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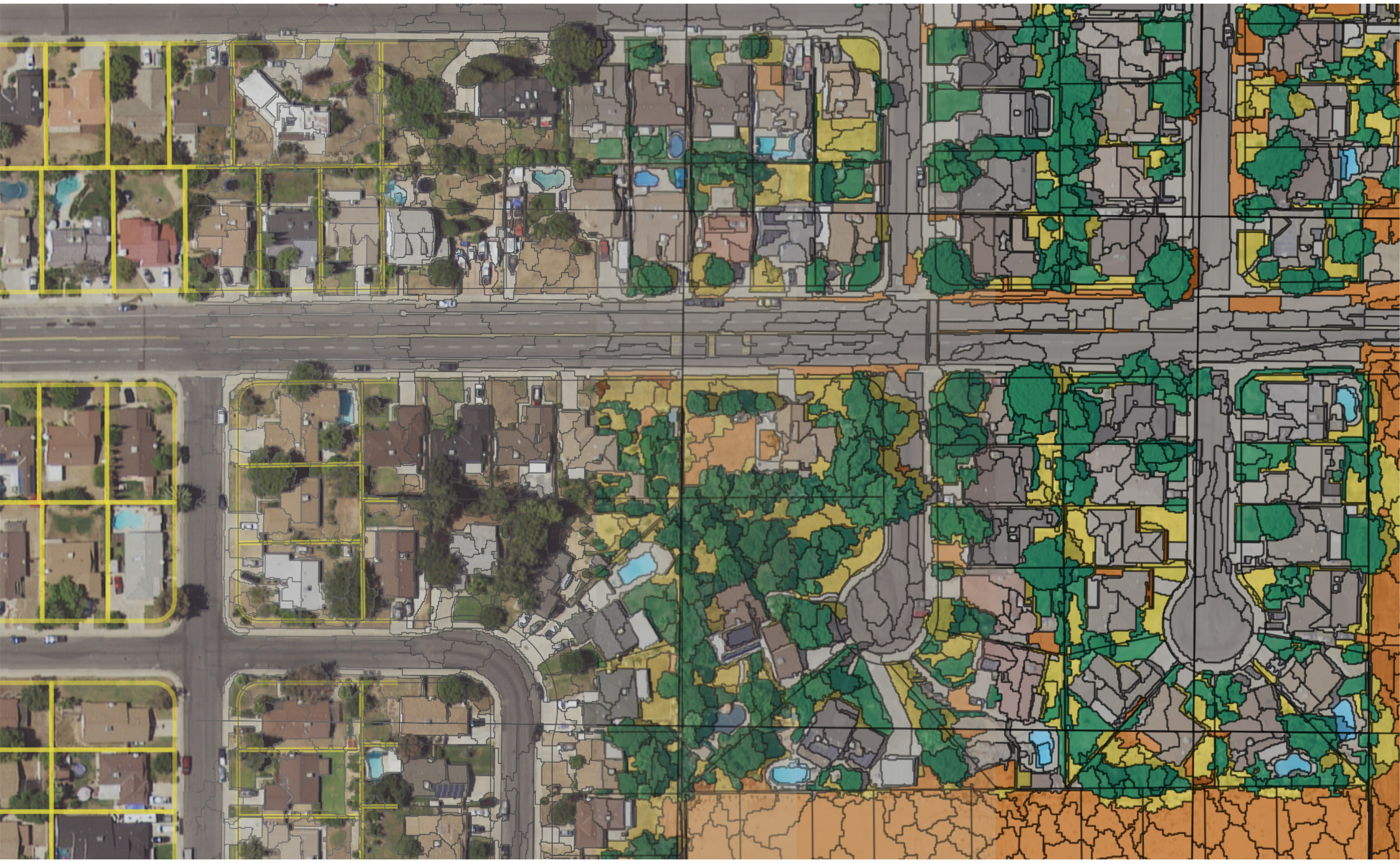

Landscape Area Measurements

Final Project Report Version 3, EA-133C-16-CQ-0044

Prepared For:

California Department of Water Resources,
Water Use Efficiency Branch

Prepared By:

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List of Abbreviations

Table 1: List of abbreviations.

Abbreviation	Meaning
AB	Assembly Bill
AG	Agriculture
APN	Assessor Parcel Number
CNN	Convolutional Neural Network
DMP	Digital Map Products, Inc.
DWR	Department of Water Resources
FP	False Positive
GIS	Geographic Information System
HC	Horse Corral
II	Irrigable Irrigated
INI	Irrigable Not Irrigated
LAM	Landscape Area Measurements
LUC	Land Use Code
MFG	Manufacturing
MH	Mobile Home
MMU	Minimum Mapping Unit
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NI	Not Irrigable
NIA	No Imagery Available
NIR	Near Infrared
ORWUS	Outdoor Residential Water Use Standards
PPV	Positive Predictive Value
RGB-NIR	Red, Green, Blue, Near Infrared
RMF	Recursive Model Fit
SB	Senate Bill
TMS	Tile Mapping Service
TN	True Negative
TP	True Positive
WDID	Water District Identifier
ZABUD	Absolute Difference Index

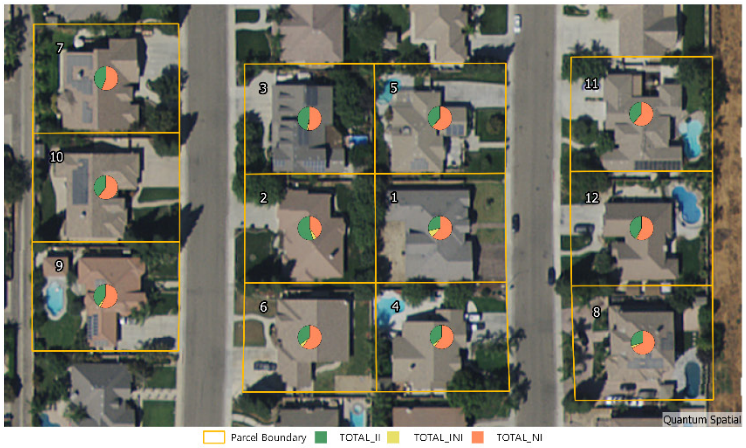
Landscape Area Measurements Project

The Landscape Area Measurements (LAM) Project is a state-wide remote sensing and machine learning project that was designed to estimate the areas of land cover and land use across urban residential spaces of California. It was implemented as a result of the 2018 Assembly Bill (AB) 1668 and the 2018 Senate Bill (SB) 606. With the goal of water conservation and drought planning after the 2012-2016 droughts in California, AB 1668 and SB 606 became effective under Governor Brown's Executive Order B-37-16. Assembly Bill 1668 directs the California Department of Water Resources (DWR), in coordination with the California State Water Resources Control Board, to develop new water use efficiency standards and guidelines for urban retail water suppliers.

In 2018 and 2021, DWR contracted Quantum Spatial, Inc. (now NV5 Geospatial) to complete the LAM Project by providing estimates of outdoor landscape area measurements for single-family and multi-family residential parcels for all qualifying urban retail water suppliers in California (n=398). The results of this project will provide crucial data for setting outdoor residential water use standards (ORWUS) and calculating water use objectives for urban retail water suppliers, as outlined in AB 1668 and SB 606.

Landscape Area Measurements

For each urban retail water supplier in the analysis, the landscape area measurements are represented by a tabular summary of the different outdoor landscape types present in the residentially zoned parcels within the supplier's service area. For each residential parcel, the total areas of impervious surfaces, pools, irrigable irrigated (II) land, irrigable-not irrigated (INI) land, not irrigable (NI) pervious land, tree canopy, commercial agriculture, horse corrals, and undeveloped land are estimated and reported. An example of the landscape area measurement results is shown in Figure 1.



Number	TOTAL_II	TOTAL_INI	TOTAL_NI
1	3,495.55	1,129.98	7,382.78
2	6,576.26	621.18	4,846.14
3	5,558.89	261.12	6,287.91
4	4,442.04	383.40	7,321.16
5	4,639.85	152.88	7,388.83
6	4,323.72	558.05	7,312.80
7	5,864.31	31.10	7,566.20
8	3,932.42	466.06	9,127.73
9	5,391.64	415.71	7,742.44
10	5,241.46	81.26	8,238.48
11	5,302.63	29.41	8,374.56
12	5,697.15	225.02	7,792.35

Figure 1: An example of the landscape area measurement results for irrigation status classifications by parcel: irrigable irrigated (TOTAL_II), irrigable-not irrigated (TOTAL_INI), and not irrigable (TOTAL_NI). Areas shown represent square feet. The pie charts for each parcel represent the proportion of irrigated, irrigable-not irrigated, and not irrigable areas within the parcel.

Landscape Classifications

The classification system used in this project was designed by NV5 Geospatial, in conjunction with DWR, to capture the full range of landscape types exemplified across California. The classification system is divided into two levels: land cover and land use. The land cover classification describes the physical representation of a feature within a landscape, such as canopy, turf, or concrete. The land use classification of a feature describes the interpreted irrigation status of that feature. Three primary land use classes were utilized in the LAM Project: irrigable irrigated, irrigable-not irrigated, and not irrigable. Land use and cover classifications are detailed in Table 6, Table 5, Table 9, Table 10, and Table 11 of this report.

Due to the large extent of the study area and the vast range of landscapes within the project area of interest, a unique land cover and land use classification model was trained for each urban retail water supplier. This allowed the landscape area measurement results to be tuned to the unique composition of each supplier, as influenced by its level of human development and ecoregion. Figure 2 highlights some of the diverse landscapes present within the LAM study area.

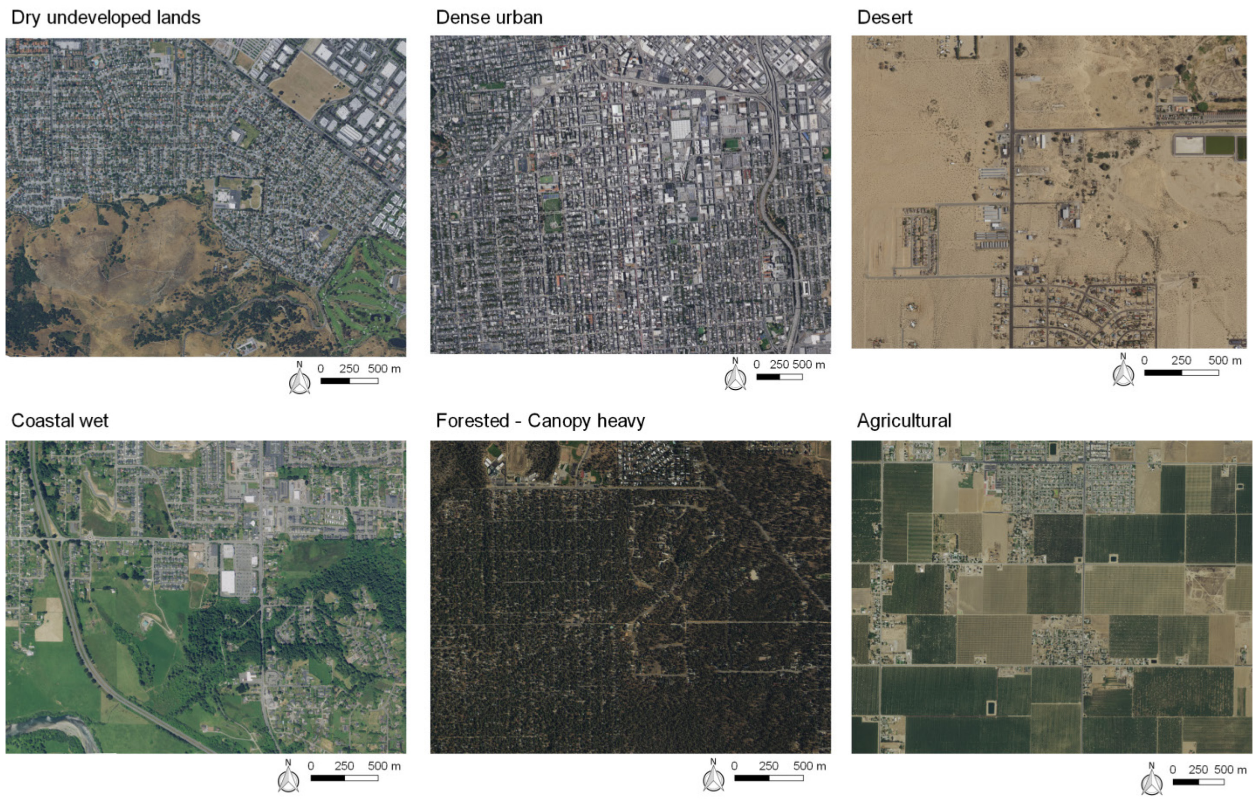


Figure 2: Examples of some of the diverse landscape types present within the Landscape Area Measurements study area. A unique land cover and land use model was created for each urban retail water supplier in order to tune the landscape area measurement results to the unique land cover characteristics within their service area boundaries.

Source Data

Source data describing each urban retail water supplier in the project were compiled to support landscape area measurements generation. The area of interest for an urban retail water supplier was determined by its service area boundary, which represents the full extent of the supplier's water delivery network. Standardized parcel data were acquired for each urban retail water supplier within the extent of their service boundaries. The parcel data include georeferenced parcel boundaries attributed with descriptors such as tax identification number, assessor's parcel number (APN), land use code (LUC) and description, street address, and acreage. The imagery used for the classification of each urban retail water supplier was four-band aerial orthoimagery (red, green, blue, and near infra-red: RGB-NIR) with a 12-inch spatial resolution that was collected in the years 2016, 2018, and 2020.

Generating Landscape Area Measurements

Classified outdoor landscape area estimates for each residentially zoned parcel within an urban retail water supplier were generated using remote sensing, imagery segmentation, and supervised machine learning classifiers. To successfully process 398 unique urban retail water suppliers from data ingestion to deliverable results, an automated processing pipeline was developed. This pipeline directed data for each urban retail water supplier through the six main project processes: source data instantiation, initial model application, manual classification of reference data, land mask digitization, recursive model fit, and summarization of results (Figure 3).

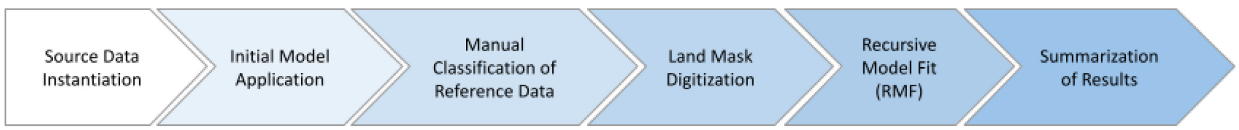


Figure 3: High level process pipeline for the Landscape Area Measurements Project. Left to right: Source Data Instantiation, Initial Model Application, Manual Classification of Reference Data, Land Mask Digitization, Recursive Model Fit (RMF), and Summarization of Results.

In order to classify the outdoor landscapes captured in the aerial imagery, regions of like-valued imagery pixels called super-pixels were identified and converted into vector objects, which act as the foundational classification unit for the project (Figure 4A and 4B). The super-pixels were then assigned to the parcel that they represented based on the parcels' georeferenced boundary. Prior to model development, a subset of residential parcels was selected from each supplier to be used as training and validation data, or reference data, in the land use and land cover modeling process. This parcel subset was manually classified by adding land use and land cover labels to each super-pixel object (four reference parcel examples are shown in Figure 5). The labeled super-pixel objects were then used to train the classifier that was applied across the entire supplier's service area to make predictions of land cover and land use in all spaces (shown in Figure 4C).

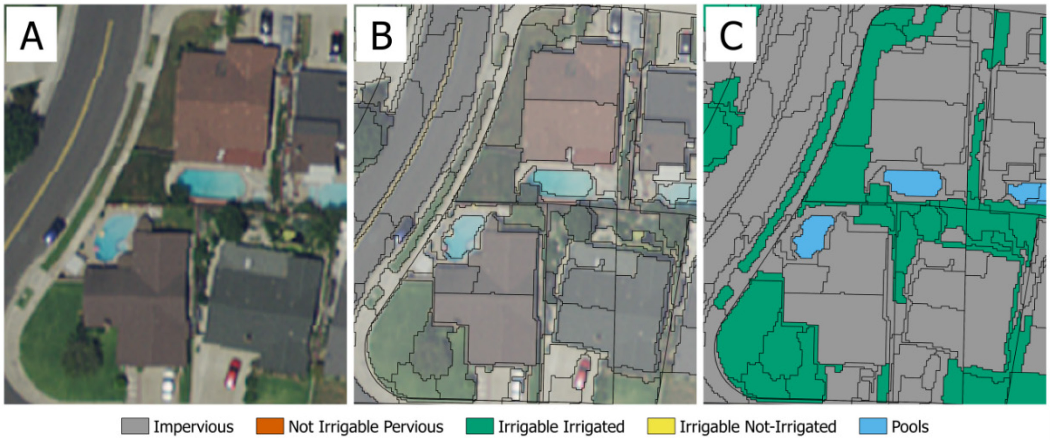


Figure 4: Urban retail water supplier classification overview. A) Aerial imagery. B) Aerial imagery segmented into super-pixel objects. C) Classified super-pixel objects that represent the 10-class classification scheme outlined in Table 10.

Imagery © 2023 Hexagon and data partners.

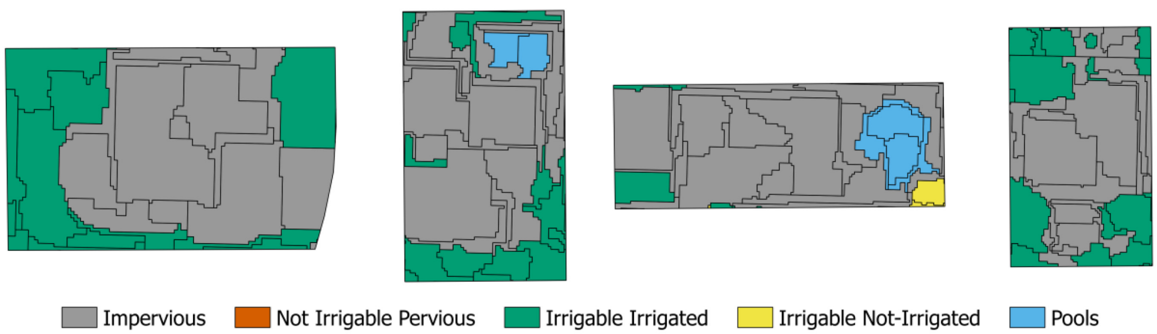


Figure 5: Four classified reference parcels used in the Landscape Area Measurements Project. The reference parcels are composed of classified super-pixel objects that have been clipped to the parcel boundaries.

Land masks that override model predictions of land cover and land use were implemented in this project to manually identify specific land cover types and ensure that they were given the 'Not irrigable' irrigation status designation. Three different land mask types were employed to capture unique landscapes and land uses present throughout the urban retail water suppliers of California: Undeveloped Lands Mask, Agricultural Lands Mask, and Horse Corral Mask.

Landscape Area Measurements Results

The results of the LAM Project provide parcel and supplier level estimates of irrigable irrigated, irrigable-not irrigated, and not irrigable areas for the 398 urban retail water suppliers in the analysis. A total of approximately 9.6 million parcels across 14,000 square miles were modeled and assessed as a part of the LAM Project. Table 2 outlines the average irrigation status compositions at the supplier, single-family parcel, and multi-family parcel levels. The pie charts in Figure 6 show the average landscape area compositions for single-family and multi-family residential parcels, respectively. The complete list of supplier-level irrigation status summaries is contained in Table 15 of Appendix D – Urban Retail Water Supplier Irrigation Status Compositions. Supplier-level irrigation status values were calculated from the topologically corrected parcel layer (Parcels B) and parcel-level irrigation status values were calculated from the original parcel layer (Parcels A). See the Parcel Topology Handling section for additional information on parcel datasets and transformations.

Table 2: Average irrigation status compositions for the Landscape Area Measurements Project. Single-family residential parcels are considered those with land use codes between 1000 and 1019. Multi-family residential parcels are considered those with land use codes between 1100 and 1999. Land use codes are defined in Table 17. Supplier-level irrigation status values were calculated from the topologically corrected parcel layer (Parcels B) and parcel-level irrigation status values were calculated from the original parcel layer (Parcels A).

Irrigation Status	Average Supplier	Average Single-Family Parcel	Average Multi-Family Parcel
II	23.3%	26.0%	18.5%
INI	11.8%	10.4%	8.2%
NI	64.9%	63.6%	73.3%

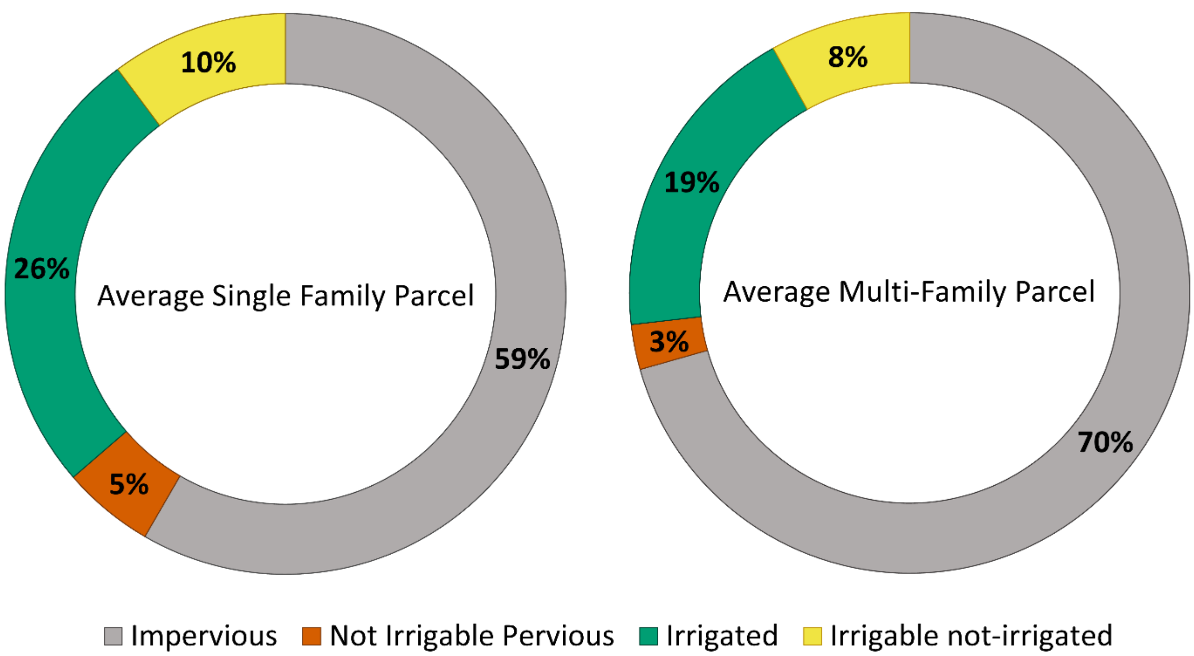


Figure 6: Pie charts showing average single-family and multi-family residential parcel landscape area compositions. Single-family residential parcels are considered those with land use codes between 1000 and 1019. Multi-family residential parcels are considered those with land use codes between 1100 and 1999. Land use codes are defined in Table 17. Parcel-level irrigation status values were calculated from the original parcel layer (Parcels A).

In August of 2018, the California Department of Water Resources (DWR) contracted Quantum Spatial, Inc. (now NV5 Geospatial), with support from Eagle Aerial Solutions, to provide outdoor landscape area measurements for single-family and multi-family residential parcels for all qualifying urban retail water suppliers in California using 2016 and 2018 source imagery. Qualifying suppliers are retail suppliers serving more than 3,000 residential connections or delivering more than 3,000 acre-feet of water annually. The project was completed in phases starting with two pilot suppliers (Phase 2A), then a set of 17 suppliers from diverse geographic areas (Phase 2B), followed by the remaining suppliers. Table 14 contains the list of all participating urban retail water suppliers and their processing phase.

In 2021, DWR contracted NV5 Geospatial to continue the LAM Project by providing updated estimates of outdoor landscape area measurements for single-family and multi-family residential parcels across 20 urban retail water suppliers in California using 2020 source imagery. To accomplish these tasks, advanced machine learning techniques were used to classify the land use and land cover of outdoor residential spaces. The results of the LAM Project will provide crucial data for setting outdoor residential water use standards and calculating water use objectives for urban retail water suppliers, as outlined in AB 1668 and SB 606.

Assembly Bill 1668 and Senate Bill 606

With the goal of water conservation and drought planning after the 2012-2016 droughts in California, the 2018 AB 1668 and SB 606 legislation were implemented under Governor Brown's Executive Order B-37-16. Assembly Bill 1668 directs the California Department of Water Resources, in coordination with the California State Water Resources Control Board, to develop new water use efficiency standards and guidelines for urban water agencies. The primary objectives of the legislation are to use water more wisely, eliminate water waste, strengthen California's drought resilience, and improve the efficient use of agricultural water[1]. The LAM Project was created to accomplish the first goal of using water more wisely by providing unbiased estimates of residential landscape areas for 398 urban retail water agencies in California.

[1] California Department of Water Resources and State Water Resources Control Board, "Making Water Conservation a California Way of Life: Primer of 2018 Legislation on Water Conservation and Drought Planning" (2018), https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Water-Use-And-Efficiency/Make-Water-Conservation-A-California-Way-of-Life/Files/PDFs/Final-WCL-Primer.pdf.

Deliverable Products Outline

The individual urban retail water supplier results for this project are compiled in an ESRI file geodatabase and are composed of feature classes, tables, and rasters. The urban retail water supplier source data used in the analysis are provided in the Source_Data Feature Dataset. These source data include the service area boundary, full parcel layer covering the service area, the filtered parcel layer including only valid single-family and multi-family land use codes (as defined through the project scoping), and a feature class representing the disputed parcels that fall within the area of interest of two or more urban retail water suppliers.

The results of the analysis are included in the Derived_Data Feature Dataset and include the land masks, the landscape area summaries for the queried parcels and topologically corrected parcels, the parcel map describing the many-to-many relationships between the original and topologically correct parcel layers, and the landscape area summaries of the manually classified validation parcels.

The classification of the void space is delivered in raster format using the 10-class classification scheme in order to provide ancillary data in spaces within the area of interest but not represented by the parcel layer.

Tables that outline and describe both the valid land use codes used in the project and the delivered data layers are also included in the file geodatabase for user reference.

The full data dictionary for the LAM Project deliverables is shown in Appendix G – Data Dictionary.

Deliverable Products

Table 3: Products delivered to DWR for the Landscape Area Measurements Project.

Product Type	Product Details
Vectors	Shapefiles (.shp) or File Geodatabase Feature Classes Derived Data • Agricultural Lands Mask • Horse Corral Mask • Undeveloped Lands Mask • Landscape Area Estimates A • Landscape Area Estimates B • Parcels A-B Relationship • Validation Parcels Source Data • Area of Interest • Parcels All • Parcels Queried • Parcels Disputed
Rasters	30 cm File Geodatabase Raster Dataset • VOID byte
Tables	Comma Separated Values (.csv) or File Geodatabase Table • DWR Data Dictionary • Valid LUC Codes • A_UID Summary • B_UID Summary
Reports	Portable Document Format (.pdf) • Urban Retail Water Supplier Technical Data Report • Landscape Area Measurements Project README
Digital Imagery	30 cm GeoTiffs (.tif) • Tiled Urban Retail Water Supplier Imagery

Table 4: Projection details for deliverable products.

EPSG	Projection	Datum
6414	NAD83(2011)/California Albers	NAD83 (National Spatial Reference System 2011)

Project Area of Interest

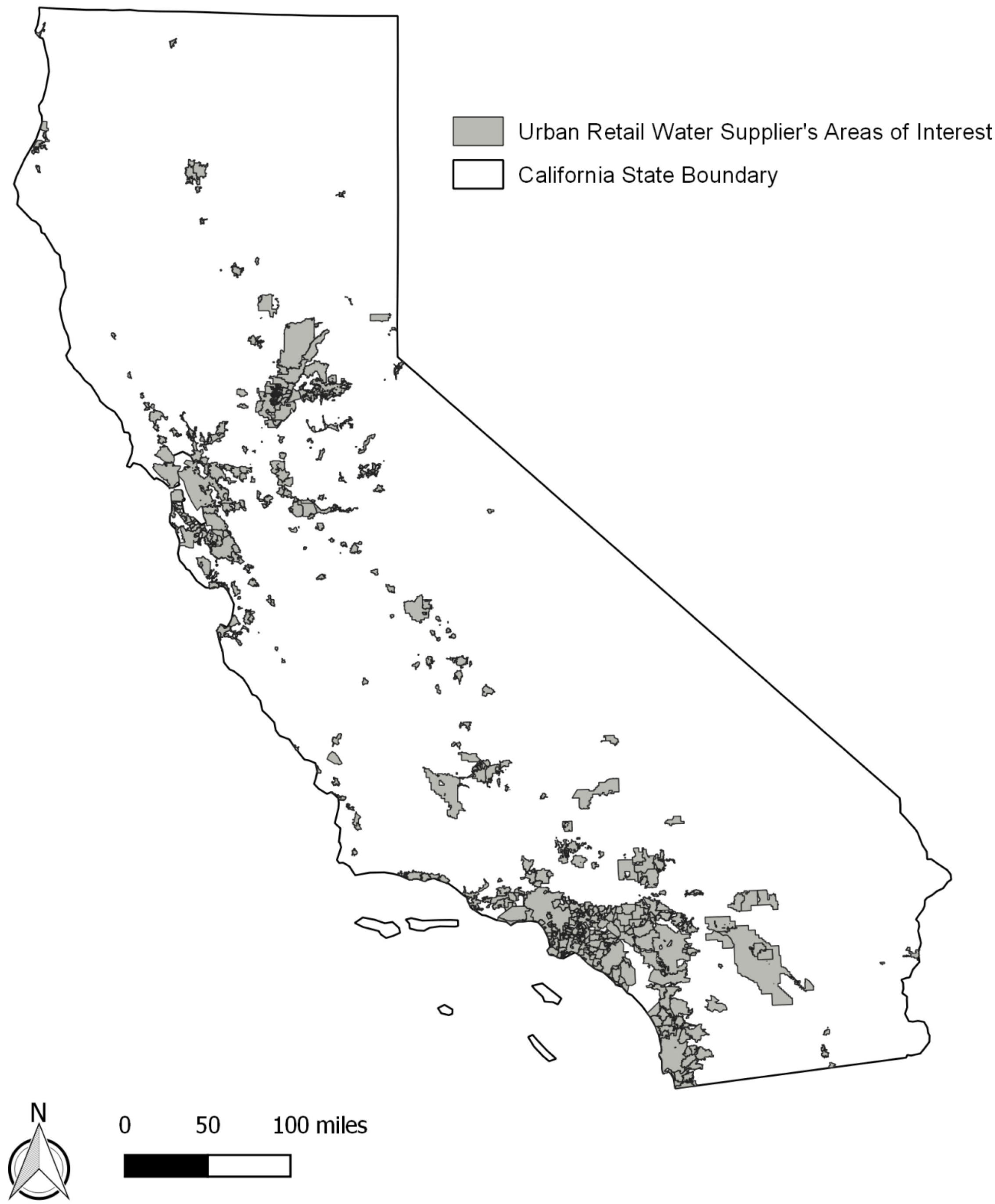


Figure 7: Map of the Landscape Area Measurement Project supplier service areas in California.

Urban Retail Water Supplier Area of Interest

The area of interest for each urban retail water supplier was determined by its service area boundary. This service area boundary represents the full extent of the supplier's water delivery network. Each service boundary used in the study was confirmed as accurate by an urban retail water supplier representative. The confirmed service boundary was used as the geographic footprint for compiling the parcels and imagery sourced from the commercial providers used in this project. Figure 7 depicts the service areas for all urban retail water suppliers in the LAM Project.

Parcel Data

Standardized parcel data were acquired from Digital Map Product, Inc. (DMP), a part of LightBox, for each urban retail water supplier matching the extent of their service boundary. The parcel data include georeferenced parcel boundaries attributed with descriptors such as tax identification number, assessor's parcel number (APN), land use code (LUC) and description, street address, and acreage. Differences in land use code assignment between county assessors were mitigated by mapping each parcel's land use code to a master code assignment shown in Table 17. Land use code standardization was completed by the parcel provider outside of the scope of this project.

Figure 8: An aerial view of the parcel layer outline on top of the urban retail water supplier RGB-NIR imagery.

Imagery © 2023 Hexagon and data partners.

Parcel Query

To assess the landscaped areas of single-family and multi-family residential parcels, a subset of valid land use codes was compiled as a joint effort between DWR and NV5 Geospatial. Single-family and multi-family residential land use codes were selected using an exclusive, rather than inclusive, fashion. Land use codes that were explicitly representative of commercial, industrial, or other non-residential land use types were excluded from the study. This exclusion left all codes that may support residential use within the query, even when codes were not explicitly residential. The purpose of the exclusive approach to the valid land use code selection was to ensure that all necessary data be captured and summarized in the project results, allowing any codes not deemed necessary at a future date to be filtered out of the landscape area summaries. The complete list of valid residential land use codes and their descriptions are included in Table 17. An example of the full and queried parcel layer is provided in Figure 9.

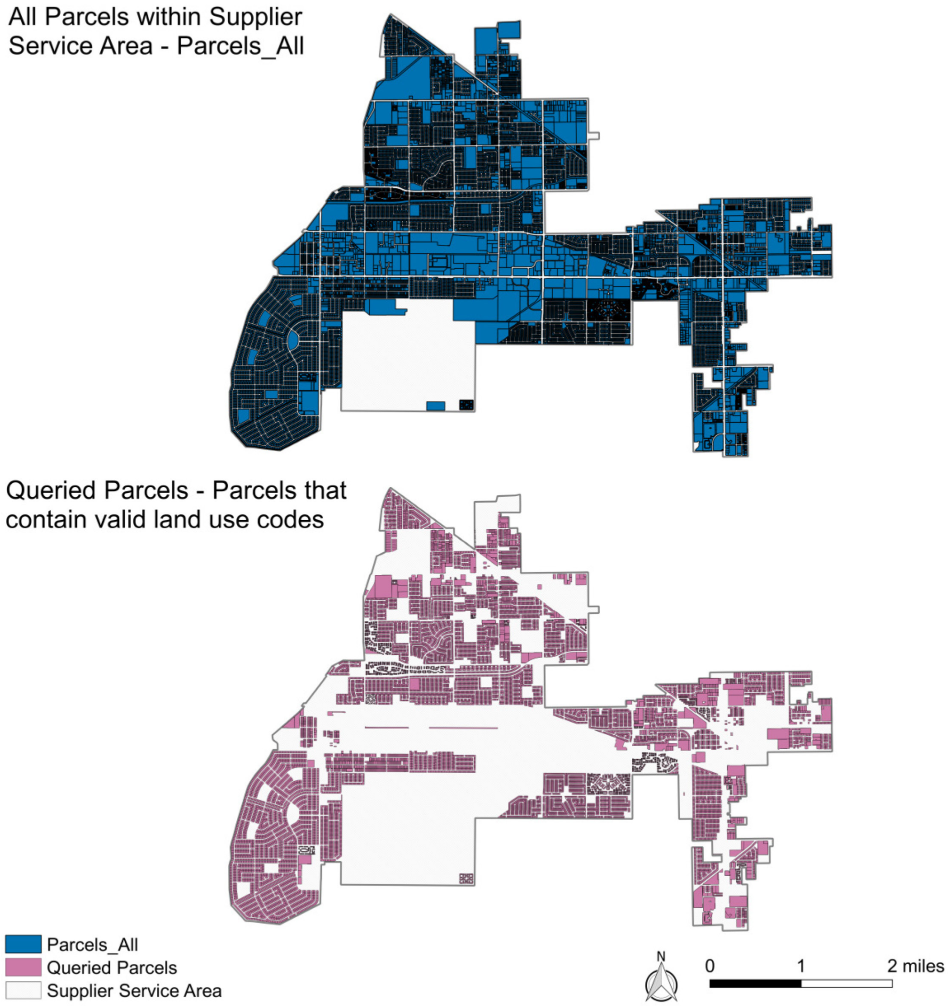


Figure 9: Comparison between the full parcel layer (Parcels_All) for an urban retail water supplier service boundary and the queried parcel layer. The queried parcels are those that contain valid land used codes. The full list of land use codes can be found in Table 17.

Void Region

To account for incomplete parcel coverage and for landscaped areas surrounding parcels but not included within the parcel layer, a void region was identified for use in the LAM Project. The void region represents geographic areas within an urban retail water supplier's service area boundary that are not covered by the source parcel layer. Often, the void region covers streets, natural lands, and open water bodies. The landscapes within the void region were classified using the urban retail water supplier model and provided as a pixel-level deliverable with the landscape area summaries. This spatial representation of land use and land cover is included with the main urban retail water supplier deliverables so that data users can assess and include any urban retail water supplier areas that should be represented as single-family or multi-family residential outdoor spaces, but that were not included in the parcel layer. An example of the classified void region is included in Figure 10 and the method of derivation and structure of the void region is shown in Figure 11.

