"Comprehensive Hydrology Modeling in a GIS Environment"

Barry Schamach
DBA, Contra Costa County Public Works Department
Co-Authors:
Mark Boucher, Senior Hydrologist, Public Works
Chris Hallford, GIS Analyst, Public Works
Wiley Osborn, GIS Programmer/Analyst, Public Works

Introduction/Overview

Contra Costa County Public Works Department regularly needs to perform hydrologic modeling, to generate projected peak storm flows. This helps engineers determine the infrastructure necessary to handle the increased runoff that development generates. Staff had been performing hydrology modeling using a proprietary in-house FORTRAN program and archiving the results as annotations (points and their peak storm flow values) on hard-copy watershed maps. The points related to hydrology data sheets in binders and/or reports. The modeling program, Hydro6, was run as an executable file and required only a stand-alone PC to perform calculations. The annotated watershed maps often existed only as hard copies in one location, putting them at risk.

Public Works needed a better way to manage its hydrology data. The first phase of the project converted the modeling program from FORTRAN into a PL/SQL database package. The second phase converted the existing paper watershed maps, which were used to organize and georeference all previous calculations, into a new watershed layer. This would enable the use of GIS to store the watershed's input parameters (zoning, roughness, annual rainfall, infiltration, etc.), and then, after running the modeling software, provide georeferencing for all hydrology calculations performed, allowing better access and utilization of the information.

Background

Contra Costa County, California is home to more than a million residents. The county spans more than 800 square miles and encompasses 80 major watersheds. The Contra Costa county Flood Control District is responsible for maintaining more than 72 miles of flood control channels, and identifying infrastructure improvements that reduce flood damages.

When reviewing plans for both private development and public works projects, it is often necessary to review the impact that new impervious surface will have on the watershed's drainage system. Thirty years ago, the Public Works Department's Senior Hydrologist, (Paul Wu, PhD), developed an in-house FORTRAN program called Hydro2, which calculates peak storm flows at a given point on a creek. This program, similar to US Army Corps of Engineers HEC-1 program, uses commonly accepted hydrology concepts to generate a Storm Hydrograph: use of the unit hydrograph, infiltration losses, and rainfall distribution curves. The Flood Control District's adopted unit hydrograph method was different than the options offered in HEC-1 (and its Windows equivalent HEC-HMS) and this method needed to be preserved. The unit hydrograph portion of Hydro2 was incorporated into a program called Hydro6.

Geographic parameters used in Hydro6 include:

- Watershed Area
- Area Rainfall Reduction Factor
- Mean Seasonal Rainfall
- Infiltration Rate
- Channel Length
- Distance from Watershed Centroid
- Elevation Difference
- Roughness Constant (n)

Storm parameters are:

- Storm Duration
- Storm Frequency (or Return Period)
- Initial Loss.

