Geo-Spatial Technologies to Support Irrigation System Management

Tecnologias Geo-Espaciais para Apoio do Manejo de Sistemas de Irrigacao

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Development of Technologies that aid irrigation water management

- Global Positioning Systems (GPS)

  Implementation 20 years ago
- Geographical Information Systems (GIS)

  Implementation 20 years ago
- Satellite Remote Sensing

  Implementation 40 years ago
- Aerial Photography for Mapping

  Implementation 60 years ago

Use of GPS to support Irrigated Agriculture

- Location of water control structures, diversion points, delivery gates, spill locations, drainage system input points, drainage water re-use structures
- Location of new agro-climatic weather stations
- Location of maintenance problems identified during walk-through maintenance activities
- Local base stations to support aerial imaging and Lidar mapping

Installation of GPS base station network

to support aerial photography and ground control activities

Data from the base stations (dual frequency systems) were used to correct the positions of the mobile units based on differential correction techniques, resulting in high positional accuracy. The network of GPS base stations installed was similar to the CORS network in the US.

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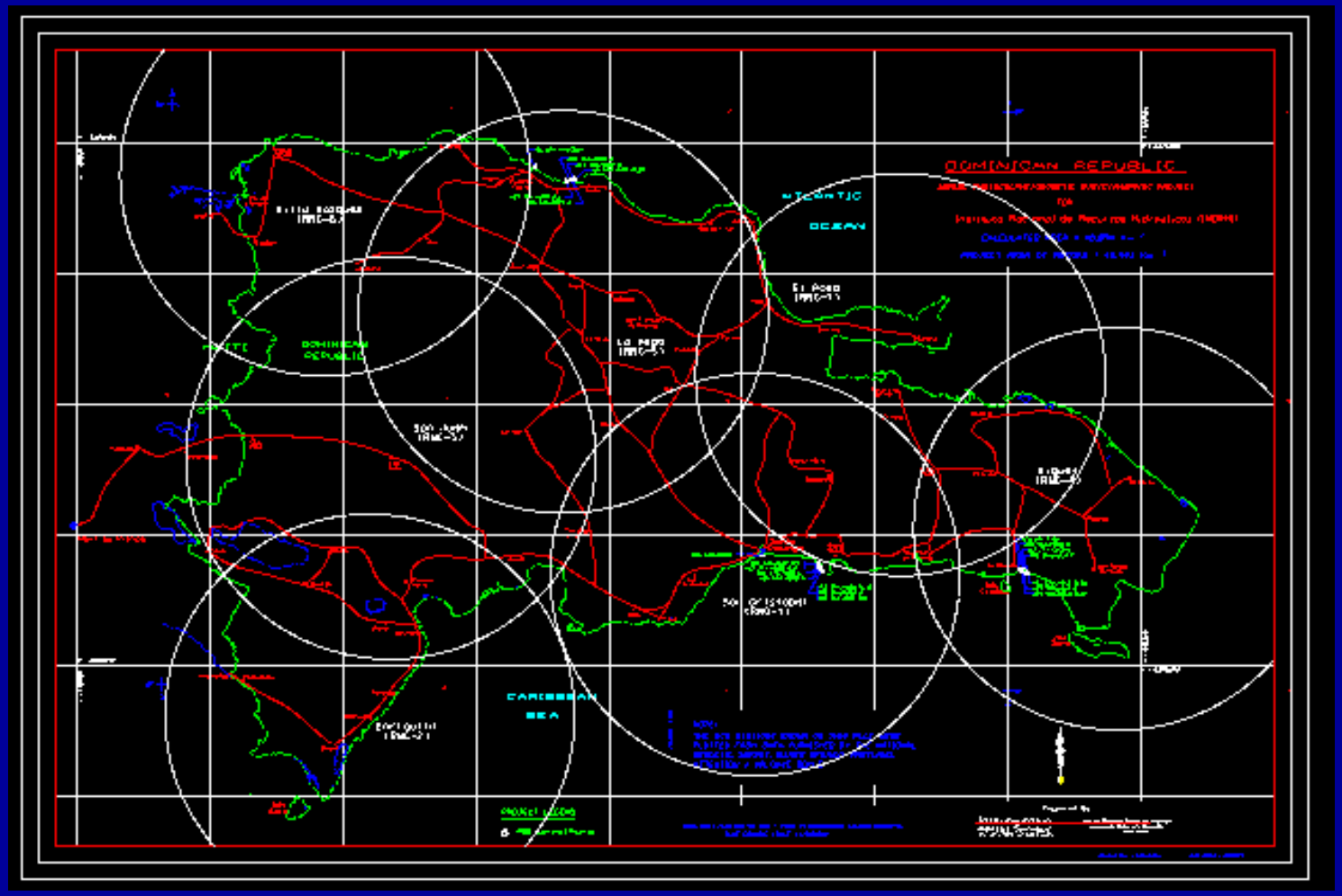
Location of the GPS Base Stations in the DR

San Cristóbal, Barahona, San Juan, Villa Vázquez,
La Vega, Nagua, Higuey



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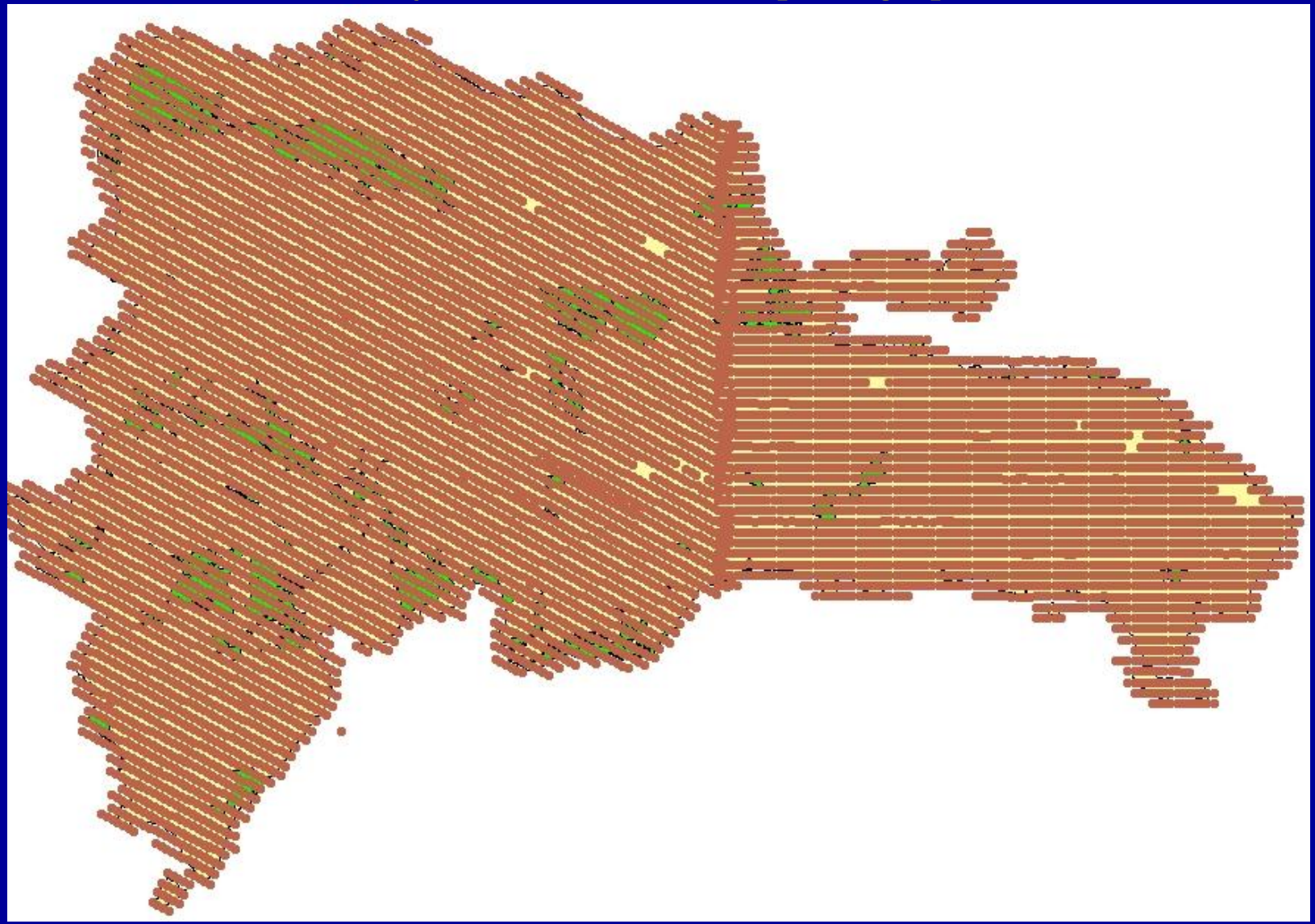
Final Results of the Aerial Photography Campaign

99.6 % of the Country covered with color photographs at 1:20000 scale



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Surveying of Ground Control Points used in the aerial triangulation and production of orthophotos

2000:

High Precision Dual frequency GPS systems were used to obtain the ground control points to support aero-triangulation for mapping

2012:

High precision Inertial Measurement Units (IMU) on aerial imaging aircrafts, allow for in-flight calibration and positioning of images, resulting in less need for ground control

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Mapping to support Irrigated Agriculture

- High resolution digital mapping of large irrigation systems allows for the development of GIS layers representing canal and drain distribution, location of water control and distribution structures
- Production of high resolution Digital Elevation Models (DEM) and contour lines that can be used in the design of irrigation systems
- Production of orthophotos used in the preparation of cadastre maps of the irrigated properties

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Diapositive of the original photo:

Used in analytical stereoplotters for the production of orthophotos and updating of topographic maps (pre 2000)

Diapositives are transparent photos (like a slide)

