ITEM: 1

SUBJECT: Update on the UC Davis Big Springs Ranch Study (Mike Deas)

DISCUSSION

In August of 2008, the State Water Resources Control Board (SWRCB) provided $303,667 in funds from the Cleanup and Abatement Account to the UC Davis, Center for Watershed Science, to undertake a 9-month long investigation of Big Springs Creek. The findings of this investigation have been compiled in the report “Baseline Assessment of Physical and Biological Conditions within Waterways on Big Springs Ranch, Siskiyou County, California,” an overview of which will be presented by Mike Deas, Watercourse Engineering, who partnered with UC Davis in this effort.

Earlier this spring, The Nature Conservancy completed their purchase of the Big Springs Ranch property, the location of the UC Davis study. Due to the presence of several large cold water springs, modifications to management of the site could lead to increased cold water flows to Big Springs Creek and the Shasta River, which would aid in attainment of the Shasta River Temperature TMDL requirements. The study will be used to guide future restoration efforts. The following is the executive summary. For the complete report go to: http://watershed.ucdavis.edu/research/klamath.html

Baseline Assessment of Physical and Biological Conditions Within Waterways on Big Springs Ranch, Siskiyou County, California

1.0 Executive Summary
Introduction
The Shasta River in Siskiyou County, California may be one of the Lower Klamath River’s more exceptional tributaries (CDFG 2004, Deas 2004, NRC 2004). The river receives more than half of its annual flow from spring complexes. These springs, fed by recharge from Mount Shasta, are nutrient-rich and fuel highly productive aquatic food webs. The natural resilience of the Shasta River, coupled with its high primary productivity, suggests a high potential for significant and immediate response to restoration and conservation actions supporting salmonids.
From 2006 to 2008, the University of California, Davis (UC Davis) Center for Watershed Sciences, in cooperation with Watercourse Engineering Inc., conducted a baseline assessment of aquatic ecosystems within the Shasta River basin. With support from The Nature Conservancy, California (TNC) and the U.S. Bureau of Reclamation, these assessments provided the first-of-their kind comprehensive evaluation of factors limiting salmonid spawning and rearing in the Shasta River and related changes in aquatic ecology over the course of a year (Jeffres et al. 2008). A principal finding of these studies was that degradation of water quality and physical habitat in Big Springs Creek, a large spring-fed tributary, coupled with loss of access to the upper reaches of the Shasta River, were significant limiting factors affecting salmonid spawning and rearing. In particular, the principle limiting factor for coho salmon was high summer temperatures in reaches downstream of Big Springs Creek.

These studies, along with earlier work by Deas et al. (2004), identified Big Springs Creek and the spring complex that feeds it as the highest priority restoration location in the Shasta River. In March 2008 TNC acquired an option to purchase the Busk Ranch (TNC exercised this option on 5 March 2009 and has since renamed the property Big Springs Ranch). The property is approximately 4,100 acres with an additional 400 acres retained by the property owner (with a conservation easement). Along with numerous cold water springs, the property encompasses 4.0 km (2.5 mi) of the Upper Shasta River, 3.5 km (2.2 mi) of Big Springs Creek, 1.6 km (1 mi) of Little Springs Creek, and portions of Parks Creek and Hole in the Ground Creek (a spring creek). The steady influx of cold (12oC/54oF) water makes the Big Springs Ranch’s spring complex a natural haven for native fishes. Cold, clear water and almost 9.7 km (6 mi) of potential prime salmonids habitat make the Big Springs Ranch one of the most ecologically important parcels in the entire Klamath River watershed.

**Big Springs Creek Project**
The UC Davis Center for Watershed Sciences and Watercourse Engineering Inc. conducted a baseline assessment of physical and biological conditions within waterways on the Big Springs Ranch. The focus of this effort was to document baseline conditions in the previously undescribed Big Springs Ranch and provide guidance to resource managers in restoration efforts. Specifically, the goal of the baseline assessment program was to support conservation and restoration planning throughout the Shasta River directed toward management of coho and Chinook salmon, and steelhead trout. To that end, the objectives of our study were four-fold:

1) document baseline aquatic habitat conditions in Big Springs Creek and other springs and spring creeks from Summer 2008 through Winter 2009. The sample sites adequately represent lateral and longitudinal gradients as well as ranges of conditions that affect salmonids in these unique systems.

