

**TECHNICAL SERVICE CENTER
Denver, Colorado**

Technical Memorandum No. 8260-95-03

**Temperatures and Warm Springs Along The Little
Colorado River**

Prepared by
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**U.S. Department of the Interior
Bureau of Reclamation**



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MEMORANDUM

To: Dave Wegner, Acting, Group Manager, Glen Canyon Environmental Studies

From: Edmond W. Holroyd, III
Research Physical Scientist

Subject: Temperatures and warm springs along the Little Colorado River

Technical Memorandum No. 8260-95-01 (hereafter 95-01) presented the analyses that determined the locations and temperatures of features in the Little Colorado River (LCR) canyon from its confluence with the Colorado River (at river mile 0) to about river mile 13 above Blue Spring. Technical Memorandum No. 8260-95-02 (hereafter 95-02) extended that work to nearly river mile 18 in a region with minimal georeferencing support and therefore greater positional error. This memorandum summarizes the river water temperatures and the locations and temperatures of warm springs.

The derivation of temperatures from FLIR images of 28 May 1994 was presented in 95-01. Georeferencing styles for LCR river miles 0-13 were presented in a memorandum dated 19 September 1994, "Subject: LCR video mosaic" and in 95-01. Georeferencing styles for LCR river miles 13-18 were presented in 95-02 and have errors up to about 30 m.

Observations

The enclosed graph shows a plot of FLIR-derived water temperatures plotted against clock time at about 20 second resolution. River mile positions are indicated at the top. Data for this graph were gathered from the middle of relatively broad sections of the river away from rapids. This helped get representative temperatures away from problem zones of thin water and stony rapids. The upper reaches (beyond mile 14.5) are cooler than the rest of the river. Temperatures are more uniform, oscillating about 20 C, in the middle portion. They warm rapidly below mile 5 until the water mixes abruptly with the colder Colorado River.

Temperatures of warm springs are plotted with identification letters. Differences from the adjacent river range from about 0.6 to nearly 3.0 degrees C. Some "springs" are questionable and need verification. Springs s and r, both of which seem to be in the river channel itself, appear to have major impacts on the river water temperature. The flows from the other springs, which originate along the shore, are apparently small compared to the adjacent river flow. The cool fluctuation of the river near spring g may be from operator adjustment of the FLIR controls.

Table 1 gives the coordinates and temperatures (degrees C) of the springs. Positions in the Arizona State Plane coordinates (meters) have been rounded to the nearest 10 meters. River miles (rm) are approximate. Though clock times on the images are in Coordinated Universal Time (CUT), 7 hours have been subtracted for the MST used in Arizona. The mosaic (first) clock time serves as an identification label.

Table 1. Locations and temperatures of apparent warm springs along the LCR.

Spring	Arizona State Plane	rm	Temp.	Clock	Mosaic	Comments
a	N 576,480 E 228,630	3.7	23.0	074220	07:42:20	good example
b	575,820 229,390	4.6	23.0	074304	07:43:04	indistinct
c	575,170 231,790	6.3	21.6	074444	07:44:44	branched?
d	575,130 231,820	6.3	22.0	074444	07:44:44	minor?
e	575,070 231,910	6.4	21.4	074448	07:44:44	long and branching

f	575,010	231,940	6.5	20.8	074452	07:44:44	minor?
g	574,590	232,170	6.7	19.6	074508	07:44:44	thin stream
h	569,290	233,070	10.8	21.0	074924	07:49:24	questionable
i	569,260	233,080	10.8	21.4	074924	07:49:24	questionable
j	568,830	234,130	11.8	22.0	075040	07:50:36	strong flow
k	568,810	234,140	11.8	22.0	075040	07:50:36	lesser tributary
l	568,720	234,140	11.9	21.6	075044	07:50:36	long and branching
m	568,700	234,130	11.9	21.0	075048	07:50:36	minor?
n	568,600	233,930	12.0	21.6	075056	07:50:36	perpendicular to river
o	567,880	233,660	12.6	21.0	075148	07:51:48	wide flow covering 1/3 river
p	567,430	233,460	12.9	20.2	075216	07:52:16	hidden by rock? at Blue Sir.
q	566,780	234,310	13.9	20.6	075352	07:53:52	possible side channel flow
r	566,620	234,080	14.2	21.2	075408	07:53:52	in river
s	563,480	235,890	17.2	19.8	075740	07:57:40	diffuse rapid river warming

The enclosed picture mosaics show pairs of video and thermal images with annotation. These should help other workers locate them in the field and in future FLIR imagery. They have been printed at 1:4000 scale with north to the top. The thermal images have cool=dark, warm=bright rather than the color coded temperatures of the previous memoranda. Wet sands are typically dark from evaporative cooling.

