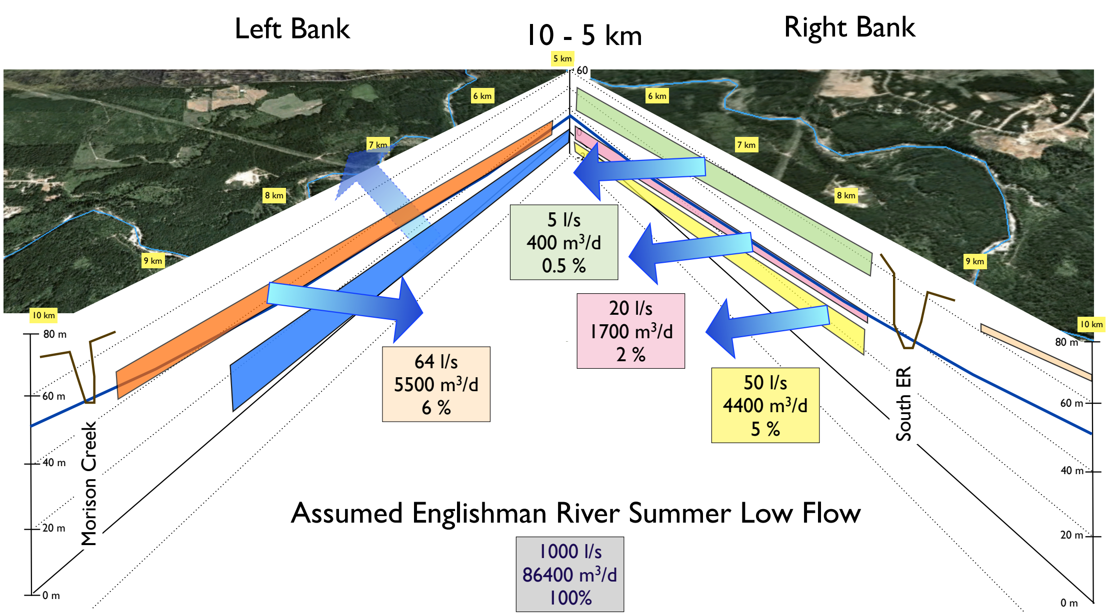
LOWER ENGLISHMAN RIVER WATERSHED GROUNDWATER AND SURFACE WATER INTERACTION



For:
Mid Vancouver Island Habitat Enhancement Society
Parksville, BC

By:

GW Solutions Inc.

February, 2012
09-04

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1 Introduction

This report describes a community-based program that was completed to characterize and to understand the interaction between groundwater and surface water moving in the Englishman River (ER) Watershed.

A report titled *Englishman River (Background Information)* has been issued in August 2009 and a progress report was issued in April 2010. They have provided a summary of the background information available on the Englishman River watershed (2009), and preliminary results (2010).

Characterizing aquifers is a complex and costly exercise because you need wells in order to reach aquifers and to monitor the depth and fluctuation of the level of the water table. The cost of drilling a well is typically between $5,000 and $10,000, and several wells per aquifer are needed to get the required information to define the movement of groundwater in an aquifer. Then you need to install monitoring equipment, to collect the data, and to store and process it. The final cost is in the hundreds of thousand of dollars if you want to do a proper assessment over a watershed containing several aquifers.

The approach that we took was to involve the community. For two reasons:

1. We would save the large cost of having to install new wells by using existing wells that owners would volunteer for monitoring, and

2. We believe that the long-term health of watersheds depends upon the stewardship of the people who live in the watersheds. By getting them involved in its study, the community connects to its watershed, its complexity and how it works. The people will then be able to more willingly modify their behaviour and management of the land, after they appreciate the direct connection between what happens at surface and what happen in the subsurface, on their property, the property of their neighbours and their local environment.

2 Objectives

The BC Ministry of Environment (BC MOE) operates a web based map site, the BC Water Atlas, where information on aquifers is available. However, the information is very limited. It provides information about the footprints of aquifers, their type, vulnerability, etc. It does not provide information on the depth, the thickness of the aquifer, or how the groundwater moves in the aquifers. So when we started the study, very little was known about the flux of groundwater near the Englishman River and the role played by the aquifers in supplying water to the river, in particular during its periods of low flows.

So one of the main objectives of the study was to update the knowledge about the aquifers along the ER, and to characterize the dynamic, the flux of groundwater between the aquifers and the river.

We also wanted to create images that illustrate the dynamic between the aquifers and the river, and the connection between the land and its recharge areas, the groundwater movement and the groundwater fluxes to the river. We have achieved these objectives and the results are presented in section 4.

We have studied the lower part of the watershed, between its estuary and the ER falls (north of the yellow line in Figure 1) because we focused on the groundwater movement in the sand and gravel aquifers, and this is where they are present. This is also the area where aquifers sustain extremely valuable salmon habitat. The most upstream boundary of the study area is the ER falls, which represent a barrier to fish migration in this river. In this report, the distance to locations along the river refers to the distance from the foreshore (e.g., the ER falls are located at 16.5 km).

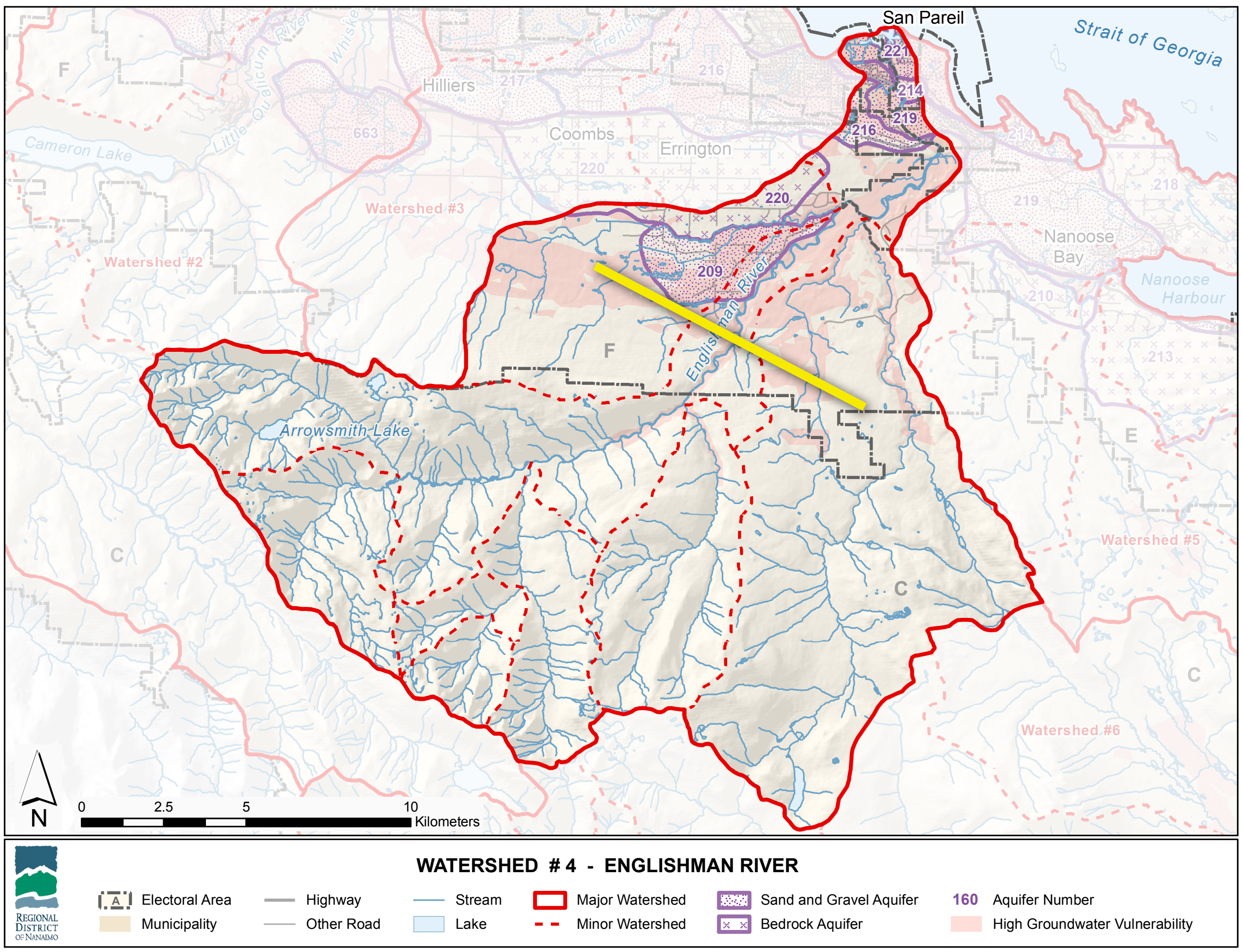

Figure 1: Englishman River Watershed (source RDN website)

3 Completed Work

The work was designed to collect information on the presence and behaviour of aquifers in the ER watershed, to define aquifers, to assess the elevation of the water table in the aquifers, to estimate the groundwater regime (groundwater flow path), to estimate the groundwater flux discharging into the ER and to define the interconnection between the aquifers and the ER in the lower 16.5 km of its reach.

Well Monitoring

The completed work has been community-based; well owners were invited to offer their wells for monitoring of the fluctuation of the water table. The following was completed:

Figure 2: Well owners near drilled well

- A total of 33 shallow dug wells were manually monitored;
- A total of 19 drilled wells were monitored; electronic data loggers were installed in 17 wells (8 of them being inactive) and data started being collected on August 17, 2009. The data gathering is on-going;

In addition, data from 5 monitoring wells operated by the BC Ministry of Environment and 2 production wells operated by the RDN were used. The locations of all monitored locations are shown in Figure 3.

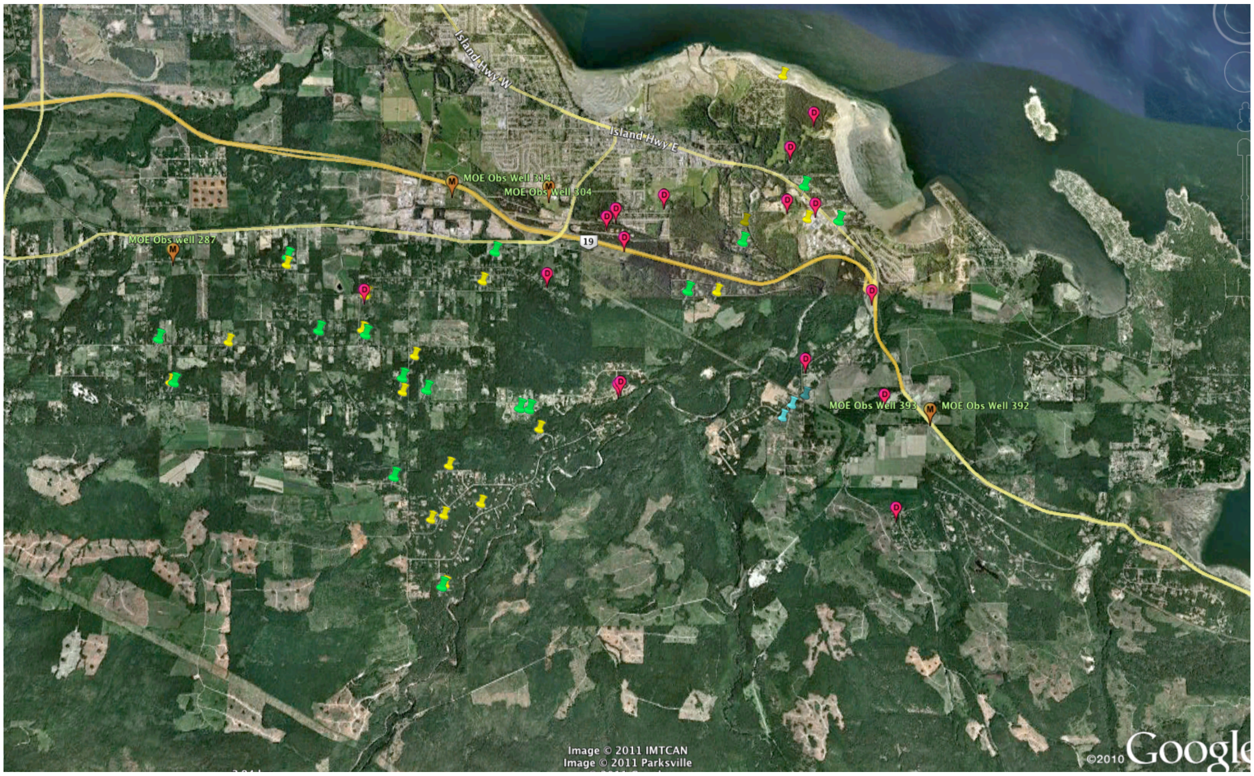

Figure 3: Dug (yellow) and drilled (green, blue and orange) wells used for data collection

Definition of the lithology

Cross sections were drawn on both sides of the ER, and also across the ER to keep defining the lithology of the subsurface, identifying permeable (aquifers) and non-permeable (aquitards) soil layers. The location of the most recently drawn cross section is shown in Figure 4. The definition of the lithology was one of the key pillars of this project and has been an on-going task, as shown by cross sections produced over time (2009 and 2010 GW Solutions reports).

