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2008 Project Update

Fiber Optic Groundwater and Fisheries Study
(WMI Task 5.6)

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Walla Walla Basin Watershed Council
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Project Overview

The Fiber Optic Groundwater and Fisheries Study is a collaboration of the Walla Walla Basin Watershed Council (WWBWC), Oregon State University (OSU), and US Fish and Wildlife Service (USFWS) to carry out the most rigorous validation of stream temperature models ever attempted in the Walla Walla River Basin. During the winter to spring 2008, the WWBWC, OSU and USFWS staff worked together to develop a study plan for the project that would encapsulate both the fisheries and the groundwater-instream scientific questions being tested with this multidisciplinary project. In July 2008, the WWBWC submitted a draft study plan outlining the specific fisheries goals, research questions and logistics (Appendix I) to the USFWS team in Vancouver, Oregon. This report was used by USFWS to formulate how they might best compliment the project while utilizing the process to further their own Walla Walla basin research and Bull Trout management goals. They finalized their involvement for the 2008 season with their work plan (Appendix II.)

As outlined in the May 2008 USFWS work plan (Appendix II), the objectives of this project are to: 1) Determine specific groundwater inflow locations along the Oregon and Washington study sections of the Walla Walla River; 2) Quantify groundwater inflow and temperature reduction locations in the study sections of the river and; 3) Cross reference groundwater inflow occurrence and quantities with fish species, life history, and habitat information.

Groundwater inflow locations were determined using temperature as the primary indicator since groundwater enters the stream system cooler than the river channel water. Fiber Optic Distributed Temperature Sensing (DTS)[1] technology allows for measurement of temperature to 0.01 deg C every meter along the river bed using standard communication fibers. Data can be obtained as often as every 30 seconds along the entire cable, with the instrument capable of immediate wireless communication of these data via cell or satellite connections. Groundwater and temperature reduction locations in the study reach were determined

[1] http://www.sensornet.co.uk/products-&-systems/sentinel-dts-product-range.cfm
http://cp.literature.agilent.com/litweb/pdf/5989-4500EN.pdf

though a detailed survey of the physical stream features and shade. Seepage runs, or instantaneous flow measurements taken throughout the reach, were used to quantify the gain and loss of water to the system, and therefore quantify the groundwater inflow. This aspect of the project was also conducted by OSU and WWBWC.

Finally, groundwater inflow occurrence was cross-referenced with fish snorkel surveys taken by the USFWS along the fiber optics reach in the summer.

2008 Field Work

Field work on the Fiber Optic Groundwater and Fisheries study in 2008 was both productive and challenging. Since use of fiber optic cable in the riverine environment is a new application of the technology, many issues had to be overcome throughout the field season. However, WWBWC and OSU staff learned how to make the project more efficient and effective over this trial field season, and the data collected was of better quality than that collected the previous season. The field activities and data collection are summarized below in accordance to the three major objectives of the project.

Objective 1: Determine specific groundwater inflow locations

On July 17th and 18th, 2008 roughly 4000 meters of fiber optic cable were deployed in the mainstem Walla Walla river from Mauer Lane downstream to the Bier farm, which is just south of the state line. Staff and students from WWBWC and OSU reeled the cable out and covered with rocks to keep it on the river bed along both banks of the river. The DTS computer logging the data was installed in a safe box at Mauer lane.

The 2008 fiber optics cable was a newer, lighter design than the 2007 cable, making it easier to deploy. The new cable also returned more light to the DTS computer, resulting in better resolution of the data. However, the cable was also more fragile and required repairs throughout the season due to beaver activity, vandalism, and wear.

In addition to the continuous temperature from the fiber optics cable, eight TitBit® temperature loggers were deployed along the cable length as a calibration-reference for the cable data. Finally, the cable and all field equipment were retrieved October 1 and 2, 2008 by WWBWC and OSU.

