One Water LA

environment
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LA DWP

# ONE WATER LA
# 2040 PLAN

## VOLUME 4

## LA River Flow Study

FINAL DRAFT | APRIL 2018

One Water LA

CITY OF LOS ANGELES

# ONE WATER LA
# 2040PLAN

## VOLUME 4
## LA River Flow Study

FINAL DRAFT • APRIL 2018

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# READER GUIDE

## SUMMARY OF ONE WATER LA

The One Water LA 2040 Plan (Plan) takes a holistic and collaborative approach to consider all of the City's water resources from surface water, groundwater, potable water, wastewater, recycled water, dry-weather runoff, and stormwater as "One Water." The Plan also identifies multi-departmental and multi-agency integration opportunities to manage water in a more efficient, cost effective, and sustainable manner. The Plan represents the City's continued and improved commitment to proactively manage all its water resources and implement innovative solutions, driven by the Sustainable City pLAn. The Plan will help guide strategic decisions for integrated water projects, programs, and policies within the City.

## PLAN ORGANIZATION

The One Water LA 2040 Plan consists of the following ten volumes:

- VOLUME 1 - Summary Report
- VOLUME 2 - Wastewater Facilities Plan
- VOLUME 3 - Stormwater and Urban Runoff Facilities Plan
- VOLUME 4 - LA River Flow Study
- VOLUME 5 - Integration Opportunities Analysis Details
- VOLUME 6 - Climate Risk & Resilience Assessment for Wastewater and Stormwater Infrastructure
- VOLUME 7 - Implementation Strategy Supporting Documents
- VOLUME 8 - Technical Support Materials
- VOLUME 9 - Stakeholder Engagement Materials
- VOLUME 10 - Programmatic Environmental Impact Report

The information presented in this Volume (Volume 4) only includes the One Water LA Technical Memorandum12.4 (TM 12.4.) that was prepared to document the low flow conditions and associated findings of the LA River Flow Study In addition, the information presented herein was utilized in the development of:

- LA River description in Chapter 3 of the Summary Report (Volume 1).
- Existing and Future LA River Flows in Chapter 4 of the Summary Report (Volume 1).
- Role of LA River in the City's watersheds in Stormwater Facilities Plan (Volume 3)
- TM 5.2 – Long-Term Concepts Development (Volume 5)

The purpose of the study presented in TM 12.4 is to identify considerations, assumptions, and areas of future study necessary to determine optimal flow conditions in the LA River. These conditions would balance the City's water supply needs with the LA River's water-dependent uses and regulatory requirements. To this end, this study summarizes available inflow sources to the LA River, the low flow conditions, the water budget, adaptive water management alternatives, as well as benefits, challenges, limitations, and costs for different alternatives.

## VOLUME 4 OVERVIEW & ORGANIZATION

An overview of information presented in this volume is provided in the table below.

| Section No. and Name | | Content Overview |
|---|---|---|
| 1 | Introduction | Provides an introduction to the LA River Flow Study. |
| 2 | Approach | Presents the approach to the study. |
| 3 | Results | Tabulates and presents the results of the study. |
| 4 | Conclusions | Provides conclusions of the study and suggestions for modeling. |
| Appendices | | Provides supporting materials and studies related to historical ecological surveys, historical low flow analysis, review of flow estimates for the ARBOR reach, analysis of the storage potential in the river, and the executive summary of the water supply and habitat resiliency study from The Nature Conservancy. |

## CITY OF LOS ANGELES

# TECHNICAL MEMORANDUM NO. 12.4
# LOS ANGELES RIVER FLOW STUDY
# SUMMARY REPORT

**FINAL**
December 2017

| | |
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# CITY OF LOS ANGELES

# TECHNICAL MEMORANDUM
# NO. 12.4
# LOS ANGELES RIVER FLOW STUDY SUMMARY REPORT

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APPENDIX C Draft Los Angeles River Low Flow Study (November 2016)
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APPENDIX E Draft Technical Memo of LA River Water Storage Potential and Maintaining Optimal Flows Using Level Controls (January 2017)
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## LIST OF ABBREVIATIONS

| **Abbreviation** | **Description** |
|---|---|
| AF | acre-feet |
| AFY | acre-feet per year |
| ARBOR | Area with Restoration Benefits and Opportunities for Revitalization |
| AWPF | Advanced Water Purification Facility |
| BMPs | Best Management Practices |
| BWRP | Burbank Water Reclamation Plant |
| cfs | cubic feet per second |
| City | City of Los Angeles |
| CWH | Council for Watershed Health |
| DCTWRP | Donald C. Tillman Water Reclamation Plant |
| ED#5 | Executive Directive No. 5 |
| EIR | Environmental Impact Report |
| EIS | Environmental Impact Statement |
| EPA | Environmental Protection Agency |
| ETo | evapotranspiration |
| EWMP | Enhanced Watershed Management Plan |
| fps | feet per second |
| ft | feet (foot) |
| ft/day | feet per day |
| ft/yr | feet per year |
| GIS | Geographic Information System |
| gpd/imp acre | gallons per day per acre of impervious area |
| GWR | groundwater replenishment |
| HEC-RAS | Hydrologic Engineering Center River Analysis System |
| HWRP | Hyperion Water Reclamation Plant |
| IEPR | independent external peer review |
| IFR | Integrated Feasibility Report |
| IRP | integrated resources plan |
| LA River | Los Angeles River |
| LAAFP | Los Angeles Aqueduct Filtration Plant |
| LADWP | Los Angeles Department of Water and Power |
| LAGWRP | Los Angeles-Glendale Water Reclamation Plant |
| LAR Watershed | LA River Watershed |
| LARCC | Los Angeles River Cooperation Committee |
| LARRMP | Los Angeles River Revitalization Master Plan |
| LASAN | Los Angeles Sanitation |
| LATC | Los Angeles Trailer and Container Intermodel Facility |
| LID | low impact development |
| LPP | locally preferred plan |
| LSPC | Load Simulation Program in C+ |

| Abbreviation | Description |
|---|---|
| MG | million gallons |
| mgd | million gallons per day |
| MS4 | Municipal Separate Storm Sewer System |
| N/A | not applicable |
| NCDC | National Climatic Data Center |
| NER | National Ecosystem Restoration |
| NFF | National Forest Foundation |
| NPDES | National Pollutant Discharge Elimination System |
| NPR | non-potable reuse |
| NRCS | Natural Resources Conservation Service |
| O&M | operations and maintenance |
| OWLA | One Water Los Angeles |
| RIVER | Riparian via Varied Ecological Reintroduction |
| RM | River Mile |
| SCMP | Stormwater Capture Master Plan |
| SFB | San Fernando Basin |
| sq mi | square miles |
| SUSTAIN | System for Urban Stormwater Treatment and Analysis Integration |
| TIWRP | Terminal Island Water Reclamation Plant |
| TM | Technical Memorandum |
| TMDL | total maximum daily load |
| TNC | The Nature Conservancy |
| UCLA | University of California Los Angeles |
| ULARA | Upper Los Angeles River Area |
| USACE | U.S. Army Corps of Engineers |
| USBR | U.S. Bureau of Reclamation |
| UWMP | Urban Water Management Plan |
| WMRP | Watershed Management and Restoration Plan |
| WRP | water reclamation plant |

# LOS ANGELES RIVER FLOW STUDY SUMMARY REPORT

## ES EXECUTIVE SUMMARY

The City of Los Angeles (City) recently embarked on the One Water LA 2040 Plan. This plan will provide a strategic vision and a collaborative approach for integrated water management. In 2006, the City completed and adopted its first integrated water resources plan (IRP). This plan was the start of a paradigm shift for the City and resulted in significant achievements. Since then, the water landscape in the City has changed with increased demands, new regulations, and threats of climate change.

In response to these changes and to help achieve water sustainability, the City initiated the One Water LA 2040 Plan. This plan builds upon the success of the Water IRP, which had a planning horizon to year 2020. The One Water LA 2040 Plan takes a holistic and collaborative approach, to consider all water resources from surface water, groundwater, potable water, wastewater, recycled water, dry-weather runoff, and stormwater as "One Water." The plan identifies multi-departmental and multi-agency integration opportunities to manage water in a more efficient, cost effective, and sustainable manner.

The One Water LA 2040 Plan represents the City's continued and improved commitment to proactively manage all its water resources and implement innovative solutions, driven by the Sustainable City pLAn. The Plan will help guide strategic decisions for integrated water projects, programs, and policies within the City.

### ES.1 Study Purpose and Objectives

The purpose of this study is to identify considerations, assumptions, and areas of future study necessary to determine optimal flow conditions in the Los Angeles River (LA River). These conditions would balance the City's water supply needs with the LA River's water-dependent uses and regulatory requirements.

The following objectives will inform the City's decision-making process during the adaptive management approach for managing flows in the LA River:

1. Understand existing low flow conditions in the LA River over the last 3 years.
2. Estimate the potential range of low flow conditions in the LA River given the City's projected changes in runoff management and wastewater flows through 2040.
3. Gain understanding of water budget assumptions in the Area with Restoration Benefits and Opportunities for Revitalization (ARBOR) study.
4. Develop conceptual adaptive water management alternatives that provide flexibility in the management of river flows and allow water supply opportunities.

## ES.2 Study Outcomes

Anticipated outcomes from the LA River Flow Study include the following:

1. Determine available inflow sources to the LA River and their respective flow rates, such as flows from water reclamation plants (WRPs) and dry weather flows, based on available information. Identify existing water-dependent uses and determine water flow rates on which they rely.
2. Summarize the water budget needed to support the ARBOR study requirements. Identify technical assumptions related to the ARBOR study water budget that may require additional consideration or supplemental data and analysis.
3. Identify conceptual adaptive water management alternatives and associated proposed concepts that would optimize the amount of flow needed to support potential future water-dependent uses and satisfy regulatory requirements.
4. Provide a summary for each alternative/concept that includes anticipated benefits and impacts, challenges, limitations, information gaps, stakeholders involved, and conceptual-level details with corresponding cost-estimates to facilitate the decision-making process.

## ES.3 Key Information Gaps and Future Study Needs

The studies conducted under this task of the One Water LA 2040 Plan (i.e., Task 12D), provided valuable information to guide water management options due to anticipated changes in WRP releases to the LA River and stormwater management plans. The following studies are recommended to address key data and information gaps in the assumptions that were applied in the studies reviewed and conducted under this task:

- Review and refine the water budget components, such as infiltration, groundwater upwelling, evaporation, and evapotranspiration.
- Development of a detailed, dynamic surface water groundwater interaction model for the Los Angeles River Watershed (LAR Watershed) is needed to understand the spatial and temporal variability in flow components.
- Determine dry weather flows needed for habitat restoration projects.
- Develop a predictive modeling tool to evaluate how changes in the hydrologic regime (amount and timing of flow) could affect quantity and/or quality of habitats and to evaluate how changes in the hydrologic regime could affect aquatic and terrestrial species that rely on existing habitats.
- Develop a water budget that addresses uncertainties in flow estimates and with consideration of recent drought management approaches, anticipated urban runoff changes, and removal of Arundo donax in waterways within, and tributary to, the LA River.

- To further refine the water budget, conduct additional site specific field work to characterize the soil-dependent infiltration rates and evaporation rates.
- Develop a more current and accurate characterization of the contribution of incidental runoff to the LA River to understand the amount of incidental flow generated and how much of that flow reaches the River.
- Develop a more current and accurate understanding of the existing LA River water uses and the flow requirements to support those uses.
- Develop a detailed adaptive management approach to establish the vision/goals for LA River restoration/revitalization and support its water uses. A detailed planning and implementation process framework with a systematic approach for resource management and monitoring to track progress is needed.
- Additional modeling required that relates modeling output to water quality compliance (UCLA)

## ES.4 Study Approach

The LA River Flow Study task for the One Water LA Plan (Task 12D) was executed through four subtasks, depicted on Figure ES.1.

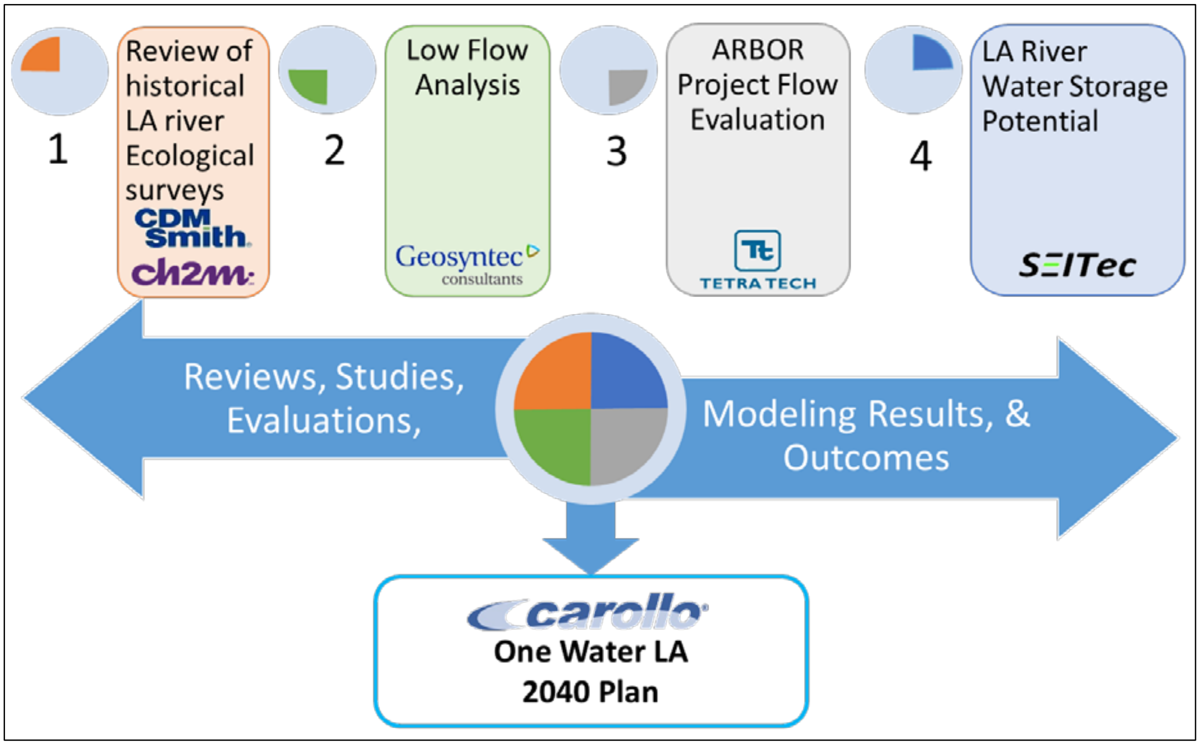

**Figure ES.1 Summary of the Sub-Tasks of Task 12D of the One Water LA 2040 Plan**

Those four subtasks resulted in the technical memoranda (TMs) referenced in this Summary Report and included as Appendices herein.

- **Subtask 1 - Review of Historical LA River Ecological Surveys (Appendix B):** The review provided an understanding of the LA River locations where studies were historically conducted and guided the flow analysis study for selection of sites for the Subtask 2 Low Flow Analysis. This included reviews of the 2006 Water IRP study and the U.S. Bureau of Reclamation US. Bureau of Reclamation 2004 LA River Physical and Biological Habitat Assessment

- **Subtask 2 - Low Flow Analysis (Appendix C):** Developed a multi-aspect study to estimate low flow rates during dry weather in the LA River under different conditions, using these flow rates to determine how water resource management decisions may impact flow width, depth, and velocity at select locations in the LA River. The approach for this analysis was to 1) model dry weather hydrology for each river mile in the LA River for existing, and a range of potential, future flow conditions, 2) select cross sections at several important locations in the LA River including soft-bottom and hard-bottom reaches based on data availability and their possible importance for habitat and recreation, and 3) model the hydraulics and analyze a range of flows at each of these locations, including the existing condition and the range of potential future conditions.

- **Subtask 3 - ARBOR Project Flow Evaluation (Appendix D):** This review of the 2015 U.S. Army Corps of Engineers' (USACE) LA River Ecosystem Restoration Integrated Feasibility Report (Feasibility Report) was conducted to gain an understanding of the water budget assumptions for the 11-mile ARBOR reach of the LA River. The Feasibility Report does not provide a water demand estimate for existing LA River needs; rather, only the water demand for proposed vegetation are included. In this Subtask 3 study documented in Appendix D, the water demand and water budget for the existing "baseline" conditions were developed using an approach similar to that used in the USACE Feasibility Report. The Feasibility Report is the documentation of the ARBOR Study and the associated analyses. For the purposes of this document, the term "ARBOR Study" is used.

- **Subtask 4 - LA River Water Storage Potential and Maintaining Optimal Flows Using Level Controls (Appendix E):** This study evaluated the in-channel and off-channel storage potential to store runoff during wet weather and dry weather conditions. Wet weather storage involved evaluating how to impound rainwater in the LA River during specific storm events. Dry weather water level devices were considered that could create a cascade of pools. Different types of water level devices were considered for placement in strategic locations. Conceptual options for conveyance of the stored water to the existing Donald C. Tillman Water Reclamation Plant (DCTWRP) and Los Angeles-Glendale Water Reclamation Plant (LAGWRP) for treatment and reuse were also evaluated. In addition, this study considered the potential for direct potable water use of the stored water. Lastly, this study included Hydrologic Engineering Center River Analysis System (HEC-RAS) modeling analysis along certain reaches of the LA River to simulate hydraulic conditions during dry weather flows with check dams, or other small water level devices, that could enable the reduction of recycled water releases to the river. This is an area in which further regulatory review and collaboration is necessary.

## ES.5 Study Findings

The expected changes in the management of wastewater and stormwater flows in the LAR Watershed will impact discharges to the river, resulting in changes to the LA River flows. The City's goal is to create a balance between the City's water supply needs and the river's water-dependent and regulatory uses. To achieve that balance, this LA River Flow Study was conducted to develop an understanding of the baseline flow conditions of the LA River and flow requirements for various existing and planned uses. This understanding of flow requirements of the river is necessary to ensure that changes made to the water supply portfolio are consistent with the restoration/revitalization plans along with other LA River water uses.

The studies conducted in the four subtasks of this LA River Flow Study were designed to achieve the expected outcomes as discussed below.

### ES.5.1 Outcome No. 1

**Determine available inflow sources to the LA River and their respective flow rates, such as flows from WRPs and dry weather flows, based on available information. Identify existing water-dependent uses and determine water flow rates on which they rely.**

Water balances for both existing and future conditions showing available inflow sources and their respective flow rates are depicted on Figures ES.2 and ES.3, respectively. These water balances were specifically developed for the One Water 2040 Plan under Task 12D, and are based on the assumptions presented in Appendix C. The details of these inputs are provided in Appendix C and are discussed below. Since WRP flows and stormwater cannot be firmly predicted for future flow conditions, a range of scenarios were established where flows were varied to understand the effects on the river flows.

Based on the review of previous studies conducted under Subtask 1, and the estimates of low flow conditions evaluated under Subtask 2, a need to resolve uncertainty in several water budget components is apparent. For example, infiltration and groundwater upwelling and evapotranspiration rates under the existing and revised habitat conditions (such as after the removal of the invasive species) require more refined and accurate estimations to establish realistic water budgets.

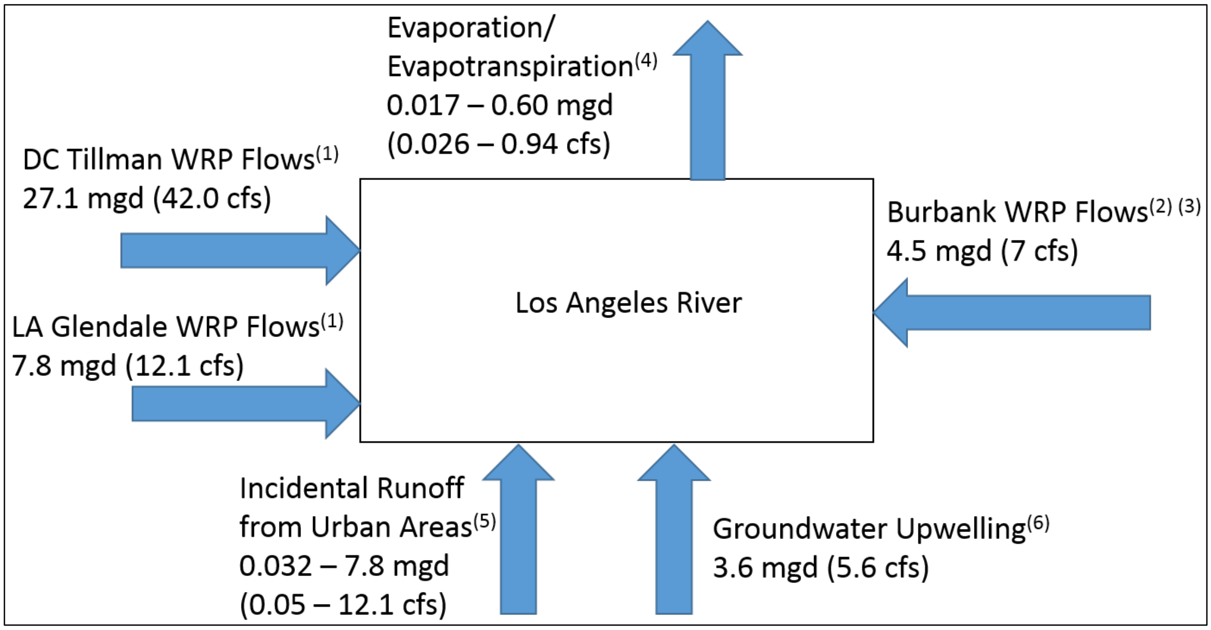

**Figure ES.2 Existing LA River Flow Components: Inputs/Outputs of the Dry Weather Flow Model**

Notes:
Data presented on this figure is based on Appendix C of this Summary Report.
Source of data:

1) DCTWRP Flows and LA Glendale Flows: 10th percentile of daily average total effluent flow between 2013-2015
2) Burbank Flows: Estimated based on National Pollutant Discharge Elimination System (NPDES) Permit
3) A 1211 wastewater change petition was recently submitted (3/17/2017) for a Burbank Water Reclamation Plant (BWRP) existing flow rate of 4.8 million gallons per day (mgd).
4) LA County Load Simulation Program (LSPC) model's Potential evapotranspiration (ET) values based on conversion of computed National Climatic Data Center (NCDC) evaporation pan data from Long Beach Airport (Gage 23129) and Burbank-Glendale-Pasadena (Gage 23152) using pan coefficients of 0.74-0.78
5) Incidental runoff from Urban Areas: Los Angeles Integrated Resources Plan: Facilities Plan, Vol 3: Runoff Management (Los Angeles Sanitation [LASAN], 2004)
6) Groundwater Upwelling: 10-year annual average from 2002-2003 through 2012-2013 (ULARA Watermaster Report, 2014)

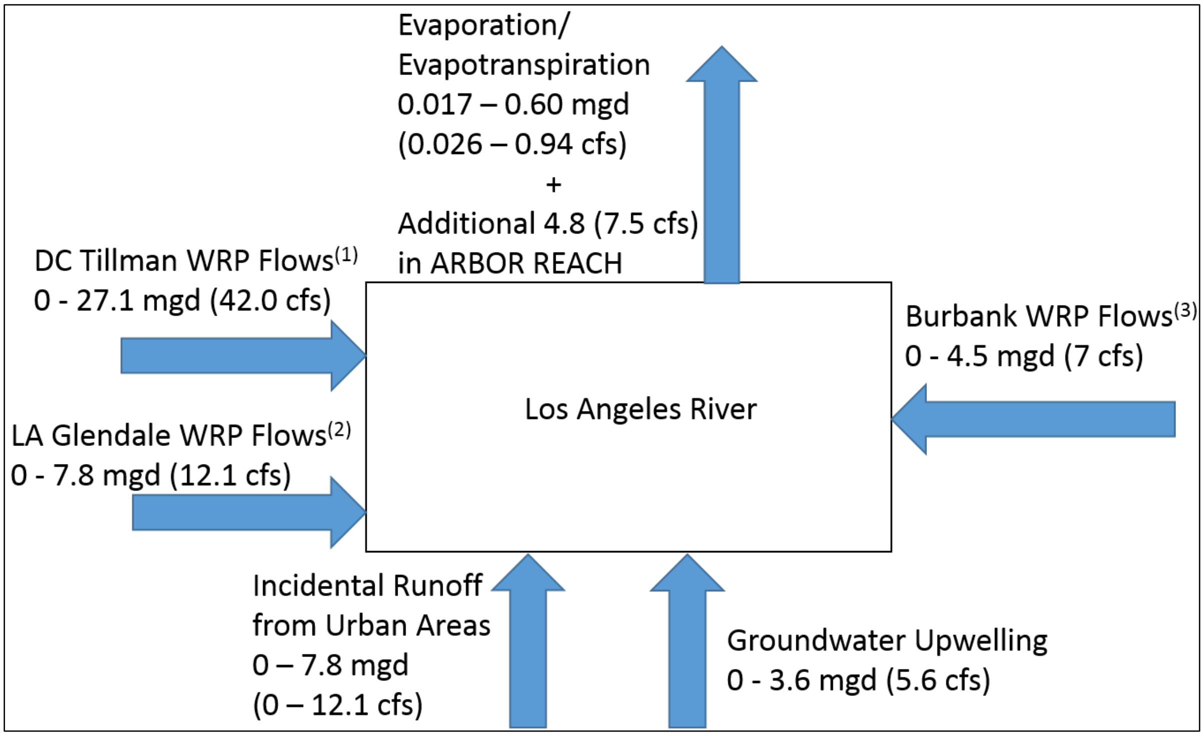

**Figure ES.3 Potential LA River Flow Components: Inputs/Outputs of the Dry Weather Flow Model**

Notes:
Data presented on this figure is based on Appendix C of this Summary Report.
Source of data:

1) DCTWRP Flows: The 2016 Board of Water and Power certified Environmental Impact Report (EIR) for the San Fernando Groundwater Replenishment (GWR) Project will not change the flows into the LA River
2) LA Glendale Flows: The IRP (2006) proposed that all treated water from the LAGWRP be used for non-potable uses with no flows into LA River, particularly during the summer months.
3) Burbank Flows: Because the BWRP is not within the planning scope of One Water LA, a potential range of flows has been assumed.

There seems to be a knowledge gap between the available flow rate information and the determination of flow rates that support existing conditions/uses for the entire LA River. A list of data gaps related to developing relationships between flow and biological habitat, special status species and their habitat, and the establishment of native/non-native habitat after removal of invasive species have been identified in Table ES.1. A predictive modeling tool is needed to evaluate how changes in the hydrologic regime (amount and timing of flow) could affect the quantity and/or quality of habitat, and to evaluate how changes in the hydrologic regime could affect aquatic and terrestrial species that rely on existing habitat. In addition, studies related to LA River water uses such as recreational water uses (e.g., kayaking), industrial process supply, navigation and commercial and sport fishing needs to be evaluated[1].

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[1] All references to "beneficial uses" in this report are to the beneficial uses identified by the Los Angeles Regional Water Quality Control Board in its *Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties*, available at http://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan/basin_plan_documentation.shtml. Notably, the *Basin Plan* includes not only existing and intermittent beneficial uses identified by the Regional Board, but also potential future beneficial use goals.

### ES.5.2 Outcome No. 2

**Summarize the water budget needed to support the ARBOR study requirements. Identify technical assumptions related to the ARBOR study water budget that may require additional consideration or supplemental data and analysis.**

The study conducted under Subtask 3 and documented in Appendix D of this Summary Report identified that the water budget results from the USACE ARBOR Study did not account for the water demand of existing habitat features. Rather, it provided the water demand for the proposed vegetation associated with the project alternatives. Native vegetation currently makes up approximately 30 percent of the study area that would not be removed and/or replaced as part of the plan, as would occur with invasive species. This means that only part of the water demand was calculated. Therefore, the study conducted and presented in Appendix D provides the following: (1) the water demands and water budgets calculated for existing, "baseline" conditions, (2) the proposed enhancements identified by "Alternative 20" (the Recommended Plan), and (3) the combined total representing post-construction conditions.

As presented in Appendix D, provided below is a summary of the assumptions used in the study and identifies the needs for additional consideration and supplemental data and analysis:

- Infiltration was based on soil type data provided by the Natural Resources Conservation Service (NRCS) and referenced in Appendix E of the Feasibility Report. The soils underlying the study area fall primarily into Hydrologic Soil Group D, which is a soil with the lowest infiltration rate of those found in the study area. Within the ARBOR Report, infiltration is indicated as a volume loss. However, Appendix C states that the observed flow versus modeling correlation shows that infiltration is insignificant and thus infiltration is very likely to be negligible.
- The ARBOR Study includes the annual evapotranspiration demand for the proposed project conditions only, and does not include the existing conditions, as indicated in Table 4 in Appendix C to this Summary Report. Furthermore, there is a discrepancy in the values of evapotranspiration rates used in these studies. A detailed investigation of evapotranspiration rates is needed to understand the rates for the existing and future conditions and their effects on the water budget.
- The availability of localized, site specific data was limited due to the variability of the study area. These include, for example, values such as specific, soil-dependent infiltration rates when the exact soils and substrate conditions are unknown, or evaporation rates from open water having partial shade during the day within the study area when evaporation rates are generalized by nearby stations. To fully characterize these data, additional laborious, site specific field work would need to occur.
- Note that stream flow is only available to habitat as it moves through the study area. Once it flows downstream of the study area it is considered as "outflow" for the purposes of the water budget balance. This is a significant caveat. What this implies is that water budgets – including the calculations herein as well as those in the ARBOR Study – may not accurately reflect what may be available to habitat within the

ARBOR reach. Since most of the annual, measured flow within the channel is from precipitation, wet-season flow accounts for over three times as much streamflow as during the dry season, the latter of which is due in large part to WRP discharge and urban runoff – both relatively constant throughout the year. Care must be taken, therefore, when considering the water budget and any results that are based on large amounts of streamflow, particularly quantities represented during the wet season. Unless these flows are captured and stored in the river for beneficial use, much of this flow would not be available for habitat.

### ES.5.3 Outcome No. 3

**Identify conceptual adaptive water management alternatives and associated proposed concepts that would optimize the amount of flow needed to support potential future water-dependent uses and satisfy regulatory requirements.**

The active management of wastewater flows and urban runoff/stormwater in the LAR Watershed will affect the volumes and rates of flow in the LA River. In the Subtask 4 study, examples of water management options for in-channel and off-channel water storage were considered that could maximize available water use while supporting beneficial uses[1] in the LA River. Five such water management conceptual options are examined that could be further evaluated and potentially applied.

1. In-channel storage of wet weather flows: The volume of stormwater storage potential through the use of rubber dams at four select locations within the mainstream of the LA River was evaluated. A total of 1,200 million gallons (MG) (3,700 acre-feet [AF]) of storage was calculated for these four locations.
2. Off-channel storage of wet weather flows: Diversion of stormwater for storage was evaluated at two select locations. The total estimated storage volume for these locations was calculated to be 1,500 MG (4,600 AF).
3. Stored water conveyance and treatment: Stormwater stored behind rubber dams could be conveyed to the DCTWRP and LAGWRP for treatment and beneficial use.
4. Potable use: Treatment of stored river water to potable water quality standards using packaged treatment systems could be delivered directly through the potable water distribution system.
5. Dry weather flow water level control: Use of a series of check dams, or other small water level devices, to create a cascade of pools to restore river hydrology is explored. By installing a series of check dams, or other small water level devices, along the LA River, water levels can be raised and the corresponding wetted perimeter increased instead of accomplishing the desired wetted area with flow only. This analysis was conducted to evaluate how recycled water releases for habitat restoration by WRPs may be significantly lowered with the use of check dams or other small water level devices. A hydraulic analysis for three locations along the LA River was conducted by analyzing three stepwise scenarios using the HEC-RAS model developed under Subtask 2.

Reducing the current estimated 40 million gallons per day (mgd) that is released by the combination of DCTWRP and LAGWRP without check dams, or other small water level devices, down to 6 mgd with check dams, or other small water level devices, would save about 34 mgd by 330 Days = 11,220 MG (34,400 AF) of water per year (given 35 rainy days per year on average).

### ES.5.4 Outcome No. 4

**Provide a summary for each alternative/concept that includes anticipated benefits and impacts, challenges, limitations, information gaps, stakeholders involved, and conceptual-level details with corresponding cost-estimates to facilitate the decision-making process.**

For the five water management concepts presented in Outcome No. 3, the Subtask 4 study developed information necessary to support the decision-making process. These five conceptual options are presented in Section 3.3, and in Appendix E of this Report. The descriptions of these concepts include preliminary cost estimates, potential benefits, anticipated challenges, and other considerations (e.g., site selection, operation and maintenance, vector control system, and cost/benefits) for further feasibility analysis.

Note that the water management concepts presented above are independent of specific water use needs at specific locations in the river. Those site-specific water needs will be identified through the various LA River-related planning and coordination activities, and the appropriate water management options applied to satisfy those (water level or flow rate) needs. A water budget for the LA River should be developed that reflects the uncertainties of river flows and include considerations of recent drought management approaches, anticipated urban runoff changes, and removal of Arundo donax in waterways within and tributary to the LA River.

These conceptual options are intended to manage water that is, or will be, discharged to the LA River and thus do not include diversion of recycled water from the WRPs for groundwater recharge prior to river discharge. In addition, the amounts of flow to be managed by the various options are not determined in this One Water LA 2040 LA River Flow Study.

## ES.6 Summary and Conclusions

The studies conducted in Task 12D provided valuable information to guide water management options due to anticipated changes in WRP releases to the LA River and stormwater management plans. Key data and information gaps warrant consideration of the following assumptions as specified in Table ES.1.

**Table ES.1 Key Data and Information Gaps and Recommendations One Water LA 2040 Plan – TM 12.4**

| Data Gaps/Unknowns | Recommended Areas of Future Study |
|---|---|
| *Refinements for estimates of water budget components:* The water budget components, such as infiltration, groundwater upwelling, evaporation, and evapotranspiration need to be reviewed and refined. | A detailed dynamic surface water and groundwater interaction model for the LAR Watershed is needed. Given the uncertainty in model, water budget components, spatial and temporal variability in infiltration, evapotranspiration, and upwelling will provide more accurate estimates of flow conditions. Once the model is calibrated with the existing (historical) data and verified, it could be potentially used for understanding the water planning scenarios (e.g., changes to the WRP flows and stormwater runoff). |
| *Determination of dry weather flows:* A value of 10 cfs (6 mgd) was used to mimic reduced dry weather flow conditions in the LA River for various scenario evaluations. This value is an arbitrary representation of a drastically low flow condition in the river. The actual lower limit of flow that can be tolerated for habitat restoration with check dams (or other water control devices) must be determined with consideration for losses along the river and evapotranspiration. In addition, as the changes in flow regime due to WRP flow and stormwater management will occur over a temporal framework, the changes in flows over the course of the water management period require analysis of a dynamic system in an adaptive management framework. | A detailed (dynamic) evaluation of flow requirements for habitat restoration is needed. The flow tolerance for current habitat, proposed future conditions, effects of changing habitat conditions as well as removal and replacement of invasive species with appropriate native vs. non-native species need to be studied. |
| *Localized conditions:* The availability of the more localized, site specific data types such as specific soil- dependent infiltration rates and evaporation rates were limited due to variability of the study area | To further refine the water budget, additional site specific field work is needed to characterize the soil-dependent infiltration rates and evaporation rates. |
| *Dry weather runoff quantities:* There is considerable uncertainty regarding the amount of incidental (dry weather) runoff from urban areas. The amount of incidental-runoff of that reaches surface water bodies needs to be determined. | More current and accurate characterization of the contribution of incidental runoff to the LA River is needed. |
| *Flows that support existing habitat:* There is a knowledge gap between the available flow rate information and the determination of flow rates that support existing habitat conditions for the entire LA River. A list of data gaps have been identified which relate to developing relationships between flow and biological habitat, special status species and their habitat, establishment of native/non-native habitat after removal of invasive species. | A predictive modeling tool is needed to evaluate how changes in the hydrologic regime (amount and timing of flow) could affect quantity and/or quality of habitats and to evaluate how changes in the hydrologic regime could affect aquatic and terrestrial species that rely on existing habitats. |
| *Flows that support other uses:* Flows for other various uses of the LA River are not specified. | Further evaluation of LA River water uses is needed. |

**Table ES.1 Key Data and Information Gaps and Recommendations One Water LA 2040 Plan – TM 12.4**

| Data Gaps/Unknowns | Recommended Areas of Future Study |
|---|---|
| *Available flows after the removal of Arundo Donax:* Arundo donax (commonly referred to as giant reed or Arundo), a water intensive invasive species reduces water that flows through the City. Arundo transpires water at a rate that is five times higher than native vegetation. Projects are underway for the removal of these species. | The impact of Arundo removal and replacement with native species on the LA River water budget should be evaluated. |
| *Special Status Species:* It is not clearly understood if there are any special status species that use the LA River. | Investigate to conclusively determine if special-status species actually use the LA River. Available data does not indicate whether flow changes would impact any special-status species. |

Notes:

(1) The upwelling of groundwater is highly dependent upon local hydrological cycles, and may or may not occur even in the absence of sustained groundwater pumping. Rising groundwater should not be considered a reliable source or a consistent base flow.

(2) All references to "beneficial uses" in this report are to the beneficial uses identified by the Los Angeles Regional Water Quality Control Board in its *Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties*, available at http://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan/basin_plan_documentation.shtml. Notably, the *Basin Plan* includes not only existing and intermittent beneficial uses identified by the Regional Board, but also potential future beneficial use goals.

The City is studying multiple aspects of the LA River, including its impact to the City's water supply. The possibility of enhancing local water supply though greater efforts in water recycling, water conservation, groundwater management, and improvements in surface water quality may all potentially decrease dry weather flows in the LA River. Future management of the LA River requires a greater understanding of how changes in flow may impact other values such as water supply, water quality, habitat, recreation, and aesthetics. Multiple uses can be balanced by utilizing an adaptive management framework that includes stakeholder participation to determine the types and locations of these uses along the LA River, and the corresponding water management options to meet the associated water demands.

The cumulative impacts of these concurrent planning efforts and projects have not yet been evaluated from a regional perspective. This is another required area of future study.

## ES.7 Stakeholder Engagement and Path Forward

With many, varied LA River planning activities underway, there is a need to coordinate stakeholder engagement and feedback in order to evaluate competing water management goals that affect the LA River flows. The emphasis is on creating a holistic adaptive management process to address all water uses of the LA River. To secure buy-in, it is important that the City incorporate input from the public, including stakeholder groups and agencies that represent a variety of interests. A framework that provides a systematic approach for resource management and ensures flexibility should be established.

Figure ES.4 presents a conceptual starting point for an adaptive management framework. The framework must follow a goal-driven process to help ensure that the water in the LAR Watershed is managed sustainably even during complex scenarios.

The framework starts with an understanding of the existing LA River water uses and the corresponding water budget that support those uses. After defining baseline water budget conditions, ecosystem level planning and analysis will be needed to develop adaptive management alternatives. Based on the projected flow conditions, an evaluation of alternatives will be necessary to guide adjustments to management actions while meeting the project objectives/outcomes and the broader goals of sustaining the LA River water uses, meeting the restoration/revitalization goals, and balancing the City's water supply needs. An implementation plan should cover the projects/activities at the reach level and evaluate their impacts to both the local reach and the downstream river. Monitoring will be needed to assess the impacts of management actions. The process should also account for risk to, and uncertainty of, the future success of ecological restoration activities, including effects of invasive species or their removal, human activities, stresses within the watershed (e.g., drought), future climate change and long-term operations and maintenance (O&M) costs. The framework should also incorporate ecological (e.g., existing conditions) and non-ecological (e.g., funding and permitting) constraints.

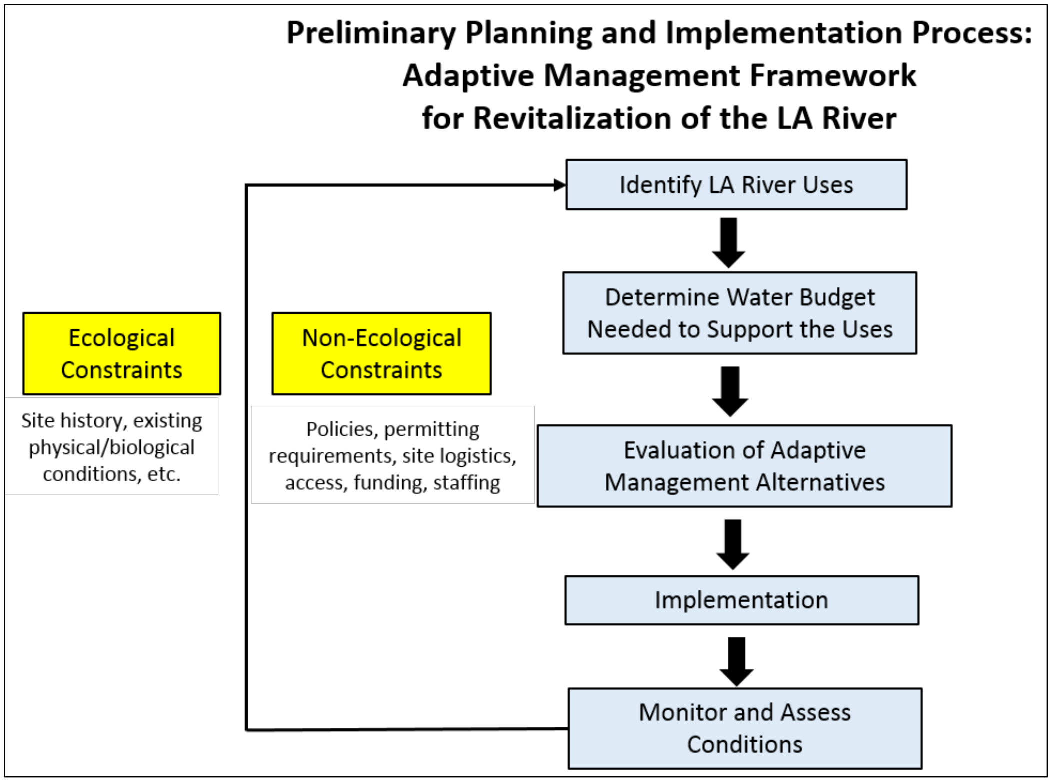

**Figure ES.4 Flow Chart Describing a Preliminary LA River Planning and Implementation Process Framework**

### ES.7.1 Actions for the Adaptive Management Framework

A series of actions that define the goals for the adaptive management framework process are discussed in Section 4.0. Those actions are to ensure that, from the beginning of the process, an adaptive management approach is considered to address the data and knowledge gaps identified above and allow flexibility to apply the lessons learned from the ongoing work to future efforts. Monitoring becomes a key component of the process to make informed decisions.

### ES.7.2 Leadership and Collaboration under the Adaptive Management Framework

The Los Angeles City Charter grants the Los Angeles Department of Water and Power (LADWP) exclusive authority over water rights. As such, LADWP must play a leadership role in the implementation of projects that exert a demand on the LA River flows. Toward that end, the City has led a collaborative process to engage City departments and other stakeholders in the planning and decision-making related to balancing the LA River's restoration and revitalization objectives. A key forum for such decision-making is the LA River Cooperation Committee (LARCC), a joint working group of the LA County Department of Public Works and the City, with the USACE serving in an advisory capacity. In 2016, the LARCC revamped their Project Evaluation Form. The objective of this evaluation form is to capture project-specific information and enlist various criteria used in the evaluation process. The Project Evaluation Form aims at capturing information in a consistent and streamlined manner to facilitate the decision-making process. For example, evaluation of the preliminary conceptual water management options presented in this LA River Flow Study would involve performing more detailed analysis and presenting results to respond to various questions within this evaluation form to facilitate decision-making.

With the multitude of planning studies related to the LA River, the development of a Planning and Implementation Process Framework that incorporates an Adaptive Management Plan would formalize the City's leadership role and provide a structure in which technical, institutional, and regulatory considerations can be evaluated for all projects that would impact LA River flows.

# LOS ANGELES RIVER FLOW STUDY SUMMARY REPORT

## 1.0 INTRODUCTION

### 1.1 Background of One Water LA

The City of Los Angeles (City) recently embarked on the One Water LA 2040 Plan. This plan will provide a strategic vision and a collaborative approach for integrated water management. In 2006, the City completed and adopted its first integrated water resources plan (IRP). This plan was the start of a paradigm shift for the City and resulted in significant achievements. Since then, the water landscape in the City has changed with increased demands, new regulations, and threats of climate change.

In response to these changes and to help achieve water sustainability, the City initiated the One Water LA 2040 Plan. This plan builds upon the success of the Water IRP, which had a planning horizon to year 2020. The One Water LA 2040 Plan takes a holistic and collaborative approach, to consider all water resources from surface water, groundwater, potable water, wastewater, recycled water, dry-weather runoff, and stormwater as "One Water." The plan identifies multi-departmental and multi-agency integration opportunities to manage water in a more efficient, cost effective, and sustainable manner.

The One Water LA 2040 Plan represents the City's continued and improved commitment to proactively manage all its water resources and implement innovative solutions, driven by the Sustainable City pLAn. The Plan will help guide strategic decisions for integrated water projects, programs, and policies within the City.

### 1.2 Purpose and Objectives of Task 12.4

The purpose of this study is to identify considerations, assumptions, and areas of future study necessary to determine optimal flow conditions in the LA River. These conditions would balance the City's water supply needs with the LA River's water-dependent uses and regulatory requirements.

The following objectives will inform the City with their decision-making during the City's adaptive management process for flows in the LA River:

1. Understand existing low flow conditions in the LA River over the last 3 years.
2. Estimate the potential range of low flow conditions in the LA River given the City's projected changes in runoff management and wastewater flows through 2040.
3. Gain understanding of water budget assumptions in the Area with Restoration Benefits and Opportunities for Revitalization (ARBOR) study.
4. Develop conceptual adaptive water management alternatives that provide flexibility in the management of river flows and allow water supply opportunities.

## 1.3 Outcomes of the LA River Flow Study

Anticipated outcomes from the LA River Flow Study include the following:

1. Determine available inflow sources to the LA River and their respective flow rates, such as flows from water reclamation plants (WRPs) and dry weather flows, based on available information. Identify existing water-dependent uses and determine water flow rates on which they rely.
2. Summarize the water budget needed to support the ARBOR study requirements. Identify technical assumptions related to the ARBOR study water budget that may require additional consideration or supplemental data and analysis.
3. Identify conceptual adaptive water management alternatives and associated proposed concepts that would optimize the amount of flow needed to support potential future water-dependent uses and satisfy regulatory requirements.
4. Provide a summary for each alternative/concept that includes anticipated benefits and impacts, challenges, limitations, information gaps, stakeholders involved, and conceptual-level details with corresponding cost-estimates to facilitate the decision-making process.

## 1.4 Key Information Gaps and Future Study Needs

The studies conducted under this task of the One Water LA 2040 Plan (i.e., Task 12D) provided valuable information to guide water management options due to anticipated changes in water reclamation plant (WRP) releases to the LA River and stormwater management plans. The following studies are recommended to address key data and information gaps in the assumptions that were applied in the studies reviewed and conducted under this task:

- Review and refine the water budget components, such as infiltration, groundwater upwelling, evaporation, and evapotranspiration.

- Development of a detailed, dynamic surface water groundwater interaction model for the LAR Watershed is needed to understand the spatial and temporal variability in flow components.

- Determine dry weather flows needed for habitat restoration projects.

- Develop a predictive modeling tool to evaluate how changes in the hydrologic regime (amount and timing of flow) could affect quantity and/or quality of habitats and to evaluate how changes in the hydrologic regime could affect aquatic and terrestrial species that rely on existing habitats.

- Develop a water budget that addresses uncertainties in flow estimates and with consideration of recent drought management approaches, anticipated urban runoff changes, and removal of Arundo donax in waterways within, and tributary to, the LA River.

- To further refine the water budget, conduct additional site specific field work to characterize the soil-dependent infiltration rates and evaporation rates.

- Develop a more current and accurate characterization of the contribution of incidental runoff to the LA River to understand the amount of incidental flow generated and how much of that flow reaches the River.

- Develop a more current and accurate understanding of the existing LA River water uses and the flow requirements to support those uses.

- Develop a detailed adaptive management approach to establish the vision/goals for LA River restoration/revitalization and support its water uses. A detailed planning and implementation process framework with a systematic approach for resource management and monitoring to track progress is needed.

## 1.5 Study Subtasks

- The LA River Flow Study for the One Water LA 2040 Plan was executed through Task 12D, and included four subtasks that resulted in the technical memoranda referenced in, and appended to, this Summary Report and Figure 1.

- Subtask 1 – Review of Historical LA River Ecological Surveys (Appendix B)

- Subtask 2 – Low Flow Analysis (Appendix C)

- Subtask 3 – ARBOR Project Flow Evaluation (Appendix D)

- Subtask 4 – Potential Water Management Options Development (Appendix E)

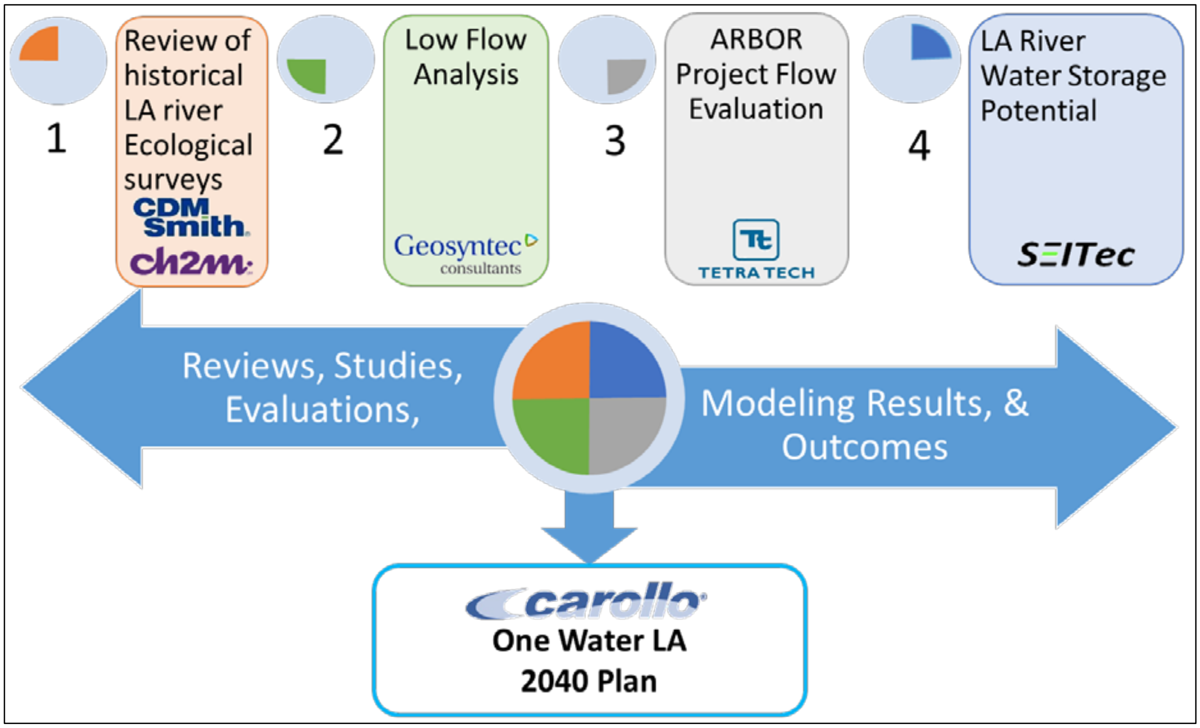

**Figure 1** Summary of the Sub-Tasks of Task 12D of the One Water LA 2040 Plan

## 2.0 APPROACH/METHODOLOGY

The approach for conducting this LA River Flow Study is summarized in the following sections. Further elaboration on the methodology is provided in the appended TMs.

### 2.1 Review of Historical LA River Ecological Surveys

For the TM provided in Appendix B of this Summary Report, a review of four studies was conducted regarding biological habitat and flow conditions in the LA River in an effort to identify how potential flow changes may impact hydrologic conditions and sensitive locations in the LA River. Those four studies are referred below as Study B1, Study B2, Study B3, and Study B4, referring to the studies described in Appendix B of this TM. Presented below is a brief summary of each of these studies and their respective findings.

#### 2.1.1 Study B1 – LA River Physical and Biological Habitat Assessment Report of 2003 Field Activities (USBR, 2004)

This study was conducted to "evaluate wildlife habitats" and "determine the relationship between such habitats and dry-season river flows." The goal of the field activities was to (1) understand and evaluate the existing wildlife habitats within the LA River channel and (2) determine the relationship between habitats and dry-season river flows. The approach primarily consisted of field surveys at representative reaches and the use of aerial videography, which helped to determine the size/density, composition, and distribution of riparian habitats. Four sites within three reaches were studied, as identified on Figure 1 in Appendix B. Table 1 presents physical characteristics of those sites.

**Table 1 Summary of Physical Characteristics of Study Sites One Water LA 2040 Plan – TM 12.4**

| Study Site | Number of Cross-Sections | Reach Length (ft) | Total Width (ft) | Wet Width (ft) | Water Depth (ft) | Estimated Velocity (fps) | Estimated Flow (cfs) |
|---|---|---|---|---|---|---|---|
| 1 – Los Feliz | 10 | 1,217 | 200 | 110-195 | 0.5-2.8 | 0.1-1.9 | 112 |
| 2 – Taylor Yard | 6 | 364 | 230 | 89-94 | 2.2-4.0 | 0.2-1.9 | 100 |
| 3 – Balboa | 4 | 111 | 175 | 50-70 | >3 | 0.1-1.0 | 12 |
| 4 – Willow Street | 0 | N/A | >300 | N/A | 2-12 | N/A | N/A |

*Source: U.S. Bureau of Reclamation (USBR) 2004*

Abbreviations:

ft = feet (foot); fps = feet per second; N/A = not applicable

Presented below is a summary of the findings of the work presented in this 2004 USBR report, conducted as part of the City's Phase II IRP:

- The LA River consists of five zones based on physical channel characteristics and habitat presence as follows: (1) concrete lined reaches without wildlife habitat, (2) unlined reaches with intermittent riparian habitat, (3) large, "continuous" riparian habitat in Sepulveda Basin, (4) shorebird habitat in concrete lined downstream reaches above the tidal zone, and (5) estuary.

- The Glendale Narrows is not concrete-lined and contains approximately 48 acres of riparian habitat; however, hydraulic control structures (sills, boulders, and cobbles) are present throughout this reach. The control structures help spread out the low flow and sustain the habitat. The study observed that most habitat areas were at a minimum, partially wetted and that denser vegetation was located in wetter areas. Habitat in the upstream study reach also suggests that water depth is more important than flow in sustaining habitats.

- Some river sections have unlined bottoms which support stands of vegetation and are of some value to wildlife. For example, although only a fraction of the total width, the wetted channel portions of Los Feliz and Taylor Yard sites are taken up by large vegetated islands along the west side of the channel. The vegetated habitat at the Balboa site was determined to be as good as, or even better than, the Los Feliz, and Taylor Yard sites.

- Riparian habitat was found in two areas: Sepulveda Basin and Glendale Narrows. Overall, the total acreage of riparian habitat for the entire study area was estimated at 48 acres, mostly in the Glendale Narrows.

- The Balboa site was identified as a "control station" due to the type of riparian habitat observed under reduced flow conditions. However, riparian habitat at this site was not considered "poorer" habitat despite decreased flows at the Balboa site.
- A healthy riparian community can be supported in the channel with very little streamflow providing that there is sufficient water depth. Even with less than ten percent of the flow volume observed at the Los Feliz and Taylor Yard sites, the riparian community at the Balboa site was as good as or better than in Glendale Narrows, which suggested that water depth is more important than flow.

### 2.1.2 Study B2 – Phase II City of Los Angeles Integrated Resources Plan for the Wastewater Program – LA River Recycled Water Evaluation Study Phase 1 – Baseline Study Final Report (CH2M:CDM, 2005)

The 2006 IRP sought to increase the use of recycled water and re-use of dry weather urban runoff. The Baseline Study was conducted in two phases as part of the Phase II IRP to evaluate limitations to supplementing LA River flow with recycled water or dry weather urban runoff. This Phase I study attempts to understand how projects under the IRP could alter/reduce the amount of water flow in the LA River channel and potentially result in impacts and benefits on biological/ecological attributes. One of the primary objectives was to establish a baseline for LA River conditions including flow, water quality, and habitat.

Presented below is a summary of the findings from this 2005 Baseline Study:

- LA River flow is heavily influenced by WRP flows, with lesser contributions from dry weather urban runoff and minimal contributions from groundwater. Flow would decrease if additional recycled water reuse and dry weather runoff diversions were implemented.
- Biological sites of interest along the LA River channel included the Sepulveda Basin, Glendale Narrows, Dominguez Gap and DeForest Park, Lower LA River, Willow Street reach, and the LA River mouth.
- Based on the findings of this Phase 1 Baseline Study, changes to low flows could result in impacts to both unlined reaches as well as lined reaches. However, a review of available data at that time (2003) did not clearly indicate that flow changes would impact any special status species, but further investigation is likely needed to conclusively determine if special status species actually use the LA River.
- Habitat at unlined portions of LA River are primarily impacted by floods (scouring effect) and to a lesser degree by low flows and water quality.
- Shorebird habitat at concrete lined portions of the LA River downstream of the Glendale Narrows is primarily impacted by low flows, followed by water quality and then flooding.

Potential impacts to the beneficial uses and habitats under reduced flow scenarios were documented in the Baseline Study. It broadly evaluated three flow scenarios: (1) support baseline flow conditions, (2) reduce contribution from wastewater effluent, and (3) reduce contribution from wastewater effluent and dry weather runoff.

Following is a summary of impacts of the flow reduction scenarios (scenarios 2 and 3):

- While groundwater recharge can only occur in the natural-bottom sections of the river, reducing flow in the river would limit the water available for recharge.[2]
- Flow reduction would primarily impact habitat-related beneficial uses. Under reduced flow conditions, both depth throughout the river and width of flow could decrease. This could result in less aquatic habitat available and may particularly impact shorebirds that feed in LA River habitats, including the estuary and Glendale Narrows.
- In concrete bottom sections of the river, algal presence dependent on wet river conditions could diminish and lead to less invertebrate production and shorebird foraging.
- Decreased depth could also result in less swimmable passage by fish and less desirable breeding environments.
- Changes in water chemistry and reduced wetness in the river resulting from decreased flow and dilution effects or changes in water supply could also encourage different vegetative and aquatic species to flourish and others to die off (e.g., algal blooms under increased nutrient conditions can result in low oxygen content in the river that is harmful for fish survival).
- Industrial process supply, navigation, and fishing uses at the downstream estuary end of the LA River are less likely to be impacted by changes to flow conditions. More detailed modeling and analysis would be necessary to identify the extent of impacts from reducing flow in the LA River.

The study also mentioned the ongoing efforts to treat and monitor eradication of invasive species in the Big Tujunga and Little Tujunga Watersheds, upstream of the Hansen Dam. The Arundo donax removal project is further discussed below in Section 3.1.3.

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[2] As the river is unlined in the natural-bottom sections due to historical groundwater upwelling conditions, groundwater recharge in these areas is likely to be relatively insignificant.

### 2.1.3 Study B3 – LA River Ecosystem Restoration Integrated Feasibility Report Volume 1: Integrated Feasibility Report (USACE, 2015)

The ARBOR Study area originally encompassed a 32-mile stretch of LA River within the City, beginning at the river origin and ending at the City of Vernon. Through further evaluation for maximum restoration potential, the revised study area focused on an 11-mile stretch that includes the Glendale Narrows. The revised study area, referred to as the ARBOR area, included the Glendale Narrows because the study suggested that the Glendale Narrows provides an important riparian habitat, and "shows the most promise for ecosystem restoration." The ARBOR Study evaluated an array of alternatives for restoring the ARBOR reach of the LA River from approximately Griffith Park to downtown Los Angeles while maintaining existing levels of flood risk management. The study area consisted of 8 reaches.

Presented below is a summary of the study/findings of the ARBOR Study:

- Biological sites of interest along the LA River channel included Sepulveda Basin, Glendale Narrows, Dominguez Gap and DeForest Park, Lower LA River, Willow Street reach, and the LA River mouth.
- Restoration of the LA River was proposed under Alternative 20, Riparian via Varied Ecological Reintroduction (RIVER), as the locally preferred plan (LPP), which includes monitoring until ecological success criteria are met, for no more than 10 years. Restoration measures of the LPP include river widening and terracing in Reaches 2, 5, 6, 7, and 8; restoring the Verdugo Wash confluence in Reach 3; daylighting three streams (storm drains); restoring the lower Arroyo Seco tributary; restoring foothill riparian and freshwater marsh at the Los Angeles State Historic Park to support increased population of wildlife and enhance habitat connectivity; and restoring channel bottom and a direct connection of the LA River into the Los Angeles Trailer and Container Intermodel Facility (LATC) site in Reach 8. Overall, the LPP would restore 719 acres of habitat throughout the ARBOR reach and provide provision of a direct connection to the significant habitat areas of the Verdugo Mountains.
- Potential projects presented in the ARBOR Study aimed to improve flow conditions and connectivity as well as increase biodiversity and habitats in LA River. Year-round flow and habitat at the ARBOR reach was the focus area of the study and serves as an established baseline for wildlife and habitat restoration potential. The 11-mile study reach has channel widths ranging up to 215 feet and contains sandbars and hydraulic structures.
- Up to 70 percent of year-round (perennial) flow consists of WRP effluent. Groundwater is also a source in the 11-mile reach of LA River and helps support existing habitat in that portion of LA River. Approximately 211,000 AFY of water is supplied annually by all sources (WRP effluent, groundwater, dry weather runoff, wet weather runoff and precipitation) combined.

- Hydrologic analysis compared the water budget (available water versus water demand) resulting from the various alternatives. However, none of the proposed alternatives affects hydrologic conditions in the ARBOR reach. Changes in flow conditions resulting from proposed alternatives primarily affect concrete-lined portions of the river where concrete would be removed.

- Water quality data suggests that total suspended solids, associated with urban land uses, is a critical parameter as it impacts not only water quality but also habitat quality and biodiversity in the river.

- Two alternatives were preferred based on LPP and National Ecosystem Restoration (NER) Plan considerations and are Alternative 20 and Alternative 13, respectively. Components of both alternatives include habitat restoration, improved habitat corridors, terraced banks, channel widening, flow diversion, return to historic flows, marsh restoration, and concrete removal.

### 2.1.4 Study B4 – Final Independent External Peer Review Report LA River Ecosystem Restoration Feasibility Study, Draft Integrated Feasibility Report and Environmental Impact Statement (Battelle, 2013)

The Final Independent External Peer Review (IEPR) Report was conducted by Battelle, an independent non-profit science and technology organization, on behalf of USACE. Panel members identified by Battelle reviewed the Draft LA River Ecosystem Restoration Integrated Feasibility Report (IFR), which included the draft EIR and Environmental Impact Statement (EIS), and provided comments regarding "adequacy and acceptability of economic, engineering, and environmental methods, models, and analyses used."

While the Panel considered the IFR to be generally comprehensive, it also noted that additional considerations should be included in relation to restoring "physical functions and ecological habitats that were historically present in the LA River system." The following comments pertaining to hydraulics, hydrology, and geotechnical analyses provided by the Panel as part of the IEPR were considered significant:

- Flood risk management should be included as an objective of the IFR as it was a critical purpose of the river in the past and the capacity for flood risk management may be impacted by the approach for habitat restoration in the river.

- Hydrologic and hydraulic analyses should expand beyond design storms and floods to include other flow conditions (e.g., seasonal and low flow) to evaluate the sustainability of river restoration under alternate flow conditions.

- Further analysis or support is necessary to identify that the replacement turf mat proposed as part of ecological restoration is structurally and geotechnically stable and able to withstand high velocity conditions during floods.

## 2.2 LA River Low Flow Study

The objective of the TM in Appendix C is to describe the results of a multi-aspect study conducted to estimate low flow rates during dry weather in the LA River under different conditions, using these flow rates to determine how water resource management decisions may impact flow width, depth, and velocity at select locations in the LA River.

The approach for this analysis was to:

- Model dry weather hydrology for each river mile in the LA River for existing, and a range of potential future, flow conditions;
- Select cross sections at several important locations in the LA River including soft-bottom and hard-bottom reaches based on data availability and their possible importance for habitat and recreation; and
- Model the hydraulics and analyze a range of flows at each of these locations, including the existing condition and the range of potential future conditions.

A hydrologic model was developed to estimate flows during dry conditions in both the existing and potential future conditions. The inputs (shown on Figure 2), assumptions, and methodology used to develop these models are summarized below and discussed further in Appendix C.

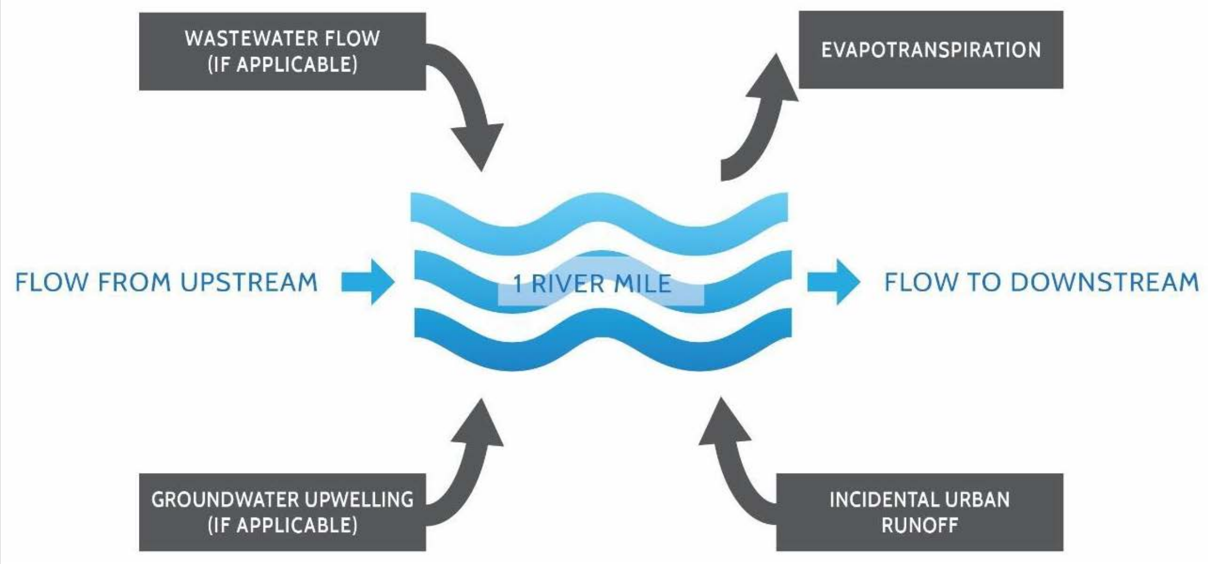

**Figure 2 Dry Weather Flows for Each River Mile in the LA River**

### 2.2.1 Existing Conditions Modeling

Below is a summary of the model inputs, outputs, and other considerations for modeling of existing flow conditions in the river:

- The flow at each river mile in the LA River was estimated for a dry, summer (July-August) day to provide a conservative scenario for dry weather flow.
- For each river mile, the flows into and out of the river segment were summed to create a mass balance and determine the flows released downstream.
- Incoming flows include flow from upstream segments of the river, incidental urban runoff entering through storm drain outfalls, flows from WRPs, and groundwater upwelling.
- Other potential flows into the river such as permitted flows from industrial permits were not included in the model.
- Outflows include evaporation or evapotranspiration and flow to downstream.
- While infiltration of water into the ground may occur in specific, localized, soft-bottom reaches, this was not accounted for in the model.
- The resulting flow rates from the combination of the flow inputs and outputs were compared to flow gage data at gauges 11092450 LA at Sepulveda Basin, F57C-R LAR above Arroyo Seco, F319-R LAR below Wardlow River Rd., and F300-R at Tujunga Ave.
- As stated in Appendix C, section 2.1.6, the flows predicted by the model are approximately 1 standard deviation (SD) below the mean flow measured for the gauge between July and August, but are well above the minimum. Because the included flow rates only include dry summer months, a flow rate one SD below the mean is representative of mid-day values during dry periods. Therefore, the model consistently predicting flows 1 SD below the mean is a good, conservative representation of typical low-flow conditions between 1987 and 2014. The observed flow versus modeling correlation also show that infiltration is insignificant, therefore any infiltration is very likely negligible.

### 2.2.2 Potential Future Flow Conditions

Below is a summary of the model inputs, outputs, and other considerations:

- Future flows from all of the WRPs may be reduced or eliminated to help meet Los Angeles' water demands through enhanced recycling.
- Groundwater management efforts underway may reduce upwelling in the ARBOR reach.

- Complete elimination of dry weather urban runoff, in combination with decreases n flows from WRPs and groundwater upwelling, could cause flow rates in the river during dry weather to decrease, potentially below levels that could sustain certain habitat or recreation.
- The evaporation and evapotranspiration rates are assumed to remain approximately constant in the future for most of the river, although these may increase as a result of climate change or decrease due to reduced flow widths. Per the ARBOR Study findings, additional evaporation and evapotranspiration rates are applied across the ARBOR reach.
- Three sites, Los Feliz (soft bottom channel just upstream of Los Feliz Blvd.), Taylor Yard (soft bottom channel approximately 1/2 mile downstream of Route 2), and Willow St. were considered for modeling due to channel complexity and sufficiency of bathymetric data.
- The soft bottom reaches support vegetation and are important locations for habitat and recreation. The importance of the soft bottom reaches, particularly those deeper areas behind a flow control, are very important locations for habitat and recreation, and were therefore given preference in site selection for hydraulic modeling in this study. Only one hard bottom reach upstream of the tidal reaches, but within the portion containing algal mats was selected for hydraulic modeling because hard bottom reaches tend to provide less habitat.

At each of the three locations, the flow depth, flow width, and velocity resulting from a range of flow rates between 10 cfs (6.5 mgd) and 110 cfs (71 mgd) were modeled to bracket the existing and potential future flows. The plots of each of these three parameters with flow rate and representative cross sections with the water surface elevation from a range of flow rates were created.

### 2.2.3 Findings of the LA River Flow Study

- The flow depth was found to be fairly insensitive to changes in flow rate at all three locations.
- Changes in flow width were insensitive to changes in flow rate at all three locations, except where the change in flow rate caused flows to leave a wider overflow area and be contained in a low flow channel.
- The velocity in the soft bottomed Glendale Narrows was typically less than 1 foot per second (fps), even at flow rates of 100 cfs. Decreases in flow down to 10 cfs (6.5 mgd) decreased the velocity to approximately 0.3-0.4 fps. Upstream of Willow St. in the hard bottom section, the velocity was approximately 3 fps in the low-flow channel and 0.6 fps in the rest of the channel. Decreasing the flow caused flow to be contained in the low-flow channel and velocity to decrease to 1.5 fps at 10 cfs (6.5 mgd).

## 2.3 Review of ARBOR Project Flows

### 2.3.1 ARBOR Study Review

This study was conducted to review the water budget as presented in the 2015 USACE ARBOR Study to gain understanding of water budget assumptions for the 11-mile ARBOR reach of the LA River.

The ARBOR Study presented the water budget required to support vegetated habitat features proposed by the Recommended Plan (Alternative 20), and is described within Appendix E-Hydrology and Hydraulics of the Feasibility Report. The discussion characterizes the existing hydrologic conditions of the study area and uses it as a basis to calculate the water demands of several restoration alternatives.

The specific objective of this review study was to gain understanding of the water budget assumptions for inflows (water sources) for the ARBOR reach study area that were used within the ARBOR Study. As noted in Appendix D of this Summary Report, the most significant limitation to the analysis in the ARBOR Study exist was that water demand for existing conditions was not accounted for in the project water budget. Native vegetation currently makes up approximately 30 percent of the study area and would not be removed or replaced as part of the plan as would occur with invasive species. This means that only part of the water demand was calculated. Therefore, the work conducted under this Subtask 3 (see Appendix D) provides the following: (1) the water demands and water budgets calculated for existing, "baseline" conditions, (2) the proposed enhancements identified by the Recommended Plan, and (3) the combined total representing post-construction conditions.

The basis of all calculations presented in Appendix D is the size of the study area, which was identified in Appendix G of the Feasibility Report as 842.37 acres. Appendix G identified 244.92 total acres of habitat that is currently present in the study area, and, using the Geographic Information System (GIS) data originally prepared for Alternative 20 in the Feasibility Report, the total size of the habitat enhancements was calculated to be 540.55 acres (with 56.90 acres of proposed enhancements remaining that do not involve establishment of habitat). Data used for the analysis are described in Appendix D and provided below in Table 2, which includes discussions of the data sources as well as the assumptions and context established for their use.

**Table 2 Values Identified and Used for the Models Developed for Existing Conditions**
**One Water LA 2040 Plan – TM 12.4**

| Water Source = | (Precipitation) + (Streamflow) + (Ground Water) |
|---|---|
| Precipitation | Description: The total volume of rain/snow that falls on the study area, as recorded at the Burbank Valley Pump Plant Weather Station (No. 41194); It has been estimated that 90% of precipitation falls during the "wet-season" (Nov-Apr) (the "dry-season" is from May-Oct); Precipitation is considered additive to streamflow |
| | Components: Rain- and snow-fall within the study area |
| Streamflow | Description: The average annual volume flowing through Station No. F57C-R of the LA River, above Arroyo Seco; This value only considers data collected since the Donald C. Tillman Water Reclamation Plant came on line in 1985, however, outflow has decreased starting in 2013 and continued to at least 2015, and is also considered; Because data was not readily available to specifically calculate streamflow averages for the "wet-season" (Nov-Apr) and "dry-season" (Dec-Mar), the "annual flow" value was used for wet-season calculations, and the "non-flood season" value was used for dry-season calculations |
| | Components: Stormflow runoff in the upper watershed, outflow from water reclamation plants, and urban sources |
| Groundwater | Description: Hydrology located subsurface that potentially contributes to surface features such as habitat – it is generally the opposite of infiltration when groundwater undergoes upwelling within the channel, as is the case with a "gaining stream" that increases streamflow volume.<br>Groundwater was not considered in the ARBOR Study; The study area has variable depth to groundwater, but there can be upwelling as the river flows towards the downstream portion of the ARBOR reach. |
| | Components: Subsurface hydrology from any source |
| Water Demand = | Water Sink = (Infiltration) + (Evaporation) + (Evapotranspiration) |
| Infiltration | Description: The potential maximum rate at which water can enter the soil at any point in time |
| | Components: The infiltration value for the study area was based on the assumption that all area currently with measurable habitat is composed of native "Group D" soils |
| Evaporation | Description: The portion of the water balance that evaporates from open water sources (i.e., not from the soil or through plant transpiration); includes evaporation from water flowing across the concrete or soft- bottom channel sections |
| | Components: The average annual evaporation rate of 2.31 feet per year (ft/yr) was used – this value was calculated by averaging across monthly evaporation rates collected at Descanso Gardens, the closest geographic source of data to the study site |
| Evapotranspiration | Description: The sum of evaporation from the land surface plus transpiration from plants |
| | Components: Two types of evapotranspiration values were incorporated in the model: 1) those established for habitats in Arizona determined to be the same or analogous to habitats identified in the study area, and 2) a value calculated for Glendale, Los Angeles Basin, using a model developed by CIMIS |

### 2.3.2 Areas of Additional Investigation

The analysis conducted in Appendix D provides water budgets for existing and proposed project conditions. These water budget calculations applied values for parameters that require further evaluation. For example, assumptions and data used for infiltration and upwelling in the study area varies significantly between the ARBOR study and the analysis conducted in Appendix D. Further studies are recommended to develop more accurate estimates of water budget components that reflect the range of uncertainties inherent in the estimates.

Specifically, the areas that need further investigation include:

- The soils underlying the study area fall primarily into Hydrologic Soil Group D, which is a soil with the lowest infiltration rate of those found in the study area. To fully characterize the specific soil-dependent infiltration rates for the entire study area where the exact soils and substrate conditions are unknown, site-specific studies are recommended.
- Evaporation rates from open water having partial shade during the day need to be studied.
- Evaluation of water demand needs to be revised after the removal of invasive species and with replacement of invasive species with habitat or non-habitat features.
- Evapotranspiration (ETo) can range from 4.1 feet per year (ft/yr) to over 8.0 ft/yr for the riparian plant palette, based on sources referenced for the ARBOR Study. The conservative value of 8.0 ft/yr was used for the analysis conducted in Appendix D to characterize the proposed riparian palette. This provides an upper end of expected ETo which is considered conservatively appropriate for the current purpose of investigating the water budget required to support proposed habitat within the ARBOR reach. As presented in Table 4 of Appendix D, the ETo values are variable among various studies. Further evaluation of ETo specifically with change in species composition after the removal of invasive species is warranted.
- The work documented in Appendix C of this Summary Report indicated that the upwelling within the ARBOR reach is generally constant throughout the year, contributing approximately 5.6 cfs (4,050 AFY) to the soft bottom reach within the Glendale Narrows. This is in contrast to the analysis mentioned above within the ARBOR Study that represents infiltration as a volume loss. Groundwater was not considered in the ARBOR Study. The study area has variable depth to groundwater, but there can be upwelling as the river flows towards the downstream portion of the ARBOR reach. A detailed surface-groundwater interaction model is needed to characterize infiltration and upwelling. It may be true that both components play a role in the hydrology of the system, but the spatial and temporal variability may exist. A coupled surface-groundwater dynamic simulation model can be developed and calibrated which can then be used to understand the future conditions and for

conducting various water source analyses. Furthermore, since previous studies also showed that the weeping holes in the concrete-lined sections of the river also release water to the channel, quantification of groundwater flows from the entire LA River is needed.

## 2.4 LA River Water Storage Potential and Maintaining Optimal Flows Using Level Controls

The purpose of this study was to identify the storage potential of the LA River and to develop water management concepts for further consideration.

