Preliminary Investigation A:
Hydrology, Hydraulics And Geomorphology Data Needs & Availability

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Introduction

Information is being collected in support of the *Arroyo Seco Watershed Restoration Feasibility Study* (*ASWRFS*). The goal of the study is to develop a technically sound strategy to naturalize the Arroyo Seco stream and improve flood management, water quality, the natural habitat of the Arroyo, and recreational opportunities and linkages.

The purpose of this technical memorandum is as follows:

1) Summarize the technical information needs required to support the *ASWRFS*;
2) Summarize the existing information gathered to date on the hydrology, hydraulics and geomorphology of the Arroyo Seco Watershed; and
3) Identify critical issues and gaps in knowledge related to these disciplines.

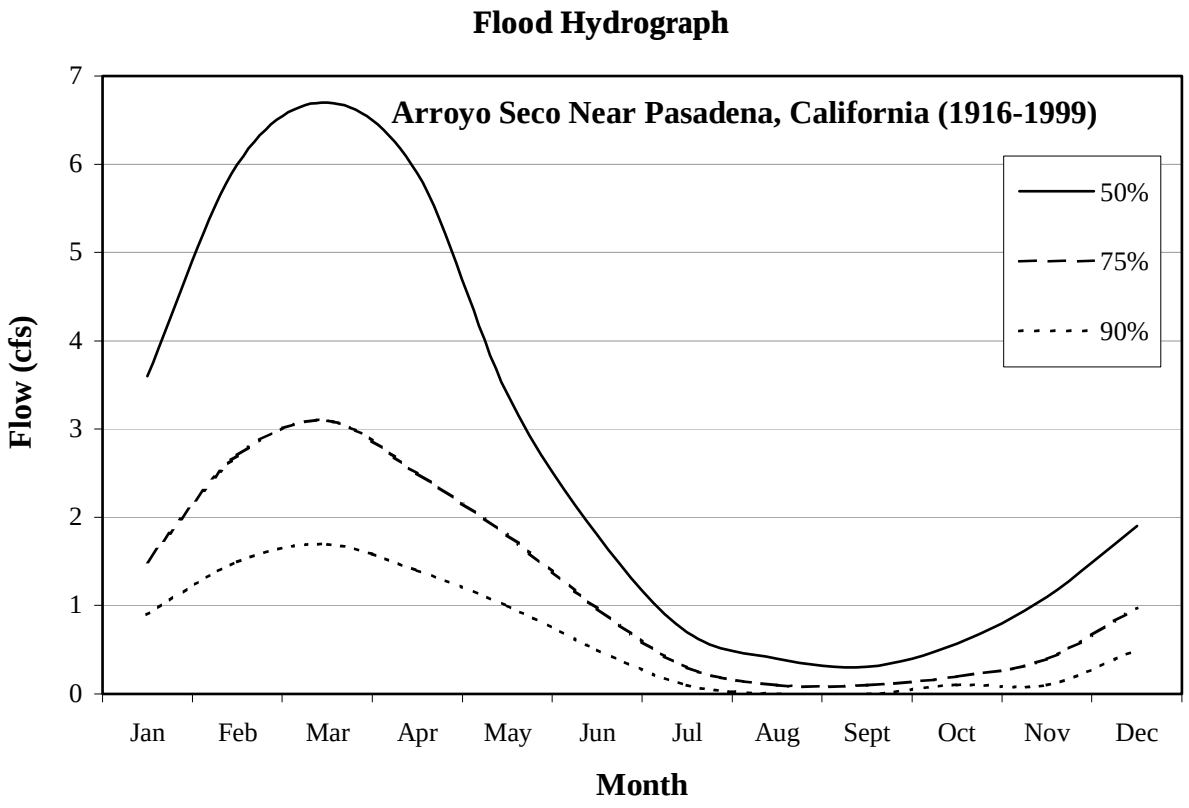
A technical memorandum summarizing our preliminary analysis and conclusions developed from these data will be completed in early March 2001. A technical memorandum on hydrologic, hydraulic and geomorphic opportunities and constraints will be provided in Phase 2 of this project.

