Integrating High Resolution Imagery with ArcGIS for Urban Water Conservation

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Background

The California Urban Water Conservation Council (CUWCC), a consortium of water utilities and other interested organizations, recognizes the potential water savings that can be realized by promoting conservation in irrigation water usage. The CUWCC's Best Management Practice 5 (BMP 5) indicates the need to monitor the amount of irrigation water necessary, especially for large commercial customers such as golf courses, hotels, campuses, and other facilities with significant irrigated landscaping. BMP 1 requires landscape audits for single-family residential customers. As a signatory to the CUWCC's Memorandum of Understanding, the City of Santa Rosa wanted to establish a system for complying with BMP's 5 and 1.

Water Conservation Requirements- The Problem

Traditional methods for determining water use efficiency at any site include ground-based measurements taken with a measuring wheel and digitization of land cover polygons from aerial photography. Both of these methods produce accurate results, but are costly and take a significant amount of time to produce.

The City had been gathering data for large commercial customers by using three processes:

1. Interns measuring landscape plans with an electronic planimeter.
2. Interns measuring sites in the field when plans are not available.
3. Customers reporting landscape measurements when applying for an irrigation efficiency rebate program.

For both commercial and residential customers, this can be a very expensive and time-consuming effort. For example, using these methods to collect this data for our 39,000 single-family customers would take approximately 117,000 labor hours. The labor equates to eight full time staff working 8 years at a cost of over $3,000,000, for an average of $77 per site. The cost and time requirements of current data collection methods prohibit gathering data at single-family residential sites. This segment of Santa Rosa's customer base uses approximately 57% of outdoor water use.

The Potential

It is clear that current data collection methods are inconsistent, staff and time intensive, and ultimately expensive. At the same time, the effort to respond to the BMP's has allowed the City to see the tremendous value of landscape data for accurately assessing the water use efficiency of its customers. With landscape information, water use efficiency can be easily evaluated and communicated to the customer. Outreach and education efforts can be focused when and where needed to affect changes in water use. Programs can be targeted to provide incentives based on measurable improvements in efficiency.

In comparison to traditional methods, the use of high resolution, multi-spectral imagery in combination with an ArcGIS software application to support analysis, reporting and mapping, will provide consistent high quality data in less than two years. This method requires very little staff time and would cost less than $127,000 for ***all*** 46,000 residential and commercial sites ($2.76 per site) – and periodic data updates could be accomplished easily and at very low cost.

The Solution – Design and Development

Multi-spectoral imaging will establish a system of landscape data collection and water use assessment for <u>all</u> parcels served by Santa Rosa's water system. This system can then be affordably maintained by the City of Santa Rosa for all commercial and residential sites. Such a system will provide the data and analysis tools (using a custom ArcGIS application – H2Observe), necessary to quickly and reliably assess water use efficiency for the vast majority of the customer base, which can then be communicated to each customer.

In order to assess the effectiveness of incorporating this project into daily operations, the City will compare water use efficiency before and after efforts to share the data with each customer. Applying landscape data to pre-project water use and weather data will allow Santa Rosa to assess historic water use efficiency. Applying landscape data to post-project water use and weather data will Santa Rosa to assess changes in efficiency, identify trends, and quantify results in gallons of water.

Being able to calculate a reasonable water budget for each site based on the landscaped area allows for the evaluation of water use efficiency for each site. The City will use efficiency trends for water demand projections and infrastructure planning. As significant geographic trends come to light (such as high water pressure in the City's system associated with low water use

efficiency) may lead directly to pilot project infrastructure changes (more aggressive pressure controls on the City's system) with possible citywide system changes over time.

By communicating water use efficiency information directly to each water customer, Santa Rosa will provide our customers with the data needed to assess the potential for water and money savings. Customers can use efficiency data to track the impacts of site-specific water conservation efforts. Each customer with a dedicated irrigation meter is to receive notice comparing the water use budget for the site with the actual water use at the site each month. Single-family residential customers will get a report each year with additional follow up information for sites significantly over water budget. In this way, customers can monitor landscape water need versus water use and work to reduce unnecessary over application of irrigation water. Those sites with unnecessarily high water use can then be easily identified and targeted for outreach and technical assistance.

