

***Arundo donax*: Distribution and Impact Report (Monterey to San Diego)**

**A California Invasive Plant Council (Cal-IPC) Project
Funded by CA State Water Boards**

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REPORT ONLINE AT: www.cal-ipc.org

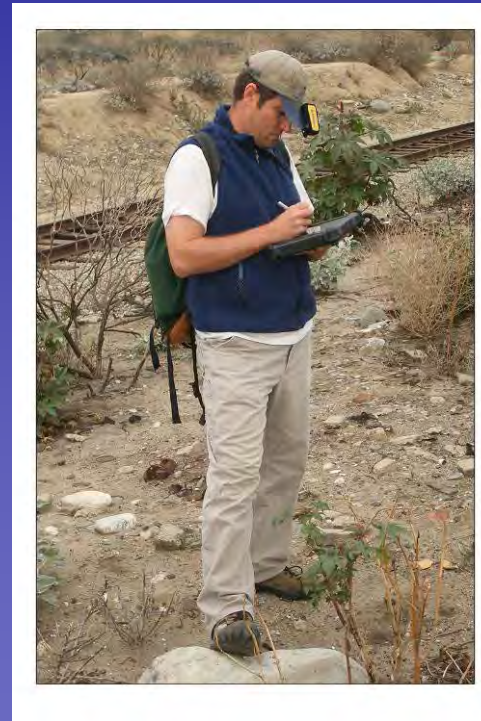
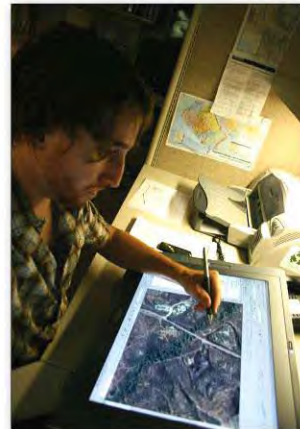
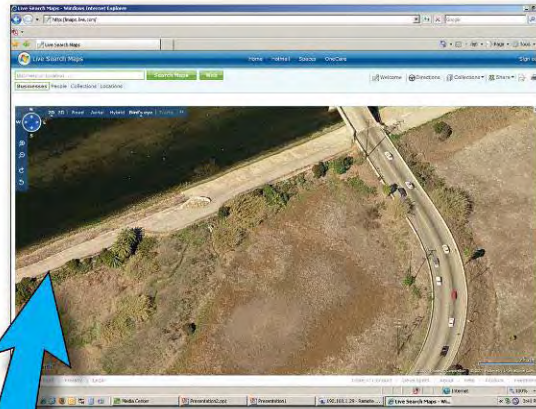
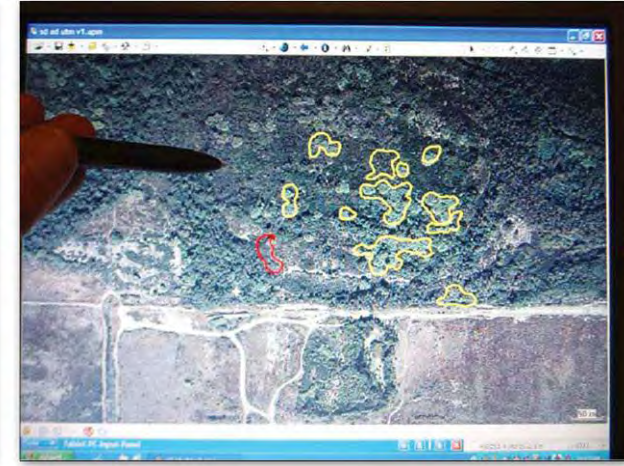


Program area: Coastal watersheds Monterey to San Diego

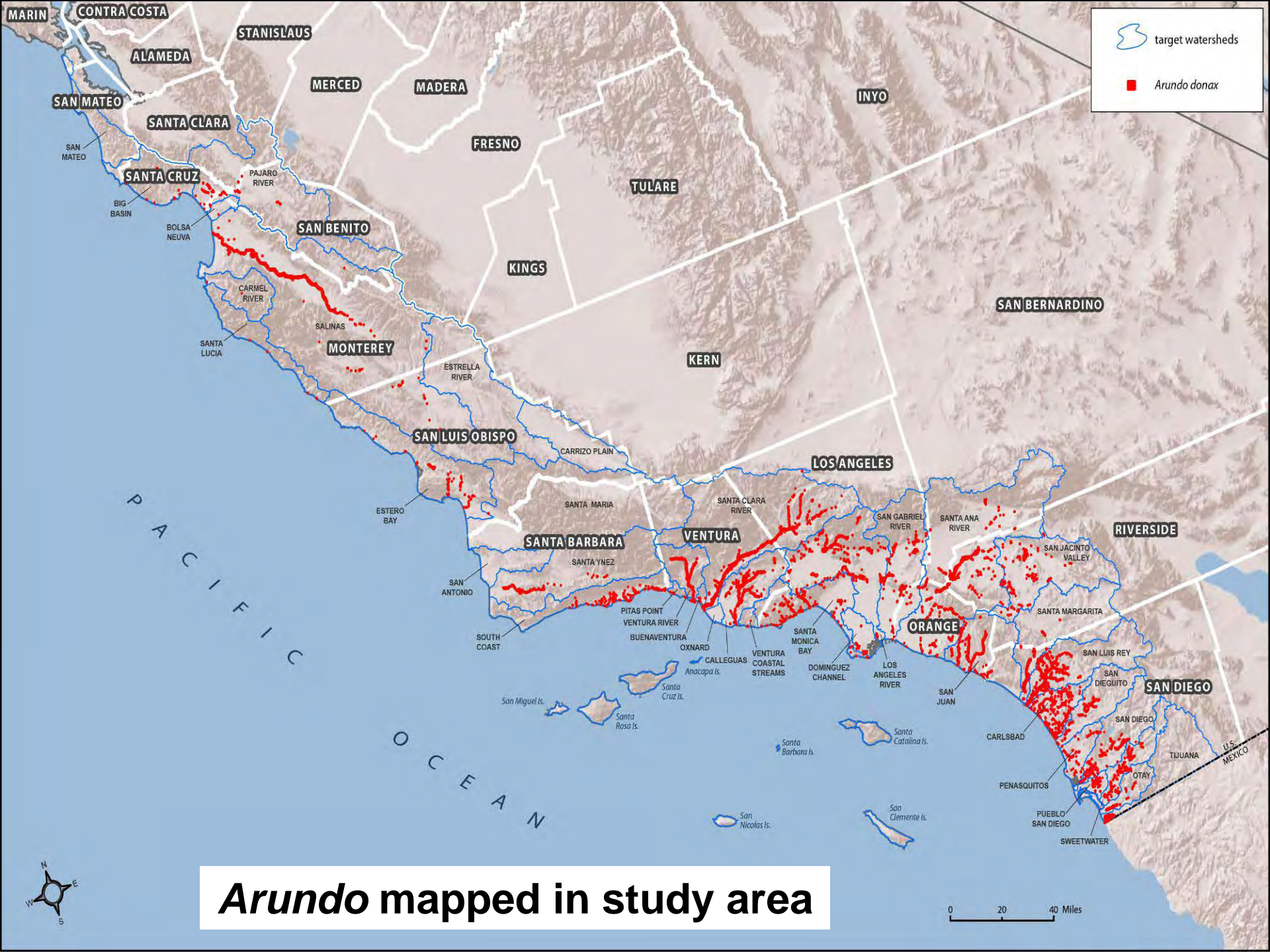
- 1. Map in high resolution (foundation)**
- 2. Describe and calculate impacts across study area:**
 - 1. Water use (transpiration)**
 - 2. Biomass**
 - 3. Fire**
 - 4. Hydrology, geomorphology (next talk)**
 - 5. Biotic (Federally listed species)**
 - 6. Cost to Benefit analysis**
 - 7. Watershed priority and capacity (see report)**

Mapping:

