CSU Geospatial Review
GEOGRAPHIC INFORMATION SCIENCE IN THE CALIFORNIA STATE UNIVERSITY SYSTEM VOLUME 9• SPRING 2011

Dominguez Hills

Using GIS to Map Streamflow Measurement Deficiencies in Remote Mountain Watersheds

Long time series of streamflow measurements are valuable for hydrological and climatological research, but the national streamflow monitoring program of the United States Geological Survey (USGS) has been in a multidecadal decline, as routine maintenance and calibration costs have led to a diminished network of operating gauges under tightened budgets. The purpose of this research is to identify drainage basins and subbasins where streamflow data are especially sparse. At these deficient locations, future streamflow information might be obtained either by the refurbishment of inactive gauges or the construction of new gauging stations. Alternatively, the identification of monitoring network gaps could be used to highlight locations suitable for hydrological modeling of the streamflow, effectively creating "virtual" gauging stations.

To begin this sort of assessment of basin coverage, it made sense to examine regions which possess sparsely-gauged, unimpaired (i.e., free from the hydrological complications of damming and diversions) streams. In the contiguous United States such streams tend to be found in thinly-populated, remote regions, characterized by mountain environments. The domain examined in this research were the remote mountain watersheds of the Central and Southern Sierra Nevada, represented by Yosemite and Sequoia-Kings Canyon National Parks, respectively. A map of the actively-gauged locations in the vicinity of Yosemite National Park is shown in Figure 1.

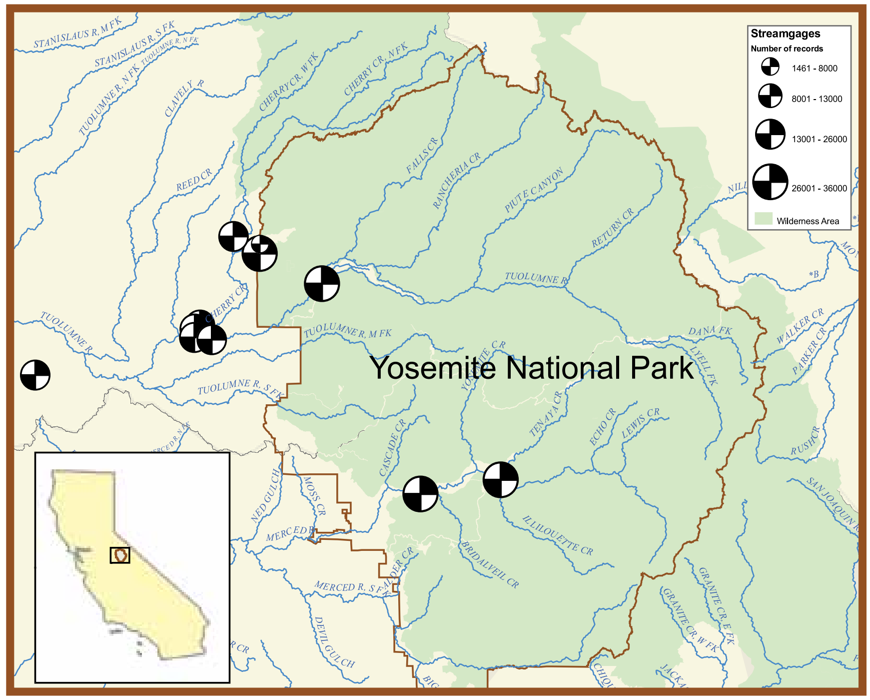

Figure 1: Active streamgauges in Yosemite National Park. The size of each symbol is proportional to the number of available streamflow records (i.e., number of measured days).

METHODOLOGY

The research began with the acquisition of the following cartographic and hydrological datasets:

- National park boundaries (National Park Service [NPS])
- National forests and wilderness boundaries (United States Forest Service [USFS])
- State and county boundaries (California Spatial Information Library [CASIL])
- Active and inactive streamgauges (United States Geological Survey [USGS] National Water Information System [NWIS])
- Waterfall names and coordinates (USGS Geographic Names Information System [GNIS])
- Streams at 1:200,000 scale (National Hydrography Dataset [NHD])
- 30 m Digital Elevation Models (DEMs) of Sequoia-Kings Canyon and Yosemite National Parks from the Sierra Nevada Ecosystem Project (SNEP)

The ESRI Arc Hydro toolbox was used to analyze the DEM, to independently generate streams consistent with the National Hydrography Dataset (which are streams appearing on a 1:200,000 scale USGS map). To begin, the Arc Hydro tools were used to determine the direction that water would flow across the raster landscape represented by the DEM, and which cells would accumulate water routed from multiple cells. Effectively,

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INSIDE

SAVE THE DATE
Please join us at the 2011 ESRI International User Conference in San Diego, California, from July 11-15.

