EPA/600/R-13/006 | January 2013 | www.epa.gov/research

United States
Environmental Protection
Agency

An Ecological Characterization and Landscape Assessment of the Humboldt River Basin

RESEARCH AND DEVELOPMENT

An Ecological Characterization and Landscape Assessment of the Humboldt River Basin

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Acronyms and Abbreviations

A Value	Gross Soil Erosion Rate
AML	Arc Macro Language
ATtILA	Analytical Tools Interface for Landscape Assessment
ARS	Agricultural Research Service
AUM	Animal-unit-months
BLM	Bureau of Land Management
BOR	U.S. Bureau of Reclamation
C Factor	Surface Cover Effect
DEM	Digital Elevation Model
EMAP	Environmental Monitoring and Assessment Program
GIS	Geographical Information System
HUC	Hydrologic Accounting Unit
IBI	Index of Biotic Integrity
K Factor	Surface Erodibility
LS Factor	Slope Length/Steepness
MRLC	Multi-Resolution Land Characteristics Consortium
NASA	National Aeronautics and Space Administration
NDA	Nevada Department of Agriculture
NLC	Nevada Legislative Counsel
NLCD	National Land Cover Database
NNHP	Nevada National Heritage Program
NPS	National Park Service
NDWP	Nevada Division of Water Planning
P Factor	Conservation Practices
R Factor	Rainfall Erosivity
RF3	River Reach File Version 3
RUSLE	Revised Universal Soil Loss Equation
SEDMOD	Spatially Explicit Delivery Model
STATSGO	State Soil Geographic Database
TM	Thematic Mapping
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USDA	U.S. Department of Agriculture

Acknowledgements

The authors would like to recognize the good people that helped us with this report; Sherman Swanson, Tad Harris, Pam Grossman, Kuen Huang-Farmer, Maria Gregorio, Angela Hammond, Richard Snell and Heather Powell. We feel that this ecological landscape analysis will be of value as a starting point to assess the condition of the Humboldt River System. We strongly believe that reporting this analysis will greatly aid in the understanding of this unique river system. We want to fully acknowledge the late Dr. Gary Vinyard for his vision and leadership and we wish to dedicate this report to his memory. We are also grateful to those who help us review this report in their time and effort including, David Goodrich, Steve Gardner, and Maliha Nash.

Notice

The information in this document has been funded in part by the United States Environmental Protection Agency under Student Services Contract number EP10D000282 to Leah Hare and Cooperative Agreement CR-826293-01 University if Nevada, Reno, Biological Resources Research Center. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document.

Executive Summary

The Humboldt River Basin covers a large part of northern Nevada. Very little is known about the water quality of the entire Basin. The people living in this area depend on clean water. Not knowing about water quality is a concern because people will need to manage the negative impacts of mining, agriculture, livestock grazing, land development, water use, and timber harvest. This area has had some of the most intense mining in Nevada history. It is also experiencing accelerated groundwater depletion and acid mine drainage from older abandoned mines. These activities may adversely effect water quality for human use and for the unique aquatic biota found there, including four threatened or endangered fishes and one amphibian candidate for listing as endangered or threatened. Landscape characterization and analysis are cost-effective tools which can be used to characterize the quality and condition of ecological resources. This information can be used by local resource managers and local stakeholders to make decisions that will help sustain the economic growth, ecological health and social benefits. This study will provide a data set and demonstration of analyses that can serve as a basis for a landscape ecological assessment. It can substantially increase our knowledge of conditions in this area using data collected from an earlier water quality study (Hare, et al., 2012).

Four water quality parameters were chosen to analyze the association between water quality parameters and landscape and soil metrics. Dissolved oxygen (DO), total kjeldahl nitrogen (TKN), total phosphorus (TP), and benthic macroinvertebrate structure index of biological integrity (IBI). DO levels vary depending on temperature change and sedimentation which can be related to land use practices. High levels of TKN and TP can indicate excess nutrient input from agriculture and manure deposition from cattle which can lead to increased algal growth and disturb the ecological balance of streams. The IBI combines metrics sensitive to stressors representing diverse aspects of the biota. Benthic macroinvertebrate structure can be effected through many land use practices which change channel shape and form, thus decreasing stream bank stability, leading to erosion and change in vegetation and habitat.

Multiple regressions were used to associate land cover/use metrics and sediment transport metrics to stream water quality parameters in watershed support areas in the Humboldt River Basin. Six landscape metrics were used; road density, stream density, soil erodibility, gross soil erosion (strong relation with the water quality metrics) percent natural grassland and road length (to a lesser degree) which all had relationships to the water quality parameters. Road length and road density are important factors in and around the populated areas of Lovelock, Battle Mountain, Winnemucca and Elko. The Index of Biotic Integrity (IBI) and total phosphorus remained low around all urban areas, total kjeldahl nitrogen and dissolved oxygen had high values primarily around the more populated areas.

The final regression models were used to predict the water quality parameters (DO, TKN, TP, and IBI) in areas were measurements do not exist. The predicted water quality values were ranked in group classes and mapped to examine their magnitude with that of land use activities like mining and cattle grazing.

1.0 Introduction

1.1 Objectives

The Humboldt River Basin is located in northern Nevada and is a part of the Environmental Protection Agency (EPA) Region 9. To ecologists and environmental scientists, a landscape is more than a vista; it comprises the features of the physical environment and their influence on environmental resources. Landscape ecology focuses on the relationships between spatial arrangements and the ecological processes of the landscape. Landscape ecology also integrates biophysical approaches with human perspectives and activities to study spatial patterns at the landscape level, as well as the ecological functionality of the region. There are many applications of this approach (Heggem, et al., Mehaffey, et al.). For example, areas most disturbed by anthropological sources can be identified by combining information on population density, roads and land cover. Vulnerability of areas can also be identified by inspecting and assessing the surrounding conditions. Potential erosion control issues can be evaluated as well by considering variables such as precipitation and the steepness of slopes. Ecological processes connect the physical features of the landscape linking seemingly separate watersheds.

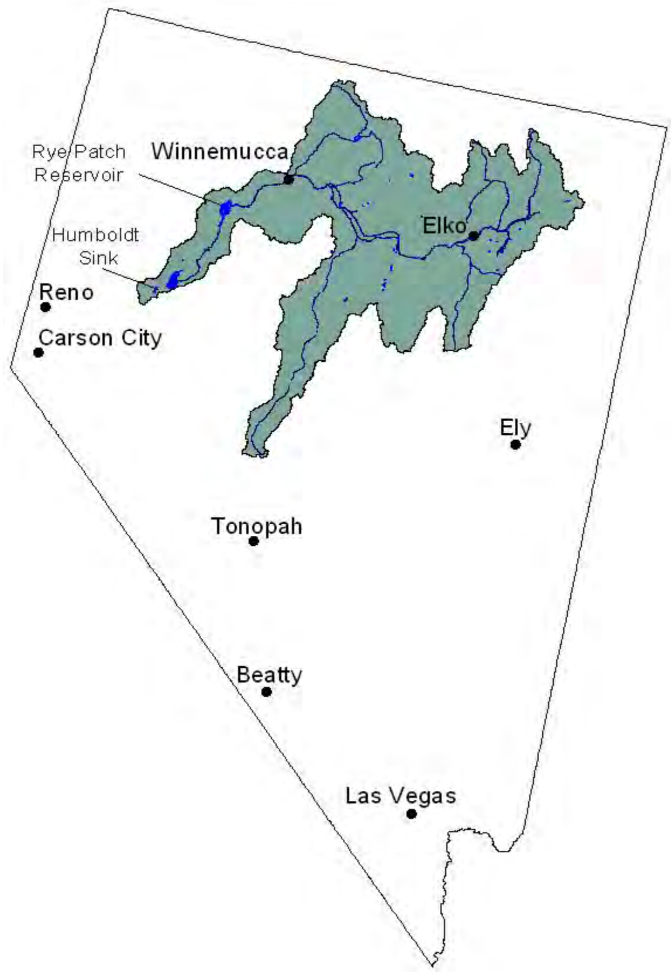

Figure 1. Location of the Humboldt River Basin.

The Humboldt River drainage (Figure 1) is of interest to water quality managers due to potential human impacts from livestock grazing, mine dewatering and runoff. This report presents an environmental assessment of the basin by studying the relationships between water quality and the landscape, while considering the potential human impacts. This assessment can be used as a tool to estimate the impact of human land use practices that are being currently implemented to improve environmental quality. Currently, the Argenta Marsh, a wetlands located in the center of the basin directly below the Humboldt River, is the subject of much discussion. What used to be an extensive riparian and wetland area of between 12,000 and 15,000 acres which connected Humboldt's main river with south channels through an expanse of swamps, tules and dense vegetation, was drained when the Humboldt River was channelized in the 1950's. Recently, effort has been made to begin a marsh restoration project to convert the area back to wetlands. Although controversy exists over the ownership of this area, converting this community pasture to a wetlands has been proposed to increase habitat for many native species (Horton, 2000). Land cover analysis could be used to assess the changes in water quality before and after restoration. The objective of this report is to provide a data set and demonstration of characterizing the Humboldt River Basin to determine the ecological status by relating known water quality to landscape metrics by way or multiple regression analyses.

This assessment can also be used for ecosystem targeting and help people make decisions on the best locations for restoration sites. The information presented in the following pages provides characterization of the area by the visualization of the conditions across the basin and within each sub-watershed.

1.2 Broad-Scale Environmental Condition

Taking a broader view, the landscape perspective changes allowing an easier understanding of land cover interactions and helps to make predictions of future anthropogenic problems. At a small-scale level, perspectives and concerns are based locally. Looking at the national setting can help place the basin in context and interpret individual conditions, as well as help determine land cover similarities elsewhere in the country which is important because local environmental issues can have regional impacts. As seen in Figure 2**,** the southwest is unique in that shrublands and barren land dominate the landscape, whereas forests are prominent in the east and agriculture in the mid-west. In the Nevada Great Basin, rivers are the flowing arteries in the midst of huge, arid, and often desolate western landscape. There are also significantly fewer roads in the west compared to the east, thus greater amounts of open areas (Figure 3).

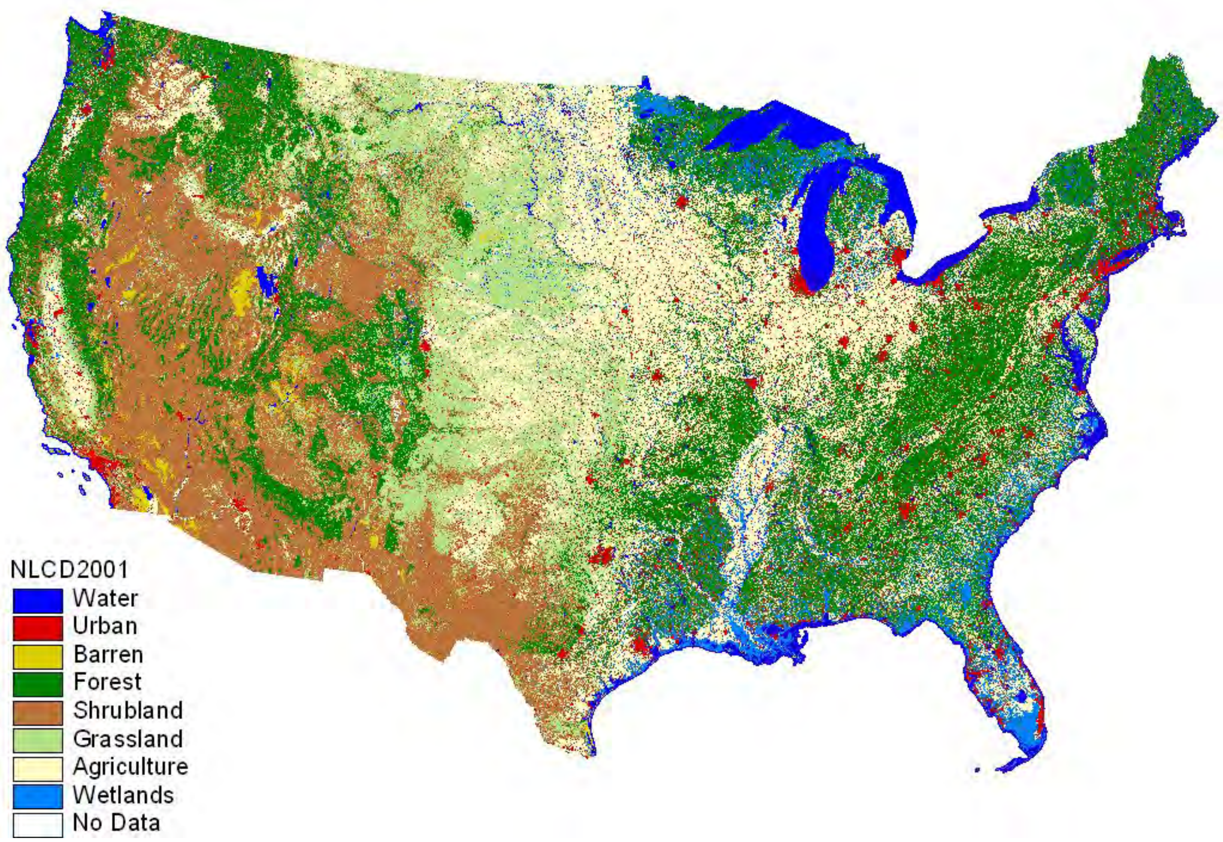

Figure 2. 2001 NLCD (MRLC, 2008).

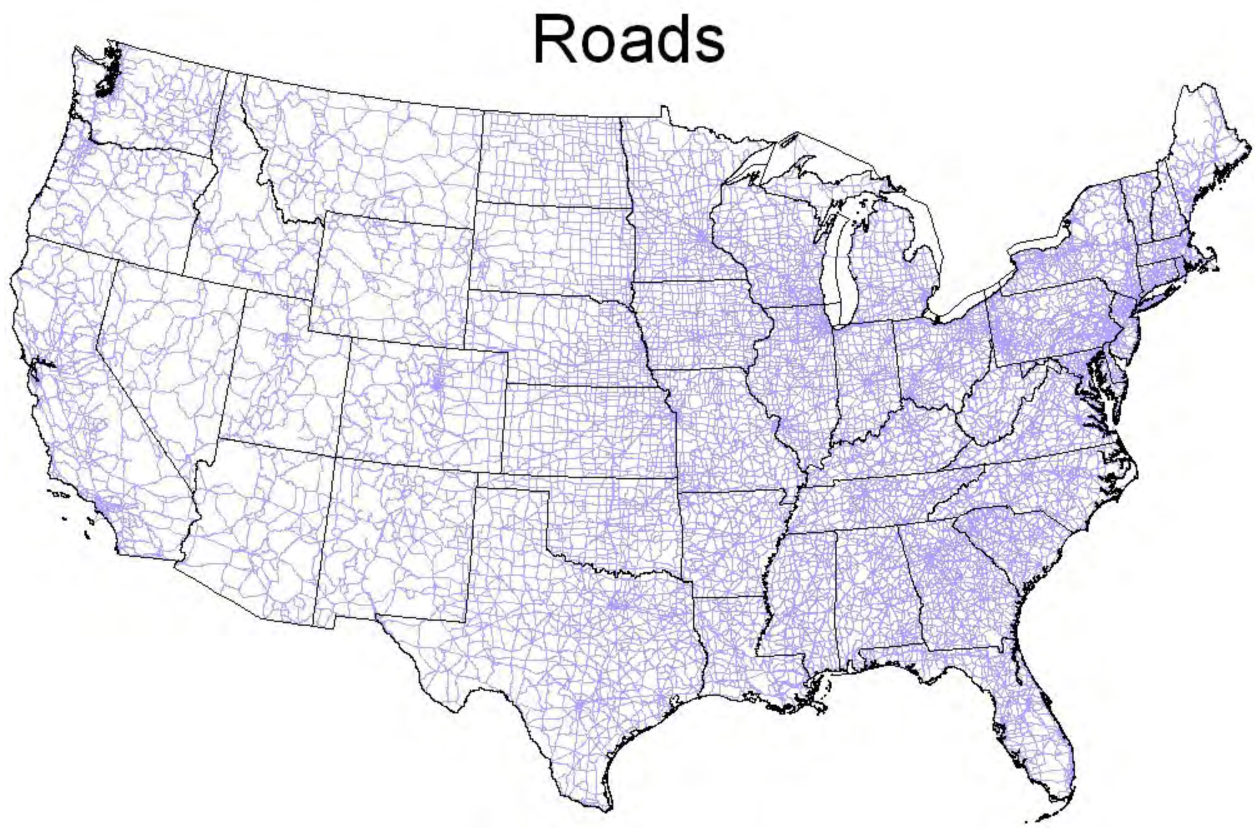

Figure 3. National Map of Roads (USGS, 1995).

1.3 Overview

The Humboldt River Basin, located in the Nevada Great Basin, holds the Humboldt River, a main artery which has been a key resource for both humans and wildlife, and is of primary importance in both the economy and ecology of the region (Figure 1). The basin's land use history began in the mid 1800's when miners traveled across Nevada's Humboldt Basin in search of California's gold. Silver, and later gold, was soon discovered in Humboldt's Carlin area, and subsequently, agricultural and livestock ranches were established to service the miners (True, 1913). In the late 1800s, heavy grazing led ranchers to supplement with hay crops, creating water conflicts. It was soon realized that sufficient water in the Lovelock Valley was going to be in short supply and a consistent water source was necessary to continue with their land use practices (Bard et al., 1981). Rye Patch Dam, located just upstream of the Humboldt sink (an intermittent lake bed with no natural outlet), was built in 1936, and is the basin's chief reservoir with most of the water diverted for irrigation for farming and mining. By the 1900s, there was grazing induced vegetation destruction and subsequent erosion. This led to many upland watersheds being managed by the United States Forest Service (USFS). Much of Nevada State is currently managed by the Bureau of Land Management (BLM), due to excessive habitat degradation from overgrazing (Figure 4). To date, livestock grazing has continued throughout the basin, drastically changing the ecological balance of the basin through the invasion of annual exotic species and introduction of more hearty, yet toxic, plants (Horton, 2000).

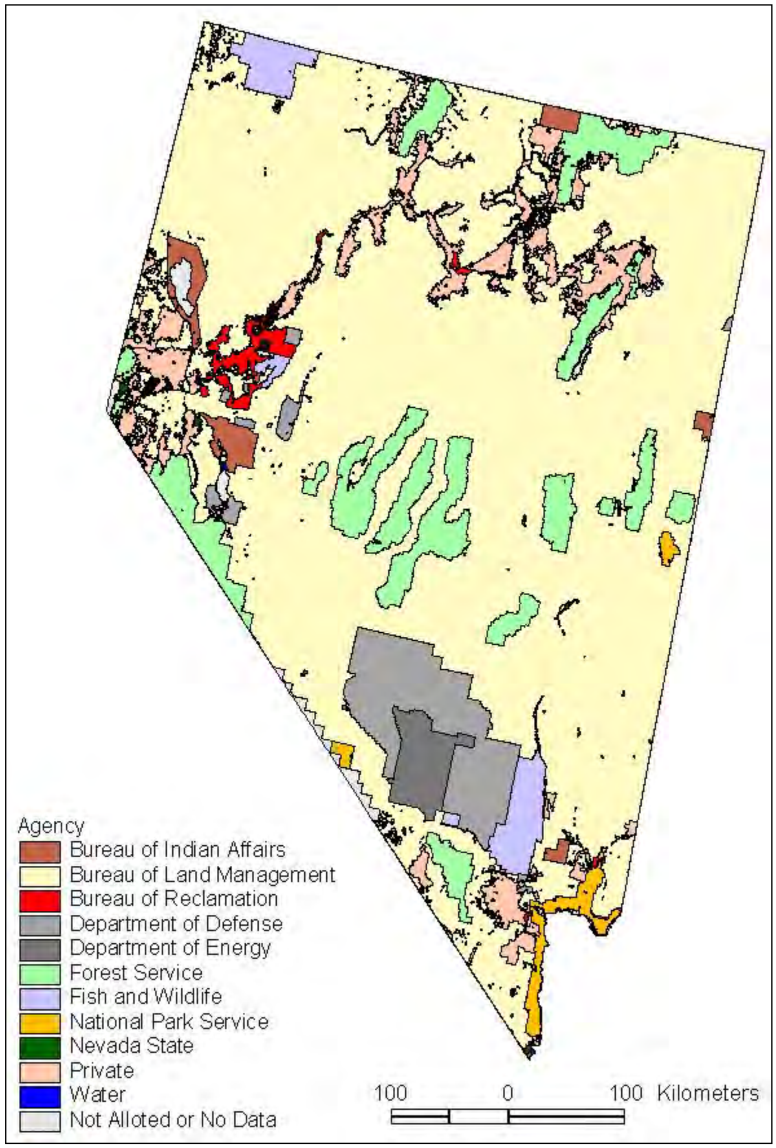

Figure 4. Jurisdictional Boundaries for Nevada (BLM, 2010).

Another prospective anthropological impact to the Humboldt Basin are the effects of mining. Nevada State is one of the largest gold producers globally, with the greatest number of mining operations in the Humboldt Basin. Early mining efforts led to deforestation in the lower basin. Currently, concerns include mine dewatering, which creates the potential for changes in water quality from chemical pollution (Horton, 2000).

2.0 The Biophysical Setting

2.1 Land Cover and Topography

The Humboldt River drainage covers an area of approximately 44,000 km^2 (~17,000 mi^2) between Latitude 41^{o}50' in the north and 38^o 45' in the south. The geography of the area, with the Sierra Nevada Mountains to Nevada's western border, stops the access of easterly storms from the Pacific Ocean, resulting in the 'rain shadow' effect. This has created an overall arid landscape in the bowl-shaped Great Basin.

Surface water flows enter the system almost entirely through melting snow from the mountain ranges. In the Humboldt River Basin, the snowmelt from the Jarbidge, Independence and Ruby Mountain ranges are the primary source of water in the basin, which generally drains northeast to southwest. These mountains are steep and deeply incised with alluvial/colluvial deposits in the canyons with fine sediment becoming the dominant substrate in the broad valleys. The topography of the basin ranges from 1175 m (3855 ft) in the valleys to over 3500 m (11,483 ft) in the mountain ranges. Existing mountain ranges border the basin to the south (Toiyabe National Forest), east (Ruby Mountains) and north (Independence, Jarbidge and Santa Rosa Mountains) (Figure 5).

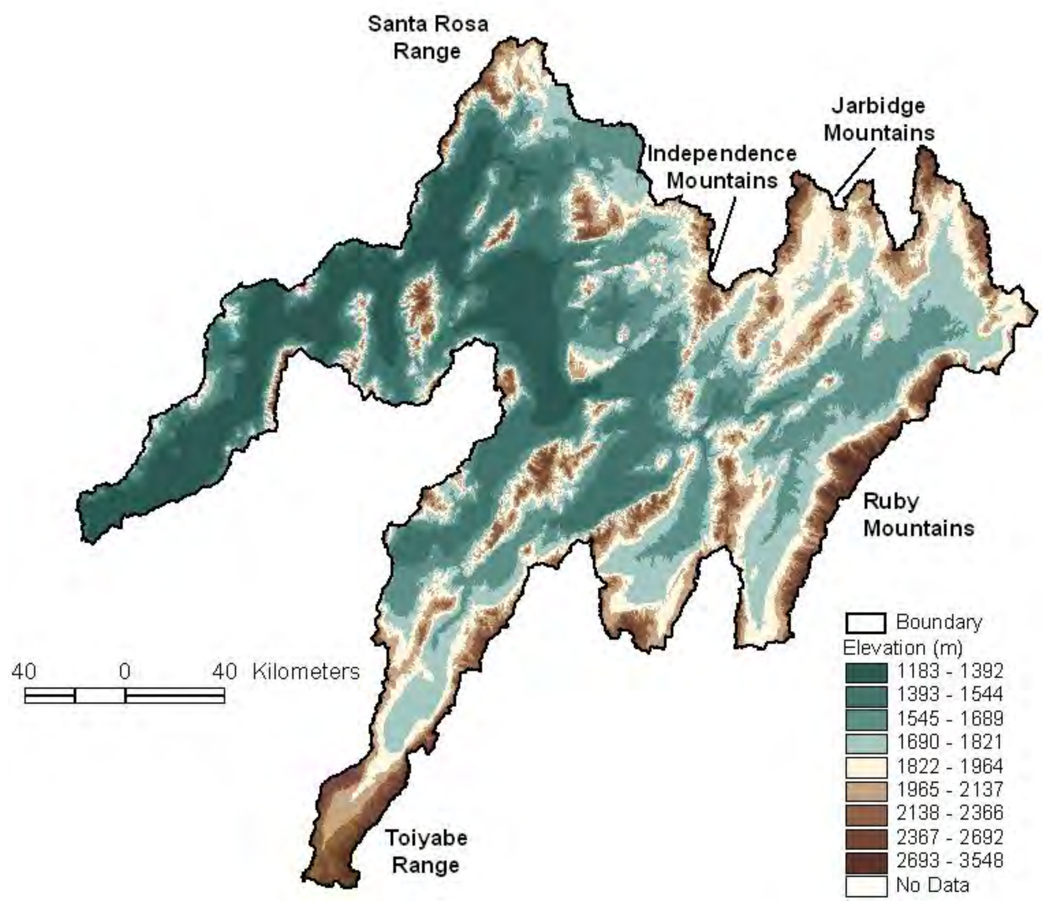

Figure 5. National Elevation Data for the Humboldt River Basin.

