PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Yakima River Basin Water Temperature Monitoring And Modeling Project

BPA project number: 20132
Contract renewal date (mm/yyyy): ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
Yakima Basin Joint Board

Business acronym (if appropriate) YBJB

Proposal contact person or principal investigator:

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NPPC Program Measure Number(s) which this project addresses
unknown

FWS/NMFS Biological Opinion Number(s) which this project addresses
unknown

Other planning document references
Wy Kan Ush Me Wa Kush Wit, Volume 2, p. 58

Short description
Implement a water temperature monitoring program in the Yakima River Basin that will provide data for the SNTEMP water temperature model. Model water temp as a function of other environmental variables, including land and water management activities.

Target species
Salmon, steelhead, resident fish, benthic macroinvertebrates

Section 2. Sorting and evaluation

Subbasin
Lower Mid-Columbia/Yakima

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more	If your project fits either of these	Mark one or more categories

caucus	processes, mark one or both	
☒ Anadromous fish ☒ Resident fish ☐ Wildlife	☐ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☒ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
20510	Yakima/Klickitat Fisheries Project	

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Monitor and evaluate Yakima River temperature regime for salmonid habitat.	a	Convene inter-agency advisory group.
		b	Place monitoring devices, download data at regular intervals.
2	Evaluate alternative water and land management scenarios with calibrated water temperature model.	a	Upgrade existing SNTEMP software to modern computing standards.
		b	Obtain additiona model parameter data.
		c	Calibrate water temperature model.
		d	Develop and evaluate alternative water/land

			management scenarios.

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	3/1999	3/2001	Evaluate Yakima River temperature regime for salmonid habitat.		31.90%
2	10/1999	12/2001			68.10%
				Total	100.00%

Schedule constraints

Completion date
12/2001

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	Principal associate, computer programmer, field technicians	%88	74,700
Fringe benefits			
Supplies, materials, non-expendable property		%2	2,000
Operations & maintenance			
Capital acquisitions or improvements (e.g. land, buildings, major equip.)	Computer for programmer, technicians.	%5	5,000
NEPA costs			
Construction-related support			
PIT tags	# of tags:		
Travel			
Indirect costs		%3	3,000
Subcontractor	Thomas R. Payne & Associates will be subcontracted to upgrade existing software.		
Other			
		TOTAL BPA FY2000 BUDGET REQUEST	$84,700

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
Yakima Basin Joint Board	Equipement and Labor	%20	22,000
		Total project cost (including BPA portion)	$106,700

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$60,000	$60,000		

Section 6. References

Watershed?	Reference
☐	Bartholow, J.M, 1989. Stream temperature investigations: field and analytic techniques. Instream Flow Information Paper No. 13. U.S. Fish Wildl. Serv. Biol. Rep. 89(17). 139 pp.
☐	Bartholow, J.M, 1996. Sensitivity of a salmon population model to alternative formulations and initial conditions. Ecological Modeling 88(215-226).
☐	Chapman, D., C. Peven, T. Hillman, A. Giorgi,, and F. Utter. 1994. Status of summer steelhead in the Mid-Columbia River. Don Chapman Consultants, Biose, Idaho 83705.
☐	Healey, M.C. 1991. Life history of chinook salmon (Oncorhynchus tshawytscha), in C. Groot and L. Margolis (eds.): Pacific salmon life histories. University of British Columbia Press, Vancouver, B.C. 564 pp.
☐	Rinella, J.F., S.W. McKenzie, and G.J. Fuhrer, 1992. Surface water quality assessment of the Yakima River Basin, Washington: analysis of available water quality data through 1985 water year. U.S.G.S. Open File Report 91-453. Portland, OR.
☐	Vaccaro, J.J., 1986. Simulation of streamflow temperatures in the Yakima River Basin, Washington, April-Octobler 1981. Water Resources Investigations Report 85-4232. U.S. Dept. of Interior Geological Survey, Tacoma, WA. 91 pp.
☐	WDOE, 1998. A total maximum daily load evaluation report for suspended sediment and DDT in the lower Yakima River Basin, Washington. Washington Dept. of Ecology, Olympia, WA. 126 pp.

