Floodplain and riparian vegetation analysis of Lower Putah Creek to inform ecological restoration, design and conservation using a height-above-river (HAR) spatial analysis technique

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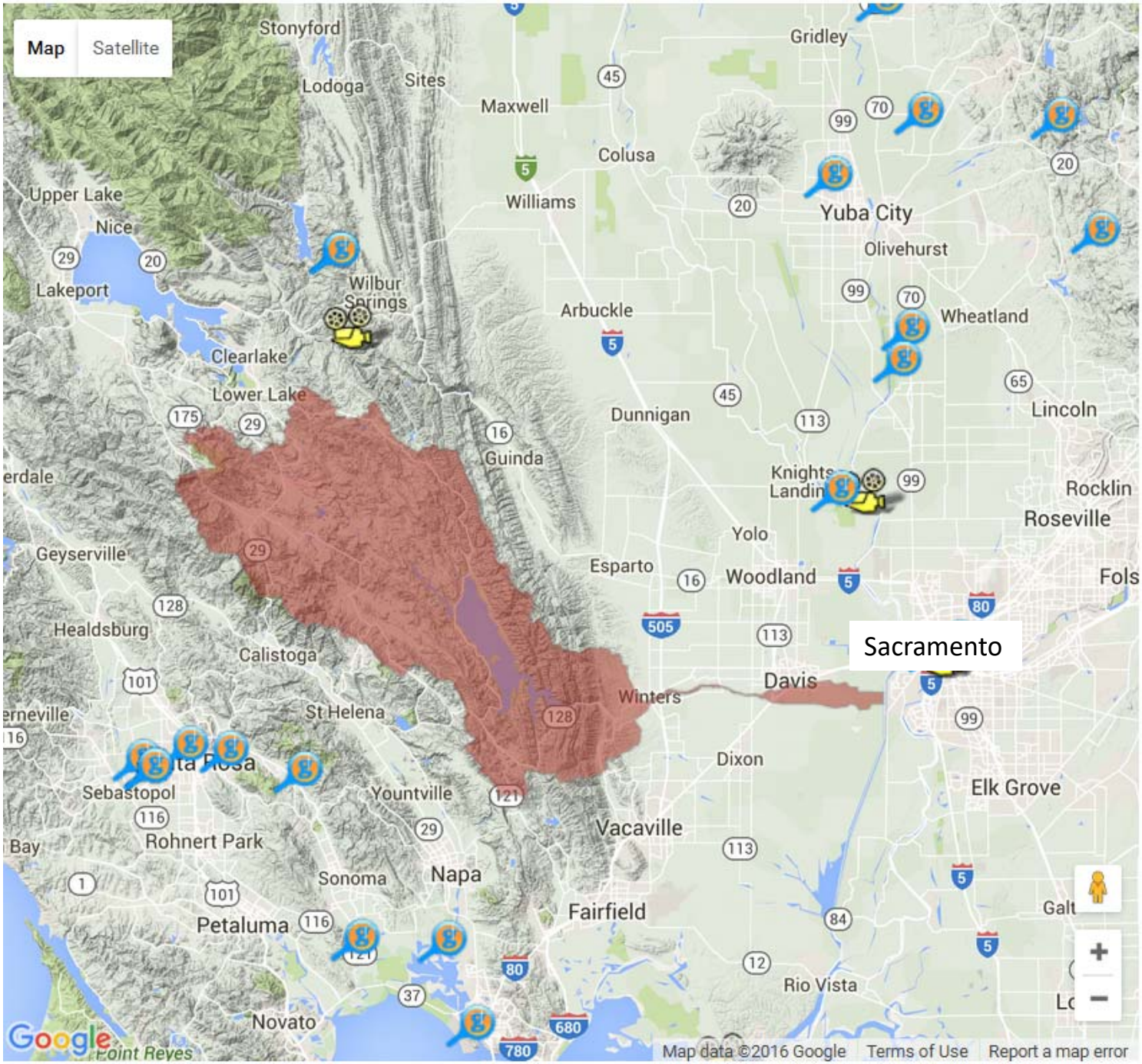
Outline

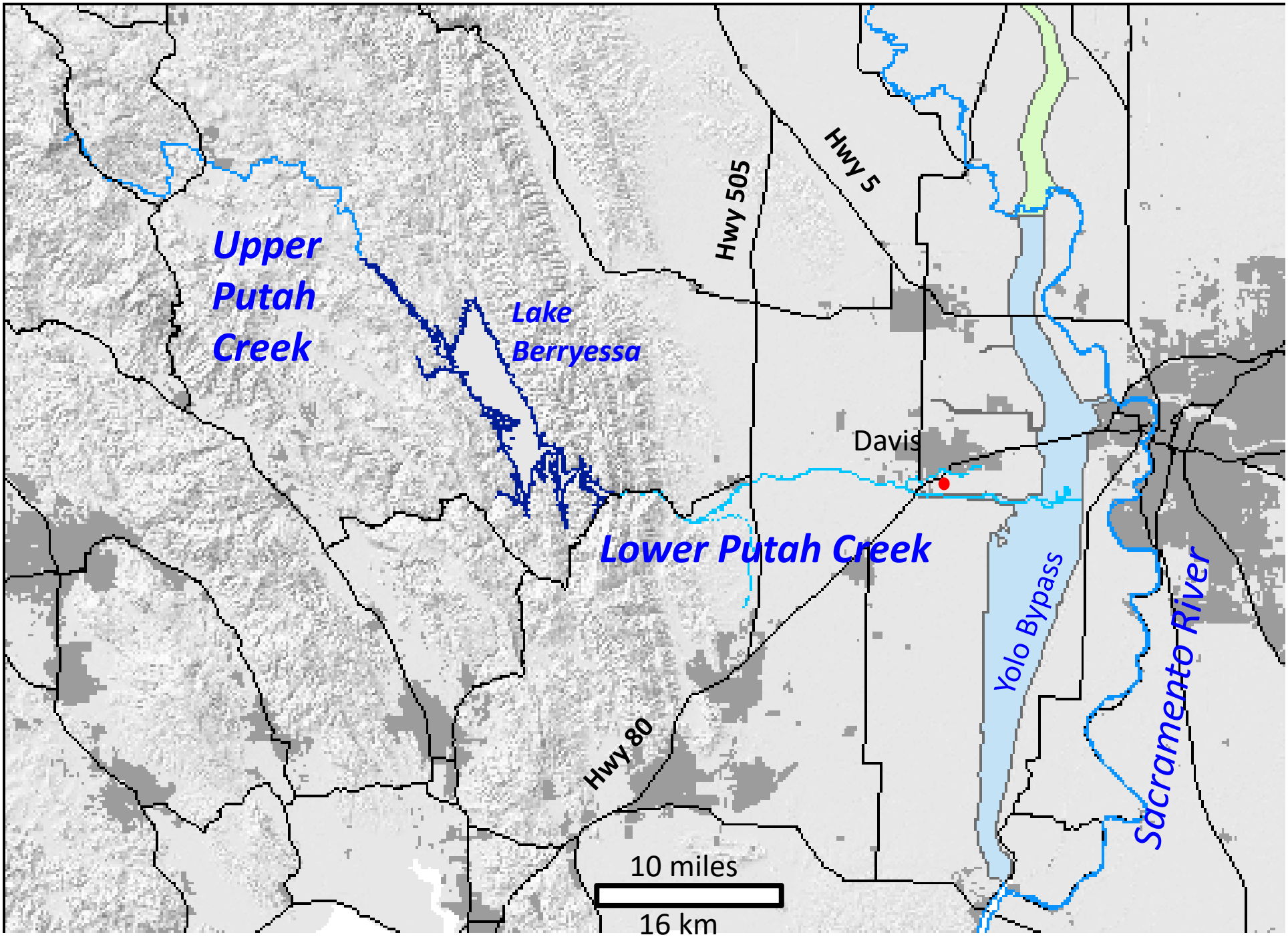
- Putah Creek: watershed context
- Floodplain analysis
  - Recruitment box theory
- Methods
  - Relative elevation and HAR concepts
  - GPS data collection
- Results
  - Sacramento River
  - Putah Creek
- Vegetation analysis
  - Cottonwood and elderberry examples
- Future work