DIRECTOR'S MESSAGE 2011

GIScience Comes Ashore

Continuing the theme begun with last year's "Offshore Research" column, this year we approach the land with a partnership with another new player in the CSU GIScience community focusing on marine and coastal research. See Chris Cogan and Corey Garza's article about the Geospatial Research, Education and Technology (GREAT) network of the CSU COAST program. With well more than half of the CSU campuses near or on the coast, it's no surprise that we have many with active members in COAST. The marine and coastal environments have significant stakeholders, and COAST's goal of fostering partnerships not only among disciplines and campuses, but also with coastal resource managers, holds considerable promise.

The goals of the group are similar to our CSU GIScience group: enhancing communication among faculty and staff with similar geospatial research interests on multiple campuses, and working together to make sure we all have the tools, software, data and training we need to better serve our students and communities. Shared interests, open communication and a cooperative structure enhance our ability to deliver a quality curriculum with active research even under increasing budgetary constraints.

What'll it be next year: Coast Range, Central Valley, the Sierra, ...?

Jerry Davis, *Director,* CSU GIS Specialty Center
San Francisco State University

GREAT, from Back Page

research to coastal management issues such as climate-mediated impacts on the coastal environment, environmental and anthropogenic effects on marine and estuarine organisms, the analysis and quantification of coastal biodiversity, and public policy development and implementation. The group builds upon the CSU's existing expertise in geospatial technology to bring together cutting-edge instrumentation and software, system-wide interdisciplinary networks and infrastructure, and earth and ocean digital databases. This combination is ideal to promote scientific research as well as classroom and field-based education and training for CSU faculty members, research associates and students. Members employ various techniques, including GIS, remote sensing, digital image processing, and spatial statistics to address spatial aspects of ecology, biology, and hydrology and provide improved coastal management options.

Several long-term goals have been identified for the network:

- Engaging external stakeholders to foster partnerships among CSU scientists, coastal resource managers and the public sector.
- Providing spatial literacy training to a diverse future work force skilled in the acquisition, analysis and application of geospatial data to address coastal management issues.
- Promoting the use of interdisciplinary spatial studies to provide quantitative and visual support for well-informed policy and management decisions.

By integrating applied research and geospatial technology, the COAST Geospatial Network is well positioned to build synergistic relationships across the 23 CSU campuses and train a new generation of CSU graduates with the spatial literacy and interdisciplinary skill sets necessary to address current and emerging issues in California's coastal environment.

MORE INFORMATION:

The Network is open to any interested CSU faculty members, research associates and students. An initial, informal working group has been formed to identify objectives and prioritize activities (http://www.calstate.edu/coast/GREAT/GREATpeople.shtml). To learn more and get involved, please contact:

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Merged bathymetric / topographic terrain model of Elkhorn Slough National Estuarine Research Reserve.

Potential for Carbon Capture and Storage in Kern County Oilfields

One partial solution that has been suggested for mitigation of greenhouse gas accumulation in the atmosphere is to inject power plant carbon dioxide (CO_2) emissions into known oil and gas reservoirs. These underground structures have proven capable of trapping fluids more buoyant than water for millions of years—preventing gases from reaching the surface.

In California, Kern County contains the largest oil reservoirs and produces 76% of California's oil and 60% of its gas. A GIS dataset of San Joaquin Valley oilfields was downloaded from the WESTCARB (the West Coast Regional Carbon Sequestration Partnership) website (www.westcarb.org) and clipped to include only fields in Kern County. This dataset was further updated and modified to include 2007 data for cumulative oil production, average depth and water salinity from the California Division of Oil, Gas and Geothermal Resources. The dataset was then used to determine which fields would be appropriate for carbon storage and how much space to store carbon has been made available by past oil production.