The Humboldt Basin is located almost entirely within subecoregion 13 (Central Basin and Range), which is generally characterized by a wide variety of habitats ranging from salt flats and sage (*Artemesia spp*) dominated basins to subalpine zones in montane environments (Figure 6). The lower elevation basin areas of subecoregion 13 receive low amounts of rainfall but are characterized as semi-desert, which are systems that typically receive between 250-500 mm of precipitation per year. A small portion to the north of the basin is within subecoregion 80 (Northern Basin and Range) consisting of sagebrush and juniper (*Juniperus sp*) woodlands. For a full description of ecoregions, see Appendix 1.

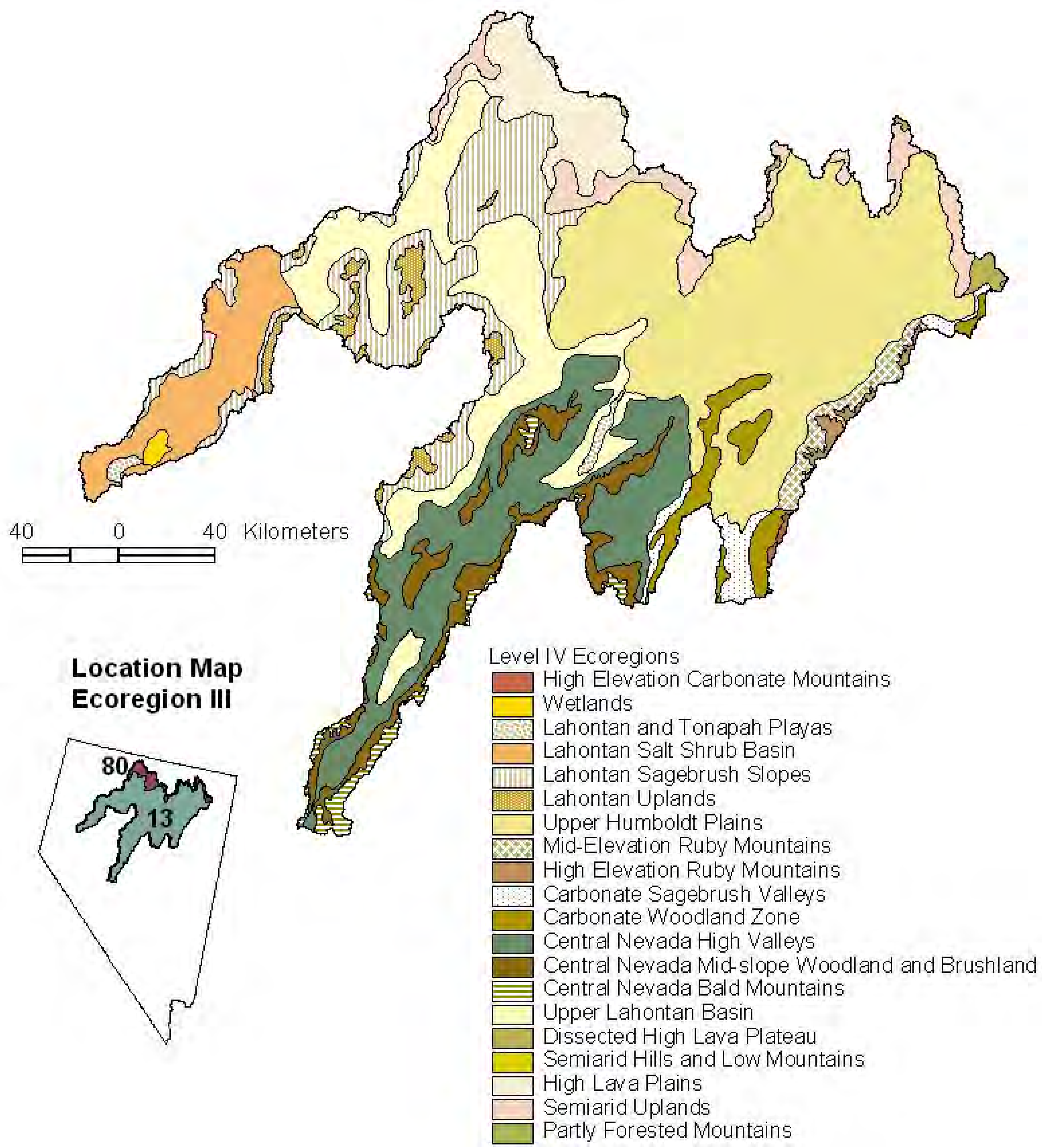

Figure 6. Ecoregions in the Humboldt River Basin.

The land cover in the basin is made up primarily of shrub/scrublands, predominantly four-winged saltbrush (*Atriplex canescens*), shadscale (*Atriplex confertifolia*), rabbitbrush (*Chrysothamnus Nutt.*), and big sagebrush (*Artemisia tridentata Nutt.*), and grasslands. Examples of grassland species include Indian rice grass (*Achnatherum hymenoides*) and invasive cheatgrass (*Bromus tectorum*). Willows (*Salix spp.*) and cottonwoods (*Populus L.*) subsist in the low elevation riparian portions of the basin. Forests are generally dominated by single-needle pinyon pine (*Pinus monophylla*) and juniper (*Juniperus sp*). In higher altitudes, bristlecone (*Pinus aristata*), whitebark pine (*Pinus albicaulis*) and white firs (*Abies concolor*) can be found (USEPA, 2007). A substantial percentage of the basin's agricultural crops provide alfalfa hay for the cattle and sheep farms that graze throughout the basin. Urban areas are minimal with sizable populations in the city of Elko in the eastern portion of the basin, Winnemucca to the west and Battle Mountain located mid-basin; all three are situated on the Humboldt River.

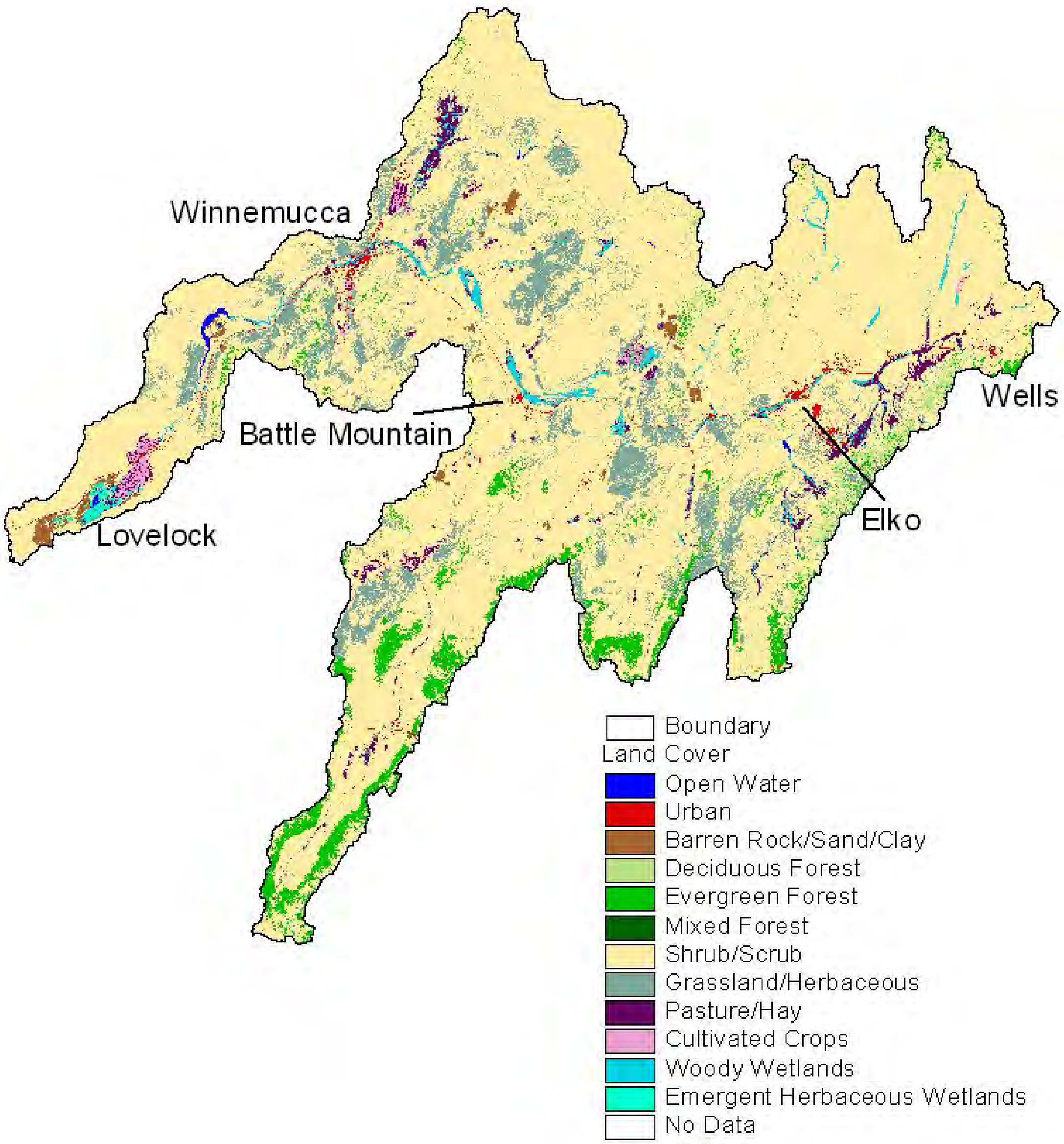

Figure 7. Land Cover/Use in the Humboldt River Basin.

2.2 Streams

Streams and rivers not only direct the flow of water but also provide necessary resources such as essential habitat for animals, the filtering of pollutants, processing of litter and debris, distribution of nutrients, and recreation. The landscape surrounding a stream provides a diverse and productive system for plants and animals. The stream network used for this assessment is the EPA River Reach File (RF3), derived from the U.S. Geological Survey (USGS) Digital Line Graph.

The main tributaries to the Humboldt River are the Reese River, Mary's River, the South, North, and East Fork of the Humboldt, and the Little Humboldt Rivers (Figure 8). Mary's River originates in the Jarbidge Mountain range and is considered to be the headwaters of the Humboldt River. Stream flow is at a maximum at Palisade. Because of this, environmental conditions within and between lotic systems in this drainage are highly variable. The mainstem of the Humboldt River is one of the longest rivers in the Great Basin having an aerial extent of 483 km (300 mi), or 1610 meandering kilometers (1000 mi) from the headwaters to its terminus within the Humboldt Lake, at an elevation of 1185 meters (3888 ft). Humboldt Lake is a body of water located in the Humboldt Sink, an 18 km (11 mi) by 6 km (4 mi) area which has no outlet.

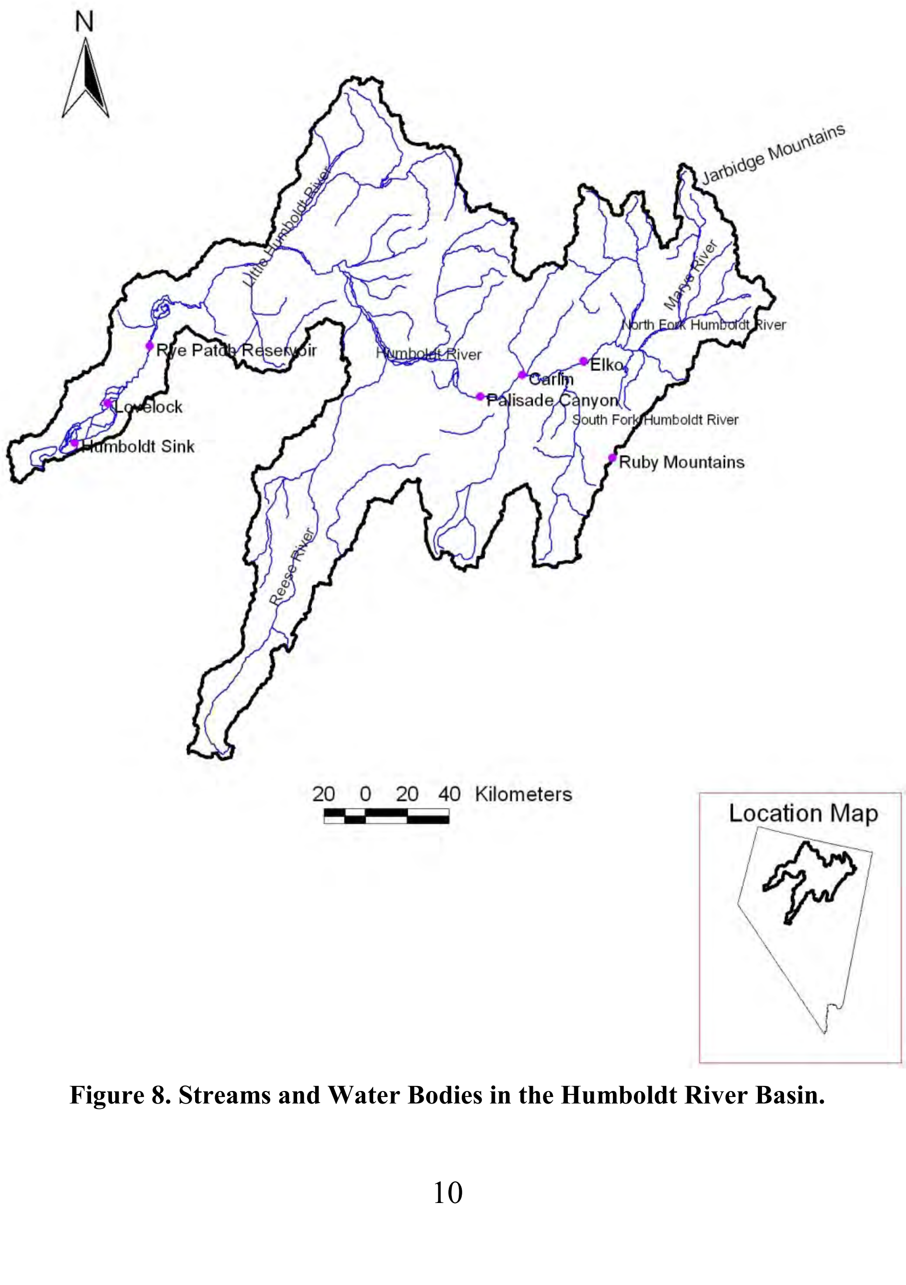

Figure 8. Streams and Water Bodies in the Humboldt River Basin.

2.3 Watershed

A watershed is an area of land in which all forms of precipitation drain into streams or permeate into the ground water at the same place. Watersheds can provide a way of evaluating landscape and water relations based on the water flow through the system. A hydrologic unit code (HUC) is an area which represents all or part of a surface drainage area, a combination of drainage areas, or a distinct hydrological feature (USGS, 2009). The United States is divided into different levels of hydrological units: regions (2-digit areas), sub-regions, accounting units, and cataloging units (Figure 9).

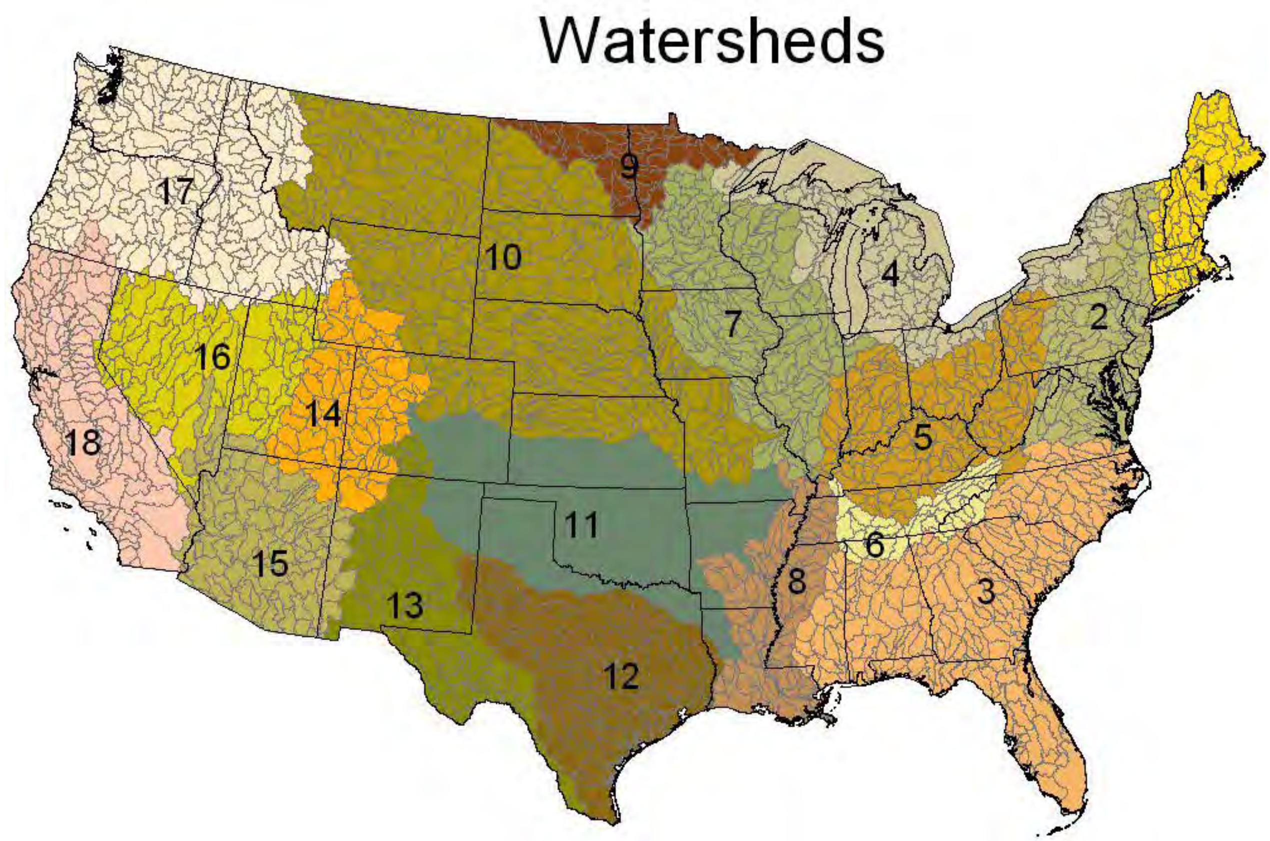

Figure 9. National Map of 8-digit HUCs. 2-digit HUCs are Illustrated in Color.

The Humboldt River Basin is located within Region 16, (Figure 9) which represents the Great Basin. The USGS's national 12-digit hydrologic units are used in this report to summarize landscape metrics. Figure 10 displays all 12-digic HUCs in the Humboldt River Basin within the larger 8-digit cataloging units, illustrated in color. For 8-digit HUC numbers and total area, see Appendix 2.

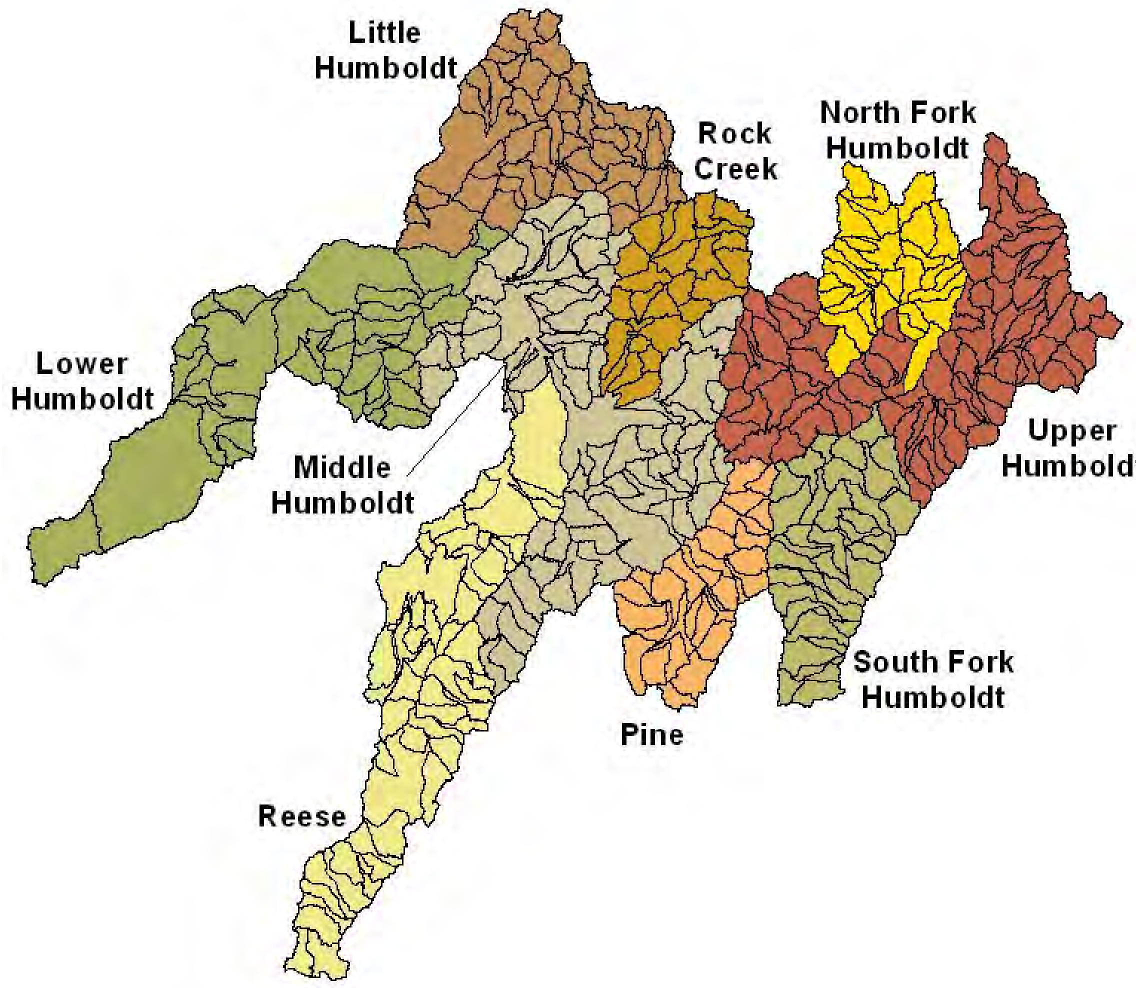

Figure 10. 12-Digit Hydrologic Unit Boundaries for the Humboldt River Basin.

3.0 Methodology

3.1 Regional Classification

The land cover used for this report is from the 2001 National Land Cover Database (NLCD) completed by the Multi-Resolution Land Characteristics Consortium (MRLC) (Homer et al, 2007). The 2001 land cover was used due to availability of datasets and the proximity to the sampling period**.** The MRLC is a federal consortium created to use Landsat 5 and Landsat 7 thematic mapping (TM) imagery to provide consistent land cover for the entire United States. Every surface reflects a unique electromagnetic radiation that can be detected to classify land cover. An example of a Landsat remote sensing image can be seen in Figure 11, with vegetation shown in red. NLCD 2001 data uses 30m Digital Elevation Model (DEM) to distinguish 29 land cover classes. In the Humboldt River Basin, there are fifteen individual NLCD classifications which, for this study, have been assembled into eight dominant categories (Table 1).

Table 1. 2001 National Land Cover Data Regional Land Cover Classes.

