RECLAMATION

Managing Water in the West

White Paper

Apple Valley Ranchos Water Company Water Conservation Technical Assistance

U.S. Department of the Interior
Bureau of Reclamation

December 2010

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

White Paper

Apple Valley Ranchos Water Company Water Conservation Technical Assistance

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Background

This paper describes the techniques used by the Bureau of Reclamation's (Reclamation) Technical Service Center (TSC) to provide technical expertise for water conservation efforts by the Apple Valley Ranchos Water Company (AVRWC). The AVRWC is a member of the Mojave Water Agency. In 2009, the TSC entered into an agreement with Reclamation's Southern California Area Office to provide technical assistance associated with a water conservation planning effort for AVRWC in Apple Valley, California. AVRWC, in accordance with its Urban Water Management Plan (Plan), is attempting to reduce overall water consumption within the city. Target applications for this project are to identify parcels with high irrigated surface and high-flow toilets and laundry washing machines. These customers would be encouraged to reduce turf areas and replace high-flow appliances. The TSC approached this challenge using a number of tools and analysis methods, which included database development, remote sensing and Geographic Information Systems (GIS) technologies, and water conservation activities analyses.

Introduction

The AVRWC's 2005 Urban Water Management Plan has been prepared in response to Water Code Sections 10610 through 10656 of the Urban Water Management Planning Act (Act), which were added by Statute 1983, Chapter 1009 and became effective on January 1, 1984. This Act requires that "every urban water supplier providing water for municipal purposes to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually prepare and adopt, in accordance with prescribed requirements, an urban water management plan." The Plan describes and evaluates water uses and supplies, conservation practices, and reclamation activities within the service area of AVRWC over the next 20 years until 2025" (Tubbs and Agarwala, 2005). The tasks and technical expertise requested from AVRWC address the conservation practices stated in the Plan and will be used to update the 2010 Plan. These tasks included extensive data compilation from a variety of sources, a geographic analysis of evapotranspiration (ET) using aerial imagery and remote sensing technologies, and a quantification of existing and potential water conservation activities.

Initial database compilation identified the number and types of end-use customers within the AVRWC service area and consisted of data obtained from the San Bernardino County, California Assessor's Office (Parcel Boundaries and Property Information), AVRWC (account level customer account information and usage),

and the U.S. Census Bureau – Economic Survey: North American Industry Classification System. The AVRWC is using the master database to generate various reports for the updated AVRWC Water Use Efficiency Business Plan.

Remote sensing and image object extraction techniques were used to classify parcels for potential water conservation activities. The purpose of this task was to use high resolution color infrared (IR) imagery to extract land use and land cover information by parcel. Specifically, the TSC provided vegetated cover by parcel that was categorized into two groups: irrigated and nonirrigated surfaces. The irrigated classification was further subdivided into two classes: "lawn" and "trees and shrubs."

Water conservation activities analyses included several efforts associated with existing and potential water conservation activities, and best management practices (BMP).

Methods

Database Development

Reclamation was tasked with indentifying the number and types of end-user customers within the AVRWC service area. Reclamation worked with staff at AVRWC to obtain a majority of the data needed for this project. The major data used for the final product were:

1. Account level data
2. Assessor parcel data
3. Dunn & Bradstreet business data

Account Level Data

AVRWC provided Reclamation with their account level data. The account level data included account number, revenue code, service address, meter size, and meter install date. AVRWC also provided to Reclamation 4 years (2006-2009) of consumption data for each of the metered accounts within its service area. In addition to the tabular data, AVRWC provided Reclamation with a polygon shapefile that delineates its service area boundary and a point shapefile of their meter locations. Table 1 is an example of the account level data.

Table 1. Example of AVRWC's Account Level Data

Account	Status	Cycle	Book	Street Address	City	ZIP	Lot	Tract	Is AMR Meter	Remote ID	Revenue Code	Meter Size Code	Meter Install Date	Meter Install Year
000001	AC	A01	009	Xxxx NAVAJO	APPLE VALLEY	92308	26	2851	YES	5141360	22	01	07-30-2009	2009
000002	AC	A01	001	Xxxx NAVAJO	APPLE VALLEY	92307	24	2851	NO		11	05	04-13-2001	2001
000003	AC	A01	001	Xxxx HWY 18	APPLE VALLEY	92307	25	2851	NO		22	11	10-21-1999	1999
000004	FI	A01	001	Xxxx HWY 18	APPLE VALLEY	92307	503-04	3032	NO	na	22	na	na	
000005	AC	A01	001	Xxxx HWY 18	APPLE VALLEY	92308	506	3032	NO		22	05	03-15-2007	2007
000006	AC	A01	001	Xxxx HWY 18	APPLE VALLEY	92307	507	3032	NO		22	05	04-01-1998	1998
000007	AC	A01	001	Xxxx HWY 18	APPLE VALLEY	92308	508	3032	NO		22	05	03-19-1999	1999
000008	AC	A01	001	Xxxx ARAPAHOE	APPLE VALLEY	92307	547	3032	NO		22	01	12-29-2008	2008
000009	AC	A01	001	Xxxx ARAPAHOE	APPLE VALLEY	92307	546	3032	NO		22	05	06-10-1998	1998
000010	AC	A01	001	Xxxx HWY 18	APPLE VALLEY	92307	510	3032	NO		22	05	06-07-2005	2005
000011	FI	A01	001	Xxxx ARAPAHOE	APPLE VALLEY	92307	544-545	3032	NO		22	05	12-13-2000	2000

The revenue code is an internal attribute in the AVRWC database that identifies the type of meter. The data provided to Reclamation contained revenue codes 11, 22, 33, 45, 52, 73, 74, and 75 (see table 2).

