3.0 SPATIAL DATA SET: The Distribution and Abundance of *Arundo* from Monterey to Mexico

3.1 Methodology

Arundo was mapped for all coastal watersheds from the Salinas River in Monterey County in the north to the Tijuana River in the south (Figure 3-1). Four additional large-form riparian invasive plant species (*Washingtonia robusta, Phoenix canariensis, Cortaderia selloana, and Cortaderia jubata*) were also extensively mapped due to their presence and high abundance within a majority of the riparian corridors that were surveyed. Due to limited high-resolution aerial photo coverage, only partial mapping of all five species occurred in the Bolsa Nueva, Pajaro River, and Big Basin watersheds just north of the Salinas River Watershed. In addition, mapping of both *Cortaderia* species was limited to the immediate coastline above Santa Barbara County. For *Cortaderia* species, central coast populations north of Santa Barbara were mapped as jubata grass (*C. jubata*), and populations south of Santa Barbara were listed as pampas grass (*C. selloana*). The photo resolution that was available for most of this region (Central Coast) was too coarse to differentiate *Cortaderia* populations to species.

The mapping methodology utilized for this project borrows techniques from previous large-scale, watershed-based weed mapping efforts that have taken place in San Diego and Los Angeles Counties. Each plant population was captured using one of the following digital mapping approaches: (a) in-house surveys compiled by heads-up digitizing on high resolution aerial photography within a GIS; (b) field surveys using high resolution aerial photography on an integrated Tablet PC/GPS or; (c) a combination of option a. and b. (in-house surveys followed up by field checking).

3.1.1. Step-by-Step Process

1) In-office Surveys

Initial mapping efforts took place in the office. The database was generated within ESRI's desktop GIS application (ArcGIS 9.3) using a geodatabase (GDB) as the chosen file format. Domains (i.e. a data dictionary) were setup before mapping commenced to help ensure data integrity by limiting the choice of values within each field. Target species were then digitized within the GIS implementing a dual-monitor workstation setup. A primary tablet monitor (Figure 3-2) hosts the GIS application where plant populations are delineated as defined areas (i.e. polygons). High-resolution (1 ft or better) vertical aerial photos[1] were the primary base layer used for delineating plant population boundaries in the GIS. After a population was digitized, key attributes were noted (Table 3-1). Relevant supporting data was also captured during this phase that included "area mapped" to discern presence/absence and homeless encampment locations within the riparian zone. A secondary reference monitor was used as an additional aid to help distinguish smaller clumps as well as those populations partially covered by thicker tree canopy cover. High-resolution oblique imagery from four directions served as the reference. These images were freely available for all urban and wildland-urban interface (WUI) areas across the project extent courtesy of Microsoft's Bing maps "bird's eye view" function (*www.bing.com/maps*). The California Coastal Records oblique imagery database *(www.californiacoastline.org)* also served as a reference source for the immediate coastline (particularly for the central coastline *Cortaderia* species mapping).

[1] Two to four time periods (2004, 2005, 2006, and/or 2008) were available depending on the given area.

