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Decision Support System Literature Review and Potential Implementation Scenarios for the Trinity River Restoration Program

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ACRONYMS

AHM	Adaptive Harvest Management
AM	Adaptive Management
ARM	Adaptive Resource Management
ASMFC	Atlantic States Marine Fisheries Commission
Atkins	Atkins North America, Inc.
Board	R.L. Harris Stakeholder Board
CMA	Catchment Management Authority
Commonwealth	Commonwealth of Australia
DFO	Canadian Department of Fisheries and Oceans
DSS	Decision Support System
EDDS	Environmental Decision Support System
EDT	Ecosystem Diagnosis and Treatment
HMWG	Adaptive Harvest Management Working Group
IAP	Integrated Assessment Plan
LWD	Large Woody Debris
M&I	Municipal and Industrial
NFWF	National Fish and Wildlife Foundation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NSW	New South Wales
PI	Principal Investigator
ROD	Record of Decision
SAB	Scientific Advisory Board
SDM	Structured Decision-Making
SSS	Stream Salmonid Simulator
TRRP	Trinity River Restoration Program
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WLCTRT	Willamette-Lower Columbia Technical Review Team

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1 Introduction

The Trinity River Restoration Program (TRRP) contracted with Atkins North America, Inc. (Atkins) to develop background information applicable to the development of a decision support system (DSS). The TRRP's Scientific Advisory Board (SAB) developed a DSS framework as part of their Draft Review of the Trinity River Restoration Program's Channel Rehabilitation Strategy, Phase 1 (Appendix H in SAB 2013). Their concept of a DSS refers to "an overall process and structure for integrating the disparate pieces of a large project to support effective decision-making" that would consist of a linked set of quantitative models, providing a connection between management actions and their potential ecological effects (SAB 2013). Atkins was tasked with developing supplemental information to assist in the development of a DSS for the TRRP, including lessons learned from a literature review of existing DSSs and potential implementation scenarios for a TRRP DSS based on interviews with TRRP staff. Utilizing lessons learned and current TRRP documentation, Atkins staff facilitated the preparation of potential DSS implementation scenarios for consideration by the Trinity Management Council (TMC). This report is the result of that effort and is divided into three sections:

- **Section 2:** This section includes eight case studies of example DSSs identified during a literature review of natural resource management programs in the United States, Canada and Australia. Atkins conducted interviews with representatives from each program and captured the primary lessons learned.
- **Section 3:** This section describes similar and compatible components of the DSS examples to a potential DSS for the TRRP. It presents a summary of the most relevant lessons learned, from both the case studies and a published literature review, to the TRRP and discusses ongoing challenges faced by DSS developers.
- **Section 4:** This section describes three potential implementation scenarios for a TRRP DSS, based on the DSS components described in Appendix H (SAB 2013), the February 2013 Fish Production Workshop and the results of a series of interviews with TRRP staff currently working on predictive ecological models for the Klamath and Trinity Rivers.

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2 Decision Support System Case Studies

To inform potential development of a DSS for the TRRP, Atkins conducted a literature review of DSSs utilized in similar programs related to multispecies management, managed river systems and/or riverine restoration. Four initial criteria were developed to guide selection of the example DSSs:

1) Related to riverine/fisheries management
2) Currently being implemented
3) Has been used for two to three years for decision-making
4) Program is representative of the size of the TRRP

An initial list of programs for consideration was developed based on input from SAB members and other recognized adaptive management (AM) experts, and supplemented by examples from the U.S. Department of the Interior's Adaptive Management Technical Guide (Williams and Brown 2012) and other published literature. While the criteria were useful in setting boundaries for the search, none of the examples met all four criteria. From the initial list, eight DSSs were selected for inclusion as case studies:

1) Horseshoe Crab-Red Knot Management
2) Adaptive Duck Harvest Management
3) Flint River (Georgia) Integrated Model
4) Lewis River (Washington) Salmon Recovery Alternatives
5) Tallapoosa River (Alabama) Flow Management
6) Cultus Lake (Canada) Salmon Management
7) Wetland Flow Management (Australia)
8) Snowy River (Australia) Restoration

Between February and March 2013, Atkins convened phone interviews with representatives from each of these programs. Interviews were structured around DSS development, implementation and maintenance/updates. Standard interview questions were sent to the representatives in advance of the calls (see Appendix A), and were tailored to the specific DSS during the interview. Two to three page summaries of each interview, supplemented by information from published studies, were prepared and sent to each representative for review and confirmation that the information presented is accurate. The summaries are provided in Sections 2.1-2.7 (the two Australian examples are grouped into one summary). Section 3 describes the lessons learned and relevance of these examples to the TRRP.

2.1 Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Constrained by Red Knot Conservation

(Unless otherwise stated, the information in this summary was obtained during an interview with Gregory Breese, USFWS, on February 19, 2013.)

2.1.1 Overview of Decision Support System

This DSS links predictive population dynamics models for two species (horseshoe crabs and red knots) to compare management actions for horseshoe crab management and update harvest specifications.

2.1.2 Decision Support System Development

The Atlantic States Marine Fisheries Commission (ASMFC) is a consortium of eastern seaboard states, the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) that jointly manages shared fisheries resources. The ASMFC was struggling with horseshoe crab management due to uncertainties about the species' biology and the importance of its eggs to shorebird diets during stopovers in Delaware Bay. Red knot populations were in decline and some scientists hypothesized that horseshoe crab fishing was the root cause; however, other scientists and fishermen argued that it was the result of another cause (Williams and Brown 2012). As a result, the USFWS and U.S. Geological Survey (USGS) proposed an AM approach to harvest management that recognized uncertainties and identified policies that are optimal with respect to both fishery and shorebird population objectives.

A small group of USFWS and USGS biologists participated in a Structured Decision Making Rapid Prototyping Workshop in 2007, and then presented the information to the ASMFC Horseshoe Crab and Shorebird Technical Committees. The process of developing the DSS was contentious due to competing values. Some participants cited the paucity of existing examples in natural resource management as cause for concern. USFWS and USGS scientists trained committee members in structured decision-making and AM, which fostered greater understanding and support. The first joint meeting of the two technical committees to develop the DSS was professionally facilitated and organized to progress from a problem statement and objectives to alternatives development and model selection (Breese n.d.). An USGS AM expert attended the meeting to train the participants on the principles of AM. A unified objective statement that captures the competing resource uses was developed and quantified (Williams and Brown 2012).

The two technical committees formed a modeling subcommittee and hired a post-doctoral candidate (funded partly by USGS and partly by the National Fish and Wildlife Foundation [NFWF]) to conduct the modeling over a two-year period, in collaboration with the modeling subcommittee. This culminated in a model structure with two components: a horseshoe crab population model that projects effects of harvest on both sexes and a red knot population model that links vital rates to horseshoe crab spawning in Delaware Bay (McGowan et al. 2011). There are three competing shorebird models with the following hypotheses: (1) horseshoe crab spawning abundance has dramatic effects on red knot survival, (2) horseshoe crab spawning abundance has a small effect on

red knot survival and a large effect on fecundity and (3) horseshoe crab populations have no effect on red knot population dynamics (Williams and Brown 2012).

Following completion of the two-year modeling effort (~2007-2009), an Adaptive Resource Management (ARM) Framework (ARMWG 2009) was presented to the ASMFC Horseshoe Crab Board, who accepted it and charged a peer review. The peer review and subsequent public comment period took approximately one year to complete. There was also disagreement over state-by-state allocations, which required an additional year to determine, following completion of the ARM Framework.

In total, it has taken five years from development to implementation of the DSS, which occurred in 2012. The cost of the DSS included funding for a post-doctoral candidate for two years, two meetings per year for two years and a peer review of the ARM Framework.

2.1.3 Decision Support System Implementation

The DSS was first implemented in 2012 to set harvest specifications for the 2013 fishing season. The only decision supported by the DSS is the selection of the optimal harvest policy. Five alternative harvest policies are available, ranging from a full moratorium to a maximum harvest of 420,000 males and 210,000 females (ARMWG 2009). The DSS is applied using Adaptive Stochastic Dynamic Programming that runs the models to infinity multiple times to capture stochasticity. The output of the program is an optimization or lookup table that recommends harvest policy for all possible combinations of population levels (ARMWG 2009). Each year the table is used to select a harvest policy based on monitoring population numbers and the relative weights of the three shorebird models. The modeling subcommittee (now the ARM Working Group) adjusts the weights of the models by comparing their results to monitored population and harvest numbers. The models themselves do not have to be run each year, only when the weighting is changed.

The ASFMC governance structure has been revised as a result of the horseshoe crab ARM program. Traditionally the ASFMC is composed of a management board for the species (i.e., Horseshoe Crab Management Board) that oversees three technical committees (species, plan review and stakeholders). The ASFMC asked the USFWS to convene a Shorebird Technical Committee in addition to the existing Horseshoe Crab Technical Committee. These two committees formed a modeling subcommittee to develop the DSS. After completion of the ARM Framework, a Delaware Bay Ecosystem Technical Committee was formed to replace the Shorebird Technical Committee and provide a more holistic perspective. The modeling subcommittee (now called the ARM Working Group) falls under the Delaware Bay Ecosystem Technical Committee and includes representatives from federal and state agencies, universities and non-profit organizations. There are stakeholder committees for both horseshoe crabs and shorebirds.

The ARM Working Group prepares a report on the optimal harvest policy for each year, which is delivered to the Horseshoe Crab Management Board for its consideration during decision-making. Public comments are considered during decision-making (both written and oral comments during meetings). Each year's harvest policy is posted on the ASFMC website, along with supporting documentation.

2.1.4 Decision Support System Maintenance and Updates

The cost of DSS maintenance is generally limited to monitoring (approximately $150,000 for the horseshoe crab trawl surveys; approximately 60 people over three weeks [about 40 of which are volunteers] for the shorebird monitoring) and committee meetings (once per year). Maintenance of the models does not require significant time or funding as they are not run every year. Maintenance of the monitoring programs is absolutely critical to implementation of the DSS as the species' population numbers are required inputs to the models. Neither monitoring program is part of base funding for either federal agency (USFWS or USGS), therefore funding is insecure. The ASFMC has developed fallback options in the event that monitoring funding is not secured.

With the use of the optimization table, the DSS is somewhat static, though the weights of the models are adjusted based on their prediction accuracy. Also, every few years (approximately five) stakeholder groups will reconvene to reevaluate objectives and the underlying hypotheses of the models based on new information, and subsequently make any necessary revisions to the models. It is important to use the same models for an extended period of time in order to observe changes in the species' populations from year to year. Sea level rise projections and other factors have not been incorporated into the models yet, and would require significant additional modeling (McGowan et al. 2011). Additionally, the hypotheses included in the current set of models represent a compromise; other issues (e.g., sex ratio linkage to fertility in horseshoe crab populations) were set aside during DSS development because of disagreement and uncertainty about the key ecological relationships. These issues were identified as research priorities and plans were made to address and incorporate them as part of the iterative decision-making process (Williams and Brown 2012).

2.1.5 Lessons Learned

1) **Objectives:** Meeting with stakeholders to collaboratively develop a problem statement and management objectives facilitated agreement on the use of an AM approach and the development of future action alternatives.
2) **Monitoring:** The DSS is dependent upon monitoring results, as the species' population numbers are required as input to the models; continued funding for the monitoring efforts is an ongoing challenge and fallback options are necessary.

2.2 Adaptive Harvest Management of Waterfowl

(Unless otherwise stated, the information in this summary was obtained during interviews with Scott Boomer, USFWS, on February 20, 2013 and Dave Case, DJ Case and Associates, on February 26, 2013.)

2.2.1 Overview of Decision Support System

This decision framework consists of four competing life-cycle models for three mallard stocks, used in concert with observed monitoring data to set annual harvest regulations.

