Grant County
PUBLIC UTILITY DISTRICT
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June 23, 2008

Washington Department of Ecology
Water Quality Program
James Bellatty
4601 N. Monroe St
Spokane, WA 99205

RE: Request for Comment - Priest Rapids Hydroelectric Project No. 2114
License Compliance Filing – White Sturgeon Management Plan

Dear Jim,

The enclosed Draft White Sturgeon Management Plan is provided to you for comment, consistent with the requirements of the Priest Rapids Hydroelectric Project License and associated obligations and mandates, including the February 2008 Biological Opinion, February 2007 Biological Opinion, 401 Water Quality Certification and the Priest Rapids Project Salmon and Steelhead Settlement Agreement.

Public Utility District No. 2 of Grant County would appreciate receiving your comments on or before July 25, 2008, so that we may respond to them by incorporating appropriate revisions to the Plan, and by including them, with our specific responses, in the Final Plan submittal to be filed with the Federal Energy Regulatory Commission for approval.

Please direct comments to me, Tom Dresser, at the address below, or email comments to tdresse@gcpud.org. Thank you in advance for your cooperation in reviewing the plan and responding with timely comments.

Respectfully,

Tom Dresser
Manager, Fish, Wildlife, and Water Quality

Enclosures: Draft White Sturgeon Management Plan
Mailing List

cc: Priest Rapids Fish Forum

Mailing List

Washington Department of Ecology
Marcie Mangold
4601 N. Monroe St
Spokane, WA 99205

Washington Department of Ecology
Water Quality Program
James Bellatty
4601 N. Monroe St
Spokane, WA 99205

Bruce Suzumoto
Assistant Regional Administrator
National Marine Fisheries Service
1201 NE Lloyd Blvd. Suite 1100
Portland, OR 97232

National Marine Fisheries Service
Scott Carlon
1201 NE Lloyd Blvd. Suite 1100
Portland, OR 97232

Bryan Nordlund
National Marine Fisheries Service
510 Desmond Drive SE Suite 103
Lacey, WA 98503

Ren Lohoefener
Regional Director
US Fish and Wildlife Service
911 NE 11th Ave
Portland , OR 97232-4128

US Fish and Wildlife Service
Jessica Gonzales
US Fish and Wildlife Service
215 Melody Lane
Wenatchee, WA 98801

Stephen Lewis
US Fish and Wildlife Service
215 Melody Lane Ste 119
Wenatchee, WA 98801-5933

Jeffrey Koenings PhD
Washington Dept of Fish and Wildlife
600 Capitol Way North
Olympia, WA 98504-0001

Washington Dept. of Fish and Wildlife
Bill Tweit
1550 Alder St NW
Ephrata, WA 98823

Rex Buck, Jr.
Wanapum Indians
P.O. Box 164
Beverly, WA 99321

Lela Buck
Wanapum Indians
P.O. Box 164
Beverly, WA 99321

Jerry Marco
Colville Fish & Wildlife Department
PO Box 150
Nespelem, WA 99155-0150

Joe Peone
Colville Fish & Wildlife Department
PO Box 150
Nespelem, WA 99155-0150

Carl Merkle
Confederated Tribes of the Umatilla
PO Box 638
Pendleton, OR 97801-0638

Phillip Rigdon
Confederated Tribes and Bands of the
Yakama Nation
PO Box 151
Toppenish, WA 98948

Paul Ward
Confederated Tribes and Bands of the
Yakama Nation
PO Box 151
Toppenish, WA 98948

Steve Parker
Confederated Tribes and Bands of the
Yakama Nation
PO Box 151
Toppenish, WA 98948

Bob Rose
Yakama Nation Fisheries
P.O. Box 151
Toppenish, WA 98948

DRAFT
06/12/2008

White Sturgeon Management Plan
for the Priest Rapids Project

Priest Rapids Hydroelectric Project (FERC No. 2114)
Public Utility District No.2 of Grant County
P.O. Box 878
Ephrata, WA 98823

June 2008

Executive Summary

The development of hydroelectric power generation facilities within the Columbia River Basin has had negative impacts on white sturgeon (*Acipenser transmontanus*). White sturgeon populations in the middle and upper Columbia River now reside in regulated and impounded reservoirs between dams. All of these populations experience complete or frequent recruitment failures that are likely related to river regulation, flooding of historical critical spawning and rearing habitats, increases in predators due to habitat alteration, introduction of exotic species, and pollution. At present, what limited natural recruitment does occur is likely insufficient to maintain existing population levels.

The Public Utility District No. 2 of Grant County (Grant PUD) owns and operates two hydroelectric dams on the Columbia River; Wanapum and Priest Rapids, known collectively as the Priest Rapids Project, and operated under the terms and conditions of Federal Energy Regulatory Commission (FERC) Hydroelectric Project License No. P-2114. Grant PUD currently operates the Priest Rapids Project through the coordinated operation of the seven-dam system and other Columbia Basin entities with current operational agreements with the fishery agencies and other operators to provide protection and enhancement for a range of fisheries within, and downstream of the project. These agreements include the Hanford Reach Fall Chinook Protection Plan, the Hourly Coordination Agreement, and the Priest Rapids Project Salmon and Steelhead Agreement. The Project is also subject to the provisions of the FERC license and related laws and regulations, as well as to the requirements (incorporated by reference in the license) of the Biological Opinion for the Priest Rapids Project issued by National Oceanic and Atmospheric Administration (NOAA) for its effects on anadromous salmon, the Clean Water Act Section 401 Water Quality Certification issued by the Washington Department of Ecology, and the Biological Opinion for the Priest Rapids Project issued by the United States Fish and Wildlife Service regarding the effects of the Project on bull trout.

White sturgeon populations in Priest Rapids and Wanapum reservoirs, on the middle Columbia River, were investigated from 1999 to 2002 as part of Grant PUD's hydroelectric project relicensing evaluations. This investigation was the first comprehensive study conducted on white sturgeon in the Project area. Results of this study indicated that resident white sturgeon populations exist in both reservoirs. White sturgeon spawning was documented in the tailrace areas of Wanapum Dam (upper boundary of the Priest Rapids reservoir) and Rock Island Dam (upper boundary of Wanapum reservoir) in June and/or July of 2000, 2001, and 2002. Information also indicates that white sturgeon do spawn within the project area and that natural reproduction has occurred. For example, approximately 22% of the sturgeon sampled in the Wanapum Reservoir were juvenile fish.

The Washington Department of Ecology (Ecology) issued a Final Water Quality Certification on April 3, 2007, with modifications filed on March 17, 2008, for the operation of the Priest Rapids Hydroelectric Project. Under the 401 Certification (6.2 (5)(b)), Grant PUD is required, in consultation with the PRFF, to develop and implement a White Sturgeon Management Plan within one year of issuance of the New License.

The Federal Energy Regulatory Commission (FERC) issued a license for the Project on April 17, 2008 (FERC 2008). Article 401 of license order requires that Grant PUD a file a White Sturgeon

Management Plan (WSMP) within 1 year of license issuance. In addition, article 401 requires the WSMP be submitted to the Commission for approval prior to implementation.

Specific Biological Objectives included in the WSMP include the following;

1) Spawning and rearing in Project area': Natural reproduction potential reached via natural recruitment.
2) Spawning, rearing, and harvest in Project reservoirs: Increase the white sturgeon population in Project reservoirs to a level commensurate with available habitat.
3) Adult and juvenile upstream and downstream migration: Provide safe, effective, and timely volitional passage, if reasonable and feasible passage means are developed.
4) Until reasonable and feasible means for reestablishing natural production and providing support for Migration are available, and recognizing that those means appear unlikely in the foreseeable future, the Biological Objective is sustaining a population at a level commensurate with available habitat through implementation of a white sturgeon supplementation program in the Project reservoirs. The supplementation program will provide an initial foundation for the Monitoring and Evaluation Program, which is designed to a) identify existing impediments to achieving the Biological Objectives, b) sustain the populations until the existing impediments can be corrected, and c) mitigate for population losses due to Project impacts.

The goal of the WSMP is to: (1) identify and address Priest Rapids Project effects on white sturgeon and, (2) develop and implement "Implementation Measures" designed to avoid and mitigate for Project effects of white sturgeon. Adaptive Management shall be applied to resolve critical uncertainties. In additional, the following tasks in achieving the Biological Objectives and to be incorporated into the WSMP and include;

Task 1. Determine the effectiveness of the supplementation program in creating a sustainable white sturgeon population in the Project reservoirs based on natural production potential and adjust the supplementation program accordingly.

Task 2. Determine the carrying capacity of available white sturgeon habitat in each reservoir.

Task 3. Participate and cooperate in the development of any regional white sturgeon management effort initiated for the purpose of addressing flow fluctuation effects on the Hanford Reach white sturgeon population as a result of Project operations. If questions arise as to the appropriate level of participation and cooperation, Grant PUD shall request clarification from Ecology.

Task 4. Determine juvenile downstream passage survival.

By March 31 following issuance of the New License, and each year thereafter for the term of the New License, Grant PUD is required to provide an annual report summarizing activities undertaken to identify and address impacts of the Project to white sturgeon, including results of those activities. This report shall include a compilation of information on other white sturgeon supplementation programs in the Columbia River Basin in order to assess whether the supplementation program being implemented at the Priest Rapids Project is: (i) consistent with other supplementation programs in the region; (ii) cost effective to implement at the Project; and (iii) whether improvements can be made which are appropriate to implement at the Project.

The WSMP identifies the following Protection, Mitigation, and Enhancement measures (PMEs) for Grant PUD to implement and, as outlined in section 3:

1) Prepare a brood stock collection and breeding plan within year one of the effective date of the New License and, if feasible, begin brood stock collection in year two of the New License;
2) Implement a white sturgeon supplementation program by releasing up to 6,500 yearling white sturgeon into the Wanapum reservoir each year and 3,500 yearling white sturgeon into the Priest Rapids reservoir for years 3, 4, and 5 of the program, with subsequent annual release levels to be determined by the Priest Rapids Fish Forum (PRFF), based on monitoring results;
3) Continue long-term index monitoring every five years over the term of the New License to monitor age-class structure, survival rates, and growth rates; identify distribution and habitat selection of juvenile sturgeon; and direct the supplementation program strategy;
4) Conduct tracking surveys of juvenile white sturgeon released with active tags as part of the supplementation program to determine emigration rates from Priest Rapids Project;
5) Compile information on other white sturgeon supplementation programs in the region.

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1.0 Introduction

The Public Utility District No. 2 of Grant County (Grant PUD) owns and operates two hydroelectric dams on the Columbia River; Wanapum and Priest Rapids, known collectively as the Priest Rapids Project, and operated under the terms and conditions of Federal Energy Regulatory Commission (FERC) Hydroelectric Project License No. P-2114. Grant PUD currently operates the Priest Rapids Project through the coordinated operation of the seven-dam system and other Columbia Basin entities with current operational agreements with the fishery agencies and other operators to provide protection and enhancement for a range of fisheries within, and downstream of the project. These agreements include the Hanford Reach Fall Chinook Protection Plan, the Hourly Coordination Agreement, and the Priest Rapids Project Salmon and Steelhead Agreement. The Project is also subject to the provisions of the FERC license and related laws and regulations, as well as to the requirements (incorporated by reference in the license) of the Biological Opinion for the Priest Rapids Project issued by National Oceanic and Atmospheric Administration (NOAA) for its effects on anadromous salmon, the Clean Water Act Section 401 Water Quality Certification issued by the Washington Department of Ecology, and the Biological Opinion for the Priest Rapids Project issued by the United States Fish and Wildlife Service regarding the effects of the Project on bull trout.

White sturgeon are the largest freshwater fish in North America. They occur throughout the U.S. portion of the Columbia River and in many of its larger tributaries. Historically, white sturgeon moved throughout the mainstem Columbia River from the estuary to the headwaters, although passage was probably limited at times by large rapids and falls (Brannon and Setter 1992).

Dam construction has created what biologists believe to be “isolated” populations of white sturgeon. Beginning in the 1930s, with construction of Rock Island, Grand Coulee, and Bonneville dams, migration was disrupted because white sturgeon generally do not pass upstream through fishways built for salmon, although they do pass downstream through dams (Lepla et al. 2001). Current populations in the Columbia River Basin can be divided into three groups: fish below the Bonneville Dam with access to the ocean; fish isolated functionally, but not genetically, between dams; and fish in several large tributaries. However, the population dynamics and factors regulating production of white sturgeon within these isolated populations are poorly understood.

1.1 White Sturgeon Management Plans in the Columbia Basin

Management programs to protect white sturgeon in the Kootenai River and the upper Columbia River are on-going and provide a relevant framework for white sturgeon management programs in the Priest Rapids and Wanapum reservoirs. These recovery programs were initiated to protect and restore white sturgeon populations before they became extinct (i.e., Kootenai population) or were extirpated (i.e.Upper Columbia population). While detailed information about the white sturgeon population in the Project area exists, these other programs have provided important information that helped shape this WSMP. Relevant information on these programs is provided in the following sections.

1.1.1 Kootenai River White Sturgeon Recovery

Studies in the late 1970s and early 1980s confirmed that white sturgeon in the Kootenai River in Idaho (spelled Kootenay in Canada) had decreased in abundance compared to data collected in the previous two decades (Partridge 1983). Of greater concern, however, was the relative absence of younger age-classes. In the early 1980s, fisheries management staff in British Columbia began documenting an apparent reduction in adult white sturgeon abundance, as well as a reduction in the numbers of young fish. A detailed monitoring program was instituted in the early 1990s by Idaho Department of Fish and Game (IDFG) to provide further empirical information about the status of this species (Apperson and Anders 1991). With funding from IDFG, the BC Ministry of Environment also started a comparable monitoring program in 1989 in the Canadian portion of the Kootenay River, as well as in Kootenay Lake.

By the mid to late 1980s, it was obvious that the near total recruitment failure of what is termed the “Kootenai White Sturgeon” stock (which includes the British Columbia portion of the drainage, i.e., the lower Kootenay River above Kootenay Lake, Kootenay Lake and the Kootenay River downstream of Nelson to Bonnington Falls) required aggressive intervention to ensure this species did not disappear (USFWS 1999). A pilot hatchery was designed and constructed near Bonners Ferry, Idaho, with funding provided by the Bonneville Power Administration (BPA). This mini-hatchery was run by the Kootenai Tribe of Idaho (KTOI), with technical direction provided by the IDFG.

In 1994, the USFWS listed the Kootenai stock of white sturgeon as endangered, which introduced a higher level of management and control by various authorities in the drainage and region. A recovery team was established to provide technical direction regarding the numbers of fish produced at the hatchery, release numbers, and breeding (to address genetic introgression issues). A final “Kootenai White Sturgeon Recovery Plan,” which had undergone public and agency review in both the U.S. and Canada, was signed by the USFWS in 1999.

A major habitat restoration focus of the Kootenai White Sturgeon Recovery Plan has been to increase the extent and duration of spring freshet flows in the Kootenai River. Essentially, this is provided through releases from the U.S. Army Corps of Engineer’s Libby Dam in Montana. To date, the results of these increased flows have been inconclusive; i.e., there is as yet no indication that high flows during the spring translates into increased survival of white sturgeon eggs and/or fry (J. Hammond, pers. comm., 2003). This assessment must be tempered, however, because of the difficulties of sampling young-of-the-year (YOY) white sturgeon fry. At present, white sturgeon must be a minimum of one to two years of age before they can be captured adequately by standard sampling gear (C. Spence, pers. comm., 2002). As a consequence, it is difficult to assess the relationship between flows and recruitment.

The KTOI Hatchery (KTOIH), which experienced significant challenges during the early years of its operation, now produces high-quality juvenile white sturgeon for a directed stocking program. In addition, there is a fail-safe hatchery for Kootenai sturgeon at the Kootenay Trout Hatchery (KTH) at Wardner, B.C. Every year, half of all the fertilized eggs produced at the KTOIH are transported to the KTH in case either facility should experience a major problem with egg and/or fry survival.

One of the ongoing issues regarding the Kootenai White Sturgeon Recovery Plan is potential genetic swamping of the “wild” sturgeon by those produced and stocked from the hatchery. A breeding plan was developed in the mid-1980s that focused on determining an appropriate method of breeding fish to maximize the genetic diversity of hatchery-produced fish (Kincaid 1993). The approach was based on conservative estimates of survival, distribution, sexual maturity, and availability of breeding fish. Some of these assumptions have since been judged as either erroneous or overly conservative. As a consequence, the Kootenai White Sturgeon Recovery Plan was rewritten in order to incorporate the newest and best available data.

Another major uncertainty in the Kootenai White Sturgeon Recovery Plan implementation centers on stocking rates and fish size at release. In the absence of empirical data or, at a minimum, acceptable biostandards, these uncertainties cannot be resolved since "historical" levels of white sturgeon abundance and recruitment in the river and the lake are unknown. Changes to the Kootenai River ecosystem from regulation by Libby Dam further complicate this problem. To date, the approach has been to annually revisit the stocking number and fish size issue based on the most up-to-date information on juvenile survival and growth rates. This type of adaptive management approach also incorporates new information on natural spawning success collected during annual monitoring programs.

