Type D - Riparian Vegetation Monitoring

Annual Status Report 2023

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Introduction

The riparian vegetation, or Type D, monitoring program initiated by the Inyo County Water Department (ICWD) was limited in scope during summer 2023 due to record high flows on the Owens River. As described in previous reports, the goal of this work is both to develop and implement a long-term riparian (vegetation zone adjacent to a river) monitoring program, and to understand relevant mechanisms required to recruit and maintain riparian tree stands along the Middle & Lower Owens River (MOR and LOR respectively). As described in ICWD Annual Reports from 2020–2022, the technical appendix to the Long Term Water Agreement (LTWA), the Green Book, does not specify an official monitoring plan for the riparian vegetation community type, defined as "Type D" vegetation therein. A complete description of the rationale and field methods for the program are described in the draft monitoring plan (Type D Monitoring Program and studies for the Long Term Water Agreement, 2020) provided as Appendix 1 to this report.

Studies and monitoring designed to understand conditions that recruit and sustain riparian vegetation are required by several governing documents including: 1) the LTWA and associated Environmental Impact Report, 2) the Greenbook, and 3) the MOU for the Lower Owens River Project (see Appendix 1). The ICWD draft riparian monitoring plan catalogs conditions in the riparian corridor generally but primarily focuses on the riparian forest vegetation community type because *i)* it is one of the most vulnerable community types in the Owens Valley, *ii)* the land area of this community type declined on the Lower Owens River between 2000-2017 (LADWP and County of Inyo, 2018) and *iii)* riparian forest establishment is a goal of the Lower Owens River Project (LORP), a large scale mitigation project identified in the LTWA. The Type D research and monitoring program seeks to describe riparian tree stand age and size structure and understand historic and current tree recruitment patterns along the Owens River.

Riparian tree recruitment processes are theoretically understood to require several steps: 1) flooding, which can cause mechanical disturbance, 2) an increase in the river stage, 3) allowing tree seed exposure to bare, wetted soils just above the frequent flood stage (above the bank) and into the floodplain. This satisfies riparian tree seed requirements of wetted soils that are free from plant competition and prevents future floods from eliminating new recruits. Because flooding is understood to be an integral part of riparian tree recruitment, it has also been demonstrated that surface water management can alter riparian tree recruitment and survival. It appears within the Owens Valley that trees may have established under a variety of circumstances, some outside of this classic model.

To identify the range of hydrologic conditions that have permitted riparian tree germination and survival, we are collecting tree core samples to age extant individuals in the river corridor. Using tree topographic elevation relative to river stage (or a tree's height above the water surface) we will compare historic flows (using extensive flow records) and subsequent river stage during the establishment year to understand what flows and thus stage height were required to reach the base of each tree. Riparian transects were established in 2020, 2021, and 2022 (*Figure 1*) to sample understory vegetation, tree stem and canopy density, size (dbh) and height, record fluvial surface (bank, floodplain, terrace) locations, and to collect tree cores for age estimates. The study thus characterizes the topographic surface elevation of each cored tree relative to river stage, and soils are collected for salinity and texture analyses.

By coring trees, it is possible to reconstruct tree ages to understand stand demographic structure and the ecological stable state of the riparian forest system. This combined information will inform a long-term riparian monitoring program and adaptive management on the Lower Owens River which could identify appropriate flows, sufficient local topography, or appropriate locations for tree plantings.

Figure 1. A close-up view of riparian transects along the Owens River in the Owens Valley, with start points in yellow and endpoints in red, spanning the width of the riparian corridor.

During the 2023 field season, no riparian transects were sampled due to record high flows resulting from 233% of normal runoff (LADWP and County of Inyo, 2023). However, additional trees were cored for age estimates based on transects previously completed from the 2022–2022 summer seasons.

Field component

The spatial extent of sampling from 2020-2022 is presented in Figure 2; no additional complete transects were added in 2023 due to ground surfaces inundated with water preventing sampling ground vegetation,