Discussion

The thermal gradients within the river were mostly from very thin water and rapids, whereby other objects, like rocks and bottom sand, were probably viewed by the FLIR instrument. It did not seem appropriate to resolve backwaters because the water may have been only a few centimeters deep in them. The patterns are still available for examination from 95-01 and 95-02.

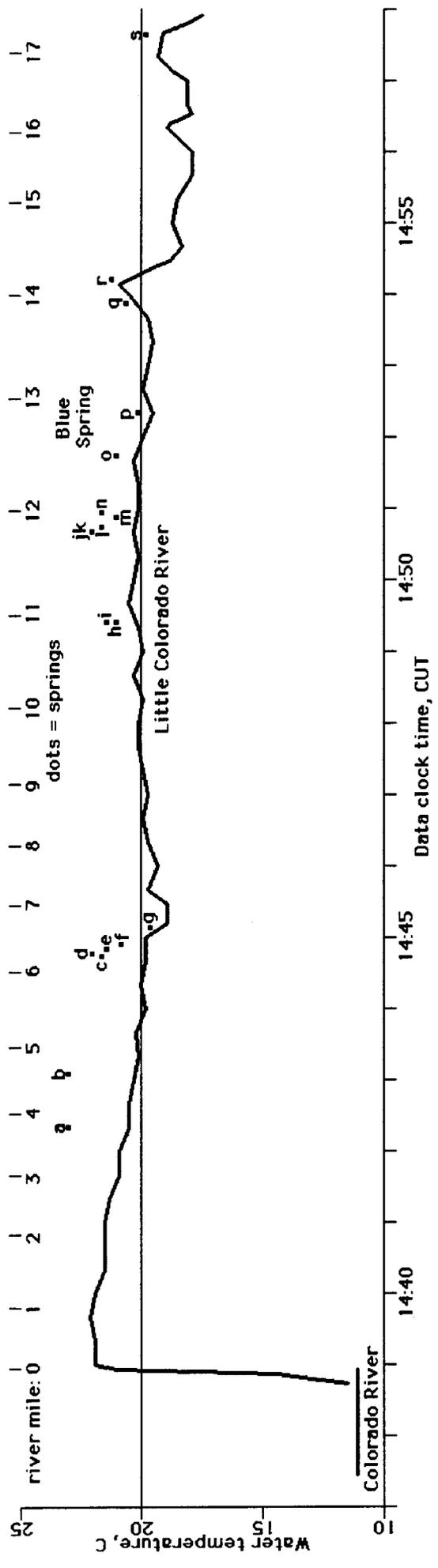
The FLIR images, at 0.2 degrees C resolution, are sensitive indicators of warm springs along the LCR. The springs observed had temperature increases of 0.6 to nearly 3.0 C warmer than the adjacent river at the time of the observations in the early morning of 28 May 1994. The cooler wet sand was an aid in visually identifying the springs.

The river should be flown at other seasons, such as cold winter and hot summer, when there might be more contrasting temperatures and/or differing flow volumes. That would help indicate which of these apparent springs are real and persistent.

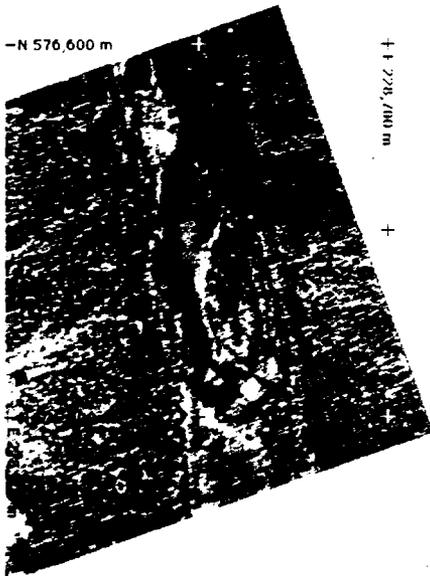
Only one spring (Blue Spring) is named on the topographic map, but its exact location is not obvious, even with respect to which side of the river it is on. I am eager to attempt a matching of the springs identified by FLIR with those identified by previous workers if their data can be provided to me. If there are significant and persistent new springs identified by the FLIR observations, and if it is appropriate to have them named, I suggest that my letter identifications eventually be replaced by names suggested by Hopi leaders, possibly taken from their legends. There appears to be a good selection of names in the Book of the Hopi by Frank Waters (1963).