Objective 2: Quantify groundwater inflow and temperature reduction locations

Four data loggers and staff gages were installed at the beginning, end, and midpoints along the fiber optics reach to measure flow through the field season. Three instantaneous flow measurements were taken at each data logger in order to create rating curves. Additionally, one seepage run was conducted on the reach September 15, 2008. Two additional seepage[2] runs along the entire length of the mainstem of the Walla Walla were also conducted on July 23 and November 3, 2008.

An extensive survey and documentation of the physical characteristics of the fiber optics reach was conducted on July 22, 2008 in order to compare the continuous temperature data

[2] Seepage run is a flow inventory where all measurable inflows (tributaries, springs), outflows (diversions) and instream flows are measured to quantify flow in a given river or river reach.

to the reach's geomorphological conditions. Specifically, it allowed us to assess correlations between channel morphology and hyporheic and groundwater temperature information. In the survey, gravel bar and pool size and extent was estimated and also documented with photographs. GPS coordinates of all gravel bars, pools, and suspected groundwater seeps were noted along with the cable meter number for reference the to the fiber optics temperature data. Other detailed notes and coordinates were taken on areas of beaver activity, sections where the cable was exposed to the air, and points of agricultural and irrigation inflows.

On September 29, 2008 a survey of effective shade along the reach was conducted using a black and white fiber optics cable and a solar pathfinder. The black and white fiber optics cable was installed above the thalweg of the river above the water to collect air temperature data for 24 hours. In tandem with the solar pathfinder, which is used to estimate effective shade throughout the year, the estimated effective shade for the reach was established. This information will be used to differentiate between the effects of the daily solar cycle with that of groundwater inputs on stream temperature.

Finally, on September 29 and 30, 2008 two tracer experiments were conducted in the fiber optics reach to study the movement of river water through hyporheic zones. In one experiment three small wells were dug in a gravel bar and surveyed to determine the gradient. Salt and dye were added to the wells and the emergence and disappearance of the dye was timed. Additionally, an array of conductivity meters connected to data loggers was deployed downstream to determine travel time of water through the gravel bar and actual velocity of the water. In the second tracer experiment salt and dye were added to the river upstream of a large gravel bar and their appearance was monitored by the array of conductivity meters directly below the gravel bar. All tracer experiments were repeated several times.

<u>Objective 3: Cross reference groundwater and fisheries data</u>
In the July, 2008, the WWBWC-OSU-USFWS worked together to refine a joint study plan for this project. This study plan helped better refine the fisheries component of the project and provide the USFWS the information they needed to facilitate their participation in the project with approval from their regional office. The final study plan is attached as Appendix I.

On August 27 and September 10, 2008 snorkel surveys of fish species in pools in the reach were conducted by the USFWS. These surveys in tandem with the fiber optics stream temperature data, have brought to light correlations between salmonid distribution and groundwater seepage in this reach. Additionally, analysis of the fisheries data combined with the output from the fiber optic and physical habitat and tracer work will be conducted during the winter 2008-9. Final results will be combined with data from the 2009 field season and finalized in 2009-2010.

<u>Field Work Challenges and Revisions</u>
The main difficulty facing the project in 2008 was the number of cable breaks that occurred. The 2008 cable was much thinner than the 2007 cable and performed better in data collection and cable deployment, however it was more fragile and susceptible to animal and other damage. Repairing the cable was also difficult because the splicing tool was shared

between the Walla Walla project and a similar project on the John Day River and housed at OSU in Corvallis. Initially, there were also problems with the DTS computer data collecting, however, these problems were solved fairly early in the field season. Finally, at the end of the irrigation season the power source was turned off by the farmer at the Mauer Lane site causing some additional data gaps. An arrangement was required to compensate the farmer and allow us to continue using his irrigation power source.

Many of the difficulties with the strength of the 2008 cable are expected to be resolved in the next field season because OSU is designing a more durable cable. This is cutting edge technology is being applied for the first time in riverine systems, so some problems are expected as we work through the application.