The Solution

H2Observe

For this project, Space imaging has developed ***H2Observe***, a custom ArcGIS based application that runs from within the ArcMap interface. Its design takes advantage of a custom, intuitive interface tightly integrated with existing data sets. This application combines four datasets to produce reports and maps needed by water conservation representatives to monitor irrigated water use. These primary datasets are:

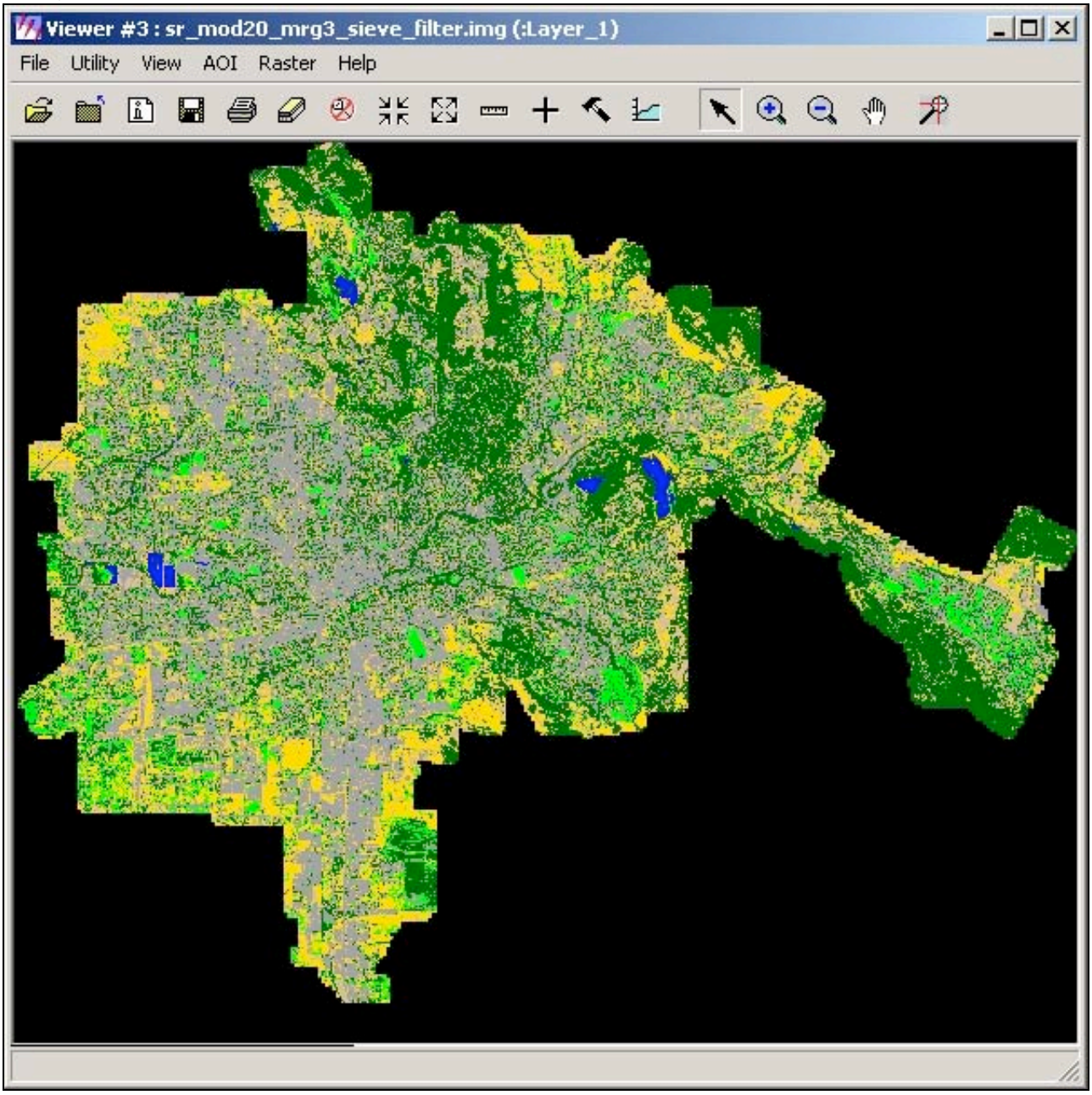
1. Customer parcels
2. Definition of various land cover types within each parcel
3. Updated weather data from state weather databases
4. Actual irrigation water use data from meter reading.

Each month, water conservation representatives will use H2Observe to ingest irrigation water use data, from meter reading data. The application will compare this data to a water use estimate that is based on an established formula that combines weather and irrigated landcover on a parcel-by-parcel basis to estimate optimal irrigation water use. Customers who have used significantly more than the estimate will then be flagged for further contact from water conservation representatives. The database will keep track of actual versus optimal water usage on a monthly basis to track gains and losses in water use efficiency for each customer.

