Spokane River Temperature Profile, Barker Road to Plantes Ferry Park, September 2005

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Spokane River Temperature Profile, Barker Road to Plantes Ferry Park September, 2005

by
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Water Resources Program
Eastern Regional Office

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Abstract

A profile of river temperatures was gathered from the Spokane River on September 20, 2005. This dataset was obtained using instrumentation programmed to take temperature, depth, and location measurements on frequent intervals while floating between Barker Road Bridge and Centennial Trail Bridge below Plantes Ferry Park in Spokane Valley, Washington. While the results of this profile confirm the Spokane River is recharged by the Spokane Valley Rathdrum Prairie Aquifer beginning near the location of Sullivan Road, data suggests the most significant volume of discharge of aquifer water to the river occurs near Mirabeau Park.

The technique, given proper ambient data gathering, can be used to assess aquifer/stream interaction and provide flux estimates in gaining reaches.

Acknowledgements

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Introduction

Understanding the hydraulic relationship between the Spokane Valley Rathdrum Prairie Aquifer (SVRPA) and the Spokane River is one of the key elements in water resource management in the region. Locating and describing the nature of where the Spokane River changes from a losing stream to a gaining stream is important in predicting flows necessary for habitat, aesthetic, economic, and regulatory reasons.

Water temperatures in the Spokane River are the product of numerous factors. Major influences include air temperature, Coeur d'Alene Lake temperature, solar input, total flow, and ground water input. Miscellaneous water temperature measurements collected longitudinally downstream from the Post Falls Dam have demonstrated that in gaining reaches, where cooler aquifer water discharges into relatively warmer surface water (warmed by impoundment behind Post Falls Dam), surface water temperatures can be significantly lowered.

Previous Work

Temperature data have been gathered by various entities on the Spokane River for years. Most recently, published studies of temperature in the Spokane River have focused on data gathering for predictive modeling of water quality conditions. See, for example, Golder Associates, Inc., 2004; Golder Associates and HDR Engineering, Inc., 2004; and Golder Associates Inc. and HDR Engineering, Inc., 2003. Golder Associates and HDR Engineering Inc.(2004) published data indicating the highest water temperatures in the river reach affected by the Post Falls Dam occur during lower flows in August. They noted that surface temperatures between the Post Falls Dam and Upriver Dam locations vary naturally 1 to 5^{o}C daily, with the greatest fluctuations in free flowing, shallower river sections.

Caldwell and Bowers (2003) noted that temperature was a useful tracer of river recharge to the aquifer system in the losing portion of the Spokane River. They concluded that water from the river recharged the aquifer system rapidly, but that temperature influence from the river recharge in the aquifer was generally restricted to a narrow area adjacent to the river. They observed that temperature variability was low outside this area of stream influence within the aquifer while the river temperatures vary widely.

Synoptic streamflow measurements have documented that the Spokane River from Post Falls Dam to Flora Road is a losing reach. River discharge measurements collected during the summer low flow months indicate consistent losses of more than 300 cfs to the aquifer along this reach. Between Flora Road and Plantes Ferry Park, river flow significantly increases, especially during the summer low flow months when flow in the river can more than double along this reach. During the summer months when river stage is at its lowest, numerous groundwater springs can be observed discharging into the river in the vicinity of the Sullivan Road Bridge and along the north riverbank in Sullivan Road Park. The elevations of the aquifer and the river bottom intersect in this reach. Together these factors support the assumption that the Sullivan

Road Bridge area is the general boundary between losing and gaining reaches of the Spokane River. Figure 1 is a location map of the area.

Recently, the United States Geological Survey employed data loggers and global positioning system technology in measurement of longitudinal surface temperatures in streams. Vaccaro and Maloy (2005) evaluated the technique on the Yakima River. That study found that long longitudinal temperature profiles of river systems could provide new perspectives on both biological habitat and ground water-surface water interaction.

This study reports the data from a temperature profile study conducted on the Spokane River on September 20, 2005 between Barker Road and the Centennial Trail Bridge below Plantes Ferry Park (Figure 1). The object of the study was to gather a longitudinal profile of temperature data, and to evaluate the technique as a method of locating and evaluating the nature of the aquifer/river interaction in the Spokane Valley. This information was gathered to be incorporated into the data set being used to construct a numerical model being prepared jointly by United States Geological Survey, Idaho Department of Water Resources, and Washington State Department of Ecology.

Methods

Data on temperature and water depth were gathered using a Solinst® Levelogger® Model 3001 towed in a protective plastic housing behind a single-seat inflatable pontoon craft. Location data was gathered and logged for time using a Trimble® GeoXM™ using TerraSync™ and Geoexplorer® CE software. Data gathering specifications are described in Table 1.

Temperature and depth data were gathered by dragging the Levelogger® in a protective housing behind the pontoon craft as it was piloted downstream. Generally, the craft was kept near the center of the stream. The GPS unit was carried aboard the pontoon craft. The housing assembly was attached to a rope approximately eight feet long, gathering temperature and depth measurements every six seconds. The GPS unit recorded position every 30 seconds. Raw data were evaluated and reduced. Table 2 contains temperature and depth measurements corresponding to the GPS located points, illustrated on Figure 2.

Data on ambient ground and surface water conditions was gathered during the study period by Levelogger® units located within the project area. Surface water data was collected from the Spokane River at a temporary gauge established at the Post Falls gauge (USGS 12419000) and at a site in the Spokane River downstream from the Sullivan Road Bridge. Those data are presented in Table 3 and illustrated on Figure 3. Ground water data (Table 4) comes from wells near Mirabeau Park (Bowdish and Frederick 208 well USGS 474134117143202, 25N/44E-04J02D1) South of the River (2nd and Best USGS 473918117124201, 25N/44E-23C01) and near Sullivan Road (Krispy Kreme, USGS 474019117114801, 25N/44E-11R04 and Sullivan Park South, USGS 474026117115301, 25N/44E-11R02). All these stations collected data on synchronized six-minute intervals (Covert et. al., 2005).

River discharge during the period is available from the Post Falls gauge (USGS 12419000), Harvard Rd. (USGS 12419500), Barker Road, (USGS 12420500) and the Spokane at Spokane gauge (USGS 12422500). These data are on 15-minute intervals in Table 5.

Results

Ambient Conditions

The study was conducted on September 20, 2005. Data collection began approximately 11:00 AM Pacific Daylight Time, and ended at 2:30 PM. High temperature for the day at the Spokane Airport was 68°F, the day's low humidity of 24% was recorded at 2:00 PM. Average sky cover was 0.2, and the average wind speed was 9.8 miles per hour from the west (National Weather Service, 2005).

Ambient surface water conditions were generally constant. Discharge varied only 10 cfs over the profile period at the Harvard Gage (Table 5). At Sullivan Rd., stage decreased 0.03 feet and temperature increased 1.24°C during the day, from just below 16°C to above 17°C (Table 3). Figure 3 illustrates stage height and temperatures for Sullivan and Post Falls data recorders.

Ground water head (Table 4) in wells adjacent to the area varied a maximum of 0.05 feet during the profile period. Temperature readings between loggers varied widely (a function of the equipment calibration), but within individual wells, temperature trends were fairly constant. Aquifer temperature averaged approximately 11°C. Both wells near Sullivan Road show readings below 12°C, thus ground water is at least 4°C cooler than surface water at this location.

Profile Conditions

The temperature profile data is illustrated on Figure 4. Effectively, two temperature profiles were collected: An upper profile beginning at Barker Road and ending as the data logger housing was caught between boulders in the Flora Road rapids; and a lower profile beginning at the Flora Road rapids ending approximately 40 feet upstream of the Centennial Trail Bridge near Plantes Ferry Park.

