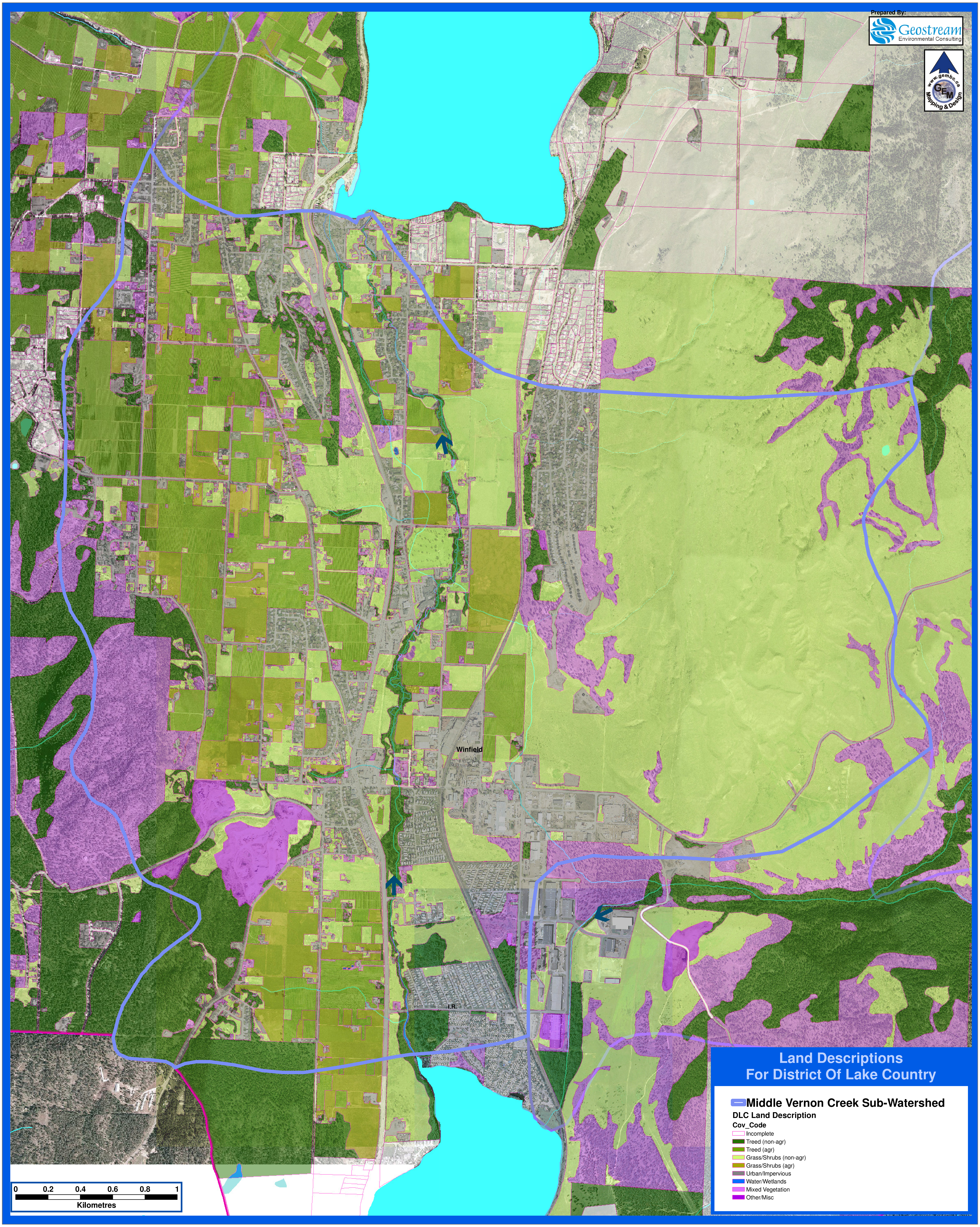
