REMOVING INVASIVE PLANTS FROM THE MOJAVE RIVER, AN EROSIVE INLAND DESERT RIVER SYSTEM IN SOUTHERN CALIFORNIA

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INTRODUCTION

In 2009, the Mojave Desert Resource Conservation District (MDRCD), in partnership with the Mojave Water Agency (MWA) and the USDA-Natural Resources Conservation Service (NRCS), began work to remove Arundo (*Arundo donex*) and saltcedar (*Tamarix ramosissima*) from areas within a 48-mile long riparian corridor within the Mojave River channel, referred to as Phases 3 and 4. Figure 1 provides a location map of the project area as it relates to the overall Mojave River watershed. As part of project planning, resource specialists from NRCS and MDRCD evaluated the potential impacts of the proposed project on stream function and riparian ecology.

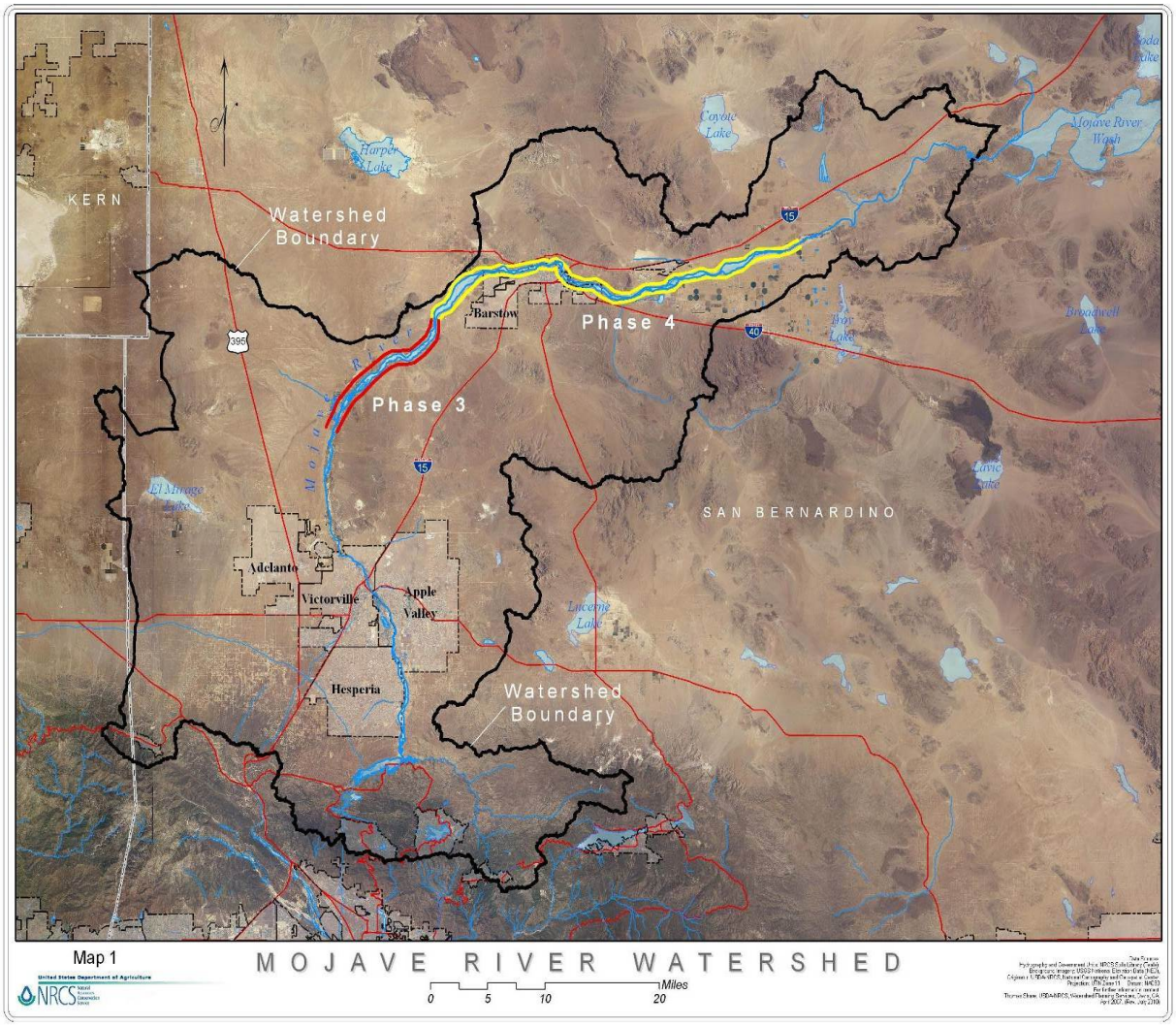

Figure 1 Map of Mojave River watershed showing the Phase 3 and 4 reaches.