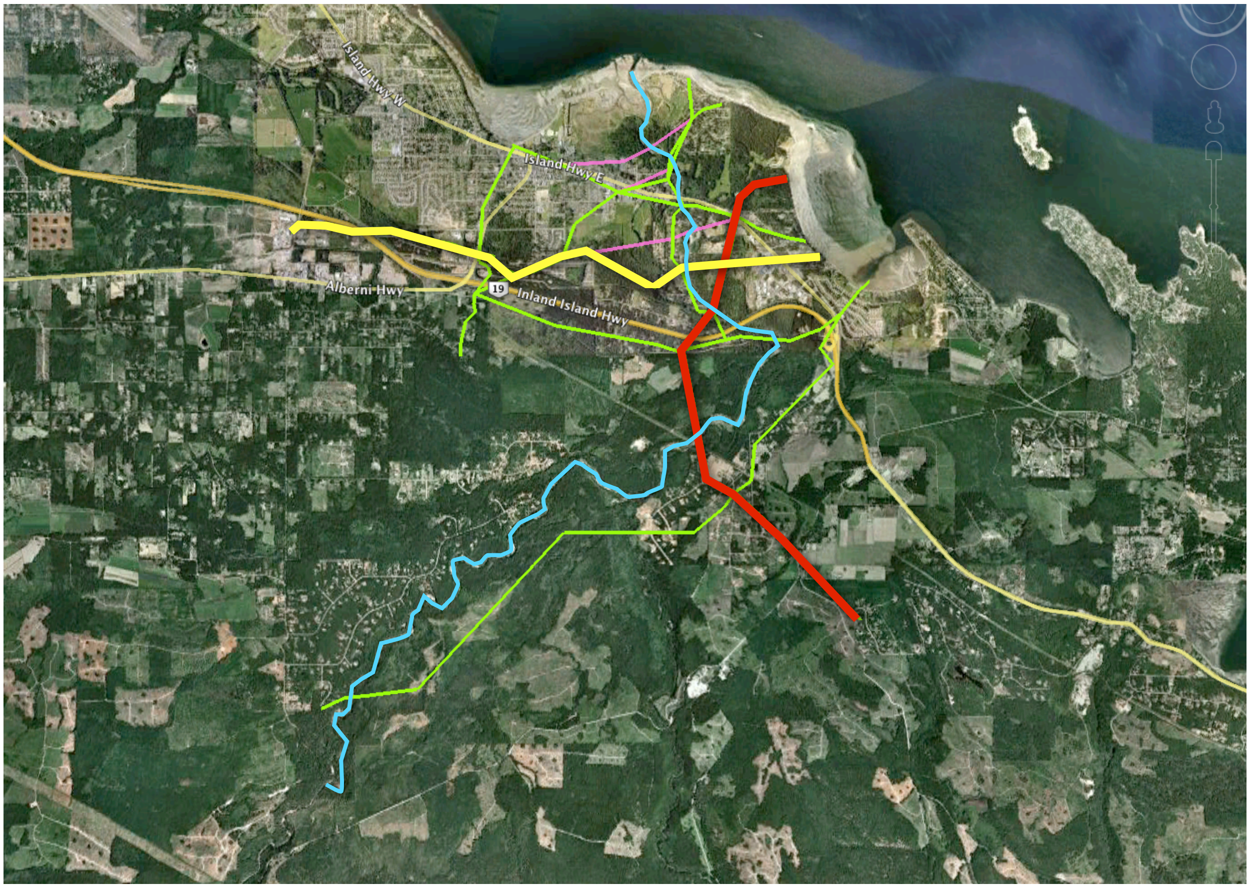

Figure 4: Location of cross sections

The cross sections were produced to summarize a simplified illustration of hydrogeological information, focusing on:

- The topography of the ground;
- The topography of the bedrock;
- The depth and thickness of aquifers;
- The depth and thickness of aquitards;
- The piezometric levels (elevation of the water table(s)); and
- The elevation of the ER.

The cross sections shown with yellow and red lines in Figure 4 are illustrated in Figures 5 and 6.

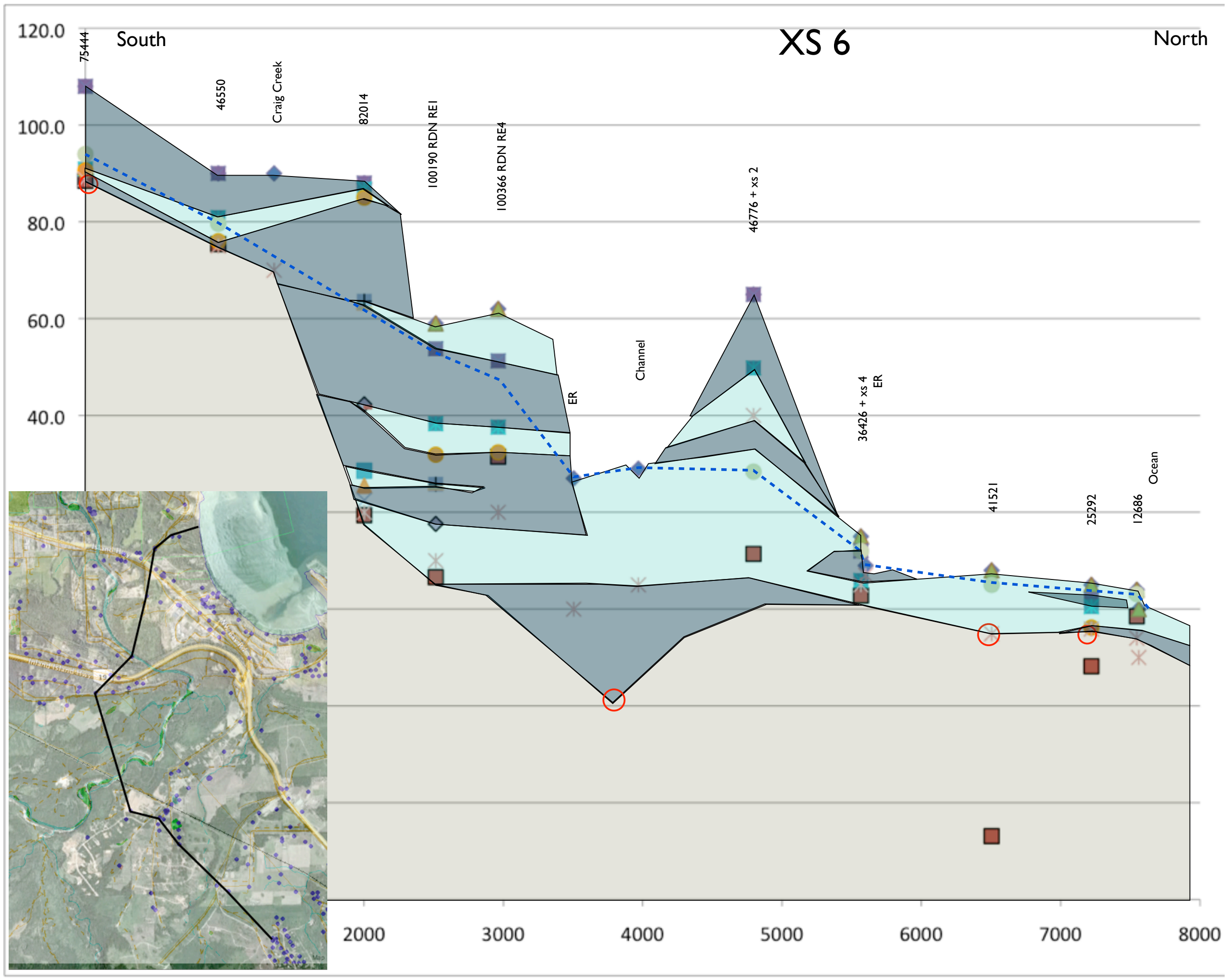

Figure 5: North south cross section (bedrock in light grey, aquifers in light blue, aquitards in grey, water table shown with dotted blue lines)

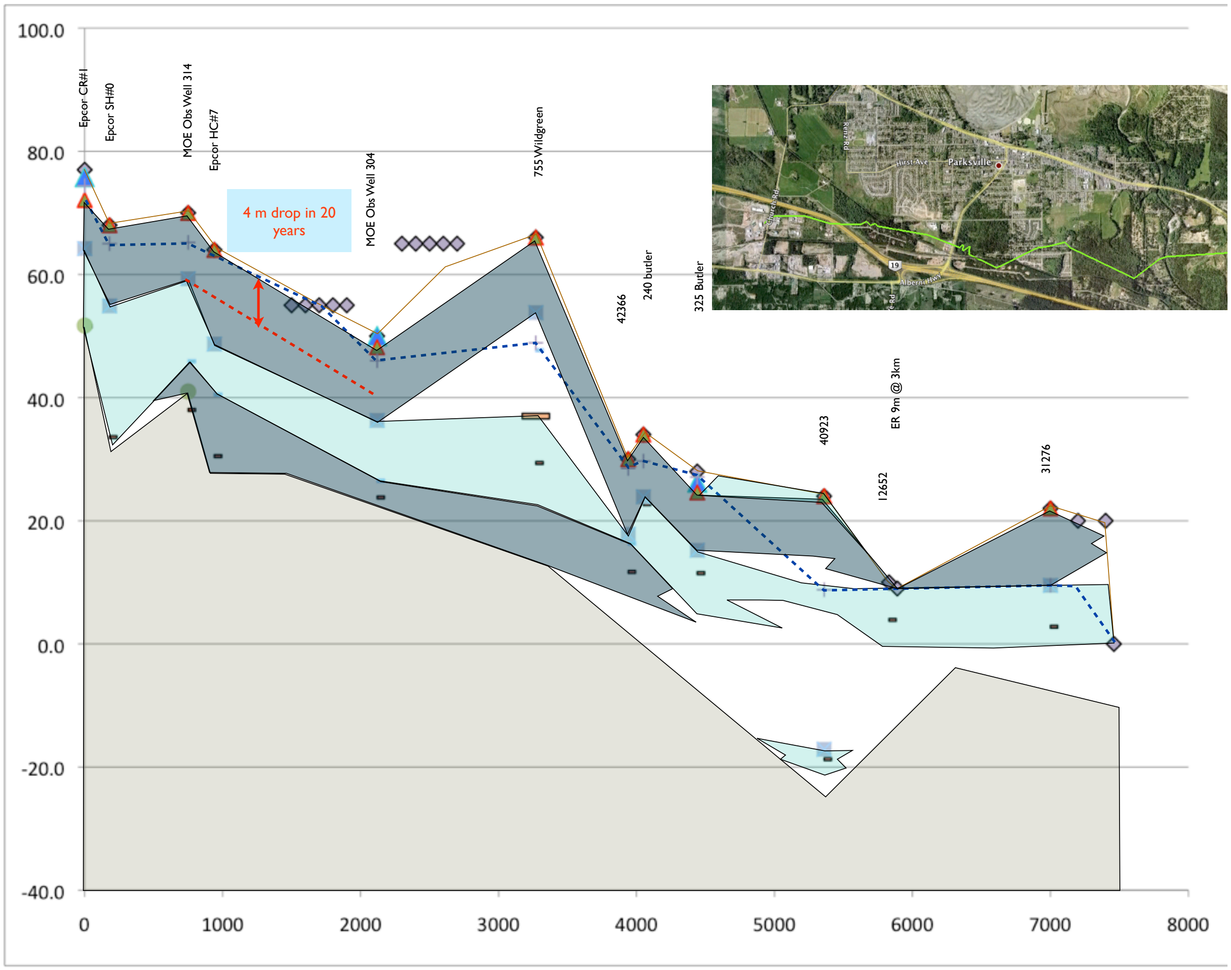

Figure 6: East west cross section

ER Water Quality Monitoring

Temperature, pH, electrical conductivity and total dissolved solids of the ER were monitored by groups of volunteers during nine monitoring events at up to 20 locations between August 2009 and September 2011. The monitored locations are shown in Figure 7.

