AWARD-WINNING RIVER RESTORATION ON THE BLUE RIVER DOWNSTREAM OF DILLON DAM IN SILVERTHORNE, CO

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Introduction

Construction of a large dam across a river can result in change to the stream's hydrologic cycle and sediment supply, which can affect the stream's stability leading to degradation of aquatic habitat. Such was the case for the Blue River below Dillon Dam in Summit County, Colorado (Figure 1). The construction of the dam has eliminated the upstream sediment supply, which has created a stream with "excess energy." This energy has caused erosion of the bed and banks. Due to the formation of an armor layer, the erosion has primarily focused on the banks creating an over-widened channel.

The stretch of river below the dam is classified as "Gold Medal" Status for one of the premier trout fisheries in Colorado. However, increased diversion of water to Colorado's Front Range, coupled with the recent drought conditions in the west, has resulted in significantly lower reservoir releases from Dillon Dam. Aquatic habitat downstream of the dam deteriorated under these new, lower-flow regimes, resulting in degradation of the fisheries. The restoration project reshaped the channel so that its size and shape were once again in balance with reservoir releases and sediment constraints.

Figure 1. Site Location Map

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Approach

The design mimicked an architectural/engineering approach normally followed in the design of buildings. The architect in building designs ensures good form and function, while the engineer is responsible for its structural integrity. In this case the architectural role was provided jointly by the fluvial geomorphologist and restoration ecologist, who determine the required channel shape and achieve the proper function. The engineer, who is an expert in fluvial hydraulics, was responsible for a design to ensure the long-term stability of the channel form.

Design

Aquatic Habitat Requirements

To create an optimal trout fishery a variety of specific habitat features are required. In general, optimal trout riverine habitat can be characterized by clear, cold water; a silt-free rocky substrate in riffle-run areas; an approximately 1:1 pool-to-riffle ratio, with areas of slow, deep water; well-vegetated stream banks; abundant instream cover; and relatively stable water flow, temperature regimes, and stream banks (Raleigh 1986). Evaluations indicated that the primary limiting factors for trout habitat below the dam were average water depth and over-wintering pool habitat.

Project design focused on creating these features. Deep over-wintering pool habitat was one of the primary objectives as low flows have reduced quality habitat during this critical life cycle. Additionally, well-oxygenated riffles (at appropriate depths and flow velocities) and glides were all included to provide the range of habitat typical of a healthy ecosystem. A meandering low-flow channel was constructed within the larger existing channel. During lower flows, all the water is contained within this area, which greatly increases the water depths and trout habitat. The design will increase the overall holding capacity of the stream and create a diverse fishing experience. Additionally, the final design will provide the fisherman with a wide variety of fishing opportunities from deep pools, rock features, riffles and glides/runs (see Photos 1 and 2).

Hydrologic Evaluation

A review of recorded stream flow records through the project reach since construction of the dam provided an indication of how the natural hydrograph has been altered. Figure 2 depicts recorded mean, maximum and minimum average daily flows. Of specific interest to design of the aquatic habitat was the magnitude and duration of the low flows. As the figure suggests, during some dry years, there is little variation in flow throughout the year with none of the peaking flood events typical of a natural system. This was the case during the drought of 2002 where releases from the reservoir were maintained at approximately baseflow levels (52 cfs) for almost 600 consecutive days.

A flow frequency analysis was performed to quantify flows in the river during low flow conditions that occur most years. The bankfull flow was found to be approximately 1000 cfs and the FEMA regulated 100-year flow is 3,360 cfs. The evaluation indicated that since the dam was constructed, flows are at or below 100 cfs for approximately 50% of the time and at or below 52 cfs 10% of the time. This provides an indication as to the large flow range that the design needed to address. Higher flows are generally a concern for channel stability and lower flows are more critical for maintaining quality trout habitat. As future water demands increase, lower flows are projected to be even more typical.