The Mojave River is located in the high desert region of Southern California. It flows from the San Bernardino Mountains, inland through the Mojave Desert, to its terminus at Soda Lake. The flows in the alluvial reaches of the river are naturally ephemeral and flashy, but are greatly influenced by upstream water storage and imports, a flood control structure, levee confinement, locally high rates of groundwater withdrawal, and discharges from a municipal waste treatment facility. This altered hydrologic regime contributed to the establishment of non-native plants such as Arundo and saltcedar. Figure 2 depicts typical conditions found in these reaches and provides an example of how saltcedar plants invade the channel bed out-competing the native vegetation for moisture. The high density of these non-native species along some reaches further affect the geomorphology, hydrology, and ecology of the riparian community, by altering stream flow patterns and restricting channel capacity, consuming relatively large amounts of groundwater, and out-competing natives.

Figure 2 Typical condition of Mojave River within the Phase 3 and Phase 4 reaches.

METHODOLOGY

The evaluation team recognized a relationship between different areas of the river channel and critical resource concerns. Critical resource concerns were identified as streambank erosion, wind erosion, wildlife habitat, water conservation, and flooding. To help evaluate the effects of the critical resource concerns, the river channel was delineated into three distinct geomorphic categories based on function and the following characteristics: active channel, active floodplain, and terrace. Sub-reaches within the Phase 3 and Phase 4 reaches were further identified based on vegetation density and channel configuration. Then, each of the five resource concerns were evaluated for each geomorphic category within each sub-reach to determine whether there would

be a positive effect, negative effect, or no effect on the adjacent land uses if vegetation was removed. The team evaluated all potential combinations of land uses and resource concerns. If a negative effect was determined based on the criteria developed by the team, then a critical area was highlighted as needing special considerations with a recommended alternative for removal of invasive plants.

LAND USES

The evaluation team identified four typical land uses that occur adjacent to the Mojave River within the project Phase 3 and 4 reaches: private open land, public open land, homes and agriculture, and transportation infrastructure. For each sub-reach, the team evaluated how the resource concerns affect the adjacent land use if the invasive plants were removed. "Adjacent" for this project was defined as the distance extending from the river channel out to the point where the resource concern no longer has an effect.

CHANNEL FEATURES

Within the Phase 3 and Phase 4 project reaches, the team delineated the sub-reaches based on geomorphic and vegetative differences inferred from the 2007 MWA ortho-photography. The active channel, the low sand bars referred to as floodplain, and terraces were delineated using the MWA ortho-photography augmented by the team's field observations.

In several instances, some features were difficult to delineate because they were not apparent on the ortho-photos. For example, the low sand bars that form the floodplain were sometimes only a few inches higher than the active channel. Oftentimes these sand bars were only distinguishable from the active channel because there was some sparse vegetation, such as grasses, growing on them; or they had not been recently scoured or reshaped. Figure 3 shows an example of channel feature delineation for sub-reach 2 within the Phase 3 reach. The active channel, as mapped for this evaluation, appears in blue, the floodplain in green, and the terrace in orange. Vegetation maps were also used as an aid in delineating the channel features.

EVALUATION OF EFFECTS

The team evaluated the effects of invasive plant removal within each sub-reach and associated geomorphic feature relative to each land use (houses and agriculture, private open space, public open space, and roads/transportation) and each resource concern (wind erosion, flooding, habitat, water conservation, and stream bank erosion), for all sub-reaches in Phases 3 and 4. Table 1 provides an inventory of the results for one sub-reach (Phase 3, sub-reach 2) as an example. In Table 1, a plus (+) symbol indicates that invasive plant removal may reduce detrimental effects of specific resource concerns on particular land use categories. A zero (0) symbol indicates that invasive plant removal would most likely have no impacts, positive or negative, on effects of resource concerns on specified land use categories. A negative (-) symbol indicates that invasive plant removal may increase negative effects of specified resource concerns on particular land use categories.

