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SMALL SCALE RENEWABLE ENERGY RESOURCES ASSESSMENT FOR NEWFOUNDLAND

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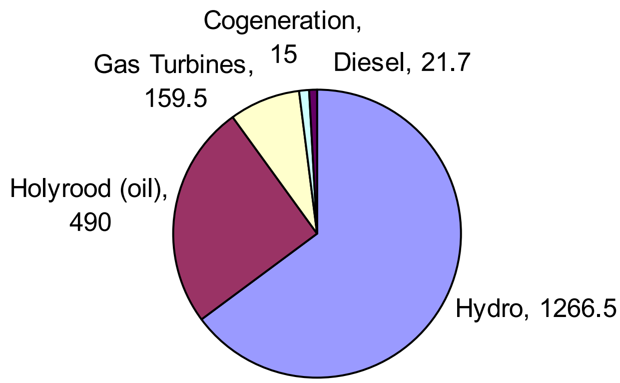
Abstract

This paper is intended as a preliminary review and analysis of the potential for small scale hydro and wind projects on the island of Newfoundland, Canada. Despite good wind and hydro resources the province uses thermal generation for about 20% of its energy requirements. Currently, Newfoundland is considering a multi billion dollar transmission line to bring hydro power from Labrador to the island and replace thermal generation. The alternative given by the province is to continue with one of various thermal generation options. This study is intended to determine whether small scale hydro and wind energy projects warrant consideration as another future generation option, and whether they could potentially replace thermal generation. To determine the total potential for small hydro and wind within the island power system several different areas are studied. Firstly, updated hydro resource potential is considered through RETScreen analysis of sites from a previous small hydro study. Wind resource potential is also analysed briefly using both island resource information and wind penetration research to gauge total potential. Finally, the ability of these projects to meet future energy demand is analysed through simplified island system simulations. It was found that there is a very large small hydro and wind resource potential available on the island and that these small projects merit consideration as a future generation option, with the potential to replace thermal generation.

Introduction

The current grid connected power system in Newfoundland has a total capacity of about 1900 MW [1] and generally produces about 8100 GWh a year [1]. The system is mainly composed of hydro projects of varying sizes as well as a large thermal generation station. The largest source of hydraulic generation is the Bay D'Espoir hydroelectric generation facility, which has a capacity of 604MW [2] and produces about 2600 GWh/yr [1]. There are another four large hydro stations with capacities from 40 to 127 MW and a few smaller hydro projects [2]. The majority of thermal generation is produced by Holyrood generation station, a 490 MW oil-fired power station which provided about 20% of the total island load in 2007 [2]. There are also several gas turbines and diesel units which produce a much smaller amount, in the range of a few GWh [2].

Figure 1. Island Interconnected System Total Installed Capacity (MW) [1],[2],[3]



Hydro potential

Newfoundland's high precipitation, ranging from 1000mm/yr to 1650mm/yr, and hilly topography create lots of potential for hydraulic generation [4]. In 1986 an inventory of small hydro potential for the entire island was completed by ShawMont Newfoundland Limited for Newfoundland and Labrador Hydro. The study found 196 sites with potential capacities between 1-20 MW, of which 160 were considered "feasible in the future" for a total of approximately 850 MW capacity [5]. Very little of the small hydro potential has been developed as there has been a moratorium on small hydro since 1998.

RETScreen Analysis of the 1986 Island Small Hydro Inventory Study

In order to determine an estimate for the current potentially feasible small hydro on the island a selection of projects from the 1986 island inventory study were analyzed using RETScreen software. Data from the study and updated cost estimates were used to approximate key indicators of economic feasibility. The values derived are then used to provide a general idea of which projects can be included in the overall potential for the island.

It is believed that the 20 years between the original study and today have created a significant change in the economic feasibility of hydro projects. This period has created increased expertise in small hydro, more efficient and less expensive equipment as well as a market environment that is far more favourable towards renewable energy in many parts of the world. For the purpose of this study it is assumed that a standard offer type program is put in place for the province, similar to those in other provinces and countries. It is believed that this program will have a significant impact on the economic viability of small hydro projects and that this, along with other factors, will mean most of the sites identified in the island inventory study will have economic potential.

Nine projects were selected for analysis with RETScreen (Figure 2). These were chosen to provide a range of capacities, physical locations and benefit/ cost values from the original study. Projects were selected from each hydrological region with feasibility ratings from “infeasible” to “very attractive.”

