Center for Water Resources Research
Annual Technical Report
FY 2006

Introduction

The Utah Center for Water Resources Research (UCWRR) is located at Utah State University (USU), the Land Grant University in Utah, as part of the Utah Water Research Laboratory (UWRL). It is one of 54 state water institutes that were authorized by the Water Resources Research Act of 1964. Our mission is related to stewardship of water quantity and quality through collaboration with government and the private sector. The UCWRR facilitates water research, outreach, design, and testing elements within a university environment that supports student education and citizen training. The UCWRR actively assists the Utah Department of Environmental Quality (UDEQ), the Utah Department of Natural Resources (UDNR), the State Engineers Office, all 12 local health departments, and several large water management agencies and purveyors in the state with specific water resources problems.

In FY 06, the UWRL expended a total of approximately $9 million in water research support. USGS Section 104 funds administered through the UCWRR accounted for about one percent of this total. These funds were used for research addressing water and wastewater management problems, outreach, information dissemination, strategic planning, water resources, and environmental quality issues in the State of Utah.

Three research projects were funded in FY 06 with funds from the 104-b program. These projects, respectively entitled "Evaluating Water Allocation Strategies in the Virgin River Basin for the Protection and Enhancement of Native Fish", "Potential Impacts of Flow Augmentation on Stream Restoration Projects", and "Irrigation Demand Forecasting for Management of Large Water Systems", dealt with water management issues involving recovery of endangered species and improvement of water system operation efficiency. The projects were implemented in three major river basins in Utah, and they involved collaboration of local, state, and federal water resources agency personnel with researchers at two different universities.

Research Program

USGS Section 104 funds were used to address endangered species recovery issues in the Virgin River in southern Utah and in the Provo River-Utah Lake drainage in the northern part of the state. These projects involved collaborative partnerships with numerous local, state, and federal agencies and with the recovery programs in those respective basins. Section 104 funds were also used to develop advanced forecasting techniques for predicting short-term irrigation water demand in the Sevier River of south-central Utah.

The project in the Virgin River, entitled "Evaluating Water Allocation Strategies in the Virgin River Basin for the Protection and Enhancement of Native Fish", focuses on evaluating existing land use practices and water allocation strategies that may be able to take advantage of new water resource infrastructure to meet water demands while providing increased instream flows within selected reaches of the Virgin River in order to meet the needs of endangered fish species.

The Provo River and Utah Lake in central Utah provide critical habitat to the June sucker, an endangered species of fish unique to these water resources. The purpose of the project entitled "Potential Impacts of Flow Augmentation on Stream Restoration Projects" is to examine sediment transport and flow hydraulics of Hobble Creek, a tributary of the Provo River, in order to evaluate potential June Sucker habitat under present and a proposed augmented flow regime. It is anticipated that augmented flows will impact suspended sediment concentrations, bedload movement, flushing of fine sediments, and stream channel geometry. Results of the research will be used to guide restoration efforts in the drainage basin such that restoration under present hydrologic conditions will still be effective with augmented flows in the future.

The project entitled "Irrigation Demand Forecasting for Management of Large Water Systems" described under the Research Project section of this report is an integrated research and information transfer project that has been developed as the result of collaboration among the Sevier River Water Users Association, the Provo, Utah Office of the US Bureau of Reclamation, and the UCWRR. The goal of the project is to develop methodologies for forecasting short-term irrigation water demand in order to provide timely, decision-relevant information to the operators of canals and reservoirs in order to improve overall system-wide efficiency.

Irrigation Demand Forecasting for Management of Large Water Systems

Basic Information

Title:	Irrigation Demand Forecasting for Management of Large Water Systems
Project Number:	2006UT69B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	UT1
Research Category:	Ground-water Flow and Transport
Focus Category:	Models, Irrigation, Management and Planning
Descriptors:	None
Principal Investigators:	Mac McKee

Publication

Irrigation Demand Forecasting for Management of Large Water Systems

Problem

The relative scarcity of water in the western US is increasing due to population and economic growth, pollution, and diversification of the types of demands that are being placed on water use (e.g., traditional consumptive uses such as irrigation and municipal supply, as well as emerging uses for such concerns as water quality maintenance and endangered species protection). This increasing relative scarcity brings: (1) a greater need to more intensively manage the resource, and (2) a requirement for better characterizations of the current and potential future states of our water resources systems--including estimates of the uncertainty contained in these characterizations--so that management decisions can be better informed.

In spite of these increasing needs for better water resources management information, investments in traditional water resources data collection programs (e.g., point stream flows, snow pack, soil moisture, etc.) are declining at the federal and state levels. For example, USGS support for maintenance of several stream gages in Utah has been withdrawn in recent years due to a lack of state cost-sharing commitments. In contrast, investments on the part of other Federal agencies (that have not traditionally played a significant role in support of water resources management) in new data collection methods are increasing (e.g., satellite imagery of land cover, snow cover, ocean surface temperatures, etc.; radar estimation of precipitation; aircraft and satellite imagery for estimation of evapotranspiration). These new data streams will have to be used to back-fill the decline in availability of traditional data. Moreover, analytic methods will need to be developed to apply to these data in order to improve the quality of the information base available to managers of large water systems.

Today's managers have not been schooled in new ways of collecting data or in the analytic approaches required to understand the data. Before new methods of gaining information and making decisions can be practical, investments must be made to place the resulting capabilities into the hands of the water managers who need them. These must be practical and effective, and the water managers must themselves see the value of the information that results.

The operation of large irrigation systems is an important area in which gains in efficiency in the management of water resources can be made realized the development and use of timely and strategic information. This is especially the case in Utah, where there exist many large irrigation and canal systems that provide significant volumes of water for use in an arid or semi-arid setting, and for which there is substantial uncertainty at any given time in the current state of the system and in the irrigation water demands that will emerge in the relative short term. This project will focus on the development of practical approaches for forecasting short-term irrigation water demands on a canal system so that overall system operation can be made more efficient.

Research is needed to develop the data now becoming available from emerging remote sensing sources into useful information for all temporal and geographical scales of water resources management. This must be done in such a way as to maximize the total value of the information coming from both these new, emerging data sources and from the traditional water resources monitoring approaches. Further, the products of such research must be of practical use to the water resources managers who (1) are now losing access to traditional data sources and (2) have not been trained in how to access and use the information flowing from new remote sensing capabilities. In addition, the research products must also be of use to a growing range of stakeholders who have heterogeneous technical backgrounds and skill levels.

Research Objectives

The purpose of this project is to develop a significantly enhanced capability within the state of Utah--that will also be appropriate for application in the arid West--to more efficiently manage the state's scarce water resources by exploiting emerging technologies in data collection and analysis. Specifically, the focal objective of this project is to develop and test methodologies from statistical learning theory for combining meteorological and hydrological data from traditional and new remote sensing sources to produce information valuable to managers of large water resources systems. These methodologies will be directed at supplying reliable predictions of irrigation water demands for periods of one to five days in advance of the time of delivery to irrigators. These forecasts are based on a methodology that utilizes data from on-ground soil moisture probes, coarse-scale satellite imagery, and, potentially, other immerging sources of remotely sensed data and/or meso-scale modeling forecasts.

Methodology

Evapotranspiration (ET) can be modeled using remotely sensed data. A number of models have been developed in this area and can be categorized into two classifications: (1) residual methods that calculate ET by subtracting sensible heat flux from net radiation (Moran et al., 1994), and (2) vegetation index-surface temperature (VI-Ts) methods that utilize scatter plots between the vegetation index and surface temperatures to approximate surface resistance (Nagler et al., 2005; Nishida et al., 2003; Nemani and Running, 1998; Yang et al., 1997). When using the VI-Ts method, however, derivation of surface resistance from a scatter plot requires a continuum of soil moisture (from dry bare soil to saturated bare soil) and vegetation status (from water-stressed full-cover vegetation to well-watered full-cover vegetation) to provide a range of surface conditions (Yang et al., 2006).

Models that are based on or that utilize remote sensing data have two central advantages over purely process-based models: (1) satellite remote sensing offers broad spatial coverage and regular temporal sampling, and (2) requirements for spatial and temporal parameterization of water-constraining variables are reduced or eliminated. Remote sensing models are thus theoretically capable of accurately predicting actual ET at regional to continental scales (Yang et al., 2006). In a recent application, Yang et al. (2006) investigated the use of support vector machines (SVMs) in modeling ET. The SVM model was trained on AmeriFlux data to produce a distributed ET product over the continental US. The output of this model will eventually become the MODIS (MOD16) product. Since the MOD16 product was not released at the time of this research, latent heat simulations from the Noah land-surface model (Ek et al., 2003) run offline at 1-km resolution through the Land Information System (LIS) (Kumar et al., 2006), the sister project of the Global Land Data Assimilation System (GLDAS) (Rodell et al., 2004), were used.

