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Managing Water in the West

Evapotranspiration Analysis of Saltcedar and Other Vegetation in the Mojave River Floodplain, 2007 and 2010

Mojave Water Agency Water Supply Management Study Phase 1

October 5, 2011

U.S. Department of the Interior
Bureau of Reclamation

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Bureau of Reclamation

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.

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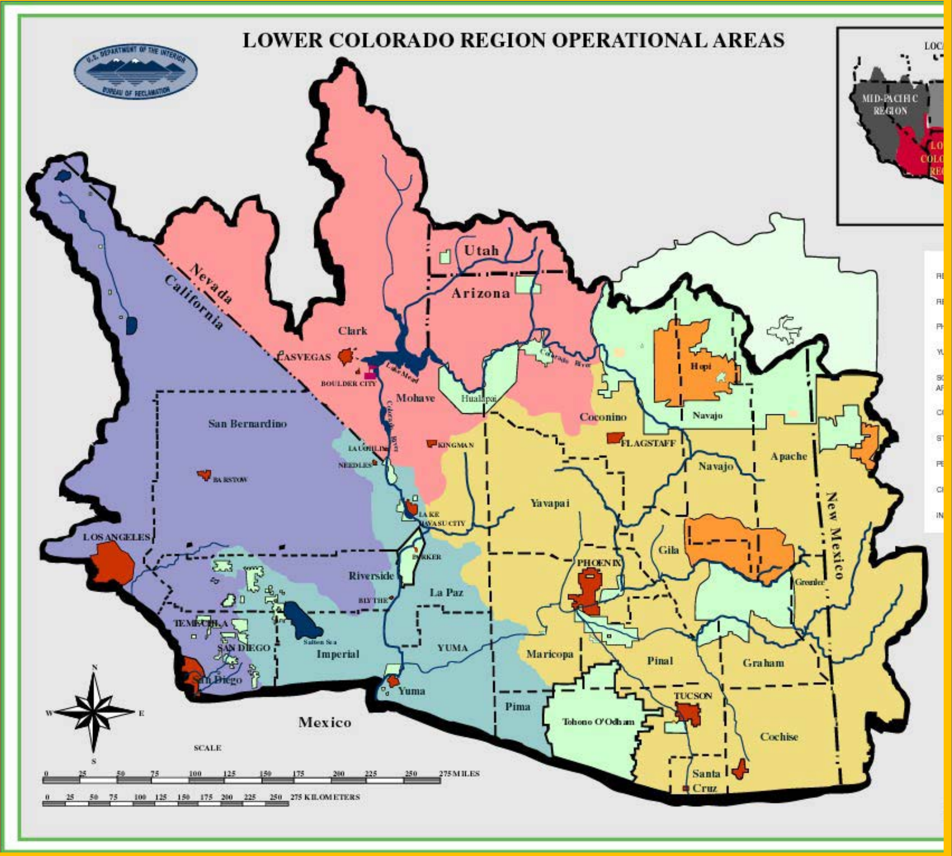
Lower Colorado Region



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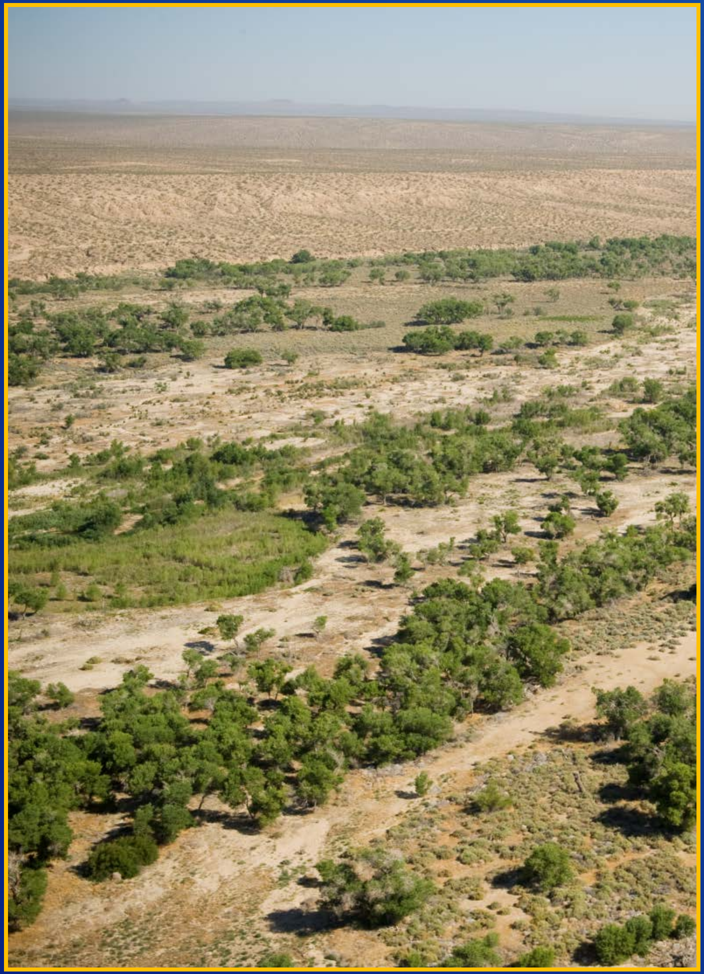
Study Background



- Reclamation's Planning Program
- Mojave Water Agency Water Supply Management Study
  - Analyze a variety of water uses within the MWA service area and develop recommendations for providing additional water supplies or reducing water use
  - Three phases
- Evapotranspiration Water Use Analysis of Saltcedar and Other Vegetation in the Mojave River Floodplain, 2007 and 2010

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Study Team

Utah State University

- Dr. Christopher Neale, Professor
- Dr. Robert Pack, Associate Professor
- Saleh Taghvaeian, Hatim Geli, and Saravanan Sivarajan, Ph.D. students
- Ashish Masih, Post-graduate Researcher

Bureau of Reclamation

- Amy Witherall, Water Resources Planner
- Jeff Milliken, Remote Sensing Scientist
- Mike Baker, Remote Sensing Scientist
- Ron Simms, Geographic Information Group Manager
- Scott O’Meara, Botanist

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Study Overview

Saltcedar (*Tamarix)*

- **Analyses included:**
  - 2007 and 2010 classification of native and non-native vegetation
  - Vegetation evapotranspiration modeling
  - Lidar elevation map development
  - Groundwater mapping
  - Water evapotranspiration cost calculations
- **Results are presented as a whole and also by Mojave Water Agency Alto, Alto Transition, Centro, and Baja subarea boundaries.**

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Definitions

- **Remote Sensing** – Uses sensors to capture the electromagnetic radiation coming from the surface at specific wavelengths.

- **Lidar** – Laser system that transmits pulses of light at high frequency, receiving the reflected returns from different surfaces and mapping the position and altitude of the return.

Evapotranspiration (ET) – the amount of water that transpires through a plant's leaves plus the amount that evaporates from the soil in which the plant is growing.