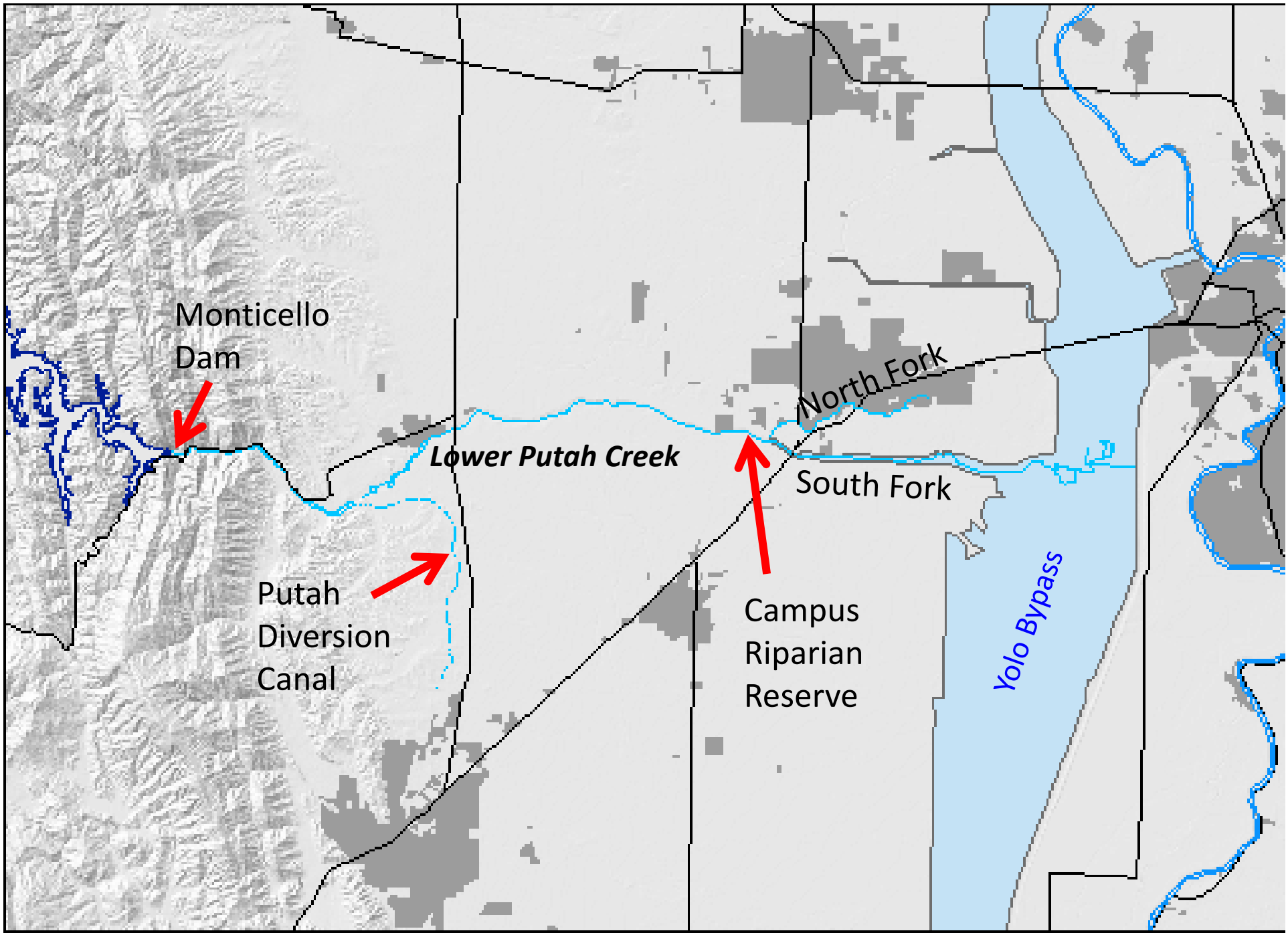
Photo courtesy of Peter Moyle

Putah Creek Watershed



http://www.sacriver.org/aboutwatershed/roadmap/watersheds/westside/putah-creek-watershed


Upper
Putah
Creek
Lake
Berryessa
Hwy 505
Hwy 5
Davis
Lower Putah Creek
Yolo Bypass
Sacramento River
Hwy 80
10 miles
16 km


Monticello
Dam
Lower Putah Creek
North Fork
South Fork
Putah
Diversion
Canal
Campus
Riparian
Reserve
Yolo Bypass

Recruitment box theory

- Explains the process of cottonwood tree establishment on floodplain surfaces, such as point bars
- First key concept: Timing between the falling limb of the hydrograph and release of cottonwood tree seed
- Second key concept: A suitable band of bank elevation on the point bar above summer base flow

See Mahoney and Rood (1998), Wetlands 18(4):634-645

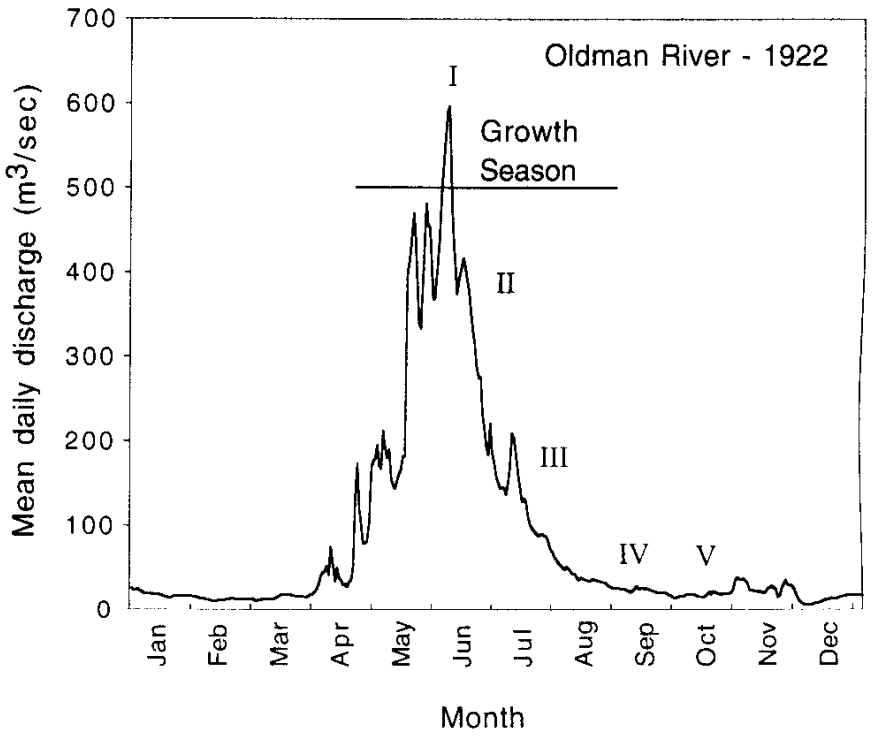


Figure 1. The daily hydrograph for the Oldman River, at Lethbridge, Alberta, for 1922, prior to the construction of major dams upstream. Roman numerals represent important components relevant to cottonwood seedlings recruitment: (I) high flows to drive geomorphological processes that create suitable moist and barren nursery sites, (II) falling flows to expose the nursery sites, (III) gradual flow decline after germination that permits the growing roots to maintain contact with the receding moisture zone, (IV) sufficient flows through the hot and dry period of mid- to late summer, and (V) sufficient flows in late summer and autumn to provide the seedlings with a favorable water balance to withstand the winter.

Mahoney and Rood 1998

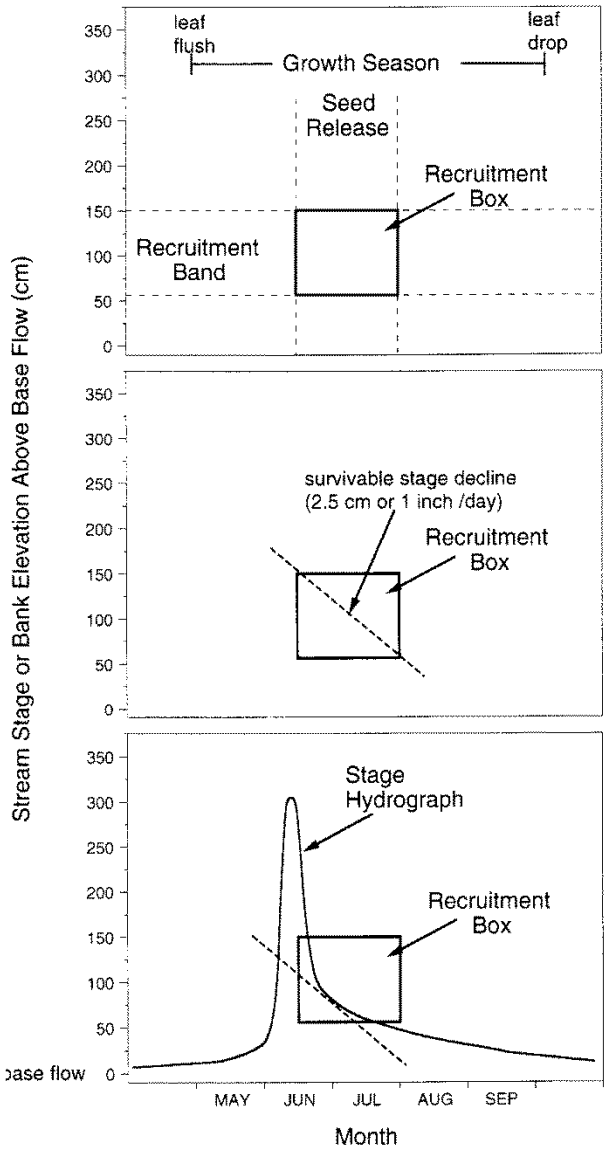
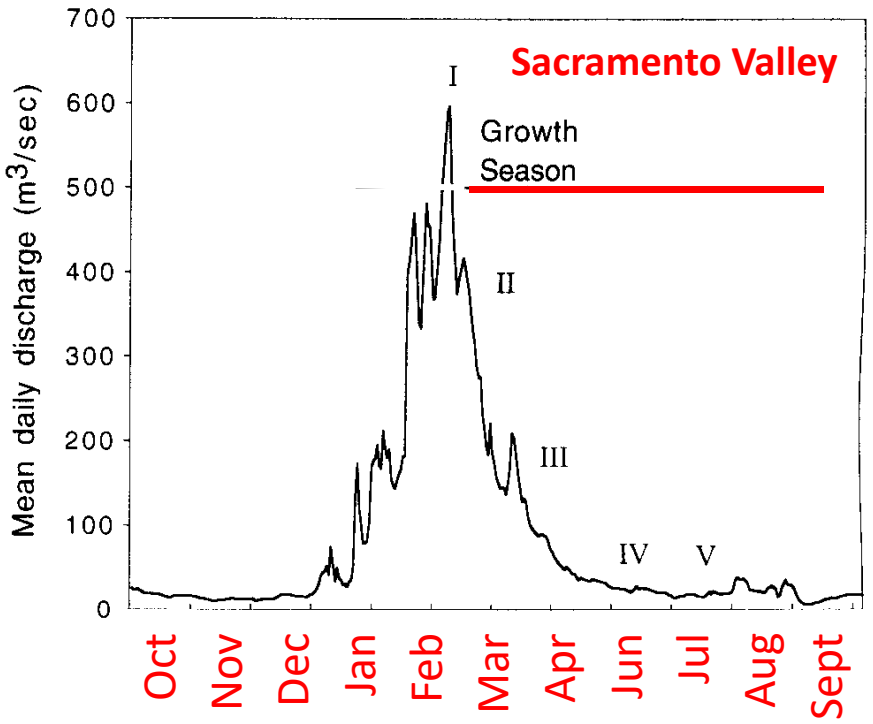


Figure 3. The 'Recruitment Box,' a zone defined in elevation and time in which riparian cottonwood seedlings are likely to become successfully established if stream flow patterns are favorable. The graphs represent phenology of components (top), survivable rate of stage decline (middle), and a hydrograph that satisfies requirements for seedling establishment (bottom).