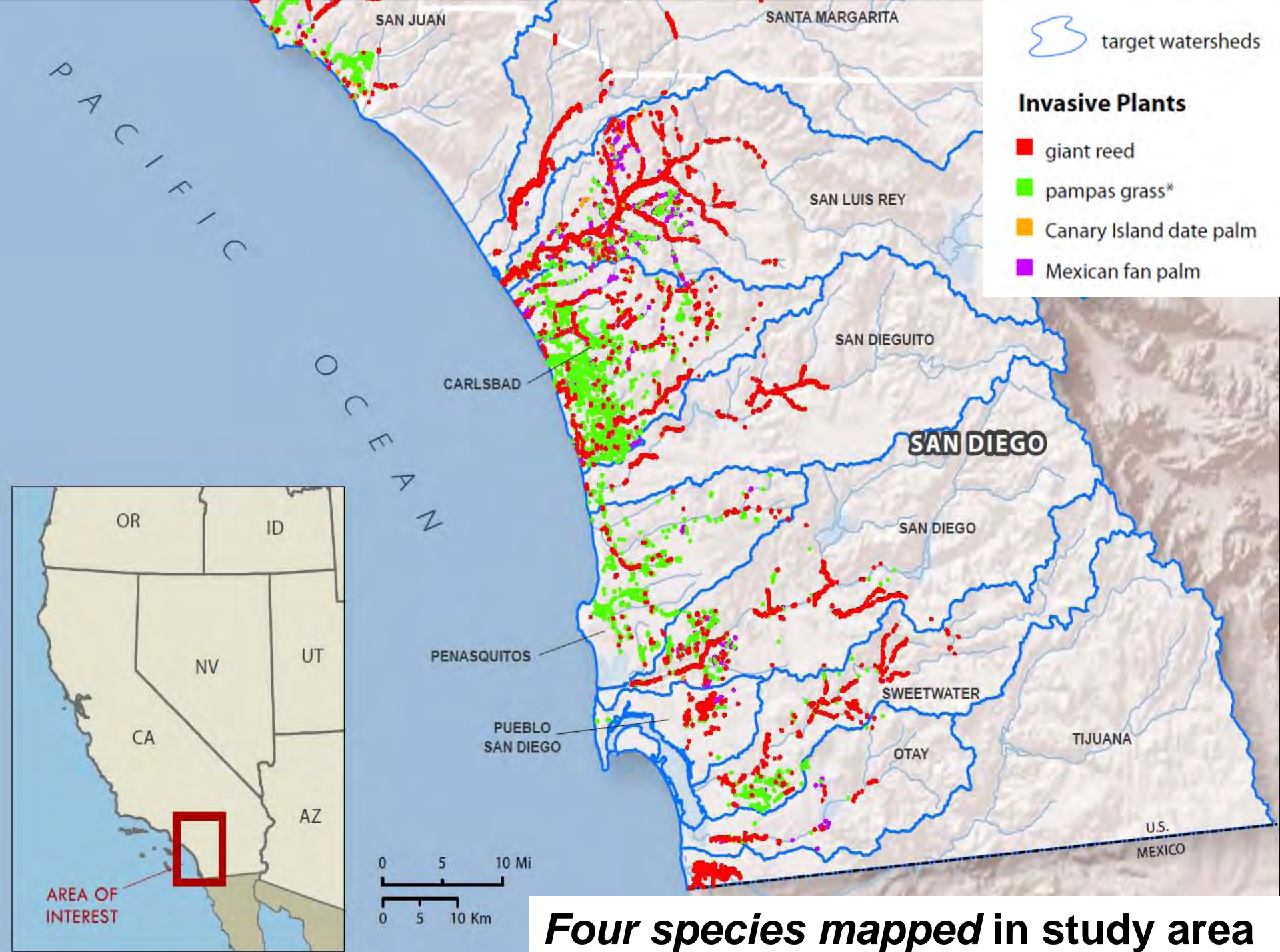
In-office



Field verification



Arundo mapped in study area



Four species mapped in study area

Watershed/Hydrological Units	Total Area (Acres)	Treated Arundo		Untreated Arundo		Total Arundo		Percent treated
		Gross Acres	Net Acres	Gross Acres	Net Acres	Gross Acres	Net Acres	
Calleguas	220,527	1.4	1.4	230.0	227.7	231.5	229.1	1%
Carlsbad HU	135,753	98.7	98.7	49.2	49.2	147.9	147.9	67%
Los Angeles River	533,834	16.3	16.3	116.5	115.1	132.8	131.4	12%
Salinas	2,272,492	137.4	106.4	1,868.7	1,225.3	2,006.1	1,331.7	8%
San Diego	278,977	56.2	56.2	94.0	93.3	150.2	149.5	38%
San Dieguito	221,555	89.8	89.8	85.2	85.2	175.0	175.0	51%
San Gabriel River	456,886	0.0	0.0	44.5	44.3	44.6	44.3	0%
San Juan	317,261	13.2	13.1	161.9	160.3	175.2	173.4	8%
San Luis Rey	358,662	612.4	612.4	71.4	71.4	683.9	83.9	90%
Santa Ana ¹	1,752,490	1,083.1	1,006.9	1,640.7	1,526.8	2,723.9	2,533.8	40%
Santa Clara	1,037,141	0.3	0.3	1,081.0	1,018.5	1,081.3	1,018.8	0%
Santa Margarita	475,449	684.7	684.7	4.2	4.2	688.9	688.9	99%
South Coast	240,092	7.8	7.8	22.0	22.0	29.8	29.8	26%
Sweetwater	146,781	5.7	5.7	36.7	36.1	42.3	41.8	14%
Tijuana ²	299,181	41.1	41.1	94.5	89.5	135.6	130.6	31%
Ventura River	144,669	143.6	117.4	188.4	132.5	332.0	249.9	47%
Totals:	14,458,055	2,995.5	2,861.9	5,911.7	5,001.8	8,907.2	7,863.7	33.6%

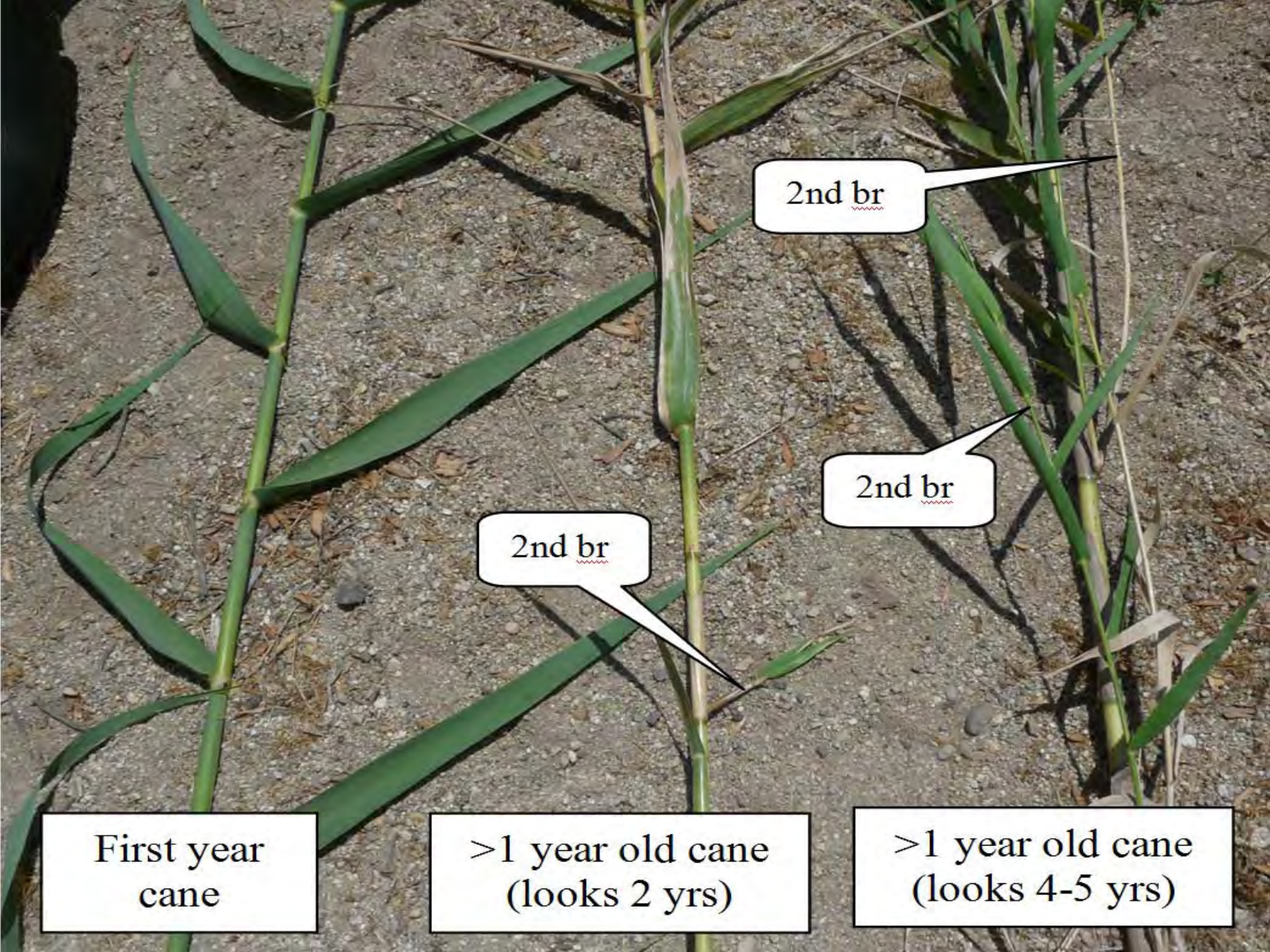
Impact: Water use and Biomass



Old canes

Old canes

First year canes



2nd br

2nd br

2nd br

First year
cane

>1 year old cane
(looks 2 yrs)

>1 year old cane
(looks 4-5 yrs)

**Leader
(green tip)**

Secondary branches and leaves

1 m

Main cane/stem

**The portion of
leader with dead
leaves below the
green tip**



Study	Location	LAI (m ² leaf/m ² ground)	Peak (mid-day) E/ (mmol/m ² /s)	Estand (mm/day) or (l/m ² /day)
Cal-IPC (this study)	Southern CA	15.8	Used 4.03	40.0
Abichandani 2007	Santa Clara, CA	14.25	4.03 ave across sites (1.89 to 5.80) season and wet vs dry	41.1 (36.4)
Watts 2009	Rio Grande, TX	4.1 (3.4-6.1) and 4.5	4.3 ave across sites (1.6 - 8.4) season	9.1 (11.0)
Spencer 2006	16 sites, US (leaf area Northern CA)	11.22	Used 4.03	28.3

Location	Description	Above ground dry mass	Source
U.S. - 13 sites across US	Biomass of stands in field	17.1 kg/m² 171 t/ha 76 US t/ac	Spencer 2006
U.S. - 14 sites, 6 coastal watersheds in southern CA	Biomass of stands in field	15.5 kg/m² 155 t/ha 69 US t/ac	This study
India	Biomass of stands in field	3.6 to 16.7 kg/m² 36 to 167 t/ha 16 to 74.3 US t/ac	Sharma et al. 1998
Southern CA (Santa Clara)	Annual yield (post fire)	49 t/ha 21.8 US t/ac	Ambrose & Rundel 2007

Study	Above ground biomass	Study
Willow forest (as crop)	4-8 t/ac (annual) 15 t/ac (4 year growth)	Turhollow 1999
Switch grass	5 t/ac	Turhollow 1999