Table 2. Total Accounts Per Revenue Code

Revenue Code	Description	Total Accounts
11 – Single Family	Single family water supplied for domestic and/or residential purposes	18,130
22 – Business	Business use including multifamily units and homeowner associations	1,589
33 – Industrial	Industrial water used as part of the industry's main processing operation	3
45 – Public Authorities	Water supplied for use by municipalities or other agencies of State or Federal Governments	42
52 – Private Fire Protection	Customers with water service supplied for fire protection	218
73 – Irrigation Golf Course	Water supplied to customers with pressure water delivery systems for irrigation purposes using golf course irrigation rates	5
74 – Irrigation Pressure	Water delivery systems for irrigation purposes under distinct pressure delivery irrigation rates	159
75 – Irrigation Gravity	Water delivery systems for irrigation purposes	1
Unknown	No revenue code provided by AVRWC	92

Table 3 provides the consumption by revenue code for 4 years (2006-2009) for all AVWRC accounts. Irrigation meters were pulled out separately, and these data are shown in table 4.

Table 3. AVRWC Annual Consumption From 2006-2009 (acre-feet)

Year	Revenue Code	Revenue Description	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
2006	11	Residential	564.97	544.34	511.05	546.58	669.25	1,084.85	1,322.95	1,433.28	1,349.79	1,240.10	1,015.08	725.65	11,007.88
	22	Business	104.93	182.71	95.24	171.81	103.13	241.93	175.96	284.92	184.95	323.49	147.46	220.24	2,236.77
	33	Industrial	0.00	0.20	0.00	0.53	0.00	0.32	0.00	0.41	0.00	0.61	0.00	0.59	2.66
	45	Public authorities	23.56	18.50	19.46	28.80	36.06	71.43	84.88	107.82	93.49	98.07	64.65	37.55	684.28
	52	Private fire protection	0.36	0.45	0.32	0.37	0.22	1.04	0.64	1.27	0.92	1.42	1.40	2.18	10.60
		2006 total	783.58	751.35	734.77	755.41	977.05	1,432.82	1,910.70	1,864.81	2,072.61	1,697.59	1,584.20	999.20	
2007	11	Residential	631.34	560.45	568.85	754.94	904.45	1,150.12	1,338.88	1,404.39	1,437.75	1,191.46	944.69	710.53	11,597.85
	22	Business	134.38	209.25	95.35	205.64	142.64	256.01	197.41	310.16	193.65	310.82	138.91	215.04	2,409.27
	33	Industrial	0.00	0.57	0.00	0.55	0.00	0.70	0.00	0.84	0.00	0.73	0.00	0.68	4.09
	45	Public authorities	22.21	15.93	24.38	42.55	60.93	75.91	90.72	107.39	98.19	88.09	63.89	32.65	722.84
	52	Private fire protection	1.62	1.08	1.52	1.04	0.29	0.44	1.72	1.02	1.54	1.05	1.70	0.94	13.94
		2007 total	977.34	793.87	813.73	1,025.92	1,426.11	1,522.55	2,165.78	1,889.97	2,256.25	1,648.88	1,451.68	982.92	
2008	11	Residential	567.97	464.99	522.28	678.33	826.50	1,043.76	1,163.98	1,324.81	1,272.44	1,137.18	954.88	661.92	10,619.05
	22	Business	112.61	188.71	106.69	202.02	133.37	232.46	167.63	318.21	186.52	248.33	158.99	188.48	2,244.03
	33	Industrial	0.00	0.39	0.00	0.28	0.00	0.63	0.00	0.58	0.00	0.62	0.00	0.50	2.99
	45	Public authorities	25.12	9.06	20.69	30.81	50.14	71.40	97.68	102.10	98.71	86.91	62.49	30.16	685.27
	52	Private fire protection	2.23	1.15	1.10	1.69	1.31	0.63	1.10	0.39	0.07	0.89	0.06	0.11	10.74
		2008 Total	810.27	675.45	708.07	935.90	1,253.29	1,400.35	1,881.26	1,813.98	2,050.46	1,531.38	1,502.71	907.22	
2009	11	Residential	547.25	440.07	459.59	573.32	798.56	975.80	1,033.94	1,207.12	1,168.14	1,031.36	868.39	597.02	9,700.56
	22	Business	117.27	172.58	93.61	164.90	123.69	218.46	158.92	254.42	171.95	234.16	159.06	174.48	2,043.49
	33	Industrial	0.00	0.64	0.00	0.53	0.00	0.63	0.00	0.71	0.00	0.64	0.00	0.37	3.53
	45	Public authorities	20.22	15.00	19.80	30.37	52.74	74.34	94.60	100.81	106.29	81.13	66.28	34.17	695.76
	52	Private fire protection	0.14	0.08	0.00	0.38	0.07	0.06	0.19	0.21	0.03	0.41	0.08	0.16	1.81
		2009 total	754.36	648.88	624.23	823.46	1,225.73	1,379.90	1,770.16	1,755.94	2,038.49	1,482.97	1,462.78	836.93	

Table 4. AVRWC Dedicated Irrigation Meters - Annual Consumption From 2006-2009 (acre-feet)

Year	Revenue Code	Irrigation Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2006	73	Irrigation (golf course)	2.56	1.43	1.43	3.20	3.20	5.02	5.02	4.56	4.56	20.85	20.85	2.56
	74	Irrigation (gravity)	24.75	41.62	41.62	65.47	65.47	105.88	105.88	156.52	156.52	104.42	104.42	24.75
	75	Irrigation (pressure)	20.18	13.79	14.87	19.16	32.23	68.85	70.67	79.26	77.49	68.81	60.21	23.87
		2006 totals	47.48	56.84	57.92	87.84	100.90	179.75	181.58	240.35	238.58	194.08	185.48	51.18
2007	73	Irrigation (golf course)	1.81	1.62	1.62	6.67	6.67	11.98	11.98	12.48	12.48	5.20	5.20	1.81
	74	Irrigation (gravity)	74.37	50.46	50.46	127.76	127.76	209.26	209.26	187.22	187.22	103.87	103.87	74.37
	75	Irrigation (pressure)	21.47	12.98	18.29	34.17	47.62	66.98	80.37	95.25	90.41	70.58	53.54	28.91
		2007 totals	97.65	65.06	70.36	168.61	182.05	288.21	301.60	294.95	290.12	179.65	162.61	105.08
2008	73	Irrigation (golf course)	1.26	0.96	0.96	6.43	6.43	9.84	9.84	8.22	8.22	5.67	5.67	1.26
	74	Irrigation (gravity)	32.79	17.86	17.86	89.09	89.09	164.01	164.01	174.60	174.60	107.59	107.59	32.79
	75	Irrigation (pressure)	32.79	17.86	17.86	89.09	89.09	164.01	164.01	174.60	174.60	107.59	107.59	32.79
		2008 totals	66.85	36.68	36.68	184.61	184.61	337.87	337.87	357.42	357.42	220.85	220.85	66.85
2009	73	Irrigation (golf course)	0.62	0.42	0.42	6.07	6.07	9.88	9.88	14.92	14.92	2.22	7.58	0.62
	74	Irrigation (gravity)	20.28	17.98	17.98	92.38	92.38	180.87	180.87	211.59	211.59	126.36	126.36	20.28
	75	Irrigation (pressure)	24.85	17.62	33.96	53.85	82.84	105.85	146.93	165.99	139.57	120.87	66.17	27.77
		2009 totals	45.75	36.01	52.35	152.31	181.29	296.59	337.68	392.51	366.09	249.45	200.10	48.66