Figure 2. Map of sites chosen for analysis using RETScreen

The RETScreen analysis was completed using method 1, the less detailed pre-feasibility method. The resource inputs were chosen based on the information given in the island inventory study but the economic inputs were based on new average cost estimates from both research and RETScreen suggested values. To ensure more accurate total costs transmission line and road lengths as well as any additional cost indicated in the island inventory study were included. Several of the costs per unit were obtained using values from a detailed cost evaluation for the Rose Blanche Hydroelectric Project [6], a 6MW project developed by Newfoundland Power in 1998 on the Southwest coast. For simplicity project designs differing from the island inventory study, including combinations of several turbines, were not considered. It should be noted that unique designs can often add value to a hydro project but require a much more detailed study.

The assumed standard offer program was a rate of 86.68$/MWh, 90% of the domestic rate charged by Newfoundland Power [7], which is comparable to other standard offer programs such as in B.C. [8]. This is a conservative rate compared to the many areas with feed-in tariffs, where the base rate available to renewable energy sources is above the rate being paid for the electricity. This is the case in Ontario where the base rate for renewable energy producers is 110$/MWh [9], about 210% of the average weighted price for the year [10]. The chosen rate has a very large impact on the profitability of the project.

It was determined that most projects would be economically viable under current conditions and with a standard offer program in place (Figure 3.). Each project studied was found to provide fairly significant revenue after a 20 year period, including those which were originally deemed infeasible. The simple payback period for the projects ranges from 7 to 13 years, which are fairly reasonable given the large profit of many of the projects. It is difficult to determine a standard for economic feasibility as it depends greatly on the acceptable initial costs, risk and profit for the investing communities. It should also be noted that these values are simply a very rough estimate of economic indicators for development of these particular projects and if any of the assumed conditions are changed then the cost could also change dramatically.

*Table 1***.** Results of RETScreen Analysis

Site Name	**Benefit /Cost ratio from island inventory study**	**Simple Payback Period (yrs)**	**Total Initial Cost** (millions of dollars)	**Total Profit after 20 years** (millions of dollars)
Bottom Brook	0.72	9.9	8.9	12
Pipers Hole River	0.90	13.0	4.8	3.4
Great Gull River	1.05	10.2	17.8	22.7
Great Rattling Brook	1.30	7.0	28.2	67.4
Squid Cove Brook	1.43	9.1	6.3	10
Little Harbour River	1.58	11.2	16.5	17
Three Brooks	1.87	7.1	9.4	22.7
White Bear River	1.98	9.8	24.1	31.9
Parsons Pond	3.22	10.4	32.4	37.6

There appears to be only a little correlation between original benefit/ cost values and either risk or profitability of the project determined using RETScreen. The total revenue after 20 years very loosely increases with the benefit/cost ratio but there are many exceptions, most notably the Great Rattling Brook project. This is likely the result in the many changed economic conditions as well as a lack of good accuracy in both the original study and this analysis. The site from the 1986 island inventory study with the lowest benefit/ cost ratio, Bottom Brook Site 2, was found to be fairly profitable, with a total profit of 13.1 million in 20 years. It seems reasonable to assume that other sites with low benefit/cost ratios also have potential. For this reason it was decided to include almost all sites when determining the total of the potential from the 1986 island inventory study that would be economically feasible now. A benefit/ cost ratio down to 0.7 was chosen; although there is a possibility some sites with potential were not included. However, given the range of values found in this analysis, some sites with little potential were likely also included. These assumptions give a total potential of about 940 MW capacity with 190 projects.

Wind potential

According to Environment Canada, Newfoundland "has the strongest winds of any province, with most stations recording average annual wind speeds greater than 20 km/h" [4]. To gain an understanding of this potential an estimate of the total island wind power was calculated using a method adapted from Archer and Jacobson's "Evaluation of Global Wind Power" [11]. It is essentially an estimate of the total energy that would be able to be produced if the entire island was converted to a wind farm. It was found that approximately $9.47 \times 10^5 GWh$ of energy could be produced, about 117 times the electricity consumed on the island in 2006 [1]. A wind resource map of the island by M. J. Khan and M. T. Iqbal [12] provides a good general overview of wind potential in different regions of the province. From this map it can be seen that the Northeast coast, the Burin Peninsula, the Northern Peninsula and parts of central Newfoundland have good potential. Supporting this conclusion are wind studies in three of these regions [13],[14],[15] and the 14 proposals for wind projects on the island since 1996, with a total capacity of about 255MW [16].