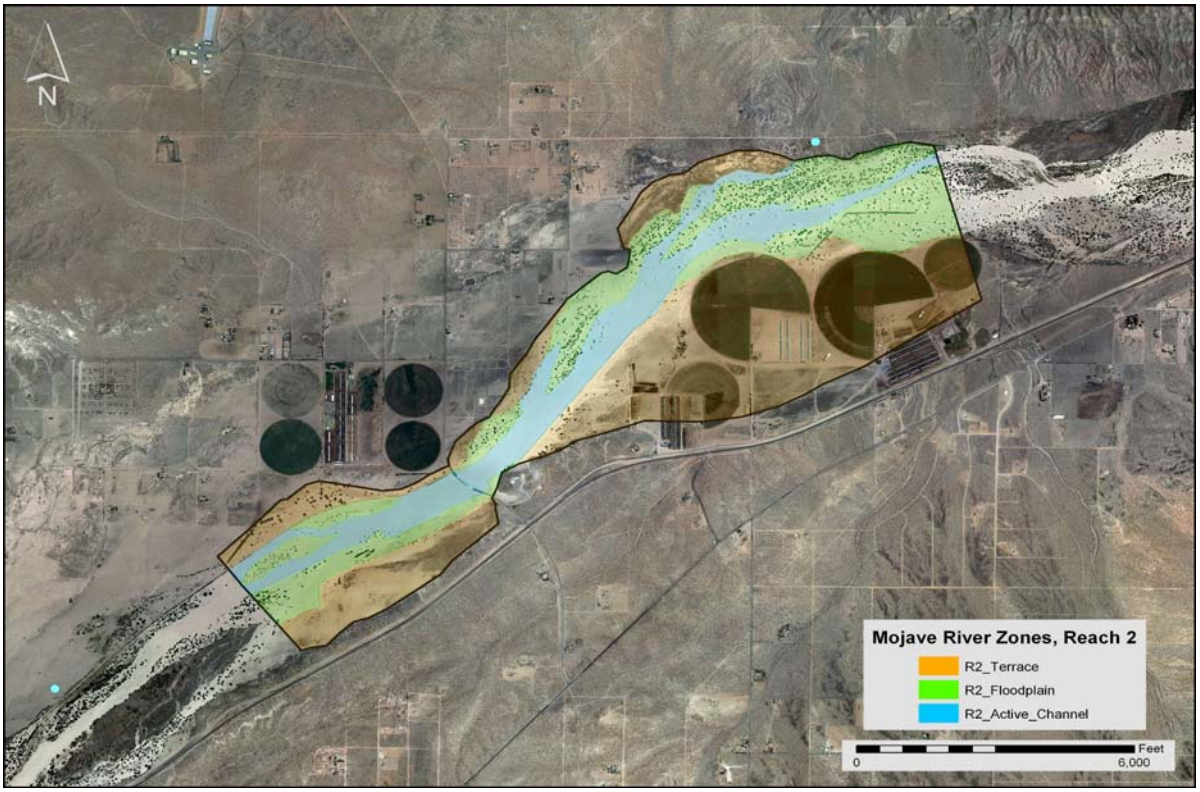

Figure 3 Channel features for Phase 3 sub-reach 2 (2007 MWA photo base).

Wind Erosion: Soil erosion due to wind was prevalent in the Phase 3 and Phase 4 reaches. Dune development and migration was easily identified in the 2005 and 2009 aerial images. In areas where invasive plants such as saltcedar existed, the soil tended to accumulate around the base of plants, functioning as soil traps. Because of this, the evaluation team recognized that invasive plants help prevent wind erosion. Modeling was performed to quantify the effects of vegetation on wind erosion.