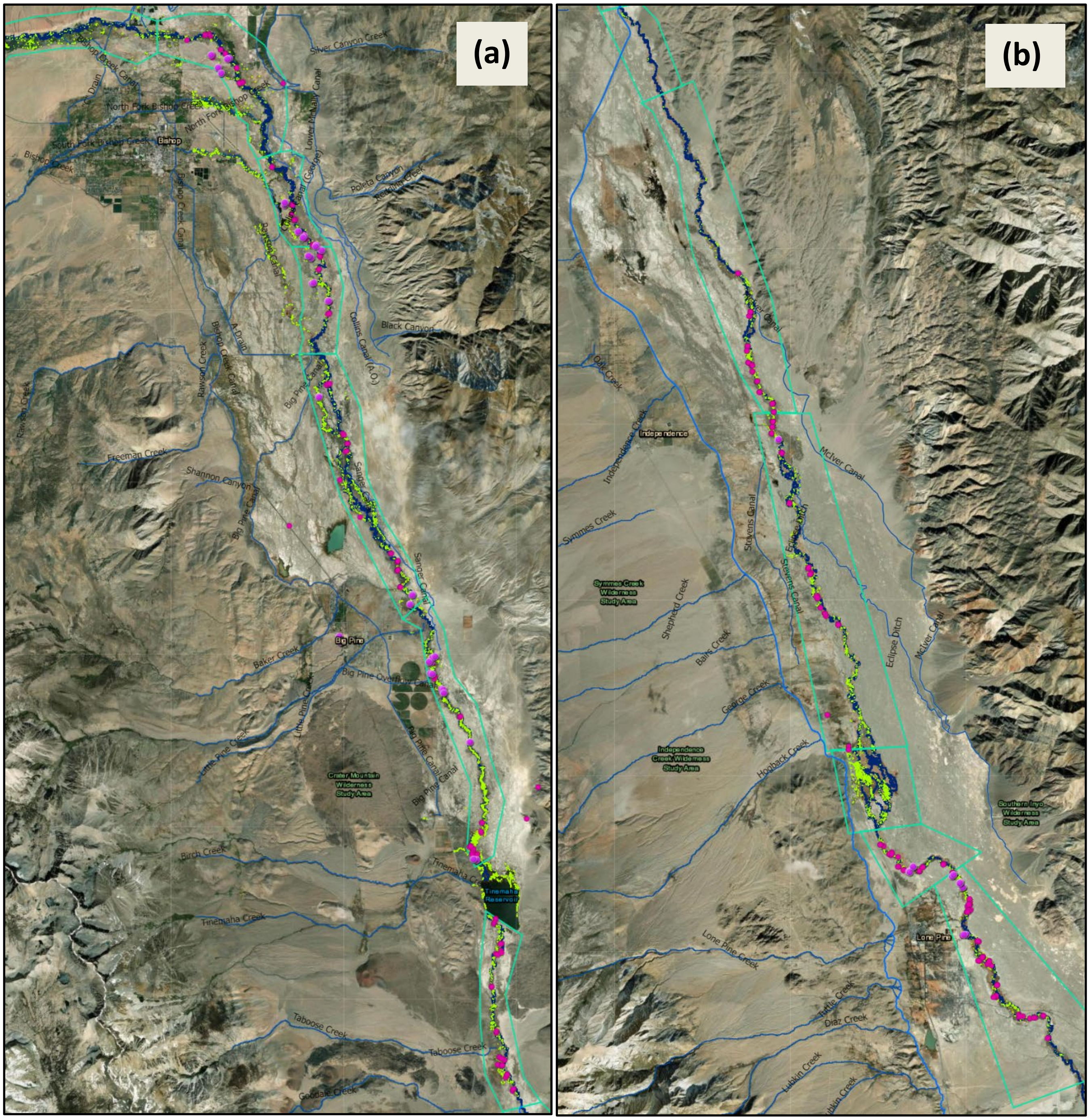

Figure 2. Transects completed during the 2020, 2021 and 2022 seasons represented as pink dots, reach boundaries depicted as blue outlines, tree polygons depicted in bright green. MOR reaches in *a*, and LOR reaches in *b*.

collecting soils or recording fluvial surfaces. During summer 2023, 79 tree cores were collected from 56 trees on previously established transects. In addition to increment cores collected from 2020 – 2022, a total of 366 trees have been sampled for age estimation. Some mature trees in all sample years were rotten in the center and the resulting core may not be useable for age estimation, thus the true number of trees post analysis may be smaller. A projected ideal quantity to adequately represent age distribution at the scale of the reach is approximately 530 - 750 trees for the Owens River (Appendix 1, Table 3), so approximately 50-70% of the projected total number of trees have been sampled. Given the abundance of rot in both willow species (*Salix laevigata* and *Salix gooddingii*), we are often required to collect two rather than one core sample which will reduce the total number of trees to closer to 600 individuals.

Preliminary results show a range of tree ages, with most less than 100 years old. Not enough data exists to summarize by reach or river section, or relate to other environmental conditions, but this type of analysis is expected in a 2025 annual report.

Expected Reporting & Data Types

Anticipated 2025 reporting will describe conditions regarding tree age structure and density, environmental conditions like canopy cover and closure, riparian corridor width (important as a habitat indicator for associated species), soil salinity and texture (relevant to tree seed germination), river stage associated with topographic germination surfaces (floodplain vs terrace), and age estimates for riparian trees by river section, reach and relevant environmental strata in including fire and hydrologic conditions (Appendix 1). Table 2 describes riparian data types collected to be analyzed in final reporting, rationale, and methods for data collection.

Table 2. Types of riparian monitoring data collected, to be analyzed in the 2024 Annual Report.

Data type	Why collected	Method
Size and size class	a proxy for age distribution	Height and diameter at breast height by species; Size classes are defined in the Type D plan (Table 1; adapted from Scott and Reynolds 2007).
Tree density	density of trees within reaches and tree patches	Trees per 100 m^2
Canopy cover & closure	how dense is canopy - for shade and associated species	Canopy closure - concave mirror with a grid (spherical densitometer) held level and green-vegetation hits within the upper canopy (> 5 m) recorded. Readings were taken at 10 m intervals along the transect centerline (see Appendix 1 - Type D monitoring plan). Canopy cover - vegetation hits (using line point technique) at the middle or uppermost vegetation tier by a riparian tree species (capable of growing to >5m) at every 1m interval along the transect centerline.
Potential crown cover	a visual measure of tree vigor	Assessed by accounting for all live and dead branches on an individual tree. It is assessed by visualizing a full tree crown as defined by the extent of branching patterns; the percentage of that area (the potential full crown) with live foliage is estimated (see Appendix 1 - Type D monitoring plan, Figure 4).
Riparian corridor width	extent of riparian vegetation zone & habitat breadth for associated species	Total transect length provides an indication of riparian corridor width.
Vegetation cover by lifeform	distribution and type of species in riparian zone	Distinguished by tier (<1.5, 1.5-5, and >5 meters), and lifeform (e.g. herb, grass, shrub, tree)
Tree elevation above river stage	requirements for tree recruitment and survival	Tree elevation relative to the surface water stage was recorded for riparian tree species using a survey transit and rod
Fluvial surface	potential germination surfaces	document change in fluvial surface (e.g. channel, bank, floodplain, terrace) along transect centerline

Data type	Why collected	Method
Soil salinity	to determine if soils are too saline and if a particular soil texture better supports tree recruitment.	Soil slurry and salinity probe; hand texture analysis in lab
Tree-core samples	age estimation	Increment borer

References

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Appendix 1

Type D Monitoring Plan (Draft)

Type D Monitoring Program and studies for the Long Term Water Agreement

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Modified for this appendix: May 2021

Introduction

Type D vegetation communities are described in the Technical appendix to the Long Term Water Agreement (LTWA; 1991), the Green Book (Section 1.B.3; 1990) as riparian and marshland vegetation "concentrated in areas of streams, swales, water conveyance canals, springs, and flowing wells…" that are "…more sensitive to water deficits…" than other vegetation types defined by the Green Book. One of the primary goals of the LTWA is to manage ground and surface water while maintaining vegetation communities found within the Owens Valley; however the riparian monitoring plan was left incomplete. Green Book section V.B.8 requires that "…a study will be initiated to refine the present methodology and investigate alternative methods to improve monitoring of riparian and marshland vegetation." In partial response to this need, Los Angeles Department of Water and Power (LADWP) initiated several vegetation mapping efforts along the Middle Owens River (2000, 2009, 2017), the Lower Owens River (2000, 2009, 2014, and 2017), and Owens River tributaries (2005). In combination, these efforts captured much of the Type D vegetation parcels delineated on the baseline map in the Owens Valley but not all (approximately 60% of the total Type D area). During the 2017 effort LIDAR (Light Detection and Ranging) was incorporated to classify individual riparian trees and tree stands with much greater precision than previous iterations that were mapped off of 2-dimensional aerial images. Inyo County Water Department staff has chosen to focus on riparian forest in a field based Type D monitoring program because this community type provides valuable habitat for associated species and is considered a sensitive community by California Department of Fish and Wildlife (CDFW, 2018). Within the Owens Valley specifically, it is one of the most threatened; as demonstrated by a substantial reduction in land cover on the Lower Owens River Project (LORP) large-scale mitigation effort (LADWP, 2018).