A downscaling/forecasting algorithm was developed that builds multiple relationships between inputs and outputs at different spatial scales. These relationships are then used to downscale and forecast the output at the finest scale. As a conservative assumption, this model assumes that the output image is available at the coarsest resolution. All inputs are upscaled to the coarsest output resolution. Upscaling is carried out using two-dimensional (2D) discrete wavelet decomposition with the basis functions suiting the property in physical terms. 2D wavelet decomposition for one level will result in one datum image (Low-Low pass filter image, or LL) and three detailed images (i.e., LH, HL, and HH). Once the inputs are available at the spatial resolution of the output, an SVM can be employed to learn the underlying physics between the inputs and the output using a random subset of pixels. The outcome of this SVM will be the LL image for this particular resolution. Since some inputs are available at higher spatial resolutions, these "leftover" inputs can still be upscaled to the output resolution and another SVM can be implemented to learn the relationship between these leftover inputs and the output. This SVM will be applied on three high-pass components of these leftover inputs. The result of this SVM will be inherently biased due to the convolution processes performed at the decomposition step. This bias is linear and it could be corrected. The linear bias corrector could be obtained at a coarser resolution where the three output detailed images are available. Once corrected for linear bias, the result of the SVM will be the three high-pass components, which can be used along with the datum image established in the first SVM to reconstruct the output at the next finer spatial resolution. The algorithm continues in this manner until all the inputs at higher spatial resolutions are consumed. Similar to the (downscaling only) explanation, the SVM can be trained against an output image ahead of time assuming all inputs are at time t and the output is at time $t+n$, where n is the number of time steps ahead. In the case of water management in the Sevier River Basin, time steps are in days. This provides the framework for the algorithm serving not only as a means for downscaling, but also for forecasting.

The algorithm will have three parameters per SVM machine. Figure 1 shows the scheme of this model. The triangles pointing up represent the 2D wavelet decomposition operations, while those pointing down represent 2D wavelet reconstruction operations. The dashed borders around the abbreviation SVM refer to "operational mode", while solid borders refer to training mode. Dotted images represent observed images. In this schema, there are two inputs and three different resolutions. One input is observed at fine resolution while the other is observed at a medium resolution. The output is observed at a coarse resolution.

Principal Findings

The above algorithm was applied to two case studies. Since ET MODIS (MOD16) is not released yet, the first case study was applied to downscale and forecast the photosynthesis (PSN) MODIS product MOD17A2 in the Sevier River Basin in Utah. A second case study, which is not reported here, successfully demonstrated the downscaling and forecasting LE model output in Bondville, Illinois. The results in this case study were validated with the AmeriFlux data over different snapshots in the irrigation season.

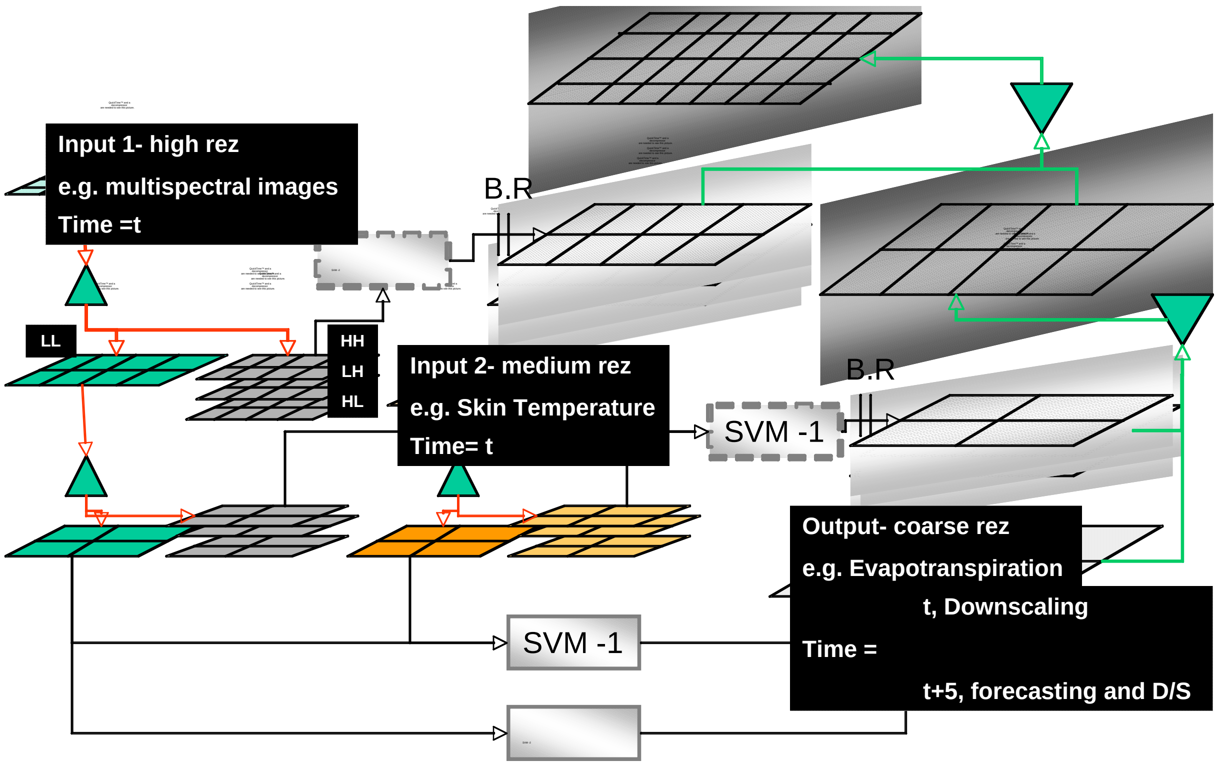

Figure 1. Flowchart of the Downscaling Algorithm (B.R. stands for "bias remover")

The Sevier River Basin, Utah

The Sevier River Basin, a closed system in rural south-central Utah, is one of the state's major drainages, encompassing 12.5 percent of the state's total area. The Sevier River Basin, shown in Figure 2, has five subwatersheds and is divided into two major divisions, the upper and lower basins, for the purpose of administration of water rights.

Average annual precipitation ranges from 6.4 to 13.0 inches in the valleys, and the growing season ranges from 60 to 178 days (Utah Board of Water Resources, 2001; Berger et al., 2002). Most of the surface water runoff comes from snowmelt during the spring and early summer months. The primary use of water in the basin is for irrigation. The average annual amount of water diverted for cropland irrigation is 903,500 acre-feet. Of this amount, approximately 135,000 acre-feet are pumped from groundwater. The irrigation season in the basin generally extends from April to the end of October. About 40 percent of the diversions are return flows from upstream use (Berger et al., 2002). More detailed information about the basin and much of the real-time database utilized in this research is available at http://www.sevierriver.org (Khalil et al., 2005).

