
Looking for springs using a thermocouple

2001 Deschutes Groundwater Inflow Survey

Deschutes River, Thurston County, Washington

February 2002


Taking flow measurements

Thurston County Department of Public Health and Social Services,
Environmental Health Division, Resource Protection Section
Thurston County Department of Water and Waste Management
With funds provided by the WRIA 13 Watershed Planning Project

Background

Maintaining base stream flows in the Deschutes River, Thurston County, Washington, has been a growing concern as land development and groundwater withdrawals increase. In 1995, the Washington Department of Ecology released a document describing water quantity/water rights issues for WRIA-13 (water resource inventory area), which includes the Deschutes River (Pacific Groundwater Group, 1995). In 1996, the Washington Department of Ecology denied several water right applications, based on the potential impact to base flows of the Deschutes River, including requested rights for the public water supply for the town of Rainier,

Segments of the Deschutes River have been identified as having elevated water temperatures during the low-flow period. It was documented during a water quality study of the watershed conducted by Thurston County during 1991 (Davis and others, 1993). A more intensive assessment of water temperatures in the river, by the Squaxin Island Tribe, further defined the river segments exhibiting temperature violations and the duration of the violations (Schuett-Hames and Child, 1996). It is anticipated that increased groundwater withdrawals from shallow aquifers in hydraulic continuity with the river will decrease base flows during summer months, exacerbating existing water temperature problems.

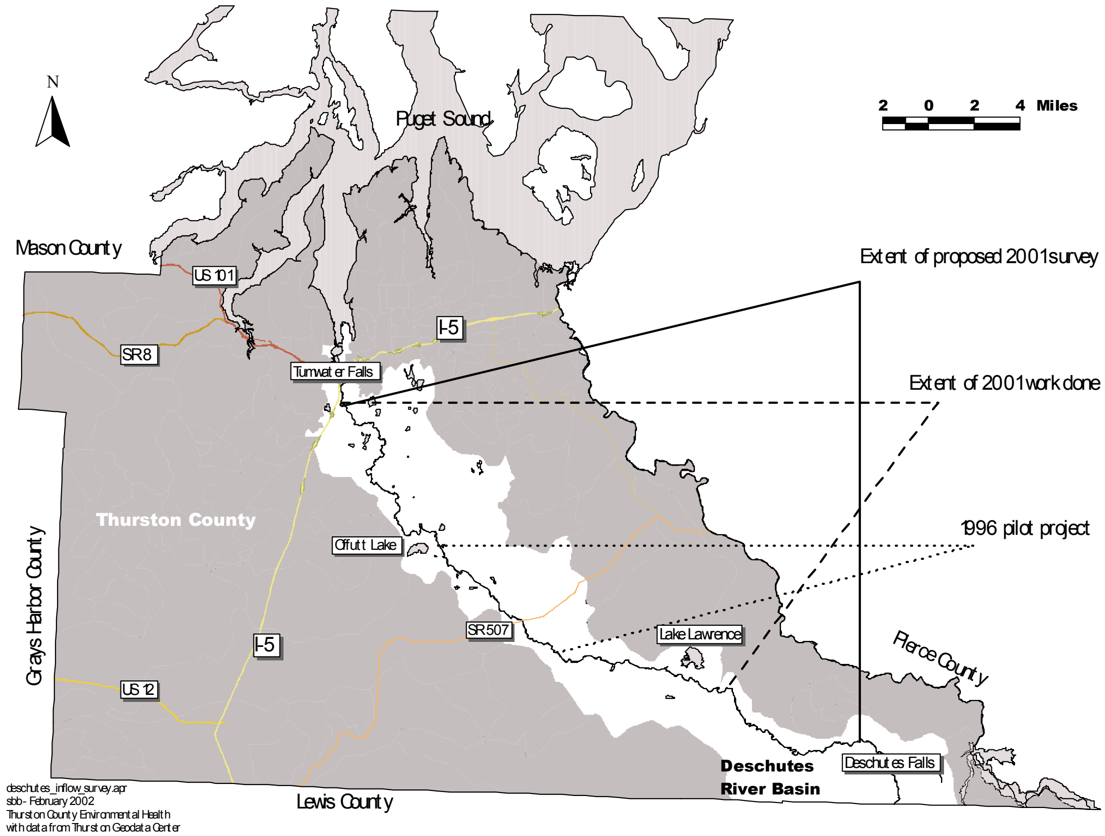
In 2001, the WRIA 13 Technical Sub-Committee recommended a groundwater inflow study to support development of the WRIA plan and build understanding for long-term water management in the watershed. On August 3rd, the WRIA 13 Planning Committee approved the project.

Project objectives

Preliminary work on the ground and surface water interactions of the Deschutes River was conducted in a pilot project in 1996 by the Thurston County Department of Public Health and Social Services, Environmental Health Division, Resource Protection Section (Mead and Davis, 1997). The results of that effort were incorporated into this report.

The objective of the 1996 pilot project was 1) to develop a technique to identify areas of major groundwater contributions to a stream system, and 2) to begin to identify specific segments of the Deschutes River receiving major groundwater inputs which are sustaining base flows. This project examined a section of the Deschutes River between Offutt Lake and just south of State Route 507 (river miles 14 to 22)(Figure 1).