A riparian vegetation (Type D) monitoring program is required by the Long Term Water Agreement; however, riparian vegetation maintenance and enrichment is also necessary to fully comply with provisions in other governing documents. The Environmental Impact Report (1991) associated with the LTWA states "Areas of riparian vegetation dependent on springs and flowing wells, stands of tree willows and cottonwoods, and areas with rare or endangered species will be identified by the Technical Group for monitoring purposes." In addition, the Lower Owens River Project was identified as a large-scale mitigation project in the LTWA and subsequent EIR (1991) as an environmental enhancement program to "…restore meadow and riparian vegetation" and to improve habitat for wildlife and recreation to compensate for pre-existing impacts within the Owens Valley. A Memorandum of Understanding (1997) further summarizes the overall LORP goal as the "establishment of a healthy, functioning Lower Owens River riverine-riparian ecosystem", and a specific goal is further described (Section II.C.b.ii.) "…to fulfill the wetting, seeding, and germination needs of riparian vegetation, particularly willow and cottonwood…" and "…diverse natural habitats consistent with the needs of the 'habitat indicator species'", many of which are riparian obligates. A subsequent implementation document, the Monitoring, Adaptive Management and Reporting Plan (MAMP; Ecosystem Sciences, 2008) describes how riparian woodlands are created and maintained including the importance of flooding for mechanical disturbance, seed dispersal and wetting of bare soil on freshly deposited banks or scoured floodplains and also describes mapping efforts to monitor vegetation (including riparian tree) extent and change along the Lower Owens River.

The above described LADWP landscape-scale mapping efforts have been valuable to quantify the area of a particular riparian vegetation type and to determine whether a change in acreage has occurred over time, however, the resolution of remote sensing based vegetation classification does not provide information about the stand density, tree health, or age structure of the population. Information on age structure is needed to predict the likelihood of long-term persistence including the capacity of a tree-stand to replace mature individuals within the population over time (Figure 1; Dickard et al., 2015). A plant population will not persist if the appropriate and often narrower subset of environmental conditions necessary for an individual to self-replace does not exist. The regeneration niche (Grubbs, 1977), encompasses the environmental conditions necessary for seed production, dispersal, germination, and subsequent seedling establishment which may be different than those required for mature individuals. Individual trees and tree stands, since they are long-lived, can persist for many years as remnant populations (Ericksson, 2000) well beyond a change in environmental conditions that would not favor recruitment of seedlings or saplings, while still playing important functional roles in the system – for avian habitat indicator species for example (MOU, 1997). Quantifying the age distribution and structure (e.g. stem or canopy density) of a stand is necessary for our capacity to predict longer-term losses of this community type and management actions that are compatible with the long-term conservation of these sensitive communities.

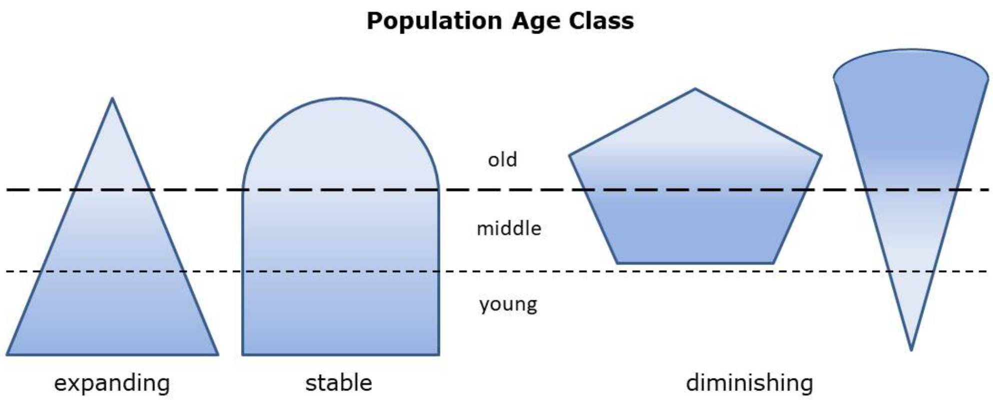

Figure 1. Age class population distribution depicted within three states: a) expanding, b) stable, and c) diminishing; adapted from Dickard et al. (2015).

Natural recruitment for riparian cottonwood and willow is dependent on fluvial disturbance regimes that redistribute sediment and expose bare soils following flood flows (Stromberg et al., 1991; Auble and Scott, 1998; Mahoney and Rood, 1998). Alterations to natural flow regimes through water impoundments typically alter the timing and reduce the magnitude of spring high flows and the mechanical disturbance required for riparian tree recruitment as well as soil water availability for adults (Stromberg, 1993). Tree-ring dating provides a record of establishment year for a tree, and via dendrochronology, or when information from multiple trees is combined, this record of establishment can be related to long-term hydrologic records (flows), geomorphic events, or environmental conditions during recruitment (Scott et al., 2017). Developing a chronology will help to identify local conditions favorable to historic establishment relevant to riparian tree management and development within the Owens Valley.

The Type D monitoring goal is to begin to characterize riparian forest structure (at a minimum age class, stem and canopy density) for the length of the Owens River from the Pleasant Valley Reservoir to the Delta. We expect to trial several sampling methods during spring (or early summer) pilot studies to develop a robust continuing field monitoring program. In the longer term, we propose a periodic resampling interval occurring in conjunction with remote sensing acquisition and associated vegetation classification occurring on an alternate but complementary schedule. Once this monitoring program has been developed it is expected to be extended to Type D parcels off of the main Owens River channel. The program ICWD proposes to understand riparian tree establishment and stand maintenance is two-fold: first, we propose studies designed to understand the historical context of tree establishment, including site characterization, which will be one-time efforts to inform long term monitoring and restoration efforts. Second, we propose methods for an ongoing riparian monitoring program.

