KERR WOOD LEIDAL
consulting engineers

Vancouver Island
201 - 3045 Douglas Street
Victoria, BC V8T 4N2
T 250 595 4223
F 250 595 4224

Technical Memorandum

DATE: July 17, 2008

TO: James Craig, BCCF

CC: Craig Wightman, BCCF

FROM: Craig Sutherland. P.Eng.

RE: **BC CONSERVATION FOUNDATION**
Englishman River Water Balance – Preliminary Regional Hydrologic Assessment
Our File 0673.010

1. Background

The Englishman River is an important salmon-producing stream on the east coast of Vancouver Island. The watershed has all species of salmon, including steelhead and is designated as a sensitive stream by the BC government under the Fish Protection Act. However, the fish stocks on the river have generally been in-decline since the mid-1980s. A Recovery Plan for the river was prepared by LGL Ltd. in 2001. This study outlined the existing (2001) baseline conditions of stream habitat and fish health, identified the key factors influencing recovery of the stream and developed goals and objectives for recovery.

The LGL study identified that one of the factors influencing recovery is low river discharges during the dry summer months. It is necessary to provide short term maintenance flow of 1.44 m^3/s or 10% of mean annual discharge (MAD) in order to sustain healthy stream habitat during the dry summer period. Currently, the provisional operational rule for the Arrowsmith Lake Dam, operated by the Arrowsmith Water Service (AWS) requires that sufficient flow be released from the dam to maintain 1.6 m^3/s in the river. This flow is slightly higher than the minimum short-term maintenance flow in order to account for municipal water demand at the point of diversion, downstream of Highway 19a. However, during the past seven years the minimum 1.6 m^3/s has not been sustained for the entire summer low-flow period. For the period of available records during operation of the AWS reservoir (2000 to 2006), the flow in the river fell below the 1.6 m^3/s threshold for 47 days on average and below the 1.44 m^3/s threshold 33 days on average (see Table 1). The lowest recorded flow during the period is 0.67 m^3/s in 2000.

These shortfalls may be due to constraints of the existing rule curve, which require outflow from the reservoir to equal inflows up to the beginning of June. However, other factors such as changes in land-use, increased water demand and changes in climate may also be influencing the water available during the low-flow season.

A hydrological assessment of the Englishman River is currently underway was as part of the Englishman River Water Intake Study for the Arrowsmith Water Service (AWS) in 2010 (KWL & AE, 2010). This assessment is reviewing the storage capacity of Arrowsmith Lake to support both current and future water supply demand and conservation flows. The assessment will review if minimum conservation flows could be maintained at current levels along the full length of the river with consideration that the proposed municipal water supply intake was moved upstream of the current location.

The preliminary results of the AWS study indicate that:

1. the existing Arrowsmith Lake Dam has sufficient storage capacity and adequate minimum discharge outlet capacity to maintain a minimum flow of 1.2 m^3/s downstream of the proposed water supply intake location under current 1:10-year drought conditions and municipal water demand conditions;
2. Arrowsmith Lake has sufficient storage to maintain minimum flow of 1.2 m^3/s under future 2050s climate and municipal water demand conditions but that the outlet structure does not have sufficient capacity to maintain this flow when water levels in the reservoir drop below El. 881.5 m, which is equivalent to about 27% of full storage in the reservoir;
3. both the storage and outlet capacity at Arrowsmith Lake are not sufficient to maintain current minimum flows of 1.6 m^3/s recommended in the provisional operating rules under both current and future climate and demand conditions;
3. increasing storage at the Arrowsmith Lake Reservoir would not increase the storage deficit due to the limited inflow to the reservoir from the relatively small watershed area above the lake of 5 km^2 or 1.5% of the total Englishman River watershed area.

