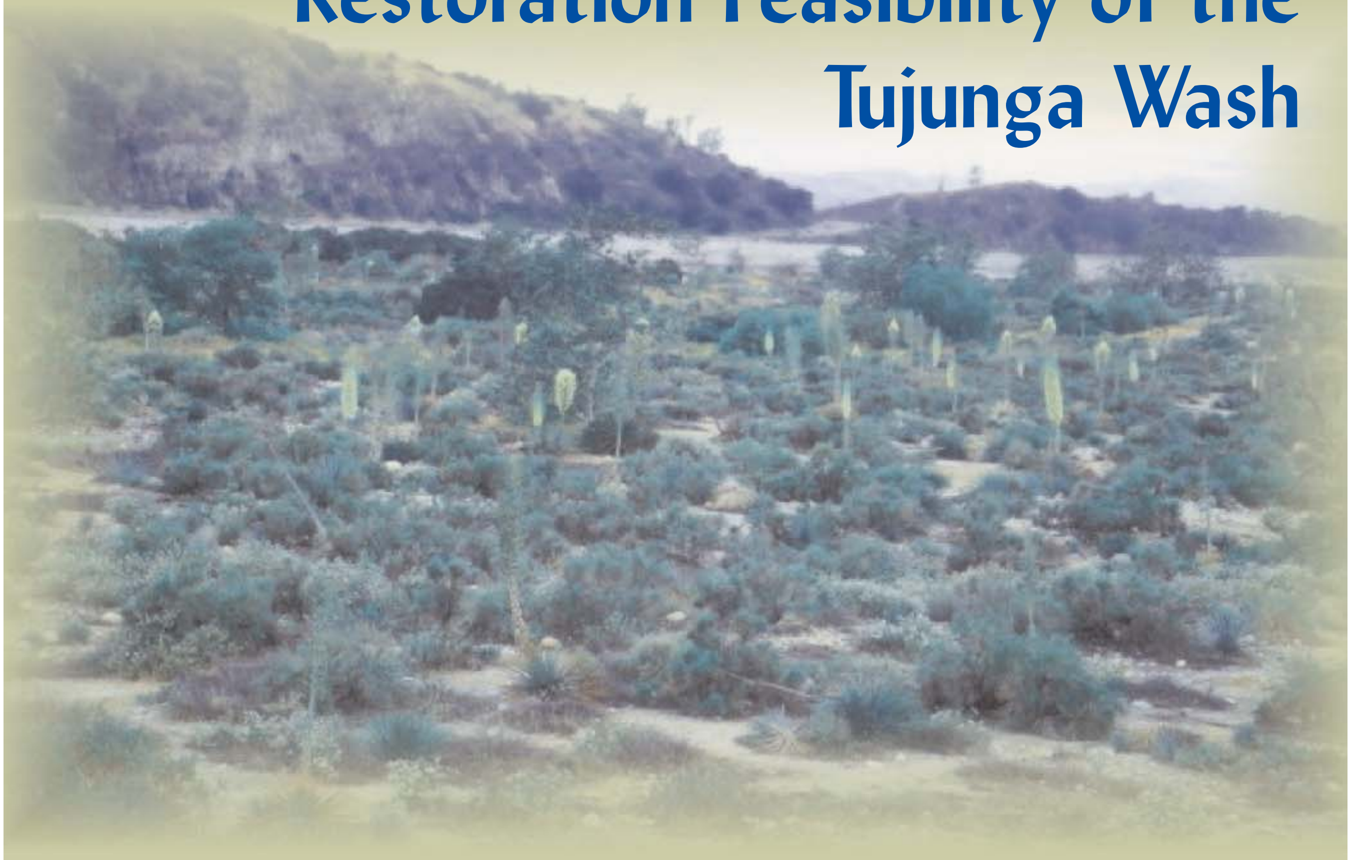
Hydrodynamic Study for Restoration Feasibility of the Tujunga Wash



A Report to

The California Coastal Conservancy
and
The Los Angeles & San Gabriel Rivers Watershed Council

By
The RIVER PROJECT
WaterCycle Inc.
Philip Williams & Associates, Ltd.

March 2002

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Cover Photo: Tujunga Alluvial fan scrub plant community above Hansen Dam, circa 1990, photo by N.C. Perala

Hydrodynamic Study for Restoration Feasibility of the Tujunga Wash Corridor

Executive Summary

The River Project undertook this study of the Tujunga Wash, funded by the California Coastal Conservancy and sponsored by the Los Angeles and San Gabriel Rivers Watershed Council, to address planning for ecological rehabilitation and enhancement projects within this once dynamic, formerly alluvial reach of the Los Angeles River system. A MIKE11 computer-based hydrodynamic model of the system was created that can be linked with an existing model of the Los Angeles River built for the Taylor Yard feasibility study, also funded by the Coastal Conservancy. This earlier model extends in skeletal form from Sepulveda Basin on the Los Angeles River to the ocean at Long Beach. Both models used existing hydrologic, hydraulic and other data available from the Army Corps of Engineers and Los Angeles County.

The Tujunga Wash model has predicted the effects of potential physical changes to parts of the system, including the effects of proposed modifications in flood management strategies. In addition to the model, we developed a planning framework that included the historical context for today's situation and current plans for change, together with evaluation criteria and five major design concepts or strategies. The most severe technical criterion is the need to reduce the high flood flow velocities (from supercritical to subcritical), implying an hydraulic threshold which is dependent on channel slope and roughness. The strategies developed may provide opportunities for system modification either as "stand-alone" concepts or in combination, depending on the storage opportunities available and consensus to be achieved among the many stakeholders.

A number of questions were formulated between the project team and the Technical Advisory Committee (TAC) in order to shape the analysis of the alternatives. The model was used to test some alternatives (concepts quantified to fulfill the criteria) that were put forward within a comprehensive technical planning framework. Use of these alternatives and further modeling will enable a wider, consensus-driven process to facilitate research, education and planning for restoration on the Tujunga Wash system.

To provide a marker for existing conditions, two alternative concepts (A & B) illustrate the channel dimensions needed to contain design flood flows; however, the land-take required makes these alternatives infeasible in most locations. However, the form of the channel needed for rehabilitation will be similar to these concepts to meet a lower design flow that is reduced by increased storage upstream. Dimensions shown for a braid channel through the spreading grounds (alternative C) are closer to what may be practicable. Analysis of the Mountains Recreation Conservation Authority (MRCA) Alternative 3 showed that this proposal does not affect flow conditions nor does it represent rehabilitation of the Tujunga Wash. Rather, it would occupy part of the "riparian" area of the Tujunga Wash that may be required for a future rehabilitation of the main channel through this reach.

Decisions on future dam operations, together with the use of the gravel pits and spreading grounds, were found to be critical to the potential for and success of enhancing channel and riparian areas downstream. Planning decisions, for example future flow releases from Hansen Dam operating as a water resource facility, could benefit rehabilitation efforts by taking into account the hydrology needs of these projects. The next stage of feasibility for in-channel and most non-channel alternatives would benefit from knowledge of the new Hansen Dam operation rules, and of the conditions under which the gravel pits could be made available for storage of floodwater. The feasibility of deepening the spreading grounds is also a possibility that could enhance the practicability of rehabilitation. If enough storage could be utilized, it is possible that the entire length of the Tujunga Wash could be rehabilitated. This possibility should be investigated before any piecemeal rehabilitation efforts are carried out.

The potential for utilizing urban runoff for ecological enhancement, similar to the work being carried out in the adjacent Sun Valley (see Sun Valley Watershed Plan), is a study that is independent of future dam operation. The benefits of utilizing runoff in this way will need a modeling linkage between surface hydrology and the existing groundwater model, perhaps utilizing GIS modeling techniques.

There are therefore many questions remaining to be answered before any priority can be attached to the major alternatives. There is considerable potential for combining alternatives; the questions are: how and where? The most exciting prospect is the potential for the use of the gravel pits and dam storage to allow the complete in-channel rehabilitation of the entire length of the Tujunga Wash, as well as braid channels in the spreading grounds, without loss of flood protection or infiltration capacity.

At this stage of planning, it was found not credible to identify the costs of each alternative without specifying their location, structural features, and extent. Greater concept refinement is needed to specify what the alternative(s) will entail and what is the likelihood of ancillary costs such as diversion of infrastructure facilities such as conduits for power, water and communications, which can prove prohibitive.

Following this study, a concept refinement phase is needed, utilizing the model and gathering further data on, for example, the availability and net storage volume of the gravel pits, as well as the future operational rules for Hansen Dam, to progress to project feasibility. Once their feasibility has been addressed, the relative costs of the alternatives can be assessed to conduct a credible cost-effectiveness analysis. However, it was possible to identify the multiple benefits of each alternative by making some assumptions based on their general characteristics.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

Section Title **Page No.**

List of Tables

List of Figures

TABLE OF CONTENTS
(continued)

Section Title **Page No.**

List of Appendices

1. Introduction

The overall goal of this study is to identify and prioritize at planning level potential restoration projects on the Tujunga Wash between Hansen Dam and the confluence with the Los Angeles River. A primary requirement is to build a sophisticated hydrodynamic model, already applied to part of the LA River system. This model can be utilized to support an approach that can serve as a template for other such multiple benefit studies.

The study therefore has two objectives. The first objective is to build a computer-based hydrodynamic model of Tujunga Wash, to evaluate the current and modified hydraulic conditions relative to potential restoration projects located downstream from the Hansen Dam, through the Tujunga Wash and into the Los Angeles River system. PWA Ltd used the hydrodynamic module MIKE 11 developed by the Danish Hydraulics Institute (DHI). A full account of the model development and application prepared by PWA Ltd. may be found in Appendix 1 attached to this report.

The second objective is to create an integrated, planning-level framework with other technical considerations as the context for the model's use. The study draws on existing ecological and geomorphic data, to identify data gaps and carry out limited fieldwork to complete the framework required. The main text of this report focuses on the framework, integrating the model results to show how a hydrodynamic model can support the process of inquiry and effectively be used to evaluate potential projects. The findings of this report tend to be more generic than the specific model results.

The study team included project coordinator Ms. Melanie Winter of The River Project, project staff Dr. John Gardiner and Dr. Christine Perala of WaterCycle Inc., and Dr. Ken Schwarz and Mr. Jeff Blank of PWA Ltd. Technical Advisory Committee members included Mr. Vik Bapna and Mr. Richard Weyermuller of Los Angeles County Dept of Public Works (LACDPW), Mr. Joe Evelyn and Mr. Brian Tracy of the Los Angeles District US Army Corps of Engineers (ACOE), Professor Keith Stolzenbach, UCLA Dept of Civil Engineering, and Mr. Mario Acevedo of the Los Angeles Department of Water and Power (DWP).

2. Development of the Hydrodynamic Model

2.1 Context of Model

The Tujunga Wash is located in the eastern San Fernando Valley (See Figure 1) and lies at the lower end of the Tujunga watershed, draining 152 sq. mi. of land in the San Gabriel Mountains. The San Gabriel Mountain range forms a watershed boundary to the north. The Tujunga sub-watershed shares a drainage divide to the west with Lopez sub-watershed, and to the east with the upper San Gabriel watershed. The Sun Valley sub-watershed nestles in the armpit of the Tujunga sub-watershed. The Big Tujunga Wash drains south into the San Fernando Valley. Little Tujunga Creek joins Big Tujunga Creek within the Hansen Reservoir. Below Hansen Dam at the northern edge of the Valley, the Tujunga Wash flows 9.5 mi to its confluence with the Los Angeles River at the southern edge of the Valley (see Figure 2).

Figure 1
Tujunga Wash Physical Setting

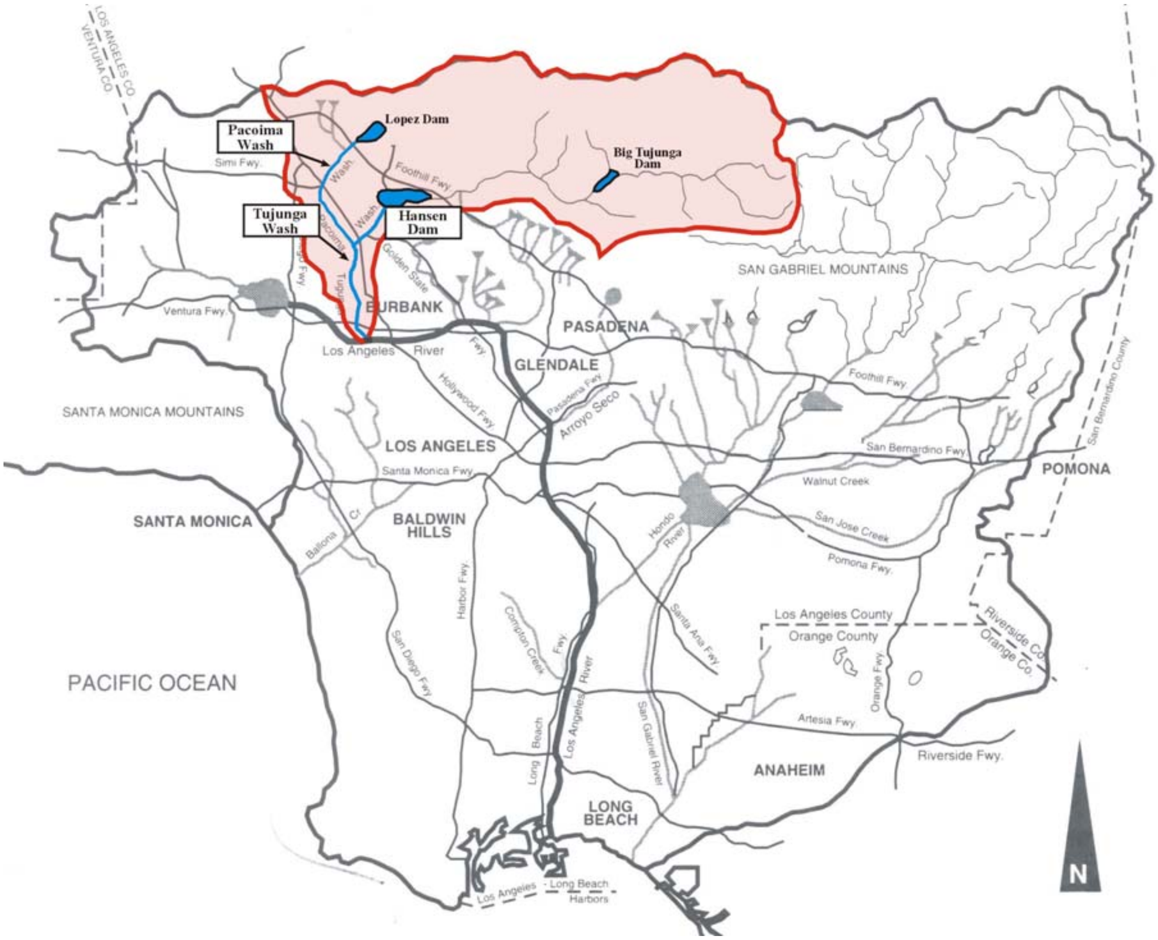


Figure 2
Watershed Boundaries

The model addresses the 9.5 miles of Tujunga Wash below Hansen Dam to the Los Angeles River. In this reach, the Tujunga Wash is a reinforced concrete box-type channel connecting with Pacoima Wash, the Branford channel and three major spreading grounds (see Figure 3). The Tujunga Wash has two distinct reaches; upstream and downstream of its confluence with Pacoima Wash. Upstream of its confluence with Pacoima Wash, the channel bottom width is 60 ft with a variable depth of 10-15 ft. and a maximum capacity of 20,800 ft/sec. Downstream of Pacoima Wash, the Tujunga channel width increases to 70ft to accommodate the additional inflows from the Pacoima and Branford channels. (see Figure 4) Depths remain similar downstream of the Pacoima channel at 10-15 ft. Channel elevations along Tujunga Wash decline from 956 ft at the base of Hansen Dam to 567 ft at the Los Angeles River confluence, representing a net slope of nearly 41 ft/mile (0.78% slope). The capacity of the channel at the confluence with the LA River is 28,200 ft/sec.

Pacoima Wash flows originate in the San Gabriel Mountains northwest of the Tujunga Wash sub-watershed, pass through the Lopez Dam sediment basin, and reach the Tujunga Wash 3 miles below Hansen Dam by way of the southeast flowing diversion channel that, like the Tujunga Wash in this reach, is a concrete box channel. The Branford drainage channel collects local surface runoff in the residential Pacoima neighborhood and joins the Pacoima Wash just prior to entering the Tujunga Wash.

2.2 Model Specification

MIKE11 is a one-dimensional hydrodynamic model that solves the vertically integrated conservation of mass and momentum equations (Saint-Venant equations). The model was selected in preference to the ACOE HEC-RAS model because it is better suited to the high slopes, high velocities and super-critical flow conditions of the Tujunga Wash system.

MIKE 11 incorporates a fully unsteady hydrodynamic module, which was used in this study and is currently unavailable in HEC-RAS for supercritical flow conditions. This module expands channel analysis and ecological enhancement capabilities by a more realistic portrayal of channel and overbank storage (floodplains, spreading grounds, gravel pits) and peak hydrograph timing and contribution. However, to facilitate future uses by parties who do not have access to MIKE 11, results from the MIKE 11 model were also translated into a HEC-RAS model.

2.3 Modeling Input Data

Channel geometry dimensions for the model were based on cross-sectional data provided by the ACOE (*Summary of Pertinent Hydraulic Data for Tujunga Wash, 1963*), and the *Hansen Dam Water Control Manual* (1990) provided by the ACOE. Channel geometry was verified at numerous locations along the channel with ACOE's as-built construction plans dated September 1950. A total of 97 cross-sections were utilized to model the 9.5 mi Tujunga Wash channel (approximately 10 per mi). Reference stations used to identify cross-section locations in the current model are different from the original ACOE documentation because the current MIKE 11 model was developed using metric units. However, to maintain consistency and to facilitate external review, specific landmarks such as bridges and roads are referenced in common.

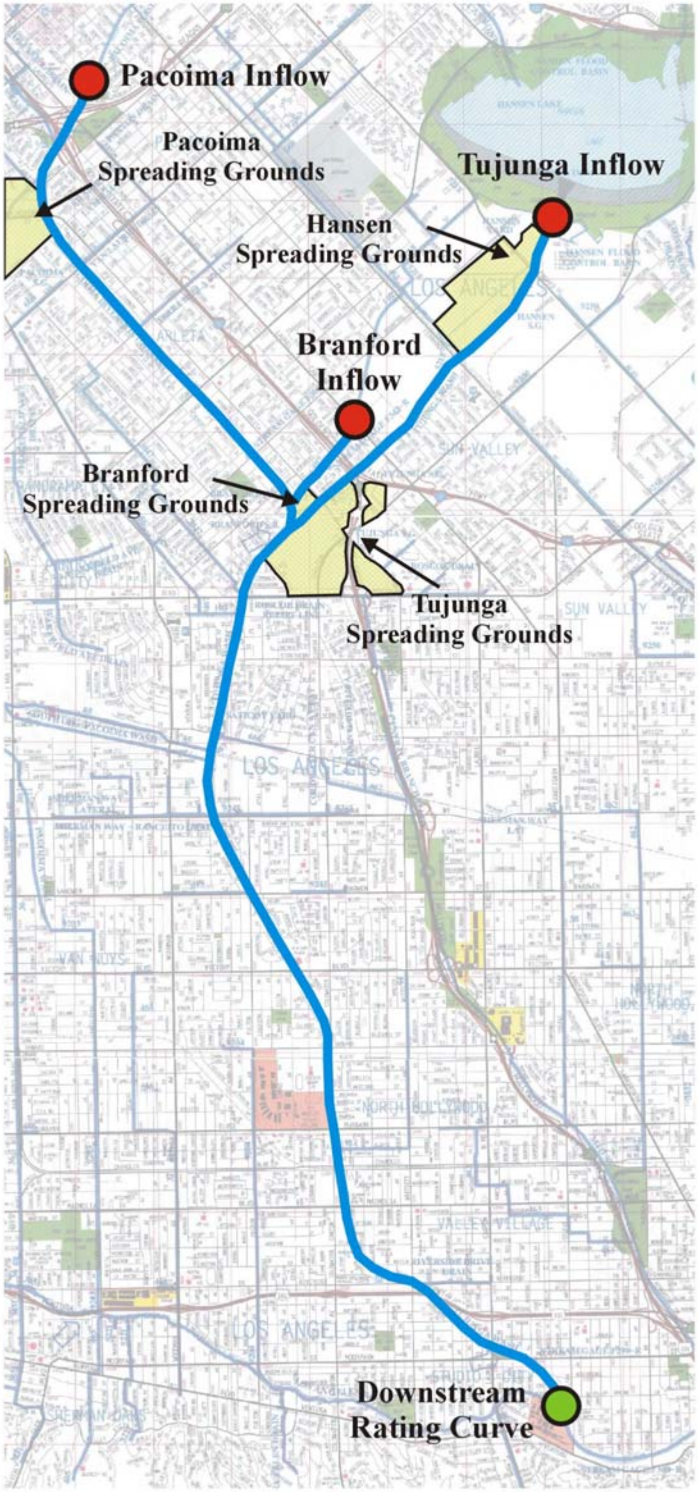


Figure 3
Mike11 Model Layout and Boundary Condition Locations

Figure 4
Existing Conditions below Pacoima Wash

2.4 Discharge

The 2-, 5-, 10-, 25-, 50- and 100-yr design flow events were chosen by the project team as representative discrete hydrologic events to model. In addition, a continuous flow period from the 1998 water year was selected to simulate a more seasonal system response. Lastly, a steady-state calculation, using predicted discharge values from ACOE 1963 hand-calculations, was computed to verify in-channel water levels. A detailed hydrologic analysis of continuous low flow input to Tujunga Wash was not conducted for the current study. Such hydrologic analysis could be evaluated in a future phase of work to refine alternative concepts.

The model's upstream boundary condition occurs as outflow at the base of the spillway channel of Hansen Dam. Additional discharge boundary conditions arise from lateral inflows from the Pacoima and Branford drainage channels. The model's downstream boundary condition is assumed to be critical depth at the Los Angeles River confluence. This assumption is based on the condition that modeled flow throughout the Tujunga Wash is super-critical and consequently no backwater effects extend upstream from the Los Angeles River boundary downstream.

In addition to these external boundary conditions, two internal rating curves represent flows diverted from the channel into the Hansen and Tujunga spreading ground. The existing conditions model utilized rating curves based on the entrance gate geometry at the spreading ground diversions. The LACDPW in cooperation with DWP is currently reviewing the operational guidelines of the Hansen and Tujunga Spreading Grounds. Efforts are underway to optimize and possibly enhance the capacity of these spreading facilities. The existing conditions used in the model may be revised if operations are modified.

2.5 Seasonal Discharge

The ability to model flow conditions continuously over the course of an entire season was based on gage records from the 1998 water year (Figure 8 of Appendix 1) for which ample stage-discharge data was available. The following data sources were used to model the 1998 season: 15-min discharge data at Hansen Dam (US Geological Survey); 5-min discharge data for Pacoima Wash (Los Angeles County Flood Control District); and 5-min discharge data for the Branford drainage channel (LACFCD). The 1998 water year was of particular interest due to the strong El Niño condition, which resulted in the wettest February on record in Los Angeles County. Seasonal flow variations are evident with average September (6 cfs) and November (9 cfs) flows being the lowest and February being the highest (562 cfs). Modeling results for flow in the Tujunga Wash during 1998 closely matched the Hansen Dam outflows. These observations and results are presented in Figure 8 of Appendix 1, which also includes a more detailed hydrograph from the modeling output that depicts conditions during the storms of February 1998.

2.6 Calibration

The boundaries of the model are as shown in Figure 3. Good calibration was achieved with corresponding peak outflows from the Hansen Dam, and with surface water elevations throughout the Tujunga Wash according to 1963 ACOE calculations, as shown in Figure 9 of Appendix 1. The model results confirmed the ‘peaky’ or ‘flashy’ nature of flood flows in Tujunga Wash, compared with the inflow to Hansen Dam.

2.7 Steady-state Discharge input and Model Verification

For input discharge, three steady-state flows for Hansen Dam, Pacoima Wash, and the Branford Channel (22,000, 7,000 and 1,000 cfs respectively) were processed through the existing conditions model to provide a comparative basis to verify water levels according to 1963 ACOE calculations. Water surface elevations from the 1963 calculations were quite similar to results from the current existing conditions model. Minor differences may be related to channel super elevations, which may not have been incorporated into the earlier ACOE calculations. These findings are presented in Figure 9 of Appendix 1.

2.8 Summary Results For Existing Conditions Model

Summary hydrodynamic information, including water surface elevation profiles and cross-sections, velocity profiles and hydrographs for representative stations along the Tujunga Wash are presented in Figure 10 of Appendix 1. Results indicate that very little flow attenuation occurs between Hansen Dam and the Los Angeles River. This is primarily owing to the lack of any channel or floodplain storage features, very low frictional losses (over a very smooth channel surface), and a steep overall channel slope (longitudinal profile).

The Tujunga Wash's overall slope of 41 ft/mi (0.78%) greatly exceeds the minimum slope required to generate critical flow. (For 2-yr peak flow rate of 865 cfs, the critical slope - at which flow changes from slow or subcritical to fast or supercritical - is roughly 10 ft/mi or 0.2%). During extreme events like the 100-yr peak discharge (47,600 cfs), the critical channel slope is even flatter, at roughly 4 ft/mi or 0.075%. Consequently, channel Froude numbers are much larger than 1.0 (creating supercritical flows) and extremely high average channel velocities (as high as 50 ft/s) are predicted by the model (see Figure 10 of Appendix 1). However, in the field, other forms of flow resistance such as turbulent eddies, etc. may preclude these extreme velocities from occurring under extreme flood conditions.

A review of Figure 10 in Appendix 1 suggests that the widening of the Tujunga Wash channel from 60 to 70 ft at the confluence of Pacoima Wash is required to maintain adequate conveyance capacity for flows greater than 100-year Return Interval (RI). As presently modeled, under extreme flow conditions, the Tujunga Wash channel provides little available capacity to accommodate additional runoff beyond the 100-yr event. This suggests that some areas within the reach may be vulnerable to overbank flooding and potential scour damage during high-magnitude flood events.

Existing physical and hydraulic conditions along Tujunga Wash, including the lack of channel-floodplain storage; low frictional losses; and steep bed slopes now prevent downstream flow attenuation. The existing channel configuration is characteristic of an urban flood control channel that provides no riparian habitat or ecosystem function.

New channel concepts were developed to address these issues by increasing channel and floodplain storage, increasing channel roughness to reduce flow velocities, and permitting better integration of channel and floodplain flows. The ultimate objective of restoring these physical forms and processes is to improve water quality, increase groundwater recharge, and provide opportunities for the creation of riparian habitat and natural ecosystem function along the Tujunga Wash corridor, while maintaining necessary flood management capabilities.

3.0 Planning Framework

A planning framework consists of technical, social, political, environmental and financial/economic issues that influence decision-making. This study was limited in its remit, but will identify constraints and opportunities that may need to be considered further in a subsequent feasibility phase. For example, a severe constraint is the existing land use, which does not allow for much widening of the channel without land purchase and property demolition along much of the length of the Tujunga Wash. However, some properties in this reach are not adequately protected from floods greater than a 100-year Recurrence Interval, especially in the area of the Pacoima confluence. Equally, there are multiple benefits to be gained from rehabilitation efforts, including improved water quality, public access, enhanced values in landscape amenity, ecological function, recreation and educational opportunities.

The following two sub-sections focus on the historical context behind the present-day situation, and then on the changes that are taking place in the present and may take place in the future to influence opportunities for rehabilitation of the Tujunga Wash.