1.1.2 Upper Columbia River White Sturgeon Recovery

White sturgeon populations in the Canadian (upper) portion of the Columbia River between the U.S.-Canada Border and Hugh L. Keenleyside Dam were initially studied in the early 1980s. General fish inventory studies conducted in this area in the early 1990s demonstrated that the size-class distribution of white sturgeon had shifted significantly in the interim from a population dominated by younger white sturgeon (less than 1.0 m total length (TL)) in the 1980s to one dominated by adults (greater than 1.5m TL) in the 1990s (Hildebrand et al 1999). Based on this information, the white sturgeon population in the Columbia River in Canada was listed by the B.C. Conservation Data Centre as endangered in 1996, and the fishery for this species (recreational and guided) was closed. Subsequent studies of the white sturgeon population that resides in the Columbia River between Hugh L. Keenleyside Dam and Grand Coulee Dam have supported the initial assumption that recruitment to this trans-boundary population is extremely limited and the remaining population is aging and declining in abundance.

Due to conservation concerns about upper Columbia white sturgeon, and in response to the provincial listing of the upper Columbia River white sturgeon population and the new Species At Risk Act (SARA) being drafted by the Canadian federal government, a decision was made by Canadian organizations in 1996 to develop a recovery plan. The process was built upon a Canadian Columbia River white sturgeon stock stabilization report (Hildebrand and Birch 1996) that was based on the Kootenai River White Sturgeon Recovery Plan.

A common commitment to a recovery program was formalized by the Department of Fisheries and Oceans Canada, B.C. Environment, B.C. Fisheries, and BC Hydro in an August 17, 2000 Letter of Understanding. The letter outlined the approach for recovery planning and described agreements on funding for the development and delivery of a recovery strategy. The agreement also defined a process for engaging First Nations and stakeholders (interested parties) in recovery planning in order to build understanding and support for the plan and to explore possible sources of funding for full implementation of the plan. Since this trans-boundary stock was not listed (and presently remains unlisted) under the U.S. Endangered Species Act, the recovery of this population required the effective inter-jurisdictional coordination of Canadian and U.S. recovery efforts. This process led to active U.S. participation by the Spokane Tribe, Colville Confederated Tribes, USFWS, the BPA, and the State of Washington.

In 2002, a bi-national technical Recovery Team, termed the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI), finalized the Upper Columbia White Sturgeon Recovery Plan (UCWSRI 2002). This plan was a cooperative effort that involved Canadian and U.S. governmental, aboriginal, industrial, and environmental organizations, as well as individual citizens. Plan development also involved an Action Planning Group, with representation by the Province, Department of Fisheries and Oceans Canada, regional governments, First Nations, members of the public, environmental and industrial stakeholders, and U.S. regulatory and tribal agencies. A recovery team consisting of technical representatives from federal, provincial, and state resource management agencies and from Canadian and U.S. tribes directs the recovery program.

Owing to the near total recruitment failure in the last two decades, a decision was made early in the recovery planning process to move immediately to development of a hatchery program to produce juvenile sturgeon for stocking into the Columbia River downstream of the Hugh L. Keenleyside Dam. Using the Kincaid (1993) breeding plan developed for the Kootenai sturgeon program as a model, a breeding plan was developed for upper Columbia sturgeon. Originally housed at the Hill Creek Hatchery at the upper end of the upper Arrow Lakes Reservoir, the rearing of all fish now occurs at the KTH (owing to operating efficiencies, staffing, and reliability of water supply).

A monitoring program is ongoing (on both sides of the international border), and the main focus is the development of a juvenile index monitoring program to assess growth, survival, health, distribution, and relative abundance of released juveniles. The information collected by this program is essential to monitor the success of the hatchery stocking program and provide information on any natural recruitment that may occur.

1.2 Status and Information Needs for the Priest Rapids and Wanapum reservoirs

As part of the relicensing process, the Resident Fish Solution Group determined that Grant PUD should conduct intensive studies on white sturgeon populations in the two impoundments (Wanapum and Priest Rapids reservoirs) that comprise the Project.

2.0 Studies and Evaluation of Project Effects

Grant PUD contracted Golder Associates Ltd. (formerly R.L. & L. Environmental Services Ltd.) to conduct research to determine the abundance, distribution, population dynamics, biophysical attributes of preferred habitat, seasonal movement patterns, and spawning characteristics of white sturgeon. This information has been used to assess the effects of the Project on white sturgeon populations in both Priest Rapids and Wanapum reservoirs.

2.1 Relicensing Studies

White sturgeon populations in Priest Rapids and Wanapum reservoirs, on the middle Columbia River, were investigated from 2000 to 2002 as part of Grant PUD’s hydroelectric project relicencing process. This investigation was the first comprehensive study that has been conducted on white sturgeon in the Project area to date.

A relatively small population of white sturgeon (lower estimated limit of 143 individuals), made up of older adults, was present in the Priest Rapids reservoir. Based on set line capture and sonic tag movement information, white sturgeon were distributed throughout the reservoir, with concentrations near Goose Island (river mile [RM] 398), Desert Aire (RM 401), Lake Geneva (RM 404), Lower Crab Creek (RM 409), and below Wanapum Dam (RM 415). Priest Rapids reservoir contained suitable habitats for white sturgeon feeding, spawning, and rearing (Batelle, unpublished data, 2001).

During set line capture programs conducted in 2000 and 2001 in the Priest Rapids reservoir, white sturgeon ranged from 161 to 299 cm in fork length, and from 31 to 103 kg in weight. Length-frequency distributions of white sturgeon exhibited very minor differences between study years. Surgical examination of captured individuals indicate the population was dominated by females (approximately 2:1), mostly in pre- or late-vitellogenic maturation stages. Captured white sturgeon in the Priest Rapids reservoir ranged from age 16 to 42. One fish (unknown sex and maturity) was recaptured during the present study, and exhibited an increase in growth of approximately 2.5 cm per year.

In the Priest Rapids reservoir, 11 white sturgeon (one non-reproductive female, four pre-vitellogenic females, three late vitellogenic females, and three early reproductive males) were implanted with sonic transmitters during the fall of 2000 and 2001. Movement information collected by boat-based surveys and remote telemetry stations indicated that sonic-tagged white sturgeon were relatively inactive from October to early April, and usually remained in one of four overwinter areas identified during the present study. One early reproductive male was observed to move between two overwinter areas, most likely in response to changes in water temperature or food supply. Preliminary observations made on two mature females implanted with temperature and depth sensors indicate that diurnal movements may occur. However, these trends were not well developed (based on less than 10 days of information), and highly varied between fish. During the spawning period, mature white sturgeon were observed to move upstream to the tailrace of Wanapum Dam between April and June, and most likely remained until August. The exact residence time for these fish was difficult to ascertain, since tag detection was sporadic due to excessive noise produced by turbine and spill events during this period.

Spawning was detected in the Priest Rapids reservoir, below Wanapum Dam, during all three years of study. Newly spawned white sturgeon eggs were collected when water temperatures below Wanapum Dam were within suitable ranges for optimal development. Preliminary information indicated that larvae incubated *in situ* also hatched within the time required for normal embryo development. Spawning habitats below Wanapum Dam were similar to other white sturgeon habitats throughout the Columbia River. The number of spawning events and egg catch-rates was highest in 2002 (i.e., three events; 0.10 eggs/mat-day), followed by 2000 (i.e., two events; 0.05 eggs/mat-day), and 2001 (i.e., one event; 0.01 eggs/mat-day). The variability in the number of spawning events and egg catch-rates may be related to differences in discharge between years; 2001 was the second lowest discharge event recorded since the early 1960s.

The population of white sturgeon (estimated between 398 and 881 individuals) in the Wanapum reservoir contained a relatively equal distribution of young and mature individuals. Approximately 20% of the total catch was composed of juvenile fish, suggesting this population experiences natural recruitment or that the reservoir receives an influx of juveniles from upstream. Based on set-line capture and sonic-tag movement information, white sturgeon were distributed throughout the free-flowing portion of the reservoir upstream of Vantage Bridge

(RM 421) to the Rock Island Dam tailrace (RM 452). Wanapum reservoir contained areas for feeding, spawning, and rearing; these areas were similar to habitats observed in reservoirs throughout the Columbia River and on the Snake River. Spawning velocities were found to be slightly lower than those observed in the Priest Rapids reservoir below Wanapum Dam, and were within optimal spawning velocities established for white sturgeon during wet water years as calculated by a habitat model (Batelle, unpublished data, 2001).

During set-line capture programs conducted in 2000 and 2001 in the Wanapum reservoir, white sturgeon ranged from 50 to 231 cm in fork length, and 1 to 118 kg in weight. Juvenile/sub-adult fish were present in the sampled population. Length-frequency distributions of white sturgeon did not vary between study years. Surgical examination of captured individuals indicated that an equal proportion of males and females was present in Wanapum reservoir. These fish were of varying sex and maturation stages. Captured white sturgeon in Wanapum reservoir ranged from age-4 to age-37, however intermediate aged fish were not well represented in the sampled population. Six fish were recaptured during the present study, and exhibited an increase in growth of approximately 6.8 cm per year.

In the Wanapum reservoir, 31 white sturgeon (five non-reproductive females, three pre-vitellogenic females, four early vitellogenic females, six late vitellogenic females, one ripe female, three non-reproductive males, two maturing males, two early reproductive males, three late reproductive males, one juvenile/subadult, and one of unknown sex and maturation stage) were implanted with sonic transmitters during capture sessions conducted in the spring and fall of each year. Movement information collected by boat-based surveys and remote telemetry stations indicated that sonic-tagged white sturgeon were relatively inactive from September to May, and usually remained in one of four overwinter areas identified during the present study. Columbia Cliffs (RM 442) was identified as a very important overwinter area during the present study, since a large proportion of sonic-tagged fish at-large resided at this location during this period. Some fish were observed to move between overwinter areas throughout the duration of the overwinter period. In October and November, few white sturgeon were also observed to move from the main overwinter area to the feeding area located near Whiskey Dick Creek (RM 426), likely to take advantage of the fall Chinook salmon that migrate during this time. One mature female that was implanted with a temperature and depth sensor (i.e., CHAT tag), moved into both deep and shallow habitats during the overwinter period, but these movements were not diurnal in nature. During the spawning period, mature white sturgeon were observed to move upstream to the tailrace of Rock Island Dam in Wanapum reservoir in early June, and most remained until late July. Short-term observations made on white sturgeon implanted with temperature and depth sensors indicated that one mature female moved into deep and shallow areas during the spawning period. These variations in depth were diurnal in nature and were more variable during the spawning season compared to the end of the overwinter period. Observations from another mature female also indicated that this fish was located in depths that were, on average, 10 m shallower during the early spawning season compared to the overwinter period.

Spawning was detected in the Wanapum reservoir, below Rock Island Dam, during all three years of study. Newly spawned white sturgeon eggs were collected when water temperatures below Rock Island Dam were within suitable ranges for optimal development. Preliminary information indicated that larvae incubated *in situ* also hatched within the time required for normal embryo development. Spawning habitats below Rock Island Dam were similar to other white sturgeon habitats throughout the Columbia River, with the exception of slightly lower water velocity during dry and normal water years as calculated by the habitat model (Batelle, unpublished data, 2001). The number of spawning events and egg catch-rates was highest in 2002 (i.e., seven events; 1.78 eggs/mat-day), followed by 2000 (i.e., five events; 0.06 eggs/mat-day), and 2001 (i.e., one event; 0.02 eggs/mat-day). The variability in the number of spawning events and egg catch-rates may be related to differences in discharge between years; 2001 was the second lowest discharge event recorded since the early 1960's.

2.1.1 Population Characteristics

Using the Schnabel population estimation method (Krebs 1989), the white sturgeon population in the Priest Rapids reservoir was estimated at approximately 134 fish, with a 95% confidence interval of 48 to 2680 fish. The confidence in this estimate is low due to the small number of fish marked and recaptured (*n*=1) in the Priest Rapids reservoir. The number of fish recaptured in the Priest Rapids reservoir was below the minimum number required to derive a population estimate using this technique.

The BayesPop™ program and the data from were used to derive an alternate population estimate for the Priest Rapids reservoir. The lower bound was set to the number of newly marked individuals, the upper bound was set to the hypothesized maximum population (approximately 3000 for the Priest Rapids reservoir), and the number of intervals was set to 901. Using this method, the estimated population of white sturgeon in the Priest Rapids reservoir was approximately 1161, with a 95% confidence interval of 143 to 4746 fish. The use of this method enabled an adequate minimum population estimate (i.e., lower 95% confidence interval) to be determined, however the estimated mean and upper bounds of the populations was not considered dependable because of the low number of recaptured fish observed during the study.

In the Wanapum reservoir, the white sturgeon population was estimated at approximately 551 fish, with a 95% confidence interval of 314 to 1460 fish. This estimate is considered preliminary since the sample size (*n*=9) is near the minimum required to derive a population estimate using the Schnabel technique. The estimated population, using the BayesPop™ (upper bound set to 5000 fish) was approximately 817, with a 95% confidence interval of 398 to 1711 fish.

2.1.2 Sex Ratio and Reproductive Potential

Sex ratio for white sturgeon captured in the Priest Rapids reservoir was 0.5:1 (6 males : 11 females) during the combined 2000 to 2001 study. Sex and maturation was not determined in 1999.

The maturation stages of the 21 white sturgeon captured in the Priest Rapids reservoir (2000 to 2001) were: seven pre-vitellogenic females; three late-vitellogenic females; five maturing males; and one late reproductive male. The sex and maturation stage of three adult fish could not be determined during surgical examination; one other fish escaped prior to being examined. Attritic oocytes were observed in the ovaries of two of the eight pre-vitellogenic white sturgeon; these two fish were captured in September 2001, which indicated that they likely spawned during the 2001 season.

The average age of pre-spawning female white sturgeon was 23 years (193.8 cm FL) and ranged from 19 to 29 years. Females not in pre-spawning condition were between age 22 and 26 (between 173.3 and 192.8 cm FL) and ranged from 18 to 28 years. The average age of females that were identified as post-spawners, by the presence of attritic oocytes, were age 24 (241.5 cm FL) and ranged from 23 to 25 years. The age of the one pre-spawning male white sturgeon was 23 years (216.0 cm FL). The average age of early reproductive males was 25 years (195.4 cm) and ranged from 16 to 42 years.

Sex ratio of white sturgeon in the Wanapum reservoir was approximately 1:1 (36 males : 35 females) during the combined 2000 to 2001 study. The maturation stages of the 95 white sturgeon captured in the Wanapum reservoir (including the fish released from the Abernathy Fish Culture Centre) during 2000 and 2001 were: 11 non-reproductive females; six pre-vitellogenic females; ten early vitellogenic females; seven late vitellogenic females; one ripe female; three females of unknown maturity (i.e., recaptured fish that were not re-examined); one non-reproductive male; 12 maturing males; 12 early reproductive males; 11 late reproductive males; and 19 juveniles. The sex and maturation of two adult fish could not be determined because excessive fluid in their body cavities obstructed the view of the gonads. Three juveniles (not included in the list above) were captured during the Grant PUD 1999 study. Attritic oocytes were observed in the ovaries of three of the six pre-vitellogenic white sturgeon; two fish were captured in early October 2000, and one fish was captured in early October 2001. The presence of attritic oocytes indicated these fish likely spawned during the 2000 and 2001 spawning periods, respectively.

The average age of pre-spawning female white sturgeon was 23 years (205.1 cm FL) and ranged from 18 to 28 years. Females that were not in pre-spawning condition were between age 17 and 25 (between 157.5 and 204.8 cm FL) and ranged from 4 to 37 years. The average age of females that were identified as post-spawners, by the presence of attritic oocytes, were age 24 (241.5 cm FL) and ranged from 19 to 34 years. The average age of pre-spawning male white sturgeon was 21 years (181.0 cm FL) and ranged from 15 to 26 years. Males that were not in pre-spawning condition were between age 19 and 22 (between 173.9 and 176.7 cm FL) and ranged from 7 to 37 years.

2.1.3 Spawning Investigations

In total, 2,347 white sturgeon eggs and five larvae were captured during 215 012.1 mat-hours of sampling in the Project area (2000 to 2002). The majority (n=2179) of white sturgeon eggs were caught below Rock Island Dam in the Wanapum reservoir, with the remainder (n=168) recorded from the Wanapum Dam tailrace in the Priest Rapids reservoir. The amount of sample effort expended was similar between reservoirs (Wanapum = 119 811 mat-hours; Priest Rapids = 95 201 mat-hours). Higher catch-rates of eggs/larvae were observed in Wanapum (0.44 eggs/mat-day) compared to Priest Rapids (0.04 eggs/mat-day) reservoirs over the duration of the spawning studies (2000 to 2002).

White sturgeon spawning activity was monitored below Wanapum Dam from May 27 to August 5, 2000, May 25 to August 10, 2001, and May 27 to August 1, 2002. In total, 30, 20, and 31 substrate mat sites were placed below Wanapum Dam in 2000, 2001, and 2002, respectively. Water temperatures, measured below Wanapum Dam by Grant PUD hydrolabs set at Beverley Bridge during the duration of the study, ranged from 12.1°C to 18.9°C in the 2000 spawn monitoring period, 12.6°C to 18.9°C in 2001, and 10.8°C to 18.5°C in 2002. Average daily discharge, measured below Wanapum Dam during the 2000, 2001, and 2002 spawning period (May 24 to August 10) was 3,787 m/s, 2,292 m/s, and 5,747 m/s, respectively.