Arundo

Impact: Fire

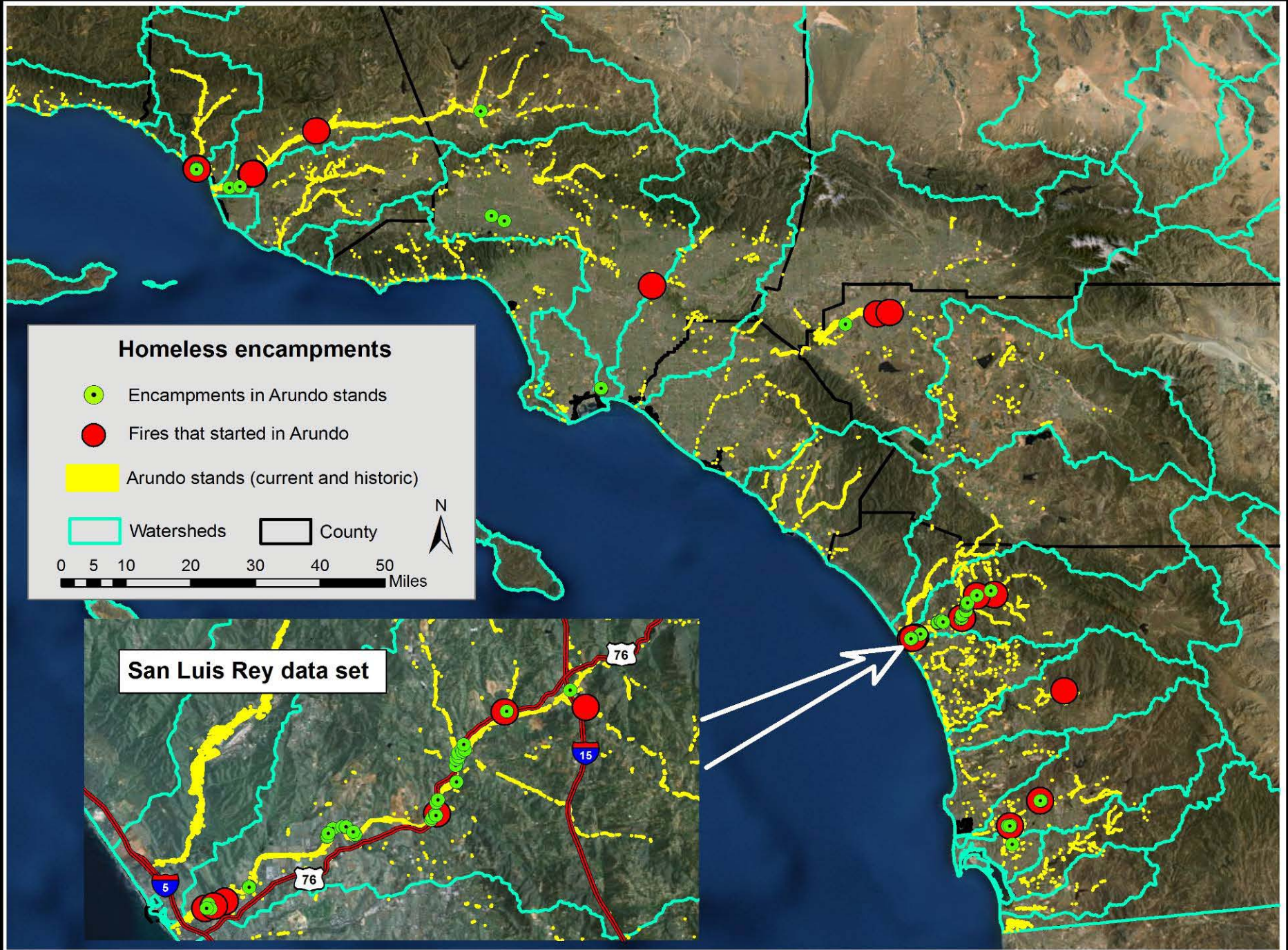


Camps on San Luis Rey Watershed

1







Homeless encampments

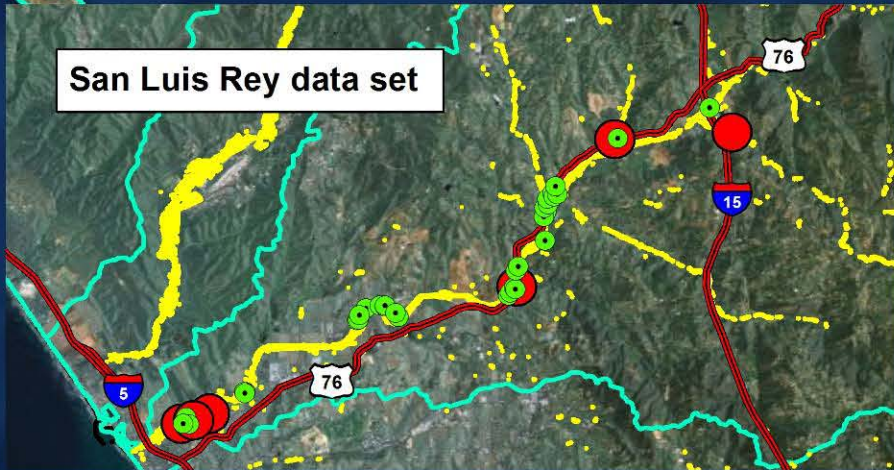
- Encampments in Arundo stands
- Fires that started in Arundo

Arundo stands (current and historic)

Watersheds County

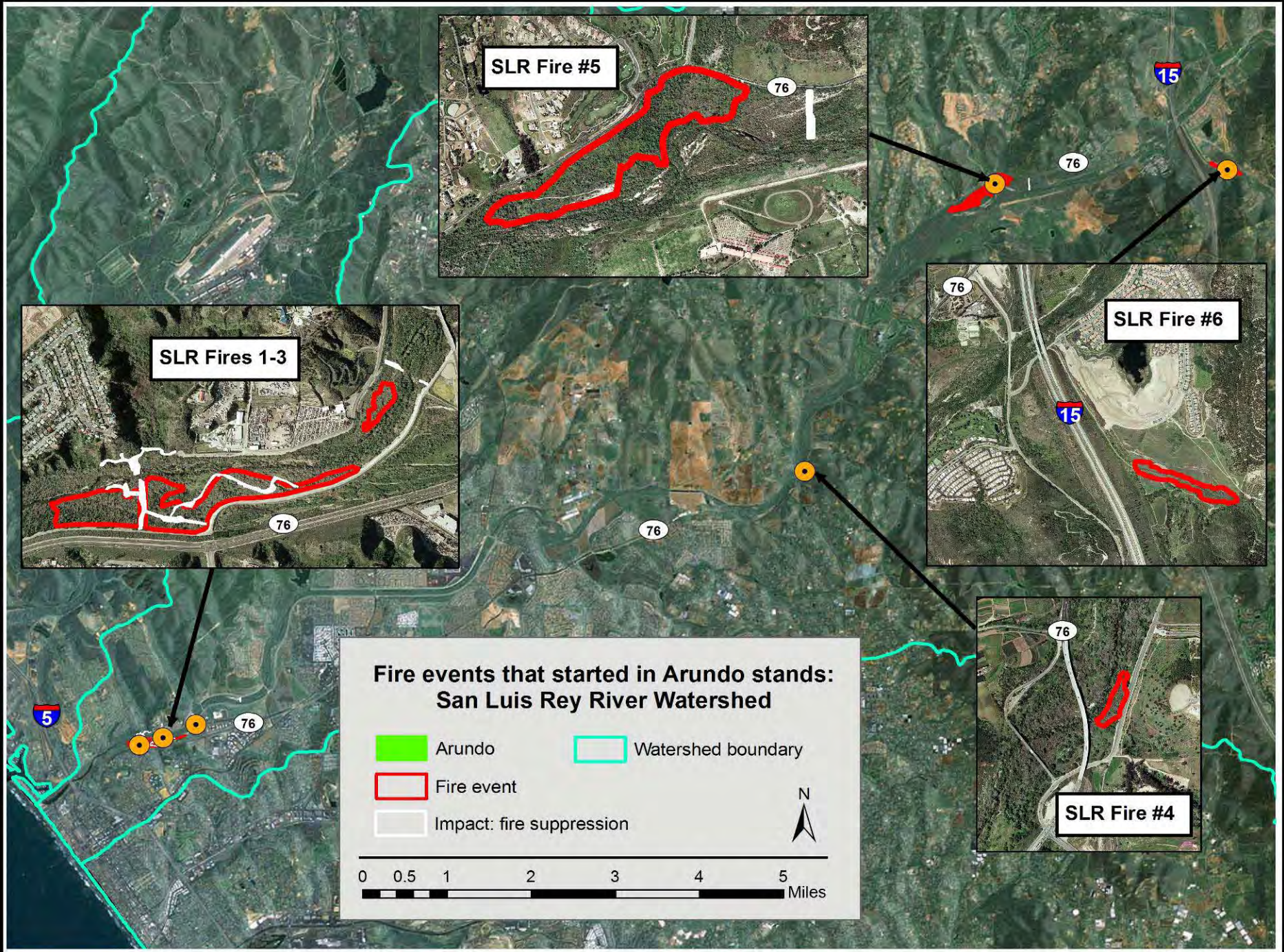


San Luis Rey data set



	Camps	People	Time Frame
San Luis Rey	34	84	2000-2009









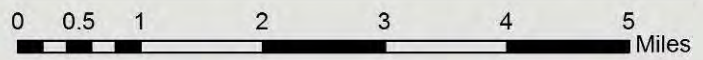
SLR Fire #5

SLR Fires 1-3

SLR Fire #6

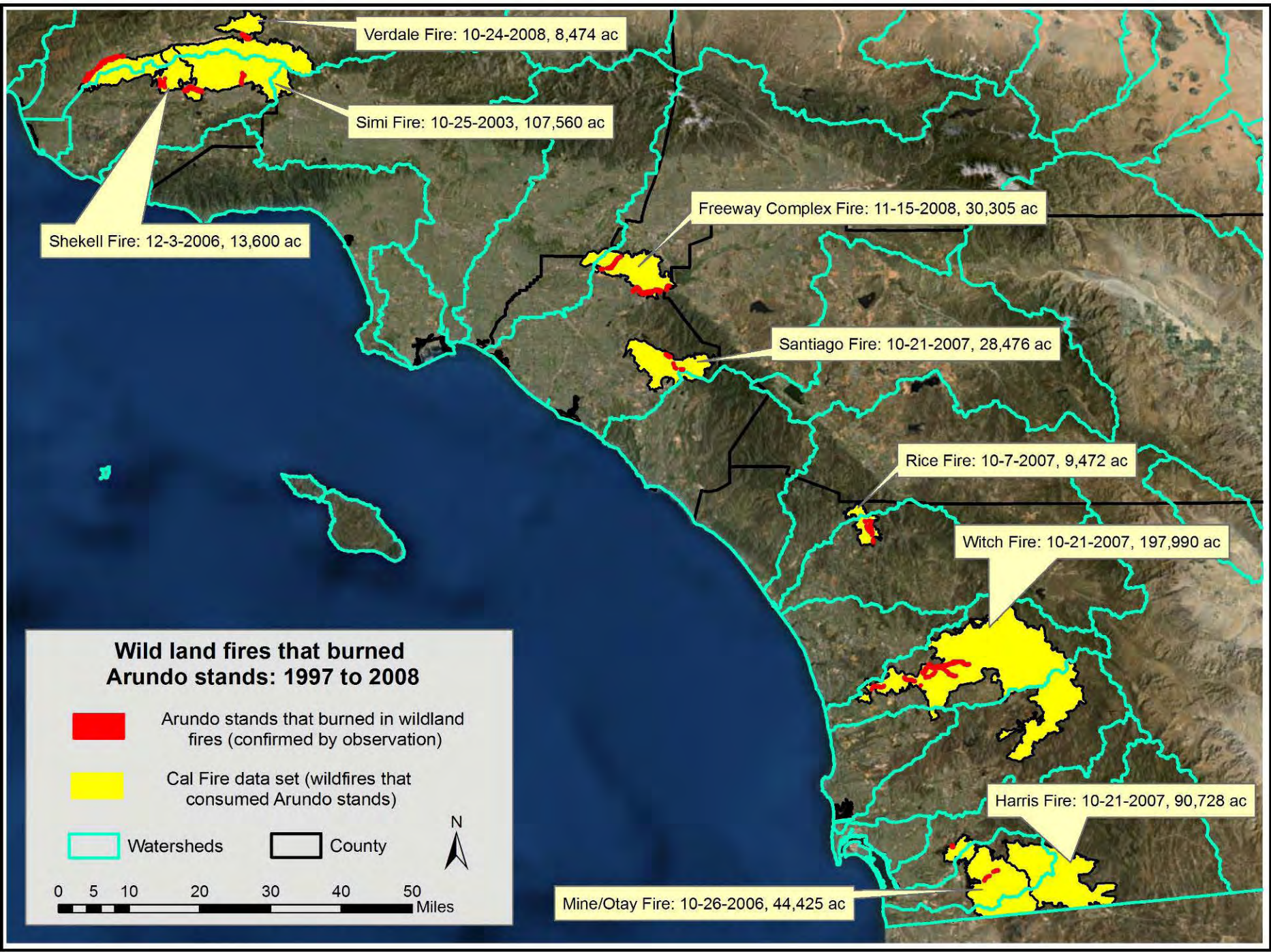
**Fire events that started in Arundo stands:
San Luis Rey River Watershed**