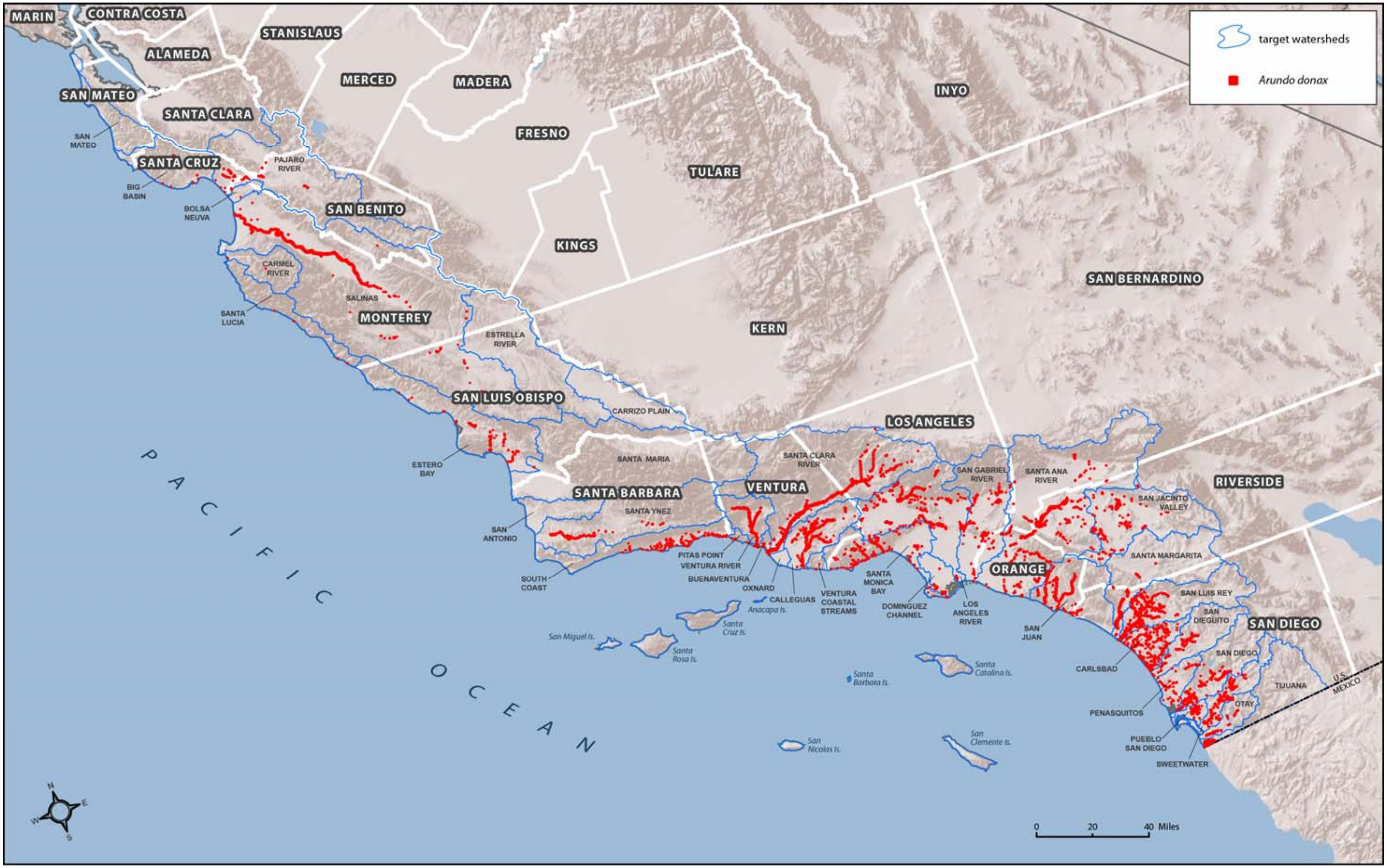

Figure 3-1. Distribution of *Arundo* mapped within the study area from Monterey to San Diego, CA.

Figure 3-2. In-office surveys using a dual-monitor workstation.

Table 3-1. Data dictionary used for plant mapping.

Attribute	Notes
Plant Species	Common and scientific names are noted.
Percent Cover	70-100%= 100%; 50-69%= 50%; 15-49%=20%; 2-14%=5%
Plant Count	Estimated number of trees within a polygon
Average Height	Estimated tree height
Treatment Status	Status was marked as: treated, untreated, funded for treatment, or status unknown
Comments	Supplementary information
Observer	Person responsible for the last edit of a particular record
Mapping Methodology	Method was noted as: in-office survey, field survey, or combination
Date Mapped	Records that were only collected in-office took the date of the base photography as the map date; all other records used their observed field date
Data Source	Organization that collected the record
Watershed Name	HUC unit name
Gross Area (Acreage)	Total overall area in acres
Net Area (Acreage)	Total net area (factoring in percent cover) in acres

2) Data Transfer to Tablet

After the initial survey of a watershed was completed, the data was "checked out" of the GIS database and transferred to a ruggedized tablet PC. The field tablets used for this project (Xplore's iX104c3) were outfitted with GPS receivers (mounted or bluetooth) with an accuracy of 2-5 m (with real-time corrections) (Figure 3-3). The most current vertical aerial photography from the GIS database was also transferred onto the tablet as a base layer for the field mapping software. ESRI's ArcPad 8.0 was chosen as the mapping application because of its seamless integration between the field computers and central database back in the office. Toolbars in ArcPad were customized to optimize the time spent collecting data in the field.