First, studies in 2020-21 will be designed to answer the following questions: *1)* what were the historic conditions (e.g. hydrologic, edaphic, or climatic) that fostered riparian tree germination and establishment along the Owens River? We predict that the majority of historic tree recruitment occurred during high flow years, with relatively little recruitment during low- runoff years. Based on preliminary observations, it appears that some trees persist along the edge of the riparian floodplain, farthest from the current channel, and could provide information on past activity of former channel meanders under different hydrologic conditions than present, which could inform the selection of favorable restoration locations. *2)* What is the age of trees located on the far edges of the floodplain or along old Owens River channel meanders, and what were the past and present hydrologic conditions that contributed to recruitment and survival? We predict that these trees will be exclusively of older age classes and establishment will have occurred only during high runoff years when inactive channel meanders would have been wetted. Finally, since fire is an active disturbance agent along the Owens River, we ask: *3)* how do riparian stands on the Owens river recover from fire and what is this influence on age structure and stand density in locations with a sufficient fire record (> 20 years on the MORP; > 7 years on the LORP). Further, what is the influence of the hydrologic regime on post-fire recovery? This will primarily be investigated on the middle Owens River with a pre-1988 fire record. We predict that tree recruitment has occurred during years when the managed hydrologic regime supported high flow events with potential for mechanical disturbance to banks, wetting of higher banks, or wetting of old, dry, and poorly vegetated meanders in proximity to a seed source. These studies will add to our understanding of the hydrologic mechanism contributing to tree recruitment in the Owens Valley and will inform management methods that will sustain riparian forest across the Owens Valley as required by the LTWA, and promote and enhance riparian recruitment along the LORP as required by the 1997 MOU.

Second, an ongoing Type D monitoring program will answer: *4)* what is the current age- and stand- structure of riparian forests along the Owens River; is the population expanding, stable or diminishing based on recruitment and age class? We predict stand and canopy density and age structure will be variable based on a combination of local geomorphic conditions and hydrologic regime. Where water is available to meet riparian tree germination and establishment requirements (wetted, bare floodplain soils and a shallow water table), we expect a variable age-class structure of trees occurring in a wider floodplain, whereas in locations with incised channels, lower water inputs or lacking high flows, there will be fewer trees in single or fewer age classes and trees will be restricted to a narrower belt along the river corridor. *5)* What is the cover and composition of the riparian vegetation community along the Middle and Lower Owens River? This will be assessed with vegetation transects that will capture species occurring within the riparian corridor.

Methods

Site description

For the purposes of this monitoring program, we focus on 172 km (107 miles) of the Owens River from the Pleasant Valley Reservoir to the Delta (Table 3, Figures 5 and 6). Relevant geomorphic processes include meander migration, cut bank erosion, and point bar deposition (LADWP and Ecosystem Sciences, 2010). The current active channel is generally inset within a larger historic channel and is actively downcutting in some reaches, potentially a consequence of changes in surface water elevation and at Tinemaha Reservoir and a managed flow regime (LADWP and Ecosystem Sciences, 2010). Average annual flow below Pleasant Valley Reservoir is 384 cubic feet per second (cfs) and following augmentation by creeks, ditches and canals, achieves an annual average of 459 cfs below Tinemaha Reservoir. The Lower Owens River Project maintains an annual 40 cfs basefow augmented by a two week seasonal habitat flow of up to 200 cfs in a normal runoff year. The dominant land form is a graded or incised alluvial/lacustrine valley (Whitehorse 2000, LADWP and Ecosystem Sciences, 2010), and soil types are predominantly mollisols with some smaller areas of entisols and aridisols also present (NRCS, 2020).

Historical context and site characteristics

To understand conditions which have permitted historic tree establishment in mixed stands of black willow (*Salix gooddingii*), red willow (*Salix laevigata*), and Fremont cottonwood (*Populus fremontii*) on the Owens River, we will characterize historic and present site conditions within existing tree stands. We will use pre-classified riparian tree stands originally mapped from 2017 remote sensing for the middle Owens River project (MORP; Jensen 2019) and within the LORP (LADWP, 2018); polygons are available within Geographic Information Systems (GIS). Both the MORP and the LORP have been divided into reaches based on similar hydrologic and geomorphic characteristics. Belt transects 10 m wide by the length of the tree patch (within the floodplain, typically 100 m or less) will be established to measure vegetation characteristics (Figure 2). These permanent vegetation transects will be systematically located within known tree patches but randomly assigned within patches. The number of transects will be apportioned based on reach length and character (Scott and Reynolds, 2007). Transects will be oriented 90° to the channel (or point bar) in order to measure river stage (water surface elevation; Bradley and Smith, 1986).

i) a. Tree aging and chronology –

To understand historic conditions contributing to tree establishment, a one-time study will be conducted to accurately determine tree age; trees greater than 8-10 cm dbh will be cored with an increment borer at breast height (1.37 m). In order to capture the variability of age distribution, it is recommended to sample 50 trees from a homogeneous reach section (Scott and Reynolds, 2007). Each tree will be cored from 2 angles to get a reliable sample, except for small trees that will be cored straight through resulting in 2 cores. Damage or mortality in *Populus fremontii* has not been anecdotally observed following decades of tree coring in hundreds of trees (Scott and Friedman, 2019). Locations of cored trees will be recorded with Global Positioning Systems (GPS) and could be tracked to assess health or survivorship. Specimen will be mounted and sanded to count annual rings. Ring widths can then be associated between trees (cross-dated) and correlated with environmental conditions during the year of establishment (e.g. precipitation and runoff, river flows, mean summer max or minimum temperature, etc.) by generating a chronology. Tree cores are generally cross-dated to ensure accurate age estimates and to correctly assign an individual tree ring to a particular calendar year. By comparing many core samples from an area with relatively homogeneous environmental conditions, rings with similar growth characteristics (widths) are matched, and taken together can provide a precise year of ring creation and thus the precise age of an individual tree. Once age has been assigned, environmental and hydrologic conditions in that year will be assessed.

i) b. Site conditions –

To characterize sites with established tree stands to inform long term management, on each transect we will collect samples for soil salinity tests, characterize soil texture (proportion of silt, sand, and clay) and land form type (e.g. point bar) or fluvial surface (bank, floodplain, terrace; Merritt et al., 2017). As necessary, we will also install temporary (removable) shallow piezometers to measure depth to water (DTW) to assess depth of saturated soil and therefore capacity of the rooting zone (or the approximate depth of the capillary fringe). We will also relate NRCS soil maps and historic hydrologic conditions, LADWP management actions, or other causal mechanisms on the Owens River to patterns of historic tree establishment.

ii) Floodplain establishment –

To understand the conditions which have permitted establishment of trees along the historic edges of the riparian floodplain and in former channel meanders to inform restoration, we will stratify the zone adjacent to the river (within 150 m of the active channel) from the larger historic floodplain (greater than 150 m from the channel edge). Transects will be randomly assigned from within each of these two categories; current floodplain (within 150 m) and historic floodplain (> 150 m from active channel).

iii) Post fire establishment –

To answer the question regarding how and to what extent riparian forest stands recover post-fire, we will sample trees from burned (pre-2002 fires on the MORP, and a 2013 fire on the LORP) and non-burned sites within the same reach. Age and growth (via annual rings) responses can then be correlated with local hydrologic or other environmental conditions collected at the site.

