Report as of FY2007 for 2006UT70B: "Evaluating Water Allocation Strategies in the Virgin River Basin for the Protection and Enhancement of Native Fish"

Publications

- Dissertations:
  - Basdekas, L. (2006). Virgin River Operations Optimization Model. Unpublished Ph.D. Dissertation, Department of Civil and Environmental Engineering, College of Engineering, Utah State University, Logan, Utah.

Report Follows

Evaluating Water Allocation Strategies in the Virgin River Basin for the Protection and Enhancement of Native Fish

Problem

Existing water resource allocation practices within the Virgin River Basin has placed an increasing focus on identification of alternative strategies that can accommodate protection and recovery efforts of native fish and in particular endangered and threatened species such as woundfin and Virgin River spinedace. In many sub-basins, existing water use continues to follow practices implemented at the turn of the century and little work has been undertaken to evaluate alternative strategies of water allocations that may improve instream flow conditions conducive to meeting recovery objectives for the listed fish species within the basin.

Research Objectives

Research is need to evaluate existing land use practices and water allocation strategies that may be able to take advantage of new water resource infrastructure (i.e., the Quail Creek/Sand Hollow systems) to meet water demands while providing increased instream flows within the Virgin River. The purpose of this project to develop an analysis framework that can incorporate existing and proposed water resource infrastructure and alternative water allocation strategies within the Virgin River Basin that can assist water and natural resource managers to manage the system for the protection and enhancement of native fish.

The objectives of the research are to:

1. Integrate the existing water resource operations model with a water temperature model and fish habitat model to allow evaluation of alternative operational scenarios on native endangered fish species.
2. Extend the existing modeling framework to include a number of proposed infrastructure changes including a gravity-flow pipeline for agricultural water releases from Sand Hollow and Quail Creek Reservoirs and the proposed Lake Powell Pipeline.
3. Integrate an economic based evaluation for operations and infrastructure that includes evaluation of endangered species cost/benefits.
4. Demonstrate the utility of the modeling framework for selected infrastructure and operational scenarios based on existing and projected future water demands.

Methodology

Several existing modeling tools have been developed related to water resources within the Virgin River including a daily operations model and a daily temperature model. However, extension of these models to consider an expanded range of operational and infrastructure options is needed. This includes the integration of temperature and habitat based metrics for the endangered fish species and the incorporation of economics as part of the evaluation process.

Research Tasks

Integration of Water Quantity and Quality Models

The project will integrate a daily system mass balance model [Adams, et al., 1992] and a water temperature model described in Neilson (2006). The daily operations model simulates storage, releases, hydropower, etc based on existing and projected demands for agriculture, municipal, and industrial uses. The temperature model (VR_Temp) was adapted for this study and modified to allow for a higher percentage of stream flow depletions, improve interpolation speed, stabilize volume calculations and use discharge coefficients in lieu of a Manning's roughness type solution.

