Establishing Environmental Flows for the Los Angeles River

Stakeholder Working Group Meeting #2 – October 18, 2019

SCCWRP
Established 1969

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

Council for Watershed Health

COLORADO SCHOOL OF MINES
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Background

- During dry period, Los Angeles River instream flow primarily wastewater treatment plant discharges from facilities managed by the cities of Los Angeles, Glendale and Burbank
- All three have plans to recycle a portion of their wastewater and have petitioned to the State Water Board Division of Water Rights to reduce discharges to river
- Reductions may affect existing beneficial uses such as recreation and aquatic life
- Water Boards support beneficial use protection and recycling
- Study goal is to evaluate impacts on a watershed level

Central Question

What are the potential impacts to existing instream beneficial uses in the Los Angeles River caused by reductions of wastewater treatment plant discharges?

Meeting Objectives and Agenda

Meeting Objectives:

- Receive stakeholder input on the technical work to date
- Review technical advisory group recommendations
- Share information about stakeholder outreach and community insights

AGENDA

1. Project overview/recap
2. Recreational use study
3. Key habitats and representative species
4. Update on modeling
5. Proposed approach to evaluate management scenarios
6. Outreach reports

Los Angeles River Environmental Flows Project Goals

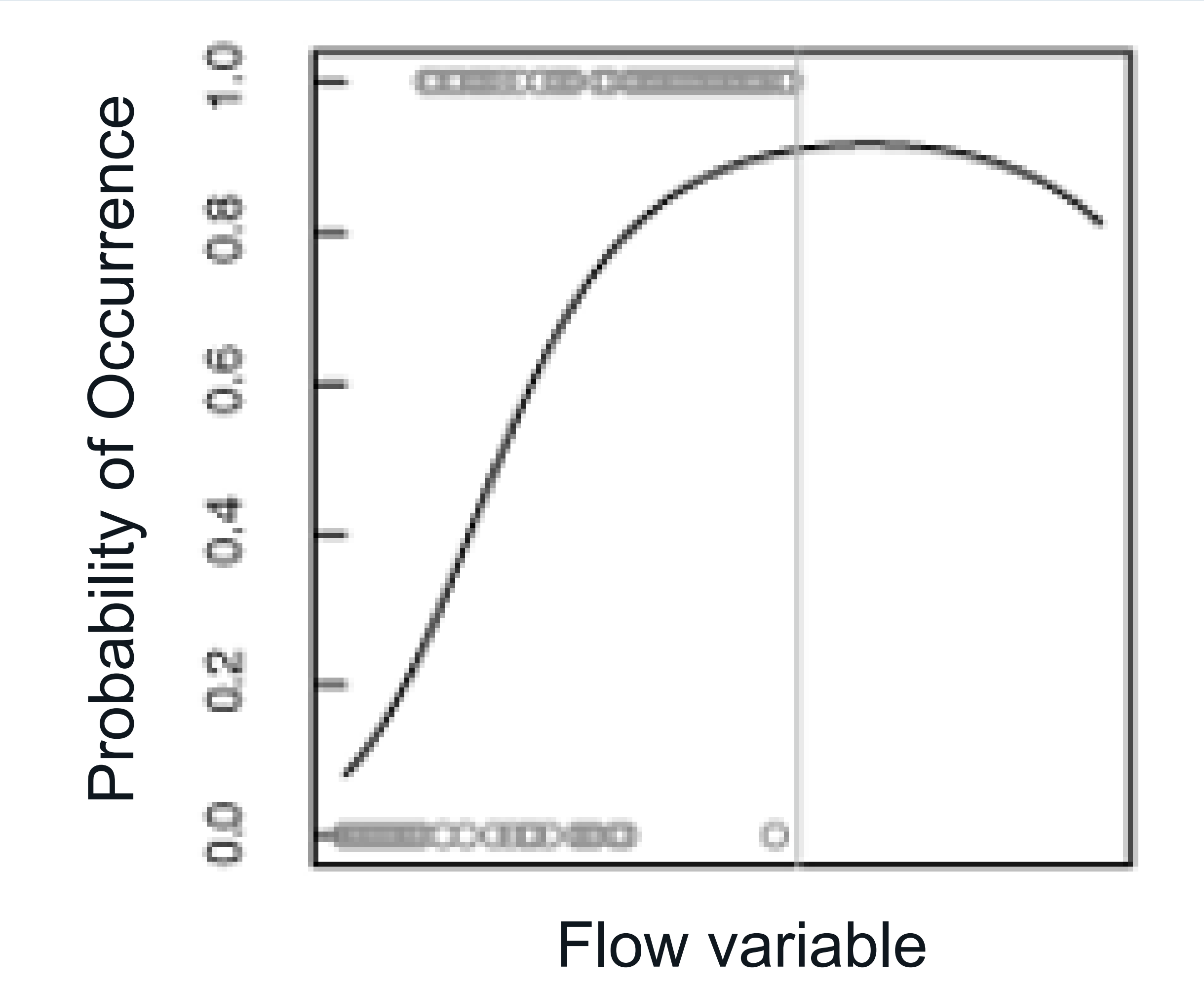
1. Develop technical tools that quantify the relationship between various alternative flow regimes and the extent to which aquatic life and non-aquatic life beneficial uses are achieved

2. Evaluate various flow management scenarios in terms of their effect on uses in the LA River.

3. Engage multiple affected parties to reach consensus about appropriate flow needs and optimal allocation of flow reduction allowances from multiple WRPs in consideration of other proposed flow management actions

What We Want

- Which species?
- Which habitats?
- What seasons?
- What scenarios?
- What management?

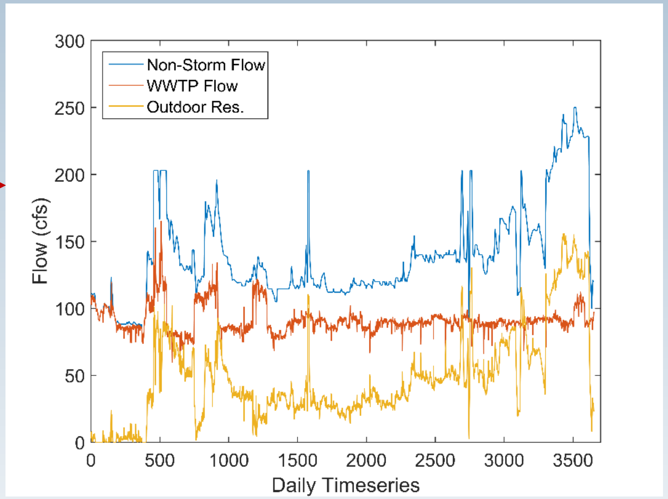


Overall Process for Developing Flow Criteria

Models

Scenario	Description
1	WRP
2	WRP + stormwater
3	WRP + conservation
4	WRP + stormwater + conservation

Scenarios



Time series output

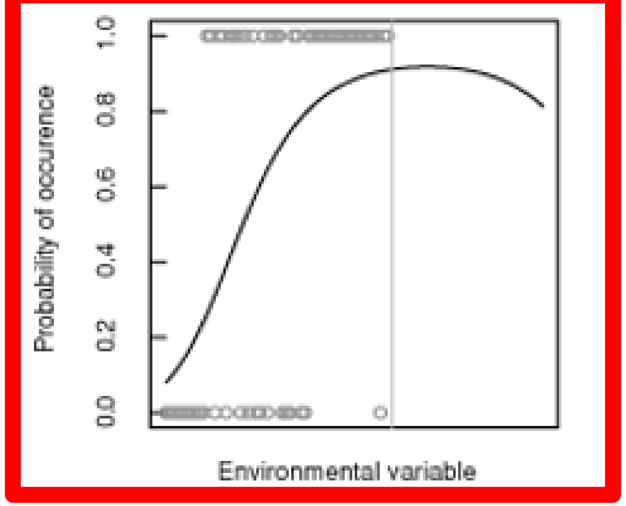
Hydrologic

- Minimum annual flow
- Duration of consecutive minimum annual flow
- Frequency of high winter flows Oct-March
- Frequency of Spring flush flows march-June
- Date of latest flood during the winter
- Decrease in flow per day in Spring following last Winter flood
- Magnitude of summer base flow

Hydraulic

- Presence of riffle (moderate depth, swift current, course substrate) habitat in Spring for spawning
- Percent of habitat as edgewater, riffle, and pools in the Spring and Summer
- Minimum and maximum bottom velocity in the Spring and summer
- Minimum depth of water in Spring, Summer, and Fall

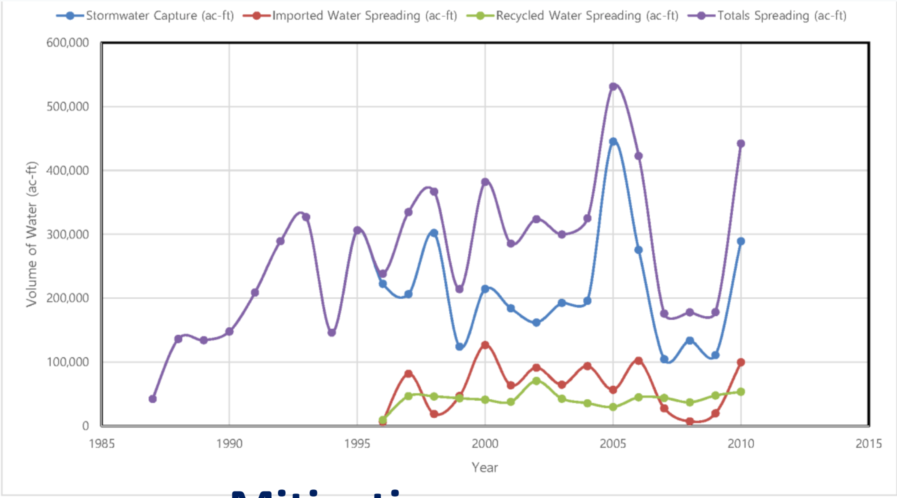
E-flow metrics



Flow-ecology relationships

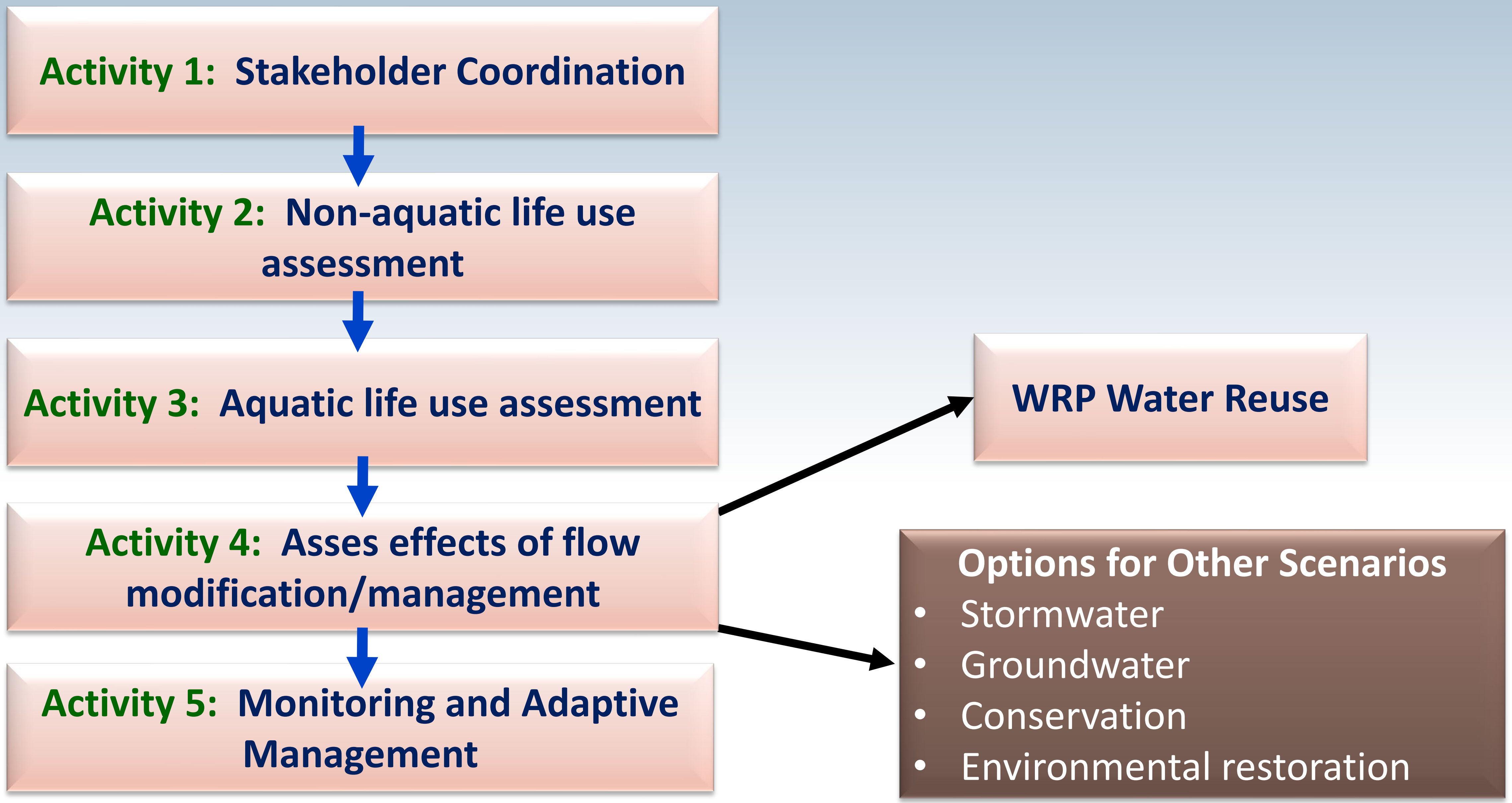
- **Flow Criteria**
  - ✓ **by reach and season**
- **Management/mitigation recommendations**