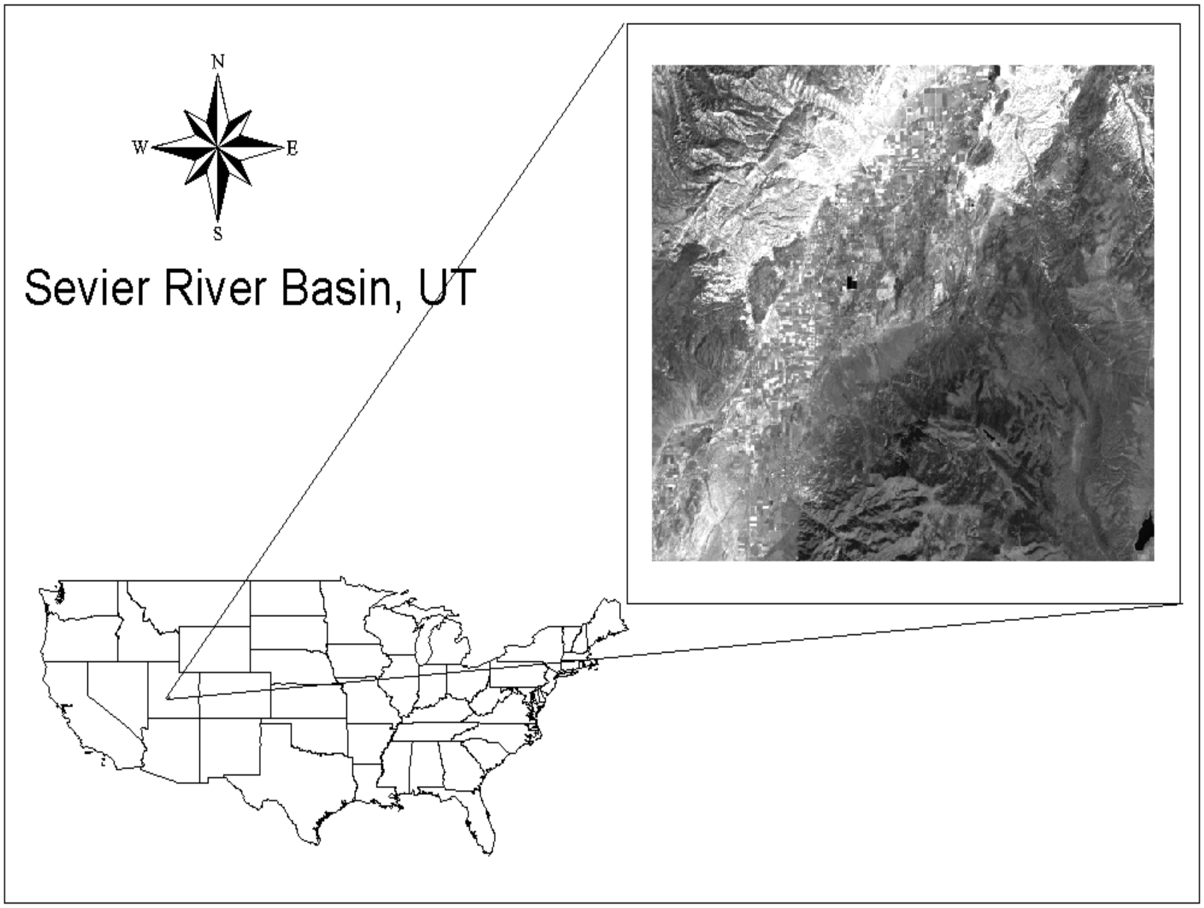

Figure 2. The Sevier River Basin, Utah

Application to the Sevier Basin

The algorithm was used to downscale the photosynthesis MODIS product (PNS- MOD17). The inputs used in this application are shown in Table 1. The Landsat TM multi-spectral image, available at 15m resolution, does not satisfy the relationship $s \times 2^n = S$, where s is the original spatial resolution (15 m), S is the upscaled spatial resolution (250 or 1000 m), and n is an integer. Therefore, the image had to be re-sampled at resolution s = 15.625 m, in which case, n will be 4 (for S = 250 m) or 6 (for S = 1000 m).

PNS was forecasted 8 days ahead using all inputs at, or upscaled to, a resolution of 1000 m. Then it was downscaled from 1000 m to 250 m using the inputs available at or upscaled to 250 m. Finally, it was downscaled to 15.625 m using the inputs available at a 15.625 m resolution. Figure 3 shows the results of the model at the three benchmark spatial resolutions. Pending the release of the ET product of MODIS MOD16, the algorithm could be applied to forecast ET in the Sevier River Basin.

Table 1: Inputs used in the Sevier River Basin Case Study

Spatial Resolution (m)	Product Description	Source	Product Code
1000	LAI/ FPAR	MODIS	MOD15A2
	Albedo	MODIS	MOD43B1
	Temperature/ Emissivity	MODIS	MOD11A1
250	Surface Reflectance	MODIS	MOD09Q1
	Vegetation Indexes	MODIS	MOD13Q1
15	Multi-Spectral	Landsat TM	

Benefits

The Sevier River Basin, managed by the Sevier River Water Users Association (SRWUA) in Utah served as a case study and experimental site for the project. It was chosen because of its significant size, its importance in the agricultural sector of the state, its highly developed on-line, real-time database, and the willingness of local water resources managers to cooperate with the research and make use of the outputs of the project. The project focused on development of approaches to reduce the uncertainty that accompanies significant water management decisions through the implementation of real-time forecasting of irrigation requirements for periods of one to five days in advance. This capability will be useful in the Sevier River Basin for managing real-time reservoir release and canal diversion decisions. The output of these models will be utilized for development and deployment of decision-support systems that will be made available to managers of reservoir releases and canal diversions.

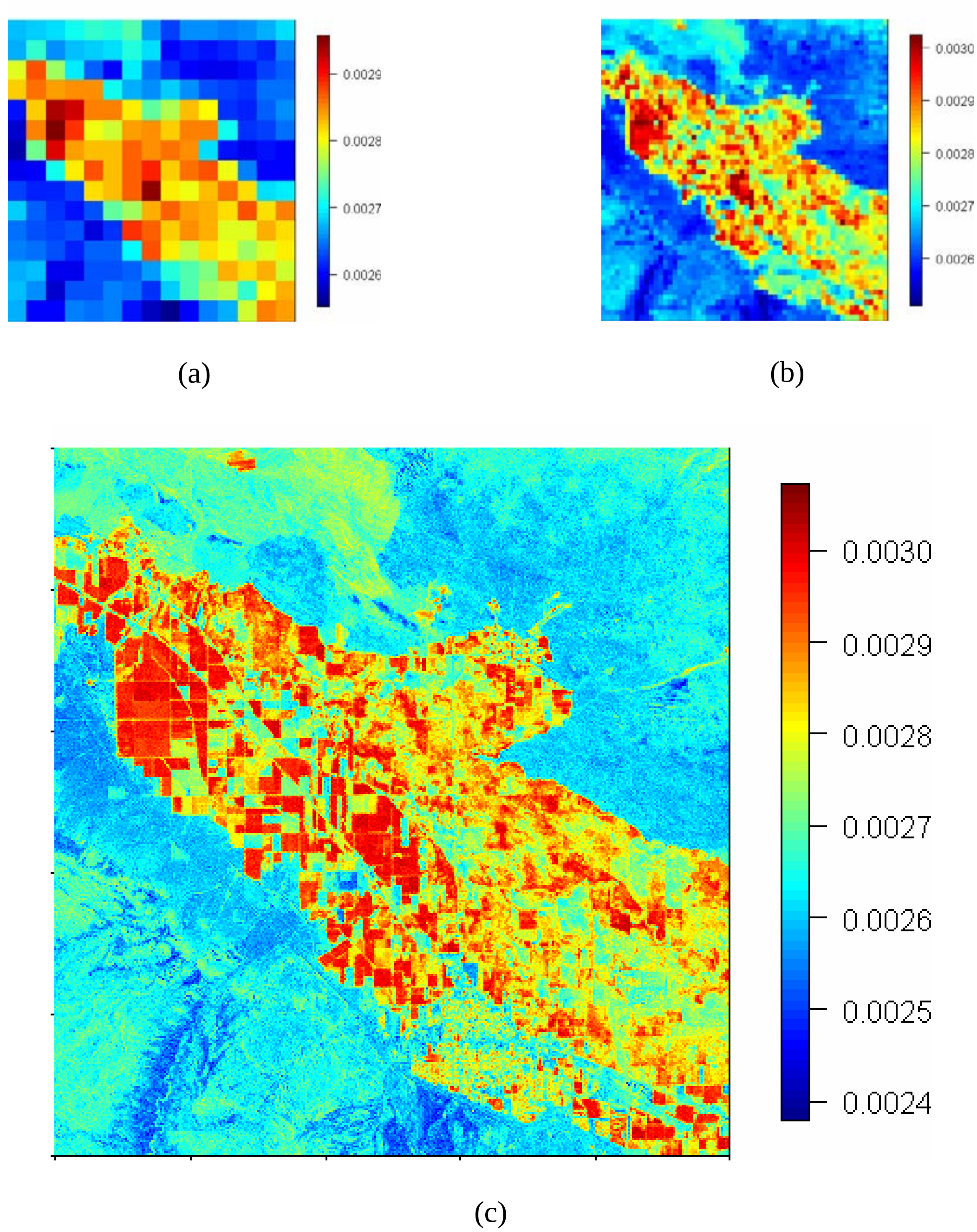

Figure 3. Net Photosynthesis Forecasting/Downscaling for the Sevier River Basin (units are in kgC/m^2): (a) PNS at 1000 m resolution forecasted to t+8 days; (b) PNS at 250 m resolution, t+8days; and (c) PNS at 15.625 m resolution, t+8days.

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

Basic Information

Title:	Evaluating Water Allocation Strategies in the Virgin River Basin for the Protection and Enhancement of Native Fish
Project Number:	2006UT70B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	UT1
Research Category:	Water Quality
Focus Category:	Water Supply, Ecology, Management and Planning
Descriptors:	Instream Flows, Water Use, Land Use, Endangered Species
Principal Investigators:	Thomas B. Hardy, Luis A Bastidas, Mac McKee

Publication

1. 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.

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.