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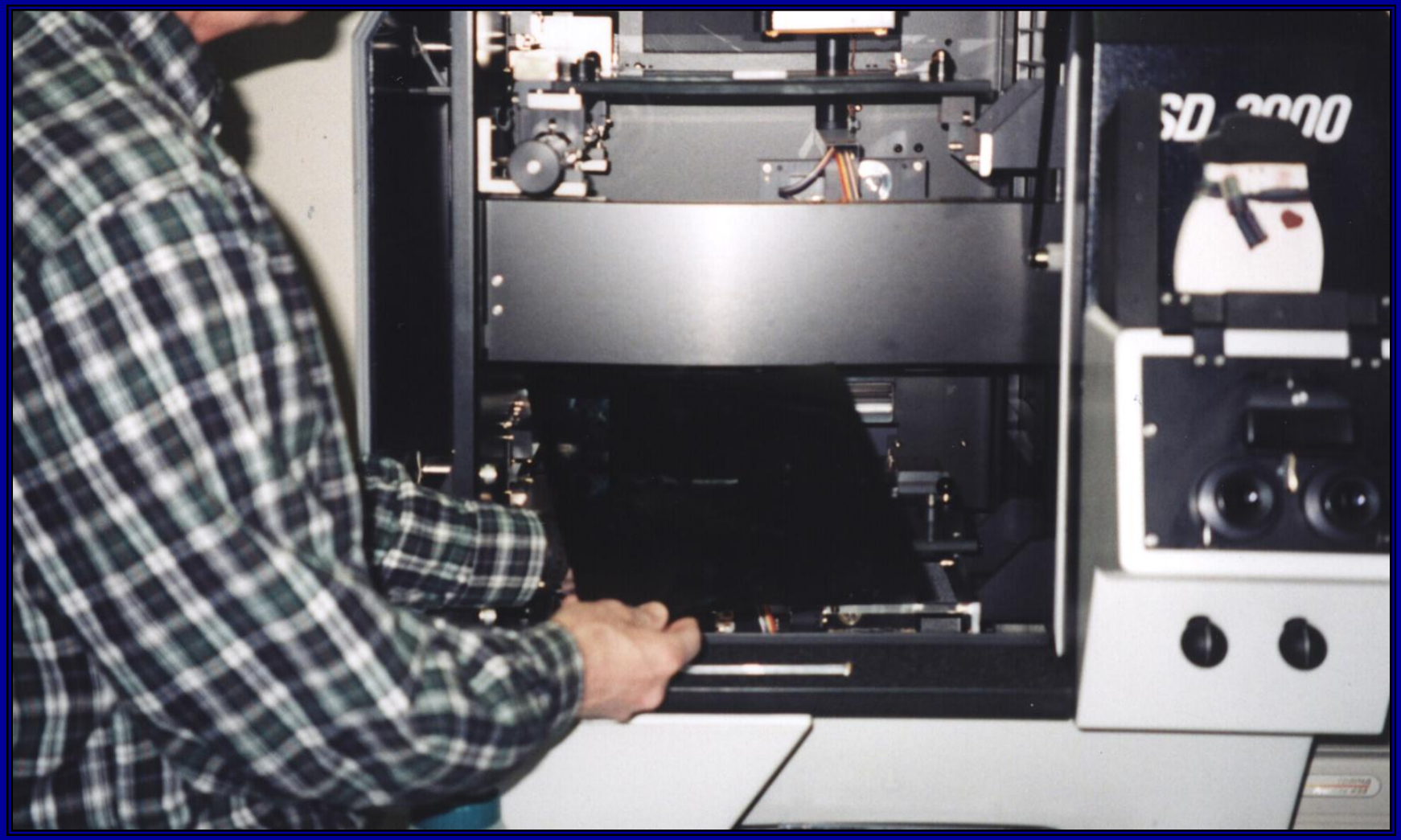
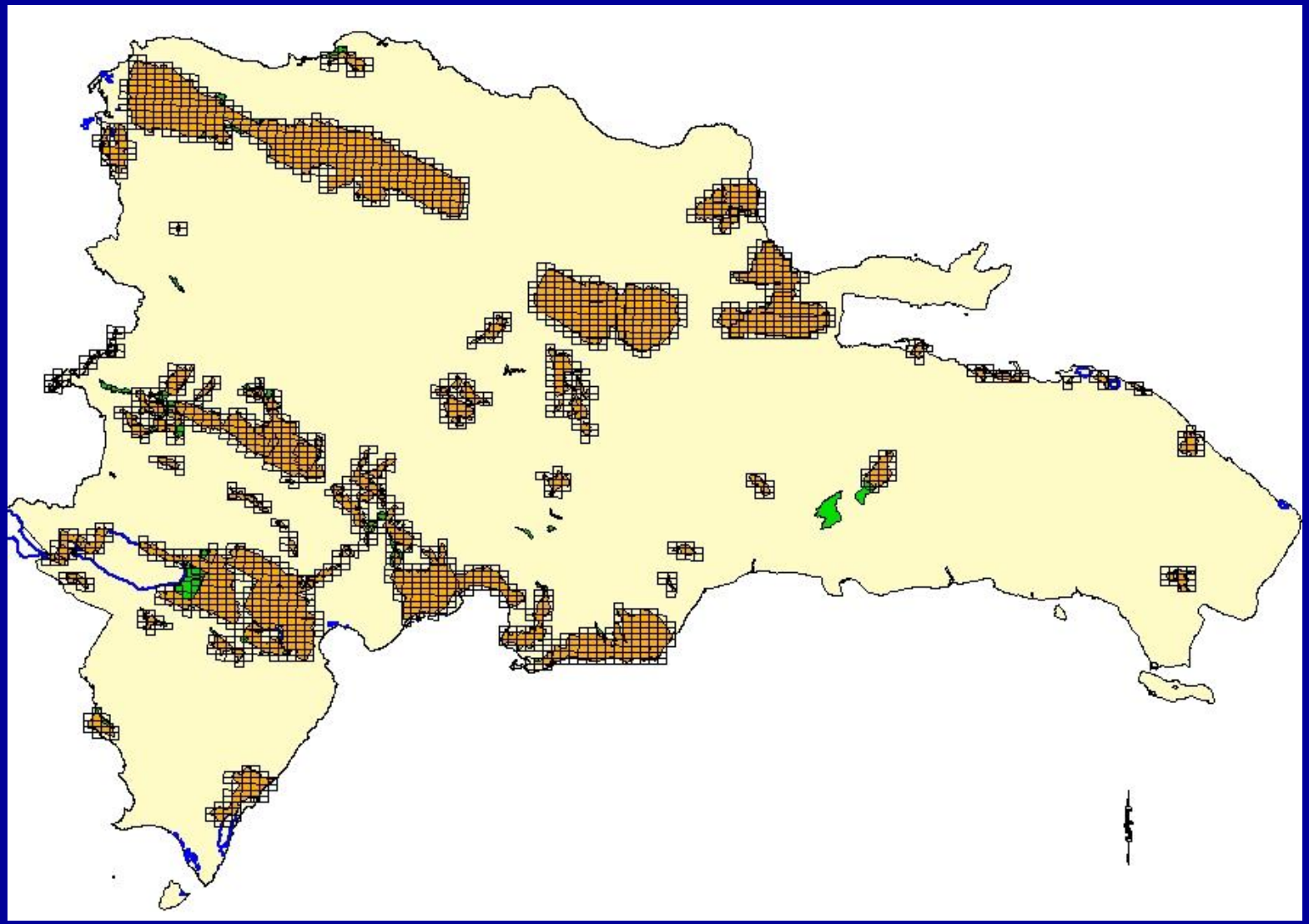
Diapositives are used in Analytical Stereo Plotters like the *Leica SD2000 for example*



