Mallett Creek, Columbia Creek, and Winthuysen Creek — hydrogeology, flows, and catchment areas

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Mallett Creek, Columbia Creek, and Winthuysen Creek flow into the sea just north of Descanso Bay on the west side of Gabriola Island—Mallett and Columbia into Cox Bay, and Winthuysen into North Cove in the Descanso Bay Regional Park. [ref.1] [ref.2] On their way to the sea, all three flow under Taylor Bay Road.

The creeks have a common geological provenance and all three were major meltwater channels at the end of the last ice age. Since then, the three creeks have been modified by human activity in differing ways, some positive and some negative, and these differences have made comparisons between them interesting and valuable sources of information.

A small group on the island, the Gabriola Streamkeepers, have been researching and monitoring creeks and wetlands since July 2012 and this report is part of their work.[1]

Common characteristics

The three creeks run side-by-side in sub-parallel valleys that are associated with the major north-end fault on Gabriola, which runs from Cox Bay to Leboeuf Bay. [ref.3] This fault is a dextral strike-slip fault that has been modified by clockwise rotation of the block to the northwest, which has opened up a series of extension fractures (Mode I) at the Cox Bay end of the fault where these creeks run. [ref.4]

Annual precipitation at these sites has been recorded to be up to 20% higher than that at the Environment Canada site at the far end of the island—though this value does vary from year-to-year. Coats Marsh has a similarly higher precipitation than is recorded at the Environment Canada site and at other sites down nearer sea level. [ref.5]

All three creeks have water-retention facilities of varying capacities along their courses built for irrigation, watering cattle, or to supply water to the fire department.[2]

Geology

The bedrock of the three creeks is Gabriola Formation sandstone of the Nanaimo Group. Overlaying the bedrock is soil with a high content of clay, likely montmorillonite that is the result of post-glacial weathering of glacial flour with a high feldspar content left by meltwater.

The creeks flow over the same specific type of Parksville-Tolmie soil, which is indicative of their common late-Pleistocene history [maps next page].

Mallett Creek

Only Mallett Creek flows year round. The maximum recorded flow in the 2015/16 season was 115 L/s litres/sec or just shy of ten thousand cubic metres a day (9936 m^3/d). The lowest recorded flow was 0.03 L/s (2.6 m^3/d), which although only a trickle, is sufficient to maintain the aquatic habitat in the pools along its course.

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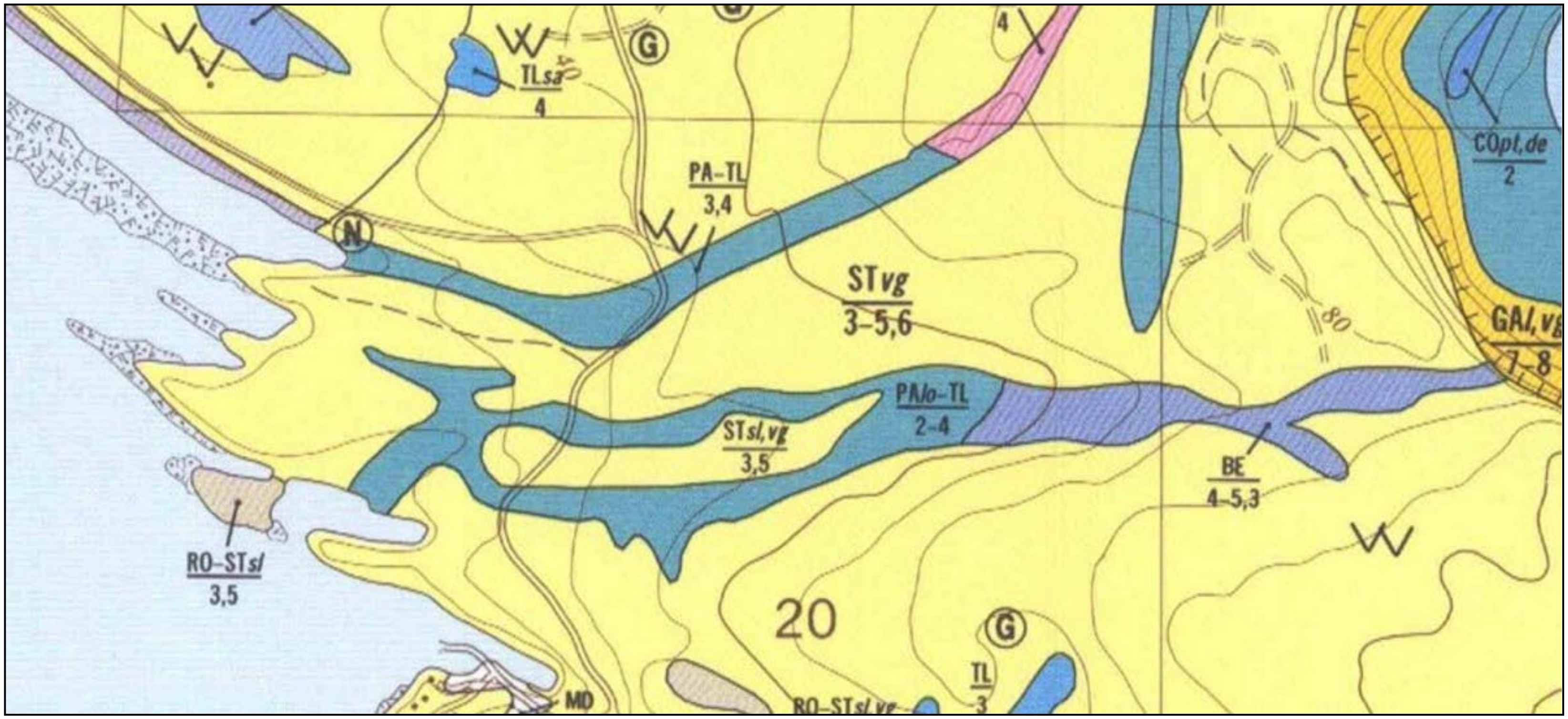
1 The GSK group, which is affiliated with the Gabriola Land and Trails Trust (GaLTT), participates in the BC Community Watershed Monitoring Network program as part of the Drinking Water and Watershed Protection Program, Regional District of Nanaimo (RDN), with Mallett Creek as their chosen creek to monitor.

