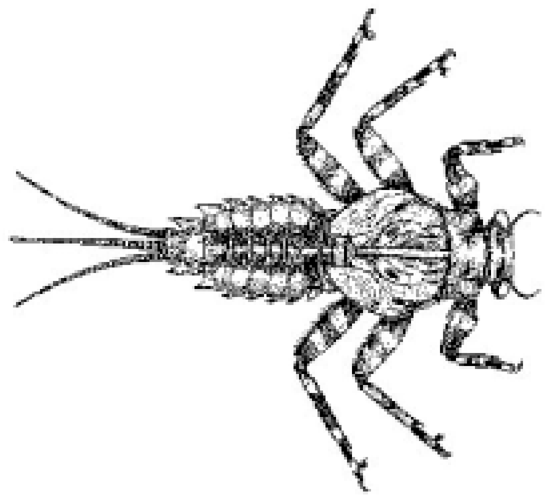
Technical Report – BIO00 - 001

Grande Ronde Section 319 National Monitoring Program Project
Temperature Monitoring Summary Report
1993 – 1998



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Introduction

Elevated stream temperatures and loss of habitat have been identified as important factors affecting declining salmon and steelhead populations in the Grande Ronde River watershed, located in the Blue Mountain ecoregion of northeast Oregon (Hafele, 1996). Livestock grazing, timber harvest, road construction, and mining have contributed to habitat degradation and elevated stream temperatures in the upper Grande Ronde watershed (Bach, 1995).

The Oregon Department of Environmental Quality (DEQ) has been conducting water quality monitoring within the basin to evaluate aquatic biological communities and the physical and chemical factors that affect them for the past five years. Monitoring began in 1993, and is funded under the US Environmental Protection Agency (EPA) Section 319 National Monitoring Program (NMP). Eleven study sites are located in five subbasins of the upper Grande Ronde River (Figure 1). Site conditions range from highly impacted to stable high quality. The study is designed to assess stream conditions in relation to different land use and management practices, and to track the response of a specific stream segment to channel restoration activities.

Variables measured include continuous water temperature, channel and riparian conditions, macroinvertebrate and fish assemblages, and water chemistry. A measure of success of channel restoration efforts would be improved habitat and reduced maximum temperatures resulting in improved biological communities.

This report summarizes water temperature data collected by DEQ biomonitoring staff at Grande Ronde NMP study sites during the period 1993 to 1998. These data summaries are intended to satisfy the following objectives:

1. describe the range of temperatures at all Grande Ronde NMP sites.
2. characterize seasonal and yearly temperature profiles at Grande Ronde NMP sites.
3. identify water temperature trends.
4. describe environmental variables related to stream water temperature.
5. assess the effect of channel restoration on stream water temperature.

Methods

Study Sites:

Site locations within the upper Grande Ronde basin are shown in Figure 1. Each study site consists of a reach length containing both riffle and pool habitat types. A list of sites and pertinent site information is presented in Table 1.

Land use in the upper Grande Ronde basin is primarily timber and grazing. Based on use, management, and prevailing habitat, the study sites represent a range of conditions. Reference sites are characterized by stable channel and riparian habitats, and occur in subbasins with minimal or no grazing activities. Reference sites selected for this study are located on Limber Jim Creek and Lookout Creek. The remaining sites cover a range of channel and riparian conditions and occur in subbasins with various degrees of grazing activities.

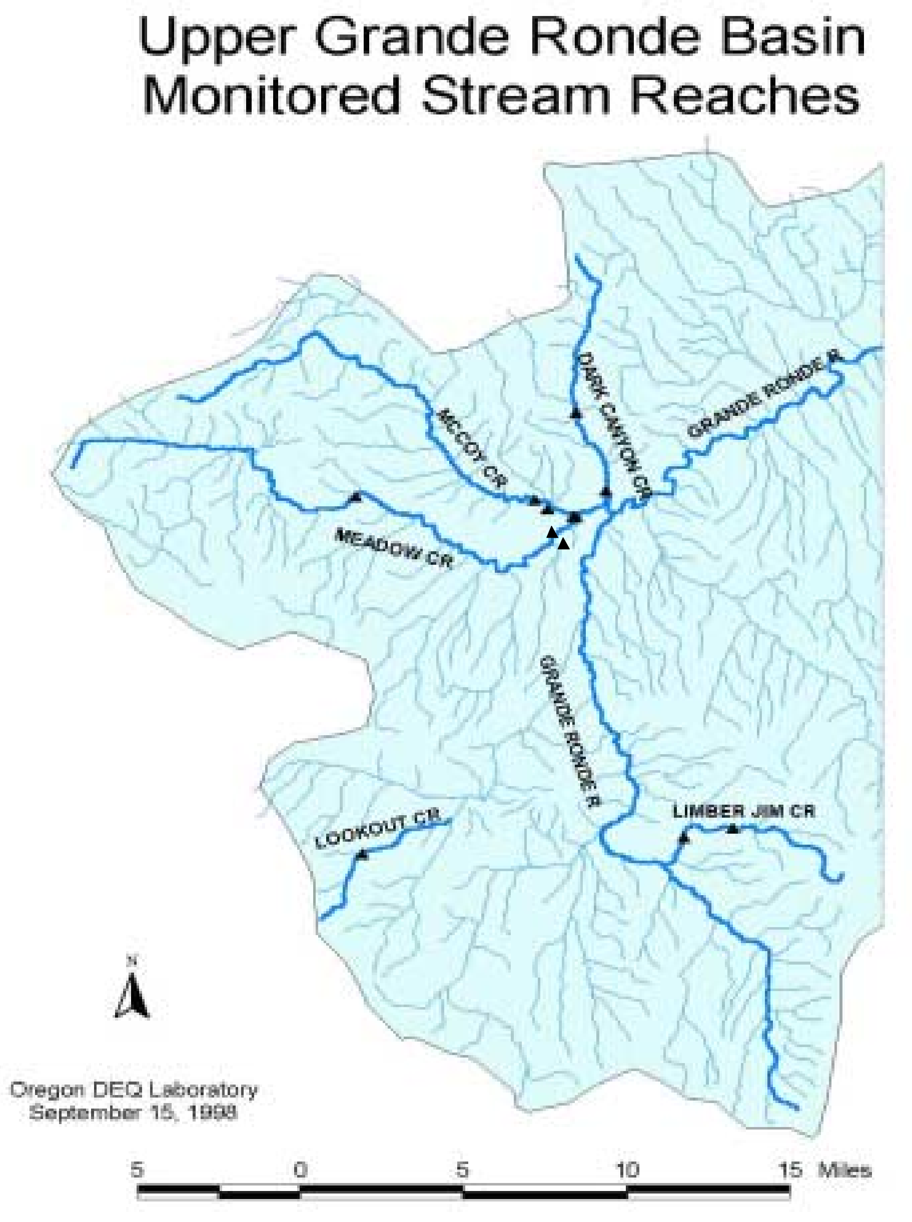

Figure 1. Oregon DEQ National Monitoring Project Study Reaches. Sites are located on wadeable streams which are tributary to the Grande Ronde River.

Table 1. Grande Ronde NMP Study Sites, 1993 –1998

Site	River Mile	Elevation (ft)	Management	Study Site Type
McCoy Creek Lower #1 (MCCL1)	0.12 – 0.30	3350	Riparian fencing	Meadow below restoration area
McCoy Creek Lower #2 (MCCL2)	0.30 – 0.41	3360	Riparian fencing	Meadow below restoration area
McCoy Creek Restored (MCCR)	0.95 – 1.45	3380	Riparian fencing - planting	Restored wet meadow
McCoy Creek Middle (MCCM)	2.0 –2.08	3400	Riparian fencing	Forested above restoration area
Dark Canyon Creek Lower (DARKL)	0.40 –0.47	3300	Seasonal grazing	Control meadow
Dark Canyon Creek Upper (DARKU)	3.00 – 3.07	3550	Seasonal grazing	Control forested
Limber Jim Creek Lower (LIML)	0.40 –0.47	4300	No grazing	Reference meadow
Limber Jim Creek Upper (LIMU)	3.20 –3.26	4650	No grazing	Reference forested
Lookout Creek (LOOK)	3.00 – 3.07	4700	No grazing	Reference forested
Meadow Creek Lower (MEADL)	2.3 – 2.41	3440	Riparian fencing	Meadow
Meadow Creek Starkey (MEADS)	12.0 – 12.12	3770	Seasonal grazing	Forested

Study Design:

Monitoring is based on a paired watershed design for two subbasins, McCoy Creek and Dark Canyon Creek. Dark Canyon Creek is the control subbasin. McCoy Creek is the treatment subbasin. The remaining sites represent a range of less impacted reference sites. Results will be used to evaluate the benefits of riparian fencing and channel restoration on McCoy Creek.

Both McCoy Creek and Dark Canyon Creek subbasins have histories of use for grazing. Lower Dark Canyon Creek continues to be used for seasonal cattle grazing. No riparian fencing is in place, and cattle use the active stream channel. General habitat quality is poor. Lower McCoy Creek is characterized by channelized banks, shallow pools and riffles, and little riparian vegetation, and is the target of restoration efforts. Riparian fencing was is in place prior to initial monitoring in 1993.

In July 1997, a half-mile section of lower McCoy Creek was diverted from its channelized segment into the remnants of an historic meandering wet meadow channel

(Figure 2). Extensive riparian planting is ongoing in this restoration area. It is hoped that restoring wet meadow conditions and improving riparian vegetation cover will reduce heating and result in cooler stream temperatures within the restoration area.

Data collected before and after the channel diversion will be used to assess the affects of channel restoration on stream temperature in Lower McCoy Creek.

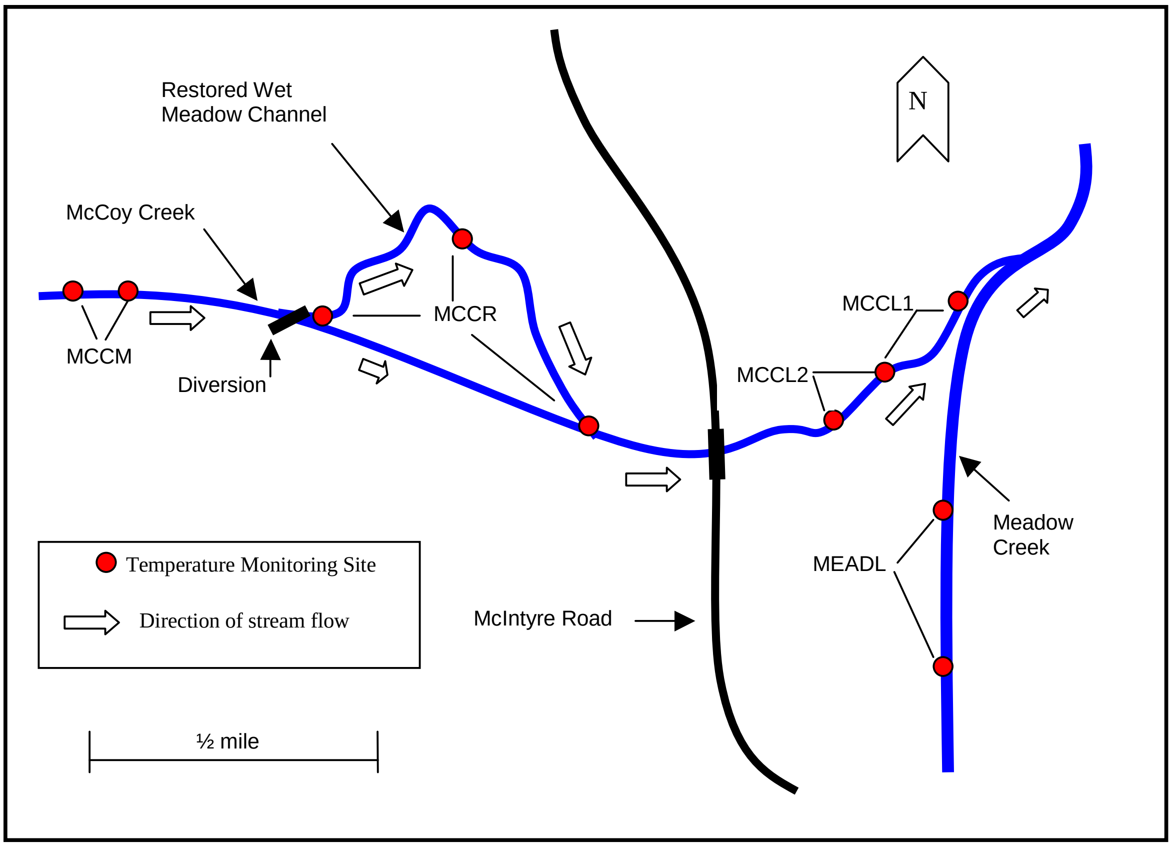

Figure 2. Schematic map of the McCoy Creek restoration project

Monitoring:

Continuous temperature data have been collected at the lower and upper boundaries of the study reaches each field season, from June through September.

