Los Angeles River Master Plan Update
Special Subcommittee Workshop on LA River Hydrology + Hydraulics
March 20, 2019, 9:00 a.m. to 12-noon

Meeting Summary

Location

Los Angeles River Center and Gardens
570 W Ave 26, Sierra Madre Room
Los Angeles, CA 90065

Attendees

Subcommittee Members

Katie Doherty, City of Los Angeles Bureau of Engineering
Edward Belden, City of Los Angeles Mayor's Office
Michael Affeldt, City of Los Angeles Mayor's Office
Stephen Mejia, Friends of the LA River (FoLAR)
Amanda Wagner, Heal the Bay
Lucy Rieves, Heal the Bay
Mia Lehrer, LA-Mas
Guadalupe Duran-Medina, Los Angeles County 1st District
Chris Perry, Los Angeles County 5th District
Stacy Farfan, Los Angeles Department of City Planning
Anthony Nercessian, Los Angeles Department of Water and Power
Rafael Villegas, Los Angeles Department of Water and Power
Manuel Aguilar, Los Angeles Department of Water and Power
Melissa Von Mayrhauser, Los Angeles Waterkeeper
Lauren Cencic, Metropolitan Transport Authority
Veronica Padilla-Campos, Pacoima Beautiful
Joseph Gonzalez, River and Mountains Conservancy
Sarah Rascon, Santa Monica Mountains Conservancy
Joe Edmiston, Santa Monica Mountains Conservancy
Shona Ganguly, The Nature Conservancy
Robin Mark, The Trust for Public Land
Chris Solek, US Army Corps of Engineers
Eileen Alduenda, Council for Watershed Health
Brian Baldauf, Mountains Recreation and Conservancy Authority

Los Angeles County Public Works/Flood Control District Staff

Genevieve Osmeña, Los Angeles Flood Control District
Iraj Nasseri, Los Angeles Flood Control District

Carolina Hernandez, Los Angeles Flood Control District
Christine Wartman, Los Angeles Flood Control District
Daniel B. Sharp, Los Angeles Flood Control District
Donna Diaz, Los Angeles Flood Control District
Mark Beltran, Los Angeles Flood Control District
Ernesto Rivera, Los Angeles Flood Control District
Helen To, Los Angeles Flood Control District
Youssef Chebabi, Los Angeles Flood Control District
Hoan Tang, Public Works
Julian Juarez, Public Works
Marcela Benavides, Public Works

Other County Staff/ICT Members
Rita Kampalath, Chief Sustainability Office

Consultant Team
Mark Hanna, Geosyntec
Al Preston, Geosyntec
Nami Tanaka, Geosyntec
Paul Senker, Geosyntec
Jose Avina, Geosyntec
Yoshi Andersen, Geosyntec
Shant Oganesian, Geosyntec
Mustafa Ghuneim, Geosyntec
Jessica Henson, OLIN
Nate Wooten, OLIN
Diana Jih, OLIN
Joan Isaacson, Kearns & West

1. Welcome and Introductions

Genevieve Osmeña of Public Works and Project Manager of the LARMP Update opened the workshop with a round of introductions for all participants, explaining the need for a workshop to establish a common understanding of the hydrology and hydraulics (H&H) considerations of the LA River.

2. Overview

- Hydrology
- Hydraulics
- LA River Watershed and System

Dr. Mark Hanna (Geosyntec) provided an overview of the hydrology and hydraulics (H&H) of the LA River. He explained the difference between hydrology and hydraulics respectively as how water moves throughout the watershed versus the structures that move it, and he introduced key examples of each category, such as topography and vegetation cover for hydrology, and spreading grounds and flood channels for hydraulics. Dr. Hanna also reviewed the factors that directly impact the channel capacity of the LA River, including cross-sectional area, depth, roughness, and slope. An animation was developed and presented showing how dry soils can absorb water much greater than already saturated soils

Hanna then discussed the types of storms conveyed by the LA River, introducing the magnitude of precipitation that statistically occurs at frequencies ranging from once per year to once every five-hundred years. Hanna noted that the storm precipitation depth increases logarithmically (i.e., progressively more slowly) as the return period of the storm increases.

Dr. Al Preston (Geosyntec) addressed the impact of climate change on storm frequency and intensity, presenting results from recent research that indicate potential for increased storm intensities. Dr. Iraj Nasseri (LA County Flood Control District) gave an overview of the complexities of the County flood system and how flood infrastructure is typically designed based on a 50-year flow for a burned watershed. Dr. Nasseri noted that these flow rates may increase in the future, or equivalently that the design events may become more frequent. Dr. Nasseri outlined efforts of the County pro-actively working with researchers at UCLA to understand and quantify potential changes.

Hanna concluded the overview by displaying hydrographs (modeled by HEC-HMS) at Glendale Narrows and Firestone Blvd for 2-year and 100-year storm events. The hydrographs at both locations and the entire LA River were then animated, demonstrating where and when the design channel capacity is exceeded during the 100-year event.

3. Timeline of the LA River

- How did we end up with current system?
- History of flooding and floodplains
- Current protection level / flood risk
- Group brainstorm – *"what are some potential solutions to reduce flood risk?"*

Dr. Hanna explained the historic floodplains and flow paths of the LA River, pointing out the drastic shift of the mouth of the River from Venice to Wilmington in 1862, as well as the location and span of the floodplains. Hanna then reviewed the series of catastrophic flood events during the 20th century that prompted the channel concretization and expanded flood control system up until the present today. News footage (from ABC) of a recent large storm from the current water year (Feb 2, 2019) was then shown and comparisons of measured rainfall depth were made, indicating that the storm was approximately a 2-year event.

The discussion of the past and present conditions of the LA River then concluded with a brainstorm session during which the LARMP Update consultant team invited ideas from the workshop participants for ways to reduce flows into the channel or to increase channel capacity (both sides of the approach to reducing flood risk). Prominent discussions resulted regarding how the overarching LARMP goals may be addressed by the H&H considerations as well as how channel capacity may be increased with changes in channel shape (e.g., widening). The workshop participants offered the following ideas to increase channel capacity and reduce flows:

Increase Capacity:

- Floodplain reclamation
- Deepen channel
- Raise levees
- Smoother channel
- Add concrete
- Change cross section
- Diversions

Reduce Flows:

- Permeability (surface, subsurface)
- Cisterns
- Stormwater capture
- Larger scale basins
  - Find storage
  - Distributed, central, small public yards
- Wetlands (constructed)
- Manage runoff at the source
  - LID, nature based (where is impact the greatest – top of the watershed)
- Green streets
- Prioritize subwatersheds by need
- Consider public/private differences for development goals

4. Tools and Analyses

- Local scale hydrology
  - HydroCalc
- Watershed scale hydrology models
  - LSPC
  - HEC-HMS
- Hydraulics
  - Manning's Equation
  - HEC-RAS

Following the brainstorming session, Dr. Iraj Nasseri of LA County Flood Control District introduced the hydrologic and hydraulic models used by public agencies and consultants in LA County. HydroCalc is based on the modified rational method and works well for smaller sub-watersheds. For larger watersheds, more complex hydrologic models are used including Loading Simulation Program in C++ (LSPC) and the USACE HEC-HMS. These larger, more complex models are required to inform channel hydraulics analyses accounting for conditions within the entire watershed. Channel hydraulics are analyzed using Manning's Equation and the USACE HEC-RAS model. Dr. Nasseri emphasized that calibration is necessary for these models to effectively estimate runoff (hydrology) and channel performance (hydraulics).

5. Solutions and Opportunities

- Evaluations
  - Solutions, Opportunities, Ideas
  - HydroCalc
  - Glendale Narrows
  - Lower Los Angeles River

Dr. Hanna introduced the commonly utilized LID/BMPs for addressing water quality, water supply, and flood in the LA River region, highlighting the significant difference in the size of different projects. He compared the 5,186 acre-feet of storage that must be implemented for the Upper LA River EWMP's water quality targets to the Hansen Basin and Sepulveda Basins that together store over 50,000 acre-feet to control peak flows during large storm events.

Hanna described exceedance probabilities and described a comparison of historical peak flow rates between urbanized and non-urbanized subwatersheds within the LA River watershed. The comparison showed how urbanization over time significantly increases peak flow rates of the smaller more frequent rainfall events but for the larger, less frequent events, runoff from urbanized areas does not show much difference (Figure 1).

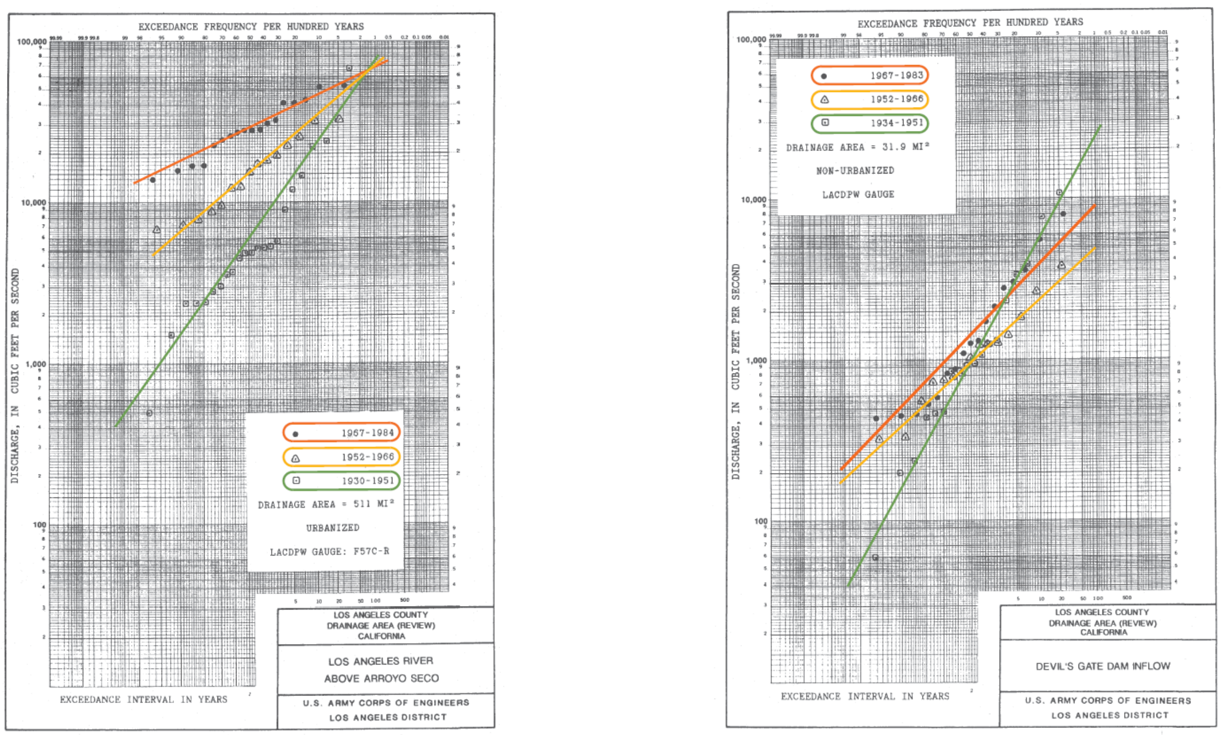

Figure 1. Exceedance Probabilities of Peak Flow Rates in Urbanized and Non-Urbanized Watersheds Over Time

The HydroCalc model was then further introduced as a means of understanding the response of runoff to hydrologic conditions within small urban areas. During a working session break, each table of participants was assigned one of six representative locations within the LA River watershed, where they had the opportunity to operate HydroCalc firsthand with guidance from consultant team facilitators. Participants viewed how much a 50% reduction of impervious area within a drainage area reduces peak runoff flow rates from both a 2-year and 100-year storm event. The results showed that the reduction in imperviousness significantly reduced 2-year peak flows but generally reduced 100-year flows by a much less (Figure 2).

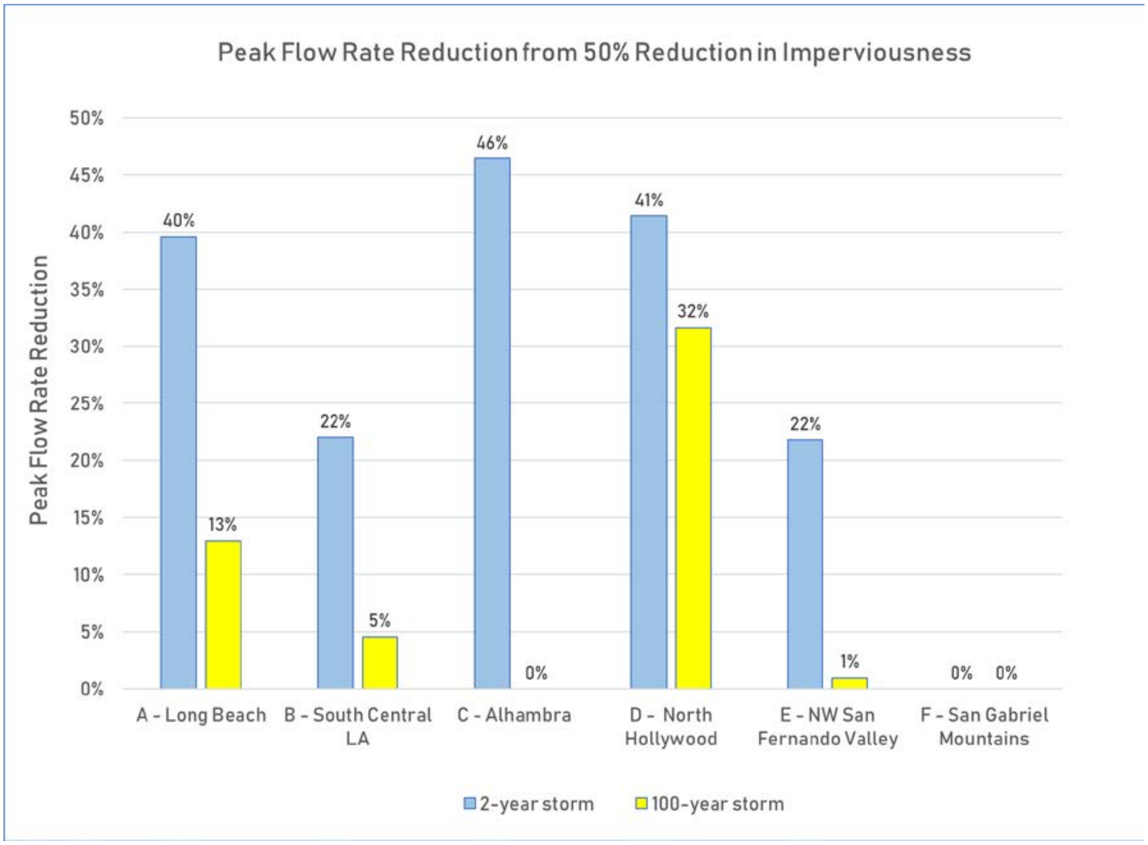

Figure 2. Resulting Peak Flow Reductions from HydroCalc Breakout Session

Following the HydroCalc breakout session, the mitigation of peak flows by reduced imperviousness (to represent capture and detention of stormwater by LID/BMPs) was further explored with results of long-term hydrologic models using LSPC as well as design storm events using HEC-HMS. Both models showed that aggressive implementation of LID/BMPs only slightly reduced (i.e., by a few percent) the largest peak flows during the 100-year event.

This led to an overview of how larger managed centralized storage can reduce peak flows, showing that increasing the size of existing basins or adding extra basins could provide some moderate additional reduction of peak flows. It was noted that there would be challenges enlarging existing basins and creating new large basins within the urban environment at hydrologically effective locations.

Various additional alternatives were also discussed such as widening of the channel, raising the height of levees, adding bypass tunnels, refurbishing the existing channel (back to original design conditions), and a combination of the aforementioned ideas.

For portions of the Glendale Narrows, a combination of ideas, such as channel refurbishment, a bypass tunnel, and a 28% reduction of imperviousness (corresponding to the 2037 ULAR EWMP target) could increase existing protection from a 4-year return period to above a 100-year return period (assuming bridge constrictions are removed as well). An animation was also presented (Figures 3 and 4) that indicated that this approach alone would not be enough to achieve the 100-year level of protection throughout the *entire* Glendale Narrows (Figure 4).

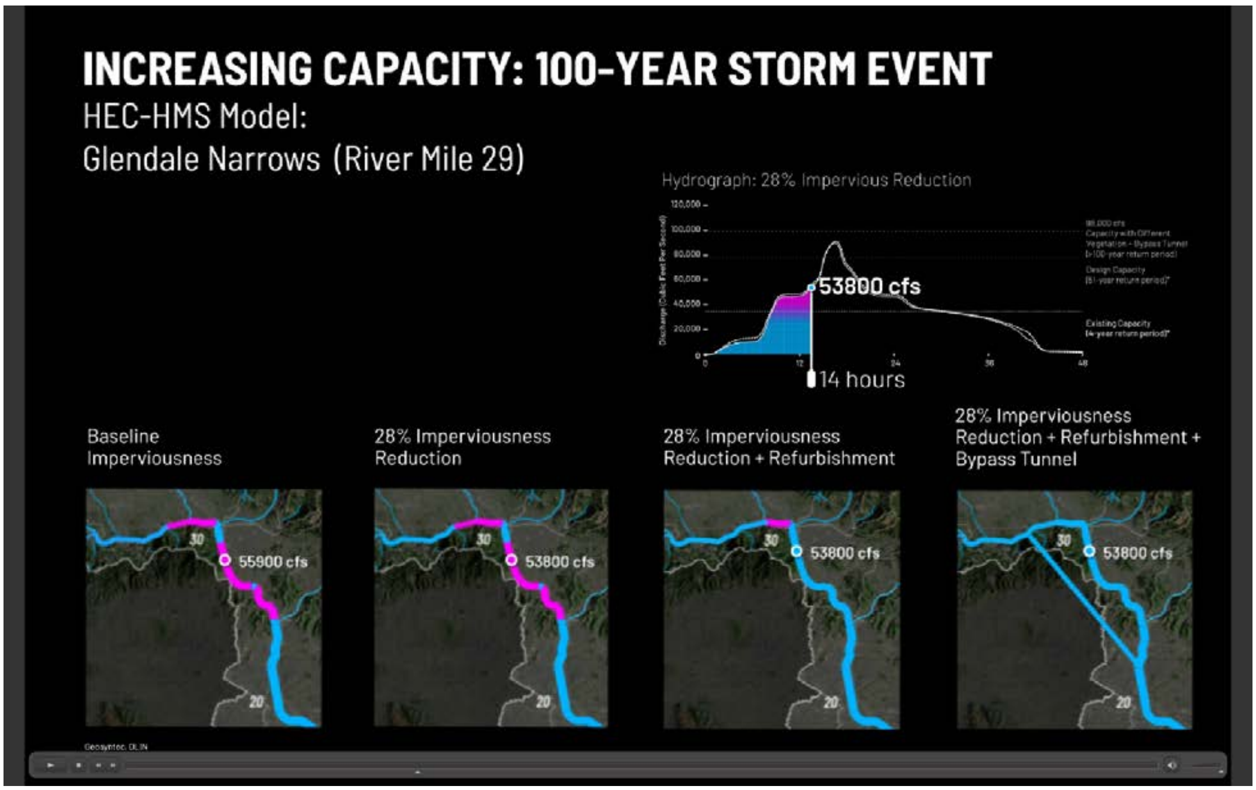

Figure 3. Glendale Narrows animation frame at hour 14 of 100-year storm event for Baseline Imperviousness, 28% Imperviousness Reduction (representing full implementation of 2037 EWMP goals), 28% Imperviousness Reduction + Refurbishment, and 28% Imperviousness Reduction + Refurbishment + Bypass Tunnel. Pink indicates exceedance of channel capacity. The animation indicates that the slight flow reduction for 28% Impervious Reduction provides limited improvement in flood risk reduction, compared to the larger subsequent improvements due to channel Refurbishment and a Bypass Tunnel.

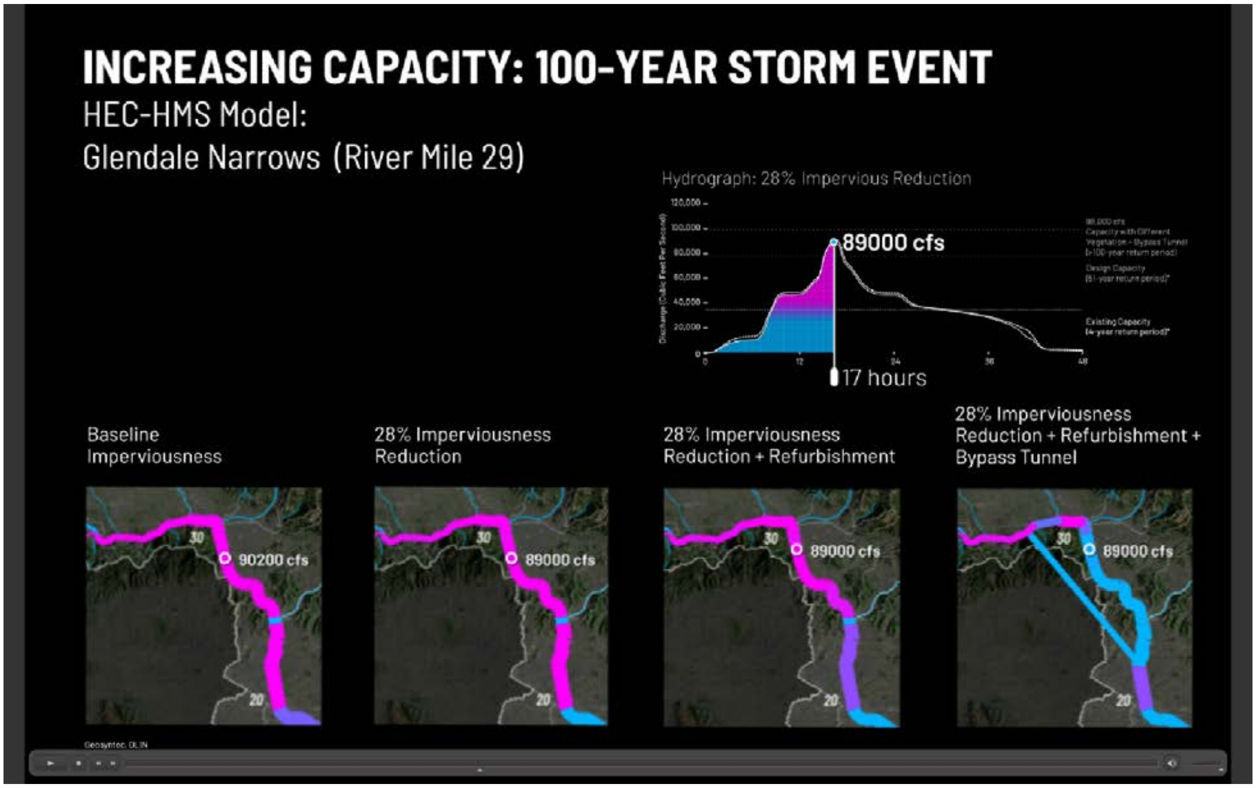

Figure 4. Glendale Narrows animation frame at hour 17 (near peak flow) of 100-year storm event for Baseline Imperviousness, 28% Imperviousness Reduction (representing full implementation of 2037 EWMP goals), 28% Imperviousness Reduction + Refurbishment, and 28% Imperviousness Reduction + Refurbishment + Bypass Tunnel. Pink indicates exceedance of channel capacity and purple indicates flow rate within 10% of channel capacity. The animation indicates that the 28% Impervious Reduction + Refurbishment + Bypass Tunnel enables the 100-year peak flow to be conveyed throughout much of the Glendale Narrows, but some reaches are still above channel capacity.

6. Wrap up

Questions and comments were taken from the audience throughout the conversation, including discussions of how hydrology and hydraulics (i.e., flood risk mitigation) is only one of the multi-benefits being considered and how the nine goals of the Master Plan integrate with one another.

Technical issues on the modeling were discussed, including how the HEC-HMS model calculates rainfall run-off (including soil infiltration and saturation) and routing to and through the channels, and that these channel flow rates are then provided to HEC-RAS to enable more detailed assessment of channel and bridge hydraulics. Additionally, it was pointed out that HEC-HMS assumes that all flow is conveyed down the channel, even when channel capacity is exceeded. As such, the flows used for the analyses and design of capacity in the Lower River assume that the Glendale Narrows have adequate capacity, with the important corollary being that addressing deficiencies in the Glendale Narrows (e.g., to meet 100-year protection) would not compromise the >100-year protection of the Lower River.

There was much discussion about differing types of “Low Impact Development” techniques and in real-time type systems that could help manage flows when needed (i.e., to “shave” the peak flows of the hydrograph). While there may be some benefit to this approach, it would be extremely difficult to implement on a distributed basis. In addition, the volumes of LID/BMPs used for water quality are an order-of-magnitude lower than the large basins (i.e., Sepulveda and Hansen) used for flood risk mitigation and the structures that already operate to manage the peak flows.

Other potential solutions were mentioned, including the use of the 5 Freeway to convey peak flows on the extreme rare occurrences. The team noted that 2D modeling developed by the US Army Corps of Engineers in 2016 indicated that this may already occur to some extent, but this is not desirable since it would impede emergency services and evacuations.

Flood plain buy-back and channel widening were discussed, including raising the question of cost of land buy-back versus cost of bypass tunnel, and furthermore, whether an increase in width of 2 to 3 times would still be required if widening is already considered in combination with other strategies, such as channel refurbishment. The team noted that there would still be complexities that would likely require widening over extended distances to be effective, as well as lengthening of bridges.

Appendix A: Sign-In Sheet

Los Angeles River Master Plan Update
Hydrology and Hydraulics Workshop
March 20, 2019 • 9 a.m. to 12 p.m.
Sign In Sheet

LOCATION
Los Angeles River Center and Gardens
Mountains Recreation & Conservation Authority
Sierra Madre Room
570 W Ave 26 #100, Los Angeles, CA 90065

NAME OF AGENCY	PRIMARY MEMBER	INITIALS
Chief Sustainability Office	Rita Kampalath	
City of Downey	Sean Ashton	
City of Los Angeles Bureau of Engineering	Katie ~~Katy~~ Doherty	KGD
City of Los Angeles Bureau of Sanitation	Susie Osuna	
City of Long Beach	Lena Gonzalez	
	Jennifer Kumiyama	
City of Los Angeles (Mayor's Office)	Edward Belden	EB
	Michael Affeldt	[illegible]
City of South Gate	Arturo Cervantes	
	Gladis Deras	
East Yard Communities for Environmental Justice	Alessandro Negrete	
Friends of the LA River (FoLAR)	Stephen Mejia	SM
Heal the Bay	Amanda Wagner	AW
	Lucy Rieves	LR
LA-Mas	Mia Lehrer	✓
Los Angeles Business Council	Mary Leslie	
Los Angeles City/County Native American Indian Commission	Rudy Ortega	
Los Angeles County 1st District	Guadalupe Duran-Medina	✓
Los Angeles County 3rd District	Virdiana Velez	
Los Angeles County 5th District	Chris Perry	CP
Los Angeles County Bicycle Coalition	Lyndsey Nolan	
Los Angeles Department of City Planning	Stacy Farfan	SF
Los Angeles Department of Water and Power	Anthony Nercessian	ATN
	Rafael Villega	RV

LA RIVER MASTER PLAN

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Los Angeles Flood Control District	Carolina Hernandez	
	Christine Wartman	CW
	Daniel B. Sharp	
	Donna Diaz	DD
Los Angeles Flood Control District	Keith Lilley	
	Mark Beltran	MB
Los Angeles Waterkeeper	Bruce Reznick	
	Melissa Von Mayhauser	MvM
Metropolitan Transportation Authority	Lauren Cencic	
Mountains Recreation & Conservation Authority	Joe Edmiston	
Pacoima Beautiful	Veronica Padilla-Campos	
Public Works	Edel Vizcarra	
	Jennifer Aborida	
	Julian Juarez	JJ
	Marcela Benavides	mB.
Rivers and Mountains Conservancy	Joseph Gonzalez	
Santa Monica Mountains Conservancy	Sarah Rascon	
Sierra Club Long Beach Area - 11 Cities	Gabrielle Weeks	
The Nature Conservancy	Shona Ganguly	
The Trust for Public Land	Robin Mark	
US Army Corps of Engineers	Chris Solek	

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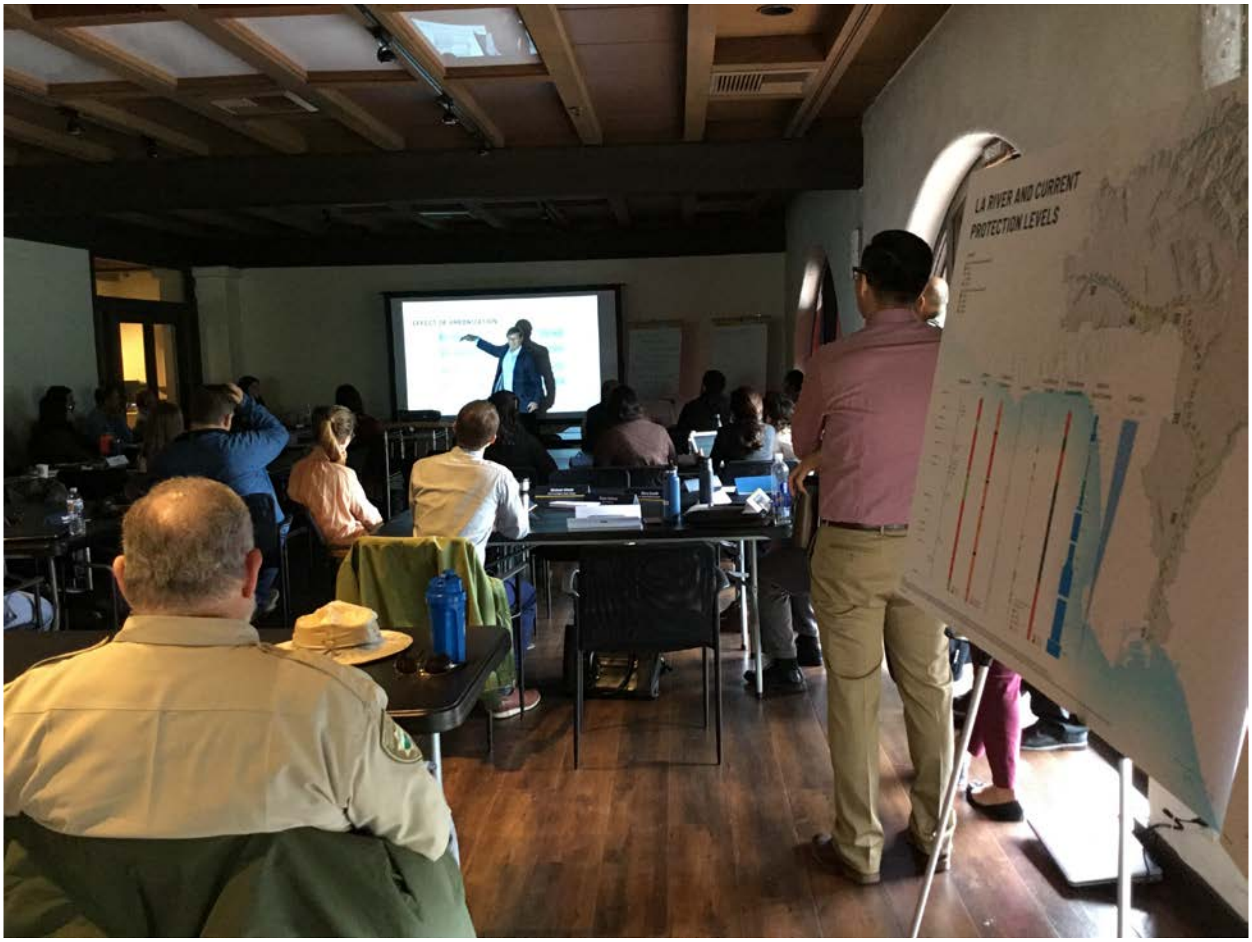
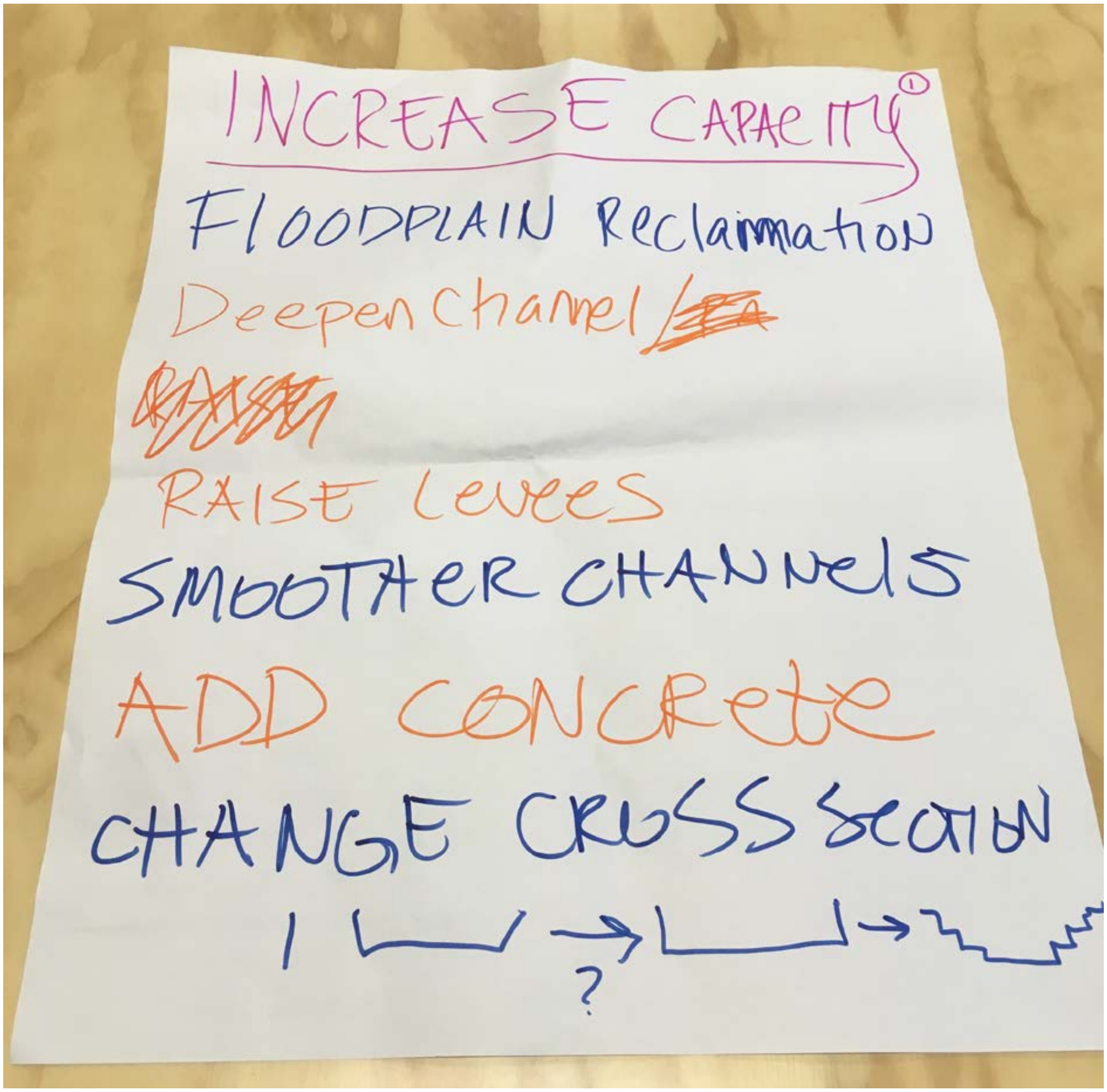
NAME OF AGENCY	PRIMARY MEMBER	INITIALS
LACFCD	GENEVIEVE OSMENA	GO
LACFCD	YOUSSEF CHEBABI	YC
LACDPW	IIRAJ NASSERI	IN
"	Ernest Rivera	ER
"	Helen Tu	HT
LA		
LACDPW	Hoan Tang	HT
LADWP	Manuel Aguilar	MA.
LADWP	Anthony Nercessian	ATN
AUWC	Kumar	KB
CWH	EILEEN ALDUENDA	EA
LACDPW	Dan Sharp	DBS
MRCA	BRIAN BALDAUF	BB

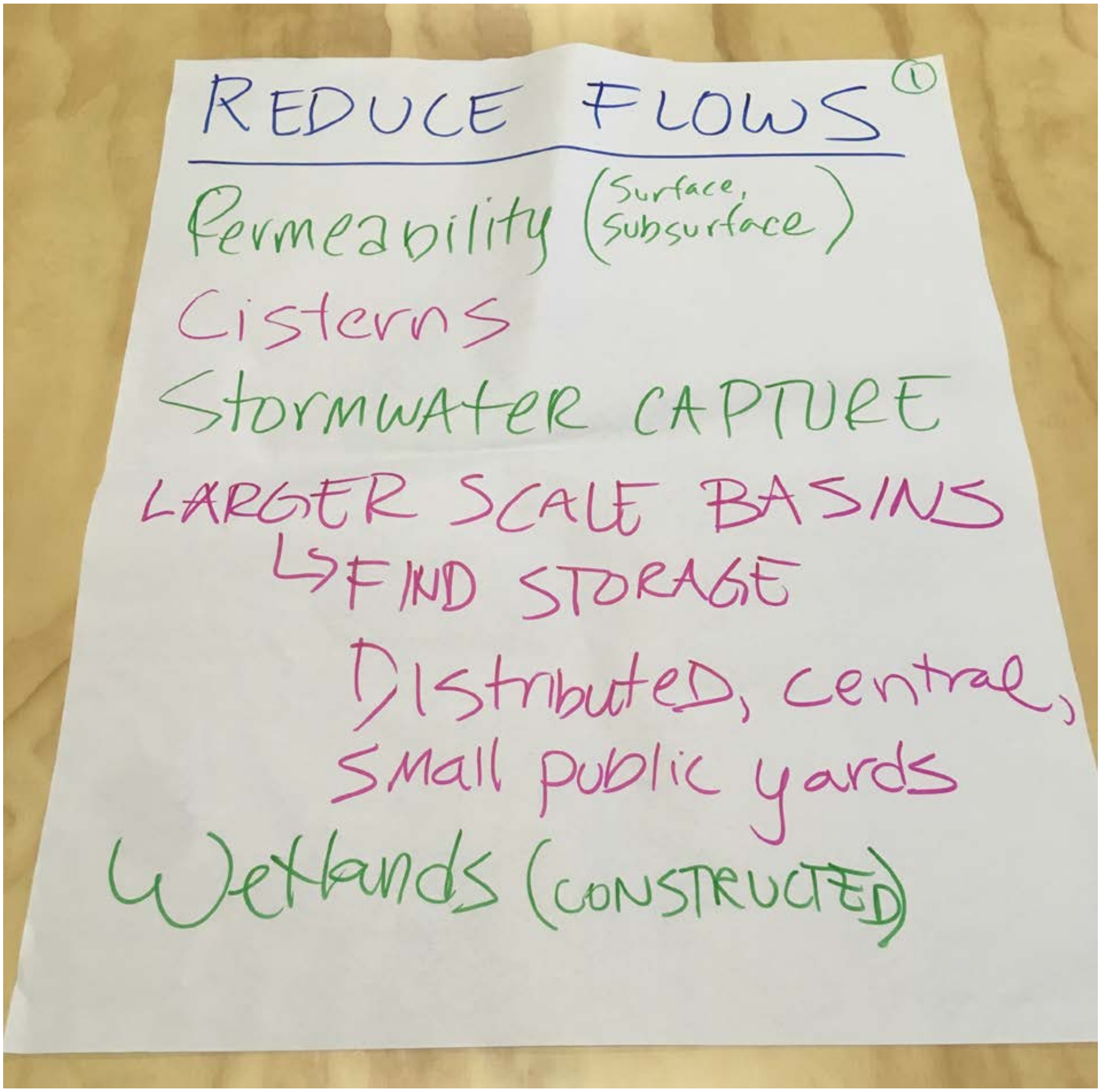
Appendix B: Photos from Workshop

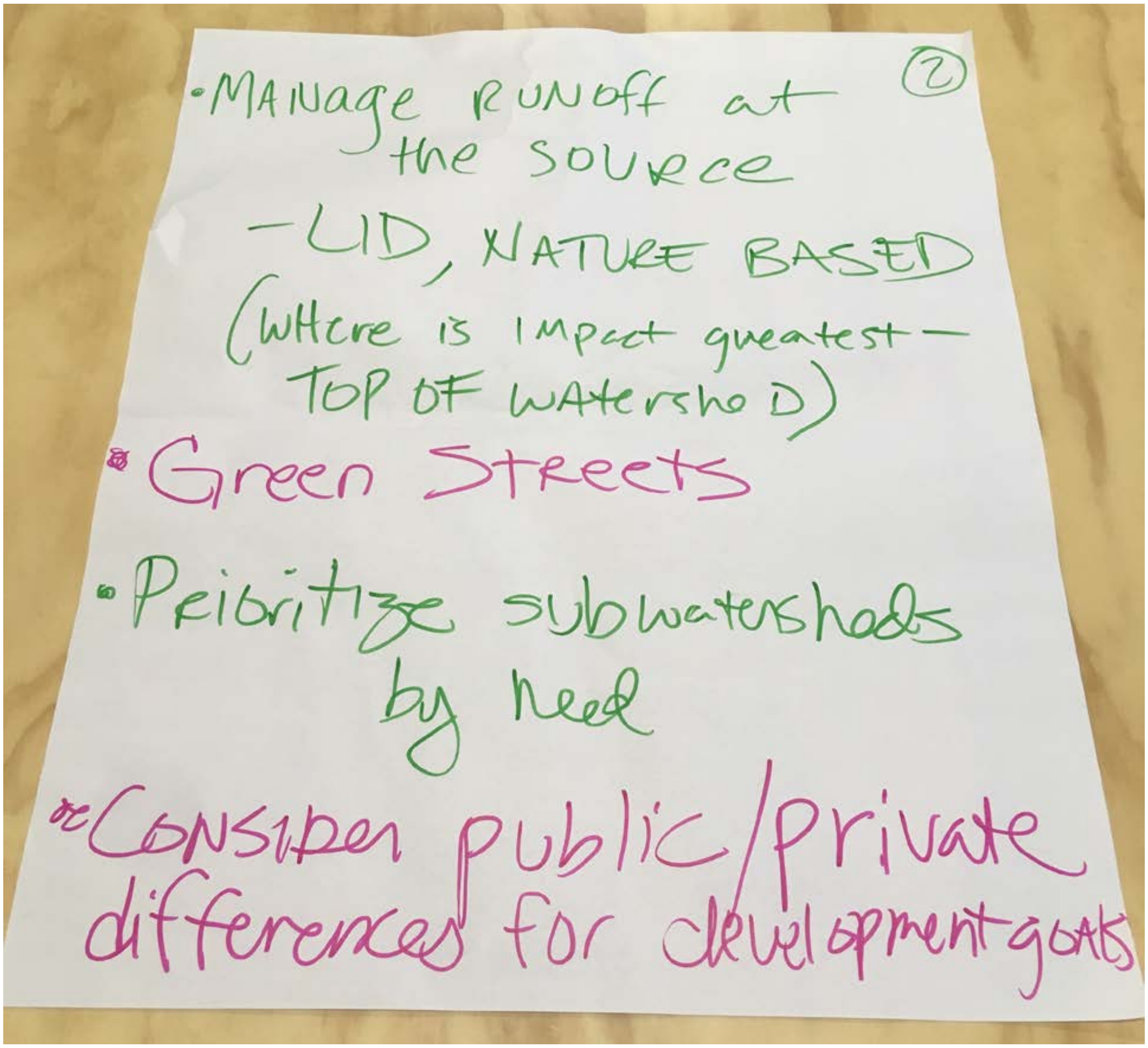

NO EXIT


LA RIVER AND CURRENT
PROTECTION LEVELS

Appendix C: Notes from Brainstorming for 'Increase Channel Capacity' and 'Reduce Flows'