The 2001 project proposed to examine the rest of the Deschutes river, from the Tumwater Falls (river mile 2) to the Deschutes Falls (river mile 41)(Figure 1), using the 1996 methods. In order to quantify the amount of water the river either gains or losses to groundwater, a seepage run[1] was



to be

Figure 1 – *The Deschutes River Watershed, Thurston County, Washington. The 1996 pilot project area, as well as the 2001 proposed and completed survey areas are shown*.

conducted at the end of the project. This would entail taking flow measurements at seven bridge crossings used in previous seepage runs (to compare against), as well as adding new flow sites based upon the locations of springs and major losing reaches.

Project Design

[1] A seepage run consists of measuring the flow of the river at several locations along its length, including any sources of input, such as tributaries. Comparisons are then made between adjacent flow stations, looking for changes in flow volume not accounted for by the tributary inputs (if there area any between the stations). Such changes are presumably a result of seepage into or out of the river. If between station “A” and “B”, there is a 10 cubic feet per second (cfs, or about 7.5 gallons per second) difference, and the tributary in between has a flow of 8 cfs, then the assumption is that 2 cfs of groundwater has seeped into the river between “A” and “B”.

The section of river selected for the 1996 pilot project was from river mile 14, just north of Offutt Lake to river mile 22, south of State Route 507 (Figure 1). This river segment was selected using data from two seepage runs, conducted in August 1988 by the U.S. Geological Survey and September 1993 by Thurston County, and U.S. Geological Survey topographic information (7.5 minute topoquads, 1:24,000 scale), all of which indicated that this was a gaining reach with major groundwater contribution. Contrary to what would be expected in reaches with groundwater input, however, segments within this reach had frequent and occasionally prolonged temperature violations (Schuett-Hames and Child, 1996).

The general approach taken was to walk or float (in a small inflatable raft) along the river edge during the low-flow period in August and September of 1996, searching for variations in water temperature and signs of seepage in the stream bed or banks. An Atkins[2] Model #39658-K® rapidly equilibrating thermocouple thermometer, with the thermocouple attached to a pole, was used to probe the river bottom and seepages along the shoreline. Areas where groundwater was discharging to the river were found by the several degree drop in temperature at those locations.

A Trimble Pro XL® global positioning system unit was used throughout the field work to record the locations where field measurements were taken and where areas of temperature differentials were found.

In some locations where a temperature differential was identified, the specific conductivity of the river and the incoming water was also measured using a Yellow Springs Instrument S-C-T model 33 meter. This was done to determine if the specific conductivity of the river and the incoming groundwater were sufficiently different that this parameter could also be used to identify gaining reaches. Use of the conductivity probe was shortly discontinued; for much of the river, the incoming groundwater had conductivity values similar to the river and therefore conductivity could not be used as an effective indicator of groundwater inputs.

To track normal daily temperature variations in the river, a HOBO temperature data logger (Instrument #272) was placed in the river at one location. The site of the logger was at approximately river mile 19.5, just downstream of the Military Road bridge. The data logger was fixed below the river surface along the west bank in an area of flowing water that was shaded from the sun. At the outset

[2] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by Thurston County.

of the project, it was unknown how significant the daily river temperature fluctuation would affect the ability to detect areas of temperature difference. The logger was used for the first 2 days of the field work, until it was determined that information was not essential in detecting areas of differing temperature.

In sections where there was no indication of springs or groundwater up-welling into the river, piezometers were used to determine if the river was losing water to the groundwater system. At various random locations in these areas, a piezometer was driven into the river bed. The piezometer was constructed of one-half inch iron pipe with one-eighth inch holes drilled in an alternating pattern around the lower six inches of the pipe. The bottom of the pipe was fitted with a bolt to prevent sediment from entering the pipe as it was driven into the river substrate. After allowing 5 to 15 minutes for the water level inside the piezometer to equilibrate, the river water level outside the piezometer and the water level inside the piezometer were measured and compared. An inside water level reading less than the outside river level indicated a loss in head or a losing reach of the river.

The placement of piezometers relative to pools and riffles may have an effect on the readings obtained. Streams are often a succession of pools and riffles, with the pools having a flat water surface and the riffles having a sloped water surface. The groundwater table that is interacting with the stream is generally a more smoothly sloping surface (Figure 2). To get reliable results, a piezometer needs to be installed at several locations within a reach or select areas that are long glides (flowing water with little riffle). For the 2001 project, the later approach was used.

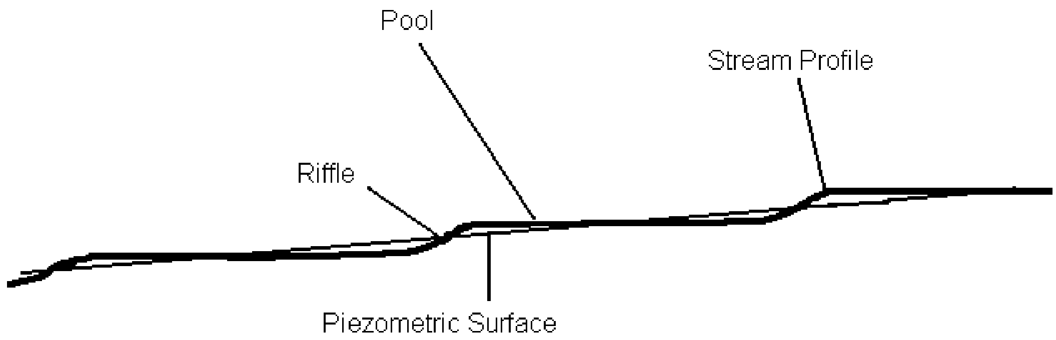


Figure 2 - *Idealized diagram of the relationship of the groundwater piezometric surface to stream pools and riffles.*