Digital Orthophotos

covering 4430 Km2 of irrigated areas in the country



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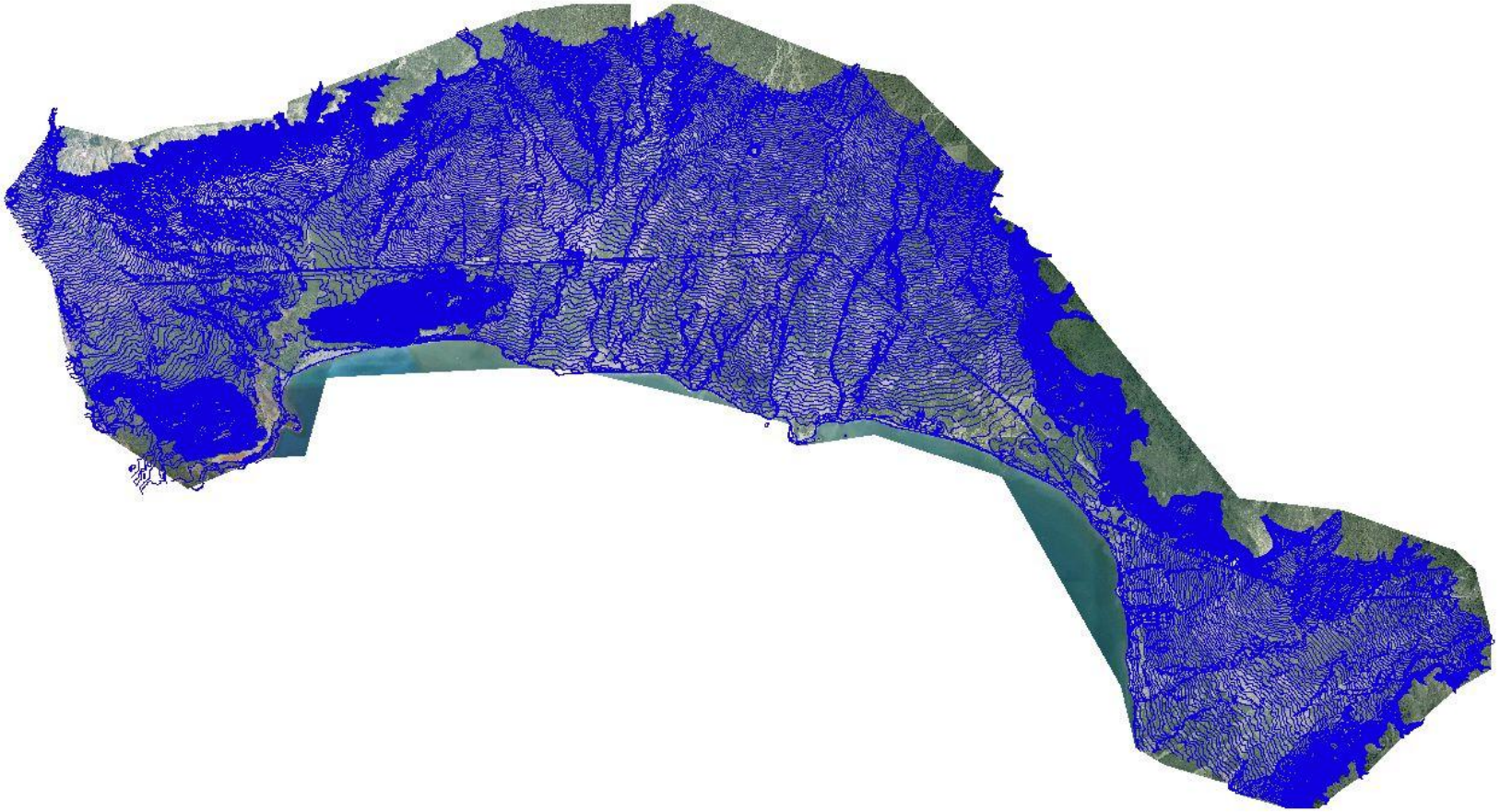
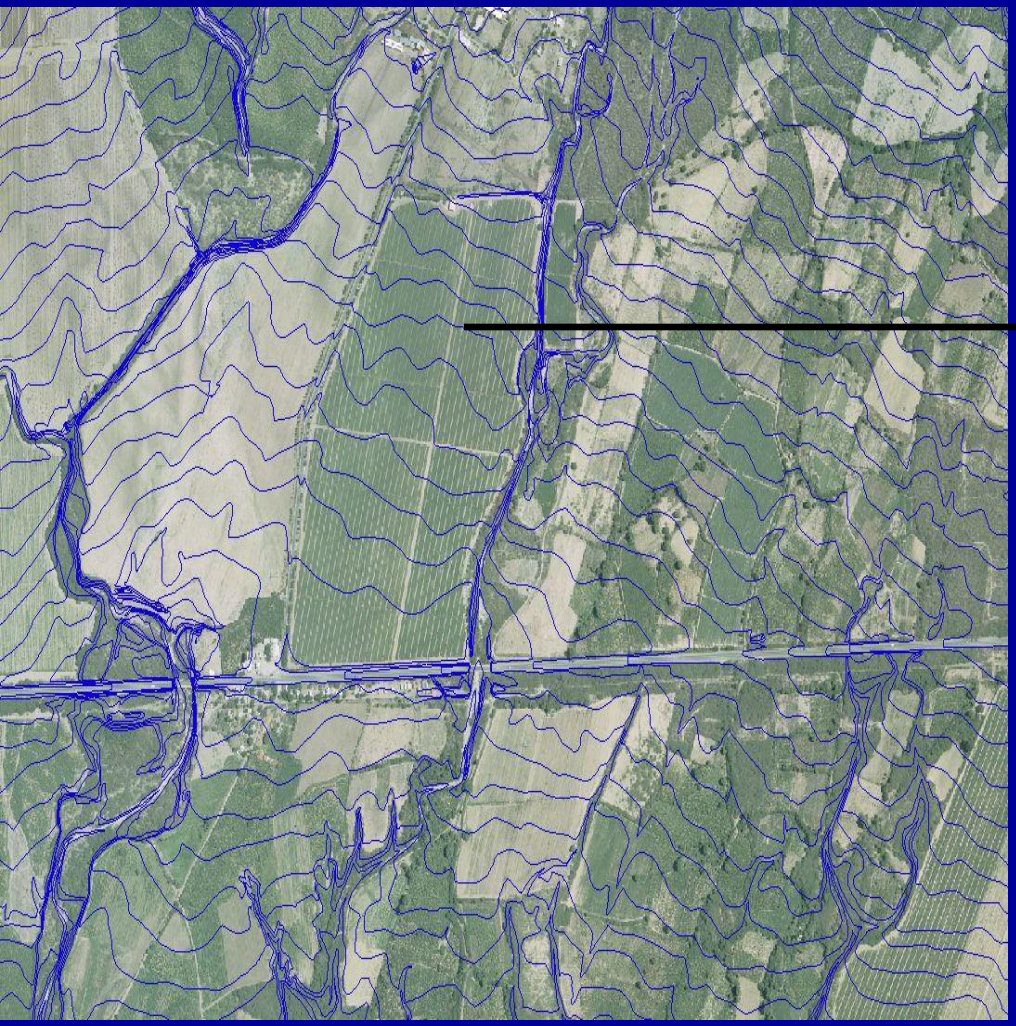
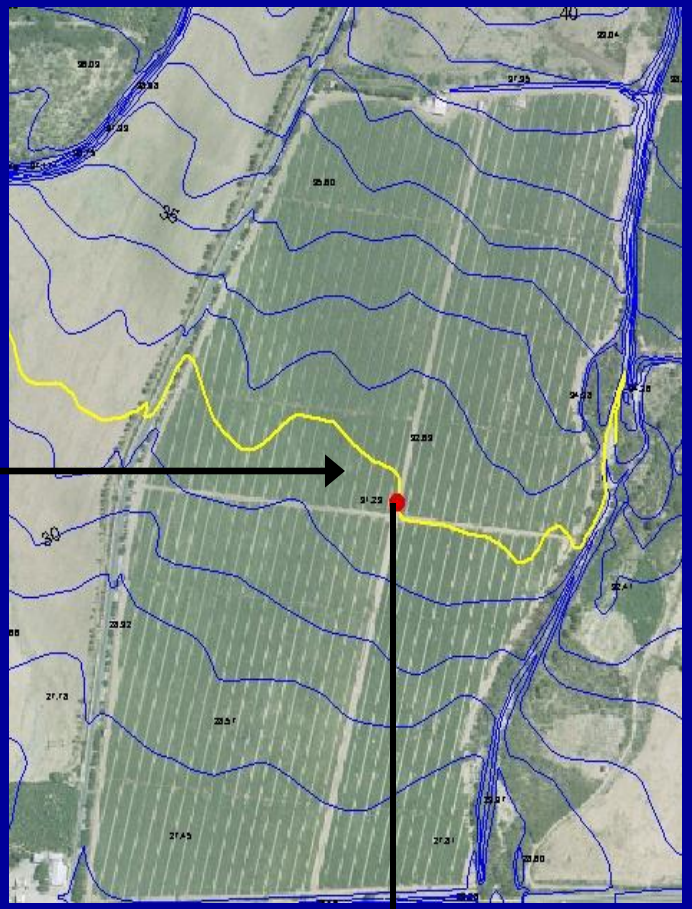
After the development of the digital products, planning for irrigation of new systems was done digitally, such as the Azua II Irrigation Project

Digital Orthophoto Mosaic with Contour Curves at 1-meter intervals



Detail of a Digital Orthophoto with Contours





COORDENADAS

X	326029
Y	2040262
Z	32

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GIS databases for Irrigated Agriculture

- GIS layers can represent linear features such canal and drains, point features such as water control and distribution structures and area features such as property boundaries
- Soils and their suitability for irrigation can be represented spatially in a GIS database along with soil physical properties such as water holding capacity and infiltration rates
- Canal and drainage command areas
- Cadastre maps, property boundaries

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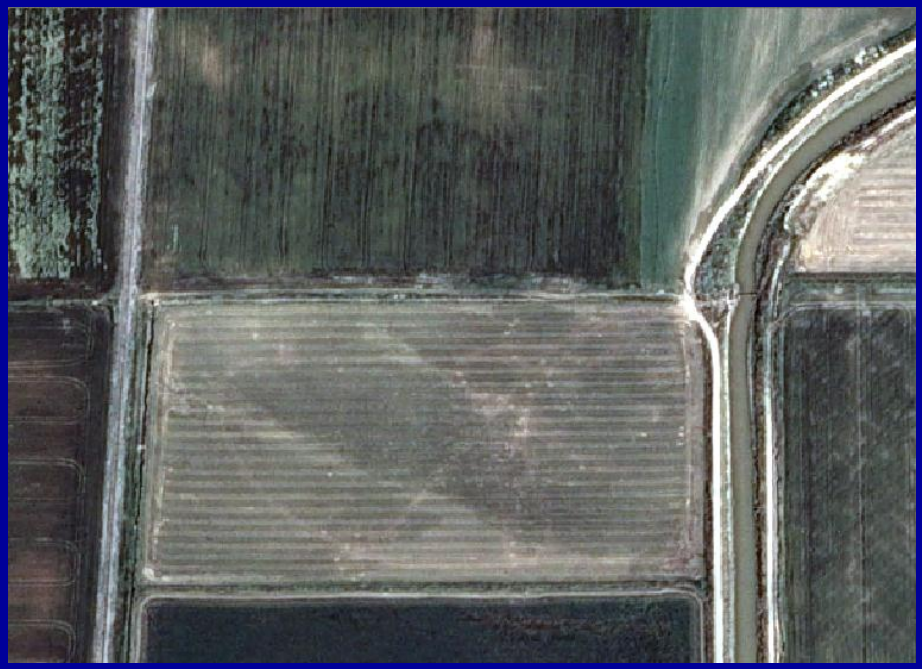
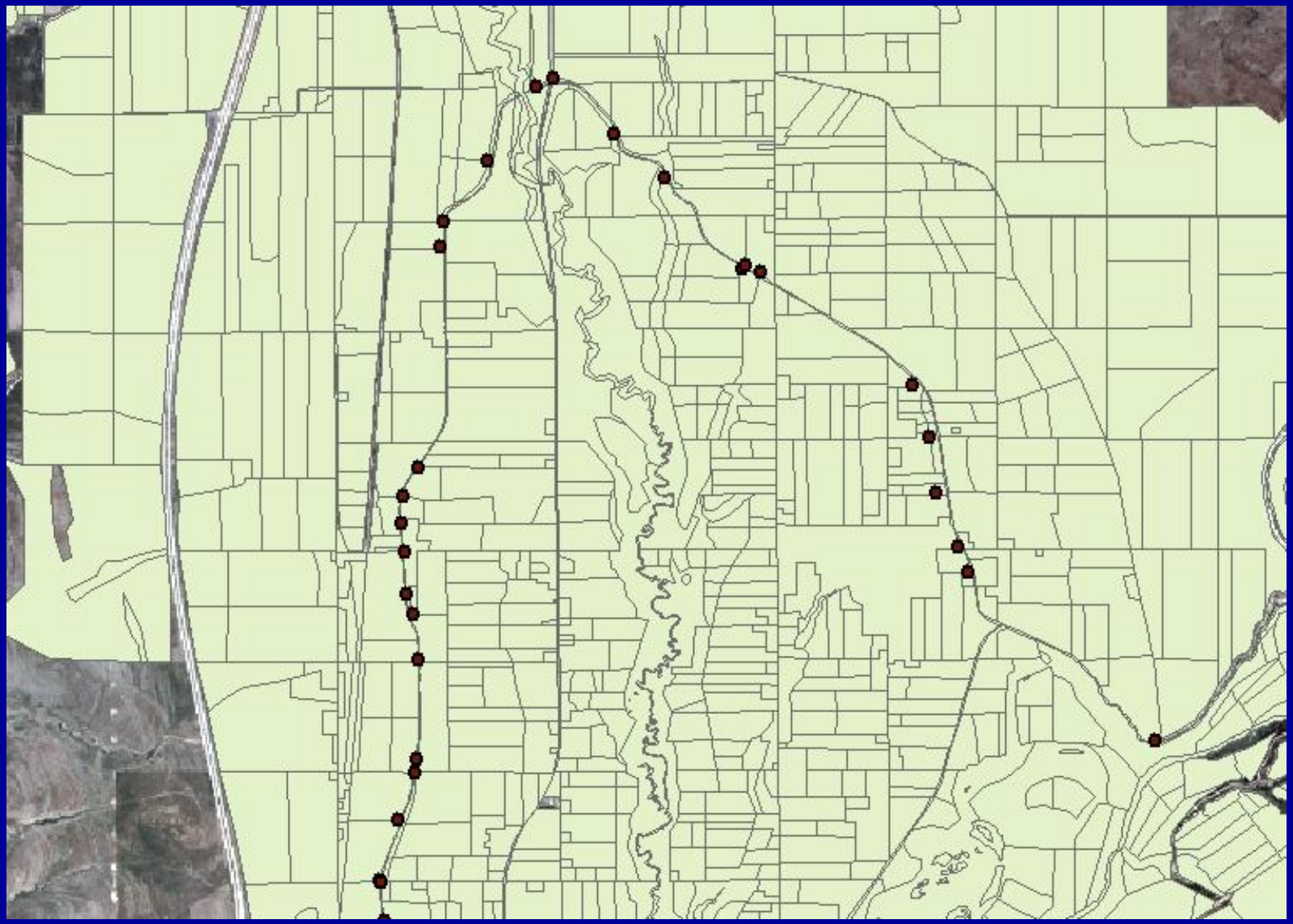
Bear River Canal Company GIS Database

NAIP Color digital orthophoto at 1-m pixel resolution base map



NAIP High resolution at 0.3 m pixels used to digitize location of gates and small tertiary canals

Some GIS Layers:
Canal Gate Locations and Water Users



What is a Digital Cadastre of Irrigators?