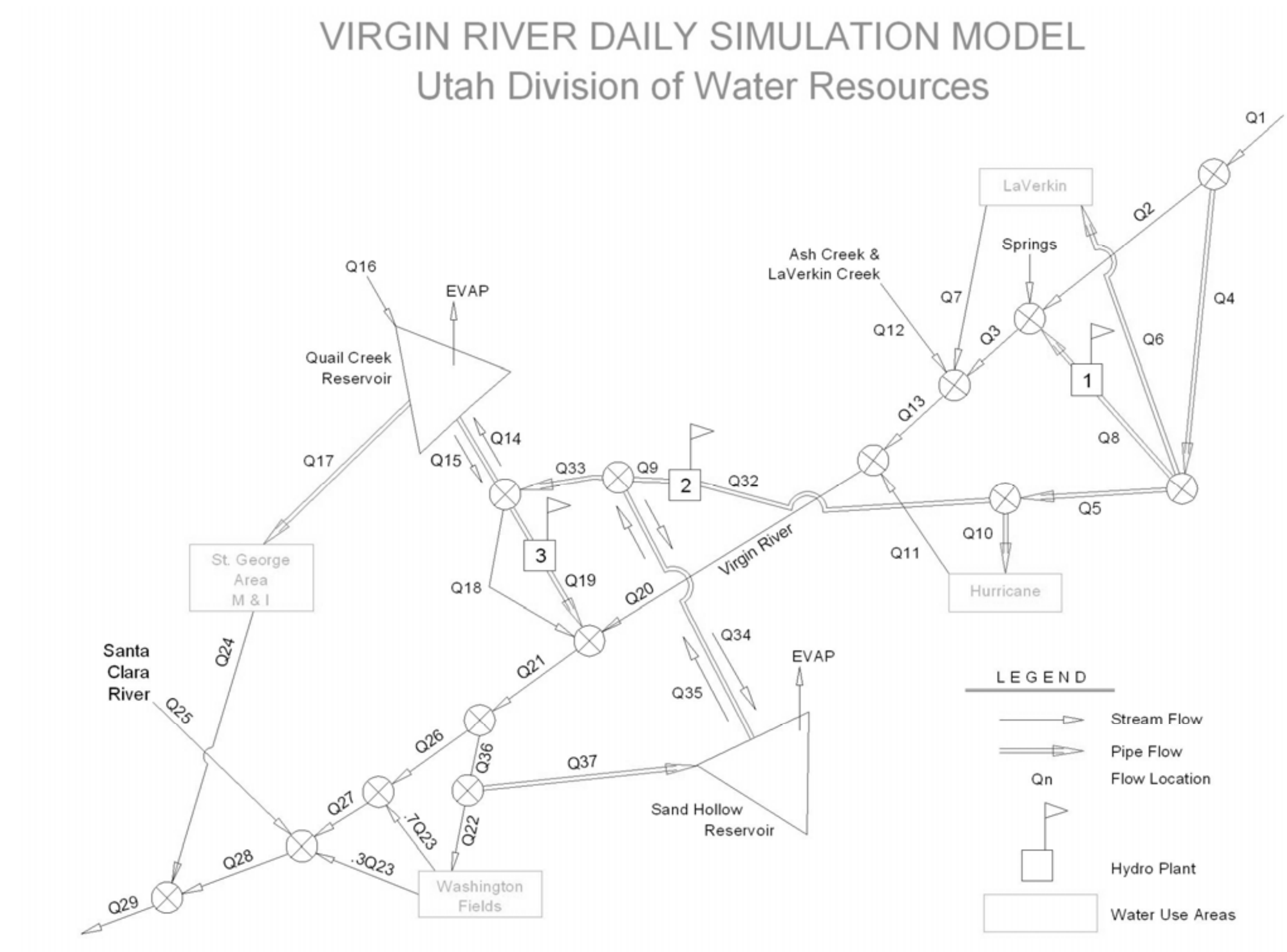

Figure 1. Virgin River daily simulation model.

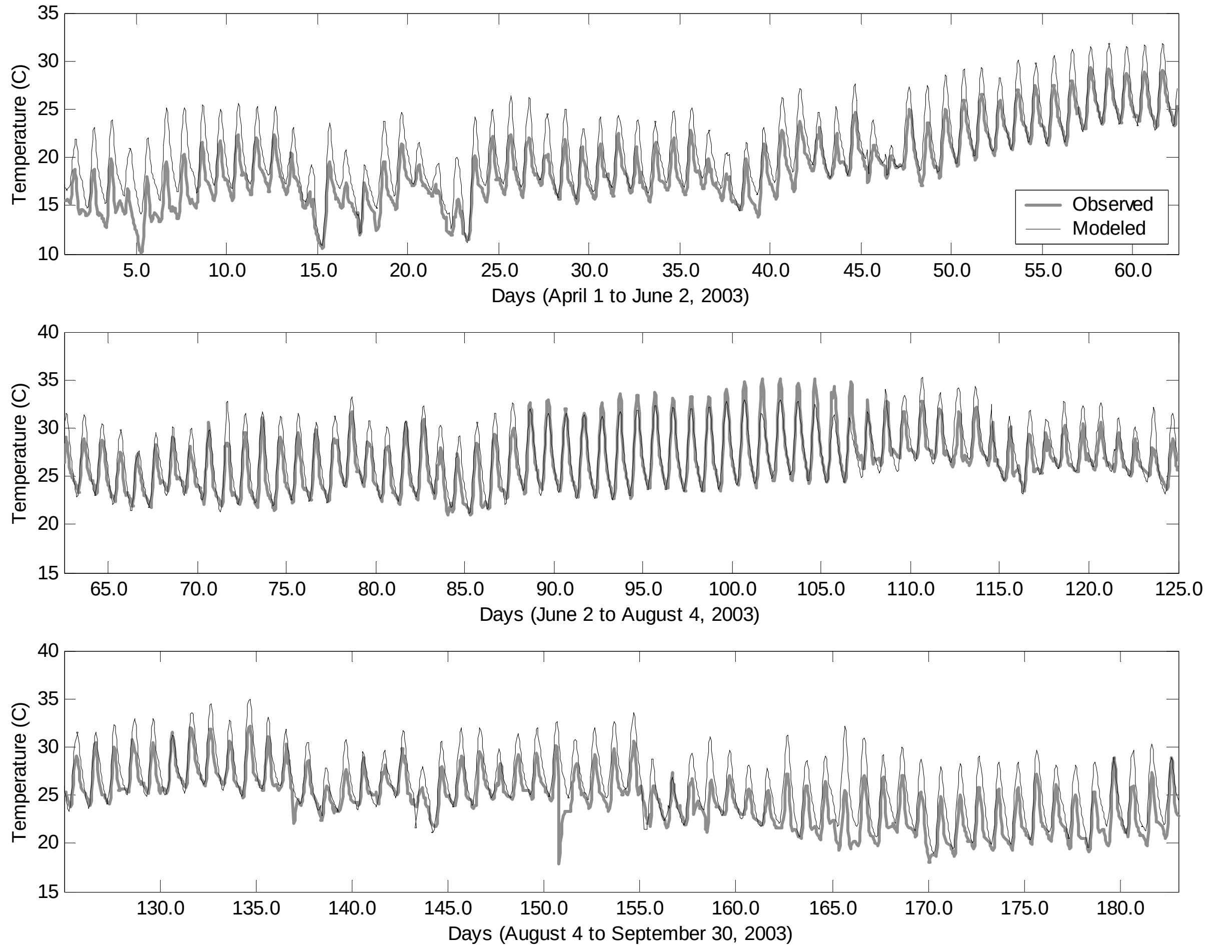

Figure 2. Observed and predicted daily maximum water temperatures in the Virgin River.

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.