The information being collected is based on our understanding of the goals and objectives of the study as defined in the memoranda prepared by the *ASWRFS* Project Team titled: Draft Goals and Objectives dated January 3, 2001 and the memo titled: Assumptions and Guidelines dated December 21, 2000 (cf. Appendices B and A).

The study area consists of the entire Arroyo Seco watershed, with special emphasis on the section below Devil's Gate Dam where most of the desired channel enhancements will occur.

Technical Information Needed For ASWRFS

This section briefly describes the specific kinds of engineering information needed to complete the *ASWRFS*, and indicates why this information is important. This information must be collected from existing reports and studies, or developed by the *ASWRFS* study team.

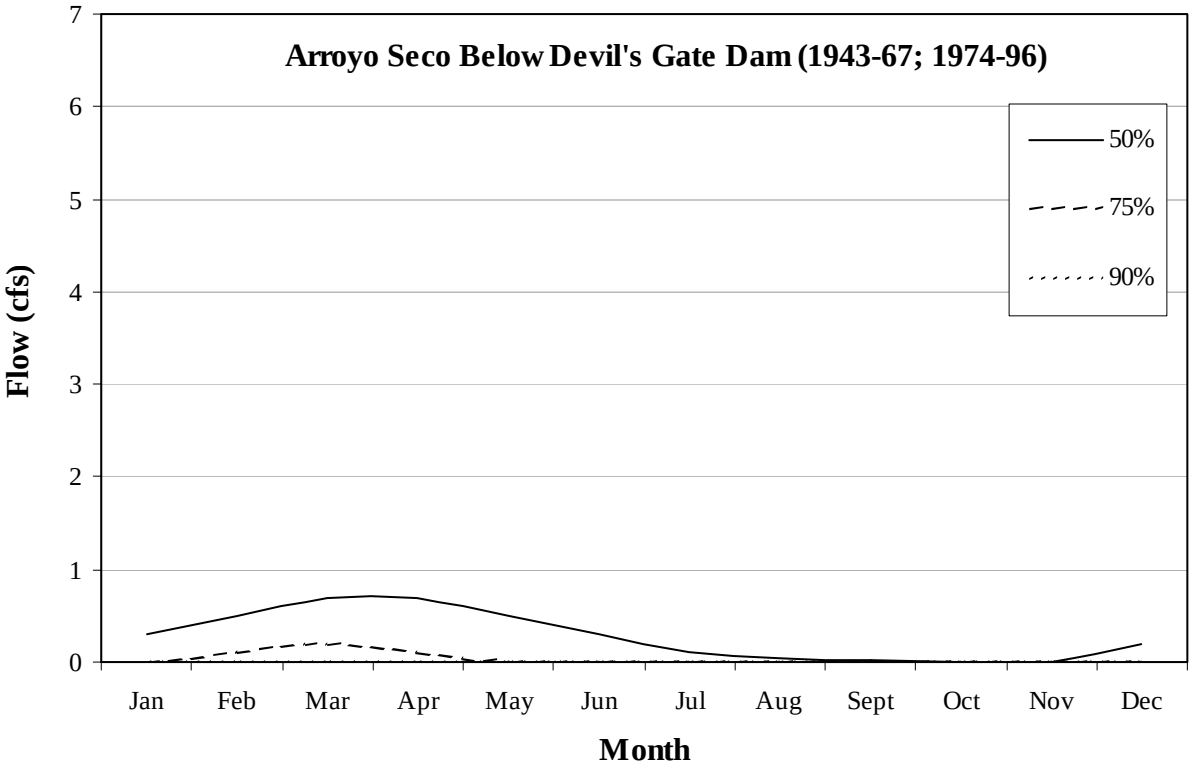


Hydrology

Hydrologic processes in the watershed are drivers for creation of channels, floodplains, and other geologic features. Success of the stream enhancement project requires an understanding of historic runoff conditions, as well as conditions expected subsequent to implementation of possible watershed enhancements. Following are the key items related to watershed hydrology that must be determined to support the *ASWRFS* effort.