It is a database containing information on all the property owners and irrigation water users within an irrigation project or system. It consists of:

- An up-to-date property boundary map containing information on every property owner or water user
- Information on total area and irrigated area of each property
- Information on the canal system that delivers water to the property

=> Because of the geographic and distributed nature of the information as well as the requirement to have an associated database, we use Geographic Information System (GIS) technology to develop this product.

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Why do we need a cadastre of irrigators?

Porque precisamos de um cadastro de irrigantes?

- In many countries, water is still distributed in fixed amounts and charged according to area served and not on by volume delivered. Therefore a good estimate of area of each irrigated property is needed for proper assessment of system operation and maintenance fees.
- An up-to-date cadastre of irrigators is necessary in the transfer of publicly operated system to private irrigator cooperatives
- A cadastre can lead to increased income for Water User Associations and improved water management

Digital Orthophoto at 1:5000 scale

The map base for the cadastre of irrigation water users

The orthophoto is a digital photograph with geographic coordinates that has been adjusted to the terrain so that areas can be correctly measured

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Printed Orthophoto at 1:4000 scale were used for field verification of property boundaries

Field brigades used printed and laminated maps to identify the property boundaries together with the land owner or a local facilitator that has a good knowledge of the irrigation system (president of a water association, ditch rider)

A brigade consisted of 4 to 6 trained cartographers with one 4x4 dual cabin pickup and 3 or 4 cross-country motorbikes

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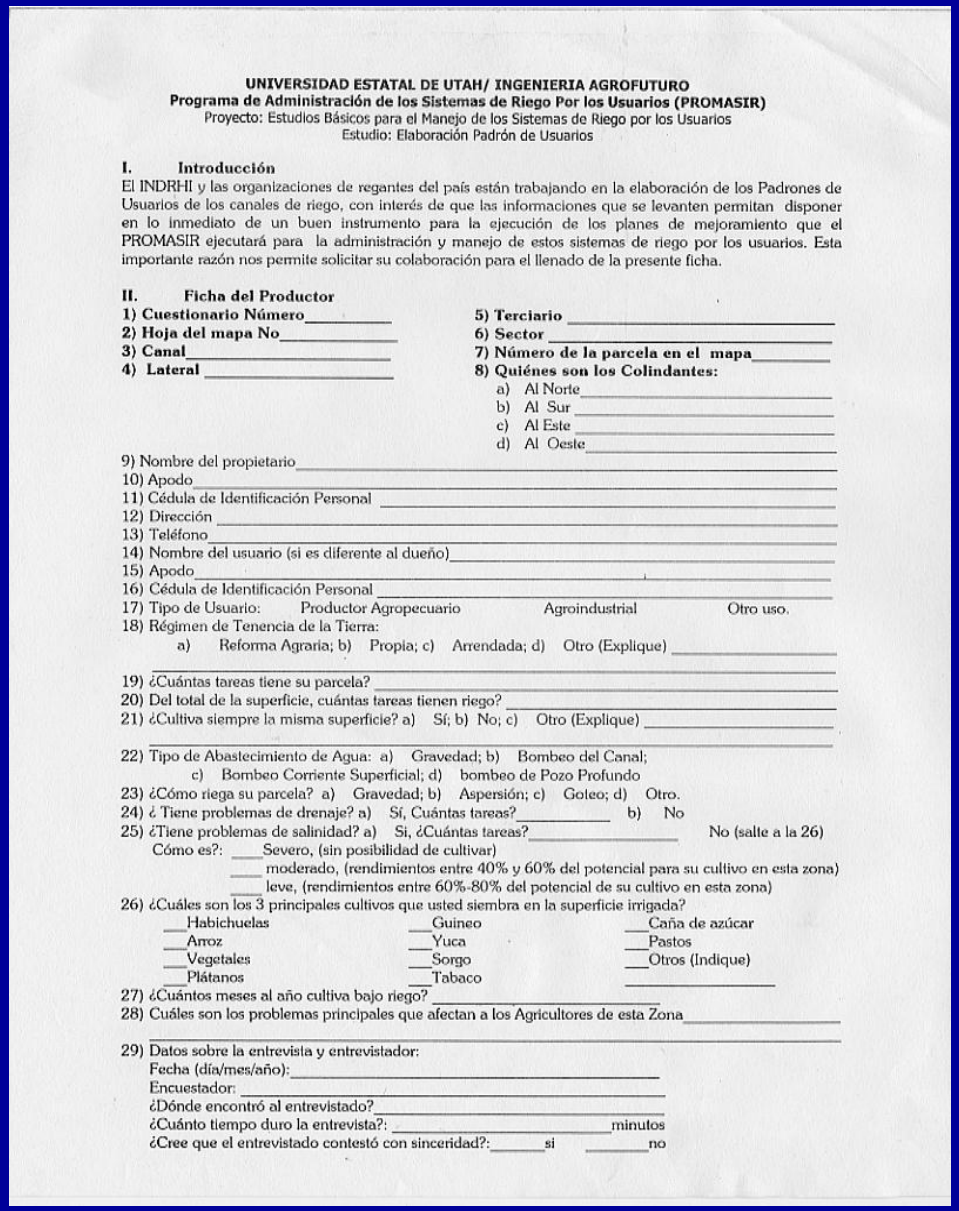
Survey Form used in Information Gathering by the Cartographers



UNIVERSIDAD ESTATAL DE UTAH/ INGENIERIA AGROFUTURO
Programa de Administración de los Sistemas de Riego Por los Usuarios (PROMASIR)
Proyecto: Estudios Básicos para el Manejo de los Sistemas de Riego por los Usuarios
Estudio: Elaboración Padrón de Usuarios

I. Introducción

El INDRHI y las organizaciones de regantes del país están trabajando en la elaboración de los Padrones de Usuarios de los canales de riego, con interés de que las informaciones que se levanten permitan disponer en lo inmediato de un buen instrumento para la ejecución de los planes de mejoramiento que el PROMASIR ejecutará para la administración y manejo de estos sistemas de riego por los usuarios. Esta importante razón nos permite solicitar su colaboración para el llenado de la presente ficha.

II. Ficha del Productor

1) Cuestionario Número_____
2) Hoja del mapa No_____
3) Canal_____
4) Lateral _____
5) Terciario _____
6) Sector _____
7) Número de la parcela en el mapa_____
8) Quiénes son los Colindantes:
a) Al Norte_____
b) Al Sur _____
c) Al Este _____
d) Al Oeste_____

9) Nombre del propietario_____
10) Apodo_____
11) Cédula de Identificación Personal _____
12) Dirección _____
13) Teléfono_____
14) Nombre del usuario (si es diferente al dueño)_____
15) Apodo_____
16) Cédula de Identificación Personal _____
17) Tipo de Usuario: Productor Agropecuario Agroindustrial Otro uso.
18) Régimen de Tenencia de la Tierra:
a) Reforma Agraria; b) Propia; c) Arrendada; d) Otro (Explique) _____
_____
19) ¿Cuántas tareas tiene su parcela? _____
20) Del total de la superficie, cuántas tareas tienen riego? _____
21) ¿Cultiva siempre la misma superficie? a) Sí; b) No; c) Otro (Explique) _____
_____
22) Tipo de Abastecimiento de Agua: a) Gravedad; b) Bombeo del Canal;
c) Bombeo Corriente Superficial; d) bombeo de Pozo Profundo
23) ¿Cómo riega su parcela? a) Gravedad; b) Aspersión; c) Goteo; d) Otro.
24) ¿ Tiene problemas de drenaje? a) Sí, Cuántas tareas?_____ b) No
25) ¿Tiene problemas de salinidad? a) Si, ¿Cuántas tareas?_____ No (salte a la 26)
Cómo es?: ___Severo, (sin posibilidad de cultivar)
____ moderado, (rendimientos entre 40% y 60% del potencial para su cultivo en esta zona)
____ leve, (rendimientos entre 60%-80% del potencial de su cultivo en esta zona)
26) ¿Cuáles son los 3 principales cultivos que usted siembra en la superficie irrigada?

__Habichuelas	__Guineo	__Caña de azúcar
__Arroz	__Yuca	__Pastos
__Vegetales	__Sorgo	__Otros (Indique)
__Plátanos	__Tabaco	_____

27) ¿Cuántos meses al año cultiva bajo riego? _____
28) Cuáles son los problemas principales que afectan a los Agricultores de esta Zona_____
_____
29) Datos sobre la entrevista y entrevistador:
Fecha (día/mes/año):_____
Encuestador: _____
¿Dónde encontró al entrevistado?_____
¿Cuánto tiempo duro la entrevista?: _____minutos
¿Cree que el entrevistado contestó con sinceridad?:_____si _____no

The cartographers conduct the survey with the property owner to obtain basic information on the water user (complete name, nickname, address) and on the property (delivery canal, water distribution problems, crops planted, salinity or drainage problems)

Information was digitized using an Access DB application to automate the data entry. This work was done in the Dominican Republic at a Lab in USU's local office.

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On-screen digitizing of the parcel boundaries in ArcInfo using the digital ortho as a backdrop

Most of the digitizing was done at USU using battalions of graduate and undergraduate student technicians. Also the merging with survey database and Quality Control