Open Water	Water
Developed, Open Space Developed, Low Intensity Developed, Medium Intensity Developed, High Intensity	Urban
Barren Land	Barren
Deciduous Forest Evergreen Forest Mixed Forest	Forest
Shrub/Scrubland	Shrubland
Grassland/Herbaceous	Grassland
Pasture/Hay Cultivated Crops	Agriculture
Woody Wetlands Emergent Herbaceous Wetlands	Wetlands

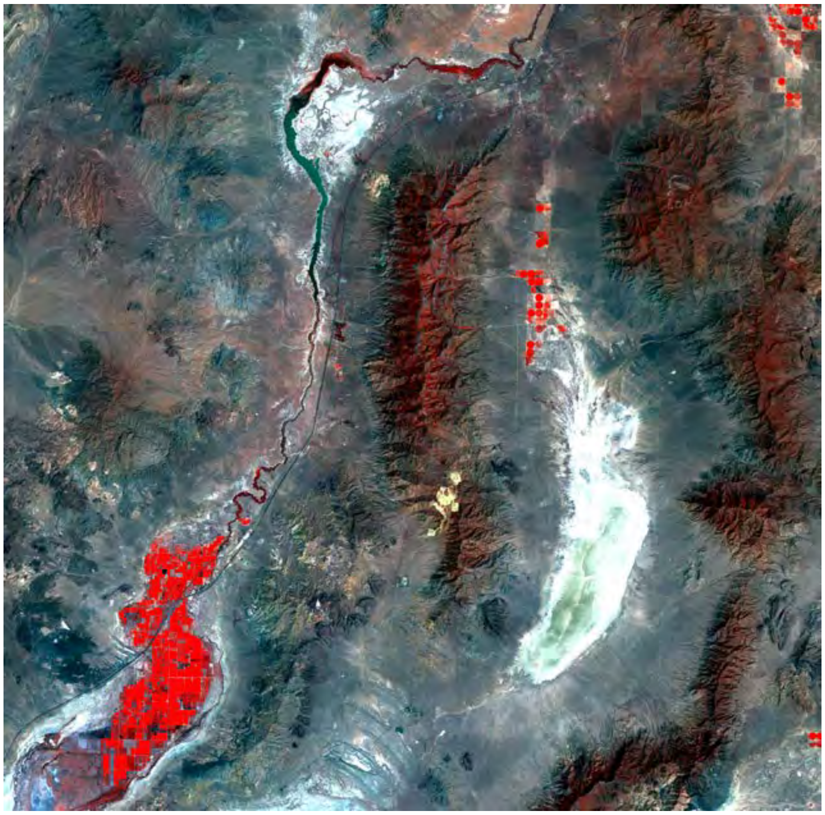

Figure 11. Lovelock, Rye Patch Reservoir^{TM}. Vegetation Shown in Red.

3.2 EPA-Delineated Sub-watersheds

A separate set of geographical information system (GIS) delineated watersheds was used for the Humboldt watersheds based on sampling points. These watersheds were delineated using DEM data to calculate flow direction and flow accumulation. This process determines boundaries and ridge tops, which divide water flow to drainage, or outlet points. A number of the original 68 watersheds were nested, which are sampling site sub-watersheds within a larger sampling sub-watershed. Final sites were chosen for analysis according to the greatest number of non-nested watersheds available, while mainly including the delineated watershed furthest downstream. A total of 41 sites were chosen for analysis (Figure 12). Corresponding site names and locations are listed in Appendix 3.

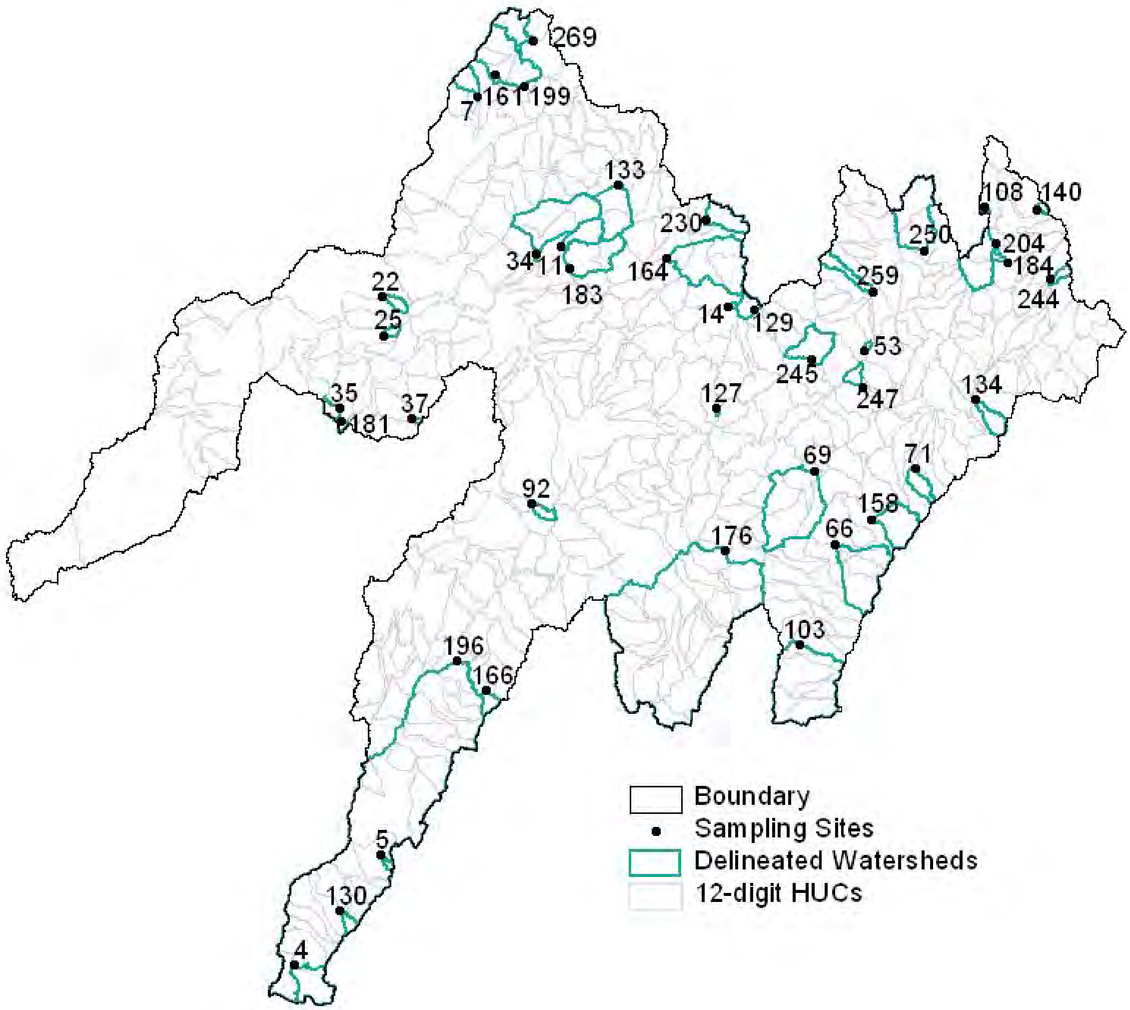

Figure 12. Humboldt Watersheds and GIS-Delineated Sub-Watersheds.

3.3 Landscape Metrics

Understanding watershed characteristics will help in the identification and interpretation of biogeographical patterns in biological communities. To characterize a watershed or a stream, it is necessary to identify the geology, geomorphology, hydrology, land cover vegetation and distribution and land use. The first step is to identify a set of landscape indicators with which to conduct a comparative landscape assessment on the sub-regional study areas. The landscape monitoring and assessment approach involves the analysis of spacially explicit patterns of, and associations between, ecological characteristics such as soils, topography, climate, vegetation, land use, and drainage pathways, and interprets the resulting information relative to ecological conditions on areas ranging in size from small watersheds (a few hundred hectares) to entire basins (several million hectares).

A combination of the NLCD and a reporting unit, either HUCs or delineated sub-watersheds, were used to generate a new dataset (ie. the amount of forest cover in each HUC). Both the HUCs and delineated watersheds, used as reporting units, were overlaid on the NLCD 2001 image. Using Analytical Tools Interface for Landscape Assessments (ATtILA), four different categories of metrics were calculated: landscape characteristics, riparian characteristics, human stressors and physical characteristics of ATtILA (Ebert, et al 2004).

Landscape characteristics include basic summary calculations, such as the percent of natural land use, forests, shrublands, as well as forest patch data. The riparian characteristics calculate the percentage of stream length adjacent to a specified component. Human stressors compute population density (and/or change) and stream/road density. Physical characteristics calculate general statistics of element as elevation slope.

Maps showing the relative ranking of each metric in the reporting unit were also produced. Figure 13 uses the 12-digit HUCs as reporting units in calculating the percent shrubland in the basin. The map is color-coded to show relative conditions among watersheds. The dark green areas have the greatest amount of shrubland, while the maroon areas have the least. The natural breaks classification method was used to display results finds groups and patterns using a statistical formula, to minimize variance within each class.

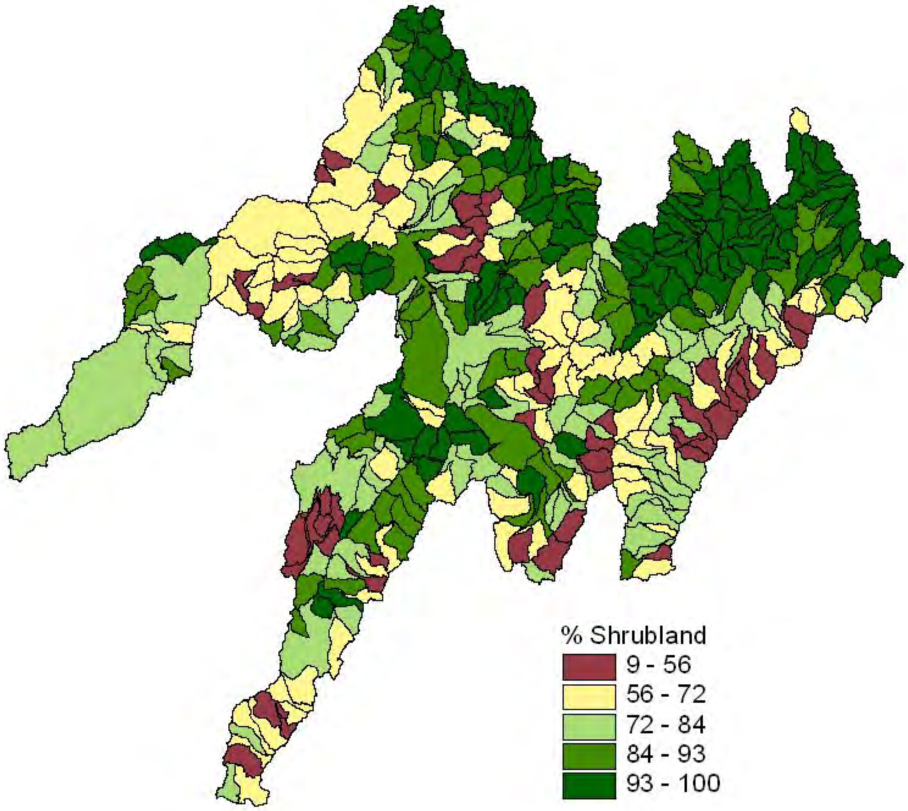

Figure 13. Example of the Maps that Appear in this Report. The Maps are Color Coded to Show Land Cover/Use Percentages.

3.4 Soil and Landform Metrics

Soil erosion metrics were calculated using the watershed analysis tool for RUSLE/SEDMOD (Van Remortel, et al 2004) soil erosion and sedimentation modeling. The revised universal soil loss equation (RUSLE) model and the spatially explicit delivery model (SEDMOD) were the primary framework for this tool. The soil and landform metrics use ArcInfo as the platform for the four AML scripts and two ANSI C++ executable programs. STATSGO soil data, NLCD 2001, boundary area, delineated watersheds, ArcHydro generated filled DEM, flow direction, flow accumulation and stream network grid were used to run the model. This tool is important because it quantifies the amount of soil coming through the system by looking at factors which influence this. The RUSLE/SEDMOD model generates master soil and landform geodatasets that are used to calculate the LS (slope length/steepness), R (rainfall erosivity), K (surface erodibility), C (surface cover effect), and P (conservation practices) factors, as well as, STATSGO derived soil parameters. These factors are used together to achieve the gross soil erosion rate (A value).

3.5 EMAP Measurements

Through the Environmental Monitoring and Assessment Program (EMAP), water column and benthic macroinvertebrate data were collected in the summers of 1998 and 1999. Sites were selected using a probability-based, or random design to represent the wadeable streams within the Humboldt River Basin using the EPA RF3. Thirty-five were sampled in 1998, while the remaining thirty-four sites were sampled in 1999. Any sites that were resampled in 1999 were not used in this report.

In general terms, a water quality standard defines the goals for a body of water by designating the use or uses to be made of the water, setting criteria necessary to protect those uses, and preventing degradation of water quality through anti-degradation provisions. Water quality standards apply to surface waters of the United States, including rivers, streams, lakes, oceans, estuaries and wetlands. Under the Clean Water Act, each state establishes water quality standards which are approved by the EPA.

Benthic macroinvertebrate assemblages reflect overall biological integrity of the stream, and monitoring these assemblages is useful in assessing the current status of the water body, as well as monitoring long-term changes. In this report, an Index of Biotic Integrity (IBI) is used to represent the overall health of the assemblages. This method evaluates biological variables using a number of criteria, and a subset of the five best performing metrics is then combined into a single, unitless index. These final variables, or metrics, should be sensitive to stressors, represent diverse aspects of the biota and be able to discriminate between reference and stressed conditions. Values range from 1 to 100 with higher numbers corresponding to healthier biotic assemblages.

3.6 Data Sources

Data sources include (1) EPA delineated watersheds, RF3 files, and Environmental Monitoring and Assessment Program (EMAP) data; (2) Natural Resource Conservation Service (NRCS) State Soil Geographic Data Base (STATSGO) soil data; (3) United States Geologic Survey (USGS) digital elevation model (DEM) and hydrologic units (HUC); (4) Multi-resolution Land Characteristics Consortium (MRLC) 2001 national land cover data (NLCD); and (5) NASA satellite thematic mapping (TM) imagery. Using this data, statistical analyses were conducted.

3.7 Data Analysis

To study the relationship between landscape and water quality, stepwise multiple regression was used to associate stream indicators with ATtILA landscape and RUSLE sediment transport metrics in each delineated sub-watershed. Prior to regression, pairwise correlations were examined between predictors (landscape and RUSLE metrics). When two predictors were found to be highly correlated ($R>|0.75|$), one was excluded from further analysis to prevent the presence of collinearity. Soil variables were standardized to achieve comparable data. A natural log transformation was performed, if necessary, to linearize relationships. Outliers were also tested for, and removed to achieve normal distribution for residuals. The amount of variability explained by the regression model was assessed using the regression coefficient of determination R^2. The multiple regression model is:

$$y=\beta_0+ \beta_1x_1+ \beta_2x_{2\ldots}+\beta_nx_n + \varepsilon$$

where y is the response predicted value, β_0 is the constant, $\beta_{1\ldots}\beta_n$ are the coefficients of the predictors (x's), and ε are the residuals. Residuals were all tested for normality, using a Shapiro-Wilk's test ($p > 0.30$). Table 8 presents the final regression models. We used R version 2.13.1 (2011-07-08) software for our statistical analyses.

4.0 Land Cover/Use

Humans have been altering land cover throughout history through fire, clearance of forests for agriculture, and livestock grazing through animal domestication, and activities have only increased with the passing of time. Thus, today's land cover can be seen as the product of past land uses. Yet, land use and land cover are inexplicably linked. Humans structure the landscape, but the landscape determines the activity. For example, soil type and topography decide the feasibility of agriculture in an area. The relationship between humans and the landscape is important in understanding changes and quantifying linkages.

4.1 Forests

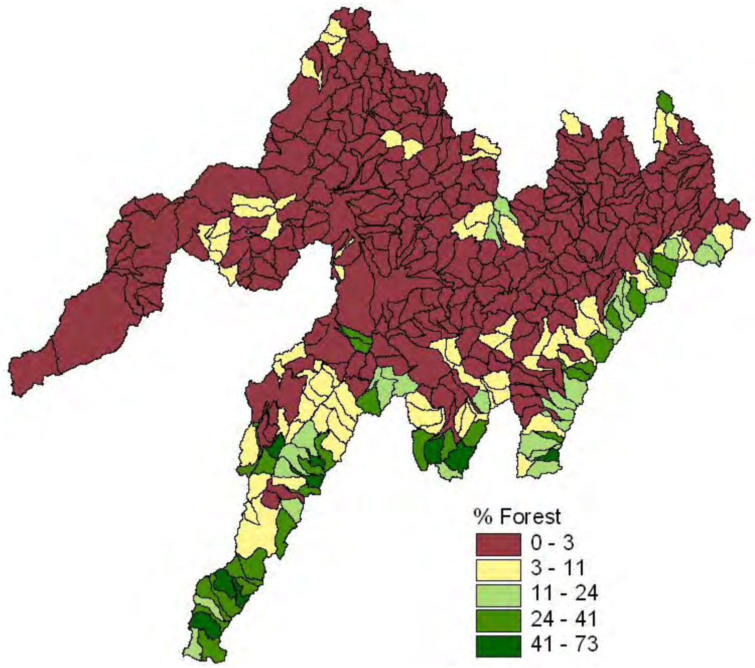

Figure 14. Percentage of Forested Land in the HUCs.

Trees are an important element for humans and wildlife. Clearly, forests are an economical natural resource. Historic use in the Humboldt River Basin has included the use of pinyon-juniper trees from the surrounding mountain ranges to supply the charcoal industry in Eureka, as well as using them for building corrals and roofs in the neighboring towns. Mining companies have been the largest consumer of lumber, accounting for most of the lumber camps and sawmills in the region (Bowers & Muessig, 1982). Yet, forest ecosystems are also of great importance to water quality and quantity, habitat and climate. Trees regulate hydrologic flow by capturing rainfall and reducing the intensity of rainfall that reaches the ground. This can increase absorption and water storage capacity while decreasing surface flow and erosion. Trees are essential for erosion control by stabilizing soil with roots systems, thus decreasing sedimentation, and improving water quality. Trees also provide habitat through food supply and shelter, and through forest litter, large woody debris which is a natural habitat for aquatic species. Air and water temperatures are also regulated by shade proved by a forest canopy (Center for Watershed Protection & USFS, 2008). In the Great Basin, forests within mountain ranges and riparian areas act as important refugia and corridors for macrofauna**.**

In the Humboldt River Basin, tree cover is a minor land cover type (Figure 14).. The greatest percentage of forest is in the Ruby Mountains and Toiyabe National Forest, which line the edges of the east and south portions of the basin. Average overall forest cover is 6.1% in the basin, with the majority of HUCs having less than 3% cover. In the individual sub-watersheds, forest cover averages higher (13%), due to many of the delineated sub-watersheds are located in the mountain ranges.

4.2 Shrubland/Grasslands

Desert shrubs are the foremost land cover component in the Humboldt River Basin. Vegetative shrubland cover in the lower volcanic ranges consists of widespread greasewood (*Sarcobatus sp.*) and shadscale. In areas with greater moisture, cover comprises of sagebrush, horsebrush (*Tetradymia sp.*) and rabbitbrush species (Horton, 2000). Shrub/scrub type vegetation is distributed throughout the basin with the largest continuous areas in the north. Cover averaged 80% within the HUCs and delineated sub-watersheds (Figure 15).

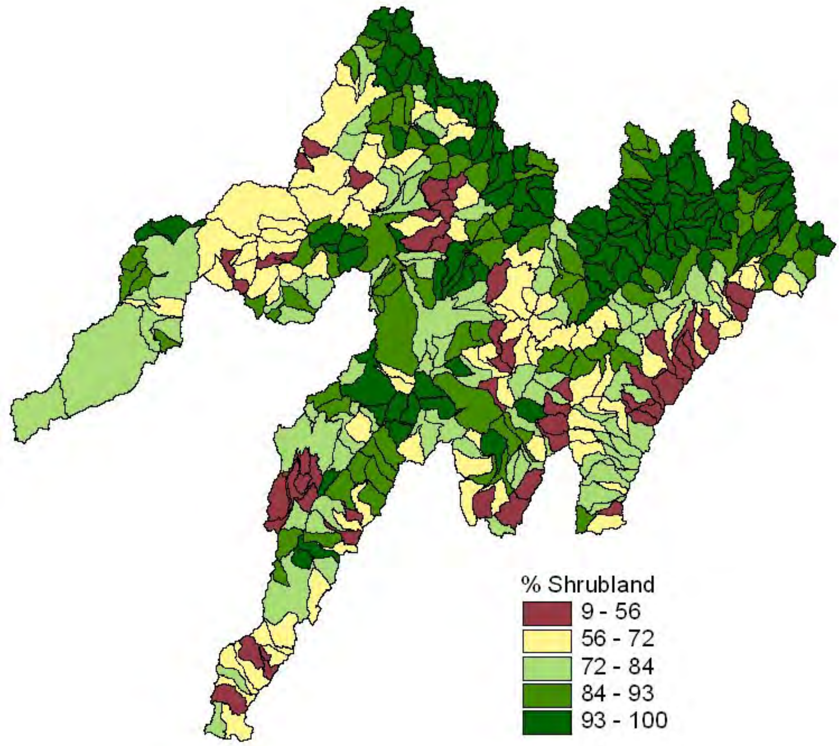

Figure 15. Percent Shrub/Scrubland in the Humboldt River Basin.

Grasslands are an important land cover type in the Humboldt Basin because they provide forage for the wildlife and livestock in the area. Native grasslands include saltgrass, a low palatable forage for livestock found in marshy areas, such as the Humboldt Lake area. This plant may reduce salinity of streams and can be vital to soil erosion control. Other foraging grasses are bluegrass (*Poa sp.*), needlegrass (*Achnatherus sp.*), Indian ricegrass (Nevada's state grass), Idaho fescue (*Festuca idahoensis*) and the Great Basin wildrye (*Leymus cinereus*) (USDA, 2010). Grasslands are located in the lowland valleys adjacent to the mainstem of the Humboldt River. Values averaged 11% throughout the basin and 6% in the delineated sub-watersheds (Figure 16).

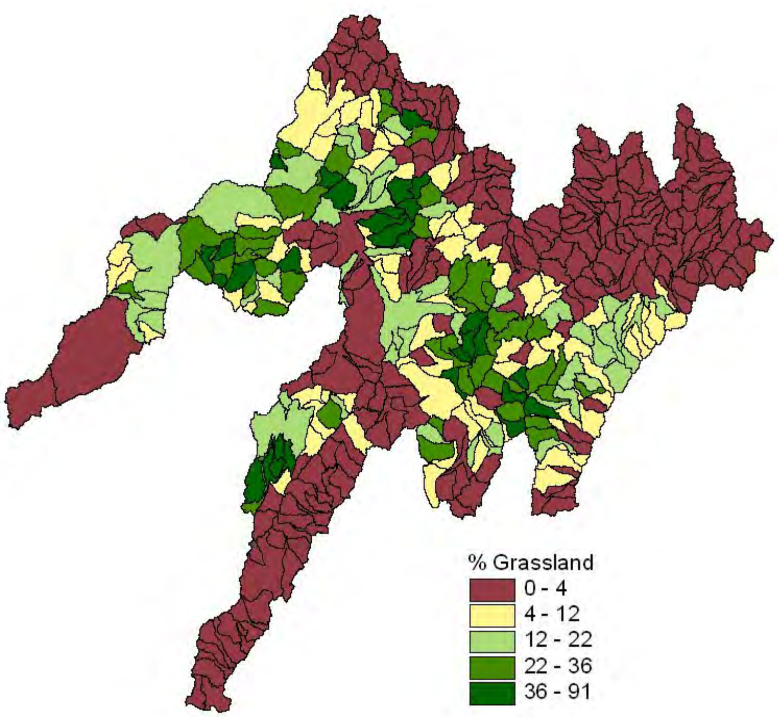

Figure 16. Percent Natural Grasslands in the Humboldt River Basin.

The changing of native grasses to exotic species is a serious problem in Nevada. Halogeton, an herbaceous, toxic annual, arrived in the basin in the early 1900s and is able to survive high salt conditions, out-competing native forage. Cheatgrass, an annual grass which is used for forage, quickly turns the landscape into monocultures, forcing out other more desirable grasses. Cheatgrass is highly flammable, susceptible to the recurrence of wildfires, does not provide adequate habitat for wildlife and threatens sensitive species in the area. Once a fire has burned an area, re-growth is dominated by the early germinating and rapidly growing cheatgrass. This trend has caused many problems in the lowland areas, increasing the severity and frequency of wildfires (Horton, 2000).