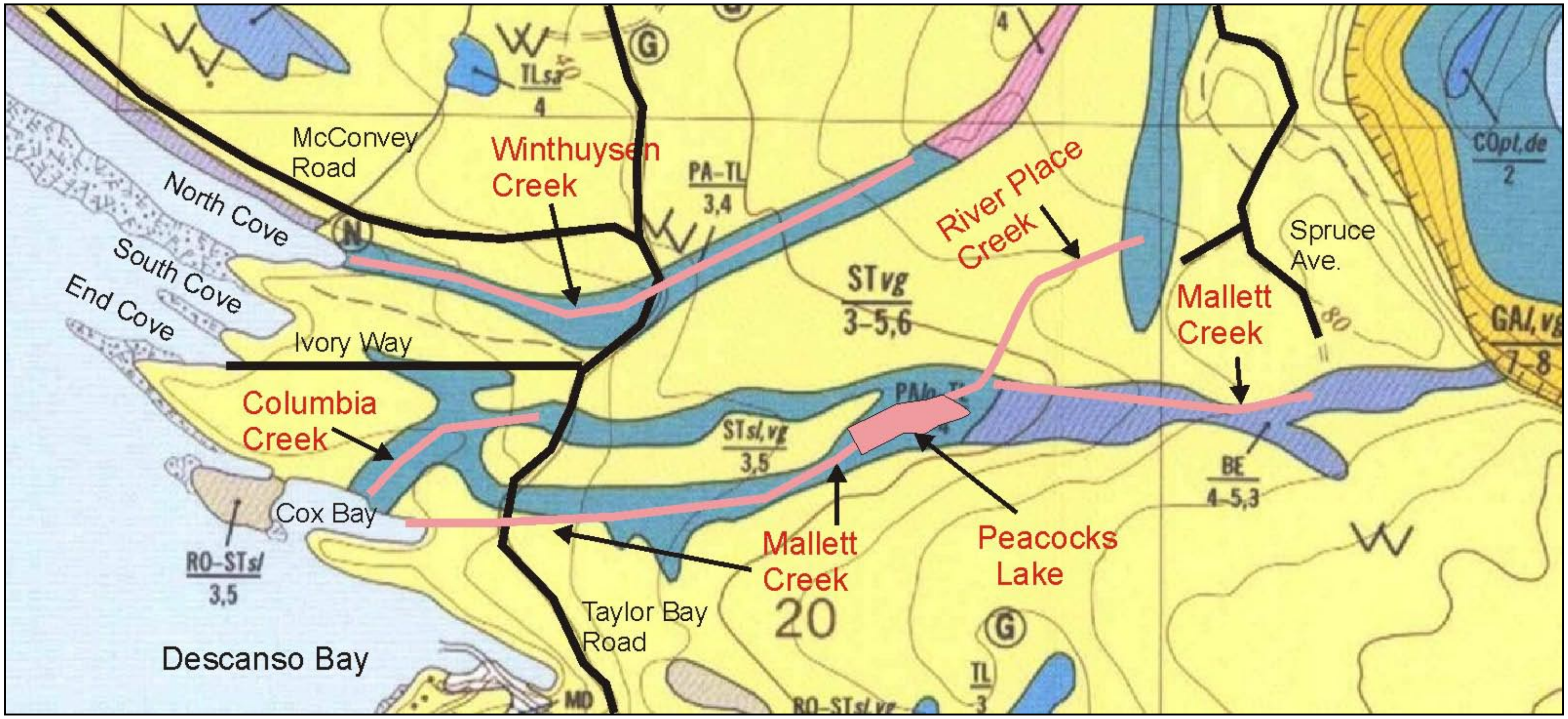
2 There is evidence that beavers have been active in the past, and may still be active, in the Mallett Creek and River Place Creek upper reaches, and so water-retention ponds may not be anything new.



An extract of the amazingly-detailed map of soil types from Kenny et al. [ref. 6]. It shows the shoreline of Gabriola from the ferry terminal at the bottom, up to the cliffs out along McConvey Rd. at the top. This extract is annotated on the next page.

Parksville-Tolmie (PA-TL and PA*lo*-TL, blue) and Brigantine (BE, purple) soils form the beds of the three creeks; top to bottom, Winthuysen, Columbia, Mallett. Saturna (ST*vg* yellow) is thin gravelly sandy soil over sandstone bedrock.

