Microhydro Feasibility Study for Salt Spring Island

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Prepared by

Elizabeth White, Earth Festival Society
Scott Davis, Friends of Renewable Energy of BC
Philip Grange, Grange Engineering Associates
Jacqueline Booth and Associates

for **CRD** and **Islands Trust**

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This report is dedicated to the memory of Jacky Booth
and her many contributions to community mapping projects.

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Executive Summary and Recommendations

This study is a preliminary overview of the potential for microhydro generation on Salt Spring Island. Both technical potential and practical potential for installations are reviewed and recommendations provided.

The availability of net metering in BC provides the opportunity for communities to meet part of their power supply through micro-scale distributed generation. The Salt Spring Island Community Energy Strategy targets for 2012 are to meet 12% of the island's GHG emissions reductions through 5% locally generated power. The annual electricity generation would need to be about 5,400 Megawatt-hours (MWh) per year to meet 5% of the 2002 electricity demand.

Salt Spring Island is a small island of 18,224 ha and 147 small watersheds. Small watersheds imply low flows and correspondingly small microhydro systems. Power generated by smaller systems generally costs more per kilowatt than that generated by larger systems due to certain fixed costs of installation, regardless of scale. The island includes ecological reserves, protected wetlands, and the largest fish bearing stream in the Southern Gulf Islands. In addition, many small surface water sources dry up during the summer months. These factors limit the location, size and economic viability of potential systems. However, the complex geography and steep terrain combined with winter rains provide many opportunities to generate small amounts of power during the winter months.

To assess the feasibility of distributed microhydro generation on Salt Spring, the project team reviewed existing rainfall and surface water data and mapping, and known potential sites, undertook ten case studies, reviewed environmental and regulatory implications, and the economic viability of installations. The results of this project are intended to inform future development and installation of microhydro facilities on Salt Spring Island and will be included in the revised Salt Spring Energy Strategy for implementation. The results may also be of interest to other communities in the CRD and Islands Trust areas.

The average annual precipitation on Salt Spring Island is about 960 mm; about 80% of this precipitation falls in the winter months, October through March. The average runoff factor for the island has been estimated at 0.48, i.e. 48% of precipitation turns into runoff. From these figures, the runoff for individual watersheds may be calculated. However, daily flow records, taken over the course of at least one winter, are required to accurately determine flow at any given location and this information was not available for any of the potential sites.

From terrain analysis, one quarter of Salt Spring has slopes equal to, or greater than 15%, indicating good potential vertical drop (i.e. head) for power development. 572 parcels of land with an area of 2 hectares (ha) or more had at least 1 ha of slope greater than 15%. Not all these parcels will have seasonal or year round creeks. but the possibility of potential sites on these parcels is considered greater than on flatter and smaller sites. Other sites may also have good microhydro potential. In fact, several of the case study sites and other potential sites are not captured by the terrain analysis.

Case studies were self-selected by landowners interested in developing microhydro on their properties. The information was gathered during visual site inspections; accurate measurements are required to verify the estimates. Of the ten case studies, all but one appeared capable of producing at least 2,000 kWh per year, or about 12% of the average Salt Spring residential customer usage of about 17,000 kWh per year. Three of the ten case studies may have the potential to produce at least 17,000 kWh per year. The estimated installed power generation capacity ranged from 0.24 kW to 12 kW. In addition to the case studies, nineteen other 'good potential' sites are identified, based on map studies and local knowledge. These sites were not assessed in detail.

Regulatory requirements are greater for microhydro than for other renewable energy systems such as solar energy. A water licence must be acquired from the Water Stewardship Division (WSD), of the Ministry of Environment (MOE), even if the stream runs through private land. Where ecologically protected areas are involved, the regulatory requirements may be onerous and may render the development of otherwise good sites unfeasible. This is documented for one of the case study sites. In addition, a water rental fee of $100 is charged every year, regardless of the amount of output, rending very small systems uneconomic.

Microhydro is generally considered the most cost-effective renewable energy technology. Basic economic analyses of 3,500 Watt and 10 kilowatt systems concluded that systems are cost-effective, yielding net benefits of about $300 and $14,000 over 20 years, over and above costs. The analysis concluded that 400 Watt systems are not cost-effective, due to the fact that capital costs were nearly the same as a 3,500 Watt system according to a study by Natural Resources Canada, and annual water rental fees were over 80% of the value of electricity savings.

On Salt Spring, the majority of homes use at least some electricity for space heating. Electricity consumption is much greater during the winter months, making microhydro a good potential match. Although the lack of measured data makes it difficult to draw any conclusions regarding the total microhydro potential, it is not unreasonable to assume that there may be over 70 developable sites, conservatively capable of producing something in the range of 800 MWh/y if they were 3 kilowatts each, enough to supply about 47 average Salt Spring homes. The total number of developable sites is likely under 300.

A general implication of this study is that microhydro is insufficient to meet the entire annual target of 5,400 MWh for locally generated renewable energy, but it could generate at least 15% of that total, and possibly as much as 60%. Thus, in order the meet the Energy Strategy electricity generation target, other technologies need to be considered such as tidal power, solar photovoltaics and wind power. It is also noted that energy efficiency measures such as attic insulation and air-source heat pumps are more cost effective than renewable energy and therefore should be prioritized.

Recommendations

The following recommendations are provided if the community wants to further pursue renewable energy options such as microhydro as part of the ongoing Salt Spring Energy Strategy.

1. Proceed with a more detailed investigation of the microhydro potential on Salt Spring Island, specifically the following:
    - undertake a more detailed mapping and field review of potential sites;
    - select three or four locations with potential for larger-scale systems for at least one winter of field measurements and site analysis, followed by engineering design, system costing, installation and monitoring;
    - encourage, through provision of information and workshops, additional landowners with appropriate sites to install microhydro systems and to share information;
    - document and assess results;
    - establish long and short-term targets for microhydro supply, in terms of kW and annual kWh.

2. Review and address regulatory issues, specifically the following:
   - as part of the current round of OCP/LUB updates, review A1 and other zoning provisions with respect to microhydro generation to clarify that rezoning is not required for a small microhydro installation;
   - as part of the current round of OCP/LUB updates, obtain a ruling from the ALC regarding microhydro installations, including net metering, on land in the ALR to clarify that small microhydro installations do not negatively impact agricultural potential and therefore are permitted within the ALR;
   - document a sample water licensing and net metering application to identify any procedural difficulties and other potential barriers.
   - approach the Ministry of Environment about waiving their annual water rental fees for very small systems, given that the fees nearly exceed all the financial benefits of the system.

3. Investigate possible solutions to cost and financing issues, specifically the following:
   - bulk purchasing of supply and install systems to reduce installation costs;
   - carbon offset initiative, either local or provincial, to provide incentives and financing;
   - other provincial and federal infrastructure funding sources.

4. Assist market development and capacity building on Salt Spring through the following:
   - develop a web-based list of manufacturers, and local suppliers and installers;
   - establish a local microhydro users group;
   - host workshops, site visits, and information sessions;
   - establish a list of installations as a tracking mechanism to determine if targets are met– possibly on a map based web application with online photographs and system specifications.

5. Encourage others to aid the development of small microhydro capacity on Salt Spring and beyond through the following:
   - provincial and federal recognition of the importance of distributed generation as part of the energy supply mix;
   - develop a provincial definition for small microhydro in BC in terms of system size, to be consistently applied by all BC agencies;
   - increase federal and provincial incentives, and the BC Hydro buy-back rate, for net metering;
   - increase federal and provincial support for small microhydro R&D and commercialization to catch up with prior and current support for other renewable technologies, such as commercial solar thermal applications (i.e., ecoENERGY Renewable Heating program);
   - establish a Canadian small microhydro industry association, equivalent to CanSIA;
   - undertake market research, including data on successful strategies for marketing other renewable energy technologies in north America and Europe.

1.0 Background

This project is part of the climate change mitigation and adaptation program referenced in the Salt Spring Island Community Energy Strategy (www.saltspringenergystrategy.org) and the Salt Spring Island Official Community Plan (www.islandstrust.bc.ca). It examines the economic and technical feasibility of Salt Spring's microhydro potential and identifies potential sites for microhydro power generation.

Salt Spring Island Community Energy Strategy Recommendation 2.8.2—Research microhydro generating potential—was the impetus for this project. Energy Strategy targets for 2012 are to meet 12% of the island's GHG emissions reductions through 5% locally generated power. The annual electricity generation would need to be about 5,400 Megawatt-hours (MWh) per year to meet 5% of the 2002 electricity demand. This power could be partly supplied through a combination of microhydro installations of 1 kilowatt (kW) or more and solar systems on farms, homes, municipal infrastructure and businesses.

Microhydro is considered a more viable power source than small-scale wind generators for Salt Spring because the latter require average wind speeds over 4 m/s (9 miles per hour), preferably with conditions of 7 m/s (15.7 Mph) on a monthly basis, which greatly restricts the number of potential wind sites on the island[1]. Solar energy generation—solar thermal and solar electricity—is viable during the sunny summer months, when microhydro generators on seasonal creeks are not.

For micro-scale generation to contribute significantly to the island's power supply and GHG reduction targets, many micro generators must be connected to the BC Hydro grid. This is possible through BC Hydro's net metering program, which allows BC Hydro customers to generate their own power from clean electricity sources[2]. Any surplus electricity is fed into the grid and is credited to the customer's account. The availability of net metering in BC provides the opportunity for communities to meet part of their power supply through micro-scale distributed generation such as that discussed in this study.

Where feasible, microhydro systems with batteries and an inverter (at an extra cost) can provide winter backup power in remote areas where there are frequent power outages and also in the event of larger power disruptions caused by earthquakes etc. If broadly developed, this capacity would increase community resilience. There are also local economic opportunities involved in the installation and maintenance of equipment, and economic benefits associated with retention of dollars in the community.

To assess the feasibility of distributed microhydro generation on Salt Spring, the project team reviewed existing rainfall and surface water data and mapping, and known potential sites, undertook several case studies, reviewed environmental and regulatory implications, and the economic viability of installations. The results of this project are intended to inform future development and installation of microhydro facilities on Salt Spring Island and will be included in the revised Salt Spring Energy Strategy for implementation. The results may also be of interest to other communities in the CRD and Islands Trust areas.

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[1] Salt Spring Island Community Energy Strategy, 2005, p. 32
http://www.saltspringenergystrategy.org/reports.htm

[2] http://www.bchydro.com/planning_regulatory/acquiring_power/net_metering.html

2.0 Scope of work

Existing Salt Spring Island mapping and hydrology data were used to generate this report. Information from site visits to ten landowners interested in installing microhydro systems has been included; this data is preliminary without accurate field measurements. Additional potential sites were identified based on experience with local streams and flows. Current regulatory requirements have been presented. Cost estimates were based on the figures provided in the Natural Resources Canada publication 'Micro-Hydropower Systems, A Buyer's Guide'[3]

The reader is encouraged to refer to the Buyer's Guide, which provides a very good introduction to the technical aspects of small microhydro systems. Other sources of information are listed in Appendix A.

The maximum size of a microhydro system varies by jurisdiction. For the purposes of this report, we have used the definition from the Buyer's Guide:

Microhydro: a hydropower system with a generating capacity of less than 100 kW.

The maximum size of residential net metering systems in BC as limited by water licensing regulations is 25 kW. The BC Hydro upper limit on net metering systems is 50 kW. Note that BC Hydro considers microhydro developments to have an installed capacity of less than 2 MW (2,000 kW); small hydro developments have installed capacities between 2 and 50 MW.