2.2.2 Decision Support System Development

Federal harvest management of migratory waterfowl dates back to the 1930s, following the passage of the Migratory Bird Treaty Act in 1918. Conventions for hunting regulation have been in place since that time, such as season lengths and bag limits. Individual states are responsible for establishing their own regulations within the federal framework, which must be equally or more stringent than the federal regulations. In the 1990s, waterfowl managers were struggling with decision-making because of environmental uncertainties (e.g., drought in late 1980s) and disagreements concerning the role of regulations. Stakeholders were dissatisfied with political intervention in the current process and wanted greater objectivity (USFWS n.d.).

As a result, a group of USFWS scientists initiated the development of a decision framework to support a formal AM approach to harvest management. A group was created to establish a DSS with five essential elements: (1) clearly specified objectives, (2) agreed upon management actions (i.e., regulatory alternatives), (3) a predictive framework (i.e., set of models that test different hypotheses), (4) credibility measures (i.e., probabilities) for the models and (5) a formal monitoring program to determine if objectives are being met and update models. The group included scientists and policymakers from all stakeholder groups, including federal and state agencies and other partners and represented a "bottom up" approach. This group became the Adaptive Harvest Management Working Group (HMWG) (USFWS 2012).

The objectives of the adaptive harvest management (AHM) program are to (1) maximize harvest over the long-term, giving equal value to harvested birds now and in future years and (2) devalue the harvest when predicted spring population size is below the goal set by the North American Waterfowl Management Plan. The three management actions are sets of hunting regulations defined by season length and daily bag limit as: (1) restrictive (short season, small daily bag), (2) moderate (moderate season and daily bag) and (3) liberal (long season, large daily bag) (USFWS n.d.); these have been modified over the course of implementation (USFWS 2012). The predictive framework comprises four life-cycle models for each of three mallard stocks with competing hypotheses on (1) the role of duck density on reproductive rate and (2) the effect of harvest on annual survival (USFWS n.d.).

The timeframe for development to implementation of the AHM program was approximately two to three years. One USFWS staff person was solely devoted to its development and had access to approximately seven other scientists and contractors. The bulk of the costs were associated with

preparation and travel for meetings, as the monitoring program was already in place. Planning and preparation for structured meetings was critical to the success of the program and that, along with the technical aspects of model development, represented a huge investment by the USFWS. The most time-intensive aspects were specifying the objectives and getting agreement on the models. Because of the long-standing history of waterfowl harvest management, many of the DSS elements already existed; however, they were formalized and codified as part of this process. The process also established trust and a sense of ownership because the stakeholders were involved in all elements of the DSS and differing opinions were built into the framework as competing hypotheses.

2.2.3 Decision Support System Implementation

The AHM program was first implemented for mid-continent mallards in 1995 and has been in effect since then. The AHM is used to set annual harvest regulations for three mallard stocks based on the status of each individual stock: Mid-continent (Mississippi and Central Flyways), Eastern (Atlantic Flyway) and Western (Pacific Flyway). An iterative process is used to set annual harvest regulations, using stochastic dynamic programming. Information on the current state of the system (population sizes, habitat conditions and harvest levels) is observed through monitoring (ground surveys, banding, harvest surveys and ancillary surveys) and feedback from hunter questionnaires (USFWS n.d., 2012). The observed data are compared to predicted values to assess the performance of the models and the credibility measures (weights of the individual models) are updated. Based on this information, the optimal management action is derived (USFWS n.d.).

Decisions are made according to the governance structure, which was in place prior to the adoption of AHM. There are four Flyway Councils (Atlantic, Mississippi, Central and Pacific), composed of representatives from each state and province in that flyway. Each council has a technical committee, composed of waterfowl biologists from the states and provinces in the flyway. The technical committees meet several times each year to review monitoring data and provide recommendations to the councils. In addition, the HMWG composed of members of the USFWS, Canadian Wildlife Service, Flyway Council Representatives and USGS scientists, provides technical guidance to the USFWS and Flyway Council on harvest strategies. Recommendations adopted by the councils are presented to the USFWS Regulations Committee for consideration in setting harvest regulations (Flyways.us 2008). State-by-state allocations are done through negotiations within the councils, which are often contentious. Interaction between the USFWS and councils occurs throughout the process; Council Chairmen attend Regulations Committee meetings and four USFWS Flyway Representatives serve as full-time liaisons between the Regulations Committee and the Councils. The USFWS is responsible for oversight.

Public input is accomplished via public attendance at council meetings and Regulations Committee meetings (during the open meeting phase) and through public reviews announced in the Federal Register. The results of meetings and decisions are publicly posted as well.

2.2.4 Decision Support System Maintenance and Updates

The budget for maintaining the DSS is essentially limited to travel and facilitation for annual meetings. Any revisions to the elements of the DSS, particularly the objectives and management

actions, would require additional time. Management of the DSS is sustained through the governance structure as described above.

New information is incorporated into the DSS primarily through updates to the credibility measures based on comparisons of model predictions and observed responses. Periodically, the predictive framework itself is updated based on new information. For example, the Atlantic Flyway Council and USFWS determined that the models have over-predicted population changes in five of the last six years. As a result, the HMWG and Atlantic Flyway Council found it necessary to revise the models for the eastern stock using more recent information and revised hypotheses. A fully revised AHM protocol would take several years to complete, thus the council and the USFWS approved a revised, provisional model for use until the updates to the eastern stock AHM protocol are completed (USFWS 2012).

2.2.5 Lessons Learned

The AHM program is widely regarded as a successful example of AM and a model for other programs. The fact that it has survived politically and institutionally for over 17 years is a testament to its success. Management decisions have been transparent, ecological uncertainty has been reduced and debates have shifted from uncertainty to objectives and management alternatives (Nichols et al. 2007). The success of the AHM program is predicated on a well-established governance structure and monitoring programs. Because of the institutional history, existing elements of the DSS could be codified instead of developed from scratch. The most intensive element of the AHM was establishing agreed-upon objectives and obtaining stakeholder approval of the models, underscoring the importance of eliciting and balancing stakeholder values and opinions (Nichols et al. 2007).

1) **External driver:** An external driver was required to expedite the DSS development process. In this case, the USFWS directed the HMWG to put their best product in place by a specified deadline.
2) **Stakeholder engagement:** The most critical stakeholders were engaged "in a serious way." The states established waterfowl harvest regulations; therefore, they were critical stakeholders in this case and were engaged from the beginning and throughout the process.
3) **Agency staff agreement:** Internal (lead agency) agreement on the process is essential. In communicating with external stakeholders (i.e., hunters), the degree of buy-in was dependent on the degree of internal (USFWS) agreement.
4) **Strong leadership:** Exceptionally strong leadership was needed to navigate the DSS development process. In this case Fred Johnson, a USFWS biologist, led the development process; however, external parties can also serve in this capacity as long as they have the necessary facilitation talent.
5) **Structured process:** A structured process was essential to establishing explicit objectives. This required substantial meeting planning and preparation, but through the process explicit objectives, necessary for AM, were developed.

2.3 Spatially-Explicit Predictive Model for the Flint River (Georgia)

(Unless otherwise stated, the information in this summary was obtained during an interview with Mary Freeman, USGS, on February 25, 2013.)

2.3.1 Overview of Integrated Model

This integrated model links simulated hydrological conditions in the Flint River to fish species distributions to produce a time series of spatially explicit, species-specific occupancy dynamics under different scenarios of water management, climate change, land use, etc.

2.3.2 Integrated Model Development

The Upper Flint River Basin, located in southwest Georgia, contains a 195-mile free-flowing segment of the Flint River and harbors a diverse array of biological communities not found in impounded rivers. The Flint River also provides water to the growing Atlanta metropolitan area, as well as other municipal and industrial (M&I) and irrigation users, and recreational opportunities such as boating and fishing. Continued population growth in the region will increase pressure on biological resources in the Flint River. For these reasons, the USGS selected the Flint River for a project on developing science to address water and ecosystem management issues (USGS 2006).

This project was conceptualized and funded entirely by the USGS as part of its "Science Thrust" program starting in 2005. The purpose of this program is to "advance the science needed to specify the hydrologic conditions necessary to support flowing-water ecosystems" (USGS 2006). The Flint River Science Thrust was focused on water availability for the ecosystem, given allocations for M&I and irrigation uses. For example, it sought to address questions such as how much flows can be changed without impairing ecological functions. An interdisciplinary team of USGS scientists determined that a spatially-explicit predictive model that links hydrological conditions to species distributions was necessary.

This was a research project and was never intended to create a DSS for use by resource managers. The science work group met with state and federal resource managers at the very beginning of the project to discuss the problem and get feedback on the proposed approach; however, a DSS was not requested by the resource managers and they were not involved in the project beyond the initial meeting.

Following the initial meeting with resource managers, the science work group convened a planning workshop to scope the project; the head of the Instream Flow Council and Brian Richter of The Nature Conservancy also participated. The science work group continued to meet in-person two to three times each year over the course of the project, which took approximately three to four years. These meetings were critical for learning what other team members were working on and determining how the different pieces fit together, especially since there was no overall coordinator position. The study involved approximately six principal investigators (PIs), but no one was assigned to the project full-time. A high-level USGS administrator selected the appropriate team members and organized the meetings.

The product was a prototype model focused on metapopulation dynamics of stream fishes in the Potato Creek catchment within the Upper Flint River system, which is representative of the geographic variation and biological diversity of the larger system but with fewer segments. It links a hydrologic model that simulates variation in streamflow under current conditions and alternative scenarios with a multistate metapopulation model that simulates fish species occupancy dynamics across stream segments. The outcome is a time series of spatially explicit, species-specific occupancy dynamics under different scenarios (e.g., water management, climate, land use) (Freeman et al. 2012). Existing empirical data from the Flint River were used to parameterize the biological model.

2.3.3 Model Implementation

As the model was never intended or designed to be a DSS, it is not being used for decision-making on the Flint River. Currently it is being used as a platform for understanding ecosystem responses to drought conditions. Field data are being collected to test the model assumptions and better inform weak areas of the model.

The team is also trying to determine what information decision-makers need so that the model can be useful to them. The model was presented to stakeholders several times in a short format, but detailed discussions with water managers about specific allocations have not occurred. A structured decision-making process with stakeholders was also conducted where stakeholder objectives and management alternatives were developed (see Conroy and Peterson 2013).

2.3.4 Lessons Learned

The lessons learned from this project resulted from omissions, rather than successes. The first is the importance of taking the time to obtain stakeholder buy-in from the start and develop a sense of ownership. Similarly, it is critical to understand the information water managers need to make decisions so that tools such as this can be designed to meet their needs. Incorporating these aspects into the DSS development process would likely have improved the overall product and its utility.

2.4 Decision-Support Tool for Assessing Watershed-scale Salmonid Habitat Recovery in the Lewis River (Washington)

(Unless otherwise stated, the information in this summary was obtained during an interview with Ashley Steel, U.S. Forest Service [USFS], on March 7, 2013.)

2.4.1 Overview of Decision Support System

A DSS was designed for and applied to the Lewis River that links watershed process, sediment routing and habitat and fish species response models to evaluate and compare potential management alternatives for salmonid habitat recovery.

2.4.2 Decision Support System Development

In the early 2000s the Willamette-Lower Columbia Technical Review Team (WLCTRT), a task force assembled by the National Oceanic and Atmospheric Administration (NOAA) and composed of federal, state and university representatives, was charged with developing restoration plans focused on salmonid recovery for all watersheds in the Lower Columbia Basin. The idea emerged to conduct a case study that could serve as an example of how to integrate multiple models to inform habitat recovery planning and make restoration decisions.

The Lewis River was selected for application of the case study because it contains a mix of the issues confronting the watersheds in the Lower Columbia River: it is the only watershed to contain all races of listed salmon and steelhead; it contains habitat types and land ownerships representative of the Lower Columbia; and its current management environment (e.g., dam relicensing, ongoing salmonid conservation and recovery planning) was conducive to a case study (Steel et al. 2007).