Agreed upon criteria

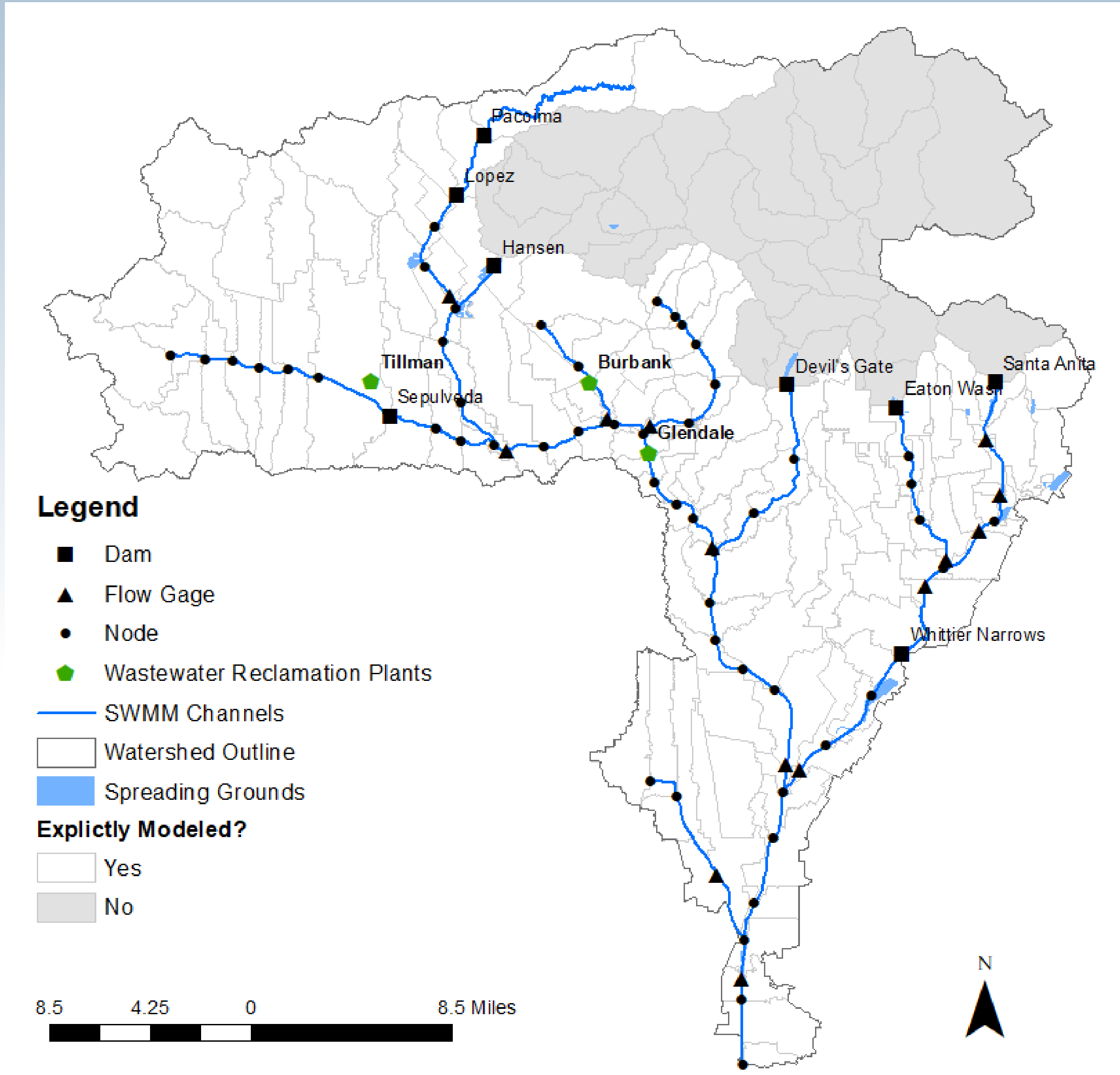


Mitigation measures

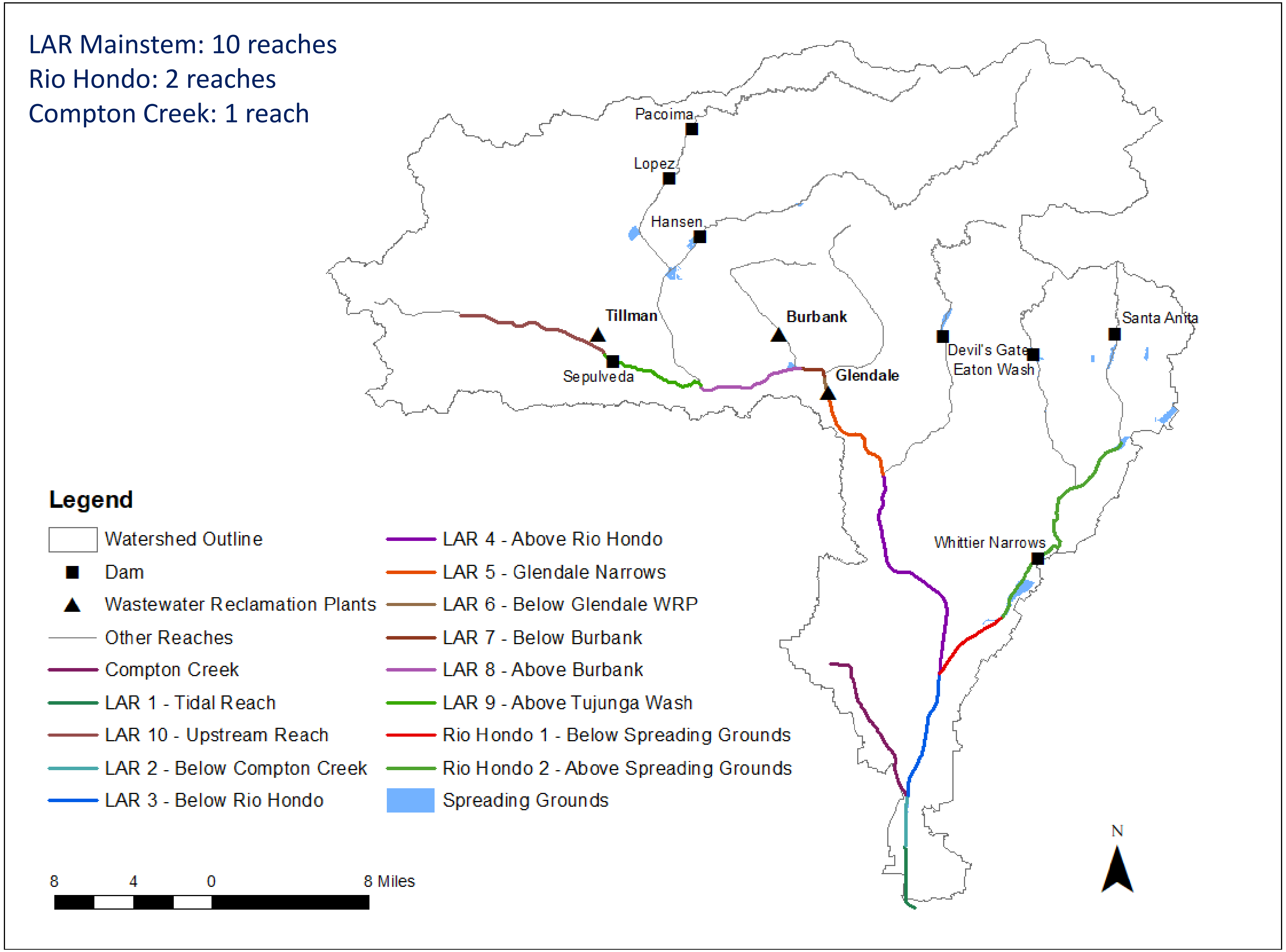
Assessing Environmental Flows for LAR



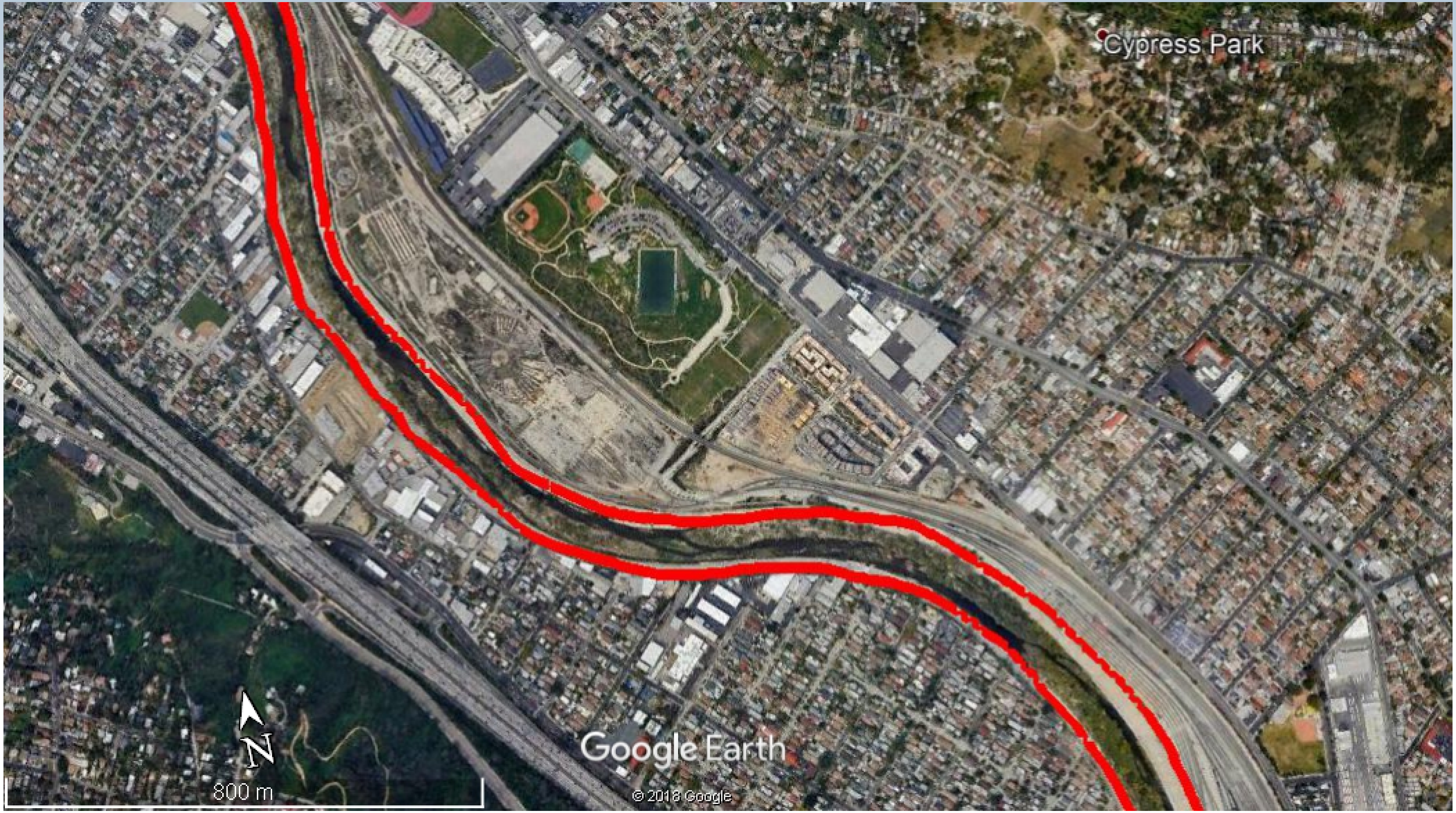
Proposed Model Domain



Proposed Analysis Reaches



Study Focus



Schedule

Activity / Sub-Tasks	2018 Q4	2019 Q1	2019 Q2	2019 Q3	2019 Q4	2020 Q1	2020 Q2	2020 Q3	2020 Q4
Activity 1 - Stakeholder coordination									
Activity 2 - Non-aquatic Life Use Assessment									
Activity 3 - Aquatic Life Beneficial Use Assessment									
Activity 4 - Apply Environmental Flows/Evaluate Scenarios									
Activity 5 - Monitoring and Adaptive Mangement Plan									
Activity 6 - Summary of results/reporting									

Stakeholder Meetings

TAC Meetings

Summary from Last Meeting

- Provided an overview of the project
- Discussed and received input on initial project elements
- Agreed on workgroup structure and approach

Last Meeting: Action Items

- Documents to be available in advance of the meetings (2-4 weeks in advance)
- Project Team to post all meeting handouts and meeting notes
- Group members to sign up for formal SWG participation
- Webpage to be launched
- Project Team to initiate AB52 Consultation as appropriate
- SWG members to advise of their ability to host remaining meetings
- Staff and group members to continue outreach to ensure community representation

Work to Date

- ✓ Data compilation (recreational uses, species, habitats, environmental conditions)
- ✓ Mapping of aquatic life and recreational uses by reach
- ✓ Completed non-aquatic life use assessment
- ✓ Further defined list of focal habitats and key species
- ✓ Characterized habitat needs and tolerance ranges
- ✓ Initiated review of biological modeling options
- ✓ Set up hydrologic and hydraulic models and initiated calibration
- ✓ Compiled water quality data and identified data gaps
- ✓ Held three TAC and two SWG meetings (including today's meeting)
  - ✓ Held one TAG webinar