-  Arundo
-  Watershed boundary
-  Fire event
-  Impact: fire suppression



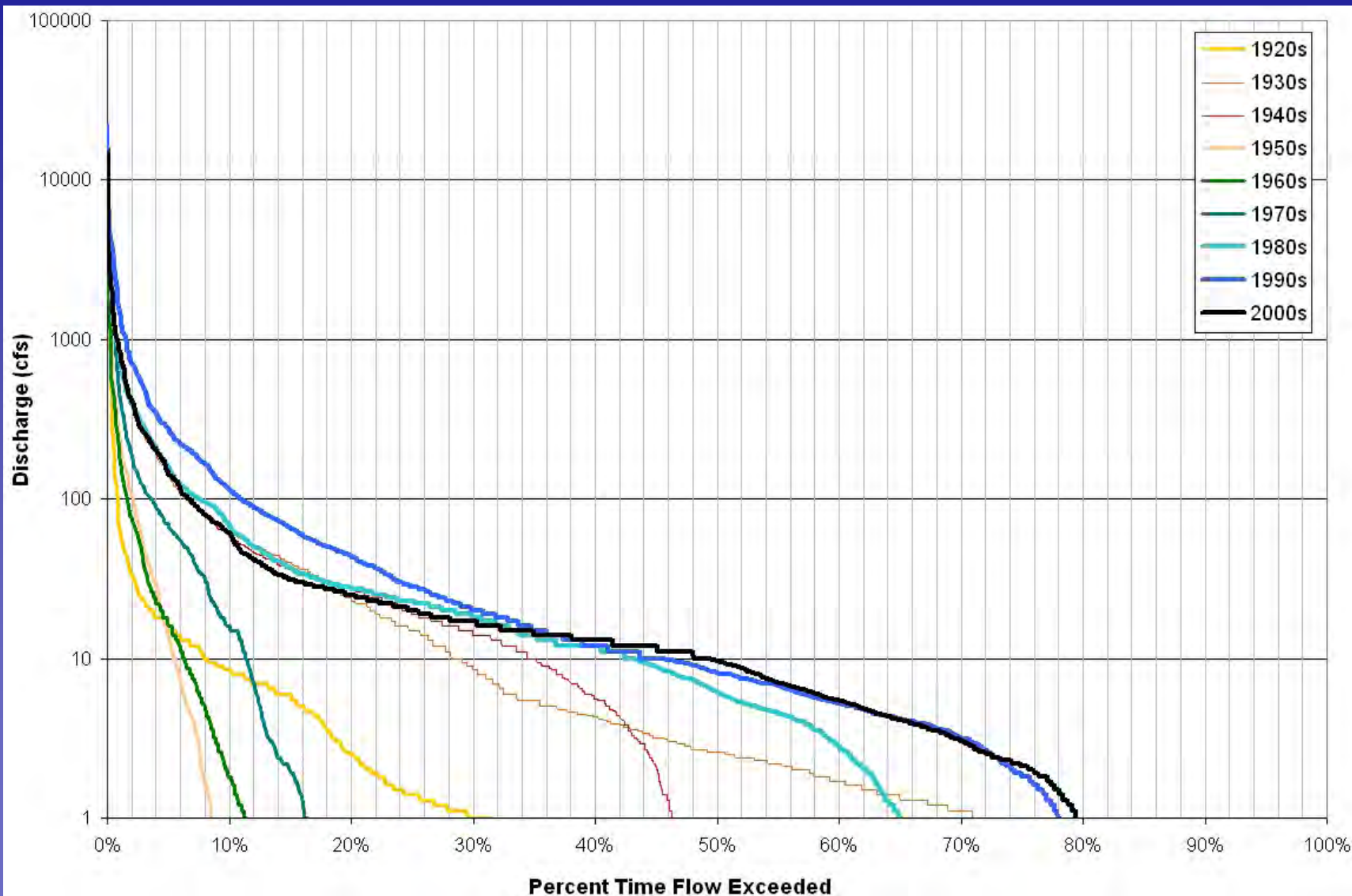
SLR Fire #4

Fires that start in Arundo		Fire: Arundo		Fire: Riparian		Suppression: Arundo		Suppression: Riparian		All Riparian Impacts	
Watershed	Gross Arundo Acres	Annual burn ac (0.8%)	10 year total	Annual burn ac (1.1%)	10 year total	Annual impacted ac (0.068%)	10 year total	Annual impacted ac (0.051%)	10 year total	Annual ac	10 year total
Calleguas	231.5	1.9	18.5	2.5	25.5	0.2	1.6	0.1	1.2	4.7	46.7
Carlsbad	147.9	1.2	11.8	1.6	16.3	0.1	1.0	0.1	0.7	3.0	29.8
Los Angeles River	132.8	1.1	10.6	1.5	14.6	0.1	0.9	0.1	0.7	2.7	26.8
Otay	18.6	0.1	1.5	0.2	2.1	0.0	0.1	0.0	0.1	0.4	3.8
Penasquitos	23.6	0.2	1.9	0.3	2.6	0.0	0.2	0.0	0.1	0.5	4.8
Salinas ¹	2006.1	1.6	16.0	2.2	22.1	0.1	1.4	0.1	1.0	4.0	40.5
San Diego	150.2	1.2	12.0	1.7	16.5	0.1	1.0	0.1	0.8	3.0	30.3
San Dieguito	175.0	1.4	14.0	1.9	19.2	0.1	1.2	0.1	0.9	3.5	35.3
San Gabriel	44.6	0.4	3.6	0.5	4.9	0.0	0.3	0.0	0.2	0.9	9.0
San Juan	175.2	1.4	14.0	1.9	19.3	0.1	1.2	0.1	0.9	3.5	35.3
San Luis Rey	683.9	5.5	54.7	7.5	75.2	0.5	4.7	0.3	3.4	13.8	138.0
Santa Ana	2723.9	21.8	217.9	30.0	299.6	1.9	18.5	1.4	13.6	55.0	549.7
Santa Clara	1081.3	8.7	86.5	11.9	118.9	0.7	7.4	0.5	5.4	21.8	218.2
Santa Margarita ²	688.9	0.6	5.5	0.8	7.6	0.0	0.5	0.0	0.3	1.4	13.9
Santa Monica	18.6	0.1	1.5	0.2	2.0	0.0	0.1	0.0	0.1	0.4	3.8
South Coast	29.8	0.2	2.4	0.3	3.3	0.0	0.2	0.0	0.1	0.6	6.0
Sweetwater	42.3	0.3	3.4	0.5	4.7	0.0	0.3	0.0	0.2	0.9	8.5
Tijuana	135.6	1.1	10.8	1.5	14.9	0.1	0.9	0.1	0.7	2.7	27.4
Ventura	332.0	2.7	26.6	3.7	36.5	0.2	2.3	0.2	1.7	6.7	67.0
Totals:	8,841.7	51.3	513.3	70.6	705.8	4.4	43.6	3.2	32.1	129.5	1,294.8

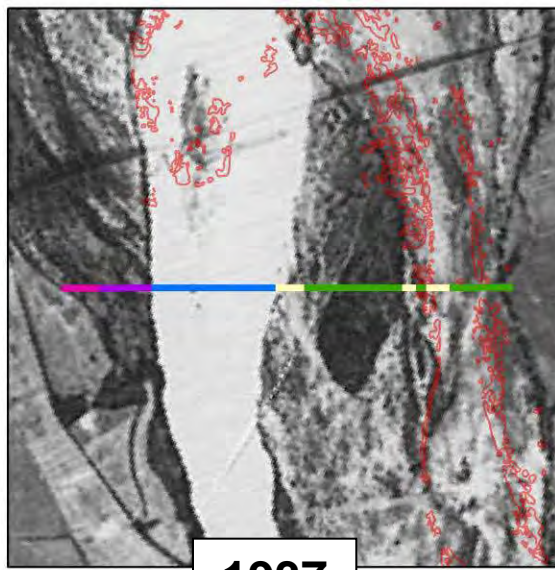


Watershed	Gross Arundo Acres	Fires that start in Arundo		Wildfires that burn Arundo		Combined Arundo fire totals	
		Burned Arundo acreage* (1 yr)	Burned Arundo acreage (10 yrs)	Burned Arundo acreage (1 yr)	Burned Arundo acreage (10 yrs)	Burned Arundo acreage (1 yr)	Burned Arundo acreage (10 yrs)
Calleguas	231.5	1.9	18.5	7.2	71.5	9.00	90.0
Carlsbad	147.9	1.2	11.8	-	-	1.18	11.8
Los Angeles River	132.8	1.1	10.6	-	-	1.06	10.6
Otay	18.6	0.1	1.5	0.1	0.5	0.20	2.0
Penasquitos	23.6	0.2	1.9	-	-	0.19	1.9
Salinas ¹	2,006.1	1.6	16.0	-	-	1.60	16.0
San Diego	150.2	1.2	12.0	-	-	1.20	12.0
San Dieguito	175.0	1.4	14.0	13.5	134.9	14.89	148.9
San Gabriel	44.6	0.4	3.6	-	-	0.36	3.6
San Juan	175.2	1.4	14.0	-	-	1.40	14.0
San Luis Rey	683.9	5.5	54.7	1.6	15.6	7.03	70.3
Santa Ana	2,723.9	21.8	217.9	9.6	95.7	31.36	313.6
Santa Clara	1,081.3	8.7	86.5	22.1	220.5	30.70	307.0
Santa Margarita ^{2,3}	688.9	0.6	5.5	-	-	0.55	5.5
Santa Monica	18.6	0.1	1.5	-	-	0.15	1.5
South Coast	29.8	0.2	2.4	-	-	0.24	2.4
Sweetwater	42.3	0.3	3.4	0.6	6.0	0.94	9.4
Tijuana	135.6	1.1	10.8	-	-	1.08	10.8
Ventura	332.0	2.7	26.6	-	-	2.66	26.6
Totals:	8,841.7	51.3	513.3	54.5	544.7	105.8	1,058.0
% of Gross Ac:			5.8%		6.1%		12%

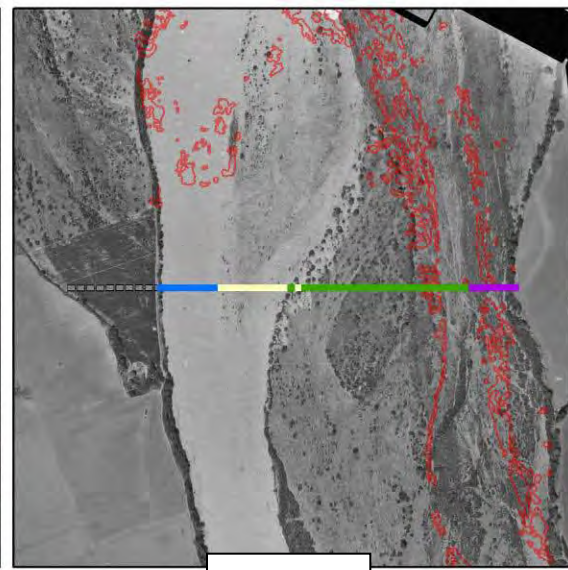
Flow duration curves plotted by decade at the Ysidora gage (11046000). Santa Margarita River