Assessor Parcel Data

The San Bernardino County Assessor's Office locates, inventories, and maintains all taxable property within San Bernardino County. AVRWC provided Reclamation with the assessor parcel data that they purchased from the San Bernardino County Assessor's Office in March 2010. The assessor's office maintains a parcel database called Property Information Management System (PIMS). PIMS offers information from the assessment roll, including ownership records, parcel history, property characteristics, and legal descriptions. Basic property information is available such as use, type, size, and access. Additional property characteristics of value to the project in PIMS are structure type, number of stories, lot, and building size.

Reclamation received a polygon shapefile that contained the parcel boundaries, an Excel spreadsheet containing the property characteristics for each parcel, and an Excel spreadsheet containing the use codes for each parcel. Both the GIS shapefile and the property characteristics table contain an Assessor Parcel Number (APN) that is unique to each parcel and is used for linking the two datasets. The use code table is linked to the property characteristics table by the use code. There are 24,031 parcels within the AVRWC service area, which resides within San Bernardino County. Table 5 breaks down the total for each land type. The land type broadly defines the land use for each parcel.

Table 5. Assessor Parcel - Totals by Land Type

Parcel Land Type	Total
01 – Industrial	678
02 – Administrative/Professional	74
03 – Commercial	760
04 – Public facilities	43
05 – Single family	20,511
06 – Multifamily	1,465
07 – Agricultural	46
08 – Multiple zoning	1
09 – Restricted	6

The property characteristics table contains multiple attributes that were useful in developing the final database product. The primary fields used were:

1. LAND-TYPE – Broadly defines the land use for each parcel
2. USE-CODE – Indicates the current use of the property and contains a short description and long description
3. SFR-CONST-YEAR – The year the Single Family Residential (SFR) was constructed

4. SFR-NBR-BATH – Number of bathrooms within the SFR
5. OTHR-CONST-YEAR – The year the Multifamily unit was constructed
6. OTHR-NBR-UNITS – Number of separate units within the building
7. OTHR-APT(X)-UNITS – Number of apartment units with bedroom and bath counts listed
8. OTHR-APT(X)-BATH – Number of bathrooms in the apartment type

The assessor data were used to identify the number of multifamily units and the number of bathrooms for single family and multifamily units. AVRWC does not have a separate revenue code for multifamily accounts, but they are currently the same revenue code as businesses (22). To identify the multifamily accounts, the parcel's property characteristics table was first linked to the use code table. The use code table breaks down each parcel with a short and long description. The short description breaks each parcel into generic use types such as vacant land, industrial type, business type, hotel/motel, multifamily, and single family. The long description provides further detail as to the use of that parcel.

After linking the databases, it was noticed that some major discrepancies occurred in the parcel data such as misspelled address names, incorrect attributes for the use code's short and long descriptions, and missing attributes. These errors, we felt, would affect the final count for end-use customers; therefore, corrections were made to these attributes by adding a field called ModCode. The parcel data were systematically reviewed by draping over 1-meter resolution, 2005 National Agricultural Image Program (NAIP) and 2009 4-band NAIP imagery. Attention was focused on those parcels that were multifamily and single family because these had the highest discrepancies. For example, some parcels were attributed as multifamily units but were clearly vacant or were a single family unit that contained a single meter with a revenue code of 11 (residential, single family). The ModCode was populated with these values: agricultural, commercial, common area, fire service, golf course, government, multifamily, park, public facilities, single family, unknown, vacant land, AVRWC, and water well site. In addition, some addresses were corrected for spelling mistakes.

Once the parcel data were processed, it was necessary to locate which parcels were tied to an AVRWC meter. To accomplish this, parcel data were linked to the AVRWC meter data by address. Multiple fields were added to help identify the use/type of parcel (Type_BOR), if the parcel is serviced by an AVRWC meter (AVRPARCEL), and if the parcel participated in the Cash for Grass program in 2008 and 2009 (C4G2008, C4G2009). A query was performed by selecting only those parcels that were serviced by AVRWC, and then the Type_BOR was populated with the ModCode.

Table 6 contains the type of parcel, number of AVRWC accounts, and acreage. These figures differ from the AVRWC meter counts in Table 2 because these counts are tied to the Assessor Parcel data, and due to inherent errors between the datasets.

Table 6. AVRWC Accounts by Assessor Parcels

Parcel Type	Count	Acres
Commercial	422	754.42
Common area	92	41.00
Golf course	25	537.45
Multifamily	725	582.83
Park	15	45.48
Public facilities	21	94.51
Single family	16,058	9,677.18
Unknown	16	0.46
Vacant land	133	364.46

Reclamation then linked these data to AVRWC consumption data for 2006-2009 and calculated the total consumption for each parcel type. Table 7 presents the values in acre-feet for each parcel type identified in table 6.