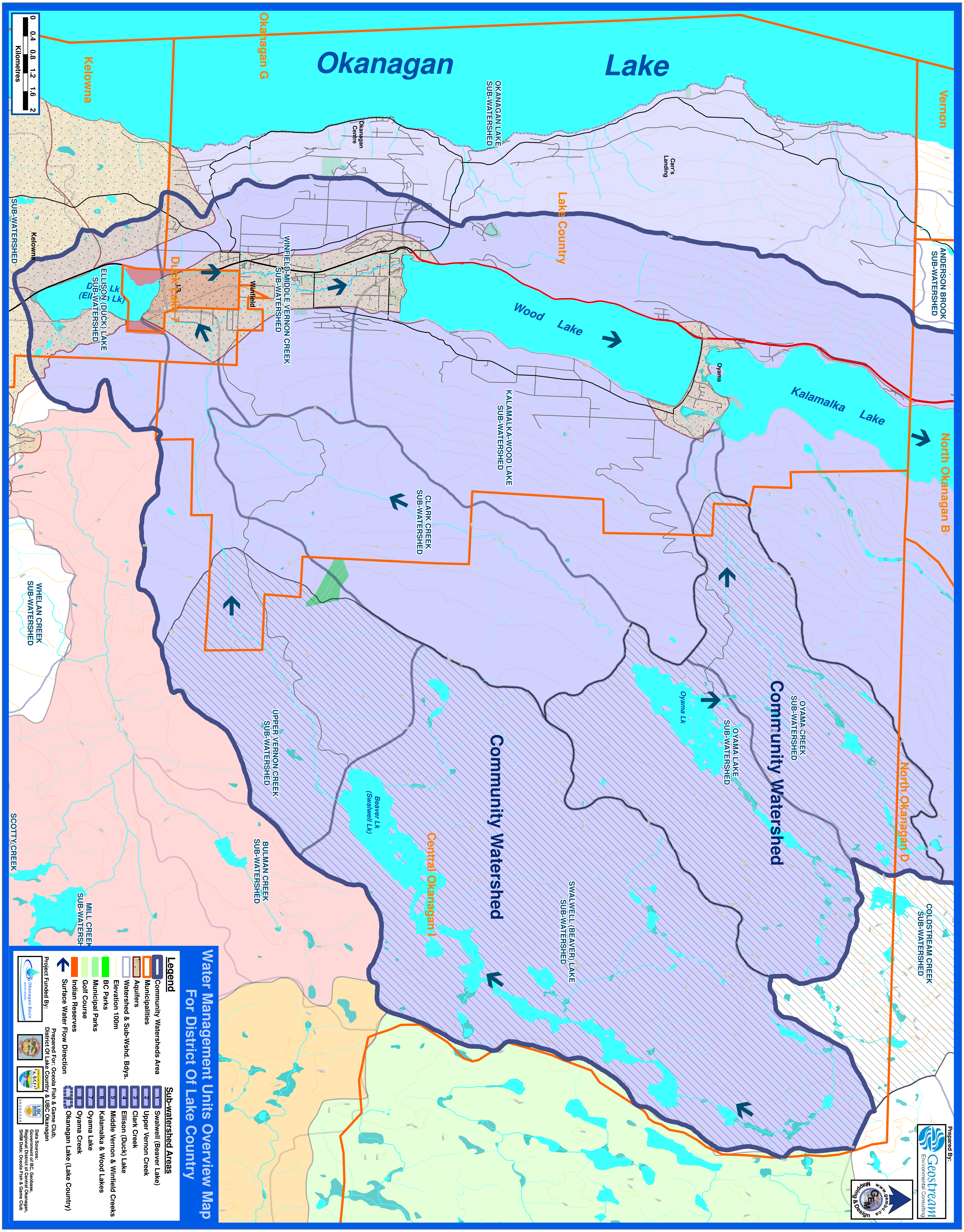
4	3	RSC	.	.	12	5							