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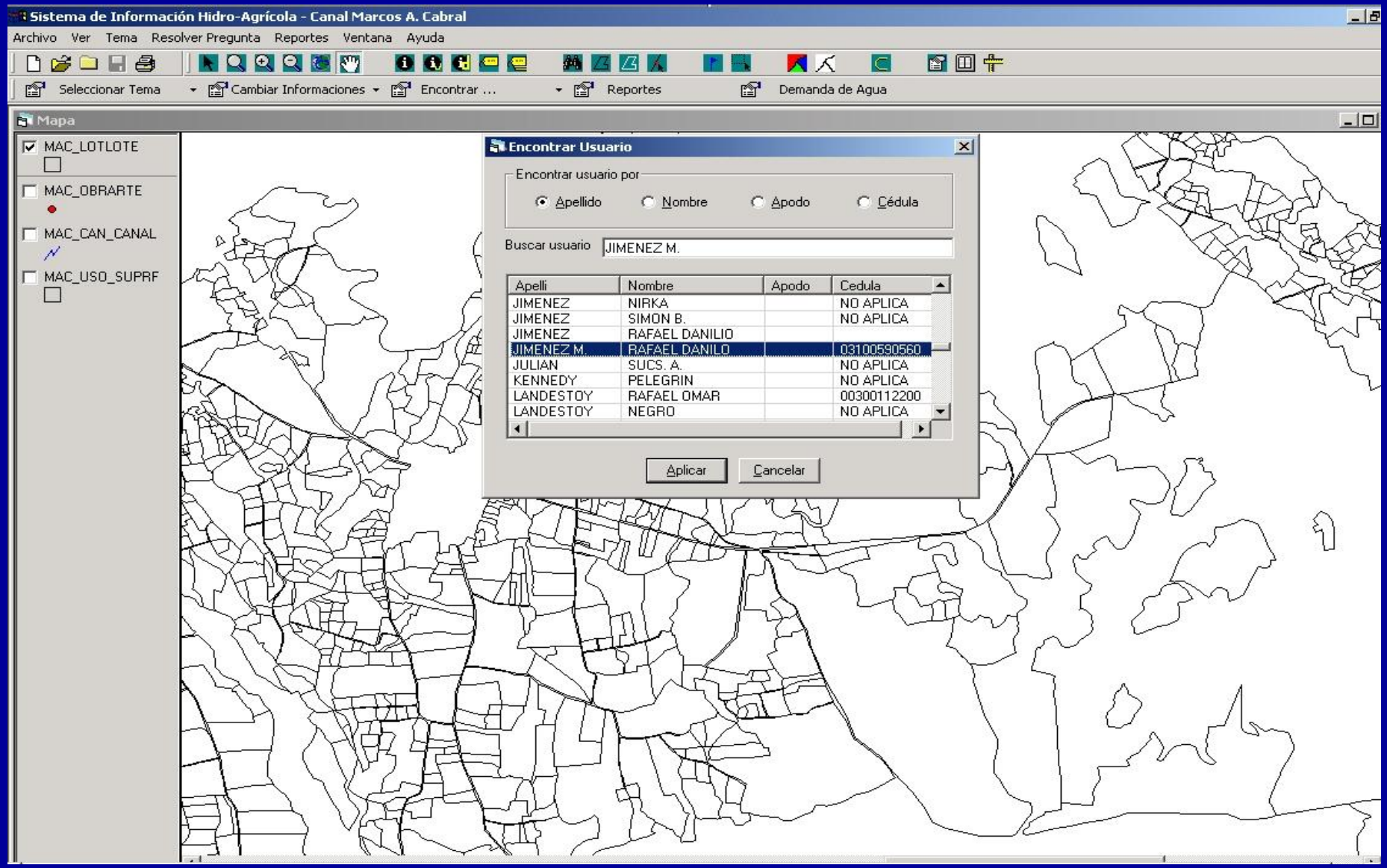
Observation: We were very good clients of FEDEX!

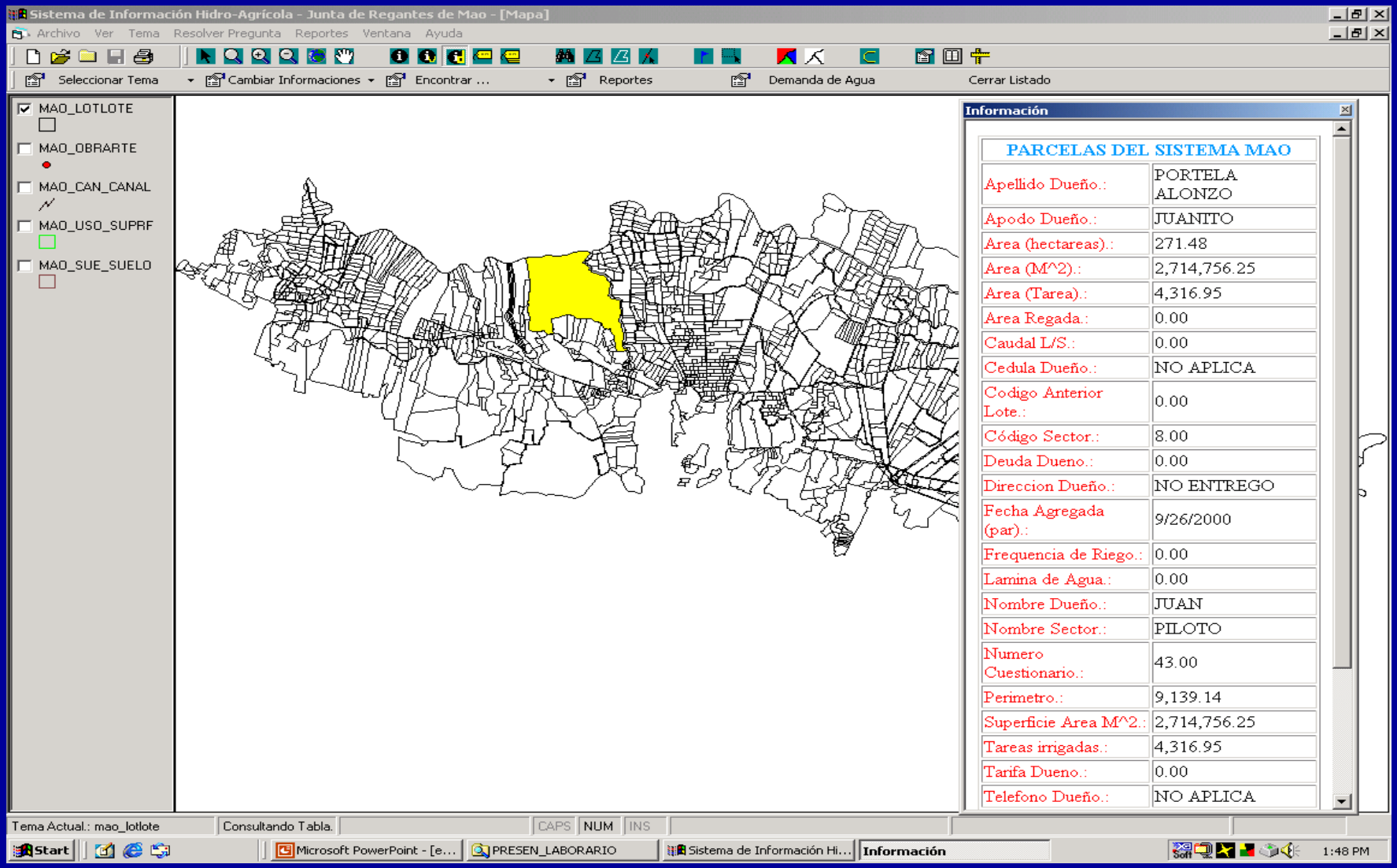
Some characteristics of the digital cadastre of irrigation water users

- Union of the geographic layer containing the property boundaries with the information in the surveys
- The geographic coordinates come from the digital orthophotos
- The property area is exact
- The database is complete because all properties within the command area of a main canal or irrigation system are included
- Can be readily and easily updated
- The property boundaries can be updated if a consolidation or division of properties occurs

Example: Search for a Water User or Irrigator



Digital Database



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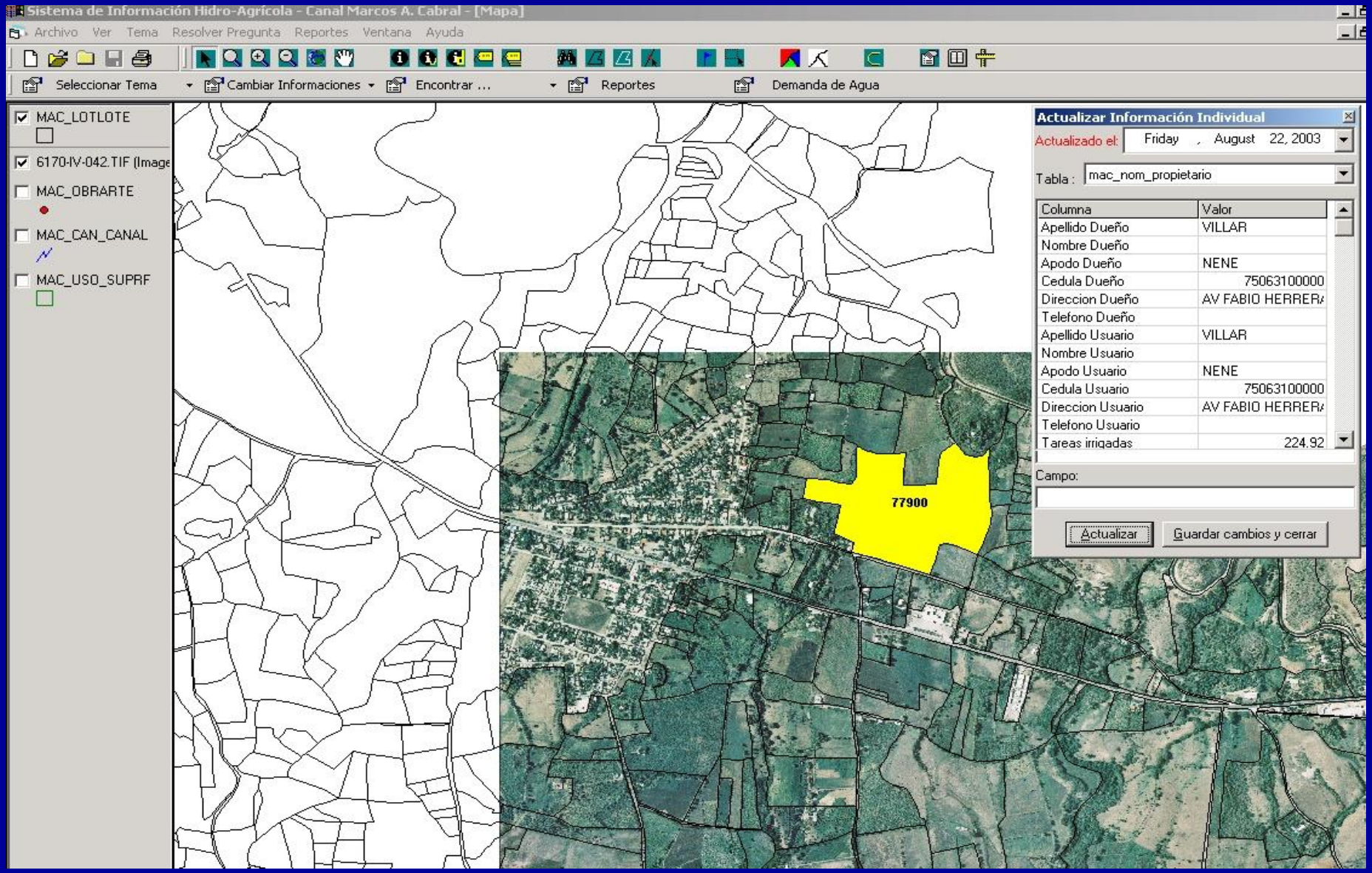
Information can be easily updated



