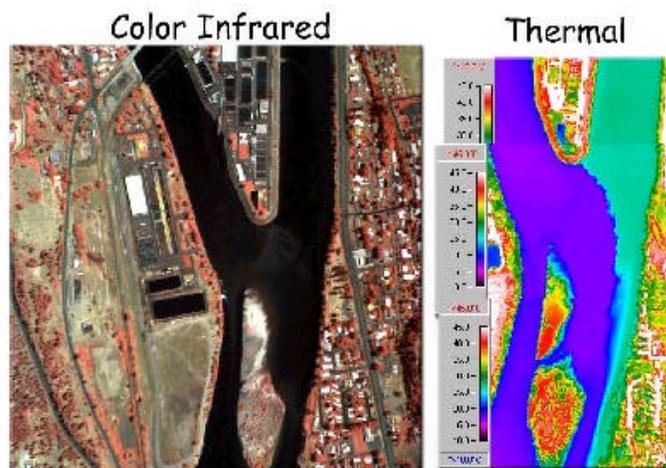


FINAL REPORT

Paired Color Infrared and Thermal Infrared Imaging And Analysis for Selected Idaho Streams



Prepared for

**IDAHO DEPARTMENT OF
ENVIRONMENTAL QUALITY**



IRZ Consulting
Hermiston, Oregon
(541) 567-0252 www.irz.com



IRZ CONSULTING, LLC

505 EAST MAIN, HERMISTON, OREGON 97838 OFFICE (541) 567-0252 FAX (541) 567-4239

Mr. Don Essig
State of Idaho Department of Environmental Quality
Division of Water Quality
4741 N. Hilton
Boise, Idaho 83706

April 25, 2001

Re: Paired Color Infrared and Thermal Infrared Imaging And Analysis for Selected Idaho Streams

Dear Don:

It was a pleasure for us to prepare the enclosed report for the Thermal Infrared and Near Infrared surveys of rivers throughout the central and southern portions of Idaho during the summer of 2000. To our knowledge this is the largest such project undertaken in this region. There is a tremendous amount of knowledge to be learned from this information. We are very proud to have developed RiverView™ software that provides you with image processing tools for the analysis of the data that we have gathered.

We appreciate all the help that you and your department provided us during this project. We are looking forward to working with you in the future. Should you have any questions, please feel free to call Thaddeus Fickel or myself at 541-567-0252 or by email at irz@irz.com

Sincerely,

IRZ Consulting, LLC

By Fred Ziari, CEO



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Introduction

Local and regional watershed issues have necessitated studies by various agencies to map river temperature and associated riparian habitat. Thermal infrared technology, otherwise known as FLIR (Forward Looking Infrared), has gained acceptance as a tool for quickly and accurately measuring the temperature of rivers and streams.

During the summer of 2000, IRZ Consulting was contracted by Idaho DEQ to provide an aerial thermal infrared survey of several rivers throughout the state of Idaho. The purpose of the project was as follows:

- To provide baseline data to be used in the development of ongoing or potential Total Maximum Daily Load standards (TMDL).
- To characterize tributary influences on river temperature.
- To document diurnal fluctuations on individual rivers from a temporally constant perspective.
- To collect near-infrared imagery for correlation with FLIR images and riparian habitat visualization.

Project overview

This project consists of study areas in the central and southern portions of Idaho. Table 1 shows the names of the rivers, the dates, and miles of the rivers flown.

Central Idaho	Date	Miles surveyed	Southern Idaho	Date	Miles surveyed
Clearwater River	Aug 3 2000	32	Jacks Creek	July 21 2000	11
S. Fork Clearwater River	Aug 3 2000	62	Big Jacks Creek	July 21 2000	27
M. Fork Clearwater River	Aug 3 2000	26	Little Jacks Creek	July 21 2000	10
Lochsa River	Aug 4 2000	68	S. Fork Owyhee River	July 22 2000	56
Selway River	Aug 4 2000	39	N. Fork Owyhee River	July 22 2000	17

Table 1 Rivers and date of Thermal Infrared Survey

To measure the coolest and warmest river diurnal temperatures, rivers were flown and image data was collected during two time windows each day. Morning flights were made between the hours of 0600 and 0800 local time. Afternoon flights were made between 1600 and 1800 local time. Historical data from dataloggers indicate that these time frames represent the daily minimum and maximum river temperatures for this time of year. The flight plan for each day was designed to maximize the time spent collecting data and minimize the time spent ferrying the helicopter between rivers. Figure 1 and Figure 2 show maps with locations and the direction (colored arrows) of flight along each river. After the morning flight the helicopter would return to base and the imagery would be downloaded and catalogued. In the evening the process would be repeated following the same flight path.

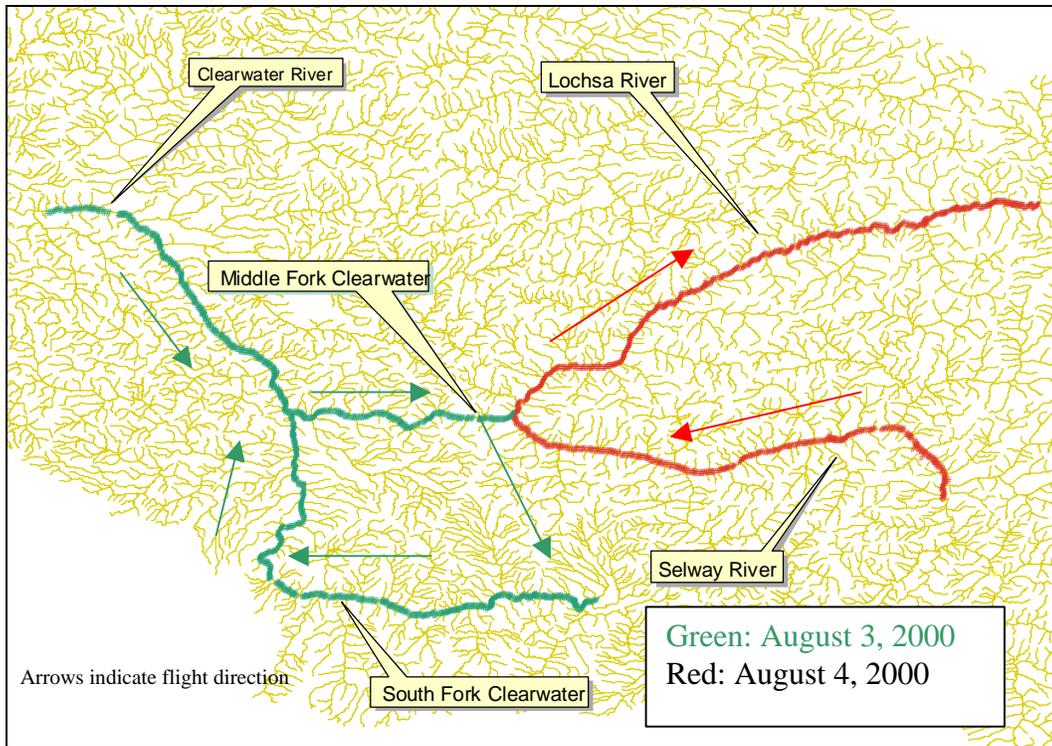


Figure 1 Central Region

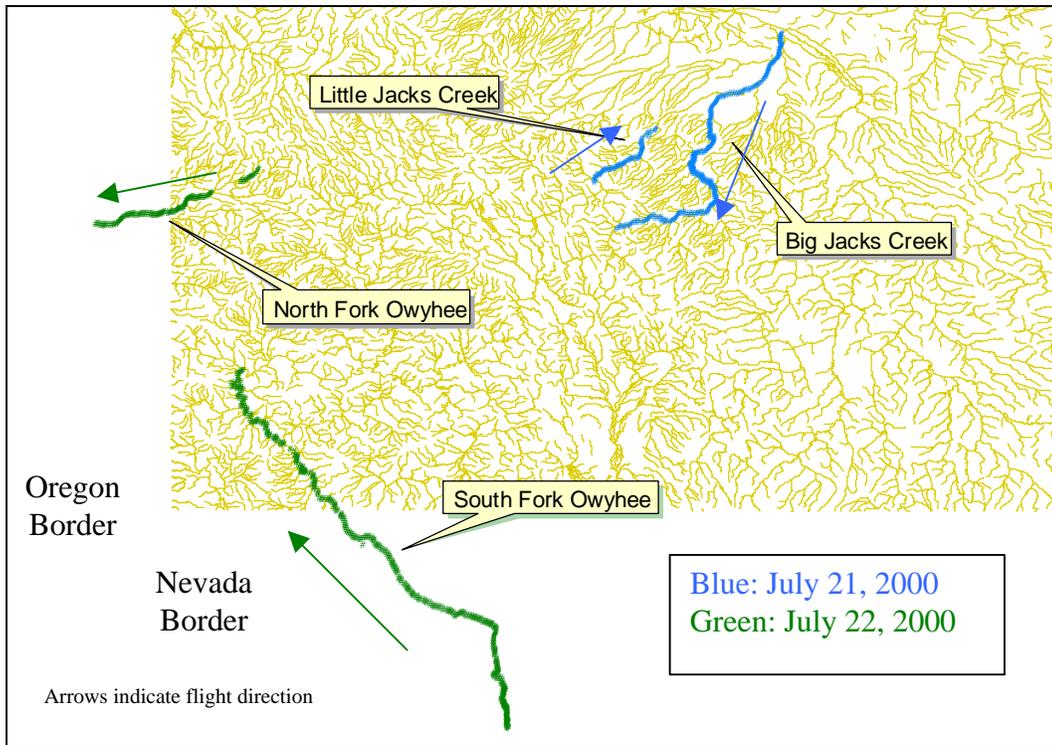


Figure 2 Southern Region

Methodology

FLIR

To measure and record river temperatures, a high-resolution thermal infrared camera was used to record imagery in the long wave region of the electromagnetic spectrum. The detector consists of a staring focal plane array with a 256 x 256 pixel density. The camera can differentiate temperatures as small as **0.07** degrees centigrade within an image or a collection of images and the accuracy of any measured temperatures are within 2 degrees centigrade of the absolute temperature.

The thermal infrared camera was mounted vertically in a custom designed gyro-stabilized, steer-able mount in an Enstrom helicopter. Images were saved on PCMCIA type II card at a rate that allowed overlap between each thermal image. Simultaneous with the thermal infrared data collection, two HI-8 video recorders were recording the thermal infrared and also visual videotape. The geographic coordinates of each image were recorded onto the thermal videotape using real time GPS with sub-meter accuracy.

Ground resolution (pixel size) of the images is determined by flight altitude. Pixel resolutions of the thermal images range from 1.5 meters on small streams to 3.5 meters on larger ones.

Digital Color-Infrared

To evaluate the riparian zone vegetation and to identify ground features (roads, cities, farms, etc.) a high resolution digital near-infrared camera that captures images using a portion of the visible spectrum *and* the near-infrared region is employed (Figure 3). This camera has a higher pixel resolution than the thermal camera and thus provides better visual perception for identifying small objects. The near-infrared portion of the electromagnetic spectrum yields a better view of riparian zone vegetation. More red in an infrared image corresponds with more vigorous growth (i.e. more green and more chlorophyll).

Pixel resolutions in the Color-Infrared images range from less than one meter on smaller rivers to 1.5 meters on larger ones.

Future uses of the color-infrared imagery could include geo-referencing the images for use estimating riparian vegetation density as a step to documenting stream shading.