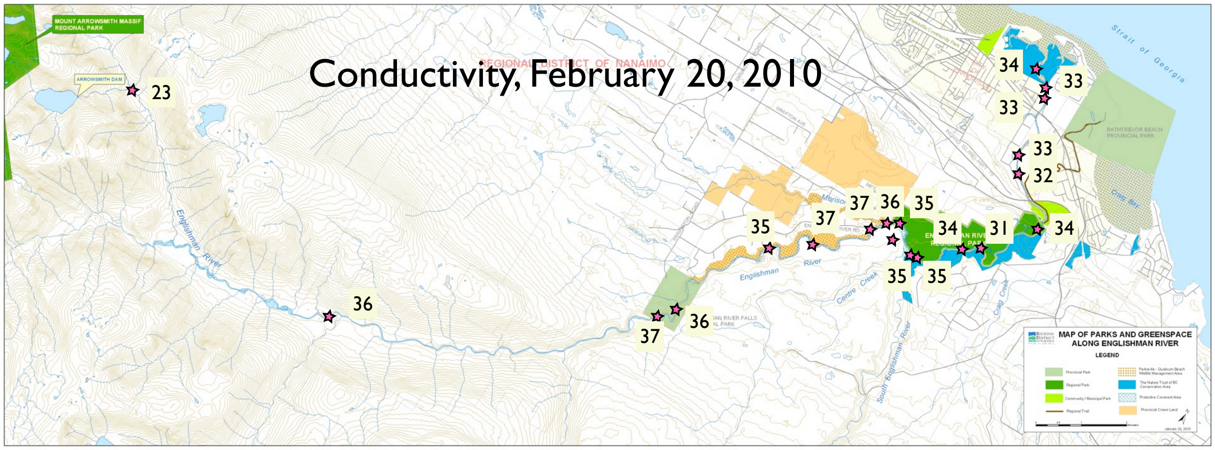

Figure 7 : Locations where surface water parameters were measured by volunteers

Survey

In February and in September 2011, GW Solutions used surveying equipment to measure the water elevation in ponds, streams, and where groundwater daylights, in order to add locations defining the high and low elevations of the water table. In this region, the water tables reach the highest level in mid winter and their lowest level in the fall.

Figure 8: Surveying being conducted in September 2011

Bank inspection

Dr. Gilles Wendling and Arnd Burgert from GW Solutions both kayaked the Englishman River starting at the Englishman River Falls (16.5 km). It happened on September 15, 2011, three weeks after the last rain and with the river flowing at a rate of approximately 2 m^3/s. The objectives were the following;

- to observe the lithology of the river banks;
- to observe the river bed;
- to note any seepage along the banks;
- to measure the temperature, pH, electrical conductivity, and total dissolved solids of the river water and springs at regular intervals; and
- to take photographs illustrating the findings.

Figure 9: ER at 14.5 km during September 15, 2011 bank inspection

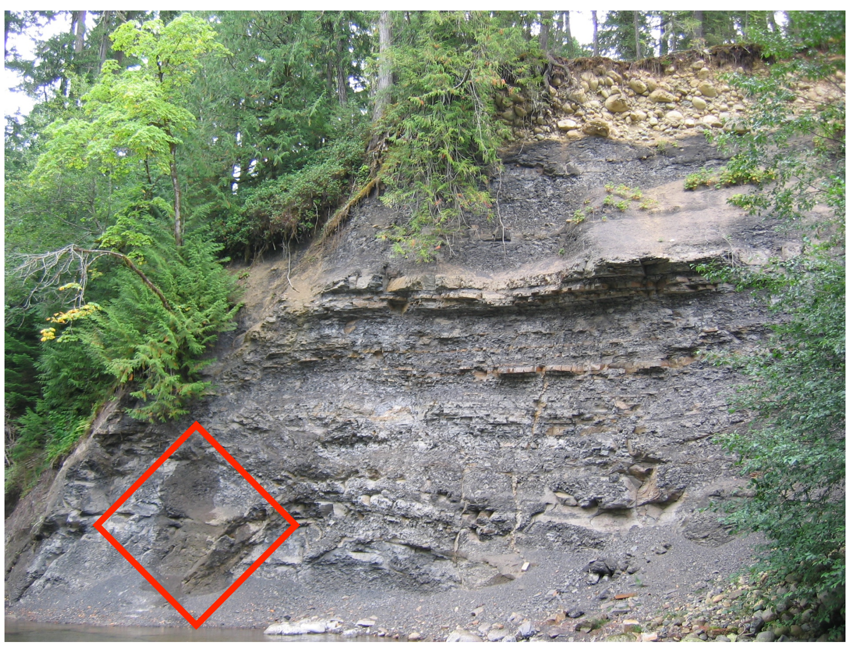

Figure 10: Seepage on bedrock face (right bank, 15.9 km)

ER Water levels and flows

The elevation profile of the ER was drawn for its lower 20 km, based on information provided by Island Timberlands. The data describing the amplitude of the fluctuation of the water level of the ER were compiled at two locations (at the Water Survey of Canada station 08HB002 and at the intersection of the South ER and the ER). This information was used to assess the hydraulic gradient between the ER and the aquifers in contact with the ER.

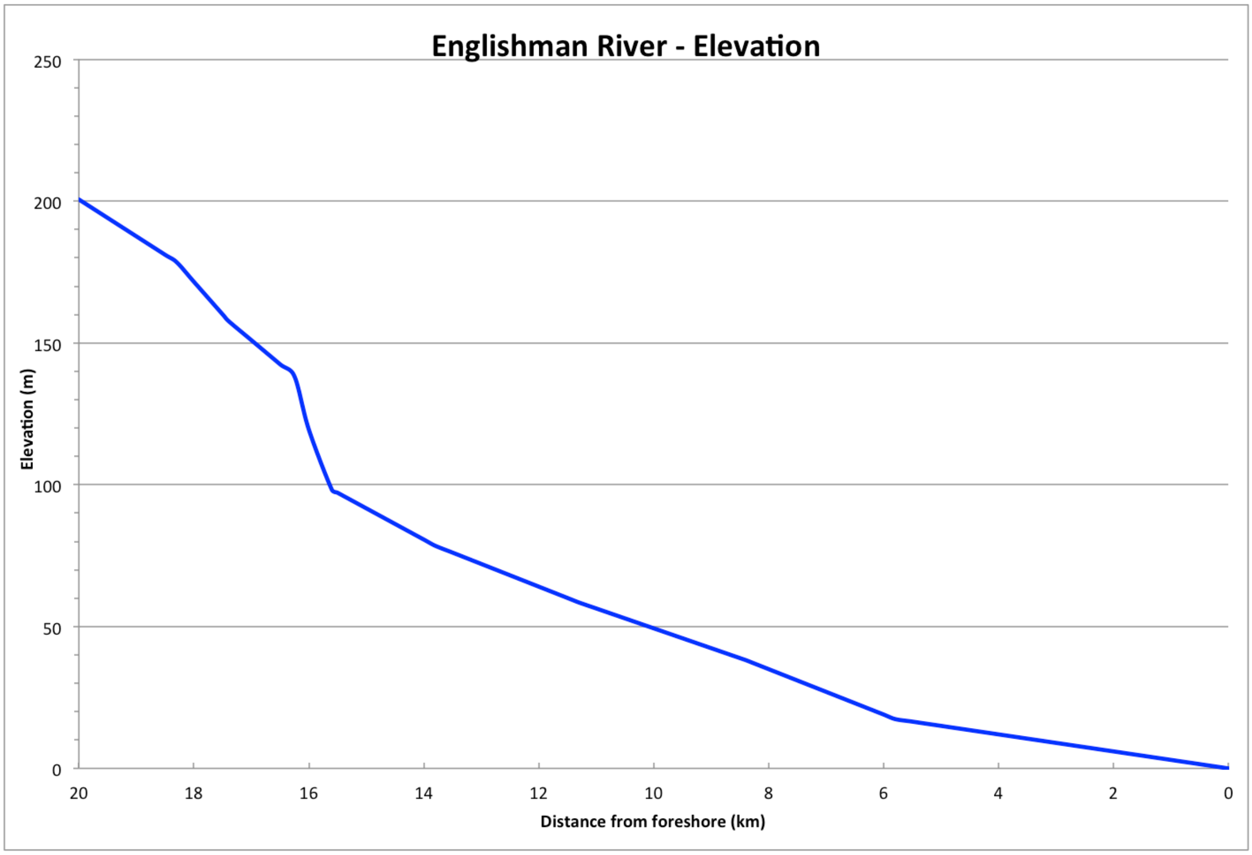

Figure 11: Profile of lowest 20 km of ER main stem

4 Results

Aquifer Delineation

Through the review of numerous well logs, the drafting of cross sections, field observations, and inspection of the river banks, GW solutions has produced a map showing the estimated footprint of the aquifers in contact with the ER (Figure 12).

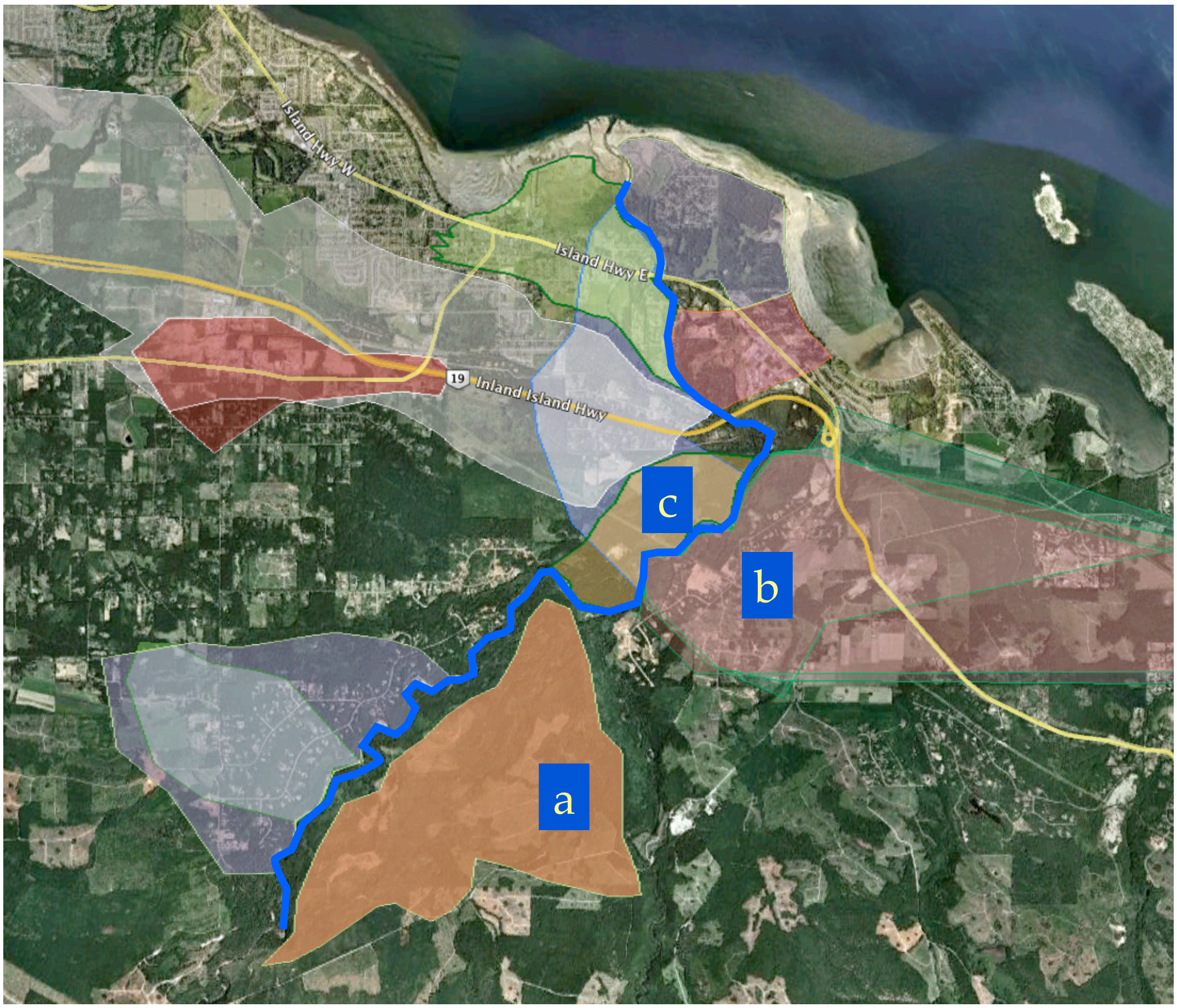

Figure 12: Estimated footprints of overburden aquifers in contact with the ER

In particular we have identified and mapped aquifers that had not been identified in the past. Along the right bank of the river, between 16 km and 10 km, we have a shallow sand and gravel aquifer (a). We have a series of 3-sandwiched aquifers in contact with the main stem of the Englishman River, between its confluence with the South Englishman river near 9 km and the river bend at 5 km (b). We also have a shallow aquifer located along the left bank, at the location of the ER Regional Park and farm land (c), and this aquifer plays an important role in providing groundwater to the river and sustaining fish habitat.