2001 Inflow Survey Design

The scope of the 2001 project was to survey a majority of the length of the Deschutes River, from the Tumwater Falls, up 40 river miles, to the Deschutes Falls. As indicated in Figure 1, the 2001 survey only made it from the Tumwater Falls to around Cougar Mountain area (about river mile 32) due to time/budget constraints.

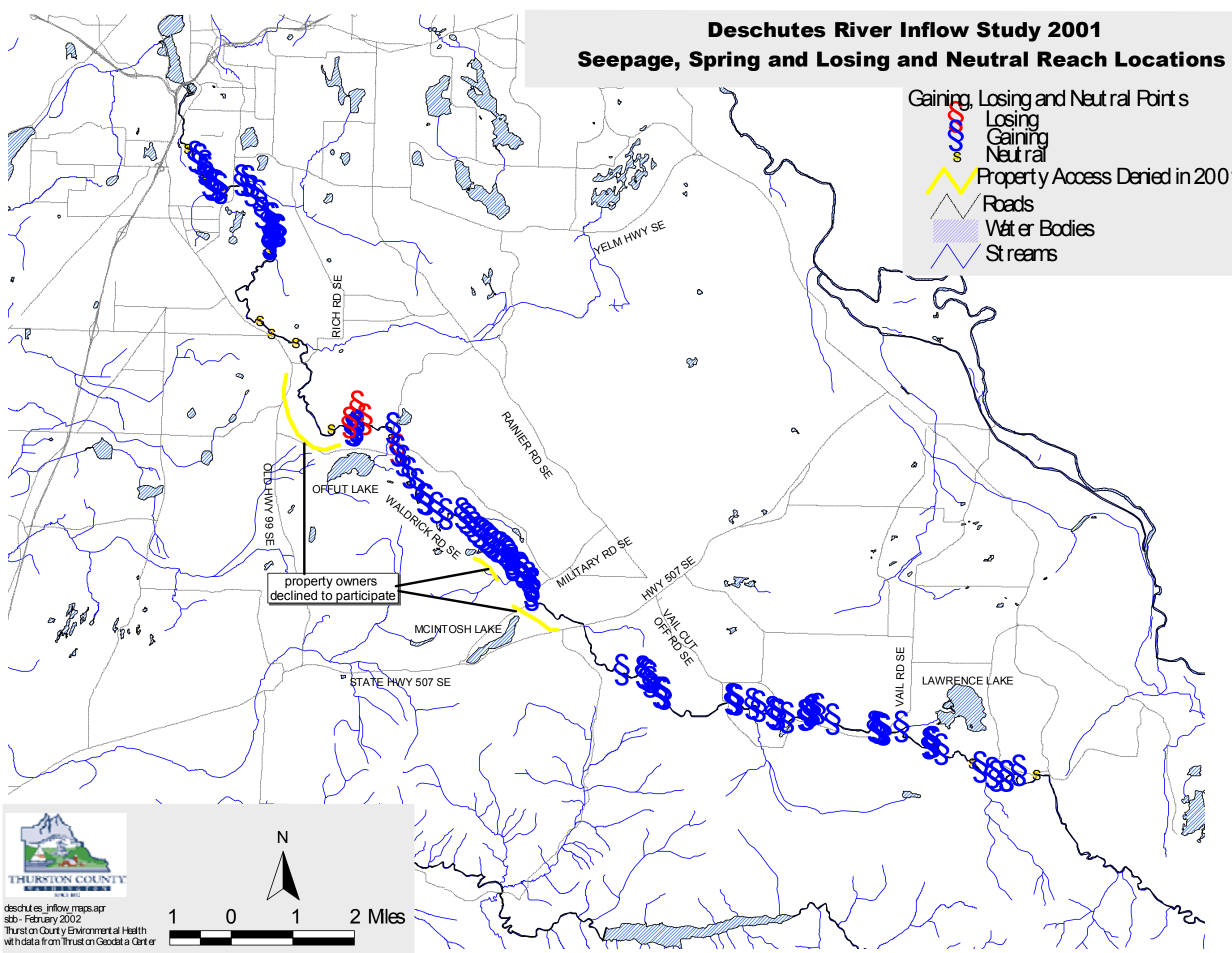
Using the methods developed for the 1996 project, an Atkins thermocouple was attached to a pole and used to probe the river banks and bed for temperature differences, while a piezometer was used to determine if reaches of the river were losing water or were neutral.

After the seeps, springs, and losing reaches had been located, flow measurement locations were chosen for a seepage run. These locations included the 14 mainstem and tributary stations used in the three previous seepage runs conducted by the U.S. Geological Survey and Thurston County, as well as eight additional stations located near concentrations of seeps and springs. The seepage run was conducted in the first week of October, 2001.