1. Peak flood flows and hydrographs with recurrence intervals from 2 years to over 100 years throughout the Arroyo Seco channel. The 2-year peak flow is the bankfull or channel-forming discharge in a natural stream system and will be used for sizing the naturalized stream channel; the 100-year flood is the regulatory flood adopted for floodplain management purposes by the Federal Emergency Management Agency.
2. Peak flood flow and hydrograph for the Capital Storm throughout the Arroyo Seco channel. The Capital Storm is the Los Angeles County Department of Public Works design storm, and consists of a 50-year storm event occurring over the entire built-out watershed.
3. Flow duration curve (percent of time flows are equaled or exceeded) and average monthly distribution of daily flows upstream and downstream of Devil's Gate Dam. Upstream data will establish natural flow patterns to be mimicked by the project; downstream data will determine baseline if reservoir operation is unchanged.

4. Location of major tributaries and peak inflows for a range of recurrence intervals.
5. Elevation-volume-discharge data for Devil's Gate reservoir. Upstream hydrographs will be routed through the reservoir to establish flood flows in the channel enhancement area.
6. Computer simulation model of Arroyo Seco watershed. The model will be used to: (1) test proposed watershed management BMPs and their effect on reducing flows in the study area; (2) test proposed operation plans for Devil's Gate reservoir; (3) compute flood peak attenuation in a naturalized floodplain below the dam.

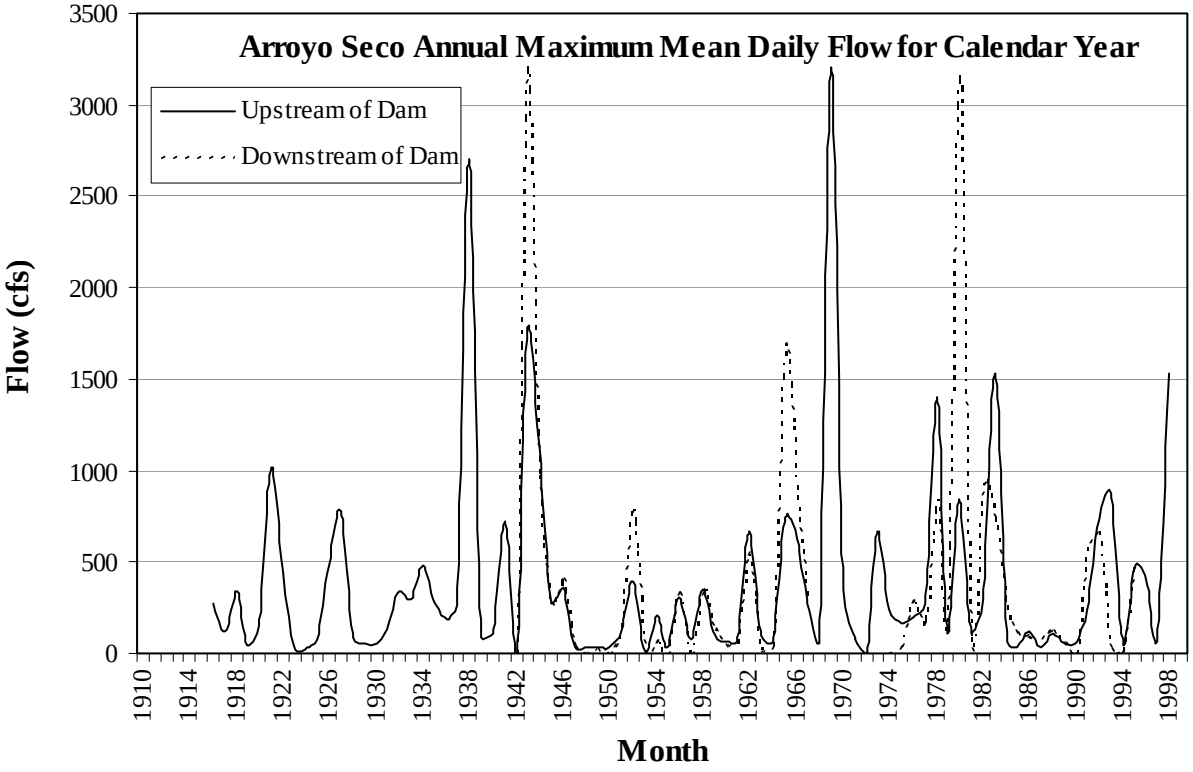


Hydraulics

In order to develop a feasible stream enhancement plan, it is necessary to understand the hydraulic conditions of the existing channel and floodplain system, and have engineering tools to support analysis of alternative channel/floodplain configurations. The following are the key items related to channel hydraulics that must be determined to support the *ASWRFS* effort.