Four typical existing conditions were modeled in and near the channel as follows:

- Dominate saltcedar with a nearly closed canopy
- Evenly mixed stand of saltcedar and native shrubs or trees with a nearly closed canopy
- Mixed stand of 25% saltcedar and 75% shrubs or trees with a nearly closed canopy
- Sparse vegetation of 25% saltcedar with 25% annual grasses

In conjunction with the four typical conditions above, four treatment options were modeled as follows:

- Dominate saltcedar killed using chemicals plus a 100 pounds per acre annual grass increase
- Evenly mixed stand of saltcedar and native shrubs or trees with saltcedar killed using chemicals, 100 pounds per acre annual grass increase
- Mixed stand of 25% saltcedar and 75% shrub or trees with saltcedar killed using chemicals, 50 pounds per acre annual grass increase
- Sparse vegetation with the 25% saltcedar canopy removed

Table 1 Example summary of effects for Phase 3, sub-reach 2

Reach Feature	**Houses & Agriculture**	**Private Open Space**	**Public Open Space**	**Roads & Transportation**
Active Channel	Wind –	Wind –	Wind –	Wind –
	Flood 0	Flood 0	Flood 0	Flood 0
	Habitat 0	Habitat 0	Habitat 0	Habitat 0
	Water Conservation +	Water Conservation +	Water Conservation +	Water Conservation +
	Streambank Erosion 0	Streambank Erosion 0	Streambank Erosion 0	Streambank Erosion 0
Active Flood Plain	Wind –	Wind –	Wind –	Wind –
	Flood -	Flood -	Flood -	Flood -
	Habitat -	Habitat -	Habitat -	Habitat -
	Water Conservation +	Water Conservation +	Water Conservation +	Water Conservation +
	Streambank Erosion -	Streambank Erosion -	Streambank Erosion -	Streambank Erosion -
Terrace	Wind -	Wind -	Wind -	Wind -
	Flood 0	Flood 0	Flood 0	Flood 0
	Habitat 0	Habitat 0	Habitat 0	Habitat 0
	Water Conservation +	Water Conservation +	Water Conservation +	Water Conservation +
	Streambank Erosion 0	Streambank Erosion 0	Streambank Erosion 0	Streambank Erosion 0

The eight options above were evaluated for two predominant soil types, Villa loamy sand and Cajon sand. Wind erosion rates for each condition and soil were estimated using the Wind Erosion Equation (Skidmore, 1968). The wind erosion modeling found that all treatment options had very high wind erosion rates compared to the soil loss tolerance of the individual example soils. Treatment for the dominant saltcedar condition resulted in an annual soil loss rate of 83 tons per acre, or 17 times the soil loss tolerance rate for Villa soil (USDA-NRCS, 2009). Treatment for the sparse vegetation area conditions resulted in an annual 395 tons per acre soil loss rate, which is 79 times the soil loss tolerance rate for Cajon soil (USDA-NRCS, 2009).

Removal of saltcedar in the Mojave River channel will increase wind erosion in varying degrees based on the method of treatment. Areas with a small, invasive plant canopy that is removed will have the lowest increase in wind erosion, approximately 1 ton per acre year, while the dominant saltcedar areas on Villa soil would have the greatest increase if removed, about 200 tons per acre year. Considerable dune activity would be expected if dense areas of invasive plants were sprayed, increasing the risk of damage due to sediment accumulation to sensitive areas such as the urban interface, rural farmsteads, roads, railroads, and producer field boundaries. Invasive plant areas not totally killed with chemicals and left clumpy with vegetation were predicted to accumulate soil around the base of the remaining plants. In areas that saltcedar was to be killed using chemicals, some annual grasses and forbs may grow due to increased sunlight and soil moisture post-spraying.

Streambank Erosion/Flooding: The evaluation team carefully assessed the risk of increased streambank erosion due to invasive plant removal because evidence has been documented in the literature that invasive plant removal, particularly saltcedar, can result in an unintended increase in streambank erosion. Helicopter herbicide applications in 2003 along a 12-km reach of the Rio Puerco, New Mexico, eliminated the saltcedar. Three years later a flood eroded about 680,000 cubic meters of sediment, increasing the mean channel width of the sprayed reach by 84 percent (Friedman, 2009). Erosion upstream and downstream from the sprayed reach during this flood was inconsequential (Friedman 2009). Streambanks for this analysis were considered a separate entity, generally being the transition between floodplain and terrace. At no location in the project area was saltcedar removal in the active channel or on the terrace considered a negative impact for streambank erosion or overbank flooding. Differences between the Rio Puerco and Mojave River are significant, but experience on the former helped guide recommendation for the Phase 3 and 4 reaches.