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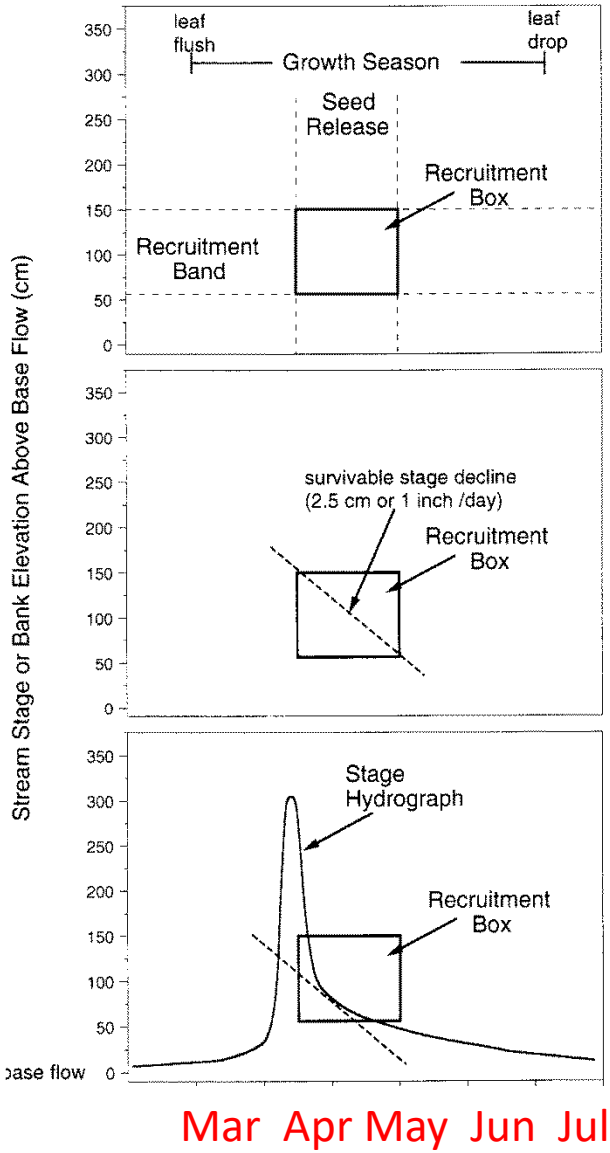
modified Mahoney and Rood 1998



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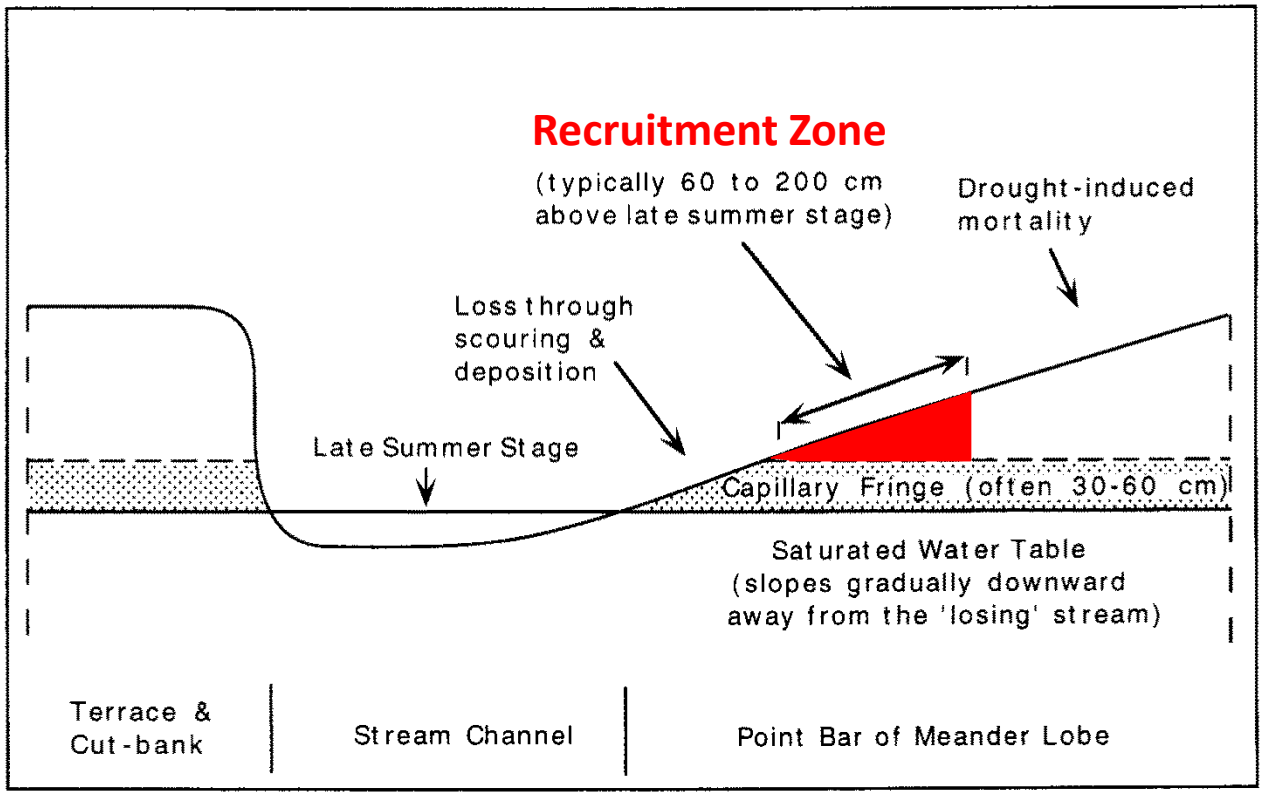


Figure 4. Cross section of a stream and riparian zone at the point bar of a meander lobe, showing the riparian water table, the capillary fringe, and the suitable band for cottonwood establishment and survival.

Mahoney and Rood 1998

Greco et al. 2008, *Landscape Research*, Vol. 33, No. 4, 461–486

"Relative elevation" concept (Greco et al. 2008)
or
"Height-above-river (HAR)" (Dilts 2010)

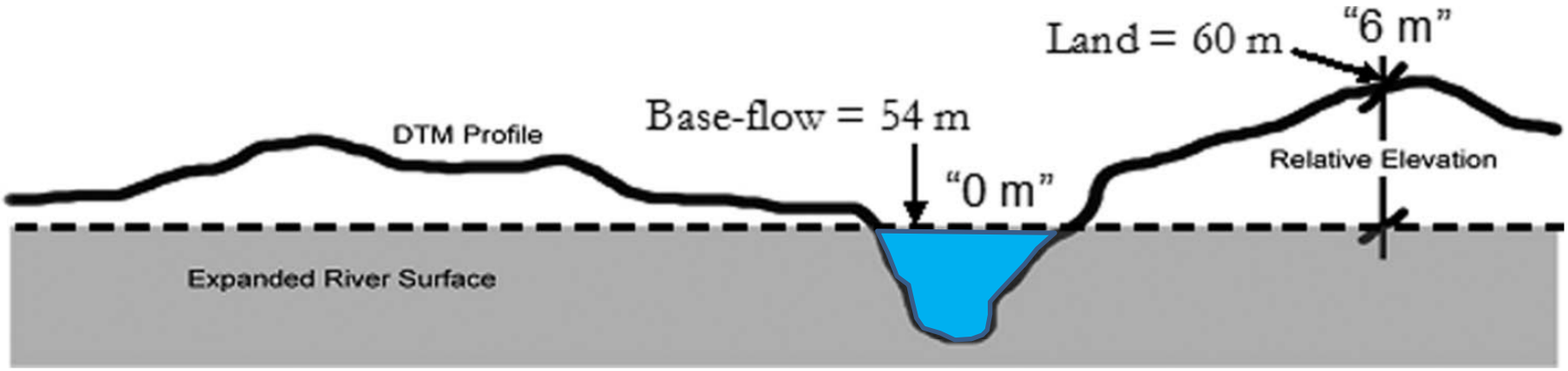


Figure 2. The relative elevation concept. The base-flow or average low-flow conditions water surface elevation of the channel (e.g. 54 m, shown as a dashed line) using mean sea level (MSL) as the datum for the elevation units is used as a local datum to subtract the local land elevation surface value from (e.g. 60 m at MSL, as depicted), in order to derive land elevation values relative to the local datum (e.g. 6 m, as shown in quotes). The relative elevation of the water surface of the main channel has a calculated value of zero (m), as shown in quotes, along its entire length.