None of the potential systems identified on Salt Spring comes close to the 100 kW maximum. The largest of the case study sites was 12 kW. Many of the potential systems fall under the definition of **Picohydro** or **nanohydro**: a hydropower system with a generating capacity of less than 5 kW. Hundreds of thousands of these low-cost systems are in operation around the world, mostly in remote rural areas[4].

Non-fishbearing seasonal creeks were considered the most likely potential sites because they are numerous and there is little risk of ecological damage, even in fragile ecosystems. Given proper attention to design, sites on year-round streams could also be safely developed for winter power generation. Ecologically protected areas of the island have been excluded from the assessment of total potential, but this exclusion does not imply that a microhydro system within a protected area would necessarily cause ecological damage. Some of the case study sites were within protected areas.

[3] 'Micro-Hydropower Systems, A Buyer's Guide' available at http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/renewables/publications/microhydro_systems.html

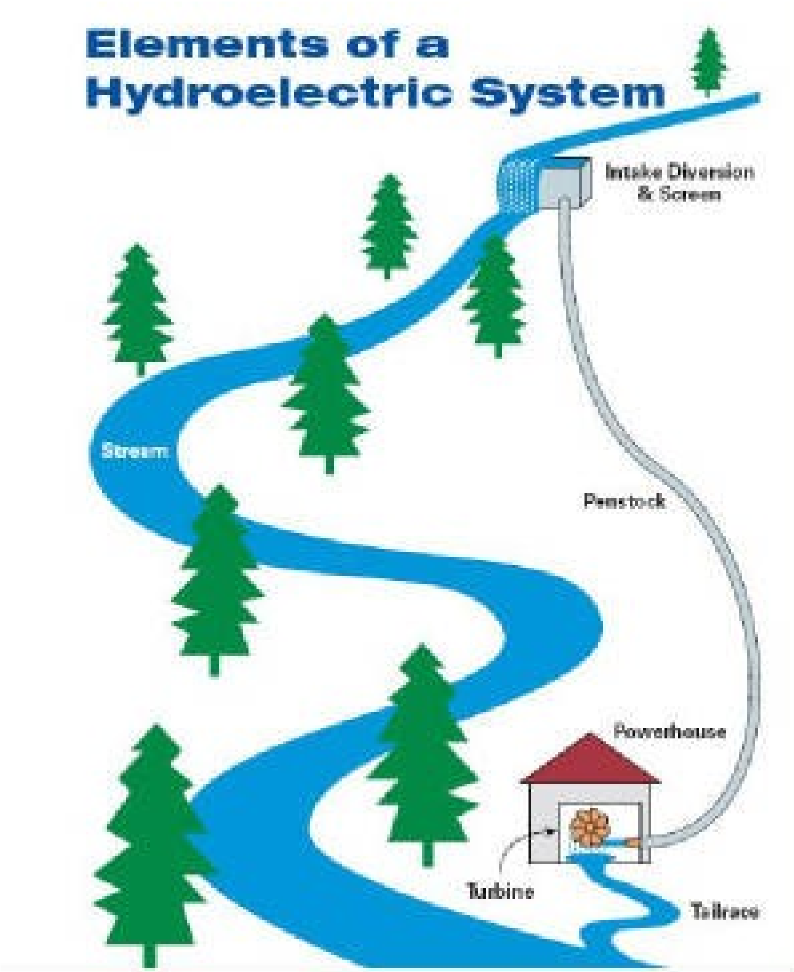
[4] ESMAP TECHNICAL PAPER 090 Stimulating the Picohydropower Market for Low-Income Households in Ecuador http://www.esmap.org/filez/pubs/ESMAPEcuadorForWeb.pdf

3.0 Introduction

Microhydro systems generate power from water flowing downhill. A typical microhydro system consists of the following components:

- The civil works and intake weir create a pool of water from which to drive the microhydro system. They are generally installed to take advantage of natural rock formations and/or bends in the stream. They are designed to minimize the impact on fish and other aquatic species by having bars blocking fish passage into the microhydro system. They also include gravel traps and diversions to prevent collection of debris such as logs and rocks. Finally, they can include spillways to protect the microhydro system from overflow during heavy flow floods.
- The intake collects water from a stream and divert it temporarily into a pipeline going downhill.
- The volume of water that is diverted is called the flow, generally expressed in terms of cubic meters per second or US gallons per minute. Microhydro systems are non-consumptive. Virtually 100% of the water is returned to the stream below the system.
- The penstock pipeline transports the water downhill, causing potential energy to increase to the forces of gravity. The penstock is generally made of plastic (HDPE or PVC) or metal (steel) pipe, with the lower reaches of the penstock needing greater strength characteristics than upper reaches due to increasing water pressure. Friction along the walls of the penstock causes some energy loss. This is reduced with larger diameter pipe.
- The vertical drop of the penstock is called head, measured in meters or feet – with gross head being the total drop and net head being the drop less losses due to friction.
- Water licenses generally mandate that at least 10% of the mean annual discharge (flow) of the stream is maintained and not diverted into the penstock. During low flow conditions, the microhydro system must be shut down so that 100% of available flow is maintained in the stream, ensuring that aquatic ecosystems are protected.
- The turbine converts potential energy from the water in the penstock to kinetic energy to run a generator. One or more nozzles spray the water against the turbine blades, causing them to turn rapidly. Different types of turbines are available for different levels of head and flow. Pelton wheels are very common, used for higher head conditions (more than 20 meters), while turgo wheels can be used for lower head and higher flows, requiring multiple nozzles.
- The generator produces electricity from the rotation of the turbine. Generators include AC induction and synchronous types, or DC permanent magnet or alternator types.
- The controls, including a mechanical governor between the penstock and the generator, or an electronic load governor between the generator and the electrical system, ensure that the electricity is produced at the correct frequency and voltage. In addition, a transformer is often needed for AC systems to change the voltage to household levels, or an inverter with batteries is required for DC systems.

The diagram below illustrates a typical microhydro system.



Credit: http://www.hydro-turbines.com/id71.html

The power output from a microhydro system is equal to the following formula:
P (watts) =
Net head (m) x (multiplication)
flow (m^3/s) x
specific gravity of water (9.8 N/m^3) x
efficiency.

The net head is equal to the total vertical drop, less the % loss due to friction in the penstock. The efficiency is affected by the turbine efficiency, ranging from 80-90% for pelton wheels, along with the generator efficiency, and from 65-75% for induction generators[5].

Salt Spring Island is a small island of 18,224 ha with 147 small watersheds[6]. Small watersheds imply low flows and correspondingly small microhydro systems. In terms of economic viability, power generated by smaller systems generally costs more per kilowatt than that generated by larger systems. The island includes ecological reserves, protected wetlands, and the largest fish bearing stream in the Southern Gulf

[5] NRCan, Micro-Hydropower Systems, A Buyers Guide, 2004
[6] Excluding watersheds on islets around the island, and lakes and flooded areas.

Islands; ecological considerations in these areas take precedence over power production. In addition, many small surface water sources dry up during the summer months. These factors limit the location, size and economic viability of potential systems.

However, the complex geography and steep terrain combined with winter rains provide many opportunities to generate small amounts of power during the winter months. There are other factors to take into account before considering these opportunities to be potential microhydro sites. Land ownership and right of way considerations, environmental concerns if a fish-bearing stream and/or sensitive ecosystem may be impacted, regulatory issues, development costs, and the presence of an enthusiast developer all impact microhydro development.

Most microhydro systems in BC provide stand-alone power where utility power is not available. For those on the utility grid, *net metering* enables utility customers to "sell" their excess electricity output to the utility by offsetting part or all of their power bill with output from their microhydro systems. The electric meters provided for net metering are bidirectional and read the "net" of electricity generated versus electricity used, thus "net metering".

For micro-scale generators, BC Hydro offers a net metering program, allowing BC Hydro customers to generate their own power from clean electricity sources (systems of up to 50 kW) and bank electricity they do not need in the grid. When the customer cannot use all of the electricity being produced, excess generation is placed on the BC Hydro grid, serving other SSI consumers. BC Hydro bills the customer for their net-consumption, equivalent to total consumption of BC Hydro electricity during the two month billing period, minus the total electricity exported onto the grid. If the customer's bill is zero, resulting from more electricity being produced than consumed, then BC Hydro will bank the power for up to 12 months, reducing successive bills. At the end of the year, BC Hydro purchases any surplus electricity at 8.16 c/kWh[7].

Net metering offers some advantages over stand-alone power systems. In a stand-alone situation, it is sometimes not possible to use the full output of a microhydro system, and so electricity may be wasted. In BC, power generated in net metering systems can be said to substitute for some of the fossil fuel generated power that BC now imports.

The following brief SWOT analysis provides an introductory overview of some of the implications for microhydro development on Salt Spring Island. Note that some characteristics appear under more than one category.

Strengths

- Microhydro is a mature technology and microhydro installations have the reputation for longevity of operation and low maintenance costs.
- Where available, waterpower can easily be the most cost effective renewable energy technology. Many systems have but one moving part, contributing to reliability.
- Net metering is available in BC and most of Salt Spring is serviced by BC Hydro.

[7] This price was recently revised from 5.4 c/kWh as a result of the 2007 Energy Plan and a BC Utilities Commission Decision in January 2009: http://www.bcuc.com/Documents/Decisions/2009/DOC_20883_G-4-09_BCH_Net-Metering_Re-Pricing.pdf

- Salt Spring's many small watersheds and steep terrain provide many opportunities for small systems.
- Microhydro technology reduces GHG emissions. Every megawatt hour (MWh) generated (thousand kilowatt-hours) displaces about 40 kilograms (kg) of CO_2 emissions on average. In an off grid situation, microhydro may be substituting for highly polluting energy sources, such as a diesel generator, which are far more polluting, producing about 1,000 kg of emissions per MWh.
- The LiveSmart BC: Efficiency Incentive Program provides financial incentives for homes to install microhydro systems.
- Microhydro system components are exempted from the Provincial Sales Tax.

Weaknesses

- The island lacks large watersheds and correspondingly large streams. We are not aware of any potential year round sites in the fifty kilowatt to one megawatt range. And the dry summers make payback very long for many otherwise interesting sites.
- Microhydro ranks behind domestic, irrigation, and fisheries requirements in terms of water allocation priority; there is little excess water during the summer months.
- Parts of Salt Spring, and all of its major streams, are protected. While the type of microhydro system proposed here can be installed and maintained with little ecological impact, development of sites within ecologically sensitive protected areas would be highly controversial.
- Current rates are not sufficient to provide adequate return on investment for small systems. Without reasonable return on investment, microhydro development may be limited.
- There are currently limited government incentives for microhydro installations.
- Infrastructure for the installation and maintenance of microhydro systems is not well developed.
- Microhydro systems, like all renewable energy systems, require regular inspection and maintenance.

Opportunities

- Salt Spring has many opportunities for a farm or household to generate a percentage of their annual electricity needs using microhydro.
- Net metering offers clean energy from private, local investment with significant CO2 reduction implications.
- Microhydro attracts enthusiastic developers—people proud of their systems and willing to share their experience with others. Salt Spring Island appears from the case studies to have many potential enthusiastic developers.
- Microhydro markets are currently under-developed.