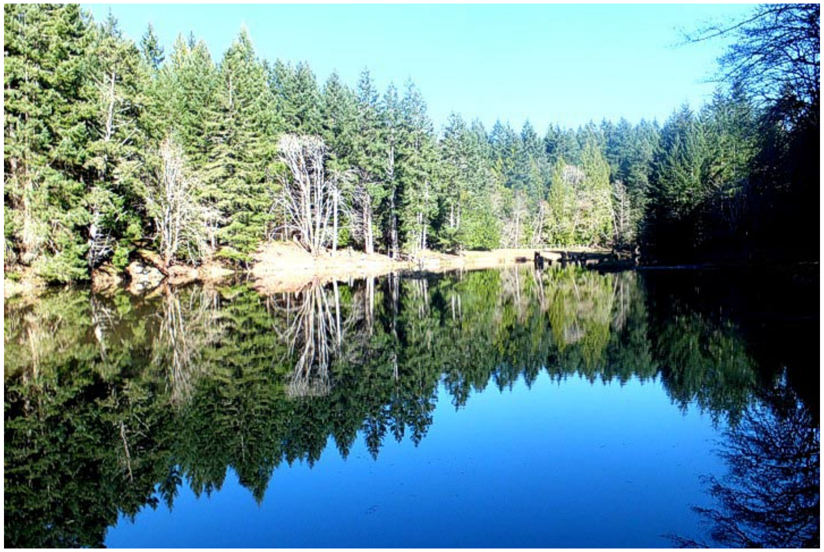
Parksville-Tolmie is “poorly drained developed on loam to silty clay textured, usually stone free, marine deposits”. Brigantine (BE purple), is “imperfectly drained sandy loam to loamy sand of marine or fluvial origin on silty clay to sandy clay loam textured, usually stone free, marine deposits”.



An annotated version of the same extract shown on the previous page. I personally would question the "marine" origin of the gleyed strata—there is some evidence that on Gabriola this is weathered glacial flour left by meltwater during the Bølling-Allerød Interstade *ca* 11200 BC after the sea had retreated as a result of isostatic rebound [ref.7]. Marine undermelt till that has weathered to clay contains dropstones and, on Gabriola, is frequently overlain with sandy glaciofluvial deposits.

Whatever its origin, this gleyed soil is keeping the creeks from seeping away into the deeper, fractured bedrock. Geysol dug from what appears to be the former Columbia Creek course was used to line the walls of Peacocks Lake during its construction.

Parksville-Tolmie and Brigantine soils are typical of "depressional areas, swales, and drainageways". The present estuary of Mallett Creek is a little to the south of its presumably historic location. Columbia Creek may, in pre-settlement times and before Taylor Bay Road was built, have been a rather more significant watercourse than it is now.



Top left: Mallett Creek below the dam.

Top right: River Place Creek in Cox Park flowing down to Peacocks Lake. It is an ephemeral creek with wetlands and a pond at its headwaters.

Bottom Left: Peacocks Lake seen from the dam.

Top left: Columbia Creek just downstream from Taylor Bay Road. Building the road has disrupted the drainage pattern.

Top right: Black-tailed deer, *Odocoileus hemionus columbianus*, on the banks of its namesake as it crosses the lawns in the Sitka Cove development. The lawns are irrigated from water drawn from Peacocks Lake.

Bottom Left: Small pond on Columbia Creek just upstream of Taylor Bay Road. Probably artificial. Water seeps through its restraining bank and the pond dries up in summer.

Left: Winthuysen Creek as it leaves the wetlands downstream of Taylor Bay Road and enters the campground in Descanso Bay Regional Park.

Top right: Fire department retention pond. No longer used. The retaining walls leak water into the creek but it retains some water year-round.

Bottom right: Winthuysen Creek wetlands downstream of Taylor Bay Road where the creek forms multiple shallow branches.

Only Mallett Creek has a significant tributary. This is River Place Creek,[3] which has wetlands in its upper course and a pond on private property at its headwaters just beyond the boundary of Cox Park.

Mallett Creek also has a retention pond, known as Peacocks Lake, named after a former land-owner who built the dam. The volume of water in the lake is about four hectare.metres (4×10^4 m^3) and a rough estimate of the surface area is between six and eight thousand square metres.[4] The creek's lower course is through a ravine where the riparian vegetation is fairly open, mainly Douglas-fir forest with some cedar.

Mallett Creek currently contains coho salmon and pumpkinseed sunfish (*Lepomis gibbosus*), and was at one time stocked with rainbow trout. [ref. 8]

Columbia Creek

Columbia Creek is the smallest of the three, seldom being much more than a drainage channel. It flows through former pasture and makes its own way under Taylor Bay Road without the help of a culvert. It has a small, probably artificial, pond on the upstream side of the road, but it only contains water in winter; there is no other water storage area along its course.

Some of the flow of Columbia Creek probably occurs in subsurface fractures in the sandstone bedrock. Flow volumes have not been regularly monitored although measurements have been made of the water's electrical conductivity, pH, and dissolved-oxygen content to establish that the flow is mainly surface run-off and not from a spring sourced deep in the bedrock. [ref. 9]

Winthuysen Creek

Winthuysen Creek is an intermittent creek. It flows freely in winter, but dries up every summer. The maximum flow in the 2015/16 season was around 50 litres/sec (4500 m^3/d).

Winthuysen Creek also has a retention pond holding about 440 m^3 when full on its course. It was formerly used by the Gabriola Volunteer Fire Department, but it is now abandoned. It leaks water slowly back into the creek, though it seldom completely dries out.

The creek is culverted beneath Taylor Bay Road and flows through Cox Community Park. Immediately on the downstream side of the culvert there is a natural area of wetland, populated with cedar and sword ferns fringed with salal. This area probably helps prolong the creek's wet season by storing winter rain and releasing it only slowly into the creek.

As the creek nears the sea, there is another culvert under a former orchard, now a campground. There are no fish in this creek, but in season, it hosts invertebrates and more than one species of amphibian.

Accessibility

The three creeks have varying degrees of accessibility for observation and monitoring purposes.

The lower reaches of Mallett Creek run adjacent to the MOTI Winston Road allowance (undeveloped) and are on private land until the creek nears the sea, [ref.10] but the present land-owner, Dr. Rooks, has been generous in allowing unrestricted access to the Gabriola Streamkeepers while the property remains unsold. Despite being on private land there is a rough trail along the lower reaches constructed by GSK and GaLTT volunteers.