The impact of saltcedar removal in the active channel will generally increase flow area and reduce drag on the flow. In most river channels this would reduce flow depths, all other factors being equal. But, the Mojave channel width to depth ratio is high enough that a difference in depth would probably be minimal, except in reaches where there has been an extended interval from the last disturbance event. The thinning of vegetation in any given stream section would probably increase the capacity of the channel in that section. Saltcedar removal is expected to have little impact on the sparsely vegetated active channel areas.

The Corps of Engineers Mojave River channel maintenance plan describes the Corps' general goals and the estimated impacts of vegetation control in the active channel (U.S. Army Corps of Engineers (A), 1997). The Corps' document concludes that current channel conditions (1997) have a potential negative effect on streambanks due to excess vegetation. The vegetation in the channel tends to redirect flows toward the levees and streambanks causing erosion of unprotected slopes and overtopping. Any vegetation maintenance is to keep the centerline clear through urbanized areas, and maintain a buffer of adjacent wetlands and riparian vegetation to preserve their function of bank protection. In alignment with the Corps' goals, the team recommended that replacing vegetation where saltcedar removal occurred be made a priority in the near bank portions of the active channel.

Water Conservation: The team evaluated water conservation within the Phase 3 and 4 reaches of the Mojave River through removal of saltcedar. Groundwater pumping has steadily increased since the 1940s, reducing aquifer storage and creating an overdraft condition. This has caused changes in the quantity and distribution of recharge in the Mojave River (Stamos, 2001), leading to a loss of riparian habitat (Lines (A, B), 1996). This is evident in the decline of water levels in wells, which have dropped between 50 to 100 feet within the study area (Stamos, 2001).

The water table in healthy cottonwood-willow woodland is typically less than 10 feet below the surface. Willows and baccharis typically grow in narrow bands along the river edge in wetter areas than the cottonwood-willow woodland. Single-species cottonwood woodlands are common on terraces and slopes that are slightly elevated above the flood plain and the water table is typically 10-15 feet below the surface. Mesquite trees are typically widely spaced along the boundary of the riparian zone where water-table depths are 10-30 feet below the surface (Lines, (B) 1996).

Water savings due to saltcedar removal has been debated in the literature (Shafroth, 2005) as well as benefit/cost studies of water conservation gain, given the cost of mitigation measures (Barz, 2009). The ability of saltcedar to exclude native competition is contentious. Saltcedar roots generally reach deeper than roots of willow, mesquite, and cottonwood; and the invasive plant is able to capture moisture to the exclusion of the natives. In addition, saltcedar is more tolerant of low soil moisture conditions and can survive long drought periods more successfully than native species. Finally, saltcedar draws salt up through the soil column and deposits it on the surface through its leaf litter. The increased salinity further hinders native species (Swift, 2006).

Saltcedar may be able to tap into the water table at depths as great as 50 feet below the ground surface. Because of its rapid growth, saltcedar is commonly the dominant plant growing in the Mojave River channel (Lines (B), 1996).

It is estimated that saltcedar with a density of 71 to 100 percent uses 2.8 feet per acre of water per year. Healthy mesquite at a density of 71 to 100 percent is estimated to use 1.4 feet per acre of water per year (Lines (B), 1996). Reducing the density of saltcedar from 100 to 50 percent reduces water use by only about 10 percent (Hughes, 1972; and Van Hylckama, 1974).

Habitat: Invasive plants throughout the Phase 3 and 4 reaches have the ability to provide some level of habitat value in the form of protective cover and nesting structure (Brown and Johnson, 1998; Stromberg, 2009; and Van Riper, 2008). However, in the bigger picture, this habitat is not valuable if considering the overall negative habitat effects caused when the invasive plants outcompete and replace native plants (Anderson, 1977; Engel-Wilson and Ohmart, 1978; Kasprzyk and Bryant 1989; Howe and Knopf, 1991; Hunter, 1988; Lovich and de Gouvenain, 1998; and Zavaleta, 2000). The habitat value of native plants for native animal species is so high that even a little native plant habitat is much more desirable than a lot of invasive plant habitat. The only habitat condition that was considered where invasive plants would be left in place, was where the water table is too low to support native riparian vegetation. Even so, this consideration was rejected (from the habitat point of view) since leaving invasive species in place increases the potential to spread the plants, and their negative effects, to other locations. There may be some onsite short-term negative impacts to wildlife from the removal of the invasive plants, but the long-term onsite and offsite effect is overwhelmingly positive. The overall effect of invasive plant removal had been evaluated by the appropriate regulatory agencies prior to beginning of the project. Appropriate actions to avoid or minimize negative impacts associated with invasive plant removal were outlined through permitting and consultation with the applicable regulatory agencies.

