ON THE APPLICATION OF GIS TO AUTOMATED PLANNING AND DESIGN OF HYDRO-SYSTEMS

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ABSTRACT

With the rapid advancements of the state of the art in computational modeling of hydroscience and engineering systems, multi-objective optimization with constraints, and information technology in hydroscience (for hydroinformatics), researchers, engineers and policy makers have been utilizing more integrated and automated tools in water resources and infrastructural system management, operations, and designs to make cost-effective, environmentally sound, and social acceptable decisions.

A brief introduction of basic concept, development and applications of such integrated system to perform many planning and design tasks systematically in Water Resources Engineering is presented. This tool uses GIS as a platform to integrate numerical data, spatial data, hydrologic models, and hydraulic models. This GIS is mainly established by 1:300 scale parcel maps, and the DEM, GPS, orthographic photos are also added and stored in different layers of the systems. By delineating and combining these stored geographic information, the watershed boundary maps, topographic maps, drainage and waterway systems, impervious surface and, land use maps, rainfall isohyetal maps and channel cross-section profiles etc, are produced.

The techniques of polygon and triangulated irregular network (TIN) are employed to calculate drainage area, channel length, channel slope, watershed infiltration rate. This data is then assembled automatically into specific input files for the embedded hydrologic and hydraulic models in the system to generate design flows. The flows then can be routed through channel systems to produce water surface profiles, or routed though a planned detention basin to mitigate flood flows. If a Land Information System (LIS) is linked to the GIS, the cost of land acquisition can be estimated as well.

1. INTRODUCTION

This system was developed by the Contra Costa County Flood Control District and the County Public Works Department. In the early 1970s, the District intended to computerize its engineering drawing business. The task started in 1975 and finished in 1978. In 1979 the District was hired by the County Assessor Office to update and manage its 300 scale (1-inch to 25 feet) parcel maps. This revenue provided additional fund for the District to further expand its computer facility.

With the 300 scale parcel maps, the District developed its base maps, which can be used for various engineering needs such as planning, design and land acquisition. In 1988, several

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applications were established in hydrology, such as hydrology maps, drainage system maps, watershed land use maps, 100-year, 500-year and dam break flood plain maps. This system was also used to map public utility systems for other departments.

In 1992, the digital 25-feet USGS contour was implemented in the system. New county 5-feet contour was developed by orthophotography in 1999.

All those spatial data were developed and stored in various layers of the system. The conventional numerical data, such as rainfall, stream flow and channel cross-section data were also collected and stored in the system. The product of the system is mainly to meet the engineering needs of the District.

2. FUNCTIONS OF THE SYSTEM

This system is able to update and produce parcel maps for the County Assessor Office. This system is also capable of producing much of the information for other county departments, such as utility lines, and evacuation plans, etc.

However, the main purpose of the system is to serve the needs of the Flood Control District. The above mentioned parcel maps can also be used in engineering for channel alignment, relocation, land acquisition and economic analysis of various alternatives.