Ongoing Monitoring I: Vegetation sampling

To understand stand structure (age and size) within tree stands to inform future management (question 4 above), and to characterize vegetation conditions for the Type D monitoring program, we will employ several methods. We will use the same transects described above in the historical context section. First we will record vegetation cover of all species along the belt transect centerline at three vegetation layers (<1.5 m, 1.5–5m, >5m) according to the point-intercept (Coulloudon et al., 1999) method using a densitometer (Merritt et al., 2017; Figure 3a). Canopy cover will be assessed every meter along the transect using the top hit of the transect centerline. Canopy closure will be assessed every 10 m along the belt transect centerline (width of the average crown diameter) using a spherical crown densiometer (Figure 3b). All trees within plots (or belt transects) will be counted and height and diameter at breast height (dbh, 1.37 m) recorded so individuals can be tallied by approximate age class (Scott and Reynolds, 2007; Table 1). Potential crown density will be assessed for each tree within the belt transect (Merritt et al., 2017; Table 2 and Figure 4). Photo points will be taken at the start (0 m) and end point of each transect. Other important site characteristics including invasive weed presence or cover will be recorded. Transect locations and bearings will be permanently recorded (using GPS) so they can be revisited in future monitoring years on a periodic basis. One of the purposes of the 2020 campaign will be to field-test the proposed sampling methods in order to develop an appropriate program informed by the data and ease of collection. Once the method has been refined based on 2020 results, it will be modified to accommodate other non-river Greenbook identified Type D parcels along tributaries, seeps or other water conveyances.

Table 1. Size (diameter at breast height [dbh]) and height classes for trees sampled along transects. Adapted from Scott and Reynolds (2007).

Tree size class	Criteria

Seedling	<1.37 m tall or ≥ 2.5 cm dbh
Pole	≥ 1.37 m and 2.5–15 cm dbh
Overstory tree	≥ 15 cm and <50 cm dbh
Legacy tree	≥ 50 cm dbh

Table 2. Vigor categories used to describe canopy condition for riparian trees within transects; adapted from Meritt et al. (2017). This visual assessment is used with the understanding that leaf stress can be caused by multiple sources including water stress, disease, insects or fire.

Vigor class	Criteria for assessment
Critically stressed	Major leaf death and or branch die back (>50% of canopy volume affected)
Significantly stressed	Prominent leaf death and or branch dieback (21-50% of canopy volume affected)
Stressed	Minimal leaf death and or branch due back (11-20% of canopy volume affected)
Mildly stressed	Little or no sign of leaf stress (between 5-10% of canopy affected)
Vigorous	No sign of leaf stress/healthy canopy (<5% of canopy affected)

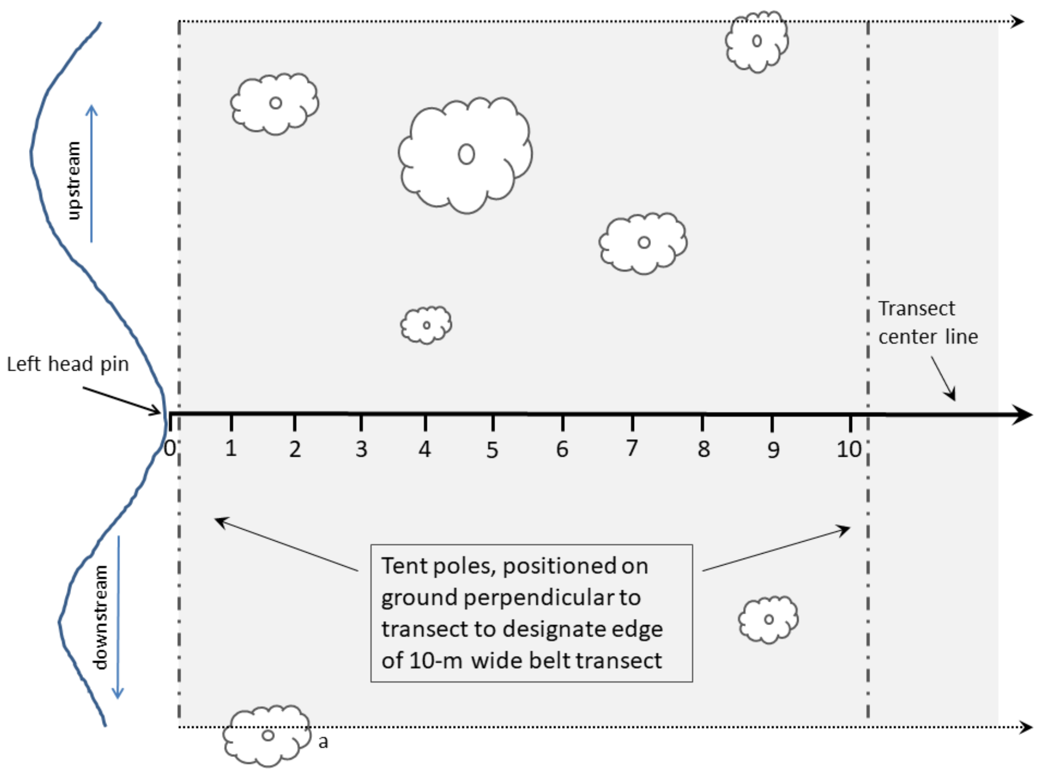

Figure 2. An example 10 m wide belt-transect layout. Transects originate at the channel edge and extend perpendicular across the riparian zone. All trees (circular polygons) within the belt (grey shading) are sampled. If more than 50 percent of a tree stem is outside of the belt it is not included; tree *a* for example would not be sampled. Adapted from Scott et al. (2007).

Figure 3. Measuring vegetation and canopy cover using *a)* a densitometer and *b)* a spherical densiometer along *c)* the center line of the belt transect.

