Applications of Multi-Media Cartography in Klamath Basin Restoration

by

Christopher Wayne

A RESEARCH PAPER

submitted to

THE DEPARTMENT OF GEOSCIENCES
OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for
the degree of

MASTER OF SCIENCE
GEOGRAPHY PROGRAM

September 1997

Directed By
Dr. Mary Lee Nolan

Acknowledgements

Many people offered me support, guidance and information during the course of this project. I would like to thank my committee, Drs. Nolan, Kimerling and Rosenfeld; Elizabeth Budy and Andy Peavy at the Winema National Forest; Dr. Doug Markle for his knowledge of the Klamath Basin; Matt and Kelly Kritzer for letting me use their house as a base during my field work; Randy Craig, for his immense help in showing me the Upper Williamson; my parents for making me smart; and most of all, Wendy Campbell for her friendship, love and intelligence.

Table of Contents

Applications of Multi-Media Cartography in Klamath Basin Restoration

ABSTRACT

The Klamath Basin of Oregon and California has been the scene of extensive ecosystem restoration activities in recent years. The need for restoration is based on changes in land use that have adversely affected water quality and wildlife habitat. Many different kinds of restoration projects are occurring at many different scales. Many groups involved have used Geographic Information Systems (GIS), including the Nature Conservancy and the Bureau of Land Management

Multi-media cartography based on an Internet site has potential to be an effective means of monitoring conditions, sharing information and integrating data from multiple scales and sources. This project is an example of Web-based multi-media cartography. The structure and design of the web site are discussed, as are the steps in designing and producing a multi-media map.

A strong case is made for the effectiveness of using web-based multi-media cartography in Klamath Basin restoration. Its advantages include the ability to integrate data from multiple scales and sources, including GPS points, digital GIS data, and photographs. It also allows users without cartographic knowledge or software to access geographic information.

1. OBJECTIVES

1.1. Discuss the need, background and current state of ecosystem restoration in the Klamath Basin. This includes the causes of land and water change that have resulted in the need for restoration, current restoration issues and relevant policy.

1.2. Make a map of the study area that shows GPS-referenced photo points of selected restoration sites in the Upper Klamath Basin. The map will show the Wood, Williamson and Sprague rivers, 4th-field Hydrologic Unit (sub-basin) boundaries of the Upper Klamath, Williamson and Sprague sub-basins, major perennial lakes and points where I took photographs of restoration activity.

1.3. Create a Web Page using HTML that illustrates applications of Multi-Media Cartography in Klamath Basin Restoration. The map described above will be included, as well as links to other relevant web sites and an HTML version of this paper. The map will be linked to files which show photographs of the point on the map and give its GPS point, as well as text describing the area.

2. JUSTIFICATION

2.1. Introduction

The Klamath Basin in Oregon and California has been an area of extensive restoration activity in recent years. Intensive management for timber production and irrigated agriculture has heavily impacted ecosystem form and function in this 10.5 million-acre basin.

The recent emphasis on ecosystem restoration in the Klamath Basin is due to both factors of need and of suitability. The need for restoration is based on changes in land use that have negatively affected water quality and quantity (USFWS 1995), which in turn has led to decreased habitat for sensitive, threatened and endangered species. A number of characteristics make this region an extremely suitable setting for restoration. These include extensive federal ownership and productive, resilient wetlands.

The planning, implementation and monitoring of ecosystem restoration in the Klamath Basin operates at a number of different scales. Consequently, the data that are used and collected are also from different scales. A Geographic Information System (GIS) is an effective tool for organizing spatial data. However, there are other ways of incorporating data from different scales and sources that are equally as effective as GIS and often better for certain applications. This project seeks to illustrate that Internet technology, GIS, Global Positioning System (GPS) and digital images can be effectively linked and used a powerful tool for relating data from multiple scales in multiple media. These media include maps, images and text. Web Sites offer the advantage of being accessible to a wide variety of users who can view geographic information without GIS software.

2.2. Issues

The driving factor of need behind Klamath Basin restoration is the decline in historically high fish populations, especially currently endangered salmonids and other anadromous fish (MESC 1997). Restoration efforts at the basin scale are focused primarily on overall water quality improvements. At the watershed level, restoration involves restoring, protecting or improving habitat. At the site level, water quality and habitat improvement is implemented through a number of techniques, including revegetation, diking, educational and interpretive sites and recreation funding (Beachler 1996).

Major issues being addressed currently (Summer 1997) fall under three broad categories: ecological issues, policy issues and technical issues. Ecological issues include impacts of upstream water quality affecting downstream habitat and species; harmful water and land use practices; conservation and improvement of current habitat, including wetlands; and restoration of degraded habitat, especially wetlands and riparian zones. Political issues are coordination of various restoration plans; water adjudication; developing practical processes for multi-entity review of projects within Klamath Watershed. (USFWS 1995); and "the quality of life and future economic vitality of the region. (Wood 1995)". The technical issues essentially are based on addressing ecological and policy issues within unalterable constraints. These include causes and locations of habitat degradation and identification and implementation of long-term habitat protection.