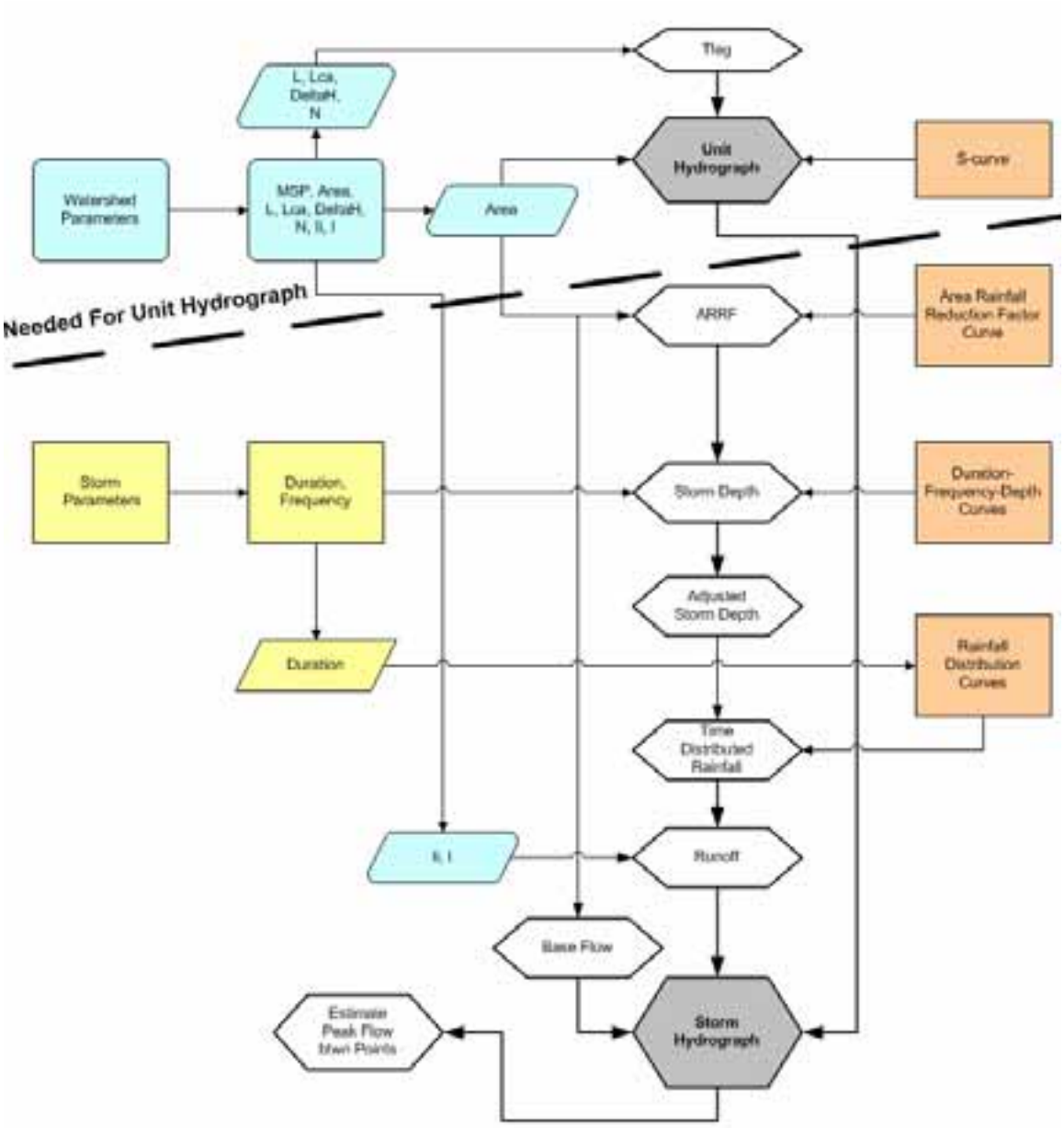

Exhibit A. Hydro6 Flowchart

Program output from Hydro6 consisted of ASCII text files. The input parameters and resultant Peak Flows were represented only on these printouts and could not be saved for later revision and/or re-analysis. Peak flows from the runs were organized via handwritten notations as data point numbers or flows on the District's hydrology maps (Exhibit B). The input parameters and other background information were sometimes stored in an associated report. Via these three separate sources (the hydrograph text printout, the annotated hydrology maps, and the reports), the department's flood control engineers obtained access to the previously run hydrology calculations with some degree of spatial context.