Piezometer (Water Table) Levels

Piezometric levels were monitored in all the wells, either manually (shallow dug wells), using data loggers, or both (for calibration purposes). Figure 13 illustrates the results obtained with the data loggers. This graph is built using water levels measured at 4:00 am, in order to present the situation of the aquifers at rest, assuming that wells have fully recovered after pumping, for the locations where the wells are in use. Precipitation events are also graphed so we can relate the observed fluctuations of the water table to potential recharge due to rain.

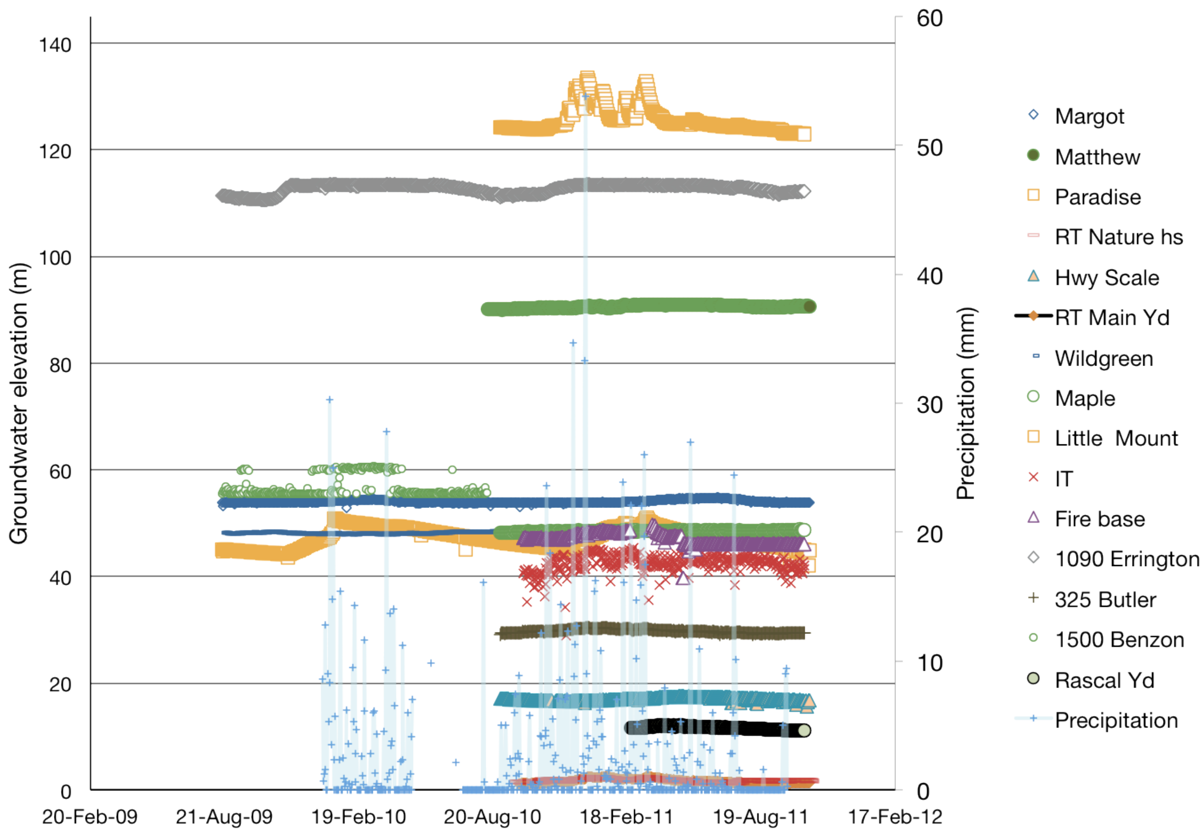

Figure 13: Piezometric levels recorded by data loggers

The data loggers and the manual monitoring of the shallow wells provided information on the highest and lowest levels of the water table measured in the aquifers. The results are presented in Figure 14, for the locations with data loggers. The difference in amplitude between the highest and lowest water level measured at a specific location ranges between 0.5 m and 10 m.

It was important for us to characterize the flux under both high and low water table conditions, particularly to assess if there were sections of the ER where there was a reversal of the flux between the river and the aquifers due to the seasonal fluctuation of the water table. And generally it does not happen. The aquifers keep providing groundwater to the river, all year long.

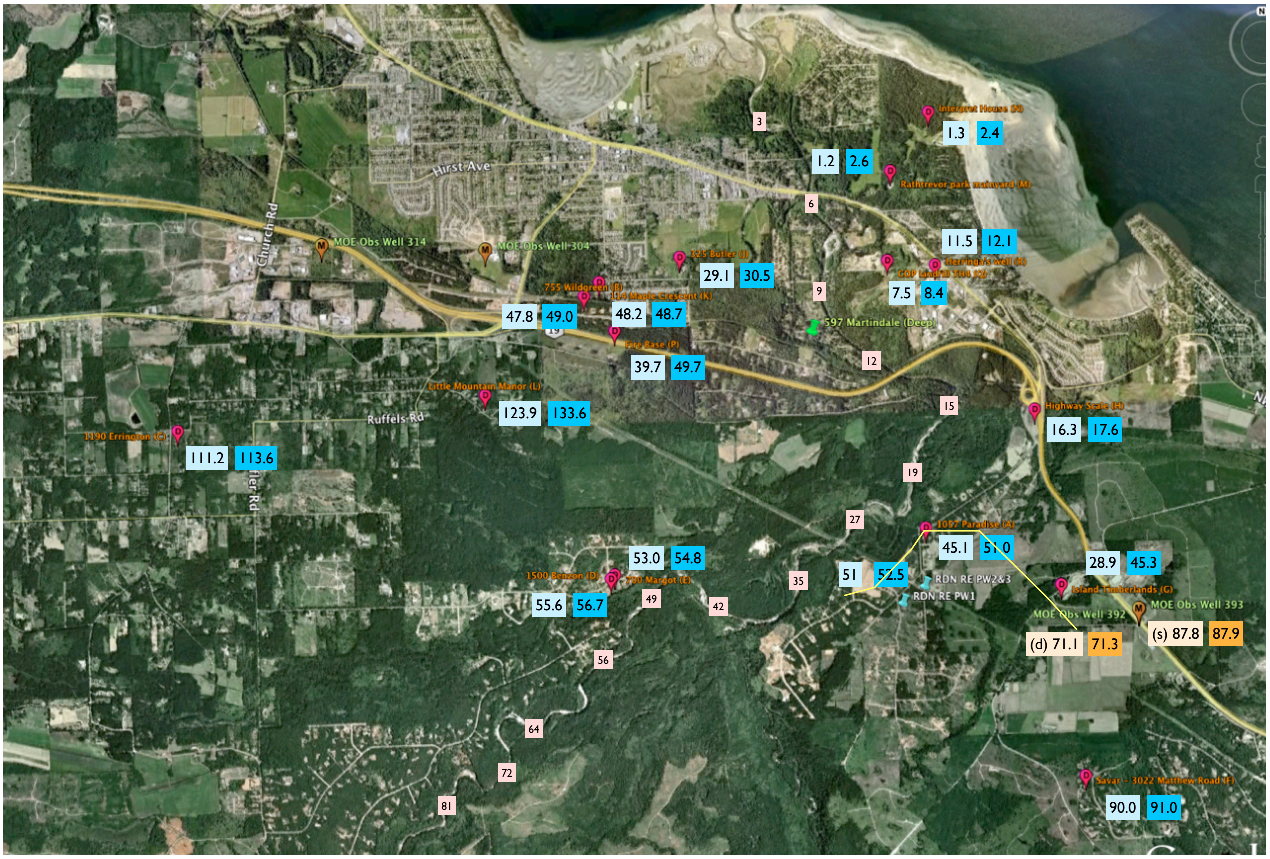

Figure 14: High and low water levels recorded by data loggers in 2010-2011

For areas lacking wells, the piezometric contouring was complemented by groundwater elevation data collected through surveying of streams and ponds where we knew that shallow unconfined aquifers were present. Figure 15 illustrates such an area (yellow rectangle in Figure 15) with the locations where survey was completed (dots and elevation values), the inferred piezometric contours (blue lines) and groundwater travel path (purple arrows).

Our study has shown that in this area, which is an important spawning and rearing ground for salmon, there is an important flux of groundwater towards the Englishman river, both under high and low water table conditions.

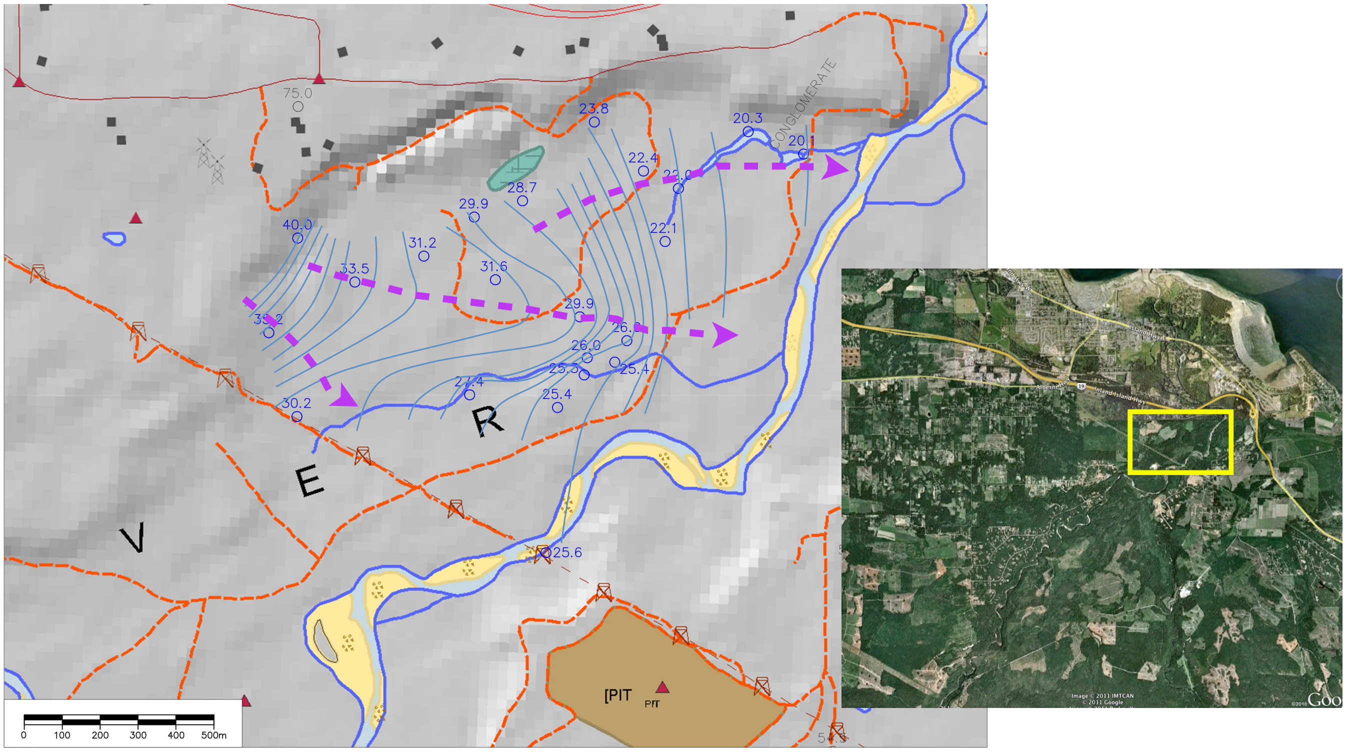

Figure 15: Groundwater flow path defined based on survey data

Flow Direction and Hydraulic gradient

The groundwater movement in the aquifers in the lower 5 km of the watershed is illustrated with the purple arrows in Figure 16. Along the left bank, we observe a clear discharge of groundwater to the Englishman River. On the right bank, the groundwater movement is more complex. There is a groundwater divide, as indicated with the yellow line. Groundwater present east of the divide will flow east towards Craig Bay. Groundwater present west of the divide will discharge into the ER.