REDUCE FLOWS ①
Permeability (Surface, Subsurface)
Cisterns
Stormwater CAPTURE
LARGER SCALE BASINS
↳FIND STORAGE
Distributed, central,
small public yards
Wetlands (CONSTRUCTED)



2
• MANAGE RUNOFF at the SOURCE
– LID, NATURE BASED
(WHere is IMpact greatest – TOP OF WAtershoD)
• Green Streets
• Prioritize subwatersheds by need
• CONSIDER public/private differences for development goals

Appendix D: H&H Workshop Slides

LOS ANGELES RIVER
MASTER PLAN UPDATE

Hydrology and Hydraulics Workshop

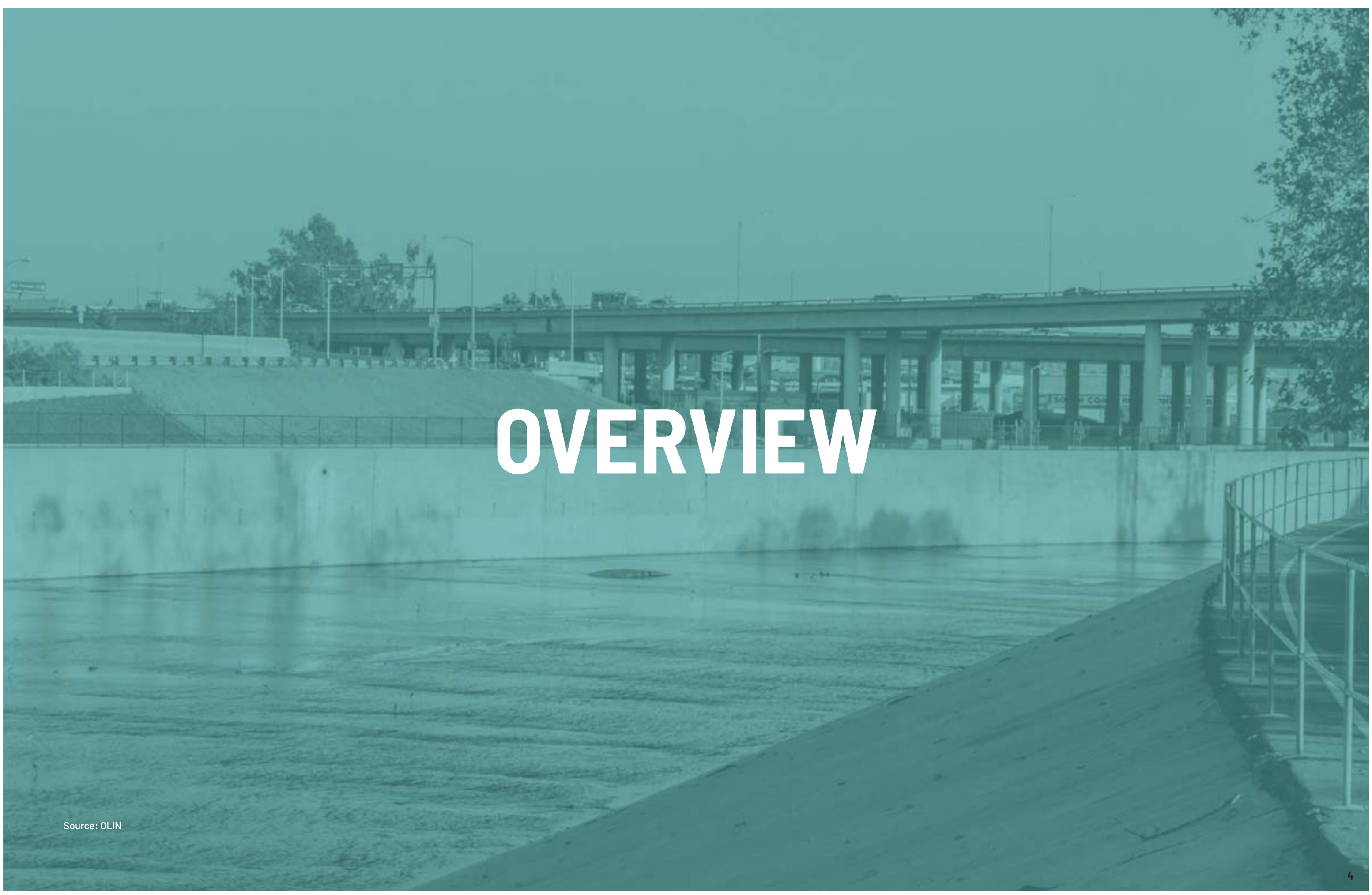
20 March 2019

WELCOME

Source: USACE, Los Angeles District, G-514 - Kelly Pipe Co Mission Road - 9-5-1930, http://cespl.maps.arcgis.com/apps/MapSeries/index.html?appid=e15694dbf7c54f8c96285a0e74039e69

OUTLINE

LA RIVER WATERSHED	TIMELINE OF THE LA RIVER	TOOLS AND ANALYSES	SOLUTIONS AND OPPORTUNITIES	WRAP UP
• Hydrology • Hydraulics • LA River	• 1850-2019 • How Did We Get Here? • Historical Flood Mapping • February 2, 2019 Storm • Current Protection Level and Flood Risk • Brainstorming Ideas	• HydroCalc • Loading Simulation Program in C++ • HEC Hydrologic Modeling System • Manning's Equation • HEC River Analysis System	• Evaluations • Worksession Breakout – Modeling the Theories Ourselves • Advanced Modeling	• Discussion • What Have We Learned? • What Needs More Study/Analysis? • Other Resources



Source: OLIN

LA RIVER HYDROLOGY AND HYDRAULICS (H&H)

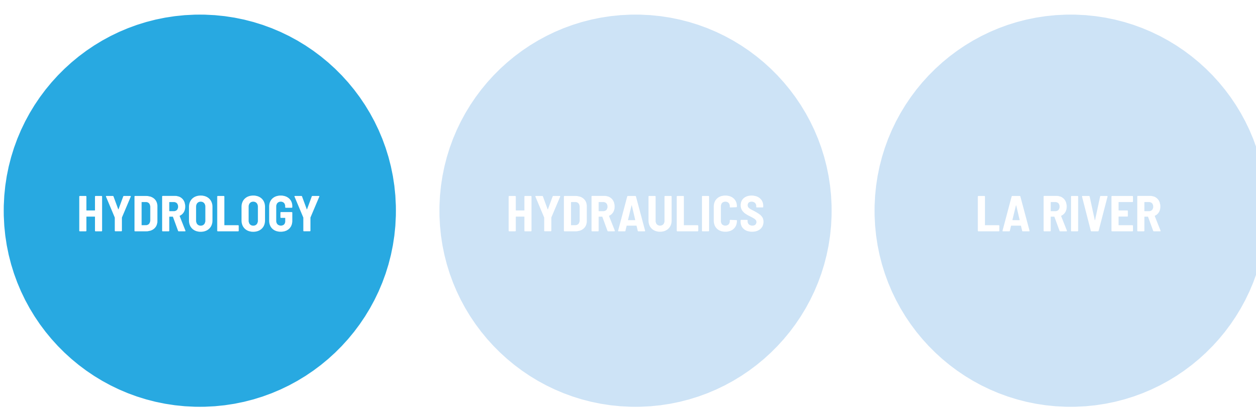
WATERSHED CONDITIONS

- Topography
- Geology & Soils
- Vegetation Cover & Land Use
- Climate/Precipitation

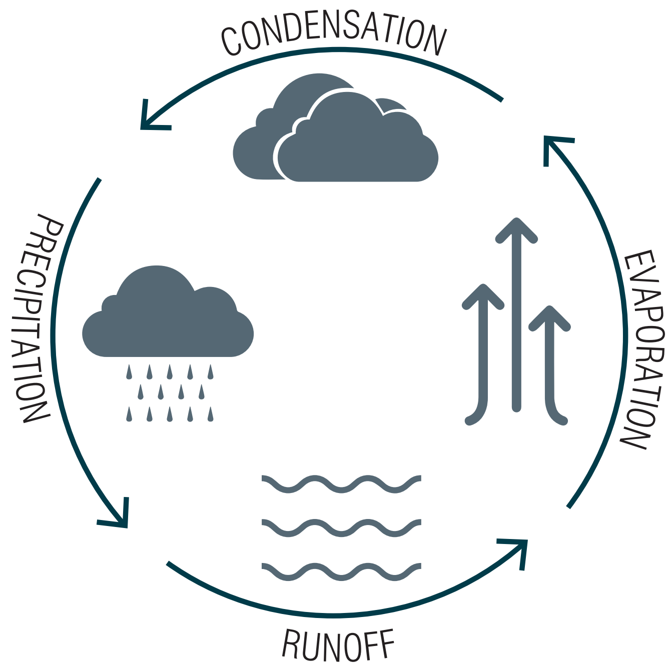
INFRASTRUCTURE

- Spreading grounds
- Detention basins
- Channels
- Storm Drains

OVERVIEW



THE HYDROLOGICAL CYCLE



THE LA RIVER WATERSHED

Source: LA County GIS Portal, Google Earth, Geosyntec

THE LA RIVER WATERSHED

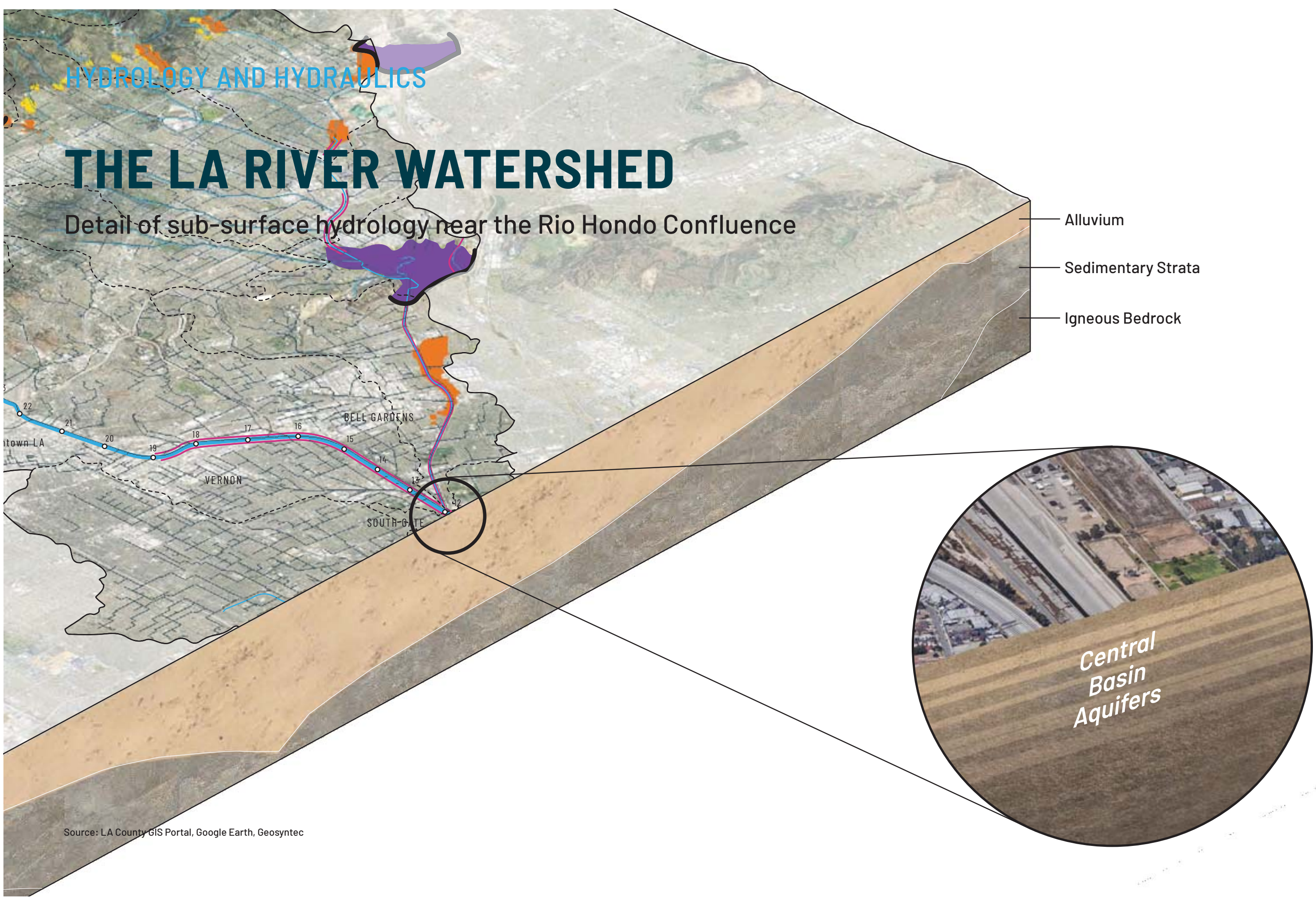
Section cut at the Rio Hondo Confluence

- Flood Control Basins
- Spreading Grounds
- Debris Basins
- Levees
- Storm Drains
- Dams
- Rivers

Source: LA County GIS Portal, Google Earth, Geosyntec

THE LA RIVER WATERSHED

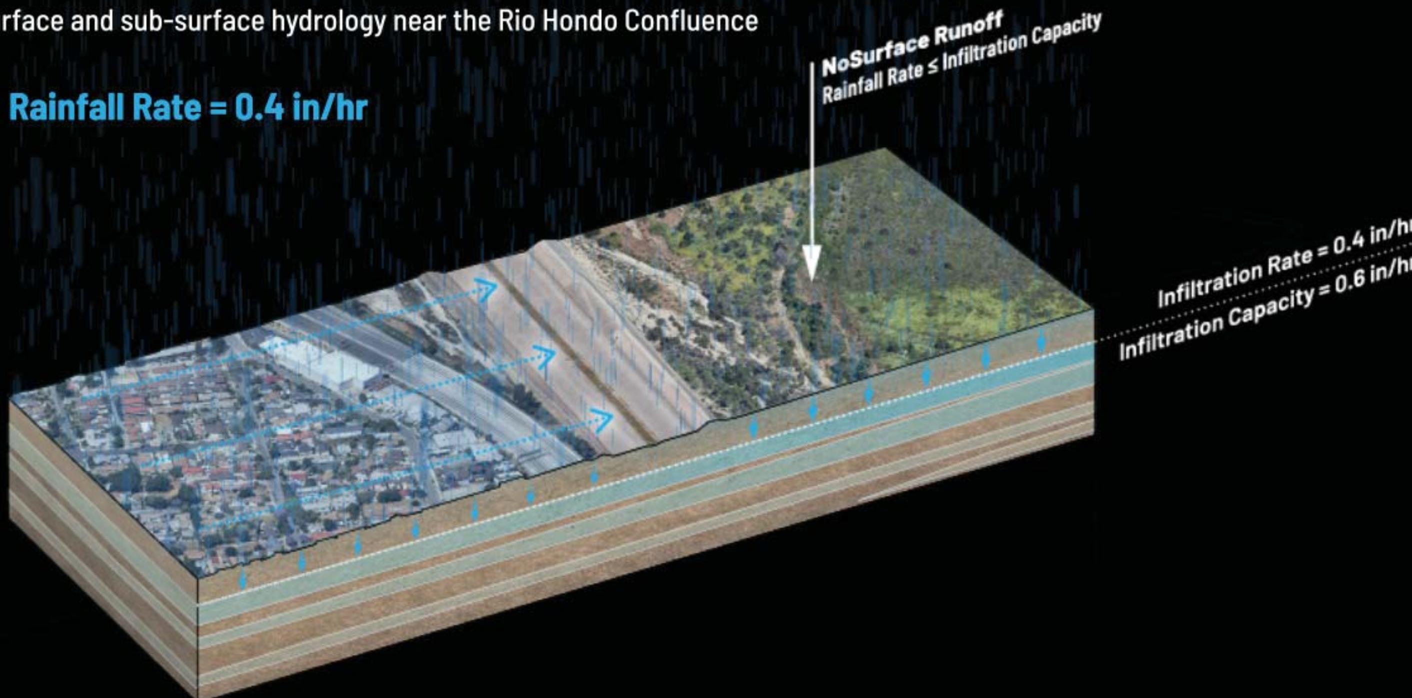
Detail of sub-surface hydrology near the Rio Hondo Confluence



Source: LA County GIS Portal, Google Earth, Geosyntec

SOIL-WATER PROCESSES

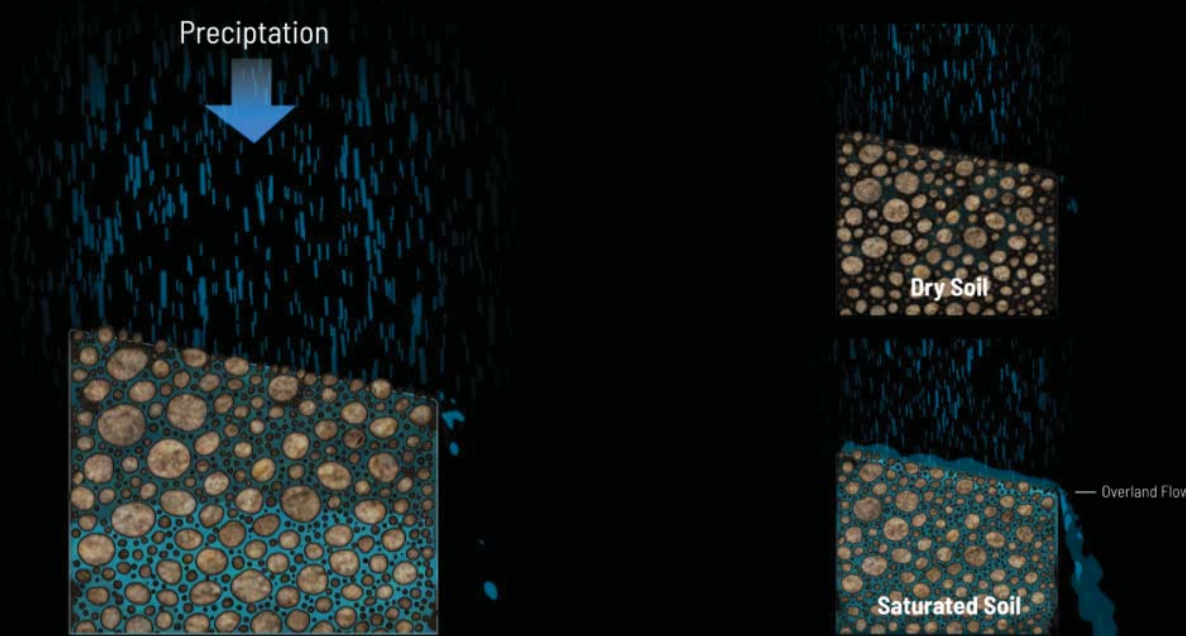
Surface and sub-surface hydrology near the Rio Hondo Confluence



Source: Geosyntec & OLIN

SOIL-WATER PROCESSES

Infiltration rate of soil decreases as it becomes saturated



Geosyntec, OLIN

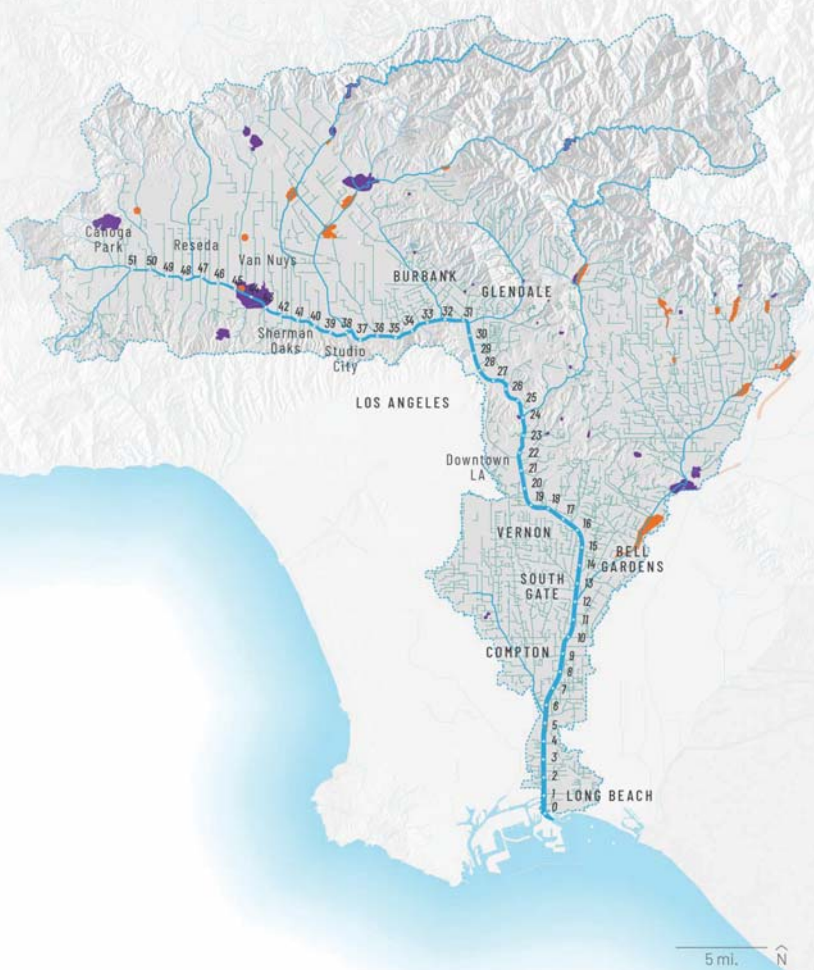
OVERVIEW

HYDROLOGY

HYDRAULICS

LA RIVER

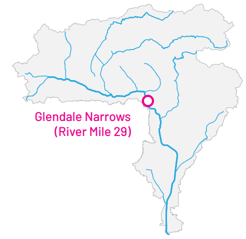
HYDRAULIC FLOOD SYSTEM



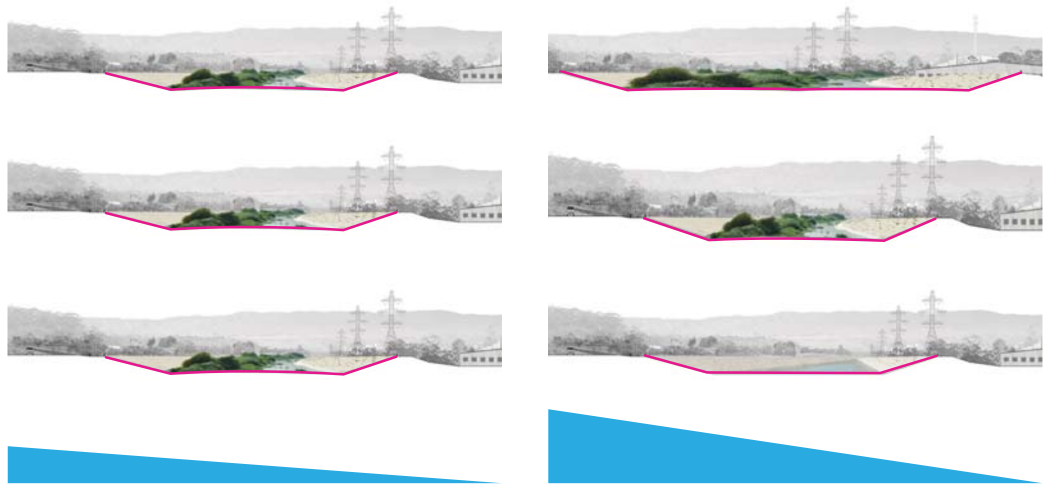
- Spreading Grounds
- Flood Control Basins
- Storm Drains
- Streams and Channels

Source: LA County GIS Portal

HYDRAULICS - CHANNEL CAPACITY



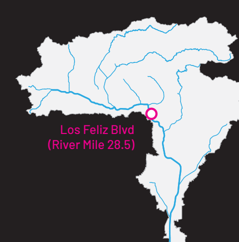
	LOWER CAPACITY	HIGHER CAPACITY
AREA		
DEPTH Hydraulic radius		
ROUGHNESS Manning's n		
SLOPE		



Source: Geosyntec, OLIN

HYDRAULICS - BRIDGES

Los Feliz Blvd on 2 February 2019



Upstream of Bridge

Downstream of Bridge

Source: Geosyntec

OVERVIEW

HYDROLOGY

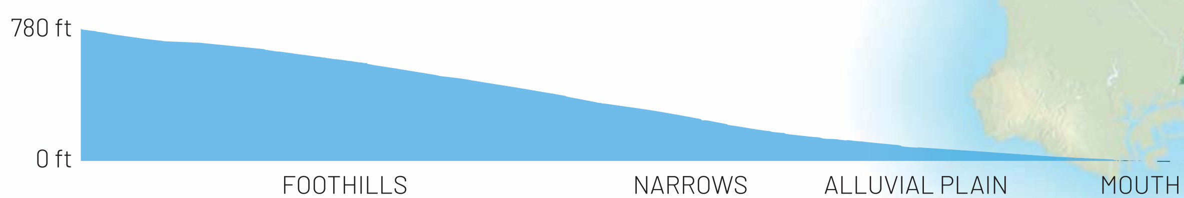
HYDRAULICS

LA RIVER

THE LA RIVER DROPS 780 FEET IN JUST 51 MILES

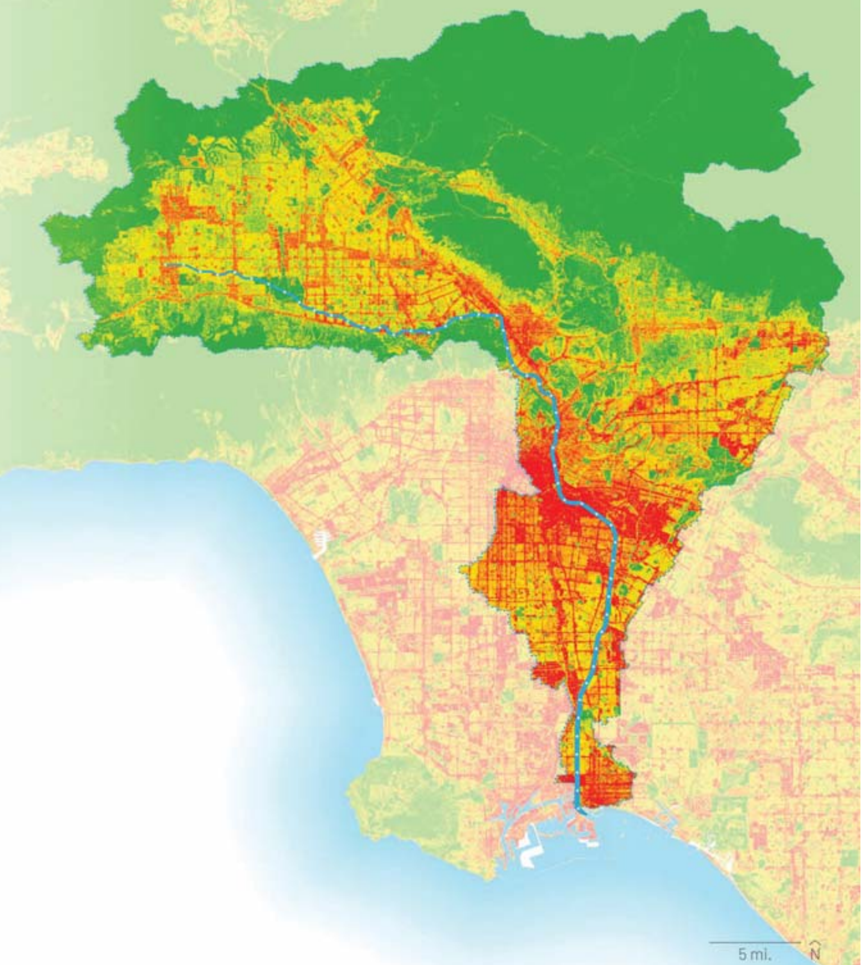
High (7,103 ft)

Low (0 ft)



Source: U.S. Geological Survey, 2013, USGS NED 1 arc-second 2013

LA RIVER WATERSHED IMPERVIOUSNESS



0% Impervious

100% Impervious

Source: LA County GIS Data Portal, NLCD 2011 Impervious Surface

85TH PERCENTILE 24-HOUR RAINFALL DEPTH

Commonly used for water quality design

85 percent of storms are less than or equal to the 85th percentile rain event.

Total Rainfall (inches)

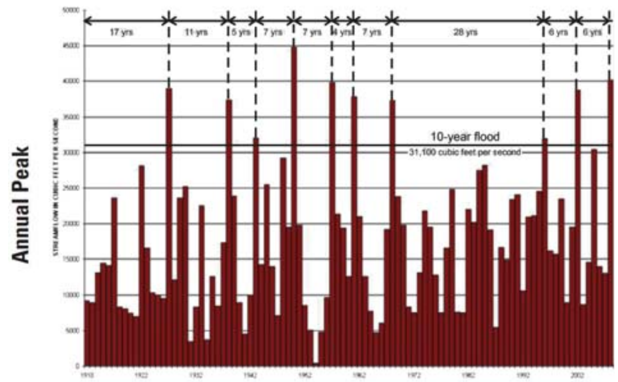
- 0.20 - 0.45
- 0.45 - 0.70
- 0.70 - 0.95
- 0.95 - 1.20
- 1.20 - 1.45

Source: Los Angeles County GIS Data Portal, 85th and 95th Percentile Rainfall, 2016

STORM PROBABILITY

Defining the 100 year storm:

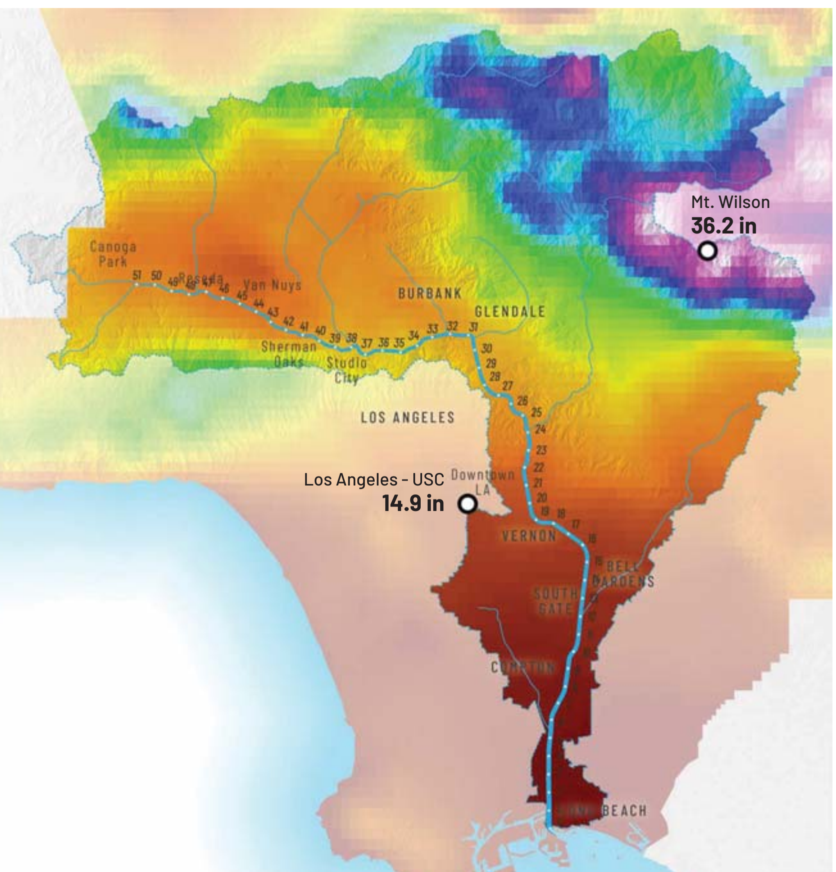
- **A storm that happens once every 100 years on average.**
- **A storm that has a 1% probability of happening in any given year.**
- Two 100-year events can happen in back-to-back years or even the same year.
- Over 30 years (i.e., the length of standard home mortgage), the probability of having a 100-year event is 25%.
- Climate change is likely to increase the frequency of extreme events.



Incidence of the 10-year flood for the Embarras River at Ste. Marie, IL (03345500). The variability in time between "10-year floods" ranges from 4 to as many as 28 years between floods.

Source: Modified from 100-Year Flood-It's All About Chance, USGS, April 2010, https://pubs.usgs.gov/gip/106/pdf/100-year-flood-handout-042610.pdf.

LA RIVER WATERSHED MEAN ANNUAL PRECIPITATION 1981-2010



38.7 in / 983 mm

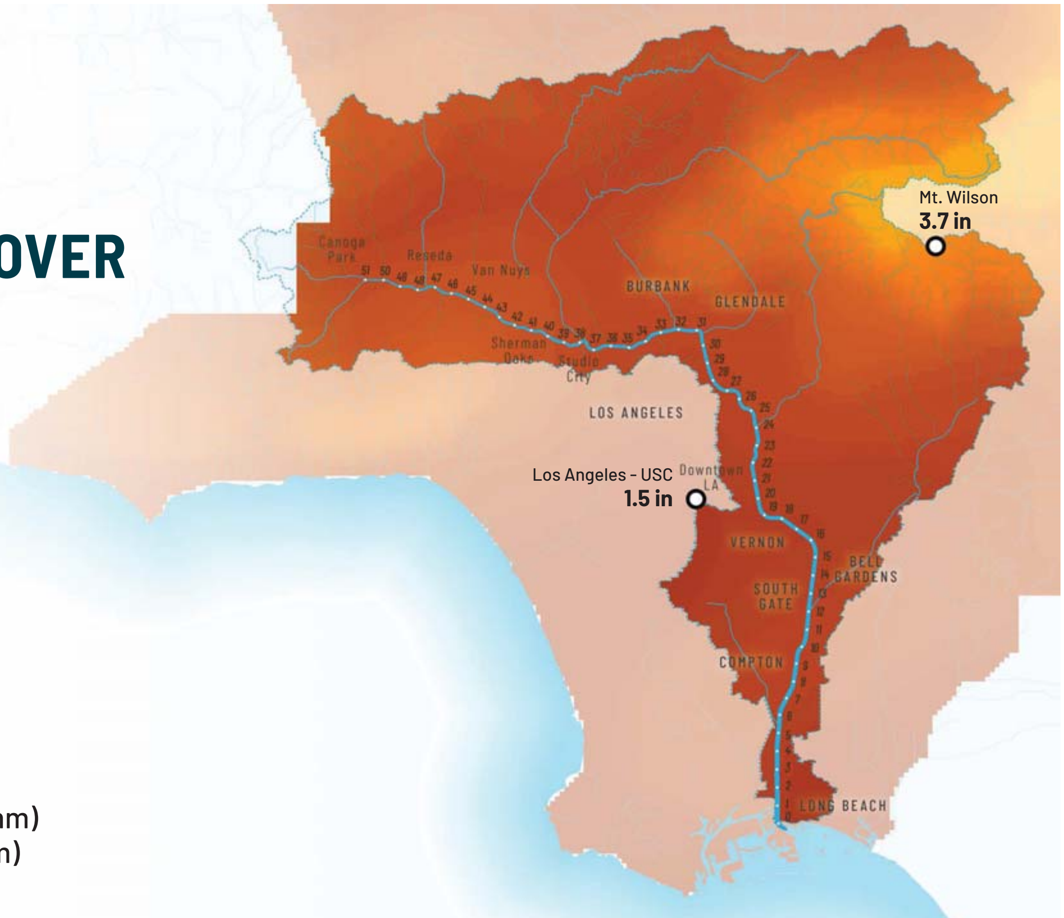
Mt Wilson

Los Angeles - USC

12.9 in / 327 mm

Source: PRISM Climate Group, Oregon State University, 30-yr Normal Precipitation: Annual, 2015

1-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

Max Rainfall (4.6 in / 116 mm)

Min Rainfall (0.7 in / 19 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

2-YEAR STORM PRECIPITATION OVER 24 HOURS

23.0 in / 584 mm

Max Rainfall (6.3 in /159 mm)

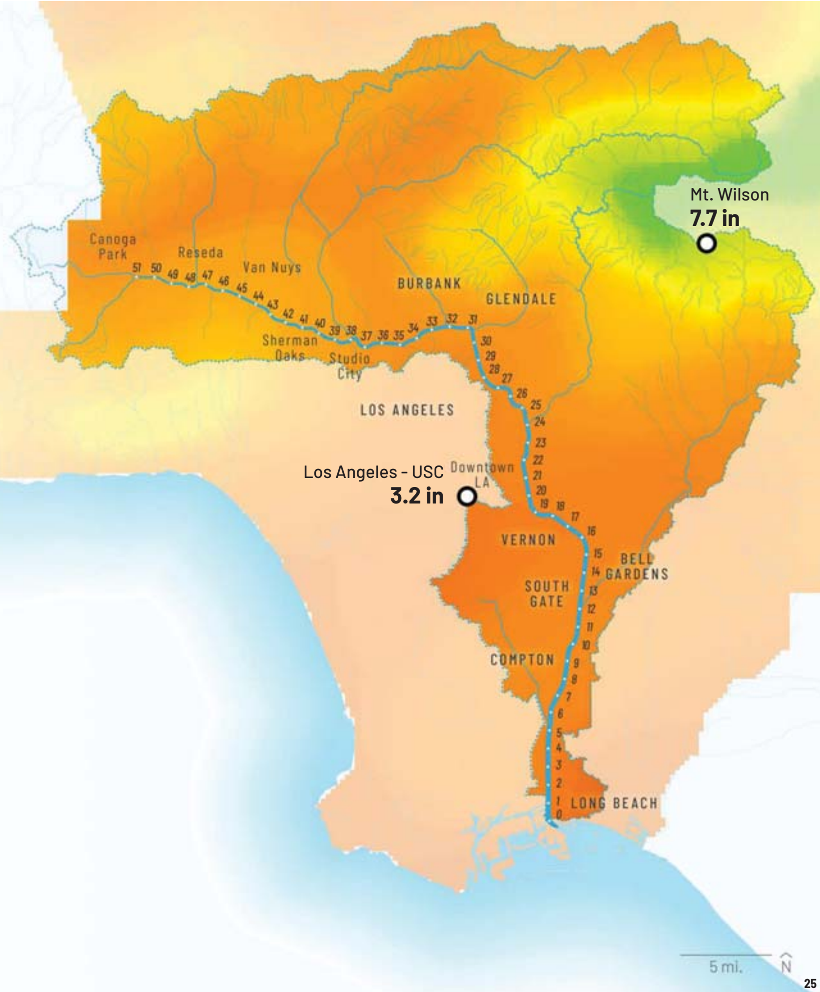
Min Rainfall (1.0 in / 25 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROLOGY AND HYDRAULICS

5-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

Max Rainfall (9.4 in / 239 mm)

Min Rainfall (1.5 in / 38 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROLOGY AND HYDRAULICS

10-YEAR STORM PRECIPITATION OVER 24 HOURS

23.0 in / 584 mm

Max Rainfall (11.5 in / 293 mm)

Min Rainfall (1.8 in / 47 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

25-YEAR STORM PRECIPITATION OVER 24 HOURS

23.0 in / 584 mm

Max Rainfall (14.2 in / 360 mm)

Min Rainfall (2.3 in / 58 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

50-YEAR STORM PRECIPITATION OVER 24 HOURS

23.0 in / 584 mm

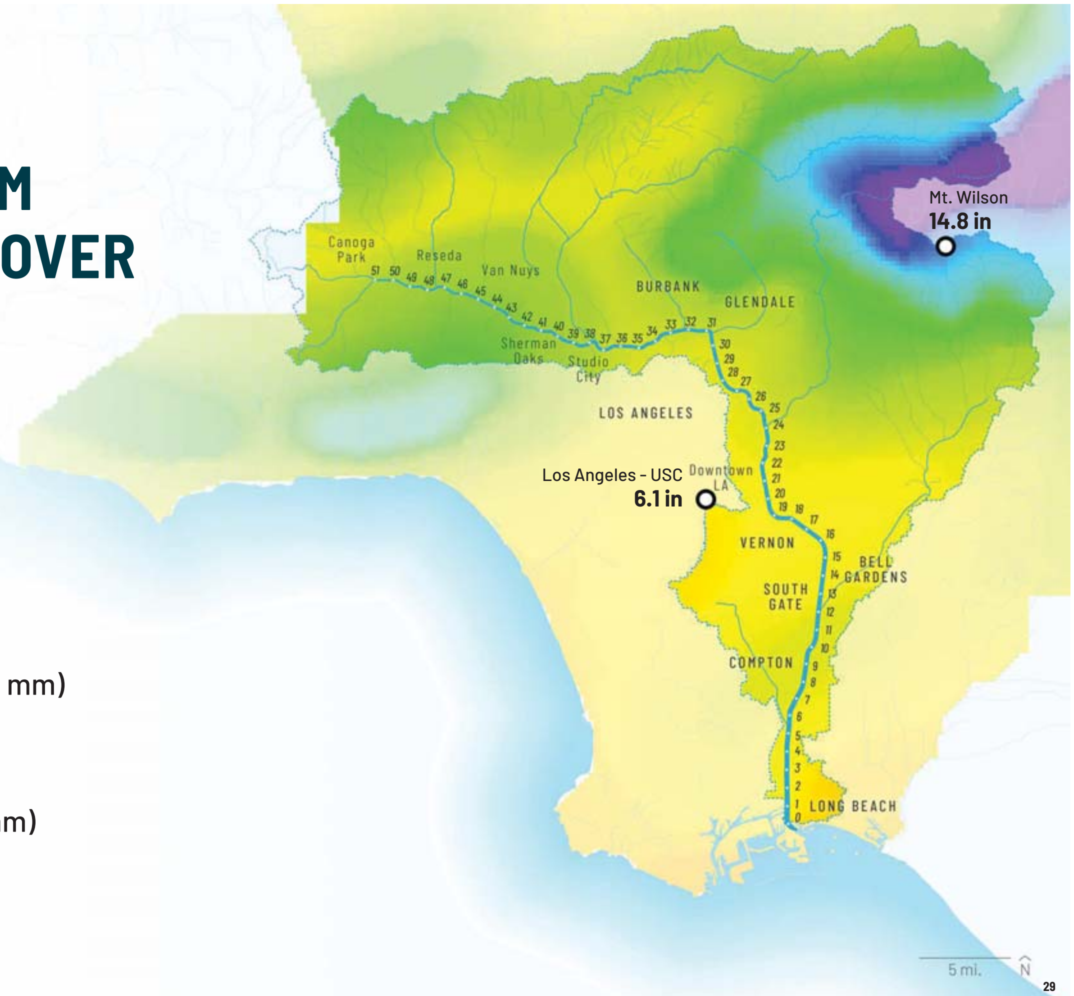
Max Rainfall (16.1 in / 410 mm)