3.1 Historical Context

The following technical discussions look at historical conditions and events in order to create a framework within which rehabilitation concepts can find an appropriate context. This is particularly important for habitat re-creation; continuity is as important for habitat corridors as it is for pedestrian and bike paths to be connected with existing trails. Any river rehabilitation must be based on understanding the relationship between flows and sediment movement, particularly when a system formed under a once-rich sediment supply regime no longer has the quantity or size range of sediment available. The ecology of the area will also have enhanced in harmony with the sediment regime, and it is important to understand how ecological functions are influenced by these changes. This section goes on to look at the major physical changes that have been imposed on the natural system in terms of dams, gravel pits and spreading grounds, resulting in the greatly altered physical system found today.

3.1.1 Sediment Regime

The Tujunga system has historically delivered high volumes of sediment from the steep, mainly granitic San Gabriel Mountain range, under a high-energy sediment transport regime. Sediment textures are generally coarser to the north, and became finer to the south as sediments were reworked by the fluvial system. The floor of the eastern San Fernando Valley is a series of southward sloping alluvial fans that have coalesced into a bajada surface. Gradients across these fan surfaces are steepest to the north towards the San Gabriel and Verdugo Mountains and decrease towards the Los Angeles River. Prior to the engineering and channelization of the Tujunga Wash and other drainage channels in the eastern San Fernando Valley, a network of as many as five wide, alluvial channels carried runoff, sand, gravel and boulders across the Valley floor (see Figure 5) under the episodic stormflows characteristic of the southern California Mediterranean hydro-geomorphic regime (Hitchcock and Wills, 2000; Kammerer 2000).

With elevations above 7100 ft, the mountain headwaters of the Tujunga Wash watershed experience orographic-enhanced precipitation under occasional intense,

Figure 5
Aerial Photgraph Looking SW from Big Tujunga, c. 1939

tropical storms arriving from the south and west. Multiple storm events closely spaced in time are known to occur, which deliver intense rainfall on mountain soils that can be already saturated. Episodic fires are common to the chaparral plant communities that dominate the southern slopes of this montane vegetation type, with fire frequency intervals estimated between 20-100 years (USACE, 1990).

A watershed fire history computed for the Tujunga watershed area estimated that 95 percent of the watershed may have burned during the period 1878-1975 (USACE, 1990). In the post-fire scenario, runoff and erosion increase significantly. Frequent tectonic movement along the numerous fault lines within the San Gabriel range can increase the quantities of fractured bedrock available for sediment transport by high magnitude storms. Such intense rainfall results in rapid runoff response, high sediment yields, mass wasting and debris flows on the steeper slopes and tributaries (USACE, 1990).

Contemporary sediment production within the watershed varies considerably, depending on terrain (USACE, 1990). In the urbanized valley, sediment production is at a minimum or has ceased. Paving of the alluvial system has fundamentally altered fluvial processes in the lower Tujunga system. Loss of storage space behind Hansen Dam owing to the high volume of sedimentation is a major constraint on contemporary dam operations (USACE, 1990).

3.1.2 Ecological Criteria

In the Tujunga Wash behind Hansen Dam lies the largest stand of alluvial fan scrub habitat remaining in Southern California, and by bio-geographical isolation, the world. This habitat contains great species richness, and still functions in contact with fluvial processes. Other now-rare habitats include riparian woodland, willow thicket, mulefat scrub, and coastal sage scrub. These habitats currently provide critical cover, forage, nesting and breeding sites for many bird, mammal, reptile, amphibian and invertebrate species, although extremely limited in area compared with their historical extent.

The Hansen Dam reservoir was evaluated by US Fish and Wildlife Service prior to 1999 for potential to support several threatened and endangered species listed for Los Angeles County, including endangered Least Bell's Vireo (*Vireo bellii pusillus*), southern willow flycatcher (*Empidonax trallii extimus*), American peregrine falcon (*Falco peregrinus anatum*), arroyo toad (*Bufo microscaphus californicus*), slender-horned spineflower (*Dodecahema leptoceras*), threatened California red-legged frog (*Rana aurora draytonii*), bald eagle (*Haliaeetus leucocephalus*), Santa Ana sucker (*Catostomus santaanae*), arroyo chub (*Gila orcutti*) and southern steelhead (*Oncorhynchus mykiss*) (USACE, 1999). The habitat for slender-horned spineflower is freshly flooded sandy substrates of alluvial washes, and could occur in the basin but is not easily found. It has been found upstream of the dam in Tujunga Wash (CDFG, 1997). Not included in the USFWS review is the Los Angeles County endangered species Nevin's barberry *(Berberis nevinii)*, which occurs in habitats of sandy to gravelly washes below 650m. (Hickman, 1993).

The biological diversity and abundance of this plant community is documented by numerous studies, conducted by the Corps, other agencies and independent biologists. According to Faber *et al*, (1989), the alluvial washes of the Tujunga system supported scattered, short-statured pioneer species found on alluvial terraces and islands of remnant geomorphic surfaces which were reworked by fluvial processes. Older 'islands' of un-reworked sediments support large shrub populations, including buckwheat (*Eriogonum fasciculatum*), a typical species of coastal sage scrub, together with succulent species such as prickly pear (*Opuntia basilaris*, other spp.)

The alluvial fan scrub community is characterized by large shrubs such as scale-broom (*Lepidospartum squamatum*), goldenbush (*Hazardia squarrosa, Isocoma menziesii*) and subshrubs such as Our Lord's Candle (*Yucca whipplei*) (Smith, 1980). This community supports a diverse annual and perennial herbaceous flora, the famous California wildflowers, including California poppy (*Eschscholzia californica*), spine flower (*Dodecahema leptoceras*), penstemons, lupines and many other showy species, which support a large and diverse fauna of birds, reptiles, mammals, butterflies and other invertebrates (Dale, 1985).

Reaches of Tujunga Wash that support near interactions among alluvial landforms, surface flows and groundwater levels also support riparian woodland. This important habitat type is characterized by canopy or gallery forest comprised of southern sycamore (*Platanus racemosa*), yellow willow (*Salix lasiandra* v. *lasiandra*), black willow (*Salix goodingii*) Fremont cottonwood (*Populus fremontii*), mulefat (*Baccharis salicifolia*) and other woody species (Faber *et al*, 1989).

The Hansen Dam reservoir currently supports critical, rare habitats for numerous bird and reptile species (Garrett, 1990). This remnant biodiversity area is an accidental artifact of land management, rather than an intentional preservation of this unique ecosystem. Protection of the remaining habitat fragments is a high priority for preservation of Southern California biodiversity. Opportunities to increase area devoted to alluvial fan scrub and its allied habitats should be given high priority in the San Fernando Valley along the Tujunga Wash system.

3.1.3 Development of the Physical System

Following damaging flood events in 1914, 1936, and 1938 (Cooke, 1984), several flood control and sediment control facilities were constructed in the Tujunga and Pacoima watersheds during the mid 20th century. These projects include the Tujunga Wash and Pacoima Wash channels, Big Tujunga Dam (el. 2304 ft); Hansen Dam (el. 1087 ft); and Lopez Dam (el. 1299 ft).

Los Angeles County and the City of Los Angeles own four spreading ground facilities adjacent to the Tujunga Wash and Pacoima Wash channels designed to increase groundwater recharge; Hansen, Tujunga, Branford and Pacoima. Flows are diverted from the Tujunga and Pacoima washes into broad, shallow infiltration basins to enable percolation to the aquifer below. During low flow conditions in Tujunga Wash, the spreading grounds may receive continuous inflow, representing up to 100% diversion of Tujunga channel flows. During larger storm event flows, a set of operations rules govern the control of the diversion gates, which control water inflow into the spreading grounds.

3.1.4 Pacoima and Lopez Dams

Upstream of Lopez dam, Pacoima Dam was constructed in 1929 as a water supply and flood control facility on the Pacoima Wash. It is a concrete arch gravity dam 365 ft high and 640 ft long, with a drainage area of 28.2 sq mi and maximum release capacity of 11,828 cubic feet per second (cfs).

Lopez Dam (6.4 mi above the confluence with the Tujunga Wash) was constructed in 1954 on Pacoima Wash as an earthfill dam 50 ft high and 1,330 ft long with a drainage area of 34 sq mi. Although the design discharge is 31,000 cfs, the maximum historic release was 3,900 cfs in 1983.

3.1.5 Hansen Dam

Hansen Dam was completed in September 1940 as a flood control facility on the Tujunga Wash. It is an earthfill dam, 97 ft high and 10,475 ft long, with a drainage area of 151.9 sq mi. It lies 15 miles below Big Tujunga dam, a water conservation and flood control facility of LACDPW. Storm flows exiting Hansen Dam and entering the Tujunga Wash are reduced to a maximum release rate of 20,800 cfs.

Since completion of the dam in 1940, relatively few damaging flows have occurred on the system. Peak outflow rates occurred in 1969 (15,993 cfs, with peak inflow of 26,012 cfs), in 1978 (13,541 cfs with peak inflow of 35,048 cfs) and in 1983 (18,104 cfs, with a peak inflow of 27,901 cfs). Some $176,384,000 worth of damages had been prevented, primarily to single and multi-family residences, by the year 1984 (USACE, 1990). Hansen Dam holds the key to the possible rehabilitation of the Tujunga Wash, as explained below in the discussion over its potential use as a water resources facility in the future

3.1.6 Spreading Grounds

The Hansen Spreading Grounds occupy an area of 156 acres located about 1,500 ft below Hansen Dam, and are owned and operated by LACDPW. Flows can be diverted into the spreading grounds out of the Tujunga Wash by a radial gate with a maximum inlet capacity of 400 cfs and a maximum permitted sediment limit of 400 ppm. The storage capacity of the spreading grounds is 330 ac-ft with a limit on water depth of 4-5 ft. The maximum percolation limit is 250 cfs, and the outlet discharge is limited by a highway culvert to 150 cfs.

Tujunga Spreading Grounds occupy an area of 188 acres, approximately 2.5 miles downstream of Hansen Dam. This area is owned by the City of Los Angeles, and operated by LACDPW, and also has an intake capacity of 400 cfs. (USACE, 1999). The long-term average intake capacity of both spreading grounds is estimated to be approximately 220 cfs (USACE, 1990).

The Branford Spreading Grounds, located near the confluence of Pacoima Wash with the Tujunga Wash, are owned and operated by LACDPW. The local storm drain system feeds the grounds (there is no inflow from the channels) and the facility discharges to the Pacoima Wash. It has maximum inlet and outflow discharges of 1,540 cfs.

3.1.7 Gravel Pits

The aerial photograph (Figure 6) shows four large gravel pits in the area of Hansen Dam. They range in size between 5,000 and 15,000 acre-ft, as measured from 1:24,000 scale USGS topo maps. For Boulevard Pits, Vulcan Materials Company maintain a standing agreement, as seen with other retired gravel operations, to turn the pit over to the City of Los Angeles to be used for landfill and then to retain surface development rights once fill has reached capacity.

These pits present a significant opportunity to supplement Hansen Dam in storing water, having between them a significant storage volume. From visual inspection of air photographs, it appears that the four pits have a gross volume of about 35,000 ac-ft. This volume is broadly equivalent to the spillway-crest storage behind Hansen Dam and half the volume of a 1-in-100-year storm (about 70,000 ac-ft). A storage volume of this magnitude would lead to a substantial decrease in flood risk downstream through the Tujunga Wash and the Los Angeles River, and may also provide additional capacity for use in multiple storms or storms greater than the 100-year design event. However, these pits currently have vertical walls and would not be able to support alteration between saturation and dry conditions in their present form. Modifications to pit structure would be necessary and the subsequent area available for storage would be less than the apparent gross volume.

Gravel pit storage may also allow a reduction in the volume of storage behind Hansen Dam, thereby protecting rare and endangered habitat, without necessarily sacrificing water conservation. The Sun Valley project is also considering use of these pits for stormwater detention in the context of flood management within that sub-watershed. Floodwaters that are temporarily stored and then released slowly after the main flood wave has passed down the channel can make a significant difference to the flood protection offered. Even if the pit storage were shared with the neighboring Sun Valley sub-watershed, it is likely that substantial benefits would accrue to the Tujunga system, including the possibility of rehabilitation of the main channel should subcritical flow be achievable.

There are concerns that storage in the pits would raise groundwater levels in the highly porous substrate, leading to inundation of existing active and closed landfills and to further pressure methane gas trapped in old landfill sites that might generate dangerous seepage into urban areas. This local concern could potentially be met adequately by installing an impermeable liner in the pits, but it is the DWP's intention to remediate the existing landfill problems associated with the spreading grounds. The initial solution is to improve the existing methane gas collection system; however if that fails to remedy the problem, more extensive and costly solutions will be assessed. Solving this problem is a high priority for the DWP (Acevedo, 2002, Pers. Com.). According to the DWP, Boulevard Pit has the most potential to be used as a detention basin or spreading facility, and recharge area lost in a braided stream in Hansen Spreading Grounds could be more than offset by converting the Boulevard Pit into a habitat/recharge facility. Linking the DWP's 'Modflow' groundwater model of the area with the MIKE11 hydrodynamic model could test this possibility.

Some of the criteria that will need to be evaluated for the potential use of the pits include hydraulics of diverting water into and out of the pits, side-slope stability issues associated with the steep pit walls, and adverse impacts to the nearby landfills resulting from increased groundwater recharge. In addition, the Sheldon Pit has exposed groundwater that may further restrict its use due to water quality concerns. Even so, the pits represent an ideal opportunity for the creation of multiple benefit projects that will compliment the existing flood control system while also restoring habitat.

Figure6
Aerial Photo Map of Gravel Pits in the Tujunga Wash Vicinity

3.2 Current and potential future change

This section describes current changes, and some of the implications, in policy related to possible operational changes in the physical structures, watershed management, the known future performance needs of the system, current land use issues and the potential benefits of public access.

3.2.1 Changing Hansen Dam and Spreading Ground Operations

As a flood and sediment control facility, Hansen Dam currently does not impound water as a reservoir. However, Hansen Dam is now under review as a future water resource under the Water Conservation Program, based on a 1999 study by USACE. This program aims to increase water retention behind the dam up to elevation 1030 ft (NGVD), in order to increase the average annual conservation yield to 20,500 ac ft, an increase of 20% over existing conditions (USACE, 1999). This would provide greater control over flood flows down the TW channel, reducing the flow of water and sediment over and through the dam. Should the program be adopted, hydrology calculations for the MIKE11 model will have to be revised.

Based on the historical average annual sedimentation rate for Hansen Dam, approximately 84% (272 afy) of all sediment entering into the Hansen Dam basin area remains behind the dam, and approximately 16% (52 afy) is conveyed downstream into the Tujunga Wash (USACE, 1999). The fraction of sediments passing the dam are generally the finer particles carried in suspension.

Increasing the storage capacity behind Hansen Dam will lead to an increase in sedimentation rates behind the dam and a reduction in the discharge of sediment downstream into Tujunga Wash. This reduction of sediment from Hansen Dam will reduce the quantities of fine sediment delivered to the spreading grounds, and may lead to an increase in the duration in which peak flows are admitted to the spreading grounds during the larger storm events.

As an integral part of detailed planning for the changing perspectives in sediment management behind Hansen Dam, ecological criteria for gravel extraction planning and management should be included. The same is true for the management of a rehabilitated braided channel, and indeed the entire spreading grounds could be managed for multiple criteria, including wildlife habitat, habitat loss mitigation, improved water quality, increased infiltration and public access for passive recreation.

The primary function of the spreading grounds is to maximize groundwater recharge. However, the spreading grounds are currently under-utilized for a number of reasons. These reasons include a reduction in potential capacity owing to the turbidity of flood waters (carrying sediment past Hansen Dam), artificial restrictions such as a culvert under the road linking the two parts of the Hansen Spreading Grounds, and spreading capacity limitations due to nearby landfills.

However, the single-purpose nature of the spreading grounds is changing, as they are becoming seen as potential sites to provide other benefits such as conservation and public access for compatible recreational uses. Recently, studies have looked at opportunities for public access to spreading grounds such as in the Rio Hondo and San Gabriel River Coastal Spreading Grounds recently re-visioned for the LACDPW Water Resources Division by Calvin R. Abe Associates, Inc. Because of regional population increases and the decline of wildlife habitat region-wide, the need for multiple benefit strategies to be applied to single-purpose facilities is increasingly recognized. The spreading grounds provide a substantial resource with enhanced opportunities to better utilize local water resources, to contribute significantly to both wildlife and community needs, and improve the quality of life in Los Angeles.

3.2.2 Ecological implications of change in dam operation

Unfortunately, there are many acres of rare habitat that would be destroyed by impounding water in a reservoir behind Hansen Dam. This would be true even if it were only flooded periodically during the year as shown in Tables 22-24 in the Final Report and Impact Statement for the proposed impoundment (USACE, 1999). From Table 3.3-1 in this publication, the greatest loss (119 acres) of willow wetland would be incurred in the first 20 vertical ft. of impoundment, with a further 28 acres and 37 acres lost in the next increments of 10 vertical ft.

However, there would be no loss of coastal sage scrub in the first 20 ft, compared with 2 and 6 acres in the next 10 ft increments, and 3 acres of mulefat scrub would be lost in the first 20 ft compared with 1 and 2 further acres in the next two 10 ft increments. It is unclear how much alluvial fan scrub will be affected. A reduction of 10 ft in the maximum impoundment under consideration would substantially reduce the negative impacts on rare habitat behind the dam; some 37 acres of willow scrub, 6 acres of coastal sage scrub and 2 acres of mulefat scrub, in addition to 34 acres of parks and ruderal land (that could be subject to habitat restoration) could be protected.

Depending on the operational rules for a revised Hansen Dam operation, rehabilitation of areas below the Dam adjacent to the Tujunga Wash could mitigate some of the habitat losses caused by using the dam for water conservation.

3.2.3 Future watershed management programs

In the past, projects were often undertaken for a single, or at most dual purpose, and without much consideration of the likely effects elsewhere in the watershed. This approach is changing rapidly, and Los Angeles County (LACDPW) has taken the initiative in relation to Watershed Management plans for stormwater, etc., assessing projects within a watershed and sub-watershed context. These changes in land and water management at LACDPW based on the watershed began recently, and more innovation is anticipated in the coming decade.

The major factors that can drive watershed management (adapted from Drennan, 2002) from the urban viewpoint include:

- Flood risk, water scarcity and polluted water
- Growth in awareness of the interdependence of stormwater, flood risk, pollution, groundwater and water supply – together with cumulative effects and the value of distributed solutions
- Desire to protect environmental values upstream and downstream
- Desire to defer costs of augmenting water supplies/wastewater treatment facilities
- Growth in awareness of the value of wetlands and local groundwater aquifers

- Desire to recover urban waterway values and integrate water into urban landscapes
- Desire of local governments to adopt sustainable city policies, leading to a healthier balance between the urban environment and the natural ecosystem

In the context of modern watershed management, ideas of ecological rehabilitation or restoration, and conservation of urban stormwater, are far more acceptable now than just a few years ago. Stormwater management is now seen as a significant resource for groundwater recharge, supporting the increasing use of water that was formerly treated as a nuisance in urban areas (Schueler and Holland, 2000). Also, a framework study and detailed assessment of the potential of stormwater to supplement flood flows in support of rehabilitation projects, as discussed above, is an important next step in determining the scale and nature of projects for the rehabilitation of the Tujunga system ecology.

Studies inspired by recent groundbreaking work (see *Second Nature: Adapting L.A.'s Landscape for Sustainable Living*, Condon and Moriarty, ed., 1999) are underway in the adjacent sub-watershed of Sun Valley. There, LACDPW and TreePeople are cooperating to identify and assess stormwater management issues in a watershed context. The Watershed Management Plan they develop will recommend the implementation of stormwater BMPs for flood and pollution control, water conservation, habitat enhancement and community greening. The retention of rainwater at or near the point of impact throughout the watershed is expected to be one of the plan's major strategies. (see http://www.sunvalleywatershed.org, Sun Valley Watershed Stakeholders Group.) The plan will not only provide a template for other watershed planning efforts to come, but will inform planning decisions made in the Tujunga Wash sub-watershed. Studies providing the framework and assessment for stormwater management as a potential water resource for rehabilitation projects would contribute greatly towards an effective watershed management plan for the area, as well as towards TMDL assessments and guidelines. Not least because use of the gravel pits is discussed in the Sun Valley study, it is strongly recommended that liaison between the two studies is established and maintained.

3.2.4 Stormwater Management

The adverse impacts associated with traditional urbanization and stormwater 'drainage', rather than 'management', include (adapted from Drennan, 2002):

- Increased stormwater volume and peak discharge rate, leading to:
    - Increased frequency of flooding
    - Increased channel erosion
    - Timing/duration of peakflows/baseflow of tributaries related to main stem
- Decreased infiltration and increased water demand, leading to:
    - Depressed groundwater levels
    - Decreased stream base-flows
- Decreased evapotranspiration, affecting local/regional climate

- Decreased depression storage, floodplains, and wetlands
- Decreased habitat and biodiversity
- Increased pollutant concentrations and loadings from urban runoff

A suite of retention and attenuation techniques (Best Management Practices or BMPs) can be distributed throughout the watershed (Urbonas & Stahre, 1993). A primary benefit of the ‘distributed solution’ offered by stormwater and source control techniques is to retain water, attenuate runoff and increase local infiltration. Taken singly or together, these benefits can reduce the impacts on both runoff quality and quantity. (see *T.R.E.E.S. Project, Trans-agency Resources for Environmental and Economic Sustainability* at http://www.treepeople.org/trees/). These practices can also reduce the peak flood discharge in the main channel by reducing the volume of runoff, although the timing of the runoff in relation to the flood wave in the main channel may limit this effect. An over-arching aim of BMPs should be to restore a more natural hydrograph. For stormwater management to play a significant role in a Tujunga Wash restoration scheme, two actions need to be undertaken. First, to identify the potential for stormwater interception, a framework study is needed to clarify how stormwater could be made available to the rehabilitated areas along the Tujunga Wash. Currently, there are two drains that enter the Tujunga Wash at Roscoe (#3847 & the Roscoe drain relief line); one comes in two blocks south at Cantara (#107) and one comes in just below Saticoy (#666) before the confluence with Pacoima Wash. Two enter at Sherman Way (the Sherman Way -Ranchito drain & #9245); one at Vanowen (#657); one below Burbank at Albers (#391) and the last one enters at Riverside Drive (the Riverside Drive Drain) (see Figure 7). Retrofitting these drainage systems offers opportunities to support rehabilitated areas when there is little or no river water available, while also increasing infiltration, provided that the runoff is adequately cleaned of pollutants picked up from urban impervious areas.

Second, a detailed assessment is needed of opportunities for urban retrofit, development or redevelopment, including the installation of source control techniques to attenuate flows and revisions to the Planning and Building Codes (see *Stormwater: Asset Not Liability*, by Dallman and Piechota, 2000). The aim would be to minimize watershed runoff input to the channel below Hansen Dam by increasing the distribution of infiltration and reducing the amount of impervious surface throughout the watershed, especially in the urbanized areas.

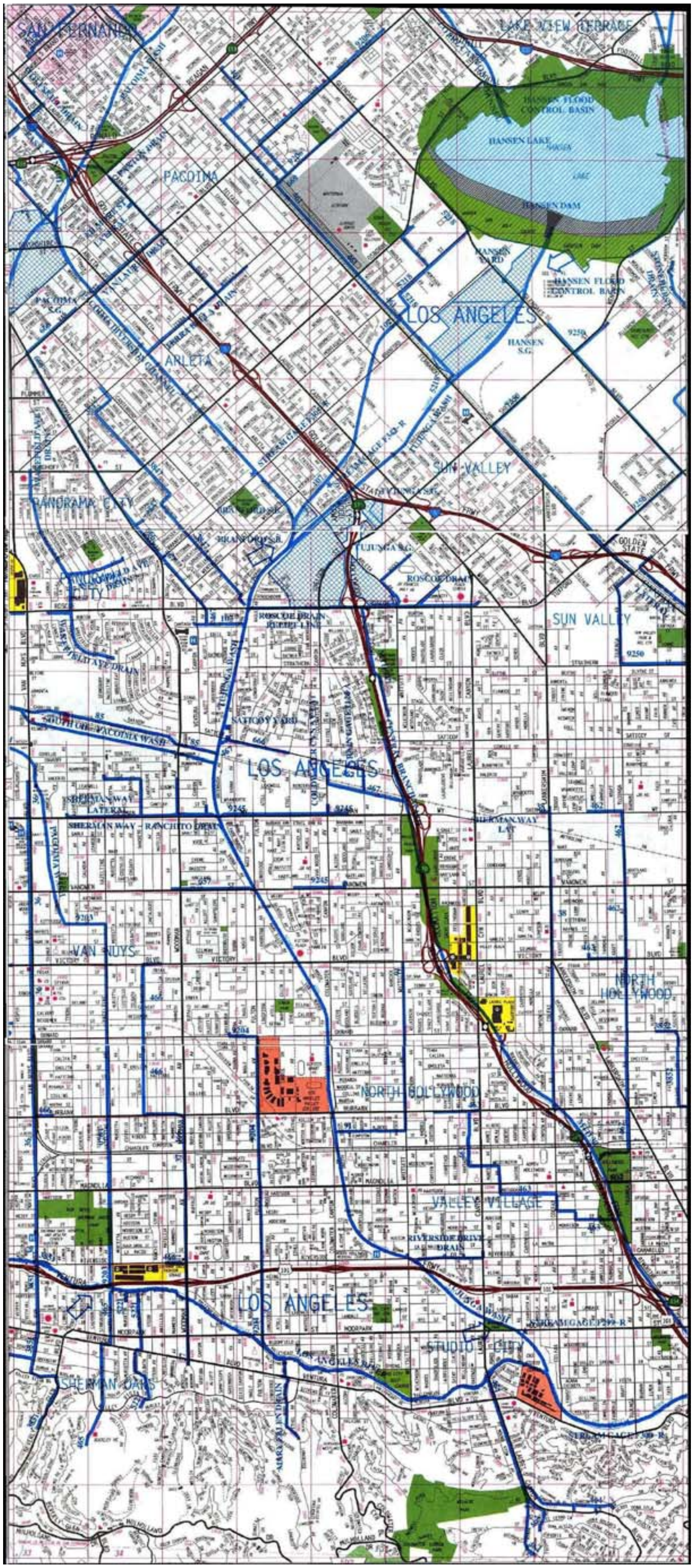


Figure 7
Existing Contributing Drains

3.2.5 Flood management and infiltration requirements

Whatever projects may be identified for rehabilitation, an essential criterion is that the standard of flood defense provided by the Tujunga Wash system is not weakened. Rehabilitation should improve the standard of flood defense where practicable. For example, the area adjacent to the Tujunga – Pacoima confluence currently has less than 100-year RI standard of flood protection. At the same time, there is to be no detriment to the amount of infiltration in the spreading grounds. Further study is needed to establish the area of spreading grounds that would be affected by rehabilitation projects, and the change of infiltration implicit in the areas covered by those projects.

Currently, there is a limitation on the spreading capacity due to concerns associated with the nearby landfills. At Hansen spreading grounds, the concerns are of inundating these landfills. At Tujunga spreading grounds, an increase in groundwater pressure has been linked to methane gas releases at a local school. The DWP is seeking to resolve this issue (see under 3.1.7 Gravel Pits) and has formed a stakeholder group that consists of LACDPW, the Upper Los Angeles River Area Watermaster, the City of Los Angeles Bureau of Sanitation, and the City of Los Angeles Department of Environmental Affairs to analyze and develop solutions to remediate this problem. A pilot study is underway to evaluate one of the solutions identified to attenuate this problem. DWP is committed to restoring the historic capacities of the spreading basins.

3.2.6 Land-use planning and zoning

The sustainability of rehabilitation projects, their location, size and characteristics, will depend on land use planning and zoning, both in their areal extent and in their nature and need for institutional and public support. If the communities are educated in the various issues and are involved in the decision-making, then there is an increased probability of widespread support for changes in land-use zoning and relevant code language. Otherwise, implementation of relatively novel policies for stormwater management, for example the use of swales and pervious paved surfaces, may be delayed and mistreated by a community ignorant of the issues and rationale. Local participation, including children at the elementary school level, is key to the sense of community ownership of these often neglected public resources that is fundamental to achieving authentic ecological enhancement.