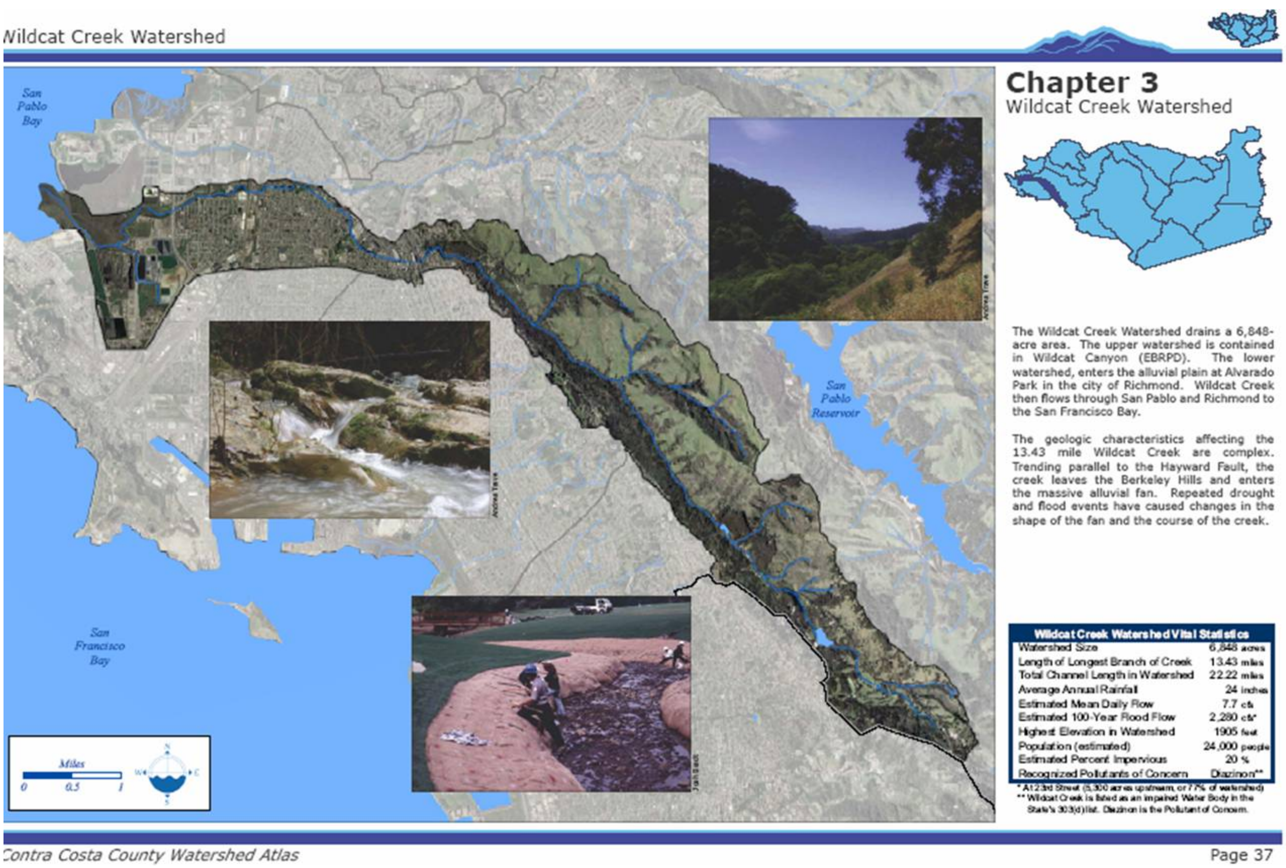


Figure 1 Watershed Map of Wildcat Creek

In hydrology, this system is capable of producing watershed maps by combining layers of watershed boundaries, elevation contours, parcel maps for land use, and stream systems. In these maps, a layer of raingage, runoff and water quality stations can also be added, then by clicking one of these stations, the station description and all rainfall or runoff data can be obtained.

Figure 1 and figure 2 show the watershed map of Wildcat Creek, which includes watershed boundary contour, topography, channel system and land use. Figure 3 show all creek systems and watersheds in Contra Costa County. Figure 4 shows the topography of the entire county. Drainage maps are produced by overlaying drainage systems over the 300 scale parcel map as shown in figure 5. By clicking the pipe system, it will display design flow, HGL, invert elevation and slope of the system. Figure 6 shows the flood plains overlaid over the parcel map, and this map identifies those parcels or households which will be inundated. Those types of maps can be used for flood insurance, flood plain management, and the estimation of the B/C ratio for flood mitigation projects.