The initial profile, between Barker Road and Flora Road Rapids (collected between 11:15 and 12:04) shows a relatively constant temperature profile in Figure 5. Temperature varied only 0.14° C over the float period. This relatively high temperature in comparison with the temperature data taken from the Post Falls gauging station (Table 3), suggests this stretch is not receiving colder aquifer water.

During the period when the probe was stationary (12:04 to 12:53), the recorder documented an increase in river temperature at that location of approximately 0.36°C. This corresponds well with the rate of increase in ambient temperature noted at the Sullivan Road recorder (Figure 3).

Following resumption of the float, from 12:53 to 14:11, river temperature along the profile decreased 1.45°C. Figures 4 and 6 illustrate this abrupt drop. In the vicinity of the Sullivan Road Bridge, river temperatures cool because of discharge of colder aquifer water. At this location, the river cools at a rate of greater than 0.001°C/second. Below this location, in the vicinity of Mirabeau Park, a significant change in temperature is observed. Here, the cooling rate is greater than two standard deviations above the mean rate of temperature change observed along the traverse (Figure 8).

Beyond Mirabeau Park to Plantes Ferry Park, temperatures return to relatively steady conditions, yet still above the 10-11°C ambient aquifer temperature.

Discussion

River-Aquifer Interaction

River temperatures upstream from Sullivan Road are ambient conditions. They reflect the initial temperature of water discharged from Post Falls Dam, and temperature effects of solar heating and nighttime cooling, as well as streamside shading.

At Sullivan Road, the springs indicate groundwater discharge to the Spokane River. These springs have an immediate and direct cooling effect on the River temperature.

Below Sullivan Park until nearly Mirabeau Park, the rate of cooling is relatively steady. This suggests a constant flux of relatively small amounts of cool groundwater to the river. Approaching Mirabeau Park, the rate of cooling accelerates. At this location, the temperature of the river drops nearly 0.1°C every 100 feet.

Figure 7 compares the cooling rate with the temperature profile for the reach between Sullivan Road and Mirabeau Park. In general, the water cooling rate, expressed as a change in temperature per foot, is quite irregular. Local areas cool quite rapidly relative to the overall reach. Figure 8 illustrates these areas, highlighting those areas where the cooling rate is greater than one or two standard deviations from the mean. These areas experience the greatest change in ground water flux entering the river.

This cooling indicates significant discharge of aquifer water (~11°C) to the river. That discharge may be related to hydrogeologic conditions including the presence of the pre-Quaternary Pines Road Knoll, some local change in gradient or hydraulic properties of the saturated sediments, or other factors.

Flux estimation

A simple mass balance calculation suggests that the temperature mixing model closely approximates direct flow measurements of groundwater discharge.

A simple mass balance calculation was performed to estimate groundwater discharge to the Spokane River based on observed flow and temperature data.

$$\mathbf{Q_{(Barker)} * T_{(Barker)} + Q_{(ground\ water)} * T_{(ground\ water)} = Q_{(Plantes\ Ferry)} * T_{(Plantes\ Ferry)}}$$

Where:

$Q_{(Barker)}$ =(our closest flow measurement to the gaining reach starting at Sullivan) = 1390 cfs

$T_{(Barker)}$ = 17.2 C

$Q_{(ground\ water)}$ = X (the unknown)

$T_{(ground\ water)}$ = 11 C

$Q_{(Plantes\ Ferry)}$ = (1390 + X) cfs

$T_{(Plantes\ Ferry)}$ (as measured at Plantes Ferry Park) = 15.84 C

$$1390(17.2) + X(11) = (1390 + X)15.84$$

$$23908 + X(11) = 22018 + 15.84(X)$$

$$1890 = 4.8(X)$$

X = Groundwater discharge = 394 cfs

This simple mass balance calculation suggests that approximately 394 cfs of groundwater was discharging to the Spokane River on September 20, 2005 between Barker Road and Plantes Ferry Park.

As a part of the ongoing SVRPA study, two seepage runs along the Spokane River have been conducted by the USGS (one in September 2004 and again in August of 2005). Their miscellaneous discharge measurements collected at Barker Road and at Centennial Trail Bridge below Plantes Ferry Park show an average increase of 399 cfs between the two sites for low-flow, late summer conditions.

Conclusions

Temperature profile data reveals the discharge relationship between the Spokane Valley Rathdrum Prairie Aquifer system and the Spokane River. In late summer/early autumn conditions, the Spokane River discharges to the SVRP aquifer upstream from Sullivan Road. Downstream from this point, the river receives aquifer water. Flux from the aquifer to the river varies with location, increasing significantly near Mirabeau Park.

The technique of temperature profiling was effective at detecting ground water discharge to the Spokane River water in a situation where sufficient temperature differential exists between the two sources of water. Critical to this procedure's success was the significant contrast between the two sources' respective temperatures. We would expect it to work as effectively if relatively warm groundwater was discharging to much colder surface water (during winter conditions). We also discovered that it is important to allow enough time for the instrumentation to reach thermal equilibrium with the source water before beginning (approximately six minutes).

This technique provides data which can be used to estimate volume of ground water discharge to surface water using simple mass balance relationships if ambient data is available.

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Table 1
Data Gathering Equipment

Equipment	Model	Data gathered	Accuracy/Resolution	Frequency
Solinst® Levelogger®	3001, L5- L100 (100 foot scale)	Temperature	0.1°C/0.01°C,	6 seconds
		Depth, barometric pressure	Auto temp compensated to 1% of full scale/0.03 feet	6 seconds
Trimble® GeoXM™ Handheld		Location, time	0.2 meters/68% precision	30 seconds

Table 2
Temperature Profile Data
Spokane River, September 20, 2005

Time (PDT)	Longitude (WGS 84)	Latitude (WGS 84)	Temperature (^{o}C)
11:14:47	-117.15588	47.67971	16.93
11:15:17	-117.15613	47.68012	16.86
11:15:47	-117.15643	47.68024	16.87
11:16:47	-117.15704	47.68143	16.84
11:18:17	-117.15779	47.68242	16.83
11:18:47	-117.15804	47.68263	16.83
11:19:17	-117.15829	47.68288	16.83
11:19:47	-117.15856	47.68306	16.83
11:20:17	-117.15878	47.68325	16.85
11:20:47	-117.15901	47.68342	16.84
11:21:17	-117.15929	47.68359	16.84
11:21:47	-117.15952	47.68373	16.84
11:22:17	-117.15975	47.68388	16.85
11:22:47	-117.15999	47.68399	16.83
11:23:17	-117.16024	47.68411	16.83
11:23:47	-117.16049	47.68422	16.83
11:24:17	-117.16082	47.68433	16.83
11:24:47	-117.16114	47.68438	16.84
11:25:17	-117.16161	47.68437	16.81
11:25:47	-117.16206	47.68433	16.81
11:26:17	-117.16243	47.68423	16.82
11:26:47	-117.16281	47.68412	16.83
11:27:17	-117.16317	47.68396	16.82
11:27:47	-117.16345	47.68385	16.79
11:28:17	-117.16370	47.68377	16.81
11:28:47	-117.16413	47.68363	16.81
11:29:17	-117.16445	47.68348	16.81
11:30:47	-117.16554	47.68245	16.83
11:31:17	-117.16561	47.68197	16.85
11:31:47	-117.16540	47.68144	16.84
11:32:17	-117.16557	47.68120	16.84
11:32:47	-117.16581	47.68104	16.84
11:33:17	-117.16615	47.68085	16.85
11:33:47	-117.16657	47.68066	16.86
11:34:17	-117.16691	47.68047	16.85
11:34:47	-117.16731	47.68025	16.85
11:35:17	-117.16786	47.68022	16.88
11:35:47	-117.16860	47.68025	16.87
11:36:17	-117.16949	47.68030	16.88
11:36:47	-117.17030	47.68001	16.87
11:37:17	-117.17070	47.67990	16.89
11:37:47	-117.17089	47.67987	16.88
11:38:17	-117.17093	47.67982	16.89
11:38:47	-117.17127	47.67972	16.89
11:39:17	-117.17165	47.67959	16.90