In 2000, 54 white sturgeon eggs and two larvae were captured during 27 967.9 mat-hours of sampling for a catch-rate of 0.05 eggs/mat-day. In 2001, nine white sturgeon eggs were captured during 42 581.6 mat-hours of sampling for a catch-rate of 0.01 eggs/mat-day; white sturgeon larvae were not captured. In 2002, 105 white sturgeon eggs were captured during 24 651.4 mat-hours of sampling for a catch-rate of 0.1 eggs/mat-day; white sturgeon larvae were not captured.

White sturgeon spawning activity was monitored below Rock Island Dam from May 28 to August 4, 2000, May 23 to August 9, 2001, and May 27 to August 1, 2002. In total, 34, 28 and 21 substrate mat sites were placed below Rock Island Dam in 2000, 2001, and 2002, respectively. Water temperatures, measured below Rock Island Dam by Grant PUD thermistors over the duration of the spawn monitoring program, ranged from 11.9°C to 18.7°C in 2000, 11.8°C to 18.5°C in 2001, and 10.7°C to 17.9°C in 2002. Average daily discharge, measured below Rock Island Dam during the 2000, 2001, and 2002 spawn monitoring periods (May 24 to August 10) was 3609 m/s, 2005m/s, 5388 m/s, respectively.

In 2000, 127 white sturgeon eggs and two larvae were captured during 48 706 mat-hours of sampling for a catch-rate of 0.06 eggs/mat-day; note that for calculation purposes, larvae are converted as eggs. In 2001, 29 white sturgeon eggs were captured during 42 582 mat-hours of sampling for a catch-rate of 0.02 eggs/mat-day; white sturgeon larvae were not captured in 2001. In 2002, 2023 white sturgeon eggs and one larvae were captured during 27 301 mat-hours of sampling for a catch-rate of 1.78 eggs/mat-day.

2.1.4 Growth

Ages were determined for 29 white sturgeon from the Priest Rapids reservoir (1999 to 2002). These fish ranged from age 16 to 42 representing the 1958 to 1984 year-classes. The age-class composition of white sturgeon captured in the Priest Rapids reservoir was concentrated between the 1972 and 1984 year-classes. The von Bertalanffy growth curve, based on these 29 fish is illustrated in Figure 3.5. Fork length was not significantly related to age in the Priest Rapids reservoir, likely because of the small sample sizes observed (Regression; $r^2 = 0.11$; p=0.08)

One recaptured white sturgeon (unknown sex and maturation) from the Priest Rapids reservoir exhibited an incremental growth-rate of approximately 2.5 cm per year. This fish was initially captured in the 1999 Grant PUD fall session and was subsequently recaptured during the 2001 fall session.

Ages were determined from 104 white sturgeon from the Wanapum reservoir. For comparative purposes and to allow grouping of the samples aged in each year of the study, ages were standardized to year of birth (year-class). The 21 fish that were less than 100 cm FL were from the 1992 to 1997 year-classes. The ninety-five fish over 100 cm FL were from the 1964 to 1990 year-classes. The majority of white sturgeon captured in the Wanapum reservoir were from the 1975 to 1984 year-classes. The von Bertalanffy growth curve based on these 104 aged fish is illustrated in Figure 3.7. Fork length was significantly related to age in the Wanapum reservoir (Regression; $r^2 = 0.89$; p=0.00).

The six recaptured white sturgeon from the Wanapum reservoir exhibited a mean incremental growth-rate of 6.8 cm per year. The actual annual growth of these six fish ranged between 4.0 and 11.5 cm per year.

2.1.5 Movements

Sonic-tagged white sturgeon in the Priest Rapids reservoir usually remained in one of four possible overwintering areas [in order of use: Goose Island (RM 398), Wanapum Dam tailrace (RM 414), near Lake Geneva (RM 404), and below Lower Crab Creek (RM 409)] from October to early April. During this time, white sturgeon movements between these overwintering areas were infrequent. Sonic-tagged white sturgeon moved upstream to Wanapum Dam tailrace (RM 414) in April or early May, likely in response to feeding and/or spawning activity; water temperatures at this time were generally between 6°C and 11°C. Sonic-tagged white sturgeon usually remained in the tailrace of Wanapum Dam until August (water temperatures between 18°C and 19°C), after which time they returned to downstream situated feeding and/or overwintering areas.

Boat-based tracking surveys to locate sonic-tagged white sturgeon were not conducted in the Priest Rapids reservoir until January 19, 2001, since fish were not tagged until late September 2000.

In 2001, three white sturgeon implanted with CHAT tags, and eight implanted with coded pinger tags were at-large in the Priest Rapids reservoir (Table 3.2). Four fish (previously tagged in late September and November 2000: P#14, P#22, P#23, and P#27) were detected below Wanapum Dam between RM 413 and RM 415 from late March to mid-June 2001. In July, these four fish were detected in the Wanapum Dam tailrace (RM 416) and because they were not in pre-spawning condition, were likely present in the area for feeding activities. By mid-July, three of these fish [one female (P#14) and two males (P#22 and P#23)] had moved downstream. One female (P#14) moved to RM 414 until late November, while one male (P#22) moved to this location until mid-August, and was always detected below Lower Crab Creek (RM 409) for the remainder of the year. One male (P#23) was located in the Priest Rapids Dam forebay (RM 397) from mid-August until early October, and later located downstream of Lake Geneva (RM 404) for the remainder of the year. Another male (P#27) was located in the Wanapum Dam tailrace from January to December 2001.

Movements of seven white sturgeon were monitored by boat and remote telemetry receiver stations after their initial capture in late September and early October 2001. One female (P#32) was located upstream of Lake Geneva (RM 405) in mid-October, and in the Priest Rapids Dam forebay (RM 397) in November and December. One female (P#36) was located in the Wanapum Dam tailrace (RM 414) in late September, and near Goose Island (RM 398) in November and December. Three females (P#40, P#44, and CHAT #159) were located in the Wanapum Dam tailrace (RM 415) from

From October to December, one female (CHAT #239) was located below Wanapum Dam (RM 414) in late October and then downstream of Lake Geneva (RM 403) in November, where she was last detected on November 21, 2001. One female (CHAT #271) was located near its initial capture area (RM 413) from early October to early November, and in December this fish was detected downstream of Lake Geneva (RM 401).

From January to March 2002, four sonic-tagged white sturgeon (P#14, P#40, P#44 and CHAT #159) were detected in the Wanapum Dam tailrace (RM 414 to 415), two fish (P#32 and P#36) were located near Goose Island (RM 398), and two fish (P#23 and CHAT #271) were located downstream of Lake Geneva (RM 401 to 403). One fish (P#14) was located at Goose Island in April and July. Another fish (P#23) was detected in the Wanapum Dam tailrace from April to July, and was subsequently detected near Goose Island in July and August. One fish (P#32) was detected in the Wanapum Dam tailrace in July; this fish and one other individual (P#36) were last located near Goose Island in August and March, respectively. One sturgeon (P#40) was last located in the Wanapum Dam tailrace on May 31, while another fish (CHAT #159) was last detected in the same area on March 21. CHAT #271 was last detected downstream of Lake Geneva (RM 404) on May 2, while CHAT #239 was not located after November 21, 2001. From January to August 2002 P#27 was detected in the Wanapum Dam tailrace. P#22) was located below Lower Crab Creek (RM 409).

A potential pre-spawning female (P#44), tagged in the Priest Rapids reservoir on October 31, 2001 was detected below Wanapum Dam (RM 415) in the Priest Rapids reservoir on May 2, 2002. This fish was subsequently detected several times by a remote telemetry station at Columbia Cliffs (RM 442) in the Wanapum reservoir from May 14-27. This fish was also detected by a remote telemetry station at the Rock Island Dam tailrace (RM 452) from June 27 to July 30, 2002. While boat-based telemetry surveys did not verify the presence of this fish in the Wanapum reservoir, it was suspected that this fish moved upstream from the Priest Rapids reservoir into the Wanapum reservoir, since the tag was detected by two different receivers in the upper section of the Wanapum reservoir and the detection patterns picked up by remote telemetry stations did not resemble noise patterns usually observed by this technology.

Sonic-tagged white sturgeon in the Wanapum reservoir usually remained in one of four possible overwintering areas [in order of use: Columbia Cliffs, below Rock Island Dam (RM 453), Sunland Estates (RM 429), and near Vantage Bridge (RM 421)] from September to May (water temperatures ranged from 2°C to 18°C; Appendix D, Figure D1 and D2). The Columbia Cliffs area appeared to be the primary overwintering location for sonic-tagged white sturgeon. Some white sturgeon moved between Columbia Cliffs and Sunland Estates during the 2000 and 2001 overwintering period; this pattern was not observed in 2002. Upstream movements from overwintering areas to the Rock Island Dam tailrace commenced in May at water temperatures from 8 to 13°C. Pre-spawning female white sturgeon were usually located in the Rock Island Dam tailrace (RM 453) by June or July when water temperatures ranged between 11°C and 18°C. Non-spawning females were located in this area from May to August (water temperatures ranged between 14°C and 19°C). Pre-spawning male white sturgeon were located below Rock Island Dam from June to July; one male remained there throughout the year. Other males (not in spawning condition) were usually located in the Rock Island Dam tailrace from June to July with some remaining in this area until late September.

From May to August 2000, 16 sonic-tagged white sturgeon at-large were located below Rock Island Dam from RM 450 to RM 453. By November 30, 19 of the 23 sonic-tagged white sturgeon at-large were located at Columbia Cliffs between RM 441 and RM 442. One white sturgeon was located downstream of Sunland Estates (RM 429), and one fish was detected below Rock Island Dam (RM 451) at this time.

A remote telemetry receiver station (set to detect coded pingers) was deployed at the Columbia Cliffs area (RM 442) on December 3, 2000. This monitor detected 18 of the 23 fish equipped with coded pingers at-large in the reservoir.

The fish with CHAT #15 was last detected on June 29, 2000 and was recaptured on October 2, 2000. The VR28T hydrophone system was unable to pick up a signal from the tag at this time, and the tag was removed so that temperature and depth data could be retrieved. The tag was returned to Vemco Ltd. and it was determined that a manufacturing defect had caused the tag to malfunction. A similar malfunction was suspected for fish implanted with CHAT #47 and CHAT #63.

From January to June 2001, 20 white sturgeon were detected in overwintering and/or feeding areas near Columbia Cliffs (RM 442), Sunland Estates (RM 429; CHAT #79; coded pinger #1), near Vantage Bridge (RM 421), between RM 424 and RM 428, and in Rock Island Dam tailrace (upstream of the Alcoa Launch) at RM 450. From early June to mid-August, 20 of 23 sonic-tagged white sturgeon at-large were detected in the Rock Island Dam tailrace area (RM 450 to RM 452); their presence in this area was likely related to feeding and/or spawning activity. Weekly tracking surveys, conducted from June to August, indicated that 13 of 23 sonic-tagged white sturgeon at-large moved between the tailrace and downstream situated feeding areas on several occasions during this period. One fish (CHAT #79) was last located below Rock Island Dam on June 27; it was assumed that the tag battery had expired.

From early September to early December 2001, 19 of 23 sonic-tagged white sturgeon at-large were detected in the overwintering and/or feeding area at Columbia Cliffs, Sunland Estates, near Vantage Bridge, and six between RM 424 and RM 428. One fish was detected in the Rock Island Dam tailrace area (RM 452) during this time.

One white sturgeon (P#34), tagged on September 29, 2001, was located below Rock Island Dam (RM 452) from October to November, and was always detected at Columbia Cliffs (RM 442) for the remainder of the year. One other fish, implanted with a CHAT #255 on September 29, 2001, was not detected since release.

In 2002, 16 of the 24 pinger-equipped white sturgeon at-large were detected at the Columbia Cliffs overwintering area from January to mid-May. From mid-May to early August, nine of these 16 fish had moved into the tailrace area below Rock Island Dam (RM 452); four were early to late reproductive males, four were early to late vitellogenic females, and one was of undetermined sex and maturity at the time of capture. These movements were considered to be spawning related. For the remaining seven of these 16 fish that were not located in the spawning area (RM 452) during this time:

- two were immature females (P#3 and P#6) were detected in the narrows below Rock Island Dam (RM 449) in mid-June and were located in the spawning area from late June to early August;
- one was a late vitellogenic female (P#9) that was located downstream of Whiskey Dick Creek (RM 426) in late March and early May and was detected in the spawning area from early June to early August;

- one was a pre-vitellogenic female (P#24) detected downstream of Scammon's Landing (RM 427) in late March, located at Columbia Cliffs in June, and detected below Rock Island Dam from July to August;
- one was a early reproductive male (P#25) that was detected downstream of Quilomene Creek (RM 433) from early May to early August;
- one was a non-reproductive male (P#29) was detected near Quilomene Creek (RM 433) in late May and early June and then located in the spawning area from late June to early August;
- one was a non-reproductive female (P#34) detected near Quilomene Creek (RM 433) in late May and early June, located in the spawning area in late June, and from July to August was detected downstream of Whiskey Dick Creek (RM 426).

Three (P#2, P#13, P#16) of the 24 pinger-equipped fish at-large were detected downstream of Whiskey Dick Creek (RM 426) in February and March 2002; one early reproductive male (P#13) was detected here until August. One non-reproductive female (P#2) was located downstream of Rock Island Dam (RM 452) from late June to early August. One maturing male (P#16) was detected at Columbia Cliffs (RM 442) on 12 June, in the narrows below Rock Island Dam (RM 449) on June 14, and in the Rock Island Dam tailrace (RM 451 to 453) from June 21 to July 30.

For the remaining five of the 24 pinger-equipped fish at-large:

- one late reproductive male (P#7) was detected in the spawning area below Rock Island Dam (RM 452) from early February to early-August;
- three fish (P#11, P#12, P#28) have not been detected since October 27, November 30, and May 11 2001, respectively; and
- one juvenile (P #21) was detected near Vantage (RM 421) from early January to early August.

2.2 Findings to Date

The four years of white sturgeon study conducted for relicensing in the Priest Rapids and the Wanapum reservoirs in 1999 (Grant PUD 1999) and 2000 to 2002 (Golder 2003) and review of existing information resulted in the following key findings:

A relatively small population of white sturgeon (lower estimated limit of 143 individuals), made up of older adults, was present in the Priest Rapids reservoir. This population could be a fragment of a larger migratory or resident population that was present prior to the construction of mid-Columbia River dams. Based on information collected from 1999 to 2001, recruitment to this population has been sporadic and limited to a strong recruitment period in the mid to late 1950s and a lesser degree of recruitment between 1969 to 1984. For reasons outlined above, however historical trends based on assigned ages of white sturgeon should be interpreted with caution.

The apparent gap in recruitment during the 1960s may correspond to the initiation of Wanapum Dam construction in 1959, and the operational changes that occurred in the years following (e.g., the reservoir was filled in 1963, and the final generation unit was operational in 1964). From 1969 to 1984, recruitment to the population appeared low, but was relatively consistent, with the exception of three years (i.e., 1970, 1971, 1973) where no evidence of recruitment was obtained. Based on the captured population, recruitment ceased in 1984. A spill operations program was initiated throughout the Columbia River basin from 1980 to 1986, where spill occurred for 12 hours at night instead of during the day. Whether these spill changes impacted recruitment in the reservoir during the 1980s is unknown.

Other basin-wide environmental effects may have also influenced white sturgeon recruitment in the Priest Rapids reservoir. For example, a decline in the abundance of young white sturgeon upstream of Hells Canyon on the Snake River was observed to correspond with an unusually prolonged drought that lasted eight consecutive years (1987 to 1994; Lepla and Chandler 2001). The effects of this drought may have impacted white sturgeon populations throughout the Columbia River. Recruitment in the Wanapum reservoir was also observed to be inconsistent from 1984 to 1992, perhaps indicating that the effects of this drought were a basin-wide phenomenon.

Another plausible explanation for the presence of the small, older population in the Priest Rapids reservoir may be due to an outmigration of young fish to downstream reservoirs. White sturgeon post-hatch larvae are typically mobile and actually use river currents as a means of dispersement from spawning areas to downstream rearing habitats. For example, sturgeon larvae have been reported 184 to 194 km (115 to 121 miles) downstream of known egg incubation and probable spawning sites (Kohlhorst 1976, McCabe and Tracy 1989). The Priest Rapids reservoir may not provide a long enough settling area for white sturgeon larvae spawned below Wanapum Dam to settle out prior to being entrained through Priest Rapids Dam. Observations made during set lining for adults indicated that higher velocities were experienced from a section that extended 16 km (10 miles) from Wanapum Dam to upstream of Lake Geneva; set lining was more difficult in these areas because of faster currents. These currents may disperse larvae, spawned below Wanapum Dam, to potential rearing areas that may occur near Lake Geneva and Goose Island or below Priest Rapids Dam. Several studies on the middle and lower Columbia River, and on the Snake River in Washington have indicated that suitable habitats for juvenile white sturgeon consist of depths between five and 14 meters, water velocities less than 0.25 m/s, as well as bottom types consisting of sand, sand/silt, or small gravels (McCabe and Tracy 1989, Parsley and Beckman 1994, Lepla and Chandler 2001). In the Snake River, larger juvenile white sturgeon (less than 120 cm TL) were observed negotiating velocities up to 2.5 m/s, however, these upper velocities were seldom used (Lepla and Chandler 2001). Kappenman et al. (1999) reported that white sturgeon less than 68 cm TL were not found in areas where mean water column velocities exceeded 1.6 m/s. Suitable rearing habitats for early life stages of white sturgeon were not identified in the Priest Rapids reservoir, but based on the above criteria, may be present at Goose Island (RM 398) or downstream of Lake Geneva (RM 404).