During the course of this study, three types of continuous monitoring thermographs have been used: multiple parameter data loggers manufactured by UNIDATA, Hobo/Stowaway miniature loggers by ONSET, and minilog miniature loggers by VEMCO.

During the initial field season of 1993, permanent UNIDATA (Unidata, 1992) logger installations were in place at the Dark Canyon Creek, Lower Meadow Creek, and McCoy Creek sites. UNIDATA loggers were installed at permanent locations at the lower boundary of each study reach each field season beginning in 1994. These loggers were installed out of the stream with attached external probes placed in stream to measure water temperature. In addition, attached external weather probes for measuring ambient air temperature were placed at the stream bank, adjacent to the water probe, elevated approximately 1 meter above ground level. Following channel restoration on McCoy Creek, a UNIDATA logger was located at the lower boundary of the new wet meadow channel. These loggers were programmed to log hourly maximum, minimum, and average water and air temperatures, using temperature data measured at five-second intervals.

HOBO and STOWAWAY (Onset, 1993) miniature temperature loggers have been used to monitor water temperature at the upper boundaries of the study reaches. These were replaced by VEMCO (Vemco, 1998) miniloggers in 1997. In the McCoy creek restored channel, a VEMCO logger was deployed at the middle transect as well as the upper boundary. These miniature loggers have been programmed to measure and log temperature at thirty-minute intervals.

Specifications:

UNIDATA

Probe: PVC with chromed brass nose cone thermister
Sensor: semiconductor strain gauge element
Accuracy: 1.0% of range (0-50 C)
Resolution: 0.4% of range (-1 to 40 C)

HOBO and STOWAWAY

Probe: external
Accuracy: +/- 0.2 C
Resolution: 0.16 C at 15 C (range is –5 to 37 C)

VEMCO

Probe: external stainless steel
Accuracy: +/- 0.2 C
Resolution: 0.1 C (range is –5 to 35 C)

Quality Assurance:

All monitoring equipment was laboratory tested for accuracy before and after each field deployment. This was accomplished by comparing logger results in cold and warm water baths to simultaneous independent thermometer results. In addition, in stream field audits were performed during the deployment period. Field and laboratory tests were performed using National Institute of Standards and Technology (NIST) registered thermometers.

To best capture temperatures representative of ambient stream conditions, probes were placed in areas of well-mixed, laminar flow. Probes were attached to the stream substrate using spikes and nylon cable ties in a manner that allowed free circulation around the sensor, which was not in contact with the substrate.

Data Analysis:

The unit for all Oregon Water Quality Standards temperature criteria is the seven-day moving average of the daily maximum temperature. The average of the daily maximum stream temperatures for the seven warmest consecutive days is calculated and compared to the standard criteria. The numeric temperature criteria that apply to streams in the Grande Ronde River Basin are presented in Table 2 (Boyd, 1998). Temperature Data collected at NMP sites were summarized using seven-day statistics and applicable criteria (Appendix A).

Table 2. Water quality numeric temperature criteria in the Grande Ronde Basin (from Boyd, 1998)

Absolute Criterion – applies year long to all streams	$\le$ 17.8 C
Salmonid Spawning Criterion – applies to stream segments supporting native salmonid spawning during specific times when spawning, egg incubation, and fry emergence occur	$\le$ 12.8 C
Bull Trout Criterion – applies to waters which support bull trout populations	$\le$ 10.0 C

Results

A summary of all Grande Ronde NMP water temperature data collected from 1993 through 1998 is provided in Appendix A. The summary includes site coordinates, logger deployment period, maximum and minimum temperature values and dates, 7-day statistic maximum and minimum values and dates, and the number of hours temperatures were above Oregon water quality criteria of 12.8C and 17.8C.

The following graphic data summaries are intended to provide an overview of data provided in Appendix A. Site name abbreviations used in the following figures are listed along with the site names in Table 1.

Range

Figure 3 summarizes the year to year differences in the 7-day average maximum water temperatures measured from 1993 through 1998. Maximum temperatures range from 14.0 C in 1995 at the Limber Jim Creek Upper site to 29.6 C at the McCoy Creek Lower #1 site in 1998. Data shown are from permanent logger installations at the lower boundary of each study reach. At five sites (MCCL1, MCCM, MEADL, DARKL, DARKU) monitoring began in 1993. Data were collected at the remaining sites beginning in 1994, except for the McCoy Creek Restored site (MCCR). Temperature data were collected in the McCoy Creek restoration area following the completion of the channel diversion in 1997. No data are available for Lower Limber Jim Creek in 1998 because of equipment failures.

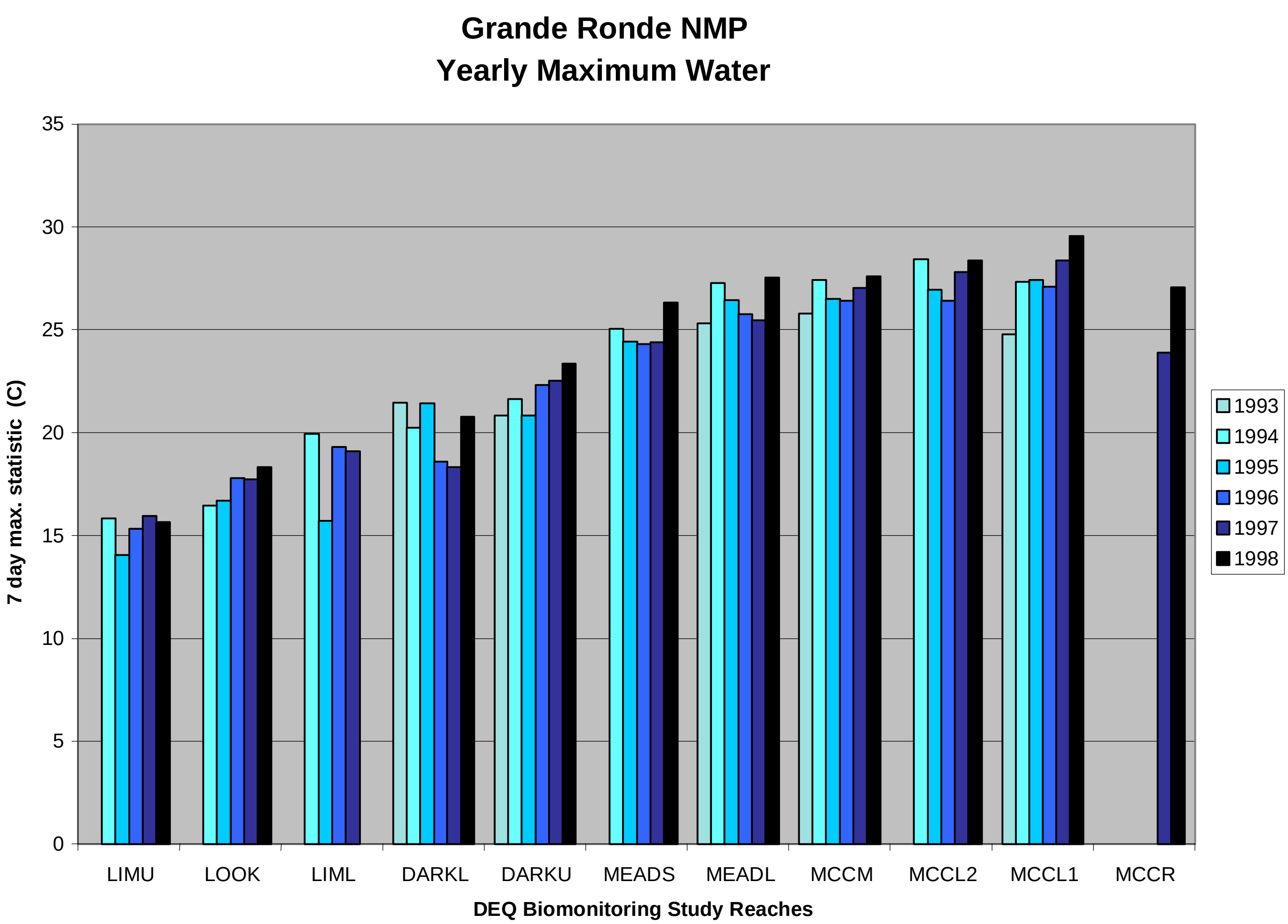

Figure 3. Range of maximum water temperatures at Grande Ronde NMP sites 1993 through 1998

Figure 4 summarizes the range of maximum water temperatures for each site using data collected from 1994 through 1998. Each box and whisker figure represents the maximum, minimum and mean of the 7-day maximum values from the individual study sites. The Oregon water quality standard of 17.8 C is shown as a point of reference.

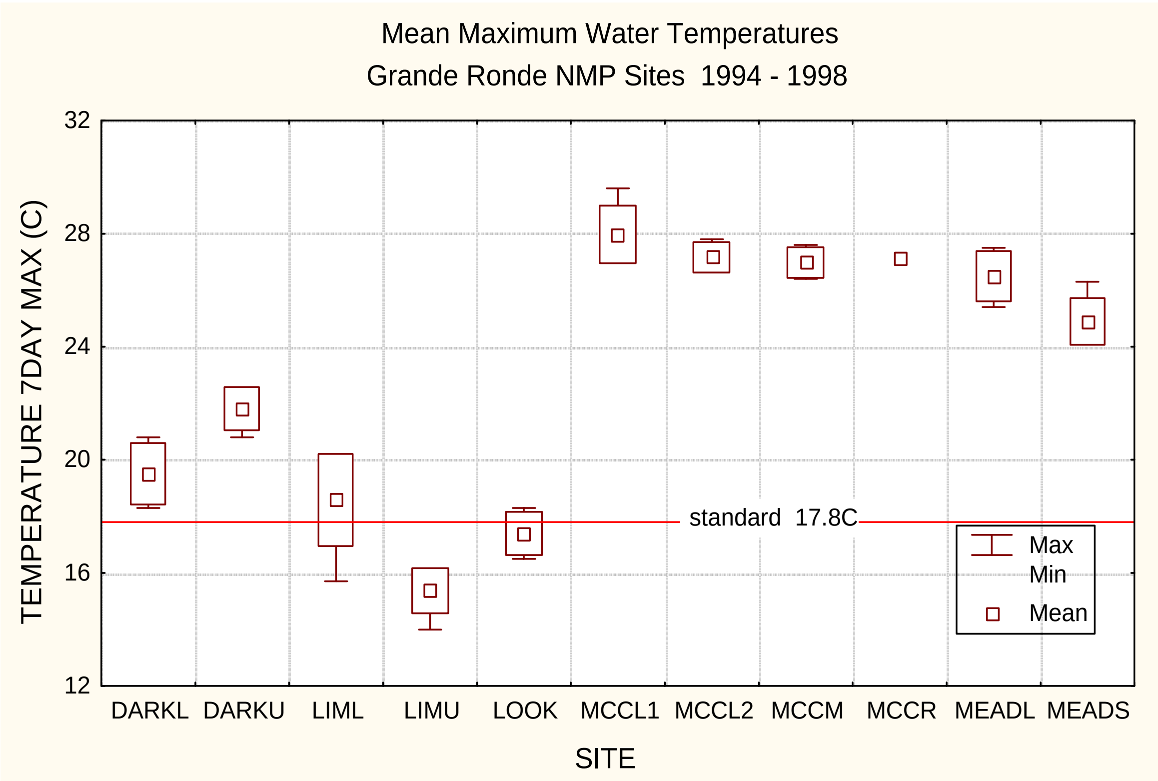

Figure 4. Mean, maximum, and minimum of the 7- day maximum water temperatures at Grande Ronde NMP sites 1994 through 1998

The range of ambient air temperatures measured at the study sites during the 1998 season are listed in Table 3. Average, maximim and minimum temperatures are listed. The sites are ranked by maximum air temperature from high to low. No data are available for the lower Limber Jim Creek (LIMBL) site because of equipment failure.