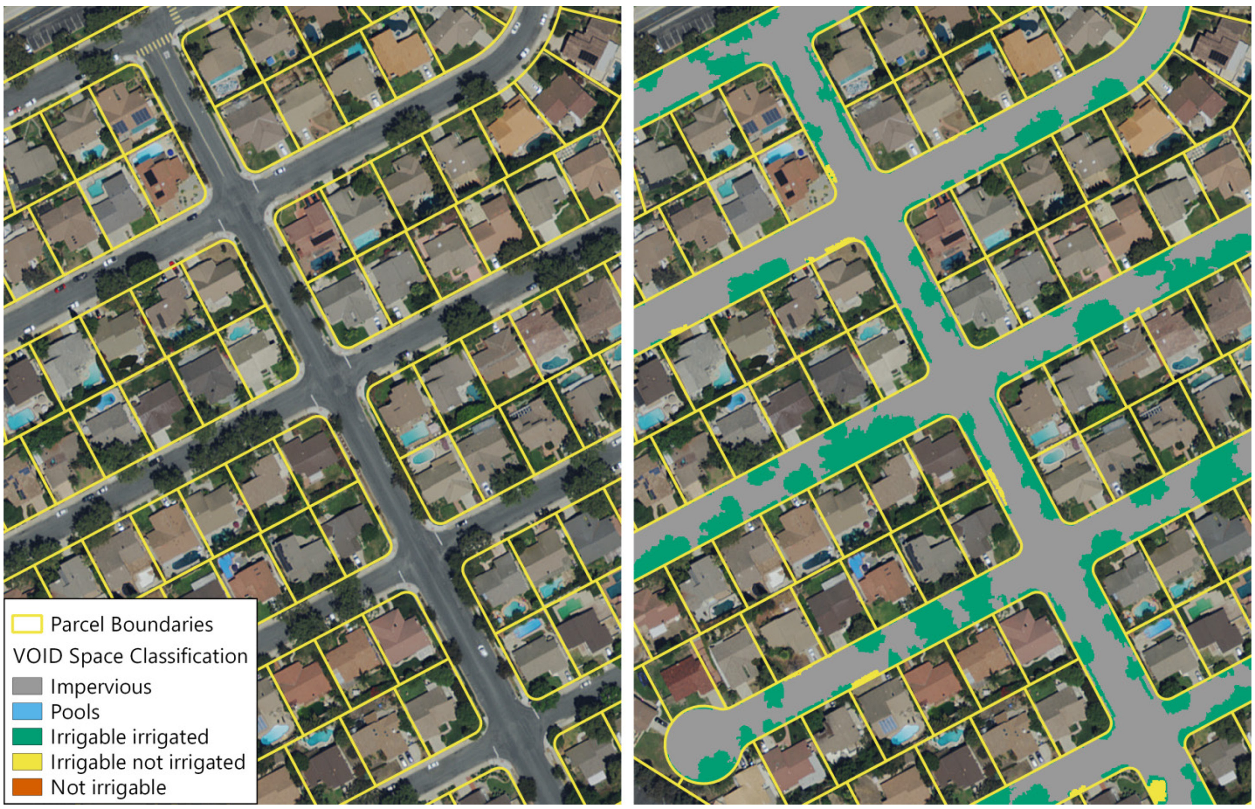


Figure 10: An example of the Void Region classification. Shown here is a section of void space that covers roadways and parkway strips.

Imagery © 2023 Hexagon and data partners.

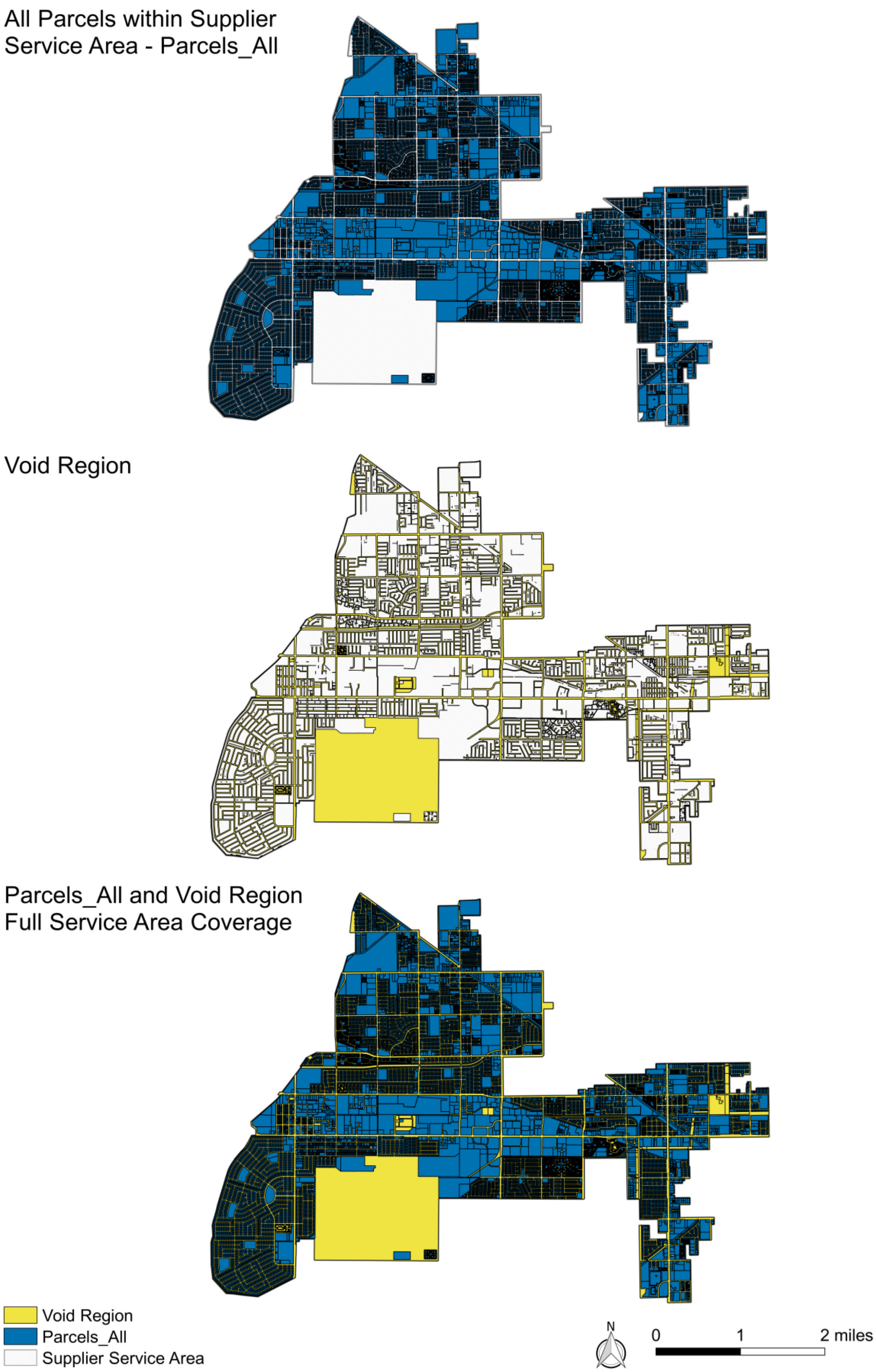


Figure 11: The creation of the Void Region. The Void Region represents the landscape areas within an urban retail water supplier service boundary that are not captured by the parcel layer.

Parcel Topology Handling

The results of the LAM Project are summarized in square feet at the parcel and supplier levels. Due to overlap present in the source parcel data, supplier-level summaries can be inflated when the same geographic area is represented in two or more distinct parcels.

In order to correct for parcel overlap and preserve correct supplier area totals, the source parcel layer (Parcels A) was processed to create a topologically correct parcel layer (Parcels B) that contained no overlap. As a part of this process the original parcel layer, or Parcels A layer, was run through a geometric union process that allows for the identification of overlapping parcel regions. The regions of overlap become unique features from the main parcels and were flattened by removing the duplicate features so that no area duplication is possible. The resulting topologically correct parcel layer, or Parcels B layer, can now generate accurate supplier-level irrigation status summaries; however, it no longer exactly represents individual parcel areas. To gain access to as much information about the landscaped areas in a supplier's service area as possible, both the original and topologically corrected parcel layers can be used. Parcel-level irrigation status summaries are best accessed using the Parcels A layer, and supplier-level irrigation status summaries are best accessed using the Parcels B or topologically corrected parcel layer. In order to understand the individual topologically corrected components of a parcel, each topologically correct feature is mapped to its source parcel in a relationship table. Ultimately this process results in three distinct parcel layers: Parcels A, Parcels B, and A to B Relationship. These layers represent the original parcels, the topologically correct parcels, and the relationship table that connects the two.

The prevalence and degree of overlap between parcels varies between suppliers and is generally present through two different circumstances. In most cases, overlap is created by slight overlap at the edges of neighboring parcels. However, overlap can also be created when there are smaller parcels located within a larger parcel. This is typically seen in multi-family land use codes. An example of each kind of overlap is shown in Figure 12 and Figure 13.

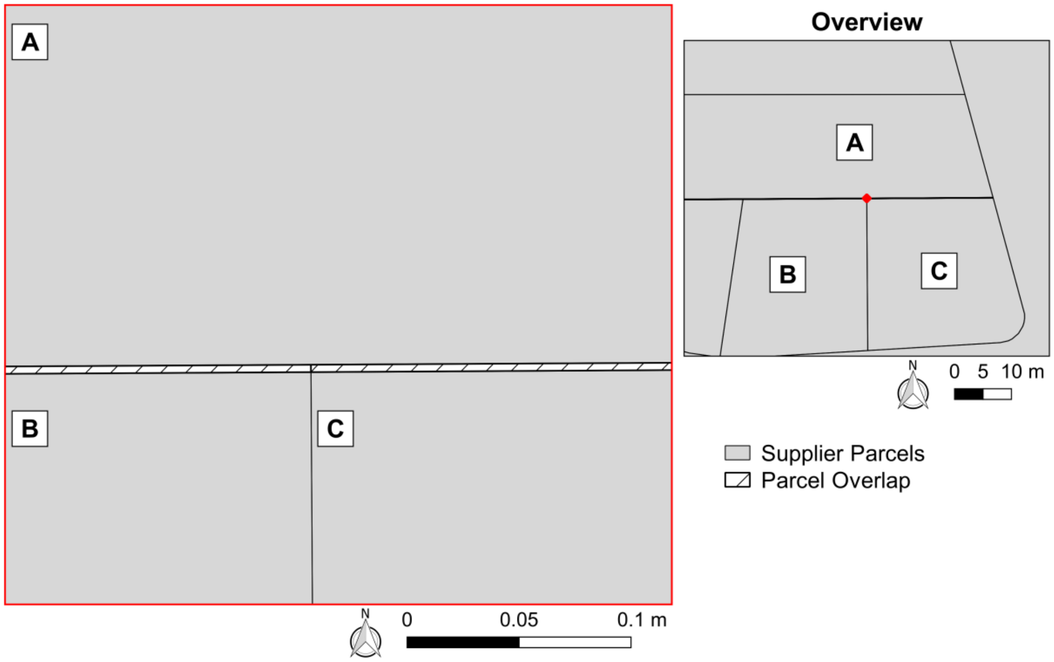
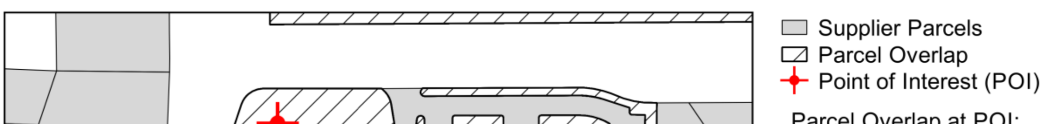


Figure 12: An example of parcel overlap at the edges of parcels A, B, and C. In this example the overlap is very slight, measuring less than 1 cm in depth along the parcel boundaries.



APN	LUC
946-4572-35	1004
946-4572-42	1004
946-4572-45	1004
946-4572-36	1004
946-4572-38	1004
946-4572-40	1004
946-4572-39	1004
946-4572-43	1004
946-4572-37	1004
946-4572-51	1010
946-4572-49	1004
946-4572-44	1004
946-4572-46	1004
946-4572-47	1004
946-4572-41	1004
946-4572-48	1004
946-4572-50	1004

Figure 13: An example of parcel overlap in a condominium development (land use code 1004). There are 17 unique parcel APNs represented at the point of interest indicated by the cross on the map.

Imagery

The imagery used for the classification of each urban retail water supplier was four band orthoimagery (red, green, blue, and near infra-red: RGB-NIR) with 12-inch spatial resolution collected in the years 2016, 2018, and 2020, acquired from Hexagon. Imagery for each urban retail water supplier was acquired to match the extent of the supplied service area boundary with the addition of a 10-meter outer buffer to ensure complete coverage of each study area.

Figure 14: Aerial imagery captured over an urban region included in the Landscape Area Measurements Project.

Imagery © 2023 Hexagon and data partners.

Imagery Preparation

To provide accurate estimates of single- and multi-family irrigation use across an urban retail water supplier, full imagery coverage across the queried parcel layer is required. To ensure full coverage, a vector layer covering the extent of the received imagery was built and tiled. The extent of this vector layer was then compared to the extent of the queried parcels layer to check for gaps, overlaps, and areas of blank or missing imagery. Finally, a visual inspection of the entire image mosaic, served via a tile mapping service (TMS), was conducted to verify that the imagery fully encompassed the parcel layer.

Segmentation Routine

After ensuring all required imagery was present, each image tile was run through an image segmentation routine. The routine scans each image tile and groups like-valued pixels into super-pixel level groupings called objects, discretizing the imagery into features that are more easily recognizable by humans (e.g., structures, cars, trees, sidewalks). This aided the classification process by allowing human photo interpreters to quickly identify land cover type and assign the appropriate classification. Figure 15 provides a few examples of the objects generated by the image segmentation routine.

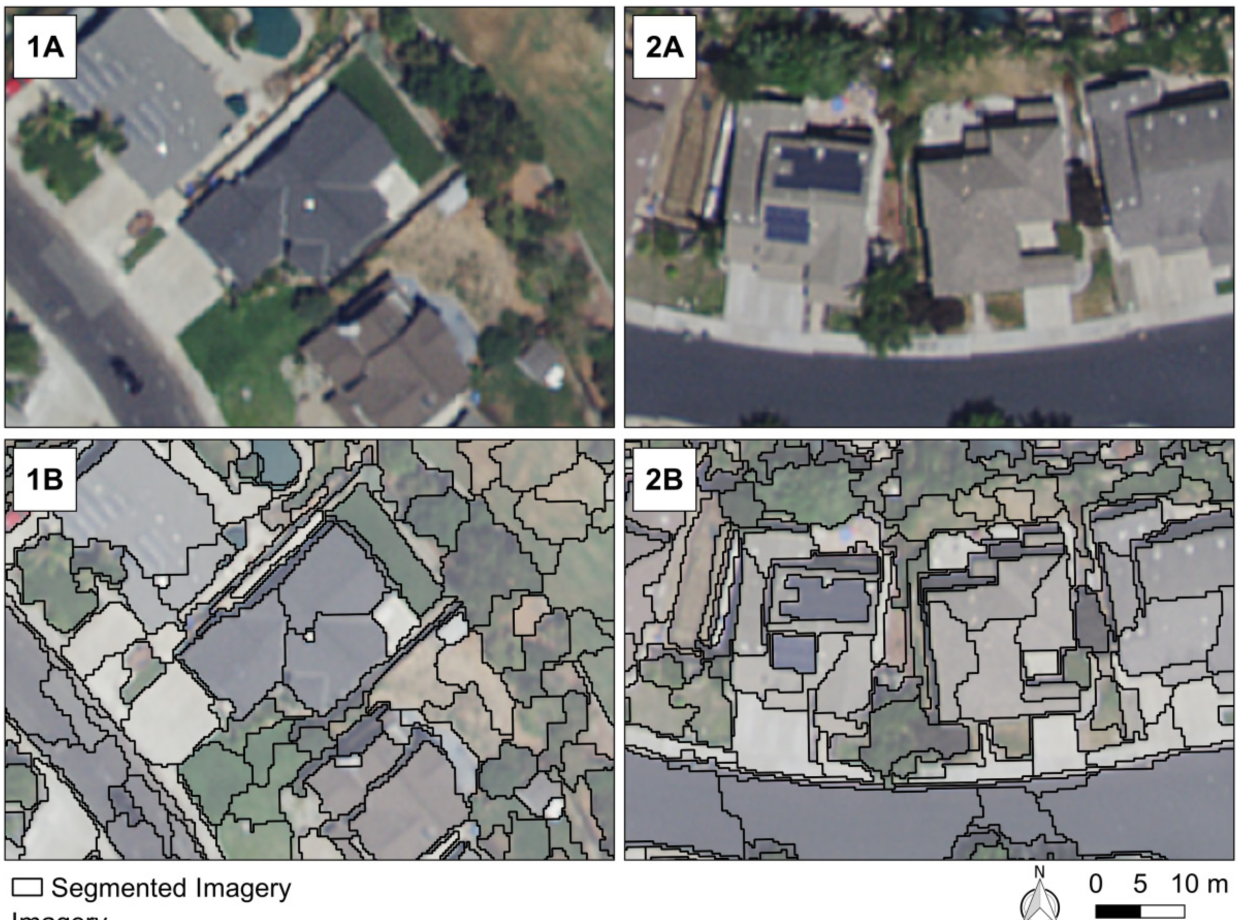


Figure 15: Examples of urban retail water supplier imagery and its segmentation. Images 1A and 2A show the RGB-NIR urban retail water supplier imagery. Images 1B and 2B show the super-pixel objects created during imagery segmentation overlaid on the imagery to show how distinct landscape features are extracted.

Imagery Derivatives for Modeling

Once super-pixel objects were generated, the pixels that fell within their boundaries were used to generate imagery derivatives that described each object. Both spectral and geometric summaries were attributed to each super-pixel object. Spectral derivatives included normalized difference vegetation index (NDVI), absolute difference index (ZABUD), normalized difference water index (NDWI), greenness, redness, blueness, NIRness, and statistical means and standard deviations of the red, green, blue, and near-infrared values. Geometric derivatives described the shape and size of super-pixel objects and included summaries such as area, perimeter, largest rectangle inside, super rectangle, and super round. Additional descriptive attributes were generated with primary classifiers that predicted cover class, water, not water, driveways, structures, vegetated, and not vegetated values for each object. In total, 76 variables were assigned to each super-pixel object for use in the modeling process.

After segmentation into super-pixel level objects, the objects were intersected with the topologically corrected vector layer. A unique identifier was assigned to each tile of objects, and because there was no parcel overlap in this layer, model predictions were guaranteed to be unique by object. This allowed for accurate supplier-wide summaries of irrigation status, regardless of overlap in the parcel data.

Processing Pipeline

The LAM Project was built from many different data processing and classification steps. In order to successfully process 398 unique urban retail water suppliers from data ingestion to deliverable results, an automated processing pipeline was developed. Systematic processing, standardized data structures, and custom digitization tools were fundamental to the success of the LAM Project. Control sheets were used to organize, track, and prioritize processing tasks within the pipeline, while triggers that registered the completion of manual steps in the process were used to resume automated processing once manual work was completed. Figure 16 shows a high-level overview of the project phases.

Figure 16: Overview of Landscape Area Measurements Project processing pipeline. Left to right: Source Data Instantiation, Initial Model Application, Manual Classification of Reference Data, Land Mask Digitization, Recursive Model Fit (RMF), and Summarization of Results.

Classification System

The classification system used in the LAM project was designed by NV5 Geospatial in conjunction with DWR to capture the full range of landscape types exemplified across California. The classification system is divided into two levels: land cover and land use. The land cover class describes the physical representation of a feature within a landscape, such as canopy, turf, or concrete (land cover classes listed in Table 5). The land use class of a feature describes the interpreted irrigation status of that feature. Three primary land use classes were utilized in the LAM Project: irrigable irrigated (II), irrigable-not irrigated (INI), and not irrigable (NI).

The full range of land cover and use classes are outlined in Table 11 and contain 28 land cover and land use combinations. Table 5 and Table 6 demonstrate the relationship between land use and land cover by highlighting the different land cover types that can represent each land use.

Table 5: Land cover class definitions.

Land Cover	Description	Irrigation Status Potential
Structures	Houses, garages, sheds, decks, swing sets, and solar panels on a structure	NI
Roads	Roads: gravel and asphalt	NI
Concrete	Concrete, pavers, and brick	NI
Impervious Other	Other impervious objects: Solar panels on the ground, tarps over pools, shade tarps, retention walls, fences, boulders, rocks, tennis courts, or movable objects presumably on impervious surfaces such as garbage bins, umbrellas, patio furniture, and trampolines	NI
Artificial Turf	Artificial turf	NI
Pools	Pools (inset or above ground), hot tubs, koi ponds, and man-made water features or fountains larger than 64 square feet in area	II
Turf	Manicured lawns, smooth in texture	II, INI
Canopy	Shrubs, trees, and other vegetation that is large enough to cast shadows.	II, INI, NI
Ground Cover	Ground cover such as landscaping mulch & rock, or coarse grasses that do not cast shadows	II, INI, NI
Bare Earth	Bare earth that is lacking vegetation. Must be between irrigated plantings or orchards to be considered irrigated.	II, INI, NI
Vehicles	Vehicles, tractors, or other movable objects such as garbage bins and umbrellas that retain the irrigation status of the land they are on	II, INI, NI
Trampolines	Trampolines that retain the irrigation status of the land they are on	II, INI, NI
Undeveloped Lands	Represents any areas deemed not irrigated by humans. They can be abandoned urban lots or native landscapes containing trees, grasses, and wetlands	NI
Horse Corrals	Represents horse corrals and arenas that are usually round or oval. Generally smooth soil texture and may contain signs of watering. Retail water suppliers will receive credit through the variance process.	NI
Open Water	Ocean coastline, lakes, rivers, or retention ponds. Retail water suppliers will receive credit through the variance process.	NI
Agricultural Lands	Represents large commercial agriculture that can be identified by vegetation planted in rows (row crops, vineyards, nurseries), trees planted in formations or rows (fruit and nut orchards or nurseries), clear signs of management with irrigation or the intention to irrigate (plowed, tilled, circular irrigation patterns, flood irrigation, presence of pivots/irrigation lines or discolored soils), or irrigated livestock pastureland.	NI

Table 6: Relationship between irrigation status and land cover classes. Asterisk (*) indicates mask classes that capture specialized land cover types.

Irrigation Status	Irrigation Status Code	Cover Classes Included
Not irrigable	NI	Impervious classes, Canopy, Ground cover, Vehicles, Trampolines, Other, Undeveloped Lands Mask*, Horse Corral Mask*, Open water, Artificial turf, Agricultural Lands Mask*
Irrigable Irrigated	II	Turf, Canopy, Ground cover, Pools, Vehicles, Trampolines, Other
Irrigable-not irrigated	INI	Turf, Canopy, Ground cover, Vehicles, Trampolines, Other

Irrigable Irrigated (II)

Irrigable irrigated vegetation is identified as areas of green and healthy vegetation that appear to be maintained and managed through active irrigation. Irrigated vegetation includes lawns that are over 60% green and not water stressed, raised planting beds and gardens that are over 10% planted, healthy and foliated shrubs and trees that have been planted, manicured, and maintained, ground cover between healthy irrigated vegetation, and vehicles or objects that are on irrigated vegetation. Pools and fountains are identified as irrigated features, and include the water surfaces for all swimming pools, hot tubs, and any other man-made swimming areas.

Irrigable-Not irrigated (INI)

Landscape features that are classified as irrigable-not irrigated include areas that are not actively irrigated, but were planted and irrigated in the past, or were graded in preparation for planting. This includes unhealthy turf that is more than 40% browned out, water stressed shrubs or canopy, planting beds and gardens that are not maintained and are less than 10% planted, and vehicles or objects placed on water stressed vegetation.

Not Irrigable (NI)

Not irrigable landscapes include impervious surfaces, open water, artificial turf, pervious not irrigable ground cover, not irrigable canopy, and masked landscapes (undeveloped lands, horse corrals, and agricultural lands). Impervious surfaces include structures and buildings, concrete pavers, asphalt roads, vehicles on roadways and driveways, boulders, and moveable objects placed on impervious surfaces. Artificial turf is a synthetic material made to imitate natural grass that is considered not irrigable in this project. Not irrigable pervious landscapes are areas that show no signs of active or previous irrigation - often native vegetation. They are identified as disorganized vegetation that is not interspersed within irrigated or irrigable vegetation. They are generally not located adjacent to structures and include native pastures, randomly spaced native trees and bushes, bare earth, pervious gravel surfaces, and vehicles or objects placed on pervious non-irrigable landscapes. Open water includes areas of natural water such as lakes, waterways, ponds, and coastal ocean.

Modeling Approach

The combined use of remote sensing and machine learning in this analysis facilitated the efficient classification of approximately 14,000 square miles of California. Due to the large extent of the study area and the vast range of landscapes contained within the urban retail water suppliers of interest, a unique classification model was trained for each urban retail water supplier. This allowed the landscape area measurement results to be tuned to the unique composition of each urban retail water supplier, as influenced by its level of human development and ecoregion.

For each urban retail water supplier, four-band, one-foot resolution aerial orthoimagery and manually interpreted imagery labels were utilized to model outdoor land cover and land use. Due to the nature of remotely sensed data, the manual and automated classification of residential parcel spaces were conducted via a top-down approach. The top-down approach indicates that landscape features were classified from an aerial view that is dependent on the imagery collected over each service boundary. Any ground-level landscape features that were obscured by canopy or buildings in the imagery were not captured in the classification. The ground condition beneath tree canopies is assumed to contain the same irrigation status class as the canopy that covers it.

In the initial analysis stages, urban retail water supplier imagery was segmented into objects by grouping zones of like-valued pixels called super-pixels. These super-pixel objects delineate separate landscape features and contain spectral and geometric summaries based on their member pixels. Super-pixel objects are the foundational classification unit for the project and allow identifiable landscape features to receive a uniform land use and land cover classification. After imagery was segmented, a unique model was trained for each urban retail water supplier using parcel similarity relationships and reference parcel data that were manually classified by human photo interpreters. An example of urban retail water supplier imagery (A), imagery segmentation (B), and classification (C) is shown in Figure 17. Rigorous internal checks were used to ensure satisfactory model performance by recursively training the model and testing the resulting classification accuracy until internal accuracy thresholds were met. Once model training was completed, the model was applied across the urban retail water supplier and an independent validation was performed using manually classified parcel data that were withheld from the model training process.

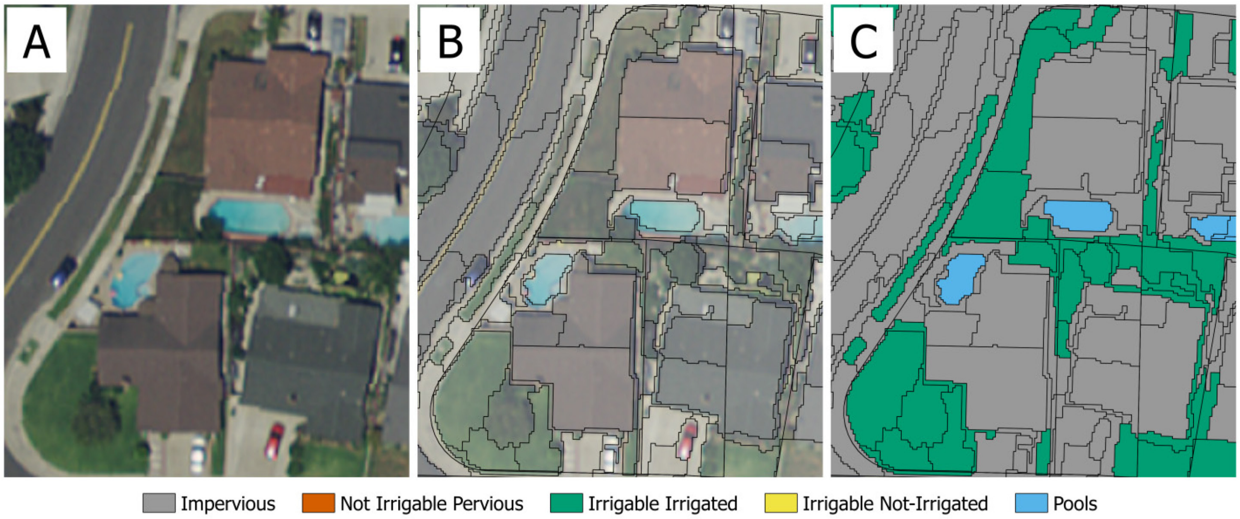


Figure 17: Imagery processing overview. A) Urban retail water supplier imagery. B) Super-pixel segmentation of urban retail water supplier imagery. C) Land cover and land use classification of super-pixel objects.

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Reference Parcels

In a modeling effort, reference data are the labeled, or classified, data that are used to both train the model and test its performance. In the scope of this project, reference data were made up of single-family or multi-family residential parcels that had their land cover and land use class assigned by a human photo interpreter from the NV5 Geospatial team. The boundary of each selected reference parcel was used to subset the source data imagery and super-pixel objects that the parcel contained. Each super-pixel object within the reference parcel was assigned a land use class or label. Examples of reference data with their irrigation status code assigned are included in Figure 18. When executing model training, these labeled reference data are used to build and inform the classification rules that the model will utilize when applied to novel data. Labeled reference data were also utilized in the validation phase of machine learning to compare the predicted class to the true class label.

High quality reference data represent a vital component of the LAM Project. Classification consistency was required from the outset of the project to ensure that each individual urban retail water supplier model was trained in the same manner and would yield accurate results for the establishment of outdoor water use standards. Each reference parcel was manually classified following specific classification guidelines established in collaboration with DWR. The classification scheme is outlined in the Reference Data section and the full classification scheme is shown in Table 11.

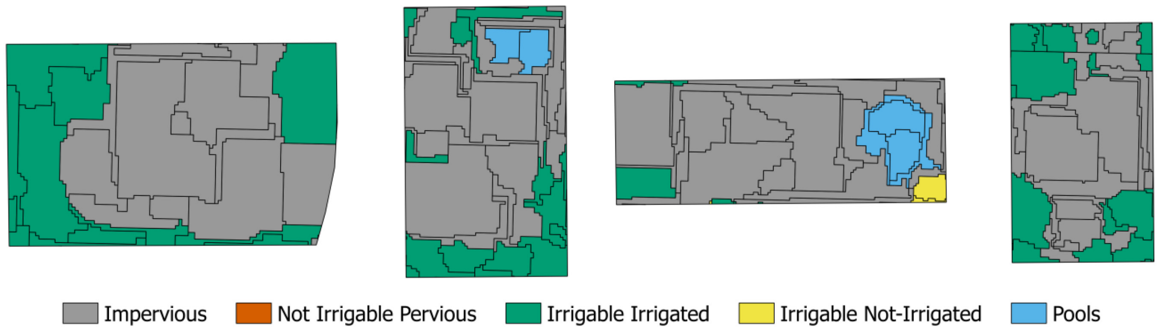

Figure 18: Four reference parcel examples that are classified to their land cover and land use classes.

Reference Data Labeling

A topologically correct super-pixel object layer and imagery layer were required to complete the classification or labeling of each reference parcel. Prior to human photo interpretation, parcel objects were classified using a primary land cover classification model. Once initially classified, the parcel was manually reviewed to correctly match the label of each super-pixel object to the land use and land cover represented in the parcel imagery. Each object was classified according to the 28-class scheme outlined in Table 11.

Special Classification Considerations

Due to the wide variety of imagery conditions and ecoregions represented in this project, a few general classification guidelines were outlined to ensure accurate and precise parcel classification. To facilitate high classification agreement between the members of the NV5 Geospatial team, photo interpreters were instructed to interpret certain objects, imagery, or landscape conditions in systematic ways. The photointerpretation of reference parcel imagery can be influenced by super-pixel shape and coverage, shadows and canopy cover, overall service area context, and irrigation context or hydro-zones.

Super-pixel Object Area

Occasionally super-pixel objects were representative of multiple features due to shadows or other imagery conditions that prevented the detection of feature boundaries. These objects were classified based on the class majority that the object represented and were never split or altered. Retaining the original structure of the super-pixel object allowed the model to gain information about mixed class objects and how to make predictions over them.

Shadows and Canopy

Due to the top-down nature of the classification approach, canopy and cast shadows can limit the interpretation of residential landscapes. Super-pixel objects representing shadows were classified based on the irrigation status of the ground that they cover, to the closest extent possible. When classifying reference parcels, the near-infrared view of the imagery is used to detect the presence of vegetation covered in shadow. Healthy vegetation appears bright in the near-infrared view. If objects represented tree or shrub canopy features that overhang features of a different class, those objects were assigned as canopy following the top-down classification approach. Canopy was classified based on the irrigation status of the ground cover where its trunk is located. Therefore, canopy coverage originating on a different parcel can receive a different irrigation status than that of the remaining canopy on the parcel of interest.

Service Area Context

The greater context of a feature was considered while classifying individual objects to their land use. It was important to assess the ecological context of the region and how wet or dry the urban retail water supplier's service area was at the time of imagery collection. Ecoregion, climate, and imagery acquisition dates can vary between areas and because of this, the context of irrigation status and land use can vary as well. For example, coastal suppliers and suppliers where imagery was taken closer to springtime tend to be exceptionally green, requiring more visible evidence of irrigation for features to be classed as irrigated (e.g., irrigation circles, piping, irrigation boom, or standing water within fields). However, urban retail water suppliers in desert regions typically appeared overwhelmingly dry, so if plantings could be identified in the imagery, it was reasonable to expect that they were receiving irrigation. Examples of a few of the various landscape types seen in the LAM Project are included in Figure 19.

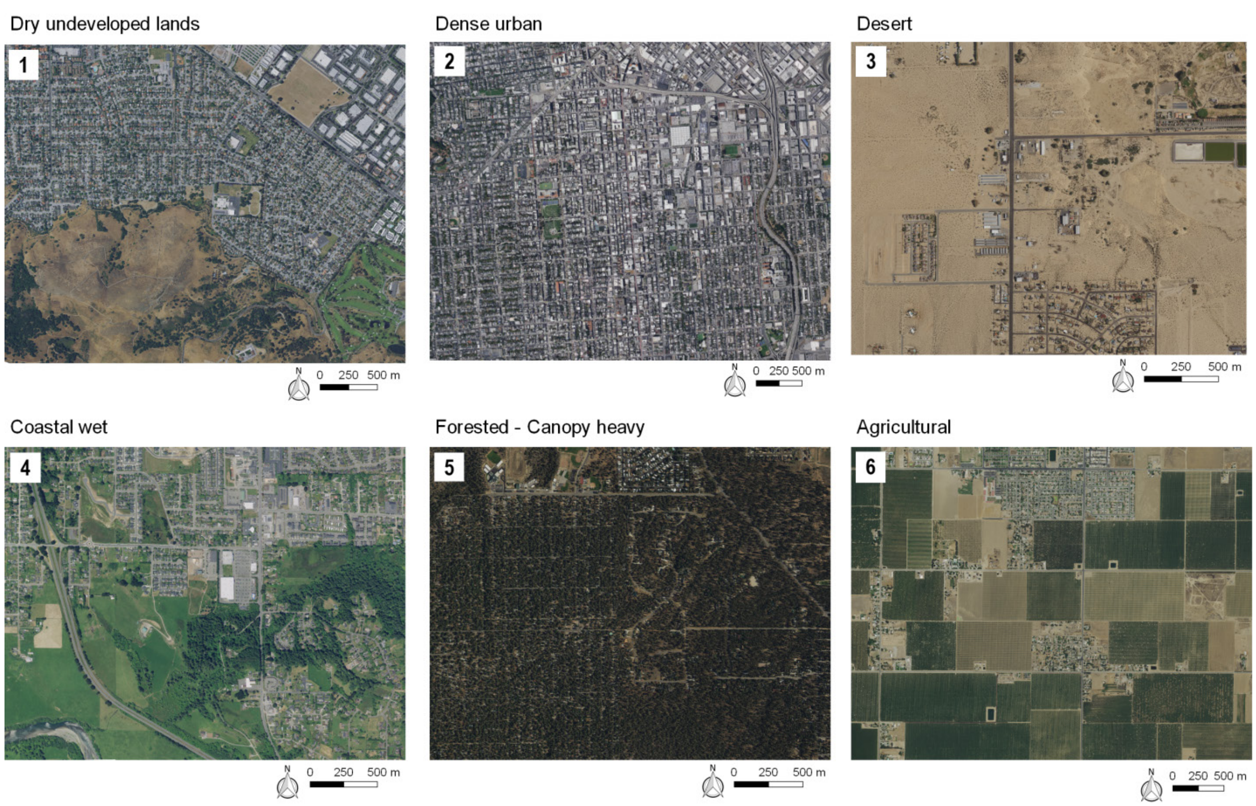

Figure 19: Examples of six different landscape types commonly seen in the Landscape Area Measurements Project. 1) Dry undeveloped lands surrounding human development. 2) Dense

urban landscapes. 3) Desert and minimally developed landscapes. 4) Coastal regions that were exceptionally green due to increased humidity and precipitation. 5) Forested and heavily canopied residential landscapes. 6) Residential landscapes with high density large-scale agriculture.

Hydro-zones

While assessing the land use of a parcel, the photointerpretation team considered the hydro-zones of the objects, or groupings of plants and other irrigated and non-irrigated features on the property. Hydro-zones are used to describe areas of a landscape that receive the same watering regime. Photo interpreters divided the landscaped areas of a parcel into their irrigated, irrigable-not irrigated, and non-irrigable hydro-zones. For example, front lawns are often bordered by a sidewalk, driveway, property line, and a house. The entire area inside those boundaries would be considered the lawn's hydro-zone. For example, if there were a few patches of brown lawn within a lawn hydro-zone that was more than 60% green and healthy; the entire hydro-zone would be assigned to the irrigated turf class. Irrigation status assignments were made to be consistent within hydro-zone boundaries based on the visually interpretable land uses in a parcel. An example of the use of hydro-zones in the classification process is shown in Figure 20.