3.2.7 Public access and use

Involving the public as well as landowners is critical to the success of ecological rehabilitation efforts. Public participation is unlikely to be more than superficial unless there is permanent access to the site, most often expressed by having viable trails and bikeways incorporated into the design. Other recreation activities, particularly bird-watching, are commonly included, and in all cases the opportunity to involve local students in the planning, design and implementation phases should not be overlooked.

The possibility of having an uninterrupted trail and/or bikeway running the length of the Tujunga Wash is only constrained by the bridges (that may constrain the rehabilitation efforts). Although this pre-feasibility modeling study is not able to go into any depth concerning the feasibility of atrail or bikeway, we can state that there is currently no opportunity for in-channel pathways because the concrete walls are vertical, and the bridges that cross the easements have inadequate clearances. Further, unless the specification for the replacement bridges planned by the City engineering are modified accordingly, the bridge widths (based as they are on the narrowest possible channel width) and possibly also height may pose seriously constraining factors to both trail and rehab potential. However, the City of Los Angeles Bureau of Engineering is planning to retrofit and in some cases reconstruct all of the Tujunga Wash bridges over the next decade. They have expressed a desire to coordinate planning and design efforts with river and bicycle advocates in order to accommodate uninterrupted trails. (Dung Tran, 2002, Pers. Comm.)

There are 18 street or railroad crossings, in order from Hansen Dam downstream, as follows:

- Glenoaks Blvd.
- San Fernando Blvd. /RR
- Laurel Canyon Blvd.
- Arleta Ave.
- Roscoe Blvd.
- Cantara St.
- Saticoy St.
- Railroad Bridge
- Sherman Way
- Vanowen/Fulton St.
- Victory Blvd.
- Oxnard St.
- Burbank Blvd.
- Chandler Blvd./ RR
- Magnolia Blvd.
- Riverside Drive
- Laurel Canyon Blvd.
- Moorpark St.

In addition there are 2 freeway crossings:

- Golden State Fwy / Hollywood Fwy (I-5 / SR-170) Interchange [between Laurel Canyon Blvd & Arleta Ave]
- Ventura Fwy (US-101) [between Riverside Dr & Moorpark St]

4.0 Evaluation Criteria and Derivation of Concepts

The following subsections describe the next stage in the process of assessment. Once the data had been collated, an essential step for the team was to identify the evaluation criteria that would allow concepts to be derived within an analytic framework. Identifying the criteria now, rather than after the concepts have been articulated, allows the team to pare down the number of concepts to be taken forward for serious examination.

It should be noted that no criteria were formulated for the degree of land-take required; this was a deliberate omission based on the lack of information on the potential areas that may be constrained. Knowledge of the widths of channel required for rehabilitation under the existing regime was held to be useful information, even if – by itself – it would probably rule out any realistic possibility of channel rehabilitation on the grounds of cost alone. The criteria were informally applied in the discussions relating to the concepts, enabling the alternatives themselves to be conceptualized without constraints that were too severe. Freedom to think creatively can be stifled with formal application of evaluation criteria.

4.1 Evaluation Criteria

The team and the Technical Advisory Committee (TAC) selected criteria for enhancing function and process for the Tujunga ecosystem, which can be used to evaluate the application of the model results. The following are the major criteria developed:

1. Protect or improve the existing standard for flood defense.
2. Maintain or enhance the current state of water quality.
3. Maintain or enhance flood and rainwater infiltration to groundwater.
4. Enhance open space supporting wildlife habitat.
5. Improve potential for public access to outdoor recreation compatible with wildlife habitat.
6. Develop strategies that are cost-effective solutions to complex problems.
7. Find solutions that are compatible with existing spreading grounds operation and the proposed changes in dam operation.

There are additional criteria to assess rehabilitation efforts based on hydraulic parameters that represent a different class of analytic criteria to those presented above. Perhaps the most significant challenge for rehabilitation design is the very steep slope of the Wash that, combined with the low roughness value of the concrete channel, means that the flow is “supercritical”. Flows can exist in two different states to achieve the same discharge, either with shallow, high velocity flow within a relatively small channel (supercritical), or vice versa (deep, low velocity) in a much larger channel (subcritical). Only smooth concrete walls can accommodate supercritical flows without erosion. To achieve the subcritical flows that will allow a more natural channel, either the channel must be considerably enlarged or the discharge must be considerably reduced. These relationships have been quantified for Tujunga Wash in Table 1, for the 100-year Design Storm Event.

In the case of many concreted systems such as the Tujunga Wash, development of adjacent land use no longer admits widening the channel without high cost and substantial social and economic disruption. Widening urban roads often has similar impacts, but the perceived benefits of the work are more easily calculated in monetary terms. In rare locations such as the spreading grounds, there may be opportunities to widen the channel sufficiently to achieve subcritical flow. However, the transition back to supercritical flow – from a softer, sloping bank to vertical concrete walls - is technically demanding and will occupy a significant length of the rehabilitation reach.

In this situation, there is no practical opportunity to rehabilitate the concrete channel itself unless the discharge can be greatly reduced. The revised operation of Hansen Dam, coupled with the possibility of using some or all of the gravel pits and modified spreading grounds, may realize the potential for storing floodwaters sufficiently to allow subcritical flows to be designed in Tujunga Wash, allowing for rehabilitation without excessive land-take. Testing this possibility will require discussions concerning the future operation of Hansen Dam, further data to be gathered on the gravel pits and local stormwater discharges, and rigorous modeling of the system including the gravel pits and spreading grounds.

4.2 Derivation of Concepts

Notwithstanding the foregoing paragraphs, five major concepts were used to create a planning framework and guide the selection of strategies for ecological rehabilitation of the Tujunga Wash system. These are based on historic natural processes in the Tujunga Wash that have been interrupted or curtailed as a result of the dams, channel armoring and development of the lower watershed. These strategies may provide opportunities for system modification either as "stand-alone" concepts or in combination, depending on the consensus achieved among the many stakeholders over time. The strategies are generic and can also be applied equally well to any similarly armored alluvial system.

1. **Increase channel and floodplain water storage**

The objective is to attenuate flood flows by enlarging the channel capacity appropriately (i.e. increasing the available cross-section) without increasing water levels in the reach, upstream or downstream. This will also help to achieve sub-critical flow conditions (flows are supercritical in existing conditions), as well as increase groundwater recharge.

2. **Increase friction energy losses/ reduce in-channel velocities**

The objective is to attenuate flood flows by increasing the roughness, thereby decreasing the flow velocity, without increasing water levels in the reach, upstream or downstream. This will also help to obtain sub-critical flow conditions (flows are supercritical in existing conditions).

3. Reduce flow volumes delivered to the main channel

The objective is to attenuate and decrease flood flows by increasing the volume of stored or detained floodwater, thus enabling strategies 1 and 2 and increasing infiltration to groundwater.

4. Re-connect the channel and its floodplain by modifying the channel's hydraulic geometry

The objective is partly to restore the functions of the original natural channel and its floodplain, within the constraints of a developed reach, by reconfiguring the channel and floodplain cross-section dimensions. This will increase infiltration to groundwater as well as restore more natural processes and functions, and enable habitat creation.

5. Restore braided (alluvial) channel function

The objective is to accommodate the restoration of the geomorphic function of the original natural channel and its floodplain, allowing morphological processes to become re-established, albeit on a modified scale and within the constraints of a developed reach.

These objectives are considered singly in this report, with the intent that subsequent efforts will develop them in combination as deemed appropriate in light of current and future planned watershed restoration efforts. They are predicated on the current flow regime. Change in this regime (through change in the operational rules of Hansen Dam, utilization of some or all of the gravel pits or increased use of, or possibly deepening, the spreading grounds) will modify these ideas considerably, opening up much greater possibilities. For example, implementing a combination suite of the above concepts would greatly reduce the required width of a rehabilitated channel, possibly to the point of eliminating the need to acquire additional properties.

5.0 Alternatives analysis

A number of questions were formulated between the project team and the Technical Advisory Committee (TAC) in order to shape the analysis of the alternatives. These questions are summarized as follows:

i. What percentage of the design storm discharge could be held by the various gravel pits downstream of Hansen Dam? What effect would flow storage in these pits have on the storm hydrograph in Tujunga Wash? Could flow storage in these pits be integrated with a revised management and maintenance program for Hansen Dam that might require less storage behind the dam as a result of pit storage?

   See under3.1.7. Gravel Pits, above, and 5.3. Off-channel storage, below – the answers to these questions require further data to be collected on the size and potential use of the pits.

ii. What opportunities exist at the spreading ground site downstream of Hansen Dam for inclusion into a channel restoration or wetland development program? Could a restoration program be developed that would not reduce infiltration and percolation functioning of the existing spreading grounds? Could such recharge functions be incorporated into a type of alluvial fan/braid channel restoration concept?

See under 5.2.Alternative C, below – there are opportunities for both types of rehabilitation. Restoration of a braid channel should not restrict recharge functions, and may reduce the rate of siltation in the spreading grounds.

iii. Could the proposed version of Alternative 3 from the recent Mountains Recreation and Conservation Authority (MRCA) report on the Tujunga Wash (Kammerer, June 2000) be analyzed in the current model? What would be the hydraulic affect of this proposed action on the main Tujunga Wash channel?

The MRCA proposal was analyzed using the model (see under 5.1.3. MRCA Channel Concept below), and it was found that there is no impact on the existing channel or its flood conveyance capacity.

iv. How much of a reduction in critical flood velocities can be achieved in the Tujunga Wash by increasing the channel width by a factor of 2, or a factor greater than 2? How wide a channel is needed to reduce average channel velocity to less than 15 ft/sec), or to less than 10 ft/sec)? Could flow diversion into one or more of the gravel pits potentially reduce channel velocities?

From Table 1 in 5.1. Channel Restoration Concepts below, doubling the channel width reduces the velocity in the Design Event from 42ft/sec to 32ft/sec, trebling the width reduces it to 29ft/sec and quadrupling reduces it to 24ft/sec. A channel of just over three times the width, with a roughness of 0.04 (compared to 0.015 at present), would achieve 15ft/sec; and four times the width with a roughness of 0.07 would achieve 10ft/sec. The threshold between super-critical and sub-critical flow is given by a Froude number of unity, when the velocity of flow is equal to the square root of the product of the depth and gravitational constant 'g'. The velocity is dependent on channel slope, roughness and hydraulic radius (the cross-sectional area divided by the channel perimeter). Lastly, the more storage is implemented in the system, for example in the gravel pits, the lower the potential velocities in the channel, but the model would have to answer the question quantitatively.

v. What size for a restored channel and floodplain system would be required to convey the design storm flood event? How could the bed and bank materials along the existing Tujunga Wash be modified to accommodate these changes in channel geometry? Could an "off-line" restoration concept be developed that would not significantly alter the existing Tujunga Wash channel, yet still provide significant restoration benefits in adjacent areas?

See Figures 8 and 9 (Alternatives A and B) below for answers to these complex questions. The potential for the "off-line" restoration concept is discussed in Alternative C and illustrated in Figure 10.

vi. The ACOE model shows that flows break out of channel for the 1:100 year flood just downstream of the Pacoima confluence. Can the new model be used to map flood inundation conditions as a refinement of the current FEMA map?

The MIKE 11 model could be used to map flood inundation conditions if it were linked to a digital elevation model of the floodplain. MIKE 11 is accepted by FEMA as a suitable model for floodplain delineation.

These questions and issues framed a preliminary alternatives analysis as reviewed below. The existing conditions hydrodynamic model described in Section 2 was developed further to evaluate the proposed new channel configurations.

5.1 Channel Restoration Concepts

Issue (iv) above addressed the impact that increasing channel width, varying channel geometry and hydraulic roughness would have on reducing flood velocities. Table 1 summarizes resulting channel velocities when channel width and roughness for the 100-yr design storm are altered. Although the entire length of Tujunga Wash was modeled, sample results for Table 1 are given as average velocities for the upper Tujunga Wash reach (approximately 4.75 mi from the Hansen Dam headworks to the Sherman Way crossing). This upper channel zone is steeper, resulting in higher flow velocities than the downstream channel zone. However, increasing channel width and roughness reduces average flow velocities. As described in Section 2.8 above, input hydrology values for the channel hydraulic analysis were based on past studies and Corps design manuals.

It should be remembered that the discharge is inversely proportional to roughness, quantified by Manning's 'n', so that (if the channel geometry were kept constant) a doubling of 'n' would lead to halving the discharge. Figures 3 and 4 show different roughness applied to discrete parts of the channel, with the values increasing as vegetation is introduced. The existing concrete roughness has a value of 0.015, compared with a riverbed armored with large flat Derrick Stones (0.02), grass with a few bushes (0.04) and shrubs lining a cycle path (0.05). The value of Manning's 'n' is a complex calculation, depending on other features such as sinuosity (meandering). Further information on these values can be found in Chow (1959), Cowan (1956) and Arcement & Schneider, (1989).

Table 1. Average Channel Velocity between Hansen Dam and Sherman Way (ft/s) for Design Storm Event

Table 1. Average Channel Velocity between Hansen Dam and Sherman Way (ft/s) for Design Storm Event

Channel Geometry	*n = 0.015 (existing)*	*n = 0.02*	*n = 0.04*	*n = 0.06*	*Maximum allowable 'n' value*
Existing Channel **Variable Width (60 - 70 feet)**	42.34	WL exceeds top of channel	WL exceeds top of channel	WL exceeds top of channel	0.015
Channel (2 x Wide) **Variable Width (120 - 140 feet)**	32.01	26.99	WL exceeds top of channel	WL exceeds top of channel	0.038
Channel (3 x Wide) **Variable Width (180 - 210 feet)**	29.44	24.84	16.73	WL exceeds top of channel	0.045
Channel (4 x Wide) **Variable Width (240 - 280 feet)**	24.22	20.42	13.76	10.90	0.070

Changing land-uses in the watershed, as well as changing runoff or watershed management approaches in the future, could potentially alter the basic input hydrology conditions. Modeling results from Table 1, together with Tables 2 and 3 from Appendix 1, were used to develop the channel configurations presented for the alternatives below.

5.1.1 Alternative A – single terrace floodplain

In Alternative A (Figure 8) the existing Tujunga Wash channel would be reconfigured and enlarged to integrate a single floodplain terrace. The terrace would be inundated at or above the 2-yr flow level. This terrace could be designed with various widths. The channel modification could be applied between Hansen Dam and Sherman Way and would provide additional flood protection, enhanced habitat quality, and potential space for future recreational use. Access to the terrace would be practicable and safe only if flood conditions of Tujunga Wash permitted it safely. Currently, it is probably too flashy, i.e. the water rises too fast, to allow recreational use in the channel. If the flows were modified sufficiently to reduce this hazard, public access would be enhanced.

Similar to the materials used in the Los Angeles River at Glendale Narrows, a 'soft bottom' section could be adopted with channel bed armoring provided by Derrick stones to provide stability for the channel bed elevation. Derrick stones are manufactured blocks of concrete about the size of a VW 'bug' automobile (Tracy, 2002, pers.comm.). The overall channel roughness would be increased owing to the soft bottom-armoring configuration and by the reinforcement of the terrace margin using biotechnical bank stabilization and native vegetation along the banks.

For Alternative A, roughness values of 0.02 and 0.04 were used for the channel and terrace sections respectively. Further modeling refinement could include a more detailed evaluation of sediment conditions in relation to roughness, and for roughness generated by flow interactions between channel and floodplain. This assessment could be based upon representative field sites and including a geomorphic investigation of historical channel/floodplain roughness values for the Tujunga Wash and surrounding alluvial fan.

In Tables 2 and 3 of Appendix 1 (Alternative A), summary modeling results are presented for nine different channel and terrace width combinations. Compared to the existing channel system, the integrated floodplain terrace of Alternative A reduces channel velocities significantly. For example, velocities for the 100-yr event decrease from 42 ft/sec for the existing Tujunga Wash above its confluence with Pacoima Wash, to 24 - 33 ft/sec for the channel and terrace configuration of Alternative A. The table shows how relatively insensitive the velocities are with increasing channel/floodplain width; from 33ft/sec for a 50ft wide channel to 24ft/sec for one 70ft wide, and 12.2ft/sec for a 25ft wide floodplain terrace to 10.22ft/sec for one 150ft wide. The high velocities occurring in the existing Tujunga Wash system are mainly driven by the steep gradient of the channel.

The estimated bed shear stress and transportable sediment size for the Tujunga Wash was compared with various other rivers throughout the world (see Figure 13, Appendix 1). The minimum estimated bed shear stress for Alternative A is comparatively high at 3.64 psf, which would mobilize a minimum sediment size of 200 mm. Further refinement of the Alternative A concept would investigate suitable in-channel particle size to maintain a stable system.

The key to rehabilitation will be to reduce the maximum discharge capacity (by utilizing storage behind Hansen Dam, in the gravel pits and spreading grounds) so that the channel width requirement can be greatly reduced, together with the velocities in the low-flow channel and floodplain. A modification of the bed long-profile could use some feature like the Derrick Stones to create a series of small steps or weirs. These weirs would dissipate energy locally and reduce the slope of the long profile locally.

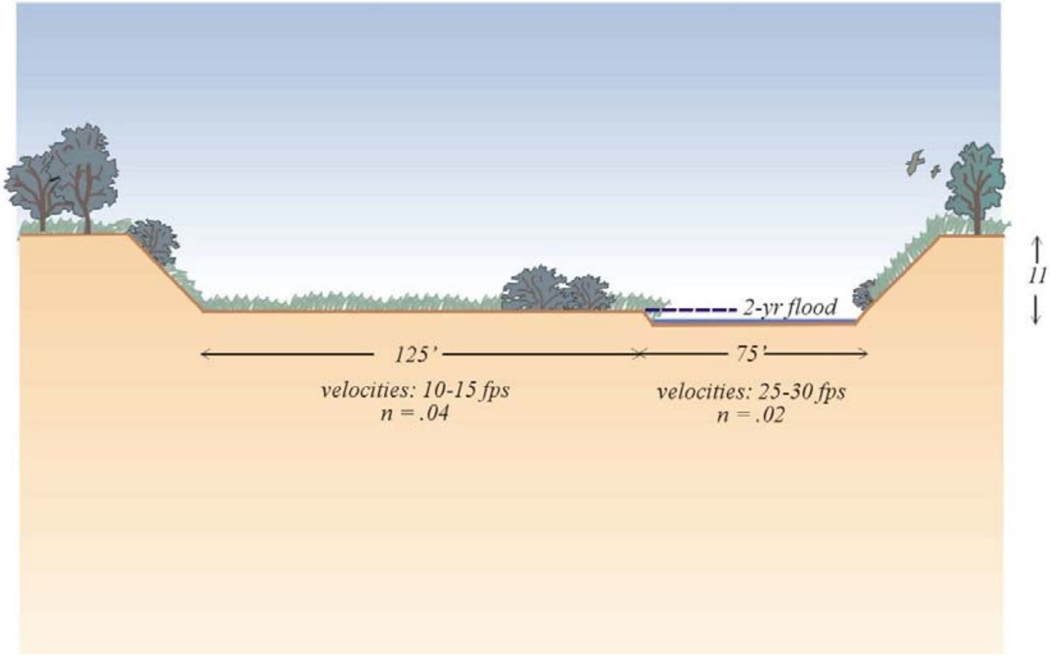


Figure 8
Alternative A:
Single
Floodplain
Terrace

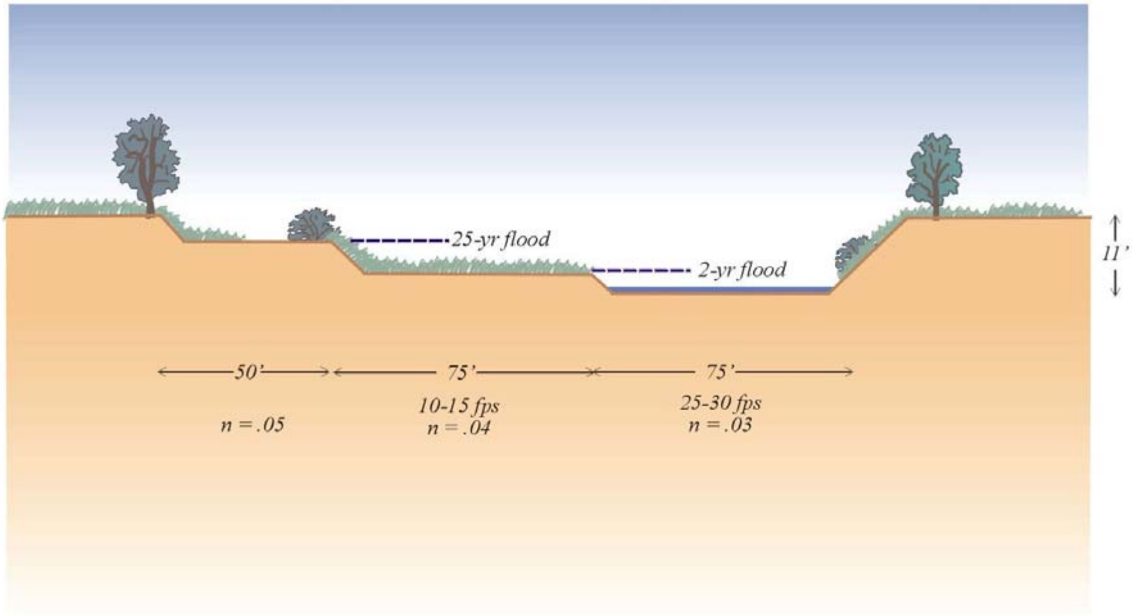


Figure 9
Alternative B: Two-tiered Floodplain Terrace

5.1.2 Alternative B – two-terrace floodplain

Alternative B includes an additional modification to the integrated channel-terrace concept developed for Alternative A. In Alternative B (Figure 9), the single terrace of Alternative A is replaced with a two-terrace configuration, with benches at the 2-yr and 25-yr water surface levels. Under Alternative B, the upper bench (25-yr) could be landscaped appropriately as a riparian canopy and could also be used for recreational purposes such as a continuous regional trail system – a bikeway and/or walking pathway. Incorporating recreational trail access at this elevation would be far safer than in Alternative A, and this feature (trail access) is a strong attraction associated with Alternative B. Consequently, the upper bench has a high overall roughness value (e.g. a Manning's 'n' value of 0.06). As in Alternative A, the channel and 2-yr terrace level have modeled roughness values of 0.02 and 0.04 respectively.

Tables 4 and 5 of Appendix 1 summarize the resulting hydraulic characteristics for Alternative B. Under the channel dimension assumptions used in the model, the two-terrace configuration provides slightly less storage and conveyance capacity than the single bench shape of Alternative A. Consequently, channel and floodplain velocities, flow depths, and average shear stress are slightly increased. As was the case for Alternative A, the high channel velocities and sheer stresses of Alternative B would require some form of channel bed and bank protection. Derrick stones could be used at selective cross-sections to stabilize the channel bed and help "anchor" the longitudinal profile and grade as well as dissipate energy in localized hydraulic jumps. The banks of the two terraces (as well as the terrace benches themselves) can be strengthened with biotechnical bank protection, which incorporates native vegetation structurally into engineered river bank stabilization.

5.1.3 MRCA Channel Concept

Alternative 3 from the MRCA report (Kammerer, 2000) was evaluated using the MIKE11 model. This alternative incorporates a "restored" open channel reach within the existing right-of-way adjacent to the present Tujunga Wash channel between Vanowen and Oxnard boulevards, south of Sherman Way. Water is supplied to this auxiliary channel from the Pacoima Diversion channel upstream through a 4-foot pipe, which is about 8,000ft long. The new channel has a 3-foot bottom width, 4:1 side slopes and a longitudinal slope equal to the Tujunga Wash slope between Vanowen and Oxnard. A hydraulic roughness value more appropriate for a natural channel (0.04) was used along this reach.

The model estimated that the maximum conveyance capacity of this proposed Vanowen to Oxnard diversion channel is around 100 cfs. The auxiliary channel is therefore relatively constrained in longitudinal extent and hydraulic capacity; it does not impact the existing channel or improve its flood conveyance capacity. The frequency of flow in this new channel is uncertain and would depend upon intake conditions from Pacoima channel, as well as bed percolation losses in the newly created channel. It does not represent rehabilitation of Tujunga Wash itself, which would remain lined with concrete, and would occupy part of the riparian area that may be required in a future rehabilitation or restoration of the main channel through this reach.

5.2 Alternative C – a new 'braid' channel

In response to question (ii), Alternative C represents a different approach from Alternatives A and B. A new secondary or auxiliary channel branches off from the existing Tujunga Wash immediately downstream of Hansen Dam (Figure 10). This auxiliary channel would travel parallel to the existing Tujunga Wash southward for roughly 3.5 miles and then rejoin the existing Tujunga Wash at Roscoe. As conceived, the new auxiliary channel would have greater sinuosity in plan form than the existing concrete channel.

The conceptual basis for Alternative C was founded on a geomorphic assessment of the historical Tujunga Wash system. The historic Tujunga Wash system operated as a series of braided channels across the alluvial fan surface of the eastern San Fernando Valley. Historically, the inundation frequency of the braid channels was dependent upon the magnitude of stormflow events. Large events, such as the March 1938 floods, generated flow across several channels on the alluvial fan surface, which was more than one mile in width. (see Figure 5).

For the braid channel concept of Alternative C, it is important to determine how flows would be allocated and transferred between the existing and the proposed braid channel. Three different approaches were developed to address this diversion: Scheme A diverts low flows; Scheme B diverts modest-sized flows; and Scheme C diverts larger flows according to the capacity and geometry of the new braid channel.

Diversion Scheme A would function in a similar manner to the current spreading grounds operation. As such, discharge occurring at rates less than or equal to the 2-yr event would be directed into the braid channel.

Under the existing regime, when Hansen Dam releases into the Tujunga Wash exceed the 2-yr threshold (roughly 900 cfs), flows would not be diverted into the braid channel and would be retained within the existing primary Tujunga Wash channel. This operation would be accomplished with a gate or equivalent structure. Scheme A would support an ecological restoration approach based upon intermittent low flows and smaller storm flow events that would support recovery of ephemeral wetlands and some riparian habitat.

Diversion Scheme B would replace the gate structure from Scheme A with a fixed broad-crested weir. This fixed weir is intended to control flow diversion between the principal Tujunga Wash channel and the auxiliary braid channel without operational adjustments during flood events. Unlike Scheme A, the weir concept for Scheme B would allow flow to enter the braid channel during higher magnitude storm events. As currently modeled, the weir geometry would allow flow rates of 750 cfs to be diverted, although other weir configurations are possible to allow greater flow. Table 2 illustrates the hydraulic characteristics expected for diversion Scheme B. Because of the low magnitude of diverted flows into the auxiliary channel, predicted velocity and shear stress are both relatively low.

The third row in Table 2 indicates a total width of "channel corridor" to add to the channel top width. The purpose of this corridor is to show the minimum potential land acquisition for a riparian buffer zone to provide wildlife habitat. The corridor is a constant 75ft, indicating 25ft on the right bank, 25ft on the left bank and a further 25ft (average) to the existing channel. This minimum amount of right-of-way is needed for an access road, and could easily provide a bikeway or walking path.