Time (PDT)	Longitude (WGS 84)	Latitude (WGS 84)	Temperature (°C)
11:39:47	-117.17200	47.67952	16.91
11:40:47	-117.17263	47.67929	16.88
11:41:17	-117.17271	47.67920	16.89
11:41:47	-117.17328	47.67911	16.91
11:42:17	-117.17343	47.67907	16.89
11:42:47	-117.17374	47.67902	16.90
11:43:17	-117.17421	47.67899	16.89
11:43:47	-117.17467	47.67892	16.90
11:44:17	-117.17505	47.67886	16.90
11:45:17	-117.17578	47.67879	16.89
11:45:47	-117.17619	47.67875	16.88
11:46:17	-117.17658	47.67869	16.90
11:46:47	-117.17696	47.67865	16.89
11:47:17	-117.17723	47.67857	16.89
11:47:47	-117.17759	47.67848	16.90
11:48:17	-117.17787	47.67839	16.90
11:48:47	-117.17821	47.67811	16.90
11:49:17	-117.17884	47.67789	16.88
11:49:47	-117.17926	47.67777	16.89
11:50:47	-117.17990	47.67738	16.86
11:51:47	-117.18034	47.67678	16.90
11:53:17	-117.18100	47.67532	16.90
11:53:47	-117.18109	47.67515	16.91
11:54:17	-117.18123	47.67483	16.91
11:54:47	-117.18131	47.67453	16.92
11:55:17	-117.18135	47.67420	16.92
11:57:47	-117.18192	47.67262	16.92
11:58:47	-117.18233	47.67218	16.88
11:59:17	-117.18251	47.67199	16.91
11:59:47	-117.18276	47.67177	16.88
12:00:47	-117.18350	47.67143	16.88
12:01:17	-117.18403	47.67128	16.89
12:01:47	-117.18421	47.67118	16.88
12:02:17	-117.18434	47.67113	16.88
12:02:47	-117.18456	47.67109	16.88
12:03:17	-117.18487	47.67100	16.90
12:03:47	-117.18524	47.67094	16.90
12:04:17	-117.18550	47.67087	16.88
12:53:17	-117.19008	47.67124	17.22
12:53:47	-117.19074	47.67133	17.22
12:54:17	-117.19124	47.67138	17.23
12:54:47	-117.19172	47.67144	17.25
12:55:17	-117.19251	47.67152	17.24
12:55:47	-117.19312	47.67162	17.22
12:56:17	-117.19358	47.67171	17.22
12:56:47	-117.19394	47.67180	17.23
12:57:17	-117.19443	47.67189	17.22
12:57:47	-117.19497	47.67205	17.23
12:58:17	-117.19552	47.67225	17.22

Time (PDT)	Longitude (WGS 84)	Latitude (WGS 84)	Temperature (°C)
12:58:47	-117.19595	47.67242	17.21
12:59:47	-117.19710	47.67288	17.22
13:00:17	-117.19773	47.67313	17.21
13:00:47	-117.19814	47.67329	17.21
13:01:17	-117.19840	47.67341	17.19
13:01:47	-117.19863	47.67342	17.18
13:02:17	-117.19889	47.67348	17.18
13:02:47	-117.19907	47.67377	17.18
13:03:17	-117.19913	47.67385	17.17
13:03:47	-117.19916	47.67386	17.06
13:04:17	-117.19918	47.67386	16.98
13:04:47	-117.19917	47.67387	16.92
13:05:47	-117.19960	47.67406	16.92
13:06:17	-117.19996	47.67426	16.99
13:06:47	-117.20025	47.67440	17.03
13:07:17	-117.20052	47.67456	17.07
13:07:47	-117.20074	47.67465	17.10
13:08:17	-117.20101	47.67472	17.04
13:08:47	-117.20127	47.67479	17.02
13:09:17	-117.20151	47.67492	17.03
13:09:47	-117.20170	47.67506	17.06
13:10:17	-117.20197	47.67525	17.08
13:10:47	-117.20243	47.67555	17.11
13:11:17	-117.20288	47.67590	17.12
13:11:47	-117.20314	47.67614	17.12
13:12:17	-117.20354	47.67640	17.11
13:12:47	-117.20396	47.67665	17.10
13:13:17	-117.20430	47.67695	17.08
13:13:47	-117.20464	47.67723	17.09
13:14:17	-117.20500	47.67761	17.08
13:14:47	-117.20536	47.67783	17.07
13:15:17	-117.20588	47.67811	17.07
13:15:47	-117.20633	47.67834	17.06
13:16:17	-117.20680	47.67850	17.06
13:16:47	-117.20738	47.67853	17.05
13:17:17	-117.20792	47.67863	17.05
13:17:47	-117.20835	47.67877	17.05
13:18:17	-117.20895	47.67890	17.03
13:18:47	-117.20947	47.67897	17.04
13:19:17	-117.21012	47.67899	17.01
13:19:47	-117.21079	47.67903	17.00
13:20:17	-117.21128	47.67907	16.97
13:20:47	-117.21183	47.67911	16.94
13:21:17	-117.21248	47.67911	16.92
13:21:47	-117.21308	47.67912	16.91
13:22:17	-117.21376	47.67908	16.88
13:22:47	-117.21444	47.67911	16.86
13:23:17	-117.21501	47.67934	16.79
13:23:47	-117.21571	47.67954	16.76

Time (PDT)	Longitude (WGS 84)	Latitude (WGS 84)	Temperature (°C)
13:24:17	-117.21640	47.67971	16.70
13:24:47	-117.21673	47.67979	16.64
13:25:17	-117.21688	47.67983	16.58
13:25:47	-117.21712	47.67980	16.54
13:26:17	-117.21738	47.67977	16.50
13:26:47	-117.21771	47.67992	16.40
13:27:17	-117.21833	47.68019	16.29
13:27:47	-117.21885	47.68043	16.25
13:28:17	-117.21933	47.68070	16.25
13:28:47	-117.21976	47.68100	16.25
13:29:17	-117.22019	47.68134	16.26
13:29:47	-117.22056	47.68169	16.24
13:30:17	-117.22072	47.68195	16.17
13:30:47	-117.22083	47.68216	16.04
13:31:17	-117.22090	47.68240	15.98
13:31:47	-117.22098	47.68272	15.95
13:32:17	-117.22109	47.68306	15.95
13:32:47	-117.22131	47.68336	15.97
13:33:17	-117.22153	47.68357	15.94
13:33:47	-117.22163	47.68369	15.94
13:34:17	-117.22187	47.68396	15.94
13:34:47	-117.22217	47.68426	15.95
13:35:17	-117.22283	47.68476	15.93
13:35:47	-117.22331	47.68540	15.95
13:36:17	-117.22357	47.68590	15.95
13:36:47	-117.22390	47.68625	15.95
13:37:17	-117.22425	47.68661	15.93
13:37:47	-117.22456	47.68690	15.91
13:38:17	-117.22492	47.68716	15.87
13:38:47	-117.22535	47.68740	15.85
13:39:17	-117.22580	47.68767	15.87
13:39:47	-117.22617	47.68787	15.85
13:40:17	-117.22672	47.68811	15.86
13:40:47	-117.22730	47.68837	15.86
13:41:17	-117.22789	47.68860	15.85
13:41:47	-117.22850	47.68882	15.87
13:42:17	-117.22906	47.68900	15.88
13:42:47	-117.22971	47.68928	15.89
13:43:17	-117.23029	47.68951	15.89
13:43:47	-117.23079	47.68971	15.89
13:44:17	-117.23136	47.68993	15.88
13:44:47	-117.23180	47.69014	15.89
13:45:17	-117.23240	47.69041	15.89
13:45:47	-117.23287	47.69066	15.88
13:46:17	-117.23343	47.69096	15.87
13:46:47	-117.23394	47.69122	15.87
13:47:17	-117.23446	47.69154	15.88
13:48:17	-117.23542	47.69217	15.86
13:48:47	-117.23595	47.69252	15.86