4.3 Agriculture

Agriculture in Nevada's semiarid climate is heavily directed to range livestock. Nevada's agriculture is primarily cattle production, and to a lesser degree, sheep ranches. Yet, a variety of other crops can be harvested where the landscape can be irrigated. Beginning with the mining boom, agriculture in Nevada started in Rye Patch Meadow and Lovelock Valley because they were the first and last places with potable water and available forage for many miles**.** Commodities initially consisted largely of vegetables and grains, but later evolved into range livestock production (Bard et al., 1981). By 1913, there were 2,689 farms accounting for over 2 million acres, with livestock grazing reaching most lowland meadows in the Humboldt Basin (True, 1913). But by the beginning of the 1900's water scarcity was already proving to be an issue. Even with the construction of the Rye Patch Dam in the 1930s, water continued to be a restricting factor. With a limited number of water storage facilities, water users, predominantly irrigators, which in 1990 were estimated to be responsible for 75% of the water use in the basin, are dependant on surface water flow.

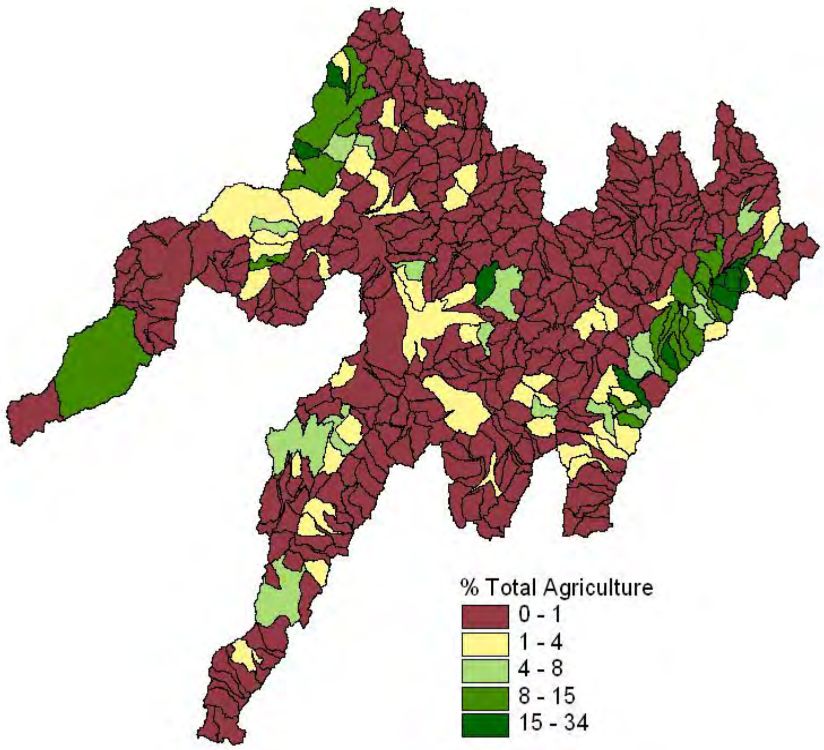

Figure 17. Percent Total Agriculture in the Humboldt River Basin.

With irrigated land comes a myriad of potential negative environmental impacts. In 2000, it was reported that agricultural nonpoint source pollution was the leading cause of water quality impacts on surveyed lakes and rivers in the United States. Irrigated runoff water may contain fertilizers and pesticides, which can contaminate water bodies, poison fish, and cause algal blooms, which deplete oxygen. Irrigation water also can erode stream banks, washing soil off fields and into water, increasing turbidity, and decreasing critical sunlight for aquatic plants. A problem endemic to arid regions is the increase of soil salinity from evaporation due to the inability of the soil to filter minerals (USEPA, 2005).

The Humboldt River Basin is located in 8 counties: Churchill, Elko, Eureka, Humboldt, Lander, Nye, Pershing and White Pine counties. Forage and pastures (native grasses), grains (wheat, oats and barley), and alfalfa (hay) are the largest commodities in the region (NDA, 2009). Alfalfa is the leading crop in the basin, much sold to dairy ranches. Other crops may consist of root crops or vegetables, such as potatoes and onions (NDA, 2009). Higher elevation pastures consist of cultivated grasses such as June grass (*Koeleria sp*), while in the lowlands, wild grasses reign. June grass is not planted, but instead sprouts up where alfalfa fields have been over-watered. The dry climate and soil type affect the type of agricultural commodities available to be harvested.

Total agriculture (includes row crops and pastures) averages 1.7% across the entire basin with less than 1% in the individual watersheds (Figure 17). This relatively low percent could be, in part, due to the large amount of area used for open range grazing, thus represented by grasslands/shrublands. The largest agricultural areas are located in the lowland valleys in the southeast portion of the basin near the Rye Patch Reservoir, the areas surrounding the town of Wells in the east, and in Humboldt County in the northwest.

4.4 Grazing

With agriculture directed primarily toward livestock, overgrazing has become problematic. Open range livestock grazing has spread since the 1800s throughout Nevada State reaching virtually every lowland meadow and upland watershed. Livestock grazing can affect many aspects of riparian areas through erosion, sedimentation, and water quality, in turn affecting aquatic life downstream. Soil quality is changed by severe trampling and compaction, causing increased erosion and limiting sustainability of plants (Figure 18). This can make streams wider and more shallow, and can increase suspended sediment concentrations (Bengeyfield, 2007).

Figure 18. Evidence of Soil Trampling.

Grazing can also change vegetative structure with the potential to introduce exotic species (USDA et al., 2009). As mentioned previously, halogeton, a toxic annual, has become a problem in the basin in that it out competes native grasses. Programs have been established to convert acres of halogeton species to other wheatgrass seedling, but it has been found that most rangeland improvements have resulted from reducing the amount of grazing and changing the timing of foraging (Young & Clements, 2006, USDA et al., 2009). High shrubland cover may also be attributed to overgrazing. For example, the big sagebrush, was not foraged because of its high oil content, and overgrazing of grasses did not allow for seed production and re-growth. As grasses decreased, and shrubland cover expanded (Young & Sparks, 2002).

Grazing allotments in the Humboldt River Basin are managed by the BLM, US Fish and Wildlife (USFWS), National Park Service (NPS) and USFS. Animal-unit-months (AUM) can illustrate the amount of use of a particular allotment. An AUM is the amount of forage needed by an animal unit (AU) for a month. This is calculated by dividing the number of days livestock are on an allotment by 30. That number is then multiplied by the number of livestock (sheep, cattle or horse). Then, that number is multiplied by the AUs. The AUs listed below were decided upon by the BLM jointly with the USFS while consolidating Nevada State's allotment database (Resource Concepts, 2001).

Animal Units:

- Mature Cow = 1
- Cow/Calf = 1.32
- Ewe w/Lamb = 0.3
- Dry Ewe = 0.2
- Horse = 1.2
- Bull = 1.5
- Yearling Bovine = 0.7

From the BLM's GIS shapefile and the United States Department of Agriculture's (USDA) allotment database, the allotment numbers were matched and AUMs inserted to achieve the following map. The USFS, private and non-BLM allotments did not have identifying numbers or AUMs thus were not transferred to the shapefile, and were classified as no data. Only one third of all Federal lands have been compiled for grazing statistics for Nevada with most BLM land and selected USFS lands completed. Allotments with multiple sections were merged together so AUMs were distributed to all. The allotments with the greatest AUM densities were in the north and eastern portions of the basin, while the allotments with the smallest number of AUMs were in the agricultural areas near Lovelock Valley and Winnemucca in the west (Figure 19).

Areas with higher densities are more susceptible to loss of ecosystem function (Figure 18). This could be especially true if ecosystem stresses are combined during the same time period such as fire, climate change, or increases in agriculture. The determination of how many animals the land will support is very important to a properly functioning condition. Currently it is determined by knowing the particular animal's forage requirement and how much forage the land has available. Knowing the types, combinations, and locations of ecosystem stress can help land managers and producers adapt management practices to best suite the needs of the ecosystem and the animal. In the future, landscape indicators for grazing such as presented here can be used with the other traditional methods to determine stocking rates for best production and to consider ecosystem function.

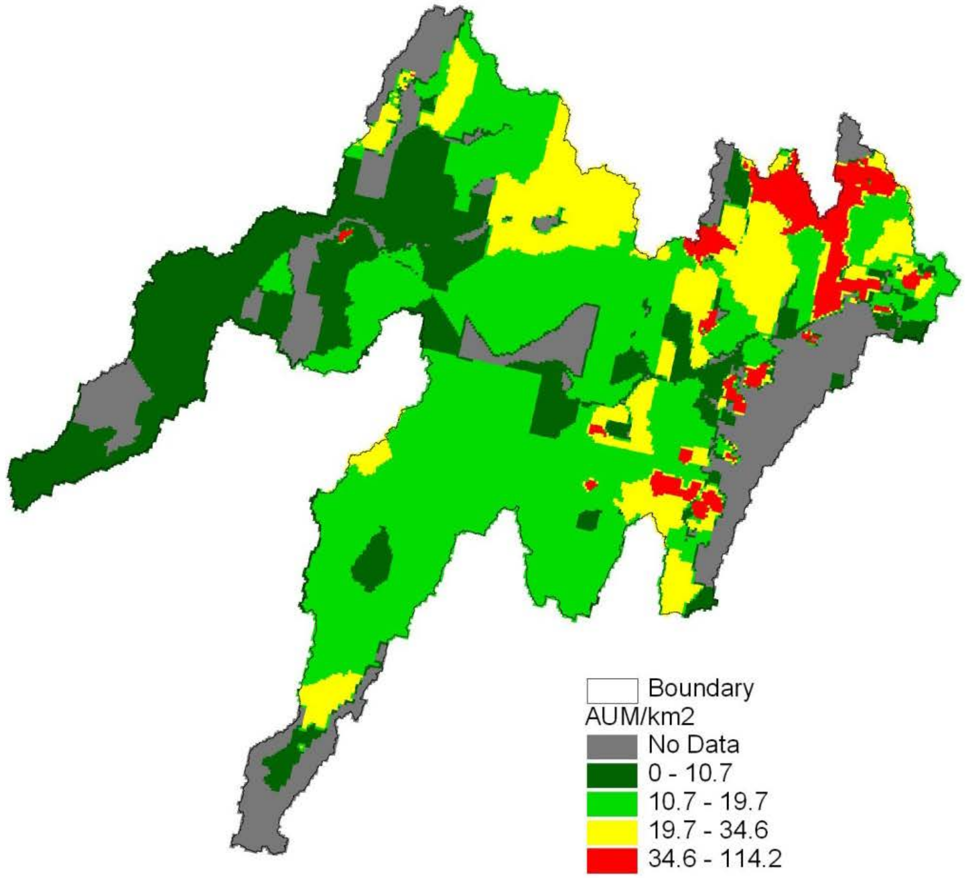

Figure 19. AUM Values Per Square Kilometer in the Humboldt River Basin.

4.5 Population Growth and Urban Development

According to the U.S. Census Bureau, in 2000, the population of the Humboldt River Basin was about 65,000 people covering an area of 43,000 km^2 (17,000 mi^2) resulting in an average population density of about 1.5 people per square kilometer (ESRI, 2010). Urban development which consists mostly of agriculture (row crops and pasture) and to a lesser extent, urban areas (towns and roads) averages 0.6% throughout the HUCs and minimal presence in the delineated sub-watersheds (Figure 20). Higher concentrations are located in the residential areas around Lovelock Valley, Winnemucca and Battle Mountain in the west, and Wells, Elko and Carlin (located due east of Elko) in the eastern portion of the basin.

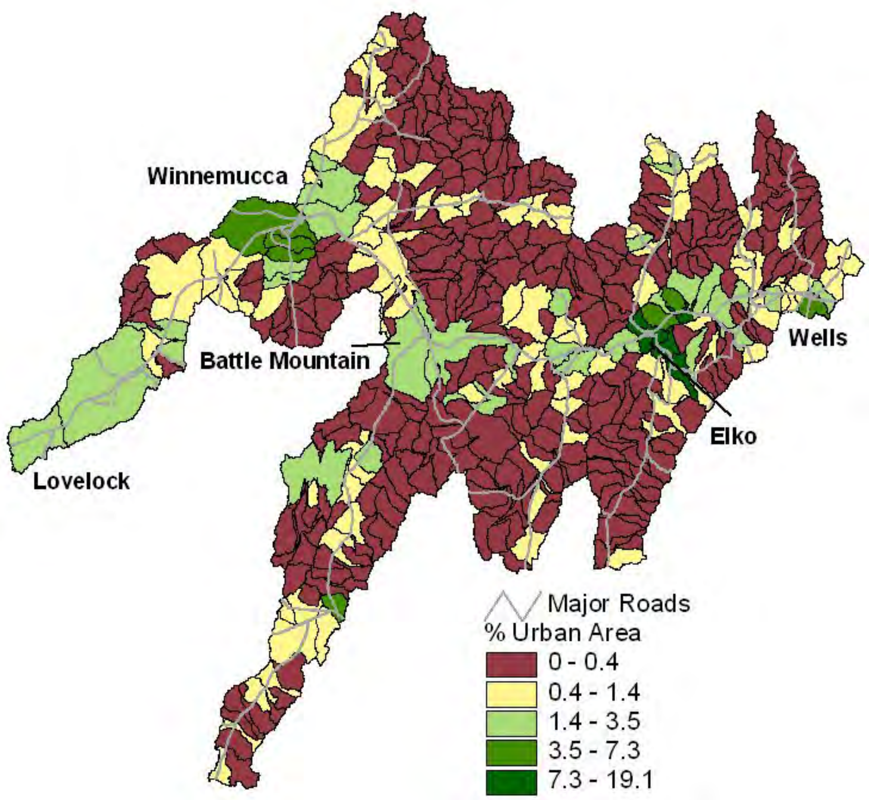

Figure 20. Percent Urban Areas in Humboldt River Basin.

From 1980 to 2000, populations in the major cities more than doubled (Table 2). The greatest increases revolved around the cities of Elko, Winnemucca, and Spring Creek, a community of the nearby city of Elko (Figure 21). The greatest factor in population increases is the gold mining opportunities in the surrounding areas. Although gold prices have fluctuated greatly, the areas in and around Elko have remained economically stable even when the rest of the country have faced recession. Along with mining jobs, come other small companies associated with mining such as metal fabrication and steel recycling, as well as community based employment.

Table 2. Major Population Areas in the Humboldt Basin from 1980-2000.

Place	County	1980	1990	2000
Battle Mountain	Lander	2,749	3,542	2,871
Carlin city	Elko	1,232	2,220	2,161
Elko city	Elko	8,758	14,736	16,708
Lovelock city	Pershing	1,680	2,069	2,003
Spring Creek CDP	Elko	--	5,866	10,548
Wells city	Elko	1,218	1,256	1,346
Winnemucca city	Humboldt	4,140	6,134	7,174
Sum		**19,777**	**37,813**	**44,811**

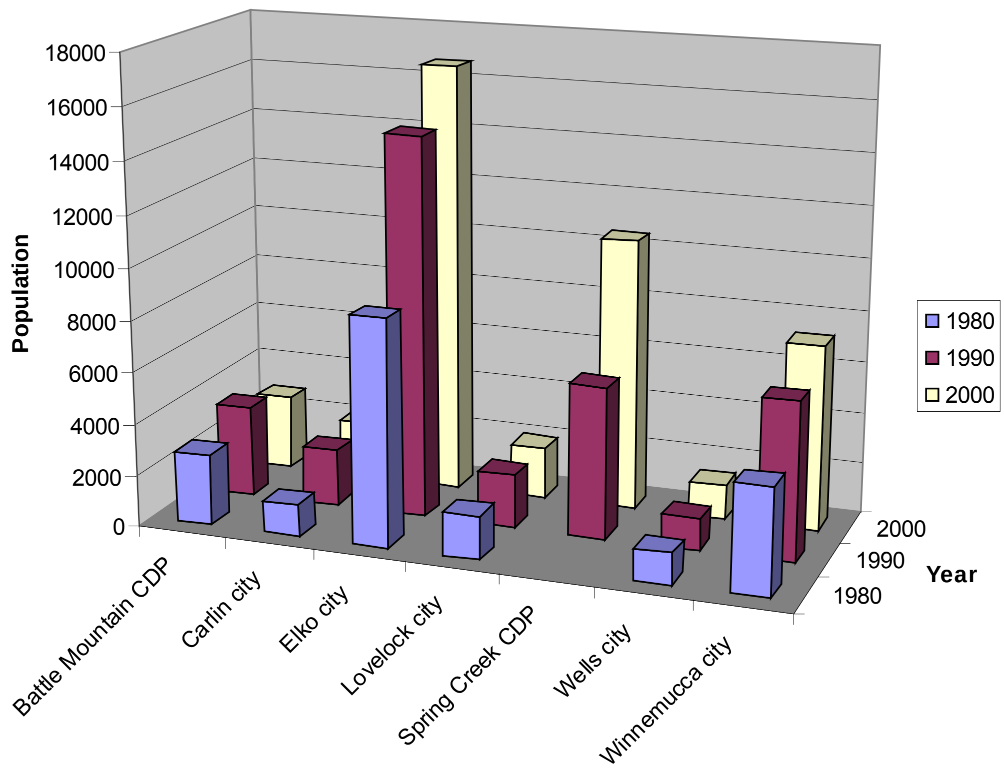

Figure 21. Population Change in the Humboldt River Basin.

4.6 Roads

Roads are necessary to join people with each other, recreational sites and other necessities. Yet, the network of roads with the associated traffic can result in environmental degradation. Roadways can change the adjacent natural habitat by impairment of species migration, be a source of pollution from runoff of vehicle-related chemicals, facilitate spread of exotic species, alter streams by sediment deposition from erosion, and change the stream hydrology by changing timing and routing of runoff (Transportation Research Board, 2002). Road density and the number of roads crossing streams are important landscape indicators to include in environmental assessments. This study calculated road metrics from 1:100,000 USGS Digital Land Graph data (U.S. Census Bureau, 2009).

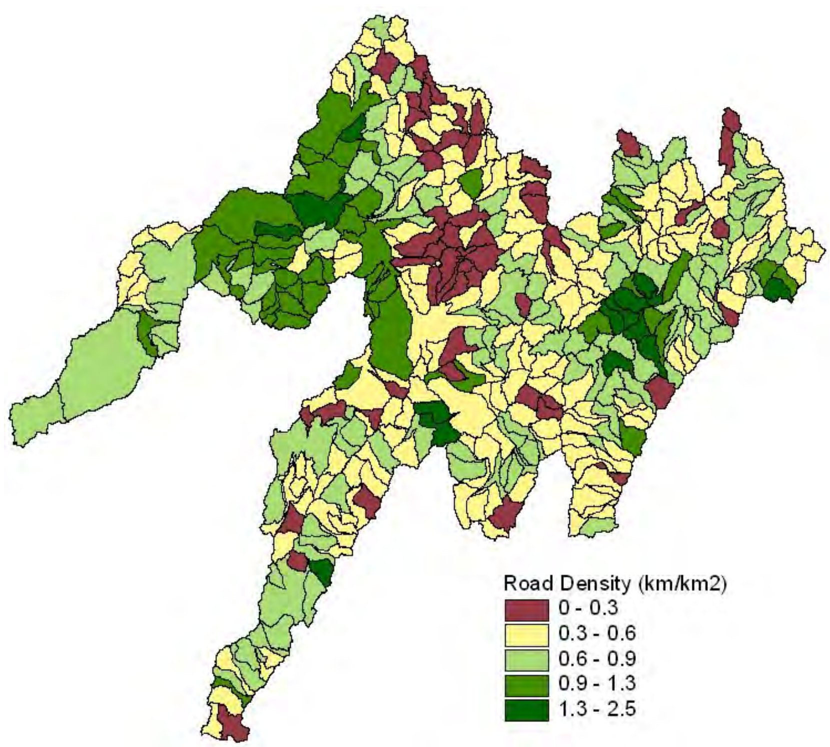

Figure 22. Road Density in the Humboldt River Basin.

According to the road map used in this study, which includes all types of roads (highways, country roads and city streets) there is a total of 31,100 km of roads in the Humboldt River Basin averaging 0.5 km per person. Road density is minimal with the highest road density in the basin located in the residential areas of Elko (Figure 22). In the individual delineated sub-watersheds, road density had less of a presence with the highest density (1.3 km/km^2) in Spaulding (site 35), south of the town of Winnemucca. Interstate Highway 80 is the primary connector, traveling east-west through the basin following the contours of the Humboldt River.

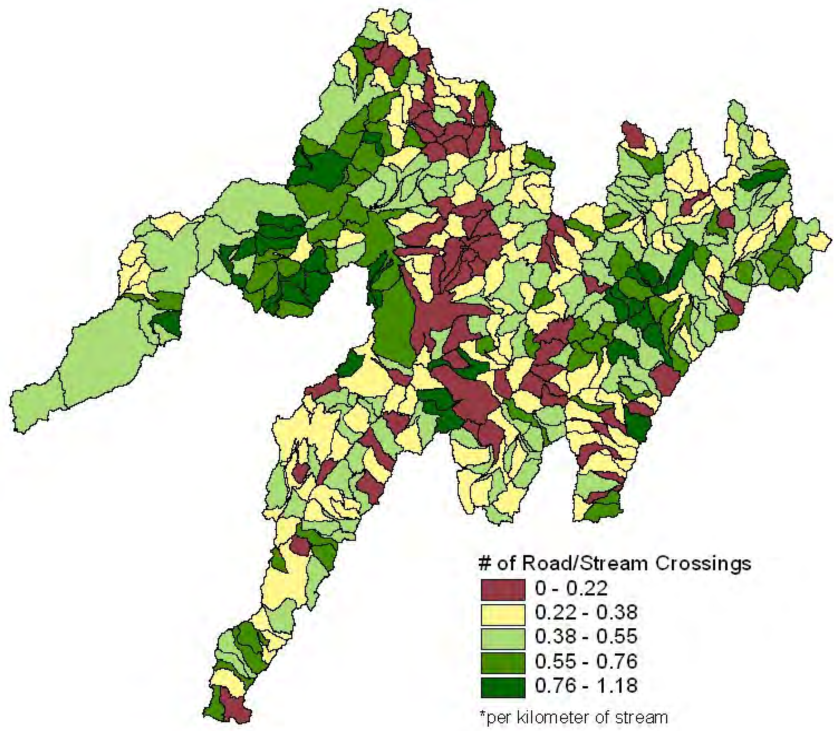

Figure 23. Number of Road/stream Crossings Per Kilometer of Stream.

The density of roads crossing streams is relatively low with a range between 0.0 and 1.2 crossings per kilometer of stream and an average of 0.4. Only five HUCs have stream crossing densities greater than one, including three watersheds located around the town of Elko (Figure 23). Only one watershed, located in the center of the basin directly above the Humboldt River, has a road/stream crossing density of zero, having no roads within its border. In the delineated sub-watersheds, road/stream crossing density values ranged between 0.0 and 1.9 crossings per kilometer (site 37) with an average of 0.4.

4.7 Mining

Mining is a valuable human land use that began in Nevada with silver in the late 1800s. In the early 1900s, gold had been discovered and continues today making Nevada one of the largest gold producer globally. The Carlin Trend, an 80-by-8 km (50-by-5 mi) belt within the Humboldt Basin, accounts for much of the mined gold. As of 2006, there were 74 hardrock mines of which 69 were gold or gold and silver mines of which all used cyanide leaching and are primarily open pit.

Open pit mines, which can be a two-thousand feet deep, may be below the water table. Mine dewatering is then necessary to remove groundwater in order to facilitate mining activities. Pumped waters are often discharged to surface receiving water creating the potential for chemical and/or thermal pollution which is monitored by state and federal agencies. Additionally, the groundwater resources being depleted are drawing down the water table creating a temporary increase in flow, currently being used for irrigation, but with the possibility of reducing baseflow in streams and springs. The potential for the creation of contaminated pit lakes in the empty areas the groundwater once occupied, and the ecosystems that the high water flow once supported have caused concern (Solnit, 2001). Research about acid mine drainage from abandoned mines has also been conducted. Runoff may contain elevated concentrations of inorganic contaminants which would then result in discharge of acidic metal-laden waters. Selenium drainage into the sink has already occurred, changing conditions for the Lahontan cutthroat trout (Glennon, 2002; Gray, 2003). Cyanide plumes have been detected from tailings seepage and contaminations of groundwater have been observed for toxic materials such as arsenic, mercury, and manganese. Increased sedimentation due to surface disturbance can cause increases in dissolved solids (Kuipers et al, 2006).