Today's Meeting

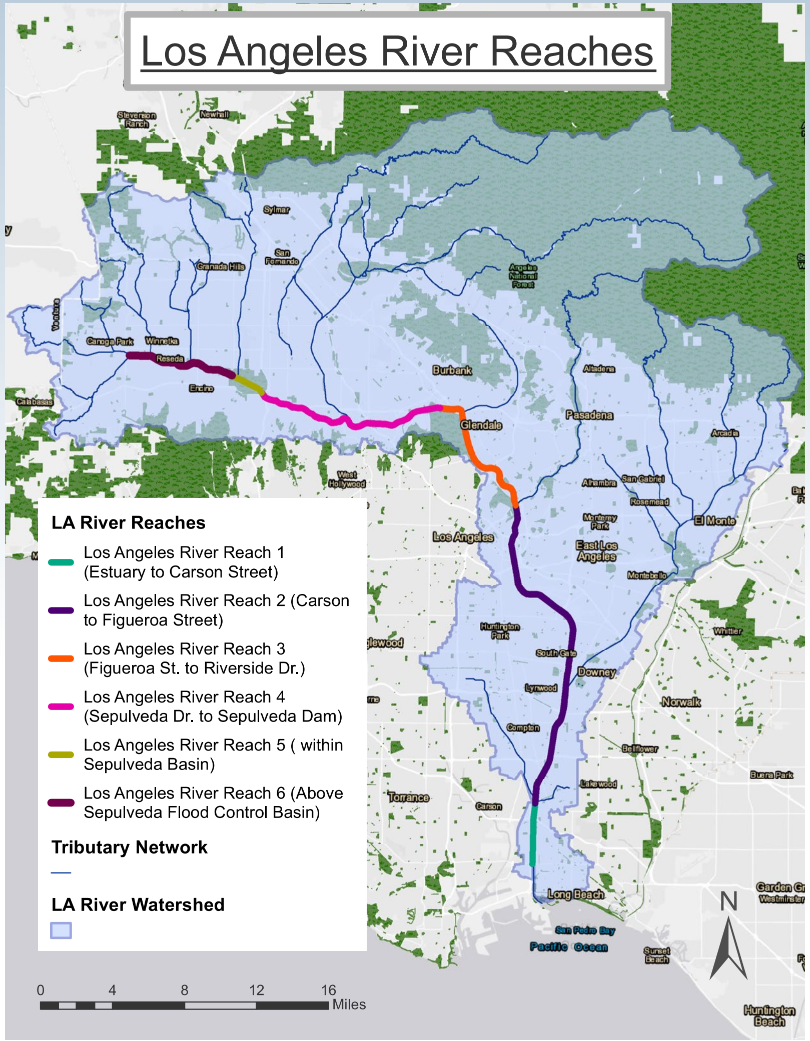
- Project overview/recap
- Recreational use study
- Key habitats and representative species
- Update on modeling
- Proposed approach to evaluate management scenarios
- Outreach reports

Yareli Sanchez – Council for Watershed Health

RECREATIONAL USE STUDY

Objective

- Understand recreational uses that occur along the main-stem of the Los Angeles River and the associated flow needs



Approach

- Recreational experts
  - NGOs, government entities, community leaders, and local businesses
  - Missions or programs related to river access, active transit, recreation, river revitalization, community engagement and education

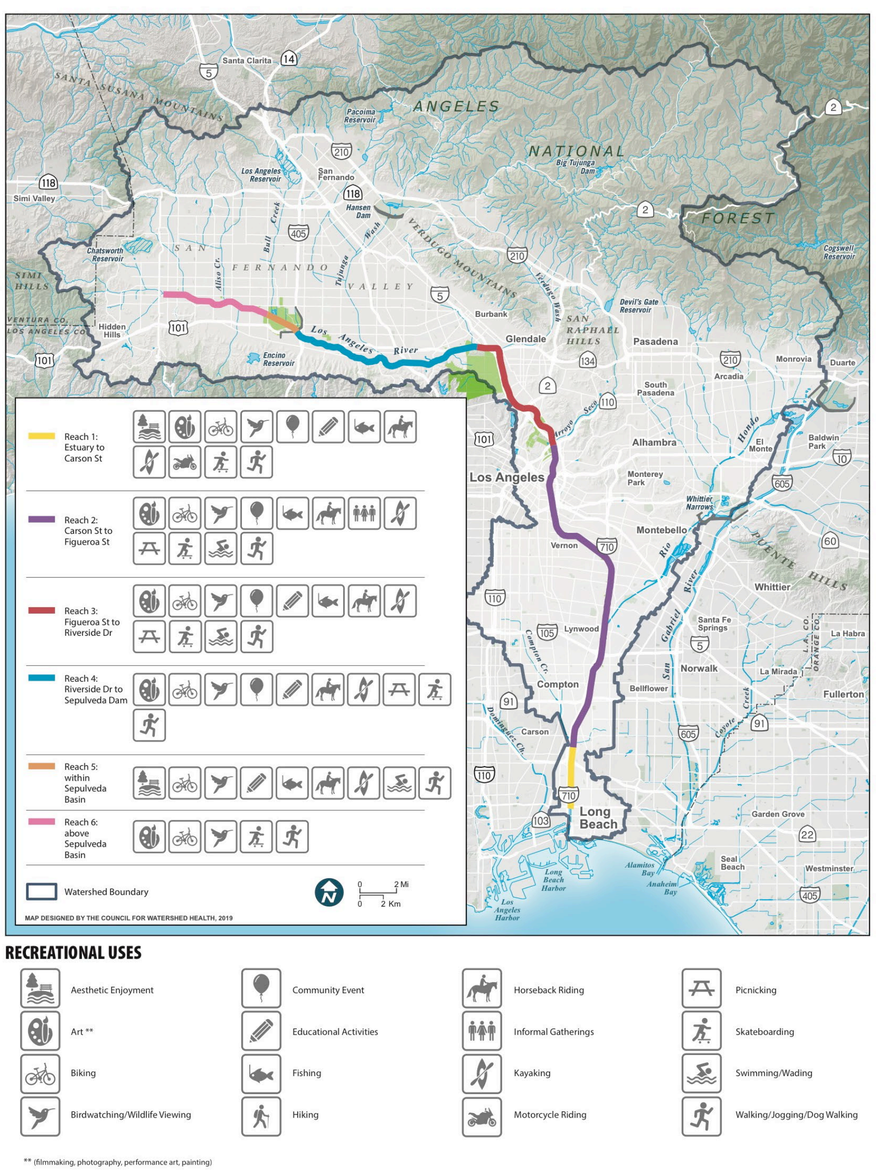
- Snowball sampling (who are we missing?)

- Interested participants invited to a focus group meeting, follow-up phone interview with individuals that were unable to attend
  - Open ended questions about recreational use along each reach
  - Experts rank indicators

Social Media Approach

- Supplementary information about recreational use
  - Used Instagram to gather supplemental information about recreational use and where uses occur
  - Geotagged photos linked to the nearest flow gauge by date
- Compare results with 2014 RECUR Report
  - Comprehensive (in person survey, online, and observation data)

Results



The Los Angeles River hosts a rich diversity of recreational uses in both soft bottom and hard bottom reaches.

Results

- Common themes
  - Difficulty in identifying flow targets
  - Safety and access
  - Relationship between recreational use and aesthetics of river

- Water quality is an important indicator for all recreational uses - enough water volume so that smell, excessive algal growth, and bio-accumulating contaminants would not cause nuisance or harm to people or wildlife.

Results

- Social media data helped identify aesthetic and educational uses along the river and the range of flow conditions associated with recreational uses

- Flow indicators important
  - Higher targets: aesthetic, boating, wading
  - Lower targets: community events, fishing, horse back riding, path activities

- Uncertainty in targets for the majority of uses
  - Flow targets for kayaking, wading, fishing

Relating Flow to Recreational Uses

- Eric ADD

Q&A – RECREATIONAL USE STUDY

September 16, 2019

TECHNICAL ADVISORY COMMITTEE (TAC) MEETING

Summary from TAC Meeting

Meeting on September 16, 2019

- Reviewed focal habitats for LA River and key hydrologic needs
- Update on model development
- Discuss potential flow management and restoration scenarios

Decisions Made:

- Agreed on process for habitat characterization and representative species selection
  - TAC webinar (Oct. 7) to discuss habitat descriptions and selected representative species
- Agreed on process for evaluating flow management scenarios

Eric Stein – SCCWRP

HABITAT CHARACTERIZATION

Habitat Characterization Process

✓ Identify and define major habitats

✓ Identify assemblages or key species

- Characterize habitat needs (hydraulic/hydrologic thresholds)
- Translate hydraulic needs to functional flow metrics
- Model occurrence of ranges with flow management scenarios

Focal Habitats

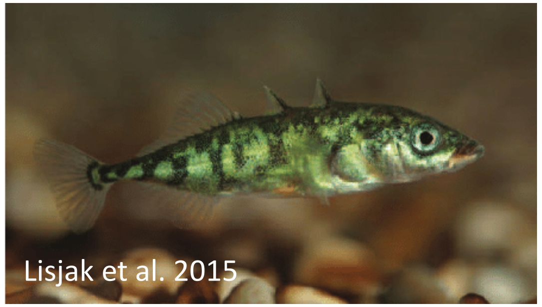
- **Cold water habitat**
- **Migration habitat**
- **Wading shorebird habitat**
- **Freshwater marsh habitat**
- **Riparian habitat**
- **Warm water habitat** – as a surrogate for invasive spp. Habitat

Cold Water Habitat

Intermittent to perennial flowing stream, typically less than 50 cm in depth and temperatures less than 30°C for survival and less than 23°C for reproduction (during spring), high canopy cover. Can include areas with groundwater upwelling or riffle-run-pool sequences. Shallow pools and edgewater habitat may also be present.

Not currently present, but could potentially be in the future

- Representative species:
  - Unarmored threespine stickleback
  - Santa Ana sucker



Migration Habitat

Flowing stream, typically greater than 50 cm depth in winter (Jan/Feb) and 20 cm depth spring (Mar/Jun), with temperatures less than 30°C and lacking physical barriers to migration and gaps in surface flow during the winter and spring migration seasons.

- Ability to promote seasonal migration to and from upper watershed breeding areas
- Overlays and co-occurs with other habitat groups

- Representative species:
  - Steelhead/Rainbow Trout


Photo Cred: Dave Giodarno


Photo Cred: National Parks Service

Wading Shorebird Habitat

Shallow water habitat outside and adjacent to the low flow channel, generally less than 10 cm in depth. Typically lacks rooted vegetation.

- Representative species:
  - Green algae - Cladophora

Freshwater Marsh Habitat

Mix of open water and emergent or aquatic vegetation, generally less than 50cm in depth over fine substrate that has been deposited on either soft bottom or concrete. Either ponded or very low flow. Shallow pools and edgewater habitat may also be present.

- Representative species:
  - Cattails
  - Duckweed


Photo Cred: KCET


Photo Cred: Bill Gray

Riparian Habitat

Vegetated areas on the benches adjacent to the low flow or active channel. Fine to coarse substrates deposited on either soft bottom or concrete. Can have intermittent to perennial flow but remains saturated for enough time to allow vegetation establishment. Shallow pools and edgewater habitat may also be present.

- Representative species:
  - Sandbar willow
  - Black willow

Photo Cred: theriverproject.org

Photo Cred: Wikimedia

Warm Water Habitat

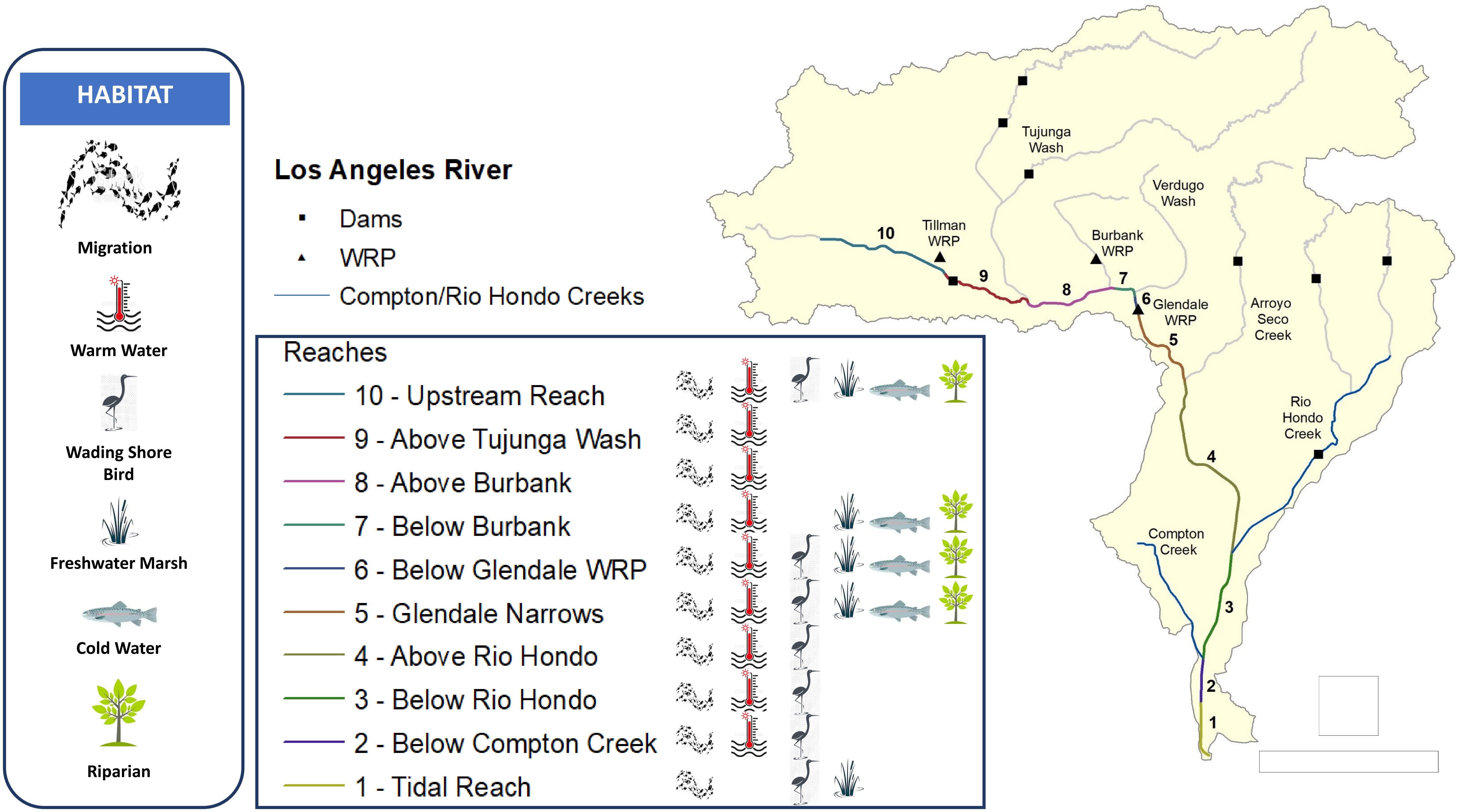
Perennially flowing stream, typically greater than 50 cm in depth and temperature greater than 30°C. Flows are often sluggish (and may include pools or ponds with or without aquatic vegetation).