The HOBO temperature logger was also not used as in the 1996 project as it was easier and quicker to use the Atkins to record the river water temperature near the location of the seepage and have a more rapid ability to identify a significant change in temperature. Instead, pairs of HOBO's were used in two locations to confirm gaining and losing reach designations (see page 10 and Figure 8 for more details). Finally, a GPS unit was not used in the 2001 project due to the equipment cost, in addition to the presence of digitized high-resolution color aerial photography of the County, taken in May 2000. Waterproof copies of these photos were used in the field to record seepage locations.

Results

The outcome of this project was to be an improved understanding of the surface and groundwater interactions of the Deschutes River. Since 2001 was considered a drought year[3], it was considered a good time to be in the river when it was at very low levels (and hopefully expose more seeps and springs along the shoreline). It was also envisioned that additional seepage runs would be performed in the following years to relate the river-groundwater interactions to varying rainfall conditions, such as the above average rainfall winter of 2001-2002.



[3] The total rainfall in the Olympia area in the 2000-2001 water year (October-September) was 32.8 inches, compared to an average of 50.6 inches. The 2000-2001 rainfall total was the lowest rainfall on record (starting in 1948) (NOAA, 2001).

Figure 3 - *Points of gains and losses from the Deschutes River. Some of the property that was not accessible in 2001 had already been surveyed in 1996*.

Both the 1996 pilot project and the 2001 project were conducted between August and October. The projects had these components: 1) walk up the bed of the river, using a temperature probe to identify groundwater inputs (colder springs); 2) use a piezometer to identify area of the river that were "losing" or "neutral" ; and 3) (for the 2001 project only) measure flow at several locations along the river to quantify the volumes of water entering and exiting the river. Figure 3 shows the locations of the springs, losing and neutral areas and the flow measurement sites. The pictures on the cover show the temperature probe and flow equipment used.

Temperature Differences

The Deschutes River temperature ranged from 11 to 16 degrees centigrade during both the 1996 and 2001 surveys. The groundwater seeps and springs ranged from 9 to 11 °C. The temperature difference between the seeps and springs and the river water was generally between 2 and 4 °C. In a number of areas, the springs were also visually identified by growths of algae and/or iron oxides staining the river banks (the iron, dissolved in the cold, low-oxygen groundwater, hits the warmer and well-oxygenated river water and precipitates out as rust).

The seep and spring locations were marked on 2000 aerial photographs of the area and digitized into an ESRI ArcView® 3.2 shapefile. Figure 3 shows the location of the seeps and springs.

Piezometric Differences

When using the piezometer, the level difference in water levels (the river level compared to the level inside the metal tube) was generally a few centimeters (2-3). In one gaining reach north of Waldrick Road, the level inside the pipe was 20 cm (8 inches) above the river level. The locations where piezometric measurements were made were marked on the same aerial photos as the seeps and springs and digitized into shapefiles as well. Figure 3 also shows the locations of losing or neutral reaches determined by the piezometric measurements.

Flow Measurements

Flow measurements were taken at 22 locations along the river and its tributaries over a three day period (a seepage study) in October 2-4, 2001. In order to examine the gains and losses of river flow due to groundwater interaction, the tributary flows were subtracted from the closest downstream river flow site.

Figure 4 shows the reaches (as separated by flow stations), with the gain or loss in cubic feet per second listed near the downstream end of each reach. The values from common locations were compared against previous seepage studies done in 1977, 1988 and 1993 (seven of the 22 locations) (Figure 5). In addition, the seven common stations flow measurements for 2001 were compared to all of the 2001 mainstem flow stations in Figure 6.

There were three areas of major groundwater inputs to the river. Starting upstream: the area just north of State Highway 507, the area just north of Offutt Lake, and the vicinity of Rich Road and Henderson Boulevard.

The gain of 10.5 cfs (a 44% gain) between SR 507 and Military Road SE remains without a clear understanding of where the water is coming into the river. During the 1996 study, no springs were identified in the area, and for the 2001 survey, the property owner declined to grant the County access through the property. In this instance, the closely spaced bridge crossings proved useful in identifying the area's significant gain in flow. Without property owner permission, it will be difficult to gain further insights into this area. It is clear, however, that just downstream, in the Silver Springs area, there were over 30 identified springs within a 2.5 mile stretch of the river (labeled as point "C" in Figure 7).