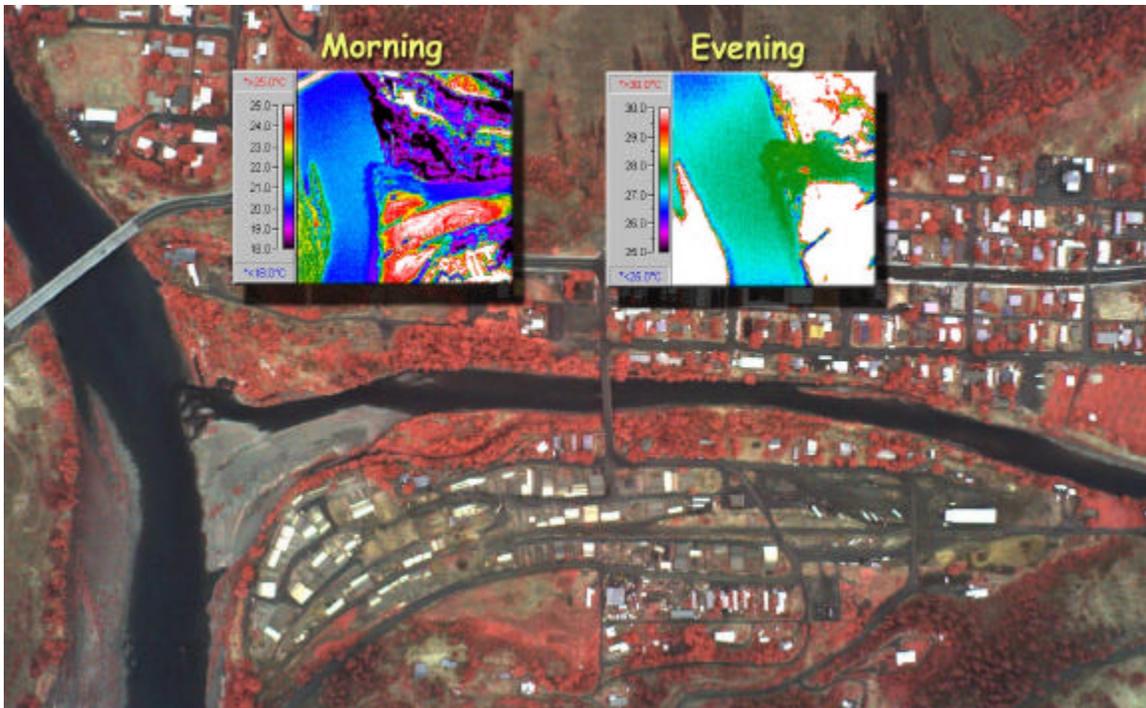


Figure 3 Confluence of South and Middle Forks of the Clearwater River. FLIR and Color-infrared.

Limitations

When measuring river temperature with FLIR imagery it is necessary to recognize that the camera is seeing and recording temperature at the surface of the water. Rivers with a turbulent flow will show very little thermal variability between surface and sub-surface temperature measurements. Some factors that might influence thermal mixing:

- Tributaries / Springs
- Irrigation return flows
- Industrial / Municipal influences

Portions of some of the rivers in the Southern project area proved difficult to accurately measure from the FLIR imagery. Either they were not of sufficient size for imaging or obscured by canopy. In a few cases they were completely dry. These rivers include:

- Jacks Creek
- Big Jacks Creek
- Little Jacks Creek
- North Fork Owyhee River

By studying the results of this type of a temperature survey informed decisions can be made regarding the placement of in-stream dataloggers to supplement and enhance the FLIR data.

During data collection on the central region in early August the sky was partially obscured by smoke from nearby forest fires. The smoke was the thickest on the eastern side of the study area, which includes the headwaters of the Lochsa River, Selway River and the South Fork of the Clearwater River. The

effects of the smoke can be seen in some of the FLIR images from these regions as a slight decrease in temperature in the periphery of the images due to the oblique angular distance. The effect of the smoke on the accuracy of the FLIR measurements was approximately 0.5 C. difference from the center of the image to the edge. Where possible, temperature measurements were made only from the central portion of the affected images.

Data Processing

Over 4,700 thermal infrared images were analyzed in the offices of IRZ Consulting and temperature information (max, min, avg.) was extracted and input into a database. The temperature value from each image is the average of several points within that image. In images where there was a broad, clear view of the river, the temperature is averaged along a line in the center of the river. Other places where the river is obscured by vegetation or is simply too small to draw a line the temperature is averaged from several points that are visible in the image, usually 8 points (Figure 4).

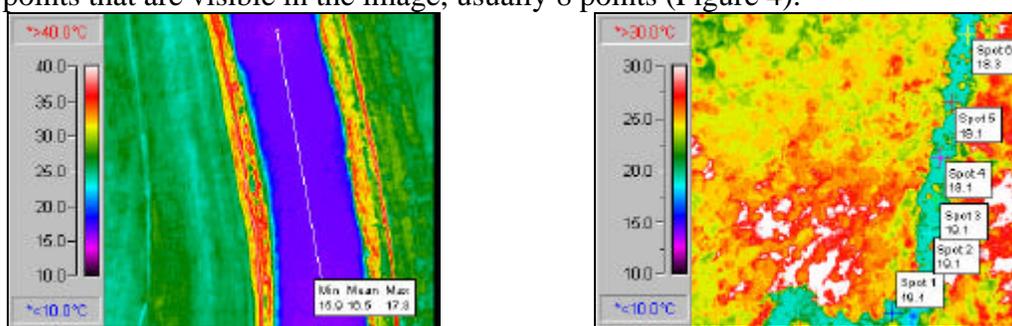


Figure 4 Line and point sampled FLIR imagery

Image Correlation

The thermal flights were scheduled to coincide with maximum summer temperatures. Unfortunately, numerous fires in the area at that time obscured the sky with smoke considerably in some locations. While the effects were minimal in the FLIR imagery, the smoke was semi-opaque in the color infrared images. Therefore, a decision was made to return when the smoke cleared in order to gather the color infrared imagery.

The color-infrared images are of much higher resolution than the FLIR images. The “footprint” of a color infrared image covers a much larger area than that of the FLIR coverage. To reduce the number of images that needed to be collected, the color infrared camera was turned 90 degrees to the direction of flight so that the river would be imaged with its longitudinal axis spanning the widest part of the imager. In the office the resulting images were rotated back into place yielding an image with an aspect ratio in a “portrait” orientation.

Each color infrared image is associated with several thermal infrared images. Organization of the images is accomplished automatically in IRZ Consulting’s **RiverView** image analysis database. Figure 5 below illustrates the relationship between the relative sizes of the images.

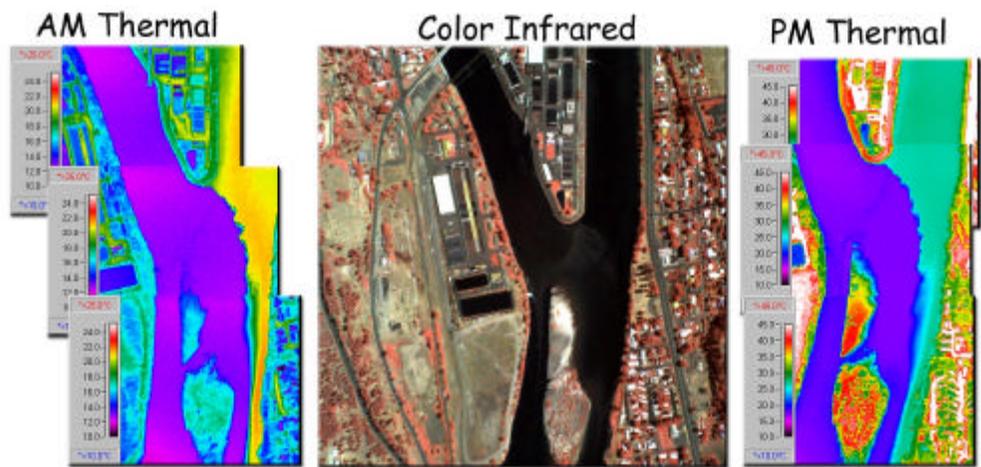


Figure 5 Image footprint comparison

Ground truthing

In-stream dataloggers at various locations throughout the study area provide ground truthing data. These devices are anchored in the stream in a fixed location and record temperatures at pre-determined intervals varying from between 15 minutes to an hour. Some were placed by Idaho DEQ and others by the U.S. Forest Service and various other agencies. Air temperature is taken from RAWS weather data in the region. Datalogger data is only available for the Central region of the study area. Some devices were placed in rivers in the southern study area but at the time of this writing they have yet to be retrieved.

FLIR vs. In-river Dataloggers

FLIR: Continuous measurement, short duration

Using an aerial survey the temperature of hundreds of river miles can be recorded in a matter of just a few hours. In effect, the flow of the river is halted in time and the temperature of the river is measured along its entire length.

Dataloggers: Single point, long duration

An in-stream datalogger records the temperature of a river or a stream from a fixed location for a long period of time. Diurnal and seasonal fluctuations can be monitored and the variability viewed and studied.

The correlation between the FLIR imagery and the datalogger data provides an important view of two very important aspects of river dynamics. Because the FLIR imagery measures temperature at the surface of the river, the dataloggers provide another view of the river. Datalogger data is enhanced by FLIR imagery because the FLIR fills in the blanks between datalogger sites. As shown in **Error! Reference source not found.**, FLIR and dataloggers temperature values correlate better in some areas than in others. The high deviation values should be investigated and potentially recalibrated or relocated. It should be noted that FLIR data is an average temperature measured at the center of the streams, normally about a 2-meter wide strip of varying length from 50 meters to 200 meters long. Dataloggers measure a single point at each site.

Site name	River mile	Morning (C)			Afternoon (C)		
		Datalogger temp	FLIR	Diff	Datalogger temp	FLIR	Diff
M. Fork Clearwater	2.8	21.7	20.2	-1.5	25.9	27.6	1.7
S. Fork Clearwater	11.7	20	19.7	-0.3	26.9	27.4	0.5
S. Fork Clearwater	16.1	19.8	19.5	-0.3	22.1	26.9	4.8
Selway River	21.4	20.9	19.4	-1.5	21.3	23.6	2.3
Selway River #1	7.9	20.2	19.4	-0.8	24	24.8	0.8
Selway River #2	7.9	20.2	19.4	-0.8	23.6	24.8	1.2
Selway River	0.7	21	19.7	-1.3	24.4	25.4	1.0
Lochsa River	0.9	20.6	19.4	-1.2	24.4	25.1	0.7
Lochsa River	15.6	19.6	19.6	0	23.4	23.5	0.1
Lochsa River	22.9	18.6	17.7	-0.9	22.6	24.3	1.7
Lochsa River	48.5	17.1	16.8	-0.3	20.5	22.7	2.2
Lochsa River	56	15.5	16	0.5	22.6	22.1	-0.5
Average difference				-0.7			1.3

Table 2 Comparison of temperature between FLIR and datalogger

Of note in the table above is the variability of the temperature at each station when comparing morning and evening FLIR images. Some possible explanations:

- Thermal stratification
- Location/placement of the datalogger
- Surface effects on the water affecting the accuracy of the FLIR imagery*

* High wind causing localized ripples and clouds being mirrored can change the reflectivity of the water causing a false temperature reading of up to 1.5 degrees. On the days these images were collected winds were generally less than 5 knots and the skies were clear.

Project Analysis

Geographic Information System (GIS)

To view, analyze, and organize the temperature information for this project, ArcView 3.2 Geographic Information System (GIS) was employed. GIS is an excellent tool for gaining a basin-wide overview of temperature dynamics. Figure 6 and Figure 7 show an example of the type of broad scale comparisons that are possible for comparing temperatures at different times, or comparing two or more rivers at a similar point in time.

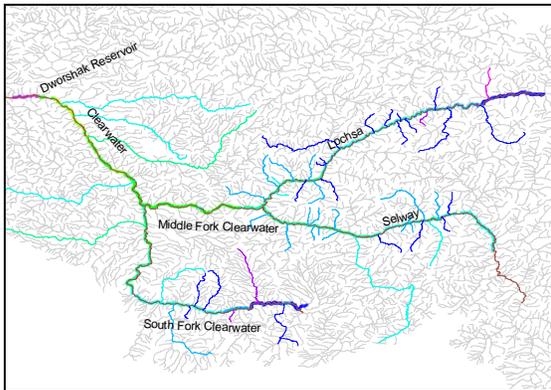


Figure 6 Central region a.m.

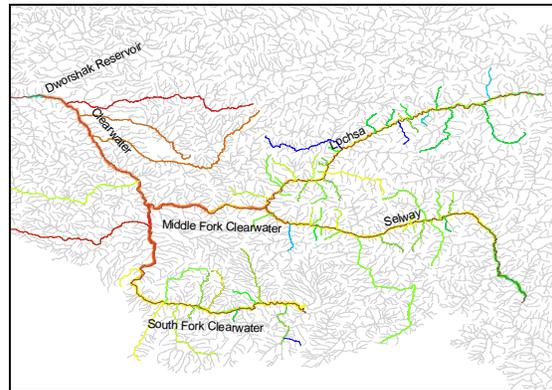


Figure 7 Central Region p.m.

During the flights, real-time differentially corrected GPS location information was being continually written onto Hi-8 videotape. The data was extracted from the videotape in the office and matched up with the corresponding images by synchronizing the image file times with GPS time. Once the image times and the GPS times were linked a GIS theme could be created.