Figure 3-3. Field surveys with ruggedized tablet PCs and integrated GPS.

3) Field Verification

After data was transferred to the field tablets, crews were sent out to verify the accuracy of the in-office surveys if locations were accessible and a line-of-sight could be established. Records were checked for spatial accuracy, percent cover estimation, and current treatment status. New populations and edits to existing populations were also collected by sketching directly on the tablet with a digital pen (Figure 3-4). The GPS functionality was only used only as a reference to orient the mapper's position on the basemap (i.e. high-resolution aerial photograph). Tracklogs in ArcPad (digital "breadcrumbs") were used to document surveyed areas and track progress/time spent mapping in the field.

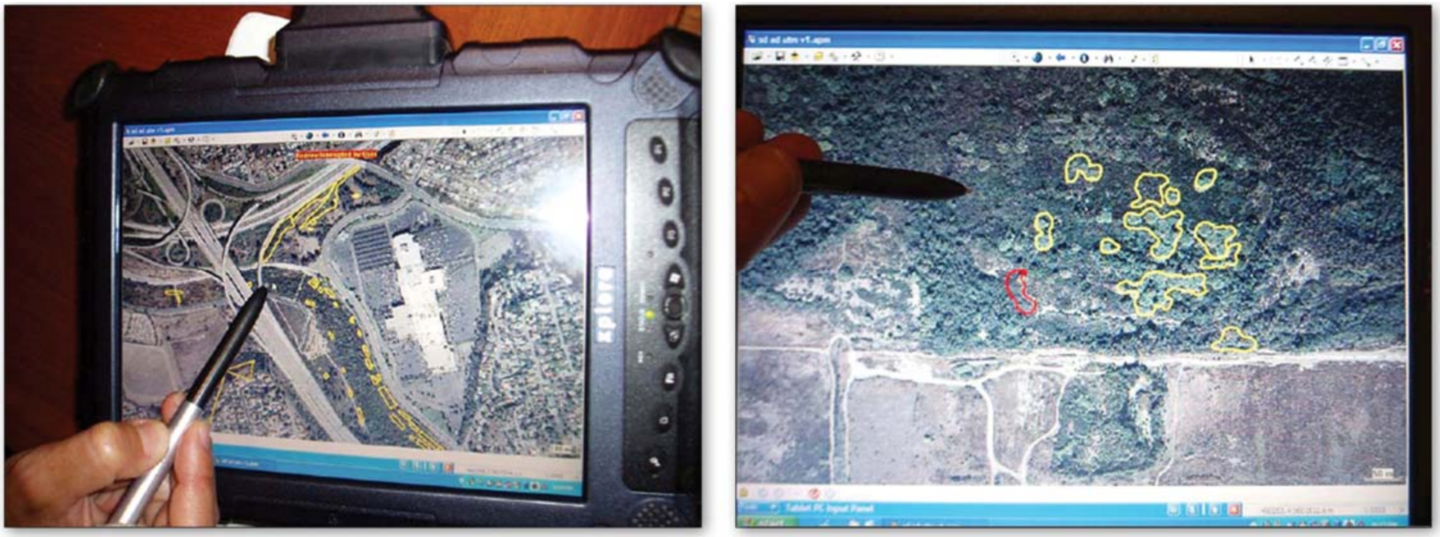

Figure 3-4. Digital sketch mapping.

4) Data Transfer To GIS

After field verification was completed for a given watershed, data is "checked" back into the GIS database at the office. Additional data attributes (watershed name, mapping status, acreage) were added through an automated process and existing attributes were re-checked for consistency.