While the primary scope and objective of this work was to quantify potential in-channel storage volumes in the river, this study also evaluated other dry weather flow level control and additional flow management strategies. Specifically, the objectives of this study were to examine and evaluate the following:

1. In-channel storage potential
2. Off-channel storage potential
3. Conveyance to DCTWRP and LAGWRP
4. Possibility of treatment for direct potable water use
5. Dry weather level control in select reaches to minimize recycled water releases into the river for habitat restoration

The stored water could then be used to help meet a portion of the water demands in the river. For dry weather flow water level control in certain reaches, smaller check dams or other small water level devices at closer intervals would be needed to create a cascade of pools and drops to control water flow rates in the river. The in-channel storage potential analysis evaluated the potential storage volume in five reaches of the LA River within the City (see Appendix E of this Summary Report for details). The study area for the storage analysis was chosen to include almost the entire reach of the LA River, upstream from the point of river channelization and downstream to the City's southern limits. The purpose was to identify and quantify the maximum volume of storage that could be made available to the City from the LA River. The results of this assessment are included in Section 3.0 of this report.

In addition to the in-channel storage potential of the river, this study also identified and quantified the potentials for off-channel storage in close proximity of the LA River to divert and store runoff during stormwater events. Conceptual options were also developed for conveyance of the stored water to the existing City's DCTWRP and LAGWRP for treatment, as well as for potential direct treatment and potable use of the stored water. Lastly, HEC-RAS modeling analysis was conducted along certain reaches to simulate hydraulic conditions during dry weather flows with check dams or other small water level devices to enable reduction of recycled water releases from the WRPs.

# 3.0 STUDY RESULTS

The findings of the individual subtask studies described above in Section 2.0 are discussed below with respect to each of the LA River Flow Study's anticipated outcomes.

## 3.1 Existing Flows (Outcome No. 1)

Determine available inflow sources to the LA River and their respective flow rates, such as flows from WRPs and dry weather flows, based on available information. Identify existing water-dependent uses and determine water flow rates on which they rely.

### 3.1.1 Existing LA River Flow Conditions

Provided below is a summary of inputs/outputs (i.e., sources and losses of LA River flows) used to model the existing conditions (Figure 3). Details of the data used for developing the model inputs and assumptions used for the analysis are included in Appendix C of this Summary Report.

- DCTWRP flows enter the river at approximately river mile 43 upstream of Sepulveda Dam. As a conservative assumption, the 10th percentile flow rate, 27.1 mgd (42.0 cfs) based on flow data for 2013-2015, was selected for the dry weather flow model; both environmental flows (that enter the river from DCTWRP via the nearby flow-through lakes) and direct flows (over the DCTWRP safety weir) were assumed to contribute to flow in the river.
- LAGWRP flows enter the river at approximately river mile 30 near the confluence with Verdugo Wash. As with DCTWRP, the 10th percentile flow rate, 7.8 mgd (12.1 cfs) based on data from 2013-2015, was selected to conservatively represent the dry weather flow in the model.
- Burbank flows are released to the Burbank Channel which enters the LA River at approximately river mile 32. Daily flow data for Burbank were not available at the time of this analysis[3], so the flow was estimated based on the National Pollutant Discharge Elimination System (NPDES) permit order and using best professional judgment. A flow rate of 4.5 mgd (7 cfs)[3] was used for the dry weather flow modeling.
- Groundwater upwelling flows were assumed to be constant and a daily flow rate of 3.6 mgd (5.6 cfs) was used. The flow was distributed evenly over the 8-mile soft-bottom reach in the Glendale Narrows area in the model.
- Incidental urban runoff occurs as a result of nuisance flows such as irrigation overspray, car washes, subsurface inflows to broken storm drains, etc. as well as permitted dry weather flows. The City's IRP estimated this value by subtracting estimates of other flow sources from the flows observed at the Wardlow Street site.

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[3] A 1211 wastewater change petition was recently submitted (3/17/2017) for an existing Burbank WRP flow rate of 4.8 mgd.

> The IRP-estimated value of 1.9e-4 mgd/impervious acre (190 gallons per day per acre of impervious area [gpd/imp acre]) was used. For each river mile, the impervious area upstream was calculated (subtracting area upstream of dams except for Sepulveda Dam) using the sub-basins in the Los Angeles County LSPC model and multiplied by this value to determine the incidental urban runoff contribution. Where sub-basins spanned more than one river mile, the flow was interpolated linearly.

For evaporation and evapotranspiration, the values from the LSPC model were used directly for both hard and soft bottom reaches. Compared to the sources of inflow to the river, evaporation is a very small outflow. It is typically less than 0.12 mgd (0.2 cfs) for each river mile, and is never higher than 0.36 mgd (0.56 cfs) except at the mouth where the LA River gets very wide due to the tidal conditions.

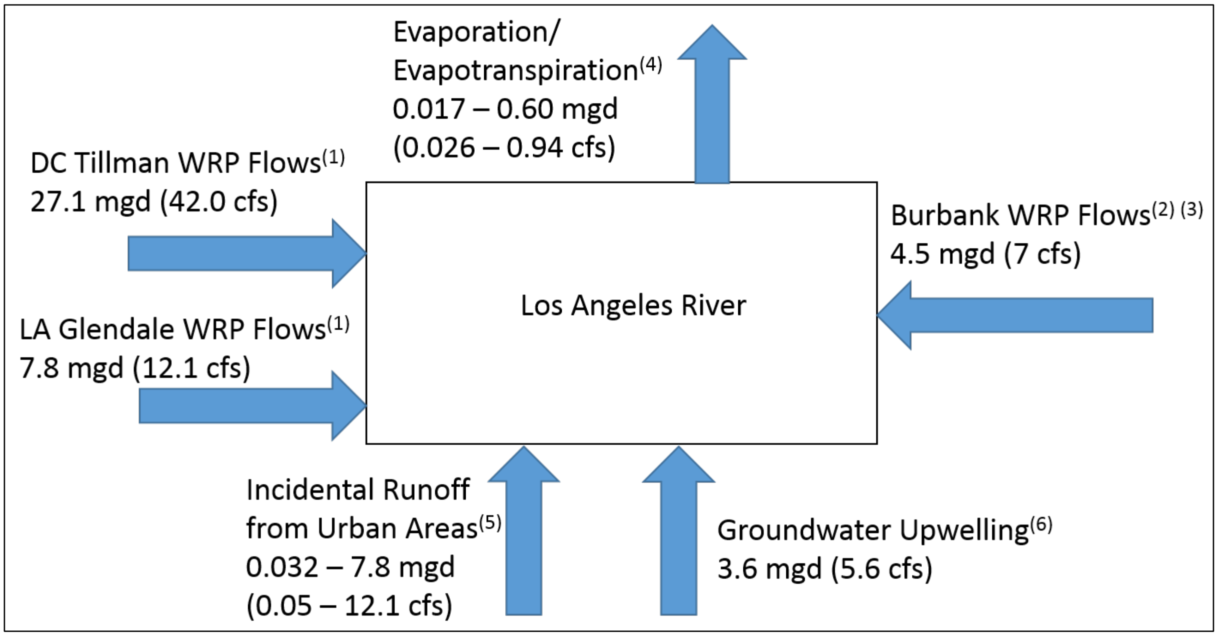


**Figure 3** **LA River Flow Components - Existing Condition Inputs into Dry Weather Flow Model**

Notes/Sources of Data:

1) DC Tillman WRP Flows and LA Glendale Flows: 10th percentile of daily average total effluent flow between 2013-2015
2) Burbank Flows: Estimated based on NPDES Permit
3) A 1211 wastewater change petition was recently been submitted (3/17/2017) for a BWRP existing flow rate of 4.8 mgd.
4) LA County LSPC model's Potential ET values based on conversion of computed NCDC evaporation pan data from Long Beach Airport (Gage 23129) and Burbank-Glendale- Pasadena (Gage 23152) using pan coefficients of 0.74-0.78
5) Incidental runoff from Urban Areas: Los Angeles Integrated Resources Plan: Facilities Plan, Vol 3: Runoff Management (LASAN, 2004)
6) Groundwater Upwelling: 10-year annual average from 2002-2003 through 2012-2013 (ULARA Watermaster Report, 2014)

The dry weather flow rates at the modeled locations of interest and other points of interest within the river under the existing conditions are summarized in Table 3 and Figure 4.

**Table 3 Dry Weather Flow Rates at Locations of Interest in the LA River One Water LA 2040 Plan – TM 12.4**

| Location | River Mile | Existing Dry Weather Flow Rates, mgd (cfs) |
|---|---|---|
| Sepulveda Basin | 46-45 | 4.3 (6.6) |
| Just Downstream of Sepulveda Dam | 44-43 | 32 (49) |
| Los Feliz Site | 29-28 | 52 (80) |
| Taylor Yard Site | 27-26 | 53 (82) |
| Leaving LA Forebay | 20-19 | 55 (85) |
| Rio Hondo Confluence | 13-12 | 63 (98) |
| Willow St Site | 4-3 | 67 (104) |

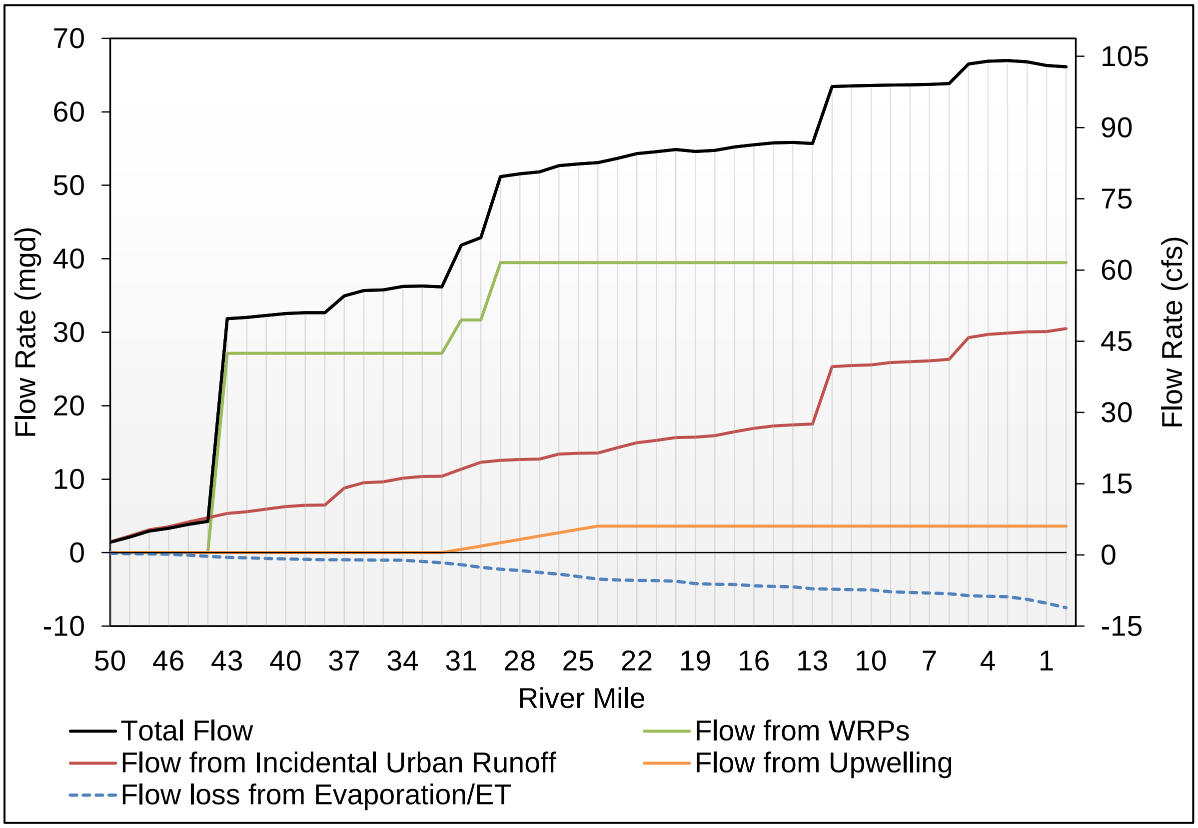


**Figure 4 Current Estimated LA River Dry Weather Flows by River Mile**

In the existing condition, 4.3 mgd (6.6 cfs) of incidental urban runoff comprise the LA River flows entering the Sepulveda Basin. Downstream of the Sepulveda Dam, the effluent flows and environmental flows from DCTWRP increase the flow rate to 32 mgd (49 cfs). Additional incidental urban runoff, WRP flows, and groundwater upwelling increase the flow rate to 52 mgd (80 cfs) and 53 mgd (82 cfs) at the Los Feliz and Taylor Yard sites, respectively. At Willow St, incidental urban runoff from the remaining watershed increases flow to approximately 67 mgd (104 cfs).

### 3.1.2 Future LA River Flow Conditions

There is considerable uncertainty as to what dry weather flow rates in the river will be in the future because not all management decisions have been made. However, the effect of management decisions on each of the inflows into the river is likely to decrease flows to some extent. The purpose of this analysis is not to provide definitive estimates of what the future flow rates in the river will be, but to provide the range of potential future flows from each of the inflows and outflows. These changes are summarized on Figure 5.

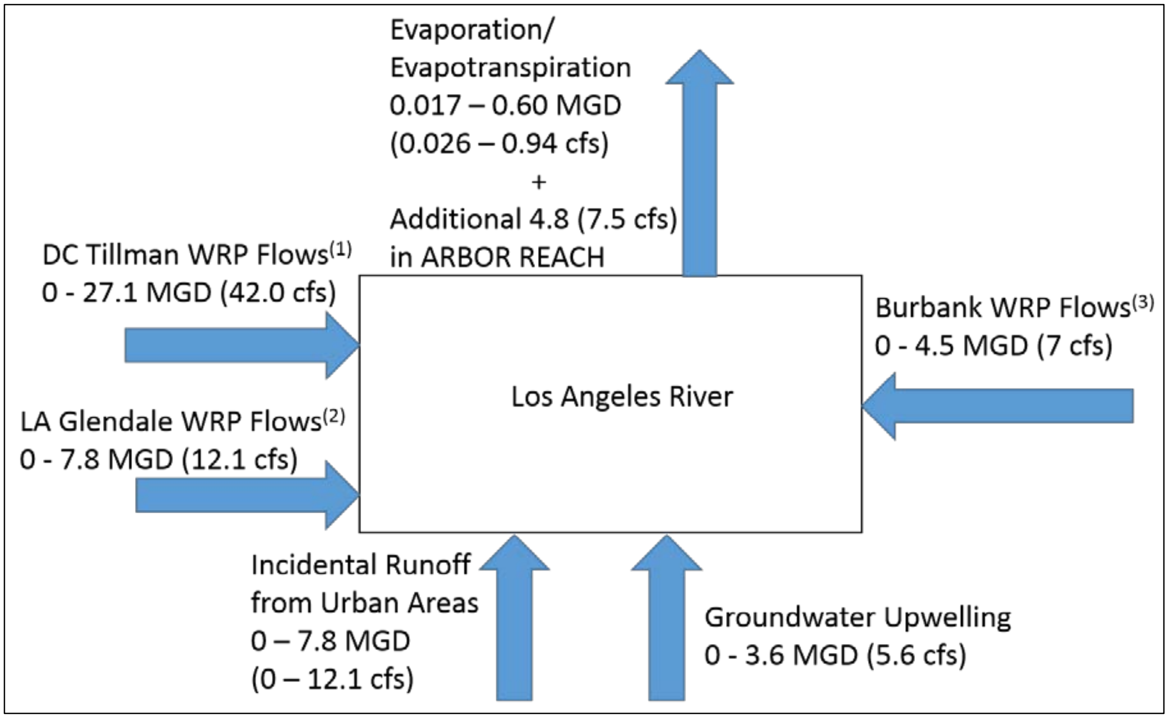


**Figure 5 LA River Flow Components - Potential Future Condition Inputs into Dry Weather Flow Model**

Notes:

1) DC Tillman WRP Flows: The 2016 Board of Water and Power certified EIR for the San Fernando Groundwater Replenishment (GWR) Project will not change the flows into the LA River.
2) LA Glendale Flows: The IRP (2006) proposed that all treated water from the LAGWRP be used for non-potable uses with no flows into LA River, particularly during the summer months.
3) Burbank Flows: Because the BWRP is not within the planning scope of One Water LA, a potential range of flows has been assumed.

To understand the effect of flow conditions on hydraulic parameters (flow depth, flow width, and velocity), flows at each of the three selected locations were modeled. The three selected locations are Los Feliz, Taylor Yard, and Willow Street. A range of flow rates between 10 cfs (6.5 mgd) and 110 cfs (71 mgd) were applied to bracket the existing and potential future flows. Appendix C of this Summary Report includes plots of each of the three hydraulic parameters with flow rate, and representative cross sections with the water surface elevation from a range of flow rates.

The flow depth was fairly insensitive to changes in flow rate at all three locations. The average change in flow depth at all three locations studied was approximately 1 foot or less for decreases in flow from the existing flow rate of 80-104 cfs (52-67 mgd) to 10 cfs (6.5 mgd).

Changes in flow width were insensitive to changes in flow rate at all three locations except where the change in flow rate caused flows to leave a wider overflow area and be contained in a low flow channel. The flow rates at which this occurred varied by cross section and location. At Los Feliz, this occurred only at one cross section and occurred below flows of 35 cfs (23 mgd). At Taylor Yard, this was typical to all cross sections and generally occurred at approximately 50 cfs (32 mgd). At Willow Street, this was typical at all cross sections and occurred between flows of 70 cfs (45 mgd) and 80 cfs (52 mgd).

The velocity in the narrows was typically less than 1 fps, even at flow rates of 100 cfs. Decreases in flow down to 10 cfs (6.5 mgd) decreased the velocity to approximately 0.3-0.4 fps. Upstream of Willow St. in the hard bottom section, the velocity was approximately 3 fps in the low-flow channel and 0.6 fps in the rest of the channel. Decreasing the flow caused the flow to be contained in the low-flow channel and velocity to decrease to 1.5 fps at 10 cfs (6.5 mgd).

In the future, changes in these dry weather flow contributors are expected. The potential net results of future conditions are summarized in Table 4.

**Table 4 Flows Associated with Current and Potential Future Inputs**
**One Water LA 2040 Plan – TM 12.4**

| Inputs | Current Flow mgd (cfs) | Potential Future Flow Range mgd (cfs) |
|---|---|---|
| DCTWRP | 27 (42) | 0-27 (0-42)(2) |
| LAGWRP | 8 (12) | 0(3) |
| BWRP | 5 (7) | 0-5 (0-7)(4) |
| Groundwater Upwelling | 4 (6) | 0 |
| Incidental Runoff | 23 (@ RM(1) 25)<br>45 (@ RM 5) | 0<br>0 |
| Evaporation/Evapotranspiration | -5 (@ RM 25)<br>-10 (@ RM 5) | -5<br>-10 |
| Total | 83 (@ RM 25)<br>107 (@ RM 5) | 37 - 44<br>32 - 39 |

Notes:

(1) RM = river mile. RM 25 is at Taylor Yard. RM5 is at Willow Street.
(2) The 2016 Board of Water and Power certified EIR for the San Fernando Groundwater Replenishment (GWR) Project will not change the flows into the LA River.
(3) The Water IRP (2006) proposed that all treated water from the LAGWRP be used for non-potable uses with no flows into LA River, particularly during the summer months.
(4) Because the BWRP is not within the planning scope of One Water LA, a potential range of flows has been assumed.

Based on these projections, dry weather flow in the LA River could decrease by as much as one-half at Taylor Yard (RM 25) and by as much as two-thirds at Willow Street (RM 5).

### 3.1.3 Other Considerations for Future Flows

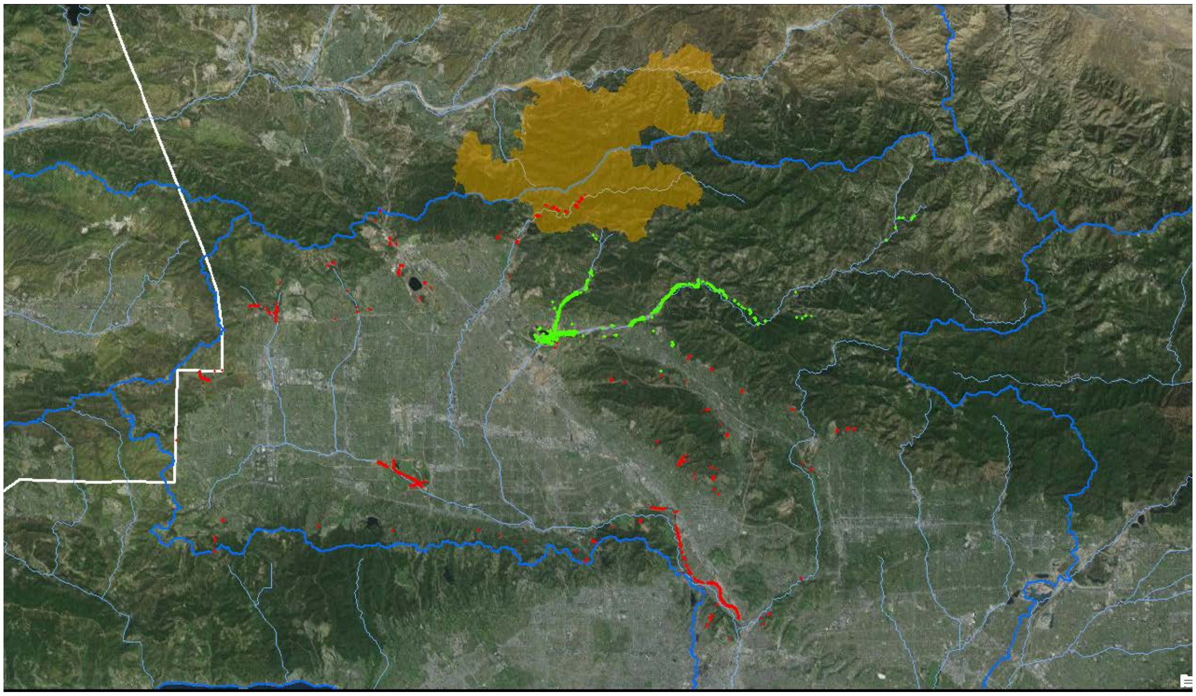
#### *Arundo donax Removal Project*

Ongoing efforts throughout the Southern California Region including the counties of Los Angeles, Ventura, Orange, and San Diego, are underway to eradicate invasive plant species, such as Arundo donax, by initiating site specific removal and a long-term plan for future eradication efforts. This removal occurs in an upstream to downstream manner in order to control the water loss from watersheds resulting from Arundo donax invasion caused by the *Arundo* leaf transpiration.

One of the ongoing efforts includes a Memorandum of Agreement developed between LADWP and the National Forest Foundation (NFF) regarding the Arundo donax Removal Project (the eradication project). The eradication project will treat and monitor eradication of Arundo donax in the Big Tujunga and Little Tujunga Watersheds, upstream of Hansen Dam. LADWP and NFF have identified the eradication project as an opportunity to remove the invasive and water use intensive species, Arundo donax, allowing for more water to be recharged into the San Fernando Groundwater Basin. The eradication project will support LADWP's stormwater capture goals as adopted in the 2010 Urban Water Management Plan and thereby support Mayor Eric Garcetti's Executive Directive's #5 (ED#5) goals of reducing dependence on imported water supplies. As part of the eradication project, a survey identified 57 acres of Arundo strands recommended for removal in this location. This eradication project is estimated to conserve and deliver for recharge into the San Fernando Groundwater Basin 1,140 AFY of water. The overall eradication project construction cost has been estimated to be $2.3 million and will be funded through a cost-share arrangement between NFF, LADWP, and other project partners.

The City has also entered into a second Arundo agreement with the Council for Watershed Health (CWH) to remove an additional 30 acres of Arundo in the remainder of the Upper LAR Watershed.

Figure 6 shows the areas with the Arundo identified within the LAR Watershed.



Notes:
Green areas: NFF project
Red areas: CWH project

**Figure 6** **Projects Related to the Arundo Donax Removal within the LAR Watershed**

### *Climate Change*

It is highly probable that flows in the LA River will vary from existing and historical flows due partly to the effects of climate change. Reduction in dry-season precipitation, urban runoff, and/or changes in WRP discharge could rapidly erode the amount of streamflow available. Further, if conditions become drier than anticipated, the habitat types will be differentially affected due to their varied reliance on water. The most sensitive habitat type to desiccation would be open water-riverine because of the majority of wetland plants within it, followed by valley foothill riparian and coastal scrub. Changes in climate change need to be incorporated into the models and studies recommended herein to evaluate the effects of potential temperature and precipitation variations on water demands and available flows in the River. As noted in the One Water LA climate change analysis, (CH2M, 2017), temperatures are predicted to increase in Los Angeles under all of the future climate scenarios. Such increasing temperatures will have an impact on water budget components such as evaporation and evapotranspiration. And, while there is relative uncertainty in annual precipitation changes, about two-thirds of the projections suggest increases in 3-day annual maximum precipitation by the end of this century, which is commonly the driving variable for flooding, especially during coastal storm and El Niño events. The median change in 3-day annual maximum precipitation for the Los Angeles downtown area by end of century is projected to increase by about 10 percent (per TM 5.5, Section 2.2.3).

***Uncertainty in Water Budget***

The reviews of previous LA River studies and the additional analyses conducted under this One Water LA 2040 LA River Flow Study reveal considerable uncertainty in the values applied for several of the water budget components. For example, more accurate estimates of infiltration, groundwater upwelling and evapotranspiration rates under the existing and revised habitat conditions (such as after the removal of the invasive species) are needed.

### 3.1.4 Flows Needed to Support Existing Water-Dependent Uses

Changes to flow in the LA River could impact the beneficial uses[1] and habitats that currently exist in the river. Beneficial uses are specified by Table 2-1 in the Los Angeles Region Basin Plan and include:

- Industrial Process Supply
- Groundwater Recharge
- Navigation
- Commercial and Sport Fishing
- Habitat (Wildlife, Estuarine, Marine, Wetland)
- Support of Rare, Threatened, or Endangered Species
- Migration of Aquatic Organisms
- Spawning, Reproduction, and/or Early Development
- Recreational water uses

There is a gap between the available flow rate information and the determination of flow rates that support existing conditions and uses for the entire LA River. Potential impacts to the beneficial uses under reduced flow scenarios have been identified by various studies, including the USBR 2004 study and the 2005 Phase II IRP – Los Angeles River Recycled Water Evaluation Study Phase 1 Baseline Study. These studies have identified gaps in understanding the effect of flow changes on biological habitat. Further studies should be conducted to elucidate and address these knowledge gaps, as described below.

- Conduct additional measurements and analyses to establish the relationship between flow and biological habitat. Particular attention should be paid to the Glendale Narrows and Willow Street as both are significant wildlife habitats in the LA River.
- Understand new flow requirements after the eradication of Arundo donax and establishment of new native and/or non-native species and biota.

- Investigate to conclusively determine if special-status species actually use the LA River. Available data does not indicate whether flow changes would impact any "special-status" species.
- Conduct field evaluations to further identify and verify sensitive locations and habitats within the LA River; identify relationships between the existing quantity and/or quality of habitats within the LA River and the current hydrologic regime.
- Develop a predictive modeling tool; and use the predictive model to evaluate how changes in the hydrologic regime (amount and timing of flow) could affect quantity (Board, 2014) and/or quality of habitats and use it to also evaluate how changes in the hydrologic regime could affect aquatic and terrestrial species that rely on existing habitats.
- Determine the requirements for the LA River water uses such as industrial process supply, navigation and commercial and sport fishing and consider flow requirements for developing and evaluating future flow scenarios and alternatives to support those uses.

## 3.2 ARBOR Study Water Budget (Outcome No. 2)

Summarize the water budget needed to support the ARBOR study requirements. Identify technical assumptions related to the ARBOR study water budget that may require additional consideration or supplemental data and analysis.

### 3.2.1 Water Budget Assumptions for ARBOR Study

The Feasibility Report presented the water budget required to support vegetated habitat features proposed by the Recommended Plan of the ARBOR Study, and is described within Appendix E-Hydrology and Hydraulics, of the ARBOR Study. Water sources identified included both surface water and precipitation. USACE estimated that existing water sources provide 211,348 AFY that flows to the study area on an annual basis. In addition, USACE also calculated that 97,722 AFY of that total source water flows to the study area during the summer months of April through September (dry-season). The water assumptions made in the ARBOR Study have been reviewed and researched, and this additional information should be reflected specifically for the LA River as ARBOR project design proceeds. There are many reaches in the LA River that have unique characteristics and this needs to be reflected when calculating a water budget.

Water demands in the ARBOR Study consisted of evaporation, evapotranspiration, and infiltration. A significant amount of infiltration was estimated based on generalized soil type characterization. However, since over half (6 miles) of the ARBOR reach of the river is unlined (USACE, 2015) due to historical groundwater upwelling, and the remainder of the ARBOR reach is lined, it is likely that the demand associated with infiltration is overestimated in the ARBOR Study. This parameter requires additional investigation and analysis.

The ARBOR Study also does not provide the water demand for existing river needs; it only provides an estimate of water demand for proposed vegetation. Native vegetation currently makes up approximately 30 percent of the study area and would not be removed/replaced as part of the plan as would occur with invasive species. This means that only part of the water demand was calculated. Therefore, the study conducted and presented in Appendix D of this Summary Report provides the following: (1) the water demands and water budgets calculated for existing, "baseline" conditions, (2) the proposed enhancements identified by the Recommended Plan (Alternative 20), and (3) the combined total representing post-construction conditions. When considering data that is part of the historic record, input values from the ARBOR Study were used as the basis of most calculations in an effort to maintain consistency with those published, as well as to produce results comparable to those already established.

### 3.2.2 Water Budget Components for Existing Conditions

The overall calculation for the water budget for the ARBOR study area is, simply:

(Water Source) – (Water Demand) = (Water Outflow)

This calculation requires two components: (1) an actual value or estimate for the extent of hydrology available to habitat, and (2) an actual value or estimate of the needs of that habitat. The water budget was further broken down into both existing conditions and proposed conditions. Establishing numerous values was required prior to calculating the water budget. The detailed approach and data used are presented in Appendix D of this Summary Report. The basis of all calculations presented in Appendix D is the size of the study area, which was identified in Appendix G of the Feasibility Report as 842.37 acres. Appendix G also identified 244.92 total acres of habitat that is currently present in the study area, and, using the GIS data originally prepared for Alternative 20 in the Feasibility Report, the total size of the habitat enhancements was calculated to be 540.55 acres (with 56.90 acres of proposed enhancements remaining that do not involve establishment of habitat).

Based on the calculations presented in Appendix D, an annual existing water budget can be calculated as follows:

**Existing Water Source**

= Precipitation (782 AFY + 87 AFY) + Streamflow (210,674 AFY) + Groundwater (0 AFY)

= 211,544 AFY

**Existing Water Demand**

= Infiltration (33,047 AFY) + Evaporation (421 AFY) + ETo (5,848 – 3,118 AFY)[4]

= 36,198 AFY

### 3.2.3 Water Budget Components for Proposed Conditions

The proposed conditions water demand for Alternative 20 is based on Table 8 of Appendix E of the Feasibility Report.

**Alternative 20 Water Demand**

= Infiltration (65,272 AFY) + Evaporation (139 AFY) + Evapotranspiration (3,118 AFY)

= 68,529 AFY

Total Existing Water Demand (36,198AFY) + Alternative 20 Water Demand (68,529 AFY)

= 104,727 AFY

### 3.2.4 Data/Information Gaps

Presented below is a summary of the assumptions related to the soil conditions of the ARBOR Study water budget that require additional consideration or supplemental data and analysis.

Infiltration was based on soil type data provided by NRCS and referenced in Appendix E of the ARBOR Study. The soils underlying the study area fall primarily into Hydrologic Soil Group D, which is a soil with the lowest infiltration rate of those found in the study area. The average infiltration rate of Group D soil is 0.3 foot per day (ft/day) or 109.5 ft/yr. These values are then multiplied by the acreages for baseline (301.8 acres) and proposed project (540.6 acres) surface types (i.e., open water or habitat growth) that are taken directly from the detailed Geographic Information System (GIS) data used in the ARBOR Study to measure habitat benefits. As stated in appendix C, Section 2.1.6, the flows predicted by the model are approximately 1 standard deviation (SD) below the mean flow measured for the gage between July and August, but are well above the minimum. Because the included flow rates only include dry summer months, a flow rate one SD below the mean is representative of mid-day values during dry periods. Therefore, the model consistently predicting flows 1 SD below the mean is a good, conservative representation of typical low-flow conditions between 1987 and 2014. The observed flow versus modeling correlation also show that infiltration is insignificant, therefore any infiltration is very likely

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[4] This estimate of ETo for existing conditions was derived from values presented in Table 4 of Appendix C of this Summary Report, where 5,848 AF is the estimated ETo for existing + proposed conditions in the Appendix C study TM and 3,118 AF estimated in the USACE Feasibility Report for proposed conditions for the Alternative 20 project. The difference is included here to represent the estimated ETo for existing conditions, i.e., 5,848-3,118=2,730 AF.

negligible. No infiltration was calculated for the concrete or grouted rock revetment sections of the river. The resulting infiltration volumes for baseline conditions and proposed habitat conditions, converted to units of AFY, are 33,047.1 AFY and 59,195.7 AFY, respectively.

Since the ARBOR reach has significant upwelling of groundwater typically characteristic of "gaining streams," it is expected that a significant amount of the predicted losses due to infiltration will not be realized, especially as flow continues towards the downstream end of the study area. The LA River Low Flow Study documented in Appendix C of this report indicates that upwelling within the ARBOR reach is generally constant throughout the year and contributes approximately 4,050 AFY to the soft bottom reach within the Glendale Narrows. However, the upwelling of groundwater is highly dependent upon local hydrological cycles, and may or may not occur even in the absence of sustained groundwater pumping. Rising groundwater should not be considered a reliable source or a consistent base flow. This contrasts with the analysis mentioned above within the ARBOR Study that represents infiltration as a volume loss. As referenced earlier, a more detailed groundwater model is needed to understand the infiltration and groundwater upwelling in this area and the net effect on LA River flows. In addition, studies have also shown that groundwater is released into the river by weeping holes in the concrete-lined areas. A detailed investigation of spatial and temporal variability of groundwater and its effect on the entire LA River flows will provide better understanding of the LA River flows.

## 3.3 Preliminary Water Management Concepts (Outcome No. 3)

Identify conceptual adaptive water management alternatives and associated proposed concepts that would optimize the amount of flow needed to support potential future water-dependent uses and satisfy regulatory requirements.

### 3.3.1 Example Conceptual Options

Water management for wastewater flows and urban runoff/stormwater in the LAR Watershed will affect the flows in the LA River. Example options for storing water in-channel and off-channel that could maximize available recycled water use while supporting beneficial uses in the LA River were evaluated in the study documented in Appendix E of this Summary Report.

Note that the water management concepts presented below are independent of specific water use needs at specific locations in the river. Those site-specific water needs will be identified through various LA River-related planning and coordination activities, and the appropriate water management options applied to satisfy those (water level or flow rate) needs.

Currently, WRPs release significant volumes of water to the LA River that augment the dry weather flows such that there is enough water in the river for the established wildlife habitats. The goal of one conceptual example is to reduce releases by operating check dams or other small water level devices to raise the water level along certain reaches. This will increase the corresponding wetted perimeter without increasing flows.

The wet weather storage potential of the LA River was quantified and the hydraulics of check dams or other small water level devices for dry weather level control was examined. Presented below are the concepts used to determine storage potential within channel and off-channel,

The storage analysis evaluated the potential storage volume in five reaches of the LA River within the City (see Appendix E for details). The study area for the storage analysis was chosen to include almost the entire reach of the LA River, upstream from the point of river channelization and downstream to the City's southern limits. The purpose was to identify and quantify the maximum volume of storage that could be made available to the City from the LA River water.

### 3.3.2 Conceptual Option 1: Use of Inflated Dams for In-Channel Storage

For wet weather storage, an evaluation was conducted of the installation of rubber dams in the LA River at suitable locations to create consecutive impoundments upstream to store rainwater. During wet weather, the dams would be deflated for the stormwater runoff event and would inflate to catch and store the tail end of the runoff hydrograph. The LA River has a large volume/capacity that could potentially be used to store stormwater runoff. Stored runoff could be beneficially used to offset freshwater uses.

An example of an inflated rubber dam considered here for wet weather flow storage is provided on Figure 7.

**Figure 7 Example Rubber Dam**

Figure 8 shows the potential dam locations for Reach 1, "Upstream of Sepulveda Dam". Overall there are a total of six potential dam locations in this reach based on the criteria described in Appendix E. For the purposes of this study and to avoid any practical uncertainties with regards to technical and technological feasibility, the maximum height of the rubber dams was limited to 18 feet high.

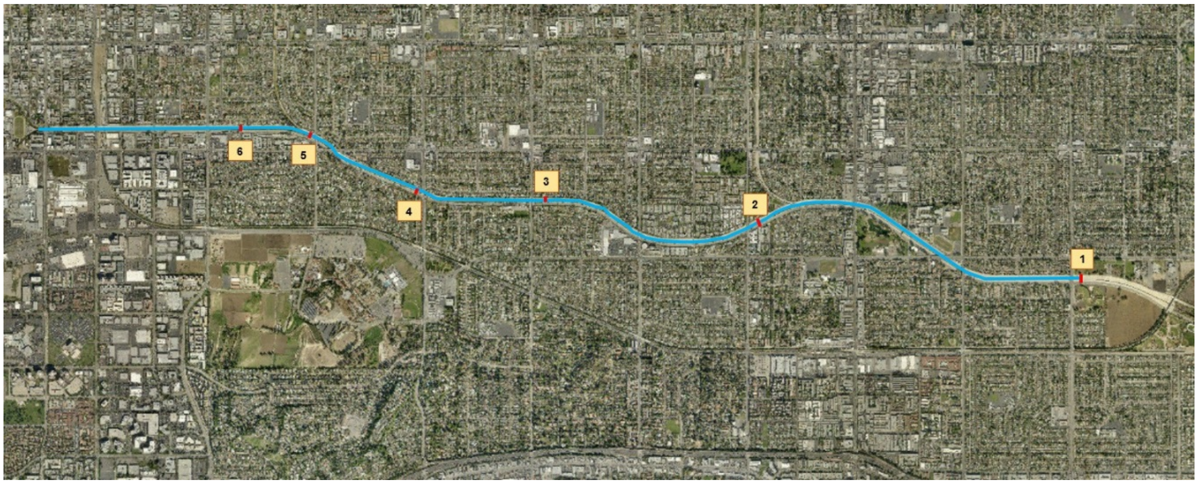

**Figure 8 Potential Dam Locations in Reach 1, "Upstream of Sepulveda Dam"**

With the dam locations identified, the storage volume between consecutive dams was calculated by multiplying the average wetted cross section area in the reach by the length of the impoundment.

Table 5 shows that using 35 inflatable dams, water could be impounded along more than 17 miles of the LA River channel, holding 1.2 billion gallons of water, or 3,700 AFY. (See Appendix E for details of the storage analysis behind these results.)

**Table 5 Estimated In-Channel Storage Potential at Study Locations One Water LA 2040 Plan – TM 12.4**

| Location | Imp. Length (ft) | Storage (MG) | Storage (AF) |
|---|---|---|---|
| Upstream of Sepulveda Dam | 22,000 | 220 | 675 |
| Sepulveda Dam | 9,000 | 220 | 675 |
| Downstream of Sepulveda Dam | 57,000 | 340 | 1,040 |
| Downstream of Arroyo Seco | 27,000 | 450 | 1,380 |
| **Total (rounded)** | **115,000** | **1,230** | **3,770** |

If such a volume could be captured with each storm, as much as 40 mgd of water could be available for up to 30 days.

### 3.3.3 <u>Conceptual Option 2: Use of Off-Channel Storage</u>

The study in Appendix E also identified two potential locations that could provide significant additional off-channel storage space for the stormwater runoff flows in the LA River. These were 1) the Sepulveda Dam Recreation Area, which is located inside the Sepulveda Dam flood control space, and 2) Silver Lake, which has recently been decommissioned as a potable water reservoir (Figure 9).

For the Sepulveda Dam recreation area, the idea is to excavate certain areas within the recreation area to create additional low lying land that would either be included in the storage space below elevation 688 feet (as discussed in Appendix E), or be used as a receiving basin for diverted water upstream.

Figure 9 Potential Off-Channel Storage Areas

In addition to Sepulveda Dam, Silver Lake has the potential to offer 500 MG of off-channel storage to store water flowing in the LA River. Any alternatives need to be considered as part of the Silver Lake Reservoir Complex master planning efforts. Table 6 summarizes the off-channel storage potential.

**Table 6 Off-Channel Storage Calculation Results Summary**
**One Water LA 2040 Plan – TM 12.4**

| Location | Storage (MG) | Storage (AF) |
|---|---|---|
| Sepulveda Dam Recreation Area | 1,040 | 3,190 |
| Silver Lake | 500 | 1,530 |
| **Total** | **1,540** | **4,720** |

### 3.3.4 Conceptual Option 3: Conveyance to DCTWRP and LAGWRP

Included in the Appendix E study were the following potential concepts to convey stored water in the LA River behind rubber dams to DCTWRP and LAGWRP:

- DCTWRP has potential access to the water stored in Reach 1, as well as water stored upstream of the Sepulveda Dam.
  - For water stored in Reach 1, diversion from upstream of Dam 1 into the existing 96-inch AVORS outfall sewer would provide gravity conveyance to DCTWRP (as shown on Figure 10).
  - For water stored upstream of Sepulveda Dam, conveyance to DCTWRP would require a new pumping facility at Burbank Blvd. connected to a new 1-mile long 24-36 inch diameter pipeline, as shown on Figure 11.
- LAG is located adjacent to the LA River and can draw water from it using a diversion pump facility and short pipeline. Figure 12 shows the concept. Water stored upstream of the ARBOR reach would be released for the specific purpose of being diverted at LAGWRP.

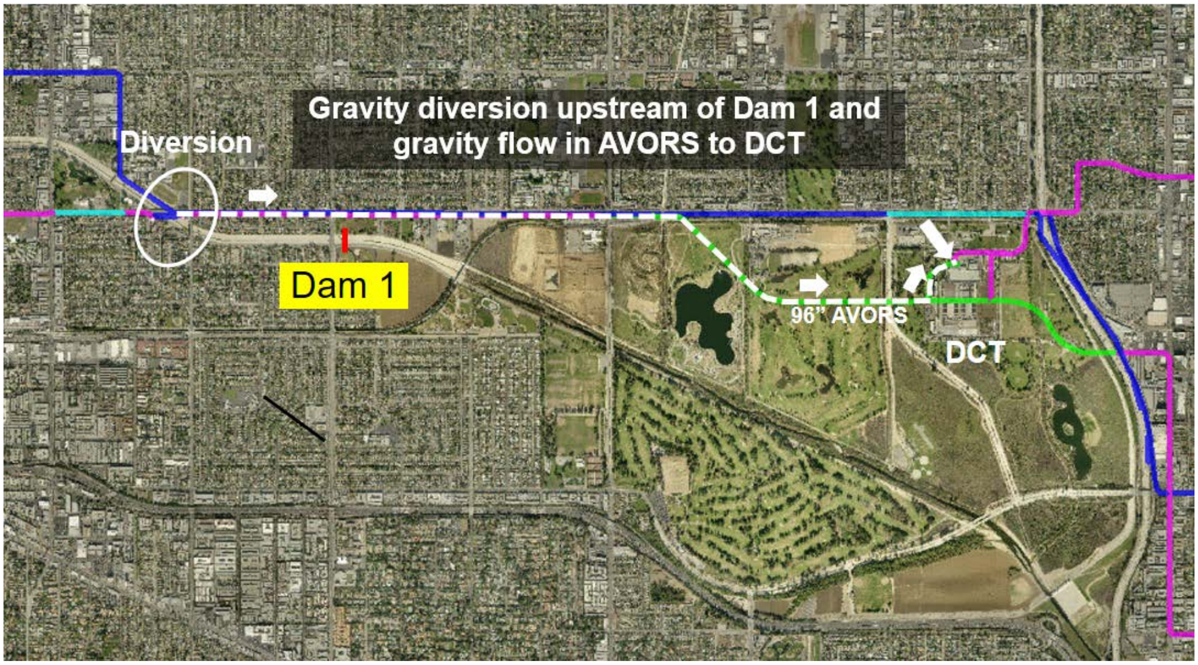

**Figure 10** Gravity Diversion and Conveyance from Dam 1 to DCTWRP

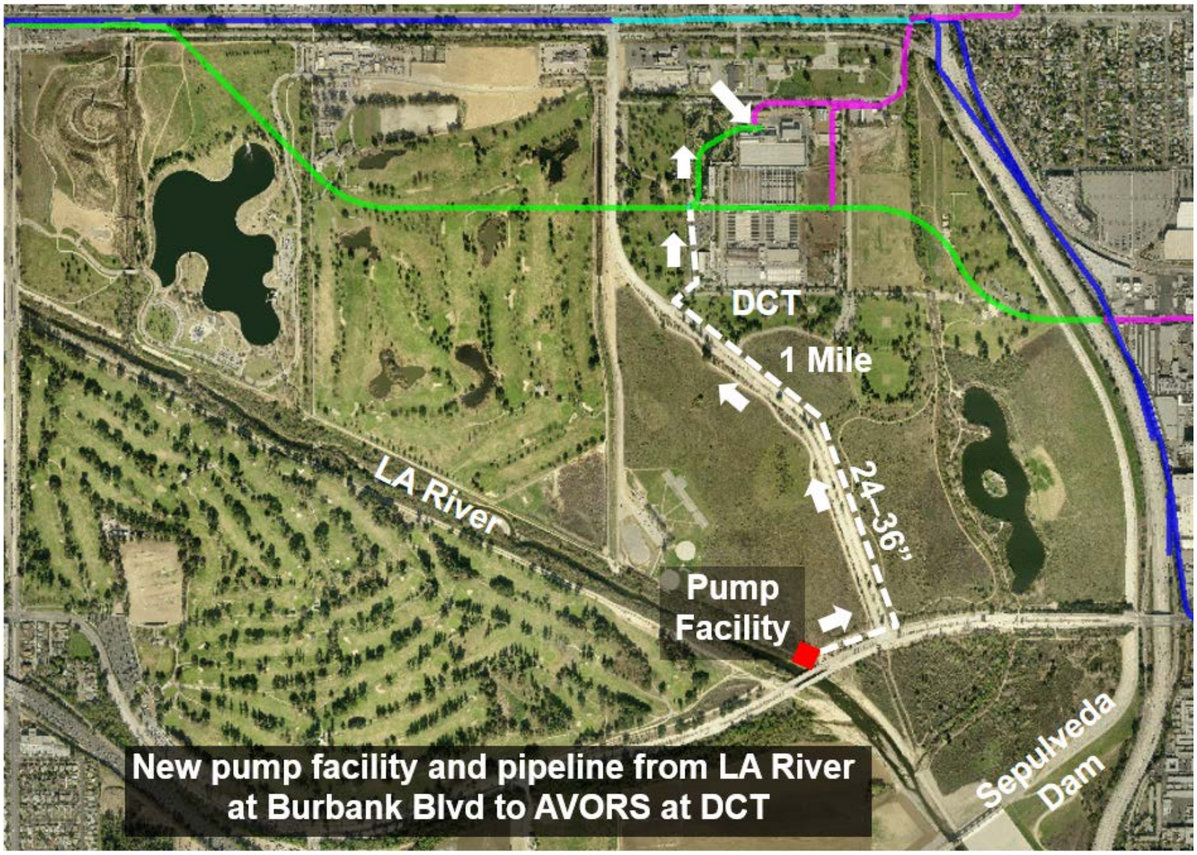

**Figure 11** Pump Facility and Pipeline from Sepulveda Dam to DCTWRP

**Figure 12** **Pumping and Conveyance Concept from LA River to LAGWRP**

### 3.3.5 Conceptual Option 4: Potable Water Use

The Appendix E study also mentioned that the stored water could be treated to potable water quality and directly injected into the potable water distribution system. A wide range of options and packaged treatment plant technologies and sizes could be used for treating water for direct potable water use. Smaller mobile systems with a small footprint, and/or larger pre-assembled and factory-tested packaged systems can be strategically located along LA River treating and feeding of water into the City's drinking water system.

Another option would be to divert the stored runoff for non-potable irrigation purposes and could be beneficially used to offset freshwater uses.

### 3.3.6 Conceptual Option 5: Dry Weather Water Level Control

An example of a check dam or other small water level device considered here for dry weather flow level control and storage is provided on Figure 13.

**Figure 13** **Example of Water Level Device to Create River Storage Capacity**

The recycled water releases by WRPs may be significantly lowered (decreased by 85 percent) by installing a series of check dams or other small water level devices to create a cascade of pools. According to the One Water LA Low Flow Study (Appendix C, Table 2), the average recycled water releases by DCTWRP and LAGWRP into the LA River based on 2013 to 2015 daily flow data were 29.8 and 10.2 mgd (46.2 and 15.8 cfs), respectively. These flows could be drastically reduced in the future.

To study the impact of check dams or other small water level devices on hydraulic parameters in the LA River, the previously developed HEC-RAS model of the river was used to simulate the following three hydraulic scenarios for three reaches: 1) Los Feliz, 2) Taylor Yard, and 3) Willow St.:

- **Scenario 1** – Existing dry weather flows inclusive of recycled water releases at DCTWRP and LAGWRP; no check dams or other small water level devices installed.
- **Scenario 2** – Reduced dry weather flow down to a very low flow rate (an arbitrary 10 cfs was selected) by cutting back on recycled water releases at DCTWRP and LAGWRP by about 85 percent, no check dams or other small water level device installed.
- **Scenario 3** – Reduced dry weather flow down to 10 cfs by cutting back on recycled water releases at DCTWRP and LAGWRP by about 90 percent, with 3-foot high check dams, or other small water level device, at intervals to result in minimum 1 foot of hydraulic depth.

Table 7, Table 8, and Table 9 show the range of flow depths, velocities, and top widths accomplished by the current augmented dry weather flow of between 80 to 104 cfs (52 to 67 mgd) within each reach, with 10 cfs flow in each reach, and with check dams or other small water level device and 10 cfs flows, respectively. The hydraulic depths, which are a measure of average depth across the cross section (defined as flow area divided by top width) with corresponding average flow velocities. The hydraulic depth decreases by reducing flows (as in Scenario 2) and it increases by installing check dams or other small water level device.

The analysis above shows that check dams, or other small water level devices, create a hydraulically feasible alternative to maintaining a certain minimum hydraulic depth along the river in lieu of maintaining a certain minimum flow rate.

**Table 7 Hydraulic Analysis Results for Scenario 1**
**One Water LA 2040 Plan – TM 12.4**

| Reach | Reach Length (ft) | Ave Slope (ft/ft) | Flow (cfs) | Ave Hyd. Depth (ft) | Ave Vel. (fps) | Ave Top Width (ft) |
|---|---|---|---|---|---|---|
| Los Feliz | 6,608 | 0.0046 | 80 | 0.95 | 0.66 | 124 |
| Taylor Yard | 3,622 | 0.0031 | 82 | 0.84 | 0.86 | 100 |
| Willow St. | 7,007 | 0.0011 | 104 | 0.19 | 1.89 | 312 |

**Table 8 Hydraulic Analysis Results for Scenario 2**
**One Water LA 2040 Plan – TM 12.4**

| Reach | Reach Length (ft) | Ave Slope (ft/ft) | Flow (cfs) | Ave Hyd. Depth (ft) | Ave Vel. (fps) | Ave Top Width (ft) |
|---|---|---|---|---|---|---|
| Los Feliz | 6,608 | 0.0046 | 10 | 0.33 | 0.33 | 32 |
| Taylor Yard | 3,622 | 0.0031 | 10 | 0.44 | 0.53 | 20 |
| Willow St. | 7,007 | 0.0011 | 10 | 0.30 | 1.43 | 24 |

**Table 9 Hydraulic Analysis Results for Scenario 3**
**One Water LA 2040 Plan – TM 12.4**

| Reach | Reach Length (ft) | Ave Slope (ft/ft) | Flow (cfs) | Ave Hyd. Depth (ft) | Ave Vel. (fps) | Ave Top Width (ft) | No. of Dams |
|---|---|---|---|---|---|---|---|
| Los Feliz | 6,608 | 0.0046 | 10 | 1.4 | 0.04 | 200 | 15 |
| Taylor Yard | 3,622 | 0.0031 | 10 | 1.71 | 0.09 | 285 | 4 |
| Willow St. | 7,007 | 0.0011 | 10 | 2.41 | 0.02 | 325 | 3 |

Reducing the current estimated 40 mgd that is released by the combination of DCTWRP and LAGWRP without check dams, or other small water level devices, down to 6 mgd with check dams or other small water level devices would save about 34 mgd by 330 Days = 11,220 MG (34,400 AF) of water per year (given 35 rainy days per year on average). Depending on the value of recycled water, the cost savings is on the order tens of millions of dollars per year. Compared with estimated cost of rubber check dams or other small water level device, which is estimated to be a few million dollars each (between $1 - $5 million depending on span and height), the return on investment is relatively short making check dams, or other small water level device, a potentially attractive alternative.

## 3.4 Summary of Concept Benefits and Challenges (Outcome No. 4)

Provide a summary for each alternative/concept that includes anticipated benefits and impacts, challenges, limitations, information gaps, stakeholders involved, and conceptual-level details with corresponding cost-estimates to facilitate the decision-making process.

Table 10 provides a review summary of the understanding of potential water management options including potential benefits, challenges, and other considerations for the feasibility of the option if considered for detailed analysis as part of the next step or phase of this study. All five concept options presented in this table are taken from the work conducted under Subtask 4, per Appendix E.

Note that the water management concepts presented above are independent of specific water use needs at specific locations in the river. Those site-specific water needs will be identified through the various LA River-related planning and coordination activities, and the appropriate water management options applied to satisfy those (water level or flow rate) needs. A water budget for the LA River should be developed that reflects the uncertainties of river flows and include considerations of recent drought management approaches, anticipated urban runoff changes, and removal of Arundo donax in waterways within and tributaries to the LA River.

These conceptual options are intended to manage water that is, or will be, discharged to the LA River; diversion of recycled water from the WRPs for groundwater recharge prior to river discharge. The amounts of flow to be managed by the various options are not determined in this TM.

While this LA River Flow Study under the One Water LA Plan has identified five, example conceptual options for LA River flow management, other options may be evaluated and considered as part of the LA River planning and adaptive management process.

### Table 10 Summary of Potential Benefits, Challenges Anticipated, Preliminary Costs, and Additional Considerations of Water Management Options
### One Water LA 2040 Plan – TM 12.4

| Options | Preliminary Cost | Potential Benefits | Challenges Anticipated | Other Considerations |
|---|---|---|---|---|
| In-Channel Storage | • Appx. $5 – 10 Million per rubber dam depending on dam height, river span, and foundation + abutment requirements | • Provides 3,700 AF stormwater runoff storage facility with annual harvest potential that is several times the size of the storage space<br>• Would constitute a significant source of local water to offset imported freshwater | • Acceptability of numerous rubber dams that convert the river to a cascade of level pools.<br>• Stakeholder coordination and engagement<br>• Opportunities for beneficial use of stored water<br>• Permitting | • Site selection<br>• Existing utility crossings<br>• Structural conditions of river levees<br>• Exfiltration and seepage<br>• Operation and maintenance<br>• Cost/Benefit |
| Off-Channel Storage | 1. **In Sepulveda Dam Flood Control Space:** Appx. $300 Million ($225 Million for excavation and hauling of 5,000 Yd$^3$ of soil + $75 million allowance for civil works on the storage basins)<br>2. **In Silver Lake:** Appx. $10 Million ($5 million diversion and pumping facility at LA river +$3 Million for pipeline from LA river to Silver Lake + $2 million outlet structure, pump back facility, and civil works at Silver Lake) | • Provides 4,600 AF stormwater runoff storage facility with annual harvest potential that is several times the size of the storage space<br>• Would constitute a significant source of local water to offset imported freshwater | • Coordination with USACE to create additional storage in Sepulveda Dam flood control reservoir<br>• Environmental impact of large excavation and earth moving operation to create additional storage in Sepulveda Dam flood control reservoir<br>• Coordination with DWP for use of Silver Lake<br>• Diversion and conveyance of LA River flow to Silver Lake<br>• Opportunities for beneficial use of stored water<br>• Permitting | • Silt accumulation in off-channel facilities<br>• Operation and Maintenance<br>• Cost/Benefit |

**Table 10 Summary of Potential Benefits, Challenges Anticipated, Preliminary Costs, and Additional Considerations of Water Management Options**
**One Water LA 2040 Plan – TM 12.4**

| Options | Preliminary Cost | Potential Benefits | Challenges Anticipated | Other Considerations |
|---|---|---|---|---|
| Diversion to DCTWPR/ LAGWRP | 1. **Gravity Flow in AVORS to DCTWRP:** Appx. $1 Million for gravity diversion facility at DAM 1<br>2. **Pumping at Burbank Blvd to AVORS:** Appx. $6 Million ($2 Million for pump facility at Burbank Blvd, $3 Million for pipeline to AVORS, and $1 Million for connection to AVORS | • Utilizes existing treatment facility and capacity<br>• Provides new source of water for the existing treatment facilities in light of reducing sewer flows due to water conservation | • Timing of available water during rainy days compared with timing of RW demand during dry days<br>• Short window of water availability and high rate of water treatment required<br>• Opportunities for beneficial use of stored water<br>• Coordination with USACE to construct new pump station and pipeline within Sepulveda Dam flood control reservoir<br>• Permitting | • Operation and maintenance<br>• Cost/Benefit |
| Direct PW use | • $2 - $10 Million per satellite treatment plant depending on site and treatment capacity | • Provides new source of raw surface water for treatment and potable water use<br>• Reduces the need for conveyance (treatment facility located next to the river and close to PW distribution network) | • Requires suitable site(s)<br>• Requires high voltage electrical supply<br>• Low treatment capacity of satellite plants<br>• Short window of water availability and high rate of water treatment required<br>• Permitting | • Operation and maintenance<br>• Cost/Benefit<br>• Public engagement for H&S assurance |
| Check Dams (or other small water level device) | • $1 - $5 Million per check dam, or other small water level device, depending on river span and foundation + abutment requirements | • Significant reduction of RW releases by DCTWRP and LAGWRP for habitat restoration<br>• Effective habitat restoration with significant positive impacts | • Stakeholder engagement and coordination<br>• Coordination with USACE<br>• Permitting | • Operation and maintenance<br>• Cost/Benefit |

# 4.0 SUMMARY AND CONCLUSIONS

## 4.1 Key Data and Information Gaps

The studies conducted in Task 12D provided valuable information to guide the consideration of water management options for the LA River. The City is studying multiple aspects of the LA River, including its impact to the City's water supply. The possibility of enhancing local water supply though greater efforts in water recycling, water conservation, groundwater management, and improvements in surface water quality has the potential of decreasing dry weather flows in the LA River. Future management of the LA River requires a greater understanding of how changes in flow may impact water supply, water quality, habitat, recreation, and aesthetics.

To meet the objectives of Task 12D, gaps in key data and information warrant additional consideration and investigation of the following assumptions (Table 11).

**Table 11 Key Data and Information Gaps and Recommendations**
**One Water LA 2040 Plan – TM 12.4**

| Data Gaps/Unknowns | Recommended Areas of Future Study |
|---|---|
| *Refinements for estimates of water budget components:* The water budget components, such as infiltration, groundwater upwelling, evaporation, and evapotranspiration need to be reviewed and refined. | A detailed dynamic surface water and groundwater interaction model for the LAR Watershed is needed. Given the uncertainty in model, water budget components, spatial and temporal variability in infiltration, evapotranspiration, and upwelling will provide more accurate estimates of flow conditions. Once the model is calibrated with the existing (historical) data and verified, it could be potentially used for understanding the water planning scenarios (e.g., changes to the WRP flows and stormwater runoff). |
| *Determination of dry weather flows:* A value of 10 cfs (6 mgd) was used to mimic reduced dry weather flow conditions in the LA River for various scenario evaluations. This value is an arbitrary representation of a drastically low flow condition in the river. The actual lower limit of flow that can be tolerated for habitat restoration with check dams (or other water control devices) must be determined with consideration for losses along the river and evapotranspiration. In addition, as the changes in flow regime due to WRP flow and stormwater management will occur over a temporal framework, the changes in flows over the course of the water management period require analysis of a dynamic system in an adaptive management framework. | A detailed (dynamic) evaluation of flow requirements for habitat restoration is needed. The flow tolerance for current habitat, proposed future conditions, effects of changing habitat conditions as well as removal and replacement of invasive species with appropriate native vs. non-native species need to be studied. |

**Table 11 Key Data and Information Gaps and Recommendations One Water LA 2040 Plan – TM 12.4**

| Data Gaps/Unknowns | Recommended Areas of Future Study |
|---|---|
| *Localized conditions:* The availability of the more localized, site specific data types such as specific soil-dependent infiltration rates and evaporation rates were limited due to variability of the study area | To further refine the water budget, additional site specific field work is needed to characterize the soil-dependent infiltration rates and evaporation rates. |
| *Dry weather runoff quantities:* There is considerable uncertainty regarding the amount of incidental (dry weather) runoff from urban areas. The amount of incidental-runoff of that reaches surface waterbodies needs to be determined. | More current and accurate characterization of the contribution of incidental runoff to the LA River is needed. |
| *Flows that support existing habitat:* There is a knowledge gap between the available flow rate information and the determination of flow rates that support existing habitat conditions for the entire LA River. A list of data gaps have been identified which relate to developing relationships between flow and biological habitat, special status species and their habitat, establishment of native/non-native habitat after removal of invasive species. | A predictive modeling tool is needed to evaluate how changes in the hydrologic regime (amount and timing of flow) could affect quantity and/or quality of habitats and to evaluate how changes in the hydrologic regime could affect aquatic and terrestrial species that rely on existing habitats. |
| *Flows that support other uses:* Flows for other various uses of the LA River are not specified. | Further evaluation of LA River water uses is needed. |
| *Available flows after the removal of Arundo Donax:* Arundo donax (commonly referred to as giant reed or Arundo), a water intensive invasive species reduces water that flows through the City. Arundo transpires water at a rate that is five times higher than native vegetation. Projects are underway for the removal of these species. | The impact of Arundo removal and replacement with native species on the LA River water budget should be evaluated. |
| *Special Status Species:* It is not clearly understood if there are any special status species that use the LA River. | Investigate to conclusively determine if special-status species actually use the LA River. Available data does not indicate whether flow changes would impact any special-status species. |

Notes:

(1) The upwelling of groundwater is highly dependent upon local hydrological cycles, and may or may not occur even in the absence of sustained groundwater pumping. Rising groundwater should not be considered a reliable source or a consistent base flow.

(2) All references to "beneficial uses" in this report are to the beneficial uses identified by the Los Angeles Regional Water Quality Control Board in its Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties, available at http://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan/basin_plan_documentation.shtml. Notably, the *Basin Plan* includes not only existing and intermittent beneficial uses identified by the Regional Board, but also potential future beneficial use goals.

## 4.2 City Projects and Concepts with Potential Impacts to LA River Flows

Table 12 provides a list of City's current and planned projects along with potential project concepts that may affect the LA River flows. This information was presented at the State Water Resources Control Board meeting as part of the informational item, "Los Angeles River Existing and Future Conditions: Instream Flow Needs", discussion led by the Division of Water Rights on November 8, 2017.

**Table 12 City Projects that May Affect Los Angeles River Flows**
**One Water LA 2040 Plan – TM 12.4**

| | No. | Projects | Reference Documents | Description | Estimated River Flow Impact (AFY) |
|---|---|---|---|---|---|
| Current and Planned City of Los Angeles (LA) Projects | 1 | US Army Corps of Engineers (Corps) ARBOR Project | Corps Ecosystem Restoration Feasibility Study Report and LA One Water Los Angeles River (LA River) Flow Study 2017 Draft | The Corps report identifies consumptive uses from various projects within the 11-mile focus study area of the LA River known as the Area with Restoration Benefits and Opportunities for Revitalization or "ARBOR," which extends from the Headworks site downstream to First Street. | 3,000 to 6,500 |
| | 2 | Sepulveda Sports Complex Water Recycling Project | LA 2012 Recycled Water Master Planning Documents /Los Angeles Department of Water and Power (LADWP) 2016-2017 Recycled Water Annual Report | This project will include the installation of approximately 11,000 feet of recycled water pipeline near Lake Balboa at the Sepulveda Basin Recreation Area. | 56 |
| | 3 | Eastside Water Recycling Project | LA 2012 Recycled Water Master Planning Documents/LADWP 2016-2017 Recycled Water Annual Report | This project will include the installation of approximately 21,000 linear feet of new pipeline in the Boyle Heights area. | 465 |
| | 4 | Increase number of LADWP recycled water customers | LA 2012 Recycled Water Master Planning Documents/LADWP 2016-2017 Recycled Water Annual Report | LADWP intends to expand its recycled water use by acquiring additional recycled water customers. | 398 |
| | 5 | Expanded recycled water use through recirculation of Sepulveda Basin flow through lakes | LADWP Water Recycling Planning Group and LA One Water LA 2040 Plan Draft | Future phases of expanded recycled water use may include re-routing flow from one or more of the flow through lakes near the Donald C. Tillman Water Reclamation Plant (DCTWRP). The three lakes -- Lake Balboa, the Wildlife Lake, and the Japanese Gardens Lake -- are designed so that recycled water flows through them and eventually discharges in the LA River. Changes to the flow through design for any of these lakes will require a new environmental analysis, as this concept was not included in the 2016 EIR for the Groundwater Replenishment (GWR) project. In 2015, as shown in the 2016 EIR, the annual average flow through the lakes was 22.3 million gallons per day (mgd). | up to 25,000 (22 mgd) |
| | 6 | LA River Dry-Weather Bacteria Compliance Approach for Segment B | Los Angeles Sanitation (LASAN) Watershed Protection Division - LA River Load Reduction Strategy | This project includes identifying and prioritizing the actively flowing outfalls in Segment B of the LA River based on flow and e. coli loading. Four priority outfalls, and conceptual structural actions to address these outfalls, have been identified to date. The estimated volume reduction is 5 to 8 mgd. | Will reduce dry weather flows to LA River to zero |
| | 7 | Enhanced Watershed Management Plan (EWMP) for Upper LA River | LASAN Watershed Protection Division - EWMP implementation projections | This is a comprehensive plan to comply with the MS4 Permit for the Upper LAR Watershed, which focuses on reducing flow during wet weather from 85th percentile rainfall events. The EWMP will reduce potential flows to the LA River by approximately 50,000 AFY when fully implemented by 2037. | |
| | 8 | Projects to enhance recharge capacity in the San Fernando Groundwater Basin (SFB) | Annual Status Reports filed in *The City of Los Angeles v. City of San Fernando*, Los Angeles Superior Court Case No. 650079 | Since 2007, LA and its partners have implemented centralized and distributed stormwater capture projects that have increased average stormwater capture capacity in the Upper LAR Watershed by 10,788 AFY. Planned centralized and distributed stormwater capture projects are expected to increase average stormwater capture in the Upper LAR Watershed by an additional 16,849 AFY within the next five years. | |
| Project Concepts | 9 | LA River Recharge into LA Forebay Concept | LA 2012 Recycled Water Master Planning Documents and LA One Water LA 2040 Plan TM 5.2 Draft | This project would divert flows from the LA River to the LA Forebay to recharge the Central Basin. It would require the development of new storage systems that can attenuate stormwater flows within the LA River, pipeline conveyance, and multiple groundwater injection wells. | up to 25,000 (22 mgd) |
| | 10 | LA/Glendale Water Reclamation Plant (LAGWRP) to Headworks Reservoir Concept | LA 2012 Recycled Water Master Planning Documents and LA One Water LA 2040 Plan TM 5.2 Draft | This project would treat LAGWRP effluent at an Advanced Water Purification Facility (AWPF) and pump water directly into the LADWP distribution system at Headworks Reservoir. LADWP 2016-2017 Recycled Water Annual Report shows a total non-potable reuse (NPR) demand of 5,171 AFY (2,735 current and 2,436 potential). Assuming half of LAGWRP's capacity of 20 mgd, there is potentially 6,000 AFY of recycled water left for direct potable reuse (DPR) at Headworks. | up to 6,000 |
| | 11 | Upper LA River to DCTWRP | LA One Water LA 2040 Plan Draft | This project would divert flows from the Upper LA River to DCTWRP for reuse. | 4,500 to 5,600 |
| | 12 | DCTWRP to SFB Injection Wells | LA One Water LA 2040 Plan Draft | This project would treat DCTWRP effluent at an AWPF, recharge it into SFB by injection wells, and later extract it for potable use. | up to 15,000 |
| | 13 | DCTWRP to Los Angeles Aqueduct Filtration Plant (LAAFP) | LA One Water LA 2040 Plan Draft | This project would expand DCTWRP's AWPF, convey direct potable reuse flows to the LAAFP, and then to LADWP distribution. | up to 15,000 |
| | 14 | DCTWRP to LADWP Distribution System | LA One Water LA 2040 Plan Draft | This project would treat DCTWRP effluent at an AWPF and pump water directly into the LADWP distribution system. | up to 15,000 |
| | 15 | Increase recycled water demand beyond 2015 UWMP | LA One Water LA 2040 Plan Draft | This project would include a NPR purple pipe system expansion near Terminal Island Water Reclamation Plant (TIWRP) and Hyperion Water Reclamation Plant (HWRP). | 16,400 to 45,400 |

## 4.3 Recent LA River Studies

### 4.3.1 UCLA's LA SUSTAINABLE WATER PROJECT: LA RIVER WATERSHED

*This content is provided directly by UCLA's LA Sustainable Water Project: LA River Watershed. For additional information regarding their studies see reference information in Appendix A*

***Introduction***

UCLA was selected by the City to evaluate three of the watersheds within the City. The purpose was to explore the potential to attain compliance with water quality standards while also integrating complementary one water management practices that can increase potential local water supplies for the City in the LAR Watershed. This LA Sustainable Water Project Los Angeles River Watershed report, is part of the UCLA's Sustainable LA Grand Challenges effort. This work complements the One Water LA 2040 Plan as it evaluates the entire watershed and a host of possible BMP scenarios as well as looks at recycled water reuse, groundwater recharge, and historic LA River flows.

The watersheds that UCLA has evaluated are:

- LA River
- Dominguez Channel and Machado Lake
- Ballona Creek

The LAR Watershed evaluation focused on attaining compliance with water quality standards while at the same time determining how integrated water management could be increased. Below summarizes in more detail the effort that UCLA completed for the City. Highlights include the following:

- Environmental Protection Agency's (EPA) System for Urban Stormwater Treatment and Analysis (SUSTAIN) used to model the LAR Watershed
- Model input included historic flows and a suite of BMPs that capture the 85th percentile storm in the watershed
- Model output related to water quality compliance
- Historic LA River flows graphed
- A summary of planned and potential projects to increase recycled water and stormwater recharge into groundwater basins

### *Current Conditions*

UCLA's study explores the potential to attain compliance with water quality standards while also incorporating complementary integrated water management practices that can increase potential local water supplies for the City in the LAR Watershed. The LAR Watershed covers approximately 825 square miles (sq mi) in the Los Angeles area and is highly urbanized. The integrated water landscape in this watershed was examined through an assessment of current practices and future opportunities in recycled water reuse (e.g, at DCTWRP, LAGWRP, and BWRP), stormwater capture, underlying adjudicated groundwater basins (e.g., ULARA), and surface waters tributary to the LA River.

Both dry and wet weather runoff contribute pollutant loads to many water bodies in Los Angeles County; implementing suites of BMPs is one mechanism to capture and infiltrate or treat and release runoff before it reaches downstream water bodies. In this study, a modified version of the EPA's SUSTAIN model was used to model the water quality impacts of implementing various suites of BMPs (vegetated swales, bioretention, dry ponds, infiltration trenches, and porous pavement) and the feasibility of attaining compliance through capturing the 85th percentile storm in the LAR Watershed. Six modeled scenarios were designed to capture the 85th percentile storm. Current and historical flows in the LA River were also examined. This analysis included the potential impacts on flow in the LA River of implementing BMP scenarios and increasing the use of recycled water from the water reclamation plants (which would reduce the effluent volumes currently discharged into the LA River).

### *Modeling*

Multiple BMP scenarios were able to capture the 85th percentile storm, and provided a variety of ancillary benefits such as peak flow attenuation along with improving water quality. Scenarios that included porous pavement were capable of infiltrating the highest volumes of water and therefore reducing peak flows by the greatest amount but were also among the most expensive on a unit cost basis. BMP scenarios with a greater emphasis on treat and release BMPs resulted in fewer exceedances of total maximum daily loads (TMDL) for metals as more flows were returned to the channel, but these options also provided less potential recharge. The City low impact development (LID) ordinance could reduce the required volume of stormwater that has to be captured for MS4 compliance by 21 percent and also result in a reduction in the annual average loads of zinc and copper by 10 percent and 7 percent, respectively, by 2028.

Current flows discharging through the Wardlow Gage near the outlet of the LA River are higher than they have been historically, due in large part to the discharge to the river channel of treated effluent from DCTWRP, BWRP, and LAGWRP and the increasing urbanization (and thus, increased impermeable area) in the LAR Watershed. With the current volumes of effluent discharged into the LA River, recent low flows in the LA River were found to be approximately 100 cfs (2003 to 2014) at Wardlow Gage (based on analysis of daily average flows). Historical low flows (1956-2013), however, were noted to be an order of magnitude lower, approximately 10 cfs (~10th percentile). There are multiple needs and required uses that water in the LA River can potentially satisfy, including municipal non-potable water supply, flood control, habitat, and recreation, which may all require different flows at different times. Thus, the impacts on in-channel flows of implementing the wide variety of plans along the LA River and its watershed must be assessed to support and maintain desired needs and required uses.

### *Results*

UCLA's modeling results show that implementing BMPs to capture the 85th percentile storm and fully using recycled water that is currently being discharged into the LA River will have a significant effect on flows.

For example, annual minimum flows even go to zero in scenarios with both BMP implementation to manage the 85th percentile storm and zero WRP discharge into the channels. Times of low flow are important to understand as the absence of flow in the channel could have significant impacts on uses; the One Water Los Angeles (OWLA) LA River Flow Study provides additional context on what in-channel low flows look like along the entire mainstem of the river. It is important to note that these projects will be undertaken over the next several years to decades. Therefore, additional work needs to be done to investigate the impacts of various levels of flow reduction that could result at various levels of reuse of WRP flows and various stages of BMP implementation in the watershed. For example, the impacts on flows in the LA River of implementing planned projects such as additional reuse of wastewater at individual WRPs could be modeled.

### *Findings*

The modeling shows that different watershed management approaches will result in different levels of flow in the LA River. With this in mind, additional research must be conducted to accurately define the minimum required flows in the LA River necessary to support desired needs and required uses. A wide variety of additional research efforts are occurring in the region to better understand the current state of the LA River and its habitat as well as identify opportunities to redevelop and revitalize this important waterbody in the City that can be surveyed to inform this work. Researchers further need to determine optimal metrics for assessing the health of the LA River able to support multiple functions.

Maximizing the use of groundwater basins is a critical piece of increasing integrated water management in the City. The ULARA basins include the San Fernando Basin, Sylmar Basin, Verdugo Basin, and Eagle Rock Basin. The City holds water rights in San Fernando, Sylmar, and Eagle Rock Basins; the majority of the City's groundwater comes from San Fernando Basin. Remediation is an important component of increasing the use of the groundwater basins in the San Fernando Valley. Remediation efforts are currently occurring in the North Hollywood, Burbank, and Glendale operating units, which pump and treat groundwater for use in local water supply. The City also has extensive plans to remediate historical contamination in the San Fernando Basin. An additional treatment facility to remediate groundwater in the San Fernando Basin is expected to treat approximately 112 mgd (123,000 AFY) when it becomes operational.

Furthermore, increasing groundwater recharge of both recycled water and captured stormwater can increase the volumes of groundwater in storage in local groundwater basins. The City is planning a large groundwater recharge project that will result in approximately 30,000 AFY of advanced treated recycled water from DCTWRP being recharged into the San Fernando Basin through the Hansen and Pacoima Spreading Grounds. In addition, multiple projects are planned to increase surface water recharge through enhancing the capability of centralized infiltration sites such as the Tujunga Spreading Grounds, Lopez Spreading Grounds, Big Tujunga Dam, Pacoima Dam, and Pacoima Spreading Grounds to store and/or infiltrate greater volumes of water. In addition to the aforementioned centralized projects, increasing the implementation of distributed, smaller-scale projects to capture stormwater across a wide variety of land use types will increase the recharge of stormwater to groundwater basins. Additional research, however, is required to quantify the water supply benefits of stormwater that is recharged into groundwater basins.

The research undertaken in this project demonstrates the complex interrelationships within urban water management. Projects that are geared towards managing stormwater to improve water quality can also increase local water supply potential. Groundwater basins provide an opportunity to store water in times of excess, whether that water comes from increasing volumes of advanced treated recycled water or captured stormwater. The regulatory and political environment is complex and provides opportunities and challenges to implementing integrated water management programs that can truly address the multiple needs of urban water landscapes. As more projects are designed with multiple goals in mind, partnerships will become established, methods of quantifying stormwater through the lens of water supply will become better defined, and regulations and policies can be adapted to reflect the equally important goals of cleaning up our surface water and increasing our local water supply resiliency in a semiarid region.

### 4.3.2 The Nature Conservancy's Water Supply and Habitat Resiliency for a Future LA River Report

The Nature Conservancy (TNC) conducted a study to understand the flow characteristics of the LA River based on the changes in the watershed hydrology. The study of the Elysian Valley included an in-depth analysis of biotic conditions of the LA River and a historical ecology investigation of the Elysian Valley and a review of historical and existing hydrological and hydraulic conditions. The Executive Summary of the 2016 TNC report is included in Appendix F of this Summary Report. The analysis conducted in this report compares the results of set of water management scenarios and their effect on species, biodiversity, and habitat resiliency.

Major findings of the study include uncertainty in flow scenarios, river biology as a function of flow rates, importance of enhancement in upstream/upland habitat, and river adjacent land use. TNC's study places an emphasis on Los Angeles River's Elysian Valley habitat from an ecological science perspective.

The watershed hydrology section of the TNC report recommends reducing in-channel dry weather flows below 13 cfs (8.4 mgd or 9,420 AFY) to mimic key elements of a natural flow regime. The study states a historic hydrological condition of dry weather flow supports more diverse vegetation assemblages and habitat-specific native faunal associations. In addition, current vegetation assemblages of the Los Angeles River include introduced and highly invasive species. Low flow conditions as of writing are higher than historical, natural low flow conditions.