Time (PDT)	Longitude (WGS 84)	Latitude (WGS 84)	Temperature (°C)
13:49:17	-117.23643	47.69285	15.88
13:49:47	-117.23678	47.69313	15.89
13:50:17	-117.23712	47.69339	15.85
13:50:47	-117.23748	47.69365	15.86
13:51:17	-117.23780	47.69391	15.85
13:51:47	-117.23812	47.69418	15.87
13:52:17	-117.23844	47.69445	15.84
13:52:47	-117.23877	47.69473	15.85
13:53:17	-117.23913	47.69498	15.85
13:53:47	-117.23947	47.69524	15.85
13:54:17	-117.23980	47.69548	15.85
13:54:47	-117.24012	47.69571	15.84
13:55:17	-117.24044	47.69595	15.84
13:55:47	-117.24073	47.69620	15.85
13:56:17	-117.24103	47.69644	15.84
13:56:47	-117.24137	47.69669	15.84
13:57:17	-117.24180	47.69695	15.85
13:57:47	-117.24226	47.69722	15.85
13:58:17	-117.24267	47.69744	15.84
13:58:47	-117.24295	47.69763	15.86
13:59:17	-117.24315	47.69772	15.88
13:59:47	-117.24336	47.69777	15.85
14:00:17	-117.24370	47.69781	15.86
14:00:47	-117.24398	47.69782	15.86
14:01:17	-117.24437	47.69777	15.85
14:01:47	-117.24495	47.69764	15.87
14:02:17	-117.24543	47.69754	15.86
14:02:47	-117.24575	47.69743	15.85
14:03:17	-117.24598	47.69718	15.85
14:04:17	-117.24591	47.69658	15.87
14:04:47	-117.24587	47.69624	15.86
14:05:17	-117.24577	47.69556	15.87
14:05:47	-117.24585	47.69503	15.87
14:06:17	-117.24621	47.69482	15.87
14:06:47	-117.24651	47.69471	15.86
14:07:17	-117.24690	47.69457	15.85
14:07:47	-117.24711	47.69457	15.86
14:08:17	-117.24757	47.69453	15.85

Table 3
Ambient Surface Water Data: 11 AM to 2:30 PM, September 20, 2005

Date	Time (PDT)	Post Falls stage height	Post Falls temperature (°C)	Sullivan stage height	Sullivan temperature (°C)
9/20/2005	11:00:00	3.64	17.26	6.91	15.97
9/20/2005	11:06:00	3.63	17.29	6.92	15.99
9/20/2005	11:12:00	3.63	17.28	6.93	16.03
9/20/2005	11:18:00	3.64	17.28	6.93	16.05
9/20/2005	11:24:00	3.63	17.29	6.9	16.09
9/20/2005	11:30:00	3.63	17.3	6.92	16.14
9/20/2005	11:36:00	3.63	17.26	6.92	16.17
9/20/2005	11:42:00	3.63	17.24	6.91	16.21
9/20/2005	11:48:00	3.63	17.25	6.93	16.23
9/20/2005	11:54:00	3.63	17.26	6.9	16.29
9/20/2005	12:00:00	3.62	17.28	6.89	16.31
9/20/2005	12:06:00	3.62	17.32	6.91	16.35
9/20/2005	12:12:00	3.62	17.32	6.89	16.39
9/20/2005	12:18:00	3.62	17.34	6.91	16.41
9/20/2005	12:24:00	3.62	17.33	6.91	16.47
9/20/2005	12:30:00	3.61	17.36	6.91	16.48
9/20/2005	12:36:00	3.62	17.37	6.92	16.53
9/20/2005	12:42:00	3.6	17.37	6.9	16.57
9/20/2005	12:48:00	3.61	17.4	6.91	16.61
9/20/2005	12:54:00	3.62	17.42	6.92	16.66
9/20/2005	13:00:00	3.61	17.4	6.89	16.68
9/20/2005	13:06:00	3.6	17.41	6.91	16.73
9/20/2005	13:12:00	3.59	17.4	6.89	16.74
9/20/2005	13:18:00	3.59	17.4	6.9	16.81
9/20/2005	13:24:00	3.58	17.38	6.89	16.85
9/20/2005	13:30:00	3.59	17.39	6.9	16.88
9/20/2005	13:36:00	3.59	17.42	6.9	16.91
9/20/2005	13:42:00	3.59	17.41	6.89	16.95
9/20/2005	13:48:00	3.6	17.44	6.92	17.01
9/20/2005	13:54:00	3.59	17.42	6.9	17.03
9/20/2005	14:00:00	3.59	17.41	6.87	17.07
9/20/2005	14:06:00	3.59	17.4	6.88	17.07
9/20/2005	14:12:00	3.57	17.42	6.89	17.08
9/20/2005	14:18:00	3.57	17.4	6.87	17.14
9/20/2005	14:24:00	3.57	17.4	6.87	17.18
9/20/2005	14:30:00	3.57	17.39	6.88	17.21