In the office each image was analyzed for its temperature information. The mean temperature from center of each image (river) was transferred to ArcView and classified by color.

The temperature of each visible tributary was measured at the mouth by sampling a single point in the margins of the FLIR imagery when available. It is important to note that the color-coding on the tributaries in the GIS themes is only a representation of the tributary temperature at a single point at the mouth of the tributary, and not the tributary as a whole.

The GIS images in Figure 8 through Figure 11 shows the temperature variations of both morning and evening flights for Central and Southern Region of the study area. All GIS themes are provided in the accompanying CD-ROMs. These graphs need to be studied in detail as they reveal a wealth of information about the watershed health. Of interest are the temperatures in the tributaries where an inverse relationship exists between the temperature of the main river and the tributaries when comparing the morning and evening temperatures. The Middle Fork of the Clearwater River below the confluences of the Lochsa and Selway Rivers is of interest in the afternoon flight (warmer, cooler then warmer for some distances).

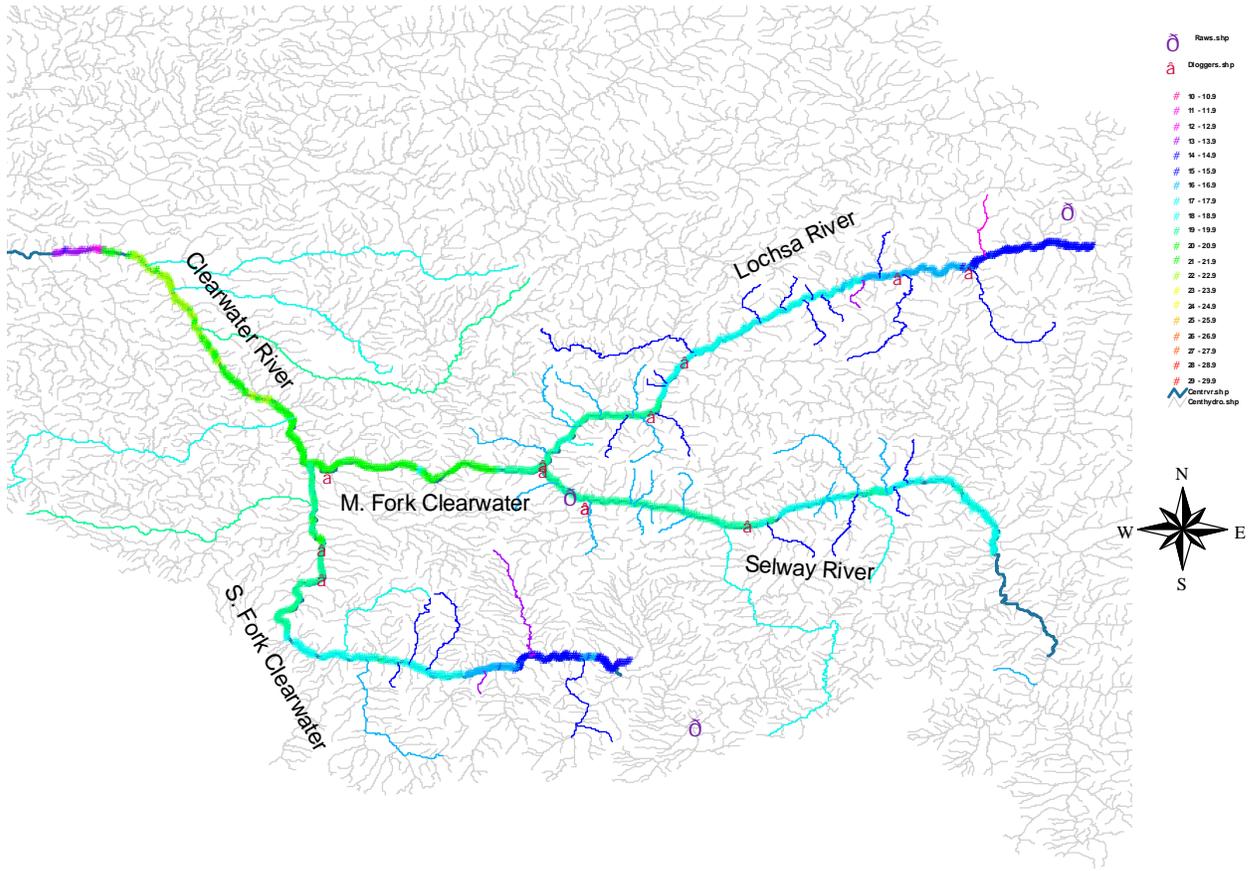


Figure 8 Central Region: August 3 and 4, morning flights

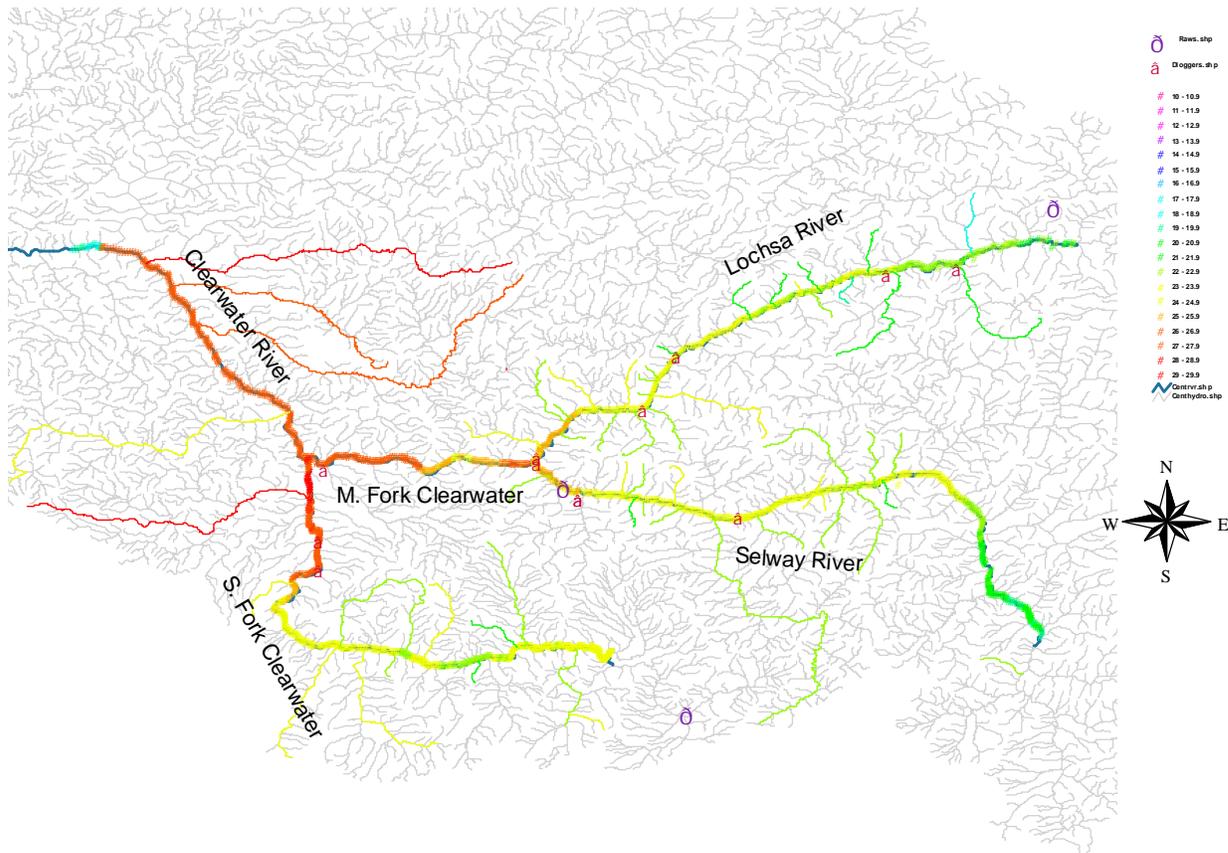


Figure 9 Central region: August 3 and 4, afternoon flights

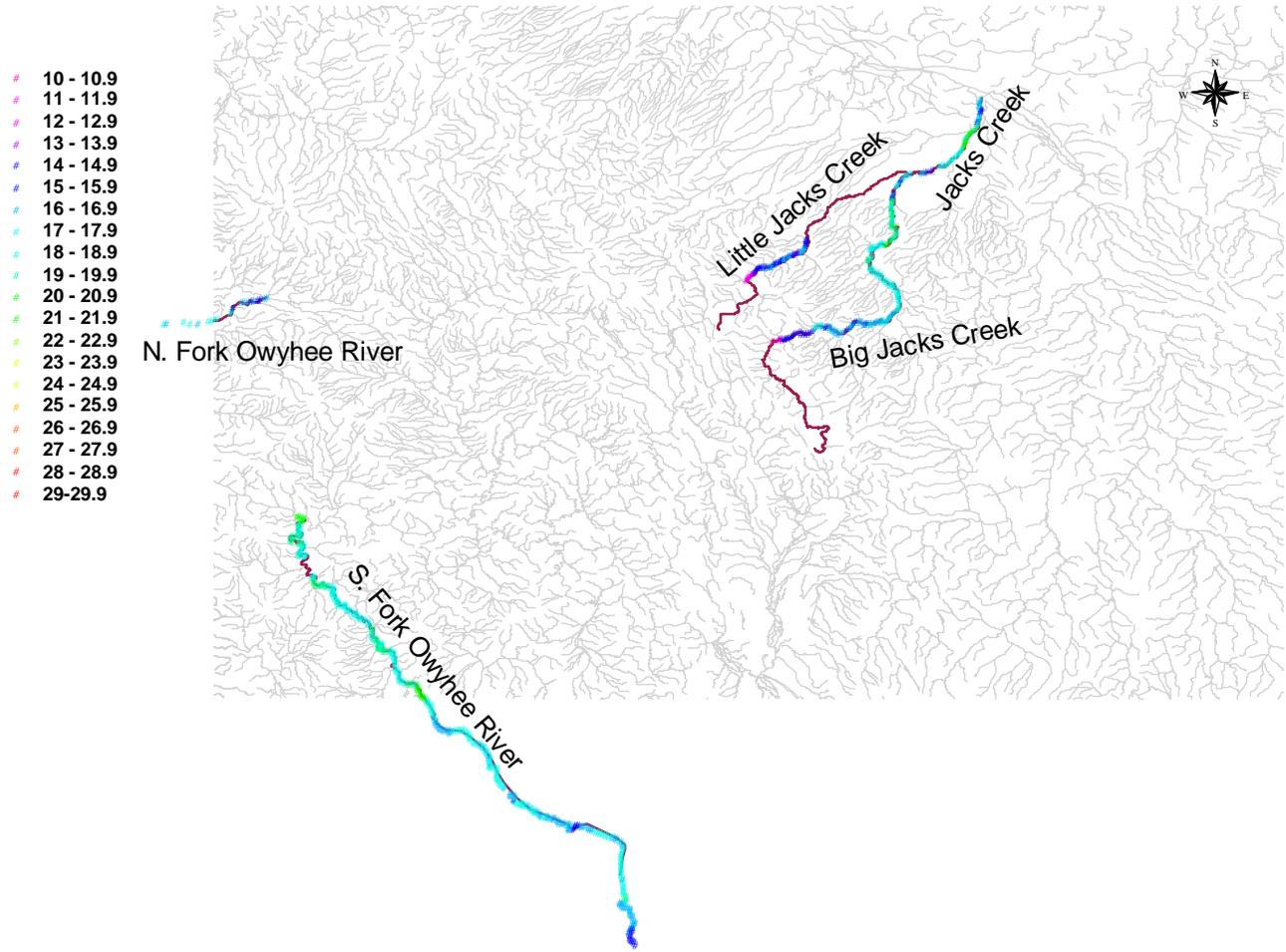


Figure 10 South region, July 21 and 22, morning

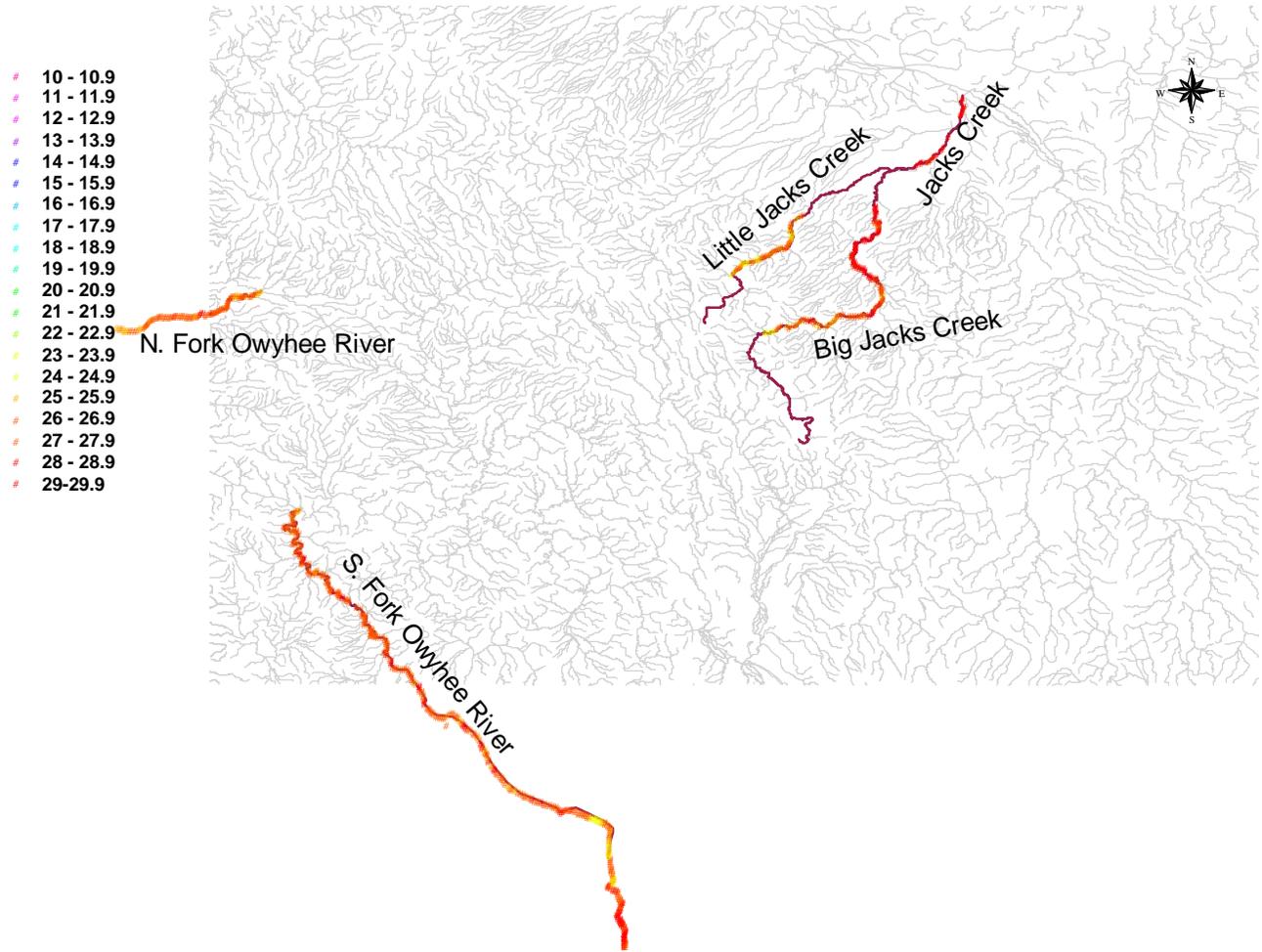


Figure 11 South region: July 21 and 22 afternoon

RiverView Image Analysis

Purpose and Description

In gathering such a large volume of images the immediate question is how to organize them in a meaningful fashion? We have multiple images of a particular stretch of a river and it is necessary to compare the different images to arrive at a conclusion. To solve this problem, IRZ Consulting developed RiverView Image Analysis (Figure 12). Using this software the user can select and view any river in the study area, browse to different sections of a river or select river miles and see all associated images at once. It also allows you to zoom in and out, print reports, and provides powerful tools to manipulate and measure temperatures in the FLIR images.

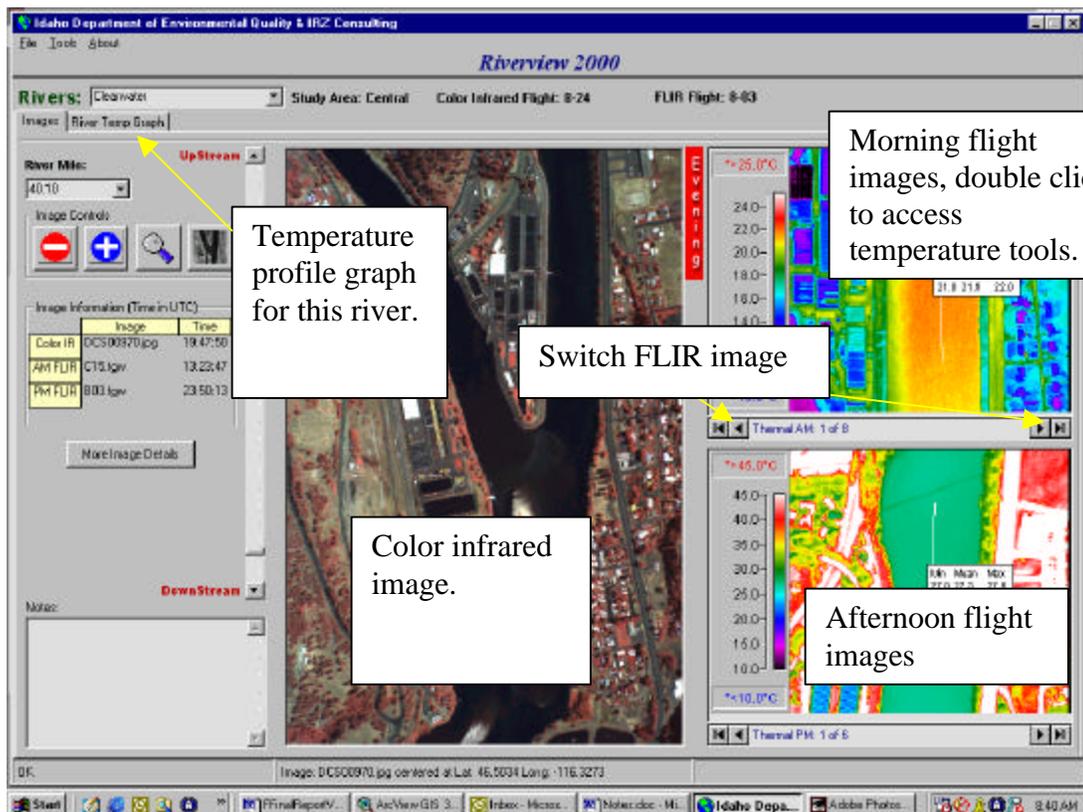


Figure 12 RiverView screen shot

Installation of RiverView

An integral part of the RiverView database is the ability for the user to access temperature information stored in the FLIR imagery. To access the temperature data in the images, the user double clicks on a FLIR image and the image analysis tools become visible in RiverView.

Install the software in the following order:

1. From setup disk install d:\thermonitor\tmw95.exe (where d: is the letter of the CD-ROM drive).
2. From the same disk, install d:\setup.exe

RiverView Functions

Image Viewer

Project images can be accessed from the CD-ROM's included in this report or the images can be copied onto the users hard drive. To copy the images onto your hard drive:

- Place Images CD#1 into your CD drive on your computer
- Using My Computer or Windows Explorer, locate the folder called d:\central (where d: is the drive designation for your CD drive).
- Copy that folder and all of its contents to a location specified on your computer.
- Repeat for Images CD#2 (South).
- Note: Both folders (Central and South) need to be in the same folder (i.e. c:\Program files\IRZRiverView).



Figure 13 RiverView Image Analysis

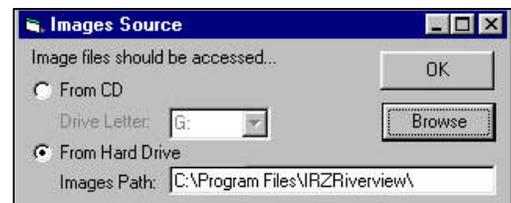


Figure 14 Image source dialog box

