

Date: January 28, 2016

To: Parker Thaler,
State Water Resources Control Board

From: Mary Ann Madej, Ph.D.
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Re: Klamath Hydroelectric Project

I am submitting this letter as part of the scoping session regarding FERC relicensing of the Klamath dams. I am commenting as a private citizen, not an agency representative, although I am submitting data collected and compiled when I worked for the U.S. Geological Survey (USGS). Attached are two types of information which highlight some of the negative impacts of the dams on salmonid habitat, and they support the views of other speakers at the scoping meeting held in Arcata, CA on January 25, 2016.

1) Stream temperature

In 2010, the USGS conducted in-situ measurements of river temperature from Iron Gate Dam to Happy Camp to supplement previous temperature monitoring efforts and to be used as input into hydraulic models. In addition, in August 2010, a thermal infrared flight was conducted in cooperation with the University of Washington to measure surface river temperature in this same reach. The attached poster highlights the results of this monitoring, which shows elevated river temperatures downstream of Iron Gate Dam, with minor cooling farther downstream as tributaries contributed cooler water. River temperatures were consistently warmer (above 20° C) than the preferred range for salmonids. These results corroborate previous studies of elevated temperatures and support the temperature-impaired listing of the Klamath River.

2) Channel geomorphology

Maps of the Klamath River mainstem geomorphology were compiled to cover the reach from Iron Gate Dam to the mouth. Mesohabitat types (MHTs) such as pools, runs, riffles, and split channel units were mapped by the U.S. Fish and Wildlife Service (2010). The visual features of the river used to classify individual MHTs included channel gradient, active-channel confinement, surface disturbance, width-to-depth ratio, dominant and sub-dominant substrates, and the presence or absence of backwater effect. The survey team identified three dominant gradient types for classifying the MHT slopes including: low-slope (LS), moderate-slope (MS) and steep-slope (SS). In addition, Ayres Associates (1999) mapped additional geomorphic features along the river (gravel bars, terraces, debris fans, floodplains, eroding riverbanks, etc.). Finally, a Lidar coverage was incorporated to show the landforms of the Klamath River valley. These data are portrayed in a series of maps of the Klamath River (see attached example). The files for the full set of maps exceed my email capacity, but can be sent by mail upon request.

Through their effects on flows and sediment transport, the Klamath dams have led to decreased channel complexity downstream of Iron Gate Dam. Here, the channel is coarse and relatively featureless (Figure 1). The area of alluvial features is low downstream of the dam until around the Scott River confluence, where sediment yield from the Scott River increases gravel

availability in the Klamath River. The lack of alluvial features limits potential salmonid spawning habitat and reduces hydraulic complexity (for example, reducing the range of flow velocities). Reduced channel complexity has been detected downstream of other dam projects as well (U. S. Forest Service, 2004).



Figure 1. Looking downstream from Iron Gate Dam, Klamath River.

Because of the impact of the dams on stream temperature and channel complexity as described here, as well as other impacts analyzed from scores of studies during the last two decades, I support the removal of the Klamath dams.

References

Ayres Associates. 1999. Geomorphic and sediment evaluation of the Klamath River, California, below Iron Gate Dam. Ayres Project No. 34-0449.00. Fort Collins, CO

U.S.D.A. Forest Service Pacific Northwest Research Station. 2004. The Geomorphic Response of Rivers to Dams. General Technical Report PNW-GTR-601. 2 CD set.

U.S. Fish and Wildlife Service. 2010. Classification and Inventory of Meso-habitat Types in the Klamath. In-house report compiled by Christine Medak and Thomas Shaw. Arcata, CA.

Attachments

- 1) Stream temperature poster.pdf
- 2) Klamath map example.doc

Stream temperature data in support of river ecosystem science in the Klamath River