2.3. Policy

All phases of ecosystem restoration must operate within the bounds of current policies at local, state, regional and national levels. The Klamath Basin crosses multiple jurisdictions, including nine counties in two states. The majority of the Upper Basin, including the areas addressed by this paper, lie entirely within Klamath County, Oregon. The two major policy sets affecting restoration there are Oregon Water Laws and the Endangered Species Act. Oregon Water Laws dictate who uses the water, how much they use, how it used and where and when. Since Oregon uses the mandate of prior appropriations (State of Oregon 1994), most of the water usage claims that were established under the Klamath Reclamation Project are still valid and form the major constraint in water adjudication. The Endangered Species Act, which mandates habitat protection for endangered and threatened species, includes protection for the Lost River sucker and the short-nosed sucker, two species native to the Upper Klamath Basin. Other relevant policy sets include Indian Laws and Tribal Subsistence Rights; comprehensive plans for each of the jurisdictions, such as National Forests and Counties; and sub-basin Cooperative Resource Management Plans (CRMPs).

2.4. Summary of Changes in Land and Water Use

To more effectively understand the current restoration scenario, it is important to understand what changes have occurred in the landscape and how these changes occurred. Changes in land use, as determined by policy decisions, have resulted in changes in the structure and function of the landscape. These changes have in turn affected the surface hydrology of the region.

Land use policy in the Sprague, Williamson and Upper Klamath Lake sub-basins has until recent times been administered by the Bureau of Indian Affairs. Most of this area was within the boundaries of the Klamath Indian Reservation, which was established in 1864 and sold piecemeal over the following century, ending with a massive land sale to the US Forest Service in 1958.

Land use policy on the reservation began with the Dawes (or Allotment) Act of 1887, in which the US Congress mandated that Indian Reservations be drawn up into individual plots of agricultural land (Stern 1965). During the period of 1891-1910 the valleys of the Sprague, Wood, and Williamson Rivers, along with other tracts of well-watered bottomland, were divided among tribal members with the intention of being farmed or grazed (ibid.). Most of this land was either leased or sold to white ranchers, as was much of the unallotted land of the Sycan and Klamath Marshes (Stern 1965). During this period grazing was intensive and largely unregulated (Frazier 1994).

Massive timber sales in the uplands of the reservation began in 1910 and continued through USFS administration (Ray 1973). During this same period livestock grazing continued to be heavy as well (Frazier 1994). The Klamath Tribes were terminated by the BIA in 1958 and their land was purchased by the USFS and several other parties.

Little change in land use policy occurred until 1986, when the Klamath Tribes were restored Federal Recognition. They entered into a Consent Decree with the US Government and the State of Oregon "to promote the sound and efficient management and conservation of fish and wildlife within the former Klamath Indian Reservation lands

(Winema National Forest 1990)." As part of this decree, Tribal members have a number of exclusive hunting, fishing and other subsistence rights on federal and state lands.

These subsistence rights have become particularly relevant in restoration policy and planning. Since fishing rights are provided for in the Consent Decree, habitat protection and enhancement is a high priority for Tribal resource managers. Much of the current water adjudication is affected by these provisions, as well as by provisions in the subsistence rights of downstream Hoopa, Karuk and Yurok Tribes (MESC 1997).

2.5. Summary of Change in Surface Hydrology

Changes in land use in the area have resulted in changes to the region's surface hydrology. The greatest hydrological change has been the conversions of wetlands to agriculture. Prior to the Klamath Reclamation Project in 1905, over 185,000 acres were covered by wetland (USFWS 1994). A second major impact associated with wetland conversion has been the channeling and diverting of many of the rivers, especially the Williamson and Wood rivers. These two factors, loss of wetlands and river channeling and damming, have had secondary impacts to the ecology of the region.

Loss of wetlands has resulted in a decreased water storage capacity; this means that more water is released during peak flows and less is available during the dry season. Habitat for both fish and waterfowl have been decreased or degraded due to changes in vegetation composition, loss of wetlands, and sedimentation of the rivers (USFWS 1995).

Grazing in the basin has been mainly in the river valleys, which were the first parts of the reservation to be sold. Grazing impacts have been extensive and severe, with animal numbers peaking in the BIA Administration years (turn of the century to Termination) (Frazier 1994). Impacts from grazing include soil compaction and removal of vegetation on the riparian areas; this in turn causes bank destabilization and increased erosion resulting in stream sedimentation (Ibid.).

Other effects of agriculture and grazing are still under debate. The USGS and others hypothesize that removal of wetland soil and vegetation conditions have resulted in the release of an excessive amount of nutrients (USFWS 1995). Early studies (Cope Rand

Means Co. 1920) indicate high levels of soil nutrients before conversion. However, no conclusions have been drawn between historic soil: water nutrient ratios and current ones.

Water temperature is also a questionable factor. No studies have been conducted on stream temperatures throughout this basin, but studies in other groundwater-driven basins like the John Day indicate that depth to groundwater is a much more important factor than land use in determining temperature on a watershed scale (Torgerson 1996).