The assessor parcel data were also used to calculate the average number of bathrooms per single family and multifamily accounts. The parcel's property characteristics table lists the number of bathrooms per parcel for single family. For multifamily units, the property characteristics table provides the number of units per parcel and number of bathrooms. Table 8 shows the results from this analysis.

Table 7. Consumption by Parcel Type - 2006-2009 (acre-feet)

Year	Type	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Totals
2006	Commercial	17.50	31.25	15.10	32.66	18.54	45.17	29.54	54.47	33.46	53.30	26.52	39.10	396.60
	Multifamily	1.62	61.57	75.15	56.89	75.22	62.67	94.33	102.51	113.56	101.73	115.39	80.19	941.02
	SFR	506.90	499.81	458.14	503.59	599.46	1,017.77	1,191.00	1,352.13	1,222.80	1,171.33	917.90	668.37	10,109.21
	Common area	15.04	2.66	10.38	2.79	14.25	6.73	43.19	9.17	51.97	8.20	46.02	2.78	213.18
	Public facility	12.33	6.58	10.75	11.58	19.47	20.05	38.07	33.98	49.35	26.85	30.48	13.35	272.83
	Vacant land	0.04	0.71	2.57	0.45	3.38	0.45	9.47	1.40	13.51	1.52	11.50	1.31	46.31
	2006 total	553.43	602.58	572.08	607.95	730.32	1,153.04	1,405.59	1,553.66	1,484.65	1,362.93	1,147.82	805.09	11,979.15
2007	Commercial	18.52	34.15	16.97	37.80	23.91	45.62	29.43	54.84	30.98	49.55	25.03	40.20	407.00
	Multifamily	65.55	80.78	55.26	82.30	71.58	97.00	96.59	111.05	107.53	108.62	73.36	84.41	1034.03
	SFR	568.27	508.43	515.34	698.07	819.19	1,078.45	1,189.67	1,342.95	1,299.30	1,117.62	856.03	651.87	10,645.20
	Common area	16.52	2.51	7.67	4.50	22.45	6.92	41.89	6.27	55.89	4.88	37.68	2.90	210.09
	Public facility	10.96	5.25	14.98	13.29	28.66	22.57	42.04	30.56	46.28	27.98	30.79	9.15	282.52
	Vacant land	0.73	6.69	0.34	6.74	0.85	10.76	1.09	15.40	1.46	11.74	0.88	6.47	63.16
	2007 total	680.57	637.81	610.56	842.70	966.64	1,261.32	1,400.71	1,561.07	1,541.44	1,320.39	1,023.77	795.00	12,642.00
2008	Commercial	19.42	33.97	18.32	41.21	22.86	49.20	28.06	57.59	34.55	51.75	30.53	40.95	428.42
	Multifamily	61.96	74.41	58.89	76.50	66.52	90.48	89.44	107.18	98.49	98.18	77.59	81.40	981.04
	SFR	512.49	418.40	472.82	623.95	746.10	970.05	1,053.98	1,239.92	1,149.22	1,063.53	863.00	604.65	9,718.11
	Common area	13.43	1.86	6.84	3.56	21.88	5.21	40.79	7.23	48.44	6.02	36.21	3.17	194.64
	Public facility	10.76	4.24	9.36	8.95	21.73	19.92	40.50	29.86	44.60	27.46	31.60	9.77	258.76
	Vacant land	0.58	2.26	0.68	7.56	1.14	8.46	1.88	10.37	2.75	9.89	2.12	3.71	51.42
	2008 total	618.65	535.14	566.92	761.72	880.23	1,143.32	1,254.66	1,452.17	1,378.06	1,256.83	1,041.05	743.65	11,632.39
2009	Commercial	22.75	35.32	17.09	39.86	21.07	50.18	24.65	56.90	26.95	53.90	23.82	38.74	411.44
	Multifamily	62.19	72.26	51.86	69.85	64.68	83.03	81.43	97.33	93.10	91.13	74.75	71.16	912.77
	SFR	492.36	394.96	413.00	521.43	718.13	907.78	931.73	1,130.81	1,054.36	960.94	779.73	549.66	8,854.92
	Common area	9.88	1.84	3.90	2.78	19.42	5.96	40.71	8.31	51.56	6.85	36.64	2.65	190.48
	Public facility	6.36	7.47	10.18	9.68	23.44	21.55	39.10	28.32	44.19	24.96	31.05	11.05	257.34
	Vacant land	1.11	1.00	0.38	2.89	0.93	7.35	1.25	9.72	1.50	8.34	1.37	2.82	38.65
	2009 total	594.65	512.85	496.40	646.47	847.67	1,075.85	1,119.07	1,331.40	1,271.67	1,146.12	947.35	676.08	10,665.59

Table 8. Average Number of Bathrooms for Single Family and Multifamily Accounts

Parcel Type	Number of Units	Number of Bathrooms	Average Number of Bathrooms
Single family	16,058	35,661.31	2.25
Multifamily	1,639	2,252	1.37

Dunn & Bradstreet Business Data

Maureen Erbeznik of Maureen Erbeznik & Associates provided to Reclamation the Dunn & Bradstreet Market Place DVD for July-September 2009. Table 9 is an example of data exported from the database using these variables.

Once exported, the data were summarized; they can be viewed in table 10. The Dunn & Bradstreet data were exported with two additional divisions, which further break down the types of businesses into more detail.