The locations of the springs can be refined. There were significant errors in the georeferencing procedures, ranging up to about 30 meters in the upper reaches. I suggest that differential GPS measurements be made from nearby points with an adequate view of the sky. Most of the springs are in deep canyon sections with nearly vertical rock walls and overhanging rock ledges where GPS will not work well. From these GPS positions the spring locations can be determined by normal surveying techniques. Such expeditions would also verify the reality of the apparent springs identified by this FLIR study.

Attachments (graph, video and FLIR mosaics)



-N 576,600 m



FLIR video and temperature patterns

28 May 1994, 07:42:20 am

0 scale 100 m
LCR river mile 3.7

N

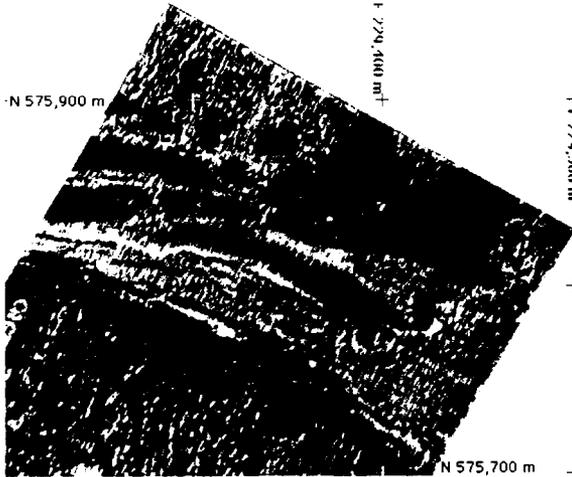
+1 228,700 m

+



flow direction

-N 575,900 m



+1 229,400 m

+

FLIR video and temperature patterns

28 May 1994, 07:43:04 am

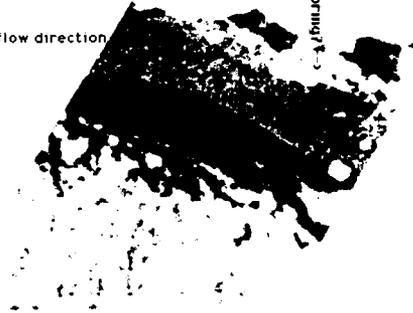
0 scale 100 m
LCR river mile 4.6

N

+1 229,500 m

+

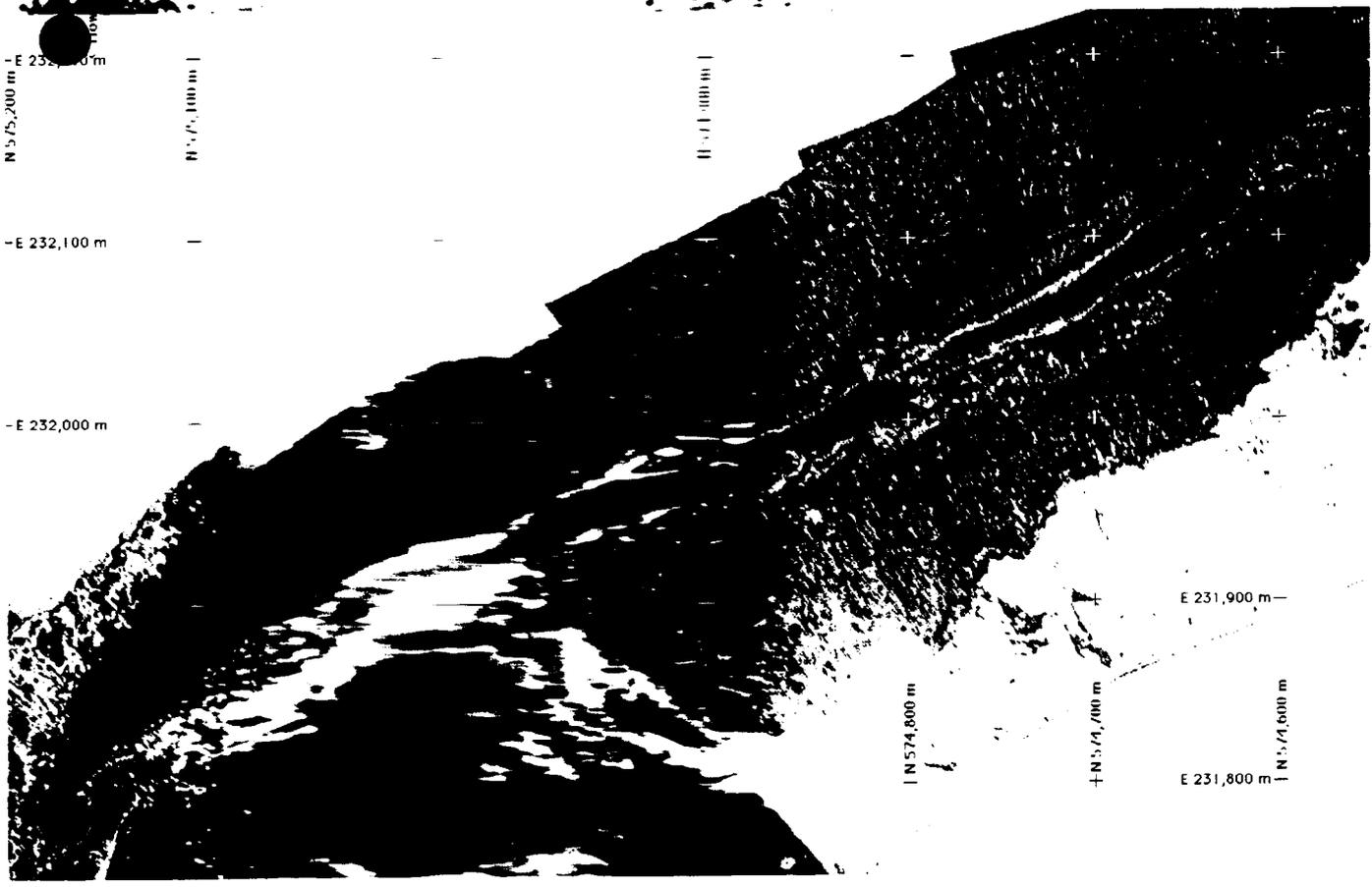
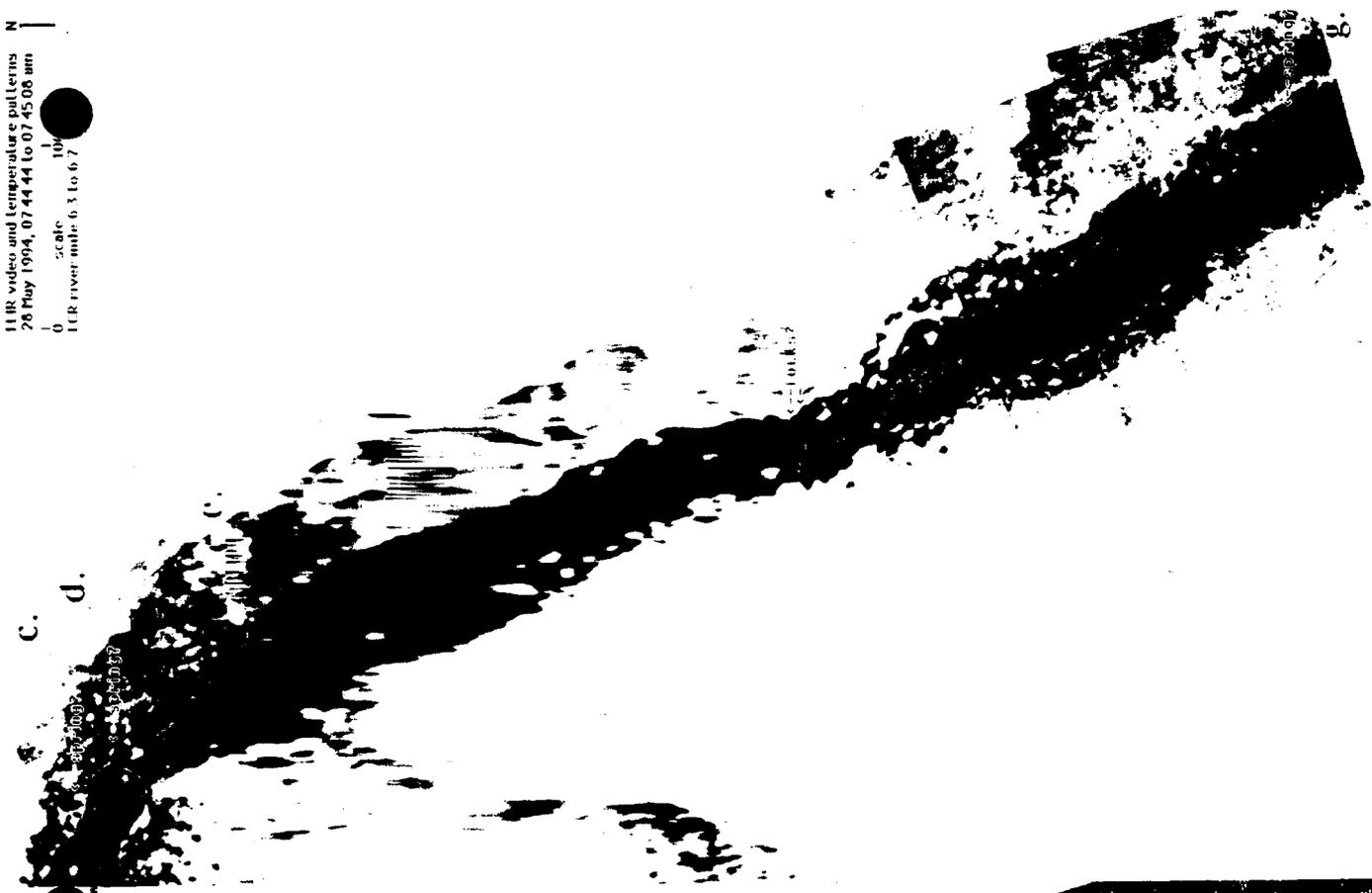
flow direction