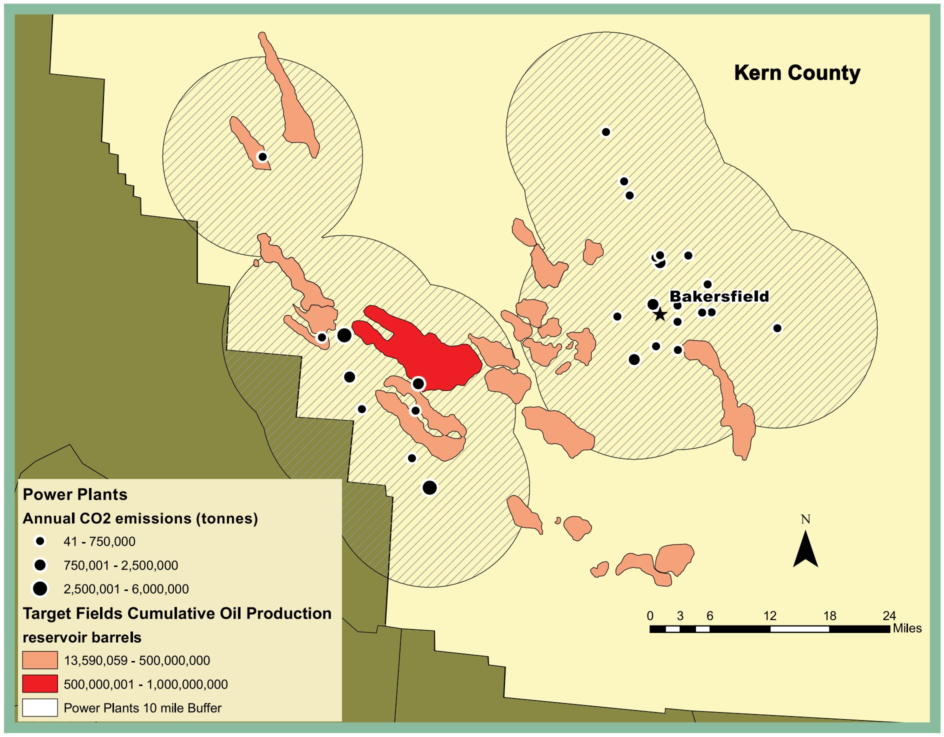

Figure 1: Location of power plant CO_2 emission sources and oil fields with the potential for sequestering large amounts of waste CO_2 in Kern County, California. The buffer shapefile indicates that most of these fields are within 10 miles of a carbon source. This distance was chosen arbitrarily to illustrate the length of the pipeline system necessary to transport CO_2 from the power plant to the field.

The Select by Attribute process in ArcGIS was used to select fields based on the following criteria:

1. Average depth greater than 3000 feet. An average depth over 3000 feet is required to provide sufficient pressure to maintain the CO_2 as a supercritical fluid.
2. Water salinity greater than 10,000 parts per million (ppm). Water salinity of over 10,000 ppm meets US EPA criteria for protection of fresh water aquifers.
3. Cumulative oil production greater than 12.5 million reservoir barrels. The US Geological Survey (Burruss et al., 2009) suggests that 12.5 million barrels of space is required to store about 1 to 1.4 million metric tons of CO_2. Because only oil production was considered and not water or gas production, the storage capacity determined in this study was a minimum value.

Twenty six oilfields met these criteria (Fig.1). These fields have a total cumulative oil production of 3.2 billion reservoir barrels of oil and should be able to store a minimum of 250 million tons of CO_2.

A downloadable GIS dataset containing the location and CO_2 production of San Joaquin Valley power plants was also available from WESTCARB. In the Kern County portion of the San Joaquin Valley, these power plants emit about 17 million tons of CO_2 per year. Therefore, the candidate fields could sequester at least 15 years of power plant emissions.

A proximity analysis indicated that all but six of the candidate fields lay within 10 miles of a carbon-emitting power plant. Therefore, most of the fields can be easily accessed by pipeline for transport of CO_2 from the power plants to the oilfields (Figure 1).

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Humboldt

Archaeological Applications of GIS: Developing a Predictive Model of the Wiyot Cultural Area in Northwest Coastal California

Predictive models in archaeology demonstrate human activities, contributing to understanding land use patterns of prehistoric peoples. The premise is that the spatial distribution of cultural remains is the result of human decision making and activities within the possibilities, conditions, and limitations set forth by the surroundings.

In this project we developed a predictive model of prehistoric site probability in the Wiyot Cultural area in Humboldt County, California. Ethnographic and archaeological records were georeferenced to contribute to regional archaeological studies and protect cultural resources by empowering tribal voices through GIS.

The study area on the north-west coast of California covers more than half of Humboldt County. The area is characterized by rugged mountains, riverine valleys, forests, coastline, estuaries and Humboldt Bay.

Secondary document analysis was used to recreate the prehistoric environment and identify prehistoric site type and use areas in the GIS. Modern-day environmental data was compiled from publicly available GIS sources; the challenge was to recreate the environment of the Wiyot area prior to 1850. This was achieved using ethnographic and historic information. Scanned historic maps aided in defining the previous extents of forest communities, prairie expanses, historic river courses, shorelines and estuarine slough networks of Humboldt Bay. Socio-geographic information from oral histories, ethnographic documents and archaeological site records was translated into GIS layers representing archaeology site types, prehistoric use areas, and cultural affiliation.