3.1.2. Data Quality

The combination of methodologies mentioned above is the obvious choice for capturing the highest possible accuracy, but there were instances where either the in-house or field surveys were not feasible. In-house surveys were not completed when high-resolution imagery (6 in-1 ft vertical or 1 m plus oblique photography) was not readily available for a particular region. As field checking commenced, it became apparent that smaller clumps were often misidentified or omitted when high-resolution imagery was unavailable.

There were instances when field surveys were not achievable due to access (i.e. private property, difficult terrain, etc.) and/or general project time constraints. For instance, the Salinas River has thousands of smaller disconnected clumps of *Arundo* that were widely dispersed across several miles. Field checking all of these populations was not practical, nor was it achievable within the given timeline and budget. Preselected locations along the Salinas River were visited and field checked where it was inherently difficult to distinguish *Arundo* populations in-office. *Cortaderia* populations along the Central Coast also were not field verified. There are hundreds of miles of coastline covered by steep bluffs in this region that have a significant amount of *Cortaderia* present throughout the landscape. Given the time constraints, the area that needed to be covered, and the fact that this was species was a lower priority in terms of project goals, ground-truthing this extent was not achievable for the project.

It should also be noted that all species mapped were defined by their full footprint extent as interpreted from a vertical perspective. For *Arundo* in particular, this means capturing both the cane emergence zone and cane drape zone (as shown in Fig 2-13). Mapping populations in this manner can have an effect on acreage estimates, depending on the photo resolution used to delineate the footprint extent. Because individual canes are much more identifiable on the 6in. and 1ft. aerial imagery, the delineated footprint of a population can be wider than a delineation of that same population using 1m imagery. Higher resolution, in turn, will boost acreage estimates, especially in areas where individual clumps are widely dispersed and cane drape zones are more extensive.

Attribute Accuracy

"Percent cover" was determined based on a rough visual interpretation from the ground. In some cases, values may be moderately under or overestimated because of issues with access to property and/or line-of-sight due to other vegetation cover, structures, etc. This holds true for *Arundo* and *Cortaderia* in particular. Based on local field comparisons of previous surveys that used a similar methodology, overall acreage totals tend to be underestimated by approximately 15-20% (Giessow pers. comm. 2010). Because the resolution of the base photography has significantly improved over time (1 m in 2001 compared to the present standard of 1 ft/6 in), it is expected that the acreage calculations now have a higher degree of accuracy.

"Treatment status" may not represent current ground conditions due to ongoing treatment programs that are currently unknown or not being tracked by the project team. Because this is intended to be a living database, the plan is to update treatment information periodically as the data becomes available.

There may be misclassifications of species because of the inability to ground truth a particular population, or because the field mapper misidentified the species. This holds true for the *Washingtonia robusta* and two *Cortaderia* species in particular. It is currently not possible to accurately distinguish between *W. robusta* and *Washingtonia filifera* when conducting in-office surveys alone.

Positional Accuracy

Positional accuracy may vary across the project extent due to fluctuating base imagery resolutions that were available when the in-house mapping took place. Data collected during the project is no better than that of the base photography's accuracy used to delineate a population's extent.

Cartographic offsets may be present in the data due to several conditions including (a) GPS accuracy affected by quality of unit, and/or poor signal due to canopy cover, terrain, cloud cover, time of day, etc; (b) scale and legibility constraints due to the basemap aerial photography's resolution and quality, and/or; (c) field mapper interpretational errors due to line-of-sight issues caused by dense vegetation, terrain, structures, etc.

Completeness

In order to accurately quantify impacts within each system, one goal for the project was to map the full baseline extent of all *Arundo* populations present within any given system over time. While the mapping team used 2006 imagery as the starting point for developing this baseline extent, some watersheds previously had large watershed-scale eradication programs in place. These include the Santa Ana, Santa Margarita, San Luis Rey, and Carlsbad watersheds. Subsequently, earlier datasets provided by local program managers as well as historic aerial photographs were used to fill in gaps for areas that were treated and re-vegetated prior to 2006. Therefore, it should be noted that the final data output is not a single snapshot for one specific year. There may be several time periods represented for a given area, particularly in San Diego County. Santa Ana Watershed *Arundo* acreage was also adjusted higher to reflect *Arundo* control (in the mid 1990's) that could not be documented in aerial photography. The acreage adjustment estimation was based on existing program management documentation and annual reports available through the Santa Ana Watershed Authority (SAWA).