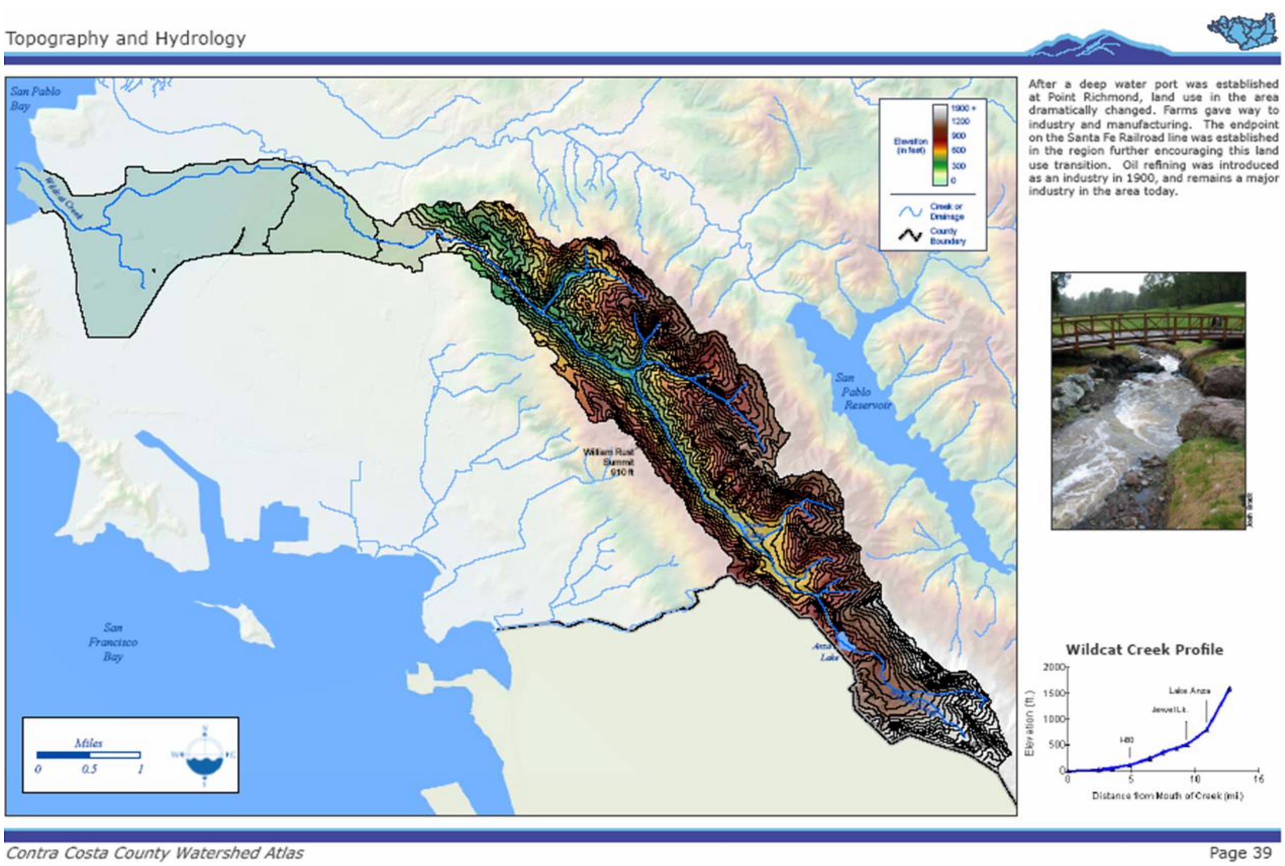
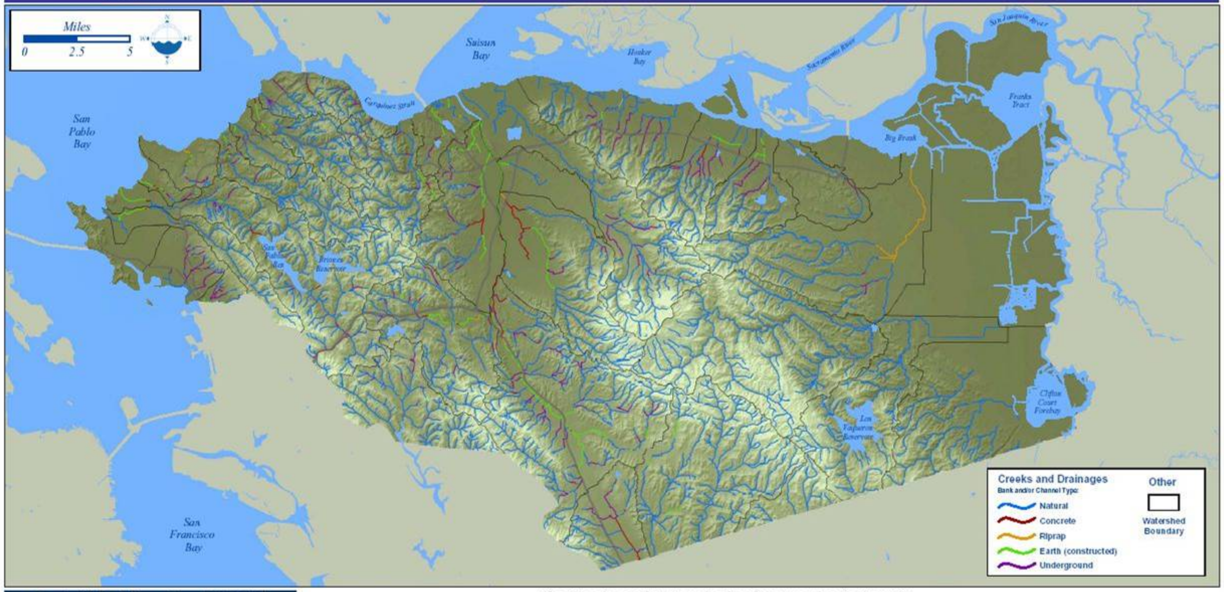