The white sturgeon population in the Wanapum reservoir (estimated between 398 and 881 individuals) contained both young and mature individuals. Approximately 20% of the total catch was composed of juvenile fish, which suggested this population either experiences natural recruitment or that juveniles recruit to the population from populations in upstream reservoirs.

Based on capture and movement studies conducted during the present study, seven locations were identified as potential rearing areas for older juvenile sturgeon. These were Vantage Bridge (RM 421), downstream of Whiskey Dick Creek (RM 426), downstream of Scammon's Landing (RM 427), Sunland Estates (RM 429), downstream of Quilomene Creek (RM 434), downstream of Tekison Creek (RM 438), and at Columbia Cliffs (RM 442). The extent and use of these areas for rearing is not well known. Suitability of the Wanapum reservoir for rearing by juvenile white sturgeon may be greater than in the Priest Rapids reservoir. This supposition is based on 1) the capture of juveniles in the Wanapum reservoir during three fall sample periods, 2) the presence of one tagged juvenile over the duration of the movement study, 3) the greater number of potential rearing areas, and 4) the greater habitat diversity likely available in the larger reservoir, especially during variable flow years.

Based on assigned ages of fish collected from 1999 to 2001, recruitment to the Wanapum population occurred between 1964 to 1997; year-class strength after this year could not be determined, since biases associated with sample gear most likely precluded the capture of smaller individuals. Since Rock Island Dam (built in 1933) is a run-of-the-river facility, water level fluctuations are dependent upon operations further upstream in the Columbia River. Limited recruitment may have occurred prior to 1964, since there was an increase in dam construction activity, and river regulation in upstream areas during this time. Recruitment in the late 1980s also may have been impacted by a prolonged drought that occurred from 1987 to 1994, which was observed to cause a decline in the abundance of young white sturgeon on the Snake River (Lepla and Chandler 2001). The large number of fish captured during the present study from the 1997 year-class may suggest that high-flow years increase the survival and recruitment of juvenile white sturgeon (i.e., high flows provide increased turbidity or water volume for predator avoidance); 1997 was the highest flow year on record since the construction of Priest Rapids Dam in 1961. Several researchers have reported a positive relationship between white sturgeon year-class strength and river outflow (e.g., Kohlhorst et al. 1991, Miller and Beckman 1995). Since aging methods for younger sturgeon are more precise (Rien and Beamesderfer 1994), the identification of the strong 1997 year-class in the Wanapum reservoir has a relatively high certainty of being accurate.

3.0 Protection, Mitigation, and Enhancement Measures

The goal of the WSMP is to promote growth of the white sturgeon population in the Priest Rapids Project area to a level that is commensurate with the available habitat by year 30 of the New License. To meet this goal, Grant PUD is proposing a supplementation program to increase the population through use of hatchery-reared fish or fish that have been trapped in the lower Columbia River for direct release into the reservoir, or other methods recommended by the PRFF. The PMEs of the WSMP are designed to meet the following objectives:

> Objective 1: Increase the white sturgeon population in the reservoirs through supplementation to a level commensurate with available habitat;
>
> Objective 2: Determine the effectiveness of the supplementation program;
>
> Objective 3: Determine the carrying capacity of available habitat in the reservoirs and;

Objective 4: Determine natural reproduction potential in the reservoirs, and then adjust the supplementation program accordingly.

This WSMP is an adaptive management approach where strategies for meeting the goals and objectives may be adjusted through a collaborative effort with the relicensing stakeholders participating in the PRFF, based on new information and ongoing monitoring results. The WSMP is also intended to be consistent with other white sturgeon management plans in the mid-Columbia region**.**

The WSTG developed the objectives and activities described in this section. The effectiveness of each strategy will be determined through the monitoring and evaluation program. Once the results of the monitoring and evaluation program have been considered, Grant PUD will determine, in consultation with the PRFF, any reasonable and feasible next steps, which may include adjusting the supplementation level.

Due to the adaptive nature of this program, the schedule for implementation of specific measures can only be estimated at this time. Table 1 provides an estimated schedule for implementing each activity, which will be adjusted through consultation with the PRFF, as new information becomes available.

3.1 Objective 1: Increase the Spawning and Rearing of White Sturgeon in the Priest Rapids Project

Grant PUD shall complete a plan for an adaptively managed, long-term, white sturgeon supplementation program in the Project area within one year of the effective date of the New License. Primary components of the proposed supplementation program are developing and implementing a broodstock collection and breeding plan, stocking juvenile white sturgeon in the reservoirs, and a monitoring and evaluation program.

3.1.1 Brood Stock Collection and Breeding Plan

Due to the low population estimates indicated by the 2001 and 2002 white sturgeon investigations, there is a low probability that brood stock from the reservoirs can be utilized as the basis for a long-term supplementation, so other sources of fish must be considered to increase the white sturgeon population (Golder 2003b). Within one year of the effective date of the New License, Grant PUD shall prepare a brood stock collection and breeding plan, in consultation with the PRFF, which considers such factors as genetics and questions of imprinting. Possible sources of fish include:

- Brood stock collected from the Priest Rapids and the Wanapum reservoirs and nearby reservoirs (or above McNary) and used in a hatchery supplementation program;
- Brood stock collected from the lower Columbia River;
- Excess juveniles from the Lk. Roosevelt recovery program;
- Juveniles purchased from a commercial facility for direct release into the reservoir; and

- Juveniles from new or existing Grant PUD-funded hatchery facilities retrofitted to accommodate white sturgeon brood stock, egg incubation, and juvenile rearing.

The initial source of brood stock will be determined within one year of the effective date of the New License, and collection will begin in year two of the New License, if fish are available and the PRFF determines that brood stock collection within such a timeframe is feasible (see Table 1, footnote 1). If collection is not feasible by year two of the New License, Grant PUD shall proceed on a schedule to be determined by the PRFF, using the adaptive management approach depicted in Table 1. The intent of brood stock collection is to use their progeny, if feasible, in the future for the white sturgeon stocking program.

3.1.2 Juvenile White Sturgeon Stocking

Beginning in year three of the New License, Grant PUD shall release up to 6,500 yearling white sturgeon into the Wanapum reservoir and 3,500 yearling white sturgeon into the Priest Rapids reservoir annually in years 3, 4, and 5. In consultation with the PRFF, yearling fish will be acquired through one or more of the following: 1) production from a Grant PUD hatchery or cooperative mid-Columbia hatchery, 2) excess yearling fish production from other compatible supplementation programs, 3) purchase from a commercial hatchery, or 4) other measures identified by the PRFF. Extenuating circumstances, such as problems with hatchery siting, disease, etc., could result in a failure to meet the three-year deadline. Grant PUD will meet with the PRFF to discuss any circumstances where the deadline will not be met, and alternatives will be developed and implemented (see Table 1, footnote 2).

Grant PUD shall ensure that all hatchery-reared juvenile white sturgeon released into the Priest Rapids and the Wanapum reservoirs are marked with Passive Integrated Transponder (PIT) tags (tags that do not emit a signal and must be activated by the reader, and be read at very close range, i.e., the fish must be in hand) and year-specific scute marks for monitoring purposes. In order to allow for tracking of juvenile white sturgeon emigration, Grant PUD shall ensure that up to one percent (or a maximum of 65) of the juvenile white sturgeon released into the Priest Rapids and the Wanapum reservoirs are large enough to allow implantation of an active tag prior to release.

The number of yearlings released in subsequent years (after the initial three-year stocking period) will range from 0 – 6,500, based on the results of the indexing program and/or the evaluation of spawning potential and could be adjusted after the evaluation period (also see Table 1, footnotes 2 and 3).

In addition, following the third year of supplementation (unless Grant PUD, in consultation with the PRFF, determines more analysis is required), Grant PUD may elect to release juveniles at younger or older ages than one year in order to compare success of fish released at varying life stages. For example, based on consultation with the PRFF, Grant PUD may elect to have a proportion of the hatchery-reared juveniles released at differing size intervals (with the minimum size being that which permits PIT-tagging), in order to monitor potential differences in survival and growth during future indexing periods. On a schedule developed in consultation with the PRFF (see Table 1), Grant PUD shall implant active tags in a percentage, to be recommended by the PRFF, of juvenile white sturgeon released as part of the supplementation program, in anticipation of future emigration rate and habitat-use tracking surveys.

Annual stocking levels of yearlings or possibly other age-classes will be adjusted based on monitoring results in any given year. Methods for determining production goals, stocking locations, and breeding plans are described in Appendix A.

In year six of the New License, Grant PUD, in consultation with the PRFF, will stock a total of 10,000 yearlings annually in the Wanapum and Priest Rapids reservoirs through the end of the term of the New License (44 years) or as adjusted by the PRFF through the adaptive management process consistent with monitoring and evaluation results.

3.2 Objective 2: Determine the Effectiveness of the Supplementation Program (Monitoring and Evaluation)

A Monitoring and Evaluation Plan shall include both a sampling program and an emigration rate assessment to determine: supplementation program effectiveness, carrying capacity for each reservoir, and reproduction potential for each reservoir.

3.2.1 Sampling Program

Using active-tagged sturgeon, develop and implement a sampling program for the evaluation of survival rates, growth rates, fish distribution, habitat selection, habitat use, habitat availability, and habitat suitability. The program shall include the following:

- Monitor to determine program effectiveness in Years 4, 5, 6, 8, and then every 3rd year for the term of the New License.
- Monitor to determine each reservoir's carrying capacity in Year 3 through the end of the term of the New License.
- Monitor to determine each reservoir's reproduction potential in Years 8, 9, 10, 13, and 18, and then every 3rd year for the term of the New License.

3.2.2 Assessment of Emigration Rate

In Years 4, 5, 6, 14,20, and any additional years as determined by the PRFF, active-tagged sturgeon shall be used to assess the emigration rate of white sturgeon out of the Priest Rapids Project. This will require one percent of each of the first three annual classes of juvenile sturgeon (up to a maximum of 65 fish each year) to be reared large enough to implant an active tag for tracking purposes. The purpose of tracking active-tagged fish is to determine juvenile white sturgeon emigration rates out of the reservoirs and habitat use within the reservoirs.

3.2.3 Supplementation Program Review

Grant PUD, in consultation with the PRFF, shall compile information annually on other white sturgeon supplementation programs in the Columbia River basin in order to assess whether: 1) Grant PUD's supplementation program is consistent (e.g., stocking rates, release age and size, brood stock source, and monitoring program) with similar regional programs; 2) harvest is appropriate to achieve management goals; 3) improvements to the Grant PUD program for the Project can be made; and 4) monitoring objectives can be met more economically.

3.3 Objective 3: Determine Carrying Capacity of Available Habitat in Priest Rapids and the Wanapum Reservoirs.

Grant PUD expects to gather sufficient information through the monitoring and evaluation activities described in section 3.2 to determine, in consultation with the PRFF, the carrying capacity of the Priest Rapids and the Wanapum reservoirs.

3.4 Objective 4: Determine Natural Reproduction Potential in the Priest Rapids and Wanapum Reservoirs.

Until reasonable and feasible means for reestablishing natural production and providing support for migration are available, and recognizing that those means appear unlikely in the foreseeable future, the Biological Objective is sustaining a population at a level commensurate with available habitat through implementation of a white sturgeon supplementation program in the Project reservoirs. The supplementation program will provide an initial foundation for the Monitoring and Evaluation Program, which is designed to a) identify existing impediments to achieving the Biological Objectives, b) sustain the populations until the existing impediments can be corrected, and c) mitigate for population losses due to Project impacts. Timelines proposed for implementation of supplementation program implementation measures are reflected in the table below.

3.5 Reporting

By March 31 following issuance of the New License, and each year thereafter for the term of the New License, provide an annual report summarizing activities undertaken to identify and address impacts of the Project to white sturgeon, including results of those activities. This report shall include a compilation of information on other white sturgeon supplementation programs in the Columbia River Basin in order to assess whether the supplementation program being implemented at the Priest Rapids Project is: (i) consistent with other supplementation programs in the region; (ii) cost effective to implement at the Project; and (iii) whether improvements can be made which are appropriate to implement at the Project.

3.6 Adaptive Management

The WSMP shall include provisions to resolve critical uncertainties to further achievement of white sturgeon Biological Objectives. In the event that adverse Project effects on white sturgeon spawning, incubation and rearing in the Hanford Reach are identified, the WSMP shall be amended to further investigate and quantify Project effects and to identify potential reasonable and feasible measures to mitigate such effects, taking into consideration the cumulative effects of the river system and using the adaptive management process. Draft plans for the investigation and evaluation shall be developed in consultation with PRFF, and proposed final plans submitted to Ecology for approval or modification.

In the event that reasonable and feasible means for reestablishing natural production and providing support for migration become available, these measures shall be considered by the PRFF and the WSMP amended as appropriate for implementation.

Grant PUD shall consult with the PRFF during the term of the New License to ensure that the juvenile white sturgeon stocking program, indexing program and associated use of active tags (with limited lives) are coordinated to most effectively meet the overall monitoring goals and schedule. Table 1 demonstrates an estimated long-term schedule, subject to Adaptive Management by Grant PUD, in consultation with the PRFF, to coordinate release, survey, tagging, and monitoring activities. Implementation of the white sturgeon program will require prior FERC approval.

Table 1 Priest Rapids Project Area White Sturgeon Monitoring and Evaluation Program Schedule. Table 1 is an estimated implementation schedule (WADOE 2007).

New License Year	Collect Brood Stock[1]	Release Fish in the Priest Rapids Project area[2]	Indexing[3]	Track Marked Fish[4]	Assess Natural Production[5]
1					
2	X				
3	X	X			X
4	X	X	X		
5	X	X	X	X	
6	X	X	X	X	
7	X	X		X	
8	X	X	X		X
9	X	X			X
10	X	X			X
11	X	X	X		
12	X	X			
13	X	X			X
14	X	X	X	X	
15	X	X			
16	X	X			
17	X	X	X		
18	X	X			X
19	X	X			
20	X	X	X	X	
21	X	X			
22	X	X			
23	X	X	X		
24	X	X			
25	X	X			

1 Collection of brood stock may include capture of mature adults from the lower Columbia River or in the mid-Columbia or Snake River where reasonable and feasible. The initial source of brood stock will be determined in year one of the program, and collection will begin in year two.

2 A total of 6,500 yearlings will be released in the Wanapum reservoir and 3,500 yearling in the Priest Rapids reservoir during each of the first three years. Total yearlings released in subsequent years will range from 0 – 6,500 based on the results of the indexing program. Hatchery fish will be acquired through purchase from a commercial hatchery, production from a Grant PUD hatchery or cooperative mid-Columbia hatchery, or other measures. Breeding plans for all options will be developed, in consultation with the PRFF.

3 Indexing will include monitoring of age, growth, habitat, survival, and condition factors of juvenile and adult sturgeon. Results will be used to determine future stocking rates, locations, and timing. The frequency of indexing may be adjusted in consultation with the PRFF.

4 Active-tagged juvenile and adult sturgeon will be tracked to assess emigration, habitat use, and potential spawning locations.

5 Conduct spawning surveys, as recommended by the PRFF, to identify natural production in the reservoir. The PRFF may adjust surveys based on flow conditions or other data.

	Repeat years 23 to 25 through end of license				

Use/Action	Objective	Measured Parameter	Schedule	Actions if Objective Achieved	Alternative Management Actions
Juvenile white sturgeon	Increase white sturgeon population in Priest Rapids Project area	Stock 10,000 yearlings in the Priest Rapids Project area	Years 3-5, each year	Maintain action. No additional action needed.	Adjust stocking level; alternative broodstock; excess production
Juvenile white sturgeon	Increase white sturgeon population in Priest Rapids Project area	Stock 0-10,000 yearlings in the Priest Rapids Project area	Years 6-50	Maintain action. No additional action needed.	PRFF to recommend stocking level
Juvenile and adult white sturgeon	Determine supplementation program effectiveness	Long-term indexing: survival rates; growth rates; tag and track fish; distribution; habitat selection, use, availability, and suitability	Years 4-6	Maintain action. No additional action needed.	Develop and implement collaborative plan to address identified problem(s), if any.
Juvenile and adult white sturgeon	Determine supplementation program effectiveness	Emigration rate; track marked fish	Years 5-7, 14, 20 and add'tl TBD	Maintain action. No additional action needed.	Develop and implement collaborative plan to address identified problem(s), if any.
Juvenile and adult white sturgeon	Supplementation program review	Compile additional information from other programs	Years 3-50	Maintain action. No additional action needed.	Develop and implement collaborative plan to address identified problem(s), if any.
Juvenile and adult white sturgeon	Determine reservoirs' carrying capacity	Long-term indexing results, emigration rate results	Years 3-50	Maintain action. No additional action needed.	Develop and implement collaborative plan to address identified problem(s), if any.
Adult white sturgeon	Natural reproduction potential	Tag adults and monitor through long-term indexing; egg mat placement	Years 8-10,13, and 18	Maintain action. No additional action needed.	Develop and implement collaborative plan to address identified

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Appendix A
Augmentation Strategies for the Priest Rapids Project Area

WHITE STURGEON (*Acipenser transmontanus*)
CONSERVATION AQUACULTURE PLAN

FOR PRIEST RAPIDS AND WANAPUM RESERVOIRS
MID-COLUMBIA RIVER.