It should be noted that *Arundo* stands were certainly missed within the study area, particularly small clumps and stands that were obscured by native tree canopy or scattered stands in areas with little *Arundo*. The mapping data set captures a majority of the population that occurs in the project area, but it does not capture all *Arundo*. For instance, a majority of neighborhoods outside of the immediate urban-wildland interface were not extensively surveyed for *Arundo*. Because these areas may be connected to streams and rivers, projects should re-evaluate this data set prior to utilizing it for a specific project or use.

Data set availability at BIOS and Cal-IPC

The GIS database (ESRI geodatabase) is currently hosted on the Department of Fish and Game BIOS (Biogeographic Information & Observation System) web-based mapping application. (http://bios.dfg.ca.gov/). The data sets are named:

Invasive Plants (Prct Cover) - Central_So. Cal Coastal Watersheds [ds646]

Invasive Plants (Species) - Central_So. Cal Coastal Watersheds [ds645]

It can be viewed and printed from this platform along with a multitude of other spatial data. The geodatabase is also available for download at Cal-IPC (http://www.cal-ipc.org/ip/mapping/arundo/index.php). This website also hosts a PDF version of this report and associated map books tied to the distribution and listed species co-occurrence with *Arundo*). There is currently no funding to maintain or update the invasives GIS data set. If future revisions do occur, updates will be indicated on the Cal-IPC website.

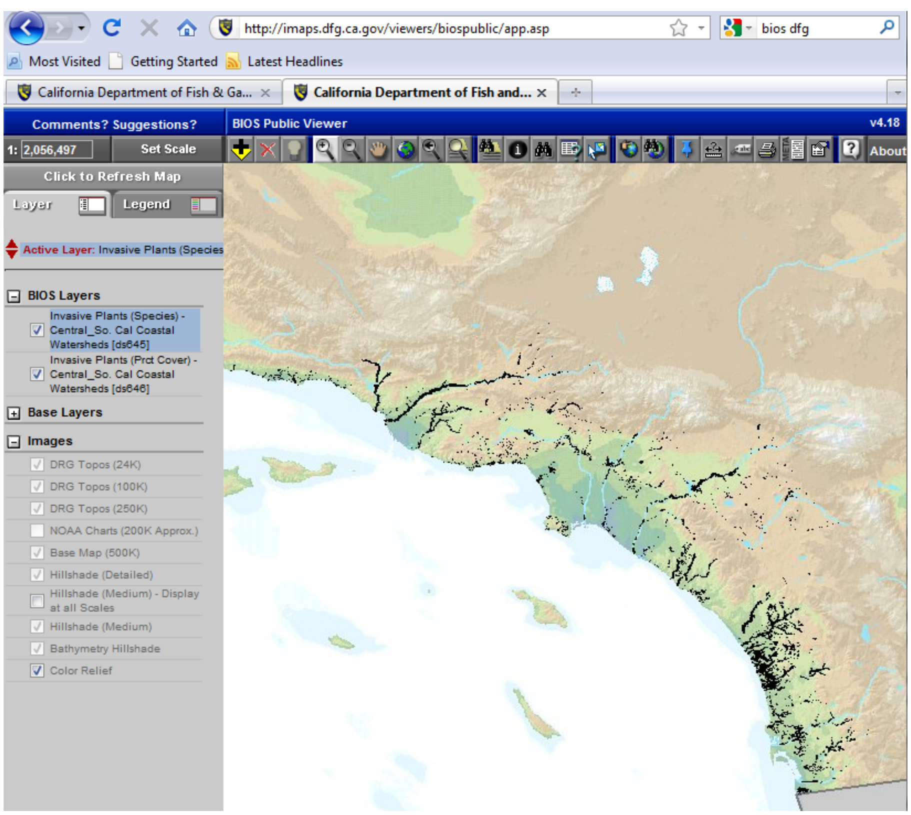

Figure 3-5. DFG BIOS data viewer with invasive plant data set active.