Figure 20: Two different hydro-zones on a parcel. The street facing yards of the parcel form an irrigated hydro-zone and the backyard, which is primarily senesced turf, forms an irrigable-not irrigated hydro-zone.

Classification Quality Control

In recognition of the potential for variation in the manually interpreted aspects of the LAM Project, multiple quality control checks were used throughout the parcel classification procedure. Each manually classified parcel underwent three phases of interpretation and classification review. At each phase, photo interpreters would review the classifications of the super-pixel objects within a parcel and correct all classification errors. The changes made during the three consecutive phases of quality control were recorded to monitor the level of agreement between photo interpreters (measured as percent change between checks) and flag particularly challenging suppliers that required additional training effort.

A parcel control sheet was used to manage the parcels through each quality control phase. This sheet contained a single row for each parcel. Attribute fields were used to track the progress of each parcel through the classification review process and record completion timings.

Classification Overseer Tool

An in-house proprietary application was created to assist in the classification effort. The Classification Overseer Tool is a custom QGIS plugin, created to distribute and modify parcels for the LAM Project. The Classification Overseer Tool (shown in Figure 21) performs repetitive tasks and provides additional tools to users to speed up the classification process. The plugin is written in Python 2.7 and can be used on any version of QGIS 2.18. The tool was hosted on a local repository and worked in conjunction with a locally hosted Postgres Database.

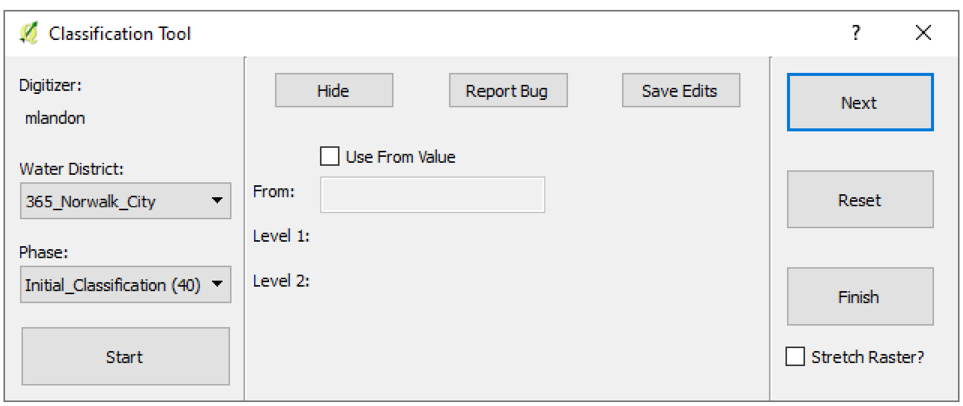

Figure 21: Classification tool user interface.

The interface was created using PyQt4 libraries and can be seen in the image above. When the tool is loaded, it fills in lists of available work by reading the control sheet table on the Postgres database. Using the buttons and combo boxes, the user can select which supplier and phase to pull parcels from. When the user selects “Start”, the tool finds and loads an appropriate parcel and checks it out to the user on the control sheet. The tool finds and loads the imagery layer for that supplier, the parcel’s vector layer, and the corresponding near infrared layer (a falsely colored raster layer that uses near infrared bands to highlight photosynthetic activity). A color style is also applied to the vector layer which represents a polygon’s current classification. The user then classifies the parcels by selecting misclassified polygons and entering the two-digit code that matches the correct classification (See Table 11 for classification codes.). After the user finishes the parcel, the tool saves the edits, removes the finished parcel from the canvas, and loads in a new parcel. The tool also checks in the parcel on the control sheet, advances it to the next phase, and checks out the new parcel. The user may repeat this process until the supplier runs out of parcels in that phase. Embedded in the tool are several other administrative functions such as the ones listed below:

- Version Control - The tool restricts which versions of the tool can be run to ensure that everyone is using the correct version.
- Deletion Detection - Prevents the user from submitting a parcel after deleting a polygon.
- Reserved Suppliers - Some suppliers are classified by specialized users and the tool will allow only specific users to work on them.
- Calibration Parcels - The tool inserts calibration parcels into the parcel classification workflow which are classified by all editors. These parcels are then analyzed by Senior Technicians to ensure consistent classification calls across all photo interpreters.
- Bug Reporting - The tool provides a link for users to submit problems with the tool or feature requests.

Recursive Modeling

For model predictions of land cover and land use to achieve a supplier-wide accuracy of 95% or greater, a sufficient number of training examples for each of the irrigation classes (II, INI, and NI) was required. The number of training examples necessary to exceed the accuracy threshold varied on a per-supplier basis, as the predictive capacity of the modeling framework is sensitive to myriad factors, including (but not limited to) the spectral and temporal character of the collected imagery, the canopy type and amount present throughout the supplier, and the ecoregion in which the supplier resides. To address this variability, a modeling framework was developed in which models are recursively fed training data and evaluated against an internal set of parcels until they are ready to be evaluated against an independent, external test set of parcels that have been withheld from the modeling procedure. This procedure is known as recursive model fitting.

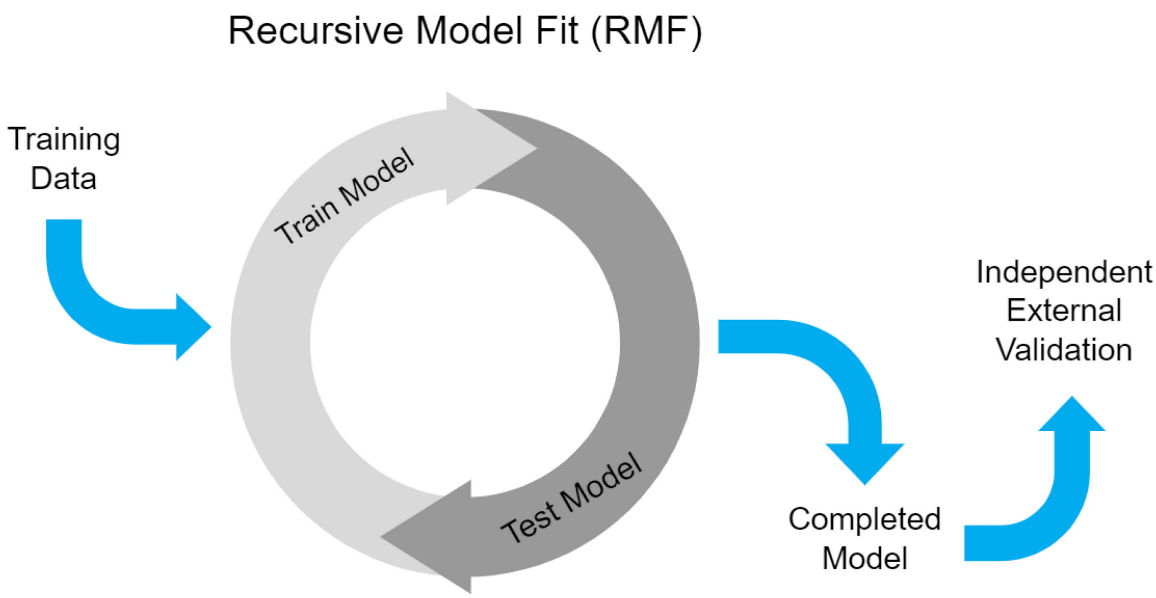

Figure 22: Recursive modeling workflow.

Recursive Model Fit Procedure

An overview of the Recursive Model Fit (RMF) procedure is as follows: for a given supplier, training data were initially selected from a parcel similarity network such that a representative sampling of II, INI, and NI was present in the training set. Then, a model trained on that dataset was built and used to create supplier-wide predictions on the super-pixel objects. Model performance was quantitatively measured by an accuracy score and confusion matrices derived from an internal parcel test set, as well as qualitatively assessed by visual inspection. If a model for a given supplier did not pass quantitative and qualitative checks, then additional training data was selected and a new model was built, and the model entered the next round of RMF. If a model passed the checks, it exited the recursive loop and was tested against the external parcel test set for a final accuracy score. Recursive Model Fit was applied to all supplier models until they met the supplier-wide accuracy threshold of 95% or greater. Figure 22 demonstrates the RMF procedure.

Parcel Similarity Network

To ensure that the reference data selected for an urban retail water supplier captured the full range of variation contained within the supplier's service area, a network - in which parcels are ranked by similarity - was built from the set of valid single-family and multi-family residential parcels. In this network, every parcel acted as a node, with edges connecting it to every other parcel in the supplier's service area. Weights were assigned to each edge, defining how similar that parcel was to any other parcel in the network. Edge weights were computed using both the Euclidean distance and cosine similarity between parcels. From this network, the similarity scores were leveraged to ensure a heterogeneous set of parcels were extracted, and thus a training dataset with a balanced sample of II, INI, and NI objects was generated. Without this network, the pool of training data (i.e., the examples a model was trained on) for a supplier could be dominated by a single class, resulting in high class omission and commission errors in the final predictions. For example, in an arid service area, the NI class dominates the pool of training data, since canopy cover is low and much of the ground has never been irrigated. Similarly, heavily forested service areas are dominated by native canopy, and heavily irrigated service areas by green lawns and trees, skewing model predictions toward those respective classes. Sampling parcels from the parcel similarity network helped to ensure a more representative pool of training data.

Reference Parcel Roles

The purpose of the reference data generation effort was to classify a subset of network connected and randomly selected parcels to be used as reference data in the modeling effort. Each reference parcel was selected from the topologically correct parcel layer based on criteria specific to the processing role that the parcel would fill. Four different subsets of parcels were collected for use in different processing steps of the LAM Project:

- Role 1: Randomly selected parcels with an area greater than 10 square meters that are used for the external validation of the model and were not included in any level of modeling. Number of Role 1 parcels per supplier: mean = 61 parcels, minimum = 50 parcels, maximum = 200 parcels, standard deviation = 23 parcels.

- Role 2: Parcels selected based on irrigation class representation from the primary supplier classifier. These parcels are used for tuning the model after initial classification. Number of Role 2 parcels per supplier: mean = 22 parcels, minimum = 7 parcels, maximum = 66 parcels, standard deviation = 5 parcels.

- Role 3: Parcels selected from within the parcel network that are used to train the model at the RMF stage. Depending on the complexity of the model, additional parcels are extracted after each round of RMF until proper classification performance is realized. Number of Role 3 parcels per supplier: mean = 93 parcels, minimum = 16 parcels, maximum = 937 parcels, standard deviation = 86 parcels).

- Role 4: Parcels selected from within the parcel network that are used as the internal validation subset. Number of Role 4 parcels per supplier: mean = 51 parcels, minimum = 15 parcels, maximum = 150 parcels, standard deviation = 13 parcels).

Modeling Inputs

The spectral and geometric attributes of each super-pixel object that are described in the Imagery Derivatives for Modeling section contain a wealth of data. These attributes were leveraged to create examples of the irrigation and cover classes on which models were trained, helping them to learn which ranges of attribute values constituted the different irrigation status and land cover classes. The values for each of these variables changed object-by-object depending on the irrigation class and cover type of the imagery from which the object was generated. The values of these variables also changed from supplier to supplier based on ecoregion and imagery collection and processing conditions, which is why a unique model was trained to suit each urban retail water supplier.

For the models to learn which ranges of attribute values correspond to which irrigation and cover classes, the data must be labeled with the appropriate irrigation and cover class codes. A human photo interpreter did this by assigning a label to each of the super-pixel objects at the 28-class level (classification shown in Table 11). This explicitly mapped object-level attribute values to irrigation and cover class type. For example, consider two different objects, A and B, captured by the segmentation routine. Object A corresponds to a dry, brown lawn, whereas object B corresponds to a green lawn that is regularly watered. Just as a mostly brown lawn is visually distinct from one that is mostly green, the values of the attributes for objects A and B will be fundamentally different. A human editor then assigns A to the class containing dry lawns (4A) and B to the class containing watered lawns (3A). Now, there are examples of value ranges for the spectral and geometric attributes that correspond to dry lawns and irrigated lawns. Manually labeling many dry and watered-lawn objects across many parcels throughout a supplier's service area provides additional examples of the attribute value ranges for classes 4A and 3A. Then, when a model is constructed, it has many examples of what constitutes dry vs. watered lawns and can more easily distinguish between the two. This will lead to more accurate and confident predictions of classes 4A and 3A and lead to less confusion of those classes with others. Example objects were selected from parcels within the parcel similarity network, leading to a pool of training data that was naturally diverse, representing the range of irrigation classes found across a supplier's service area.

Manual Model Adjustment

While sampling training data from the parcel similarity network provided good baseline model performance for a supplier, sometimes additional handling was required to generate sufficiently accurate predictions. For such scenarios, a procedure exists to manually adjust the training data upon which a model was built. At the beginning of each round of RMF, the number of examples for a given irrigation and cover class could be boosted or reduced in order to correct confusion between classes. Training data from other suppliers could also be incorporated if the supplier in question lacks enough examples of a particular class. For example, in an arid service area where there are few instances of watered vegetation, training data from a heavily irrigated service area could be pulled in to provide the model additional examples of class 3A and 3B. For each model built from adjusted training data, an automated report detailing the specific classes edited and the resulting confusion matrices and accuracy metrics was generated for posterity. These manual adjustments balanced the training data for a supplier at the 28-class level (classification shown in Table 11), providing even finer-grained control over the training data than from using the parcel similarity network alone. Such precise control was often necessary to ensure models achieve 95% accuracy in a reasonable number of RMF rounds, particularly in service areas dominated by a single irrigation or cover class (for example, heavily forested or arid service areas).

Land Masks

Land cover classification confusion can occur due to spectral similarities between land cover types that have vastly different land uses and irrigation statuses. For example, native riparian vegetation that should receive the not irrigable irrigation status can easily be confused with irrigated landscaping based on its vibrant green appearance and high near-infrared reflectance in aerial imagery. Land masks were implemented in the LAM Project to manually identify specific land cover types and ensure that they were given the appropriate irrigation status designation. Land masks also served to improve model accuracy by eliminating the classification confusion across these specific landscapes.

Three different land mask types were employed to capture unique landscapes and land uses present throughout the urban retail water suppliers of California: the Undeveloped Lands Mask, Agricultural Lands Mask, and Horse Corral Mask. Minimum mapping units (MMU) were utilized for the Undeveloped Lands Mask and Agricultural Lands Mask (0.25 acres and 1.0 acre, respectively) to ensure equitable mask application across all urban retail water suppliers. Minimum mapping units determine the smallest feature that should be captured in a mapping effort. Therefore, when considering the 0.25 acre MMU for the Undeveloped Lands Mask, a digitizer would not mask a region of undeveloped land that was only 0.1 acres in area. All three masks are considered to represent not irrigable landscapes within the scope of this project but are accounted for separately to facilitate the generation of variance metrics surrounding the potential residential irrigation of agricultural land or horse corrals for dust control.

Undeveloped Lands Mask

The Undeveloped Lands Mask was used to designate landscapes that were not irrigated at the time of imagery collection and did not appear to have been irrigated in the past. This mask typically represents native landscapes including riparian vegetation, native estuary or coastal vegetation, submerged or emergent aquatic vegetation, rangeland, and native canopy cover. The minimum mapping unit for the Undeveloped Lands Mask is 0.25 acres. This includes any continuous area of undeveloped land that falls within the queried parcel boundaries that meets or exceeds 0.25 acres. An example of Undeveloped Lands Mask is provided in Figure 23.

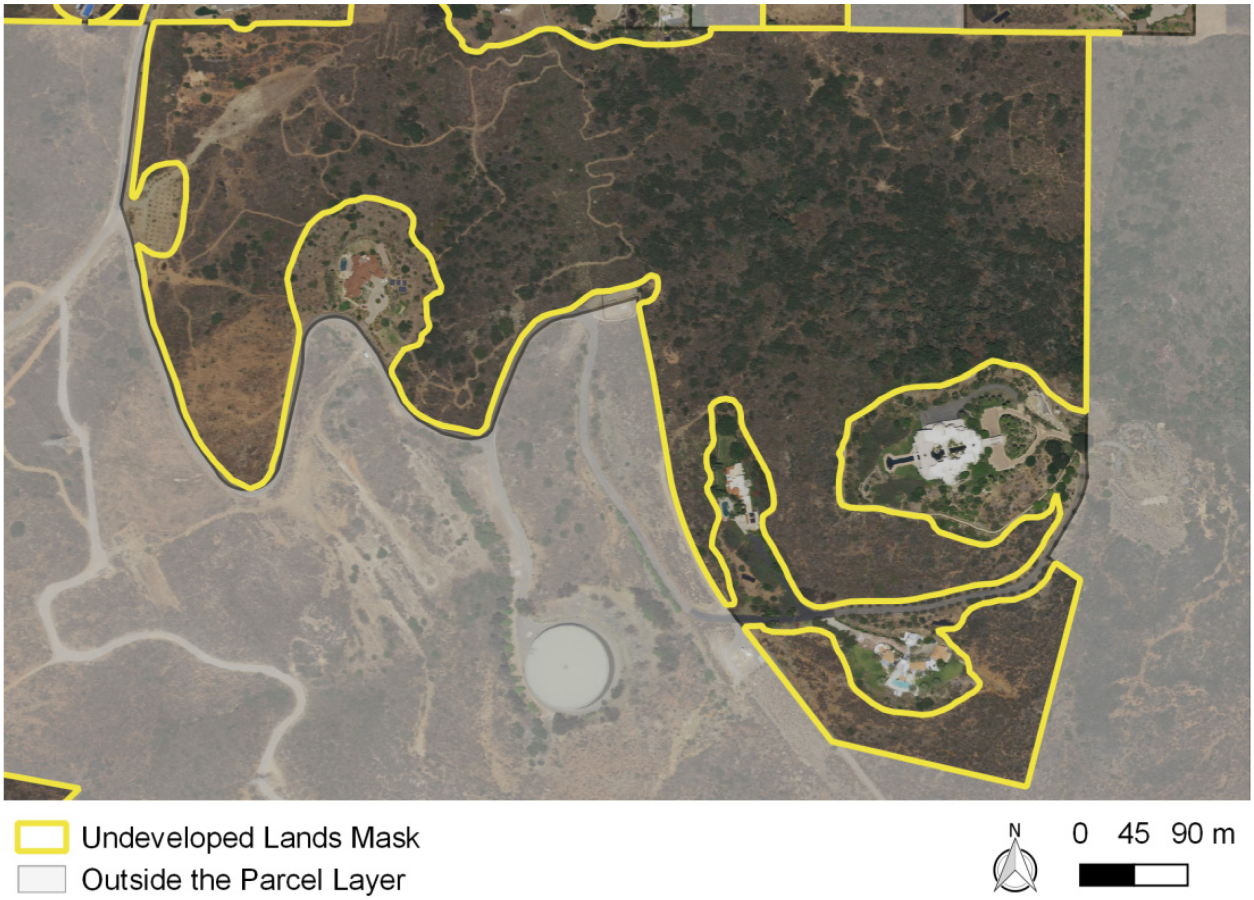

Figure 23: Example of Undeveloped Lands Mask (outlined in yellow). This mask captures not irrigable landscape features that are greater than 0.25 acres in area.

Imagery © 2023 Hexagon and data partners.

Agricultural Lands Mask

The Agricultural Lands Mask was developed to accurately gauge residential water use by excluding large scale commercial agricultural operations within the residential parcels of an urban retail water supplier. The minimum mapping unit for agricultural lands is one acre. This includes one acre of continuous agriculture, one acre total within a single queried parcel boundary, or any portion of an agricultural plot that meets or exceeds one acre and falls within a queried parcel boundary. Features that were commonly used in identifying agricultural lands are vegetation planted in rows (e.g., row crops, vineyards, nurseries), trees planted in formations or rows (e.g., fruit and nut orchards or nurseries), clear signs of management with irrigation or the intention to irrigate (e.g., plowed, tilled, circular irrigation patterns, flood irrigation, presence of pivots and irrigation lines, or discolored soils), or irrigated livestock pastureland. An example of Agricultural Lands Mask is provided in Figure 24.

Figure 24: Example of Agricultural Lands Mask (outlined in yellow). This mask captures large scale commercial agriculture that is greater than one acre in area.

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Horse Corral Mask

The Horse Corral Mask was used to identify horse corrals and the unique combination of land cover and land use that they represent. In some urban retail water suppliers of California, horse corrals are irrigated to prevent dust and comply with California's Clean Air Act. Horse corrals and arenas are considered not irrigable features within the scope of this analysis but are held separately from other not irrigable landscapes in order to provide a deeper level of understanding regarding residential land use. A horse corral is defined as an area where a horse is actively exercised or ridden that may require irrigation to mitigate the large amount of dust generated. Horse corrals were visually identified and differentiated from pastures using their smooth, bare texture and the lack of "horse houses," shade structures, or barns directly adjacent to or within the corral. Additionally, they contained no visible vegetation growth, were typically fully enclosed within a fence, and may have contained equestrian agility features. Paddocks, turnouts, pastures, and horse corrals in disuse that did not meet the above criteria were not captured within the Horse Corral Mask. The irrigation statuses of the features in disuse were instead determined by the machine learning classification based on their spectral presentations. Examples of masked horse corrals are shown in Figure 25.

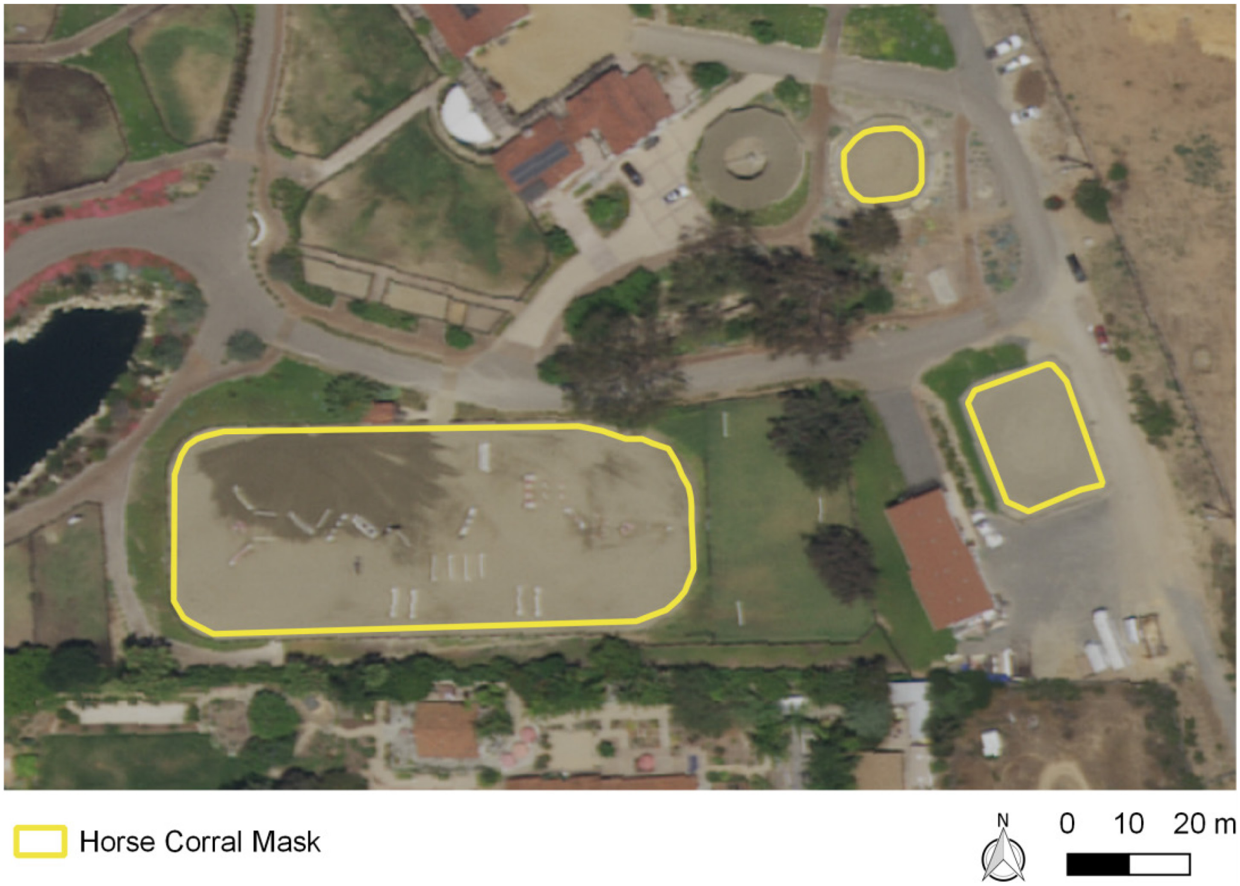

Figure 25: Example of Horse Corral Mask (outlined in yellow).

Imagery © 2023 Hexagon and data partners.

Masking Application and Procedure

After urban retail water supplier modeling was completed, land masks were applied to the classification results by assigning the mask class and irrigation status code to each super-pixel object that the mask vector intersects. A buffering space was left between the mask vector and the edge of the mask landscape feature due to the variable shapes and extents of super-pixel objects. This prevented the misclassification of potentially irrigated or irrigable landscapes surrounding masked landscapes. If mask vectors were digitized following the mask feature boundary, then super-pixel objects that extend beyond the mask feature may be captured and classified, resulting in an overestimation of mask feature area. Figure 26 demonstrates the application of the Horse Corral Mask and highlights the importance of distancing mask shapes from irrigated or irrigable landscape features.

As a part of the digitization process, mask polygons were snapped to the vertices and segments of adjacent mask polygons to prevent classification gaps between mask classes. A hierarchical order of importance was placed on each of the three mask types in cases where multiple mask shapes intersect a single super-pixel object. Horse Corral Mask shapes hold the highest level of importance, followed by the Agricultural Lands Mask and Undeveloped Lands Mask, respectively.

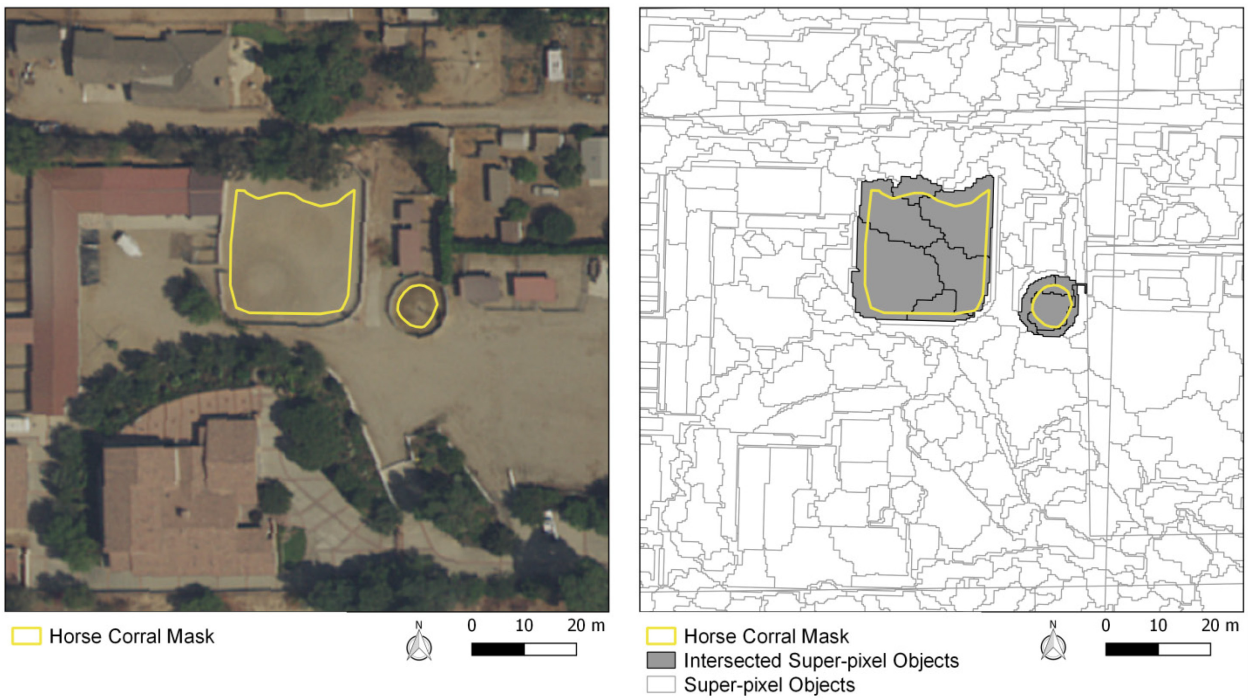

Figure 26: Example of mask application to segmented imagery. All super-pixel objects that touch the mask vector are classified to that mask type. Note that the mask vector shown in yellow on the left does not extend to the horse corral fence or touch any of the canopy that is bordering the horse corral. This helps to prevent the overestimation of mask area and preserves correct canopy classifications made around the horse corral.

Imagery © 2023 Hexagon and data partners.

Mask Evaluation

To ensure that the highest quality and accuracy is achieved from the masking effort, the process is broken down into four phases: Initial, Quality Control, Feedback, and Feedback Review. During the Initial Phase, the mask vectors are manually digitized in accordance with our standard operating procedures and masking criteria. The Quality Control Phase is conducted by a senior editor capable of correcting any topological errors, mistakes, or misses that may have occurred during the Initial Phase. The Feedback Phase is then conducted by DWR and their consultants. Any points of concern or disagreement are returned as a point vector file with accompanying descriptive attributes. During the Feedback Review Phase, each point of concern or disagreement is assessed by a senior editor to ensure that all mask shapes are in accordance with masking protocols. Any points of misunderstanding or confusion that exist after the

Feedback Review Phase are then clarified directly with DWR via a screen share session with a senior editor.

Landscape Area Measurements Products

For each urban retail water supplier in the analysis, the final data products include a spatial and tabular description of the landscape areas that were modeled for each residentially zoned parcel in the query. The modeled areas were derived from a classified map of land use and land cover generated using recursive modeling. Outdoor landscape area measurements were summarized in square feet at the parcel- and supplier-level.

Outdoor landscape area summaries were provided for each parcel according to the ten-class land cover and use classification scheme outlined in Table 10 and according to the irrigation status classification outlined in Table 9. Parcel summaries were created for the original parcel layer (Parcels A) and the topologically corrected parcel layer (Parcels B). See the Parcel Topology Handling section for additional information on parcel datasets and transformations. The 'A' layer summaries were created to provide parcel-level information about outdoor land use. The identifying parcel attributes have been retained in the summary layer to support parcel lookup. Landscape area estimate summaries created with the Parcels B layer were created to accurately summarize landscape area measurements at the supplier-level by removing any overlap present in the original parcel layer. Figure 27 provides an example of the irrigation status summaries created at the parcel-level.

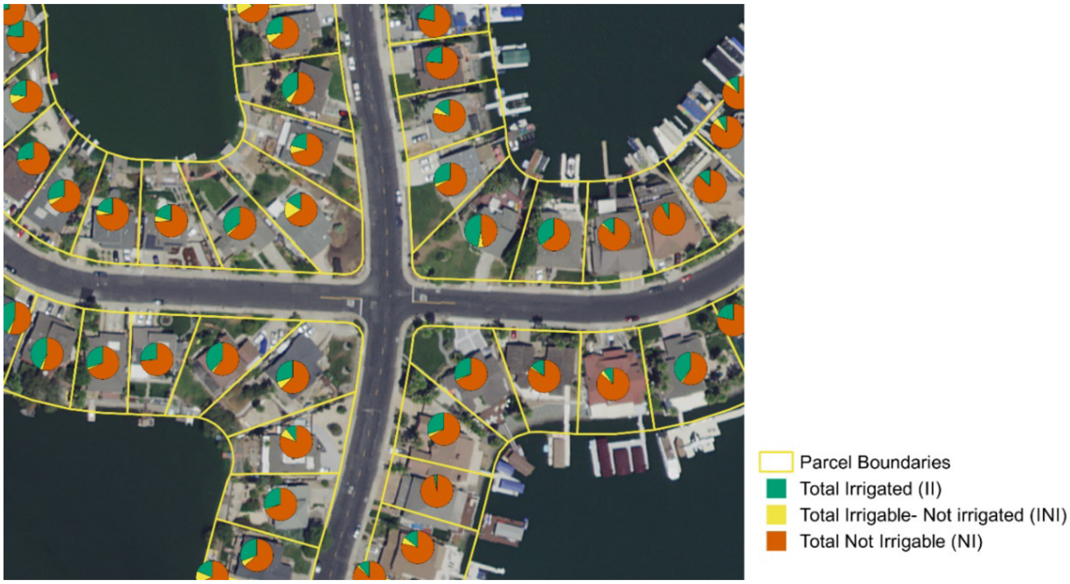

Figure 27: An example of the summarized landscape area measurements for an urban retail water supplier. The pie charts included on each parcel indicate the proportion of the parcel represented by each irrigation status class.

Imagery © 2023 Hexagon and data partners.

Methods

In order to test that each urban retail water supplier was modeled accurately, an independent validation exercise was performed using the Role 1 external validation parcels after modeling was complete. As a part of this process, model predictions of irrigation status were compared to the manually classified Role 1 parcels using confusion matrices. Confusion matrices are a powerful way to visualize and measure the performance of a classification model. They are a tabular representation of the correct and incorrect classifications across a predicted space. The column values of the confusion matrices represent the reference data classifications from the manually classified parcels. The row values of the confusion matrices represent the model predicted classifications. Correct class predictions are shown along the main diagonal of the confusion matrix, where the predicted class matches the reference class. Erroneous classifications are shown in confusion matrix cells off the main diagonal where the predicted class does not equal the reference class. An example of a generic three-class confusion matrix is shown in Figure 28.

Model Prediction \ Reference (Validation Class)	A	B	C
A	**True Positive A**	Error BA	Error CA
B	Error AB	**True Positive B**	Error CB
C	Error AC	Error BC	**True Positive C**

Figure 28: An example of a three-class confusion matrix to show how the model predictions are evaluated against the reference classification. Correct class predictions are shown along the main diagonal of the confusion matrix. Erroneous classifications are shown in confusion matrix cells off the main diagonal where the predicted class does not equal the reference class.

The general framework for evaluating the performance of a supplier's land use and land cover classification involved assessing the classification accuracy at three different resolutions. Accuracies were calculated at the point, parcel, and supplier levels in order to provide detailed information about the classification quality at each scale. The variation in these metrics is the result of cancellation of classification confusion within the different units of observation (point, parcel, or supplier). When predictions are summarized to a more generalized unit, errors cancel. When calculating accuracy at the point level, no cancellation of errors occurs. Point-level accuracy represents the accuracy of classification at any given location of the super-pixel based mapped classification. When calculating the parcel and supplier-level accuracies, errors are canceled at the parcel and supplier levels, respectively. For example, if 10 square feet of canopy on a parcel is predicted to be irrigated when it should be irrigable-not irrigated and 8 square feet of canopy is predicted to be irrigable-not irrigated when it should be irrigated, at the parcel level, 8 square feet of irrigation status confusion cancels, with 2 square feet of irrigable-not irrigated area remaining misclassified as irrigated. A visualization of this example is shown in Figure 29. A worked example of supplier-level error cancellation is included in Appendix B – Error Cancellation.

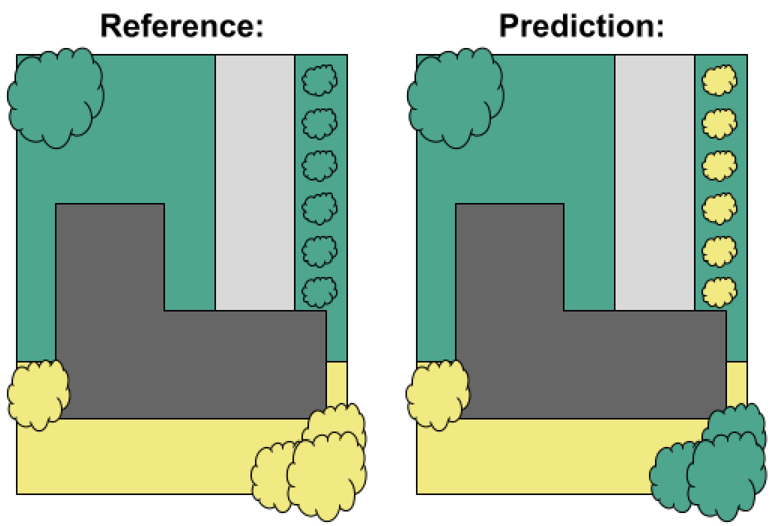

Figure 29: Parcel-level error cancellation visualization.

In addition to calculating accuracies at multiple resolutions, two different types of accuracy assessments were included at each scale. The first is the overall accuracy of the classification and is an accounting of the proportion of correct classifications compared to total classifications (shown in Equation 2). The second is the area-weighted accuracy. In the LAM Project, this is the primary metric used to determine whether the supplier service area modeling has performed appropriately. The area-weighted accuracy metric utilizes the by-class positive predictive value (PPV) (shown in Equation 3) of the un-masked super-pixel objects and the class rates of prevalence across the service area to weight the overall accuracy of the LAM product (shown in Equation 1). Positive predictive value is a measure of the proportion of the true positive predictions to the total number of positive predictions. This descriptive statistic reveals how confident predictions of each class are, i.e., how likely positive predictions represent the positive class in the reference data. Class prevalence was measured by calculating the proportion of class area compared to the total area predicted for an urban retail water supplier, using the topologically corrected parcel layer to make this assessment. Weighting the positive predictive values by the supplier-wide rates of prevalence facilitated the incorporation of the full extent of the derived land masks into the accuracy assessment and allowed us to gain information about the accuracy of predictions across the supplier's service area.