This resulted in variables drawn not only from environmental information, but variables relevant to cultural traits and practices of the Wiyot tribe. For instance, because the Wiyot were a maritime culture the location of permanent settlements in relationship to sloughs navigable by redwood dugout canoe were significant. Environmental classifications were achieved by isolating or combining environmental traits to derive classes describing mutually exclusive and distinctive topographic classes. Each layer was classed as interval, nominal, or ordinal in preparation for statistical analysis.

Logistic regression assessed significance among the variables. Statistical comparisons of frequency histograms of random points were compared with archaeological site data, combined with a forward-conditional regression, was used to select significant variables. Topographic setting, distance to prairies, and distance to navigable waterways met significance criteria of .05, while distance to freshwater, slope, elevation, and vegetation setting were excluded. Logistic regression calculates a relative probability value for each cell that ranges from 0 to 1, with values of 0 to .5 indicating non-site cells, and values of .6 to 1 indicating site-location cells.

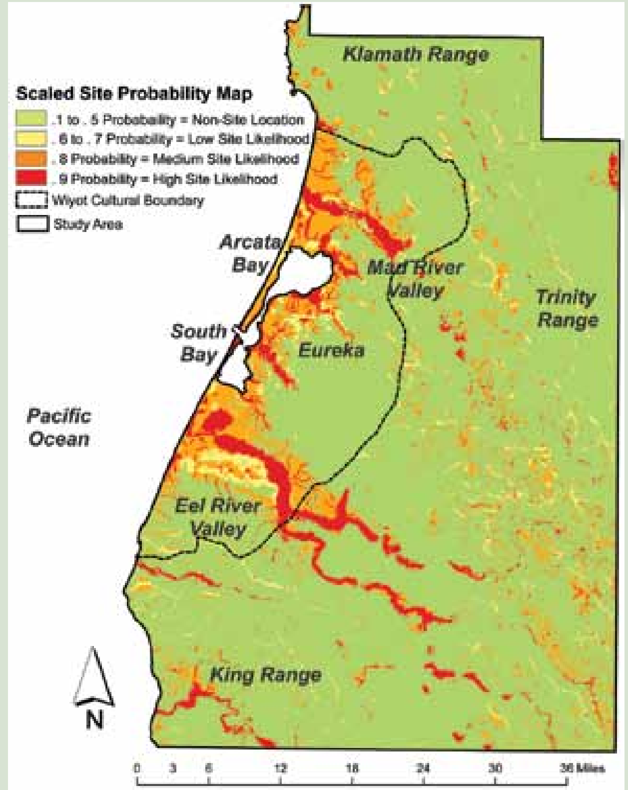

Figure 1: The model was developed using a set of known archaeology sites. A separate set of archaeology sites reserved for validation testing. Results showed 67% of the test sites were located in cells with values of 0.6 to 0.9, where the model indicated archaeology sites were most likely.

Statistical testing showed favorable results. Kvamme's Gain Statistic measured a 71% improvement in the models utility over random guessing. Frequency distributions of sites and non-sites formed strongly opposing cumulative percentage curves, which when compared, indicated the model has a predictive strength of 66% within the study area.   A minor problem, attributed partially to raster edge effects, was the occurrence of 15% of validation test sites falling in predicted non-site cells, but within 200m of a predicted site-cell. This indicates the model may be improved through refinement of classifications, adjusted raster cell size, or additional variables.

The final predictive model provided strong representation of the prehistoric settlement patterning in the traditional Wiyot area, particularly at the time of contact with Europeans. Currently in use by the Wiyot Tribe at Table Bluff in their efforts to preserve prehistoric sites on lands encompassing their traditional cultural area, we hope this model will be put used by a range of planning and management agencies. Circulation of this information brings together many voices to preserve a collective heritage in our rapidly developing world and allowsfor communal growth while honoring contemporary and past community identities.

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Estimating Carbon Storage and Sequestration by Urban Trees:
Effect of Remote Sensing Imagery with Different Spatial Resolutions

Urban forests are an important component of urban-suburban environments. Urban trees provide not only a full range of social and psychological benefits to city dwellers, but also valuable ecosystem services to communities, such as removing atmospheric carbon dioxide, improving air quality, and reducing storm water runoff.

There is an urgent need for developing strategic conservation plans for environmentally sustainable urban-suburban development based on the scientific understanding of the extent and function of urban forests. Traditional field inventorying is often used to obtain urban forest spatial coverage and followed by a random field sampling to document and quantify environmental benefits provided by urban trees (e.g., USDA Forest Service i-Tree). One of the key drawbacks of these approaches is that only a fraction of the area of interest can be measured and quantified. Field measurements are also labor-intensive and expensive. Satellite remote sensing greatly increases our ability to monitor land cover over large areas.