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Definitions continued

- **Multispectral** – A remote sensing system that measures reflected light from the surface in specific bandwidths

- **Canopy acres** – Areas covered by vegetative canopies

- **Crop coefficient** – The ratio between actual ET of a crop and reference ET

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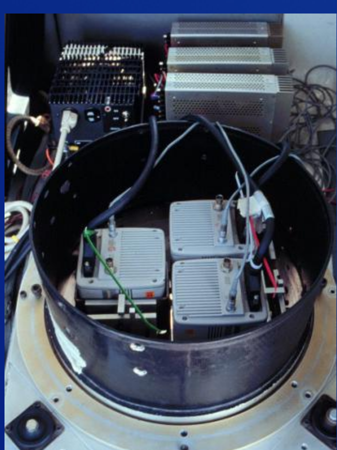
Remote Sensing Services Laboratory

USU Cessna TP206
Remote Sensing Aircraft

USU Multispectral Digital System

Detail of Multispectral Cameras



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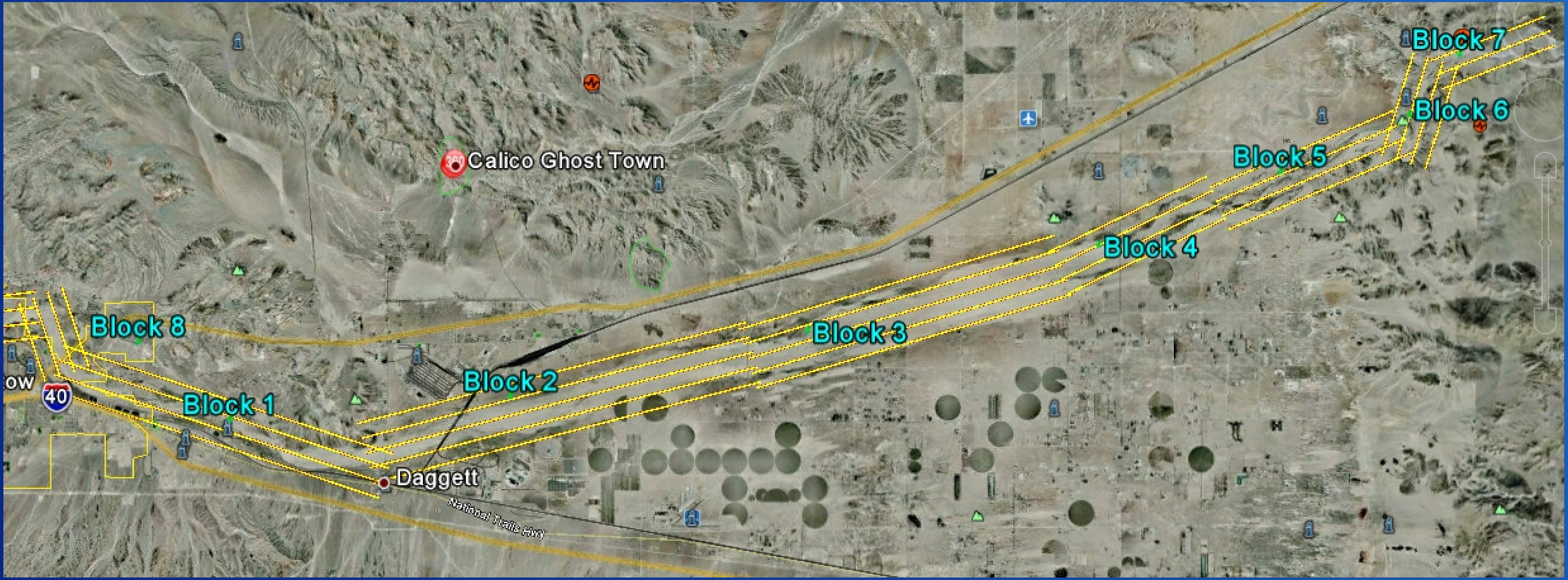
Lidar/Multispectral Flight



Imagery Acquired on June 29 and June 30, 2010 under clear sky conditions

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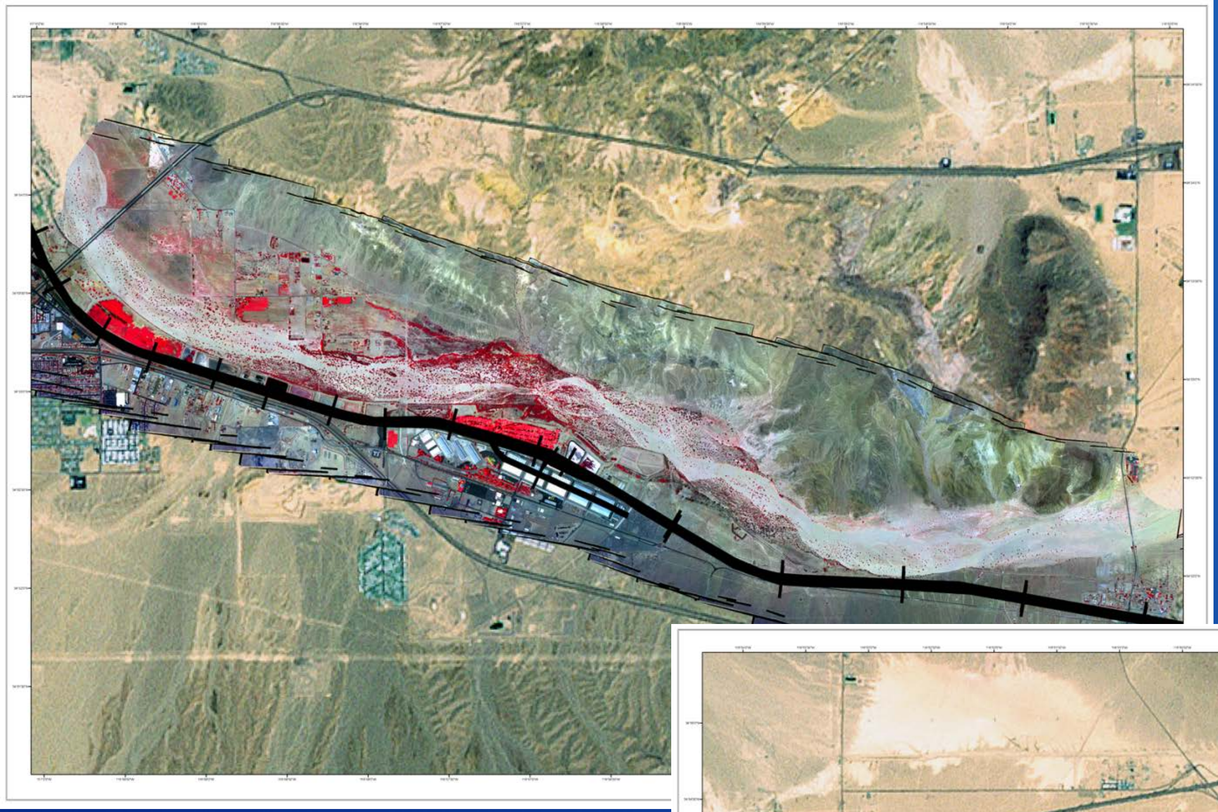
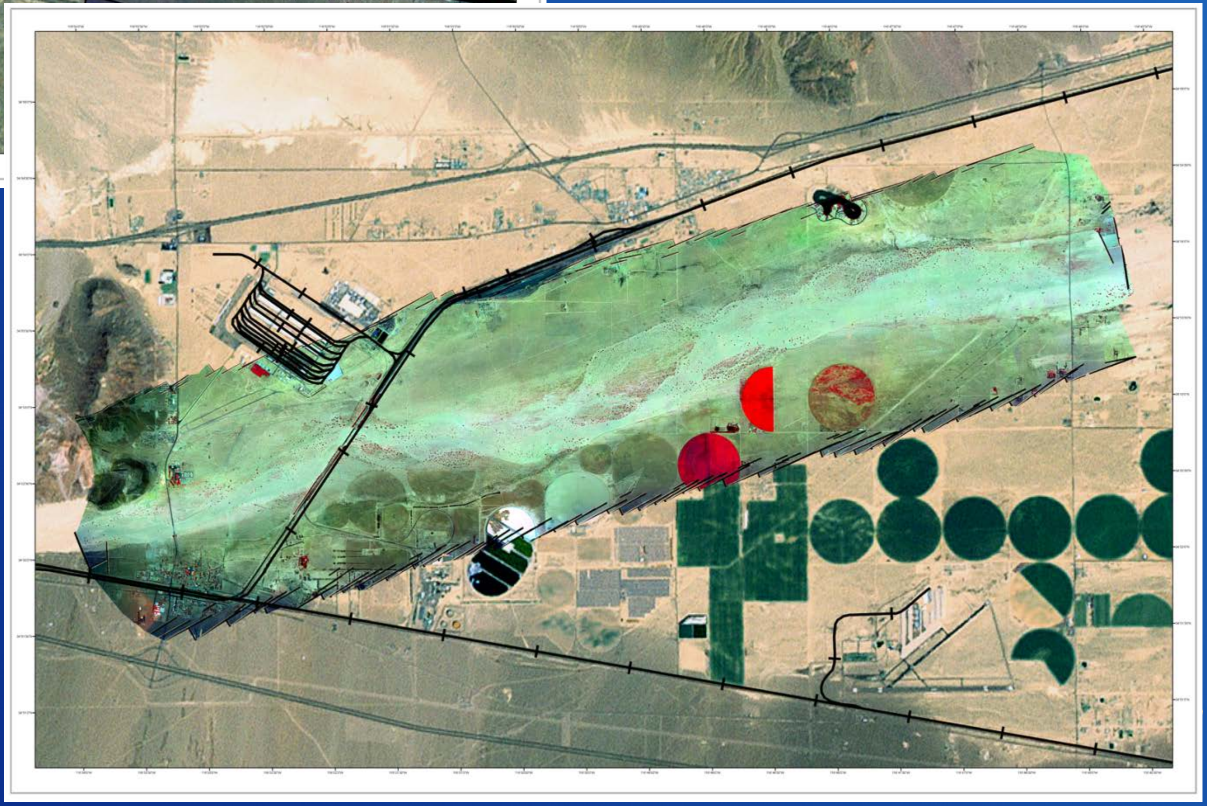
Multispectral Ortho Imagery