The first time the database is opened it will need to be instructed where to find the images. Click on TOOLS in the menu and IMAGE LOCATION. In the dialog box (Figure 14) that appears select the location for accessing the images. *Note: if you type the path in the IMAGES PATH text box it is necessary to include the backslash at the end of the path.*

Viewing project images is as easy as selecting a river from the RIVERS drop down list in the upper left hand portion of the screen. When all images have been loaded you can navigate upstream or downstream with the buttons and/or the slider bar just to the left of the Color Infrared image. For each Color-Infrared image in the database there will be several FLIR images associated with it. The window in the upper right hand corner of the screen shows the FLIR images from the morning flight and the window in the lower right corner of the screen shows the FLIR images for the evening flight. On either side of the Color-Infrared image are two locator icons labeled “Morning” and “Evening”. These locators show the approximate location of the FLIR images in relation to the Color-Infrared images.

Longitudinal Profile Graphs

Upon selecting a river for viewing, the database immediately gathers all the temperature information for that river and assembles a longitudinal profile of that river (Figure 15 Longitudinal profile graph. Other temperature data associated with the river is displayed as well, such as in-stream dataloggers and tributaries. Click on the “River Temp Graph” tab in the main viewing window to access the Longitudinal Profile Graph.

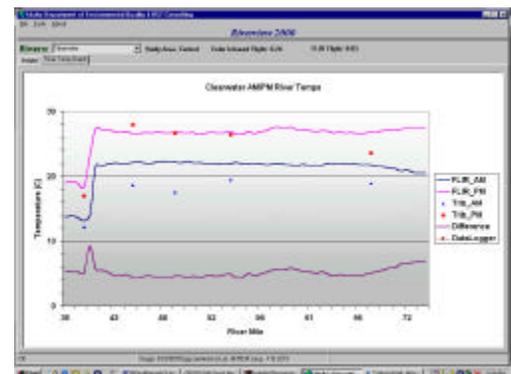


Figure 15 Longitudinal profile graph

Printed Reports

To print a hard copy report of the images on the screen along with other pertinent information about the images (location, time, notes etc.) select FILE and PRINT. A dialog box will appear to edit printer settings if desired and the page will be sent to the default (or specified) printer.

FLIR Image Analysis

Each FLIR image can be manipulated and analyzed to bring out subtle details or to measure the temperature of specific areas of the image. Double click on a FLIR image, or right click and choose EDIT to access the special tools (Figure 16). Online help is also available as a menu option.

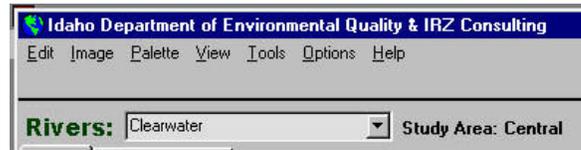


Figure 16 Temperature analysis tools

Change the color palette

To change the color palette, click on Palette. There are many different color palettes available. You can also access the palette options by double clicking on the Color bar in the FLIR image and select the new palette from the resulting list.

Adjust temperature span

Adjusting the high and low temperature levels in the FLIR image can enhance subtle differences in temperature. To change the temperature span click on IMAGE, then SET TEMP SPAN. The resultant window will allow options for setting the temperature span (Figure 17).

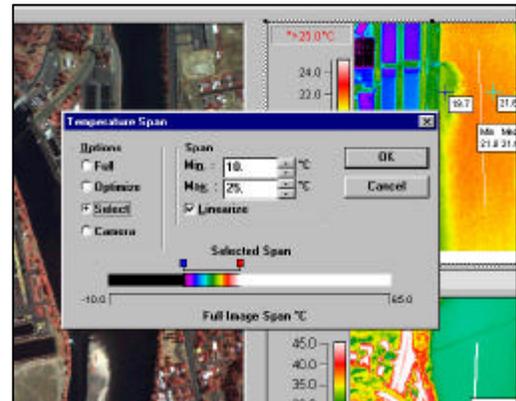


Figure 17 Adjusting temperature span

Measuring temperature in FLIR images

The toolkit can be accessed by selecting VIEW and HIDE TOOL KIT followed by VIEW SHOW TOOL KIT¹. Selecting the different tools in the tool kit will allow for precise spot, line and area measurements within the selected FLIR images (Figure 18). A detailed description of the functionality of the tools can be found in the online help.

The purpose of the temperature analysis tools in RiverView is to give the user enhanced information within the image. In order to preserve the integrity of the database, the changes that a user makes to any image will be temporary and the image will revert to the saved version upon the selection of another image.