APPENDIX C

SHIM
Digital Shapefiles and Photos


Prepared By:
Geostream
Environmental Consulting
www.gembc.ca
GEM
Mapping & Design
Winfield
I.R.
0
0.2
0.4
0.6
0.8
1
Kilometres
Land Descriptions
For District Of Lake Country
Middle Vernon Creek Sub-Watershed
DLC Land Description
Cov_Code
Incomplete
Treed (non-agr)
Treed (agr)
Grass/Shrubs (non-agr)
Grass/Shrubs (agr)
Urban/Impervious
Water/Wetlands
Mixed Vegetation
Other/Misc



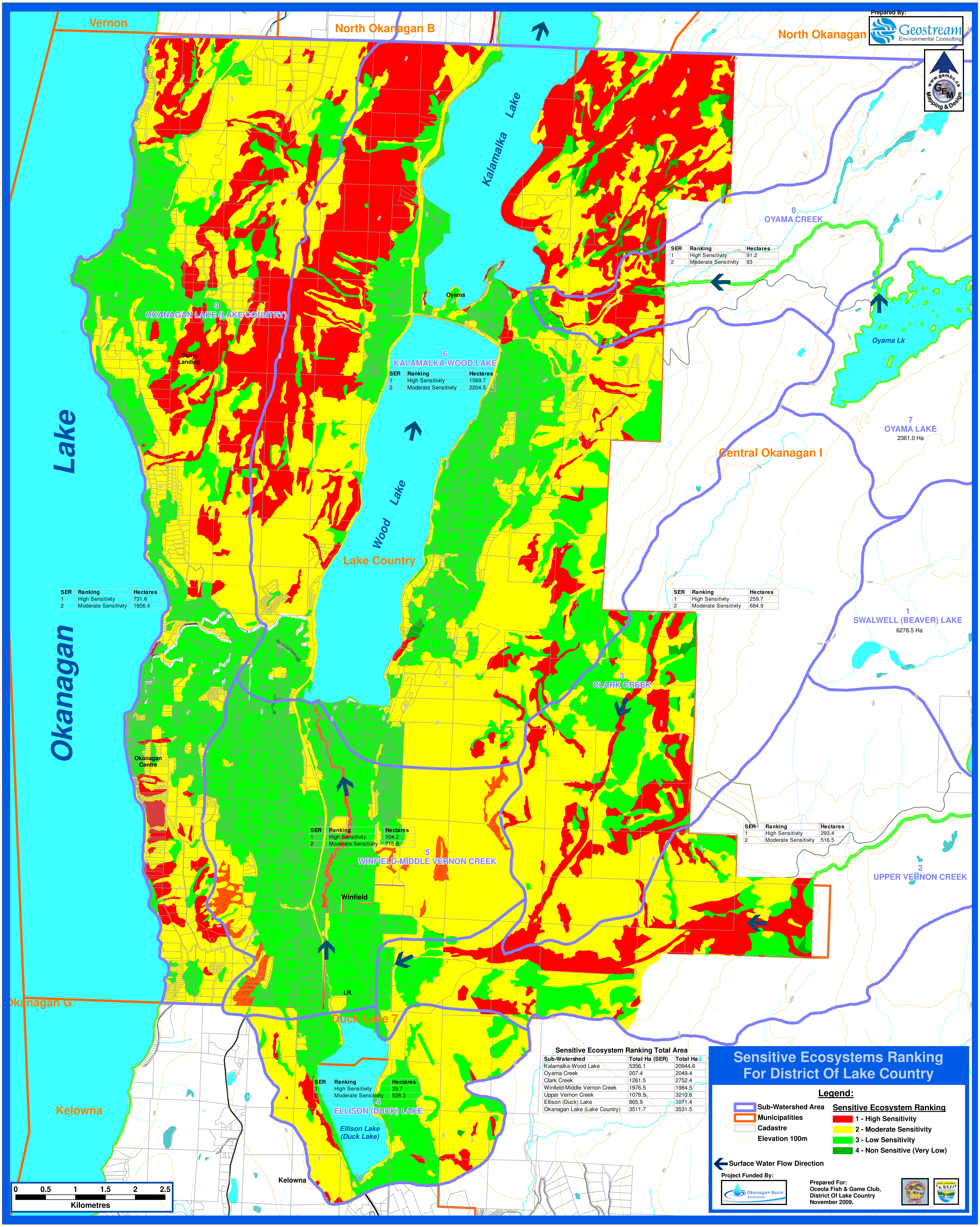
Water Management Units Overview Map
For District Of Lake Country
Legend
Community Watersheds Area
Municipalities
Aquifers
Watershed & Sub-Wshd. Bdys.
Elevation 100m
BC Parks
Municipal Parks
Golf Course
Indian Reserves
Surface Water Flow Direction
Sub-watershed Areas
1 Swalwell (Beaver Lake)
2 Upper Vernon Creek
3 Clark Creek
4 Ellison (Duck) Lake
5 Middle Vernon & Winfield Creeks
6 Kalamalka & Wood Lakes
7 Oyama Lake
8 Oyama Creek
9 Okanagan Lake (Lake Country)
Project Funded By:
Prepared For: Oceola Fish & Game Club, District Of Lake Country & UBC Okanagan
Data Sources: Government of BC, Geobase, Regional District of Central Okanagan, SHIM Data: Oceola Fish & Game Club
Prepared By:
Geostream Environmental Consulting
Kilometres
0 0.4 0.8 1.2 1.6 2
Okanagan Lake
Okanagan G
Kelowna
Vernon
Lake Country
North Okanagan B
North Okanagan D
Central Okanagan 1
Okanagan Centre
Carr's Landing
Winfield
Oyama
Wood Lake
Kalamalka Lake
Oyama Lk
Beaver Lk (Swalwell Lk)
OKANAGAN LAKE SUB-WATERSHED
ANDERSON BROOK SUB-WATERSHED
ELLISON (DUCK) LAKE SUB-WATERSHED
WINFIELD-MIDDLE VERNON CREEK SUB-WATERSHED
KALAMALKA-WOOD LAKE SUB-WATERSHED
CLARK CREEK SUB-WATERSHED
UPPER VERNON CREEK SUB-WATERSHED
OYAMA LAKE SUB-WATERSHED
OYAMA CREEK SUB-WATERSHED
SWALWELL (BEAVER) LAKE SUB-WATERSHED
COLDSTREAM CREEK SUB-WATERSHED
WHELAN CREEK SUB-WATERSHED
BULMAN CREEK SUB-WATERSHED
Community Watershed