Wind Penetration

As it is clear that there is significant technical and economic potential for wind projects on the island it seems likely the limiting factor for wind development will be the power system and transmission capacity for wind. High wind penetration issues and solutions have already been studied and put into practice in Europe and, more recently, here in North America. The main factors affecting integration costs of wind were found to be the penetration level, forecasting reliability, geographic diversity, control/ flexibility of hydro and of the overall power system [17], [18], [19]. With an updated transmission and control system in place the island system would likely be ideal for high wind penetration. The 930 MW of large hydro should be able to be used as low cost dispatchable generation, avoiding the high spinning reserve costs of other types of generation. This type of system is currently being studied by 22 countries in the IEA Task 24 research project [20]. Another benefit of the development of many small wind projects spread throughout the island is that it should allow higher wind penetration at lower cost then large wind farms. Increased geographic diversity has been found to lower integration costs through more constant and less demand on spinning generation due to an overall "smoothing" effect [17], [18]. A study in Quebec simulated both large scale wind generation and small, distributed wind and found that: "The benefits of such an approach [small, distributed wind] would be numerous: reduction of the amount of required backup capacity, elimination of periods with zero wind production, less impact on river flows" [21]. Other systems with large amounts of hydropower have considered total wind penetration up to 23% [22] and 30% [18] to be technically, and potentially economically, feasible. This suggests it would be possible, with updated transmission and system control, to integrate up to 440MW of wind capacity, about 1350GWh/yr, into the island system.

HOMER Analysis of Thermal Generation Replacement

As a preliminary step in determining how well small hydro and wind projects will be able to replace thermal generation and meet future generation requirements HOMER (Hybrid Optimization Model for Electric Renewables) software will be used to analyze potential future generation scenarios. This software is used to compare generation by potential new small hydro and wind projects to the current thermal generation and future generation requirements, which are entered as the load. HOMER calculates the energy balance every hour for a year by determining the total generation and comparing it to a load provided by the user [23]. For this analysis the software was used solely to determine production and load comparison data and the cost optimization functions were not used. HOMER is designed for smaller systems and the inputs had to be adjusted to allow it to be used for these pre-feasibility energy calculations.

Load Inputs:

The load was chosen to represent the portion of the total island load that must be met using thermal generation or new generation options minus the expected energy production of new hydro projects already proposed.

HOMER requires a weekday and weekend daily load profile (with hourly data) for each month and allows all values for the year to be scaled to give a certain average daily load. Daily load profiles were selected from 2004 Holyrood thermal generation data, the most recent hourly data available. The monthly load profile was then updated by manually scaling the daily load profiles to give monthly averages from 2007 generation data [24] (see Table 1, Appendix). This was done to give the most up to date profiles possible with the data available. These load profiles were used for all simulations while the inputted daily average load for the year was changed to give the portion of the island load to be met for that year.

Daily average load = $(E_{thermal} + E_{growth} - E_{hydro})/365$

$E_{thermal}$ = 2007 thermal generation
E_{growth} = load growth since 2007 calculated from predicted total island load [1]
E_{hydro} = expected energy production of the 3 larger hydro projects already planned by Newfoundland and Labrador Hydro [25]

Note that this load assumes no demand side management, an option that could potentially lower the new generation requirements in terms of both capacity and energy production.

Wind Resource Inputs:

To model a large number of wind projects as one wind farm the monthly average wind speed for four coastal sites spread throughout the province [26] were taken and averaged to get a general monthly average wind speed for use in all the simulated wind projects (see Table 2, Appendix). Other parameters were also chosen to reflect a typical site in coastal Newfoundland. The altitude was assumed to be 50m and advanced parameters were taken directly from those used in a pre-feasibility study for wind power in Holyrood, Newfoundland [27].

Wind Project Inputs:

As no shading effect is considered with HOMER the total of all wind projects could be modelled as one wind farm with the corresponding number of turbines. This composite wind farm must represent both new small wind projects and the two wind 27MW projects currently under development. Each small wind project was chosen to be represented as having six generic 1.5MW turbines. An additional 36 turbines were added to account for the 54MW from the current wind projects which are meant to be completed this year. The total energy production by these 36 turbines only was 198 GWh, which corresponds well with the 100GWh per project predicted by Newfoundland and Labrador Hydro [28], [29].