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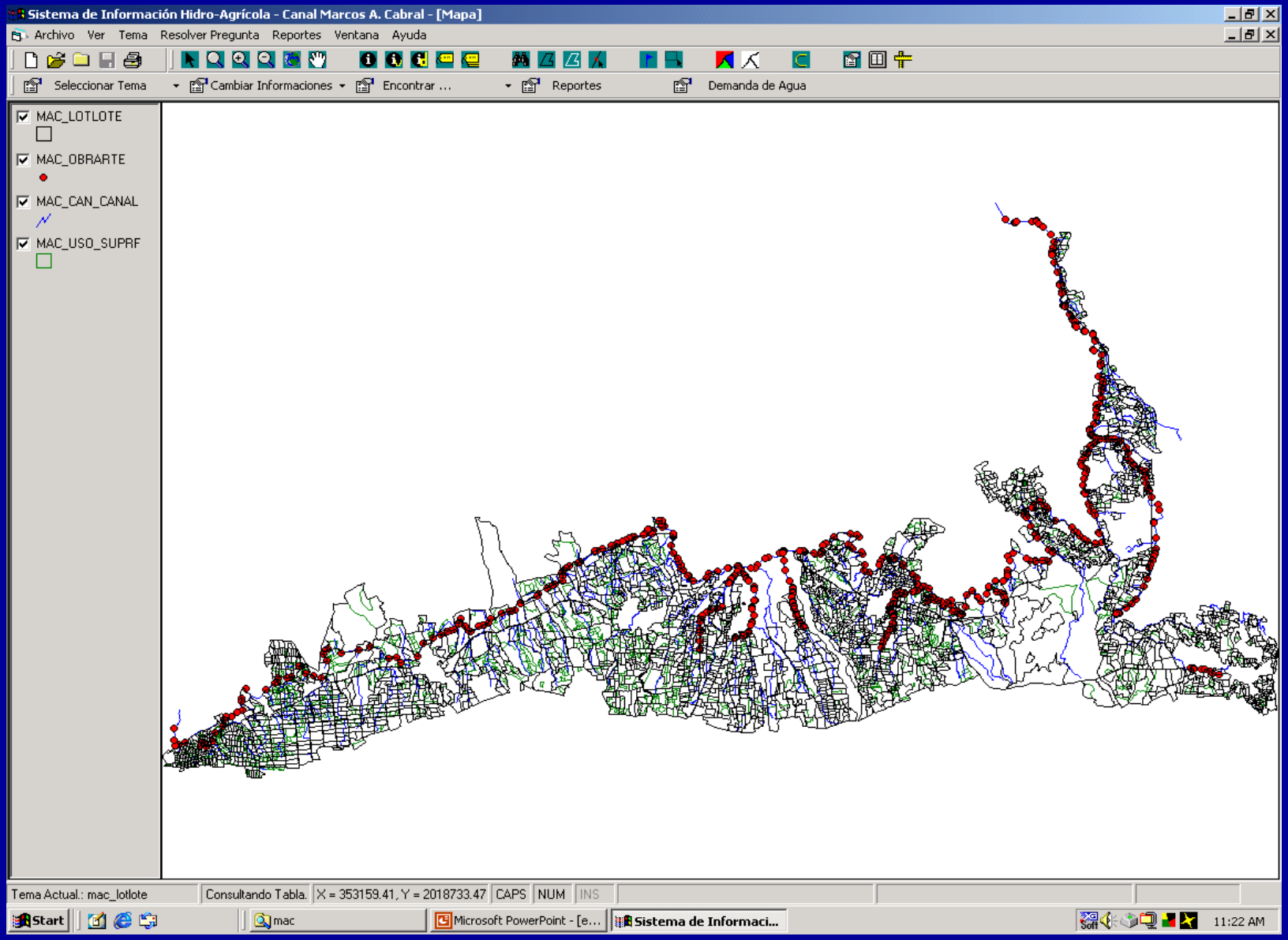
Information on irrigation infrastructure for Marcos A. Cabral System



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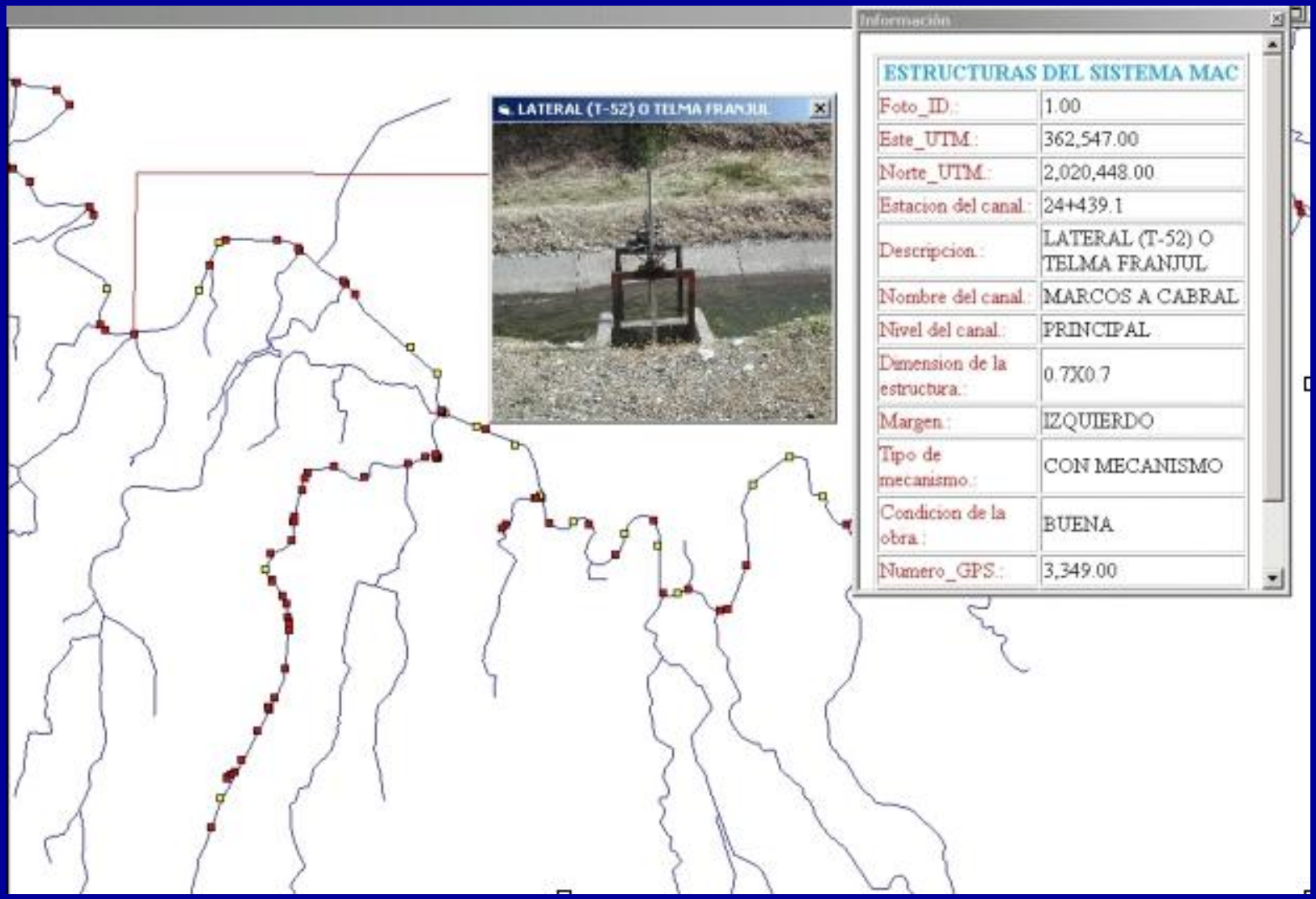
Irrigation Water Control Structures



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GIS Canal Distribution Layer

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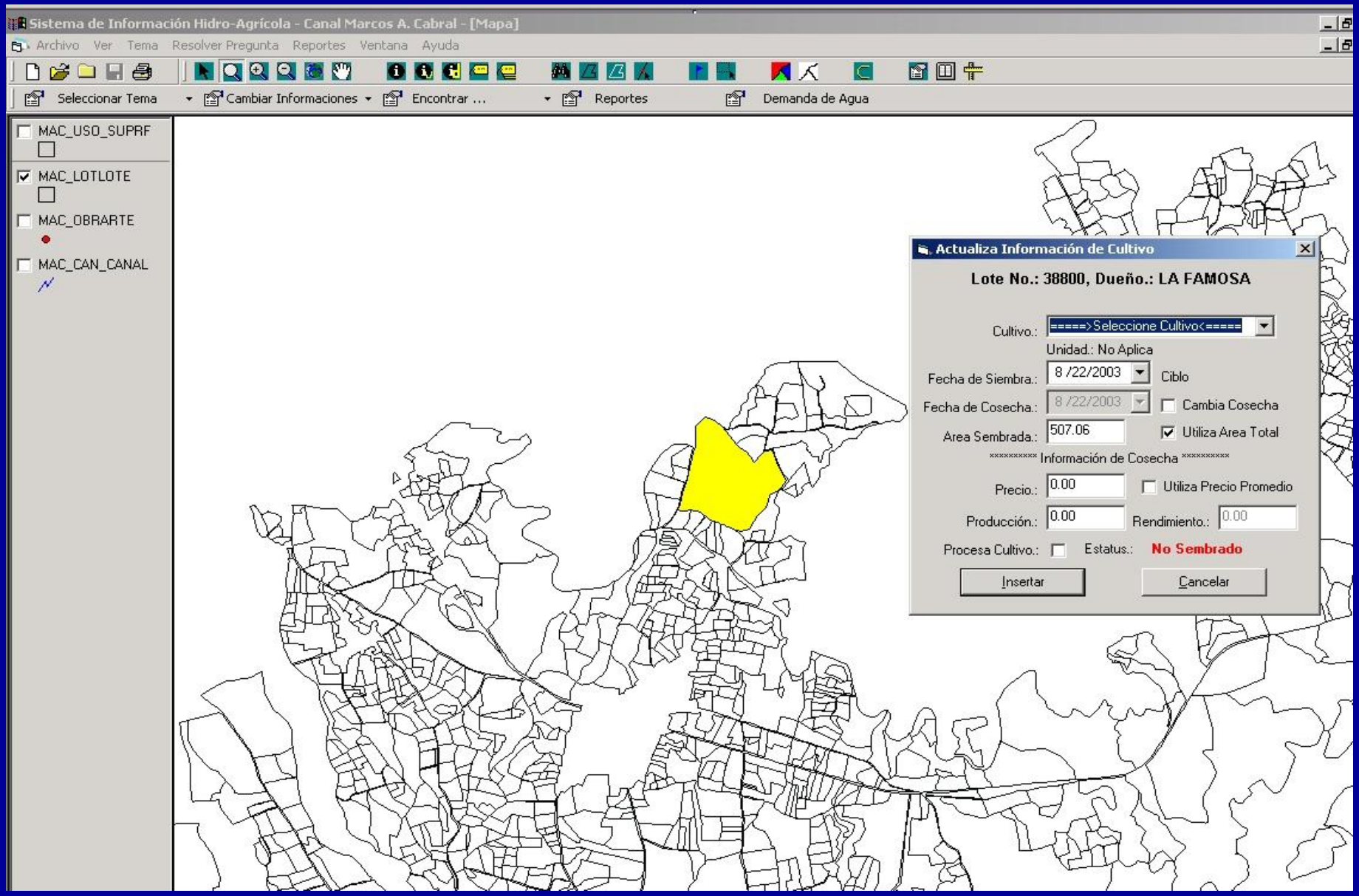
Presently: Crop Layer can be Easily Updated