Surrogate for invasive species

- Representative species:
  - African clawed frog
  - Mosquitofish

Californiaherps.com

glacvcd.org


HABITAT
Migration
Warm Water
Wading Shore Bird
Freshwater Marsh
Cold Water
Riparian
Los Angeles River
Dams
WRP
Compton/Rio Hondo Creeks
Reaches
10 - Upstream Reach
9 - Above Tujunga Wash
8 - Above Burbank
7 - Below Burbank
6 - Below Glendale WRP
5 - Glendale Narrows
4 - Above Rio Hondo
3 - Below Rio Hondo
2 - Below Compton Creek
1 - Tidal Reach
Tujunga Wash
Verdugo Wash
Tillman WRP
Burbank WRP
Glendale WRP
Arroyo Seco Creek
Rio Hondo Creek
Compton Creek
10
9
8
7
6
5
4
3
2
1

Habitat Characterization Process

✓ Identify and define major habitats

✓ Identify assemblages or key species

- Characterize habitat needs (hydraulic/hydrologic thresholds)
- Translate hydraulic needs to functional flow metrics
- Model occurrence of ranges with flow management scenarios

Developing Species Boundary Conditions

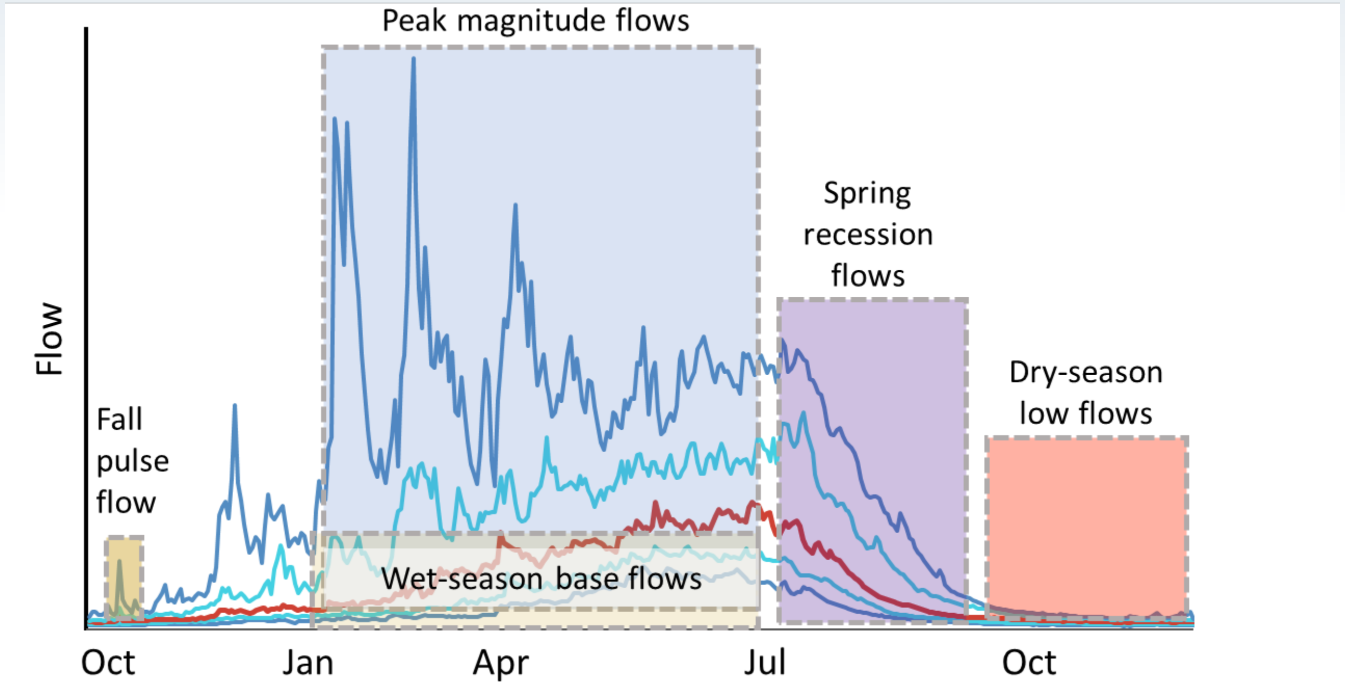
- Cold water habitat example:
  - Santa Ana sucker (*Catostomus santaanae*)

Life history needs: flow, hydraulics, and temperature

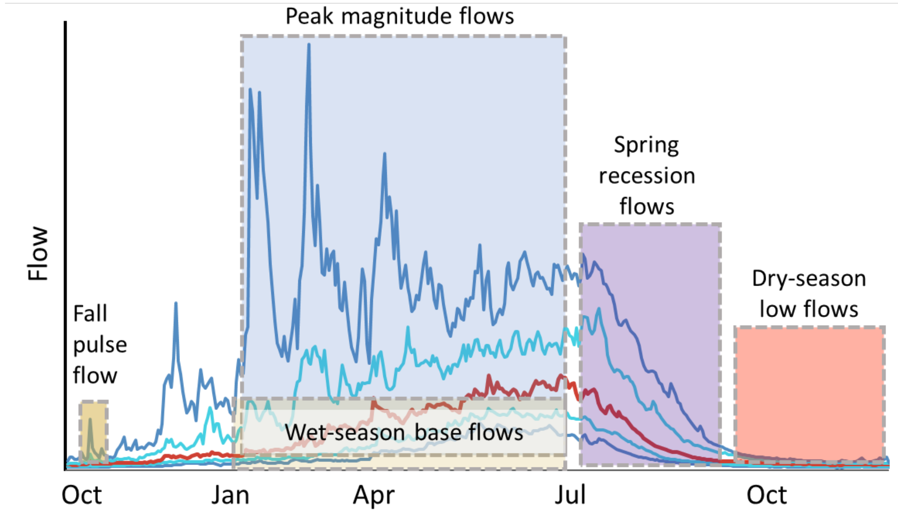
Life history	Velocity (m/s)	Habitat	Timing	Substrate	Veg/cover	Depth	Temp (C)
Spawning	0.2-0.24, flowing		Spring-early summer	Gravel		0.5m - 1.5m near deep water	
Fry	low	Quiet edge water near deep flowing water		Silt / sand	High sun exposure <25% canopy cover	<1cm-10cm	18-24
Juvenile	0.0-0.6, flowing	Riffle		Sand / gravel	<25% canopy cover	15-40cm, >35cm	15–22
Adult	0.0-0.5, flowing	Riffle, run, pool, deep holes		Gravel / cobble	<25% canopy cover	>40-70cm	15–22

Translation of Flow Needs

- Translate general flow needs to functional flow metrics
- *Functional flows:* key aspects of the flow regime that directly relate to ecological, geomorphic or biogeochemical processes in riverine systems (Yarnell et al. 2015)



Functional Flow Metrics



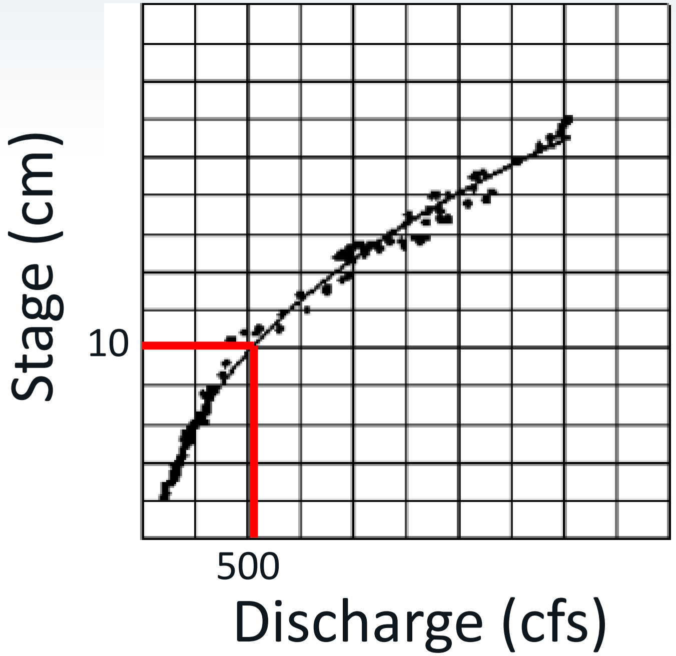
Metrics describe key characteristics of each flow component

Flow Component	Flow Characteristic	Flow Metric
Fall pulse flow	Magnitude (cfs)	Peak magnitude of fall season pulse event (maximum daily peak flow during event)
	Timing (date)	Start date of fall pulse event
	Duration (days)	Duration of fall pulse event (# of days start-end)
Wet-season base flows	Magnitude (cfs)	Magnitude of wet season baseflows (10th and 50th percentile of daily flows within that season, including peak flow events)
	Timing (date)	Start date of wet season
	Duration (days)	Wet season baseflow duration (# of days from start of wet season to start of spring season)
Peak flow	Magnitude (cfs)	Peak-flow magnitude (50%, 20%, 10% exceedance values of annual peak flow --> 2, 5, and 10 year recurrence intervals)
	Duration (days)	Duration of peak flows over wet season (cumulative number of days in which a given peak-flow recurrence interval is exceeded in a year).
	Frequency	Frequency of peak flow events over wet season (number of times in which a given peak-flow recurrence interval is exceeded in a year).
Spring recession flows	Magnitude (cfs)	Spring peak magnitude (daily flow on start date of spring-flow period)
	Timing (date)	Start date of spring (date)
	Duration (days)	Spring flow recession duration (# of days from start of spring to start of summer base flow period)
	Rate of change (%)	Spring flow recession rate (Percent decrease per day over spring recession period)
Dry-season base flows	Magnitude (cfs)	Base flow magnitude (50th and 90th percentile of daily flow within summer season, calculated on an annual basis)
	Timing (date)	Summer timing (start date of summer)
	Duration (days)	Summer flow duration (# of days from start of summer to start of wet season)

Example Translation to Functional Flow Metrics

- Sandbar willow
  - 10 cm depth for 60 days →
    Spring flow magnitude < 500 cfs
    Spring flow duration ≥ 60 days
  - Sand and gravel bars → Cannot model

Both "raw metrics" and functional flow metrics will be analyzed based on H&H models



Summary of TAC Recommendations

Habitat Characterization

- Keep coldwater fish habitat as a potential habitat that can occur
- Add migration habitat - consider ability of coldwater fish to migrate up the system
- Incorporate edgewater/pools within some reaches that this habitat can occur
- There will be uncertainty in characterizing habitat needs. Approach species tolerances as ranges that reflect level of confidence in tolerances

Q&A: Discussion Topics

- Reaction to habitat descriptions
- Representative endmember species selection
- Flow-ecology profiles

Next Steps

- TAC to receive and review:
  - Flow/hydraulic tolerances for each end member species
    - Based on observational/experimental studies in literature
    - Based on expert knowledge (TAC)
    - Based on hindcasting occurrence data and physical condition
    - Defining cut offs for tolerance ranges and uncertainty
    - *** likely the most important step in developing the model
- Develop flow-ecology modeling approach (next TAC meeting)
  - Based on flow/hydraulic tolerance ranges for each habitat type

BREAK – 10:50 - 11:05

Kris Taniguchi-Quan – SCCWRP on behalf of CSM

MODELING UPDATE

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HYDROLOGIC & HYDRAULIC MODELING

Dr. Terri Hogue, Dr. Jordy Wolfand, Dr. Reza Abdi, Daniel Philippus, Victoria Hennon, Dr. Nasrin Alamdari

HOGUE HYDROLOGY GROUP

Overview

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1. **Water quantity modeling update**
   - Overall coupled model approach
   - Calibration status

2. **Water quality modeling approach**
   - Proposed water quality modeling approach

3. **Discussion of scope of estuary model**

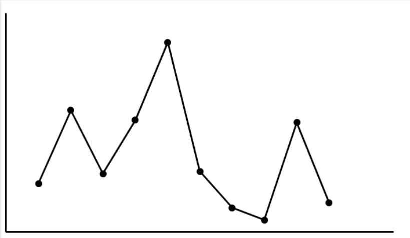
Create model

Hydrology, hydraulics, groundwater, tidal

Management scenarios

Scenario
recycling
recycling + stormwater
recycling + conservation
…

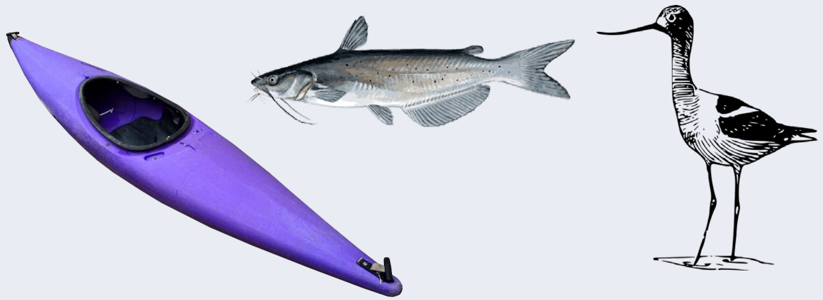
Timeseries output



Flow metrics

- Minimum annual flow
- Date of latest flood during the winter
- Minimum and maximum bottom velocity
- …