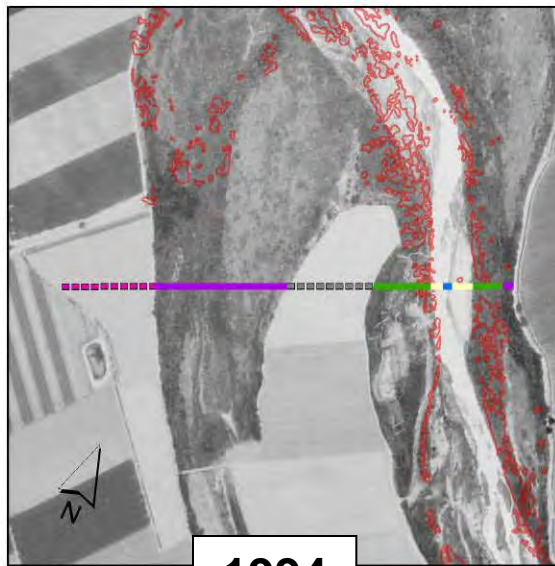
Historic analysis: Example from Salinas



1937



1956



1994



2006

Cross Section Geomorphology

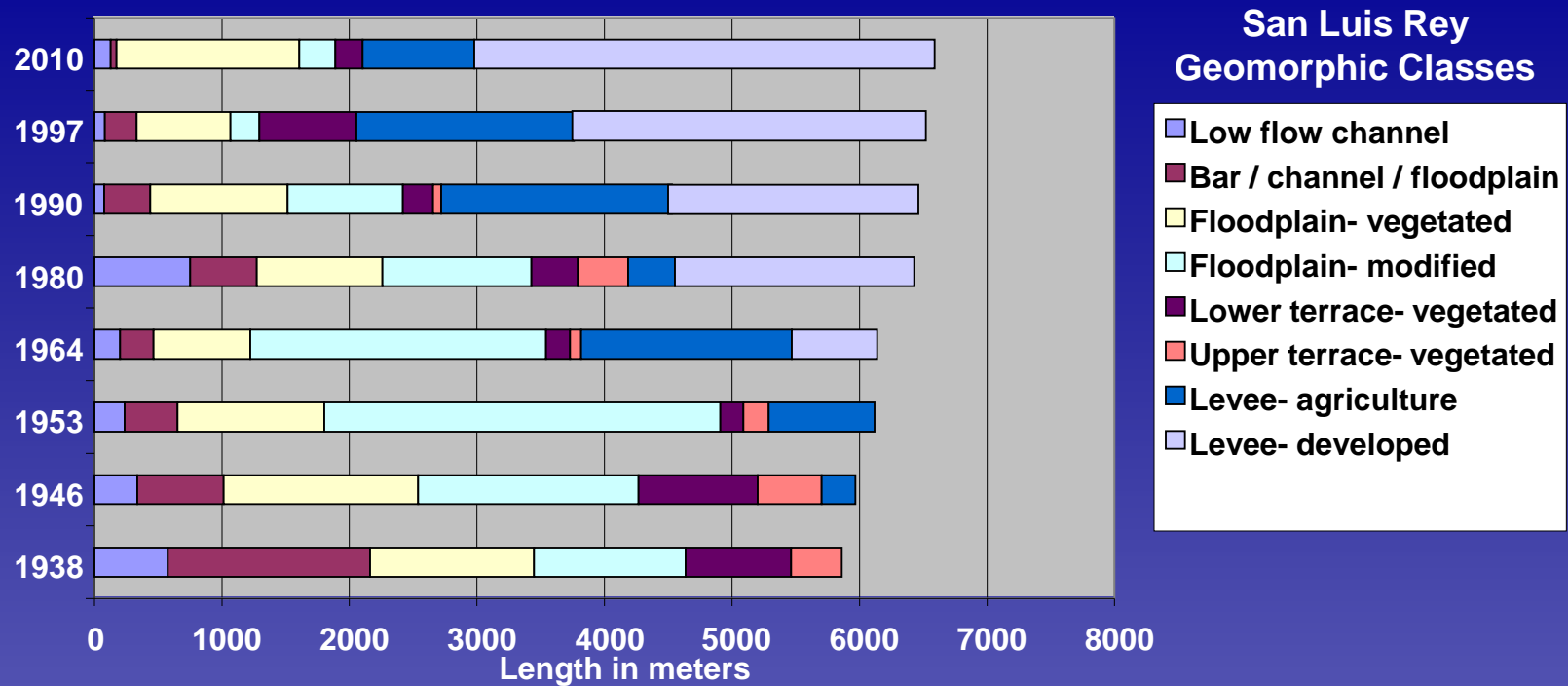
- Bar / Channel / Floodplain - unvegetated
- Flood Plain Modified / Ag/ grading / developed
- Floodplain - vegetated
- Hill Slope

Arundo

- Levee Protected - agricultural
- Levee Protected - developed
- Low Flow Channel
- Floodplain / Low Terrace – vegetated
- Upper Terrace - vegetated

Arundo

- Mapped (2006)



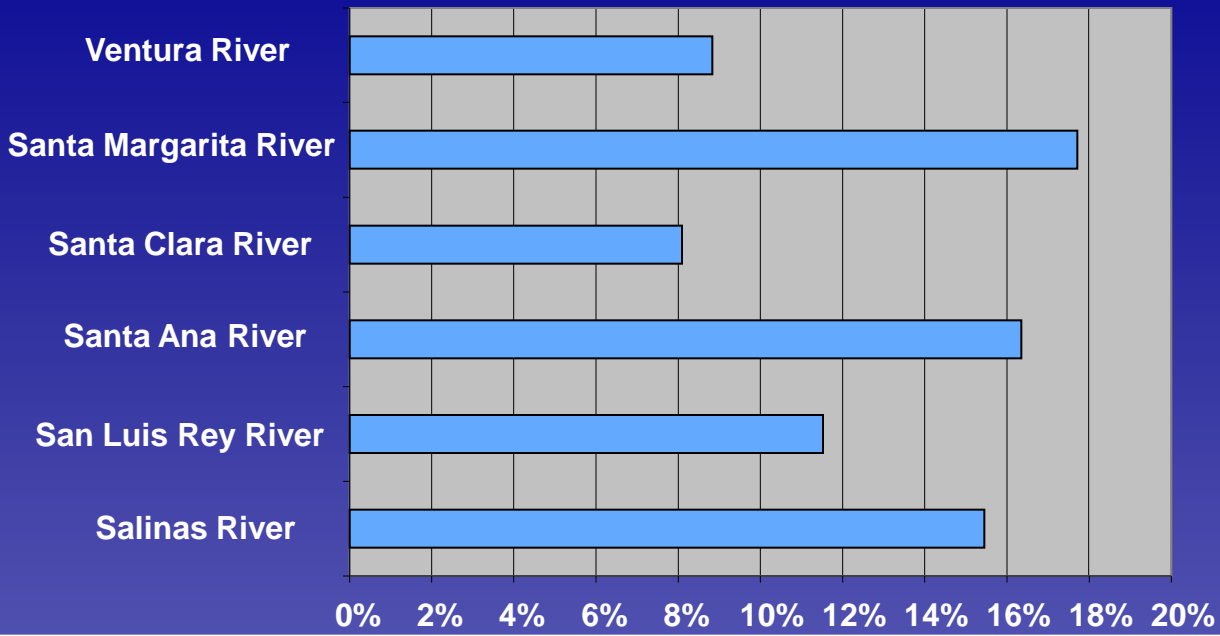
Historic analysis outcome (generalized)

1. Many of the study systems had significantly less riverine area
2. Channel/bar areas are a smaller proportion of system
3. Floodplain areas are larger proportion of system
4. Systems are wetter (more vegetated)

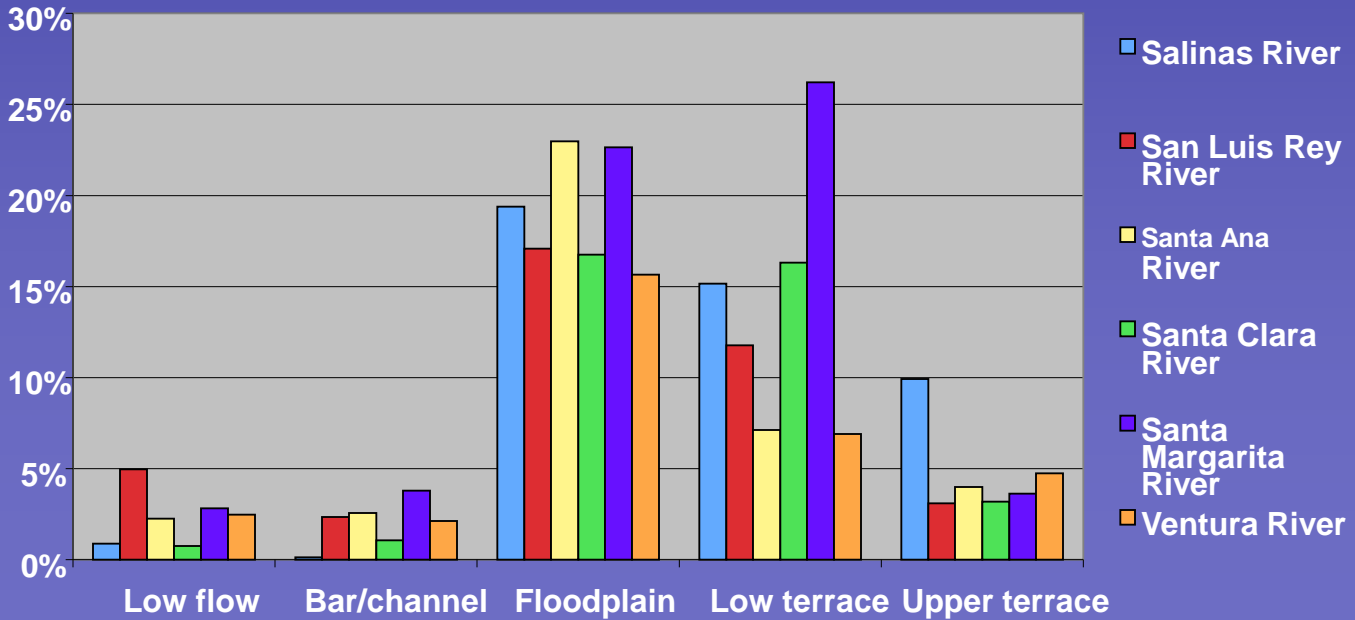
Arundo exploits wetter hydrology and abundance of floodplain areas

Percent of system invaded (lower portions of watershed)

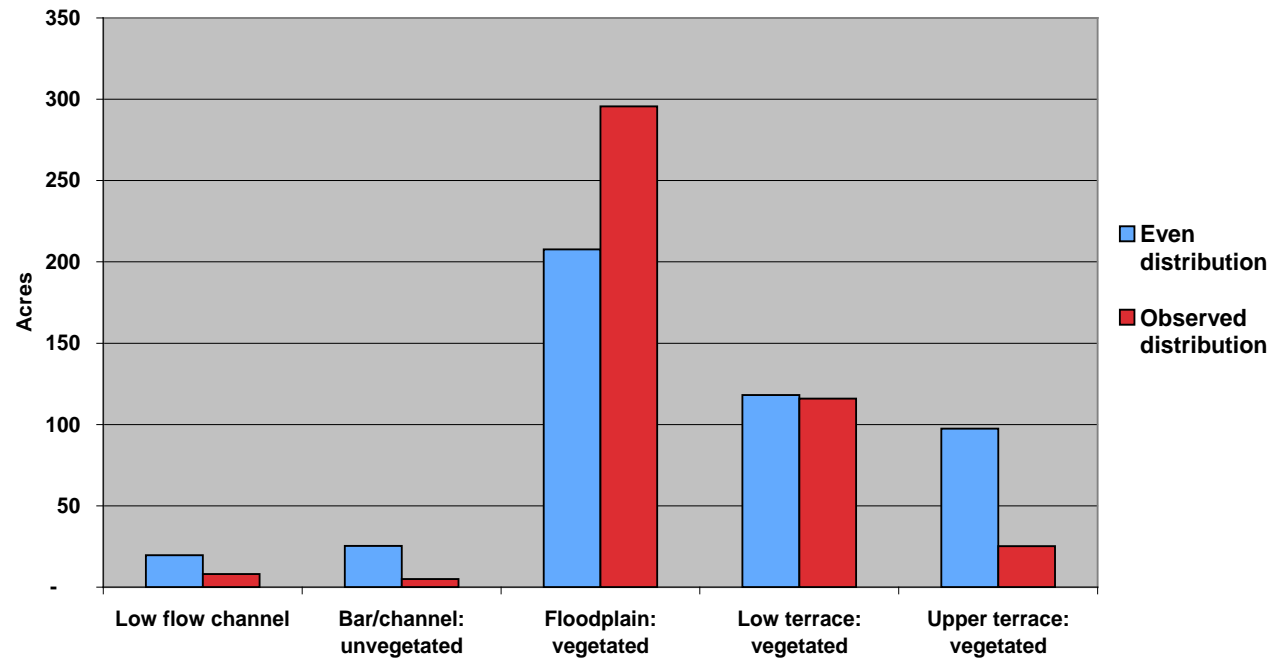
***Impact:
Hydrology and
Geomorphology***