A de-trending process of a topographic map

Greco et al. 2008, *Landscape Research*, Vol. 33, No. 4, 461–486

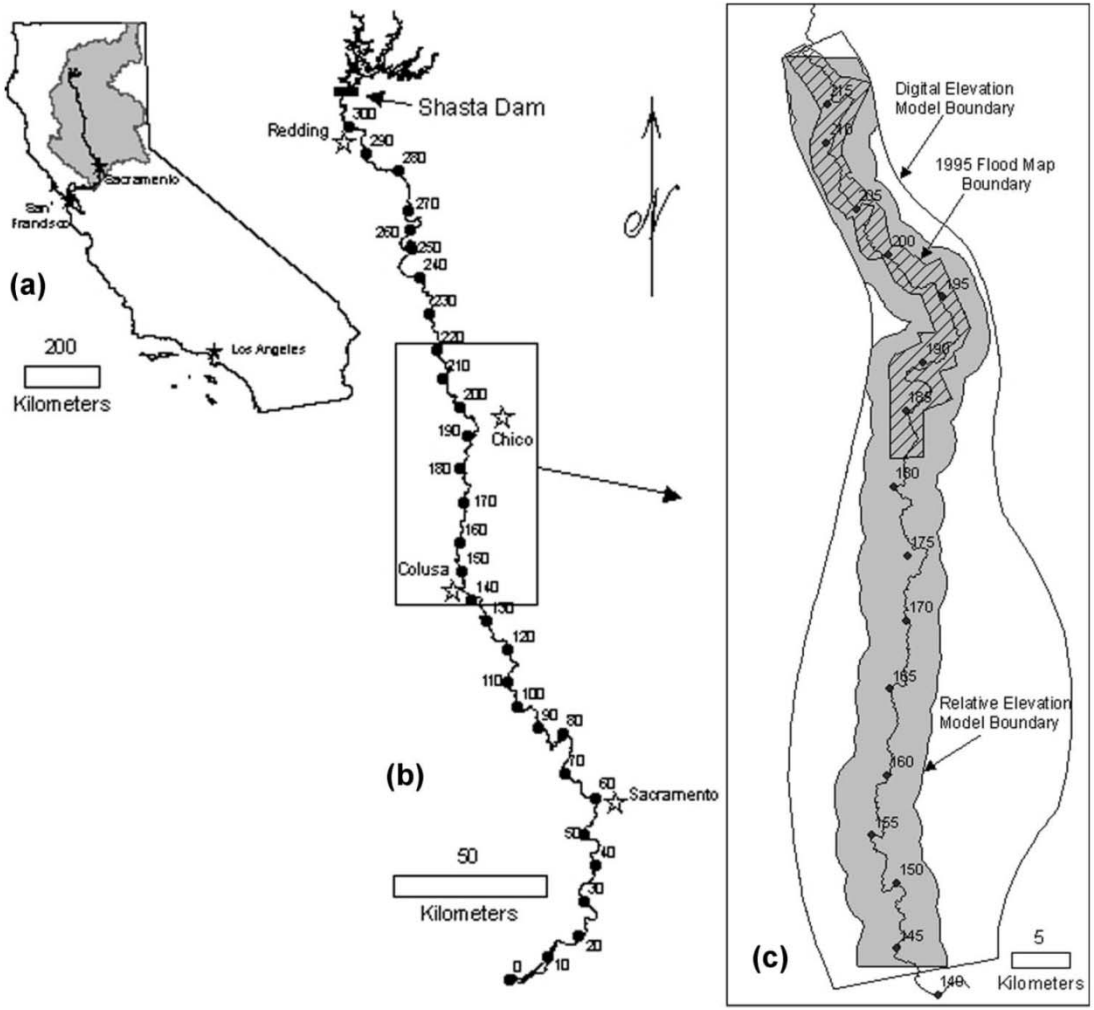


Figure 3. Location maps of the Sacramento River and the study areas. a) The Sacramento River and its watershed (grey tone) within the state of California. b) The Sacramento River is shown in 10-mile increments from river-mile 0 in the San Francisco Bay Delta to river-mile 300 near Shasta Dam. c) Study area boundaries: the raster digital elevation model boundary (no fill), the relative elevation model boundary (grey tone), and the observed 1995 flood map boundary (hatched pattern). River-miles are shown in five-mile increments.

Greco et al. 2008, *Landscape Research*, Vol. 33, No. 4, 461–486

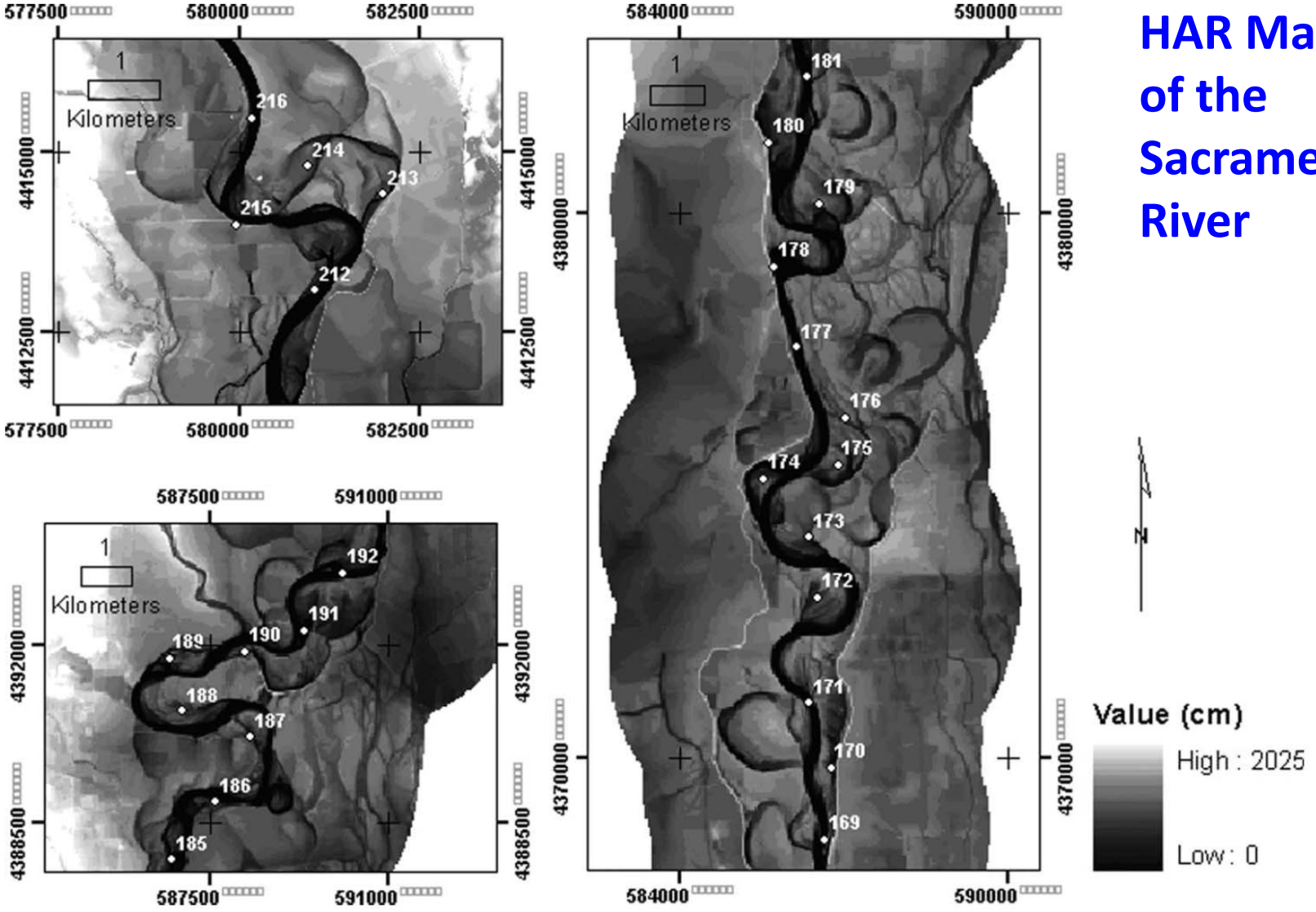


Figure 4. Example relative elevation surface maps of three areas within the study reach of the Sacramento River, USA. River-miles are shown as white points and text. Tick marks show the UTM coordinate system (zone 10, NAD27).