Block 1 and 2

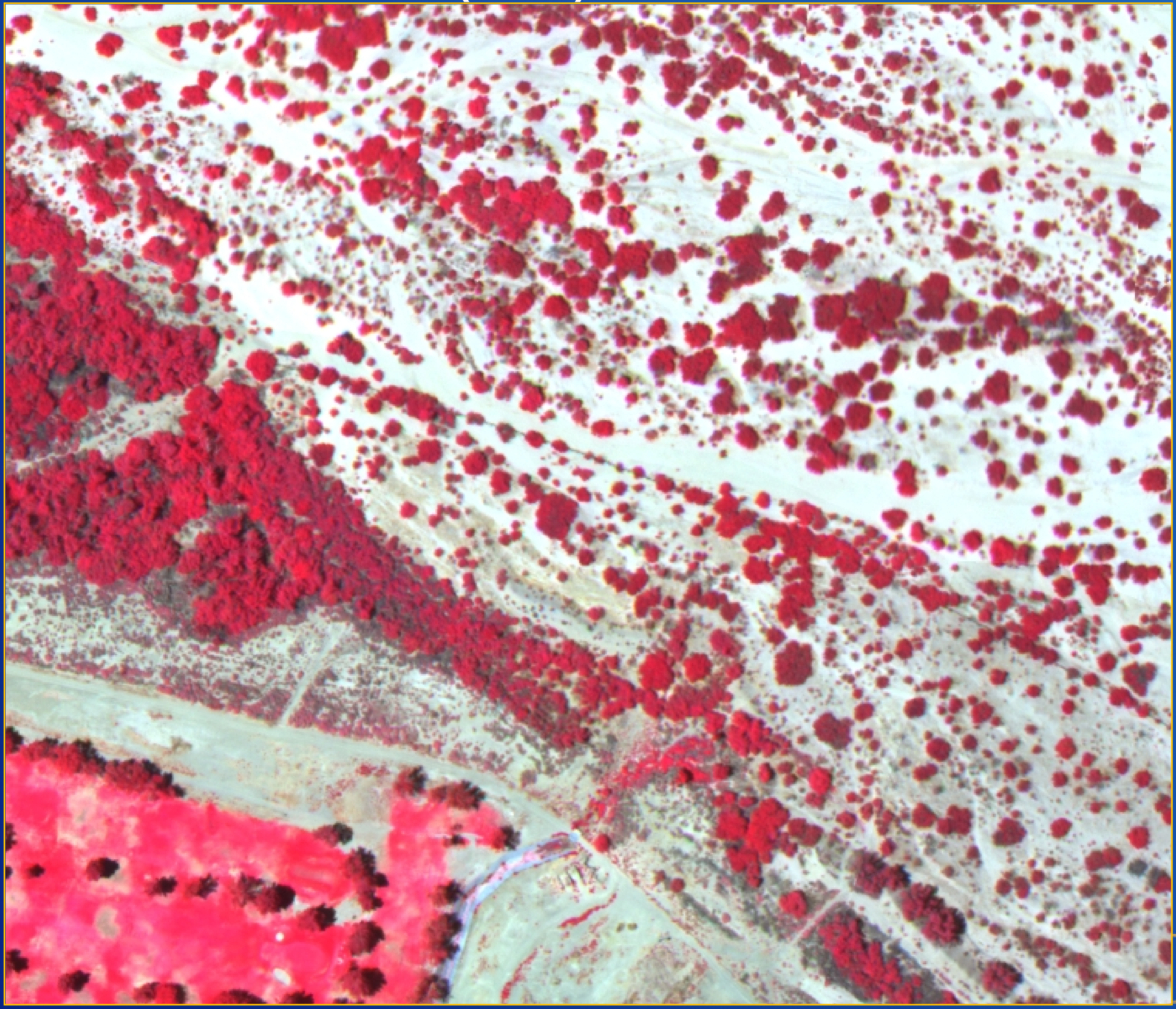




Ortho-rectification using direct geo-referencing with lidar point cloud data

Multispectral Image Detail

Pixel resolution: 0.35 meter (1 foot)



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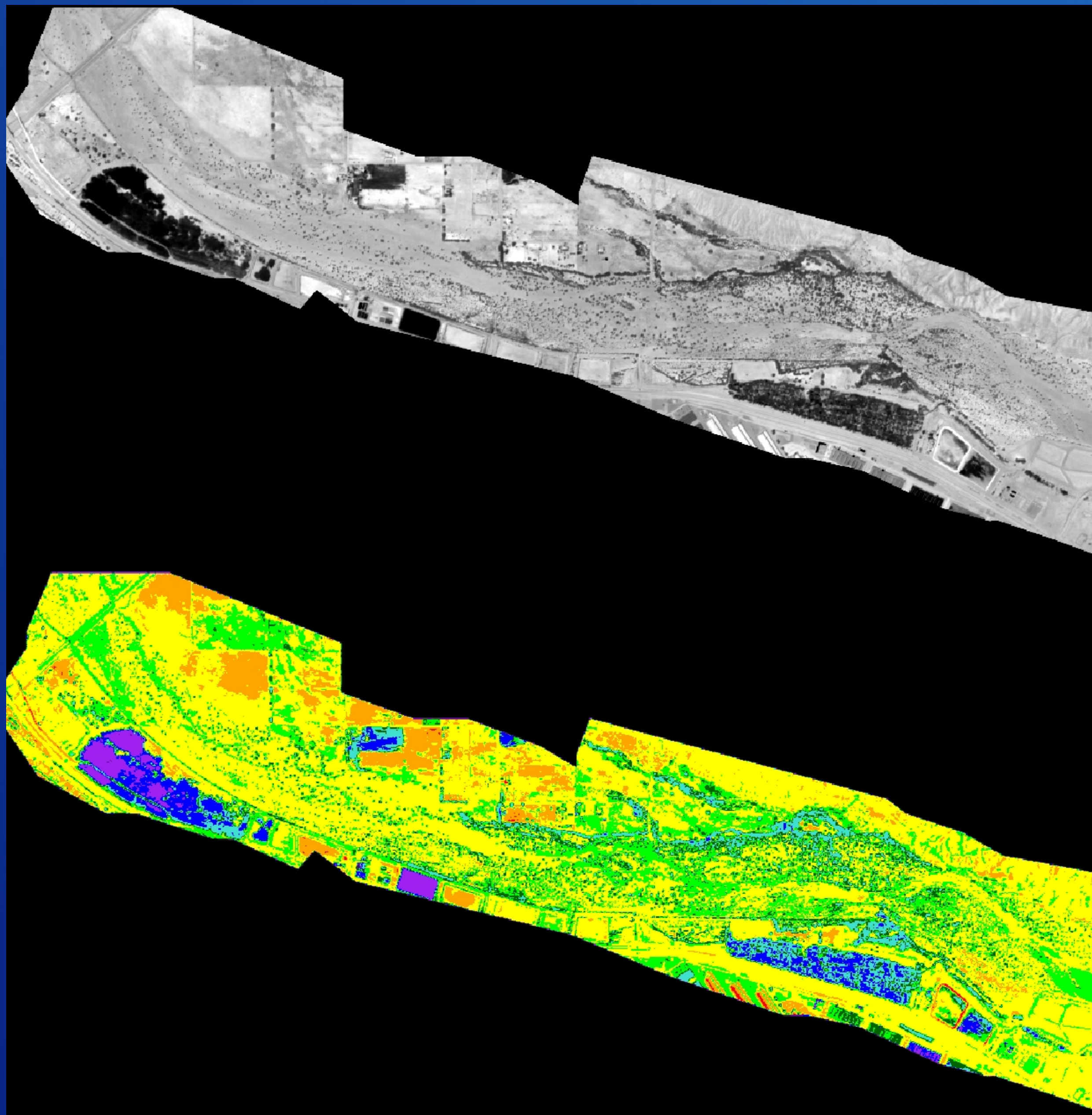
Thermal Infrared Imagery