Table 4
Ambient Ground Water Data, 11:00 AM to 2:30 PM, September 20, 2005

Time (PDT)	71447 Sullivan Krispy Kreme		71425 Sullivan Park South		71424 Bowdish & Frederick 208		63114 2nd & Best	
	Head (ft)	Temp (°C)	Head (ft)	Temp (°C)	Head (ft)	Temp (°C)	Head (ft)	Temp (°C)
11:00:00	19.51	9.33	16.52	11.52	13.54	8.95	6.47	11.92
11:06:00	19.5	9.33	16.53	11.52	13.55	8.93	6.46	11.93
11:12:00	19.51	9.33	16.51	11.52	13.54	8.93	6.47	11.94
11:18:00	19.48	9.33	16.51	11.53	13.54	8.94	6.47	11.94
11:24:00	19.51	9.33	16.52	11.52	13.52	8.94	6.46	11.94
11:30:00	19.5	9.35	16.51	11.52	13.53	8.93	6.46	11.94
11:36:00	19.51	9.34	16.51	11.52	13.53	8.95	6.46	11.92
11:42:00	19.51	9.34	16.51	11.52	13.54	8.93	6.47	11.91
11:48:00	19.51	9.33	16.51	11.53	13.5	8.94	6.47	11.93
11:54:00	19.5	9.34	16.52	11.54	13.51	8.94	6.46	11.92
12:00:00	19.51	9.33	16.5	11.52	13.52	8.94	6.47	11.94
12:06:00	19.52	9.33	16.52	11.52	13.52	8.93	6.46	11.92
12:12:00	19.52	9.33	16.5	11.53	13.53	8.94	6.46	11.93
12:18:00	19.52	9.34	16.51	11.52	13.52	8.95	6.46	11.92
12:24:00	19.51	9.34	16.51	11.51	13.54	8.93	6.46	11.94
12:30:00	19.51	9.33	16.5	11.52	13.52	8.95	6.47	11.94
12:36:00	19.51	9.34	16.5	11.52	13.53	8.93	6.47	11.92
12:42:00	19.5	9.33	16.5	11.54	13.54	8.95	6.47	11.93
12:48:00	19.51	9.34	16.53	11.53	13.53	8.96	6.45	11.93
12:54:00	19.51	9.34	16.51	11.52	13.54	8.94	6.47	11.96
13:00:00	19.52	9.34	16.51	11.53	13.54	8.95	6.46	11.92
13:06:00	19.52	9.34	16.5	11.53	13.52	8.95	6.46	11.94
13:12:00	19.51	9.33	16.52	11.52	13.52	8.94	6.46	11.93
13:18:00	19.49	9.34	16.49	11.54	13.52	8.94	6.46	11.92
13:24:00	19.49	9.34	16.5	11.55	13.52	8.95	6.45	11.93
13:30:00	19.51	9.33	16.51	11.52	13.5	8.94	6.44	11.89
13:36:00	19.51	9.34	16.49	11.51	13.5	8.94	6.45	11.92
13:42:00	19.49	9.34	16.5	11.52	13.5	8.95	6.45	11.93
13:48:00	19.47	9.35	16.5	11.53	13.51	8.95	6.45	11.92
13:54:00	19.47	9.34	16.5	11.52	13.5	8.95	6.45	11.93
14:00:00	19.47	9.35	16.48	11.54	13.5	8.93	6.44	11.94
14:06:00	19.48	9.34	16.48	11.52	13.49	8.94	6.44	11.92
14:12:00	19.47	9.35	16.48	11.53	13.5	8.94	6.44	11.93
14:18:00	19.5	9.33	16.52	11.52	13.5	8.95	6.43	11.92
14:24:00	19.48	9.35	16.5	11.51	13.5	8.94	6.44	11.94
14:30:00	19.48	9.35	16.5	11.52	13.5	8.93	6.44	11.94

Table 5
Spokane River Gauged Flows
Flows in Cubic Feet per Second (cfs)
September 20, 2005

Time (PDT)	Post Falls	Harvard	Barker	Spokane at Spokane
11:00:00	2000	1560	1390	1710
11:15:00	2000	1560	1390	1710
11:30:00	2020	1560	1390	1710
11:45:00	2000	1560	1390	1700
12:00:00	2000	1560	1390	1680
12:15:00	2000	1570	1390	1670
12:30:00	2000	1560	1390	1680
12:45:00	2020	1560	1390	1680
13:00:00	2000	1570	1390	1680
13:15:00	2010	1560	1390	1680
13:30:00	2000	1560	1390	1680
13:45:00	2010	1560	1390	1680
14:00:00	2000	1560	1390	1680
14:15:00	1990	1560	1390	1680
14:30:00	2000	1560	1390	1620