Table 9. Example of Dunn & Bradstreet Data

SIC4CODE	SIC4CODE1	Number of Bus.	% Total	Total Employees	Total Sales	Average Employees	Average Sales
0742	Veterinary services specialties	2	1.0	42	1.3	21	0.7
1521	Single family housing construction	1	0.5	11	0.6	11	0.6
1541	Industrial buildings and warehouses	3	1.4	94	17.3	31	5.8
1542	Nonresidential construction	4	1.9	139	28.0	35	7.0
1611	Highway and street construction	2	1.0	28	3.4	14	1.7
1623	Water sewer and utility lines	1	0.5	15	6.0	15	6.0
1629	Heavy construction	2	1.0	75	2.7	38	2.7

Table 10. Dunn & Bradstreet Market Data

SIC Division 1	Total
Agriculture forestry and fishing	1
Construction	16
Finance insurance and real estate	7
Manufacturing	10
Nonclassified establishments	1
Public administration	3
Retail trade	11
Services	41
Transportation and public utilities	5
Wholesale trade	3

Landscape Surface Areas

For the purposes of extracting precise parcel scale information, NAIP imagery product was used. The NAIP imagery has 1-meter spatial resolution, has a multiband product (visible and IR bands), is current, and is very inexpensive. The image was processed using Definiens eCognition and Erdas Imagine Image Processing software. Additional geoprocessing was conducted with the ESRI GIS software ArcMap.

The NAIP scenes are provided in quarter quads (one-quarter of a 7.5-minute U.S. Geological Survey quadrangle). To cover the entire AVRWC service area, 11 quarter quads were acquired, and these were mosaiced together to produce one image. This image was subsequently subsetted using the AVRWC service area boundary. During the classification process, it was found that even the subsetted image was too large to effectively process, so the project area was further subsetted into six areas. The majority of the image analysis was done inside of the image analysis software eCognition. eCognition is an object based image processing software that classifies according to similarity between like objects rather than the more well-known classification based on pixel analysis. Figure 1 shows a small area and the segmentation used for subsequent classification. The scene is an IR depiction where the more vibrant vegetation shows up as bright red. Trees and shrubs can be differentiated from the lawns by the slightly darker red color and the presence of a black edge, which would be shadow areas. The scene was classified into two broad classifications: irrigated and nonirrigated. These were subsequently reclassified into three classes, which included irrigated lawns, trees and shrubs, and unclassified. Figures 2 and 3 show the detail for a small area before and after classification. In figure 3, light green is lawn, and dark green is trees and shrubs (parcels not classified are either not AVRWC customers or have participated in the Cash for Grass program).

After an acceptable level of classification was achieved, the results were exported to ArcMap and joined to the parcel level shapefile. Each parcel now had a number of polygons representing either lawns or trees and shrubs. Area was calculated for each polygon. The classes were summed by exporting the .dbf table associated with the shapefile to Microsoft Excel. Pivot tables were used to produce various summaries of the GIS data.

The data on irrigated areas are compiled in a number of different ways. These include a summary of irrigated class by parcel type, summary of irrigated class per APN, and summary of irrigated class and APN. Table 11 summarizes the irrigated acres within AVRWC. These summaries split the irrigated classification into two classes: irrigated lawns and trees/shrubs. Figure 4 shows the data in table 11 graphically.

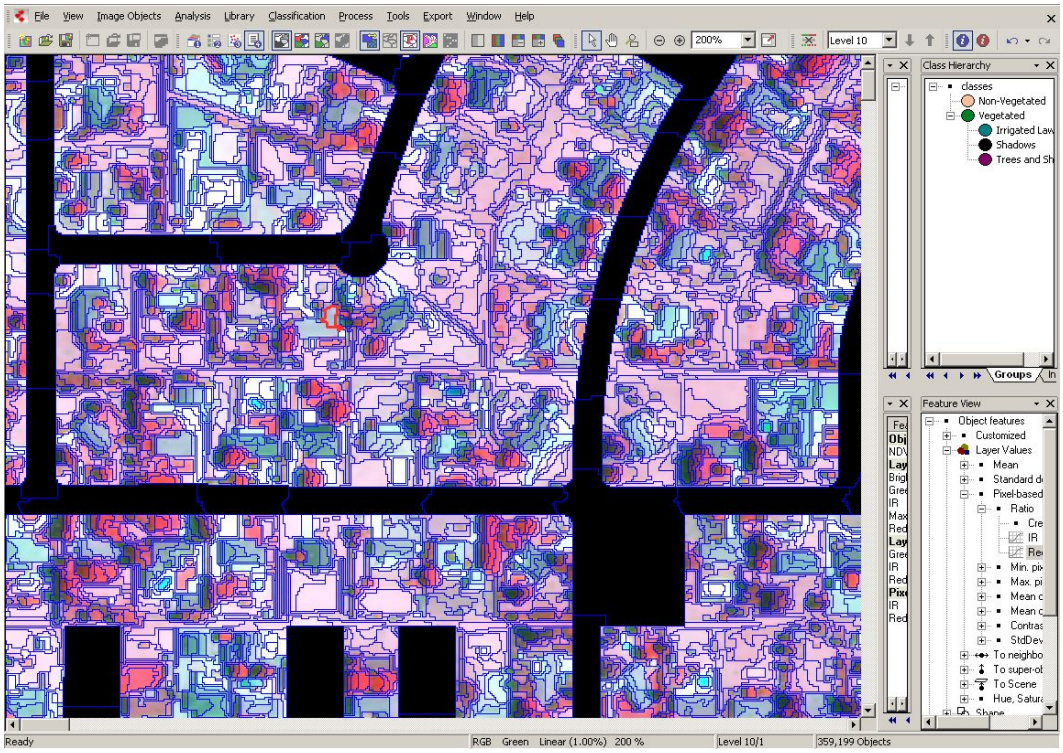

Figure 1. Example of image segmentation.