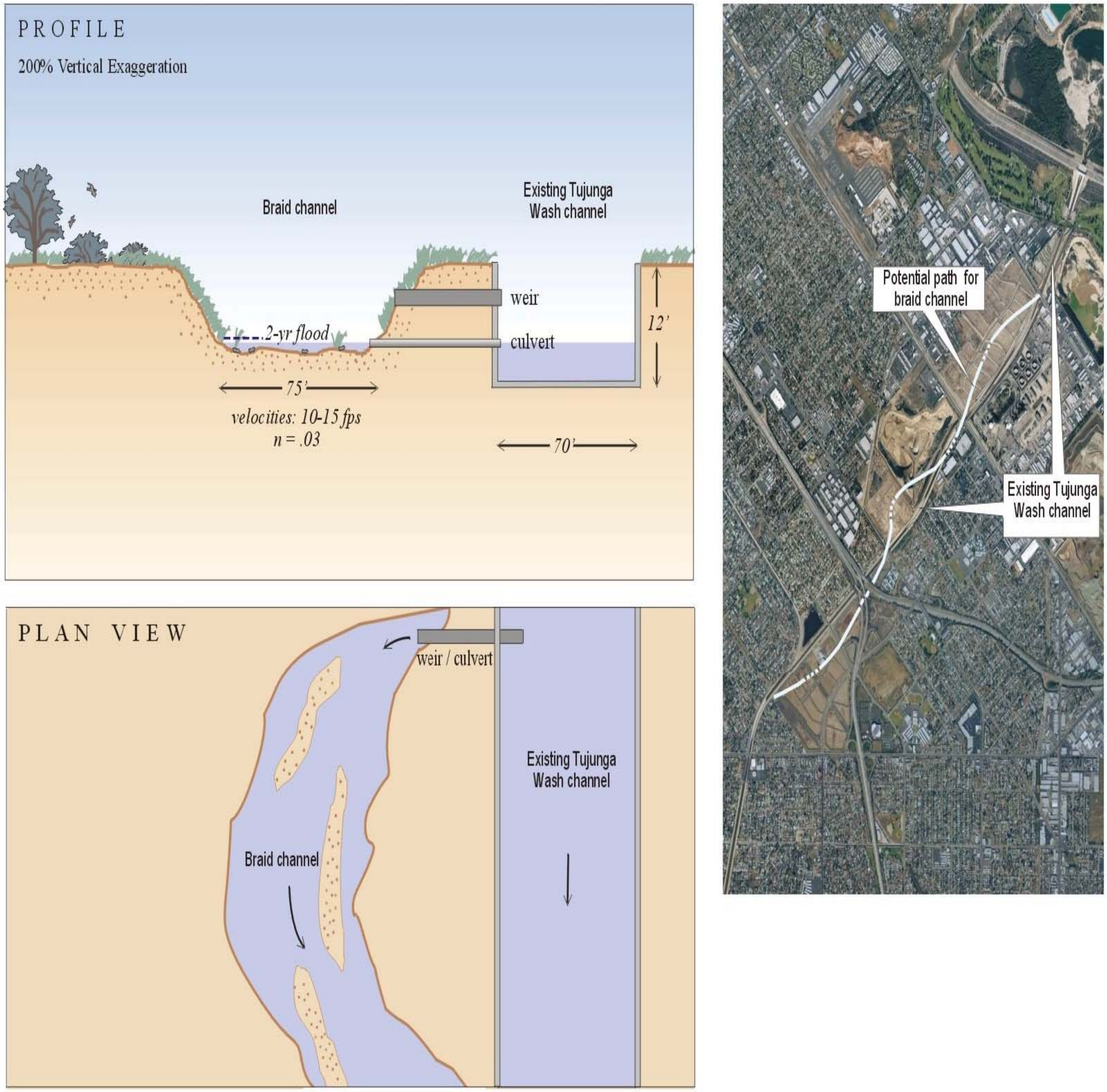


Figure 10
Alternative C: Secondary Braid-Channel Bypass

Table 2. Alternative C: Hydraulic Characteristics of Secondary Braid Channel between Hansen Dam and Sherman Way, Comparison of Schemes A, B and C. (100-yr Flow Event)

Different diversion schemes were developed to allocate and transfer flow between the existing channel and the auxiliary braid channel (see below).

Alternative C - A secondary braid channel, between Hansen Dam and Sherman Way, is diverted from the existing channel, which remains unaltered. Three

	Auxiliary Channel Top Width (ft)**								
	50			**75**			**100**		
Diversion Scheme (100-yr Flow Event)	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Total Width of Channel Corridor (ft) (25' Right-of-Way between and along channel edge)	125			150			175		
Average Primary Channel Velocity (ft/s)	41.5	32 / 38*	31 / 38*	41.5	32 / 38*	29 / 37*	41.5	32 / 38*	28 / 36*
Average Auxiliary Channel Velocity (ft/s)	0	9.3	11.3	0	7.2	11.6	0	6.1	11.8
Flow Diverted into Auxiliary Braid Channel (cfs)	0	750	1700	0	750	3400	0	750	4800
Average Primary Channel Depth (ft)	10.5	7.5 / 10.4*	7.3 / 10.4*	10.5	7.5 / 10.4*	6.6 / 10.2*	10.5	7.5 / 10.4*	6.1 / 9.9*
Average Auxiliary Channel Depth (ft)	0	5.2	7.3	0	3.1	6.6	0	2.2	6.2
Auxiliary Channel Bed Shear Stress (lb/ft2)	N/A	3.14	4.41	N/A	1.87	3.99	N/A	1.33	3.75

* Upstream of the Pacoima Wash Confluence / Downstream of the Pacoima Wash Confluence

** Channel and floodplain roughness are assumed to be 0.02 and 0.04 respectively.

Diversion Scheme A: All flows will be diverted into the auxiliary braid channel at or below the 2-yr event. Above the 2-yr event, the braid channel will be closed to all flow.

Diversion Scheme B: A broad-crested weir will control the flow diversion between the main Tujunga Wash channel and the auxiliary braid channel. The maximum diversion discharge is 750 cfs.

Diversion Scheme C: No diversion structure controls the flow allocation between the main Tujunga Wash channel and the auxiliary braid channel. The cross-sectional geometry directly controls the flow allocation, resulting in a maximum diversion discharge is 4800 cfs with the 100-foot wide auxiliary channel width.

Diversion Scheme C is similar to Scheme B, however the fixed-weir diversion structure is replaced by a stream confluence. Discharge to the braid channel through such a stream junction is governed by the cross-sectional geometry at the entrance of the new braid channel, as well as in-channel hydraulic conditions at the confluence. Maximum flow capacity into the braid-channel is roughly 4,800 cfs for the 100-foot channel width option shown in Table 2. Table 2 also describes how increases in diversion discharge result in increased braid channel velocity, water depth, sediment transport and scouring capacity.

One advantage of Scheme C is that the existing Tujunga Wash is not adversely impacted and existing flood conveyance conditions are not affected. As currently modeled, the restored "braid" channel does not include any benched terrace features or grade control structures. Such features could be included in the modeled concept, in order to adjust channel geometry to attain target flow velocities and surface water elevations for designated recurrence intervals. As shown in the plan of Figure 10, a potential pathway for the braid channel could be through the existing spreading ground areas adjacent to Tujunga Wash. It is unlikely that sufficient land area is available adjacent to Tujunga Wash other than the spreading grounds. This would require changes in the maintenance operations of the spreading grounds.

Under a revised Hansen Dam management regime involving storage of floodwater for water resources, a braided channel enhancement project could receive greater flow duration out of the dam than under present conditions. In addition, the reduction of sediment in channel flows (resulting from increased detention times behind the dam) should allow greater flow durations even within the current limit of turbidity for flows entering the spreading grounds. However, relying on flood flows (even of greater duration), to feed a braided channel project is unlikely to support biodiversity in a rehabilitated channel corridor. Supplementary flows could come either from stormwater (as is currently supporting the Branford Spreading Grounds), or from further releases from water stored behind Hansen Dam under the proposed new storage regime. For the latter to be realized, the need for these releases should be made known and included within the discussion and decision-making over the new dam regime, particularly in relation to the interests of the Water Master.

Further refinement and development of this concept would be necessary to understand potential impacts to existing infiltration capabilities at the spreading ground. While a braid channel might reduce the pond area of the existing spreading ground facility, the new braid channel might potentially allow infiltration under greater flow frequency and duration than at present. Any shortfall in infiltration could be made up by lowering the surface of the existing spreading grounds (see below). Issues of sediment management and operations maintenance are likely to have an important role in refinement of this concept, and should include a new function, allowing native vegetation to participate within the fluvial system while controlling invasive weeds. A riparian zone of willow scrub can be designed to filter sediment from flows entering the spreading grounds from the new channel. This approach would require a change in spreading grounds maintenance practices.

Further study of this approach could resolve how developing a braid channel might improve or impact infiltration and recharge operations at the spreading grounds. An idea from the DWP is to deepen the existing spreading basins so they can hold additional water. If the basins were deepened by up to 10 feet, with no limit on the maximum depth of the water, much more stormwater could be captured (Acevedo, pers. comm). Supplementary flows could come from stormwater, which currently supports the Branford Spreading Grounds, to mitigate any loss of infiltration area by providing a greater duration of flow and recharge, as well as supporting the riparian corridor along the braid channel.

5.3 Off-Channel Storage Opportunities

Issue (i) above questioned how the gravel pits that neighbor the Tujunga Wash might be integrated into a floodplain management program. More specifically, how could these pits be used to hold stormwater and how would this storage affect storm hydrographs and flow volumes in the channel?

Figure 6 shows the location of the four principal gravel pits near the Tujunga Wash, their estimated storage volumes, and the percent reduction in storm volume associated with each of the pits. Estimates of the pit storage volumes were derived from 1:24,000 scale USGS maps. Pit A (5,000 ac-ft) and Pit B (10,000 ac-ft) are located immediately adjacent to the Tujunga Wash while Pits C (~5,000 ac-ft) and D (~15,000 ac-ft) are further away. Referring back to 3.1.7, there are already potential demands for use of some of these pits to play a role in improving flood protection in the Sun Valley sub-watershed. Nevertheless, the pits may be sufficiently large to allow joint use. If this alternative is pursued, subsequent studies should include field verification and review of more detailed topographic mapping sources. Based on our initial estimates, it appears that using the gravel pits to retain stormflows merits further serious consideration. This approach, in coordination with subsequent modifications to stormflow management at Hansen Dam, could potentially result in reduced stormflows and velocities in Tujunga Wash.

6.0 Summary of Options

6.1 In-Channel System Modification

Referring to Figures 8 and 9, Alternatives A and B can be recognized as the nearest modification to ‘restoration’, as opposed to rehabilitation, because they propose to remove concrete from the channel. It is the best option for recovery of some river and floodplain function and riparian habitat, and would provide the most powerful foundation for more extensive ‘restoration’ plans in the future. It is likely to increase, rather than decrease, the percolation of floodwater into groundwater, protecting the capacity of the spreading grounds.

The effective capacity of the main channel to contain the 100-year flood can be increased by virtue of increased storage behind Hansen Dam and/or in the gravel pits. It would then be possible to install weirs or checkdams in the channel in order to reduce the velocity of flow below the critical flow threshold. In this case, the transition zones into and out of the restoration reach would be shorter, far easier and less expensive to design and install. A further reduction in velocity for a given discharge from Hansen Dam would be possible if the in-channel modifications were accompanied by lowering of the spreading grounds, with or without the installation of a braid channel through the spreading grounds. It is possible that a combination of water storage behind Hansen Dam, in the gravel pits and in the spreading areas (and with checkdams in the channel in order to reduce the velocity of flow below the critical flow threshold) could substantially progress the rehabilitation of Tujunga Wash.

It would seem there may be a high value to in-channel modifications that create a recreational amenity, including incorporation of a bikeway and other pedestrian or equestrian paths. (The ACOE’s Environmental Assessment for a proposed 19-mile segment of the Los Angeles River Bikeway, puts the projected benefit-to-cost ratio at 2.32 to 1). Alternative B would work best with regard to this feature, since the user is on the upper terrace and less subject to inundation and safety issues, etc. However, for this use of the terrace to be practicable, the trail would have to negotiate the underside of the bridge. The scheduled re-engineering of the Tujunga Wash bridge-crossings should take this requirement into account. Access to Alternative A would be low in elevation with respect to the channel, on the 2-year floodplain, and possibly subject to the risk of sudden flooding, but a possible solution may be a combination of Alternative B between bridges transitioning into Alternative A under them.

6.2 Physical Changes outside the Channel

Modifying the spreading grounds to accommodate a ‘braid’ channel would allow multi-purpose use of the area and simulate the original process of the river in flood. The most realistic simulation would be Alternative C, featuring a bifurcation of flow between the main channel and the braid channel. This alternative would also require less operation and maintenance cost, but may need some control over flow access to the spreading grounds to avoid excessive sedimentation. The importance of this issue, and the cost of design and installation, would be decreased if the velocities in the braid channel were reduced below 11 ft/sec (‘C’ in Table 2). This velocity could be reduced if the effective capacity of the main channel to contain the 100-year flood were increased, by virtue of increased storage behind Hansen Dam and/or in the gravel pits (allowing checkdams in the channel in order to reduce the velocity of flow below the critical flow threshold). This effective increase in channel capacity could be achieved with the added benefit of a potential increase in the duration of flows through the braid channel.

Creating floodplain ponds could provide structural and biological diversity without much change to the main system. It is not seen as an important tool for ecological enhancement, but as a possible additional enhancement to other more major works. This is because ponds already exist on the system, and primarily benefit ducks and other deep-water fowl, rather than more sensitive species. Replacing spreading ground area with a pond would probably not gain much ecosystem benefit. Unless it was fed with supplementary water from another source (such as stormwater or groundwater), the pond would not have any more water supply efficacy than the surrounding spreading grounds.

Utilizing the gravel pits would make a great difference to the effective capacity of the main channel. Future modeling should look at the potential of the pits to store water in such a way as to be complementary to Hansen Dam in supporting the restoration efforts in Tujunga Wash, for example in-pumping out stored water to maintain flows through the restored reach.

The question of public access under Alternative C will be a matter of County policy. Recently restored spreading grounds in the LA County area do allow the public access, although currently the public is excluded from spreading grounds adjacent to Tujunga Wash. A bikeway or other walking pathways could easily be incorporated into the design, and public usage would probably be assured by having a pond feature in the design of the modified spreading grounds. Many large gravel pits are used as fisheries, but the role of these pits as temporary storage facilities may militate against this use. Public access to the gravel pits would need to be assessed against the need to ensure public safety. A new land use classification blending park and public infrastructure may need to be created to satisfy County liability concerns. That said, there would be great benefit to creating a multi-use project that expanded publicly accessible open space in this community.

6.3 Modify dam operations

Like the gravel pits, the revised operation of Hansen Dam could support restoration efforts in Tujunga Wash. Conserving water and releasing it slowly would allow substantial changes to be made to the main channel, because using check dams in the main channel could induce a sub-critical flow regime.

6.4 Modify stormwater system in urban areas to support ecological enhancements

A framework study is needed to identify the potential for stormwater to be intercepted and attenuated, allowing stormwater to be made available for support of the rehabilitated areas along Tujunga Wash. Such an approach could provide swales of various dimensions distributed throughout the lower catchment along the flow routes of streets and subsurface pipes. Now-impervious surfaces could be made not only pervious, but also vegetated with plant species appropriate to the long summer droughts characteristic of the San Fernando Valley. A detailed assessment is needed of urban retrofit, development or redevelopment opportunities, including the installation of source control techniques to attenuate flows. This assessment should also address revisions to City Planning and Building Codes, in order to remove institutional barriers to implementation of these new techniques.

7.0 Cost and Benefits

At this stage of planning, it is not credible to identify the costs of each alternative without specifying their location, structural features, and extent. Common components of cost usually include right-of-way acquisition & bridge reconstruction. However, the County is already a major landowner along the Wash and the city plans to retrofit all the bridge crossings over the next decade. Greater concept refinement is needed to specify what the alternative(s) will entail and what is the likelihood of ancillary costs such as potential diversion of other infrastructure (such as water, power and communications) services, which can prove costly. A concept refinement phase is therefore needed to progress to project feasibility. Once the feasibility has been addressed, the relative costs of the alternatives can be assessed to conduct a credible cost-effectiveness analysis. However, it is possible to identify the multiple benefits of each alternative based on their general characteristics.

Unless environmental economics are employed (for example, travel cost, hedonic pricing, public willingness to pay for or accept a ‘good’ or goods etc.), it is difficult to quantify environmental, social or community benefits (so-called ‘intangible’ benefits) in monetary terms. Rather, cost effectiveness is used, whereby the “best value for the money” is assessed. This general principle can also be seen to operate where enhancement works are proposed to meet legislation such as the Endangered Species Act (ESA) and Total Maximum Daily Loads (TMDL).

The potential environmental, social and community benefits associated with rehabilitating Tujunga Wash system include the following:

- Improved water quality – cooler water (from tree shade), reduced turbidity and nitrate and phosphate concentrations from plant and beneficial bacterial uptake.
- Improved water resources for LA (through prolonged infiltration).
- Improved standard of flood protection on both Tujunga Wash and Los Angeles River.
- Landscape enhancement; not just more trees but cleaner air, carbon sequestration, etc.
- Wildlife habitat – increasing the acreage of habitat types and biodiversity, and providing much-needed wildlife corridors, breeding and feeding areas for birds, mammals, invertebrates etc.
- Public amenity and formal/informal recreation open space.

- Potential for continuous bike trail along the length of a rehabilitated Tujunga Wash providing a more natural and attractive commuter resource and connecting up with the Los Angeles River bikeway through downtown Los Angeles and to Long Beach.
- Outdoor educational classrooms accessible to urban schools.
- Enhanced base flow duration in both Tujunga Wash and Los Angeles River.
- Instilling professional and public confidence in the benefits of restoration.
- An increase in public awareness and pride in local environmental resources – resulting in less urban vandalism.

There may, however, be calculable benefits in terms of flood risk reduction, depending on the key elements and corresponding alternatives. The aim would be to achieve a minimum of a 1-in-100 year standard of protection throughout Tujunga Wash (there is an area local to the confluence with Pacoima Wash that does not have this standard at present). There may also be flood risk reduction benefits to the LA River (LAR), since the Tujunga Wash (TW) is a major tributary. The TW model, once connected with the LAR model created by the Taylor Yard study, would be able to compare flood flows in the LA River with and without change in the TW system. The TW model would also be able to generate flood maps once linked with a digital ground model of the TW floodplain, to compare the rehabilitated TW with the existing channel flood hazard areas.

It would seem there may be a high value to in-channel modifications that create a recreational amenity, including incorporation of a bikeway and other pedestrian or equestrian paths. The ACOE's Environmental Assessment for a proposed 19-mile segment of the Los Angeles River Bikeway puts the projected benefit-to-cost ratio at 2.32 to 1.

8.0 Recommendations for future efforts on Tujunga Wash

1) Stormwater Management Retrofit Study

The potential for utilizing urban runoff for ecological enhancement is one study that does not need to wait for a decision on the future dam operation. The benefits of utilizing runoff in this way will need a modeling linkage between surface hydrology and the existing groundwater model, perhaps utilizing GIS modeling techniques. While not quite as high a priority as the major storage facilities in (1) above (in terms of enabling rehabilitation of the channel), this study is nevertheless important and can be seen as a counterpart of the work being carried out in the adjacent Sun Valley. It can proceed at the earliest opportunity.

2) Key elements needed to conduct Feasibility Studies for Rehabilitation Efforts

The major question for the success of any channel rehabilitation effort is whether the flow velocities can be reduced below some critical flow threshold to values under, for example, 10 f/sec. Clearly, decisions on future dam operations and use of the gravel pits will be critical to the success of enhancing channel and riparian areas downstream, and should take into account the hydrology needs of enhanced areas.

Before taking any in-channel and most non-channel alternatives to the next stage of feasibility, the new dam operation rules need to be agreed upon and made available by the County and the Corps. Progress toward feasibility will require a determination as to the possible configurations and availability of the gravel pits for floodwater storage and use. The feasibility of deepening the spreading grounds could also have a significant impact on rehabilitation efforts.

If enough storage can be mobilized, it is possible that the entire length of Tujunga Wash could be rehabilitated. Rehabilitation efforts should therefore be integrated throughout the Tujunga Wash system, taking into account system-wide hydrology and hydraulics and avoiding piecemeal enhancement efforts.

3) Future Hydrodynamic Modeling

The Existing Conditions Model was created, calibrated and verified as a faithful representation of the present state of Tujunga Wash, before being used to establish primary dimensions of the major alternatives and the proposed MRCA channel. Future model refinement may include simulation of flow storage opportunities at the gravel pits and the spreading grounds, and to modify inflow hydrographs from Hansen Dam in accordance with the proposed/pending operational rules. Such refinements in the model will improve the ability to analyze the effectiveness of project alternatives (including combinations of alternatives) in the Tujunga Wash system for a range of flows corresponding to various storms and storage scenarios. A detailed hydrologic analysis of continuous low flow input to Tujunga Wash could be evaluated in a future phase of work to refine alternative concepts, especially with respect to use of stormwater flows.

Interpretation of modeling results should lead to a better understanding of flow storage required for comprehensive rehabilitation of Tujunga Wash, optimizing channel cross-sections and land-take for low flow and high flow conditions. Storage is vulnerable to the multiple storm scenario, and the hydrodynamic model should be developed with enough data resolution to simulate channel conditions under such a complex inflow scenario. Further modeling refinement could also include a more detailed evaluation of sediment conditions in relation to roughness, and for roughness generated by flow interactions between channel and floodplain. This assessment could be based upon representative field sites and including a geomorphic investigation of historical channel/floodplain roughness values for the Tujunga Wash and surrounding alluvial fan. This may also include the cost/benefit analysis of the different alternatives modeled.

4) Regaining Fluvial Process in the Tujunga Wash System

The braid channel concept is the only alternative currently available that offers authentic recovery of historic physical processes. Further development of this concept is needed to understand potential impacts to existing infiltration capabilities at the spreading ground. While a braid channel might reduce the pond area of the existing spreading ground facility, it might potentially allow infiltration under greater flow frequency and duration than at present. Issues of sediment management and operations maintenance are likely to have an important role in refinement of this concept, and should include a new function, allowing native vegetation to participate within the fluvial system while controlling invasive weeds. Further study of this approach could resolve how developing a braid channel might improve or impact infiltration and recharge operations at the spreading grounds, with or without deepening the existing spreading grounds. It would also provide for a maintenance regime of this fluvial system.

5) Prioritization of Rehabilitation Alternatives

The Hansen spreading grounds appear to provide a major restoration opportunity. However, there are many issues to be addressed before priorities can be attached to any project alternatives. As discussed above, there is considerable potential for combining alternatives in different reach locations. The use of gravel pits, spreading grounds, and Hansen Dam, to store additional discharge could potentially enable the in-channel rehabilitation along the entire length of Tujunga Wash, as well as braid channels, without loss of flood protection or infiltration capacity. A comprehensive river plan, containing a creative restoration vision, should be developed in parallel with the advancement and refinement of the current hydrodynamic model. Modeling of the system may prioritize projects based on the analysis of costs and benefits prepared as part of the future modeling. Such steps should occur before projects are proposed which are not considered within a comprehensive watershed framework. Piecemeal efforts can militate against a more comprehensive solution.

Additional modeling may not have to wait until questions about the availability and use of the key elements are finally answered. The model could enable scenarios to be tested with assumptions over the key elements before their confirmation. This approach could determine the likelihood of a comprehensive solution, meaning rehabilitation of most or all of Tujunga Wash from Hansen Dam to the LA River. It could also give valuable information on the preferred quantity and duration of both ‘conservation’ and flood flow releases from Hansen Dam (low and high flows respectively), as well as storage volumes needed in the gravel pits and spreading grounds during the 100-year event. It could also provide information on standards of flood protection in Tujunga Wash and in the Los Angeles River related to different storage scenarios.

This information would be useful to decision-makers concerned about management of the watershed of the LA River, including those assessing the future operational rules for Hansen Dam. Taken together with the study of stormwater management downstream of the dam, the results of this model test could be a dramatic example of the potential benefits of a watershed management approach on all projects downstream of Hansen Dam. The resulting rehabilitation projects would be seen as sustainable and substantial savings could accrue from avoiding projects seen as inappropriate within the watershed planning framework.

9.0 References

Acevedo, Mario, 2002. Los Angeles Department of Water and Power. Personal Communication.

Arcement, G. J. & Schneider, V. R. 1989. *Guide for selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains*. Water Supply Paper 2339, 3-8, US Geological Survey, Washington D.C.

Chow, V.T. 1959. *Open Channel Hydraulics*. 1st ed. 1973, McGraw-Hill International Editions

Condon and Moriarty, ed., 1999. *Second Nature: Adapting L.A.'s Landscape for Sustainable Living*, TreePeople

Cooke, R.U., 1984. *Geomorphological Hazards in Los Angeles*. London: Allen and Unwin.

Cowan, W.L. 1956. Estimating hydraulic roughness coefficients. *Agricultural Engineering*. Vol.37, no. 7, pp473-475.

Dale, N. 1985. *Flowering plants of the Santa Monica Mountains, coastal and chaparral regions of southern California*. Capra Press,

Dallman, S. and Piechota, T., 2000. *Stormwater: asset not liability*. The Los Angeles and San Gabriel Rivers Watershed Council, California.

Drennan, Michael, 2002. Montgomery Watson Harza. Personal Communication.

Faber, P.M., Keller, E., Sands, A. and Massey, B.M., 1989. *The ecology of riparian habitats of the Southern California coastal region: a community profile*. US Fish & Wildlife Service, Biol. Rep. 85(7.27).

Garrett, K. (ed.) 1993. *Biota of the Los Angeles River*. Los Angeles County Museum of Natural History.

Hickman, J.C. ed. 1993. *The Jepson Manual: higher plants in California*. University of California Press Ltd. Berkeley, California.

Hitchcock, C.S. and Wills, C.J., 2000. *Quaternary Geology of the San Fernando Valley, Los Angeles County, California*, Map Sheet 50. California Department of Conservation, Division of Mines and Geology.

Kammerer, M. 2000. *Geomorphic and Hydrologic Feasibility Study: Tujunga Wash Restoration Project*. For the Mountains Recreation and Conservation Authority.

Schueler, T. R. and Holland, H.K. 2000. *The practice of watershed protection*. Published by the Center for Watershed Protection, Ellicott City MD. www.cwp.org.

Smith, R.L. 1980. Alluvial sage vegetation of the San Gabriel River floodplain. *Madrono* 27 (3): 126-138.