PART II - NARRATIVE

Section 7. Abstract

Water temperature strongly influences invertebrate and fish community structure, growth rates, and life history characteristics. The land and water resources of the Yakima River Basin have been developed extensively by the U.S. Bureau of Reclamation's Yakima Project, primarily for irrigated agriculture and hydroelectric power generation. Water temperature as a fish habitat parameter has not been monitored in a comprehensive program throughout the Yakima Basin, nor has a model been developed to evaluate alternative management scenarios. The long term objectives of this proposal are to develop a program to (1) monitor water temperatures, (2) upgrade existing SNTEMP software to modern standards, (3) obtain additional data to calibrate an SNTEMP model for the Yakima Basin, and (4) evaluate alternative management scenarios. User-friendly computer software for temperature modeling would benefit fish

restoration efforts in the entire region. An incremental water temperature model for the Yakima Basin will benefit fisheries, water, and land management in the Basin by providing a scientific means of evaluation.

Section 8. Project description

a. Technical and/or scientific background

Water temperature strongly influences invertebrate and fish community structure, growth rates, and life history characteristics. Salmon, for example, are profoundly influenced by water temperatures. A 2-degree centigrade decrease in average water temperatures during egg incubation can delay hatching by two months (Healey 1991), which in turn may affect fry survival. Water temperature may be an important environmental factor determining whether the resident or the anadromous form (steelhead) of rainbow trout (*Oncorhynchus mykiss*) will dominate a particular stream (Chapman et al. 1994). A clear understanding of the relationship between water temperature and environmental variables is critical to interpreting biological processes and evaluating biological responses to land and water management actions.

The land and water resources of the Yakima River Basin have been developed extensively by the U.S. Bureau of Reclamation's Yakima Project, primarily for irrigated agriculture. Hydroelectric power generation is also an important component of the Project. Within the Yakima Basin are five major storage reservoirs, 14 major diversions on the mainstem, three hydroelectric plants, and six major irrigation projects (Rinella *et al.* 1992). Nearly 500,000 acres of agricultural lands in the basin are irrigated from the Yakima River and tributaries.

The Yakima River Basin Water Enhancement Project (YRBWEP) was enacted by Congress to enhance and recover anadromous fisheries in the Basin and to provide a more secure water supply for irrigation. Implementation of YRBWEP is expected to influence aspects of water management and river regulation in the Yakima Basin. Predicting, monitoring, and evaluating the effects of potential change on water temperatures will be critical to understanding impacts on aquatic habitats, anadromous fishes, and water resources.

Water temperature has been previously identified as a water quality parameter of concern in the Yakima Basin (WDOE 1998). At times, water temperatures in the lower river may exceed levels suitable for salmon (Vacarro 1986). Management of Yakima Project facilities and other aspects of development in the Basin has undoubtedly altered water temperatures in portions of the Yakima River through winter storage and summer release. The influence of reservoir storage has been found to diminish as the distance downstream increased during summer, until air temperature becomes the primarily influence on water temperature (Vacarro 1986).

The development of a complete, incremental water temperature model for the Yakima Basin would provide a means of examining the effects of flow management alternatives on temperature in various reaches of the river under YRBWEP. Data on water temperature is needed for predation monitoring related to the Yakima Fisheries Project (a hatchery supplementation program), because temperature influences feeding rates in fish that eat young salmon, such as smallmouth bass and northern squawfish (K. Ham, WDFW, pers. comm.). Numerous ongoing activities could use a basin-wide, year-round temperature model, linked to the operations of the Yakima Project, for monitoring and predicting the success of fishery and water management actions.

b. Rationale and significance to Regional Programs

The importance of water temperature as a fish habitat parameter cannot be over stated. An evaluation and understanding of water temperature is fundamentally related to all efforts underway in the region to improve salmon habitat and populations.

c. Relationships to other projects

Water temperature as a fish habitat parameter has not been monitored in a comprehensive program throughout the Yakima Basin, nor has a model been developed to evaluate alternative management scenarios. The Region has made a substantial commitment to Yakima Basin through the construction of Phase I-II Fish Passage and Protective Facilities, the Yakima Fisheries Project, the Yakima Species Interaction Study, and numerous other projects. The water temperature monitoring and modeling project will contribute significantly to our understanding of fish habitat.

d. Project history (for ongoing projects)

e. Proposal objectives

The long term objectives of this proposal are to develop a program to (1) monitor water temperatures, (2) upgrade existing SNTEMP software to modern standards, (3) obtain additional data to calibrate an SNTEMP model for the Yakima Basin, and (4) evaluate alternative management scenarios.

For fiscal year 2000, the first objective is to monitor water temperatures throughout the Yakima Basin. The product will be an annual report relating the observed water temperature trends in the basin to salmonid habitat.

The second objective is to upgrade the existing water temperature modeling software to modern computer standards. The product will be a software based tool that will be capable of evaluating daily mean, maximum, and minimum stream temperatures as a function of numerous environmental variables. The software will be applicable to any size river basin and will be reside in the public domain. This will allow the technology, once developed for the Yakima River, to be transferred to any river basin in the Pacific Northwest and beyond.