Prepared for:
Public Utility District No. 2 of Grant County

by

GOLDER ASSOCIATES LTD.

201 Columbia Avenue
Castlegar, B.C.
V1N 1A2
Phone: (250) 365-0344
Fax: (250) 365-0988
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1.0 Introduction

1.1 Background

The development of hydroelectric power generation facilities within the Columbia River Basin has had negative impacts on white sturgeon (Acipenser transmontanus). White sturgeon populations in the middle and upper Columbia River now reside in regulated and impounded reservoirs between dams. All of these populations experience complete or frequent recruitment failures that are likely related to river regulation, flooding of historical critical spawning and rearing habitats, increases in predators due to habitat alteration, introduction of exotic species, and pollution. At present, what limited natural recruitment that does occur, is likely insufficient to maintain existing population levels. As such, these populations may continue to decline in abundance to the point where they either become extirpated from mid-Columbia River reservoirs or continue to exist only at low levels that are dependent upon occasional immigration from upper or lower Columbia River populations.

The Public Utility District No. 2 of Grant County (GCPUD) is presently in the midst of FERC relicensing for their Priest Rapids Project in the middle Columbia River. As part of the relicensing process, GCPUD commissioned intensive studies on white sturgeon populations in the two impoundments (Wanapum and Priest Rapids reservoirs) that comprise the Priest Rapids Project. The results of these studies, undertaken from summer 1999 to early fall 2002, have indicated that resident white sturgeon populations are present in both reservoirs. White sturgeon spawning was documented in the tailrace areas of Wanapum Dam (upper boundary of the Priest Rapids reservoir) and Rock Island Dam (upper boundary of the Wanapum reservoir) in June and/or July of 2000, 2001, and 2002. Despite the apparent occurrence of annual spawning in each reservoir, young sturgeon represented a very minor component of the population that is dominated by large mature fish. The information obtained for the white sturgeon population in the Priest Rapids Project area is very similar to that recorded for an upstream population that resides between Grand Coulee Dam in Washington and Hugh L. Keenleyside Dam in British Columbia (Hildebrand et al. 1999). This transboundary population is presently the target of an intensive international recovery effort that incorporates a conservation aquaculture component designed to supplement the native population until such time as adequate levels of natural recruitment can be restored.

This report outlines a conceptual plan for the development of a middle Columbia River white sturgeon conservation aquaculture facility and population supplementation plan in the GCPUD project area. For the purposes of this document, the proposed supplementation efforts will be limited to Priest Rapids and the Wanapum reservoirs (Figure 1.1). Specific items addressed in this conceptual plan include:

- brief review of sturgeon life history;
- general overview of white sturgeon hatcheries with specific reference to conservation aquaculture hatcheries in the Columbia River basin;

- discussion of critical issues relevant to the use of a conservation aquaculture program in the mid-Columbia River;
- overview of sturgeon hatchery practices;
- logistical considerations regarding a mid-Columbia River conservation aquaculture facility;
- suggestions for preliminary production and release targets and strategies.

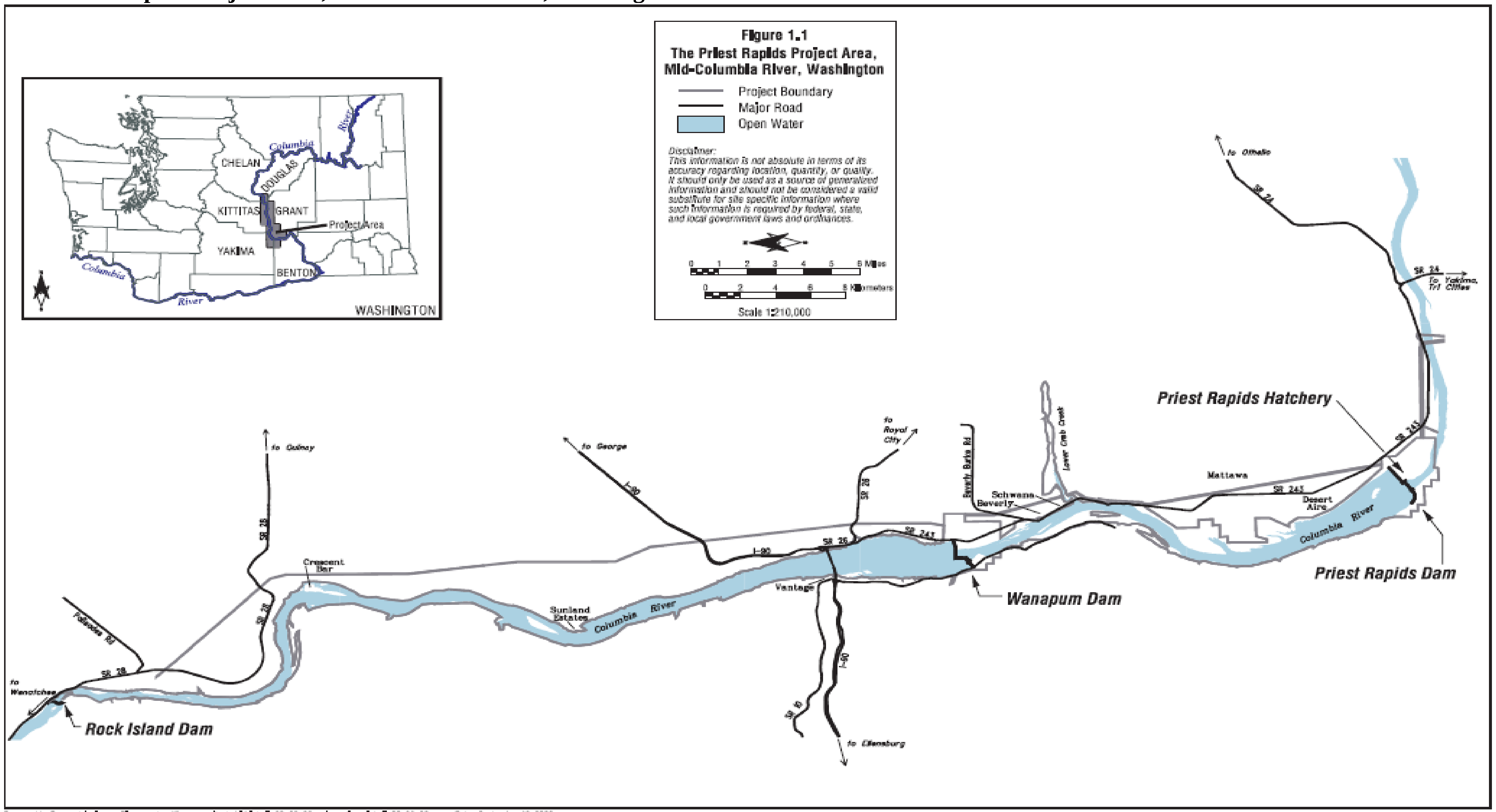
During the development of this conceptual plan, interviews and discussions were held with agency and tribal biologists, hatchery staff in the U.S. and Canada, as well as commercial sturgeon hatchery managers. Information obtained from these sources was provided on the understanding that it would be used in the development of this conceptual plan only.

1.2 Species Account

Sturgeons are a primitive group of teleost fish that evolved approximately 250 million years ago. They are distinguished from modern teleosts by a skeleton that is mostly cartilage, a notochord that persists into adulthood, primitive fin and jaw structures, a spiral valve intestine, and a heterocercal tail. They belong to the Order Acipenseriformes/Family Acipenseridae, representatives of which are known for their longevity and large size (the largest confirmed record in the Fraser River, British Columbia was 629 kg; Scott and Crossman 1973). Sturgeon have five rows of large dermal bony plates called scutes as well as some ganoid scales. Their protrusible mouths draw in fish and benthic organisms that are detected by sensitive barbels beneath their snouts (Conte et al. 1988).

The white sturgeon inhabits drainage systems of the Pacific Coast of North America from the Aleutian Islands of Alaska south to Ensenada, Mexico. Tagged individuals have been known to move up the Pacific Coast 1,000 km (Chadwick 1959). One fish tagged below Bonneville Dam in 1983 was later recovered in 1986 nearly 3,200 km away in Bristol Bay, Alaska (Anderson 1988). The white sturgeon is usually uniformly gray on the dorsal surface with lighter coloration ventrally and is identified by the arrangement of its four barbels in a transverse row beneath a short, broad snout, with barbels closer to the tip of the snout than to the mouth, and by its 38 to 48 lateral scutes. Like other sturgeon, white sturgeon feed on an array of benthic invertebrates although larger individuals are piscivorous.

Figure 1.1 The Priest Rapids Project Area, mid-Columbia River, Washington.



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White sturgeon populations can be anadromous, semi-anadromous, and landlocked but according to Conte et al. (1988), are best defined as semi-anadromous. Conte et al. (1988) report that only a relatively small number of sturgeon species such as the green sturgeon (Acipenser medirostris) and Atlantic sturgeon (Acipenser oxyrhynchus) are truly anadromous living almost exclusively in a marine environment and returning to fresh water only to spawn. White sturgeon live primarily in estuaries of large rivers, are euryhaline, and often form landlocked (resident) populations in lakes and reservoirs. White sturgeon spawn several times during their life, with females spawning at intervals ranging from 2 to 8 years (possibly longer in some populations). Males mature from ages 9 to 22, females from ages 11 to 34, and at the time of spawning they are at least 110 cm in length. Because of their longevity, sturgeon require more time to mature and produce viable sperm and eggs compared to other teleost fish.

Mature adults participate in a seasonal migration to spawning areas, and reproductively active fish usually spawn in areas of swift current over rocky bottoms, deep gravel riffles, or deep holes. In fall and winter, anadromous adults leave the ocean and estuaries and move upriver to spawn. Downstream migration occurs in late spring and summer. Spawning in the Columbia River typically occurs from May through July at water temperatures of 9 to 17°C. Fecundity rates of mature females range from 100,000 to 4,700,000 eggs. White sturgeon are broadcast spawners and the eggs are spawned into fast, moving water where they are dispersed over a large area. The relatively large black eggs are demersal and adhesive. Hatching occurs in 7 to 8 days at water temperatures of 14 to 16°C. After hatching, larval sturgeon disperse downstream with river currents to suitable rearing habitats where they enter a hiding phase until they begin exogenous feeding and begin foraging on natural benthic food sources.

1.3 History of Sturgeon Hatcheries

Virtually all sturgeon stocks worldwide have experienced declines over in the last one-hundred years, not only because of the impact of human activities on sturgeon habitat but also because the high value of their flesh and caviar has resulted in over-fishing. These pressures, in concert with the effects of dam construction and watershed development, are the major factors behind the threatened and endangered status of sturgeon globally.

Historically, sturgeon products have been highly valued in Europe, Asia, and North America. Before 1900 the U.S. sturgeon landings were estimated at 6,800 metric tonnes (MT) on the East Coast and 4,500 MT on the West Coast. Today the U.S. commercial fishery is very limited and is focused primarily on white sturgeon. The international demand for sturgeon flesh and caviar has historically placed significant pressure on the world's sturgeon stocks. Declines in abundance of numerous sturgeon species were recognized in Russia and the U.S. as early as the second half of the nineteenth century. The first recorded attempts at artificial propagation of sturgeon were made by Ovsyandikov in Russia in 1870 and Green in the U.S. in 1875. Significant efforts to artificially propagate sturgeon continued in North America between 1875 and 1912, however, by 1920 practically all these efforts were abandoned (Conte et al. 1988).

Sturgeon hatchery research continued in the Soviet Union however, and was accelerated during the 1950s as part of mitigation programs to compensate for habitat alterations. Technical obstacles to artificial propagation were overcome, and by the 1980s the Soviets operated approximately 20 hatcheries producing 70 to 100 million fingerlings annually. These programs reportedly restored fisheries on three sturgeon species to historical levels and contributed 75 percent to the world's sturgeon catch. The annual international sturgeon fishery landings today are between 20,000 and 40,000 MT and are primarily located in the former Soviet Union and in Iran. The success of the sturgeon mitigation programs in the Soviet Union rekindled interest in sturgeon research in the U.S. The work of Detlaf, Gerbilisky, Ginzburg, Kozin, and their associates laid the groundwork for the advancement of sturgeon programs throughout North America (Conte et al. 1988).

In 1979, a grant from the U.S. Fish and Wildlife Service to researchers at the University of California led to a resurgence of sturgeon research. The development of hatchery technologies for white sturgeon has allowed the advancement of a growing commercial sturgeon aquaculture industry on the West Coast. A hatchery manual for white sturgeon (Conte et al. 1988) was developed by University of California (Davis) researchers and has been used to provide much of the information included in this conceptual plan.

Within the native range of white sturgeon in North America, particular attention has been placed on the advancement of a specific type of sturgeon hatchery involved in what is termed "conservation aquaculture". Essentially these facilities are used as tools for the recovery of endangered sturgeon species/stocks. Given the issues associated with legislation regarding endangered species in North America (the Endangered Species Act in the U.S. and the proposed Species at Risk Act in Canada), it is deemed unacceptable to stock large numbers of generic-stock white sturgeon as a method to recover endangered populations. Instead, a conservation aquaculture program was developed that factors in issues/concerns such as genetic make-up, genetic swamping, interaction with adjacent populations, breeding plans, family numbers, etc., as compared to a typical hatchery where production numbers and fish health are the dominant concerns. At present, the two white sturgeon conservation aquaculture facilities operating in the Pacific Northwest are:

- Kootenai Sturgeon Hatchery run by the Kootenai Tribe of Idaho on the Kootenai River near Bonners Ferry, Idaho; and,
- Kootenay Trout Hatchery (Sturgeon Facility) run by the B.C. Ministry of Water, Land and Air Protection (WLAP) at the upper end of Lake Koocanusa near Wardner, B.C. This facility recently took over the production that formerly occurred at the Hill Creek Hatchery (also run by WLAP) at the north end of upper Arrow reservoir, B.C.

These facilities were constructed specifically to produce fish for the recovery of the Kootenai white sturgeon. The former Hill Creek facility, originally designed as a bull trout hatchery but modified into a sturgeon hatchery, was built to restore what are generically referred to as the upper Columbia white sturgeon. Both of these populations are considered endangered, and are the focus of specific recovery plans. A Recovery Team directs the operational production at these facilities in terms of the numbers and size of fish produced. The ultimate goal of each conservation aquaculture program is to ensure the continued existence of these two populations while attempting to maximize genetic diversity and keep hatchery-produced fish as "wild" as possible. This approach is fundamentally different from a fish production facility.

2.0 Critical Uncertainties

2.1 Current Status in Priest Rapids and Wanapum

Mark-recapture data were used to generate preliminary population estimates for white sturgeon in Priest Rapids and the Wanapum reservoirs (Golder 2003). The white sturgeon populations in Priest Rapids and the Wanapum reservoirs were estimated at approximately 134 (95% CI = 48 to 2680) and 551 (95% CI = 314 to 1460) fish, respectively. These population estimates are considered preliminary since the number of recaptures is near the minimum required to derive a population estimate using this technique. The confidence in this estimate is further reduced by the small number of fish recaptured in the three years of study (this includes the 1999 mark-period sampled by GCPUD). What can be stated with a fair degree of confidence however, is that the white sturgeon population in each of these reservoirs is small and comprised of mostly larger, older fish. With the exception of what appears to be significant recruitment by the 1997 year-class, there has been sporadic, limited annual recruitment to the Wanapum population since the early 1990s but virtually no recruitment in the 1970s and 1980s (Golder 2003). The absence of young fish in catches from the Priest Rapids pool suggests this population may experience frequent annual recruitment failures.

2.2 Outstanding Issues Requiring Resolution

Before any decision is made with regards to a sturgeon production facility, there is a fundamental question that needs to be answered. The regulatory agencies, in consultation with tribal interests and various stakeholders, must decide what the management objectives are for white sturgeon in these two reservoirs. These objectives will determine the size and type of facility (if any) that should be constructed and significantly influence the production plan and release targets. Listed below is a series of alternatives that the appropriate agencies could consider in their deliberations:

Assume a wait-and-see approach, maintaining the status quo re: dam operations and no-harvest regulations, to see what happens to the sturgeon populations over time.