Most of the observations of the creek in the following notes were made at the culvert

[3] Often wrongly identified as the upper reaches of Mallett Creek, including on current RDN maps.

[4] Water licence C126213 quotes 40705 m^3 which is an obvious exact translation of the old 33 acre-feet.

under Taylor Bay Road on the downstream side, but occasional visits were also made, with supportive land-owner permission, to the upstream side of the culvert and along the course of the creek to the lake. Only one or two observations were made upstream of the lake on Mallett Creek near where it drains the parcel of land on which the Gabriola Medical Clinic is located.

River Place Creek runs through Cox Community Park and access is unrestricted except at its headwaters, which are outside the park.

Regular observations of Peacocks Lake were not made—the number of visits required would have been perceived as being unreasonably high, and advance notice during winter downpours unreasonably short. Observations would, in any case, have been of frustratingly-limited value as unknown quantities of water were being withdrawn from the lake during the dry season by the fire department and for irrigation in the Sitka Cove development.

There is no access to Columbia Creek other than where it crosses Taylor Bay Road, and in theory—it was never visited—at the beach below the high-water mark.

There were no restrictions on access to Winthuysen Creek, either above or below the culvert.

Catchment areas

The catchment areas of the creeks were of interest, particularly of Mallett Creek; however, the conventional notion of a catchment area as a fixed geographical area defined by local topography does not apply on Gabriola. Catchment areas on the island are more dynamic than this.

At the start of the rainy season, the level of water in the fractured rock is low; consequently, relatively little of the precipitation runs off. Some areas within a catchment area may even be isolated from the rest of that area.

Conversely, at the end of the rainy season, the soil is saturated and the fractures are full to overflowing. Practically all of the precipitation runs off in ephemeral creeks and subsurface flows.

Fractures are also leaky, and their leakiness depends on the level of the water in them, so a few days of heavy rain can result in more run-off than when the same volume of rain falls steadily over a longer period. [ref. 11]

For these reasons, the fraction of the precipitation that flows into lakes, creeks, and wetlands varies considerably throughout the year, as does the effective areas of the supposedly fixed catchment areas. Further technical discussion is in an appendix.

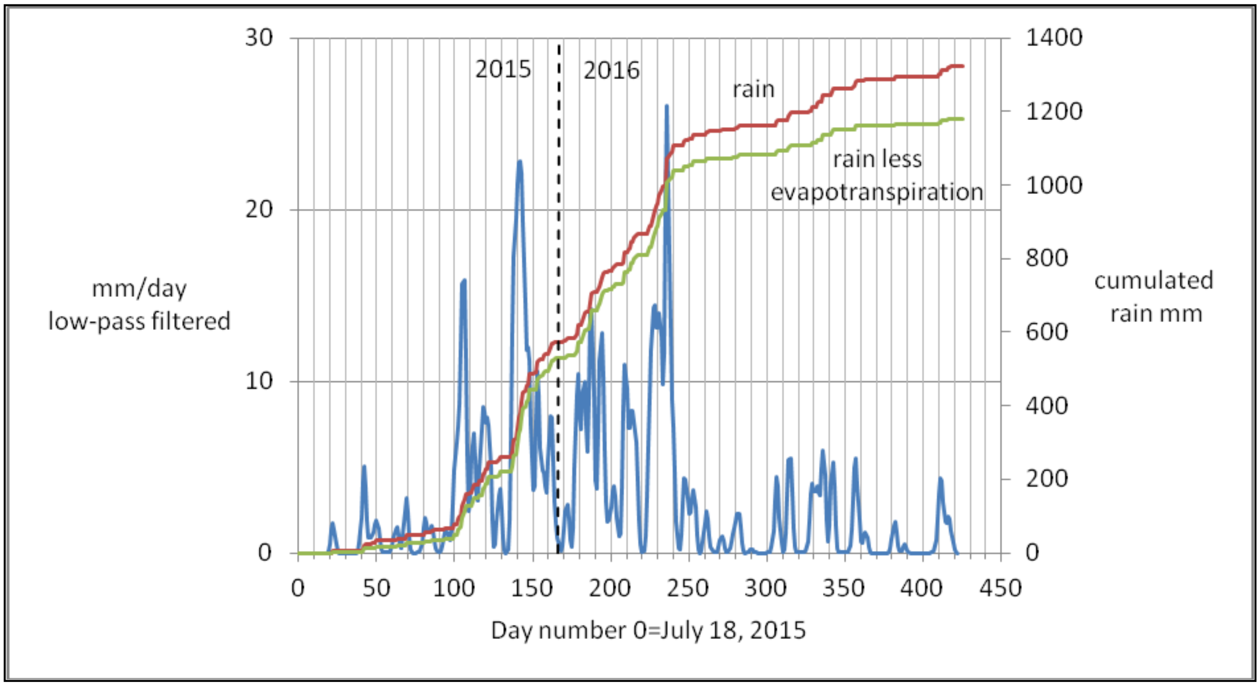
Observations

The following report of observations are nominally for the period: July 18, 2015 (day 0); through January 1, 2016 (day 167); to July 17, 2016 (day 365). They thereby encompass a complete wet-season cycle, although, because the ending of the season in 2016 was a little late, some figures are given here up until September 15, 2016 (day 425).

Flow was recorded in Mallett Creek throughout the period. [ref. 12]

Ponding in Winthuysen Creek after the dry season was first observed on November 8, 2015 (day 108). Flow continued throughout the winter until it ceased on June 5, 2016 (day 323), 215 days later.