Land Cover Mapping

A high resolution land cover map is a key component to the H2Observe technical solution (see Figure 1). The land cover map is used by the H2Observe application to calculate the areas of the irrigated vegetation within each parcel to create the parcel land cover database. In order to do this, the application needs detailed land cover information in the form of a classified map. The imagery used to generate this maps needs to have good spectral definition, but because of the nature of urban mapping, also requires a high degree of spatial resolution and accuracy.

Figure 1: The landcover map derived from high resolution IKONOS imagery for the City of Santa Rosa, CA.



The land cover map was derived from Space Imaging's IKONOS imagery. This multispectral imagery provides 11-bit, 1-meter resolution imagery of the blue, green, red and near-infrared bands with a high degree of spatial accuracy. This provides the necessary spectral and spatial resolution required to support such detailed delineation on a per parcel basis.

Image classification was undertaken using ERDAS Imagine and Definiens eCognition software. The classification scheme was relatively simple, given the needs of the H2Observe and the formula used for calculating irrigation requirements. Figure 2 presents a detailed example of the source IKONOS infrared imagery and the resultant land cover classification for a small area of interest within the City.

Figure 2: Source IKONOS imagery and detailed land cover classification example.

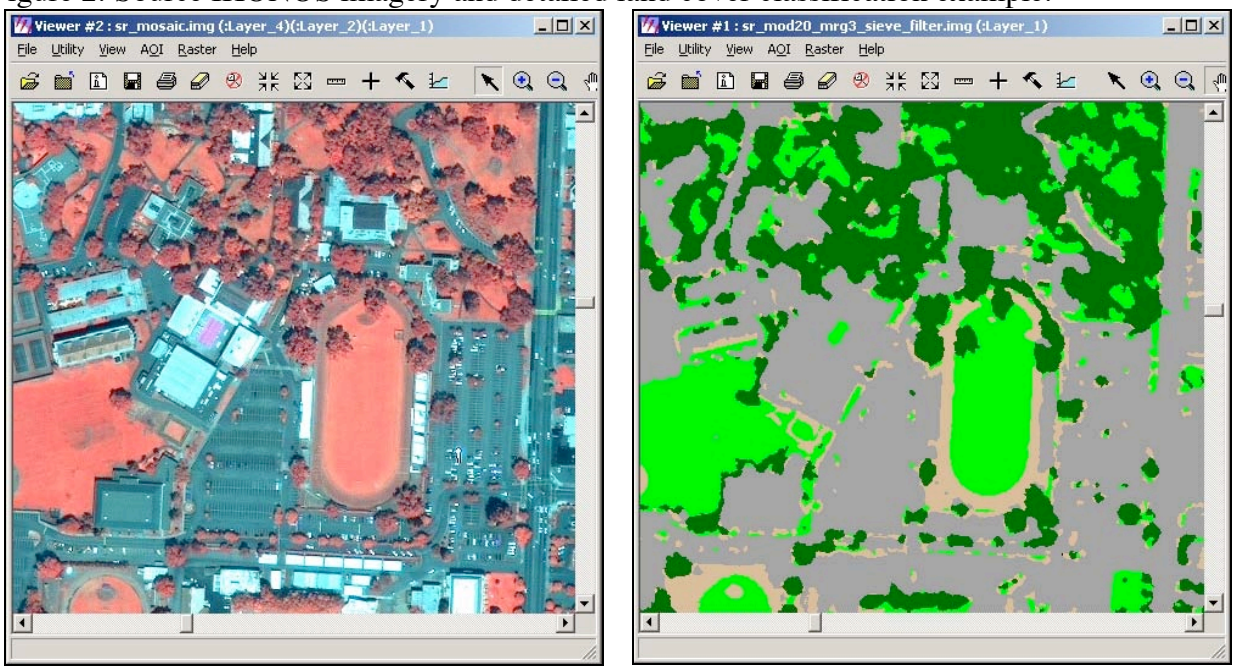


Figure 2 shows the source IKONOS 1-meter image on the left showing color-infrared band combination. On the right is the classification derived using ERDAS Imagine software. This map, once converted into a vector coverage, will be used by the H2Observe application to calculate areas of irrigated vegetation types within each parcel within the custom ArcGIS application.

A simple, yet effective, land cover classification was used to derive the following classes:

- Tree (Includes Ornamental Vegetation)
- Irrigated Grass
- Non-Irrigated Vegetation (Natural)
- Bare Ground
- Impervious
- Water

Not all of these classes are required by the H2Observe application. The Non-Irrigated Vegetation, Bare Ground and Impervious classes were included so the City of Santa Rosa can use the map for other purposes, within other departments, as needed.