2) establish a monitoring infrastructure and protocols that capture, to the extent possible, seasonal changes in habitat conditions and food web structure.

3) identify and, where possible, quantify factors that limit salmonid production downstream in the Shasta River

4) identify a range of options that may be viable for improved water resource and habitat management that will directly improve salmonid spawning and rearing conditions
This baseline assessment greatly increases understanding of hydrological and ecological processes not only within Big Springs Ranch, but also provides important insights into the Shasta River. Using an interdisciplinary approach, we were able to describe physical and ecological limiting factors affecting salmonids in Big Springs Creek. Study elements included a wide range of field investigations, laboratory investigations, and computer model simulations. We collected physical data documenting hydrology, water temperature, water quality, geomorphology and physical habitat; obtained ecological data through surveys of primary producers, aquatic macroinvertebrates, and, using light stable isotopes, food web structure; and conducted extensive fish surveys to determine seasonal habitat utilization. This data, along with knowledge gained from previous and ongoing studies on the Shasta River, were used to develop preliminary restoration strategies for Big Springs Creek. A two-dimensional hydrodynamic and water temperature model was developed to identify potential flow and thermal benefits associated with selected passive (no direct actions in the stream channel) and active (direct in-channel activities) restoration actions after 1, 5, and 20 years.

Key observations and conclusions identified in this seminal investigation of Big Springs Creek include:

**Streamflow**

**Findings**
- During the non-irrigation season portion of the assessment period (1 October 2008, to 8 January 2009) streamflows in Big Springs Creek (mean = 82 ft³/s) were minimally variable and nearly five times mean streamflows recorded in the Upper Shasta River (above the Big Spring Creek confluence and including Parks Creek inflows; mean = 15 ft³/s).

- During irrigation season (1 April 2008 to 1 October 2008) Big Springs Creek streamflow declined by 35% (mean = 54 ft³/s). This seasonal reduction was derived almost entirely from water diversions from Big Springs Lake and apparent reduced spring flow contributions associated with seasonal groundwater pumping local to and upgradient (east and south) of the Big Springs complex. Streamflow magnitudes in the Upper Shasta River above the Parks Creek confluence fluctuated little during the study period. Streamflows in Parks Creek were variable during the irrigation season and doubled (increasing from approximately 6 ft³/s to 13 ft³/s) following cessation of irrigation season on 1 October 2008.

**Streamflow: - Conclusion**

The Big Springs complex forms a considerable and important component of baseflow for the Shasta River downstream of Big Springs Creek. Seasonal depletion is evident during summer periods when diversions and possibly groundwater withdrawals deplete flows not only in Big Springs Creek, but also upstream reaches of the Shasta River and Parks Creek.
**Water Temperature**

**Findings**

- Big Springs Lake, an artificial impoundment intended to provide water to irrigated agriculture, forms the headwater temperature boundary condition for Big Springs Creek. The lake is fed by a spring complex at the eastern shoreline. Water that discharges from the lake into the creek ranges from approximately 10°C in winter to over 15°C in summer. Considerable spring inflows averaging approximately 11°C contribute to the baseflow of the creek.

- Big Springs Creek is prone to high thermal loading. This stems, in part, from water management practices prior to ownership by TNC, where depletion and tailwater return contributed to heat gain. However, much of the heating is associated with the degraded channel form. More than a century of intense grazing has removed all riparian vegetation. Additionally, grazing has led to erosion of channel banks and the formation of a broad, shallow channel that maximizes heating due to insulation. During daytime in spring and summer, water discharged from Big Springs Lake and the adjacent spring complex warms at a rate greater than 3°C per km (5°C per mi) before reaching the confluence with the Shasta River. However, due to a short transit time, waters within the creek are completely replaced during the night by spring flow. Coupled with local nighttime meteorological conditions, the result is daily lows throughout the summer averaging 11°C to 12°C. These low nighttime values are a potentially valuable attribute for anadromous fish.

