10.0 SUMMARY OF DATA FOR *ARUNDO*: PHYSICAL CHARACTERISTICS, DISTRIBUTION, ABUNDANCE, IMPACTS, AND WATERHSHED CONTROL PROGRAMS' STATUS AND PRIORITY

Conclusions from this impact report are presented below and based on collected data and observations for the greater study area: coastal watersheds in California from Monterey to San Diego (Figure 3-1).

Physical Characteristics and Biology

- Mature stands are taller than what has been typically reported in the literature: 6.5 m mean, range of 2.6 – 9.9 m. (Section 2.3)
- Adjustments need to be made when scaling up from cane-specific data to stand data due to canes not emerging within all areas of *Arundo* canopy. Areas along edges and gaps within stands have zero to few canes. (Section 2.3)
- Biomass per unit area is very high for mature *Arundo* stands and it is in general agreement with the literature: 15.5 kg/m^2. (Section 2.4)
- Leaf area of secondary branches is the primary photosynthetic area for older canes, and this constitutes the majority of the mature stand leaf area (75%). This has not been clearly recorded in the literature. (Section 4.1)
- Measurements of leaf area (LAI) in mature *Arundo* stands are very high (15.8 LAI). This is in general agreement with the literature. (Section 4.1)
- Additional studies examining LAI and stand structure would further establish that mature *Arundo* stands have very high LAI. Examination of native riparian vegetation LAI may also be beneficial.
- Reviewed literature demonstrates that *Arundo* spreads through asexual propagation (fragments of rhizomes and infrequently canes). Seeds are not viable. This makes *Arundo* spread dependent on flood action or anthropogenic disturbance. (Section 2.5)
- Review of historic aerial photography indicates that spread of *Arundo* within a watershed is very episodic- large magnitude (50 to 100–year) events are necessary for the plant to actively invade significant new areas in a riparian system, particularly floodplains and terraces. (Section 2.6.4)

These observations are important in that they characterize *Arundo* stands within the study area. These baseline attributes are used to quantify and explore multiple impacts associated with *Arundo* in later sections.

***Arundo* Impacts: Transpiration and Water use**

- Due to high leaf area of mature stands, stand-based transpiration is very high (E_{stand} 40 mm/day). There are two other studies evaluating stand-based *Arundo* transpiration. One study on the Santa Clara watershed (within this project's study area) is in agreement (41.1 mm/day). The other study on the Rio Grande River is lower (9.1 mm/day). (Section 4.1).
- Stand-based transpiration rates of *Arundo*, when used to calculate total water over larger areas, indicate very high levels of water use: 48 ac-ft/ac per year. (Section 4.2)
- Net water savings for areas after *Arundo* removal are high (20 ac-ft/yr), even when *Arundo* water use is lowered 24 ac-ft/ac per yr to reflect levels that may be closer to physiological water transpiration limits. (Section 4.2)

- New studies using different approaches to measure stand-based water use of *Arundo* are needed to corroborate and refine stand-based water use found in this and other studies. New studies need to be on mature stands of *Arundo*. Stands under treatment or in post-fire or flood recovery should be excluded, as these are not representative of the majority of *Arundo* stands within the study area. (Section 4.2)

Water use by *Arundo* appears to be a significant impact on invaded systems. Water use by vegetation is difficult to measure. Additional baseline and comparative studies are needed.

Distribution and Abundance

- *Arundo* mapping documented a total (gross) of 8,907 acres of *Arundo*. 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 *Arundo* 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 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)
- *Arundo* is most abundant in broad, low-gradient riparian areas where it averages 13% cover. (Section 5.2)
- *Arundo* cover can be very high for large sections (reaches > 0.5 mi long). *Arundo* was observed occurring at >40% cover on specific reaches on all three watersheds that were examined in detail: Santa Margarita, San Luis Rey and Santa Ana. (Section 5.1)

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.

***Arundo* Impacts: Hydrology and Geomorphology**

- Mature *Arundo* stands, due to high cane density, functionally raise the elevation profile by 5 feet, lowering flow capacity. (Section 5.1.4.6)
- *Arundo* stands occur predominantly in floodplain and terrace portions of the river and are nearly absent from the low flow and active channel areas. (Sections 5.1 & 5.2)
- *Arundo* stands on floodplains adjacent to the active channel function as a wall or levee, focusing flows within channel areas. Over time this results in a deepening of the channel and a transformation of the system from a braided unstable channel form to a laterally stable single-thread channel form. (Section 5.1.4.6)
- Floodplain areas (floodplains and low terraces) have become much more vegetated on most systems over the last eighty years. This vegetation is both native woody vegetation and *Arundo*. Mature *Arundo* stands, however, have much higher stem density and biomass per unit area, generating the observed effects noted above. (Section 5.2.3)