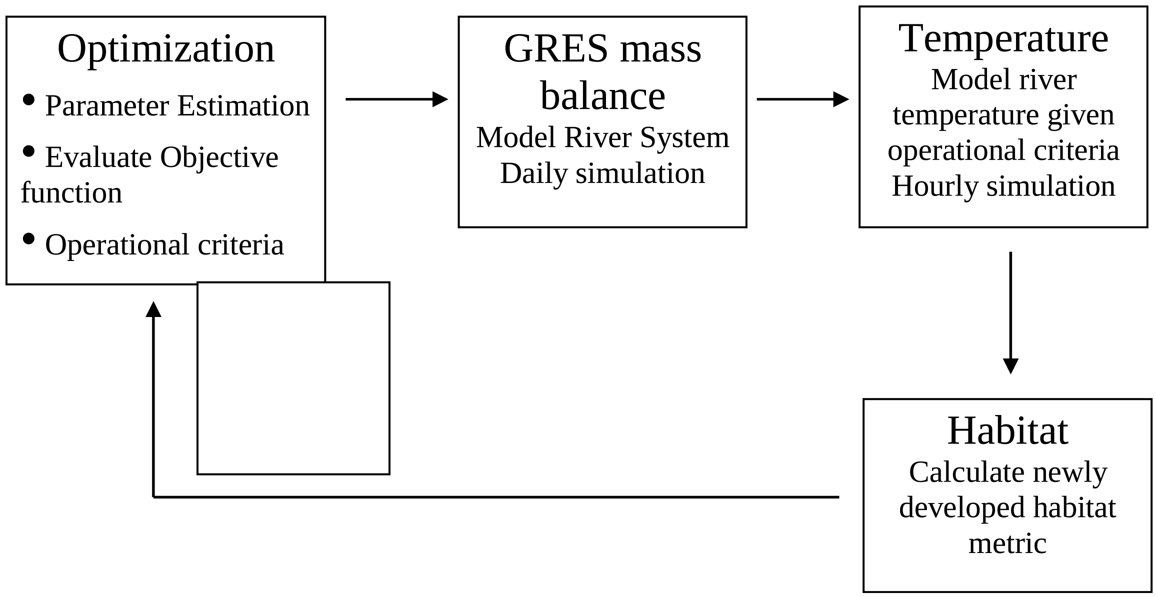

Figure 3. Integrated optimization framework.

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.

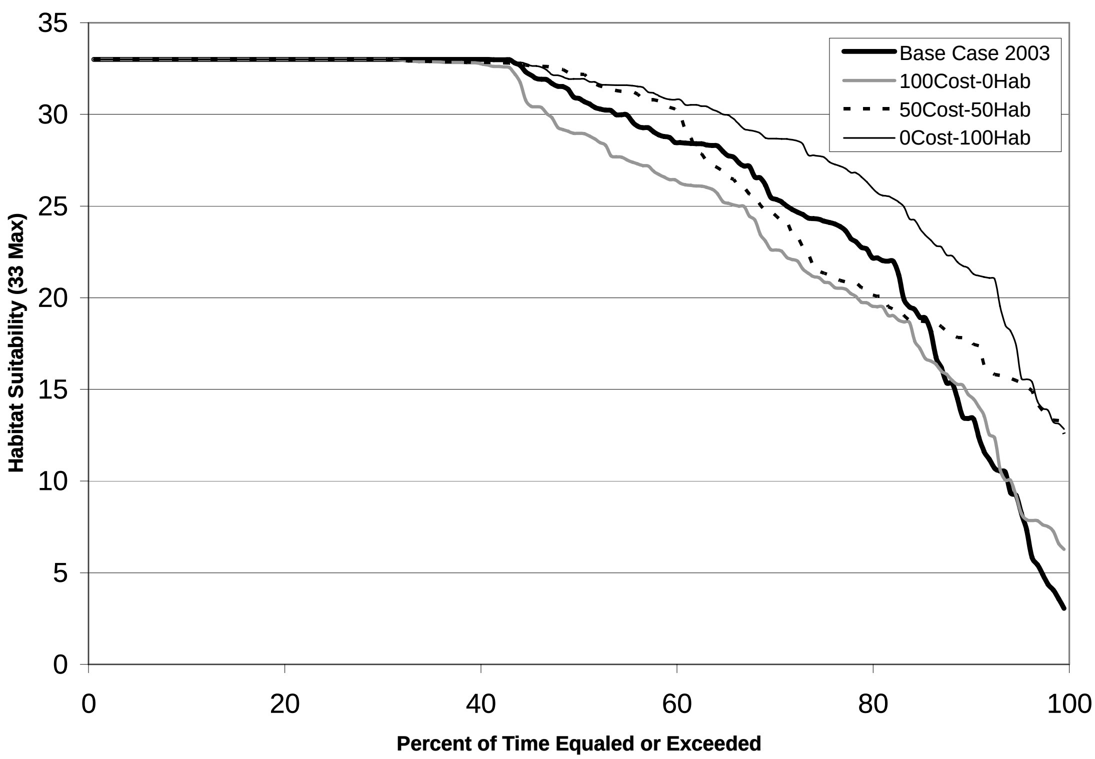

Figure 4. Habitat suitability metric associated with four alternative operational scenarios.

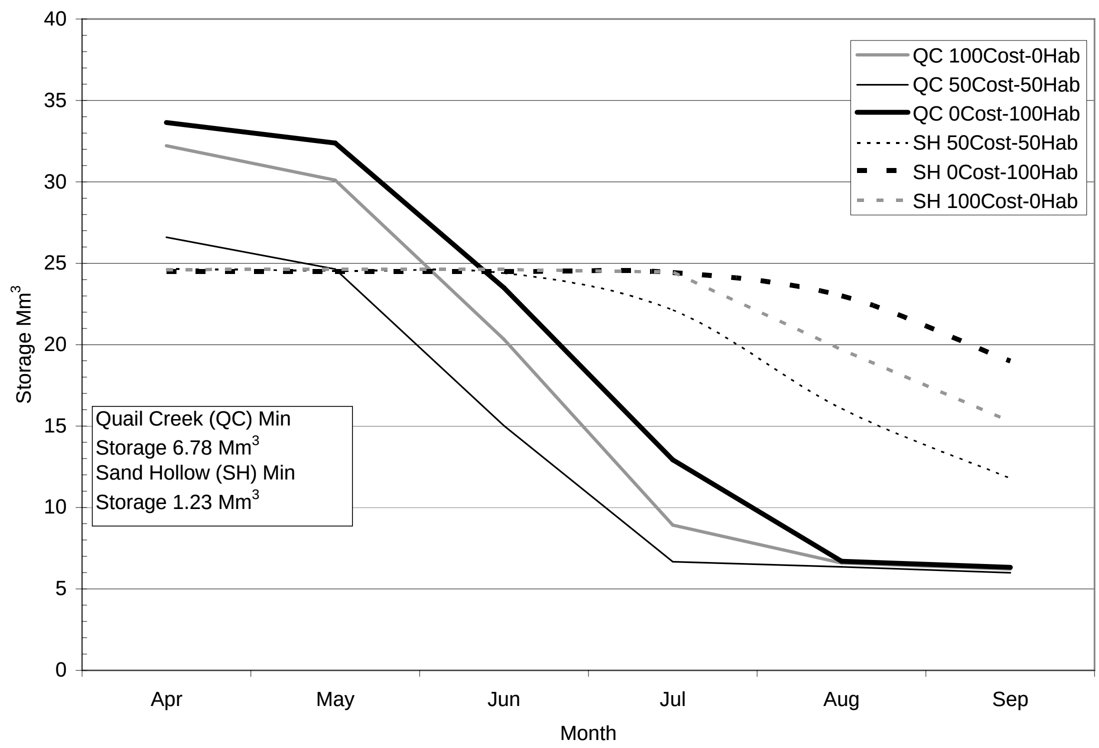

Figure 5. End-of-month storage for Quail Creek and Sand Hallow reservoirs under different operational and infrastructure scenarios.

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.

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Potential Impacts of Flow Augmentation on Stream Restoration Projects

Basic Information

Title:	Potential Impacts of Flow Augmentation on Stream Restoration Projects
Project Number:	2006UT72B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	UT3
Research Category:	Water Quality
Focus Category:	Ecology, Surface Water, Methods
Descriptors:	None
Principal Investigators:	Rollin Hotchkiss, Mark Belk, Russell Rader

Publication

Potential Impacts of Flow Augmentation on Stream Restoration Projects

Introduction and Purpose

As a method of helping the endangered June Sucker populations recover, the State of Utah has proposed restoring Hobble Creek in Springville to create spawning habitat (Stamp et al. 2003). This restoration area lies west of I-15 in Springville, Utah (see Figure 1). The restoration effort raises a few questions: 1) where is the optimum location for June Sucker fry to go after hatching upstream? 2) Can or will Hobble Creek deliver the fry to that location? 3) What are the sediment transport characteristics of Hobble Creek and how will they affect any created spawning habitat? This project answered the first two questions; work on the third question is ongoing through funding obtained as a result of this initial support.