TABLE 1: Summary of Early Land Use Changes Affecting Hydrology

Historic event	Year	Area Affected	Land Use Change	Hydrologic Impact
Allotment Act	1890s-1920s	River Valleys on Klamath Indian Reservation: Wood, Sprague, Williamson	Conversion of wetlands to pasture, rangeland and farmland	Minor: only a few small irrigation projects; some loss of wetlands
Sale of Indian Allotments & BIA Grazing Era	1910s- 1940s	River Valleys on Klamath Indian Reservation: Wood, Sprague, Williamson; Klamath and Scan Marshes	Conversion of wetland to pasture, range and agriculture	Wetlands drained; grazing impacts including channel destabilization and bank erosion
Klamath Irrigation Project	1905-1949	Upper-Middle Basin, especially Lost, Butte and Upper Klamath Sub-basins	Conversion of wetlands to irrigated farmland	Loss of wetland functions; lowering of lake levels, change in timing of flows and dry-season water storage
BIA Logging Era	1910- 1950s	Upland Forests on Reservation Lands	Loss of virgin forest, conversion to production forest or rangeland	Faster snowmelt from decreased shading, change in timing of flows.

3. METHODS

3.1. Introduction

I decided that an Internet site would be a good format for presenting multi-media cartography after discussion with a number of individuals involved in restoration planning. Advantages of a web site include:

- The ability to present data in both text and images
- The ability to link documents, images and maps to each other.
- Access to a wide range of data and formats by users with little or no cartographic skills.
- Their modular structure, i.e.: they can be updated and expanded without major configuration or re-design, simply by adding new links to new files.

3.2. Web page design and structure

The first step in determining the structure of the web site was to decide who my audience would be. Because of the interest expressed by various agencies involved in planning, I made the following assumptions about my audience.

- They were familiar with the area to the degree that a detailed geographic description was not necessary.
- They are mostly government or non-profit organizations and would have access to fairly sophisticated computers and at least Netscape 2.02.
- The degree of cartographic knowledge would vary; some might be GIS Project Directors, while others would be simply end-users.
- Their familiarity with restoration and issues and policy would vary along similar lines, but they had at least a local knowledge of the scenario and often much more knowledge and expertise in the field than me.

Based on these assumptions, and technology to which I had access, I decided that frames would be the best format. Frames allow several files to be viewed simultaneously, and different files can be brought up in one frame while the others remain the same. The

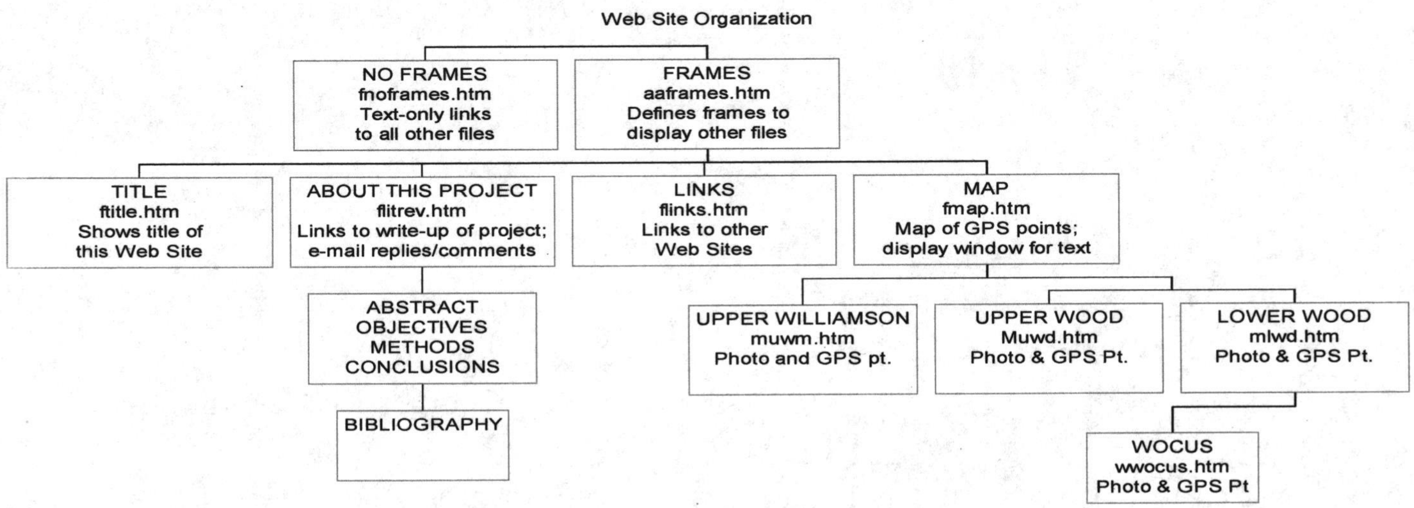
Netscape Frames Viewer is included in all modules above 1.x, so I assumed that most of my audience would be able to view it. However, I also made a No Frames version that allowed users without Frame Viewer access to the files.

I built a frames file with four frames that displayed the following files:

- A title file that serves as a banner site heading;
- A main file, which shows the map file and allows users to link to GPS-Referenced photo points plotted on the map; this is also the frame for viewing the text and for viewing the images of the GPS points;
- An "About This Project" file, which has links to a description of the project (what you are reading now) that appears in the main window; it also has a visitor counter and an e-mail link for users to send me comments and feedback;
- A links file, which provides links to other sites of interest to users, such as other Klamath Basin Restoration sites, involved agencies' sites and sites for accessing digital data.