Figure 2 Watershed Map of Wildcat Creek

Creeks and Watersheds



Countywide Creek Channel Length Statistics*	Miles	Percent
Length of Longest Creek in County **	34.57	
Total Length of Creeks & Drainages in County	1,349.63	
Type of Bank or Channel:		
Natural (no obvious reinforcements)	1,148.16	85.1%
Concrete	133.34	9.9%
Earth (constructed)	56.31	4.2%
Riprap	11.13	0.8%
Underground	112.56	8.3%

Notes on Channel Length Statistics Table:

*Data relate to mapped channels only. Does not include storm drains. Bank type for segments shorter than 100 feet was not mapped.

** Marsh Creek is the longest creek entirely within the County.

The Creeks and Watersheds of Contra Costa County

Contra Costa County has 31 major watersheds and sub-watersheds containing more than 1300 miles of creeks and drainages. All but eight of these watersheds are entirely within Contra Costa County. While the Walnut Creek Watershed is very large (93,556 acres) and spans many cities, many of the other watersheds are conveniently "community-sized". For instance, Alhambra and Pinole Creeks are closely identified with (and are important features of) the Cities of Martinez and Pinole respectively.

Creeks and drainages in low-lying urban areas often have concrete-lined or constructed earth banks, or they may actually run underground through pipes and culverts. Such constructed features are designed to manage flood risks and/or minimize the land area necessary to convey water downstream, but may lack the aesthetic and ecological values of a more natural creek system.

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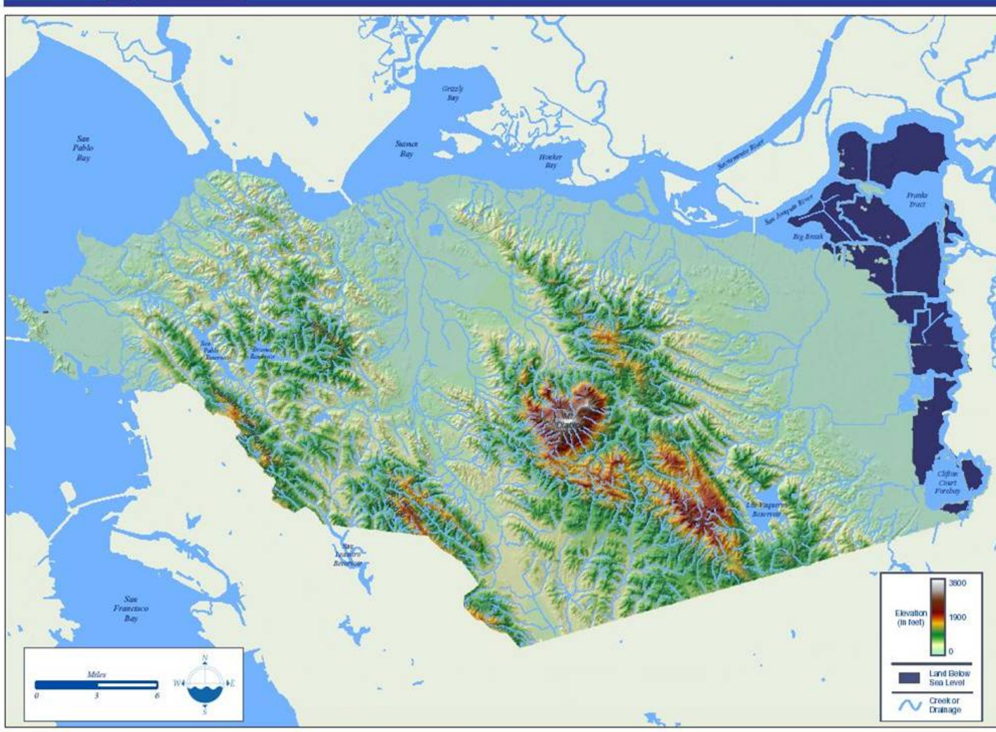
Figure 3 Watersheds and Creek System in Contra Costa County