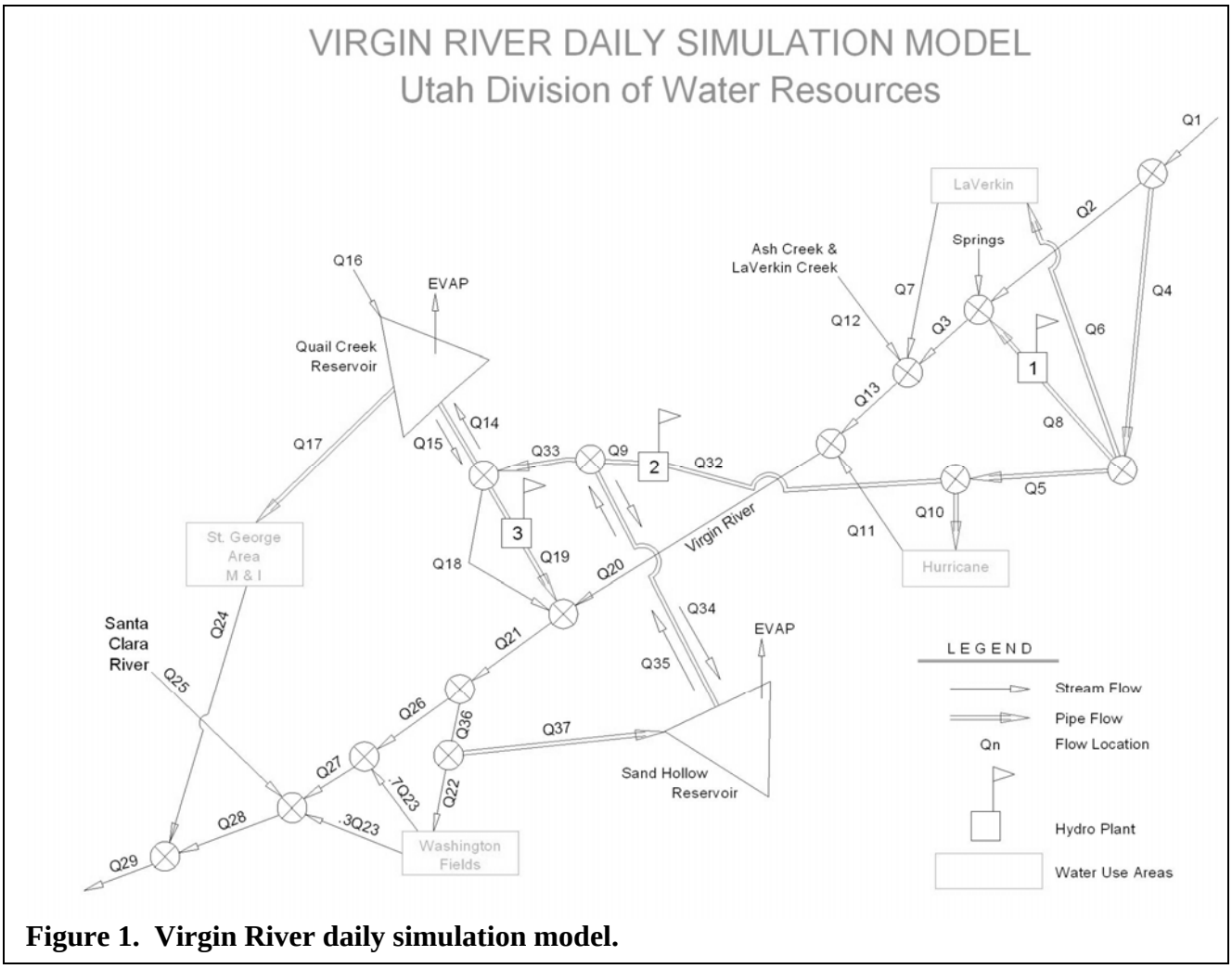

Figure 1. Virgin River daily simulation model.