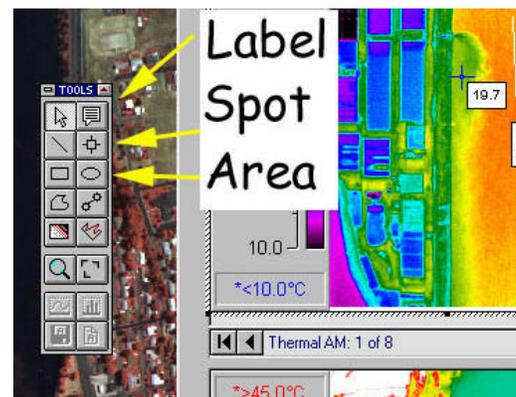


Figure 18 Image tool kit

¹When the temperature menu is first activated the tool kit is hidden behind the RiverView window, to get the tool kit to show you must first hide it, then show it again.

Central Region Rivers

Clearwater River

In August and September of 1999 IRZ Consulting conducted a thermal infrared survey of the Snake River from Hells Canyon Dam to Lower Granite dam. Additionally we flew the Clearwater from its confluence with the Snake River upstream to the confluence of the North Fork Clearwater River at Orofino, ID. During the summer of 2000 the flights on the Clearwater River began at Orofino and continued upstream. (Figure 19) shows temperature profile of the North Fork of the Clearwater River and the influence of Dworshak reservoir contributing approximately 10 degrees cooler water than the main stem of the Clearwater River.

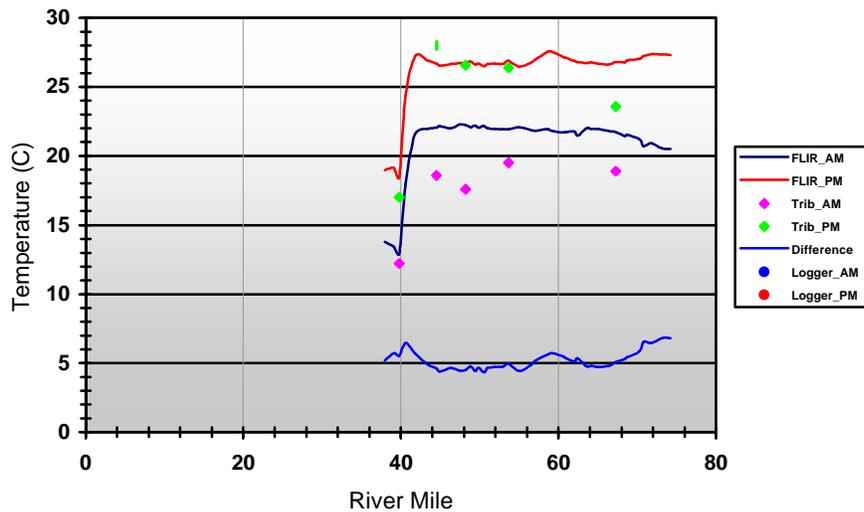


Figure 19 Clearwater River Temperature profile

Clearwater River Tributaries

Tributary temperatures in this river appear to be characterized by cooler inflows in the morning (about 3-5 degrees C.) relative to the Clearwater River. In the afternoon the tributary temperatures appear to be much closer to that of the Clearwater River. An exception would be Lawyer Creek, which maintains it's relatively cool temperature throughout the day Table 3 Clearwater River tributaries and associated temperatures).

River Mile	Tributary Name	Temp AM	Temp PM
39.8	North Fork Clearwater	12.2	17.0
44.5	Orofino Creek	18.6	28.0
48.2	Jim Ford Creek	17.6	26.6
53.7	Lolo Creek	19.5	26.4
67.3	Lawyer Creek	18.9	23.6

Table 3 Clearwater River tributaries and associated temperatures

No in-stream temperature dataloggers were available for the Clearwater at the time of this writing. Figure 20 and Figure 21 show some paired images from this river. The influences of cooler water discharge from a number of ponds into river are visible.

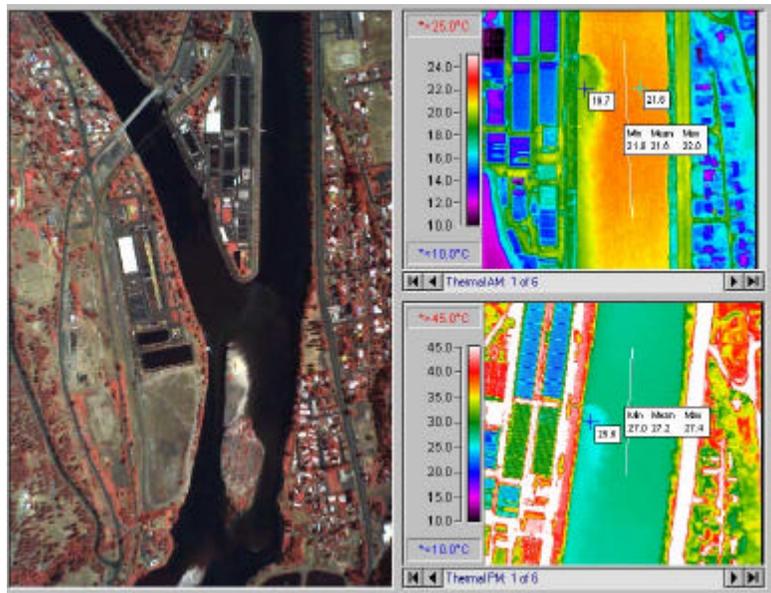


Figure 20 Cool water discharge: Mile 40.6

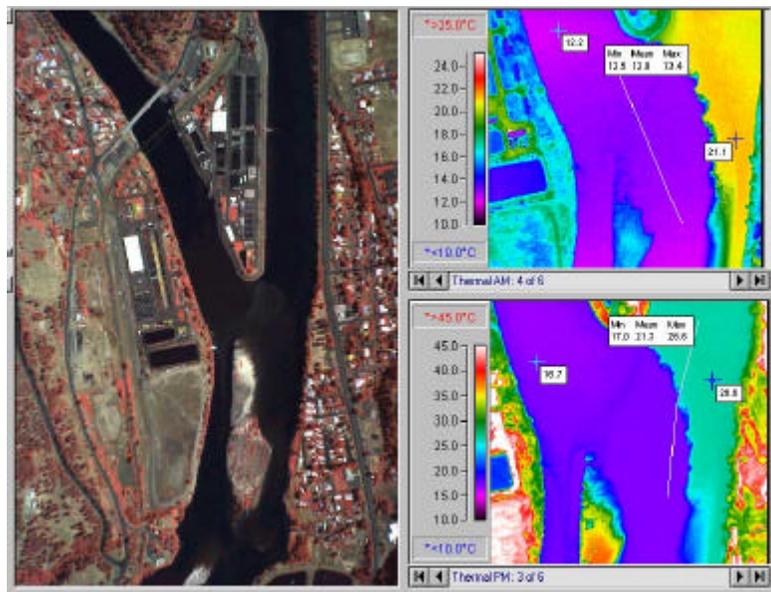


Figure 21 Confluence of North Fork Clearwater River

Clearwater River Summary

The most dramatic feature of this river would be the confluence with the North Fork Clearwater River and the dynamic influx of cold water into the Main Stem of the Clearwater.

- Mixing of the North Fork and Main Stem takes place over approximately 2 miles downstream from the confluence.
- Tributaries are cooler relative to the Clearwater River in the morning than in the evening.

Middle Fork Clearwater River

This river was flown upstream from its River confluence with the Main Stem of the Clearwater to the confluence with the Lochsa and Selway Rivers (Figure 22). Although several small tributaries feed this river none of them were of sufficient size to be measurable in the margins of the thermal images that were collected.

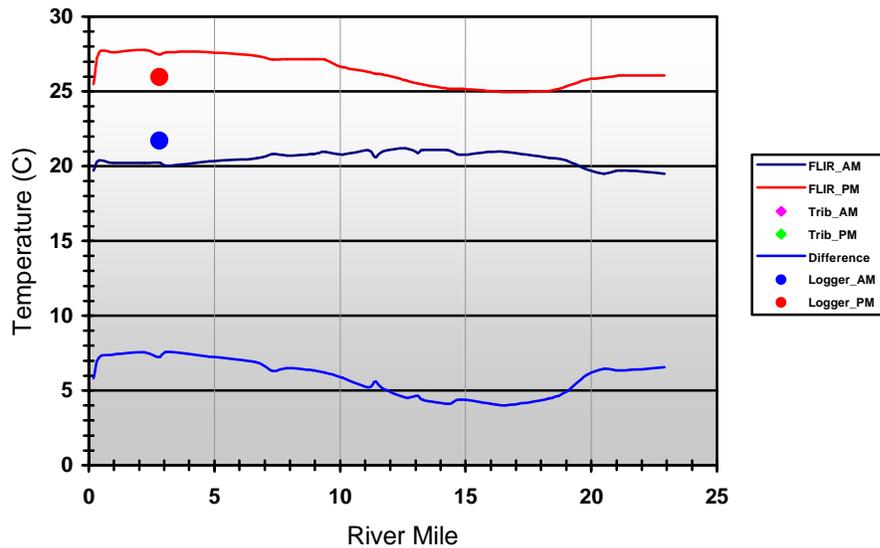


Figure 22 Middle Fork Clearwater River temperature profile.

Middle Fork Clearwater River Dataloggers

This river has a datalogger in the stream near mile 2.0. Variation in the temperatures between the morning and evening flights in Figure 22 indicate that there is some thermal stratification in the river at this location. Figure 23 shows how the temperature of the river fluctuated at this location on August 3, 2000, the day of the flight. River Miles 10 to 20 are showing interesting warming and cooling trends, and should be investigated.