Change dam operations while maintaining the no-harvest regulations and see what happens to the sturgeon populations over time;

Construct and operate a sturgeon production hatchery (as opposed to a conservation aquaculture facility) whose purpose is to produce a fixed number of certain-sized sturgeon for release into these two reservoirs. The end point is to produce fish for harvest as soon as possible and not to increase population size to a point where sufficient natural recruitment occurs in the future (although this may be a potential unplanned outcome). The source of the fish (i.e., their genetic origin/status) is not as important as out-planting large numbers of healthy fish at a large enough size to ensure high levels of survival.

Construct and operate a conservation aquaculture facility whose purpose is to supplement existing sturgeon populations in the two reservoirs until such time as natural recruitment will be sufficient to maintain these populations. The end point is restoration of the sturgeon populations through minimal and limited hatchery supplementation while providing for no or minimal harvest. The source of the fish (i.e., their genetic origin/status) is more important than out-planting large numbers of healthy fish.

Construct and operate a conservation aquaculture facility whose purpose is to rebuild and maintain the existing sturgeon in the two reservoirs recognizing that natural recruitment will likely never be sufficient to maintain healthy sturgeon populations capable of sustaining any appreciable level of harvest. The end point is restoration and maintenance of the sturgeon populations through intensive hatchery intervention for the foreseeable future in order to provide a future harvest fishery. The source of the fish (i.e., their genetic origin/status) is equally as important as out-planting large numbers of healthy fish.

Obviously, there are also numerous subsets of these various alternatives. Outlining even these basic objectives, however, serves to demonstrate the substantially different production goals and methods inherent within each alternative and emphasizes the importance of the stakeholders and agencies in establishing what their objectives are and how they wish to achieve them.

This document lays out the major issues involved in establishing a sturgeon hatchery associated with building the facility. Due to critical uncertainties regarding mid-Columbia River sturgeon aquaculture program (as discussed above), several assumptions were made in the preparation of this conceptual plan. These assumptions are as follows:

- natural reproduction is presently and will continue to be insufficient to maintain the existing populations of sturgeon in the two reservoirs
- the carrying capacity of the reservoirs is substantially greater than the existing population levels;
- recruitment to the existing populations at levels necessary to sustain or increase the populations will only be achieved through a supplementation program;
- the existing potential for downstream passage will require that sturgeon stocked in these reservoirs must be genetically similar to the existing fish to minimize the risk of downstream genetic “pollution”;
- the supplementation program would entail i) the collection of broodstock (likely from within the project), ii) the construction or adaptation of facilities for holding and spawning adult fish and rearing of juveniles, and iii) the subsequent release of juveniles into the project area.

2.3 Production Goals

An annual production goal, contingent on management objectives as described above, must be set in order to establish the fundamental aspects of a sturgeon conservation aquaculture program for Priest Rapids and the Wanapum reservoirs. Yearling production targets of 9,000 to 12,000 were established for the Upper Columbia River White Sturgeon Recovery Plan and the Kootenai River White Sturgeon Recovery Plan (at the Kootenay Trout Hatchery in B.C. and the Kootenai Sturgeon Hatchery in Idaho; Ron Ek, WLAP, and John Siple, Kootenai Tribe of Idaho, pers.

comm., 2002). The use of production goals that approximate those of the two other supplementation/recovery programs currently underway in the Columbia River Basin is considered a reasonable target (i.e., 10,000 hatchery-raised juveniles), at least at this conceptual planning stage.

Following discussions with the WDFW and WLAP in B.C., an annual white sturgeon natural mortality rate of 10% is assumed to occur in the wild. Recent age analysis of recaptured tagged sturgeon suggests that current aging techniques using pectoral fin ray samples may substantially under-estimate the age at which sturgeon mature (Rien and Bemeasderfer 1994). With this in mind, a conservative estimate of 30 years for female maturation was assumed. It was also assumed that the hatchery-reared progeny would exhibit a 1:1 male-to-female ratio in surviving juveniles (Ron Ek, WLAP, pers. comm., 2003).

2.4 Population Model Scenarios

Population trajectories were modeled for the white sturgeon populations in Priest Rapids and the Wanapum reservoirs with a simple age-structure demographic model using: i) hypothetical hatchery and wild sturgeon recruitment rates; ii) current data on abundance, growth, maturation, adult survival; iii) the assumptions outlined above (Section 2.3); and iv) assumptions inherent in the model (UCRWSRI 2002). The following scenarios represent expected population responses to supplementation measures (i.e., releasing 3500 and 6500 hatchery-raised juveniles into Priest Rapids and the Wanapum reservoirs per year for 20 years, respectively). Through several model scenarios, it was determined that 20 years was the minimum amount of time required to increase the white sturgeon population to a level that may be appropriate for the size of these reservoirs (i.e., adult populations of approximately 4,000 and 2,000 individuals for Wanapum and Priest Rapids reservoirs, respectively). Because of the approximate 30 year age until full maturation, adult numbers are projected to decline to very low numbers over the next 30 years even with the immediate release of hatchery-reared juveniles. After this period, adult numbers build as hatchery sturgeon mature. Population trajectories modeled for Priest Rapids and the Wanapum reservoirs are illustrated for baseline scenarios only.

2.4.1 The Priest Rapids reservoir

2.4.1.1 Baseline Population

A baseline scenario was modeled based on the assumptions stated in Section 2.4. This scenario resulted in approximately 2,000 adult sturgeon 30 years of age or older (Figure 2.1) of which at least 262 would be mature females (Figure 2.2). The age-composition of a stable sturgeon population is expected to contain a higher proportion of juveniles, followed by sub-adults, with adults comprising the lowest proportion of the population. Restoration of a stable sturgeon age distribution for this scenario can be expected in approximately 50 years; the point where the age-composition ceases to fluctuate (Figure 2.3).

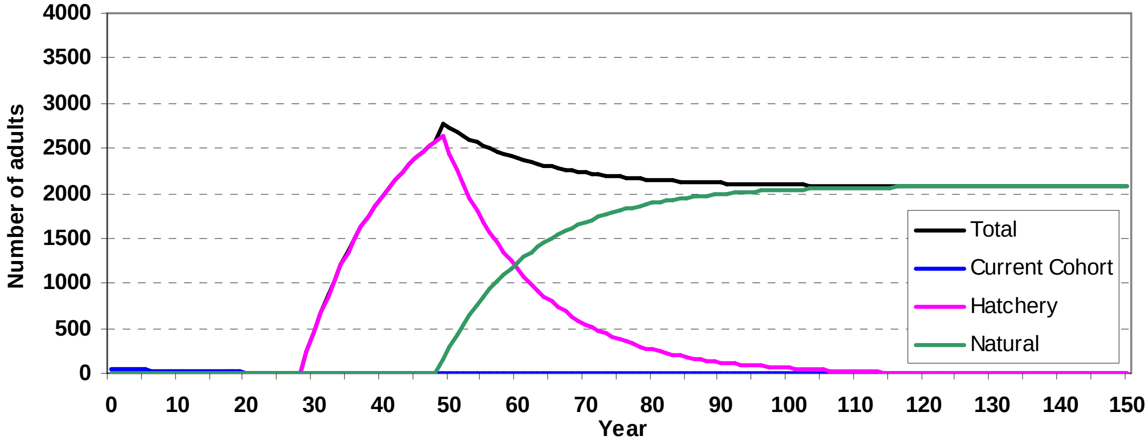

Figure 2.1 **Projected future wild and hatchery adult white sturgeon population size following implementation of a baseline scenario in the Priest Rapids reservoir.**

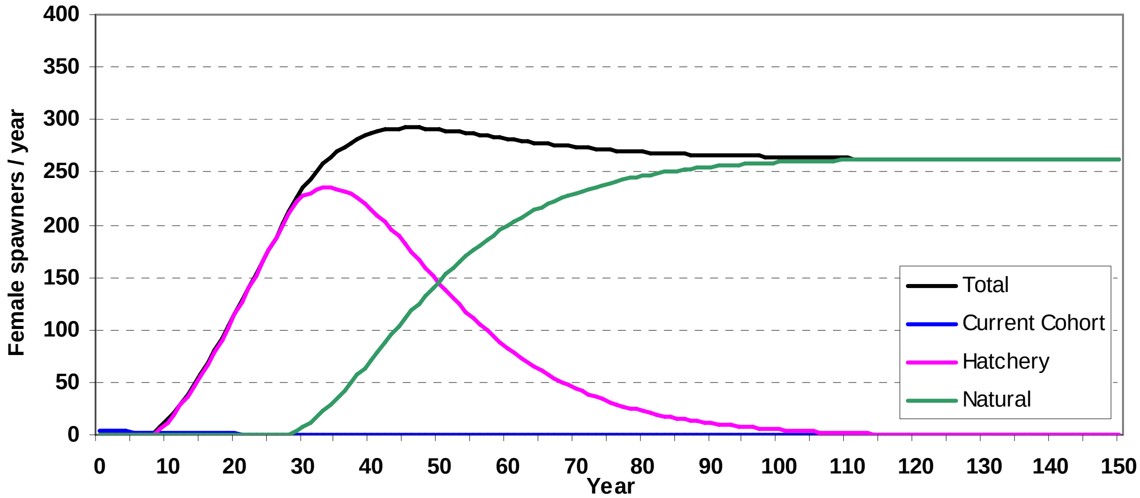

Figure 2.2 **Projected future reproductive potential of white sturgeon following implementation of a baseline scenario in the Priest Rapids reservoir.**

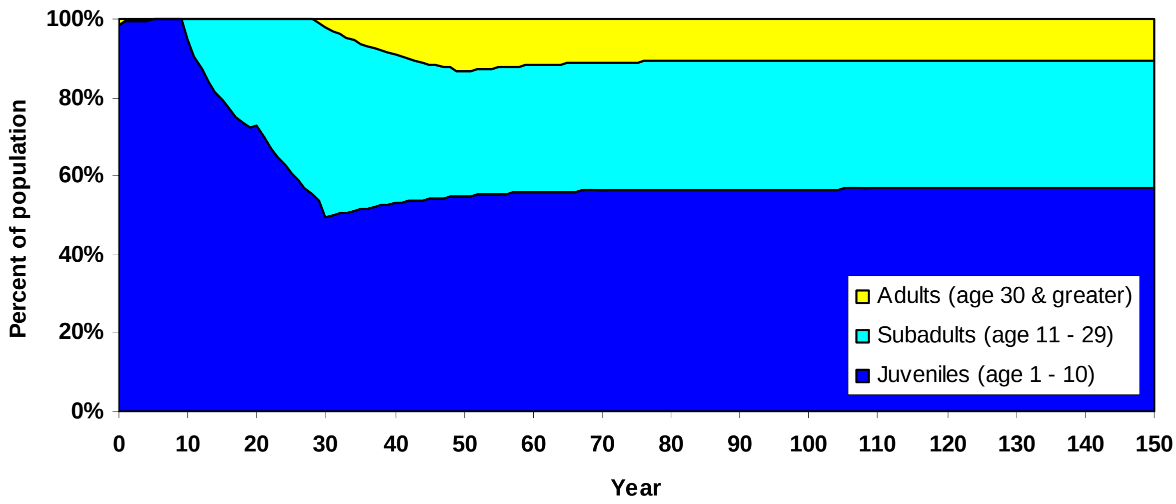

Figure 2.3 Projected changes in sturgeon age composition following implementation of a baseline scenario in the Priest Rapids reservoir.

2.4.1.2 Sub-adult Harvest

Below Bonneville Reservoir, a 10% harvest mortality rate is observed for 12 to 17 year old fish (T. Rien, Oregon Department of Fish and Wildlife, pers. comm., 2003). However, this mortality rate would decrease the projected number of adults to approximately 300 fish, well below the estimated capacity of the reservoir, based on its size (Golder 2003). Therefore, the baseline scenario was used (Section 2.4.1.1) and sub-adult mortality due to harvest (or incidental mortality from catch-and-release) was set to 5%. This scenario resulted in approximately 750 adult sturgeon 30 years of age or older of which at least 130 would be mature female). Restoration of a stable sturgeon age distribution for this scenario can be expected in approximately 50 years. If harvest to the adult population occurred at this level (i.e., 5%), the projected adult population would be approximately 1,200, with at least 200 mature females.

2.4.1.3 Decreased Juvenile Survival

This scenario was included to illustrate the importance of long-term population monitoring during supplementation programs due to the inherent assumptions of the model. The baseline scenario was used (Section 2.4.1.1) and juvenile survival was decreased by an additional 1% (higher than this percentage resulted in numbers close to the existing population in the Priest Rapids reservoir). This scenario resulted in approximately 800 adult sturgeon 30 years of age or older of which at least 100 would be mature females. Restoration of a stable sturgeon age distribution can be expected in approximately 50 years.

2.4.1.4 Adult Age 25 years

This scenario was included to illustrate the importance of long-term population monitoring of the carrying capacity of the Priest Rapids reservoir, since the model is based on the assumption that adult age-at-maturation is 30 years. The baseline scenario was used (Section 2.4.1.1) and adult age-at-maturation was decreased from 30 to 25 years. This scenario resulted in approximately

3,000 adult sturgeon 25 years of age or older, of which at least 300 would be mature females. Restoration of a stable sturgeon age distribution can be expected in approximately 50 years. If the carrying capacity of the Priest Rapids reservoir cannot sustain the projected adult population estimated by the model, then additional harvest mortality (see Section 2.4.1.3) could be implemented (e.g., increasing the sub-adult harvest to 5% would reduce the adult population to approximately 1,400 adults and 200 mature females).

2.4.2 the Wanapum reservoir

2.4.2.1 Baseline Population

A baseline scenario was modeled based on the assumptions stated in Section 2.4. This scenario resulted in approximately 4,000 adult sturgeon 30 years of age or older (Figure 2.4) of which at least 1,300 would be mature females (Figure 2.5). Restoration of a stable sturgeon age distribution for this scenario can be expected in approximately 50 years (Figure 2.6).

2.4.2.2 Sub-adult Harvest

The baseline scenario was used (Section 2.4.2.1) and sub-adult mortality due to harvest (or incidental mortality from catch-and-release) was set to 5% (higher harvest mortality resulted in an adult population close to that presently estimated for the Wanapum reservoir). This scenario resulted in approximately 1,450 adult sturgeon 30 years of age or older (Figure 2.16) of which at least 100 would be mature females. Restoration of a stable sturgeon age distribution for this scenario can be expected in approximately 60 years. If harvest to the adult population occurred at this level (i.e., 5%), the projected adult population would be approximately 2,400, with at least 160 mature females.

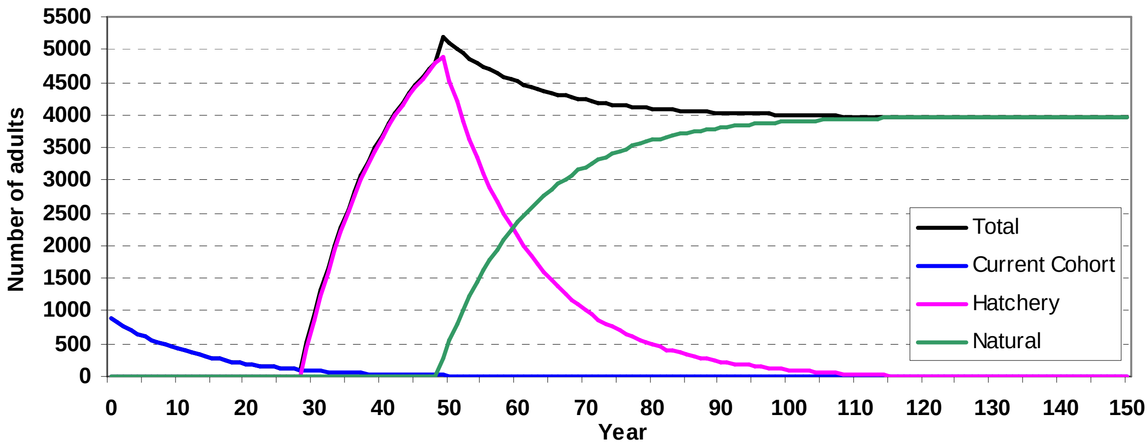

Figure 2.4 Projected future wild and hatchery adult white sturgeon population size following implementation of a baseline scenario in the Wanapum reservoir.