Table 3. Air temperatures at Grande Ronde NMP Sites July through September, 1998

Site	Maximum (C)	Minimum (C)	Average (C)
Meadow Cr. Lower (MEADL)	37.4	4.4	15.6
McCoy Cr. Lower (MCCL1)	37.1	- 4.0	15.6
McCoy Cr. Restored (MCCR)	36.5	-3.8	15.3
Meadow Cr. Starkey (MEADS)	36.2	0.2	15.9
McCoy Cr. Middle (MCCM)	35.9	0.2	17.0
Dark Canyon Cr. Lower (DARKL)	35.6	-0.7	16.0
Dark Canyon Cr. Upper (DARKU)	35.0	-1.3	14.5
Lookout Cr. (LOOK)	34.4	-2.6	13.4
LimberJim Cr. Upper (LIMBU)	32.5	-0.7	13.4

Temperature Profiles

Figure 5 traces water temperature data logged at upper Limber Jim Creek and lower McCoy Creek during the 1994 and 1998 summer seasons. These profiles represent the seven-day average of daily maximum temperatures. Profiles for the other study sites have similar shape, and fall between these high and low extremes. Peak temperatures occur between mid-July and mid-August. The Oregon Water Quality Standard (17.8 C) is included as a point of reference.

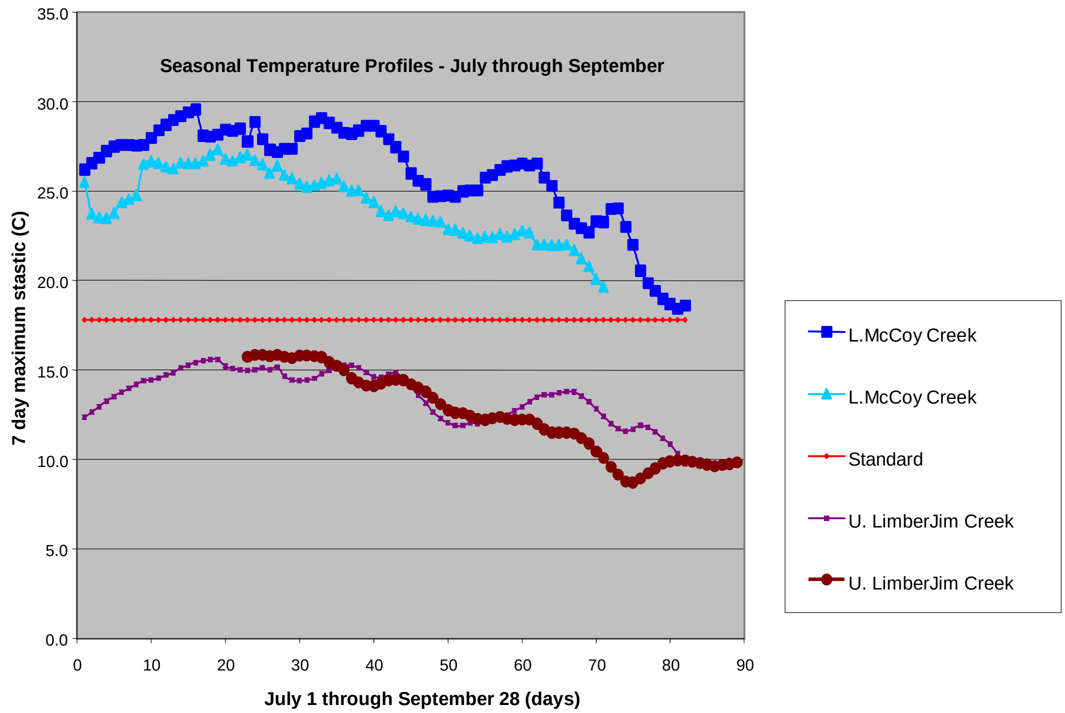

Figure 5. Water temperature profiles of the coolest and warmest Grande Ronde NMP sites recorded during the 1994 and 1998 summer seasons

Figure 6 plots the yearly mean of maximum water temperatures combined from all sites by year from 1994 through 1998. The 7-day maximum temperatures from all sites were combined for each year and summarized as mean, maximum and minimum temperatures. The coolest water temperatures occurred in 1995, and the warmest temperatures occurred in 1998.

Figure 7 traces yearly maximum water temperatures for each site through time from 1993 through 1998.

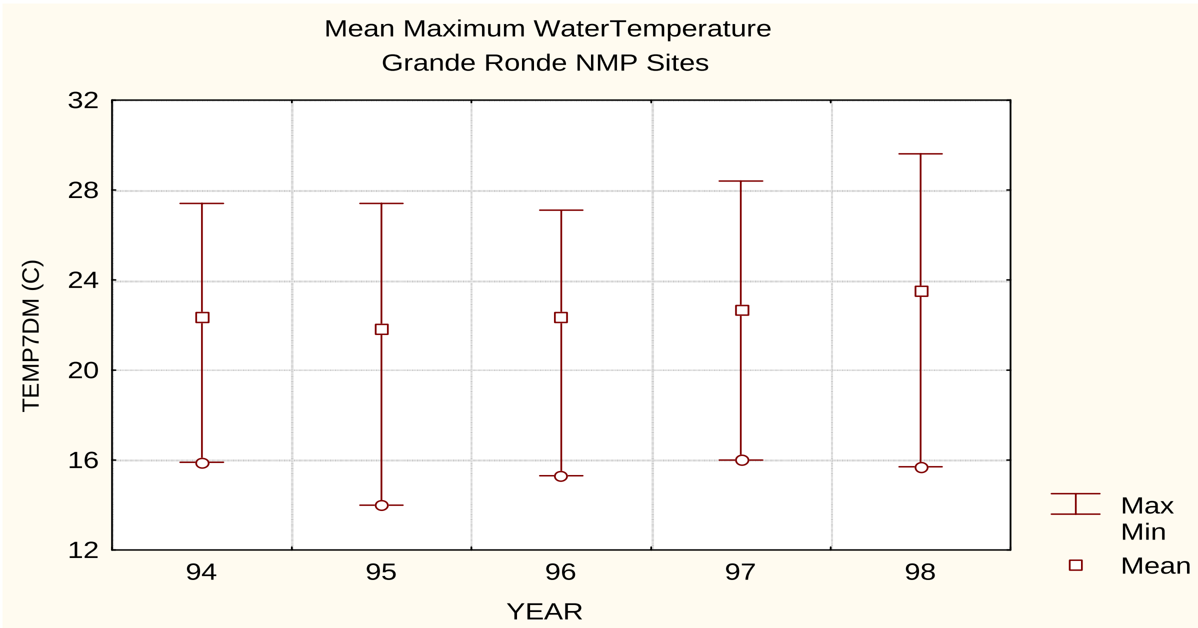

Figure 6 Yearly maximum, minimum, and mean water temperatures using combined values from Grande Ronde NMP sites 1994 through 1998

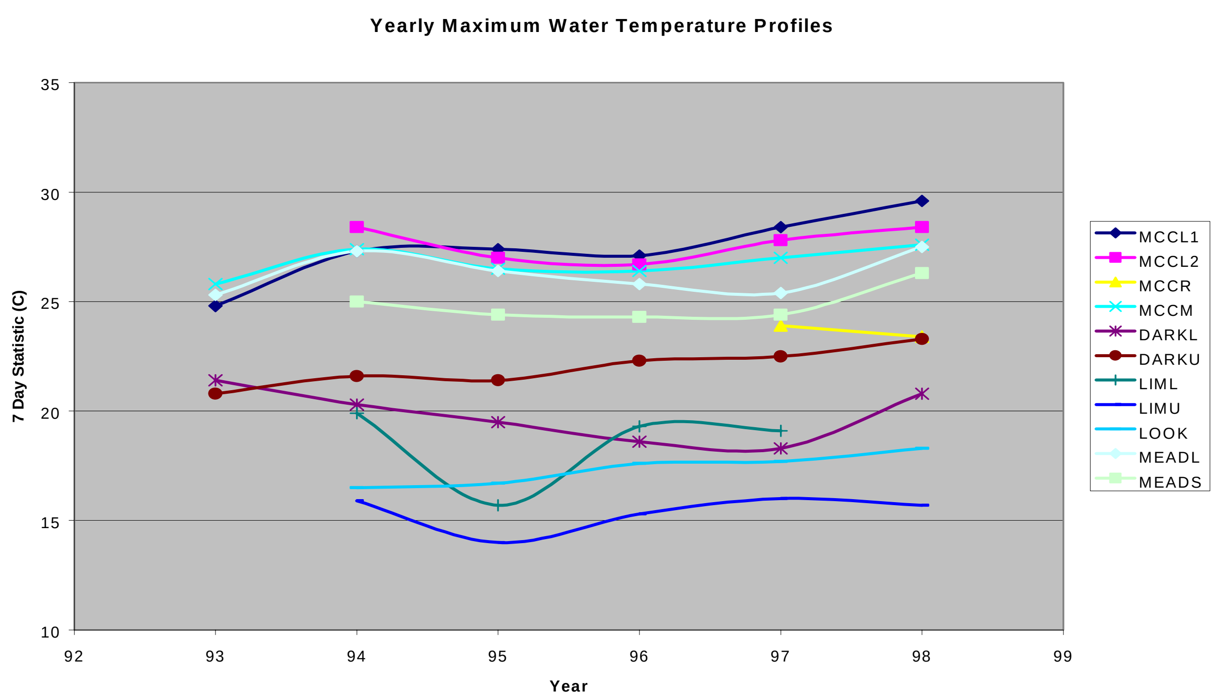

Figure 7. Yearly maximum water temperature profiles for Grande Ronde NMP sites, 1993 through 1998

Figures 8 and 9 are ambient air temperature profiles. Data represented were collected July through September, 1998. Figure 8 is the profile at the LimberJim Creek Upper site, which has was the coolest site. Figure 9 is the profile at the McCoy Creek Lower #1 site, which was a warmer site (Table 3).