Funding from NOAA's research arm supported the development of this case study. Three full-time NOAA employees worked on the case study, as well as three to four contractor staff. The case study took approximately four years to complete, of which the majority of the time was spent developing a process for DSS development. Essentially the case study team created a framework for the decision-support tool, including designing a strategy, determining how to evaluate outcomes and linking the various components. Most of the components already existed, but a few had to be developed. Specifically, a contractor was hired to route the sediment down the river and the economic models had to be developed. Similarly, most data were available, though a small amount had to be collected to calibrate the sediment model and limited watershed evaluation and stream survey work was required.

The Lewis River decision-support tool was intended to evaluate alternative watershed-scale management strategies by predicting and allowing comparisons of the future landscapes under each alternative. The case study team selected six management alternatives for the Lewis River, based on a hypothetical budget of approximately $2 million. The management alternatives included an expert-opinion scenario developed by a small group based on their knowledge of watershed processes and the Lewis River watershed in particular. The alternatives can be summarized as: (1) removing barriers or upgrading fish passage; (2) removing barriers and protecting riparian habitat; (3) removing barriers and decommissioning roads on federal lands; (4) using the Ecosystem

Diagnosis and Treatment (EDT) model to identify restoration and protection actions; (5) using landscape screens (sediment, hydrology and riparian condition) to identify subwatersheds with impairments; and (6) using expert knowledge to determine best areas for restoration and preservation. For each strategy, specific actions were identified and spatially located (Steel et al. 2007).

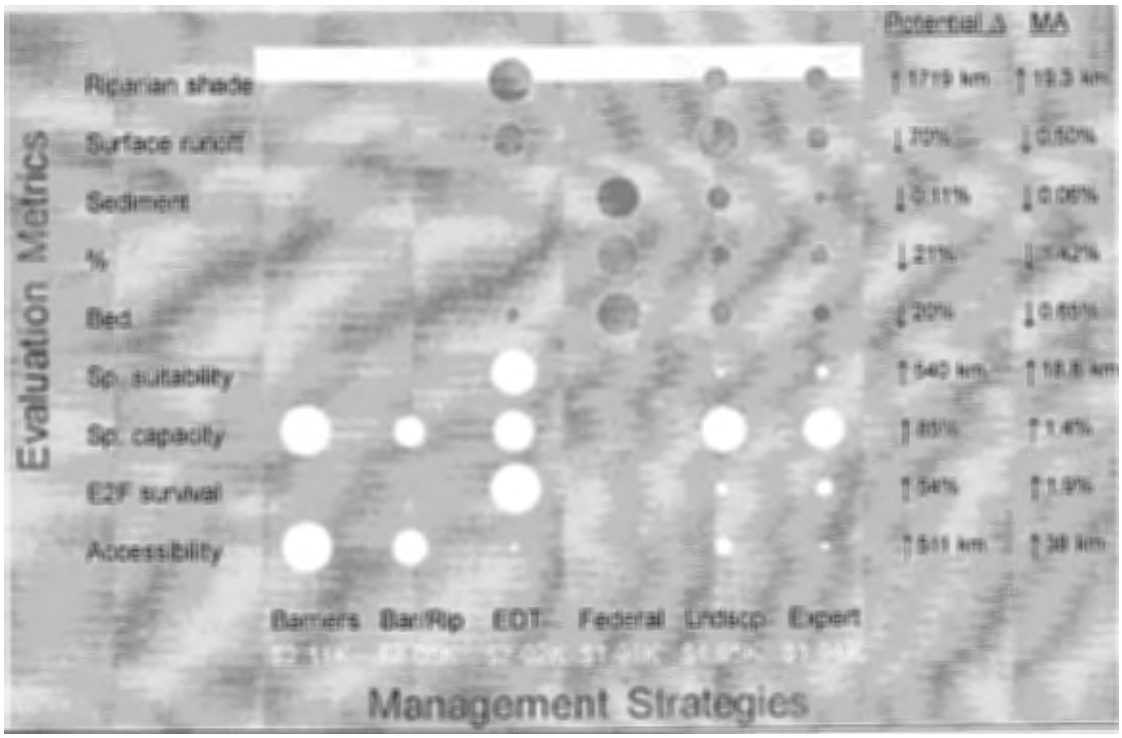
After all data were generated for the base scenarios or modified for the potential conservation strategies, the case study team ran watershed process models, a routing model and habitat and fish response models on the original or modified datasets. For each strategy, key physical processes (e.g., sediment delivery, water and wood) were modeled to predict in-stream conditions. These conditions were used to model species-specific spawning habitat suitability for winter and summer steelhead, fall and spring Chinook salmon, chum salmon, spawner capacity for Chinook salmon, and egg-to-fry survival for steelhead, Chinook and coho salmon (Fullerton et al. 2009). Most components of the tool are transportable to other systems. Results were reach-specific and summary metrics were produced to allow comparisons across management alternatives (Steel et al. 2007; see ***Figure 1***).

Input was obtained through presentations to the WLCTRT (approximately once a month) and expert panels (for the landscape and expert knowledge alternatives). While the expert input was informative for developing the restoration designs, preparing the maps and materials for their review took considerable time and effort. There was no public involvement and no public meetings during development of the decision-support tool; however, representatives from specific interest and user groups were consulted and many were part of the expert panels.

2.4.3 Decision Support System Implementation

The Lewis River decision-support tool was developed as a case study to demonstrate how to use multiple models (some competing, some complementary) to evaluate habitat management scenarios and was not specifically developed for on-the-ground implementation on the Lewis River. It was also not intended to write recovery plans or make decisions for managers, but instead to be used as a management tool to inform those efforts. There were internal disagreements over competing restoration approaches and this tool provides a way to compare those approaches side by side, to use information from multiple sources to make a robust decision, and to facilitate more objective discussions. It allows trade-offs to be explicitly and transparently considered, both in terms of spatial allocations of funds and benefits to particular species or habitat types (Steel et al. 2007).

The DSS influenced the development of watershed recovery plans in the Willamette-Lower Columbia Basin, as well as approaches in other watersheds such as Puget Sound. It led to the selection of a stronger, multi-model approach for several other watersheds. The DSS was applied to a watershed planning project in the upper Lewis River watershed above the dams. Seven management strategies were evaluated to determine the best use of the restoration funding (Aquatics Fund from settlement agreement for dam relicensing) to benefit anadromous fish and their habitats (Fullerton et al. 2009). In this instance, the DSS was used to inform restoration funding decisions.



Courtesy of Ashley Steel.

Note: Potential Δ represents the area needing improvement and MA represents the maximum improvement achievable with the best option.

FIGURE 1: EVALUATION METRIC RESULTS FOR SIX MANAGEMENT STRATEGIES IN LEWIS RIVER DECISION SUPPORT SYSTEM

2.4.4 Lessons Learned

A lesson learned from this process was not to underestimate the amount of time required for the DSS development process, as well as to obtain the necessary external input during the development process. In order to obtain expert input, materials and maps had to be prepared in advance and the time for presentations and reviews had to be factored into the schedule.

2.5 Development of a Decision Support Tool for Evaluating Operations of the R.L. Harris Dam on the Tallapoosa River (Alabama)

(Unless otherwise stated, the information in this summary was obtained during an interview with Elise Irwin, USGS, on March 8, 2013.)

2.5.1 Overview of the Decision Support System

This DSS established prescriptive flow regimes for a variety of stakeholder values, including hydropower production, recreational boater weekends (October) and protection of ecological resources (i.e., spawning windows). The Tallapoosa River DSS is an example of how to incorporate stakeholder objectives and values into decisions regarding flow modifications in a regulated river system.

2.5.2 Decision Support System Development

The Tallapoosa River in east central Alabama is a priority for aquatic conservation. One of the highest-quality segments of natural habitat was threatened with destruction due to daily low flows that dried the river bed, extreme flow variation from floods to trickles, and daily temperature changes resulting from pulsed water releases for hydropower generation.

A workshop was convened of all stakeholders having an interest in establishing an AM plan for the Tallapoosa River below the R.L. Harris Dam to improve habitat conditions. Participants engaged in an open discussion for building consensus on management objectives and values. Suggested objectives were judged in an electronic poll by one representative from 23 participating groups.

Through the facilitated workshops, stakeholders arrived at ten fundamental objectives representative of all interest groups; however, many of the objectives were in conflict. The primary conflict involved maximizing hydropower production versus improving biodiversity and downstream boating opportunities. These competing stakeholder objectives were incorporated into a decision support framework. A Bayesian network was constructed for use as a decision support model (Kennedy et al. n.d.). Tradeoffs among objectives were needed to create a starting point for development of alternative management actions.

Modeled decisions included four alternative flow regimes, the provision of spawning windows (periods during which flow is minimized to increase spawning success), and increased weekend flows in October for improved recreational boating opportunities. Relations between flow and system response were modeled using probabilistic dependencies based on empirical data whereas the relationship between stakeholder satisfaction and system response was determined based on stakeholder opinion (Kennedy et al. n.d.). Management alternatives were developed for each of the three main decision points: four alternative daily flow patterns, spawning window options, and two boating flow options. The resulting models are used to predict outcomes of future flow manipulations which then are compared with actual flows to facilitate learning.

Development of the flow regime model took approximately one year and involved staff from public agencies (i.e., three individuals working part-time for the USGS), utility company staff and state agency staff. Significant funding for the project came from Alabama Power.

Stakeholders developed a governance structure: the R.L. Harris Stakeholder Board. Special care was taken to be as inclusive as possible so that all groups and individuals with an interest in the system could have a part in the management decisions. The Board includes representatives from federal, state and local agencies, conservation groups, river-boating and sport fishing groups, property owners, and Alabama Power. Equity in stakeholder representation was sought in order to avoid skewed voting from over-representation of any one group or perspective. In development of the Board's Charter, a provision was included that does not allow previous decisions to be revisited. Also attendance at meetings is a required; if a board member misses two meetings they can be removed.

The governance structure developed by the stakeholders allowed for the creation of Technical Advisory Groups. These groups serve in an advisory capacity and report to the Board so appropriate decisions are made. A monitoring program was developed based on many of the uncertainties contained in the decision support model (Kennedy et al. n.d.).

2.5.3 Decision Support System Implementation

Alabama Power staff makes the day-to-day decisions regarding which flow regime is applicable to dam operations per constraints of the plan hypothesized to meet stakeholder objectives. Because of minimal violations, the Technical Committees of the R.L. Harris Stakeholder Board do not meet on annual basis, but rather as conditions require. The USGS has an independent stream gage and can independently verify compliance with the plan. One aspect of the plan that could be better implemented is tracking the satisfaction of stakeholders.

2.5.4 Lessons Learned

1) **Keep the end-in-mind:** What does restoration mean? The framework of the DSS was tied to management objectives and quantitative metrics were used to measure success.
2) **Structured decision-making:** The principles of structured decision-making were utilized to establish a restoration plan and guide implementation. Both fundamental objectives and means objectives were recognized in the planning process.
3) **Stakeholder engagement:** All stakeholders were involved all in DSS development and objective-based planning was used to bring the group together.
4) **Models:** The models used in the DSS were simple and means objectives were tied to some probability of occurrence.

2.6 Structured Decision-Making to Help Implement a Precautionary Approach to Endangered Species Management (Cultus Lake Sockeye Salmon – Fraser River System, Southwestern British Columbia)

(Unless otherwise stated, the information in this summary was obtained during an interview with Robin Gregory, Decision Research, on March 8, 2013.)

2.6.1 Overview of the Decision Support Summary

The structured decision-making process utilized to facilitate decision-making for increasing populations of the endangered Cultus Lake sockeye salmon consisted of a series of three facilitated workshops, development of management objectives, performance measures, and a predictive simulation model. Additionally, the DSS involved creation of alternative management actions using an iterative process designed to reach agreement among workshop participants concerning a mix of management alternatives.