Min Rainfall (2.5 in / 66 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

100-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

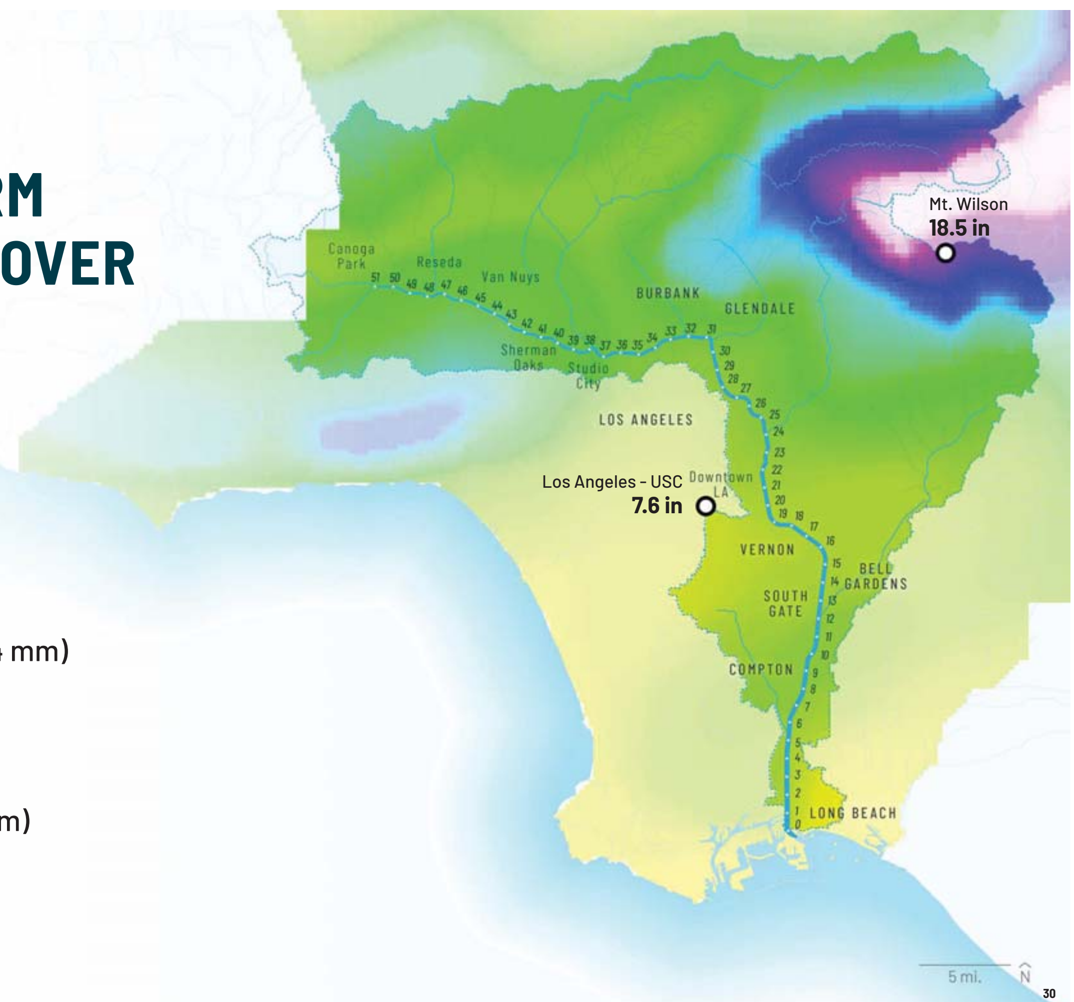
— Max Rainfall (18.1 in / 460 mm)

— Min Rainfall (2.9 in / 74 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

500-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

— Max Rainfall (22.6 in / 574 mm)

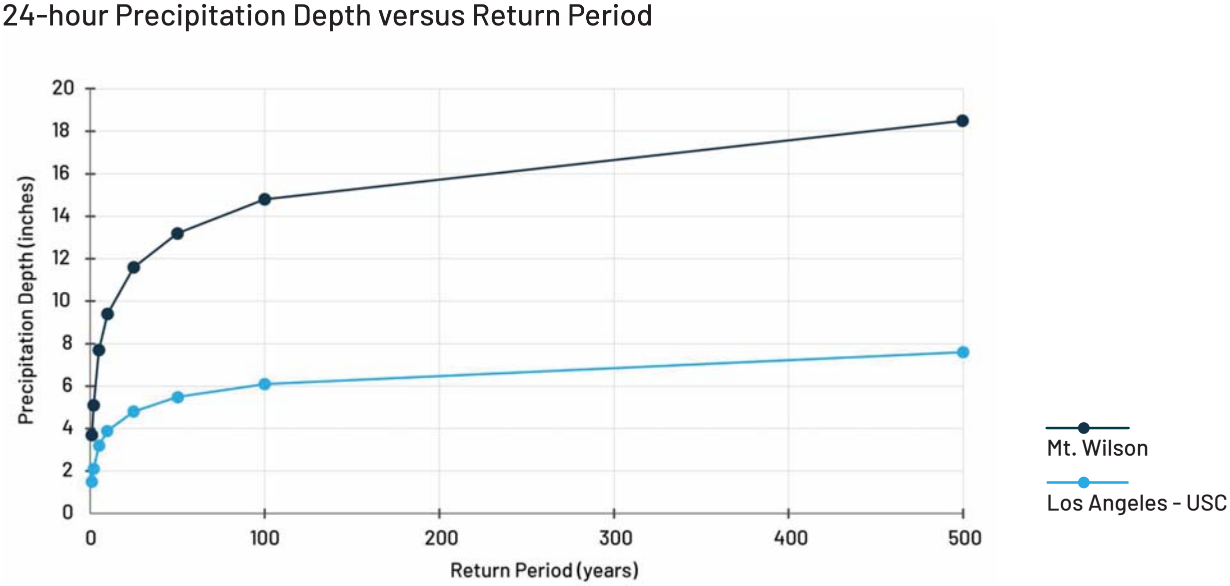
— Min Rainfall (3.6 in / 92 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

STORM RETURN PERIODS

24-hour Precipitation Depth versus Return Period

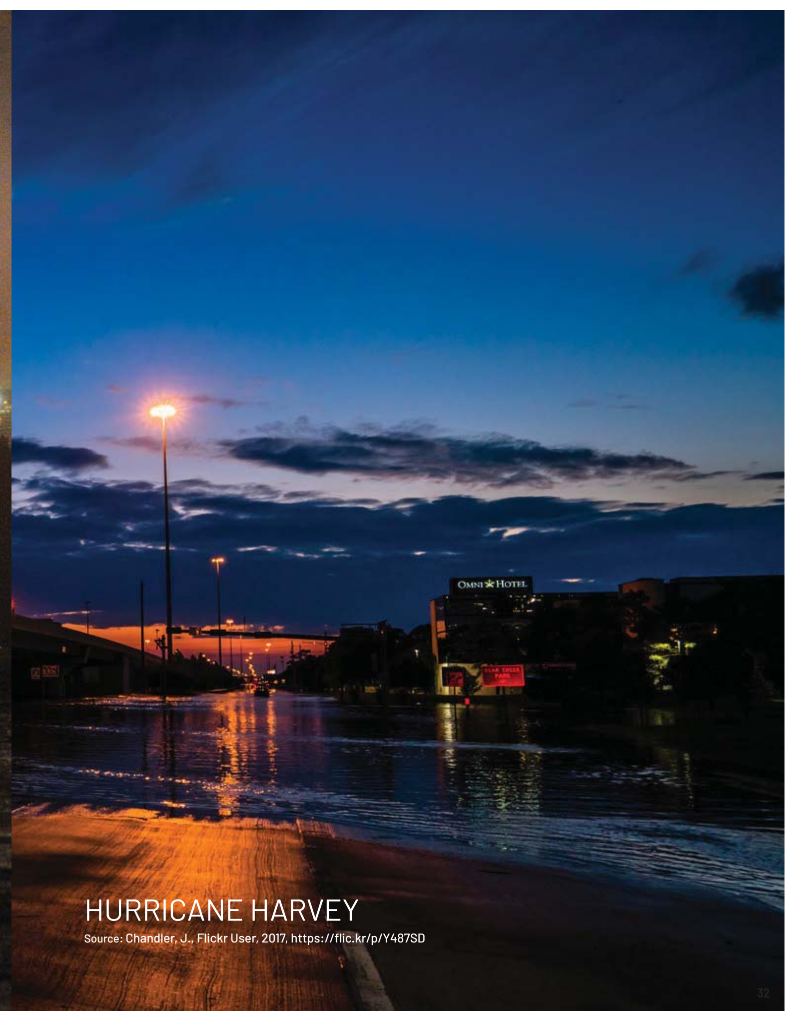


Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

EXTREME EVENTS HAPPEN

SUPERSTORM SANDY

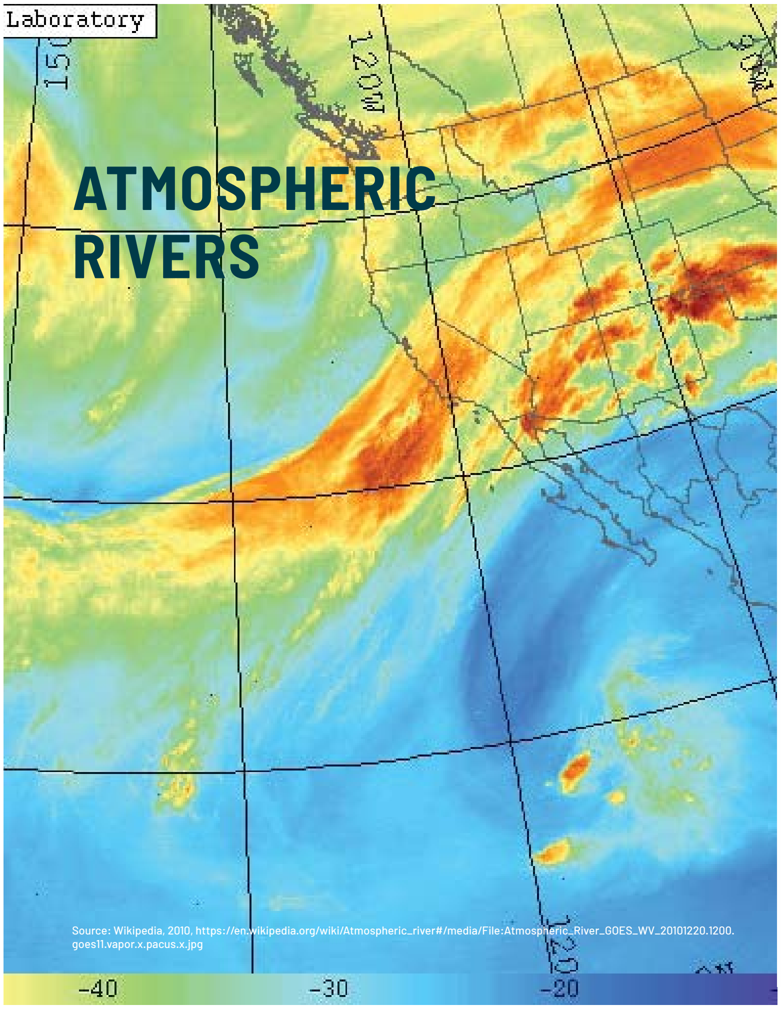
Source: Jolliffe, R., Flickr User, 2012, https://flic.kr/p/dpcGmB



HURRICANE HARVEY

Source: Chandler, J., Flickr User, 2017, https://flic.kr/p/Y487SD

ATMOSPHERIC RIVERS



Source: Wikipedia, 2010, https://en.wikipedia.org/wiki/Atmospheric_river#/media/File:Atmospheric_River_GOES_WV_20101220.1200.goes11.vapor.x.pacus.x.jpg

Los Angeles Times

MONDAY, FEBRUARY 18, 2019

latimes.com

CHILDREN play at the Whittier Narrows Recreation Area. Officials with the U.S. Army Corps of Engineers say that the 60-year-old Whittier Narrows Dam could fail in the event of a very large, very rare storm.

This could leave us all wet

California's 'other big one' — a mega-storm of biblical scope — could swamp cities in the L.A. Basin, experts say

By Louis Sahagun

Scientists call it California's "other big one," and they say it could cause three times as much damage as a major earthquake ripping along the San Andreas fault.

Although it might sound absurd to those who still recall five years of withering drought and mandatory water restrictions, researchers and engineers warn that California may be due for rain of biblical proportions — or what experts call an ARkStorm.

This rare mega-storm — which some say is rendered all the more inevitable because of climate change — would last for weeks and send more than 1.5 million people fleeing as floodwaters inundated cities and formed lakes in the Central Valley and Mojave Desert, according to the U.S. Geological Survey. Officials estimate the structural and economic damage from an ARkStorm (for Atmospheric River 1,000) would amount to more than $725 billion statewide.

In heavily populated areas of the Los Angeles Basin, epic runoff from the San Gabriel Mountains could rapidly overwhelm a flood control dam on the San Gabriel River and unleash floodwaters from Pico Rivera to Long Beach, according to a recent analysis by the U.S. Army Corps of Engineers.

In a series of recent public hearings, corps officials told residents that the 60-year-old Whittier Narrows Dam no longer met the agency's tolerable-risk guidelines and could fail in the event of a very large, very rare storm, such as the one that devastated California more than 150 years ago.

Specifically, federal engi-

[See Mega-storm, A10]

Whittier Narrows Dam

South El Monte

Top of dam's operational pool

San Gabriel spillway

Rio Hondo outlet

Earthen embankment

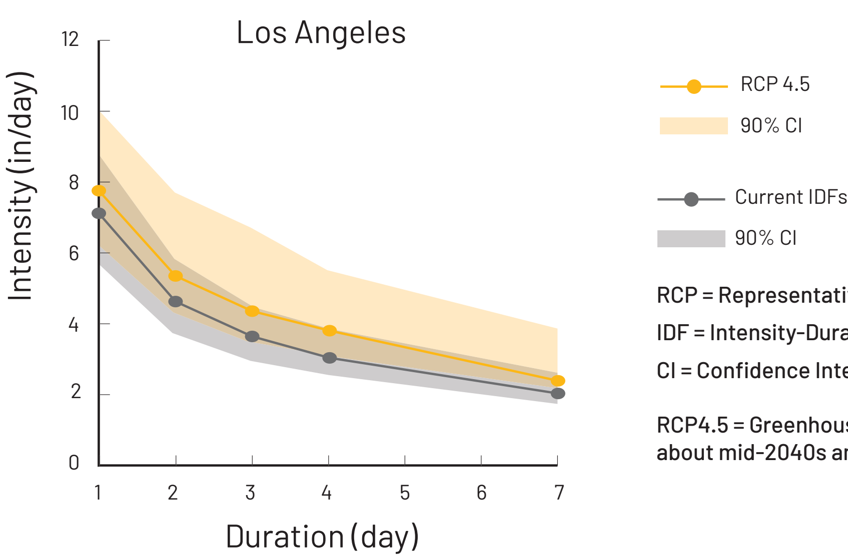
ELECTION 2020

Source: Sahagun, L. LA Times. February 2019, https://www.latimes.com/local/california/la-me-ln-mega-storm-dam-failure-20190218-story.html

HYDROLOGY AND HYDRAULICS

CLIMATE CHANGE

Current rainfall design frequencies may underestimate future climate conditions.



RCP = Representative Concentration Pathways

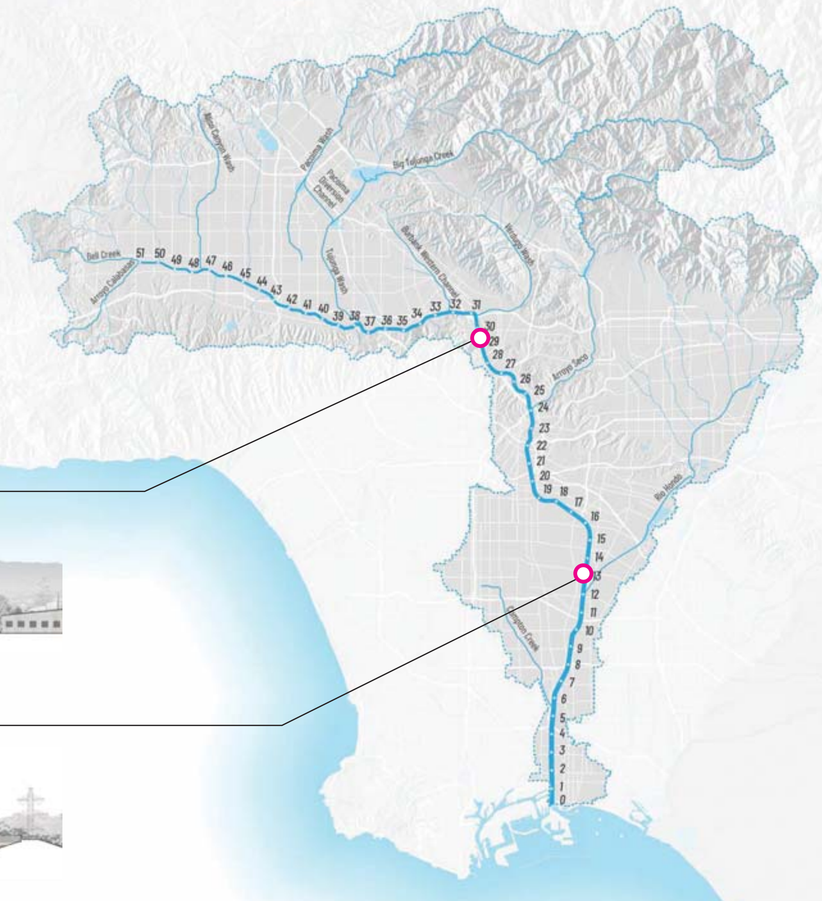
IDF = Intensity-Duration-Frequency

CI = Confidence Interval

RCP4.5 = Greenhouse gas concentrations continue upward until about mid-2040s and then plateau.

Source: Modified from AghaKouchak, Amir, Elisa Ragno, Charlotte Love, and Hamed Moftakhari. (University of California, Irvine). 2018. Projected changes in California's precipitation intensity-duration-frequency curves. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CCCA4-CEC-2018-005, Geosyntec, OLIN

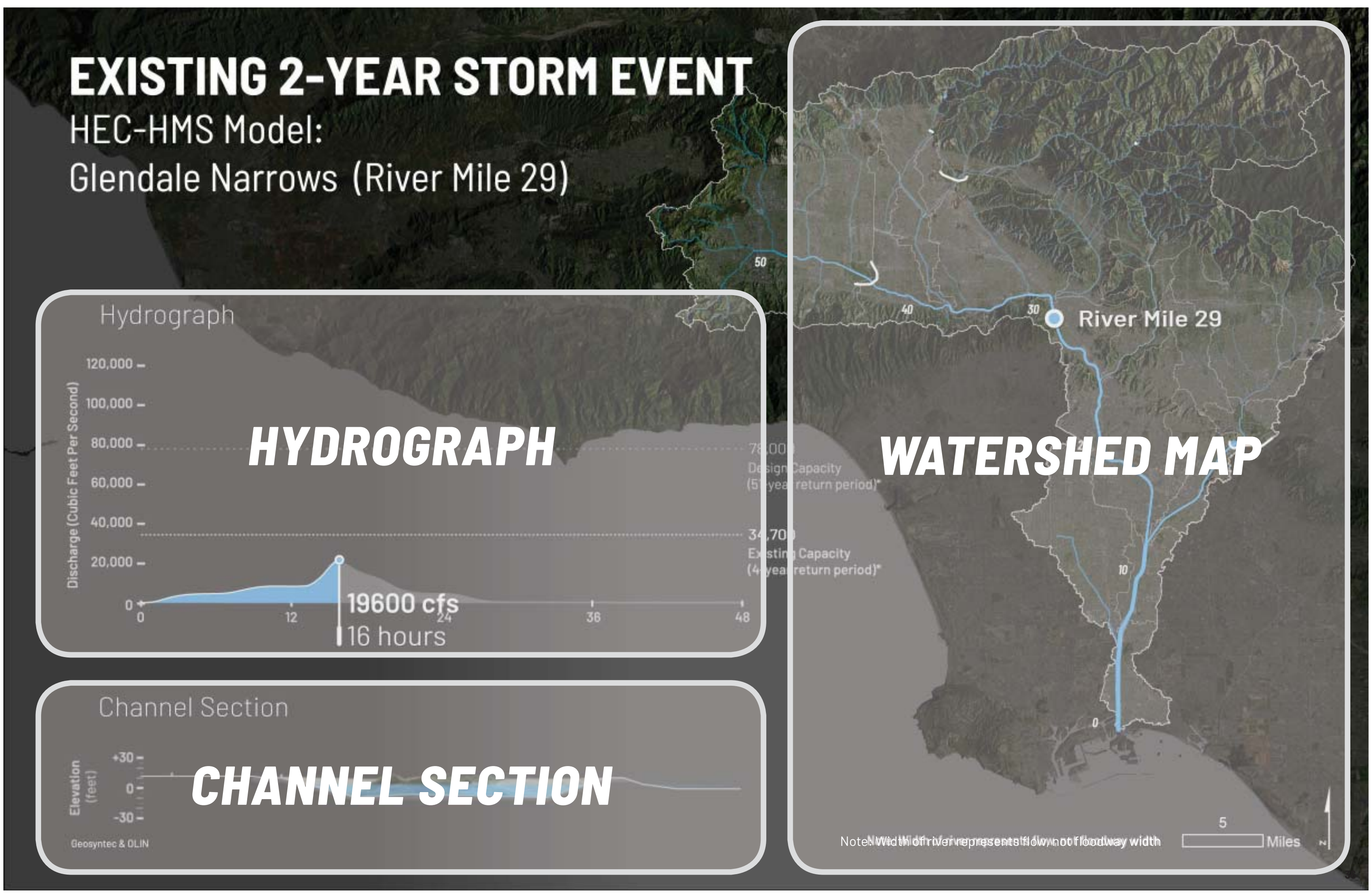
ANALYSIS LOCATIONS

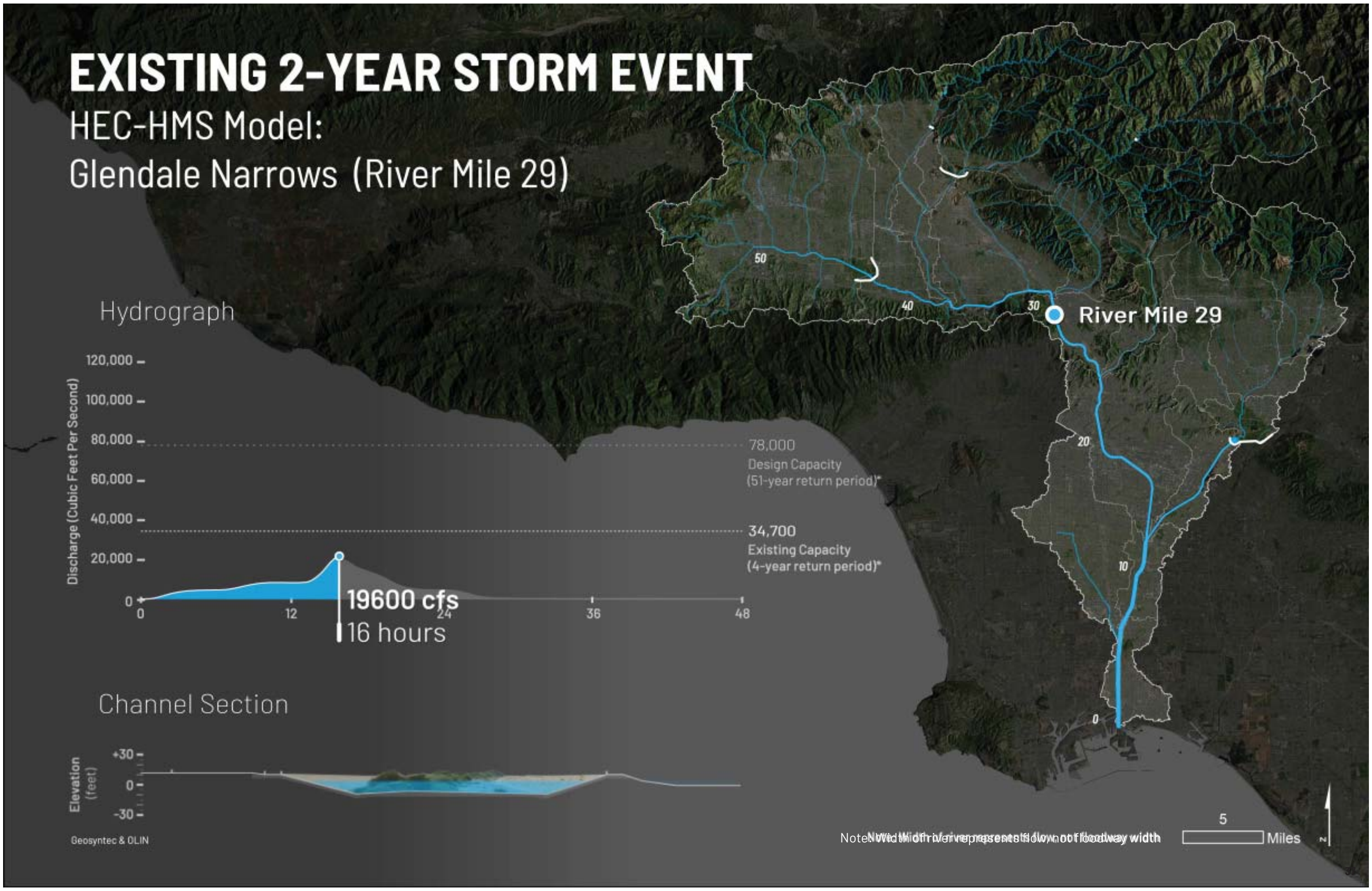


Section at Glendale Narrows (River Mile 29)

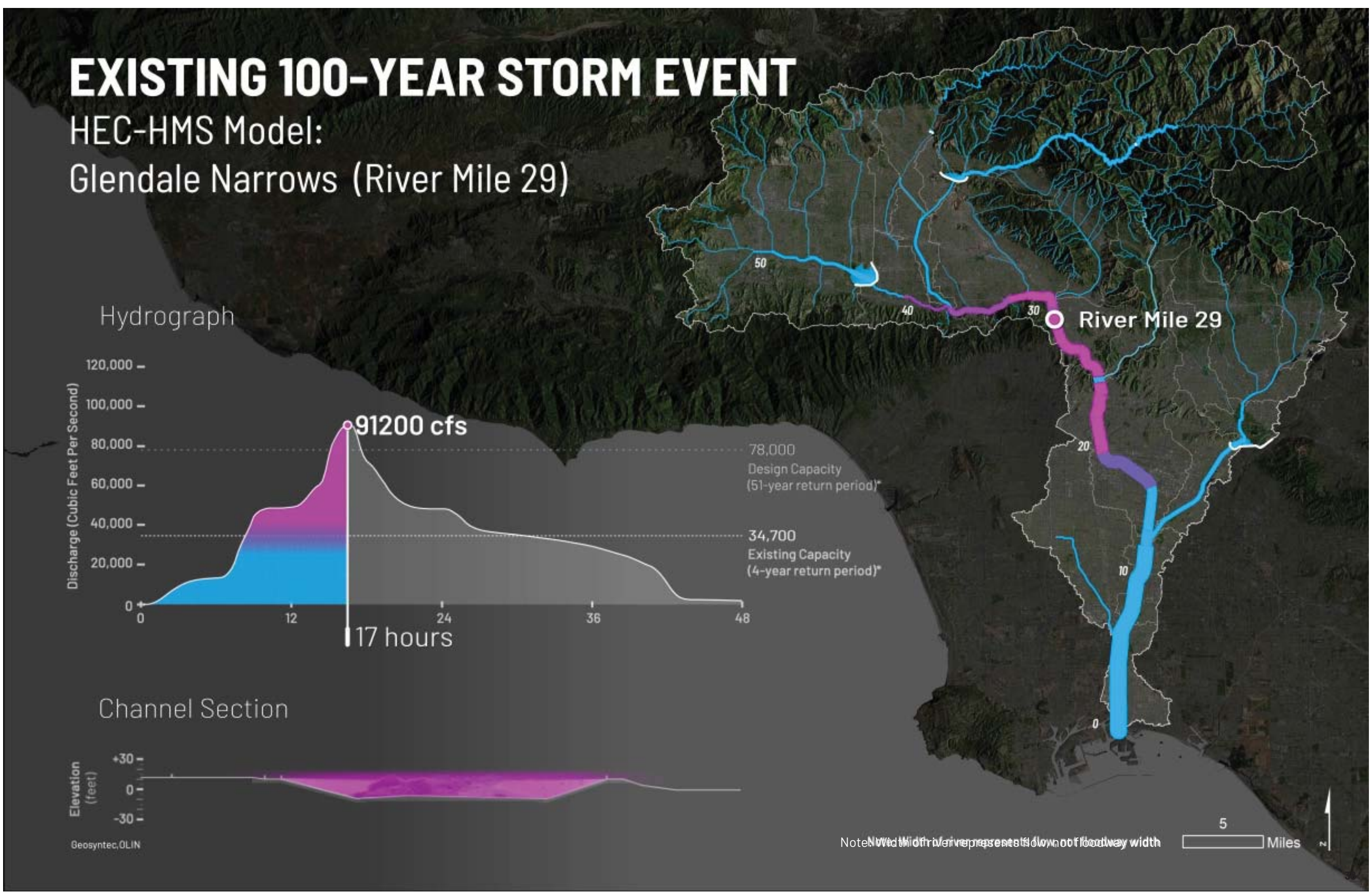
Section at Firestone Blvd (River Mile 13)

Source: Geosyntec, OLIN

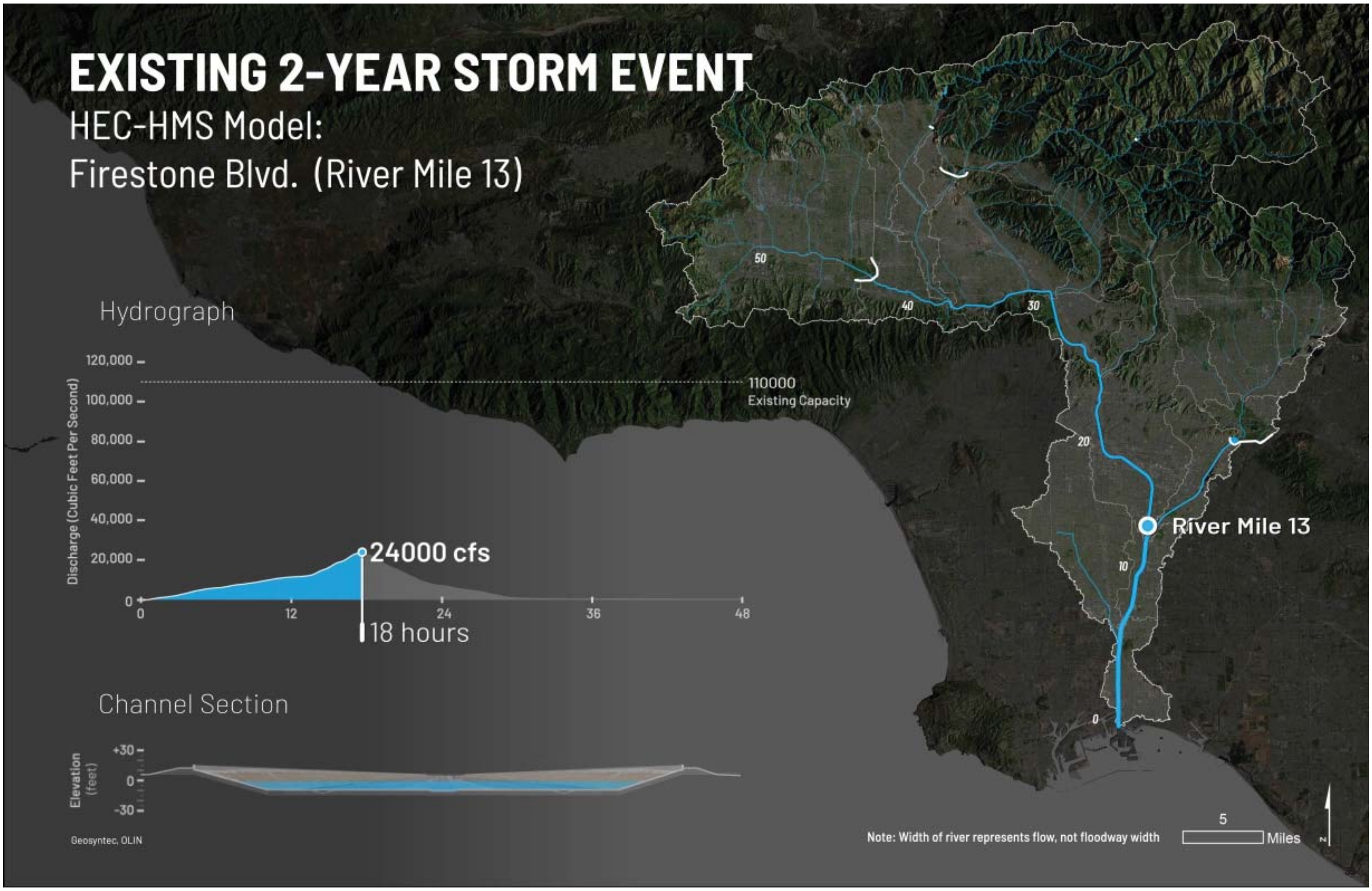


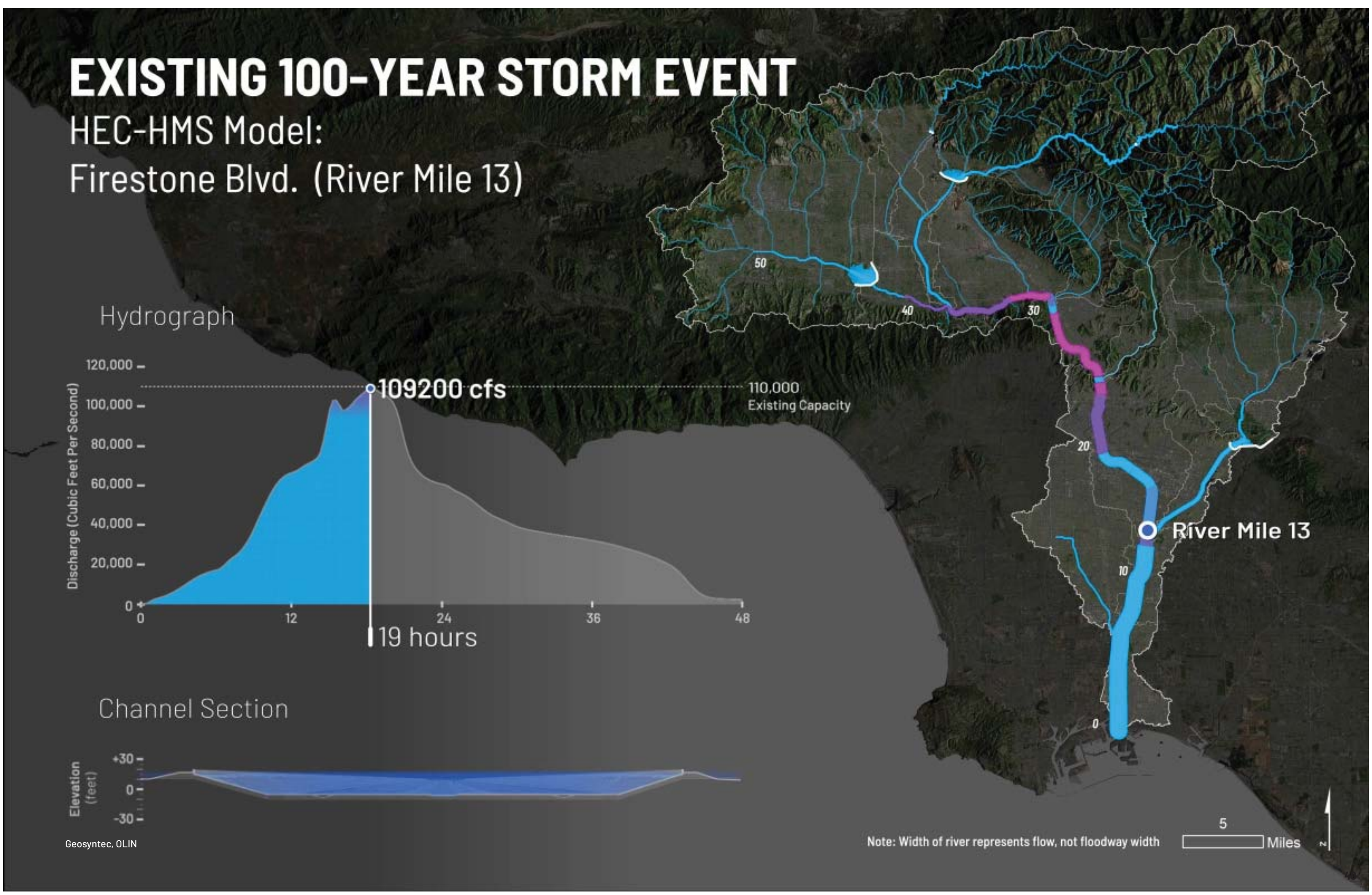


EXISTING 2-YEAR STORM EVENT
HEC-HMS Model:
Glendale Narrows (River Mile 29)
Hydrograph
Discharge (Cubic Feet Per Second)
120,000
100,000
80,000
60,000
40,000
20,000
0
0
12
24
36
48
78,000
Design Capacity
(51-year return period)*
34,700
Existing Capacity
(4-year return period)*
19600 cfs
16 hours
Channel Section
Elevation (feet)
+30
0
-30
Geosyntec & OLIN
50
40
30
20
10
0
River Mile 29
Note: Width of river represents flow, not floodway width
5
Miles



EXISTING 100-YEAR STORM EVENT
HEC-HMS Model:
Glendale Narrows (River Mile 29)
Hydrograph
Discharge (Cubic Feet Per Second)
120,000
100,000
80,000
60,000
40,000
20,000
0
0
12
24
36
48
91200 cfs
78,000
Design Capacity
(51-year return period)*
34,700
Existing Capacity
(4-year return period)*
17 hours
Channel Section
Elevation (feet)
+30
0
-30
Geosyntec, OLIN
50
40
30
20
10
0
River Mile 29
Note: Width of river represents flow, not floodway width
5
Miles


EXISTING 2-YEAR STORM EVENT
HEC-HMS Model:
Firestone Blvd. (River Mile 13)
Hydrograph
Discharge (Cubic Feet Per Second)
120,000
100,000
80,000
60,000
40,000
20,000
0
110000
Existing Capacity
24000 cfs
0
12
24
36
48
18 hours
Channel Section
Elevation (feet)
+30
0
-30
Geosyntec, OLIN
50
40
30
20
10
0
River Mile 13
Note: Width of river represents flow, not floodway width
5
Miles


EXISTING 100-YEAR STORM EVENT
HEC-HMS Model:
Firestone Blvd. (River Mile 13)
Hydrograph
Discharge (Cubic Feet Per Second)
120,000
100,000
80,000
60,000
40,000
20,000
0
109200 cfs
110,000
Existing Capacity
0
12
24
36
48
19 hours
Channel Section
Elevation (feet)
+30
0
-30
Geosyntec, OLIN
50
40
30
20
10
0
River Mile 13
Note: Width of river represents flow, not floodway width
5
Miles


Q & A AND DISCUSSION
Source: USCAE, Los Angeles District, EHyperionAve1928, http://cespl.maps.arcgis.com/apps/MapSeries/index.html?appid=e15694dbf7c54f8c96285a0e74039e69
41


TIMELINE OF THE LA RIVER
Source: Corps of Engineers Los Angeles District, 1895-1915, Farmland and the Los Angeles River , https://commons.wikimedia.org/wiki/File:Farmland_and_the_Los_Angeles_River_looking_north_from_Elysian_Park_toward_Mount_Washington,_1895-1915_(CHS-2209).jpg
42

HOW DID WE GET HERE?