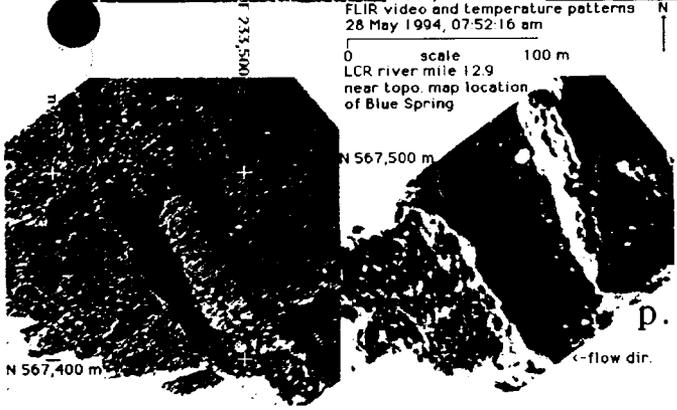
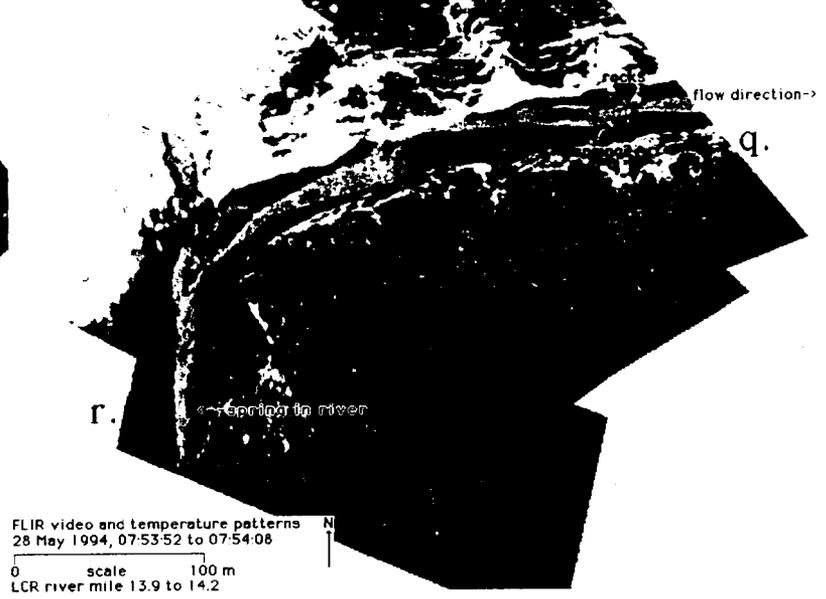
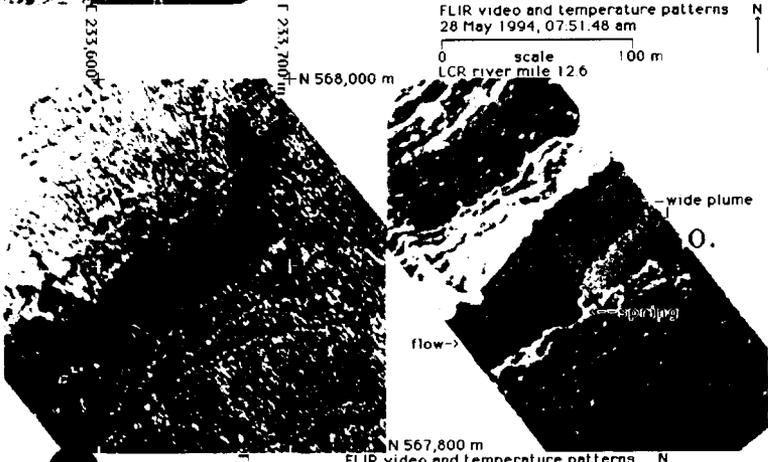