Although most potential mine runoff would not directly flow to mainstream waters, specifically because of the lack of rain in the region, the presence of mines and mine waste can still affect the surrounding area. (Gray, 2003, Earman and Hershey, 2004). In the case of the Rain Gold Mine near Elko, acid mine drainage has been a problem since 1990 from waste rock piles, contaminating 2 miles of Dixie Creek (Site 69) with elevated levels of mercury and arsenic (Earthworks, 2004). When gold ore is mined, sulfur is typically contained, which when exposed to air or water forms sulfuric acid. This acid draws out other metals such as arsenic, antimony, lead and mercury. (Solnit, 2001, Earman and Hershey, 2004). A more likely interaction of mine activities to surface waters is historic mill tailings, or spent ore. Since most tailings were placed in lowlands, rain activities can carry acids and metals a short distance before being stopped by the natural geology and soils. Through evaporation, small ephemeral ponds can be created which can hold high concentrations of metals (Nash, 2003).

Using 2005 mine data created by USGS, a one kilometer diameter buffer was created around each mine to represent the relative affect of each mine. One kilometer was determined by comparing satellite imagery to land cover data to determine the extent of the mine's anthropological influence. Past producing gold mines, currently producing gold mines and processing plants have been included (Figure 24).

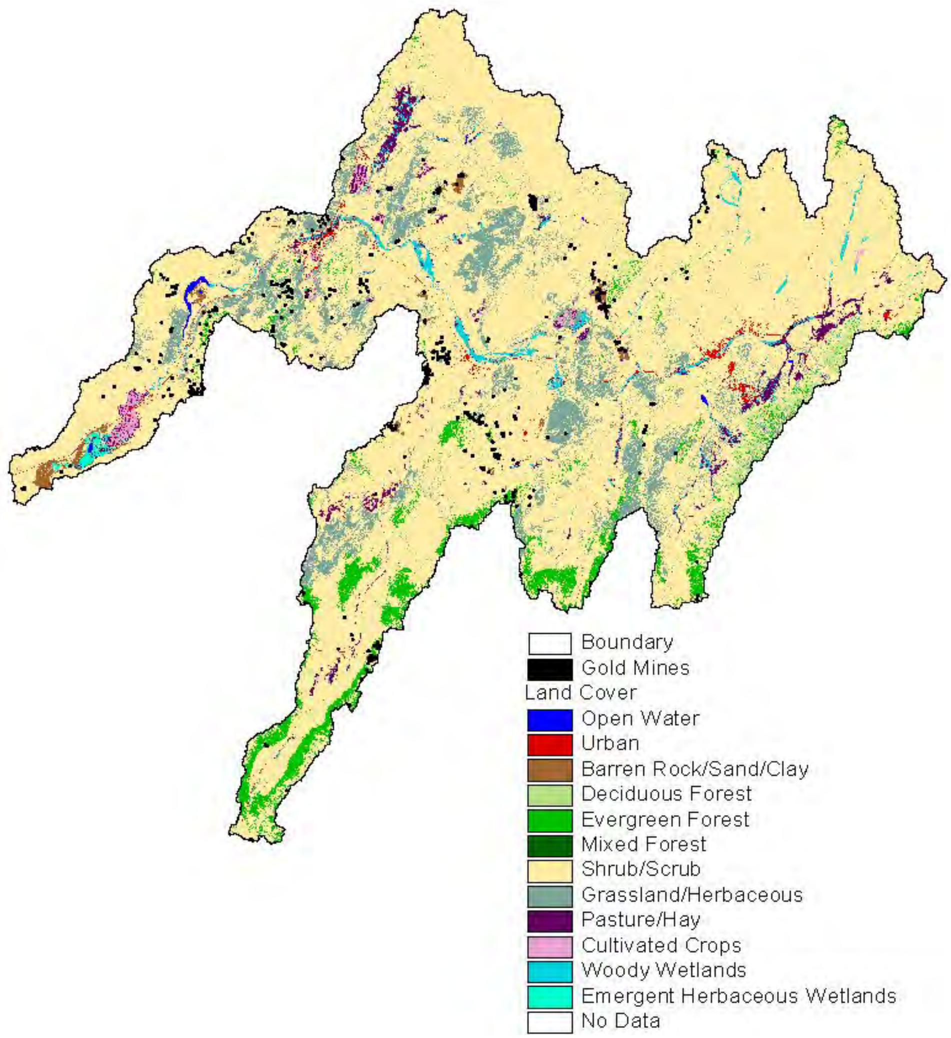

Figure 24. Humboldt Land Cover Including Mine with 1km Buffer.

Trends related to mining and water quality can be observed in the nested sites of the Reese River. Site 280 is the most upstream watershed that is nested within watershed 4 which is then within watershed 3 and so on up to watershed 196 (Figure 25). As seen in Table 3, pH, chloride (Cl) and sulfate (SO_4) increased downstream while IBI decreased. Many other variables had overall increases, but had their highest values at site 6 and 96, with a drastic decrease at 196, such as for Total Dissolved Solids (TDS), Total Kjeldahl Nitrogen (TKN), lead in sediment (Pb-S), mercury in sediment (Hg-S), arsenic in sediment (As-S), nickel in sediment (Ni-S) and arsenic in water (As-W). Dissolved Oxygen (DO) decreased slowly until site 6, which had the lowest sampled value in the basin at 2.4 mg/L.

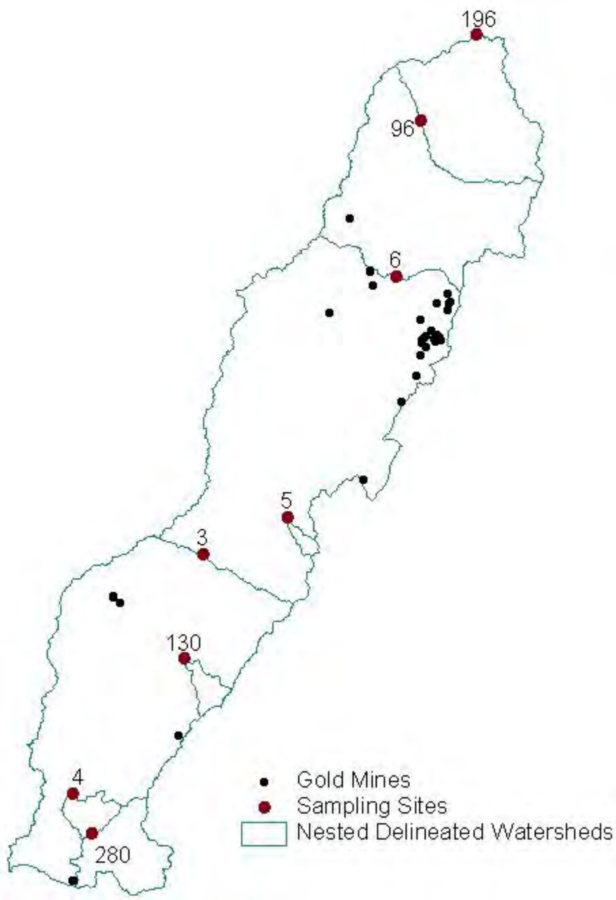

Figure 25. Nested Sites in the Reese River with Past and Present Gold Mines and Processing Plants.

Table 3. Water Quality and Metal Data for Nested Sites within the Reese River Area.

Site	Au Mines	DO	pH	TDS	TKN	Cl	SO_4	IBI	As-W	As-S	Hg-S	Ni-S	Pb-S
280	0	8.4	7.4	61	0.12	--	--	92	0	11.3	--	12.7	3.1
4	0	6.9	7.7	80	0.12	1.4	2.3	68	1.8	2.2	0.16	4.1	5.2
3	6	5.6	8.1	212	0.40	5.9	13.4	38	7.8	4.1	0.14	1.3	8.8
6	32	2.4	8.1	708	0.66	58.3	128	10	--	27.6	1.40	15.2	52.7
96	33	11.3	8.4	1010	1.20	114	259	28	75	13.0	0.08	20.0	12.0
196	33	10.5	8.9	549	0.27	--	--	18	37.6	9.3	--	16.8	1.0

*S= Sediment. W=Water. Hg only sampled in 1998.

The pH, which measures of acididity or basicity of water, does not appear to be affected by mine drainage which typically decreases with an increase of mining discharge. Acidic compounds such as ferric iron runoff affects the alkalinity of water, producing more acidity and lowering the pH. In the case of the Reese River, pH increases slightly as water flows downstream.

Site 6 appears to be the most affected by all variables. With the lowest IBI and DO and some of the highest values for TKN, SO_4, Arsenic, mercury and lead, this watershed is being disturbed. Twenty six mines are directly in this watershed, with most nearby the sampling site.

Examining the relationships between past and present gold mines and water quality and metal indicators in the basin, a number of correlations were found. Although correlations do not imply cause and effect relationships, they can provide insight into the ecological processes at work. Significant correlations are termed weak, moderate, or strong where $r < 0.50$, $0.50 < r < 0.75$, and $r > 0.75$, respectively.

Overall, there were positive correlations for all relationships, with the exception of a weak negative correlation between past gold mines and IBI (Table 4). There was only one moderate correlation which was between present gold mines and mercury (1998 sampling season only).

Table 4. R Values of Significant Correlations ($P<0.05$) Between Past and Present Gold Mines and Ecological Indicators.

	Past Gold Mines	Present Gold Mines
Aluminum (sediment)	0.34	
Arsenic (sediment)		0.30
Mg (sediment)	0.43	0.39
Mercury (sediment)*		0.63
DO	0.39	0.32
TKN		0.32
TDS	0.42	
IBI	-0.32	

*1998 sampling season only

4.8 Riparian Land Cover/Use

Riparian buffers, areas connected to or adjacent to a stream bank or other body of water, are complex ecosystems connecting the landscape to the stream system. These zones act as traps, filtering sediments and nutrients, slowing water flow and providing stable stream banks, and improving water quality. Riparian buffers along stream banks can affect water quality through amount and type of cover, which can determine soil loss and sediment movement. Characterization of these conditions can identify areas in need of improvements. Vegetation moderates temperature and provides habitat and is a source of nutrients for wildlife. Buffers are most effective when they constitute native grasses and deep rooted trees and shrubs. Lack of necessary vegetation can result in increased erosion, reduction of water storage capacity, and a decrease in water quality (Snyder et al., 2003).

Buffer distances of 30 and 90 meters on both sides of the streams are used to calculate land cover metrics. The relative amount of land cover/use in a 30 meter riparian buffer (each side of streams) within the Humboldt River Basin can be seen in Figure 26. Looking at the entire basin, riparian land cover/use is similar to the total watershed assessment. Percent wetlands, natural grasslands and agriculture have a slightly higher proportion in the riparian buffer area. Shrublands and forests were slightly lower. The range of human use, not including mines, within the 30 meter buffer is between 0.0% and 41.6% and an average of 3.5%, with agriculture land use accounting for close to 97% of that amount. The descriptive statistics for total watershed assessment, as well as 30 m and 90 m riparian buffer are displayed in Appendix 4.

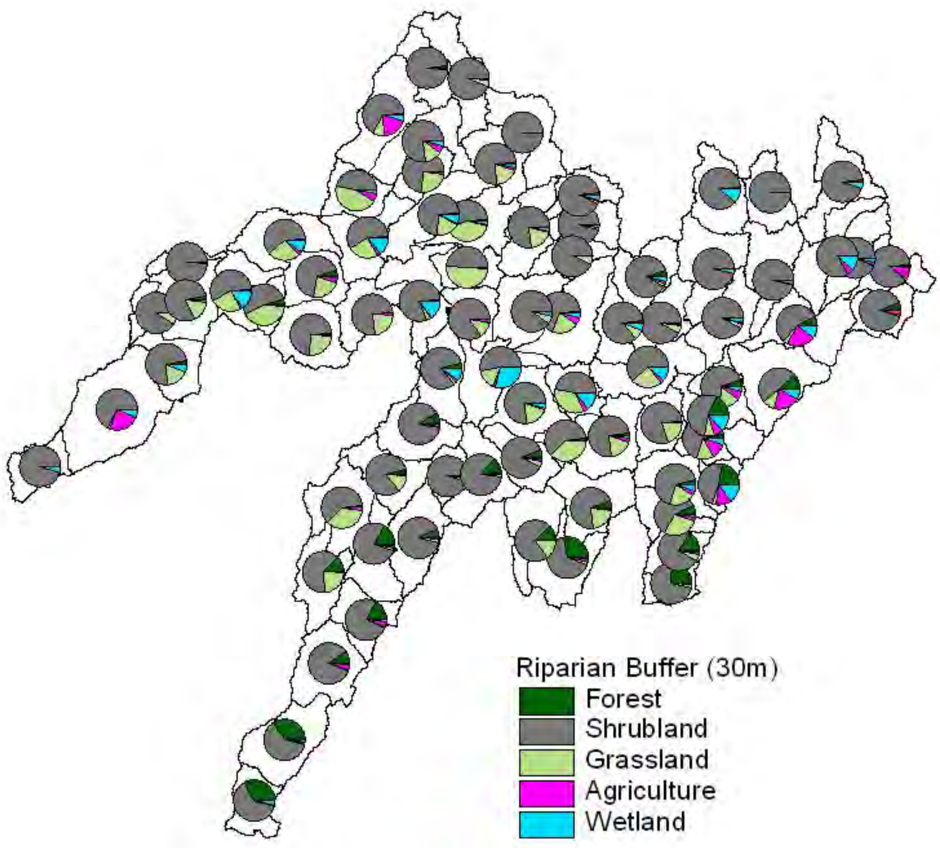

Figure 26. Percentage of Riparian Buffer in Forest, Shrubland, Grassland, Agriculture and Wetland Calculated within a 30m Buffer.

5.0 Land Cover Comparison

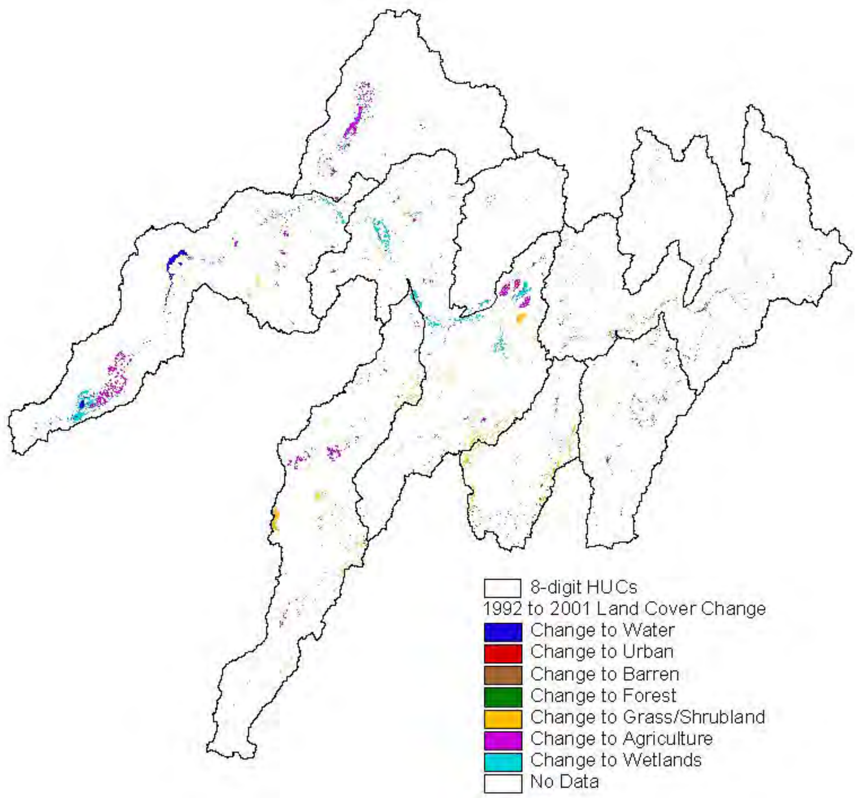

Figure 27. Retro Fit Land Cover Change.

Over time, the landscape is changed from one cover type to another by natural changes, such as fires and flooding, and anthropogenic mechanisms, including urbanization, logging and farming.

The MRLC's NLCD 1992/2001 Retrofit Land Cover Change Product was developed to be an accurate analysis between the 1992 and 2001 land cover years. Because of new mapping technologies, new input data and mapping legend changes, direct pixel comparison between the two years would not exact. This retrofit product was used to analyze changes in the landscape in the Humboldt River Basin (Figure 27). Increases in agriculture in Lovelock and Winnemucca are apparent as well as increases in wetlands along the mainstem of the Humboldt River, due primarily to restoration efforts. Other changes include increases in forest, specifically in the Pine watershed. This area includes the Wilderness Study Area in Robert's Mountains, created in 1980 and encompassing 15,000 acres of land under the Federal Land Policy and Management Act, which states that study areas must be managed to maintain wilderness suitability or not cause undue degradation. In addition to changes in land use, there may be another contributing factor for the increase in forest cover. Vegetation in this region requires high moisture for seed establishment. In the mid 1980s, there were months with above average precipitation, which would help re-vegetate.

Since the Retrofit NLCD combines grass and shrubland, a visual comparison was made between the 1992 and 2001 NLCDs in the Humboldt Basin to observe changes. In five of the 8-digit HUCs, there was a decrease in shrubland and forest cover, while large grassland increases evident. According to the Desert Research Institute (DRI), wildfires devastated Nevada in 1999, with the majority occurring in the Humboldt Basin. The 1999 wildfire season ranked first in regard to acres burned and second in the number of total fires (Brown & Hall, 2000). With the invasion of cheatgrass, natural re-vegetation of burned areas is being overtaken by this exotic species. Looking at the land cover overlaid with the fire boundaries as seen in Figure 28, grassland increases have occurred in all burned areas.

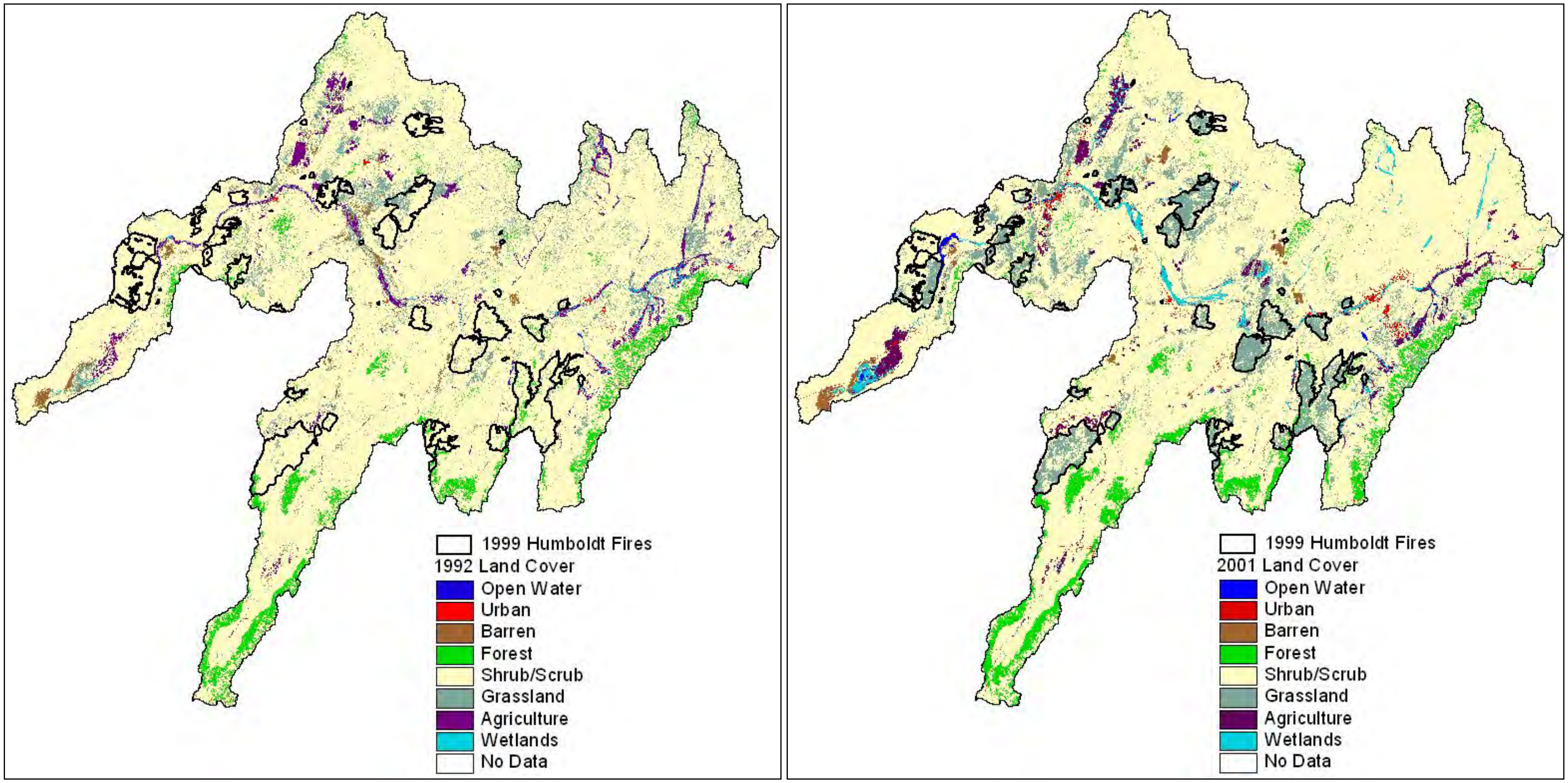

Figure 28. National Land Cover Dataset for 1992 and 2001 Showing the Burn Locations for the 1999 Fire Season.

6.0 Soil Cover

The automated GIS Watershed Analysis Tool was used for soil erosion modeling. This program computes soil erosion and sediment delivery metrics based on the Revised Universal Soil Loss Equation (RUSLE) soil erosion framework and the Spatially Explicit Delivery Model (SEDMOD) sedimentation framework. Rainfall derived erosivity (R), soil surface cover characteristics (C), soil surface erodibility (K), slope length and steepness (LS), and soil management practices (P) are multiplied to reach the gross erosion rate (A) for each of the Humboldt's 45 delineated watersheds. Complete data can be found in Appendix 5.

6.1 R Factor

The R factor, which represents rainfall-runoff erosivity, is a measure of the erosion force of a rainfall event at particular locations with the final value quantifying the amount of runoff, as well as the intensity of the raindrops' effect. A cumulative summation of a normal year's rain is used to determine this index. Greater R factors can identify areas with greater potential for erosion.

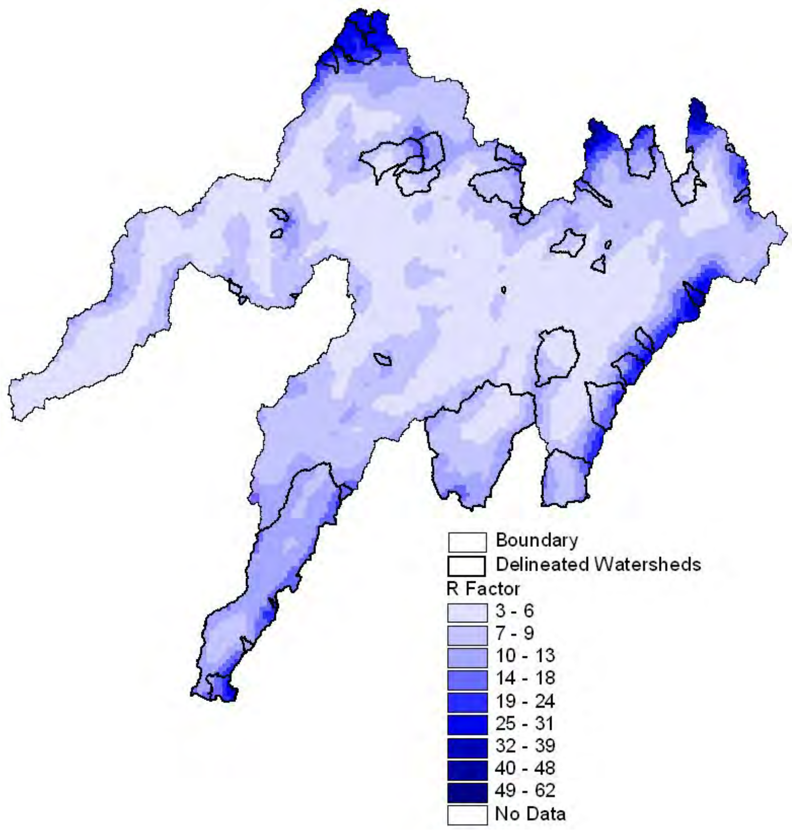

Figure 29. Rainfall Erosivity in the Humboldt River Basin.