Figure 3-6. Cal-IPC web site project page for *Arundo* mapping downloads.

3.2 Results: Acreage by Watershed and Region

Arundo acreage for coastal watersheds from Monterey to San Diego was estimated to be 8,907 acres at its peak distribution (Table 3-2). This captures the 'full maximum extent' of *Arundo* on all watersheds within the study area prior to the initiation of control programs (Figure 3-1). This data will be used to examine and quantify impacts in the chapters that follow. In most areas mapped, dense stands (>80% cover) were the 'typical' stand structure. This is not surprising given the clonal nature of the plant. The largest exception to this observation was the Salinas River, which had many expansive areas with low *Arundo* cover. This is unusual for *Arundo* and may reflect water management practices on the river that have made flows seasonal over the last 20 years. For this reason, 'net' acreage is also given (gross acreage multiplied by the noted stand-specific *Arundo* cover). Examination of Table 3-2 shows that most *Arundo* stands on watersheds were mapped as having high cover, such that gross and net acreage values are similar. Later sections of the report use acreage values that are most relevant to the particular effect being looked at. The fire chapter uses gross acreage, while biomass and water use (which are sensitive to cane density) use net figures.

This study's mapped value of 8,907 acres, although high, is far lower than some estimates of *Arundo* acreage, even for individual watersheds. Santa Ana River has been reported as having over 10,000 acres of *Arundo* (Iverson 1993). This highlights the need for a more standardized and consistent approach to mapping *Arundo*. Many programs continue to map *Arundo* in mixed vegetation classes. This can lead to drastic overestimation of *Arundo* biomass and distribution. Vegetation mapping is very different then species-specific mapping and they should not be used interchangeably. Newer programs, such as on the Ventura and Salinas Rivers and in the San Diego region, use *Arundo*-specific mapping. This data set will aid all programs in using a standardized approach to gauging *Arundo* distribution and abundance.

The *Arundo* mapping also tracked treatment status. Impressively 36% of *Arundo* distribution is already under management/control (Table 3-2). This reflects a substantial investment of federal, state, and local resources. It is encouraging to see significant acreage has been controlled. Several watersheds have achieved particularly high rates of initiated control including: Santa Margarita (99%), San Luis Rey (90%), Carlsbad HU (67%), San Dieguito (51%), Ventura (47%), and Santa Ana (40%). Several watersheds that are heavily invaded have had little or no work occur in them, such as Salinas, Santa Clara, and Calleguas. A later section of this report will examine watershed-based programs and their status.

The *Arundo* mapping acreage is an important tool for not only quantifying impacts but also planning and implementing control efforts. These accurate estimates of *Arundo* acreage allow for better project descriptions, budgets and rationalization of project needs. High quality spatial mapping also assists with environmental planning and permitting. Agencies can more precisely see where *Arundo* occurs, and sensitive species and other concerns can be addressed more specifically. State level funding and project prioritization decisions may also be made in a broader context. Multiple factors still need to be weighed, but this high-resolution mapping gives land managers a stronger quantification of both benefit and cost, much more than was possible prior to the project.

As noted under the discussion of accuracy, this data set under-represents the acreage of *Arundo*. The *Arundo* mapped only accounts for stands that were visible in imagery and field reconnaissance. While there are very few instances of misclassification, there are *Arundo* clumps and portions of stands that are missed due to obstructed views and/or it was too small to see. Previous work by the authors has indicated that detailed re-mapping of areas during control has typically indicated a 15-20% underestimation of *Arundo*. This data set may be slightly more accurate (10-15% underestimate) in many areas as aerial imagery has improved in quality and resolution within the last several years. It is highly unlikely that *Arundo* acreage has been over estimated by this study.