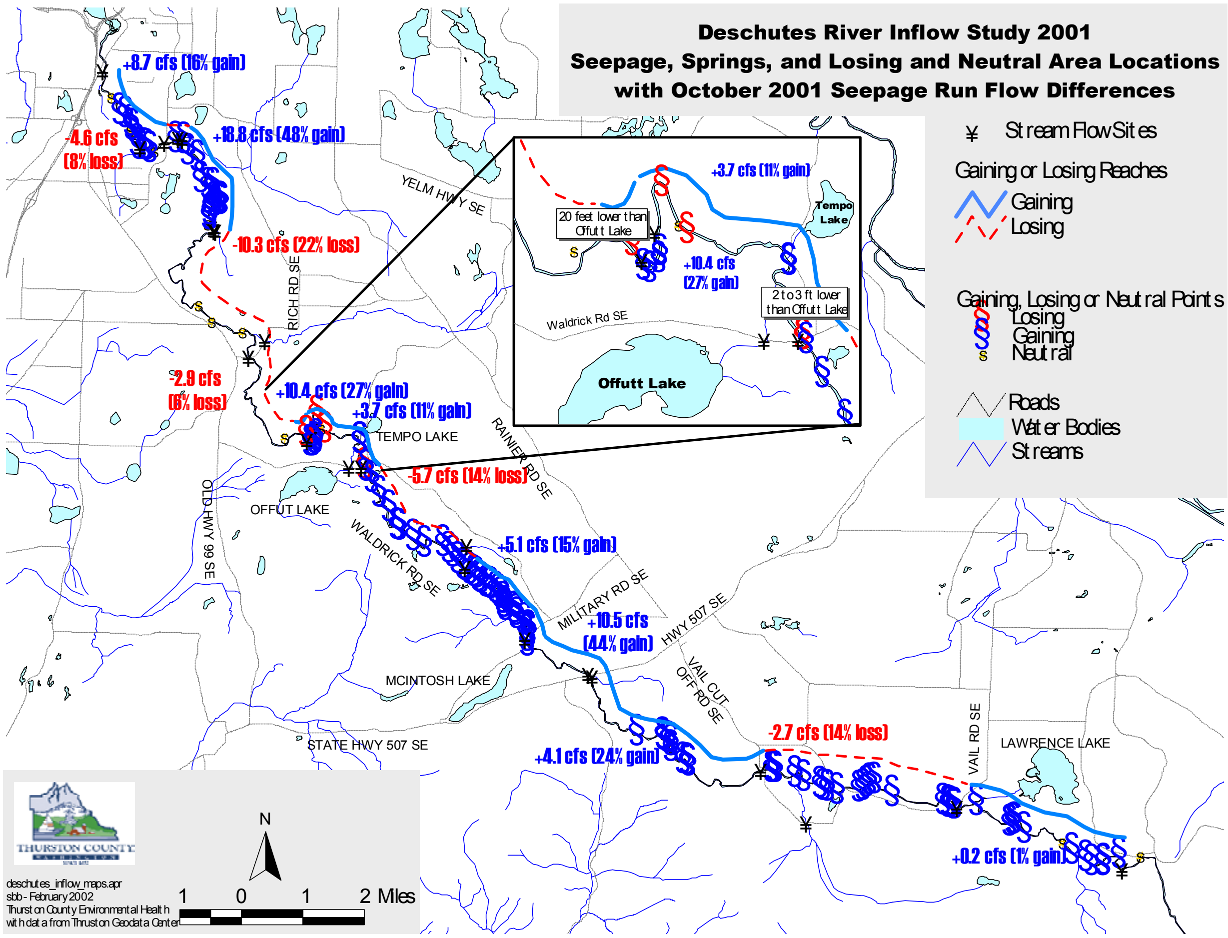


Figure 4 - *Gaining and losing reaches of the Deschutes River. The gains or losses are displayed near the downstream end of each reach (percent of gain or loss compared to the total flow of the upstream station in parenthesis)*.

As shown in the inset of Figure 4, just north of Offutt Lake, a small, quarter-mile long reach gained 10 .4 cubic feet per second (a 27% gain) from several large springs on the outside of a river-bend, just north of Offutt Lake. Although Offutt Lake has a stream outlet that flows eastward to the river, the elevation difference between the lake and the river to the east is 2-3 feet. In contrast, the elevation difference between the lake and the river-bend directly to the north is twenty feet. The geologic materials at the surface around Offutt and Tempo Lakes, and river in the vicinity are Vashon Recessional outwash (sands and gravels), underlain by glacial till (hardpan)(Dion and others, 1998), leading to the presumption that Offutt Lake water flows downhill through the gravels to the Deschutes River. There were also significant springs located near Tempo Lake, which sits 30 feet higher in elevation than the river.

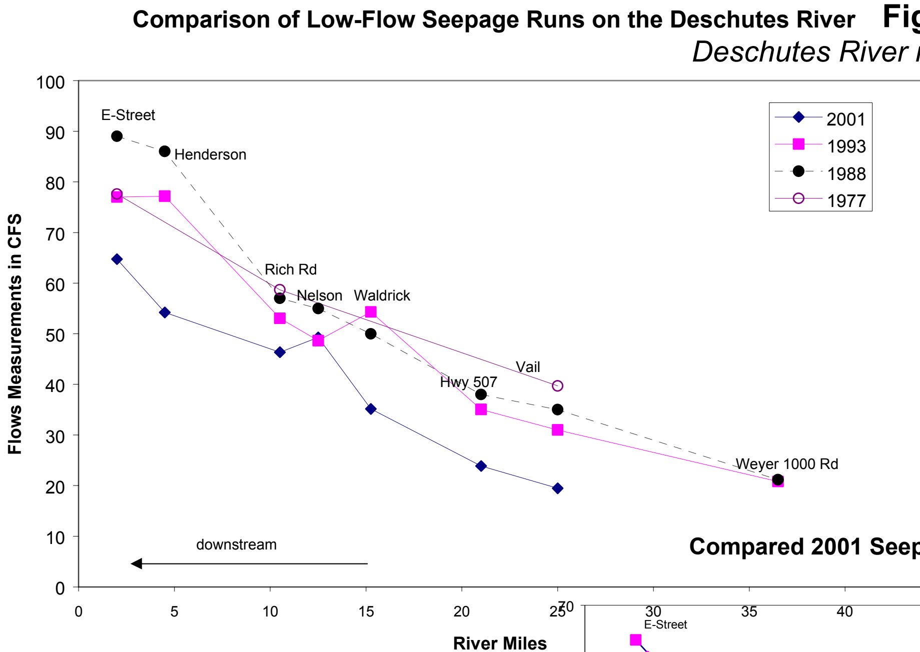


Figure 5 – *October 2001 Deschutes River mainstem flow values compared with flows taken from previous seepage runs*