Geomorphic forms within watersheds



San Luis Rey



Santa Margarita

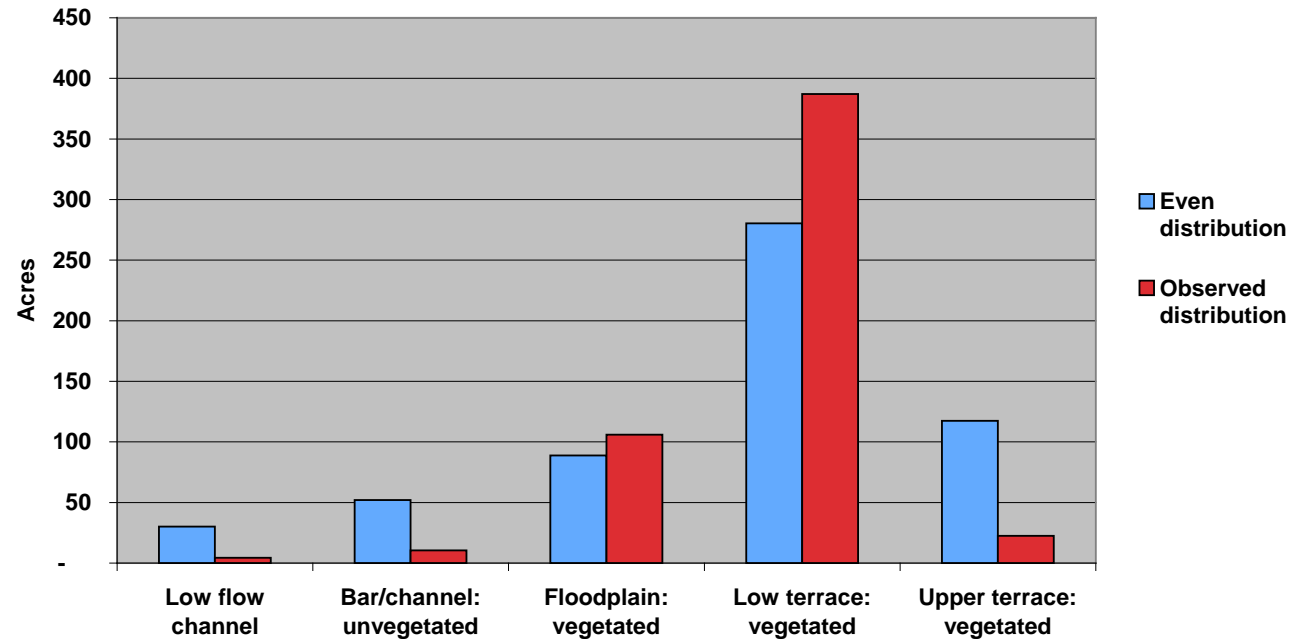


Table 3.2: Santa Ana River - Summary of GIS Analysis

Reach No.	Reach Length (mi)	Average Slope	Average Floodplain Width (ft)	Average Low Flow Channel Width (ft)	Width Ratio (%) ¹	Vegetated Area (%) ²	Arundo Area (%) ³
1	3.16	0.0012	9146	90	1.0%	98%	12.5%
2	12.17	0.0025	1758	136	7.7%	82%	41.2%
3	2.08	0.0030	733	207	28.3%	56%	10.5%
4	2.35	0.0047	2312	219	9.5%	76%	19.4%
5	9.67	0.0038	749	197	26.3%	30%	0.2%
6	3.98	0.0058	529	151	28.5%	36%	0.4%
7	3.44	0.0097	1441	133	9.3%	49%	0.0%
Weighted Average		0.0039	1942	159	15.7%	59.8%	16.6%
Total	36.86						

1 – Width Ratio = Average Floodplain Width / Average Low Flow Channel Width

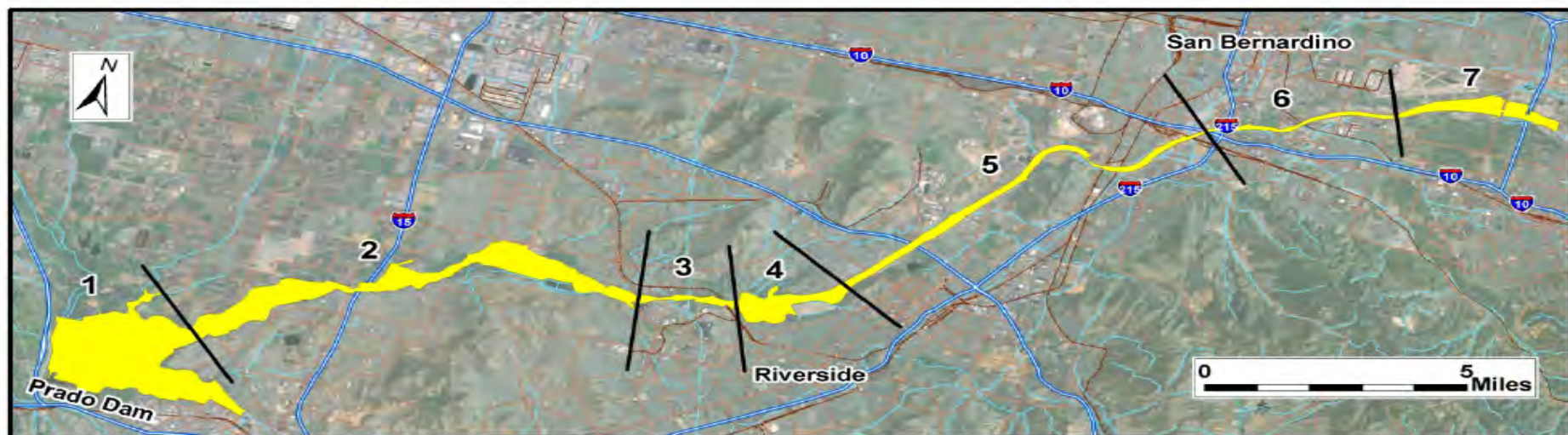
2 – Vegetated Area = Percent area of the total floodplain with more than 50% vegetation cover

3 – Arundo Area = Maximum percentage area of the floodplain and channel surface occupied by Arundo (Cal-IPC 2010b)

1 – Width Ratio = Average Floodplain Width / Average Channel Width

2 – Vegetated Area = Percent area of the floodplain and channel surface with more than 50% vegetation cover

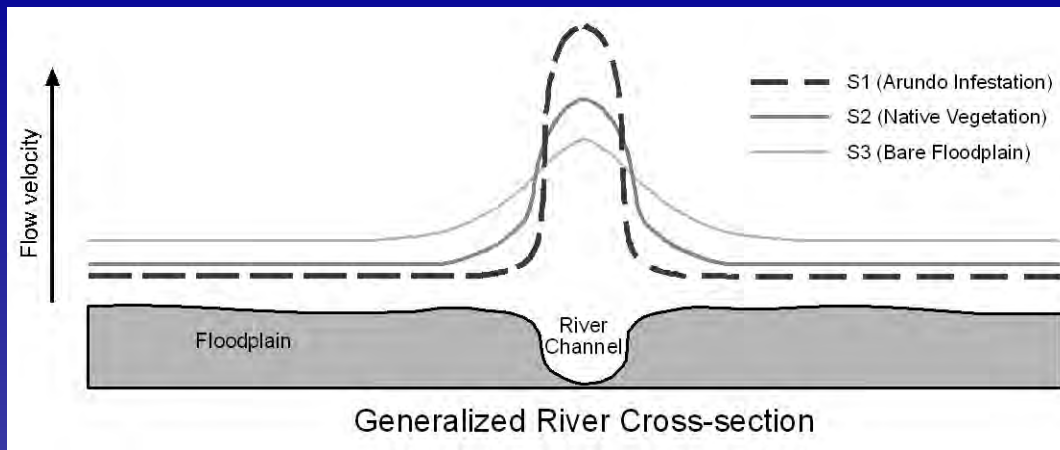
3 – Arundo Area = Percent area of the floodplain and channel surface occupied by Arundo (Cal-IPC 2010b)



Geomorphologic Class	Arundo Present: Gross Acres	Geomorphology Mapped (Current Day): Gross Acres	% Arundo (Net)
Low flow channel	63	3,393	1.5%
Bar/channel	165	6,575	1.5%
Floodplain	4,221	18,263	19.7%
Low terrace	2,176	12,424	15.4%
Upper terrace	206	4,085	4.8%
Total:	6,831	44,741	



Scenario	Average Depth	Average Flow Velocity	
		Channel	Overbank
1 – Arundo Infestation	Deeper	Faster	Slower
2 – Native Vegetation	<i>(baseline)</i>	<i>(baseline)</i>	<i>(baseline)</i>
3 – Bare Floodplain	Shallower	Slower	Faster
4 – 1997 Floodplain	Variable	Variable	Variable