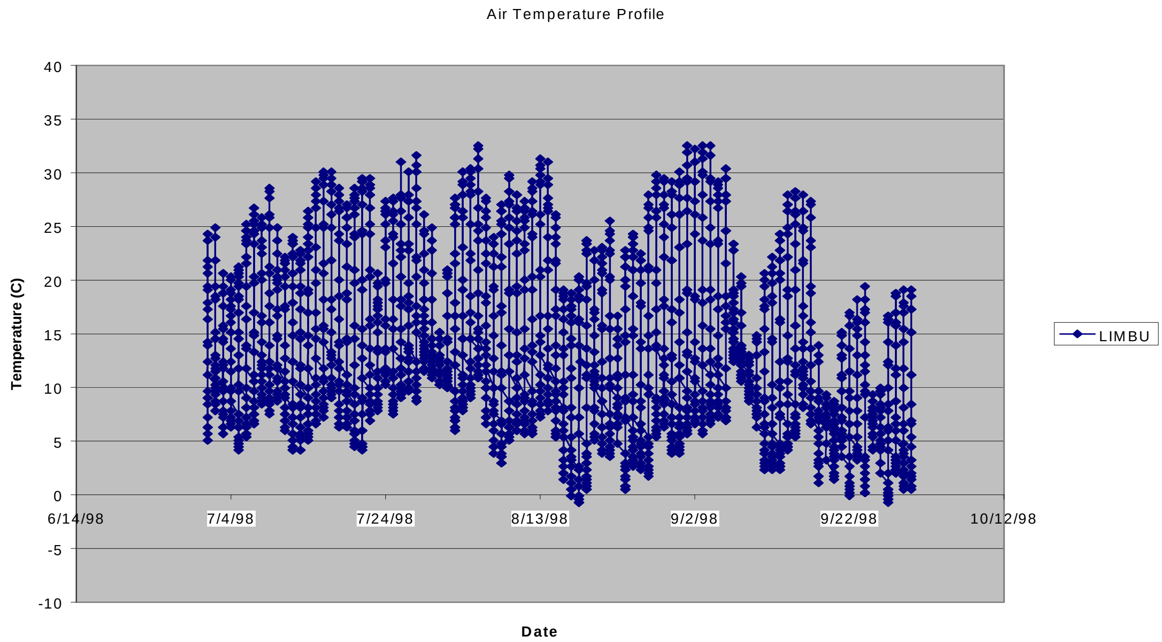

Figure 8. Ambient air temperature at LimberJim Creek Upper Site, July through September, 1998

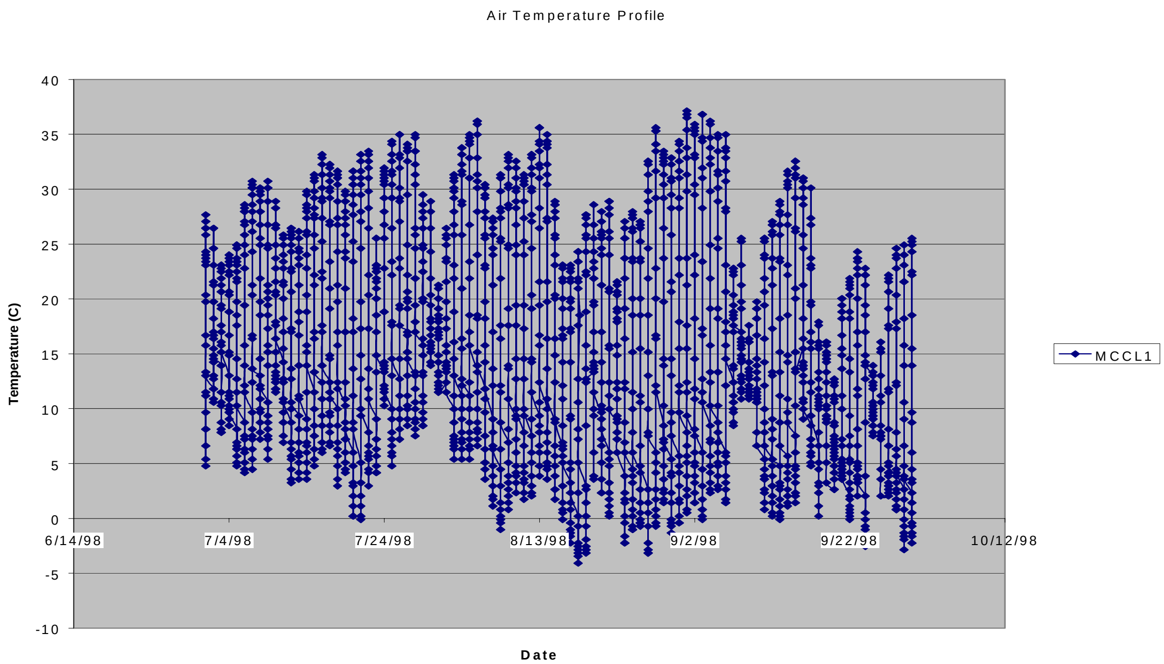

Figure 9. Ambient air temperature at McCoy Creek Lower Site, July through September, 1998

McCoy Creek Profiles

Figures 10 and 11 are yearly longitudinal water temperature profiles, which focus on the McCoy Creek sites using data collected from 1995 through 1998. The profiles trace seven day moving average water temperatures from the middle site at river mile 2.08, through the restored wet meadow area, down to the lower boundary of McCoy Creek Lower #1 at river mile 0.12. Vertical lines delineate the restored channel section, which lies between river miles 0.95 and 1.45. Figure 10 traces yearly temperatures collected above and below the restored section, with no data collected within the restored area represented. Figure 11 includes temperature data collected at the upper and lower boundaries and within the restored channel section during 1997 and 1998.

McCoy Creek longitudinal profiles show a general warming trend from 1995 through 1998, and that similar cooling has occurred in the area of wet meadow restoration (river mile 0.95 to 1.45) both before and after the channel diversion was completed in 1997 (Figure 8). Temperatures increase sharply in the lower section.

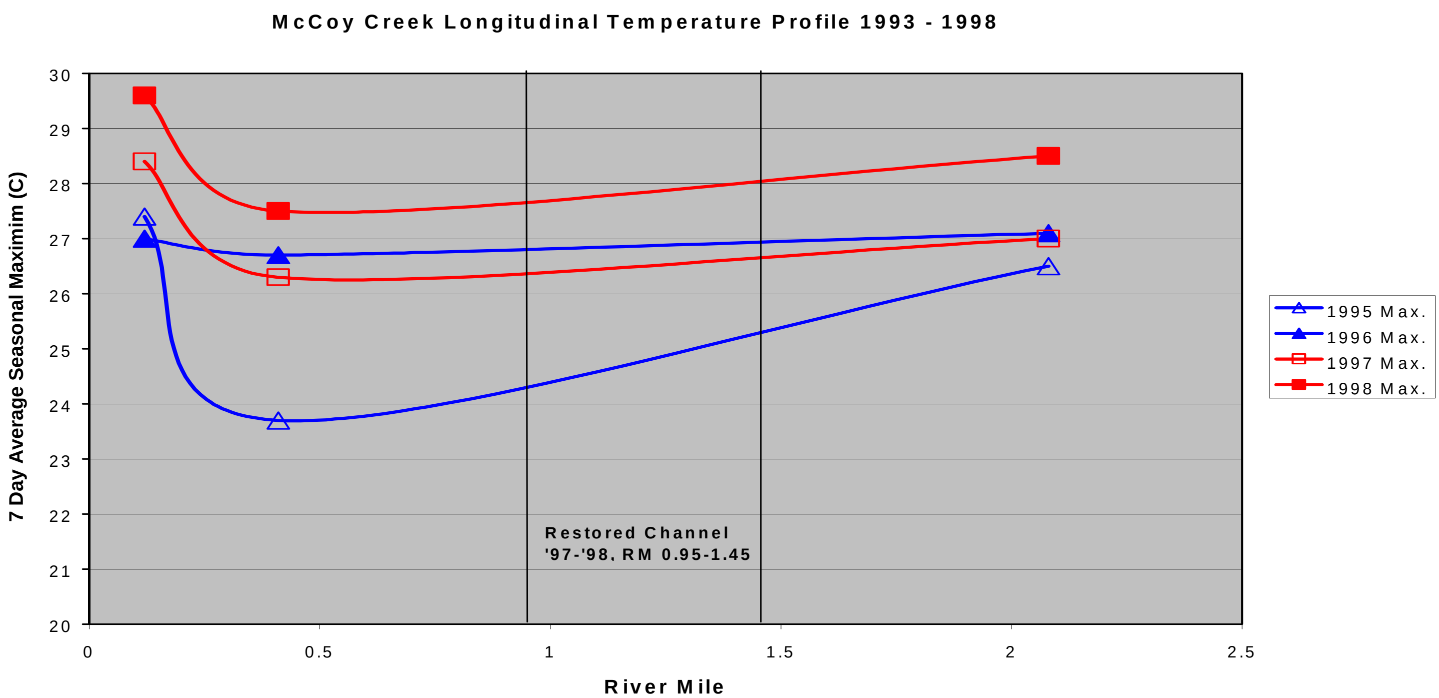

Figure 10. Yearly maximum temperatures above and below the section of McCoy Creek restored in 1997.

The 1998 water temperature data shown in Figure 11 trace a drop of over 4.5 degrees within the new restored reach, which was created by diversion in July 1997. The 1997 data shown in Figure 11 indicate a similar decrease in temperature within the restored channel segment. In 1997, temperature data were collected at the upper transect (river mile 1.45) and middle (river mile 1.25) transects of the new restored channel segment.

Data form the lower boundary of the restored reach (river mile 0.95) were not available due to equipment loss. In 1998, data were collected at transects in the upper, middle, and lower segments of the reach.

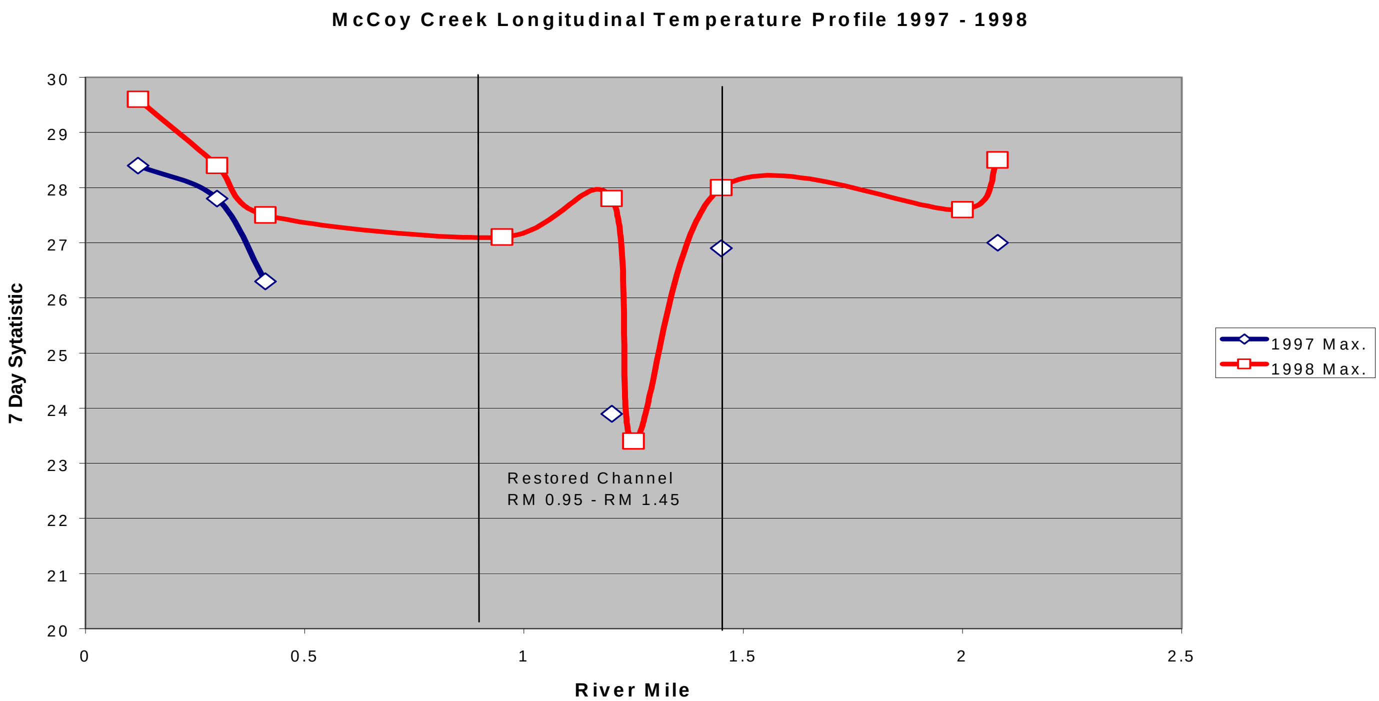

Figure 11. Yearly maximum temperatures above, below, and within the section of McCoy Creek restored in 1997.

Discussion

Range

Yearly 7-day maximum water temperature profiles show water temperatures range from 29.6 C at McCoy Creek Lower #1 in 1998 to 14.0 at Limber Jim Creek Upper in 1995 (Figures 3 and 7). These two sites bracket the high and low temperature extremes each year throughout the study from 1994 through 1998. The average difference between the coolest and warmest sites has been 13.5 C. Within this range, a pattern of two groups is clear (Figure 4):

(1) Six warmer sites, with mean maximum temperatures ranging between 24 C to 28 C, located in the McCoy Creek and Meadow Creek subbasins.
(2) Five cooler sites, with mean maximum temperatures ranging between 15C and 23 C, located in the Lookout Creek, LimberJim Creek, and Dark Canyon Creek subbasins.