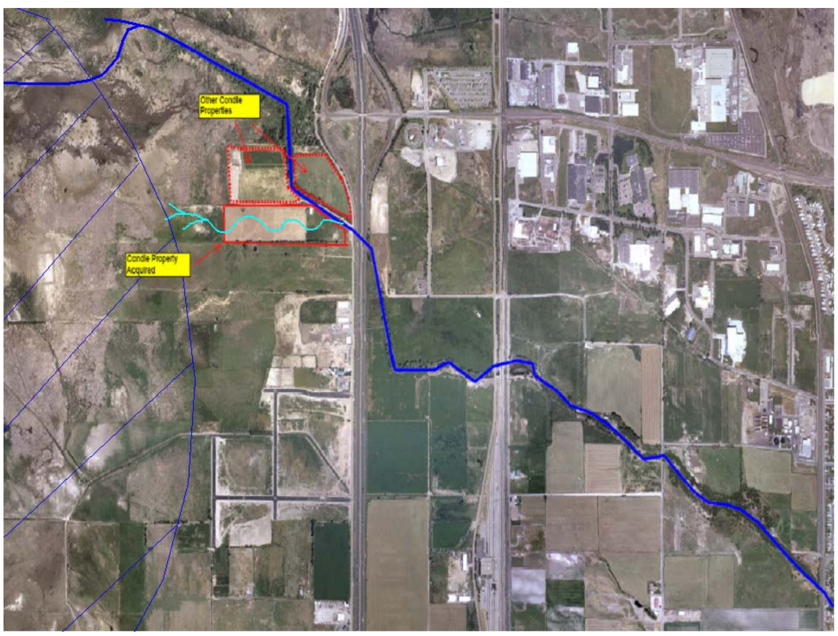

Figure 1. The proposed restoration area for lower Hobble Creek. Flow is from right to left.

June Sucker Fry Survival

In order to address the issue of identifying the optimum location for June Sucker fry survival, we investigated resource availability, areas for refuge from predation, temperature gradients in the lake/stream interface; and simulated larval drift rates of the stream to characterize where larvae will end up under the current creek flow regimes.

We set up a survey grid using geographic coordinates around the lake-stream interface of Hobble Creek and Utah Lake to sample for benthic invertebrates and zooplankton to find the areas of maximum resource potential. We sampled 4 different "zones": within the creek itself, in the dense emergent vegetation (>10 stems/ m^2) nearest the shore, in a defined zone of sparse vegetation (<10 stems/ m^2), and in the open lake where no emergent vegetation was present. In all cases, statistical analyses showed significant variation between sites, with the open lake being the area with highest counted zooplankton numbers per liter of water sampled. The creek, as expected, had very little zooplankton compared to the lake zones; for this reason we removed it from the analysis in order to see the differences between lake zones (see Figure 2).

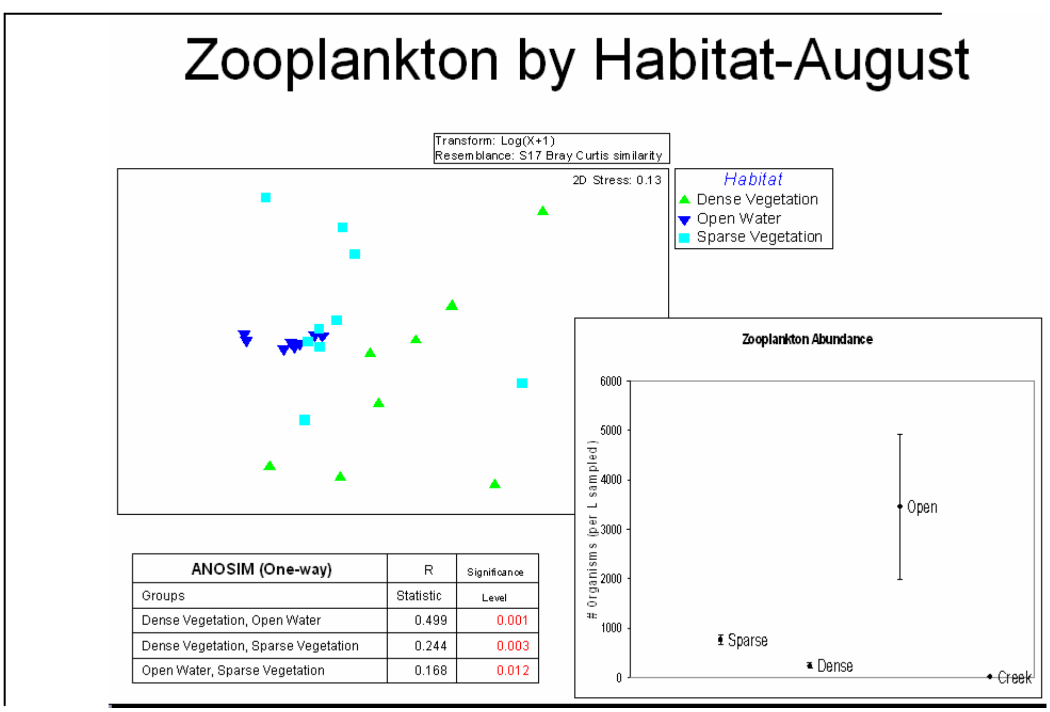

Figure 2. Zooplankton Statistical Analyses.

Areas of refuge were analyzed by setting up minnow traps along the same transects that were used for plankton sampling. Traps were left for 24 hours and minnow and small fish were identified by specie and counted. Analyses indicated that dense vegetation areas are the zones where small fish were congregating in greatest number and the difference between zones was highly significant (see Figure 3).

Finally, to further characterize habitat and the optimum location for June Sucker fry, we placed temperature probes in the three lake zones from June to November, 2007. Dense vegetation had significantly lower mean temperature than the open lake or sparsely vegetated zones (Figure 4).

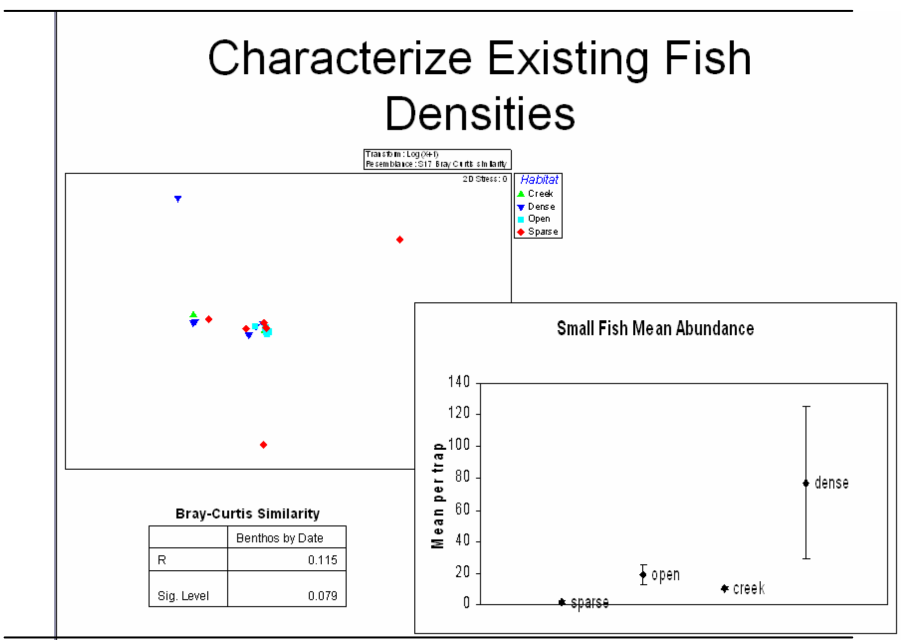

Figure 3. Minnow and small fish analysis.

By taking resource availability, refuge areas, and temperature data into account, decision makers will be more able to make appropriate decisions on the stream restoration process. It appears that there is significant opportunity to formulate June Suck fry nursery areas on the border of Utah Lake at the mouth of Hobble Creek.

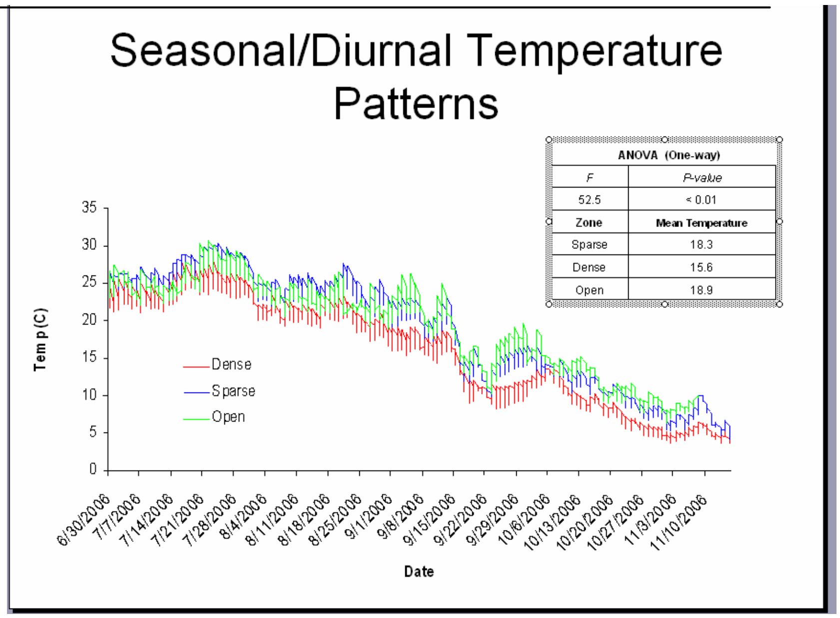

Figure 4. Temperature data from June to October.

