Photo courtesy of David Gordon, *Pacific Environment.*

# Side Channel Mapping and Fish Habitat Suitability Analysis using Lidar Topography and Orthophotography

by Joseph L. Jones

## Introduction

Preserving and restoring salmon habitat are critical issues in western Washington State. Much of the resources brought to bear on these issues are being focused on rivers and streams having the greatest potential for creating or restoring habitat capable of supporting juvenile salmon. The U.S. Geological Survey Washington Water Science Center, in cooperation with the Port Gamble S'Klallam Tribe, explored the possibility of using lidar elevation data and digital color orthophotography to map and evaluate potential salmon habitat. River side channels, relic or abandoned channels and flood channels, were targeted specifically because rehabilitation plans for the river focus around the creation of stable log jams that create habitat for juvenile salmon, raise the upstream river stages, and provide additional shallow water refuge areas. The effort resulted in development of a methodology that allows rapid identification of areas where potential habitat has the highest potential for creation or restoration.

The area under consideration, the lower 12.5 miles of the Dosewallips River, drains the eastern Olympic Mountains in Washington State (Figure 1). The basin is about 100 square miles and ranges in elevation from sea level to over 6,000 feet. Mean annual discharge is around 300 cubic feet per second (cfs), with minimum flows around 60 cfs and maximum flows of several thousand cfs. The river serves as critical spawning and rearing habitat for at-risk salmon stocks and though the watershed is a high priority regional conservation area for fish and wildlife, little river-floodplain habitat exists with which to prioritize and plan habitat protection and restoration efforts.

Large woody debris (LWD) functions as a key structural component in Pacific Northwest river-floodplain environments. Historical logging and stream channel clean-outs have reduced instream LWD quantities and altered its habitat-forming characteristics to the detriment of salmon and other aquatic and terrestrial species. A key element in Pacific Northwest salmon habitat restoration includes the addition of LWD to river channels to increase habitat complexity, provide cover, form holding pools, and reconnect river channels with their associated floodplains. However, limited restoration dollars and LWD requires that restoration planners pinpoint effective rehabilitation areas and avoid others which endanger public infrastructure and private property.

The Dosewallips basin in the vicinity of the lower reach being considered here was clearcut decades ago, and the second growth forest is now maturing and contributing large woody debris (LWD) to the river; however, the logs are not yet large enough to serve as anchor pieces for log jams that represent important habitat features in salmon bearing rivers. Small pieces of LWD serve a limited role as salmon habitat from year to year, but they are not stable enough to provide permanent pools and force the hydraulic and geomorphic processes (flooding, sedimentation) that would naturally allow side channels to serve their original function in the ecosystem. As a result, many of the side channels are inactive relics from a time when old growth log jams littered the floodplain. The U.S. Forest Service (USFS) has agreed to make a few very large old growth logs with root wads available for placement in the river as anchor pieces that will collect smaller pieces of LWD that currently are flushed downstream during winter floods. Due to the limited availability of these anchor pieces, the Tribe and USFS would like to place them in locations where they will have the maximum effect on salmon habitat—downstream of the side channels targeted in this study.

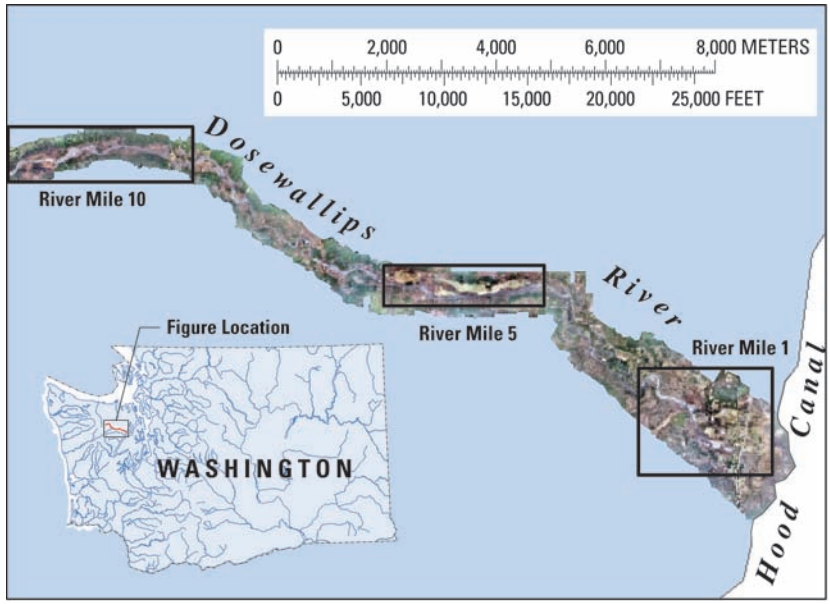

Figure 1. Map of the Dosewallips River study area.