Profiles

Seasonal water temperature profiles shown in Figure 5 are typical of all sites. These profiles show peak temperatures regularly occur between mid-July and early August (Appendix A). The profiles in figure 5 are of the warmest and coolest sites, and trace similar shapes throughout the course of the sampling season. The 1998 ambient air temperature profiles from cool and warm sites also have similar shapes (figures 8 and 9). The similarity of profiles at all sites suggests the streams are responding similarly to broad seasonal conditions affecting the entire study area. Upper Limber Jim Creek has consistently been the coolest site. Lower McCoy Creek has consistently been the warmest site except during 1993. In 1993, the warmest 7-day maximum temperature was recorded at the middle McCoy Creek site (25.8 C), and lower Meadow Creek was slightly warmer (25.3 C) than lower McCoy Creek (24.8 C).

Yearly profiles of maximum water temperatures from 1993 through 1998 (figure 7) show most similar profile shapes occur for sites located in the same subbasin, particularly the McCoy Creek, Meadow Creek, and Limber Jim Creek subbasins. For example, the Lower Meadow Creek profile is most similar to the Meadow Creek Starkey profile, and the Lower Limber Jim Creek profile is more similar to Upper Limber Jim Creek than to any other profiles. This suggests stream temperatures are affected by subbasin specific conditions, such as land use, stream discharge levels, and habitat conditions, as well as to more general basin wide conditions, such as seasonal weather patterns and day length.

Trends

A slight warming trend from 1995 to 1998 is evident in the mean values of the combined maximum water temperature data plotted in Figure 6. Results show the coolest mean of combined maximum temperatures for all sites occurred in 1995, and the warmest mean of combined temperatures occurred in 1998. The dissimilar profiles from different subbasins, displayed in Figure 7, indicate this general trend is not equal at all sites. Temperatures do not shift proportionally at all sites from year to year. For example, the coolest temperatures occurred in 1997 at lower Dark Canyon Creek, while 1995 was the coolest year at Lower Limber Jim Creek. Analyses of variables at the subbasin level would be of interest in assessing and comparing temperature trends at individual sites.

Environmental Variables affecting Stream Temperatures

Results show seasonal stream temperature profiles from different sites to be similar in shape, but different in magnitude during the study period 1994-1998 (Figure 5). Stream temperatures are responding to general seasonal conditions similarly, yet site specific mean maximum temperatures range between 16 C and 28 C (Figure 4). Environmental attributes, which vary from site to site, can be associated with warmer or cooler stream temperatures. Environmental variables measured at Grande Ronde NMP sites which can be associated with differences in stream temperatures include general habitat condition, subsurface groundwater inflow, shade and solar input, and channel morphology.

Habit conditions were evaluated at each site using a Rapid Bioassessment Protocol (RBP) habitat assessment matrix (DEQ 1997). Evaluation included assessment of channel and riparian conditions. This was a holistic habitat assessment that resulted in a numeric score (RBP score). Associations of habitat quality with maximum temperatures can be inferred from Figure 12.

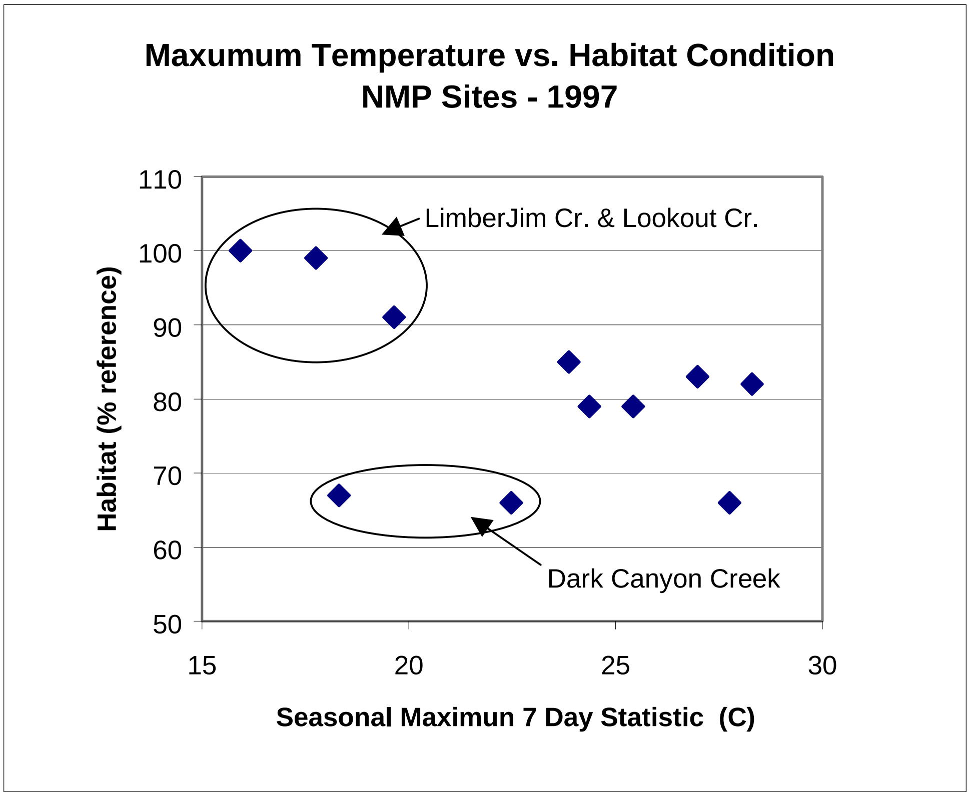

Figure 12. Habitat condition is associated with maximum stream temperatures at Grande Ronde NMP sites. Each data point represents an individual site.

In Figure 12, habitat quality is expressed as a percent of the best reference site score. The Upper Limber Jim Creek site, having the highest RBP score, is ranked as 100 %. With the exception of the Dark Canyon Creek sites, the association of temperature regime and habitat condition is clear. The coolest temperatures were measured at the Limber Jim Creek Sites and Lookout Creek. These sites are ranked between 90% to 100% of best reference conditions. Stable channel and riparian habit characterize these sites. Maximum temperatures at these sites were less than 20C. Habitat quality at the remaining sites ranged from 60% to 85% best reference conditions. Channel and riparian habitats were more or less degraded at these sites. Other than Dark Canyon Creek, seasonal maximum temperatures were greater than 23C at sites where habitat quality scored below 85%.

In general, lower temperatures are associated with higher habitat scores. Conversely, higher temperatures associate with lower habitat scores. Dark Canyon Creek poses an interesting exception. Channel and riparian habitat are in poor condition, yet stream temperatures remain cooler throughout the summer season. Two attributes of Dark Canyon help explain this: cooling subsurface water inflow and topography.

Subsurface water, which is insulated from surface heating processes, is most often cool (7.2 -12.8 C), with little fluctuation (Boyd 1998). Cold springs and seeps are numerous in Dark Canyon. Cold pockets within the channel have been noted during macroinvertebrate and fish sampling, particularly in the lower study reach. In 1996, fluorescent dye for measuring water movement was injected into Dark Canyon Creek at river mile 2.0 during low flow conditions. None of this dye was recovered by subsequent sampling at the lower monitoring site (river mile 0.40). Stream flow volumes measured at the points of injection and sampling were roughly equivalent (Whitney 1996). This suggests extensive exchange of surface and ground water in this section of the creek during low flow conditions. It is likely that inflowing subsurface water contributes to the cooler temperatures measured in Dark Canyon creek during summer low flow conditions.

The topography of Dark Canyon also provides shade to the creek. Unlike McCoy Creek, which flows through wide meadow habitat, Dark Canyon Creek flows through a steep, narrow canyon. The steep, close canyon walls protect the stream channel from heating by direct sunlight for a greater portion of the hot summer days.

The principal source of heat delivered to a stream is solar energy striking the stream surface directly (Brown 1970). Less surface area exposed to direct solar radiation translates to less heat energy transferred to the stream. Shade and channel width clearly affect the amount of direct solar radiation reaching the stream surface. A shaded stream channel is less exposed to solar radiation than an unshaded channel. A narrow channel exposes less surface area than a wide channel.

In addition to the RBP assessment, a more rigorous measure of a number of specific habitat variables is part of the Grande Ronde NMP sampling. Measurement of these variables is within the boundaries of each study reach. The average length of the study reaches is approximately 0.2 mile. Variables quantified include exposure to solar radiation, shade, channel width, and stream flow volume. Grande Ronde NMP results illustrate the association of lower stream temperatures with reduced exposure to solar radiation, increased shade, and narrower channels.
Solar radiation data have been collected at all sites using a Solar Pathfinder instrument. The pathfinder is designed to determine the percentage of solar radiation blocked by features in the landscape like trees and hills (Solar Pathfinder, 1995). Using Solar Pathfinder data, the percent of potential available radiation reaching the site locations has been calculated. These results are listed in Table 4.

Table 4. Average maximum water temperature and average exposure to solar radiation, July, August, and September 1993 through 1996

Site	Average Maximum Water Temperature (C)	Average Solar Exposure (% surface)
McCoy Cr. Lower #1 (MCCL1)	27	100
McCoy Creek Middle (MCCM)	26.4	51.4
McCoy Cr. Restored * (MCCR)	26.1	97.8
McCoy Cr. Lower #2 (MCCL2)	26.1	100
Meadow Cr. Lower (MEADL)	25.6	99.5
Meadow Cr. Starkey (MEADS)	24.9	40
Dark Canyon Cr. Upper (DARKU)	21.5	36.9
Dark Canyon Cr. Lower (DARKL)	20.8	58.2
LimberJim Cr. Lower (LIML)	19.4	83.1
Lookout Creek (LOOK)	17.3	49.3
LimberJim Cr. Upper (LIMU)	15.6	29.3

- *1997 data from the lower boundary of the restored channel

Sites are listed in Table 4 in the order of their maximum water temperatures, with the warmest site at the top of the rank, and the coolest site at the bottom. The warmest site, Lower McCoy Creek #1, has a corresponding solar exposure of 100%. The coolest site, LimberJim Creek Upper, has a corresponding solar exposure of 29.3 %.

In general, the data summarized in Table 4 show the warmer sites experience greater solar exposure than the cooler sites. However, there are several exceptions. The LimberJim Creek Lower site (LIML) has cooler water temperature, but the average solar exposure is relatively high (83.1%). On the other hand, the Meadow Creek Starkey and McCoy Creek Middle sites have warmer water temperatures, but average solar exposures are relatively low (40% and 51.4%). It is important to note that the solar path data are collected within the boundaries of the individual study reaches, and do not reflect upstream conditions, which influence the temperature of the water before it enters the study reach. For example, LimberJim Creek flows through a heavily forested area until it reaches the open meadow area where the Lower site (LIML) is located. The Upper site (LIMU) is representative of this forested area, where solar exposure is low, and water temperature is cool. LimberJim creek is cool when it flows out of the forest into the meadow area at the lower site. The opposite situation occurs at the Meadow Creek Starkey (MEADS) and McCoy Creek Middle (MCCM) sites. At these sites, the water entering the study reach is warm. Significant heating or cooling has not been measured as the water flows through the short distance of these reaches from upper to lower boundaries (Appendix A).

In addition to solar path data, stream cover has been measured at all study reaches using a densiometer. Densiometer readings reflect the amount of cover provided to the stream channel by overhanging banks, rock outcrops, large wood, and riparian vegetation. The association of cooler water and cover measured by densiometer is shown in Figure 13, which plots shade measurements, expressed as % cover against maximum temperatures. The regression line fit through these data indicates a positive association between % cover and cooler temperatures. The wide scattering of data points above and below the regression line, particularly in the area where cover ranges between 30% and 50%, can be attributed to the influence of other environmental variables, such as groundwater exchange and differences in channel morphology.