Several challenges, however, remain to accurately map urban trees and estimate various environmental benefits. One of these challenges is to deal with the effect of changing spatial resolutions and/or scales.

In this study, we examined the uncertainties of carbon storage and sequestration associated with the tree canopy coverage of different spatial resolutions. Multi-source satellite imagery data were acquired for the City of Fullerton, located in Orange County, California. The tree canopy coverage of the study area was classified at three spatial resolutions: 30 m (Landsat-5 Thematic Mapper, i.e., NLCD 2001), 15 m (Advanced Spaceborne Thermal Emission and Reflection Radiometer, i.e., ASTER), and 2.5 m (QuickBird). The amount of carbon stored in the trees represented on the individual tree coverage maps and the annual carbon taken up by the trees were estimated with an urban forestry analysis model (i.e., CITYgreen) developed by American Forests, a nonprofit conservation organization. CITYgreen is GIS software and an extension to the ESRI's ArcGIS.

The results indicate that trees account for a significant proportion of Southern California suburban landscapes (Fig. 1). NLCD 2001 significantly underestimates suburban tree coverage. NLCD 2001 tree canopy density data improves tree coverage estimation; but a great amount of trees are still largely omitted. Both ASTER and QuickBird imagery can capture most patches of trees. Estimated carbon uptake and storage vary greatly depending on the spatial resolution of satellite imagery. Carbon uptake and storage estimated with NLCD 2001 are minimal (i.e., 0.21 g/m^2 and 0.03 kg/m^2, respectively); carbon uptake and storage estimated with Quickbird (i.e., 14.5 g/m^2 and 1.9 kg/m^2, respectively) are 66% higher than those with NLCD tree canopy density data. Accurate tree canopy density data are needed to extrapolate the estimates from the fine-resolution stand-level to the low-resolution landscape-scale.

ACKNOWLEDGEMENTS

This research was funded by CSUF Intramural Research Grants. QuickBird and ASTER imagery data were provided through a NASA funded remote sensing grant (PI: Dr. Robert Voeks). Special thanks to Aaron Tran (University of California, Berkeley), Alaric Qin and Arden Liao (Troy High School, Fullerton) for processing part of the imagery data during the summers of 2009 and 2010.

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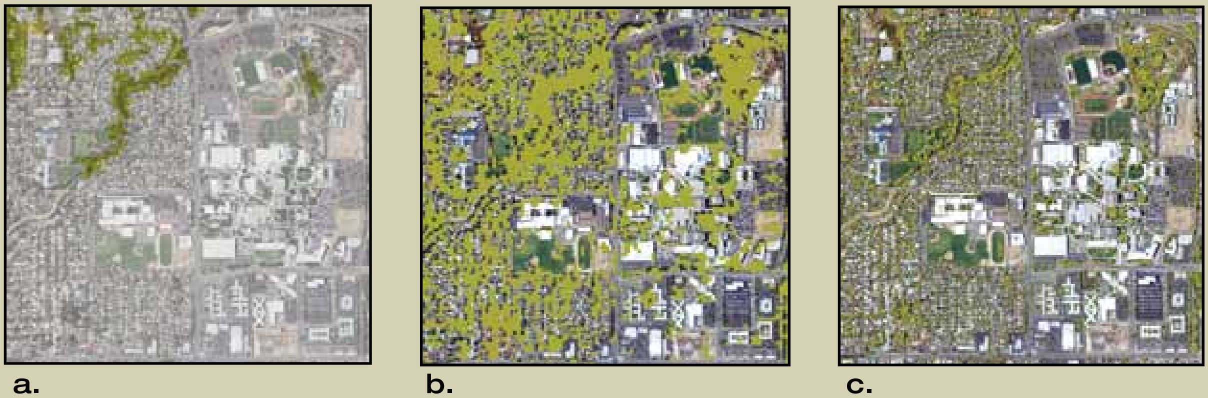

Figure 1: Tree covers of a residential neighborhood around the CSUF main campus, derived from **(a)** NLCD Tree Canopy Density Data (30m), **(b)** ASTER imagery (15m), and **(c)** QuickBird imagery (2.5m). The tree layers are overlaid on the 1m NAIP aerial imagery. ASTER and QuickBird imagery captures most patches of trees with different accuracy. The tree density changes from 0 to 64% in the NLCD product in which a great amount of trees are excluded.