Topography and Hydrology



Major Landforms

Two major complexes of mountains, ridges, and hills define the physical and hydrological landscape of the County and shape where residents live and work. The first of these ridgeline complexes centers on Mount Diablo, which rises to 3,849 feet above sea level near the center of the County, and extends south to the Altamont Pass area and the remainder of the Diablo Range in Alameda County. The second major complex of hills and ridges lies between the eastern shore of San Francisco Bay and the major valleys in the center of the County. Las Trampas Ridge, the Oakland Berkeley Hills, and the Briones Hills are some of the well-known features in this second area.

Tectonic processes created these mountain and ridge complexes. As the Pacific Plate has slipped northward past the North American Plate, hills and mountains have been created over the millennia. Like a piece of fabric that folds and creases when the edges are pulled in different directions, the surface of Contra Costa County has been pulled northward on the bay shore and southward along the edge of the Central Valley, creating a series of folds and creases that become ridges and valleys. Due to the orientation of the tectonic movement, ridgelines in the County often run from the northwest to the southeast.

These mountain and ridge complexes form the headwaters for nearly all the creeks in the County. Most of these headwater areas have rugged terrain and are not heavily populated or developed. Many headwater areas are used for private rangeland, public parks and watershed land. As creeks flow down to major valleys and coastal plains, the surrounding watershed becomes increasing developed. This trend--light development in the upper watershed and heavier development in the lower watershed--is common in Contra Costa County.

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Figure 4 Topography of Contra Costa County