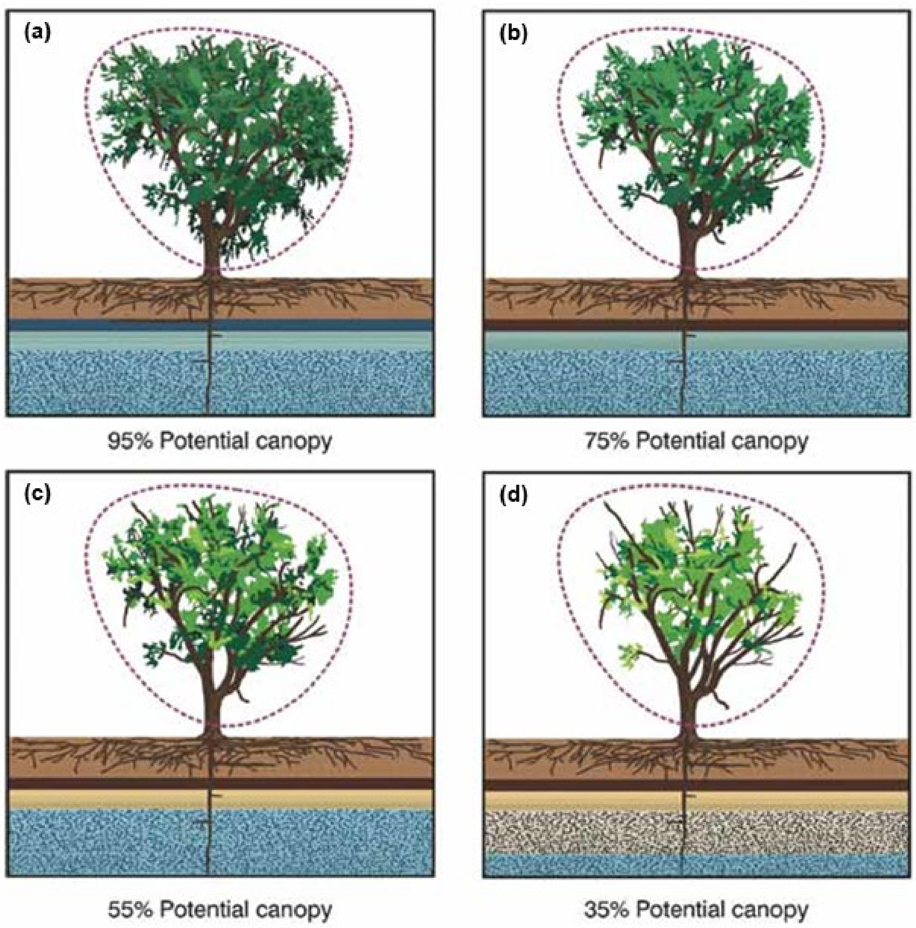

Figure 4. Percent potential canopy classes are estimated by visualizing a full canopy as defined by branching patterns (dotted line), and then estimating and recording the percentage of that area that is foliated. Examples depict *a)* mildly stressed, *b)* significantly stressed, *c)* significantly stressed, and *d)* critically stressed individuals; see Table 2. Adapted from Merritt et al. (2017).

Sampling effort by reach: One time studies and ongoing monitoring

Owens River reaches have been delineated for each of the MORP and LORP river sections by geomorphology, hydrology and vegetation characteristics (Whitehorse Associates, 2004; LADWP and Ecosystem Sciences, 2010). Variability in the length of a reach, the presence of riparian trees, and the historic or recent fire regime informed the proposed sampling effort. Three reaches will be skipped: reach 7 of the MORP because of the Tinemaha Reservoir, reach 1 of the LORP due to a lack of riparian trees, and reach 4 of the LORP which has become a cattail (*Typha* spp.) and hard-stem bulrush (*Schoenoplectus acutus*) dominated marsh. A summary of sampling effort by reach for the 2020 field season is provided in Table 3, and reach-scale maps are provided in Figures 5 and 6. The 2020 summer season effort will provide a pilot sample to determine the level of reach-scale variability used to estimate the final number of transects to be completed by vegetation parcel for the Type D long term monitoring program which will extend beyond the Owens River riparian zone.

MORP Reaches –

Reach 1) A fire in 2018 removed almost all riparian trees from reach 1 and prohibits sampling from this reach directly, however there are trees present on Horton creek within Type D vegetation parcels that would provide information about impacts of Pleasant Valley Reservoir construction on channel incision and down-cutting effects moving upstream onto the tributary. We propose 20-25 trees to be cored from each of 2 zones, above and below the down-cut section of channel, sampled along 10-15 riparian vegetation transects within each stratum.

Reach 2) An 18-year old fire (2002) with extant trees permits a post-recovery comparison with non-burned areas within reach 2. Established trees along the west edge of the riparian floodplain, abutting a steep geomorphic break between floodplain and upland, likely recruited during historic over-bank flood events. Dating these floodplain trees and comparing hydrologic conditions to trees that recruited pre- and post-fire may provide information from a range of conditions relevant to establishing trees along the MORP and the LORP. We propose sampling 10 transects each for *i)* the west edge of the floodplain, *ii)* burned, and *iii)* non-burned areas with 15 trees to be cored from each zone.

Reach 3) This reach is similar length to reach 2 but with a slightly longer time since fire of 23 years (1997). We propose a similar post-fire comparison between trees located in old channel meanders along the former floodplain, burned, and unburned sections of this reach with 10 transects in each, and 15-20 cored trees from each section.

Reach 4) This is the first section of the MORP that does not have known significant fire impacts and is otherwise relatively uniform. We propose sampling one section from this reach with 15-20 transects and 40-50 cored trees. Sampling will include (as in Reaches 2 and 3) the entire wetted floodplain and wetted former channel meanders to the west of the active channel to include all relevant trees (i.e. even if they are outside Type D parcel boundaries).

Reach 5) The longest reach to be included in the study, with several formerly active channel meanders that support riparian trees. Reach 5 receives water inputs from the Big Pine canal during operational spreading (from the west), through activating former channel meanders when the Owens River stage is sufficiently high, and via several east-side canals. We propose this reach be divided into three sections to compare paired current active channel and wetted former channel meanders, and in the south formerly burned and unburned sections. Each section will receive 20 transects and core 30-50 trees, split between the two channels (active and former meanders, or burned vs unburned).

Reach 6) This reach supports the most dense riparian forest on the entire Owens River. It "approaches 80% canopy closure" and sustains the highest habitat quality for wildlife (LADWP and Ecosystem Sciences, 2010). Fire (1988) affected the norther third of this reach. The northern portion is also influenced by water inputs from Big Pine creek to the west and maintains a wide riparian floodplain. The southern quarter receives an annual average of approximately 30-35 cfs from Fish Springs and together with influence of Tinemaha Reservoir backwaters, supports the widest section of riparian floodplain along the Owens River. Accordingly, this reach will be divided into 3 sections – the burned northern portion of the reach, from Big Pine creek to just north of Fish Springs, and from Fish Springs to Tinemaha. We will sample 10-15 transects from each and core 30-50 trees per section. *Reach 8)* This reach is influenced by seepage from Tinemaha reservoir from the north and surface water inputs from Taboose Creek, with an otherwise narrow river corridor and floodplain in between wetted zones. These hydrologic features divide this reach into three segments; we will sample 10-15 transects and core 20-25 trees from each section: *i)* from just below the Tinemaha dam to an obvious floodplain constriction, *ii)* from the narrow floodplain above and also below the wetted influence of Taboose Creek, *iii)* within zone of influence of Taboose creek just above and below Calvert Slough that exhibits substantial woodland development.