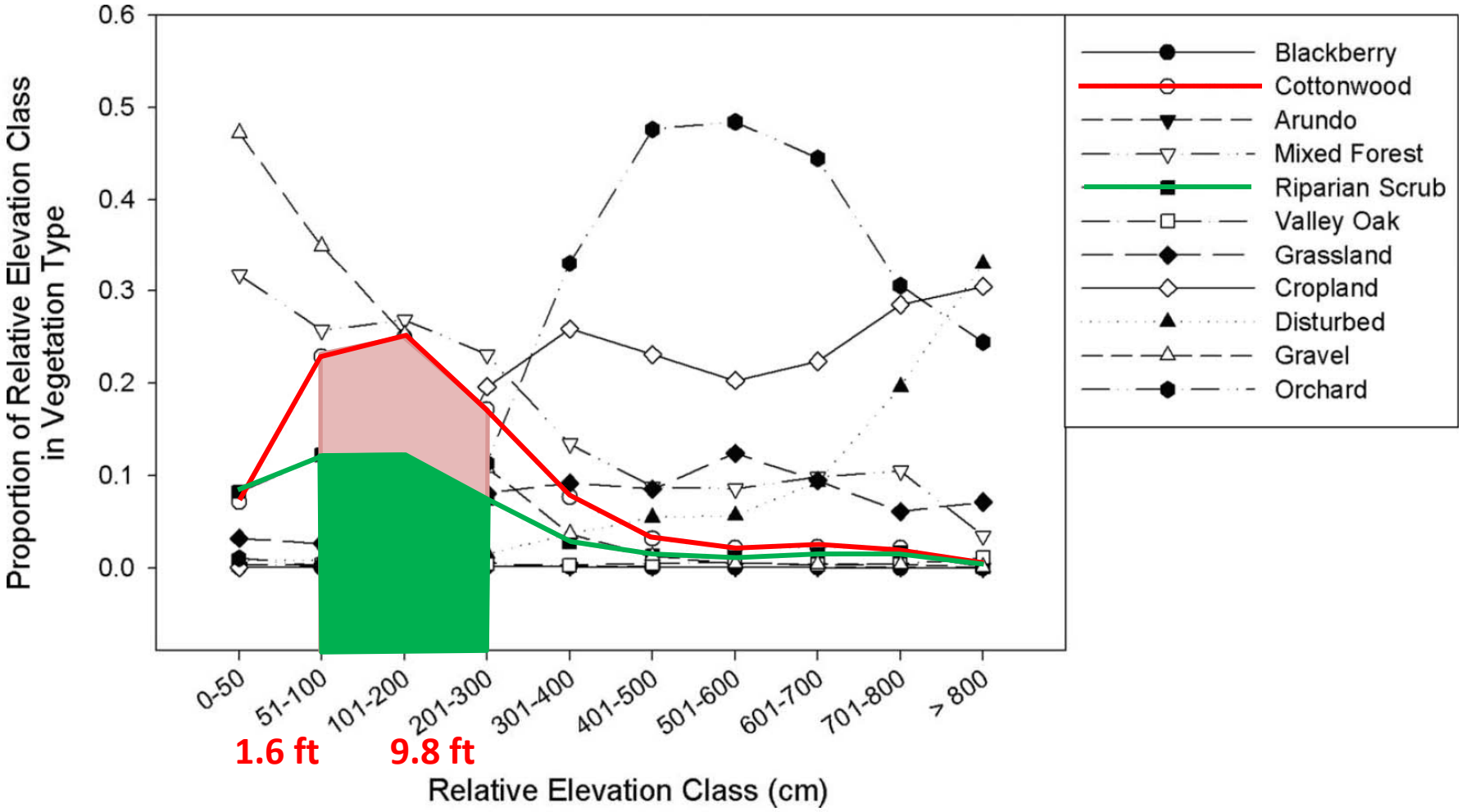


Figure 9. The proportion of the total area of each relative elevation class covered by each vegetation community and land cover type. Note the proportions sum to 1.0 for each relative elevation class.

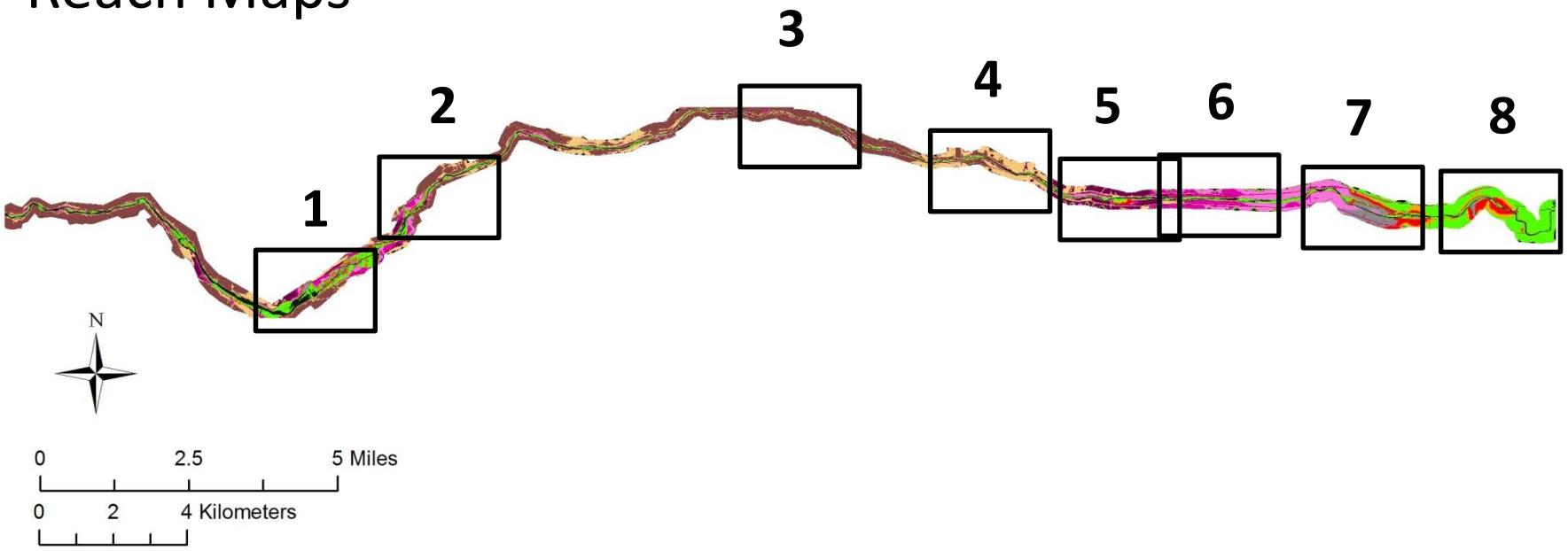
"The Effective Recruitment Box" = observed patterns of recruitment

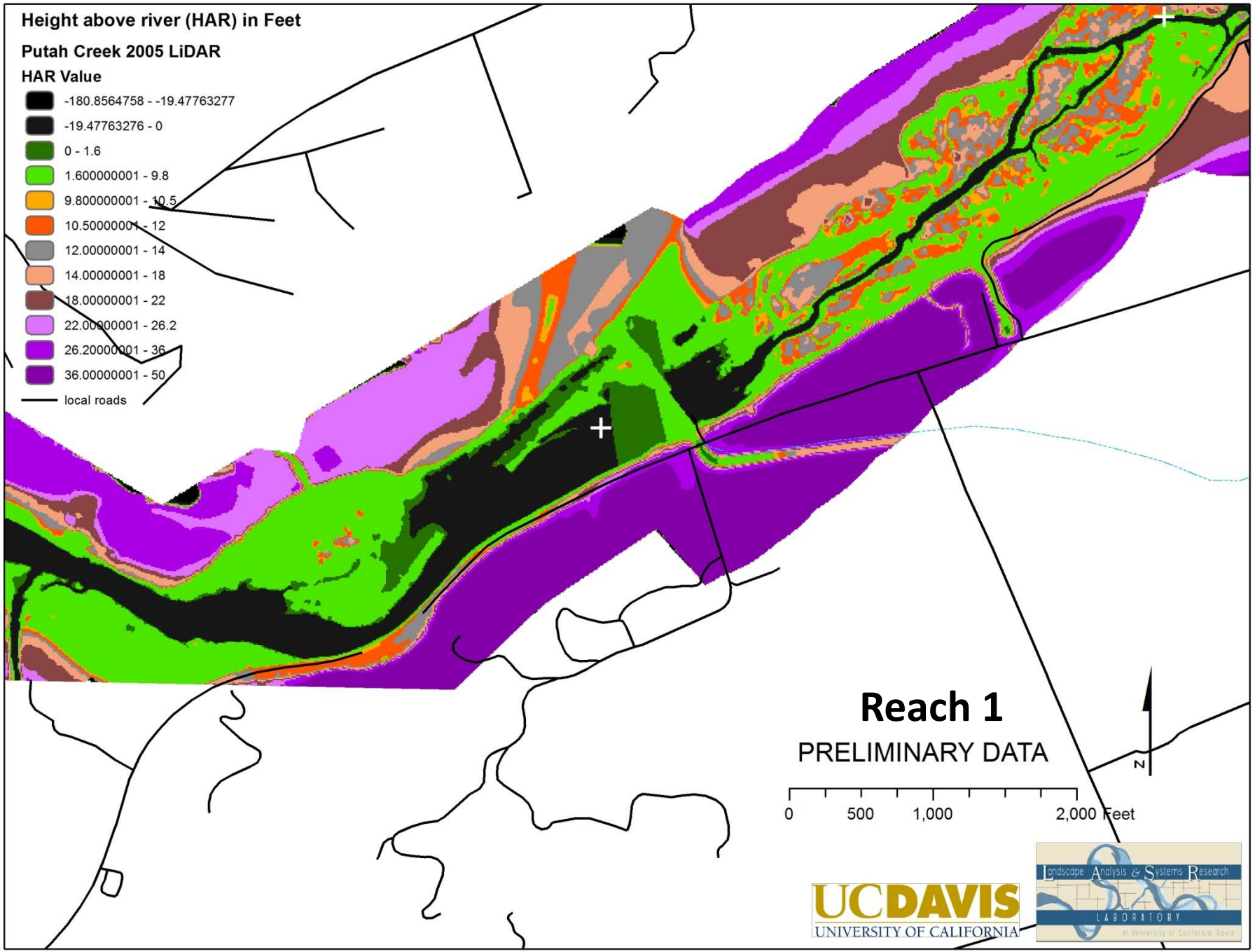
HAR Map of Putah Creek

- Based on 2005 LiDAR data and a water surface mapped by JSA
  - Water surface matches well to partially mapped LiDAR water surface
  - Estimated flow: 20 cfs releases (5 cfs at I-80)
- Used the HAR algorithm in the "Riparian" toolbox in "Topographic Tools" for ArcGIS (v10.3)
- Results presented from upstream (at Putah Diversion Dam) to downstream (the Putah Creek Sinks)
- 8 example reach maps