- Infrastructure for the installation and maintenance of microhydro systems is not well developed, providing potential local business opportunities.

Threats

- BC Hydro is the only electricity supplier, is available in most areas of Salt Spring, and offers convenience and low energy prices, which discourage investment in renewables.
- Regulatory requirements are greater for microhydro installations than for other renewable energy systems.
- Microhydro systems may be impacted by flash floods and logging practices that affect stream flow and create debris and excessive sedimentation that can damage installations.
- Climate change may affect the viability of installations through long-term changes in precipitation patterns, and increases in frequency and intensity of severe weather events such as wildfires and storms.

4.0 Study approach

The study team began by identifying a series of possible case study sites, using the list of attendees of a microhydro net metering workshop held on Salt Spring in November, 2007[8] and other local contacts. Scott Davis walked each prospective site, roughly estimated flow rates and head, and discussed potential opportunities with the landowner, who was instructed how to proceed with detailed flow measurements, if appropriate. Mr. Davis also provided a follow-up letter to each landowner. The site characteristics for each case study were tabulated and potential power outputs estimated.

Surface water studies of Salt Spring were reviewed and rainfall data and surface flow information summarized. Existing surface water mapping was compiled and a catchment area map produced for a sample case study. A very broad-brush mapping analysis of Salt Spring was then undertaken to estimate the number and likely locations of possible microhydro sites. Note that these figures are based on a number of assumptions, stated in the text below, and not on detailed field measurements.

Relevant agencies were consulted during the course of this study. BC Hydro provided mapping of their distribution grid[9] and information about net metering requirements. North Salt Spring Waterworks District provided information about the Maxwell Lake supply line and other potential opportunities. Islands Trust was contacted with respect to available mapping, Development Permit Area 4 and Riparian Area Regulations. Kathy Reimer of the Salmonid Enhancement Society provided information about the protection of fish habitat. The Water Licensing Branch of the B.C. Ministry of the Environment was contacted regarding the need for obtaining a license for very small systems.

5.0 Surface water and Terrain

In the absence of any surface flow data for the region except that at the outfall of a lake, an effort has been made to estimate volume of runoff from smaller catchments based on that data and rainfall /runoff characteristics; i.e. 48% of rainfall turns into runoff.

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[8] given by Kevin Pegg of Energy Alternatives, November 18, 2007

[9] see Appendix C for sketch of BC Hydro distribution grid.

It is assumed that flow will occur primarily during the wet season, 5—6 months at a rate over 60% of the mean annual rate. This depends on several assumptions including that the lateral distribution of rainfall is similar across the island, and the average at a chosen site is the same as derived from records from several gauges located near the north end of the island.

The resulting volume of runoff will in fact occur during storms, probably up to three days long, so use of average figures would be optimistic in estimates unless sufficient storage were available (unlikely in small catchments). Site flow measurements are a much superior basis for energy estimates.

The terrain analysis was an effort to illustrate that the island has plenty of sloped sites with catchments of various sizes. We chose to illustrate areas over 15% slope. To enable individual property owners to consider an installation we thought to show larger properties that might contain the entire works within their own property and thus avoid the necessity for easements.

5.1 HYDROLOGY

There are several rainfall stations on Salt Spring Island that have a long term of record, primarily nearer the north part of the island. Precipitation statistics are well represented.

There is only one long term surface flow station with a lengthy period of record, but between that and other shorter records there is some average information about surface run-off. These data however relate to the outfall of a lake which gives a modified rainfall to runoff relationship due to storage in the lake. Use of data for extrapolation to catchments without lake storage could lead to erroneous conclusions, but may be useful for feasibility study of proposed sites to illustrate average production potential.

Prediction of energy production at a specific site would have much greater reliability if based on at least one season of rainfall and runoff data taken at the site.

The information below has been derived from two reports, the 'SSI Water allocation plan'[10] and 'Nine Lakes on Saltspring Island'[11]

5.1.1 SURFACE FLOW

Data is from stations on Cusheon (1977—1984),
Fulford (1983—1990, Apr.—Sept only) and
Duck (3 years record, Jan.—July only) creeks.
Cusheon records are usable for estimating runoff in other watersheds.

Cusheon Creek (Lake outlet, stn location 08HA026)
Catchment Area = 724 ha.
Mean Annual Discharge (MAD) = 0.116 cubic metres per sec.
Runoff for this catchment (Barnet) = 3.66 dam^^3 /ha.
Runoff Factor(Sprague) = 0.434

Fulford creek (Stn location 08HA055) extrapolated from Cusheon data
Catchment area = 2294 ha.
MAD = 2294/724 * 0.116= 0.368 cubic metres per sec.

This method may be applied to other small watersheds to give an estimate of annual average surface flow production:

Average **Runoff Factor for Salt Spring Island** = 0.48 (Averaged by Sprague from 11 authors)

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[10] SSI. WATER ALLOCATION PLAN—Barnett, Blecic & Van Bruggen—November 1993

[11] NINE LAKES ON SALTSPRING ISLAND…—Sprague Assocs. Ltd.—August 2007.

LOW FLOW Period.
Only Fulford creek (due to the two tributaries, Kyler and Reid creeks) records had flow in all months. The period when other main creeks had less than 10% MAD, or even no flow months, was from June to October. “It may be assumed that all streams on SSI experience mean monthly low flow during June through October, a five month period.”

HIGH FLOW Period
“Based on the Cusheon Creek flow records the high flow period (>60%MAD), is the six months of November through April.”
NB: These figures will be estimates only and are no substitute for site specific measurements.

This suggests a method of estimating average flows of over 60% MAD for smaller catchments of interest, for example:

Case Study Site # 8
Catchment area =53.4ha.
Estimated MAD = 53.4/724 * 0.116 = 0.0085cms.=270dam^^3

Inference: the flows in the months November—April period may therefore have average flow rates greater than 0.6 * 0.0085 = 0.0051 cms (5.1 L/sec)

This does not imply that there is continuous daily flow at the site at any level. So that without storage to average the outflow through a turbine, energy would be lost at times of high flow greater than the intake capacity. The decision as to system size and intake capacity is critical to the feasibility of the investment in equipment.

5.1.2 RAINFALL DATA

Based on two stations at Ganges and Vesuvius for the 29 year period 1951—1980.

Ganges average annual rain = 1065.2 mm
average days with measurable rain = 144
average days with snow = 8

Vesuvius average annual rain = 908.8 mm
average days with measurable rain = 142
average days with snow = 8

Cusheon average annual rain = 980 mm. (a local station)

Conclusion **Annual average precipitation** for Salt Spring Is. = **959mm**.(Sprague 2007)

ST. MARY’S LAKE PRECIPITATION DATA
The following information is taken from Environment Canada precipitation data for the eleven year period 1996 through 2006 for St. Mary’s Lake, Climate ID: 1016995[12]
The months in Table 1 below highlighted in red (November through April) are thought to be those with greater than 60% mean annual discharge (i.e. surface flow) as recorded at Cusheon Lake. It is possible that rainfall in October does not result in surface flows due to unsaturated watersheds.

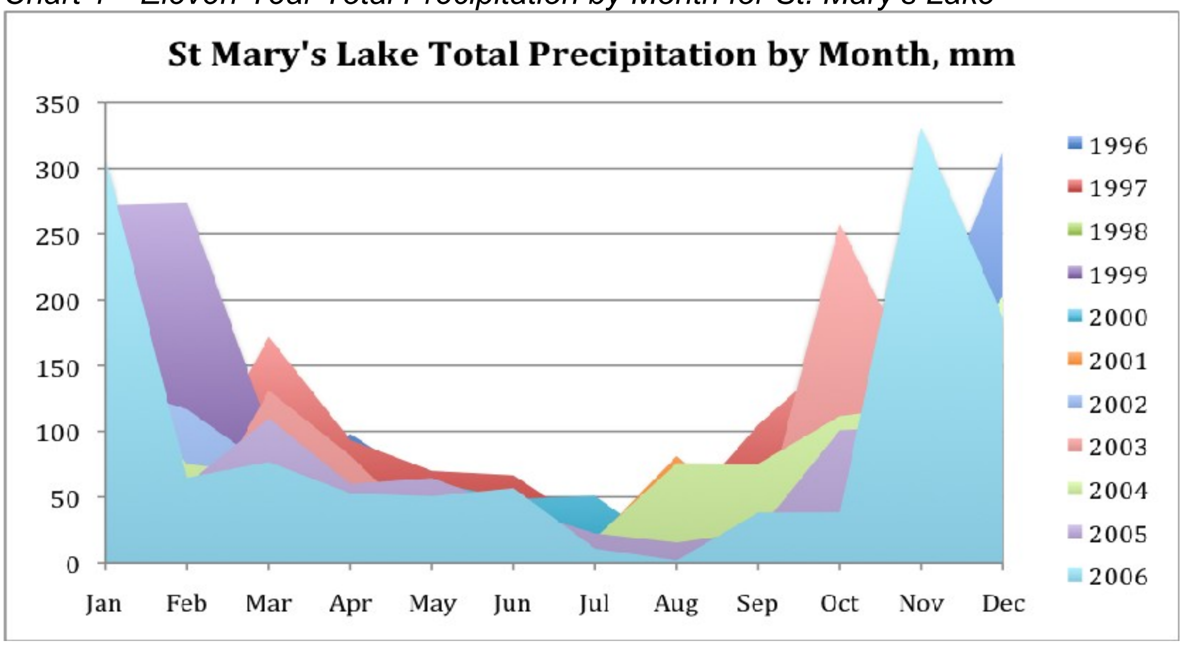
Table 1— Eleven Year Total Precipitation by Month for St. Mary’s Lake

[12] http://climate.weatheroffice.ec.gc.ca/climateData/monthlydata_e.html?timeframe=2&Prov=XX&StationID=93&Year=1996&Month=1&Day=1

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Avg
Jan	170.2	163	193.3	271.8	143.7	115.3	136.9	178	158.7	215.8	307.1	**171.2**
Feb	107.6	56.7	100.6	273.6	64.4	42.8	116.7	18.4	75	60	64.8	**81.7**
Mar	54	171.9	69.4	101.4	66.3	74.1	72.5	131.2	67.8	110	76.7	**82.9**
Apr	98	93.3	17.6	22.4	30	53.1	47.6	81.5	16.8	59.9	52.8	**47.8**
May	57.9	69.9	39.5	26.2	61.4	34.5	23.8	21	26.8	64.5	50.6	39.7
Jun	9.8	66.6	23.4	48.6	48.4	26	25.2	17.6	24	41.4	56.8	32.3
Jul	12.4	25.2	29.6	33.2	50.8	17.2	13.6	16.9	19	22.4	10.8	20.9
Aug	16.4	34.2	5.8	29.8	6.2	81.2	6.1	2	75.8	15.4	1.8	22.9
Sep	33.4	105	11.8	11.2	24.5	25.4	14.4	19.8	75.3	24	38.2	31.9
Oct	178.6	160.4	80.8	129.8	98.8	74	21.8	257.8	111.6	100.9	38.4	104.4
Nov	160	123.5	292.5	173	75.7	178.6	102	133.4	119.6	103.7	330.9	**149.4**
Dec	312.8	99.4	186.6	153	134.3	182.8	191	115.8	202.9	156.3	186.3	**160.1**
Tot	**1211.1**	**1169.1**	**1050.9**	**1274**	**804.5**	**905**	**771.6**	**993.4**	**973.3**	**974.3**	**1215.2**	**945.2**
Avg	100.9	97.4	87.6	106.2	67.0	75.4	64.3	82.8	81.1	81.2	101.3	78.8

Chart 1 below shows the data from Table 1 in graph form and clearly demonstrates the predominance of winter precipitation.

