

Using GIS Technology to Analyze and Understand Wet Meadow Ecosystems

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Abstract—A Cibola National Forest wet meadow restoration was implemented as part of the Forest Road 49 enhancement near Grants, New Mexico. An Arc/View 3.0 Geographic Information System (GIS) was used to track the recovery of this ecosystem. Layers on topography, hydrology, vegetation, soils and human alterations were compiled using a GPS and commonly available data. Cartographic information allows visual interaction of natural features that could not be interpreted from tabular data sets. First results indicate that stream confinements by the railroad trestle, old channel fill, old two-track roads, Forest Road 49, and mis-graded construction affected the flow and location of spring floodwaters in 1998.

Agua Fria meadow is a small, 2.6 km² forest opening located in the Zuni Mountains 32 km southwest of Grants, New Mexico, and bisected by Forest Road (FR) 49 (Jemison and others 1998). It is representative of numerous fourth order streams in the Rio Grande basin affected by grazing, water erosion and changes in water flow due to human impacts (Jackson 1994a). The lower end of the meadow was blocked 3-15,000 years ago by one of the El Malpais sequence of lava flows (Mabery, 1997). Thick organic soil layers recently exposed by channel erosion suggest the area was a typical 'wet meadow', retaining much of the water that flowed into the area. Circa-1900 logging in the upper watershed, and the location of transportation routes could have contributed to preresoration conditions of increased surface runoff, elevated channel flow rates and channel erosion. The decreased elevation of the old channel could have lowered the water table across the meadow, with the net effect being a change towards a more xeric ecosystem.

Funds to reroute Agua Fria Creek were provided in 1995 via a Forest Road improvement project with the Federal Highway Department. The goal of the restoration design was to increase the period of flow through the meadow (Jackson, 1994b). Slower water velocity and more water absorption over a larger area of the meadow were planned through construction of a highly sinuous channel (fig. 1).

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The new channel runs down the center of the meadow, 2-3 m in elevation above the old channel. It is only .60-.75 m deep in contrast to the old channel which was incised as much as 3 m in places (fig. 2). Thus the new channel has a much smaller cross sectional area which encourages flooding and water retention in the meadow.

Importance of GIS

As a technology, GIS is an information management and analysis tool (Harlin and Lanfear, 1993). Map layers and associated databases can be compiled and serve as reference tools for effective communication of past, present and potential conditions. Data incorporated into a GIS can include point data, such as photo-points or the location of objects and spatial data, such as historical landuse maps and vegetation coverages.

Environmental data frequently collected in wetland monitoring projects includes vegetation, soil moisture, stream channel profile and water table level (Brinson, 1996 and Harlin and Lanfear, 1993). The location and/or extent of these data can be mapped with a Global Positioning System (GPS) unit and presented in 2- and 3-dimensional models. GPS mapped data can be easily combined with existing GIS map layers to increase previous coverages and analyze spatial interactions between mapped features.

Questions that can be addressed using GIS/GPS are:

- How does elevation affect water flow across the meadow?
- Are the new channel elevations and grades adequate to meet restoration specifications?
- Why is the channel breached in some areas?
- What is the potential extent of the new wet meadow?
- How does soil moisture distribution across the meadow change over time?
- How does vegetation adjacent to the channel change over time?
- How does channel morphology change over time?
- How do past and present land uses (railroad, roads, borrow pits, etc.) affect current conditions?

Methods

A Trimble Geoexplorer II GPS with post-processing differential correction and Arc/View GIS 3.0 software were used to acquire the locations of the project fence perimeter, FR 49,



Figure 1—This photo shows the “green belt” surrounding the meanders of the newly installed channel. This channel is shallow and wide with 37 meanders in the study area. The old channel show in figure 1 is relatively straight and more deeply incised.