Streamflow Measurement Defiiciencies, page 1

these water-accumulating cells trace out the trajectory of surface water streams of small and large order. To define the minimum stream size, a threshold of 50,000 cells aggregately draining to any downhill cell was used. Considering the spatial resolution of 30 m^2 per cell, this amounted to minimum catchment sizes of 45 km^2. The raster grid of the catchments was converted to a series of catchment polygons (i.e., a raster-to-vector conversion), and vector drainage lines (i.e., streams) were automatically traced along the flow accumulation points.

Locations of interest along various streams were manually added to the GIS database. The generic term *hydropoint* refers to any point on the map for which the hydrological properties are desired. For this research, the hydrological property of most interest was the upstream drainage area which routes surface water to that location. There were four types of hydropoints adopted:

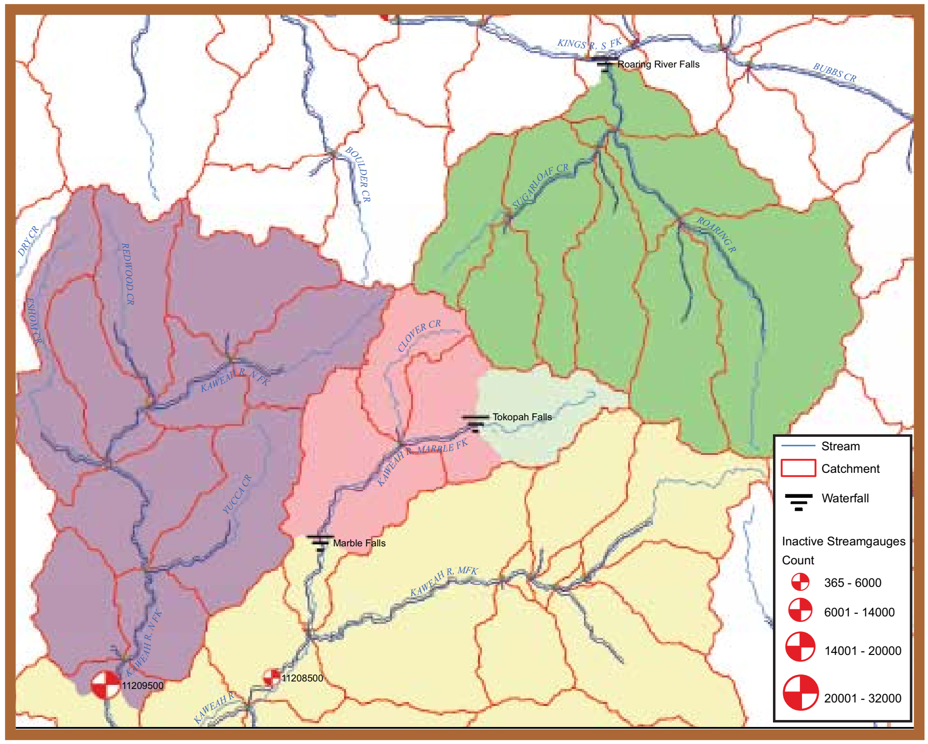

Figure 2: Catchments and watershed areas in Sequoia-Kings Canyon National Park. The red-bordered outlines are the DEM-dependent catchments. The colored polygons are the computed watersheds upstream of each hydropoint.

1. Active streamgauges
2. Former streamgauges
3. Stream confluences (with NHD-recognized tributaries and trunk streams)
4. Waterfalls

The coordinates of active and former streamgauges were obtained from the USGS NWIS. The stream confluences were automatically generated as hydropoints; by default, the Arc Hydro catchment function defines the drainage divide between two stream watersheds as the common catchment boundary, and the confluence of the streams is necessarily the downstream terminus shared by the two catchments. Thus, the hydropoints characterized by stream confluences were implicitly added during catchment processing.

Waterfalls were included as hydropoints for two reasons. First, they are cartographically-notable points along a stream; like tributary confluences, they are non-arbitrary locations to assign basin boundaries. Second, they represent defined locations where it might be desirable to know the stream discharge (i.e., flow over the falls). Determining discharge at any ungauged point requires separate hydrological modeling, and such an effort necessitates knowing the upstream drainage area. One of the fundamental properties associated with a hydropoint is its upstream drainage area, so the insertion of waterfall coordinates as hydropoints seemed an appropriate inclusion to support future stream modeling efforts.

Waterfall names and coordinates were obtained from the USGS Geographic Names Information System (GNIS) and added to the GIS map. Waterfall coordinates were provided to the nearest ten-thousandth of a degree, and the locations of active and inactive streamgauges were available with comparable precision. Nonetheless, there is no way that the hydropoints would *exactly* lie atop the stream line features—and thereby satisfy GIS demands of topological contiguity—so the waterfall and active/inactive streamgauge point features were all snapped to the stream line features. Once topologically correct, these hydropoints underwent the watershed delineation process, where their upstream areas were automatically computed from polygon features. Examples of these watershed polygons are shown in Figure 2.