Flow metrics → Beneficial uses



Establish flow criteria

- By reach and season
- Management/mitigation recommendations

WATER QUANTITY MODELING UPDATE

Processes to Model

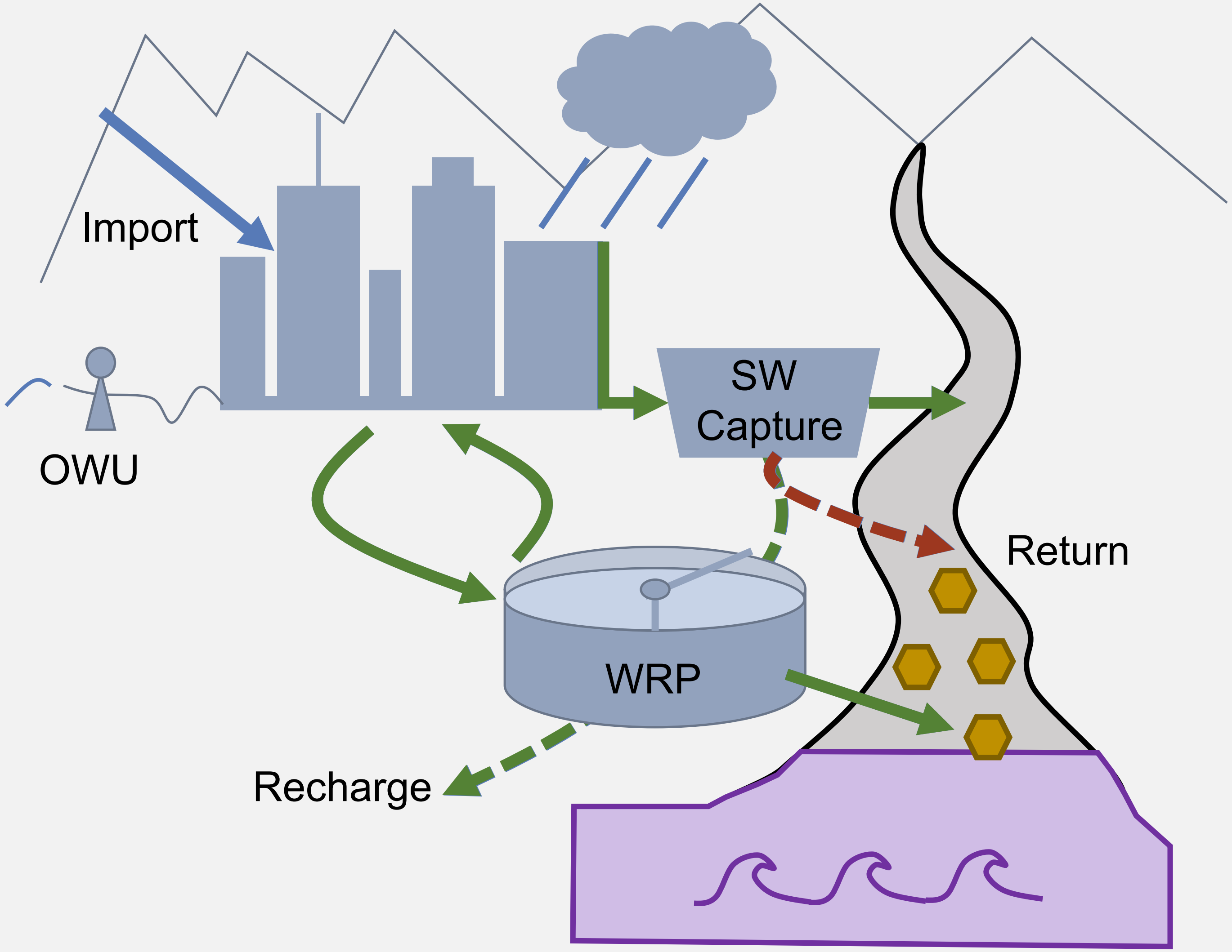
HYDROLOGY (Runoff / Point Sources / Diversions)

HYDRAULICS (Channel flow)

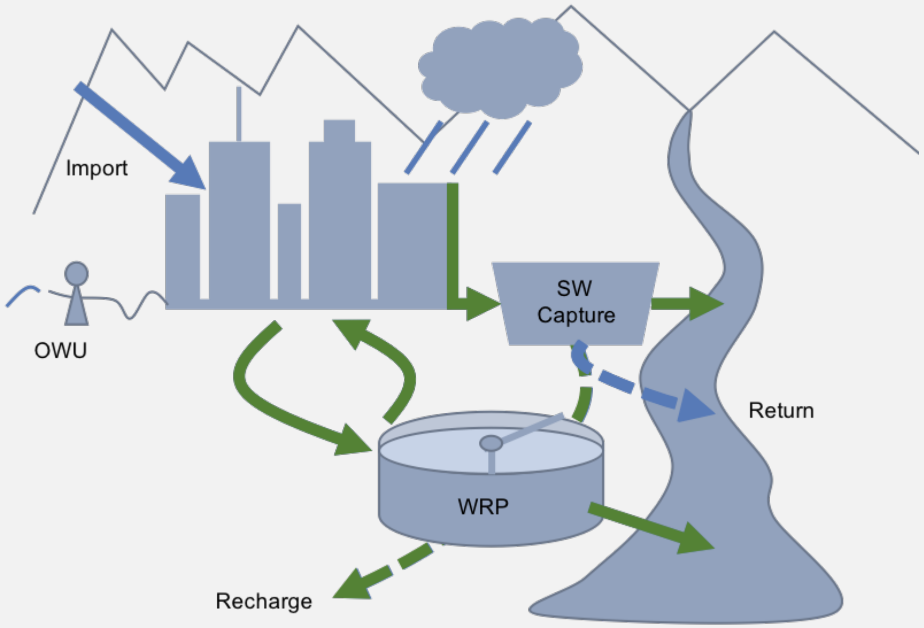
GROUNDWATER

ESTUARY

WATER QUALITY



Hydrology



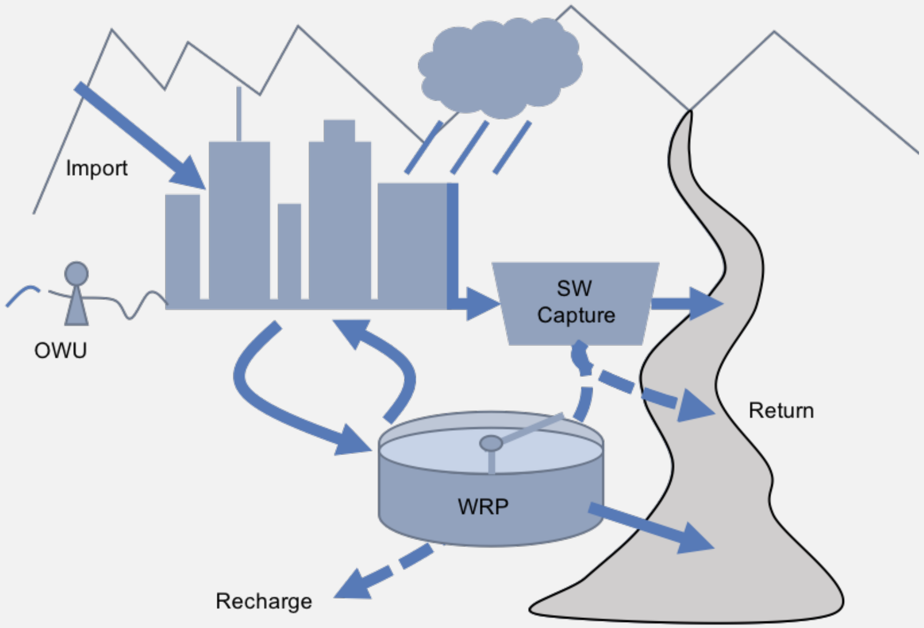
PURPOSE

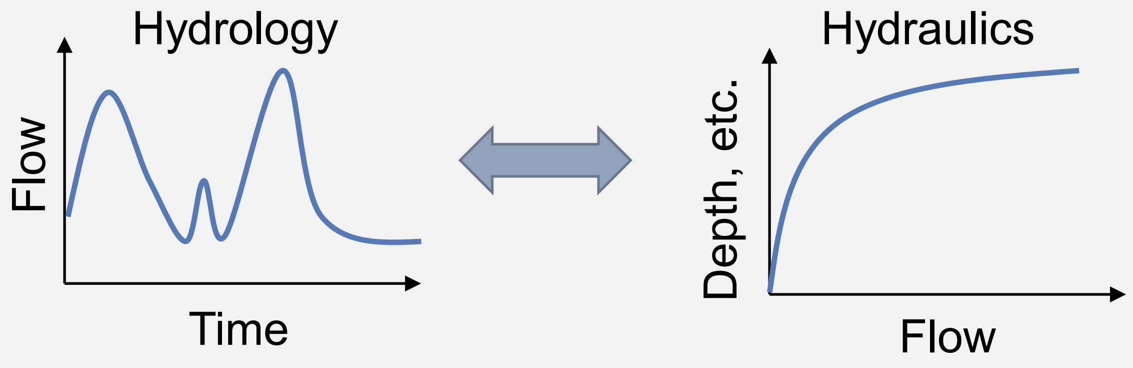
- Generate flow timeseries as inputs to ecological models
- Scenario testing: wastewater reuse, stormwater, restoration/rehabilitation efforts

METHOD

- EPA SWMM

Hydraulics





PURPOSE

- Generate velocity/depth as inputs to ecological models
- Scenario testing: wastewater reuse, stormwater, restoration/rehabilitation efforts

METHOD

- Couple EPA SWMM to USACE HEC-RAS

Groundwater

Glendale Narrows

PURPOSE

- Simulate losses and gains within the river due to groundwater

METHOD

- EPA SWMM informed by ***Los Angeles River Coupled Groundwater-Surface Water Study***

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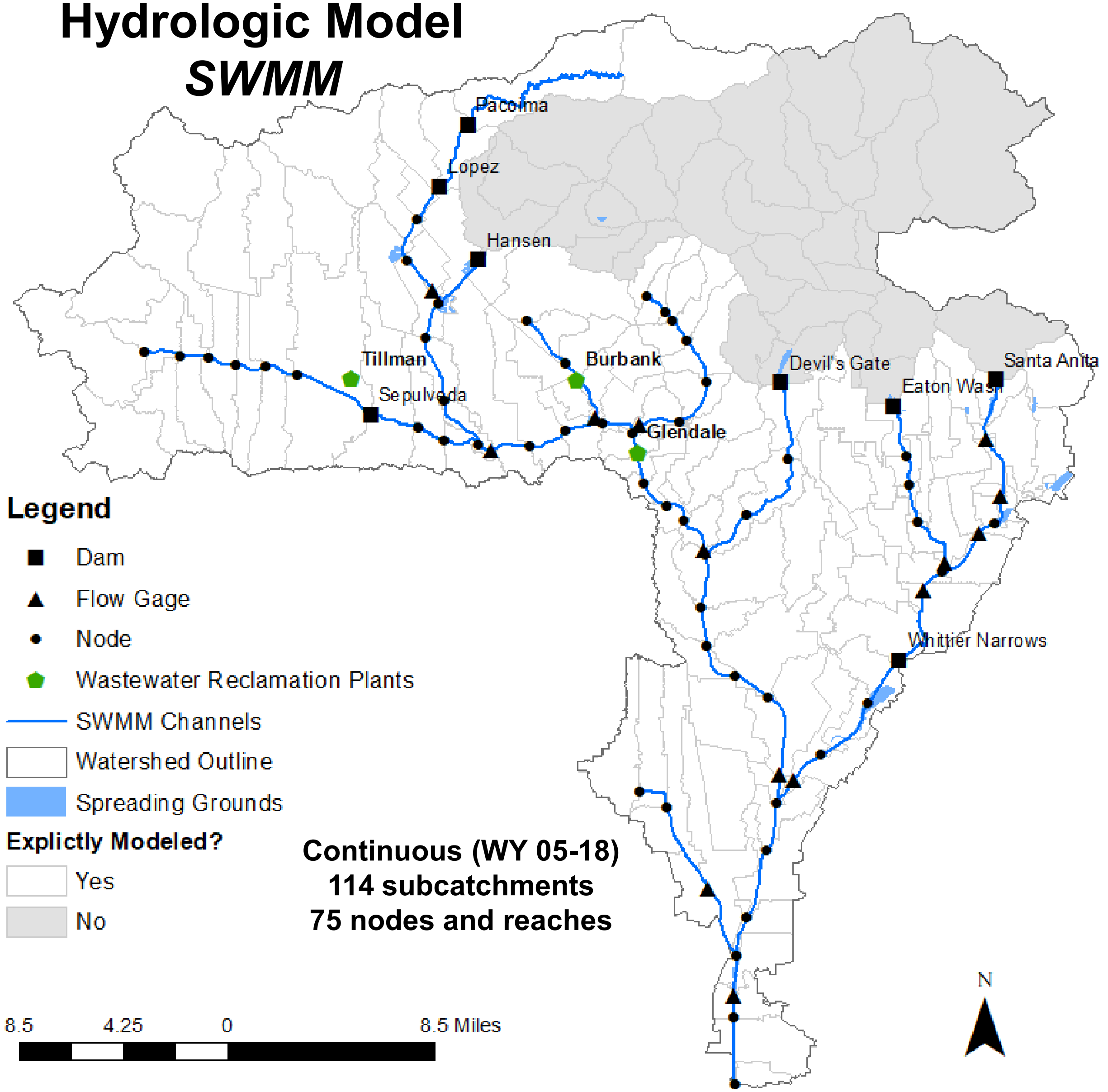
COUPLED HYDROLOGIC & HYDRAULIC MODEL