Equations

$$1.\ Weighted\ Accuracy = (PPV_{II} * Rate_{II}) + (PPV_{INI} * Rate_{INI}) + (PPV_{NI} * Rate_{NI}) + (1.0 * Rate_{Mask})$$

$$2.\ Overall\ Accuracy = \frac{Correct\ Predictions}{Total\ Predictions} = \frac{TP + TN}{P + N}$$

$$3.\ Positive\ Predictive\ Value = \frac{TP}{TP + FP}$$

PPV: Positive predictive value | Rate: Class prevalence rate | P: Positive condition | N: Negative condition | TP: True positive | FP: False positive | TN: True negative

Mask Handling in Validation

Special consideration of the derived land masks was required when calculating each type of accuracy for this analysis. Due to the heads-up digitization of the land masks, multiple phases of quality control, and final review by DWR, the positive predictive value used to weight the area of the masked super-pixel objects was considered to be 100%. To avoid overestimating the influence of the masked objects in the weighted accuracy assessment, the positive predictive values for and prevalence of the three irrigation status classes were calculated by isolating only the unmasked reference objects (shown in Figure 30C). The masked objects were then accounted for using their prevalence and a positive predictive value of 100% as shown in Equation 1.

The unweighted overall accuracy incorporated masked objects in a different manner. Because the overall accuracy metric is not weighted by class prevalence, the derived land masks were applied to the reference objects prior to the assessment (shown in Figure 30D). Mask application overrides the model classifications and assigns all masked objects to the not-irrigable class. In the overall accuracy assessment, all reference objects were considered and the proportion of correct predictions to total predictions was calculated (overall accuracy equation shown in Equation 2).

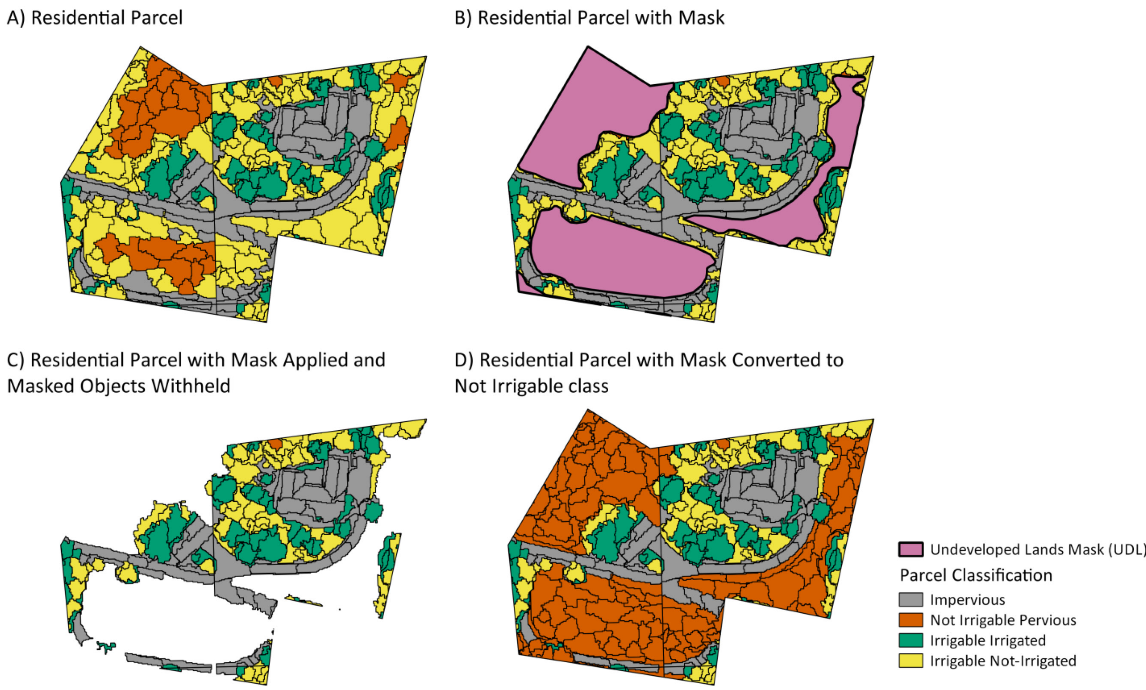

Figure 30: Example of mask handling during model validation. A residential parcel (A) that contains Undeveloped Lands Mask (B) was treated differently when calculating the weighted and unweighted model accuracies. Weighted accuracies were calculated using the positive predictive values of the unmasked super-pixel objects (C) which are weighted by the class prevalence of the not irrigable, irrigable-not irrigated, irrigable irrigated, and mask classes. The unweighted accuracies were calculated by assigning all masked super-pixel objects to the not irrigable class and then calculating the overall accuracy (D).

Pilot Phase Validation Data Comparison

As part of the pilot phase of the LAM Project, Phase 2B urban retail water suppliers (listed in Table 14) went through an additional independent validation exercise using reference data generated by DWR and their consulting team. In this exercise, a parcel-size based stratified random sample of approximately 225 reference parcels were selected by DWR for all Phase 2B pilot service areas. Single-family residential parcels were divided into three parcel size strata for sampling: the bottom 50th percentile, the 50th-90th percentile, and the top 10th percentile. All other parcels in the parcel query were divided into the bottom 90th percentile and the top 10th percentile for sampling. The correct land cover and land use classification, as determined by DWR and their consulting team, was selected for each super-pixel object in the reference parcels to match the urban retail water supplier imagery. These reference data were used to assess the accuracy of the modeling effort in lieu of the NV5 Geospatial reference data for all 2B urban retail water suppliers.

The reference data generated by DWR and their consulting team were also leveraged to evaluate the level of classification agreement between the reference datasets generated by

NV5 Geospatial and DWR. The two validation datasets were created independently using an object-based classification approach following the same classification scheme. Due to differences in the shape and area of super-pixel objects created by the segmentation routines utilized by the two groups, a geographic intersection was performed on the data to identify where the validation data were in agreement and where they were in disagreement.

The results of the in depth 2B validation exercise shaped the model quality standards and external validation metrics used for the LAM Project. Two specific performance criteria were developed for use in the urban retail water supplier modeling effort as a result of the 2B validation assessment.

1. Area-weighted supplier accuracy will be greater than 95%.
2. Precision of accuracy assessment will be determined using the validation parcel count assessment to identify if an asymptote is present in the accuracy curve.

The second criterion was evaluated by running an accuracy simulation in which reference parcel subsets were iteratively selected from the Role 1 parcels and used to assess whether the variation within the urban retail water supplier was appropriately captured and represented in the validation parcel pool. Parcel sampling occurred using a bootstrap approach where *n* number of parcels were randomly selected from the available parcels and used to calculate the supplier-level weighted accuracy. The parcel sampling was repeated many times for each *n* number of parcels and the mean accuracy was plotted. The number of parcels selected (*n*) ranged from 5 to the maximum number of Role 1 parcels in steps of 5. For example, if an urban retail water supplier has 50 Role 1 validation parcels, the accuracy simulation would be generated using groups of 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 parcels. An example of an accuracy simulation is included in Figure 31.

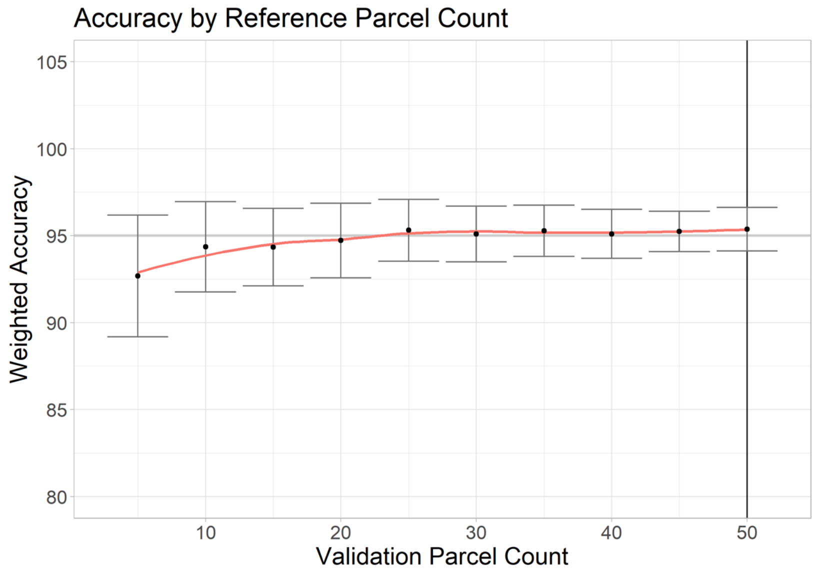

Figure 31: Accuracy simulation example. Parcel sampling occurred using a bootstrap approach where *n* number of parcels were randomly selected from the available parcels and used to calculate the supplier-level weighted accuracy.

The interpretation of the accuracy simulation followed two performance metrics. In order to determine if the variation in the supplier service area was appropriately captured in the modeling effort and the validation parcel subset, the mean simulated accuracy generated using the maximum number of validation parcels must be greater than 95%. If the mean accuracy calculated with the maximum *n* was greater than 95%, then an analyst inspected the accuracy simulation plot (like the one shown in Figure 31) to determine if the plotted accuracies at each *n* number of parcels was approaching an asymptote. If the plotted accuracies are highly variable or the accuracies did not appear to be approaching an asymptote, additional validation parcels were extracted to appropriately capture the variation of the supplier service area. If the mean accuracy calculated with the maximum *n* was less than 95%, additional model tuning was performed.

The employment of these thresholds served to establish close alignment between the work of DWR and NV5 Geospatial while ensuring consistent and accurate results across the entire project area. These standards were set in place to ensure that the data generated in this project are "reasonably accurate for the intended uses, taking into consideration California's diverse landscapes and community characteristics"[2] as directed by AB 1668 and SB 606.

[2] California Department of Water Resources and State Water Resources Control Board, "Making Water Conservation a California Way of Life: Primer of 2018 Legislation on Water Conservation and Drought Planning" (2018), https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Water-Use-And-Efficiency/Make-Water-Conservation-A-California-Way-of-Life/Files/PDFs/Final-WCL-Primer.pdf.

Once initial results were generated for each urban retail water supplier, DWR distributed the data to the agencies to provide an opportunity to review the data, submit feedback related to the parcel query, and determine the ownership of disputed parcels between agencies.

Landscape Area Measurements Feedback

Feedback received from the urban retail water supplier agencies was used to add parcels that were missed using the valid land use code filter, remove parcels that were not being served as single-family or multi-family residential parcels, add or remove disputed parcels from the parcel query, or adjust the service area boundaries that were supplied at the beginning of the LAM Project. All data used to modify the source data in the analysis were submitted to DWR via a Monday.com feedback form (shown in Figure 32). DWR reviewed the feedback and pre-processed the data to prepare it for adjusting the spatial source data layers. The feedback data were then used to make the necessary source data adjustments in a programmatic and ordered manner outlined in Figure 33 and described in subsequent sections.

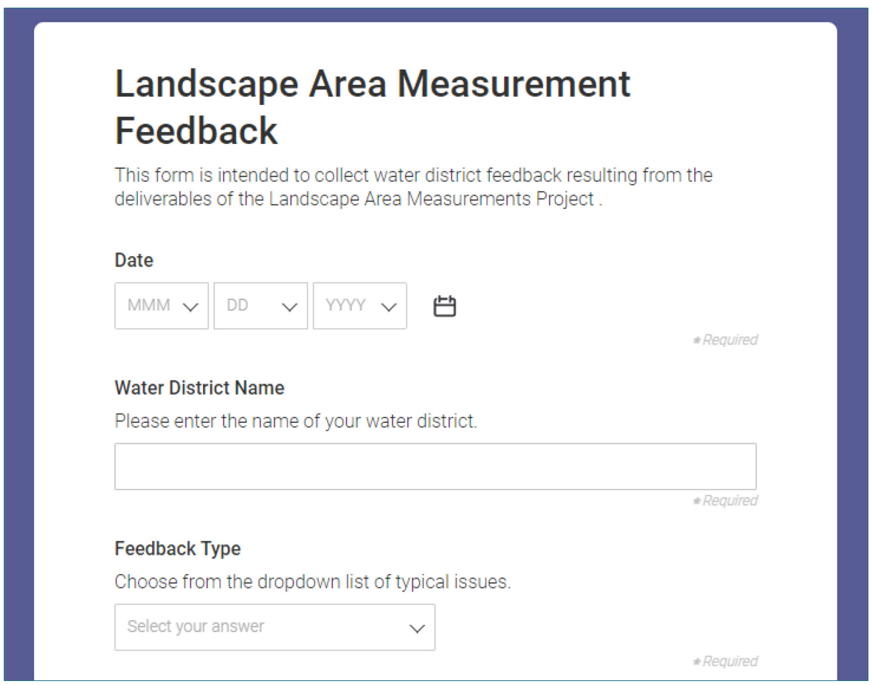

Figure 32: Screen capture of the online form used to submit feedback comments and data for the Landscape Area Measurements Project review process.

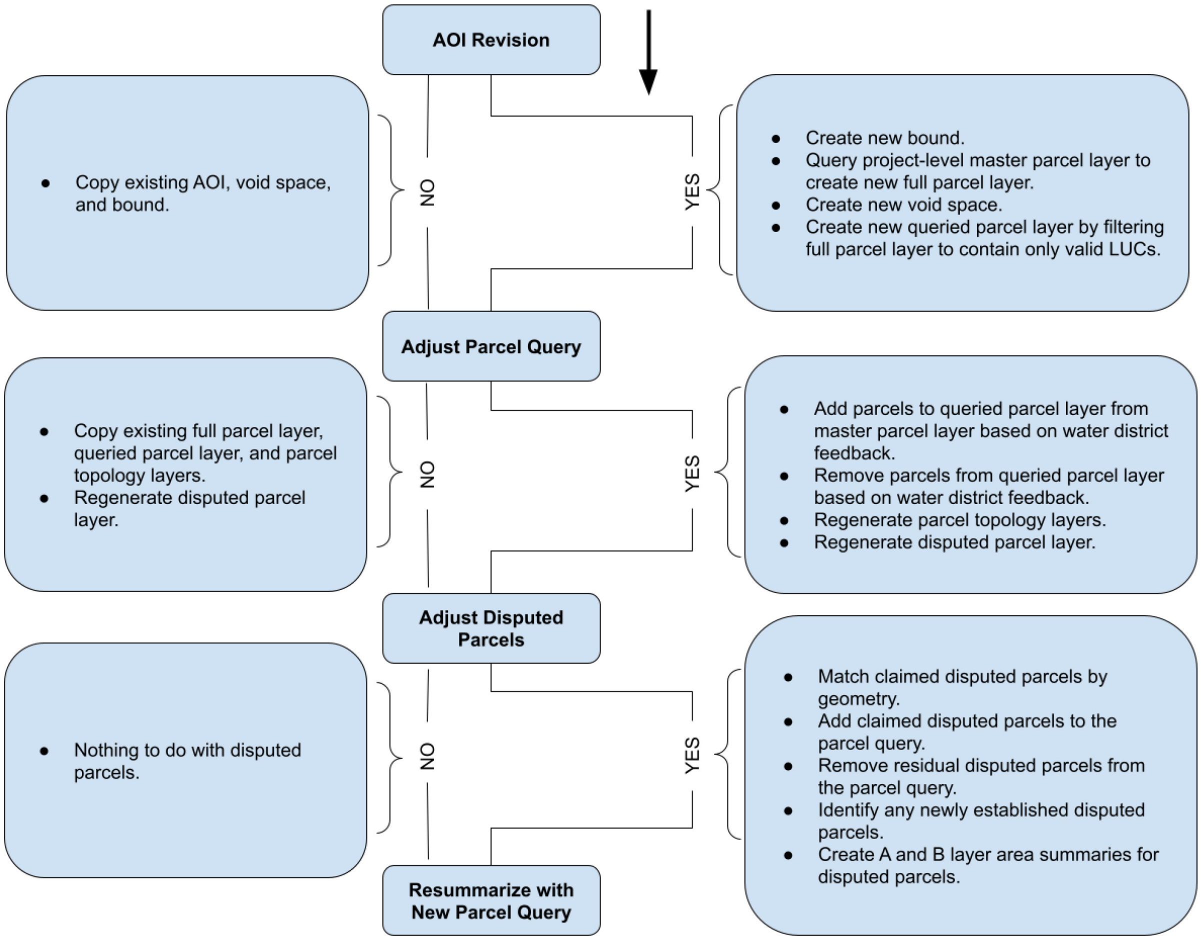

Figure 33: Data adjustment flowchart for processing Landscape Area Measurements Project feedback.

Derived Products

It is important to note that the adjustments to the Landscape Area Measurements data happened at the source data level, i.e., the parcel data or the service area boundary. The derived data generated in the first part of the analysis did not change; they were summarized to different geographic extents. The total extent of the project imagery, modeled results, and parcel layers match that of the originally supplied urban retail water supplier service boundaries and were not modified as a part of the LAM Project review process. Likewise, manually digitized land mask extents match the originally derived parcel query and were not adjusted.

Master Parcel Layer

As a result of feedback received from urban retail water suppliers that included expanded service area boundaries or parcel additions that fell outside of the original supplier service boundary, a project-wide master parcel layer was generated by combining the full parcel layers of all 398 urban retail water suppliers in the analysis. This parcel layer was used for adding parcels into datasets that were not part of a supplier's full parcel layer due to the originally provided service boundary as outlined in The Removal or Addition of Parcels Section.

Updating Parcel Attribution Data

An important outcome of the LAM Project review process was the recognition that parcels with NULL land use codes were impacting the parcel queries of some suppliers within the study. These parcels appeared to represent single-family or multi-family residential lots but did not contain a valid residential land use code. It was determined that the original parcel data were provided in a manner that reduced overlap within the parcel layer by removing exact parcel duplications (for example, only including one parcel out of ten that have identical parcel boundary geometries). This however, reduced the quality of the parcel layer attribution by excluding the Assessor Parcel Numbers (APNs) of duplicated parcels, and reduced the number of valid LUCs with which to generate the single-family and multi-family parcel query. To address this issue, additional parcel attribution data were acquired and attached to the full parcel layers of the urban retail water suppliers. New single-family and multi-family parcel queries were then established and used to generate updated landscape area estimates. All source data feedback and modifications were processed using the updated parcel layers so that all supplier deliveries contain the updated parcel attribution.

Supplier Service Boundary Modifications

For suppliers requiring a service area boundary adjustment, a new supplier boundary (area of interest with a 10-meter outer buffer), full parcel layer, valid parcel query, and void shape were created. During service boundary modifications, the urban retail water supplier service boundary could either expand or contract relative to the original project boundary. If the service boundary modification results in an expansion of the original area of interest, the full parcel layer was regenerated by extracting parcels from the project-wide master parcel layer. When parcels were not available in the master parcel layer due to a lack of coverage in the original parcel datasets, no parcels were included for the region and the new service boundary regions were summarized in the VOID layer. If no imagery was available in the expanded service boundary, landscape areas were summarized to the "NIA" (No Imagery Available) class. Figure 34 shows an example of a service boundary expansion that extends outside of the imagery coverage for the LAM Project.

Figure 34: An urban retail water supplier service boundary modification results in an expansion of the area of interest that extends outside of the available imagery for the Landscape Area Measurements Project. The black and white regions of the map represent locations without imagery coverage.

Imagery © 2023 Hexagon and data partners.

The Removal or Addition of Parcels

Parcels that needed to be removed from an urban retail water supplier's parcel query were geometrically matched to the parcel layer and removed from the query to generate an updated single-family and multi-family residential parcel layer. Suppliers that required new parcels to be added to their parcel query went through a parcel addition process. The parcels to be added to the query were geometrically matched to and extracted from the master parcel layer whenever possible. However, when the agency-supplied parcels were not found in the master parcel layer, either because they were outside of the master parcel layer coverage or because the supplier submitted their own parcel layer with parcel geometries different than those in the master parcel layer, these parcels were brute force appended to the queried parcel layer. Most brute force appended parcels did not contain the full attribute data required of the queried parcel deliverable and therefore contain NAs in the field where the information is missing. Additionally, brute force appended parcels may not have had imagery coverage due to the original extent of the urban retail water supplier boundary. In the case that no imagery was available, landscape areas for these parcels were summarized to the "NIA" (No Imagery Available) class. Finally, some brute force appended parcels covered regions of parcels already captured in the parcel query due to differences in parcel geometries coming from different datasets (Figure 35). If parcels were duplicated due to the brute force appending of parcels that needed to be added, the overlap was resolved by the topological correction of the parcel layer and did not impact the supplier-level landscape area measurements.

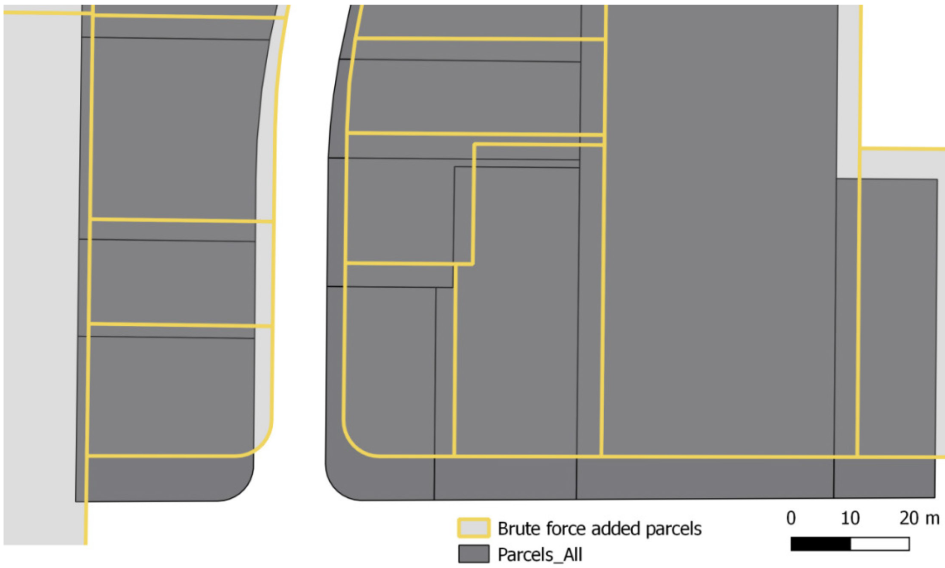

Figure 35: An example where an urban retail water supplier supplied parcels to add to the analysis that had different geometries and georeferencing than the parcels used in the Landscape Area Measurements analysis.

Disputed Parcel Adjustments

To revise the parcel query and assign disputed parcels to their correct urban retail water supplier, agencies were advised to work with neighboring urban retail water suppliers and establish ownership of disputed parcels that fall within two or more service area boundaries. Disputed parcel feedback was formatted such that only parcels claimed by the supplier were submitted to NV5 Geospatial for inclusion in the single-family and multi-family residential parcel query.

Disputed parcels that are claimed by an agency are added to the parcel query while the remaining disputed parcels are removed from the parcel layers because they are served by a different supplier. The original disputed parcels were selected from the parcel layer that was generated prior to the inclusion of the additional parcel attribution used to repair NULL land use codes. Due to parcel layer updates that correct for NULL land use codes, disputed parcels may remain after the disputed parcel adjustment. Disputed parcels may also remain after feedback adjustments were complete due to service boundary modifications or a lack of response from the disputing urban retail water suppliers. The remaining disputed parcels were delivered as a separate geodatabase feature class, and their landscape area estimates were summarized according to the original and topologically corrected parcel layers. The disputed parcel landscape area summaries were not included in the urban retail water supplier landscape area totals included in the pdf report or in the “Area_of_Interest” feature class.

No Imagery Available

A populated NIA (No Imagery Available) field in the landscape area summaries can be caused by service boundary expansions, parcel additions outside of the original supplier boundary, and specular reflectance in the imagery. Specular reflectance in regions of the urban retail water supplier imagery causes all four bands of the source imagery to contain 255 values, which the imagery segmentation routine then identifies as ‘no data’ and therefore does not represent the region as an imagery object to classify (Figure 36). These regions are typically 1.2 meters squared in area but range up to 5.2 meters squared. This results in a landscape area classification of NIA in specular reflectance pixel zones. The NIA class is not included in the ‘MODEL_AREA’ total of the parcel summaries because there was no available data on which to model.

Figure 36: The glare from the car shown in this image has caused specular reflectance in the imagery. The white arrow points to the bright region of specular reflectance that would be represented as NIA in the landscape area summaries.

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Delivery Formats for Adjusted LAM Results

Suppliers requiring parcel query or service boundary modifications were summarized using an updated delivery format. The updated delivery format includes the NIA class, and the landscape area summaries for outstanding disputed parcels divided as “Parcels_A_Disputed” and “Parcels_B_Disputed” for the original and topologically corrected parcel layers, respectively. Suppliers that did not require adjustments were delivered according to the original delivery schema, not containing disputed parcel landscape area summaries, nor the NIA class. If any of the suppliers that did not require adjustments had cases of specular reflectance, those cases were treated as having been fully modeled by taking the proportions of the irrigation classes across the parcel and extending those proportions to match the full parcel area.

LAM Summary Portal

To offer continued support for creating modified Residential LAM datasets based on supplier feedback, NV5 Geospatial has created a LAM Summary Portal for use by DWR. The Summary Portal accepts queried parcel datasets as inputs to the system and provides landscape area measurement summaries as outputs (where predictions were already created in the LAM Project). Table 15 denotes the supplier results that have been created using the Summary Portal.

During the 2018 LAM Project, some regions of the project area were identified to have imagery capture conditions that were not suitable for photo interpretation or modeling of the ground condition. Highly forested service areas exhibited severe shadowing from tree canopy and/or minimal ground visibility in areas of dense canopy. In these service areas the native tree canopy obscures visibility of parcel landscape features. Figure 37 demonstrates an area with high canopy cover and shadowing in South Tahoe.

Limited ground-level visibility in these service areas has resulted in a large proportion of the landscape being classified as the 'not irrigable' irrigation status classification. Upon 2018 LAM Project review, landscape area predictions were not perceived to reflect the ground conditions within some supplier service area boundaries despite passing the accuracy specification outlined in the 2018 LAM Project. For this reason, four urban retail water suppliers were selected for a follow-on assessment designed to explore the impacts of canopy on predicted irrigation status throughout forested regions of California included in the 2018 LAM Project.

- South Tahoe (SOUTHTAHOEPU349)
- North Tahoe (NORTHTAHOEPU245)
- Tuolumne (TUOLUMNEUTIL368)
- Georgetown (GEORGETOWNDI131)

Figure 37: An example of aerial imagery and parcel boundaries from South Tahoe. Shadows and tree crowns dominate the imagery and obscure the ground-level landscape features of the parcels.

Imagery © 2023 Hexagon and data partners.

Forested Service Area Methods

The forested service area assessment incorporated publicly available Light Detection and Ranging (lidar) datasets into the LAM analysis. Lidar uses laser pulses to collect three-dimensional information about the earth's surface. The combination of lidar and imagery allowed for spectral and structural thresholding of the service area to select a parcel subset with enough ground visibility to model the ground condition. The results of the subset analysis were then used to represent the larger service area in regions that could not be modeled from an aerial perspective.

Lidar Source Data

North Tahoe:

- Pre-processed canopy height model (1 meter resolution) acquired from OpenTopography[3]
  - Source Lidar Point Density: 11.82 points per square meter
  - Survey Date: 8/11/2010 - 8/24/2010

South Tahoe:

- Pre-processed canopy height model (1 meter resolution) acquired from OpenTopography[3]
  - Source Lidar Point Density: 11.82 points per square meter
  - Survey Date: 8/11/2010 - 8/24/2010

Tuolumne:

- LAZ Files - CA CalaverasTuolumne 2011[4]
  - Point Density: 6.20 points per square meter
  - Survey Date: 11/21/2011 - 12/12/2011

Georgetown:

- LAZ Files - CA UpperSouthAmerican Eldorado 2019[5]
  - Point Density: 43.18 points per square meter
  - Survey Date: 10/21/2019 - 03/05/2020
- LAZ Files - USGS LPC CA NoCAL Wildfires B1 2018[6]
  - Point Density: 10.95 points per square meter
  - Survey Date: 07/14/2018 - 08/20/2018

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[3] Watershed Sciences, Inc. (2010). Lake Tahoe Basin LiDAR, Airborne Lidar, distributed by OpenTopography. https://doi.org/10.5069/G9PN93H2

[4] U.S. Geological Survey. (2014). 3D Elevation Program Lidar Point Cloud (ver. - CA CalaverasTuolumne 2011), accessed December 14, 2021 at URL https://apps.nationalmap.gov/lidar-explorer

[5] U.S. Geological Survey. (2021). 3D Elevation Program Lidar Point Cloud (ver. - CA UpperSouthAmerican Eldorado 2019), accessed December 14, 2021 at https://apps.nationalmap.gov/lidar-explorer

[6] U.S. Geological Survey. (2020). 3D Elevation Program Lidar Point Cloud (ver. - USGS LPC CA NoCAL Wildfires B1 2018), accessed December 14, 2021 at https://apps.nationalmap.gov/lidar-explorer

Lidar Processing

For two of the service areas in this analysis (South and North Tahoe) a preprocessed canopy height model was available for download from OpenTopography[3]. No additional processing was required prior to incorporating the data into the analysis. For the Tuolumne and Georgetown service areas, the lidar was downloaded, filtered for noise, height normalized, and processed into a raster canopy height model with a resolution of one meter. A canopy height model represents the height above ground for features in the lidar point cloud. It is calculated by subtracting the digital terrain model from the digital surface model. This results in a dataset where ground level is set to 0 and all other heights are represented relative to ground level.

Parcel Selection

In order to create a modeled product that reflects the ground condition in these forested service areas, a subset of parcels with sufficient ground level visibility was required. Ideal parcels would have minimal canopy occlusion and shadowing. To support parcel selection, structural and spectral metrics were created from the imagery and lidar to describe each parcel. Once the metrics were calculated, appropriate thresholds were set, and a representative sample of parcels throughout each service area was selected.

Ground level visibility was determined through the implementation of structural and spectral thresholds that assess occlusion due to above-ground features and cast shadows. Using the canopy height model, a structural metric, deemed parcel openness, was created for each parcel to identify sufficiently uncanopied parcels in this analysis. Parcel openness was calculated by measuring the percentage of area within a parcel that is less than 1.5 meters tall relative to the total area. Features less than 1.5 meters tall are assumed to provide visibility to ground level features such as shrubs, turf, and impervious surfaces. Features greater than 1.5 meters tall, such as trees and buildings, are assumed to obscure visibility to ground level. Parcel openness allows for the quantification of ground level occlusion caused by canopy, buildings, and other features.

For the Tahoe service areas, an additional spectral metric was developed to support the selection of parcels with ground level visibility. Extensive shadowing was present in the Tahoe imagery due to mountainous terrain and imagery collection conditions. In order to detect shadows and measure their extent, a shadow mask was generated based on the Red Green Blue (RGB) Brightness of the imagery pixels. The pixel brightness was measured by the sum of the red, green, and blue values divided by the maximum brightness (255). Black pixels have very low RGB brightness while white pixels have high RGB pixel brightness. Shadows are expected to have low RGB pixel brightness. A threshold was set for pixel brightness that identified shadowed pixels and was customized for each imagery set. Parcels with low proportions of shadowed pixels and high parcel openness represent ideal parcels for modeling.

Parcels with at least 35% parcel openness were selected for inclusion in the analysis. In the Tahoe service areas, parcel openness and pixel brightness thresholds were combined to identify open ground that was not obscured by shadows and was therefore appropriate for photo interpretation. In South Tahoe and North Tahoe, parcels with at least 35% parcel openness and less than 50% of the open ground containing shadow were selected as the parcel subset. For Georgetown and Tuolumne, parcels with at least 35% parcel openness for the areas not covered by the Undeveloped Lands Mask were selected and used as the valid parcel subset. Spectral metrics assessing shadow extent were not relevant to Tuolumne or Georgetown.

Additionally, all queried parcels with land use codes between 0-999 and 2000-3999 were removed from the single-family and multi-family queried parcel datasets at DWR's request (valid land use query outlined in Table 18). Table 7 summarizes the results of the parcel subsetting procedure for each supplier. The 'Subset' parcel layer represents the subset of the full single- and multi-family layer selected using the spectral and structural thresholds.

Table 7: Summary of parcel subset selection results. Asterisk (*) in "Mean Percent Open Ground" column indicates the representation of mean percent open ground of parcel areas not captured in the Undeveloped Lands Mask. Parcel Count, Mean Percent Shadow, Mean Percent Open Ground, and Mean Parcel Size were calculated from the original parcel layer (Parcels A). Total acreage was calculated from the topologically corrected parcel layer (Parcels B). See the Parcel Topology Handling section for additional information on parcel datasets and transformations.

Supplier	Subset Parcel Count	Subset Acreage	Proportion of Full Supplier Parcel Count (%)	Proportion of Full Supplier Area (%)	Mean Percent Shadow (%)	Mean Percent Open Ground (%)	Mean Parcel Size (acres)
South Tahoe	11,716	993.8	31.7	28.4	31.1	56.8	4.7
North Tahoe	703	229.6	18.7	32.9	35.1	48.3	0.5
Tuolumne	4,134	7,157.1	33.8	53.5	NA	48.8*	2.5
Georgetown	1,105	4,307.0	34.2	33.5	NA	51.4*	3.9

Modeling

Once the representative parcel subset was selected, a general land cover and land use model was applied to the selected parcels and landscape area measurements were summarized. The lidar-derived products were not used in the modeling process due to the age of the lidar datasets. Lidar data were only used during parcel subset selection.

Once the landscape area measurement summaries were created for the parcel subset, the results were extrapolated to the total area of the single-family and multi-family parcel query following a procedure provided by DWR. Irrigation status summaries for parcels outside of the modeled subset were estimated by calculating the proportions of irrigable irrigated and irrigable-not irrigated areas predicted in the parcel subset and multiplying them by the square area of the single-family and multi-family parcel layer that was excluded from the parcel subset.

The calculated irrigable irrigated and irrigable-not irrigated values for the parcels outside of the modeled subset were then multiplied by 0.6 as an adjustment factor for heavily canopied landscapes. This method extends the proportions of the parcel subset to the full parcel query. Table 15 contains the results for Georgetown, Tuolumne, North Tahoe, and South Tahoe generated using the forested service area methods.

2020 Landscape Area Measurements

In 2021, DWR contracted NV5 Geospatial to continue the LAM Project by providing updated estimates of outdoor landscape area measurements for single-family and multi-family residential parcels across 20 urban retail water suppliers (Table 8) in California using 2020 source imagery. The 2020 project was focused on creating updated landscape area measurement estimates for the pilot districts that were originally classified using 2016 imagery. Two Phase 3 districts (Casitas Municipal and Valley of the Moon) were included due to missing coverages in the original LAM 2018 Project.

Table 8: Suppliers included in the 2020 Landscape Area Measurements Project. WDID = Water District Identifier.

Phase	Agency Name	WDID	Contract Number
2B	Arroyo Grande City Of	ARROYOGRANDE013	013
2B	Calaveras County Water District	CALAVERASWDI035	035
2B	California Water Service Company - Bakersfield	BAKERSFIELDC043	043
2B	California Water Service Company - East Los Angeles	EASTLOSANGEL047	047
3	Casitas Municipal Water District	CASITASCITYC404	404
2B	City of Redding	CITYOFREDDIN284	284
2B	Desert Water Agency	DESERTWATERA096	096
2B	Folsom City Of	FOLSOMCITYOF123	123
2B	Glendale City of	GLENDALECITY133	133
2B	Great Oaks Water Company Incorporated	GREATOAKSWAT153	153
2B	Joshua Basin Water District	JOSHUABASINW176	176
2B	Las Virgenes Municipal Water District	LASVIRGENESM189	189
2B	McKinleyville Community Services District	MCKINLEYVILL215	215
2A	North Marin Water District	NORTHMARINWA244	244
2B	Olivenhain Municipal Water District	OLIVENHAINMU251	251
2B	Pleasanton City Of	PLEASANTONCI274	274
2A	Rancho California Water District	RANCHOCALIFO282	282
2B	Redwood City	REDWOODCITYW286	286
2B	Santa Cruz City Of	SANTACRUZCIT329	329
3	Valley Of The Moon Water District	VALLEYOFTHEM380	380

2020 Update Methods

In the 2020 LAM update, an improved modeling framework was developed and implemented. In the 2018 LAM Project, an object-based imagery analysis was used to classify the land cover and irrigation status of landscapes contained within single-family and multi-family residential parcels. Through internal testing of more current deep learning algorithms, it was determined that the LAM program would be better supported by leveraging an alternative modeling framework. In the 2020 analysis, a convolutional neural network (CNN) was used to classify the areas of interest for the pilot districts originally modeled with 2016 imagery. The classification scheme for land cover and irrigation status was unchanged.

The primary benefit of a CNN for the targeted classification scheme, compared to object-based imagery analysis, is the increased influence of surrounding contextual information and feature proximity in the classification. In a CNN framework, the classifier more effectively utilizes information from adjacent and proximate features when predicting land cover and irrigation status. Increased consideration of feature context allows for more accurate and consistent classification of landscape features within hydro-zones.

Landscape Area Measurements Changes: 2016-2020

Changes in irrigation status assessments between 2016 and 2020 were the result of changes in the extent and composition of queried single-family and multi-family parcels, true change in irrigation practices, and may have been influenced by the seasonality of imagery collection, water availability, and land use model performance.