Along the right bank, north of the old highway and its orange bridge, groundwater fans either directly toward the ocean or towards the ER and its estuary, the topography being relatively flat, and precipitation generating a slight groundwater mound between the ER and Rathtrevor Park.

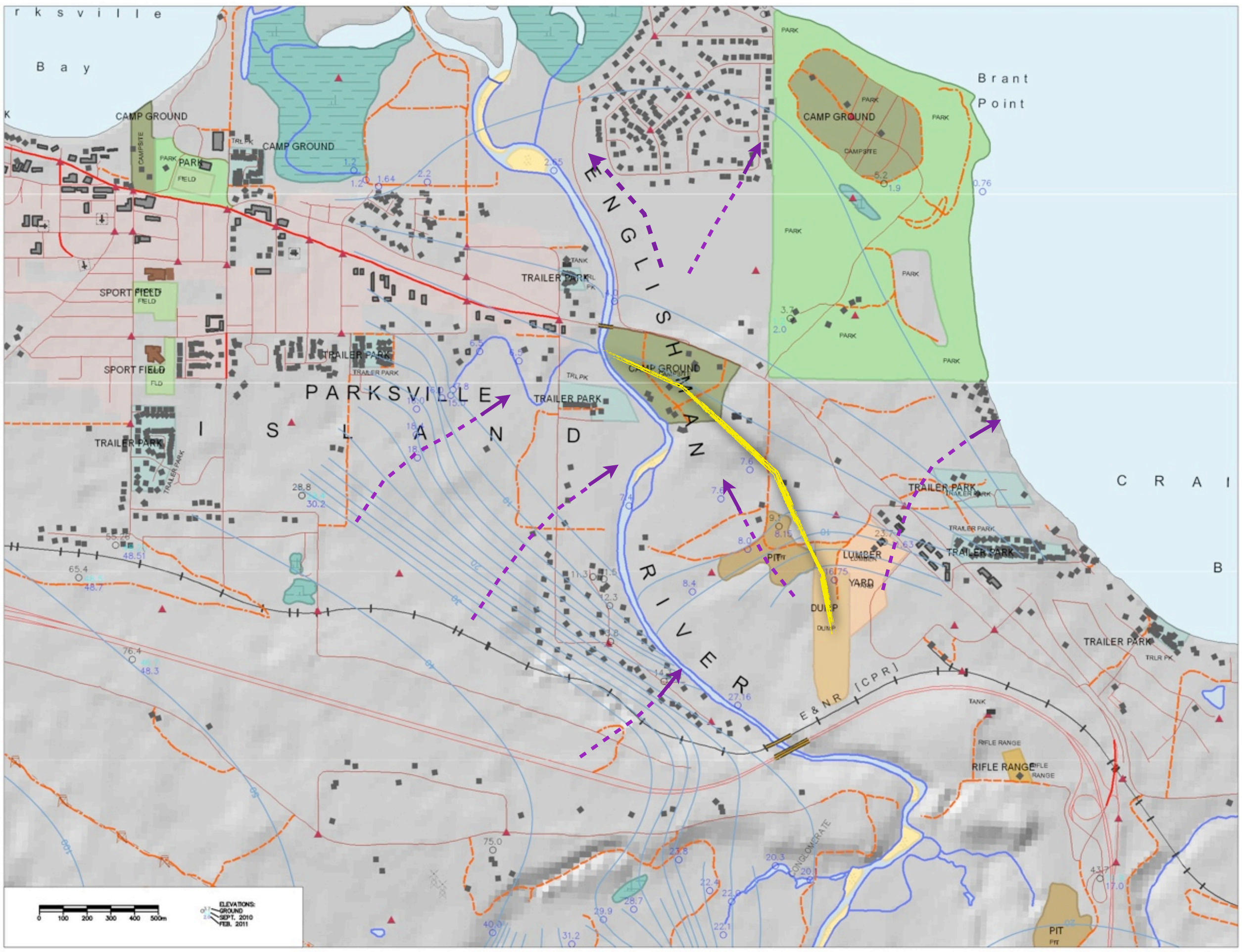

Figure 16: Groundwater direction in lower 5 km of ER watershed

The general movement of groundwater in the aquifers is illustrated with the blue arrows in Figure 17, based on the interpretation of available information. We note that for the sandwiched system between 9 km and 5 km, it appears that the hydraulic gradient indicates a groundwater movement in the shallow and medium aquifer towards the river, and a movement more towards Craig Bay and the Strait of Georgia in the lower aquifer.

There are indications of a deep aquifer in a buried valley acting as a bypass of the river bend. This would require further investigation to be confirmed.

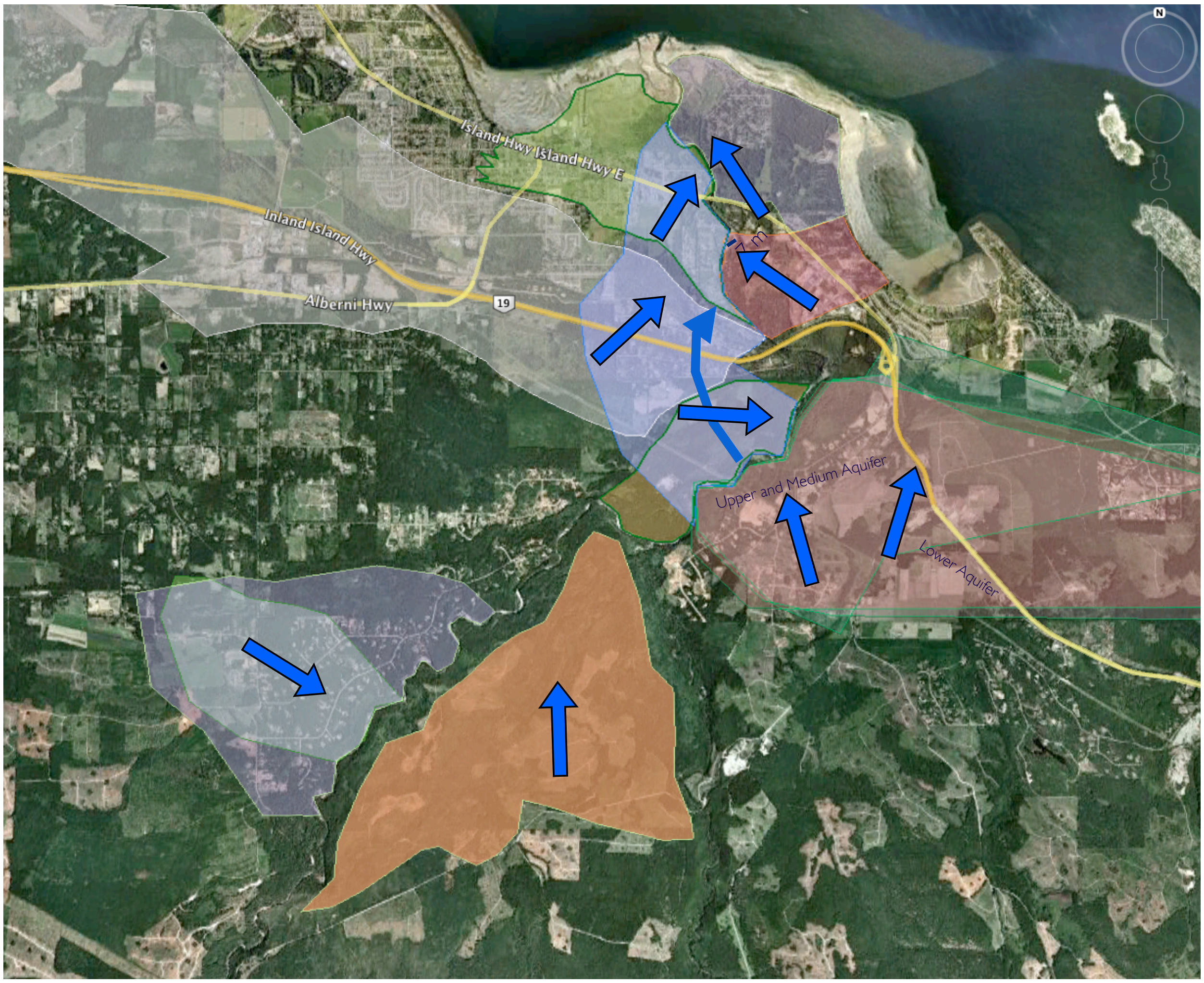

Figure 17: General groundwater directions in overburden aquifers in ER lower watershed

Groundwater Flux

So now that we have reached an understanding about the direction of the groundwater movement in the aquifers, we need to know how much groundwater is moving through the aquifers, and the flux of groundwater toward the ER.

The flux of groundwater through an aquifer is conceptually illustrated in Figure 18. A coarse gravel will have large voids between its particles and will let water move very freely. The size of the pores, the tubes made by the voids between the particles of a fine sand, by comparison, will be much smaller. The resulting hydraulic conductivity of the fine sand will be maybe 100 times smaller. The transmissivity of an aquifer is obtained by multiplying the thickness of the aquifer by the value of its hydraulic conductivity.

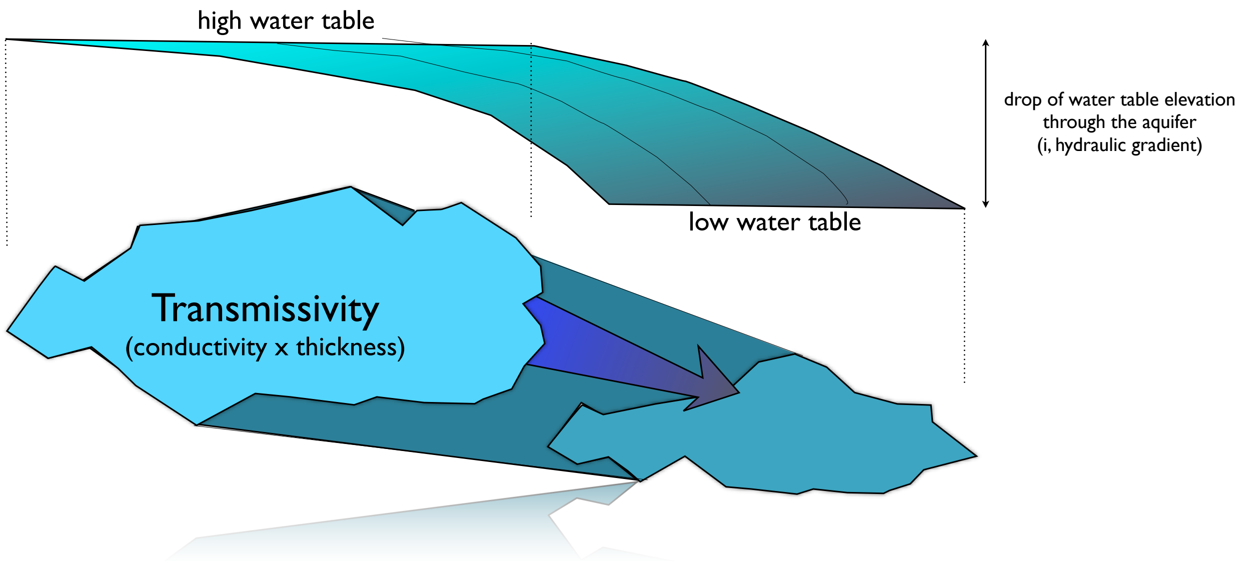

Figure 18: Illustration of the groundwater flux through an aquifer

The groundwater flux is also a function of the drop in energy as groundwater moves through the aquifer. The level of energy is given by the elevation of the water table. So by measuring the water table at two locations along the flow path of the groundwater, one can estimate the slope of the water table, which is also called the hydraulic gradient.

By multiplying this hydraulic gradient by the transmissivity we can estimate the movement of groundwater through the aquifer. And by multiplying by the section of the aquifer it goes through, we obtain the flux of groundwater moving through the aquifers.

The depth to water measured in the wells has given us the information to estimate the slope of the water table. So now we have an estimate of the direction of the water, shown with the blue arrows, and the slope of the water table indicated by the water table elevation lines in Figure 19.