DELINEATION OF NEGATIVELY EFFECTED AREAS

The team delineated the reach areas determined to be negatively affected due to invasive plant removal as depicted in Figures 4 and 5. These highlighted areas are deemed critical, as the proposed actions could increase the effects of resource concerns on adjacent land uses and should not have any plant removal or treatment, unless it is performed in such a way that the negative effects may be mitigated, using alternatives offered in the report. Figure 6 provides a close up view of areas delineated as “critical”. This type of map allows the user to control vegetation removal in an exact manner.

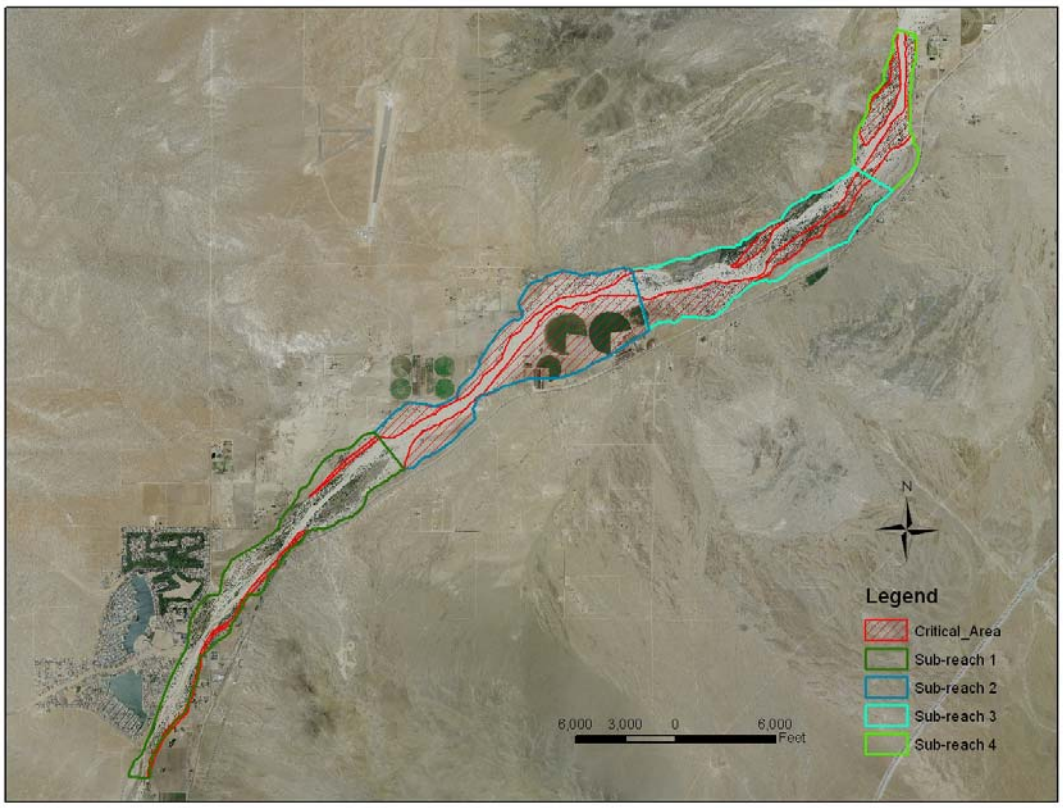

Figure 4 Negatively affected areas for Phase 3 reach.