1. Existing Arroyo Seco channel capacity and deficiencies. This will determine areas where the existing channel cannot carry the Capital Storm discharge and where modifications would have to be made to the existing system to provide adequate flood protection.
2. Floodplain storage volume. Flood storage in the Arroyo Seco floodplain could reduce peak discharges if the channel is naturalized and flows are allowed to spread out into the overbank areas.
3. Map of existing flood-prone areas.
4. Computer simulation model of Arroyo Seco channel hydraulics. The model will be used to: (1) test alternative naturalized channel designs; (2) determine depths and velocities in

a naturalized floodplain; (3) determine hydraulic characteristics in alternative naturalized channel designs as input to geomorphic evaluations.



Geomorphology

An understanding of the geomorphic processes active in the Arroyo Seco watershed and channel is important to ensure that stream restoration efforts are successful. The input, transport, and storage of sediment in the stream channel play a fundamental role in providing the substrate, channel form, and stability of a channel and the basis of aquatic and riparian habitat. Geomorphic information needed for the Arroyo Seco stream restoration project includes:

1. Assessment of the location, volume, grain size, and timing of sediment inputs to the stream channel. Sediment load and flow rate are critical factors in channel function, and must be understood to design a properly functioning stream system. This is particularly important on the Arroyo Seco due to the high sediment production from the upstream watershed.
2. Channel invert profile. Channel slope is one of the key factors in stream geomorphology.
3. Map of the underlying geologic or constructed constraints on the stream. Locations of terraces, rock outcrops, and man-made constraints on channel and floodplain width and elevation must be incorporated into the stream enhancement plan.
4. Understanding of the sediment transport and storage capacity of different reaches of the Arroyo Seco. These factors control potential stream channel formation and adjustment to upstream flow and sediment inputs.

Summary Of Available Data

Available Hydrologic Information

Streamgage Data. Daily streamflow records were collected for the two active gaging stations on Arroyo Seco. Gage sites and periods of record are summarized below.

Table 10: Streamflow Data

Gage Name	Arroyo Seco near Pasadena, CA	Arroyo Seco below Devil's Gate	*
Location	Upstream of Devil's Gate Dam	Immediately downstream of Devil's Gate Dam	*
Operation Agency	USGS	LACDPW	Pasadena Water and Power
Gage Number	11098000	P277-R, F277-R	*
Drainage Area	16 square miles	32.5 square miles	*
Period of Record	1916 - 1999	1942 – 1969; 1974 - 1996	1919 - 1965

* Information not provided by Pasadena Water and Power

Devil's Gate Dam Rehabilitation Hydrologic Analysis

This study was performed by Harza Engineering as part of the recent dam and spillway rehabilitation project. The following reports were collected and reviewed.

- Rehabilitation of Devil's Gate Dam, June 1993.
- Design Criteria Report for the Rehabilitation of Devil's Gate Dam, February 1994.
- Design Criteria Report for the Rehabilitation of Devil's Gate Dam, Appendices A – D, February 1994.
- Design Criteria Report for the Rehabilitation of Devil's Gate Dam, Appendices A – G, November 1994.

These reports describe hydrologic modeling analyses using the U.S. Army Corps of Engineers HEC-1 model and the LACDPW Runoff Forecast model for the area upstream of Devil's Gate Dam. The models were used to analyze the Capital Storm and two Probable Maximum Storms (general storm and local thunderstorm). Modeling results include inflow and outflow hydrographs at Devil's Gate reservoir for these storms. Hydrologic modeling does not extend to the watershed downstream of the dam.

Hahamonga Watershed Park Master Plan.