HISTORY OF FLOODING AND FLOODPLAINS

A RECENT STORM

CURRENT PROTECTION AND FLOOD RISK

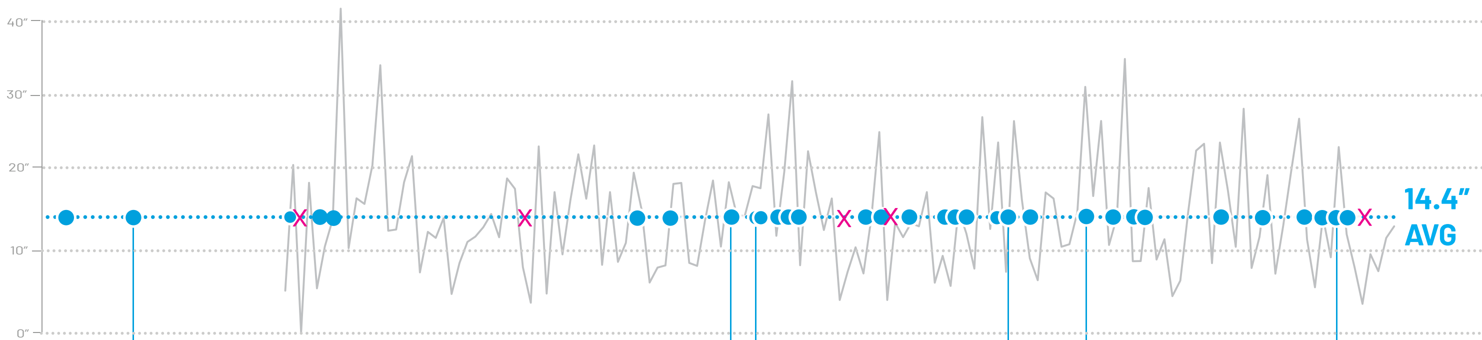
HISTORICAL FLOODING AND RIVER PATHS

Areas Subject to Inundation
Historical River Paths

Source: Based on Blake Gumprecht, "The Los Angeles River: Its Life, Death, and Possible Rebirth.", 2001, California State University, Northridge Environmental Geography Lab, Historical Ecology, 2008, Geosyntec, OLIN

HISTORICAL RAINFALL EVENTS

— Annual average rainfall (Downtown City of Los Angeles)
● Major storm and flooding events
X Major droughts



1862
Noachian Deluge of California:
- 30 consecutive days of rain
- **35" in LA City**
- **LA River mouth shifts from Venice to Wilmington**

1934
Major Storm:
- **7.36" in LA in 24 hours**
- 45 deaths regionally

1938
Los Angeles Basin Flood:
- 10" rain
- **115 deaths**
- **5,601 homes lost**
- **$70 million damage**

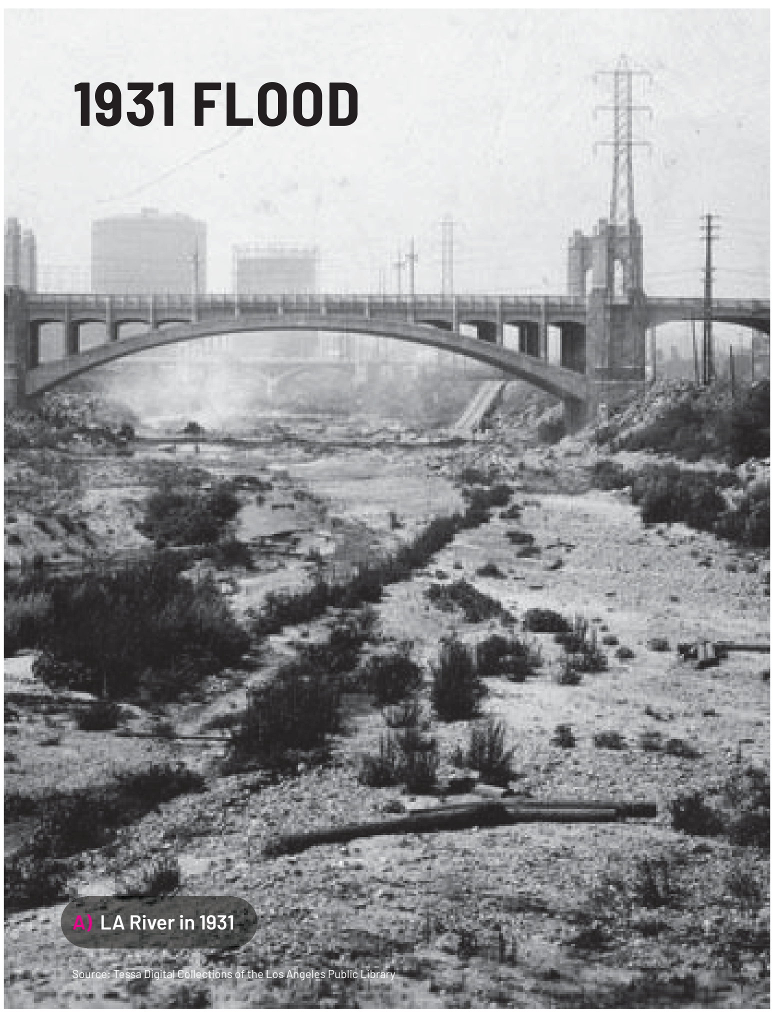
1969
Heavy Rains:
- **13.4" in 10 days**
- 87 deaths in California

1980
6 Storms:
- **12.75" in 9 days**
- 30 deaths regionally

2010
El Nino fuels winter storms:
- downed trees and powerlines
- mud and debris flows prompted evacuation

Source: Western Regional Climate Center, Cooperative Climatological Data Summaries, 2018 & County of Los Angeles Chief Executive Office's Office of Emergency Management, History of Floods, Mudslides, Debris Flows, Landslides in Los Angeles County Operational Area, 2012, https://ceo.lacounty.gov/wp-content/uploads/OEM/HazardsandThreats/Landslides/HAZARDS%20AND%20THREAT%20FLOODS%20-%20MUDSLIDES%20-%20LANDSLIDES%20HISTORY.pdf, Geosyntec, OLIN

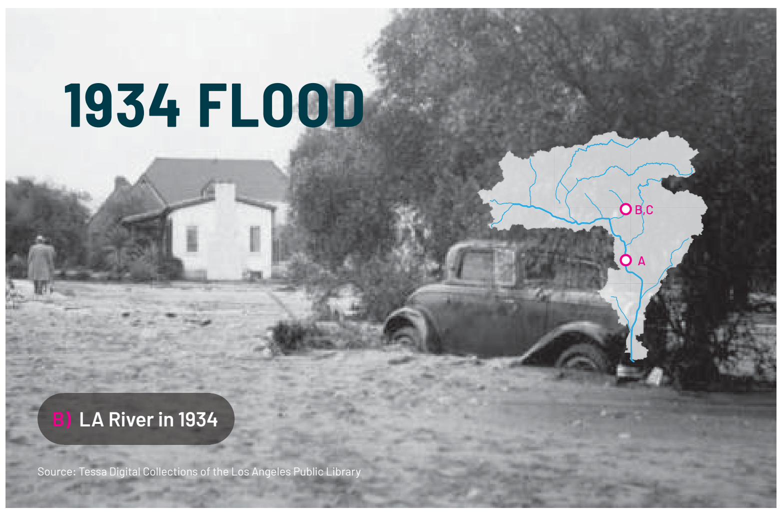
1931 FLOOD



A) LA River in 1931

Source: Tessa Digital Collections of the Los Angeles Public Library

1934 FLOOD



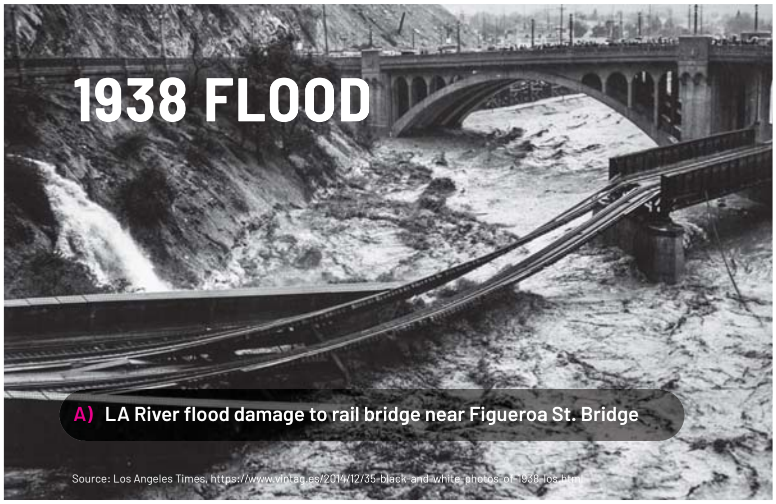
B) LA River in 1934

Source: Tessa Digital Collections of the Los Angeles Public Library

C) LA River in 1934

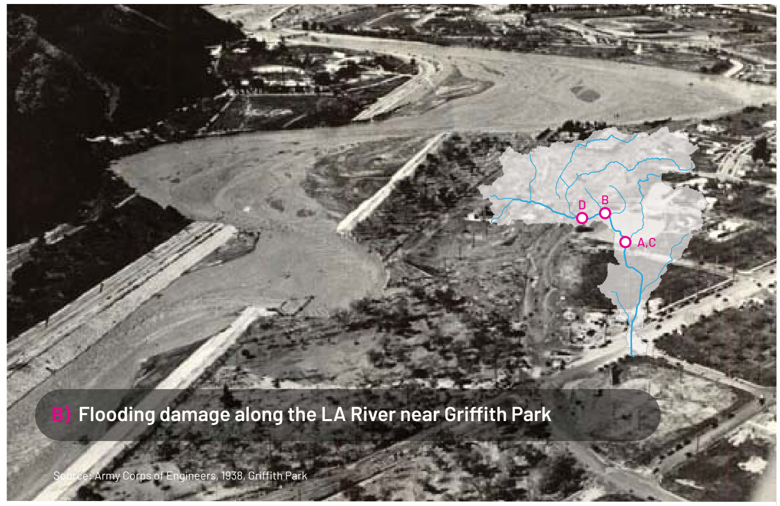
Source: Tessa Digital Collections of the Los Angeles Public Library

1938 FLOOD



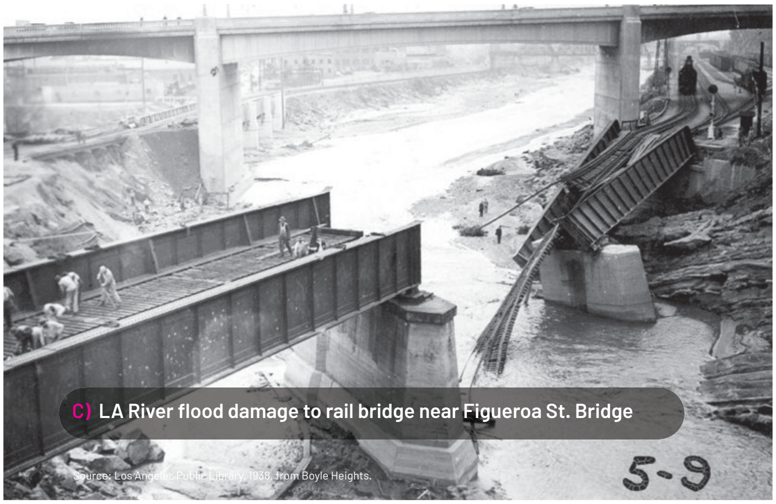
A) LA River flood damage to rail bridge near Figueroa St. Bridge

Source: Los Angeles Times, https://www.vintag.es/2014/12/35-black-and-white-photos-of-1938-los.html



B) Flooding damage along the LA River near Griffith Park

Source: Army Corps of Engineers, 1938, Griffith Park



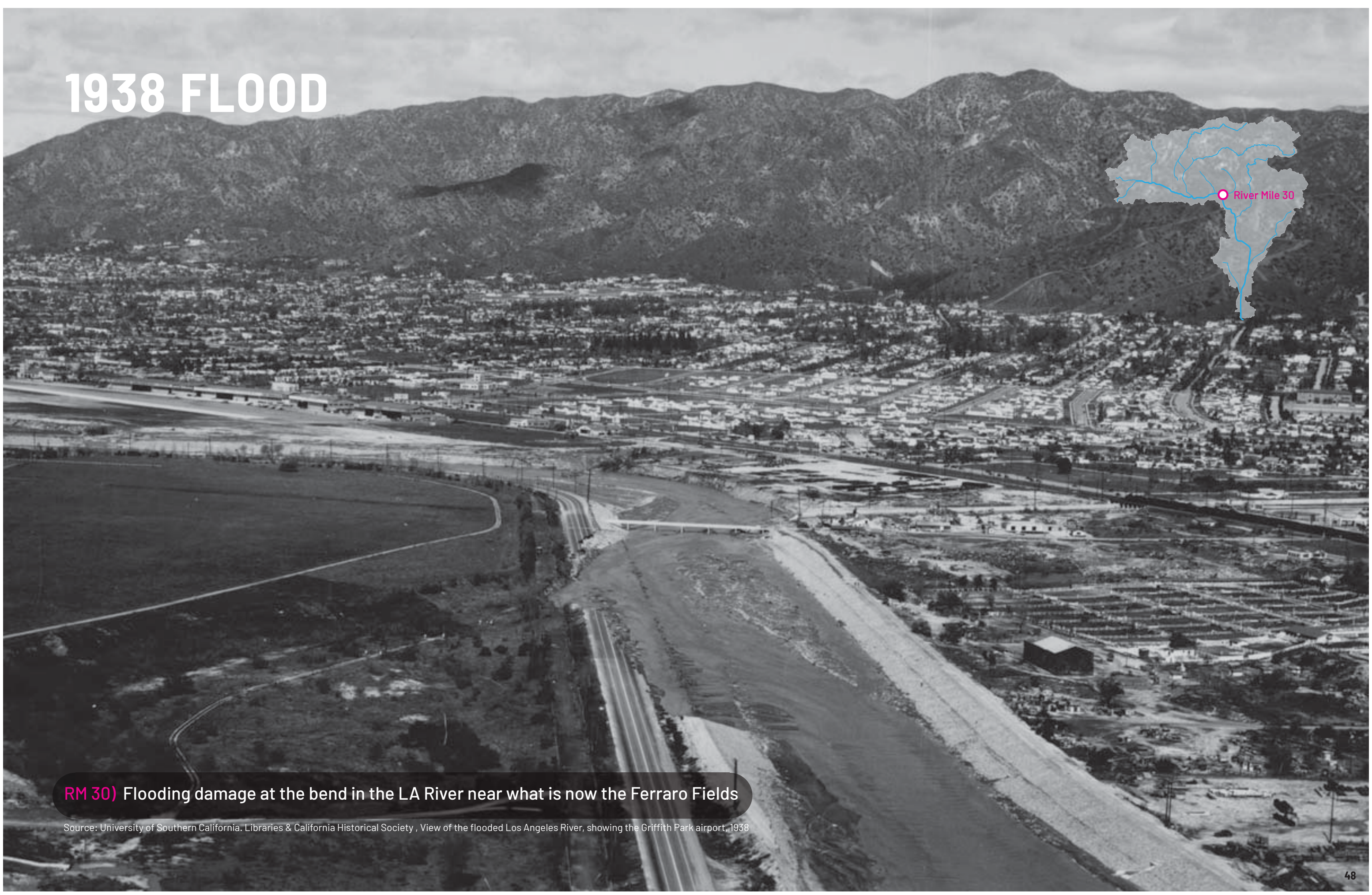
C) LA River flood damage to rail bridge near Figueroa St. Bridge

Source: Los Angeles Public Library, 1938, from Boyle Heights.

D) Colfax Avenue bridge damage along the LA River

Source: Los Angeles Times, https://www.vintag.es/2014/12/35-black-and-white-photos-of-1938-los.html

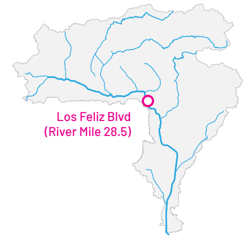
1938 FLOOD

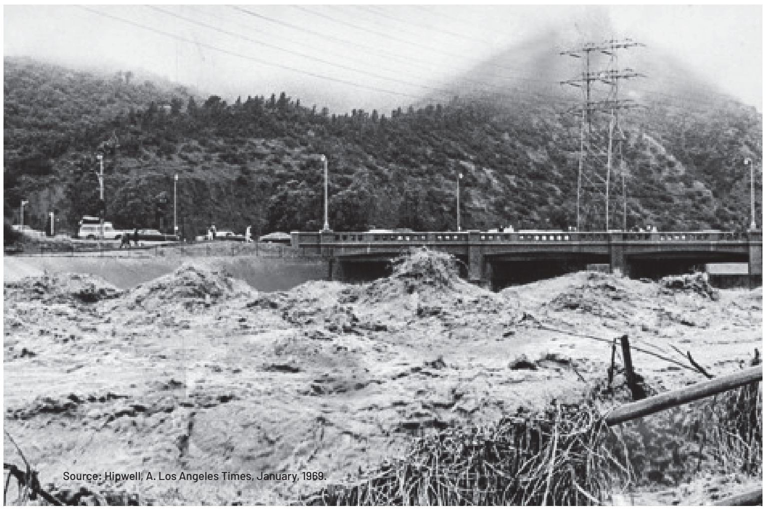


RM 30) Flooding damage at the bend in the LA River near what is now the Ferraro Fields

Source: University of Southern California. Libraries & California Historical Society , View of the flooded Los Angeles River, showing the Griffith Park airport, 1938

1969 FLOOD



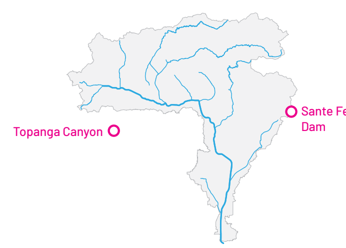

Source: Hipwell, A. Los Angeles Times, January, 1969.

LA River at Los Feliz Boulevard


Source: Tessa Digital Collections of the Los Angeles Public Library, 1969

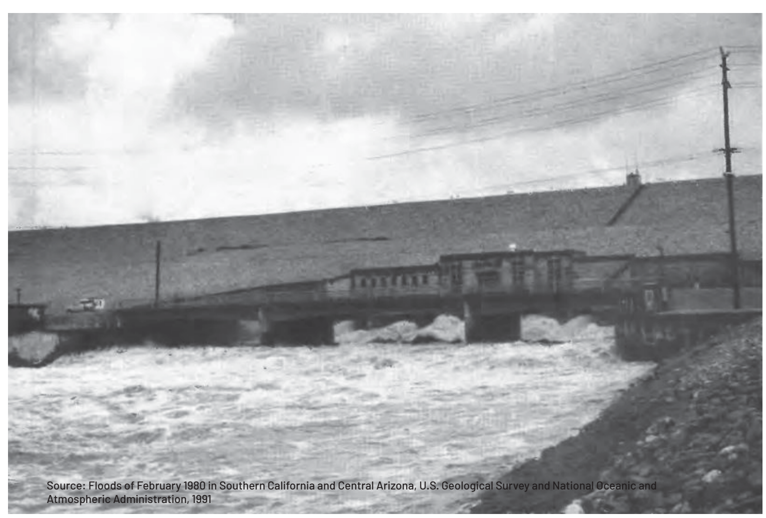
LA River bridge damage (location unknown)

1980 FLOOD




Source: Floods of February 1980 in Southern California and Central Arizona, U.S. Geological Survey and National Oceanic and Atmospheric Administration, 1991

House along Topanga Canyon, Santa Monica Mountains


Source: Floods of February 1980 in Southern California and Central Arizona, U.S. Geological Survey and National Oceanic and Atmospheric Administration, 1991

San Gabriel River below the Sante Fe Dam

IMPROVEMENTS AFTER THE 1980 FLOOD

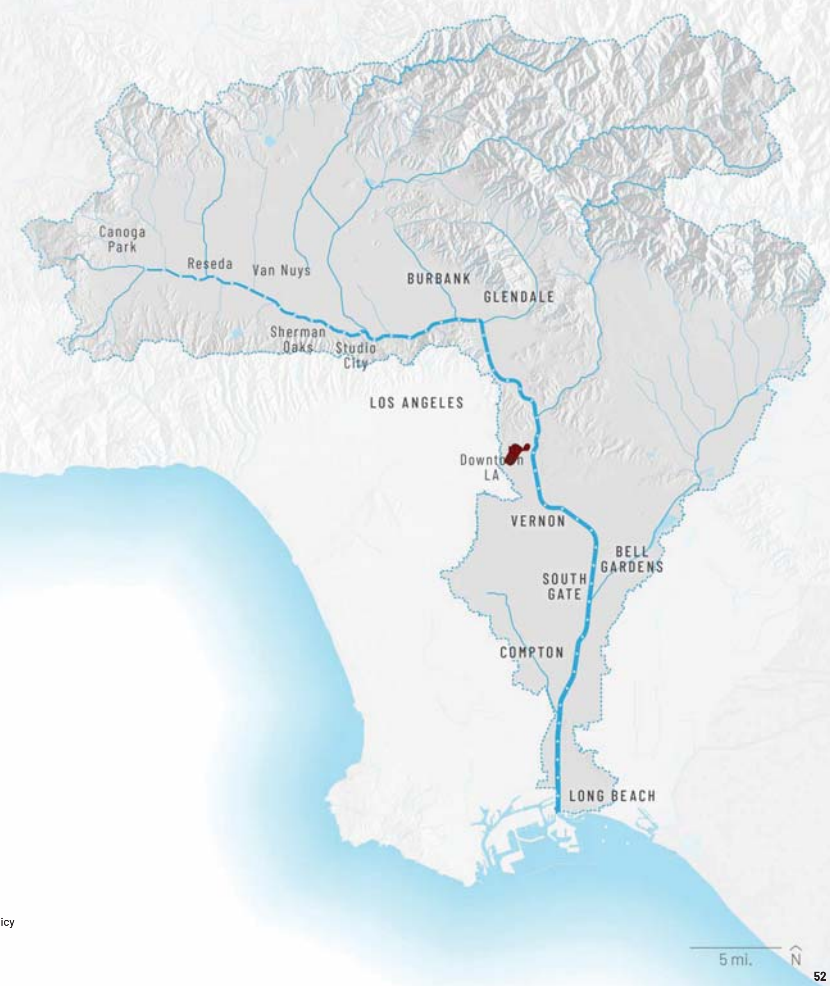
Source: OLIN

HYDROLOGY AND HYDRAULICS

1877 URBAN FOOTPRINT

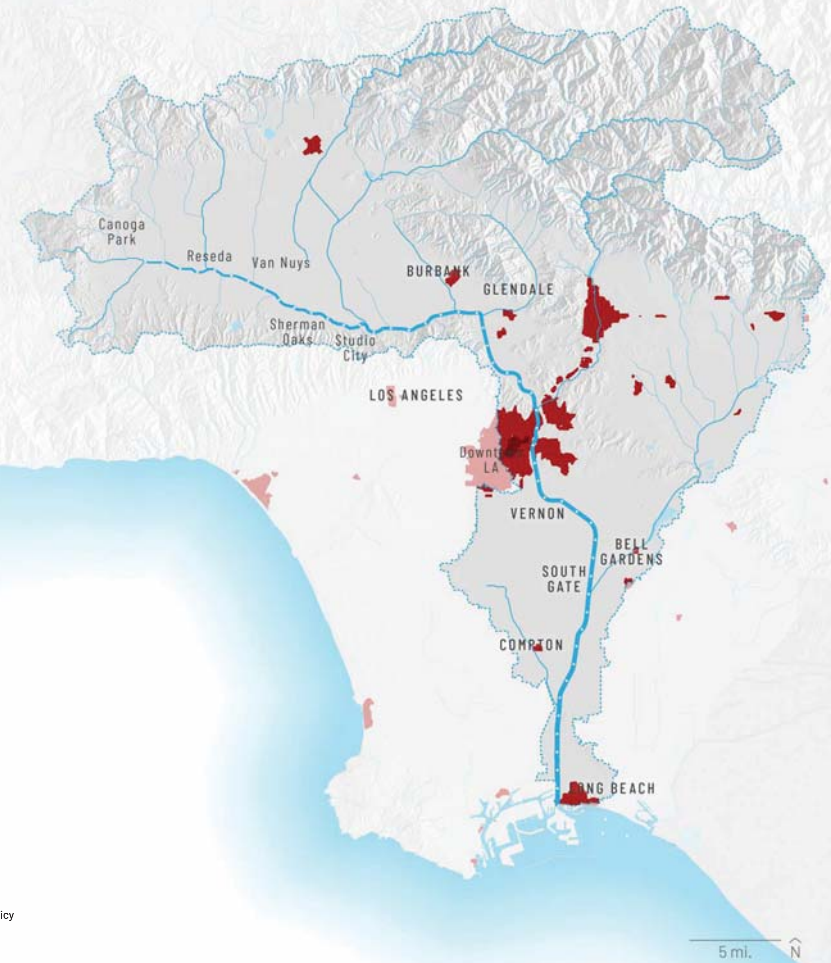
Historical Urban Footprint

1877



Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1907 URBAN FOOTPRINT

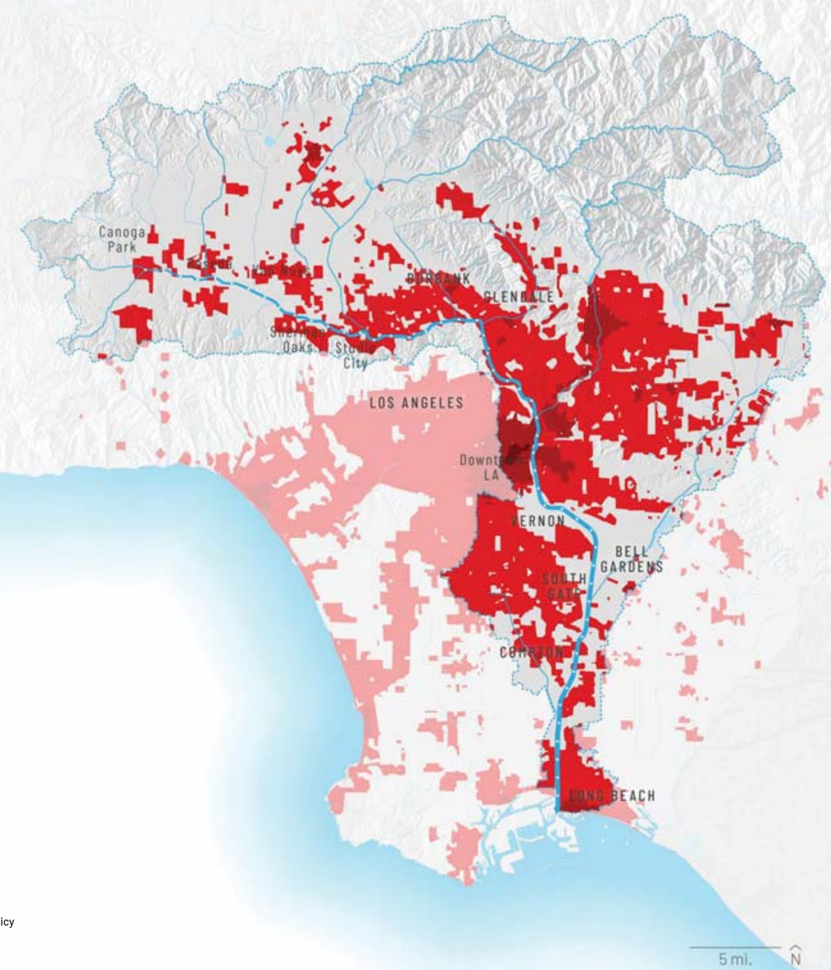


Historical Urban Footprint

- 1877
- 1907

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1937 URBAN FOOTPRINT

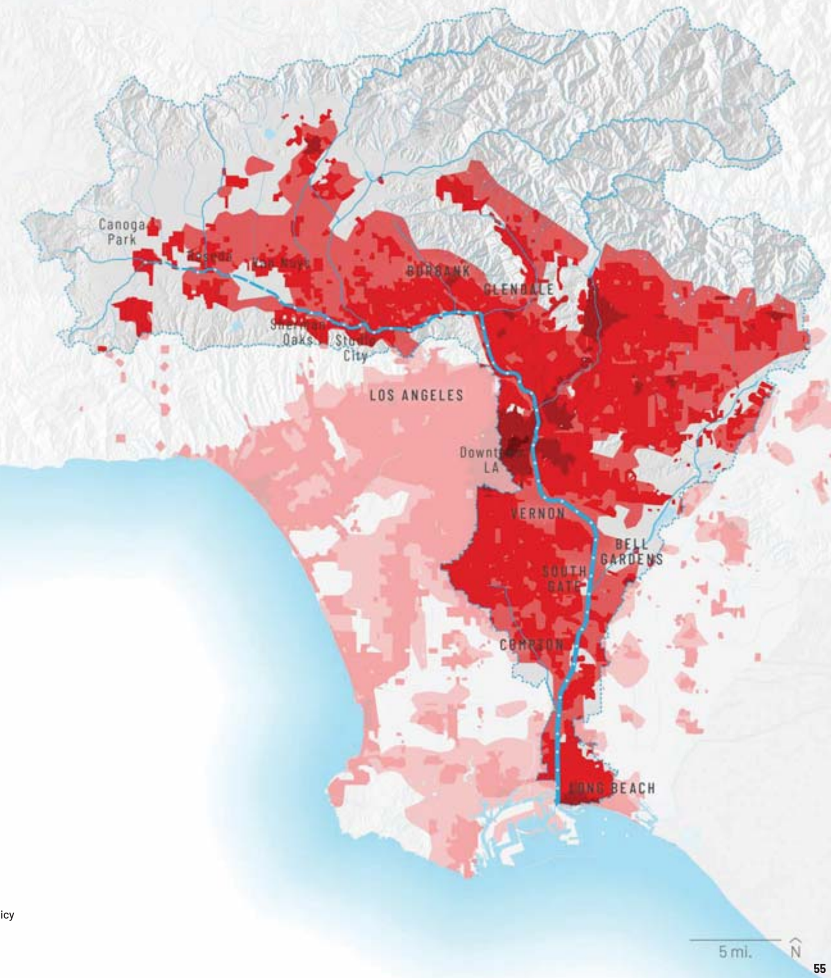


Historical Urban Footprint

- 1877
- 1907
- 1937

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1950 URBAN FOOTPRINT

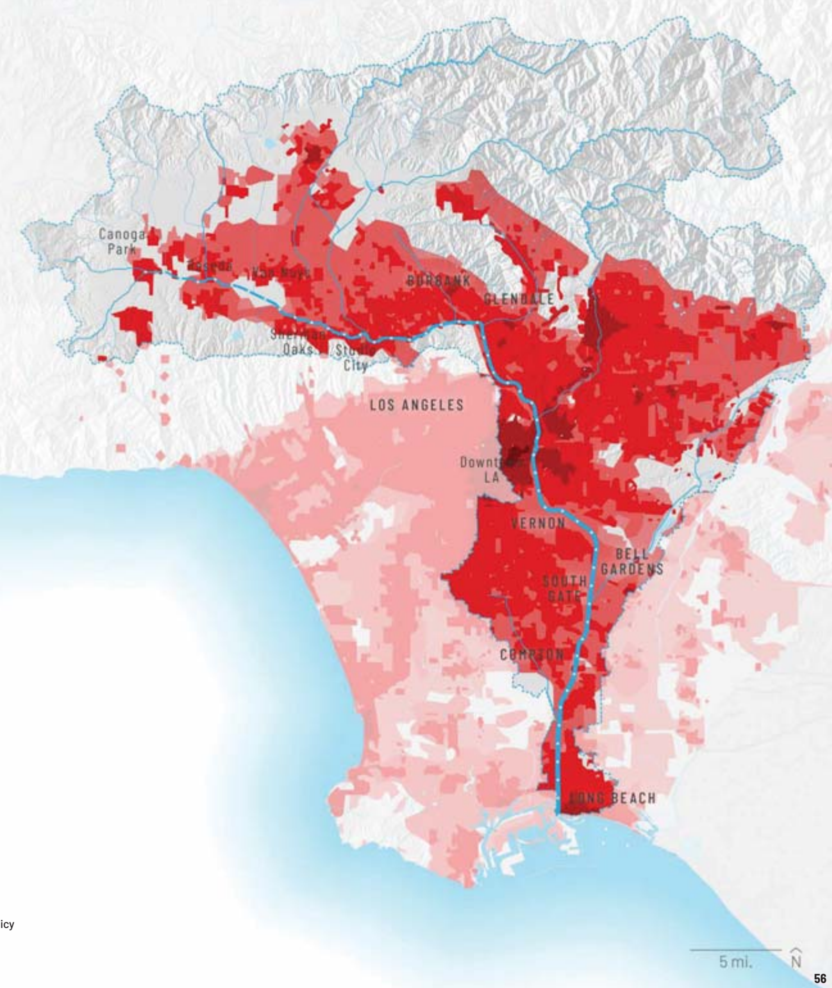


Historical Urban Footprint

- 1877
- 1907
- 1937
- 1950

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1970 URBAN FOOTPRINT

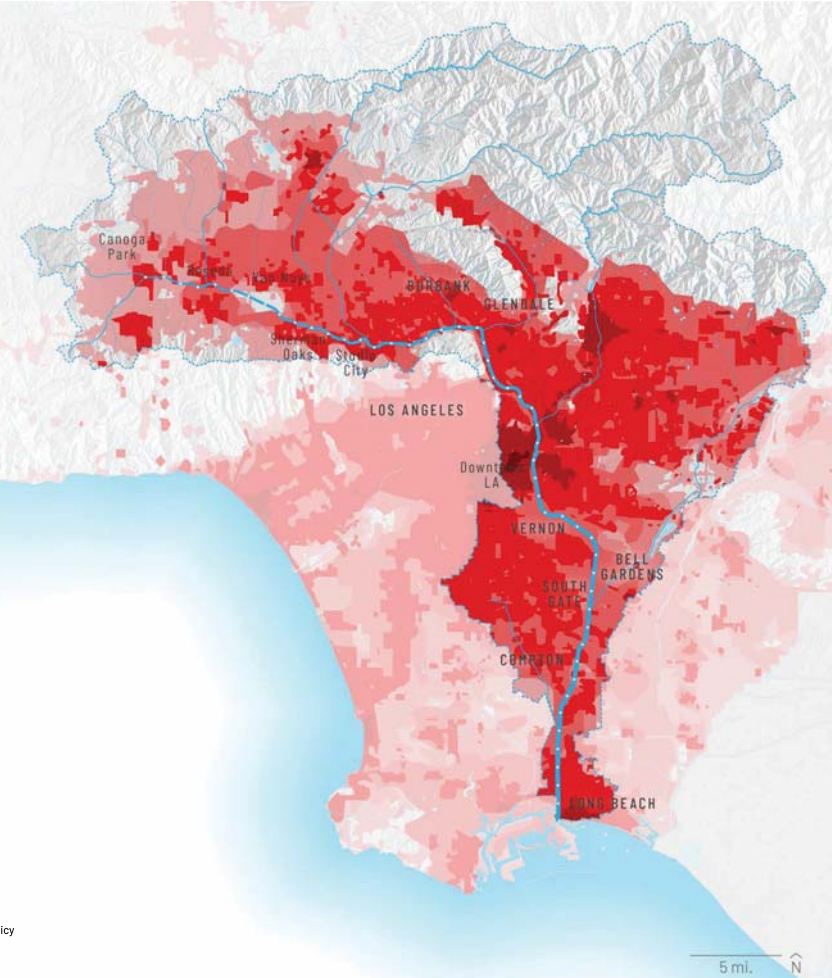


Historical Urban Footprint

- 1877
- 1907
- 1937
- 1950
- 1970

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

2010 URBAN FOOTPRINT

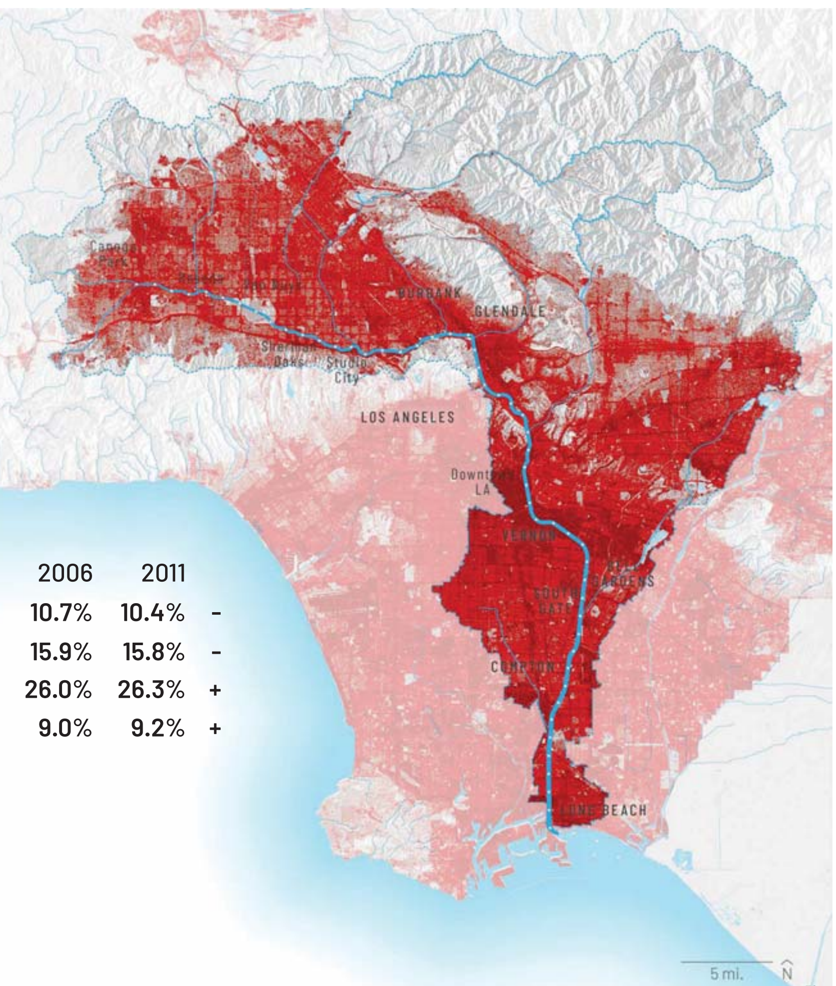


Historical Urban Footprint

- 1877
- 1907
- 1937
- 1950
- 1970
- 2010

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

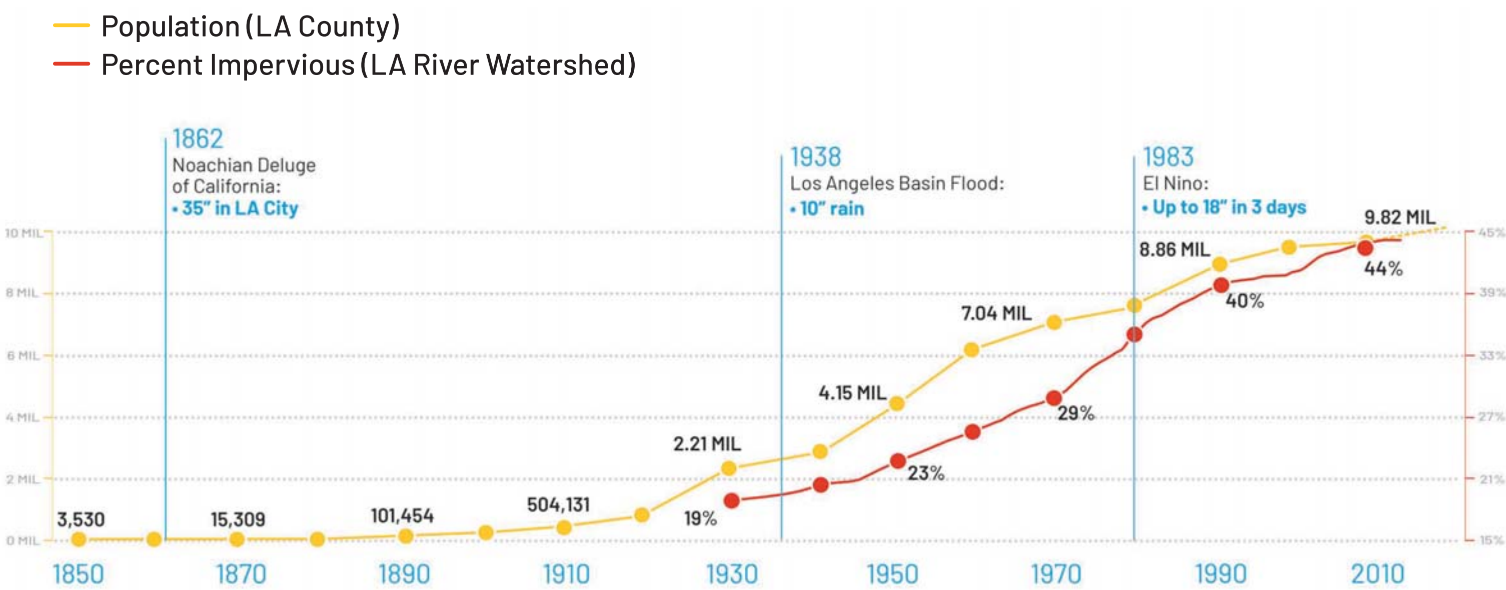
NEARLY ALL OF THE LA RIVER CORRIDOR IS DEVELOPED



Developed Land Cover of the LA River Watershed	2001	2006	2011	
Developed, Open Space	11.1%	10.7%	10.4%	-
Developed, Low Intensity	16.3%	15.9%	15.8%	-
Developed, Medium Intensity	25.4%	26.0%	26.3%	+
Developed, High Intensity	8.6%	9.0%	9.2%	+

Source: National Land Cover Database 2011

LA COUNTY POPULATION AND DEVELOPMENT



Source: Cheyenne Cummings, "Analysis and Implications of Impervious Surface Change Due to Urbanization in the Los Angeles River" (master's thesis, California State University Dominguez Hills, 2016). "Historical General Population City & County of Los Angeles", *Los Angeles Almanac*, 1850-2010, http://www.laalmanac.com/population/po02.php

HOW DID WE GET HERE?