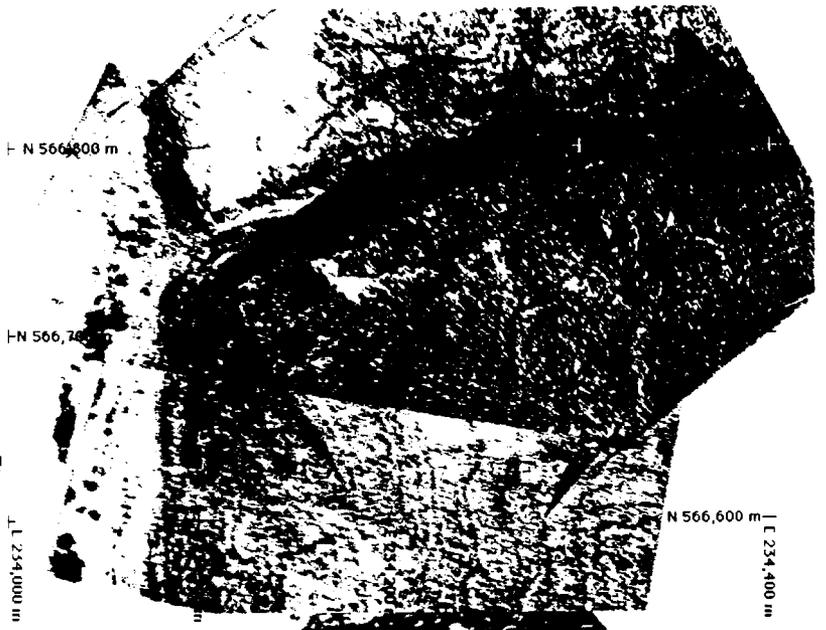
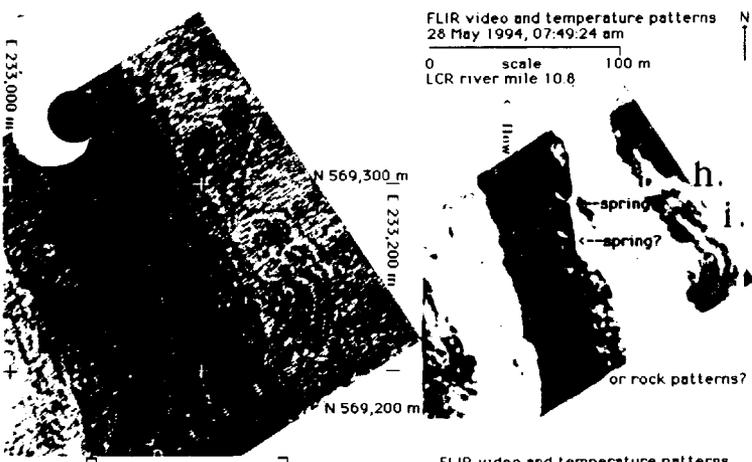