Effects of water management actions, such as reduction/elimination of effluent flows to the river and stormwater capture implemented across the watershed, suggest that the flow conditions resemble historic hydrologic conditions. This scenario does the best job of supporting native wildlife species, with the highest level of native biodiversity, and ecosystem restoration. The study recommends the development of an ecosystem-wide dialog among stakeholders that identifies consensus for water management options.

## 4.4 Existing and Parallel Planning Efforts

The studies documented in this Summary Report were intended to initiate consideration of current and future planning activities, including the One Water LA 2040 Plan that may impact LA River flows. Other key planning studies with projects identified to possibly impact LA River water demands are described below – please note that this list is not comprehensive. For example, plans from the cities of Burbank and Glendale to utilize additional recycled water for non-potable uses from the BWRP and LAGWRP, thereby reducing the discharge from these plants to the LA River, are not discussed in this section.

There continues to be extensive visioning, planning, and studying of the LA River. It is important that the City carefully manage the water demands both in and outside of the LA River. The cumulative impacts of these concurrent planning efforts and projects have not yet been evaluated from a regional perspective. This is another required area of future study.

### 4.4.1 Los Angeles River Master Plan (LARMP)

On October 18, 2016, the County of Los Angeles Board of Supervisors passed a motion to initiate an update to the Los Angeles River Master Plan prepared in 1996 by LA County (LAC) Department of Public Works, LAC Department of Parks and Recreation, LAC Department of Regional Planning, along with the National Park Service's Rivers, Trails, and Conservation Assistance Program, and the Los Angeles River Advisory Committee. The LARMP update is in part meant to coordinate numerous ongoing efforts to revitalize the Los Angeles River and to ensure all stakeholders are engaged in a transparent manner towards a unified vision that reflects the needs of all communities along the 51-mile Los Angeles River. Many existing planning efforts will be incorporated into the LARMP update.

The Steering Committee is currently being formed and is expected to begin meeting in early 2018. A draft plan and final plan are scheduled to be completed by December 2019 and June 2020, respectively.

### 4.4.2 Urban Water Management Plan (UWMP)

The 2015 UWMP forecasts future water demands and water supplies through year 2040 under average and dry year conditions. The long term strategies laid out in the 2015 UWMP will also meet LA's Sustainable City pLAn (pLAn) goals, which reduce per capita water use by 25 percent by 2035, reduce imported purchased water by 50 percent by 2025, and 50 percent of water sourced locally by 2035. These strategies include:

- Expanding water conservation with additional 110,100 acre-feet per year (AFY) in average years or 143,900 AFY in dry years
- Expanding water recycling 7 folds from 10,000 AFY to 75,400 AFY
- Enhancing stormwater capture 2 to 3 folds from 64,000 AFY to 132,000 AFY in conservative case or 178,000 AFY in aggressive case
- Remediate the San Fernando groundwater basin to remove contamination and to restore the beneficial use of the basin including the recovery of full groundwater rights and the support of groundwater recharge with recycled water and stormwater

Projected water demands are primarily driven by population growth. LA's population is projected to increase by an additional 450,000 people and in 2040 total water demand is forecasted to reach 675,700 AFY under average weather. However, additional water conservation will be implemented to comply with Mayor's water use reduction targets, which will also reduce inflows to the wastewater treatment plants.

### 4.4.3 Recycled Water Master Planning Documents (RWMP)

In October, 2012, LADWP, in partnership with LASAN and the Bureau of Engineering, completed a three year effort to develop a series of master planning documents that comprise the City's RWMP. The RWMP provides a clear direction for the City to achieve its goal of 59,000 AFY of recycled water use by 2035 and potential conceptual options to increase water recycling beyond that goal.

The goal of 59,000 AFY will be achieved by utilizing GWR and NPR along with other recycled water initiatives. The GWR project will provide up to 30,000 AFY of recycled water for spreading at the Hansen Spreading Grounds and the Pacoima Spreading Grounds. NPR implementation will include planned and potential NPR projects with 11,350 AFY and 9,650 AFY of recycled water demands, respectively.

Long-Term Concepts have been identified beyond 2035 that could maximize the City's recycled water asset further than the near-term reuse goal of 59,000 AFY. The long-term concepts are included in the RWMP documents as conceptual options and will be studied in the future considering water demand projections, the development of alternative water supply, and as recycled water regulations continue to evolve.

The recycled water supplies for many of the identified projects and concepts are sourced from DCTWRP and LAGWRP. Their implementations may have impacts on the amount of effluent flows being discharged into the LA River.

### 4.4.4 Stormwater Capture Master Plan (SCMP)

The SCMP is a planning document that outlines LADWP's strategies over the next 20 years to implement stormwater projects and programs with emphasis on water supply criteria, though other benefits of stormwater capture and partnership opportunities were considered as part of the development process. Currently, LADWP and its partners recharge the local groundwater aquifers with approximately 64,000 AFY through active and incidental infiltration. The SCMP demonstrates that an additional 68,000 to 114,000 AFY could be realistically captured over the next 20 years through the implementation of a suite of centralized projects, and the adoption of distributed programmatic approaches. These stormwater capture efforts will reduce runoff and associated pollutant discharges to the Los Angeles River which will improve water quality and assist with regulatory compliance. Projects and programs proposed in the SCMP will be implemented through collaborative efforts by multiple agencies and partnerships in order to leverage resources and funding. LADWP will be the lead on projects and programs most beneficial from a water supply perspective.

### 4.4.5 Enhanced Watershed Management Plan (EWMP)

The Los Angeles County Municipal Separate Storm Sewer System Permit allows permittees to comply with water quality mandates for Los Angeles River and tributaries through regional collaboration in the implementation of Enhanced Watershed Management Programs (EWMPs). The City developed the EWMP for Upper Los Angeles River in collaboration with 19 co-permittees in the watershed, covering a watershed area of 485 square miles. The Upper Los Angeles River EWMP will implement watershed control measures to maximize stormwater capture for groundwater recharge through infiltration and/or direct use such as irrigation, while creating additional benefits for the communities in the watersheds. Examples of watershed control measures include low-impact development, green streets, and regional projects. Implementation of these watershed control measures will result in significant reductions of pollutant loadings to Los Angeles River, as well as in reductions of the amount of runoff as the watershed will become less impervious over time. This will likely impact river flows during dry and wet periods, but make Los Angeles River cleaner for recreational and ecosystem beneficial uses.

### 4.4.6 Los Angeles River Revitalization Master Plan (LARRMP)

In April 2007, the City completed a nearly 2-year planning process for the 32 mile stretch of the LA River that lies within the City. The LARRMP provides a 25-50-year blueprint for transforming the river into an "emerald necklace" of parks, walkways, and bike paths, as well as providing better connections to the neighboring communities, protecting wildlife, promoting the health of the river, and leveraging economic reinvestment.

One of long term goals is to restore the LA River's ecological and hydrological functioning by the re-creation of a continuous riparian habitat and through removal of the concrete walls where feasible. In addition to recovering its ecological function, revitalization of the LA River includes capturing peak flows to reduce flow velocities in the channel in order to achieve ecological restoration and access points. These changes can create the development of multi-benefit green spaces within the LA River channel that provide open space and water quality benefits.

The LARRMP also showcases areas of opportunity that will act as examples of potential for river revitalization. Improvements to these areas will be developed through community outreach with neighborhood residents.

### 4.4.7 Arroyo Seco Watershed Management and Restoration Plan

The Arroyo Seco Watershed Management and Restoration Plan (WMRP) was completed in 2006 for the purposes of managing and restoring water quality and habitat in the Arroyo Seco watershed, which is tributary to the Los Angeles River. The WMRP focuses on two key elements, water quality and habitat improvement, and subjects them to in-depth technical analysis and presented with detailed project descriptions.

The outcome of the WMRP is a series of recommended water quality and habitat improvement projects within the Arroyo Seco Watershed. For example, some of the improvement projects may include removal of concrete lined channel sections, and restoration of native vegetation with root uptake, which would impact flows to the Los Angeles River and potentially add significant consumptive uses. The introduction of wildlife and fish into this area is another factor that could harbor minimum flow requirements, further adding to the Los Angeles Rivers' existing consumptive uses.

### 4.4.8 Lower Los Angeles River Revitalization Plan (LLARRP)

LA River revitalization efforts along the lower portion of the LA River are being conducted in coordination with the efforts in the upper portion of the river. The densely populated communities along the lower LA River, begin at Vernon and run south until the ocean in Long Beach. This stretch comprises more than 10 cities, including Maywood, South Gate, Lynwood and Long Beach. In October 2015, Governor Jerry Brown approved Assembly Bill 530. This bill created the LLARRP Working Group to update the lower portion of the

County's river master plan. The purpose of the LLARRP Working Group is to provide input and direction to the formulation of the revitalization plan for the Lower LA River.

The LLARRP will be a robust restoration proposal that lays the groundwork for a revitalized Lower LA River, connecting residents to the river that flows through their communities. This program will identify the full range of modifications and best management practices necessary to restore, enhance, and revitalize the existing LA River infrastructure along the 19-mile Lower LA River. The draft of the LLARRP is anticipated to be released in early 2018.

### 4.4.9 Arroyo Seco Watershed Ecosystem Restoration Study

The purpose of the Arroyo Seco Watershed Ecosystem Restoration Study is to evaluate opportunities for restoring ecosystem function along the 11-mile reach of the Arroyo Seco, which is tributary to the Los Angeles River.

The Arroyo Seco Watershed Ecosystem Restoration Study will identify candidate projects that are most likely to effectively provide ecosystem restoration benefits, which could be identified as concrete channel removal, wetland restoration and/or fish passage projects. As in the case of the WMRP, the ecosystem restoration projects selected may introduce additional consumptive uses to the Arroyo Seco, and ultimately the Los Angeles River. The USACE has put the study on hold due to lack of federal funding.

## 4.5 Stakeholder Involvement and Path Forward

With many varied LA River planning activities, there is a need to coordinate stakeholder engagement and feedback in order to evaluate competing water management goals that affect the LA River flows. The emphasis is on creating a holistic adaptive management process to address all water uses. To secure buy-in, it is important that the City incorporate input from the public including stakeholder groups and agencies that represent a variety of interests. A framework that provides a systematic approach for resource management and ensures flexibility should be established.

For better management of this water resource, a strategic focus on effective integration of competing goals, for example, flood protection, habitat/biological integrity/ecosystem services benefits, recreational uses (REC-1, REC-2), and social and aesthetic benefits need to be considered. To develop a prioritization process, recommendations include considerations of protection of beneficial uses, restoration and revitalization projects, water quality benefits, costs, and stakeholder input on achieving goals of the LA River. The details of the framework and anticipated actions to achieve success in implementation of various projects are discussed below.

### 4.5.1 LA River Planning and Implementation Process Framework

Figure 14 presents a conceptual starting point for an adaptive management framework. The framework must follow a goal-driven process to help ensure that the water in the LAR Watershed is managed sustainably even during complex scenarios.

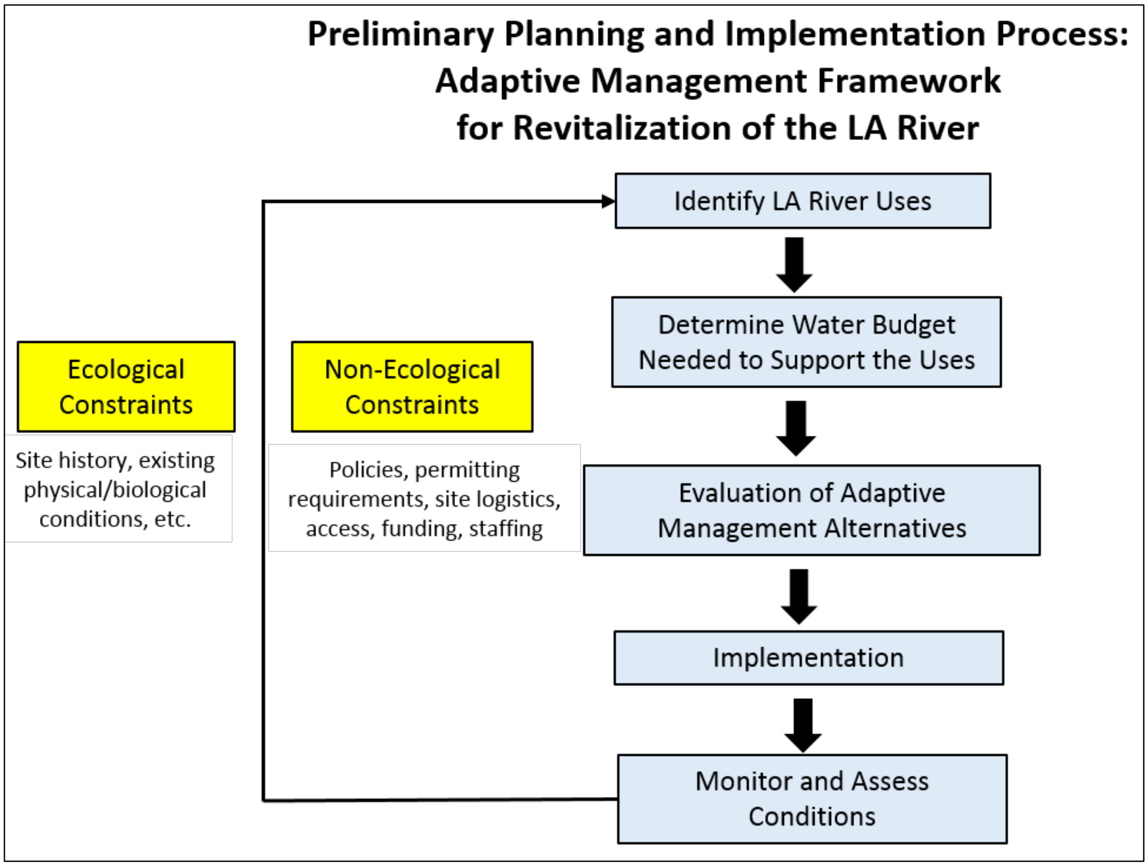

**Figure 14** **Flow Chart Describing a Preliminary LA River Planning and Implementation Process Framework**

The framework starts with understanding the LA River water uses and water budget that support those uses. After defining the baseline water budget conditions, ecosystem level planning and analysis will be needed to develop adaptive management alternatives. Based on the projected flow conditions, evaluation of alternatives will be necessary to guide adjustments to management actions while meeting the project(s) objectives/outcomes and the broader goals of sustaining the LA River water uses, meeting the restoration/revitalization goals, and balancing the City's water supply needs. Implementation plan should cover the projects/activities at the reach level and/or at the river level. Monitoring will be needed to track the progress made. The process should also account for risk to, and uncertainty of, the future success of ecological restoration activities, include effects of invasive species, human activities, stresses within the watershed (e.g., drought), future climate change and long-term O&M costs. The framework should also incorporate ecological (e.g., existing conditions) and non-ecological (e.g., funding and permitting) constraints for considerations.

The risk and uncertainty associated with various aspects of the projects should be identified and evaluated, particularly regarding the hydrologic and ecological restoration components.

The plan should also include the priorities and timeline for restoration. A monitoring plan needs to be developed before implementing the restoration activities. The implementation plan should cover the projects/activities at the reach level and/or at the river level. Monitoring at both levels will be needed to track the progress made.

The adaptive management approaches presented herein include examples of options to manage water in the LA River to satisfy the beneficial uses of the river. Multiple uses can be balanced by utilizing an adaptive management framework that includes stakeholder participation to determine the types and locations of these uses along the LA River, and the corresponding water management options to meet the associated water demands.

### 4.5.2 Actions for the Adaptive Management Framework

Presented below is a series of actions that define the goals for the adaptive management framework process. The actions are not specified in any particular order; however, collectively, these define the components of an adaptive management approach to address the data and knowledge gaps identified above and allow flexibility to apply the lessons learned from the ongoing work to future efforts. Monitoring becomes a key component of the process to make informed decisions.

1. Understand water supplies and resources:
    a. Conduct additional surface water groundwater interaction studies to refine water budget
    b. Assess feasibility of water management concepts presented in this TM and identified in other projects/studies
    c. Define water management scenarios (e.g., temporal shift in WRP flows; stormwater management activities timeline and other related projects)
    d. Improve water resources data collection and monitoring
    e. Coordinate intra-agency data collection efforts, integrate all data, and use data for decision making
    f. Define baseline conditions against which evaluations will be made
2. Understand short-term and long-term goals:
    a. Update short-term and long term goals to ensure water demands for various uses are met
    b. Evaluate temporal profile of water management actions such as WRP flows and stormwater management and other demands
    c. Align restoration objectives with resources
    d. Integrate resources to benefit the projects and efforts

3. Understand effects of projects under consideration on ecosystem
    a. Develop baseline for ecosystem level planning for the entire River
    b. Understand historic hydrologic conditions and impact on habitat diversity
    c. Apply lessons learned from historical conditions and habitat resiliency
    d. Assess the effects of planned projects on ecosystem/restoration
    e. Collaborate among agencies/stakeholders to compile data on water resources/habitat/biota etc. to keep a single inventory of resources
4. Understand water needs:
    a. Determine flows (quantity and quality) that support instream habitat with water management actions
    b. Groundwater replenishment needs
    c. Prioritization of other water uses needs
5. Support healthy ecosystem:
    a. Improve ecosystem health, resiliency, and water uses
    b. Prevent and eradicate invasive species
    c. Protect and restore instream habitat and access for fish and wildlife
6. Implementation and monitoring:
    a. Implement projects as planned
    b. Monitor systems for gathering data and evaluating success
    c. Shape the next series of steps
7. Evaluate impacts of climate change:
    a. Understand the effect of climate change on water resources and adjust goals
    b. Develop climate change adaptation and resiliency strategies
8. Education and involvement for stewardship:
    a. Understand stakeholder viewpoints and incorporate into the decision-making process
    b. Organize and unify various initiatives and strategies of stakeholders
    c. Educate stakeholders about the projects, process and their role
    d. Specify objectives and tradeoffs that capture the values of stakeholders
9. Other considerations:
    a. Identify key uncertainties and plan for actions
    b. Risk tolerance for potential consequences of management actions
    c. Account for future impacts of present decisions

### 4.5.3 Leadership and Collaboration under the Adaptive Management Framework

The Los Angeles City Charter grants LADWP exclusive authority over water rights. As such, LADWP must play a leadership role in the implementation of projects that exert a demand on the LA River flows. Toward that end, the City has led a collaborative process to engage City departments and other stakeholders in the planning and decision-making related to balance the LA River's restoration and revitalization objectives. A key forum for such decision-making is the LARCC, a joint working group of the LA County Department of Public Works and the City, with the USACE serving in an advisory capacity. The LARCC was formalized in the Los Angeles River Memorandum of Understanding of 2009 and meets at least twice per year to share information, evaluate, and make recommendations about public, private, and non-profit sector projects along the upper reach of the Los Angeles River.

In 2016, the LARCC revamped their Project Evaluation Form. The objective of this evaluation form was to capture project-specific information and enlist various criteria used in the evaluation process. The Project Evaluation Form aims at capturing information in a consistent and streamlined manner to facilitate the decision-making process. Evaluation of the presented preliminary conceptual water management options would involve performing more detailed analysis and presenting results to respond to various questions within this evaluation form to facilitate decision-making.

With the multitude of planning studies related to the LA River, the development of a Planning and Implementation Process Framework that incorporates an Adaptive Management Plan would formalize the City's leadership role and provide a structure in which technical, institutional, and regulatory considerations can be evaluated for all projects that would impact LA River flows.

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# APPENDIX B – DRAFT REVIEW OF HISTORICAL LA RIVER ECOLOGICAL SURVEYS (DECEMBER 2016)

CDM Smith

## Memorandum

*To:* *Tom West, Carollo Engineers*

*Prepared By:* *Tiffany Lin and Juan Ramirez, CDM Smith*

*Reviewed By:* *Jennifer Jones, Robin Nezhad, and Jennifer Thompson, CDM Smith*

*Date:* *February 10, 2016*

*Subject:* *One Water Los Angeles*
*Task 12D, Review of Historical LA River Ecological Surveys*

## 1.0 Background

The LA River is a 50-mile long river that begins at the confluence of Bell Creek and Arroyo Calabasas in the Santa Monica Mountains foothills and ends in Los Angeles Harbor in Long Beach. During the late 1800s and early 1900s, wet seasons resulted in significant flooding in the floodplain causing extensive property damage as well as casualties. Consequently, the United States Army Corps of Engineers (USACE) channelized the LA River and lined the majority with concrete in the 1930s in an attempt to prevent future flooding. Although channelization improved flooding conditions, physical alterations to the LA River also impacted the river ecologically such that biodiversity and habitat quantity and quality decreased. Flow in the LA River now exists in two states: (1) low flow during dry seasons and (2) high flow during wet seasons. Efforts have been made in recent years to revitalize the LA River with goals including, but not limited to, improving flow and connectivity, sustainability, natural habitat and biodiversity presence, and recreational value.

This technical memorandum reviews four studies regarding biological habitat and flow conditions in the LA River in an effort to identify how potential flow changes may impact hydrologic conditions and sensitive locations in the LA River. Using these studies as a baseline, the memorandum presents recommendations for monitoring approaches and locations for biological surveys for future flow studies that aim to preserve ecosystems in the LA River.

## 2.0 Summaries of Previous Studies

### 2.1 Los Angeles River Physical and Biological Habitat Assessment Report of 2003 Field Activities (USBR, 2004)

In 2003, biologists and the Los Angeles Study Group conducted a study to “evaluate wildlife habitats” and “determine the relationship between such habitats and dry-season river flows.” The team collected video of the LA River from Sepulveda Basin to Long Beach Harbor to obtain an overview of existing LA River conditions. Using the video data, the study area, which extends from the Donald C. Tillman Water Reclamation Plant (DCTWRP) outfall downstream of Sepulveda Dam to Willow Street Bridge, was sectioned into three representative reaches for further evaluation as follows: (1) Upstream LA River, (2) Glendale Narrows, and (3) Downstream LA River. Four study sites were selected in the three reaches where the biological habitat, physical measurements (including channel width and depth), flow, and velocity data were collected to the extent possible.

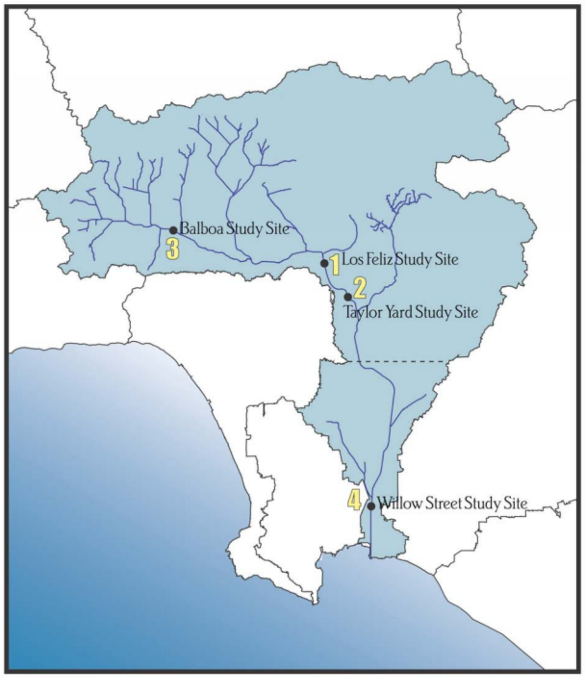

**Figure 1 – Los Angeles River Watershed and USBR 2004 Study Site Locations (source: USBR 2004)**

### *2.1.1 Biological Habitat*

The goal of the field activities associated with this habitat assessment study was to (1) understand and evaluate the existing wildlife habitats within the LA River channel and (2) determine the relationship between such habitats and dry-season river flows. The methodology approach primarily consisted of field surveys at representative reaches and the use of aerial videography (VHS format), which helped to determine the size/density, composition and distribution of riparian habitats. Four sites within three reaches were studied, as identified in Figure 1 above. The study area is roughly 40 miles of the LA River from Sepulveda Dam downstream to Willow Street Bridge.

Based on the findings of this study, riparian habitat was found in two areas: Sepulveda Basin and Glendale Narrows. Total acreage of riparian habitat between Route 134 and Los Feliz and between Los Feliz and Fletcher was estimated to be nine and three acres, respectively. The most extensive riparian habitat within the study area is located between Fletcher Drive and Figueroa Street within the Taylor Yard reach, estimated at over 32 acres. The Balboa site was identified as a “control station” due to the type of riparian habitat observed under reduced flow conditions. However, riparian habitat at this site was not considered "poorer" habitat despite decreased flows at the Balboa site. Overall, the total acreage of riparian habitat for the entire study area was estimated at 47.5 acres, mostly in Glendale Narrows.

Some river sections have unlined bottoms which support stands of vegetation and are of some value to wildlife. For example, although only a fraction of the total width, the wetted channel portions of Los Feliz and Taylor Yard sites are taken up by large vegetated islands along the west side of the channel. The vegetated habitat at the Balboa site was determined to be as good as or even better than the Los Feliz and Taylor Yard sites.

Numerous hydraulic control structures, both natural and man-made, were observed in the channel (i.e., Taylor Yard), which direct the limited stream volume and ultimately provide opportunities for development of extensive patches of riparian habitat. The study concluded that a healthy riparian community can be maintained in the channel with very little stream flow providing that there is sufficient water depth. Even with less than ten percent of the flow volume observed at Los Feliz and Taylor Yard sites, the riparian community at the Balboa site was as good as or better than in Glendale Narrows, which suggested that water depth is more important than flow. No recommendations relative to habitat surveying were mentioned.

### *2.1.2 Flow and Water Level*

Physical measurements from the four study sites are described below and summarized in Table 1:

- *Los Feliz*: The Los Feliz study site is located in the Glendale Narrows reach upstream of Los Feliz Boulevard. The 1,200-foot long, 200-foot wide reach was divided into ten cross-sections. The center section of the river in this reach is wet with the west side of the channel inhabited by vegetation approximately 55-feet wide and extending up to four feet above the water. Hydraulic structures (concrete sills) are present in the reach.
- *Taylor Yard*: The Taylor Yard study site is also located in the Glendale Narrows reach approximately 0.5 mile downstream of Route 2 Bridge. This reach was investigated over six cross-sections across hydraulic structures (boulder and cobble field), pools, "run habitat," and riffles. A large vegetated island with average width of 111 feet is present on the west side of the river, reducing the wetted channel width to less than 100 feet despite the total channel width being more than twice that. Velocities and water depth were observed to be higher on the eastern concrete apron.
- *Balboa*: The Balboa study site is located in the upper portion of LA River in the Sepulveda Basin north of Sepulveda Dam. This site is considered a control site for the Taylor Yard and Los Feliz sites as it is outside of the project area. Check dams made from quarried stones cause pools to form in the river and are present both upstream and downstream of Balboa Boulevard. Wetted channel width is approximately one-third of the total channel width and is bordered by vegetated islands on both sides. Despite significantly lower flow at this study site

(less than 10 percent of flow observed at both Glendale Narrows sites), riparian habitat was present and similar to habitat observed at the Taylor Yard and Los Feliz study sites.

- *Willow Street*: The Willow Street study side is located in the downstream portion of LA River between Willow Street Bridge and Route 91 and is influenced by tidal zones. Barrier structures that may have been high flow deflectors are located upstream of Willow Street. Although channel width is 470 feet below the barriers, channel width is much narrower (less than 350 feet) upstream of it. A low flow trough approximately 23 feet wide is present along with sandbars, debris islands, and bridge crossings. Water depth was measured at 12 inches in the trough and 2 inches in sheet flow conditions. Flow measurements were not collected as this site was intended for biological surveys.

**Table 1 – Summary of Physical Characteristics of Study Sites**

| Study Site | Number of Cross-Sections | Reach Length (ft) | Total Width (ft) | Wet Width (ft) | Water Depth (ft) | Estimated Velocity (fps) | Estimated Flow (cfs) |
|---|---|---|---|---|---|---|---|
| 1 – Los Feliz | 10 | 1,217 | 200 | 110-195 | 0.5-2.8 | 0.1-1.9 | 112 |
| 2 – Taylor Yard | 6 | 364 | 230 | 89-94 | 2.2-4.0 | 0.2-1.9 | 100 |
| 3 – Balboa | 4 | 111 | 175 | 50-70 | >3 | 0.1-1.0 | 12 |
| 4 – Willow Street | 0 | NA | >300 | NA | 2-12 | NA | NA |

Source: USBR 2004

The study indicates that the LA River consists of five zones based on physical channel characteristics and habitat presence as follows: (1) concrete-lined reaches without wildlife habitat, (2) unlined reaches with intermittent riparian habitat, (3) large, “continuous” riparian habitat in Sepulveda Basin, (4) shorebird habitat in concrete-lined downstream reaches above the tidal zone, and (5) estuary.

Glendale Narrows is not concrete-lined and contains approximately 48 acres of riparian habitat, however, hydraulic control structures (sills, boulders, and cobbles) are present throughout this reach. The control structures help spread out the low flow and sustain the habitat. The study observed that most habitat areas were at a minimum, partially wetted and that denser vegetation was located in wetter areas. Habitat in the upstream study reach also suggests that water depth is more important than flow in sustaining habitats. Evidence of flood events was observed and may impact the presence and quality of riparian habitat. Groundwater up-welling in the unlined reach may also impact riparian habitat by providing flows in LA River.

The study recommends additional measurements and analyses to establish the relationship between flow and biological habitat. Particular attention should be paid to Glendale Narrows and Willow Street as both are significant wildlife habitats in the LA River.

## 2.2 Phase II City of Los Angeles Integrated Resources Plan for the Waste Water Program – Los Angeles River Recycled Water Evaluation Study Phase 1 Baseline Study (CH:CDM, 2005)

The Integrated Resources Plan (IRP) aims to increase the use of recycled water and re-use of dry weather urban runoff. The Baseline Study was conducted in two phases as part of the Phase II IRP to evaluate limitations to supplementing LA River flow with recycled water or dry weather urban runoff. This Phase I study attempts to understand how projects under the IRP could alter/reduce the amount of water flow in the Los Angeles River channel and potentially result in impacts and benefits on biological/ecological attributes. One of the primary objectives is to establish a baseline for LA River conditions including flow, water quality, and habitat. Phase II would expand on data and analyses based on gaps identified during Phase I.

Ongoing efforts throughout the Southern California Region including the Counties of Los Angeles, Ventura, Orange, and San Diego, are underway to eradicate by initiating site specific removal and a long-term plan for future eradication efforts. This involves removal of invasive plant species, with removal occurring in an upstream to downstream manner, to control the water loss from watersheds resulting from *Arundo donax* invasion caused by the Arundo leaf transpiration. For the purposes of this study (Task 12D), projects, and initiatives planned within the watersheds and in the LA River, associated with *Arundo donax* eradication, have been taken into consideration, as part of the potential future scenarios, as we develop the water management alternatives.

One of the ongoing efforts includes the Memorandum of Agreement developed between LADWP and the National Forest Foundation (NFF), for a period of three years, regarding the Arundo donax Removal Project (The eradication project). The eradication project will treat and monitor eradication of Arundo donax in the Big Tujunga and Little Tujunga Watersheds, upstream of Hansen Dam. LADWP and NFF have identified the eradication project as an opportunity to remove the invasive and water use intensive species, Arundo donax, allowing for more water to be recharged into the San Fernando Groundwater Basin. The eradication project will support LADWP's stormwater capture goals as adopted in the 2010 Urban Water Management Plan and thereby support Mayor Eric Garcetti's Executive Directive No. 5 goals of reducing dependence on imported water supplies. Survey identified 57 acres of Arundo strands recommended for removal in this location as part of the eradication project. This eradication project is estimated to conserve and deliver for recharge into the San Fernando Groundwater Basin 1,140 acre-feet per year of water. The overall eradication project construction cost has been estimated to be $2.3 million and NFF, LADWP, and other project partners will cost-share in the budget of the eradication project.

### *2.2.1 Biological Habitat*

Biological sites of interest along the LA River channel included Sepulveda Basin, Glendale Narrows, Dominguez Gap and DeForest Park, Lower LA River, Willow Street reach, and the LA River mouth. Habitat and wildlife observed at these locations are described as follows:

- The Sepulveda Basin reach between Balboa Avenue and Burbank Boulevard supports wetland plant species, nesting shorebirds, and other wetland resources. Wildlife species within the basin include arroyo chub, yellow-breasted chat, and western pond turtle. Riparian areas within the basin (including along Encino and Haskell Creeks) consists of extensive emergent march habitat with arroyo willow, black willow, sandbar willow, and Fremont cottonwood.

- The Glendale Narrows reach has extensive wetland and riparian habitat development, including areas of bulrush and cattail, and riparian woodlands of willow. Wildlife species along this reach include Swainson's thrush, yellow-crowned night heron, osprey, wood duck, two-striped garter snake, and other species otherwise rare or absent in the lower River area.

- The Dominguez Gap and DeForest Park sites (located along the LA River in the City of Long Beach) have a mixture of non-native and native habitats. Non-native habitats are dominated by landscape and ornamental trees; native habitats are dominated by cottonwood, willow, emergent marsh species, some native scrub species, open water, and seasonal wetland species. Wildlife species include green heron, mallard, and American widgeon.

- Lower LA River, particularly south of Rosecrans Avenue, is a concrete-lined channel used by shorebirds, especially during the fall migration (July to September).

- The Willow Street reach is soft bottomed, tidally influenced, and partially brackish during some portion of the year. It supports shrubs and herbaceous species (e.g., mulefat, cattail, umbrella plant, and knotweed) and estuarine species, including invertebrates and fish.

- The LA River mouth at Queensway Bay supports invertebrate macrofauna, including jackknife clam, bay ghost shrimp, Pacific gaper, horse mussel, and littleneck clam. Common species include gobies, northern anchovy, croakers, topsmelt, diamond turbot, queenfish, California halibut, Pacific sardine, and others.

Based on the findings of this Phase 1 baseline study, changes to low flows could result in impacts in both unlined reaches as well as lined reaches. However, a review of available data to date does not clearly indicate that flow changes would impact any special-status species, but further investigation is likely needed to conclusively determine if special-status species actually use the LA River. Nonetheless, potential habitats that could be impacted include marine habitats, estuary/ coastal salt marsh, wet concrete channel bottom with algal growth (shorebird habitat), soft bottom channel reaches with riparian vegetation, and soft bottom channel reaches with marsh. Of these habitats, the shorebird habitat and soft bottom reaches are most likely to be influenced by changes in flow conditions. In addition, diversion of urban runoff and/or production and use of recycled water from water reclamation plants (WRP) beyond the levels presently planned could influence special-status and wildlife indicator species. Such species that may be sensitive to changes in site conditions (e.g., possible reduction of LA River flows, etc.) occur in aquatic/riverine habitats, wet concrete channels with algal growth, fresh emergent marsh habitat, and river riparian habitat.

This Phase I baseline study concluded that flow could be a critical factor and recommended the following next steps: conduct field evaluations to further identify and verify sensitive locations and habitats within the LA River; identify relationships between the existing quantity and/or quality of habitats within the LA River and the current hydrologic regime and develop a predictive modeling tool; and use the predictive model to evaluate how changes in the hydrologic regime (amount and timing of flow) could affect quantity and/or quality of habitats and to evaluate how changes in the hydrologic regime could affect aquatic and terrestrial species that rely on existing habitats.

### *2.2.2 Flow and Water Level*

For purposes of this baseline study, low flow was considered the 10th percentile flow and represented dry conditions. Flow in the LA River is supplied primarily by WRP flows with dry weather runoff and groundwater contributing significantly less flow. Groundwater contributions to LA River flow is limited to Glendale Narrows where groundwater levels are higher in this reach and channel bed is not lined with concrete.

Average low flow conditions during the early to mid-1900s was 10 mgd or less. With the addition of Los Angeles-Glendale Water Reclamation Plant (LAGWRP) flows in the 1970s, average low flow conditions more than doubled to 25 mgd and again to 60 mgd after DCTWRP began to release flow to LA River in 1985. At the time of the baseline study, average low flow conditions were observed to be approximately 42 mgd. Average low flow was also observed to decrease moving downstream in LA River but urban runoff and WRP effluent contributions increase. Evapotranspiration is a source of water loss at the downstream reaches of LA River while infiltration is negligible due to a clay layer under Sepulveda Basin.

Dry season water quality analysis generally showed higher temperature and pH in the downstream reaches due to WRP effluent flow and algal growth in areas of low flow, respectively. Dissolved oxygen was considered supersaturated, which suggests that those areas are dominated by algal communities. Fecal coliform concentrations were generally high throughout the study area, however, it was lower between Sepulveda Basin and Glendale Narrows. Fecal coliform levels were particularly high downstream of Glendale Narrows. TDS levels decrease below Sepulveda Basin as a result of WRP effluent flow and a lack of saltwater tidal influence. Conversely, WRP effluent in Sepulveda Basin increases BOD levels, which are low above the basin. Due to increased groundwater influence and less algal growth at Glendale Narrows, BOD levels decrease in downstream reaches. Ammonia levels are highest between Sepulveda Basin and Glendale Narrows, while nitrate and nitrite generally increase throughout the study area. Also influenced by algal presence as well as sediments, phosphorus levels decrease below the 405 freeway. Metals, including arsenic, copper, iron, nickel, and zinc, generally increases moving downstream, likely attributed to urban runoff especially from surrounding industrial areas.

Three potential future flow scenarios, which vary in percentages of water input sources for LA River, were evaluated for impacts on river habitat, flow and connectivity, and water quality. The first scenario essentially represents baseline conditions with the second scenario diverting WRP effluent and the third scenario diverting both WRP effluent as well as dry weather urban runoff. Analysis of the different scenarios indicate that the second flow scenario would reduce the percentage of WRP contribution, increase percentage of urban runoff input, and decrease nutrient levels downstream of LAGWRP. Similarly, the third scenario would decrease nutrient and potentially other water quality constituents downstream of LAGWRP but also allow groundwater contribution to represent a larger fraction of flow observed in Glendale Narrows by reducing the percentage of WRP and urban runoff inputs.

The Phase I Baseline Study makes the following conclusions:

- LA River flow is heavily influenced by water reclamation plant flows (55 mgd) with lesser contributions from dry weather urban runoff (30 mgd) and minimal contributions from groundwater (3 mgd). Flow would decrease by approximately 30 percent if recycled water reuse and dry weather runoff diversion were implemented.
- Habitat at unlined portions of LA River are primarily impacted by floods (scouring effect) and to a lesser degree by low flows and water quality.
- Shorebird habitat at concrete-lined portions of LA River downstream of Glendale Narrows is primarily impacted by low flows, followed by water quality and then flooding.

## 2.3 Los Angeles River Ecosystem Restoration Integrated Feasibility Report Volume 1: Integrated Feasibility Report (USACE, 2015)

The Integrated Feasibility Report (IFR) study area originally encompassed a 32-mile stretch of LA River beginning at the river origin ending at the City of Vernon. Through further evaluation for maximum restoration potential, the revised study area focused on an 11-mile stretch (referred to as ARBOR) that includes Glendale Narrows. The revised study areas included Glendale Narrows because the study suggested that Glendale Narrows provides an important riparian habitat and “shows the most promise for ecosystem restoration.” The IFR evaluated an array of alternatives for restoring 11 miles of the Los Angeles River from approximately Griffith Park to downtown Los Angeles (known as the ARBOR reach) while maintaining existing levels of flood risk management. The study area consisted of the following 8 reaches: (1) Reach 1 - Pollywog Park/Headworks to Midpoint of Bette Davis Park; (2) Reach 2 - Midpoint of Bette Davis Park to Upstream End of Ferraro Fields; (3) Reach 3 - Ferraro Fields to Brazil Street; (4) Reach 4 - Brazil Street to Los Feliz Boulevard; (5) Reach 5 - Los Feliz Boulevard to Glendale Freeway; (6) Reach 6 - Glendale Freeway to I-5 Freeway; (7) Reach 7 - I-5 Freeway to Main Street; and (8) Reach 8 - Main Street to First Street.

### *2.3.1 Biological Habitat*

Based on the findings of the IFR, the LA River study area includes several scarce/rare ecosystem types that support significant life functions for myriad species. In terms of species richness, the LA River is within a region that includes over 50 plant alliances or groupings of plants that share similar structural conditions and approximately 1,000 plant types (depending on location within the watershed). In terms of rarity, the upper LA River watershed has a relatively high occurrence of rare plant species, due to underlying soil properties and other geomorphic and environmental conditions. The lower watershed includes rare special status invertebrates. In terms of wildlife, the LA River supports approximately 140 bird species, which are federally protected under the Migratory Bird Treaty Act; over 20 species of mammals; and nine species of bat. Current channelized conditions in the mainstream no longer support endemic native fish species but do support non-native fish species. Limited numbers of least Bell's vireo nest on the upper LA River but its historic range includes the ARBOR reach. In addition, the remaining fragments of LA River aquatic and riparian habitat within the urban landscape context contribute significantly to the integrity of the larger ecosystem by supporting metapopulations. The existing habitats in the Glendale Narrows and connection to major tributaries provide the backbone for restoration of regional habitat connectivity and wildlife movement between significant ecological areas including the Santa Monica Mountains, Verdugo Hills, and nationally significant San Gabriel Mountains National Monument.

Restoration of the LA River was proposed under Alternative 20, Riparian via Varied Ecological Reintroduction (RIVER), as the locally preferred plan (LPP), which includes monitoring until ecological success criteria are met, for no more than 10 years. Restoration measures of the LPP include river widening and terracing in Reaches 2, 5, 6, 7, and 8; restoring the Verdugo Wash confluence in Reach 3; daylighting[1] three streams (storm drains); restoring the lower Arroyo Seco tributary; restoring foothill riparian and freshwater marsh at the Los Angeles State Historic Park to support increased population of wildlife and enhance habitat connectivity; and restoring channel bottom and a direct connection of the LART into the LATC site in Reach 8. Overall, the LPP would restore 719 acres of habitat throughout the ARBOR reach and provide provision of a direct connection to the significant habitat areas of the Verdugo Mountains.

### *2.3.2 Flow and Water Level*

Concrete-lined sections of LA River are generally surrounded by urbanized and industrial areas, which are less preferable for habitat restoration. The eight reaches in the 11-mile study area is differentiated based on geomorphic criteria (e.g., bed type, slope type, surrounding land use). Similar to goals in other restoration plans, potential projects presented in the IFR aimed to improve flow conditions and connectivity as well as increase biodiversity and habitats in LA River. Year-round flow and habitat at the ARBOR reach was the focus area of the study and serves as an

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[1] Daylighting in this instance is defined as opening underground pipes and storm drains near their confluence with the LA River to restore them to a natural stream channel.

established baseline for wildlife and habitat restoration potential. The 11-mile study reach has channel width ranging up to 215 feet and contains sandbars and hydraulic structures.

As previously described, up to 70 percent of year-round (perennial) flow consists of WRP effluent. Groundwater is also a source in the 11-mile reach of LA River and helps maintain existing habitat in that portion of LA River. Approximately 211,000 AFY of water is supplied annually by all sources (effluent, groundwater, dry weather runoff, wet weather runoff and precipitation) combined. Alternatives proposed in the IFR were assessed based on opportunity, benefits, feasibility, cost effectiveness, and other considerations. Improved wildlife habitat was emphasized but other concerns were addressed, including flood diversion to prevent impacts from high flow velocities. Peak velocities and flows during the rainy season have previously exceeded 25 fps and 180,000 cfs, respectively. Wet weather flow conditions became more problematic as urbanization in Los Angeles increased. However, dry season flows are minimal (less than 100 cfs). Hydrologic analysis compared the water budget (available water versus water demand) resulting from the various alternatives. However, none of the proposed alternatives affects hydrologic conditions in the ARBOR reach. Changes in flow conditions resulting from proposed alternatives primarily affect concrete-lined portions of the river where concrete would be removed.

Water quality data suggests that TSS, associated with urban land uses, is a critical as it impacts not only water quality but also habitat quality and biodiversity in the river. LA River impairments include: ammonia, nutrients (algae), metals (lead and selenium), bacteria, cyanide, benthic macroinvertebrate, oil, and trash.

Two alternatives were preferred based on LPP and NER Plan considerations and are Alternative 20 and Alternative 13, respectively. Components of both alternatives include habitat restoration, improved habitat corridors, terraced banks, channel widening, flow diversion, return to historic flows, marsh restoration, and concrete removal. The two alternatives differ in the locations where these components are proposed with more locations specified in Alternative 20. Implementation of the preferred subset of alternatives forecasted biological, hydrologic, and water quality benefits.

## 2.4 Final Independent External Peer Review Report Los Angeles River Ecosystem Restoration Feasibility Study, Draft Integrated Feasibility Report and Environmental Impact Statement (Battelle, 2013)

The Final Independent External Peer Review (IEPR) Report was conducted by Battelle, an independent non-profit science and technology organization, on behalf of USACE. Panel members identified by Battelle reviewed the LA River Ecosystem Restoration IFR, which included the draft EIR and EIS, and provided comments regarding "adequacy and acceptability of economic, engineering, and environmental methods, models, and analyses used."

### *2.4.1 Biological Habitat*

The review included evaluation of the Combined Habitat Assessment Protocol (CHAP) habitat analysis, which included a comprehensive analysis of current conditions, future conditions without remediation, and future conditions under several restoration alternatives. Based on the review, an assessment of monitoring needs, maintenance activities, and adaptive management strategies to assess the extent to which the restoration projects would achieve the stated goals and objectives was not well described. Post-project monitoring and maintenance actions to evaluate how successfully the project met the project objectives should be included in future LA River documents.

In addition, the review panel found that the risk and uncertainty associated with various aspects of the project had not been clearly identified and communicated, particularly regarding the hydrologic and ecological restoration components. The panel noted that there was little consideration of the risks and risk mitigation that could affect the success of the restoration, such as adverse weather, disease, invasive species, stresses from the surrounding urban environment, and human disturbance. The panel recommended a hydrologic risk and uncertainty analysis be conducted of the predicted flooding following completion of the project; evaluating the risk to, and uncertainty of, the future success of ecological restoration activities, including effects of failures of plantings, disease, disturbance from invasive species, human activities, stresses created by surrounding urbanization, and future climate change; and potentially revising cost estimates to account for higher than expected long-term operations and maintenance (O&M) costs to achieve stated restoration goals.

### *2.4.2 Flow and Water Level*

While the Panel considers the IFR generally comprehensive, it also noted that additional considerations should be included in relation to restoring “physical functions and ecological habitats that were historically present in the Los Angeles River system.” The following comments pertaining to hydraulics, hydrology, and geotechnical analyses provided by the Panel as part of the IEPR are considered significant:

- Flood risk management should be included as an objective of the IFR as it was a critical purpose of the river in the past and the capacity for flood risk management may be impacted by the approach for habitat restoration in the river.

- Hydrologic and hydraulic analyses should expand beyond design storms and floods to include other flow conditions (e.g., seasonal and low flow) to evaluate the sustainability of river restoration under alternate flow conditions.

- Further analysis or support is necessary to identify that the replacement turf mat (HPTRM) proposed as part of ecological restoration is structurally and geotechnically stable and able to withstand high velocity conditions during floods.

# 3.0 Recommendations

## 3.1 Monitoring Approach

The monitoring approach for future LA River studies at both existing and proposed monitoring sites is recommended to include the following:

- Physical measurements (channel width, wetted width, water depth, etc.)
- Flow and velocity measurements
- Water quality samples
- Biological surveys
- Habitat and vegetation mapping, including invasive species
- Description of adjacent land uses
- Operation and maintenance of infrastructure
- Presence of hydraulic control structures (number, type, frequency, dimensions, etc.)
- Photographs

## 3.2 Monitoring Sites

Further field investigations are warranted to confirm the characterization (e.g., composition of both plants and wildlife species) and location of existing sensitive biological habitats along the LA River. In addition to the four sites described from the LA River Physical and Biological Habitat Assessment Report (USBR, 2004), the following sites (shown in Figure 1) are recommended for additional monitoring (listed in order of importance):

- USACE LA River Headworks Ecosystem Restoration Site
    - Opportunities to restore aquatic and associated terrestrial habitat directly adjacent to a concrete-lined portion of the LA River
    - Located adjacent to proposed Sennet Creek riparian habitat
    - Opportunity to evaluate water (flow, volume) requirements to sustain restored habitat
    - Build on previous USACE development of the conceptual design of hydraulic features (flow conveyance, diversion, inlet/outlet) required to support various alternatives for habitat restoration
    - Focused on historic floodplain

  - Considered as a key site under ARBOR
  - Opportunity to establish/increase regional and aquatic habitat connectivity
  - Construction not anticipated until at least 2018 (pending construction of a reservoir on the site as well)
- Site downstream of the Arroyo Seco confluence
  - Considered a key site under ARBOR
  - Different channel characteristics than upstream sites
  - Opportunity to increase stream habitats
  - Opportunity as a confluence gateway
  - Build on previous water quality evaluations conducted by the Arroyo Seco Foundation and Friends of the Los Angeles River
- Site in The Nature Conservancy's (TNC) LA River Restoration Feasibility Study Area
  - Identified in Reaches 5 and 6 in the USACE's LA River Ecosystem Restoration IFR
  - Located in the east and west banks of the LA River in the Elysian Valley and Atwater Village
  - Close proximity to Taylor Yard and Rio de Los Angeles State Park
  - Build on recent habitat surveys conducted by TNC
- Site in the estuary
  - Opportunity for evaluation of hydrologic and sediment transport processes at mouth of LA River
  - Value of remnant coastal salt marsh for wildlife and estuarine fisheries
  - Identified as critical spawning and nursing grounds for fish
  - Provides forage for waterfowl

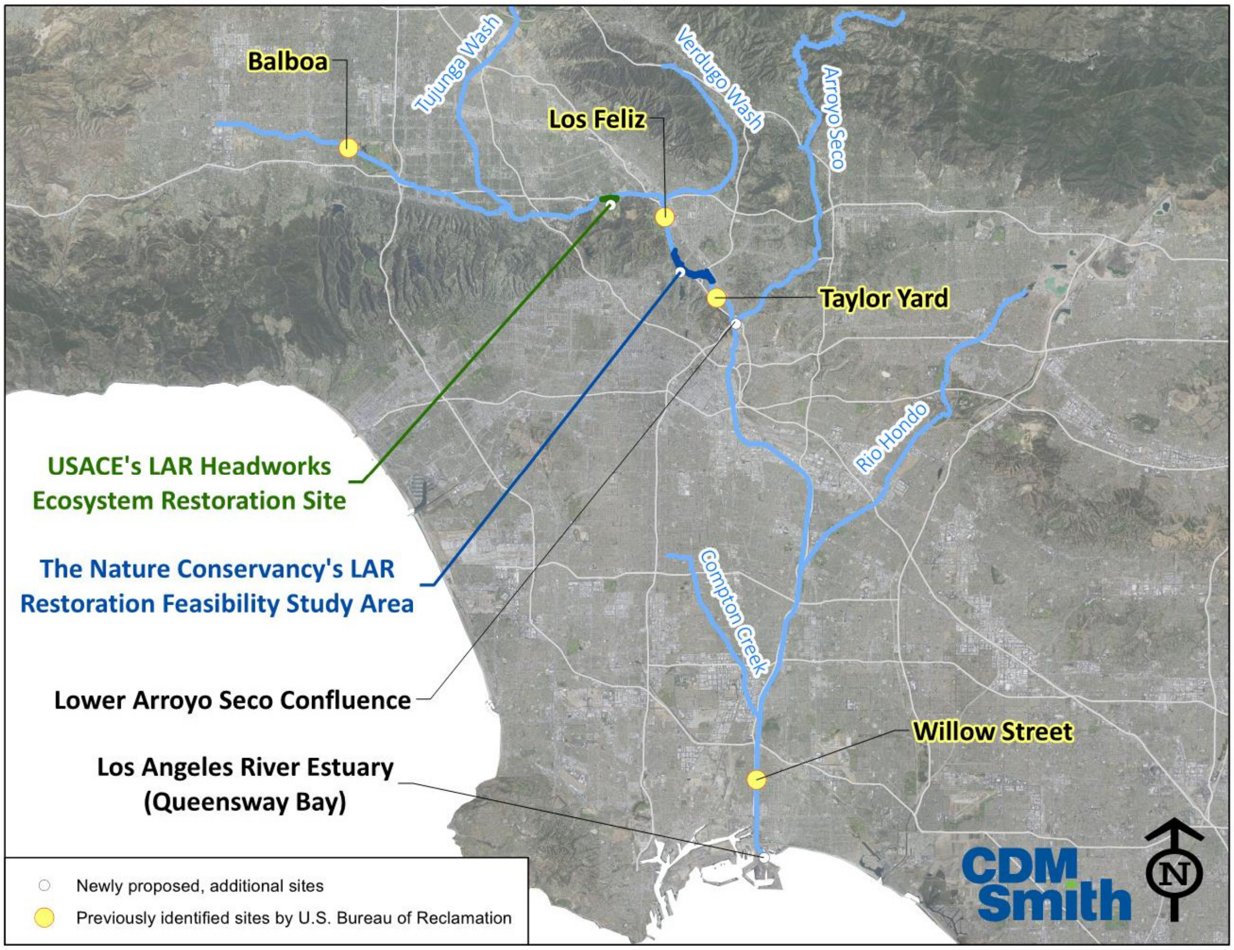

**Figure 1 – Map of existing and proposed monitoring locations in the Los Angeles River**

## 3.3 Flow Reduction

Changes to flow in the LA River could impact the beneficial uses and habitats that currently exist in the river. Existing beneficial uses, as specified by Table 2-1 in the Los Angeles Region Basin Plan, include:

- Industrial Process Supply
- Groundwater Recharge
- Navigation
- Commercial and Sport Fishing
- Habitat (Wildlife, Estuarine, Marine, Wetland)

- Rare, Threatened, or Endangered Species
- Migration of Aquatic Organisms
- Spawning, Reproduction, and/or Early Development

Potential impacts to the beneficial uses and habitats under reduced flow scenarios were documented in the Phase II City of Los Angeles Integrated Resources Plan for the Waste Water Program – Los Angeles River Recycled Water Evaluation Study Phase 1 Baseline Study (January 2005). The Baseline Study broadly evaluated three flow scenarios: (1) Maintain baseline flow conditions, (2) reduce contribution from wastewater effluent, and (3) reduce contribution from wastewater effluent and dry weather runoff. Potential impacts from the second and third scenarios are discussed in greater detail in the Baseline Study and are summarized below.

While groundwater recharge can only occur in the natural-bottom sections of the river, reducing flow in the river would limit the water available for recharge. However, flow reduction would primarily impact habitat-related beneficial uses. Under reduced flow conditions, both depth throughout the river and width of flow could decrease. This could result in less aquatic habitat available and may particularly impact shorebirds that feed in LA River habitats, including the estuary and Glendale Narrows. In concrete bottom sections of the river, algal presence dependent on wet river conditions could diminish and lead to less invertebrate production and shorebird foraging. Decreased depth could also result in less swimmable passage by fish and less desirable breeding environments. Changes in water chemistry and reduced wetness in the river resulting from decreased flow and dilution effects or changes in water supply could also encourage different vegetative and aquatic species to flourish and others to die off (ex. algal blooms under increased nutrient conditions can result in low oxygen content in the river that is harmful for fish survival). Industrial process supply, navigation, and fishing uses at the downstream estuary end of the LA River are less likely to be impacted by changes to flow conditions. More detailed modeling and analysis would be necessary to identify the extent of impacts from reducing flow in the LA River.

## 4.0 Limitations

- This review of LA River habitat and flow studies is limited to a small number of available studies and limited scope of the evaluation conducted.
- Although many LA River-related studies have been conducted, only a small fraction were conducted in more recent years.
- Dry weather flow studies in LA River are subject to the accuracy of low flow measurements, which can be challenging to achieve.

## 5.0 References

- US Bureau of Reclamation, Los Angeles River Physical and Biological Habitat Assessment Report of 2003 Field Activities, April 2004

- USACE, Los Angeles River Ecosystem Restoration Integrated Feasibility Report Volume 1: Integrated Feasibility Report, September 2015

- CH:CDM, Phase II City of Los Angeles Integrated Resources Plan for the Waste Water Program – Los Angeles River Recycled Water Evaluation Study Phase 1 Baseline Study, January 2005

- Battelle Memorial Institute, Final Independent External Peer Review Report Los Angeles River Ecosystem Restoration Feasibility Study, Draft Integrated Feasibility Report and Environmental Impact Statement, November 2013

- California Regional Water Quality Control Board Los Angeles Region, Water Quality Control Plan Los Angeles Region, June 1994

# APPENDIX C – DRAFT LOS ANGELES RIVER LOW FLOW STUDY (NOVEMBER 2016)

**CITY OF LOS ANGELES**

# TECHNICAL MEMORANDUM
# LOS ANGELES RIVER LOW-FLOW STUDY

**FINAL**
August 2017

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# CITY OF LOS ANGELES

# TECHNICAL MEMORANDUM
# LOS ANGELES RIVER LOW-FLOW STUDY

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# LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| ARBOR | Area with Restoration Benefits and Opportunities for Revitalization |
| Blvd | Boulevard |
| BMPs | Best Management Practices |
| Burbank | Burbank Water Reclamation Plant |
| CA | California |
| cfs | Cubic feet per second |
| City | City of Los Angeles |
| DC Tillman | Donald C Tillman Water Reclamation Plant |
| EWMP | Enhanced Watershed Management Program |
| ET | Evapotranspiration |
| ft | feet |
| HEC-RAS | Hydraulic Engineering Center River Analysis System |
| hr | hour |
| in | inches |
| IRP | Integrated Resources Plan |
| LA River | Los Angeles River |
| LASAN | Los Angeles Bureau of Sanitation |
| LACFCD | Los Angeles County Flood Control District |
| LADPW | Los Angeles County Department of Public Works |
| LA Glendale | Los Angeles Glendale Water Reclamation Plant |
| LSPC | Loading Simulation Program in C++ |
| Max | Maximum |
| mgd | Million gallons per day |
| Min | Minimum |
| N/A | Not Applicable |
| NCDC | National Climate Data Center |
| NPDES | National Pollutant Discharge Elimination System |
| PET | Potential Evapotranspiration |
| RM | River Mile |
| SD | Standard Deviation |
| St | Street |
| TM | Technical Memorandum |
| ULAR | Upper Los Angeles River |
| ULARA | Upper Los Angeles River Area |
| U.S. | United States |
| USACE | United States Army Corps of Engineers |
| USGS | U.S. Geological Survey |
| WMG | Watershed Management Group |
| WRP | Water reclamation plant |
| XS | Cross section |

# LOS ANGELES RIVER LOW-FLOW STUDY

## 1.0 INTRODUCTION

### 1.1 One Water LA

The City of Los Angeles (City) recently embarked on the One Water LA 2040 Plan. This plan will provide a strategic vision and implementation plan to manage its water resources and build sustainable water infrastructure for the entire City. In 2006, the City prepared its first integrated water resources plan (IRP). This plan was the start of a paradigm shift for the City and resulted in significant achievements through implementation of its recommendations for better wastewater management and water recycling. However, the water landscape in the City has changed drastically with increased population, new regulations, a severe statewide drought, and threats of climate change.

In response to these changes and to achieve water sustainability, the City initiated the One Water LA 2040 Plan. This plan builds upon the great success of the IRP, which had a planning horizon of year 2020. The One Water LA 2040 Plan takes a holistic and collaborative approach, to consider all water resources from surface water, groundwater, potable water, gray water, wastewater, recycled water, and stormwater as "One Water". The plan identifies multi-departmental and multi-agency integration opportunities to manage water in a more efficient, cost effective, and sustainable manner.

The One Water LA 2040 Plan represents the City's improved and unchanged commitment to proactively manage all its water resources and implement innovative solutions. The Plan will guide the City with strategic and multi-billion dollar decisions for water infrastructure projects that will make Los Angeles a resilient and sustainable City.

### 1.2 Purpose of Task 12D

The purpose of Task 12D of the One Water LA project is to evaluate the impact that decreases in dry weather flow in the Los Angeles River (LA River) could have on recreation and habitat values of the river. The Los Angeles River drains an approximately 850 square miles, largely urbanized watershed. During dry weather, flows in the river occur from water reclamation plants, upwelling from groundwater, limited tributary flows, and incidental runoff from urban areas. The City of Los Angeles is investigating multiple aspects of the LA River, including its water resource value. The possibility of enhancing local water supply though greater efforts in water recycling, water conservation, groundwater management, and improvements in surface water quality may all potentially decrease dry weather flows in the LA River. Future management of the LA River requires a greater understanding of how changes in flow may impact other values such as water supply, water quality, habitat, recreation, and aesthetics.

## 1.3 Objectives of This TM

The objective of this Technical Memorandum (TM) is to describe the results of a multi-aspect study which estimates low flow rates during dry weather in the LA River under different conditions, and uses these flow rates to determine how water resource management decisions may impact flow width, depth, and velocity at select locations in the River. The dry weather hydrologic analyses are based on a normal summer afternoon to simulate conditions which would occur on one of the lowest flow days of a given year. This condition was selected as a conservative estimate of dry weather flows and reflects no precipitation, low incoming flows from water reclamation plants, low dry weather urban runoff, and high evaporation and evapotranspiration, which will cause flows in the river to be near the minimum. The results of this study can be used to inform management decisions that could affect the dry weather flows in the LA River.

# 2.0 APPROACH

The approach for this analysis was to:

1. Model dry weather hydrology for each River mile in the Los Angeles River for existing and a range of potential future flow conditions;
2. Select cross sections at several important locations in the LA River including soft-bottom and hard-bottom reaches based on data availability and their possible importance for habitat and recreation; and
3. Model the hydraulics and analyze a range of flows at each of these locations including the existing condition and the range of potential future conditions.

Each of these analyses is described in more detail below.

## 2.1 Dry Weather Hydrologic Model

A hydrologic model was developed to estimate flows during dry conditions in both the existing and potential future conditions. The inputs, assumptions, and methodology used to develop these models are discussed in the sections below.

### 2.1.1 Existing Conditions

The flow at each river mile in the LA River was estimated for a dry, summer (July-August) day to provide a conservative scenario for dry weather flow. To create these conditions, values for each input into the model were selected to reflect sustained dry weather conditions and high air temperatures. Precipitation was excluded from the model due to the dry conditions. The values estimated for flow from water reclamation plants and dry weather urban runoff were on the far low end of the range of measured values. Evaporation rates were selected based on values measured during the warmest days of the year in the warmest part of the day. More details about how each of these values were selected to reflect a hot, dry, summer day is included in the sections below. For each river mile the flows into and out of the river segment were summed to create a mass balance and determine the flows released downstream as shown in Figure 1.

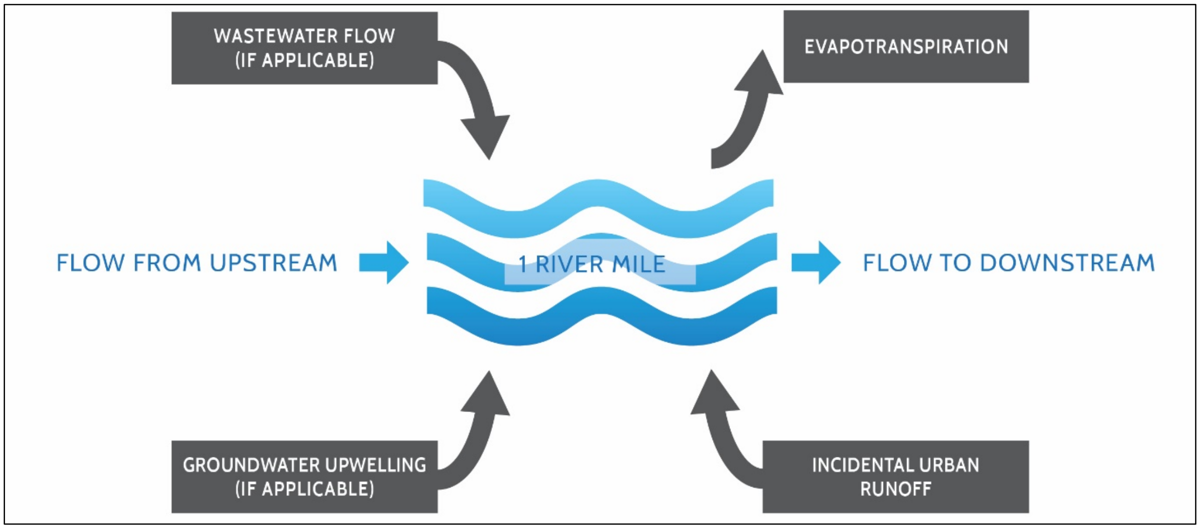


**Figure 1 Dry Weather Flows for Each River Mile in the Los Angeles River**

Incoming flows include flow from upstream segments of the river, incidental urban runoff entering through storm drain outfalls, flows from WRPs, and groundwater upwelling. Other potential flows into the river such as permitted flows from industrial permits were not included in the model for the following reasons:

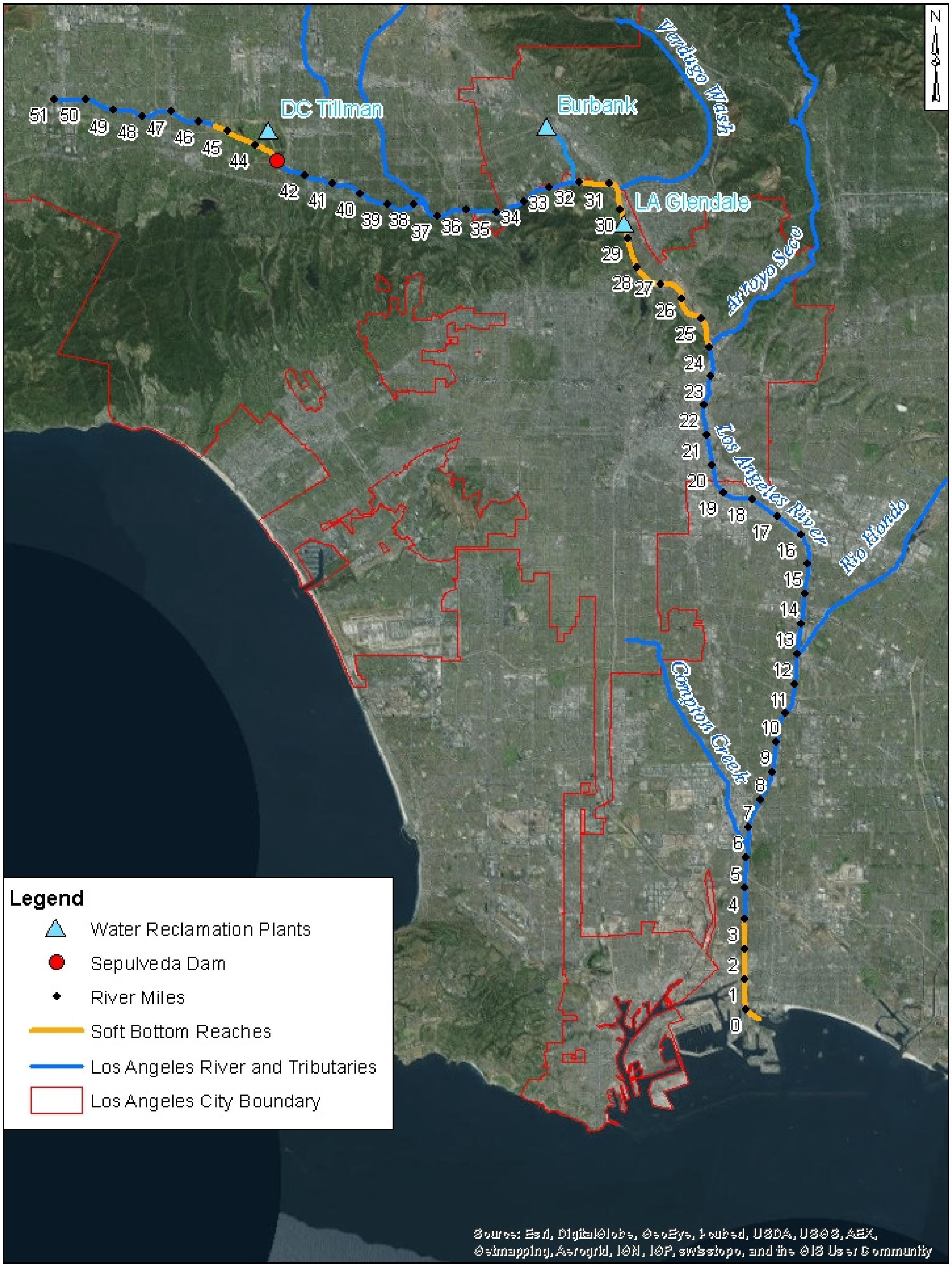
1. The flow rates are small compared to the water reclamation plants
2. The flows from industrial permits are not included in the One Water LA plan, and are not expected to change in the future conditions as a result of this plan unlike flows from WRP and dry weather urban runoff which are expected to change
3. There is a large number of NPDES permits, but reliable flow data for mid-summer conditions are difficult to obtain
4. Excluding these flows provides for a conservative estimate of dry weather flow rates.

Outflows include evaporation or evapotranspiration and flow to downstream. While infiltration of water into the ground may occur in specific, localized, soft-bottom reaches, this was not accounted for in the model. As explained below, the ULARA Watermaster reports used to estimate groundwater upwelling in soft-bottom reaches demonstrate that, overall, flow occurs from groundwater to the river in soft bottom reaches and not from the river to groundwater. Because the scale of the model is only at 1 river mile, small, localized areas of infiltration that may be present were not accounted for in the model as outflows.

Evaporation was applied over the whole river, evapotranspiration was applied in reaches where riparian vegetation exists, incidental urban runoff was applied along the entire river based on impervious tributary area, flows from WRPs were applied at three outfall locations, and groundwater upwelling flows were applied only within the soft bottom reaches where upwelling has been identified. These flow inputs and outputs are summarized in Table 1 and discussed in more detail in the sections below. Figure 2 shows the river miles (RM) used in the table below and the locations of the flow inputs.

**Table 1 Existing Condition Inputs into Dry Weather Flow Model**
**One Water LA 2040 Plan**

| Input | Inflow to River, mgd (cfs) | Outflow from River, mgd (cfs) | Location | Reference |
|---|---|---|---|---|
| DC Tillman Flow | 27.1 (42.0) | N/A | RM 43 | 10th percentile of daily average total effluent flow between 2013-2015 |
| LA Glendale Flow | 7.8 (12.1) | N/A | RM 30 | 10th percentile of daily average total effluent flow between 2013-2015 |
| Burbank Flow | 4.5 (7.0) | N/A | RM 32 | Estimate based on NPDES Permit CA0055531 |
| Groundwater Upwelling | 3.6 (5.6) | N/A | Applied evenly throughout soft bottom reach | Annual average since 1971 in ULARA Watermaster Report 2012-2013 (ULARA Watermaster, 2014) |
| Incidental Runoff from Urban Areas | 0.032-7.8 (0.05-12.1) | N/A | Applied at each river mile using $1.9e^{-4}$ mgd per impervious acre (190 gpd/imp acre) for all contributing area downstream of dams except Sepulveda | Los Angeles Integrated Resource Plan: Facilities Plan, Volume 3: Runoff Management (LASAN, 2004) |
| Evaporation/ ET | N/A | 0.017-0.60 (0.026-0.94) | 0.017 in/hr below RM 24, 0.021 in/hr above RM 24, varies due to surface area of each river mile | LA County LSPC model's Potential ET values based on conversion of computed NCDC evaporation pan data from Long Beach Airport (Gage 23129) and Burbank-Glendale-Pasadena (Gage 23152) using pan coefficients of 0.74-0.78 |



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

**Figure 2 Los Angeles River and Other Features of the Hydrology Study**

### 2.1.2 Water Reclamation Plant Flows

Three water reclamation plants have flows into the LA River or tributaries to the LA River: The Donald C. Tillman Water Reclamation Plant (DC Tillman), the Los Angeles-Glendale Water Reclamation Plant (LA Glendale), and the Burbank Water Reclamation Plant (Burbank).

DC Tillman flows enter the river at approximately river mile 43 upstream of Sepulveda Dam. Flows from this plant are split between environmental flows, such as irrigation of the Japanese Gardens and Balboa Lake, and direct flows to the river "over the weir". Daily total flows from the plant were obtained for 2013-2015. The flows are summarized in Table 2 and Figure 3. The flow rate was fairly constant from DC Tillman staying typically between 25 and 35 mgd (40-50 cubic feet per second [cfs]), including both direct flows and environmental flows, except for brief periods. As a conservative assumption, the 10th percentile flow rate, 27.1 mgd (42.0 cfs), was selected for the dry weather flow model, both environmental flows and direct flows were assumed to contribute to flow in the river.

**Table 2 Summary of Effluent Flows from 2013 to 2015 at DC Tillman and LA-Glendale Water Reclamation Plants**
**One Water LA 2040 Plan**

| Statistic | DC Tillman Daily Flow Summary, mgd (cfs) | LA Glendale Daily Flow Summary, mgd (cfs) |
|---|---|---|
| Average | 29.8 (46.2) | 10.2 (15.8) |
| Maximum | 44.6 (69.1) | 20.3 (31.4) |
| 90th Percentile | 31.9 (49.4) | 12.9 (20.0) |
| 80th Percentile | 31.0 (48.1) | 12.1 (18.7) |
| 70th Percentile | 30.6 (47.4) | 11.4 (17.6) |
| 60th Percentile | 30.2 (46.7) | 10.7 (16.6) |
| Median | 29.8 (46.0) | 10.1 (15.7) |
| 40th Percentile | 29.3 (45.3) | 9.5 (14.7) |
| 30th Percentile | 28.7 (44.4) | 9.0 (13.9) |
| 20th Percentile | 28.0 (43.4) | 8.4 (13.0) |
| 10th Percentile | 27.1 (42.0) | 7.8 (12.1) |
| Minimum | 9.6 (14.8) | 4.5 (7.0) |

LA Glendale flows enter the river at approximately river mile 30 near the confluence with Verdugo Wash. Effluent flow data were also obtained for 2013-2015 for LA Glendale as shown in Table 2 and Figure 4. The flow rate was more seasonal at this location with higher flows in the winter than in the summer. The 10th percentile flow rate, 7.8 mgd (12.1 cfs) was selected conservatively for the dry weather flow model similar to DC Tillman.

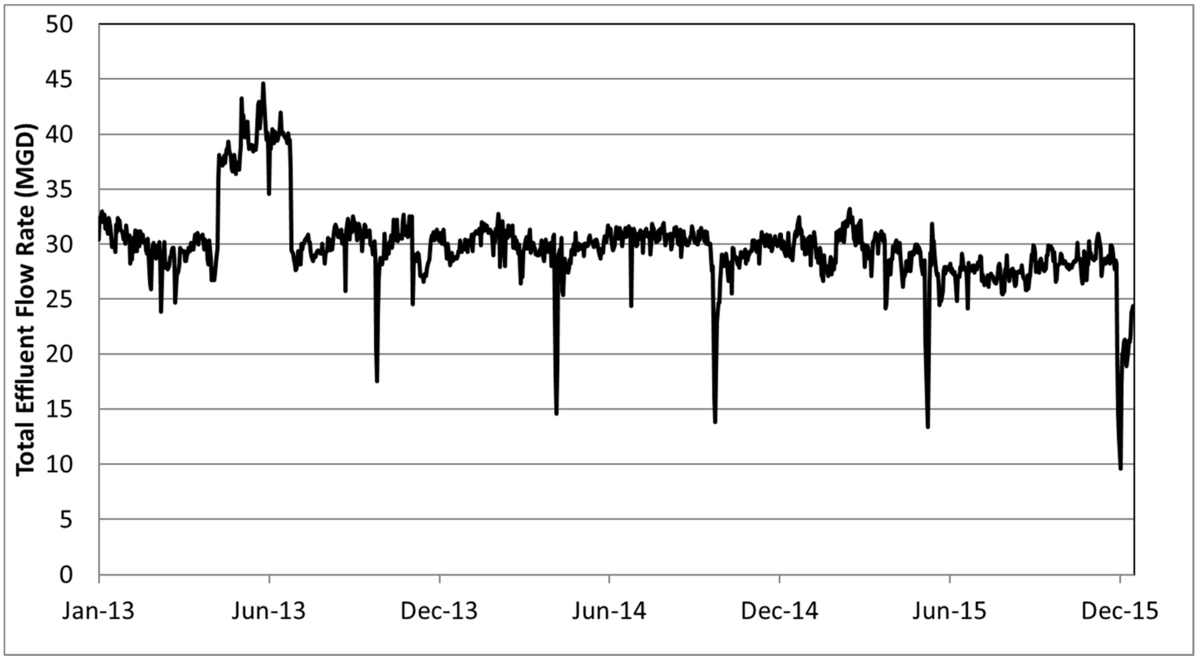


**Figure 3** **Daily Effluent Flows from DC Tillman Between 2013 and 2015**

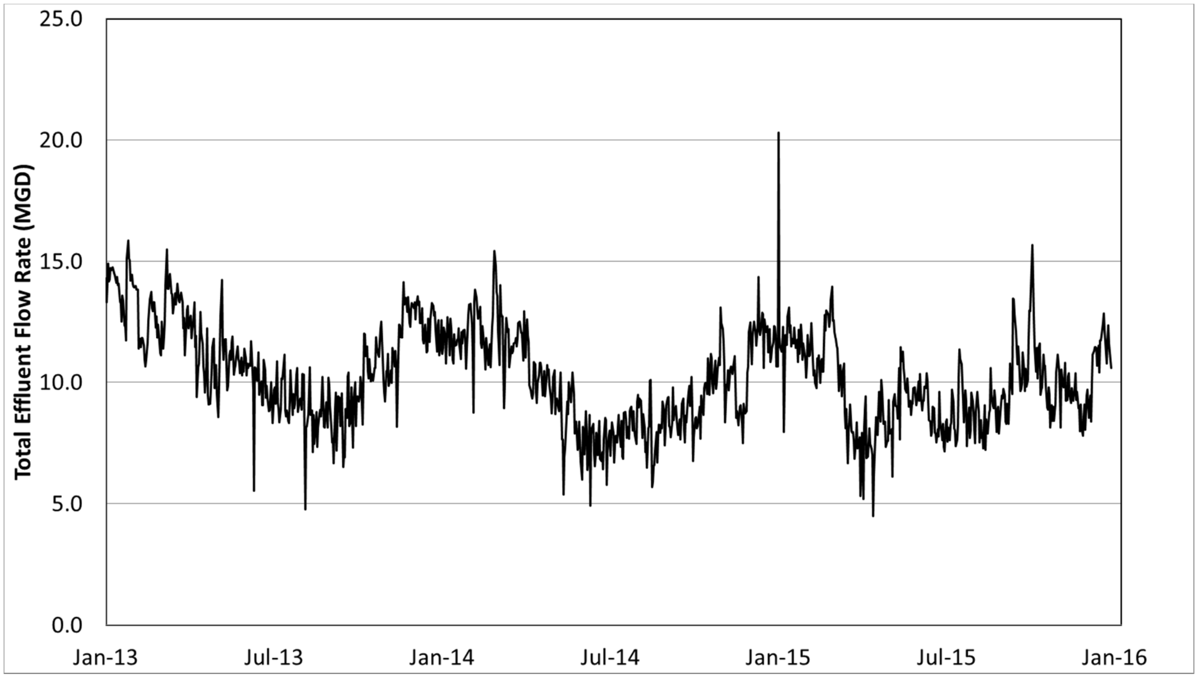


**Figure 4** **Daily Effluent Flows from LA Glendale Between 2013 and 2015**

Burbank flows are released to the Burbank Channel which enters the LA River at approximately river mile 32. Daily flow data for Burbank were not available at the time of this analysis, so the flow was estimated based on the National Pollutant Discharge Elimination System (NPDES) permit order for this plant (CA0055531) and using best professional judgment. Documentation for the permit states that in 2005 dry weather average flow was approximately 5.8 mgd (9 cfs). To represent the middle of the day (low peaking factor) during dry weather, a lower flow rate of 4.5 mgd (7 cfs) was used for the dry weather flow modeling.