The onset of flow in River Place Creek was not observed, but flow had practically ceased on April 10, 2016 (day 267), approximately 150 days later. Anecdotal reports that this creek flows year round are false.



GRAPH 1: Precipitation. Rain or rain equivalent—snow was only measured when it had melted in the gauge.

Blue line (left hand scale) indicates rainfall rate (mm/d) smoothed with a filter with a time-constant of 3–4 days.

Red line (right hand scale) indicates accumulated rain since day 0.

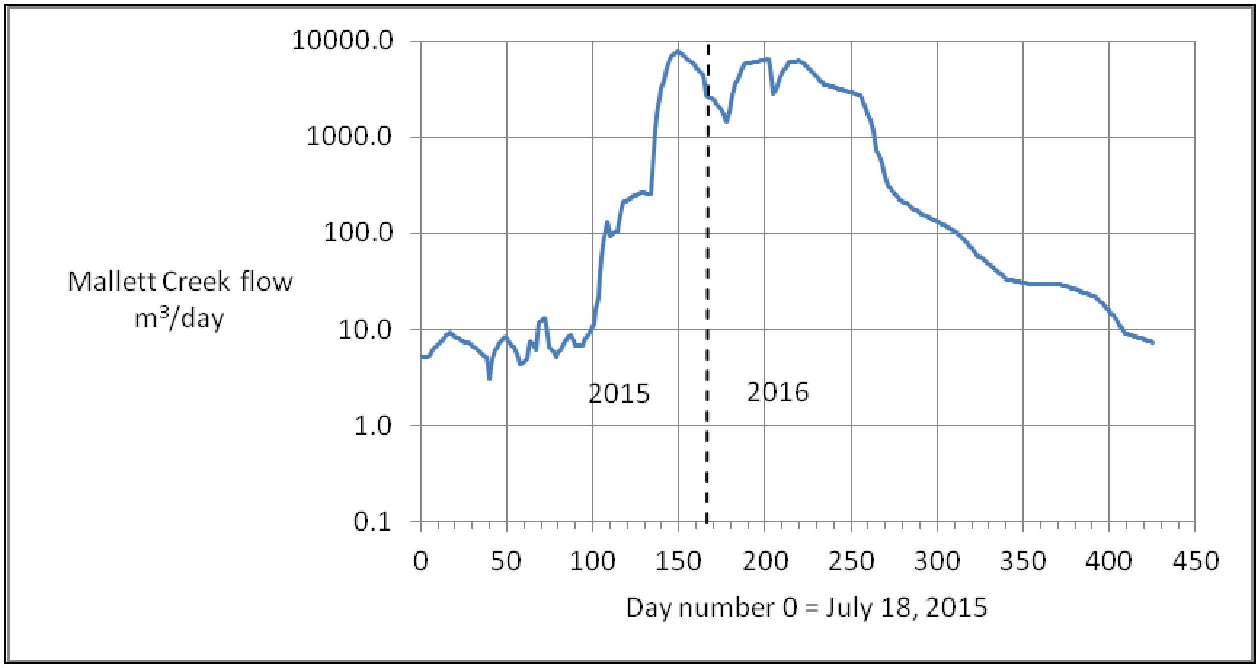
Green line (right hand scale) is the effective accumulated rainfall, which is the measured rainfall less a seasonal allowance for evapotranspiration with negative values counted as no precipitation.

Precipitation

Precipitation as recorded on calibrated gauges[5] in the Mallett Creek watershed is shown in Graph 1. Evapotranspiration was estimated based on the time of year and scaled for an annual loss of 500 mm. [ref. 13]

As discussed in the appendix, the effective precipitation is the observed precipitation less the portion of this that is lost to the atmosphere through evapotranspiration. The cumulative effective precipitation has been calculated in these notes by adding up day-by-day the precipitation that day less the estimated evapotranspiration for that day, omitting from the summation all results when the daily evapotranspiraton exceeded the daily precipitation.

[5] Calibrated using a one-metre diameter pool. Two gauges were used a short distance apart at every site in case one was "lost" or had a suspiciously high or low reading.



GRAPH 2: Mallett Creek flow rate at the culvert on Taylor Bay Road.

In the summer, flow is continuous but below 10 m^3/d (0.12 L/s).

In the fall, the rate increases 10-fold to a few hundred cubic metres a day as precipitation in the area between the dam and the culvert comes into effect. During this brief period, Peacocks Lake is being filled, but there is not yet any flow through the outlet pipes at the dam.

Once the lake is full, flow begins from the outlet pipes, and the creek flow rate rises sharply to its winter peaks at over 1000 m^3/d.