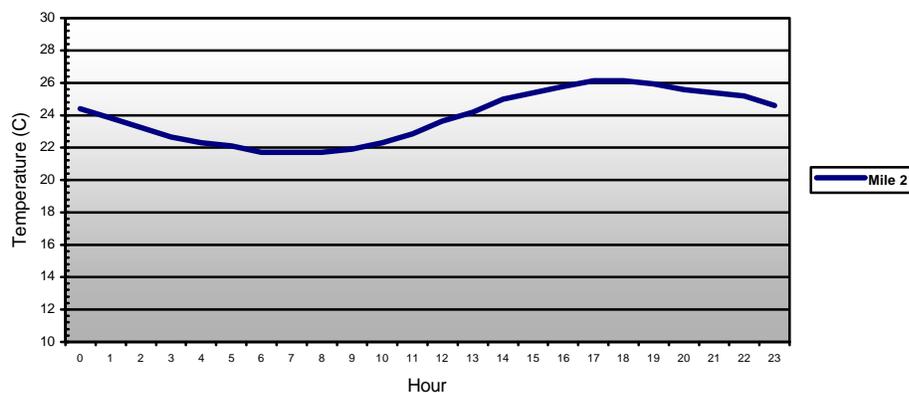


Figure 23 Diurnal fluctuation of Middle Fork datalogger on August 3

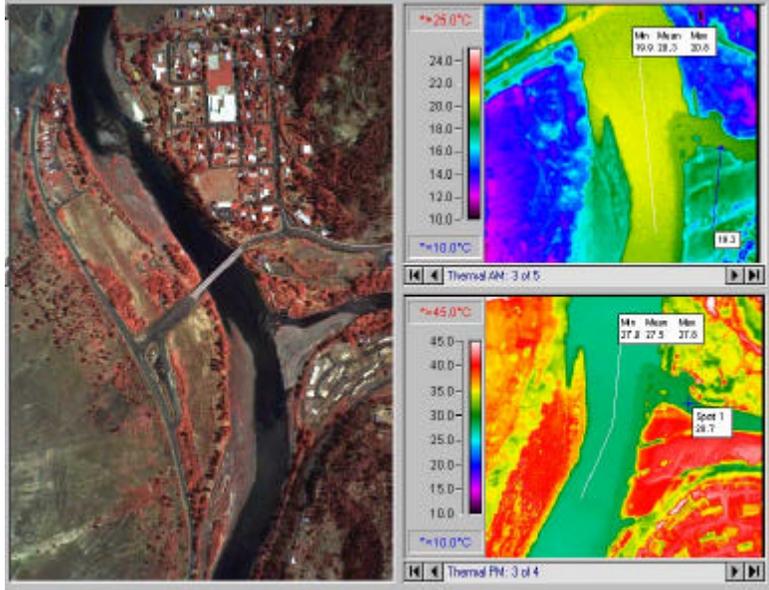


Figure 24 Confluence of Middle and South Fork Clearwater River

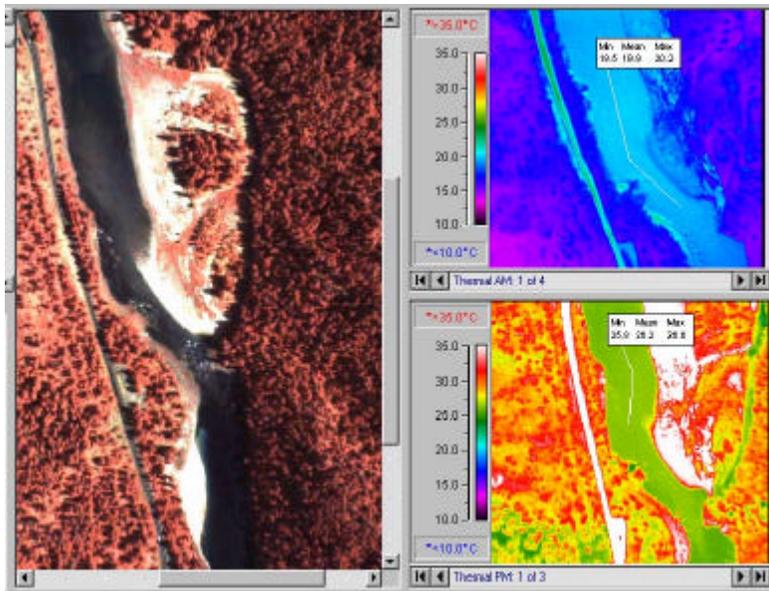


Figure 25 Middle Fork Clearwater River at Mile 20.5

Middle Fork Clearwater River Summary

Although it is a relatively short river, the dynamics of the Middle Fork of the Clearwater River are unlike the other rivers in this study area. Figure 24 and Figure 25 show some representative paired images from this river.

Some interesting features:

- Relatively flat temperature profile from beginning to end.
- Heating in the a.m. and cooling in the p.m. occurs in the first 5 miles, possibly as a result of the influence of either the Lochsa or Selway.
- Information from a single datalogger indicates that there are at least some locations where thermal mixing is not taking place.
- Closer monitoring on this river should be done between mile 10 and mile 20 to observe the cause of the inverse relationship between the morning and evening temperatures.

South Fork Clearwater River

The South Fork of the Clearwater River (Figure 26) was flown downstream from near Elk City, ID to the confluence with the main stem of the Clearwater River. Of all of the rivers in the Central region this one showed the most variability from the headwaters to the mouth. Of particular interest in the graph below is the manner in which the morning temperatures continue to drop at mile 50.0 whereas the afternoon temperature line remains essentially steady with a slight increase in temperature from mile 50.0 to the mouth. Also of note is the relationship between the tributary temperatures and the main river. In the morning the tributaries are noticeably lower in relation to the South Fork Clearwater than in the afternoon.

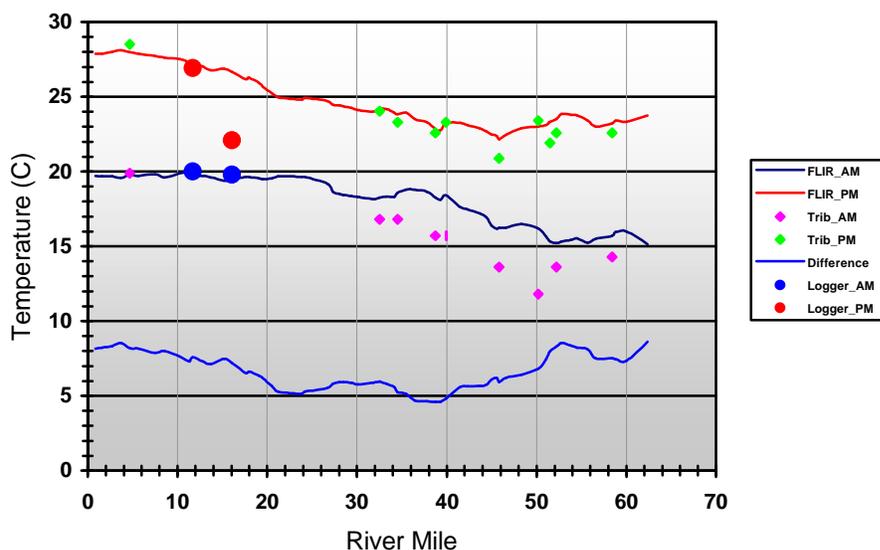


Figure 26 South Fork Clearwater River temperature profile.

South Fork Clearwater Tributaries

The tributaries of the South Fork (Table 4) of the Clearwater show variability between the morning and evening flights.

- Morning temperatures tend to be a few degrees cooler than the main river, possibly contributing to cooling of the river at the headwaters.
- In the afternoon tributaries temperatures tend to be closer to the temperature of the main river, thus providing very little cooling effect.

River Mile	Tributary Name	Temp AM	Temp PM
58.4	Crooked River	14.3	22.6
52.2	Newsome Creek	13.6	22.6
51.5	Leggett Creek	N/A	21.9
50.2	Santlam Creek	11.8	23.4
45.8	Rainy Day Creek	13.6	20.9
39.9	Silver Creek	15.7	23.3
38.7	Peasley Creek	15.7	22.6
34.5	Johns Creek	16.8	23.3
32.5	Meadow Creek	16.8	24.5
32.5	Mill Creek	N/A	23.6
4.7	Cottonwood Creek	19.9	28.5

Table 4 South Fork Clearwater Tributaries

South Fork Clearwater Dataloggers

There are two dataloggers in the South Fork of the Clearwater River, at mile 11 and 16. Temperatures at mile 11 and in the morning at mile 16 match within 1 degree to the FLIR images at that river mile. In the afternoon however the temperature of the datalogger is sharply lower than the FLIR imagery shows as measured at the surface of the river (Figure 27).

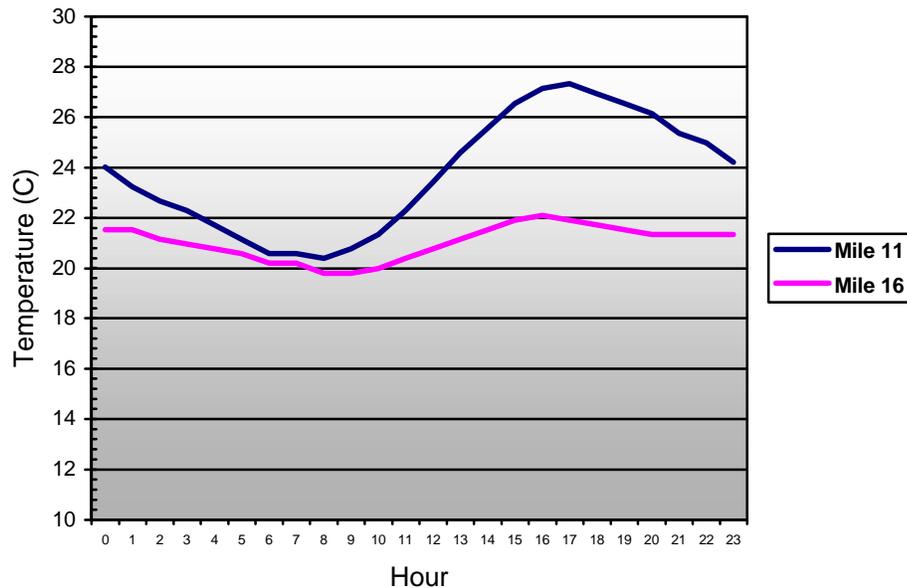


Figure 27 Datalogger plot of South Fork Clearwater River

Figure 27 may partially explain the difference between the relationship of the FLIR temperatures and the datalogger temperatures in Figure 26. The relatively flat temperature line at mile 16 might indicate:

- The datalogger is located near a spring or other type of inflow
- Datalogger is buried in mud or sediment
- Datalogger is malfunctioning.

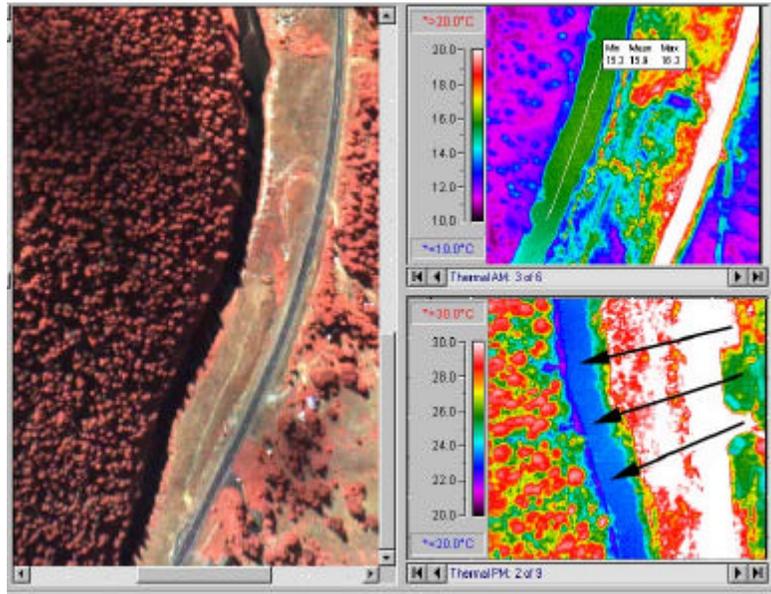


Figure 28 Possible thermal refugia in South Fork Clearwater River.

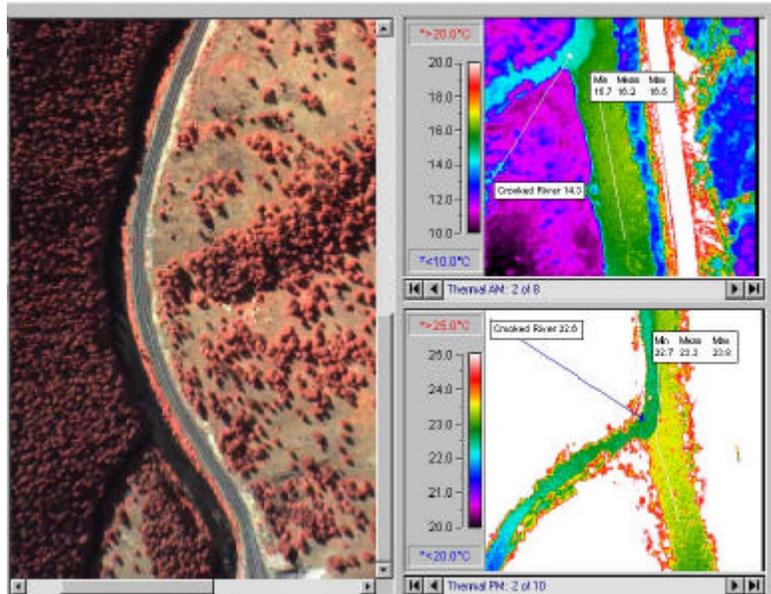


Figure 29 Confluence of Crooked River.

South Fork Clearwater River Summary

Tributary temperatures on the South Fork appear to contribute to river cooling in the morning but have little or no cooling effect in the afternoon.

FLIR Imagery and datalogger temperatures hint at areas of thermal refugia in this river. Further studies might focus on a more complete placement of dataloggers throughout the length of the river to see if there are other areas of (possible) thermal refugia as seen at the datalogger site at mile 16 in Figure 26.

Selway River

The Selway River was flown downstream from the confluence of Moose Creek to the mouth. On the afternoon flight there was a thunderstorm that dropped a small amount of rain on the first few miles as we headed downstream from Moose Creek. While it was raining the river was still in sunlight due to the sun angle. There is a slight dip in the river temperatures on this river between mile 30.0 and 38.0 in the afternoon, which may be at least partially explained by the presence of rain (Figure 30).