Delivery of June Sucker Fry to Utah Lake via Hobble Creek

Knowing the target areas of development is one thing, whether the fry will make it to those locations or not is another. To help answer that question for the current creek flow regimes, we looked into where stream conditions will deliver the larvae.

Larval drift was simulated with the use of synthetic drift beads, small spheres designed to be neutrally buoyant that mimic larvae drifting with the currents. Beads were deployed in Hobble Creek at the 1600 W St Bridge and drift nets were set up west of I-15 in the levied section of the creek and beyond close to the lake-stream interface. The larval drift simulation was performed in late June when larvae are hatching in natural conditions. Figure 5 shows the starting location and drift net locations in the stream.

Beads began arriving in the most upstream sample site after 2.5 hours and arrived fairly constantly throughout the day with 30 minute sample times. Only 1 bead was collected at site 2 and no beads were found in sample site 3. From this experiment, we conclude that the stream flow characteristics are insufficient to deliver the larvae to the lake habitat under the present configuration of Hobble Creek.

Figure 5. Drift bead sampling locations.

Sediment Transport and Spawning in Hobble Creek

To address the issues of sediment transport capacities of Hobble Creek, we intend to model the stream using the Surface Model Software (SMS) system (SMS, 2006). In order to calibrate the sediment transport rate equations within the model, we have performed an extensive ongoing analysis of bedload transport rates, stream bed compositions and a detailed geometric survey of a 15.2 mile reach of Hobble Creek.

Bedload samples were taken during spring runoff event of 2006 using Bunte/Abt sampling traps. (Bunte and Abt, 2001) These were analyzed within sites to quantify lateral variations over time and between sites to determine the degree to which downstream fining occurs. Both dimensions of bedload are of interest to the restoration project, as incoming sediment that is too fine will prevent appropriate oxygenation of spawned eggs, and sediment that is too coarse will prevent redds from being built.

Several sites were selected based on a two fold criteria: proximity to roads and/or bridges, and uniform flow conditions that would facilitate discharge measurements. Bedload was measured over a 35 day period and was correlated with a simultaneously measured discharge (see figure 6). The flow rate peaked at 13.3 m^3/s (representing approximately a 5 year flood) and decreased daily down to 2.1 m^3/s, at which point bedload movement had ceased.

Figure 6. Students taking discharge measurements and bedload samples from a footbridge.

Data show that bedload D_{50} changed as a function of decreasing discharge and as a function of distance downstream. Also, bedload transport was positively correlated with stream discharge rates. Downstream fining was observed and quantified in streambed composition as well. When compared to bedload, we saw that streambed composition was coarser and more drastically affected by the I-15 culvert (see Figure 8). The I-15 culvert affect on particle size distributions can be seen clearly in Figure 9, where the curves on the left are particle size distributions from volumetric streambed samples taken immediately above and below the culvert.

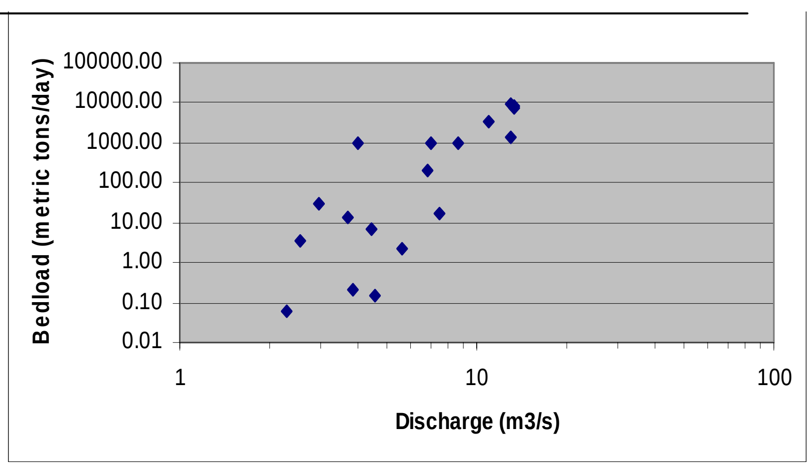

Figure 7. Bedload transport rates and flow rate on a log-log scale.

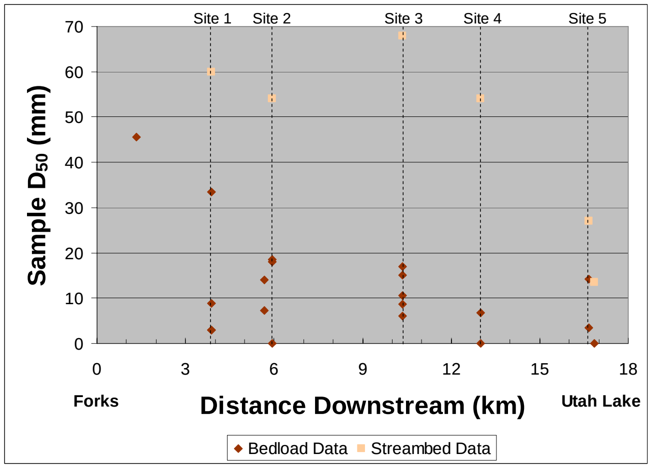

Figure 8. D50 sizes for bedload and streambed material.

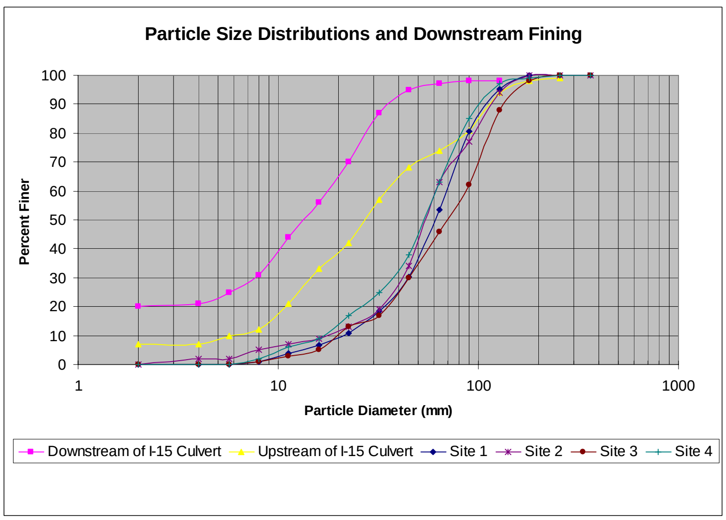

Figure 9. Particle size distributions for streambed material along Hobble Creek.

The difference between particle sizes around the culvert strongly indicates that the culvert causes a disconnect in the natural sediment transport capacity of the stream. It appears that appropriate spawning habitat for June Sucker based on sediment size is located upstream from the I-15 culvert.

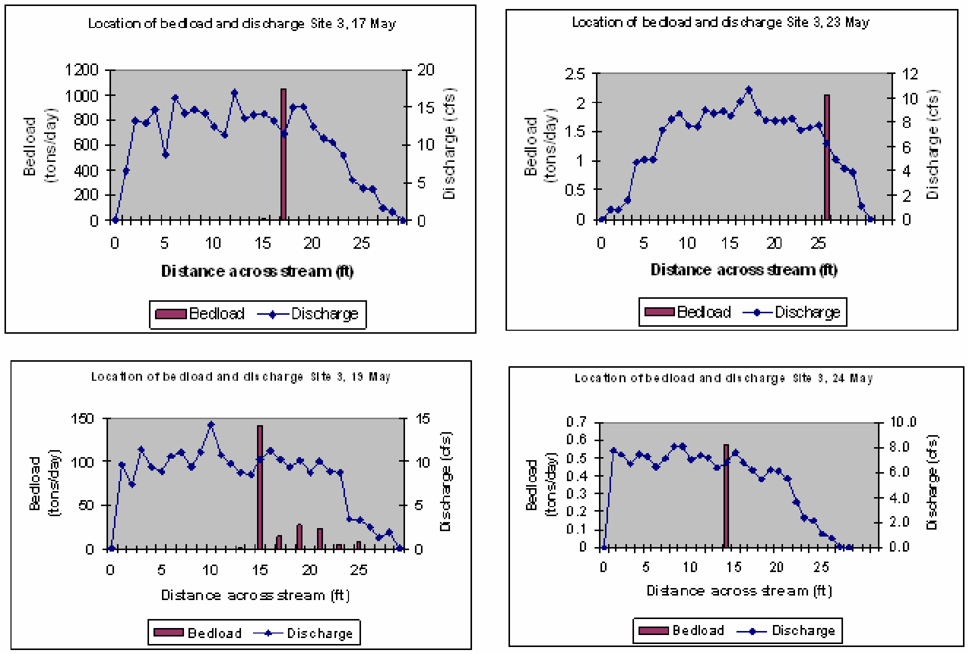

Figure 10. Lateral variation in bedload changing from day to day at a given site.