Hydro Resource Inputs:

Baseline Data:
To determine the monthly flow variation that best represents the total throughout the province the monthly average flow for 5 rivers, one from each of the 5 regions of the province, was obtained from the Department of Environment and Conservation [30]. These values were then normalized using the mean flow for the year in that location. The normalized values for each month were then averaged to give a set of general monthly normalized flow data. (see Table 3, Appendix)
The rivers were chosen based on either having been an index gauge from the full island inventory study [5] (3 out of the 5) or on the basis of being within the range for small hydro and having fairly typical values of flow for the streams gauged in the region.

Hydro Project Inputs

To model the number of projects being simulated as one large hydro project the flow rates were scaled and the input head chosen such that the nominal capacity of the system was the average capacity found in the island inventory study [5] multiplied by the number of projects. The design flow rate was also scaled accordingly while the minimum and maximum flow ratios, efficiency and pipe head loss were chosen based on average values from small hydro projects.

Through this adjustment of hydraulic resource and turbine inputs the contribution of many small hydro projects was able to be roughly represented in HOMER. The results obtained using these values were verified against the results of the island inventory study [5]. The total energy production values for various numbers of projects calculated by HOMER were found to be within 0.1-6.6% of the sum of predicted energy production values for that number of projects from the island inventory study.

Simulations

A total of 23 simulations were run, modelling different numbers of wind and hydro projects for the years 2007, 2012, 2017, 2020 and 2025. The results were used to develop two possible plans for integration of small hydro and wind into future generation as well as find the amount of extra management of current large hydro required to make full use of these small hydro and wind projects. The first plan builds slowly up to 45 hydro projects and 20 wind projects in 2025 and involves creation of at least one new large hydro project as well (beyond what is already proposed). The second plan builds up to 55 hydro projects and 20 wind projects and does not involve the new large hydro. Both plans allow elimination of all of Newfoundland and Labrador Hydro's gas turbine and Holyrood generation but only with a certain amount of "energy management". This is the total amount of energy that must be shifted from current production patterns to allow full use of wind and small hydro resources. A much more detailed analysis would be required to determine an acceptable value; however, all were well below the total hydraulic system energy storage, which was at or above 1000GWh for all of 2007 [31]. The results below give a good overview of the most relevant findings.

Table 2. Sample Island New Generation Plan 1

Year	Load to be met (GWh)	# of hydro project	# of wind projects	Total small projects energy production (GWh)	Other generation Required (GWh)	Options to fulfill other generation requirements	Generation to be shifted from current use pattern (GWh)
2012	1,868	5	5	300	1,370	1 Unit Holyrood + Gas Turbines	60
2017	2,203	25	10	1,006	686	Gas Turbines	176
2020	2,419	35	10	1,111	519	Large Hydro	233
2025	2,756	45	20	1,876	256	Large Hydro	422