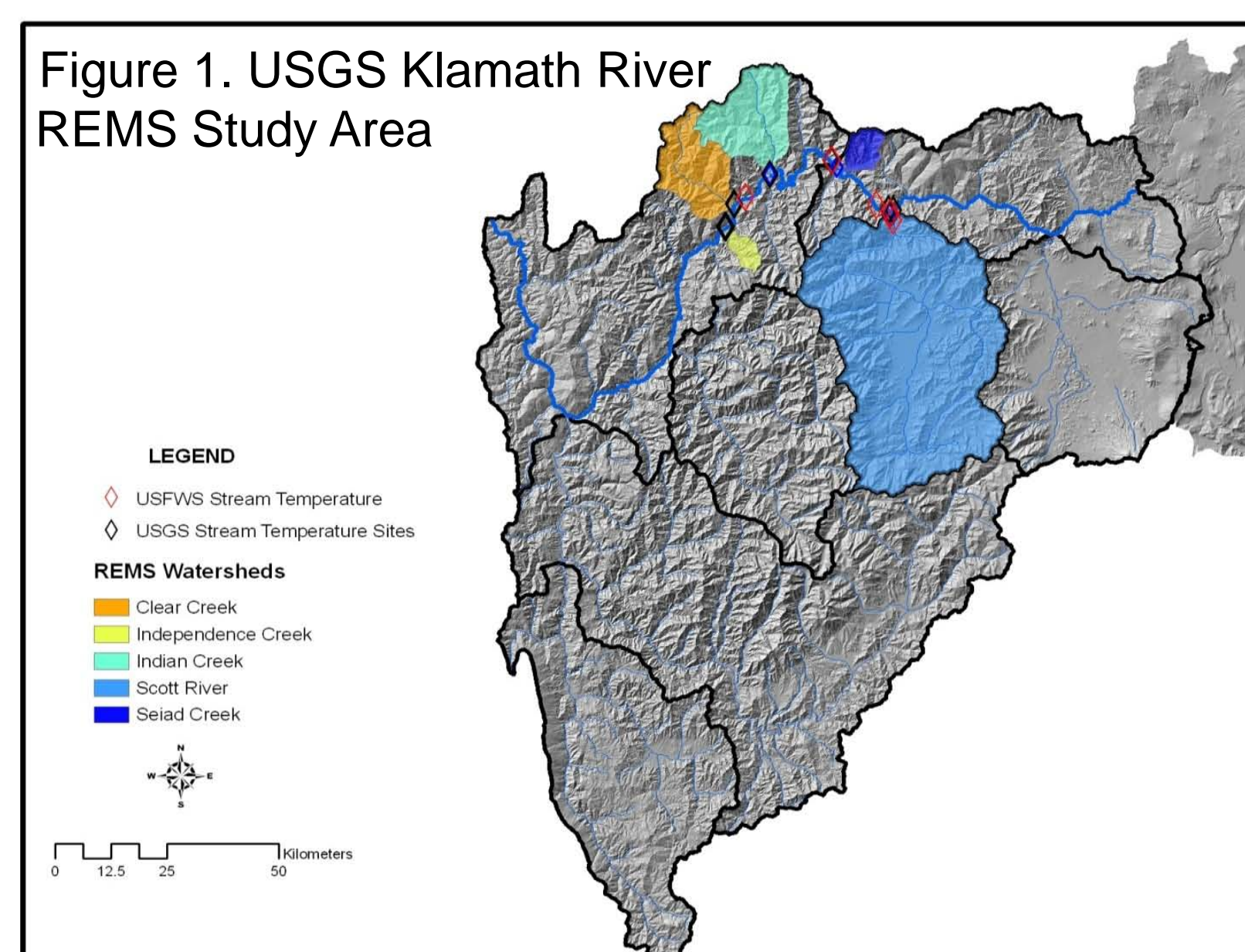


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Introduction

The USGS is engaged in an integrated science program studying physical processes that create mainstem thermal patchiness and cold-water refugia at tributary confluences within the Klamath River watershed. This project was designed as part of a River Ecosystems Models and Science (REMS) framework that uses multi-scale, multi-disciplinary approaches to address hydrologic and ecologic issues in river systems. Basin-scale hydrologic models provide boundary conditions for current and future climate scenarios and coupled physical and bio-energetic models at the reach and habitat-scale will be used to evaluate the effects of temperature regimes on key fish species. To support these efforts, in-situ stream temperatures and thermal remote sensing (TIR) imagery were collected at low flow conditions during the summer of 2010 along an 80 km mainstem reach and at five tributary confluences. This assessed the spatial and temporal variability of surface stream temperatures throughout the study area.



Background

Stressful stream temperatures are normal for the Klamath River, which lies on an "ecological edge" with respect to water temperatures for coldwater fish species. Elevated stream temperatures along the Klamath River occur more frequently and for longer durations than in adjacent anadromous streams. Analysis of historic stream temperature data show an increase of ~ 1.0° C since 1962 and stream temperature modeling indicates the cumulative exposure to stressful temperatures has been increasing in frequency and duration (Bartholow, 2005). Atypical low-flows during September 2002 coupled with an above average salmonid run and warm water temperatures, which are not unusual in the Klamath River during September, created ideal conditions for pathogens to infect salmonids resulting in an unprecedented fish-kill of over 33,000 adult salmon and steelhead (DFG, 2004). The fish-kill of 2002, FERC relicensing of a series of dams, and proposed dam removal initiated renewed stream temperature monitoring and numerous reviews of conditions required for ameliorating detrimental temperatures.