Additional objectives will be addressed as the project proceeds.

f. Methods

This study plan describes the goal of developing a water temperature model for the Yakima River Basin, states tasks necessary to achieve the goal, and estimates the amount of time and funding required. The development of the modeling program is in three phases: (1) formation of a technical advisory group to provide peer review and guidance for the project, (2) comprehensive data collection and model calibration, and (3) computer software upgrade, integration, and distribution among cooperators. The end product would be a computer-based model capable of predicting and evaluating the incremental effects of river regulation and water management actions on the water temperature regime of the Yakima River.

Study Area. The study area is the Yakima River Basin, Washington, which has a drainage area of about 6,000 square miles. The watershed begins on the crest of the Cascade Mountains, and the Yakima River flows southeastward for about 200 miles until it's confluence with the Columbia River near Richland, Washington. Water storage reservoirs are near the headwaters of the Yakima, Tieton, Bumping, Kachess, and Cle Elum rivers. The basin also includes major unregulated tributaries such as Satus, Toppenish, Ahtanum, Rattlesnake, Wilson, Menastash, and Taneum creeks, as well as the Little Naches, American, and Teanaway rivers. Major irrigation return flows which enter the river from Sulphur Creek and drains such as Granger, Marion, and Moxee can comprise nearly 80% of the flow in the lower Yakima River during the height of the irrigation season (Rinella *et al.* 1992).

Study Phase 1: Study Management

Study Management. One of the primary goals of this project is to develop a cooperative program to evaluate water temperatures in the Yakima Basin by sharing data among state, tribal, and federal agencies. Existing efforts and facilities will be used to the greatest extent possible. The Yakima Basin Joint Board (YBJB) and the US Fish & Wildlife Service (USFWS) will cooperate to conduct the majority of the field

work, data management, and model calibration. The computer software upgrade will be subcontracted with Thomas R. Payne & Associates. In order to meet the interests of the various interests in the Yakima Basin and to insure treaty rights and trust assets are fully considered, the following Technical Advisory Group (TAG) will review and help guide the project. These individuals have already been contacted and committed verbally to serving as advisors:

Individual	Representing	Role
Patrick Monk	Yakima Basin Joint Board	Investigator
Jeff Thomas	US Fish & Wildlife Service	Investigator
Thomas R. Payne	Thomas R. Payne & Assoc.	Investigator
John Bartholow	US Geological Survey	Reviewer
Kale Gullet	Yakama Indian Nation	Reviewer
Stuart McKenzie	Yakima Basin Irrigation Districts	Reviewer
Chris Lynch	US Bureau of Reclamation	Reviewer
Todd Pearsons	Washington Dept. Fish & Wildlife	Reviewer
John Vaccaro	US Geological Survey	Reviewer

The TAG will help determine the extent of the data collection program, review and approve the study plan, identify data sources for the model, and provide input for and evaluate all work products. TAG meetings will occur at least semi-annually for an update and review session.

Study Phase II: Data Collection and Model Calibration

Model Development. The Stream Network Temperature Model (SNTEMP), developed by the U.S. Fish and Wildlife Service (Bartholow 1989), is applicable to any size of river basin and is capable of predicting the average daily temperature and diurnal temperature fluctuations of river systems. SNTEMP's predictive capability depends, however, on a record of empirical data which is used to calibrate the model. The calibrated model enables temperature predictions under multiple meteorological scenarios (average year, hot year, etc.) with varying flow conditions for a broad range of locations in the stream network system. SNTEMP is highly complex because it evaluates stream temperature as a function of many interactive variables. The model requires calibration data for the following:

1. meteorology, including mean daily air temperature, mean daily relative humidity, mean daily wind speed, and solar radiation during daylight hours;

2. hydrology, including discharge of the mainstem and significant tributaries and diversions, and river water temperature data from numerous points in the watershed including tributaries; and

3. stream geometry, including average stream width, shading, latitude, azimuth, elevation, distances, and topographic shading.

Scope. The mainstem Yakima River and the major, regulated tributaries will be the focus of the effort. It will be necessary to develop separate models for each "reach" of the river to calibrate SNTEMP with a high degree of accuracy. Reach boundaries will be developed based upon consistent geomorphic and hydrologic features as well as Yakima Project facilities and operations. Each reach model will become a puzzle piece which, when linked with all the other pieces, will provide an "image" of the entire basin. This approach provides the maximum amount of flexibility to explore management issues, because portions of the basin can be isolated to examine specific issues, and the examination of these issues can then be related to the entire basin.