2008 Analysis Work

Data analysis for the Fiber Optics and Fisheries Study and QA/QC started in December 2008 with the final report available in November 2009.

2008 Outreach Work

The 2007 and 2008 studies and results were presented by OSU on September 15, 2008 at the monthly WWBWC council meeting. Additionally, OSU presented this study at the Watershed Management Initiative Technical Review Team meeting to regional scientists on December 5, 2008

Future Work

The rigorous temperature, physical, and biological study of the fiber optics reach provides an in-depth, multi-dimensional view of the effects of groundwater and temperature on fish species in the Walla Walla River, and it will continue in 2009. The cable will be deployed again in 2009 and fish surveys and complementary data surveys will be conducted again. A full analysis and report will be available in November 2009, as outlined in the May 2008 work plan.

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Appendices

Appendix I
Draft Fisheries – Fiber Optic Study Project Plan

Appendix II
Final USFWS 2008 Work Plan for Fisheries Component of Project

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WWBWC-OSU-USFWS Groundwater-Fisheries Collaborative Study

6/27/2008

Prepared for the USFWS and OSU by

Bob Bower,
Hydrologist, WWBWC.

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Forward:
After reading through the Bull Trout Recovery Plan (USFWS, 2004), the 2008 USFWS Study Plan and reviewing the USFWS comments at the 2008 Walla Walla Research, Monitoring and Evaluation meeting, I believe I can better prepare an overview of the purpose and staffing needs for this collaborative project. The following is a study plan to lay out those connections along with the basic logistical information needed for planning a collaborative project. I have taken the liberty to use the same format that USFWS used in its' 2008 Study plan.

Introduction:
Stream temperature is a key determinant of habitat for ESA listed salmon and bull trout. During the low-flow or irrigation season (June through November), streams are fed primarily by groundwater, which is generally cool, and temperature is further moderated by hyporheic passage of stream water through permeable bed materials. While it is common in fisheries research to observe that coldwater fish often use what is likely groundwater and hyporheic cooled areas of streams and river, little research has been done to quantify the hydrogeology and fisheries interrelationships. With groundwater supplies throughout the Columbia River basin in decline, it is critical for ESA species research to develop tools that will make clearer the linkages between groundwater and fish.

These kinds of linkages between groundwater and ESA recovery efforts are occurring "with increasing frequency." (Vottler, 1998). In Texas, the region containing the Edwards Aquifer has had the management of that system become controversial and divisive over the past 40 years. The conflict *"erupted between rural and urban interests and between pumpers and those living downstream of its spring outlets who depend on spring flows for their surface water."* In this situation the Endangered Species Act (ESA) became the instrument that eventually brought state regulation to the Aquifer. Other recent publications also stress the importance for fisheries research to focus on a better understanding of groundwater and habitat relations.

In November 2006, British Columbia's Salmon recovery group Watershed Watch published a report titled *Review of Groundwater-Salmon Interactions in British Columbia* that highlighted the growing importance of this issue. In their report they state that;

"*… information on such interactions is often scares and/or scattered. Interest in groundwater-surface water issues and associated water conflicts and shortages will only increase, due to steadily increasing demands for already oversubscribed water resources, the effects of climate change on water use and demand, and the prevalent view that groundwater is an automatic alternative to surface water when surface water rights are unavailable. These factors inevitably result in heightened concerns about surface and groundwater depletion, including effects on wild salmon and other ecosystem values.*" (Douglas, 2006[3])
Similar conclusions were shared in Trout Unlimited's *Gone to the Well Once Too Often: The Importance of Groundwater to Rivers in the West* a report by TU's Western Water Project. They

[3] http://www.watershed-watch.org/publications/files/Groundwater+Salmon++hi+res+print.pdf

began the paper by saying:

"Many ask, 'Why should people who care about healthy rivers also care about ground water management?' Our answer: ground and surface water are connected to each other and as a result, pumping ground water can adversely affect river flows. In too much of the West, new water users start using ground water because river flows are insufficient. Ground water is seen as a new source to solve their water needs, but ground and surface waters are not separate and will rise and fall together. Ultimately, rivers bear the burden." (Trout Unlimited, 2007[4]).