2.6.2 Decision Support Summary Development

After it was determined by the federal minister not to formally list the Cultus Lake sockeye salmon with protective status, the Canadian Department of Fisheries and Oceans (DFO) made a decision to engage stakeholders with a structured decision-making (SDM) process to develop management options. The overall goal was to develop a plan that would maximize conservation while allowing stakeholders to enjoy the natural resources of Cultus Lake. The DFO invited representatives from stakeholder groups to participate in the SDM process and a 10-12-person consultative committee was formed that included representatives from commercial fishing interests, recreational fishing interests, conservation groups, the province of British Columbia and DFO managers (see Gregory and Long 2009). Members of the general public were not invited to participate because of the short time-frame available to implement the SDM process and because of other means available for the public to provide input. Committee members participated in a series of three facilitated workshops over approximately a one-month period. Committee members desired to develop a decision-making framework that would address both short- and long-term management plans (covering the full 4-year Cultus Lake sockeye salmon life-cycle). While there was some initial pushback from scientists and policy makers because of the new management approach, all committee members bought into the SDM process during the conduct of the three workshops.

During the first workshop, committee members defined objectives and performance measures around four primary objectives: conservation, cost, catch, and employment (Gregory and Long 2009). Performance measures were used to "operationalize" objectives and assist in the choice among management actions. A simulation model, led by staff from the DFO, was used to estimate the consequences of each alternative. Gregory indicated the SDM process was iterative as committee members refined alternative management actions during the second and third workshops based on their predicted performance and included exploitation rates for Cultus stocks, differential late harvest exploitation rate restrictions, fishery location options, enhancement options for Cultus Lake sockeye (hatchery fish), and freshwater habitat enhancement options (e.g., removal of Northern Pike minnow and invasive species control). A key aspect of the SDM process was the continued refinement of alternative management actions.

Committee members agreed the SDM process introduced rigor into deliberations regarding objectives, management options, and tradeoffs as part of the precautionary approach to management of the Cultus Lake sockeye. The committee agreed on freshwater projects best suited for conserving Cultus Lake sockeye and salmon enhancement levels. The committee did not come to an agreement on a commercial exploitation rate for late-run Fraser sockeye within the allotted time period; however, during subsequent conversations the SDM framework was used to help establish a rate. The need for an ongoing planning process beyond year 2006 and the consideration of other interests (e.g., First Nations cultural impacts, tourism) was generally recognized during the three workshops.

2.6.3 Decision Support System Implementation

The structured decision-making process developed for the endangered Cultus Lake sockeye salmon influenced policy with regard to management of this endangered species. Future committee deliberations were not convened as the responsibilities were satisfactorily managed internally by DFO. Additionally, results of this process have served as an example of how a SDM process can be developed to meet the objectives of involved stakeholders within a relatively short time period. This effort was considered a pilot study with the thought that if a plan could be prepared using SDM techniques under such severe time constraints and financial pressure, the process would be useful for other natural resource management situations.

2.6.4 Lessons Learned

1) **Stakeholder involvement:** In this example, all parties were included in the development of the DSS so that key concerns could be addressed.
2) **Broad range of management actions:** A broad range of management actions was developed to create a plan that would be acceptable to a broad range of interest groups.
3) **Precautionary actions:** Precautionary actions were explicitly considered, as appropriate, for avoiding undesirable outcomes.
4) **Management of uncertainty:** Both biological and ecological response uncertainties were accounted for during implementation of the SDM process.
5) **Information needs and data gaps:** The SDM approach helps to identify data gaps and, perhaps most importantly, information that is unnecessary for informing the development of research and monitoring programs.
6) **Transparency:** The SDM approach can provide a transparent process for documenting decision-making.

2.7 IBIS Environmental Decision Support System for Ramsar Wetland Systems in New South Wales and Decision-Support Tool for Snowy River Rehabilitation (Australia)

(Unless otherwise stated, the information in this summary was obtained during an interview with Carmel Pollino, Australian Commonwealth Scientific and Industrial Research Organisation [CSIRO], on March 14, 2013.)

2.7.1 IBIS Environmental Decision Support System for Ramsar Wetlands in New South Wales

2.7.1.1 Overview of Decision Support System

The IBIS Environmental Decision Support System (EDSS) links hydrological and ecological models to determine the ecological impacts of potential environmental flow scenarios on three wetland systems.

2.7.1.2 Decision Support System Development

Three Ramsar Convention Wetlands of International Importance (Ramsar Wetlands) are located at the bottom of catchments in the Murray-Darling Basin in New South Wales (NSW): Gwydir Wetlands, Macquarie Marshes and Narran Lakes. The Murray-Darling Basin is highly developed and changes in flow regimes have detrimentally affected the wetlands. Approximately ten years ago, plans were developed for sharing water among the users in the basin; however, these plans were expiring and new plans had to be negotiated. The government of NSW decided to put in place DSSs that integrated different models to determine the ecological impacts of potential environmental flow scenarios on the three wetlands. Funding was provided by the Commonwealth of Australia (Commonwealth), but the program was managed by the NSW government.

In Australia, water management is performed at the catchment scale via Catchment Management Authority (CMA) committees, whereas long-term water resource planning is conducted by the state government offices. The state initiated and managed the DSS program, but the CMA was very wary because of issues between the two institutions. Workshops were held within the catchments but the toxic relationship between the two entities made this very difficult. As a result, the primary parties engaged in DSS development were the NSW representatives, consultants and Commonwealth planners. The state government did not believe they had time to include stakeholders in the development of the DSS thus there was no public engagement.

Development of the IBIS EDSS began with a prototype phase to design the EDSS and determine the questions it was intended to answer. The prototype phase took eight months, during which one person was dedicated full-time, one half-time and two at 20 percent. Initially the focus of the EDSS was on annual flow deliveries, but after the prototype was developed the focus shifted to long-term planning (i.e., 100+ year flow scenarios) following disagreements on its intended purpose and scale. The EDSS was completed within two years of initiation. The team for developing the full EDSS included a post-doctoral candidate (50%), coder (40%), programmer (40%) and manager/model designer (20%), which was not sufficient.

The IBIS EDSS links outputs from hydrological models that produce daily time series of inundation area, flow and volume to Bayesian network ecological response models representing important ecological functions, vegetation species and communities and waterbird and fish species. The three applications of the EDSS range from simple habitat conditions models (Gwydir Wetlands) to a more detailed, mechanistic model of the factors affecting recruitment of waterbird fledglings (Narran Lakes) (Merritt et al. 2010). External consultants developed the hydrological models whereas the ecological models were developed by in-house staff.

2.7.1.3 Decision Support System Implementation

The primary user of the EDSS is the NSW Department of Environment, Climate Change and Water who compares scenarios relating water delivery (volume and timing) to ecological outcomes to inform decisions (Merritt et al. 2010). In keeping with its intended use, the EDSS is not used for decision-making on an annual basis, but rather has been used for evaluating scenarios at the basin scale. In 2007 the Water Act was passed which requires water management plans at the basin scale. The rules set forth in these basin plans are then translated down to individual catchments. The EDSS is part of the basin scale and is used to provide advice to the Commonwealth on the ecological benefits of environmental flows to wetlands. The Murray-Darling Basin plan was signed in 2012 and the next step is to develop catchment plans. Over the next three to four years it is anticipated that the EDSS will be used in a more dynamic way to evaluate ecological outcomes. Significant time and resources were invested in development of the EDSS and the department is committed to its use, while the CMAs remain wary because of concerns regarding uncertainties associated with inundation and ecological modeling.

2.7.1.4 Decision Support System Maintenance and Updates

The EDSS is a modular system composed of an external hydrologic model, a simplistic hydrodynamic model, an inundation model and ecological response models. The hydrologic model is continuously updated by the NSW government. The ecological response models can be updated, but it is not as easy and has not yet been performed. An individual within the NSW government has the sole responsibility of managing and maintaining the EDSS in order to maintain version control. (Note: This individual is now a part-time governmental employee, raising concerns about institutional memory of the EDSS.)

2.7.2 Decision-Support Tool for Snowy River Rehabilitation

2.7.2.1 Overview of Decision Support System

The Snowy tool is a Bayesian network designed to link hydraulic modeling output to ecological response models such that the outcomes of river rehabilitation activities can be evaluated.

2.7.2.2 Decision Support System Development

The Snowy River, located in NSW and Victoria, has experienced significant declines over the past 50 years due to impacts from a dam located at its headwaters. Up to 90 percent of flows have been extracted from the system and pumped into the Murray-Darling Basin and large quantities of

sediment have accumulated in the river below the dam. Additionally, riparian vegetation along the river has been removed due to extensive agricultural operations in the watershed. Recently strong emphasis has been placed on better managing flows, which are now approximately 25 percent of their original volume. The Snowy Rehabilitation Project, involving the Victorian government and other regional bodies, resulted in funding for rehabilitation works in the Lower Snowy such as large woody debris (LWD) placement.

The DSS (Snowy tool) was initiated by the Victorian government, which provided the funding, with management by the Victorian East Gippsland CMA. As part of the rehabilitation project, significant scientific research and modeling, particularly hydrodynamic modeling, had already been conducted. The tool was intended to be an integrated model composed of a series of sub-models, designed to assess the cumulative outcomes and risks of implementing different management activities. Activities included riparian vegetation management, management of vegetation on in-channel benches and installation of LWD in channel. The DSS was intended to predict the outcomes of these activities on scour holes for fish habitat and migration, occurrence of overbank inundation, avulsion likelihood and bench and bank stability (Glendining and Pollino 2009). For example, the DSS would be used to inform CMA decisions about LWD placement, given stakeholder concerns such as the potential for the debris to block gulches and inundate farmland.

Originally a consulting company was hired to use the hydrodynamic models to design LWD placement sites; however, the options they developed were not feasible. Thus significant pressure was placed on the ultimate DSS design team to develop a DSS within a three-month period. Though significant modeling and scientific research had already been performed, no ecological research was conducted, leaving a major data gap.

The tool is a Bayesian network (as opposed to a software interface in the case of the IBIS EDSS) that incorporates data from the hydraulic model (HEC-RAS), expert opinion and a set of ecological response models (Glendining and Pollino 2009). The components of the DSS were simplistic and include vegetation on banks and benches, inundation and LWD. Riparian vegetation management and LWD placement were the only management actions evaluated. The fish model was shelved because there was insufficient data. The sub-models were very subjective and based on limited information, and because of the different scales, flow regimes and types of management actions tested in the physical modeling studies, they could not be integrated (Glendining and Pollino 2009).

2.7.2.3 Decision Support System Implementation

Because of the limitations described above, the Snowy tool was not implemented and probably will never be updated. Placement of LWD had already begun before the DSS was completed; however, the hydrodynamic modeling component of the DSS did inform the design. The tool succeeded in embedding existing knowledge within a model framework, but did not produce any new information.

2.7.3 Lessons Learned

1) **Scoping:** Scoping of the DSS is essential; determining the scale of the DSS (spatial, temporal), management activities and questions that need to be answered are essential first steps. The IBIS EDSS used a prototype to accomplish this essential component.

2) **Stakeholder engagement:** Stakeholder engagement in DSS development improves implementation success. Obtaining broad input early on makes implementing management actions easier because there are no surprises.
3) **Data gaps and scientific research:** Underlying scientific research is necessary for designing future monitoring programs. In the case of the Snowy River, glaring gaps in ecological understanding severely limited the success of the DSS. Conducting the underlying scientific studies can not only inform DSS development but also the design of monitoring programs.
4) **Decision support tools as guides:** Decision-making tools designed early on in project development can guide modeling and data collection through an integrated process (Glendining and Pollino 2009).

3 Relevance of Case Studies to Trinity River Restoration Program

Lessons learned from the case studies referenced above and applicable to the development of a DSS for TRRP are presented below. In the first section, similar and compatible components of each case study DSS are compared with a hypothetical TRRP DSS. In the next section a compiled list of lessons learned from the case studies is presented. Additionally, the lessons learned from a publication which reviewed a number of environmental DSSs (McIntosh et al. 2011), many of which are similar to those from the case study DSSs, are included. Finally, the third section provides a brief discussion of ongoing challenges with DSS development, adoption and maintenance.