The files that are displayed in these frames are linked to other files, provided a webbed site structure *(Fig. 1)*. As a contingency for users who have browsers that are unable to view frames, I also built a no-frames file that showed a text file with links to each of the files shown in the frames. The links in the no-frames file call up the files in a separate browser, rather than in the main frame.

Fig. 1: Web Site Structure



3.3. Map Design and Production

The map in the main frame is the centerpiece of this project-- it is what makes this a multi-media cartography site rather than simply a multi-media site. Making the map involved the following steps:

- **Determine study area and sampling design.**

I wanted to show a variety of locales, but also offer some degree of comparison between them. I chose two general areas: the Wood River and the upper Williamson River. The Wood River was chosen because there is a variety of visible stream conditions in a short stretch of the river: a relatively healthy upper stretch and a degraded and impacted mouth. The upper Williamson was chosen also for its varied stream conditions and the different stages of restoration projects occurring there.

The specific reaches sampled on these two rivers were chosen deliberately rather than randomly. Data collection differed for each of them.

I floated from RM 5 on the Wood River, through privately owned pastureland, to the mouth where it enters Agency Lake. The mouth is currently bounded on the west by the BLM's Wood River Ranch Restoration project; this project is in the early stages of implementation and seeks to "restore the property to its previous function as a wetland community (BLM 1996)." I used a Garmin 45 GPS unit, which has an accuracy of 100m without differential correction (Garmin 1996), and a 35mm camera with a zoom and macro lens. This was an effective way to see an entire reach of river and was a beautiful ride besides. However, it prevented me from seeing as many different places of the river as I might have if I were driving.

I visited spots on the upper Williamson with Randy Craig of OSU, who is doing channel condition research there for the Klamath Tribes. He took me by truck to number of his study sites in various stages of restoration, from nearly recovered areas to parcels that are still being grazed. I was able to bring along a SVHS video camera in addition to my regular camera and the Garmin GPS.

- **Build a base map**

Following data collection, I had to decide how this information was to be portrayed on a multi-media map. My next task, then, was to build a base map. ArcInfo was used to collect and manipulate data from a number of sources. I used the following base coverages:

- 5th Field Watershed Boundaries, a polygon coverage ftp'ed from the Winema National Forest, based on USGS data.
- Streams, based on the EPA River reach files which are attribute-enhanced 1:100,000 Digital Line Graphs
- Lakes, acquired from the O.S.U. Forest Science Department Database and of unknown origin.

All of these coverages were in UTM Projection (Clarke 1866 Spheroid) and so did not have to be re-projected. The streams and watershed boundaries were based on 1:100, 000 scale; the lakes coverage was 1:250,000.

These coverages had to be generalized to make a map that would not appear too cluttered when it appeared in a 4" x 6" frame. The first step was generalizing the 5th-field watershed so they showed only the 4th-Field watersheds. I used ArcEdit to select polygons with the same 4th-field Hydrologic Unit Code (HUC) and used the Merge command to create three new polygons from the several dozen smaller ones: the Williamson (HUC 18010201), Sprague (HUC 18010202) and Upper Klamath Lake (HUC 18010203) sub-basins

I used a similar procedure to generalize the streams coverage. However, some attribute values were lost during the data transfer and so I used a manual selection to delete arcs. I removed all streams except the main stem of the Wood, Sprague and Williamson Rivers.

The lakes did not have to be generalized, since there were only three polygons: Crater Lake, Upper Klamath-Agency Lakes and Aspen Lake. All were preserved.

I used ArcView to combine these coverages into a single layout. I used ArcView because it easy to experiment with map colors and scale, which was necessary before I turned it into an image to be posted a Web Site.

- **Plot GPS Points**

To plot the GPS points on the map, I first made a spreadsheet containing all of the GPS points, the time they were taken, what photo and/or video they were associated with and on what route they were taken. The Garmin 45 doesn't allow for differential correction and I did not have any interface cables to make a point file by downloading the data into a computer. Instead, I plotted the points on a paper map. Given the GPS resolution of 100 meters, I decided that a 1:100,000-scale map would be the appropriate scale. All the points were located on the Williamson River USGS quad.

A total of 18 points were plotted. Of these, I chose three to include on the map: one each from the upper Wood River, the lower Wood River and the upper Williamson. These were digitized using ArcInfo and saved as a point coverage. I then converted this into UTMs and included it on the ArcView project.

- **Produce the map as an image**

Once all of the coverages were brought into the ArcView project I made a layout to include a scale bar, legend and north arrow. I kept the colors to four, anticipating that this map was to go through a number of conversions, and the less complex the image was the more likely was faithful reproduction.

This proved true, but not as I had anticipated. I exported the ArcView layout as both an Adobe Illustrator (*.ai) and an Encapsulated PostScript (*.eps) file. However, I was unable to successfully bring any of these images up in Adobe Photoshop, Canvas 5, or Freehand. Various incomplete or inaccurate versions appeared but never the map as it had been saved.