The USFWS has already done some work in the area of making these scientific connections between fisheries and groundwater interactions. In 1998 a report titled *Fisheries Stewardship Progress Report Coaster Brook Trout (Rawlings, 1998[5])* found that "*…streams that retain low temperatures and stable flows (indicating high groundwater input) are able to support a year-round population of coldwater fish and therefore are the streams in which the Alpena FRO is concentrating their electrofishing studies."* This collaborative study would go beyond "indications" of groundwater connections and help to build a multidisplinary understanding. Further more, this project will complement the USFWS's general management (research) goals in the basin in two direct areas:

- Project will help monitor and record water temperatures in the mainstem river system (Task 2.3, USFWS 2008 Study plan).
- Project will provide high resolution temperature, flow, digital elevation information and fisheries information for the development of their Hydrodynamic Modeling (PHABSIM) study from Nursery Bridge to the Burlingame Diversion (Walla Walla Research, Monitoring and Evaluation meeting, May 2008).

This project will also fulfill a specific Recovery Action listed in the Umatilla-Walla Walla Recovery Unit's Bull Trout Recovery Plan which states:

<u>1.2.19 In the Walla Walla basin, investigate groundwater-surface water interactions and implement study recommendations</u>. Work with water management agencies to address how groundwater withdrawal affects instream flows. Evaluate effects of historical gravel removal downstream of Nursery Bridge (Chapter 10, page 105).

In the Walla Walla basin we have a unique opportunity to make these linkages through a collaborative research effort between the Walla Walla Basin Watershed Council, Oregon State Universities Department of Biological and Ecological Engineering and the United States Fish and Wildlife Service, Portland. Through the use of 5 kilometers of temperature sensing fiber optic cable (OSU), snorkel surveys along the study reaches (USFWS) and the collection of hydrologic and geomorphologic data (WWBWC) we will be able to better quantify the critical connections between groundwater, hyporheic exchanges and fisheries rearing and passage. The project is scheduled to be done over a 3 year period, with field data collected in 2008, 2009 and final reports being generated in 2010.

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4 http://www.tu.org/site/c.kkLRJ7MSKtH/b.3338279/
5 http://www.fws.gov/midwest/alpena/rpt-costr98.html

Research Objectives:

1. Determine groundwater and hyporheic interactions as they occur through spatial locations and as they vary in time: diurnally and seasonally.
2. Quantify groundwater and hyporheic interactions volumetrically and relative to channel morphology including; relative to pool, rifle, glide, gradient, irrigation diversion withdraws/inputs, shade and basic water chemistry.
3. Quantify groundwater and hyporheic interactions as they relate to aquifer pumping during irrigation season (i.e. do they significantly decrease as well pumping increases) and how this relates to fish use of these groundwater microhabitats.
4. Quantify and correlate groundwater data and fisheries survey information including species diversity, spatial distribution (seasonally), and native vs. nonnative. In the last final survey of the irrigation season, when bull trout begin to return to this section of river assess groundwater inputs with microhabitat (i.e. at a fish location), mesohabitat (i.e. within a stream reach) and macrohabitat (i.e. within a basin) scales.
5. Utilize groundwater, surface flow and temperature data to recalibrate *Walla Walla River Heat Source* model (OSU using Mathlab).

Bull Trout Management Questions:

What are water temperatures in the Walla Walla Basin throughout the year? What are water temperatures when bull trout are and are not in areas of groundwater and hyporheic exchange? What water temperatures will bull trout tolerate? Would groundwater flow increase (e.g. aquifer recharge) help create more tolerable micro and mesohabitat for bull trout?