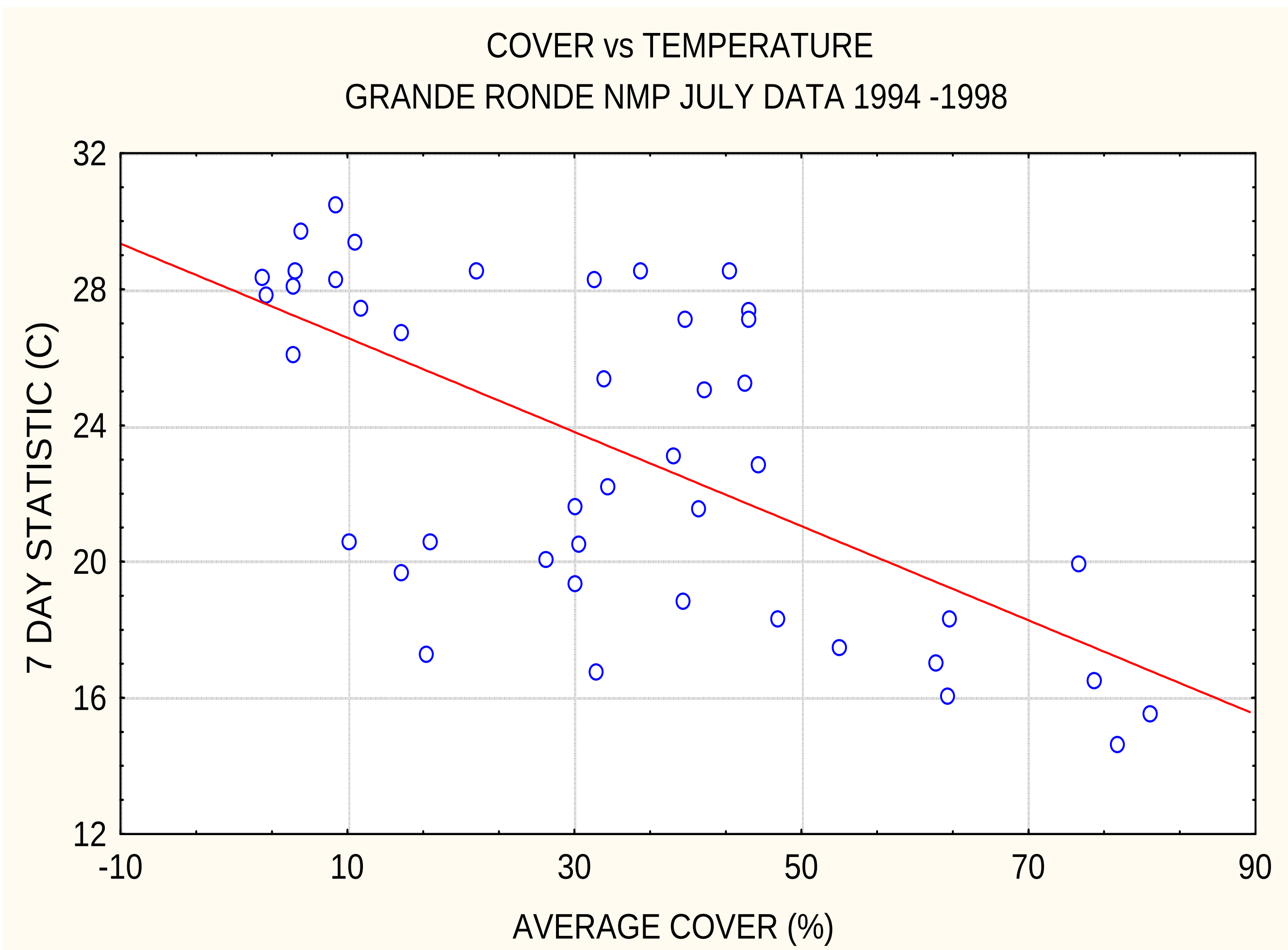

Figure 13. Shade related to maximum temperature.

Channel width was measured at six transects per study reach. Figure 14 graphically displays the association between channel width and maximum water temperatures. Cooler temperatures are positively associated with narrower channels.

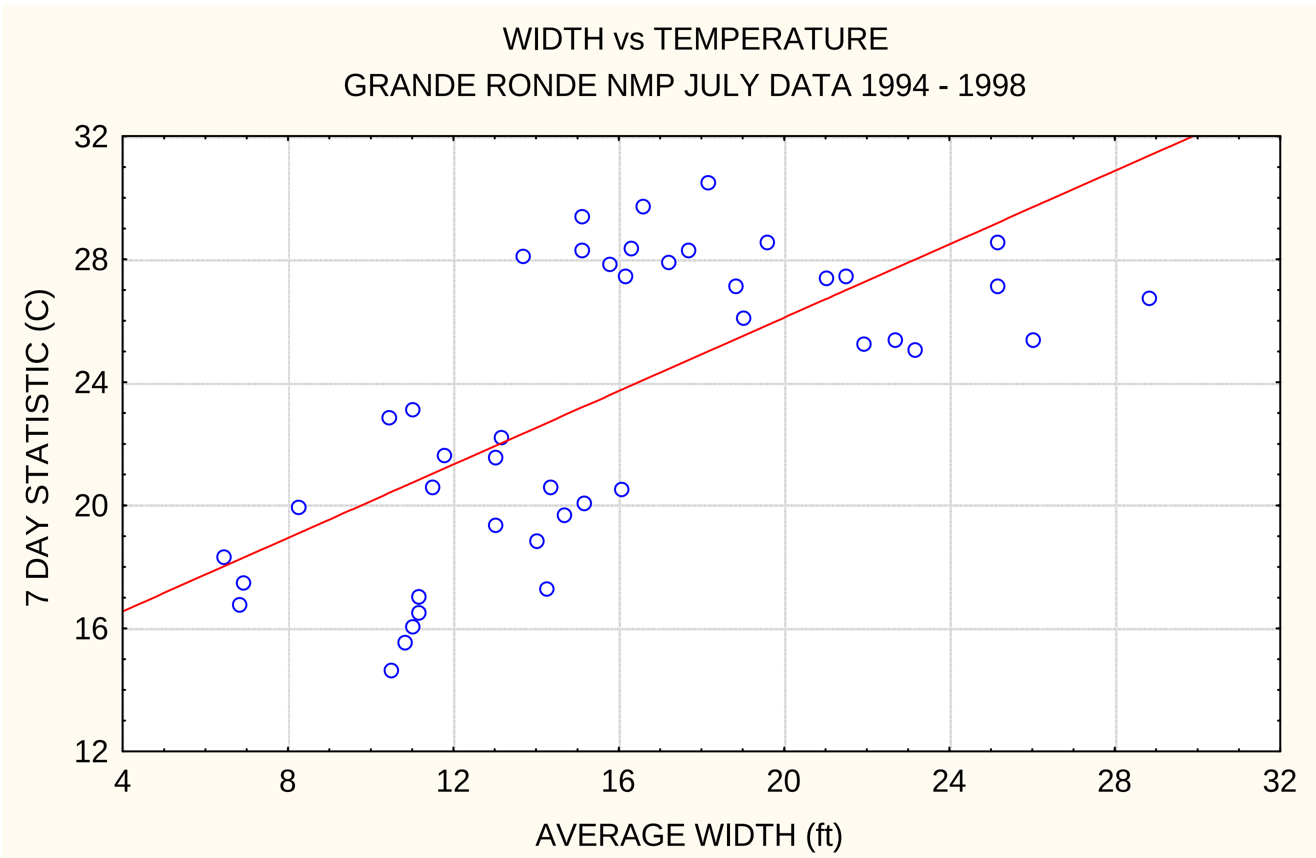

Figure 14. Channel width related to maximum temperatures

Stream flow volume (discharge) has been measured at all sites during each site visit. Discharge data coupled with water temperature data can be useful in detecting cooling subsurface water inflow into a warmer stream channel. For example, results show cooling has occurred in the lower McCoy Creek meadow area between river mile 2.0 and 0.4 both before and after a section of this reach was diverted from the ditched channel to a historic wet meadow meander channel in 1997(Figure 10). A summary of discharge data collected from 1994 to 1998 indicates this section, between the Middle and Lower study sites, is a gaining reach (Figure 15). This suggests cooler groundwater inflow has historically influenced temperatures in this section (RM 2.0 to 0.4).

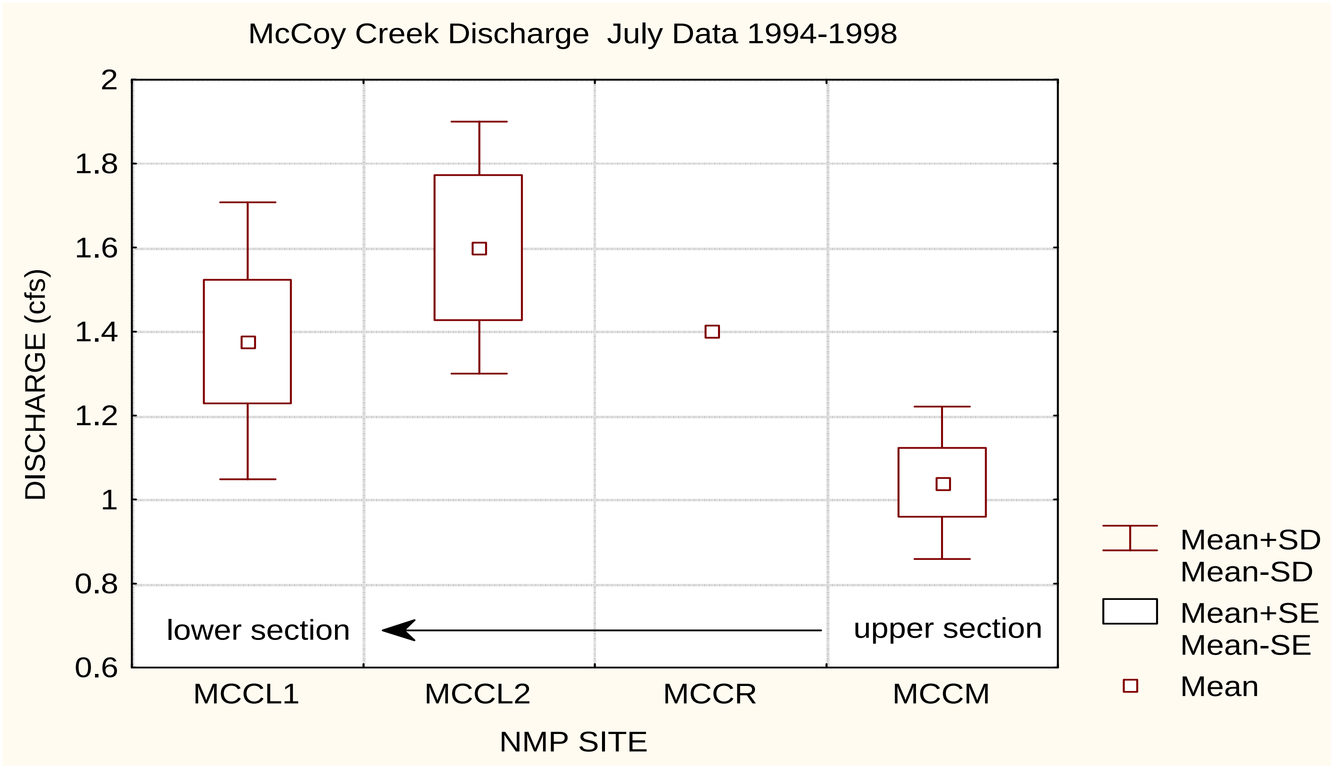

Figure 15. McCoy creek flow volumes.

Figure 15 displays mean discharge values, which increase as McCoy creek flows through the meadow area from the middle site (MCCM) to the lower site (MCCL2). Volume then decreases between MCCL2 and MCCL1. The temperature profile (Figure 10) for this section shows cooling occurs within the gaining reach between MCCM and MCCL2, and that warming occurs in the loosing section between MCCL2 and MCCL1. There is typically no surface water flowing into McCoy Creek in late July, which is when these discharge volumes have been recorded. Increased volume associated with cooling temperature indicates McCoy Creek has benefited from cool subsurface water inflow.