Chart 1—Eleven Year Total Precipitation by Month for St. Mary's Lake



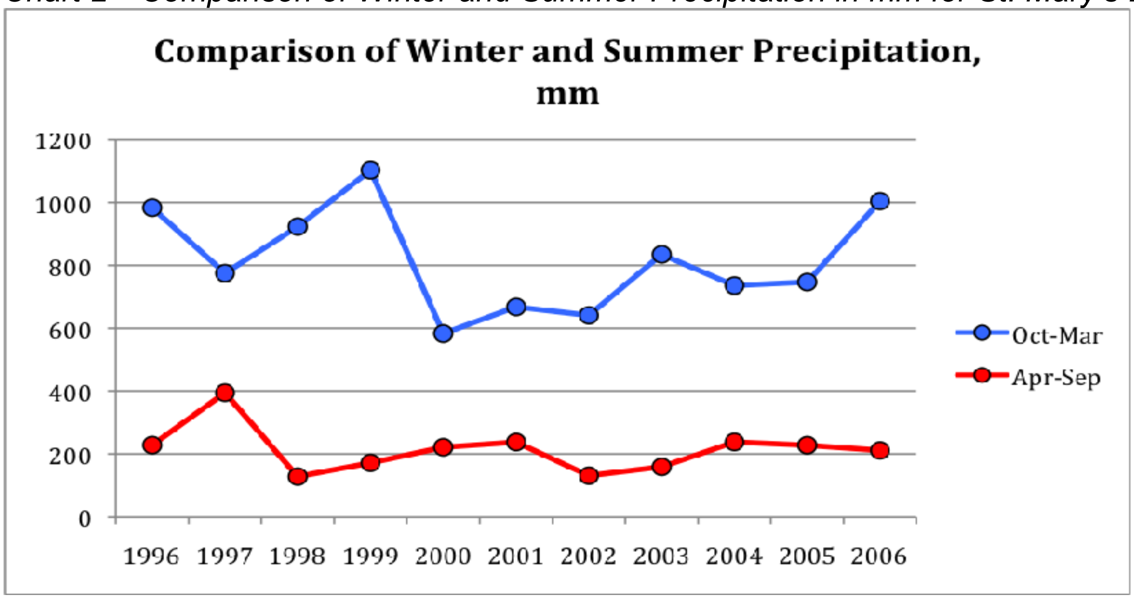
The majority of the precipitation occurs in the six month period October through March, as shown in Table 2.

Table 2—Comparison of Winter and Summer Precipitation in mm for St. Mary's Lake

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Avg
Tot	1211.1	1169.1	1050.9	1274	804.5	905	771.6	993.4	973.3	974.3	1215.2	945.2
Oct-Mar	983.2	774.9	923.2	1102.6	583.2	667.6	640.9	834.6	735.6	746.7	1004.2	749.7
Apr-Sep	227.9	394.2	127.7	171.4	221.3	237.4	130.7	158.8	237.7	227.6	211	195.5
Oct-Mar %	81%	66%	88%	87%	72%	74%	83%	84%	76%	77%	83%	79%

Chart 2 shows the data from Table 2 in graph form and again clearly demonstrates the predominance of winter precipitation. Over the eleven year period, 79% of the average annual precipitation occurred in the winter months, October through March.

Chart 2—Comparison of Winter and Summer Precipitation in mm for St. Mary's Lake



5.2 TERRAIN

Maps 1, 2 and 3 were generated from available digital data bases.

Areas shaded in grey are ecologically protected in some way. These areas are either an ecological reserve, are covenanted for ecological protection, are part of a drinking watershed, and/or are designated Development Permit Area (DPA) 4—Lakes, Streams and Wetlands, or DPA 3—Shoreline. Because of the ecological sensitivity of these areas, especially with regard to fish habitat, they have been excluded from microhydro considerations for the purposes of the mapping analysis, although some of the case study examples lie within these areas. Note that provincial and regional parks have not been excluded.

Map 1 shows the boundaries of Salt Spring's 147 small watersheds (from TRIM aerial mapping).

Map 2 shows slopes greater than 15%.

This slope was selected arbitrarily as an indicator of the number of properties in steep sloping areas. Clearly this would not be the case for slopes at the higher reaches of small watersheds due to the lack of drainage area to collect rainfall. Slopes lower than 15% may also have potential.

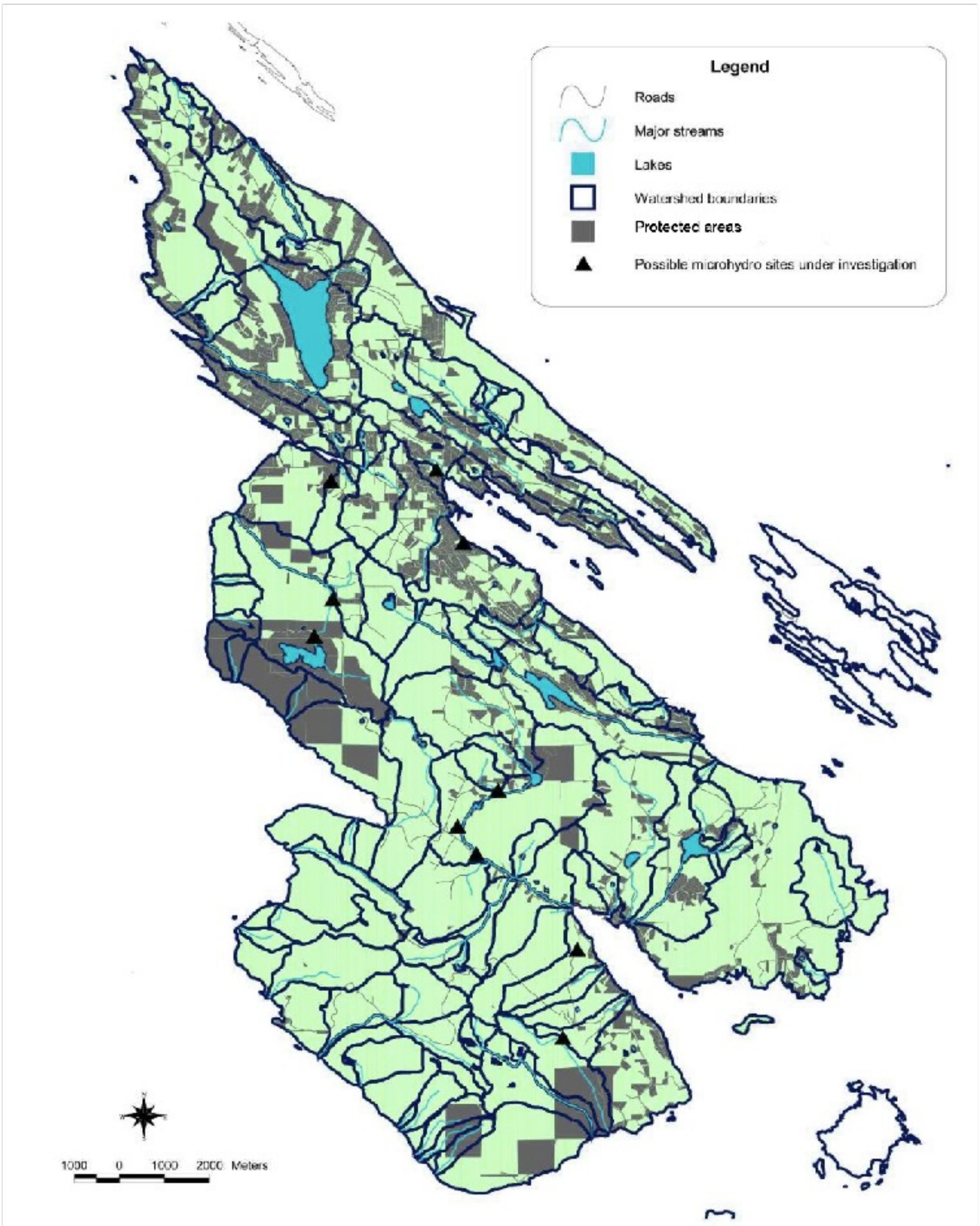
Map 3 shows properties of 2 ha or more which contain at least 1 ha of 15% slope.

The intent here was to further refine the site characteristics, selecting those parcels which if they contain a drainage channel would have sufficient head, and allow a private landowner ability to install works entirely on their own property, thus easing approval process. It is emphasized that this analysis is very approximate and broad-brush, simply as illustration that the island may have numerous sites worth consideration.

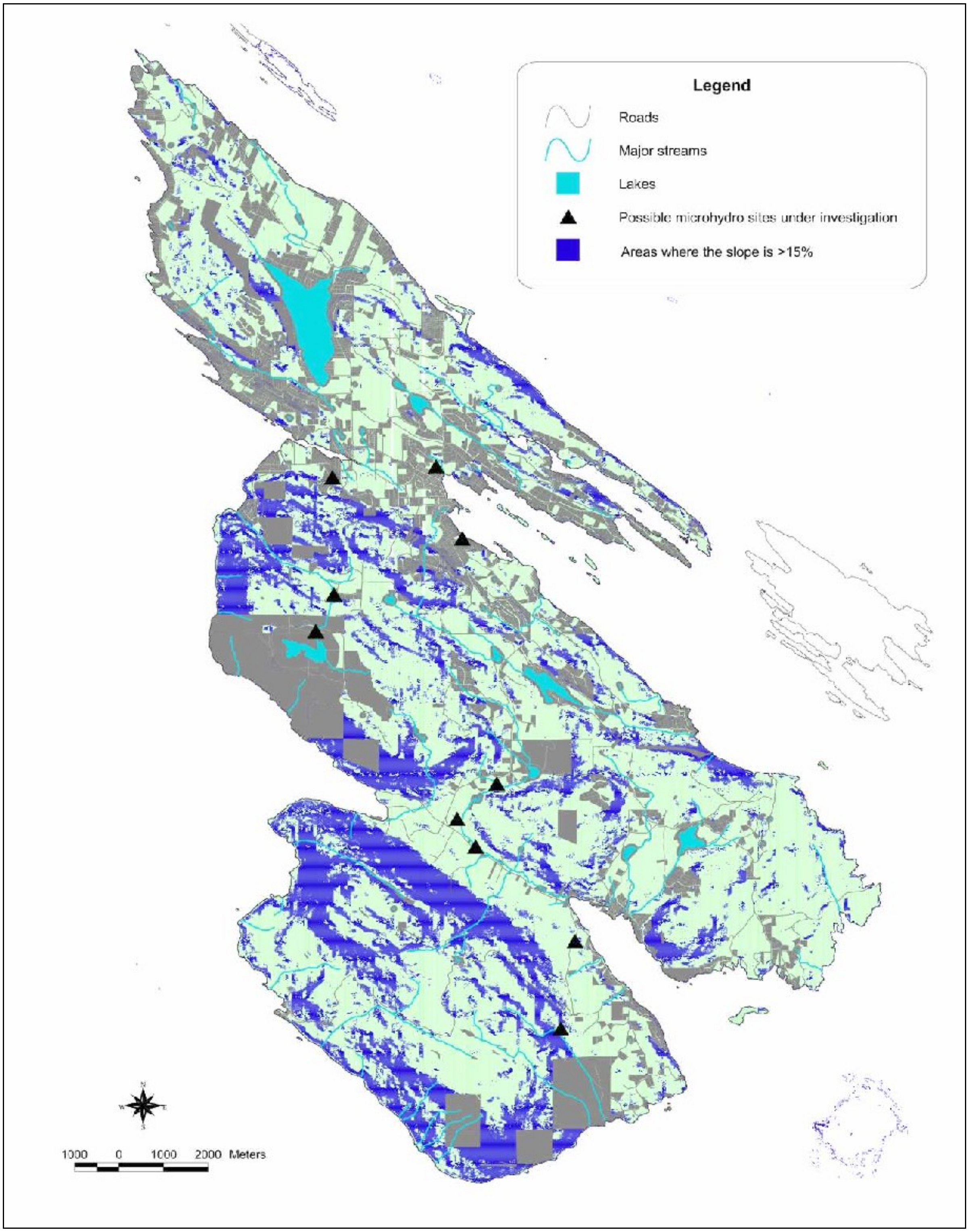
Given the above limitations, an analysis of Map 3 shows that there are 572 properties on Salt Spring with steep slopes and an area of >2Ha, of which 461 are privately owned (see Table 3).