3.1 Similar and Compatible Components

As noted in Section 2, the DSS case study examples were selected based on their relevance to the TRRP using several criteria, thus each have components similar to and compatible with a potential DSS for the TRRP. Below is a summary of the example DSS components most similar to the TRRP. In general, the example DSSs were simpler and had fewer components than the potential DSS for the TRRP (see Section 4.1).

- **Adaptive Management of Horseshoe Crab Harvest in Delaware Bay**: Designed to support multispecies management (i.e., horseshoe crabs and red knots) and the effects of harvest management actions on both species' populations.
- **Adaptive Harvest Management of Waterfowl**: Evaluates the effects of different harvest management actions on mallard duck stocks. Similar to the TRRP, a robust monitoring program and governance structure were in place prior to development of the DSS, which facilitated its implementation.
- **Spatially-Explicit Predictive Model for the Flint River**: Predicts the effects of hydrologic conditions on various fish species by linking a hydrologic model with a meta-population model. DSS also allows users to evaluate and compare the effects of different water management scenarios on fish species.
- **Salmonid Habitat Recovery on the Lewis River**: Most similar to the TRRP in terms of the ecosystem, species and habitat management issues and actions, and desired outcomes. Evaluates the effects of different salmonid recovery alternatives, each with multiple management actions, on ecosystem restoration goals.
- **Dam Operations on the Tallapoosa River**: Designed to prescribe flow regimes on the river to meet multiple fundamental objectives, which reflect competing uses including hydropower production, aquatic conservation (e.g., spawning windows) and recreation.
- **Cultus Lake Salmon Management**: Used a structured decision-making process to develop management actions for managing Cultus Lake salmon, given multiple and competing uses.
- **IBIS EDSS for Australian Wetlands**: Links hydrologic and ecologic models to evaluate the impacts of different flow scenarios in three wetland systems. DSS is used to inform basin-scale water management plans.
- **Snowy River Rehabilitation**: Some of the issues (e.g., reducing sediment, riparian vegetation management) and management actions (e.g., LWD placement) are similar to those on the Trinity River. Intended to be an integrated model composed of sub-models (e.g., hydraulic model, ecologic models).

3.2 Lessons Learned

3.2.1 Lessons Learned from Decision Support System Case Studies

Below are the primary lessons learned from the DSS case studies, organized by eight themes applicable to the TRRP. The example(s) from which the lesson learned came are identified in parentheses.

- Stakeholder engagement
  - Stakeholders should be involved in the development of the DSS to establish a sense of ownership and increase confidence in model output (AHM, Flint River, Tallapoosa River, IBIS, Cultus Lake)
  - Stakeholders should be involved in development of programmatic objectives to be addressed by the DSS (Horseshoe Crab-Red Knot, AHM)
  - DSS development can be used to bring stakeholders with differing views and opinions together by providing a means to objectively compare alternatives (Lewis River, Tallapoosa River, Cultus Lake)
- Simple design updated over time
  - Several examples developed a DSS prototype to evaluate functionality prior to launching a more robust system (Horseshoe Crab-Red Knot, Flint River, IBIS)
  - Keep it simple; utilize existing models and make arrangements to update over time to incorporate new learning (Horseshoe Crab-Red Knot, AHM, Tallapoosa River, Cultus Lake IBIS, Snowy River)
- Scoping of the DSS is essential
  - Identify specific questions that will be addressed by DSS so it is designed to meet end user's needs (all)
  - Intended end-use of the DSS should influence design and structure of framework (e.g., inform or drive decision-making) (all)
- Time to develop
  - In these examples, DSS development required anywhere from 30 days to 5 years. The bulk of the time was for structured meetings on objectives and to obtain approval of the models (including preparation) and scoping the DSS. In these examples there was not a focus on developing new models.
- Monitoring
  - Monitoring feedback is critical to success of the DSS. Additionally, the DSS can inform future research priorities by identifying data gaps and unnecessary information (for decision-making) (Horseshoe Crab-Red Knot, AHM, Tallapoosa River, Snowy River)
- Maintenance
  - Plan for long-term implementation (who will be responsible) (IBIS)
  - Avoid assigning sole responsibility to one individual (IBIS)
- Leadership
  - Need for a strong leader/champion to coordinate the overall effort (AHM)
- Governance
  - Need well-established governance structure (AHM)

3.2.2 Lessons Learned from Environmental Decision Support System Literature Review

In 2011, McIntosh et al. conducted a literature review of challenges and best practices of EDSSs. A summary of the lessons learned most applicable to the TRRP is presented below as a supplement to the lessons learned from the DSS case studies. There is a large degree of overlap between with the lessons learned from the case studies, confirming that the eight examples are representative of the larger set of DSSs sampled in McIntosh et al. Furthermore, McIntosh et al. provide corresponding recommendations to accompany the lessons learned, which are summarized below.

- Improving EDSS end user and stakeholder involvement
  - Whether broader stakeholder engagement matters materially to the success of the EDSS endeavor depends on the purpose and intended role of the EDSS.
    - Need to define the scope and extent of participatory activities at the beginning of the project so the investment in stakeholder engagement (if not necessary) does not become a drain on the budget.
    - If stakeholder engagement is deemed necessary, someone should be designated as the representative or champion.
  - Determine end users, stakeholders, clients, and others and their responsibilities of each at the beginning of EDSS development. Work with them to define what constitutes project success and consider whether an EDSS is the most cost-effective approach. Make sure the EDSS is developed to be end user-driven.
  - Provide stakeholders the opportunity to contribute to and challenge model assumptions before results are reported, thereby creating a sense of EDSS ownership.
  - Strive to include and communicate model-based uncertainties to users.
  - Discuss development timelines with users and provide feedback on their input in order to build trust and commitment. The use of a facilitator and prototypes may be required.
  - Eliciting information from the EDSS end user is an active process and may require social scientists and others to provide better understanding of the human factors involved in EDSS design.
- Improving EDSS adoption
  - Find a champion in the user organization to promote the EDSS beyond the technical staff to the policy staff.
  - Create a plan for continuity of the EDSS support that includes transition from development team to stakeholders and clients for adoption.
  - Actively build capacity using open-source and collaborative software tools to promote adoption and ensure user commitment.
  - Do not oversell the EDSS by using flashy technologies (graphical user interface or visualization tools) because it can lead to unrealistic stakeholder expectations. Be honest about system weaknesses and needed improvements.
  - Defining the problem or question to be addressed is the first and most fundamental stage of DSS development.
    - Agree on EDSS objectives and functionalities and implement strategies to achieve those that are easier and less costly to use and that can be easily updated.
  - Rely on simpler tool design and distribution of adequate documentation to make EDSS easier to use independently.

- Improving the EDSS development process
  - The resources required for developing successful EDSSs are easily underestimated during EDSS development and planning, with risks to the longevity of the EDSS.
    - Develop a business plan that explicitly defines expected costs and outcomes over the lifetime of the product (training, support, maintenance).
    - When an EDSS depends on one or a few developers for ongoing maintenance, it is less resilient to personnel changes.
  - Develop and maintain scoping documents that help in specifying issues raised and decisions made in communicating the information to all parties involved.
  - Develop EDSS tools incrementally using known technology (start simple and small).
    - Follow an iterative and evolutionary development approach to incorporate end user needs in the EDSS, instead of solely relying on software developer and scientist assumptions.
    - Base model selection on spatial and temporal scale and level of complexity required for problems, and to fit with end user decision strategies (also see Gibbs et al. 2012 for model selection and integration recommendations).
  - Develop a systematic way to ensure the accuracy of raw data.
  - Develop efficient ways to extract and combine data and/or develop simple or more highly aggregated models.
    - Generate data or estimate it where needed.

3.3 Ongoing Challenges

McIntosh et al. (2011) identified four main categories of challenges facing environmental DSS (EDSS) development and implementation:

1) Engagement challenges related to the quantity, quality and appropriateness of end user involvement in the development of the EDSS;
2) Adoption challenges related to the failure to use the EDSS as a result of factors ranging from lack of capacity to the characteristics of the system;
3) Business, cost and technology challenges related to making the EDSS sustainable in the long-term by understanding costs and using appropriate technology; and
4) Evaluation challenges related to defining and measuring the success of the EDSS.

The first three of these challenges were demonstrated by the DSS case studies presented earlier. One of the most common lessons learned was the importance of engaging stakeholders in DSS development from the start, if deemed appropriate. Stakeholder engagement can be one of the most time-consuming and expensive phases of DSS development, thus the appropriateness and extent of stakeholder participation should be determined early on and scoped carefully. Indeed, in the DSS case study examples where stakeholder participation was solicited, meetings to gain agreement on objectives and models were often the most time consuming phases of the DSS development process. In these cases an independent facilitator familiar with the principles of structured decision-making and AM was used to reduce conflict and expedite collaboration among stakeholders with divergent views. On the other hand, some of the case studies that did not include stakeholder engagement in DSS design and development learned of its importance later in the process.

The case studies highlighted the challenge of ensuring that the DSS is adopted and used for decision-making. Of the eight case studies, only four are currently being used for decision-making (i.e., Horseshoe crab harvest management, adaptive mallard harvest management, Tallapoosa River flow management and the IBIS EDSS for wetland flow management); the SDM process was used for one-time decision-making for Cultus Lake. Several of the example DSSs were developed as prototypes or pilot studies, and were not designed to be used for decision–making (i.e., Flint River, Lewis River); the Snowy River DSS tool was not implemented because there was insufficient ecological data to incorporate in the model and decisions needed to be made immediately. As part of the larger literature review Atkins observed that many agencies have developed DSSs as conceptual or pilot exercises over the past decade, but the prototypes have not actually been applied. Those that are being applied have fewer components and are much simpler than the DSS framework proposed for the TRRP.

The challenge of long-term sustainability was demonstrated in three of the DSS examples (i.e., Horseshoe crab harvest management, adaptive mallard harvest management and IBIS EDSS). The adaptive mallard harvest management DSS has been implemented for the longest period of time (17 years); it requires little ongoing maintenance and the budget is essentially limited to the costs of annual meetings. Similarly, the horseshoe crab harvest management DSS requires limited maintenance and its budget requirements are low; however, it is dependent on horseshoe crab trawl surveys, the funding of which is uncertain from year to year. Responsibility for maintaining the IBIS EDSS was given to one individual in order to maintain version control; however, this person is now part-time, putting the long-term sustainability of the IBIS EDSS at risk.

The challenge of defining and measuring the success of the DSS was not specifically discussed during the interviews. The success of the adaptive mallard harvest management DSS, widely regarded as the gold standard for AM programs, is attributed to a well-established governance structure and monitoring programs, agreed-upon objectives and models and transparent management decisions.