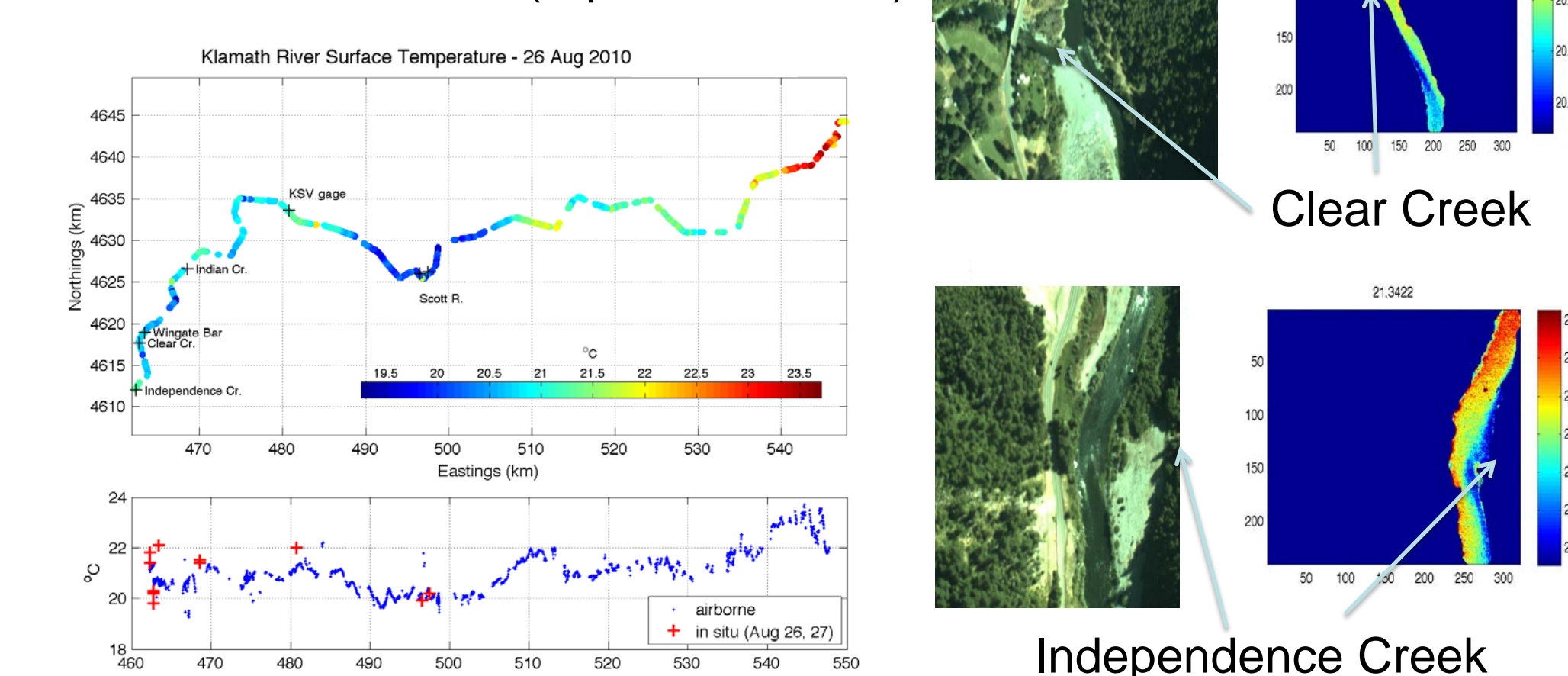
Methods

We collected spatial and temporal datasets to assess lateral, longitudinal, and vertical stream temperature variability. Thermal remote sensing (TIR) provided a synoptic longitudinal view of surface stream temperatures at the reach and confluence scale and insitu data were used to assess temporal and vertical variations at the confluence and habitat unit scale. Five confluence sites (Fig.1) were targeted for data collection and during the summer of 2010 we deployed 30 insitu temperature probes throughout the REMS study area to supplement an existing array of USFWS probes that are part of a long-term monitoring program. The objective for the TIR was to collect a diurnal set of imagery during an afternoon (8/25/10) and morning (8/26/10) at each of the 5 tributary confluences and along the 80km study reach. Variability was assessed using statistical measures of dispersion (max, min, range, std dev, variance, kurtosis).

Results

Water temperatures and measures of variability are shown at the reach, confluence, habitat unit scale. TIR data (Fig.2 & 3 and Table 1) from 8/26/10 indicate the highest stream temperatures occurred downstream of IGD. Progressive downstream cooling began near the Shasta River confluence and become more pronounced near the Scott River confluence. In the vicinity of Seiad Creek stream temperatures and variability increased. Further downstream mainstem cool patches occur between Indian and Independence creeks. Along the 80km study reach median surface temps were > 20°C at 92% of the sampled locations and temperatures ranged from 19.2 to 23.7°C. Reach scale data show ~ 4.5°C variability and confluence scale data show <1.0°C variability. Diurnal variations based on TIR data at the Scott and Seiad confluences was ~8°C.