Table 1: Recorded Flows for Englishman River at WSC Gauge (08HB002)

	Recorded Daily Flows		Number of Days	
Year	Mean Annual Flow (m^3/s)	Minimum Flow (m^3/s)	Less than 1.6 m^3/s	Less than 1.2 m^3/s
2000	8.98	0.67	28	20
2001	9.41	1.12	40	3
2002	12.64	0.97	68	30
2003	15.86	1.02	74	38
2004	10.6	1.15	21	3
2005	12.54	1.22	27	0
2006	17.22	0.74	74	44
2007	14.86	1.56	5	0

2. Design Concept

As an alternative to storage at Arrowsmith Lake, a potential option that could be used to improve water supply during the low-flow season is to construct low head (1 m to 2 m high) weirs at the outlet of other headwater lakes in the watershed. Water could be stored in the lakes and then could be released during the low-flow period. They could be operated in a similar manner to the existing Arrowsmith Lake dam but could be significantly smaller.

Two lakes that have been identified as having potential as upland storage sites include Shelton Lake, and Healy Lake in the headwaters of the South Englishman River (see Figure 1). The lake surface areas are 28.9 ha and 38.2 ha for Healy Lake and Shelton Lake, respectively. Although further habitat assessment work would have to be completed to determine the maximum allowable storage in the lakes, we assumed that one metre top storage would be allowable. This would provide a total storage volume of approximately 671,000 m^3.

3. Hydrological Assessment

A preliminary hydrological assessment of the South Englishman Watershed was completed as part of this study. The South Englishman River has a total watershed area of approximately 100 km^2 at the mouth. Centre Creek flows into the South Englishman River about 300 m upstream of the South Englishman River confluence with the Englishman River mainstem. As Centre Creek flows contribute to such a short section of South Englishman, the hydrological assessment focuses on that part of the South Englishman River upstream of the confluence with Centre Creek.

As there were no discharge records available for the South Englishman River at the time of this study, the hydrological assessment was completed based on a regional assessment using the mean annual runoff mapping developed for the British Columbia Streamflow Inventory (Coulson and Obedkof, 1998) and regional runoff curves developed as part of the Streamflow in the Lower Mainland and Vancouver Island study (Obedkoff, 2003).

3.1 Mean Annual Discharge Estimate

An estimate of the mean annual discharge for the South Englishman River upstream of Centre Creek was performed using the hydrological GIS tool in the Rapid Hydropower Assessment Model (RHAM) (KWL, 2007). This GIS tool allows estimation of mean annual discharge at any point by combining a topographic Digital Elevation Model with the annual runoff mapping (Coulson and Obedkof, 1998). The DEM is used to determine the accumulated area upstream of the point of interest on the river channel. This area is then multiplied by the values from the mean annual runoff isolines to estimate the mean annual discharge, such that:

Area Accumulation x Mean Annual Runoff Depth (MAR) = Mean Annual Discharge (MAD)

The mean annual flow estimated using the RHAM model are shown in Table 2.

Table 2: MAD and MAR estimates from RHAM model

Watershed	Area (sq. km)	Median Elevation (m)	MAR_1 (mm)	MAD_2 (m^3/s)
South Englishman River upstream of Centre Creek	78	480	1100	2.72
Healy Lake at Outlet (includes Shelton Lake catchment area)	11.6	737	1590	0.586
Arrowsmith Lake	5.4	1125	1900	0.324
Englishman River (Recorded)	324	571	1400	14.4

Notes:
1 – Mean Annual Runoff (MAR) is equal to the mean annual discharge divided by the watershed area.
2 – Mean Annual Discharge (MAD) is the long term average of daily discharges

To check the values estimated by RHAM, they have been compared with the regional runoff curves prepared in Obedkof (2003). As shown in Figure 2, the estimated values fall within the range of values estimated for the east coast of Vancouver Island.

It is also interesting to note that RHAM estimates a value of 0.32 m^3/s for the MAD at Arrowsmith Lake. This compares well with the average recorded value of 0.34 m^3/s (Approximately 6% difference) (Based on daily flow records from 1991 to 1997) and is similar to a comparisons made between the RHAM and gauged watersheds across BC during development of the RHAM model.

3.2 Monthly Average and Drought Flows

In order to estimate the storage volume required to maintain minimum monthly flows through the summer, monthly average and drought flows are required. The percentage monthly flows (ie: percentage of the total annual flow volume for each month) recorded for the Englishman River (Water Survey of Canada Gauge 08HB002) were used to estimate the monthly flows for the South Englishman River above Centre Creek.