HISTORY OF FLOODING AND FLOODPLAINS

A RECENT STORM

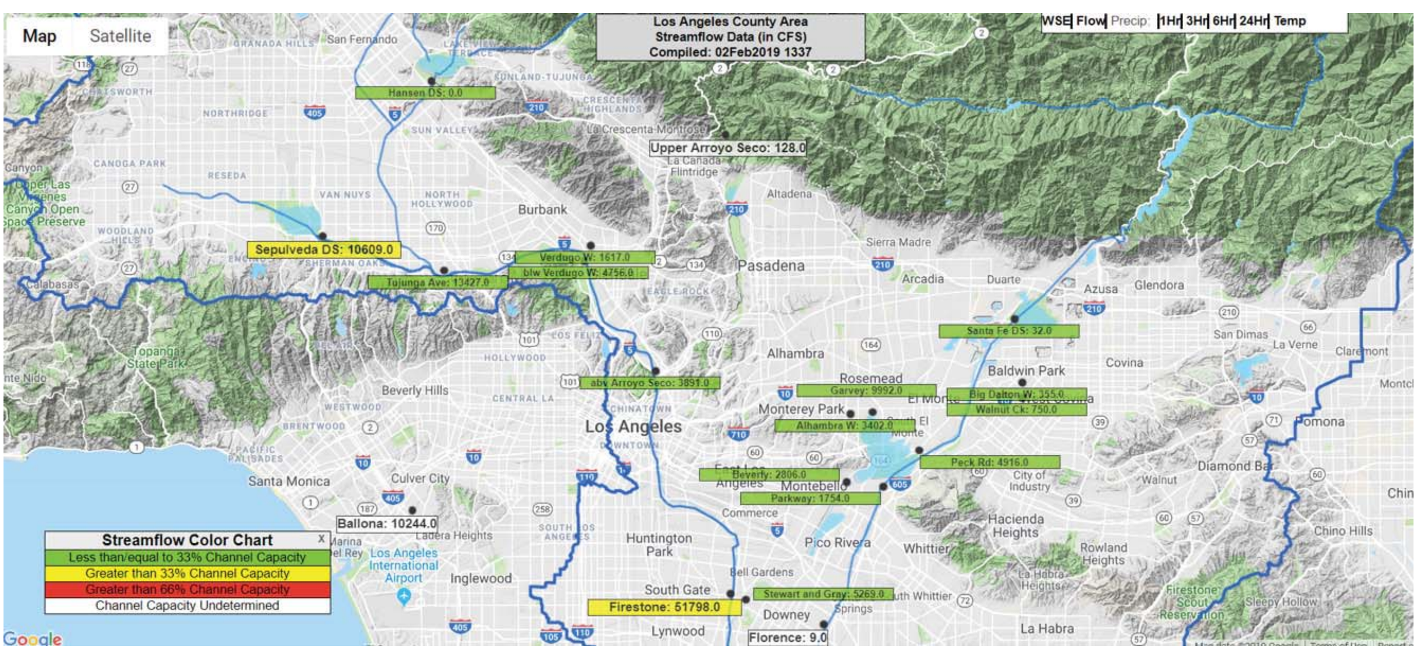
CURRENT PROTECTION AND FLOOD RISK

CONTEXT - RECENT STORM (FEB 2, 2019)

ABC News 7, Rain Swollen Los Angeles River Roars in Glendale:
https://abc7.com/weather/video-rain-swollen-los-angeles-river-roars-in-glendale/5118212/

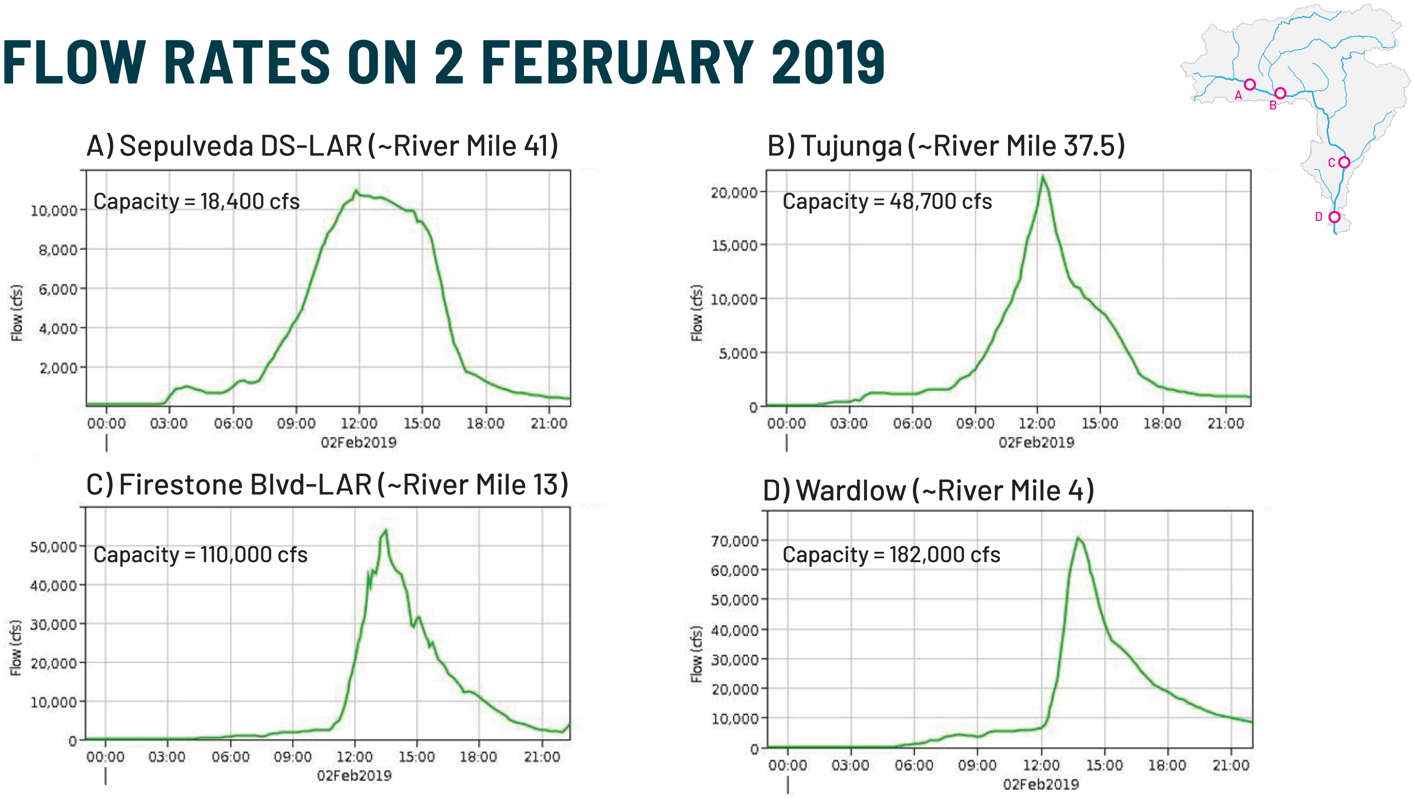
HYDROLOGY AND HYDRAULICS

FLOW RATES ON 2 FEBRUARY 2019, 1:37 PM



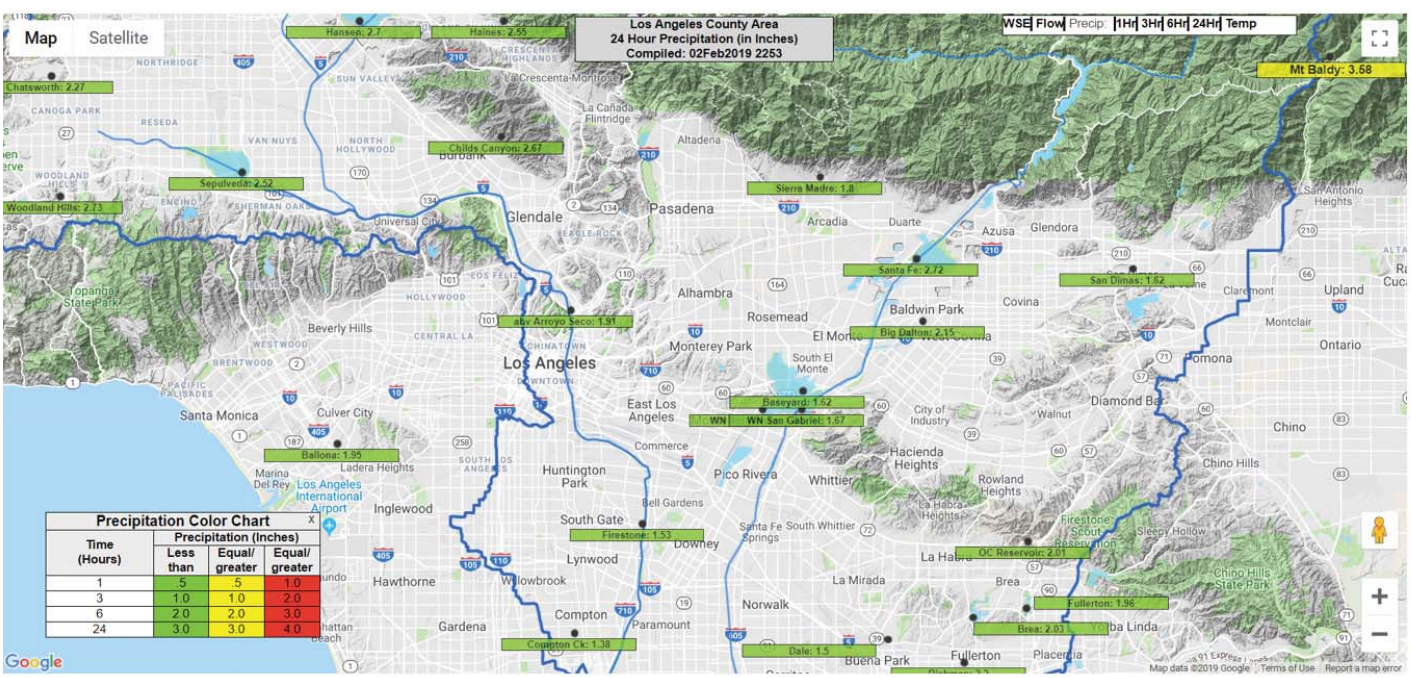
Source: Los Angeles County Area Streamflow Data, Accessed Feb 2, 2019, http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF

FLOW RATES ON 2 FEBRUARY 2019



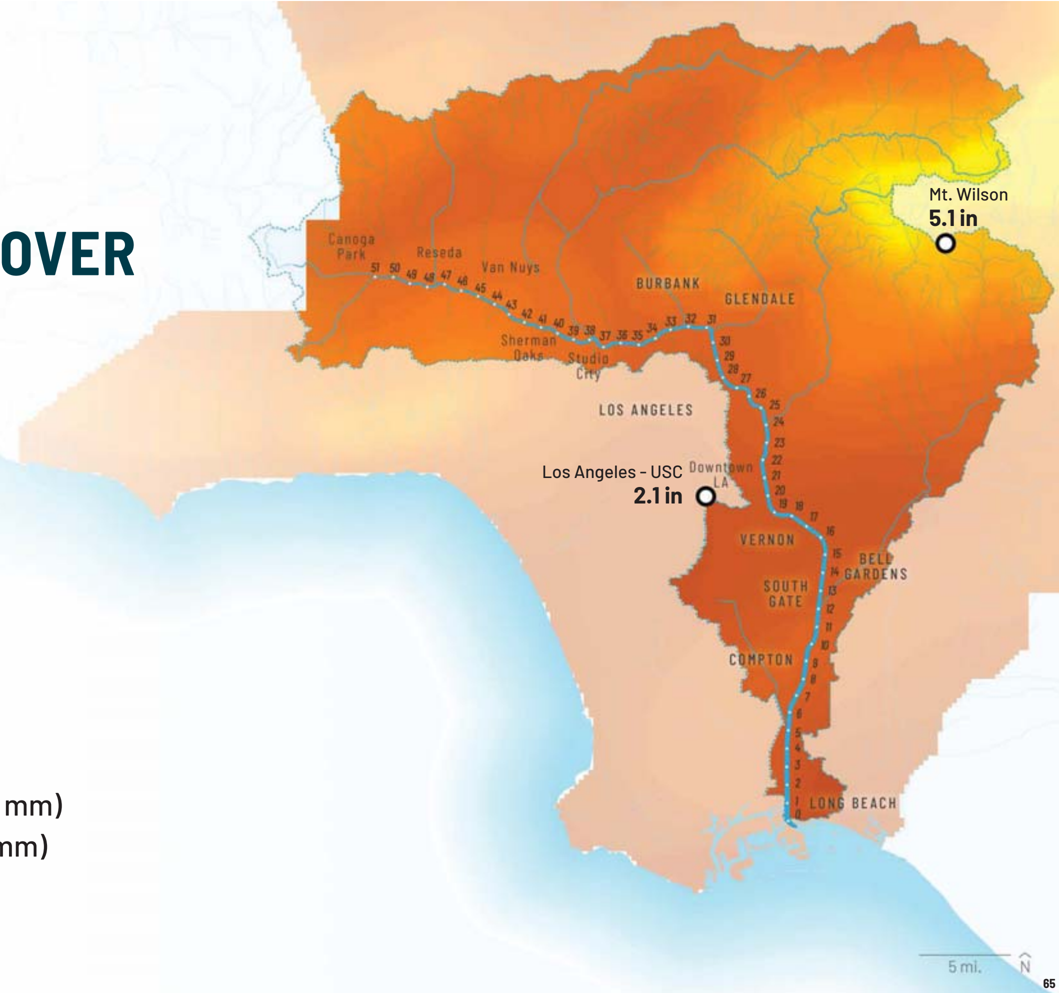
Source: Los Angeles County Area Streamflow Data, Accessed Feb 2, 2019, http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF, Geosyntec, OLIN

HOW MUCH RAIN FELL?



Source: Los Angeles County Area Streamflow Data, Accessed Feb 2, 2019, http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF

2-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

Max Rainfall (6.25 in /159 mm)

Min Rainfall (1.00 in / 25 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HOW DID WE GET HERE?

HISTORY OF FLOODING AND FLOODPLAINS

A RECENT STORM

CURRENT PROTECTION AND FLOOD RISK

CURRENT PROTECTION LEVEL

Level of Protection (interpolated)[1]
- < 10 yr
- < 50 yr
- < 100 yr
- > 100 yr

Level of Protection (point data)[2,3]
- < 10 yr
- < 50 yr
- < 100 yr
- > 100 yr

Footnotes:
1. Level of channel protection within ARBOR Study reaches from U.S. Army Corps of Engineers (USACE): Los Angeles District. 2015. Los Angeles River Ecosystem Restoration Integrated Feasibility Report, Final Feasibility Report and Environmental Impact Statement/Environmental Impact Report, Appendix E. Table 17: Original Design Discharge and Existing Channel Capacity.
2. Level of channel protection from downstream of Sepulveda to upstream of ARBOR Study reaches and downstream of ARBOR Study reaches to Rio Hondo confluence interpolated from point locations within USACE: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part I Hydrology Technical Report: Base Conditions. Plate 4: Levels of Protection Base Conditions.
3. Level of channel protection from Rio Hondo confluence to Pacific Ocean interpolated from point locations within USACE: Los Angeles District. 1999. Los Angeles River Improvement Projects Including Rio Hondo and Compton Creek. Final Design Memorandum No. 3 & No 5. Table A-2: Revised Maximum Deliverable Discharge and USACE: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part II Hydrology Report, Project Alternatives. Plate 11: NED Plan Levels of Protection.

Source: Geosyntec, OLIN

Q & A AND DISCUSSION

Source: OLIN

IDEAS TO...

REDUCE FLOWS INTO THE CHANNEL

INCREASE CHANNEL CAPACITY

TOOLS AND ANALYSES

Source: OLIN

HYDROLOGY & HYDRAULICS MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
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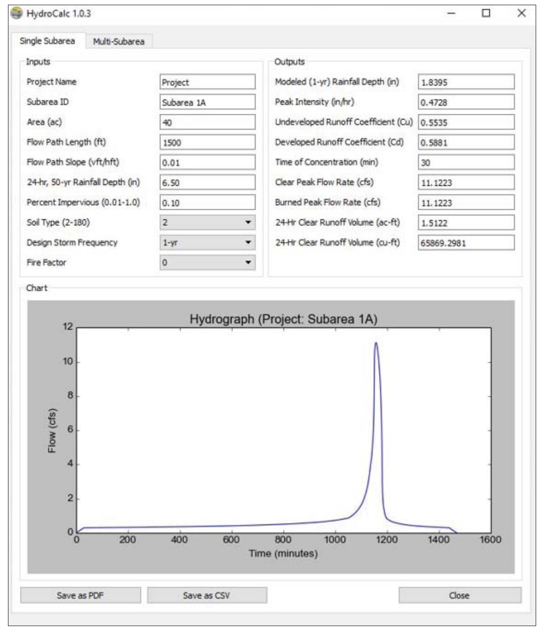
DEVELOPER	LA County Public Works	LA County Public Works	US Army Corps of Engineers	Robert Manning	US Army Corps of Engineers
DATE	2018	2013	2018	1889	2018
PURPOSE	Modified Rational Method for local scale flood and drainage analyses	Designed for water quality best management practice	Designed explicitly for flood risk management	Uniform and steady-state analysis of channels	Varying and unsteady analysis of channels and floodplains
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

HYDROCALC

- Developed by LA County Public Works
- Modified Rational Method
- Local scale flood analyses
- Drainage anaylses
- Easy to use interface



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

HYDROCALC

H&H MODELING TOOLS

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	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
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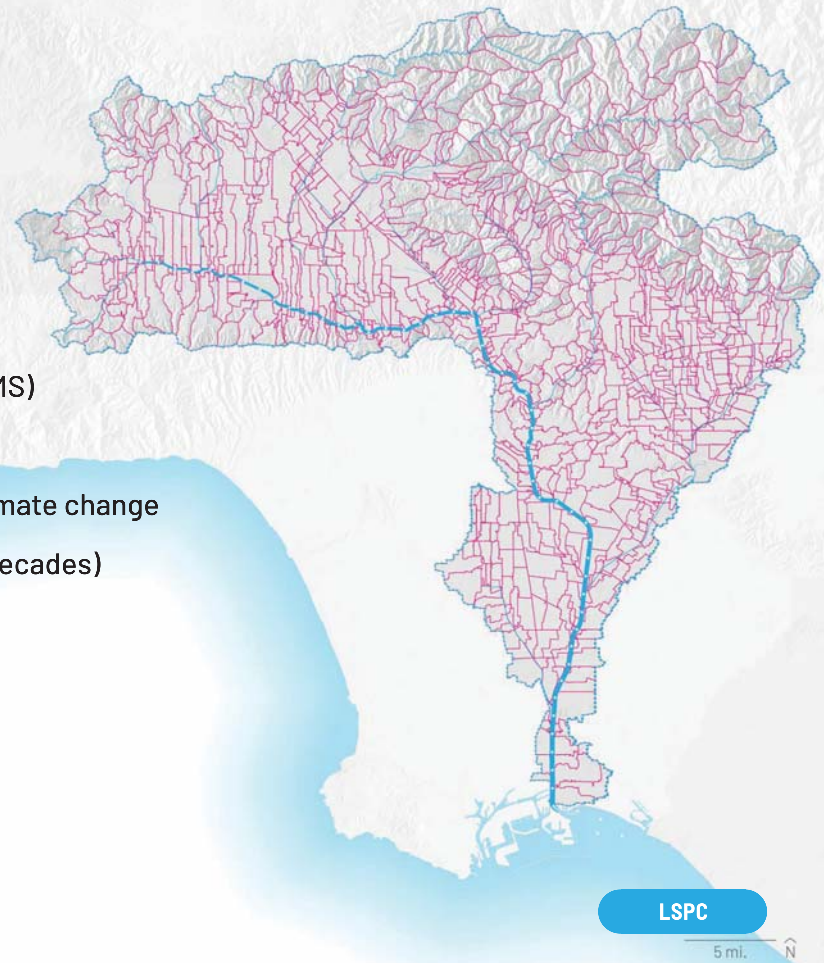
HYDROCALC | LSPC | HEC-HMS | MANNING'S | HEC-RAS

LOADING SIMULATION PROGRAM IN C++ (LSPC)

- Developed by LA County Public Works as part of Watershed Management Modeling System (WMMS)
- Primarily for water quality
- Modified to assess supply benefits including climate change
- Evaluates long-term time-series (i.e., years to decades)



Source: LA County Public Works

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
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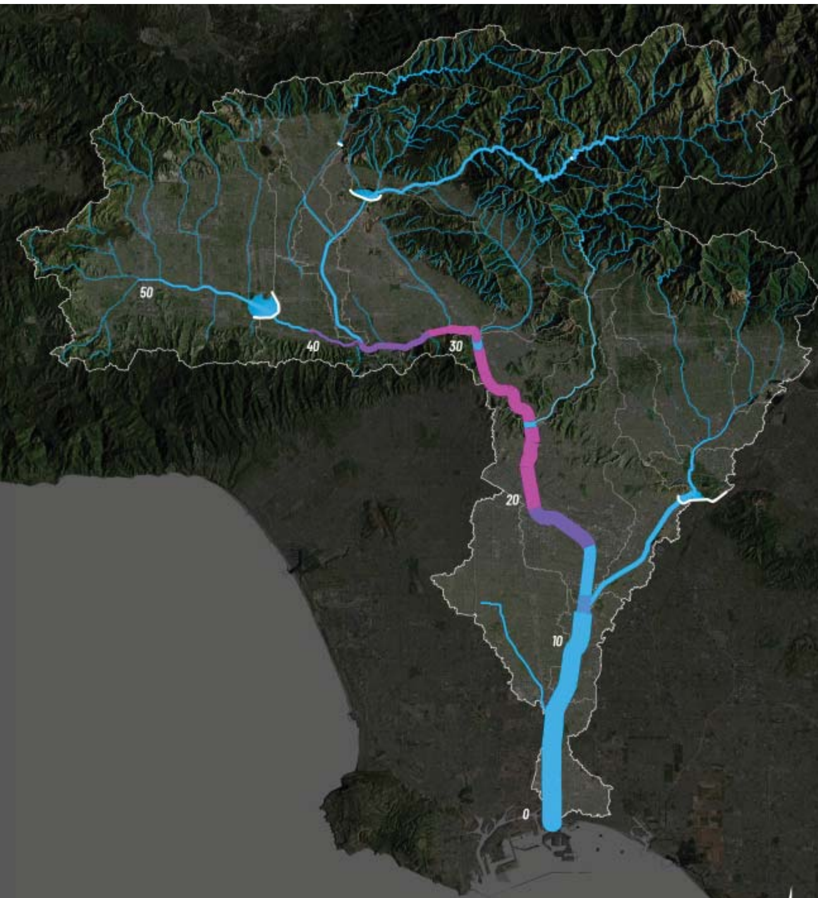
HYDROCALC LSPC HEC-HMS MANNING'S HEC-RAS

HYDROLOGY AND HYDRAULICS

HEC-HMS

Precipitation runoff simulation

- Event based precipitation events
  (e.g., 2-year, 100-year, ...)
- Infiltration
- Surface runoff
- Routing through drains and channels
- Flood control basins



U.S. Army Corps of Engineers, Los Angeles District. Los Angeles County Drainage Area (LACDA): Hydrologic Analysis. 2010. Figure 5: LACDA - HEC-HMS Model Schematic.

HEC-HMS

HYDROLOGY AND HYDRAULICS

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
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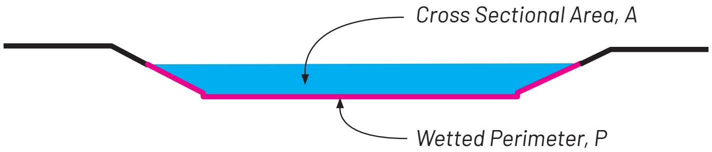
MANNING'S EQUATION

Empirically derived in 1889

$$Q = \frac{K\,A\,R^{2/3}\,S^{1/2}}{n}$$

Q = flow rate
A = cross-sectional area of flow
P = wetted perimeter
R = hydraulic radius = A/P
S = slope of the channel at the point of measurement
n = surface roughness (based upon channel material and condition)
K = constant dependent upon units



- Online Calculator: http://onlinecalc.sdsu.edu/onlinechannel01.php

Dense Vegetation

n = 0.06

Well-maintained Vegetation

n = 0.03

Concrete

n = 0.016

Source: Geosyntec, OLIN

MANNING'S

MANNING'S EQUATION

Empirically derived in 1889

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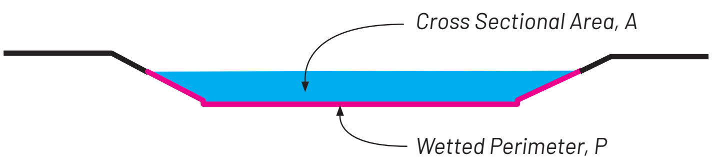

- Online Calculator: http://onlinecalc.sdsu.edu/onlinechannel01.php

Manning's n for Channels (Chow, 1959)

Type of Channel and Description	Minimum	Normal	Maximum
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.020
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.030
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth, winding, and sluggish			
1. no vegetation	0.023	0.025	0.030
2. grass, some weeds	0.025	0.030	0.033
3. dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. earth bottom and rubble sides	0.028	0.030	0.035
5. stony bottom and weedy banks	0.025	0.035	0.040
6. cobble bottom and clean sides	0.030	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.050	0.080	0.120
2. clean bottom, brush on sides	0.040	0.050	0.080
3. same as above, highest stage of flow	0.045	0.070	0.110
4. dense brush, high stage	0.080	0.100	0.140
5. Lined or Constructed Channels			
c. Concrete			
1. trowel finish	0.011	0.013	0.015
2. float finish	0.013	0.015	0.016
3. finished, with gravel on bottom	0.015	0.017	0.020
d. Concrete bottom float finish with sides of:			
1. dressed stone in mortar	0.015	0.017	0.020
2. random stone in mortar	0.017	0.020	0.024
3. cement rubble masonry, plastered	0.016	0.020	0.024
4. cement rubble masonry	0.020	0.025	0.030
5. dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of:			
1. formed concrete	0.017	0.020	0.025
2. random stone mortar	0.020	0.023	0.026

Source: Geosyntec, OLIN

MANNING'S

MANNING'S EQUATION

Does not account for upstream/downstream effects or hydraulic structures (e.g., bridges)

$$Q = \frac{K\,A\,R^{2/3}\,S^{1/2}}{n}$$

Variable		Dense Vegetation	Well-maintained Grasses	Concrete
constant	K	1.49 ft $^{1/3}$/s	1.49 ft $^{1/3}$/s	1.49 ft $^{1/3}$/s
cross-sectional area of flow	A	4,000 ft^2	4,000 ft^2	4,000 ft^2
hydraulic radius	R	15	15	15
slope of the channel	S	0.005	0.005	0.005
surface roughness	n	0.06	0.03	0.016
flow rate	Q	43,000 cfs	85,000 cfs	160,000 cfs

Source: Geosyntec, OLIN

MANNING'S

H&H MODELING TOOLS

	HYDROLOGY			*HYDRAULICS*	
	UNIT HYDROLOGY	*LARGER WATERSHED*		*CHANNELS*	
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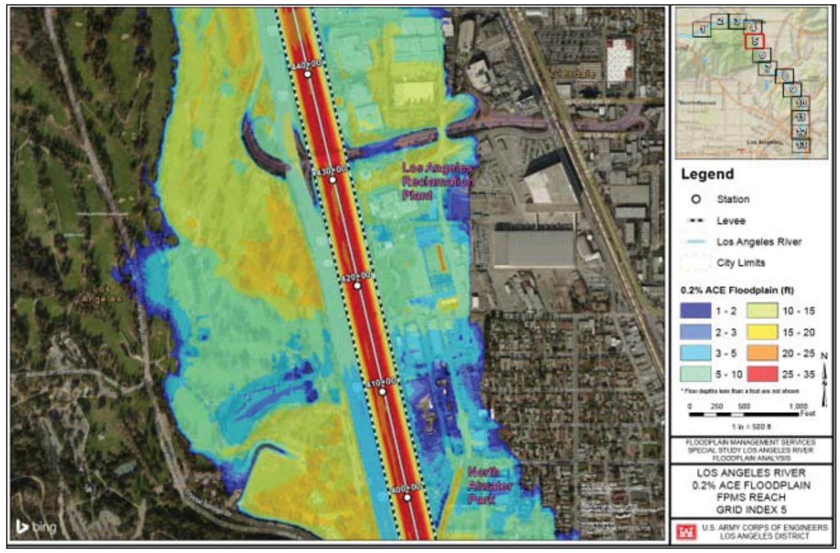
HEC-RAS

- Steady and unsteady hydraulic computations for network of open channels and floodplain
- 1-D – Energy equation
- 2-D – Shallow water equation
- Combine 1D/2D
  (i.e., 1-D for channel, 2-D for floodplain)
- Accounts for upstream and downstream conditions



Source: USACE, Los Angeles River 0.2% ACE Floodplain FPMS Reach Grid Index 5.

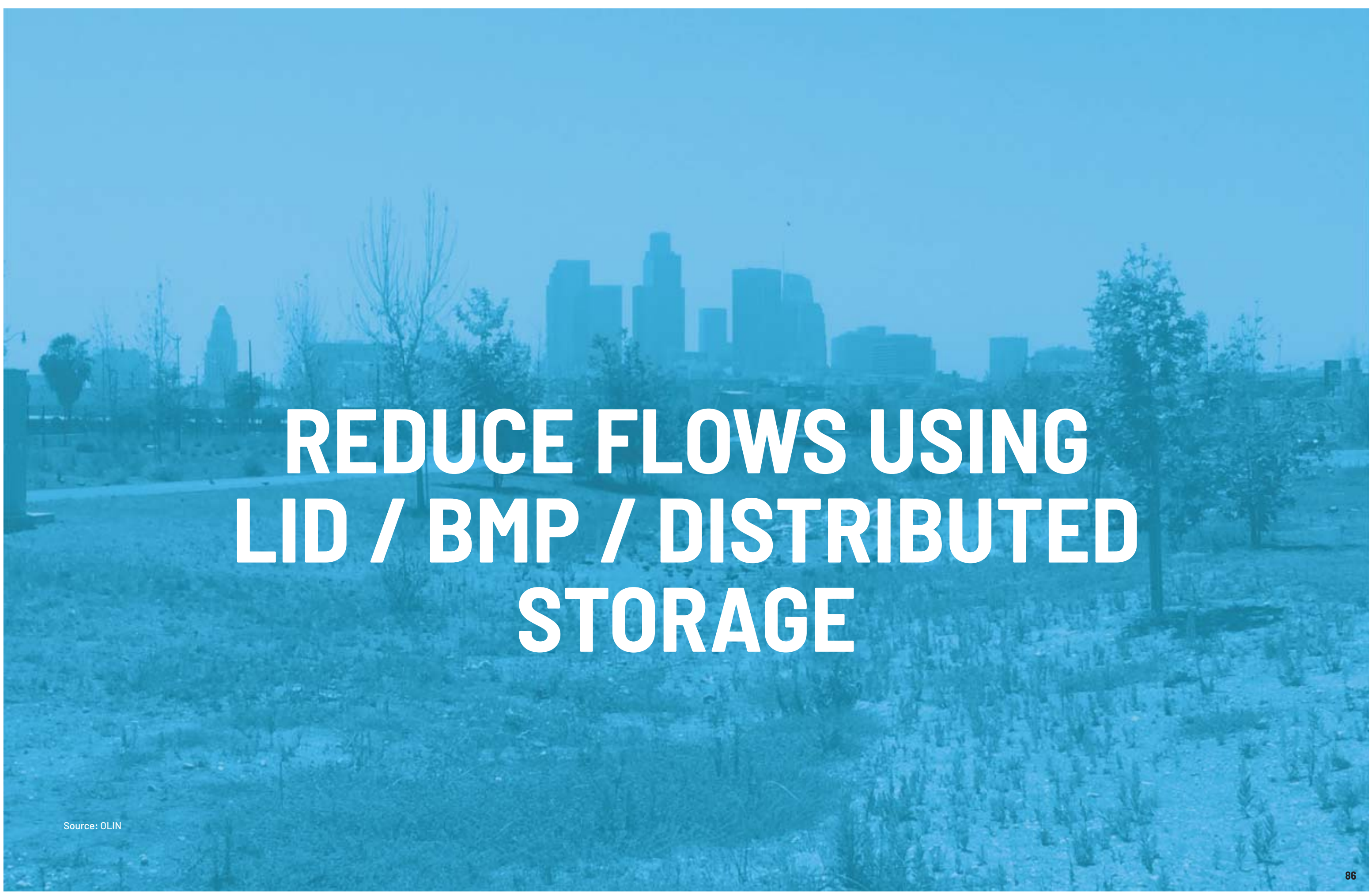
HEC-RAS

Q & A AND DISCUSSION

Source: OLIN

SOLUTIONS AND OPPORTUNITIES

Source: OLIN



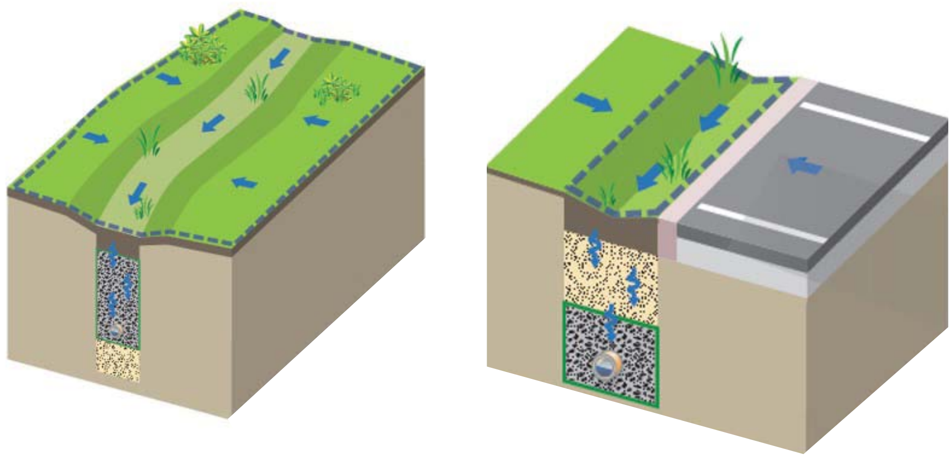
REDUCE FLOWS USING LID / BMP / DISTRIBUTED STORAGE

Source: OLIN

LOW IMPACT DEVELOPMENT (LID) EXAMPLES

Capture and retain the 85th percentile precipitation event runoff

- Standalone Bioretention
- Bioretention + Drywells
- Pervious Pavement + Drywells
- Water Quality
- Conservation



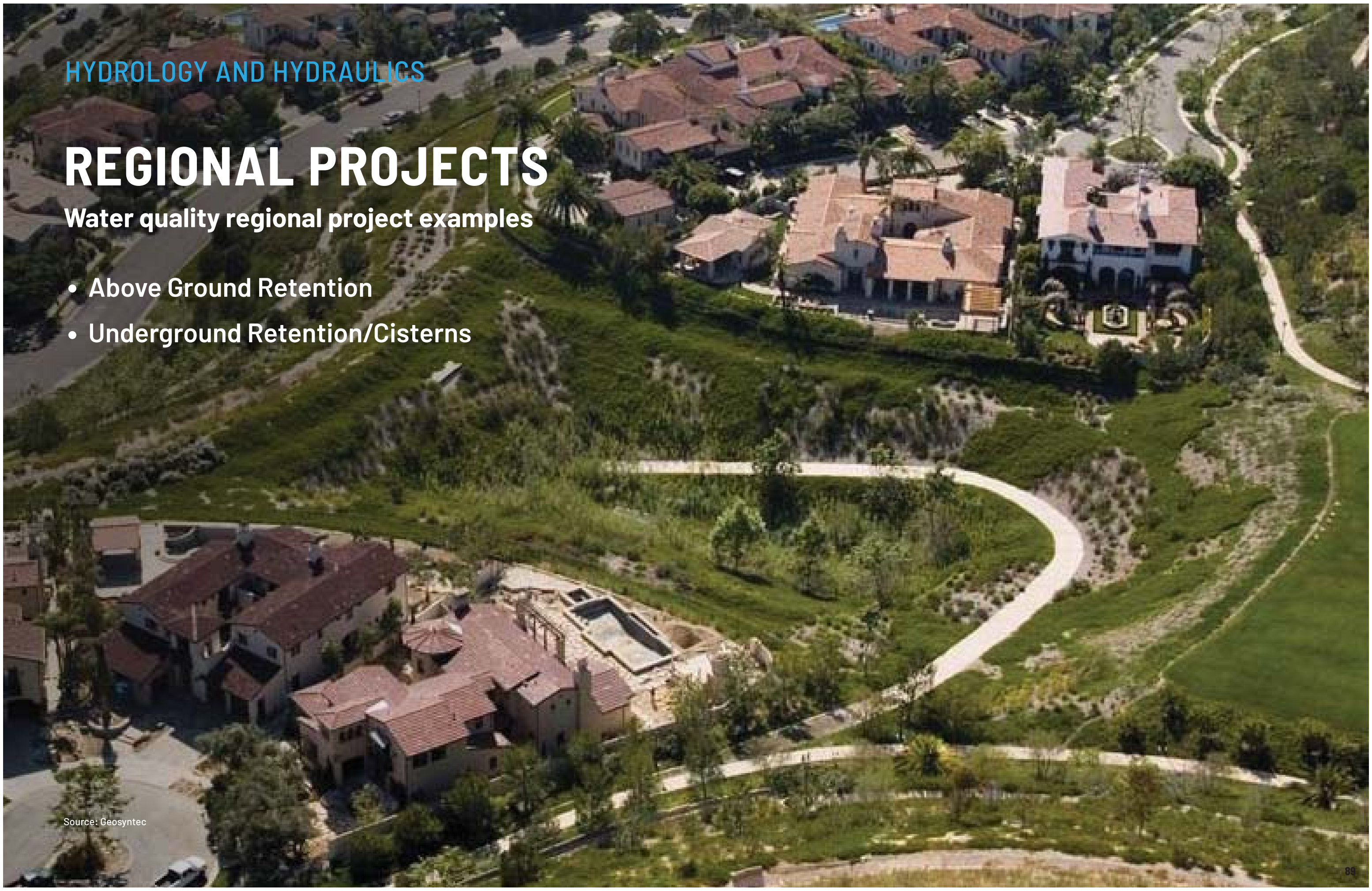
Source: Geosyntec

GREEN STREETS

Green infrastructure along, on, and within the public right-of-way

- Rain Gardens
- Bioretention
- Permeable Pavement
- Infiltration Trench
- Drywells

Source: Geosyntec



REGIONAL PROJECTS

Water quality regional project examples

- Above Ground Retention
- Underground Retention/Cisterns

Source: Geosyntec

REGIONAL PROJECTS

Project Examples

Flood Risk Reduction

Sepulveda Basin

Water Supply

Tujunga Spreading Grounds

Source: Sepulveda Basin Wildlife, https://sepulvedabasinwildlife.org/wildlifeareas.html, & Los Angeles County Public Works

REGIONAL PROJECTS

	WATER QUALITY	WATER SUPPLY	FLOOD
PROJECT FOOTPRINT	0.2 - 15 acres or less	15-160 acres	50+ acres
DESIGN CAPACITY	85th percentile event or smaller	Up to 5 year storm	50 year storm or greater
PRIMARY PURPOSE	Water quality improvement	Water supply benefits	Flood risk reduction
CONSTRUCTION COST	$ $	$ $ $ $ $	$ $ $ $ $

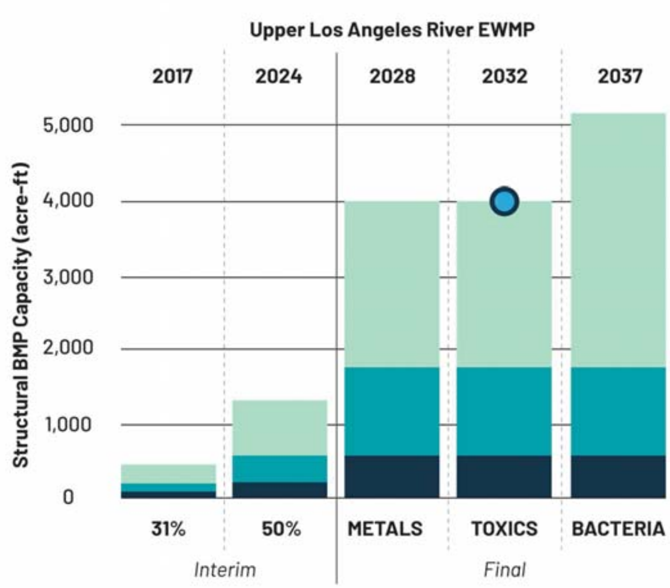
Source: Geosyntec

WATER QUALITY OBJECTIVES

Upper LA River (ULAR) Enhanced Water Quality Management Plan (EWMP)

5,186 AF total in ULAR by 2037

- Total Regional Best Management Practices (BMPs): **3,449 AF**
- Green Streets: **1,196 AF**
- Total LID Best Management Practices (BMPs): **541 AF**
- Residual Toxics Source Control Measures

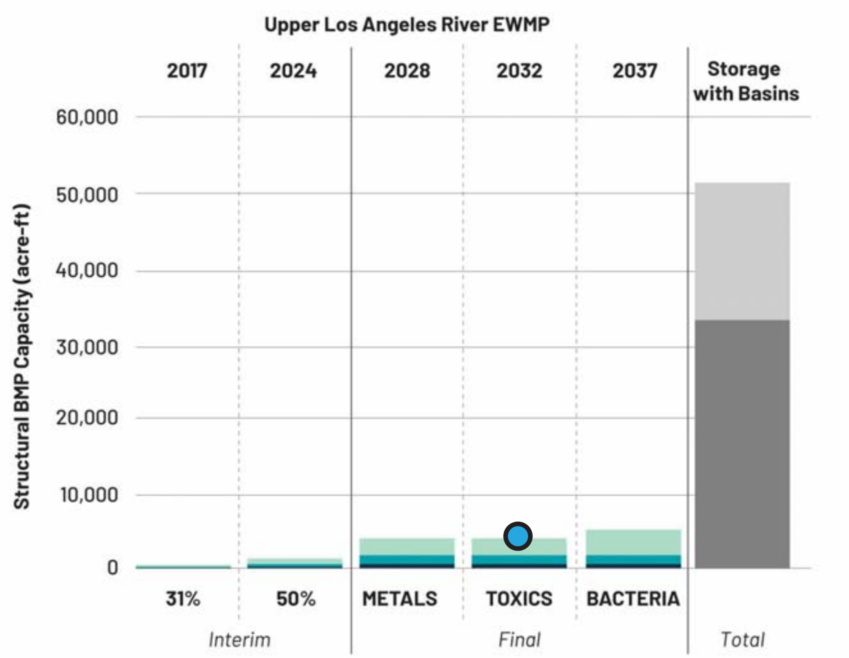


Source: ULAR EWMP (2016), https://www.waterboards.ca.gov/losangeles/water_issues/programs/stormwater/municipal/watershed_management/los_angeles/upper_losangeles/20160127/UpperLARiver_mainbody_revEWMP_Jan2016.pdf

WATER QUALITY OBJECTIVES

Upper LA River (ULAR) Enhanced Water Quality Management Plan (EWMP)

- Sepulveda Basin: **18,127 AF**
- Hansen Basin: **33,348 AF**
- Total Regional Best Management Practices (BMPs): **3,449 AF**
- Green Streets: **1,196 AF**
- Total LID Best Management Practices (BMPs): **541 AF**
- Residual Toxics Source Control Measures



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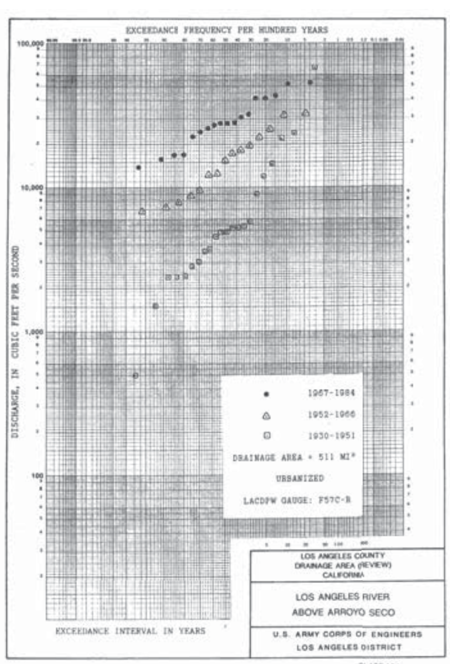
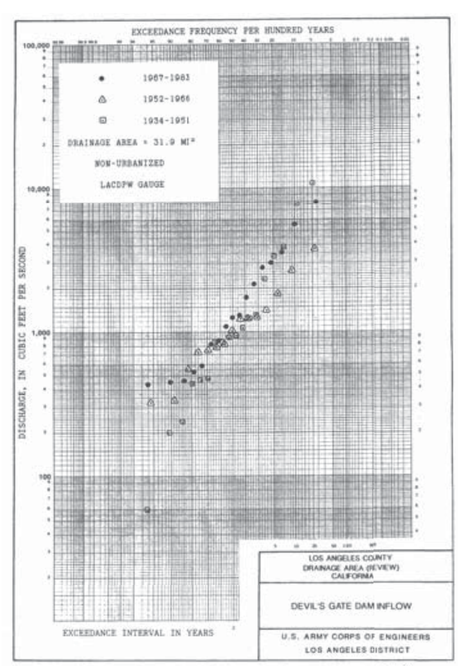
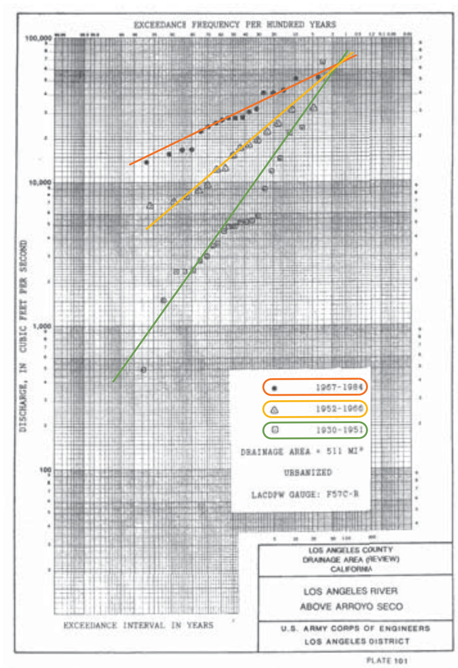
EFFECT OF URBANIZATION

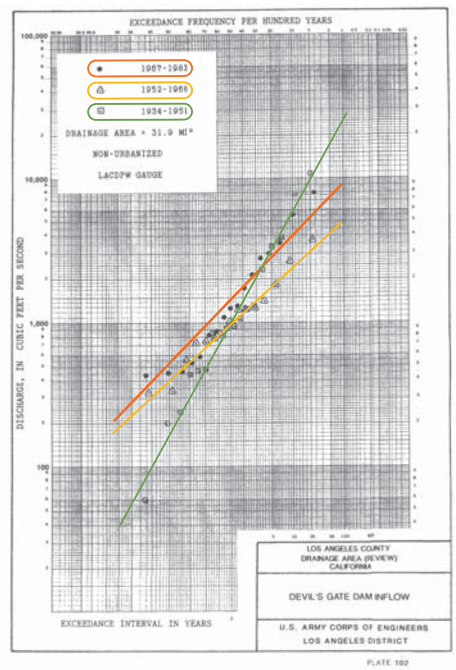




Source: U.S. Army Corps of Engineers: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part I, Hydrology Technical Report, Base Conditions