Figure 1
Location Map
Spokane River Temperature Profile

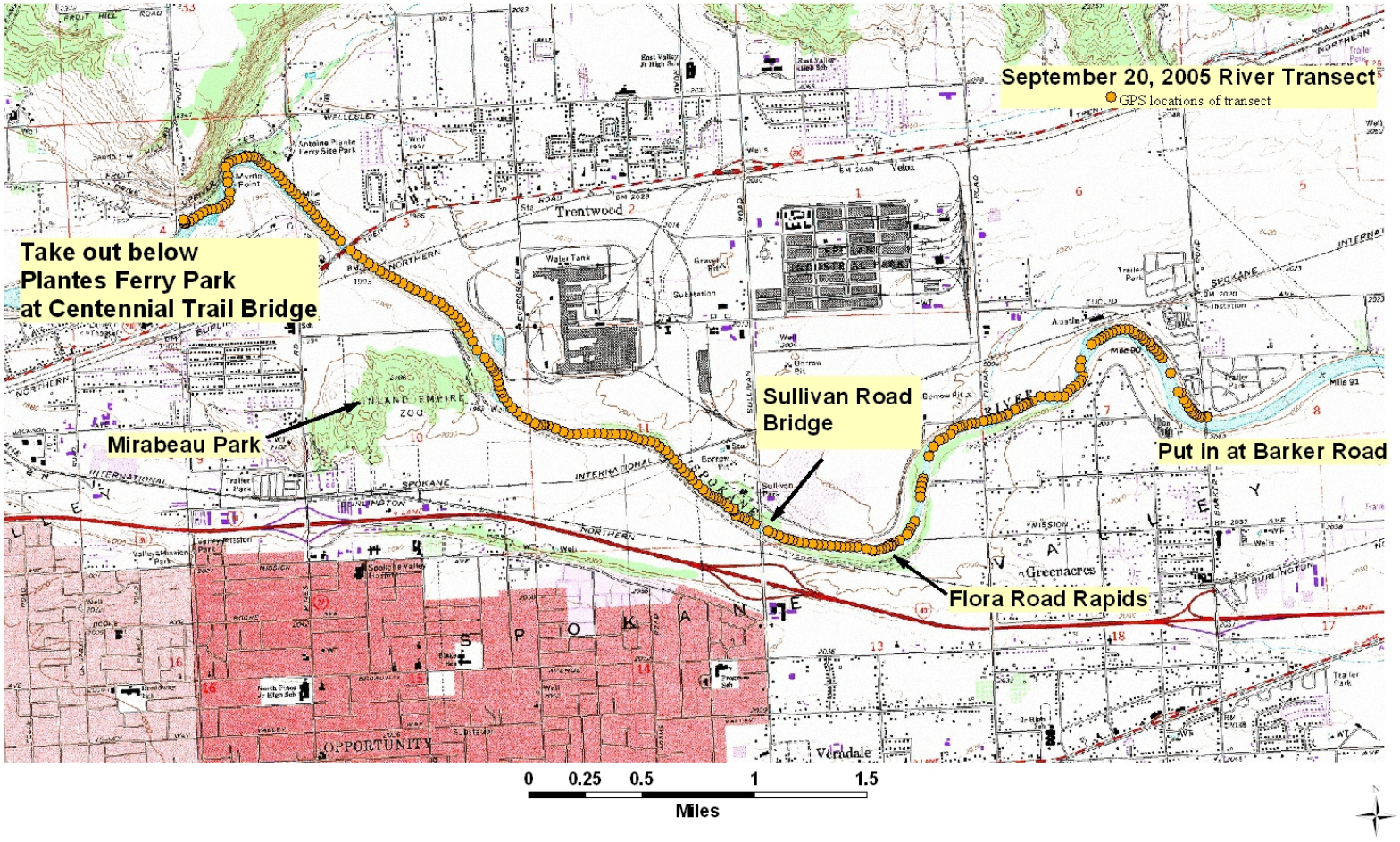

Figure 2
Temperature Readings Every 30 Seconds
Spokane River Temperature Profile

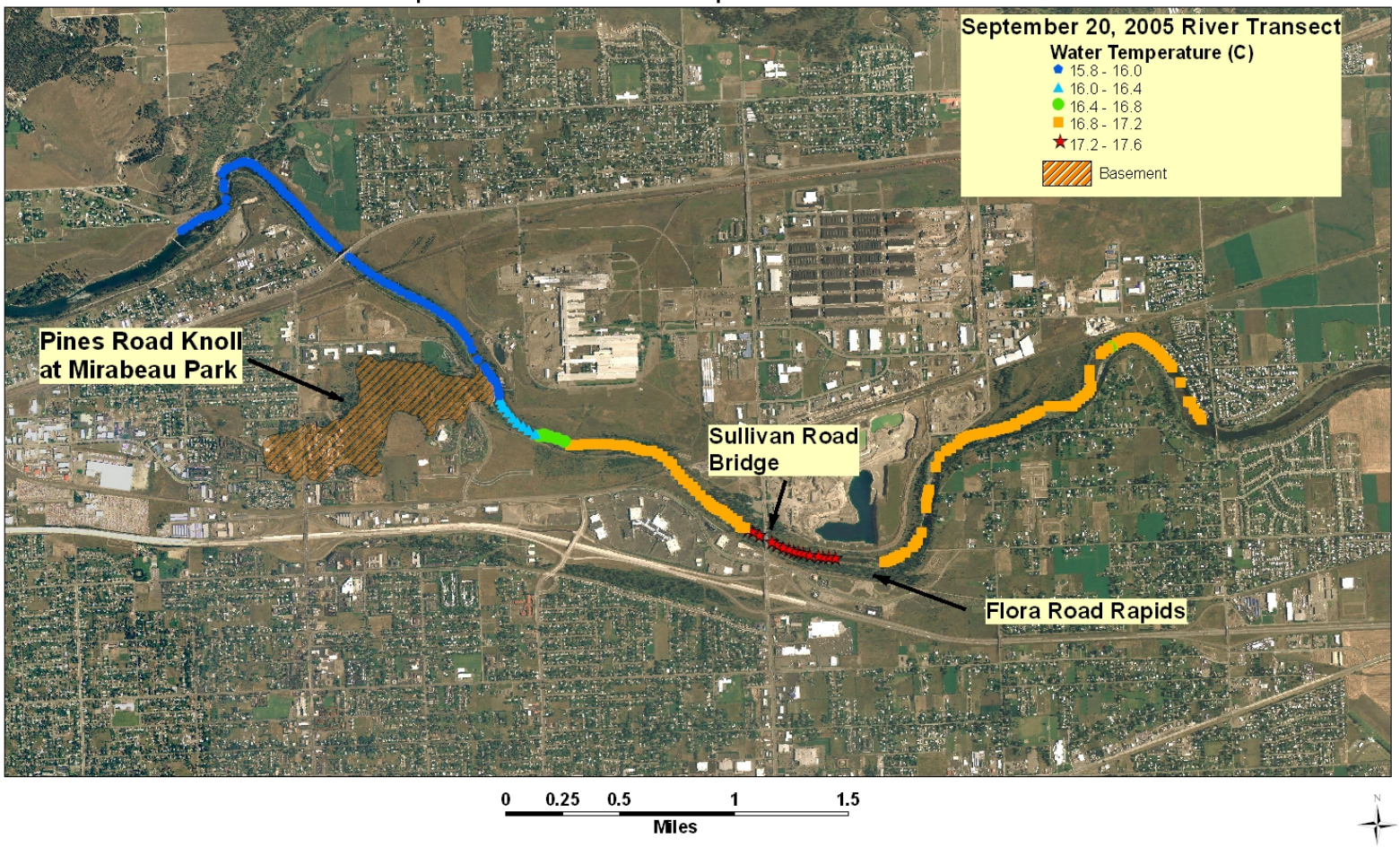

Figure 3
Ambient Surface Water Conditions-Spokane River
September 20, 2005

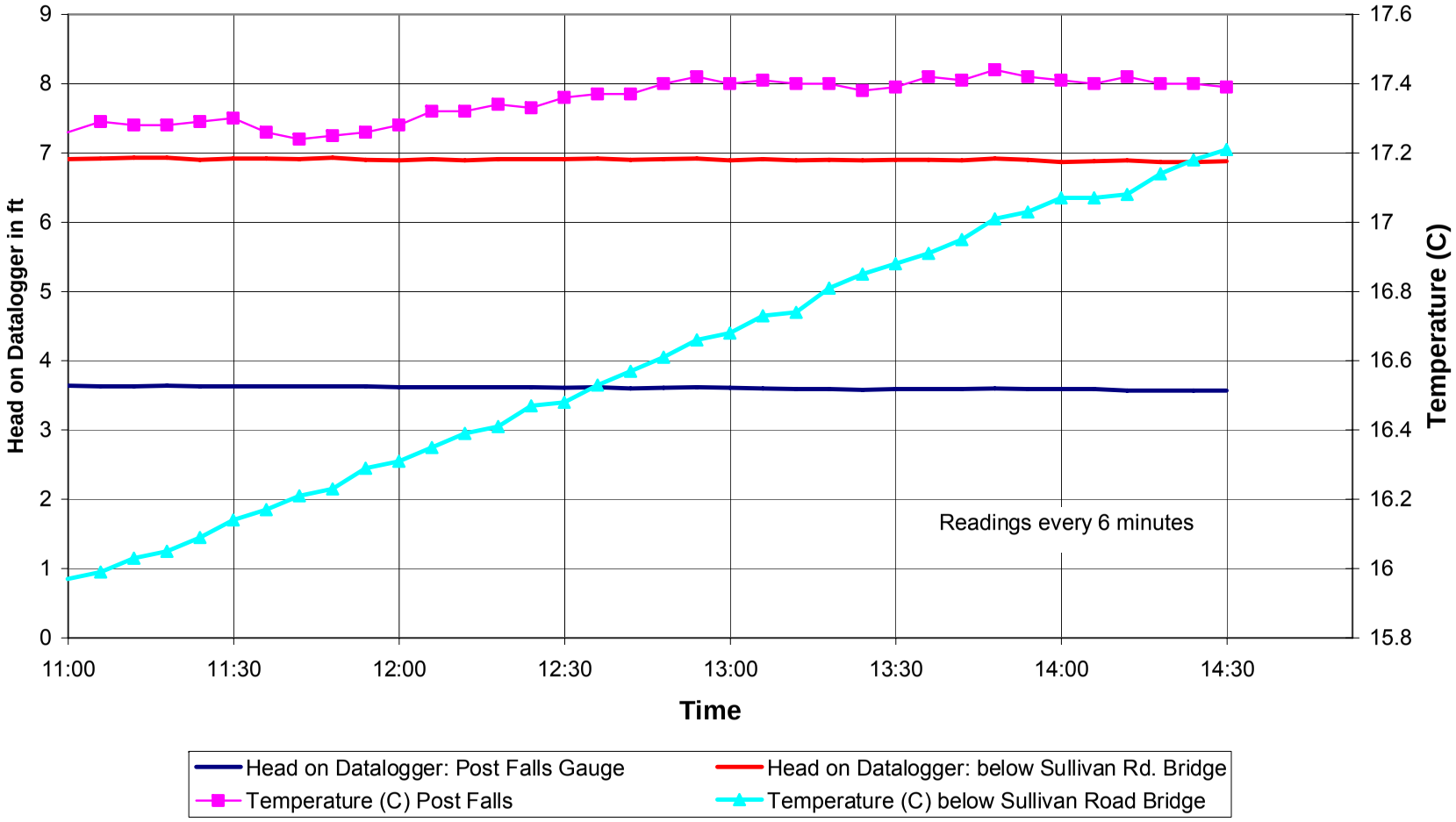

Figure 4
Temperature Profile-Spokane River
Barker Road to Plantes Ferry Bridge
September 20,2005