Data Collection. The objective of data collection is to provide the necessary information to develop and calibrate the SNTEMP model. Some of the required data is now being collected and is readily available. Additional data collection will need to be developed, and all of the data will need to be synthesized.

Hydrology data will be obtained from three sources: Reclamation, USGS, and other agencies. Both Reclamation and USGS maintain a network of stream gages in the Yakima Basin which already collect hydrology data, but a number of major tributaries are not gaged or measurements are taken by other agencies. The Yakama Indian Nation and the Bureau of Indian Affairs collect temperature and stream flow data on Reservation tributaries. Additionally, conservation and irrigation districts monitor water quality and flow on certain tributaries. A USGS hydrology model being developed with Reclamation as part of the Watershed and Reservoir Systems Management Program may be useful to provide flow data on ungaged tributaries. An initial role of the Technical Advisory Group will be to determine the need for additional streamflow data collection efforts.

Water temperature data will be collected with electronic, programmable thermographs (Optic Stowaway) manufactured by Onset Corporation, Pocasset, MA. For most tributaries it will be necessary to collect water temperatures in the Yakima River above and below the confluence with the tributary and in the tributary itself. Air temperature and relative humidity stations will need to be set up at intervals along the basin near the water.

Additional meteorology data is collected by Washington State University-Prosser, Reclamation, and other agencies that maintain weather stations in the Basin. Percent sunshine, wind speed, air temperature and other parameters can be obtained from these sources. Stream geometry data will be collected from USGS quad maps and geographic information system (GIS) sources, which provide information such as elevation, aspect, latitude, distance, and stream width.

Current Results. Data collection efforts were initiated by the Yakima Basin Joint Board in 1995 on the 11 mile reach of the Yakima River from Prosser Dam to just downstream of the Chandler Powerhouse, a hydroelectric power generation facility operated by Reclamation. In 1997, the data collection effort included the Chandler reach, and was expanded to include additional recording stations from Sunnyside Dam to the confluence of the Yakima and Columbia rivers. Using 1995 and 1997 hydrology, meteorology, and physical data, an SNTEMP model of the Chandler reach was developed. The model was successful in providing highly accurate predictions of water temperatures in the Yakima River just upstream of the Chandler Powerhouse. There was a strong, positive relationship between observed and predicted water temperatures ($r = 0.9918$).

Study Phase III: Computer Software Upgrade and Integration

SNTEMP was developed for mainframe computer systems in use nearly 20 years ago. Although powerful, the program now operates on a personal computer in DOS, which is cumbersome to use by today's software standards. The SNTEMP software is overdue for upgrading to work in a Microsoft Windows environment. The key is to do so while retaining the physical algorithms of the original model, which allow for very accurate predictions of water temperature. Additional features could be added to enhance the output of the program. For example, the SNTEMP user is unable to readily export the results of the model (such as predicted temperatures), to other software programs, and SNTEMP itself is incapable of graphing model output. A graph function in a new program could provide a variety of presentations, such as a plan view and/or longitudinal profile showing the temperature of the water, color coded from dark blue to red, or the water temperature at a given location in relation to parameters such as flow or air temperature.

g. Facilities and equipment

All water temperature, stream flow, and environmental data will be stored at the US Bureau of Reclamation-Upper Columbia Area Office. Electronic, programmable data loggers will be used to collect water temperature data. Vehicles, boats, motors, and office space are already available to the project participants. Meteorology and hydrology data is being collected by participating agencies.

h. Budget

A portion of the effort will be funded by the Yakima Basin Joint Board (YBJB), an association of irrigation districts. The Board will fund the purchase of data loggers and equipment to begin data collection at a cost of $12,000. The Board will also fund a portion of the labor for the duration of the project, estimated at $11,000 annually. The Board is seeking cooperative agreements with agencies or other funding sources to develop and fund the remainder of the program, and to date the USFWS has expressed an interest in providing labor for the project.

New computers are being requested for a computer programmer ($3,000) and field technician (Approximately 2 years of effort will be required to collect the necessary field data).

The majority of project costs will be salaries. A senior scientist (Thomas R. Payne) will be contracted to review the software upgrade, 56 hours at $84/hr. A computer programmer will upgrade the existing software, 1714 hours at $35/hr. Additional labor will be required to conduct the field work and manage the data, 350 hours at $30/hour. Management of the programmer is an indirect cost at 5% of the programmers wages ($3,000).