Methods:

This project will utilize approximately 5 kilometers of fiber-optic temperature sensing cable coupled with snorkeling surveys and a survey-grade GPS channel survey to link physical habitat, fisheries information, with groundwater and hyporheic exchanges in two sections of the Walla Walla River. The first designated section is on the Oregon portion of the basin between Tumalum Bridge (RM 43.7) and Birch Creek Confluence (RM[6] 41.5) at the WA/OR Stateline. Fiber optic equipment will be deployed the week of July 14th, 2008. This equipment will stay in the Oregon section of the river through the remaining part of the summer and be removed in fall 2008 (likely November, 2008). At least one snorkel survey for species, location and time of day will be conducted. Ideally this survey will be done at a time of year when Bull Trout having moved down into this section of the river for rearing (October/November). A survey grade GPS will also be used to survey the cable (following installation) to determine spatial location and gradient for this reach. Temperature loggers and flow data will also be collected through the installation period to be used in the analysis phase of the project.

In 2009, the second study section of the Walla Walla River will be on the Washington section of the river from approximately the Yellowhawk Creek Confluence (RM 39.4) to the GFID #13 diversion (near Beet Road, RM 37.6). This second year of data collection will utilize the off-season analysis of the 2008 field season to fine tune the habitat and fisheries survey methods. Fiber optic cable will be deployed as early in the irrigation season as is safe (limited by high flows of spring freshet) and run until the late irrigation season, or fall 2009.

[6] Actual River Mile determined from Walla Walla TMDL temperature modeling and river digitizing project.

The technology that makes these groundwater measurements possible has become feasible only in the last year; know as Fiber Optic Distributed Temperature Sensing (DTS)[7]. The technology allows for measurement of temperature to 0.01 deg C every meter along standard communication fibers up to 30,000 meters in length. By putting rugged fibers in streams it is possible to continuously monitor stream temperature for indefinite periods of time even under aggressive impact conditions (e.g., cow hooves and rolling boulders). Data can be obtained as often as every 30 seconds along the entire cable, with the instrument capable of immediate wireless communication of these data via cell or satellite connections.

Temperature recorders, flow measurements, water quality measurements and habitat information will be collected at least once every 250 meters of fiber optic cable.

Data management/Analysis:
All data will be recorded in the field and entered into Excel database. Fiber optic temperature data will be analyzed utilizing methods as described in Selker, 2006. Temperature loggers will go through pre/post deployment calibration process per the WWBWC water quality management plan. Flow measurements and other water quality measurements and instruments will follow standard USGS and ODEQ (EPA) protocols and procedures. General physical data, fiber optic information and fisheries information will be compared to examine general patterns and values of association. More in-depth statistical analysis will be conducted following the 2009 field season based on continued discussions between USFWS, OSU and WWBWC and the interim results.

Anticipated Results:
High resolution groundwater data will be correlated with fisheries information to explore the research objectives outlined above. Data will be shared and tabulated, and shared graphically and in GIS map forms. Results are likely to provide enough information for a publication submittal by OSU, USFWS and WWBWC. Continued development of the fiber optic equipment for even more advanced habitat assessments is likely for numerous ESA and salmon species in the Pacific Northwest.

Fiber Optic Method and Analysis References:

- *Selker, J.S., L. Thévenaz, H. Huwald, A. Mallet, W. Luxemburg, N. van de Giesen, M. Stejskal, J. Zeman, and M. Westhoff, and M.B. Parlange. Distributed Fiber Optic Temperature Sensing for Hydrologic Systems. Water Resource. Res. DOI:10.1029/2006WR005326. 2006*
- *Selker, J.S., N. van de Giesen, M. Westhoff, W. Luxemburg, and M. Parlange.Fiber Optics Opens Window on Stream Dynamics. Geophys. Res. Let. DOI:10.1029/2006GL027979. 2006.*

Project Team:
Oregon State University:
- ❑ Dr. John Selker, Biological & Ecological Engineering
- ❑ Dr. Richard Cuenca, Biological & Ecological Engineering
- ❑ OSU Graduate Student(s) Engineering/Fisheries Science (potential)