Temperature

20 – 30 C

30 – 35 C

35 – 40 C

40 – 45 C

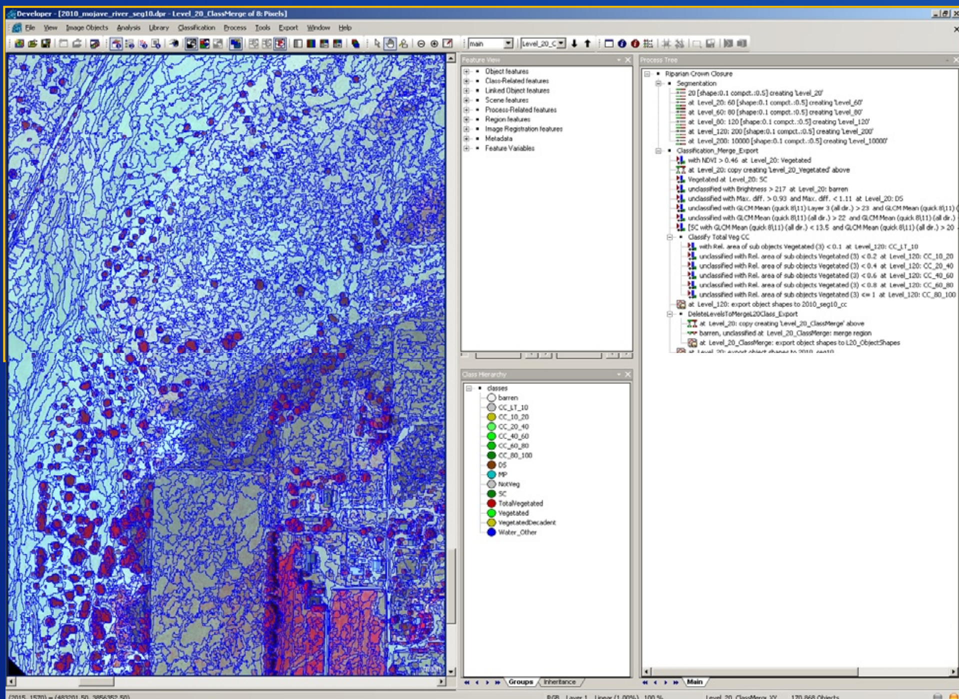
34 – 50 C

50 – 55 C

55 – 60 C

> 60 C

Classification Methodology



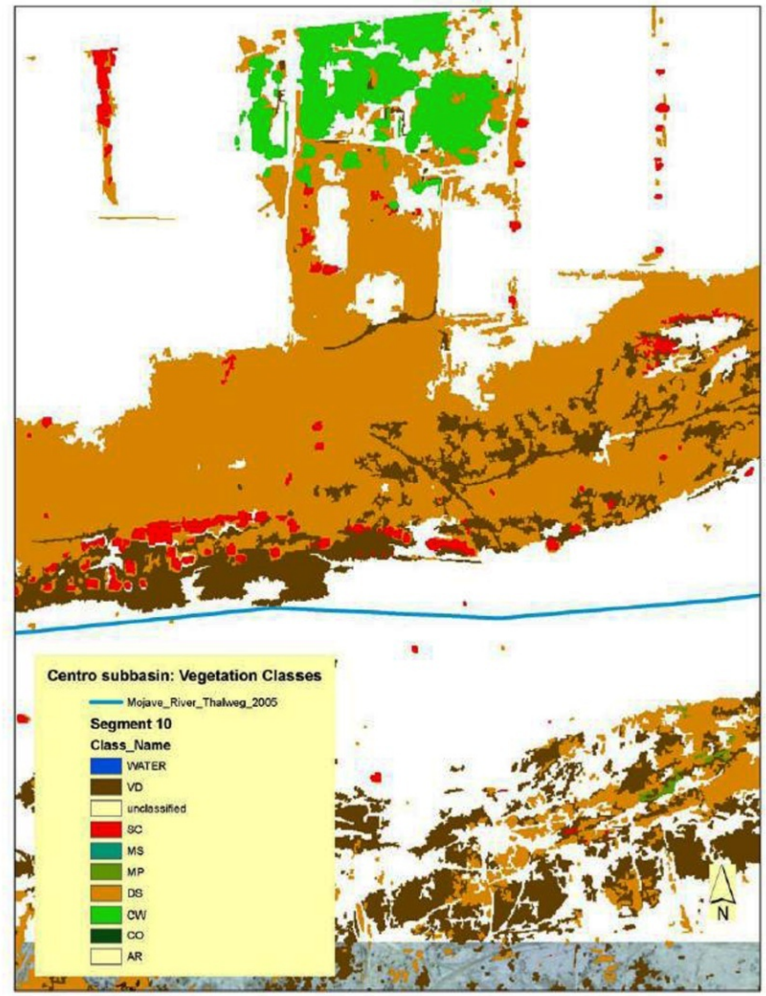


Figure 22. Vegetation classification in raster format.

eCognition Image Processing Software

Species/community-level polygons in blue over color infrared imagery base layer

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Classification Results

Table 1. Saltcedar canopy acres, 2007-2010

	--------Saltcedar Canopy acres--------			
Subarea	**2007**	**2010**	**Δ**	**%Δ**
Alto	84.3	2.5	-81.9	-97.1%
Alto Transition	201.0	77.9	-123.1	-61.3%
Centro	732.9	634.1	-98.8	-13.5%
Baja	383.1	358.7	-24.4	-6.4%
MOJAVE BASIN TOTAL ACRES	**1,401**	**1,073**	**-328**	**-23.4%**

Δ=change

- **Net saltcedar reduction of 328 canopy acres over the entire basin**
- **Saltcedar ET was reduced by 797 acre-feet over three years.**

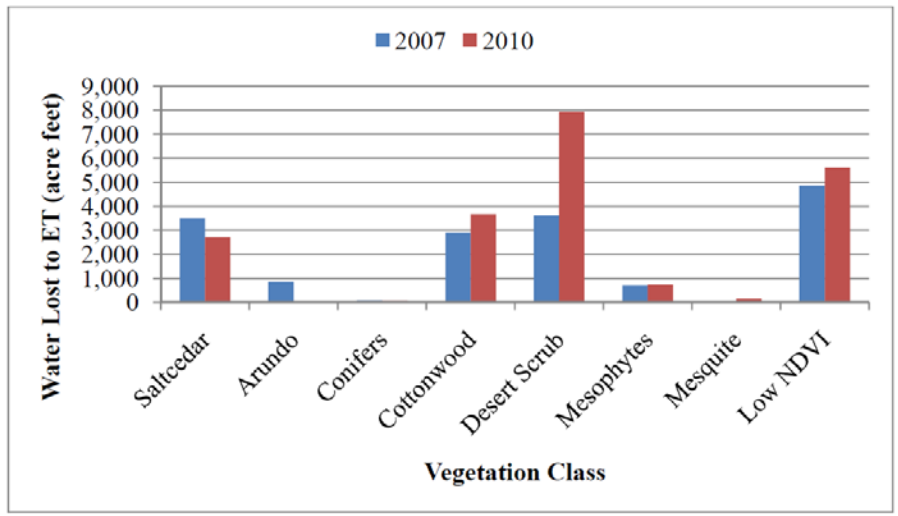

Figure 1. Water lost to ET by vegetation class in the Mojave River Basin, 2007 and 2010.