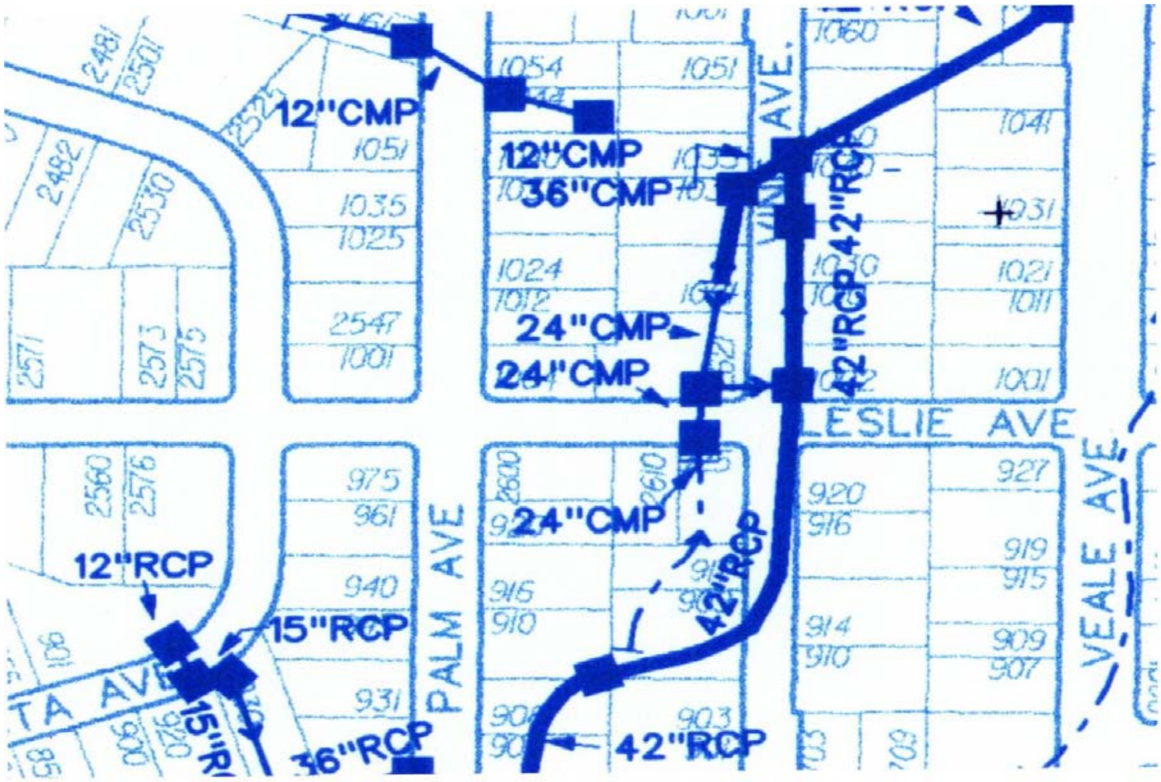

Figure 5 Drainage System

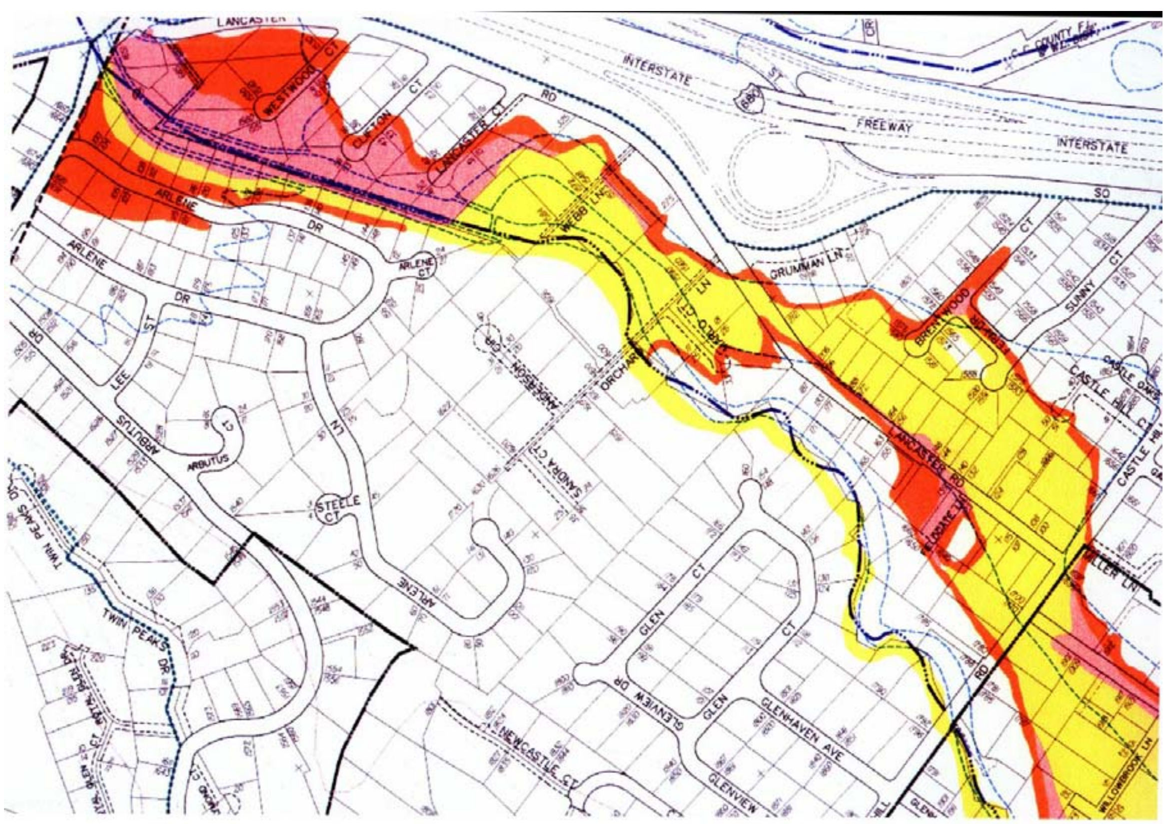

Figure 6 Flood Plans

Figure 7 displays the schematic diagram to illustrate the structure of an automated planning and design of hydro-systems. This system uses GIS as a platform to integrate numerical data, spatial data, and hydrologic and hydraulic models. With interface programs, the input files can be created automatically by delineating the stored numerical and spatial data. Then the input files under the instruction of the operator will be fed to those embedded hydrologic and hydraulic models. The generated outputs will be displayed numerically and graphically. They also can be stored for future use or analysis.