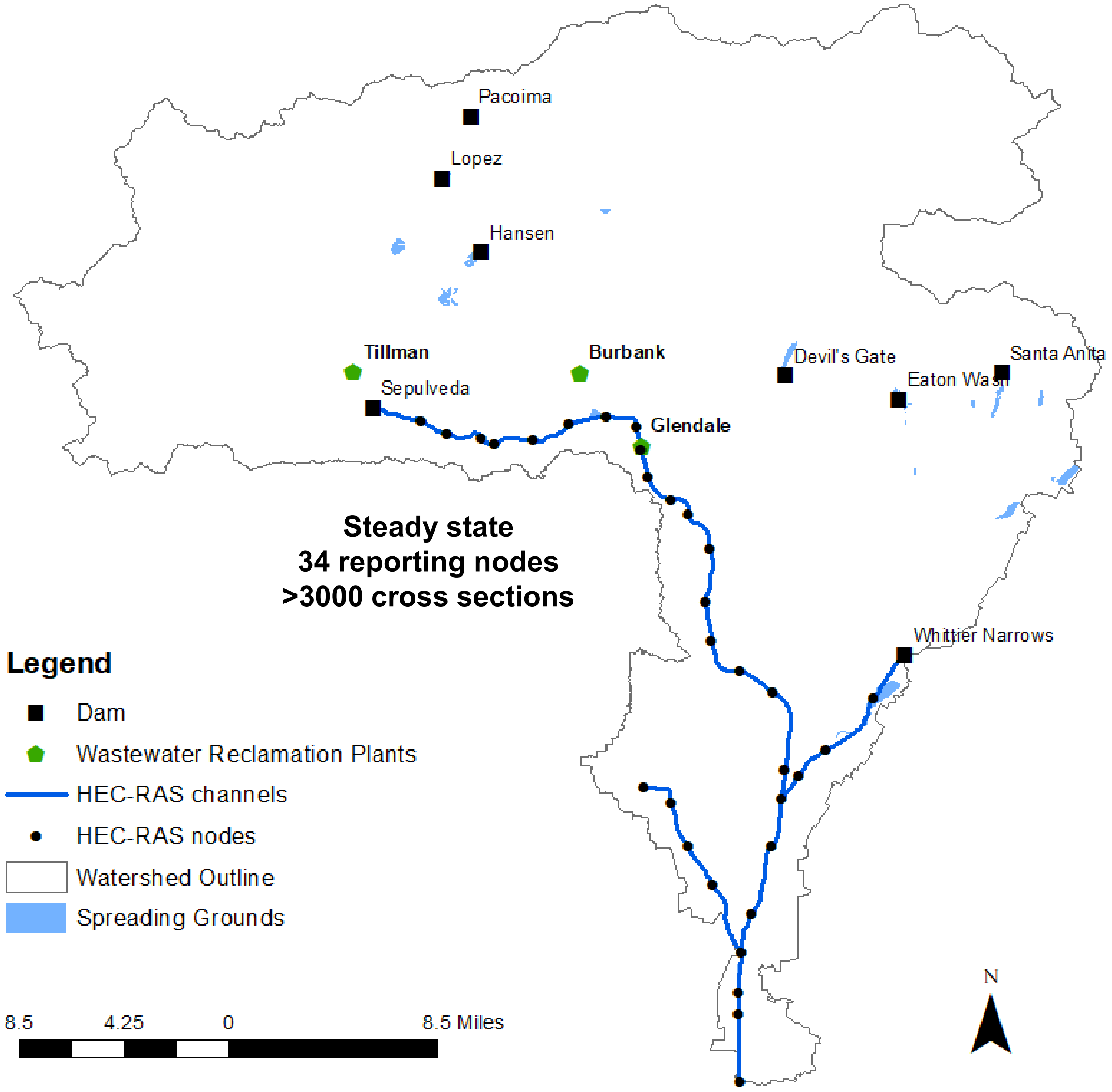
Coupled SWMM & HEC-RAS Model

Hydrologic Model
SWMM



Continuous (WY 05-18)
114 subcatchments
75 nodes and reaches

Hydraulic Model
HEC-RAS



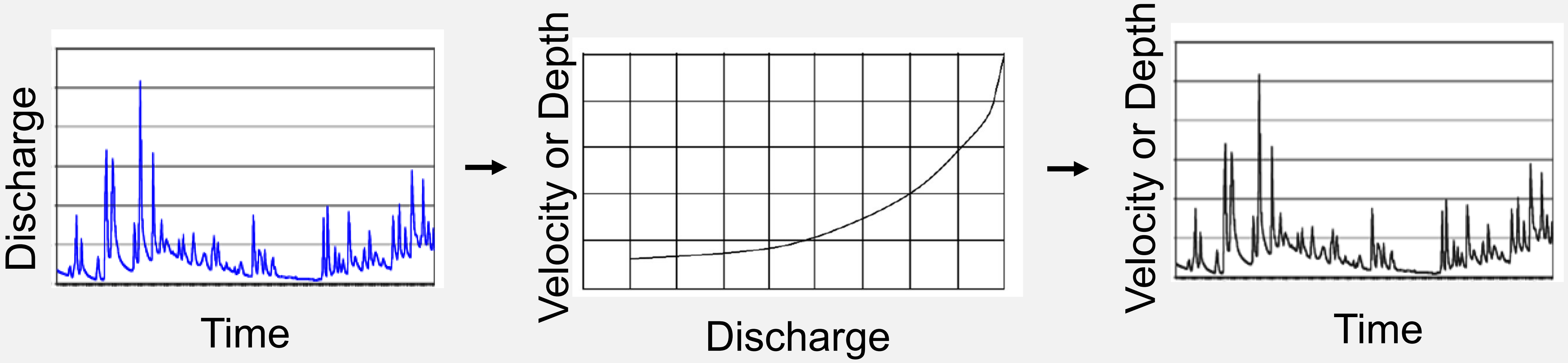
Steady state
34 reporting nodes
>3000 cross sections

Coupled SWMM & HEC-RAS Model

Hydrology Model
SWMM
Unsteady (WY 2005 to 2018, hourly timestep)

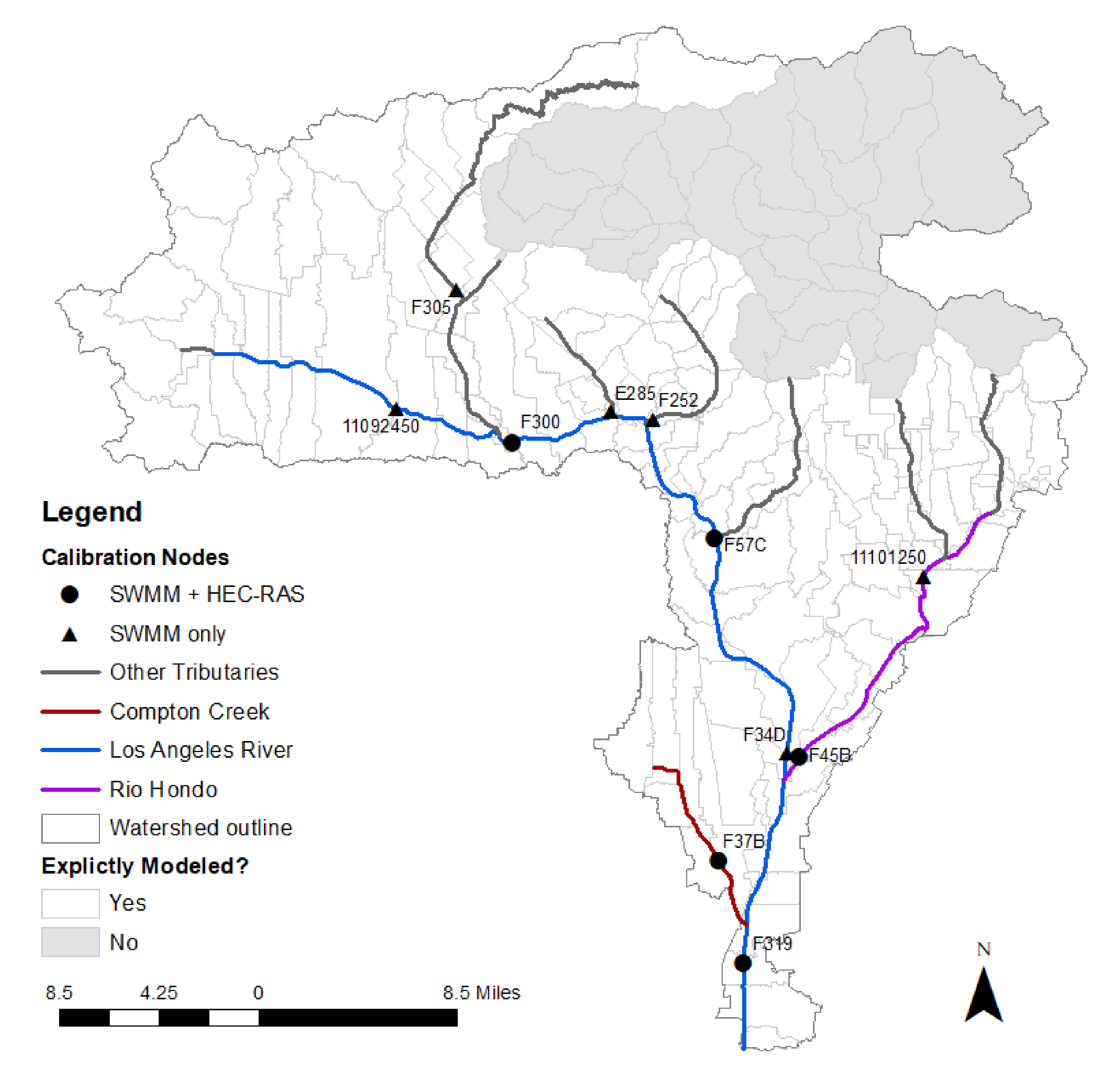
Hydraulic Model
HEC-RAS
Steady state to create rating curves

Output
Timeseries



Model Calibration is ongoing

- **HEC-RAS (hydraulics)**
  - 5 gages
  - Manual adjustment of Manning's n
- **SWMM (hydrology)**
  - 11 gages
  - Automated scatter search (NGSA-II) of 500 solutions
  - Adjustment of % directly connected imperviousness, Manning's n, depression storage, catchment width, hydraulic conductivity



WATER QUALITY

Water Quality

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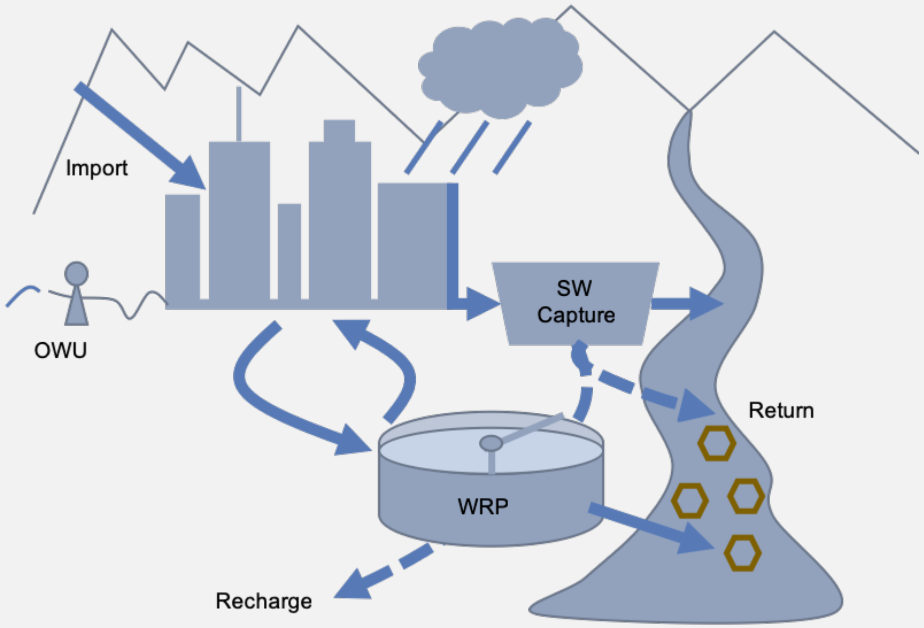


PURPOSE

- Simulate water quality in the LA River mainstem

PARAMETERS

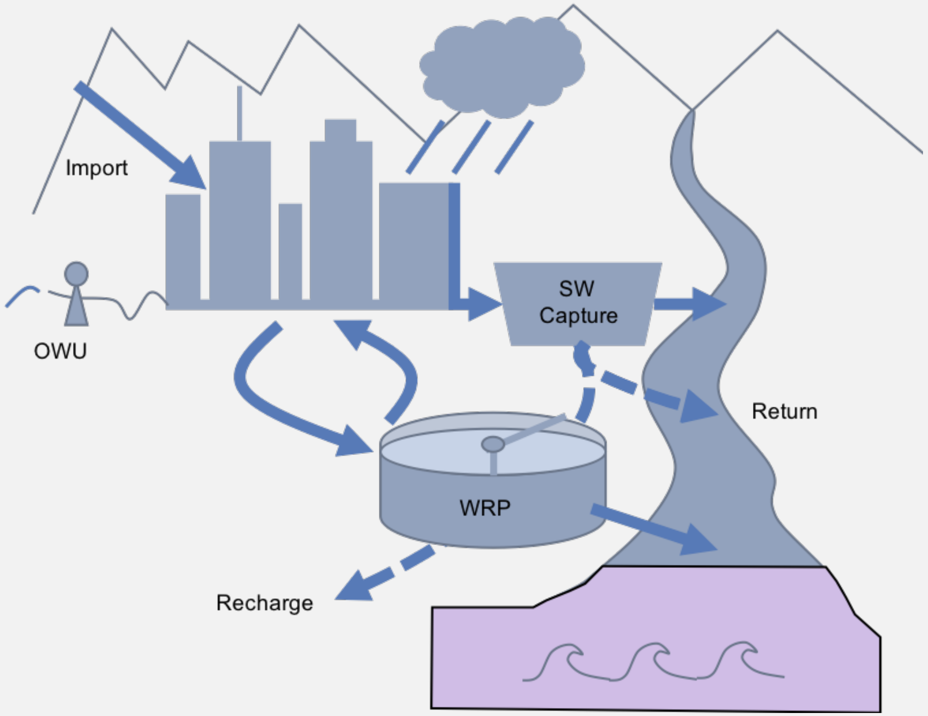
- Temperature
- Metals: Copper, Lead, Zinc
- TSS
- Specific conductance

PROPOSED APPROACH

- SWWM coupled with HEC-RAS
- iTree Cool River for temperature

ESTUARY MODELING

Estuary Model



PURPOSE

- Simulate effects of hydrologic changes on beneficial uses in tidally-influence portion of the river
- How do changes in salinity, temperature, and depth impact wading shore birds?

PROPOSED APPROACH

- HEC-RAS for coarse resolution model
- Potentially apply iTree Cool River for temperature

Q&A – MODELING UPDATE

CONTACT

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Eric Stein - SCCWRP

FLOW MANAGEMENT SCENARIOS

Elements to Consider in Management Scenarios

- Varying amounts of reduced discharge from three water reclamation plants

- Stormwater capture along Rio Hondo and Compton Creeks
  - Any potential stormwater capture in upper watershed (e.g. Arroyo Seco, Tujunga)?