- Active channel areas (low flow and bar channel areas with little vegetation) have significantly declined over time on most systems. (Section 5.2.2)
- The over-vegetated floodplains and narrow stable deep channels result in modifications of sediment transport and stream power during flow events. (Section 5.1.4.7)
- Most riverine systems have become significantly compressed (narrower) over time as terrace and floodplain areas have been permanently separated from the river system with levees that protect both urbanization and agricultural land use. (Section 5.2)
- Most riverine systems in the study area have converted from: broad riparian systems with little vegetation cover and channels that were laterally unstable (braided) to narrow riparian systems with highly vegetated floodplains that have a single deep channel. (Section 5.2)
- Most *Arundo* has been removed from the Santa Margarita River for 13 years. The geomorphic response to large flow events in that time has been a significant widening of the low flow and bar channel area (38% increase). Flows also actively pass through floodplain areas; this is a major change in function and process. Moderately-sized events (15 year) now flow through significant portions of channel, bar, and floodplain areas. Before *Arundo* was removed, flows were restricted to channel and bar areas. (Section 5.2.4)
- Loss of flow capacity and presence of *Arundo* biomass is likely contributing to overbank flows and bridge loss and damage. (Section 5.2.5.1)
- Flow events mobilize large amounts of *Arundo* biomass. Part of this biomass load ends up on coastal beaches where it is frequently removed by public agencies and carries an estimated annual cost of $197,000. This does not include impacts on habitat quality. (Section 5.2.5.2)

Hydro-geomorphic impacts are significant. This has ramifications to both the ecosystem and infrastructure in and around invaded rivers. Watershed-based analysis on sediment movement and impacts should be explored in greater detail to further document and quantify relationships.

***Arundo* Impacts: Fires**

- *Arundo* stands are highly flammable throughout the year with large amounts of fuel (15.5 kg/m^2 of biomass), a large amount of energy (287.1 MJ/m^2), and a tall well-ventilated structure with dry fuels distributed throughout the height profile. (Section 6.1)
- Fires frequently start in *Arundo* stands. The primary ignition sources are transient encampments and discarded cigarettes from highway overpasses. (Section 6.1)
- *Arundo* stands strongly attract transient use (dense cover and shelter). This was documented throughout the study area with numerous high use locations noted in both urban and agricultural areas. (Section 6.3.1)
- Fires initiated in *Arundo* stands occur due to fuel and ignition source occurring at the same location. This is a newly defined class of fire events. (Section 6.4.1)
- Fires that are initiated in *Arundo* burn both *Arundo* stands and native riparian areas. In addition, suppression of fires also impacts riparian habitat. Impacts were calculated for all watersheds using San Luis Rey as a case study. Over a ten-year period for the study area, *Arundo*-initiated fire events are estimated to have burned 513 acres of *Arundo* and 706 acres of native riparian habitat. Fire suppression over a ten-year period has impacted 44 acres of *Arundo* and 32 acres of native riparian vegetation. (Section 6.5)
- Wildfires burn a significant acreage of *Arundo* stands. Over ten years, 6.1% of *Arundo* stands (544 acres) burned within the study area. (Section 6.5)
- Due to high fuel load and stand structure, areas with *Arundo* burn hotter and more completely then native vegetation during wildfire events. (Section 6.4.2)

- *Arundo* stands appear to be conveying fires across riparian zones- linking upland vegetation areas that would have been separated by less flammable riparian vegetation. This can have catastrophic impacts like those observed in the 2008 Simi fire. The 8,474-acre fire crossed the Santa Clara River and then burned an additional 107,560 acres. (Section 6.4.2)
- *Arundo* fires accelerate the dominance of *Arundo* in invaded areas due to rapid re-growth and low mortality of *Arundo*. (Section 6.5.1)
- *Arundo* fire events lead to both direct mortality of wildlife and plants (some of which are sensitive) as well as a longer-term quality reduction of burned riparian areas (post-fire recovery of vegetation and structure). (Section 6.5.2)
- Emergency actions tied to *Arundo* fire suppression also result in impacts (disturbance of both *Arundo* and riparian vegetation) that degrade riparian habitat and/or may result in mortality of species. (Section 6.5.4)

Documentation and separation of *Arundo*-initiated fires from wildland fires that burn *Arundo* is an important finding. Impacts from *Arundo*-initiated fires are common and are the result of *Arundo* invasion. Harboring ignition sources in combination with combustible fuels year round creates this unique fire risk and impact. This needs to be further studied and documented. If validated, impacts to wildfire spread could be the greatest single impact.