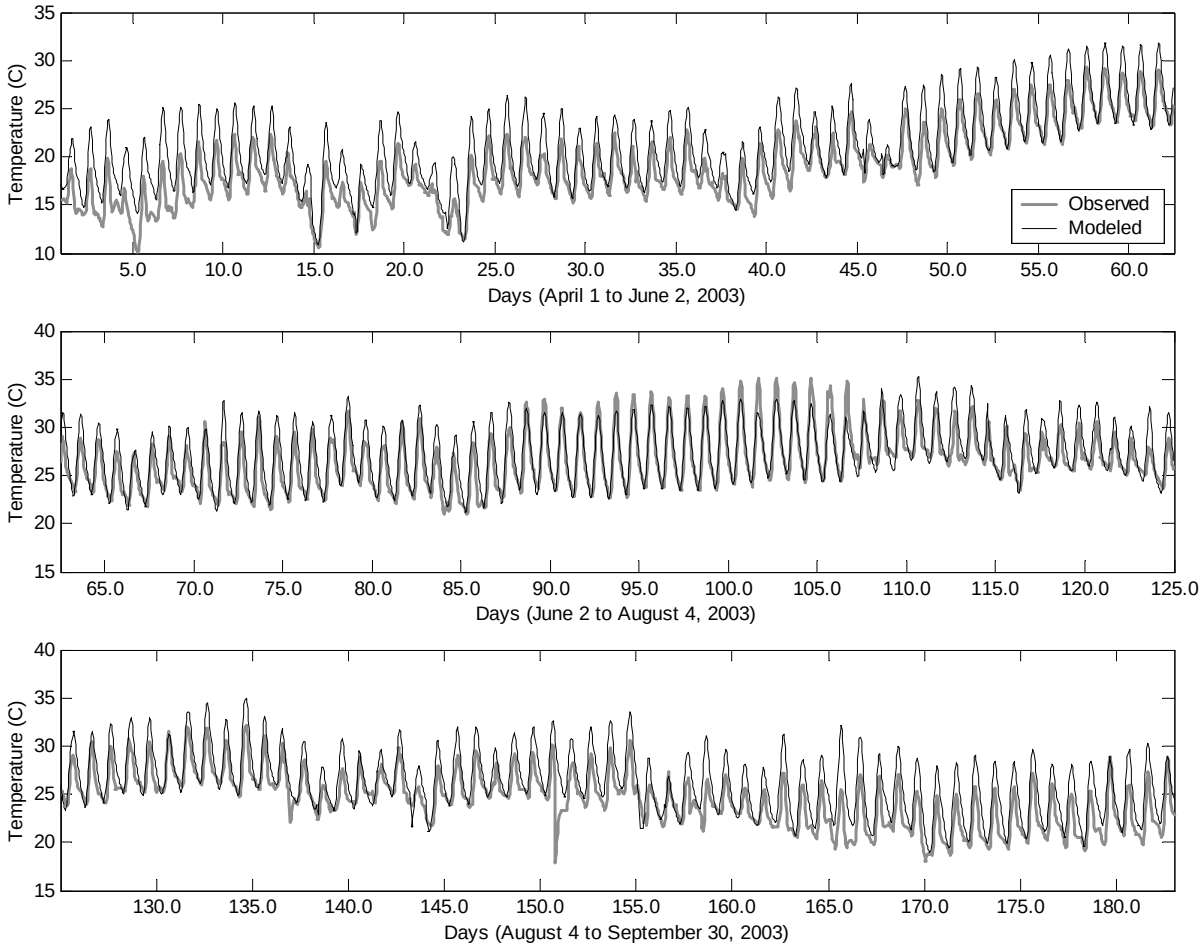

Figure 2. Observed and predicted daily maximum water temperatures in the Virgin River.

Development of an Integrated Habitat and Temperature Metric for Endangered Fish

A new temperature based habitat suitability metric for endangered woundfin was developed and integrated into the temperature model. Maximum daily water temperatures are used to calculate the new habitat suitability metric that ranges from a value of one, indicating no degradation in habitat due to temperature to a value of 0.0 indicating complete degradation. Antecedent thermal acclimation time and instantaneous water temperatures for the endangered woundfin fish are considered as well. The metric allows habitat to be quantified for use in comparative analyses between operational scenarios.

Implementation of an Optimization Framework and Incorporation of Economics

The component models were integrated into optimization framework, as well as the addition of economics into the integrated modeling framework. The integrated modeling framework was applied, as a demonstration project in the Virgin River Basin, for use in the comparative analysis of water resource system operational scenarios. Results were compared on the basis of quantified fish habitat and net cost. This new model framework, the Virgin River Operation Optimization Model (VROOM), is considered a basin level planning model.

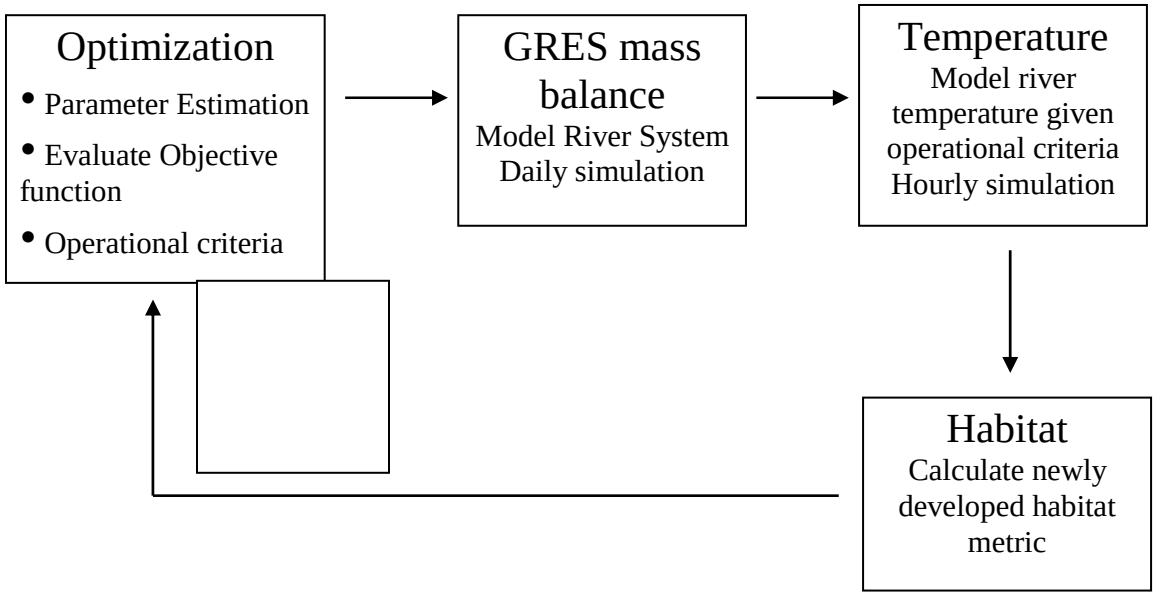

Figure 3. Integrated optimization framework.