These figures represent 38% of all parcels of 2 ha or more and 33% of all private properties of 2 ha or more. Clearly only a percentage of these properties will contain a viable drainage channel. Again only specific site investigation will provide accurate energy potential.

Map 1— Watershed Boundaries



Map 2—Slopes of 15° and greater



Map 3—Parcels of 2 ha or more containing 15° or greater slopes

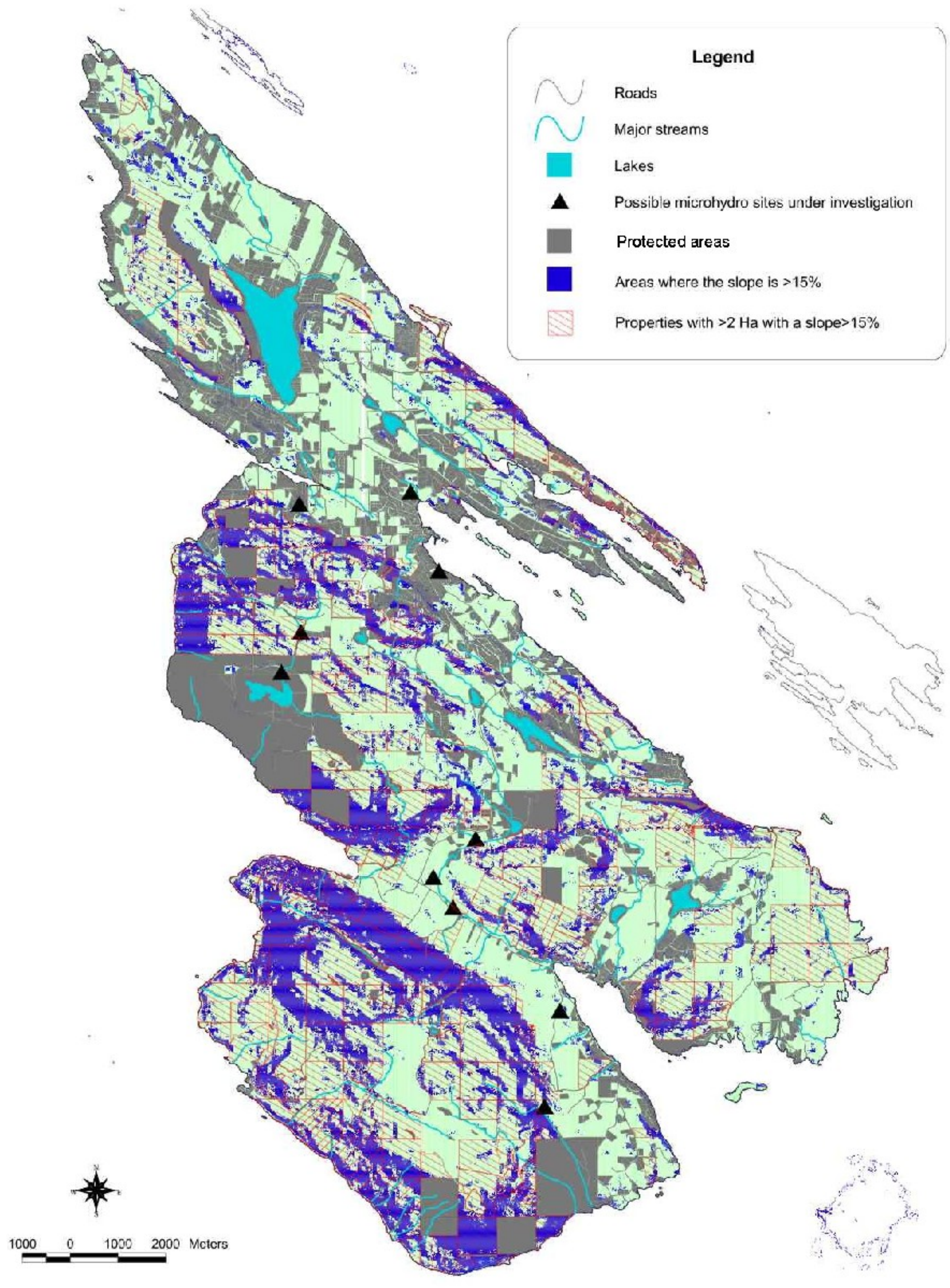


Table 3—Statistical analysis of Salt Spring properties with slopes > 15%

All Salt Spring Properties (note that non-properties—lakes, roads etc. are not included in area calculations)		
STATUS	**Total Ha**	**# properties**
unclassified		8
Community Park		11
Conservancy		6
Covenant		11
Crown Tenure		4
Ecoreserve		1
First Nations Reserve		1
North Salt Spring Waterworks District		2
Private		1386
Provincial Crown		25
Provincial Park		50
Regional Park		2
Salt Spring Water Preservation Society		3
Strata Common Property		10
Trust Fund Board		3
Unconfirmed		1
Total	**17513.66**	**1524**

Properties ≥ 2 ha where >1 Ha of the property has a slope of >15%		
STATUS	**Total Ha**	**# properties where >1ha has a slope of >15%)**
unclassified	12.96	4
Community Park	11.66	5
Conservancy	60.63	5
Covenant	105.51	10
Crown Tenure	3.47	2
Ecoreserve	9.06	1
North Salt Spring Waterworks District	7.60	2
Private	2701.70	461
Provincial Crown	426.27	25
Provincial Park	666.59	45
Regional Park	98.32	2
Salt Spring Water Preservation Society	7.15	2
Strata Common Property	61.04	5
Trust Fund Board	33.01	3
Total	**4204.99**	**572**

Total Area of Island including lakes, roads etc.	18534.83 ha
Total area with slope >15%	4604.40 ha

% SSI with slope>15%	24.84%

6.0 Case study results

The following results are based on site visits to ten private properties. The data presented in Table 4 were roughly estimated by visual inspection during each site visit and do not represent accurate field measurements. Accurate field measurements are essential before proceeding with the development of any particular site. Of the ten case studies, all but one—Case Study #10— appeared capable of producing at least 2,000 kWh per year, or about 12% of the average Salt Spring residential customer usage of about 17,000 kWh per year[13]. Three of the ten case studies had the potential to produce at least 17,000 kWh per year. Excluding Case Study #10, the estimated installed outputs ranged from 0.24 kW to 12 kW, with the median being 0.78 kW if the smaller output versions for each case study were developed and 1.6 kW if the larger output versions were developed. Note that most of this power would be generated during the winter months, even for year-round creeks, when electricity use is highest for residential customers.

Where utility power is not available, small amounts of power can make a significant contribution to an efficient household. Stand alone power costs are high, and microhydro can produce power for an efficient home very cost effectively. Outputs of a few hundred watts are highly valued in an off-grid situation. They may also be valuable for education and marketing. The landowner of Case Study #7, located on a high-traffic commercial property, was interested in developing his site primarily as a public demonstration.

Among the ten case studies there were no sites with potential larger than 12 kW, but there were three in the 6—12 kW range. The best flow durations were on the few water courses running all year, such as case study #1, but these sites had relatively low head. Case studies #3 and #5 demonstrate useful potential output from seasonal creeks with higher heads.

If all the estimated potential in the case studies were developed, the total would be about 33 kW and the annual output would be about 170 MWh, or enough to power 10 average Salt Spring homes. Note that one site, case study #1, provides almost half the estimated potential. Since accurate field measurements, taken daily over the course of at least one winter, are needed to verify the estimations in Table 4, extreme caution is advised in drawing any conclusions from these preliminary figures.

[13] Salt Spring Island Community Energy Strategy Baseline Report Update, January 2007

Table 4—Summary of case study results (information from Scott Davis)

Case Study Summary Data, preliminary, verify with accurate field measurements

Case Study #	*Version**	*Tributary or Watershed*	*Report-ed months of flow*	*Head, metres*	*Penstock length, metres*	*Pipe diameter inches*	*Flow US gpm*	*Flow litres per second*	*Est. Output in kW*	*Approx. annual output in kWh*
1		Fulford Creek	12	40	550	8	1,244	80	9.2	80,647
2		Maxwell Creek	5	19	200	6	400	25	1.8	6,480
3	3.1	Big Creek	5	80	400	2	50	3	1.0	3,652
	3.2		5	80	400	4	327	21	6.3	23,000
4	4.1	Bittancourt Brook, to sea	5	30	100	2	75	4.7	0.55	2,009
	4.2		5	30	100	3	216	13	1.6	5,844
5	5.1	unnamed brook, to sea	5	60	300	2	52	3	0.78	2,849
	5.2		5	60	300	3	152	9.5	2.2	7,920
	5.3		5	60	300	4	325	20	4.8	17,280
	5.4		5	60	300	6	945	60	12	43,200
6		Maxwell Creek & Gosset pond outflow	12	25	180	2	40	2.5	0.24	2,104
7		Crofton Brook	12	15	140	6	50	16	0.25	2,191
8	8.1	Juniper Creek	5	20	200	6	100	6	0.75	2,739
9		Hamilton Horne brook, unnamed tributary flows to sea	5				Estimated, pending data		1.0	3,000
10	10.1	Fulford Creek tributary	5	14	60	2	40	2.5	0.125	475
	10.2	Quarmtine Brook	5	6	0.3	2	100	6.3	0.15	548

* versions are possible variations in design, including penstock diameter, intake location, etc.

6.1 Sample—Case Study Site # 8

For purposes of illustration, a catchment area map—Map 4—was developed for Case Study #8, which was on the property of one of the study team members. From this map, the following data were derived:

Catchment area =53.4ha.
Estimated MAD = 53.4/724 * 0.116 = 0.0085 cubic meters per second

From page 12, the flows in the months November—April period may therefore have average flow rates greater than 0.6 * 0.0085 = 0.0051 cubic meters per second (5.1 L/sec).