Figure 2—Previous restoration projects amplified erosion in the old channel on the south side of the meadow. This photo shows the ensuing escarpment, looking upstream.

two-track roads, stream channels, train trestle, borrow pit location, and the 1998 spring flood extent for Agua Fria meadow. In conjunction with a laser leveller, the GPS unit recorded point locations for a submeter accuracy surface elevation map. Point data collected includes the locations of stream flow measurements, head cutting, core sampled trees, rock weirs and carbon dated soils.

Results

A map of the flood water extent in the spring of 1998 was created by walking the perimeter of the flood areas with a GPS unit (fig. 3). The extent of the flood was visually identified by standing water, wet soils, soil deposits and soggy vegetation. Major breaches of the new channel are also identified on the map. This information will be important to track the success of the new channel, the vegetative response, and the reoccurrence of seasonal flooding. Previous human alterations act as constraining features to the water in Agua Fria meadow. Flooding is at least partially confined by the railroad bed, roads, and the old channel.

Personal observations during 1998 spring runoff demonstrated that rates of erosion and deposition can be very rapid at Agua Fria. Soil carbon dates for soil samples collected

between 75 and 90 cm below the soil surface at the lower end of the project area were dated at AD 1430-1670 and AD 770-380. Combined with other information about the area this information could help us determine the sequence of events that have taken place in the meadow.

Runoff water flowed at Agua Fria for approximately 2-3 months in the spring of 1998. Flood waters flowed above the bankfull stage and across the meadow for more than half the time. Variations in the gradient of the new channel from the project design caused water to flow into areas not predicted. For example, less slope than expected directly downstream of FR 49 and fill materials placed in the old channel, higher than the adjacent surface, directed over-bank flows away from the new channel into a two-track road.

Two-track roads above and below FR 49 partially diverted water away from the new stream channel. Above FR 49, a two-track that crossed the new channel caused more water to flow across rather than around a constructed channel meander. Below FR 49, flood water diverted onto a two-track road by gradient and fill variations flowed into the borrow pit (fig. 3). These diversions of water increased the area of the lands projected to be inundated with floodwaters, a major goal of the restoration. However, while increasing the extent of the areas flooded, these two-track roads have the