In the entire Humboldt Basin, R factors ranged from 3 to 62 with the majority of values less than ten, while in the individual delineated watersheds, R factor values ranged between 6 and 30. The areas with the greatest potential for rainfall erosion are located in the Ruby, Independence, Jarbidge and Santa Rosa mountain ranges (Figure 29). For comparison, average R factors throughout the continental United States vary from less than one hundred in the arid Great Basin to a couple hundred along the pacific coast, and up to 700 in the gulf coast (Troeh, 2005) (Figure 30).

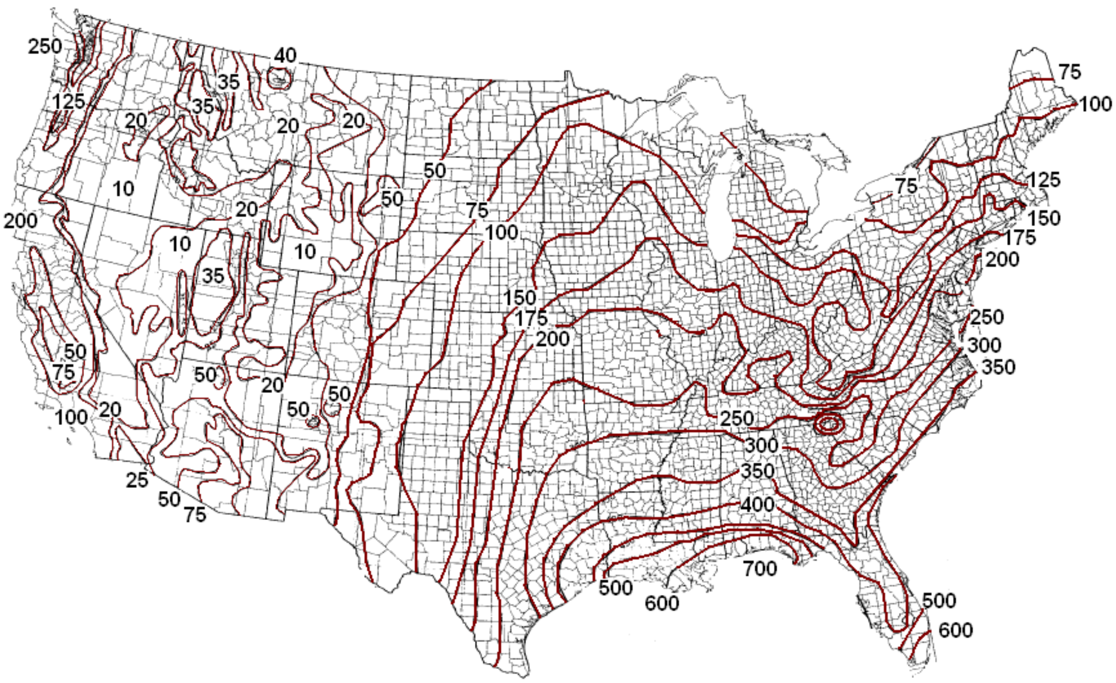

Figure 30. Average Rainfall Erosivity (R Factor) for the Continental United States (Troeh, 2005).

6.2 C Factor

The C factor, or cover management factor, reflects the effect of cropping and management practices on erosion rates (Figure 31). Simply, the C Factor indicates how conservation plans, such as changes in plant and soil cover and biomass will affect soil loss. For example, for most of the basin, values are less than 0.16. This signifies that erosion will be reduced up to 16% compared to the amount that would have occurred naturally (ARS, 2010). This is an important variable because it represents how conservation changes can reduce erosion. To calculate this factor, RUSLE uses sub-factors canopy, surface cover, surface roughness and prior land use to compute a soil loss ratio. The C factor is an averaged soil loss ratio weighted by R factor distribution. In the delineated watersheds, values were very low ranging from 0.06 to 0.20 with an average of 0.09.

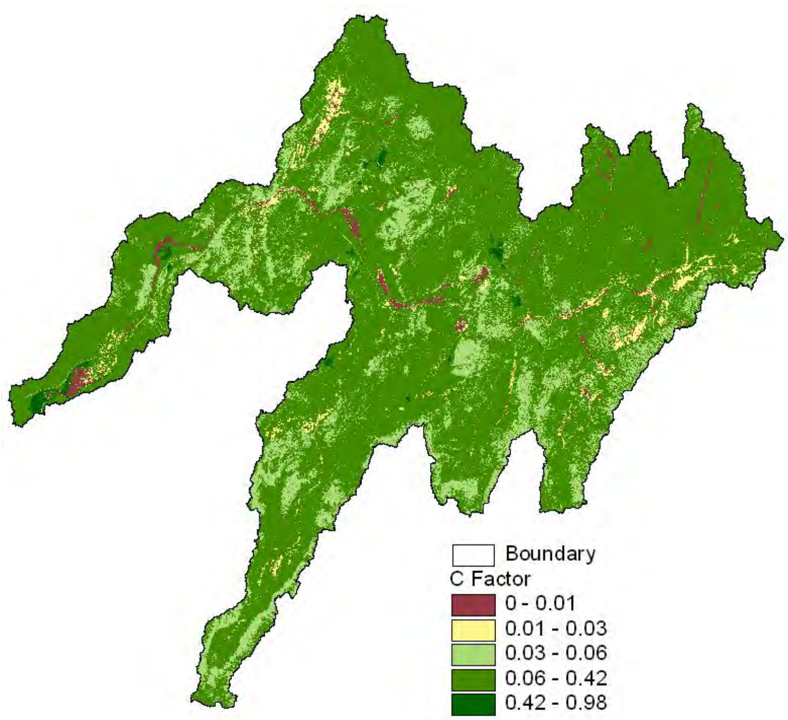

Figure 31. C Factor Values for the Humboldt River Basin.

6.3 K Factor

Soil erosion is an environmental variable that can have profound effects on and off site. With grazing a key factor of erosion through the trampling of stream banks, increased sedimentation can be an affect. Mining operations may dump large amounts of sediment directly into streams. An excess of sediment can change the quality of the water affecting aquatic life and beneficial uses downstream. Large amounts of sediment reduce capacity and increases flood damage (Julien, 1998).

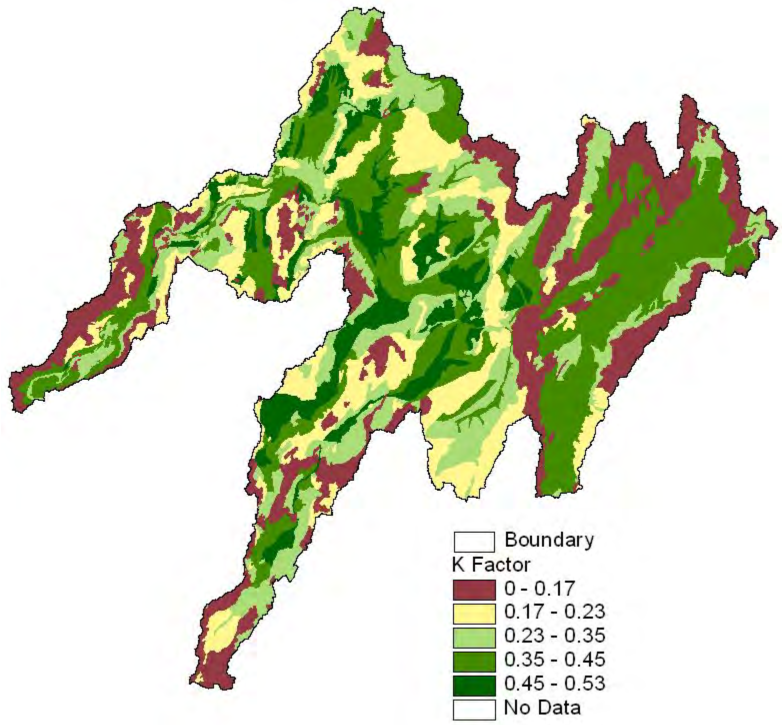

Figure 32. K Factor Values in the Humboldt River Basin.

Surface soil erosion can also affect soil productivity and ecosystem function. Since nutrients and organic matter are typically most dense in the surface soil layer, erosion washes away the most productive layer. Soil erodibility, expressed here as the K factor, evaluates the potential for erosion using the Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) database soil data. The K factor represents the combination of soil type and detachability, as well as transportability of the eroded sediment. Table 5 describes the general relative distribution of K Factor values.

Table 5. General Distribution of K Factor values.

K Factor	Definition
0-0.15	Fine textured soils high in clay, resistant to detachment
0.05-0.2	Coarse textured soils which may be high in sand, low runoff
0.25-0.4	Moderately susceptible to detachment, moderate runoff
>0.4	High silt content, susceptible to detachment, high runoff rates, higher erodibility

In the Humboldt Basin, potential soil erodibility ranged from 0.00-0.56, and an average of 0.29 while the delineated sub-watersheds have values between 0.12 and 0.35 (Figure 32). The areas with the highest erodibility are in the valley floors near streams, coinciding with areas that are traditionally used for grazing and agriculture. Figure 33 displays the surface soil types for the basin summarized by user defined classes. For the list of defined classes, see Appendix 6.

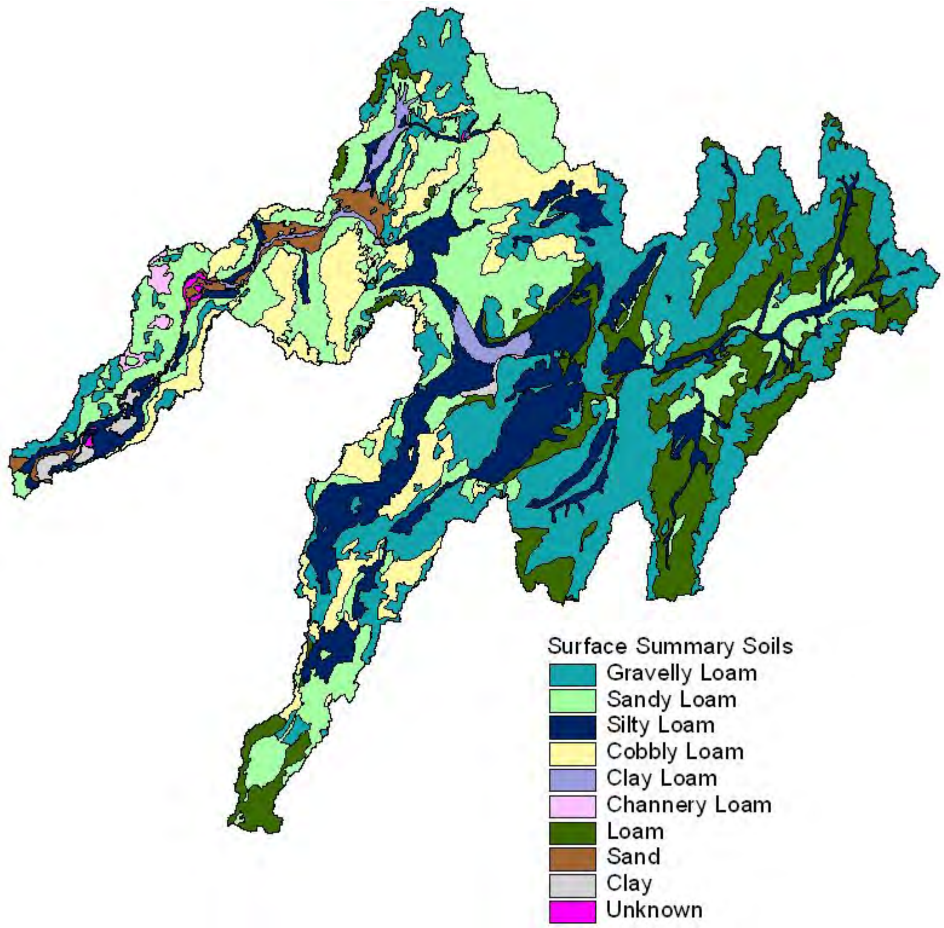

Figure 33. Map of Surface Layers in the Humboldt River Basin.

6.4 P Factor

The P factor, computed as the ratio of soil loss, represents how management practices on surface conditions connected with upslope and downslope tillage affect erosion by modifying flow factors. Practices may include vegetation erosion management, contour farming, terracing, subsurface drainage or strip cropping. These practices affect erosion by directing runoff and increasing or decreasing erosivity.

Factors included in the P factor involve runoff rate, management practices, and transport capacity affected by slope and roughness of the surface. Practices that do little to reduce soil erosion have numbers nearing 1.0 (Renard et al., 1997). In the Humboldt River Basin, the P Factor for all delineated watersheds is 1.0.

6.5 LS Factor

The LS factor consists of slope length, which is the distance of flow along its path, and steepness, which represents the effect of the slope gradient of erosion (Van Remortel et al., 2005). The LS factor examines the steepness of the slope, the susceptibility of soil to erode and the relationship between slope and length. As slope length increases, runoff accumulates and detachment potential and transport capacities increase, thus a considerable increase in soil loss. An LS value of 1.0 is equal to a 9% slope steepness for a 72.6 ft (22.1 m) unit plot. The values are also determined by erosion susceptibility. Examples of the tables used to determine the LS factor, based on land use practices and land type, can be found in Renard et al, 1997.

Overall values were relatively low with values ranging from 2.3 to 17.5 in the delineated watersheds. Because of the detailed resolution of the data, an entire basin map is not appropriate. Figure 34 displays the North Fork Humboldt area for LS values.

6.6 A Value

The A value computes the gross soil erosion per unit area using the formula: A=R*C*K*LS*P. Values range depending on rainfall, soil type, slope, and conservation practices in the specific locations. As seen in Figure 35, overall values in the west are lowest in Nevada and North Dakota and highest along the coast of California, Oregon and Washington. In the Humboldt Basin, values averaged from 476 to 15,818 kg/ha/y in the delineated sub-watersheds with the highest value located in North Fork Little Humboldt River (site 269).

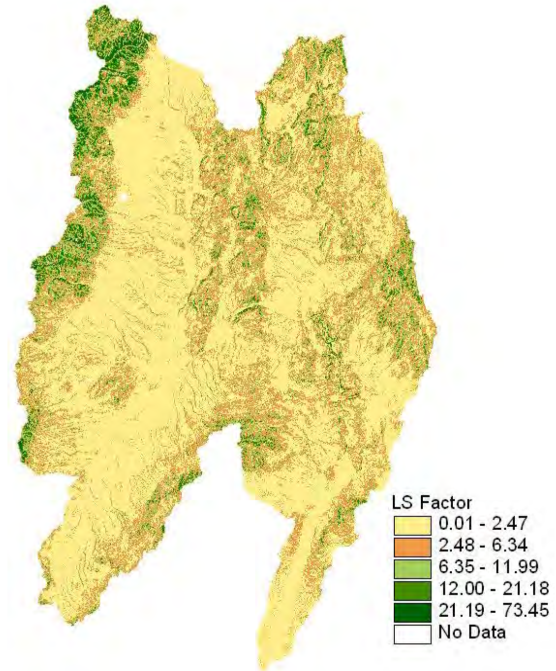

Figure 34. LS Values for the North Fork Humboldt Area.

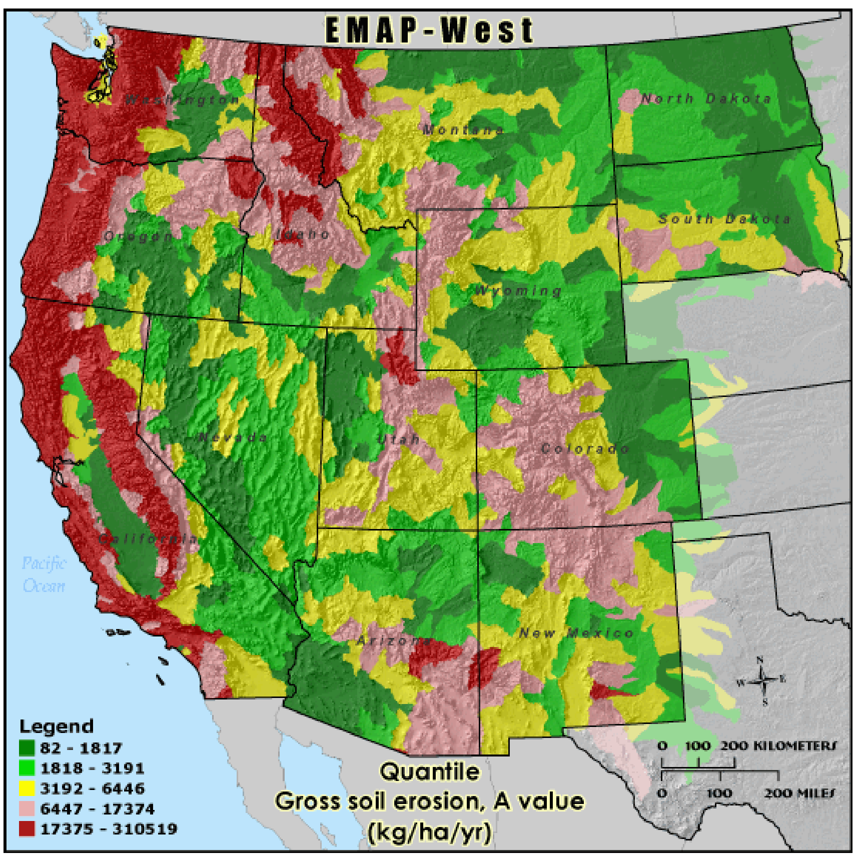

Figure 35. A Values Throughout the Western United States (USEPA, 2010).

7.0 Ecological Indicators

The State of Nevada has established water quality standards that include water quality criteria representing maximum concentration of pollutants that are acceptable, if State waters are to meet their designated uses, such as use for irrigation, watering of livestock, industrial supply and recreation. (Table 6).

Table 6. Water Quality Standards for Nevada.

Indicator	Standards for Nevada
Dissolved Oxygen	≥5 mg/L (non-trout waters) ≥6 mg/L (trout waters)
pH	6.5-9.0
Total Phosphorous	≤0.1 mg/L

Considering that a large portion of the water flowing through the Basin is supplied by surface water runoff, the topography and land cover within the basin can affect the water entering the system, which in turn affects the biology of the stream. These ecological indicators are measurable characteristics of the environment and can provide information on ecological resources. In this chapter, variations of these ecological indicators are examined. For a complete data set, see Appendix 7.

7.1 Dissolved Oxygen

Dissolved oxygen (DO) is the amount of gaseous oxygen dissolved in water and available for organismsal respiration. (Figure 36). Decreases in DO can be associated with inputs of organic matter, increased temperature, a reduction in stream flow, and increased sedimentation. DO values ranged from 5.5 to 11.2 mg/L with a mean of 8.0 mg/L among samples. Two sites had DO values that went below 6 mg/L, which represents the lower limit determined suitable for trout by Nevada State standards, located in the Reese River to the south and at the top left area of the basin.

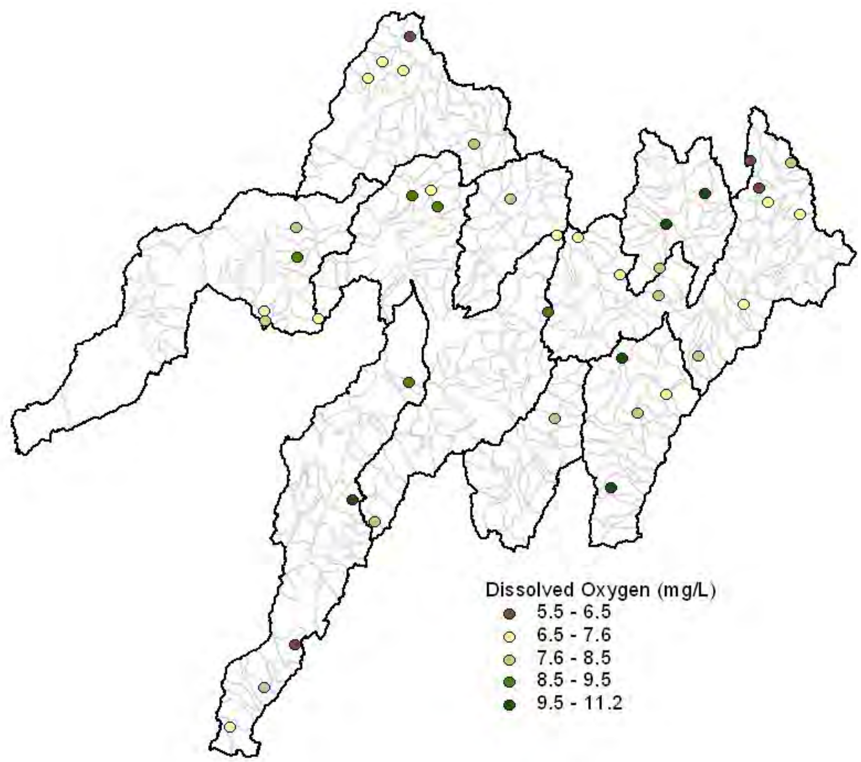

Figure 36. Dissolved Oxygen in the Humboldt River Basin.

7.2 pH

Hydrogen ion activity (pH), is a numerical measure of the concentration of the constituents that determine water acidity, specifically hydrogen ion concentration (Figure 37). pH is measured on a logarithmic scale of 1.0 (acidic) to 14.0 (basic) with 7.0 signifying neutral. The pH of the Humboldt Basin watersheds ranges from 6.6 to 11.7 with a mean of 8.4. Three samples, all located in the upper portion of the basin, were greater than 9.0, representing the upper limit set for Nevada. No sites were below the lower limit of 6.5.

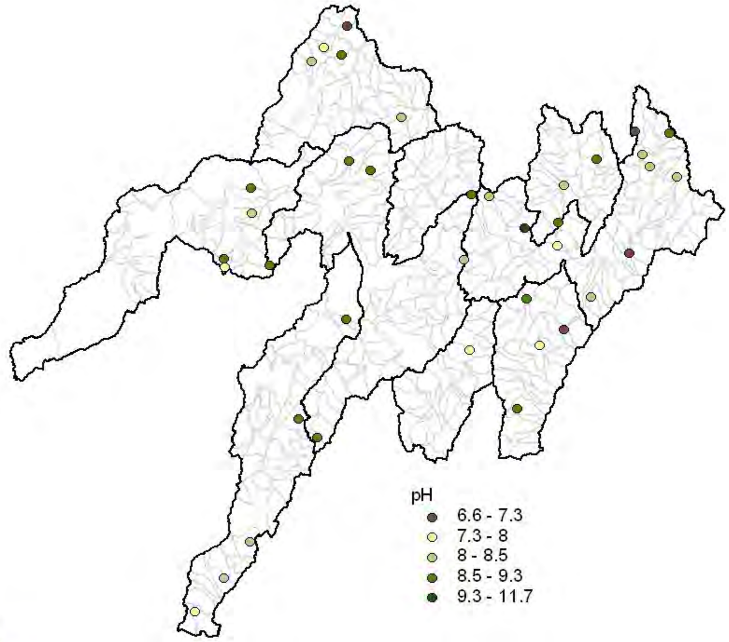

Figure 37. pH in the Humboldt River Basin.