True Change in Irrigation Practices

Landscape compositions and outdoor water use changes directly influence the irrigation status composition of residential parcels. Parcel landscapes can transition from primarily not irrigable (NI) to irrigated (II) through new residential development (Figure 38A). They can also transition from irrigated (II) to irrigable not-irrigated (INI) by allowing healthy turf to senesce (Figure 38B). The application of water can also transition senesced irrigable-not irrigated (INI) turf to irrigated (II) turf (Figure 38C). Additionally, parcel landscapes can transition from irrigated (II) or irrigable-not irrigated (INI) to not-irrigable (NI) via the installation of artificial turf or the construction of impervious surfaces (Figure 38D).

Figure 38: Generalized examples of irrigation status change on residential parcels over time. Example A demonstrates irrigation status change from not irrigable (NI) to impervious and irrigable irrigated (II) due to new development. Example B demonstrates a change in the irrigation status from irrigable irrigated (II) to irrigable-not irrigated (INI). Example C demonstrates a change in the irrigation status of the turf grass from irrigable not-irrigated (INI) to irrigable irrigated (II). Example D demonstrates a change in the irrigation status of the turf grass from irrigable-not irrigated (INI) in 2016 to not irrigable (NI) due to the installation of artificial turf.

Imagery © 2023 Hexagon and data partners.

Changes in Parcel Query

Changes in the location and number of valid single-family and multi-family residential parcels between analysis years were the result of the updated parcel data, the refined land use code query, new development within the supplier service area, and land use code change on existing parcels.

Updated Parcel Data

The parcel datasets used in the 2020 analysis contained updates and modifications that differentiated them from the 2016 datasets. Changes in land use attribution, parcel geolocation, parcel subdivision, and parcel boundaries were present throughout the project area. For some service areas, a shift in parcel footprints occurred systematically across the parcel layer and was a result of changes implemented at the county assessor level. The attribution and spatial representation of parcel datasets were not modified in any way by NV5 Geospatial or DWR as a part of this project.

Updated Land Use Code Query

Through the course of previous work and based on feedback from suppliers, the valid single-family and multi-family land use code subset was refined in the 2020 analysis. It was determined that land use codes in the “Miscellaneous” and “Commercial” categories (codes between 0010-0999 and 2000-3999, respectively) generally did not contain residential landscape features. Therefore “Miscellaneous” and “Commercial” codes that were previously included in the 2018 LAM analysis were removed to better isolate single-family and multi-family residential parcels. The refined parcel query implemented in the 2020 LAM Project included “Residential (Single)”, “Residential Income (Multi-Family)”, and select “Institutional” and “Historic-Private” codes. The full list of land use codes is included in Table 17 and the updated single-family and multi-family query is provided in Table 18.

New Development

Parcel additions and removals between analysis years may result in different total areas that are assessed and impact the varieties and quantities of specific landscape types that are assessed. This has the potential to influence the proportions of irrigated, irrigable, and not irrigable features represented for a supplier. Parcels are most commonly added and removed from datasets through the process of new development via parcel subdivision. During parcel subdivision, an existing parcel within the service area is divided into multiple parts that become new parcels. These parcels are given new Parcel Identification Numbers (PIN) and other parcel attributes while the larger parcel that was subdivided is removed from the dataset. Figure 39 shows an example of new development and subdivided parcels in the Pleasanton service area.

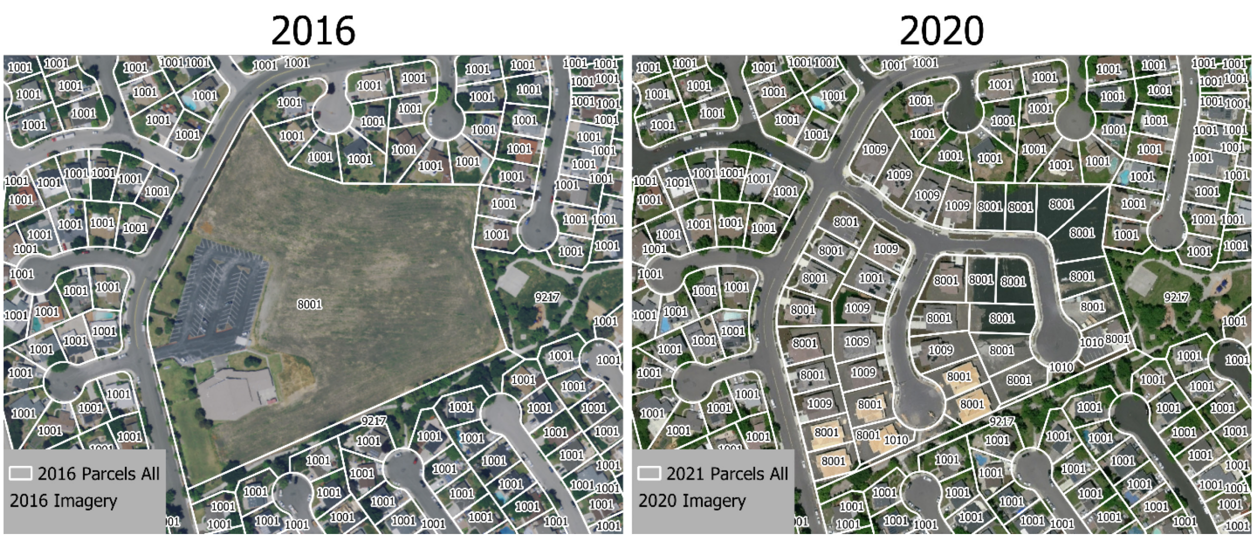


Figure 39: New development and parcel subdivision in Pleasanton. Left: 2016 imagery and parcel layer. Right: 2020 imagery and parcel layer.

Imagery © 2023 Hexagon and data partners.

Model Performance

The implementation of an updated modeling framework in the 2020 LAM Project introduced variations in the LAM results over time. In some areas these variations were not indicative of true change in the landscape but instead represented enhanced performance and contextual considerations of the new modeling approach. The 2020 model displayed greater ability to classify hydro-zones into uniform irrigations statuses than the modeling methods used in classifying the 2016 data. As a result, more canopy was classified as ‘irrigable-not irrigated’ in 2020 relative to the original 2016 LAM results. Another impact is that more non-vegetated ground cover within planting beds, such as bare soil in gardens or mulched areas between shrubs, was classified as ‘irrigable irrigated’. NV5 Geospatial recognizes that these impacts require consideration in interpretation of the results but is confident the improved modeling framework yields an overall more accurate product to support the LAM program moving forward.

Changes in Imagery

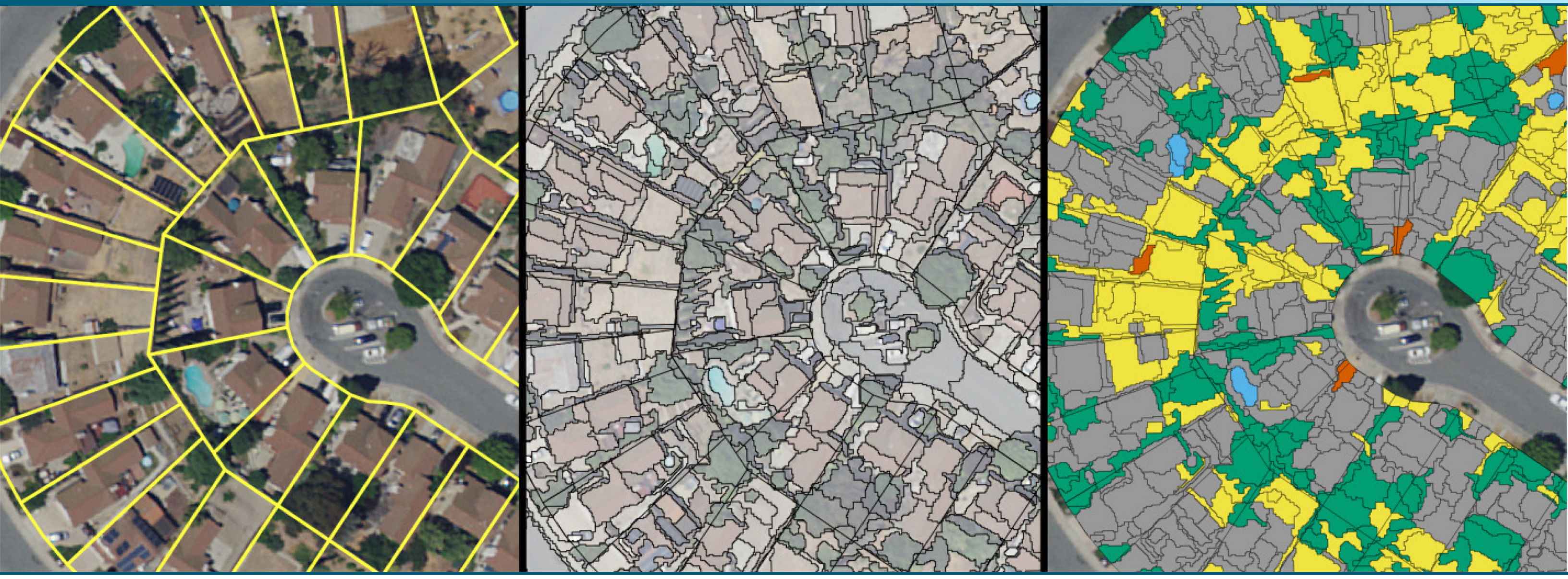
Imagery capture conditions may vary between acquisition years, creating visual differences in the source imagery collected for each analysis period. The imagery capture date, seasonal water availability, and weather conditions may impact the vibrancy and greenness of vegetation captured within a service area. Imagery capture conditions and post processing methods may also impact the clarity, color balance, and sharpness of the source imagery.

2020 Landscape Area Measurement Results

Outdoor landscape area summaries were provided for each of the 20 suppliers following the format of the 2018 LAM Project deliverables. Parcel-level summaries were delivered according to the ten-class land cover and use classification scheme outlined in Table 10 and according to the irrigation status classification outlined in Table 9. Parcel summaries were created for the original parcel layer (Parcels A) and the topologically corrected parcel layer (Parcels B).

Additionally, an analysis of change between 2016 and 2020 was performed for each Phase 2A and 2B supplier. No overarching trend in land cover and use classification was found across suppliers. Rather, the increase or decrease of irrigable landscapes over time were different between suppliers. The results of the change analysis for each supplier are included in the supplier-specific reports provided with the data deliveries.

CONCLUSION



The results of the 2018 and 2020 LAM Projects provide parcel and supplier level estimates of irrigated, irrigable-not irrigated, and not irrigable areas for the 398 urban retail water suppliers in the analysis. A total of approximately 9.6 million queried parcels across 14,000 square miles were modeled and assessed as a part of the LAM Projects.

Urban retail water suppliers were composed of 23.3% irrigated area, 11.8% irrigable-not irrigated area, and 64.9% of not irrigable area on average (standard deviations: 8.8% II, 5.7% INI, and 9.3% NI). The diverse landscape types and ecoregions represented by the urban retail water suppliers in this analysis resulted in equally diverse urban retail water supplier irrigation status compositions. Urban retail water supplier-level irrigated area percentages ranged from 0.3% to 46%, while irrigable-not irrigated area percentages ranged from 0.05% to 30%, and not irrigable area percentages ranged from 38% to 97%. Supplier-level irrigation status values were calculated from the topologically corrected parcel layer (Parcels B). See the Parcel Topology Handling section for additional information on parcel datasets and transformations. The complete list of supplier-level irrigation status summaries is contained in Table 15 of Appendix D – Urban Retail Water Supplier Irrigation Status Compositions. Figure 40 shows the distribution of supplier-level irrigation status compositions represented by the 398 urban retail water suppliers in this analysis.

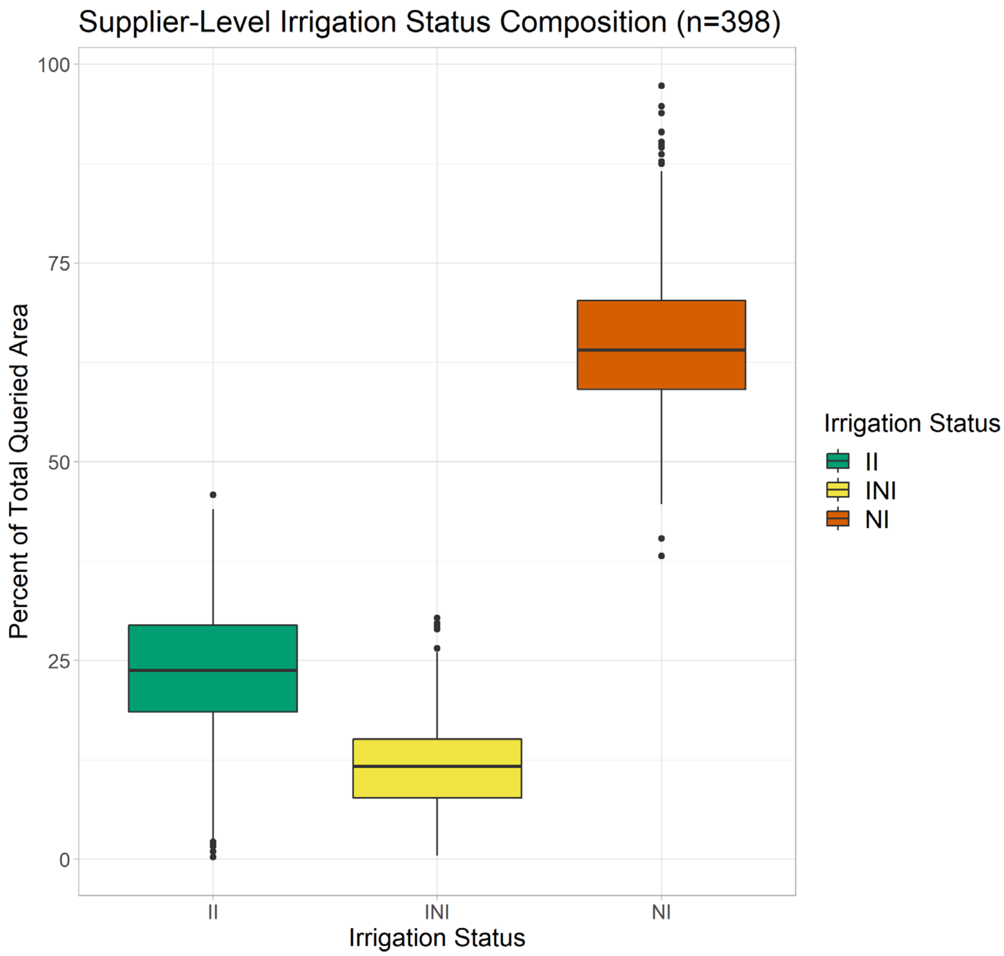


Figure 40: Box and whisker plot describing the range of urban retail water supplier-level irrigation status compositions for the Landscape Area Measurements Project. Irrigation status percentages represent the percent of irrigated (II), irrigable-not irrigated (INI), and not irrigable (NI) area compared to the total area of the topologically corrected, queried parcel layer (Parcels B) for the urban retail water suppliers in the study (n=398). Each box, whisker, and point set represents the range of values seen across the 398 urban retail water suppliers in the analysis. The boxes extend from the 25th to the 75th percentile of the data range. The horizontal line across the middle of each box represents the median percentage for that irrigation status. The whiskers of the boxes extend to the largest and smallest values no further than 1.5 times the interquartile range. Individual points plotted beyond the whiskers show suppliers that are identified as outliers of the whisker range.

Single-family and multi-family residential parcels contained in this analysis ranged from 0.004 square feet to 1,305 acres in size and averaged 1.0 acres (standard deviation: 4.86 acres). The average irrigation statuses at the parcel-level were 25.4% irrigated area, 10.3% irrigable-not irrigated area, and 64.3% of not irrigable area (standard deviations: 16.2% II, 12.9% INI, and 18.8% NI). Parcel-level size and irrigation status values were calculated from the original parcel layer (Parcels A). See the Parcel Topology Handling section for additional information on parcel datasets and transformations. Figure 41 shows the average landscape area compositions for single-family and multi-family residential parcels, respectively. Table 16 of Appendix E – Results Summary by Land Use Code shows the mean and median landscape area composition for each land use code contained in the queried parcels of the analysis.

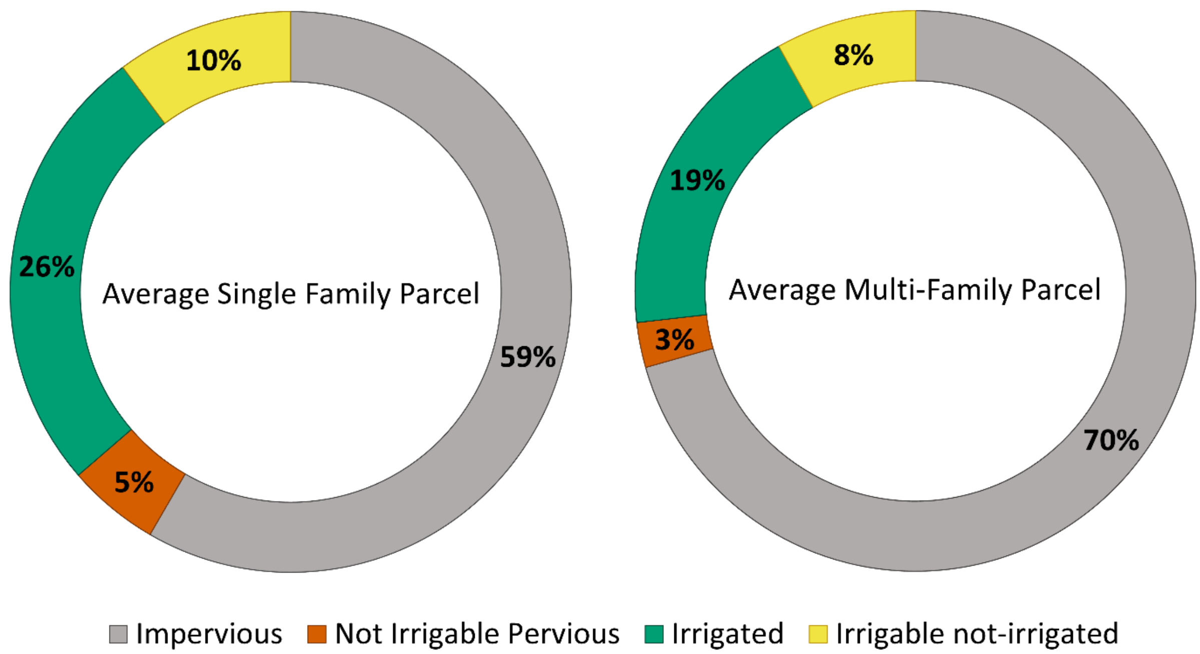


Figure 41: Pie charts showing average single-family and multi-family residential parcel landscape area compositions. Single-family residential parcels are considered those with land use codes between 1000 and 1019. Multi-family residential parcels are considered those with land use codes between 1100 and 1999. Land use codes are defined in Table 17.

Table 9: Irrigation status identification codes.

Irrigation Status	Code	Included from 10-class	Codes for included 10-class classes
Not irrigable	NI	Impervious, Not irrigable pervious, Undeveloped lands, Horse corrals, Open water, Artificial turf, Agricultural lands	1, 5, 6, 7, 8, 9, 10
Irrigable irrigated	II	Pools, Irrigated pervious	2, 3
Irrigable-not irrigated	INI	Irrigable-not irrigated pervious	4

Table 10: Ten-class identification codes.

Class	Code
Impervious	1
Pools	2
Irrigated pervious	3
Irrigable-not irrigated pervious	4
Not irrigable pervious	5
Undeveloped lands	6
Horse corrals	7
Open water	8
Artificial turf	9
Agricultural lands	10

Table 11: 28-class classification codes and descriptions.

Irrigation Status	Land Cover	Class	Class Code	Description
NI	**Structures**	**1A**	**11**	Houses, garages, sheds, decks, swing sets, and solar panels on a structure.
NI	**Roads**	**1B**	**12**	Roads (gravel and asphalt). *Do not use this class in rock landscape beds.*
NI	**Concrete**	**1C**	**13**	Concrete, pavers, and brick (sidewalks and empty pools).
-	**-**	**1D**	**-**	Empty slot
NI	**Other**	**1E**	**15**	Other impervious objects: Solar panels on the ground, tarps over pools, shade tarps, retention walls, fences, boulders, rocks, tennis courts or movable objects presumably on impervious surfaces such as garbage bins, umbrellas, patio furniture, trampolines.
NI	**Vehicles**	**1F**	**16**	Vehicles or tractors on roadways or driveways.
NI	**Artificial Turf**	**9A**	**91**	Artificial Turf (Homogenous color, smooth texture).
II	**Pools**	**2A**	**21**	Pools (inset or above ground), hot tubs, koi ponds, and man-made water features or fountains larger than 64 square feet in area.
II	**Turf**	**3A**	**31**	Lawn (>60% healthy growth), smooth in texture.
II	**Canopy**	**3B**	**32**	Shrubs, trees, and vegetation with healthy growth *(large enough to cast shadows).*
II	**Ground Cover**	**3C**	**33**	Ground cover between irrigated vegetation: landscaping mulch & rock, or coarse grasses (*plantings do not cast shadows). (If planting beds are greater than 10% planted).*
II	**Bare Earth**	**3D**	**34**	Rarely used: Bare earth between irrigated plantings or orchards.
II	**Vehicles**	**3E**	**35**	Vehicles, tractors, or other movable objects such as garbage bins, umbrellas, tarps on vehicles or boats that are presumably on irrigated landscapes.
II	**Trampolines**	**3F**	**36**	Trampolines that are presumably on irrigated vegetation.
INI	**Turf**	**4A**	**41**	Lawn (> 40% browning): water stressed grass with evidence of past irrigation. Should be smooth in texture (if coarse textured it should be 4C: ground cover).

Irrigation Status	Land Cover	Class	Class Code	Description
INI	**Canopy**	**4B**	**42**	Shrubs, trees, and vegetation adjacent to irrigable-not irrigated landscapes or visibly water stressed *(large enough to cast shadows). (Structured planting bed less than 10% planted).*
INI	**Ground Cover**	**4C**	**43**	Ground cover between class irrigable-not irrigated vegetation: landscaping mulch and rock, or coarse grasses *(plantings do not cast shadows). (Structured planting bed less than 10% planted even if healthy).*
INI	**Bare Earth**	**4D**	**44**	Rarely used: Bare earth between irrigated plantings or orchards.
INI	**Vehicles**	**4E**	**45**	Vehicles, tractors, or other movable objects such as garbage bins, umbrellas, tarps on vehicles or boats that are presumably on irrigable-not irrigated landscapes.
INI	**Trampolines**	**4F**	**46**	Trampolines that are presumably on irrigable not irrigated vegetation.
-	**-**	**5A**	**-**	Empty slot
NI	**Canopy**	**5B**	**52**	Shrubs, trees, and vegetation that are typically native, not planted in rows, or do not have any prior evidence of irrigation *(casts shadows).*
NI	**Ground Cover**	**5C**	**53**	Generally native grasses, pasturelands that are puffy or textured in appearance and do not contain any prior evidence of irrigation (*plantings do not cast shadows). Planting beds with rock-mulch, but no plants.*
NI	**Bare Earth**	**5D**	**54**	Bare earth that is very smooth in texture. Can be dirt roads, cleared earth around newly constructed homes, or abandoned urban lots.
NI	**Vehicles**	**5E**	**55**	Vehicles, tractors, or other movable objects such as garbage bins, umbrellas, tarps on vehicles or boats that are presumably on not irrigable landscapes.
NI	**Trampolines**	**5F**	**56**	Trampolines that are presumably on not irrigable landscapes.
NI	**Undeveloped Lands**	**6A**	**-**	**Class NOT used while classifying reference parcels. Classified using a vector layer that represents the Undeveloped Lands Mask (in context of irrigation). Represents any areas deemed not irrigated by humans; they can be abandoned urban lots or native landscapes containing trees, grasses, and wetlands.

Irrigation Status	Land Cover	Class	Class Code	Description
NI	**Horse Corrals**	**7A**	**-**	**Class NOT used while classifying reference parcels. Classified using a vector layer that represents the Horse Corral Mask. Represents horse corrals and arenas that are usually round or oval. Generally smooth soil texture and may contain signs of watering.
NI	**Open Water**	**8A**	**81**	Ocean coastline, lakes, rivers, or retention ponds.
NI	**Agricultural Lands**	**10A**	**-**	**Class NOT used while classifying reference parcels. Classified using a vector layer that represents the Agricultural Lands Mask. Represents large commercial agriculture that can be identified by vegetation planted in rows (row crops, vineyards, nurseries), trees planted in formations or rows (fruit and nut orchards or nurseries), clear signs of management with irrigation or the intention to irrigate (plowed, tilled, circular irrigation patterns, flood irrigation, presence of pivots/irrigation lines or discolored soils), or irrigated livestock pastureland.

Area Based Error Cancellation Procedure

1. Create a confusion matrix using reference data against model predictions for the mapped product.
2. When calculating the error rate for a summary unit (map, parcel, or supplier), confusion that is internal to the unit is allowed to cancel.
3. The residual error is calculated as the over-predicted class minus the under-predicted class.
4. The residual error is carried forward into the summary unit.
5. The error that was found to be unbiased at the summary unit is added to the major diagonal.
6. This process is repeated for all classes.

Example of Supplier Level Error Cancellation

Table 12: Mapped-level confusion matrix for an urban retail water supplier. Data used: full set of DWR validation parcels (n=321). Values shown indicate meters squared.

Prediction:	Actual 1:	Actual 2:	Actual 3:
1	3,337.89	65.52	1,195.44
2	14,074.28	1,820.46	13,783.08
3	25,094.96	24,220.37	1,626,412.28

Accuracy: 95.41%

Error (Prediction-Actual) between classes 1 and 2:

Error 1-2: 65.52 m^2

Error 2-1: 14,074.28 m^2

In this case, there is a larger over-prediction of class 2 that should be class 1 than class 1 that should be class 2, so the smaller of the two values is subtracted from the larger and the error in that class combination is set to 0 m^2.

Error 1-2: 0 m^2

Error 2-1: 14,074.28 - 65.52 = 14,008.76 m^2

The value of the canceled error is then added to both class's correct predictions (1-1 and 2-2).

Error 1-1: 3,337.89 + 65.52 = 3,403.41 m^2

Error 2-2: 1,820.46 + 65.52 = 1,885.98 m^2

Error (Prediction- Actual) between classes 1 and 3:

Error 1-3: 1,195.44 m^2

Error 3-1: 25,094.96 m^2

In this case, there is a larger over prediction of class 3 that should be class 1 than class 1 that should be class 3, so the smaller of the two values is subtracted from the larger and the error in that class combination is set to 0 m^2.

Error 1-3: 0 m^2

Error 3-1: 25,094.96 - 1,195.44 = 23,899.52 m^2

The value of the canceled error is then added to both class's correct predictions (1-1 and 3-3).

Error 1-1: 3,403.41 + 1,195.44 = 4,598.85 m^2

Error 3-3: 1,626,412.28 + 1,195.44 = 1,627,607.72 m^2

Error (Prediction- Actual) between classes 2 and 3:

Error 2-3: 13,783.08 m^2

Error 3-2: 24,220.37 m^2

In this case, there is a larger over prediction of class 3 that should be class 2 than class 2 that should be class 3, so the smaller of the two values is subtracted from the larger and the error in that class combination is set to 0 m^2.

Error 2-3: 0 m^2

Error 3-2: 24,220.37 - 13,783.08 = 10,437.29 m^2

The value of the canceled error is then added to both class's correct predictions (3-3 and 2-2).

Error 2-2: 1,885.98 + 13,783.08 = 15,669.06 m^2

Error 3-3: 1,627,607.72 + 13,783.08 = 1,641,390.80 m^2

Table 13: Updated confusion matrix to account for error cancellation at the supplier level. Values shown indicate meters squared.

Prediction:	Actual 1:	Actual 2:	Actual 3:
1	4,598.85	0	0
2	14,008.76	15,669.06	0
3	23,899.52	10,437.29	1,641,390.80

APPENDIX C – URBAN RETAIL WATER SUPPLIER LIST

Table 14: Landscape Area Measurement Project participating urban retail water suppliers. WDID = Water District Identifier.

Phase	Agency Name	WDID	Contract Number
2A	North Marin Water District	NORTHMARINWA244	244
2A	Rancho California Water District	RANCHOCALIFO282	282
2B	Arroyo Grande City Of	ARROYOGRANDE013	013
2B	Calaveras County Water District	CALAVERASWDI035	035
2B	California Water Service Company - Bakersfield	BAKERSFIELDC043	043
2B	California Water Service Company - East Los Angeles	EASTLOSANGEL047	047
2B	City of Redding	CITYOFREDDIN284	284
2B	Desert Water Agency	DESERTWATERA096	096
2B	Folsom City Of	FOLSOMCITYOF123	123
2B	Glendale City of	GLENDALECITY133	133
2B	Great Oaks Water Company Incorporated	GREATOAKSWAT153	153
2B	Joshua Basin Water District	JOSHUABASINW176	176
2B	Las Virgenes Municipal Water District	LASVIRGENESM189	189
2B	McKinleyville Community Services District	MCKINLEYVILL215	215
2B	Olivenhain Municipal Water District	OLIVENHAINMU251	251
2B	Pleasanton City Of	PLEASANTONCI274	274
2B	Redwood City	REDWOODCITYW286	286
2B	Santa Cruz City Of	SANTACRUZCIT329	329
2B	South Tahoe Public Utility District	SOUTHTAHOEPU349	349
3	Adelanto City of	ADELANTOCITY001	001
3	Alameda County Water District	ALAMEDACOUNT002	002
3	Alco Water Service	ALCOWATERSER003	003
3	Alhambra City of	ALHAMBRACITY004	004
3	Amador Water Agency - Tiger Creek Powerhouse	AMADORWATERA005	005
3	American Canyon City of - Water	AMERICANCANY006	006
3	Anaheim City Of	ANAHEIMCITYO007	007
3	Antioch City Of	ANTIOCHCITYO009	009
3	Apple Valley Ranchos Water Company	APPLEVALLEYR010	010
3	Arcadia City of	ARCADIACITYO011	011
3	Arvin Community Service District	ARVINCOMMUNI014	014
3	Atascadero Mutual Water Company	ATASCADEROMU015	015

Phase	Agency Name	WDID	Contract Number
3	Atwater City Of	ATWATERCITYO016	016
3	Azusa City of - Water (Azusa Light and Water)	AZUSACITYOFW017	017
3	Bakersfield City Of	BAKERSFIELDC018	018
3	Bakman Water Company	BAKMANWATERC019	019
3	Banning City of - Water	BANNINGCITYO020	020
3	Beaumont - Cherry Valley Water District	BEAUMONTCHER021	021
3	Bella Vista Water District	BELLAVISTAWA022	022
3	Bellflower-Somerset Mutual Water Company	BELLFLOWERSO023	023
3	Benicia City Of	BENICIACITYO024	024
3	Beverly Hills City Of	BEVERLYHILLS025	025
3	Big Bear City Community Service District	BIGBEARCITYC026	026
3	Big Bear Lake City Of	BIGBEARLAKEC027	027
3	Blythe City of - Water	BLYTHECITYOF028	028
3	Brawley City of - Water	BRAWLEYCITYO029	029
3	Brea City of	BREACITYOFWA030	030
3	Brentwood City Of	BRENTWOODCIT031	031
3	Buena Park City Of	BUENAPARKCIT032	032
3	Burbank City Of	BURBANKCITYO033	033
3	Burlingame City Of	BURLINGAMECI034	034
3	Calexico City of	CALEXICOCITY036	036
3	California American Water Company - Los Angeles	LOSANGELESCA037	037
3	California American Water Company - Monterey District	MONTEREYDIST038	038
3	California American Water Company - Sacramento District	SACRAMENTODI039	039
3	California American Water Company - San Diego County District	SANDIEGOCALI040	040
3	California American Water Company - Ventura District	VENTURADISTI041	041
3	California City Community Service District	CALIFORNIACI042	042
3	California Water Service Company - Bear Gulch	BEARGULCHCAL044	044
3	California Water Service Company - Chico	CHICOCALIFOR045	045
3	California Water Service Company - Dominguez	DOMINGUEZCAL046	046
3	California Water Service Company - Hermosa/Redondo	HERMOSAREDON048	048
3	California Water Service Company - Livermore	LIVERMORECAL049	049
3	California Water Service Company - Los Altos	LOSALTOSCALI050	050
3	California Water Service Company - Marysville	MARYSVILLECA051	051
3	California Water Service Company - Mid Peninsula	CWSMEDPENINS052	052
3	California Water Service Company - Oroville	OROVILLECALI053	053
3	California Water Service Company - Palos Verdes	PALOSVERDESC054	054
3	California Water Service Company - Salinas	SALINASCALIF055	055
3	California Water Service Company - Selma	SELMACALIFOR056	056
3	California Water Service Company - South San Francisco	SOUTHSANFRAN057	057

Phase	Agency Name	WDID	Contract Number
3	California Water Service Company - Stockton	STOCKTONCALI058	058
3	California Water Service Company - Visalia	VISALIACALIF059	059
3	California Water Service Company - Westlake	WESTLAKECALI060	060
3	Camarillo City of	CAMARILLOCIT061	061
3	Cambria Community Services District	CAMBRIACOMMU062	062
3	Camrosa Water District	CAMROSAWATER063	063
3	Carlsbad Municipal Water District	CARLSBADMUNI064	064
3	Carmichael Water District	CARMICHAELWA065	065
3	Carpinteria City Of	CARPINTERIAC066	066
3	Casitas Municipal Water District	CASITASCITYC404	404
3	Ceres City Of	CERESCITYOFW068	068
3	Cerritos City of	CERRITOSCITY069	069
3	Chino City of	CHINOCITYOFW070	070
3	Chino Hills City of	CHINOHILLSCI071	071
3	Citrus Heights Water District	CITRUSHEIGHT073	073
3	City of Anderson	CITYOFANDERS008	008
3	City of Arcata	CITYOFARCATA012	012
3	City of Chowchilla	CITYOFCHOWCH072	072
3	City of Crescent City	CITYOFCRESCE087	087
3	City of Fortuna	CITYOFFORTUN124	124
3	City of Red Bluff	CITYOFREDBLU283	283
3	City of Shasta Lake	CITYOFSHASTA340	340
3	City of Susanville	CITYOFSUSANV357	357
3	City of Yreka	CITYOFYREKAW401	401
3	Cloverdale City Of	CLOVERDALECI074	074
3	Clovis City Of	CLOVISCITYOF075	075
3	Coachella City of	COACHELLACIT076	076
3	Coachella Valley Water District	COACHELLAVAL077	077
3	Coalinga City Of	COALINGACITY078	078
3	Coastside County Water District	COASTSIDECOU079	079
3	Colton City of	COLTONCITYOF080	080
3	Compton City of	COMPTONCITYO081	081
3	Contra Costa Water District	CONTRACOSTAW082	082
3	Corcoran City Of	CORCORANCITY083	083
3	Corona City of - Water	CORONACITYOF084	084
3	Covina City of	COVINACITYOF085	085
3	Crescenta Valley Water District	CRESCENTAVAL088	088
3	Crestline Village Water District	CRESTLINEVIL089	089
3	Cucamonga Valley Water District	CUCAMONGAVAL090	090

Phase	Agency Name	WDID	Contract Number
3	Cupertino City Of	CUPERTINOCIT091	091
3	Daly City	DALYCITYWATE092	092
3	Davis City Of	DAVISCITYOFW093	093
3	Delano City Of	DELANOCITYOF095	095
3	Delo Water	DELOROWATERC094	094
3	Diablo Water District	DIABLOWATERD097	097
3	Dinuba City Of	DINUBACITYOF098	098
3	Discovery Bay Town Of	DISCOVERYBAY099	099
3	Downey City of - Water	DOWNEYCITYOF100	100
3	Dublin San Ramon Services District	DUBLINSANRAM101	101
3	East Bay Municipal Utility District	EASTBAYMUNIC102	102
3	East Niles Community Services District	EASTNILESCOM103	103
3	East Palo Alto Service Area	EASTPALOALTO105	105
3	East Valley Water District	EASTVALLEYWA106	106
3	Eastern Municipal Water District	EASTERNMUNIC107	107
3	El Centro City of	ELCENTROCITY108	108
3	El Dorado Irrigation District	ELDORADOIRRI109	109
3	El Monte City Of	ELMONTECITYO110	110
3	El Segundo City of	ELSEGUNDOCIT111	111
3	El Toro Water District	ELTOROWATERD112	112
3	Elk Grove Water District	ELKGROVEWATE113	113
3	Elsinore Valley Municipal Water District	ELSINOREVALL114	114
3	Escondido City of	ESCONDIDOCIT115	115
3	Estero Municipal Improvement District	ESTEROMUNICI116	116
3	Exeter City Of	EXETERCITYOF118	118
3	Fair Oaks Water District	FAIROAKSWATE119	119
3	Fairfield City Of	FAIRFIELDCIT120	120
3	Fallbrook Public Utilities District	FALLBROOKPUB121	121
3	Fillmore City of	FILLMORECITY122	122
3	Fountain Valley City of	FOUNTAINVALL125	125
3	Fresno City Of Service area	FRESNOCITYOF126	126
3	Fruitridge Vista Water Company	FRUITRIDGEVI127	127
3	Fullerton City Of	FULLERTONCIT128	128
3	Galt City Of	GALTCITYOFWA129	129
3	Garden Grove City of	GARDENGROVEC130	130
3	Georgetown Divide Public Utility District	GEORGETOWNDI131	131
3	Gilroy City Of	GILROYCITYOF132	132
3	Glendora City of	GLENDORACITY134	134
3	Golden State Water Company - Artesia	ARTESIAGSWCW135	135