Field mapping of these side channels is problematic because access is limited, the floodplain is heavily forested, and many of the channels are only slightly lower than the floodplain. LIDAR elevation data has been used to identify subtle terrain features, such as remnants of earthquake faulting, landslides, and glacial deposits in forested landscapes (Sherrod, et al., 2004, Haugerud, et al., 2003). Thus, these data may also be used to identify similarly subtle geomorphic features in a forested landscape such as side channels. They also allow the evaluation of side channel potential as habitat by determining their elevation relative to the adjacent river surface.

## Channel Identification Methods

Multiple lines of evidence were used to identify side channels -- color-enhanced lidar elevation data, color-enhanced slope derivative of lidar data, and orthophotography features. Four reaches of different geomorphic character were selected to assess the effectiveness of the approach in different settings. The lowest reach, river mile 1, is the mouth of the river, a broad flat distributary a few thousand feet wide. The next reach upstream, river mile 5, is a relatively flat valley about 1000 feet across surrounded by steep forested slopes. River mile 10 is similar to that, but less than 1000 feet across with a steeper and more abrupt transition at the valley's edges. River mile 12 is a narrow reach with little sedimentation or habitat potential so it was eliminated from the study once it became obvious there would be few, if any, side channels to identify.

Directly inspected lidar elevation data were color enhanced by setting display parameters such that the maximum color stretching would show subtle changes in elevation. The lidar data of 15cm accuracy or better were collected from a helicopter flying along the river at around 1500 feet altitude, and were processed into a 2 meter grid model of bare earth. Digital color orthophotography was rectified using this elevation model and is three-band (red, green, blue) with 6-inch resolution. For reaches of stream varying from a few hundred meters to approaching a kilometer (depending on the local geomorphology and forest density), maximum and minimum elevations of the surrounding floodplain were identified, and all values outside of that range were excluded from display. The result is that when using a color display spectrum with the greatest variety and a narrow elevation range, subtle changes in elevation appear and reveal side channels, often with the classic V-pointing-upstream appearance many are familiar with from elevation contour maps (Figure 2, red lines are the digitized channels).

Side channels were digitized heads-up on the computer display. The slope derivative of elevation data was explored by trial and error, initially using ranges of slopes where the slopes of natural geomorphic features tend to be concentrated (Ritter, 1978); the slope range of 4-11 degrees (shown as red on Figure 3) was selected as best identifying the sides of side channels. Direct inspection of the orthophotography involved looking for primarily three features: standing water (Figure 4, top center), vegetation features such as greener ground cover (Figure 4, center), and linear occurrences of distinct tree types (Figure 4, lower left). The latter was discovered only after evaluation of field-mapped channels (after digitizing side channels using the methods described here). These channels consistently coincided with a distinctive deciduous tree of unidentified type. It should be noted; however, that vegetation clues and slope characteristics probably vary from one location to another.

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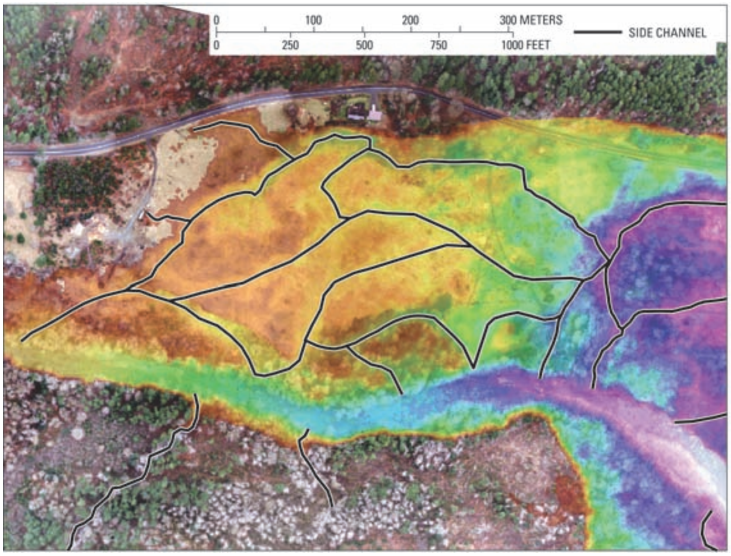


Figure 2. Map of side channels overlaying lidar elevation data color enhanced with maximum stretch overlaid on digital color orthophotography.