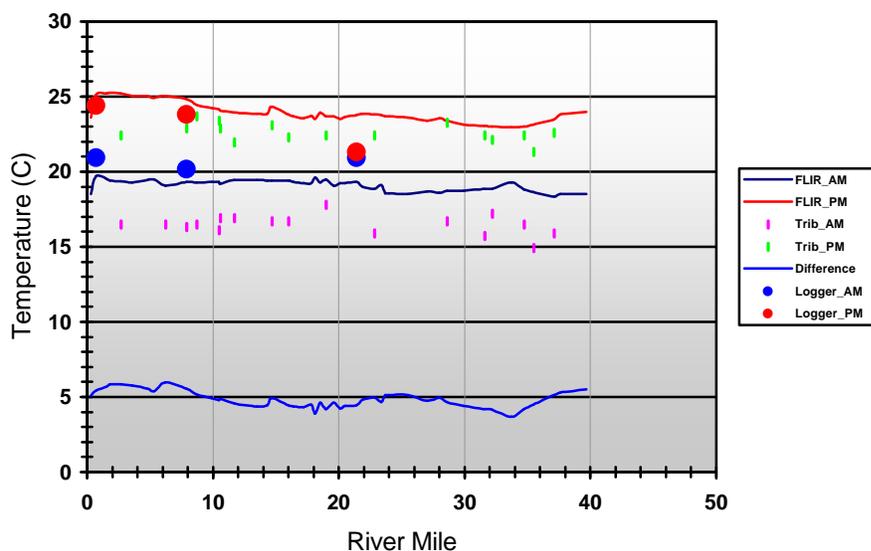


Figure 30 Selway River temperature profile

Selway River Tributaries

Tributaries on the Selway river are consistently measured a few degrees cooler than the main river by the FLIR imagery. The Selway River has a unique temperature feature among all of the other rivers in this study region as it maintains its temperature within about 3 degrees from the headwaters to the mouth. This may be a feature of the Selway River basin as a whole as the tributaries reveal the same phenomenon as well (Table 5).

River Mile	Tributary Name	Temp AM	Temp PM
37.1	Halfway Creek	15.9	22.6
35.5	Lone Pine Creek	14.9	21.3
34.7	Meeker Creek	16.5	22.4
32.2	Marten Creek	17.2	22.1
31.6	Mink Creek	15.3	22.2
31.6	Three Links Creek	16.1	22.6
28.6	Pinchot Creek	16.9	23.4
28.6	Coyote Creek	16.5	23.1
28.6	Wolf Creek	16.7	23.3
22.8	Otter Creek	15.9	22.4
19.0	Meadow Creek	17.8	22.4
16.0	Sob Creek	16.7	22.3
14.7	Glover Creek	16.7	23.1
11.7	Wash Creek	16.9	22.0
11.7	Island Creek	16.9	21.9
10.6	Boyd Creek	16.9	22.9
10.5	Slide Creek	16.1	23.4
8.7	Nineteen Mile Creek	16.5	23.7
7.9	Rackliffe Creek	16.3	22.9
6.2	O'Hara Creek	16.5	N/A
2.7	Swiftwater Creek	16.5	22.4

Table 5 Tributaries of the Selway River

Selway River Dataloggers

Three dataloggers on the Selway reveal variability between surface temperatures and temperatures deeper within the channel (Figure 30, Figure 31). Of particular interest is the datalogger at mile 21, which shows little variability between morning and afternoon temperatures. This could be attributable to the location of the datalogger itself or an indication that it is buried in mud or otherwise malfunctioning.

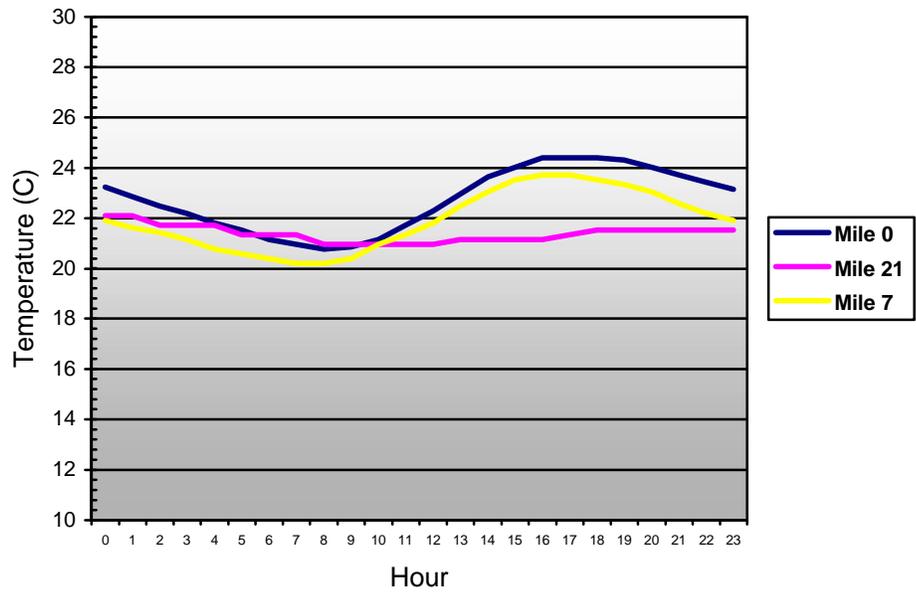


Figure 31 Datalogger plot of Selway River, August 4, 2000

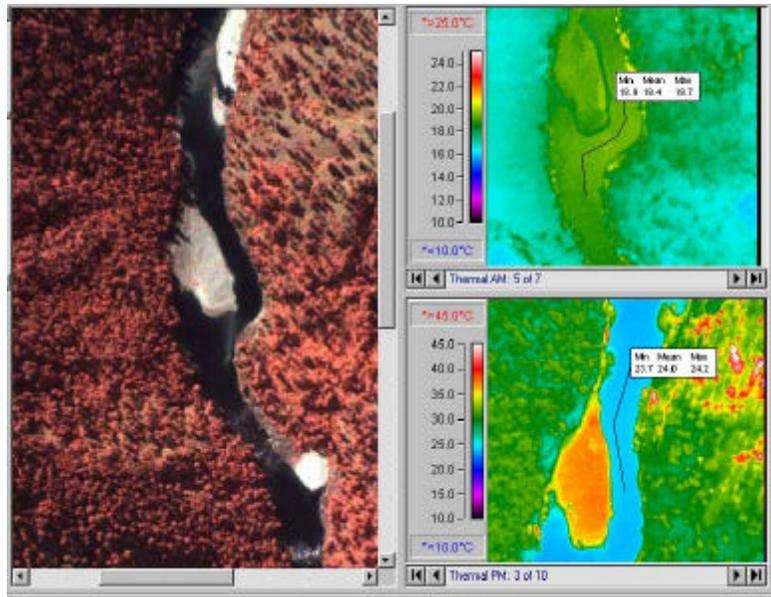


Figure 32 Selway River: Approximate location of datalogger at mile 21

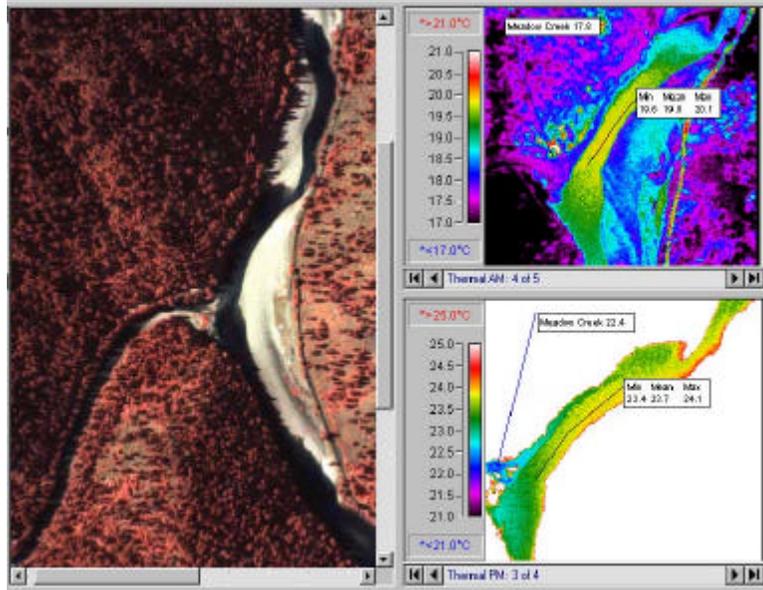


Figure 33 Selway River, confluence of Meadow Creek.

Selway River Summary

The Selway is river has several unique characteristics among the rivers in the Central Idaho study region including:

- Flat temperature profile
- Cool tributaries both morning and afternoon
- Possible thermal stratification as seen in datalogger data.

Further study might focus on placing more dataloggers between mile 30 and 40. It would also be interesting to see if the uniform temperature profile of the Selway River is a common phenomenon on this river throughout the year or if it is due to some other influence. In the future another FLIR study might make more flights on this river over the period of several weeks. Figure 32 and Figure 33 are of some images on the Selway River.

Lochsa River

The Lochsa River was flown upstream from the mouth to the ranger station at Powell. A large number of the major tributaries were visible and good measurements could be made. Of note in Figure 34 is the relationship between the morning and evening flights. Note how the lines initially diverge from the mouth and as you go upstream a pattern of converging and diverging temperatures becomes apparent.

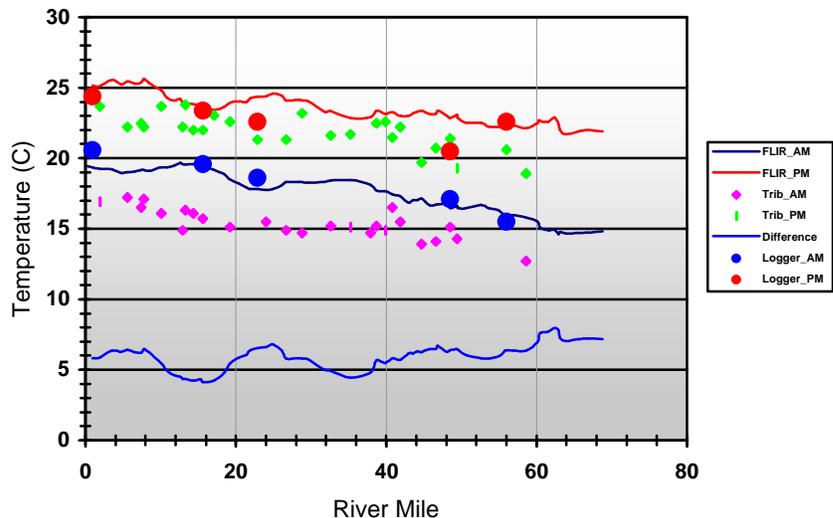


Figure 34 Lochsa River temperature profile

Lochsa River Tributaries

Of all the rivers in the Central study region the Lochsa River had the most tributaries of significant size to be measured in the margins of the thermal images (Table 6). The temperatures of the tributaries on the Lochsa River therefore show a more complete picture of the Lochsa basin as a whole. Like many

other tributaries in this study area the Lochsa tributaries make contributions of colder water in the morning than in the afternoon relative to the main river.

River Mile	Tributary Name	Temp AM	Temp PM
1.9	Pete King Creek	16.9	23.7
5.6	Handy Creek	17.2	22.2
7.4	Canyon Creek	16.5	22.5
7.8	Apgar Creek	17.1	22.2
10.1	Deadman Creek	16.1	23.7
12.9	Coolwater Creek	14.9	22.2
13.3	Bimerick Creek	16.3	23.8
14.3	Fire Creek	16.1	22.0
15.6	Split Creek	15.7	22.0
17.1	Tumble Creek	N/A	22.9
17.1	Old Man Creek	N/A	23.2
19.2	Tomcat Creek	14.9	22.4
19.2	Macaroni Creek	15.3	22.8
22.9	Eel Creek	N/A	21.3
24.0	Fish Creek	15.5	N/A
26.7	Lone Knob Creek	14.9	21.3
28.8	No-See-Um Creek	14.7	23.2
32.6	Bald Mountain Creek	15.2	21.6
35.2	Holly Creek	15.1	21.7
37.9	Stanley Creek	14.7	N/A
38.7	Skookum Creek	15.5	23.6
38.7	Unknown RMI 38.7	14.9	21.4
39.9	Eagle Mountain Creek	14.9	22.6
40.8	Unknown RMI 40.5	16.9	20.8
40.8	Lost Creek	N/A	21.1
40.8	Unknown RM 41.0	16.1	22.5
41.9	Unknown 41.8	15.5	22.2
46.6	Weir Creek	14.1	20.7
44.7	Indian Meadow Creek	13.9	19.7
48.5	Fish Lake Creek	15.1	21.4
49.4	Post Office Creek	14.3	19.3
56.0	Warm Springs Creek	15.6	20.6
58.6	Squaw Creek	12.7	18.9

Table 6 Lochsa River tributaries

Lochsa River Dataloggers

Five dataloggers equally spaced along the length of the Lochsa River show a common pattern of heating and cooling throughout the river. The sole exception would be at mile 56, which shows a higher temperature factor during the heat of the day than the others (Figure 35).