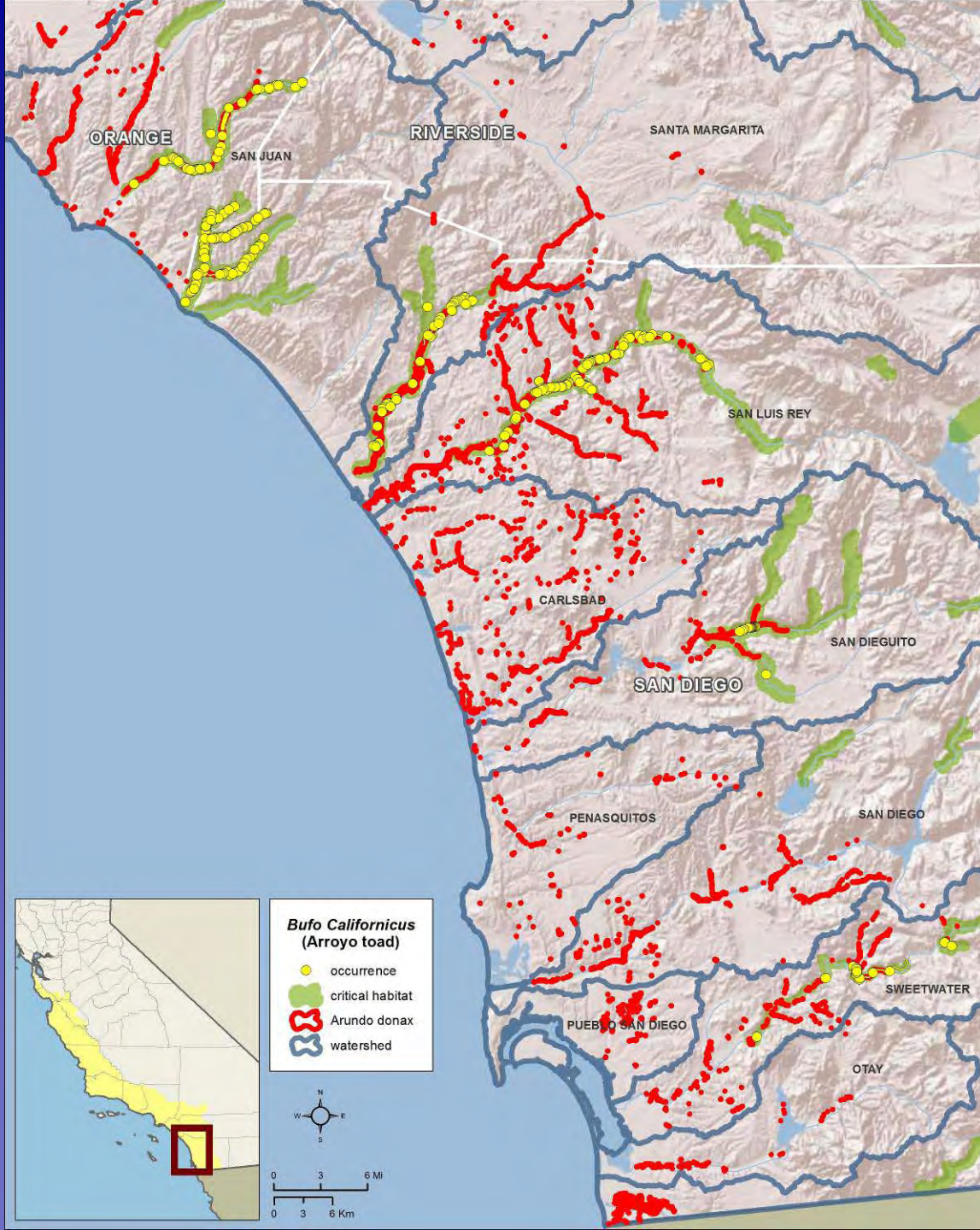


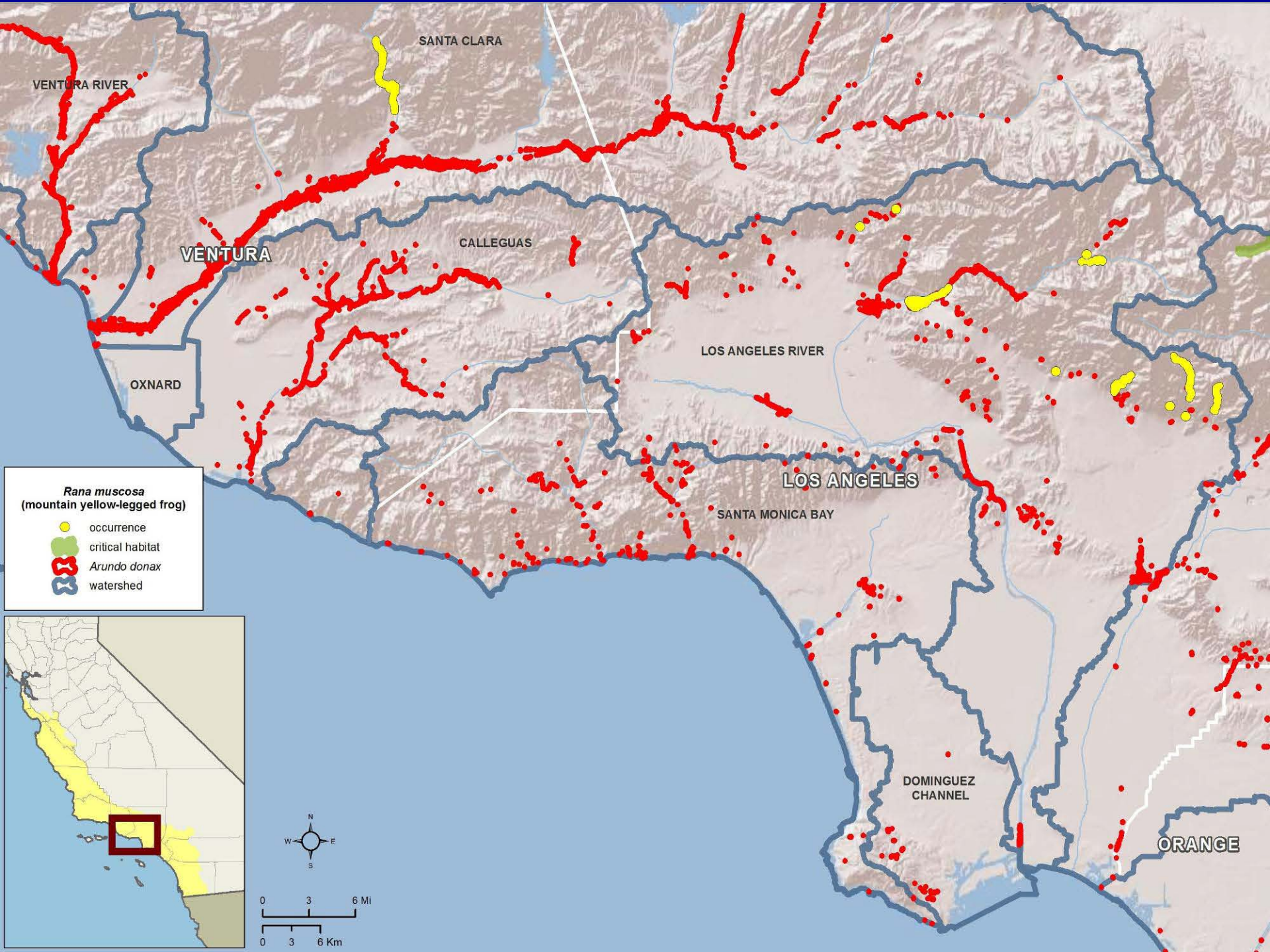
Flow Event	Channel: Stream Power (sed trans)				Floodplain: Stream Power (sed trans)			
	Arundo	Native	Bare	Mix 1997	Arundo	Native	Bare	Mix 1997
5-year	1.41	1.00	0.88	1.02	0.23	1.00	1.33	0.95
10-year	1.59	1.00	0.86	1.06	0.38	1.00	1.22	0.92
25-year	1.51	1.00	0.80	1.10	0.50	1.00	1.17	0.89
50-year	1.50	1.00	0.77	1.13	0.59	1.00	1.16	0.92
100-year	1.50	1.00	0.74	1.14	0.66	1.00	1.15	0.95
Average Annual	1.50	1.00	0.83	1.07	0.49	1.00	1.20	0.93

Impact: Biotic 22 Fed Listed Species

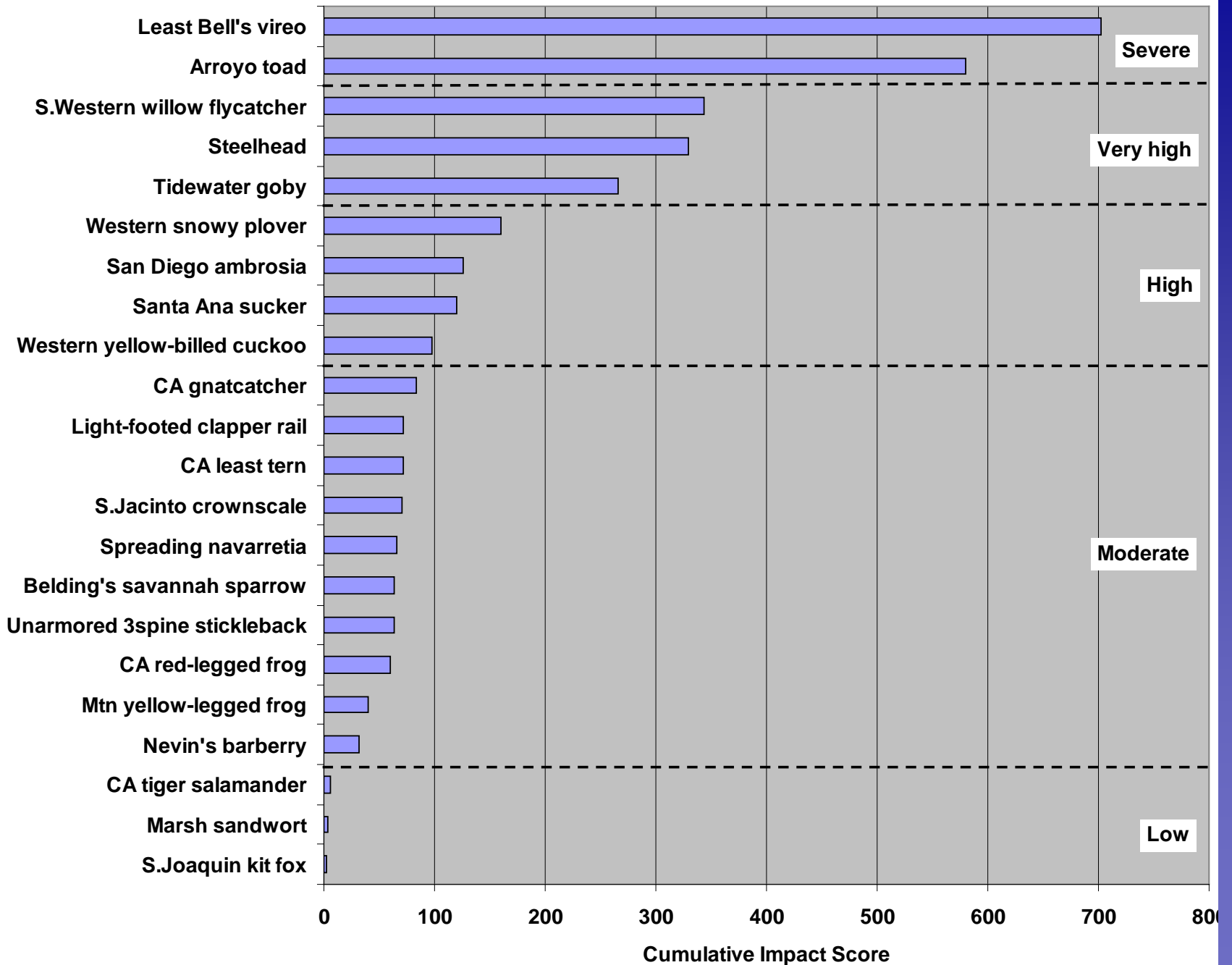
Score	Impact Level	Impacts
10	Very severe	Very significant alteration of abiotic structure and biological function, and direct take of individuals
9	Severe	Significant alteration of abiotic structure and biological function and direct take of individuals
8	Very high	Alteration of abiotic structure and biological function, direct take possible
7	High	Alteration of abiotic structure and biological function: impacts on mobility
6	Moderate/High	Minor alteration of abiotic structure and/or biological function
5	Moderate	Minor alteration of abiotic structure and/or biological function
4	Low/Moderate	Low abiotic or biotic impacts
3	Low	Slight changes in food resources, harboring pathogen/predator OR Minor changes to estuary systems
2	Very low	Minor interaction: mobility
1	Very low/Improbable	
0	None	

Overlap Score	Arundo abundance (nearby or upstream of sensitive species)	Listed species <i>relative</i> abundance & distribution	Interaction Level
10	Very High	Very high (core area)	High interaction
9	High	High	
8	High	Moderate	
7	Moderate	High	
6	Moderate	Moderate	Moderate interaction
5	Low	High	
4	High/Moderate	Low	
3	Low	Moderate	
2	Low	Low	Low interaction
1	Any	Historic range* or a few records of more 'abundant species	Possible or potential interaction
0	Any	Not recorded	No interaction