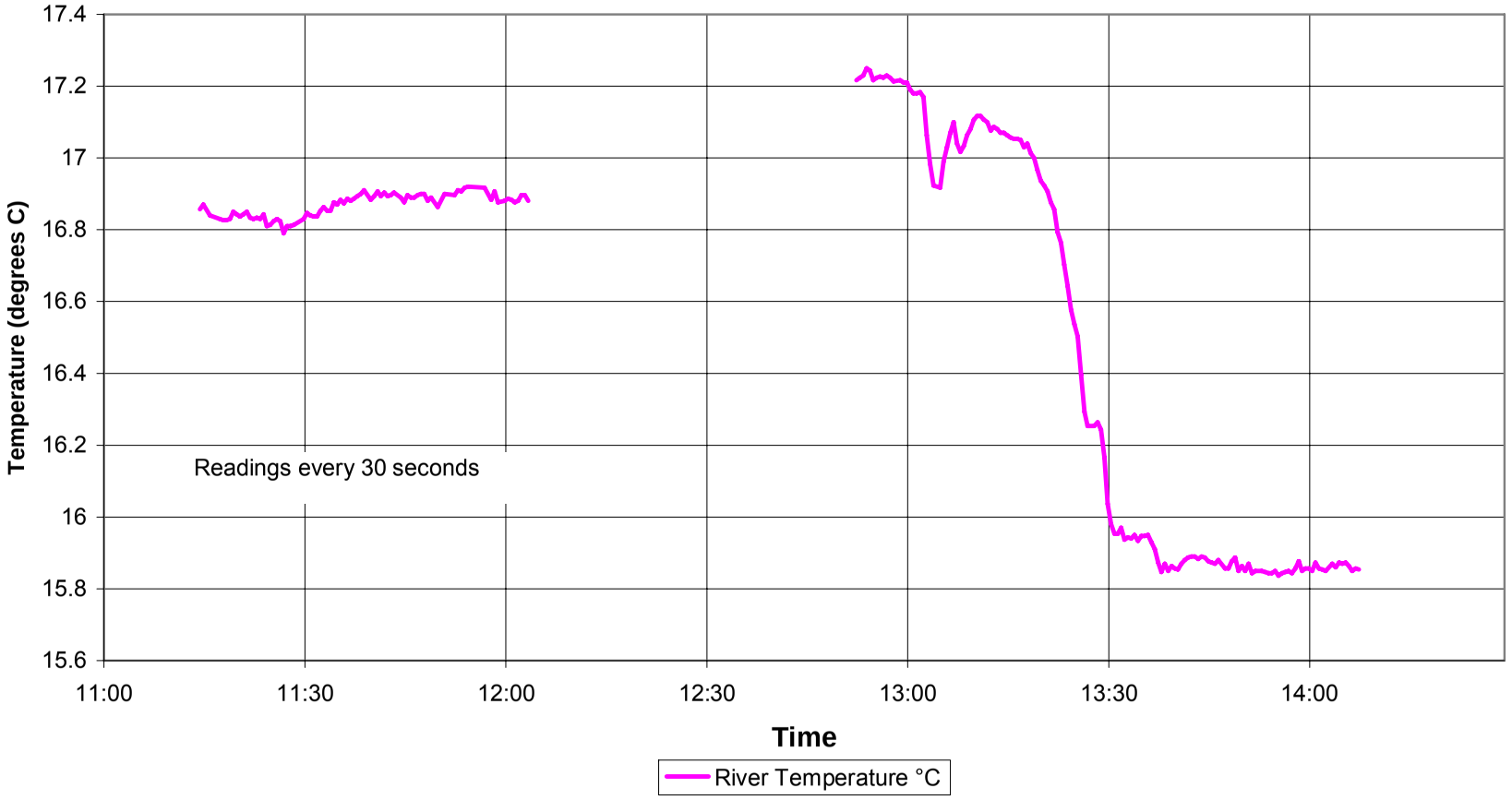

Figure 5
Temperature Profile-Upper Section
Barker Rd. to Flora Rapids

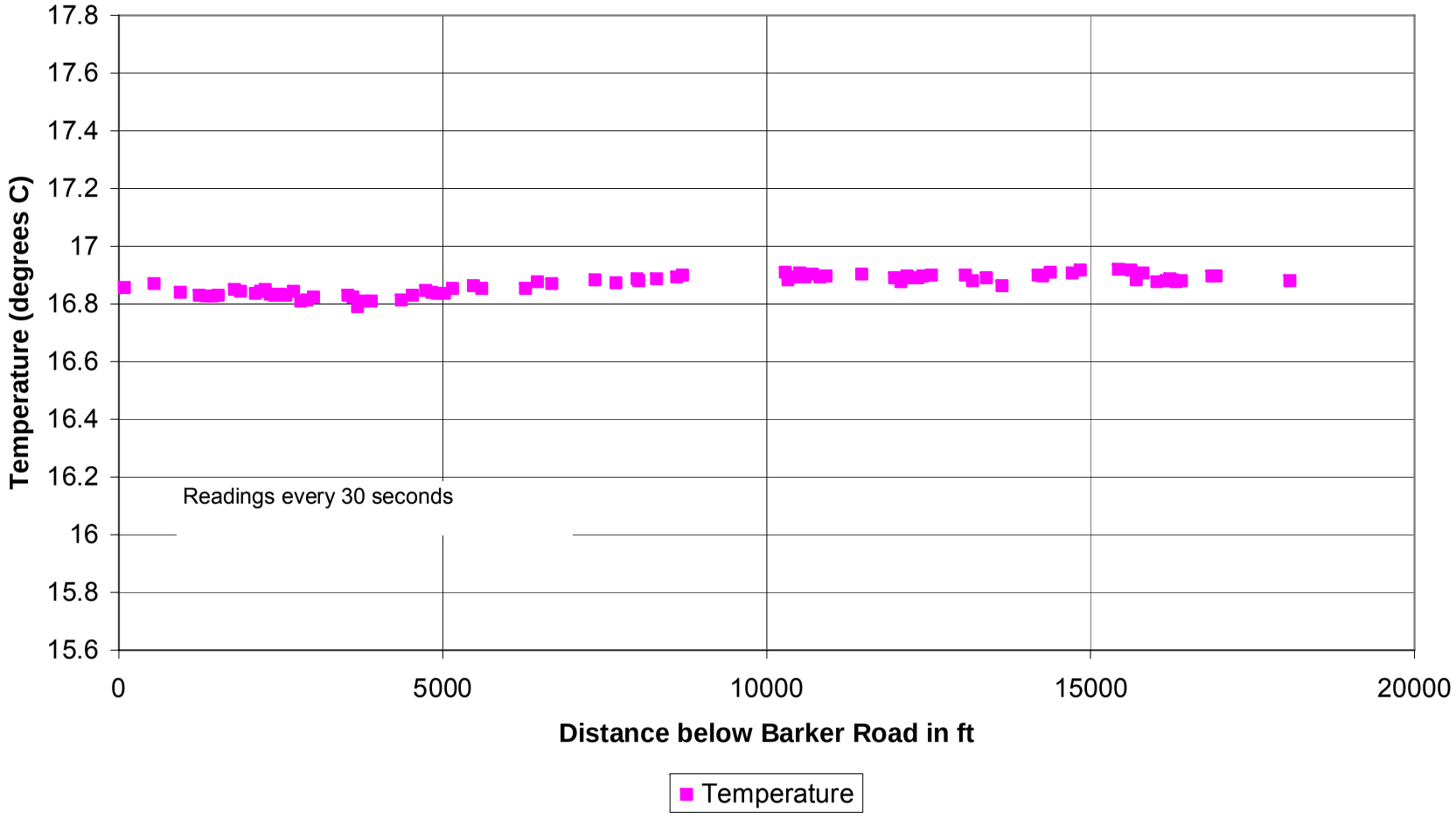

Figure 6
Temperature Profile-Lower Section
Flora Rapids to Plantes Ferry Park