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LEGEND

Saltcedar within the Study Area of Interest:

- Saltcedar: Present in 2007 and 2010
- Saltcedar: Present in 2007; Not present in 2010

Mojave River
Saltcedar (Acres)

Sub-area	2007.00	2010.00	Change
Alto	84.32	3.20	(81.12)
Alto-X	201.02	77.88	(123.14)
Centro	734.00	595.53	(138.47)
Baja	384.85	364.29	(20.56)
Total Acres:	1404.19	1040.90	(363.29)

Reasons for loss of Saltcedar between 2007 and 2010 include:
- Eradication & removal
- Desertification / Loss of Groundwater
- Fire
- Human encroachment & development

Saltcedar in the Mojave River 2007 - 2010

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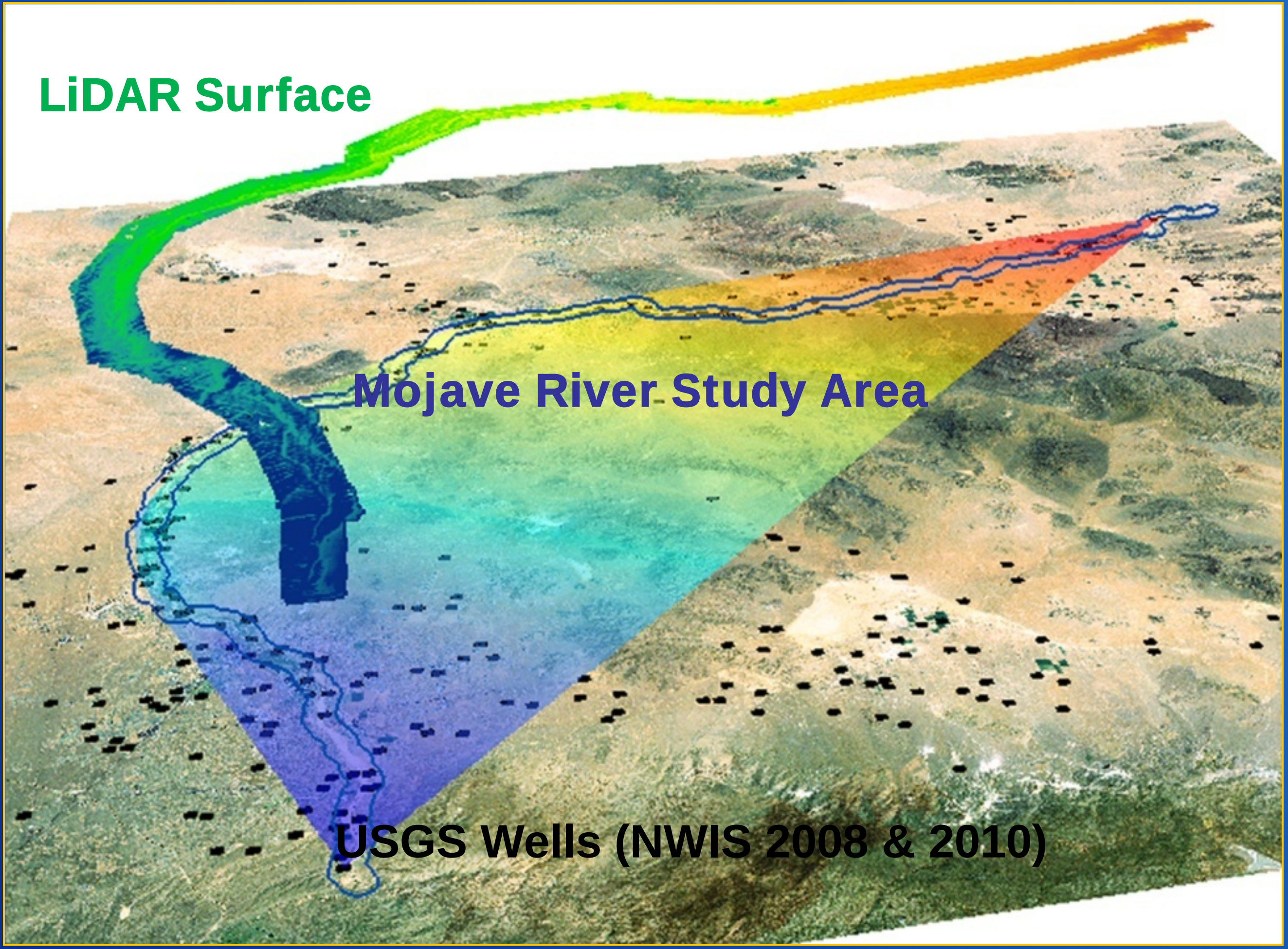
Lower Colorado Region GIS Geographic Information Systems

Multispectral Imagery flown by Utah State University, June, 2010
Vegetation Classifications by Mike Baker & Jeff Milliken, Reclamation
Change detection map by Ron Simms, Reclamation 2011.08.09

Groundwater Methodology

USGS depth-to-groundwater subtracted from lidar to derive groundwater elevations within the Mojave River study area for 2008 and 2010



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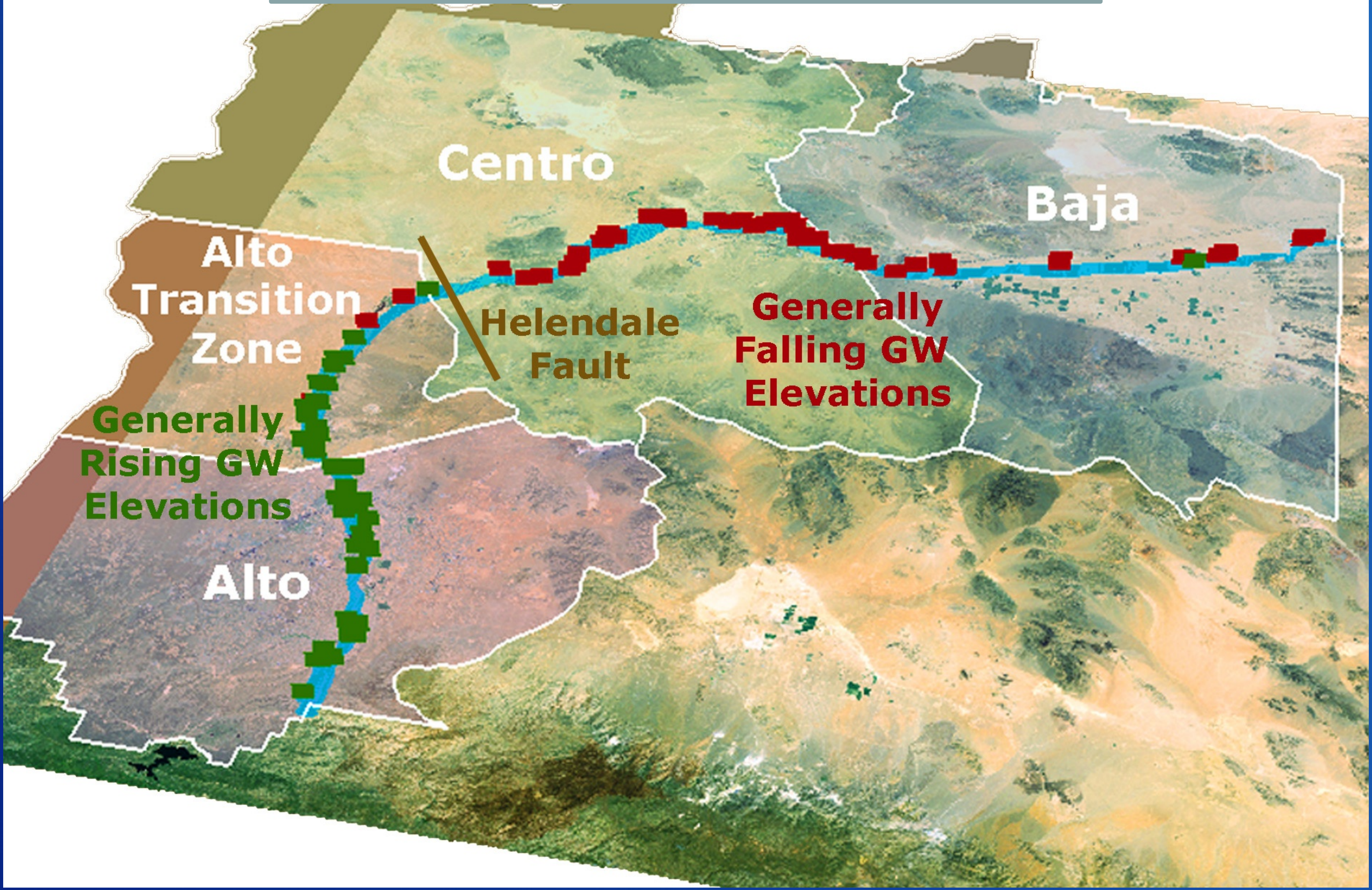
Groundwater Elevations in 2010