IDENTIFYING SUBBASINS

The extreme example of a poorly gauged basin would be a very large river with active gauges spread far apart. To assess the sparseness of gauging, it is useful to consider the exclusive drainage area—the *subdrainage*—possessed by an individual hydropoint, as well as the mean discharge of the trunk stream. The subdrainage area between contiguous hydropoints within a basin can be readily determined by Arc Hydro; a conceptual map of two overlapping hydropoint drainages, and their associated subbasin, is shown in Figure 3.

Evaluating the dual factors of hydropoint subdrainage area and the mean hydropoint

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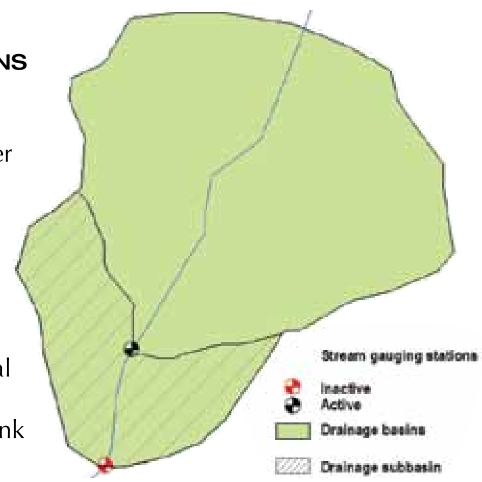

Figure 3: Conceptual figure of the drainage basin and subbasin areas. The overlapping polygons of the drainage areas for two hydropoints (active and inactive streamgauges) are shown. The subbasin is the unique area captured by the downstream basin.

Streamflow Measurement Defiiciencies from page 6

discharge will be an ongoing subject of research to fully characterize the streamgauging deficiencies in basins. In particular, advances in the work will require hydrological modeling, as a natural extension is using the computed subareas to estimate discharge within ungauged subbasins. The work to-date has been an interesting opportunity to utilize the power of GIScience to map the scarcity of streamflow measurements. It has also provided a directed research opportunity for two CSUDH undergraduate seniors, Kathleen Nugal and Osinachi Ajoku, to apply hydrological concepts and field work from their senior-level Rivers and Streams course to the research domain. Importantly, they have also been able to hone their GIS expertise, broadening what have they learned in their undergraduate GIS coursework into a deeper set of marketable GIS skills for their post-graduation careers in geography and earth science.

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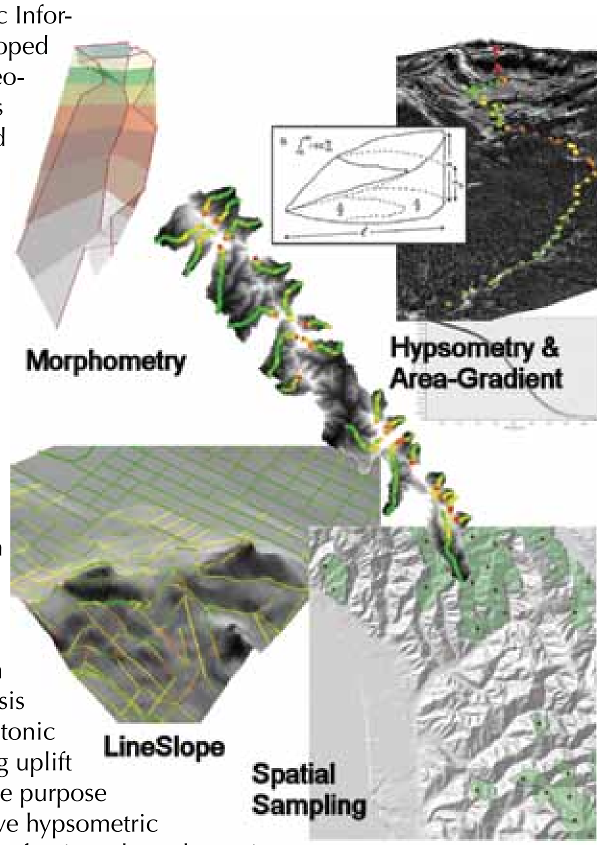
Geoprocessing Methods for Hypsometry, Morphometry and Spatial Sampling

The Institute for Geographic Information Science has developed a suite of Python-based geoprocessing tools for spatial analysis of geomorphic, biogeographic, and atmospheric systems. These tools range from addressing specific research questions to field and image data integration methods, with applications in physical geography, geology, ecology and environmental analysis.