Section 9. Key personnel

Jeff Thomas
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Mr. Jeffrey Thomas has conducted instream flow studies for over a decade for the USFWS in numerous river basins in the Mid-west and West. He is trained in the use of SNTEMP and other IFIM-based software. Mr. Thomas has a Master of Science degree in Fisheries from Colorado State University and a Bachelor's degree in Agricultural Engineering from the University of Kentucky. His role will be as co-investigator, coordinating the data gathering, management, and water temperature modeling, and assuring the Federal responsibility to protect Indian Trust Assets is met. (Mr. Thomas was unavailable at the time I prepared this proposal, so I apologize for the sketchy details of this resume—P.M.)

Tom Payne
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Mr. Thomas R. Payne, Certified Fisheries Scientist, is Principal Associate of Thomas R. Payne & Associates, Fisheries Consultants, located in Arcata, California. He is a specialist in the application of the Instream Flow Incremental Methodology (IFIM) to determine the impacts of flow alteration on aquatic ecosystems. In the past fifteen years, he has conducted or reviewed over two hundred instream flow studies on proposed and existing hydroelectric and irrigation projects. Projects have been located in areas ranging from mountain streams in Hawaii to major rivers on the East Coast, with an emphasis on high gradient streams in the Pacific Northwest. Work associated with IFIM and directed by Mr. Payne includes fish population sampling, habitat mapping and typing, hydraulic measurements, habitat use determinations, computer simulations, license application

preparation, agency negotiations, post-project analysis, and expert witness testimony. He is also responsible for all business functions of TRPA, such as personnel management, project management, proposal preparation, accounting, and quality control.

After taking the complete training sequence in the IFIM offered by the U.S. Fish & Wildlife Service, Mr. Payne and TRPA translated the IFIM computer programs from mainframe versions to run on micro-computers. These translated versions are now in use by public and private resource agencies throughout the U.S. and several foreign countries. Mr. Payne has presented numerous workshops in the use of IFIM to state and federal agencies and taught graduate-level courses as an Associate Professor of Fisheries at Humboldt State University. A recent update of the software to Windows-based computers has been completed and distributed, along with an expanded version of a water temperature computer model for use in temperature simulations of stream segments.

As an environmental biologist for the U.S. Fish & Wildlife prior to forming TRPA in 1982, Mr. Payne reviewed proposed hydroelectric projects and coordinated inter-agency participation in setting license terms and provisions for the protection of fishery resources in Washington State. He is experienced in monitoring and management of sport, commercial, and Indian salmon inland and troll fisheries, recovering coded-wire tags and harvest information from Indian gillnet fisheries, performing salmon population-estimate studies, sampling tributary streams for aquatic habitat quality, salmonid utilization, and accessibility, directing stream clearance operations for log-jam removal and fish habitat improvement, and building and operating a fish weir and small hatchery.

For private industry he has performed chronic and acute toxicity tests on several fish species with various pesticides and chemicals, helped design and construct toxicant delivery apparatus and environmental control systems, and acquired and maintained fish stocks for laboratory testing. Mr. Payne has B.S. and M.S. degrees in Fisheries Biology from Humboldt State University, where he also teaches graduate level fisheries courses, and is certified as a fisheries scientist by the American Fisheries Society.

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Patrick A. Monk currently works as an independent consulting fish biologist. Recent clients include Yakima Basin Joint Board, Kittitas Reclamation District, AgriNorthwest, Inc., Okanogan Irrigation District. Mr. Monk has effectively represented agricultural entities in a variety of forums ranging from litigation to technical work groups aimed at enhancing salmonid resources. Activities include analysis and dissemination of fisheries information, Endangered Species Act evaluations, designing and conducting field studies of fish and their habitats, preparing proposals and budget statements. Currently Mr. Monk is co-authoring a report on biologically-based flows for the Yakima River Basin in cooperation with private, state, federal, and Tribal biologists as part of a Congressional mandate to improve fish runs and the water supply for irrigation. Education: Mr. Monk is currently completing requirements for a Master of Science degree in Fishery Resources, University of Idaho (Thesis currently under review). Mr. Monk was awarded a Bachelor of Science in Zoology, University of Wisconsin-Madison, May 1989. His principal role in this project will be a co-investigator, gathering and synthesizing field data, developing the water temperature model, and writing reports.

Section 10. Information/technology transfer

Developing Windows-compatible water temperature modeling software will be a significant improvement in the Region's ability to assess fish habitat and evaluate alternatives. This software will be in the public domain and we envision it becoming available to anyone by allowing access to it on the Internet.

The results of monitoring and modeling activities will be made available to the public by a series of reports. Additionally, water temperature data will be provided to Reclamation and posted on their HYDROMET computer system.

Congratulations!