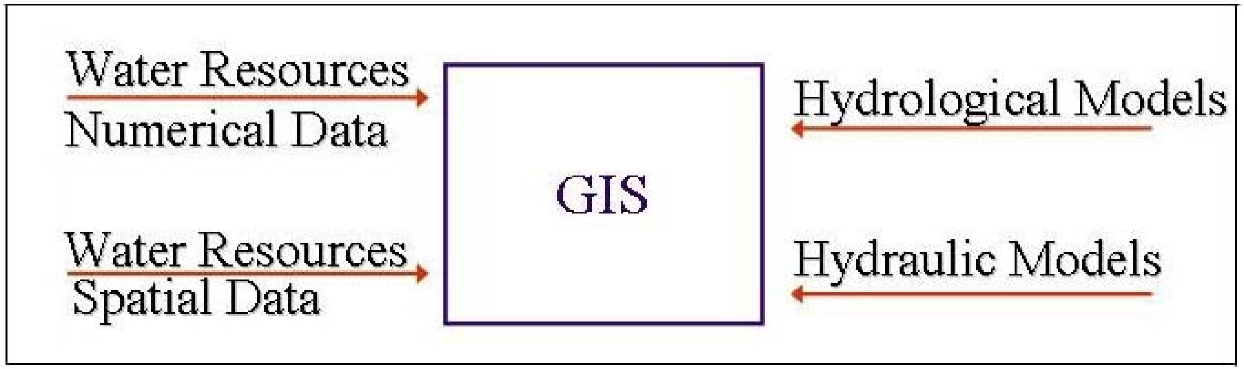

Figure 7 Schematic Diagram of the Automated System

If a design flow is needed to be generated at a location of a watershed, just use the mouse to click at the location in the watershed map. This system will be able to automatically calculate upstream drainage area by using a polygon method. This system will also estimate the channel length, L, and channel length from the centroid, Lca, channel slope, watershed infiltration rate, etc. An input file will be assembled automatically as well, and the input file is then sent to the embedded hydrology model such as HYDRO or HEC-HMS. The generated flood hydrograph and peak flow will be displayed numerically and graphically.

If a water surface profile is needed for a channel reach, then input file will be assembled automatically by the system with a design flow and channel x-sections for the HEC-RAS. The resulting profile can be outputted numerically and graphically.

If the flood mitigation is desired, the flood hydrograph can be routed through a planned or a designed flood detention basin. Figure 8 shows the results of the design of flood detention basins. Two detention basins are studied based on the flood routing, earth work, and the cost of land acquisitions.

3. FUTURE DEVELOPMENT OF THE SYSTEM

A layer of 2-feet elevation contour is under testing, and it should be implemented in the near future. This will further improve the resolution of the system.

A website, *www.ccmaps.us/gis*, is already available to the general public. However, the current website only allows users to view some numerical and spatial data. In the future, it will be able to allow users to review and download all the numerical and spatial data they need. A prepaid account will be set up for the users, and a fee can be charged against the account when service through the internet is provided.

Ultimately, the systems will be open for those capable users to make custom-made plots and maps by combining special selected layers of spatial data. Certain users might also be allowed to access the automated planning and design of hydro-systems to perform hydrologic and hydraulic analysis. In this case, it is as if the office is open 24 hours a day and 365 days a year to serve its customers.