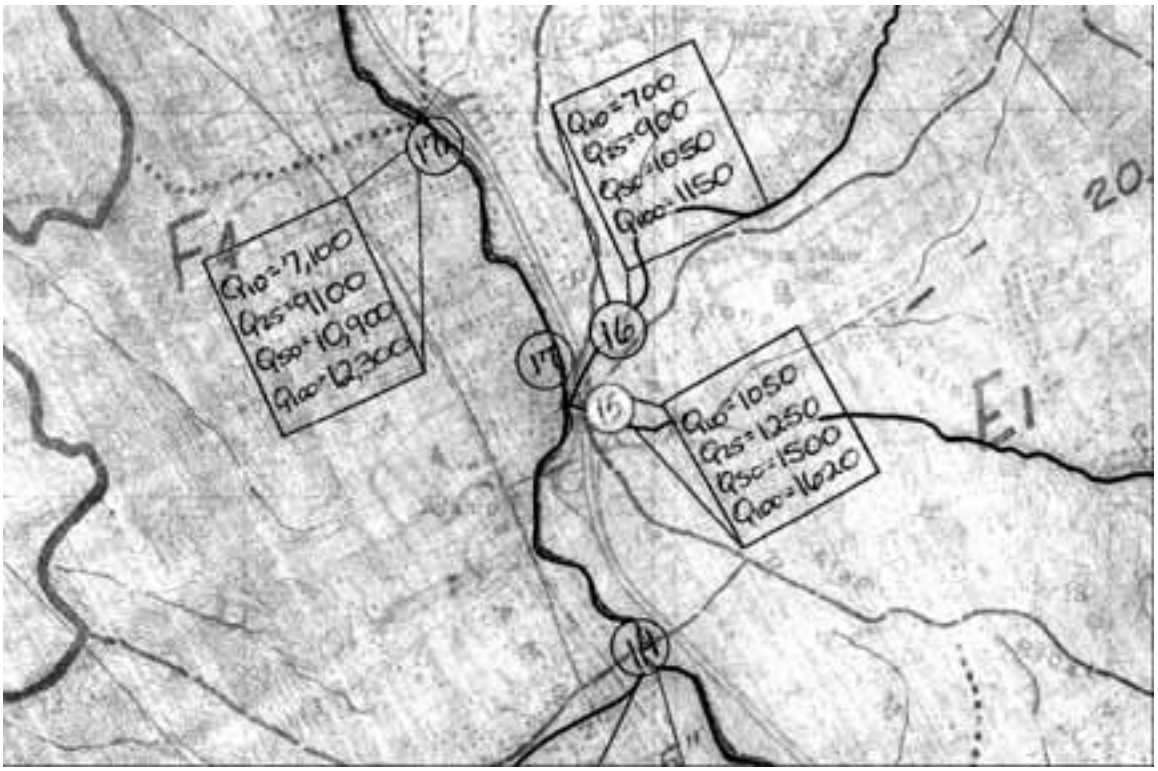

Exhibit B. Annotated Hydrology Map

Pilot Proposal

In 2004, when the department migrated to the Windows XP platform, thought was given to the potential that Flood Control's Hydro6 program may someday not be stable on standard-issue PCs. In addition, the annotated hydrology maps were beginning to physically deteriorate, and were not archived anywhere else putting the Public Works' hydrology dataset at-risk. The Public Works department had begun a business continuity plan and the need for archiving documents was seen as a critical task.

For many years, the Flood Control staff has created hydrographs for private engineering firms for a fee due to the proprietary nature of the program and County Councils advice not to make the program public. The growing use of GIS and internet spurred the desire to find ways to allow private engineering companies to run the hydrology program themselves, potentially via the internet using an online Oracle application that could also tie to GIS.

The Flood Control District came to the Computer Services Division and asked that we explore some new ways of performing the Hydro6 calculations and storing the resulting hydrology dataset. The major deliverables were identified as follows:

- Convert stand-alone Hydro6 program into a database program
- Provide a means of protecting the 'at-risk' paper annotated hydrology maps.
- Provide a new means of storing/organizing the data of all previously run hydrographs (to replace the annotated hydrology maps).
- Provide a new means of storing/retrieving storm hydrograph data, including the input parameters

Public Works had begun to develop a Creek Layer in GIS, and we had in-house GIS expertise, as well as PL/SQL programming resource. We proposed the following pilot project to the Flood Control district:

I. Convert the Hydro6 program into an Oracle database package called Hydro7. The package is called using an Oracle Forms front-end, and stores the resulting storm hydrograph data for future use.
II. Scan the existing annotated hydrology map paper archive, geo-rectify the resulting tiffs, and store images as rasters within an SDE raster catalog.
III. Perform data take-off on the rasters to populate hydrology calculation point features with archival peak flow annotation.

Moving forward, all future Hydro7 calculation points would be stored and attributed in the Hydro Calculation feature class.

I. Hydro7 Program

With the goal of replacing the functionality of existing Hydro6 FORTRAN program, we converted all calculation algorithms into stored database functions and procedures. A database schema was created for the persistent storage of all input parameters and the key output values of lag time, 1-inch volume, unit hydrograph, and storm hydrograph. We created an application (using the Oracle IDE) to run hydrology calculations, store the resulting output, and print out the results. Hydro7 is currently undergoing beta testing by the District's senior hydrology section.