Evaluation of Alternative Operations and Infrastructure Scenarios

Two optimization objectives were selected to minimize net cost and maximize endangered fish habitat for various hydrologic year types and water demand conditions. Dry, average and wet hydrologic year types were molded separately in combination with existing water demands and a future water demand estimate. Infrastructure options considered were:

1) A gravity fed pipeline to transport released cold water from Quail Creek Reservoir upstream to the Virgin River,

2) The proposed Lake Powell pipeline to Sand Hollow reservoir to satisfy anticipated population growth, and

3) Reduction in demand by purchasing water.

Given the multiobjective nature of the problem an optimization procedure was developed to produce a tradeoff surface or Pareto front. On a Pareto front each solution on the front is equally as good as any other point on the front of non-dominated solutions. A tradeoff surface is desired so that a subjective determination as to the merits of a particular solution can be made by a user.

Principal Findings

A tool was successfully created that allows a user to evaluate different management options including new infrastructure and/or target environmental flows based on maximum daily water temperatures. This tool allows for testing alternatives and optimizing the operations of a water management system while trying to best meet the needs of municipal and industrial, agriculture, hydropower, and environmental flow requirements. Options for optimization or decision variables included reduction of service area demands, the proposed addition of the Quail Creek flow back pipeline, and the Lake Powell pipeline, as well as the flow rates within the proposed pipelines.

A single objective global optimization algorithm was used in conjunction with an objective function weighting scheme to approximate a Pareto front of net costs and habitat units. This piece wise approach to multiobjective optimization was used due to the squared off nature of the response surface that resulted from a set of 5000 Monte Carlo test simulations. The modeling framework successfully identified feasible operational and infrastructure scenarios that optimized use of water to meet multiobjetives such as beneficial out-of-stream uses while protecting and/or enhancing endangered native fish species within the Virgin River Basin.