Prepared By:

Geostream Environmental Consulting

Surface Water and Groundwater in the Middle Vernon Creek Watershed: Ellison (Duck) Lake to Wood Lake

Prepared For: Oceola Fish & Game Club, District Of Lake Country & UBC Okanagan


Sensitive Ecosystems Ranking
For District Of Lake Country
Prepared By:
Geostream Environmental Consulting
www.gembc.ca
GEM Mapping & Design
Vernon
North Okanagan B
North Okanagan
Kalamalka Lake
Oyama
8
OYAMA CREEK
SER Ranking Hectares
1 High Sensitivity 91.2
2 Moderate Sensitivity 83
Oyama Lk
9
OKANAGAN LAKE (LAKE COUNTRY)
Carr's Landing
6
KALAMALKA-WOOD LAKE
SER Ranking Hectares
1 High Sensitivity 1569.7
2 Moderate Sensitivity 2204.5
7
OYAMA LAKE
2361.0 Ha
Central Okanagan I
Okanagan Lake
Wood Lake
Lake Country
SER Ranking Hectares
1 High Sensitivity 731.6
2 Moderate Sensitivity 1656.4
SER Ranking Hectares
1 High Sensitivity 259.7
2 Moderate Sensitivity 684.9
1
SWALWELL (BEAVER) LAKE
6278.5 Ha
3
CLARK CREEK
Okanagan Centre
SER Ranking Hectares
1 High Sensitivity 104.2
2 Moderate Sensitivity 716.8
5
WINFIELD-MIDDLE VERNON CREEK
SER Ranking Hectares
1 High Sensitivity 293.4
2 Moderate Sensitivity 516.5
2
UPPER VERNON CREEK
Winfield
I.R.
Okanagan G
Duck Lake 7
Kelowna
SER Ranking Hectares
1 High Sensitivity 39.7
2 Moderate Sensitivity 528.3
4
ELLISON (DUCK) LAKE
Ellison Lake (Duck Lake)
Kelowna
0 0.5 1 1.5 2 2.5
Kilometres
Sensitive Ecosystem Ranking Total Area
Sub-Watershed | Total Ha (SER) | Total Ha
Kalamalka-Wood Lake | 5356.1 | 20944.6
Oyama Creek | 207.4 | 2049.4
Clark Creek | 1261.5 | 2752.4
Winfield-Middle Vernon Creek | 1976.5 | 1984.5
Upper Vernon Creek | 1078.5 | 3210.6
Ellison (Duck) Lake | 865.9 | 1071.4
Okanagan Lake (Lake Country) | 3511.7 | 3531.5
Legend:
Sub-Watershed Area
Municipalities
Cadastre
Elevation 100m
Sensitive Ecosystem Ranking
1 - High Sensitivity
2 - Moderate Sensitivity
3 - Low Sensitivity
4 - Non Sensitive (Very Low)
Surface Water Flow Direction
Project Funded By:
Okanagan Basin Water Board
Prepared For:
Oceola Fish & Game Club,
District Of Lake Country
November 2009.