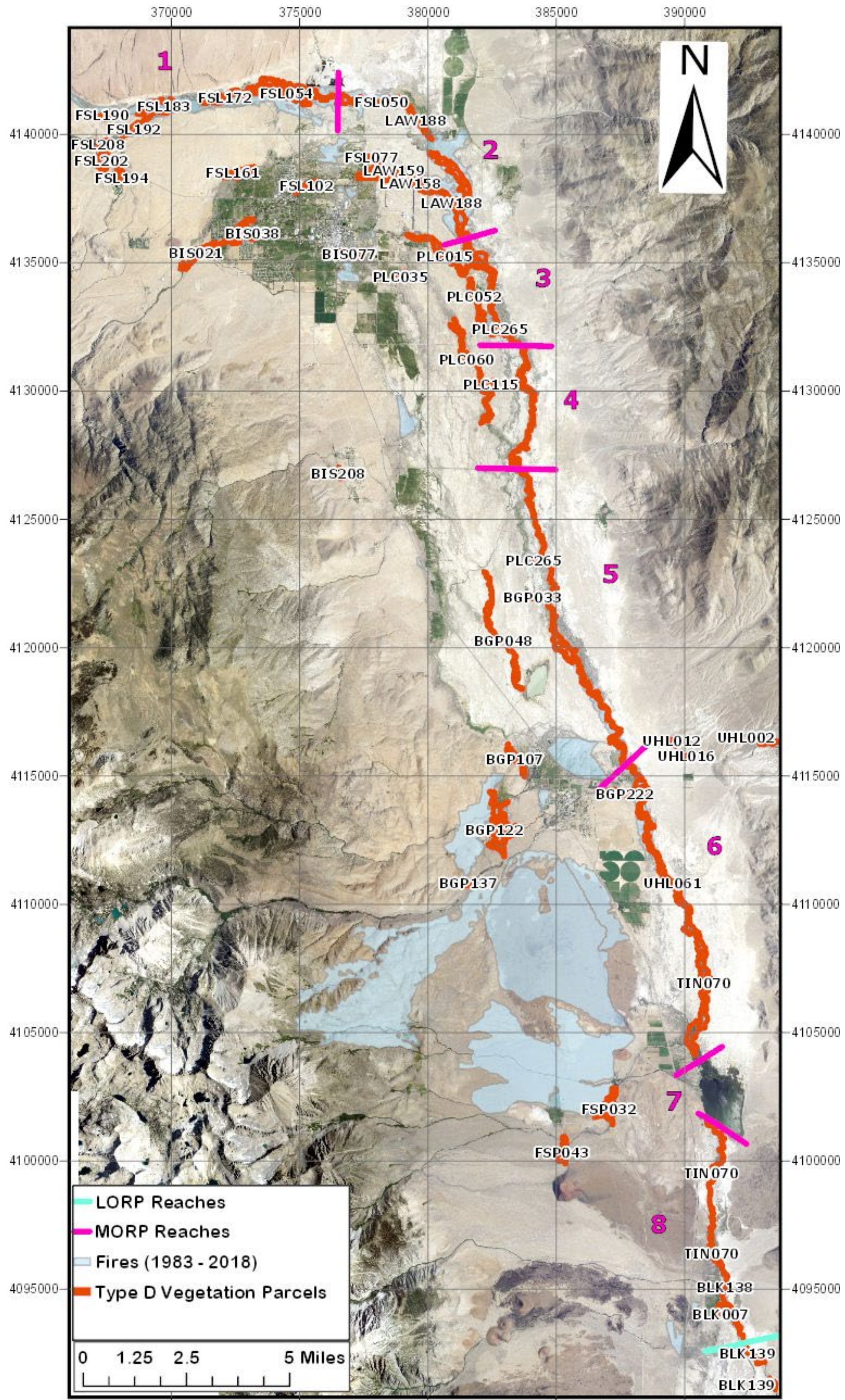

Figure 5. Middle Owens River (MORP) reaches 1-8 depicted with Type D vegetation parcel boundaries and fire extent for 35-year record.

LORP Reaches –

Reach 2) This reach supports a narrow, sparsely vegetated, dry incised channel and floodplain now confined to the width of the historic Owens River channel. Fires in 2008 and 2013 consumed most of the trees in the northern portion of this reach, so there are few to be sampled until the south half, which is uniform in its character, so we propose 10-15 transects and a sample of 40-50 cored trees.
Reach 3) The floodplain in this reach is wet-incised and generally narrow; varying in width from 150–300 ft (Whitehorse Associates, 2004). The northern third of this reach supports a wider-floodplain with riparian trees not present in the 1981 imagery, possibly indicating pre- or post-LORP implementation years with hydrologic conditions suitable for tree recruitment. A 2018 fire in the southern third precludes sampling due to lack of trees, while a small mid-reach 1998 fire does not preclude sampling. The riparian zone is relatively homogeneous, but does support trees in the historic floodplain or old channel meanders so we propose 30 transects and a sample of 50 cored trees.
Reach 5) The densely vegetated wet-incised floodplain in this reach is also narrowly constricted to the historic Owens River Channel, between 150–200 ft wide (Whitehorse Associates, 2004). The northwest half of this reach burned in a 2013 fire which was restricted to the east side of the river, so did not affect most riparian trees along the channel. This reach has been identified by MOU parties as having great riparian floodplain potential and the latent capacity to host larger woodland patches. Trees present in 1981 imagery on the eastern flank of the floodplain abutting a steep embankment may be relicts from former over bank flows. We propose 20 transects and 30-50 cored trees for this reach.
Reach 6) Flood plain width in this wet, graded reach is variable, from 150–700 ft wide, also suggesting latent riparian forest potential. A fire in 2013 affected the middle third of this reach, although some trees persisted. Approximately 1.5 km north and 1 km south of the fire were unaffected and are relatively homogeneous. We propose 30 transects and 30-50 cored trees for this reach, which may contain some burned sections (to be determined following field reconnaissance).