The hypsometric curve (area–altitude relation) of a watershed is used to describe the distribution of watershed area with elevation, usually as a proportion of area above each proportion in elevation (Langbein 1947). Strahler (1952) proposed that the dimensionless hypsometric integral be used as a measure of landscape evolution. In recent decades, hypsometric analysis has been used in the context of tectonic geomorphology applied to studying uplift history (e.g. Grove et al. 2010). The purpose of the **Hypsometry** tools is to derive hypsometric and gradient values for a sequence of points along the main drainage path of a watershed in order to better characterize its morphology.

Species distribution modeling requires collecting spatial samples of environmental variables and the development of sampling schemes for field data collection. For **Spatial Sampling** tools, we took two approaches, (1) a Stratified Systematic Unaligned Sample and (2) Polygon Proportional Area. With the former we started with the "stratified systematic unaligned sampling" algorithm (SSUS) originally proposed by Berry and Baker (1968), creating a randomly generated set of points within input polygons. Though randomly generated, the algorithm minimizes spatial autocorrelation, an issue for satisfying statistical assumptions of independent sampling. The Proportional Area approach distributes a total number of samples among multiple polygons, based on area, used to constrain feature input into the CreateRandomPoints tool.

Other tools in the suite include:

- MODIS extraction and analysis tools for consecutive-day snow cover (J. Davis and C. Powell) and global atmospheric aerosol patterns (W. Goedecke).
- Morphometry tools for building 3D breaklines from sequences of total station points, which we've used to build terrains of gullies and landslides.
- A set of utilities including **LineSlope** which breaks 3D lines into short segments and codes their node-to-node line gradient.

Tools are freely available from the IGISc website, http://gis.sfsu.edu, and at Esri ArcScripts.

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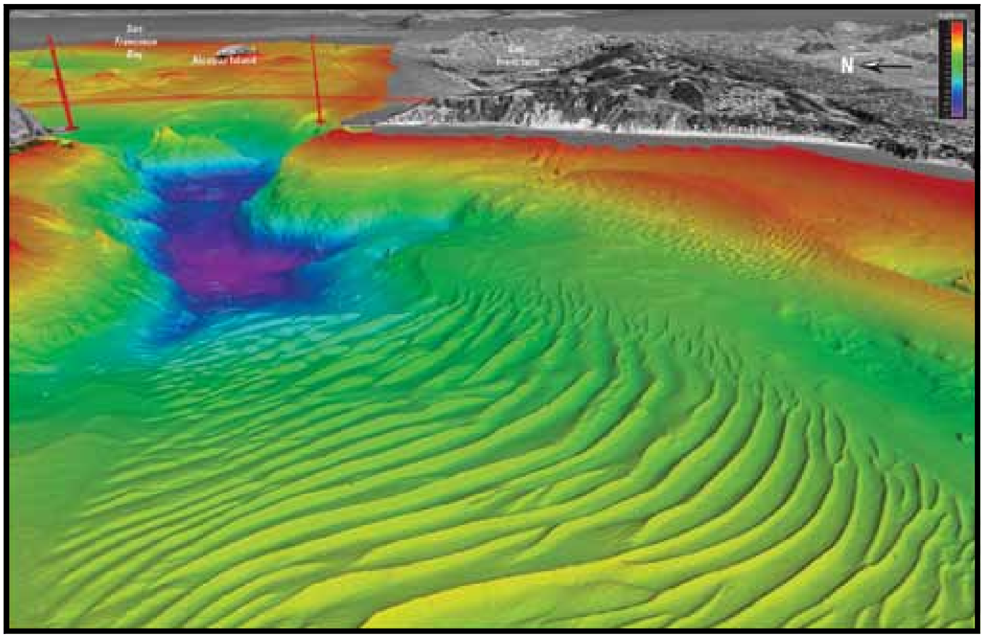
New CSU Coastal Geospatial Research, Education, and Technology Network (GREAT)



CSUMB seafloor bathymetry of the Golden Gate, San Francisco, California shown in shaded relief and color by depth. Merged bathy-topo image produced in collaboration with the United States Geological Survey and United States Army Corps of Engineers.

The CSU Council on Ocean Affairs, Science and Technology (COAST), the umbrella organization for CSU marine and coastal research and education, is establishing a new network in coordination with the CSU GIS Specialty Center: the COAST Geospatial Research, Education, and Technology Network (www.calstate.edu/coast/GREAT/). This multi-campus network promotes the application of interdisciplinary geospatial data visualization and analysis to coastal and marine environmental issues while providing training to students in the latest data collection, visualization and analysis techniques.

The COAST Geospatial Network is an interdisciplinary group of researchers with interests in the physical, biological, and social sciences and expertise in both marine and terrestrial systems. The focus is on the application of geospatial

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