Figure 2. Sample Island New Generation Plan 1 Diagram

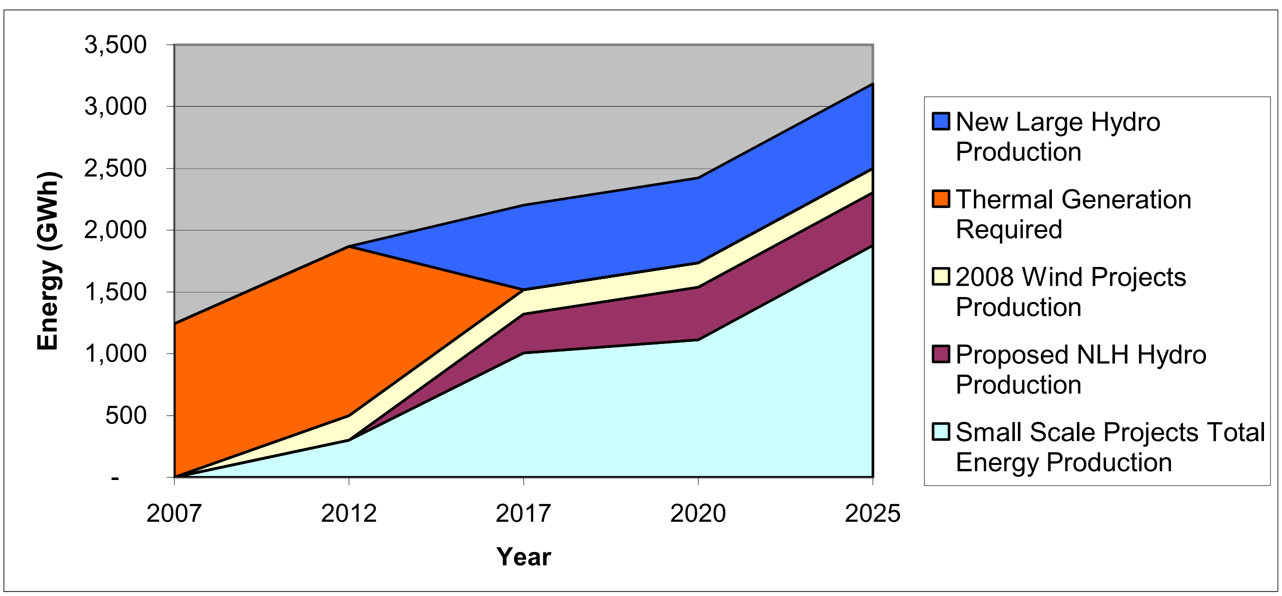
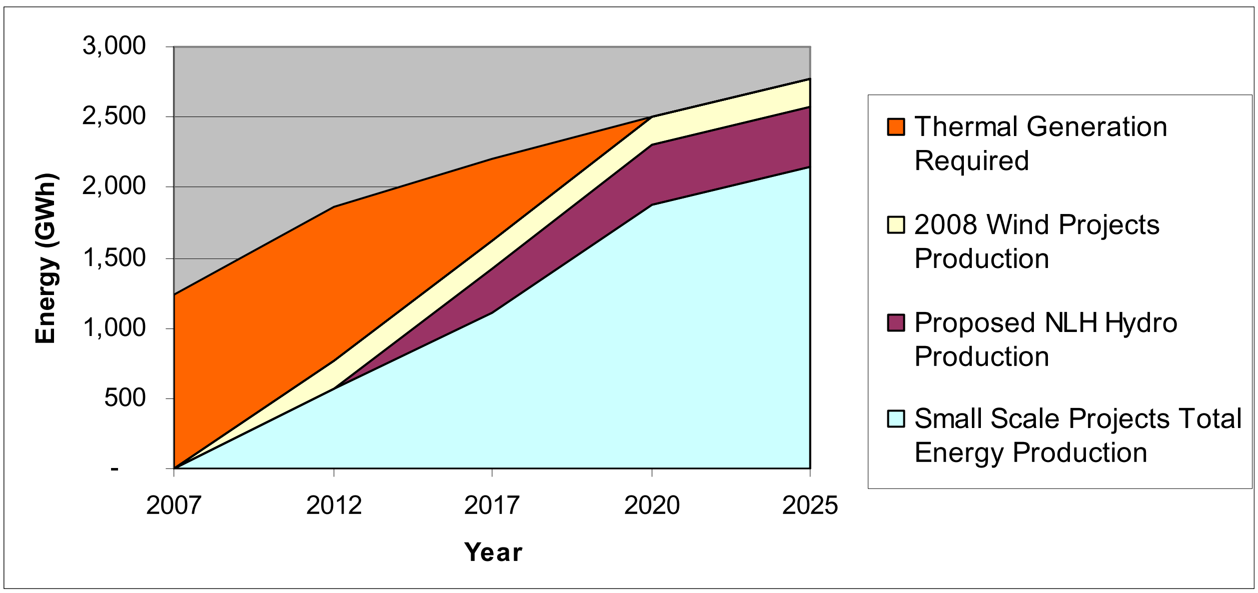


Table 3. Sample Island New Generation Plan 2

Year	Load to be met (GWh)	# of hydro project	# of wind projects	Total small projects energy production (GWh)	Other generation required (GWh)	Options to fulfill other generation requirements	Generation to be shifted from current use pattern (GWh)
2012	1,868	15	5	570	1,100	1 Unit, Holyrood + Gas Turbines	96
2017	2,203	35	10	1,111	580	Gas Turbines	193
2020	2,419	45	20	1,876	-	none	523
2025	2,756	55	20	2,147	-	none	543

Figure 3. Sample Island New Generation Plan 2 Diagram



Total Small Hydro Potential:
When all small hydro projects identified as potentially feasible were included in a simulation of the years 2007 and 2025 it was found that 5219 GWh of energy could be produced and only about 25% and 45% of this would be required to meet the load without any wind generation in the system.

This preliminary analysis suggests island thermal generation can be gradually eliminated using a combination of a few large hydro projects and many small wind and hydro projects along with a certain amount of energy shifted from current use patterns.