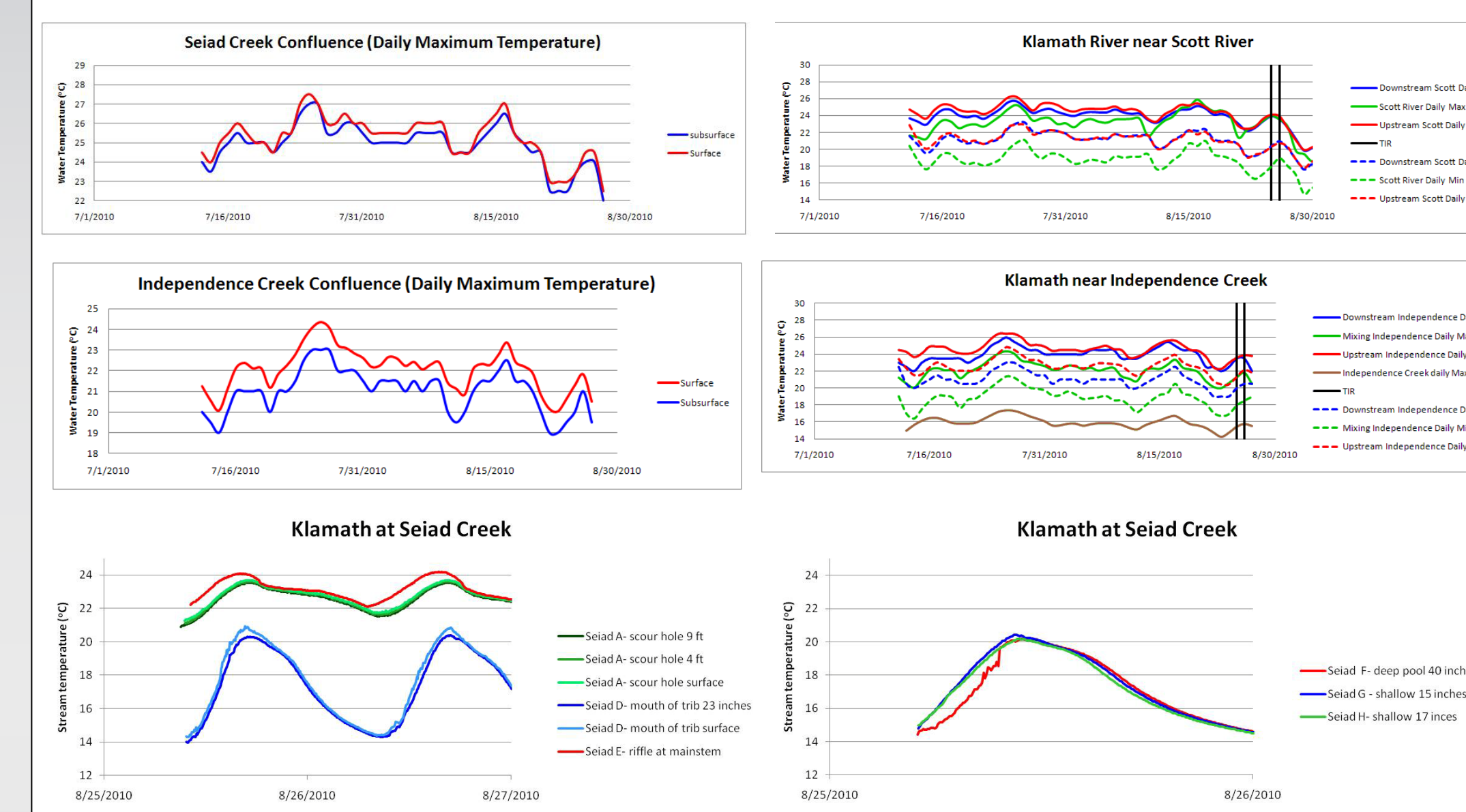
Figures 2 & 3. TIR reach and confluence scale data (1 pixel = 0.8m²)



Site	LP	SR	SR	SR	SC	SC	IC	IC	CC	CC	IndC	IndC
Date	8/26	8/25	8/26	8/26	8/25	8/26	8/26	8/26	8/26	8/26	8/26	8/26
Time	1002	1721	0857	1101	1741	0915	1116	0929	1128	0940	1143	0952
N=	1390	129	165	155	213	180	208	163	226	181	260	148
Max	23.70	28.65	20.58	21.78	29.80	21.80	23.36	21.09	23.08	21.70	23.07	21.30
Min	19.26	27.72	19.38	21.37	27.02	19.45	21.41	20.34	21.18	20.11	21.66	20.77
Range	4.44	0.93	1.20	0.41	2.78	2.35	1.95	0.75	1.90	1.59	1.41	0.53
Std Dev	0.84	0.17	0.22	0.10	1.05	0.44	0.65	0.12	0.61	0.30	0.36	0.10
Variance	0.70	0.03	0.05	0.01	1.10	0.19	0.42	0.01	0.37	0.09	0.13	0.01
Kurtosis	0.67	-0.06	0.16	-0.94	-1.61	1.74	-0.91	5.31	-0.33	0.55	-0.31	1.69

Insitu data (Fig. 4 to 9) were analyzed for lateral, vertical and temporal variability at the confluence and habitat unit scale. Mean seasonal diurnal variations were ~ 2 to 3°C at the Scott, Seiad, and Independence confluences and ~ 4 to 6°C within Seiad Creek and the Scott River. Thermal stratification was measured at Seiad and Independence confluences where mean seasonal vertical variations were ~0.5 to 1.0°C. A 2 °C thermocline was measured within a 1m deep pool near the Seiad Creek mouth but was destroyed by mixing and/or loss of riparian shade by 3pm.