Phase	Agency Name	WDID	Contract Number
3	Golden State Water Company - Barstow	BARSTOWGSWCW136	136
3	Golden State Water Company - Bay Point	BAYPOINTGSWC137	137
3	Golden State Water Company - Bell- Bell Gardens	BELLBELLGARD138	138
3	Golden State Water Company - Claremont	CLAREMONTGSW139	139
3	Golden State Water Company - Cordova	CORDOVAGSWCW140	140
3	Golden State Water Company - Culver City	CULVERCITYGS141	141
3	Golden State Water Company - Florence- Graham	GRAHAMGSWCWA142	142
3	Golden State Water Company - Norwalk	NORWALKGSWCW143	143
3	Golden State Water Company - Orcutt	ORCUTTGSWCWA144	144
3	Golden State Water Company - Placentia	PLACENTIAGSW145	145
3	Golden State Water Company - San Dimas	SANDIMASGSWC146	146
3	Golden State Water Company - Simi Valley	SIMIVALLEYGS147	147
3	Golden State Water Company - South Arcadia	SOUTHARCADIA148	148
3	Golden State Water Company - South San Gabriel	SOUTHSANGABR149	149
3	Golden State Water Company - Southwest	SOUTHWESTGSW150	150
3	Golden State Water Company - West Orange	WESTORANGEGS151	151
3	Goleta Water District	GOLETAWATERD152	152
3	Greenfield City Of	GREENFIELDCI154	154
3	Greenfield County Water District	GREENFIELDCO155	155
3	Groveland Community Services District	GROVELANDCOM156	156
3	Grover Beach City of - Water	GROVERBEACHC157	157
3	Hanford City Of	HANFORDCITYO158	158
3	Hawthorne City Of	HAWTHORNECIT159	159
3	Hayward City Of	HAYWARDCITYO160	160
3	Healdsburg City Of	HEALDSBURGCI161	161
3	Helix Water District	HELIXWATERDI162	162
3	Hemet City of	HEMETCITYOFW163	163
3	Hesperia Water District	HESPERIAWATE164	164
3	Hi Desert Water District	HIDESERTWATE165	165
3	Hillsborough Water Department	HILLSBOROUGH166	166
3	Hollister City Of	HOLLISTERCIT167	167
3	Humboldt Bay Municipal Water District - City of Eureka	HUMBOLDTBAYM117	117
3	Humboldt Community	HUMBOLDTCOMM168	168
3	Huntington Beach City of	HUNTINGTONBE169	169
3	Huntington Park City of	HUNTINGTONPA170	170
3	Imperial City of - Water	IMPERIALCITY171	171
3	Indian Wells Valley Water District	INDIANWELLSV172	172
3	Indio Water Authority	INDIOWATERAU173	173
3	Inglewood City of	INGLEWOODCIT174	174

Phase	Agency Name	WDID	Contract Number
3	Irvine Ranch Water District	IRVINERANCHW175	175
3	Jurupa Community Services District	JURUPACOMMUN177	177
3	Kerman City Of	KERMANCITYOF178	178
3	Kingsburg City Of	KINGSBURGCIT179	179
3	La Habra City of	LAHABRACITYO180	180
3	La Palma City of	LAPALMACITYO181	181
3	La Verne City Of	LAVERNECITYO182	182
3	Laguna Beach County Water District	LAGUNABEACHC183	183
3	Lake Arrowhead Community Services District	LAKEARROWHEA184	184
3	Lake Hemet Municipal Water District	LAKEHEMETMUN185	185
3	Lakeside Water District	LAKESIDEWATE186	186
3	Lakewood City of	LAKEWOODCITY187	187
3	Lamont Public Utility District	LAMONTPUBLIC188	188
3	Lathrop City Of	LATHROPCITYO190	190
3	Lemoore City Of	LEMOORECITYO191	191
3	Liberty Utilities	LIBERTYUTILI192	192
3	Lincoln City Of	LINCOLNCITYO194	194
3	Lincoln Avenue Water Company	LINCOLNAVENU193	193
3	Linda County Water District	LINDACOUNTYW195	195
3	Livermore City Of	LIVERMORECIT196	196
3	Livingston City of	LIVINGSTONCI197	197
3	Lodi City Of	LODICITYOFWA198	198
3	Loma Linda City of	LOMALINDACIT199	199
3	Lomita City of - Water	LOMITACITYOF200	200
3	Lompoc City of	LOMPOCCITYOF201	201
3	Long Beach City of	LONGBEACHCIT202	202
3	Los Angeles City Department of Water and Power	LOSANGELESCI203	203
3	Los Angeles County Waterworks District 29 - Malibu & Marina Del Rey	MALIBUMARINA204	204
3	Los Angeles County Waterworks District 40 - Antelope Valley	ANTELOPEVALL205	205
3	Los Banos City of	LOSBANOSCITY206	206
3	Lynwood City of	LYNWOODCITYO207	207
3	Madera City Of	MADERACITYOF208	208
3	Mammoth Community Water District	MAMMOTHCOMMU209	209
3	Manhattan Beach City of	MANHATTANBEA210	210
3	Manteca City Of	MANTECACITYO211	211
3	Marin Municipal Water District	MARINMUNICIP212	212
3	Marina Coast Water District	MARINACOASTW213	213
3	Martinez City Of	MARTINEZCITY214	214
3	Menlo Park Municipal Water District City of	MENLOPARKMUN216	216

Phase	Agency Name	WDID	Contract Number
3	Merced City Of	MERCEDCITYOF217	217
3	Mesa Water District	MESAWATERDIS218	218
3	Mid-Peninsula Water District	MIDPENINSULA219	219
3	Millbrae City Of	MILLBRAECITY220	220
3	Milpitas City Of	MILPITASCITY221	221
3	Mission Springs Water District	MISSIONSPRIN222	222
3	Modesto City Of	MODESTOCITYO223	223
3	Monrovia City of	MONROVIACITY225	225
3	Monte Vista Community Water District	MONTEVISTACO226	226
3	Montebello Land And Water Company	MONTEBELLOLA227	227
3	Montecito Water District	MONTECITOWAT228	228
3	Monterey Park City Of	MONTEREYPARK229	229
3	Morgan Hill City Of	MORGANHILLCI230	230
3	Morro Bay City Of	MORROBAYCITY231	231
3	Moulton Niguel Water District	MOULTONNIGUE232	232
3	Mountain House Community Services District	MOUNTAINHOUS233	233
3	Mountain View City Of	MOUNTAINVIEW234	234
3	Myoma Dunes Mutual Water Company	MYOMADUNESMU235	235
3	Napa City of	NAPACITYOFWA236	236
3	Nevada Irrigation District	NEVADAIRRIGA237	237
3	Newhall County Water District	NEWHALLCOUNT238	238
3	Newman City Of Service Area	NEWMANCITYOF239	239
3	Newport Beach City of	NEWPORTBEACH240	240
3	Nipomo Community Service District	NIPOMOCOMMUN241	241
3	Norco City of - Water	NORCOCITYOFW242	242
3	North Coast County Water District	NORTHCOASTCO243	243
3	North Tahoe Public Utilities District	NORTHTAHOEPU245	245
3	Norwalk City Of	NORWALKCITYO246	246
3	Oak Park Water Service	OAKPARKWATER365	365
3	Oakdale City Of	OAKDALECITYO247	247
3	Oceanside City Of	OCEANSIDECIT248	248
3	Oildale Mutual Water Company	OILDALEMUTUA249	249
3	Olivehurst Public Utilities District	OLIVEHURSTPU250	250
3	Ontario City of	ONTARIOCITYO252	252
3	Orange City of	ORANGECITYOF253	253
3	Orangevale Water Company	ORANGEVALEWA254	254
3	Orchard Dale Water District	ORCHARDDALEW255	255
3	Otay Water District	OTAYWATERDIS256	256
3	Oxnard City of	OXNARDCITYOF257	257

Phase	Agency Name	WDID	Contract Number
3	Padre Dam Municipal Water District	PADREDAMMUNI258	258
3	Palmdale Water District	PALMDALEWATE259	259
3	Palo Alto City Of	PALOALTOCITY260	260
3	Paramount City of - Water	PARAMOUNTCIT262	262
3	Pasadena City Of	PASADENACITY263	263
3	Paso Robles City Of	PASOROBLESCI264	264
3	Patterson City of	PATTERSONCIT265	265
3	Petaluma City Of	PETALUMACITY266	266
3	Phelan Pinon Hills Community Services District	PHELANPINONH267	267
3	Pico Rivera City of	PICORIVERACI268	268
3	Pico Water District	PICOWATERDIS269	269
3	Pismo Beach City of	PISMOBEACHCI270	270
3	Pittsburg City Of	PITTSBURGCIT271	271
3	Placer County Water Agency	PLACERCOUNTY272	272
3	Pomona City Of	POMONACITYOF275	275
3	Port Hueneme City Of	PORTHUENEMEC276	276
3	Porterville City Of	PORTERVILLEC277	277
3	Poway City of	POWAYCITYOFW278	278
3	Quartz Hill Water District	QUARTZHILLWA279	279
3	Rainbow Municipal Water District	RAINBOWMUNIC280	280
3	Ramona Municipal Water District	RAMONAMUNICI281	281
3	Redlands City of	REDLANDSCITY285	285
3	Reedley City Of	REEDLEYCITYO287	287
3	Rialto City of	RIALTOCITYOF288	288
3	Rincon Del Diablo Municipal Water District	RINCONDELDIA289	289
3	Rio Linda Elverta Community Water District	RIOLINDAELVE290	290
3	Rio Vista City Of	RIOVISTACITY291	291
3	Ripon City Of	RIPONCITYOFW292	292
3	Riverbank City Of	RIVERBANKCIT293	293
3	Riverside City of	RIVERSIDECIT294	294
3	Riverside Highland Water Company	RIVERSIDEHIG295	295
3	Rohnert Park City Of	ROHNERTPARKC296	296
3	Rosamond Community Service District	ROSAMONDCOMM297	297
3	Roseville City Of	ROSEVILLECIT298	298
3	Rowland Water District	ROWLANDWATER299	299
3	Rubidoux Community Service District	RUBIDOUXCOMM300	300
3	Rubio Canon Land and Water Association	RUBIOCANONLA301	301
3	Sacramento City Of - Water	SACRAMENTOCI302	302
3	Sacramento County Water Agency	SACRAMENTOCO303	303

Phase	Agency Name	WDID	Contract Number
3	Sacramento Suburban Water District	SACRAMENTOSU304	304
3	San Bernardino City Of	SANBERNARDIN305	305
3	San Bernardino County Service Area No 64 Spring Valley Lake	SPRINGVALLEY306	306
3	San Bernardino County Service Area No 70 J Oak Hills	OAKHILLSSANB307	307
3	San Bruno City Of	SANBRUNOCITY308	308
3	San Buenaventura City of - Water	SANBUENAVENT309	309
3	San Clemente City of	SANCLEMENTEC310	310
3	San Diego City of	SANDIEGOCITY311	311
3	San Dieguito Water District	SANDIEGUITOW312	312
3	San Fernando City of	SANFERNANDOC313	313
3	San Francisco Public Utilities Commission - City Distribution Division	SANFRANCISCO314	314
3	San Gabriel Valley Municipal Water District	WDSANGABRIEL315	315
3	San Gabriel Valley Water Company	WCSANGABRIEL316	316
3	San Gabriel Valley Water Company - Fontana	FONTANASANGA317	317
3	San Jacinto City of	SANJACINTOCI318	318
3	San Jose City Of - Evergreen Edenvale Coyote Alviso NSJ	SANJOSECITYO319	319
3	San Jose Water Company	SANJOSEWATER320	320
3	San Juan Capistrano City of - Water	SANJUANCAPIS321	321
3	San Juan Water District	SANJUANWATER322	322
3	San Lorenzo Valley Water District	SANLORENZOVA323	323
3	San Luis Obispo City of	SANLUISOBISP324	324
3	Sanger City Of	SANGERCITYOF325	325
3	Santa Ana City of	SANTAANACITY326	326
3	Santa Barbara City of	SANTABARBARA327	327
3	Santa Clara City Of	SANTACLARACI328	328
3	Santa Clarita Water Division	SANTACLARITA067	067
3	Santa Fe Irrigation District	SANTAFEIRRIG330	330
3	Santa Fe Springs City of	SANTAFESPRIN331	331
3	Santa Margarita Water District	SANTAMARGARI332	332
3	Santa Maria City of	SANTAMARIACI333	333
3	Santa Monica City of	SANTAMONICAC334	334
3	Santa Paula City of	SANTAPAULACI335	335
3	Santa Rosa City Of	SANTAROSACIT336	336
3	Scotts Valley Water District	SCOTTSVALLEY337	337
3	Seal Beach City Of	SEALBEACHCIT338	338
3	Shafter City Of	SHAFTERCITYO339	339
3	Sierra Madre City of - Water	SIERRAMADREC341	341
3	Solano Irrigation District - Suisun Solano Water Authority	SOLANOIRRIGA353	353
3	Soledad City Of	SOLEDADCITYO342	342

Phase	Agency Name	WDID	Contract Number
3	Sonoma City Of	SONOMACITYOF343	343
3	Soquel Creek Water District	SOQUELCREEKW344	344
3	South Coast Water District	SOUTHCOASTWA345	345
3	South Feather Water and Power	SOUTHFEATHER346	346
3	South Gate City of	SOUTHGATECIT347	347
3	South Pasadena City of	SOUTHPASADEN348	348
3	Stockton City Of	STOCKTONCITY350	350
3	Suburban Water Systems - La Mirada	LAMIRADASUBU352	352
3	Suburban Water Systems- San Jose Hills	SANJOSEHILLS351	351
3	Sunny Slope Water Company	SUNNYSLOPEWA354	354
3	Sunnyslope Community Water District	SUNNYSLOPECO355	355
3	Sunnyvale City Of	SUNNYVALECIT356	356
3	Sweetwater Authority	SWEETWATERAU358	358
3	Tehachapi City Of Water Service Area	TEHACHAPICIT359	359
3	Temescal Valley Water District	TEMESCALVALL360	360
3	Thousand Oaks City of	THOUSANDOAKS361	361
3	Torrance City Of Municipal Water District	TORRANCECITY362	362
3	Trabuco Canyon Water District	TRABUCOCANYO363	363
3	Tracy City of - Water Service	TRACYCITYOFW364	364
3	Truckee-Donner Public Utility District	TRUCKEEDONNE366	366
3	Tulare City Of	TULARECITYOF367	367
3	Tuolumne Utilities District - Tuolumne City System	TUOLUMNEUTIL368	368
3	Turlock City Of Water Service Area	TURLOCKCITYO369	369
3	Tustin City Of	TUSTINCITYOF370	370
3	Twentynine Palms Water District	TWENTYNINEPA371	371
3	Ukiah City Of	UKIAHCITYOFW372	372
3	Upland City of	UPLANDCITYOF373	373
3	Vacaville City Of	VACAVILLECIT374	374
3	Valencia Water Company	VALENCIAWATE375	375
3	Vallecitos Water District	VALLECITOSWA376	376
3	Vallejo City Of	VALLEJOCITYO377	377
3	Valley Center Municipal Water District	VALLEYCENTER378	378
3	Valley County Water District	VALLEYCOUNTY379	379
3	Valley Of The Moon Water District	VALLEYOFTHEM380	380
3	Valley Water Company	VALLEYWATERC381	381
3	Vaughn Water Company	VAUGHNWATERC382	382
3	Ventura County Waterworks District No 01 - Moorpark	MOORPARKVENT383	383
3	Ventura County Waterworks District No 8 - Simi Valley	SIMIVALLEYVE384	384
3	Victorville Water District	VICTORVILLEW386	386

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3	Vista Irrigation District	VISTAIRRIGAT387	387
3	Walnut Valley Water District	WALNUTVALLEY388	388
3	Wasco City Of	WASCOCITYOFW389	389
3	Watsonville, City of	WATSONVILLEC390	390
3	West Kern Water District	WESTKERNWATE391	391
3	West Sacramento City Of	WESTSACRAMEN392	392
3	West Valley Water District	WESTVALLEYWA393	393
3	Westborough County Water District	WESTBOROUGHC394	394
3	Western Municipal Water District	WESTERNMUNIC395	395
3	Westminister City Of	WESTMINISTER396	396
3	Whittier City of	WHITTIERCITY397	397
3	Windsor Town Of	WINDSORTOWNO398	398
3	Woodland City Of	WOODLANDCITY399	399
3	Yorba Linda Water District	YORBALINDAWA400	400
3	Yuba City	YUBACITYWATE402	402
3	Yucaipa Valley Water District - Water	YUCAIPAVALLE403	403

Appendix D – Urban Retail Water Supplier Irrigation Status Compositions

Table 15: Summary of irrigation status areas and total percent canopy for each urban retail water supplier in the analysis. Values were calculated from the topologically corrected parcel layer (Parcels B). See the Parcel Topology Handling section for additional information on parcel datasets and transformations. WDID = Water District Identifier.

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
ADELANTOCITY001	5,443,844	23,013,123	71,887,215	-	8	LAM 2018
ALAMEDACOUNT002	174,502,793	51,574,794	420,788,244	67,200	28	LAM 2018
ALCOWATERSER003	11,527,417	7,636,349	50,322,429	-	14	LAM 2018
ALHAMBRACITY004	21,647,829	16,538,935	72,866,374	63	23	LAM 2018
AMADORWATERA005	25,017,685	21,382,775	323,050,434	-	57	LAM 2018
AMERICANCANY006	8,267,137	10,840,742	35,604,228	-	22	LAM 2018
ANAHEIMCITYO007	144,655,258	38,187,889	335,339,590	1,144,936	22	LAM 2018
ANTELOPEVALL205	113,102,322	66,336,868	404,554,323	218	21	LAM 2018
ANTIOCHCITYO009	64,851,512	37,307,354	144,171,108	-	24	LAM 2018
APPLEVALLEYR010	37,446,397	150,627,246	324,731,304	449	12	LAM 2018
ARCADIACITYO011	58,354,958	23,631,467	87,995,528	43	34	LAM 2018
ARROYOGRANDE013	15,471,048	8,027,123	63,105,572	-	18	LAM 2020
ARTESIAGSWCW135	10,584,407	6,761,450	40,724,067	36	18	LAM 2018
ARVINCOMMUNI014	6,601,144	4,926,893	15,273,046	-	22	LAM 2018
ATASCADEROMU015	22,320,767	80,317,194	456,572,940	-	43	LAM 2018
ATWATERCITYO016	24,307,364	10,008,499	41,238,872	-	12	LAM 2018
AZUSACITYOFW017	37,588,979	21,094,424	103,175,203	13	18	LAM 2018
BAKERSFIELDC018	163,880,870	10,370,350	269,763,943	-	22	LAM 2018
BAKERSFIELDC043	173,630,278	71,506,934	402,942,844	-	22	LAM 2020
BAKMANWATERC019	12,560,476	7,250,613	18,934,701	-	24	LAM 2018
BANNINGCITYO020	17,290,005	17,412,954	94,079,152	-	17	LAM 2018
BARSTOWGSWCW136	8,651,892	24,107,253	146,372,256	-	10	LAM 2018
BAYPOINTGSWC137	4,026,523	9,887,790	26,181,865	-	22	LAM 2018
BEARGULCHCAL044	158,354,102	39,227,586	643,424,341	6	69	LAM 2018
BEAUMONTCHER021	43,175,416	33,607,629	129,588,907	-	21	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
BELLAVISTAWA022	65,560,050	106,723,276	652,880,107	26	42	LAM 2018
BELLBELLGARD138	6,207,181	5,587,376	31,496,631	-	15	LAM 2018
BELLFLOWERSO023	11,226,200	4,946,717	37,332,195	25	16	LAM 2018
BENICIACITYO024	27,483,096	8,297,134	39,479,662	339,855	37	LAM 2018
BEVERLYHILLS025	45,146,293	5,034,624	58,768,707	128	38	LAM 2018
BIGBEARCITYC026	2,562,669	4,934,576	80,270,910	0	31	LAM 2018
BIGBEARLAKEC027	5,931,518	17,074,918	114,902,381	6	52	LAM 2018
BLYTHECITYOF028	10,766,428	8,306,952	46,879,979	-	14	LAM 2018
BRAWLEYCITYO029	14,696,636	10,461,014	31,451,191	-	16	LAM 2018
BREACITYOFWA030	25,266,621	5,634,134	58,251,762	-	22	LAM 2018
BRENTWOODCIT031	50,144,040	15,271,094	111,803,669	-	21	LAM 2018
BUENAPARKCIT032	25,593,306	13,956,564	81,095,766	13	17	LAM 2018
BURBANKCITYO033	47,858,217	15,792,688	109,960,076	233	24	LAM 2018
BURLINGAMECI034	22,887,678	1,817,875	33,413,649	-	47	LAM 2018
CALAVERASWDI035	24,173,701	49,461,889	503,114,572	-	20	LAM 2020
CALEXICOCITY036	15,240,189	10,117,654	32,662,572	-	12	LAM 2018
CALIFORNIACI042	4,452,602	19,481,081	75,283,667	-	7	LAM 2018
CAMARILLOCIT061	33,815,108	6,843,567	61,920,037	-	25	LAM 2018
CAMBRIACOMMU062	5,433,331	7,872,764	32,707,715	-	48	LAM 2018
CAMROSAWATER063	50,372,121	26,343,535	177,802,502	-	34	LAM 2018
CARLSBADMUNI064	81,256,084	22,642,089	159,310,797	-	33	LAM 2018
CARMICHAELWA065	67,352,763	27,294,254	58,363,550	-	47	LAM 2018
CARPINTERIAC066	14,719,429	7,221,163	34,484,107	-	36	Summary Portal 2018
CASITASCITYC404	29,950,845	35,314,697	328,342,000	-	14	LAM 2020
CERESCITYOFW068	28,498,825	7,540,972	53,867,853	-	21	LAM 2018
CERRITOSCITY069	27,349,797	1,539,296	60,657,773	13	22	LAM 2018
CHICOCALIFOR045	101,752,458	69,328,290	180,061,983	-	43	LAM 2018
CHINOCITYOFW070	44,773,409	11,004,878	116,541,835	13	16	LAM 2018
CHINOHILLSCI071	64,457,690	5,424,199	197,520,057	1,245	27	LAM 2018
CITRUSHEIGHT073	88,168,901	33,055,069	115,315,296	-	41	LAM 2018
CITYOFANDERS008	12,275,024	7,697,049	30,060,559	-	37	LAM 2018
CITYOFARCATA012	13,031,399	11,812,450	41,579,409	-	50	LAM 2018
CITYOFCHOWCH072	8,264,703	8,112,283	25,792,372	-	21	LAM 2018
CITYOFCRESCE087	6,592,774	28,182,837	60,232,631	-	49	LAM 2018
CITYOFFORTUN124	11,868,688	17,927,832	66,115,438	-	40	LAM 2018
CITYOFREDBLU283	14,680,139	7,330,819	21,177,530	-	38	LAM 2018
CITYOFREDDIN284	114,819,899	62,150,421	307,593,818	-	23	LAM 2020

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
CITYOFSHASTA340	7,602,529	15,167,918	53,873,378	-	55	LAM 2018
CITYOFSUSANV357	7,716,948	9,175,532	20,016,772	-	35	LAM 2018
CITYOFYREKAW401	8,105,433	8,542,123	32,248,123	22	35	LAM 2018
CLAREMONTGSW139	53,075,171	14,525,601	65,837,998	758	31	LAM 2018
CLOVERDALECI074	8,074,981	5,054,701	23,421,598	-	42	LAM 2018
CLOVISCITYOF075	107,726,381	32,932,244	193,011,662	0	30	LAM 2018
COACHELLACIT076	21,592,767	9,171,047	66,192,432	-	25	LAM 2018
COACHELLAVAL077	350,771,322	93,239,237	1,481,098,238	-	15	LAM 2018
COALINGACITY078	6,252,605	3,963,879	19,966,621	-	10	LAM 2018
COASTSIDECOU079	14,429,749	5,214,419	37,890,065	-	31	LAM 2018
COLTONCITYOF080	21,944,625	18,347,460	71,885,796	-	19	LAM 2018
COMPTONCITYO081	18,914,125	13,225,070	50,557,956	38	19	LAM 2018
CONTRACOSTAW082	226,848,665	56,563,612	384,577,974	-	41	Summary Portal 2018
CORCORANCITY083	11,563,889	7,019,904	61,988,853	-	12	LAM 2018
CORDOVAGSWCW140	45,679,078	7,599,216	62,292,664	-	35	LAM 2018
CORONACITYOF084	117,779,087	39,839,373	222,396,660	-	23	LAM 2018
COVINACITYOF085	13,942,212	13,931,329	44,572,834	-	23	LAM 2018
CRESCENTAVAL088	23,063,019	3,535,338	41,326,738	-	38	LAM 2018
CRESTLINEVIL089	1,139,725	3,471,172	39,355,065	-	73	LAM 2018
CUCAMONGAVAL090	148,494,580	65,752,775	282,977,810	-	28	LAM 2018
CULVERCITYGS141	15,774,834	2,178,486	32,578,922	43	27	LAM 2018
CUPERTINOCIT091	14,995,793	3,427,189	22,803,763	-	41	LAM 2018
CWSMEDPENINS052	71,818,893	29,201,302	160,170,823	-	37	LAM 2018
DALYCITYWATE092	13,112,772	12,779,211	58,165,596	9	20	LAM 2018
DAVISCITYOFW093	60,610,868	10,853,069	68,554,305	-	35	LAM 2018
DELANOCITYOF095	17,814,221	11,560,452	51,343,506	-	16	LAM 2018
DELOROWATERC094	4,702,477	5,095,304	76,549,726	-	83	LAM 2018
DESERTWATERA096	84,144,214	8,492,935	316,584,332	-	18	LAM 2020
DIABLOWATERD097	31,548,575	20,181,626	113,260,282	-	19	LAM 2018
DINUBACITYOF098	12,947,447	9,935,794	35,636,436	-	24	LAM 2018
DISCOVERYBAY099	12,654,368	2,301,804	45,707,932	-	10	LAM 2018
DOMINGUEZCAL046	42,269,679	20,261,628	145,760,692	380	16	LAM 2018
DOWNEYCITYOF100	45,417,793	15,953,302	103,189,079	131	20	LAM 2018
DUBLINSANRAM101	53,794,616	6,938,026	116,474,913	-	24	LAM 2018
EASTBAYMUNIC102	753,363,351	617,166,138	2,201,664,155	21	42	LAM 2018
EASTERNMUNIC107	363,038,743	382,743,566	1,932,071,766	33	19	LAM 2018
EASTLOSANGEL047	27,524,094	4,218,673	88,973,244	-	14	LAM 2020