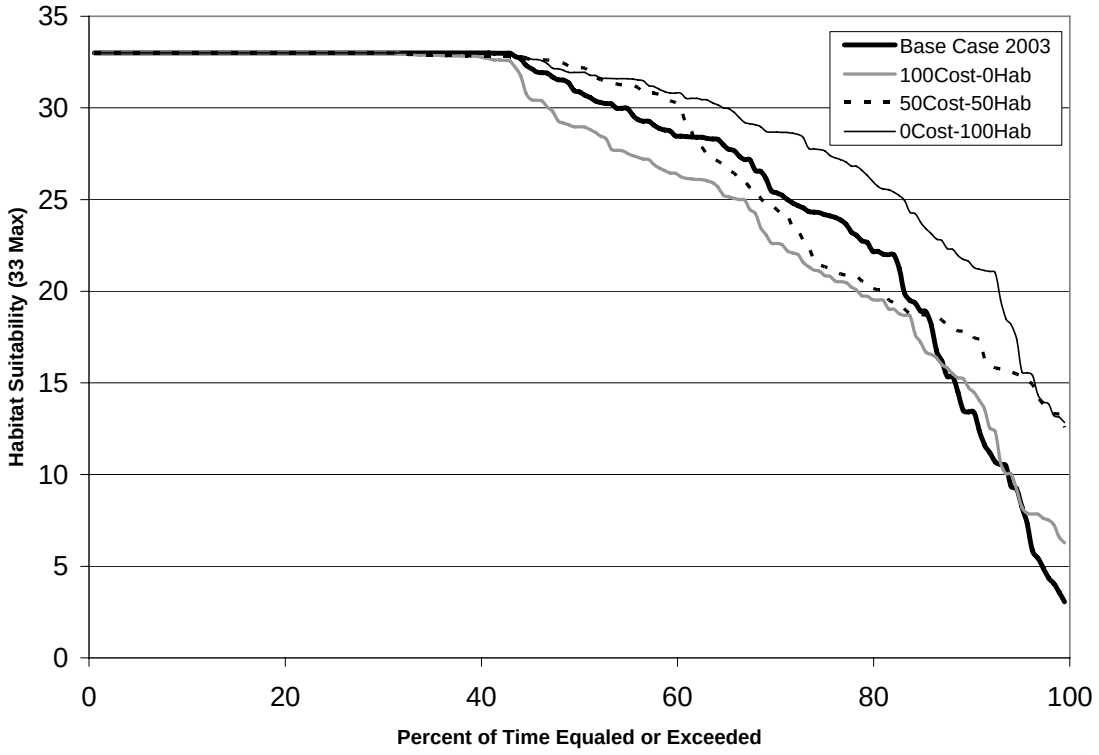

Figure 4. Habitat suitability metric associated with four alternative operational scenarios.

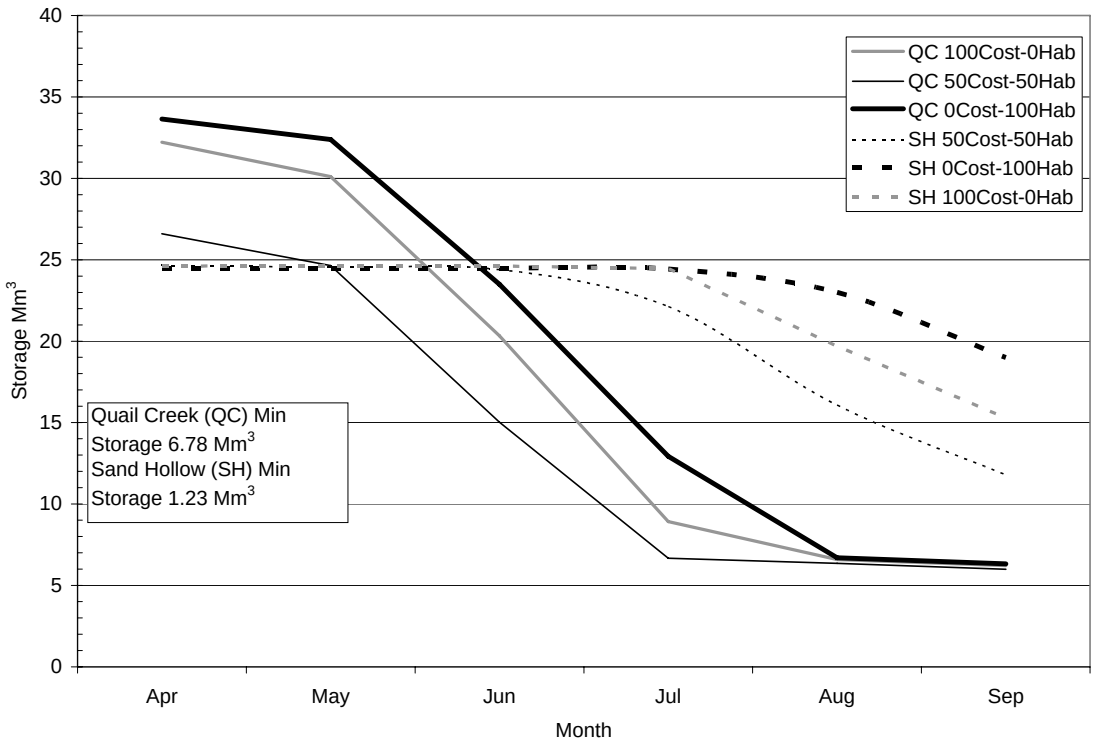

Figure 5. End-of-month storage for Quail Creek and Sand Hallow reservoirs under different operational and infrastructure scenarios.

Significance

This research is important to advance the water resource decision process in which environmental constraints related to endangered species can be evaluated. The research will also provide a benefit to the Virgin River Program in that a rational reproducible evaluation of cost/benefits in the form of a quantified temperature based fish habitat suitability metric can be examined in light of proposed water management strategies. The modular nature of the modeling packages lends itself to modification when more and or better data or models become available.

References

Adams, T. D., D. B. Cole, C. W. Miller, and N. E. Stauffer 1992, GENRES A Computer Program System for Reservoir Operation with Hydropower, 116 pp, Utah Division of Water Resources, Salt Lake City.

Neilson, B. T. (2006), Dynamic Stream Temperature Modeling: Understanding the Causes and Effects of Temperature Impairments and Uncertainty in Predictions, Utah State University, Logan.