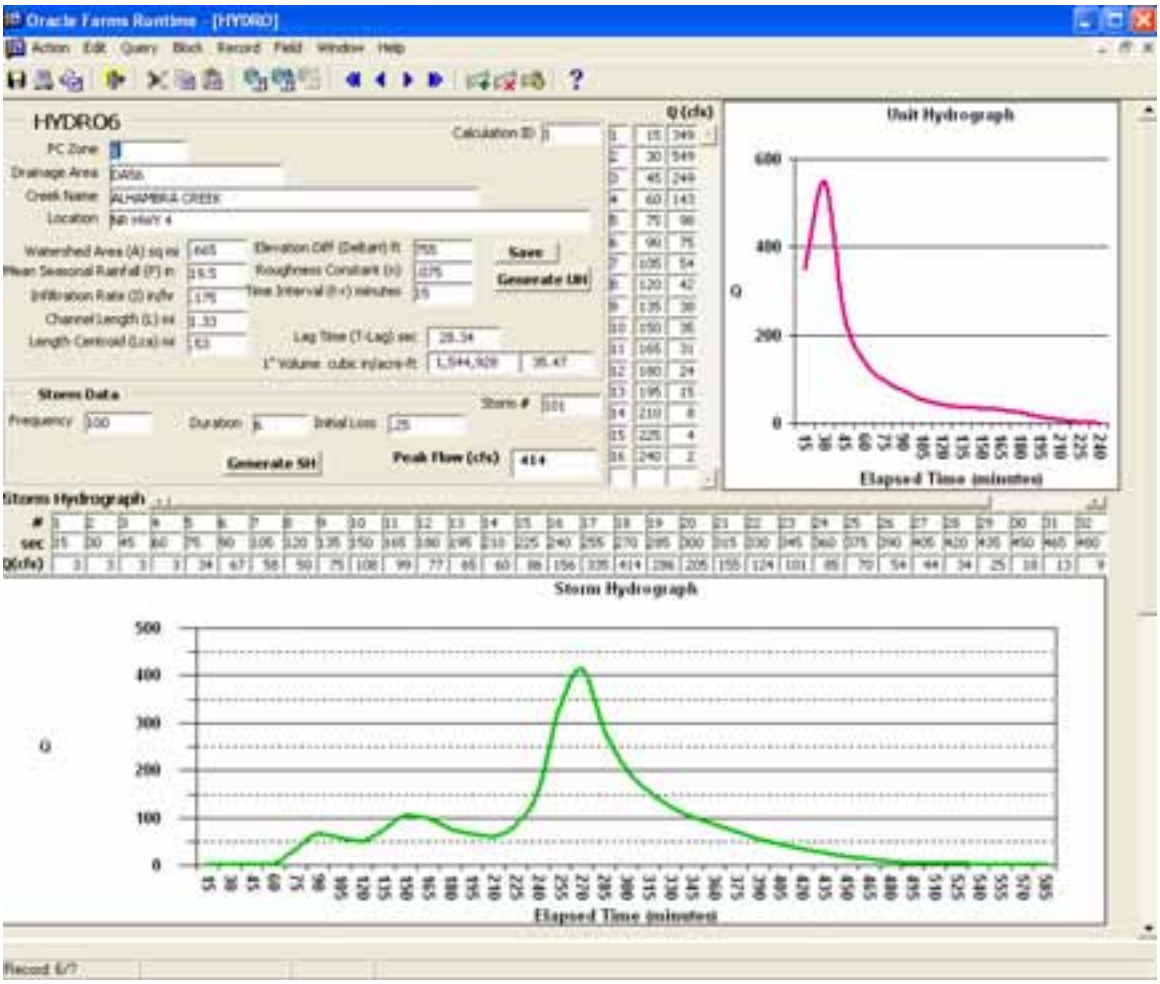

Exhibit C. Oracle Hydro7 Program

II. Annotated Map Scanning & Georectifying

The annotated hydrology maps were scanned into high-resolution tiffs. The tiffs were then geo-rectified and loaded into an Oracle instance, where they are stored as rasters within an SDE raster catalog.