WDID	Irrigated Area (ft²)	Irrigable-Not irrigated Area (ft²)	Not Irrigable Area (ft²)	No Imagery Available Area (ft²)	Total Canopy (%)	Data Source
EASTNILESCOM103	26,906,679	15,265,277	68,089,922	-	16	LAM 2018
EASTPALOALTO105	6,466,773	4,094,128	15,973,833	-	27	LAM 2018
EASTVALLEYWA106	56,403,638	55,747,720	125,311,917	-	26	LAM 2018
ELCENTROCITY108	18,217,813	17,319,856	61,227,372	-	13	LAM 2018
ELDORADOIRRI109	296,856,450	176,229,867	3,396,949,210	-	57	LAM 2018
ELKGROVEWATE113	51,619,975	28,366,429	111,360,475	-	21	LAM 2018
ELMONTECITYO110	5,195,852	2,932,502	15,368,842	-	22	LAM 2018
ELSEGUNDOCIT111	7,094,383	591,307	16,484,769	29	18	LAM 2018
ELSINOREVALL114	113,727,568	115,510,540	440,097,889	12	24	LAM 2018
ELTOROWATERD112	40,877,648	4,292,117	60,778,676	-	30	LAM 2018
ESCONDIDOCIT115	100,446,321	78,698,750	232,957,251	-	34	Summary Portal 2018
ESTEROMUNICI116	13,326,311	1,679,988	44,694,580	-	18	LAM 2018
EXETERCITYOF118	8,945,998	3,815,940	16,635,457	-	25	LAM 2018
FAIRFIELDCIT120	68,546,722	30,109,954	132,385,364	-	29	LAM 2018
FAIROAKSWATE119	68,191,461	36,716,514	87,174,361	37	55	LAM 2018
FALLBROOKPUB121	58,456,559	76,203,394	346,757,753	-	38	LAM 2018
FILLMORECITY122	5,912,013	4,115,761	18,573,587	-	18	LAM 2018
FOLSOMCITYOF123	62,766,238	20,556,686	125,551,845	-	25	LAM 2020
FONTANASANGA317	112,518,649	58,159,544	259,234,722	-	22	LAM 2018
FOUNTAINVALL125	28,800,960	4,951,300	70,480,491	25	15	LAM 2018
FRESNOCITYOF126	475,177,208	172,741,880	837,917,556	-	32	LAM 2018
FRUITRIDGEVI127	11,865,199	5,115,645	18,997,982	3,960,763	30	LAM 2018
FULLERTONCIT128	89,615,375	24,109,044	162,288,595	25	26	LAM 2018
GALTCITYOFWA129	21,955,100	7,357,200	42,695,450	-	20	LAM 2018
GARDENGROVEC130	58,026,760	28,469,373	165,354,385	38	19	LAM 2018
GEORGETOWNDI131	13,263,366	26,269,471	520,438,795	-	2	LAM 2018
GILROYCITYOF132	33,811,600	14,388,355	76,875,957	-	25	LAM 2018
GLENDALECITY133	74,594,330	19,755,742	180,894,839	-	27	LAM 2020
GLENDORACITY134	44,323,036	22,054,535	109,976,610	-	30	LAM 2018
GOLETAWATERD152	55,663,826	30,870,790	138,236,165	176	30	LAM 2018
GRAHAMGSWCWA142	7,685,947	4,556,452	33,713,167	38	20	LAM 2018
GREATOAKSWAT153	47,089,783	14,249,241	120,137,053	-	12	LAM 2020
GREENFIELDCI154	4,567,865	4,080,872	15,489,799	-	15	LAM 2018
GREENFIELDCO155	9,910,663	4,867,863	20,948,151	-	18	LAM 2018
GROVELANDCOM156	1,529,189	11,598,866	140,804,952	-	57	LAM 2018
GROVERBEACHC157	5,335,435	4,152,375	21,448,911	-	23	LAM 2018
HANFORDCITYO158	47,138,019	15,643,607	121,831,628	-	19	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
HAWTHORNECIT159	5,266,599	2,795,579	28,312,132	-	13	LAM 2018
HAYWARDCITYO160	47,345,729	28,282,417	179,092,165	-	25	LAM 2018
HEALDSBURGCI161	13,263,231	6,488,275	28,073,469	-	42	LAM 2018
HELIXWATERDI162	265,721,825	35,418,810	489,734,596	12,574	35	LAM 2018
HEMETCITYOFW163	7,287,611	14,324,023	44,548,765	-	11	LAM 2018
HERMOSAREDON048	30,313,711	2,071,634	95,614,859	2,420	22	LAM 2018
HESPERIAWATE164	32,075,284	134,172,941	522,724,616	4,598	13	LAM 2018
HIDESERTWATE165	8,487,208	88,536,570	415,596,535	186	19	LAM 2018
HILLSBOROUGH166	48,695,255	10,717,606	68,769,964	-	54	LAM 2018
HOLLISTERCIT167	9,318,503	6,172,871	34,593,632	-	23	LAM 2018
HUMBOLDTBAYM117	13,025,462	16,360,558	43,782,587	-	39	LAM 2018
HUMBOLDTCOMM168	21,232,623	24,462,882	138,205,999	128	61	LAM 2018
HUNTINGTONBE169	88,929,626	5,193,285	239,727,004	-	20	LAM 2018
HUNTINGTONPA170	5,374,111	2,873,458	22,636,889	13	15	LAM 2018
IMPERIALCITY171	8,779,157	8,277,793	24,152,846	-	15	LAM 2018
INDIANWELLSV172	23,933,743	48,202,740	176,020,145	19	18	LAM 2018
INDIOWATERAU173	63,472,624	13,008,888	150,029,275	-	18	LAM 2018
INGLEWOODCIT174	19,587,107	8,932,558	62,945,632	-	18	LAM 2018
IRVINERANCHW175	188,318,926	5,459,028	474,887,555	51	27	LAM 2018
JOSHUABASINW176	10,902,260	2,181,502	468,815,821	-	5	LAM 2020
JURUPACOMMUN177	87,781,534	71,526,430	259,097,558	-	19	LAM 2018
KERMANCITYOF178	8,900,296	3,833,199	18,825,245	-	22	LAM 2018
KINGSBURGCIT179	11,432,234	2,321,445	18,678,952	-	22	LAM 2018
LAGUNABEACHC183	16,591,112	3,451,116	35,419,274	338	36	LAM 2018
LAHABRACITYO180	30,059,312	11,659,956	61,334,435	2,187	19	LAM 2018
LAKEARROWHEA184	8,150,816	5,478,323	87,383,104	7	62	LAM 2018
LAKEHEMETMUN185	25,873,576	41,783,272	134,293,789	11	25	LAM 2018
LAKESIDEWATE186	33,135,851	25,776,678	178,178,372	-	39	LAM 2018
LAKEWOODCITY187	27,963,264	9,441,371	73,044,438	106	14	LAM 2018
LAMIRADASUBU352	64,778,048	36,772,400	159,886,996	25	23	LAM 2018
LAMONTPUBLIC188	8,611,047	5,692,686	16,438,620	-	22	LAM 2018
LAPALMACITYO181	5,576,313	1,091,297	15,999,005	13	15	LAM 2018
LASVIRGENESM189	139,588,034	29,702,758	536,826,366	-	22	LAM 2020
LATHROPCITYO190	11,068,408	7,739,743	46,928,467	-	13	LAM 2018
LAVERNECITYO182	29,537,420	4,106,933	61,135,028	31	27	LAM 2018
LEMOORECITYO191	21,740,531	7,756,985	54,158,595	-	13	LAM 2018
LIBERTYUTILI192	32,737,388	21,911,637	108,155,044	101	17	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
LINCOLNAVENU193	10,404,252	12,728,097	20,426,144	-	40	LAM 2018
LINCOLNCITYO194	55,540,710	18,053,397	112,676,700	-	27	LAM 2018
LINDACOUNTYW195	10,749,973	11,946,710	18,605,705	-	27	LAM 2018
LIVERMORECAL049	54,574,777	24,561,469	127,683,886	-	23	LAM 2018
LIVERMORECIT196	27,169,306	5,222,165	48,055,989	-	31	LAM 2018
LIVINGSTONCI197	7,377,709	2,692,895	17,006,613	-	28	LAM 2018
LODICITYOFWA198	49,171,347	5,316,811	80,308,231	-	25	LAM 2018
LOMALINDACIT199	18,643,996	6,442,766	36,309,817	-	24	LAM 2018
LOMITACITYOF200	7,776,883	4,290,458	19,707,030	-	21	LAM 2018
LOMPOCCITYOF201	18,679,731	9,852,468	50,685,762	-	23	LAM 2018
LONGBEACHCIT202	114,942,420	42,288,237	340,544,403	-	19	LAM 2018
LOSALTOSCALI050	101,276,403	28,152,028	130,175,803	-	47	LAM 2018
LOSANGELESCA037	78,212,764	45,666,275	150,723,445	216,486	34	LAM 2018
LOSANGELESCI203	1,486,124,854	775,040,545	4,207,554,272	381	34	LAM 2018
LOSBANOSCITY206	21,387,049	11,987,279	54,547,594	-	19	LAM 2018
LYNWOODCITYO207	12,333,587	7,541,570	34,948,356	-	20	LAM 2018
MADERACITYOF208	28,019,102	18,253,232	78,939,885	-	21	LAM 2018
MALIBUMARINA204	69,811,425	29,512,735	315,584,632	1,295	61	LAM 2018
MAMMOTHCOMMU209	6,052,819	4,592,549	48,697,900	-	36	LAM 2018
MANHATTANBEA210	15,174,400	689,427	41,819,213	1,003	26	LAM 2018
MANTECACITYO211	45,768,290	15,772,371	174,142,048	-	21	LAM 2018
MARINACOASTW213	7,343,507	9,621,580	32,024,512	-	17	LAM 2018
MARINMUNICIP212	226,009,388	81,135,539	448,508,986	-	63	LAM 2018
MARTINEZCITY214	31,406,699	14,614,498	82,186,313	74,532	47	LAM 2018
MARYSVILLECA051	7,393,819	3,027,574	12,461,535	-	25	LAM 2018
MCKINLEYVILL215	33,864,802	14,326,079	128,395,227	-	14	LAM 2020
MENLOPARKMUN216	13,796,592	1,413,366	14,879,895	-	46	LAM 2018
MERCEDCITYOF217	60,730,038	25,554,547	105,175,111	-	22	LAM 2018
MESAWATERDIS218	38,729,488	13,378,849	99,000,142	-	17	LAM 2018
MIDPENINSULA219	17,594,390	9,849,404	37,367,581	-	43	LAM 2018
MILLBRAECITY220	15,026,444	3,489,014	26,905,722	0	35	LAM 2018
MILPITASCITY221	20,465,159	15,327,238	86,839,523	178,693	21	LAM 2018
MISSIONSPRIN222	15,521,864	43,563,396	105,096,593	-	15	LAM 2018
MODESTOCITYO223	176,375,329	74,829,469	423,980,423	-	29	LAM 2018
MONROVIACITY225	27,468,960	5,693,449	54,118,878	13	41	LAM 2018
MONTEBELLOLA227	3,703,035	3,770,414	17,972,306	-	16	LAM 2018
MONTECITOWAT228	64,839,858	42,535,565	163,795,815	1,329	53	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
MONTEREYDIST038	102,942,243	94,709,865	542,759,396	-	50	LAM 2018
MONTEREYPARK229	18,863,627	16,060,452	63,607,091	-	25	LAM 2018
MONTEVISTACO226	30,174,977	24,711,885	84,197,761	1,102	18	LAM 2018
MOORPARKVENT383	34,032,702	16,571,989	149,073,891	-	29	LAM 2018
MORGANHILLCI230	40,872,727	15,306,254	86,579,617	38,712,904	25	LAM 2018
MORROBAYCITY231	3,753,073	3,649,242	21,514,600	-	21	LAM 2018
MOULTONNIGUE232	149,500,274	14,543,937	201,193,689	-	39	LAM 2018
MOUNTAINHOUS233	7,435,221	1,325,465	29,055,595	-	18	LAM 2018
MOUNTAINVIEW234	46,703,329	7,195,207	100,336,162	7	29	LAM 2018
MYOMADUNESMU235	16,652,105	1,179,976	23,374,272	-	21	LAM 2018
NAPACITYOFWA236	96,501,956	44,702,884	238,269,635	73	42	LAM 2018
NEVADAIRRIGA237	113,473,862	90,845,933	556,785,785	12	63	Summary Portal 2018
NEWHALLCOUNT238	41,876,429	10,763,521	169,883,950	-	34	LAM 2018
NEWMANCITYOF239	7,242,578	3,517,008	16,629,955	-	21	LAM 2018
NEWPORTBEACH240	39,839,730	1,756,684	99,264,354	-	27	LAM 2018
NIPOMOCOMMUN241	12,094,259	27,283,057	77,809,132	-	33	LAM 2018
NORCOCITYOFW242	28,379,376	28,581,690	126,279,202	-	18	LAM 2018
NORTHCOASTCO243	17,682,866	12,324,113	53,473,758	4	35	LAM 2018
NORTHMARINWA244	79,137,857	36,559,581	257,095,727	-	17	LAM 2020
NORTHTAHOEPU245	7,608,340	1,545,741	21,257,417	-	11	LAM 2018
NORWALKCITYO246	6,032,440	2,133,373	19,430,737	-	16	LAM 2018
NORWALKGSWCW143	10,086,842	9,134,203	36,045,965	-	15	LAM 2018
OAKDALECITYO247	14,430,137	6,850,018	29,780,701	-	24	LAM 2018
OAKHILLSSANB307	15,312,162	18,854,343	315,768,669	34	13	LAM 2018
OAKPARKWATER365	11,213,009	1,013,629	15,579,188	-	35	LAM 2018
OCEANSIDECIT248	123,886,897	69,294,880	282,967,988	9	29	LAM 2018
OILDALEMUTUA249	22,771,185	12,844,674	56,684,330	653	17	LAM 2018
OLIVEHURSTPU250	9,726,621	11,331,713	24,321,330	-	22	LAM 2018
OLIVENHAINMU251	141,273,012	31,108,519	312,647,849	-	28	LAM 2020
ONTARIOCITYO252	83,106,513	27,272,594	195,808,310	-	17	LAM 2018
ORANGECITYOF253	84,284,515	14,493,524	156,408,360	-	30	LAM 2018
ORANGEVALEWA254	36,371,243	16,779,566	42,890,399	9	42	LAM 2018
ORCHARDDALEW255	7,278,903	4,790,164	19,759,606	-	18	LAM 2018
ORCUTTGSWCWA144	38,447,141	21,079,550	80,623,452	-	20	LAM 2018
OROVILLECALI053	4,651,572	8,608,560	15,090,203	-	31	LAM 2018
OTAYWATERDIS256	178,353,415	32,468,451	458,694,027	32	33	LAM 2018
OXNARDCITYOF257	63,958,852	12,480,996	163,241,706	214	16	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
PADREDAMMUNI258	123,853,907	51,592,797	690,810,498	232	47	LAM 2018
PALMDALEWATE259	41,113,613	59,726,064	225,546,481	-	13	LAM 2018
PALOALTOCITY260	81,472,116	9,899,818	93,740,307	3	45	LAM 2018
PALOSVERDESC054	125,475,870	49,352,384	207,116,222	1,682	41	LAM 2018
PARAMOUNTCIT262	8,586,510	5,229,550	32,186,790	13	17	LAM 2018
PASADENACITY263	112,124,705	70,155,538	179,251,302	50	41	LAM 2018
PASOROBLESCI264	32,959,350	21,893,204	101,976,661	-	27	LAM 2018
PATTERSONCIT265	12,574,676	7,314,768	54,507,942	-	20	LAM 2018
PETALUMACITY266	61,063,100	10,470,132	115,399,763	-	36	LAM 2018
PHELANPINONH267	18,173,266	84,647,611	722,178,982	-	18	LAM 2018
PICORIVERACI268	13,241,188	7,152,586	34,184,979	-	19	LAM 2018
PICOWATERDIS269	8,138,901	3,546,888	19,506,337	-	20	LAM 2018
PISMOBEACHCI270	8,111,222	2,591,673	27,553,271	-	21	LAM 2018
PITTSBURGCIT271	28,829,640	21,641,396	94,959,000	-	23	LAM 2018
PLACENTIAGSW145	43,183,964	14,192,621	76,915,875	-	27	LAM 2018
PLACERCOUNTY272	176,324,311	70,984,698	451,575,723	10	50	Summary Portal 2018
PLEASANTONCI274	89,955,082	21,896,320	195,779,905	-	20	LAM 2020
POMONACITYOF275	51,257,305	45,271,101	150,733,711	1,859	28	LAM 2018
PORTERVILLEC277	54,811,465	42,442,778	216,301,106	-	16	LAM 2018
PORTHUENEMEC276	4,574,867	1,767,150	15,365,832	-	14	LAM 2018
POWAYCITYOFW278	76,147,471	91,593,739	263,236,868	-	43	LAM 2018
QUARTZHILLWA279	19,797,145	13,526,431	52,919,917	571	20	LAM 2018
RAINBOWMUNIC280	126,162,052	55,900,145	694,792,453	-	39	LAM 2018
RAMONAMUNICI281	77,585,603	102,936,757	654,270,305	8	31	LAM 2018
RANCHOCALIFO282	260,555,112	74,999,441	952,364,075	-	17	LAM 2020
REDLANDSCITY285	105,883,123	39,263,202	169,671,392	13,351,376	36	LAM 2018
REDWOODCITYW286	48,433,550	15,320,407	92,190,682	-	30	LAM 2020
REEDLEYCITYO287	15,857,586	6,082,883	27,715,991	-	25	LAM 2018
RIALTOCITYOF288	29,388,144	18,835,848	57,075,212	-	13	LAM 2018
RINCONDELDIA289	41,056,174	45,060,584	107,148,708	-	30	LAM 2018
RIOLINDAELVE290	40,261,934	37,284,862	201,059,048	-	16	LAM 2018
RIOVISTACITY291	8,942,077	1,422,493	18,787,364	-	20	LAM 2018
RIPONCITYOFW292	17,232,251	1,786,490	35,280,530	-	32	LAM 2018
RIVERBANKCIT293	12,047,426	4,320,215	27,158,642	-	25	LAM 2018
RIVERSIDECIT294	279,135,500	77,671,811	490,534,831	-	32	LAM 2018
RIVERSIDEHIG295	14,590,656	9,544,720	41,138,671	-	21	LAM 2018
ROHNERTPARKC296	21,491,065	9,890,597	49,364,093	-	28	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
ROSAMONDCOMM297	3,729,075	10,839,137	70,962,608	-	10	LAM 2018
ROSEVILLECIT298	145,632,037	10,907,178	319,716,366	-	30	Summary Portal 2018
ROWLANDWATER299	19,149,832	22,937,862	71,664,188	13	26	LAM 2018
RUBIDOUXCOMM300	15,616,626	16,124,834	40,288,868	-	18	LAM 2018
RUBIOCANONLA301	15,292,038	6,330,711	14,611,535	146	51	LAM 2018
SACRAMENTOCI302	324,259,846	165,163,468	544,112,080	-	25	LAM 2018
SACRAMENTOCO303	201,270,594	51,456,936	677,615,891	0	18	LAM 2018
SACRAMENTODI039	149,542,477	106,953,934	403,118,718	89	25	Summary Portal 2018
SACRAMENTOSU304	171,931,466	70,523,142	224,658,587	-	34	LAM 2018
SALINASCALIF055	50,137,834	34,051,090	184,500,319	-	26	LAM 2018
SANBERNARDIN305	73,665,960	99,720,974	228,478,797	-	24	LAM 2018
SANBRUNOCITY308	16,114,942	6,016,720	40,539,912	-	29	LAM 2018
SANBUENAVENT309	51,481,619	23,097,293	141,948,508	160	22	LAM 2018
SANCLEMENTEC310	44,022,738	10,432,889	90,036,629	-	37	LAM 2018
SANDIEGOCALI040	39,178,445	5,091,614	111,530,010	-	14	LAM 2018
SANDIEGOCITY311	668,342,621	139,922,764	1,617,346,337	-	32	LAM 2018
SANDIEGUITOW312	39,882,778	13,792,790	63,986,200	-	40	LAM 2018
SANDIMASGSWC146	42,855,569	16,472,913	98,972,898	118	28	LAM 2018
SANFERNANDOC313	8,525,522	2,546,715	17,855,202	-	25	LAM 2018
SANFRANCISCO314	86,981,462	41,705,900	328,528,527	4	25	LAM 2018
SANGERCITYOF325	17,329,446	5,607,375	31,460,664	-	20	LAM 2018
SANJACINTOCI318	5,640,131	10,710,112	24,719,136	-	19	LAM 2018
SANJOSECITYO319	52,606,249	28,949,062	211,227,140	-	21	LAM 2018
SANJOSEHILLS351	79,209,659	73,110,936	218,708,642	101	24	LAM 2018
SANJOSEWATER320	551,289,069	330,853,810	1,255,686,919	116	36	LAM 2018
SANJUANCAPIS321	50,136,525	9,558,209	75,774,773	-	39	LAM 2018
SANJUANWATER322	99,874,499	44,936,021	182,648,267	364,532	52	LAM 2018
SANLORENZOVA323	14,190,713	26,556,955	370,090,592	-	83	LAM 2018
SANLUISOBISP324	33,213,390	20,637,980	94,598,751	228	29	LAM 2018
SANTAANACITY326	70,563,653	41,967,250	198,385,216	-	18	LAM 2018
SANTABARBARA327	69,734,417	68,301,959	181,835,022	2,592	46	Summary Portal 2018
SANTACLARACI328	57,893,123	16,212,092	131,939,953	-	26	LAM 2018
SANTACLARITA067	114,106,723	46,346,864	308,331,185	-	27	LAM 2018
SANTACRUZCIT329	46,494,338	21,402,087	168,069,274	-	18	LAM 2020
SANTAFEIRRIG330	105,322,921	46,752,958	175,359,058	-	47	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
SANTAFESPRIN331	5,160,503	1,251,679	16,817,432	-	15	LAM 2018
SANTAMARGARI332	111,908,319	4,290,825	257,308,212	-	30	LAM 2018
SANTAMARIACI333	25,225,201	24,999,438	92,692,571	-	18	LAM 2018
SANTAMONICAC334	36,385,790	3,542,150	66,193,403	98	32	LAM 2018
SANTAPAULACI335	14,301,467	7,848,771	48,425,356	-	32	LAM 2018
SANTAROSACIT336	170,893,146	72,577,833	381,414,882	-	37	LAM 2018
SCOTTSVALLEY337	9,510,193	6,664,613	44,081,398	-	67	LAM 2018
SEALBEACHCIT338	11,153,597	558,395	31,767,761	-	18	LAM 2018
SELMACALIFOR056	15,711,956	8,127,393	35,933,534	-	25	LAM 2018
SHAFTERCITYO339	13,959,164	5,611,749	88,234,338	-	30	LAM 2018
SIERRAMADREC341	14,754,831	6,930,530	19,058,372	-	47	LAM 2018
SIMIVALLEYGS147	26,306,135	9,206,307	53,851,576	-	21	LAM 2018
SIMIVALLEYVE384	78,015,112	73,754,488	170,205,262	-	25	LAM 2018
SOLANOIRRIGA353	12,462,340	11,256,610	42,675,712	-	18	LAM 2018
SOLEDADCITYO342	5,110,753	4,273,927	17,609,827	-	17	LAM 2018
SONOMACITYOF343	16,180,990	7,986,794	30,914,723	-	43	LAM 2018
SOQUELCREEKW344	47,745,552	13,067,650	110,510,589	6	51	LAM 2018
SOUTHARCADIA148	7,144,519	13,470,931	33,060,646	25	20	LAM 2018
SOUTHCOASTWA345	27,433,148	4,230,509	58,469,787	37	30	LAM 2018
SOUTHFEATHER346	64,681,041	48,376,611	983,640,671	67	41	LAM 2018
SOUTHGATECIT347	18,264,130	9,201,217	61,349,458	-	17	LAM 2018
SOUTHPASADEN348	21,489,015	7,172,792	30,565,615	-	43	LAM 2018
SOUTHSANFRAN057	10,792,536	14,810,795	53,546,224	-	22	LAM 2018
SOUTHSANGABR149	3,117,040	7,493,630	21,582,225	-	20	LAM 2018
SOUTHTAHOEPU349	23,073,695	24,240,380	104,930,706	-	7	LAM 2018
SOUTHWESTGSW150	57,059,804	41,539,110	202,101,559	3,148	16	LAM 2018
SPRINGVALLEY306	8,366,125	5,517,148	24,379,339	-	16	LAM 2018
STOCKTONCALI058	77,733,522	74,603,630	217,151,546	-	23	LAM 2018
STOCKTONCITY350	131,705,913	45,545,098	498,229,074	-	25	LAM 2018
SUNNYSLOPECO355	16,391,775	8,511,810	63,488,282	-	18	LAM 2018
SUNNYSLOPEWA354	14,573,678	5,326,598	28,731,965	-	26	LAM 2018
SUNNYVALECIT356	77,518,822	12,937,428	186,322,491	1	28	LAM 2018
SWEETWATERAU358	115,084,782	18,103,640	219,118,695	-	19	LAM 2018
TEHACHAPICIT359	8,244,602	5,291,145	16,435,737	-	21	LAM 2018
TEMESCALVALL360	12,090,607	3,292,356	39,191,779	-	24	LAM 2018
THOUSANDOAKS361	59,565,910	28,271,113	98,869,119	-	31	LAM 2018
TORRANCECITY362	41,089,619	15,546,760	108,681,529	0	25	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
TRABUCOCANYO363	8,880,792	2,374,468	28,775,495	-	40	LAM 2018
TRACYCITYOFW364	53,681,785	10,166,734	125,009,124	-	25	LAM 2018
TRUCKEEDONNE366	23,325,404	15,119,579	232,035,868	-	56	LAM 2018
TULARECITYOF367	54,887,035	20,038,651	85,293,660	-	29	LAM 2018
TUOLUMNEUTIL368	32,971,069	45,438,277	504,569,329	-	6	LAM 2018
TURLOCKCITYO369	53,799,929	12,657,656	91,401,745	-	27	LAM 2018
TUSTINCITYOF370	45,810,743	8,628,939	77,578,745	106	29	LAM 2018
TWENTYNINEPA371	1,349,576	30,377,371	482,169,979	386	12	LAM 2018
UKIAHCITYOFW372	9,815,843	9,007,763	24,145,443	-	46	LAM 2018
UPLANDCITYOF373	67,572,294	19,184,036	113,907,514	-	28	LAM 2018
VACAVILLECIT374	68,913,270	28,414,091	134,464,797	-	28	LAM 2018
VALENCIAWATE375	76,351,449	14,395,257	140,225,826	-	27	LAM 2018
VALLECITOSWA376	88,581,974	23,406,599	247,865,347	12	33	Summary Portal 2018
VALLEJOCITYO377	65,910,963	68,886,024	220,839,369	45	34	LAM 2018
VALLEYCENTER378	123,745,772	141,885,492	967,240,874	65,401	42	LAM 2018
VALLEYCOUNTY379	10,835,334	12,265,574	48,838,428	38	19	LAM 2018
VALLEYOFTHEM380	40,124,578	15,952,639	100,047,499	-	29	LAM 2020
VALLEYWATERC381	23,889,168	5,421,925	32,021,950	22	52	LAM 2018
VAUGHNWATERC382	66,276,605	11,600,209	114,911,413	13	21	LAM 2018
VENTURADISTI041	71,632,677	31,288,510	120,079,713	-	32	LAM 2018
VICTORVILLEW386	50,443,264	118,274,249	353,200,934	-	15	LAM 2018
VISALIACALIF059	125,532,613	52,401,864	238,245,223	-	28	LAM 2018
VISTAIRRIGAT387	121,120,828	104,780,500	311,575,342	10,877	34	Summary Portal 2018
WALNUTVALLEY388	72,676,510	50,859,813	236,870,693	101	32	LAM 2018
WASCOCITYOFW389	10,666,543	7,154,541	21,631,072	-	19	LAM 2018
WATSONVILLEC390	25,634,298	22,138,752	176,340,098	-	42	LAM 2018
WCSANGABRIEL316	86,561,501	56,648,026	258,959,350	25	24	LAM 2018
WDSANGABRIEL315	12,591,905	9,319,369	37,900,399	13	21	LAM 2018
WESTBOROUGHC394	1,858,817	1,571,362	9,426,251	93	19	LAM 2018
WESTERNMUNIC395	116,865,567	144,314,567	495,373,579	-	22	LAM 2018
WESTKERNWATE391	7,227,412	18,172,895	149,329,613	-	7	LAM 2018
WESTLAKECALI060	34,178,796	6,905,001	57,195,787	-	43	LAM 2018
WESTMINISTER396	25,978,406	13,882,964	94,795,003	-	15	LAM 2018
WESTORANGEGS151	31,034,038	13,881,424	116,980,344	16	17	LAM 2018
WESTSACRAMEN392	38,448,054	15,101,382	96,881,695	-	27	LAM 2018
WESTVALLEYWA393	55,668,934	31,066,337	171,597,942	-	19	LAM 2018

WDID	Irrigated Area (ft^2)	Irrigable-Not irrigated Area (ft^2)	Not Irrigable Area (ft^2)	No Imagery Available Area (ft^2)	Total Canopy (%)	Data Source
WHITTIERCITY397	24,957,769	10,795,057	56,190,241	13	25	LAM 2018
WINDSORTOWNO398	27,760,422	13,419,315	107,809,965	-	37	LAM 2018
WOODLANDCITY399	39,136,534	20,371,254	77,897,876	-	30	LAM 2018
YORBALINDAWA400	103,214,735	28,182,001	147,166,311	295	28	LAM 2018
YUBACITYWATE402	58,602,841	33,032,232	99,114,520	-	27	LAM 2018
YUCAIPAVALLE403	63,818,003	37,607,429	215,817,431	690	30	LAM 2018

Appendix E – Results Summary by Land Use Code

Table 16: Median and mean irrigation status coverage percentages summarized by land use code (LUC) for all the queried parcels in the Landscape Area Measurements Project. Mean and median coverages were calculated from the original parcel layer (Parcels A). See the Parcel Topology Handling section for additional information on parcel datasets and transformations. Land use codes are defined in Table 17.

LUC	Median NI coverage (%)	Mean NI coverage (%)	Median II coverage (%)	Mean II coverage (%)	Median INI coverage (%)	Mean INI coverage (%)
10	83.7	76.9	12.5	17.6	1.2	5.6
13	21.6	17.0	27.2	24.1	51.3	58.9
16	94.9	94.9	2.4	2.4	2.7	2.7
17	86.9	87.0	7.0	6.1	7.3	6.9
18	81.8	76.1	13.4	16.8	2.8	7.2
19	99.0	99.2	0.0	0.0	1.0	0.7
20	97.5	88.3	0.0	5.7	0.3	5.9
21	91.6	78.5	2.4	12.6	1.6	8.9
22	98.8	75.4	0.3	18.6	0.1	6.0
24	48.4	51.3	36.3	41.5	0.5	7.3
1000	82.9	75.1	7.0	14.8	3.2	10.2
1001	59.9	59.7	27.4	28.0	7.3	11.9
1002	81.3	77.8	13.9	17.1	0.0	4.9
1003	61.7	62.0	27.0	27.0	6.9	11.0
1004	81.2	79.3	15.6	17.3	0.7	3.3
1005	84.5	81.9	12.8	15.1	1.1	3.0
1006	81.4	77.1	11.5	13.6	4.2	8.8
1007	94.6	92.1	0.7	5.3	0.0	2.6
1008	81.5	72.6	6.8	13.2	7.3	12.0
1009	73.0	71.2	20.9	23.0	0.8	5.8
1010	63.9	59.1	25.8	32.5	2.6	8.5
1011	61.9	63.3	28.9	26.2	1.2	5.0
1012	99.9	97.4	0.0	0.5	0.1	2.1
1014	72.7	72.3	20.1	21.3	2.8	6.4
1015	73.3	67.5	10.8	20.5	3.1	11.4
1016	80.3	77.3	5.8	10.6	7.5	12.0
1100	67.3	65.6	19.2	21.3	7.8	12.2

LUC	Median NI coverage (%)	Mean NI coverage (%)	Median II coverage (%)	Mean II coverage (%)	Median INI coverage (%)	Mean INI coverage (%)
1101	69.5	67.8	19.0	21.3	6.4	10.5
1102	76.5	74.2	15.2	17.6	4.4	8.2
1103	79.1	76.7	13.6	16.0	3.1	6.9
1104	84.8	81.7	11.5	14.0	1.4	4.3
1105	73.8	72.8	20.5	21.7	3.5	5.5
1106	49.8	51.1	28.4	29.3	16.1	19.6
1107	95.4	92.2	3.7	6.3	0.0	1.5
1108	71.5	70.9	19.6	21.2	2.9	8.0
1109	82.3	78.8	11.3	14.1	3.6	6.4
1110	74.2	72.4	17.6	19.7	2.9	8.0
1111	71.3	67.0	22.6	25.0	5.2	8.0
1112	81.5	79.1	13.7	15.8	1.3	5.1
1113	74.7	71.6	13.6	18.0	7.0	10.4
1999	60.2	60.1	28.0	28.5	7.1	11.4
2000	70.4	67.2	21.4	25.3	2.1	7.5
2001	78.2	74.1	13.6	18.7	2.3	7.2
2002	64.1	64.1	35.9	35.9	0.0	0.0
2003	81.4	68.9	2.9	14.5	12.7	16.6
2008	81.0	81.0	14.9	14.9	4.1	4.1
2009	96.2	96.2	0.0	0.0	3.8	3.8
2011	54.6	54.6	5.0	5.0	40.4	40.4
2012	88.6	77.0	1.2	9.4	4.0	13.6
2013	74.3	74.3	5.5	5.5	20.2	20.2
2014	79.5	79.5	0.8	0.8	19.7	19.7
2016	78.1	78.1	1.5	1.5	20.4	20.4
2019	95.8	93.4	2.6	2.3	3.0	4.3
2020	97.0	97.0	0.5	0.5	2.5	2.5
2023	88.7	83.2	9.5	12.0	2.6	4.8
2024	68.4	68.2	9.7	13.9	0.0	17.9
2025	94.6	94.6	0.0	0.0	5.4	5.4
2026	100.0	100.0	0.0	0.0	0.0	0.0
2027	70.7	70.7	20.7	20.7	8.6	8.6
2028	61.9	61.9	15.8	15.8	22.3	22.3
2031	85.7	81.0	0.9	9.4	13.4	9.5
2033	68.4	71.6	4.8	11.7	10.5	16.7
2034	72.9	71.3	21.3	23.9	4.8	4.9
2036	88.5	83.0	5.4	9.1	4.3	7.9
2037	95.9	95.9	4.1	4.1	0.0	0.0

LUC	Median NI coverage (%)	Mean NI coverage (%)	Median II coverage (%)	Mean II coverage (%)	Median INI coverage (%)	Mean INI coverage (%)
2040	93.0	93.0	5.6	5.6	1.3	1.3
2042	92.4	86.8	5.0	9.0	0.0	4.3
2043	80.5	76.2	19.2	22.1	0.3	1.7
2044	92.1	85.0	4.6	9.2	0.4	5.8
2052	100.0	98.3	0.0	1.0	0.0	0.7
2054	69.9	69.9	27.7	27.7	2.5	2.5
3000	90.5	83.2	2.7	8.5	6.9	8.3
3001	66.5	68.7	22.2	19.9	6.3	11.3
3003	68.9	69.1	21.9	24.8	3.0	6.1
3004	83.0	73.1	14.4	22.8	4.2	4.1
3006	55.6	56.3	30.0	35.2	11.0	8.5
3008	86.8	86.9	10.4	10.9	0.0	2.2
3010	93.6	88.9	4.7	8.9	0.6	2.2
3011	82.4	80.0	14.1	17.2	0.7	2.8
4000	34.0	34.0	65.3	65.3	0.7	0.7
4004	52.8	48.8	27.8	33.0	18.2	18.2
4007	69.3	74.6	22.1	17.8	2.5	7.6
4018	78.1	78.1	16.3	16.3	5.6	5.6
4020	74.0	74.0	25.3	25.3	0.7	0.7
4027	31.2	38.6	42.1	39.5	24.7	21.9
4028	31.3	34.3	47.7	41.4	22.9	24.3
5000	65.4	56.5	10.9	12.5	18.3	31.0
5001	83.2	76.8	16.1	17.8	1.2	5.3
5002	72.5	72.5	0.1	0.1	27.5	27.5
5003	81.5	82.2	6.2	8.1	3.7	9.8
5004	70.8	70.8	0.8	0.8	28.4	28.4
5013	86.0	86.0	12.2	12.2	1.8	1.8
5020	96.1	96.1	2.5	2.5	1.4	1.4
6003	32.1	32.1	2.9	2.9	65.1	65.1
6021	83.4	83.4	14.8	14.8	1.8	1.8
6504	34.5	49.0	20.4	29.8	4.7	21.3
7000	66.7	61.4	15.1	23.3	10.5	15.3
7001	97.5	97.5	0.7	0.7	1.8	1.8
7004	83.5	75.8	11.9	14.6	4.6	9.7
7005	43.2	52.7	25.5	31.1	12.2	16.2
7006	90.8	92.5	2.2	2.2	5.7	5.3
7012	81.6	67.6	1.1	4.1	12.8	28.3
7016	85.2	78.5	6.0	8.1	9.5	13.4

LUC	Median NI coverage (%)	Mean NI coverage (%)	Median II coverage (%)	Mean II coverage (%)	Median INI coverage (%)	Mean INI coverage (%)
7017	92.1	92.1	5.6	5.6	2.4	2.4
7018	63.9	63.9	0.0	0.0	36.1	36.1
7019	99.1	99.1	0.0	0.0	0.9	0.9
7023	57.7	55.0	9.0	14.4	30	30.6
8000	65.2	62.1	17.9	26.0	3.8	11.8
8001	64.3	59.6	4.8	16.3	16.0	24.1
8002	74.3	67.9	10.1	17.3	6.0	14.7
8003	67.6	63.0	8.6	11.4	25.5	25.7
8004	49.7	51.1	35.7	36.4	7.3	12.5
8006	63.5	55.4	21.0	26.0	12.6	18.6
8007	63.7	58.2	7.6	17.5	15.1	24.4
8008	64.8	57.7	13.4	25.3	14.4	17.0
8009	0.0	0.0	0.0	0.0	100.0	100.0
8010	57.7	49.6	15.0	14.1	21.3	36.3
8014	48.9	46.0	37.0	37.6	22.3	16.4
9000	50.5	55.3	38.3	31.1	13.6	13.7
9100	47.6	47.6	32.2	32.2	20.2	20.2
9101	69.4	66.9	14.8	19.8	11.7	13.3
9102	58.9	59.6	2.2	10.2	34.5	30.3
9106	72.2	71.0	19.8	21.3	4.1	7.6
9107	77.7	61.9	11.8	13.9	12.8	24.2
9110	53.8	53.8	4.1	4.1	42.0	42.0
9200	95.3	86.2	4.4	13.3	0.0	0.6
9202	74.2	74.2	21.1	21.1	4.6	4.6
9203	59.1	57.0	13.0	16.2	25.9	26.8
9209	8.7	8.7	52.7	52.7	38.6	38.6
9210	64.6	57.0	29.9	35.3	6.7	7.7
9211	55.5	55.5	41.6	41.6	2.8	2.8
9216	43.0	43.0	52.7	52.7	4.3	4.3
9217	77.5	72.0	13.8	16.9	5.6	11.2
9219	42.1	42.1	26.5	26.5	31.3	31.3
9300	88.0	77.3	10.5	18.8	0.4	3.9
9301	63.2	63.8	18.0	21.3	7.8	14.8

Appendix F – Land Use Codes

Table 17: Parcel land use codes used in the 2018 Landscape Area Measurements Project.

Code	Code Description	Valid Code
0010	**Miscellaneous (General)**	**TRUE**
0011	Pipeline or Right-of-Way	FALSE
0012	Rail (Right-of-way & track)	FALSE
0013	Road (Right-of-way)	FALSE
0014	Utilities (Right-of-way ONLY)	FALSE
0015	**Sub-Surface Rights (mineral)**	**TRUE**
0016	**Surface Rights (Grazing, timber, coal, etc.)**	**TRUE**
0017	**Leasehold Rights (misc.)**	**TRUE**
0018	**Possessory Interest (misc.)**	**TRUE**
0019	Petroleum & Gas Wells (misc.)	FALSE
0020	**Water Rights (misc.)**	**TRUE**
0021	**Right-of-Way (not rail, road or utility)**	**TRUE**
0022	**Easement (misc.)**	**TRUE**
0023	**Homestead (Misc.)**	**TRUE**
0024	**Common Area (misc.)**	**TRUE**
0025	**Royalty Interest**	**TRUE**
0026	**Working Interest**	**TRUE**
0027	Vacant parcels with improvements	FALSE
0500	**Personal property (general)**	**TRUE**
0510	**Vehicles (general)**	**TRUE**
0511	**Motor vehicles (cars, trucks, etc.)**	**TRUE**
0512	**Travel trailers**	**TRUE**
0513	**Watercraft (ships, boats, PWCs, etc.)**	**TRUE**
0514	**Aircraft**	**TRUE**
0515	**Rolling stock (railroad)**	**TRUE**
0516	**Spacecraft**	**TRUE**
0519	**Misc vehicles not otherwise classed (antiques, etc.)**	**TRUE**
0520	**Business personal property (general)**	**TRUE**

Code	Code Description	Valid Code
0521	Equipment / supplies	TRUE
0522	Inventory	TRUE
0523	Goods in transit	TRUE
0524	Livestock (animals, fish, birds, etc.)	TRUE
0525	Crops (in ground)	TRUE
0526	Crops (harvested)	TRUE
0529	Misc Business Personal Property not otherwise classed	TRUE
0530	Structures (general)	TRUE
0532	Structures on leased land (may include Mobile Homes -- see "MH Land Use")	TRUE
0533	Temporary structures	TRUE
0539	Misc structures not otherwise classed (billboards, etc.)	TRUE
0540	Intangible personal property	TRUE
0599	Misc personal property not otherwise classed	TRUE
1000	Residential (General) (Single)	TRUE
1001	Single Family Residential	TRUE
1002	Townhouse (Residential)	TRUE
1003	Cluster home (Residential)	TRUE
1004	Condominium (Residential)	TRUE
1005	Cooperative (Residential)	TRUE
1006	Mobile home	TRUE
1007	Row house (Residential)	TRUE
1008	Rural Residence (Agricultural)	TRUE
1009	Planned Unit Development (PUD) (Residential)	TRUE
1010	Residential Common Area (Condo/PUD/etc.)	TRUE
1011	Timeshare (Residential)	TRUE
1012	Seasonal, Cabin, Vacation Residence	TRUE
1013	Bungalow (Residential)	TRUE
1014	Zero Lot Line (Residential)	TRUE
1015	Misc Residential Improvement	TRUE
1016	Manufactured, Modular, Pre-Fabricated Homes	TRUE
1017	Patio Home	TRUE
1018	Garden Home	TRUE

Code	Code Description	Valid Code
1019	**Landominium**	**TRUE**
1100	**Residential Income (General) (Multi-Family)**	**TRUE**
1101	**Duplex (2 units, any combination)**	**TRUE**
1102	**Triplex (3 units, any combination)**	**TRUE**
1103	**Quadruplex (4 units, any combination)**	**TRUE**
1104	**Apartment house (5+ units)**	**TRUE**
1105	**Apartment house (100+ units)**	**TRUE**
1106	**Garden Apt, Court Apt (5+ units)**	**TRUE**
1107	**Highrise Apartments**	**TRUE**
1108	**Boarding House, Rooming House, Apt Hotel, Transient Lodgings**	**TRUE**
1109	**Mobile Home Park, Trailer Park**	**TRUE**
1110	**Multi-Family Dwellings (Generic, any combination 2+)**	**TRUE**
1111	**Fraternity House, Sorority House**	**TRUE**
1112	**Apartments (generic)**	**TRUE**
1113	**Dormitory, Group Quarters (Residential)**	**TRUE**
1114	**Residential Condominium Development (Association Assessment)**	**TRUE**
1901	**Residential Parking Garage**	**TRUE**
1902	**Residential Storage Space**	**TRUE**
1999	**Single Family Residential**	**TRUE**
2000	Commercial (General)	FALSE
2001	Retail Stores (Personal Services, Photography, Travel)	FALSE
2002	Store (multi-story)	FALSE
2003	Store/Office (mixed use)	FALSE
2004	Department Store (apparel, household goods, furniture)	FALSE
2005	Department Store (multi-story)	FALSE
2006	Grocery, Supermarket	FALSE
2007	Regional: Shopping Center, Mall (w/Anchor)	FALSE
2008	Community: Shopping Plaza, Shopping Center, Mini-Mall	FALSE
2009	Neighborhood: Shopping Center, Strip Center, Enterprise Zone	FALSE
2010	Shopping Center COMMON AREA (parking, etc.)	FALSE
2011	Veterinary, Animal Hospital	FALSE
2012	Restaurant	FALSE
2013	Drive-thru Restaurant, Fast Food	FALSE

Code	Code Description	Valid Code
2014	Take-out Restaurant (food preparation)	FALSE
2015	Bakery	FALSE
2016	Bar, Tavern	FALSE
2017	Liquor Store	FALSE
2018	Convenience store (7-11)	FALSE
2019	Convenience Store (w/fuel pump)	FALSE
2020	Service station (full service)	FALSE
2021	Service station w/convenience store (food mart)	FALSE
2022	Truck stop (fuel and diner)	FALSE
2023	Vehicle Rentals, Vehicle Sales (auto/truck/RV/boat/etc.)	FALSE
2024	Auto repair (& related), Garage	FALSE
2025	Car wash	FALSE
2026	Dry Cleaner, Laundry	FALSE
2027	Service Shop (TV, radio, electric, plumbing)	FALSE
2028	Florist, Nursery, Greenhouse (retail/wholesale)	FALSE
2029	Wholesale Outlet, Discount Store (Franchise)	FALSE
2030	Printer - Retail (PIP, QwikCopy, etc.)	FALSE
2031	Mini-Warehouse, Storage	FALSE
2032	Day care, Pre-school (Commercial)	FALSE
2033	Motel	FALSE
2034	Hotel	FALSE
2035	Parking Garage, Parking Structure	FALSE
2036	Parking Lot	FALSE
2037	Funeral Home, Mortuary (Commercial)	FALSE
2038	Casino	FALSE
2039	Hotel-Resort	FALSE
2040	Hotel/Motel	FALSE
2041	Gas Station	FALSE
2042	**Stores & Apartments**	**TRUE**
2043	Commercial Building, Mail Order, Show Room (Non-auto), Commercial Whse	FALSE
2044	**Comm/Ofc/Res Mixed Use**	**TRUE**
2045	Appliance Store (Circuit City, Good Guys, Best Buy)	FALSE
2046	Kennel	FALSE

Code	Code Description	Valid Code
2047	Laundromat (self-service)	FALSE
2048	Nightclub (Cocktail Lounge)	FALSE
2050	Farm Supply & Equipment (Commercial)	FALSE
2051	Garden Center, Home Improvement (Do-It-Yourself)	FALSE
2052	**Commercial Condominium (not offices)**	**TRUE**
2053	Drug Store / Pharmacy	FALSE
2054	Bed & Breakfast	FALSE
3000	Commercial Office (General)	FALSE
3001	Professional Bldg (legal; insurance; real estate; business)	FALSE
3002	Professional Bldg (multi-story)	FALSE
3003	Office Bldg (General)	FALSE
3004	Office Bldg (multi-story)	FALSE
3005	Dental Bldg	FALSE
3006	Medical Bldg	FALSE
3007	Financial Bldg (Bank, S&L; Mtge; Loan; Credit)	FALSE
3008	**Condominium Offices**	**TRUE**
3009	Skyscraper/Highrise (Commercial Offices)	FALSE
3010	**Mixed Use (Commercial/Industrial)**	**TRUE**
3011	**Common Area (commercial, not shopping center or Association Asmnt.)**	**TRUE**
3012	Mobile Commercial Units	FALSE
4000	Recreational/Entertainment (General)	FALSE
4001	Recreation Center	FALSE
4002	Public Swimming Pool	FALSE
4003	Boat slips, Marina, Yacht Club (recreation/pleasure), Boat Landing	FALSE
4004	Bowling Alley	FALSE
4005	Arcades (Amusement)	FALSE
4006	Skating rink, Ice Skating, Roller Skating	FALSE
4007	Clubs, Lodges, Professional Associations	FALSE
4008	Museums, Library, Art Gallery (Recreational)	FALSE
4009	Country Club	FALSE
4010	Stadiums	FALSE
4011	Arenas, Convention Center	FALSE
4012	Auditoriums	FALSE