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4 Implementation of a Potential Decision Support System for Trinity River Restoration Program

Van Delden (2011) describes a generic process for developing a DSS, in which the first three steps are: (1) defining the scope, (2) selecting the models and (3) integrating the models (Appendix B). As part of defining the scope, the components of the DSS are determined. The Decision Support System Framework described in Appendix H of the Phase I Report (SAB 2013) outlines the primary components of a DSS for the TRRP as:

1) Stakeholder objectives
2) Management alternatives
3) An integrated suite of models and
4) Objective-driven monitoring

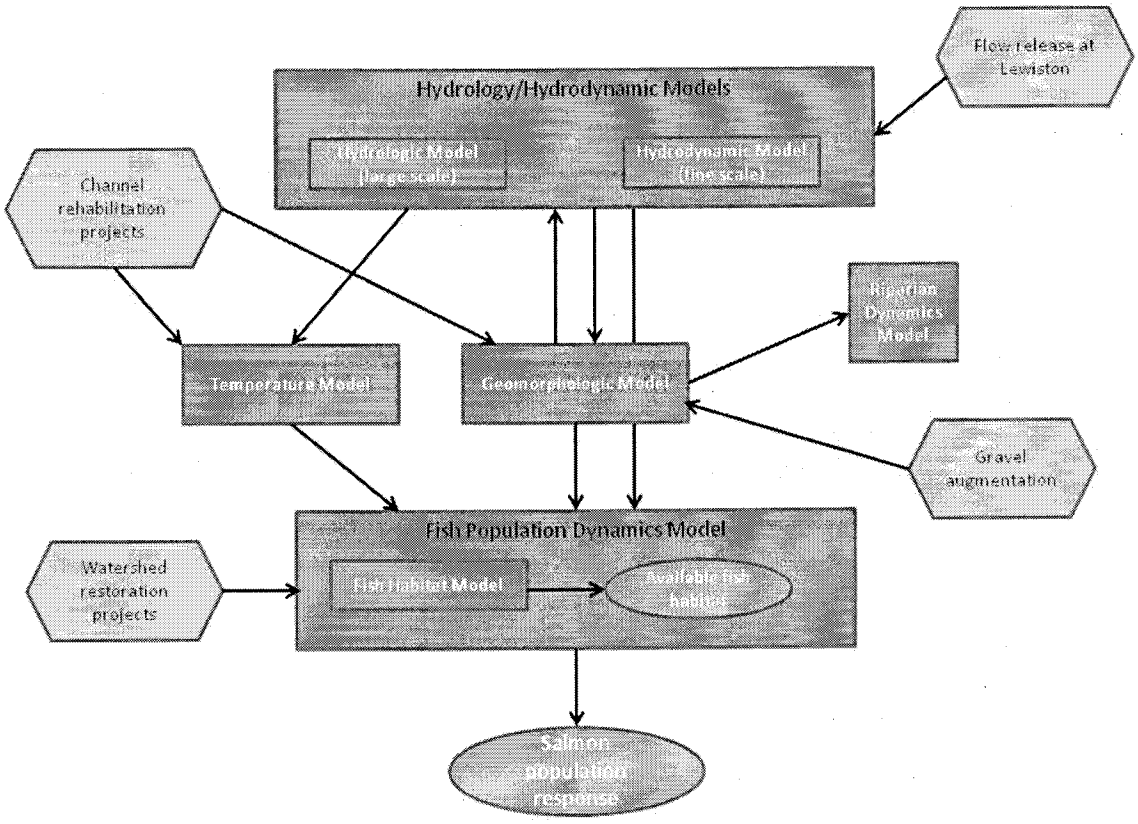
The objectives of the TRRP are described in the Integrated Assessment Plan (TRRP and ESSA Technologies Ltd. 2009), but would be clarified and quantified through development of a DSS. The four management alternatives are well-defined in the Record of Decision (ROD) and provide the context for the questions to be addressed by the DSS. For this review, Atkins focused on the third component, an integrated suite of models. Atkins conducted interviews with TRRP staff on the current status of the model components and used the information from these interviews to develop potential implementation scenarios as described in the sections below.

4.1 Components of Decision Support System for Trinity River Restoration Program

The SAB's DSS framework comprises the following model components:

1) Hydrology/hydrodynamics
2) Morphodynamics
3) Temperature
4) Riparian vegetation
5) Fish population dynamics
6) Water management

The linkages between the model components and the four management actions in the DSS framework are illustrated in ***Figure 2***. In Appendix H of the Phase I Report, the SAB described the current status of model development for each of the model components, and provided their recommendations on which model(s) should be selected for the DSS. Atkins conducted interviews with model users and developers to verify the model status and data needs and obtain their input on the most appropriate model(s) to use in the DSS. The model component options are outlined in Appendix B and notes from these interviews are included as Appendix C.



Legend:
Model components blue and brown rectangles
Management actions green hexagons
Key model outputs purple ovals

FIGURE 2: MODEL COMPONENTS, MANAGEMENT ACTIONS AND KEY MODEL OUTPUTS FOR TRRP DSS

The model options within each component are in varying stages of development; the fish population dynamics and water management components are the only two not yet developed for the Trinity River. A fish production model is under development for the Klamath River and following its completion, will be applied to the Trinity River. To facilitate DSS planning efforts, the TRRP Fish Work Group outlined three levels of progressive model development ("Development of a Salmonid Production Model for the Trinity River", March 8, 2013). These three levels were further subdivided into intermediate steps for the purpose of developing implementation scenarios:

- Level 1: Life-cycle model for spring and fall Chinook, excluding the freshwater rearing of the yearling life history component
  - Level A: Ocean-type Chinook
  - Level B: Add upstream adult migration model
  - Level C: Add ocean component
- Level 2: Year around river habitat model with overwinter rearing, incorporating coho salmon and stream type Chinook salmon overwintering life stage
  - Level D: Expanded flow-habitat information downstream of North Fork
  - Level E: Add overwinter rearing (stream-type Chinook, coho)
- Level 3: Multi-species approach (other anadromous fish) plus predation and competition
  - Level F: Add steelhead and lamprey

During the interviews, Atkins solicited input on the minimal requirements of each model for the DSS, as well as rough estimates of the cost and time required. This input was used to develop three potential DSS implementation scenarios for presentation to the TMC as described below.

4.2 Implementation Scenarios

The following three tables detail the three scenarios, including the models, data needs, assumptions, timeframe and budget. The budgets and timeframes are rough estimates for discussion purposes only. One underlying assumption in all scenarios is that the Klamath River fish production model will continue to be developed and that the Trinity River model will be built upon it. In each scenario the fish production model is the primary variable because it is the only model that is still being developed. Application of the fish production model to the Trinity River assumes that partner agencies will provide their data for use in the model. The water management model component is not included in these basic scenarios as several staff interviewed questioned its value as a component of the DSS model.

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*There may be overlap between the budget estimates for Stream Salmonid Simulator (SSS) model development/application to Trinity River and those for new data development.
**Text in red indicates a change from the previous scenario(s).

TABLE 1: SCENARIO 1

Model Component	Needs	Assumptions/Comments	Timeframe	Budget Estimates
Fish Population Dynamics • Ocean-type Chinook SSS model (Level 1, Sub-level A) o Spring and fall Chinook o Extends to Weitchpec where it will link to Klamath SSS model o No new habitat modeling below North Fork (use meso-habitat typing and combination of Trinity and Klamath 2-D modeling as starting point)	Continuation of Klamath SSS development and application to Trinity Development of meso-habitat layer for 40 miles Topographic/habitat field data from North Fork to Weitchpec Development of meso-habitat layer for North Fork to Weitchpec	• Time and budget estimates are extremely rough • Klamath SSS model development will continue and Trinity will tier off of the Klamath model • **There will be a significant time commitment by TRRP partner staff, including compiling datasets into necessary formats, that has not been factored in to these estimates** • Does not include time for data organization or DSS administration	1 year for data collection; 2 years total	$279,000 - $342,000 (depending on application of cost-shared burden rate) $92,000 for new data development
Temperature • StreamTemp	Modification to 1-2 day timestep	"Clunkiness" would prohibit running many scenarios (e.g., springtime tributary temperatures)	1 week	$6,000 (1 week of contractor time @ $150/hour, approximated)
Riparian • TARGETS	Update with new data; programming; training	• TARGETS model has not been reviewed and was last applied in 2006 • Could be updated over time	5 months	$48,000 (2 months of contractor time @ $150/hour, approximated)
Hydraulic and Hydrologic • 1-D HEC-RAS supplemented by 2-D for 1-mile project segments (see below)	None; already being implemented	This approach is being used by the Design Team	2 months	No additional funds required
Morphodynamic • SRH-2D (with sediment transport) for 1-mile project segments	Add sediment transport	• This approach has been used by the Federal Design Team for two sites • Other models are available, but SRH-2D has most capability and modeler (USBR staff) support	1 month	$24,000 (1 month of USBR staff time @ $150/hour, approximated)
	TOTAL	• Assume all other model revisions occur during SSS timeframe • Assume staff working on other models (not SSS) are @ 100% for time purposes	**2 years**	**$449,000 - $512,000**

TABLE 2: SCENARIO 2

Model Component	Needs	Assumptions/Comments	Timeframe	Budget Estimates
Fish Population Dynamics • Upstream adult migration SSS model (Level 1, Sub-level B) o Includes all aspects of Sub-level A plus upstream adult migration	Continuation of Klamath SSS development and application to Trinity Parameterization for Trinity Incorporating submodel into larger model Development of meso-habitat layer for 40 miles Topographic/habitat field data from North Fork to Weitchpec Development of meso-habitat layer for North Fork to Weitchpec	• Time and budget estimates are extremely rough • Klamath SSS model development will continue and Trinity will tier off of the Klamath model • **There will be a significant time commitment by TRRP partner staff, including compiling datasets into necessary formats, that has not been factored in to these estimates** • Does not include time for data organization or DSS administration	1 year for data collection; 2 years total (for Sub-level A) plus 2 additional months	$279,000 - $342,000 (depending on application of cost-shared burden rate) (for Sub-level A) plus $15,000 $92,000 for new data development
Temperature • StreamTemp	Modification to 1-2 day timestep	"Clunkiness" would prohibit running many scenarios (e.g., springtime tributary temperatures)	1 week	$6,000 (1 week of contractor's time @ $150/hour, approximated)
Riparian • TARGETS	Update with new data; programming; training	• TARGETS model has not been reviewed and was last applied in 2006 • Could be updated over time	5 months	$48,000 (2 months of contractor's time @ $150/hour, approximated)
Hydraulic and Hydrologic • 1-D HEC-RAS supplemented by 2-D for 10-mile reaches (see below)			2 months	No additional funds required
Morphodynamic • SRH-2D (with sediment transport) for 10-mile reaches (to prioritize projects in context of one another)	Add sediment transport and run 10-mile reach models	• This approach has been used by the Federal Design Team for two sites • Other models are available, but SRH-2D has most capability and modeler support • The same tools would be used for developing the 10-mile reach model runs, but model developer (USBR staff) would need to do the work	1 month to add sediment transport; 3 months for 10-mile reach runs	$24,000 (1 month of USBR staff time @ $150/hour, approximated) plus $72,000 (3 months of USBR staff time) = $96,000 (total)
	TOTAL	• Assume all other model revisions occur during SSS timeframe • Assume staff working on other models (not SSS) are @ 100% for time purposes	**2 years and 2 months**	**$536,000 - $599,000**

TABLE 3: SCENARIO 3

Model Component	Needs	Assumptions/Comments	Timeframe	Budget Estimates
Fish Population Dynamics • Ocean component SSS model (Level 1, Sub-level C) o Includes all aspects of Sub-levels A and B, plus ocean component	Continuation of Klamath SSS development and application to Trinity Parameterization for Trinity Incorporating submodel into larger model Development of meso-habitat layer for 40 miles Topographic/habitat field data from North Fork to Weitchpec Development of meso-habitat layer for North Fork to Weitchpec Klamath/Trinity focused analysis of existing data	• Time and budget estimates are extremely rough • Klamath SSS model development will continue and Trinity will tier off of the Klamath model • **There will be a significant time commitment by TRRP partner staff, including compiling datasets into necessary formats, that has not been factored in to these estimates** • Does not include time for data organization or DSS administration • Most model development effort would be accomplished on the Klamath side if it is funded • Cohort reconstruction of fall Chinook and transferable to spring Chinook	1 year for data collection; 2 years and 2 months total (for Sub-level B) plus 1 additional month	$294,000 - $357,000 (depending on application of cost-shared burden rate) (for Sub-level B) plus $10,000 $108,000 for new data development
Temperature • StreamTemp or RMA2/11 (see Assumptions/Comments)	StreamTemp: Modification to 1-2 day timestep RMA2/11: Develop model	• "Clunkiness" would prohibit running many scenarios (e.g., springtime tributary temperatures) • May want to use RMA2/11 (sub-daily timestep) for diurnal variation	1 week	StreamTemp: $6,000 (1 week of contractor's time @ $150/hour, approximated) or RMA2/11: $100,000 for contractor's time
Riparian • SRH-2DV	Model needs to be developed for Trinity	Being developed by USBR team and Trinity timeline would need to accommodate USBR schedule	1 year	
Hydraulic and Hydrologic • 3-D hydraulics at site-specific 300-ft (average) design features	Additional model development	Would allow assessment of the effects of detailed elements (e.g., wood jam)	2 months	$48,000 (2 months of USBR staff time @ $150/hour, approximated)
Morphodynamic • SRH-2D (with sediment transport)	Add sediment transport	• This approach has been used by the Federal Design Team for two sites • Other models are available, but SRH-2D has most capability and modeler support	1 month	$24,000 (1 month of USBR staff time @ $150/hour, approximated)
	TOTAL	• Assume all other model revisions occur during SSS timeframe • Assume staff working on other models (not SSS) are @ 100% for time purposes	**2 years and 3 months**	**$490,000 - $553,000** **or** **$590,000 - $653,000 (with RMA2/11)**

6 Appendices

Appendix A Questions for Decision Support System Case Study Interviews
Appendix B Trinity River Restoration Program Decision Support System Presentation to Trinity Management Council (April 3, 2013)
Appendix C Notes from Interviews on Trinity River Restoration Program Model Components

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Appendix A: Questions for Decision Support System Case Study Interviews

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DSS Development:
Please provide a general description of the resource issue and the impetus for the DSS.