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Classified Lidar Point Clouds

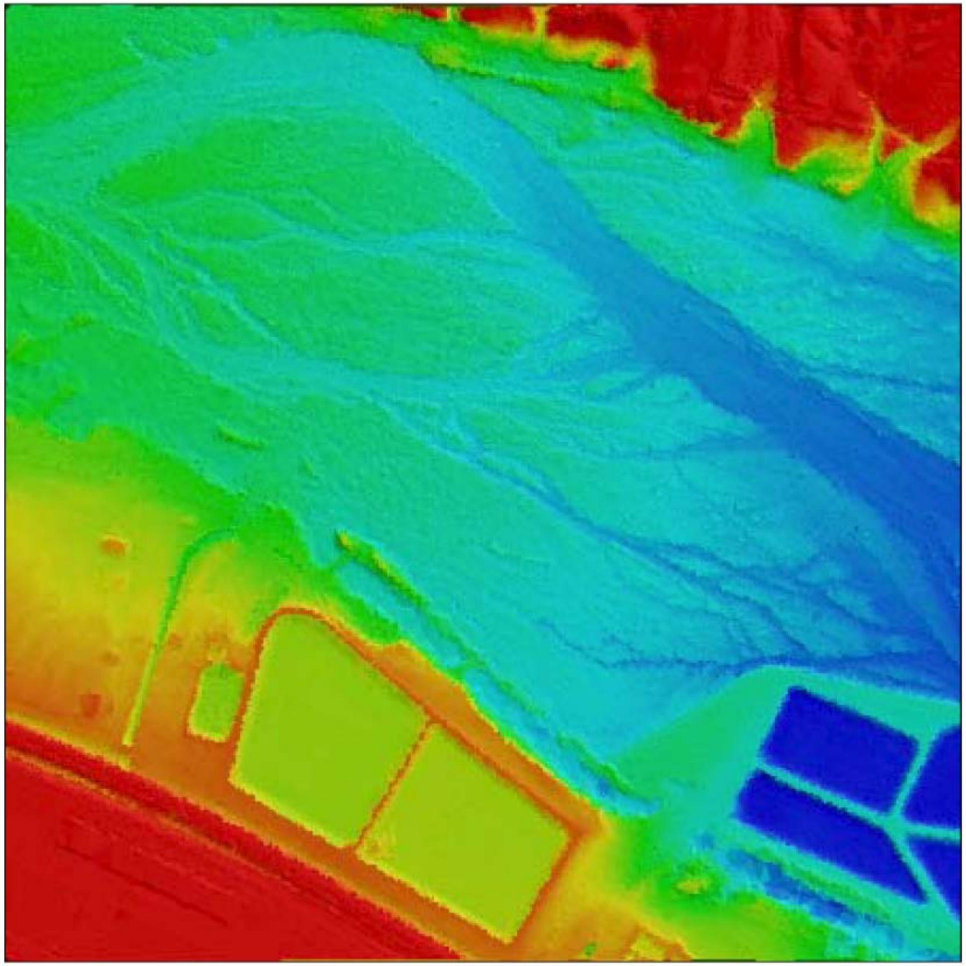
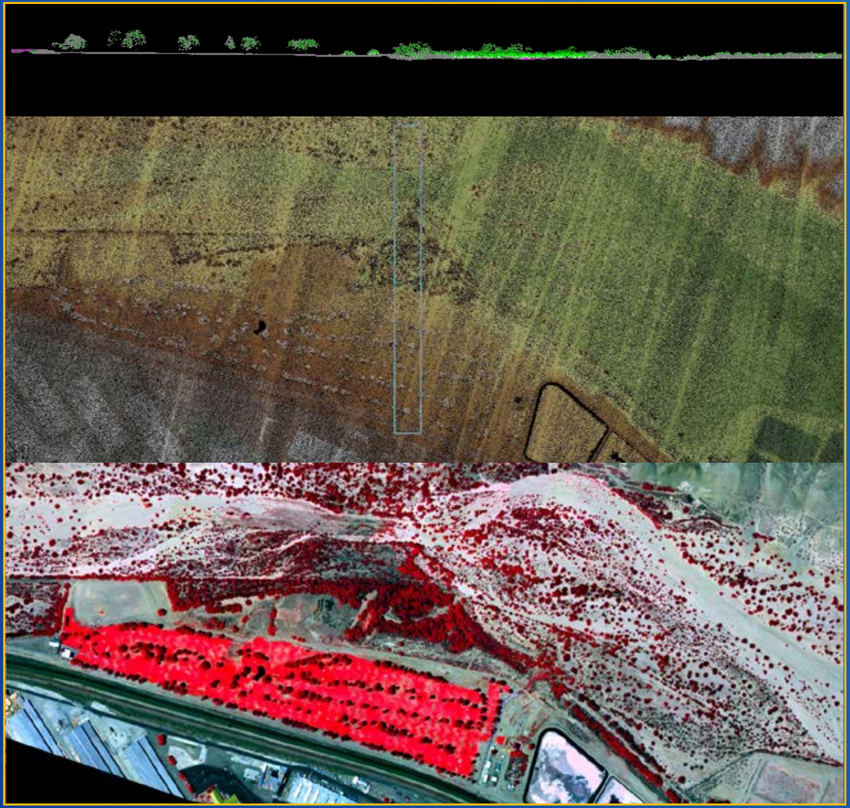


Figure 11. Example plot and individual lidar tile delivered in LAS v.1.2 format (blue colors are lower elevations while red colors are higher elevations). See lower right corner of images in Figure 10 for reference.



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Energy Balance Approaches Used to Estimate Evapotranspiration

- The Two-source model
- SEBAL: Surface Energy Balance for Land
- Crop coefficient model used to extrapolate over the growing season

Table 5. Comparison of seasonal saltcedar ET results (in millimeters of water) for the SEBAL and Two-Source models, Block 1, using modeled canopy height

	2010			2007	
	SEBAL	TSM		SEBAL	TSM
Total ET (mm)					
March to May	107	102		112	107
May to September	533	503		509	480
September to November	230	216		226	212
Total ET (mm)	**870**	**820**		**847**	**799**
Reference ET (grass)	1589	1589		1561	1561

Table 6. Comparison of seasonal saltcedar ET results for the SEBAL and Two-Source models, Block 1, using canopy height derived from lidar

	2010			2007	
	SEBAL	TSM		SEBAL	TSM
Total ET (mm)					
March to May	104	104		109	109
May to September	514	515		491	492
September to November	221	222		217	217
Total ET (mm)	**838**	**840**		**816**	**818**
Reference ET (grass)	1589	1589		1561	1561