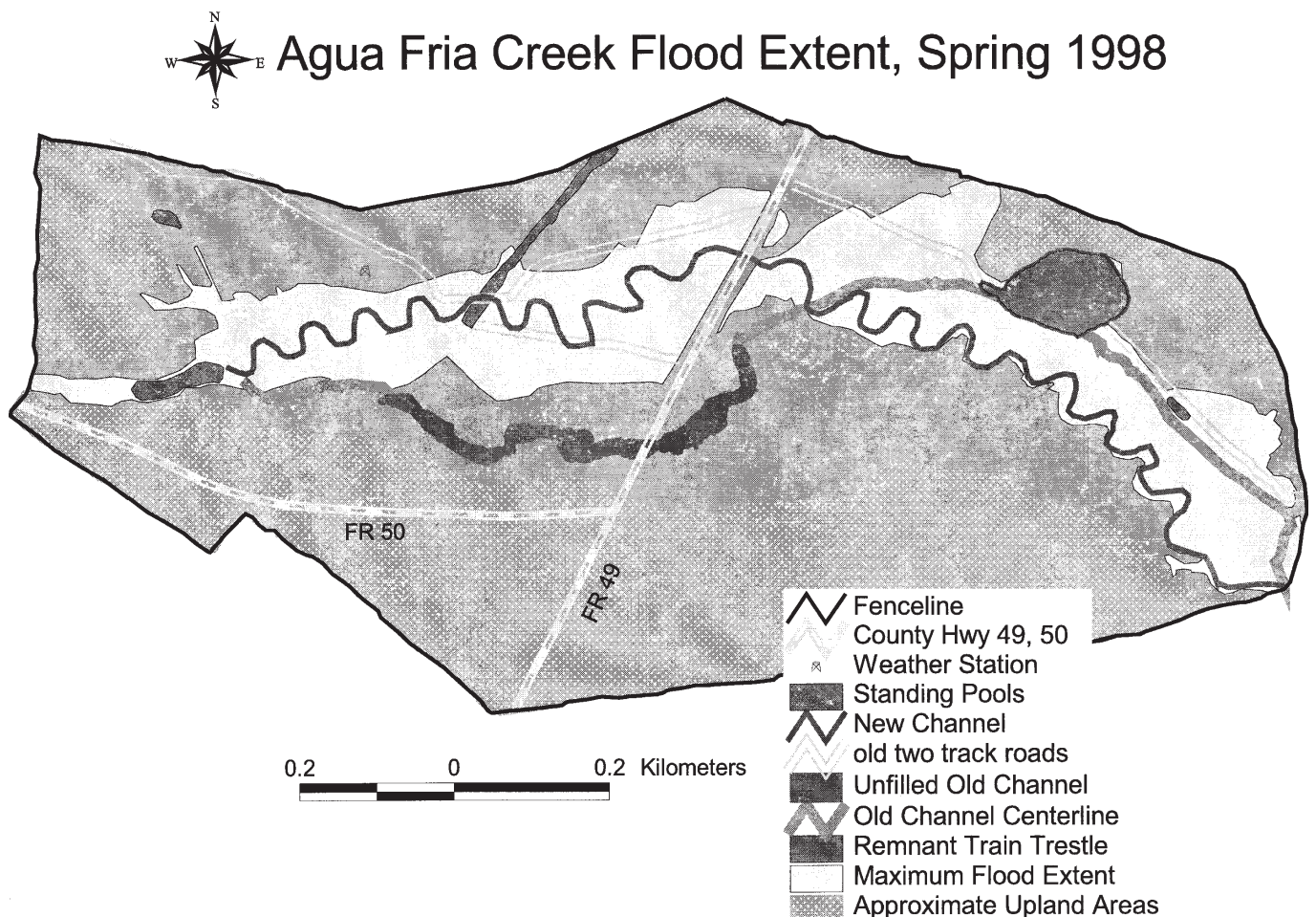


Figure 3—1998 spring Flood Map.

potential to be eroded into straight channel sections. Straight channel sections would allow water to flow quickly through them and could over time return the channel and meadow to pre-project conditions.

The over-bank flows downstream of FR 49 that were diverted into the borrow pit, filled the pit and flowed toward the lower end of the project area (fig. 3). These flows ran

across the surface and followed the course of the old stream channel, most of which had been previously filled in with soil from the borrow pit. Increased surface slope at the lower end of the study area caused overland flows to initiate erosion and headcutting in the area where the diverted water rejoined the new channel (fig. 4). By the time runoff stopped, headcuts had formed up to 1.50 m deep and 30 m to 50 m long (fig. 5).



Figure 4—Downstream of the new channel breach, below Forest Road 49, standing water and sheet flow cover the reseeded and filled old channel, during the spring of 1998.



Figure 5—Major erosion due to spring 1998 flooding. This photo is taken looking upstream from the fenceline project boundary. The second to last constructed concrete weir is in the center of the photograph.

Management Implications

GIS and GPS technology is becoming more commonly used as management and reference tools in the Southwest Region of the USFS. Currently an interoffice IBM system with Arc/Info, database management and statistical software is being by the USFS nationwide. This hardware and software upgrade will facilitate data transfer, analysis, storage, analysis and the creation of GIS products. This project will demonstrate how the successes and failures of ecosystem alterations can be studied and documented. This information will provide guidance for other projects that address similar issues and have access to similar technologies.

Future Work

GPS and GIS will continue to be used to collect, analyze and store information about Agua Fria meadow. In addition to the stream flow and climatic data being collected, continuous monitoring of watertable levels and soil moisture will be initiated in 1998. Vegetation cover and stream channel longitudinal profiles will be surveyed every spring and fall.

GIS coverages of natural and human induced attributes and interactions will continue to be compiled and analyzed to increase our understanding of the ecosystem functions at

work in Agua Fria meadow. Perhaps using GIS elevation maps and groundwater observation well information, water table elevations can be geographically hypothesized. Soil moisture and groundwater data may help validate possible ecosystem changes.

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