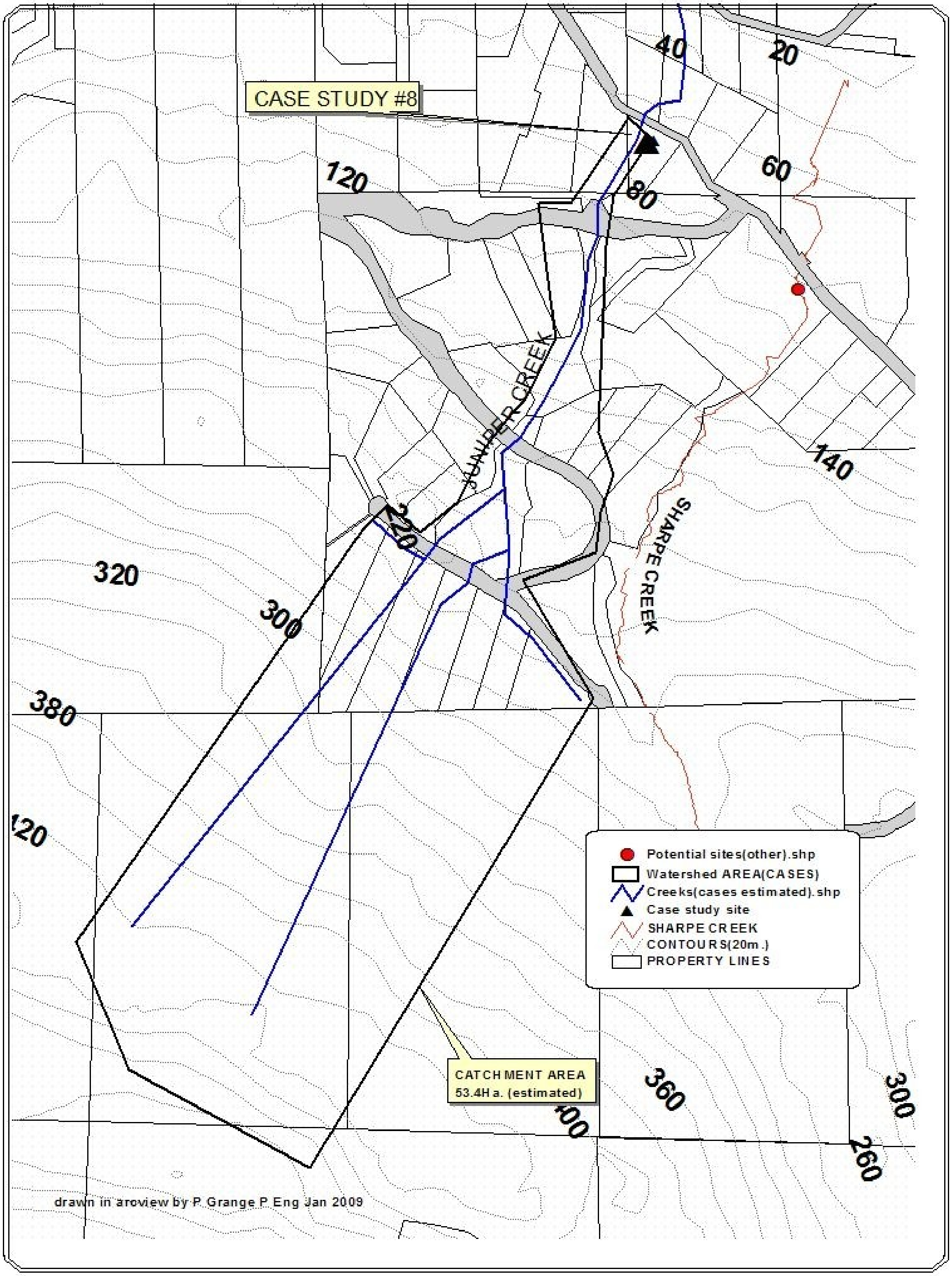
Excerpted from Scott Davis field notes for Case Study #8:

Setting: Rural home
Water source: intermittent brook, Juniper Brook
Flow duration: Variable, unclear.
Estimated quantity at time of visit: **6 litres per second**, 100 US gpm, minimum likely,
Perhaps five times that amount is actually available perhaps **5 months per year**
Length: Strictly according to map study, about 100 meters is long enough to go from the highest point on the property to the lowest, thus possible penstocks on the property would be approximately this length or shorter.
Head: The map shows about 20 meters of head maximum.
Estimated output: 750 watts

More accurate measurements are required. It's difficult to make generalizations at this head. Any site can be custom engineered, but the price usually precludes this solution. However, some combinations of head and flow offer real bargains because they can be done with "off the shelf" components, reducing the custom engineering required.

Especially at sites with heads under 100 feet, only specific data will determine if legitimate lower cost options are available.

Map 4—Watershed for case study #8

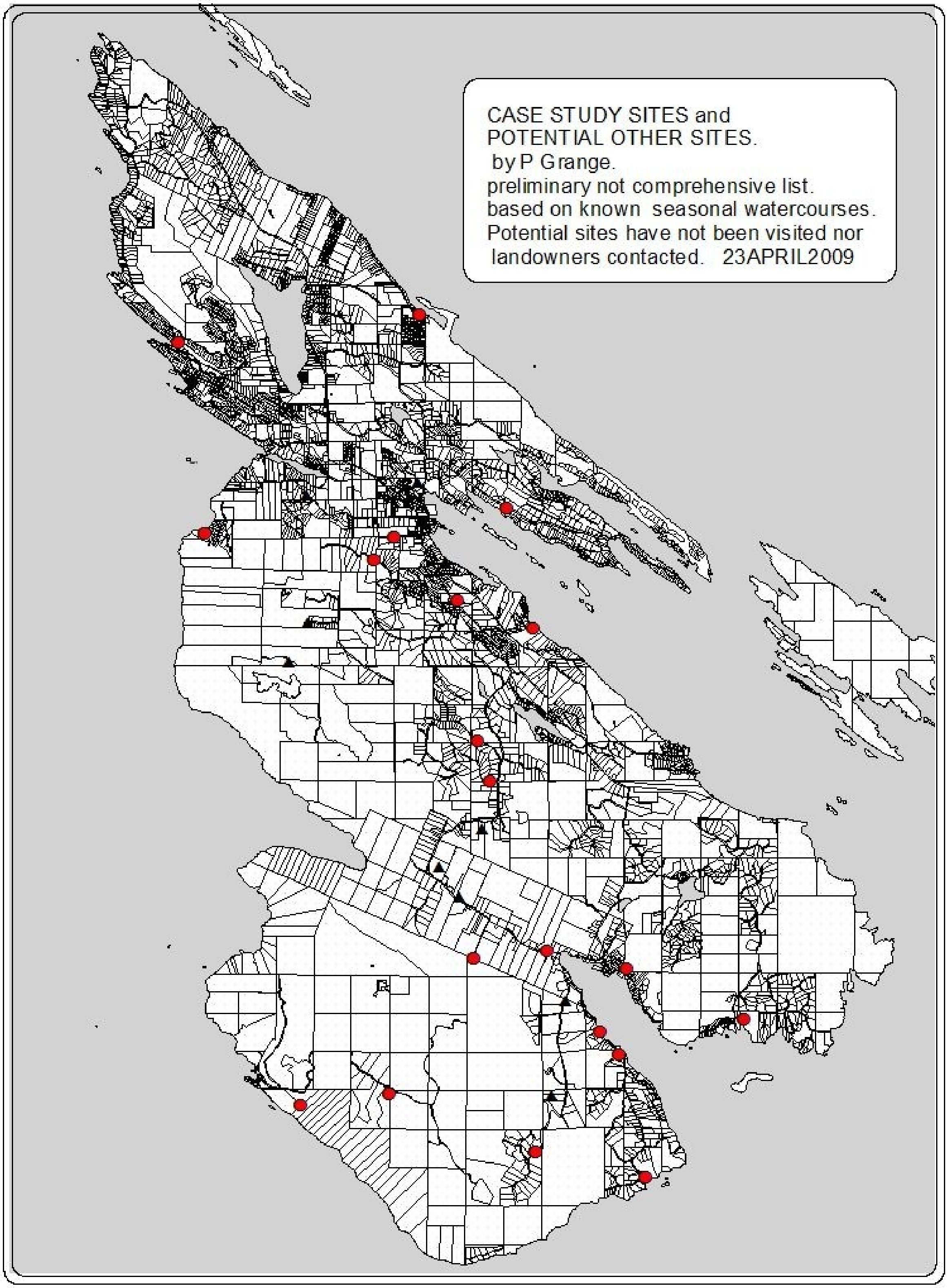


6.2 Other potential sites

Based on a review of the mapping and prior knowledge of the island's watercourses, the following sites with apparently good potential were identified and are shown on Map 5. Several of these sites are on public property; all merit further investigation.

1. Parminter brook—drains the Channel Ridge development area, hydro line nearby.
2. Walker Hook—a drainage area from Le Page road to the sea, ravine too steep for fish, hydro line nearby.
3. Cranberry Creek—in a steep ravine above the foreshore, Lake Maxwell drainage area, hydro line nearby.
4. Ganges Creek at Drake road—Steep ravine down from Wilkie Way, outflow into Park and fish habitat downstream at estuary.
5. Ganges Creek at Wilkie Way—above a steep ravine--private property up and downstream, hydro line nearby.
6. Bullock Creek—good sized catchment with fish habitat, the drop to the ocean is steep and in a road culvert, no fish passage.
7. Mawhinna Creek—steep ravine between Fulford Ganges and Beddis roads, hydro line nearby, there are existing water licences however.
8. Boulder Bay #3—large property above ocean outfall, Salt Spring Way drainage.
9. Ford Creek above Dukes road-Maxwell Mountain Drainage, hydro line nearby.
10. Garner Creek—Maxwell Mountain Drainage, hydro line nearby.
11. Jones Road—Kyler (or Sawmill) creek. Storage up on hillside (Rose Murgie Pond)
12. Fulford Ganges Rd, east side Fulford valley—steep ravine, drainage from upper hillside and Andreas Voight nature reserve area, discharge into Fulford Creek.
13. Weston Creek—discharge to ocean, no fish passage.
14. Kings cove creek—Beaver Point Hal drainage, no fish passage, hydro line nearby.
15. Fern Creek—Isabella Point Road, steep drop in ravine (a Park), to ocean.
16. Larlow Creek-Isabella Point Road, steep slopes upstream of highway.
17. Lumley Creek—steep ravine, highway road allowance to beach.
18. Mt Tuam Strata—Big creek and Waterfall creeks, steep mountain sites from Hope HiIl drainage.
19. Fullers Creek (2 sites)—western slopes of Mt Bruce to waterfall above Sansum Narrows.

Map 5—Other potential sites



6.3 North Salt Spring Waterworks District

When discussing opportunities for microhydro generation on Salt Spring, invariably the subject arises of the North Salt Spring Waterworks District (NSSWD) supply line from Maxwell Lake. Gravity water systems can offer an opportunity to generate or recover power. It is a common practice to harness this power in off grid areas.

Energy can be recovered from a system by taking advantage of "extra" water flow or pressure in the system[14]. This can take the form of extra water at the intake, and/or because of extra pressure available that is not used for another purpose. Another possibility for energy recovery comes when water is moved from one reservoir to another. The West Vancouver waterworks operates a relatively small 23 kilowatt turbine. The electrical output from this much larger water system is limited by other higher priority demands on the gravity water pressure.

Unfortunately, microhydro generation is not feasible for NSSWD. There is no surplus water to move through the pipe and no extra pressure in the system. Pressure reducers are used, but they work to regulate pressure for users including fire protection. The capacities of the system are strained. Every year there is more demand on the already extremely complicated system. There is no single opportunity where a lot of energy is dissipated, such as moving water from one reservoir to another. In all, there is no place to recover significant amounts of power from the NSSWD system.