Instead I printed a high-resolution (300 dots per inch) color map and scanned it at 300 dpi. This created a very large TIFF file (10.2-Mb) that looked very accurate. I used Adobe Photoshop to edit the map, including adding labels to certain features and making a neatline. The final product is shown in Fig. 2.

4. CONCLUSIONS

4.1. Findings

What I found on the ground was that the rivers of the area, from a physical stand point at least, are restorable. Despite impacts, the stream banks are very resilient and recovery was evident in reaches that had been excluded. The Wood River showed strong resistance as well as resilience: there was still a deep, well vegetated channel even in reaches where I saw cattle munching on grass right on the bank. The Williamson River, however, showed much more degraded conditions. Nevertheless, in areas that were being restored, recovery was visible after only a few years.

Using photographs, video and GPS to monitor conditions proved to be a very accessible technology. The video camera was very heavy, however, and did not really provide many benefits beyond what a film camera offered. Further, processing video images requires fairly sophisticated equipment: a video player that allows frame-by-frame viewing and remote control from the computer, as well as software for grabbing the images and turning them into digital images.

To test whether a small, commercial-grade GPS like the Garmin 45 was effective, I tried navigating back to the photo points on the upper Williamson. I took along the photographs and used a USFS recreation map to find the township and range, then used the GPS to navigate back to the points. I was able to successfully do this, but I found the photographs to be essential as well as the GPS. The map got me to the right road, the GPS got me to the general area of the photo point, but I needed to have the photo in hand to find the exact spot. Nonetheless, the economy and ease of use of the Garmin 45, as opposed to a more accurate and sophisticated unit, made up for its coarse accuracy.

This accuracy level was also quite suitable for the scale map that I made. The purpose of the map was spatially accurate representation of points across a landscape; but the landscape was well over 2.5 million acres, and the web site map was only 4" x 6" (or thereabouts, depending on the monitor size). Thus 100m accuracy was not a barrier to accurate spatial representation.

Besides the coarse GPS resolution, another potential area for loss of spatial accuracy was in the conversion of the ArcView layout to an image. It is possible that some more experimentation might have allowed for a direct digital conversion. Since I was unsuccessful at this, however, and had to produce a paper map which I then scanned, the data had to make a digital --> analog --> digital conversion. There was a potential for loss of accuracy during each of these steps.

4.2. Problems and Alternate Approaches:

Image file size was a problem and limited the effective scope of this project. All images, including the air photos, ground photos and the map, were converted to .JPG format before being posted on the Web page. However, when scanned or converted from video, the images are saved as .TIFFs, which are up to five times as large as a .JPG file.

Since I was using several different computers to work on this project, I kept my files on floppy disks. This was necessary because the different programs I used were on many different computers, and different stages of the project design and production had to be done on different machines. Unfortunately, even as a .JPG file, the Upper Williamson air photos took up more space than one floppy could hold. Consequently, I spent a lot of time electronically transferring files between computers and networks. This was also true of the ArcInfo coverages used to make the ArcView layout.

Another problem is that capabilities of Web browsers vary. When I was making this web page, I found that my files often looked very different on not only different browsers but even differernt monitors. One major variation in browsers is the inability of Netscape 1.xx to view frames. I used frames anyway, because I felt that the advantages offered by using frames was greater than the disadvantages that a few people might experience from not being able to use them. As a contingency, I made a No Frames file, which was only displayed if the server could not read frames.

4.3. Conclusions

Based on the results of this project, I can draw the following conclusions:

- GPS-referenced photos are an effective, low-cost, user-friendly way to monitor restoration progress. Although I have used high-end GPS before, I think that even someone with no GPS experience could use a low-end one like the Garmin 45 to both mark photo locations and find their way back to previously referenced points.

- GIS allows for effective and accurate integration of data from multiple scales: in this case, large-scale GPS points were included on a map based on small-scale (1:100,000 - 1:250,000) maps of rivers, lakes and watersheds.
- The Internet and its associated tools are an effective way to make geographic data available to people without GIS or cartography experience.
- The Internet offers unprecedented flexibility in linking images and text directly to geographic data.
- This type of project can easily be conducted and expanded upon by any of the agencies, groups or even individuals involved in restoration. Because all of the data is ultimately put into a common format, many different sites and projects can be linked together.
- However, for this to be a fully effective technique to be used for analysis across the entire Klamath Basin, certain protocols for map scale, spatial accuracy and presentation format need to be developed. The Klamath Basin Fisheries Task Force is currently working on standardized forms for requesting funding for restoration projects (Beachler 1996).

Bibliography

Anderson, Stephen, 1996. "Restoring the Williamson River Delta." *The Nature Coservancy of Oregon Newsletter*, Fall 1996, p.1-3.

Avery, T. E., and G.L. Berlin, 1992. *Fundamentals of Remote Sensing and Airphoto Interpretation*. New York: Macmillan Publishers.

Beachler, Robert E., 1996. *Hydrologic and Hydrographic Database Design in Support of Anadromous Fisheries Restoration Planning*. http://dgeo67.geo.sbg.ac.at/ Esri.mirror/w...mon/userconf/proc96/TO300/PAP277/P277.HTM. Visited 7/30/97.