- Tailwater associated with flood irrigation practices adjacent to Big Springs Creek can exacerbate thermal loading associated with degraded channel form and lack of riparian shading. Temperatures over 30°C were measured in tailwater return flows in May, 2008, indicating that water management practices are a likely source of warming. However, more information is needed to quantify the water quality impacts of tailwater.

- During summer 2008, the previous landowner reduced grazing pressures within Big Springs Creek. This allowed observation of the impact of seasonal growth of aquatic vegetation on channel form, hydrology and water quality. Left undisturbed, aquatic macrophyte growth caused a narrowing and deepening of the channel through increased river stage, which improved physical habitat for salmonids. Shading associated with extensive vegetation growth, a reduced airwater interface available for heat exchange, and a shorter transit time due to channel narrowing all led to moderated water temperatures in the creek. These observations indicate that even basic cattle exclusion practices can markedly modify channel form and provide direct thermal benefits.

- Modifications to Big Springs Creek include crossings for water pipelines and roads, and modest bank stabilization efforts. One such feature, an inoperative water wheel structure, creates a large backwater in the upper creek, leading to marked increased channel widths (90 m) and shallow depths (0.5 m).
resulting in increased thermal loading. Water temperatures increase as much as 3.9°C in the 420 m reach upstream of the water wheel. Model results indicate that removing the water wheel could decrease the maximum heating rate by 1°C; however, temperatures at the mouth of Big Springs Creek would be largely unaffected by the removal of this structure.

**Conclusion: Water Temperature**
The spring complex that feeds Big Springs Creek is a distributed collection of springs encompassing a fairly large spatial area. Considerable accretions of spring flow at a stable temperature of approximately 11°C create a wide range of thermal conditions. During summer, the springs provide cool water inputs into an otherwise warm system, and in winter the spring flow provides relatively warm waters to a system that would typically be notably colder. Given that historic land and water use practices on the ranch have created a thermally degraded condition, there is considerable potential for restoration of cooler thermal conditions through cattle exclusion and improved irrigation water management.

**Water Quality**
**Findings**
- Unlike most rivers, where elevated nitrogen and phosphorous levels are caused by anthropogenic sources, elevated inorganic nitrate (0.39 mg/l) and inorganic orthophosphate (0.16 mg/l) levels in Big Springs Creek are naturally derived from geologic sources along the groundwater flowpath (i.e. from source or recharge area to the Big Springs complex).
- A longitudinal attenuation of nitrate was observed during the spring and summer months as distance increased from the spring source. This decrease is likely inversely proportional to the abundance of aquatic macrophytes in the channel as determined from qualitative macrophyte biomass observations throughout the year. A similar rate of attenuation was not observed in orthophosphate, suggesting that the system experiences nitrogen limitation in Shasta River reaches downstream from Big Springs Creek.

**Conclusion: Water Quality**
Unique water chemistry in Big Springs Creek includes large, dispersed springs of constant temperature with notable inorganic nitrogen and phosphorus concentrations. These high nutrient levels result in unusually high primary production, which forms a critical base of the food web. This food web is an important element of ecology of Big Springs Creek and is capable of supporting juvenile salmonids.

**Geomorphology**
**Findings**
- Cross-sectional channel forms in Big Springs Creek are characterized by predominantly rectangular geometries with large width-to-depth ratios. Mean width to depth ratios observed in Big Springs Creek are more than double
those observed in spring-fed creeks throughout eastern Oregon and western Idaho.

- Big Springs Creek exhibits three discrete longitudinal differences in channel slope. Gradient differences are controlled by erosion-resistant bedrock outcroppings in the channel bed and channel margins.

- Qualitative observations suggest fine sediment (sand and silt) transport and depositional dynamics are strongly influenced by aquatic macrophyte growth. Water velocities within and adjacent to macrophyte beds are reduced, resulting in increased sedimentation, particularly within dense macrophyte beds along the channel margins. However, increased water velocities between macrophyte stands (i.e., main channel) promote suspension of fine sediment and the winnowing of fine sediment from available spawning gravels—a beneficial outcome.