HAR Map of Lower Putah Creek

Reach Maps




Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
Reach 1
PRELIMINARY DATA
0
500
1,000
2,000 Feet
N
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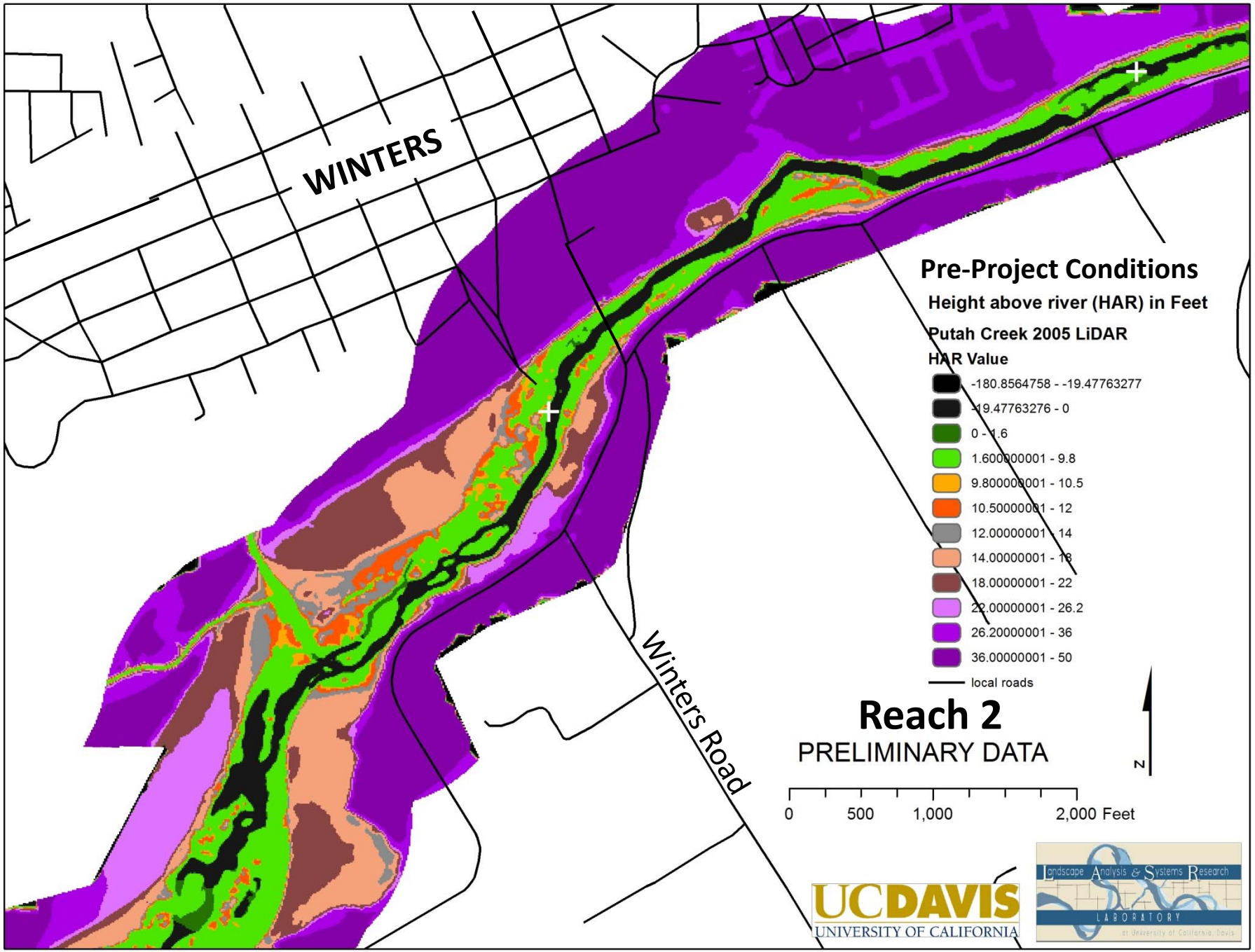
WINTERS
Winters Road
Pre-Project Conditions
Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
Reach 2
PRELIMINARY DATA
N
0
500
1,000
2,000 Feet
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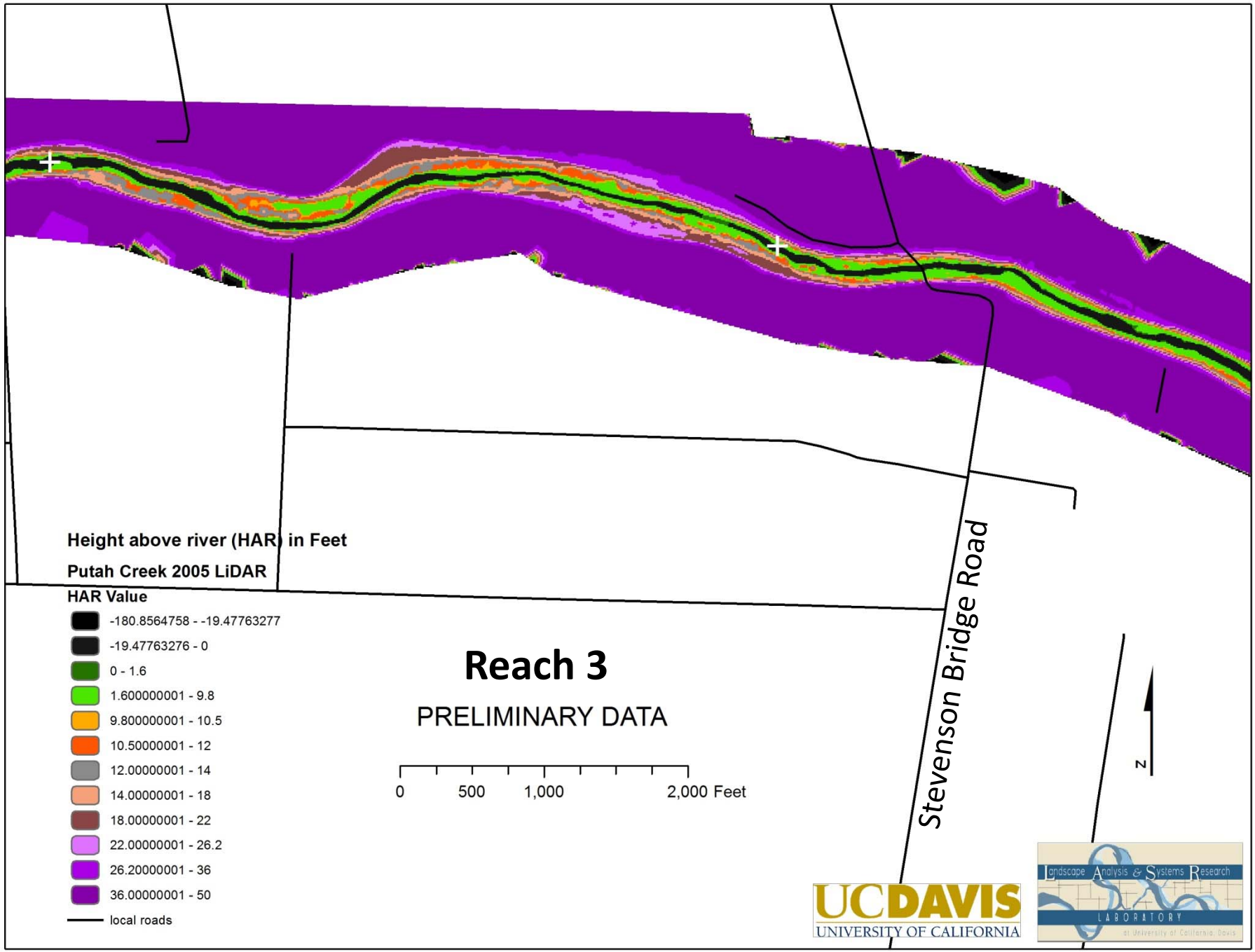
Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
Reach 3
PRELIMINARY DATA
0
500
1,000
2,000 Feet
Stevenson Bridge Road
N
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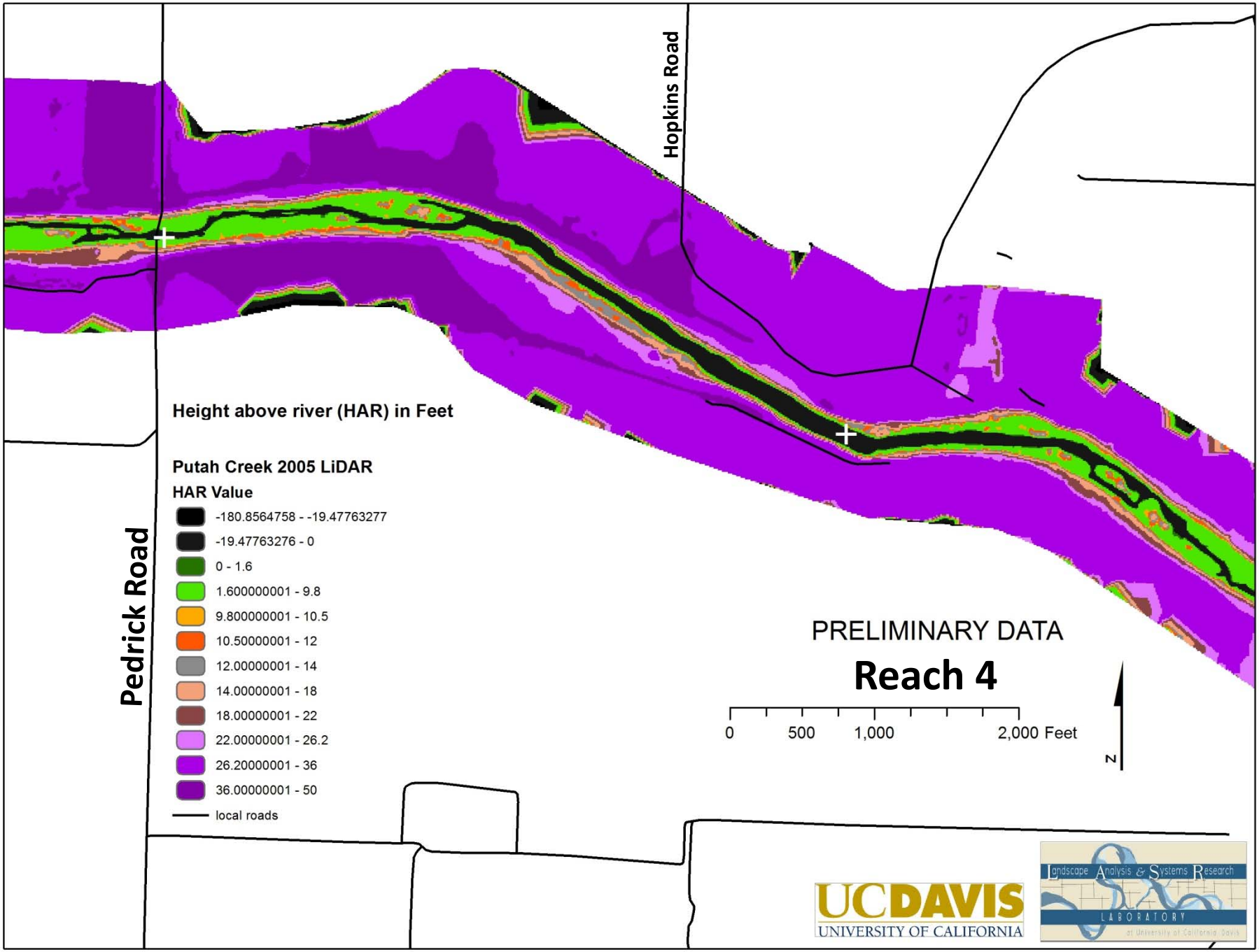