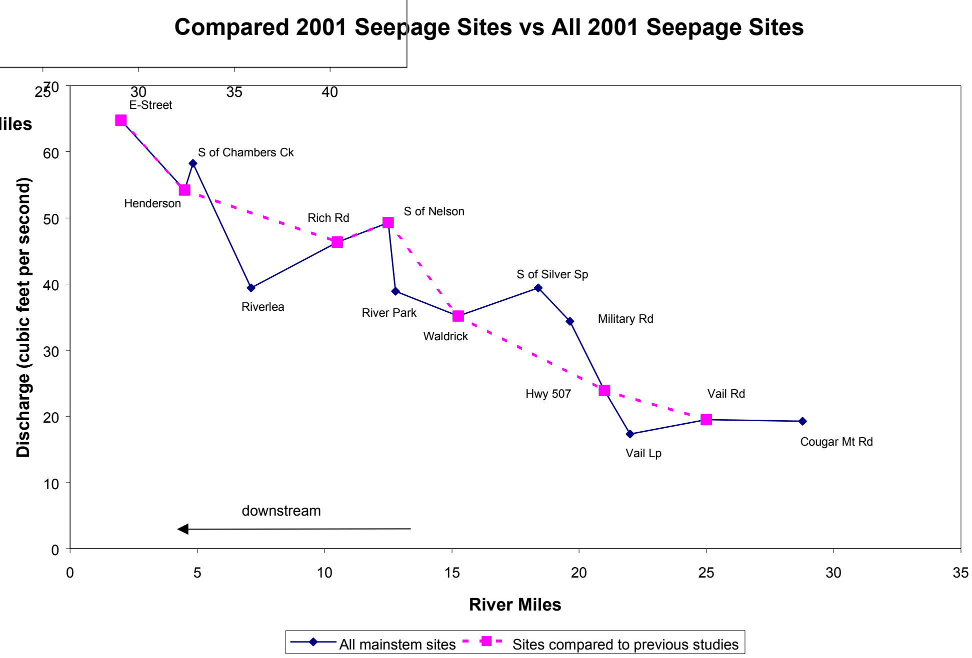


Figure 6 - *2001 flow sites that were in common with previous seepage runs (mainly bridge crossings), compared to the entire set of flow sites measured in 2001. Note the mainstem flow gains and losses that were not represented by the sites common to previous seepage runs.*

Figure 7 shows the springs compared to the areas where glacial till and bedrock is present. The large number of springs (and corresponding gain of 18 cfs) that were found between Rich Road SE and Henderson Blvd. SE correspond well with the lack of till in that area. The large groundwater influx is assumed to be from the Vashon Advance aquifer, previously confined by till to the south. This influx of groundwater to the river is also identified by groundwater flow directions mapped by the US Geological Survey for that area (Dion and others, 1998).