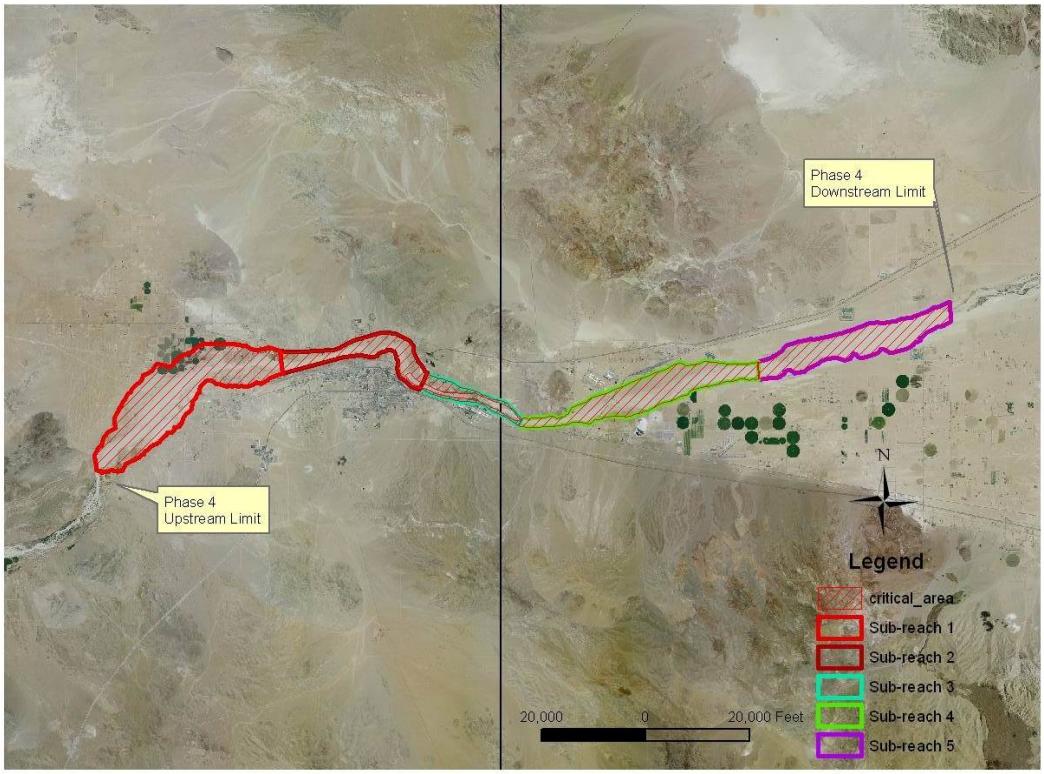

Figure 5 Negatively affected areas for Phase 4 reach.