***Arundo* Impacts: Federally Endangered and Threatened Species**

- *Arundo* impacts to 22 federally endangered and threatened species from five taxonomic groups varied from: very severe (score of 10) to very low/improbable (score of 1). (Section 7.3.1)
- Documented and potential abiotic and biotic impacts from *Arundo* are described for each species. Abitoic impacts include modification of geomorphology, hydrology, flood disturbance, fire disturbance, water use, and nutrient budgets. Biotic impacts include alteration of vegetation/community structure (displacement of native vegetation), filling in 'open' un-vegetated portions of habitat, creating physical structure that impedes movement, creation of structure in estuaries that facilitates predation, biomass debris that degrades breeding areas, stand structure that is of low value for nesting, and biomass that is of low forage value for both insects and animals. (Section 7.2)
- *Arundo* co-occurs with sensitive species on many watersheds in the study area. This overlap in distribution was evaluated using the *Arundo* mapping data and sensitive species occurrence data (Appendix B). Interaction between *Arundo* and each species was scored. *Arundo* present upstream of sensitive species was specifically accounted for as impacts occur to downstream areas from alteration of sediment loads, geomorphic forms, biomass discharge and other factors. (Section 7.2)
- A cumulative impact score was calculated using the species' specific impact score and the overlap score. This allows each species and each watershed to be evaluated for magnitude of impact. Least Bell's Vireo and Arroyo toad ranked as the most 'severely impacted'. Three species ranked 'very high', four species ranked 'high', ten species were 'moderate', and three species were 'low'. (Section 7.2)
- Several fish species ranked very high on the cumulative impact scoring. This is a group of species that have not been closely associated with *Arundo* impacts prior to this study. Most fish species had impacts related to modification of channel form (single versus braided), channel depth (shallow versus deep), sediment transport, and potential biomass/debris impacts. (Section 7.2)

- Estuaries and beaches were shown to have moderate impacts resulting from both *Arundo* stands, which create physical structure that facilitates predation, and *Arundo* debris that covers open sandy areas required by ground-nesting avian species. (Section 7.2)
- Watershed rankings of *Arundo* impacts on sensitive species shows that there are four watersheds designated as 'severely impacted', two as 'highly impacted', eight as 'moderately impacted', and five as 'lowly impacted'. (Section 7.2)
- Three of the four 'severely impacted' watersheds have well-developed watershed-based *Arundo* control programs in place. (Section 7.2)

Impacts to habitat are significant. *Arundo*'s overlapping distribution with sensitive species creates pressures on a wide range of species. Impacts range from abiotic to direct biotic interaction. The most significant impacts relate to abiotic modification of the system (water, fire, geomorphic form), but these are the most difficult to document and quantify due to their scale. Additional research and documentation are needed to increase our understanding of how *Arundo* modifies ecosystem-regulating processes.

Cost to Benefit Analysis

- Cost of *Arundo* control is $25K per acre, as documented by $70 million of work completed on control programs within the study area over the past 20 years. (Section 8.1)
- This would total $196 million in control costs at the study area's peak *Arundo* distribution and $124 million at current *Arundo* distribution levels. (Section 8.1)
- Benefits from control and reduction of impacts was calculated for fire, water use, sediment trapping, flood damage (bridges), habitat, and beach debris. Analysis was conservative. (Section 8.2)
- Benefits: $380 million at peak *Arundo* distribution and $239 million at current *Arundo* distribution levels. (Section 8.2)
- Benefit to cost ratio of 1.9:1. (Section 8.2)

Arundo control is of substantial net benefit. Many impacts were not included in the analysis, and benefits were valued conservatively. The actual benefit of *Arundo* control is likely much higher than calculated.

Watershed Programs

- Watershed-based control is a priority and is facilitated by a strong lead entity that manages the program. Effective programs must have the capacity to manage project funds, obtain right of entry agreements, and hold regulatory permits. (Section 9.1)
- Permitting is complicated and expensive, but required. Programs with broad and active permits are able to implement programs more effectively and quickly. (Section 9.1)
- Watershed programs should use accurate and standardized mapping to represent *Arundo* acreage. This allows better management of programs, facilitates comparison of projects, and increases accountability. (Section 9.1)
- A significant amount of *Arundo* control has already occurred within the study area and many watershed-based control programs have already formed. (Section 9.1)
- Priorities for *Arundo* control are: (Section 9.2)
    - Long term re-treatment of program areas that have already had initial control: this protects the investment already made.

- Control *Arundo* on watersheds with low levels of invasion: this eradicates populations before they become abundant, which is more cost effective and avoids future impacts.
- Treat watersheds with significant *Arundo* invasion based on: level of impacts and capacity of groups proposing work.

Watershed-based management of *Arundo* is greatly facilitated by the establishment of a program lead. Programs with tracking systems for work completed, in addition to long-term stability, have the greatest ability of completing true watershed based control (eradication).

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APPENDIX A. Detailed Maps of *Arundo* Distribution Within the Study Area

Arundo distribution data from Monterey to San Diego, CA
(see Chapter 3 for information on mapping methodology)

Spatial data set (GIS geo database) are available for download at:
http://www.cal-ipc.org/ip/mapping/*Arundo*/index.php

The spatial data set is also viewable at the DFG BIOS web site:
http://bios.dfg.ca.gov/

Project data sets are named:
Invasive Plants (Species) - Central_So. Cal Coastal Watersheds [ds645]
Invasive Plants (Prct Cover) - Central_So. Cal Coastal Watersheds [ds646]

APPENDIX B. Occurrence Data and Critical Habitat Areas for Federally Listed Species and Distribution of *Arundo*.

Spatial data for federally listed species includes:

- **Critical habitat areas designated by USFWS**
- **Occurrence data compiled by the Ventura USFWS Office**
- **Occurrence data from the California Natural Diversity Database (CNDDB: CA DFG)**
- **Additional occurrence data from USGS, SANDAG, and other sources**

Spatial data set (GIS geo database) are available for download at:
http://www.cal-ipc.org/ip/mapping/*Arundo*/index.php

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