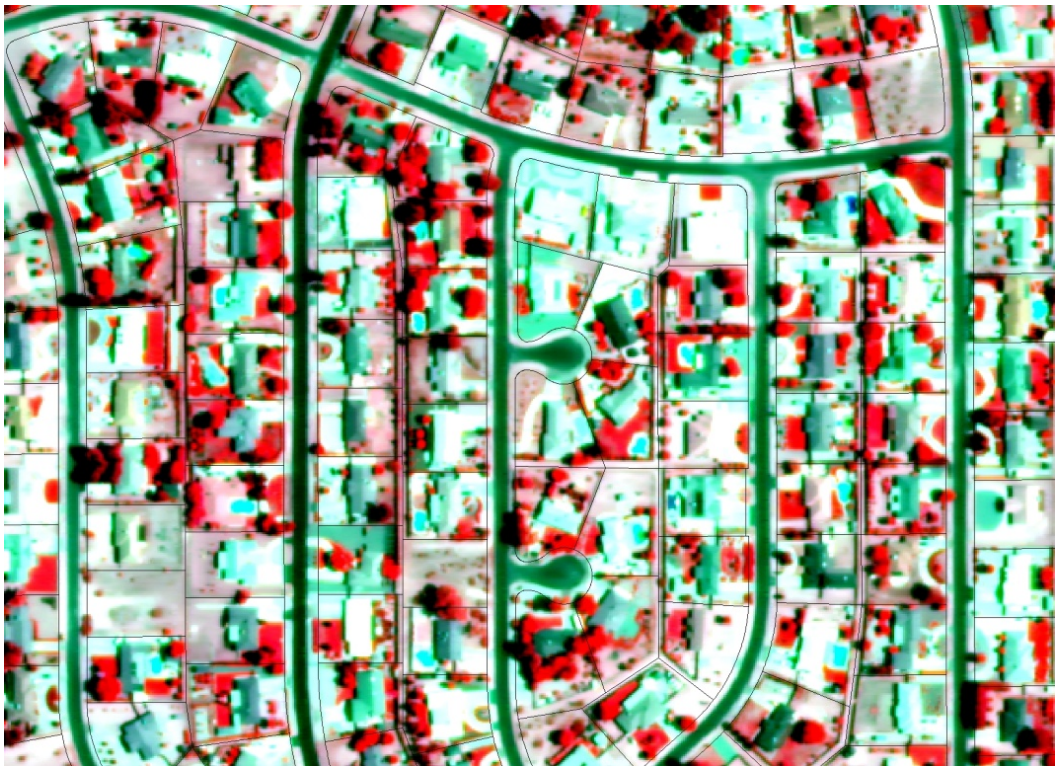

Figure 2. IR image subset of AVRWC.

Figure 3. Classified image.

Table 11. Summary of Irrigated Areas (acres) by Parcel Classification

Parcel Type	Irrigated Lawn	Trees and Shrubs	Total
Commercial	16.4	7.0	23.4
Common area	17.3	8.1	25.4
Golf course	248.2	9.8	257.9
Multifamily	36.0	21.9	57.8
Park	51.7	2.1	53.8
Public facilities	54.5	19.9	74.4
SFR	917.2	391.8	1,309.0
Unknown	0.8	0.2	1.0
Vacant land	0.9	0.3	1.2
Grand total	1,342.9	461.0	1,803.9

The data were also summarized by individual APN in square feet (ft^2) (see table 12). Each record shows the amount of irrigated lawn and trees/shrubs for each individual parcel and gives the parcel type: commercial, SFR, multifamily, etc.

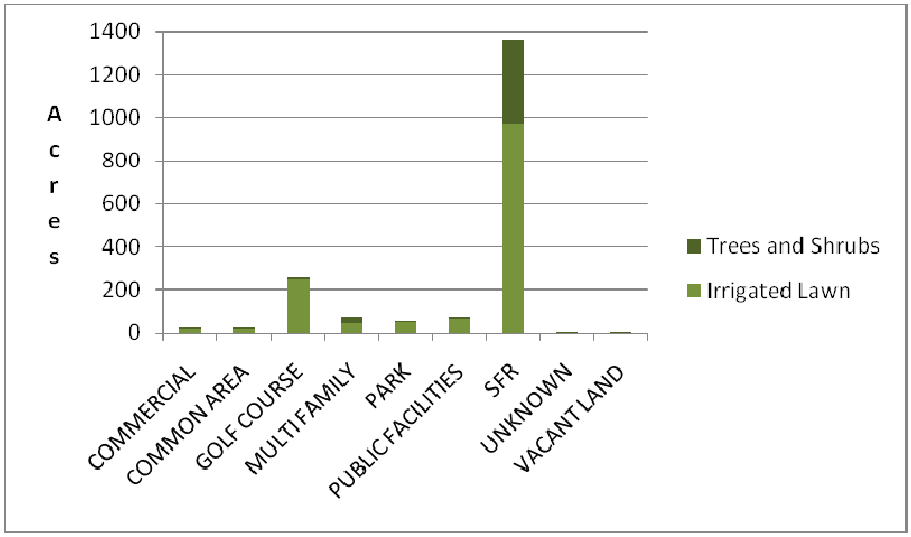

Figure 4. Summary of irrigated areas by parcel classification.

The data are also summarized by parcel classification. Table 13 shows a portion of the raw data for the parcel classification "SFR in the APN classification. These areas are summed by square feet. Figure 5 shows a histogram of the available total irrigated areas that might be considered for "Cash for Grass" within the parcel class SFR with the square feet converted to acres. The histograms are binned into 0.01-acre intervals; therefore, the first bar represents the number of parcels with 0.01 acre or less of the summed amount, which, in this example are the summed acres for both irrigated lawn and trees/shrubs. The second bar shows the number of parcels that fall into the range of 0.01 to 0.02 acre of irrigated lawn and trees/shrubs etc.

Table 12. Example of Data Compiled by Individual APN

APN	Irrigated Lawn (ft^2)	Trees and Shrubs (ft^2)	Total (ft^2)	Type BOR
43402105	44.54		44.54	Commercial
43402133	43.70		43.70	Commercial
43402135	355.44	118.48	473.92	SFR
43402146	9,764.89	2,609.99	12,374.88	Commercial
43402150	3,056.30	585.31	3,641.61	Compliance
43402151	21,884.41	5,611.69	27,496.10	Multifamily
43402159	3,349.75	646.25	3,996.00	Commercial
43405156	3,597.52	3,080.51	6,678.03	SFR
43405175	4,207.59	74.68	4,282.27	SFR
43405178		1,000.02	1,000.02	Commercial
43405181	2,048.90	1,652.69	3,701.59	Commercial
43405182	2,505.76	4,385.30	6,891.06	Commercial

Table 13. Example of the Data for SFR by Parcel Number (APN)