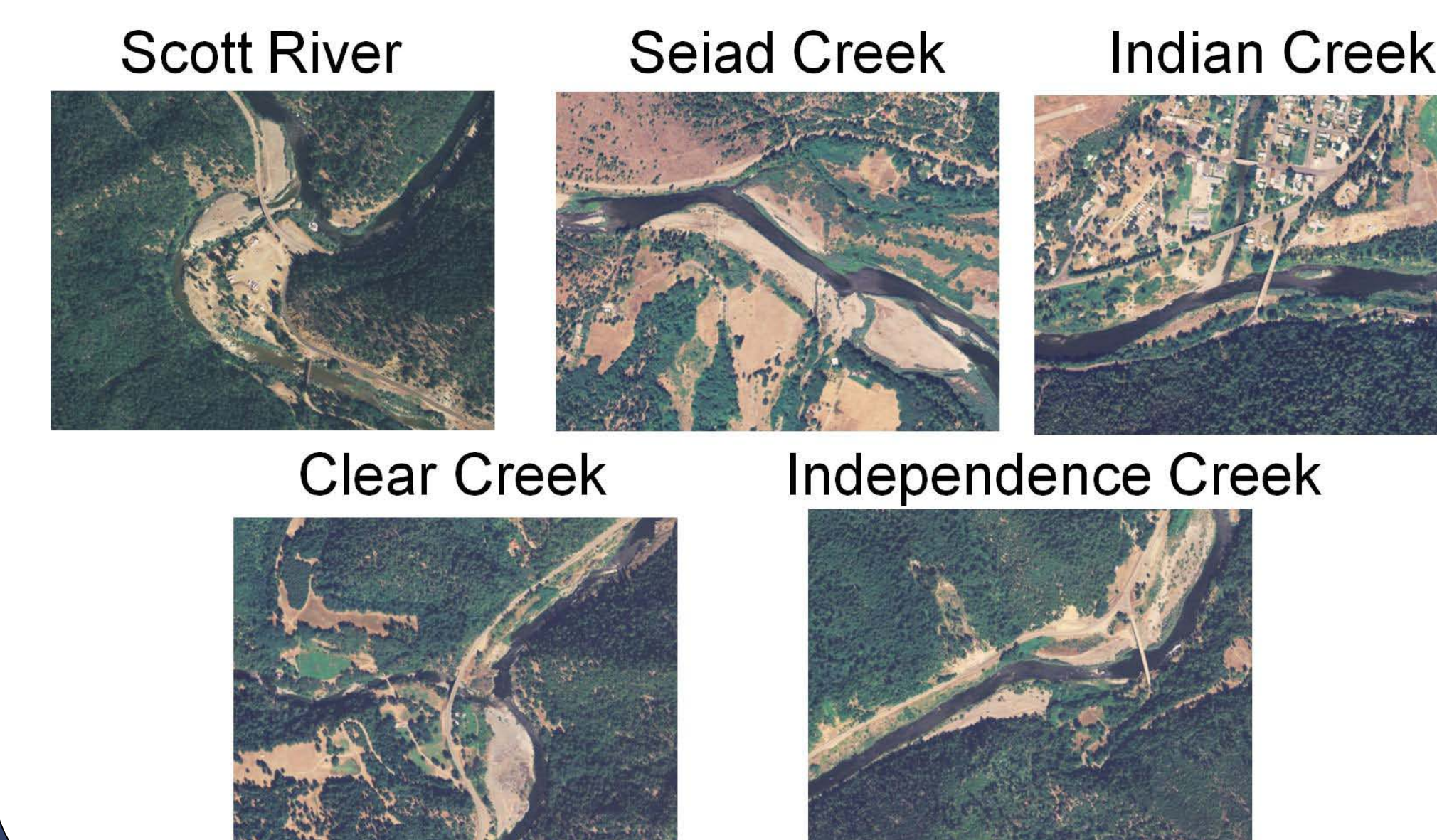
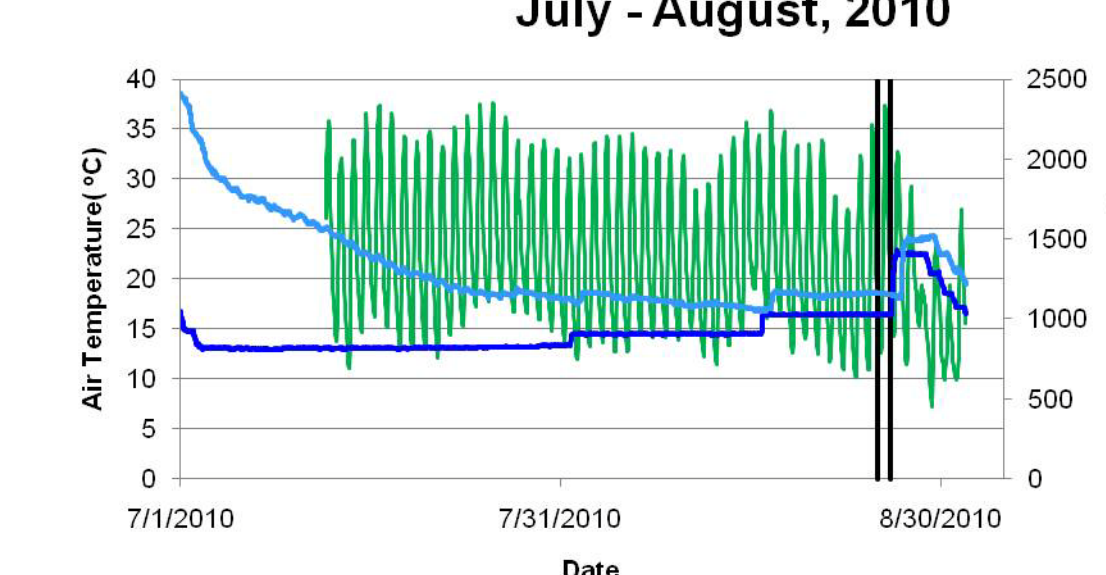
Figures 4 to 9. Insitu seasonal and diurnal data collected at the confluence and habitat unit scale.