- In-channel cattle grazing influenced channel morphology through bank erosion and fine sediment mobilization. Bank trampling appeared to be the dominant source of fine sediment in Big Springs Creek. Furthermore, the removal of aquatic macrophytes through cattle grazing appeared to mobilize fine sediment trapped in macrophyte beds.

- The rock structure that supported the historic water wheel creates a large backwater resulting in extremely wide and shallow channel geometries for approximately 420 meters upstream. Slow water velocities throughout this reach appear to promote fine sediment accumulation.

Conclusion: Geomorphology
The relatively stable spring-dominated hydrology of Big Springs Creek (i.e., the predominance of groundwater-derived baseflows and a lack of large, precipitation driven flood events) results in stable channel morphologies exhibiting moderate gradients and high cross-sectional width-to-depth ratios. Natural channel change in Big Springs Creek appears largely limited to alterations in bedform configuration due to the growth (and destruction by grazing) of submerged aquatic macrophytes. Channel restoration activities in spring-fed creeks like these require different approaches from snowmelt- and rainfall-dominated systems. Stable, predictable flows enable the use and management of a wide variety of passive actions (e.g., riparian fencing to promote macrophyte and riparian growth) during restoration.

Food Webs

Findings

- Standing crops of both epilithon and aquatic plants increased throughout the study period with the submergent aquatic macrophytes *Myriophyllumsibericum* (northern watermilfoil) and *Polygonumamphibium* (water smartweed) accounting for the bulk of the macrophyte biomass.
The aquatic macroinvertebrate communities in Big Springs Creek and the Shasta River were dominated by members of the collector-gatherer feeding guild while shredders and invertebrate predators were relatively rare.

Amphipods (Hyalella sp.) were especially abundant in Big Springs Creek during the summer and fall sample periods with densities exceeding 80,000 individuals per square meter of streambed during the fall.

Natural abundance stable isotope analysis indicated that most primary consumers in Big Springs Creek were deriving their carbon from sources of fine particulate organic matter, epilithic biofilms and attached algae.

The diets of juvenile salmonids during the spring sample period could not be accurately assessed using stable isotope analysis due to the presence of residual maternal yolk in their body tissues. However, juvenile salmonids had clearly reached isotopic equilibrium with their riverine diets by the summer and fish appeared to be feeding opportunistically on the invertebrate assemblage.

**Conclusion: - Food Webs**
Abundant growth of submergent and emergent macrophytes was a salient feature of Big Springs Creek throughout much of the year. While these plants serve as important habitat for macroinvertebrates and fish, they make limited contributions to carbon flow in the food web prior to senescence, decomposition and entry into the detrital pool. Fine particulate organic matter was the major source of carbon fueling secondary production in Big Springs Creek and members of the collector-gatherer functional feeding group dominated the invertebrate assemblage. While overall taxonomic richness was low, aquatic macroinvertebrate densities are remarkably high throughout much of the year. Collectively, our results suggest that Big Springs Creek has a unique intrinsic potential to provide high-quality rearing-habitat for juvenile salmonids.

**Fish and Fish Habitat**

**Findings**

When water temperatures increased in late May, 2008, approximately 225 juvenile coho from Big Springs Creek and the Shasta River migrated to the pool at the outlet of Big Springs Lake, where they remained throughout the summer and fall. This was the only location where juvenile coho were observed in Big Springs Creek during the summer months.

Food was never limiting for over summering coho salmon. Primary production, as fueled by naturally elevated levels of inorganic nutrients (nitrogen and phosphorus) from the springs complex, provides abundant food sources that, coupled with cool summer water temperatures, lead to optimal conditions for growth of coho salmon, albeit in a very small area.
- Relatively warm waters during winter result in the early emergence and rapid growth of juvenile salmonids in Big Springs Creek. Further, warm winter water temperatures allow for growth of aquatic vegetation and benthic invertebrates that provide cover and food for juvenile salmonids rearing in Big Springs Creek.