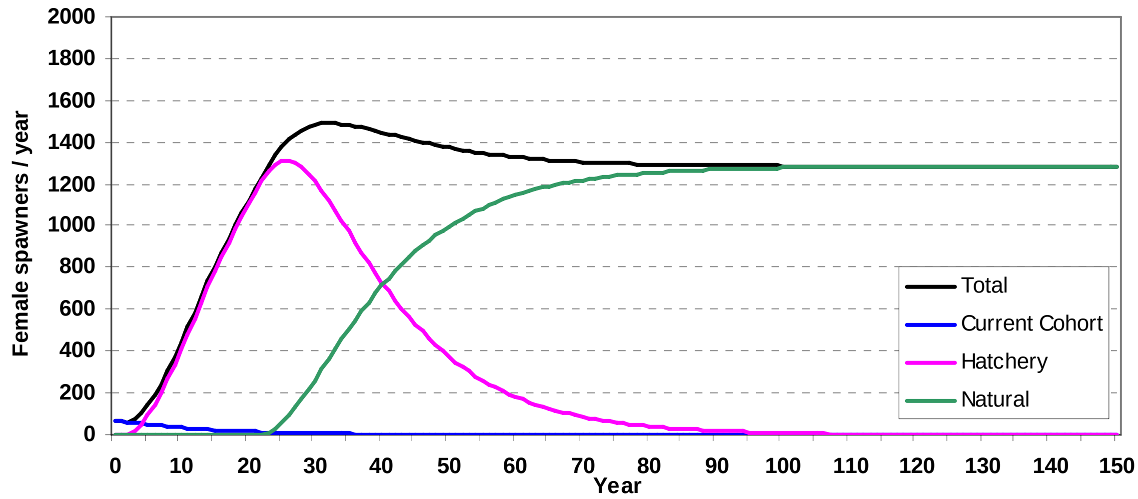

Figure 2.5 **Projected future reproductive potential of white sturgeon following implementation of a baseline scenario in the Wanapum reservoir.**

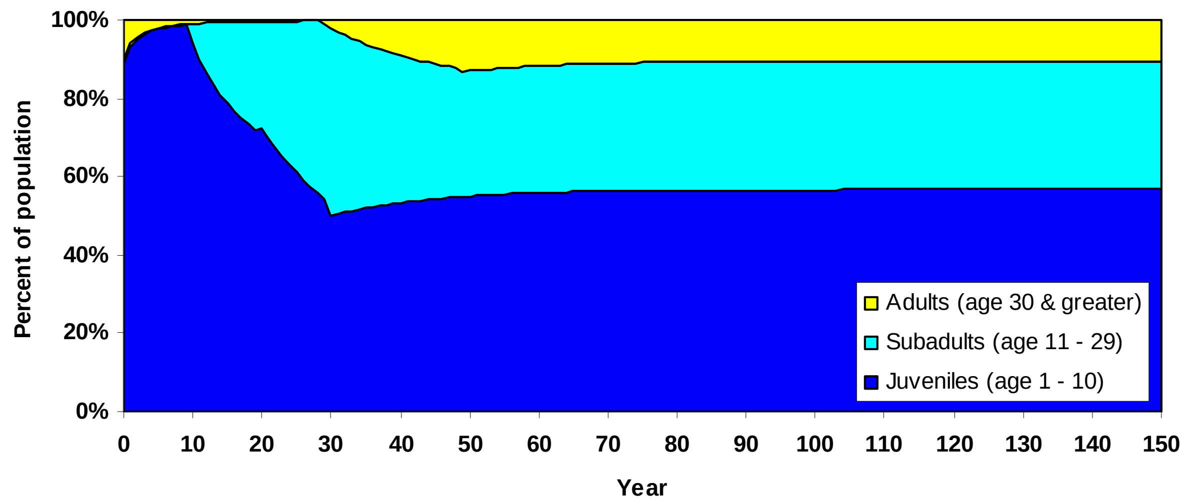

Figure 2.6 **Projected changes in sturgeon age composition following implementation of a baseline scenario in the Wanapum reservoir.**

2.4.2.3 Decreased Juvenile Survival

This scenario was included as outlined in Section 2.4.1.3. This scenario resulted in approximately 1,300 adult sturgeon 30 years of age or older of which at least 80 would be mature females. Restoration of a stable sturgeon age distribution can be expected in approximately 60 to 70 years.

2.4.2.4 Adult Age 25 years

This scenario was included as outlined in Section 2.4.1.4. This scenario resulted in approximately 5,000 adult sturgeon 25 years of age or older, of which at least 200 would be mature females. Restoration of a stable sturgeon age distribution can be expected in approximately 60 years. If the carrying capacity of the Wanapum reservoir cannot sustain the projected adult population estimated by the model, then additional harvest mortality (see Section 2.4.2.3) could be implemented (e.g., increasing the sub-adult harvest to 5% would reduce the adult population to approximately 2,700 adults and 100 mature females).

2.5 Holding Period

The size at which to release juvenile sturgeon back into the wild is still the subject of study. U.S. Geological Survey (USGS) research to date indicates that juvenile sturgeon susceptibility to predation declines after they reach a length of approximately 15 cm (Mike Parsley, USGS, pers. comm., 2003). Rearing fish to a minimum of 15 cm requires from between 6 and 12 months depending upon water temperature. Preliminary studies on the Kootenai River indicate that size and condition of recaptured hatchery-reared fish was independent of differences in size or condition at release (Ireland et al. 2003). However, not enough information was available to determine minimum size requirements for release of hatchery-reared juveniles. Specific benefits of extended hatchery-based rearing may be identified in the near future [i.e., on the Kootenai River (Ireland et al. 2003) and mid-Columbia River (Blaine Parker, Columbia River Inter-Tribal Fisheries Commission (CRITFC), pers. comm., 2003)]. For the purpose of this supplementation plan, it is assumed juveniles would be held for one full year at the hatchery prior to release, consistent with hatchery programs on the Kootenai and upper Columbia rivers. This assumption means that juveniles would be held concurrent with adult broodstock and therefore, separate holding facilities/structures would be required for each.

2.6 Genetic Issues

Maintaining the genetic integrity of wild sturgeon populations is an important consideration in any recovery program involving hatcheries. White sturgeon aquaculture in the Columbia Basin is relatively new and as a result, policies regarding genetic issues are not developed. At present, existing hatcheries use locally obtained broodstock, which is considered the most desirable alternative (Brad James, WDFW, pers. comm., 2002). With regards to the Priest and the Wanapum reservoirs, broodstock collected from these pools would also most likely be considered as the preferred option. It is important to note however, that WDFW is currently collecting sturgeon broodstock from the McNary Reservoir as part of a cooperative aquaculture program with CRITFC in order to provide fish for planned experimental out-plants into the Rock Island Reservoir (Brad Cady and Brad James, WDFW, and Blaine Parker, CRITFC, pers. comm., 2003). Based upon this precedent, a second option may be to collect broodstock from McNary Reservoir where adult white sturgeon are more abundant. This may serve to reduce the sample effort (and associated costs) expended to obtain the required numbers of broodstock from the smaller population within the project area. Furthermore, the sturgeon population in the middle Columbia River downstream from Rock Island Dam and the lower Columbia River below Bonneville Dam may be part of one large population (Anders and Powell 2001). If so, this would mean that broodstock could potentially be collected from areas that support the highest population densities, such as from below Bonneville Dam where the population is considered to be quite healthy.

At the Kootenay Trout Hatchery and Kootenai Sturgeon Hatchery facilities, white sturgeon progeny are held separately based upon parentage. Familial segregation is maintained until the juvenile fish are large enough to be PIT tagged (approximately 30 to 45 g). This is an important consideration since segregation of family groups at the hatchery translates to a need for additional holding capacity, thereby increasing overall costs.

For the purpose of this conceptual plan, the holding capacity of the required hatchery facility and associated cost estimates are based on the following assumptions:

- a maximum of 12 adult white sturgeon would be collected from the Priest Rapids and the Wanapum reservoirs annually for broodstock;
- male broodstock will be held separately from female broodstock ;
- the progeny will be divided into a maximum of ten families (1000 progeny from each family for a total of 10,000 juveniles);
- the progeny from each family will be held separately and raised for 10 to 12 months; and,
- all fish will be marked with a PIT tag and a secondary mark (scute removal) prior to release.

3.0 Sturgeon Hatchery Practices

3.1 Hatchery Procedures

Development of a conceptual plan for a white sturgeon hatchery requires a basic understanding of sturgeon aquaculture procedures. These are outlined below and have been derived largely from Conte et al. (1988) with some additional input from more local sources.

The techniques for fertilizing sturgeon eggs differ from those used with salmonids because of inherent differences in sperm and egg structure, physiology, and biochemistry. In the hatchery, ovulation of female white sturgeon is induced by the administration of exogenous gonadotropins or gonadotropin-releasing hormones. The females are kept separate from males to prevent spontaneous spawning and problems associated with adhesion of fertilized eggs. The mature ovum is heavily pigmented and approximately 3.7 to 4.0 mm in diameter. Sturgeon sperm differ from salmonid sperm in a number of ways including morphology and a longer duration of motility.

Timing is critical to the successful fertilization of white sturgeon eggs. All equipment and protocols necessary to complete the steps leading to egg incubation must be understood and prepared in advance. Rapid and irreversible changes occur to both sperm and eggs upon contact with fresh water, e.g., hydration of the jelly layer and resultant stickiness of the eggs, and loss of motility in sperm. To control these processes in the hatchery, sperm are collected without contacting water.

The rate of embryonic development of white sturgeon is influenced by water temperature. Higher incubation temperatures reduce the time required for development but these temperatures must remain within the optimal temperature range of 14 to 17°C for maximum egg to larval survival. Hatching occurs after 7 to 8 days producing larvae approximately 13 mm in length. External feeding begins approximately 10 days after hatching when the larvae measure approximately 23 mm.

Sturgeon hatcheries may be required to deal with three types of broodstock: 1) wild-caught, non-ripe fish that require holding and further maturation; 2) wild-caught, ripe fish that are close to spawning; and 3) juvenile, hatchery-reared fish that are being raised as future broodstock. Due to increased complications associated with handling and transferring large fish, collected broodstock should ideally be less than 70 kg.

Sturgeon may be collected directly from the spawning grounds during the spring spawning migration when both eggs and sperm are ripe. Fewer fish need be captured in such areas due to the higher percentage of mature ripe fish. This strategy is currently used to obtain broodstock for a commercial white sturgeon hatchery located in Portland, Oregon (Pelfrey's Sturgeon Hatchery). Ripe broodstock are captured in the spring (end of May) using gill nets in the Bonneville Dam tailrace area and held for approximately 3 weeks to support this program (Henry Pelfrey, Pelfrey's Sturgeon Hatchery, pers. comm., 2002).

Pre-spawning broodstock may also be collected during the fall or winter prior to the spring/summer spawning period. When collecting broodstock from non-spawning areas, large numbers must be captured and examined to obtain sufficient mature sturgeon that will spawn within 6 months of capture. This strategy is currently being used with an experimental white sturgeon propagation program run jointly by WDFW and CRITFC in the middle Columbia River. In this program, non-ripe sturgeon broodstock are collected from the McNary Reservoir using baited set-lines then held for several months at McNary Dam (Brad Cady and Brad James, WDFW, and Blaine Parker, CRITFC, pers. comm., 2002). Collection of non-ripe broodstock is the most commonly used method in Columbia Basin sturgeon hatchery programs and for the purposes of this conceptual plan, is considered as the primary broodstock collection strategy.

White sturgeon do not exhibit sexual dimorphism; therefore, both sex and maturation status must be determined via physical examination at capture. This is most easily accomplished with ripe individuals collected from spawning areas; non-ripe fish usually require surgical examination. Most commonly, sturgeon broodstock are collected from non-spawning areas, examined in the field to assess suitability as broodstock, and then transferred to the hatchery where spawning time can be manipulated as desired. The field-testing required to determine the stage of sturgeon follicle development and their receptiveness to hormonally induced ovulation involves a surgical examination at the time of capture, which begins with making a small incision through the ventral midline; anaesthetization is usually not required. Sexing males and ascertaining their developmental stage is determined visually. Oocyte samples are taken to determine late-stage maturity of eggs based upon egg polarization and position of the nucleus or germinal vesicle. Following surgical examination, female fish are tagged to allow later identification, and held until the oocyte samples are processed. Sturgeon are given a prophylactic salt treatment when they are first delivered to the hatchery facility and periodically throughout the holding period to reduce stress-related bacterial and fungal infections. Broodstock do not have to be fed during captivity although if they will take food if it is provided. Currently, adult broodstock is fed live rainbow trout at both the Hill Creek and Kootenai Sturgeon hatcheries (Ron Ek, WLAP, and John Siple, Kootenai Tribe, pers. comm., 2002).

A significant portion (30 to 40%) of the females selected during the primary field examination and held at the hatchery for further development may not progress to the ripe stage due to handling stress. Therefore, immediately before a female is chosen for spawning induction, a second, more detailed surgical examination is performed to determine egg condition. The final selection of females before spawning induction is made one day before the desired spawning date and is based upon a physiological in vitro test of oocyte maturation.

To spawn sturgeon successfully in captivity, the broodstock are induced to ovulate (females) or spermiate (males) with exogenous hormone injections. Two types of hormones are commonly used: common carp pituitary (CCP) or luteinizing hormone releasing hormone analogue (LHRHa). Spawning induction includes two injections of the hormone preparation. The initial (primary) injection is separated from the second (resolving) injection by 12 hours. Ovulation can be expected between 20 to 40 hours after the resolving injection depending on the size of the fish and the water temperature. Males typically begin to milt after 20 hours. Fish should be checked every 6 hours following the final injection for signs of ovulation or milting.

Milt is extracted from males with a syringe while eggs are usually surgically removed. For hatchery programs that do not require large numbers of eggs, sufficient numbers may often be obtained through non-surgical means, i.e., extrusion. Milt may be collected several hours before fertilization but care must be taken to prevent contaminating the sperm with water. Sperm samples should undergo microscopic examination to check viability. Dilution of sperm with water occurs at the moment of fertilization, as once activated, the sperm must be used within a few seconds. The eggs are fertilized by adding the diluted milt solution directly to the egg containers. The eggs are then stirred gently by hand for up to 3 minutes and the de-adhesion process begun. De-adhesion of fertilized sturgeon eggs is critical to prevent clumping. This is accomplished either by occlusion of the sticky surface with river silt or by chemical alteration of the sticky jelly coat; use of a river silt solution is most common. The solution is added to the egg container and stirred by hand or with a large feather until the eggs no longer stick to each other. This process may take as long as 1 hour.

Fertilized eggs are transferred to incubation containers. Sturgeon eggs are especially susceptible to fungal infections so incubation systems using modified MacDonald jars that provide gentle agitation are commonly used to minimize fungal related losses. Ultraviolet treatment of the water source is recommended. Eggs remain in the incubation containers until hatching at which time newly hatched sturgeon larvae move vertically in the water column and pass from the incubation containers to fry collection tanks.

Early larval culture tanks may be circular or rectangular; circular self-cleaning tanks are preferred. Stocking density should be approximately 15 to 20 yolk sac/L. Culling should be conducted to maintain a density of 3 to 5 g/L. Larvae delivered to the tanks soon after hatching will generally swim freely throughout the water column. Within 5 to 6 days after hatching they will exhibit a strong negative phototaxic response and aggregate at the bottom of the tank. Approximately 3 to 5 days after this transition from pelagic to benthic behaviour, larval development is near completion and the fry will be ready to begin exogenous feeding. Once the fry begin external feeding they will disperse throughout the tank.

Sturgeon fingerling production is one of the most difficult aspects of the hatchery system. Once larvae absorb their yolk sacs, survival is dependent upon both the hatchery system and nutritional input. Feeding should begin before complete yolk sac absorption. Both prepared rations and natural feeds such as tubificid worms are commonly used to nourish sturgeon fry during the first two months. The most commonly used prepared rations after this period are products such as Biodiet® semi-moist ration and Silvercup© dry ration. Weaning of fish from diets of natural feed to prepared rations or from semi-moist rations to less expensive dry rations is often necessary. Feeding rates are typically 25% of the tanks total biomass every 24 hours partitioned into 2 to 3 hour intervals. Mechanical feeders are successfully used at sturgeon hatcheries and can result in a significant reduction in person-hours devoted to feeding fry. The early feeding period must be monitored continuously and feeding rates adjusted accordingly. Other critical periods occur during ration transitions. Egg-to-fry survival rates at the Hill Creek and Kootenay Trout hatcheries typically average about 25% (Ron Ek, WLAP, pers. comm., 2002).

Diseases observed in sturgeon hatchery programs include myxobacteriosis, columnaris, Costia, and external fungus. Treatments for these are identical to those used for salmonids. Outbreaks of white sturgeon Iridovirus have also been known to impact sturgeon hatchery programs in the Columbia Basin.

Generally, once fish reach a length of 15 cm they can be released into the natural environment. Holding fish in a floating net pen within the release waterbody for 24 hours is a technique sometimes used to allow fish to adjustment to their new environment, although this approach is not used for sturgeon releases in the upper Columbia Basin.

3.2 Equipment

A list of necessary equipment required to set up and run a sturgeon hatchery is provided below. This list is preliminary and is intended to present a general idea of necessary items. Most of these items are recommended by Conte et al. (1988). The list is reasonably comprehensive but the reader should note that not all of these items would necessarily be required. For example, adult broodstock capture could be accomplished through sub-contract or other means in which case a capture boat (Item 1) would not be necessary. Although ultraviolet treatment (Item 13) of incubation water is used at other Columbia Basin sturgeon hatchery facilities this would not be necessary if pathogen-free well water-were used.

1) Capture Boat. Used to capture and collect sturgeon broodstock.

2) Transportation Truck and Tanks. Used to transfer adult fish to the hatchery from capture sites and transfer juveniles from the hatchery to release sites. Trailers should be heavy duty, double-axle and rated at 4 ton minimum. An insulated fiberglass 1500 L tank with an attached cover is recommended for transporting adult fish. Tanks should be equipped with an aeration system and backup. A maximum loading density of 150 kg/m3 is recommended for adult fish.