WWBWC
- ❑ Bob Bower, Hydrologist
- ❑ WWBWC Hydro Technicians

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[7] http://www.sensornet.co.uk/products-&-systems/sentinel-dts-product-range.cfm
http://cp.literature.agilent.com/litweb/pdf/5989-4500EN.pdf

USFWS

- Darren Gallion, Lead Fisheries Biologist
- Don Anglin, Walla Walla Basin Fisheries Research Program Manager,
- USFWS Field Technicians

WDFW (potential):

- Glen Mendel, Lead Fisheries Biologist (Walla Walla basin)
- WDFW Field Technicians

Project Deliverables and Reporting:
The project team will generate stand-alone report outlining the project objectives, methods, results and conclusions which will be provided to the project collaborators and funding agencies.[8] Copies of any laboratory and/or field data along with the final report will be provide in paper form (when appropriate) and electronically on completion of the project. All electronic information will use the following labeling format for incorporation into the WMI monitoring database and electronic archives:

Key dates for deliverables are as follows:

- **July 1st 2008.** Draft outline of fiber optic study plan.
- **July 14th 2008** Deployment of fiber optic cable, temperature loggers, and collect first set of basic flow and temperature data. WWBWC/OSU staff collects data and checks cables every 10-14 days during operations.
- **July 16th, 2008 through September 16th, 2008.** USFWS conducts 1-day snorkel survey.
- **September 16th 2008 through December 1st, 2008** (depending on bull trout moving down into this section of river). USFWS conducts 1-day snorkel survey.
- **December, 2008.** Remove field equipment from Walla Walla River.
- **March, 2009.** Draft results from 2008 season presented to project collaborators. Results help determine data collection and analysis for 2009 field season.
- **2009 Field season: To be determined for Washington Study area.**
- **May 15th, 2010.** Final report, presentations and data sharing to project collaborators and regional fisheries and salmon recovery conferences.

[8] A thesis or dissertation can suffice for model's final reports, as long as it provides the deliverables outlined in this plan.