The Hahamonga Watershed Park Master Plan developed by the City of Pasadena included an analysis of hydrologic, hydraulic and geomorphic conditions in the Hahamonga (Devil's Gate) basin and the upstream watershed. This work is summarized in a report entitled "Flood Hazard, Sediment Management, and Water Feature Analyses, Hahamonga Watershed Park, Pasadena,

CA" by Philip Williams & Associates (January 17, 2000). This report provides the following information useful to the *ASWRFS*.

- Annual precipitation amounts for nine LACDPW gages located in a near the Arroyo Seco watershed
- Monthly distribution of average precipitation for three National Weather Service gages near the study area
- Evapotranspiration data for Devil's Gate Reservoir
- Operation rules for Devil's Gate Dam
- Summary of surface and ground water supply management at Devil's Gate
- Flood-frequency analysis for the USGS gage upstream of the dam and for total reservoir inflow
- Results of routing 2-yr, 10-yr, 50-yr, and Capital Storm hydrographs through the reservoir (inflow hydrograph plots, maximum stages in the reservoir). This can be used with the stage-discharge curve for the reservoir to compute downstream peak flows for these recurrence intervals.

LACDPW Hydrologic Modeling

Previous hydrologic analyses for Arroyo Seco conducted by Los Angeles County were performed using tabular methods. No simulation model for the entire watershed currently exists. However, LACDPW staff is currently in the process of developing a simulation model of the watershed using the Watershed Modeling System (WMS) software. This software links GIS technology and common hydrologic modeling techniques, including the LACDPW hydrologic methodology. LACDPW will use this model to simulate the Capital Storm. The model will then be provided to the project team to conduct other hydrologic analyses necessary for the *ASWRFS*. The LACDPW model will have the following characteristics:

- The model will be executed for the Capital Storm, but 2-year through 500-year rainfall data will be incorporated into the database.
- The watershed above Devil's Gate will be subdivided into about 100-acre subbasins. The area below Devil's Gate will be subdivided into about 40-acre subbasins.
- The model will assume build-out land use conditions.
- The model will simulate an "adequately collected system," meaning that there are adequate minor facilities (e.g., streets, inlets, storm drains) to get all the runoff into the main channel.
- The model will route flows through Devil's Gate reservoir and the downstream floodplain.

Flood Insurance Study Reports

Flood Insurance Studies (FISs) are prepared by the Federal Emergency Management Agency (FEMA) for flooding sources throughout the country. FISs are published by community, and include hydrology tables with 10-, 50-, 100-, and 500-year peak discharge values. Research with FEMA and the Cities of Los Angeles, Pasadena and South Pasadena determined that no FIS report information has been published for Arroyo Seco. Thus no flood flow data are available from this source.

Available Hydraulic Information

As-Built Drawings of Existing Arroyo Seco Channel. Design drawings for repairs to the original Arroyo Seco channel were provided by LACDPW. They cover the reach from the Los Angeles River to Devil's Gate Dam. Drawings show plan views and details for minor channel repairs; they do not include channel profiles or cross sections.

Table of Channel Capacity Deficiencies. LACDPW staff provided a table of locations where the existing Arroyo Seco channel capacity is less than the Capital Storm design flow. This does not show channel capacities for all locations in the study area; it only includes data for deficient areas. The table appears to report channel capacity based on bankfull conditions without any freeboard allowance.

Devil's Gate Dam Rehabilitation Hydraulic Analysis. Harza used the U.S. Army Corps of Engineers HEC-2 model to analyze a portion of Arroyo Seco below Devil's Gate Dam. The hydraulic analysis was performed to determine tailwater conditions for the new dam spillway outlet structure. The model started 1,000 feet upstream of the Rose Bowl and extended to the Devil's Gate Dam outlet. Five discharges were simulated in the range from 15,000 cfs to 35,350 cfs. Water surface profiles were developed for each flow analyzed.

WSPG Model of Arroyo Seco. LACDPW staff has indicated that a Water Surface Pressure Gradient (WSPG) model may have been developed for the Arroyo Seco channel at one time. WSPG is the Los Angeles County hydraulic modeling package. However, at this time they have not been able to locate the model.