Tran, Dung, 2002. City of Los Angeles Bureau of Engineering, Bridge Improvement Program Project Manager Personal Communication

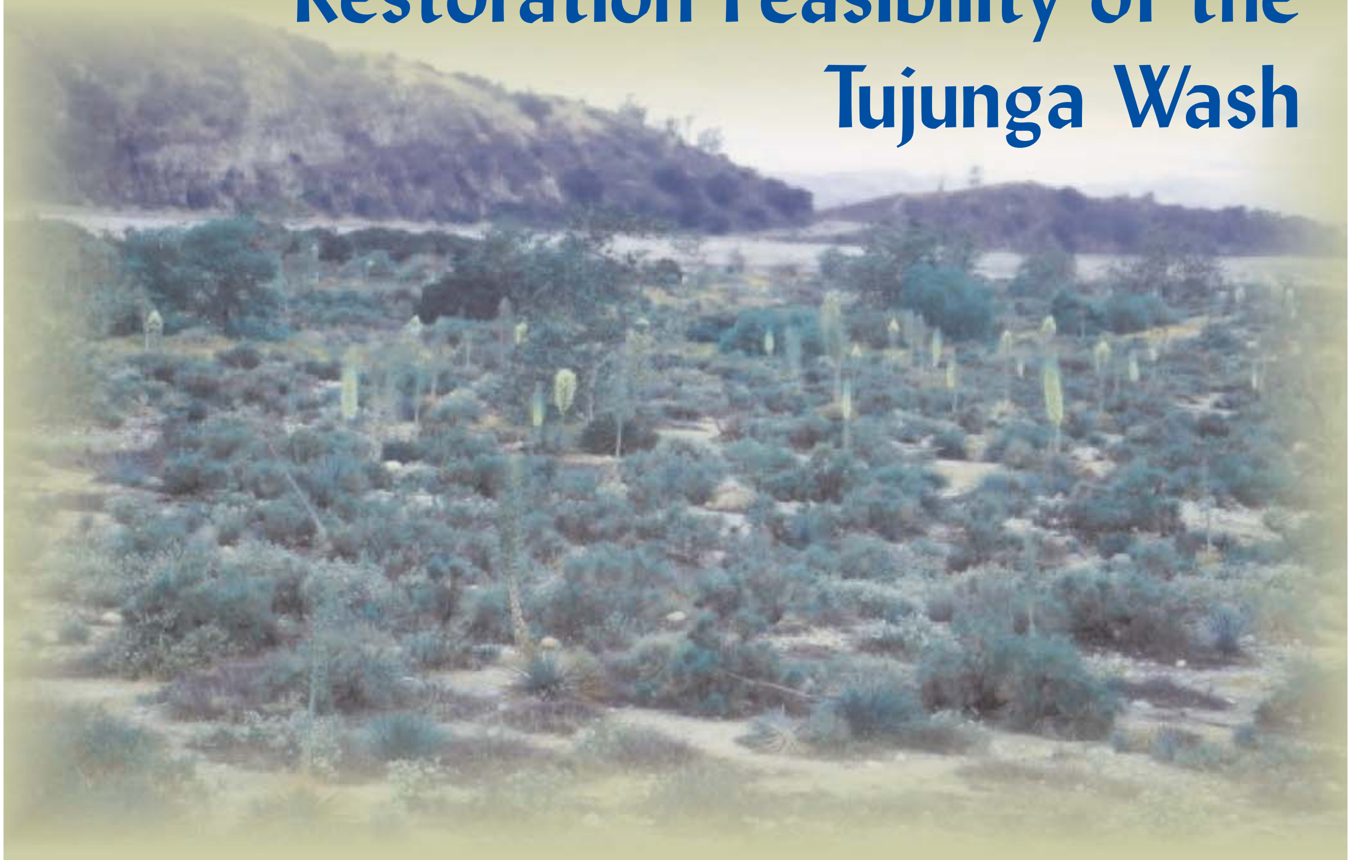
TreePeople, 1999 *T.R.E.E.S. Trans-agency Resources for Economic and Environmental Sustainability* http://treepeople.org/trees

Urbonas, B. and Stahre, P. 1993. *Stormwater; best management practices and detention for water quality, drainage and CSO management*. Prentice- Hall, Inc., Simon & Schuster. ISBN: 0-13-847492-3.

U.S. Army Corps of Engineers, 1990. *Hansen Dam Water Control Manual*.

U.S. Army Corps of Engineers, 1999. *Water Conservation and Supply at Hansen and Lopez Dams Feasibility Study*; Final Report and Environmental Impact Statement. Los Angeles County Drainage Area, Los Angeles District, Corps of Engineers.

Hydrodynamic Study for Restoration Feasibility of the Tujunga Wash



Appendices

Appendix 1. Modeling Report by PWA Ltd. "The Tujunga Wash: An Investigation of Channel Hydraulic Conditions and Potential Restoration Alternatives".

Appendix 2. Hydrodynamic Model - Mike 11 & HEC-RAS Models

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TUJUNGA WASH:
An Investigation of Channel Hydraulic Conditions and Potential Restoration Alternatives

Prepared for

WaterCycle LLC

and

The River Project

Prepared by

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Philip Williams & Associates (PWA) conducted a hydraulic analysis of the Tujunga Wash channel system for WaterCycle LLP and The River Project as part of a broader feasibility study to evaluate potential restoration opportunities along the Tujunga Wash corridor. This PWA report includes a description of how an existing conditions hydrodynamic model was developed for Tujunga Wash. Topics addressed include the hydrologic setting of the project area, channel geometry, hydrologic input parameters, and modeling boundary conditions. The existing conditions model was then used to analyze and compare hydraulic conditions associated with potential restoration alternatives. Three new channel alternatives were evaluated and are discussed in this report. In addition, non-channel storage opportunities were examined and the effect of a previously recommended channel plan from the Mountains Recreation and Conservation Authority (MRCA, 2000) was analyzed. This current report focuses on the modeling study and alternatives assessment and does not include many elements of the broader feasibility study including restoration objectives, target habitat goals, land-uses, easements, utilities, and costs. In this report "the project team" refers to participating staff from WaterCycle, The River Project, and the Tujunga Wash Technical Advisory Committee.

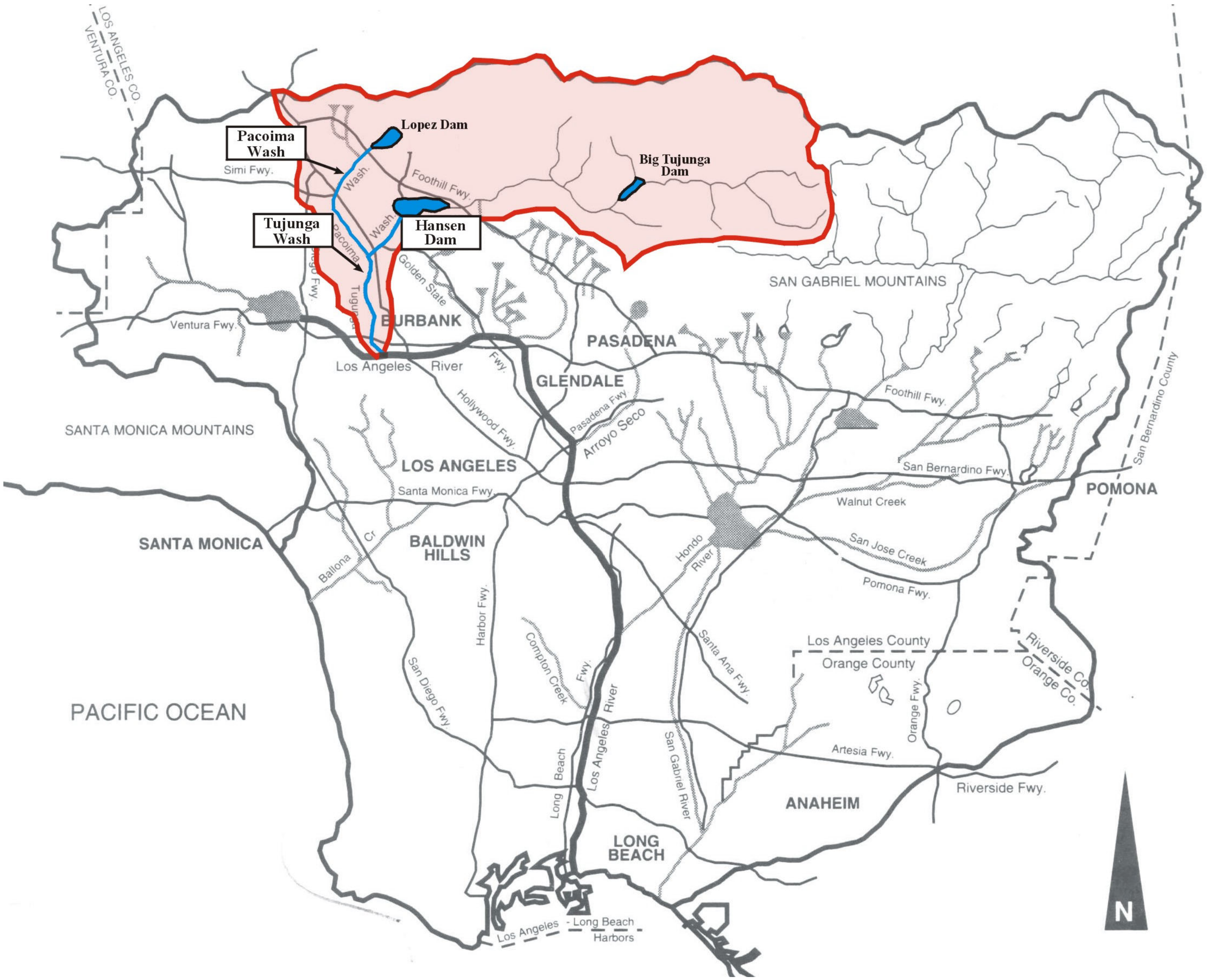
2. HYDROLOGIC AND GEOMORPHIC SETTING

Tujunga Wash is located in the eastern San Fernando Valley (Figure 1). The channel flows 9.5 miles between Hansen Dam at the northern edge of the Valley and the Los Angeles River confluence at the southern edge of the Valley (Figure 2). The floor of the eastern San Fernando Valley is a series of southward sloping alluvial fans, which have coalesced into alluvial apron (bajada) surface. Gradients across these fan surfaces are steepest to the north towards the San Gabriel and Verdugo mountains and decrease towards the Los Angeles River. Likewise, sediment textures are generally coarser to the north and finer to the south. Prior to the engineering and channelization of Tujunga Wash and other drainage channels in the eastern San Fernando Valley, a network of up to 5 wide alluvial channels carried runoff, sand, and gravel across the Valley floor under episodic stormflows characteristic of the southern California Mediterranean hydro-geomorphic regime (Hitchcock and Wills, 2000; Kammerer-MRCA, 2000).

With elevations above 7100 ft, the mountain headwaters of the Tujunga Wash watershed (150 mi^2) experience orographically enhanced precipitation. Episodic intense rainfall results in rapid runoff response, high sediment yields, and even debris flows on the steeper slopes and tributaries. In the post-fire scenario, runoff and erosion increase significantly. Following damaging flood events in 1914, 1934, and 1938 (Cooke, 1984), several flood control and sediment control facilities were constructed in the Tujunga and Pacoima watersheds in the mid 20th century. These projects included the Tujunga Wash and Pacoima Wash channels, Big Tujunga Dam (el. 2304 ft); Hansen Dam (el. 1087 ft); and Lopez Dam (el. 1299 ft) (Figure 1). Storm flows exiting Hansen Dam and entering the Tujunga Wash flood control channel are reduced to a maximum release rate of 20,800 cubic feet per second (cfs).

The Tujunga Wash flood control canal is a rectangular reinforced concrete channel. Upstream of its confluence with Pacoima Wash, channel bottom widths are 60-ft with a variable depth of 10-15 ft. Downstream of Pacoima Wash, the Tujunga channel width increases to 70-ft to accommodate the additional inflows from the Pacoima and Branford channels. Depths remain similar downstream of the Pacoima channel at 10-15 ft. Channel elevations along Tujunga Wash drop from 956 ft at the base of Hansen Dam to 567 ft at the Los Angeles River confluence, representing a net slope of nearly 41 ft/mi. Pacoima Wash flows originate in the San Gabriel Mountains northwest of the Tujunga Wash watershed, pass through the Lopez Dam sediment basin, and reach Tujunga Wash 3 miles below Hansen Dam by way of the southeast flowing diversion channel (Figure 2). The Branford drainage channel collects local surface runoff in the residential Pacoima neighborhood and joins the Pacoima Wash just prior to entering Tujunga Wash.

The County and City of Los Angeles operate four spreading ground facilities (Hansen, Tujunga, Branford and Pacoima) adjacent to the Tujunga Wash and Pacoima Wash channels to increase groundwater recharge (Figure 1). Flows are diverted from the Tujunga and Pacoima washes into broad shallow infiltration basins to enable percolation to the aquifer below. During low flow conditions in Tujunga



f i g u r e 1

Tujunga Wash Physical Setting

Tujunga Wash Hydrodynamic Modeling

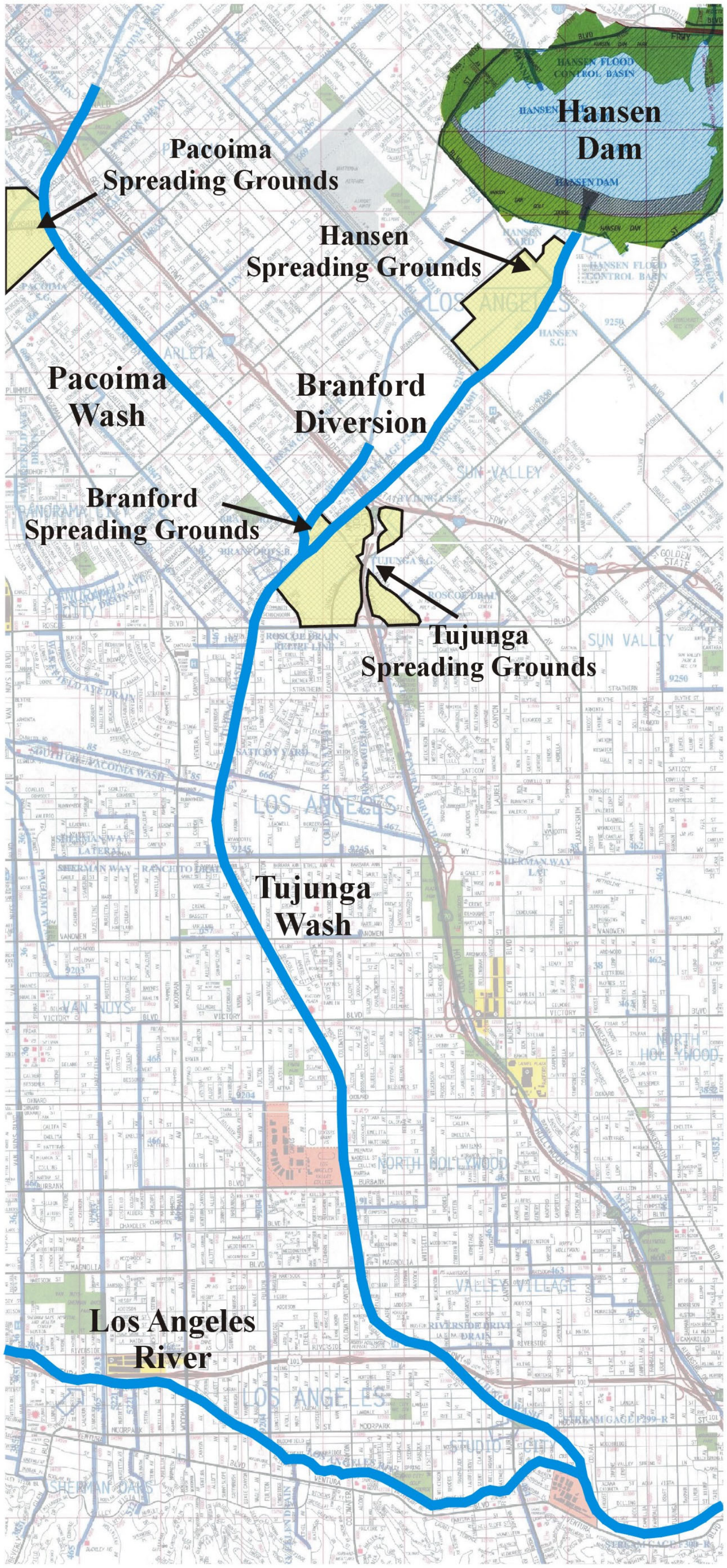


figure 2

Project Site Layout

Tujunga Wash Hydrodynamic Modeling

PWA

Wash the spreading grounds may receive continuous inflow, representing a 100% diversion of Tujunga channel flows. During larger storm event flows, diversion gates into the spreading grounds are closed.

3. HYDRODYNAMIC MODEL DEVELOPMENT

3.1 MODEL SELECTION

PWA used the hydrodynamic module of MIKE 11 to evaluate hydraulic conditions in the Tujunga Wash system. MIKE 11 is a one-dimensional hydrodynamic model, developed by the Danish Hydraulics Institute (DHI), which solves the vertically integrated conservation of mass and momentum equations (Saint-Venant equations). The MIKE 11 model was selected in preference to the U.S. Army Corps of Engineers (ACOE) HEC-RAS application because it is better suited to the high slopes, high velocities and super-critical flow conditions of the Tujunga Wash system. MIKE 11 also incorporates a fully unsteady hydrodynamic module, which was used in this study and is currently unavailable in HEC-RAS for supercritical flow conditions. Additionally, this module expands channel analysis and ecological enhancement capabilities by more realistically portraying channel and overbank storage (floodplains, spreading grounds, gravel pits) and peak hydrograph timing and contribution. However, to better facilitate future uses by parties who do not have access to MIKE 11, a HEC-RAS model was translated from the MIKE 11 model. Appendix A includes an example of HEC-RAS river cross-section output for the existing conditions model, as well as an example for one of the alternatives.

3.2 MODELING INPUT DATA

3.2.1 Channel Geometry

Channel geometry dimensions for the model were based on cross-sectional data provided by the U.S. Army Corps of Engineers (*Summary of Pertinent Hydraulic Data for Tujunga Wash, 1963*), and the *Hansen Dam Water Control Manual* (1990) provided by the ACOE. Channel geometry was verified at numerous locations along the channel with ACOE as-built construction plans dated September 1950. A total of 97 cross-sections were utilized to model the 9.5 mi Tujunga Wash channel (approximately 10 per mi). Reference stations used to identify cross-section locations in the current model are different from the original ACOE documentation because the current MIKE 11 model was developed using metric units. However, to maintain consistency, and facilitate external review, specific landmarks such as bridges and roads are referenced in common.

3.2.2 Discharge

The 2-, 5-, 10-, 25-, 50- and 100-yr design flow events were chosen as representative discrete hydrologic events to model by the project team. In addition, a continuous flow period from the 1998 water year was selected to simulate a more seasonal system response. Lastly, a steady-state calculation, using predicted discharge values from ACOE 1963 hand-calculations, was computed to verify in-channel water levels. A detailed hydrologic analysis of continuous low flow input to Tujunga Wash was not conducted for the current study. Such hydrologic analysis could be evaluated in a future phase of work to refine alternative concepts.

3.2.2.1 Boundary conditions

External and internal boundary conditions were established within the hydrodynamic modeling framework (Figure 3). The model's upstream boundary condition occurs as outflow from Hansen Dam at the base of the spillway channel. Additional discharge boundary conditions arise from lateral inflows from the Pacoima and Branford drainage channels. The model's downstream boundary condition is assumed to be critical depth at the Los Angeles River confluence. This assumption is based on the condition that modeled flow throughout the Tujunga Wash is super-critical and consequently no backwater effects extend upstream from the Los Angeles River boundary downstream. In addition to these external boundary conditions, two internal rating curves represent flow leaving the channel through headworks into the Hansen and Tujunga spreading ground. The existing conditions model utilized rating curves based on the entrance gate geometry at the spreading ground diversions. The Los Angeles County Department of Public Works is currently reviewing the operational guidelines of the Hansen Spreading Grounds. The existing conditions model may be revised if operations are modified.

3.2.2.2 Discrete storm event discharge

To model the standard 2- through 100-yr discrete hydrologic events, input discharge for Tujunga Wash was developed from Hansen Dam reservoir routing calculations as follows: First, for the selected recurrence interval events (discharge-frequency curve, Figure 4) a scaling ratio was developed between peak inflows to Hansen Dam and the project design peak inflow hydrograph (133-yr event). The source of the discharge-frequency curves in Figure 4 is ACOE *Water Control Manual, Hansen Dam, Tujunga Wash, Los Angeles County, California, 1990.* The project design peak inflow hydrograph is also taken from the Hansen Dam Water Control Manual. The scaling ratio was then used to uniformly scale the Hansen Dam design storm inflow hydrograph down to the corresponding recurrence intervals (inflow curves of Figure 5). Using such a hydrograph scaling approach does not account for variations in hydrograph shape associated with flows other than the design magnitude event. Most likely, the shape of the design inflow hydrograph is representative of other high magnitude events, such as events greater than the 50-yr recurrence. For lower magnitude events such as the 2- and 5-yr events the design hydrograph shape may be less appropriate in terms of flow duration, but is likely suitable in terms of estimated peak flow. The use of the design hydrograph for lower magnitude flows does not adversely affect the discussion of alternatives below because the channel concepts presented below were sized according to required peak flow conveyance.

Next, routing through the Hansen reservoir was performed for each selected inflow event, according to guidelines presented in the Hansen Dam Water Control Manual. Reservoir routing is a process used to predict temporal and spatial variations in discharge due to the influence of a reservoir. The routing method employs the continuity equation to develop an empirical relationship between storage within the reservoir (stage-storage curve, Appendix Figure A-1) and discharge at the outlet (rating curves, Appendix Figures A-2 through A-4).

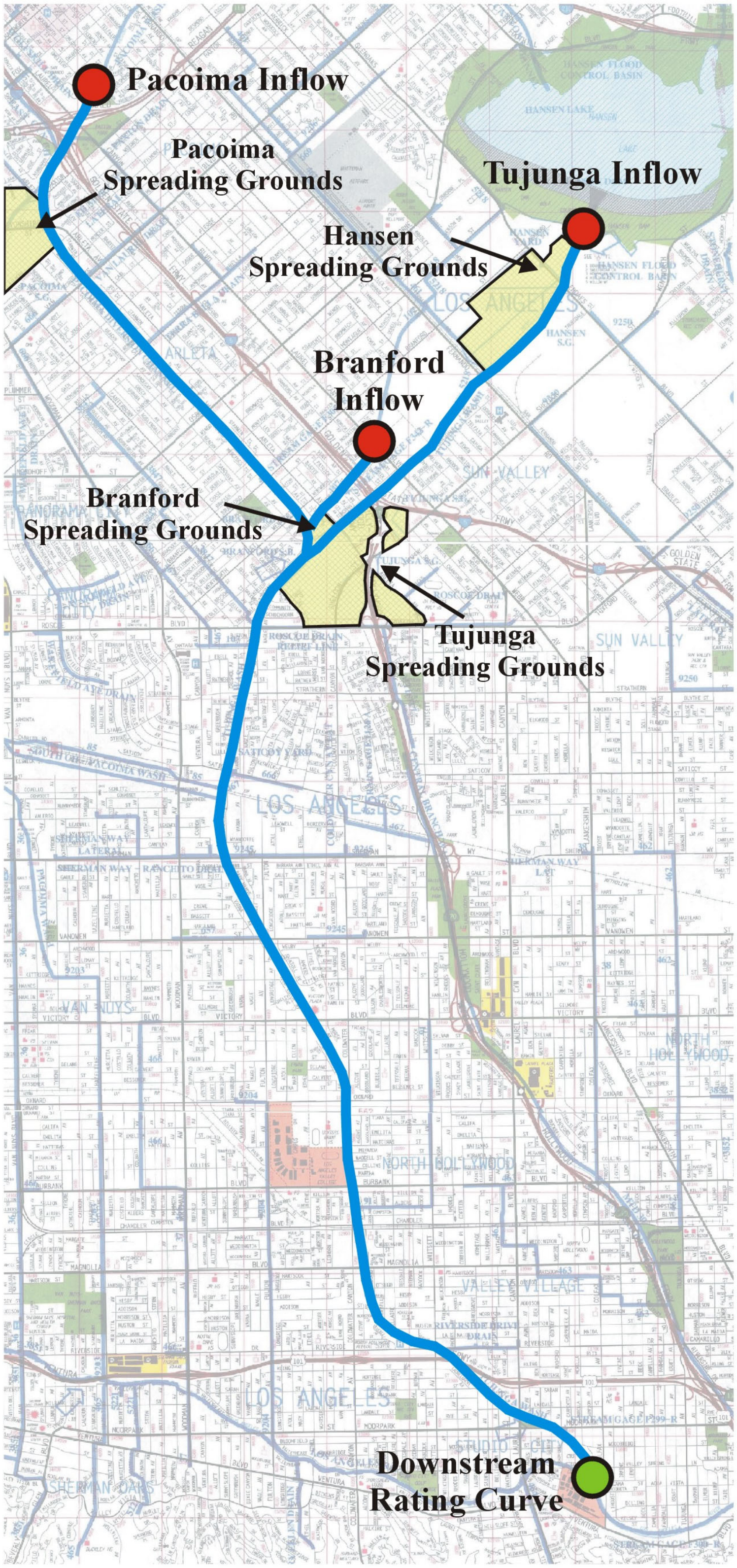


figure 3

MIKE 11 Model Layout and Boundary Condition Locations

Tujunga Wash Hydrodynamic Modeling

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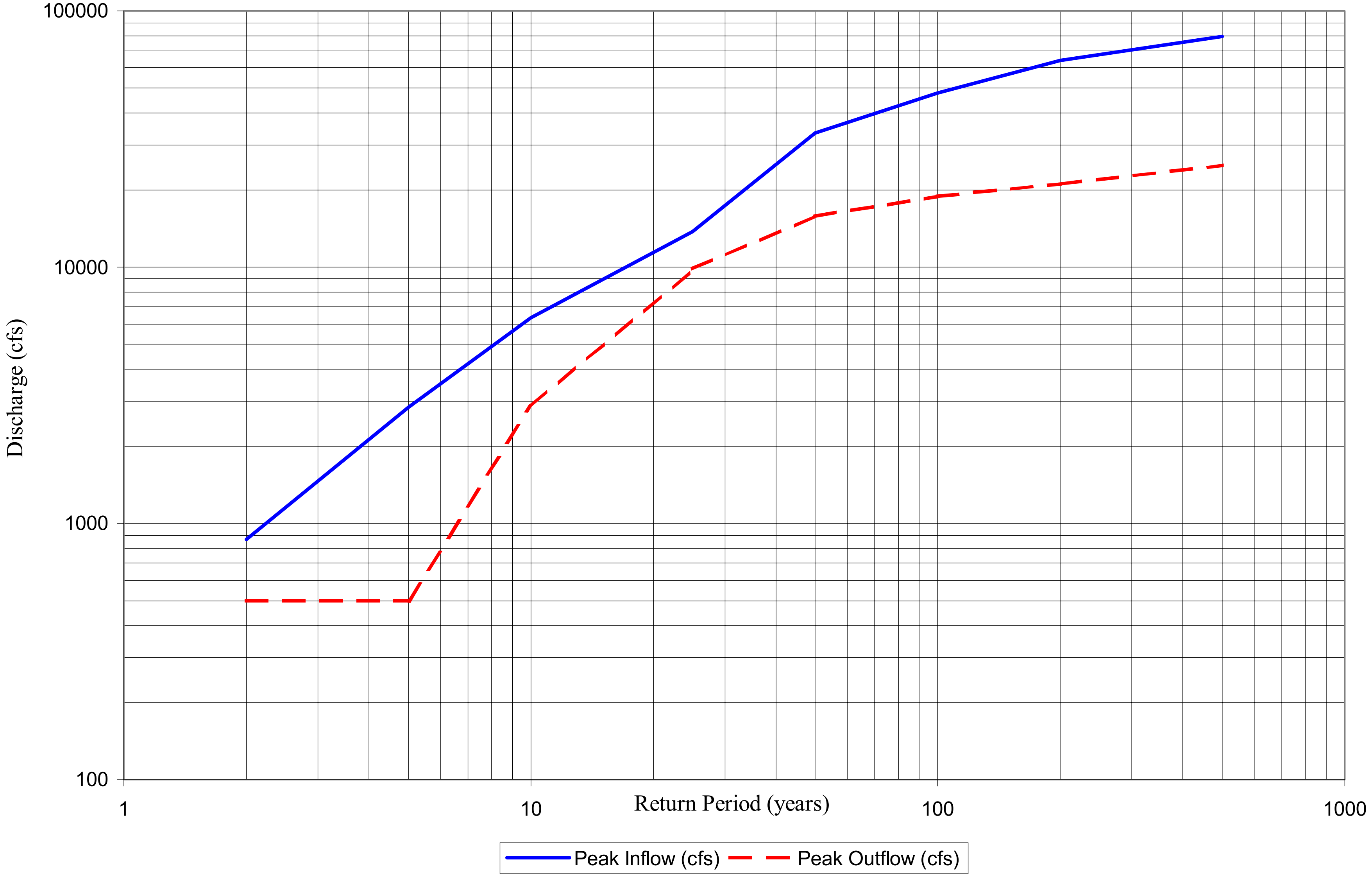

f i g u r e 4

Hansen Dam Discharge Frequency Curves

Tujunga Wash Hydrodynamic Modeling

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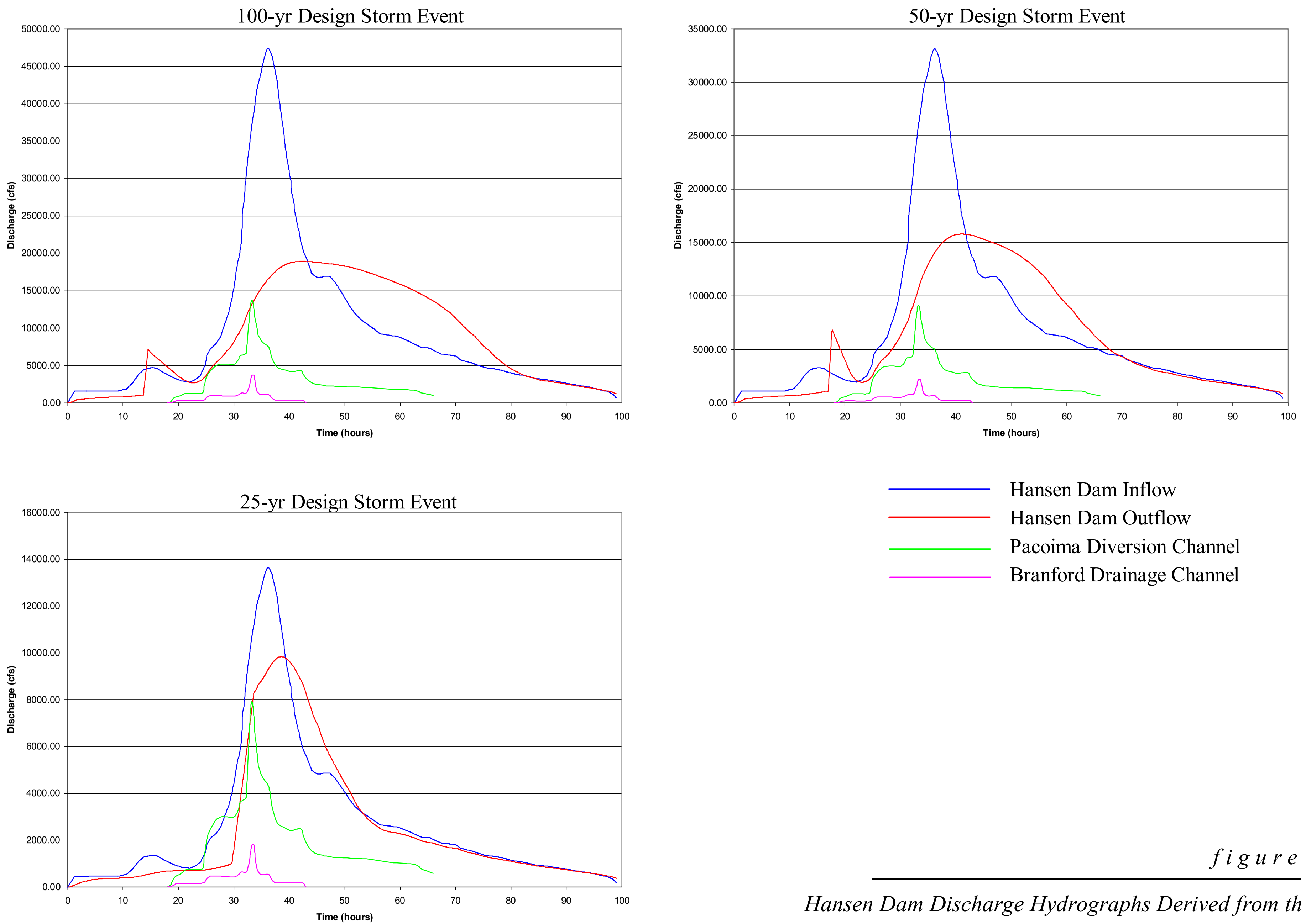
Location: Hansen Dam, Tujunga Wash, California
Total Drainage Area: 151.9 (sq. mi.)
Source: Hansen Dam Water Control Manual (1990), Plate 8-1