The Fiber Optics Groundwater and Fisheries Study

2008 USFWS Fish Sampling Study Plan

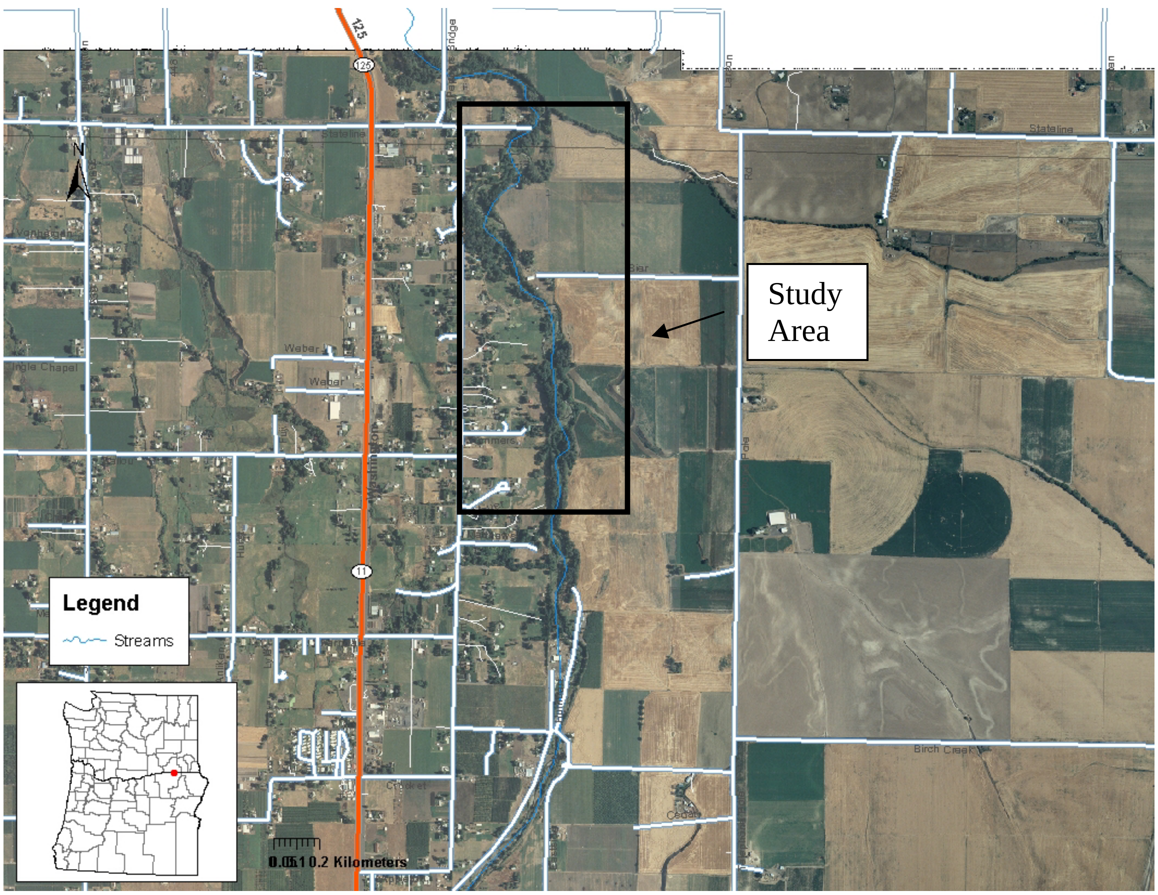
Darren Gallion, Lead Fish Biologist

Background

The WWBWC, OSU and the USFWS are cooperating on a study to measure ground water influence in the WW River using water temperature as the primary metric to indicate the presence of groundwater seepage into the stream channel. The plan is to use fiber optic cable for a spatially explicit (every 0.5 m) record of water temperature on various temporal scales (e.g. hourly). The FWS role in this work to provide the salmonid distribution information that will be compared to water temperature distribution data.

Study Area

2.4 km of the WW River in Oregon between Mauer Lane and Bud Bier's property near the OR/WA state line.



Question
Is there a correlation between the distribution (spatial presence/absence) of groundwater seepage (cool water temperatures) into the WW River channel and the distribution of salmonids?

Objectives
1) Deploy the fiber optic cable and other equipment to examine the quality, quantity and distribution of the resulting temperature information, and

2) Determine if there is a correlation between cold-water fish species (e.g. salmonids) and the spatial distribution of water temperature.

Task 1) Collect fish distribution information

Task 2) Collect mesohabitat characteristics

Methods and Data Analysis
Water Temperature Methods:
WWBWC and OSU are deploying a fiber optic cable along 2.4 km of the WW River in Oregon from July through November to record water temperatures every 6 minutes and every 0.5 meters.

Water Temperature Data:
OSU will summarize water temperature data and provide information to the USFWS for comparisons to fish distribution data.

Proposed Fish Sampling and Habitat Sampling Unit:
There are approximately 25 pools in the study area which will be sampled once during the week of August 25-29 and once during the week of September 8-12.

Proposed Fish Sampling and Habitat Sampling Methods:
Conduct snorkel surveys to count salmonids by species – Chinook, *O. mykiss*, whitefish and bull trout and collect mesohabitat characteristics. See Protocols – SOP 506.0

Proposed Fish Data and Habitat Data Analysis:
Use regression analysis to compare either numbers or presence/absence of Chinook, *O. mykiss*, whitefish and bull trout with the mesohabitat variables and water temperature data to determine if there is a correlation.

Anticipated Results
We anticipate there will be a positive correlation between the numbers of salmonids and areas with cooler water temperatures (e.g. influenced by ground water/hyporheic water).

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