McCoy Creek Restoration

McCoy creek flows approximately two miles through open meadow habitat from below the Middle McCoy study site to its confluence with Meadow Creek (Figure 2). This section was channelized in the 1960's to prevent flooding and to maximize pasture area. The channelized section has been fenced to exclude grazing in the riparian area since the beginning of this NMP study in 1993, but habitat recovery has been slow. The stream channel remains shallow and wide, formation of new meanders and point bars has been minimal, and deposition of fines and growth of riparian vegetation has been slow. Beavers have not succeeded in the channelized section. Exposure to solar radiation is high (table 4), and shade by vegetative cover is minimal. Although pockets of cool inflowing groundwater exist, water temperature is high.

In July 1997, McCoy creek was diverted at the upper end of the channelized section. By design, the diverted water flowed into a half-mile section of remnant meandering channel, which had been left dry after the creek was channelized. Response within this newly restored channel section (MCCR) was quick and dramatic. The remnant channel defined meanders and a lower gradient. Fine soil was available. Existing vegetation, particularly willows, grew quickly in the new riparian area. By the end of the first summer season, parts of the restored channel were completely covered by new willow growth. Beavers moved in and succeeded in building dams, which created several large, deep pools and numerous smaller pools.

Solar exposure data measured in the restored channel in 1997 is high (97.8%). However, the quickly growing willow plants have begun to provide cover to the channel. The mean width of the restored channel is greater than mean widths measured in the channelized section, but the mean depth is also greater in the restored reach. This results in a lower width to depth ratio in the restored section, which translates to less exposed surface area per unit of stream volume. Table 5 lists cover, channel width, channel depth, and channel width:depth measured in the restored section (MCCR) and in the channelized section (MCCL1 and MCCL2).

Table 5.

Site	Cover (%)	Mean Channel Width (ft.)	Mean Channel Depth (ft.)	Width:depth
McCoy Cr. Restored (MCCR)	21.3	19.6	1.4	14.0
McCoy Cr. Lower #2 (MCCL2)	10.5	15.1	.5	25.6
McCoy Cr. Lower #1 (MCCL1)	8.8	18.2	.7	25.5

Following the channel diversion in 1997, cooler temperatures were measured within the boundaries of the restored reach. Compared to the temperature of the water flowing into the restored section, maximum water temperatures measured in the middle of the reach were 3.0 C cooler in 1997, and 4.6 C cooler in 1998 (Figure 11). In 1998, water temperature measured at the bottom of the reach was 0.9 C cooler than the temperature measured at the top. As the creek continues to flow down stream into and through the channelized section below the restored reach, heating continues.

Discharge measurements show the restored channel to be a gaining reach (Figure 15). Cooling within the restored section can be attributed to the lower gradient, meandering, deeper channel, which allows increased connection and mixing with cool subsurface water. The surface of this cooler water is shaded by growing vegetation. Further protection from solar heating is provided by increased depth and lower width to depth ratio.

Conclusions

In general, results confirm a clear relationship between stream temperatures and channel morphology and channel cover. A narrower channel exposes less surface area to heating. Sites with narrower channels were cooler than sites with wider channels. Cover provides protection from heating. Sites with more cover were cooler than sites with less cover.

Results suggest inflow of cool subsurface water can be an important component in maintaining cool stream temperatures. This can be inferred from the temperature profiles of Lower Dark Canyon Creek and Lower McCoy Creek. Dye study results and discharge data indicate these reaches gain volume from subsurface water inflow. This inflow maintains cooler stream temperatures, even in channels that are wide and shallow with little cover.

Cooler stream temperatures can be achieved and maintained by improving channel morphology, increasing cover shading the channel, and by promoting a healthy water table connecting the stream channel with subsurface water. The McCoy Creek restoration efforts have made improvements in each of these areas. The restored channel is deeper, and riparian plantings and existing plants are growing to cover channel. The lower gradient, meandering restored channel allows more mixing with subsurface water. Early results are encouraging. Temperatures are cooler within the restored section.

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Appendix A. Grande Ronde National Monitoring Program
Water Temperature Monitoring Results Data Summary

Table A-1 1993 – 1995

Site Name (transect number)	River Mile	Latitude	Longitude	Monitoring start date	Monitoring stop date	Seasonal Maximum		Seasonal Minimum		7-Day averages			Hours > 12.8 (C)	Hours > 17.8 (C)
						Date	Value (C)	Date	Value (C)	Date	Max. (C)	Min.(C)		
McCoy Creek Lower #1 (T-1)	0.12	45 15 44	118 24 09	07/15/1993	09/30/1993	08/06/1993	25.4	09/22/1993	5.0	08/06/1993	24.8	13.6	1350	475
McCoy Creek Middle (T-6)	2.08	46 16 15.6	118 25 47.4	07/15/1993	09/30/1993	08/06/1993	26.5	09/22/1993	3.3	08/06/1993	25.8	14.3	1302	445.2
Meadow Creek Lower (T-1)	2.30	45 15 42	118 24 02	07/17/1993	09/30/1993	08/06/1993	25.8	09/22/1993	5.2	08/06/1993	25.3	15.5	1426	543
Dark Canyon Creek Lower (T-1)	0.40	45 16 30	118 22 56	07/15/1993	09/30/1993	08/06/1993	21.7	09/24/1993	7.1	08/06/1993	21.4	13.4	1161	205
Dark Canyon Creek Upper (T-1)	3.00	45 18 50	118 24 06	07/15/1993	09/30/1993	08/04/1993	21.4	09/22/1993	4.9	08/06/1993	20.8	10.6	691	129
McCoy Creek Lower #1 (T-1)	0.12	45 15 44	118 24 09	06/16/1994	09/12/1994	07/17/1994	28.4	09/12/1994	8.0	07/19/1994	27.3	13.1	1741.2	982.8
McCoy Creek Lower #2 (T-1)	0.30	45 15 48	118 54 16	06/16/1994	09/11/1994	07/24/1994	29.4	09/05/1994	7.8	07/19/1994	28.4	12.2	1633.2	946.8
McCoy Creek Middle (T-1)	2.00	45 16 12	118 25 36	06/16/1994	09/30/1994	07/21/1994	28.6	09/25/1994	8.4	07/19/1994	27.4	15.4	2232	1165
McCoy Creek Middle (T-6)	2.08	46 16 15.6	118 25 47.4	06/16/1994	09/11/1994	07/21/1994	28.1	06/17/1994	8.1	07/19/1994	27.2	15.0	1857.6	1030.8
Meadow Creek Lower (T-1)	2.30	45 15 42	118 24 02	06/16/1994	09/30/1994	07/24/1994	27.9	06/17/1994	8.4	07/19/1994	27.3	16.1	2319	1317
Meadow Creek Starkey (T-1)	12.00	45 16 13	118 32 21	06/16/1994	09/30/1994	07/24/1994	25.4	06/17/1994	7.1	07/22/1994	25.0	15.7	2006	935
Dark Canyon Creek Lower (T-1)	0.40	45 16 30	118 22 56	06/16/1994	09/30/1994	07/08/1994	20.8	06/17/1994	7.8	07/27/1994	20.3	15.5	2270	486
Dark Canyon Creek Lower (T-6)	0.47	45 16 40.7	118 22 51.7	06/16/1994	09/11/1994	08/04/1994	21.9	06/17/1994	8.6	08/04/1994	21.3	15.1	1908	414
Dark Canyon Creek Upper (T-1)	3.00	45 18 50	118 24 06	06/16/1994	07/19/1994	07/17/1994	22.3	06/17/1994	6.5	07/16/1994	21.6	10.5	374	142
Dark Canyon Creek Upper (T-6)	3.07	45 18 55.1	118 24 9.7	06/16/1994	09/11/1994	08/02/1994	21.4	06/17/1994	6.1	07/24/1994	20.5	11.7	1010.4	172.8
Lookout Creek (T-1)	3.00	45 05 31.1	118 31 49.3	07/27/1994	09/30/1994	07/28/1994	16.8	09/13/1994	6.9	07/30/1994	16.5	10.9	387	0
Limber Jim Creek Upper (T-1)	3.20	45 06 26.9	118 17 54.5	07/20/1994	09/30/1994	08/02/1994	16.6	09/12/1994	4.7	07/27/1994	15.9	11.0	346	0
Limber Jim Creek Lower (T-1)	0.40	45 06 9.1	118 19 43.7	06/23/1994	09/11/1994	08/02/1994	20.6	09/11/1994	4.4	07/30/1994	19.9	11.3	837.6	123.6
McCoy Creek Lower #1 (T-1)	0.12	45 15 44	118 24 9	06/16/1995	09/30/1995	07/18/1995	28.5	09/22/1995	3.9	08/03/1995	27.4	11.6	1865	893.5
McCoy Creek Lower #2 (T-1)	0.30	45 15 48	118 24 16	06/16/1995	09/30/1995	07/18/1995	28.3	09/22/1995	3.9	08/03/1995	27.0	11.6	1845	910
McCoy Creek Lower #2 (T-6)	0.41	45 15 49.1	118 24 23.5	06/16/1995	09/30/1995	07/24/1995	25.4	09/22/1995	4.5	08/22/1995	23.7	10.0	1989	851
McCoy Creek Middle (T-6)	2.08	45 16 15.6	118 25 57.4	06/16/1995	09/30/1995	07/18/1995	28.1	09/22/1995	4.9	08/03/1995	26.5	13.6	1982.5	895.5
Meadow Creek Lower (T-1)	2.30	45 15 42	118 24 02	06/15/1995	09/30/1995	07/18/1995	27.9	09/22/1995	7.5	08/03/1995	26.4	14.6	2266	1072
Meadow Creek Starkey (T-6)	12.12	45 16 17	118 31 56	06/16/1995	09/30/1995	07/18/1995	25.8	09/22/1995	4.6	08/03/1995	24.4	13.1	1737.5	665
Dark Canyon Creek Lower (T-1)	0.40	45 16 30	118 22 56	06/16/1995	09/30/1995	07/09/1995	21.2	06/21/1995	8.4	08/03/1995	19.5	13.9	1950.6	219.6
Dark Canyon Creek Lower (T-6)	0.47	45 16 40.7	118 22 51.7	06/16/1995	09/30/1995	07/19/1995	22.6	06/21/1995	8.3	07/18/1995	21.4	13.4	1788	333
Dark Canyon Creek Upper (T-6)	3.07	45 18 55.1	118 22 51	06/16/1995	09/30/1995	07/25/1995	21.6	09/22/1995	7.1	07/22/1995	20.8	11.1	1053.5	179.5
Lookout Creek (T-6)	3.07	45 05 31.2	118 31 19	06/16/1995	09/30/1995	08/05/1995	17.5	06/19/1995	4.6	08/03/1995	16.7	9.3	403	0
Limber Jim Creek Upper (T-6)	3.26	45 06 30	118 17 34	06/16/1995	08/28/1995	08/05/1995	14.6	06/19/1995	4.1	08/04/1995	14.0	9.8	146.5	0
Limber Jim Creek Lower (T-6)	0.47	45 06 13	118 19 50	06/16/1995	09/30/1995	09/04/1995	17.3	09/22/1995	2.0	09/02/1995	15.7	7.7	390.5	0