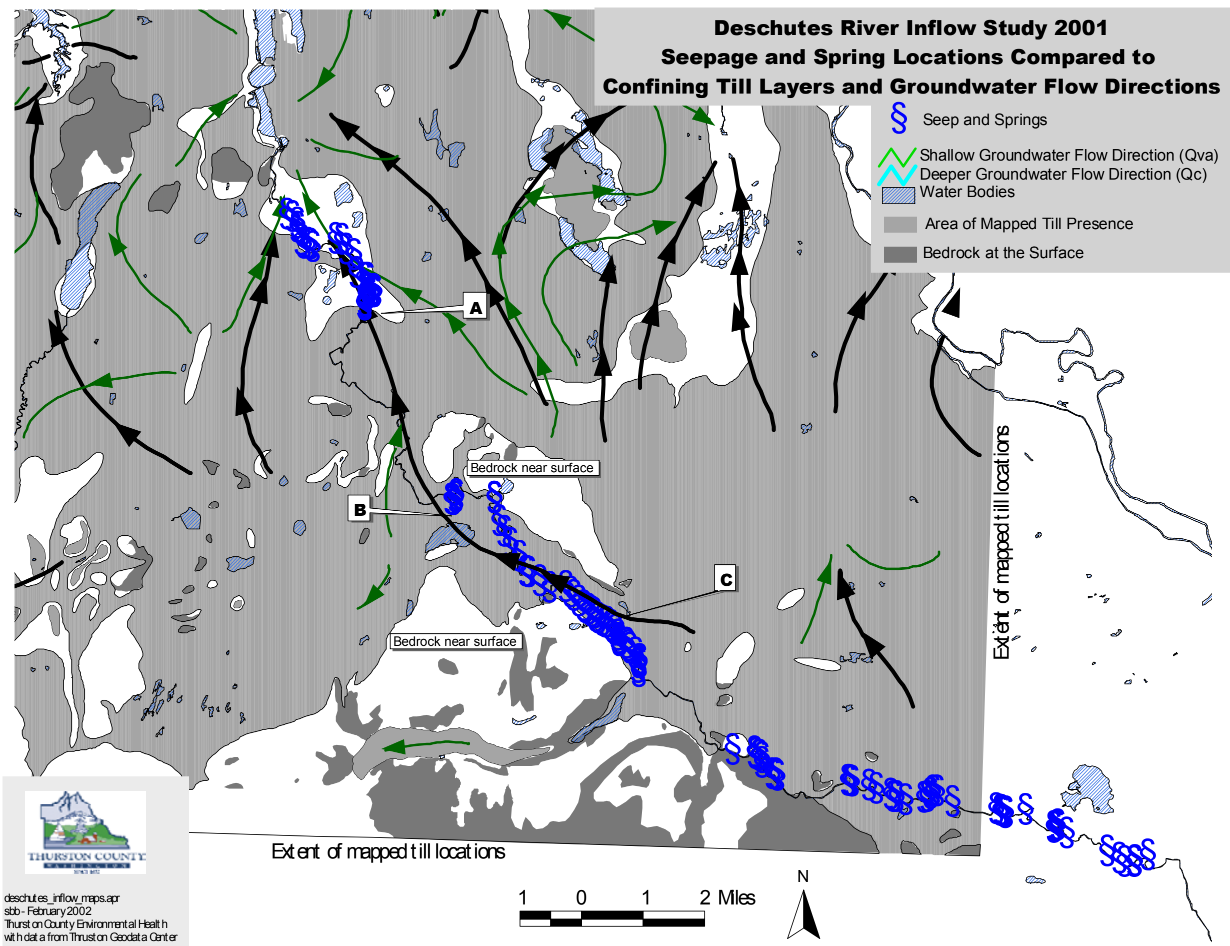


Figure 7 – *Spring locations and the area underlain by till or bedrock. Note the presence of a large number of springs at "A", where the till layer stops and water from the Vashon Advance aquifer can drain into the river (this reach gains over 18 cfs (a 48% gain). "B" and "C" are at either end of a channel created by bedrock hills. Large amounts of groundwater are funneled from prairie to the east through this channel and continue along the Deschutes River floodway.*