6.4 Cost of microhydro systems

The costs associated with developing microhydro systems varies immensely. Each site has many unique factors.

- From the case studies, the length of pipe required varies from nearly zero to 550 meters.
- A particular site may offer more than one potential solution.
- A site may have volunteer labour available, or used equipment.
- If the certainty and reliability of a professionally engineered system is not required, do-it-yourself systems can reduce costs considerably. One company in BC has proprietary software that allows a mass produced pump, costing perhaps $900, to do the work of a turbine costing $4,000 or more (under the right circumstances).
- Under the right circumstances, a relatively inexpensive induction motor may be used as a generator, substituting an item that costs hundreds of dollars for one that costs thousands of dollars.
- The distance from the powerhouse to the point of use can be short and inexpensive or relatively far away.
- Power output is a function of the vertical drop (i.e., "head") of the water in a pipeline (i.e. penstock) from the intake to the powerhouse, less the energy loss from friction in the penstock (i.e., "net head", times the flow of water through the pipe, times the efficiencies of the turbine and generator.
- Microhydro can be developed from as little as half a meter of head or hundreds of meters of head. Flow rates can range from fractions of a liter per second to 125 liters per second or more. There is

[14] *'Flow Energy Management & Pressure Energy Recovery'* CRD Discussion Paper 031-4, 2008 http://www.wastewatermadeclear.ca/inthecrd/paper031-4.htm

a long history of development and many different technologies might be appropriate at a given site. For example, imagine a property that has a total drop of 20 meters available. Economic or site factors might mean that only part of the potential be used. There may be more than one place on the property to site a turbine that uses 8 meters of head, if that meets needs and unique site conditions better.

- Microhydro development has long been a custom civil engineering project, and so low cost mass produced options may not be available, keeping costs high.

All these factors ensure that costs vary widely. To offer a reasonable solution to this variability, the pricing here is based upon the recent values published by Natural Resources Canada in the Microhydro Buyers' Guide[15].

This data comes from Canadian and BC suppliers and developers. It was modified as necessary for the individual conditions of the case studies with updated pricing. The value of these estimates is that they provide relative costs and demonstrate important features of microhydro development. Adjustments can be made for individual site characteristics. For example, the penstock budget could be raised or lowered according to how long and what diameter pipe is needed at a particular site.

Table 5 is based on data from the Natural Resources Canada Microhydro Buyers' Guide. Note that the high cost per kilowatt for smaller systems can be misleading. Where utility power is not available, small amounts of power deliver many benefits. Other technologies, such as solar photovoltaics, are more expensive per kilowatt hour. Where a good site is available, microhydro is a very cost effective renewable technology.

Table 5—Relative costs of systems

Component	***400 watt***	***3.5 kilowatt***	***10 kilowatt***
Penstock	$1,000	$3,600	$3,500
Turbine-generator	$2,500	$3,300	$6,000
Transmission line	$500	$1,500	$3,500
Powerhouse	$200	$1,000	$3,000
Miscellaneous	$1,200	$1,650	$1,800
Total Equipment Cost	**$9,800**	**$10,950**	**$21,400**
Cost per kilowatt	$24,500	$3,700	$2,590

[15] http://www.canren.gc.ca/prod_serv/index.asp?CaId=196&PgId=1303

7.0 Implications

Waterpower is quite efficient. The case studies suggest that small flows of water (3+ liters per second) dropping modest distances (30 meters or so) can generate a significant portion of the energy a household needs. The case studies also demonstrate that a wide variety of heads and flows can be tapped to generate power. Requirements of a potential site include flow of water, vertical drop, access to the grid or some other use, and a willing developer. Every microhydro site is unique, making generalization difficult.

If 70 sites were developed (perhaps 25% of the total potential), they might supply about 800 MWh/y[16], enough to supply about 47 average Salt Spring homes. Houses designed to conserve electricity, usually off-grid homes, use a fraction of the electricity of grid-connected homes. But the trade-offs are air quality and GHG emissions, since non-electric heat sources are invariably more polluting than electricity produced from water power, which is still the case for most of BC's electricity generation. If the average system cost was $11,000, the total cost of developing the sites would be $0.8 million.

7.1 Financial

Microhydro is generally considered the most cost effective renewable energy technology. Like other renewables, the ongoing costs are the financing of the initial investment and maintenance, which is minor. Where there is no utility power, microhydro is the first choice to power a remote household or cottage[17]. At an appropriate site, waterpower can deliver generous amounts of power at the lowest cost.

Net metering allows utility customers to invest in technology to generate power, deliver it to the grid, and get paid for it. The large number of suitable parcels serviced by BC Hydro on Salt Spring increases the number of sites available for this kind of green investment. The BC Hydro buy-back rate is now 8.16 cents per kWh.

Current financial incentives in BC consist of PST exemptions on purchase of equipment and incentives of up to $1,300 under the LiveSmart BC program.[18]

Table 6—LiveSmart BC incentives

Microhydro	0.4 kW	0.8 kW	1.2 kW	1.6 kW	2.0 kW
South Coastal region	$260	$520	$780	$1,040	$1,300

For larger installations owned by businesses, municipalities, institutions and organizations, the federal ecoENERGY for Renewable Power[19] provides an incentive of one cent per kilowatt-hour for up to 10 years to eligible low-impact, renewable electricity projects constructed before to March 31, 2011.

[16] Half of the case studies were larger than 1kW. If half of the 572 parcels had the potential for 1kW+ systems, and assuming that 25% of those had a suitable set-up for micro-hydro with the placement of the creek and grid line, then there would be about 72 systems. If these are 3 kW systems, total output is about 800 MWh/y.

[17] ESMAP TECHNICAL PAPER 090 '*Stimulating the Picohydropower Market for Low-Income Households in Ecuador'*
http://www.esmap.org/filez/pubs/ESMAPEcuadorForWeb.pdf

[18] http://www.livesmartbc.ca/homes/h_rebates.html

[19] http://www.ecoaction.gc.ca/ecoenergy-ecoenergie/power-electricite/index-eng.cfm

Predicting market penetration

The market penetration of an energy technology such as microhydro can be predicted by how well it provides return on investment. While other hard to calculate values may trigger some sales of almost anything, significant market penetration does require that the technology delivers payback or return on investment. If the payback times are long, the market penetration is weak. However, if the payback time is short, market penetration can be very high. Tools to improve payback include rebates, tax credits, low-interest financing, and utility buy-back rates. Rebates and tax credits at time of purchase provide no incentive to keep systems running after they have been installed. By contrast, long term low interest financing and utility buy-back rates provide built-in incentives to keep systems functioning. Where net metering enjoys better market penetration, buy-back rates are often a leading incentive.

Economic Assessment

The following table outlines the cost-effectiveness of a microhydro system on Salt Spring Island based on the capital costs provided in this report, based on the three systems shown in Table 5.

The costs include:

- Capital costs, including equipment, construction and installation
- Water license application fees ($100): http://www.env.gov.bc.ca/wsd/water_rights/licence_application/cabinet/app_form_water.pdf
- Water rental fees ($100/year): http://www.env.gov.bc.ca/wsd/water_rights/water_rental_rates/cabinet/new_rent_structure.pdf
- For systems more than 5kW, a $600 fee for an electrical inspection by BC Hydro under the net metering program: http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/info_net_metering_faq.Par.0001.File.info_net_metering_faq.pdf

The benefits include:

- LiveSmart BC: Efficiency Incentive Program rebates, less a net cost of $150 for the required, two energy evaluations: http://www.livesmartbc.ca/rebates
- Avoided costs of electricity valued at 5.91 ¢/kWh up to 1,350 kWh every two months (tier 1), and 8.27 ¢/kWh for additional demand (tier 2)
- As assumed average capacity factor of 42%, meaning that the system would produce the equivalent electricity in a year of its operating at its rated (maximum) capacity for 42% of the year
- Payments for annual electricity generation beyond household demand, valued at 8.16 ¢/kWh (based on recent BC Utilities Commission decision)
- An assumed 30% average increase in rates and payments for excess generation over 20 years (less than 1.5% per year)

For the purpose of the analysis, the benefits have been discounted at 8% per year, net of normal inflation, representing the time value of money.

A 3,500 Watt, medium sized system that costs $10,950 is cost-effective, producing electricity at an average cost of 8.6 cents per kilowatt-hour (kWh). This will displace electricity demand valued at about $875/year. Over a 20 year period, the investment will yield a return of nearly $300 and have a simple payback of 10 years.

A 10 kilowatt, larger system has even better economics, generating electricity at an average cost of 6.1 ¢/kWh and displacing over $1,200 of electricity purchases each year. This system will produce more than the total annual electricity demand, allowing for an additional revenue stream from the sale of excess electricity at a value of over $1,600 per year. Over a 20 year period, the investment will yield a net return of over $14,000 and have a simple payback of 6 years.

A small, 400 watt system is not cost-effective against annual electricity savings. However, costs for such systems could be reduced through the use of recycled piping for the penstock and sweat equity to install the system. The investment will generate over $120 of annual electricity demand.

Table 7—Lifecycle cost analysis

	System Size		
	400 Watt	3500 Watt	10,000 Watt
Capital Cost	$9,800	$10,950	$21,400
BC Hydro Net Metering Fee	$-	$-	$600
Water License Application	$100	$100	$100
LiveSmart Incentive (net of cost for energy evaluation)	$110	$1,150	$1,150
Annual Output (kWh/year)	1,472	12,877	36,792
Water Rental Fee ($/year)	$100	$100	$100
20 year Levelized Cost ($/kWh), assuming an 8% real discount rate	$0.745	$0.086	$0.061
Average Electricity Demand per House (kWh/yr)	17,000	17,000	17,000
Avoided cost of electricity ($/yr)	$121.71	$873.78	$1,214.74
Value sales to grid via net metering ($/yr)	-	$-	$1,615.03
Net Present Value (2009$), assuming an average 30% rate increase over 20 years	-$9,218.38	$270.81	$14,186.18
Simple payback, assuming an average 30% rate increase (years)	168	10	6
		Cost-effective	Cost-effective

7.2 Environmental

Microhydro has many positive environmental implications. Both off grid and on, microhydro technology reduces pollution dramatically. It substitutes for utility power from coal and other combustion sources. Off grid, every kilowatt is worth about a cord of wood for heating when other needs have been met. Every thousand kilowatt-hours of microhydro power save about 40 kilograms of CO_2e.

The very small scale installations that are the subject of this report have few negative impacts if well conceived and well executed. Some water is taken, screened, and returned to a watercourse. Microhydro is a "non consumptive" use. Microhydro systems typically take a small fraction of the available water, which is returned to the stream after spending a few minutes at most in a pipe. Salt Spring has many seasonal creeks that can be harnessed with minimal ecological implications.

The island's larger year round streams are fishbearing, ecologically sensitive, and are protected under local, provincial and federal legislation.

"Fish have been identified in all significant stream channels and lakes"; "The flow from St Mary,

Blackburn, Cusheon, Maxwell, Ford and Weston Lakes flow into fishbearing streams."[20]

While well-designed microhydro installations do not negatively affect fish habitat, and have less impact than the removal of water for irrigation purposes, installations on Salt Spring's fishbearing streams require greater care and involve more regulatory oversight than those in other locations. Water must be maintained in the stream (not used for microhydro) to maintain fish habitat:

"10—20% MAD=fair spawning/rearing habitat, 5—10% MAD = Poor spawning/rearing habitat,"[21]
"extractive licence demands should only be allowed for period when mean flow is > 60%MAD.