We also saw an interesting phenomenon in the bedload transport. The bedload was not necessarily located in the deepest or fastest moving water and was not uniformly distributed across the width of the stream. Furthermore, the locations across the stream where it was found would change from day to day. This lateral variation can be seen in the plots below. All four plots are from data from the same site; the red bar represents the bedload transport rate at a given location across the stream. The blue line is the unit width of discharge across the stream. The bedload does not necessarily line up with the peak unit discharge, and changes locations from anywhere between 14’ and 26’ from the right bank.

Since the restoration project intends to create spawning habitat, the affects of changing the stream geometries on sediment need to be known. Using the data acquired during this study, we will be able to accurately model both the present and future conditions of the stream for areas that may experience scour and deposition problems.

Summary of Conclusions from this Project

In summary, we have learned

1. It is likely that appropriate June Sucker Fry habitat can be created in the littoral zone of Utah Lake at the Hobble Creek outlet.
2. Current stream configuration is inadequate to deliver the June Sucker Fry to the mouth of Hobble Creek. A channel designed to do so will not meander, like one might presume of a 'natural' channel, but will take the straightest route to water as possible.
3. Adequate spawning gravels are located upstream from the I-15 culvert. We are analyzing the ability of adult June Sucker to traverse this culvert under spawning discharge conditions.

Literature Cited

Bunte, K. and S.R. Abt (2001). *Sampling Surface and Subsurface Particel-Size Distributions in Wadable Gravel- and Cobble-ben Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring*. Gen. Tech. Rep. RMS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

Stamp, M.; D. Olsen, N. Norman, and S. Herstein (2003). *Hobble Creek Habitat Enhancement Concepts to Benefit the Endangered June Sucker*. Report Submitted to Reed Harris, Program Director for JSRIP. Utah Dept. of Natural Resources. 1594 W North Temple Box 146301, SLC, Utah, 84114.

Surface Modeling Software v. 9.0. 2006. Environmental Modeling Research Laboratory, BYU. Provo Utah 84602.

Information Transfer Program

The individual research projects documented in the Research Project section of this report have integrated within them information and outreach components. These include publication of research findings in the technical literature and provision of findings and water management models and tools on the web pages of the Utah Center for Water Resources Research (UCWRR) and individual water agencies.

Beyond this, Information Transfer and Outreach activities through the UCWRR, the Utah Water Research Laboratory (UWRL), and Utah State University (USU) have had an impact on the technical and economic development of the State of Utah. As part of the UCWRR outreach activities supported by USGS 104 funds, there continues to be a vigorous dialogue and experimentation with regard to efficiency and effectiveness of outreach activities of the UCWRR. Faculty are engaged in regular meetings with State of Utah water resources agencies, including the Department of Environmental Quality (DEQ), the Department of Natural Resources (DNR), and the State Engineer's Office to provide assistance in source water protection, on-site training, non-point source pollution management, technology transfer, and development of source water protection plans (SWPPs) within the context of water-related issues in Utah.

UCWRR staff through the facilities at the UWRL, provides short courses both on- and off-site within the State of Utah, regionally, and internationally. Generally offered from one- to five-days duration, short courses are tailored to meet the needs of the requestor. The following is a partial list of short courses, field training, and involvement of UCWRR staff in information transfer and outreach activities.

Short Courses

UNESCO, the Brazilian Dam Safety Group, and RJC Engenharia, Sao Paulo, Brazil. "National Workshop Dam Safety Portfolio Risk Assessment and Management." Sao Paulo, Brazil, February 7, 2006. David S. Bowles.

Utah On-Site Wastewater Treatment Training Program. Level 1 Certification: "Soil Evaluation and Percolation Testing." Cedar City, Utah, April 4-5, 2006; Vernal, Utah, May 2-3, 2006; Provo, Utah, August 1-2, 2006; Ogden, Utah, September 12-13, 2006. Judith L. Sims, Peg Cashell, Brian Cowan, and Richard Jex.

Utah On-Site Wastewater Treatment Training Program. Level 2 Certification: "Design, Inspection, and Maintenance of Conventional Systems." Logan, Utah, May 22-23, 2006; Logan, Utah, October 2-3, 2006. Judith L. Sims, Peg Cashell, Brian Cowan, and Richard Jex.

Utah On-Site Wastewater Treatment Training Program. Level 3 Certification: "Design, Inspection, and Maintenance of Alternative Systems." Logan, Utah, May 24-26, 2006; Logan, Utah, October 4-6, 2006. Judith L. Sims, Peg Cashell, Brian Cowan, and Richard Jex.

Utah On-Site Wastewater Treatment Training Program. Level 1 Recertification: "Soil Evaluation and Percolation Testing." Cedar City, Utah, April 6, 2006; Vernal, Utah, May 4, 2006; Provo, Utah, August 3, 2006; Ogden, Utah, September 14, 2006. Judith L. Sims, Peg Cashell, Brian Cowan, and Richard Jex.

Utah On-Site Wastewater Treatment Training Program. Level 2 Recertification: "Design, Inspection, and Maintenance of Conventional Systems." Cedar City, Utah, April 7, 2006; Vernal, Utah, May 5, 2006; Provo, Utah, August 4, 2006; Ogden, Utah, September 15, 2006. Judith L. Sims, Peg Cashell, Brian

Cowan, and Richard Jex.

Utah On-Site Wastewater Treatment Training Program. Level 3 Recertification: "Design, Inspection, and Maintenance of Alternative Systems." Logan, Utah, March 22, 2006; Logan, Utah, August 10, 2006; Logan, Utah, October 18, 2006. Judith L. Sims, Peg Cashell, Brian Cowan, and Richard Jex.

Utah State University. "Physical Habitat Modeling." Utah State University, Logan, Utah, May 22-26, 2006; Yamaguchi University, Japan, September 2-5, 2006; Tokyo University, Japan, September 6-9, 2006. Dr. Thomas B. Hardy.

Utah State University. "U.S. Society on Dams 2006 Workshop on Dam Safety Risk Assessment: Decision-Making Examples and Areas of Concern." San Antonio, TX, May 4, 2006. David S. Bowles (Organizer and Presenter).

Utah Water Research Laboratory, Utah State University. "Physical Habitat Simulation and Habitat Time Series Short Course." Utah State University, Logan, UT, May 22-26, 2006. Dr. Thomas B. Hardy.

Principal Outreach Publications

Principal outreach items include the Comprehensive Water Education Grades K-6 manual (several thousand copies of the manual have been distributed throughout the country, and distribution is now being planned in the United Kingdom and Australia), newsletters addressing the on-site wastewater issues (Utah WaTCH), and Mineral Lease Report to the Utah Office of the Legislative Fiscal Analyst.

Other publications from the UWRL appear regularly as technically-reviewed project reports, professional journal articles, other publications and presentations, theses and dissertation papers presented at conferences and meetings, and project completion reports to other funding agencies.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	1	0	0	0	1
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	4	0	0	0	4

Notable Awards and Achievements

Dr. Thomas B. Hardy has received a Certificate of Appreciation from the USDA Forest Service for commitment and contributions to their resource protection efforts, August, 2006.

Dr. Thomas B. Hardy was invited by the National Center for Conservation Science and Policy to be a founding member of the "National Science Advisory Board," created by combining the staff and programs of Headwaters and the World Wildlife Fund's Klamath-Siskiyou Regional Office, July 2006.

Dr. Jagath J. Kaluarachchi received a citation in "Who's Who in Science and Engineering," *Marquis Who's Who,*" 8th Edition, 2005-2006.

Dr. Jagath J. Kaluarachchi received the "Researcher of the Year Award" for the Department of Civil and Environmental Engineering, College of Engineering, Utah State University, Logan, Utah, 2006.

Dr. Mac McKee has been elected as a board member on the Universities Council on Water Resources (UCOWR).

Dr. Laurie McNeill received the "Teacher of the Year Award" for the Department of Civil and Environmental Engineering and the College of Engineering, Utah State University, Logan, Utah, 2006.

Dr. David G. Tarboton was elected Member of "Consortium of Universities for Advancement of Hydrologic Science, Inc." Board of Directors, 2005-2007.

Dr. David G. Tarboton is a member of the Steering Committee for the "National Center for Airborne Laser Mapping," 2003-present.

Publications from Prior Projects