Table A-2. 1996- 1997

Site Name (transect number)	River Mile	Latitude	Longitude	Monitoring start date	Monitoring stop date	Seasonal Maximum Date	Seasonal Maximum Value (C)	Seasonal Minimum Date	Seasonal Minimum Value (C)	7-Day averages Date	7-Day averages Max. (C)	7-Day averages Min.(C)	Hours > 12.8 (C)	Hours > 17.8 (C)
McCoy Creek Lower #1 (T-1)	0.12	45 15 44	118 24 09	06/06/1996	09/30/1996	07/02/1996	28.5	09/23/1996	4.1	07/12/1996	27.1	12.2	1995.5	944
McCoy Creek Lower Reach #2 (T-1)	0.30	45 15 49.1	118 24 23.5	06/06/1996	09/30/1996	07/02/1996	27.9	09/23/1996	4.0	07/24/1996	26.7	12.3	2101	951
McCoy Creek Middle (T-1)	2.00	45 16 12	118 25 36	06/06/1996	09/30/1996	07/02/1996	27.9	09/23/1996	3.8	07/12/1996	26.4	15.2	2295	1128
McCoy Creek Middle (T-6)	2.08	46 16 15.6	118 25 47.4	06/06/1996	09/30/1996	07/02/1996	28.3	09/23/1996	3.2	07/12/1996	27.0	14.6	2161.5	1022.5
Meadow Creek Lower (T-1)	2.30	45 15 42	118 24 02	06/06/1996	08/04/1996	07/02/1996	27.1	06/19/1996	7.8	07/24/1996	25.8	16.6	1371	832
Meadow Creek Lower (T-6)	2.46	45 15 34.4	118 24 8	06/06/1996	09/30/1996	07/02/1996	26.9	09/23/1996	5.5	07/25/1996	25.7	15.9	2339.5	1099.5
Meadow Creek Starkey (T-1)	12.0	45 16 13	118 32 21	06/06/1996	09/30/1996	07/03/1996	25.8	09/26/1996	3.8	07/12/1996	24.3	14.5	2053	826
Meadow Creek Starkey (T-6)	12.12	45 16 17	118 31 56	06/06/1996	09/30/1996	07/26/1996	26.4	09/23/1996	3.0	07/25/1996	25.5	14.0	1929.5	813.5
Dark Canyon Creek Lower (T-1)	0.40	45 16 30	118 22 56	06/06/1996	09/30/1996	08/01/1996	19.4	06/19/1996	8.4	07/29/1996	18.6	16.1	2275	190
Dark Canyon Creek Lower (T-6)	0.47	45 16 40.7	118 22 51.7	06/07/1996	09/30/1996	08/14/1996	23.7	09/23/1996	6.3	08/12/1996	22.8	13.6	1860.5	516
Dark Canyon Creek Upper (T-1)	3.00	45 18 50	118 24 06	06/07/1996	09/30/1996	07/26/1996	23.2	09/23/1996	4.1	07/11/1996	22.3	10.1	1230	349
Dark Canyon Upper (T-6)	3.07	45 18 55.1	118 22 51	06/07/1996	08/05/1996	07/26/1996	23.2	06/19/1996	5.3	07/24/1996	22.3	10.5	587	180.5
Lookout Creek (T-1)	3.00	45 05 31.1	118 31 49.3	06/06/1996	09/30/1996	07/26/1996	18.3	09/23/1996	4.0	07/25/1996	17.8	10.4	723	29
Lookout Creek (T-6)	3.07	45 05 31.2	118 31 19	06/06/1996	09/30/1996	07/25/1996	18.3	09/23/1996	3.5	07/25/1996	17.6	10.0	578.5	11.5
Limber Jim Creek Upper (T-1)	3.20	45 06 26.9	118 17 54.5	06/06/1996	09/30/1996	08/11/1996	15.6	09/23/1996	1.7	07/26/1996	15.3	10.4	428	0
Limber Jim Creek Upper (T-6)	3.26	45 06 30	118 17 34	06/06/1996	09/23/1996	09/22/1996	30.9	06/19/1996	3.0	07/25/1996	19.4	14.7	1193.5	149.5
Limber Jim Creek Lower (T-1)	0.40	45 06 9.1	118 19 43.7	06/06/1996	09/30/1996	08/11/1996	20.0	09/23/1996	0.4	07/26/1996	19.3	10.4	848	107
Limber Jim Creek Lower (T-6)	0.47	45 06 13	118 19 50	06/06/1996	08/20/1996	08/11/1996	19.4	06/19/1996	3.0	07/26/1996	19.0	10.4	630.5	77.5
McCoy Creek Lower #1 (T-1)	0.12	45 15 44	118 24 09	06/17/1997	09/30/1997	08/06/1997	29.7	09/28/1997	6.3	08/05/1997	28.4	13.2	1966	978
McCoy Creek Lower #2 (T-1)	0.30	45 15 48	118 54 16	06/17/1997	09/30/1997	08/06/1997	29.4	09/28/1997	5.8	08/05/1997	27.8	12.6	1812	861.5
McCoy Creek Lower #2 (T-6)	0.41	45 15 49.1	118 24 23.5	06/17/1997	09/28/1997	08/06/1997	27.6	09/28/1997	6.5	08/05/1997	26.3	12.8	1809.5	780.5
McCoy Creek Restored Channel (T-3)	1.20	45 16 8.55	118 25 8.53	08/02/1997	08/22/1997	08/06/1997	25.1	08/21/1997	13.5	08/05/1997	23.9	16.9	503	306
McCoy Creek Restored Channel (T-6)	1.45	45 16 18.72	118 25 24.38	08/02/1997	08/23/1997	08/06/1997	28.4	08/11/1997	12.0	08/05/1997	26.9	16.1	518	317
McCoy Creek Middle (T-6)	2.08	46 16 15.6	118 25 47.4	06/18/1997	10/06/1997	08/06/1997	28.3	10/05/1997	5.5	08/05/1997	27.0	16.0	2123	1013.5
Meadow Creek Lower (T-1)	2.30	45 15 42	118 24 02	06/17/1997	08/12/1997	08/06/1997	26.8	06/24/1997	11.3	08/05/1997	25.4	18.8	1349	925
Meadow Creek Lower (T-6)	2.41	45 15 34.4	118 24 8	06/17/1997	09/30/1997	08/06/1997	26.6	09/28/1997	9.2	08/05/1997	25.6	18.2	2329.5	1277.5
Meadow Creek Starkey (T-1)	12.0	45 16 13	118 32 21	06/18/1997	09/30/1997	08/06/1997	25.4	09/20/1997	7.1	08/05/1997	24.4	16.1	2035	868
Meadow Creek Starkey (T-6)	12.12	45 16 17	118 31 56	06/18/1997	09/30/1997	08/05/1997	27.1	09/20/1997	6.1	08/05/1997	25.9	15.6	2003.5	816.5
Dark Canyon Creek Lower (T-1)	2.30	45 16 30	118 22 56	06/19/1997	09/30/1997	08/06/1997	18.9	06/24/1997	10.6	08/07/1997	18.3	16.2	2146	142
Dark Canyon Creek Lower (T-6)	2.41	45 16 40.7	118 22 51.7	06/17/1997	09/30/1997	06/17/1997	27.8	09/28/1997	8.7	08/05/1997	23.4	14.7	2072	537.5
Dark Canyon Creek Upper (T-1)	3.00	45 18 50	118 24 06	06/20/1997	09/30/1997	08/05/1997	23.1	09/20/1997	7.1	08/05/1997	22.5	11.9	1220	326
Dark Canyon Creek Upper (T-6)	3.07	45 18 55.1N	118 22 51W	06/20/1997	09/30/1997	08/05/1997	23.6	06/24/1997	7.7	08/05/1997	22.9	12.4	1233	254
Lookout Creek (T-1)	3.00	45 05 31.1	118 31 49.3	06/20/1997	09/30/1997	08/07/1997	18.3	06/22/1997	5.8	08/06/1997	17.7	10.9	688	15
Lookout Creek (T-6)	3.07	45 05 31.2N	118 31 49W	06/20/1997	09/30/1997	08/07/1997	18.8	06/22/1997	5.9	08/06/1997	18.1	11.1	704	15.5
Limber Jim Creek Upper (T-1)	3.20	45 06 26.9	118 17 54.5	06/20/1997	09/30/1997	08/07/1997	17.0	09/28/1997	4.9	08/05/1997	16.0	11.2	495	0
Limber Jim Creek Upper (T-6)	3.26	45 06 30	118 17 34	06/21/1997	09/29/1997	08/07/1997	16.2	09/28/1997	4.9	08/05/1997	15.0	11.1	377	0
Limber Jim Creek Lower (T-6)	0.47	45 06 13	13 118 19	06/20/1997	09/30/1997	08/06/1997	20.6	09/28/1997	4.0	08/05/1997	19.1	11.1	833	42

Table A-3. 1998

Site Name (transect number)	River Mile	Latitude	Longitude	Monitoring start date	Monitoring stop date	Seasonal Maximum Date	Seasonal Maximum Value (C)	Seasonal Minimum Date	Seasonal Minimum Value (C)	7-Day averages Date	7-Day averages Max. (C)	7-Day averages Min.(C)	Hours > 12.8 (C)	Hours > 17.8 (C)
McCoy Creek Lower #2 (T-1)	0.30	45 15 48	118 54 16	06/25/1998	09/30/1998	07/25/1998	29.8	09/30/1998	7.8	07/27/1998	28.4	14.8	1903.5	941.5
McCoy Creek Lower #2 (T-6)	0.41	45 15 49.1	118 24 23.5	06/25/1998	09/30/1998	07/26/1998	28.7	09/30/1998	8.3	07/19/1998	27.5	13.7	1899	996.5
McCoy Creek Restored Channel (T-1)	0.95	45 15 56.7	118 25 6.1	06/25/1998	09/30/1998	07/16/1998	28.5	09/30/1998	9.2	07/16/1998	27.1	17.5	2181.5	1331
McCoy Creek Restored Channel (T-3)	1.20	45 16 8.55	118 25 8.53	06/25/1998	09/30/1998	07/16/1998	29.3	06/27/1998	9.9	07/16/1998	27.8	17.3	2236	1430
McCoy Creek Restored Channel	1.25	45 16 9.0	118 25 11.6	06/25/1998	09/29/1998	07/17/1998	24.9	09/29/1998	8.9	07/16/1998	23.4	16.9	2022	951.5
McCoy Creek Restored Channel (T-6)	1.45	45 16 18.72	118 25 24.38	06/25/1998	09/30/1998	08/05/1998	29.3	09/30/1998	7.8	07/27/1998	28.0	17.6	2087	1257
McCoy Creek Middle (T-1)	2.00	45 16 12	118 25 36	07/01/1998	09/30/1998	07/16/1998	28.6	09/30/1998	8.8	07/19/1998	27.6	16.5	2038	1269
McCoy Creek Middle (T-6)	2.08	46 16 15.6	118 25 47.4	06/25/1998	09/30/1998	07/16/1998	29.8	09/30/1998	8.3	07/18/1998	28.5	16.3	2089	1221.5
Meadow Creek Lower (T-1)	2.30	45 15 42	118 24 02	07/01/1998	09/30/1998	07/16/1998	28.6	09/30/1998	10.0	07/18/1998	27.5	18.1	2113	1519
Meadow Creek Lower (T-6)	2.41	45 15 34.4	118 24 8	06/25/1998	09/30/1998	07/16/1998	29.4	09/30/1998	9.3	07/18/1998	28.2	17.2	2197	1434
Meadow Creek Starkey (T-1)	12.0	45 16 13	118 32 21	07/01/1998	09/30/1998	07/16/1998	27.1	09/30/1998	7.9	07/19/1998	26.3	15.8	1942	1066
Meadow Creek Starkey (T-6)	12.12	45 16 17	118 31 56	06/25/1998	09/30/1998	07/16/1998	28.4	09/27/1998	7.0	07/19/1998	27.4	15.0	1959.5	1027
Dark Canyon Creek Lower (T-1)	0.40	45 16 30	118 22 56	07/01/1998	09/30/1998	07/10/1998	21.7	09/29/1998	11.3	07/09/1998	20.8	14.7	2156	533
Dark Canyon Creek Lower (T-6)	0.47	45 16 40.7	118 22 51.7	06/25/1998	09/30/1998	07/26/1998	26.1	09/30/1998	8.6	07/27/1998	25.2	15.4	1936.5	731.5
Dark Canyon Upper (T-1)	3.00	45 18 50	118 24 06	07/01/1998	09/30/1998	07/16/1998	23.8	09/29/1998	7.9	07/19/1998	23.3	11.5	1413	396
Lookout Creek (T-1)	3.07	45 05 31.1	118 31 49.3	07/01/1998	09/30/1998	08/04/1998	20.0	09/30/1998	7.9	08/06/1998	18.3	11.8	1005	46
Limber Jim Creek Upper (T-1)	3.20	45 06 26.9	118 17 54.5	07/01/1998	09/30/1998	08/05/1998	16.6	09/27/1998	5.2	07/19/1998	15.7	10.0	656	0
Limber Jim Creek Upper (T-6)	3.26	45 06 30	118 17 34	06/25/1998	09/30/1998	08/05/1998	16.6	06/27/1998	4.6	07/19/1998	15.6	9.9	585.5	0