Mallett Creek flow

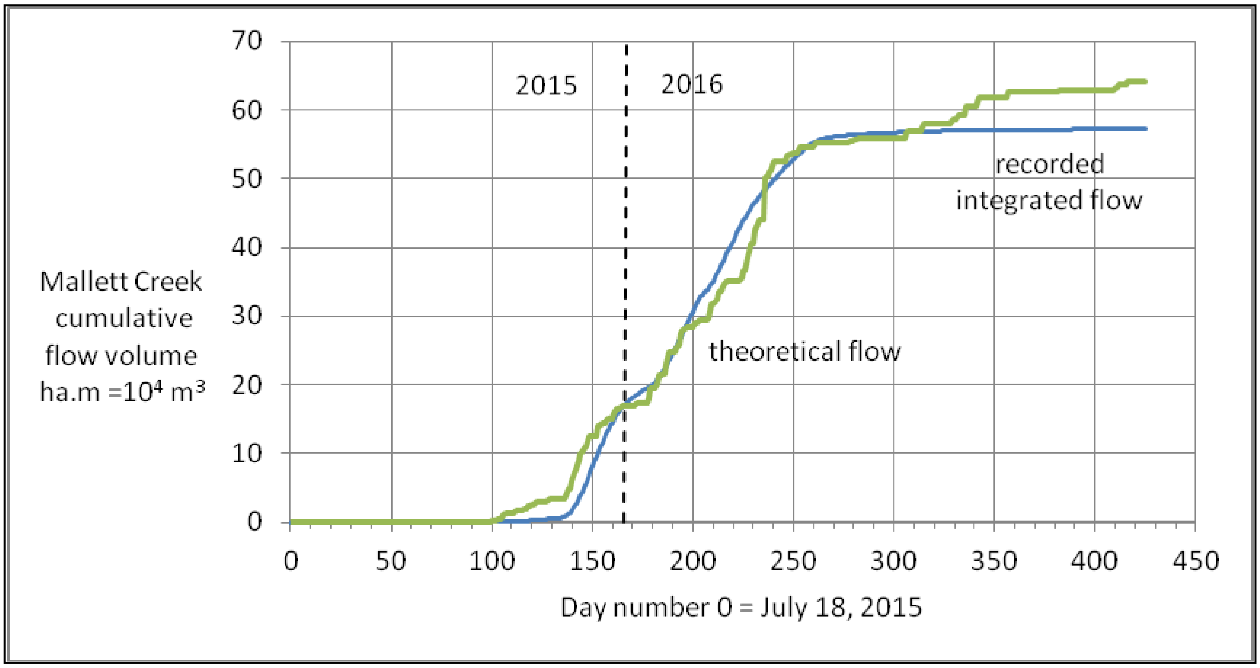
Ideally, any model of the flow of the creek at the culvert should take the lake into account. However, lacking some of the data needed to do this, I have instead analysed the whole catchment area as a "black box", that is looked at only the inputs and outputs of the system (excepting the withdrawals of water from the lake) without regard to what might be going on inside.

Graph 2 shows the recorded flow throughout a complete annual cycle.

Withdrawals allowed by the water licence are substantial but, in practice, not so severe. The irrigation use is limited in principle to 2.5 ha.m per year (25163 m^3/yr. which is 20.4 acre-feet).

The fire department use is limited to 1.6 ha.m per year (15542 m^3/yr. which is 12.6 acre-feet). The fire truck holds about 9 m^3 (2000 gallons) and is loaded for training purposes only a handful of times per year.

The summer flow of the creek was established as being from the dam as it appears to emerge only a short distance below the dam, where the electrical conductivity, pH, dissolved-oxygen content, and temperature of the water is practically the same as that in the lake. The seepage is either through the rip-rap or through shallow subsurface bedding-plane parallel fractures in the bedrock supporting the dam.



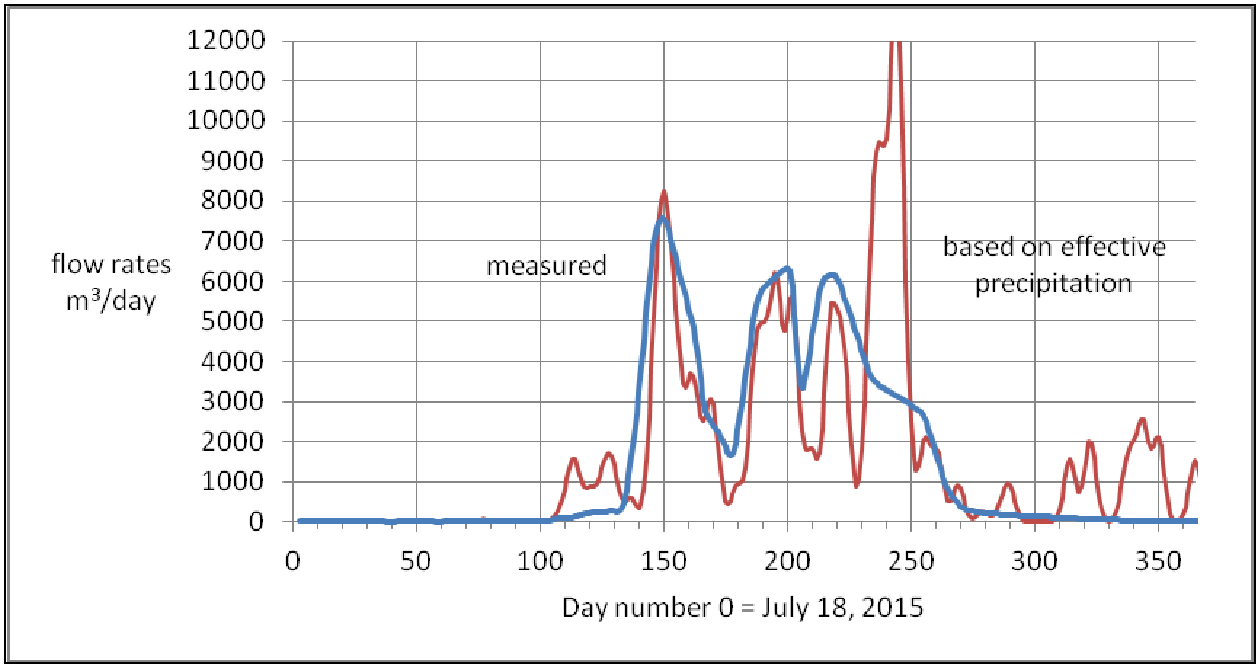
GRAPH 3: Integrated flow in hectare.metres = 10^4 cubic metres.

The blue line indicates the flow volume based on observed values of flow rate.

The green line indicates the flow volume calculated from the precipitation data (see text).