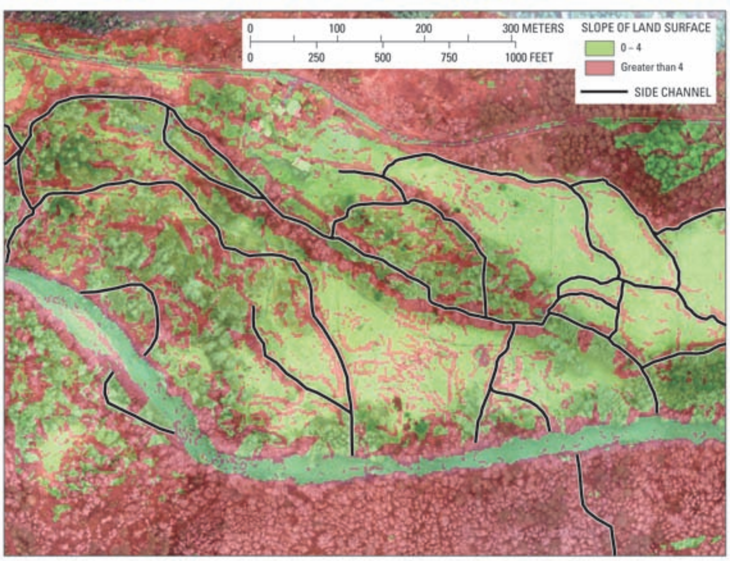


Figure 3. Map of side channels overlaying 4- to 11-degree slopes (red) and digital color orthophotography.

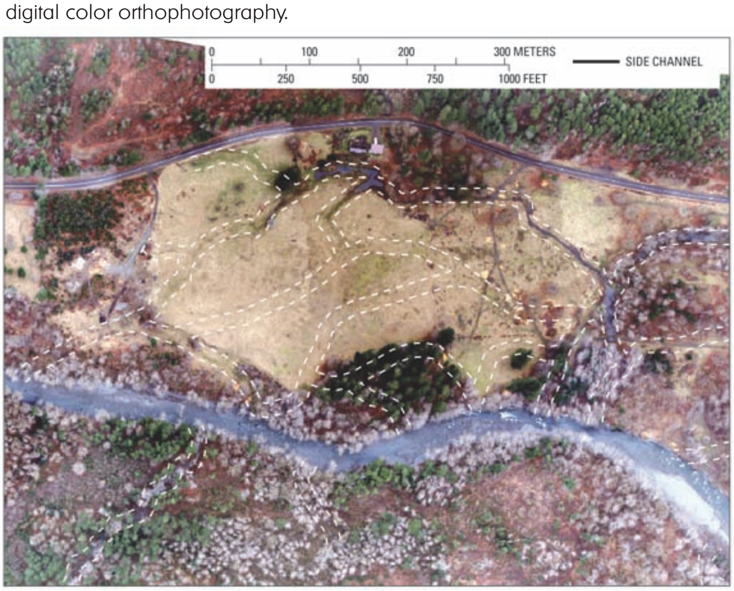


Figure 4. Map of side channels overlaying digital color orthophotography.

Given that the elevation features are subtle and involve substantial interpretation, great attention was given to reinforcement between the three (or five, if the orthophotography inspections are counted separately) methods of interpretation. The application of the methods to reaches with differing geomorphic character also revealed the importance of using multiple lines of evidence, as the three methods of interpretation were, individually, either more or less useful in each area. For the lower reach, elevation was most useful; for the next reach upstream, slope was most useful; farther upstream, visual interpretation of the orthophotography contributed more information; for the uppermost reach, the river was incised to the degree that no potential habitat was identified (however, other geomorphic features such as benches could have been identified had that been an objective).