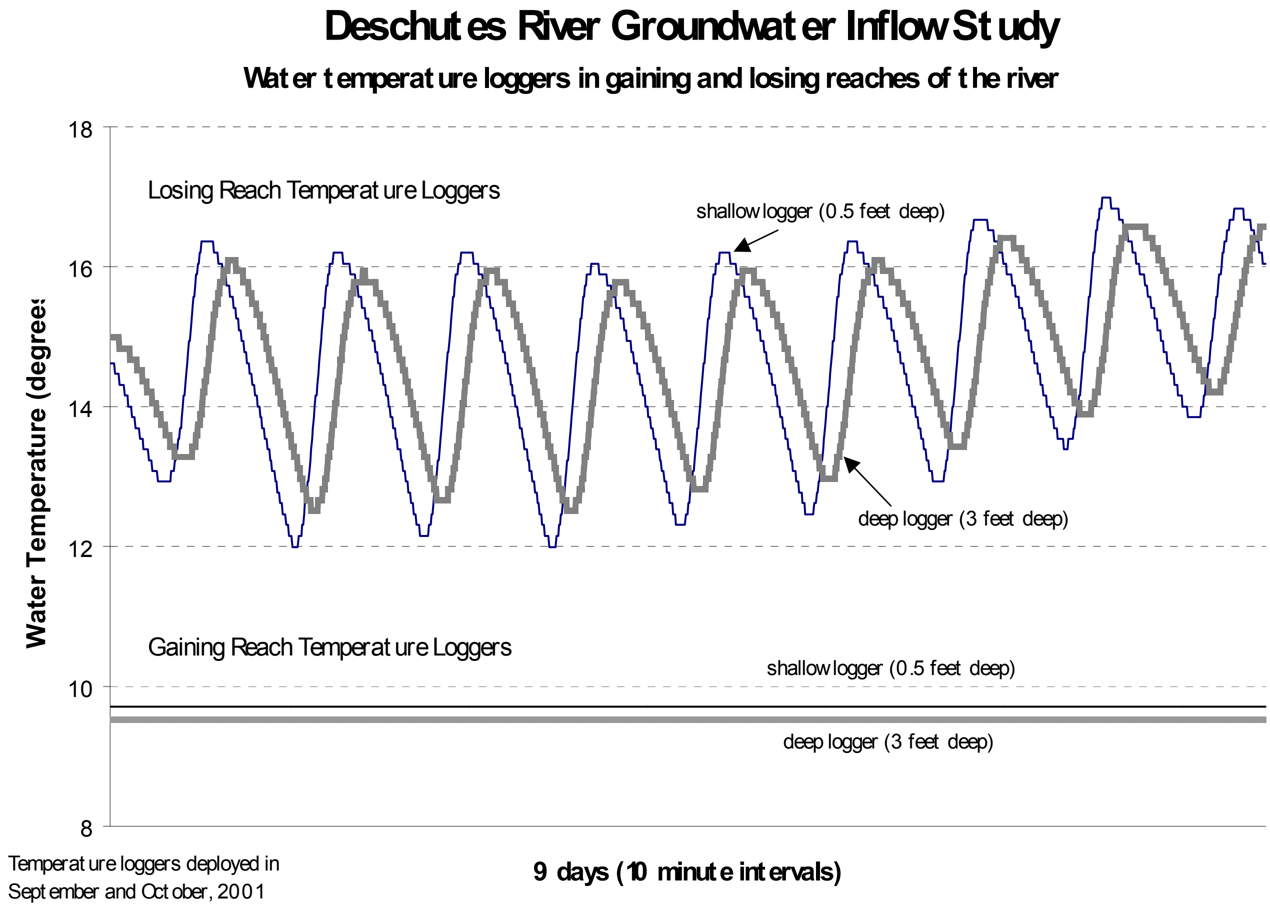


Figure 8 – *Plots of the temperature loggers in gaining reaches (the lower set of temperatures) and a losing reach (the upper, fluctuating set of temperatures).*

Temperature Loggers

Pairs of temperature loggers were placed in the river bed at a gaining and a losing area of the river (both near Waldrick Road SE). One logger was placed about 0.5 feet into the river bed, while the other was placed at 3 feet below the bed.

In theory, in a losing area river water is traveling down through the river bed and the deep logger should show a similar temperature changes as the shallow one (i.e., daily temperature changes due to sunlight warming followed by night-time cooling). The data collected by the HOBO temperature loggers displayed exactly that. There was about a four hour lag in temperature changes in the deep logger compared to the surface, and the deep logger temperature highs and lows were about half a degree less than the surface highs and lows (Figure 8).

In a gaining area, the expectation is that there would be less temperature fluctuations and the water would be colder than the

river in general. In this case, the volume of groundwater entering the river was large enough to completely mask any daily temperature changes due to solar heating and cooling.
Data from the temperature loggers from the gaining and losing reaches was as expected and help confirm the gaining/losing designations based on piezometric differences and spring identifications. Use of the temperature loggers would be very helpful in areas that have the potential to change between gaining or losing reaches based on changes in rainfall and/or seasonal fluctuations in the groundwater levels relative to the river levels.

The main drawback to using the temperature loggers in this manner is the lengthy installation time needed. It took about six hours to time to dig a hole large enough to place the deeper logger 3 feet down in gravel, and required the same amount of time to recover the loggers. Improvements need to be made in the installing the loggers while maintaining the temperature isolation between the shallow and deep loggers. A modified piezometer that could be pounded into the gravel is a possible solution.

Conclusions

- Stream surveying using a combination of visual seepage observations and temperature measurements provides an effective tool for qualitatively determining whether or not a stream is gaining flow from ground water. This procedure is most effective and practical where the stream is shallow enough to be surveyed by wading and where the stream banks are unvegetated enough that seepage can be observed.

- The gains and losses of flow from the Deschutes River to groundwater vary greatly, sometimes over a very short distance (i.e., around Offutt Lake).

- It is necessary to conduct additional seepage runs under different rainfall conditions. This will allow a better correlation between annual rainfall and the groundwater and surface water interactions. These interactions affect river levels and river temperature. With the spring locations identified, it would take a modest amount of effort to improve our understanding of how the river interacts with groundwater and how both are affected by changes in annual rainfalls by conducting additional seepage runs.
  - The intensive seepage run done in 2001 was conducted when rainfall was 20 inches behind average (the lowest on record from 1948). Making additional seepage runs under near average and above average rainfall years will greatly improve the quantification of gains and losses of groundwater to and from the river.
  - Previous seepage studies were based on convenient bridge crossings due to time or budget constraints. When compared to the 2001 seepage run, it is obvious that large gains and losses were not accounted for by the previous flow studies.
  - This year was one of the driest in recorded history. Additional seepage runs at the 22 sites conducted in future years under average and above average rainfall conditions would document how the gains and losses change under different hydrologic conditions.

- Some spring concentrations are well correlated with geological features, such as the lack of a confining till layer between Rich Road SE and Henderson Blvd. SE. and the resulting influx of groundwater from the Vashon Advance aquifer.
  - The concentration of springs north of Military Road SE matches up with a large drainage channel that was fed by glacier melt-water and flows from Rainier (as a result of the glacier blocking drainage to Puget Sound).

- The 10 cfs gain north of Offutt Lake, as well as the smaller gain south of Tempo Lake appear to be drainage from these lakes into the river (which is 20-30 feet lower in elevation) through the gravels and sands left by the glacial retreat.

- The area around Offutt Lake changes rapidly from gaining to losing and back. Further study of this area is desired. This would include more frequent piezometer and flow measurements between Waldrick Road SE and the River Bend neighborhood. The drainage north from the lake to the river takes on more importance in light of the logjam and the reported increase in Offutt Lake levels; it is presumed that would the increase in lake levels would result in greater flow of water northward through the sand and gravels of the outwash soils to the river. This could possibly mitigate the amount the lake level rises as an affect from the logjam (backing up water from the lake's outlet stream).

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