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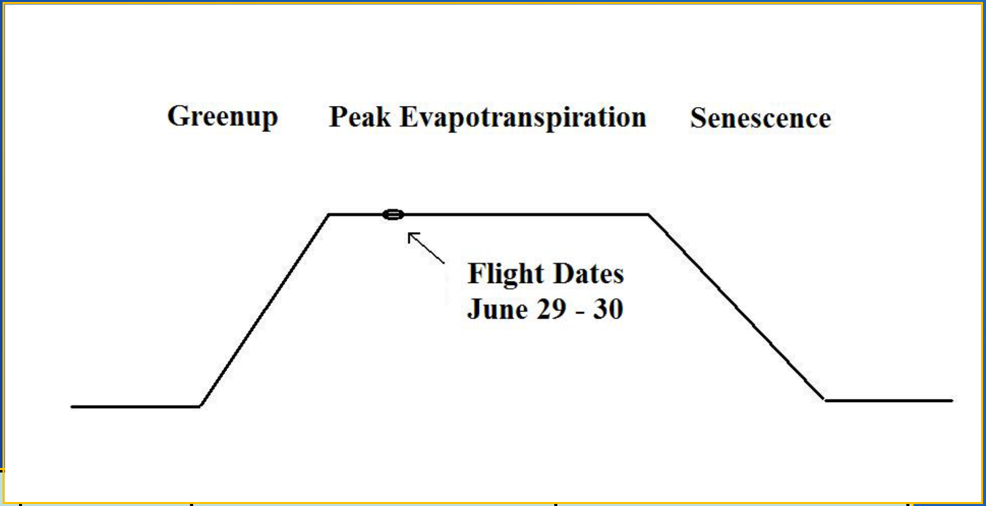
Seasonal ET Estimation using ET fractions (crop coefficients)

$$Kc = ET_a / ET_0$$

ET_a = Actual ET from Energy Balance Model

ET_0 = Reference ET from CIMMIS Weather Station



Phenology Dates	Code	Greenup Begins	Peak ET	Senescence Begins	Senescence Ends
Salt Cedar (Tamarisk)	SC	3/1	5/1	9/1	11/1
Mesquite	MS	4/1	5/15	8/1	9/15
Cottonwood	CW	4/1	5/15	9/15	11/1
Desert Scrub	DS	3/1	4/15	7/1	8/1
Decadent Vegetation	VD	4/1	5/15	8/1	9/15
Mesophytes	MP	4/1	5/15	7/1	8/1
Conifer	CO	3/1	5/15	10/1	11/15
Arundo	AR	4/1	6/1	10/1	11/1

Table 9. ET fraction of different vegetation types for the 4 groundwater subareas.

	ALTO							
	SC	DS	CW	MS	VD	MP	CO	AR
Initial Greenup Kc	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Peak Kc	0.49	0.34	0.71	0.36	0.33	0.56	0.36	0.4
Final Senescence Kc	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	ALTO TRANSITION							
	SC	DS	CW	MS	VD	MP	CO	AR
Initial Greenup Kc	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Peak Kc	0.5	0.27	0.63	0.23	0.33	0.49	0.35	0.41
Final Senescence Kc	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	CENTRO							
	SC	DS	CW	MS	VD	MP	CO	AR
Initial Greenup Kc	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Peak Kc	0.48	0.23	0.62	0.42	0.25	0.39	0.32	0.66
Final Senescence Kc	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	BAJA							
	SC	DS	CW	MS	VD	MP	CO	AR
Initial Greenup Kc	0.15	0.15	0.15	0.15	0.15	0.15	0	0
Peak Kc	0.47	0.25	0.56	0.27	0.24	0.43	0	0
Final Senescence Kc	0.15	0.15	0.15	0.15	0.15	0.15	0	0

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Table 19. Evapotranspiration and estimated seasonal water use by saltcedar in the Alto subarea during 2007 and 2010 seasons.

Year	2007	2010
Initial Greenup Kc	0.15	0.15
Peak Kc	0.48	0.48
Final Senescence Kc	0.15	0.15
Total Area (acres)	85	2.5
ET Greenup Period (mm)	101	96
ET Peak Period (mm)	444	465
ET Senescence Period (mm)	194	194
Total Seasonal ET (mm)	739	755
Volume (m3)	253,639	7,546
Volume (gallons)	67,004,350	1,993,490
acre-feet	210	6

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Table 21. Evapotranspiration of saltcedar by canopy density or closure class for 2007 and 2010 in the Alto subarea.

	LT_10	10_20	20_40	40_60	60_80	80_100
Initial Greenup Kc	0.15	0.15	0.15	0.15	0.15	0.15
Peak Kc	0.47	0.51	0.48	0.48	0.61	0.48
Final Senescence Kc	0.15	0.15	0.15	0.15	0.15	0.15
2007	**LT_10**	**10_20**	**20_40**	**40_60**	**60_80**	**80_100**
Total Area (acres)	9	4	3	5	6	58
ET Greenup (mm)	100	106	101	101	123	101
ET Peak Period (mm)	439	475	447	447	572	447
ET Senescence (mm)	192	209	196	196	256	196
Total Seasonal ET (mm)	731	790	744	744	952	744
acre-feet	22	10	7	12	18	141
2010	**LT_10**	**10_20**	**20_40**	**40_60**	**60_80**	**80_100**
Total Area (acres)	6	5	10	12	16	30
ET Greenup (mm)	95	101	96	96	118	96
ET Peak Period (mm)	460	497	468	468	599	468
ET Senescence (mm)	192	209	196	196	256	196
Total Seasonal ET (mm)	747	807	760	760	973	760
acre-feet	1	2	2	0.1	0.2	0.3

LT_10=Less than 10% canopy closure, **10_20**=10-20% canopy closure, etc.

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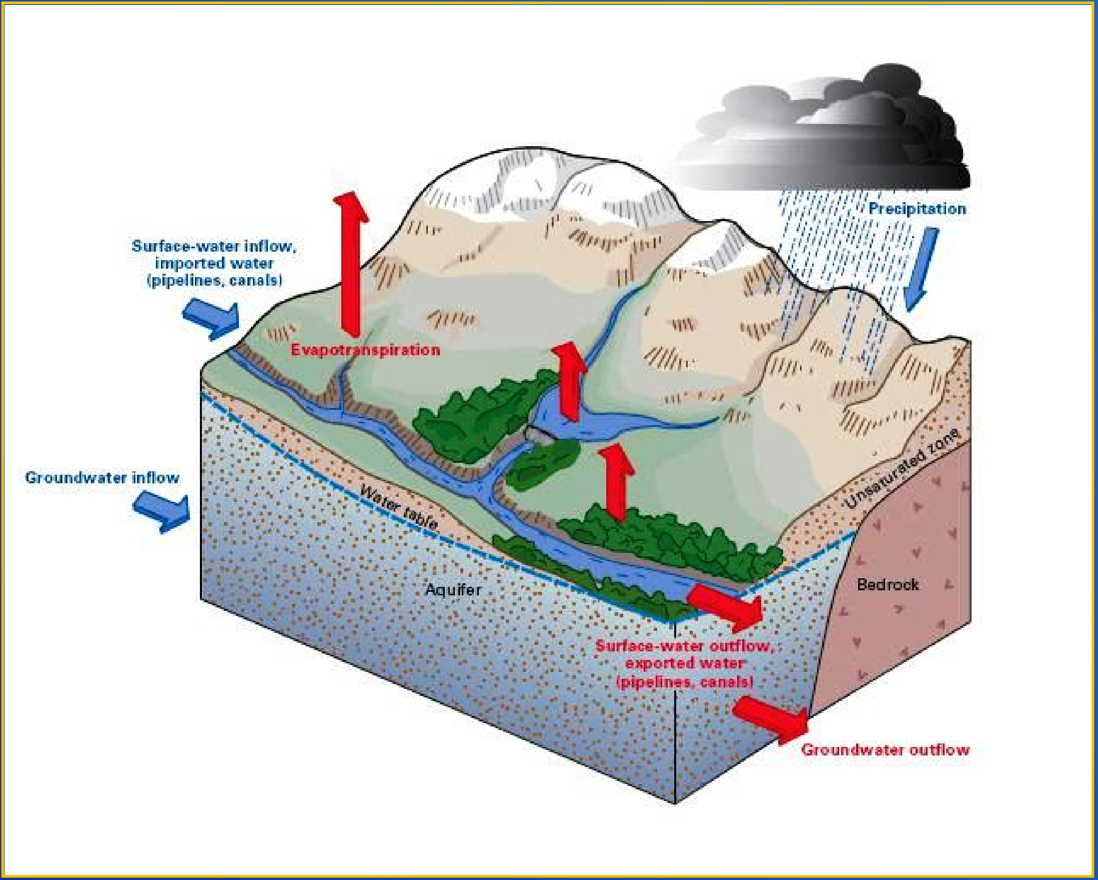
Water Salvage