In summary, the existing flows for dry weather for DC Tillman, LA Glendale, and Burbank water reclamation plants are 27.1 mgd (42.0 cfs), 7.8 mgd (12.1 cfs), and 4.5 mgd (7.0 cfs), respectively.

### 2.1.3 Groundwater Upwelling

Groundwater upwelling occurs in the soft bottom reach between river mile 32 and 25. This portion of the river between river mile 32 and 25 is often called the Narrows. The Upper Los Angeles River Area (ULARA) Watermaster report from 2012-2013 estimated that the annual average upwelling volume since 1971 has been approximately 3,257 acre feet per year (ULARA Watermaster, 2014). The City of Los Angeles assumed that groundwater upwelling in the Narrows is approximately constant throughout the year (LASAN, 2004). Therefore, this value was assumed to be constant and converted to a daily flow rate of 3.7 mgd (5.6 cfs). The flow was distributed evenly over the 8 mile soft-bottom reach in the model.

The volume of upwelling in other reaches, including the soft bottom reaches in the Sepulveda Basin and near the mouth in Long Beach, as well as hard bottom reaches with tile drains and pressure relief mechanisms, has not been studied and no quantification analyses have been performed, hence groundwater upwelling was only applied to the soft bottom reach in the Narrows.

### 2.1.4 Incidental Urban Runoff

Incidental urban runoff occurs as a result of nuisance flows such as irrigation overspray, car washes, subsurface inflows to broken storm drains, etc. as well as permitted dry weather flows. The City of Los Angeles Integrated Resources Plan estimated this value by subtracting estimates of other flow sources from the flows observed at the Wardlow Street stream gage (LASAN, 2004). They found that the dry weather flow contributed approximately 26.6 mgd (41 cfs) to that point in the river. Distributing this flow throughout the developed portion of the watershed downstream of dams (140,300 acres), the flow per developed acre was found to be 1.9e-4 mgd/impervious acre (190 gpd/imp acre). For this analysis, the impervious area downstream of dams (from the Los Angeles County Loading Simulation Program in C++ [LSPC] model) was found to be 156,400 acres, which is approximately 11% higher than the developed area used by the Integrated Resources Plan, so it provides a flow rate approximately 2.9 mgd (4.5 cfs) higher than the total estimated by the IRP. Both the IRP and this study assume (as a conservative assumption) that the dams other than Sepulveda Dam would not be discharging on this dry weather day. Therefore, only areas downstream of these dams were assumed to contribute incidental urban runoff.

The IRP estimated value of 1.9e-4 mgd/impervious acre (190 gpd/imp acre) was estimated prior to the passing of Prop O, which may have decreased incidental urban runoff.

However, considerable uncertainty exists as to how much incidental runoff currently occurs from urban areas during dry weather, and how much of that reaches the surface water bodies. Other sources provide different estimates of incidental urban runoff. The Enhanced Watershed Management Program (EWMP) for the Upper Los Angeles River (ULAR) estimates an average value for incidental urban runoff of 4.8e$^{-4}$ mgd/impervious acre (480 gpd/imp acre) based on estimates of per capita water use (ULAR watershed management group [WMG], 2016) combined with outdoor use assumptions. This estimate was created long after the passing of Prop O, but estimates dry weather incidental runoff flow rates or more than double the estimates from the IRP. In contrast, recent monitoring data from the City of Los Angeles' Prop O Penmar project suggests a value as low as 0.2e$^{-4}$ mgd/impervious acre (20 gpd/imp acre) may be occurring in certain locations. The value of 1.9e$^{-4}$ mgd/impervious acre (190 gpd/imp acre) from the IRP was based on monitoring flows in the LA River and the sources of flow to the LA River. It is also approximately midway between estimates from other sources. It was therefore selected for this study, though there is considerable uncertainty associated with it. As additional data becomes available, this value can be revised or tailored to different parts of the City.

For each river mile, the impervious area upstream was calculated (subtracting area upstream of dams except for Sepulveda Dam) using the subbasins in the Los Angeles County LSPC model and multiplied by this value to determine the incidental urban runoff contribution. Where subbasins spanned more than one river mile, the flow was interpolated linearly.

### 2.1.5 Evaporation/Evapotranspiration

Time series of potential evapotranspiration (PET) were created for the Los Angeles County LSPC model using combinations of National Climate Data Center (NCDC) evaporation pan data with pan coefficients (Los Angeles County Department of Public Works [LADPW], 2010). For the Los Angeles River, two gages were used from the model: gage 23129 Long Beach Airport downstream of river mile 24, and 23152 Burbank-Glendale-Pasadena upstream of river mile 24. The hourly PET from 1985 to 2012 between 12:00 p.m. and 5:00 p.m. in the months of June, July, and August was selected, and the average value from this selection was used from both gages. The average PET for this selection at 23129 was 0.017 inch/hour and the average PET for this selection at gage 23152 was 0.021 inch/hour. To convert these values to volumetric flow rates, the approximate width of the channel during dry weather flow was estimated by scaling from satellite imagery. In the soft bottom reaches, the thick vegetation would contribute to evapotranspiration. However, the adjustment coefficients for pan evaporation data are similar for evaporation and evapotranspiration, in this case. LA County used pan coefficients of 0.74-0.78 for June through August to adjust the computed evaporation pan values to potential evapotranspiration values (LADPW, 2010). Recommended average pan coefficients for converting pan evaporation data into evaporation rates for shallow, open water bodies are typically 0.7-0.75 (Taghvaeian and Sutherland, 2015). Therefore, the computed evaporation from shallow open water bodies are nearly as high as the evapotranspiration computed for use in the LSPC model. Therefore, the values from the LSPC model were used, directly for both hard and soft bottom reaches. Compared to the sources of inflow to the river, evaporation is a very small outflow. It is typically less than 0.12 mgd (0.2 cfs) for each river mile, and is never higher than 0.36 mgd (0.56 cfs) except at the mouth where the LA River gets very wide due to the tidal conditions.

### 2.1.6 Validation of Dry Weather Flows

The resulting flow rates from the combination of the flow inputs and outputs were compared to flow gage data from both the United States Geological Survey (USGS) and the Los Angeles County Flood Control District (LACFCD) on the LA River to determine if these were representative of summer, dry flow conditions. The daily mean flow rate in July and August between 1987 and 2014 was obtained for gages 11092450 LA at Sepulveda Basin (USGS), F57C-R LAR above Arroyo Seco (LACFCD), F319-R LAR below Wardlow River Rd (LACFCD), and F300-R at Tujunga Ave (LACFCD).

For each of these locations, the flows predicted by the model are approximately 1 standard deviation (SD) below the mean flow measured for the gage between July and August, but are well above the minimum (Table 3). Because the included flow rates only include dry summer months, a flow rate one standard deviation below the mean is representative of mid-day values during dry periods. Therefore, the model consistently predicting flows 1 standard deviation below the mean is a good, conservative representation of typical low-flow conditions between 1987 and 2014.

**Table 3 Measured Flow Rates Between July and August Compared to Flow Predicted by the Model**
**One Water LA 2040 Plan**

| Gage | River Mile | Mean, mgd (cfs) | SD, mgd (cfs) | Max, mgd (cfs) | Min, mgd (cfs) | Modeled, mgd (cfs) | One Standard Deviation Below the Mean, mgd (cfs) |
|---|---|---|---|---|---|---|---|
| 11092450 LAR at Sepulveda Dam | 43-42 | 43 (66) | 13 (21) | 332 (513) | 21 (32) | 32 (50) | 29 (46) |
| F300-R at Tujunga Ave | 37-36 | 44 (67) | 11 (18) | 180 (279) | 9 (14) | 36 (55) | 32 (50) |
| F57C-R LAR above Arroyo Seco | 25-24 | 76 (117) | 22 (34) | 217 (336) | 45 (69) | 54 (83) | 54 (83) |
| F319-R LAR below Wardlow River Rd | 4-3 | 90 (139) | 21 (32) | 233 (361) | 56 (86) | 68 (105) | 69 (107) |

## 2.2 Potential Future Conditions

There is considerable uncertainty as to what dry weather flow rates in the river will be in the future because not all management decisions have been made. However, the effect of management decisions on each of the inflows into the river is likely to decrease flows to some extent. The purpose of this analysis is not to provide definitive estimates of what the future flow rates in the river will be, but to provide the range of potential future flows from each of the inflows and outflows. These changes are summarized below in Table 4.

**Table 4 Potential Future Condition Inputs into Dry Weather Flow Model**
**One Water LA 2040 Plan**

| Input | Inflow to River, mgd (cfs) | Outflow from River, mgd (cfs) | Location | Reference |
|---|---|---|---|---|
| DC Tillman Flow | 0-27.1 (0-42.0) | N/A | RM 43 | Partially or completely recycled |
| LA Glendale Flow | 0-7.8 (0-12.1) | N/A | RM 30 | Partially or completely recycled |
| Burbank Flow | 0-4.5 (0-7.0) | N/A | RM 32 | Partially or completely recycled |
| Groundwater Upwelling | 0 to 3.6 (0 to 5.6) | N/A | Applied evenly throughout soft bottom reach | Likely to be reduced or removed due to improved groundwater management |
| Incidental Runoff from Urban Areas | 0-7.8 (0-12.1) | N/A | Applied at each river mile using between 0 and $1.9e^{-4}$ mgd per impervious acre (190 gpd/imp acre) for all contributing area downstream of dams except Sepulveda | Dry weather urban runoff eliminated per the draft ULAR EWMP (ULAR WMG, 2015). Likely to be reduced throughout the watershed over time, although there are some NPDES permits that allow for dry weather flows. |
| Evaporation/ ET | N/A | 0.017-0.60 (0.026-0.94) + additional 4.8 (7.5) in ARBOR reach | 0.017 in/hr below RM 24, 0.021 in/hr above RM 24. Additional 4.8 mgd from RM 23-33 | LA River Ecosystem Restoration Feasibility Study Appendix E (USACE, 2013): Tables 8 and 11 |

### 2.2.1 WRP Flows

Future flows from all of the water reclamation plants may be reduced or eliminated to help meet Los Angeles' water demands through enhanced recycling.

### 2.2.2 Groundwater Upwelling

The groundwater upwelling that currently occurs in the soft bottom Area with Restoration Benefits and Opportunities for Revitalization (ARBOR) reach may be reduced or eliminated in the future through focused groundwater management. However, many EWMP projects, when implemented, will increase infiltration of stormwater to groundwater aquifers in the San Fernando Valley. This could increase the flow from upwelling into the ARBOR reach which could counteract the groundwater management efforts to reduce upwelling.

### 2.2.3 Incidental Urban Runoff

Incidental runoff from urban areas is likely to be reduced as more stormwater best management practices (BMPs) are implemented in the future. These flows mostly include nuisance flows from irrigation overspray, car washing, etc., but also include some permitted dry weather flows. The EWMPs call for complete elimination or capture of dry weather nuisance flows. The ULAR EWMP shows nuisance dry weather runoff from all municipalities in the EWMP group being completely eliminated by 2037 (ULAR WMG, 2016). This may eventually be the case for the entire LA River watershed. Complete elimination of dry weather urban runoff, in combination with decreases in flows from water reclamation plants and groundwater upwelling, could cause flow rates in the river during dry weather to decrease below levels that could sustain habitat or recreation. Therefore, some level of dry weather urban runoff has value to the river.

### 2.2.4 Evaporation and Evapotranspiration

The evaporation and evapotranspiration rates are assumed to remain approximately constant in the future for most of the river, although these may increase as a result of climate change or decrease due to reduced flow widths. The U.S. Army Corps of Engineers (USACE) prepared the Los Angeles River Ecosystem Restoration Study to evaluate different restoration scenarios for a ARBOR reach of the Los Angeles River between river mile 23 and 33. Table 8 of Appendix E of that study predicts 1.061 billion gallons per year (3,257 acre feet per year) of additional evaporation and evapotranspiration for Alternative 20 in the ARBOR reach (USACE, 2015). This value was distributed throughout the year using Table 11 of Appendix E to determine the fraction of that evapotranspiration that occurs in August. This value was used to estimate the flow rate of evapotranspiration after restoration of the ARBOR reach, resulting in an additional 4.8 mgd (7.5 cfs), which was distributed evenly across the ARBOR reach (approximately 0.44 mgd/mile or 0.68 cfs/mile) over the approximately 11-mile ARBOR reach (RM 33 to 22).

## 2.3 Locations of Interest

Eight locations were considered for hydraulic modeling of the low flows. Four of these locations were the locations where the U.S. Bureau of Reclamation assessed the physical and biological habitat in the river corridor (U.S. Bureau of Reclamation, 2004). The other four were sites suggested by CDM Smith. Each of these sites is summarized in Table 5.

**Table 5 Summary of Considered Locations of Interest**
**One Water LA 2040 Plan**

| Location ID | River Mile | Description | Data Available | Selection for Modeling |
|---|---|---|---|---|
| **LA River Physical and Biological Habitat Assessment Locations (Bureau of Reclamation, 2003)** | | | | |
| Los Feliz | 28 | Soft bottom channel just upstream of Los Feliz Blvd | USACE HEC-RAS model, Cross sections from U.S. Bureau of Reclamation, 2004 | **Selected** for modeling due to channel complexity and sufficiency of bathymetric data |
| Taylor Yard | 26 | Soft bottom channel approximately 1/2 mile downstream of Route 2 | USACE HEC-RAS model, Cross sections from U.S. Bureau of Reclamation, 2004 | **Selected** for modeling due to channel complexity and sufficiency of bathymetric data |
| Balboa | 45 | Within Sepulveda Basin | Single profile of one of the check dams from U.S. Bureau of Reclamation, 2004 | **Not selected** due to insufficiency of bathymetric data |
| Willow Street | 3 | Hard bottom reach just upstream of Willow Street in Long Beach | USACE HEC-RAS model | **Selected** for modeling due to channel complexity and sufficiency of bathymetric data |
| **CDM Suggested Sites** | | | | |
| LA River Headworks Ecosystem Restoration Site | 35 | Hard bottom reach several miles upstream of the soft bottom reach | USACE HEC-RAS model | **Not selected** due to lack of channel complexity and similarity to Willow Street site |
| Nature Conservancy | 27 | Soft bottom reach between Los Feliz Blvd and Taylor Yard | USACE HEC-RAS model (though soft bottom reaches not well represented) | **Not selected** due to lack of bathymetric data and similarity to Los Feliz and Taylor Yard sites |
| Downstream of Arroyo Seco Confluence | 24 | Hard bottom reach between Arroyo Seco confluence and Rio Hondo confluence | USACE HEC-RAS model | **Not selected** due to similarity to Willow Street site |
| Estuary | 0 | In the tidal area of the river dominated by tidal flows | None | **Not selected** due to lack of influence from dry weather flows on tidal area |

Because only a limited number of sites could be modeled in this analysis, these eight sites were screened to determine the most suitable and relevant sites to conduct hydraulic modeling of the dry weather flows. In considering each location of interest for hydraulic modeling, the importance of the habitat and the availability of data for hydraulic modeling were considered. The U.S. Bureau of Reclamation selected four sites: two in the soft bottom reach in the narrows (Los Feliz and Taylor Yard), one in Sepulveda Basin (Balboa), and one just upstream of the soft bottom reach near the estuary (Willow Street). CDM Smith also suggested four sites: a hard bottom site several miles upstream of the soft bottom site (LAR Headworks Ecosystem restoration site), a soft bottom site in the narrows (Nature Conservancy), a hard bottom reach downstream of the Arroyo Seco confluence, and a soft bottom reach within the tidal influenced area (estuary).

### 2.3.1 Location Importance to Habitat and Recreation

The soft bottom reaches support vegetation and are important locations for habitat and recreation. These sites often have irregularly-shaped cross sections with large cobble bottoms, significant filamentous algae and vegetated islands. Flow controls such as rises in the bed elevation or concrete sills near bridges lead to areas of greater depths. The importance of the soft bottom reaches, particularly those deeper areas behind a flow control, are very important locations for habitat and recreation and were therefore given preference in site selection.

The hard bottom reaches typically do not support vegetation, and have either a rectangular or trapezoidal shape, sometimes with a small low-flow channel near the center. While the slope varies slightly, transitions in cross section geometry are typically mild so that the flow depth changes more gradually along the river than in the soft bottom reaches. Hard bottom reaches near the downstream end of the river, from Rosecrans Blvd to Willow Street (river miles 2.9-10) often have a large algal mat which supports avian wildlife (U.S. Bureau of Reclamation, 2004). Within the tidally-influenced portion of the river on the downstream end, significant habitat exists, but the flow regimes are not affected by the dry weather flows, ~65 mgd (~100 cfs) compared to the tides. Because hard bottom reaches tend to provide less habitat, only one hard bottom reach upstream of the tidal reaches, but within the portion containing algal mats was selected for hydraulic modeling. Each of these reaches included several representative cross sections which were all used to model the flow depth, flow width, and velocity under different flow rates.

### 2.3.2 Availability of Models and Data

The USACE has developed Hydraulic Engineering Center River Analysis System (HEC-RAS) models for most Los Angeles River reaches. However, the USACE modeled locations do not include the Sepulveda Basin. These models contain mostly rectangular or trapezoidal channel cross sections with low flow channels, where appropriate. Because these models were created to model large storm events, they typically do not contain much detail in the geometry of the river, particularly in the soft bottom reaches. The soft bottom reaches are typically modeled as simple trapezoids with a higher roughness coefficients to account for the cobble and vegetation. While this may be appropriate for large storm events, a more detailed bathymetry is needed for dry weather flows which are more affected by the micro-topography, flow controls, vegetation, and stream bottom. To determine the differences between two, much smaller flow rates other data sources were necessary to model the soft-bottom reaches.

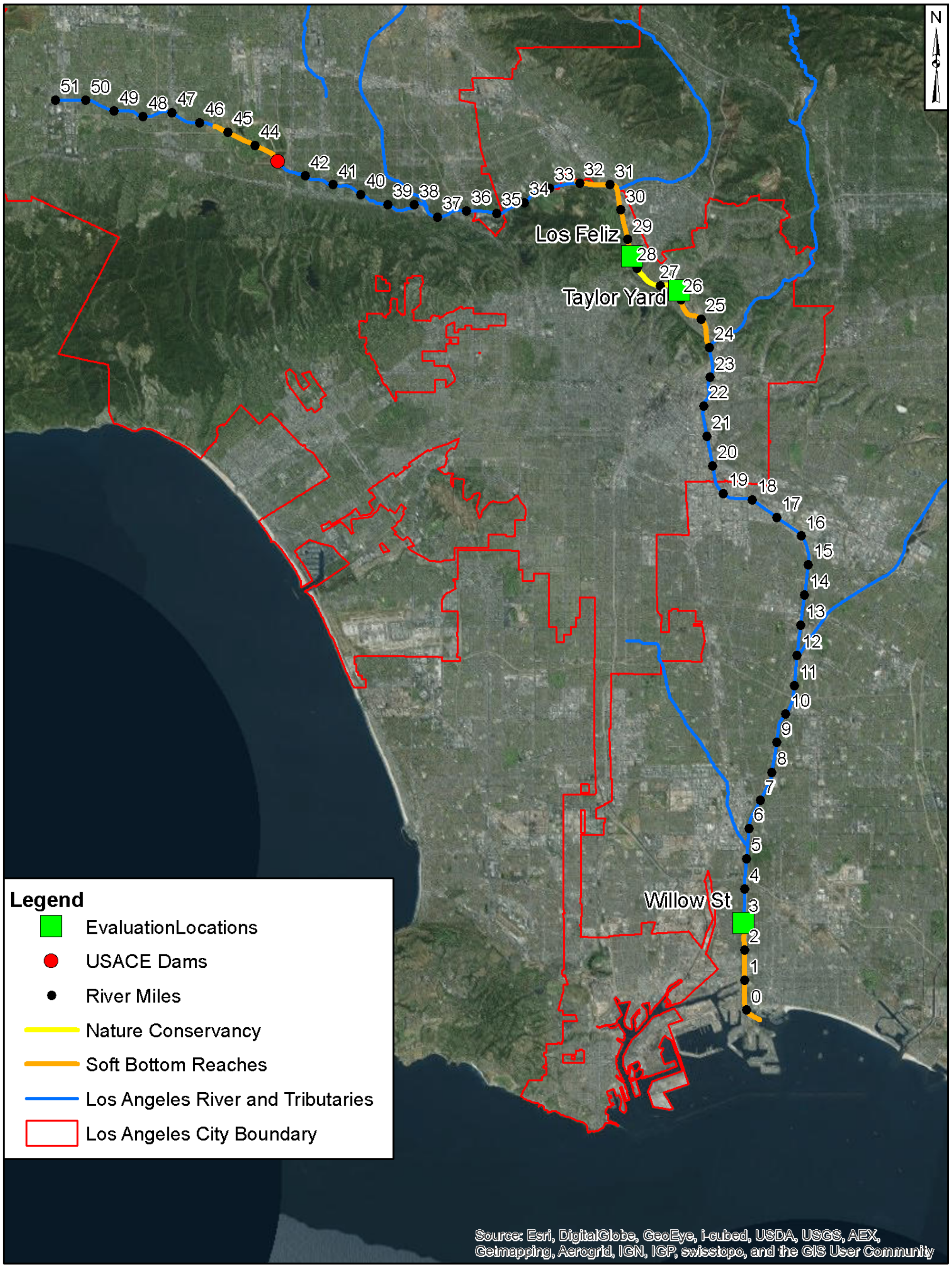
For the physical and biological habitat assessment, the U.S. Bureau of Reclamation surveyed 10 cross sections at the Los Feliz site and six cross sections at the Taylor Yard site (U.S. Bureau of Reclamation, 2004). While still somewhat coarse, these cross sections provide additional bathymetric detail which can enable hydraulic modeling of these locations. They also provided information about the flow rates, velocities, and bed materials observed which can aid in calibration of the model.

Within Sepulveda Basin, the U.S. Bureau of Reclamation surveyed only a single profile of one of the check dams. This is insufficient for modeling the Sepulveda Basin, particularly when no HEC-RAS model or other bathymetry is available.

### 2.3.3 Site Selection

Based on the consideration of the habitat importance, the Los Feliz, Taylor Yard, and Willow Street locations were selected for hydraulic modeling (Figure 5). The Los Feliz site is located at approximately river mile 28 and is a soft bottom reach just upstream of Los Feliz Blvd. The Taylor Yard site is located at approximately river mile 26 about 0.5 mile downstream of Route 2. The Willow Street site is located between river mile 3 and 4 just upstream of Willow Street in a hard bottom reach covered in an algal mat.

While the Balboa site in Sepulveda Basin is an important habitat and recreational area, there are currently insufficient data to model this area with any degree of accuracy necessary for low flows. The LA River Headworks Ecosystem Restoration Site is a hard bottom reach with minimal habitat importance and was therefore not selected for hydraulic modeling. The Nature Conservancy site lies between the Los Feliz and Taylor Yard sites and is well represented by these two locations. The location downstream of the Arroyo Seco confluence has attributes very similar to those just upstream of Willow Street Therefore, the Willow Street site was considered representative of this location. The estuary site is not affected by changes in dry weather flow rate due to the tidal influences and was therefore not selected for hydraulic modeling of dry weather flows.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

**Figure 5** Selected Locations for Hydraulic Modeling of Dry Weather Flows

## 2.4 Hydraulic Model

A hydraulic model was created for each of the locations of interest in order to evaluate the flow conditions (flow depth, flow width, velocity, wetted perimeter) associated with the range of potential dry flows. The model inputs, development, and assumptions are discussed in detail for each model below.

### 2.4.1 Los Feliz Location

#### *2.4.1.1 Model geometry*

USACE created a HEC-RAS model of the Los Angeles River and its tributaries from Sepulveda Dam (river mile 43) to river mile 27 at the Route 2 Bridge. The Los Feliz site is approximately 1.5 miles upstream of the downstream boundary of the model. This model was adapted for the hydraulic modeling of the Los Feliz site by replacing and adding cross sections in the soft bottom reaches with those surveyed by the U.S. Bureau of Reclamation. The U.S. Bureau of Reclamation surveyed 10 cross sections beginning at the concrete sill on the upstream side of Los Feliz Blvd and stretching 1217 feet upstream. These cross sections included the elevation, station, distance to the next upstream cross section, notes on the location of different bed materials (concrete sidewall, vegetated island, cobble, etc.), and the water surface extents and elevation for a flow rate of approximately 72 mgd (112 cfs) which was the measured flow at the time of surveying.

The concrete sill on the upstream side of Los Feliz Blvd corresponds to cross section 8541.532 in the HEC-RAS model. That cross section is a trapezoid in the USACE model with a channel bottom width of 190 feet. The surveyed cross section contains more detail, but has a similar bottom width (195 feet). To incorporate the surveyed cross sections, this cross section geometry was replaced with the surveyed cross section at the concrete sill surveyed by U.S. Bureau of Reclamation. The concrete sill acts as a hydraulic flow control which increases the depths upstream. The remaining nine surveyed cross sections covering the area of pooled water caused by the concrete sill were added into the HEC-RAS model upstream based on the measured distances between cross sections. The bank stations were set to the observed water surface elevation. Upstream of the surveyed cross section, the most upstream surveyed cross sections was interpolated 5,600 feet upstream to the Colorado Blvd Bridge in 100 foot intervals to smooth the transition from the surveyed cross sections to the trapezoidal cross sections upstream in the model.

The elevations in the US Bureau of Reclamation cross sections do not specify a vertical datum. Observations of the cross sections showed that the vertical datum used must be very different from that used by the HEC-RAS model. For example, the channel elevation at cross section 8541.532 is 381.1 feet in the USACE model, but 93 feet in the surveyed cross sections, a difference of 288.1 feet. In order to align the elevations in the surveyed cross sections to those in the model, the observed elevations were all increased by 288.1 feet prior to incorporating them into the model. Appendix B contains the model geometry schematic, profile, and cross sections.

#### *2.4.1.2 Boundary conditions and roughness coefficients*

The boundary conditions for all upstream and downstream boundaries were set to be normal flow, based on the slope of the channel at those locations. While normal flow may not apply to the location of interest, the upstream boundaries are many miles upstream of the location of interest, and the downstream boundary condition is approximately 1.5 miles downstream of the location of interest, so, the effect of these boundary conditions on the locations of interest is negligible.

To determine the roughness coefficients, the observed flow rate of 72 mgd (112 cfs) during the U.S. Bureau of Reclamation survey was applied to the model and the modeled water surface elevation was compared to the observed water surface elevation during the survey. The U.S. Bureau of Reclamation report did not indicate velocities at individual cross sections, but did provide a range of observed velocities. The range of velocities reported (0.1 feet per second to 1.0 feet per second) was also compared to the range of velocities predicted by the model in this reach. The Manning's roughness for the concrete areas remained at 0.015. The Manning's roughness of the cobble channel bottom and vegetated island were adjusted until the observed and model predicted water surface elevation and velocity agreed well with each other.

The Manning's roughness coefficient ranged from 0.07 to 0.15 in the cobble channel area and from 0.1 to 0.17 in the vegetated island. These are much higher than the original Manning's roughness coefficient in the soft bottom reaches of 0.03 and 0.04. However, the flow depth at this low flow is typically around 2 feet, so the large cobbles covered in filamentous algae (as was observed in the U.S. Bureau of Reclamation report) and the thick vegetation would have a much larger effect at this lower depth with a wide flow width than they would in a 50-year design storm condition, where depths are much higher. Manning's roughness generally decreases with increases in flow and depth (USACE, 2010a). The HEC-RAS Hydraulic Reference Manual suggests Manning's roughness coefficients of 0.07-0.15 for very weedy reaches of main channels, and between 0.03-0.5 for vegetal lining of channels (USACE, 2010b). Overland flow estimates of Manning's in hydrologic methods are much higher than those for channel estimates (0.15-0.41 for grass per the TR-55 method). The wide width relative to the depth along with the vegetation and large cobble compared to the depth make the low flows in this case somewhat more like overland flow than channel flow. So, while this Manning's roughness is on the high end of the range for channel flow, given the dense vegetation on the vegetated island, the large size of the cobble relative to the depth of flow, and the high flow width relative to the depth, a Manning's roughness on the higher end of the range is justified to align the observed depths, velocities, and flow rates with those predicted by the model. Because the flows used in this modeling will remain at or below this flow rate, it is justifiable to use a Manning's roughness coefficient determined by calibrating to this low flow.

### 2.4.2 Taylor Yard Location

#### *2.4.2.1 Model geometry*

USACE created a HEC-RAS model of the Los Angeles River from river mile 27 at the Route 2 Bridge to river mile 19 near the 26th St. Bridge. The Taylor Yard site is approximately 0.5 miles downstream of the upstream boundary of the model. This model was adapted for the hydraulic modeling of the Taylor Yard site by replacing and adding cross sections at this location with those surveyed by the U.S. Bureau of Reclamation. The U.S. Bureau of Reclamation surveyed six cross sections beginning at a cobble field and stretching 364 feet upstream. These cross sections included the elevation, distance from the beginning of the cross section, distance to the next upstream cross section, notes on the location of different bed materials (concrete sidewall, vegetated island, cobble, etc.), and the water surface extents and elevation for a flow rate of approximately 65 mgd (100 cfs) which was the measured flow at the time of surveying.

The cobble field that acts as the hydraulic control for this section approximately corresponds to cross section 138850 in the USACE model. The trapezoidal cross section in the model at this location was replaced by the surveyed cross section which includes the cobble field, the concrete sidewall, and the vegetated island on the west side of the channel. The remaining five surveyed cross sections were added into the model upstream based on the measured distance between the cross sections, and existing cross sections in the model were replaced. The bank stations were set to the observed water surface elevation. To smooth the transition from these natural bottom, surveyed cross sections to the trapezoidal cross sections in the model and to minimize the influence of the trapezoidal cross sections on the location of interest in the model, new cross sections were interpolated at 100 foot intervals 2,400 feet upstream of the surveyed cross sections to the Route 2 Bridge and downstream of the surveyed cross sections to existing cross section 138100 (approximately 750 feet downstream).

Similar to the Los Feliz site, the U.S. Bureau of Reclamation cross sections do not specify a vertical datum, but are clearly using a different vertical datum than that used by the HEC-RAS model. However, the difference between the bottom elevations was not 288.1 feet, as it was at the Los Feliz site, but was 240.37 feet at the location of the cobble field. It is possible that the survey conducted for these two sites each used a different, local datum. The elevations in the surveyed cross sections were all increased by 240.37 feet in order to tie in to the existing HEC-RAS model. Appendix B contains the model geometry schematic, profile, and cross sections.

#### *2.4.2.2 Boundary conditions and roughness coefficients*

The boundary conditions for all upstream and downstream boundaries were set to be normal flow, based on the slope of the channel. The upstream boundary is approximately 0.5 mile upstream of the location of interest, but the flows are small enough that this boundary condition should have minimal effect on the flow attributes at the location of interest. The downstream boundary condition is many miles downstream and does not affect the flow at the location of interest.

To determine the roughness coefficients, a similar process as at the Los Feliz site was used. The observed flow rate during the U.S. Bureau of Reclamation survey was applied to the model (100 cfs) and the modeled water surface elevation was compared to the observed water surface elevation during the survey. The U.S. Bureau of Reclamation report did not indicate velocities at individual cross sections, but did provide a range of observed velocities. The range of velocities reported (0.2 foot per second to 1.9 feet per second) was also compared to the range of velocities predicted by the model in this reach. The Manning's roughness for the concrete areas remained at 0.015. The Manning's roughness of the cobble channel bottom and vegetated island were adjusted until the observed and model predicted water surface elevation and velocity agreed well with each other.

The Manning's roughness coefficient ranged from 0.1 to 0.15 in the cobble channel area and from 0.12 to 0.17 in the vegetated island. This is a similar range as the Los Feliz site and reflects the similar condition of the cobble bed and vegetated island. These are reasonable Manning's values for low flows in this type of channel, as explained in the previous section.

### 2.4.3 Willow Street

#### *2.4.3.1 Model geometry*

USACE created a HEC-RAS model of the Los Angeles River from river mile 12 near the Imperial Highway Bridge to the mouth of the river. The Willow Street site is between river miles 3 and 4 between Willow Street and Wardlow Street The geometry at this site is well defined as a trapezoidal concrete channel with a low-flow channel near the center of the river. The geometry of the model cross sections in this site was not adjusted because no data were available to refine them, and the model already contained adequate detail for modeling of this hard bottom reach. However, in order to model the low flows accurately, the bank stations were moved to the edge of the low-flow channel. This allowed the model to compute the velocity along the shallow part of the channel and in the dry flow channel separately and provided more accurate flow characteristics. Because the Manning's roughness coefficient was not changed and was the same for the low-flow channel and the main channel, this change in bank station location did not affect the roughness of the channel. To increase stability, the distance between cross sections in this reach was decreased by interpolating cross sections at 10 feet increments using HEC-RAS.

Six cross sections between Willow Street and Wardlow St were selected as representative cross sections for this reach. The downstream cross section (XS 17700) is approximately 500 feet upstream of the Texaco pipeline which crosses the river approximately 1,500 feet upstream of the Willow St Bridge. The most upstream cross section is XS 19700 which is approximately 2,500 feet upstream of the Texaco pipeline and 2,000 feet downstream of the Wardlow Street Bridge. The six cross sections span a reach that is 2,000 feet long. Appendix B contains the model geometry schematic, profile, and cross sections.

#### *2.4.3.2 Boundary conditions and roughness coefficients*

The boundary conditions on both the upstream and downstream boundary were set to be normal flow, based on the slope of the channel. The upstream boundary is approximately 8 miles upstream and does not affect the location of interest. The downstream boundary is approximately 3 miles downstream and also has negligible effect on the location of interest. Manning's roughness coefficients were not changed from the original model for the concrete channel (0.014). No measured depth-flow rate combinations were available for this location, so the model could not be validated. However, this location has considerably less variability in slope, geometry, and roughness than the other two locations and small changes in these attributes would have only small effects on the flow depth, width, or velocity for the low range of flows modeled.

### 2.4.4 Flow Rates

At each of the three selected locations of interest, a range of flow rates were run in the model in 3.2 mgd (5 cfs) increments to fully bracket a range of dry weather conditions, including the existing conditions, at each site. Using a range of flows allows for examination of the effects of incremental changes in flow on flow depth, flow width, and velocity.

The change in flow depth, flow width, and velocity were plotted with flow rate for each of the modeled cross sections at each location (10 at Los Feliz, 6 at Taylor Yard, and 6 at Willow Street). The average from all cross sections was also plotted at each location at each parameter. Cross sections and water surface profiles showing the water surface elevations from selected flow rates within the range were also created. In the plots, cross sections, and profiles, the existing flow rates from the dry weather flow model are highlighted for each location.

# 3.0 RESULTS

## 3.1 Dry Weather Flows

The dry weather flow rates under the existing conditions are summarized on Figure 6 and Table 6 at the modeled locations of interest and other points of interest within the river. A detailed table of flows for each river mile is included in Appendix C for both cfs and mgd units. In the existing condition, flow rates are 4.3 mgd (6.6 cfs) entering the Sepulveda Basin, made up of incidental urban runoff. Downstream of the Sepulveda Dam, the effluent flows and environmental flows from DC Tillman increase the flow rate to 32 mgd (49 cfs). Additional incidental urban runoff, WRP flows, and groundwater upwelling increase the flow rate to 52 mgd (80 cfs) and 53 mgd (82 cfs) at the Los Feliz and Taylor Yard sites, respectively. At Willow Street, incidental urban runoff from the remaining watershed increases flow to approximately 67 mgd (104 cfs).

Under future conditions, the flows have the potential to decrease dramatically. Each of the inflows could potentially be significantly reduced or may remain the same, so the potential future flow rates at any of these sites could range from 0 up to the existing flow rate depending on the management actions taken to the various inflows. For this reason, hydraulic modeling was conducted over the range of potential dry weather flow conditions.

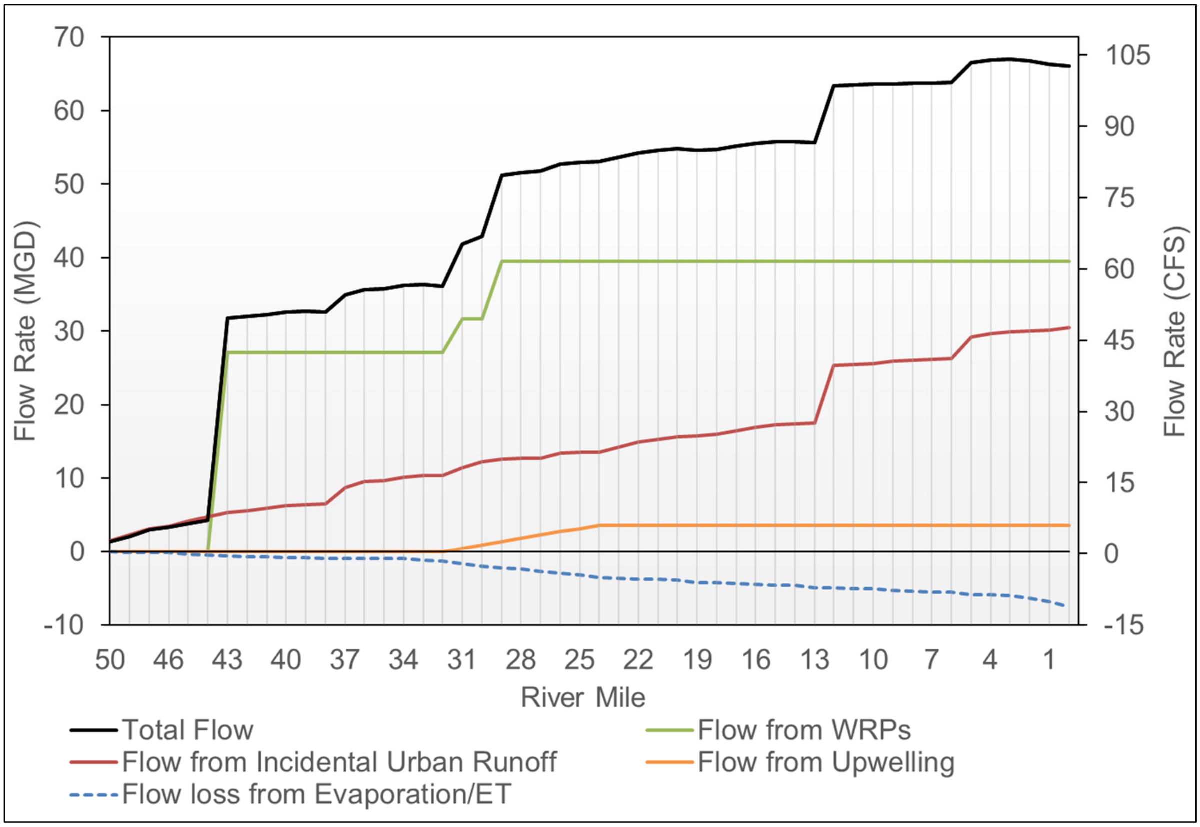


**Figure 6** Dry Weather Flow Rate in the LA River by River Mile

**Table 6** Dry Weather Flow Rates at Locations of Interest in the Los Angeles River
One Water LA 2040 Plan

| Location | River Mile | Existing Dry Weather Flow Rates, mgd (cfs) |
|---|---|---|
| Sepulveda Basin | 46-45 | 4.3 (6.6) |
| Just Downstream of Sepulveda Dam | 44-43 | 32 (49) |
| Los Feliz Site | 29-28 | 52 (80) |
| Taylor Yard Site | 27-26 | 53 (82) |
| Leaving LA Forebay | 20-19 | 55 (85) |
| Rio Hondo Confluence | 13-12 | 63 (98) |
| Willow Street Site | 4-3 | 67 (104) |

## 3.2 Flow characteristics

At each of the three locations, the flow depth, flow width, and velocity resulting from a range of flow rates between 6.5 mgd (10 cfs) and 71 mgd (110 cfs) were modeled to bracket the existing and potential future flows. The sections below include plots of each of these three parameters with flow rate and representative cross sections with the water surface elevation from a range of flow rates. In each of these figures, the existing flow rate for that location is highlighted. Because HEC-RAS uses the units of cfs for flow, only these units are shown in the figures and tables below created using HEC-RAS outputs. Water surface profiles, all cross sections, and tables of other flow parameters are included in Appendix B.

### 3.2.1 Los Feliz Site

Cross sections (XS) showing the depth of flow at 10 (6.5 mgd), 20 (13), 40 (26), 60 (39), 80 (52 mgd), and 100 cfs (65 mgd), as well as the existing flow rate are shown on Figure 7 through Figure 10. While flows rates were modeled in 5 cfs (3.2 mgd) increments, only these flow rates are shown in the cross sections for clarity. Figure 11 through Figure 13 show the flow depth, flow width, and velocity, respectively, as a function of flow rate at all cross sections at the site. The effect of different flow rates on each of these flow characteristics is discussed in the sections below.

#### *3.2.1.1 Flow depth*

The effect of flow rate on the flow depth varies due to the different geometries of the cross sections in this location (Figure 7 through Figure 10). The minimum depth at all flow rates occurs at the concrete sill of the bridge which is acting as a weir (Figure 11). At the existing flow rate, the depth at this location is less than 0.5 foot and would only decrease by approximately 0.2 foot at a flow rate of 10 cfs (6.5 mgd). The maximum depth at all flow rates occurs just upstream of the sill in the deepest part of the pooled water created by the concrete sill. The depth at the existing flow rate at this location is approximately 2.7 feet and would only decrease by approximately 0.3 foot if the flow was decreased to 10 cfs (6.5 mgd). Further upstream, in narrower cross sections, changes in flow have a greater effect on flow depth. At the cross section 1,217 feet upstream of the concrete sill, the change in depth from the existing flow rate to 10 cfs (6.5 mgd) would be approximately 1.2 feet. The average depth is 2 feet at the existing condition and ranges between 1.3 feet and 2.2 feet for flow rates between 10 cfs (6.5 mgd) and 100 cfs (65 mgd) (Figure 11).

#### *3.2.1.2 Flow width*

Flow width was relatively insensitive to the changes in flow rate at most cross sections due to the wide, shallow geometry at these low flow rates (Figure 12). The two farthest upstream cross sections, which have the narrowest channel shape show the largest change with changes in flow rate, while on the downstream portion of the site, changes in flow width are negligible between 10 cfs (6.5 mgd) and 100 cfs (65 mgd). The average flow width decreases by less than 20 feet between 10 cfs (6.5 mgd) and 100 cfs (65 mgd) (Figure 12).

### 3.2.1.3 *Velocity*

The highest velocity is at the concrete sill because it is the shallowest cross section (Figure 13). This is also the location where the velocity is most sensitive to changes in flow rate. Even at this cross section, velocities are relatively small ranging from 1.4 feet per second at the existing flow rate to 0.55 feet per second at 10 cfs (6.5 mgd). At the other cross sections, velocities are always less than 1 foot per second, even at 100 cfs (65 mgd). The average velocity changes from approximately 0.75 feet per second at the existing flow rate to 0.3 feet per second at 10 cfs (6.5 mgd). Velocity changes are not monotonic for some ranges of flow rates at the sill due to the heterogeneity of the cross section bottom. Sudden changes in wetted area and resulting average Manning's roughness from one flow rate to another can cause the average velocity to change in a non-monotonic way at those flow rates. This was only observed at the concrete sill and at the farthest upstream cross section.

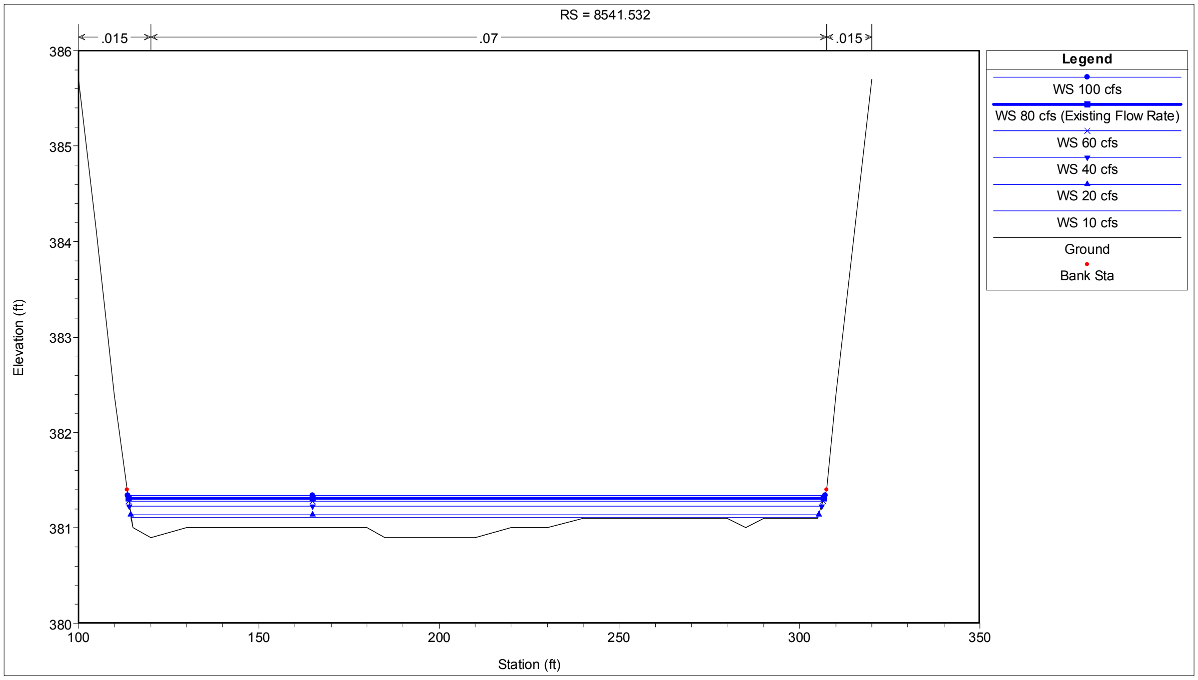


**Figure 7** **Cross Section of the Concrete Sill at the Los Feliz Site (XS 8541, RM 28.46)**

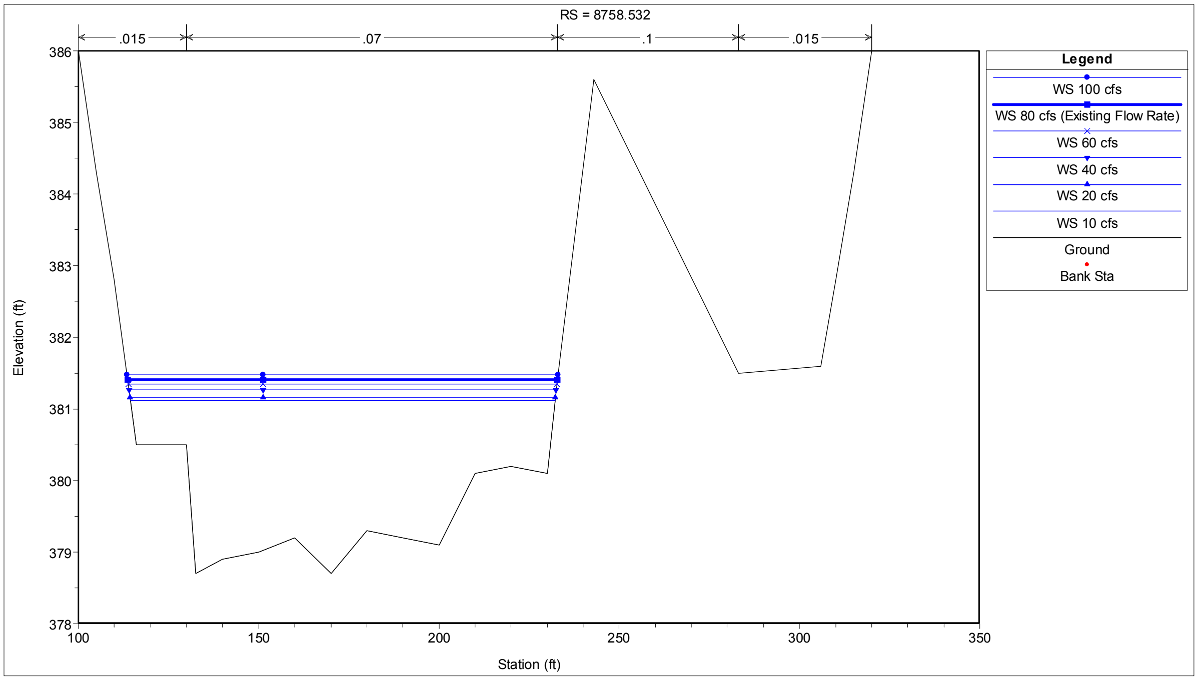


**Figure 8** Cross Section 217 Feet Upstream of the Concrete Sill at the Los Feliz Site (XS 8758, RM 28.50)

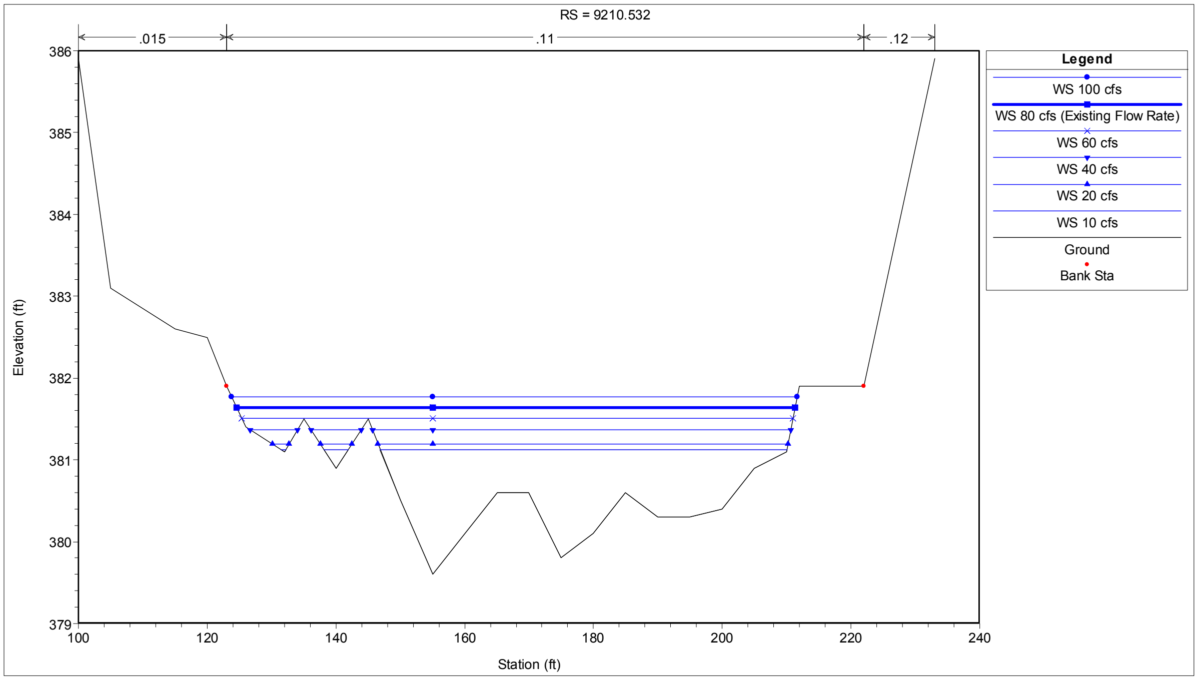


**Figure 9** Cross Section 669 Feet Upstream of the Concrete Sill at the Los Feliz Site (XS 9210, RM 28.59)

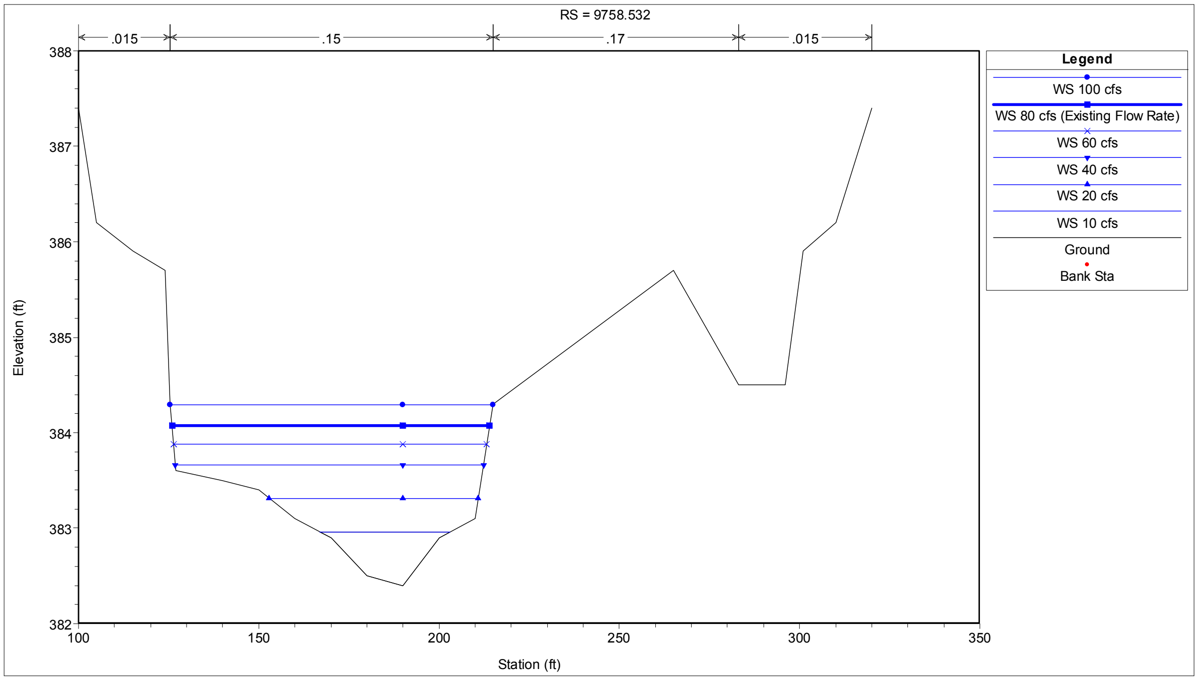


**Figure 10** Cross Section 1217 Feet Upstream of the Concrete Sill at the Los Feliz Site (XS 9758, RM 28.69)

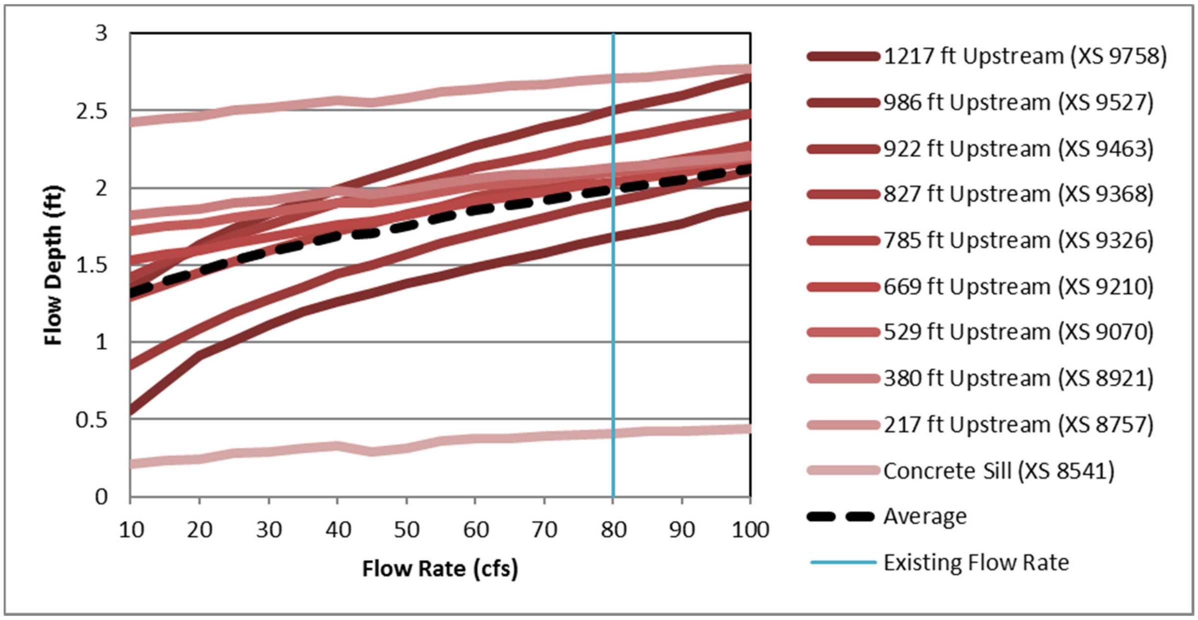


**Figure 11** Flow Depth as a Function of Flow Rate at Cross Section in the Los Feliz Site

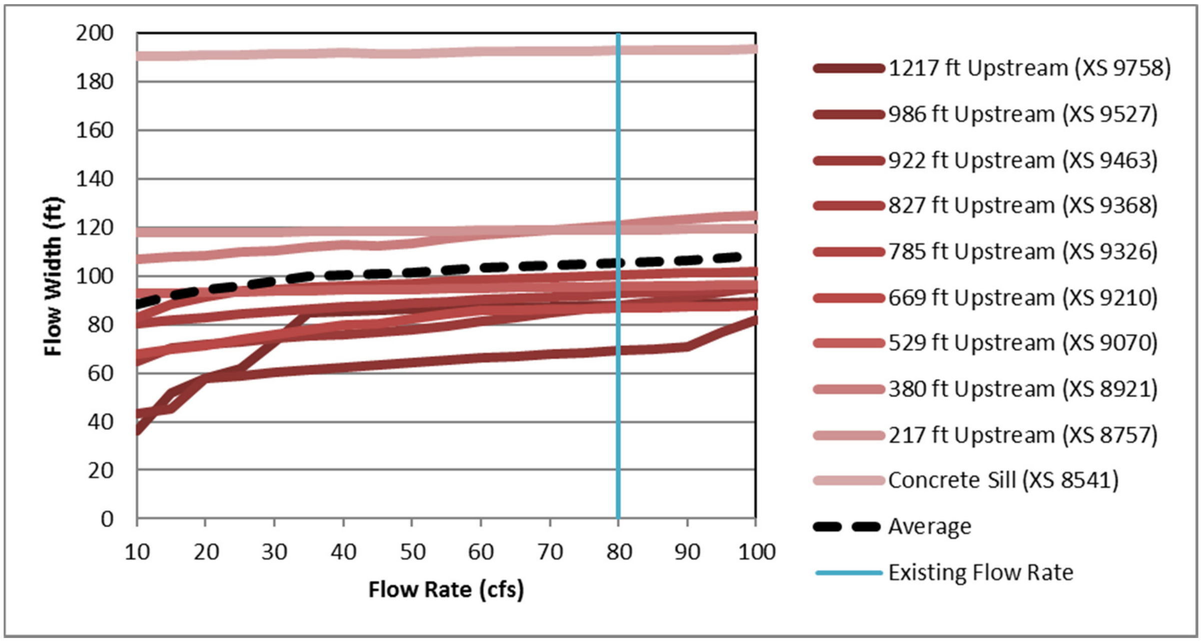


**Figure 12** **Flow Width as a Function of Flow Rate at Cross Section in the Los Feliz Site**

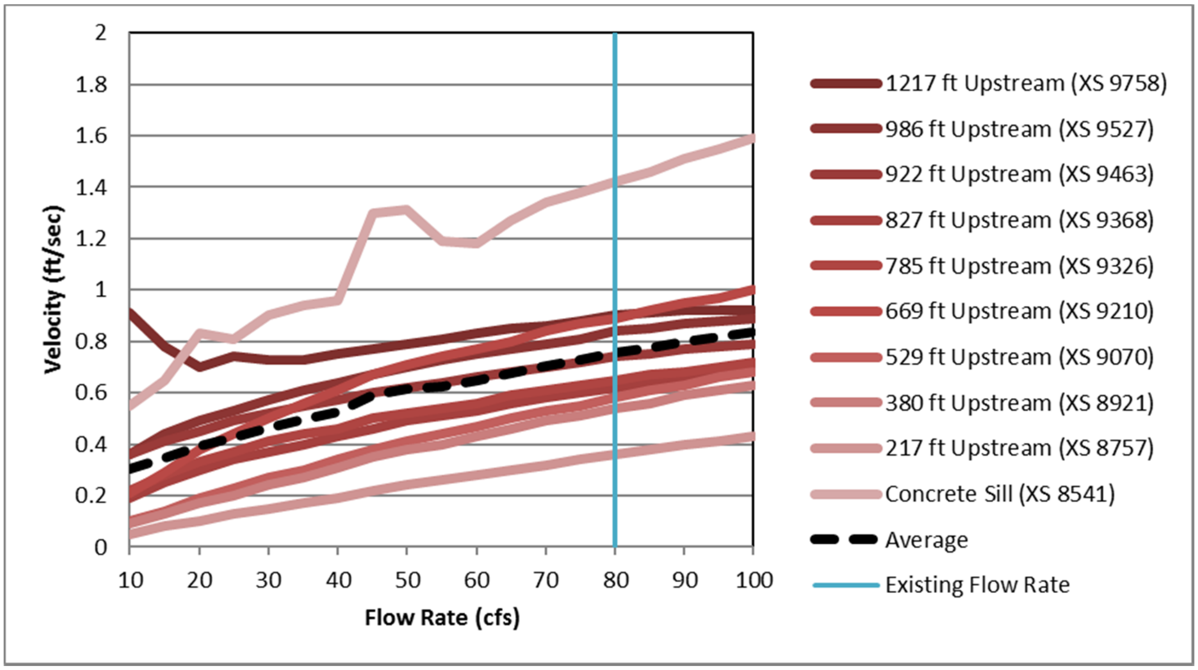


**Figure 13** **Velocity as a Function of Flow Rate at Cross Section in the Los Feliz Site**

### 3.2.2 Taylor Yard Site

Cross sections showing the depth of flow at 10 (6.5 mgd), 20 (13), 40 (26), 60 (39), 80 (52 mgd), and 100 cfs (65 mgd), as well as the existing flow rate are shown in Figure 14 through Figure 16. While flows rates were modeled in 5 cfs increments, only these flow rates are shown in the cross sections for clarity. Figure 17 through Figure 19 show the flow depth, flow width, and velocity, respectively, as a function of flow rate at all cross sections at the site. The effect of different flow rates on each of these flow characteristics is discussed in the sections below.

#### *3.2.2.1 Flow Depth*

The effect of flow rate on the flow depth is fairly consistent across all of the cross sections (Figure 17). The change from the existing flow rate to 10 cfs (6.5 mgd) decreases the depth at all cross sections by approximately 1.2 feet. The average flow depth decreases from approximately 2.8 feet at the existing flow rate to 2.6 feet at 10 cfs (6.5 mgd). Similar to the Los Feliz site, the lowest depths observed for all flow rates occurred at the flow control. The highest depths occurred 140 feet upstream of the flow control. The flow depth at all other cross sections was similar. This change in flow depth at this location is slightly larger than at the Los Feliz site, but the cross sections are more homogenous, so the effect if more consistent across the site.

#### *3.2.2.2 Flow Width*

The effect of changes in flow rate on flow width were much larger at this location than at Los Feliz (Figure 18). The largest effects occur below flow rates of approximately 50 cfs (32 mgd) because this is the flow rate in which the flow begins to leave the wider areas and be more contained in the narrower portion of the channel. The average flow width decreases from approximately 85 feet at the existing flow rate to 45 feet at 10 cfs (6.5 mgd).

#### *3.2.2.3 Velocity*

Similar to Los Feliz, the highest velocity is at the flow control because it is the shallowest cross section (Figure 19). At the other cross sections, velocities are always less than 1 foot per second and decrease more steadily with flow rate. The average velocity changes from approximately 0.8 foot per second at the existing flow rate to 0.45 foot per second at 10 cfs (6.5 mgd) (Figure 19). Non-monotonic changes in the average velocity with flow rate were observed only at the flow control at flow rates where there are sudden changes in geometry or average Manning's roughness.

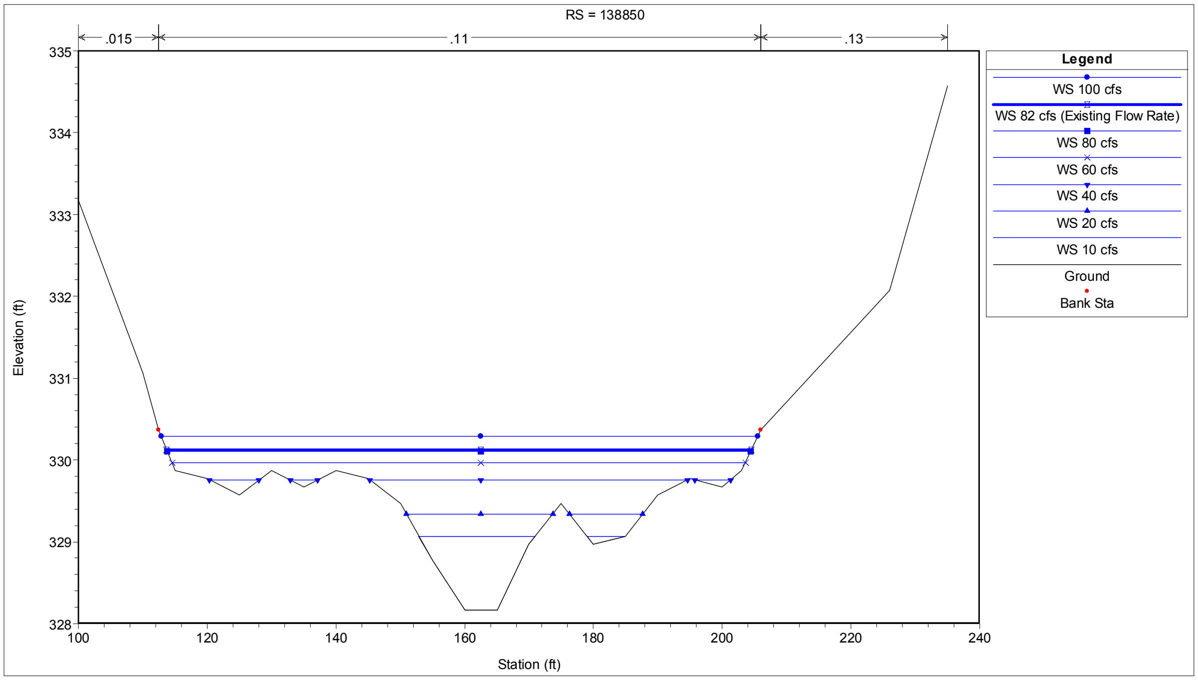


**Figure 14** Cross Section of the Flow Control at the Taylor Yard Site (XS 138850, RM 26.20)

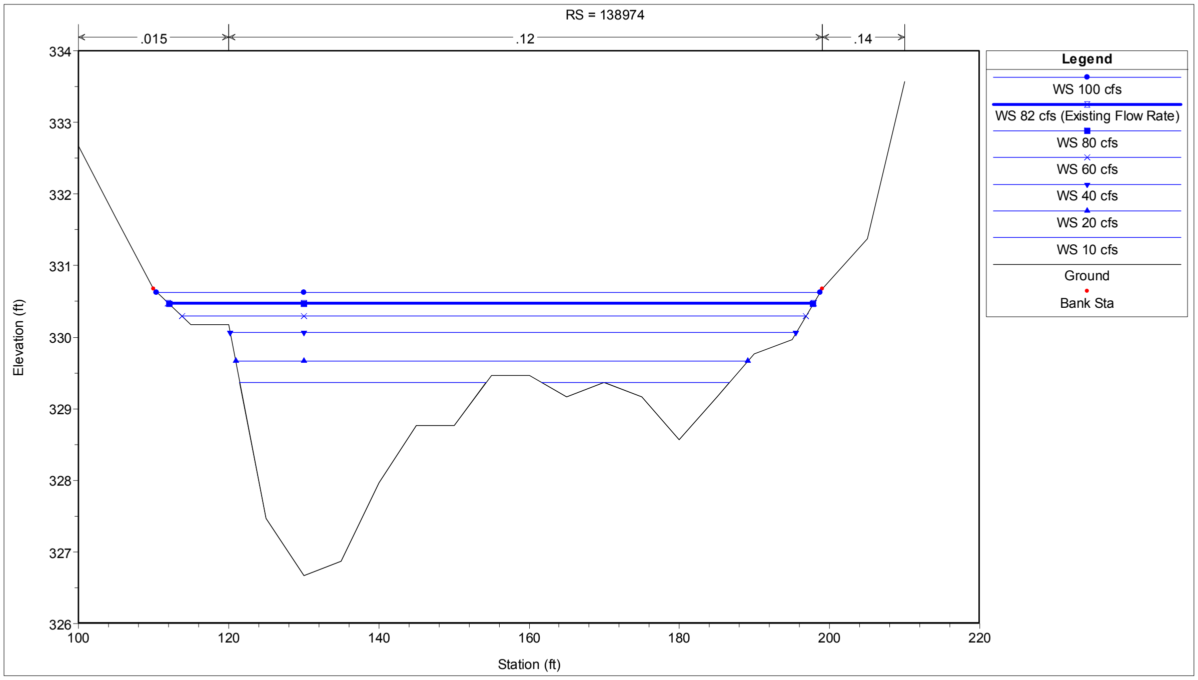


**Figure 15** Cross Section 140 Feet Upstream of the Flow Control at the Taylor Yard Site (XS 138974, RM 26.23)

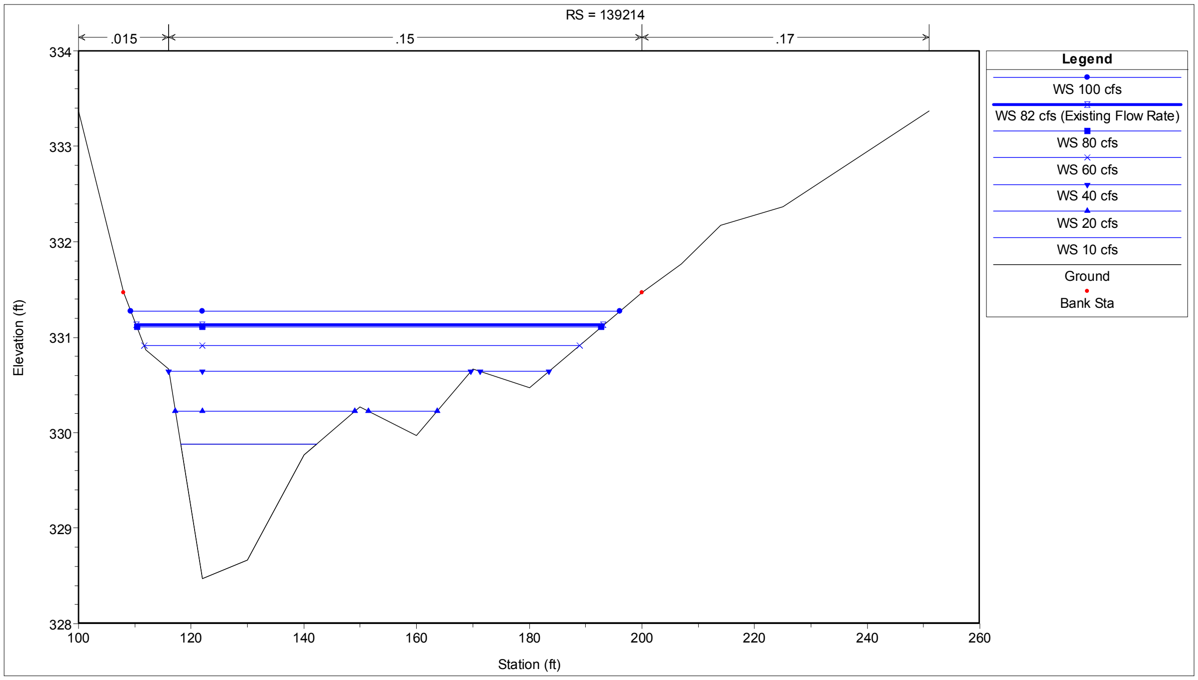


**Figure 16** Cross Section 364 Feet Upstream of the Flow Control at the Taylor Yard Site (XS 139214, RM 26.27)

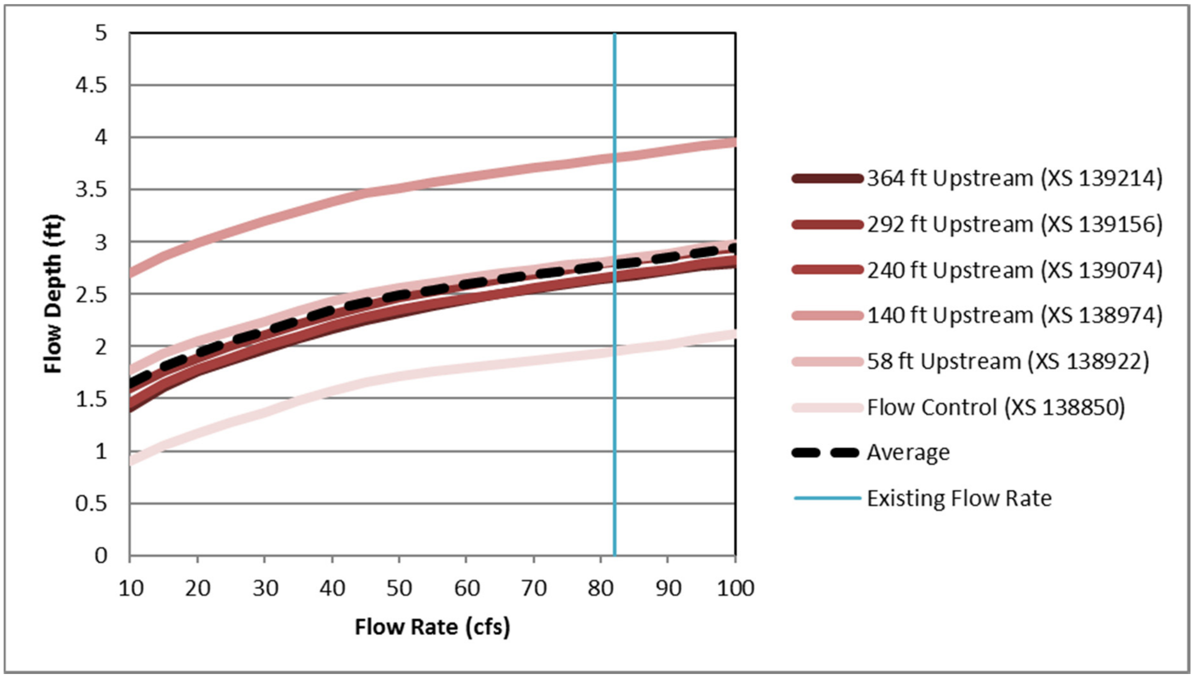


**Figure 17** Flow Depth as a Function of Flow Rate at Cross Sections in the Taylor Yard Site

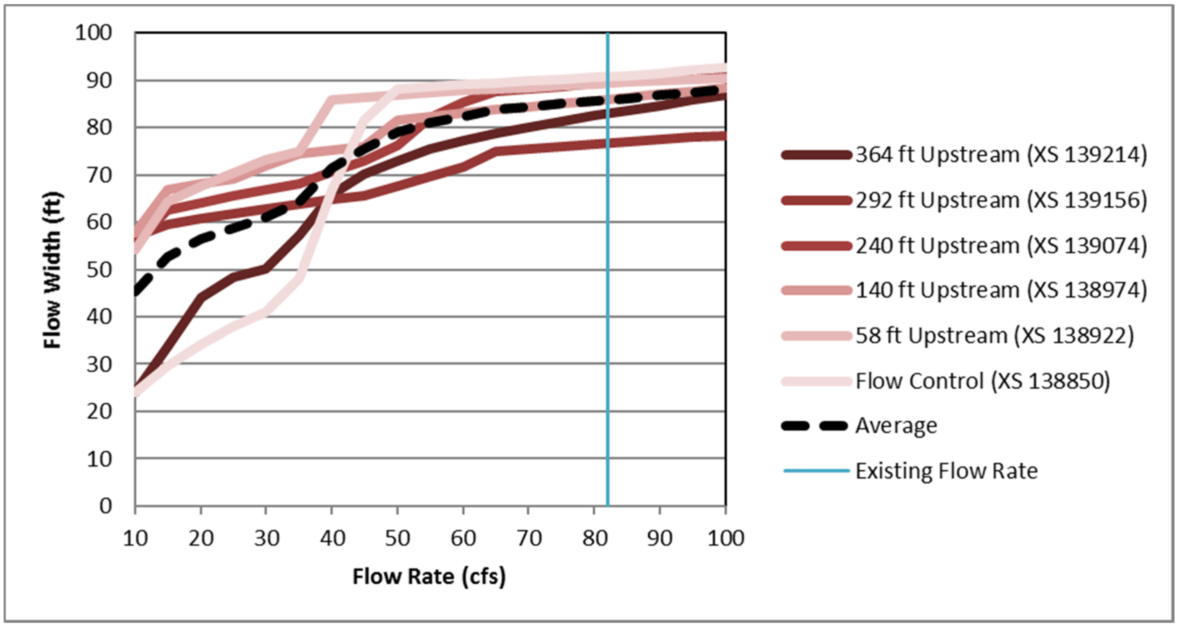


**Figure 18** Flow Width as a Function of Flow Rate at Cross Sections in the Taylor Yard Site

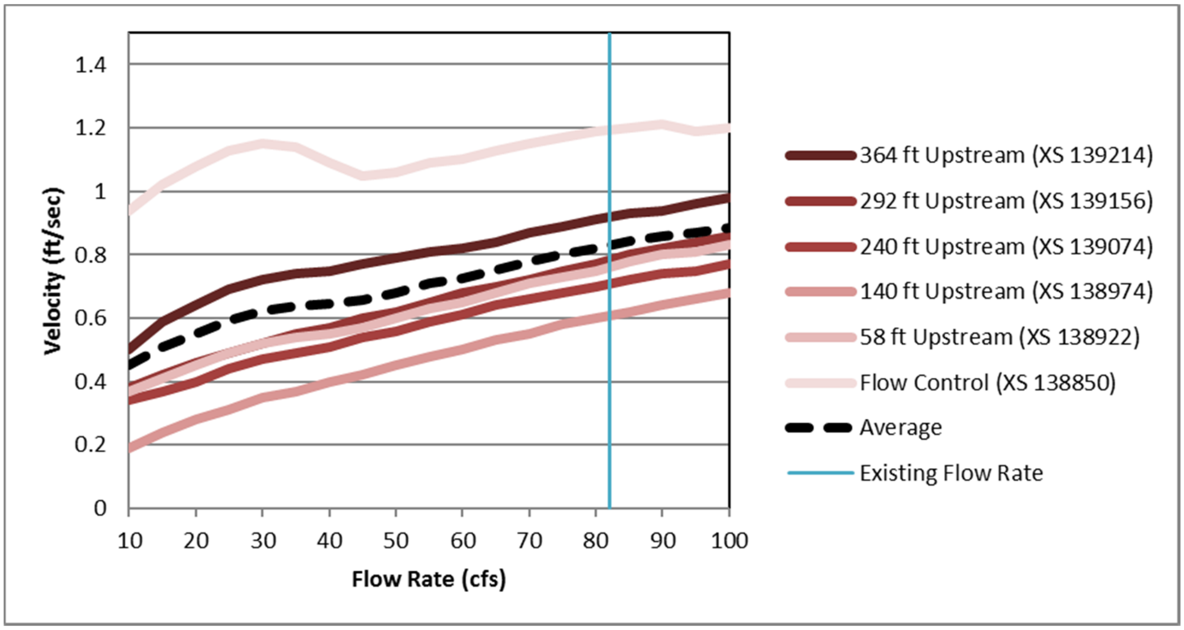


**Figure 19** Velocity as a Function of Flow Rate at Cross Sections in the Taylor Yard Site

### 3.2.3 <u>Willow Street Site</u>

Cross sections showing the depth of flow at 10 (6.5 mgd), 20 (13), 40 (26), 60 (39), 80 (52 mgd), 100 cfs (65 mgd), and 110 cfs (71 mgd) , as well as the existing flow rate are shown in Figure 20 through Figure 22. While flows rates were modeled in 5 cfs (3.2 mgd) increments, only these flow rates are shown in the cross sections for clarity. Figure 23 through Figure 26 show the flow depth, flow width, velocity in the low-flow channel, and velocity outside the low-flow channel (where applicable), respectively, as a function of flow rate at all cross sections at the site. The effect of different flow rates on each of these flow characteristics is discussed in the sections below.