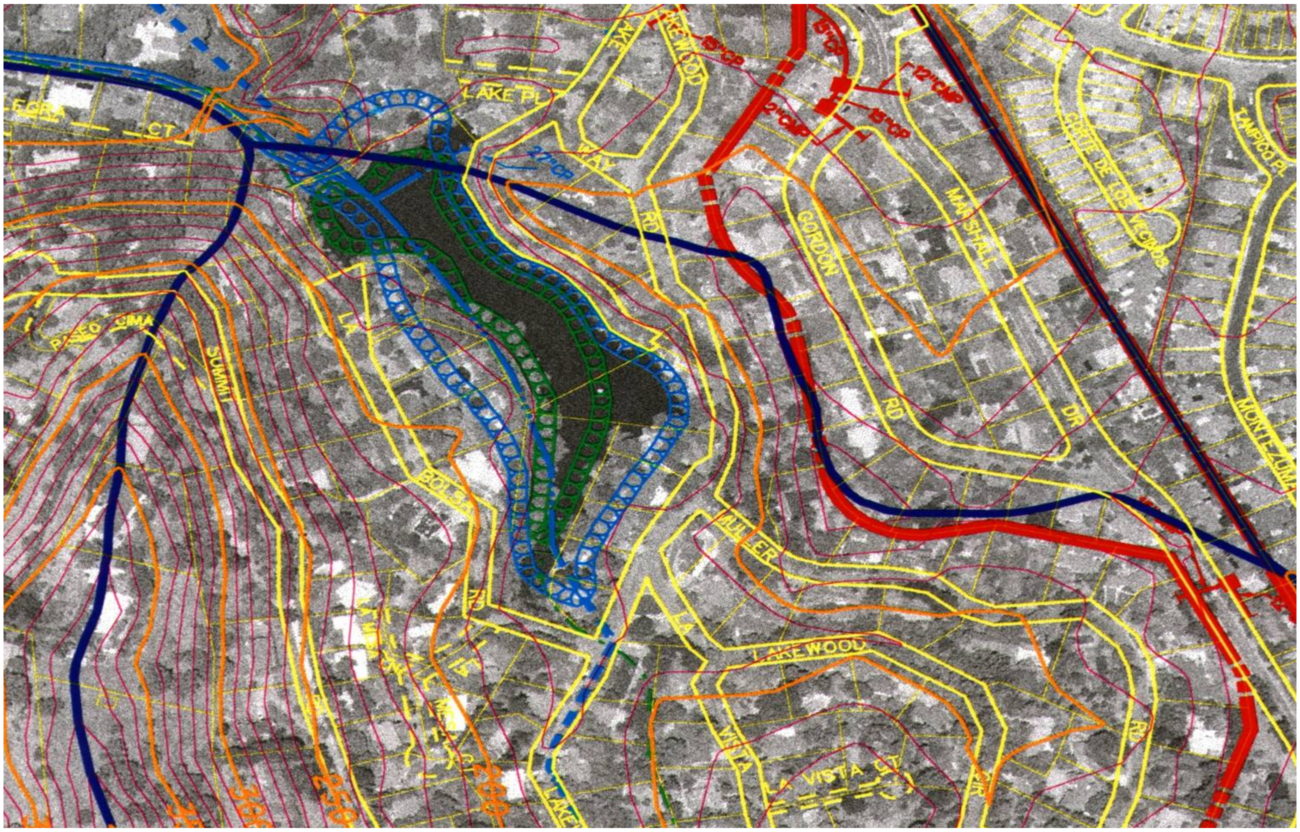

Figure 8 Designs of Detention Basins

The District is also planning to accept engineering calculation packages and plans from consultant engineers through internet for approvals or permits. This will improve the efficient and add convenience to the general public and private engineers.

4. DISCUSSION

The GIS developed by Contra Costa County Flood Control District and the County Public Works Department was built from the 300 scale parcel maps and 5-feet elevation contour. With those high resolution spatial data, this GIS has become a powerful tool for engineering planning and design. The system has been automated and streamlined for routine applications.

The GIS can provide the following benefits, such as, increasing efficiency, reducing cost, improving quality by eliminating human error, and to enhancing presentability. However, the accuracy of the GIS products is still restricted by the accuracy of the numerical and spatial data used, and the hydrologic and hydraulic models employed in the system.

REFERENCES

Hydrologic and Hydraulic-Modeling Support with GIS, ESRI, Redlands, CA 2000
GIS and Water Resources, AWRA, Herndon, VA 1996
Contra Costa Watershed Atlas, Contra Costa County Flood Control District, Martinez, CA 2003