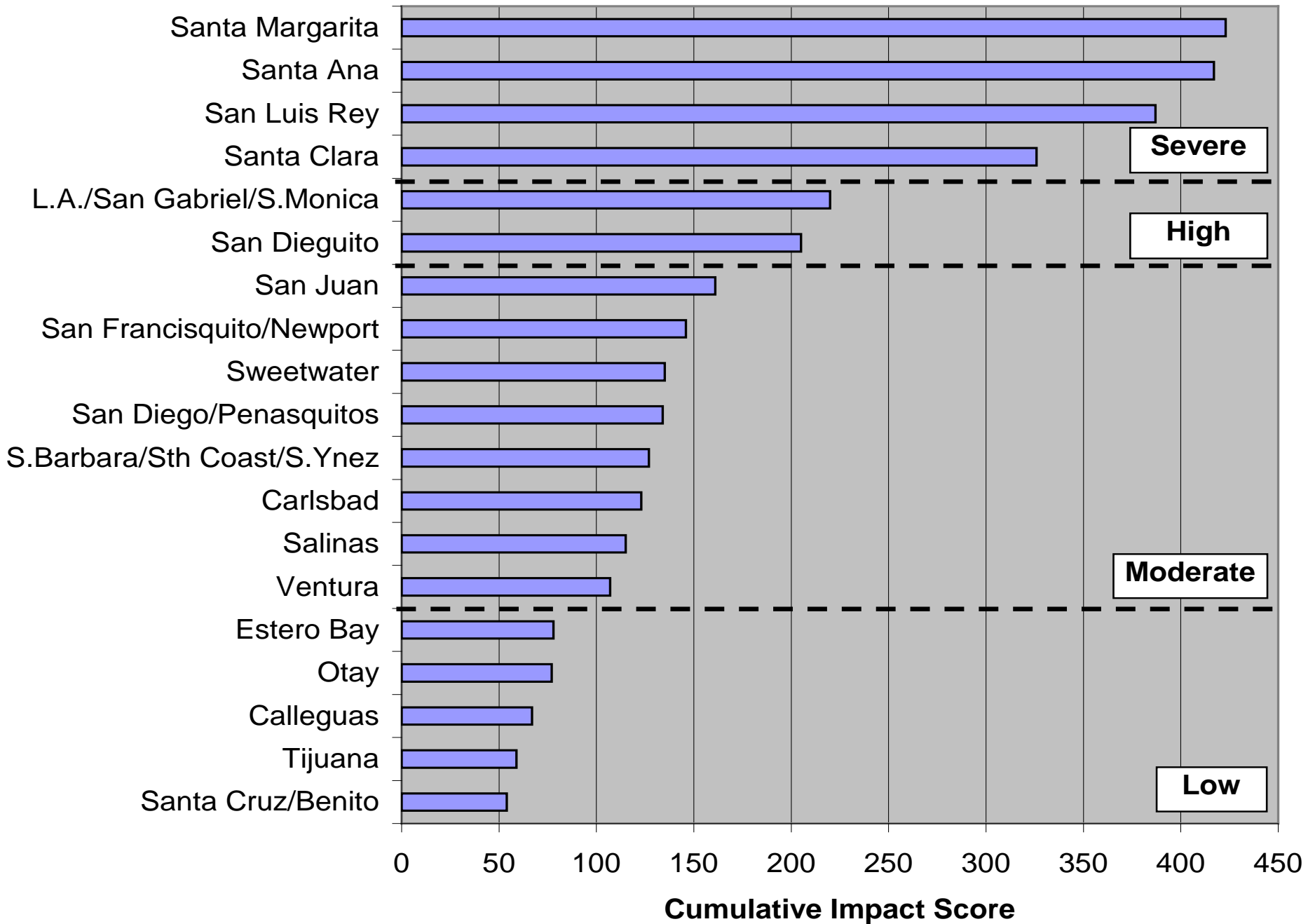




Cumulative Impact Score by Species



Cumulative Impact Score by Watershed



Estimated Benefits of controlling *Arundo* (peak distribution)

Watershed	Water use 10 yr	Sediment removal	Flood damage: bridge & levee	<i>Arundo</i> fires 10 yr total	Wildfire: 500K per 200 ac	Habitat rest 25K	Beach debris	10 year benefit
Calleguas	2,290,974	250,000	2,500,000	2,647,254	578,711	5,226,429	-	13,493,368
Carlsbad	1,478,605	-	0	1,691,321	369,736	3,376,431	-	6,916,093
Los Angeles	1,313,470	250,000	1,000,000	1,518,553	331,968	2,996,281	328,125	7,738,397
Otay	185,848	-	0	213,205	46,608	424,270	-	869,931
Penasquitos	235,419	-	0	270,114	59,049	537,429	-	1,102,011
Salinas	13,314,032	1,000,000	4,400,000	3,196,956	501,000	32,857,393	-	55,269,381
San Diego	1,494,312	-	500,000	1,717,948	375,557	3,410,654	-	7,498,471
San Dieguito	1,749,387	-	0	2,001,092	437,455	3,994,761	-	8,182,694
San Gabriel	442,969	250,000	1,000,000	509,607	111,404	1,010,978	328,125	3,653,083
San Juan	1,733,768	-	400,000	2,003,022	437,876	3,955,339	-	8,530,006
San Luis Rey	6,837,215	500,000	1,200,000	7,820,834	1,709,696	15,612,946	328,125	34,008,816
Santa Ana	25,332,010	250,000	5,000,000	31,150,080	6,809,654	57,433,784	-	125,975,527
Santa Clara	10,185,377	-	2,900,000	12,365,274	2,703,147	23,122,958	328,125	51,604,881
Santa Margarita	6,887,344	-	2,300,000	1,097,819	1,722,231	17,222,313	328,125	29,557,833
Santa Monica	184,819	-	0	213,038	46,572	421,728	-	866,157
South Coast	298,082	-	0	340,965	74,538	680,677	-	1,394,261
Sweetwater	417,636	-	0	484,249	105,861	952,443	-	1,960,188
Tijuana	1,305,930	-	100,000	1,550,381	338,926	2,971,387	-	6,266,624
Ventura River	2,498,351	-	2,900,000	3,796,682	829,985	5,526,884	328,125	15,880,026
TOTALS:	\$78,185,547	\$2,500,000	\$24,200,000	\$74,588,396	\$17,589,972	\$181,735,081	\$1,968,750	\$380,767,747

**Estimated Cost
of controlling
*Arundo***

Watershed	PEAK Net Acres	Cost peak distribution		
		Management: 5k	Implementation: 20k	Total
Calleguas	229	1,145,750	4,583,000	5,728,750
Carlsbad	148	739,472	2,957,889	3,697,362
Estero Bay	10	48,828	195,310	244,138
Los Angeles	131	656,886	2,627,543	3,284,429
Otay	19	92,945	371,781	464,726
Pajaro River	8	40,681	162,723	203,404
Penasquitos	24	117,737	470,947	588,683
Pueblo S.Diego	15	75,009	300,035	375,043
Salinas	1,332	6,658,544	26,634,177	33,292,721
San Diego	149	747,328	2,989,310	3,736,638
San Dieguito	175	874,894	3,499,577	4,374,471
San Gabriel	44	221,535	886,141	1,107,677
San Juan	173	867,083	3,468,333	4,335,416
San Luis Rey	684	3,419,392	13,677,570	17,096,962
Santa Ana	2,534	12,668,913	50,675,651	63,344,563
Santa Clara	1,019	5,093,858	20,375,431	25,469,289
Santa Margarita	689	3,444,463	13,777,850	17,222,313
Santa Monica	18	92,430	369,722	462,152
Santa Ynez	6	30,104	120,414	150,518
South Coast	30	149,075	596,300	745,375
Sweetwater	42	208,866	835,464	1,044,330
Tijuana	131	653,115	2,612,459	3,265,574
Ventura River	250	1,249,462	4,997,848	6,247,311
TOTALS:	7,859	\$39,296,369	\$157,185,475	\$196,481,844

**Benefit to cost
ratio of 1.94 to
1 (using
conservative
benefit
valuations)**



Report and Spatial data: www.Cal-IPC.org

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Arundo donax: Distribution and Impacts

From 2008-2010, Cal-IPC mapped *Arundo donax* at high resolution on all coastal watersheds in California from Monterey to San Diego. Impacts from Arundo invasion were calculated over the study area, including impacts to biomass production, water use, fire, geomorphic and fluvial processes, and endangered species. New findings include documentation of fire events starting in Arundo stands and significant modification of fluvial processes. All impacts are quantified over the study region and by individual watershed. The study determines a typical benefit-to-cost ratio of 2:1 for Arundo removal projects.



Arundo donax: Impacts and Distribution

Download the report

- Full report (252 pp., 13 MB pdf)
- Front pieces and Executive Summary
- 1. Introduction and 2. Arundo Biology
- 3. Spatial Data Set: Monterey to Mexico
- 4. Impacts of Arundo: Arundo water use and stand transpiration (5.5 MB)
- 5. Impacts of Arundo: hydrology, geomorphology, and flooding (3.3 MB)
- 6. Impacts of Arundo: fire
- 7. Impacts of Arundo: federally endangered and threatened species
- 8. Cost to Benefit Analysis
- 9. Watershed-based Arundo Control Programs
- 10. Summary of Data and Literature Cited
- Appendix A. Detailed Maps of Arundo Distribution (22 MB)
- Appendix B. Occurrence Data and Critical Habitat Areas for Federally-Listed Species (172 MB)



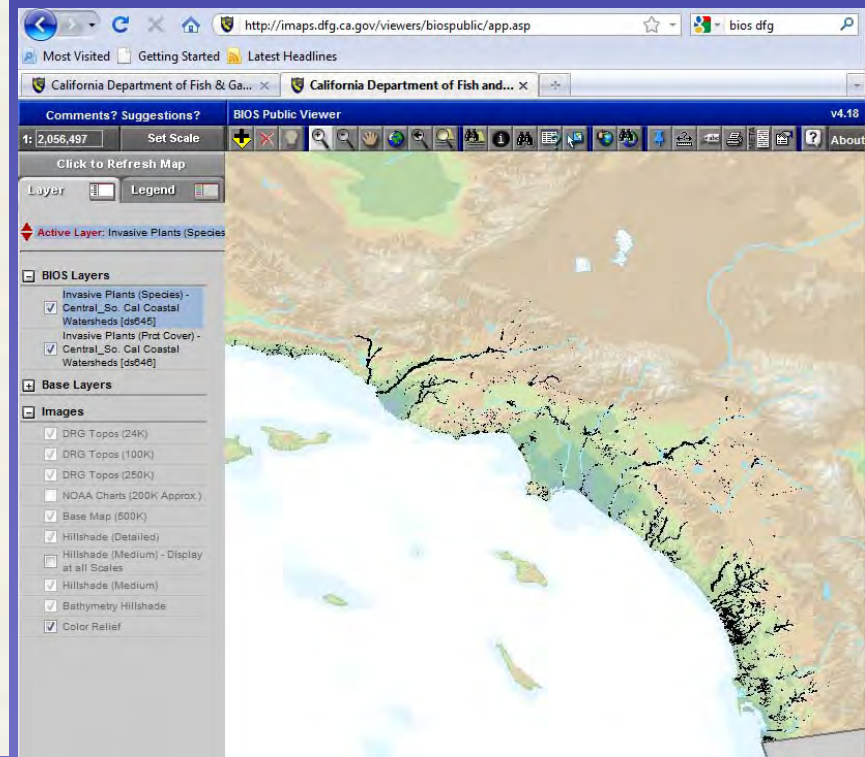
Appendix A contains maps of Arundo distribution.



Appendix B shows federally listed species

Download the data

- GIS geodatabase (ZIP 58 MB).
- Hydrologic analysis by northwest hydraulic consultants, inc. (4 MB)



Spatial data on DFG BIOS data viewer