EFFECT OF URBANIZATION





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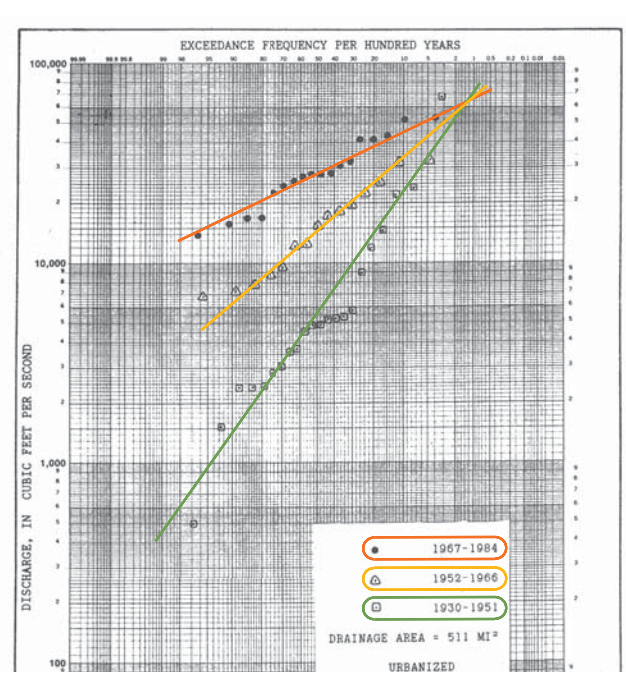
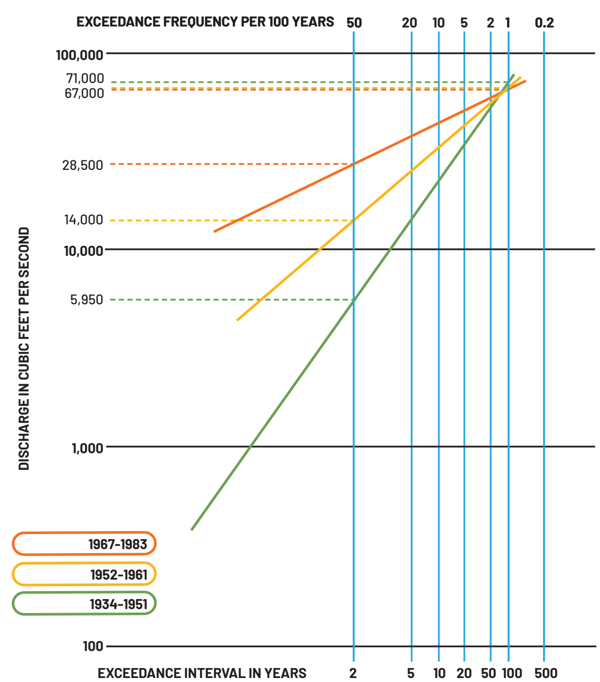
HYDROLOGY AND HYDRAULICS

EFFECT OF URBANIZATION





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H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
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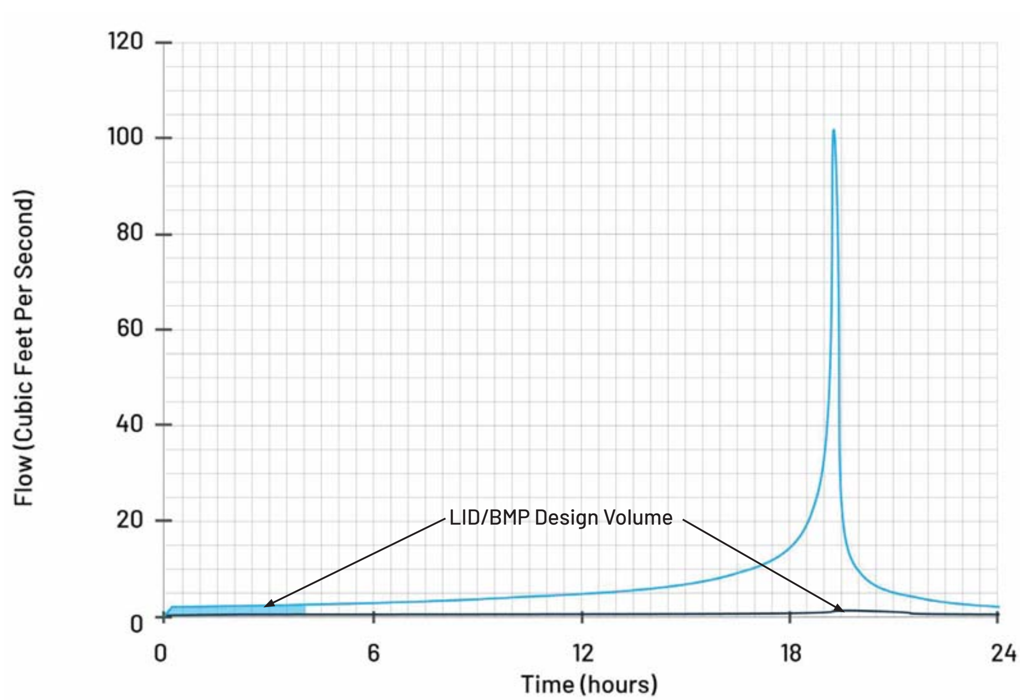
HYDROCALC LSPC HEC-HMS MANNING'S HEC-RAS

HYDROCALC



Hydrograph: Sub Area 1

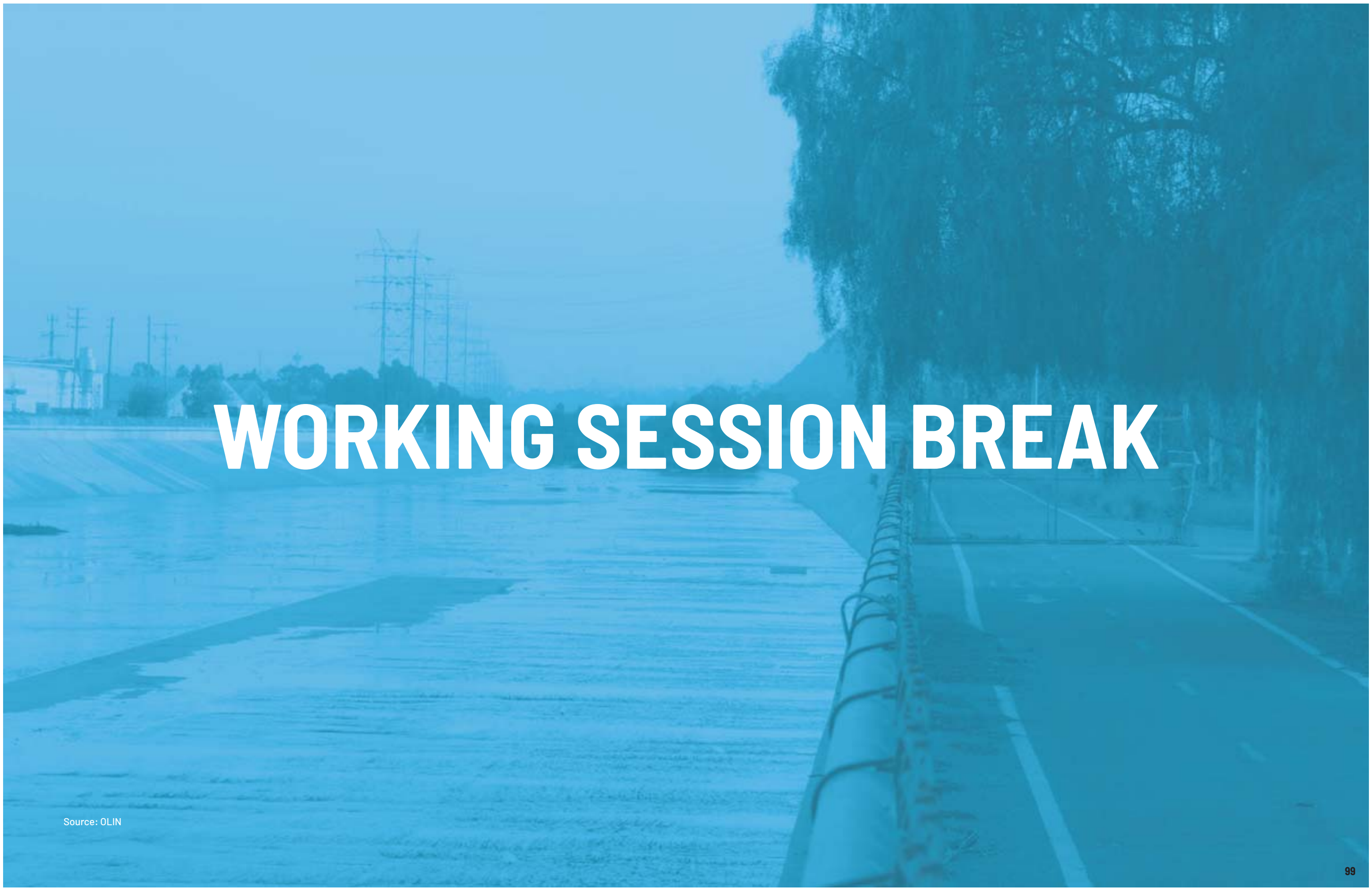
- E.g. 40 acre parcel
- LID/BMP "filled up" within first 4 hours of a storm
- Minimal ability to impact peak flow rate

100-Year Storm

85th Percentile Storm

Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

HYDROCALC

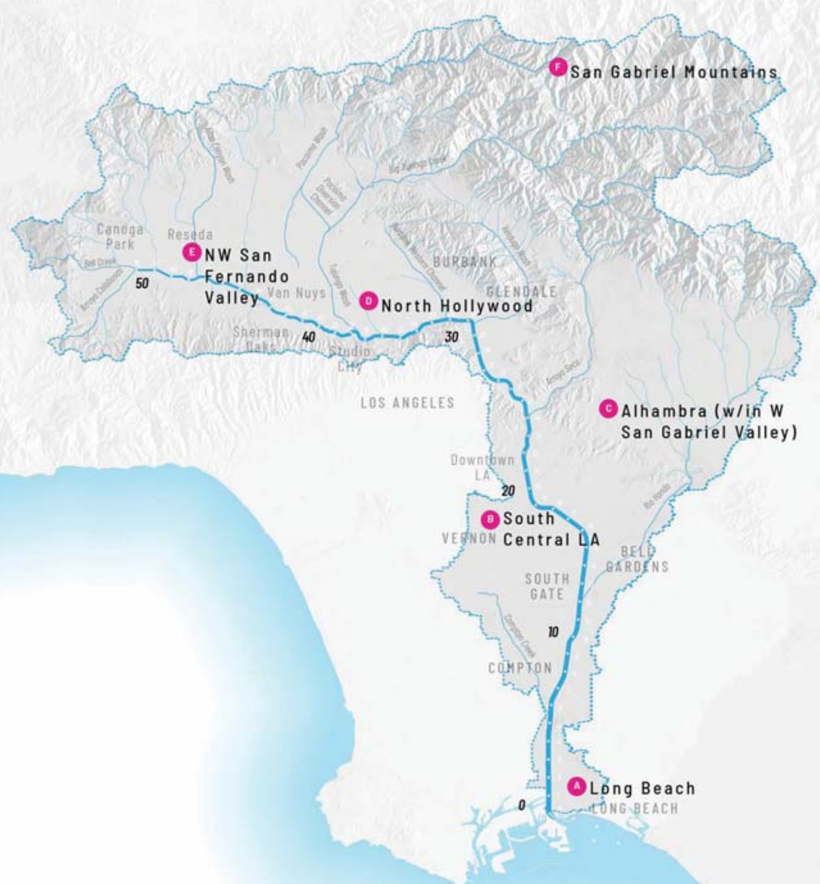


WORKING SESSION BREAK

Source: OLIN

HYDROLOGY AND HYDRAULICS

HYDROCALC



HydroCalc Example Sites

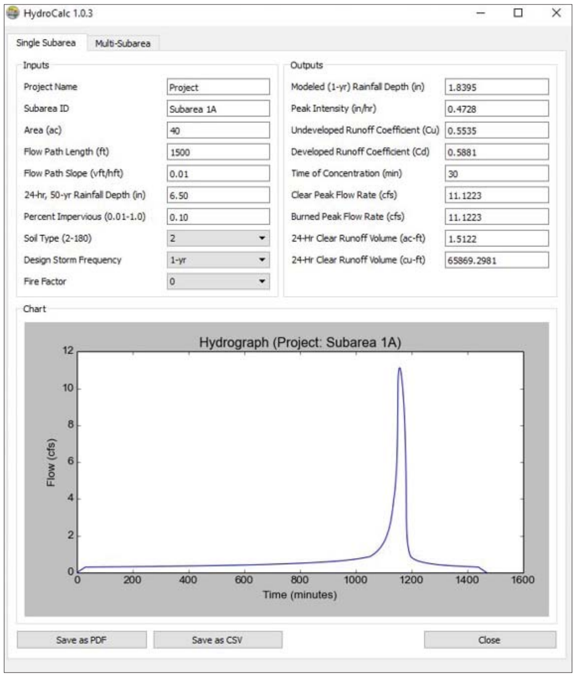
- Site Locations

Source: Geosyntec, OLIN

HYDROCALC

HYDROLOGY AND HYDRAULICS

HYDROCALC

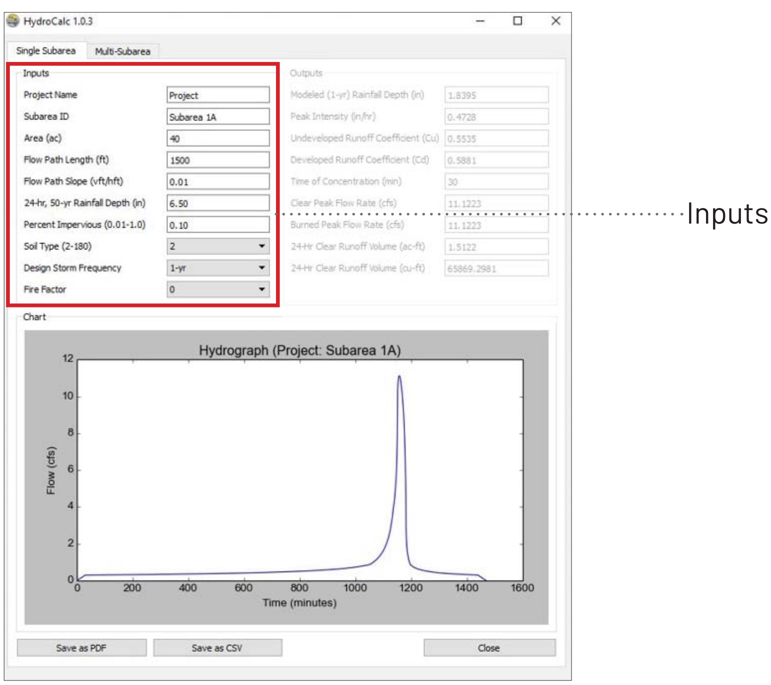


Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

HYDROCALC

HYDROLOGY AND HYDRAULICS

HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

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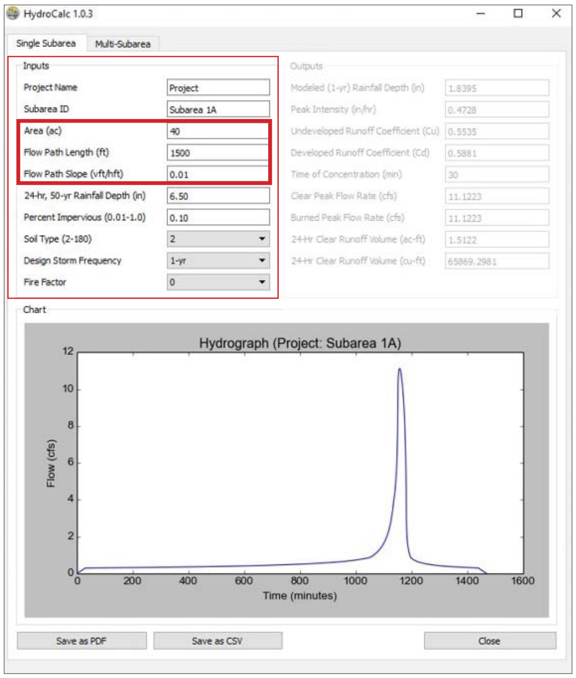

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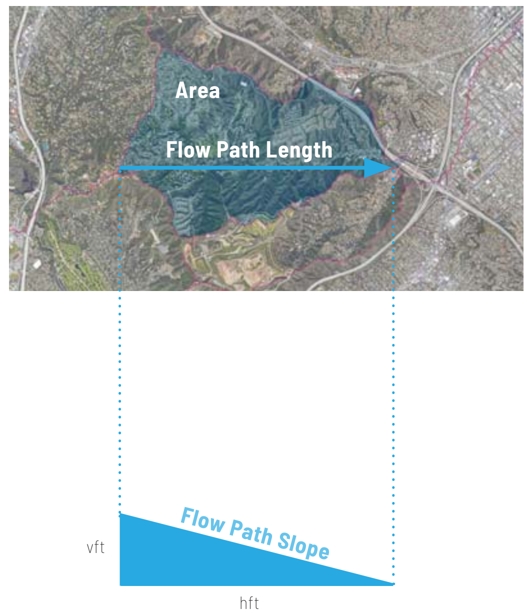
Subarea



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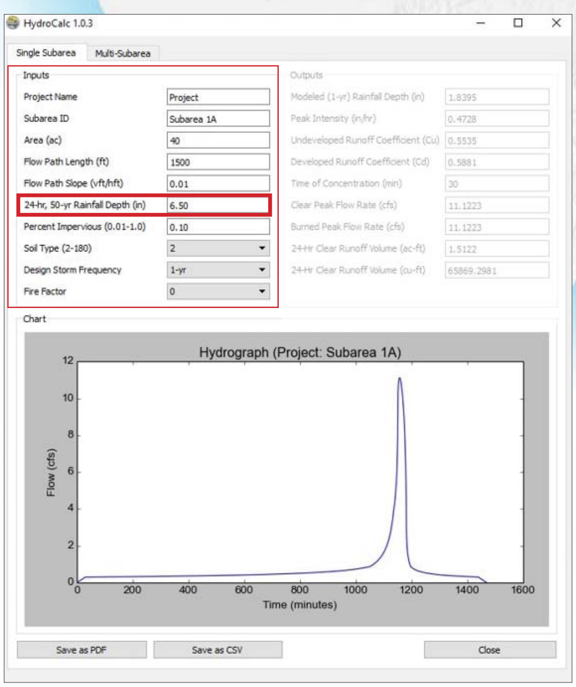
HYDROLOGY AND HYDRAULICS

HYDROCALC



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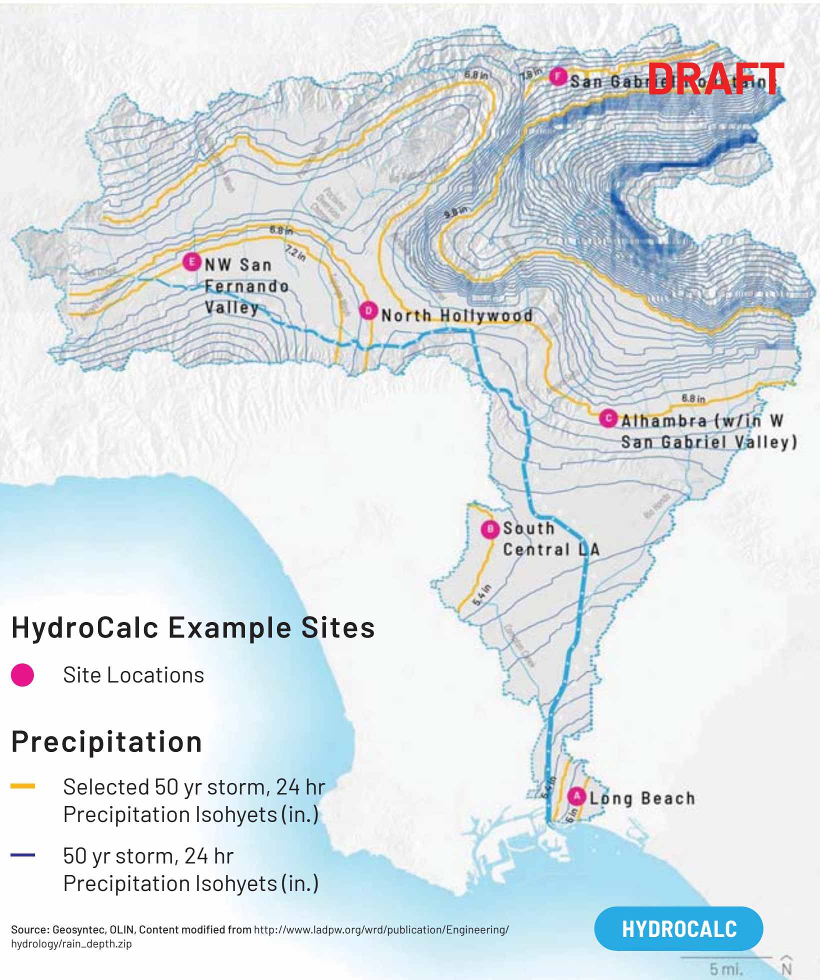


HydroCalc Example Sites

- Site Locations

Precipitation

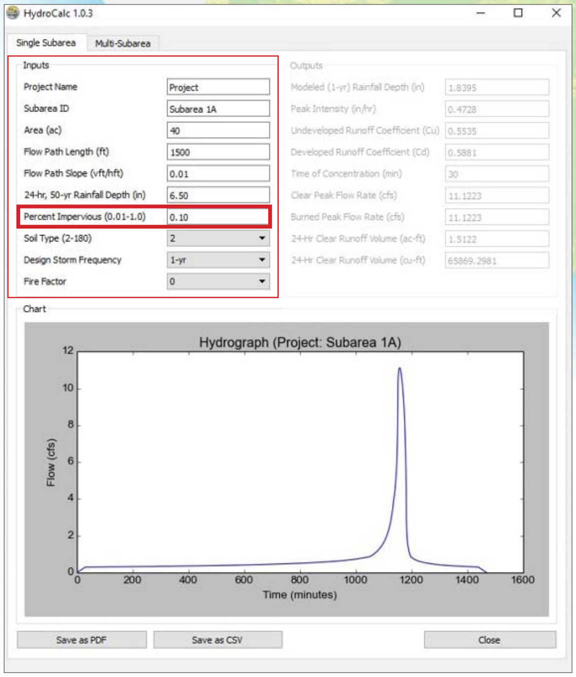
- Selected 50 yr storm, 24 hr Precipitation Isohyets (in.)
- 50 yr storm, 24 hr Precipitation Isohyets (in.)

Source: Geosyntec, OLIN, Content modified from http://www.ladpw.org/wrd/publication/Engineering/hydrology/rain_depth.zip

HYDROCALC

HYDROLOGY AND HYDRAULICS

HYDROCALC



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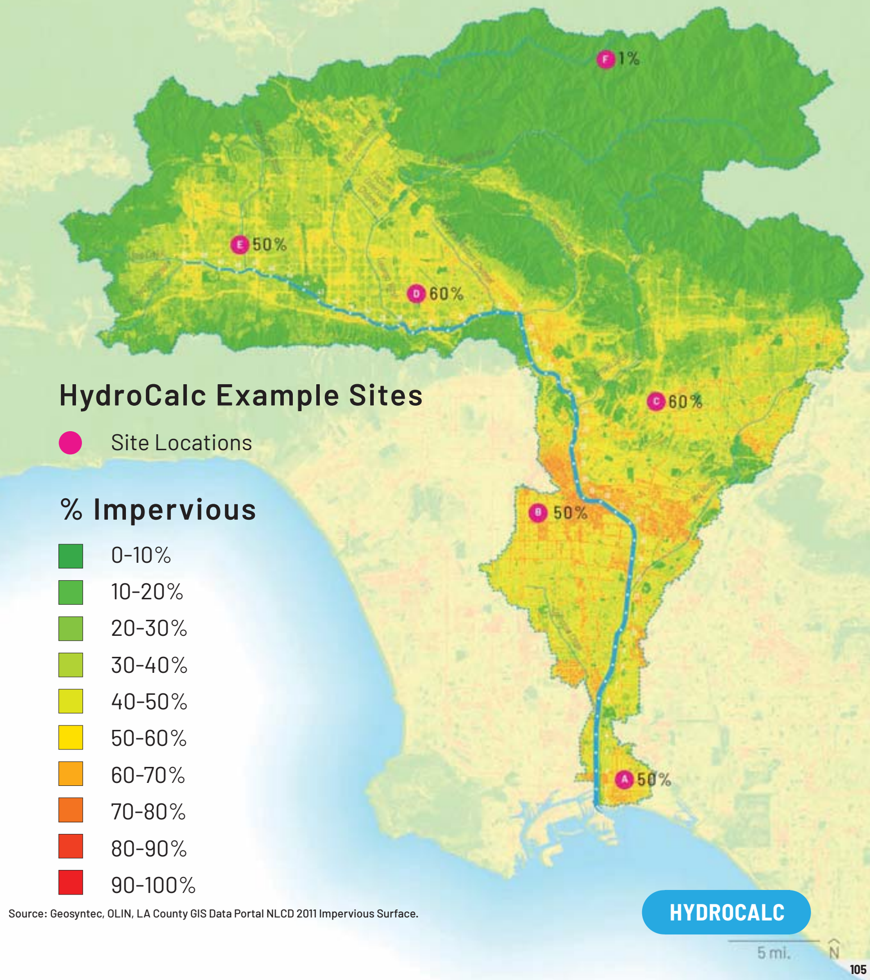
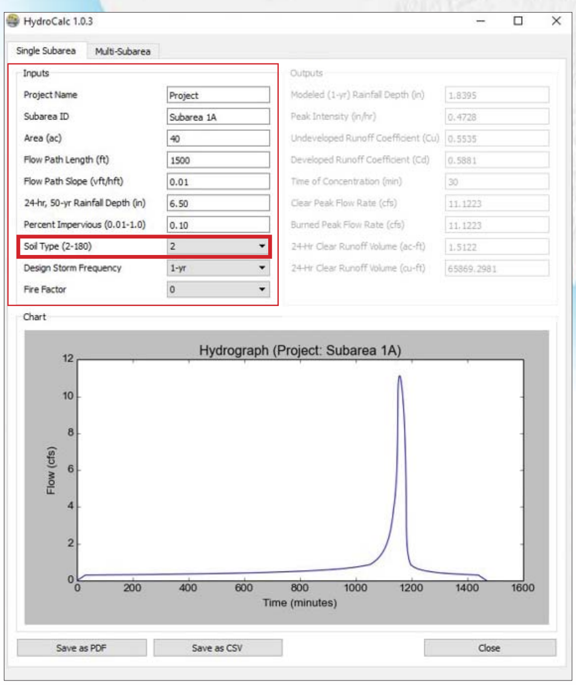


Source: Geosyntec, OLIN, LA County GIS Data Portal NLCD 2011 Impervious Surface.

HYDROCALC

HYDROLOGY AND HYDRAULICS

HYDROCALC



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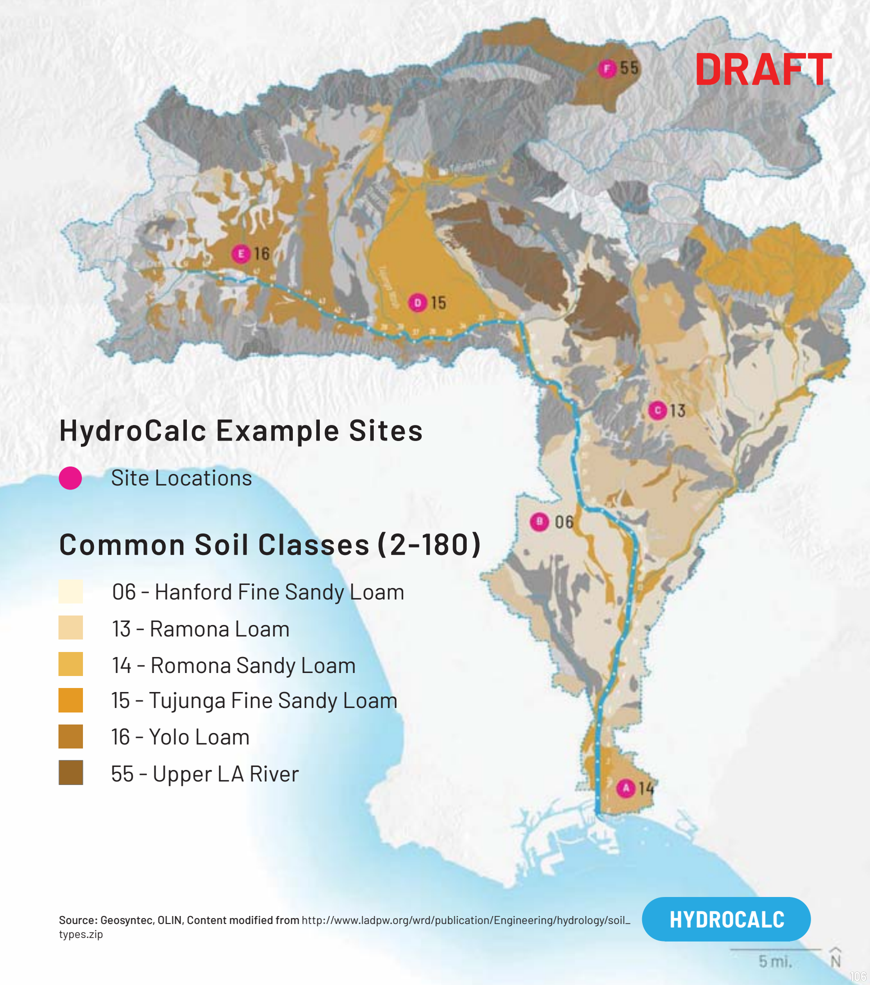
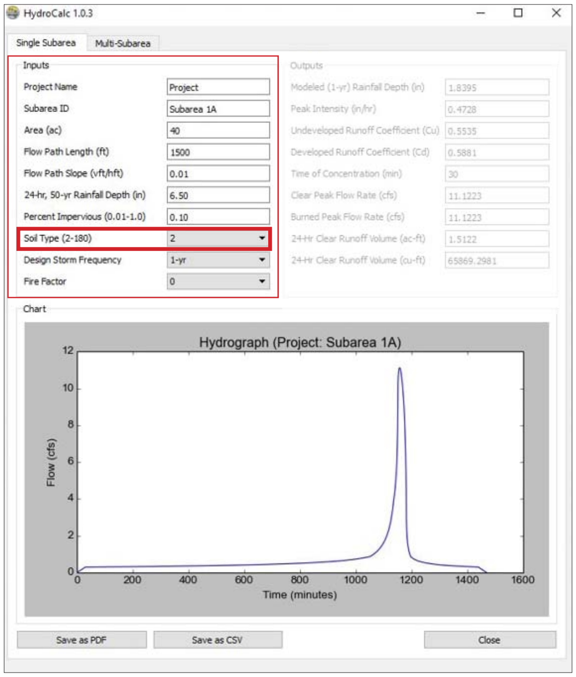


Source: Geosyntec, OLIN, Content modified from http://www.ladpw.org/wrd/publication/Engineering/hydrology/soil_types.zip

HYDROCALC

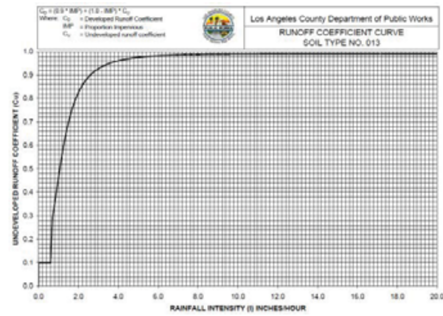
HYDROLOGY AND HYDRAULICS

HYDROCALC

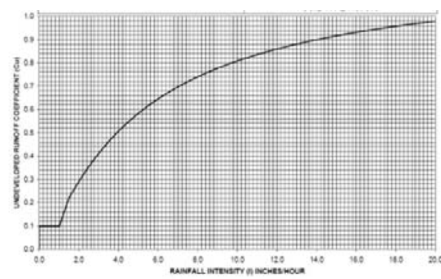


Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

13 - Ramona Loam



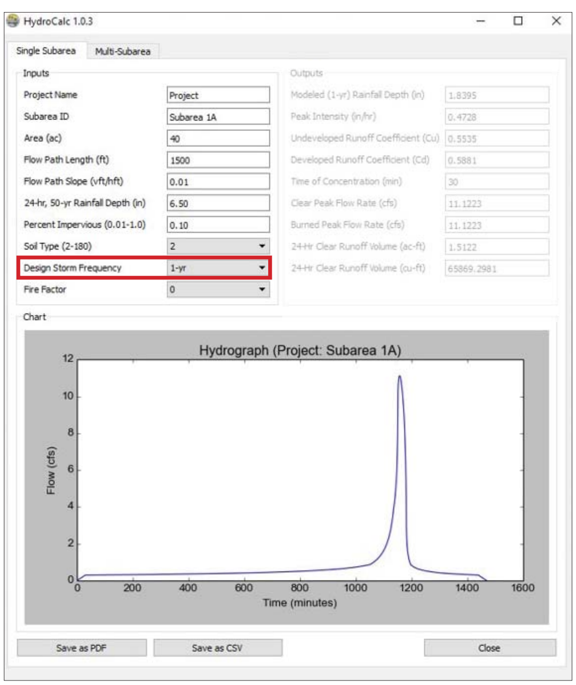
15 - Tujunga Fine Sandy Loam



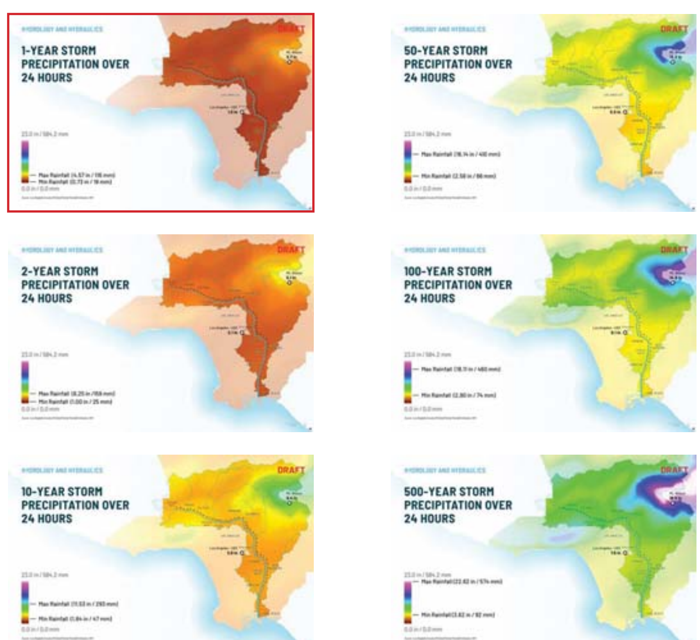
HYDROCALC

HYDROLOGY AND HYDRAULICS

HYDROCALC



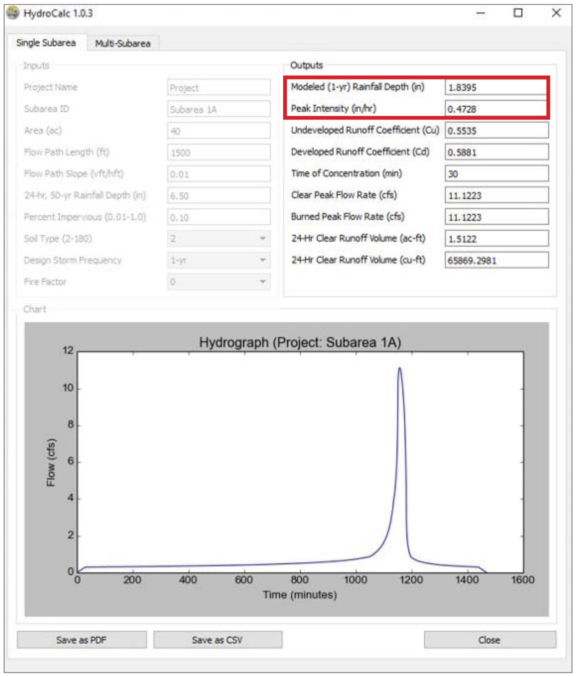
Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip



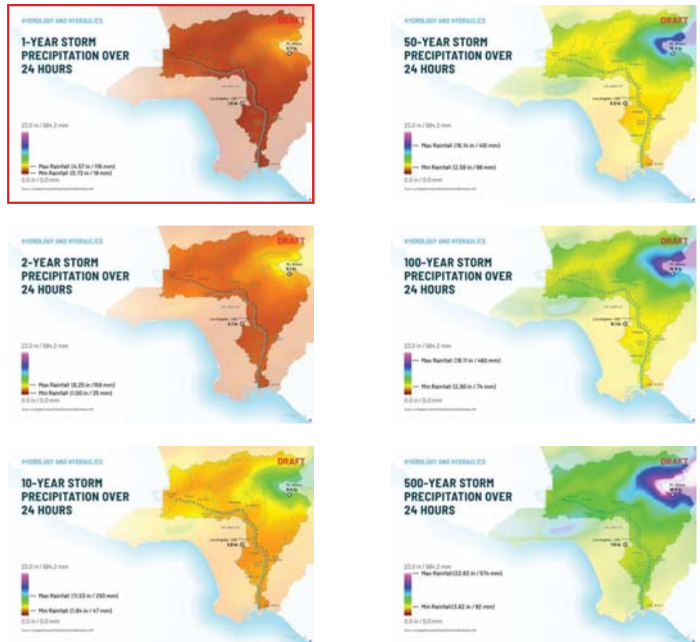
Source: Geosyntec, OLIN, Content modified from Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROCALC

HYDROLOGY AND HYDRAULICS
HYDROCALC



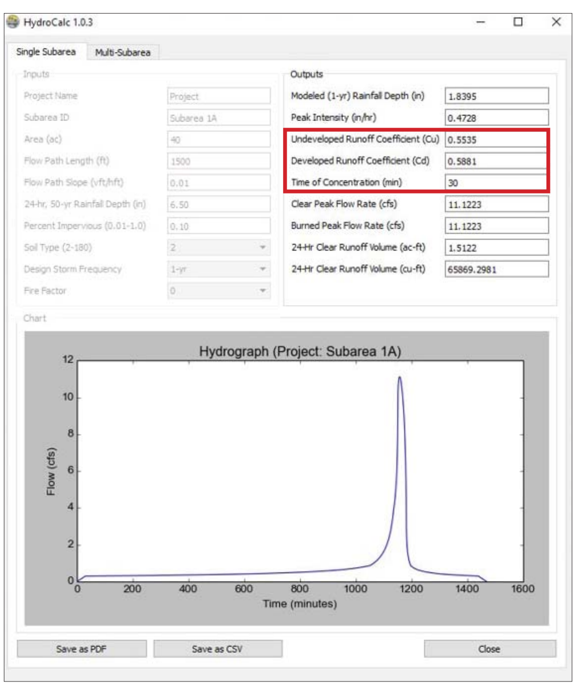
Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip



Source: Geosyntec, OLIN, Content modified from Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROCALC

HYDROLOGY AND HYDRAULICS
HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

- Fraction of rain that runs off undeveloped surfaces

  - soil type

  - rain intensity

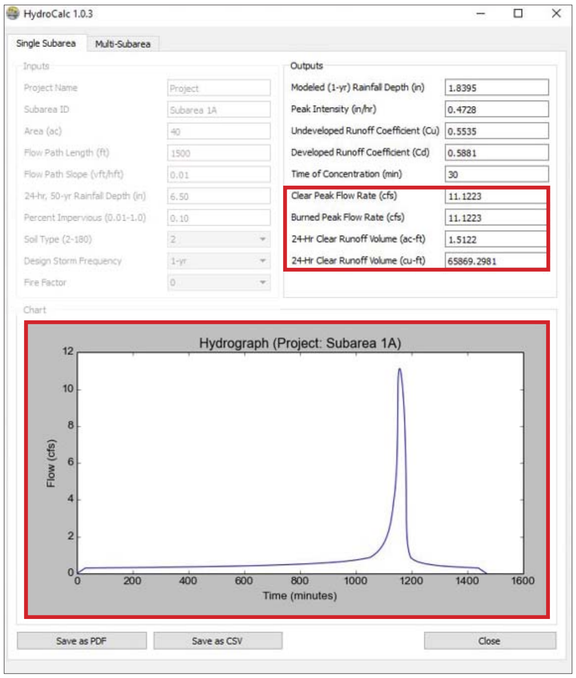
- Fraction of rain that runs off developed surfaces

  - undeveloped surfaces + imperviousness

- Travel time for water from furthest point in subarea

HYDROCALC

HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

Peak Flow Rates

- Relevant for drainage design and flood risk management
- Will be higher for burned watersheds