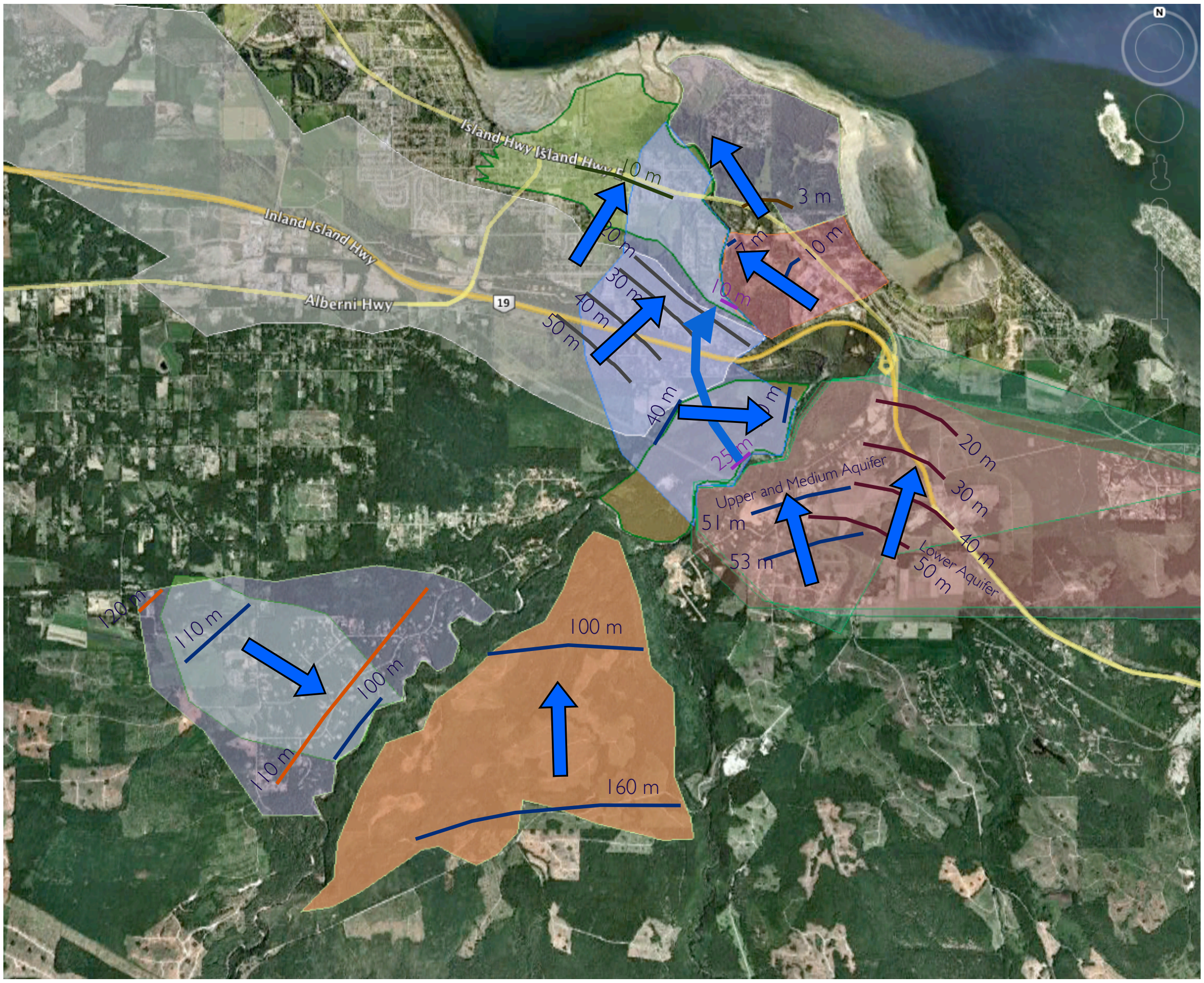

Figure 19: Estimated hydraulic gradients in overburden aquifers

Figure 20: Locations where hydraulic conductivity data is available

The BC Ministry of Environment has tabulated information about the estimated hydraulic conductivity of aquifers, after compiling and reviewing engineering reports (Figure 20). The red symbols show the locations where BC MOE data about the hydraulic conductivity of aquifers is available.

Groundwater Surface Water Interaction

In order to visualize the flux between the aquifers and the Englishman River under low summer flow conditions, we created this series of images (Figure 21 to 23). In Figure 21, you are traveling down the Englishman River, between 16 km and 10 km. On your left you see the face of the left bank, and on your right the right bank. The picture of the land, on both sides allows you to position yourself in the watershed. The blue line represents the elevation of the river. The coloured shapes represent the sections where the aquifers intersect both banks. And the arrows express the flux of groundwater discharging into the river. The estimate of the flux is summarized in the boxes, in l/s and m^3/day. The ratio between the flux from the aquifers and the summer river lowest flow rate is expressed as a percentage, to show how much the aquifers participate in providing water to the ER during its period of low flows.

So between 16 km and 10 km, the aquifers are providing water to the ER, but slightly, with fluxes representing about 2% of the ER summer flow.

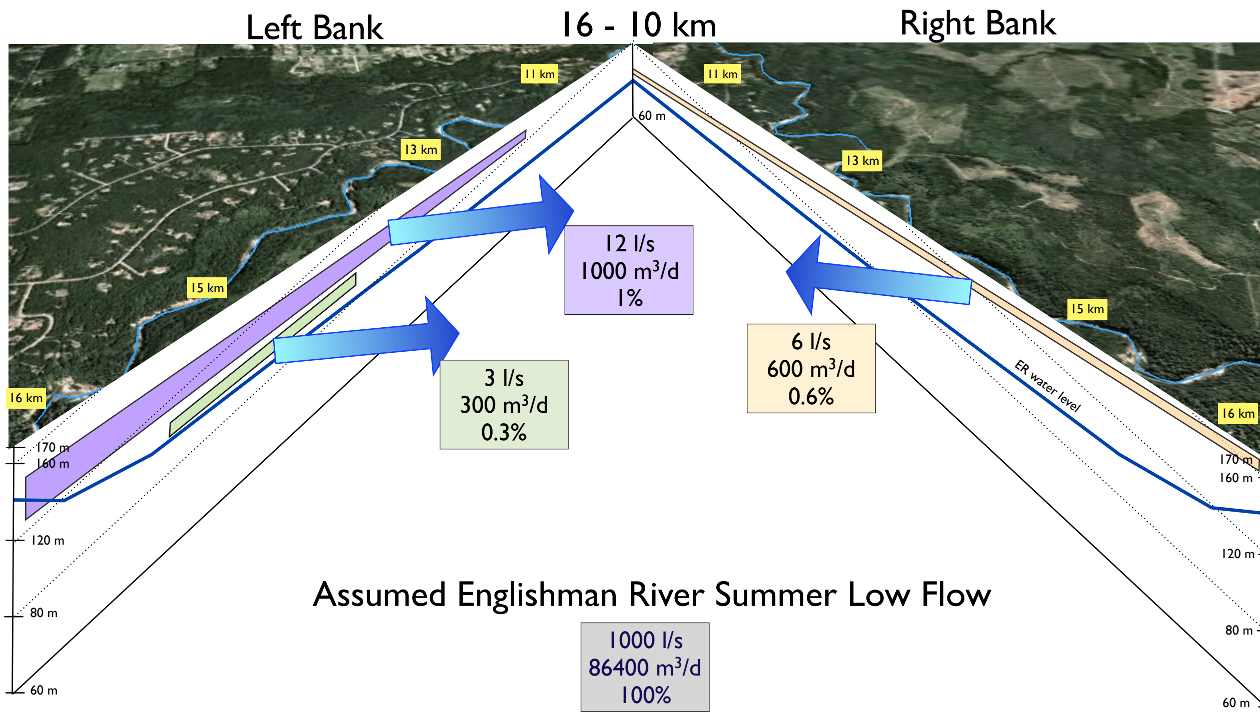

Figure 21: Estimated groundwater flux to ER from overburden aquifers between 16 km and 10 km

Between 10 and 5 km (Figure 22), we have more aquifers, they are thicker and providing larger fluxes. Together, they supply over 13% of the summer low flow of the ER.

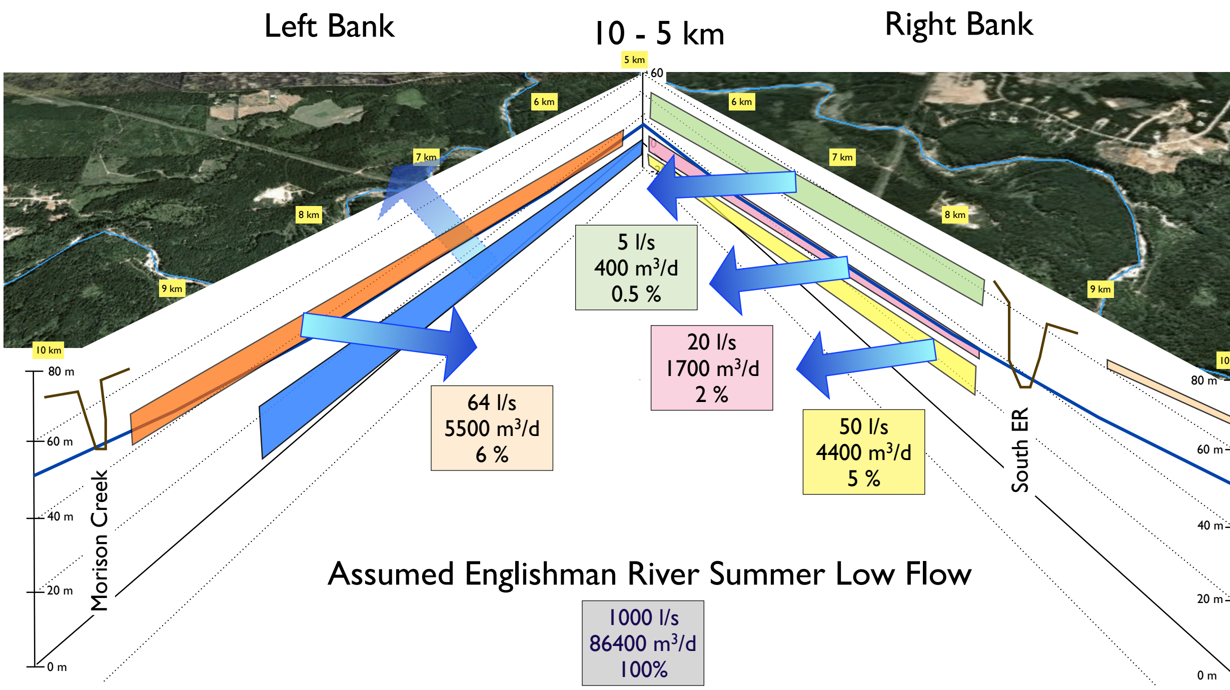

Figure 22: Estimated groundwater flux to ER from overburden aquifers between 10 km and 5 km

As we keep traveling down the river (Figure 23), we are now between the river bend at 5 km and the estuary. There are several aquifers on both banks of the river. Their geometry is complex and they provide an estimated 10% of the summer flow.