Graph 3 shows the cumulative flow of Mallett Creek. The recorded integrated flow is the blue line and the theoretical flow the green line.

The theoretical estimate is from the precipitation data after allowing for evapotranspiration, and assuming an effective catchment area C_G of 103 ha with a ground absorption constant G of 688 mm. These values are empirical and were chosen to achieve the best match between the two curves. As explained in the appendix, the assumption is that the effective catchment area is g(t).C_G where g(t) exponentially increases from 0 to 1 throughout the wet season at a rate determined by the ratio of the effective precipitation to date and the constant G.



GRAPH 4: Flow rates in Mallett Creek.

The blue line indicates the flow rate based on observed values of flow rate.

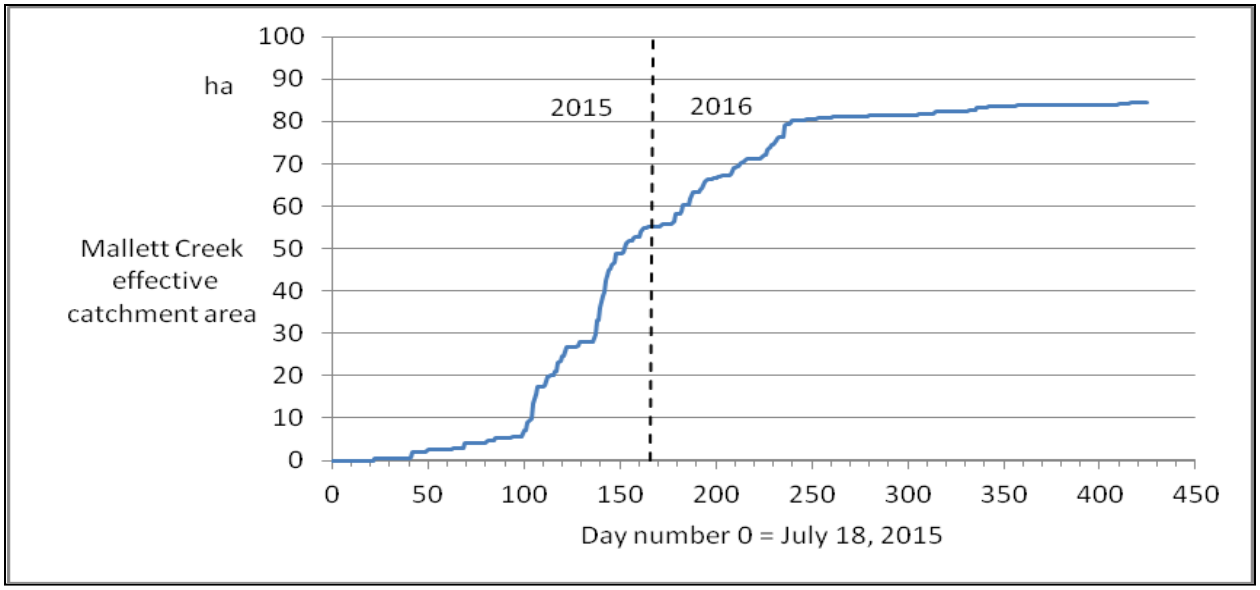
The red line indicates the flow rate calculated from the precipitation data with a 9-day delay (see text).

Graph 4 is an attempt to show how the flow in Mallett Creek is matched with precipitation. Flow rates based on precipitation were calculated using the same values for C_G and G as for Graph 3.

A straightforward direct correlation is not to be expected because some precipitation is lost to the atmosphere, some is absorbed by the ground, some is used to replenish the lake, and it takes time for precipitation to reach the culvert where measurements were made downstream of the lake.

Nevertheless, there is clearly a correlation between the two. An interesting feature of the two curves is that there are times when there is precipitation (the red line) but no corresponding increase in observed flow (the blue line). These must be times when the level of water in Peacocks Lake is below the level of the outflow pipes at the dam.

In order to achieve the match shown in Graph 4, the curve based on the precipitation data (the red line) had to be delayed by nine days.



GRAPH 5: Effective catchment area of Mallett Creek.

At the start of the wet season most of the precipitation not lost to evapotranspiration soaks into the ground. As the fractures in the bedrock fill, more and more of the precipitation results in run-off to the creek. The effective catchment area also sharply increases once the water in Peacocks Lake reaches the outflow pipes.

The linear length of Mallett Creek from the road culvert to its headwaters is about 1270 m, and there is an additional approximately 500 m along River Place Creek for a total of 1770 m. An effective catchment area of 80 ha therefore implies an average bandwidth for the catchment of ±226 m either side of the creeks.

Concluding remarks

Of over-riding importance in maintaining the health of Mallett Creek is the continuing flow of water from the lake throughout the summer. Removing the dam and "naturalizing" the creek would quite literally destroy it as habitat for most of the aquatic life presently there, notably the salmon. There is, in any case, some evidence that before the dam was constructed, there were beaver dams in the area.

Monitoring the creek could be improved by keeping records of water withdrawn, or if such records already exist, they be available.

The water licence requires that water levels in the reservoir be recorded monthly. More frequent observations would be more useful to anyone making science-based observations of the lake and its ecosystem.

The surface water licences currently in effect allow for an inordinate amount of withdrawal based on historical surveys that took no account of the ecological values of the creek. Thankfully, withdrawals by the present holders of the licence seem reasonably low—one truck load of water for the Gabriola Volunteer Fire Department for example, probably draws down the lake by no more than a millimetre.

Consideration might be given to increasing the level of leakage in summer. The present level was set by accident, not by design, and the flow gets particularly feeble in the absence of rain, and the dependence on the volume of the trickle with level in the lake is not known.