## Determining Channel Elevation Relative To River Surface

To evaluate the relative potential of side channels to serve as future shallow water refugia, the relative elevation above the adjacent river stage was determined by creating a digital surface of river stage (at the time of lidar data collection) and subtracting this from the land surface, yielding a data set of height-above-river for the entire floodplain. The river elevation surface was constructed by digitizing lines across the floodplain that were assigned the elevation of the river surface at the line, then the lines were densified and processed into a TIN (Figure 5) and subsequently a raster grid, which was subtracted from the lidar grid. By visually inspecting this relative elevation information with the channels overlaid (Figure 6), the digitized side channels can be directly evaluated by the river rehabilitation planners. As an alternative method of presenting the relative elevation of the side channels, the lines representing them were processed into segments of 0.5-meter increments of elevation above the adjacent river stage (Figure 7) by converting the height-above-river grid to polygons and intersecting that with side-channel lines.

## Results And Interpetation

The products resulting from the methods of analyzing the remote sensing data, side channels, and height-above-river information can be combined to identify areas with the most potential for the creation or restoration of natural habitat for salmon. By combining the digital color orthophotography, side channels, and height-above-river elevation data into a single map (Figures 8, 9, and 10; rivers miles 1, 5, and 10, respectively), members of the restoration teams can identify areas that warrant detailed investigation and field study. For example, once the side channels have been mapped for the entire length of the river under consideration, along with floodplain elevations relative to the river, the rehabilitation team will want to consider other important aspects of a reach's potential for rehabilitation. These may vary by location, but in the Dosewallips basin they would likely include answering questions such as

- Where does LWD currently accumulate?
- Is there existing canopy to regulate the stream temperature?
- Is the streambed substrate suitable for spawning?
- Is there a suitable location for placing an anchor piece

where it will function as desired?

and practical issues such as

- whether access is possible, and
- whether or not there are public or private infrastructure that must be protected from flooding.

Once a number of reaches have been identified as suitable in these additional aspects, further interpretation of these maps produced with remote sensing analyses would allow planners to answer a number of important questions about the relative potential of the reaches to be rehabilitated, such as

- What is the total length of side channels in a stream reach?
- How high are the side channels above the river surface and what are the total lengths at different elevations?
- Are the various channels truly accessible to the river or are there natural or man made "high spots" that make it inaccessible?
- How high are the areas near the side channel above the river surface?
- What is the total area of land in a reach that is within a half meter above the local river surface?

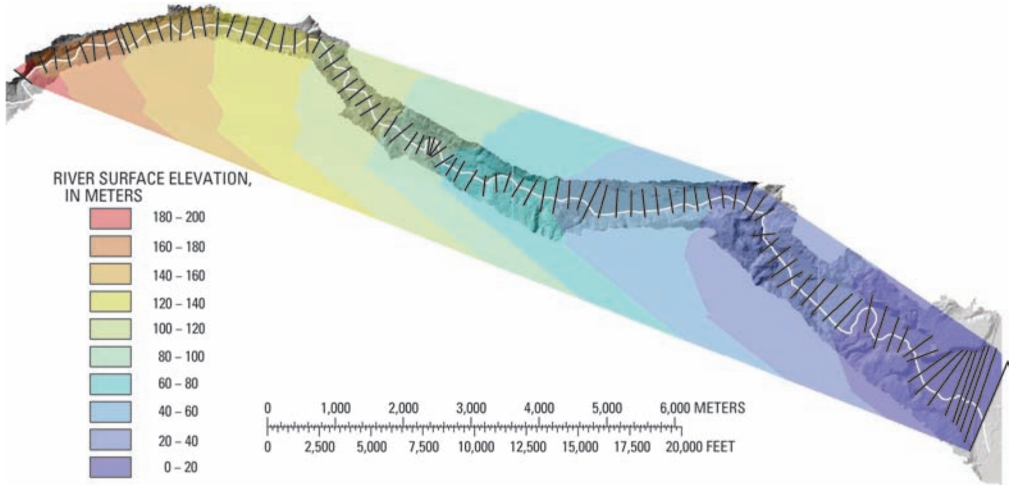


Figure 5. Map cross-sections and river elevation surface overlaying shaded relief map.