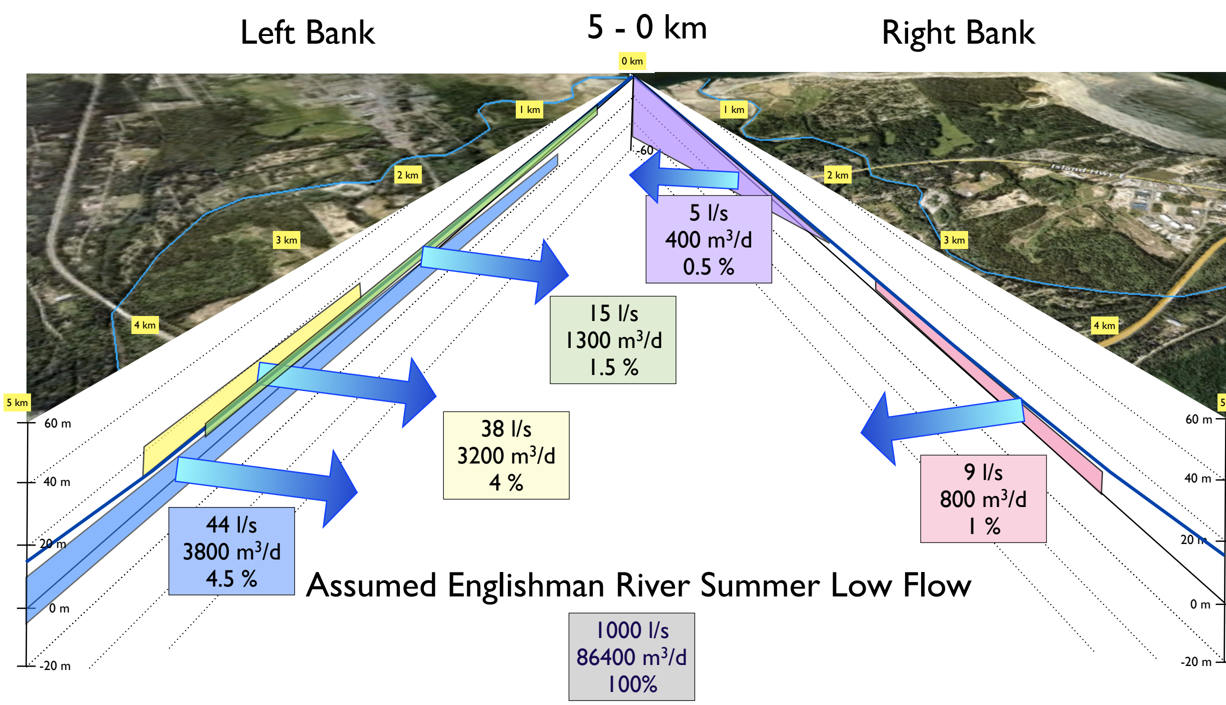

Figure 23: Estimated groundwater flux to ER from overburden aquifers between 5 km and 0 km

Recharge Areas

One of the objectives of our project was to delineate the land where aquifers connect to the Englishman River and are being recharged. We have created these "butterfly" views for this purpose. We have used the views of both the right bank and the left bank of the river showing where the aquifers are in contact with the river (presented in Figures 21 through 23) and have added the footprint of these aquifers, using color coding. For example, in Figure 24, we have a shallow aquifer in purple on the left bank. The purple shaded area shows its footprint. The thick dash line delineates the boundary of the estimated recharge area. This is the area where precipitation will generate infiltration that will reach the aquifer and will continue its travel as groundwater discharging into the river.

On the right bank, the boundary of the recharge area does not correspond to the footprint of the aquifer, because there is a groundwater divide. Water droplets falling left of the divide will end up in the Englishman River. The ones falling on the right side will end up discharging into the South Englishman River.

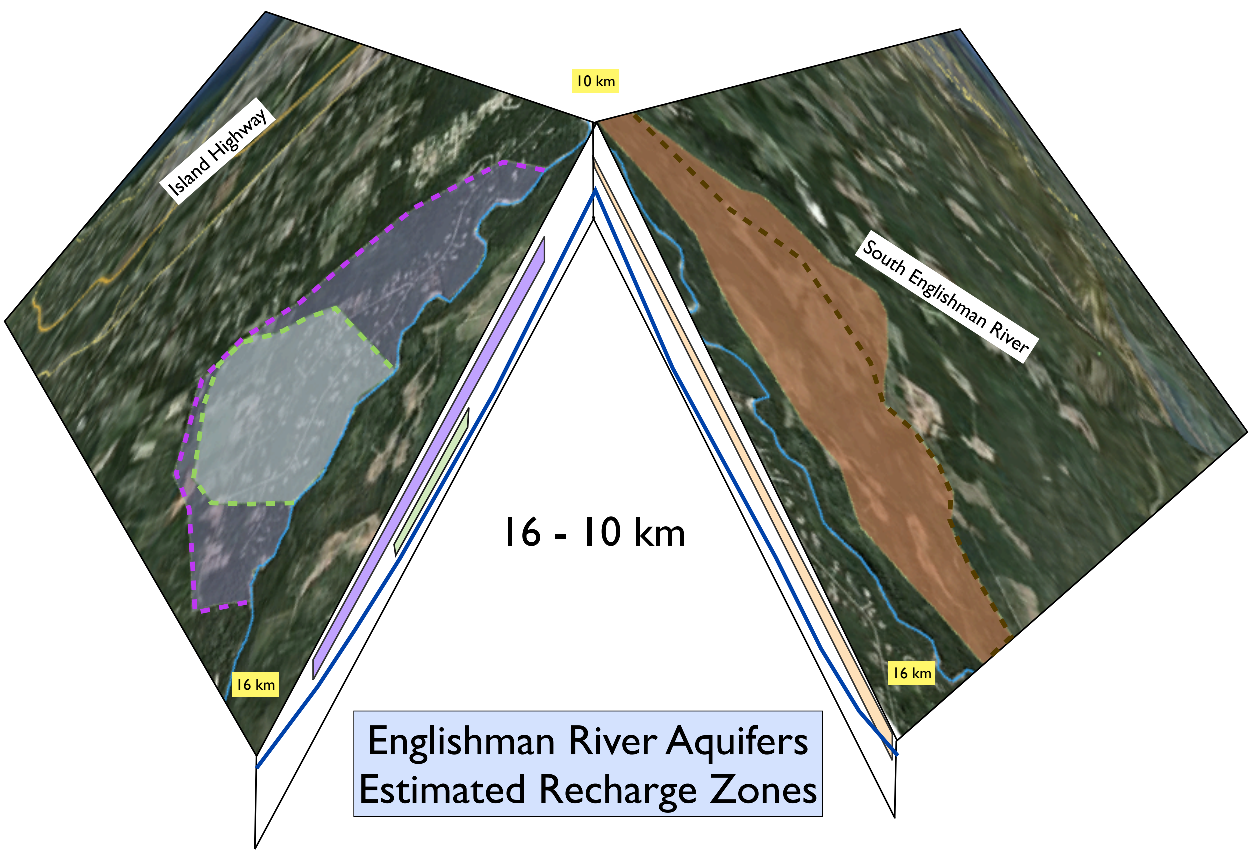

Figure 24: Estimated recharge zones of overburden aquifers contributing to ER, 16 km to 10 km

As we travel down the river between 10 km and 5 km (Figure 25), the sequence of aquifers is more complex. On the left bank, the whole footprint of the upper (orange) aquifer participates to the generation of groundwater discharging into the Englishman River. On the right bank, the aquifers have a large footprint but only a small portion of them will act as a recharge zone for groundwater discharging to the ER.

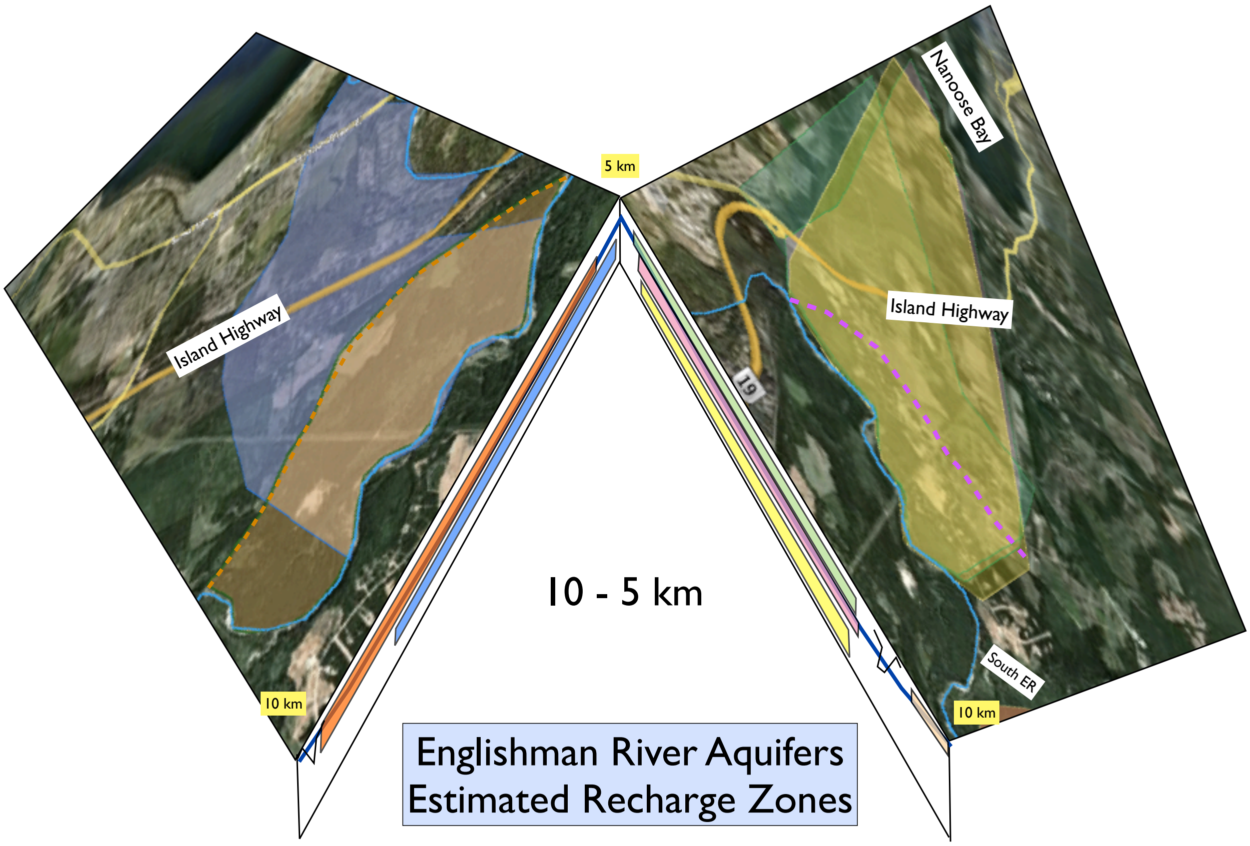

Figure 25: Estimated recharge zones of overburden aquifers contributing to ER, 10 km to 5 km

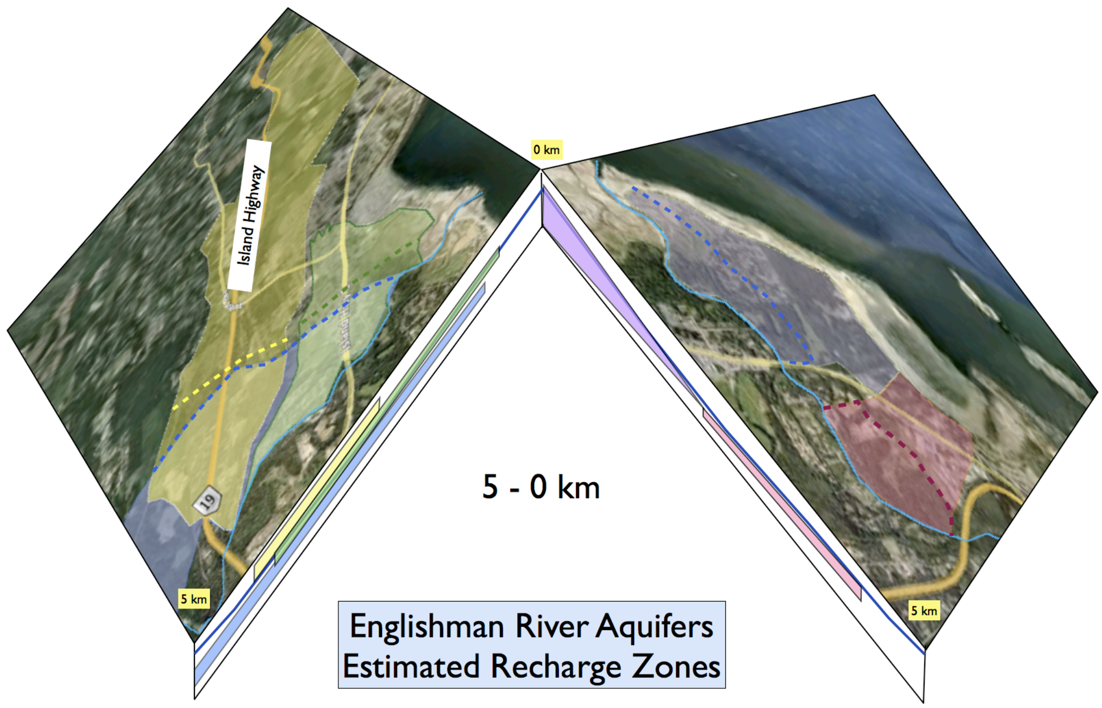

Figure 26: Estimated recharge zones of overburden aquifers contributing to ER, 5 km to 0 km

In Figure 26, we are now in the lowest section of the Englishman River, between 5 km and the estuary. On both sides, we show the estimated footprints of the aquifers and their respective recharge zones for which groundwater discharges to the Englishman River. Beyond the thick dashed lines, groundwater discharges directly to the ocean.