Classification techniques used in this project began with a standard unsupervised classification, which identifies roughly 50% of the high-resolution imagery. At the same time, a segmentation layer was generated using eCognition. This was followed by a series of spatial models to reduce confused classes, using the segmentation layer and some classification that was done in eCognition, as well as texture bands, and other layers generated from various ancillary data provided by the City of Santa Rosa. The final map was then edited to clear up any remaining confused classes.

In addition, to optimize the use of the large land cover image in the ArcGIS H2Observe application, a version of the map was produced which contained only the classes necessary to the water budget calculations. This was then converted into a vector coverage for use by H2Observe analysis functions. Accordingly, two land cover maps are available, one for immediate use in analysis tools, and a more detailed second image.

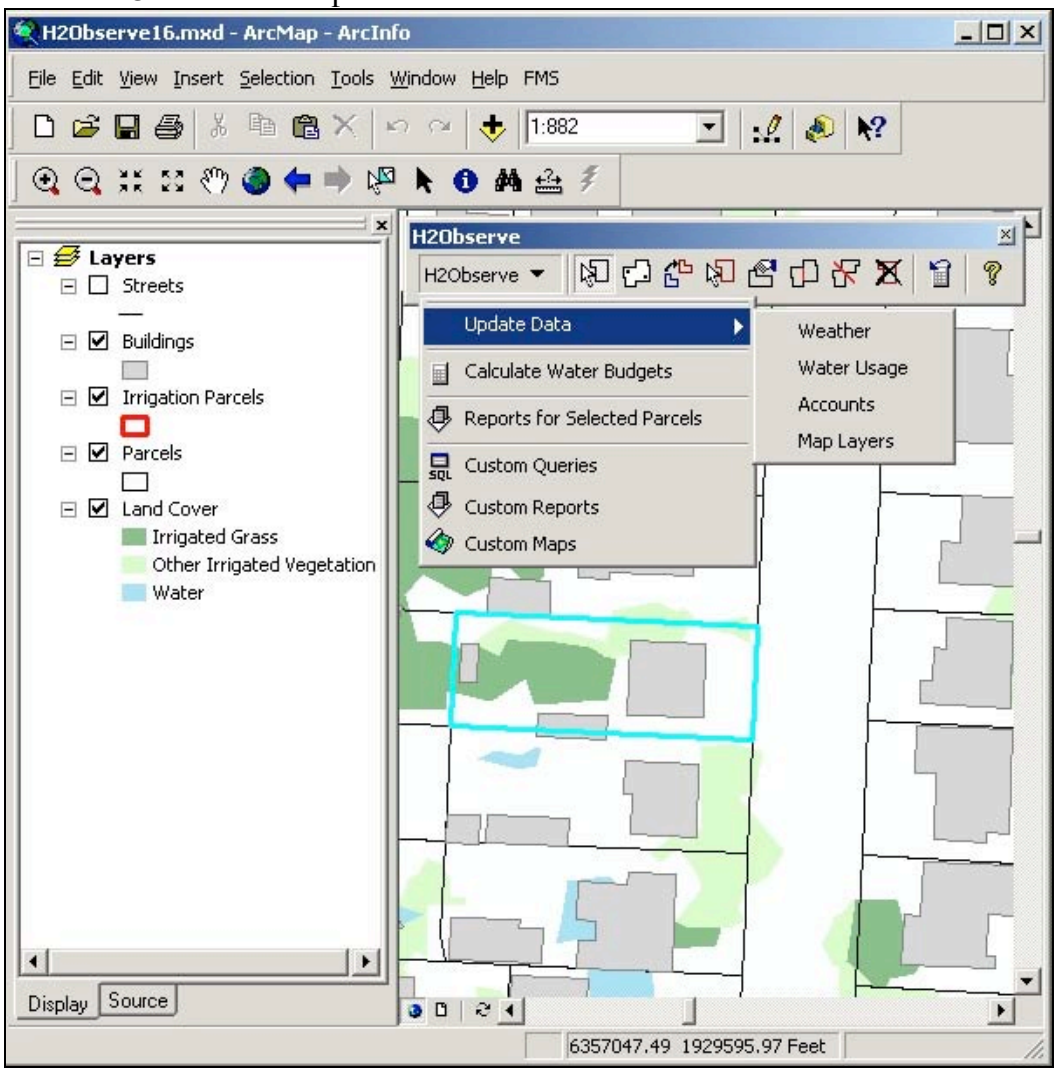
The H2Observe ArcGIS Application

To aid City staff in calculating water usage and estimating requirements, a custom, yet simple, application was developed using ArcGIS. This application operates as a custom toolbar within the ArcMap interface. It provides a series of tools and functions focused at guiding City staff through typical, and repeatable, analysis, reporting and mapping functions. Figur3 presents the H2Observe interface within ArcMap.