7.3 Total Kjeldahl Nitrogen

Nutrient inputs to streams are important, as substantial inputs (eutrophication) from anthropogenic sources can result in increased algal growth which can upset the ecological balance of the stream (Figure 38). Total Kjeldahl Nitrogen (TKN), which is the combination of organic nitrogen and ammonia, comes mainly from agricultural processes, such as pesticides and fertilizers, and sewage. Total nitrogen was not used, because of lack of nitrite data for 1999. With the high proportion of land used

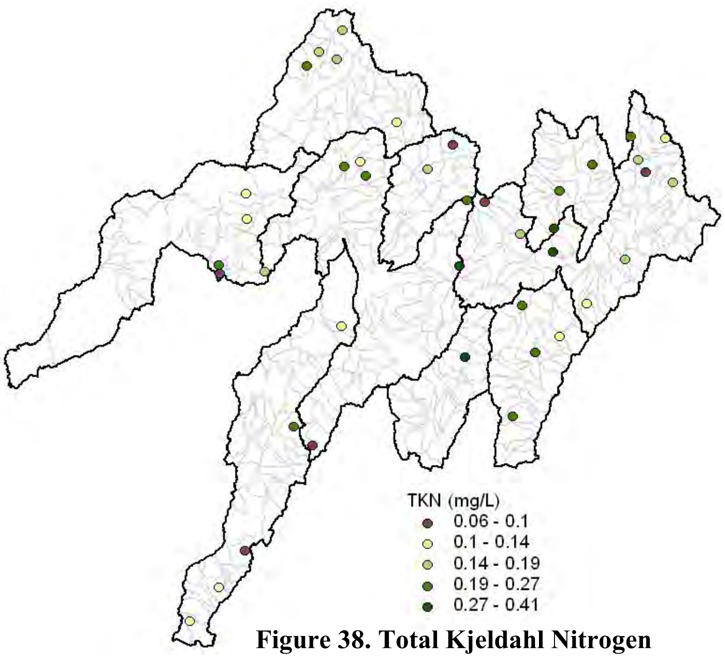

Figure 38. Total Kjeldahl Nitrogen in the Humboldt River Basin.

for grazing in the Humboldt River Basin, manure deposition from cattle can add nutrients, such as TKN, from the manure to the streams. Similarly, loss of nutrients from human activities can also reduce stream productivity. Values for TKN range from 0.06 to 0.41 mg/L with and average of 0.18. The highest value (0.41 mg/L) is located at site 247 in the North Fork Humboldt area.

7.4 Total Phosphorus

Phosphorus is often a limiting factor in growth of aquatic vegetation as it is an essential nutrient for plant and bacterial activity (Figure 39) . Yet, an excess of

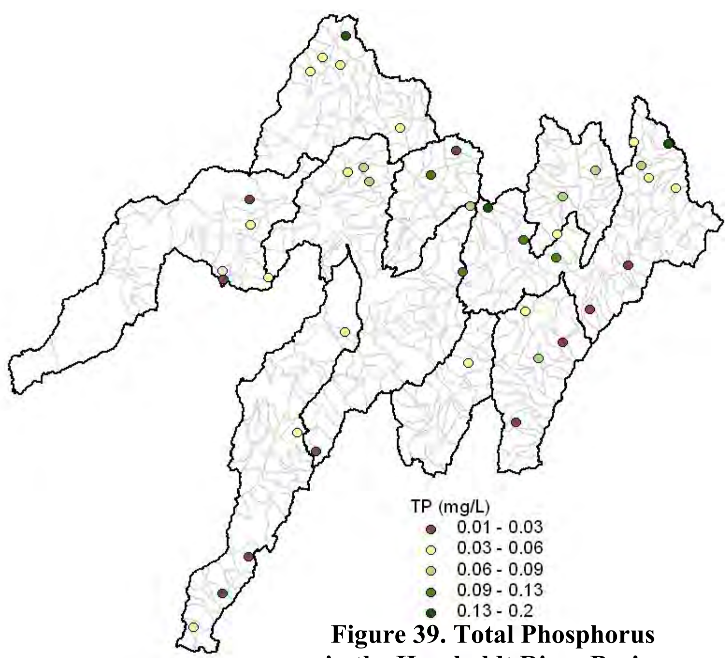

Figure 39. Total Phosphorus in the Humboldt River Basin.

phosphorus may reduce habitat, disrupt ecological cycles and affect macroinvertebrate communities. An increase in phosphorus, which could be the result of nutrient input from agriculture, is reflected in increased growth of algae. Samples for total phosphorous (TP) in the Humboldt River Basin ranged from 0.01 to 0.20 mg/L with a mean of 0.06 mg/L. Six sites had TP levels above the Nevada water quality standard of 0.1 mg/L all located in the upper reaches of the basin.

7.5 IBI

The Index of Biological Integrity (IBI) combines metrics sensitive to stressors representing diverse aspects of the biota in order to differentiate between stressed and unstressed conditions (Figure 40). An IBI score is representative of the health of a stream. Changes in aquatic species can occur from a number of actions. Breakdown of stream banks change channel shape, structure and form, and decrease stream bank stability. This can lower the groundwater table, increase water turbidity, and change type of vegetation and aquatic habitat, thus changing habitat diversity (Bellows, 2003). Values ranged from 16 to 96 with an average of 50. Although there is no standard, higher values are indicative of healthier systems. Five sites had values below 20.

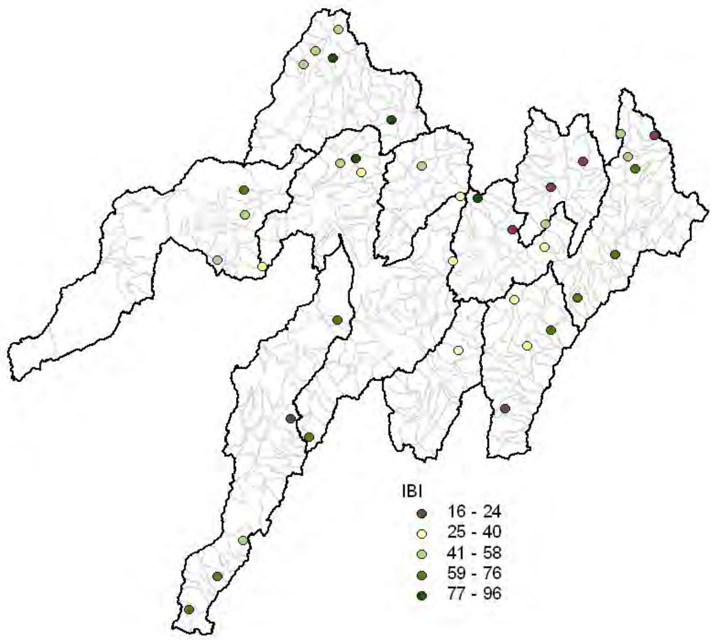

Figure 40. Index of Biological Integrity in the Humboldt River Basin.

7.6 TDS

Total dissolved solids (TDS) include calcium, carbonate, chloride, sulfate, phosphate, nitrate, organic ions and other ions that can pass through a filter (Figure 41). Although a certain level of TDS are necessary for aquatic life, excessive levels can be harmful. Increased levels of dissolved solids can result in reducing water clarity, thus limiting photosynthesis of aquatic plants. High concentrations of dissolved solids can be attributed to the surrounding geology, runoff from streets and agriculture, soil erosion and the organic particles of decayed of plants and animals. With the recommended standard for TDS in drinking water is 500 mg/L, four sites were in exceedance in the Humboldt Basin. Values ranged from 17 to 692 mg/L with a mean of 202 mg/L. Exceedances for each indicator are summarized in Table 7. Only those sites that had such exceedances are listed.

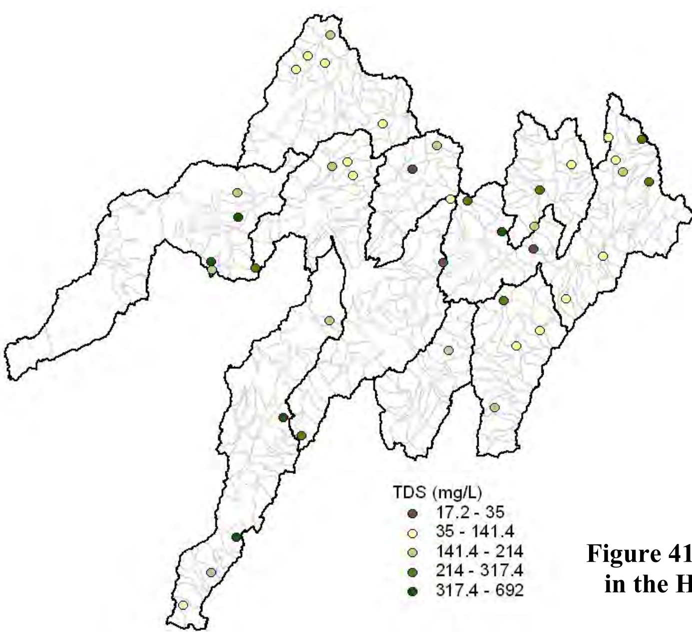

Figure 41. Total Dissolved Solids in the Humboldt River Basin.

Table 7. Indicator Exceedances.

Site	DO (mg/L)	pH	TKN (mg/L)	TP (mg/L)	TDS (mg/L)	IBI
5	5.5					
11		9.2				
25					516	
35					692	
103						18.0
129				0.16		
140				0.20		16.0
164				0.13		
196					549	18.0
245		11.7		0.11	505	18.0
247			0.41	0.12		
250		9.3				
259						16.0
269	5.5			0.20		

8.0 Landscape and Water Relationships

8.1 Regression Models

Riparian metrics were highly correlated to whole watershed metrics and were thus eliminated. Percent shrub/scrubland was also eliminated, since the percent of shrub/scrubland in the delineated sub-watersheds is simply the inverse of the percentage of forest, grassland and other land uses that make up the area. Using shrub/scrubland would not further elucidate the relationships between the land cover and water quality indicators. RUSLE R and C Factors were eliminated for strong correlation with other independent variables. Of the remaining landscape metrics six variables (A Value, K Factor, percent natural grassland, stream density, road length and road density) were used in the stepwise multiple regression. Different predictors were significantly related to each of the water quality metrics (Table 8). The amount of variability explained by models ranged from 24% to 54% (R^2, Table 8). Road length and road density are important factors in and around the populated areas of Lovelock, Battle Mountain, Winnemucca and Elko. The Index of Biotic Integrity (IBI) and total phosphorus remained low around all urban areas, Total kjeldahl nitrogen and dissolved oxygen had high values primarily around the more populated areas.

While all of predictors (png, strmdens, rdlen and rddens) enhanced TKN in streams. Soil factors (A Value and K Factor) decreased IBI and DO in streams.

Table 8. Multiple Regression Models "*" Denotes Log-Transformation

Dependent Variable	R^2	Formula
DO	0.384	6.949-0.028*AValue+0.0304*KFactor
TKN*	0.544	-3.097+0.00902*png+0.012*strmdens+0.00801*rdlen+0.00897*rddens
TP*	0.257	-4.75+0.0208*strmdens+0.00921*rddens
IBI	0.241	68.97+0.341*AValue-0.467*KFactor

8.2 Model Application

Using the 2001 NLCD and averaged RUSLE grids, predictions were made of potential IBI and water quality indicators in the Humboldt Basin within each 12 digit HUC. Predicted dissolved oxygen had higher values around the major urban areas with the lowest values located to the north and in the lower reaches of the Reese River. High predicted TKN values were spread throughout the basin with the higher values in the urban areas of Lovelock, Winnemucca, and Elko, while low values were congregated around the southern portions. Total phosphorus had overall low predicted values throughout the basin with the highest values located around the main stem of the Humboldt through the center. Surrounding the more populated areas, IBI remained relatively low with the lowest values around Battle Mountain and Elko and the highest values in the upper reaches of the basin and the southern tip of the Reese River. See Appendix 8 for the predicted model averages in each hydrologic unit.

9.0 Conclusion

Nevada has a basin and range physiography. A repeating pattern of fault block mountains and intervening valleys. Most of the state is internally drained and lies within the Great Basin ecoregion. Valley ecoregions are predominantly shrub or shrub- and grass-covered. Mountains may be brush-, woodland-, or pinion-juniper forested systems. The Humboldt River Basin is in the northern portion of Nevada, and encompasses approximately 17,000 square miles. The Humboldt River is the largest river system in the lower 48 states that begins and ends on the North American continent. The Humboldt River is a terminal system ending in the Humboldt Sink. The Humboldt River Basin is sparsely populated with two major land use types mining and agriculture (hay and cattle).

The Humboldt River, hydrologically, is fairly unique. The river trends east-west, and gains most of its water from snowmelt in the alpine regions of the Basin and Range ecosystem (Ruby Mountains, Jarbidge Mountains, and Independence Mountains in the eastern part of the watershed, and Toiyabe Mountains in the south-central portion). Agricultural activity in the valleys increases water withdrawals for irrigation. Water into the river comes from snowmelt, and open pit mining discharge. Flow is highly variable from season to season and year to year (depending on the amount of snow every winter). These unique features and the high desert environment contribute to the formation of a very large number of ephemeral and intermittent streams.

The objective of this study is to provide an additional supportive methodology tool using remote sensing and geographic information systems (GIS) to derive and connect land cover and human land use patterns in relationship to ecological features to support decision making. Physically, ecosystems are always in motion reacting to natural climatic and anthropogenic conditions. These changes, in environmental condition, will affect the chemical and biological community structure, which cause further alterations to the environment. Water quality issues in the Humboldt River Basin are nutrients (nitrogen, phosphorus and sediment), temperature, total suspended solids and metals. Traditional water quality measures give some information but are very limited in time and space. A landscape metric analysis explains more about ecologic condition and function, because landscape metrics tend to integrate time and space. Landscape metric analysis and water quality measures used together provides a very powerful environmental condition and risk analysis tool. This report provides a full set of landscape metrics to analyze. This report demonstrates how to take those metrics and derive basin-wide water quality predictions, and make those predictions in places where there are no water quality measurements.

Finding environmental problems is sometimes easier than finding solutions. This study found that past grazing practices has impacted stream flood plain vegetation, which holds together the stream channel and stream banks during flood events, and holds the water on the landscape. Adding more knowledge through landscape analyses will help land managers find troubled areas and help to choose the correct adaptive management practices to mitigate problems. Through further study more relationships can be discovered and additional predictive models mapped.

Improved knowledge of aquatic and upland interactions, at local to watershed scales, is essential in evaluating and designing land management alternatives for stream and wetland resources. Nevada's arid environment, coupled with the fact that most of the biodiversity in this state is associated with riparian or aquatic habitats, makes the management of these systems a matter of particular importance. The authors recommend that decision makers, stakeholders, ranchers, Federal, State, Tribes and local officials consider our approach and use this information to begin adaptive management practices.

Water quality in the Humboldt Basin had few cases of water quality standard exceedances. Road density and length, in addition to gross soil erosion and soil erodibility are main contributors to potential water quality degradation, along with stream density and percent natural grassland. Other contributors may include grazing density and gold mines. Mining can deplete groundwater resource while creating the potential for chemical pollution. Trends seen in nested watersheds show that as water flows from upstream watersheds downstream in a system with an expanding number of mines, increases in TDS, Hg, Cl and SO_4 occur while decreasing values of IBI. Sites 6 and 96, where most past and present gold mines occur, seem to have the most extreme values for many indicators such as mercury, TKN, lead and arsenic. Regression models demonstrate the watersheds that have a high potential for water quality impacts affected by one or more land cover use and/or erosion potential.

For the following maps, final metrics included in the prediction models are shown displaying their extreme values. For this, ten natural breaks were found for each variable, as defined by ATtILA, and the highest (or lowest) class was selected. Each variable was overlaid to show the HUCs that are affected (Figure 42, 43). For the final joined map, all affected watersheds were joined and then overlaid (Figure 44). This shows the watersheds that have the most potential to be affected by the land cover/use and sedimentation. Significant watersheds lie mainly along the mainstem of the Humboldt.

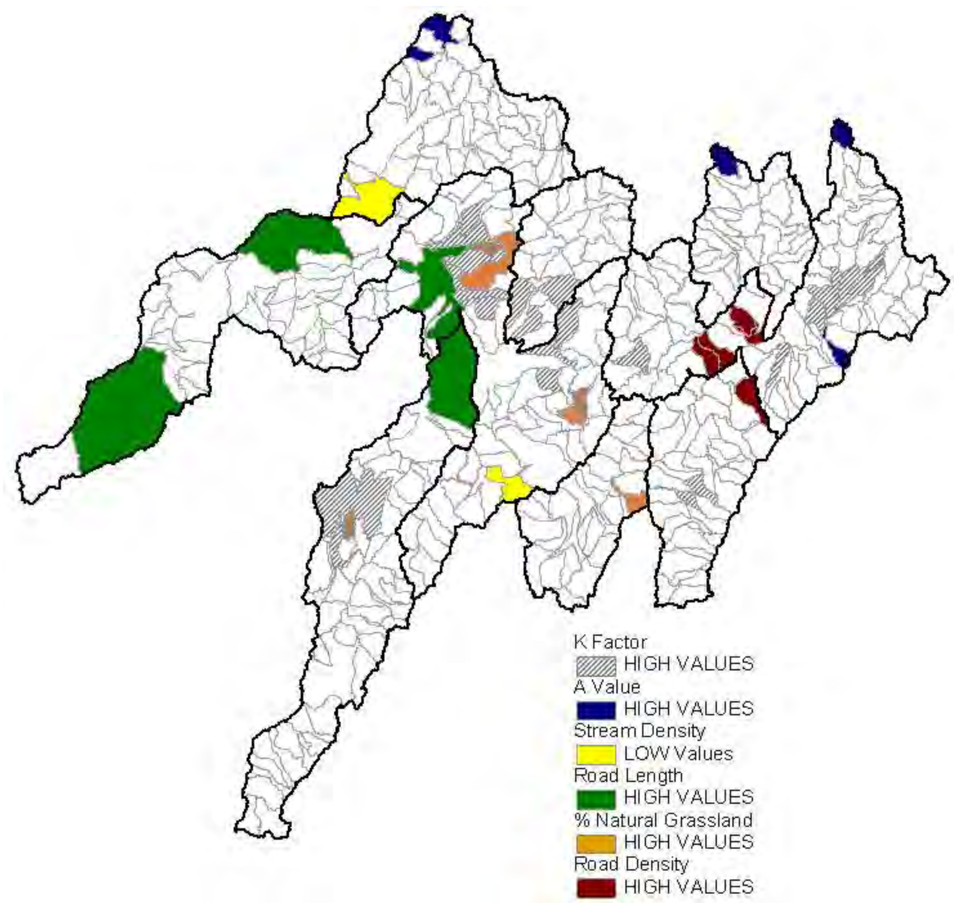

Figure 42. Land Cover/RUSLE Extreme Values for 12-digit HUCs.

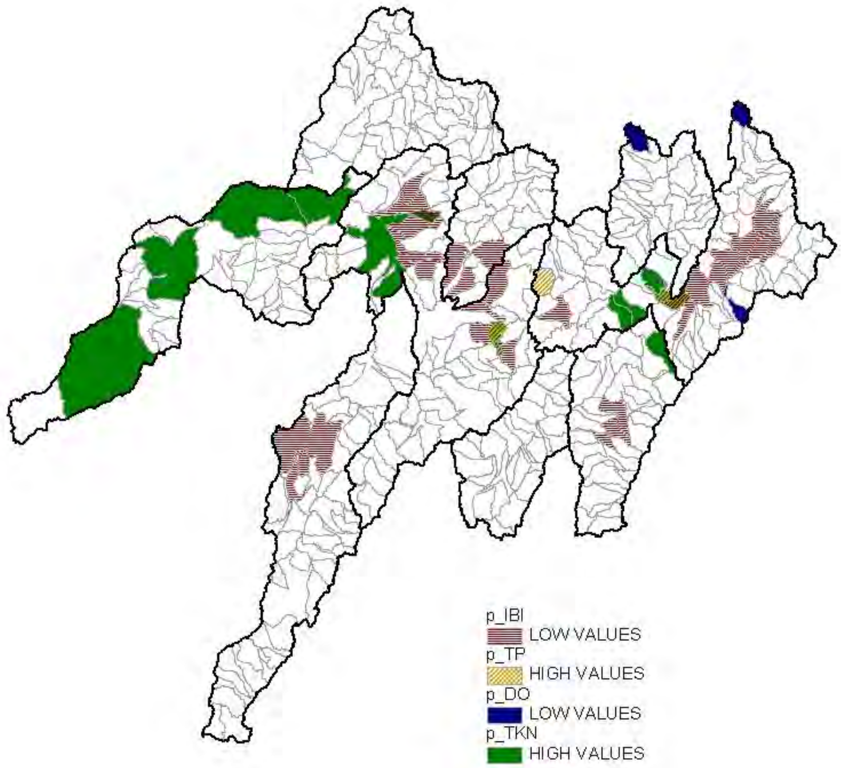

Figure 43. Predicted Water Quality Indicators Extreme Values for 12-digit HUCs.

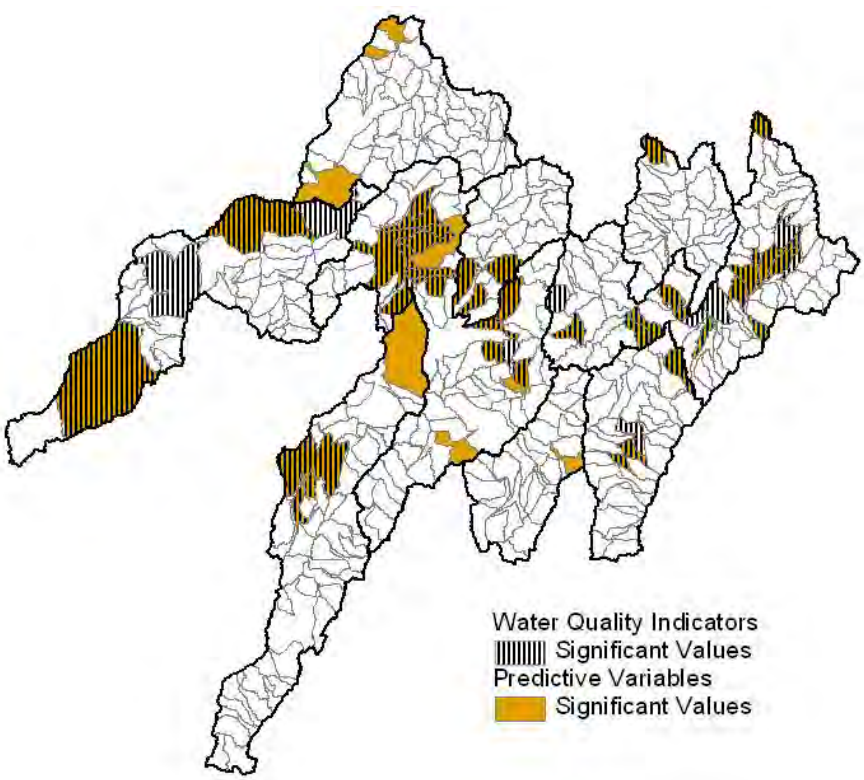

Figure 44. Humboldt Basin Subwatersheds Having Landscape Metrics Associated with Water Quality Degradation.

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Appendix 1. Humboldt Ecoregions (USEPA, 2007).

Level IV Ecoregions		Physiography	Vegetation
13e	High Elevation Carbonate Mountains	High rugged mountains. Cold water streams fed by snow melt.	Spruce-fir forest. Understory of brush species and grasses. Limited areas of alpine meadows or tundra.
13g	Wetlands	Flat terrain with saline or freshwater wetlands.	Tule marshes. Non-native tamarisk becoming common.
13h	Lahontan and Tonopah Playas	Broad alkali flats, playas, sand dunes and plains. Saline lakes and marshes occur. Water more alkaline.	Mostly barren. Does contain saltbrush and other extremely salt-tolerant plants.
13j	Lahontan Salt Shrub Basin	Rolling plains, scattered hills and sand sheets. Surface water more alkaline.	Saltbrush. Riparian woodland.
13k	Lahontan Sagebrush Slopes	Hills, upper alluvial fans and low mountain slopes.	Great Basin sagebrush community and sagebrush steppe.
13l	Lahontan Uplands	Low fault block mountains. Streams fed by springs and snow melt.	Juniper steppe woodland. Riparian vegetation can be lacking.
13m	Upper Humboldt Plains	Rolling plains, alluvial fans, foothills and few hot springs.	Great Basin sagebrush community and sagebrush steppe.
13n	Mid-Elevation Ruby Mountains	Mid-elevation mountains. Snow-melt and cold springs feed lakes and streams.	Juniper-pinyon woodland and mountain-mahogany.
13o	High Elevation Ruby Mountains	High elevation mountains containing glacial features. Small cold lakes fed by snow melt.	Great Basin pine forest community. Aspen groves. Alpine tundra. Rocky mountain flora is dominant.
13p	Carbonate Sagebrush Valleys	Flat to gently sloping basins, floodplains and hill slopes. Scattered ridges. Stream flow variable.	Great Basin sagebrush community. Understory composed of grasses.
13q	Carbonate Woodland Zone	Mid-elevation sloping mountains. Underground drainage common with many springs.	Juniper-pinyon woodland and some Great Basin sagebrush community.
13r	Central Nevada High Valleys	Rolling to hilly, high elevation valleys. Alluvial fans. Substrates are of fine sediments.	Mostly Great Basin sagebrush community. Riparian habitat lacking.
13s	Central Nevada Mid-slope Woodland and Brushland	Mid-elevation slopes and summits. Streams fed by snow melt and cold springs.	Juniper-pinyon woodland and mountain-mahogany.
13t	Central Nevada Bald Mountains	High-elevation mountains with moderate to high gradient headwater streams fed by snowmelt and cold springs.	Mostly mountain-mahogany. Only Great Basin tree communities occur.
13z	Upper Lahontan Basin	Flat to rolling valleys with plains, hills and eroded gullies. Some hot springs.	Mostly saltbrush-greasewood and Great Basin sagebrush community.
80a	Dissected High Lava Plateau	Rolling volcanic plateaus dissected by shear-walled canyons. Variable flow.	Mostly sagebrush steppe. Overgrazed areas.