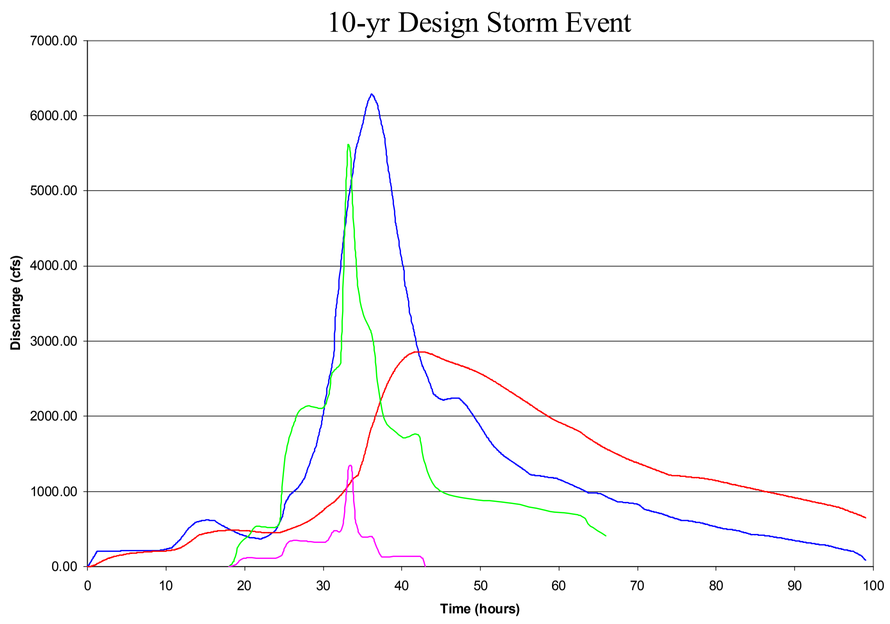


f i g u r e 5

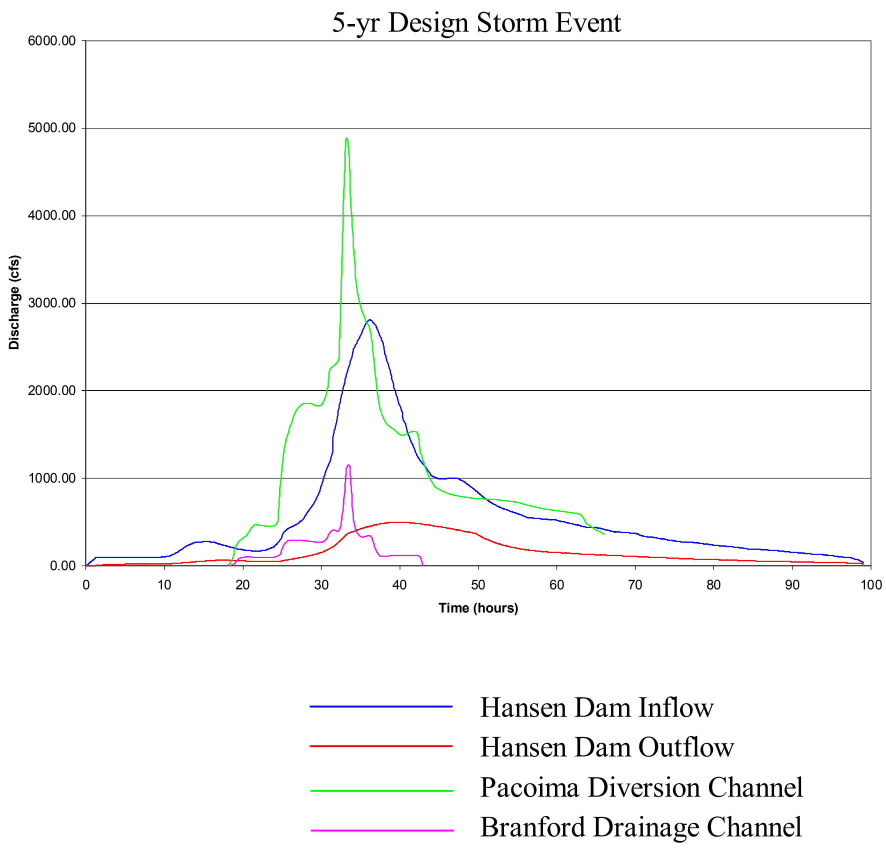
Hansen Dam Discharge Hydrographs Derived from the Scaled Inflow and Reservoir Routing Process

Tujunga Wash Hydrodynamic Modeling

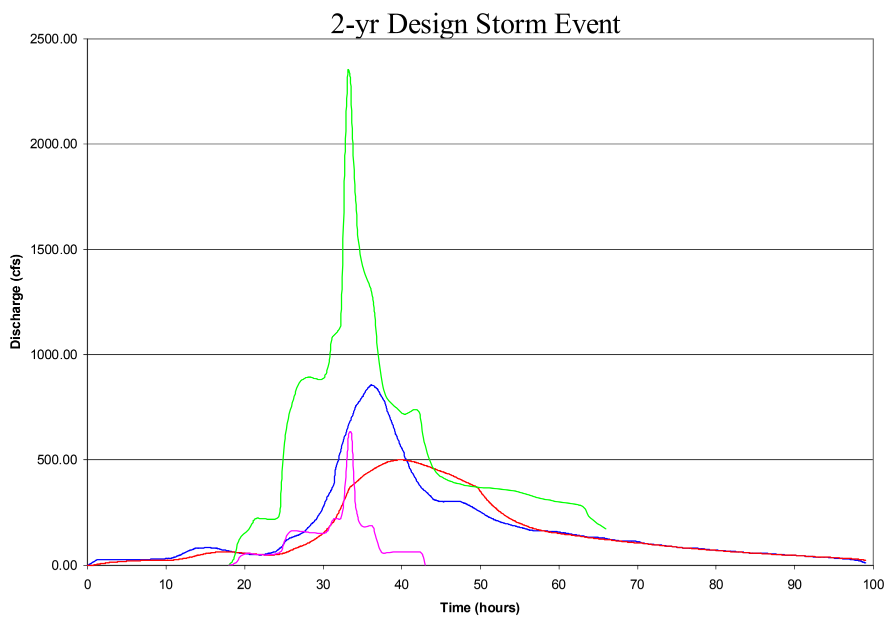
PWA



10-yr Design Storm Event



5-yr Design Storm Event



2-yr Design Storm Event

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Hansen Dam Discharge Hydrographs Derived from the Scaled Inflow and Reservoir Routing Process

Tujunga Wash Hydrodynamic Modeling

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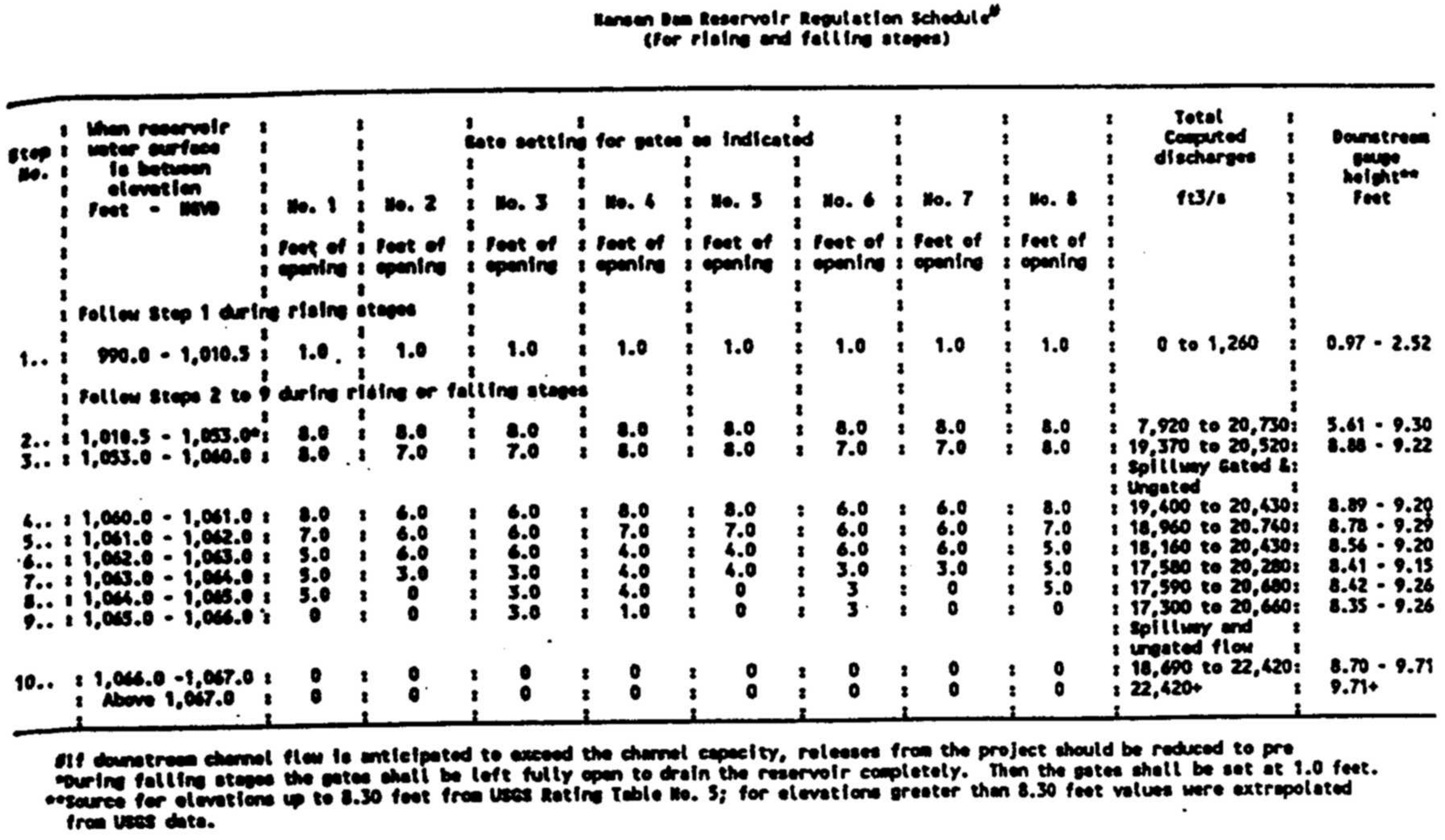
The following is an excerpt from the Hansen Dam Water Control Manual that describes the operation and routing of Hansen Dam flows:

> *Hansen Dam is operated according to the Reservoir Regulations Schedule (Figure 6). This is achieved by allowing the reservoir to fill to an elevation of 1,010.5 ft, with a fixed gate opening of 1.0 ft. After the water level exceeds 1,010.5 ft; all gates are opened fully to 8.0 ft until the downstream channel capacity of 20,800 cfs is reached. Above a water surface elevation of 1,053 ft, the gates are progressively closed until a pool elevation of 1,066 is reached. At this point, uncontrolled spillway flows occur, equal to roughly the downstream channel capacity. On the falling limbs of the hydrograph, the same gate schedule is followed until the reservoir is completely drained. Keeping the gates open at 1.0 ft until the water surface elevation reaches 1,010.5 ft is intended to minimize the floating debris problem, and keeping the gates fully open as the reservoir drains is intended to minimize the sedimentation problems.*

Resulting outflow hydrographs developed from the reservoir routing process are shown in Figure 7. Comparing predicted peak discharges of Figure 7 to corresponding peak outflows from the Hansen Dam discharge-frequency curve (Figure 4) shows overall agreement, with some minor value discrepancies. These differences occurred as a result of digitizing the rating curves and stage-storage relationship and creating a digital representation of an analog record. To rectify this, a scaling correction was applied to the outflow hydrographs of Figure 7 to match peak frequency values seen in Figure 4. Resulting outflow hydrographs from Hansen Dam based on this 3-part process of inflow scaling, reservoir routing, and minor rectification are shown in Figure 5. The outflow hydrographs of Figure 5 represent the input discharge (the inflow boundary condition to the MIKE-11 model) at the base of Hansen Dam. The principal assumption in this method is that inflow hydrograph shapes can be scaled according to peak values derived from discharge-frequency relationships. While more accurate results might be obtained using a comprehensive hydrologic simulation, this is beyond the scope and needs of the current feasibility study. At a future phase it may be appropriate to develop volume-frequency relationships for Tujunga Wash as a basis to analyze potential off-channel storage alternatives and flow conditions to support riparian vegetation.

Design flow hydrographs for discharge contributed to Tujunga Wash from the Branford and Pacoima channels were provided by the ACOE (*Los Angeles County Drainage Area Final Feasibility Interim Report, Part I Hydrology Technical Report, 1991*). The design flow hydrographs for Branford and Pacoima channels were then scaled (as described above for Tujunga Wash) for the other selected frequency events.

The current study evaluated inflow to the Tujunga Wash from the Hansen Dam and Pacoima Wash sources. Flow contributions to Tujunga Wash from other sources such as local storm drains were not input into the model. Such local flows likely represent less than 5% of the total discharge volume for the watershed. During storms, runoff from the adjacent urban areas is also more likely to enter the channel and pass downstream before the arrival of the primary hydrograph peak in the Tujunga Wash channel. While local drainage contributions are relatively small in terms of volume, this runoff is potentially an



Hansen Dam Reservoir Regulation Schedule#
(For rising and falling stages)

Step No.	When reservoir water surface is between elevation Feet - NGVD	Gate setting for gates as indicated								Total Computed discharges ft3/s	Downstream gauge height** Feet
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8		
		Feet of opening	Feet of opening	Feet of opening	Feet of opening	Feet of opening	Feet of opening	Feet of opening	Feet of opening		
	Follow Step 1 during rising stages										
1..	990.0 - 1,010.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0 to 1,260	0.97 - 2.52
	Follow Steps 2 to 9 during rising or falling stages										
2..	1,010.5 - 1,053.0*	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7,920 to 20,730	5.61 - 9.30
3..	1,053.0 - 1,060.0	8.0	7.0	7.0	8.0	8.0	7.0	7.0	8.0	19,370 to 20,520 Spillway Gated & Ungated	8.88 - 9.22
4..	1,060.0 - 1,061.0	8.0	6.0	6.0	8.0	8.0	6.0	6.0	8.0	19,400 to 20,430	8.89 - 9.20
5..	1,061.0 - 1,062.0	7.0	6.0	6.0	7.0	7.0	6.0	6.0	7.0	18,960 to 20.740	8.78 - 9.29
6..	1,062.0 - 1,063.0	5.0	6.0	6.0	4.0	4.0	6.0	6.0	5.0	18,160 to 20,430	8.56 - 9.20
7..	1,063.0 - 1,064.0	5.0	3.0	3.0	4.0	4.0	3.0	3.0	5.0	17,580 to 20,280	8.41 - 9.15
8..	1,064.0 - 1,065.0	5.0	0	3.0	4.0	0	3	0	5.0	17,590 to 20,680	8.42 - 9.26
9..	1,065.0 - 1,066.0	0	0	3.0	1.0	0	3	0	0	17,300 to 20,660 Spillway and ungated flow	8.35 - 9.26
10..	1,066.0 -1,067.0	0	0	0	0	0	0	0	0	18,690 to 22,420	8.70 - 9.71
	Above 1,067.0	0	0	0	0	0	0	0	0	22,420+	9.71+

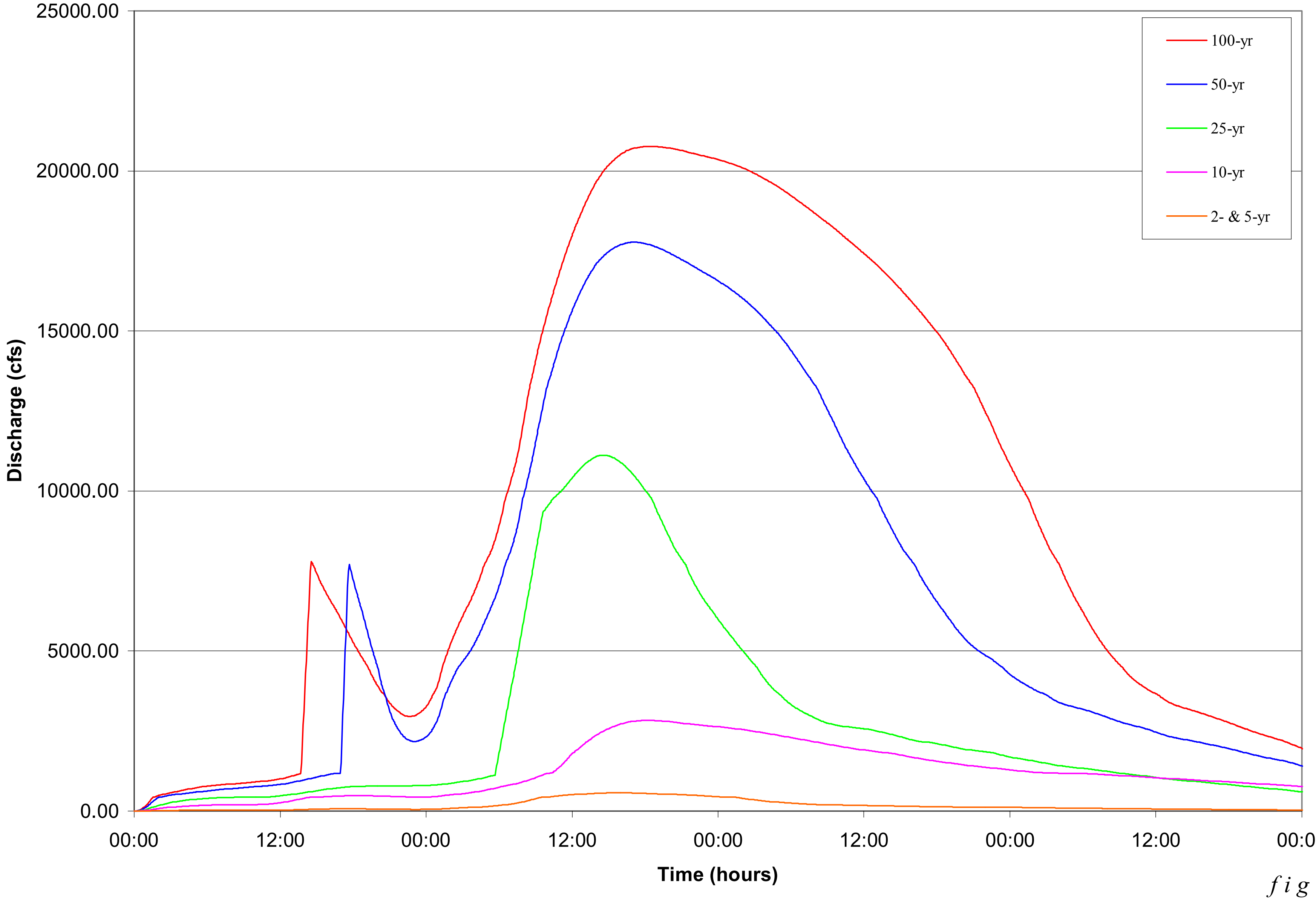
#If downstream channel flow is anticipated to exceed the channel capacity, releases from the project should be reduced to pre
*During falling stages the gates shall be left fully open to drain the reservoir completely. Then the gates shall be set at 1.0 feet.
**Source for elevations up to 8.30 feet from USGS Rating Table No. 5; for elevations greater than 8.30 feet values were extrapolated from USGS data.

Source: Hansen Dam Water Control Manual

figure 6

Hansen Dam Reservoir Operation Schedule

Tujunga Wash Hydrodynamic Modeling



f i g u r e 7

Hansen Dam Reservoir Routing Results (non-rectified)

Tujunga Wash Hydrodynamic Modeling

PWA

important source of flow during the dry season. Such dry season low flows are a potential resource for ecological enhancement.

3.2.2.3 Seasonal discharge

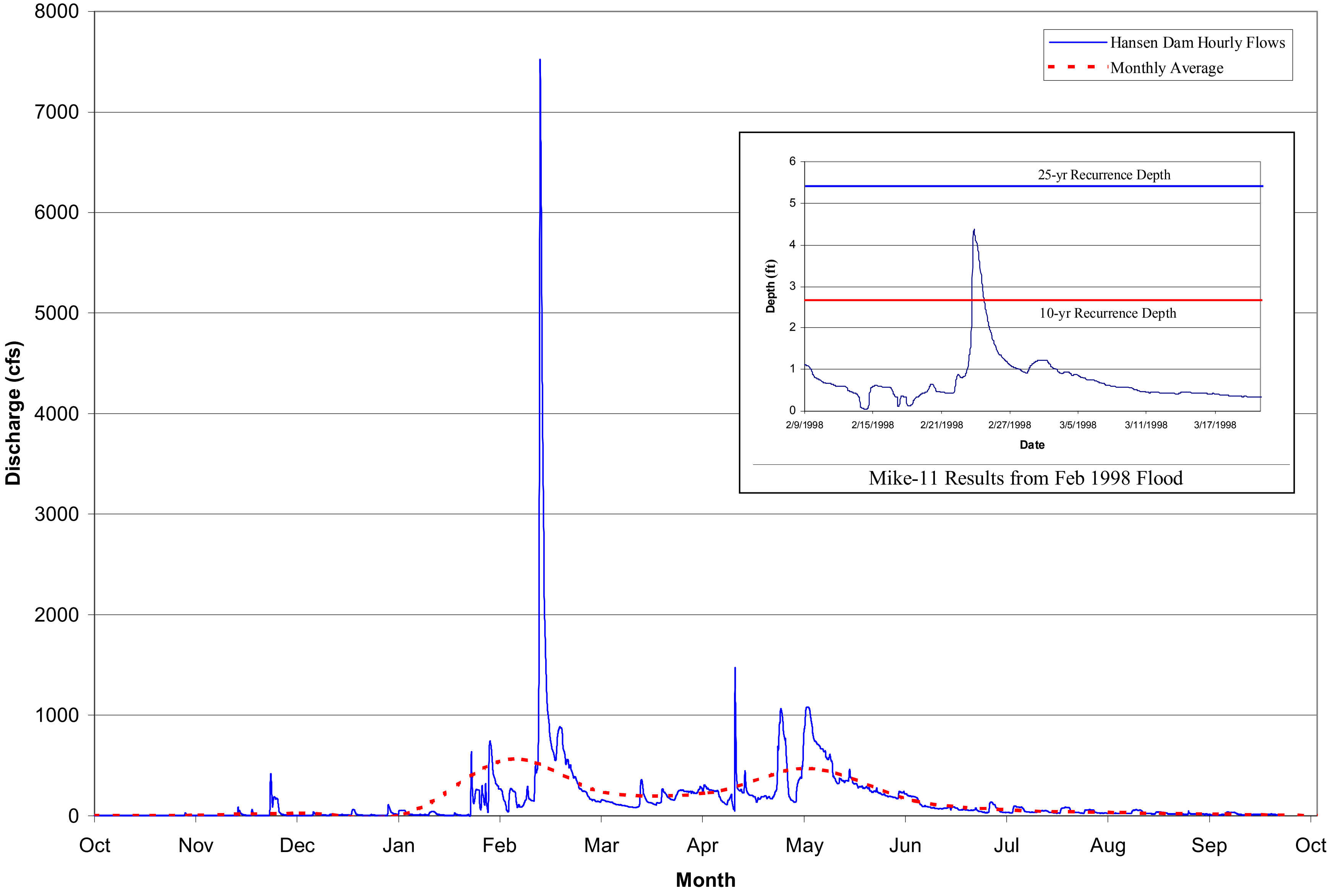
The ability to model flow conditions continuously over the course of an entire season was based on gage records from the 1998 water year (Figure 8) for which ample stage-discharge data was available. The following data sources were used to model the 1998 season: 15-min discharge data at Hansen Dam (US Geological Survey); 5-min discharge data for Pacoima Wash (Los Angeles County Flood Control District); and 5-min discharge data for the Branford drainage channel (LACFCD). The 1998 water year was of particular interest due to the strong El Niño condition, which resulted in the wettest February on record in Los Angeles County. In Figure 8, seasonal flow variations are evident with average September (6 cfs) and November (9 cfs) flows being the lowest and February being the highest (562 cfs). Modeling results for flow in Tujunga Wash during 1998 closely match the Hansen Dam outflows presented in Figure 8. Figure 8 also includes a more detailed hydrograph from the modeling output that depicts conditions during the storms of February 1998.