3) Support Equipment. Used to handle large sturgeon, move them safely and efficiently, and hold them during surgical examinations and gamete removal and includes:

    a. tube nets that are used to move fish to and from capture boat, and at the hatchery to move fish between tanks or onto stretchers;

    b. stretchers to transport larger fish short distances around the work area and to hold fish during examination and processing; and,

    c. a 2.5 cm diameter Tygon® tube connected to a source of non-chlorinated water positioned in the sturgeon's mouth to provide flow of oxygenated water over the gills during long periods (in excess of 3 minutes) when the fish is out of water for examination or processing.

4) Short-Term Adult Holding Tanks. Individual sturgeon may be held in small tanks containing non-aerated water for up to 30 minutes although aeration should always be used when available. Holding temperatures should be 15 to 17ºC.

5) Mid-Term Adult Holding and Transport Tanks. Recommended rectangular tank 1.8 to 2.1 m long, 0.46 to 0.91 m wide, 0.61 to 0.91 m deep with a 500 to 1500 L capacity. The tank should be provided with a water exchange system to maintain dissolved oxygen concentration at 5 mg/L. A maximum loading density of 150 kg/m3 is recommended.

6) Maturation Tanks. Designed for long-term maintenance of broodstock. Recommended design is a 6.1 m circular design, fiberglass tank (center drain) with a maximum capacity of 40 000 L and a minimum water depth of 0.61 m that provides a working capacity of 20,000 L. Water exchange is provided at 76 L/min minimum and a forced air system designed to maintain minimum dissolved oxygen concentrations of 5 mg/L. Water should be introduced at an angle to promote a spin that aids in removing waste through the center drain. The tank should be covered to reduce fish stress. To ensure adequate oxygen content in the tank, the effluent should be maintained at a 5 mg/L minimum. Water exchange rate should be at least 10 to 15 volumes/day when loaded to capacity. Capacity loading is about 15 brood fish with a mean weight of about 30 kg. Water temperatures should be maintained at about 10 to 15ºC. Even though larger diameter holding tanks are recommended, 3 m diameter circular holding tanks are used to hold adult broodstock at McNary Dam and at the Kootenai Sturgeon Hatchery

7) Spawning Tanks. Rectangular tanks designed to hold sturgeon during spawning operations. For fish in the 23 to 46 kg size class, a tank of dimensions 2.1 m long, 0.61 m wide, and 0.61 m deep is recommended. The tank should be equipped with a cover screen and the interior coloured medium-green or blue to prevent strong light penetration and to aid in viewing the darker-coloured eggs once the female begins ovulation. A water exchange of about 5 or more volumes/hr is recommended, as is supplementary aeration.

8) Ultraviolet Treatment System. Used to sterilize incubation water.

9) Modified MacDonald Jars. Used for the egg incubation to hatch stage.

10) Fry Collection Tanks. Used to hold newly hatched sturgeon fry.

11) Circular Fry Culture Tanks. Used to hold sturgeon fry during the rearing phase. Usually 112 cm in diameter, 46 cm deep, flat-bottomed, equipped with a centered and screened standpipe, a spray-bar water delivery system and air stone system. Water depth is maintained at 30.5 cm with an inflow of 8 to 19 L/min. Dissolved oxygen levels should be maintained at 5 mg/L minimum.

12) Mechanical Fish Feeders. Used to feed sturgeon fry.

13) Floating Net Pens. Used to hold juveniles in their release environment for 24 hours prior to release.

14) Miscellaneous Surgical and Laboratory Equipment. Used during surgical examination procedures to determine sex, maturity, etc. and includes an otoscope (used during surgical procedures to examine gonads) and a microscope (used to examine sperm for motility/viability).

15) Thermal Valve System. Used to mix different water sources (e.g., river water and well-water) to desired temperatures.

3.3 Water Source

Specific water volume and water quality criteria for sturgeon hatcheries have not been defined for North American species. However, the chemical and physical criterion established for salmonids provides a reasonable base until specific criteria for sturgeon are established (Conte et al. 1988). A decline in white sturgeon broodstock health has been observed when holding temperatures exceed 17ºC (Ron Ek, WLAP, pers. comm., 2002). Maintaining a water temperature range of 10 to 17ºC appears to be suitable for all hatchery operations based upon the information sources queried. Dissolved oxygen concentrations should not fall below 5 mg/L (Conte et al.1988) although 7 mg/L is the minimum criteria used at the Canadian sturgeon facilities.

A hatchery site with several water sources of varying temperatures is an important consideration because the ability to blend water with thermal valves is less expensive than mechanically heating or cooling water to the proper temperature. Natural populations of sturgeon in the Sacramento River system spawn between 13 and 17ºC with peak spawning occurring at 15ºC. Male captive reared white sturgeon have successfully matured in California hatcheries using this criteria. Heating water during winter periods is necessary at the Canadian facilities and constitutes a major cost of the facility operation (Ron Ek, WLAP, pers. comm., 2002).

The Kootenai Sturgeon Hatchery produces approximately 12,000 juvenile white sturgeon annually, a production goal similar to that anticipated under this conceptual plan. The Kootenai Sturgeon Hatchery receives an inflow of 0.98 m3/min to conduct basic hatchery operations with maximum inflows of approximately 1.89 m3/min occasionally needed for brief periods (John Siple, Kootenai Tribe of Idaho, pers. comm., 2002). Based on this experience, an inflow of 1.89 m3/min should be adequate to support a similar sturgeon hatchery program at either a new or modified existing facility in the mid-Columbia area.

Water sources for existing hatchery programs vary by location; e.g., the Kootenai Sturgeon Hatchery is run entirely on river water whereas Pelfrey's Sturgeon Hatchery is run entirely on well water. Controlling water temperature is a vital aspect of a sturgeon hatchery program. For the purposes of this planning document, we assumed that use of both well and Columbia River water would be desirable to negate the need for mechanical water heating or cooling. We further assumed that full use of either water source would at times be necessary, e.g., use 100% well water during the fall/winter incubation/rearing period. This conceptual plan therefore includes a 1.89 m3/min river pump and intake system and a 1.89 m3/min well pump system,

3.4 Hatchery Building

All established sturgeon production facilities in the Columbia Basin (Kootenay Trout Hatchery, Kootenai Sturgeon Hatchery, and Pelfrey's Sturgeon Hatchery) maintain their facilities in an enclosed building(s). An exception to this was the CRITFC/WDFW experimental program in which adult broodstock are held outside in 3 m-diameter, circular raceways on the McNary Juvenile Fish Facility grounds. For consistency with current established sturgeon hatchery programs, all hatchery facilities proposed for the GCPUD Program will be enclosed.

The Kootenai Sturgeon Hatchery utilizes three insulated, metal pole buildings totalling 557 m2 in floor space. This includes office and restroom space. A similar sized building(s) would likely be necessary to conduct a mid-Columbia River program.

4.0 Site Options

4.1 New Site Development

Development of a sturgeon production program will likely entail building a totally new facility or extensive modifications to an existing facility. Ideally, the facility should be located adjacent to either Priest Rapids or the Wanapum reservoirs and close to the Columbia River to allow ready access to river water as well as juvenile/adult release locations and adult collection sites.

The following discussions focus on modifications to existing hatchery facilities in the vicinity of the project area. Modifications required to convert or expand these facilities for sturgeon production.

4.2 Existing Site Development

1. 4.2.1 Priest Rapids Hatchery

The Priest Rapids Hatchery is located on the northeastern shore of the Columbia River immediately downstream from Priest Rapids Dam. This facility, which began continuous operation in 1963, was constructed by the GCPUD to partially mitigate fall chinook losses after the construction of Priest Rapids and Wanapum dams. Originally, this facility consisted of a 1844 m concrete channel to provide spawning habitat for adult fall chinook. The facility was later developed into a fully operational hatchery in the 1970s. Currently, mitigation production is set at a minimum of 45.36 MT of juvenile fall chinook annually which equates to releases of 5 to 7 million smolts. The hatchery is funded by the GCPUD and operated by WDFW personnel.

The hatchery consists of the original concrete spawning channel, a 372 m2 hatchery/incubation building containing 80 stacks of vertical incubators, one large concrete adult holding pond, and 12 vinyl-lined raceways with approximate dimensions of 30.5 m long, 2.4 m wide, 1.2 m deep. Water is obtained from the Columbia River and six on-site wells. Maximum inflow to the hatchery is 2.9 m3/s from the river and 30.23 m3/min from the six wells. Two additional wells exist adjacent to the other six but are not used, apparently because their use reduces the output of the original six.

The current schedule for fall chinook production is as follows:

- September through November. Collect, hold, and spawn adult fall chinook.

- November through June. Incubation and rearing. Transfer of chinook fry to the vinyl raceways typically begins in early March. These fish are later transferred to the partitioned concrete spawning channel in May. All smolts are released from the channel directly to the Columbia River by the end of June; the facility is empty in July and August.

By comparison, a tentative sturgeon production schedule might resemble the following:

- March through July. Collect adult broodstock and hold at Priest Rapids Hatchery.

- July and August. Spawn adult broodstock then return them to Columbia River.

- August through July. Incubate and rear juvenile sturgeon.

- August (Year 2). Release juvenile sturgeon.

Modifications to the Priest Rapids Hatchery to accommodate sturgeon culture, while appearing an attractive and logical alternative to building an entirely new hatchery, are not without significant problems. The above schedules indicate an overlap between the fall chinook program and the sturgeon program would occur in all months except July and August. However, other factors to consider are: 1) the overall hatchery building could be reduced in size as restrooms/offices already exist in the current hatchery, 2) additional river pump and intake system would not be necessary, 3) four of the existing vinyl-lined raceways could potentially be used to hold adult broodstock thereby reducing holding tank and building space requirements, and 4) an additional well may not be needed.

Modification of the existing well-water system to provide necessary inflows may also be possible. Using river water for the sturgeon program is another option, but would most likely require mechanical heating/cooling capability and possibly an ultraviolet treatment system. In addition, the hatchery water distribution system may require substantial modifications to accommodate additional hatchery operations. Finally the hatchery drainage system at the Priest Rapids Hatchery may not allow hatchery operations to expand beyond their present levels, i.e., the system may be inadequate to support an additional sturgeon program. In this event, major modifications to the drainage system would be necessary.

5.0 Juvenile Rearing, Marking, Stocking and Monitoring

The following section provides suggestions for juvenile sturgeon rearing, marking, and stocking, as well as monitoring programs that may be necessary for white sturgeon supplementation in Priest Rapids and the Wanapum reservoirs. It is recommended that more detailed plans be developed prior to commencing a supplementation program.

5.1 Hatchery Rearing

A hatchery program must be carefully designed and implemented to successfully rear and monitor the production of hatchery-raised white sturgeon as well as ensure that genetic diversity of the existing population is maintained (UCRWSRI 2002). Culture methods and techniques should be constantly updated and refined to ensure high-quality sturgeon production and maintain fish health. Hatchery-reared juvenile sturgeon should be monitored continuously for disease, growth, and deformity. Diseased or abnormal fish should be culled to ensure the healthiest individuals are released into Priest Rapids and the Wanapum reservoirs. A back-up facility should be maintained to provide a fail-safe for each brood year in the event of an emergency.

5.2 Juvenile Marking

Hatchery-reared juveniles should be marked (to differentiate them from wild stock) and programs developed to:

- effectively monitor natural recruitment;
- evaluate hatchery fish survival, growth, contributions of different release groups, and regulation of future broodstock use;
- assess sources contributing to recruitment failure and provide feasible alternatives for restoration of suitable conditions for natural recruitment;
- identify limiting life stages, critical habitats, food habits, contaminant uptake; and,
- fine-tune stocking strategies to optimize survival.

Hatchery-reared juvenile fish can be marked with uniquely number ISO-compliant PIT tags and year-specific scute removal patterns. In the upper Columbia River, scute marks are used to provide a rapid assessment of hatchery origin and brood year. The use of scute marks should be coordinated with other sturgeon culture facilities for easy identification of hatchery facility origin and to monitor movements. Selected juveniles could also be held in the hatchery longer to attain sizes necessary for sonic tag implantation to further assess entrainment and immigration into and out of the study area.

5.3 Stocking

Previous movement studies conducted in the upper and middle Columbia River suggest that juvenile white sturgeon are located in the same habitats as adults (Golder 2002). Based on previous capture and movement studies conducted in Priest Rapids and the Wanapum reservoirs, hatchery-reared juveniles should be released in the following areas:

- Goose Island (RM 398);
- downstream of Lake Geneva (RM 404);
- downstream of Lower Crab Creek (RM 409);
- downstream of Wanapum Dam (RM 414 to 415);
- Columbia Cliffs (RM 442);
- Sunland Estates (RM 429);
- Below Rock Island Dam (RM 453); and,
- near Vantage bridge (RM 421).

Release sites can be modified as necessary through the use of juvenile monitoring programs such as those suggested in Section 6.2. The number of juveniles initially released into these reservoirs can be divided evenly among each site listed; this can be modified if juvenile monitoring studies determine higher survival rates are specific to particular sites.

5.4 Additional Monitoring Recommendations

1. 5.4.1 Adult Assessment and Habitat Use

It is important to further assess and continuously monitor adult sturgeon population dynamics, and the carrying capacity of Priest Rapids and the Wanapum reservoirs. Such information is critical in determining the success of the supplementation program and whether modifications are necessary to the overall plan (e.g., more/less production required to achieve goals). Capture (adult and juvenile) programs will enable calculation of more accurate population estimates, allow for monitoring of the existing and hatchery cohorts, and further assess age, growth, survival and mortality. Previous telemetry programs conducted in Priest Rapids and the Wanapum reservoirs identified movements related to spawning, overwintering and feeding, and provided information on the location of critical habitats, and habitat use. These programs could be used to monitor future hatchery-releases and determine if these fish are using similar habitats as ‘wild’ fish. Telemetry programs could also monitor entrainment and immigration in the existing and hatchery cohorts. Spawning habitats that were identified in Priest Rapids and the Wanapum reservoirs (Golder 2003) could be monitored to determine spawning periodicity and intensity, especially upon maturation of the hatchery cohort. Habitats previously identified during telemetry and spawning programs can be further assessed (e.g., velocity, depth, substrate) to develop area-use curves for determining habitat availability in Priest Rapids and the Wanapum reservoirs and identify limiting habitats for various life stages.

1. 5.4.2 Juvenile Indexing Program

A juvenile indexing program, similar to that used in the upper Columbia River (Golder, unpublished), is recommended for determining in-reservoir juvenile abundance, distribution, growth, and survival. Such a program should be conducted each year that juveniles are stocked into Rocky Reach Reservoir. Capture via gill net and observation of juveniles by underwater video systems have proven the most effective for obtaining growth and survival information, as well as documenting habitat use (Golder, unpublished). Coordinated capture programs with agencies and stakeholders downstream of the Priest Rapids reservoir, may also determine downstream displacement rates.

6.0 Discussion

This conceptual plan has included a short summary of sturgeon life history, a brief history of sturgeon aquaculture, a concise statement as to what will be required from the regulatory agencies, a review of basic sturgeon hatchery practices including a list of necessary equipment, and a discussion of hatchery site options. This macro-scale analysis was made for the purpose of conceptual planning only.

The use of hatchery programs to restore or supplement sturgeon populations in the Columbia Basin hydroelectric reservoirs is still in its infancy. Sturgeon research is ongoing and many critical uncertainties exist. Policies pertaining to sturgeon supplementation will continue to evolve as new information becomes available. Changes in policy or new information on white sturgeon population metrics or genetics may also dramatically affect the direction of sturgeon supplementation programs based on the assumptions used in this conceptual plan. For example, if the white sturgeon populations inhabiting the mainstem Columbia River were determined to be genetically homogeneous then use of broodstock from the most abundant locations might be possible.

Supplementation using local broodstock has to date been the preferred strategy to assist in sturgeon recovery efforts elsewhere in the Columbia Basin. Assuming genetics considerations allow the classification of middle Columbia River white sturgeon populations as the same stock, a centralized sturgeon production facility could potentially be established in the middle Columbia River basin to provide fish for mid-Columbia River reservoirs and also for Snake River reservoirs where similar isolated, poorly reproducing populations exist. Such a facility would require production capability (and costs) well in excess of those outlined in this plan.

A sturgeon supplementation program should include a monitoring and evaluation component to assess the overall success of the program and direct program changes as needed. Suggestions were made for establishing preliminary monitoring programs, however, specific plans are recommended once a detailed supplementation program has been developed. Because of the longevity of white sturgeon, future monitoring and evaluation efforts must be considered long-term and planned accordingly.

7.0 Conclusions

Based on the information obtained for the development of this conceptual plan, modification of the existing Priest Rapids Hatchery is the preferred option at this time. This facility is close to the target release and broodstock collection areas and has the capability to use water from both river and well sources. The availability of well water is a potential concern and needs to be investigated in detail. The current hatchery water distribution system and drainage system may require significant modifications; this also needs to be assessed. Improvements to the well, water distribution, and drainage systems in order to accommodate a sturgeon program may also have benefits for the existing fall chinook program.

8.0 Literature Cited

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