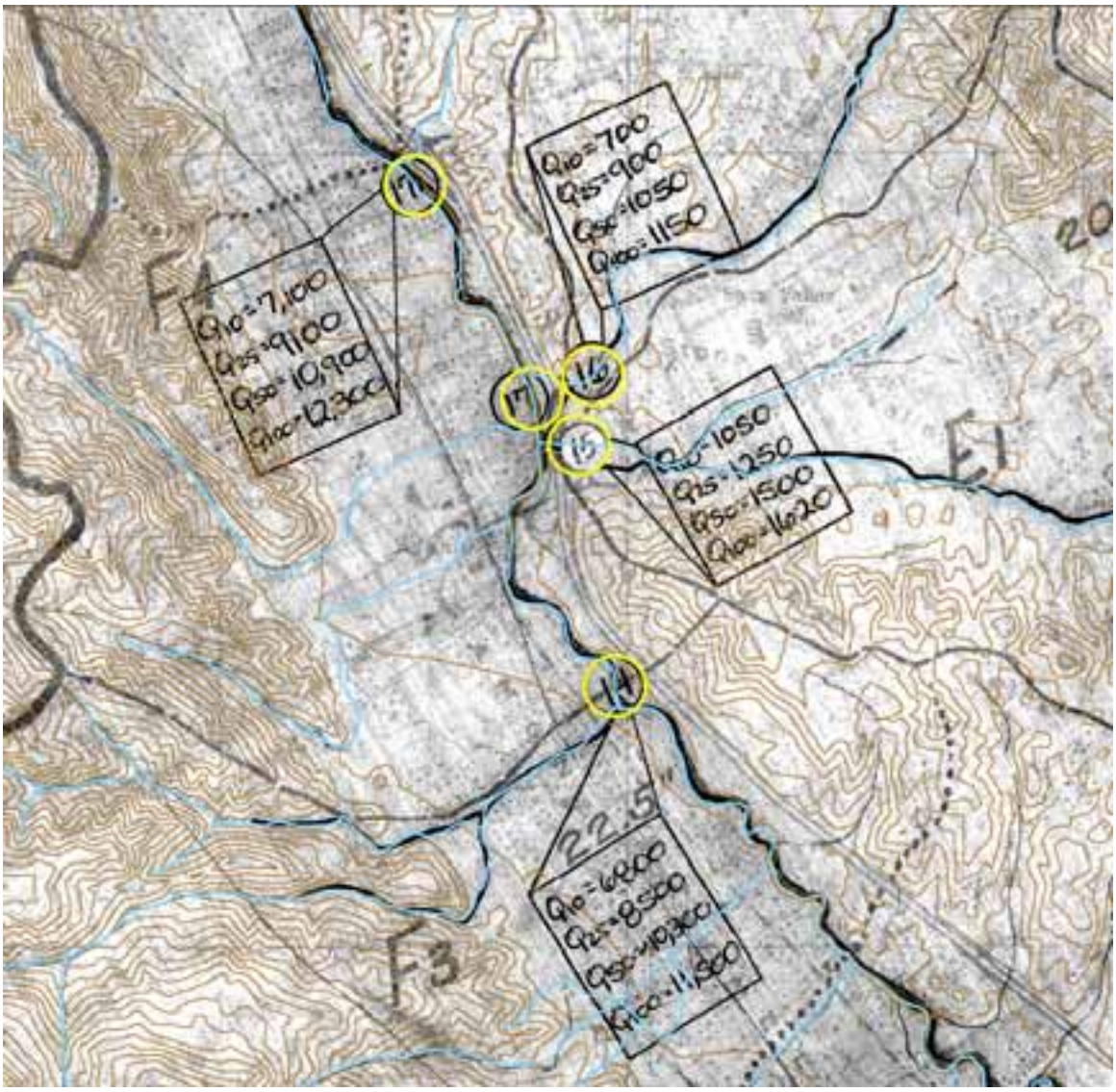

Exhibit D. Scanned/Georectified Map

III. Data Takeoff

Data takeoff represents the most critical phase of this process, in that we are creating new spatial data that is essentially replacing the archived map data. As such, the methodology for data take-off is carefully established, reviewed by the 'customer', and documented thoroughly. The raster scan (from the previous step) is helpful in providing some degree of spatial context via contour lines and drainage features. The following methodology was established for placement of the Hydrologic points:

1. The confluence layer, point layer (points 10'upstream/downstream from all creek confluences), and creek layer are used as snapping guides when creating the points.
2. Flow direction of the creek is determined by using the digital elevation model and the ArcHydro drainage layer as references
3. Hydrologic points are placed according to their type. A protocol was established for placement of the points, which is applied after determining if a point was a 'confluence', 'infrastructure', or 'subwatershed'.

Attribute take-off is then performed. Pilot project attributes were entered manually, future users will employ an ArcObjects VBA form to input attributes to Oracle.

Exhibit E. New Hydrologic Data Points Displayed as Part of Creek Layer *(TO BE ADDED LATER)*

Storing New Hydrologic Points w/Spatial Context

Staff is currently in the process of enhancing the Hydro7 application by adding a geospatial component. When completed, the following benefits will be realized:

- District and private engineers will be able to use a spatial query to determine the existence of previously generated storm hydrographs
- The process of entering all the storm hydrograph parameters will be streamline. Instead of entering each of the dozen parameters by hand, reference layers (digital elevation model, isohyets layer, land use (to derive roughness constant) will be utilized to automatically generate the necessary input parameters (except for storm characteristics).
- Once an API has been created for ArcHydro, we will automate the process of watershed delineation, so that it will no longer be a manual process, thus saving much engineering labor.

Conclusion

Initial results have been promising, and it is likely that the pilot project will be approved and the rest of the project will be successful. The goal of protecting the at-risk documents can be realized, and staff will have a stable Hydro program that stores all calculation results for future reference. In addition, GIS will provide a greater level of automation for entering the parameters into Hydro 7, and will provide a way of accessing previously run Hydrographs in a spatial context.