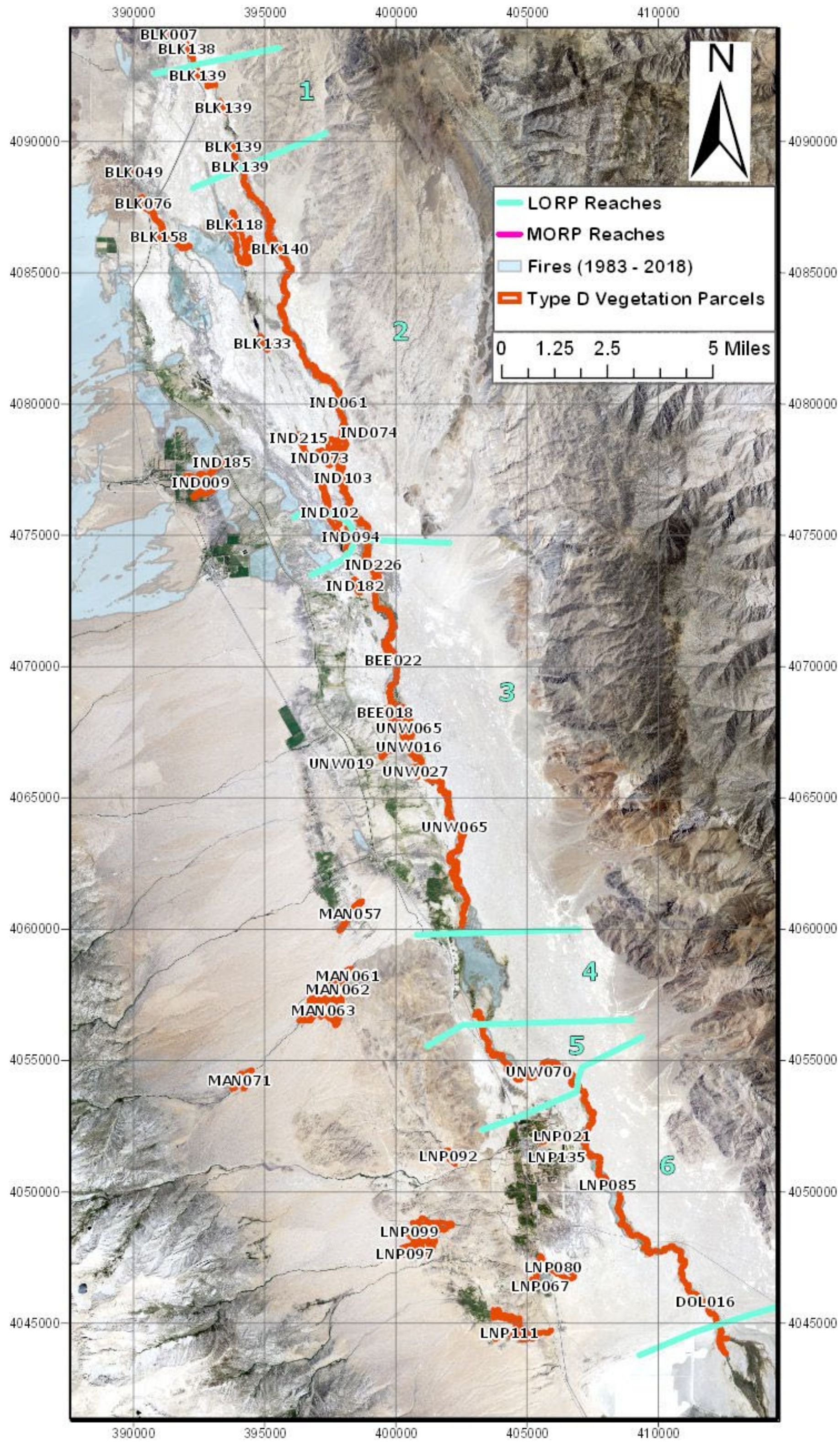

Figure 6. Lower Owens River (LORP) reaches 1-6 depicted with Type D vegetation parcel boundaries and fire extent for a 35-year record.

Table 3. Approximate sampling effort by reach and section of the Owens River (middle or lower).

Portion	Reach	Length (km)	(mi)	Transects	Trees	Cores
MORP	1	23.6	14.7	20	40 - 50	80 - 100
	2	14.1	8.8	30	45 - 50	90 - 100
	3	7.6	4.7	30	45 - 50	90 - 100
	4	6.9	4.3	30	40 - 50	80 - 100
	5	18.5	11.5	60	90 - 150	180 - 300
	6	17.2	10.7	60	60 - 100	120 - 200
	8	11	6.8	40	60 - 75	120 - 150
LORP	2	25.3	15.7	20	40 - 50	80 - 100
	3	24	14.9	30	50	100
	5	6.9	4.3	20	30 - 50	60 - 100
	6	16.9	10.5	30	30 - 50	60 - 100
				370	**530 - 750**	**1060 - 1500**

Ongoing Monitoring II: Remote sensing acquisition and vegetation classification

The field monitoring program outlined above (vegetation sampling section) will occur periodically (e.g. every 5-10 years for each Owens River reach, or Type D parcel) and may be modified based on findings from the 2020 field campaign intended to refine the sampling protocol. This program will be complemented by acquisition of remotely sensed data (satellite, aerial, and/or LIDAR) that can be used to assess landscape-scale vegetation change over time via two methods and time-scales. A first analysis will include quantifying change in cover or greenness from baseline using Normalized Difference Vegetation Index (NDVI) or Normalized Difference Water Index (NDWI) through landsat or sentinel data. This will occur on an annual basis. We will aggregate pixels spatially at the parcel scale over the months of May-August. A second analysis will involve generating a vegetation classification (specifically tree cover) to be compared with previous mapping iterations (e.g. 2017) on a periodic basis, on an opposite schedule to the concurrent field program (an iteration of 5-10 years). Vegetation classification can be accomplished using freely-available 4-band National Agriculture Imagery Program (NAIP) aerial imagery combined with LIDAR to improve accuracy (by adding an additional height dimension), if LIDAR data acquisition is feasible. Alternatively classification accuracy could be improved using unmanned aerial vehicle (UAV) imagery (which can also be acquired at low cost) to generate 3D models and better identify tree stands from other vegetation. Changes in: *i)* the areal extent of mapped trees, *ii)* their spatial location or *iii)* cover or greenness will be compared between the two time periods.

Changes since baseline

The above described methods do not account for changes that may have occurred since the implementation of the LTWA. Further, only 18 of the approximately 80 Type D vegetation parcels have baseline transect data. To assess potential changes that may have occurred since the 1984-1987 baseline vegetation parcel delineation, we propose a one-time study to classify vegetation present within aerial imagery flown in 1981. Since this imagery is only 3-band (red, green, blue), there is less information available to decipher differences in vegetation other than color. We will therefore begin by only classifying riparian tree communities (not all vegetation types), since the trees are often identifiable by their shadows. Area or extent of riparian tree vegetation present in the 1981 imagery will be compared with the area delineated in the vegetation classification generated from 2017 remotely sensed data (LADWP, 2018; Jensen, 2019).

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