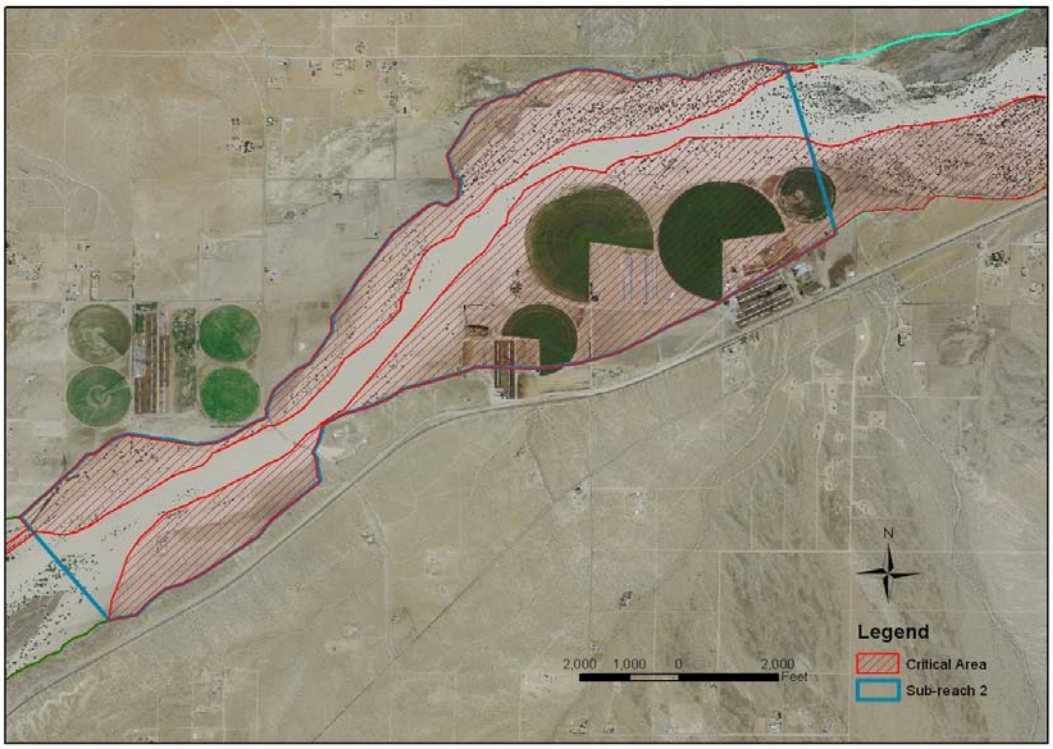

Figure 6 Zoomed in view of Phase 3, sub-reach 2 showing negatively affected areas.

TREATMENT ALTERNATIVES FOR CRITICAL AREAS

The team developed treatment alternatives for removing vegetation within the critical areas of the Phase 3 and 4 reaches. Alternatives included specific methods for vegetation removal, patterns of removal, amounts of vegetation removal, and re-vegetation directions. As an example, for active channel, floodplain, and terraces with mixed stands of saltcedar (25 to 50 percent canopy by area), the team developed the following directions:

1) Treat strips of saltcedar, where the strips are perpendicular to the prevailing wind direction, as evident by sand buildup behind existing saltcedar with a strip width no greater than 10 times the height of the average invasive plant, or (if not stripped) treat only 50 percent of all invasive plants in an every other plant pattern. The untreated strips should be at least 15 feet wide to stop saltation. Treated plants (dead) should remain standing, rather than being chipped on site or removed, to keep the standing plants in place (Skidmore, 1986); and

2) In conjunction with number 1, seed or plant native, soil-stabilizing, vegetation, such as desert panicgrass, (*Panicum urvilleanum)*; desert saltgrass, (*Distichis spicata)*; creeping wildrye, (*Leymus* (Elymus) *triticoides)*; scratchgrass, (*Muhlenbergia asperfolia);* and scale broom, *Lepidospartum squamatum*. Desert panicgrass appears to be adapted to deep sandy soils and dunes. The team observed this species in the active channel, as well as the active floodplain. Scratchgrass is adapted to floodplains with both saline or non-saline sandy soils. NOTE: the above species, except for wildrye, are warm season grasses and should be dormant during foliar herbicide applications and, if dormant, it is assumed that they would not be damaged during fall or early winter herbicide application. However, efforts should be made to direct spraying away from grasses and only onto target plants. The availability of seed or planting stock for creeping

wildrye and desert saltgrass can be intermittent. If desired, there is potential for conducting seeding trials using scratchgrass and, in the future, desert panicgrass with seed from Tucson PMC. Seeding or planting rates should be determined on the site-specific conditions and approved by an NRCS planting plan.

Other specific directions and alternatives were developed for floodplains and terraces with dominant saltcedar (stands with >50% canopy by area) and streambanks or levees with dominate invasive plants (stands with >50% canopy by area of invasive plants). Additional considerations were developed and outlined for establishment of native plants post removal of invasive plants.

SUMMARY

The team generally assessed the potential impacts of the proposed project on locally-identified resource concerns, including streambank erosion, wind erosion, wildlife habitat, water availability and use, and flooding. Recognizing that geomorphic units that together comprise the riparian corridor would respond differently to vegetation removal, the active channel, active floodplain and terraces within the 48-mile long study reach were mapped using GIS equipment and field reconnaissance. For each geomorphic unit, the team assessed whether vegetation removal would have a positive, negative, or insignificant effect on each of the resource concerns and adjacent land uses. Any areas having a negative effect due to vegetation removal were identified as critical and removal would either be avoided or mitigated. The planning report developed by the NRCS/MDRCD team included a map showing critical areas within the inventoried reach, technical guidelines for evaluating other reaches of the channel, and listed approved mitigation alternatives for critical areas.

Since 2009, the MDRCD has spent approximately $ 3,000,000 removing non-native vegetation either mechanically or through chemical treatment according to the plan. The work performed to date includes about 30 of the 48 miles evaluated within the plan. The remaining work will be completed as money becomes available.

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