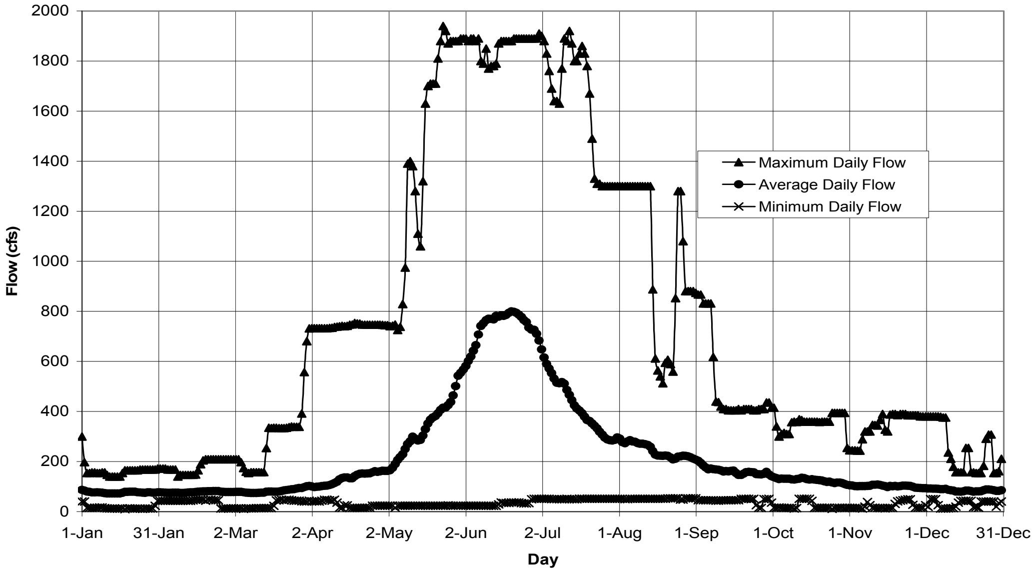

Figure 2. Blue River Daily Flow Data from Gage USGS 09050700, 1960-2001

Fluvial Geomorphic Investigation

Due to the dam, the fluvial geomorphic investigation could not rely on the typical reference reach evaluation. The geomorphic analysis was conducted in a qualitative manner by using 1. a standardized characterization of the stream; and 2. the flow statistics downstream of the dam. The first was used to develop reasonable ranges for the channel morphology relying on regional data (Andrews 1984) and typical references (Leopold et al 1964 and Rosgen 1996). The second was used to estimate the cross-sectional geometry of the stream. Regional experience was used to decide on the spacing of pools while pool depths were determined by relying on habitat requirements for trout. Finally, the desired three-dimensional geometry of the river was checked by conducting calculations in fluvial hydraulics, based on an analytical model developed by Odgaard (1986). The design process was interactive/iterative and relied on published generalized knowledge, as well as expertise, experience and intuition of the design team as a whole.

Fluvial Hydraulic Analysis

A fluvial hydraulic analysis was then conducted to assess stream bed and bank stability, determine the rock size required for a stable channel and estimate the natural variations in the stream's cross section through the different riffle, pool and glide sections. All of the calculations cannot be covered in this document, therefore a list of appropriate references are shown in Table 1. The information was used to design bank protection as shown in Photo 3.

Table 1. Summary of Hydraulic Calculations

Criteria	Reference	Formula	Result
Bed and Bank Stability (minimum d_{50})	Annandale 1995	K = Ms * Kb * Kd * Js	Loosely packed = 250 mm Tightly packed = 200 mm
	Rooseboom 1982	$V_{shearcrit}(\rho_s, \rho, d_{50}, C_d) := 0.12 \cdot \sqrt{\frac{4 \cdot (\rho_s - \rho) \cdot g \cdot d_{50}}{3 \cdot \rho \cdot C_d}}$	280 mm
	Shields 1936	$\theta(\tau_0, \rho_s, \rho, d_{50}) := \left[\frac{\tau_0}{g \cdot \rho \cdot \left(\frac{\rho_s}{\rho} - 1 \right) \cdot d_{50}} \right]$	260 mm
Bend Morphology	Odgaard 1986	$S_{Tc0} := \left(3 \cdot \frac{\alpha}{2} \right) \cdot \frac{(\sqrt{\theta}) \cdot (m_{dash} + 1) \cdot F_{Dc} \cdot d_c \cdot b}{\kappa \cdot (m_{dash} + 2) \cdot b \cdot r_c}$	See Figures 3 and 4

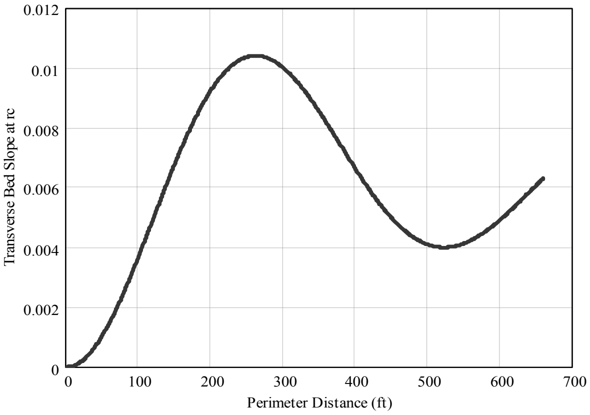

Figure 3. Transverse Bed Slope as a Function of Distance through a Meander Bend

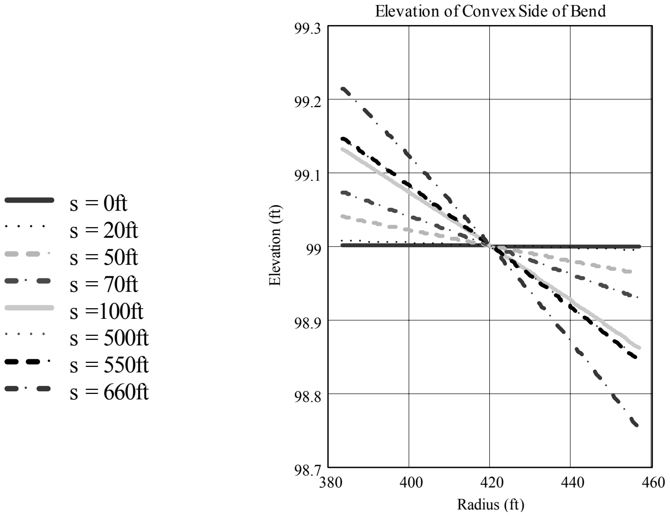

Figure 4. Cross Sectional View of Transverse Bed Slope through a Meander Bend at various locations along the perimeter (distances)

Construction

The river restoration followed a naturalistic approach with the goal of establishing natural stream function and appearance. None of the typical, structural habitat features often used in river restoration designs, such as jetties, vortex structures or weirs was incorporated in the design. The goal of the design was to create a restored river that does not have the appearance of having been tampered with by man, but functions as and has the appearance of a natural stream (see Photos 1 and 2).

Award

This project won the "Project of the Year Award in the Utility Drainage and Environmental – Small Communities Category by the Colorado Chapter of the American Public Works Association."

Photos

Photo 1. Pre-construction, taken from bridge below dam.

Photo 2. Post-construction, taken from bridge below dam.

Photo 3. During construction, placement of large boulders to stabilize banks (d_{50} calculated by hydraulic engineer)

References

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