Code	Code Description	Valid Code
4013	Driving Range (Golf)	FALSE
4014	Race track (auto; dog; horse)	FALSE
4015	Gym, Health Spa	FALSE
4016	Dance Hall	FALSE
4017	Riding Stable, Trails	FALSE
4018	Campground, RV Park	FALSE
4019	Fairgrounds	FALSE
4020	Theater (movie and legitimate)	FALSE
4021	Drive-In Theater	FALSE
4022	Amusement Park, Tourist Attraction	FALSE
4023	Piers, Wharf (Recreation)	FALSE
4024	Fish Camps, Game Club, Target Shooting	FALSE
4025	Outdoor Recreation: Beach, Mountain, Desert	FALSE
4026	Pool Hall, Billiard Parlor	FALSE
4027	Park, Playground, Picnic Area	FALSE
4028	Golf Course	FALSE
4029	Racquet Court, Tennis Court	FALSE
4030	Zoo	FALSE
4031	Go-carts, Miniature Golf, Water slides	FALSE
5000	Industrial (General)	FALSE
5001	Manufacturing (light)	FALSE
5002	Light Industrial (10% improved office space; Machine Shop)	FALSE
5003	Warehouse (Industrial)	FALSE
5004	Storage yard, Open Storage (light equipment, material)	FALSE
5005	Food Packing, Packing Plant (fruit; vegetable; meat, dairy)	FALSE
5006	Assembly (light industrial)	FALSE
5007	Food Processing (candy; bakery; potato chips)	FALSE
5008	Recycling (metal; paper; glass; etc.)	FALSE
5009	Communications (see 6500 series)	FALSE
5010	Condominiums (Industrial)	FALSE
5011	R&D Facility, Laboratory, Research Facility, Cosmetics, Pharmaceutical	FALSE
5012	Industrial Park	FALSE
5013	Multi-Tenant Industrial Bldg.	FALSE

Code	Code Description	Valid Code
5014	Marine Facility/Boat Repairs (small craft or sailboat)	FALSE
5015	Lumber & Wood Product MFG (including furniture)	FALSE
5016	Paper Product MFG & related products	FALSE
5017	Printing & Publishing (Light Industrial)	FALSE
5018	Industrial Loft Building, Loft Building	FALSE
5019	Construction/Contracting Services (Industrial)	FALSE
5020	Common Area (Industrial)	FALSE
6000	Heavy Industrial (General)	FALSE
6001	Transportation	FALSE
6002	Distribution Warehouse (Regional)	FALSE
6003	Mining (oil; gas; mineral, precious metals)	FALSE
6004	Storage yard (junk; auto wrecking, salvage)	FALSE
6005	Distillery, Brewery, Bottling	FALSE
6006	Refinery, Petroleum Products	FALSE
6007	Mill (feed; grain; paper; lumber; textile; pulp)	FALSE
6008	Factory (apparel, textile products, leather, medium mfg.)	FALSE
6009	Processing Plant (minerals; cement; rock; gravel; glass; clay)	FALSE
6010	Lumberyard, Building Materials	FALSE
6011	Shipyard/Storage - Built or Repaired (seagoing vessels)	FALSE
6012	Slaughter House, Stockyard	FALSE
6013	Waste Disposal, Sewage (processing; disposal; storage; treatment)	FALSE
6014	Quarries (sand; gravel; rock)	FALSE
6015	Heavy Manufacturing	FALSE
6016	Labor Camps (Industrial)	FALSE
6017	Winery	FALSE
6018	Chemical	FALSE
6019	Foundry, Industrial Plant (metal; rubber; plastic)	FALSE
6020	Cannery	FALSE
6021	Bulk Storage, Tanks (gasoline, fuel, etc.)	FALSE
6022	Grain Elevator	FALSE
6023	Dump Site	FALSE
6024	Cold Storage	FALSE
6025	Sugar Refinery	FALSE

Code	Code Description	Valid Code
6500	Transportation & Communications (General)	FALSE
6501	Airport & related	FALSE
6502	Railroad & related	FALSE
6503	Freeways, State Hwys	FALSE
6504	Roads, Streets, Bridges	FALSE
6505	Bus Terminal	FALSE
6506	Telegraph, Telephone	FALSE
6507	Radio or TV Station	FALSE
6508	Truck Terminal (Motor Freight)	FALSE
6509	Cable TV Station	FALSE
6510	Harbor & Marine Transportation	FALSE
6511	Microwave	FALSE
6512	Commercial Auto Transportation/Storage	FALSE
6513	Pollution Control	FALSE
7000	Agricultural / Rural (General)	FALSE
7001	Farm (Irrigated or Dry)	FALSE
7002	Ranch	FALSE
7003	Range land (grazing)	FALSE
7004	Crop land, Field Crops, Row Crops (all soil classes)	FALSE
7005	Orchard (fruit; nut)	FALSE
7006	Vineyard (Agricultural)	FALSE
7007	Poultry Farm (chicken; turkey; fish; bees; rabbits)	FALSE
7008	Dairy Farm	FALSE
7009	Timberland, Forest, Trees (Agricultural)	FALSE
7010	Wildlife (Refuge)	FALSE
7011	Desert or Barren Land	FALSE
7012	Pasture, Meadow	FALSE
7013	Misc. Structures - Ranch, Farm, Fixtures	FALSE
7014	Grove (Agricultural)	FALSE
7015	Feedlots	FALSE
7016	Livestock	FALSE
7017	Horticulture, Growing Houses, Ornamental (Agricultural)	FALSE
7018	Well Site (Agricultural)	FALSE

Code	Code Description	Valid Code
7019	Truck Crops	FALSE
7020	Reservoir, Water Supply	FALSE
7021	Irrigation, Flood Control	FALSE
7022	Natural Resources	FALSE
7023	Rural Improved / Non-Residential	FALSE
8000	Vacant Land (General)	FALSE
8001	Residential-Vacant Land	FALSE
8002	Commercial-Vacant Land	FALSE
8003	Industrial-Vacant Land	FALSE
8004	Private Preserve, Open Space-Vacant Land (Forest Land, Conservation)	FALSE
8005	Institutional-Vacant Land	FALSE
8006	Government-Vacant Land	FALSE
8007	Multi-Family-Vacant Land	FALSE
8008	Agricultural-Unimproved Vacant Land	FALSE
8009	Waste Land, Marsh, Swamp, Submerged-Vacant Land	FALSE
8010	Recreational-Vacant Land	FALSE
8011	Water Area (Lakes; River; Shore)-Vacant Land	FALSE
8012	Unusable Land (Remnant, Steep, etc.)	FALSE
8013	Abandoned Site, Contaminated Site	FALSE
8014	Under Construction	FALSE
8500	Special Purpose	FALSE
8501	SBE - Special Assessments	FALSE
8502	Regulating Districts & Assessments; Tax Abatement	FALSE
8503	Redevelopment Agency or Zone	FALSE
8504	Centrally Assessed	FALSE
9000	Exempt (full or partial)	FALSE
9001	Indian Lands	FALSE
9100	Institutional (General)	FALSE
9101	Religious, Church, Worship (Synagogue, Temple, Parsonage)	FALSE
9102	Parochial School, Private School	FALSE
9103	College, University, Vocational school-PRIVATE	FALSE
9104	Hospital-PRIVATE	FALSE
9105	Medical Clinic	FALSE

Code	Code Description	Valid Code
9106	**Homes (retired; handicap, rest; convalescent; nursing)**	**TRUE**
9107	**Children's Home, Orphanage**	**TRUE**
9108	Cemetery (Exempt)	FALSE
9109	Crematorium, Mortuary (Exempt)	FALSE
9110	Charitable organization, Fraternal	FALSE
9111	Recreational Non-Taxable (Camps, Boy Scouts)	FALSE
9112	Private Utility (Electric; Water; Gas; etc.)	FALSE
9200	Governmental/Public Use (General)	FALSE
9201	Military (office; base; post; port; reserve; weapon range; test sites)	FALSE
9202	Forest (park; reserve; recreation, conservation)	FALSE
9203	Public School (administration; campus; dorms; instruction)	FALSE
9204	Colleges, University-PUBLIC	FALSE
9205	Post Office	FALSE
9206	Cultural, Historical (monuments; homes; museums; other)	FALSE
9207	Govt. Administrative Office (Federal; State; Local; Court House)	FALSE
9208	Emergency (Police; Fire; Rescue; Shelters, Animal Shelter)	FALSE
9209	Other exempt property	FALSE
9210	City, Municipal, Town, Village Owned (Exempt)	FALSE
9211	County Owned (Exempt)	FALSE
9212	State Owned (Exempt)	FALSE
9213	Federal Property (Exempt)	FALSE
9214	Public Health Care Facility (Exempt)	FALSE
9215	Community Center (Exempt)	FALSE
9216	Public Utility (Electric; Water; Gas; etc.)	FALSE
9217	Welfare, Social Service, Low Income Housing (Exempt)	FALSE
9218	Correctional Facility, Jails, Prisons, Insane Asylum	FALSE
9219	Hospital-PUBLIC	FALSE
9300	**Historical-PRIVATE (General)**	**TRUE**
9301	**Historical Residence**	**TRUE**
9302	Historical Retail	FALSE
9303	Historical Warehouse	FALSE
9304	Historical Office	FALSE
9305	Historical Transient Lodging (hotel/motel)	FALSE

Code	Code Description	Valid Code
9307	Historical Recreation, Entertainment	FALSE
9308	Historical Park, Site, Misc.	FALSE
9309	**Historical District**	**TRUE**

Table 18: Restricted Land Use Code query used to determine valid single-family and multi-family parcels for the 2020 Landscape Area Measurements Updates and Forested Service Area Assessments.

Code	Code Description	Valid Code
1000	**Residential (General) (Single)**	**TRUE**
1001	**Single Family Residential**	**TRUE**
1002	**Townhouse (Residential)**	**TRUE**
1003	**Cluster home (Residential)**	**TRUE**
1004	**Condominium (Residential)**	**TRUE**
1005	**Cooperative (Residential)**	**TRUE**
1006	**Mobile home**	**TRUE**
1007	**Row house (Residential)**	**TRUE**
1008	**Rural Residence (Agricultural)**	**TRUE**
1009	**Planned Unit Development (PUD) (Residential)**	**TRUE**
1010	**Residential Common Area (Condo/PUD/etc.)**	**TRUE**
1011	**Timeshare (Residential)**	**TRUE**
1012	**Seasonal, Cabin, Vacation Residence**	**TRUE**
1013	**Bungalow (Residential)**	**TRUE**
1014	**Zero Lot Line (Residential)**	**TRUE**
1015	**Misc Residential Improvement**	**TRUE**
1016	**Manufactured, Modular, Pre-Fabricated Homes**	**TRUE**
1017	**Patio Home**	**TRUE**
1018	**Garden Home**	**TRUE**
1019	**Landominium**	**TRUE**
1100	**Residential Income (General) (Multi-Family)**	**TRUE**
1101	**Duplex (2 units, any combination)**	**TRUE**
1102	**Triplex (3 units, any combination)**	**TRUE**

Code	Code Description	Valid Code
1103	Quadruplex (4 units, any combination)	TRUE
1104	Apartment house (5+ units)	TRUE
1105	Apartment house (100+ units)	TRUE
1106	Garden Apt, Court Apt (5+ units)	TRUE
1107	Highrise Apartments	TRUE
1108	Boarding House, Rooming House, Apt Hotel, Transient Lodgings	TRUE
1109	Mobile Home Park, Trailer Park	TRUE
1110	Multi-Family Dwellings (Generic, any combination 2+)	TRUE
1111	Fraternity House, Sorority House	TRUE
1112	Apartments (generic)	TRUE
1113	Dormitory, Group Quarters (Residential)	TRUE
1114	Residential Condominium Development (Association Assessment)	TRUE
1901	Residential Parking Garage	TRUE
1902	Residential Storage Space	TRUE
1999	Single Family Residential	TRUE
9106	Homes (retired; handicap, rest; convalescent; nursing)	TRUE
9107	Children's Home, Orphanage	TRUE
9300	Historical-PRIVATE (General)	TRUE
9301	Historical Residence	TRUE

Derived Data

Agricultural Lands Mask

Table 19: Data dictionary for the Agricultural_Lands_Mask Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
MASK_TYPE	String	25	Type of land mask contained within the feature class	Ex. AG
LAST_MOD	Date	8	The date the Agricultural_Lands_Mask was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Horse Corral Mask

Table 20: Data dictionary for the Horse_Corral_Mask Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
MASK_TYPE	String	25	Type of land mask contained within the feature class	Ex. HC
LAST_MOD	Date	8	The date the Horse_Corral_Mask was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Landscape Area Estimates A

Table 21: Data dictionary for the Landscape_Area_Estimates_A Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
LAST_MOD	Date	8	The date Landscape_Area_Estimates_A was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
APN	String	40	Property APN/ID as inventoried by the tax assessor	Ex. 125-100-11
ZIP	String	5	Property zip code returned from corrected address process	Ex. "92120" in 123 main street unit A Anytown CA 92120
LUC	String	4	Four-digit Land Use Code (held as string field to preserve leading zeros). Indicates the use of a property. Refer to LUCDSC field for the corresponding description.	Ex. 0015, 9016, etc.
A_UID	String	50	Unique ID added to the original parcel layer by NV5 Geospatial	Ex. Ranch00000000341
IMP_AREA	Double	8	Area of impervious surfaces in square feet	Ex. 90.2356
I_AREA	Double	8	Area of irrigated land in square feet	Ex. 623.2356
INI_AREA	Double	8	Area of irrigable but not currently irrigated land in square feet	Ex. 102.2356

Field Name	Type	Length	Description	Attribute Values
NI_AREA	Double	8	Area of not irrigable land in square feet	Ex. 823.2356
POOL_AREA	Double	8	Area of pools in square feet	Ex. 56.2356
HCL	Double	8	Area of horse corrals and arenas in square feet	Ex. 100.2356
UDM	Double	8	Area of undeveloped (for the purpose of irrigation) land in square feet	Ex. 14623.2356
AG	Double	8	Area of agricultural land in square feet	EX. 2635. 7853
TOTAL_AREA	Double	8	Area of the parcel in square feet	Ex. 4623.2356
MODEL_AREA	Double	8	Area of the parcel in square feet that was not masked by the Agricultural, Horse Corrals or Undeveloped Lands Mask	Ex. 1548.7068
CAN_AREA	Double	8	Area of canopy in square feet	Ex. 56.426433
TOTAL_II	Double	8	Total irrigated area in square feet. This is a sum of the I_AREA and POOL_AREA fields.	Ex. 689.2983
TOTAL_INI	Double	8	Total irrigable-not irrigated area in square feet. This is identical to the INI_AREA field.	Ex. 1693.8394
TOTAL_NI	Double	8	Total not irrigable area in square feet. This is a sum of the IMP_AREA, NI_AREA, HCL, UDM, and AG fields	Ex. 3984.9548
IMP_BIAS	Double	8	Impervious estimated bias error	Ex. 0.030722
I_BIAS	Double	8	Irrigated estimated bias error	Ex 0.114912
INI_BIAS	Double	8	Irrigable but not irrigated estimated bias error	Ex. -0.114912
NI_BIAS	Double	8	Not irrigated estimated bias error	Ex. -0.034945
POOL_BIAS	Double	8	Pool estimated bias error	Ex. 0.030722
IMP_VAR	Double	8	Impervious estimated variance	Ex. 0.001544
I_VAR	Double	8	Irrigated estimated variance	Ex. 0.000927
INI_VAR	Double	8	Irrigable-not irrigated estimated variance	Ex. 0.000012
NI_VAR	Double	8	Not irrigated estimated variance	Ex. 0.003022
POOL_VAR	Double	8	Pool estimated variance	Ex. 0.000049
OVERLAP	String	4	Binary values 0 - one to one A_UID to B_UID relationship, 1 - one to many A_UID to B_UID relationship.	Ex. 1

Field Name	Type	Length	Description	Attribute Values
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Landscape Area Estimates B

Table 22: Data dictionary for the Landscape_Area_Estimates_B Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
LAST_MOD	Date	8	The date Landscape_Area_Estimates_B was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
B_UID	String	50	Unique ID added by NV5 Geospatial to the topologically corrected parcel layer (to account for parcel overlap in the original parcel layer)	Ex. EastB0000000028
IMP_AREA	Double	8	Area of impervious surfaces in square feet	Ex. 90.2356
I_AREA	Double	8	Area of irrigated land in square feet	Ex. 623.2356
INI_AREA	Double	8	Area of irrigable but not currently irrigated land in square feet	Ex. 102.2356

Field Name	Type	Length	Description	Attribute Values
NI_AREA	Double	8	Area of not irrigable land in square feet	Ex. 823.2356
POOL_AREA	Double	8	Area of pools in square feet	Ex. 56.2356
HCL	Double	8	Area of horse corrals and arenas in square feet	Ex. 100.2356
UDM	Double	8	Area of undeveloped (for the purpose of irrigation) land in square feet	Ex. 14623.2356
AG	Double	8	Area of agricultural land in square feet	EX. 2635. 7853
TOTAL_AREA	Double	8	Area of the parcel in square feet	Ex. 4623.2356
MODEL_AREA	Double	8	Area of the parcel in square feet that was not masked by the Agricultural, Horse Corrals, or Undeveloped Lands Mask	Ex. 1548.7068
CAN_AREA	Double	8	Area of tree canopy in square feet	Ex. 56.426433
TOTAL_II	Double	8	Total irrigated area in square feet. This is a sum of the I_AREA and POOL_AREA fields.	Ex. 689.2983
TOTAL_INI	Double	8	Total irrigable-not irrigated area in square feet. This is identical to the INI_AREA field.	Ex. 1693.8394
TOTAL_NI	Double	8	Total not irrigable area in square feet. This is a sum of the IMP_AREA, NI_AREA, HCL, UDM, and AG fields.	Ex. 3984.9548
IMP_BIAS	Double	8	Impervious estimated bias error	Ex. 0.030722
I_BIAS	Double	8	Irrigated estimated bias error	Ex 0.114912
INI_BIAS	Double	8	Irrigable but not irrigated estimated bias error	Ex. -0.114912
NI_BIAS	Double	8	Not irrigated estimated bias error	Ex. -0.034945
POOL_BIAS	Double	8	Pool estimated bias error	Ex. 0.030722
IMP_VAR	Double	8	Impervious estimated variance	Ex. 0.001544
I_VAR	Double	8	Irrigated estimated variance	Ex. 0.000927
INI_VAR	Double	8	Irrigable-not irrigated estimated variance	Ex. 0.000012
NI_VAR	Double	8	Not irrigated estimated variance	Ex. 0.003022
POOL_VAR	Double	8	Pool estimated variance	Ex. 0.000049
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479

Field Name	Type	Length	Description	Attribute Values
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Parcels A-B Relationship

Table 23: Data dictionary for the Parcels_A_B_Relationship Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
APN	String	40	Property APN/ID as inventoried by the tax assessor	Ex. 125-100-11
ZIP	String	5	Property zip code returned from corrected address process	Ex. "92120" in 123 main street unit A Anytown CA 92120
LUC	String	4	Four-digit Land Use Code (held as string field to preserve leading zeros). Indicates the use of a property. Refer to LUCDSC field for the corresponding description	Ex. 0015, 9016, etc.
A_UID	String	50	Unique ID added to the original parcel layer by NV5 Geospatial	Ex. Ranch00000000341
B_UID	String	50	Unique ID added by NV5 Geospatial to the topologically corrected parcel layer (to account for parcel overlap in the original parcel layer)	Ex. EastB0000000028

Field Name	Type	Length	Description	Attribute Values
A_many	String	4	0 = one to one A_UID to B_UID relationship, and 1 = one to many A_UID to B_UID relationship in the A_UID	Ex. 1
B_many	String	4	0 = one to one B_UID to A_UID relationship, and 1 = one to many B_UID to A_UID relationship in the B_UID	Ex. 0
LAST_MOD	Date	8	The date Parcels_A_B_Relationship was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Undeveloped Lands Mask

Table 24: Data dictionary for the Parcels_A_B_Relationship Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
MASK_TYPE	String	25	Type of land mask contained within the feature class	Ex. UDL
LAST_MOD	Date	8	The date Undeveloped_Lands_Mask was last updated. Used for version control	Ex. 04/02/2019

Field Name	Type	Length	Description	Attribute Values
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Validation Parcels

Table 25: Data dictionary for the Validation_Parcels Feature Class of the LAM file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
LAST_MOD	Date	8	The date Validation_Parcels was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
APN	String	40	Property APN/ID as inventoried by the tax assessor	Ex. 125-100-11
ZIP	String	5	Property zip code returned from corrected address process	Ex. "92120" in 123 main street unit A Anytown CA 92120

Field Name	Type	Length	Description	Attribute Values
LUC	String	4	Four-digit Land Use Code (held as string field to preserve leading zeros). Indicates the use of a property. Refer to LUCDSC field for the corresponding description	Ex. 0015, 9016, etc.
A_UID	String	50	Unique ID added to the original parcel layer by NV5 Geospatial	Ex. Ranch00000000341
B_UID	String	50	Unique ID added by NV5 Geospatial to the topologically corrected parcel layer (to account for parcel overlap in the original parcel layer)	Ex. EastB0000000028
IMP_AREA	Double	8	Area of impervious surfaces in square feet	Ex. 90.2356
I_AREA	Double	8	Area of irrigated land in square feet	Ex. 623.2356
INI_AREA	Double	8	Area of irrigable but not currently irrigated land in square feet	Ex. 102.2356
NI_AREA	Double	8	Area of not irrigable land in square feet	Ex. 823.2356
POOL_AREA	Double	8	Area of pools in square feet	Ex. 56.2356
HCL	Double	8	Area of horse corrals and arenas in square feet	Ex. 100.2356
UDM	Double	8	Area of undeveloped (for the purpose of irrigation) land in square feet	Ex. 14623.2356
AG	Double	8	Area of agricultural land in square feet	EX. 2635. 7853
TOTAL_AREA	Double	8	Area of the parcel in square feet	Ex. 4623.2356
MODEL_AREA	Double	8	Area of the parcel in square feet that was not masked by the Agricultural, Horse Corrals or Undeveloped Lands Mask in square feet	Ex. 1548.7068
CAN_AREA	Double	8	Area of parcel that was canopy in square feet	Ex. 56.426433
OVERLAP	String	4	Binary values 0 - one to one A_UID to B_UID relationship, 1 - one to many A_UID to B_UID relationship.	Ex. 1
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Source Data

Area of Interest

Table 26: Data dictionary for the Area_of_Interest Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in Appendix A of the contract	Ranges from 1 through 403
APP_DATE	Date	8	Date the area of interest file was approved by the urban retail water supplier	Ex. 12/02/2018
APP_BY	String	50	Name and title of the individual who approved the urban retail water supplier boundary	Ex. Jane Doe, Calaveras Water District Manager
LAST_MOD	Date	8	The date Area_of_Interest was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
TOTAL_II	Double	8	Total irrigated area in square feet	Ex. 689.2983
TOTAL_INI	Double	8	Total irrigable-not irrigated area in square feet	Ex. 1693.8394
TOTAL_NI	Double	8	Total not irrigable area in square feet. This is a sum of the IMP_AREA, NI_AREA, HCL, UDM, and AG fields.	Ex. 3984.9548
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479

Field Name	Type	Length	Description	Attribute Values
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Parcels All

Table 27: Data dictionary for the Parcels_All Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
PIN	String	40	Parcel Identification Number	Ex. 125-100-11
FIPS	String	5	Federal Information Processing Code for the State + Federal Information Processing Code for the County. First two digits are state code, last three digits are county code	Ex. 06041
APN	String	40	Property APN/ID as inventoried by the tax assessor	Ex. 125-100-11
APNUNF	String	40	Property APN/ID as inventoried by the tax assessor with the dashes removed	Ex. 12510011
HSNUM	String	10	Property street number returned from corrected address process	Ex. "123" in 123 E Main St Anytown CA
DIR	String	2	Property street directional prefix returned from corrected address process	Ex. "E" in 123 E Main St Anytown CA
STNAME	String	28	Property street name returned from corrected address process	Ex. "Main" in 123 E Main St Anytown CA
SUFFIX	String	4	Property street suffix returned from corrected address process	Ex. "St" in 123 E Main St Anytown CA

Field Name	Type	Length	Description	Attribute Values
QUADRANT	String	2	Property street name directional suffix returned from corrected address process	Ex. "W" in 123 Main St W Anytown CA
UNITPRFX	String	4	Property Unit type returned from corrected address process	Ex. "Unit" in 123 main street unit A Anytown CA
UNITNUM	String	8	Property Unit number returned from corrected address process	Ex. "A" in 123 main street unit A Anytown CA
CITY	String	28	Property city name returned from corrected address process	Ex. "Anytown" in 123 main street unit A Anytown CA
STATE	String	2	Property state returned from corrected address process	Ex. "CA" in 123 main street unit A Anytown CA
ZIP	String	5	Property zip code returned from corrected address process	Ex. "92120" in 123 main street unit A Anytown CA 92120
ZIP4	String	4	Last four digits of the larger nine-digit zip code	Ex. 1006
XCOORD	String	11	Latitude	Ex. -122.662918
YCOORD	String	11	Longitude	Ex. 38.133250
LUC	String	4	Four-digit Land Use Code (held as string field to preserve leading zeros). Indicates the use of a property. Refer to LUCDSC field for the corresponding description.	Ex. 0015, 9016, etc.
LUCDSC	String	73	Standardized land use description. Descriptive text corresponding to the land use code (LUC)	Ex. SINGLE FAMILY RESIDENTIAL
LUCCTR	String	5	Land Use Code category	Ex. 1001
LUCCTRDSC	String	100	Land Use Code category description. Descriptive text corresponding to the land use category (LUCCTR)	Ex. RESIDENTIAL
LOCATIONID	String	50	Persistent unique Id for each parcel, where there is a matched property record	Ex. US_06_041_12510011
ASSACREAGE	String	14	Assessed acreage of the parcel	Ex. 1197
CALACREAGE	String	15	GIS calculated acreage of the parcel	Ex. 1140.32
PERIMFEAT	String	1	A binary field denoting if the polygon is a perimeter feature	Ex. N

Field Name	Type	Length	Description	Attribute Values
PRCLDMPID	String	21	DMP persistent ID on property	Ex. 100660192_204808495
PROPDMPID	String	21	DMP persistent ID on property	Ex. 100660192_204808495
LAST_MOD	Date	8	The date Parcels_All was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2018
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Parcels Disputed

Table 28: Data dictionary for the Parcels_Disputed Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
DIST_NAME	String	70	Name of the urban retail water supplier as outlined in Appendix A of the contract	Ex. Rancho California Water District
DIST_WDID	String	70	Urban retail water supplier WDID as outlined in Appendix A of the contract	Ex. ARROYOGRANDE013
DIST_NUM	Short Integer	3	Urban retail water supplier number as outlined in appendix A of the contract	Ex. 013
APN	String	40	Property APN/ID as inventoried by the tax assessor	Ex. 125-100-11

Field Name	Type	Length	Description	Attribute Values
ZIP	String	5	Property zip code returned from corrected address process	Ex. "92120" in 123 main street unit A Anytown CA 92120
LUC	String	4	Four-digit Land Use Code (held as string field to preserve leading zeros). Indicates the use of a property.	Ex. 0015, 9016, etc.
OVLP_NAME	String	70	Overlapping urban retail water supplier	Ex. Grover Beach
OVLP_WDID	String	70	Overlapping WDID	Ex. GROVERBEACHC157
OVLP_NUM	Short Integer	3	Overlapping urban retail water supplier contract number	Ex. 157
LAST_MOD	Date	8	The date Parcels_Disputed was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2016
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

Parcels Queried

Table 29: Data dictionary for the Parcels_Queried Feature Class of the deliverable file geodatabase.

Field Name	Type	Length	Description	Attribute Values
OBJECTID	OID	4	An OBJECTID is an ESRI required field. It is a unique, not null integer field used to uniquely identify rows in tables in a geodatabase. OBJECTIDs are limited to 32-bit values, which store a maximum value of 2,147,483,647	Ranges from 1 through n and is unique only within the feature class itself
Shape	Geometry (Polygon)	0	ESRI required field used to indicate the geometry type of a feature class or shapefile	Polygon
PIN	String	40	Parcel Identification Number	Ex. 125-100-11

Field Name	Type	Length	Description	Attribute Values
FIPS	String	5	Federal Information Processing Code for the State + Federal Information Processing Code for the County. First two digits are state code, last three digits are county code	Ex. 06041
APN	String	40	Property APN/ID as inventoried by the tax assessor	Ex. 125-100-11
APNUNF	String	40	Property APN/ID as inventoried by the tax assessor with the dashes removed	Ex. 12510011
HSNUM	String	10	Property street number returned from corrected address process	Ex. "123" in 123 E Main St Anytown CA
DIR	String	2	Property street directional prefix returned from corrected address process	Ex. "E" in 123 E Main St Anytown CA
STNAME	String	28	Property street name returned from corrected address process	Ex. "Main" in 123 E Main St Anytown CA
SUFFIX	String	4	Property street suffix returned from corrected address process	Ex. "St" in 123 E Main St Anytown CA
QUADRANT	String	2	Property street name directional suffix returned from corrected address process	Ex. "W" in 123 Main St W Anytown CA
UNITPRFX	String	4	Property Unit type returned from corrected address process	Ex. "Unit" in 123 main street unit A Anytown CA
UNITNUM	String	8	Property Unit number returned from corrected address process	Ex. "A" in 123 main street unit A Anytown CA
CITY	String	28	Property city name returned from corrected address process	Ex. "Anytown" in 123 main street unit A Anytown CA
STATE	String	2	Property state returned from corrected address process	Ex. "CA" in 123 main street unit A Anytown CA
ZIP	String	5	Property zip code returned from corrected address process	Ex. "92120" in 123 main street unit A Anytown CA 92120
ZIP4	String	4	Last four digits of the larger nine-digit zip code	Ex. 1006
XCOORD	String	11	Latitude	Ex. -122.662918

Field Name	Type	Length	Description	Attribute Values
YCOORD	String	11	Longitude	Ex. 38.133250
LUC	String	4	Four-digit Land Use Code (held as string field to preserve leading zeros). Indicates the use of a property. Refer to LUCDSC field for the corresponding description.	Ex. 0015, 9016, etc.
LUCDSC	String	73	Standardized land use description. Descriptive text corresponding to the land use code (LUC)	Ex. SINGLE FAMILY RESIDENTIAL
LUCCTR	String	5	Land Use Code Category	Ex. 1
LUCCTRDSC	String	100	Land Use Code category description. Descriptive text corresponding to the land use category (LUCCTR)	Ex. RESIDENTIAL
LOCATIONID	String	50	Persistent unique Id for each parcel, where there is a matched property record	Ex. US_06_041_12510011
ASSACREAGE	String	14	Assessed acreage of the parcel	Ex. 1197
CALACREAGE	String	15	GIS calculated acreage of the parcel	Ex. 1140.32
PERIMFEAT	String	1	A binary field denoting if the polygon is a perimeter feature	Ex. N
PRCLDMPID	String	21	DMP persistent ID on property	Ex. 100660192_204808495
PROPDMPID	String	21	DMP persistent ID on property	Ex. 100660192_204808495
VOID	Short Integer	21	Denotes if the polygon is a void shape	Ex. 1
LAST_MOD	Date	8	The date Parcels_Queried was last updated. Used for version control	Ex. 04/02/2019
IMG_YEAR	Short Integer	4	Year of the 4-band imagery that was used to derive the data	Ex. 2016
Shape_Length	Double	8	ESRI required field populated with the perimeter length of the polygon feature (in meters)	Ex. 127.207479
Shape_Area	Double	8	ESRI required field populated with the area of the polygon feature (in square meters)	Ex. 743.08018

The file geodatabase containing the following vector and raster data was created for the LAM Project to derive irrigated and irrigable landscape area estimates for single- and multi-family residential parcels for urban retail water suppliers in California. The data were created by NV5 Geospatial (previously Quantum Spatial, Inc.) under contract number EA-133C-16-CQ-0044. The geodatabase contains two feature datasets, Derived_Data and Source_Data.

Derived_Data

The Derived_Data contains the following polygon vector data: Agricultural_Lands_Mask, Horse_Corral_Mask, Landscape_Area_Estimates_A, Landscape_Area_Estimates_B, Parcels_A_B_Relationship, Undeveloped_Lands_Mask, and Validation_Parcels. The year of collection for the 1 foot, 4 band imagery used for the analysis is depicted in each vector layer under the field IMG_YEAR.

The Agricultural_Lands_Mask, Horse_Corral_Mask, and Undeveloped_Lands_Mask are vector layers interpreted from imagery as not irrigable in the context of single- or multi-family water use. These layers are manually generated and reviewed by the DWR staff in order to increase the accuracy of irrigation estimates. The Agricultural_Lands_Mask represents irrigated farmlands, row crops, orchards, and hay pastures. The Horse_Corral_Mask represents horse corrals and horse arenas. The Undeveloped_Lands_Mask represents land that is undeveloped in the context of irrigation. These undeveloped lands can consist of vacant lots with no presence of a concrete foundation, interstitial riparian corridors, wetlands, native grasslands, native shrubs, and/or native forest canopy.

Landscape_Area_Estimates_A and Landscape_Area_Estimates_B are vector polygon layers that contain the landscape area estimates summarized to the parcel level, measured in square feet. Landscape_Area_Estimates_A is the landscape area estimate dataset for the original parcel layer. Landscape_Area_Estimates_B represents the area estimates for the topologically corrected parcel layer. It was created to accurately summarize landscape area estimates at the supplier level by accounting for parcel overlap in the original parcel layer. To create supplier-level, three-class summaries (irrigated, irrigable-not-irrigated, and not irrigable) sum the columns TOTAL_II, TOTAL_INI, and TOTAL_NI of the Landscape_Area_Estimates_B.

The Parcels_A_B_Relationship describes the one-to-one, and one-to-many relationships between each A_UID (unique polygon identifier within Landscape_Area_Estimates_A), and B_UID (unique polygon identifier within Landscape_Area_Estimates_B). A one-to-one relationship means there is only one B_UID for the corresponding A_UID, and therefore the parcel does not overlap another. When this is the case, fields A_many and B_many, will equal 0. If there is a one-to-many relationship (more than one object with the same A_UID or B_UID), then the A_many and/or B_many fields will equal 1. The Parcels_A_B_Relationship is a crosswalk table provided for in-depth interpretation of the two layers.

The Validation_Parcels layer is a vector polygon layer that contains the landscape area summaries for validation parcels that were manually classified by NV5 Geospatial personnel, measured in square feet. These parcels are provided to allow for model and manual classification comparison. Each parcel is marked with its corresponding B_UID (unique polygon identifier within Landscape_Area_Estimates_B) and if the parcel does not overlap another then it will also be labeled with the associated A_UID (unique polygon identifier within Landscape_Area_Estimates_A) and parcel APN. Parcels that contain overlap are additionally identified with a 1 in the OVERLAP field.

Source_Data

The Source_Data feature dataset contains the following polygon vector data: Area_of_Interest, Parcels_All, Parcels_Disputed, and Parcels_Queried.

The Area_of_Interest represents the water supplier approved service boundary. After a 10-meter buffer was applied, this layer was used to acquire the source imagery and parcels needed to summarize the single- and multi-family landscape area measurements. The Area_of_Interest layer also includes fields that represent the total supplier landscape area estimates based on the topologically corrected parcel layer, measured in square feet.

Parcels_All is the whole parcel dataset within the Area_of_Interest.

Parcels_Disputed are single- and multi-family parcels that are shared spatially with a neighboring urban retail water supplier. Landscape area measurements are not provided for disputed parcels.

Parcels_Queried is the Parcels_All layer filtered to single- and multi-family parcels based on the corresponding Land Use Code (LUC). Valid LUCs are listed in the Valid_LUC_Codes table. The Parcels_Queried also contains the void areas which are areas within the Area_of_Interest that either contained no LUC from which land use could be derived or that were not included in the parcel vector layer. The “void” area within an Area of Interest generally represents public land such as roadways and water bodies.

The Valid_LUC_Codes is a filtered list of land use codes representing single- and multi-family parcels which created the Parcels_Queried layer from the Parcels_All layer.

The VOID_byte is a raster-based estimate of landscape areas that were within the service boundary but either contained no LUC from which land use could be derived or that were not included in the parcel vector layer. It contains the raster-based, 10-class classification of landscape areas (for 10-class identification codes please see Table 10). This raster can be used to summarize the irrigation status for areas that were not included in the parcel dataset used in the analysis but are considered within the purview of the LAM Project.

The CADWR_Data_Dictionary is a table of all fields, field type, field length, and field description of each feature layer in the geodatabase. Please reference this table or the geodatabase metadata to interpret data values.

Please note: In both the Source_Data and Derived_Data feature datasets, the Shape_Length and Shape_Area fields are ESRI-required fields with units defined by the coordinate reference system. These fields have units of meters and meters-squared, respectively, whereas all calculated landscape area estimates are reported in units of square feet.