Hopkins Road
Pedrick Road
Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
PRELIMINARY DATA
Reach 4
0
500
1,000
2,000 Feet
N
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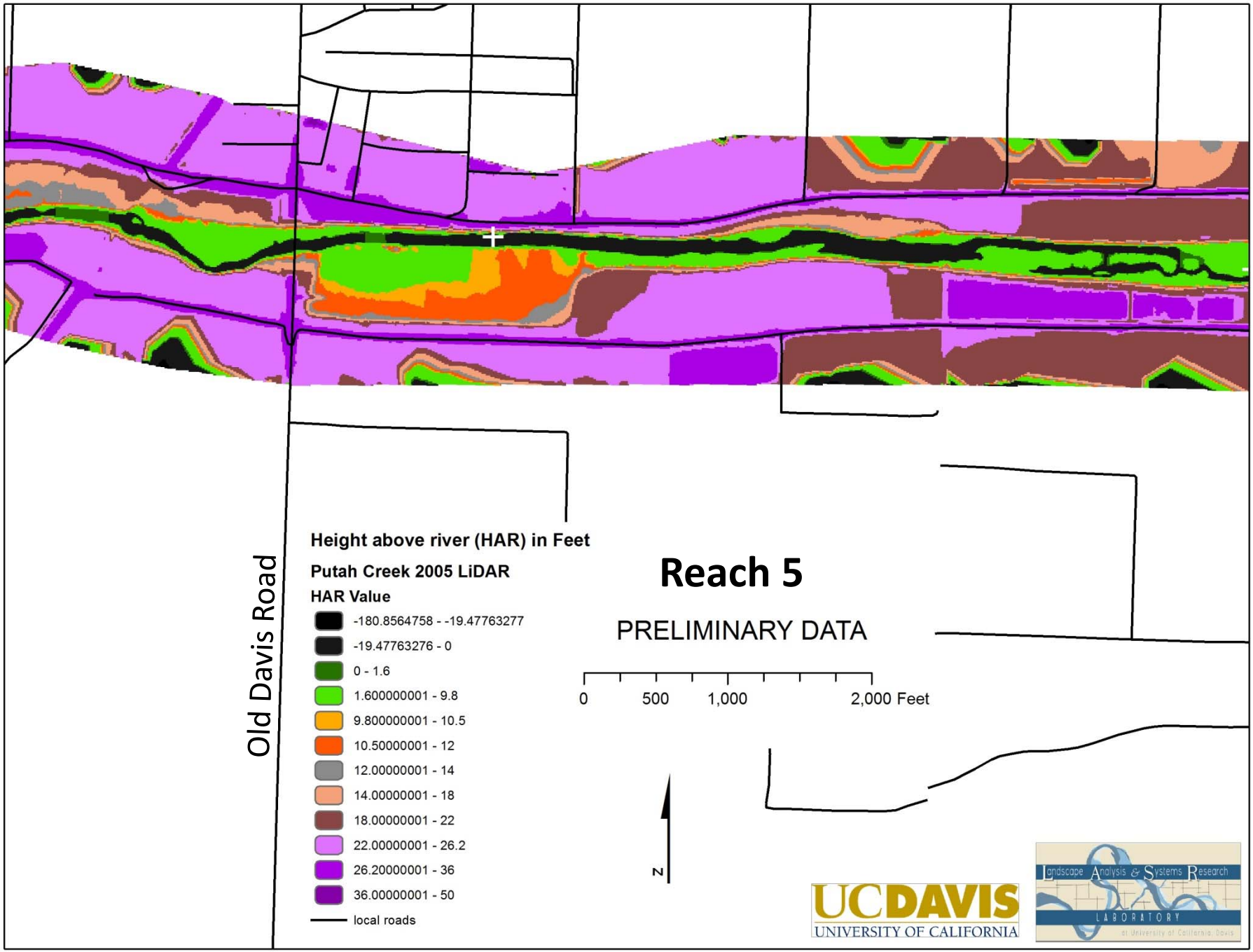
Old Davis Road
Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
Reach 5
PRELIMINARY DATA
0
500
1,000
2,000 Feet
N
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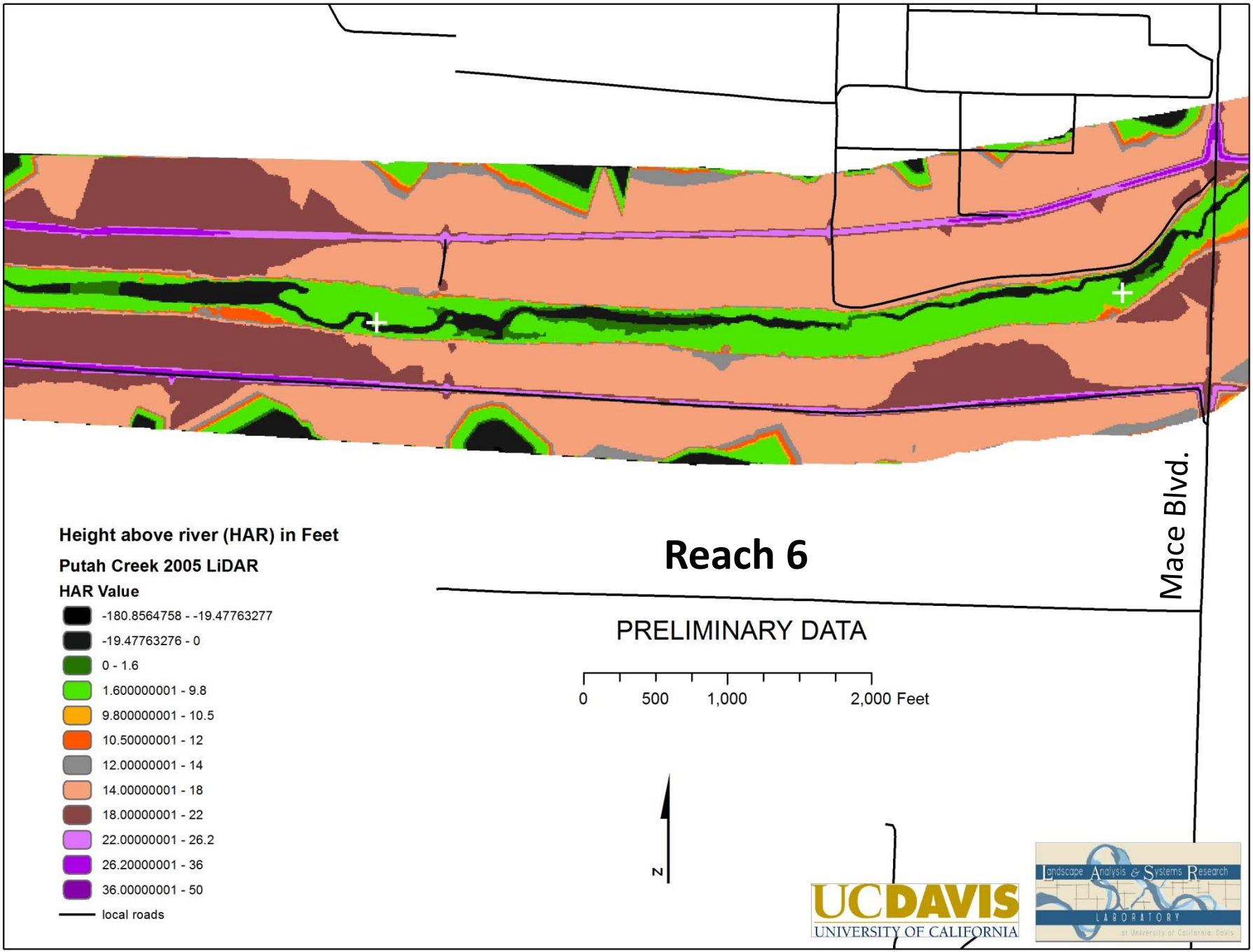
Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
Reach 6
Mace Blvd.
PRELIMINARY DATA
0
500
1,000
2,000 Feet
N
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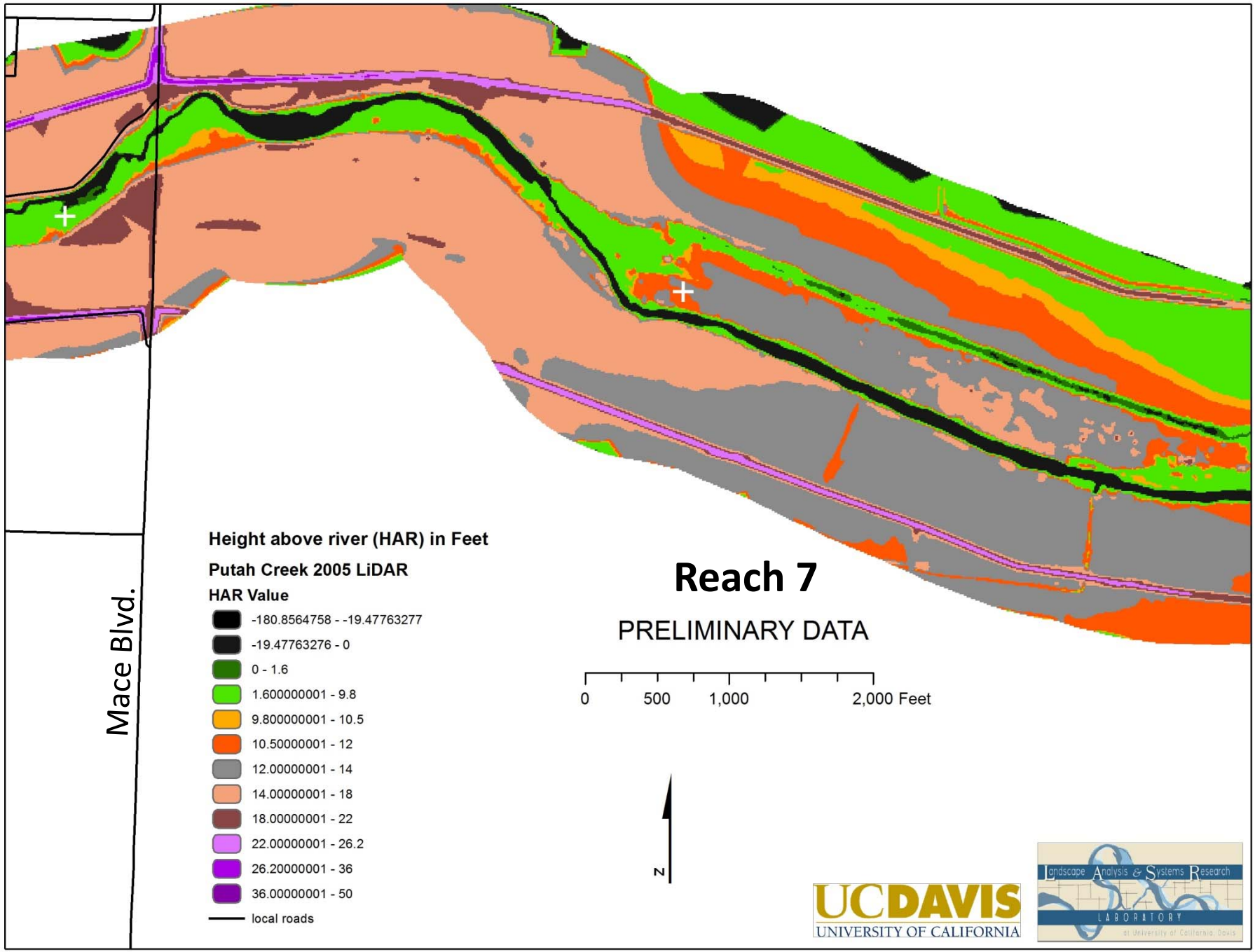
at University of California, Davis