Regulating Effects

Water temperature, electrical conductivity, total dissolved solids (TDS) and pH were measured by volunteers along the river at up to 20 locations during 9 monitoring events. This was done throughout the year under both high and low flow conditions. Figure 27 illustrates the variation in water temperature versus distance from the foreshore for these monitoring events.

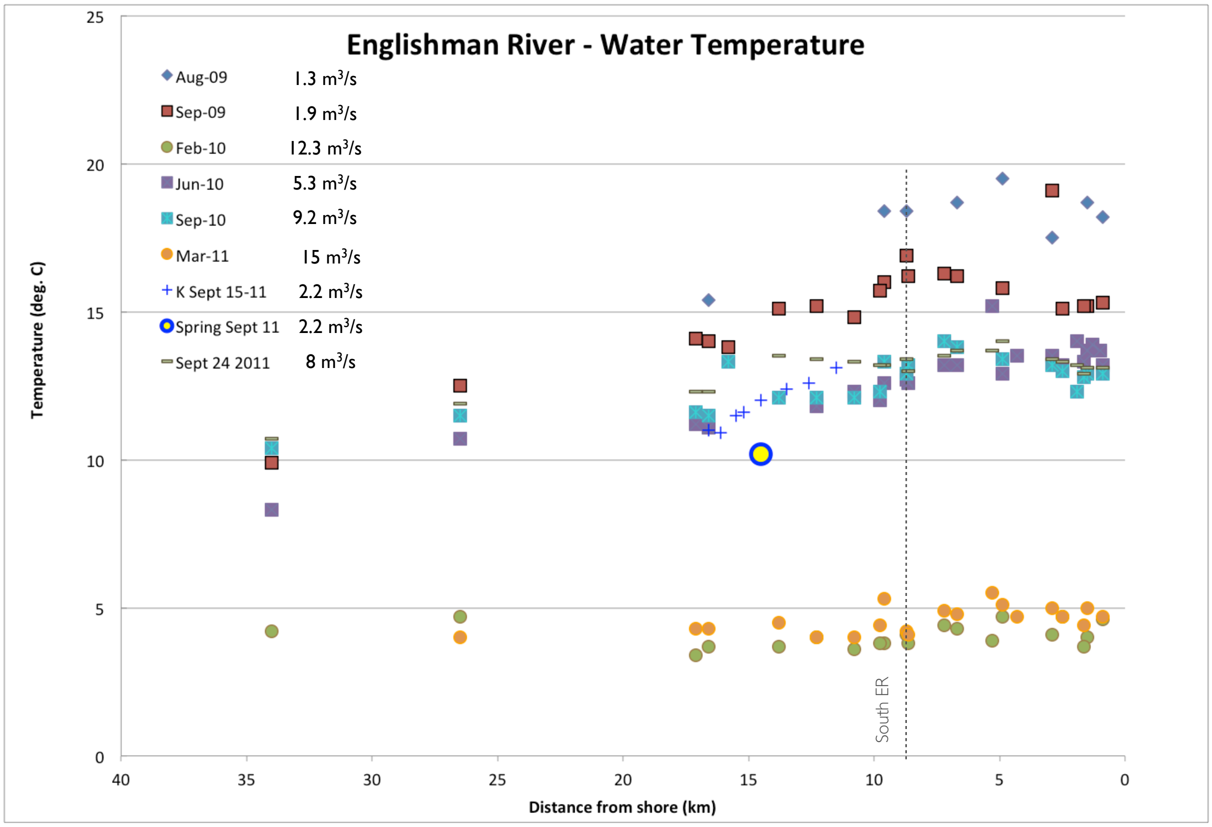

Figure 27: Water temperature of ER

Three key observations are made. First, water is cooler at high altitude and during the winter. Second, during the winter, river water results predominantly from runoff and is cold. In the summer, water is warmer and we observe that the water has a relative constant temperature in the lower 16 kilometers as shown by a “plateau” on the graph. This indicates that although water flows slowly and gets warmed up due to exposure to the sun and warm air, it is simultaneously cooled by groundwater discharging into the river at a constant temperature of 10°C. This was confirmed by measuring the temperature from the spring at 14.5 km, which was near 10°C, as illustrated by the blue circle.

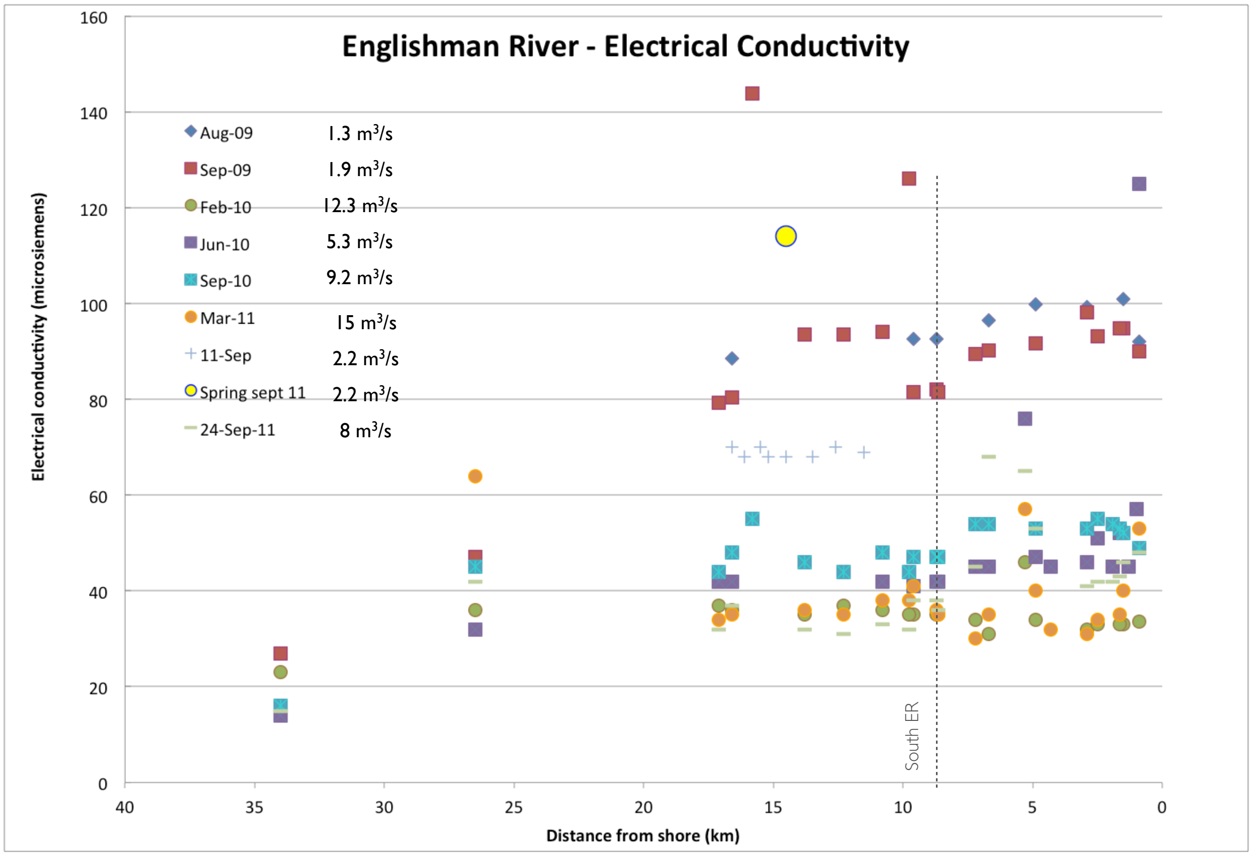

Figure 28: Electrical conductivity of ER

Rain water has a low electrical conductivity, typically less than 40 µsiemens. This is reflected by the low values measured in the winter, when the river mostly consists of rain water. In the summer and fall the electrical conductivity is higher because the groundwater component is greater. This is clearly illustrated by the highest conductivity values (between 80 and 100 µsiemens) measured when the flow was the lowest, at 1.3 and 1.9 m^3/s. The conductivity measured in the spring, consisting only of groundwater, confirms the higher electrical conductivity of groundwater, around 115 µsiemens.

5 Conclusions and Recommendations

Based on the completed study, GW Solutions draws the following conclusions:

- We were able to reach our objectives because of the involvement of the local community. A lot of high quality and very valuable data was collected by volunteers and through people providing access to their wells.
- The interaction between the overburden aquifer and the ER starts at 16 km, with the first occurrence of permeable granular deposits. It increases along the main stem of the river and becomes more significant in the lower 10 km. The groundwater flux increases because the aquifers get more numerous and thicker. In the lower section of the watershed and down to its estuary, the overburden aquifers contribute approximately 30% of the summer low flow.
- The bedrock plays an important role in providing groundwater, too. It probably provides 30% to 40% of the summer low flow. However, it is still poorly understood and the groundwater flow in the bedrock aquifers needs to be further characterized.
- The Arrowsmith dam plays an important role in maintaining summer low flow at a healthy level for fish habitat.

GW solutions makes the following recommendations:

- The characteristics of the aquifers (e.g., geometry, transmissivity, etc.) need to be better defined in order to refine the estimation of the groundwater fluxes. Several aquifers and a large portion of the lower watershed are still either not or poorly characterized.
- We need to build modeling tools through a collaborative effort. Both the tools and the results should be easily shared and accessible. It should become one of the elements of a watershed management plan.
- We recommend installing a flow gauge at the Englishman River falls because this is where overburden aquifers start contributing to the river. It will provide valuable information to segregate the various sources of water making up the flow in the river.
- A snow pillow should be installed at higher elevation. This is particularly important because of the projected shift in river dynamic expected to result from climate change.
- Groundwater flow through bedrock is an important player in the watershed. Therefore we highly recommend that a network of monitoring wells be completed in the bedrock aquifers to characterize the groundwater flowing through bedrock.
- Land planning is water planning. Zoning and Official Community Plans have to be designed with the overarching priority of protecting watersheds. We now understand the

importance of the aquifers and their water tables in providing flow to surface water bodies. It is critical that we take appropriate measures not to stress the aquifers and that our management of the land does not reduce aquifer recharge.

- We need to design new land developments in ways that are friendlier to the watersheds. Increasing residential density, building smaller transport systems, and promoting walking are part of the solution. Integrating water friendly designs is required to move towards a zero water footprint.

- Well owners who have volunteered to date should be encouraged to keep monitoring the depth to water in their wells. New well owners should be added to the network to increase the coverage of the area where data is collected.

- GW Solutions recommends monitoring the water quality in the ER twice a year and recording data on water temperature, pH, electrical conductivity, and total dissolved solids (TDS) using field equipment.

6 Acknowledgment

This work has been initiated by the Mid Vancouver Island Habitat Enhancement Society (MVIHES). This study was made possible by the grants provided by RBC Blue Water Project, the Real Estate Foundation of BC, GW Solutions Inc, Living Rivers, the Regional District of Nanaimo, TD Friends of the Environment, and Pacific Salmon Foundation, and by the volunteers who participated in the project.

GW Solutions thanks also Island Timberlands, the City of Parksville, the BC Ministry of Environment, and the local residents who graciously shared information and provided access to their properties and wells.

7 Education and Public Outreach

Public meetings were organized at the beginning of the project and throughout its completion, providing information on its progress. A final presentation was delivered on November 4, 2011, in Parksville, BC. The results are also presented in a series of presentations available on the web site of the Mid Vancouver Island Habitat Enhancement Society and on YouTube.

8 Closure

The information presented herein is based on information provided in part by others. The assessment has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied.

This report was prepared by personnel with professional experience in hydrogeology. Reference should be made to the 'GW Solutions Inc. General Conditions and Limitations', attached in Appendix 1 that forms a part of this report.

GW Solutions was pleased to produce this document. If you have any questions, please do not hesitate to contact me.

Yours truly,

GW Solutions Inc.

Gilles Wendling, Ph.D., P.Eng.
President

Appendices

Appendix 1 – GW Solutions General Conditions and Limitations

Appendix 1

GW Solutions Inc.
General Conditions and Limitations

GW Solutions Inc. Reports – General Conditions

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS’s client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS’s client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS’s investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 Information Provided to GW SOLUTIONS by Others

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS’s liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:
(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;
(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.