Discussion

TIR and insitu data reveal significant variability at all scales. Longitudinal variability at the reach scale was 4.5 °C. Seasonal diurnal and vertical variability at the confluence scale were ~0.5 to 3°C and ~0.5 to 1.0°C respectively. Mainstem thermal patchiness and poorly-mixed flows at tributary confluences provide habitat for salmonids existing at the margin of their environmental tolerances. Spatial and temporal variability may be generated by addition of cooler tributary flows, topographic shading, thermal stratification, or hyporheic flow.

Air Temperature and Streamflow July - August, 2010



Conclusions

Reach scale TIR data show ~ 4.5°C variability and confluence scale TIR data show <1.0 °C variability. Precision is typically better than accuracy for radiometers thus we have higher confidence in the relative temperature differences whereas the TIR may not accurately represent absolute temperatures. Insitu data indicate poorly-mixed flows at stream confluences which may be problematic for TIR calibration. Continued monitoring, analysis of confluence channel hydraulics, and basin-scale solar radiation, topographic shading, and air temperature modeling will help explain some of the observed complexities. Geologic evidence indicates that the REMS study reach may occupy an underfit paleodrainage with the mainstem flowing through an unusually wide valley with low slopes and a lack of riparian cover. Underfit channel morphology and confluence morphodynamics likely play key roles in temperature variability.

Future Work

Future work will focus on determining how climate and geomorphology influence physical processes that create mainstem thermal patchiness and cold-water refugia at tributary confluences and development of basin, reach and habitat scale physical models.