3.2.2.4 Steady-state discharge input and model verification

Lastly in terms of input discharge, three steady-state flows for Hansen Dam, Pacoima Wash, and the Branford Channel (22,000, 7,000 and 1,000 cfs respectively) were processed through the existing conditions model to provide a comparative basis to verify water levels according to 1963 ACOE calculations. Figure 9 compares water surface elevations from the 1963 calculations to results from the current existing conditions model. Figure 9 indicates that the current modeling results are quite similar to earlier findings. Minor differences may be related to channel super elevations, which may not have been incorporated into the earlier ACOE calculations.

3.3 SUMMARY RESULTS FOR EXISTING CONDITIONS MODEL

Summary hydrodynamic information, including water surface elevation profiles and cross-sections, velocity profiles, and hydrographs for representative stations along Tujunga Wash are presented in Figure 10. Results indicate that very little flow attenuation occurs between Hansen Dam and the Los Angeles River. This is primarily due to the lack of any channel or floodplain storage opportunities, very low frictional losses, and a steep overall channel slope. For example, Tujunga Wash's overall slope of 40 ft/mi exceeds the minimum slope required to generate critical flow (for 2-yr peak flow rate of 865 cfs, critical slope is roughly 10 ft/mi). During more extreme events like the 100-yr peak discharge (47,600 cfs), critical channel slope is even flatter, at roughly 4 ft/mi. Consequently, channel Froude numbers are much larger than 1.0 and extremely high average channel velocities (as high as 50 ft/s) are predicted (Figure 10). Under such conditions other forms of flow resistance such as turbulent eddies, etc. may preclude these extreme velocities.

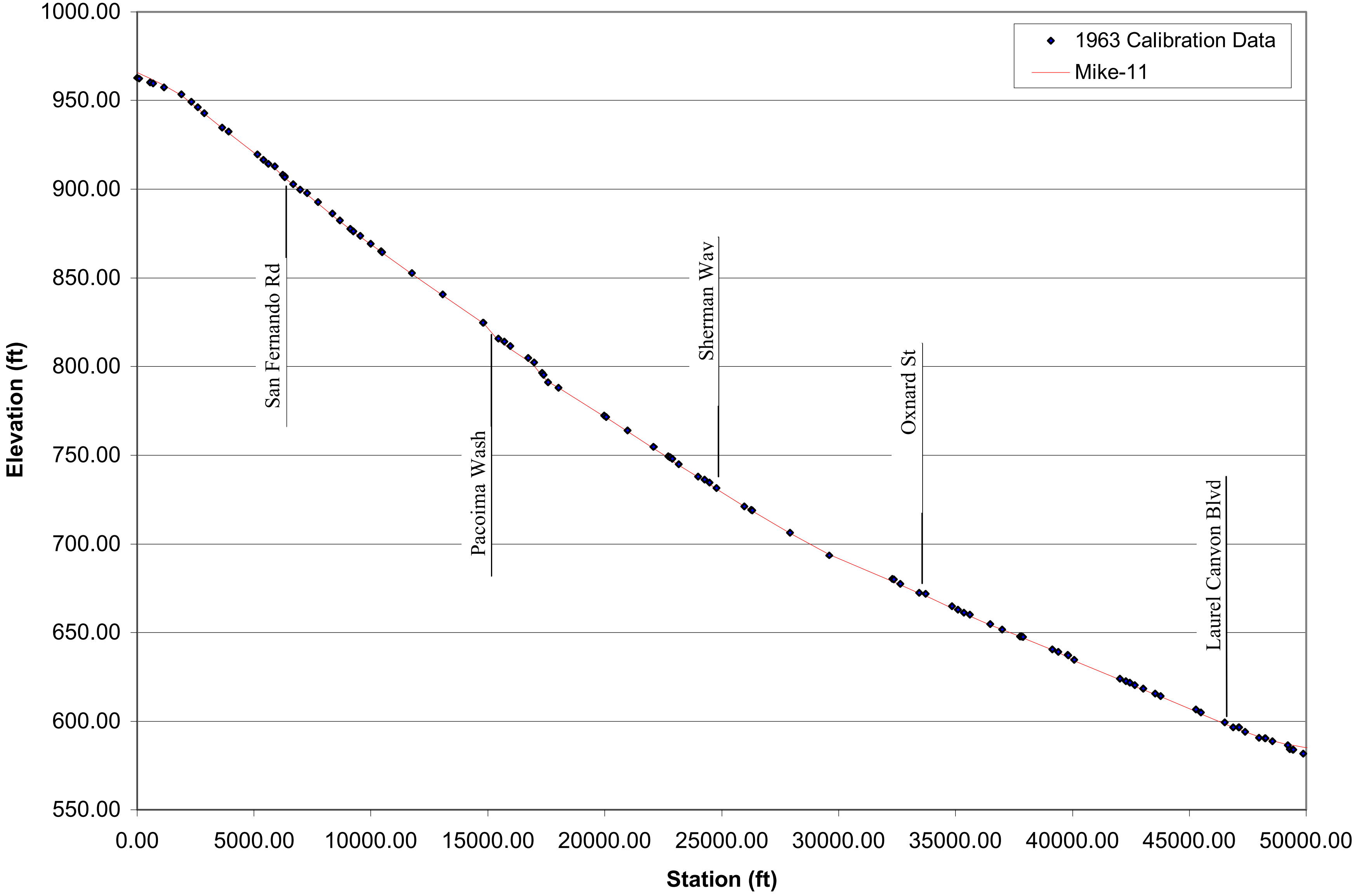


f i g u r e 8

1998 Water Year

Tujunga Wash Hydrodynamic Modeling

PWA



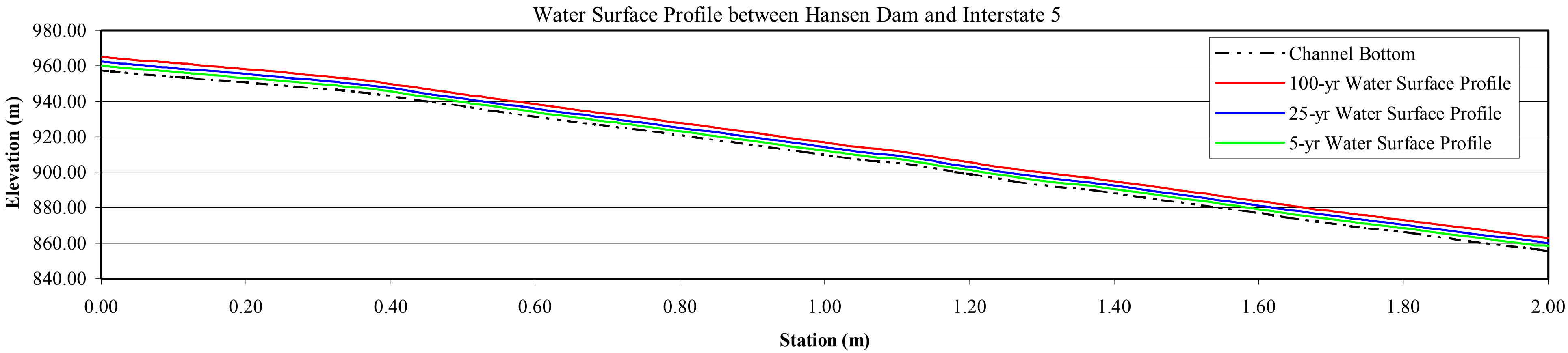
f i g u r e 9

COE 1963 Calibration Results

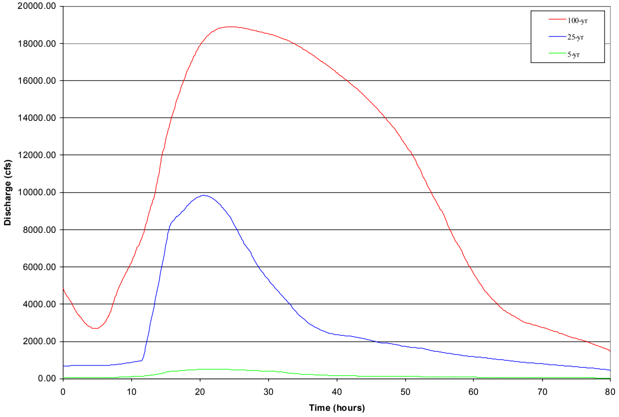
Tujunga Wash Hydrodynamic Modeling

PWA

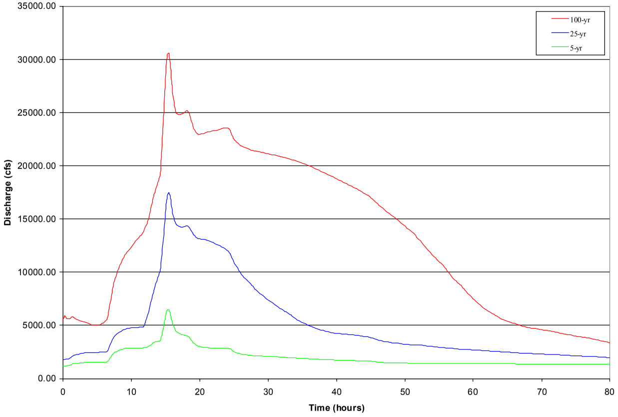
Water Surface Profile between Hansen Dam and Interstate 5



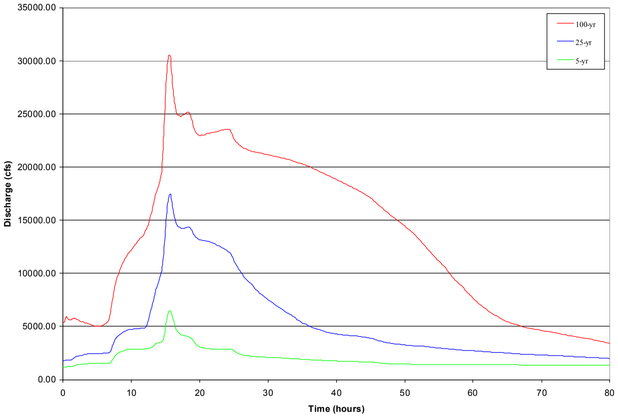
Predicted Discharge at Hansen Dam



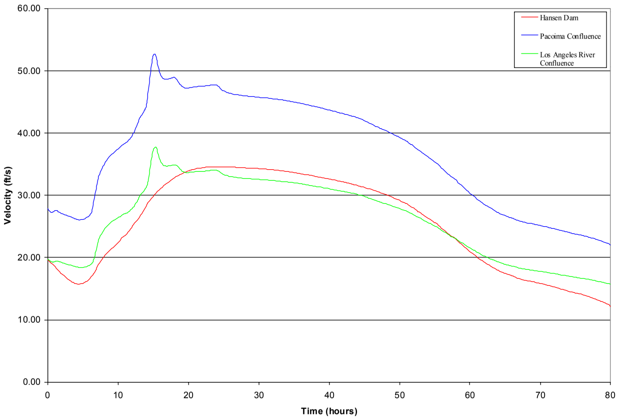
Predicted Discharge at Pacoima Wash Confluence



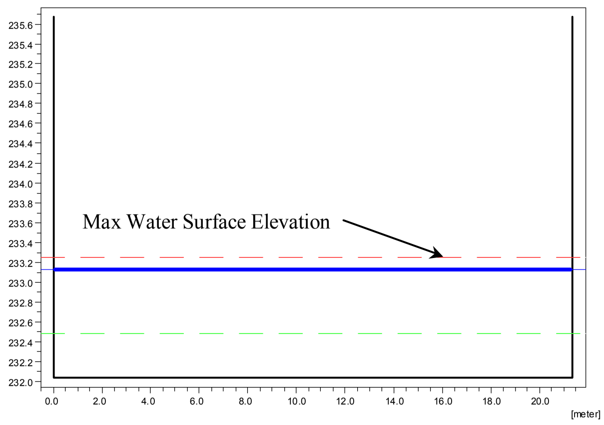
Predicted Discharge at Los Angeles River Confluence



Velocity Profile during 100-yr Storm Event



Typical Channel Cross-Section



f i g u r e 10

Summary of Hydrodynamic Results for Existing Conditions

Tujunga Wash Hydrodynamic Modeling

PWA

It is also apparent from Figure 10, that the widening of the Tujunga Wash channel from 60- to 70-ft at the confluence of Pacoima Wash is required to maintain adequate conveyance capacity. As presently modeled, under extreme flow conditions, the Tujunga Wash channel provides little available capacity to accommodate additional runoff beyond the 100-yr event.

Existing physical and hydraulic conditions along Tujunga Wash (the lack of channel-floodplain storage; low frictional losses; and steep bed slopes) prevent downstream flow attenuation. The existing channel configuration is characteristic of an urban flood control channel which provides little riparian habitat or ecosystem functioning. New channel concepts, presented below in Section 4, were developed to address these issues by increasing channel and floodplain storage, increasing channel roughness to reduce flow velocities, and better integrating channel and floodplain flows. The ultimate objective of restoring these physical forms and processes is to improve riparian habitat and ecosystem functioning along the Tujunga Wash corridor, while still maintaining necessary flood management capabilities.

4. ALTERNATIVES ANALYSIS

Discussions among the project team and the Technical Advisory Committee (TAC) generated an issue list and some preliminary questions to help direct the alternatives analysis. The questions raised, which were pertinent to the current modeling analysis are paraphrased as follows:

1. What percentage of the design storm discharge could be held by the various gravel pits downstream of Hansen Dam? What effect would flow storage in these pits have on the storm hydrograph in Tujunga Wash? Could flow storage in these pits be integrated with a revised management and maintenance program for Hansen Dam that might require less storage behind the dam as a result of pit storage?
2. What opportunities exist at the spreading grounds site downstream of Hansen Dam for inclusion into a channel restoration or wetland development program? Could a restoration program be developed that would not reduce infiltration and percolation functioning of the existing spreading grounds? Could such recharge functions be incorporated into a type of alluvial fan/braid channel restoration concept?
3. Could the proposed version of Alternative 3 from the recent Mountains Recreation and Conservation Authority (MRCA) report on Tujunga Wash (Kammerer, June 2000) be analyzed in the current model? What is the hydraulic affect of this proposed action on the main Tujunga Wash channel?
4. How much of a reduction in critical flood velocities can be achieved in Tujunga Wash by increasing the channel width by a factor of 2, or a factor greater than 2? How wide of a channel is needed to reduce average channel velocity to less than 15 fps, or less than 10 fps? Could flow diversion into the gravel pits potentially reduce channel velocities?
5. What size restored channel and floodplain system would be required to convey the design storm flood event? How would bed and bank materials along the existing Tujunga Wash channel be modified to accommodate these changes in channel geometry? Could an “off-line” restoration concept be developed that would not significantly alter the existing Tujunga Wash channel, yet still provide significant restoration benefits in areas adjacent to the channel?
6. The U.S. Army Corps model shows that flows break out of channel for the 1:100 year flood just downstream of the Pacoima confluence. Can the new model be used to map flood inundation conditions as a refinement of the current FEMA map?

These questions and issues framed a preliminary alternatives analysis as reviewed below. The existing conditions hydrodynamic model described in Section 3 was modified to evaluate new channel configurations.

4.1 NON CHANNEL STORAGE OPPORTUNITIES

Issue 1 above questioned how the gravel pits which neighbor the Tujunga Wash channel might be integrated into a floodplain management program. More specifically, how could these pits be used to hold stormwater and how would this storage affect storm hydrographs and flow volumes in the channel? Figure 11 shows the location of 4 principal gravel pits near Tujunga Wash, their estimated storage volumes, and the percent reduction in storm volume that the pits offer. Pit A (5,000 ac-ft) and Pit B

(10,000 ac-ft) are located immediately adjacent to the Tujunga Wash channel while Pits C (~5,000 ac-ft) and D (~15,000 ac-ft) are further from the channel. It should be noted that these volume estimates were derived from 1:24,000 scale USGS maps. Subsequent studies should include field verification and review of more detailed topographic mapping sources.

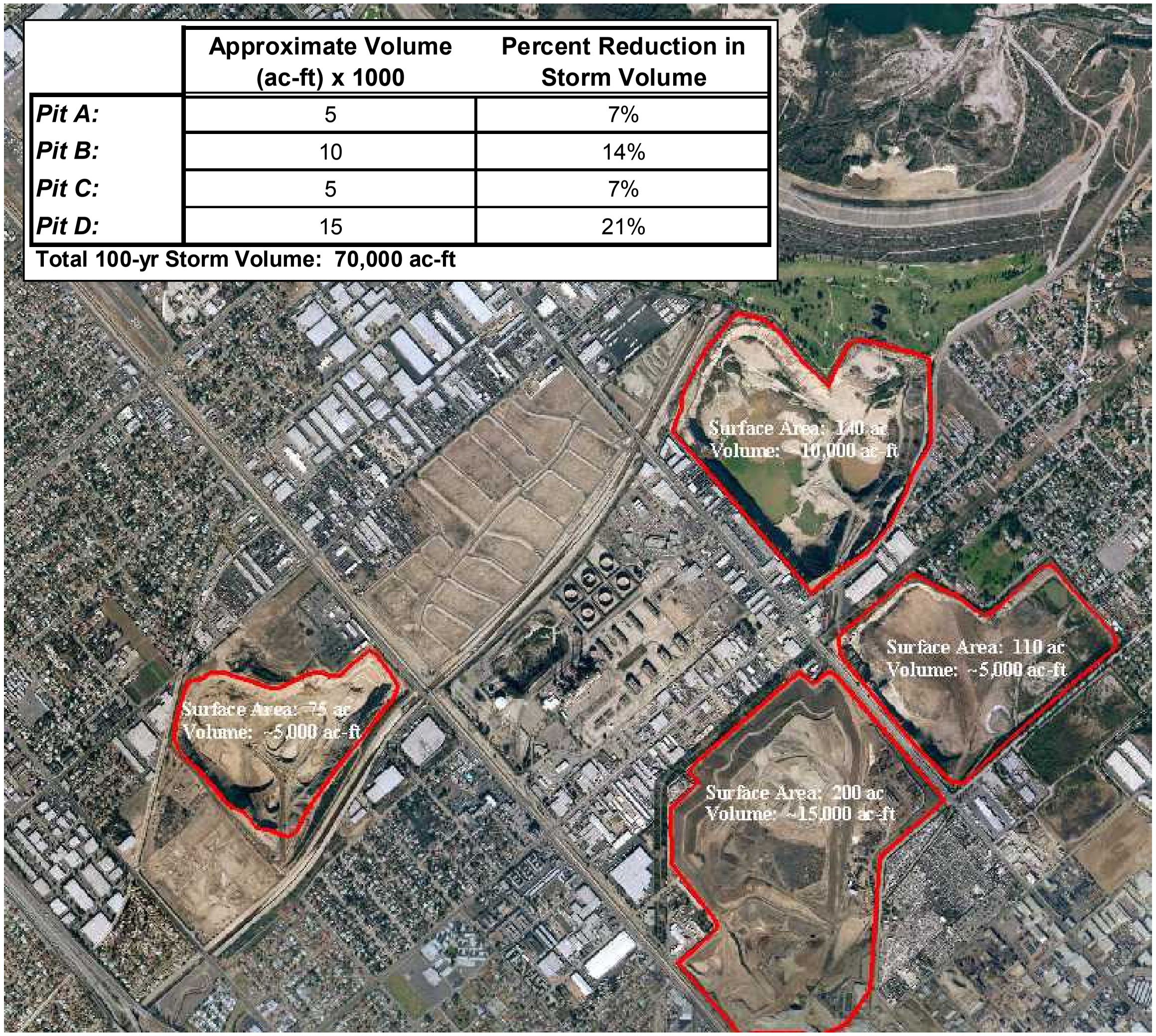
Based on our initial estimates, it appears that using the gravel pits to retain stormflow merits further consideration. This approach, in coordination with subsequent modifications to stormflow management at Hansen Dam, could potentially result in reduced stormflows and velocities in the Tujunga Wash channel.

4.2 CHANNEL RESTORATION CONCEPTS

Issue 4 above addressed what impact increasing channel width and hydraulic roughness would have on reducing flood velocities. Table 1 summarizes resulting channel velocities when channel width and roughness for the 100-yr design storm are altered. Conditions were modeled from the Hansen Dam headworks to the Sherman Way crossing (approximately 4.75 mi). As described in Section 3 above, input hydrology values for the channel hydraulic analysis were based on past studies and design manuals. Changing land-uses in the watershed, as well as, changing runoff or watershed management approaches in the future would potentially alter the basic input hydrology conditions. Modeling results from Table 1 and other channel configurations were used to develop the channel configurations presented below for Alternatives A, B, and C.

Table 1. Average Channel Velocity between Hansen Dam and Sherman Way (ft/s) for Design Storm Event

Channel Geometry	*n = 0.015 (existing)*	*n = 0.02*	*n = 0.04*	*n = 0.06*	*Maximum allowable 'n' value*
Existing Channel Variable Width (60 - 70 feet)	42.34	WL exceeds top of channel	WL exceeds top of channel	WL exceeds top of channel	0.015
Channel (2 x Wide) Variable Width (120 - 140 feet)	32.01	26.99	WL exceeds top of channel	WL exceeds top of channel	0.038
Channel (3 x Wide) Variable Width (180 - 210 feet)	29.44	24.84	16.73	WL exceeds top of channel	0.045
Channel (4 x Wide) Variable Width (240 - 280 feet)	24.22	20.42	13.76	10.90	0.070



	Approximate Volume (ac-ft) x 1000	Percent Reduction in Storm Volume
Pit A:	5	7%
Pit B:	10	14%
Pit C:	5	7%
Pit D:	15	21%

Total 100-yr Storm Volume: 70,000 ac-ft

f i g u r e 11

Aerial Photo Map of Gravel Pits in Tujunga Wash Vicinity

Tujunga Wash Hydrodynamic Modeling

PWA

4.2.1 Alternative A

In Alternative A (Figure 12) the existing Tujunga Wash channel would be reconfigured and enlarged to integrate a single floodplain terrace. The terrace would be inundated at or above the 2-yr flow level. This terrace could be designed with different widths. The channel modification could be applied between Hansen Dam and Sherman Way and would provide additional flood protection, enhanced habitat quality, and potential space for future recreational development.

Similar to the materials used in the Glendale Narrows, a ‘soft bottom’ section could be adopted with channel armoring provided by Derrick stones or biotechnical structures where required. The overall channel roughness would be increased due to the soft bottom armoring configuration and native vegetation within both the channel and terrace. For Alternative A, roughness values of 0.02 and 0.04 were used for the channel and terrace sections respectively. Further modeling refinement could include a more detailed evaluation of sediment conditions in relation to roughness. This assessment could be based upon representative field sites and a geomorphic investigation of historical channel/floodplain roughness values for the Tujunga Wash and surrounding alluvial fan.

In Tables 2 and 3 summary modeling results are presented for Alternative A for nine different channel and terrace width combinations. Compared to the existing channel system, the integrated floodplain terrace of Alternative A reduces channel velocities significantly. For example, velocities for the 100-yr event decrease from 42 ft/s for the existing Tujunga Wash to between 24- and 33 ft/s for the channel and terrace configuration of Alternative A. The high velocities occurring in the existing Tujunga Wash system are mainly driven by steep channel slopes. High channel slope and velocities provide a mechanism to transport sediment along a non-armored channel bottom with available sediment supply. Figure 13 (U.S. Bureau of Reclamation, 1987) illustrates the relationship between bed shear stress and transportable sediment size for various rivers throughout the world. The minimum estimated bed shear stress for Alternative A is comparatively high at 3.64 psf, which would require a nominal sediment size of 200 mm. Further refinement of the Alternative A concept would investigate suitable channel sediment sizes to maintain a stable channel system.