Bienz, Craig S., 1982. *A Management Plan for Klamath Marsh, Oregon.* Vancouver: 49th Annual Pacific Northwest Pollution Control Association.

Bureau of Land Management, 1996. *Wood River Wetland Record of Decision and Resource Management Plan*. Dept. of Interior: Klamath Falls, OR.

Carlson, Garwin T., 1979. *Soil Resource Inventory, Winema National Forest*. USDA Forest Service, Pacific Northwest Region.

Christy, John A. 1996. *Nineteenth-Century Vegetation of Williamson River Delta, Klamath County, Oregon*. Oregon Natural Heritage Program.

Cope Rand Means Co., 1920. *Report on Williamson River Marshes, Upper Klamath Lake Region.* Berkley: University of California Water Resources Center Archives.

Delcourt, Hazel R. and Paul A. Delcourt, 1988. "Quaternary landscape ecology: Relevant scales in space and time." *Landscape Ecology,* vol. 2. No. 1, pp. 23-24.

Dicken, Samuel N. and Emily F., 1985. *The Legacy of Ancient Lake Modoc: A Historical Geography of the Klamath Lakes Basin, Oregon and California*. Eugene: University of Oregon Press.

Engman, E.T. and R.J. Gurney, 1991. *Remote Sensing in Hydrology*. Chapman and Hall, London.

Everitt, J. H., et al., 1990. “Aerospace Video Imaging systems for Rangeland Management.” *Photogrammetric Engineering and Remote Sensing*. V.80 No. 3, March 1990, pp. 343-349.

Fox, Lawrence, et al, eds., 1995. *Klamath Basin GIS Directory*. Klamath Falls: US Fish and Wildlife Service.

Frazier, Brent, 1994. *A Historical Summary of Livestock Grazing on Former Lands of the Klamath Tribes Currently Part of the Winema and Fremont National Forests.* Winema National Forest Report.

Garmin International, 1996. *GPS 45 Personal Navigator Owner's Manual and Reference.*

Green, M. H. and John A. Kinch, 1997. "Up, up and away: Kite photography on the rise for habitat monitoring." *The Nature Conservancy*, v.47, no. 4.

Greer, Jerry D., et al.,1990. "Color Infrared Photography for Resource Management." *Journal of Forestry*, July 1990, pp.12-17.

Higgens, Patrick, 1996. "Helping Salmon with the Klamath Resource Information System." *ESRI ARC News*, Fall 1996, p. 35.

Howe, Carrol B. 1992. *Unconquered, Uncontrolled: The Klamath Indian Reservation.* Bend: Maverick Press.

Jackson, R.H., 1981. *Land Use in America.* New York: WIley and Sons.

Johnson, R.A., et al, 1990. "An Application of GIS Techniques for Evaluating Hydrologic Restoration Alternatives in the Shark Slough Basin, Everglades National Park." In *Proceedings of Resource Technology 90.* Washington: American Society for Photogrammetry and Remote Sensing.

Kalma, J.D. and I.R. Calder, 1992. *Land Surface Processes in Large-Scale Hydrology.* WMO Operational Hydrology Report no. 803. Geneva: World Meterological Organization.

Kentula, Mary E. at al., 1993. *An Approach to Improved Decision making in Wetland Restoration and Creation.* Boca Raton: CRC Press.

Kuittinen, R., 1992. Remote Sensing for Hydrology: Progress and Prospects. WMO Hydrology Report no. 36. Geneva: World Meterological Organization.

Midcontinent Ecological Science Center (MESC) 1997. *Klamath River Institutional Analysis: Chapter I. Introduction. http://www.mesc.nbs.gov/klamath/chapter1.html.*

Miller, J.R. et al, 1995. "Changes in the Landscape Structure of a SE Wyoming Riparian Zone Following Shifts in Stream Dynamics," *Biological Conservation* 72: 371-9.

ABV also has a number of limitations. Video images have poorer resolution than photographs (though this is becoming less so as technology gets better), and video images lack stereo viewing (3-diminsional) capability. Video imagery, although in digital format, often requires post-processing, both of GPS readings and of individual frames to be used. This has proven especially true of thermal ABV, the frames of which must be converted into a number of digital formats and overlaid with color map files before being analyzed (Torgerson 1996).

Previous studies

GIS has been used to **inventory stream conditions** and compare these conditions between a dozen 2nd and 3rd order streams draining into Lake Superior (Richards and Host 1994). The purpose of the study was to conduct a "GIS-based analysis of watershed-scale land use patterns to quantify critical components of stream habitat features and their subsequent influence on stream macroinvertebrate assemblage compositions". A vector-based GIS was used to designate land use areas both over the entire watershed and within 100m riparian buffer zones. Land use was classified from existing spatial data sets that were derived from remote sensing data. The researchers used a 16ha mapping resolution (in raster, this would be 400m pixel). Stream characteristics were collected at sample points within each stream every 200m. This study is an excellent illustration of the ability of GIS to integrate and analyze data from different scales, from satellite images to ground-collected data.

Change detection studies are another common application of GIS. These types of studies typically have one or two main goals: determine what change has occurred, and determine the cause for the change. Studies have been conducted to assess change at scales from continental to an individual stream reach.