TIR and insitu temperature data

integrate with climate and topographic models

TIR calibration

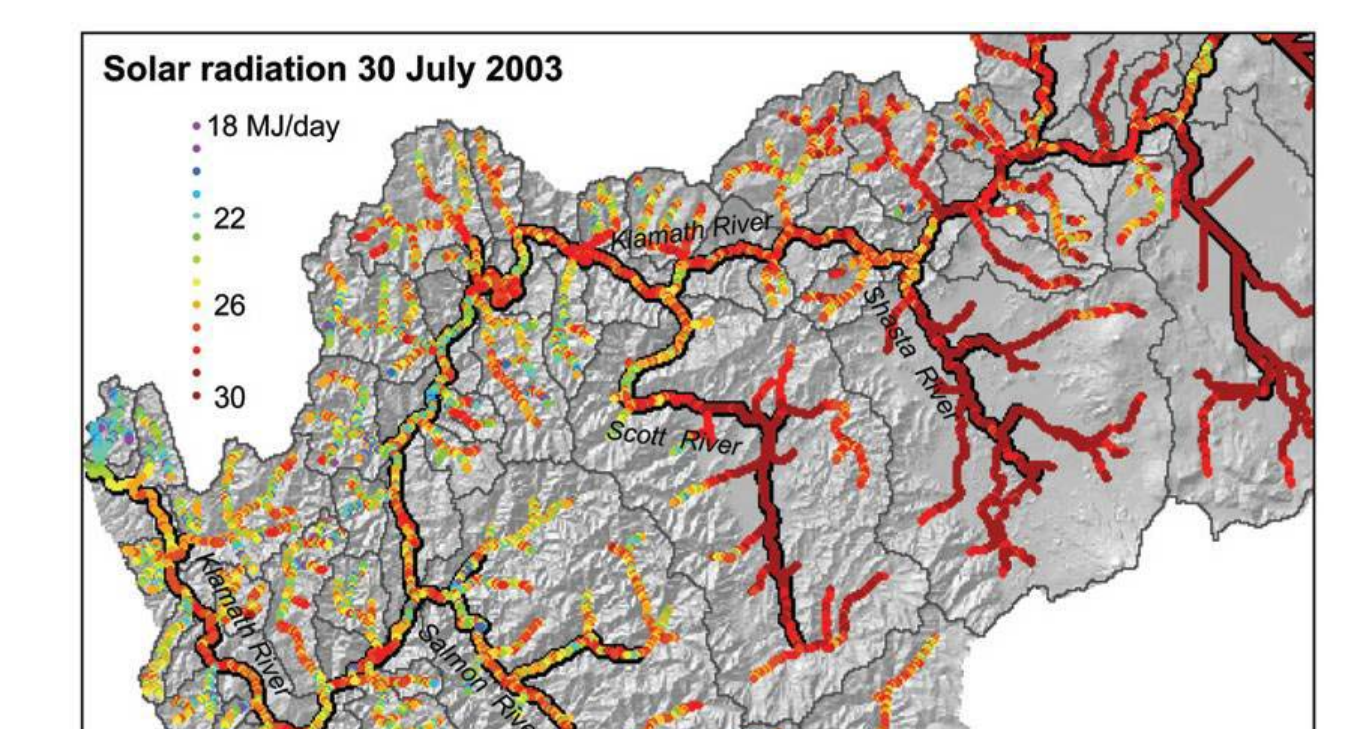
channel topography using bathymetric lidar survey

Distributed temperature sensing (DTS)

investigate variability, thermal patchiness, hyporheic flow

Monitor effects of dam removal

sediment, stream temperature, channel changes



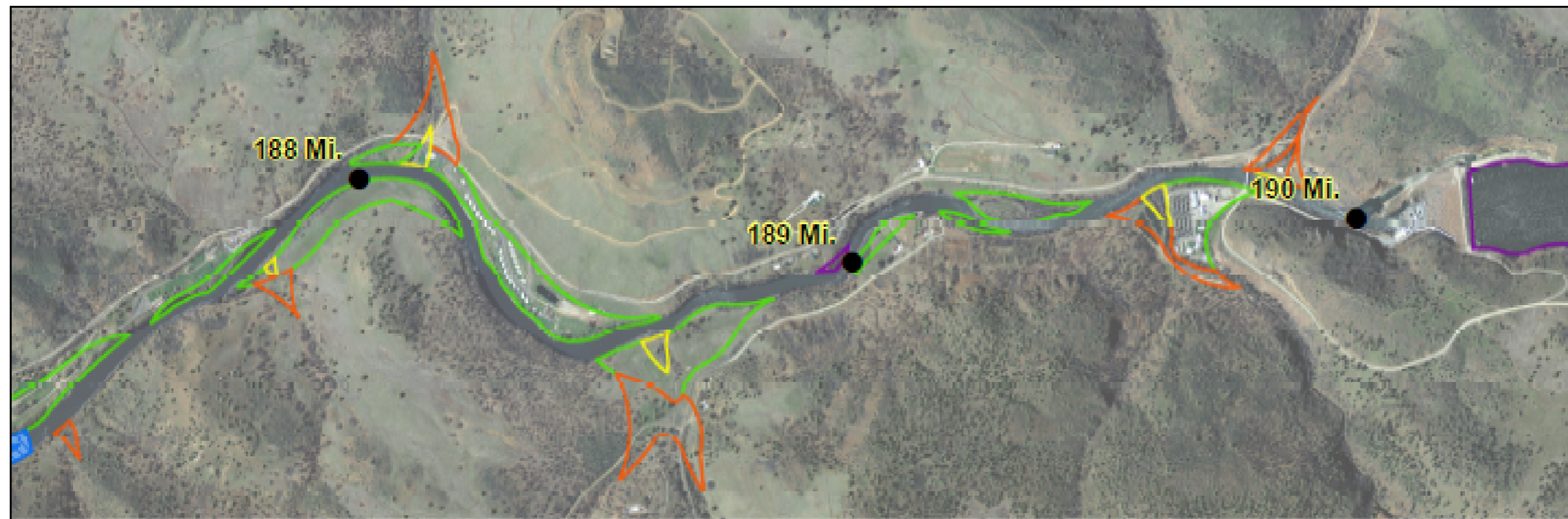
* from Flint and Flint, 2008

References

1. DFG, 2004, September 2002 Klamath River Fish-Kill: Final Analysis of Contributing Factors and Impacts, 183 p.
2. Bartholow, 2005, Recent Water Temperature Trends in the Lower Klamath River, CA, North American Journal of Fisheries Management, 25:152-162.
3. L.E. Flint and A.L. Flint, 2008, A Basin-Scale Approach to Estimating Stream Temperatures of Tributaries to the Lower Klamath River, California, Journal of Environmental Quality, 37:57-68