APN	Irrigated Lawn (ft^2)	Trees and Shrubs (ft^2)	Total (ft^2)
43402135	355.44	118.48	473.92
43405156	3,597.52	3,080.51	6,678.03
43405175	4,207.59	74.68	4,282.27
43426101	53.86		53.86
43426102	2,087.71	1,087.87	3,175.58
43426201	2,734.63	2,954.13	5,688.76
43426202	3,991.48	1,464.20	5,455.68
43426203	1,359.80	790.30	2,150.09
43426204	917.72	273.83	1,191.54
43426205	1,422.74		1,422.74
43426206	563.96	74.47	638.43
43426207	426.48		426.48
43426208	258.50		258.50
43426209	4,551.46	20.12	4,571.57
43426210	1,870.14	539.97	2,410.12

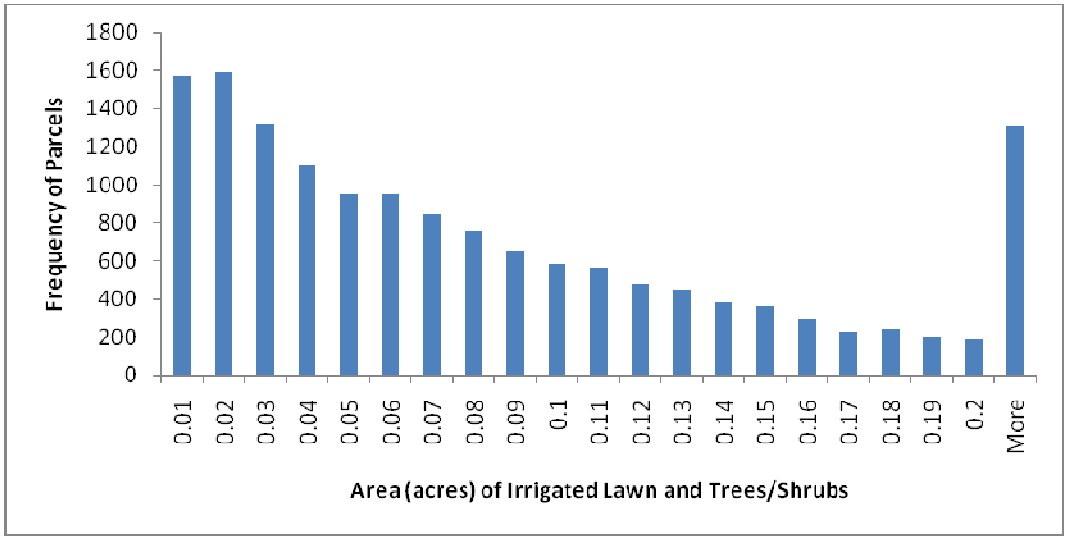

Figure 5. Histogram showing the area and frequency of irrigated lawn and trees/shrubs for SFR.

These data should allow one to estimate what is potentially still available for turf removal from each of the parcel types. These summaries may be produced for all parcel types listed in table 11. Because these data are also tallied by APN, AVRWC can query the dataset for parcels with unusually high irrigated areas. Used in combination with the spatial vectors created for this project, AVRWC can

also query by geographical location. This table can now be linked back to any other database using the APN as the common field.

Irrigation Water Use

Landscape irrigation quantities were estimated by applying various irrigation application rates to landscape surface areas measured from high resolution imagery. The assumed application rates were developed based on dedicated irrigation accounts' meter data and theoretical irrigation demands from local weather station information. The landscape surface areas were measured from recent high resolution imagery using remote sensing and GIS techniques.

This analysis of irrigation water use was performed on a sample of AVRWC customers representing approximately 90 percent of the total water use. The analysis could not be performed on the entire service area due to inconsistencies between the San Bernardino County Assessor parcel data and the AVRWC parcel data. The sample is assumed to represent the entire service area.

Irrigation Application Rates

Estimates of systemwide irrigation application rates were developed based on a comparison of actual application rates from several dedicated irrigation account areas and theoretical irrigation demands calculated from local weather station information.

Weather information was used to estimate theoretical irrigation demands for two types of landscape areas: (1) warm season turf grass, and (2) trees and shrubs. Irrigation demand is that amount of water needed by plants minus the amount of the plant demand met by rainfall. Theoretical irrigation demand can be calculated using local weather station data. Plant demand is typically calculated by multiplying a plant specific coefficient (kc) times the rain-adjusted net reference ET rate (net ETo).

A California Irrigation Management Information System weather station is located near the AVRWC service area in Victorville, for which ETo and rainfall data are available. Monthly and total annual net ETo were calculated from these data for 2006-2009. Irrigation demands were then calculated by applying kc values for warm season turf grass and for trees and shrubs. A kc value of 0.8 was used for turf grass as recommended by Allen et al. (1998), and a kc value of 0.5 was used for trees and shrubs as recommended by the California Department of Water Resources (2000).

Actual landscape irrigation usage is always greater than irrigation demand due to the inefficiencies of irrigation systems. All systems lose water to surface runoff, evaporation, and deep percolation. In this evaluation, an overall average

irrigation system efficiency rate of 75 percent was assumed to calculate application rates for both warm season turf grass and for trees and shrubs.

The 2006-2009 average annual and monthly theoretical irrigation application rates for the two landscape types are summarized in table 14.

Table 14. 2006-2009 Average Theoretical Irrigation Application Rates (feet)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Turf grass	0.2	0.2	0.4	0.5	0.7	0.8	0.8	0.8	0.6	0.4	0.2	0.1	5.8
Trees and shrubs	0.1	0.1	0.3	0.3	0.5	0.5	0.5	0.5	0.4	0.2	0.2	0.1	3.6

AVRWC supplies water to approximately 150 accounts where all of the metered usage is strictly for landscape irrigation (dedicated irrigation accounts). These accounts are mostly for parks, golf courses, and common areas within subdivisions and apartment complexes. Water usage at seven dedicated irrigation account test areas was evaluated. These areas were predominantly turf areas and included two golf courses, four parks, and a subdivision common area. In this evaluation, the annual water usage was simply divided by the irrigated area to calculate the annual application rate. Application rates within the subdivision common area and one of the golf courses were excessively high. The other golf course apparently supplements the AVRWC supplied water with that from a reservoir, and the metered application rate calculated was very low. The 2006-2009 average annual and monthly irrigation application rates for the four remaining test areas (parks) are summarized in table 15.