spring b.

N 575,700 m

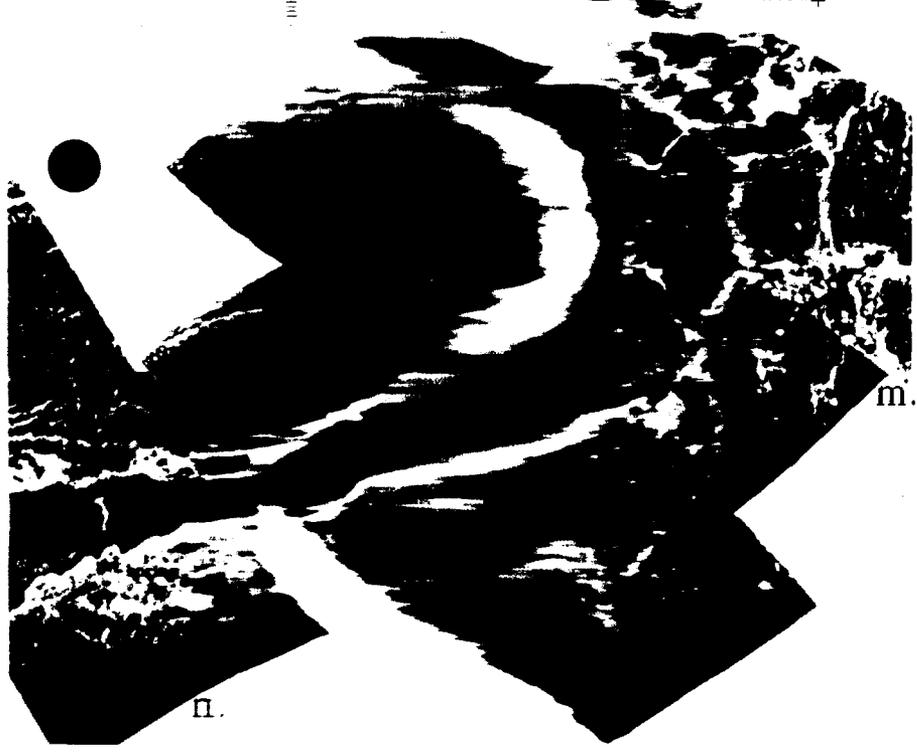
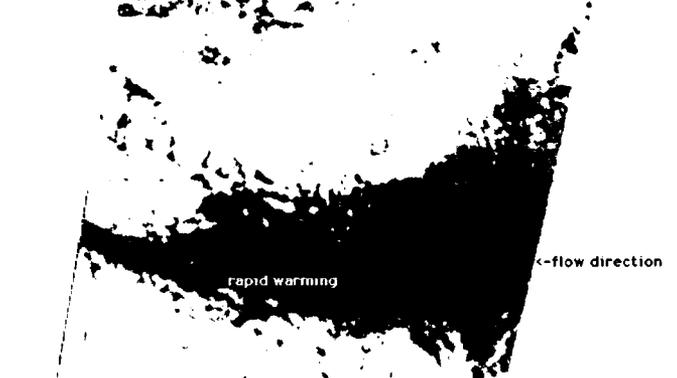
IR video and temperature patterns
28 May 1994, 07:44:44 to 07:45:08 am
0 100
IR river mile 6.3 to 6.7





temperature patterns
50:36 to 07:50:56 am

100 m
18 to 120



FLIR video and temperature patterns
28 May 1994, 07:57:40 am
0 scale 100 m
LCR river mile 17.2

S.

N

j.
k.
l.
m.

n.