FEMA Floodplain Maps. Floodplain maps have not been published for Arroyo Seco. As described above, FEMA has not published flood insurance studies for Los Angeles, Pasadena or South Pasadena that include Arroyo Seco. FEMA began their studies in the 1970's nationwide, and they may have assumed that the improved channel in the Arroyo Seco had adequate 100-year discharge capacity at that time.

Available Geomorphic and Sediment Information

Existing information on the geomorphology and sediment input and transport in the Arroyo Seco basin has been obtained from the following sources to date.

- The Hahamonga Watershed Park Master Plan flood and sediment management report referenced previously (Philip Williams & Associates, 2000)
- The "Rehabilitation of Devil's Gate Dam Design Criteria Report" (Harza 1994)

- Analysis of aerial photographs
- USGS topographic maps.

Summary Of Hydrology Data And Study Needs

This section provides a detailed discussion of data needs and additional studies required to plan and design the *ASWRFS*. A table is provided at the end of the discussion, which summarizes this discussion (Table 1).

Hydrologic Needs

1. Acquire the WMS watershed model from LACDPW when it is completed. This will allow peak flows of various return periods to be computed throughout the study area for existing conditions and for alternative watershed management strategies to be evaluated. It can also be used to assess the impacts of possible water conservation storage in Devil's Gate reservoir on flood releases and downstream peak flow rates.
2. Conduct additional research into local groundwater conditions in the Arroyo Seco floodplain downstream of Devil's Gate Dam. Determine potential interactions between surface and ground water if the concrete channel is replaced by an unlined natural channel. Ground water may be increased and provided.

Hydraulic Needs

1. Determine existing channel capacities in sections where there are not current deficiencies. The table provided by LACDPW to date only includes information for deficient sections.
2. Determine existing channel geometry data (depth, side slope) that can not be ascertained from the drawings currently provided to the project team.
3. Extend the Harza HEC-2 model downstream from the Rose Bowl to the Los Angeles River confluence. This will allow different naturalized cross sections to be evaluated in terms of impact on floodplains, channel velocities, flood depths, and other factors.

Geomorphic Needs

1. Develop a method of determining sediment transport characteristics between Devil's Gate Dam and the Los Angeles River. Sediment transport modeling can be accomplished using the results of the hydrologic and hydraulic modeling discussed above.
2. Determine where local scour and erosion or deposition may occur if channel is removed.
3. Determine if there is potential for long term degradation (lowering of channel bottom) or aggradation (sediment deposition over a large area).

Ultimately all of this information will help in the development of a sediment management plan.

Table 11: Summary of Data Needs and Availability (Hydrology)		
Information/Data Need	Currently Available	Data Gap and/or Action Plan
Peak flows in study area for 2-yr to 500-yr return periods	Devil's Gate Dam inflow	Missing peak flows for key locations from Devil's Gate to the Los Angeles River. Will be generated from watershed model under development by LACDPW.
Capital Storm flows in study area	Devil's Gate Dam inflow and outflow; Arroyo Seco channel in deficient reaches below Devil's Gate	Missing non-deficient reaches of Arroyo Seco. Should be available from LACDPW.
Flow duration curve upstream and downstream of Devil's Gate Dam	Yes	None
Monthly flow distribution upstream and downstream of Devil's Gate Dam	Yes	None
Location of major tributaries, and peak inflows for range of frequencies	No	Should be available from LACDPW
Elevation-volume-discharge table for Devil's Gate Reservoir	Yes	
Groundwater elevations along Arroyo Seco channel	No	Need to research data availability from local sources
Hydrologic model of Arroyo Seco watershed	No	Under development by LACDPW
Existing channel capacities and deficiencies	Capacities and deficiencies in deficient sections only	Need capacities in non-deficient sections. Should be available from LACDPW.
Floodplain storage volume	Estimated from USGS maps by MWH	None
Map of existing flood-prone areas	None	Could be developed by Corps of Engineers or LACDPW if necessary
Hydraulic model of Arroyo Seco channel/floodplain	None	In Phase 2 work plan
Sediment input characterization	Yes	None
Channel invert profile	Yes	None
Map of geologic and man-made constraints	Information is available, but map has not been prepared	MWH to prepare map
Sediment transport and storage capacity of Arroyo Seco	None	In Phase 2 work plan