Table 15. 2006-2009 Average Actual Irrigation Application Rate (feet)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Test area 3	0.1	0.1	0.1	0.5	0.5	0.7	0.7	0.8	0.8	0.7	0.8	0.1	5.8
Test area 4	0.1	0.1	0.2	0.2	0.6	0.6	1.0	1.0	0.8	0.8	0.2	0.2	5.8
Test area 5	0.0	0.0	0.1	0.1	0.4	0.4	0.7	0.7	0.6	0.6	0.3	0.3	5.9
Test area 7	0.1	0.1	0.3	0.3	0.6	0.6	0.7	0.7	0.5	0.5	0.2	0.2	4.8

Assumed annual application rates were applied to the various land use categories based on comparison of the theoretical and actual application rates discussed above. The turf application rates used (in feet) were 6 for all residential and public areas and 9 for commercial and common areas. The trees and shrubs rates used (again in feet) were 3.6 for all residential and public areas and 4 for commercial and common areas. The higher rates used for commercial and common areas are based on the assumption that these users typically overirrigate,

which is supported by the subdivision common area meter data evaluated (approximately 12 feet per year on average).

The water usage results from applying the above assumed irrigation application rates to the landscape areas for 2008, and the dedicated 2008 meter usage, are summarized in table 16.

Table 16. Summary of Irrigation Usage Analyses Results

Parcel Type	Irrigation Usage (acre-feet)	Total 2008 Metered Usage (acre-feet)	Percent Irrigation of Total AVR Usage	Percent Irrigation for Parcel Type
Commercial	191.6	428.4	1.4	44.7
Common areas	188.1	194.6	1.4	96.6
Public properties	427.2	685.0	3.1	62.4
MFR	359.2	981.0	2.6	36.6
SFR	7,220.9	9,718.1	51.9	74.3
Dedicated irrigation	1,889.7	1,889.7	13.6	100.0
Private fire protection	0.0	10.7	0.0	0.0
Totals	10,276.6	13,907.6	73.9	na

Note: MFR = multifamily residential

Discussion

The use of these GIS and remote sensing technologies is becoming standard in the analysis and interpretation of irrigation within cities. Given the recognition by States and counties that water resources are "of limited supply and are subject to ever increasing demands,"[1] these techniques should find increasing use as governmental bodies seek to maximize their water efficiency. These efforts are aided by the fact that datasets necessary for this type of analysis are readily available for little to no cost. High resolution aerial imagery is becoming easy to come by and is being updated on a frequent basis. Water budget calculations are not difficult, and ETo values may be estimated from State reference tables or nearby weather stations. Naturally, there are caveats and pitfalls to this sort of analysis, and these are discussed below.

Datasets with information salient to water budget analysis may be acquired from a variety of agencies. This may require some searching about but, typically, these are readily provided. More sophisticated datasets, such as the Dunn & Bradstreet data, have fees associated with them. Once acquired, the data will require

[1] California Code of Regulations, Title 23. Waters Division 2. Department of Water Resources Chapter 2.7. Model Water Efficient Landscape Ordinance

considerable manipulation and data mining. This will require some skills with data handling software such as Microsoft Access. Another problem that became

an issue with this project and may be expected from many "free" datasets is the problem of data accuracy and consistency. Some time was spent finding the errors, and additional time was spent deciding whether to fix the problem or accept the errors as expected with no further time expended.

High resolution imagery is necessary to identify and determine the area of irrigated urban landscaping. Central to using imagery for any type of vegetation work is the IR band. This is a common enough acquisition in most aerial image flights, but one must often specifically request the IR band. This imagery must be used with appropriate software and a knowledgeable and trained person to perform the work. The software required would typically be image-processing software and GIS. Additional data manipulation is often also performed within some sort of spreadsheet. Many agencies already have software and staff that could perform this work.

Estimating landscape irrigation rates can be subjective because plant consumption quantities are typically derived from both assumed dedicated irrigation accounts and theoretical irrigation demands. The assumed irrigation rates from dedicated accounts depends heavily upon accurate data. In some cases, these data may need to be verified with local authorities. The assumed theoretical irrigation demands rely on mean values. In areas where the weather fluctuates greatly, these values may vary from year to year, making long-term projections tenuous and laced with caveats. The Apple Valley region has fairly consistent ET values, and we expect the values used are valid.

Conclusion

The use of existing data, along with high resolution imagery, provides water managers the ability to use relatively precise measurements to improve water conservation decisionmaking. This dataset allows AVRWC to identify those parcels above a critical irrigated percentage value and the opportunity to solicit those customers for conversion from irrigated to desert landscaping. Future evaluations using updated imagery can also provide a cost-effective way to ensure compliance. Those parcels identified as having high-flow appliances can now be easily identified and approached to enroll in the rebate programs. Similarly, this approach can be used to identify, by parcel, the amount of pervious versus impervious surface. This would allow the city to potentially charge the individual parcels the appropriate amount for storm water runoff, rather than a broad estimation that may overcharge some and undercharge others. This type of analysis can also be used to determine the appropriate size of drainage structures, given the amount of impervious surface. Urban maps can be updated easily using high resolution images and mapping. Traffic patterns, building heights, and urban

forest characterizations are just a few of the many other capabilities that might be useful using urban GIS data and high resolution imagery.

References Cited

Allen, R.G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements. Food and Agriculture Organization of the United Nations, Paper 56.

Tubbs, C., and P. Agarwala. 2005. Apple Valley Ranchos Water Company. Urban Water Management Plan.

California Department of Water Resources - University of California Cooperative Extension. 2000. A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California. The Landscape Coefficient Method and WUCOLS III*.