The recorded flows for the Englishman River have also been used to estimate the 5-year low flow and 10-year low flow for the summer period. Low-flow frequency analysis was carried out using 34 years of the monthly average flows for April to November period. Separate 5-year and 10-year flow estimates were calculated for each month and a ratio of the low-flow estimate to the mean flow was calculated. These ratios were then used to estimate the 5-year and 10-year monthly low flows for the South Englishman River above Centre Creek. The results of the analysis are shown in Table 3.

Table 3: Monthly low-flow discharge estimates based on Englishman River (WSC 08HB002)

Month	Englishman R. (MAD = 14.4 m^3/s)			Monthly Low-flow to MAD Ratio		South Englishman R. Above Centre Creek (MAD = 2.72 m^3/s)		
	Monthly Median[1]	5-Year Low	10-year low	5-Year Low	10-year low	Monthly Avg.	5-Year Low	10-year low
April	13.34	9.72	7.68	0.68	0.53	2.52	1.84	1.45
May	10.82	6.54	5.44	0.45	0.38	2.04	1.24	1.03
June	6.57	3.27	2.54	0.23	0.18	1.24	0.62	0.48
July	2.80	1.08	0.81	0.08	0.06	0.53	0.20	0.15
August	0.85	0.45	0.37	0.03	0.03	0.16	0.09	0.07
September	1.13	0.45	0.32	0.022	0.06	0.21	0.09	0.06
October	8.97	1.38	1.05	0.10	0.07	1.69	0.26	0.20
November	24.91	9.43	6.38	0.65	0.44	4.70	1.78	1.21

Note: 1 – Monthly median based on Englishman River flow records (WSC 08HB002) up to 1999, prior to summer flow augmentation from the AWS Reservoir.

3.3 Storage Assessment

A monthly water budget was completed for the South Englishman River above Centre Creek. This assessment was used to estimate the total volume required for storage within the South Englishman River above Centre Creek catchment by calculating the flow deficit volume using the estimated monthly low-flow values, the evaporation from the lake surfaces and the minimum short-term maintenance flow (either 5% or 10% of MAD). An example of the calculation for the 10-year low flow condition is shown in Table 4.

The total storage required to maintain minimum flows of 5% MAD and 10 % MAD for the 5-year low-flow and 10-year low-flow conditions are shown in Table 5. The table shows both the volume and the depth of storage required on Healy Lake and Shelton Lake to maintain the minimum flows 4 years out of 5 on average (5-year low flow condition) or 9 years out of 10 on average (10-year low flow condition).

Table 4: Monthly Water Budget for South Englishman River above Centre Creek for 10-year low flow condition

Month	Natural Flow (m^3/s)	Evaporation[1] (m^3/s)	Required Flow (10% MAD) (m^3/s)	Flow Deficit	Storage Deficit (1,000 m^3)	Cumulative Storage (1,000 m^3)
April	1.45	0.015	0.272	1.16		
May	1.03	0.023	0.272	0.73		
June	0.48	0.028	0.272	0.18		
July	0.15	0.032	0.272	-0.15	405	405
August	0.07	0.026	0.272	-0.23	610	1015
September	0.06	0.017	0.272	-0.23	597	1611
October	0.20	0.008	0.272	-0.08	218	1830
November	1.21	0.003	0.272	0.93		
Note: 1 – Evaporation based on adjusted monthly pan evaporation data from Saanichton CDA.						