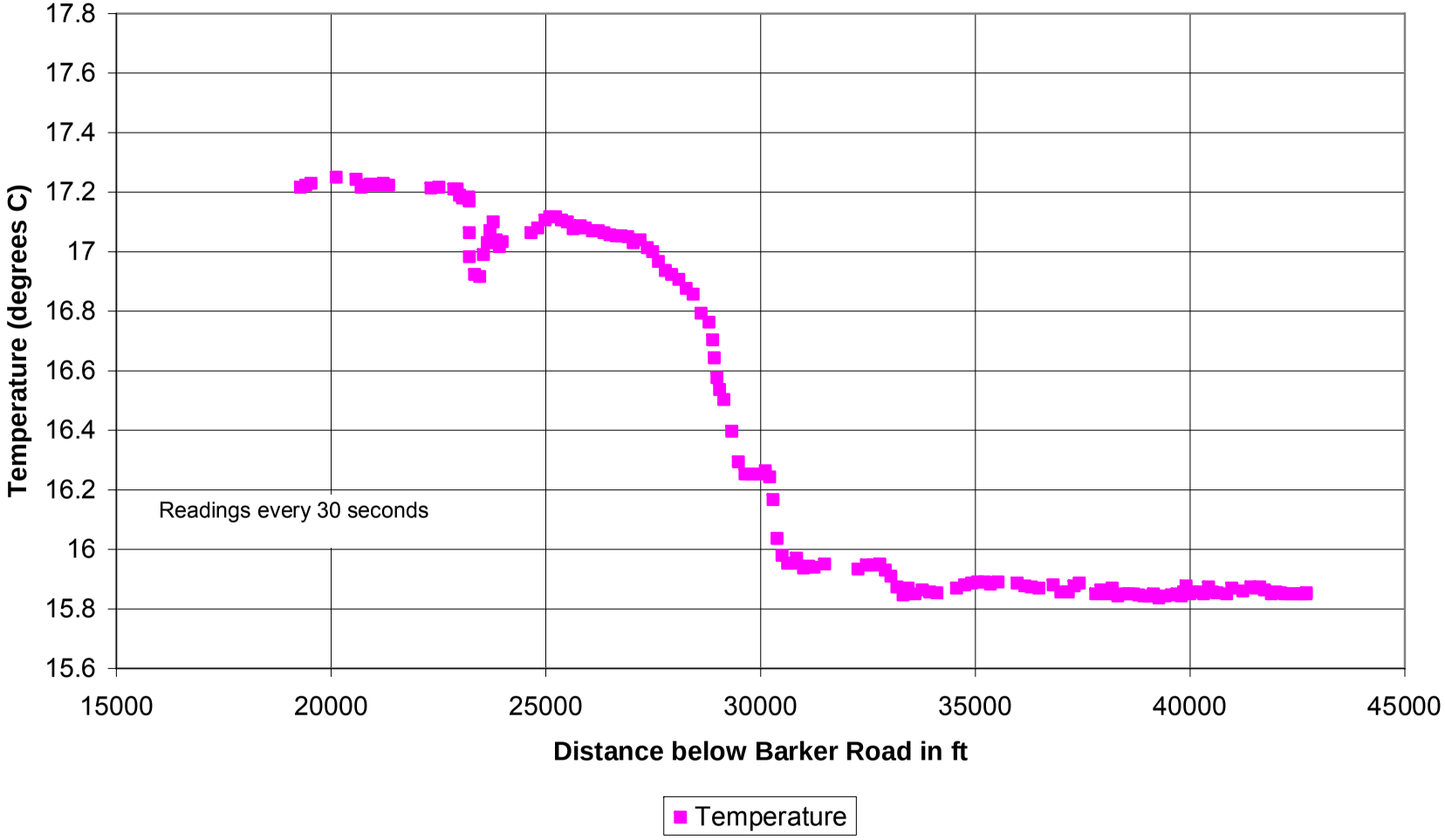

Figure 7
Change in Temperature per foot, Sullivan Rd. to Mirabeau Park

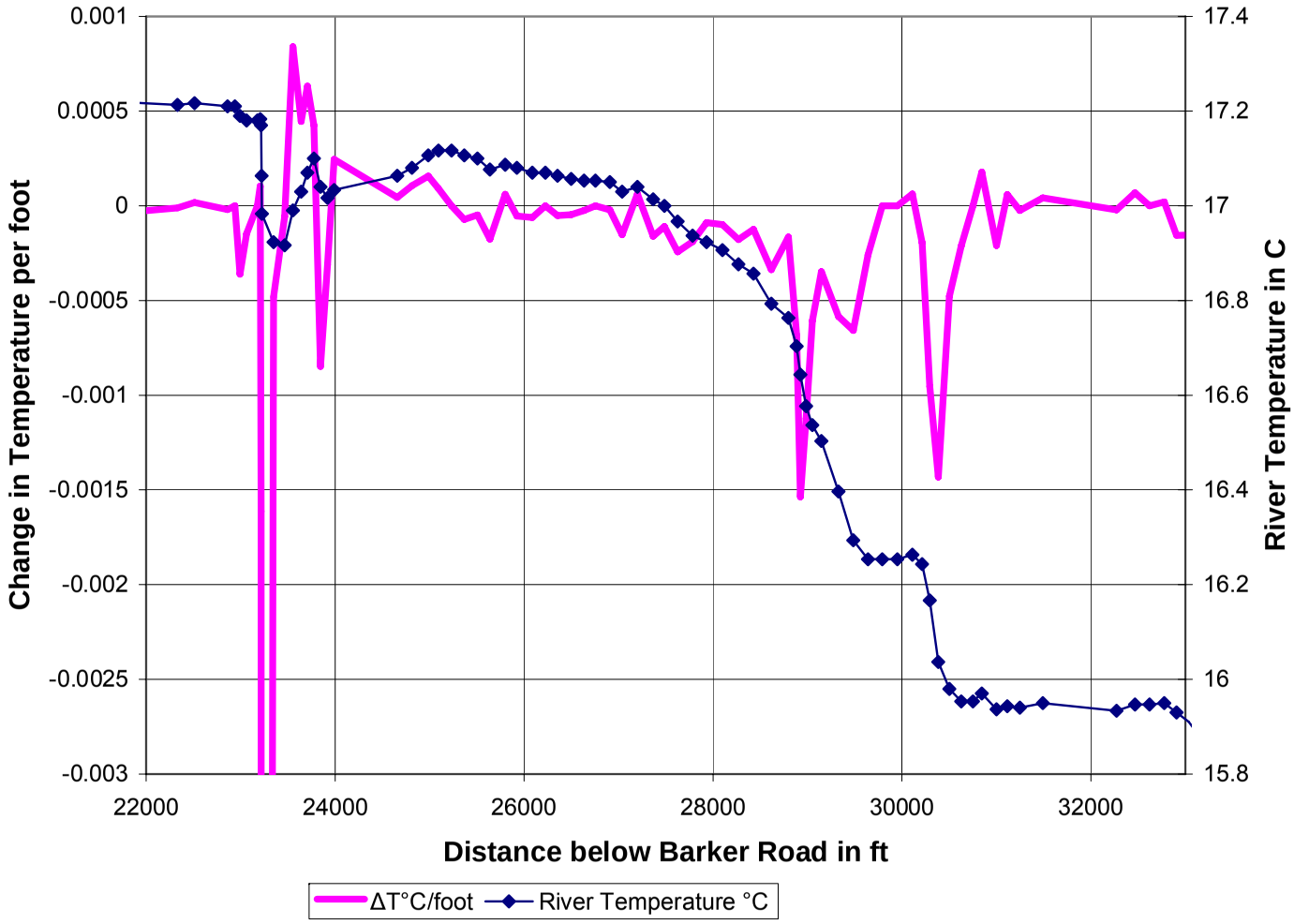

Figure 8
High Cooling Rate Locations
Spokane River Temperature Profile