Acknowledgements

Paul Zedonis provided USFWS stream temperature data



Top Frame

Ayres Geomorphology

Map Class

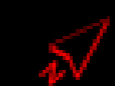
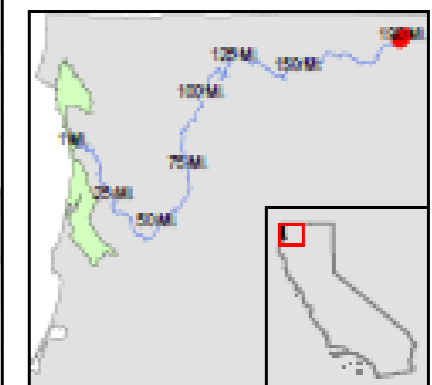
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- River bar/sediment
- Debris fan
- Erosion
- Rock Outcrops
- Terrace
- Bedrock
- QIs
- Rapids
- Riffles

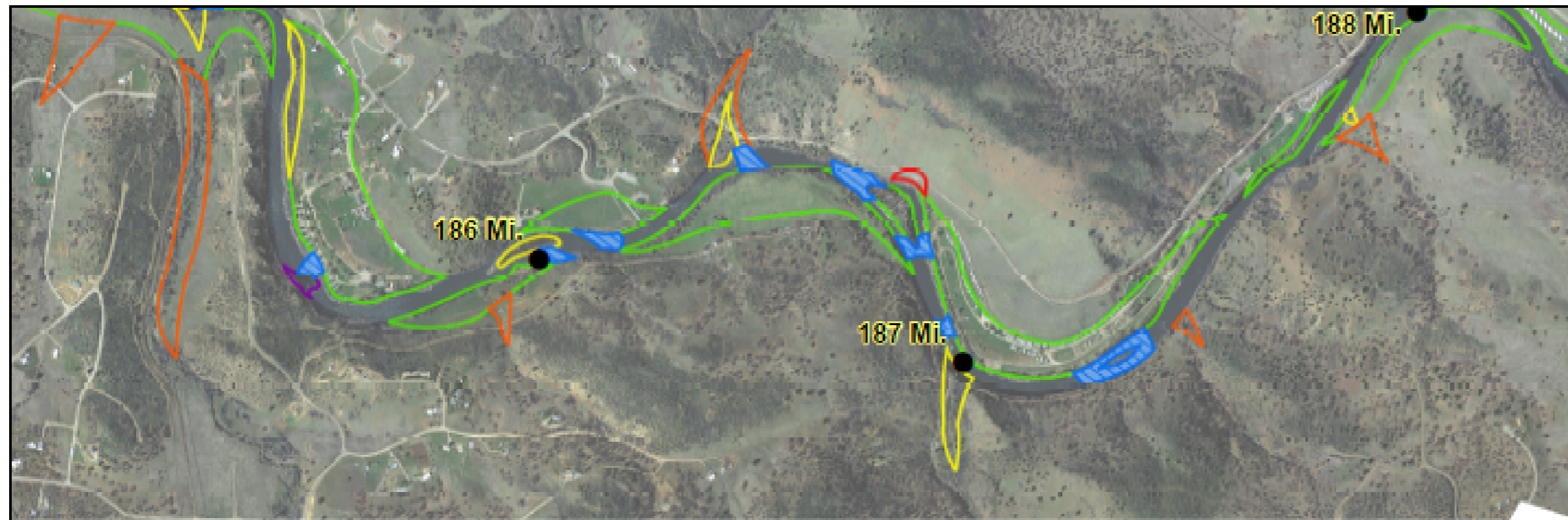


Bottom Frame

USF&W Mesohabitat

- Pool
- Low Slope
- Moderate Slope
- Steep Slope
- Streams/Rivers





Top Frame

Ayres Geomorphology

Map Class

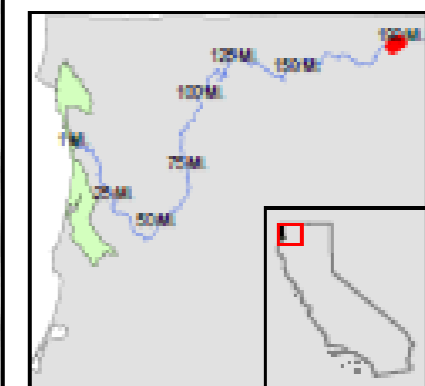
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186 - 187 River Miles