#### *3.2.3.1 Flow Depth*

The flow depth at this location was very consistent across all of the cross sections due to the homogeneity in the cross section shape. The flow depth decreases from between approximately 1.1 feet at the existing flow rate to approximately 0.3 foot at 10 cfs (6.5 mgd) (Figure 23). The magnitude of this change in flow depth is similar to that observed in the soft-bottom channels.

#### *3.2.3.2 Flow Width*

The low-flow channel has a strong effect on the flow width at this site. Below 70-80 cfs (45-52 mgd), the flow is completely contained in the low-flow channel, so the change in flow width with flow rate is very small. When the flow rate increases, the flow fills the low-flow channel and fills the flat bottom of the rest of the channel causing the flow width to increase suddenly (Figure 24). Between 75 and 80 cfs (48-52 mgd), the flow width increases from approximately 34 feet to 300 feet as it fills the flat bottom which increases the wetted perimeter available for habitat by almost a factor of 10. Once this flat bottom is full, the change in flow width once again becomes small with changes in flow rate. The existing flow rate causes shallow flow over the whole channel, so the flow width is approximately 300 feet. At the future flow rate, the flow width is within the low-flow channel and would be only 25 feet.

#### *3.2.3.3 Velocity*

The velocity at this site is different between the deeper, narrower flow in the low-flow channel and the shallow flow in the rest of the channel when the low-flow channel is filled. Velocities are higher in the low-flow channel. Therefore, the velocities in the low-flow channel and the velocities in the rest of the channel are plotted separately with flow rate in Figure 25 and Figure 26, respectively. Velocities in the low-flow channel are approximately 3 feet per second at the existing condition where the dry flow channel is filled, while the velocity in the rest of the channel is only 0.6 foot per second. In the future condition, if flow is completely contained in the low-flow channel, the velocity decreases to approximately 1.5 feet per second at a flow rate of 10 cfs (6.5 mgd) (Figure 25).

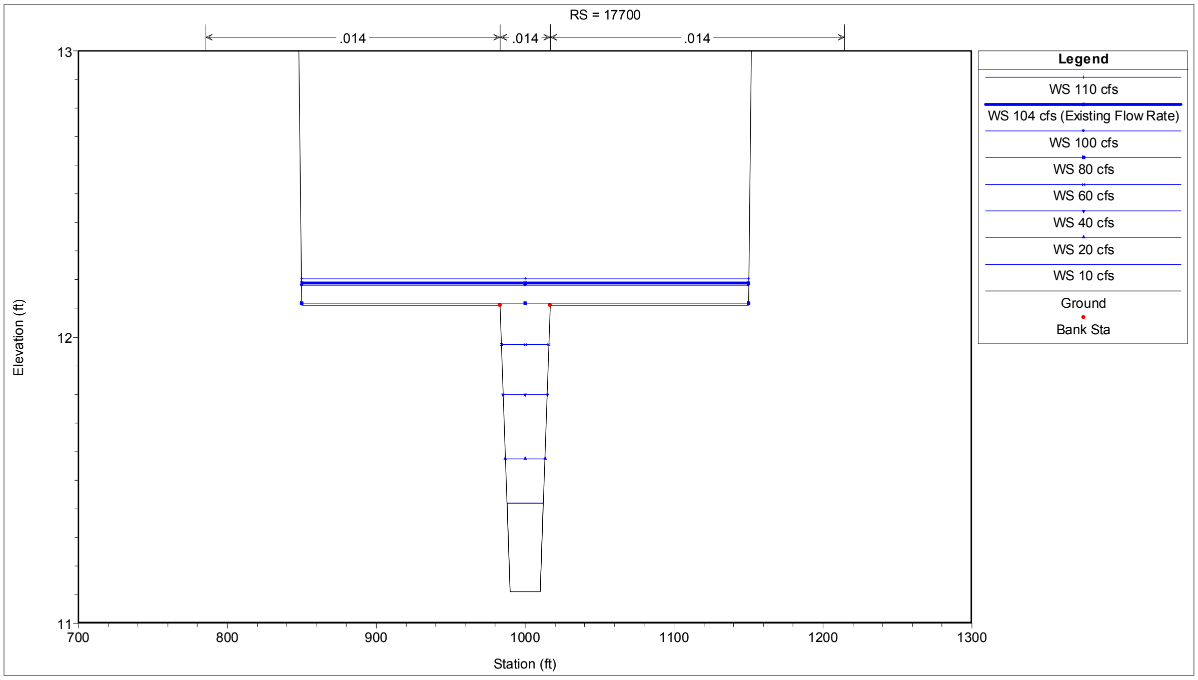


**Figure 20** Cross section 500 Feet Upstream of the Texaco Pipeline at the Willow Street Site (XS 17700, RM 3.23)

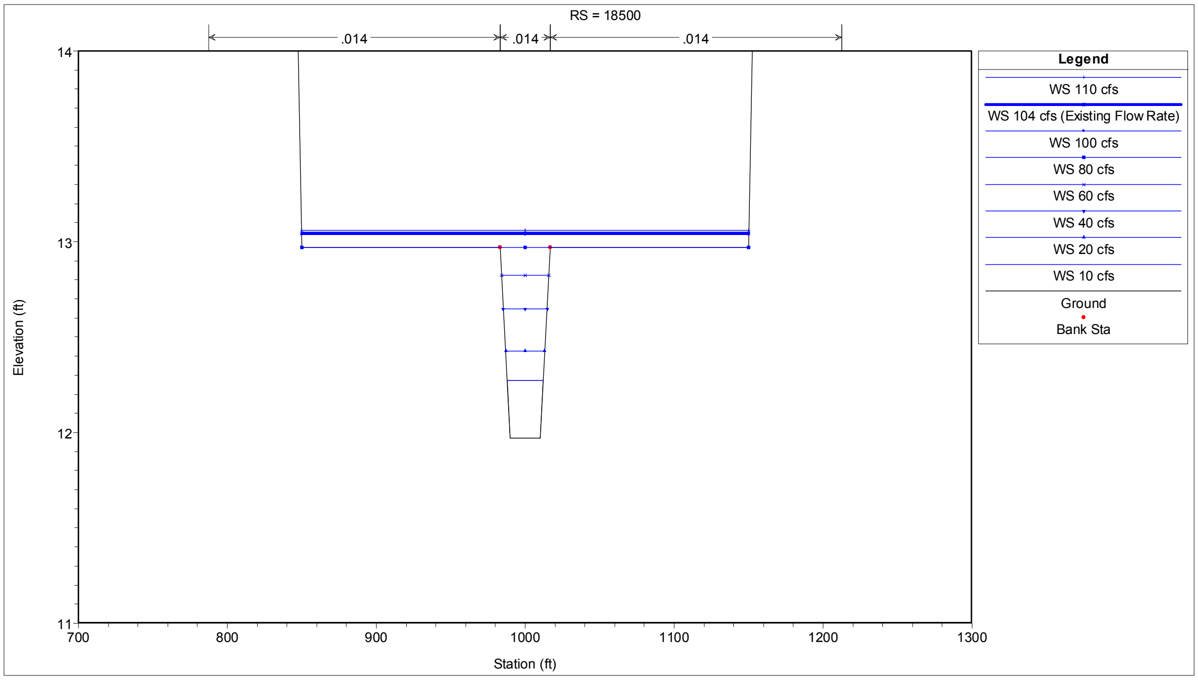


**Figure 21** Cross section 1312 Feet Upstream of the Texaco Pipeline at the Willow Street Site (XS 18500, RM 3.38)

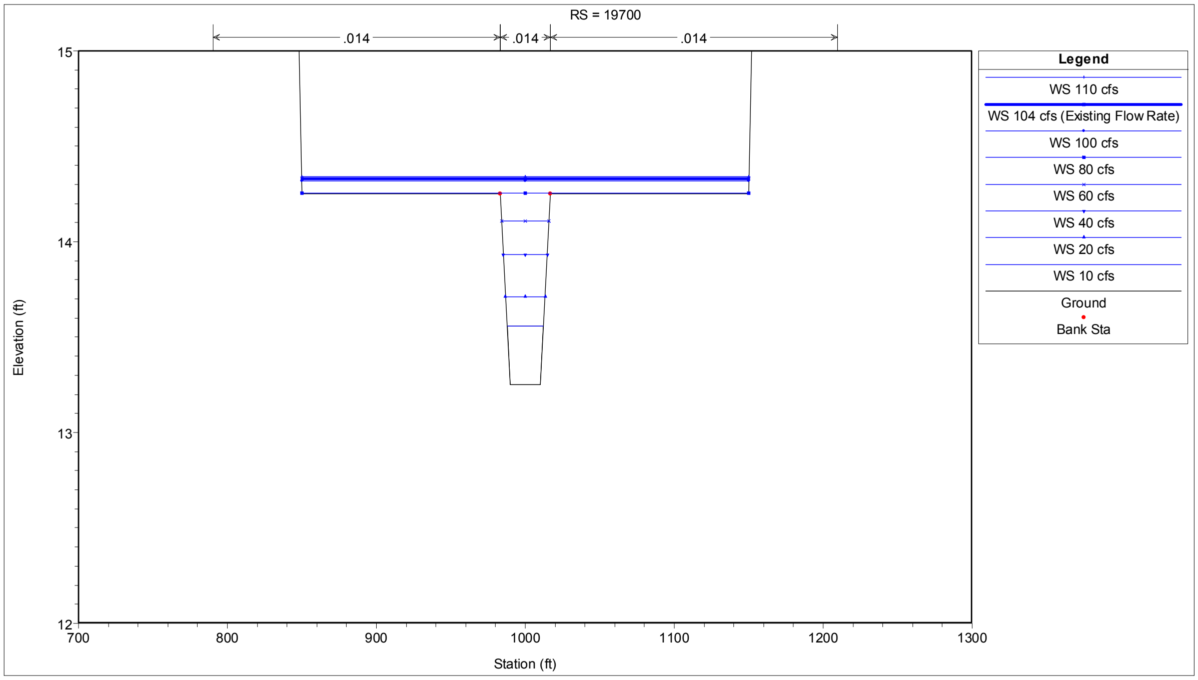


**Figure 22** Cross section 4126 Feet Upstream of the Texaco Pipeline at the Willow Street Site (XS 19700, RM 3.61)

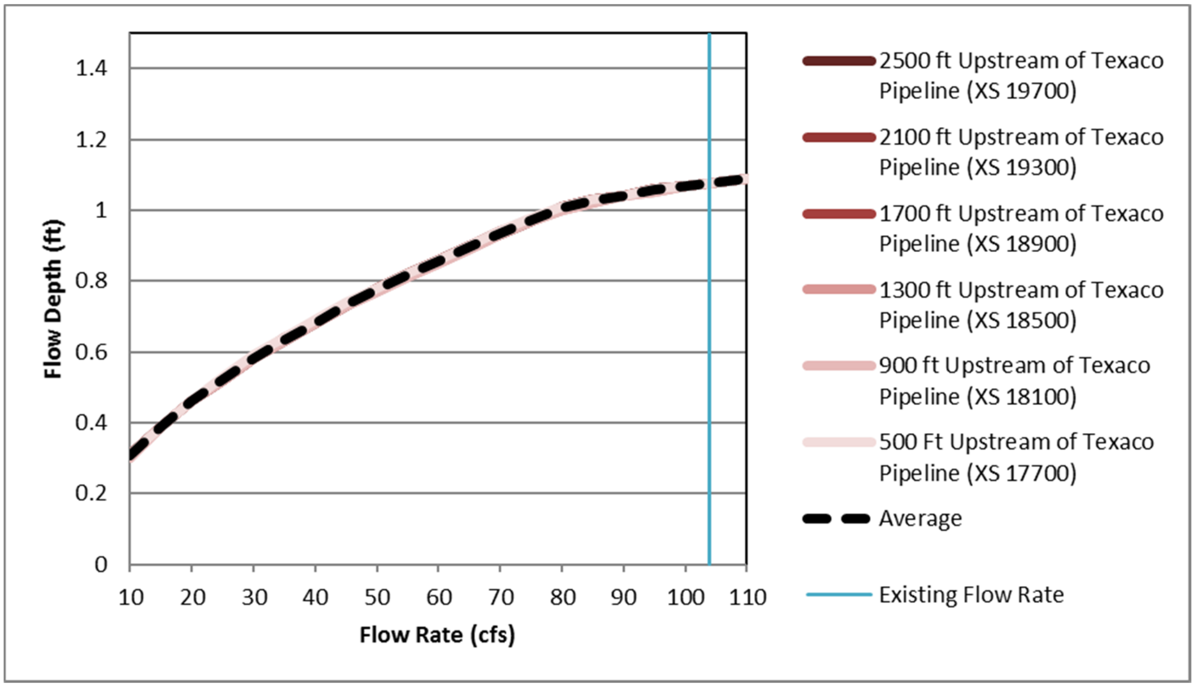


**Figure 23** Flow Depth as a Function of Flow Rate at Cross Section in the Willow Street Site

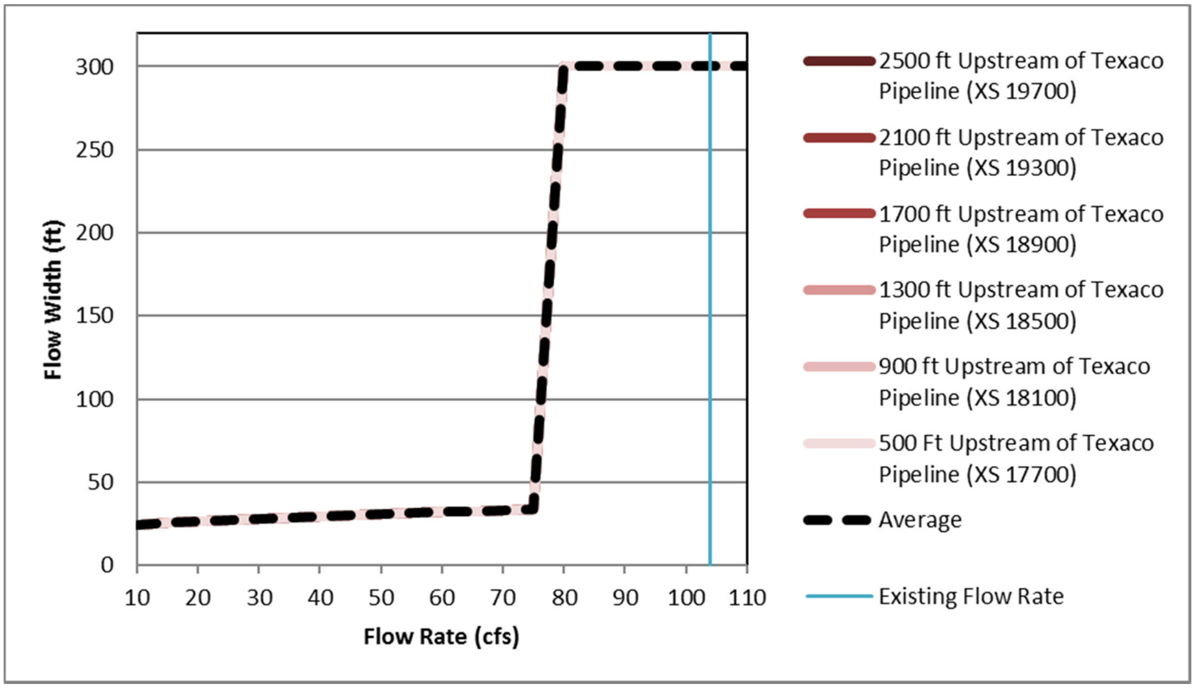


**Figure 24** Flow Width as a Function of Flow Rate at Cross Section in the Willow Street Site

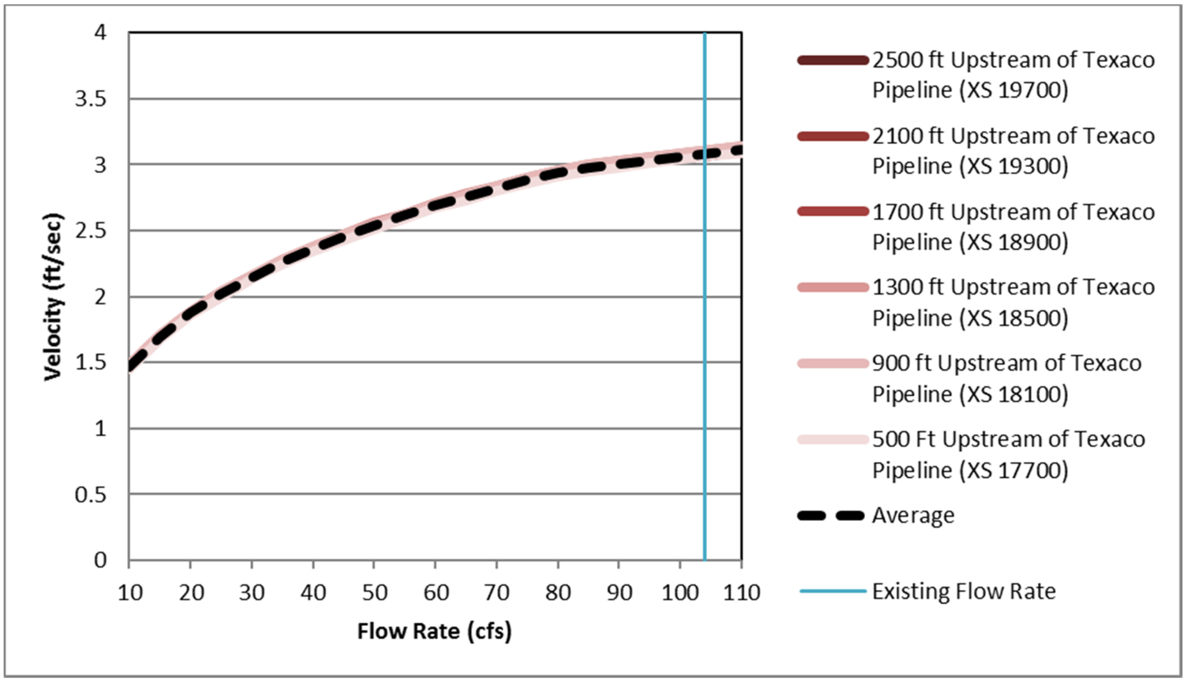


**Figure 25** Velocity in the Low-Flow Channel as a Function of Flow Rate at Cross Section in the Willow Street Site

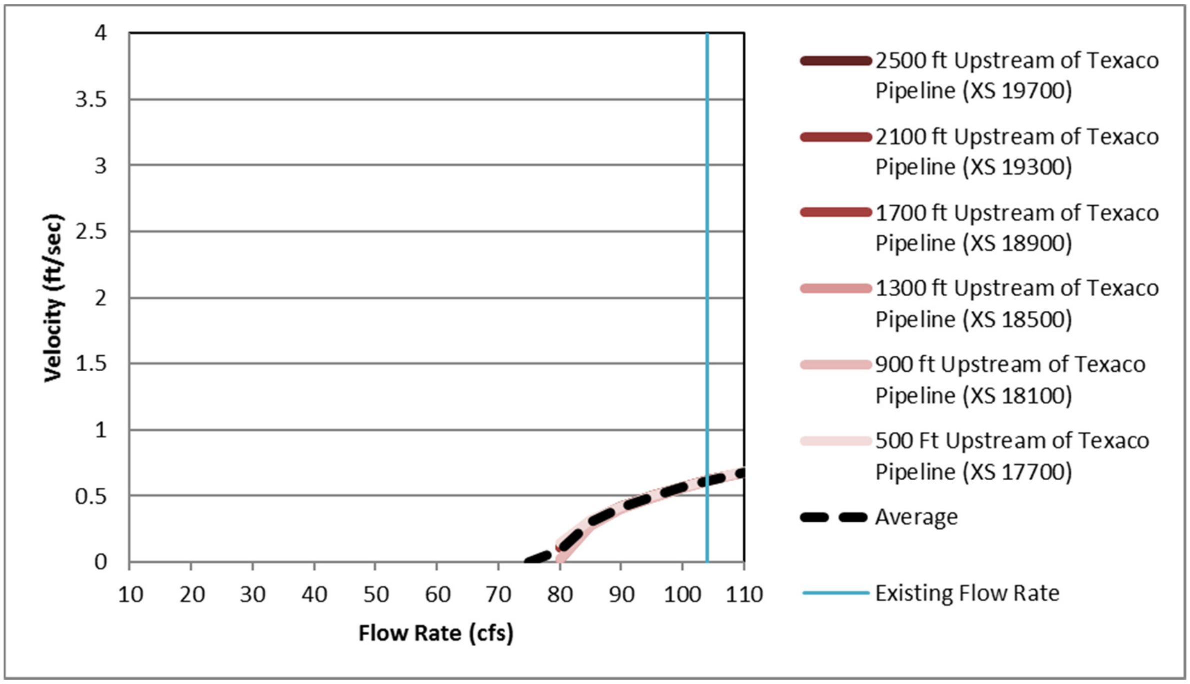


**Figure 26** Velocity Outside the Low-Flow Channel as a Function of Flow Rate at Cross Section in the Willow Street Site

# 4.0 CONCLUSIONS

The dry weather flow rate in the river increases with distance downstream due to urban dry weather runoff, WRP flows, and groundwater upwelling. The majority of the flow comes from the WRP flows, followed by urban dry weather runoff. Approximate flow rates are 4.3 mgd (6.6 cfs) upstream of Sepulveda Basin, 32 mgd (49 cfs) immediately downstream of Sepulveda Dam, 52 mgd (80 cfs) in the narrows, and 64 mgd (100 cfs) at Willow Street. Flow rates at each river mile are shown in Figure 6 and Tables 10 and 11 in Appendix C. Future management of the flow inputs are likely to decrease flow rates in the river, though there is considerable uncertainty associated with the potential decrease in each source of dry weather flow. The model developed in this study can be used to evaluate different management scenarios for individual inflows to observe the effect they will have on dry weather flow rate within in the river.

Hydraulic parameters affecting habitat and recreation (flow width, flow depth, velocity, and wetted perimeter) were evaluated based on a range of dry weather flows between 10 cfs (6.5 mgd) and the existing flow rate at three locations of interest in the river. These results are shown in Figures 7 through 26 in Section 3.2. The flow depth was fairly insensitive to changes in flow rate at all three locations. The average change in flow depth at all three locations studied was approximately 1 foot or less for decreases in flow from the existing flow rate of 80-104 cfs (52-67 mgd) to 10 cfs (6.5 mgd).

Changes in flow width were insensitive to changes in flow rate at all three locations except where the change in flow rate caused flows to leave a wider overflow area and be contained in a low flow channel. The flow rates at which this occurred varied by cross section and location. At Los Feliz, this occurred only at one cross section and occurred below flows of 35 cfs (23 mgd). At Taylor Yard, this was typical to all cross sections and generally occurred at approximately 50 cfs (32 mgd). At Willow Street, this was typical at all cross sections and occurred between flows of 70 cfs (45 mgd) and 80 cfs (52 mgd).

The velocity in the narrows was typically less than 1 foot per second, even at flow rates of 100 cfs. Decreases in flow down to 10 cfs (6.5 mgd) decreased the velocity to approximately 0.3-0.4 foot per second. Upstream of Willow Street in the hard bottom section, the velocity was approximately 3 feet per second in the low-flow channel and 0.6 foot per second in the rest of the channel. Decreasing the flow caused flow to be contained in the low-flow channel and velocity to decrease to 1.5 feet per second at 10 cfs (6.5 mgd).

The flow depth, flow width, and velocity in the river are important parameters to consider when evaluating habitat and recreational opportunities in the river. The results of the hydraulic modeling in this study can be used to inform how a specific change in flow rate will affect these parameters at specific locations in of interest the river. This information can help managers to make decisions about how to best balance the uses of water in the river.

While this study is very useful for this purpose, using a 1-dimensional hydraulic model with somewhat coarse geometry to model very low flows places limitations on the ability to predict other parameters and evaluate the effect of changes in flow rate on habitat in more detail. Additional, more detailed geometry data, especially within the soft bottom reaches, would enable more refined 2-dimensional or 3-dimensional models that could more precisely capture the changes in physical parameters with changes in flow rate. Sediment transport could also be introduced as part of a 2-dimenstional or 3-dimensional model to better capture how the river geometry in the soft-bottom reaches is changed due to large storm events.

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# APPENDIX A

## REFERENCES

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LASAN City of Los Angeles Department of Public Works, Bureau of Sanitation and Department of Water and Power, (2004) City of Los Angeles Integrated Resources Plan: Facilities Plan. Volume 3: Runoff Management.

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USACE U.S. Army Corps of Engineers (2015) Los Angeles River Ecosystem Restoration Feasibility Study Draft-Appendix E

# APPENDIX B

## HEC-RAS MODEL INPUTS AND OUTPUTS

# Model Schematics

## Los Feliz

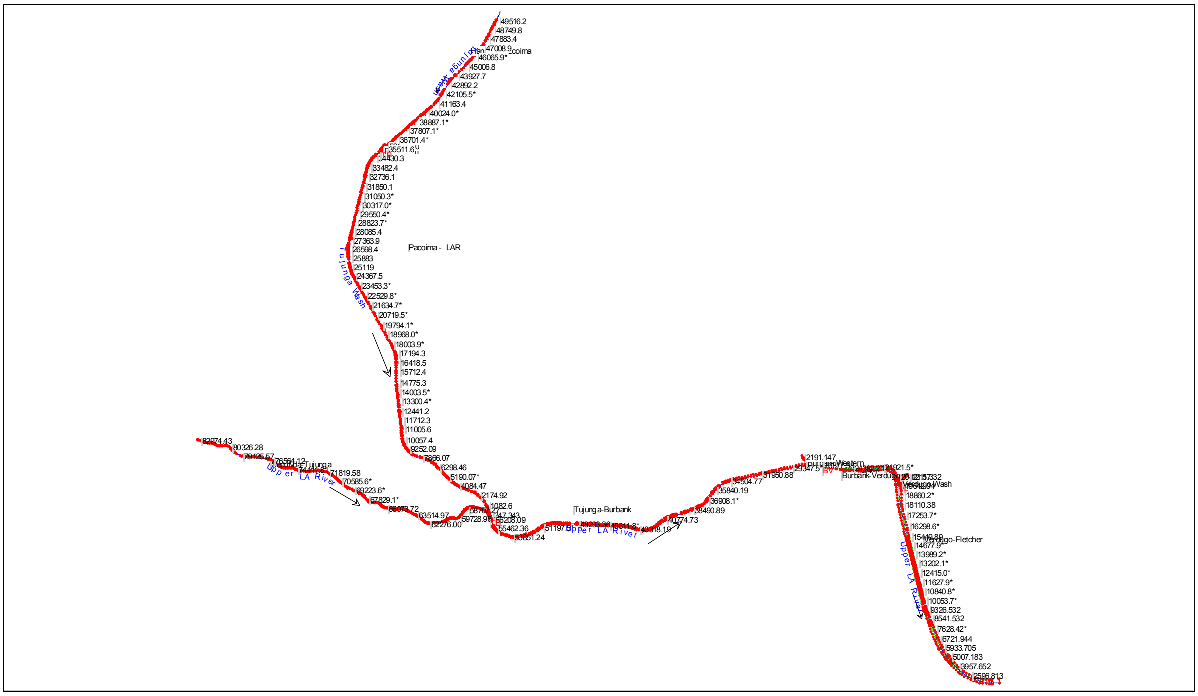

Figure 27 Model Schematic of the Los Feliz Model

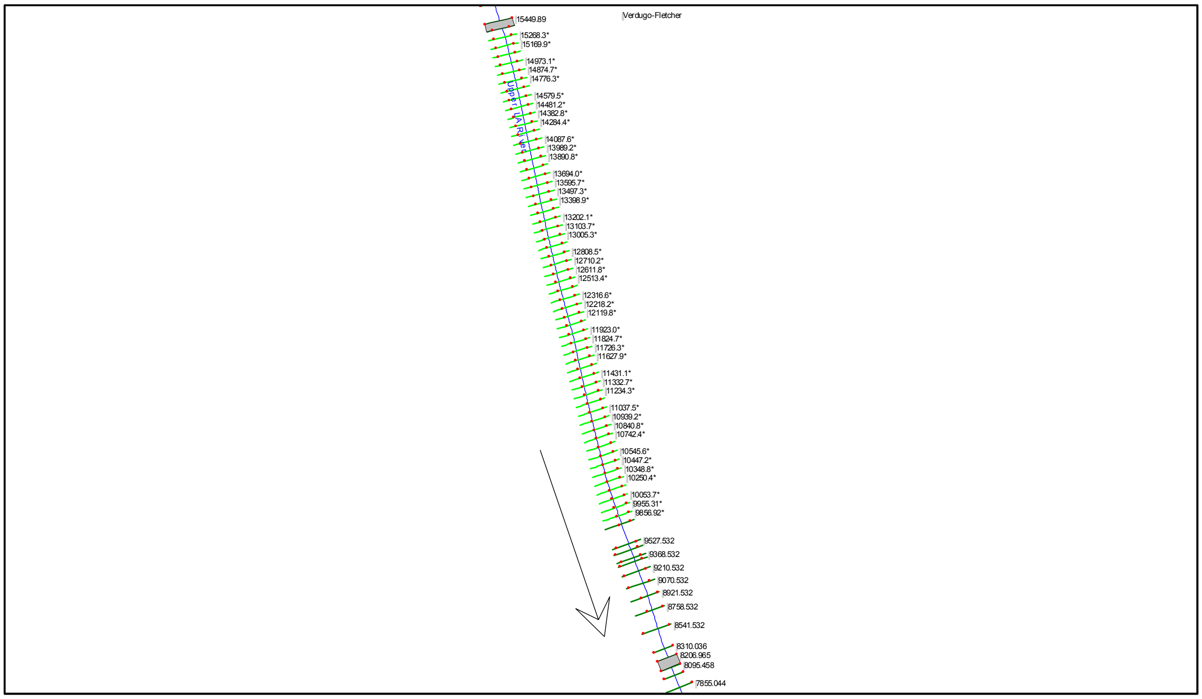

Figure 28 Model Schematic of the Los Feliz Model Zoomed in on the Location of Interest

## Taylor Yard

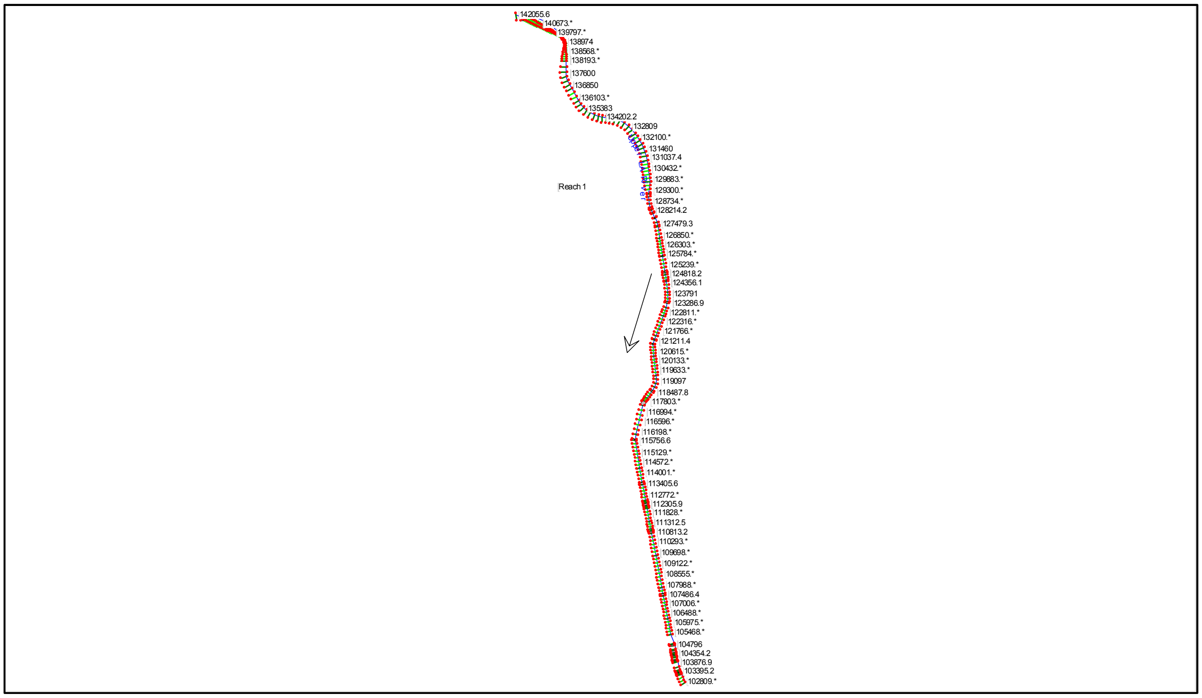

Figure 29 Model Schematic of the Taylor Yard Model

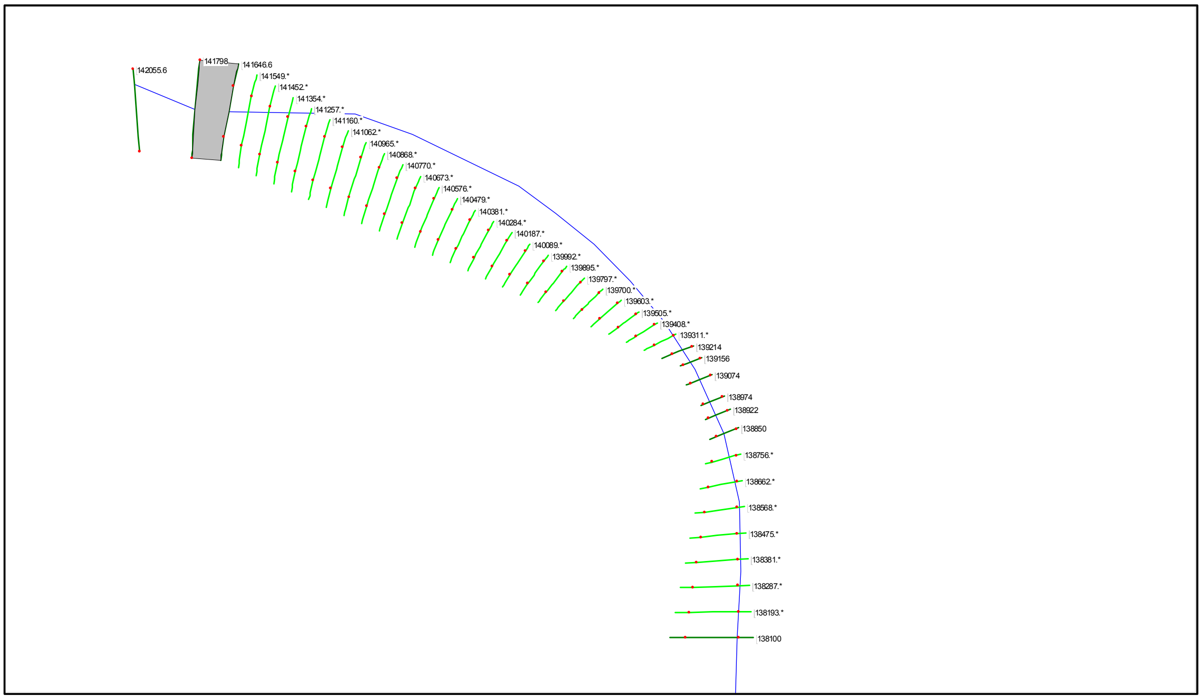

Figure 30 Model Schematic of the Taylor Yard Model Zoomed in on the Location of Interest

## Willow Street

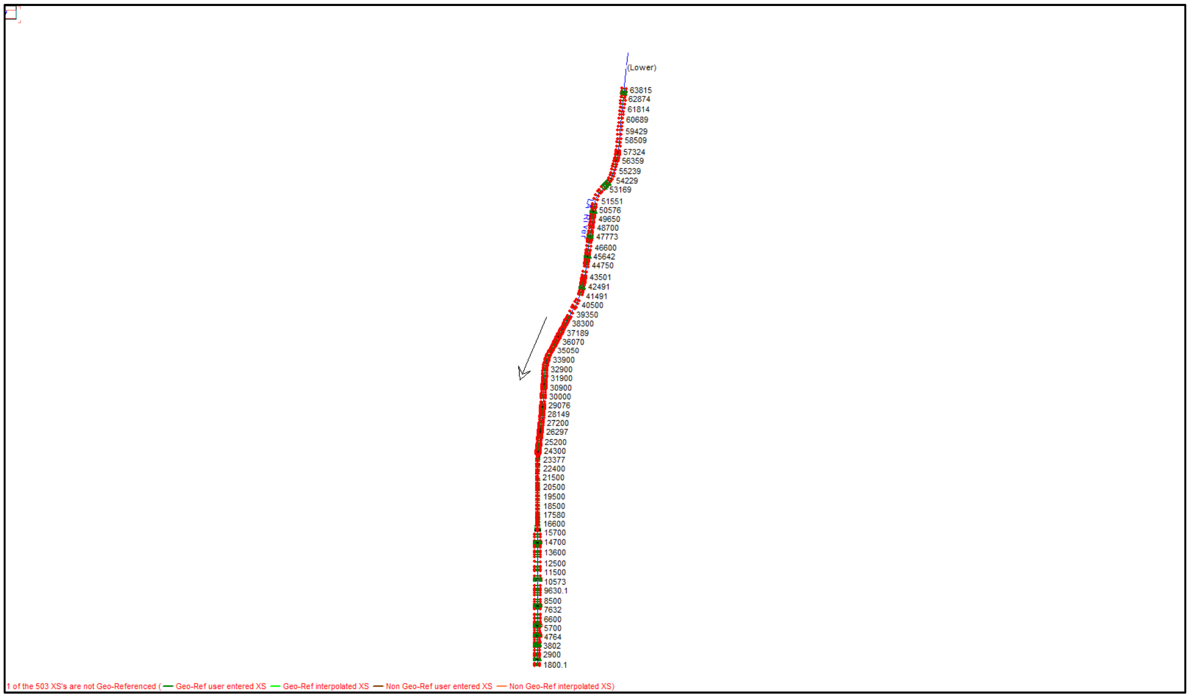

Figure 31 Model Schematic of the Willow Street Model

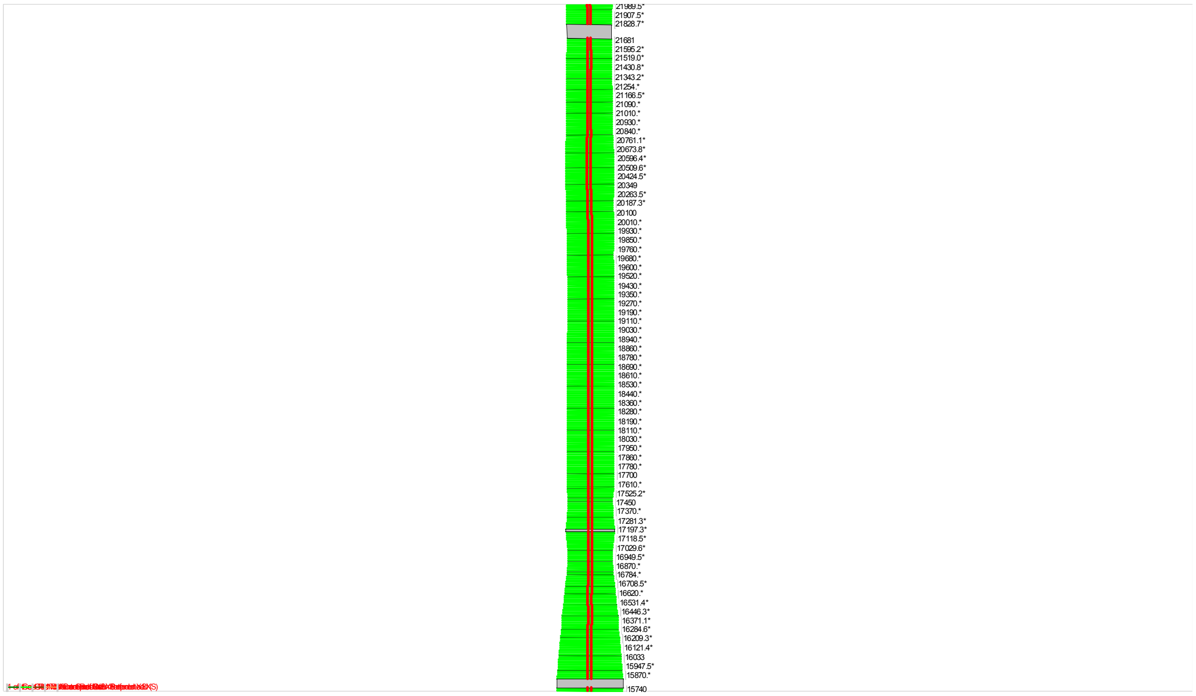

Figure 32 Model Schematic of the Willow Street Model Zoomed in on the Location of Interest

# WATER SURFACE PROFILES

## Los Feliz

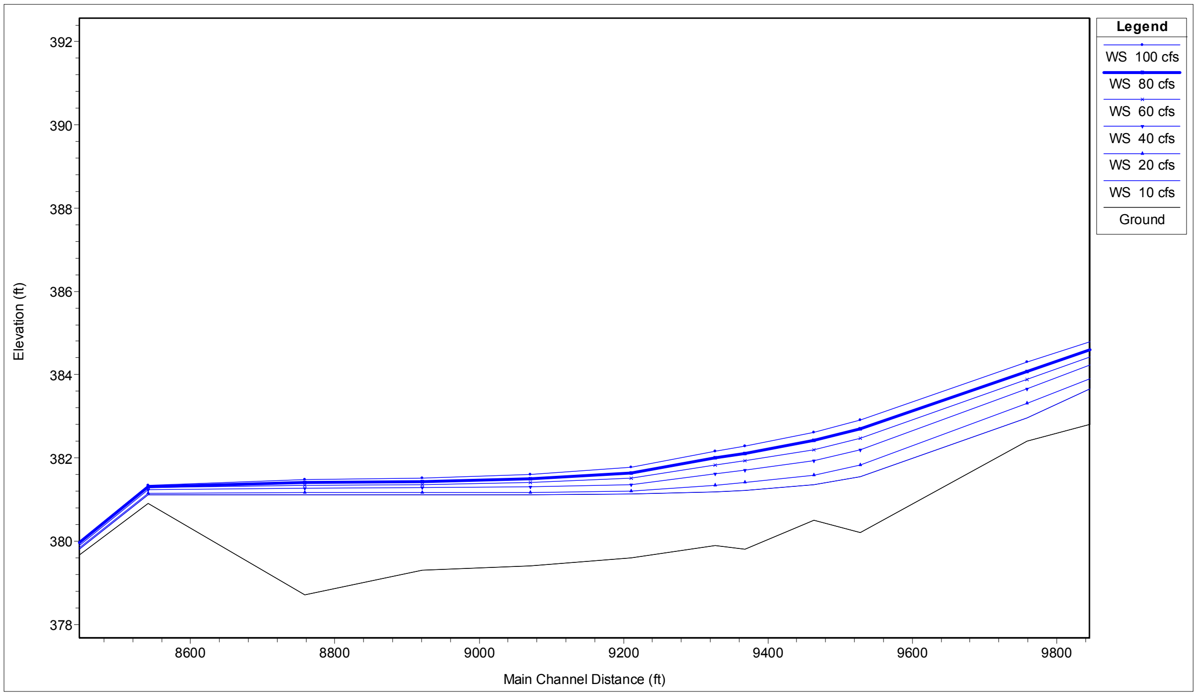

**Figure 33 Water Surface Profile Between Los Feliz Blvd and Colorado Blvd**

## Taylor Yard

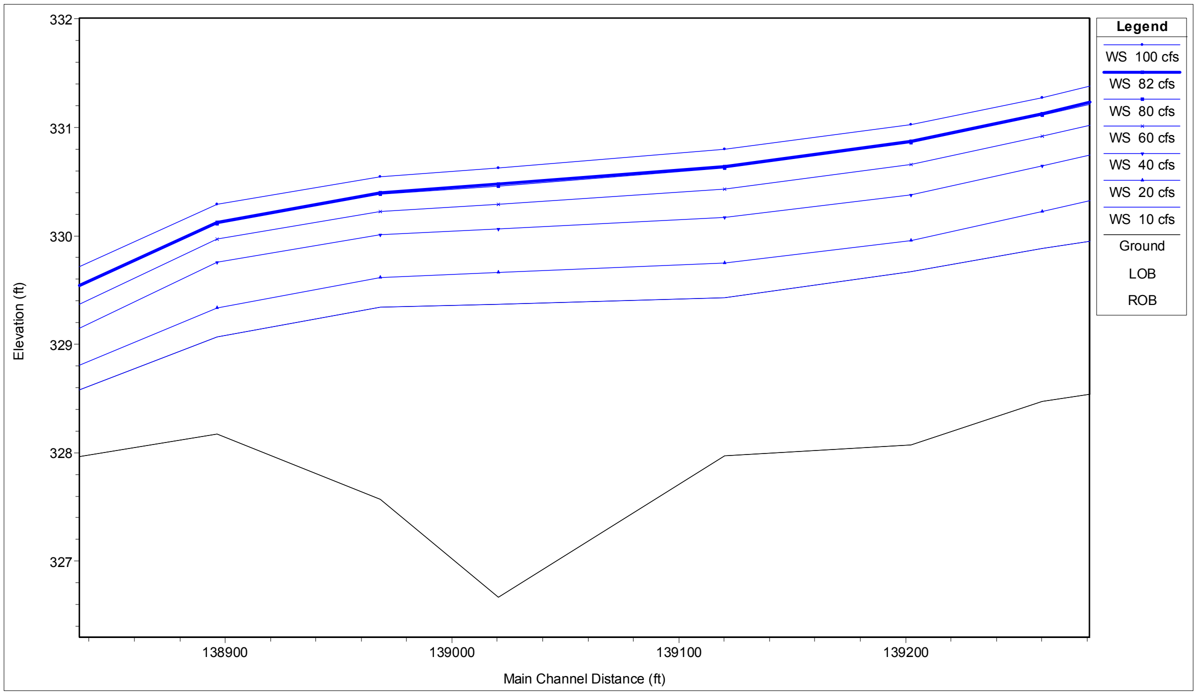

**Figure 34 Water Surface Profile of the Taylor Yard Site**

## Willow Street

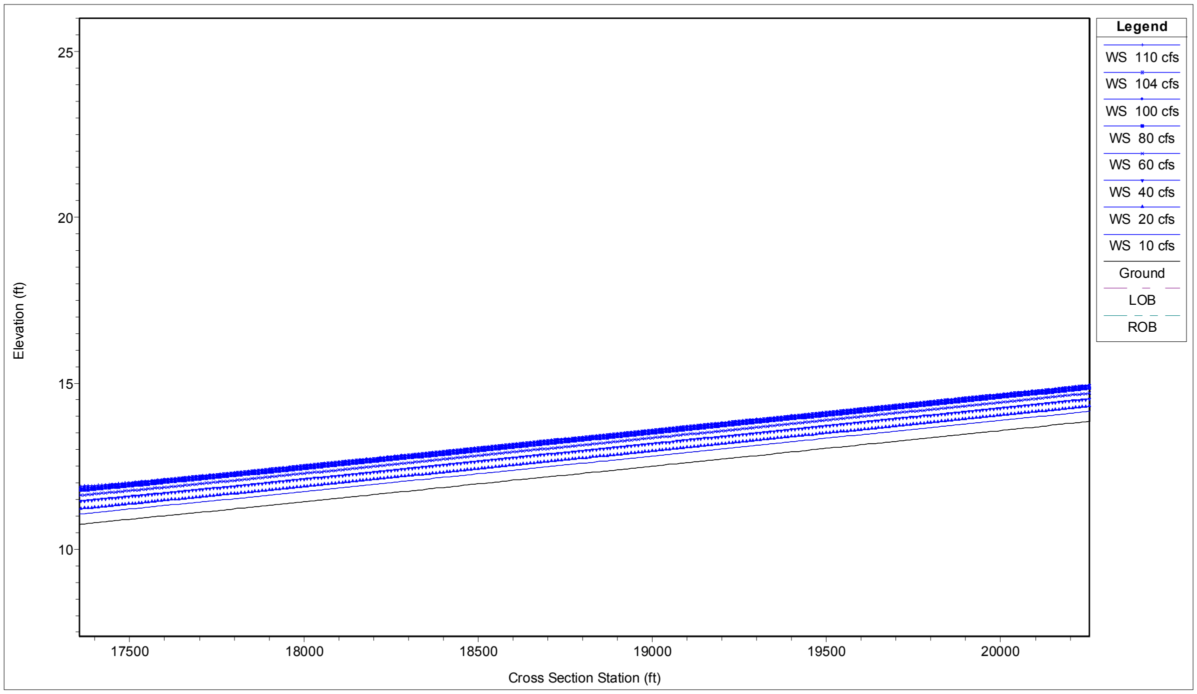

**Figure 35** Water Surface Profile Between Willow Street and Wardlow Street

# CROSS SECTIONS

This section contains only cross sections not included in the main text.