To calculate irrigated landscape area for each parcel, a simple overlay of land cover and parcels is undertaken. A water budget is calculated for each month using the area of irrigated grass, other irrigated vegetation, and water on the parcel, together with the expected evapotranspiration for the month. The month is defined as the period between the dates in which the water meter is read. Since water meters are read on different dates for each customer, the evapotranspiration is calculated separately for each customer by summing the daily values from a weather table for each day in the monthly period.

The calculated monthly water budgets are compared to monthly water usage read from the customer's water meter. This is used to determine which customers are using more water than they should for landscape irrigation. Indoor water usage can be estimated from the number of residents on each parcel, which is stored in the database.

Figure 3: The H2Observe ArcMap interface.



Each month, new water usage and weather data need to be added to the system. This information is used to calculate water budgets for the new month. To minimize the size of the active database, the application stores only 5 years of water budget information. Water budgets over 5 years old are exported to a separate database before being deleted from the active database.

The output of the water budget calculations is stored in a database table. This table contains one record for each month, for each parcel. The table allows an easy comparison between the water budget for the month and the water usage for the month. There is also a summary table that stores the total water usage and water budget for all months, for each parcel. This summary table

can be used in queries that search for customers that are consistently using more water than is necessary for their landscape.

To ensure that the H2Observe application continues to support City requirements in the future, a suite of editing and data updating tools is included. To support integration with ArcMap, all required GIS layers and tables are stored in a Personal GeoDatabase. City staff can update data over time and regenerate analysis and map/report outputs as required.

When the land cover layer is updated, irrigated landscape is recalculated for each parcel. A tool is also available to identify individual parcels that need irrigated landscape recalculated and the monthly time periods to apply this to. This is required for parcel boundaries that have changed over time.

An "Irrigation Parcels" GIS layer is also used by the application. This layer consists of parcels that have been copied by the user from the parcels layer and modified in some way. When the user knows that a parcel has two water meters, it can be copied to the irrigation parcels layer and split into two separate parcels. This is useful for when the parcel has a duplex with separate houses and the boundary between the houses is easily defined in the landscape. Irrigation parcels can also be parcels that are derived from multiple parcels combined into one. This would be the case when more than one parcel uses the same water meter. The H2Observe toolbar has tools for copying parcels to the irrigation parcel layer, splitting irrigation parcels, and combining irrigation parcels. When water budgets are calculated, irrigation parcels are used as input, rather than the corresponding copied parcels.

The H2Observe application is integrated with Crystal Reports for reporting purposes. The user can select parcels individually by clicking on the map, and then produce reports on efficiency and quantity of water use for those parcels. Queries can also be applied that will select parcels that are apparently using more water than is necessary. Further analysis can then be done on these parcels to determine if customers should be contacted. Customers determined to be using more water than is necessary can be contacted for more information and to give advice on methods to save water. This will ultimately benefit the customer by reducing their water bill and benefit the City by reduced water usage.

The H2Observe application also allows users to define their own custom queries that can be saved for future use. In addition, custom report templates can be created and used, along with standard report templates, for displaying the results of custom queries.

The Results

Using a combination of high resolution mapping methodologies and the H2Observe application, both developed by Space Imaging, the City of Santa Rosa will be able to identify customers who are using more water than necessary to irrigate their landscaping.

There are some technical issues which have made creation of the landcover map difficult, beyond what is normally encountered in the high resolution urban mapping. The first issue was the collection date of the imagery, which was in early June. This was apparently early enough that much of the natural vegetation was still very green. This added significant confusion in the separation between natural versus irrigated vegetation.

Another issue that had to be dealt with was the fact that tree canopy conceals the irrigated lawns beneath them. In Santa Rosa there are many neighborhoods with large amounts of overhanging tree canopy over lawns. This leads to the false result that a given parcel may have little or no lawn, but a large area of tree cover. While the amount of tree cover may be accurate, the underestimation of irrigated lawn will result in an underestimated water budget. This customer will then always be flagged as being over their water budget.

The project team is currently looking at possible solutions to this problem. One possibility is to increase the ET figure for trees with the assumption that there is normally lawn underneath them and that the lawn, being shaded, requires less irrigation. Future activities will derive solutions to these issues as the analysis process and technical options evolve.

Summary and What's Next

The project is not yet complete. Testing is underway with the data and ArcGIS application. Final Results from the project will not be available until later this fall. The City expects to implement H2Observe and expects to begin seeing results by November 2003.

For more information about the technical process and the project please contact either of the authors.