The catchment area of the creeks is certainly larger than is visible from surface water flows alone and way beyond any offset required by riparian area regulations.

Appendix: Catchment areas

Definition

Before computing the size of catchment areas we first have to define what we mean by a "catchment area".

The conventional idea that these are time-invariant numbers based solely on the local topography is not useful on Gabriola. On the island, catchment areas, meaning the areas in which all precipitation funnels into a particular creek or lake are a function of how full the local fractured-rock aquifers are, and also, but to a much lesser extent, how saturated the soil is.

At the start of the rainy season, the ground is dry and the aquifers are low; consequently relatively little water runs off over the surface. Some areas within the catchment area, as defined by the local topography, may even be completely isolated from the creek or lake.

Conversely, at the end of the rainy season, the ground is saturated and the aquifers are full to overflowing; consequently practically all of the precipitation runs off over the surface or in subsurface flows. Areas, as defined by the local topography that were earlier not connected to the creek or lake become connected by ephemeral watercourses that were earlier dry.

A definition of catchment area is as follows:

Let the precipitation in the general catchment area be R(t) m/day for days numbered t, t=1,2,3…T.

Divide this precipitation into a fraction $\varepsilon(t).R(t)$ m/day where $\varepsilon(t)$ is dimensionless and represents the fraction of R(t) that does not evaporate and is not transpired by trees and vegetation. $\varepsilon(t).R(t)$ is the effective precipitation in the catchment area.

Let the general catchment area be divided into P small polygons numbered p, p=1,2,3…P that don't overlap and completely cover the area. Let each polygon have a common area dA m^2.

Further divide the effective precipitation into a second fraction $\eta(p,t).\varepsilon(t).R(t)$ m/day where $\eta(p,t)$ is dimensionless and represents the fraction of the effective precipitation falling on polygon p that does not enter the ground to become groundwater and is not otherwise prevented from reaching the creek or lake.

Put $\eta(p,t) = 0$ for $p > P$ and all t, thereby restricting the maximum size of the catchment area to P polygons. However we allow that it might be that $\eta(p,t) = 0$ for some t, even when $p \leq P$.

In this part of the analysis I should strictly speaking be taking account of the delay between rain falling and the run-off entering the creek or lake, but analysis shows that the average delay is only around 4 or 5 days.

There is admittedly some delay when the level of the lake, in this case Peacocks Lake, reaches the outflow pipes and the excess water begins to flow downstream but is slowed by the restricted size of the two outflow pipes, but to avoid cluttering the equations with not much improvement in accuracy, I will assume that T is significantly greater than the delay and so it can be ignored.

Then the volume V(t) m^3/day of water entering the creek, lake or wetland is:

$$V(t) = \Sigma_p [\ \eta(p,t)\ \varepsilon(t)\ R(t).\ dA]$$

which we can write as:

$$V(t) = \Sigma_p[\eta(p,t)/P]\ .P\ dA.\ \varepsilon(t)\ R(t)$$
$$= g(t)\ C_G\ .\ \varepsilon(t)\ R(t)$$

where:
$g(t) = \Sigma_p[\eta(p,t)/P]$ the averaged value of $\eta(p,t)$ at time t for all $p \leq P$;

C_G m^2 is P dA, the conventionally-defined geographically-fixed catchment area; and

$\varepsilon(t)$ $R(t)$ m/day is the daily effective precipitation.

The function $g(t).C_G$ m^2 is here defined as the effective catchment area.

Note that increases in the effective catchment area can be the result of an actual physical expansion of the land area contributing to run-off, but also the result of land within the established catchment area becoming less effective at absorbing the precipitation thereby also increasing run-off. It can also be a result of the lake reaching its overflow level, thereby adding land upstream of the lake to the catchment area.

Evaluation

For the sake of discussion, suppose that g(t) has the form:
$g(t) = 1 - \exp(-\Sigma_t[\varepsilon(t)\ R(t)]\ /G)$

that is:
—at the start of the season g(t) is 0 by virtue of $\exp(-\Sigma_t[\varepsilon(t)\ R(t)]) = 1$ for $t = 0$
at this moment all of the precipitation that is not evaporated or used by vegetation goes into the ground to dampen the soil and recharge aquifers or the lake

—as the season progresses, the fraction of the precipitation lost decreases exponentially (for mathematical convenience) with a decay constant of G metres of accumulated precipitation. When aquifers are fully charged and the soil saturated, all of the precipitation not evaporating or used by vegetation, which is mostly dormant in the wet season, is available as run-off to the creek or lake.

We can then write the accumulated flow of water into the lake $\Sigma_T V(t)$ m^3 from time t = 1 to T as:

$\Sigma_T V(t) = \Sigma_T[\ \varepsilon(t)\ R(t).\ g(t)\ C_G]$
$= \Sigma_T [\varepsilon(t).R(t)\{1-\exp(-\Sigma_T[\varepsilon(t)\ R(t)]/G)\}C_G\ ]$

Among the measured variables are V(t) and R(t).

The function $\varepsilon(t)$ can be estimated based on seasonal mean parameters including relative humidity, temperature, and wind velocity. See File 673t for details.

The constants G and C_G are unknown and have to be found by matching the value of function
$\Sigma_T V(t)$ with the value of $\Sigma_T V(t)$ actually observed at various stages in the wet season—that is for various values of T.

The purpose of using cumulative flow and cumulative precipitation less evapotranspiration rather than the day-to-day terms is that it conveniently filters out short-term variations that are of no interest. Correlating short-term variations can easily be complicated by short-term delays of only a few days that are again of limited interest.

In the graphs in the main text, t = 0 corresponds to July 18, 2015 in the middle of the dry season so a complete cycle includes the whole of the wet season.

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