## Los Feliz

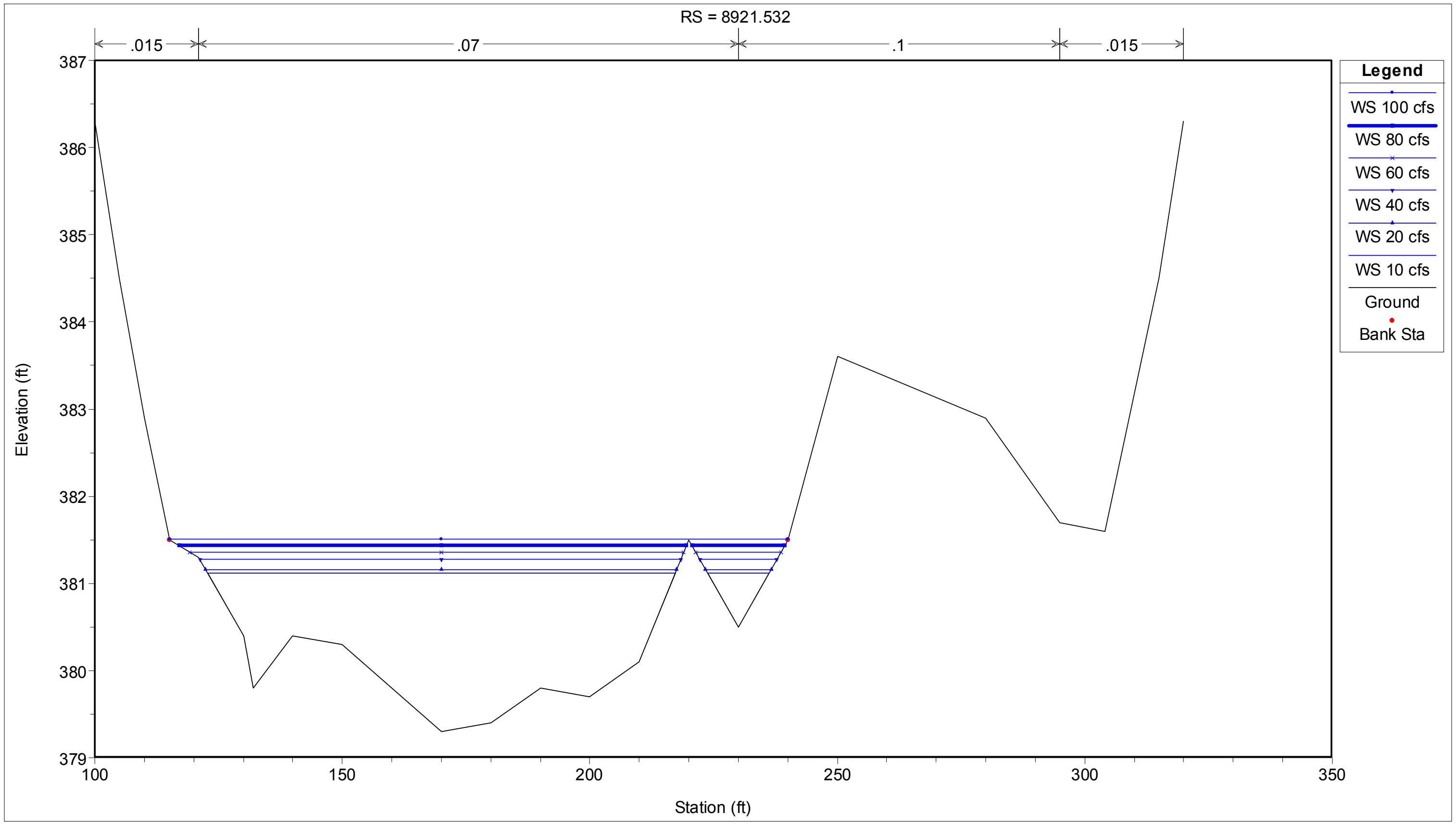

Figure 36 Los Feliz Model Cross Section at XS 8921

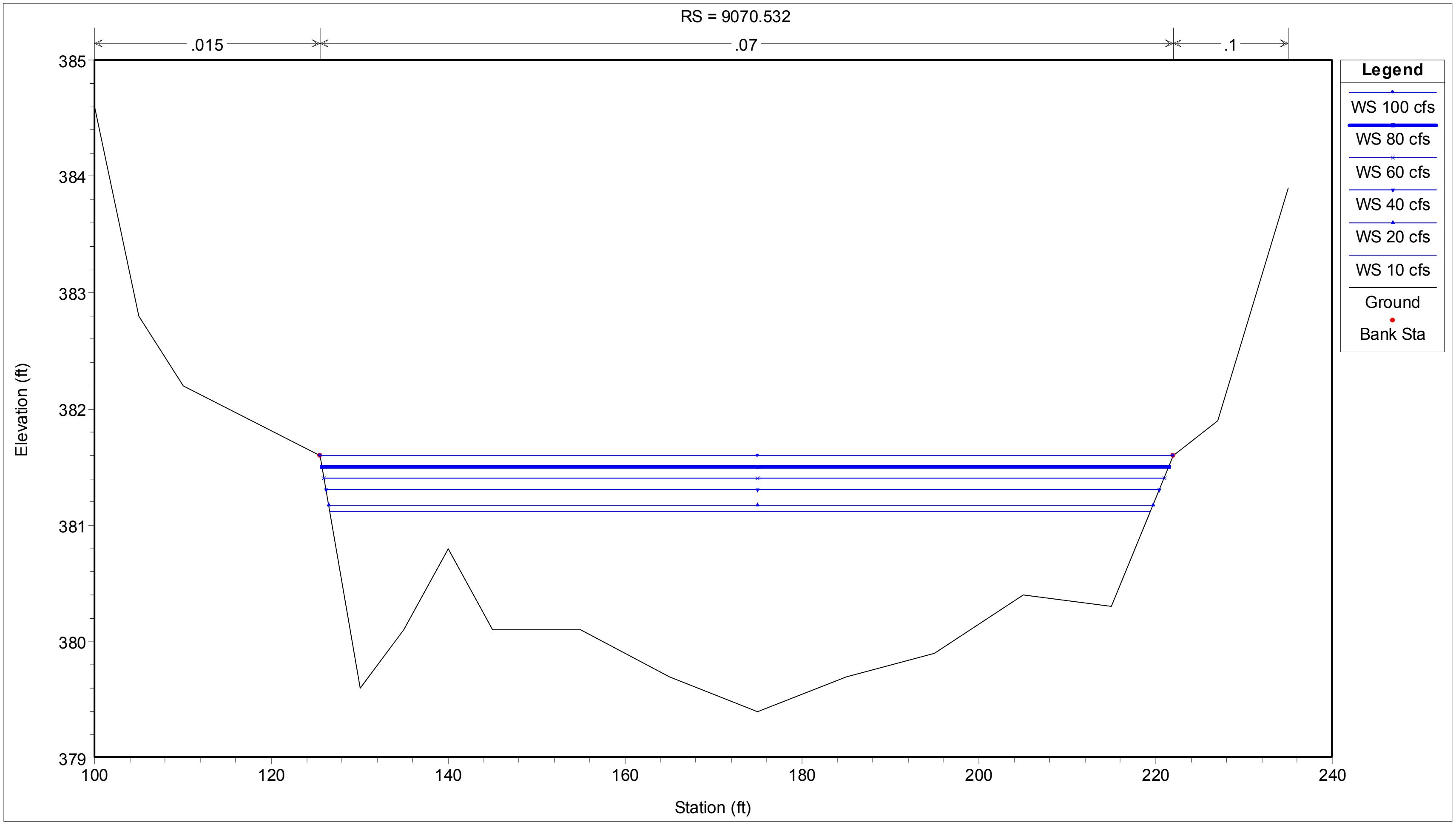

**Figure 37** **Los Feliz Model Cross Section at XS 9070**

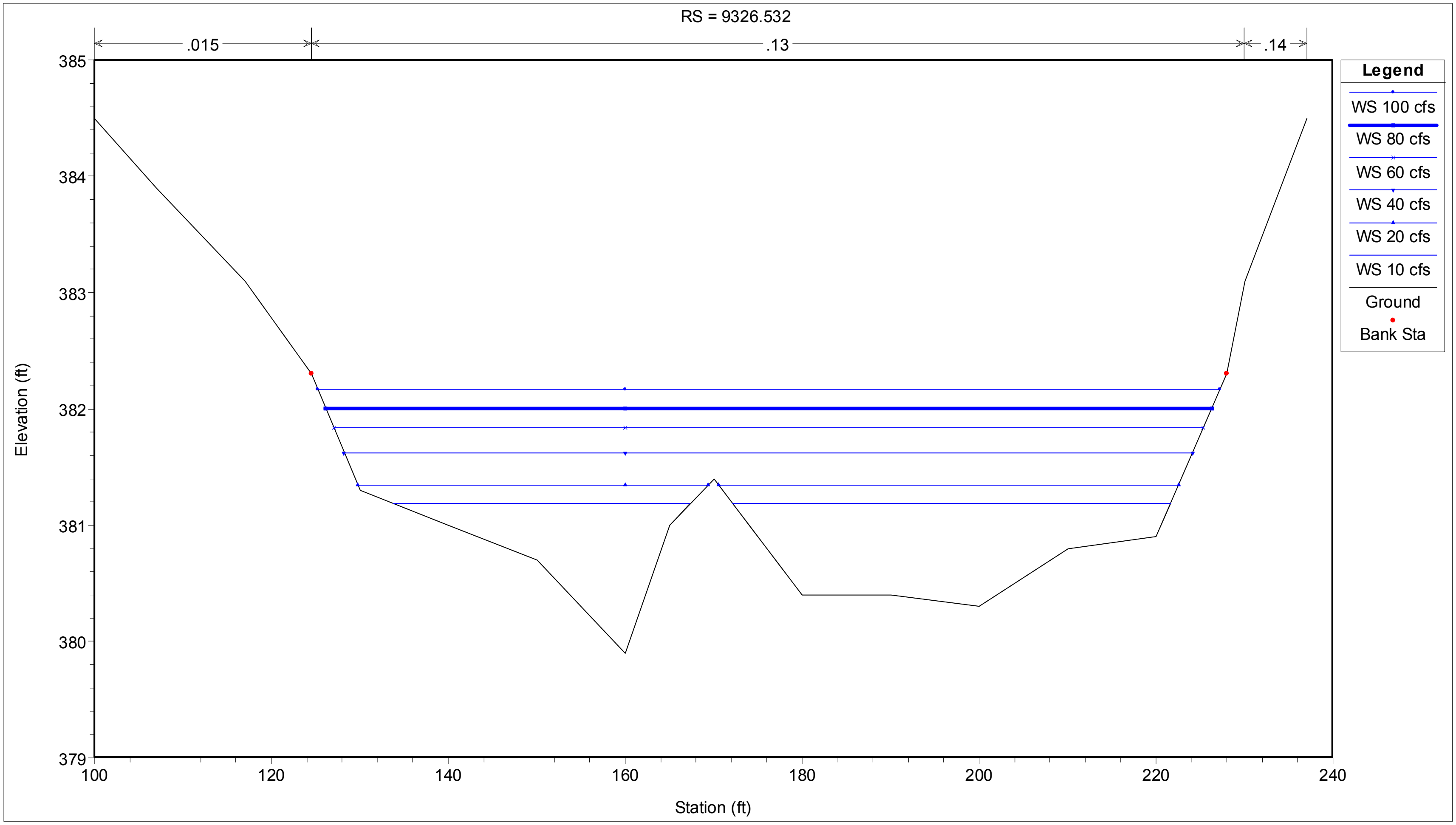

**Figure 38** **Los Feliz Model Cross Section at XS 9326**

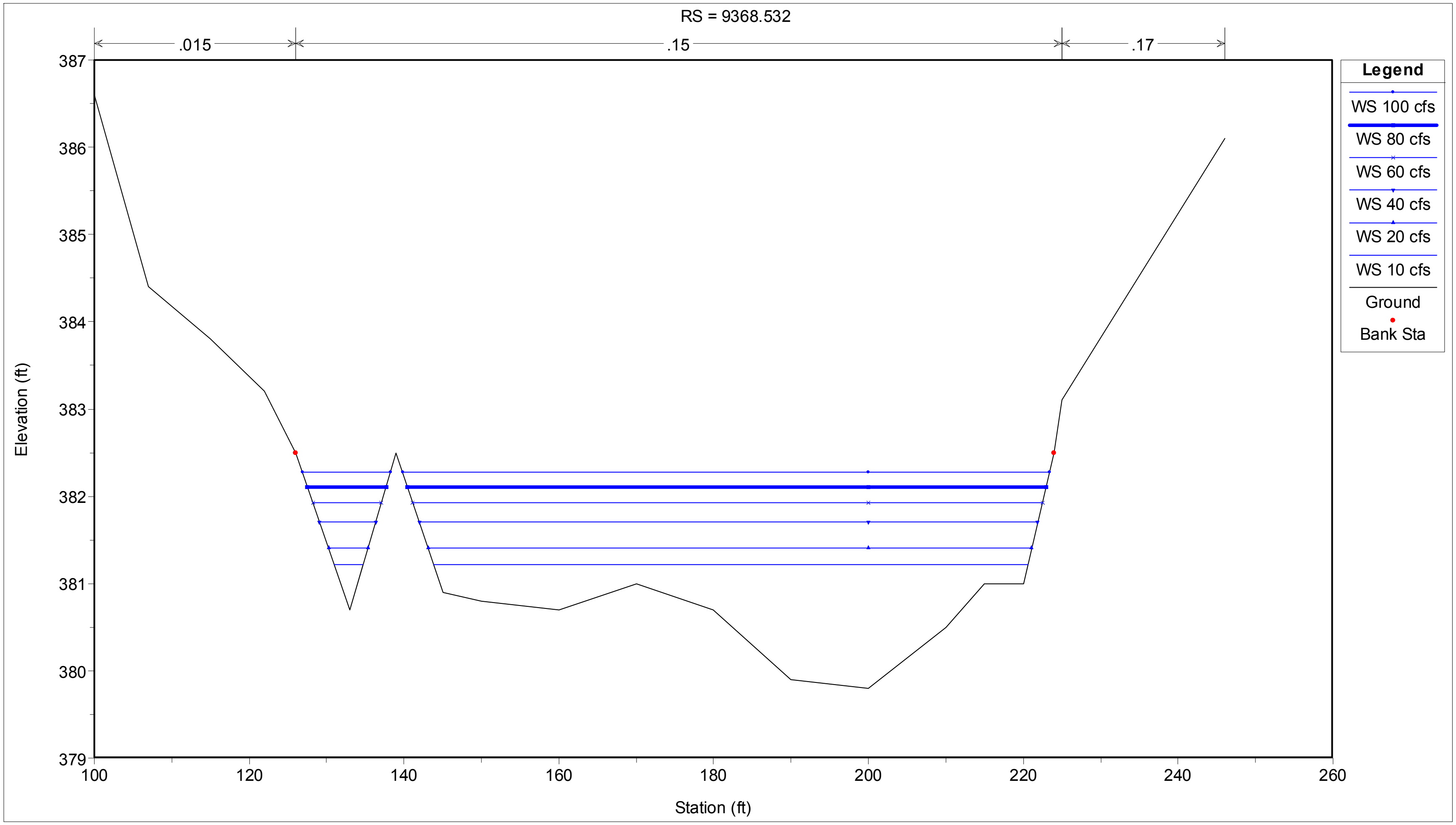

**Figure 39** Los Feliz Model Cross Section at XS 9369

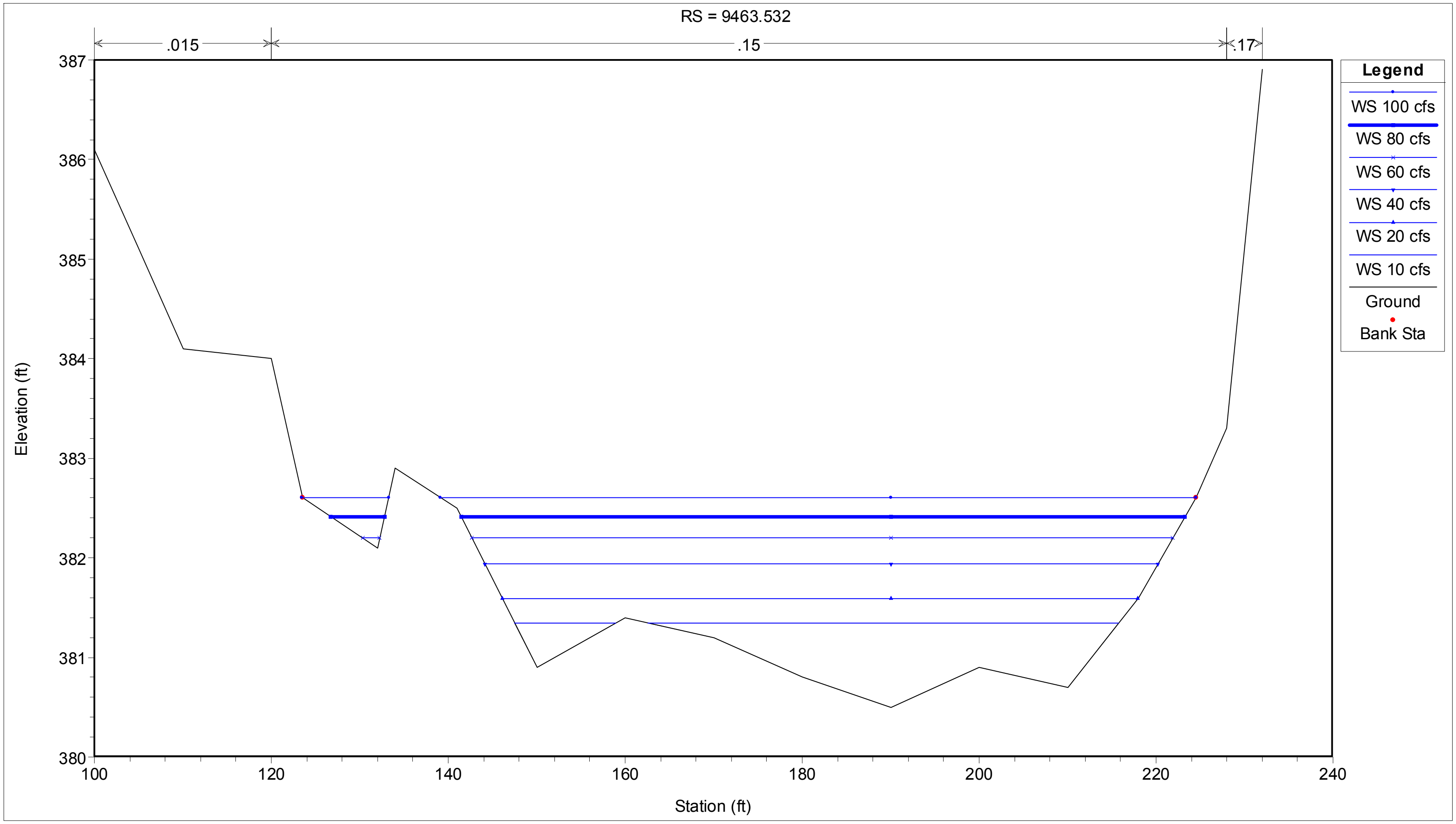

**Figure 40** Los Feliz Model Cross Section at XS 9463

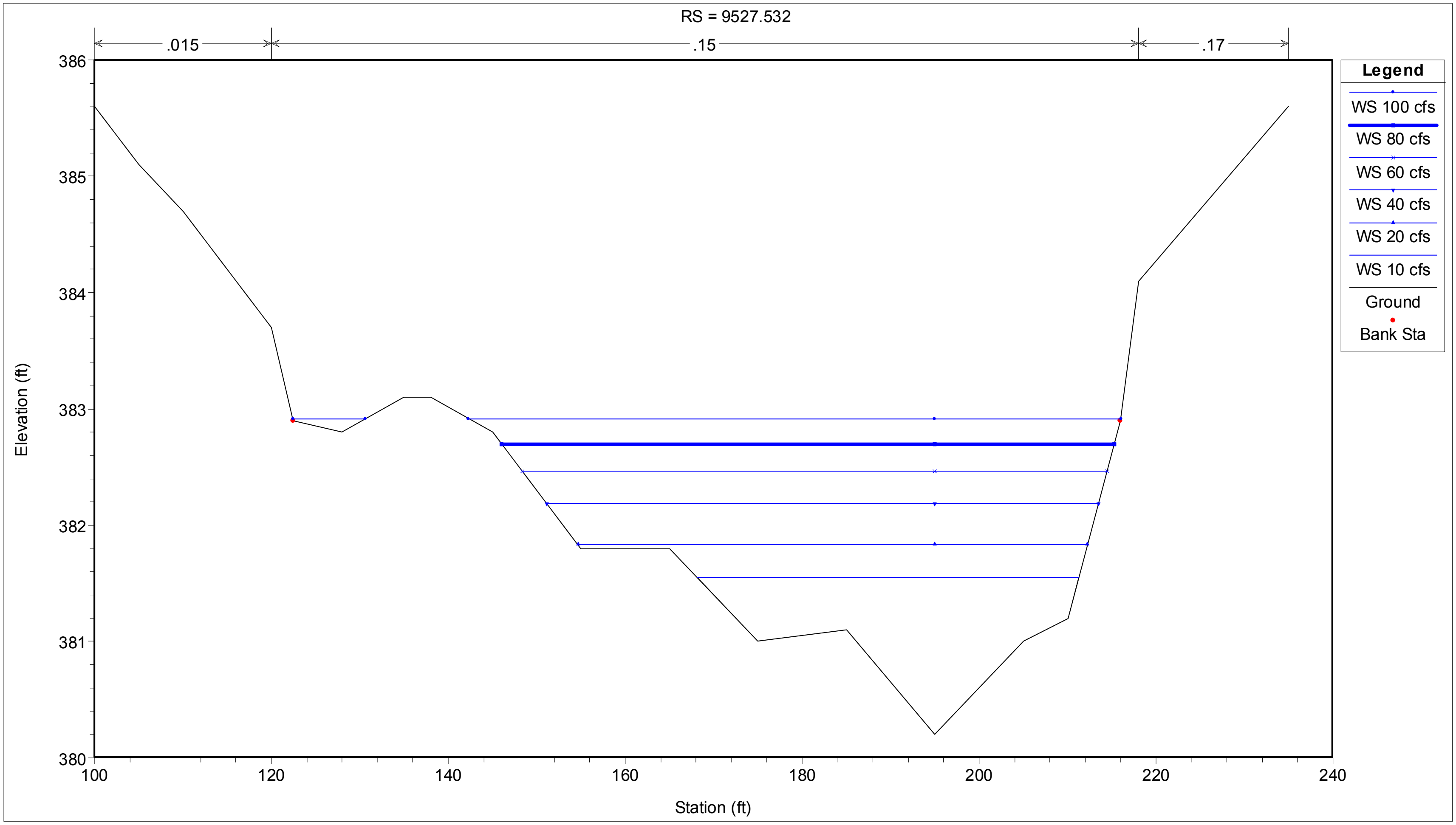

**Figure 41** **Los Feliz Model Cross Section at XS 9527**

## Taylor Yard

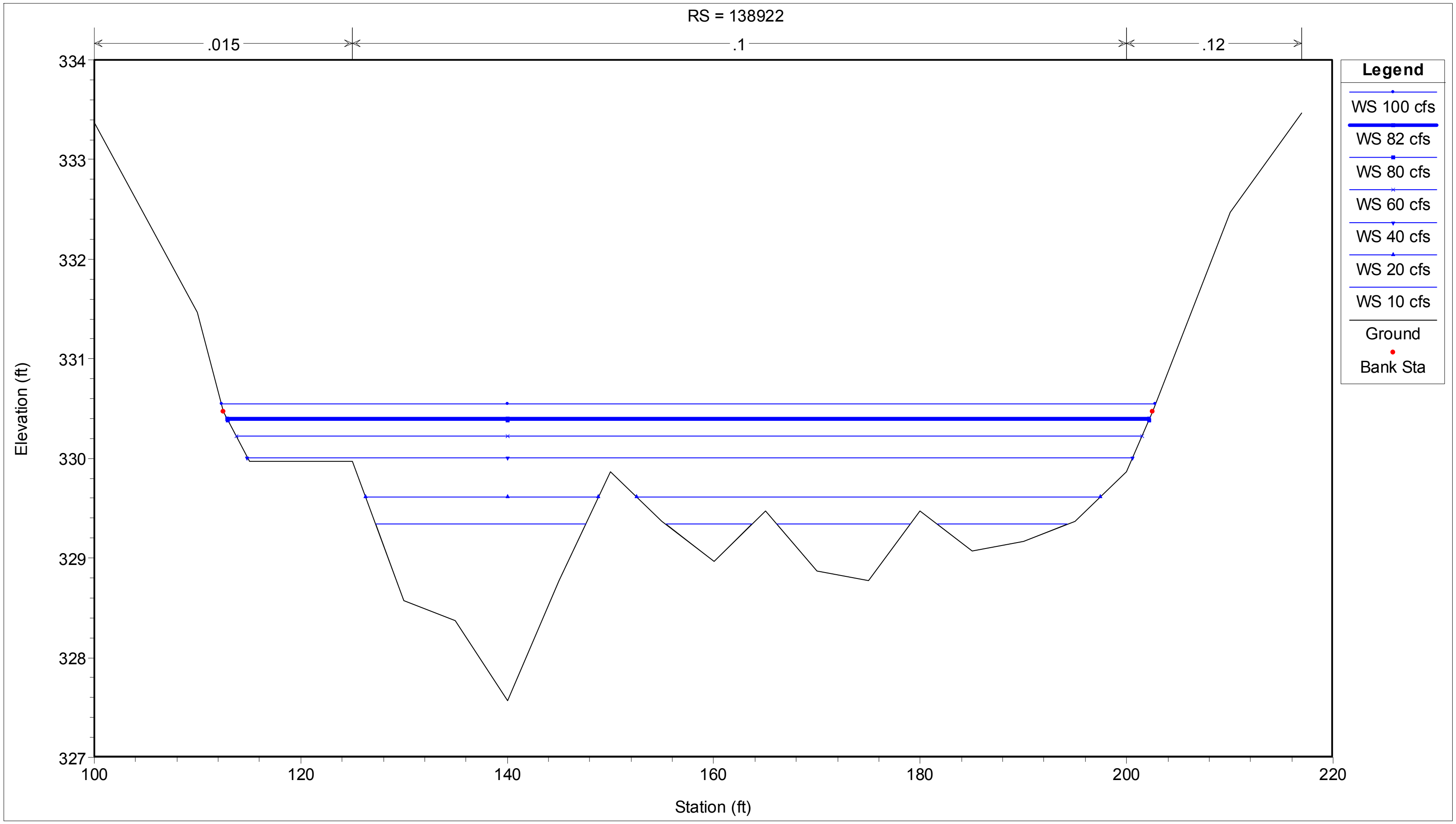

**Figure 42** Taylor Yard Model Cross Section at XS 138922

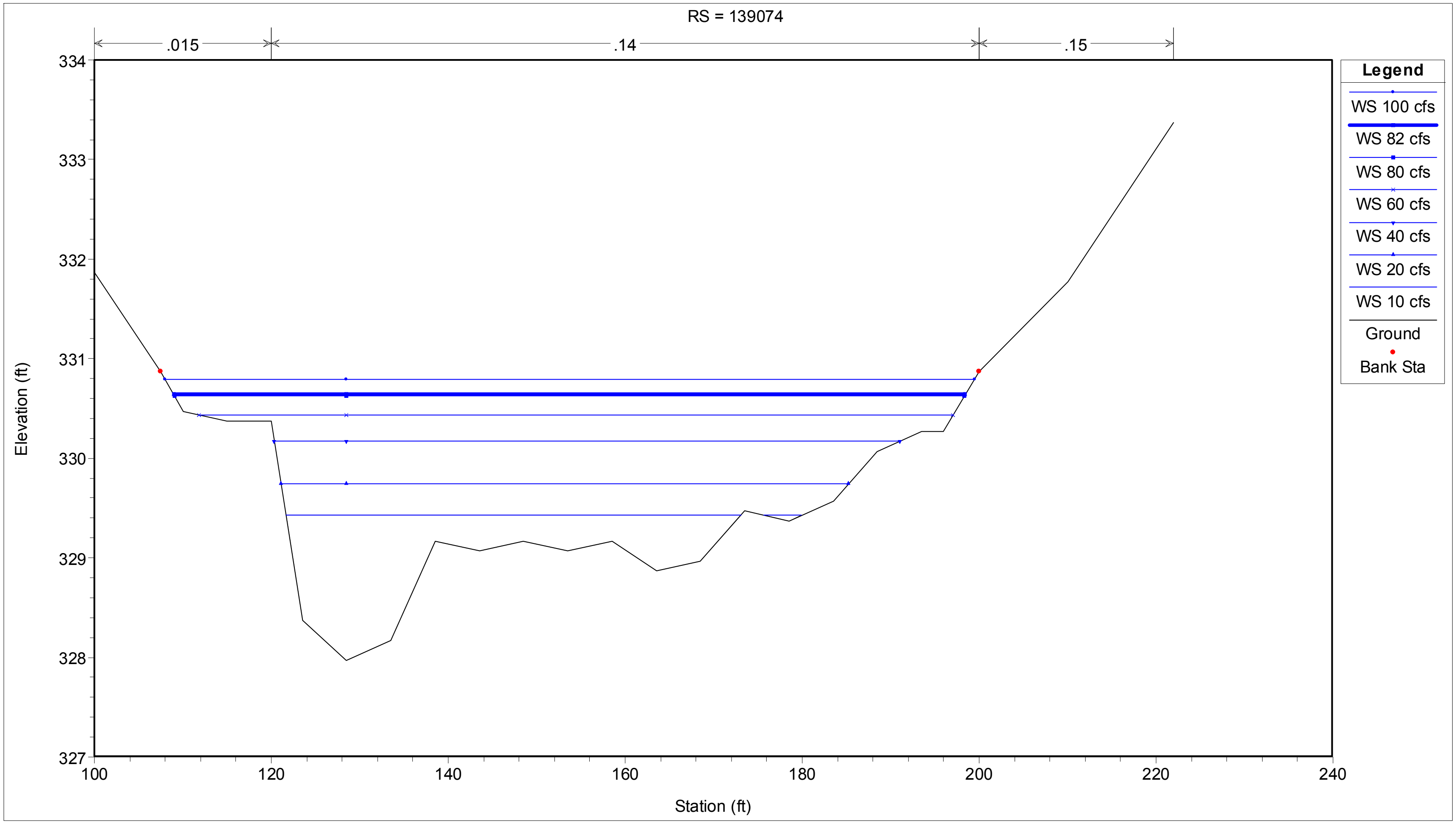

**Figure 43** Taylor Yard Model Cross Section at XS 139074

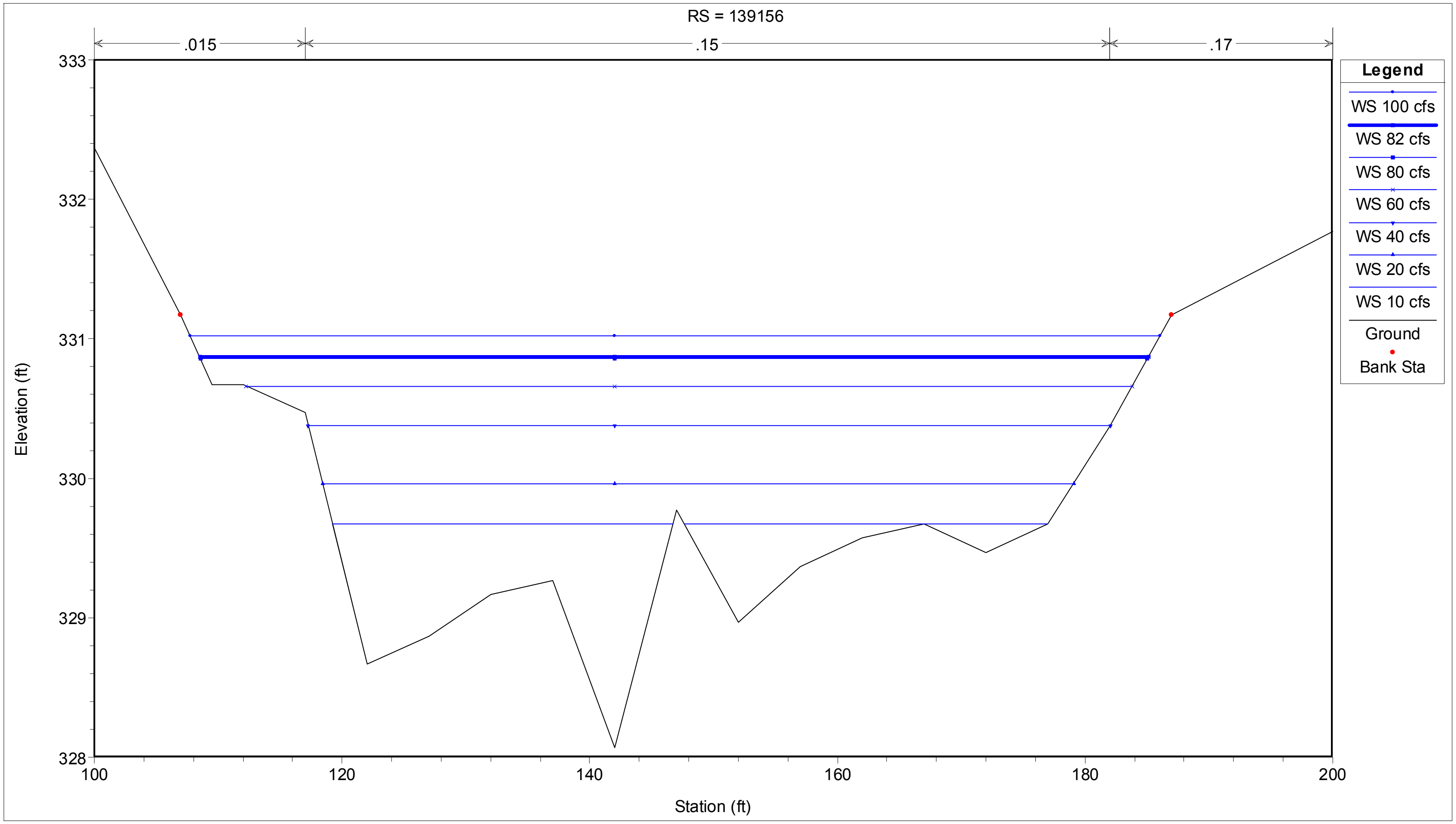

**Figure 44** Taylor Yard Model Cross Section at XS 139156 Willow Street

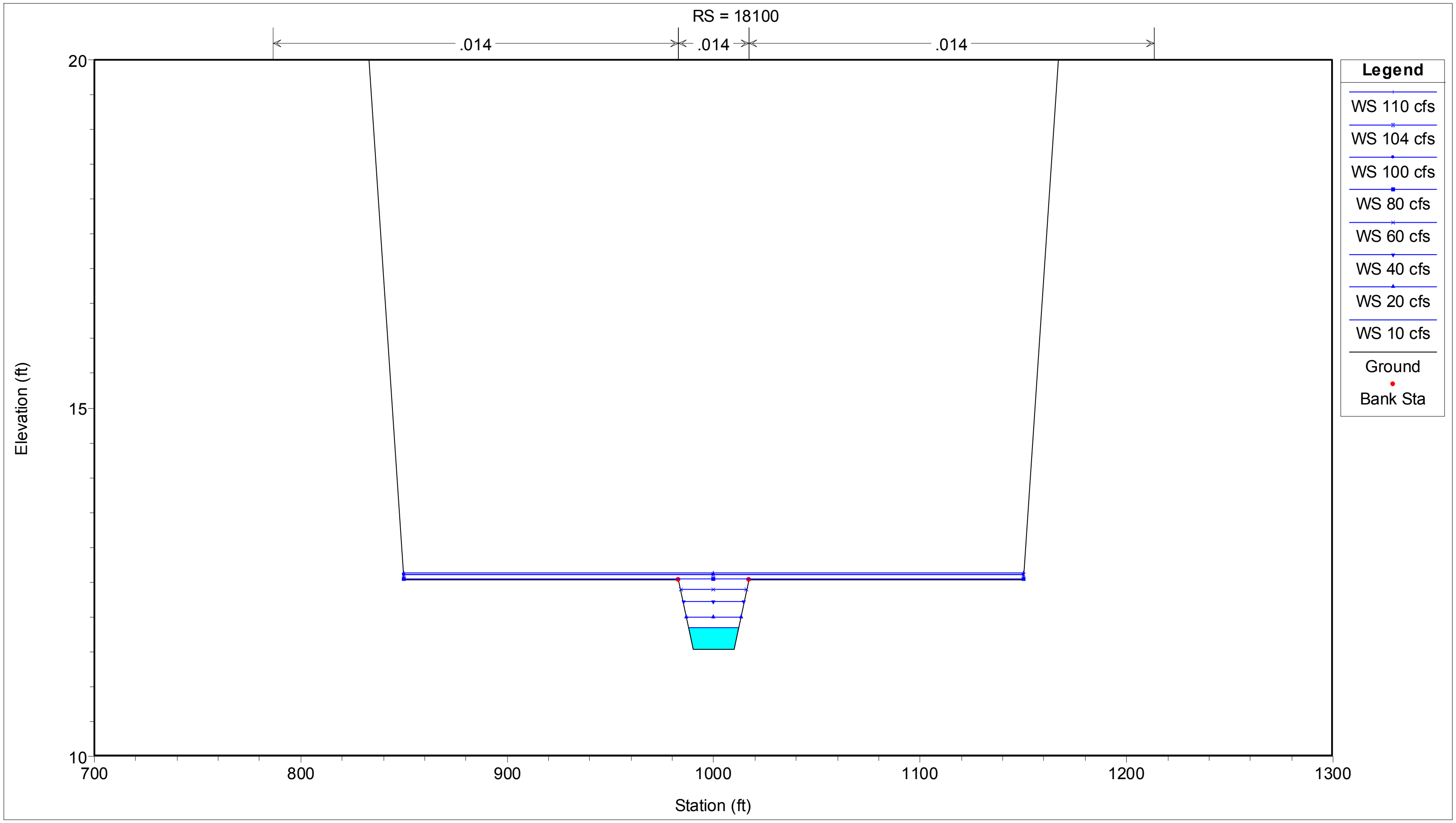

**Figure 45** **Taylor Yard Model Cross Section at XS 18100**

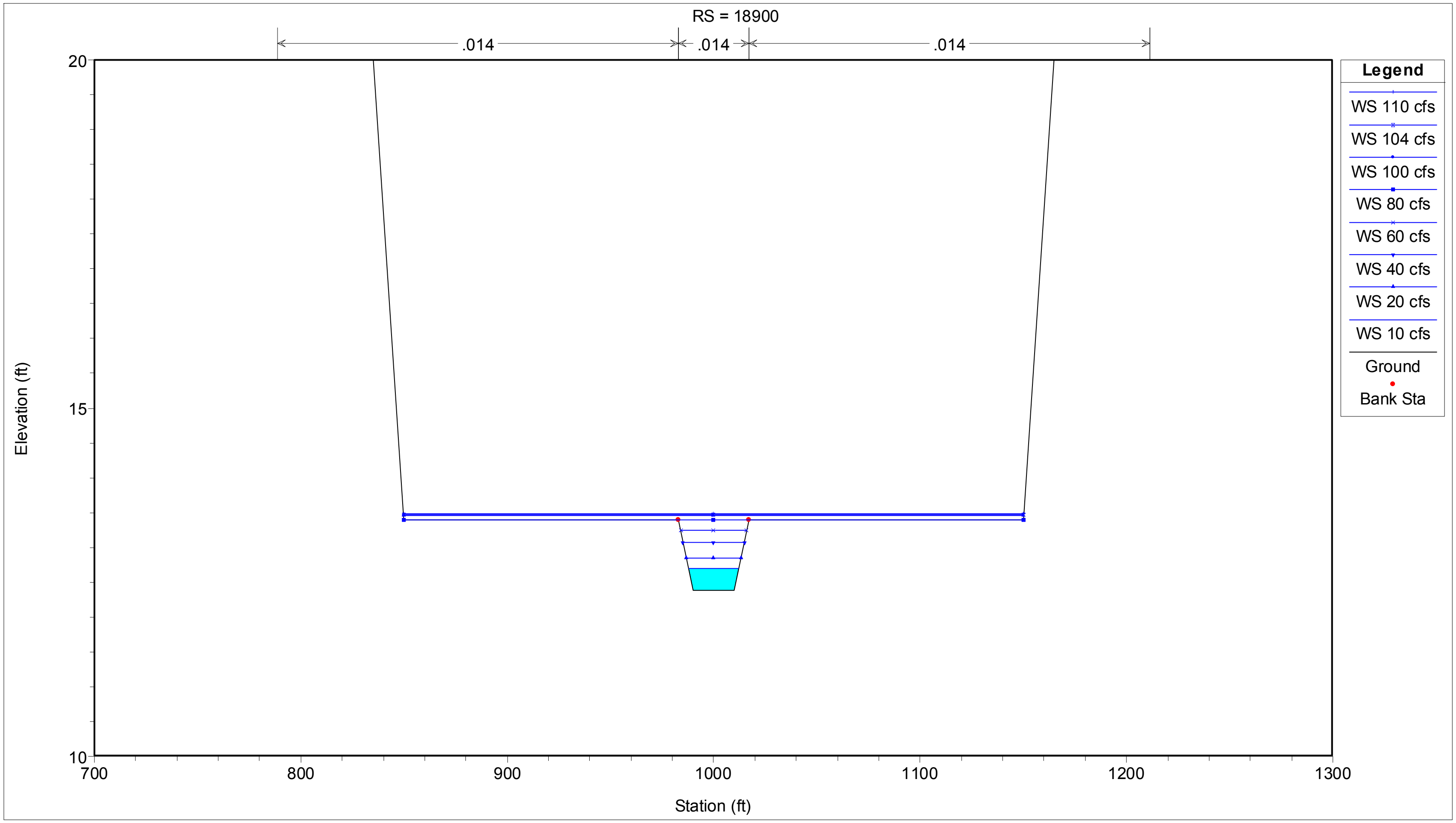

**Figure 46** **Taylor Yard Model Cross Section at XS 18900**

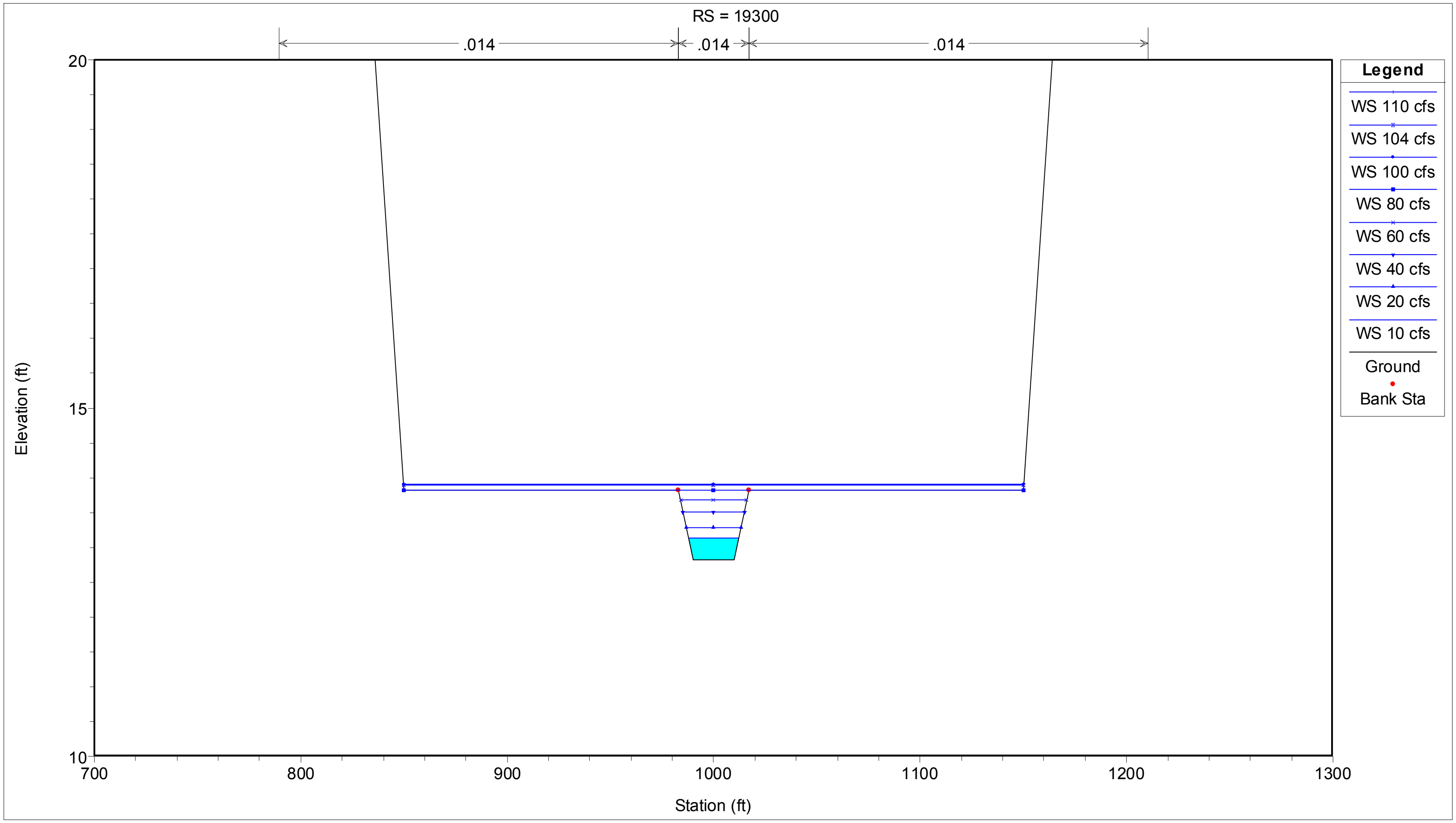

**Figure 47** Taylor Yard Model Cross Section at XS 19300

# Flow Parameter Tables

## Los Feliz

**Table 7 Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9758.532 | 10 | 382.4 | 382.96 | 382.97 | 0.04116 | 0.91 | 10.99 | 36.01 | 0.29 | 0.56 |
| 9758.532 | 15 | 382.4 | 383.14 | 383.15 | 0.023168 | 0.78 | 19.23 | 51.64 | 0.23 | 0.74 |
| 9758.532 | 20 | 382.4 | 383.31 | 383.32 | 0.012956 | 0.7 | 28.5 | 57.99 | 0.18 | 0.91 |
| 9758.532 | 25 | 382.4 | 383.41 | 383.41 | 0.012237 | 0.74 | 34 | 61.77 | 0.17 | 1.01 |
| 9758.532 | 30 | 382.4 | 383.51 | 383.52 | 0.01177 | 0.73 | 41 | 72.9 | 0.17 | 1.11 |
| 9758.532 | 35 | 382.4 | 383.6 | 383.61 | 0.011433 | 0.73 | 48.26 | 85.09 | 0.17 | 1.2 |
| 9758.532 | 40 | 382.4 | 383.66 | 383.67 | 0.010808 | 0.75 | 53.27 | 85.46 | 0.17 | 1.26 |
| 9758.532 | 45 | 382.4 | 383.72 | 383.73 | 0.01008 | 0.77 | 58.49 | 85.85 | 0.16 | 1.32 |
| 9758.532 | 50 | 382.4 | 383.78 | 383.79 | 0.009672 | 0.79 | 63.19 | 86.19 | 0.16 | 1.38 |
| 9758.532 | 55 | 382.4 | 383.83 | 383.84 | 0.009303 | 0.81 | 67.81 | 86.53 | 0.16 | 1.43 |
| 9758.532 | 60 | 382.4 | 383.88 | 383.89 | 0.00899 | 0.83 | 72.3 | 86.85 | 0.16 | 1.48 |
| 9758.532 | 65 | 382.4 | 383.93 | 383.94 | 0.008629 | 0.85 | 76.91 | 87.19 | 0.16 | 1.53 |
| 9758.532 | 70 | 382.4 | 383.98 | 383.99 | 0.008396 | 0.86 | 81.19 | 87.5 | 0.16 | 1.58 |
| 9758.532 | 75 | 382.4 | 384.03 | 384.04 | 0.008287 | 0.88 | 85.07 | 87.78 | 0.16 | 1.63 |
| 9758.532 | 80 | 382.4 | 384.08 | 384.09 | 0.008055 | 0.9 | 89.32 | 88.08 | 0.16 | 1.68 |
| 9758.532 | 85 | 382.4 | 384.12 | 384.14 | 0.007855 | 0.91 | 93.46 | 88.38 | 0.16 | 1.72 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9758.532 | 90 | 382.4 | 384.17 | 384.18 | 0.007672 | 0.92 | 97.54 | 88.67 | 0.16 | 1.77 |
| 9758.532 | 95 | 382.4 | 384.24 | 384.25 | 0.007038 | 0.92 | 103.61 | 89.1 | 0.15 | 1.84 |
| 9758.532 | 100 | 382.4 | 384.29 | 384.31 | 0.00666 | 0.92 | 108.82 | 89.47 | 0.15 | 1.89 |
| | | | | | | | | | | |
| 9527.532 | 10 | 380.2 | 381.55 | 381.55 | 0.002387 | 0.36 | 27.76 | 43.07 | 0.08 | 1.35 |
| 9527.532 | 15 | 380.2 | 381.69 | 381.7 | 0.002863 | 0.44 | 34.25 | 45.43 | 0.09 | 1.49 |
| 9527.532 | 20 | 380.2 | 381.83 | 381.84 | 0.003805 | 0.49 | 41.08 | 57.58 | 0.1 | 1.63 |
| 9527.532 | 25 | 380.2 | 381.94 | 381.94 | 0.003902 | 0.53 | 47.07 | 58.97 | 0.1 | 1.74 |
| 9527.532 | 30 | 380.2 | 382.03 | 382.03 | 0.00404 | 0.57 | 52.39 | 60.18 | 0.11 | 1.83 |
| 9527.532 | 35 | 380.2 | 382.11 | 382.12 | 0.004122 | 0.61 | 57.56 | 61.33 | 0.11 | 1.91 |
| 9527.532 | 40 | 380.2 | 382.19 | 382.2 | 0.004202 | 0.64 | 62.44 | 62.39 | 0.11 | 1.99 |
| 9527.532 | 45 | 380.2 | 382.26 | 382.27 | 0.004306 | 0.67 | 66.94 | 63.36 | 0.12 | 2.06 |
| 9527.532 | 50 | 380.2 | 382.33 | 382.34 | 0.004375 | 0.7 | 71.39 | 64.31 | 0.12 | 2.13 |
| 9527.532 | 55 | 380.2 | 382.4 | 382.41 | 0.004408 | 0.73 | 75.86 | 65.24 | 0.12 | 2.2 |
| 9527.532 | 60 | 380.2 | 382.47 | 382.47 | 0.004447 | 0.75 | 80.15 | 66.12 | 0.12 | 2.27 |
| 9527.532 | 65 | 380.2 | 382.53 | 382.54 | 0.004498 | 0.77 | 84.23 | 66.95 | 0.12 | 2.33 |
| 9527.532 | 70 | 380.2 | 382.59 | 382.6 | 0.004547 | 0.79 | 88.19 | 67.75 | 0.12 | 2.39 |
| 9527.532 | 75 | 380.2 | 382.64 | 382.65 | 0.004595 | 0.81 | 92.05 | 68.51 | 0.12 | 2.44 |
| 9527.532 | 80 | 380.2 | 382.7 | 382.71 | 0.004642 | 0.84 | 95.8 | 69.25 | 0.13 | 2.5 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9527.532 | 85 | 380.2 | 382.75 | 382.76 | 0.00469 | 0.85 | 99.45 | 69.96 | 0.13 | 2.55 |
| 9527.532 | 90 | 380.2 | 382.8 | 382.81 | 0.004736 | 0.87 | 103.09 | 70.76 | 0.13 | 2.6 |
| 9527.532 | 95 | 380.2 | 382.86 | 382.87 | 0.005139 | 0.88 | 107.47 | 76.99 | 0.13 | 2.66 |
| 9527.532 | 100 | 380.2 | 382.92 | 382.93 | 0.00541 | 0.89 | 111.85 | 81.95 | 0.13 | 2.72 |
| | | | | | | | | | | |
| 9463.532 | 10 | 380.5 | 381.35 | 381.35 | 0.004272 | 0.36 | 27.4 | 64.63 | 0.1 | 0.85 |
| 9463.532 | 15 | 380.5 | 381.48 | 381.48 | 0.004119 | 0.41 | 36.52 | 70.21 | 0.1 | 0.98 |
| 9463.532 | 20 | 380.5 | 381.59 | 381.59 | 0.003962 | 0.45 | 44.31 | 71.8 | 0.1 | 1.09 |
| 9463.532 | 25 | 380.5 | 381.69 | 381.69 | 0.003842 | 0.49 | 51.48 | 73.03 | 0.1 | 1.19 |
| 9463.532 | 30 | 380.5 | 381.78 | 381.78 | 0.003801 | 0.52 | 57.96 | 74.09 | 0.1 | 1.28 |
| 9463.532 | 35 | 380.5 | 381.86 | 381.86 | 0.003769 | 0.55 | 64.08 | 75.09 | 0.1 | 1.36 |
| 9463.532 | 40 | 380.5 | 381.94 | 381.94 | 0.00376 | 0.57 | 69.82 | 76.01 | 0.11 | 1.44 |
| 9463.532 | 45 | 380.5 | 382 | 382.01 | 0.003827 | 0.6 | 74.85 | 76.81 | 0.11 | 1.5 |
| 9463.532 | 50 | 380.5 | 382.07 | 382.08 | 0.003832 | 0.62 | 80.04 | 77.62 | 0.11 | 1.57 |
| 9463.532 | 55 | 380.5 | 382.14 | 382.14 | 0.003847 | 0.64 | 85.32 | 79.15 | 0.11 | 1.64 |
| 9463.532 | 60 | 380.5 | 382.2 | 382.2 | 0.003923 | 0.66 | 90.25 | 81.1 | 0.11 | 1.7 |
| 9463.532 | 65 | 380.5 | 382.25 | 382.26 | 0.004008 | 0.68 | 94.92 | 82.9 | 0.11 | 1.75 |
| 9463.532 | 70 | 380.5 | 382.31 | 382.32 | 0.004082 | 0.7 | 99.52 | 84.63 | 0.11 | 1.81 |
| 9463.532 | 75 | 380.5 | 382.36 | 382.37 | 0.004148 | 0.72 | 104.05 | 86.31 | 0.12 | 1.86 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9463.532 | 80 | 380.5 | 382.41 | 382.42 | 0.004207 | 0.74 | 108.51 | 87.93 | 0.12 | 1.91 |
| 9463.532 | 85 | 380.5 | 382.46 | 382.47 | 0.004263 | 0.75 | 112.88 | 89.49 | 0.12 | 1.96 |
| 9463.532 | 90 | 380.5 | 382.51 | 382.52 | 0.004311 | 0.77 | 117.31 | 91.19 | 0.12 | 2.01 |
| 9463.532 | 95 | 380.5 | 382.56 | 382.57 | 0.004381 | 0.78 | 121.68 | 93.25 | 0.12 | 2.06 |
| 9463.532 | 100 | 380.5 | 382.61 | 382.62 | 0.004435 | 0.79 | 126.03 | 95.16 | 0.12 | 2.11 |
| | | | | | | | | | | |
| 9368.532 | 10 | 379.8 | 381.22 | 381.22 | 0.000675 | 0.19 | 52.09 | 80.52 | 0.04 | 1.42 |
| 9368.532 | 15 | 379.8 | 381.32 | 381.32 | 0.000963 | 0.25 | 60.13 | 81.87 | 0.05 | 1.52 |
| 9368.532 | 20 | 379.8 | 381.4 | 381.4 | 0.001206 | 0.3 | 67.18 | 83.03 | 0.06 | 1.6 |
| 9368.532 | 25 | 379.8 | 381.49 | 381.49 | 0.001375 | 0.34 | 74.27 | 84.19 | 0.06 | 1.69 |
| 9368.532 | 30 | 379.8 | 381.56 | 381.56 | 0.001533 | 0.37 | 80.6 | 85.21 | 0.07 | 1.76 |
| 9368.532 | 35 | 379.8 | 381.63 | 381.64 | 0.001655 | 0.4 | 86.8 | 86.2 | 0.07 | 1.83 |
| 9368.532 | 40 | 379.8 | 381.7 | 381.7 | 0.001767 | 0.43 | 92.62 | 87.11 | 0.07 | 1.9 |
| 9368.532 | 45 | 379.8 | 381.75 | 381.76 | 0.001931 | 0.46 | 97.13 | 87.82 | 0.08 | 1.95 |
| 9368.532 | 50 | 379.8 | 381.81 | 381.82 | 0.002021 | 0.49 | 102.46 | 88.64 | 0.08 | 2.01 |
| 9368.532 | 55 | 379.8 | 381.87 | 381.88 | 0.002094 | 0.51 | 107.74 | 89.45 | 0.08 | 2.07 |
| 9368.532 | 60 | 379.8 | 381.93 | 381.93 | 0.002178 | 0.53 | 112.56 | 90.18 | 0.08 | 2.13 |
| 9368.532 | 65 | 379.8 | 381.97 | 381.98 | 0.002278 | 0.56 | 116.87 | 90.83 | 0.09 | 2.17 |
| 9368.532 | 70 | 379.8 | 382.02 | 382.03 | 0.002367 | 0.58 | 121.13 | 91.47 | 0.09 | 2.22 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9368.532 | 75 | 379.8 | 382.07 | 382.07 | 0.002448 | 0.6 | 125.33 | 92.09 | 0.09 | 2.27 |
| 9368.532 | 80 | 379.8 | 382.11 | 382.12 | 0.002526 | 0.62 | 129.41 | 92.69 | 0.09 | 2.31 |
| 9368.532 | 85 | 379.8 | 382.15 | 382.16 | 0.0026 | 0.64 | 133.39 | 93.28 | 0.09 | 2.35 |
| 9368.532 | 90 | 379.8 | 382.2 | 382.2 | 0.002656 | 0.65 | 137.53 | 93.88 | 0.1 | 2.4 |
| 9368.532 | 95 | 379.8 | 382.24 | 382.25 | 0.002724 | 0.67 | 141.34 | 94.43 | 0.1 | 2.44 |
| 9368.532 | 100 | 379.8 | 382.28 | 382.29 | 0.002787 | 0.69 | 145.09 | 94.97 | 0.1 | 2.48 |
| | | | | | | | | | | |
| 9326.532 | 10 | 379.9 | 381.19 | 381.19 | 0.000798 | 0.22 | 46 | 83.05 | 0.05 | 1.29 |
| 9326.532 | 15 | 379.9 | 381.27 | 381.27 | 0.001195 | 0.28 | 53.26 | 88.27 | 0.06 | 1.37 |
| 9326.532 | 20 | 379.9 | 381.35 | 381.35 | 0.001502 | 0.33 | 59.98 | 91.58 | 0.07 | 1.45 |
| 9326.532 | 25 | 379.9 | 381.42 | 381.43 | 0.001651 | 0.37 | 67.27 | 93.68 | 0.08 | 1.52 |
| 9326.532 | 30 | 379.9 | 381.49 | 381.5 | 0.001764 | 0.41 | 73.81 | 94.46 | 0.08 | 1.59 |
| 9326.532 | 35 | 379.9 | 381.56 | 381.56 | 0.00184 | 0.44 | 80.21 | 95.22 | 0.08 | 1.66 |
| 9326.532 | 40 | 379.9 | 381.62 | 381.63 | 0.001904 | 0.46 | 86.27 | 95.93 | 0.09 | 1.72 |
| 9326.532 | 45 | 379.9 | 381.67 | 381.67 | 0.002063 | 0.5 | 90.58 | 96.43 | 0.09 | 1.77 |
| 9326.532 | 50 | 379.9 | 381.73 | 381.73 | 0.002106 | 0.52 | 96.16 | 97.08 | 0.09 | 1.83 |
| 9326.532 | 55 | 379.9 | 381.78 | 381.79 | 0.002131 | 0.54 | 101.73 | 97.72 | 0.09 | 1.88 |
| 9326.532 | 60 | 379.9 | 381.84 | 381.84 | 0.002179 | 0.56 | 106.72 | 98.29 | 0.1 | 1.94 |
| 9326.532 | 65 | 379.9 | 381.88 | 381.88 | 0.002254 | 0.59 | 111.06 | 98.78 | 0.1 | 1.98 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9326.532 | 70 | 379.9 | 381.92 | 381.93 | 0.002318 | 0.61 | 115.37 | 99.27 | 0.1 | 2.02 |
| 9326.532 | 75 | 379.9 | 381.97 | 381.97 | 0.002373 | 0.63 | 119.63 | 99.75 | 0.1 | 2.07 |
| 9326.532 | 80 | 379.9 | 382.01 | 382.01 | 0.002425 | 0.65 | 123.78 | 100.22 | 0.1 | 2.11 |
| 9326.532 | 85 | 379.9 | 382.05 | 382.05 | 0.002475 | 0.67 | 127.82 | 100.67 | 0.1 | 2.15 |
| 9326.532 | 90 | 379.9 | 382.09 | 382.1 | 0.002502 | 0.68 | 132.11 | 101.14 | 0.11 | 2.19 |
| 9326.532 | 95 | 379.9 | 382.13 | 382.14 | 0.002547 | 0.7 | 135.97 | 101.57 | 0.11 | 2.23 |
| 9326.532 | 100 | 379.9 | 382.17 | 382.17 | 0.002588 | 0.72 | 139.78 | 101.99 | 0.11 | 2.27 |
| | | | | | | | | | | |
| 9210.532 | 10 | 379.6 | 381.13 | 381.13 | 0.000366 | 0.21 | 48.48 | 67.68 | 0.04 | 1.53 |
| 9210.532 | 15 | 379.6 | 381.17 | 381.17 | 0.000715 | 0.29 | 51.19 | 69.72 | 0.06 | 1.57 |
| 9210.532 | 20 | 379.6 | 381.19 | 381.2 | 0.001155 | 0.38 | 53.13 | 71.14 | 0.08 | 1.59 |
| 9210.532 | 25 | 379.6 | 381.24 | 381.25 | 0.001515 | 0.44 | 56.81 | 73.76 | 0.09 | 1.64 |
| 9210.532 | 30 | 379.6 | 381.28 | 381.28 | 0.001938 | 0.5 | 59.45 | 75.59 | 0.1 | 1.68 |
| 9210.532 | 35 | 379.6 | 381.32 | 381.33 | 0.002295 | 0.56 | 62.69 | 77.77 | 0.11 | 1.72 |
| 9210.532 | 40 | 379.6 | 381.36 | 381.37 | 0.002609 | 0.61 | 66.11 | 80.02 | 0.12 | 1.76 |
| 9210.532 | 45 | 379.6 | 381.38 | 381.38 | 0.003196 | 0.67 | 66.94 | 80.55 | 0.13 | 1.78 |
| 9210.532 | 50 | 379.6 | 381.42 | 381.42 | 0.00346 | 0.71 | 70.28 | 82.44 | 0.14 | 1.82 |
| 9210.532 | 55 | 379.6 | 381.47 | 381.48 | 0.003538 | 0.74 | 74.62 | 84.4 | 0.14 | 1.87 |
| 9210.532 | 60 | 379.6 | 381.51 | 381.52 | 0.003681 | 0.77 | 78.17 | 85.68 | 0.14 | 1.91 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9210.532 | 65 | 379.6 | 381.54 | 381.55 | 0.003887 | 0.8 | 80.79 | 85.94 | 0.15 | 1.94 |
| 9210.532 | 70 | 379.6 | 381.57 | 381.58 | 0.004036 | 0.84 | 83.62 | 86.22 | 0.15 | 1.97 |
| 9210.532 | 75 | 379.6 | 381.61 | 381.62 | 0.004149 | 0.87 | 86.56 | 86.51 | 0.15 | 2.01 |
| 9210.532 | 80 | 379.6 | 381.64 | 381.65 | 0.004247 | 0.89 | 89.46 | 86.8 | 0.16 | 2.04 |
| 9210.532 | 85 | 379.6 | 381.67 | 381.69 | 0.004345 | 0.92 | 92.27 | 87.07 | 0.16 | 2.07 |
| 9210.532 | 90 | 379.6 | 381.7 | 381.72 | 0.004432 | 0.95 | 95.04 | 87.34 | 0.16 | 2.1 |
| 9210.532 | 95 | 379.6 | 381.74 | 381.75 | 0.004518 | 0.97 | 97.73 | 87.6 | 0.16 | 2.14 |
| 9210.532 | 100 | 379.6 | 381.77 | 381.78 | 0.004585 | 1 | 100.46 | 87.87 | 0.16 | 2.17 |
| | | | | | | | | | | |
| 9070.532 | 10 | 379.4 | 381.12 | 381.12 | 0.000019 | 0.1 | 101.81 | 92.83 | 0.02 | 1.72 |
| 9070.532 | 15 | 379.4 | 381.15 | 381.15 | 0.000039 | 0.14 | 104.85 | 93.08 | 0.02 | 1.75 |
| 9070.532 | 20 | 379.4 | 381.17 | 381.17 | 0.000066 | 0.19 | 106.57 | 93.22 | 0.03 | 1.77 |
| 9070.532 | 25 | 379.4 | 381.21 | 381.21 | 0.000092 | 0.23 | 110.53 | 93.55 | 0.04 | 1.81 |
| 9070.532 | 30 | 379.4 | 381.24 | 381.24 | 0.000123 | 0.27 | 112.86 | 93.74 | 0.04 | 1.84 |
| 9070.532 | 35 | 379.4 | 381.27 | 381.27 | 0.000154 | 0.3 | 115.91 | 93.98 | 0.05 | 1.87 |
| 9070.532 | 40 | 379.4 | 381.3 | 381.31 | 0.000185 | 0.34 | 119.09 | 94.24 | 0.05 | 1.9 |
| 9070.532 | 45 | 379.4 | 381.3 | 381.3 | 0.000238 | 0.38 | 118.48 | 94.19 | 0.06 | 1.9 |
| 9070.532 | 50 | 379.4 | 381.33 | 381.33 | 0.000272 | 0.41 | 121.38 | 94.43 | 0.06 | 1.93 |
| 9070.532 | 55 | 379.4 | 381.37 | 381.38 | 0.000294 | 0.44 | 125.73 | 94.78 | 0.07 | 1.97 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9070.532 | 60 | 379.4 | 381.41 | 381.41 | 0.000323 | 0.47 | 128.9 | 95.03 | 0.07 | 2.01 |
| 9070.532 | 65 | 379.4 | 381.43 | 381.43 | 0.000362 | 0.5 | 130.75 | 95.18 | 0.07 | 2.03 |
| 9070.532 | 70 | 379.4 | 381.45 | 381.45 | 0.000398 | 0.53 | 132.97 | 95.36 | 0.08 | 2.05 |
| 9070.532 | 75 | 379.4 | 381.48 | 381.48 | 0.000432 | 0.55 | 135.38 | 95.55 | 0.08 | 2.08 |
| 9070.532 | 80 | 379.4 | 381.5 | 381.51 | 0.000465 | 0.58 | 137.78 | 95.74 | 0.09 | 2.1 |
| 9070.532 | 85 | 379.4 | 381.52 | 381.53 | 0.000498 | 0.61 | 140.07 | 95.93 | 0.09 | 2.12 |
| 9070.532 | 90 | 379.4 | 381.55 | 381.55 | 0.00053 | 0.63 | 142.35 | 96.11 | 0.09 | 2.15 |
| 9070.532 | 95 | 379.4 | 381.57 | 381.58 | 0.000562 | 0.66 | 144.65 | 96.29 | 0.09 | 2.17 |
| 9070.532 | 100 | 379.4 | 381.6 | 381.6 | 0.000592 | 0.68 | 146.93 | 96.47 | 0.1 | 2.2 |
| | | | | | | | | | | |
| 8921.532 | 10 | 379.3 | 381.12 | 381.12 | 0.000016 | 0.09 | 112.93 | 106.77 | 0.02 | 1.82 |
| 8921.532 | 15 | 379.3 | 381.15 | 381.15 | 0.000033 | 0.13 | 116.15 | 107.89 | 0.02 | 1.85 |
| 8921.532 | 20 | 379.3 | 381.16 | 381.16 | 0.000056 | 0.17 | 117.74 | 108.44 | 0.03 | 1.86 |
| 8921.532 | 25 | 379.3 | 381.2 | 381.2 | 0.000079 | 0.2 | 121.98 | 109.88 | 0.03 | 1.9 |
| 8921.532 | 30 | 379.3 | 381.22 | 381.22 | 0.000108 | 0.24 | 124.23 | 110.64 | 0.04 | 1.92 |
| 8921.532 | 35 | 379.3 | 381.25 | 381.25 | 0.000137 | 0.27 | 127.35 | 111.68 | 0.05 | 1.95 |
| 8921.532 | 40 | 379.3 | 381.28 | 381.28 | 0.000166 | 0.31 | 130.65 | 112.77 | 0.05 | 1.98 |
| 8921.532 | 45 | 379.3 | 381.26 | 381.27 | 0.000218 | 0.35 | 129.04 | 112.24 | 0.06 | 1.96 |
| 8921.532 | 50 | 379.3 | 381.29 | 381.29 | 0.000252 | 0.38 | 131.95 | 113.2 | 0.06 | 1.99 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8921.532 | 55 | 379.3 | 381.33 | 381.34 | 0.000275 | 0.4 | 136.82 | 115.42 | 0.07 | 2.03 |
| 8921.532 | 60 | 379.3 | 381.36 | 381.36 | 0.000305 | 0.43 | 140.2 | 117.06 | 0.07 | 2.06 |
| 8921.532 | 65 | 379.3 | 381.38 | 381.38 | 0.000346 | 0.46 | 141.8 | 117.83 | 0.07 | 2.08 |
| 8921.532 | 70 | 379.3 | 381.39 | 381.4 | 0.000384 | 0.49 | 143.9 | 118.84 | 0.08 | 2.09 |
| 8921.532 | 75 | 379.3 | 381.41 | 381.42 | 0.00042 | 0.51 | 146.29 | 119.97 | 0.08 | 2.11 |
| 8921.532 | 80 | 379.3 | 381.43 | 381.44 | 0.000455 | 0.54 | 148.79 | 121.15 | 0.09 | 2.13 |
| 8921.532 | 85 | 379.3 | 381.45 | 381.46 | 0.000492 | 0.56 | 151.06 | 122.2 | 0.09 | 2.15 |
| 8921.532 | 90 | 379.3 | 381.47 | 381.48 | 0.000528 | 0.59 | 153.35 | 123.26 | 0.09 | 2.17 |
| 8921.532 | 95 | 379.3 | 381.49 | 381.5 | 0.000563 | 0.61 | 155.69 | 124.33 | 0.1 | 2.19 |
| 8921.532 | 100 | 379.3 | 381.51 | 381.52 | 0.000596 | 0.63 | 158.04 | 124.97 | 0.1 | 2.21 |
| | | | | | | | | | | |
| 8758.532 | 10 | 378.7 | 381.12 | 381.12 | 0.000003 | 0.05 | 188.82 | 117.7 | 0.01 | 2.42 |
| | 15 | 378.7 | 381.15 | 381.15 | 0.000006 | 0.08 | 192.25 | 117.83 | 0.01 | 2.45 |
| | 20 | 378.7 | 381.16 | 381.16 | 0.00001 | 0.1 | 193.85 | 117.89 | 0.01 | 2.46 |
| | 25 | 378.7 | 381.2 | 381.2 | 0.000014 | 0.13 | 198.28 | 118.06 | 0.02 | 2.5 |
| | 30 | 378.7 | 381.22 | 381.22 | 0.000019 | 0.15 | 200.52 | 118.15 | 0.02 | 2.52 |
| | 35 | 378.7 | 381.24 | 381.24 | 0.000025 | 0.17 | 203.64 | 118.27 | 0.02 | 2.54 |
| | 40 | 378.7 | 381.27 | 381.27 | 0.00003 | 0.19 | 206.92 | 118.4 | 0.03 | 2.57 |
| | 45 | 378.7 | 381.25 | 381.25 | 0.00004 | 0.22 | 204.91 | 118.32 | 0.03 | 2.55 |

**Table 7** **Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 378.7 | 381.28 | 381.28 | 0.000047 | 0.24 | 207.73 | 118.43 | 0.03 | 2.58 |
| | 55 | 378.7 | 381.32 | 381.32 | 0.000052 | 0.26 | 212.61 | 118.62 | 0.03 | 2.62 |
| | 60 | 378.7 | 381.34 | 381.35 | 0.000059 | 0.28 | 215.85 | 118.75 | 0.04 | 2.64 |
| | 65 | 378.7 | 381.36 | 381.36 | 0.000068 | 0.3 | 217.17 | 118.8 | 0.04 | 2.66 |
| | 70 | 378.7 | 381.37 | 381.37 | 0.000076 | 0.32 | 219 | 118.87 | 0.04 | 2.67 |
| | 75 | 378.7 | 381.39 | 381.39 | 0.000084 | 0.34 | 221.11 | 118.95 | 0.04 | 2.69 |
| | 80 | 378.7 | 381.41 | 381.41 | 0.000093 | 0.36 | 223.32 | 119.04 | 0.05 | 2.71 |
| | 85 | 378.7 | 381.42 | 381.43 | 0.000101 | 0.38 | 225.25 | 119.12 | 0.05 | 2.72 |
| | 90 | 378.7 | 381.44 | 381.44 | 0.00011 | 0.4 | 227.19 | 119.21 | 0.05 | 2.74 |
| | 95 | 378.7 | 381.46 | 381.46 | 0.000119 | 0.41 | 229.18 | 119.29 | 0.05 | 2.76 |
| | 100 | 378.7 | 381.47 | 381.48 | 0.000127 | 0.43 | 231.15 | 119.38 | 0.05 | 2.77 |
| | | | | | | | | | | |
| 8541.532 | 10 | 380.9 | 381.11 | 381.11 | 0.01 | 0.55 | 18.3 | 190.49 | 0.31 | 0.21 |
| 8541.532 | 15 | 380.9 | 381.13 | 381.14 | 0.011036 | 0.65 | 23.03 | 190.79 | 0.33 | 0.23 |
| 8541.532 | 20 | 380.9 | 381.14 | 381.15 | 0.016718 | 0.83 | 24.23 | 190.86 | 0.41 | 0.24 |
| 8541.532 | 25 | 380.9 | 381.18 | 381.19 | 0.01213 | 0.81 | 30.88 | 191.28 | 0.36 | 0.28 |
| 8541.532 | 30 | 380.9 | 381.19 | 381.2 | 0.013802 | 0.9 | 33.25 | 191.43 | 0.38 | 0.29 |
| 8541.532 | 35 | 380.9 | 381.21 | 381.22 | 0.012985 | 0.94 | 37.31 | 191.69 | 0.37 | 0.31 |
| 8541.532 | 40 | 380.9 | 381.23 | 381.25 | 0.011837 | 0.96 | 41.72 | 191.97 | 0.36 | 0.33 |

**Table 7 Detailed Flow Parameters for Los Feliz Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8541.532 | 45 | 380.9 | 381.19 | 381.22 | 0.027255 | 1.3 | 34.63 | 191.52 | 0.54 | 0.29 |
| 8541.532 | 50 | 380.9 | 381.21 | 381.24 | 0.024727 | 1.31 | 38.12 | 191.74 | 0.52 | 0.31 |
| 8541.532 | 55 | 380.9 | 381.26 | 381.28 | 0.0159 | 1.19 | 46.38 | 192.26 | 0.43 | 0.36 |
| 8541.532 | 60 | 380.9 | 381.28 | 381.3 | 0.014067 | 1.18 | 50.83 | 192.54 | 0.4 | 0.38 |
| 8541.532 | 65 | 380.9 | 381.28 | 381.31 | 0.0163 | 1.27 | 51.03 | 192.55 | 0.44 | 0.38 |
| 8541.532 | 70 | 380.9 | 381.29 | 381.31 | 0.017445 | 1.34 | 52.32 | 192.63 | 0.45 | 0.39 |
| 8541.532 | 75 | 380.9 | 381.3 | 381.33 | 0.017788 | 1.38 | 54.26 | 192.76 | 0.46 | 0.4 |
| 8541.532 | 80 | 380.9 | 381.31 | 381.34 | 0.017783 | 1.42 | 56.47 | 192.89 | 0.46 | 0.41 |
| 8541.532 | 85 | 380.9 | 381.32 | 381.35 | 0.018362 | 1.46 | 58.04 | 192.99 | 0.47 | 0.42 |
| 8541.532 | 90 | 380.9 | 381.32 | 381.36 | 0.018861 | 1.51 | 59.63 | 193.09 | 0.48 | 0.42 |
| 8541.532 | 95 | 380.9 | 381.33 | 381.37 | 0.019164 | 1.55 | 61.34 | 193.2 | 0.48 | 0.43 |
| 8541.532 | 100 | 380.9 | 381.34 | 381.38 | 0.019411 | 1.59 | 63.06 | 193.31 | 0.49 | 0.44 |

## Taylor Yard

**Table 8** **Detailed Flow Parameters for Taylor Yard Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 139214 | 10 | 328.47 | 329.88 | 329.89 | 0.003329 | 0.5 | 20 | 24.13 | 0.1 | 1.41 |
| 139214 | 20 | 328.47 | 330.23 | 330.23 | 0.006773 | 0.64 | 31.11 | 44.03 | 0.13 | 1.76 |
| 139214 | 40 | 328.47 | 330.64 | 330.65 | 0.007789 | 0.75 | 53.04 | 65.71 | 0.15 | 2.17 |
| 139214 | 60 | 328.47 | 330.92 | 330.93 | 0.006895 | 0.82 | 72.78 | 77.25 | 0.15 | 2.45 |
| 139214 | 80 | 328.47 | 331.11 | 331.12 | 0.006487 | 0.91 | 88.3 | 82.43 | 0.15 | 2.64 |
| 139214 | 100 | 328.47 | 331.27 | 331.29 | 0.006221 | 0.98 | 102.08 | 86.77 | 0.16 | 2.8 |
| 139214 | 82 | 328.47 | 331.13 | 331.14 | 0.006461 | 0.91 | 89.73 | 82.89 | 0.15 | 2.66 |
| | | | | | | | | | | |
| 139156 | 10 | 328.07 | 329.67 | 329.67 | 0.004116 | 0.38 | 26.43 | 56.85 | 0.1 | 1.6 |
| 139156 | 20 | 328.07 | 329.96 | 329.96 | 0.003403 | 0.46 | 43.54 | 60.65 | 0.1 | 1.89 |
| 139156 | 40 | 328.07 | 330.38 | 330.38 | 0.003084 | 0.57 | 69.79 | 64.79 | 0.1 | 2.31 |
| 139156 | 60 | 328.07 | 330.66 | 330.67 | 0.00315 | 0.68 | 88.81 | 71.56 | 0.11 | 2.59 |
| 139156 | 80 | 328.07 | 330.86 | 330.87 | 0.003246 | 0.77 | 103.58 | 76.47 | 0.12 | 2.79 |
| 139156 | 100 | 328.07 | 331.02 | 331.04 | 0.003236 | 0.86 | 116.56 | 78.36 | 0.12 | 2.95 |
| 139156 | 82 | 328.07 | 330.87 | 330.88 | 0.00325 | 0.78 | 104.91 | 76.67 | 0.12 | 2.8 |
| | | | | | | | | | | |

**Table 8** **Detailed Flow Parameters for Taylor Yard Model One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 139074 | 10 | 327.97 | 329.43 | 329.43 | 0.002358 | 0.34 | 29.66 | 55.62 | 0.08 | 1.46 |
| 139074 | 20 | 327.97 | 329.75 | 329.75 | 0.002087 | 0.4 | 49.39 | 64.17 | 0.08 | 1.78 |
| 139074 | 40 | 327.97 | 330.17 | 330.18 | 0.00208 | 0.51 | 77.94 | 70.74 | 0.09 | 2.2 |
| 139074 | 60 | 327.97 | 330.43 | 330.44 | 0.002477 | 0.61 | 97.78 | 85.23 | 0.1 | 2.46 |
| 139074 | 80 | 327.97 | 330.62 | 330.63 | 0.002545 | 0.7 | 114.51 | 89.31 | 0.11 | 2.65 |
| 139074 | 100 | 327.97 | 330.8 | 330.81 | 0.00245 | 0.77 | 130.18 | 91.55 | 0.11 | 2.83 |
| 139074 | 82 | 327.97 | 330.64 | 330.65 | 0.002543 | 0.71 | 116.06 | 89.54 | 0.11 | 2.67 |
| | | | | | | | | | | |
| 138974 | 10 | 326.67 | 329.37 | 329.37 | 0.00026 | 0.19 | 53.3 | 57.69 | 0.03 | 2.7 |
| 138974 | 20 | 326.67 | 329.66 | 329.66 | 0.000473 | 0.28 | 72.15 | 68.15 | 0.05 | 2.99 |
| 138974 | 40 | 326.67 | 330.06 | 330.06 | 0.000706 | 0.4 | 100.95 | 75.33 | 0.06 | 3.39 |
| 138974 | 60 | 326.67 | 330.29 | 330.29 | 0.000947 | 0.5 | 118.98 | 83.03 | 0.07 | 3.62 |
| 138974 | 80 | 326.67 | 330.46 | 330.47 | 0.00115 | 0.6 | 133.38 | 85.71 | 0.08 | 3.79 |
| 138974 | 100 | 326.67 | 330.63 | 330.64 | 0.001256 | 0.68 | 147.94 | 88.34 | 0.09 | 3.96 |
| 138974 | 82 | 326.67 | 330.48 | 330.48 | 0.001167 | 0.61 | 134.76 | 85.97 | 0.09 | 3.81 |
| | | | | | | | | | | |
| 138922 | 10 | 327.57 | 329.34 | 329.34 | 0.001602 | 0.37 | 26.96 | 54.24 | 0.09 | 1.77 |
| 138922 | 20 | 327.57 | 329.62 | 329.62 | 0.00164 | 0.45 | 44.3 | 67.53 | 0.1 | 2.05 |
| 138922 | 40 | 327.57 | 330.01 | 330.01 | 0.001456 | 0.55 | 73.1 | 85.77 | 0.1 | 2.44 |

## Table 8 Detailed Flow Parameters for Taylor Yard Model One Water LA 2040 Plan

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 138922 | 60 | 327.57 | 330.23 | 330.23 | 0.001563 | 0.65 | 91.86 | 87.76 | 0.11 | 2.66 |
| 138922 | 80 | 327.57 | 330.38 | 330.39 | 0.001754 | 0.75 | 105.97 | 89.22 | 0.12 | 2.81 |
| 138922 | 100 | 327.57 | 330.55 | 330.56 | 0.001798 | 0.83 | 120.58 | 90.48 | 0.13 | 2.98 |
| 138922 | 82 | 327.57 | 330.4 | 330.41 | 0.00177 | 0.76 | 107.32 | 89.36 | 0.12 | 2.83 |
| | | | | | | | | | | |
| 138850 | 10 | 328.17 | 329.07 | 329.08 | 0.014465 | 0.94 | 10.64 | 24.03 | 0.25 | 0.9 |
| 138850 | 20 | 328.17 | 329.34 | 329.36 | 0.014689 | 1.08 | 18.45 | 34.07 | 0.26 | 1.17 |
| 138850 | 40 | 328.17 | 329.75 | 329.77 | 0.014346 | 1.09 | 36.82 | 66.68 | 0.26 | 1.58 |
| 138850 | 60 | 328.17 | 329.97 | 329.99 | 0.012912 | 1.1 | 54.41 | 89.07 | 0.25 | 1.8 |
| 138850 | 80 | 328.17 | 330.11 | 330.13 | 0.011598 | 1.19 | 67.25 | 90.64 | 0.24 | 1.94 |
| 138850 | 100 | 328.17 | 330.29 | 330.31 | 0.009053 | 1.2 | 83.54 | 92.6 | 0.22 | 2.12 |
| 138850 | 82 | 328.17 | 330.12 | 330.15 | 0.011467 | 1.2 | 68.54 | 90.8 | 0.24 | 1.95 |

## Willow Street

**Table 9** **Detailed Flow Parameters for Taylor Yard Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel in Chnl (ft/s) | Vel out Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17700 | 10 | 11.11 | 11.42 | 11.45 | 0.001013 | 1.45 | | 6.88 | 24.34 | 0.48 | 0.31 |
| 17700 | 20 | 11.11 | 11.57 | 11.63 | 0.001019 | 1.86 | | 10.77 | 26.49 | 0.51 | 0.46 |
| 17700 | 40 | 11.11 | 11.8 | 11.88 | 0.001015 | 2.34 | | 17.11 | 29.65 | 0.54 | 0.69 |
| 17700 | 60 | 11.11 | 11.97 | 12.08 | 0.001017 | 2.67 | | 22.51 | 32.1 | 0.56 | 0.86 |
| 17700 | 80 | 11.11 | 12.12 | 12.25 | 0.001013 | 2.91 | 0.15 | 29.91 | 300.04 | 0.57 | 1.01 |
| 17700 | 100 | 11.11 | 12.18 | 12.31 | 0.001004 | 3.04 | 0.57 | 48 | 300.31 | 0.58 | 1.07 |
| 17700 | 104 | 11.11 | 12.19 | 12.32 | 0.001003 | 3.06 | 0.62 | 50.76 | 300.36 | 0.58 | 1.08 |
| 17700 | 110 | 11.11 | 12.2 | 12.33 | 0.001001 | 3.09 | 0.69 | 54.74 | 300.42 | 0.58 | 1.09 |
| | | | | | | | | | | | |
| 18100 | 10 | 11.54 | 11.84 | 11.88 | 0.001076 | 1.48 | | 6.75 | 24.27 | 0.5 | 0.3 |
| 18100 | 20 | 11.54 | 12 | 12.05 | 0.001072 | 1.89 | | 10.59 | 26.39 | 0.53 | 0.46 |
| 18100 | 40 | 11.54 | 12.22 | 12.31 | 0.001066 | 2.38 | | 16.83 | 29.52 | 0.55 | 0.68 |
| 18100 | 60 | 11.54 | 12.39 | 12.51 | 0.001062 | 2.7 | | 22.18 | 31.96 | 0.57 | 0.85 |
| 18100 | 80 | 11.54 | 12.54 | 12.68 | 0.001061 | 2.96 | 0.03 | 27.3 | 300 | 0.58 | 1 |
| 18100 | 100 | 11.54 | 12.61 | 12.74 | 0.001039 | 3.09 | 0.56 | 46.78 | 300.3 | 0.59 | 1.07 |
| 18100 | 104 | 11.54 | 12.62 | 12.75 | 0.001038 | 3.11 | 0.61 | 49.57 | 300.34 | 0.59 | 1.08 |
| 18100 | 110 | 11.54 | 12.63 | 12.76 | 0.001037 | 3.14 | 0.68 | 53.49 | 300.4 | 0.59 | 1.09 |
| | | | | | | | | | | | |

**Table 9** **Detailed Flow Parameters for Taylor Yard Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel in Chnl (ft/s) | Vel out Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18500 | 10 | 11.97 | 12.27 | 12.31 | 0.001076 | 1.48 | | 6.75 | 24.27 | 0.5 | 0.3 |
| 18500 | 20 | 11.97 | 12.43 | 12.48 | 0.001073 | 1.89 | | 10.59 | 26.39 | 0.53 | 0.46 |
| 18500 | 40 | 11.97 | 12.65 | 12.74 | 0.001069 | 2.38 | | 16.81 | 29.51 | 0.56 | 0.68 |
| 18500 | 60 | 11.97 | 12.82 | 12.94 | 0.001066 | 2.71 | | 22.16 | 31.94 | 0.57 | 0.85 |
| 18500 | 80 | 11.97 | 12.97 | 13.11 | 0.001063 | 2.96 | 0.02 | 27.14 | 300 | 0.59 | 1 |
| 18500 | 100 | 11.97 | 13.04 | 13.17 | 0.001039 | 3.09 | 0.56 | 46.78 | 300.3 | 0.59 | 1.07 |
| 18500 | 104 | 11.97 | 13.05 | 13.18 | 0.001038 | 3.11 | 0.61 | 49.57 | 300.34 | 0.59 | 1.08 |
| 18500 | 110 | 11.97 | 13.06 | 13.19 | 0.001037 | 3.14 | 0.68 | 53.49 | 300.4 | 0.59 | 1.09 |
| | | | | | | | | | | | |
| 18900 | 10 | 12.39 | 12.7 | 12.73 | 0.001031 | 1.46 | | 6.84 | 24.32 | 0.49 | 0.31 |
| 18900 | 20 | 12.39 | 12.85 | 12.91 | 0.001035 | 1.87 | | 10.72 | 26.46 | 0.52 | 0.46 |
| 18900 | 40 | 12.39 | 13.07 | 13.16 | 0.001038 | 2.36 | | 16.98 | 29.59 | 0.55 | 0.68 |
| 18900 | 60 | 12.39 | 13.25 | 13.36 | 0.001039 | 2.68 | | 22.35 | 32.03 | 0.57 | 0.86 |
| 18900 | 80 | 12.39 | 13.4 | 13.53 | 0.001031 | 2.93 | 0.12 | 28.99 | 300.03 | 0.58 | 1.01 |
| 18900 | 100 | 12.39 | 13.46 | 13.59 | 0.001011 | 3.05 | 0.57 | 47.74 | 300.31 | 0.58 | 1.07 |
| 18900 | 104 | 12.39 | 13.47 | 13.6 | 0.00101 | 3.07 | 0.62 | 50.51 | 300.35 | 0.58 | 1.08 |
| 18900 | 110 | 12.39 | 13.48 | 13.61 | 0.00101 | 3.1 | 0.68 | 54.41 | 300.41 | 0.58 | 1.09 |
| | | | | | | | | | | | |
| 19300 | 10 | 12.82 | 13.13 | 13.16 | 0.001028 | 1.46 | | 6.85 | 24.33 | 0.49 | 0.31 |

**Table 9** **Detailed Flow Parameters for Taylor Yard Model**
**One Water LA 2040 Plan**

| River Station | Q total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel in Chnl (ft/s) | Vel out Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chnl | Max Channel Depth (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19300 | 20 | 12.82 | 13.28 | 13.34 | 0.001036 | 1.87 |  | 10.71 | 26.46 | 0.52 | 0.46 |
| 19300 | 40 | 12.82 | 13.5 | 13.59 | 0.001041 | 2.36 |  | 16.96 | 29.58 | 0.55 | 0.68 |
| 19300 | 60 | 12.82 | 13.68 | 13.79 | 0.001043 | 2.69 |  | 22.32 | 32.01 | 0.57 | 0.86 |
| 19300 | 80 | 12.82 | 13.83 | 13.96 | 0.001035 | 2.93 | 0.11 | 28.75 | 300.03 | 0.58 | 1.01 |
| 19300 | 100 | 12.82 | 13.89 | 14.02 | 0.001009 | 3.05 | 0.57 | 47.82 | 300.31 | 0.58 | 1.07 |
| 19300 | 104 | 12.82 | 13.9 | 14.03 | 0.001008 | 3.07 | 0.62 | 50.58 | 300.35 | 0.58 | 1.08 |
| 19300 | 110 | 12.82 | 13.91 | 14.04 | 0.001008 | 3.1 | 0.68 | 54.48 | 300.41 | 0.58 | 1.09 |
|  |  |  |  |  |  |  |  |  |  |  |  |
| 19700 | 10 | 13.25 | 13.56 | 13.59 | 0.001029 | 1.46 |  | 6.85 | 24.33 | 0.49 | 0.31 |
| 19700 | 20 | 13.25 | 13.71 | 13.77 | 0.001036 | 1.87 |  | 10.71 | 26.46 | 0.52 | 0.46 |
| 19700 | 40 | 13.25 | 13.93 | 14.02 | 0.001042 | 2.36 |  | 16.96 | 29.58 | 0.55 | 0.68 |
| 19700 | 60 | 13.25 | 14.11 | 14.22 | 0.001044 | 2.69 |  | 22.31 | 32.01 | 0.57 | 0.86 |
| 19700 | 80 | 13.25 | 14.26 | 14.39 | 0.001036 | 2.94 | 0.11 | 28.72 | 300.03 | 0.58 | 1.01 |
| 19700 | 100 | 13.25 | 14.32 | 14.45 | 0.001009 | 3.05 | 0.57 | 47.81 | 300.31 | 0.58 | 1.07 |
| 19700 | 104 | 13.25 | 14.33 | 14.46 | 0.001009 | 3.07 | 0.62 | 50.58 | 300.35 | 0.58 | 1.08 |
| 19700 | 110 | 13.25 | 14.34 | 14.47 | 0.001008 | 3.1 | 0.68 | 54.48 | 300.41 | 0.58 | 1.09 |

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# APPENDIX C

## DRY WEATHER FLOW RATES BY RIVER MILE

**Table 10 Dry Weather Flow Rates by River Mile in the Los Angeles River (mgd units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (mgd) | Upwelling flow (mgd) | Urban Dry Weather Flow (mgd) | ET (mgd) | Flow from Upstream (mgd) | Flow Released Downstream (mgd) |
|---|---|---|---|---|---|---|---|
| 51-50 | | 0.00 | 0.00 | 1.48 | 0.075 | 0.00 | 1.40 |
| 50-49 | | 0.00 | 0.00 | 0.35 | 0.033 | 1.40 | 1.72 |
| 49-48 | | 0.00 | 0.00 | 0.43 | 0.033 | 1.72 | 2.12 |
| 48-47 | | 0.00 | 0.00 | 0.86 | 0.033 | 2.12 | 2.94 |
| 47-46 | | 0.00 | 0.00 | 0.40 | 0.025 | 2.94 | 3.32 |
| 46-45 | Interpolated contributing area | 0.00 | 0.00 | 0.66 | 0.149 | 3.32 | 3.83 |
| 45-44 | Interpolated contributing area | 0.00 | 0.00 | 0.57 | 0.149 | 3.83 | 4.25 |
| 44-43 | Sepulveda Dam, Tillman WRP | 27.14 | 0.00 | 0.60 | 0.149 | 4.25 | 31.84 |
| 43-42 | Just Downstream of Sepulveda Dam | 0.00 | 0.00 | 0.24 | 0.066 | 31.84 | 32.02 |
| 42-41 | | 0.00 | 0.00 | 0.33 | 0.066 | 32.02 | 32.28 |
| 41-40 | | 0.00 | 0.00 | 0.35 | 0.083 | 32.28 | 32.55 |
| 40-39 | | 0.00 | 0.00 | 0.17 | 0.050 | 32.55 | 32.67 |
| 39-38 | | 0.00 | 0.00 | 0.04 | 0.050 | 32.67 | 32.66 |
| 38-37 | Tujunga Wash and Pacoima comes in | 0.00 | 0.00 | 2.30 | 0.017 | 32.66 | 34.94 |
| 37-36 | | 0.00 | 0.00 | 0.74 | 0.017 | 34.94 | 35.67 |
| 36-35 | | 0.00 | 0.00 | 0.13 | 0.025 | 35.67 | 35.77 |

**Table 10** **Dry Weather Flow Rates by River Mile in the Los Angeles River (mgd units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (mgd) | Upwelling flow (mgd) | Urban Dry Weather Flow (mgd) | ET (mgd) | Flow from Upstream (mgd) | Flow Released Downstream (mgd) |
|---|---|---|---|---|---|---|---|
| 35-34 | | 0.00 | 0.00 | 0.47 | 0.017 | 35.77 | 36.23 |
| 34-33 | | 0.00 | 0.00 | 0.23 | 0.166 | 36.23 | 36.30 |
| 33-32 | | 0.00 | 0.00 | 0.03 | 0.166 | 36.30 | 36.16 |
| 32-31 | Burbank WRP | 4.52 | 0.45 | 0.98 | 0.265 | 36.16 | 41.85 |
| 31-30 | Verdugo Wash comes in | 0.00 | 0.45 | 0.93 | 0.365 | 41.85 | 42.87 |
| 30-29 | LA Glendale WRP | 7.82 | 0.45 | 0.28 | 0.249 | 42.87 | 51.17 |
| 29-28 | | 0.00 | 0.45 | 0.11 | 0.182 | 51.17 | 51.55 |
| 28-27 | | 0.00 | 0.45 | 0.06 | 0.249 | 51.55 | 51.81 |
| 27-26 | | 0.00 | 0.45 | 0.67 | 0.249 | 51.81 | 52.69 |
| 26-25 | | 0.00 | 0.45 | 0.12 | 0.332 | 52.69 | 52.92 |
| 25-24 | | 0.00 | 0.45 | 0.04 | 0.332 | 52.92 | 53.08 |
| 24-23 | Arroyo Seco comes in, Begin LA Forebay | 0.00 | 0.00 | 0.72 | 0.134 | 53.08 | 53.67 |
| 23-22 | | 0.00 | 0.00 | 0.68 | 0.040 | 53.67 | 54.30 |
| 22-21 | | 0.00 | 0.00 | 0.31 | 0.040 | 54.30 | 54.58 |
| 21-20 | | 0.00 | 0.00 | 0.38 | 0.081 | 54.58 | 54.88 |
| 20-19 | End LA Forebay | 0.00 | 0.00 | 0.06 | 0.322 | 54.88 | 54.62 |
| 19-18 | | 0.00 | 0.00 | 0.22 | 0.081 | 54.62 | 54.76 |
| 18-17 | | 0.00 | 0.00 | 0.52 | 0.054 | 54.76 | 55.22 |

**Table 10 Dry Weather Flow Rates by River Mile in the Los Angeles River (mgd units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (mgd) | Upwelling flow (mgd) | Urban Dry Weather Flow (mgd) | ET (mgd) | Flow from Upstream (mgd) | Flow Released Downstream (mgd) |
|---|---|---|---|---|---|---|---|
| 17-16 | Interpolated contributing area | 0.00 | 0.00 | 0.46 | 0.161 | 55.22 | 55.51 |
| 16-15 | | 0.00 | 0.00 | 0.33 | 0.081 | 55.51 | 55.76 |
| 15-14 | Interpolated contributing area | 0.00 | 0.00 | 0.15 | 0.081 | 55.76 | 55.83 |
| 14-13 | | 0.00 | 0.00 | 0.11 | 0.242 | 55.83 | 55.70 |
| 13-12 | Rio Hondo comes in | 0.00 | 0.00 | 7.81 | 0.081 | 55.70 | 63.43 |
| 12-11 | Interpolated contributing area | 0.00 | 0.00 | 0.15 | 0.040 | 63.43 | 63.54 |
| 11-10 | | 0.00 | 0.00 | 0.09 | 0.040 | 63.54 | 63.59 |
| 10-9 | | 0.00 | 0.00 | 0.33 | 0.269 | 63.59 | 63.65 |
| 9-8 | Interpolated contributing area | 0.00 | 0.00 | 0.11 | 0.081 | 63.65 | 63.68 |
| 8-7 | | 0.00 | 0.00 | 0.12 | 0.081 | 63.68 | 63.72 |
| 7-6 | | 0.00 | 0.00 | 0.21 | 0.081 | 63.72 | 63.85 |
| 6-5 | Compton Creek, interpolated contributing area | 0.00 | 0.00 | 2.94 | 0.269 | 63.85 | 66.52 |
| 5-4 | | 0.00 | 0.00 | 0.45 | 0.081 | 66.52 | 66.89 |
| 4-3 | Interpolated contributing area | 0.00 | 0.00 | 0.16 | 0.081 | 66.89 | 66.97 |
| 3-2 | | 0.00 | 0.00 | 0.18 | 0.336 | 66.97 | 66.82 |

**Table 10 Dry Weather Flow Rates by River Mile in the Los Angeles River (mgd units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (mgd) | Upwelling flow (mgd) | Urban Dry Weather Flow (mgd) | ET (mgd) | Flow from Upstream (mgd) | Flow Released Downstream (mgd) |
|---|---|---|---|---|---|---|---|
| 2-1 | | 0.00 | 0.00 | 0.04 | 0.537 | 66.82 | 66.32 |
| 1-0 | Mouth | 0.00 | 0.00 | 0.41 | 0.604 | 66.32 | 66.12 |

**Table 11 Dry Weather Flow Rates by River Mile in the Los Angeles River (cfs units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (cfs) | Upwelling flow (cfs) | Urban Dry Weather Flow (cfs) | ET (cfs) | Flow from Upstream (cfs) | Flow Released Downstream (cfs) |
|---|---|---|---|---|---|---|---|
| 51-50 | | 0 | 0 | 2.29 | 0.12 | 0 | 2.17 |
| 50-49 | | 0 | 0 | 0.54 | 0.05 | 2.17 | 2.66 |
| 49-48 | | 0 | 0 | 0.67 | 0.05 | 2.66 | 3.28 |
| 48-47 | | 0 | 0 | 1.33 | 0.05 | 3.28 | 4.56 |
| 47-46 | | 0 | 0 | 0.62 | 0.04 | 4.56 | 5.13 |
| 46-45 | Interpolated contributing area | 0 | 0 | 1.03 | 0.23 | 5.13 | 5.93 |
| 45-44 | Interpolated contributing area | 0 | 0 | 0.88 | 0.23 | 5.93 | 6.58 |
| 44-43 | Sepulveda Dam, Tillman WRP | 42 | 0 | 0.92 | 0.23 | 6.58 | 49.27 |
| 43-42 | Just Downstream of Sepulveda Dam | 0 | 0 | 0.37 | 0.10 | 49.27 | 49.54 |
| 42-41 | | 0 | 0 | 0.51 | 0.10 | 49.54 | 49.95 |

**Table 11 Dry Weather Flow Rates by River Mile in the Los Angeles River (cfs units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (cfs) | Upwelling flow (cfs) | Urban Dry Weather Flow (cfs) | ET (cfs) | Flow from Upstream (cfs) | Flow Released Downstream (cfs) |
|---|---|---|---|---|---|---|---|
| 41-40 | | 0 | 0 | 0.55 | 0.13 | 49.95 | 50.37 |
| 40-39 | | 0 | 0 | 0.26 | 0.08 | 50.37 | 50.55 |
| 39-38 | | 0 | 0 | 0.06 | 0.08 | 50.55 | 50.54 |
| 38-37 | Tujunga Wash and Pacoima comes in | 0 | 0 | 3.55 | 0.03 | 50.54 | 54.07 |
| 37-36 | | 0 | 0 | 1.15 | 0.03 | 54.07 | 55.19 |
| 36-35 | | 0 | 0 | 0.20 | 0.04 | 55.19 | 55.35 |
| 35-34 | | 0 | 0 | 0.73 | 0.03 | 55.35 | 56.06 |
| 34-33 | | 0 | 0 | 0.36 | 0.26 | 56.06 | 56.16 |
| 33-32 | | 0 | 0 | 0.05 | 0.26 | 56.16 | 55.96 |
| 32-31 | Burbank WRP | 7 | 0.70 | 1.51 | 0.41 | 55.96 | 64.76 |
| 31-30 | Verdugo Wash comes in | 0 | 0.70 | 1.44 | 0.56 | 64.76 | 66.33 |
| 30-29 | LA Glendale WRP | 12.1 | 0.70 | 0.43 | 0.39 | 66.33 | 79.18 |
| 29-28 | | 0 | 0.70 | 0.17 | 0.28 | 79.18 | 79.77 |
| 28-27 | | 0 | 0.70 | 0.09 | 0.39 | 79.77 | 80.17 |
| 27-26 | | 0 | 0.70 | 1.04 | 0.39 | 80.17 | 81.52 |
| 26-25 | | 0 | 0.70 | 0.18 | 0.51 | 81.52 | 81.89 |
| 25-24 | | 0 | 0.70 | 0.06 | 0.51 | 81.89 | 82.14 |
| 24-23 | Arroyo Seco comes in, Begin LA Forebay | 0 | 0 | 1.11 | 0.21 | 82.14 | 83.05 |

**Table 11** **Dry Weather Flow Rates by River Mile in the Los Angeles River (cfs units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (cfs) | Upwelling flow (cfs) | Urban Dry Weather Flow (cfs) | ET (cfs) | Flow from Upstream (cfs) | Flow Released Downstream (cfs) |
|---|---|---|---|---|---|---|---|
| 23-22 | | 0 | 0 | 1.04 | 0.06 | 83.05 | 84.03 |
| 22-21 | | 0 | 0 | 0.48 | 0.06 | 84.03 | 84.45 |
| 21-20 | | 0 | 0 | 0.59 | 0.12 | 84.45 | 84.92 |
| 20-19 | End LA Forebay | 0 | 0 | 0.09 | 0.50 | 84.92 | 84.51 |
| 19-18 | | 0 | 0 | 0.34 | 0.12 | 84.51 | 84.73 |
| 18-17 | | 0 | 0 | 0.80 | 0.08 | 84.73 | 85.44 |
| 17-16 | Interpolated contributing area | 0 | 0 | 0.71 | 0.25 | 85.44 | 85.90 |
| 16-15 | | 0 | 0 | 0.51 | 0.12 | 85.90 | 86.28 |
| 15-14 | Interpolated contributing area | 0 | 0 | 0.23 | 0.12 | 86.28 | 86.38 |
| 14-13 | | 0 | 0 | 0.17 | 0.37 | 86.38 | 86.18 |
| 13-12 | Rio Hondo comes in | 0 | 0 | 12.09 | 0.12 | 86.18 | 98.15 |
| 12-11 | Interpolated contributing area | 0 | 0 | 0.24 | 0.06 | 98.15 | 98.32 |
| 11-10 | | 0 | 0 | 0.14 | 0.06 | 98.32 | 98.40 |
| 10-9 | | 0 | 0 | 0.51 | 0.42 | 98.40 | 98.49 |
| 9-8 | Interpolated contributing area | 0 | 0 | 0.17 | 0.12 | 98.49 | 98.54 |
| 8-7 | | 0 | 0 | 0.19 | 0.12 | 98.54 | 98.60 |
| 7-6 | | 0 | 0 | 0.32 | 0.12 | 98.60 | 98.80 |

**Table 11** **Dry Weather Flow Rates by River Mile in the Los Angeles River (cfs units)**
**One Water LA 2040 Plan**

| LA River Mile | Description and Notes | Point Source Flow (cfs) | Upwelling flow (cfs) | Urban Dry Weather Flow (cfs) | ET (cfs) | Flow from Upstream (cfs) | Flow Released Downstream (cfs) |
|---|---|---|---|---|---|---|---|
| 6-5 | Compton Creek, interpolated contributing area | 0 | 0 | 4.55 | 0.42 | 98.80 | 102.93 |
| 5-4 | | 0 | 0 | 0.70 | 0.12 | 102.93 | 103.51 |
| 4-3 | Interpolated contributing area | 0 | 0 | 0.24 | 0.12 | 103.51 | 103.62 |
| 3-2 | | 0 | 0 | 0.28 | 0.52 | 103.62 | 103.39 |
| 2-1 | | 0 | 0 | 0.07 | 0.83 | 103.39 | 102.62 |
| 1-0 | Mouth | 0 | 0 | 0.63 | 0.94 | 102.62 | 102.32 |

# APPENDIX D – DRAFT REVIEW OF ARBOR PROJECT FLOWS (DECEMBER 2016)

Preliminary Draft Date: 8/18/2016

First Draft Date: 8/31/2016

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Lead Author: Tetra Tech

# CITY OF LOS ANGELES

# REVIEW OF ARBOR PROJECT FLOWS

## FINAL DRAFT

December 2016

# CITY OF LOS ANGELES

# TECHNICAL MEMORANDUM

# REVIEW OF ARBOR PROJECT FLOWS

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# LIST OF ABBREVIATIONS

| **Abbreviation** | **Description** |
|---|---|
| af | acre-feet |
| AFY | acre-feet per year |
| ARBOR | Area with Restoration Benefits and Opportunities for Revitalization |
| CDFW | California Department of Fish and Wildlife |
| cfs | cubic feet per second |
| CHAP | Combined Habitat Assessment Protocol |
| CWHR | California Wildlife Habitat Relationships |
| ETo | evapotranspiration |
| Feasibility Report | Los Angeles River Ecosystem Restoration Feasibility Report |
| ft/day | feet/foot per day |
| ft/yr | feet per year |
| HEP | Habitat Evaluation Procedure |
| HGM | Hydrogeomorphic Method |
| HUS | Habitat Units |
| in/yr | inches per year |
| TM | technical memorandum |
| USACE | U.S. Army Corps of Engineers |

# REVIEW OF ARBOR PROJECT FLOWS

## 1.0 INTRODUCTION

This technical memo (TM) reviews the water budget as presented in the 2015 U.S. Army Corps of Engineers' (USACE) *Los Angeles River Ecosystem Restoration Feasibility Report* (Feasibility Report) to gain understanding of water budget assumptions in the Area with Restoration Benefits and Opportunities for Revitalization (ARBOR) reach of the river. The ARBOR reach is an 11.5 mile section of the river from the north side of Griffith Park to First Street in downtown Los Angeles, and is also the Study Area of the current TM. The Study Area is shown in Figure 1 and further described in Section 3.0, "Study Area," herein.