At the extremely small scale, GIS has been used to monitor landscape change across northern Alaska. Walker and Walker (1991) integrated data from a number of different scales, from microsite (**1m2)** to macroregion (1,000,000,000,000 m2). These spatial scales were cross-referenced with various disturbances, both natural and human, to establish a working system for monitoring change in a hierarchical format.

At the medium scale, Simpson et al. (1994) used aerial photography and GIS to determine changes in two contiguous landscapes of ~242 acres each. One of the landscapes was very flat and had been continuously modified by agricultural settlement. The second was more dissected, had been settled more sporadically and showed a more fragmented land use pattern. Thus conditions were compared in both space and time.

On its 4750-acre Williamson River Delta Project in the Klamath Basin, the **Nature** Conservancy (1996) has used GIS to create a map of pre-disturbance vegetation on the site. This map was derived from both historic survey records and historic aerial photographs, which proved of limited utility since the site was converted from wetland to farming before the photos were ever taken. This map will be used to guide the implementation and planning of the restoration project, which is still in the stage of evaluating alternatives on the restoration plan.

Lastly, at the reach scale, Miller et al (1995) used GIS and aerial photography to assess riparian landscape change after changes in the flood regime in the 761-acre Rawhide Wildlife Management area, in southeast Wyoming on the North Platte River. The flood regime in the reach had been drastically changed to upstream dam construction. Black and white 1:20,000 airphotos from 1937 and 1990 were scanned, turned into gray-scale images and registered to UTMs. These were then rectified to fit 1:24,000 USGS quads. The vegetation patches were digitized then rasterized into 5m pixels. This resulted in derived vegetation patch characteristics for each of the two years, which indicated that the river is still a major agent of disturbance, with more change closer to the river.

Modeling effects of restoration plan alternatives is becoming a more common use of GIS. In the past modeling was a highly mathematical discipline; with GIS's spatial components, however, it has become a much more user-friendly application. The Nature Conservancy (1997) has used their GIS to create maps illustrating each of the alternatives for their Williamson Delta restoration plan. These maps used factors such as vegetation and micro-topography to derive figures depicting the hydrologic regime and plant communities of each restoration plan, with accompanying tabular data.

A similar study was conducted in Everglades National Park to model several changes in levies that control flooding there (Johnson et al 1990).

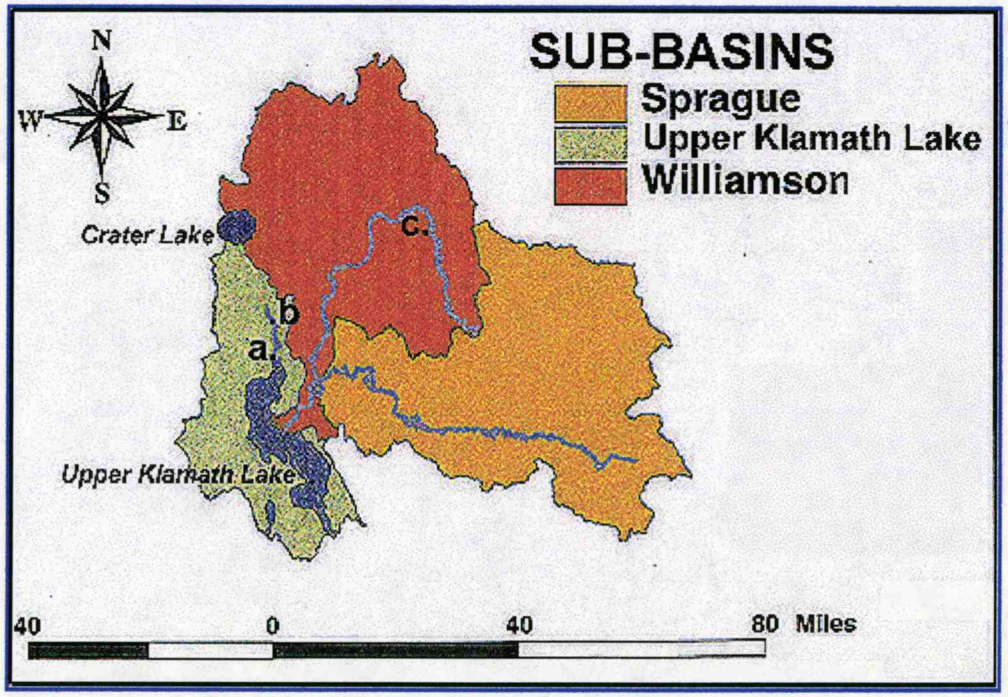
APPENDIX C: Color Figures of Web Pages

The following figures are print-outs from Netscape 3.03 showing the Web Pages that I made as part of this project. The links file and the description of the project are not shown. The links are listed in Appendix A, and this paper is the description of the project.

The figures are arranged as they are linked on the site, more or less.