Level IV Ecoregions		Physiography	Vegetation
80b	Semiarid Hills and Low Mountains	Hills, low mountains and alluvial fans.	Mostly sagebrush steppe and juniper-pinyon woodland.
80g	High Lava Plains	Flat to hilly volcanic plateau. Lakes and ephemeral pools levels are variable.	Sagebrush steppe.
80j	Semiarid Uplands	Hills, low to mid elevation mountain slopes and volcanic cones.	Mostly juniper steppe woodland and sagebrush steppe.
80k	Partly Forested Mountains	Partially glaciated. High, rugged mountains containing glacial features.	Great Basin pine forest community.

Appendix 2. Regional HUC Numbers and Corresponding Names.

8-digit HUC	Name	Area sq. km	Area sq. miles
16040101	Upper Humboldt	7045	2720
16040102	North Fork Humboldt	2559	988
16040103	South Fork Humboldt	3289	1270
16040104	Pine	2551	985
16040105	Middle Humboldt	8236	3180
16040106	Rock	2300	888
16040107	Reese	5983	2310
16040108	Lower Humboldt	6708	2590
16040109	Little Humboldt	4507	1740

Appendix 3. List of Sampling Sites.

Site	Stream Name	Longitude	Latitude
4	Upper Reese River	-117.47055560	38.85000000
5	Brewer Canyon	-117.23138890	39.23861111
7	Mullinix	-117.53888890	41.56138889
11	Evans (lower) Creek	-117.00388890	41.11083333
14	Boulder Creek	-116.33722220	41.10361111
22	Thomas Creek	-117.73333330	40.89861111
25	Elbow Canyon	-117.67833330	40.75638889
34	Kelly	-117.15722200	41.13611111
35	Spaulding	-117.79666670	40.53972222
37	Panther	-117.50361110	40.55666667
53	Dorsey Creek	-115.74972220	41.05805558
66	Smith Creek	-115.70250000	40.46055556
69	Dixie Creek	-115.85027780	40.66750000
71	Talbot Creek	-115.44750000	40.73861111
92	Trout Creek	-116.94638890	40.38472222
103	Huntington Creek	-115.76138890	40.14000000
108	Chimney Creek	-115.38555560	41.56416667
127	Welsh Canyon	-116.29777780	40.79027778
129	Beaver Creek	-116.22527780	41.11194444
130	Marysville Creek	-117.34277780	39.04166667
133	Little Humboldt River	-116.88611110	41.39277778
134	Boulder Creek	-115.25972220	40.98333333
140	Hot Creek	-115.16638890	41.59000000
158	South Fork Humboldt River	-115.57555560	40.55944444
161	Round Corral Creek	-117.48250000	41.64194444
164	Willow Creek	-116.62500000	41.20694444
166	Iowa Canyon	-116.96250000	39.79833333
176	Pine Creek	-116.13527780	40.37111111
181	Table Mountain	-117.78027780	40.50166667
183	Jake Creek	-117.06166670	41.17027778
184	Mary's River	-115.24222220	41.41277778
196	Reese River	-117.10361110	39.86555556

Site	Stream Name	Longitude	Latitude
199	Martin Creek	-117.35777780	41.62500000
204	Hank's Creek	-115.30638890	41.46277778
230	Rock Creek	-116.50055560	41.34666667
244	Pole Creek	-115.05722220	41.39222222
245	Susie Creek	-115.95388890	40.99972222
247	Sherman Creek	-115.72666670	40.94944444
250	Beaver Creek	-115.59361110	41.39666667
259	Gance Creek	-115.76694440	41.24083333
269	Upper Little Humboldt River	-117.36222220	41.76750000

Appendix 4. Descriptive Statistics for 12-Digit HUCs and Delineated Watersheds

	HUCs			Delineated Watersheds		
	Mean	Min	Max	Mean	Min	Max
% Forest	6.1	0.0	72.6	12.9	0.0	69.6
% Agriculture	1.7	0.0	34.0	0.6	0.0	11.3
% Shrubland	79.5	9.0	100.0	79.6	27.1	100.0
% Natural Grassland	10.5	0.0	91.0	5.9	0.0	72.9
% Urban	0.6	0.0	19.1	0.1	0.0	0.7
% Wetlands	1.1	0.0	21.9	0.5	0.0	3.4
% Barren	0.4	0.0	30.9	0.3	0.0	11.8
Stream Density (km of streams/area in km2)	0.9	0.2	1.9	0.9	0.5	1.3
Road Density (km of roads/area in km2)	0.7	0.0	2.5	0.5	0.0	1.1
# Road/stream crossings per km of stream in HUCs	0.4	0.0	1.2	0.4	0.0	1.9
Total # of road/stream crossings in HUCs	43.0	0.0	526.0	67.0	0.0	859.0
% stream length adjacent to forest 30m	5.5	0.0	56.7	13.8	0.0	67.1
% stream length adjacent to agriculture 30m	2.9	0.0	40.3	1.2	0.0	18.6
% stream length adjacent to shrubland 30m	75.2	3.0	100.0	76.0	26.1	100.0
% stream length adjacent to natural grasslands 30m	11.9	0.0	97.0	5.8	0.0	73.9
% stream length adjacent to all human use 30m (land cover)	3.5	0.0	41.6	1.4	0.0	18.6
% stream length adjacent to wetlands 30m	3.3	0.0	38.6	2.7	0.0	15.0
% stream length adjacent to barren 30 m	0.5	0.0	32.5	0.3	0.0	11.9
% stream length adjacent to forest 90m	5.7	0.0	62.0	14.0	0.0	69.8
% stream length adjacent to agriculture 90m	2.7	0.0	36.5	1.0	0.0	16.5
% stream length adjacent to shrubland 90m	76.4	4.2	100.0	77.0	26.9	100.0
% stream length adjacent to natural grasslands 90m	11.4	0.0	95.8	5.6	0.0	73.1
% stream length adjacent to all human use 90m (land cover)	3.3	0.0	37.7	1.2	0.0	16.5
% stream length adjacent to wetlands 90m	2.7	0.0	35.9	1.9	0.0	9.9
% stream length adjacent to barren 90 m	0.5	0.0	37.7	0.3	0.0	11.8

Appendix 5. RULSE Variables.

Site ID	A Value (kg/ha/yr)	R Factor	K Factor	LS Factor	C Factor	P Factor
4	6948	20	0.16	12.05	0.081	1.00
5	14785	20	0.29	17.54	0.063	1.00
7	11409	22	0.25	9.32	0.098	1.00
11	1762	7	0.33	5.47	0.071	1.00
14	3436	11	0.16	8.56	0.098	1.00
22	6715	12	0.22	14.56	0.089	1.00
25	5332	9	0.22	12.03	0.093	1.00
34	2234	9	0.32	3.28	0.196	1.00
35	2230	9	0.23	6.02	0.090	1.00
37	5560	10	0.25	12.07	0.093	1.00
53	723	8	0.12	3.44	0.099	1.00
66	4233	13	0.25	8.07	0.080	1.00
69	1102	6	0.30	3.55	0.088	1.00
71	5005	15	0.18	12.29	0.065	1.00
92	4153	10	0.15	15.90	0.078	1.00
103	1923	10	0.35	3.47	0.091	1.00
108	2897	14	0.15	6.24	0.100	1.00
127	1236	6	0.20	8.48	0.056	1.00
129	4193	13	0.16	10.59	0.090	1.00
130	7150	12	0.24	13.32	0.070	1.00
133	3085	12	0.20	5.98	0.097	1.00
134	15818	30	0.19	15.94	0.079	1.00
140	2647	12	0.13	7.57	0.100	1.00
158	8757	18	0.17	16.84	0.073	1.00
161	6438	21	0.22	6.44	0.097	1.00
164	1848	9	0.21	4.62	0.099	1.00
166	3873	16	0.16	9.41	0.069	1.00
176	1086	9	0.26	3.22	0.083	1.00
181	3109	10	0.19	7.34	0.098	1.00
183	3540	10	0.20	7.82	0.094	1.00
184	476	6	0.20	2.38	0.100	1.00
196	2503	12	0.25	5.41	0.084	1.00
199	9409	25	0.24	7.50	0.098	1.00
204	922	7	0.13	4.60	0.099	1.00
230	3741	13	0.16	8.23	0.094	1.00
244	3473	15	0.13	8.22	0.100	1.00
245	1283	7	0.22	4.38	0.098	1.00
247	1532	7	0.15	6.97	0.099	1.00
250	2204	14	0.18	4.29	0.100	1.00
259	2751	11	0.25	5.74	0.098	1.00
269	10829	29	0.29	5.65	0.100	1.00

Appendix 6. User Defined Summary of Surface Layers in the Humboldt River Basin.

Summary Soils	*Soil Groups*	*Summary Soils*	*Soil Groups*
Sandy Loam	Fine Sandy Loam	**Gravelly Loam**	Extremely Gravelly Loam
	Gravelly Sandy Loam		Gravelly Loam
	Gravelly Fine Sandy Loam		Very Gravelly Loam
	Gravelly Coarse Sandy Loam	**Silt Loam**	Gravelly Silt Loam
	Gravelly Very Fine Sandy Loam		Silt Loam
	Sandy Loam		Very Cobbly Silt Loam
	Cobbly Fine Sandy Loam	**Cobbly Loam**	Cobbly Loam
	Fine Sandy Loam		Very Cobbly Loam
	Gravel Coarse Sandy Loam	**Sand**	Fine Sand
	Gravelly Sandy Loam		(Gravelly) Loamy Sand
	Gravelly Very Fine Sandy Loam		Sand
	Very Fine Sandy Loam		Very Gravelly Coarse Sand
Clay	Silty Clay	**Clay Loam**	Silty Clay Loam
	Clay	**Channery Loam**	Very Channery Loam
Loam	Loam		

Appendix 7. Ecological Indicators.

Site	DO (mg/L)	pH (unitless)	TKN (mg/L)	TP (mg/L)	TDS (mg/L)	IBI (unitless)
4	6.9	7.7	0.12	0.05	80	68.0
5	5.5	8.5	0.09	0.02	424	44.0
7	7.6	8.1	0.22	0.05	92	48.0
11	8.8	9.2	0.22	0.08	115	28.0
14	7.1	8.6	0.24	0.09	114	34.0
22	8.5	8.7	0.14	0.03	182	68.0
25	9.1	8.3	0.11	0.04	516	44.0
34	9.5	9.0	0.24	0.05	202	46.0
35	7.6	8.7	0.27	0.05	692	58.0
37	7.5	8.7	0.17	0.04	299	38.0
53	8.2	8.7	0.35	0.06	161	58.0
66	7.9	7.8	0.24	0.08	117	38.0
69	10.0	8.6	0.22	0.04	286	40.0
71	8.4	8.4	0.11	0.03	99	76.0
92	8.8	8.6	0.12	0.05	199	62.0
103	11.2	8.6	0.26	0.02	214	18.0
108	6.4	7.0	0.24	0.04	93	48.0
127	9.1	8.1	0.37	0.10	35	30.0
129	7.6	8.5	0.07	0.16	278	96.0
130	7.9	8.5	0.12	0.03	183	68.0
133	8.0	8.1	0.13	0.06	103	80.0
134	7.5	7.3	0.15	0.03	107	70.0
140	8.2	8.6	0.14	0.20	317	16.0
158	6.7	6.6	0.11	0.02	85	66.0
161	7.0	7.8	0.15	0.06	98	56.0
164	8.2	--	0.18	0.13	17	48.0
166	7.8	8.8	0.10	0.03	249	70.0
176	8.5	7.6	0.32	0.05	165	34.0
181	8.3	8.0	0.09	0.01	185	--
183	6.8	--	0.11	0.09	117	86.0
184	7.5	8.3	0.06	0.04	150	72.0
196	10.5	8.9	0.27	0.05	549	18.0
199	7.5	8.8	0.15	0.04	138	82.0
204	6.5	8.1	0.15	0.08	141	50.0
230	--	--	0.09	0.01	185	--
244	7.0	8.3	0.16	0.06	238	--
245	7.2	11.7	0.17	0.11	505	18.0
247	8.2	7.6	0.41	0.12	34	32.0
250	9.9	9.3	0.26	0.07	104	24.0

Appendix 7. Ecological Indicators (cont).

Site	DO (mg/L)	pH (unitless)	TKN (mg/L)	TP (mg/L)	TDS (mg/L)	IBI (unitless)
259	9.8	8.4	0.25	0.07	237	16.0
269	5.5	7.1	0.19	0.20	159	52.0
Mean	8.0	8.4	0.18	0.06	202	50
Upper 95% Conf.	8.4	8.6	0.21	0.08	247	56.8
Lower 95% Conf.	7.6	8.1	0.16	0.05	156	43.2
Median	7.9	8.5	0.16	0.05	161	22
Minimum	5.5	6.6	0.06	0.01	17	16
Maximum	11.2	11.7	0.41	0.20	692	96
Standard Deviation	1.25	0.82	0.08	0.05	148.3	21.5

Appendix 8. Predicted Models

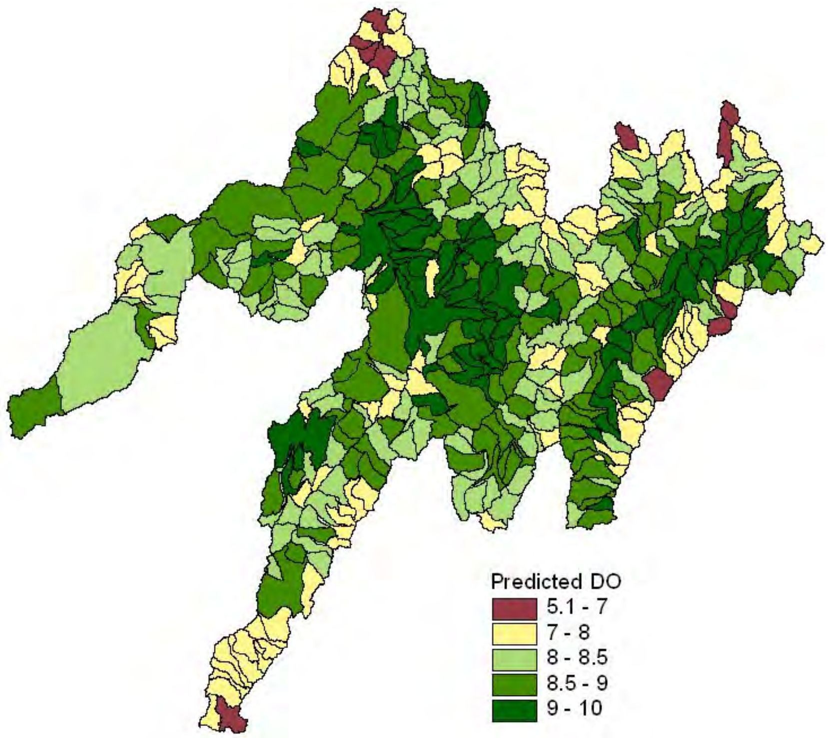

Figure 45. Predicted Dissolved Oxygen Values for the Humboldt River Basin.

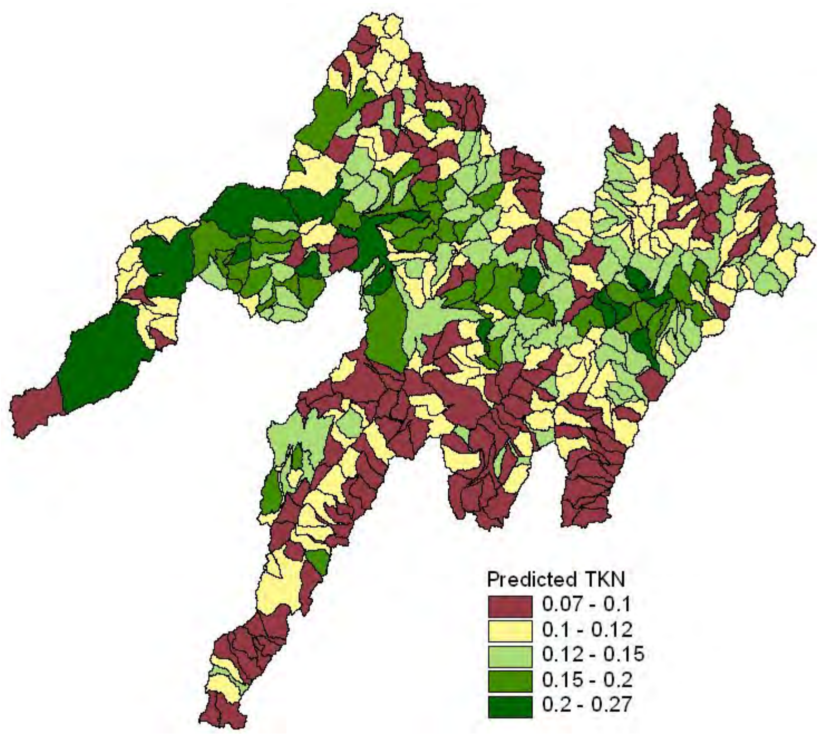

Figure 46. Predicted Total Kjeldahl Nitrogen Values for the Humboldt River Basin.

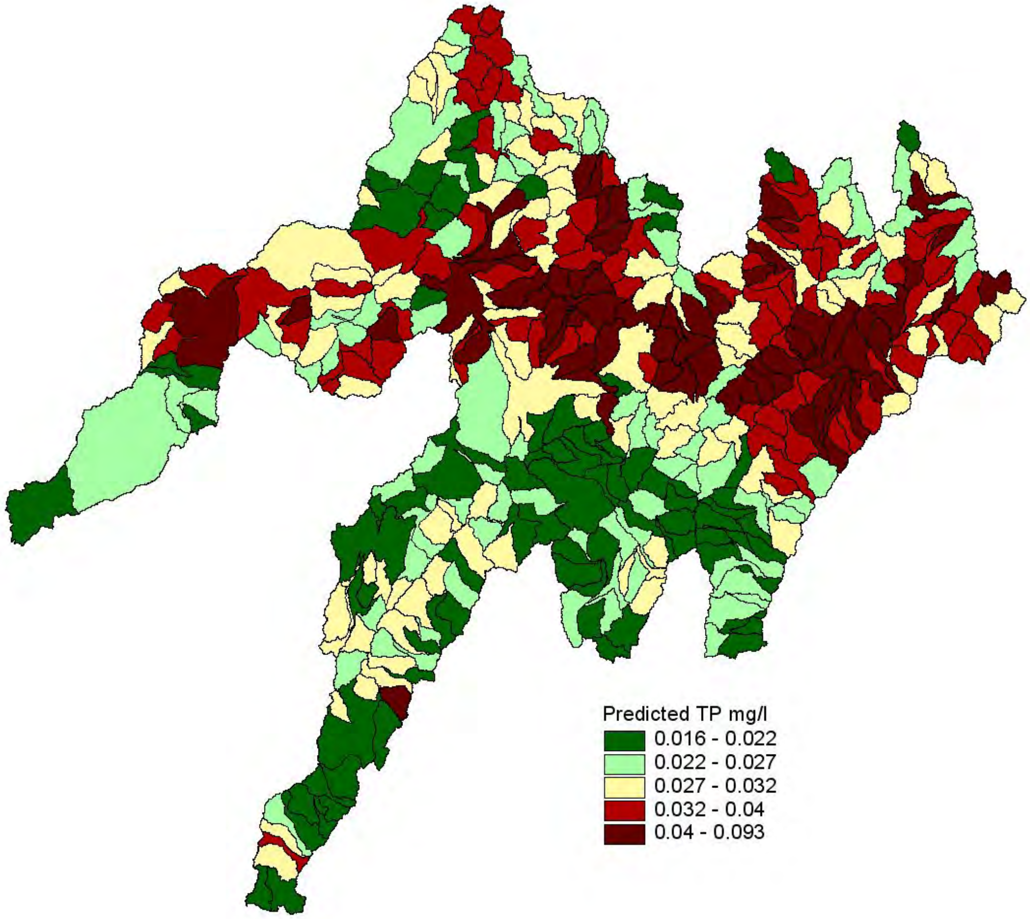

Figure 47. Predicted Total Phosphorus Values for the Humboldt River Basin.

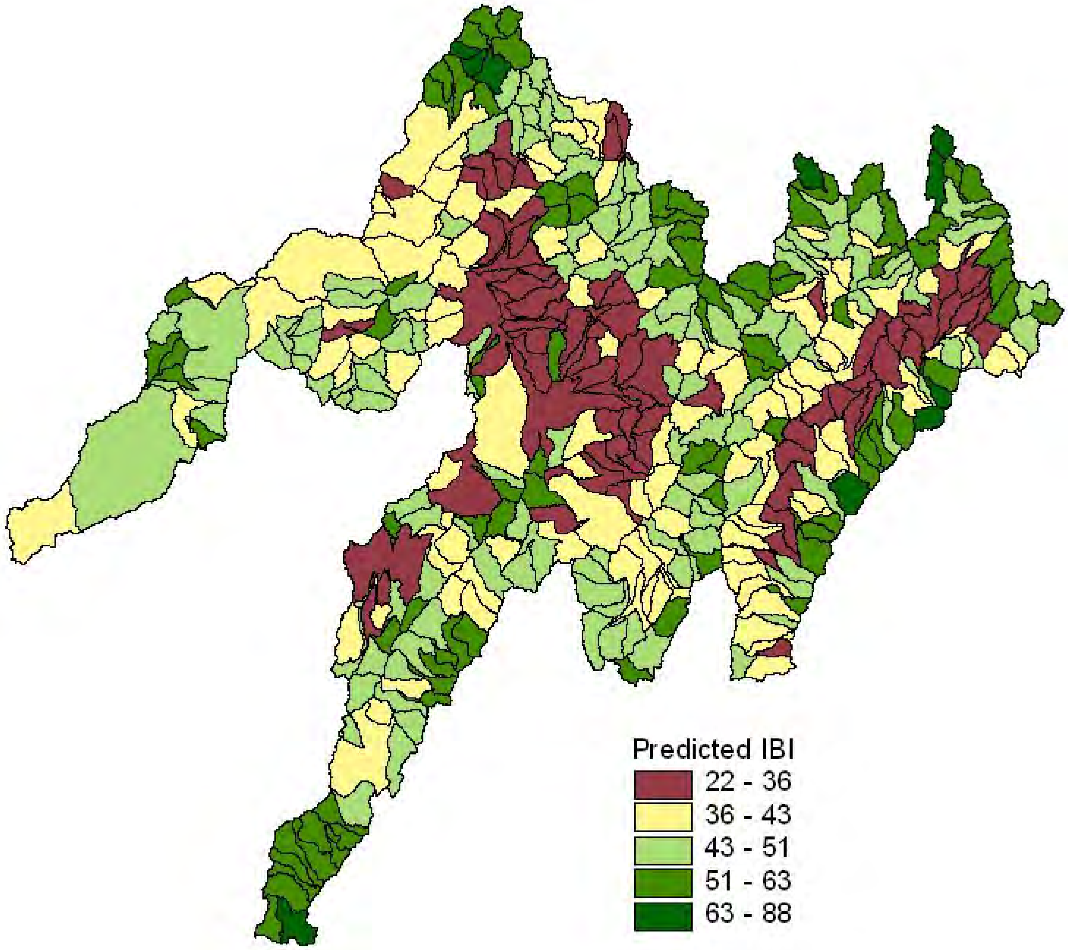

Figure 48. Predicted IBI for the Humboldt River Basin.

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EPA/600/R-13/xxx
January 2013
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