- During October, adult Chinook salmon returned to spawn in the lower section of Big Springs Creek. Several active redds were found on the lower creek, the only location where suitable gravels currently exist. With adult Chinook present, mature male Chinook parr were observed in the redds and participating in spawning activities. Maturation as parr is a relatively unique life history strategy and is likely the result of the productive spring-fed system.

- A school of adult and juvenile steelhead was observed immediately above the water wheel throughout the study period. The steelhead utilized the relatively deep backwater upstream of the water wheel. It is unknown if these are resident rainbow trout or steelhead oversummering in Big Springs Creek.

**Conclusion: - Fish and Fish Habitat**

Conditions throughout much of Big Springs Creek are too warm for oversummering of juvenile coho salmon. Currently, localized cool water sources with adequate depth are where coho find habitat throughout the summer months. Despite current degraded conditions, attributes that could potentially provide unique and valuable habitat for anadromous fishes, and in particular coho salmon, include nutrient rich spring inflows and unique habitat conditions along upper Big Springs Creek. Springs moderate temperatures in the creek, with relative cool water in summer and warm water in winter. Naturally elevated levels of inorganic nitrogen and phosphorus result in substantial primary production, which in turn fuels the food web that provides abundant, high-quality food for juvenile salmonids rearing in Big Springs Creek.

**Restoration Strategies**

The data collected and detailed observations made in this study allow for development and evaluation of an array of restoration strategies. These fall into two categories: passive restoration strategies that include actions where no direct in-channel work is carried out, and active restoration actions that include direct in-channel activities.

- Passive restoration strategies
  - **Riparian fencing**: Excluding and/or management of livestock in the riparian zone can reduce channel bank degradation, allow woody and herbaceous riparian vegetation growth, and in-channel vegetation growth to narrow and deepen the channel. A narrower, deeper channel will reduce heating through a smaller air-water interface and reduced travel time. Coupled with more effective shading from riparian
vegetation on a narrower stream, the new channel morphology will lead to reduced temperature throughout the system.

- **Tailwater management** - Irrigation management actions, such as capture of agricultural tailwater for reuse to eliminate warm inputs to Big Springs Creek will be beneficial to instream water temperatures. Tailwater could also be managed to discharge waters that are not elevated in temperature.

- **Management and irrigation efficiency** - Improved conveyance, water application rates, field rotation (e.g., hay vs. grazing), retirement of unsuitable lands (e.g., avoid flood irrigating steep lands adjacent to creek), etc., can reduce diversions or modify diversion timing, leaving more cool water in the creek to support anadromous fishes.

- **Active restoration**
  - **Planting emergent and riparian vegetation** - Planting of emergent and riparian vegetation to stabilize stream banks and help trap fine sediment. Vegetation should be established above the water wheel to reduce sediment flux to Big Springs Creek prior to removal of the structure.
  
  - **Placement of large woody debris** - Currently, instream structure in Big Springs Creek is largely absent, yet has been shown to be a vital component in high quality coho salmon habitat. Instream structures such as large woody debris (LWD) placed in a spring-fed creek will have a much longer lifespan than instream structures placed in a non-spring-fed river due to the absence of high-flow events. Trees placed in the stream will create velocity refugia and overhead cover for rearing juvenile salmonids. geomorphic impacts of LWD placement will include localized scour of fine sediments, which will increase depths near the LWD.

  - **Sediment Management** - If active restoration is to take place in the channel, a fine sediment management plan should be in place to monitor sediment flux as a result of restoration activities. This will allow for realtime management to strike a balance between long term restoration of habitat with short term sediment management.

- **Modeling Potential Restoration Actions:**
  - One element of this study was the development of a two-dimensional water flow and temperature model to assess potential impacts of various actions including increasing flows, narrowing the stream, and providing riparian shading. This proof of concept application has provided key insight into rates of heating along the creek and the implications of different prescriptions on thermal conditions along the creek during summer periods (e.g., the impact of additional riparian shading versus
narrowing of the channel). The model is limited to Big Springs Creek and does not include downstream effects in the Shasta River.