GPS Photo Points In Upper Klamath Sub-Basins

Click Here for A Full-Screen Map



a. Lower Wood River

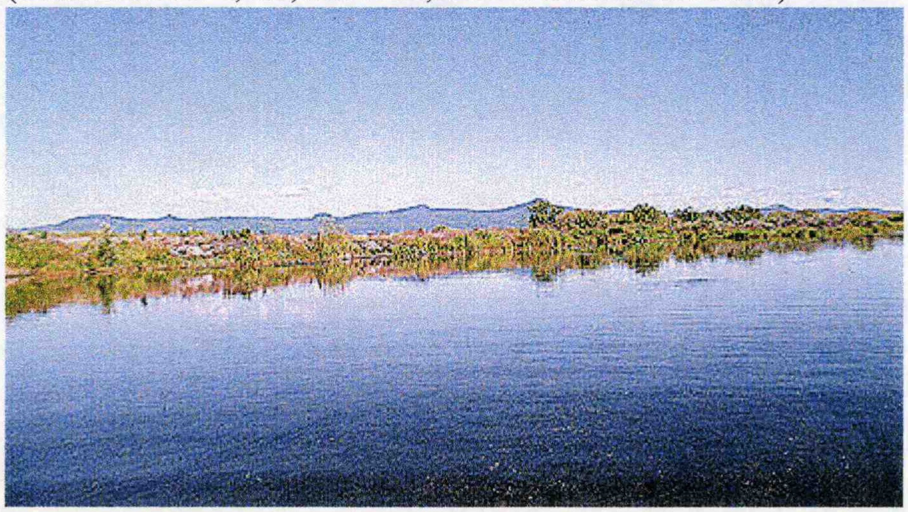
b. Upper Wood River

c. Upper Williamson River

Click Here to Reload the Main Frames

The Lower Wood River

(UTM Zone 10: 4,716,710N 586,554E Willamette Meridian)



This is the Lower Wood River, just above the mouth at River Mile 0.5. It has a straight course, undercut banks, and a wide, shallow channel. This photo faces the BLM's Wood River Ranch Restoration Project to the west. This project is seeking to restore channel conditions and native vegetation, including wocus marsh. Compare this with the The Upper Wood River

Back to the Main Map

Wocus Marsh

(UTM Zone 10: 4,717,493N 586,447E Willamette Meridian)

This is a wocus marsh. Wocus marsh once covered thousands of acres around Agency and Upper Klamath lakes. Wocus seeds were harvested as a

and constituted a major food source for the Klamath Indians. Most of these marshes have been drained for agriculture. Restoring these wetlands is one of the goals of current restoration efforts.

Back to the Main Map

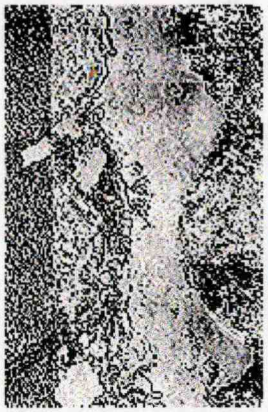
The Upper Wood River

(UTM Zone 10: 4,721,704N 582,666E Willamette Meridian)

This is the Upper Wood River, just below the bridge at River Mile 5. It has a meandering course, vegetation straight to the water, and a deep, narrow channel. Compare this with the The Lower Wood River

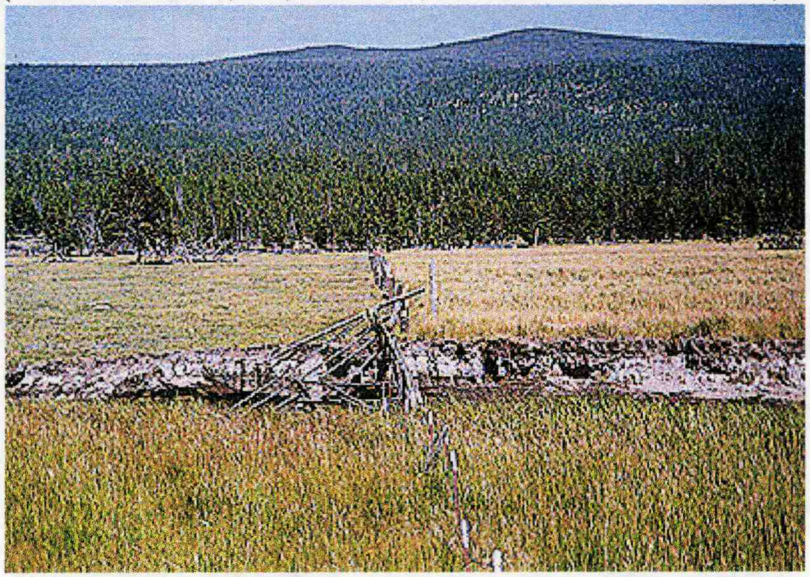
Back to the Main Map

Restoration and Recovery on the Upper Williamson



These are two airphotos of the same reach of river. On the left is August 18, 1961, on the right August 18, 1995. The images below were taken July 7 1997. They both show an area 1.25 miles North-South and .75 miles East-West in T30S R10E Sec. 25 & 36

(UTM Zone 10: 4,755,694N 623,661E Willamette Meridian)



The land on the left of the fence is currently being grazed ; on the right is land that has been excluded from grazing for several years. These differences are visible both on the ground and from the air; the ungrazed parcel is south of Point A on the airphotos.

Back to the Main Map