How was the DSS initiated?

Who was involved in developing and funding the DSS?

Please describe the process (and parties involved) for developing and gaining approval of the DSS.

What is the intended purpose and use of the DSS?

What was the timeframe for developing the DSS?

What models and tools were available prior to developing the DSS, and what new models and tools were required?

What are the components of the DSS?

DSS Implementation:
Is the DSS currently being implemented?

If not, what is delaying/impeding its implementation?

If so, how long has it been implemented?

What types of decisions is the DSS used for supporting?

Please describe the process for applying the DSS, including how information is transmitted, how the outputs are reviewed, who is involved and how are approved actions implemented.

Please describe the governance structure for your program in relation to the DSS. What are the roles and responsibilities? How is oversight of the DSS managed?

How is public input incorporated into the DSS and subsequent decision making? Are the results publicly available on a website?

DSS Maintenance and Updates:
What is the annual budget for maintaining the DSS?

Please describe the level of sustained management needed for maintaining and updating the DSS. How has new information from monitoring or other studies (to reduce uncertainties) been incorporated into updates of the DSS?

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Appendix B: Trinity River Restoration Program Decision Support System Presentation to Trinity Management Council (April 3, 2013)

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Appendix C: Notes from Interviews on Trinity River Restoration Program Model Components

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This appendix represents the results of nine phone interviews conducted with TRRP staff from March 12-20, 2013. These are the raw notes from those interviews and have not been processed. The information obtained from these interviews was used to develop the three implementation scenarios in Section 4.2.

Fish Production Model Notes (Joe Polos, Supervisory Fish Biologist, U.S. Fish and Wildlife Service Arcata Office)

- The model is being calibrated/validated over the next year
- The Trinity River is an input node to the model
- Would have to add Spring Chinook for Trinity (Klamath is only Fall Chinook)
- May need to take interim steps to get to full model (i.e., the full life-cycle model is developed later not as part of the base model)
- Model development scenarios
  - Level 1: Life-cycle model for spring and fall Chinook, excluding the freshwater rearing of the yearling life history component
  - Level 2: Year around river habitat model with overwinter rearing, incorporating coho salmon and stream type Chinook salmon overwintering life stage
  - Level 3: Multi-species approach (other anadromous fish) plus predation and competition
- Assumptions under each scenario:
  - Individuals that have developed SSS will be engaged to assist with developing the Trinity component of the model
  - It will be necessary for TRRP partner agencies to contribute to this effort, especially in compiling datasets that their respective agencies maintain
  - For datasets and models that are identified as available there will still be the need to compile and summarize the information in the proper formats to be incorporated into the model (Eric Peterson, data steward, will be responsible)
- Potential sub-level scenarios
  - Level 1
    - Level A. Ocean-type Chinook (need limited habitat data downstream of North Fork).
    - Level B. Add upstream adult migration model.
    - Level C. Add ocean component.
  - Level 2
    - Level D. Expanded flow-habitat information downstream of North Fork.
    - Level E. Add overwinter rearing (stream-type Chinook, coho).
  - Level 3
    - Level F. Add steelhead and lamprey.
- Minimal model to evaluate the two main restoration actions would include:
  - Temperature model – need approx. 12 cross-sections between North Fork and Klamath confluence
  - Flow-habitat relationship for lower river – collect data in one year for the range of flows needed (see data needs)
- Data needs
  - Limited field work between North Fork and confluence with the Klamath to inform habitat-flow relationships

Fish Habitat Model Notes (Thom Hardy, Chief Science Officer, Texas State University)

- No data below the North Fork (160 miles)
- Reviewed hydraulic calibration and simulation at 11 sites
- Have begun to validate the data by comparing predicted with observed
- Have preliminary equation for spawning, fry, rev. juveniles (predicted/observed)
- Basic models are very close to completion. Sometime this summer they will complete what they are currently doing (calibrating/validating) for 11 sites to extrapolate.
- Overlay predicted and observed in GIS
- QAQC – detailed data, procedure
- Could populate model
- SAB recommendations
  - Continue development and testing of predictive habitat models – already doing this, modeling spawning, fry, presmolt
  - Review and extend GRTS sampling – this is different than what is being done for the SSS model (need to talk to Damon, Russell, Nick)
  - Collecting additional flow-to-habitat data at higher flow levels – agree
- Can extrapolate from North Fork to mouth but sketchy/rough. Ramp up data collection at 6-8 sites downstream of North Fork.
- He is not concerned about the daily temperature model
- Sub-level fish production models
  - Level A (ocean-type Chinook) – extrapolate downriver with understanding that need to refine with more data over time
  - Level B (upstream adult migration model)
  - Level C (ocean component) – can be done relatively easily (black box)
- Summary
  - Most pieces are close for a first cut, but need to make caveats explicit and understood. Target error for reduction by collecting data (need to determine how many and which sites). Could be ready in 2 years.
- Next steps
  - Need conversation with Damon, Russell, Nick and Tom on time, resources, budget

Fish Production Model Notes (Russ Perry, Research Fisheries Biologist, U.S. Geological Survey Columbia River Research Laboratory; John Plumb (U.S. Geological Survey, Columbia River Research Laboratory); Joe Polos, (Joe Polos, Supervisory Fish Biologist, U.S. Fish and Wildlife Service Arcata Office); Damon Goodman (U.S. Fish and Wildlife Service); Nick Som (U.S. Fish and Wildlife Service)

- There was agreement on the three sub-levels (of the Fish Work Group's Level 1) as proposed.
- Assumptions and caveats that apply to all sub-levels below:
  - The estimated time, resources, and budget required are extremely rough and only intended to be used in the initial TMC discussion on the DSS.
  - The approach for applying SSS to the Trinity for these sub-levels has not yet been defined, much less the level of effort and cost required.
  - There is an underlying assumption that the Klamath SSS model development will continue and that the Trinity model will be tier off of the Klamath model. This will provide an economy to the TRRP since the structure and some of the sub-components (i.e., upstream fish movement) of the Klamath model will be in place to build upon. If the Klamath efforts do not continue, the costs to develop the Trinity component will likely be greater.
  - There will be a significant time commitment by TRRP partner staff to support this effort, including compilation of datasets maintained by TRRP partners into formats needed to support the model and model development.
- Sub-level A
  - It was clarified that this sub-level model will extend to Weitchpec, where it will be linked with the Klamath SSS model which goes to the ocean.
  - There was consensus the proposed Level 1 sub-level A represents the absolute minimum level fish production model needed for the DSS
  - Flow-to-habitat data needs
    - In the absence of new habitat modeling below the North Fork, the model could be built using meso-habitat typing and a combination of currently-available 2-D modeling from both the Trinity and Klamath, as noted below:
      - Google Earth, groundtruthing of meso-habitat typing
      - Below the North Fork the river is very different than the upper Trinity where Trinity habitat data were collected so these data are likely not useful to represent the lower Trinity River.
      - Mid- and lower Klamath data could be a starting point with the expectation that it would be replaced as more habitat work is done downstream in the future.
    - For additional data collection there would be a time lag between when money is allocated in the Federal budget and when data become available (potentially 2-3 years).
  - There was consensus that the sub-level A model represents a framework for moving forward, but teleconference participants cautioned that it may not be sufficient to support decision-making, primarily because of the lack of habitat modeling below the North Fork.
  - Timeline:
    - There was agreement that it would take approximately two years to develop the sub-level A from the current stage of development.

        - Additionally, the current flow-to-habitat data would need additional processing.
        - In addition to the habitat data, other datasets maintained by TRRP partners would need to be compiled to support the development of the Trinity component of SSS (see assumptions from Fish WG).
    - Cost:
        - USGS modelers: 2 FTEs at 50% level for 2 years = $279,000 to $342,000 depending on application of cost-shared burden rate
        - Data development: $92,000
        - Note: There may be some overlap between these two cost estimates
- Sub-level B
    - Additional costs/time for sub-level B (above and beyond sub-level A):
        - Parameterization for Trinity (Thom Hardy) = $10,000
        - Incorporating submodel into larger model (Russ Perry's group) = $5,000 (couple of weeks if in the appropriate format)
        - Total = $15,000 (1-2 months)
- Sub-level C (above and beyond sub-levels A and B)
    - The ocean component has been projected for the Klamath, but has not been funded yet.
    - This would be mostly Russ's and Joe's time to bring the existing model into the SSS.
    - Most of the model development effort could be accomplished on the Klamath side if it received funding and the sub-level C model version would require approximately $10,000 and one month's time after the Klamath work is done.
- Sub-level D
    - This was not discussed in-depth, but it would require significant additional data collection. The very rough cost estimate for collecting flow-to-habitat data at 11 sites in the lower Trinity River was approximately $500,000.

Temperature Model Notes (Rod Wittler, U.S. Bureau of Reclamation)

- Upstream watershed – don't have routing model. Have VIC but not WEEP (sp?). Don't have capability to get precipitation to reservoir.
- Trinity River Reservoir – HEC5Q (temperature/water quality model) is a good representation of the reservoir. Doesn't need to be updated now.
- Lewiston – CVO maintains full modeling capability and CVO models meet needs year to year. TRRP piggybacks on CVO models. Model for Lewiston (W2 model) done on a shoestring and ready for use.
- Two models for the river (both have hydrodynamic component to them):
  - 1) StreamTemp (SNTEMP) – long time of use, good record, well calibrated
    - Daily output (works on daily heat budget) – put in average temperature for 7 days (weekly input) and get daily output. Doesn't work for sub-daily.
    - Nodes = 1 day apart. Nodes closer with slower discharge – can't do. Nodes vary with discharge. Design for times when temperature is most important.
    - Would be adequate at Volkswagen to Chevy level fish production models.
  - 2) RMA2/11 (hydrodynamic/water quality) – only tracks temperature (RMA11), works well in upper reach, domain = Lewiston to the confluence with the Klamath, sub-daily
    - In house experience is nil – would need training/instructional time before running (2-3 years learning curve) (Note: Eric Peterson indicated Mike Deas would overhaul model and provide in-house training)
    - Created synthetic cross-sections from aerial photos for the lower 70 miles to match lower hydrodynamics. Some uncertainty but through calibration satisfied that output is reliable.
- There are two issues with tributaries:
  - Time of year when temps are most important and their impact
    - Springtime temps are difficult because of trib inputs
    - SNTEMP potentially better in the springtime
    - Could make improvements to do with tribs
    - Both models work well when tribs are not as important (fall)
  - Orientation of tribs in watershed (north facing vs. south facing)
    - Behave differently because of orientation, which is difficult to plug into the model
- Data needs
  - A more in-depth review of the data is needed if the temp models will be used beyond flow decision making. Also depends on where they are intended to be used.
  - Groundwater contributions should be further evaluated depending on the time of year.
  - Regarding supplementing riparian veg change studies with aerial photogrammetry surveys – Zedonis conducted a study in 1998 to calibrate SNTEMP and turn shading on and off to compare model results. There was very little difference (< 0.1 degF). Rod is not worried about the impacts of fringe vegetation on heat budget for either model.
- Summary
  - Current temperature models are used for flow decision making and Rod is comfortable with this use.
  - The basic building blocks are in place so once needs are known the models could be applied quickly.