- Restoration along Compton, Rio Hondo, Arroyo Seco
  - Implications for water consumption
  - Constraints on restoration goals

Bounding Ranges of Scenarios

- Bound scenarios based on extremes
  - i.e., 0% reduction vs. 100%, 0% stormwater capture vs. 100% stormwater capture

Less options and flexibility, but simpler and less computationally demanding

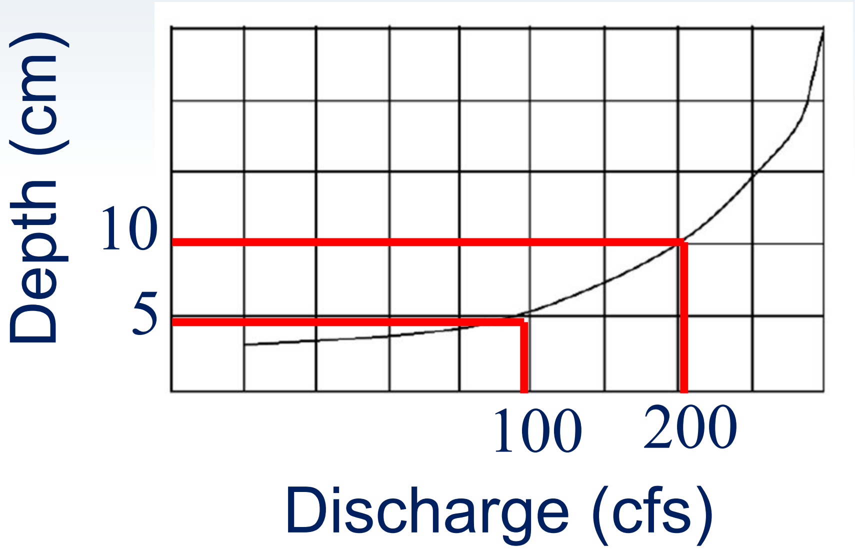
- Define scenarios based on sensitivity of system to response
  - Develop sensitivity curves to help define ranges of scenarios

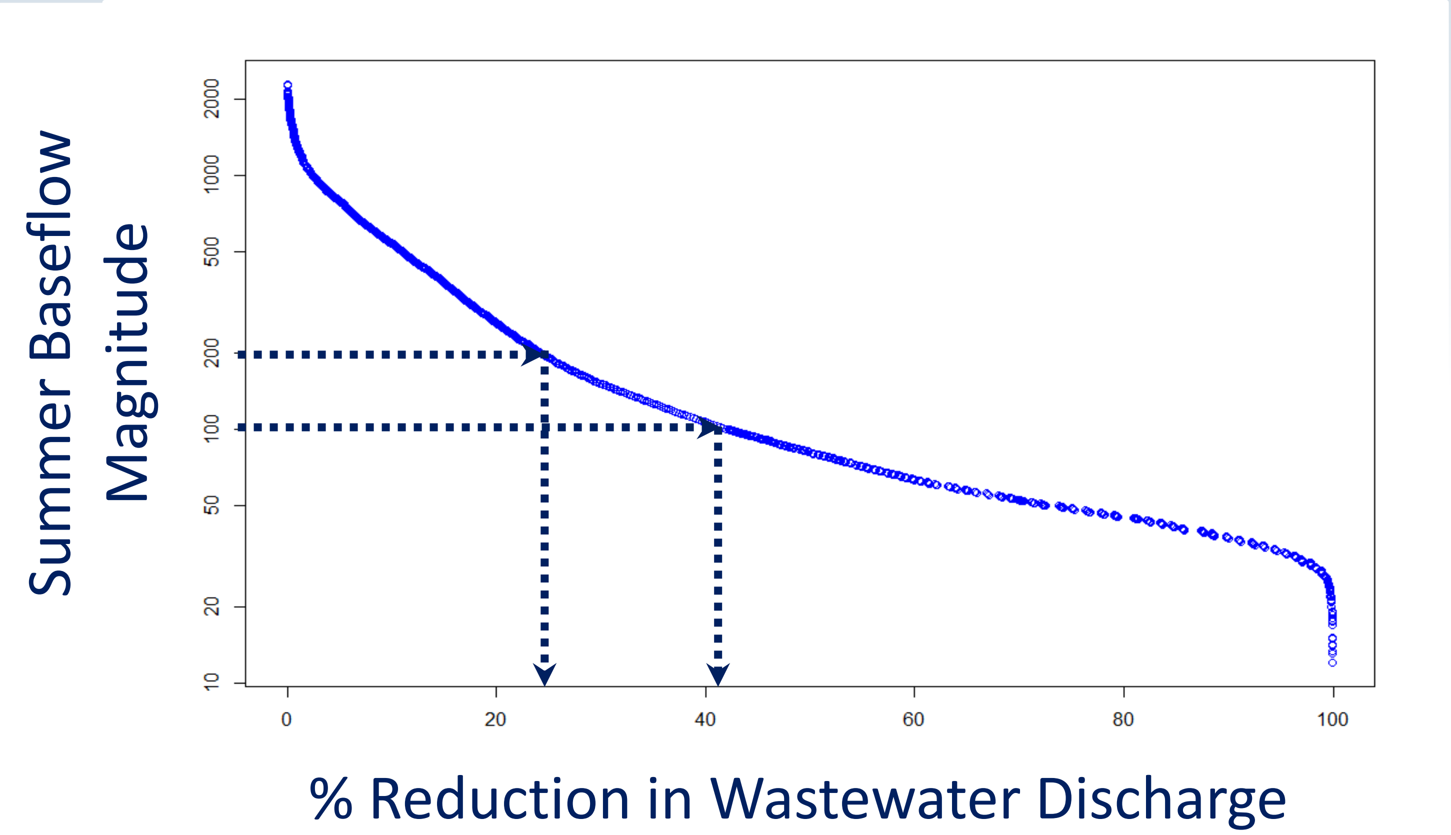
TAC Recommended this option - provides flexibility in terms of management options and allows for defining ranges of acceptable flow metrics

Sensitivity Curves Approach

- Example: % reduction in wastewater discharge

Wading shorebird summer baseflow depth: 5-10 cm





Sensitivity Curves Approach

- Develop multiple sensitivity curves base on:
  - Key hydrologic properties
  - Various management scenarios
  - Water year type (wet, moderate, dry)
  - Seasons
  - Locations

Example Restoration Scenarios

- Constraints on restoration goals:
  - Restoration of Compton Creek: what flows are necessary to support riparian species?

- Offsetting habitat in upper reaches to create more suitable habitats

Discussion: Flow Management Scenarios

- Sensitivity curve approach
- Defining elements of scenarios
  - Constraints or considerations

Action Items and Next Steps

- Defining flow needs for each habitat/species
- Develop flow ecology modeling approach
- Next SWG meeting – tentatively April 2020
  - Flow ecology modeling
  - Preliminary results from hydrologic modeling

Questions

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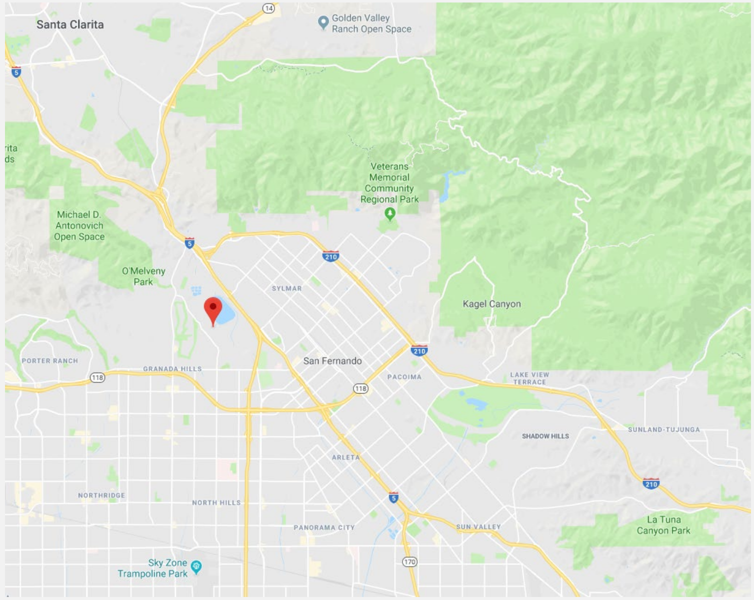
FOR REFERENCE

Activity / Sub-Task	Products	2018	2019				2020			
		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Activity 1 - Stakeholder coordination										
Stakeholder Advisory Group (SAG) Meetings	Charter, needs assessment, meeting notes		S1		S2		S3		S4	
Technical Advisory Committee (TAC) Meetings	Meeting notes, feedback		T1	T2	T3	T4	T5	T6	T7	
Activity 2 - Non-aquatic Life Use Assessment										
2A Characterize non-aquatic life uses	Map of NAL uses/indicators by reach									
2B Determine flow use relationships	Flow-use relationships & targets									
Activity 3 - Aquatic Life Beneficial Use Assessment										
3A Asses hydrologic baseline condition	Baseline hydrology/data gaps									
3B Identify priority ecological endpoints	List of priority endpoints, data summary									
3C Determine flow ecology relationships for stream endpoints	Flow eco models/targets by reach for BMI & verts									
3D Determine flow ecology relationships for marsh/estuary	Flow eco models/targets for marsh/est habitats									
Activitiy 4 - Apply Environmental Flows and Evaluate Scenarios										
4A Update hydrologic modeling	Hydro & hydraulic models of LAR									
4B Analyze tolerances to flow modifications	Flow tolerance ranges for riparian hab, BMI, verts									
4C Analyze wastewater reuse scenarios	Map wastewater reuse scenario effects on uses									
4D Evaluate stormwater management scenarios	Map of stormwater/wastewater scenarios effects									
4E Evaluate groundwater interaction scenarios	Map of groundwater/wastewater scenarios effects									
4F Evaluate habitat restoration effects	List of potential hab rest projs and map of uses									
4G Evaluate flow alteration effects on tidal portion of LA River	Map of scenario effects on tidal portion of LAR									
4H Establish recommended flow criteria	Recommended flow criteria by reach & season									
Activity 5 - Monitoring and Adaptive Mangement Plan	Proposed monitoring strategy									
Activity 6 - Summary of results/reporting	Draft and final project report									

Model inputs

Spatial Data		Data Source
Subcatchments	Area	LA County sewersheds
	Soil parameters	USDA-NRCS SSURGO database
	Slope	National Elevation Dataset DEM, LA LIDAR
	Imperviousness	NLCD, SCAG
Nodes	Invert elevation	National Elevation Dataset DEM
Channels	Flow network	LA County sewer network, NHD flow lines
	Length	NHD flow lines, LA County channel network
	Geometry	LA reports, HEC-RAS models, LIDAR data



Timeseries Data	Data Source
Dams	LA County, USACE
Spreading grounds	LA County
Water reclamation plants	LA City, others
Precipitation	LA County
Evapotranspiration	CIMIS
Flow	LA County

Stormwater Capture Master Plan - Scenarios

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1. **Self-mitigating permeable pavement**
2. **On-site infiltration**: permeable pavement receiving run-on, simple rain garden, complex bioretention, dry wells
3. **On-site direct use**: simple direct use, complex direct use
4. **Green street programs:** permeable pavement receiving run-on, simple rain garden, complex bioretention, ROW bulb-out
5. **Subregional infiltration**: underground gallery, infiltration basin
6. **Subregional direct use**: complex direct use

Stormwater Capture Master Plan

BMP sizes of 1.5, 1.2, and 1 times the 85th percentile storm depth were applied for categories A, B, and C, respectively.