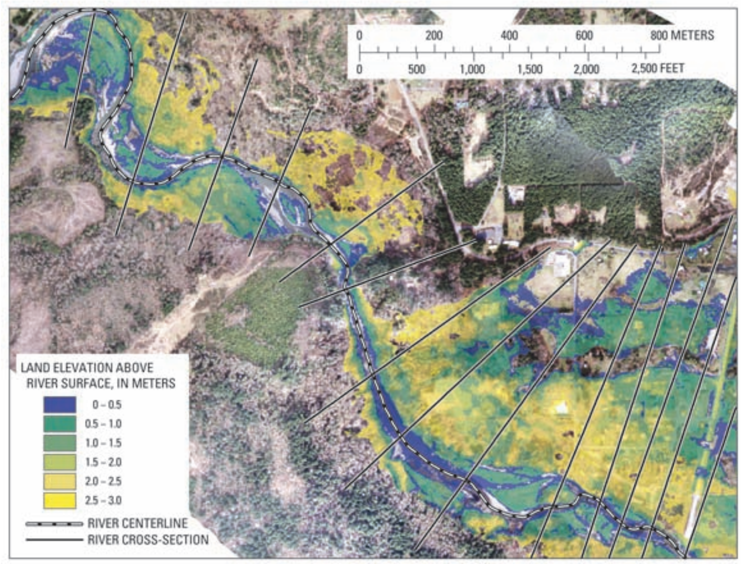


Figure 6. Map of relative land elevation above river stage in 0.5-meter increments overlaying digital photograph.

Armed with the answers to these and other questions, planners can devise restoration schemes and launch additional field studies to further evaluate the suitability of specific rehabilitation schemes for the selected reaches. In the event that additional questions arise, additional iterations of interpretation of the remote sensing data can easily be conducted. For example, given a specific reach that has been identified as a good location for placing an anchor piece—stable channel and existing LWD—a more accurate estimate can be made of the potential increase in river surface elevation due to proposed modifications for that site (including hydraulic modeling given adequate resources). The GIS analyst in this case would produce estimates and maps of the reactivated channel lengths and inundated land areas for that river elevation. Such iterations could be repeated as field studies revealed new information or information needs until the rehabilitation planning team is adequately confident they have removed as many of the uncertainties as possible.

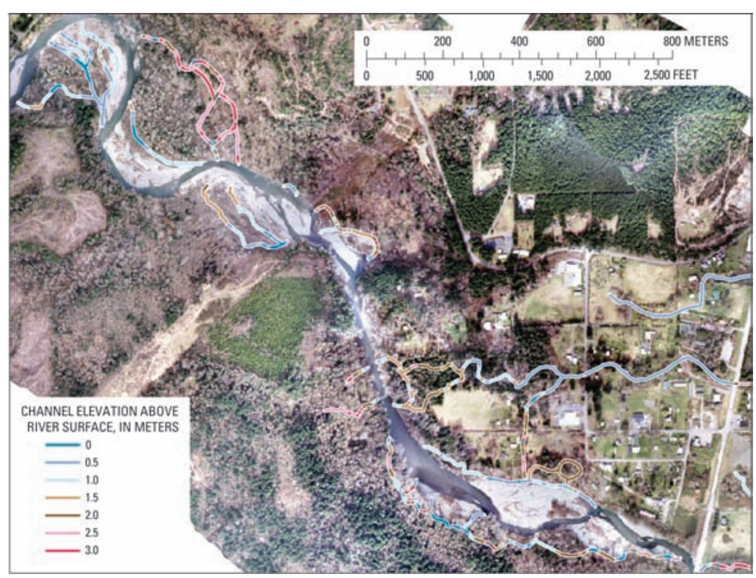


Figure 7. Map of side channel segments in height-above-river increments of 0.5 meter overlaying digital photograph.

## Summary

Remote sensing data, lidar and digital color orthophotography, allow rapid identification of subtle terrain features such as abandoned channels and overflow channels, that may be a problem to identify by physical inspection, whether due to access to the site or simply the difficulty in recognizing them. Interpretation of lidar elevation data, the slope derivative of that, and characteristics of

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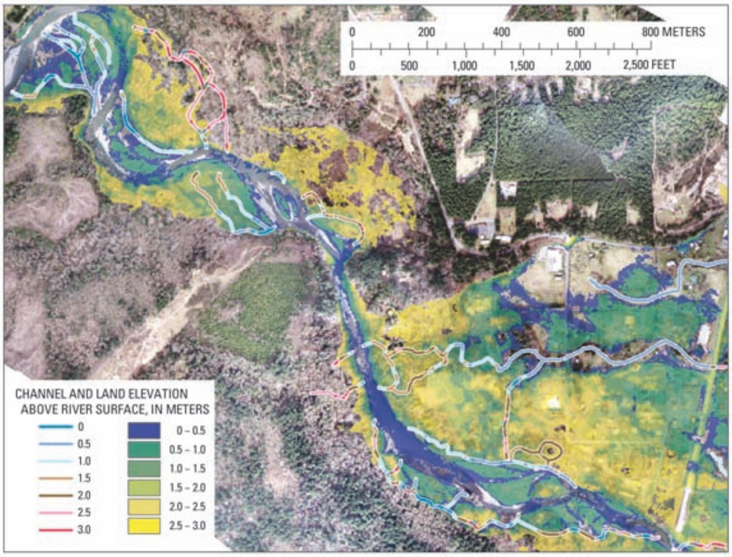