The Feasibility Report presented the water budget required to support vegetated habitat features proposed by the Recommended Plan (or the ARBOR Study), and is described within Appendix E, Hydrology and Hydraulics of the Feasibility Report (USACE, 2015). The discussion characterizes the existing hydrologic conditions of the study area and uses it as a basis to calculate water demand of several restoration alternatives. Water sources identified included both surface water and precipitation. Water demands included evaporation, evapotranspiration, and infiltration. USACE estimated that existing water sources provide 211,348 acre-feet/year (AFY) that flows to the study area on an annual basis. In addition, USACE also calculated that 97,722 AFY of water that flows to the study area during the summer months (April through September), or "dry-season."

## 2.0 OBJECTIVES OF THE TECHNICAL MEMO

The specific objectives of this TM is as follows:

- To gain understanding of the assumptions on inflows (water sources) for the ARBOR reach that was used within the Feasibility Report for the ARBOR Reach.
- To estimate the water demand to sustain both existing and proposed vegetation/ habitat. The Feasibility Report does not provide the water demand for existing needs—only the water demand for proposed vegetation. Therefore, this TM fulfills the need to clarify the water demand for sustaining both existing and proposed habitat.

Limits to the analysis in the Feasibility Report exist and are mostly that water demand for existing conditions was not considered. Native vegetation currently makes up approximately 30% of the study area and would not be removed/replaced as part of the plan as would occur with invasive species. This means that only part of the water demand was calculated.[1]

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[1] While this is consistent with USACE requirements for considering environmental impacts and benefits of proposed projects, it nevertheless requires additional analysis for the purposes herein.

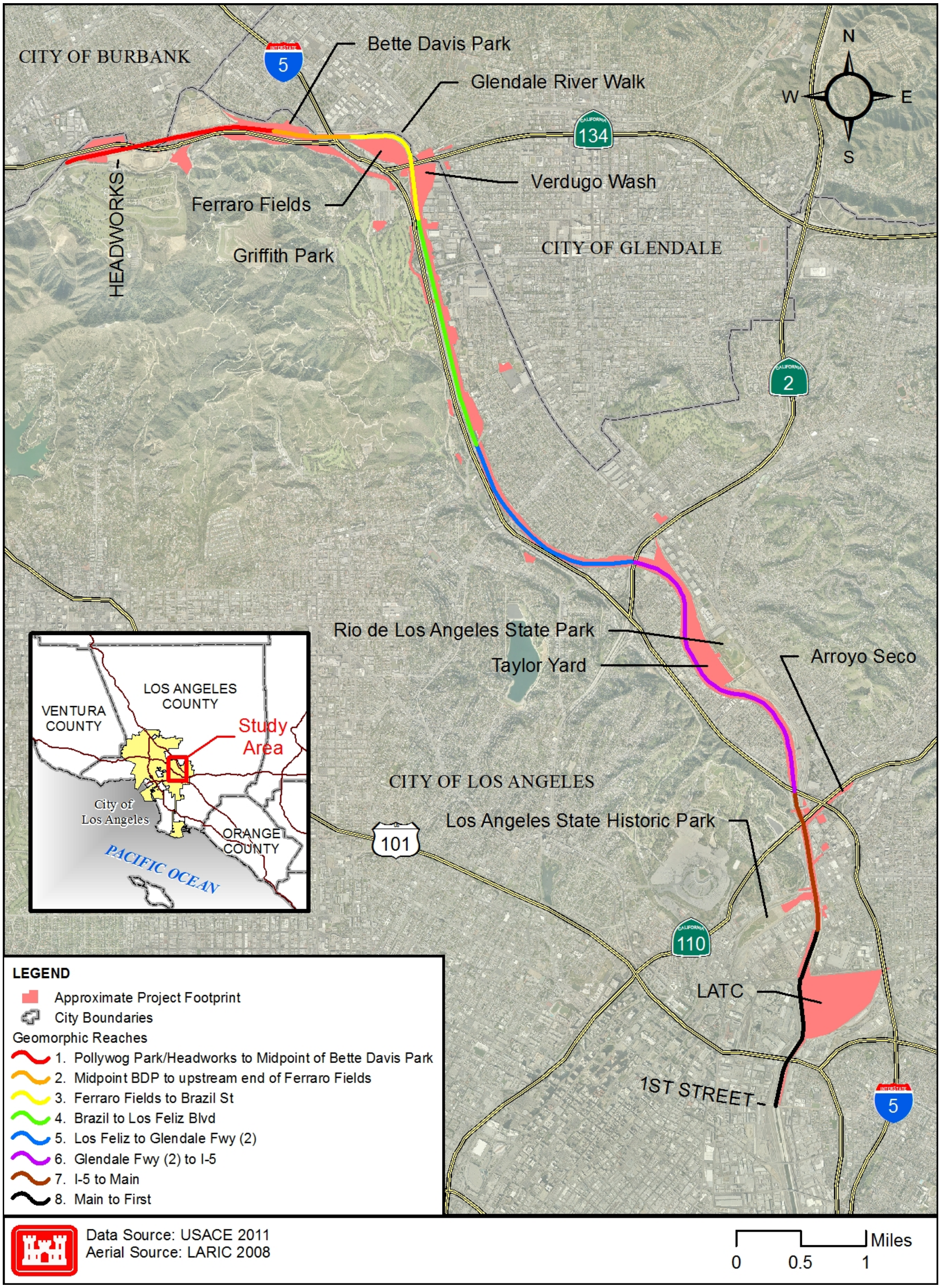

**Figure 1** **Study Area**

Therefore, this TM provides the following: (1) the water demands and water budgets calculated for existing, "baseline" conditions, (2) the proposed enhancements identified by Alternative 20, and (3) the combined total representing post-construction conditions. When considering data that is part of the historic record, input values from the Feasibility Report were used as the basis of most calculations in an effort to maintain consistency with those published, as well as to produce results comparable to those already established.

## 3.0 STUDY AREA

The Feasibility Report analyzed alternatives to restoring 11.5 miles of the river from Griffith Park to downtown Los Angeles, as shown in Figure 1, above, and represents the Recommended Plan also known as "Alternative 20." This area, referred to as the "study area" in this TM, was described by Appendix G of the Feasibility Report to be 842.37 acres, overall. Using the Feasibility Report GIS data prepared for Alternative 20, the area of proposed habitat enhancements was calculated to be 540.55 acres. Appendix G also identified 244.92 acres of habitat currently present in the study area. The remaining 56.90 acres represent proposed enhancements that would not involve habitat.

## 4.0 APPROACH/METHODOLOGY

Basic definitions and assumptions were made for this TM to establish the basis for the analyses. Availability of the more localized, site specific data types were limited due to variability of the study area. These include, for example, values such as specific soil-dependent infiltration rates when the exact soils and substrate conditions are unknown…or evaporation rates from open water having partial shade during the day within the study area when evaporation rates are generalized by nearby stations. To fully characterize these data, additional laborious, site specific field work would need to occur. Therefore, to increase the efficiency of the analysis, reasonably characteristic published data were used as inputs to spreadsheet models. These models were developed to calculate water demands and water budgets. When input data were not directly available, the best applicable data were used along with assumptions associated with their use. When open to interpretation, we took a conservative approach to any discrepancies that may exist between the data used and other potential sources of data. In this case, a conservative approach translates to actually having more water available for the habitat in the ARBOR reach than calculated herein.

Data used for this analysis are described in the sections below and in Table 1, which includes discussions on where they were sourced as well as the assumptions and context established for their use.

The overall calculation for the water budget for the ARBOR reach is, simply, (Water Source) – (Water Demand) = (Water Outflow). This calculation requires two components: (1) an actual value or estimate for the extent of hydrology available to habitat, and (2) an actual value or estimate of the needs of that habitat. Water budget was further broken down into both existing conditions and proposed conditions. Establishing numerous values was required prior to calculating the water budget. These values as well as their descriptions and key assumptions are provided in Table 1, below. Additional discussion of each of these values is presented in subsequent sections. The basis of all calculations presented in this TM is the size of the study area, which was identified in Appendix G of the Feasibility Report as 842.37 acres. Appendix G identified 244.92 total acres of habitat that is currently present in the study area, and, using the GIS data originally prepared for Alternative 20 in the Feasibility Report, the total size of the habitat enhancements was calculated to be 540.55 acres (with 56.90 acres of proposed enhancements remaining that do not involve establishment of habitat).

## 4.1 Precipitation

The mean seasonal precipitation in the study area was identified to be 17.5 inches per year (in/yr), as recorded at the Burbank weather station (see Appendix E of the Feasibility Report). This results in an annual mean precipitation volume for the study area of 1,227.76 AFY, or 1,104.99 AFY for the wet-season and 122.78 AFY for the dry-season. The values in the Feasibility Report were less than those calculated in this TM, and as a result, were used for this analysis to maintain the conservative approach. The values used were 782 AFY of precipitation falling during the wet season and 87 AFY during the dry-season.

## 4.2 Streamflow

Streamflow was estimated both annually and during the summer months in Appendix E of the Feasibility Report, and indicates that subsequent to 1985 and the Donald C. Tillman Water Reclamation Plant coming online, the average daily flow in the study area was 291 cubic feet per second (cfs) annually and 134 cfs during non-flood season (i.e., dry-season). In units of AFY, these values are 210,674.5 and 97,011.6, respectively.[2] The post-2012 flow data used include daily flows released into the Los Angeles River for four years from January 2012 to December 2015 from the two Water Reclamation Plants including Donald. C. Tillman and Los Angeles Glendale Reclamation Plant. Flow data released from the Burbank Water Reclamation Plant was not available. Using these 2012-2015 streamflow data, the streamflow values decrease to 54,327 AFY during the dry-season.

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[2] These numbers are slightly higher than those presented later in Table 8 of the Feasibility Report, but the difference is caused by rounding 290.73 cfs and 133.8 cfs, respectively.

**Table 1 Values Identified and Used for the Models Developed for this TM**

| **Water Source =** | **(Precipitation) + (Streamflow) + (Ground Water)** |
|---|---|
| **Precipitation** | **Description**: The total volume of rain/snow that falls on the study area, as recorded at the Burbank Valley Pump Plant Weather Station (No. 41194); It has been estimated that 90% of precipitation falls during the "wet-season" (Nov-Apr) (the "dry-season" is from May-Oct); Precipitation is considered additive to streamflow |
| | **Components**: Rain- and snow-fall within the study area |
| **Streamflow** | **Description**: The average annual volume flowing through Station no. F57C-R of the Los Angeles River, above Arroyo Seco; This value only considers data collected since the Donald C. Tillman Water Reclamation Plant came on line in 1985, however, outflow has decreased starting in 2013 and continued to at least 2015, and is also considered; Because data was not readily available to specifically calculate stream flow averages for the "wet-season" (Nov-Apr) and "dry-season" (Dec-Mar), the "annual flow" value was used for wet-season calculations, and the "non-flood season" value was used for dry-season calculations |
| | **Components**: Stormflow runoff in the upper watershed, outflow from water reclamation plants, and urban sources |
| **Groundwater** | **Description:** Hydrology located subsurface that potentially contributes to surface features such as habitat – it is generally the opposite of infiltration when groundwater undergoes upwelling within the channel, as is the case with a "gaining stream" that increases streamflow volume. Groundwater was not considered in the Feasibility Report; The study area has variable depth to groundwater, but there is can be upwelling as the river flows towards the downstream portion of the ARBOR reach. |
| | **Components:** Subsurface hydrology from any source |
| **Water Demand =** | **Water Sink = (Infiltration) + (Evaporation) + (Evapotranspiration)** |
| **Infiltration** | **Description**: The potential maximum rate at which water can enter the soil at any point in time |
| | **Components**: The infiltration value for the study area was based on the assumption that all area currently with measurable habitat is composed of native "Group D" soils |
| **Evaporation** | **Description**: The portion of the water balance that evaporates from open water sources (i.e., not from the soil or through plant transpiration); includes evaporation from water flowing across the concrete or soft-bottom channel sections |
| | **Components**: The average annual evaporation rate of 2.31 ft/yr was used – this value was calculated by averaging across monthly evaporation rates collected at Descanso Gardens, the closest geographic source of data to the study site |
| **Evapotranspiration** | **Description**: The sum of evaporation from the land surface plus transpiration from plants |
| | **Components**: Two types of evapotranspiration values were incorporated in the model: 1) those established for habitats in Arizona determined to be the same or analogous to habitats identified in the study area, and 2) a value calculated for Glendale, Los Angeles Basin, using a model developed by CIMIS |

Note that streamflow is only available to habitat as it moves through the study area. Once it flows downstream of the study area it is considered as "outflow" for the purposes of the water budget balance. This is a significant caveat. What this implies is that water budgets – including the calculations herein and by the Feasibility Report – may not accurately reflect what may be available to habitat within the ARBOR reach. Since a majority of the annual, measured flow within the channel is from precipitation, wet-season flow accounts for over three times as much streamflow as during the dry season, the latter of which is due in large part to water reclamation plant discharge and urban runoff – both *relatively* constant throughout the year. Care must be taken, therefore, when considering the water budget and any results that are based on large amounts of streamflow, for example, quantities represented during the wet season. A majority of this flow would not be available for habitat use.

## 4.3 Infiltration

Infiltration was based on soil type data provided by NRCS and referenced in Appendix E of the Feasibility Report. The soils underlying the study area fall primarily into Hydrologic Soil Group D, which is a soil with the lowest infiltration rate of those found in the study area. The average infiltration rate of Group D soil is 0.3 foot per day (ft/day) or 109.5 feet per year (ft/yr). These values are then multiplied by the acreages for baseline (301.8 acres) and proposed project (540.6 acres) surface types (i.e., open water or habitat growth) that are taken directly from the detailed GIS data used by the Feasibility Report to measure habitat benefits. No infiltration was calculated for the concrete or grouted rock revetment sections of the river. The resulting infiltration volumes for baseline conditions and proposed habitat conditions, converted to units of AFY, are 33,047.1 AFY and 59,195.7 AFY, respectively.

It should be noted that the source of these data come from the Feasibility Report and are generalized for Group D soils. Since the ARBOR reach has significant upwelling of groundwater typically characteristic of "gaining streams," it is expected that a significant amount of the predicted losses due to infiltration will not be realized especially as flow continues towards the downstream end of the study area. The Geosyntec TM (Geosyntec, 2016) documented this in its discussion of upwelling within the ARBOR reach as being approximately constant throughout the year and contributing approximately 3,257 AFY to the soft bottom reach within the Glendale Narrows. This is in contrast to the analysis mentioned above within the Feasibility Report that represents infiltration as a volume loss. The current analysis uses the Feasibility Report's findings for infiltration for the following reason: Upwelling is highly dependent on the depth below ground of the groundwater table which is affected by upstream infiltration as well as drawdown by the Cities of Los Angeles', Glendale's and Burbank's water wells in the area. Further, given a high enough water table, upwelling would increase toward the downstream portion of the ARBOR reach due to the uplift where San Fernando Basin groundwater flows into the Central Basin. This occurs just downstream of Taylor Yard. But again, as mentioned above, a conservative approach to the water budget would still account for infiltration because that would translate to actually having more water available for the habitat in the ARBOR reach than if infiltration were non-existent.

This could be studied further by groundwater modeling. Indeed, a more detailed groundwater model would likely show less infiltration with additional flow continuing downstream to the ocean. As indicated below in Section 5, "Analysis/Findings," this becomes a significant fact due to infiltration being an extremely large component of the overall water demand within this reach.

### 4.4 Evaporation

For an alternative that incorporates ponding of water, such as Alternative 20, evaporation is thought to be an important factor for understanding the water budget. Under baseline conditions, the area of "Open Water (Channel)" listed in Appendix G of the Feasibility Report was used to calculate evaporation under the assumption it is the only habitat type listed with significant propensity to pond and evaporate water. Under baseline conditions, the total evaporation volume for the study area was calculated to be 420.91 AFY, based on 182.21 acres of open water being present. Based on the GIS data for Alternative 20, the proposed enhancements are expected to add an additional 59.18 acres of open water habitat to the study area, resulting in a total evaporation volume of 557.62 AFY as part of the "with-project," proposed habitat enhancements.

### 4.5 Evapotranspiration

See the discussion under the section titled "Habitat Types," immediately below, for information on evapotranspiration.

### 4.6 Habitat Types

Habitat types are generally characterized by a dominant plant species, vegetation form, or a physical characteristic. The habitat types identified under baseline conditions were from the *California Wildlife Habitat Relationships* (CWHR) habitat classification scheme (Mayer and Laudenslayer, 1988) used by the California Department of Fish and Wildlife (CDFW). Three habitat types were identified, with each specifically reliant on hydrology in the study area: Valley Foothill Riparian, Coastal Scrub, and Open Water (Table 2). In contrast, the "habitat types" described under the restoration alternatives, listed in each "plant palette," are informal and are not from CWHR. To bridge this discrepancy and be able to compare pre- and post-construction conditions, each baseline habitat type was matched to a similar "plant palette" using the overlapping species in each. For example, the plant palette for Open Water shown in Table 2 represents common species that inhabit open water fringes and freshwater marshes, While the CWHR habitat classification does not specifically call out freshwater marsh, the plant palette below is consistent with representative species and those intended for the ARBOR project. Further, use of a buffer/transitional zone within the channel is considered important to help reconnect overbank areas with the river channel.

And while "coastal scrub" occurs most frequently in the surrounding hills, the species recommended in the Feasibility Report for a buffer/transitional zone within the channel are most indicative of the Coastal Scrub habitat class within the CWHR system.[3]

Quantifying evapotranspiration, or the sum of evaporation and plant transpiration, is essential for understanding the water budgets of habitat types. For the proposed project, the best available evapotranspiration values are from riparian habitats of the Sonoran Desert of Arizona, as shown in Table 13 (from Appendix E of the Feasibility Report). These values had been applied to several other USACE projects in the Arid Southwest, and their applicability to habitat types of the chaparral ecosystem is appropriate because of overlapping of shared habitats and species. The only exception is Coastal Scrub, which generally does not share species with the "Quailbush-Sagebrush" of the Sonoran Desert (Greeley and Hansen, 1998). It does, however, share similar growing conditions, vegetation structure, and precipitation volumes with Coastal Scrub (Meyer, 2005), suggesting its use as an analogue is appropriate.

It should be noted that while evapotranspiration can range from 4.1 ft/yr to over 8.0 ft/yr for the riparian plant palette, based on sources within the Feasibility Report, the conservative value of 8.0 ft/yr was used herein to characterize the proposed riparian palette. This provides an upper end of expected evapotranspiration (ETo) which is considered conservatively appropriate for the current purpose of investigating the water budget required to support proposed habitat within the ARBOR reach.

For additional context, data for the evapotranspiration rate for Glendale, CA (CADWR, 2015), in its entirety, was also included in this analysis (Tables 2 and 3). It is anticipated that the total evapotranspiration rate for the proposed project (i.e., existing conditions plus proposed habitat enhancements) should be roughly less than, but comparable to the value based on the evapotranspiration rate for Glendale.

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[3] The plant palette within the Feasibility Report is tied to the economic analysis that estimates a return-on-investment for each additional habitat unit that the restoration project provides. When combined with the costs for each alternative, the analysis provides a benefit/cost ratio used by USACE for plan selection.

**Table 2 Habitat Types Matched for Comparability**

| CWHR Habitat Class | Plant Palette | Associated Species | |
|---|---|---|---|
| Valley Foothill Riparian | Riparian | *Ambrosia psilostachya* | Western ragweed |
| | | *Artemisia douglasiana* | Mugwort |
| | | *Baccharis salicifolia* | Mulefat |
| | | *Mimulus cardinalis* | Scarlet monkeyflower |
| | | *Platanus racemosa* | Western sycamore |
| | | *Populus fremontii* | Fremont's cottonwood |
| | | *Salix laevigata* | Red willow |
| | | *Salix lasiolepis* | Arroyo willow |
| Coastal Scrub | Buffer/ Transitional | *Artemisia californica* | California sagebrush |
| | | *Eriogonum fasciculatum* | California buckwheat |
| | | *Eschscholzia californica* | California poppy |
| | | *Helianthus annuus* | Sunflower |
| | | *Leymus condensatus* | Giant wild rye |
| | | *Lotus scoparius* | Deerweed |
| | | *Malacothamnus fasciculatus* | Chaparral mallow |
| | | *Malosma laurina* | Laurel sumac |
| | | *Rhus integrifolia* | Lemonade berry |
| | | *Salvia apiana* | White sage |
| Open Water | Open Water/ Freshwater Marsh | *Carex praegracilis* | Clustered field sedge |
| | | *Cyperus odoratus* | Fragrant flatsedge |
| | | *Eleocharis parishii* | Parish's spikerush |
| | | *Juncus effusus* | Common rush |
| | | *Mimulus cardinalus* | Scarlet monkeyflower |
| | | *Schoenoplectus californicus* | California bulrush |
| | | *Typha angustifolia* | Narrow leaved cattail |
| | | *Typha latifolia* | Common cattail |
| Evapotranspiration for Glendale, CA | All combined | The reference crop used for the CIMIS program is grass, which is closely clipped, actively growing, completely shading the soil, and well-watered (source: CADWR, 2015) | |

To calculate the annual water budget, evapotranspiration values from existing habitat types need to be added to those that are proposed. It was previously calculated within the Feasibility Report that the proposed habitat enhancements for Alternative 20 would require a water budget of 68,529 AFY to support the proposed habitat in the study area. These values, however, do not include the needs of existing habitat identified under baseline conditions, as previously mentioned. These needs are addressed in the sections, below.

| Table 3 Evapotranspiration Rates for Habitat Types of the Proposed Project | | |
|---|---|---|
| **CWHR Habitat Class** | **Plant Palette** | **Ave. ETo Value (ft/yr)** |
| Valley Foothill Riparian | Riparian | 8.00(1) |
| Coastal Scrub | Buffer/Transitional | 3.20(1) |
| Open Water - Riverine | Open Water | 9.00(1) |
| Evapotranspiration for Glendale, CA | All combined | 4.32(2) |

Notes:

(1) Greeley and Hansen, 1998
(2) CADWR, 2015

## 4.7 Additional Information

The area of each project feature – independently or combined – largely determines the outcome of the models used to understand the hydrology needed to support vegetation. All area-values for proposed enhancements came from the Combined Habitat Assessment Protocol (CHAP)[4] GIS Alternative Summary for Alternative 20. These data were provided as "polygons" at their finest level of detail within the habitat analysis. Because each polygon is defined by a proposed enhancement action, the impact of each on habitat was relatively clear and quantifiable. For this TM analysis, each polygon was classified by whether it would affect evaporation, infiltration, or evapotranspiration, and if so, in what way. The polygon descriptions inferred that the habitat enhancements would occur in areas without existing habitat, although not explicitly stated. A portion of the habitat enhancements will include removal of invasive species (48.26 acres), but it is unclear whether these sites will be converted to habitat or non-habitat features. Either way, the relatively small footprint of invasive removal would not have a substantive effect on the water budget. For this analysis, it is assumed the area of habitat enhancement would be additive to habitat quantified under existing conditions. Input data for existing conditions was acquired from Appendix G, Habitat Evaluation (CHAP) within the Feasibility Report.

# 5.0 ANALYSIS/FINDINGS

Comparisons were made with the evapotranspiration components of a recent low-flow Study (Geosyntec, 2016) that analyzed available water during peak low-flow of the driest annual period. Considering evapotranspiration, the Geosyntec study indicated that the ARBOR reach restoration would result in 4.8 mgd (5,377 AFY) evapotranspiration due to the additional habitat (proposed) within that reach. This number is built upon the proposed-condition-only number within the Feasibility Report (3,118 AFY = 2.8 mgd) to which existing

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[4] The CHAP analysis method is similar in purpose to other habitat assessment methods such as the Habitat Evaluation Procedure (HEP) and the Hydrogeomorphic Method (HGM) analyses. Habitat output is typically measured in Habitat Units (HUs) within these assessments.

ETo was added based on a "worst-case" condition during August months. The 4.8 mgd is on the same order of magnitude as the number estimated within this study or current TM, estimated to be 5,848 AFY or 5.2 mgd for existing plus proposed annual ETo demand. The difference between the two AFY values is likely due to (1) the source of ETo rates that is used, and/or (2) the greater accuracy of the current TM which is based on specific habitat types and open water acreages. Based on the overall water demand as presented herein, the difference between the two reported ETo values within the Geosyntec 2016 study and this TM represents a 0.4 percent change. A comparison is shown in Table 4, below, which considers the annual ETo demand for the ARBOR reach.

**Table 4 Comparison of Annual Evapotranspiration Values**

| Data Source | mgd | Acre-Feet | Notes |
|---|---|---|---|
| Current TM | 5.2 | 5,848 | Based on specific acreages of habitat types and their corresponding average annual ETo rates; includes demand values for existing and proposed conditions |
| Geosyntec Consultants (2016) | 4.8 | 5,377 | Based on the proposed-condition-only number within the Feasibility Report plus existing ETo demand for "worst-case" conditions during August months. |
| USACE 2015 or the Feasibility Report | 2.8 | 3,118 | Only includes demand values for proposed project conditions |

Of greater note is the amount of infiltration indicated in the Geosyntec report. That report did not consider infiltration as a water demand since this reach of the Los Angeles River is considered a "gaining stream" in which upwelling of groundwater typically occurs rather than infiltration. As indicated in Section 4.3, above, this may be true—although the dynamics of localized groundwater would still account for infiltration. While this could be studied further by groundwater modeling, it is likely that a groundwater model would show less infiltration than indicated by the Feasibility Report and also used herein. This is highly significant since infiltration accounts for over 90 percent of the water demand, so even the largest water demand deficit in Table 5 would not occur with even a 25 percent decrease in infiltration losses, as modeled.

Concerning climate change, it is highly probable that variability from these results will occur in the future due to altered weather patterns in Southern California. Reduction in dry-season precipitation, urban runoff, and/or changes in water reclamation plant discharge could rapidly erode the amount of stream flow available and create even more of a deficit. Further, if conditions become dryer than anticipated, the habitat types will be differentially affected due to their varied reliance on water. The most sensitive habitat type to desiccation would be open water-riverine because of the majority of wetland plants within it, followed by valley foothill riparian and coastal scrub. Sensitivity to desiccation will be at its highest for all vegetation immediately following planting, prior to becoming established. Supplemental irrigation is proposed by the project to maintain the plantings for a period of time – typically up to five years if necessary.[5] Microhabitat conditions, or the specific habitat characteristics surrounding one or a few plants, will ultimately determine whether planted vegetation will become established and thrive. Under natural conditions, individual plants only thrive in sites with conditions that fully support their needs. The success of vegetation would also be determined by the location of plants relative to the stream channel – their lateral and vertical distance from the hydrology source. This aspect of the plant palette and the location of its species is expected to be determined during design.

## 6.0 CONCLUSIONS

Specific conclusions are as follows:

- Water budget results from the Feasibility Report did not account for the water demand of existing habitat features. This has been accounted for herein based on acreage of existing habitat.
- Dry season flow is more indicative of what would actually be available for habitat demand on a consistent basis since average wet season flow is three times the amount of dry season flow. Further, since this greater amount of wet season flow is due to rainfall, it is very concentrated in small periods and the flow mostly continues beyond the ARBOR reach if not otherwise captured.
- Of the total water demand in both the existing and proposed condition, the largest component contributing to the demand is the water loss from infiltration. This loss contributes over 90 percent of the total water demand.

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[5] Irrigation requirements can be calculated using available models such as what is provided by the University of California, Division of Agriculture and Natural Resources; Center for Landscape & Urban Horticulture (2016). Land managers responsible for landscaping would also provide a guidance resource for the water needs of recently established native plants.

- The minimum amount of water needed to sustain the proposed project is 34,405 AFY during the wet-season and 64,241 AFY during the dry-season, as modeled by the current TM. Assuming these stream flows are the most accurate and appropriate for this analysis, these results indicate additional hydrology would be required to sustain existing and proposed habitat enhancements in the post-2012 conditions unless the following reasonable assumptions are made that reduce infiltration losses.
  - Reducing the infiltration volume by only 25 percent removes the water demand deficit.
  - Reducing the infiltration volume is reasonable since the infiltration assumptions were conservative, as mentioned above. Therefore, any upwelling would reduce infiltration. Even without upwelling, the infiltration rate would reduce as the vadose zone – the unsaturated zone between the surface and water table – becomes saturated.
- The findings of this TM indicate stream flow is the key driver in determining whether enough hydrology will be available to support habitat in the study area following the completion of construction. Based on Figure 6 in the Geosyntec TM (Geosyntec, 2016), flows from the two water reclamation plants plus incidental urban runoff are the two main sources of dry weather stream flow. As such, they represent annually consistent stream flow.
- Meeting habitat water demand is dependent on the areal distribution of water contacting the streambed/banks to a greater extent than the dependency on high volumes of water. This is because a majority of the water flow would continue downstream so that excess water would not be beneficial when only considering the ARBOR reach. This of course depends on modeling proof for having enough water that would in fact flow downstream given the substrate interface. Further, any localized water deficit could be mitigated with hydraulic structures such as small rubber dams, boulder arrays, or coffer-type structures.
- Therefore, dry weather flow should continue to be sufficient for existing habitat as well as proposed additional habitat based on:
  - Flow width and depth being somewhat insensitive to changes in the flow rate in locations modeled within the Geosyntec TM (Geosyntec, 2016)
  - Availability of water displayed within Table 5, above, combined with the reasonable assumption that even a 25 percent reduction in infiltration would take place as would be expected when the substrate becomes saturated over the water table

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# APPENDIX E – DRAFT TECHNICAL MEMO OF LA RIVER WATER STORAGE POTENTIAL AND MAINTAINING OPTIMAL FLOWS USING LEVEL CONTROLS (JANUARY 2017)

# LA River Water Storage Potential Study
# Maintaining Optimal Flows Using Level Controls

## Technical Memorandum

Prepared by

SEITec

January 4, 2017

SEITec

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# Attachments

**Attachment I, PowerPoint Presentation**

**Attachment II, Hydraulic Cross Sections for Each Considered Scenario**

# 1. Introduction

This work was performed under the City of Los Angles One Water LA 2040 task order No. 17.

The Los Angeles (LA) river has a large volume that could potentially be used to store rainwater runoff. The stored rainwater would be beneficially used to offset freshwater use in the City. In addition, there is a need to minimize the reclaimed water (RW) releases from DCT and LAG for purposes of natural habitat preservations and restoration. Currently, DCT and LAG release significant volumes of water annually to augment the dry weather flows such that there is enough water in the river for the established wildlife habitats. The idea is to reduce the required releases by providing check dams to raise the water level along these reaches and increase the corresponding wetted perimeter instead of accomplishing the desired wetted area with flow only. The purpose of this work was to quantify the wet weather storage potential of the LA River and examine the hydraulics of check dams for dry weather level control.

For wet weather storage, the basic concept is to install rubber dams in the LA river at suitable locations to create consecutive impoundments upstream to store rainwater. During wet weather, the dams would be deflated for most of the stormwater runoff event, and would inflate towards the end of the event to catch and store the tail end of the runoff hydrograph. The stored water could then be used to offset freshwater use in the City. For dry weather flow water level control in certain reaches, smaller check dams at closer intervals would be needed to create a cascade of pools and drops to minimize RW releases into the river.

## Study Area

The study area was chosen to include almost the entire reach of the LA River, upstream from the point of river channelization and downstream to the City of Los Angeles Southern limits. The purpose was to identify and quantify the maximum volume of storage that could be made available to the City by the LA River. Figure 1 shows the five distinct segments (reaches) that made up the total study area.

The reaches were logically defined by the presence of two physical features in the river; 1) Sepulveda Dam, and 2) the ARBOR reach, as follows:

1. Upstream of Sepulveda Dam
2. Sepulveda Dam flood storage space
3. Sepulveda Dam to Glendale Narrows
4. Glendale Narrows (ARBOR Reach)
5. Downstream of Arroyo Seco to City limits

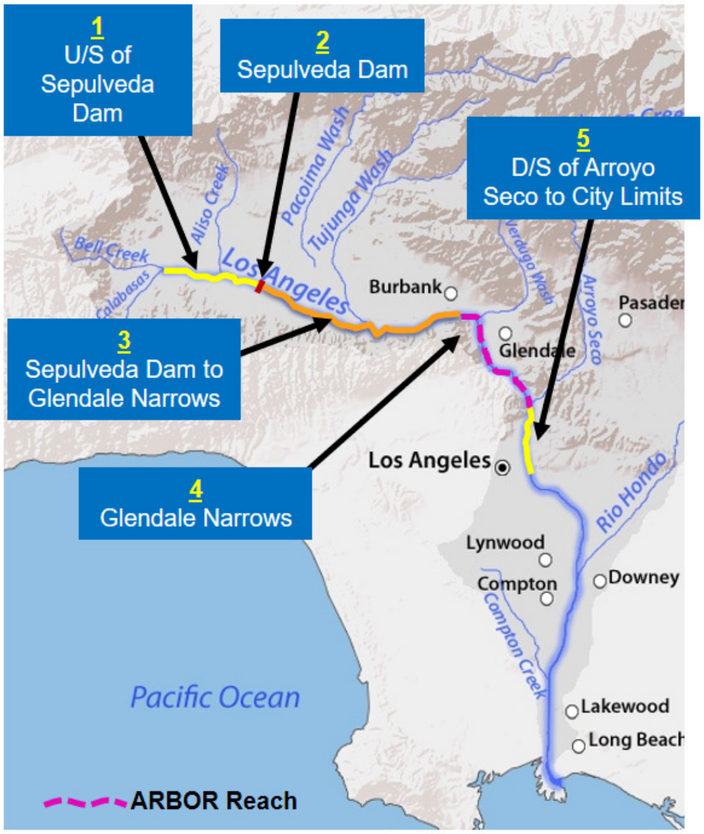


**Figure 1: Study Area and River Reaches**

## Study Scope and Objectives

While the primary scope and objective of this work was to quantify the in-channel storage potentials of the river, this study also identified and quantified the potentials for off-channel storage in close proximity of the LA River to divert and store runoff during stormwater events. Furthermore, this study developed conceptual options for conveyance of the stored water to the existing City of LA water reclamation facilities, namely DC Tillman (DCT) and LA Glendale (LAG). In addition, this study examined the potential for direct potable water use of the stored water. Lastly, this study performed HEC-RAS modeling analysis along certain reaches to simulate hydraulic conditions during dry weather flows with check dams to minimize reclaimed water releases. Therefore, the specific objectives of this study were to examine and evaluate the following:

1. In-channel storage potential
2. Off-channel storage potential
3. Conveyance to DC Tillman and LA Glendale WR facilities
4. Possibility of treatment for direct potable water use
5. Dry weather level control in select reaches to minimize RW releases into the river for habitat restoration

# 2. In-Channel Storage Potential

## Methodology and Results

For the purposes of this study and to avoid any practical uncertainties with regards to technical and technological feasibility, the maximum height of the rubber dams was limited to 18 ft high. For each dam location, a minimum freeboard of 1.5 feet between the dam crest and the adjacent river bank was considered to determine the maximum dam height. Therefore, for bank heights of more than 18 + 1.5 = 19.5 ft, the dam height was 18 ft, while for bank heights of less than 19.5 ft the dam height was determined as bank height minus 1.5 ft freeboard.

Because of the river slope, the depth of impoundment decreases with distance upstream, thereby decreasing the utility of the river section for storage. It follows that closer dam spacing that locates the dam within the impoundments leads to a higher utilization of the river for storage and vice versa. So, in order to better utilize the available storage, the depth of impoundment upstream that coincides with the tailwater depth at the next dam upstream was selected to be 1/3 of the upstream dam height. This is somewhat arbitrary and will require economic optimization as a tradeoff between value of storage versus cost of the dams.

Locating the first dam at the downstream end of each reach, the location of the next dam upstream was identified as where the depth of the impoundment was about 1/3 of the embankment height minus 1.5 ft freeboard (i.e. the height of the upstream dam). In this way, the locations of consecutive dams upstream were identified. These were examined for local features such as road crossings and river confluences to make sure that they are feasible.

Figure 2 shows the selected dam locations for the Reach 1, "Upstream of Sepulveda Dam". Overall there are a total of six potential dam locations in this reach based on the criteria described above.

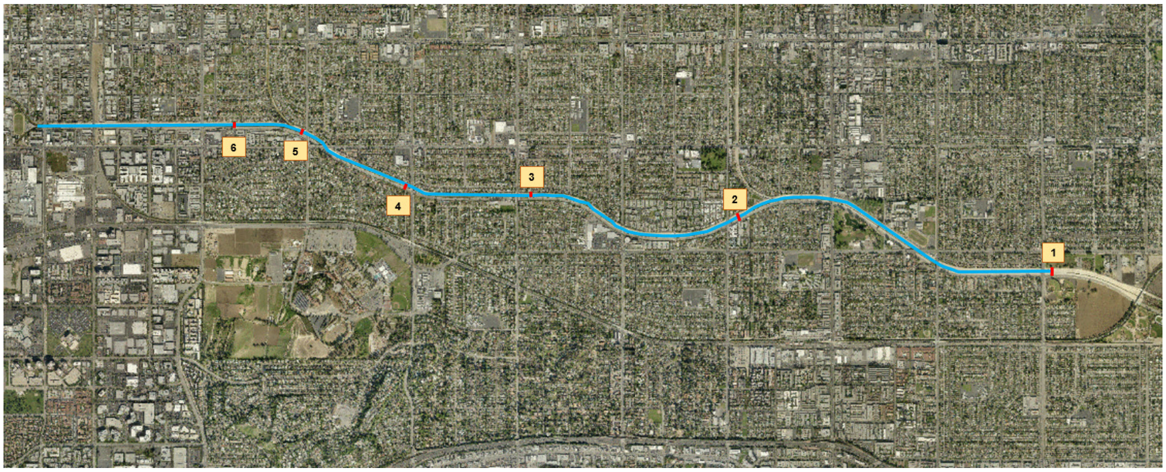


**Figure 2: Selected Potential Dam Locations in Reach 1, "Upstream of Sepulveda Dam"**

Figure 3 shows the section geometry of the river at the identified potential dam location No. 1 in Reach 1. Similar cross section geometries where developed for each dam location.

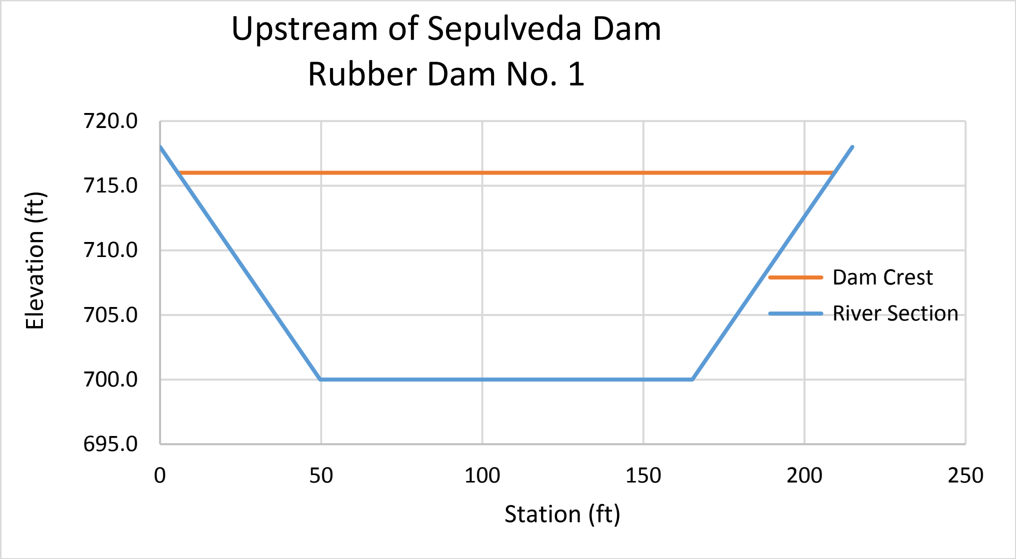


**Figure 3: Section Geometries at the Potential Dam Location NO. 1 in Reach 1**

With the dam locations identified, the storage volume between consecutive dams was calculated by multiplying the average wetted cross section area in the reach by the length of the impoundment. Table 1 shows the volume calculation results.

**Table 1: Impoundment Volume Calculation Results for Reach 1**

| Station at Dam Location | Dam No. | Selected Dam Height | Impndmt Length (ft) | River Section Area U/S (ft$^2$) | River Section Area at Dam (ft$^2$) | Average Wetted Section Area (ft$^2$) | Impndmt Storage (ft$^3$) | Impndmt Storage (MG) |
|---|---|---|---|---|---|---|---|---|
| **0** | 1 | 16 | 7,066 | 660 | 2,554 | 1,607 | 11,356,308 | 84.9 |
| **7,066** | 2 | 17 | 4,804 | 527 | 2,087 | 1,307 | 6,281,173 | 47.0 |
| **11,870** | 3 | 17 | 3,609 | 526 | 2,061 | 1,294 | 4,668,261 | 34.9 |
| **15,479** | 4 | 17 | 2,612 | 525 | 2,047 | 1,286 | 3,359,038 | 25.1 |
| **18,091** | 5 | 16 | 1,975 | 308 | 1,337 | 822 | 1,624,116 | 12.1 |
| **20,066** | 6 | 16 | 2,002 | 308 | 1,333 | 820 | 1,642,456 | 12.3 |
| **Total** | | | **22,068** | | | | | **216.4** |

In order to determine the storage potential within the flood control storage space of the Sepulveda Dam, which is defined by the Sepulveda Dam downstream and Rubber Dam NO. 1 of Reach 1 upstream, it was assumed that the existing spillway gates at the dam could be operated to retain some water impoundment within the flood control storage space of the dam upstream, up to a certain level that does not result in flooding of property and roads upstream. Examination of aerial photos of the Sepulveda Dam flood control reservoir together with topographical elevation contours revealed that water may be impounded upstream of the dam up to El. 688 without flooding of property or roads upstream. This is illustrated in Figure 4, in which the inundation area by an impoundment at El. 688 is superimposed on an aerial photograph of the Sepulveda Dam flood control space.

**Figure 4: Inundation Area at El. 688 Upstream of Sepulveda Dam**

Therefore, the available stormwater storage potential of the flood control space upstream of the Sepulveda dam was taken to be the flood control storage volume corresponding to El. 688. This was determined by calculating the Sepulveda Dam elevation – storage curve using the USGS 4.0-ft contour interval topographic map available in the City of Los Angeles online data base called Navigate LA, as well as published data for Sepulveda Dam, shown in Table 2.

**Table 2: Sepulveda Dam Data**

| | |
|---|---|
| Drainage Area | 152.0 mi$^2$ |
| Reservoir Elevation | |
| Spillway Crest (gates lowered) | 700.0 ft |
| Flood Control Pool (spillway gates raised) | 710.0 ft |
| 100-yr Flood Event | 712.1 ft |
| Top of Dam | 725.0 ft |
| Reservoir Area | |
| Spillway Crest (gates lowered) | 794 ac |
| Top of Spillway Gates (raised position) | 1,348 ac |
| Top of Dam | 2,591 ac |
| Reservoir Gross Capacity | |
| Spillway Crest (gates lowered) | 7,280 af |
| Top of Spillway Gates (raised position) | 18,129 af |
| Top of Dam | 46,764 af |
| Allowance for Sediment | 0 af |
| Dam: - Type | Earthfill |
| Height above Original Streambed | 57 ft |
| Top Length | 15,440 ft |
| Outlets: | |
| Uncontrolled | |
| Number and Size of Gates | 4 - 6 ft W x 6.5 ft H |
| Gate Sill Elevation | 668 ft |
| Controlled | |
| Type of Gates | Vertical Lift |
| Number and Size of Gates | 4 - 6 ft W x 9 ft H |
| Gate Sill Elevation | 668 ft |
| Maximum Capacity at Spillway Crest | 16,500 ft$^3$/s |
| Regulated Capacity at Spillway Crest | 16,500 ft$^3$/s |
| Spillway: | |
| Type | Concrete Ogee |
| Crest Length | 399 ft |
| Design Discharge | 99,540 ft$^3$/s |
| Sources: Sepulveda Dam Water Control Manual dated May 1989, LACDA Feasibility Study and appendices dated 1992, and updated survey dated Nov. 2004. | |

Table 3 summarizes the calculation results for determining the Sepulveda Dam elevation – storage curve between the gate sill El. 668 (per data in Table 2) and impoundment El. 688 (per Figure 4).

**Table 3: Sepulveda Dam Elevation-Storage Calculation Results**

| Contour ft | Area ft$^2$ | Storage ft$^3$ | Storage MG | Storage AF | Cum. Storage MG |
|---|---|---|---|---|---|
| **668** | 0 | 0 | 0.00 | 0.00 | 0.0 |
| **672** | 76,074 | 152,148 | 1.14 | 3.49 | 1.1 |
| **676** | 627,092 | 1,406,332 | 10.52 | 32.28 | 11.7 |
| **680** | 937,440 | 3,129,064 | 23.41 | 71.83 | 35.1 |
| **688** | 5,226,022 | 24,653,848 | 184.41 | 565.97 | 219.5 |

Figure 5 shows the plotted elevation – storage curve. Based on the results, the potentially available volume upstream of Sepulveda Dam for stormwater storage is 220 MG.

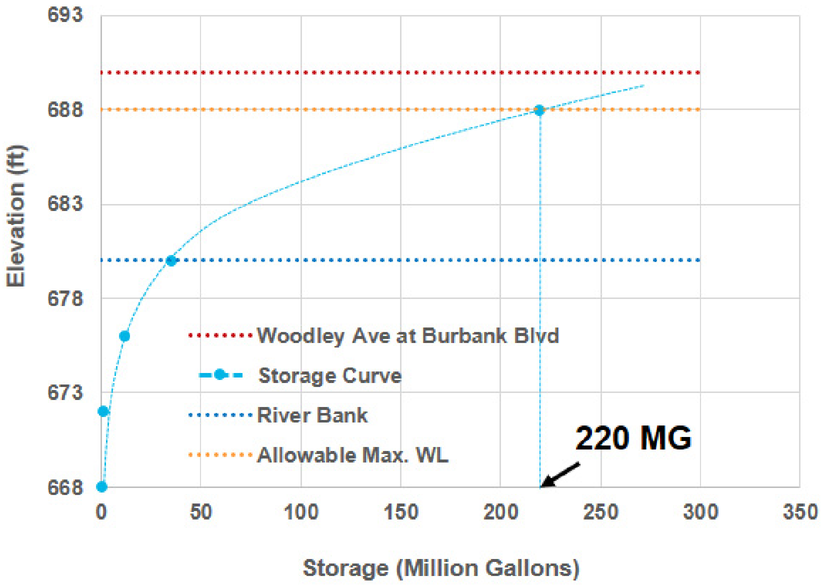


**Figure 5: Calculated Sepulveda Dam Elevation-Storage Curve**

For the remaining reaches downstream of the Sepulveda dam, rubber dam locations and impoundment volumes were determined using the same procedure as was used for Reach 1. Enclosed PowerPoint presentation in Attachment I provides dam locations, cross section geometries, and impoundment calculation results for the other reaches except for Reach 4, “ARBOR Reach”, for which no storage potential evaluation analysis were performed. This was because this reach is currently under evaluation by the US Army Corps of Engineers (ACE) for several river revitalization projects. Therefore, identification of any rubber dam locations at this stage would be premature. Table 4 summarizes the results of the in-channel storage evaluation analysis.

**Table 4: In-Channel Storage Evaluation Results Summary**

| Reach | Impoundment Length (ft) | Storage (MG) | Storage (AF) |
|---|---|---|---|
| Upstream of Sepulveda Dam | 22,000 | 220 | 675 |
| Sepulveda Dam | 9,000 | 220 | 675 |
| Sepulveda Dam to Glendale Narrows | 57,000 | 340 | 1,040 |
| Downstream of Arroyo Seco | 27,000 | 450 | 1,380 |
| **Total** | **115,000** | **1,200** | **3,700** |

## 3. Off-Channel Storage Potential

This study identified two potential locations that could provide significant additional storage space for the stormwater runoff flows in the LA River. These were; 1) The Sepulveda Dam Recreation Area, which is located inside the Sepulveda Dam flood control space, and 2) Silver Lake, which has recently been decommissioned as a potable water reservoir. Figure 6 shows these locations.

**Figure 6: Potential Off-Channel Storage Areas**

For the Sepulveda Dam recreation area, the idea is to excavate certain areas within the recreation area to create additional low lying land that would either be included in the storage space below El. 688 previously discussed, or be used as a receiving basin for diverted water upstream. Figure 7 shows the possible plots of land within the Sepulveda Dam recreation area that could be excavated to create additional storage. The numbers shown on each plot indicate the area of the plot in acres.

**Figure 7: Potential Excavation Areas (acres) within the Sepulveda Dam Recreation Area**

Table 5 shows the calculation results for potential additional storage assuming each plot shown in Figure 7 could be excavated by an average depth of 10 feet.

**Table 5: Calculated Additional Storage at Sepulveda Dam**

| Plot | Area (acres) | Excavation Vol. (1000 CY) 1) | Storage Vol. MG |
|---|---|---|---|
| **1** | 27 | 436 | 88 |
| **2** | 9 | 145 | 29 |
| **3** | 78 | 1,258 | 254 |
| **4** | 35 | 565 | 114 |
| **5** | 62 | 1,000 | 202 |
| **6** | 53 | 855 | 173 |
| **7** | 54 | 871 | 176 |
| **Total** | **318** | **5,130** | **1,040** |

1) Assuming average excavation depth of 10 feet

**Figure 8: Location of Silver Lake Relative to the LA River**

Figure 8 shows the location of Silver Lake relative to the LA River, which is owned and operated by the LA Department of Water (DWP). The lake is about 1 Mile west of the river and 100 ft higher in elevation. The 900 MG reservoir has been decommissioned and is no longer being used for potable water storage. Current plans are to fill the lake up to about El. 450 for recreational use. This will leave about 500 MG of disused storage in the lake. DWP is currently working on filling the lake with reclaimed water from LAG with a pipeline via the LA River. This provides an opportunity to design and use the same pipeline to pump stormwater from LA River to Silver Lake for storage. Therefore, Silver Lake has the potential to offer 500 MG of off-channel storage to store stormwater runoff flowing in the LA river. Table 6 summarize the off-channel storage calculation results.

**Table 6: Off-Channel Storage Calculation Results Summary**

| Location | Storage (MG) | Storage (AF) |
|---|---|---|
| **Sepulveda Dam Recreation Area** | 1,040 | 3,190 |
| **Silver Lake** | 500 | 1,530 |
| **Total** | **1,500** | **4,600** |

# 4. Conveyance to DCT and LAG

DCT has potential access to the water stored in Reach 1, as well as water stored upstream of the Sepulveda Dam. For water stored in Reach 1, diversion from upstream of dam 1 into the existing 96" AVORS would accomplish gravity conveyance to DCT. This is shown in Figure 9.

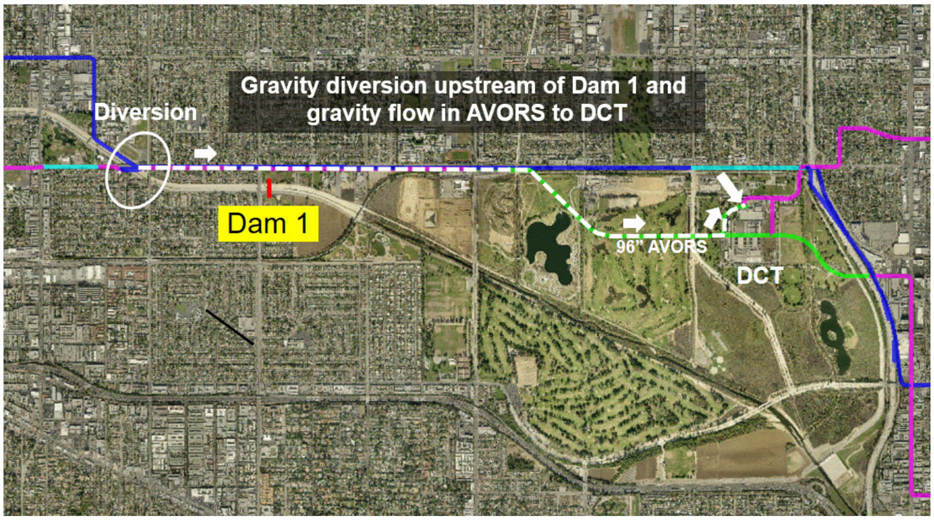


Figure 9: Gravity Diversion and Conveyance from Dam 1 to DCT

For water stored upstream of Sepulveda Dam, conveyance to DCT would require a new pumping facility at Burbank Blvd. connected to a new 1-mile long 24-36" diameter pipeline, as shown in Figure 10.

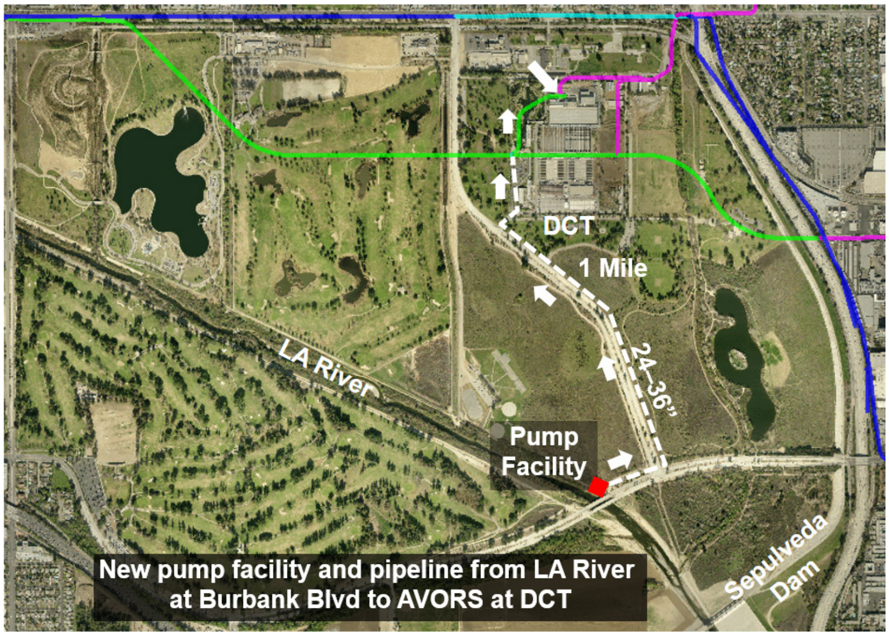


Figure 10: Pump Facility and Pipeline from Sepulveda Dam to DCT

LAG is located adjacent to the LA River and can draw water from it using a diversion pump facility and short pipeline. Figure 11 shows the concept. Water stored upstream of the ARBOR reach would be released for the specific purpose of being diverted al LAG.

**Figure 11: Pumping and Conveyance Concept from LA River to LAG**

## 5. Direct Potable Water Use

The stored water could be treated to potable water quality and directly injected into the potable water distribution system. There is ample precedence to this practice nationwide and by DWP. This is because stormwater runoff is surface water, and as such there are no regulatory obstacle for its treatment to potable water quality for direct use. DWP recently used portable water treatment units to treat the water at the Silver Lake Reservoir and directly inject it into the city's drinking-water system.

There are a wide range of options and packaged treatment plant technologies and sizes that could be used for direct potable water use. Smaller systems are mobile with a small footprint, and have a capacity range of 0.5 – 2.0 mgd. They can either be mobilized after each event or be permanently located along the LA River. The units would directly tie into the City’s drinking water system. Larger pre-assembled and factory-tested packaged systems are available with expandable capacities. These can be strategically located along LA River treating and feeding of water into the City’s drinking water system.

# 6. Dry Weather Water Level Control

The Los Angeles River Physical and Biological Habitat Assessment Report of 2003 Field Activities (USBR, 2004) *"…. water depth is more important than flow in sustaining habitats"*. The finding was based on observations in Balboa study site, located in the upper portion of LAR in the Sepulveda Basin north of Sepulveda Dam, where

*".. check dams made from quarried stones cause pools to form in the river and are present both upstream and downstream of Balboa Boulevard. Wetted channel width is approximately one-third of the total channel width and is bordered by vegetated islands on both sides. Despite significantly lower flow at this study site (less than 10 percent of flow observed at both Glendale Narrows sites), riparian habitat was present and similar to habitat observed at the Taylor Yard and Los Feliz study sites."*

Therefore, it follows that the reclaimed water releases for habitat restoration by DTC and LAG may be significantly lowered (decreased by 85%) by installing a series of check dams to create a cascade of pools. The check dam may be short height rubber dams. According to the One Water LA Low-Flow Study, the median RW releases by DCT and LAG into the LA river based on 2013 to 2015 daily flow data were 29.8 and 10.2 mgd (46.2 and 15.8 cfs) respectively (Geosyntec 2016, Table 2, P. 12)), which are primarily to augment the dry weather flow to sustain the riparian habitat along Glendale Narrows, and could be drastically reduced by using check dams.

For this study, in order to study the impact of check dams on hydraulic parameters in LA rivers, the previously developed HEC-RAS model of the river for three reaches; 1) Los Feliz, 2) Taylor Yard, and 3) Willow St. were used to simulate a number of hydraulic scenarios as follows:

**Scenario 1** – Existing dry weather flows inclusive of RW releases at DCT and LAG, no check dams

**Scenario 2** – Reduced dry weather flow down to 10 cfs by cutting back on RW releases at DCT and LAG by about 85%, no check dam

**Scenario 3** – Reduced dry weather flow down to 10 cfs by cutting back on RW releases at DCT and LAG by about 90%, with 3-ft high check dams at intervals to result in minimum 1 ft of hydraulic depth

The selection of 10 cfs (6 mgd) reduced dry weather flow in the river for Scenarios 2 and 3 is arbitrary and was only made to represent a drastically low flow condition in the river. The actual lower limit of flow that can be tolerated for habitat restoration with check dams must be determined by consideration of losses along the river and evapotranspiration, in the next study phase.

According to the One Water LA Low-Flow Study, the existing dry weather flow rates at Los Feliz, Taylor Yard, and Willow St. are 52, 53, and 67 mgd (80, 82, 104 cfs) respectively (Geosyntec, 2016, Table 6, P. 30). Given that the combined releases by DCT and LAG amount to 29.8 + 10.2 = 40 mgd (62 cfs), the existing dry weather flows in the river (excluding releases by DCT and LAG) range from 12 mgd (18 cfs) at Los Feliz to 27 mgd (42 cfs) at Willow Street. Therefore, the selection of 10 cfs (6 mgd) flow for scenarios 2 and 3 represents a worst case future low flow condition in the river when natural dry weather flows are practically non-existent and almost all dry weather flows in the river are the result of releases by DCT and LAG. For this condition, the combined DCT and LAG releases for habitat sustenance is 6 mgd (10 cfs), which amounts to 34 mgd (85%) reduction in RW releases into the river.

For each reach and case Scenario, the hydraulic profile along the reach was calculated and flow depth and velocity were determined. Case Scenario 3 determined the location and number of check dams required in each reach. The results are provided herein.

Tables 7, 8, and 9 show the results of the hydraulic analysis for Scenarios 1, 2, and 3 respectively.

**Table 7: Hydraulic Analysis Results for Scenario 1**

| Reach | Reach Length (ft) | Ave Slope (ft/ft) | Flow (cfs) | Ave Hyd. Depth (ft) | Ave Vel. (fps) | Ave Top Width (ft) |
|---|---|---|---|---|---|---|
| **Los Feliz** | 6,608 | 0.0046 | 80 | 0.95 | 0.66 | 124 |
| **Taylor Yard** | 3,622 | 0.0031 | 82 | 0.84 | 0.86 | 100 |
| **Willow St.** | 7,007 | 0.0011 | 104 | 0.19 | 1.89 | 312 |

Table 7 shows the range of flow depths, velocities, and top widths accomplished by the current augmented dry weather flow of between 80 to 104 cfs (52 to 67 mgd) within each reach. The hydraulic depths, which are a measure of average depth across the cross section (defined as flow area divided by top width) range from about 1.0 ft in Los Feliz to about 0.2 ft in Willow St., with corresponding average flow velocities of about 0.7 fps in Los Feliz to about 1.9 fps in Willow St.

In Los Feliz and Willow St. reaches, the water spreads thinly across the prismatic hard bottom channel while in Taylor yard the water is confined to well defined path carved between islands in the irregular and soft bottom channel. In Willow St. reach there is a trapezoidal low flow channel in the center of the cross section where most of the flow is concentrated.

**Table 8: Hydraulic Analysis Results for Scenario 2**

| Reach | Reach Length (ft) | Ave Slope (ft/ft) | Flow (cfs) | Ave Hyd. Depth (ft) | Ave Vel. (fps) | Ave Top Width (ft) |
|---|---|---|---|---|---|---|
| **Los Feliz** | 6,608 | 0.0046 | 10 | 0.33 | 0.33 | 32 |
| **Taylor Yard** | 3,622 | 0.0031 | 10 | 0.44 | 0.53 | 20 |
| **Willow St.** | 7,007 | 0.0011 | 10 | 0.30 | 1.43 | 24 |

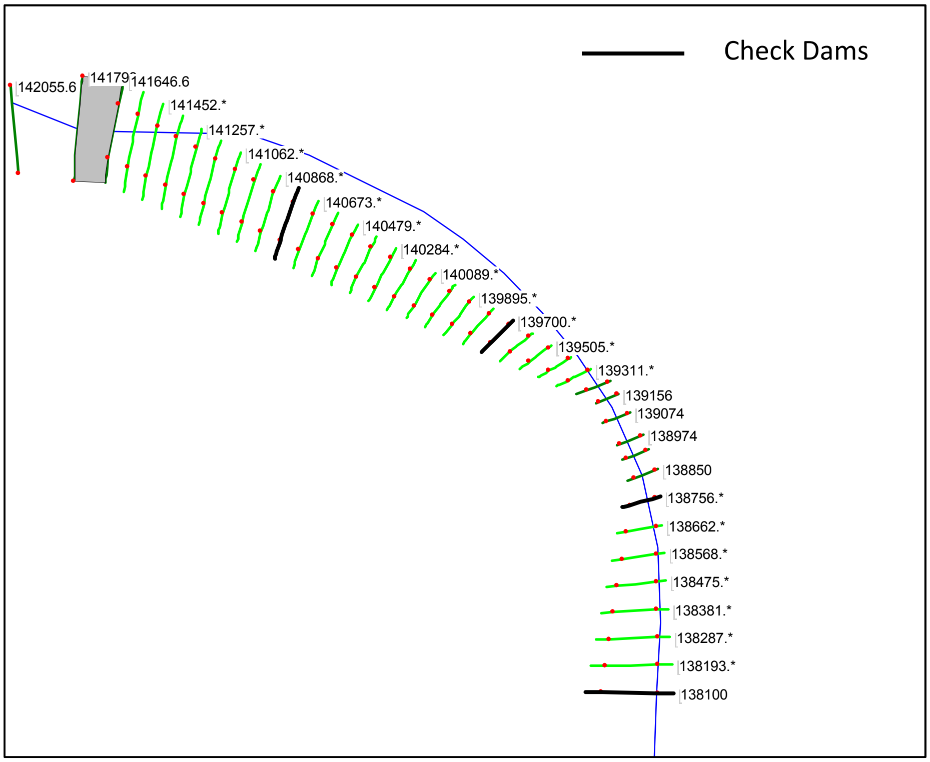
Table 8 shows the range of flow depths, velocities, and top widths if the flow is reduced down to 10 cfs in each reach. The hydraulic depths reduced to about 0.3-0.4 ft in Los Feliz and Taylor Yard, and increase to 0.3 ft in Willow St., the flow velocities decrease, while there is a drastic change is in the top width of flow. These reflect confinement of the flow to the low-flow channel, particularly in the Willow St. reach, where it is well defined.

**Table 9: Hydraulic Analysis Results for Scenario 3**

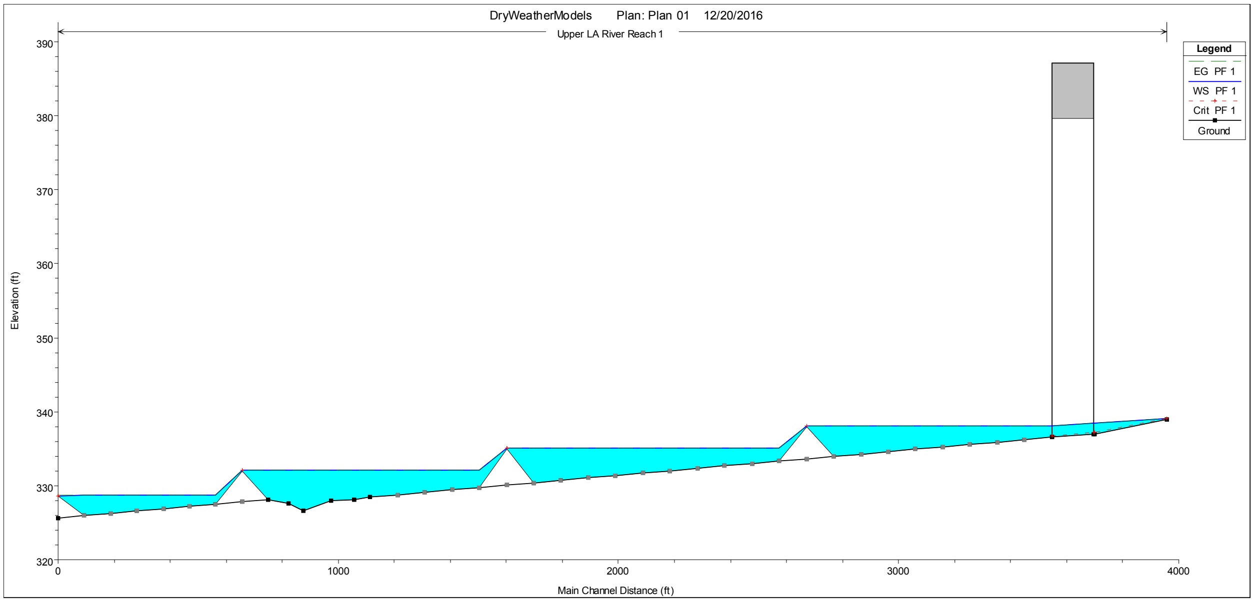
| Reach | Reach Length (ft) | Ave Slope (ft/ft) | Flow (cfs) | Ave Hyd. Depth (ft) | Ave Vel. (fps) | Ave Top Width (ft) | No. of Dams |
|---|---|---|---|---|---|---|---|
| **Los Feliz** | 6,608 | 0.0046 | 10 | 1.4 | 0.04 | 200 | 15 |
| **Taylor Yard** | 3,622 | 0.0031 | 10 | 1.71 | 0.09 | 285 | 4 |
| **Willow St.** | 7,007 | 0.0011 | 10 | 2.41 | 0.02 | 325 | 3 |

Table 9 shows what would happen to the range of flow depths, velocities, and top widths if the river reaches are provided with 3-ft high check dams to create a cascade of pools of minimum depth of 1.0 ft. while the flow is reduced down to 10 cfs in each reach. The hydraulic depths throughout are between 1.0 to 3.0 feet while the ponded water reaches across the cross section of the channel flowing at extremely low velocity. The number of dams depend on the average slope range from 1 dam every 2,335 ft in Willow St. (3 dams over about 7,007 ft) to 1 dam every 905 ft in Taylor Yard (4 dams over 3,622 ft) and 1 dam every 264 ft in Los Feliz (15 dams over 6,608 ft).

Figure 12 shows the HEC-RAS model plan of cross sections and computed hydraulic profile for Taylor yard for case scenario 3, as an example. Similar plans and profile plots were generated for each reach and case scenario and are included in Attachment II of this technical memo.



PLAN



HYDRAULIC PROFILE

**Figure 12 HEC-RAS Model Plan and Profile – Taylor Yard, Scenario 3**

As noted, the 10 cfs (6 mgd) flow value used in the analysis is an arbitrary low flow value used in this analysis to represent significant reduction in the river flow compared with free-flowing (no check dams) conditions. The analysis above shows that use of check dams is a hydraulically feasible alternative in terms of maintaining a certain minimum hydraulic depth along the river in lieu of maintaining a certain minimum flow rate.

Reducing the current 40 mgd release by DCT and LAG without check dams down to 6 mgd with check dams would save about 34 mgd x 330 Days = 11,220 MG (34,400 ac-ft) of water per year (given 35 rainy days per year on average). Depending on the value of RW, the value of water savings is in the order tens of millions of dollars per year. Compared with estimated cost of rubber check dams, which is in the order of a few million dollars each (between $1 Million to $5 million depending on span and height), the duration for return on investment is quite short making check dams a potentially attractive alternative.

For additional level control at small check dams or at large wet weather storage rubber dams, Dry weather flow level control capability may be provided by equipping the dam with outlet works capable of varying the discharge flow downstream over the range of influent flows and water levels. Outlet works for small dams generally consists of either an open channel or a pressurized flow bypass conduit, equipped with a vertical lift sluice gate of suitable size and dimensions upstream, with invert close to the river bed. For a single span dam, the bypass conduit would most likely be a pressure pipe of certain diameter around the dam through one abutment equipped with a submerged vertical lift sluice gate. Figure shows the configuration of one such vertical lift sluice gate.

**Figure 13: Typical Submerged Sluice Gate for Impoundment Level Control**

Therefore, any rubber dam requiring upstream impoundment level control during dry weather flows, would be equipped with outlet works of suitable size similar to the arrangement shown in Figure 13. During dry weather flows, the dam would be fully inflated and the sluice gate would be adjusted to result in the desired impoundment water level upstream. The sluice gate adjustments may be easily automated using a power actuator with feedback from a level sensor upstream. The actuator would adjust the gate opening to maintain the target water level over the range of influent dry weather flows. The size and dimensions of the outlet works (gate and channel) depend on the degree of submergence of the gate opening (available hydraulic head) at the target water level and range of influent dry weather flows into the impoundment, and would be determined during preliminary design.

During wet weather flows, the dam would be operated the same as the other dams without outlet works, and the sluice gate would be fully closed.

## 7. Summary

Table 10 provides a summary of the benefits and challenges brought about by the various water management measures examined in this study.