Table 5: Approximate Volumes and Depth of Storage for minimum flow in South Englishman River

MAD	Mean Flow Condition		5-year Low Flow Condition		10-year Low Flow Condition	
	Volume (1,000 m^3)	Depth[1] (m)	Volume (1,000 m^3)	Depth[1] (m)	Volume (1,000 m^3)	Depth[1] (m)
5% (0.136 m^3/s)	-	-	382	0.6	490	0.7
10% (0.272 m^3/s)	564	0.9	1,419	2.1	1,830	2.7

Note: Depth of storage required on Healy Lake and Shelton Lake to provide required storage volume

4. Summary of Results

The results of the preliminary hydrological assessment indicate that:

1. The storage available at Healy and Shelton Lakes would likely be large enough to sustain minimum summer flow on the South Englishman River above Centre Creek of 10% MAD (0.272 m^3/s) up to the 10-year low flow condition. However, it would require construction of top storage up to 2.7 m deep on both lakes.
2. Sustaining a minimum summer flow of 5% MAD (0.136 m^3/s) on the South Englishman for the 5-year to 10-year drought would require between 0.6 to 0.7 m of top storage on both Healy and Shelton Lakes. Considering construction of top storage at only one of the lakes to sustain 5% MAD during the summer period would require approximately 1.3 m of top storage on Healy Lake or 1.0 m of top storage on Shelton Lake.
3. It appears that Shelton Lake and Healy Lake may be able to provide sufficient storage to maintain minimum flows in the South Englishman. However, due to the lack of continuous flow data for the South Englishman River this assessment has been based on regional hydrological trends. Collecting streamflow data, especially during the critical low flow period, would allow for more detailed assessment of the storage potential at Healy and Shelton Lakes.
4. In addition to confirming the storage potential at the lakes by collecting streamflow data, further field assessment should be carried out to determine the impacts of increasing storage at the lake to aquatic and riparian habitat, as well as to assess engineering feasibility of constructing weirs at the outlets of the lakes.
5. Records indicate that discharge in the Englishman River has fallen below the required water supply flows (1.6 m^3/s at the WSC gauge) every year since construction of the AWS reservoir. A review of the operating procedures and licensed rule curves of the AWS reservoir should also be completed to determine if an alternate management strategy could be developed in order to achieve the preferred minimum flows in the Englishman River.

5. Recommendations

Based on the findings of the preliminary hydrological assessment, we recommend that:

1.) Continuous daily streamflow data is collected during the critical low-flow period (June to October) on the South Englishman River above Centre Creek;

2.) Assessment of the riparian and aquatic habitat is carried out to assess the impacts of adding up to 2.7 m of top storage to the lakes;

3.) A preliminary engineering investigation of construction of the weirs at the outlet of Shelton and Healy Lakes is carried out to assess field conditions, determine potential weir construction methodology and prepare preliminary concept cost estimates for construction; and

4.) Review the operating procedures at the AWS reservoir to determine if alternate operating rules could be used to help achieve the minimum preferred flows in the Englishman River.

6. Closing

If you have any questions or concerns regarding this assessment, please contact the undersigned at (250) 595-4223.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Reviewed by:

PROFESSIONAL
PROVINCE OF
C. E. SUTHERLAND
29725
BRITISH COLUMBIA
ENGINEER

July 18 2008

Craig Sutherland, P.Eng.
Water Resources Engineer

Wendy Yao, P.Eng
Technical Review

CS/

Encl.

References

Coulson, C.H. and Obedkoff, W. British Columbia Streamflow Inventory. Report prepared for Province of British Columbia, Ministry of Environment, Lands and Parks, March 1998.

Obedkoff, W. Streamflow in the Lower Mainland and Vancouver Island. Report prepared for Province of British Columbia, Ministry of Sustainable Resource Management, April 2003.

Kerr Wood Leidal (KWL). Run of River Hydro-electric Assessment for British Columbia. Report prepared for BC Hydro, November 2007