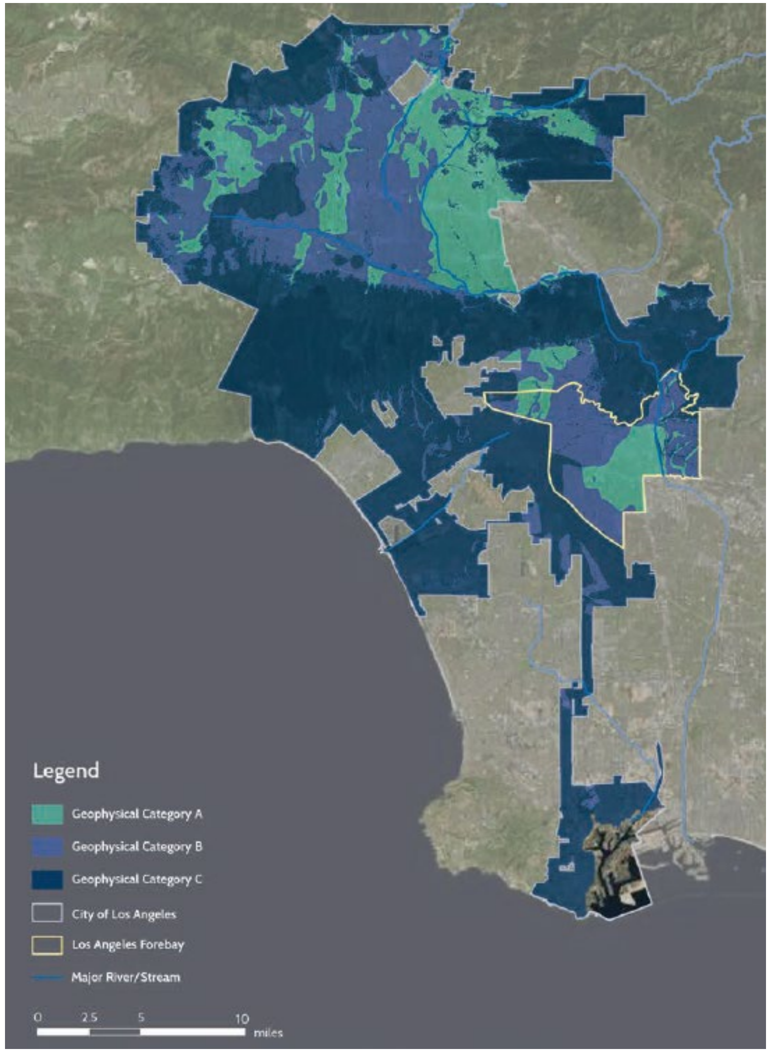


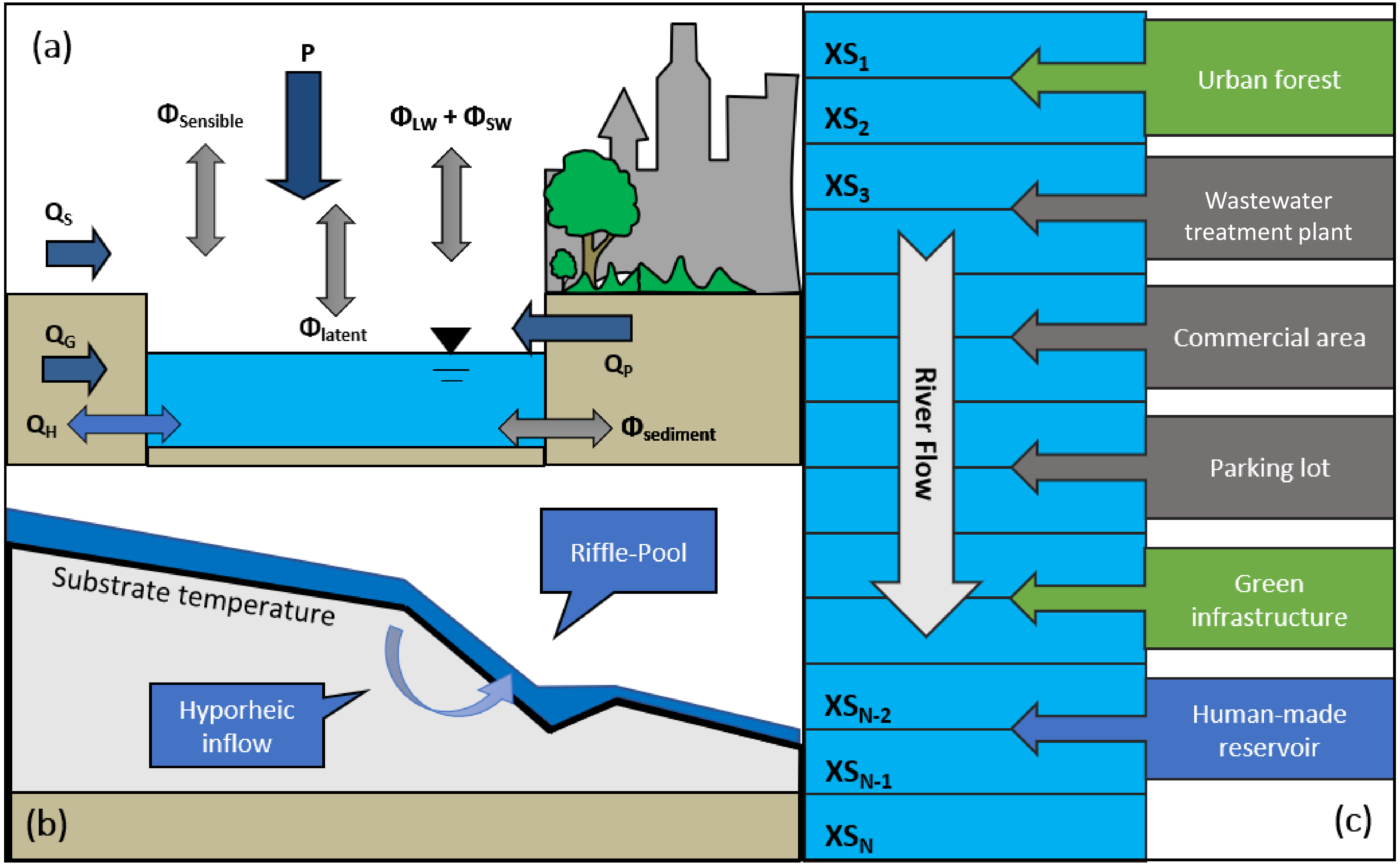
Table 5. BMP Implementation Rates for Geophysical Categorization in the Conservative Scenario

Land use	A	B	C
High Density Single Family Residential	35%	25%	15%
Low Density Single Family Residential with Moderate Slope	30%	20%	10%
Low Density Single Family Residential with Steep Slope	22%	12%	2%
Multi-family Residential	35%	25%	15%
Commercial	37%	27%	17%
Institutional	57%	47%	37%
Industrial	50%	40%	30%
Transportation	52%	42%	32%
Secondary Roads	47%	37%	27%

Table 6. BMP Implementation Rates for Geophysical Categorization in the Aggressive Scenario

Land use	A	B	C
High Density Single Family Residential	50%	40%	30%
Low Density Single Family Residential with Moderate Slope	40%	30%	20%
Low Density Single Family Residential with Steep Slope	25%	15%	5%
Multi-Family Residential	50%	40%	30%
Commercial	55%	45%	35%
Institutional	95%	85%	75%
Industrial	80%	70%	60%
Transportation	85%	75%	65%
Secondary Roads	75%	65%	55%

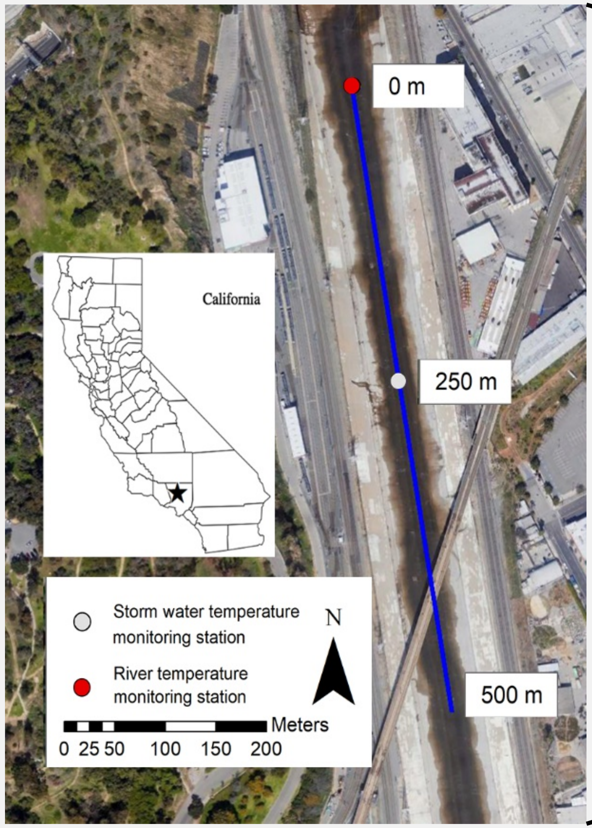
i-Tree Cool River Model Description

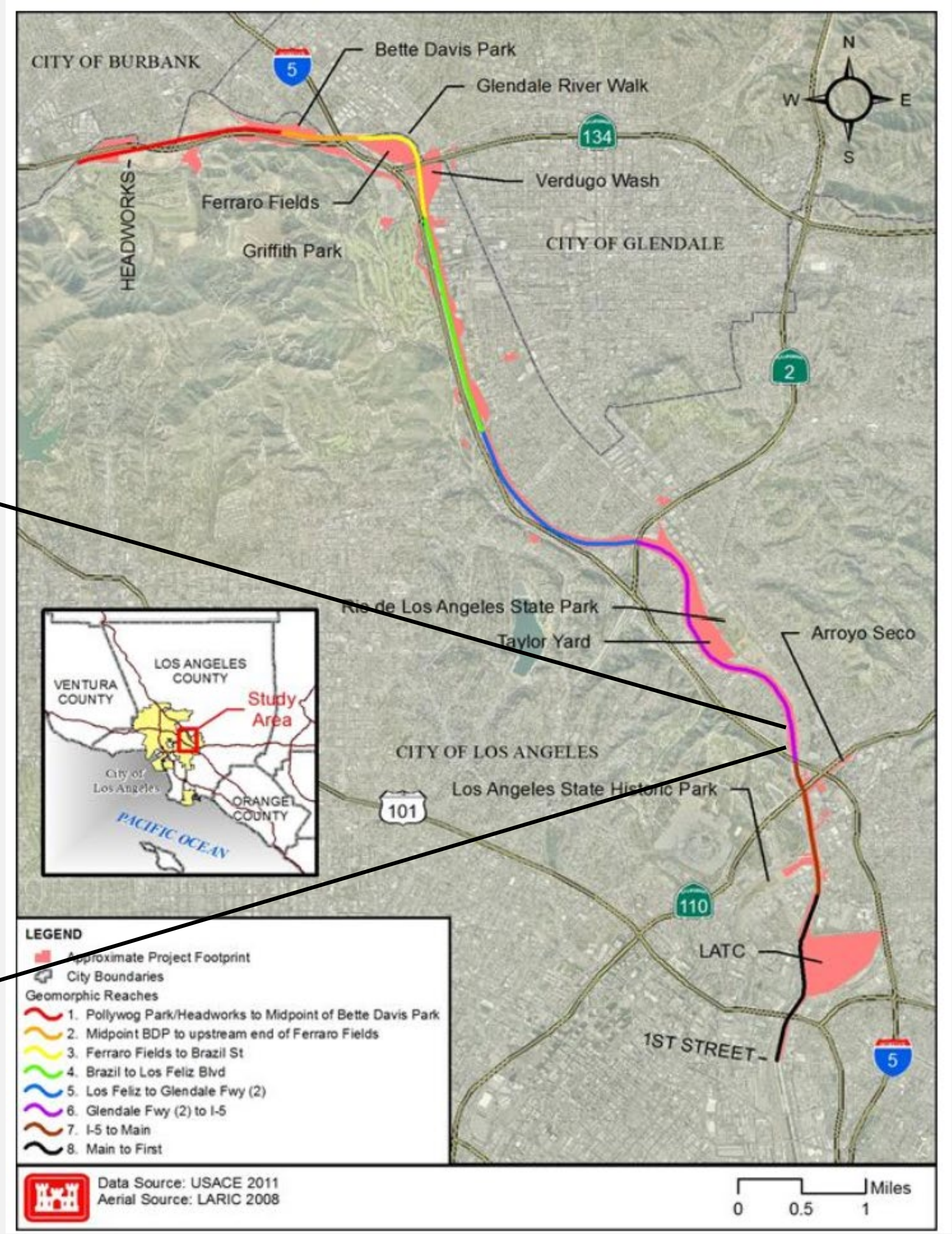


a) River cross-section view, demonstrating the energy and water balances. b) River longitudinal section for a riffle-pool bedform. c) River plan view demonstrating the lateral inflows that can be added to the river flow in either dry or wet weather.

i-Tree Cool River: LA River Case Study

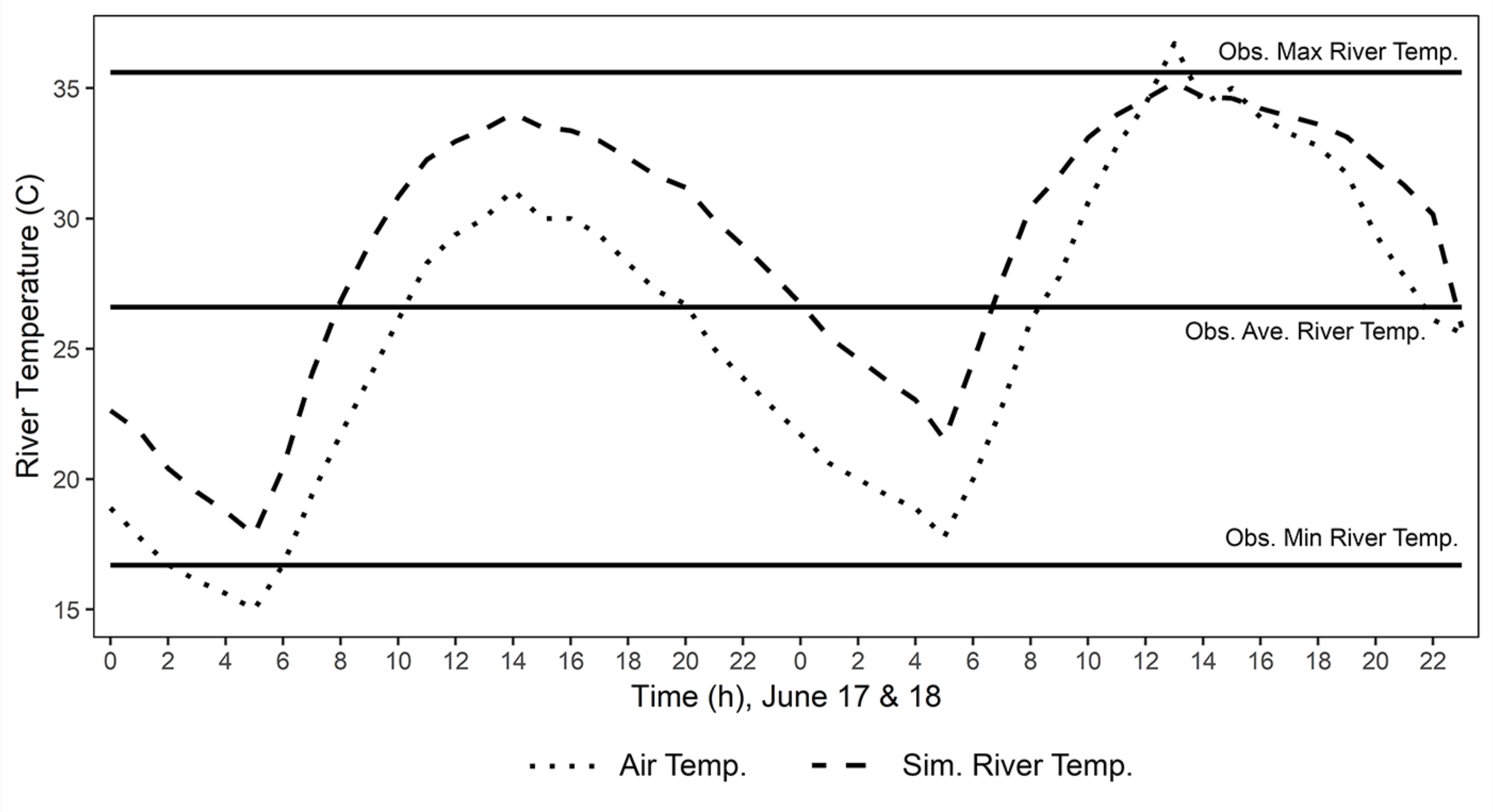
Simulated both a 500 m reach and a 11 mi stretch of LAR





Abdi et al. 2019 – Under Review

Validation of i-Tree Cool River for LA River



The hourly observed air temperature and simulated river temperature in the LA River for June 17 to 18, 2016