- debris bulking

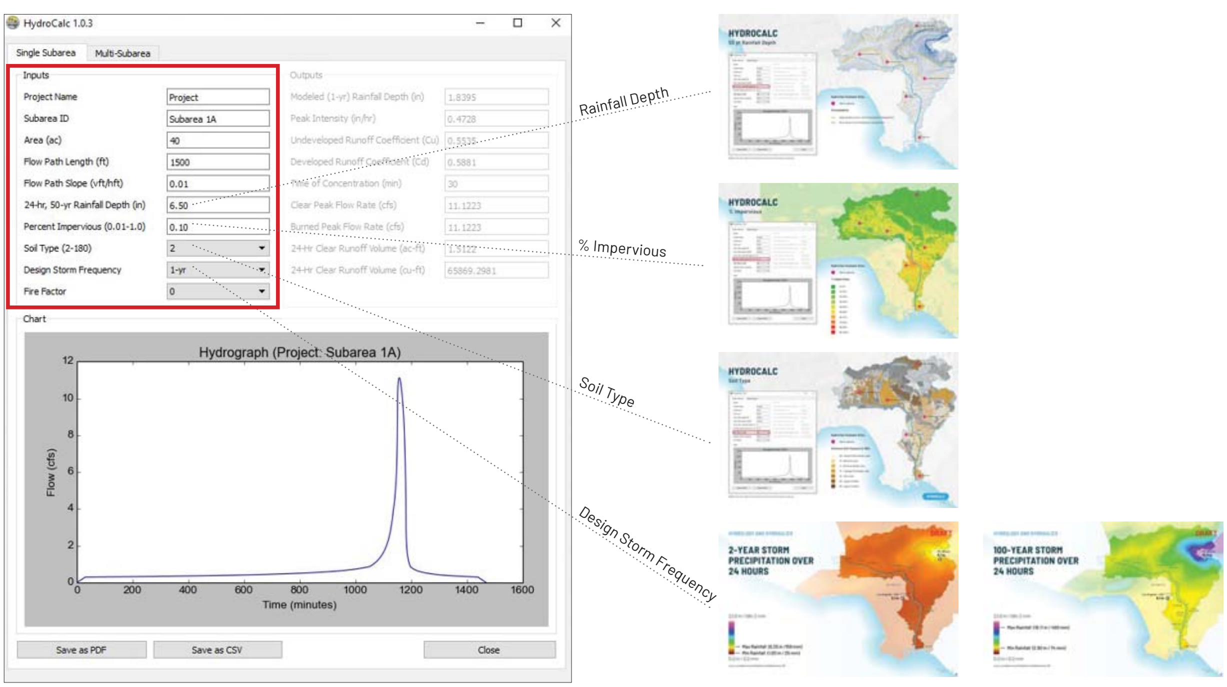
- hydro-phobic soil

Volumes

- Relevant for LID / BMP design

HYDROCALC

HYDROCALC



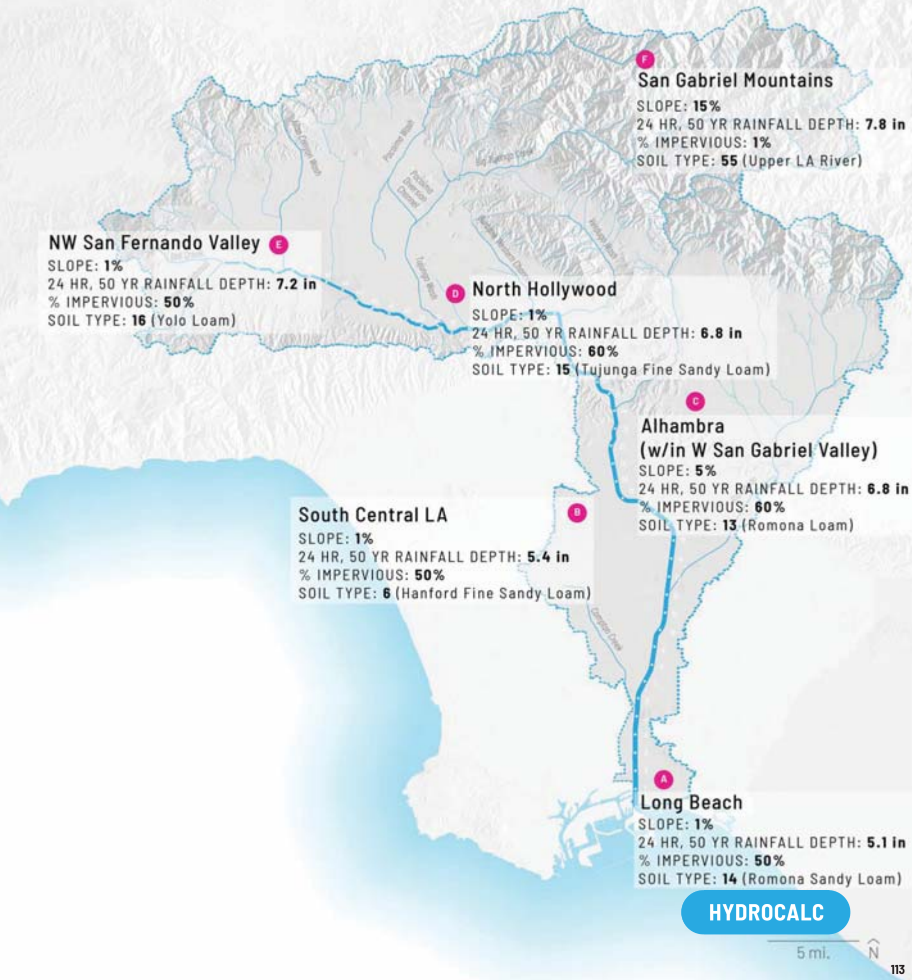
Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

Source: Geosyntec, OLIN, Content modified from http://www.ladpw.org/wrd/publication/Engineering/hydrology/rain_depth.zip; http://www.ladpw.org/wrd/publication/Engineering/hydrology/soil_types.zip; Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROCALC

HYDROLOGY AND HYDRAULICS

HYDROCALC



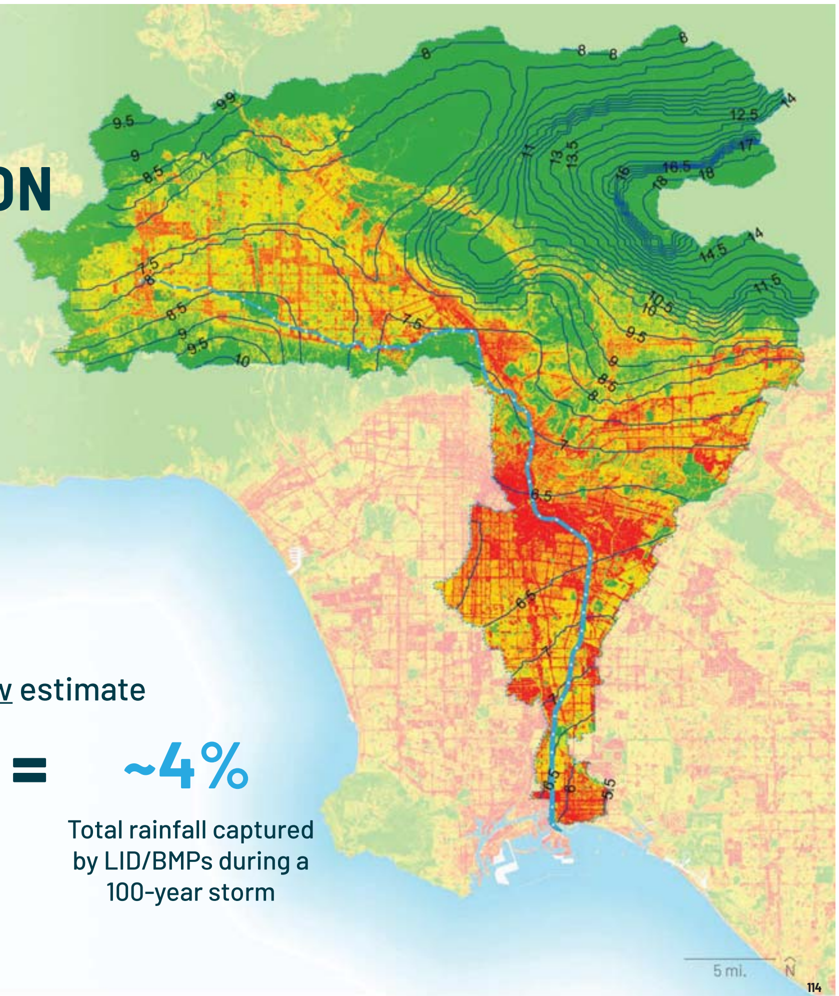
HydroCalc Example Sites

Site Locations

Source: Geosyntec, OLIN

HYDROLOGY AND HYDRAULICS

WATERSHED CALCULATION



0% Impervious

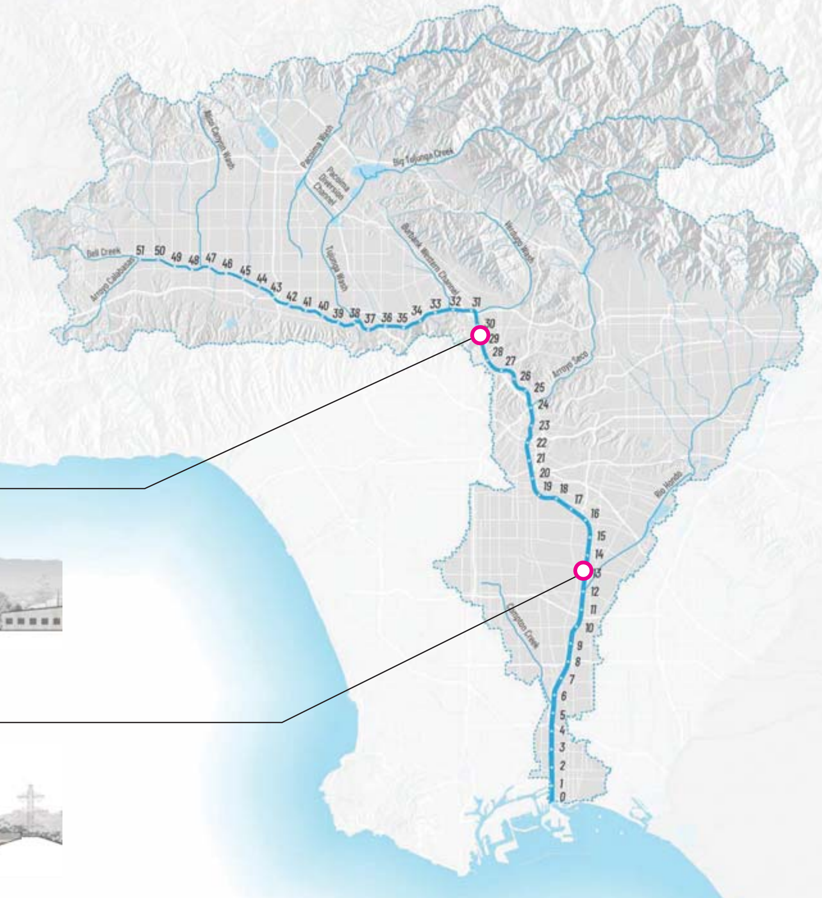
100% Impervious

This is a volume estimate only, not a peak flow estimate

~27%	x	~15%	=	~4%
Percentage of rain that falls on impervious surface		Percentage of rain that LID/BMP captures from a 100-year storm		Total rainfall captured by LID/BMPs during a 100-year storm

Source: LA County GIS Data Portal NLCD 2011 Impervious Surface.

EXAMPLE LOCATIONS



Section at Glendale Narrows (River Mile 29)

Section at Firestone Blvd (River Mile 13)

Source: Geosyntec, OLIN

NARROWS ARBOR REACHES

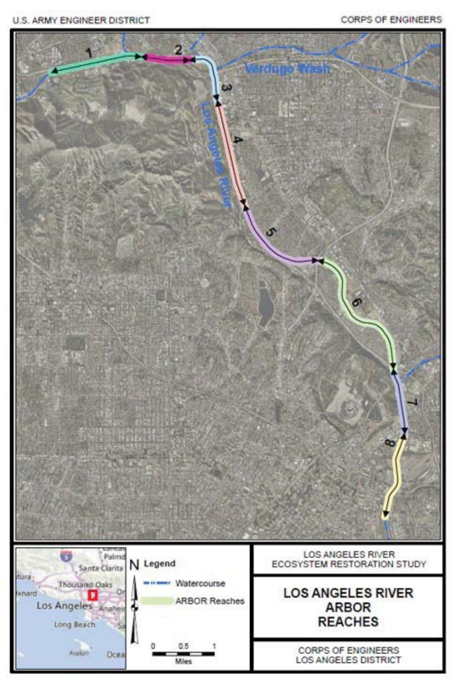
Some sections only manage to the 4-year storm

Table 17: Original Design Discharge and Existing Channel Capacity

Reach[a]	River Stations	Design[b] Discharge ft³/s	Design Return Period [e] yr	Current Freeboard Criteria[c] ft	Existing[d] Channel Capacity ft³/s	Existing Return Period [e] yr	100-Year Discharge[e] ft³/s
Reach 1	625+77 to 547+45	40,000	12	3	29,300	4	81,000
Reach 2	546+45 to 510+05	40,000	7	3	25,800	3	88,900
Reach 3a	504+93 to 477+85	40,000	7	3	63,000[f]	32	88,900
Reach 3b	475+68 to 452+58	78,000	51	3	84,000[f]	69	94,600
Reach 4	432+16 to 359+75	78,000	51	3	34,700	4	94,600
Reach 5	358+63 to 271+89	78,000	51	3	34,000	4	94,600
Reach 6a	270+28 to 262+73	78,000	51	2.5	64,500	24	94,600
Reach 6b	257+85 to 144+23	83,700	57	2.5	50,500	11	93,800
Reach 7a	142+91 to 131+22	83,700	57	2.5	135,400[f]	>500	93,800
Reach 7b	128+71 to 86+61	104,000	83	3	83,700	32	109,000
Reach 8	86+07 to 10+31	104,000	83	3	89,600	42	109,000

Notes:
(a) Letters a & b in Reach names denote a change in the river due to a confluence or change in channel dimensions.
(b) Original design discharge for clean prismatic channel.
(c) Freeboard from EM 1110-2-1601; 3 feet for leveed sections and 2.5 feet for trapezoidal entrenched sections.
(d) Existing channel capacity with vegetation, sedimentation and freeboard. The values shown are the minimum within the reach. Discharges above these listed do not necessarily cause damages.
(e) Return periods for Design Discharge and Existing Channel Capacity are based on discharge frequency analysis for the 1992 LACDA Feasibility Study.
(f) In some limited reaches the existing channel capacity is greater than the original design discharge because of more than adequate freeboard.
(g) Refer to Plates 21a through 24b to see the floodplains for various return frequency flows within the study limits.

HH Appendix 61 September 2015



Source: U.S. Army Corps of Engineers, Los Angeles District. Los Angeles River Ecosystem Restoration Project, Volume III, Appendix E (HH Appendix). 2015.

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
DEVELOPER	LA County Public Works	LA County Public Works	US Army Corps of Engineers	Robert Manning	US Army Corps of Engineers
DATE	2018	2013	2018	1889	2018
PURPOSE	Modified Rational Method for local scale flood and drainage analyses	Designed for water quality best management practice	Designed explicitly for flood risk management	Uniform and steady-state analysis of channels	Varying and unsteady analysis of channels and floodplains
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

LSPC MODEL: LOS ANGELES BASIN STUDY

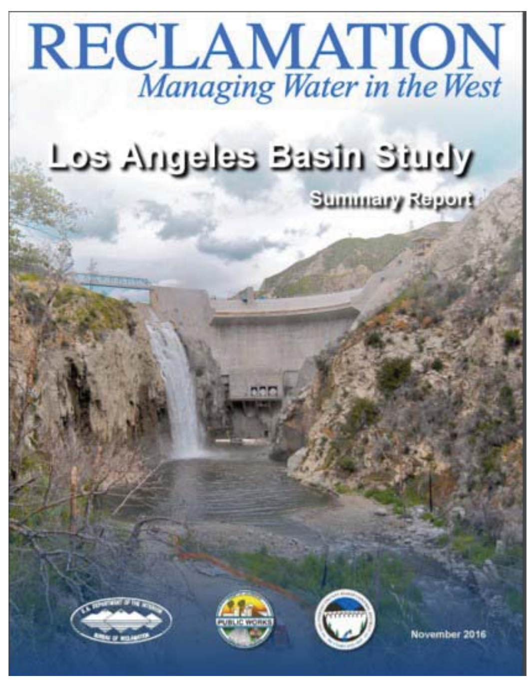
Updated by Reclamation to include LID/BMP

- Supply effects of climate change and LID studied
- Adjusted impervious land-use areas within all subwatersheds to represent widespread LID implementation
- 47 different climate-change projections

Two Levels of LID

- 0.75 inches of storage, 3-day drawdown
- 1.0 inches of storage, 1.5-day drawdown

- **Up to ~48,000 ac-ft/year of additional stormwater conserved in LA River watershed from LID**

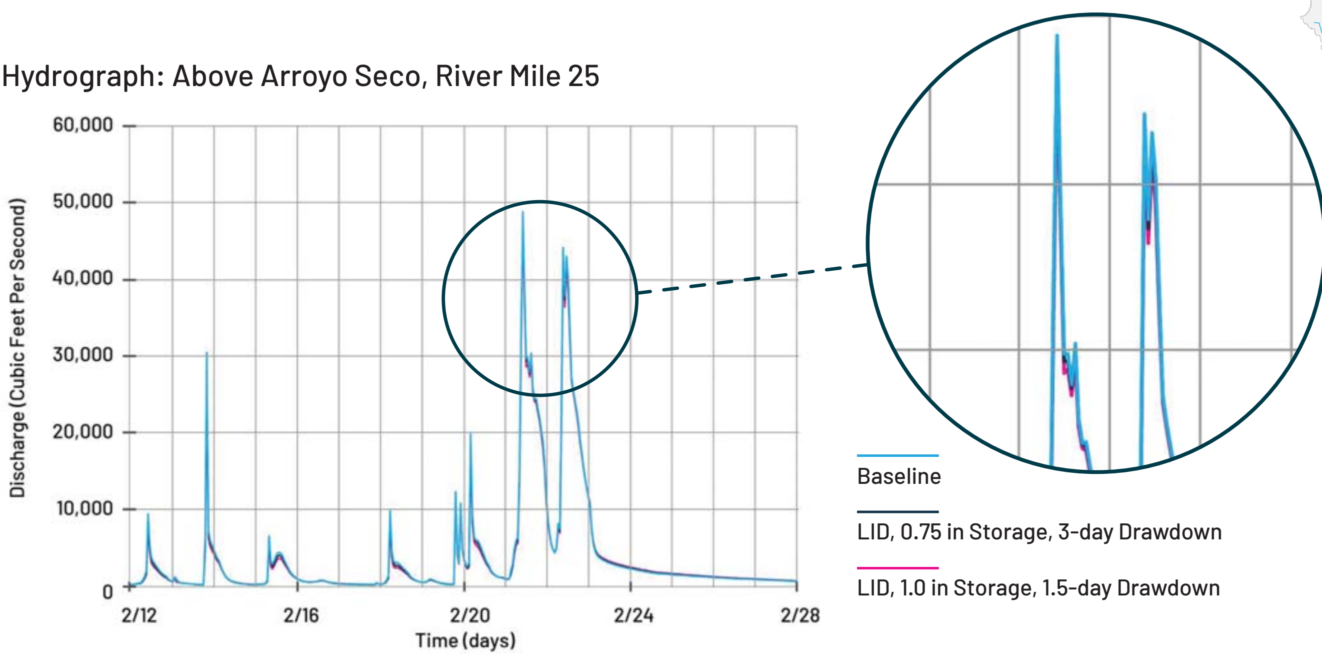


Source: Simes, J. U.S. Department of the Interior & Alexanderson, L., Bradbury, D. County of Los Angeles Public Works, November 2016, https://www.usbr.gov/lc/socal/basinstudies/LABasin.html

LSPC BASIN PLAN RESULTS: FEBRUARY 1998

Similar to Wet February 2019

Hydrograph: Above Arroyo Seco, River Mile 25



Source: USBR, LA County, Geosyntec, OLIN

H&H MODELING TOOLS

HYDROLOGY: UNIT HYDROLOGY (HYDROCALC); LARGER WATERSHED (LSPC, HEC-HMS)

HYDRAULICS: CHANNELS (MANNING'S, HEC-RAS)

	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
DEVELOPER	LA County Public Works	LA County Public Works	US Army Corps of Engineers	Robert Manning	US Army Corps of Engineers
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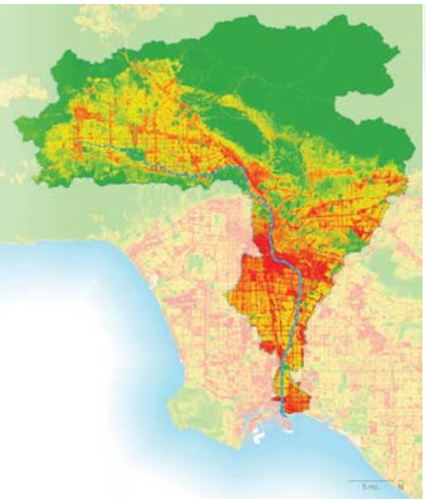
HYDROCALC LSPC HEC-HMS MANNING'S HEC-RAS

IMPERVIOUS SURFACE BASELINE

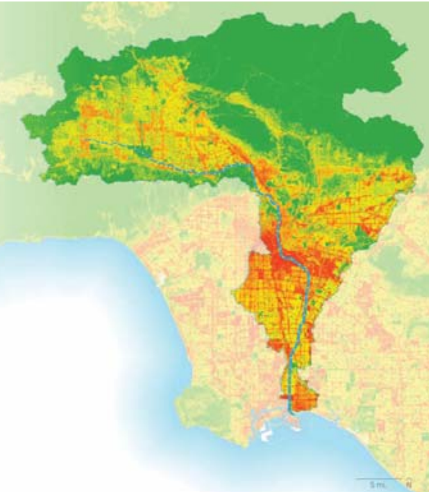


0% Impervious

100% Impervious

Baseline Condition

IMPERVIOUS SURFACE 10% REDUCTION



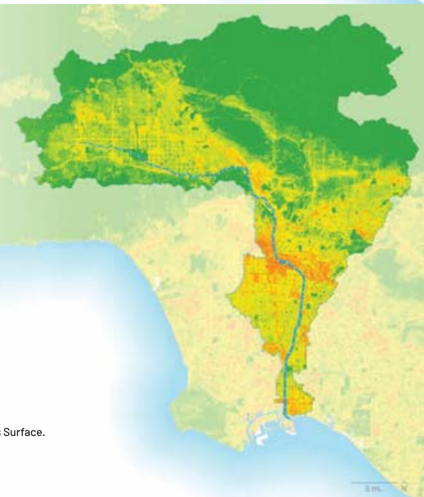
0% Impervious

100% Impervious

Volume Reduction: 1,866 AF

Fraction of 2037 Goals: 36%

IMPERVIOUS SURFACE 28% REDUCTION



0% Impervious

100% Impervious

Volume Reduction: 5,186 AF

Fraction of 2037 Goals: 100%

Source: LA County GIS Data Portal NLCD 2011 Impervious Surface.

IMPERVIOUS SURFACE 50% REDUCTION

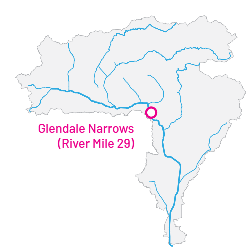
0% Impervious

100% Impervious

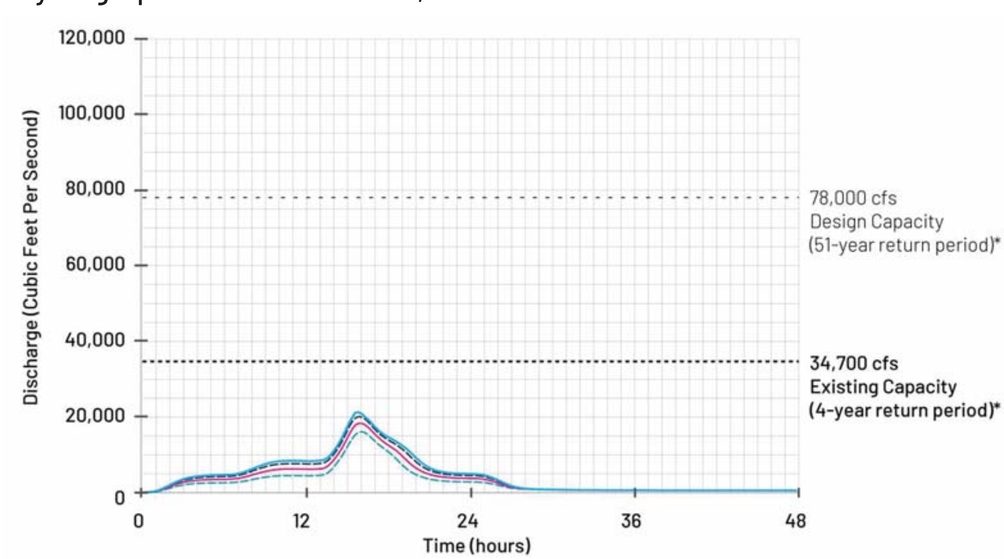
Volume Reduction: 9,331 AF

Fraction of 2037 Goals: 180%

NARROWS 2-YEAR STORM



Hydrograph: Glendale Narrows, River Mile 29



Baseline Imperviousness

10% Reduction in Imperviousness

28% Reduction in Imperviousness

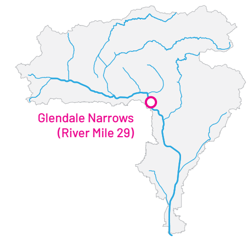
50% Reduction in Imperviousness

HEC-HMS

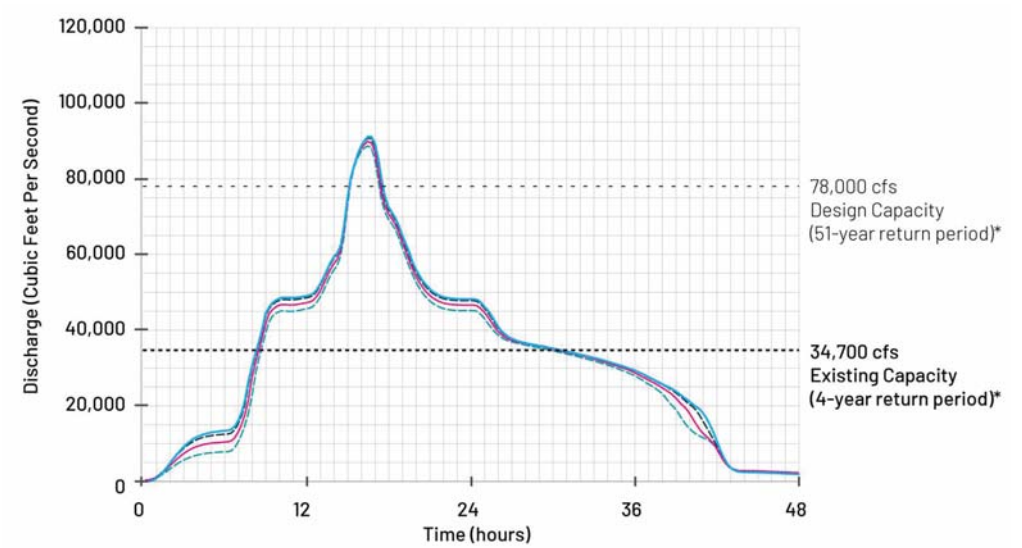
Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

NARROWS 100-YEAR STORM



Hydrograph: Glendale Narrows, River Mile 29



Baseline Imperviousness

10% Reduction in Imperviousness

28% Reduction in Imperviousness

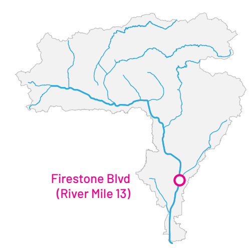
50% Reduction in Imperviousness

Source: Geosyntec, OLIN

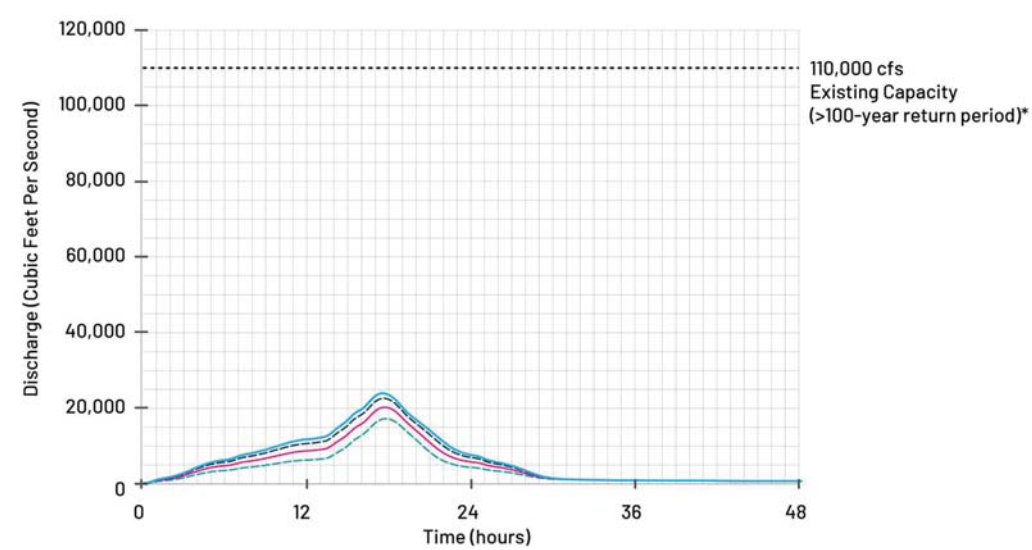
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

HEC-HMS

FIRESTONE 2-YEAR STORM



Hydrograph: Firestone Blvd, River Mile 13



Baseline Imperviousness

10% Reduction in Imperviousness

28% Reduction in Imperviousness

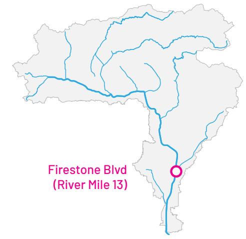
50% Reduction in Imperviousness

Source: Geosyntec, OLIN

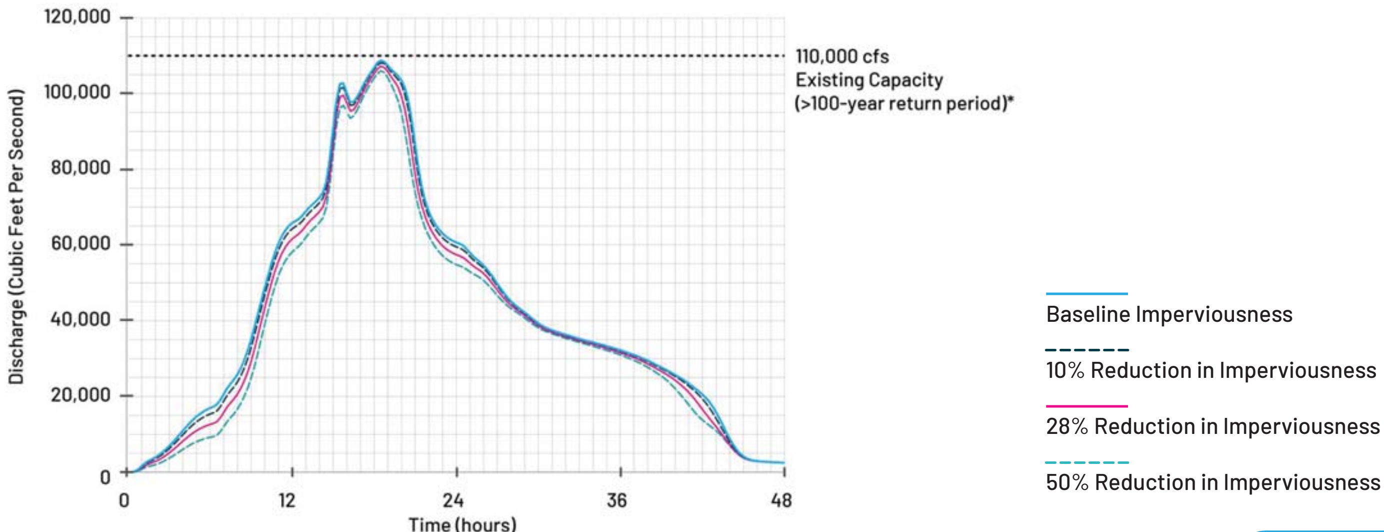
* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)

HEC-HMS

FIRESTONE 100-YEAR STORM



Hydrograph: Firestone Blvd, River Mile 13



HEC-HMS

Source: Geosyntec, OLIN
* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)

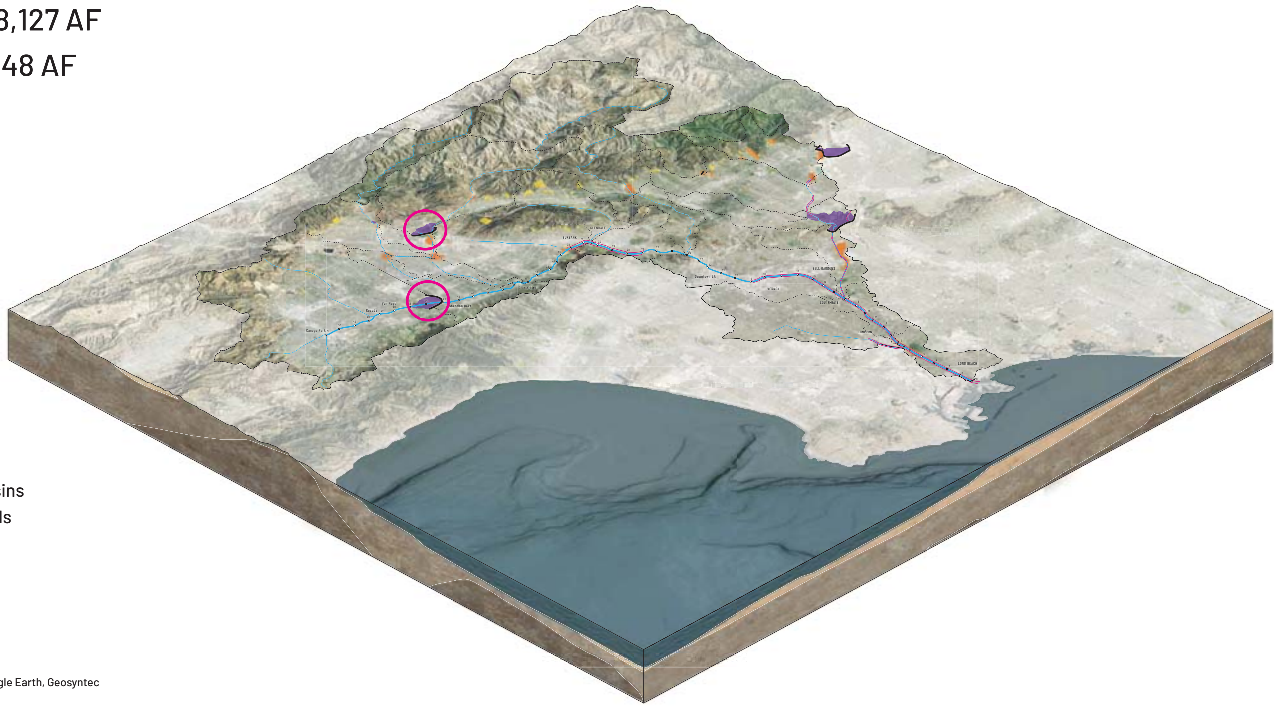
REDUCE FLOWS BY ADDING CENTRALIZED STORAGE

Source: OLIN

FLOOD CONTROL BASINS

Sepulveda: 18,127 AF

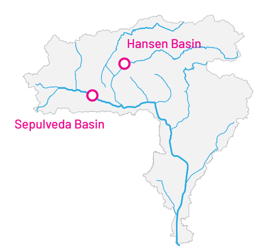
Hansen: 33,348 AF



- Flood Control Basins
- Spreading Grounds
- Debris Basins
- Levees
- Storm Drains
- Dams
- Rivers

Source: LA County GIS Portal, Google Earth, Geosyntec

FLOOD CONTROL BASINS

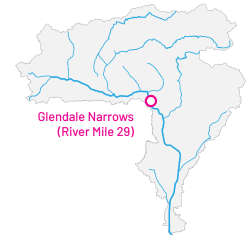


Sepulveda Basin

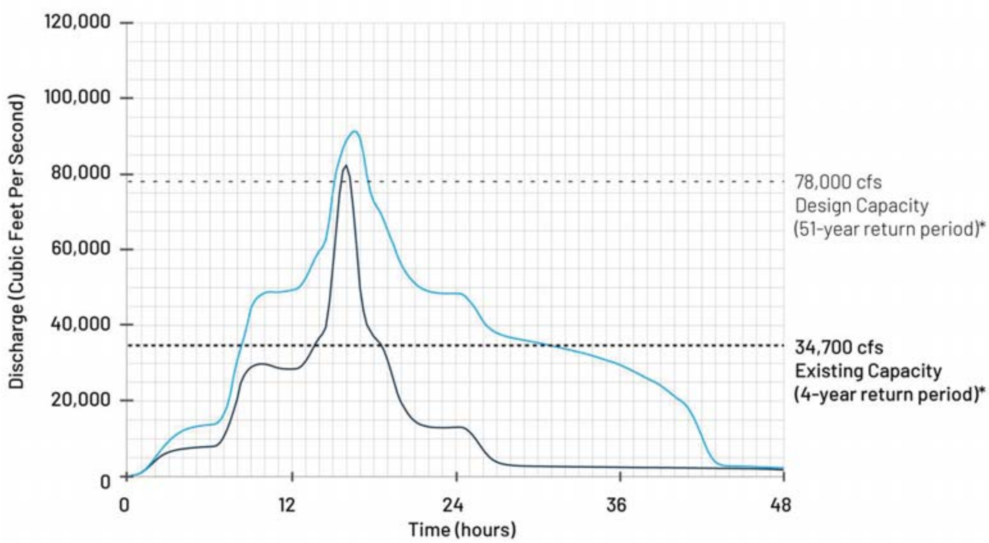
Hansen Basin

Source: Google Earth

NARROWS 100-YEAR STORM WITH LARGER BASINS



Hydrograph: Glendale Narrows, River Mile 29



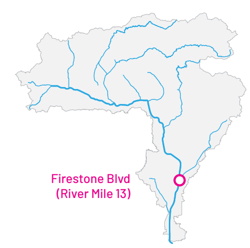
Baseline

With Larger Basins

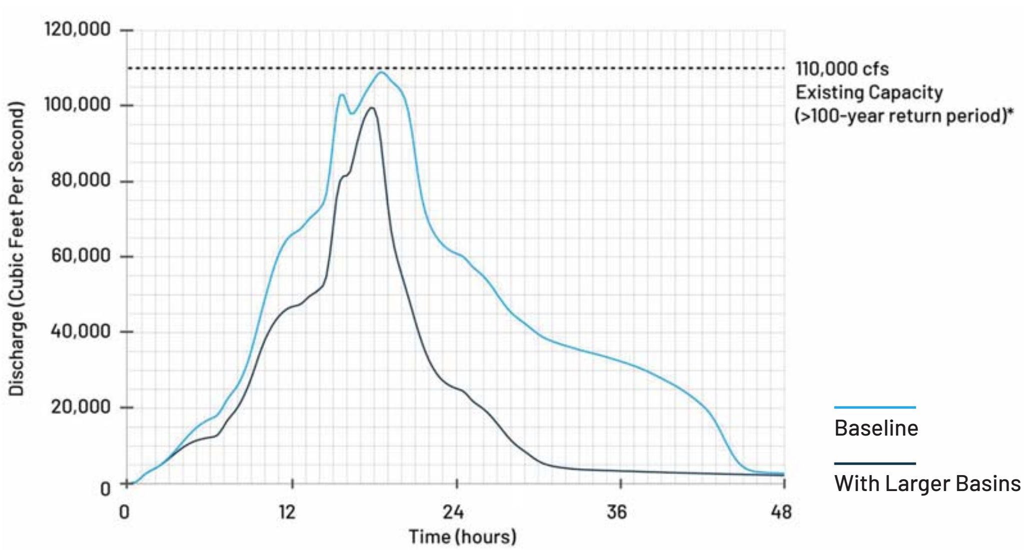
Source: Geosyntec, OLIN
Hydrograph assumes Sepulveda and Hansen Basins are enlarged significantly enough that no outflow occurs.
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

HEC-HMS

FIRESTONE 100-YEAR STORM WITH LARGER BASINS



Hydrograph: Firestone Blvd, River Mile 13



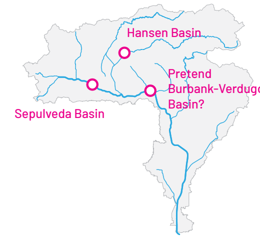
Baseline

With Larger Basins

Source: Geosyntec, OLIN
Hydrograph assumes Sepulveda and Hansen Basins are enlarged significantly enough that no outflow occurs.
* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)

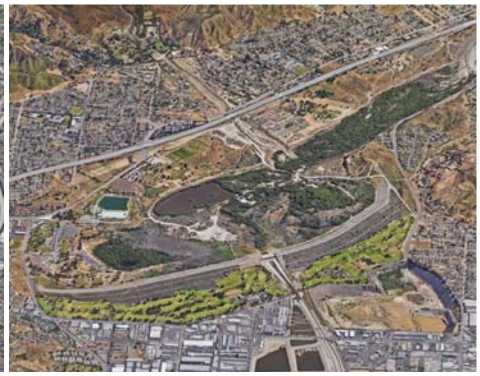
HEC-HMS

FLOOD CONTROL BASINS



Sepulveda Basin

Hansen Basin



Burbank-Verdugo Basin?

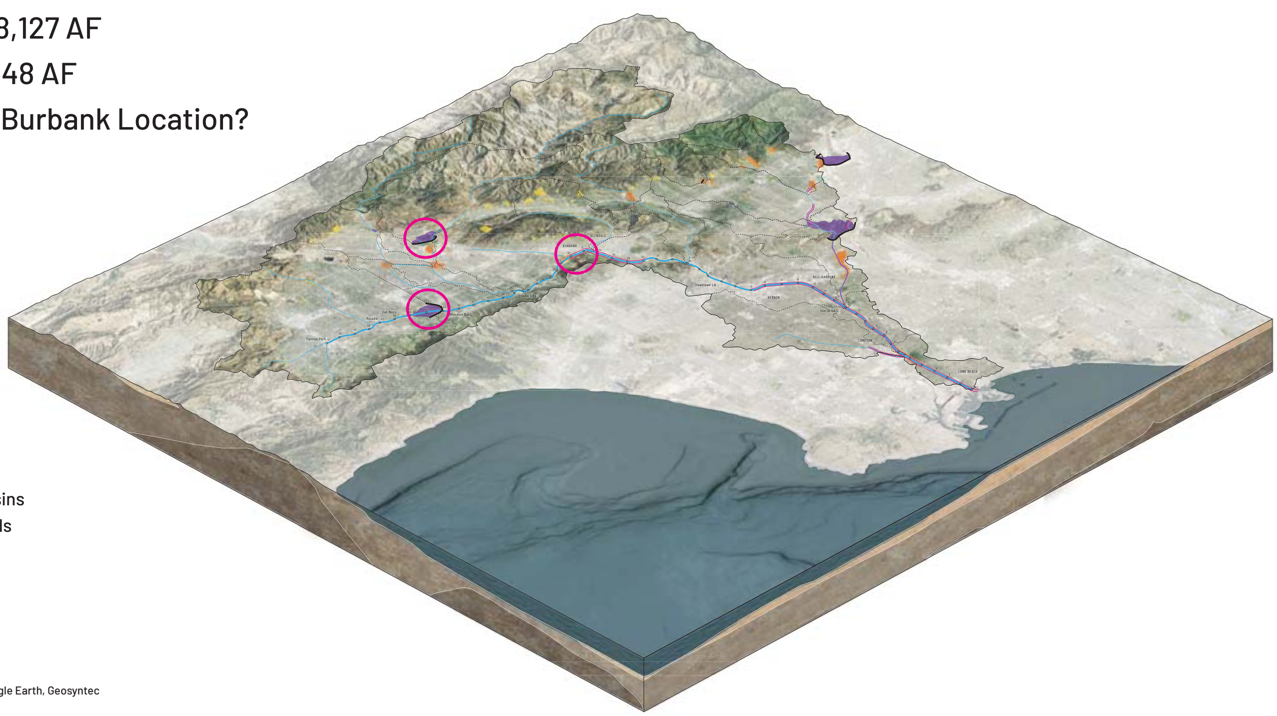
Source: Google Earth

FLOOD CONTROL BASINS

Sepulveda: 18,127 AF

Hansen: 33,348 AF

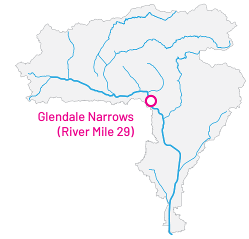
Verdugo and Burbank Location?