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Revision History

Revision #	Date	Status	Revision	Author
0	July 17, 2008		FINAL	CS

BC CONSERVATION
FOUNDATION
ENGLISHMAN RIVER
WATER BALANCE

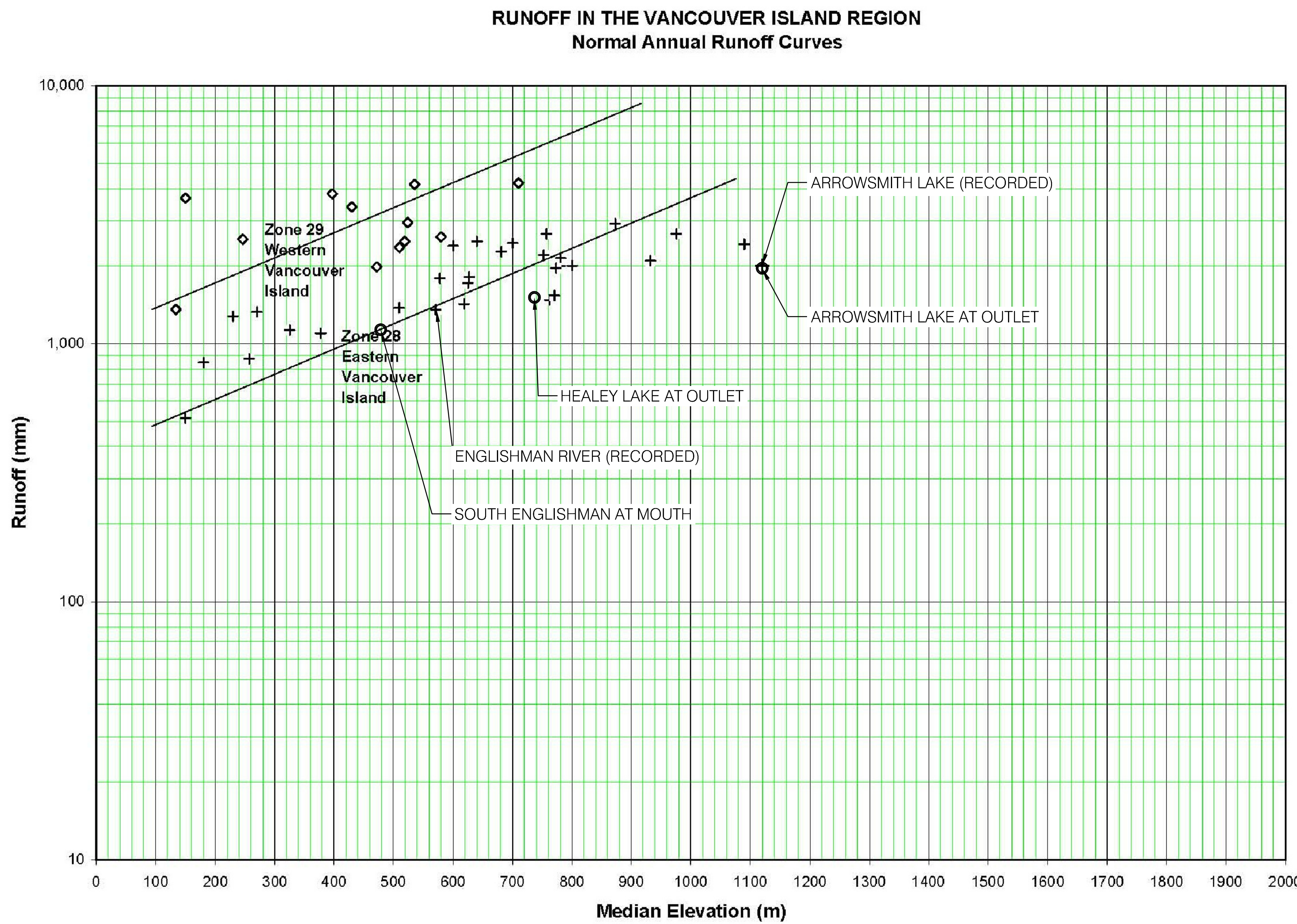
KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

5000 0 5000
Scale in Metres 1:200,000

Project No.	Date
673.005	MAY 2008

LOCATION PLAN

FIGURE 1



BC CONSERVATION FOUNDATION
ENGLISHMAN RIVER WATER BALANCE

LEGEND

- ◇ WESTERN VANCOUVER ISLAND GUAGES (MEASURED)
- + EASTERN VANCOUVER ISLAND GUAGES (MEASURED)
- o RHAM MODEL (ESTIMATES)

KERR WOOD LEIDAL associates limited CONSULTING ENGINEERS

Project No.	Date
673.005	MAY 2008

REGIONAL RUNOFF ENVELOPE CURVES

FIGURE 2