The terms of the water license water license specify how much water can be withdrawn. 10% of MAD is standard. As microhydro systems return water to the creek channel, these restrictions apply to the reaches between the intake and the powerhouse that have reduced flows due to the microhydro system. This suggests that more acceptable sites would be tributary to main channels and in topographically steeper sites, which contain no fish habitat in themselves.

7.3 Regulatory

Water license

"All water in British Columbia is owned by the Crown on behalf of the residents of the province. Authority to divert and use surface water is obtained by a licence or approval in accordance with the statutory requirements of the Water Act and the Water Protection Act. In British Columbia, simply having access to surface water within or adjacent to property does not authorize a right to divert, use or store water."[22]

A water license should be acquired from the Water Stewardship Division (WSD), of the Ministry of Environment (MOE), even if the stream runs through private land. An application form for a water licence may be downloaded from the MOE website[23] and the completed application submitted to the local FrontCounter BC office in Nanaimo[24]. The license fee is $100 for 'Residential (Self-supplied) Waterpower', defined as "water that is used to generate power for residential use (up to 25 kW for one household)". The application requirements include a drawing, topographical map, a copy of the Registered Survey Plan for the parcel, and proof of land ownership. The approval process takes about four months, during which time FrontCounter BC handles the necessary referrals to different agencies.

For an overview of the agencies involved and the regulatory implications of large installations, see "Independent Power Production in B.C.: An Inter-agency Guidebook for Proponents"[25]

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[20] SSI. WATER ALLOCATION PLAN—Barnett, Blecic & Van Bruggen—November 1993
[21] Barnett et al--"Instream flow requirement based on Provincial version----method"
[22] http://www.env.gov.bc.ca/wsd/water_rights/licence_application/index.html
[23] http://www.env.gov.bc.ca/wsd/water_rights/licence_application/cabinet/water_licence_application_basic.pdf
[24] Nanaimo FrontCounter BC Office, 2080 Labieux Rd, Nanaimo BC V9T 6J9 Tel: 250 751-7220 Fax: 250 751-7224

[25] http://www.al.gov.bc.ca/clad/IPP_guidebook.pdf

Net metering

BC Hydro has set up a process to make the interconnecting of small generating units (with a capacity rating of 50 kilowatts or less) to BC Hydro's distribution system as practicable as possible.
The process involves submitting a completed application and an electric, single-line diagram to BC Hydro. BC Hydro then reviews and accepts the application/submission. The customer and BC Hydro sign a Net Metering Interconnection Agreement. The customer acquires all required permits and confirms passing the electrical inspection to BC Hydro. Systems over 5kW must be inspected by BC Hydro, for which they charge a fee. There may be an acceptance test by BC Hydro prior to connection to BC Hydro's Distribution System. Full information is on the BC Hydro website.[26]

7.4 Regulatory case study

The landowner of Case Study 1, located on a fishbearing stream, decided to proceed with an application for a water license for a microhydro installation. He believes it possible to generate between 9kW and 20kW for five months of the year, when flow exceeds 60% MAD, with no impact on fish habitat. The regulatory hurdles for this particular case study are listed below to demonstrate that it can be onerous, or impossible, to obtain approvals when ecologically protected land and tenure issues are involved. Note that this is an unusual case and that most of these restrictions would not apply to a typical homeowner seeking to harness a seasonal creek on their property.

1. BC had not yet processed any water licenses for net metering and there was some confusion at FrontCounter BC as to how such an application should be classified, especially when the applicant is a commercial farm rather than a residence. The Ministry of Environment, water licenses, confirmed that:

   Under the Water Act there are three power purpose categories that can be used for water licences which enable hydroelectric power generation. They are Power General, Power Commercial and Power Residential. The Power Residential category can be used for installations which provide power up to 25 kW, for one household. The application fee for this type of water licence is $100 with an annual rental rate of $100 or $0.01 per 1000 cubic metres, whichever is greater.

   BC Hydro assured us that the residential category did indeed include net metering.[27]

2. The proposed intake is on a neighbours' property. Under the water licensing regulations an easement to allow access to the work, registered on the neighbour's title, is required before a water license is granted. This delays the process until an easement can be negotiated and registered.

3. The stream is fishbearing and therefore Fisheries and Oceans Canada must approve the application.

4. There is a conservation covenant on this portion of the stream. It is unclear from the wording of the covenant whether or not the type of works proposed is allowable or not, if it does not affect fish habitat. The covenant holder would have to agree to the works. Fisheries will discuss with the covenant holder.

[26] http://www.bchydro.com/planning_regulatory/acquiring_power/net_metering.html
[27] Laila Bassim, Specialist Engineer, Generator Interconnection & Transmission Services BC Hydro, personal communication

5. The stream is in a DPA 4, probably requiring a Development Permit. The preliminary Islands Trust staff report reads as follows:

   1) The proposed development is in Development Permit Area 4 - Lakes, Streams and Wetlands according to the Salt Spring Island Official Community Plan Volume II. The applicant may have to apply for a Development Permit from our office depending on the policies and guidelines listed below for Development Permit Area 4.

   2) The applicant must also contact the Ministry of Environment in regard to the Riparian Areas Regulation, specifically obtaining a Riparian Areas Assessment report.

   3) The proposal for a micro-hydro generating plant is not a permitted use in this zone (A1). A re-zoning application (Bylaw amendment) must be submitted to allow a micro-hydro generating plant to be a permitted use on this property.

   4) An Agricultural Land Reserve application must be submitted as this property is in the Agricultural Land Reserve and the applicant will be using the land for non-farm purposes (the proposal is to supply power for a dwelling and possibly to the Provincial power grid through the micro-hydro generating facility).

   5) A copy of the restrictive covenant must be supplied.

   It appears from the above that A1zoning does not permit microhydro generation and a rezoning is required. This is something that needs to be addressed in the current round of OCP/LUB updates. For land in the ALR, it would be worth getting a ruling from the ALC regarding net metering installations.

From all the above, it seems unlikely that this particular application will proceed. At the very least it would take many months to gather the necessary data to prove to all parties that the works would not negatively impact fish habitat. The cost of rezoning alone would add several thousand dollars to the costs, not to mention the various engineering and biologists reports, and the costs associated with the easement. This example clearly points out that regulatory barriers can make or break a site, this being possibly the best of the case study sites from a purely technical perspective.

8.0 Implementation Planning

The large number of potential sites suggests that a more thorough investigation, particularly of sites on public land, is warranted. One approach would be to select three or four locations for at least one winter of field measurements and site analysis, followed by engineering design, system costing, installation and monitoring. If the results confirmed the preliminary findings presented here, information and marketing initiatives for private landowners could develop a small local market for equipment suppliers and installers. A series of workshops, and study of one or more of the trial demonstration sites, could form the basis of such a program.

In addition to financial benefits, there are many reasons why landowners may choose to proceed with developing a microhydro system. Reasons voiced during the case study visits included the following:

- Need for backup power during power outages;
- Concerns about climate change;
- Interest in the technology for its own sake;
- Expectations of rising energy costs and more frequent supply disruptions;
- Desire to demonstrate use of alternative technology.

In the short term, a marketing and education program may result in a small number of willing landowners developing some sites. The technology does present excellent CO_2 reduction per dollar spent compared to other renewable energy technologies (although conservation and efficiency measures are generally more cost-effective).

In the long term, a sufficient return on investment is needed to create the conditions for the widespread development of microhydro resources on Salt Spring. Recent changes in rates and regulatory conditions, give reason for optimism. A Salt Spring microhydro users group could be an effective lobby organization for change, and could also provide needed data about distributed microhydro generation in rural communities. A carbon offset initiative, either local or provincial, could provide financial incentives and financing.

APPENDIX A—**Resources and References**

Natural Resources Canada '*Microhydropower Systems: A Buyer's Guide'* 2004 http://www.canren.gc.ca/prod_serv/index.asp?CaId=196&PgId=1303

BC Water License documents: Water Stewardship Division, Department of Environment: http://www.env.gov.bc.ca/wsd/a-z_index.html

BC Hydro documents related to net metering: http://www.bchydro.com/planning_regulatory/acquiring_power/net_metering.html

BC microhydro case studies at RETSCREEN: HTTP://WWW.RETSCREEN.NET/ANG/T_CASE_STUDIES.PHP?Q=RESIDENTIAL+OFF-GRID&IDMODELE=0

Homeowner grants for net metering microhydro installations: LiveSmart BC http://www.livesmartbc.ca/homes/h_rebates.html available on Salt Spring through CityGreen www.citygreen.ca

Davis, Scott '*Microhydro: Clean Power from Water'* New Society Publishers 2003

Davis, Scott *'Microhydro Solutions: In Their Own Words'* New Society Publishers 2009

Smith, Nigel *'Motors as Generators for Micro Hydro Power'* Intermediate Technology Publications, UK, 1997

Williams, Arthur *'Pumps as Turbines: A User's Guide'* Intermediate Technology Publications, UK, 1995

Green, John et al *'Stimulating The Picohydropower Market For Low-Income Households In Ecuador'* ESMAP Technical Paper 090, 2005 http://www.esmap.org/filez/pubs/esmapecuadorforweb.pdf

Home Power Magazine www.homepower.com see issue 100 p 32 for article on dispelling the myths

Rothschild, Eddie / Shiskowski, Dean *'Flow Energy Management & Pressure Energy Recovery'* CRD Discussion Paper 031-4, 2008 http://www.wastewatermadeclear.ca/inthecrd/paper031-4.htm

Reinhard, Hass '*Building PV markets: the impact of financial incentives'* Renewable Energy World, July/August 2002

Database of (US) State Incentives for Renewable Energy: http://www.dsireusa.org/

Energy Alternatives Ltd., Victoria 1-800-265-8898 local supplier of microhydro equipment http://www.energyalternatives.ca/

WeGo Solar, Chemainus and Victoria 1-250-246-4305 local supplier of microhydro equipment http://wegosolar.com/

APPENDIX B—**Abbreviations**

ALC	BC Agricultural Land Commission
ALR	BC Agricultural Land Reserve
BC	British Columbia
CanSIA	Canadian Solar Industries Association
CO2, CO2e	Carbon dioxide, carbon dioxide equivalent (used interchangeably in this report)
CRD	Capital Regional District of Victoria
dam	dekameter, ten metres, 33 feet
DPA	Development Permit Area
GHG	greenhouse gas
ha	hectare, 2.47 acres
kW	kilowatt
kWh	kilowatt hour
l/sec	litres per second
LUB	Land Use Bylaw, regulates Salt Spring Island's Official Community Plan
MAD	Maximum Allowable Demand
MOE	BC Ministry of the Environment
m/s	metres per second
MW	Megawatt, one thousand kilowatts
MWh	Megawatt hour, one thousand kilowatt hours
NRCan	Natural Resources Canada
NSSWD	North Salt Spring Waterworks District
OCP	Salt Spring Island's Official Community Plan
PST	Provincial sales tax
PV	Photovoltaic, solar electric
SSI	Salt Spring Island
WSD	Water Stewardship Division of the BC Ministry of Environment

APPENDIX C— **Sketch map of BC Hydro distribution grid for Salt Spring Island**