Mace Blvd.
Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
Reach 7
PRELIMINARY DATA
0
500
1,000
2,000 Feet
N
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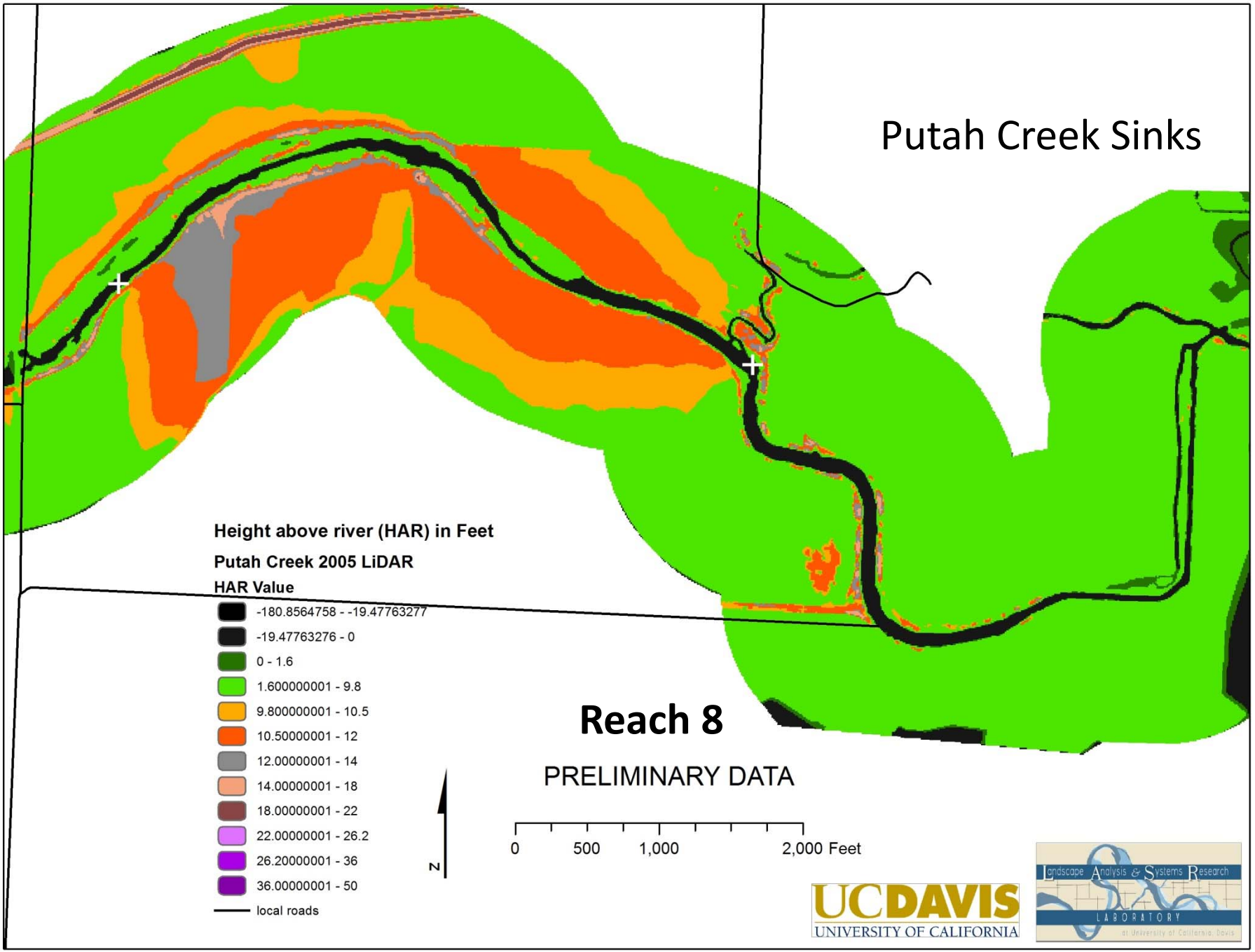
Putah Creek Sinks
Height above river (HAR) in Feet
Putah Creek 2005 LiDAR
HAR Value
-180.8564758 - -19.47763277
-19.47763276 - 0
0 - 1.6
1.600000001 - 9.8
9.800000001 - 10.5
10.50000001 - 12
12.00000001 - 14
14.00000001 - 18
18.00000001 - 22
22.00000001 - 26.2
26.20000001 - 36
36.00000001 - 50
local roads
Reach 8
PRELIMINARY DATA
N
0
500
1,000
2,000 Feet
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HAR Distribution of *Sambucus mexicana* (elderberry) on Putah Creek (n = 437)

Elderberry HAR Distribution	
Mean	27.28301574
Standard Error	0.474715093
Median	30.61288452
Mode	21.40689087
Standard Deviation	9.923703001
Sample Variance	98.47988125
Kurtosis	-0.529376216
Skewness	-0.689626404
Range	46.91171265
Minimum	0.879882813
Maximum	47.79159546
Sum	11922.67788
Count	437
Confidence Level(95.0%)	0.93301443

Elderberry has a mean relative elevation (or height above river, HAR) of **27 ft** with a std dev of 10 ft, meaning 67% of all mapped elderberry is distributed between **17 ft and 37 ft** above the channel's low flow (the "effective recruitment box").

- it is predominantly an upland species

Effective Recruitment Box

HAR Distribution of *Populus fremontii* (cottonwood) on Putah Creek

(n = 56)	
HAR- ALL PF	
Mean	13.70027334
Standard Error	0.814632193
Median	12.26997185
Mode	15.28557968
Standard Deviation	6.096149125
Sample Variance	37.16303416
Kurtosis	-0.527084103
Skewness	0.389608142
Range	25.93993759
Minimum	-0.846981049
Maximum	25.09295654
Sum	767.2153072
Count	56
Confidence Level(95.0%	1.632559385

Range: 0 - 25 ft
0 – 762 cm

67% from 8 – 19 feet

(n = 22)	
HAR <24" dbh	
Mean	11.74381
Standard Error	1.241501
Median	9.082588
Mode	7.673851
Standard Deviation	5.823156
Sample Variance	33.90914
Kurtosis	-0.53407
Skewness	0.146385
Range	22.14374
Minimum	-0.84698
Maximum	21.29676
Sum	258.3638
Count	22
Confidence Level(95.0%)	2.581843

0 - 21 ft
0 – 640 cm

67% from 6 – 17 feet

(n = 34)	
HAR >24" dbh	
Mean	14.96622
Standard Error	1.03123
Median	13.54314
Mode	#N/A
Standard Deviation	6.013054
Sample Variance	36.15681
Kurtosis	-0.98326
Skewness	0.573599
Range	18.0983
Minimum	6.994659
Maximum	25.09296
Sum	508.8516
Count	34
Confidence Level(95.0%	2.098054

7 - 25 ft
213 – 762 cm

67% from 9 – 21 feet

Future Work

- Offset DGPS data collection of other tree species to estimate HAR distribution (effective recruitment box):
  - Cottonwood (*Populus fremontii*)
  - Various willow species (*Salix* spp.)
  - Walnut (*Juglans* spp.)
  - Valley oak (*Quercus lobata*)
- Further refinement of the HAR model