Figure 8. River Mile 1: Map of side channel segments in height-above-river increments of 0.5 meter overlaying elevation above river surface and digital photography.

digital photographs, such as standing water, greenness, and vegetation type, can be used to map these channels directly into a GIS. Using a river surface elevation model, both channel and land surface elevations can be compared directly to the river surface to identify areas that are at any number of elevations above the river. These interpretations can allow river restoration planners to quickly identify areas that warrant physical inspection, thus minimizing field expenditures and reserving more resources for actual restoration projects.

## References


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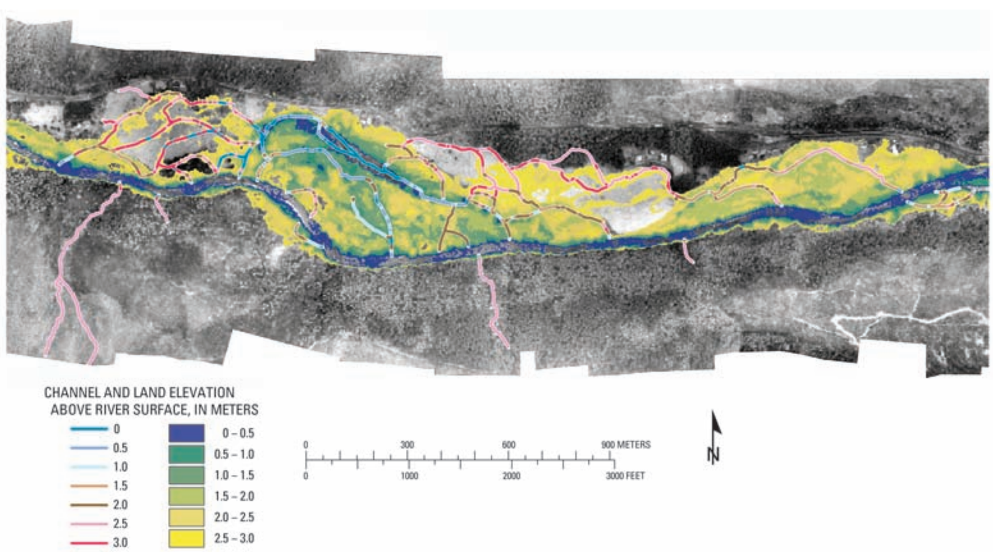


Figure 9. River Mile 5: Map of side channel segments in height-above-river increments of 0.5 meter overlaying elevation above river surface and digital photography.

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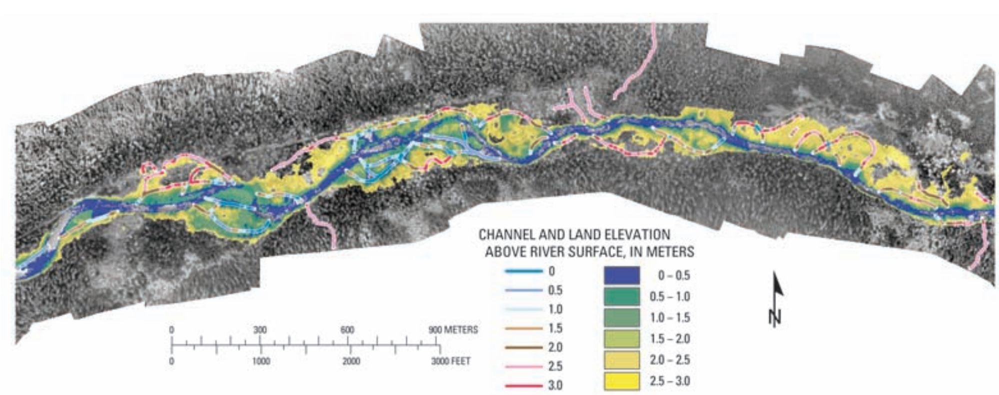


Figure 10. River Mile 10: Map of side channel segments in height-above-river increments of 0.5 meter overlaying elevation above river surface and digital photography.