- Potential scenarios
  (a) Use SNTEMP for Volks to Chevy fish production model scenarios. Would still need cross-sections from North Fork to confluence with Klamath. Any other data needs?
    a. Add-on: improvements for tribs?
  (b) Use RMA2/11 for Volks to Cadillac fish production model scenarios. Would still need cross-sections from North Fork to confluence with Klamath. Any other data needs? Would also need to factor in 2-3 years for learning curve.

StreamTemp Notes (Paul Zedonis, U.S. Bureau of Reclamation)

- The original SALMOD utilized SNTEMP. It was also used for developing the ROD flows.
- Refinements were made to adapt it to a Windows environment, allow graphing functions, etc. The refined version is called StreamTemp. It hasn't been refined since 2012.
  - It is very user friendly and transparent.
  - A daily model was created a few years ago
  - It can easily be modified to a 1-2 day timestep (~1 week of effort – Dwayne Goforth with Norman Doe Associates).
    - There would be many subroutines because the 1 day travel time would have to be repeatedly applied down the entire stretch of the river. "Clunky" and would prohibit running many scenarios (e.g., springtime trib temperature scenarios).
  - Already incorporates old empirical data on stream geometry from the 1990s that Mike Deas also used.
- Trib temps with snowmelt in the springtime are "a bear" with both StreamTemp and RMA 2/11.
- RMA 2/11 – huge, would take a while to understand, short timestep (but is that necessary?).
  - The influence of the channel rehab projects is greater because of a shorter timestep – run the model following channel rehab project.
  - Cross-sections are not a big deal and could use Google Earth to do – Klamath did this quickly
- His recommendation is to be consistent with the Klamath
  - He thought Klamath was going to use RBM10 but App H says they are using a combo of WRIMS and RMA11.

Riparian Model Notes (James Lee, Riparian Ecologist, Hoopa Valley Tribe)

- TARGETS
  - James has no experience applying and it has not been applied since 2006. There is limited documentation and it has not been reviewed; all models need to be reviewed eventually.
  - It is pretty simple, cross-section based, but a 2-D planform based model is needed.
  - TARGETS represents a minimal model, but it needs to be better documented and related to the annual monitoring work (last time this was done was WY2006). Estimated ~1-2 months of John Bair's time to update the model, primarily documentation and relating it to the morphological and riparian work that is going on. How has the monitoring supported (or not) the modeling that's been done?
  - James now has a copy of it. He is not sure if it would be better to revamp TARGETS or replace it with something more advanced like SRH-1DV.
  - Useful for flow scheduling but doesn't show succession.
  - Could start with TARGETS and add on over time.
- SRH-1DV
  - Both TARGETS and SRH-1DV have limited spatial and temporal scales in line with predicted purpose of predicting short-term responses of riparian vegetation to flow.
  - Vegetation component is not complete. Have to work out kinks in hydraulics and sedimentation.
- SRH-2D
  - SRH-2D could be used as a template to add vegetation (James likes this idea). Wouldn't be that different from updating TARGETS.
- CASIMIR-Vegetation
  - 2-D model
  - Currently being explored. Looks like it has a lot of applications, but James is still investigating.
  - Greater spatial (more detail) and temporal (broader range) scales and incorporates vegetation succession.
  - Resources required: 1 year of programmer's time to make the model software package. There are a lot of existing data so that is not a limitation.
- A "Cadillac" riparian vegetation model would predict the distribution, composition, etc. of vegetation on the floodplain over a long period of time. Planform. CASIMIR-Vegetation does this.
- Data gap = how vegetation and channel morphology interact over time for a ways out into the future.
- Scenario options
  - Start with revamping TARGETS and add on over time
  - Use SRH-1DV
  - Use SRH-2D as a template and add vegetation
  - Go for Cadillac version – CASIMIR-Vegetation

Hydraulic and Hydrodynamic Model Notes (DJ Bandrowski, Implementation Branch Chief, U.S. Bureau of Reclamation)

- HEC-RAS and SRH-2D are already in place
- HEC-RAS (1-D)
  - Full 40-mile river model
  - Utilized since 2006
  - Recently updated (draft released in 2012) with 2011 bathymetry and terrestrial topography.
- 2-D model
  - Design team is doing for 1-mile reaches
  - Used 2-D models since 2009 (SRH-2D/IRIC/FASTMECH/River 2-D).
    - From 2009-2011 2-D hydraulic models were used to varying degrees
    - From 2011-present their use is the norm
    - Relating hydraulics back to habitat conditions in terms of design alternatives
    - Using for almost every site
  - A 2-D model for the entire river is not applicable
- Design team has 4 design groups (HVT, Yurok, Federal, State). Different groups can use the models they find most appropriate.
- Agree with SAB recommendation to have a 1-D hydrologic model supplemented by a 2-D hydrodynamic model at selected sites (this is already being done). Agree with all SAB recommendations.
- There is a definite benefit to collecting data on preexisting habitat at sites to compare pre- and post-construction
  - Plans to do each year:
    - On the ground mapping surveys, prioritized for sites to be constructed in upcoming years
    - Update water surface data
- Potential scenario options
  - Take example 10-mile segment of river and use to prioritize projects in this segment by looking at them in context with one another. Run 10-mile reach models. These would require the same models/tools available but need an external person to look at the whole reach (Young Lai) – approx. 3 month effort.
  - Continue to use hydraulic models to select preferred alternatives (1-mile segments) – this is what is being done now (1 month for output).
  - Assess effects of a detailed element (wood jams) with 3-D model. Would require additional model development (external support). Also looking at safety/liability. Fish production doesn't apply at feature based (?)
  - Whole 40 miles – 2-D models not useful

Morphodynamic/Sediment Transport Model Notes (DJ Bandrowski, Implementation Branch Chief, U.S. Bureau of Reclamation)

- Morphodynamic modeling requires 2-D hydraulic model to assess the relationship of the bed to the hydraulics
- Used for channel rehabilitation and gravel augmentation decisions
- SRH-2D
  - Used at Lowden to look at the effects of augmentation downstream (channel geometry/topography) in 2011
  - In 2012 used SRH-2D to look at pool filling at Upper Junction City
  - Young Lai is incorporating lateral bank erosion and vertical bed change. Vertical and lateral migration and deposition. He is the only one who can do this. Done as a research project for Upper Junction City and will be part of the SRH-2D package.
  - The Federal design group is the only one that has used this but there is a plan to use morphodynamic models in the future and it may become the standard.
  - Can incorporate temperature and vegetation components into the SRH-2D
  - Can only use at 1-mile reach
  - There is a lot of variability compared to hydraulic models
- Have to use the same model or there will be too much variability. DJ recommends staying with SRH-2D (it has the most capability, is furthest along and can use Yong Lai).
- There is a 1-D component of sediment transport but it may not be applicable to the Trinity River and they are past this. (Ernie said SRH-1D available for entire system and SRH-2D could be used at selected sites)
- Potential scenario options
  - Can't run sediment transport
  - Approx. 1 month effort required to add sediment transport
  - Detailed 3-D model – would require few months of Yong Lai's time

WRIMS Notes (Nancy Parker, U.S. Bureau of Reclamation)

- Whether this is in the form of a spreadsheet or WRIMs model software is a personal preference. Either one would take a couple of hours (very easy)
- The software (Free Solver) exists; just need someone to run it.
- Would model from Lewiston to confluence with the Klamath
- Questions
  - What are the flows between the top and bottom of the system?
    - Baseline of current conditions based on historical data and other models (this exists)
  - What are the decisions that need to be made? (with a more sophisticated model)
    - Fish species of interest? Flows for those species? Erosion issues – flows to limit? Riverbed composition?
    - Differences with climate change to flows in the river (rainfall runoff) – route down the river
    - Water demand and storage – current and future management issues
    - These questions will determine whether a daily or monthly time step is needed
- Central Valley Operations are an input to the TRRP. If TRRP needs change it could complicate CVO.
- Data needs = inventory of gaging stations and their POR. The data that exist and the questions to be answered determine the type of model to develop. If you want more questions to be answered, more data may be needed.

Data Development Costs (Eric Peterson, TRRP Data Steward, U.S. Bureau of Reclamation)

- Eric developed a spreadsheet of costs for sub-levels A-C that are over and above existing resources and current levels of effort. This does not include data organization for SSS model or DSS administration.
  - It does not include time to compile and summarize data from various agencies in the proper formats to be incorporated into the SSS model. There are a lot of political challenges in acquiring these data and the time required for reorganizing the data is very difficult to predict and expected to vary a lot. He guessed approx. $10,000 of staff time per input dataset.
  - Assume the figures translate to $100/hour.
  - Outmigrants – have sufficient data for the mainstem; don't need trib data at all
  - For sub-level C (adult migration model) the model would need to be built for upstream migration, but costs are not included because this spreadsheet only covers data development.
  - For the adult migration model, temperatures may be more difficult to model in the summer so a sub-daily model (RMA2/11) may be needed for people to have faith in the decision support provided.
    - Mike Deas could overhaul and give training so in-house staff can run
  - Costs significantly rise with sub-level D (down river modeling)

Scenarios (see tables for more details)

- Scenario 1
  - Fish production = Level A (Ocean-type Chinook) with extrapolation and additional flow-habitat data collection at 6-8 sites downstream of North Fork (1 year for data collection; 2 years total) ($92,000 for data acquisition in Eric's estimate)
  - Temperature = StreamTemp (~1 week of contractor time) plus 12 cross-sections between North Fork and confluence
  - Riparian = revamp TARGETS (1-2 months)
  - Hydraulic and hydrologic = continue current strategy (use 1-D HEC-RAS supplemented by 2-D for 1-mile reaches) (1 month for output)
  - Morphodynamic = add sediment transport to SRH-2D (1 month)
  - No WRIMS
  - Data acquisition costs associated with SSS needs
- Scenario 2
  - Fish production = Level B (upstream adult migration model)
    - Perry/Hardy time for parameterization and incorporation into larger model ($15,000, 1-2 months)
    - $92,000 for data acquisition
  - Temperature = SNTEMP with 12 cross-sections between North Fork and confluence or possibly RMA2/11 ($100,000 for contractor)
  - Riparian = revamp TARGETS (1-2 months)
  - Hydraulic and hydrologic = (use 1-D HEC-RAS supplemented by 2-D for 10-mile segments and run 10-mile reach models) (approx. 3 month effort)
  - Morphodynamic = add sediment transport to SRH-2D (1 month)
  - No WRIMS
- Scenario 3
  - Fish production = Level C (ocean component)
    - Russ/Joe time to bring existing model into the SSS (1 month; $10,000)
    - $108,000 for data acquisition
  - Temperature = SNTEMP with 12 cross-sections between North Fork and confluence or possibly RMA2/11 ($100,000 for contractor)
  - Riparian = Use SRH-2D as a template and add vegetation
  - Hydraulic and hydrologic = (use 1-D HEC-RAS supplemented by 2-D for 10-mile segments and run 10-mile reach models) (approx. 3 month effort)
  - Morphodynamic = add sediment transport to SRH-2D (1 month)
  - No WRIMS

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