4.2.2 Alternative B

Alternative B includes an additional modification to the integrated channel-terrace concept developed for Alternative A. In Alternative B (Figure 14) the single terrace of Alternative A is replaced with a two-terrace configuration, with benches at the 2-yr and 25-yr water surface levels. For Alternative B, the upper bench (25-yr) could be landscaped appropriately as a riparian canopy and could also be used for recreational purposes. Consequently, the upper bench has a high overall roughness value (0.06). As in Alternative A, the channel and 2-yr terrace level would have roughness values of 0.02 and 0.04 respectively.

figure 12

Tujunga Channel
Alternative A

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200% Vertical Exaggeration

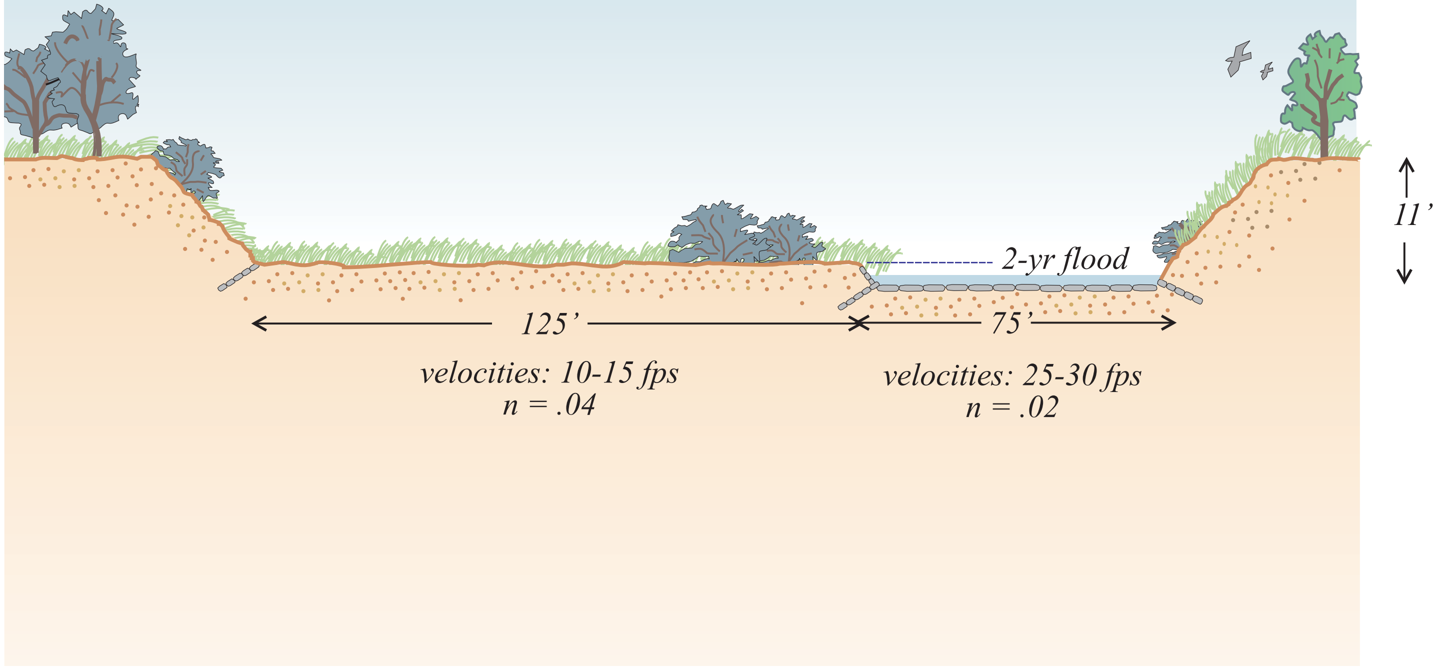

Table 2. Hydraulic Characteristics of Channel above Pacoima Wash Confluence (100-yr Flow Event)

Alternative A - Reconfigured channel between Hansen Dam and Sherman Way with integrated single terrace floodplain, inundated at or above the 2-year flow level.									
	Primary Channel Top Width (ft)								
	50*			**60**			**70**		
Floodplain Terrace Top Width (ft)	**25***	**75**	**150**	**25**	**75**	**150**	**25**	**75**	**150**
Total Channel Width (Primary Channel and Floodplain Terrace) (ft)	75	125	200	85	135	210	95	145	220
Total Width of Channel Corridor (ft) (25' Right-of-Way along channel edge)	125	175	250	135	185	260	145	195	270
Average Primary Channel Velocity (ft/s)	33	29	26	30	28	25	28	26	24
Average Primary Channel Depth (ft)	9.9	8.2	6.9	7.8	7.3	6.6	7.3	6.8	6.2
Average Floodplain Terrace Flow Velocity (ft/s)	12.2	11.6	11.1	11.5	11	10.5	11.2	11	10.2
Average Floodplain Terrace Depth (ft)	8.4	6.7	5.4	6.3	6.2	5.1	5.8	5.3	4.7
Average Bed Shear Stress (lb/ft2)	6.11	4.98	4.11	4.71	4.51	3.91	4.37	4.04	3.64

* Minimum channel width requirement to maintain flood protection

** Channel and floodplain roughness are assumed to be 0.02 and 0.04 respectively

Table 3. Hydraulic Characteristics of Channel Below Pacoima Wash Confluence (100-yr Flow Event)

Alternative A - Reconfigured channel between Hansen Dam and Sherman Way with integrated single terrace floodplain, inundated at or above the 2-year flow level.									
	Primary Channel Top Width (ft)								
	60*			**75**			**90**		
Floodplain Terrace Top Width (ft)	**75***	**125**	**175**	**75**	**125**	**175**	**75**	**125**	**175**
Total Channel Width (Primary Channel and Floodplain Terrace) (ft)	130	185	235	145	200	250	160	215	265
Total Width of Channel Corridor (ft) (25' Right-of-Way along channel edge)	180	235	285	195	250	300	210	265	315
Average Primary Channel Velocity (ft/s)	35	31.5	29	32	30.3	28.5	31	29.5	28
Average Primary Channel Depth (ft)	11	10.3	9.6	10.2	9.7	9.3	9.9	9.5	8.9
Average Floodplain Terrace Flow Velocity (ft/s)	13	11.8	11.3	11.8	11.3	10.7	11.2	10.7	10.2
Average Floodplain Terrace Depth (ft)	7.5	6.8	6.1	6.7	6.2	5.8	6.5	6	5.4
Average Bed Shear Stress (lb/ft2)	5.47	5.06	4.64	5.00	4.70	4.47	4.85	4.58	4.23

* Minimum channel width requirement to maintain flood protection

** Channel and floodplain roughness are assumed to be 0.02 and 0.04 respectively

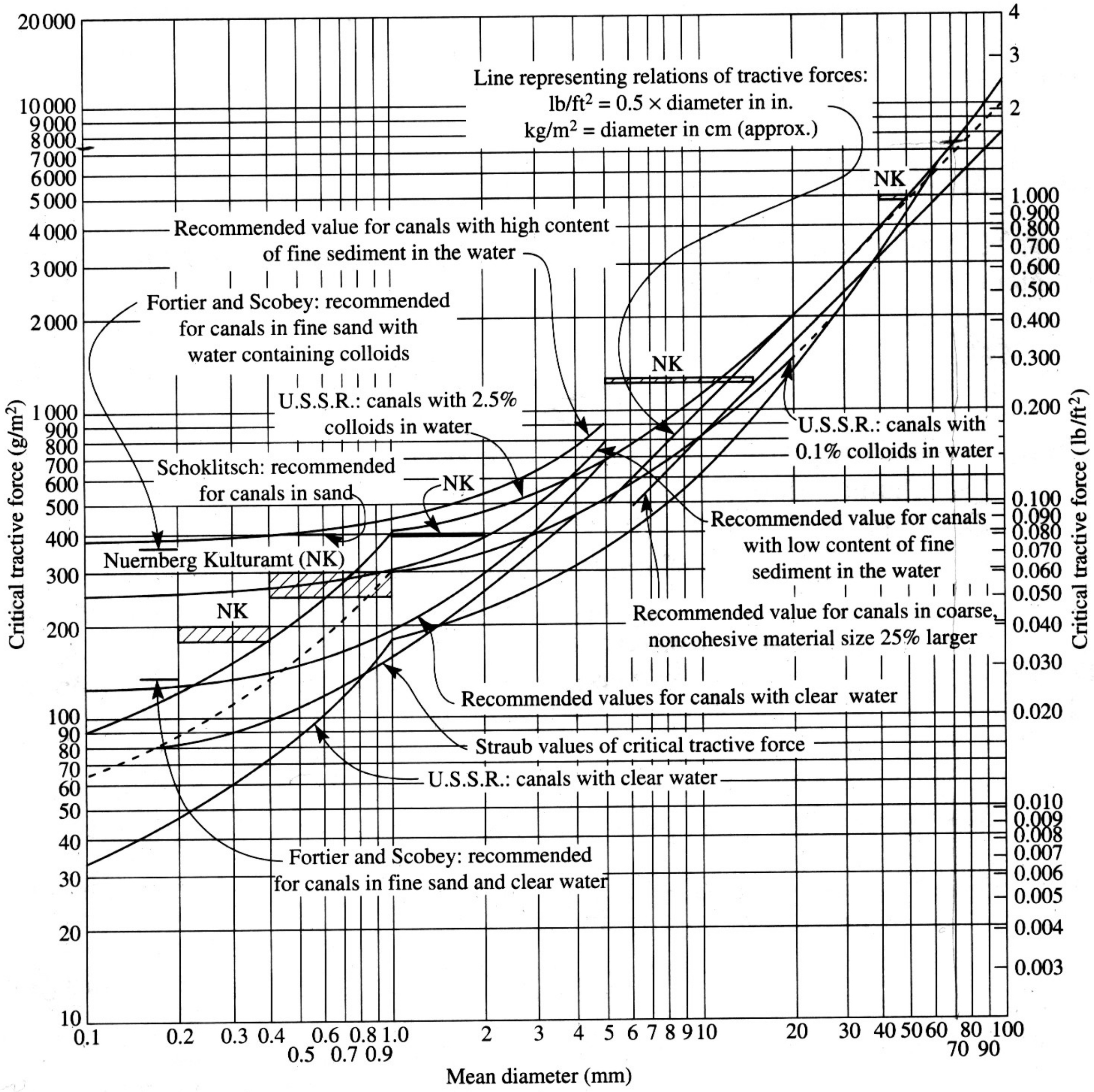

figure 13

Shear Stress versus Transportable Sediment Size

Tujunga Wash Hydrodynamic Modeling

Source: U.S. Bureau of Reclamation, 1987

Tables 4 and 5 summarize resulting hydraulic characteristics for Alternative B. The two-terrrace configuration provides slightly less storage and conveyance capacity than the single bench shape of Alternative A. Consequently, channel and floodplain velocities, flow depths, and average shear stress are slightly increased. As was the case for Alternative A, the high channel velocities and sheer stresses of Alternative B would require some form of channel bed and bank protection. Derrick stones could be used at selective cross-sections to stabilize the channel bed and help "anchor" the longitudinal profile and grade. The channel banks to the two terraces (as well as the terrace benches themselves) can be strengthened with adequate plantings and other bio-technical erosion prevention techniques.

4.2.3 Alternative C

Alternative C represents a different approach from Alternatives A and B in that a new auxilary channel branches off from the existing Tujunga Wash channel immediately downstream of Hansen Dam (Figure 15). This auxiliary channel would travel along side the existing Tujunga Wash southward for roughly 4.5 miles and then rejoin the existing Tujunga Wash channel at Sherman Way. As conceived, the new auxiliary channel would have greater channel sinuosity in plan form than the existing wash. The conceptual basis for Alternative C was founded on a geomorphic assessment of the historical Tujunga Wash system. The historic Tujunga Wash system operated as a series of braided channels across the alluvial fan surface of the eastern San Fernando Valley. Historically, the inundation frequency of the braid channels was dependent upon the magnitude of stormflow events. Large events, such as the March 1938 floods, generated flow across several channels on the alluvial fan surface.

For the braid channel concept of Alternative C it is important to determine how flows are allocated and transfered between the existing flood control channel and the proposed braid channel. Three different approaches were developed to address this diversion: Scheme A diverts low flows; Scheme B diverts modest-sized flows; and Scheme C diverts larger flows according to the capacity and geometry of the new braid channel.

Diversion Scheme A would function in a similar manner to the current spreading grounds operation. As such, discharge occuring at rates less than or equal to the 2-yr event would be directed into the braid channel. When Hansen Dam releases into Tujunga Wash exceed the 2-yr threshold (roughly 900 cfs), flows will not be diverted into the braid channel and will be retained within the existing primary Tujunga Wash channel. This operation would be accomplished with a gate or equivalent structure. Scheme A would support an ecological restoration approach based upon continuous low flows and smaller storm flow events figure 14

Tujunga Channel
Alternative B

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200% Vertical Exaggeration

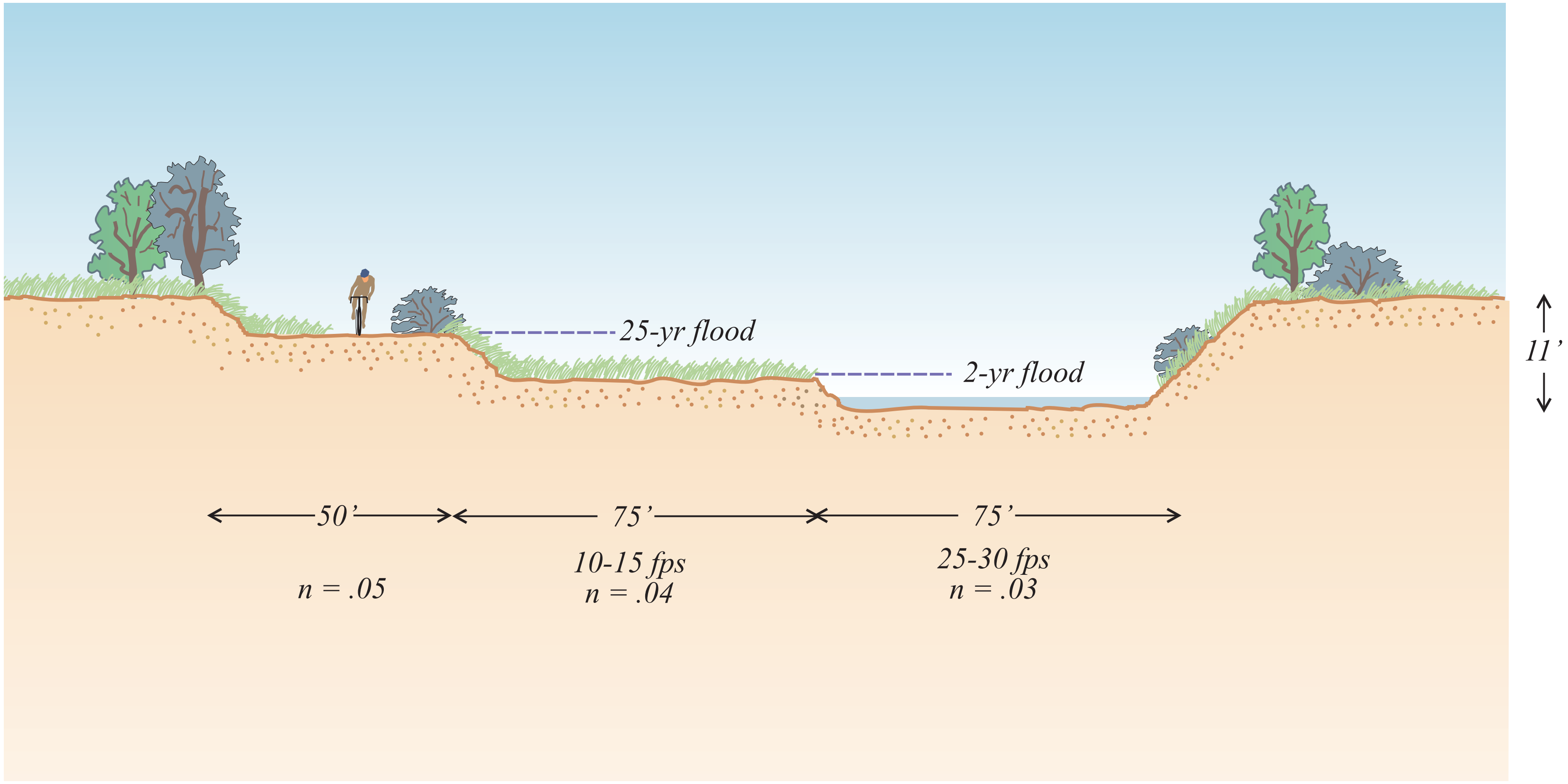

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Table 4. Hydraulic Characteristics of Channel above Pacoima Wash Confluence (100-yr Flow Event)

Alternative B- Reconfigured channel between Hansen Dam and Sherman Way with integrated two-level terrace floodplain configuration, which correspond to the 2- and 25-year flow level.									
	Primary Channel Top Width (ft) **								
	50*			**60**			**70**		
Floodplain Terrace Top Width (ft)**	**25***	**75**	**150**	**25**	**75**	**150**	**50**	**75**	**150**
2-yr/25-yr Terrace Width (ft)	33/17	50/25	100/50	33/17	50/25	100/50	33/17	50/25	100/50
Total Channel Width (Primary Channel and Floodplain Terrace) (ft)	100	125	200	110	135	210	120	145	220
Total Width of Channel Corridor (ft) (25' Right-of-Way along channel edge)	150	175	250	160	185	260	170	195	270
Average Primary Channel Velocity (ft/s)	31	29	26.5	30	28.8	26	29.5	28.3	25.6
Average Primary Channel Depth (ft)	9.3	8.3	7	8.3	7.8	6.8	7.9	7.5	6.6
Average Floodplain Terrace Flow Velocity (ft/s)	12.6	12	11.3	11.8	11.3	11.1	10.9	10.7	10.5
Average Floodplain Terrace Depth (ft)	7.8	6.8	5.5	6.8	6.3	5.5	6.4	6	5.1
Average Bed Shear Stress (lb/ft2)	5.71	5.04	4.17	5.04	4.71	4.11	4.78	4.51	3.91

* Minimum channel width requirement to maintain flood protection

** Channel and floodplain roughness are assumed to be 0.02 and 0.04 respectively

Table 5. Hydraulic Characteristics of Channel Below Pacoima Wash Confluence (100-yr Flow Event)

Alternative B- Reconfigured channel between Hansen Dam and Sherman Way with integrated two-level terrace floodplain configuration, which correspond to the 2- and 25-year flow level.									
	Primary Channel Top Width (ft)**								
	60			**75**			**90**		
Floodplain Terrace Top Width (ft)**	**75**	**125**	**175**	**75**	**125**	**175**	**75**	**125**	**175**
2-yr/25-yr Terrace Width (ft)	50/25	83/42	117/58	50/25	83/42	117/58	50/25	83/42	117/58
Total Channel Width (Primary Channel and Floodplain Terrace) (ft)	135	185	235	150	200	250	165	215	265
Total Width of Channel Corridor (ft) (25' Right-of-Way along channel edge)	185	235	285	200	250	300	215	265	315
Average Primary Channel Velocity (ft/s)	33.5	31.2	30.6	32.4	30.9	30.5	31.2	30.8	30.3
Average Primary Channel Depth (ft)	11.3	10.4	9.7	10.5	10	9.7	10.2	9.7	9.3
Average Floodplain Terrace Flow Velocity (ft/s)	12.4	11.8	11.3	11.9	11.3	11	11.1	10.9	10.7
Average Floodplain Terrace Depth (ft)	7.8	6.9	6.2	7	6.5	6.2	6.7	6.2	5.8
Average Bed Shear Stress (lb/ft2)	5.65	5.12	4.70	5.18	4.88	4.70	5.00	4.70	4.47

** Channel and floodplain roughness are assumed to be 0.02 and 0.04 respectively *figure* 15

Tujunga Channel
Alternative C

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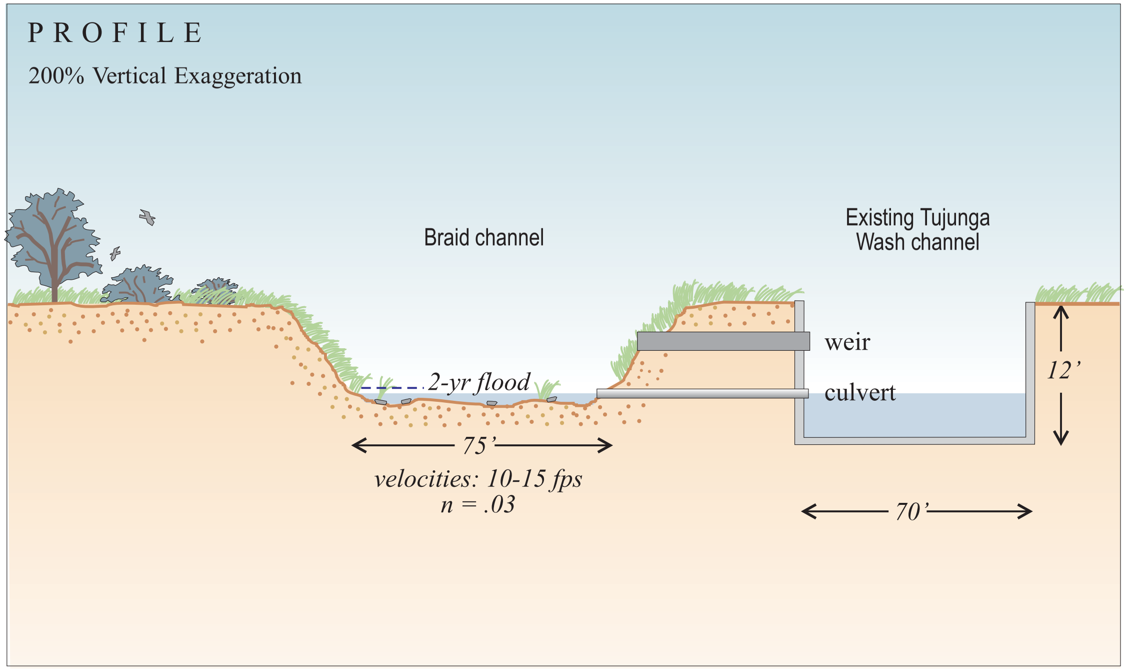
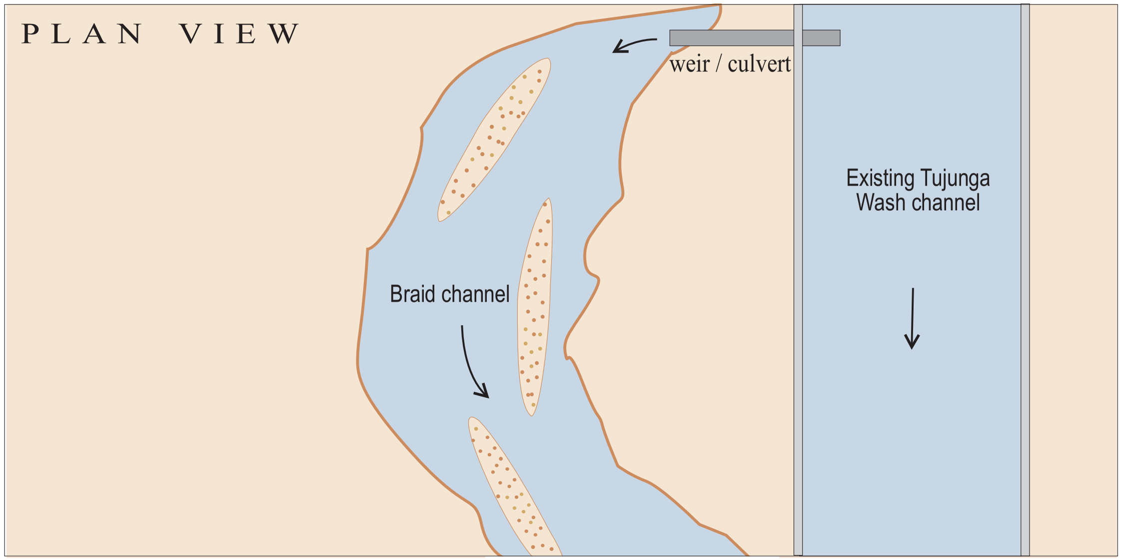
PROFILE

200% Vertical Exaggeration



PLAN VIEW



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Diversion Scheme B would replace the gate structure from Scheme A with a fixed broad-crested weir. This fixed weir is intended to control flow diversion between the principal Tujunga Wash channel and the auxiliary braid channel without operational adjustments during flood events. Unlike Scheme A, the weir concept for Scheme B would allows flow to enter the braid channel during higher magnitude storm events. As currently modeled, the weir geometry would allow flow rates of 750 cfs to be diverted, although other weir configurations are possible to allow greater flow. Table 6 illustrates the hydraulic characteristics expected for diversion Scheme B. Because of the low magnitude of diverted flows into the auxiliary channel, predicted velocities and shear stress are relatively low.

Diversion Scheme C is similar to Scheme B, however the fixed-weir diversion structure is replaced by a stream confluence. Discharge to the braid channel through such a stream junction is governed by the cross-sectional geometry at the entrance of the new braid channel, as well as, in-channel hydraulic conditions at the confluence. Maximum flow capacity into the braid-channel is roughly 4,800 cfs for the 100-foot channel width option shown in Table 6. Table 6 also describes how increases in diversion discharges result in increased braid channel velocity, water depth, and sediment scouring capacity.

One advantage to Scheme C is that the existing Tujunga Wash channel is not adversely impacted and existing flood conveyance conditions are not affected. As currently modeled, the restored “braid” channel does not include any benched terrace features or grade control structures. Such features could be included in the modeled concept to adjust channel geometry to attain target flow velocities and surface water elevations for designated recurrence intervals. As shown in the plan of Figure 15, a potential pathway for the braid channel could be through the existing spreading ground areas adjacent to Tujunga Wash. Further refinement and development of this concept would be necessary to understand potential impacts to existing infiltration capabilities at the spreading ground. While a braid channel might reduce the pond area of the existing spreading ground facility, the new braid channel might potentially allow infiltration under greater flow frequency than present. Further study of this approach could resolve how developing a braid channel might improve or impact infiltration and recharge operations at the spreading grounds.

4.2.4 MRCA Channel Concept

Alternative 3 from the MRCA report (Kammerer, 2000) was evaluated through the current model. This alternative incorporates a restored open channel reach within the existing right-of-way adjacent to the present Tujunga Wash channel between Vanowen and Oxnard boulevards. Water is supplied to this auxiliary channel from the Pacoima Diversion channel upstream through a 4-foot pipe, which is about 8,000-ft long. The restored channel has a 3-foot bottom width, 4:1 side slopes and a longitudinal slope equal to the Tujunga Wash slope between Vanowen and Oxnard. A hydraulic roughness value more appropriate for a natural channel (0.04) was used along this reach. It is estimated that the maximum conveyance capacity of this diversion channel is around 100 cfs. The proposed Vanowen to Oxnard diversion channel does not impact the existing channel or its flood conveyance capacity. Limitations of this proposed channel include that it is relatively limited in both longitudinal extent and hydrologic impact. The frequency of flow in this designed open channel is uncertain and would depend upon intake conditions from the Pacoima channel, as well as, bed percolation losses in the newly created stream.

Alternative C - A secondary braid channel, between Hansen Dam and Sherman Way, is diverted from the existing channel, which remains unaltered. Three different diversion schemes were developed to allocate and transfer flow between the existing channel and the auxiliary braid channel (see below).

	Auxiliary Channel Top Width (ft)**								
	50			**75**			**100**		
Diversion Scheme (100-yr Flow Event)	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Total Width of Channel Corridor (ft) (25' Right-of-Way between and along channel edge)	125			150			175		
Average Primary Channel Velocity (ft/s)	41.5	32 / 38*	31 / 38*	41.5	32 / 38*	29 / 37*	41.5	32 / 38*	28 / 36*
Average Auxiliary Channel Velocity (ft/s)	0	9.3	11.3	0	7.2	11.6	0	6.1	11.8
Flow Diverted into Auxiliary Braid Channel (cfs)	0	750	1700	0	750	3400	0	750	4800
Average Primary Channel Depth (ft)	10.5	7.5 / 10.4*	7.3 / 10.4*	10.5	7.5 / 10.4*	6.6 / 10.2*	10.5	7.5 / 10.4*	6.1 / 9.9*
Average Auxiliary Channel Depth (ft)	0	5.2	7.3	0	3.1	6.6	0	2.2	6.2
Auxiliary Channel Bed Shear Stress (lb/ft2)	N/A	3.14	4.41	N/A	1.87	3.99	N/A	1.33	3.75

* Upstream of the Pacoima Wash Confluence / Downstream of the Pacoima Wash Confluence

** Channel and floodplain roughness are assumed to be 0.02 and 0.04 respectively

Diversion Scheme A: All flows will be diverted into the auxiliary braid channel at or below the 2-yr event. Above the 2-yr event, the braid channel will be closed to all flow.

Diversion Scheme B: A broad-crested wier will control the flow diversion between the main Tujunga Wash channel and the auxiliary braid channel. The maximum diversion discharge is 750 cfs.

Diversion Scheme C: No diversion structure controls the flow allocation between the main Tujunga Wash channel and the auxiliary braid channel. The cross-sectional geometry directly controls the flow allocation, resulting in a maximum diversion discharge is 4800 cfs with the 100-foot wide auxiliary channel width.

Table 6

Alternative C Results

5. NEXT STEPS

The primary objective of the current study was to establish a baseline conditions hydrodynamic model for the Tujunga Wash system which could then be used to evaluate potential restoration alternatives. Three channel concepts were evaluated through the created baseline conditions model and other topics related to potential off-channel storage were also examined during this study. It is recommended that a planning level feasibility study should follow the current modeling study. The goal of such a feasibility study would be to develop the suggested concepts (or new concepts) into more rigorously defined project alternatives. In addition to more detailed hydrology and hydraulic analysis of project alternatives, socio-economic, land-use zoning and availability, and other environmental considerations should be addressed specific to the Tujunga Wash corridor. A planning level feasibility study could also include relative costs associated with potential restoration alternatives. It is intended that the model developed for the current study will be useful to watershed stakeholders throughout future project phases and will contribute to improving ecologic, habitat, and hydrologic conditions along the Tujunga Wash.

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7. REFERENCES

Cooke, R.U., 1984. *Geomorphological Hazards in Los Angeles*. London: Allen and Unwin.

Hitchcock, C.S. and Wills, C.J., 2000. *Quaternary Geology of the San Fernando Valley, Los Angeles County, California*, Map Sheet 50. California Department of Conservation, Division of Mines and Geology.

Kammerer, M. 2000. Geomorphic and Hydrologic Feasibility Study: Tujunga Wash Restoration Project. For the Mountains Recreation and Conservation Authority.

Los Angeles County Flood Control District. Discharge data for Hansen Dam, Pacoima Wash, and Branford Drainage Channel for water years 1989 to 2001.

U.S. Army Corps of Engineers, 1963. *Summary of Pertinent Hydraulic Data for Tujunga Wash*.

U.S. Army Corps of Engineers, 1990. *Hansen Dam Water Control Manual*.

U.S. Army Corps of Engineers, 1991. *Los Angeles County Drainage Area Final Feasibility Interim Report, Part 1: Hydrology Technical Report*.

APPENDIX A

A-1: Hansen Dam Stage-Storage Curve

A-2: Hansen Dam Gate Outlet Rating Curves

A-3: Hansen Dam Spillway Rating Curve

A-4: Hansen Dam Ungated Outlet Rating Curves

A-5: Sample HEC-RAS Output for Tujunga Wash Model

APPENDIX 2

Tujunga Wash: An investigation of Channel Hydraulic
Conditions and Potential Restoration Alternatives is available on compact disk
Mike-11 & HEC-RAS Models

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