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Training of Water User Association Personnel and INDRHI Irrigation District Personnel

- Basic Windows: 4
- Use of the Agro-hydrological System software: 4
- Updating the Water Users Database: 4
- Updating the Agricultural Statistics: 4

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Observations

- The cadastre was necessary information in the transfer of the irrigation systems from government control the Water Users Associations
- USU facilitated the transfer of 40 irrigation systems in the Dominican Republic, setting up the democratic structure, training the WUA staff on operation and maintenance of the irrigation system, administration and governance
- The use of the digital cadastre of irrigators and related database by the transferred Water User Associations increased their O&M assessment inputs by up to 70% is some cases

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Remote Sensing in Irrigated Agriculture

- Used to obtain the different crops and corresponding areas in an irrigated system. Example: Bureau of Reclamation LCRAS system
- Estimate seasonal crop evapotranspiration and irrigation water demand
- Estimate crop yield and production statistics
- Monitor the surrounding environment and natural vegetation to the irrigated area
- Water rights: monitor irrigate area and determine who is irrigating
- Estimate groundwater pumping and usage

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Remote Sensing Services Laboratory - RSSL

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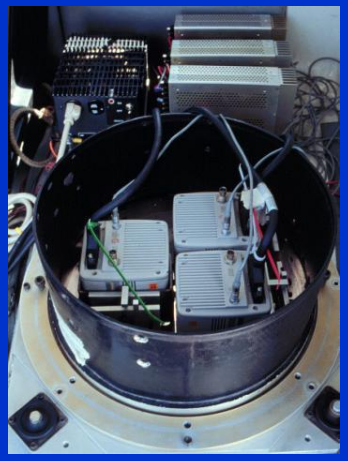
USU Cessna TP206
Remote Sensing Aircraft

USU Multispectral Digital System equipment rack with FLIR SC640 thermal infrared camera in the foreground.

Detail of Multispectral Cameras



Green

Red

NIR

3bands

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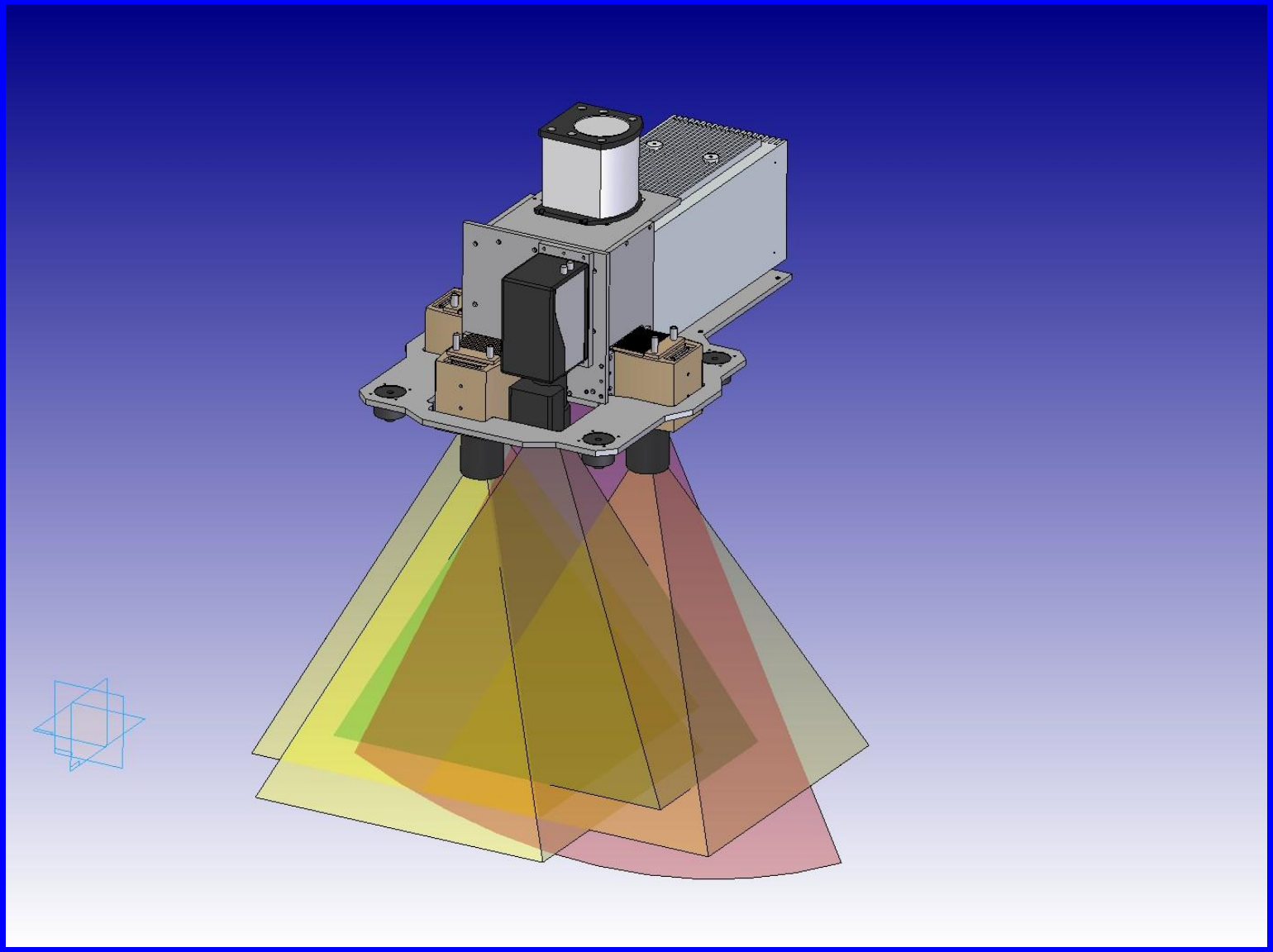
USU Airborne multispectral system merged with LASSI Lidar



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USU Airborne multispectral system merged with LASSI Lidar

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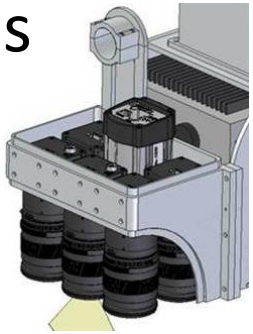
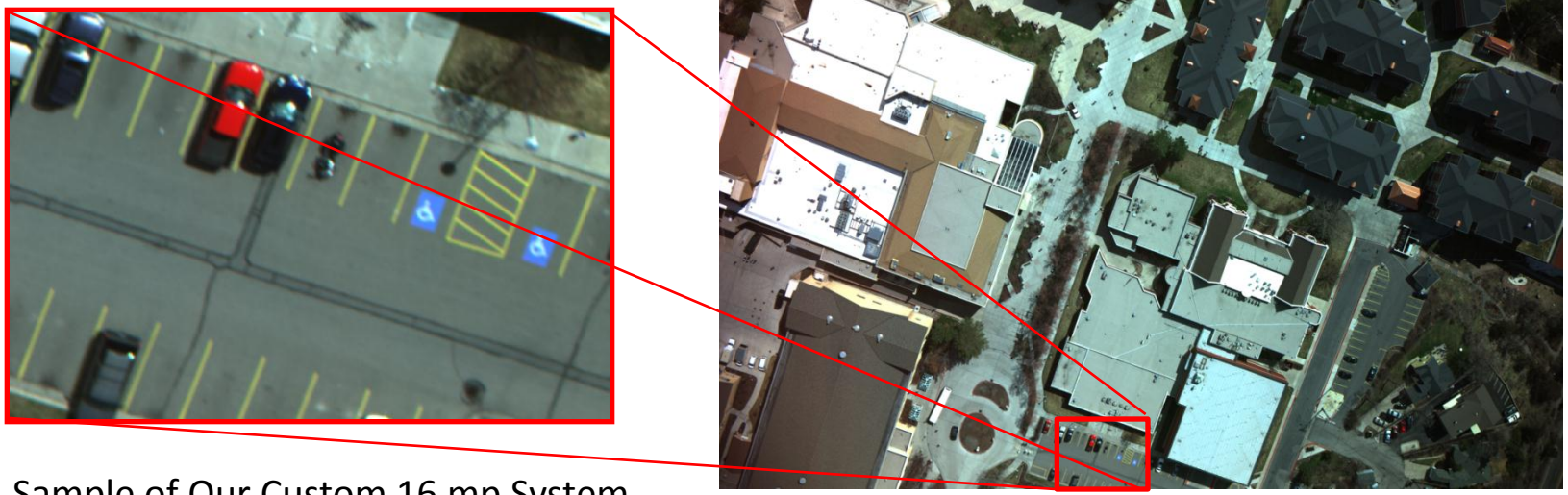
Details on MS Camera System

- Four co-boresighted multispectral cameras
  - 16 megapixels each for IR, R, G, B bands
  - 64 megapixels total
  - Integrated with lidar
  - Calibrated



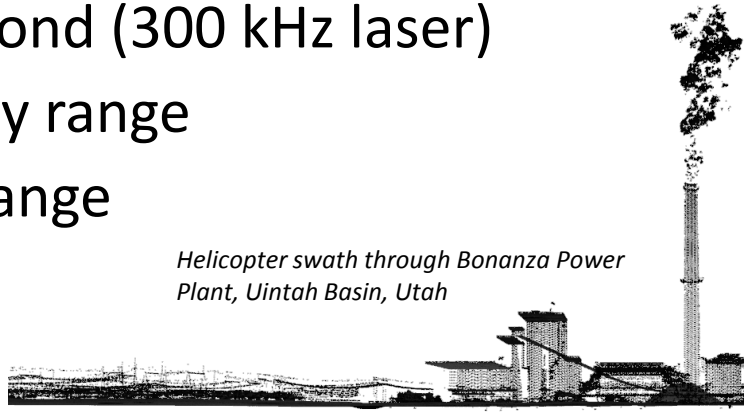
Camera Hardware



Sample of Our Custom 16 mp System
(R,G,B channels shown)