3.3 Conclusions: Distribution and Abundance

- *Arundo* mapping documented a total (gross) of 8,907 acres of *Arundo* within the study area. Net acreage, adjusted for *Arundo* cover, was 7,864 acres. This represents the peak distribution of *Arundo* in the study area prior to control activities. (Section 3.2)
- Over 3,000 gross acres of *Arundo* have been treated to date within the study area. This is 34% of the peak *Arundo* acreage occurring within the study area. (Section 3.2)
- Three large, contiguous watershed units have the highest levels of *Arundo* control observed in the study area: Santa Margarita at 99%, San Luis Rey at 90% and Carlsbad HU at 70 %. (Section 3.2)
- Most other invaded watersheds in the study area with more than 100 acres of *Arundo* have had at least 30% of their *Arundo* treated. Noted exceptions to this are Calleguas, Salinas and Santa Clara watersheds, which have less than 10% of their *Arundo* acreage under treatment. (Section 3.2)

Distribution and abundance data is extremely valuable because it quantifies past and current levels of invasion on watersheds, allows detailed examination and quantification of impacts, and facilitates watershed based control. Programs can use the spatial data to implement watershed based control, develop proposals and budgets, and manage control programs.

Table 3-2. *Arundo* acreage in central and southern California by hydrologic unit.

Hydrological Unit	Total Area (Acres)	Treated *Arundo*		Untreated *Arundo*		Total *Arundo*		Percent treated
		Gross Acres	Net Acres	Gross Acres	Net Acres	Gross Acres	Net Acres	
Big Basin[3]	235,181			0.3	0.3	0.3	0.3	0%
Bolsa Nueva	32,649			0.2	0.2	0.2	0.2	0%
Buena Ventura	13,226			0.5	0.5	0.5	0.5	0%
Calleguas	220,527	1.4	1.4	230.0	227.7	231.5	229.1	1%
Carlsbad[3]	135,753	103.7	103.7	44.0	44.0	147.7	147.7	70%
Carmel River	163,643			0.0	0.0	0.0	0.0	0%
Carrizo Plain	278,848							
Domigz Channel	81,760			2.6	2.6	2.6	2.6	0%
Estero Bay[3]	480,544	1.2	1.2	15.0	8.6	16.1	9.8	12%
Estrella River	610,278							
Los Angeles	533,834	16.3	16.3	116.5	115.1	132.8	131.4	12%
Otay	98,380			18.6	18.6	18.6	18.6	0%
Oxnard	18,721							
Pajaro River	838,942			8.1	8.1	8.1	8.1	0%
Penasquitos	103,790	2.2	2.2	21.4	21.4	23.6	23.5	9%
Pita's Point	14,051			0.5	0.5	0.5	0.5	0%
Pueblo S. Diego	37,546	0.0	0.0	15.4	15.0	15.4	15.0	0%
Salinas	2,272,492	137.4	106.4	1,868.7	1,225.3	2,006.1	1,331.7	8%
San Antonio	135,624							
San Diego	278,977	56.2	56.2	94.0	93.3	150.2	149.5	38%
San Diego Bay	10,931							
San Dieguito	221,555	89.8	89.8	85.2	85.2	175.0	175.0	51%
San Gabriel	456,886	3.5	3.5	41.0	40.8	44.6	44.3	8%
San Juan[3]	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%
San Mateo[3]	164,484							
Santa Maria	1,188,373			0.1	0.1	0.1	0.1	0%
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 Lucia[3]	193,641			0.1	0.1	0.1	0.1	0%
Santa Margarita	475,449	684.7	684.7	4.2	4.2	688.9	688.9	99%
Santa Monica[3]	267,152	0.4	0.3	18.3	18.2	18.6	18.5	2%
Santa Ynez	576,066			21.4	6.0	21.4	6.0	0%
South Coast[3]	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[3]	22,475			0.1	0.1	0.1	0.1	0%
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**	

[1]Adjusted- added 400 ac treated for older treatments that were not detectable; [2]Adjusted- added 40 ac treated for older treatments that were not detectable; [3]Hydrologic Unit composed of many smaller coastal streams/watersheds.