**Table 10: Benefits and Challenges of Examined Water Management Measures**

| Measure | Cost | Potential Benefits | Challenges | Other Considerations |
|---|---|---|---|---|
| In-Channel Storage | • Appx. $5 – 10 Million per rubber dam depending on dam height, river span, and foundation + abutment requirements | • Provides 3,700 ac-ft stormwater runoff storage facility with annual harvest potential that is several times the size of the storage space<br>• Would constitute a significant source of local water to offset imported freshwater | • Acceptability of numerous rubber dams that convert the river to a cascade of level pools.<br>• Stakeholder coordination and outreach<br>• Opportunities for beneficial use of stored water<br>• Permitting | • Site selection<br>• Existing utility crossings<br>• Structural conditions of river levees<br>• Exfiltration and seepage<br>• Operation and maintenance<br>• Cost/Benefit |
| Off-Channel Storage | 1. **In Sepulveda Dam Flood Control Space:** Appx. $300 Million ($225 Million for excavation and hauling of 5,000 Yd$^3$ of soil + $75 million allowance for civil works on the storage basins)<br>2. **In Silver Lake:** Appx. S10 Million ($5 million diversion and pumping facility at LA river +$3 Million for pipeline from LA river to Silver Lake + $2 million outlet structure, pump back facility, and civil works at Silver Lake) | • Provides 4,600 ac-ft stormwater runoff storage facility with annual harvest potential that is several times the size of the storage space<br>• Would constitute a significant source of local water to offset imported freshwater | • Coordination with USACE to create additional storage in Sepulveda Dam flood control reservoir<br>• Environmental impact of large excavation and earth moving operation to create additional storage in Sepulveda Dam flood control reservoir<br>• Coordination with DWP for use of Silver Lake<br>• Diversion and conveyance of LA River flow to Silver Lake<br>• Opportunities for beneficial use of stored water<br>• Permitting | • Silt accumulation in off-channel facilities<br>• Operation and Maintenance<br>• Cost/Benefit |

| Measure | Cost | Potential Benefits | Challenges | Other Considerations |
|---|---|---|---|---|
| Diversion to DCT/LAG | 1. **Gravity Flow in AVORS to DCT:** Appx. $1 Million for gravity diversion facility at DAM 1<br>2. **Pumping at Burbank Blvd to AVORS:** Appx. $6 Million ($2 Million for pump facility at Burbank Blvd, $3 Million for pipeline to AVORS, and $1 Million for connection to AVORS | • Utilizes existing treatment facility and capacity<br>• Provides new source of water for the existing treatment facilities in light of reducing sewer flows due to water conservation | • Timing of available water during rainy days compared with timing of RW demand during dry days<br>• Short window of water availability and high rate of water treatment required<br>• Opportunities for beneficial use of stored water<br>• Coordination with USACE to construct new pump station and pipeline within Sepulveda Dam flood control reservoir<br>• Permitting | • Operation and maintenance<br>• Cost/Benefit |
| Direct PW use | • $2 - $10 Million per satellite treatment plant depending on site and treatment capacity | • Provides new source of raw surface water for treatment and potable water use<br>• Reduces the need for conveyance (treatment facility located next to the river and close to PW distribution network) | • Requires suitable site(s)<br>• Requires high voltage electrical supply<br>• Low treatment capacity of satellite plants<br>• Short window of water availability and high rate of water treatment required<br>• Permitting | • Operation and maintenance<br>• Cost/Benefit<br>• Public outreach for H&S assurance |
| Check Dams | • $1 - $5 Million per check dam depending on river span and foundation + abutment requirements | • Significant reduction of RW releases by DCT and LAG for habitat restoration<br>• Effective habitat restoration with significant positive impacts | • Stakeholder outreach and coordination<br>• Coordination with USACE<br>• Permitting | • Operation and maintenance<br>• Cost/Benefit |

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# Attachment I, LA River Storage Potential Study

## PowerPoint Presentation dated April 25, 2016

# Los Angeles River Water Storage Potential

**Special Study**
***One Water Los Angeles***

April 25, 2016

SEITec

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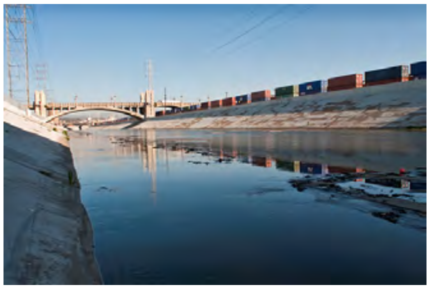
## Agenda

1. Background and Purpose
2. Basic Concept
3. Storage Potential
4. Conveyance Options
5. Treatment
6. Next Steps

SEITec

## Background and Purpose

- The LA river has a large volume that could potentially be used to store rainwater
- Stored rainwater would be used to offset freshwater use in the City
- The purpose of this work is to determine the storage potential of the LA River in certain reaches



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## Basic Concept

- Install rubber dams in LA river at select locations
- Deflate dams to pass flood flows
- Inflate dams to store the tail end of runoff hydrographs
- Use stored water to offset freshwater use in the City

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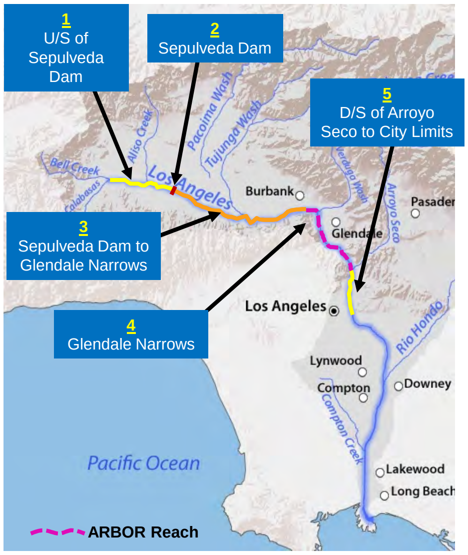
## Study Area

1. Upstream of Sepulveda Dam
2. Sepulveda Dam flood storage space
3. Sepulveda Dam to Glendale Narrows
4. Glendale Narrows (ARBOR Reach)
5. Downstream of Arroyo Seco to City limits



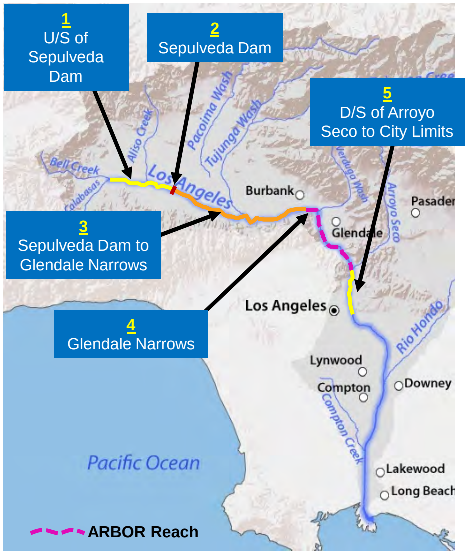
## Study Scope

A. In-channel storage potential

B. Off-channel storage potential

C. Conveyance to DC Tillman and LA Glendale WR facilities

D. Possibility of treatment for direct potable water use



# A. In-Channel Storage Potential

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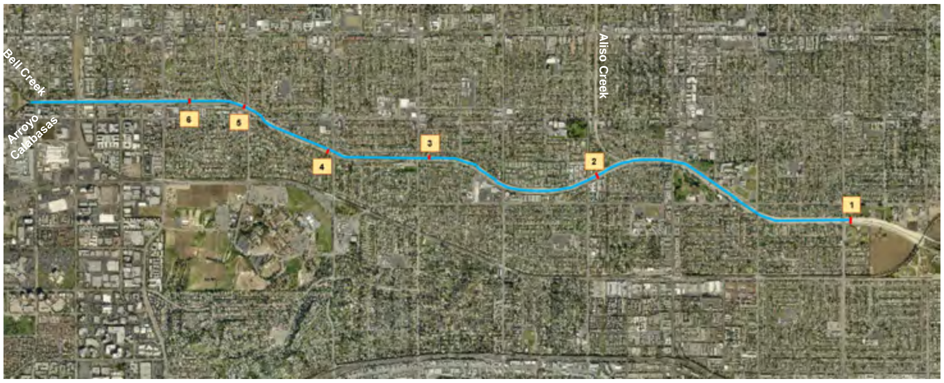
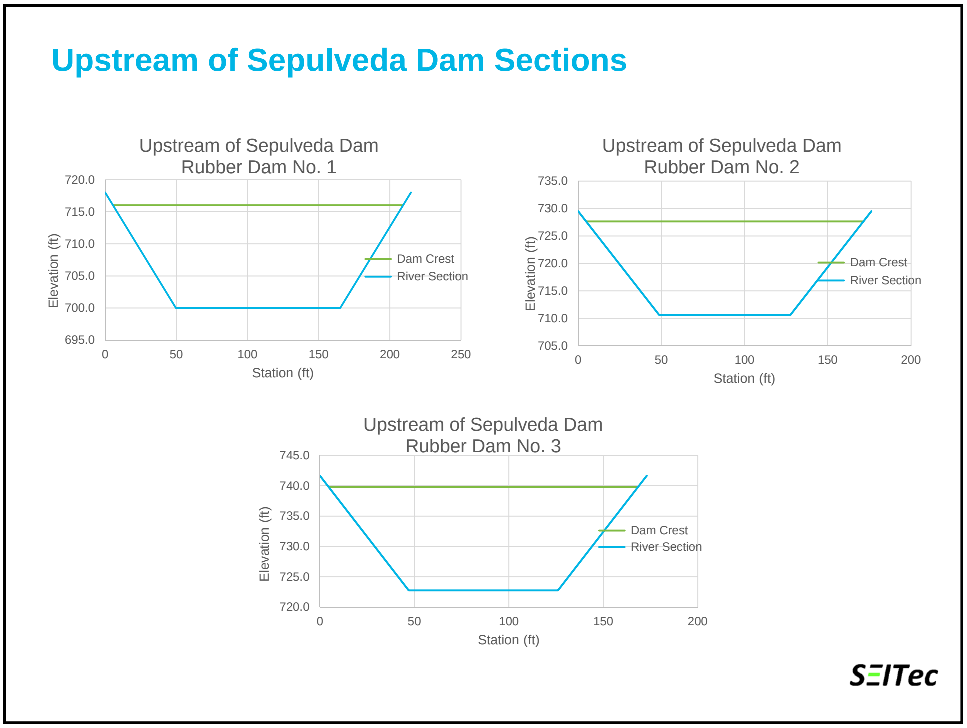
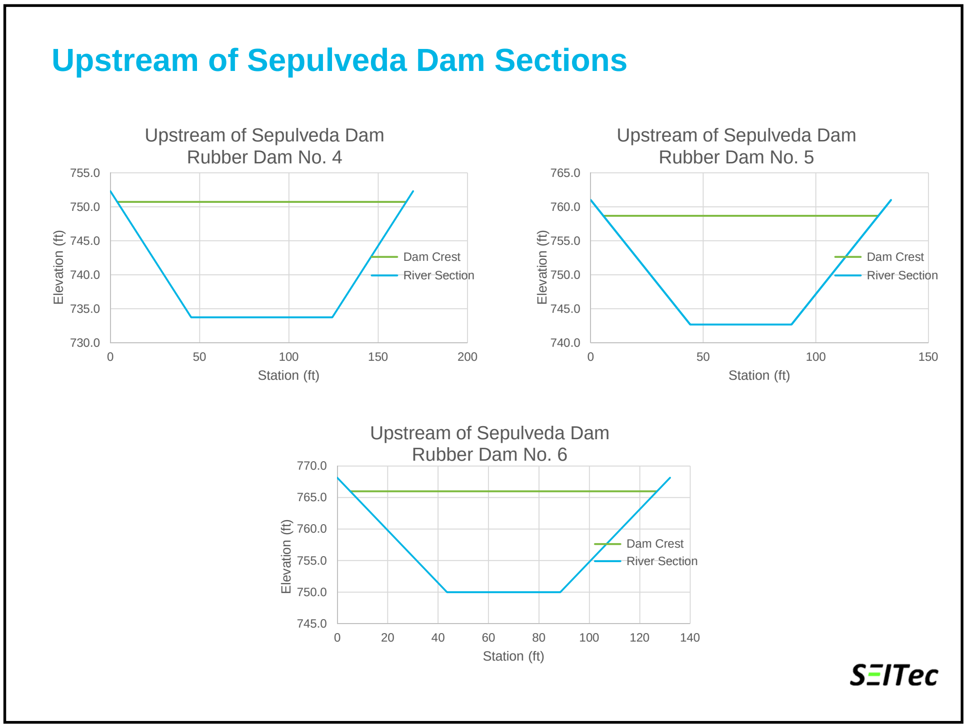
## 1. Upstream of Sepulveda Dam



Dam Locations



## Upstream of Sepulveda Dam Sections



## Upstream of Sepulveda Dam Sections

## 1. Upstream of Sepulveda Dam – Storage

| Dam No. | Station (ft) | Bed El. (ft) | Bed Width (ft) | Dam Height (ft) | Dam Crest Width (ft) | Water Depth at U/S End of Impoundment (ft) | Impoundment Length (ft) | Impoundment Storage (MG) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 700.0 | 116 | 16 | 204 | 5.3 | 7,066 | 84.9 |
| 2 | 7,066 | 710.6 | 79 | 17 | 167 | 5.7 | 4,804 | 47.0 |
| 3 | 11,870 | 722.8 | 79 | 17 | 163 | 5.7 | 3,609 | 34.9 |
| 4 | 15,479 | 733.7 | 79 | 17 | 162 | 5.7 | 2,612 | 25.1 |
| 5 | 18,091 | 742.7 | 45 | 16 | 122 | 5.3 | 1,975 | 12.1 |
| 6 | 20,066 | 750.0 | 45 | 16 | 122 | 5.3 | 2,002 | 12.3 |
| **Total** | | | | | | | **22,068** | **216.4** |

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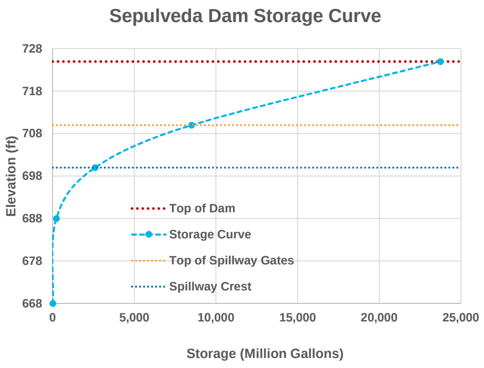
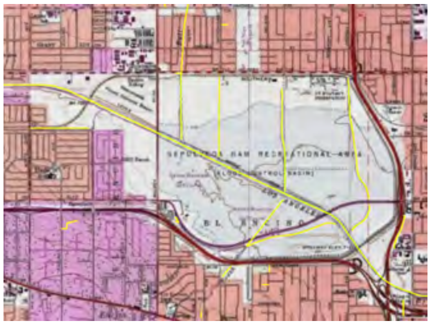
## 2. Sepulveda Dam Storage Space





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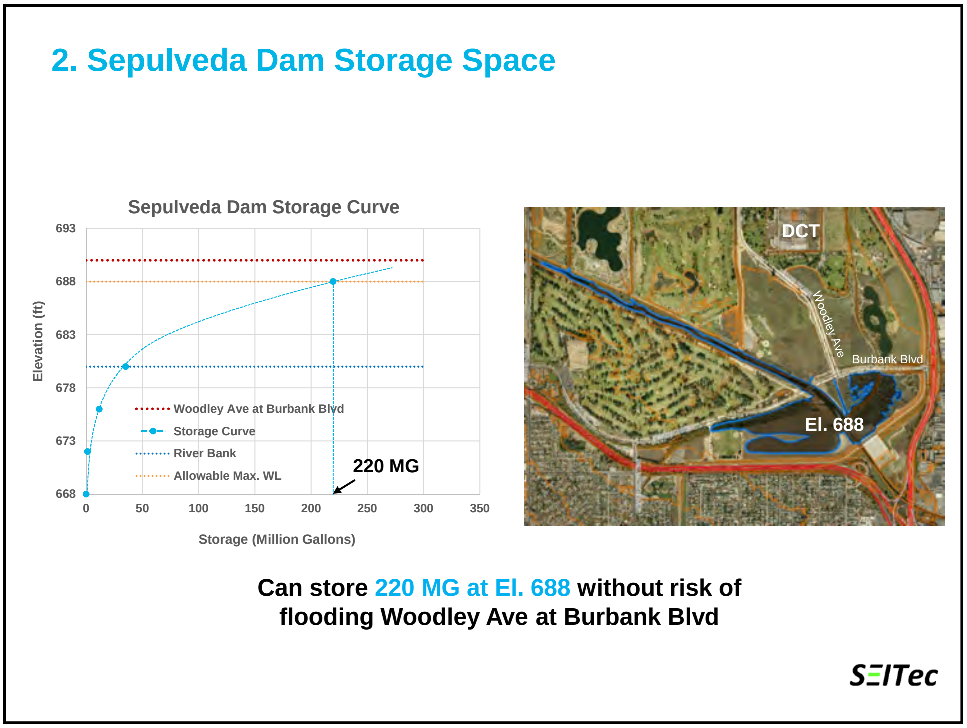
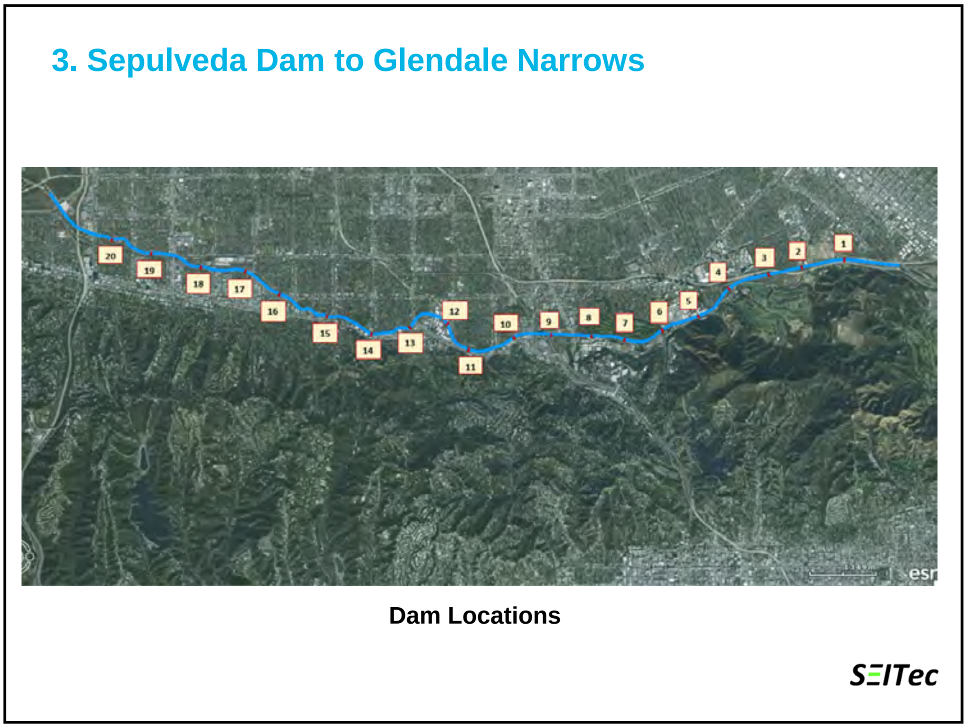


## 2. Sepulveda Dam Storage Space

**Can store 220 MG at El. 688 without risk of flooding Woodley Ave at Burbank Blvd**

SEITec



## 3. Sepulveda Dam to Glendale Narrows

**Dam Locations**

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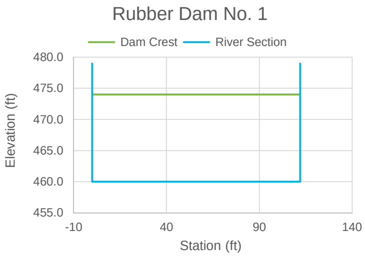
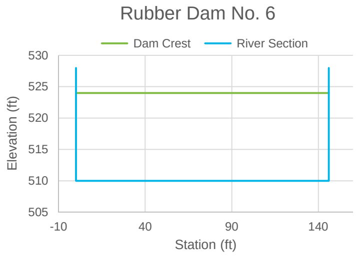
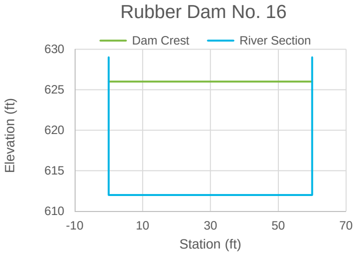
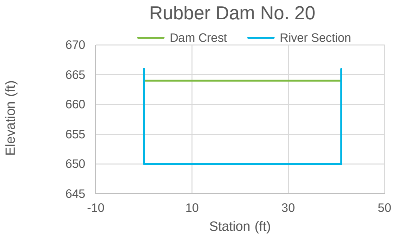
# Sepulveda Dam to Glendale Narrows – Sections


Rubber Dam No. 1


Rubber Dam No. 6


Rubber Dam No. 16


Rubber Dam No. 20

# 3. Sepulveda Dam to Glendale Narrows - Storage

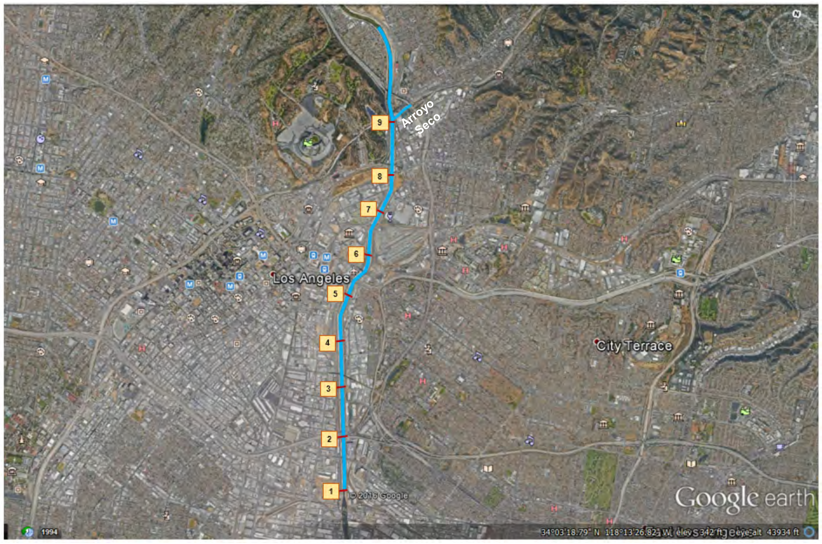
| Dam No | Station (ft) | Bed El. (ft) | Bed Width (ft) | Dam Height (ft) | Dam Crest Width | Water Depth at U/S end of Impoundment | Impoundment Length | Impoundment Storage (MG) |
|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 460 | 112 | 14 | 112 | 4 | 2,700 | 21 |
| **2** | 2,700 | 470 | 125 | 14 | 125 | 4 | 2,400 | 20 |
| **3** | 2,400 | 480 | 125 | 14 | 125 | 4 | 2,700 | 23 |
| **4** | 2,700 | 490 | 130 | 14 | 130 | 4 | 2,900 | 25 |
| **5** | 2,900 | 500 | 125 | 14 | 125 | 4 | 2,500 | 22 |
| **6** | 2,500 | 510 | 146 | 14 | 146 | 4 | 2,900 | 28 |
| **7** | 2,900 | 520 | 125 | 14 | 125 | 4 | 2,200 | 19 |
| **8** | 2,200 | 530 | 125 | 14 | 125 | 4 | 2,600 | 22 |
| **9** | 2,600 | 540 | 116 | 14 | 116 | 4 | 2,500 | 20 |
| **10** | 2,500 | 550 | 120 | 14 | 120 | 4 | 3,200 | 26 |
| **11** | 3,200 | 560 | 114 | 14 | 114 | 3 | 2,400 | 16 |
| **12** | 2,400 | 571 | 58 | 14 | 58 | 5 | 3,100 | 13 |
| **13** | 3,100 | 580 | 58 | 14 | 58 | 4 | 2,600 | 10 |
| **14** | 2,600 | 590 | 60 | 14 | 60 | 4 | 3,200 | 13 |
| **15** | 3,200 | 600 | 60 | 14 | 60 | 2 | 3,500 | 13 |
| **16** | 3,500 | 612 | 60 | 14 | 60 | 6 | 2,600 | 12 |
| **17** | 2,600 | 620 | 60 | 14 | 60 | 4 | 3,000 | 12 |
| **18** | 3,000 | 630 | 51 | 14 | 51 | 4 | 3,500 | 12 |
| **19** | 3,500 | 640 | 50 | 14 | 50 | 4 | 2,900 | 9 |
| **20** | 2,900 | 650 | 41 | 14 | 41 | 4 | 3,600 | 10 |
| TOTAL | | | | | | | **57,000** | **343** |

## 4. Glendale Narrows (ARBOR Reach)

1. Only scenic reach of LA River with vegetation in stream bed
2. Inundation is likely to adversely impact vegetation
3. Consideration for in-channel storage requires coordination with USACE

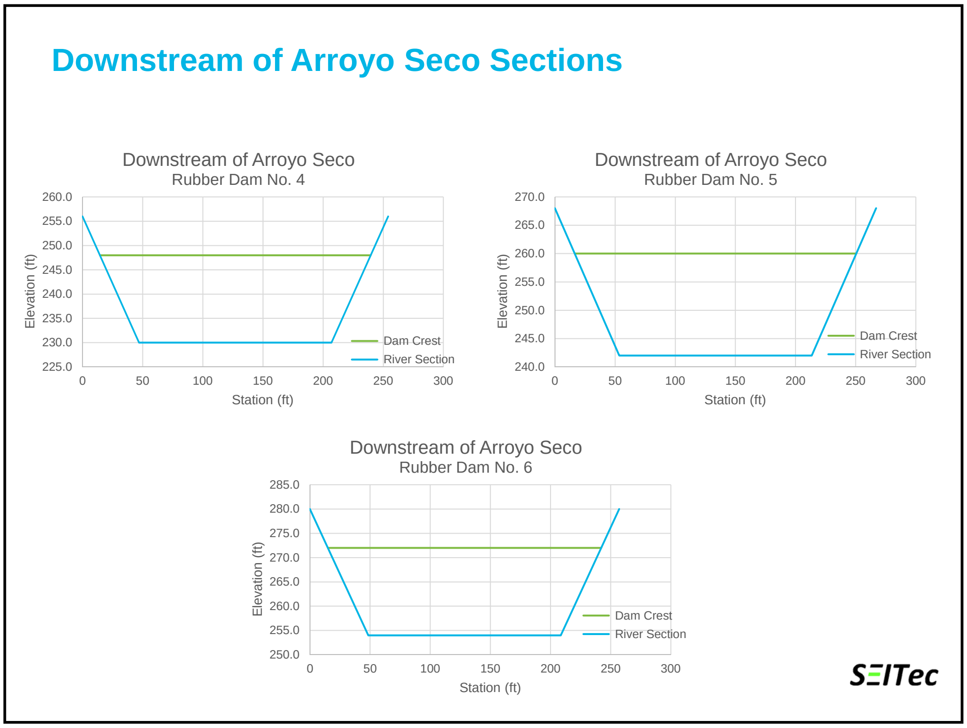
---

## 5. Downstream of Arroyo Seco



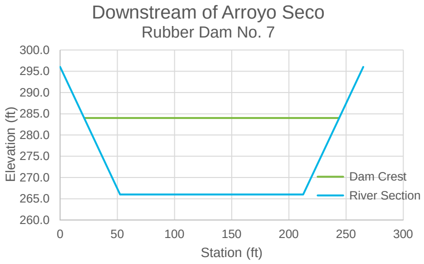
Dam Locations

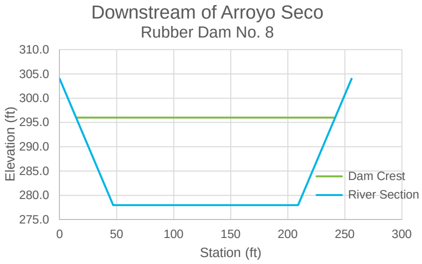
## Downstream of Arroyo Seco Sections

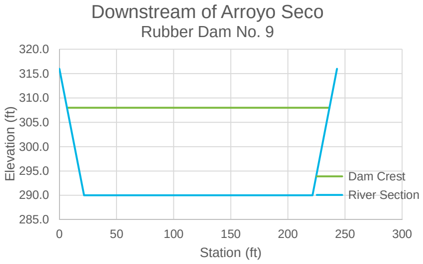


## Downstream of Arroyo Seco Sections

## Downstream of Arroyo Seco Sections


Downstream of Arroyo Seco
Rubber Dam No. 7


Downstream of Arroyo Seco
Rubber Dam No. 8

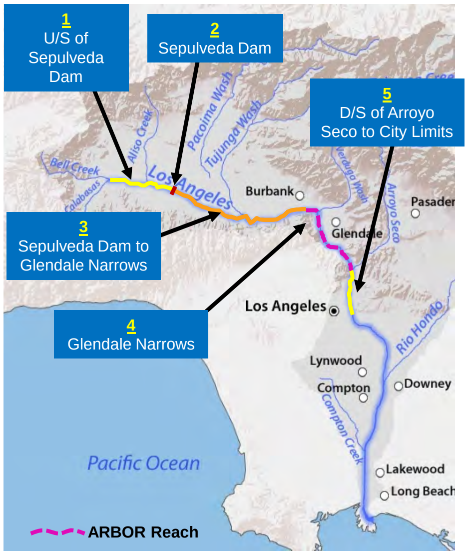

Downstream of Arroyo Seco
Rubber Dam No. 9

## 5. Downstream of Arroyo Seco - Storage

| Dam No. | Station (ft) | Bed El. (ft) | Bed Width (ft) | Dam Height (ft) | Dam Crest Width | Water Depth at U/S End of Impoundment (ft) | Impoundment Length (ft) | Impoundment Storage (MG) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 194 | 163 | 18 | 234 | 6.0 | 3,100 | 54 |
| 2 | 3,100 | 206 | 161 | 18 | 234 | 6.0 | 2,500 | 43 |
| 3 | 5,600 | 218 | 160 | 18 | 227 | 6.0 | 2,900 | 49 |
| 4 | 8,500 | 230 | 160 | 18 | 225 | 6.0 | 2,600 | 44 |
| 5 | 11,100 | 242 | 160 | 18 | 234 | 6.0 | 2,700 | 46 |
| 6 | 13,800 | 254 | 160 | 18 | 227 | 6.0 | 2,600 | 44 |
| 7 | 16,400 | 266 | 160 | 18 | 223 | 6.0 | 2,500 | 43 |
| 8 | 18,900 | 278 | 162 | 18 | 227 | 6.0 | 2,800 | 49 |
| 9 | 21,700 | 290 | 200 | 18 | 230 | 0.0 | 5,300 | 77 |
| **Total** | | | | | | | **27,000** | **451** |

## In-Channel Storage Results Summary

| Location | Imp. Length (ft) | Storage (MG) | Storage (AF) |
|---|---|---|---|
| 1. Upstream of Sepulveda Dam | 22,000 | 220 | 675 |
| 2. Sepulveda Dam | 9,000 | 220 | 675 |
| 3. Downstream of Sepulveda Dam | 57,000 | 340 | 1,040 |
| 5. Downstream of Arroyo Seco | 27,000 | 450 | 1,380 |
| **Total** | **115,000** | **1,200** | **3,700** |



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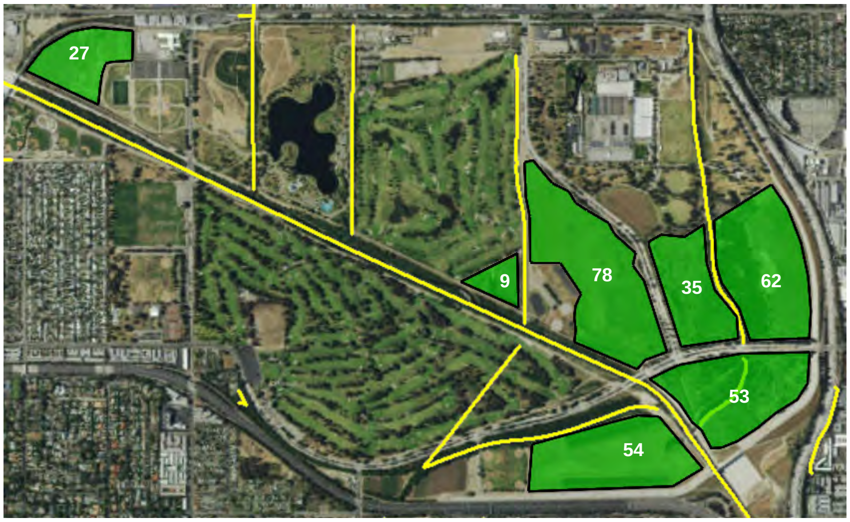
## B. Off-Channel Storage

## Potential Locations for Off-Channel Storage

1. **Sepulveda Dam Recreation Area** – Excavation and soil removal in certain areas to create additional storage space
2. **Silver Lake** – Pumping and conveyance of from LA river to use the upper portion of reservoir that is to remain unfilled

---

## 1. Sepulveda Dam Recreation Area – Areas (acres) of potential excavation to gain additional storage



## 1. Sepulveda Dam Recreation Area – Potential additional storage volume

| Area (acres) | Excavation Vol. (1000 CY)* | Storage Vol. MG |
|---|---|---|
| 27 | 436 | 88 |
| 9 | 145 | 29 |
| 78 | 1,258 | 254 |
| 35 | 565 | 114 |
| 62 | 1,000 | 202 |
| 53 | 855 | 173 |
| 54 | 871 | 176 |
| **318** | **5,130** | **1,040** |

* Assume 10 ft Av. Excavation Depth

Could gain additional 1000 MG storage in Sepulveda Dam Recreation Area through excavation of select areas

## 2. Silver Lake

1. Located within 1 Mile from and 100 ft above LA River
2. 900 MG reservoir is no longer used for PW. Will be less than half-filled for recreational use
3. DWP is currently working on filling the lake with RW from LAG with pipeline via LA River
4. Could use same pipeline to pump stormwater from LA River to Silver Lake

Could gain additional 500 MG storage by using unused space at Silver Lake

## Off-Channel Storage Results Summary

| Location | Storage (MG) | Storage (AF) |
|---|---|---|
| Sepulveda Dam Recreation Area | 1,040 | 3,190 |
| Silver Lake | 500 | 1,530 |
| **Total** | **1,500** | **4,600** |


i
Sepulveda Dam Recreational Area

ii
Silver Lake

---

## C. Conveyance to DCT and LAG

## 1. Conveyance of Stored Stormwater to DC Tillman WRP

A. Conveyance of Stored Water at Upstream Dams

B. Conveyance of Stored Water at Sepulveda Dam

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## A. Conveyance of Stored Stormwater at Upstream Dams

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## B. Conveyance of Stored Stormwater at Sepulveda Dam

New pump facility and pipeline from LA River at Burbank Blvd to AVORS at DCT

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## 2. Conveyance of Stored Stormwater to LAG

Water stored upstream is released for diversion at LAG

New pump facility and discharge line from LA River at LAG

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## D. Treatment for Direct Potable Water Use

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## Treatment of Stored Stormwater for Direct PW Use

1. Stored stormwater runoff is surface water, which can be treated to potable water quality standards
2. DWP recently used portable water treatment units to treat the water at the Silver Lake Reservoir and put it back into the city's drinking-water system.

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## Portable Surface Water Treatment Packages

- Mobile with small footprint
- Capacities 0.5 – 2.0 mgd
- Can mobilize after each event or permanently locate along LA River
- Treating and feeding of water into the City’s drinking water system

---

## Larger Packaged Surface Water Treatment Units

- Pre-assembled and factory-tested package systems
- Capacities 2.0+ mgd
- Can strategically locate along LA River
- Treating and feeding of water into the City’s drinking water system

## Next Steps

1. Develop concept designs and confirm concept feasibilities
2. Prepare cost estimates and conduct cost/benefit analysis
3. Establish project priorities and implementation timeline
4. Identify potential funding sources
5. Prepare grant applications

---

**End**

# Attachment II, LA River Storage Potential Study

# Hydraulic Cross Sections for each Considered Scenario

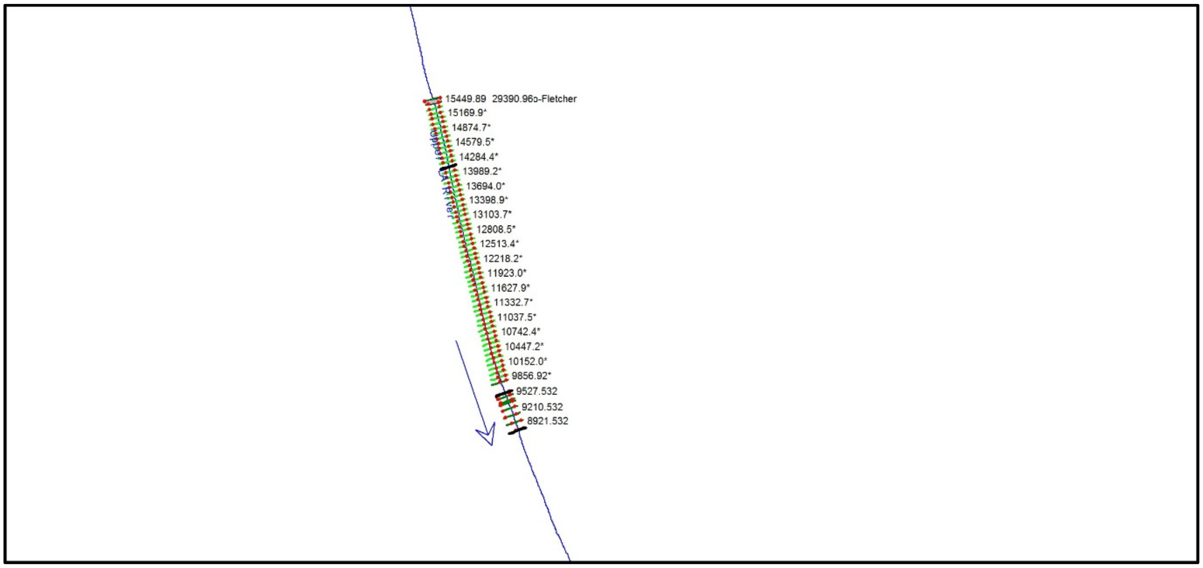

**Figure 1** HEC-RAS Model Plan – Los Feliz

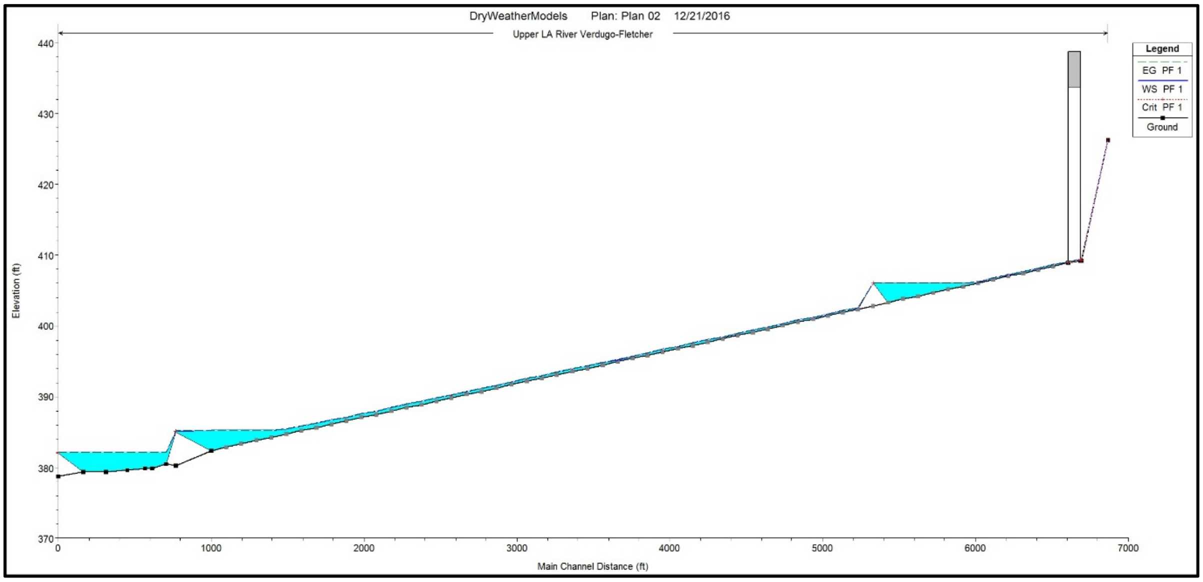

**Figure 2** HEC-RAS Model Profile – Los Feliz

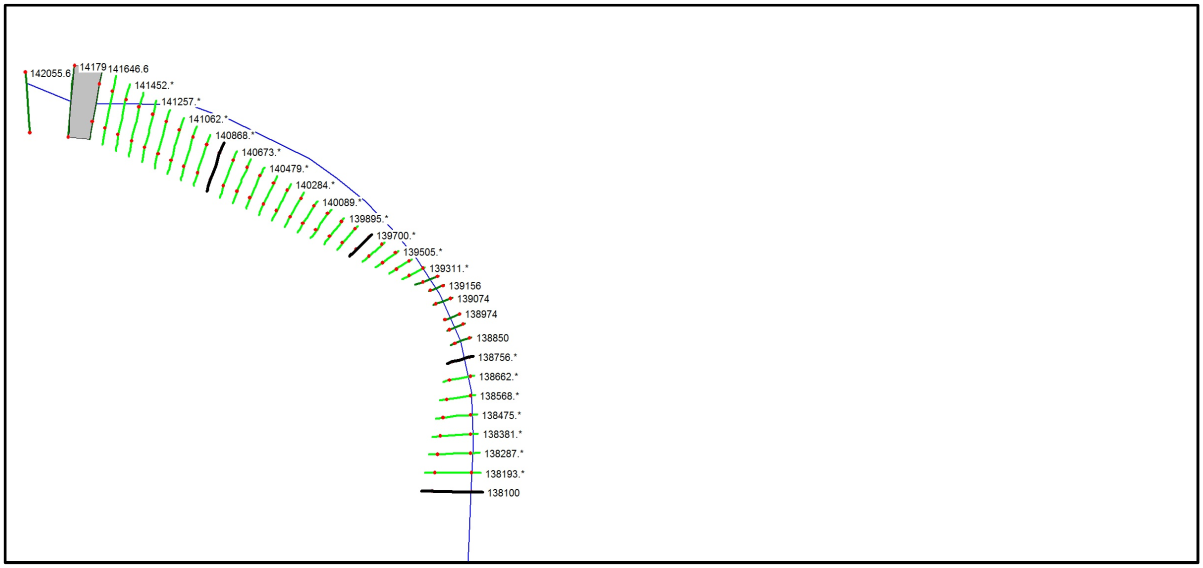

Figure 3 HEC-RAS Model Plan – Taylor Yard

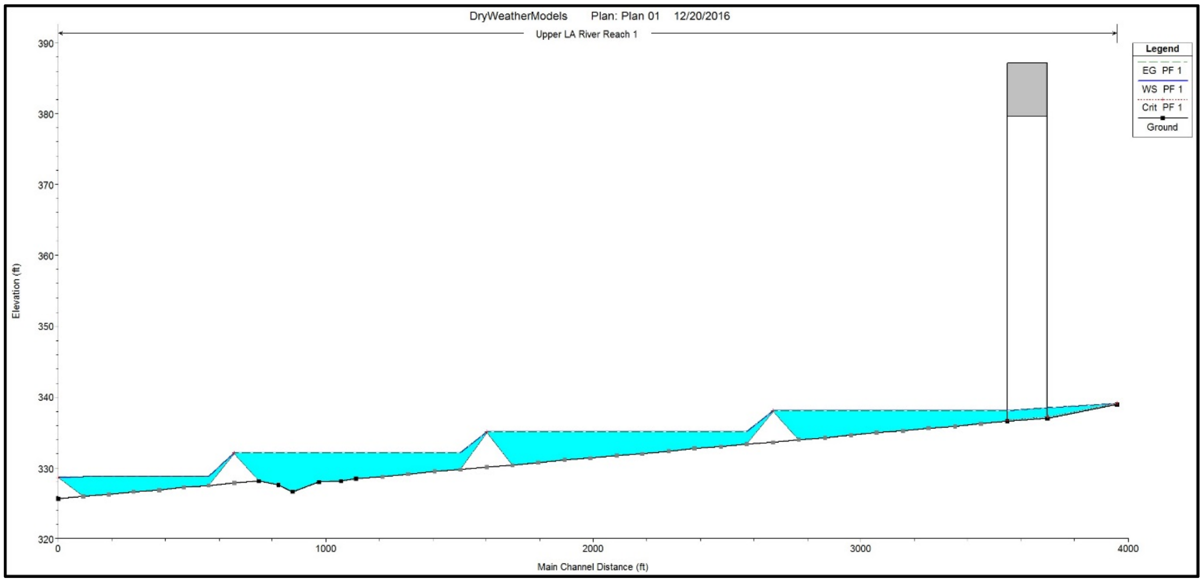

Figure 4 HEC-RAS Model Profile – Taylor Yard

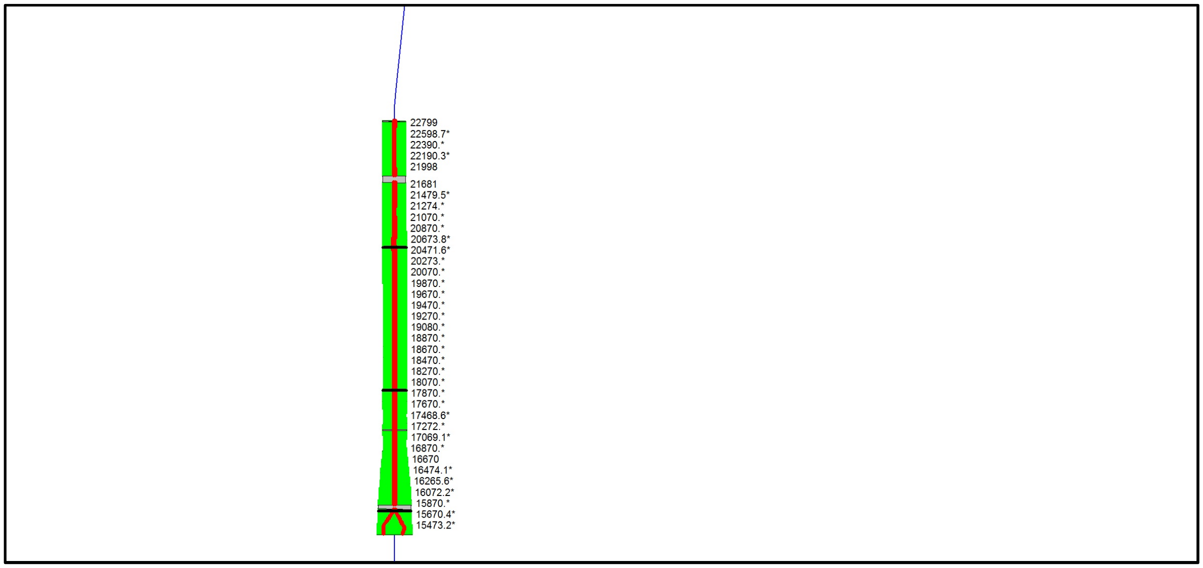

**Figure 5** HEC-RAS Model Plan – Willow St

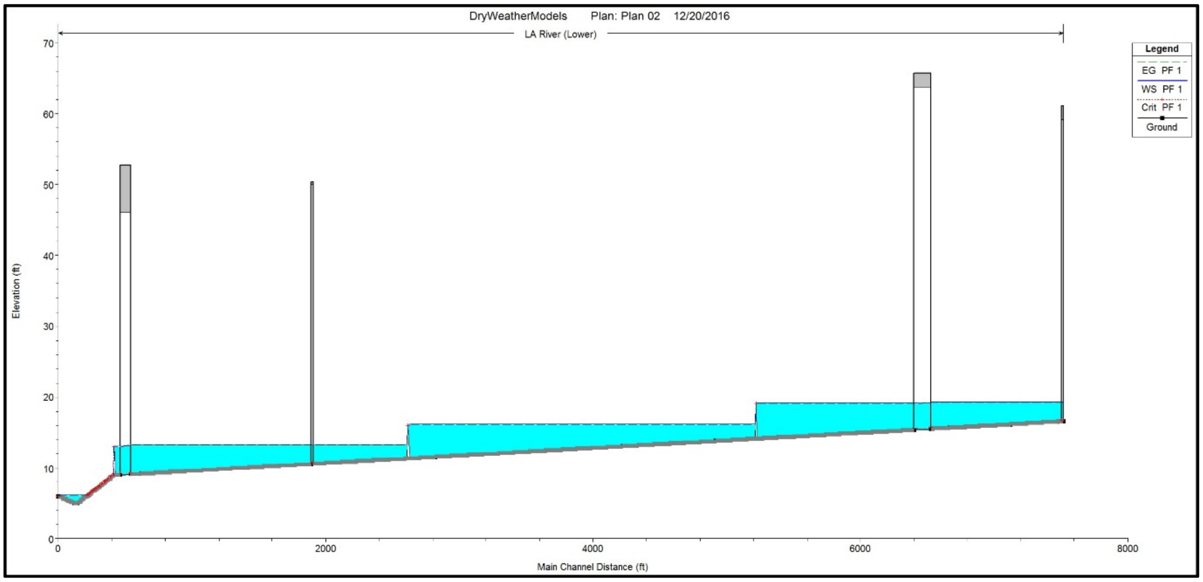

**Figure 6** HEC-RAS Model Profile – Willow St

# APPENDIX F – WATER SUPPLY AND HABITAT RESILIENCY FOR A FUTURE LOS ANGELES RIVER: SITE-SPECIFIC NATURAL ENHANCEMENT OPPORTUNITIES INFORMED BY RIVER FLOW AND WATERSHED-WIDE ACTION (DECEMBER 2016)

# Water Supply and Habitat Resiliency for a Future Los Angeles River:

## Site-Specific Natural Enhancement Opportunities Informed by River Flow and Watershed-Wide Action

---

## Los Feliz to Taylor Yard

The Nature Conservancy
Protecting nature. Preserving life.™

Funded by a Grant from the Santa Monica Mountains Conservancy

December 2016

LAND IQ

NATURAL HISTORY MUSEUM
LOS ANGELES COUNTY

WRC
Consulting Services, Inc.

connectiveissue INC

The Nature Conservancy's Urban Conservation Program Team that includes Brian Cohen (Conservation Analyst), Shona Ganguly (External Affairs Manager), Sophie Parker, Ph.D. (Senior Scientist), John Randall (Lead Scientist), Jill Sourial (Urban Conservation Program Director), and Lara Weatherly (Intern) led the process to create this report. Land IQ conducted surveys and analysis on behalf of The Nature Conservancy with the support of the Natural History Museum, WRC Consulting, Travis Longcore at the University of Southern California, and Connective Issue. When referring to this study, cite The Nature Conservancy's Urban Conservation Program.

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# Executive Summary

The mission of The Nature Conservancy [Conservancy] is to conserve the lands and waters on which all life depends. As the Conservancy engages with the Los Angeles region, they are investigating what it means to carry out this mission in the highly urbanized Los Angeles River ecosystem. As a starting point, it is known that the basic ecological principles of science apply to all environmental systems, regardless of their location. Therefore, the Conservancy is testing these principles by applying them in the Elysian Valley of the Los Angeles River and identifying habitat enhancement requirements, opportunities, and constraints.

As a basic principle of ecological systems, a watershed's hydrology determines the flow characteristics of its river system. These flows define what the biological characteristics of that river will be, which in turn determine what kinds of habitat enhancement projects will succeed at various locations along a river. The study of the Elysian Valley included one full year of multi-taxa biological surveys, a historical ecology investigation of the Elysian Valley, and a review of historic and existing hydrological and hydraulic conditions. Major findings of this study are:

- **Multiple Flow Scenarios = Uncertainty**: There are currently multiple visions for the flow characteristics of the Los Angeles River as a whole due to differing management priorities of the agencies and stakeholders that have governance over different aspects of this hydrologic system. Bringing the various hydrologic plans and possibilities for the watershed into a single integrated vision of system flow characteristics will allow certainty and clarity at the site level for the design of habitat projects anywhere in the River system, including the Conservancy's study area.
- **Flows Drive Biology**: The study area currently has higher flood and much higher dry weather flow rates than its historic condition. These high flow rates are supporting and encouraging non-native and invasive species. This leads to a lower level of biological diversity and resiliency than what would exist under lower flow rates, particularly during dry weather conditions.
- **Prioritize Complementary Habitats**: Enhancing and increasing the amount of perennial riparian habitat in-stream alone will not create as much biological value as identifying complementary enhancement opportunities outside of the River channel in adjacent upper terrace floodplain and upland habitats (e.g. alluvial scrub, mulefat scrub, willow scrub, oak-sycamore woodland, sage scrub, and grassland).
- **River Adjacent Land Use**: Land uses adjacent to the River and throughout the watershed are a part of the solution and part of the Los Angeles River's biological and hydrologic system. The landscaping and hydrology of these areas should be designed to provide a value-added role to the habitat functions of the Los Angeles River ecosystem.

Next steps for advancing the discussion of habitat enhancement include working with local stakeholders and agencies to find consensus on a flow condition for the River and its Watershed as a whole. In the study area itself there are six complementary project opportunities that could be implemented in the near term to advance understanding of habitat enhancement for the Los Angeles River. These smaller, localized projects can be used as pilot projects for the complicated jurisdictional and regulatory processes that all future habitat projects will have to navigate. They will provide a manageable and controlled process that will bring the necessary agencies together to identify the most effective processes for future projects throughout the Los Angeles River ecosystem.

# Alternative Watershed Hydrology Scenarios

Currently, there is not a single management plan for the Los Angeles River watershed ecosystem as a whole. Based on the drivers of the jurisdictional agency involved, there are different narratives for what the hydrology of the system should be. Until consensus is forged on the most appropriate hydrologic characteristics of the system, inconsistency between stakeholders and lack of clarity for project design at the site scale will persist. A common narrative for the entirety of the Los Angeles River and its watershed is needed to enable partnership and coordinated "collective impact" for the work of all stakeholders at the project level.

## Scenario 1: Existing Condition

- In-Channel Result Compared to Historic Condition: Higher Dry Weather Flows & Higher Peak Flood Flows

  The infrastructure management choices in the watershed up to this point have led to higher than historic peak flood flows from urban land uses and high levels of treated wastewater released into the River during dry weather.

  The higher flood flows have increased the infrastructure capacity required to protect against flood impacts, which constrains the integration of recreational and urban amenities into the River. This is the primary technical constraint for the strategies identified in both the Army Corps' Ecosystem Restoration Integrated Feasibility Report, and the City's River Revitalization Master Plan. Reducing these flow volumes would assist both of these efforts.

  Dry weather flows from water reclamation plant effluent prevents the River from achieving a more historic condition, which is required by some native wildlife species adapted to this semi-arid ecosystem. The year-round flows, orders of magnitude higher than would be natural, generally favor non-native species and reduce biodiversity and habitat resiliency.

## Scenario 2: Stormwater Capture Focus

- In-Channel Result Compared to Historic Condition: Higher Dry Weather Flows & Higher Peak Flood Flows, But Lower Peak Flood Flows than Existing Condition

  This scenario would be achieved if the upstream water reclamation plants limited additional reuse of their effluent water, but stormwater capture was implemented at a broad scale throughout the watershed. This outcome would depend on the separate management decisions of local agencies that are largely driven by the priorities of State funding sources and regulatory programs.

  This scenario is the most consistent with the design assumptions of the Army Corps' Ecosystem Restoration Feasibility Study and the City of Los Angeles' River Revitalization Master Plan. The lower flows during wet weather would provide a greater level of protection to infrastructure in the riparian zone during rain events. The higher flows during dry weather supports a recreational experience that has water in the River year round, which is more similar to the rivers people associate with temperate climates. However, many of the native riparian species are adapted to a drier period each year, so the existing higher dry weather flows means it is not as effective at supporting native species, biodiversity, or ecological resiliency.

### Scenario 3: Effluent Recycling Focus

- In-Channel Result Compared to Historic Condition: Similar, But Higher Dry Weather Flows from Urban Runoff & Higher Peak Flood Flows, But Lower Dry Weather Flows than Existing Condition due to Reduction in Wastewater Release

  This scenario would be achieved if water reclamation plants upstream did not discharge to the River and instead recycled the water for a beneficial use that reduced demand for imported water, and if stormwater capture efforts were not undertaken throughout the watershed. This outcome would depend on the separate management decisions of different local agencies that are largely driven by the priorities of State funding sources and regulatory programs.

### Scenario 4: Water Supply and Habitat Resiliency

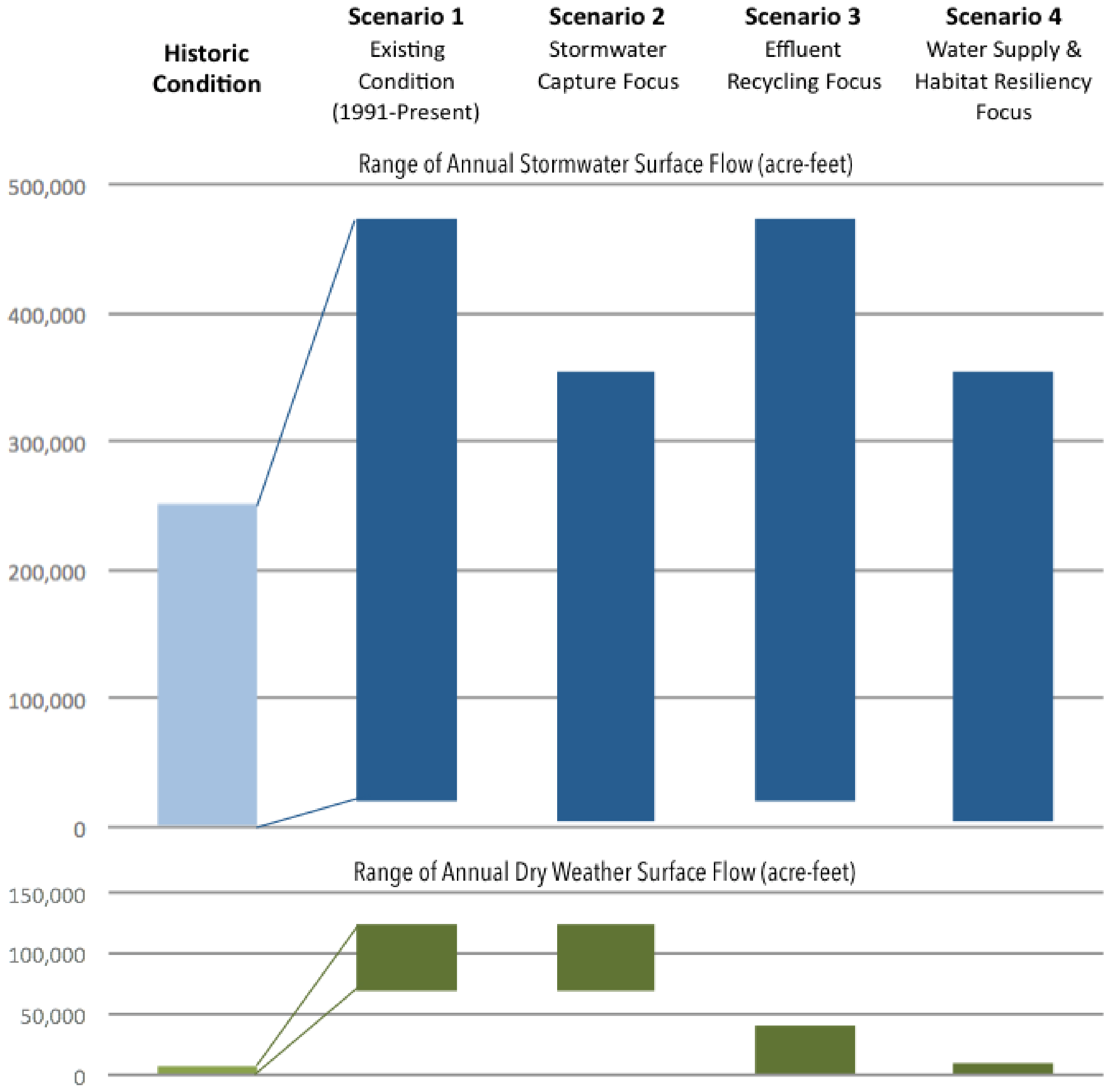
- In-Channel Result Compared to Historic Condition: Similar Dry Weather Flows & Higher Peak Flood Flows, But Lower Peak Flood Flows than Existing Condition

  This scenario would be achieved if the upstream water reclamation plants maximize recycled water, which would reduce or eliminate effluent flows to the River, **AND** stormwater capture was implemented at a large scale across the watershed. This scenario is the most responsive to ongoing Western drought conditions that necessitate reducing imported water and increasing the use and efficiency of all local water supply sources.

  This scenario most closely resembles historic hydrologic conditions in the watershed and River, and allows for the River to dry during dry weather. Therefore, it does the best job of supporting native wildlife species, with the highest level of native biodiversity and ecosystem restoration.

  In addition, the region's habitat regulations fit this scenario best because in traditional natural science practice, the historic, predevelopment condition is what defines the higher environmental value. Modeling watershed hydrology regime management after the historic condition would enable the greatest level of alignment between all future stakeholder activities and regulatory programs.

Identifying a common flow narrative is needed as a basis for a common vision for the Los Angeles River ecosystem. This can be used to organize and unify the various missions and strategies of all the stakeholders that interact with and impact the functioning of this ecosystem. Therefore, The Nature Conservancy recommends the development of an ecosystem wide dialog among stakeholders that identifies consensus for one of the alternatives listed here, or some other single scenario that is deemed suitable by the stakeholders and jurisdictional agencies.



Notes:

1. Typical Discharge Conditions in the Elysian Valley (Above the Confluence of the Arroyo Seco) based upon DWR/ULARA Annual Reports 1928/9 to 2012/13 and Report of Referee Vol 2 (1962).
2. Dry Weather Flow Inputs in the Elysian Valley include Rising Groundwater, Water Reclamation Plants (WRPs) (Tillman, LA-Glendale, Burbank), Industrial Discharge and Urban Runoff.
3. Reductions in Dry Weather Surface Flow in Scenarios 3 and 4 assume elimination of effluent discharges from the 3 WRPs into the River and that instead the water is recycled for uses that reduce demand for imported water (e.g. Tillman WRP Groundwater Replenishment Project, GRP). Scenario 4 additionally assumes that urban runoff is captured and infiltrated outside of the channel to recharge groundwater, improve water quality and create ecologically appropriate habitat (e.g. ephemeral freshwater wetland, alluvial scrub, mulefat scrub and willow scrub) complementary to the in-channel riparian habitat.
4. In Scenarios 2 and 4, additional Stormwater Flow Capture in the San Fernando Valley assumed to be 100,000 acre-feet by 2035, per aggressive capture scenario in LADWP Stormwater Capture Master Plan (2015). Fulfills LA Water Integrated Resource Plan (IRP) and One Water LA water sustainability objectives

**Figure ES-1.** **Range of Typical Annual Surface Flow for Stormwater and Dry Weather in the Elysian Valley for the Historic Condition and Four Watershed Hydrology Scenarios.**

# Elysian Valley Study Area

The Elysian Valley was chosen for this study for a number of reasons. It is at the juncture of two council districts and is the focus of a great deal of stakeholder advocacy through groups such as Friends of the Los Angeles River. It is close to a number of other open space areas that can be leveraged for habitat enhancement purposes. These areas include Griffith and Elysian Parks, California State Parks Bowtie Parcel, the Taylor Yard G2 Parcel, Los Angeles State Historic Park, and a number of pocket parks in the surrounding neighborhoods. A bike path runs through the study area, which provides the opportunity to incorporate recreational amenities and access into any pilot project.

Historically, this reach has always had detectable surface water because the water table is naturally very high, while other areas of the River, both upstream and downstream of this reach would have no surface water during dry weather. The exceptions to this perennial surface water are during periods of prolonged drought that lower the water table considerably and by the water extractions by private companies and the City that began in the late 1800s.

Today, there is surface flow in the River year-round due to treated effluent from the city's water reclamation plants and runoff from the surrounding hardscape. The current condition of constant flow combined with the 'soft bottom' of the channel has allowed for riparian vegetation to establish. This differs from other areas of the River that are fully paved, making ecosystem restoration more feasible in the near term while existing hydrologic conditions remain unchanged. The flood control channel in this part of the River is called 'soft bottom' because construction lowered the streambed elevation, penetrating the unconsolidated aquifer, which prohibited encasing the bottom with concrete.

# Existing Conditions Species Occurrence

Although the Los Angeles River in the Elysian Valley is significantly different from its historic condition, there is still a great deal of ecological function in this area (Table ES-1 and Figure ES-3). The 'soft bottom', dry weather surface water flows, and relaxed vegetation clearing practices by the local agencies have allowed for a diverse community of plants and animals to survive here.

**Table ES-1 Summary of Biotic Conditions (Survey Period: Oct 2014 to Sep 2015).**

| Plants | Reptiles & Amphibians | Birds | Insects | Mammals | Fish |
|---|---|---|---|---|---|
| •76 native species<br>•167 total sp.<br>•Invasive plants, like giant reed & castor bean<br>•4 Vegetation Communities<br>•Native willow, oak and sycamore trees | •5 natives, incl. western toad & Pacific chorus frog<br>•7 total species<br>•2 invasive species<br>•Lizards, like western fence lizard use River pocket parks | •89 native species<br>•106 total sp.<br>•Birds use in-stream & adjacent upland habitat<br>•Breeding documented or inferred for 33 bird species | •102 taxonomic families<br>•Native plants are diversity hotspots<br>•Low diversity of aquatic insects<br>•Invasive Argentine ants<br>•Native harvester ants | •10 native species<br>•17 total sp, like coyote, desert cottontail, Calif. ground squirrels<br>•5 bat sp., like Yuma myotis and big brown bat<br>•6 non-native, like domestic mouse | •No native fish<br>• 1992 & 2007 surveys found 5 non-native fish, like carp & mosquito fish<br>•Lack of hydrological connections and refugia for natives |

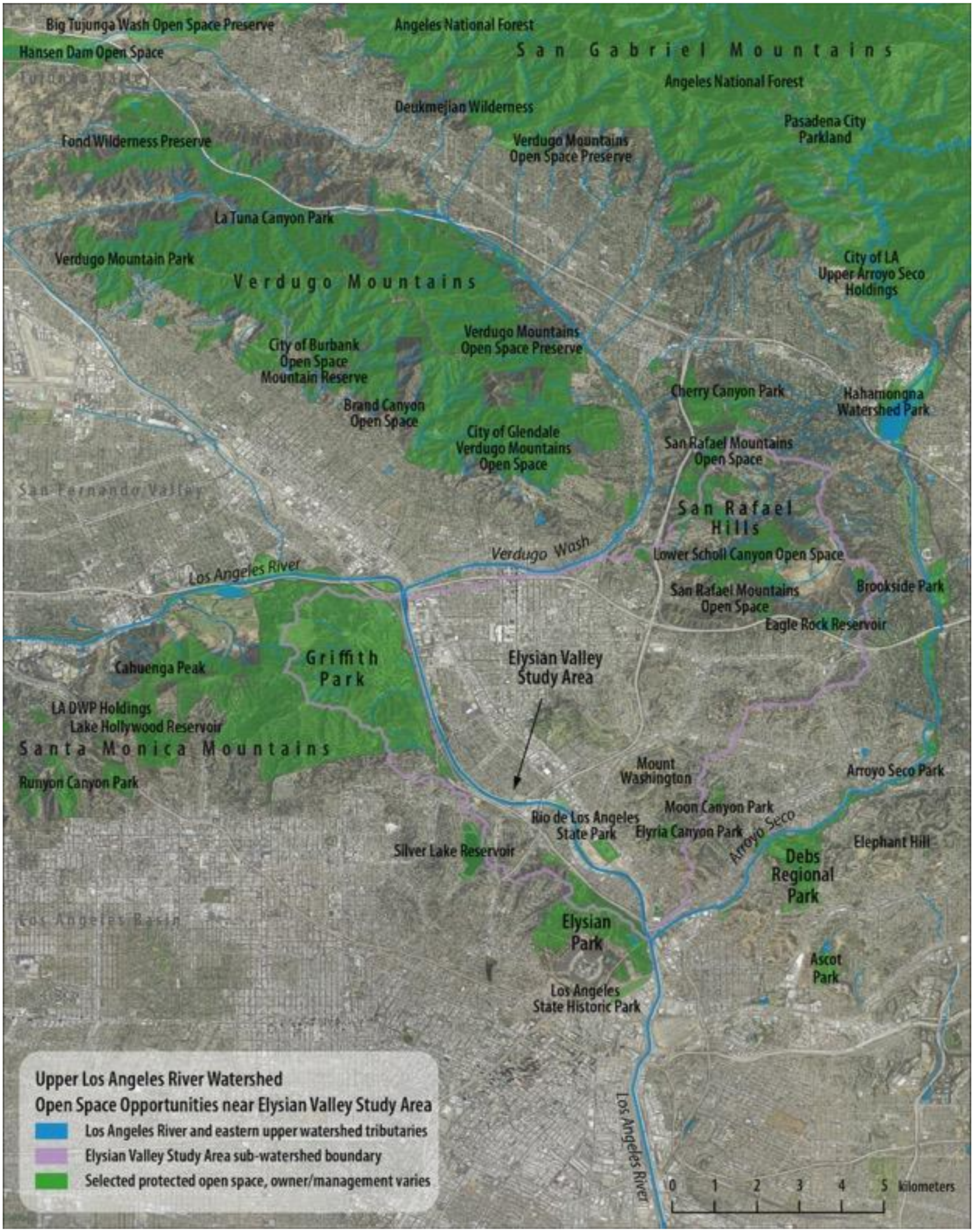


**Figure ES-2** Location of the Elysian Valley Study Area in the Upper Los Angeles Watershed.

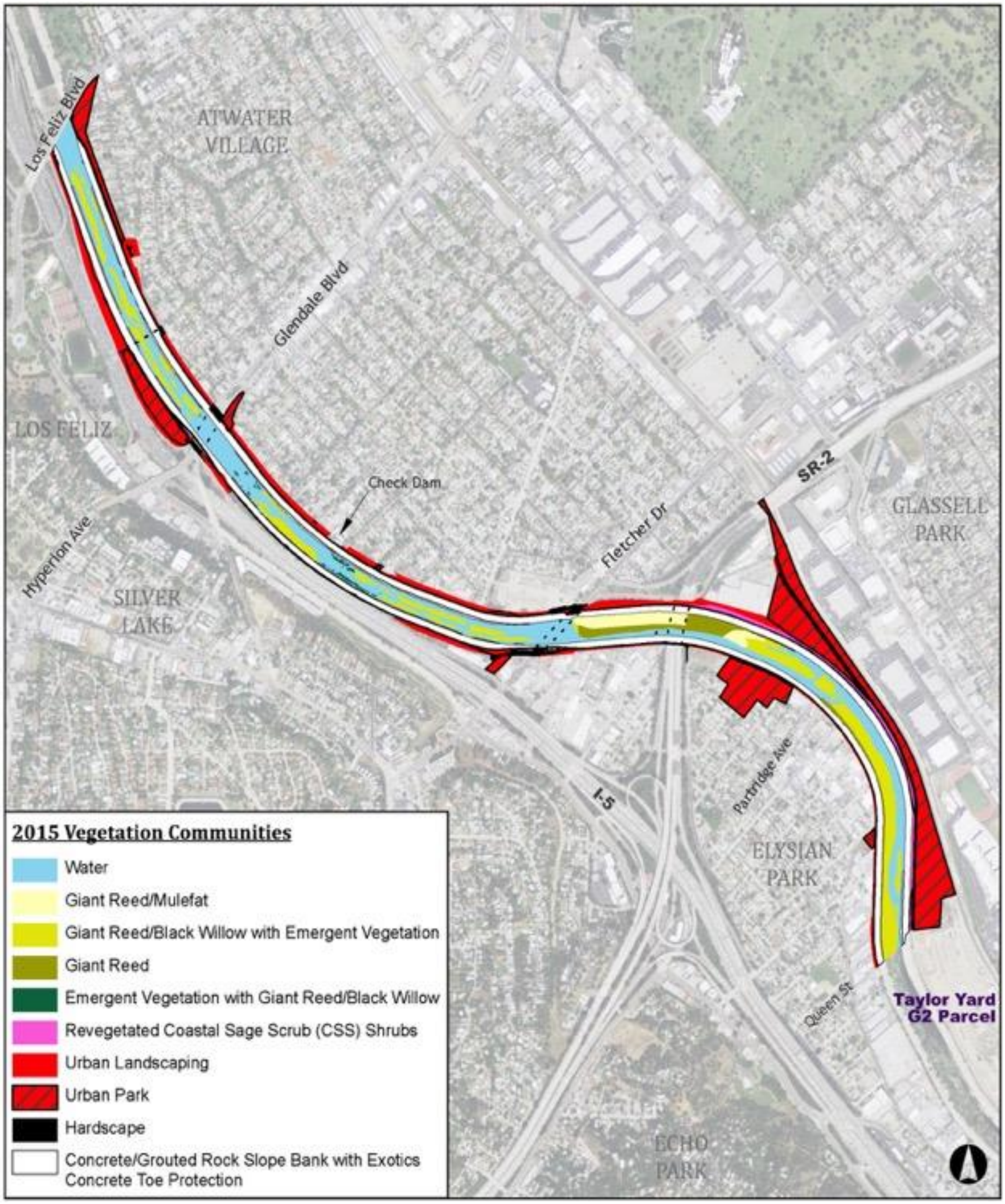


**Figure ES-3** Vegetation Communities within the Study Area.

# Habitat Enhancement Pilot Project Opportunities

Under current conditions, six project opportunities were identified for the study area that achieve a range of ecological benefits (Table ES-2 and Figure ES-4). These opportunities achieve maximum habitat enhancement value if implemented together, but can also be implemented separately or incrementally as circumstances allow.

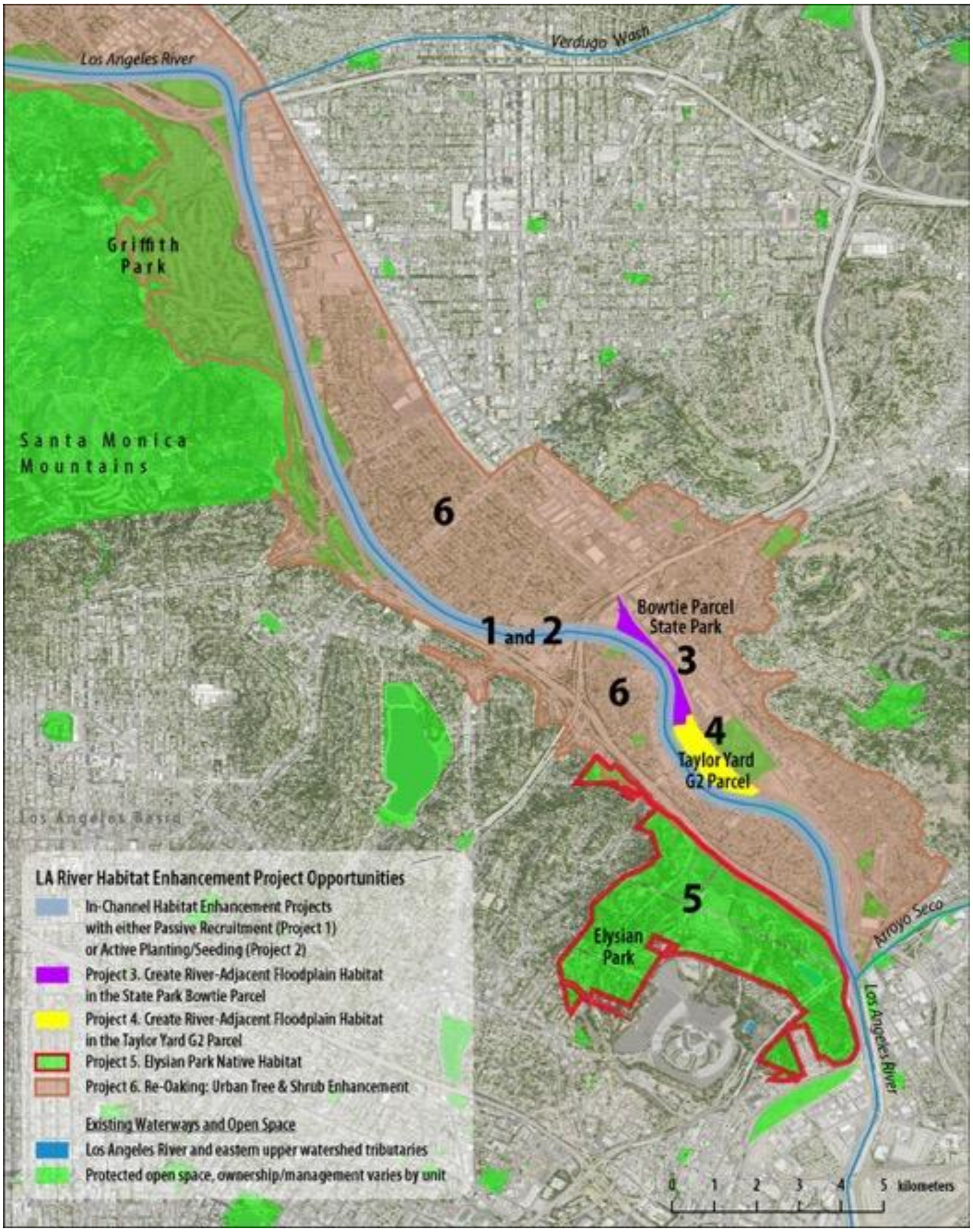


**Figure ES-4 Habitat Enhancement Project Opportunities in the Elysian Valley.**

**Table ES-2 Habitat Enhancement Project Opportunities and expected outcomes under four different Watershed Hydrology Scenarios.**

Watershed Hydrology Scenarios

| **In-Channel Result Compared to Historic Condition** | **Scenario 1** Existing Condition (1991–Present) | **Scenario 2** Stormwater Capture Focus | **Scenario 3** Effluent Recycling Focus | **Scenario 4** Water Supply & Habitat Resiliency Focus |
|---|---|---|---|---|
| Stormwater Flow: | Higher Peak Flood | Higher Peak Flood; But, Lower than Existing | Higher Peak Flood | Higher Peak Flood; But, Lower than Existing |
| Dry Weather Flow: | Higher | Higher | Similar, But Higher Due to Urban Runoff | Similar |
| **Project Opportunities** | | | | |
| **In-Channel** | | | | |
| **1. In-Channel Habitat Enhancement with Passive Recruitment** | 5–10 years to control giant reed; passive increases over 3–5 years in quality of existing riparian habitat | Same as Scenario 1, but possibility of cleaner urban runoff inputs leading to higher quality aquatic habitat | 3–5 years to control giant reed; passive increases over 3–5 years in quality of existing riparian habitat | Same as Scenario 3, but likely faster giant reed control, & reduced threat of scouring flows during plant establishment period |
| **2. In-Channel Habitat Enhancement with Active Planting/ Seeding** | 5–10 years to control giant reed; increases in quality of existing riparian habitat in 1–3 years | Same as Scenario 1, but possibility of higher quality aquatic habitat; & reduced risk of scouring flows during plant establishment period from large storm | 3–5 years to control giant reed; increases in quality of existing riparian habitat in 1–3 years | Same as Scenario 3, but likely faster giant reed control, & reduced threat of scouring flows during plant establishment period |
| **Outside Channel** | | | | |
| **3. Create River-Adjacent Floodplain Habitat in the California State Parks Bowtie Parcel** | 1–3 years of weed control; over 3–5 years increases in quality of adjacent in-channel riparian habitat and creation of high quality floodplain scrub habitat | Same as Scenario 1, but more funding opportunities for creating ephemeral wetland habitat on-site that also provides stormwater capture | Similar to Scenario 1 | Same as Scenario 2, with higher biodiversity supported by higher quality, complementary in-stream habitat |
| **4. Create River-Adjacent Floodplain Habitat in the Taylor Yard G2 Parcel** | 1–3 years of weed control; over 3–5 years increases in quality of adjacent in-channel riparian habitat and creation of high quality floodplain scrub habitat | Same as Scenario 1, but more funding opportunities for creating ephemeral wetland habitat on-site that also provides stormwater capture | Similar to Scenario 1 | Same as Scenario 2, with higher biodiversity supported by higher quality, complementary in-stream habitat |
| **5. Elysian Park Native Habitat Enhancement** | Higher quality upper terrace and upland habitat, providing complementary ecosystem services and habitat for riparian wildlife in 3–5 years, & engage local community | Same as Scenario 1, but more funding opportunities related to stormwater capture projects | Same as Scenario 1 | Same as Scenario 2 |

| | | | | |
|---|---|---|---|---|
| **6. Re-Oaking: Urban Tree & Shrub Enhancement** | Increase oak woodland canopy for benefit of wildlife over 1–10 years<br>Public engagement | Same as Scenario 1, but more funding opportunities related to stormwater capture projects | Same as Scenario 1 | Same as Scenario 2 |

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