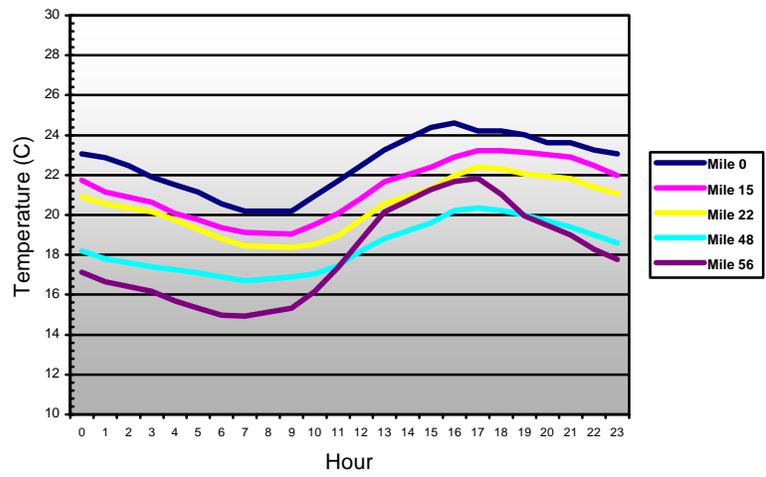


Figure 35 Datalogger plot of Lochsa River, August 4 2000

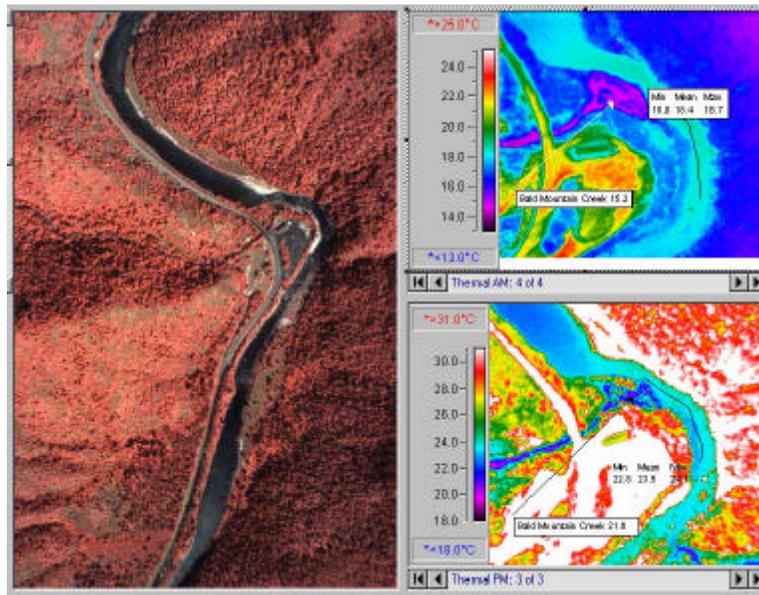


Figure 36 Lochsa River Mile 32.6, Bald Mountain Creek Confluence

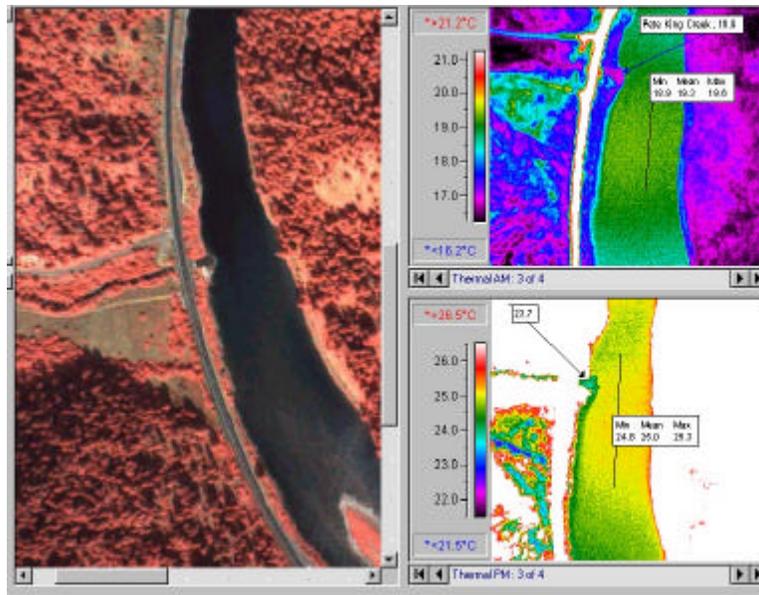


Figure 37 Lochsa River, Pete King Creek confluence

Lochsa River Summary

Figure 36 and Figure 37 show paired images of two of the confluences on this river. The Lochsa River is characterized by an inverse relationship between morning and afternoon temperatures. Some reasons for this might include:

- Depth of the river
- Specific types of flow
- Other topographic characteristics

Southern Region Rivers:

Jacks Creek, Big Jacks Creek, Little Jacks Creek

Imaging on the Jacks creeks was the most problematic. The rivers were small and occasionally dry (Figure 38). The lower reaches of Jacks Creek was segmented by vegetation. There are no dataloggers available for any of these rivers and any tributaries were not of sufficient size to be visible in the margins of the images (Figure 39, Figure 40, and Figure 41).



Figure 38 Little Jacks Creek at mile 3.4

Big Jacks, Little Jacks and Jacks Creeks had several sections that were dry or segmented. It was difficult to locate areas of the FLIR imagery to accurately measure temperature. The longitudinal temperature profiles in the graphs below should be used for gaining a rough estimate of the relative temperatures of the rivers and the fluctuations between morning and evening flights

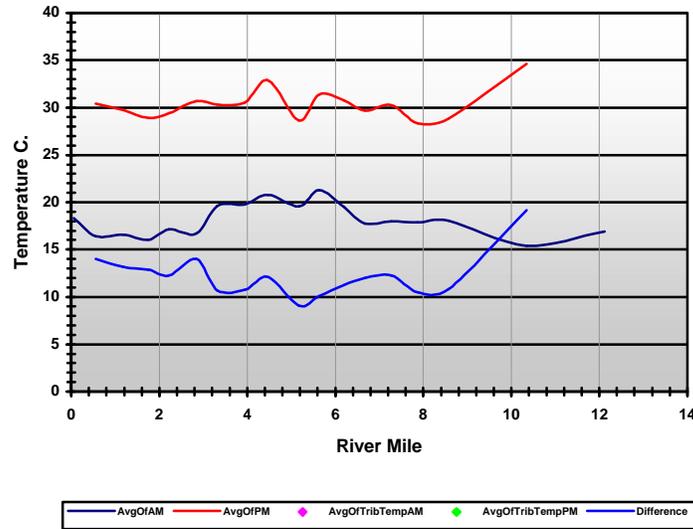


Figure 39 Jacks Creek Temperature profile

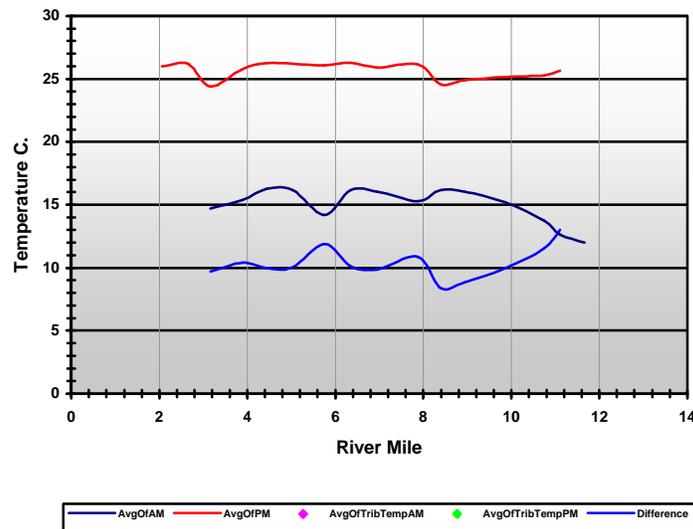


Figure 40 Little Jacks Creek Temperature profile (dry to approx mile 2.0)

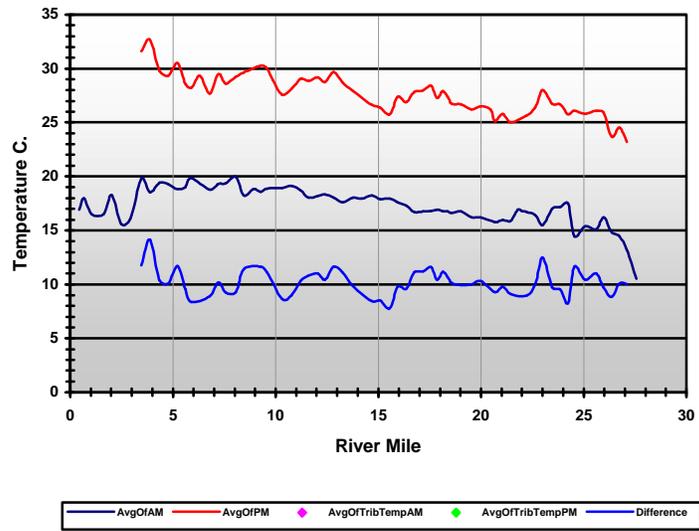


Figure 41 Big Jacks Creek temperature profile

North and South Forks Owyhee River

Both the North (Figure 42) and South (Figure 43) forks of the Owyhee River are characterized by large temperature fluctuations. The North fork was dry or nearly so at the headwaters and further down stream had pooled up with very little flow. The longitudinal profile of the South Fork of the Owyhee River shows signs of thermal stratification from approximately mile 28 through mile 50 and beyond.

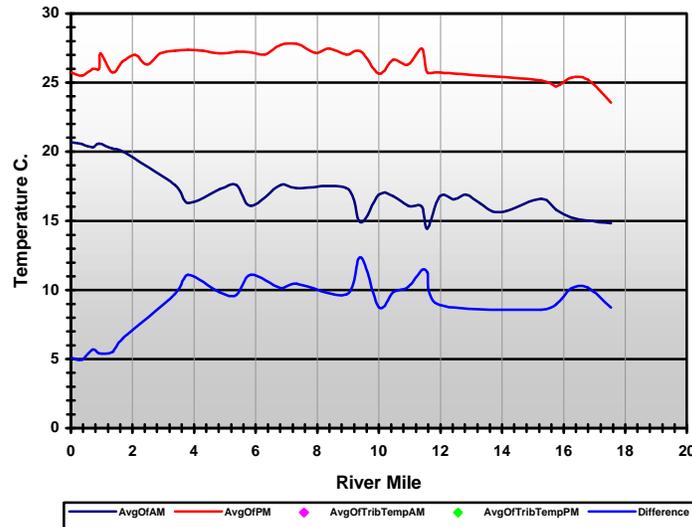


Figure 42 North Fork Owyhee River Temperature Profile

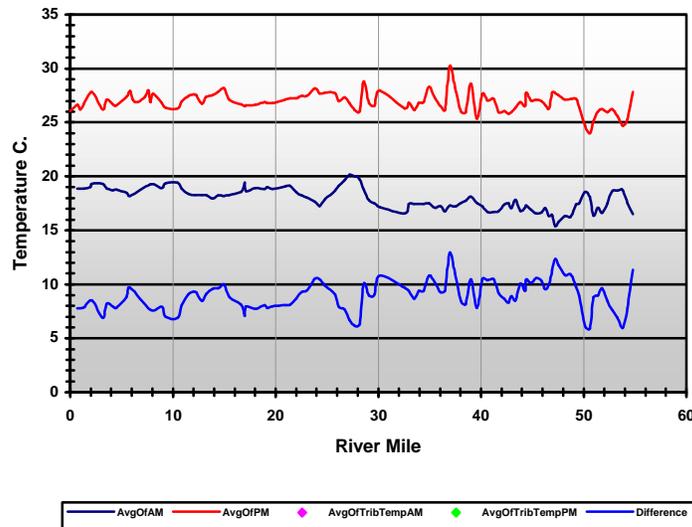


Figure 43 South Fork Owyhee River Temperature Profile