- In addition to identifying potential implications of increased flow, reduced channel width, and shade from riparian vegetation, specific modeling assumptions associated with an approximate time frame of when restoration prescriptions would be effective or provide benefit was completed. Time frames of 1, 5, and 20 years were assumed and different assumptions on the extent and efficacy of restoration measures was applied.

- Simulation results suggest an immediate response to cattle exclusion (1 year) with eventual reductions of up to 4oC in mean daily maximum temperatures for long-term restoration conditions (20 years). These conditions will not only provide benefit to Big Springs Creek, but to downstream reaches of the Shasta River.

- The flow and temperature model can interface with existing TMDL models or be extended to include additional water quality parameters. As such, this tool would be available to assess and identify TMDL implementation plan activities, determine potential efficacy of specific actions, and prioritize actions for completion.

- Assumptions employed in the Shasta River TMDL relating to Big Springs Creek were reviewed. Flow assumptions in the TMDL were confirmed with field observations from the 2008 field study – summer flows in Big Springs Creek contribute on the order of 60 ft³/s to the Shasta River. However, TMDL assumptions regarding heating in Big Springs Creek between the lake and the Shasta River were low. Field studies indicate that water released from the lake can exceed 15oC (versus the assumed 12oC). Furthermore, assumptions made about inflow temperatures to the Shasta River under existing conditions and, in particular, during future scenarios were several degrees lower than those observed and modeled under a restored condition. These findings can be incorporated into the TMDL implementation plan activities as appropriate.

- Monitoring is a critical element of any restoration program. To assess the efficacy of restoration prescriptions, baseline monitoring programs must be in place prior to, during, and after restoration. A comprehensive monitoring plan will allow for real-time information gathering that will measure the success of restoration activities and provide guidance if restoration/ranch management actions need to be altered. The report provides specific recommendations for flow, temperature, water quality, geomorphology, food webs, and fish monitoring.
Conclusion: Restoration Strategies
Big Springs Creek and associated springs complex provide multiple attributes that support coho salmon and other fish species of interest. However, land and water use has degraded streamflow and water temperatures, limited seasonal sequestering of nutrients in plant biomass, modified the geomorphology, disrupted food webs, and limited coho and other salmonid production in the creek and in downstream Shasta River reaches.

Beyond formulating baseline conditions for habitat and habitat usage in Big Springs Creek, this project introduces a limited set of potential passive and active restoration actions. These actions are not intended to be exhaustive, but provide fodder for future exploration of opportunities to restore this unique aquatic system as additional research sheds light on critical elements of the creek and associated land use actions (both on site and in the general local area).

Summary and Recommendations
Ecologic, hydrologic and geomorphic assessment activities at Big Springs Ranch indicate that salmonid habitat conditions in Big Springs Creek are severely degraded due to past ranch management. However, during the course of this study, Big Springs Creek demonstrated high resiliency, with significant improvements in conditions with only minor changes in management. Aquatic macrophyte growth was prolific in Big Springs Creek when cattle were excluded from the stream. The aquatic macrophytes added habitat complexity, increased depth, and trapped fine sediment in the margins, revealing suitable spawning gravels in the channel. Despite degraded conditions in much of Big Springs Creek, isolated locations currently exist where juvenile coho are able to grow at rates nearly double that of an adjacent watershed. Using physical and ecological data, a hydrodynamic and temperature model was built to assess restoration alternatives. The model will help ranch managers prioritize restoration options for a rapid recovery of Big Springs Creek.

Despite the large amount of information collected during this study, many questions remain about the unique ecologic conditions in Big Springs Creek, how those conditions will change in response to a range of restoration activities, and how those changes will impact downstream reaches of the Shasta River. For this reason, we recommend continued investment in improving the ecologic and hydrologic models for Big Springs Creek. The baseline dataset developed during this study will be the foundation of a monitoring program that should accompany any restoration effort. This monitoring program will be used to determine degrees of success in restoring Big Springs Creek and to help guide ranch management and restoration activities. The quality of the baseline data and models allows for a novel approach to real-time monitoring and assessment that can be used elsewhere in the Shasta River and the Klamath River basin.