Inflows

- Precipitation
- Ground water
- Surface water

Outflows

- Evaporation
  - Open water
  - Bare soil
- Transpiration
- Ground water
- Surface water



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Water Cost Methodology

- **Theoretical costs based on water lost to ET**
- **2011 acquisition costs of $10,221 per acre-foot used for both 2007 and 2010 data**
- **Costs calculated for saltcedar by canopy closure class and other vegetation classes excluding desert scrub**

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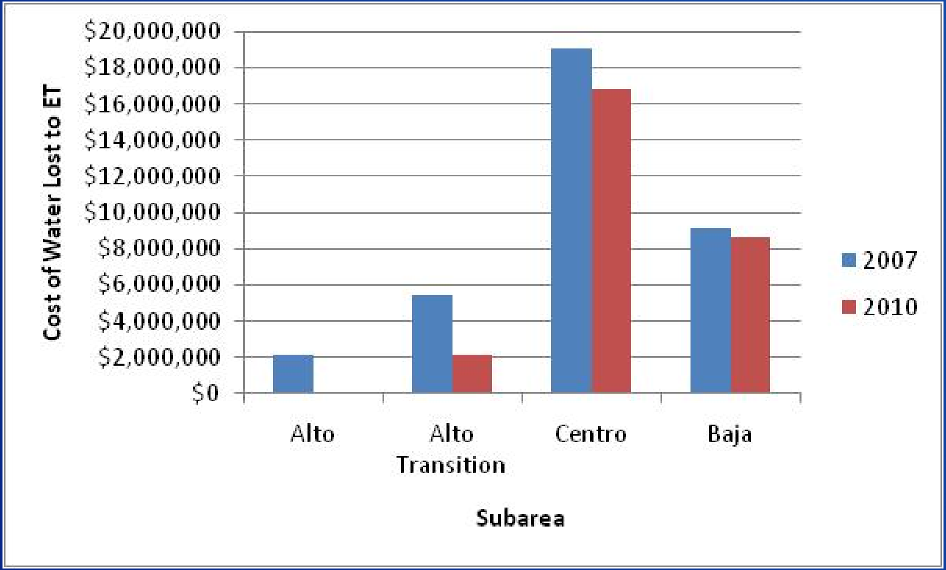
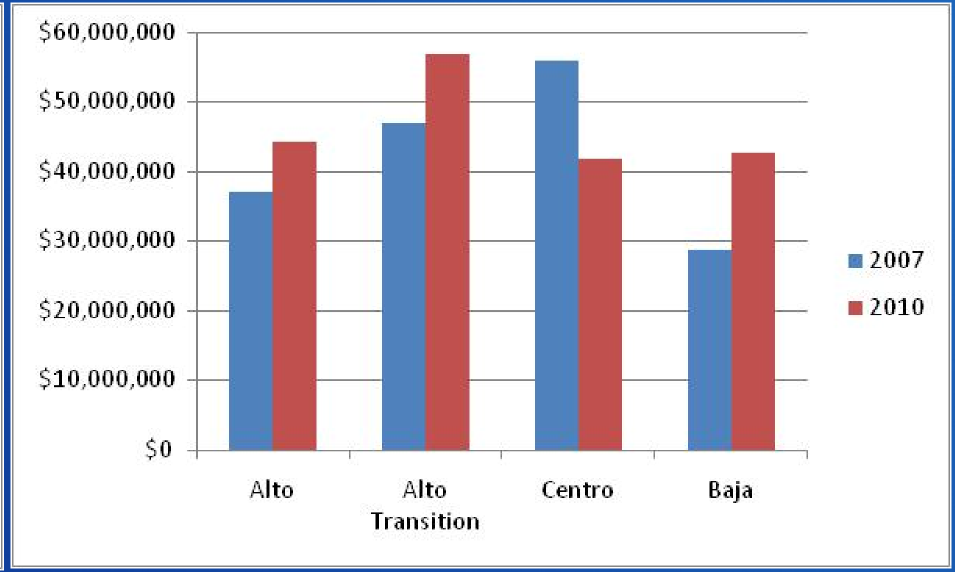
Water Cost Results

Saltcedar



Other Vegetation



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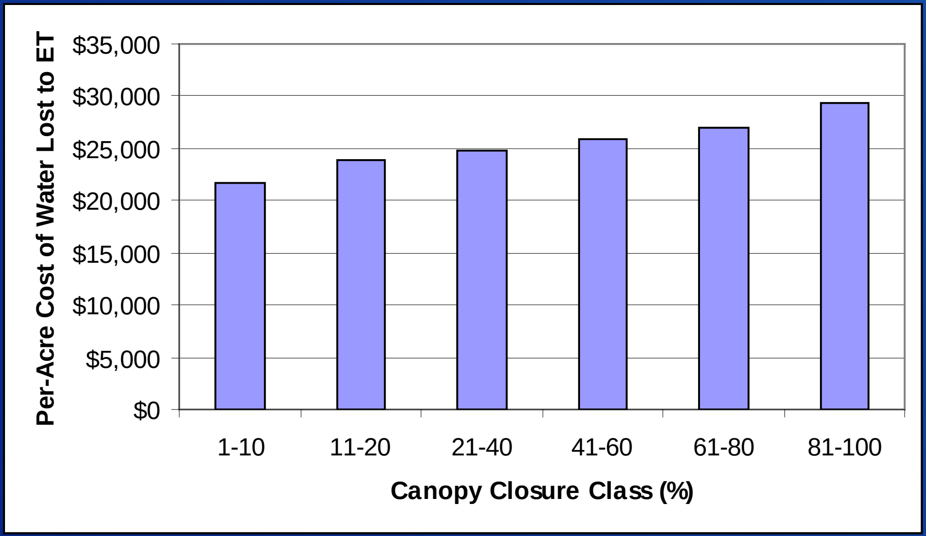
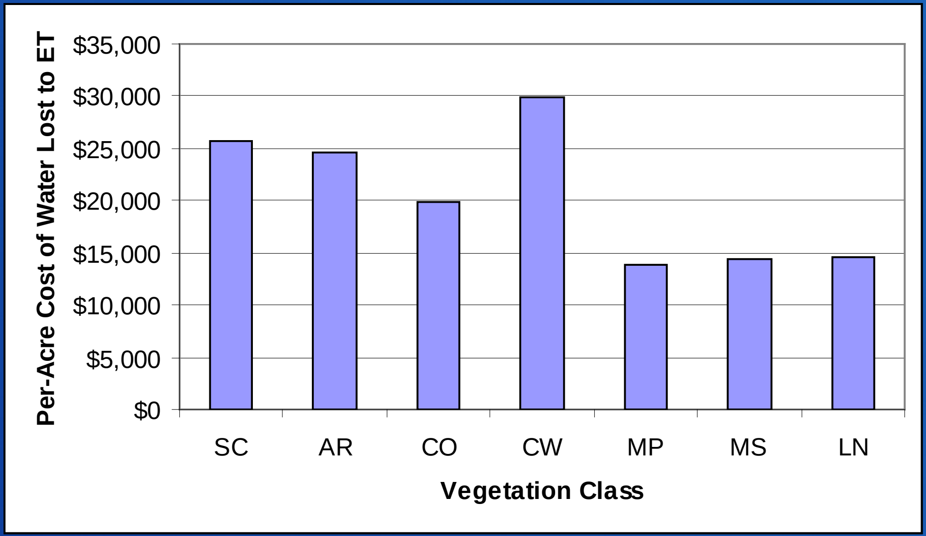
Water Cost Results: Per-Acre Costs

Saltcedar



All Vegetation



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Results and Conclusions

- ET reduced by ~800 AF/yr between 2007 and 2010
- Theoretical avoided cost of $8.1 million
- Management of remaining 1000 canopy acres could lead to additional water savings
- High density stands should be prioritized for removal
- Decrease in ET from upstream to downstream
- Desert scrub ET estimates likely overestimated
- Controlling regrowth less expensive than controlling established stands

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Questions?

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