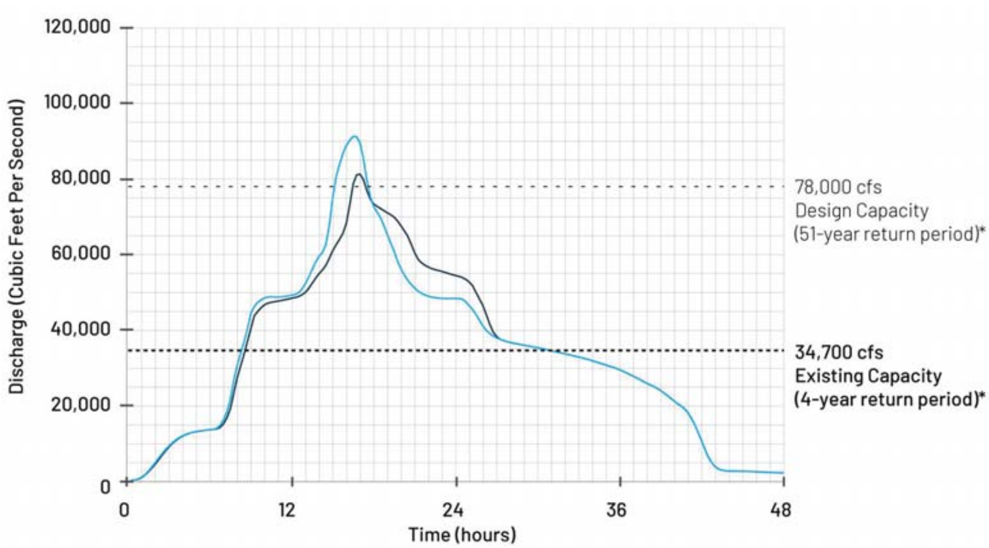
- Flood Control Basins
- Spreading Grounds
- Debris Basins
- Levees
- Storm Drains
- Dams
- Rivers

Source: LA County GIS Portal, Google Earth, Geosyntec

NARROWS 100-YEAR STORM WITH EXTRA BASINS



Hydrograph: Glendale Narrows, River Mile 29



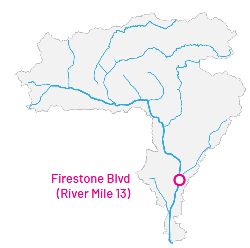
Baseline

With New Basins

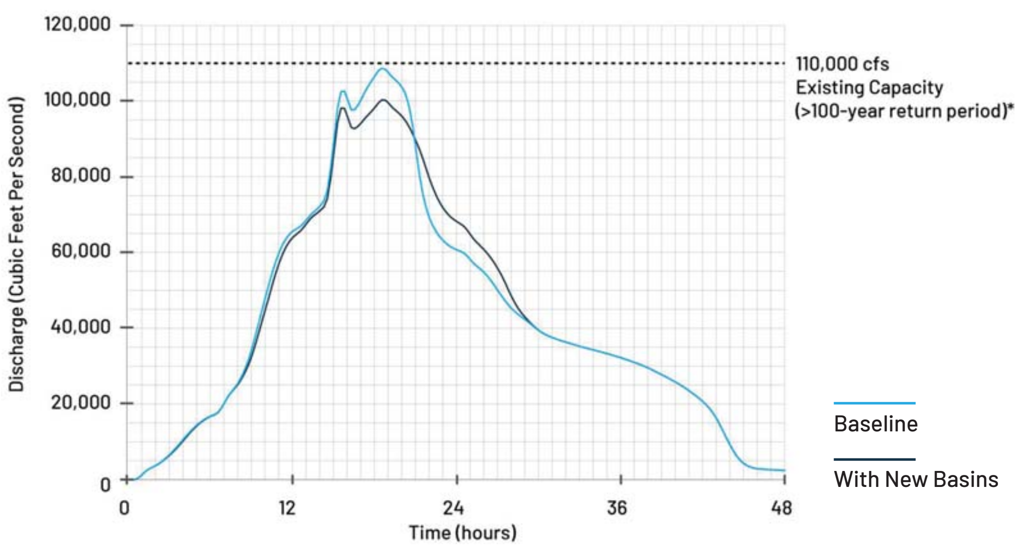
Source: Geosyntec, OLIN
Newly developed Flood Control Basins "modeled" on Burbank and Verdugo Washes, just upstream of confluence with LA River. New basins assume similar operations to Sepulveda.
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

HEC-HMS

FIRESTONE 100-YEAR STORM WITH EXTRA BASINS



Hydrograph: Firestone Blvd, River Mile 13



Source: Geosyntec, OLIN
Newly developed Flood Control Basins "modeled" on Burbank and Verdugo Washes, just upstream of confluence with LA River. New basins assume similar operations to Sepulveda.
* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)

HEC-HMS

INCREASE CHANNEL CAPACITY BY WIDENING THE CHANNEL

Source: OLIN

INCREASE CHANNEL WIDTH

Need to increase by 2 to 3 times

	Existing	Required
K	1.49 ft $^{1/3}$/s	1.49 ft $^{1/3}$/s
A	4,000 ft^2	9,200 ft^2
R	13.5 ft	15.8 ft
S	0.0044	0.0044
n	0.06	0.06
Q	37,000 cfs	95,000 cfs

Source: Geosyntec, OLIN

MANNING'S

NARROWS ARBOR REACHES

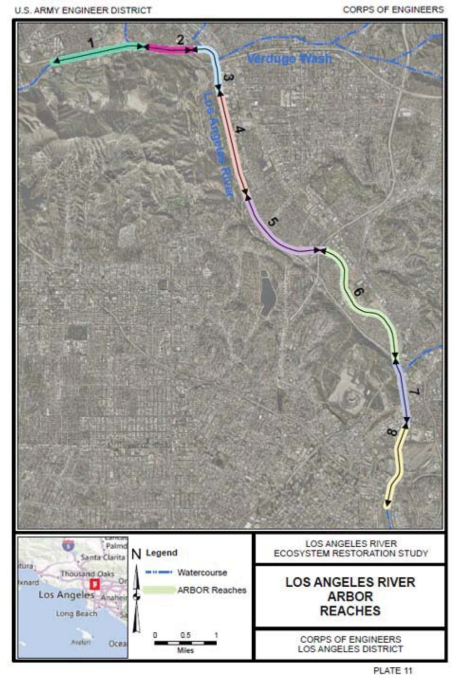
Some sections only manage to the 4-year storm

Table 17: Original Design Discharge and Existing Channel Capacity

Reach[a]	River Stations	Design[b] Discharge ft³/s	Design Return Period [e] yr	Current Freeboard Criteria[c] ft	Existing[d] Channel Capacity ft³/s	Existing Return Period [e] yr	100-Year Discharge[e] ft³/s
Reach 1	625+77 to 547+45	40,000	12	3	29,300	4	81,000
Reach 2	546+45 to 510+05	40,000	7	3	25,800	3	88,900
Reach 3a	504+93 to 477+85	40,000	7	3	63,000[f]	32	88,900
Reach 3b	475+68 to 452+58	78,000	51	3	84,000[f]	69	94,600
Reach 4	432+16 to 359+75	78,000	51	3	34,700	4	94,600
Reach 5	358+63 to 271+89	78,000	51	3	34,000	4	94,600
Reach 6a	270+28 to 262+73	78,000	51	2.5	64,500	24	94,600
Reach 6b	257+85 to 144+23	83,700	57	2.5	50,500	11	93,800
Reach 7a	142+91 to 131+22	83,700	57	2.5	135,400[f]	>500	93,800
Reach 7b	128+71 to 86+61	104,000	83	3	83,700	32	109,000
Reach 8	86+07 to 10+31	104,000	83	3	89,600	42	109,000

Notes:
(a) Letters a & b in Reach names denote a change in the river due to a confluence or change in channel dimensions.
(b) Original design discharge for clean prismatic channel.
(c) Freeboard from EM 1110-2-1601; 3 feet for leveed sections and 2.5 feet for trapezoidal entrenched sections.
(d) Existing channel capacity with vegetation, sedimentation and freeboard. The values shown are the minimum within the reach. Discharges above these listed do not necessarily cause damages.
(e) Return periods for Design Discharge and Existing Channel Capacity are based on discharge frequency analysis for the 1992 LACDA Feasibility Study.
(f) In some limited reaches the existing channel capacity is greater than the original design discharge because of more than adequate freeboard.
(g) Refer to Plates 21a through 24b to see the floodplains for various return frequency flows within the study limits.

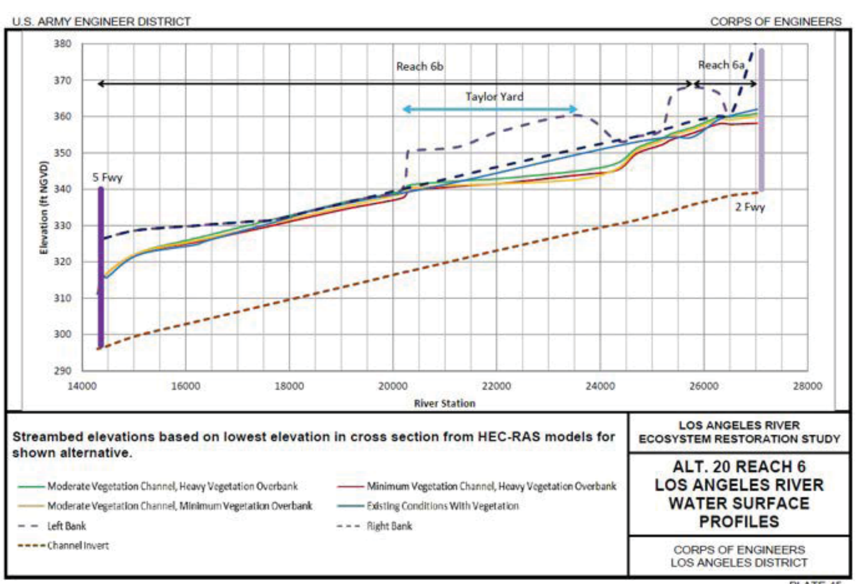
HH Appendix 61 September 2015

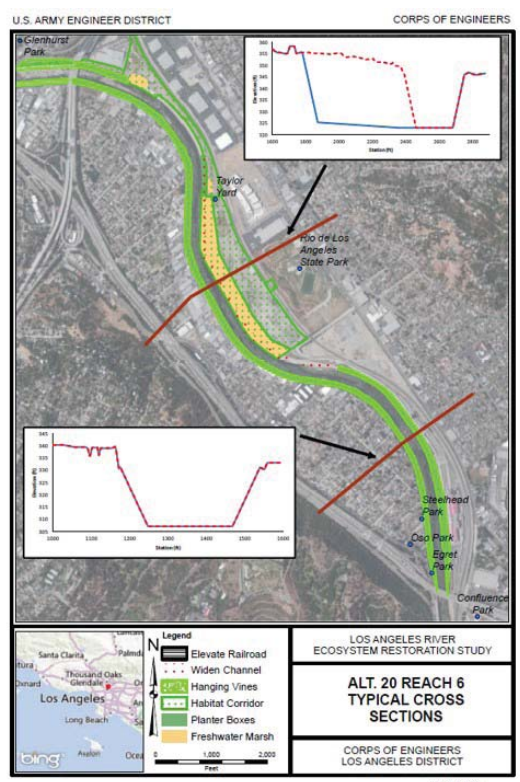


Source: U.S. Army Corps of Engineers, Los Angeles District. Los Angeles River Ecosystem Restoration Project, Volume III, Appendix E (HH Appendix). 2015.

INCREASE CHANNEL WIDTH

Width increase needs to be for extended distances





Source: Los Angles River Ecosystem Restoration Feasibility Study, Appendix E, Hydrology and Hydraulics, US Army Corps of Engineers, Los Angeles District, September 2015

INCREASE CHANNEL WIDTH

May require bridge lengthening or re-design and increasing channel width impacts the right-of-way, private and public real estate, transportation, etc.

Source: Geosyntec, OLIN

INCREASE CHANNEL WIDTH

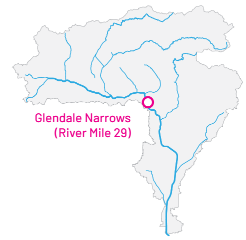
Existing Section: **34,700 cfs capacity**

Alternative Section: **95,000 cfs capacity**

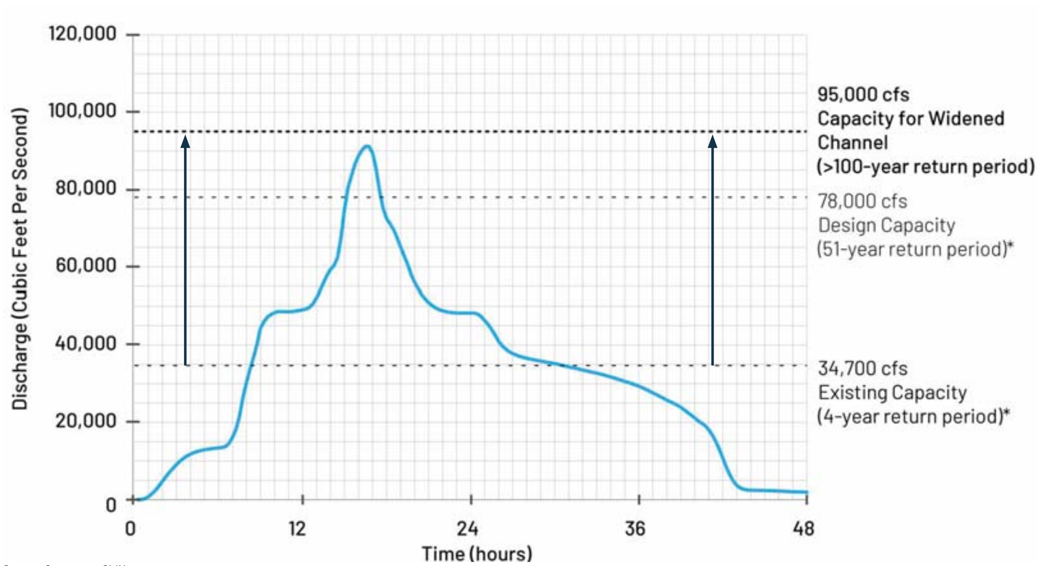
Source: Geosyntec, OLIN

MANNING'S

100-YEAR STORM WITH A WIDER CHANNEL



Hydrograph: Glendale Narrows, River Mile 29

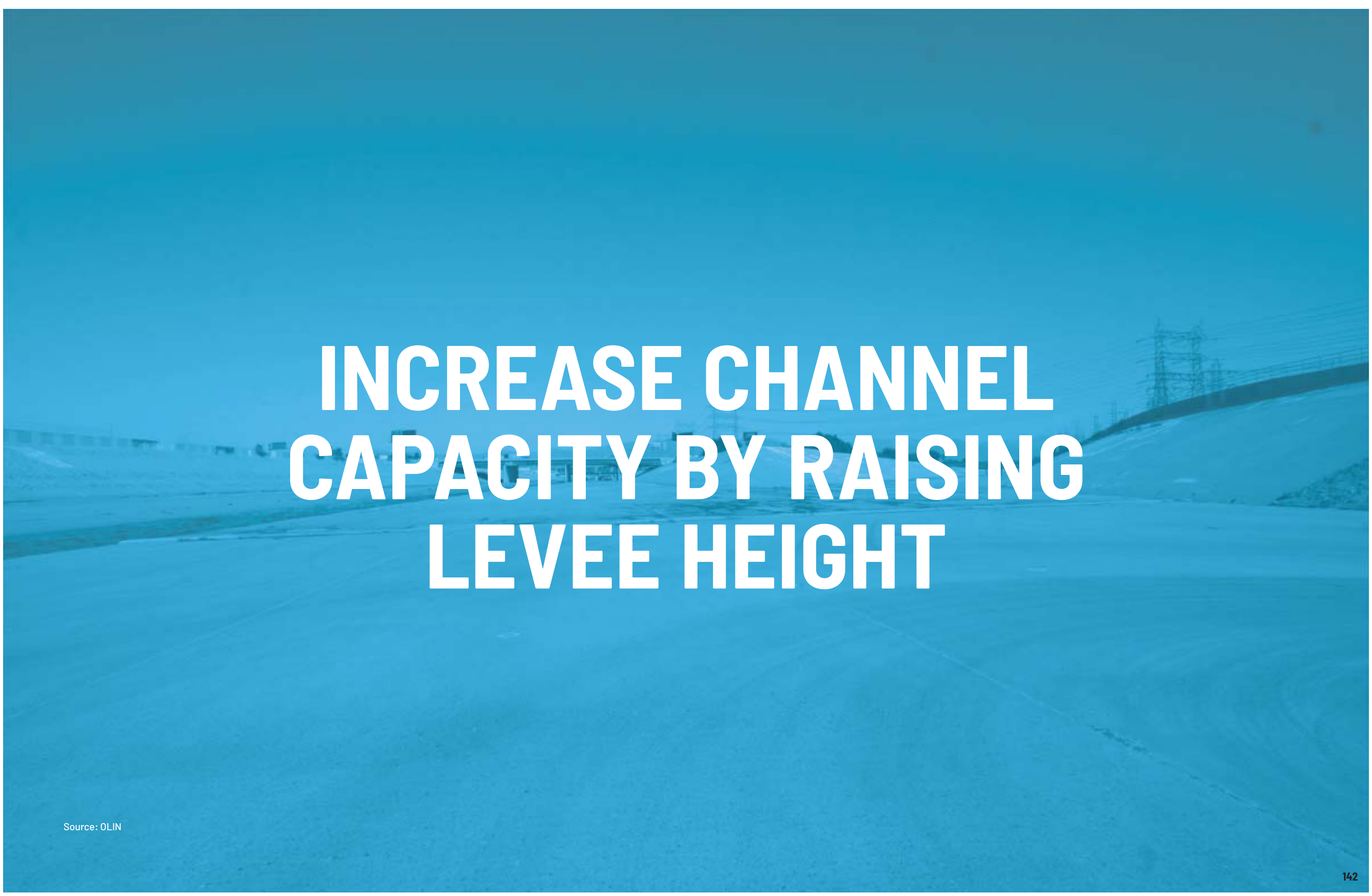


Baseline

MANNING'S

HEC-HMS

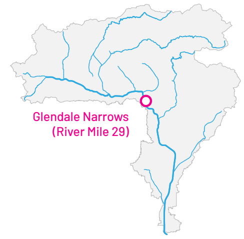
Source: Geosyntec, OLIN
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)



INCREASE CHANNEL CAPACITY BY RAISING LEVEE HEIGHT

Source: OLIN

INCREASE LEVEE HEIGHT / PARAPET WALLS



Existing Section: **34,700 cfs capacity**

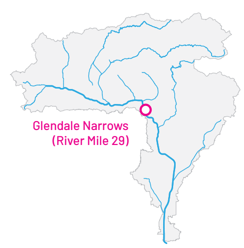
Alternative Section: **95,000 cfs capacity**

12' - 18' high parapet walls
Estimate based on Manning's equation

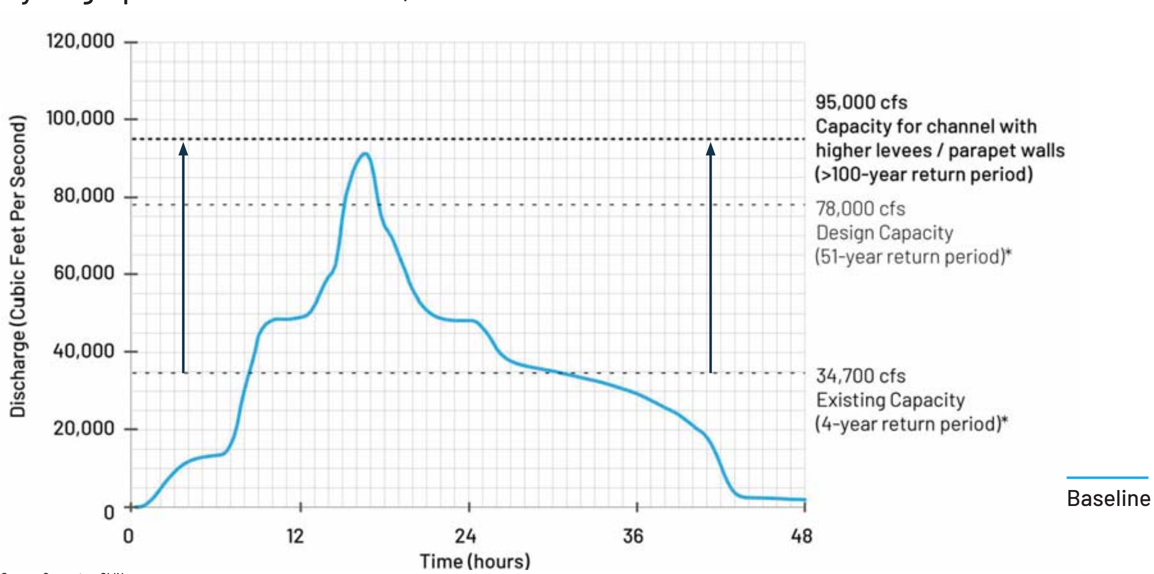
Source: Geosyntec, OLIN

MANNING'S

100-YEAR STORM WITH HIGHER LEVEES / PARAPET WALLS



Hydrograph: Glendale Narrows, River Mile 29



Source: Geosyntec, OLIN
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

MANNING'S

HEC-HMS

INCREASE CHANNEL CAPACITY BY ADDING BYPASS TUNNEL

Source: OLIN

ADD A BYPASS TUNNEL

Existing Section: **34,700 cfs capacity**

Alternative Section: **54,700 cfs capacity**

Source: Geosyntec, OLIN

MANNING'S

BYPASS TUNNEL

- 40 foot diameter concrete tunnel
- 9 miles long
- 0.6% Slope
- Half full
- 20,000 cfs capacity
- Hydraulic challenges
- $2.5 Billion (scaled from Delta Tunnels estimate)

Source: Geosyntec, OLIN

TUNNEL EXAMPLES

TUNNELS	OWNER	DIAMETER (FT)	LENGTH (MI)
Delta Tunnels	CA DWR	2′ x 40′	35
Pawtucket Tunnel	Narragansett Bay Commission	28′	2.5
Euclid Creek Storage Tunnel	Northeast Ohio Regional Sewer District	24′	3.5
Anacostia River Tunnel	DC Water and Sewer Authority	23′	2.4
Lower & Middle River Des Peres Storage Tunnel	Metropolitan St. Louis Sewer District	30′	9

Source: DCWater.com, narrabay.com

HYDROLOGY AND HYDRAULICS

TARP TUNNEL

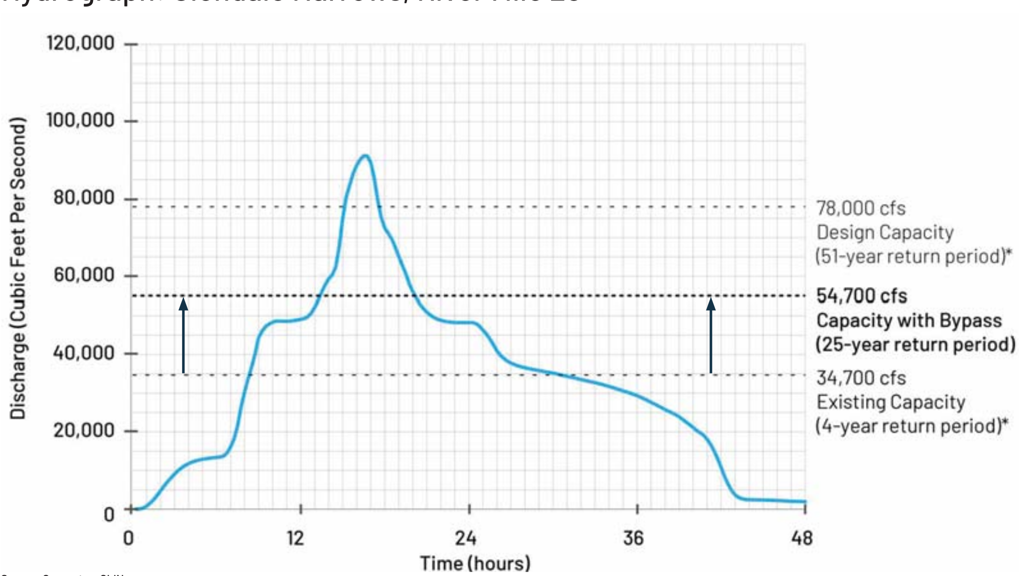
Chicago

Source: OLIN

HYDROLOGY AND HYDRAULICS

100-YEAR STORM WITH BYPASS TUNNEL

Hydrograph: Glendale Narrows, River Mile 29



Baseline

MANNING'S

HEC-HMS

Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

INCREASE CHANNEL CAPACITY BY REFURBISHING THE CHANNEL

Source: OLIN

REFURBISHMENT

To increase channel capacity: remove invasives, remove sediment, maintain channel, replace exotic with native grasses.

Existing Section: **34,700 cfs capacity**

n = 0.06

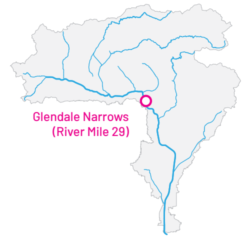
Alternative Section: **78,000 cfs capacity**

n = 0.03

Source: Geosyntec, OLIN

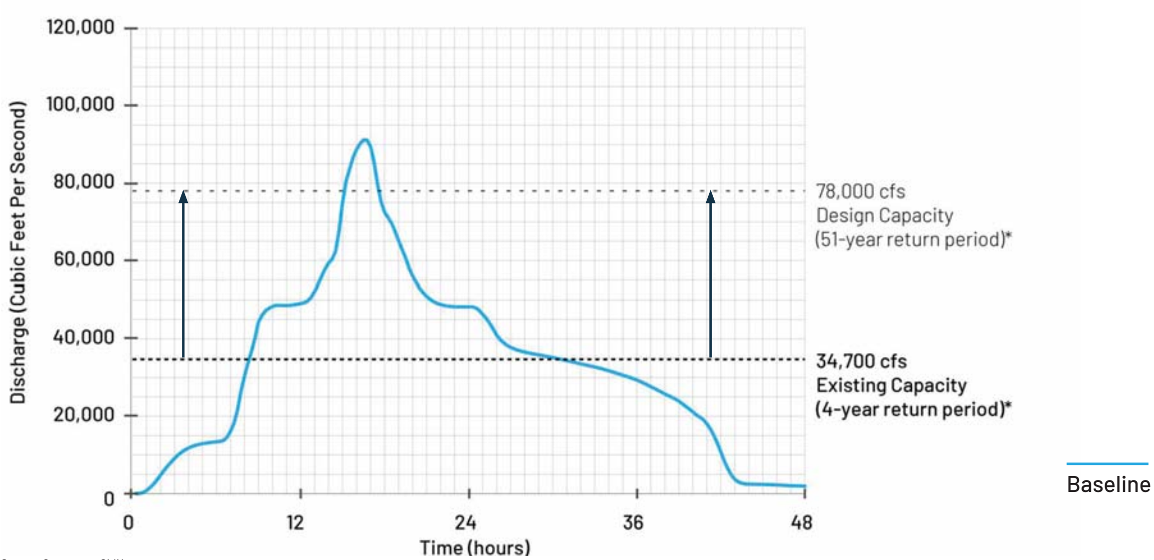
HEC-RAS

100-YEAR STORM WITH REFURBISHMENT



To increase channel capacity: remove invasives, remove sediment, maintain channel, replace exotic with native grasses.

Hydrograph: Glendale Narrows, River Mile 29



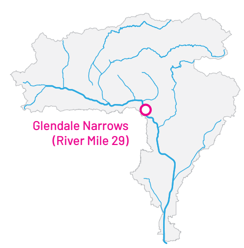
HEC-HMS

HEC-RAS

Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

CONCRETE



To increase channel capacity: harden the channel bottom to reduce friction.

Existing Section: **34,700 cfs capacity**

n = 0.06

Alternative Section: **120,000 cfs capacity**

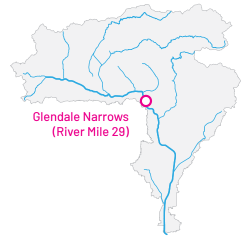
n = 0.016

Source: Geosyntec, OLIN

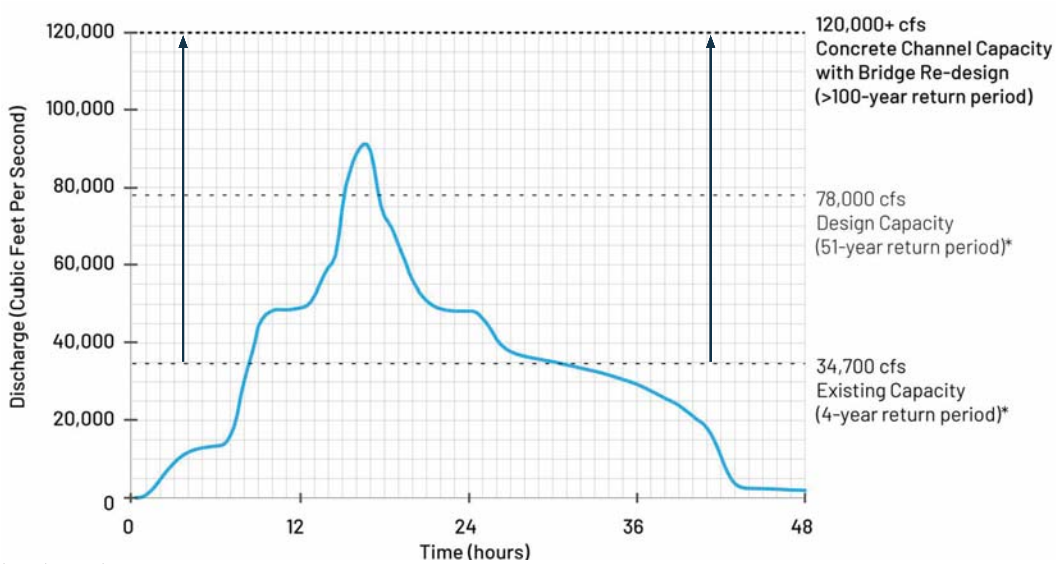
HEC-RAS

100-YEAR STORM WITH CONCRETE BOTTOM

To increase channel capacity: Harden the channel bottom to reduce friction.



Hydrograph: Glendale Narrows, River Mile 29



Baseline

HEC-HMS

HEC-RAS

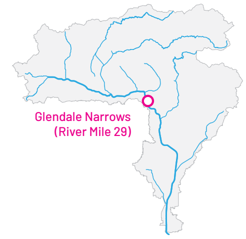
Source: Geosyntec, OLIN
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

INCREASE CHANNEL CAPACITY BY COMBINING IDEAS

Source: OLIN

REFURBISHMENT + BYPASS TUNNEL

Remove invasives and sediment, maintain channel, optional native grasses, build bypass



Existing Section: **34,700 cfs capacity**

Alternative Section: **98,000 cfs capacity**

MANNING'S

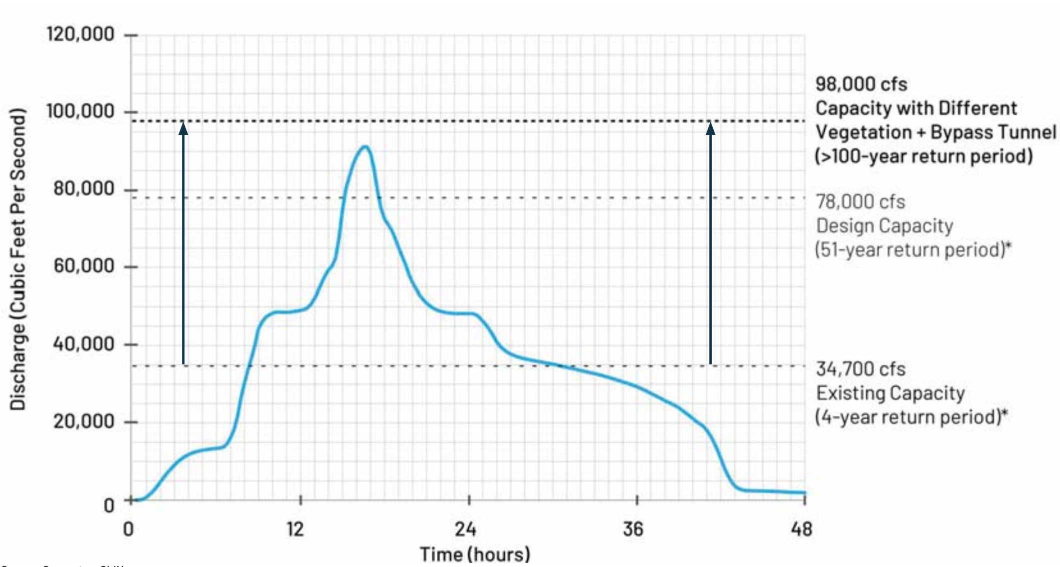
HEC-RAS

Source: Geosyntec, OLIN

REFURBISHMENT + BYPASS TUNNEL

Remove invasives and sediment, maintain channel, optional native grasses, build bypass

Hydrograph: Glendale Narrows, River Mile 29



Baseline

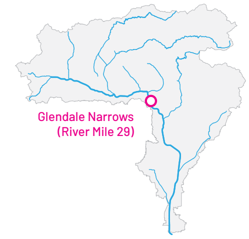
HEC-HMS

MANNING'S

HEC-RAS

Source: Geosyntec, OLIN

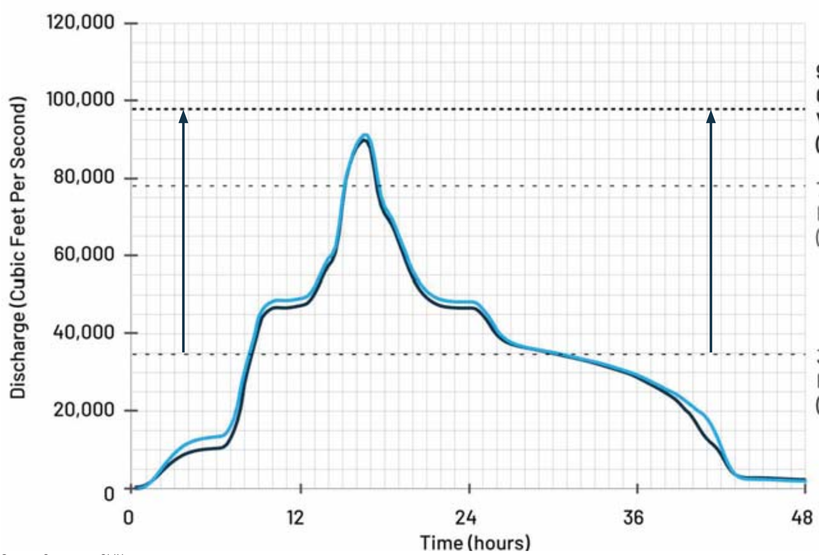
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)



REFURBISHMENT + BYPASS + EWMP 2037

Remove invasives, remove sediment, maintain channel, optional native grasses, build bypass, 28% impervious surface reduction

Hydrograph: Glendale Narrows, River Mile 29



Source: Geosyntec, OLIN
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

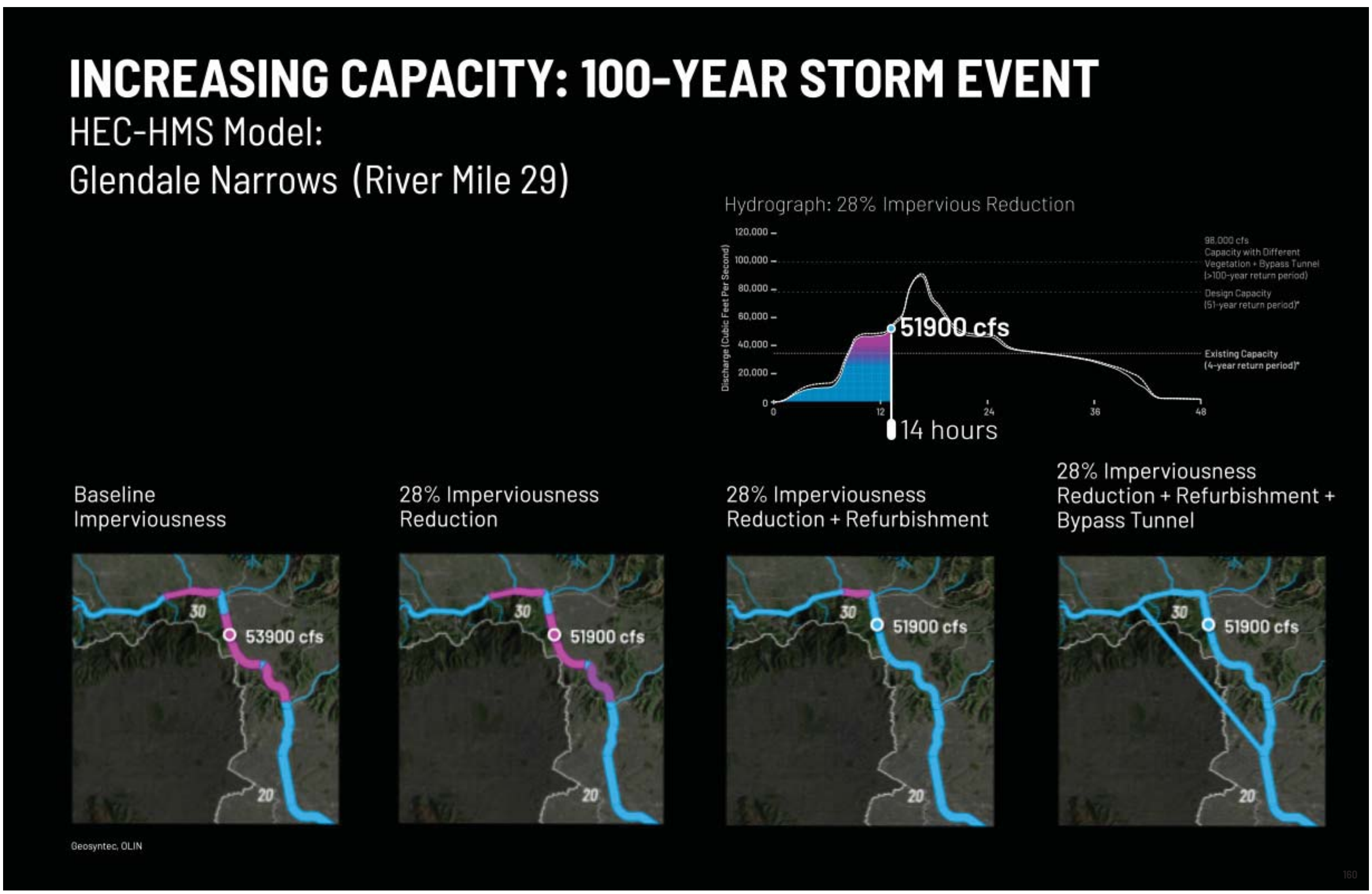
Baseline

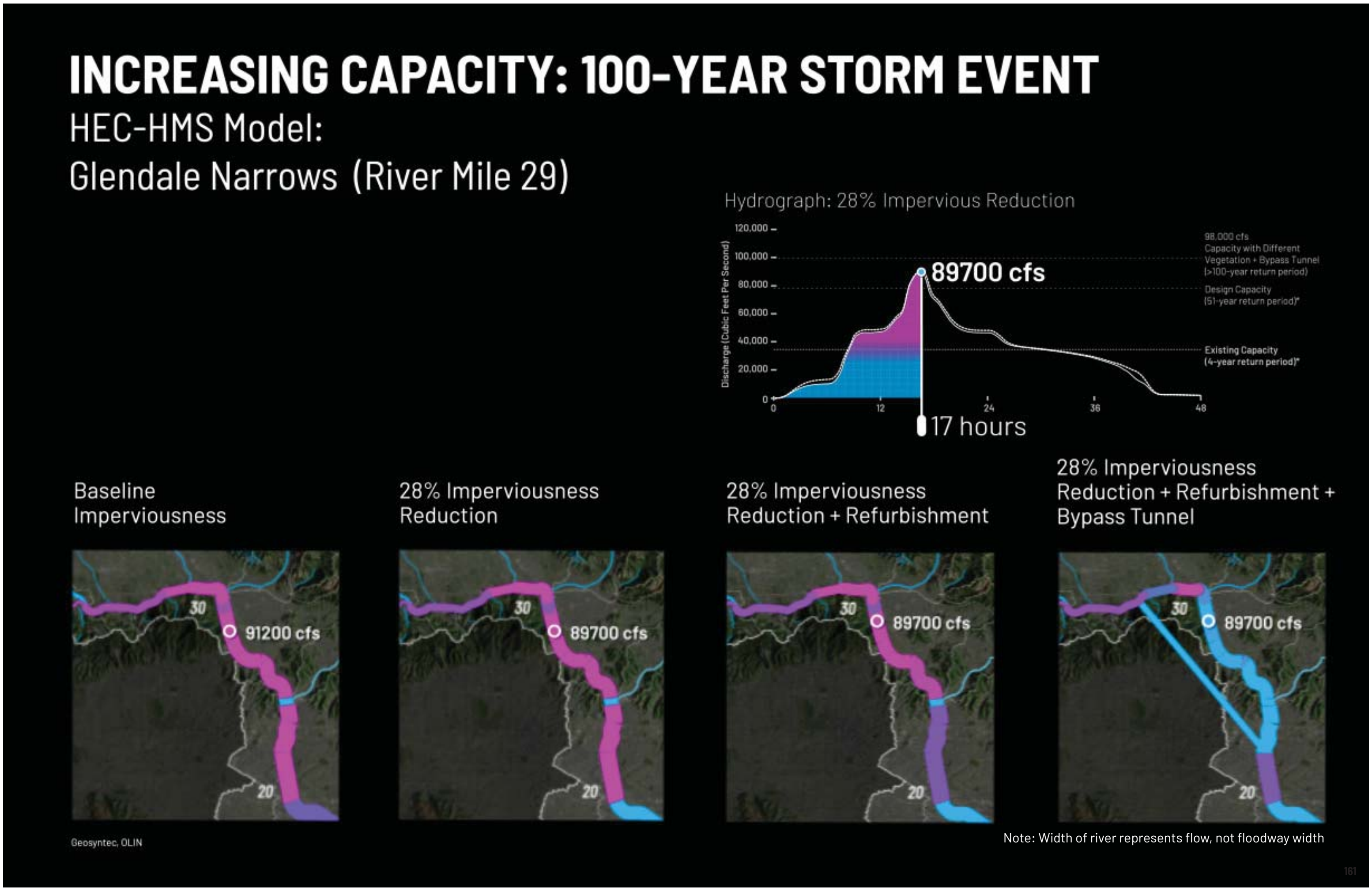
28% Reduction in Imperviousness

HEC-HMS

MANNING'S

HEC-RAS





IDEAS TO...

REDUCE FLOWS TO THE CHANNEL

- Low Impact Development
- Best Management Practices
- Distributed Storage
- Increase Sepulveda and Hansen Flood Control Basins
- Additional Flood Control Basins

INCREASE CHANNEL CAPACITY

- Increase Channel Width
- Increase Levee Height
- Bypass Tunnel
- Sediment Removal/Vegetation Conversion
- Concrete

HYDROLOGY AND HYDRAULICS

Q & A AND DISCUSSION

PARTICIPANTS

- **Iraj Nasseri, Ph.D., P.E.** (Los Angeles County Flood Control District)
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WRAP UP

What have we learned?

What needs more study/analysis?

Web Resources:

- County real-time precipitation gages
  https://dpw.lacounty.gov/wrd/precip/alert_rain/index.cfm
- USACE real-time precipitation gages
  http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larP
- USACE real-time flow rates
  http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF
- County HydroCalc
  http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip
- USACE HEC-HMS
  https://www.hec.usace.army.mil/software/hec-hms/
- USACE HEC-RAS
  https://www.hec.usace.army.mil/software/hec-ras/
- Manning's calculator
  http://onlinecalc.sdsu.edu/onlinechannel01.php

LA RIVER MASTER PLAN

LARiverMasterPlan.org