Some issues not considered in this analysis were: transmission, firm capacity requirements, effects of many small hydro and wind versus projects one large project and environment impacts.

Power System and Transmission

Transmission and operation of systems with significant amounts of small scale generation, similar to the system we are proposing, requires better transmission and power system control. These issues are currently being researched extensively in many other parts of the world, including Europe, the US and Japan. There are many solutions already being developed and tested in these regions. An updated transmission and operation system should allow small hydro, large hydro and wind generation to be used in combination so as to provide greatest system reliability, improved security and minimize environmental impacts. As discussed when considering wind penetration, many researchers and power utilities have found that the use of flexible large hydro systems to offset less controlled systems such as wind and run of the river hydro allows for a much higher penetration [32], [33], [34]. There has also been a significant amount of recent research into distributed generation, which is very similar to the system being proposed although generally also includes very small generation as well. In recent research it is generally agreed that, combined with dispatchable generation and a more sophisticated transmission and control system, high distributed generation penetration can be achieved and can actually improve system reliability [35], [36], [37]. There are many transmission system-dependant technical issues that must be overcome [38] and more detailed study is required to determine actual requirements and costs.

Conclusion

This study provides an initial overview of potential for small scale hydro and wind projects on the island from current information available. Analysis of data on small hydro has shown that there is a total potential of almost one thousand megawatts which would be technically and economically feasible with supporting policy and updated transmission. Wind resource research also showed a very high potential and, equally importantly, a high wind penetration capability within the current power system. However, to enable any significant amount of development updated transmission and control systems would again be required. Further analysis on incorporating small scale generation projects into the island power system using HOMER software demonstrated that replacement of thermal generation is possible using a small fraction of the total resource potential, but only under certain conditions. Fairly significant numbers of projects would have to be developed and system control must allow management of large hydro so that most small wind and hydro power can be used. Further study is required in the areas of transmission and overall system management to fully asses the feasibility of this scheme. It is established that there is a significant resource potential in the province that could likely be developed using recent technological and power system advancements in wind integration, distributed generation and power system management. This initial investigation into small hydro and wind as a generation option on the island demonstrates a substantial potential that merits further exploration.

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Appendix

Table 1: Monthly thermal generation and load information used in HOMER analysis (kWh)

Month	2007 Holyrood Generation
Jan	133,061,670
Feb	146,066,760
March	169,562,610
Apr	140,079,870
May	135,656,640
June	107,482,410
July	78,601,950
Aug	11,173,680
Sept	145,530
Oct	97,169,940
Nov	114,178,050
Dec	154,948,500

Table 2: Average wind speed values (m/s)

	Daniel's Harbour	Bonavista	Burgeo	St. John's	Mean Value
January	7.5	10	7.6	7.8	8.2
February	6.7	9.4	7.3	7.5	7.7
March	6.4	8.6	7.1	7.2	7.3
April	6.1	7.8	6.9	6.7	6.9
May	5.8	6.9	5.4	6.1	6.1
June	6.1	6.9	4.9	6.1	6.0
July	6.1	6.7	4.4	5.8	5.8
August	6.1	6.9	4.5	5.8	5.8
September	6.7	7.8	4.9	5.8	6.3
October	6.9	8.9	5.9	6.4	7.0
November	7.5	9.4	7.1	6.9	7.7
December	7.5	10	7.5	7.5	8.1

Table 3: Flow data (m^3/s)

	Rocky River	Sheffield Brook	White Bear	Torrent River	Loyd's River	Normalized Average Monthly Flow
Jan	26.51	13.5	60.98	6.85	19.22	1.0113
Feb	28.31	7.19	71.12	7.01	30.98	1.0882
Mar	17.12	16.31	28.39	6.79	12.4	0.7252
Apr	16.39	31.97	48.86	14.79	26.1	1.1962
May	10.93	11.19	52.28	71.41	68.48	1.6818
June	5.61	8.97	25.23	33.14	15.77	0.7194
July	4.03	Not Available	16.97	20.72	8.74	0.4723
Aug	22.14	8.67	25.56	15.32	19.85	0.8055

Sept	2.81	6.36	31.32	27.03	19.02	0.6481
Oct	7.34	13.92	19.79	18.6	11.39	0.6228
Nov	19.66	9.87	54.58	26.41	37.72	1.1578
Dec	17.5	12.37	32.82	9.47	20.24	0.7812

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