ROW 3D Mapping System

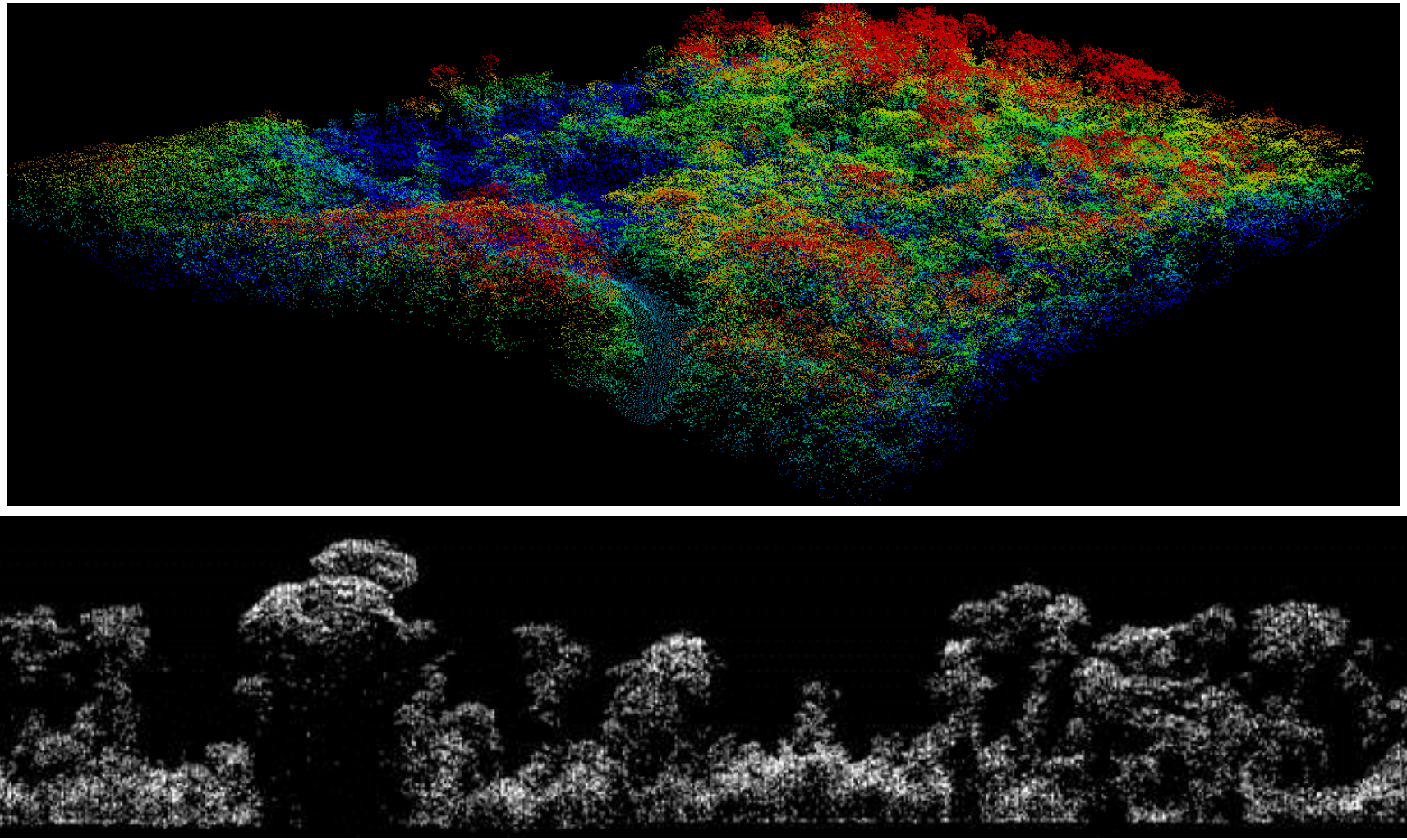
– 3D Lidar
  - Based on Riegl Q560
  - 150,000 measurements/second (300 kHz laser)
  - 25 mm range accuracy at any range
  - 31 mm footprint @ 100 m range
  - 60 degree swath angle
  - Integrated with cameras

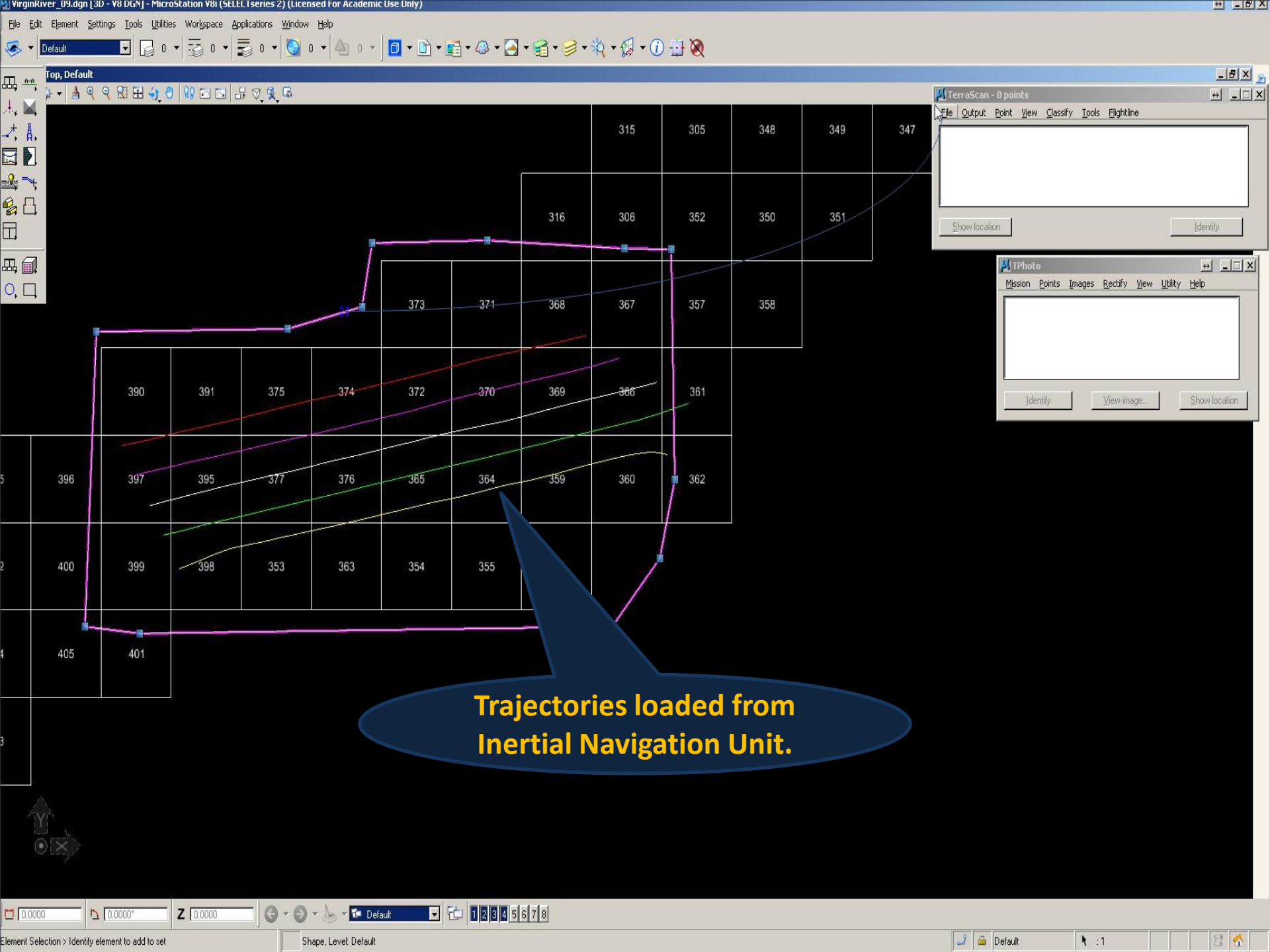


Helicopter swath through Bonanza Power Plant, Uintah Basin, Utah

Helicopter swath through Utah State University from 200 m using Riegl Q560 lidar system

LASSI Lidar Image of Tropical Rainforest

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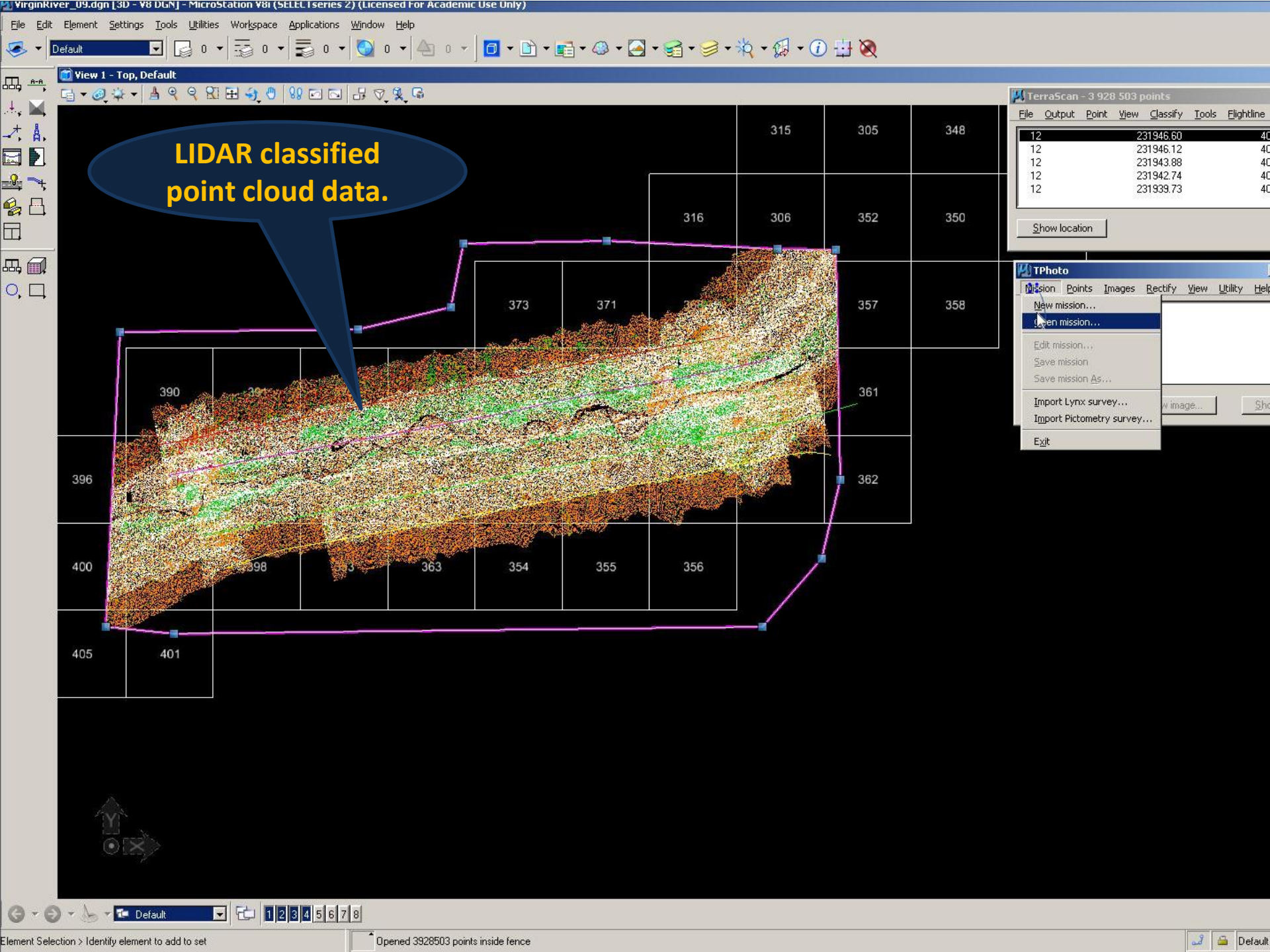
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Edit mission...
Save mission
Save mission As...
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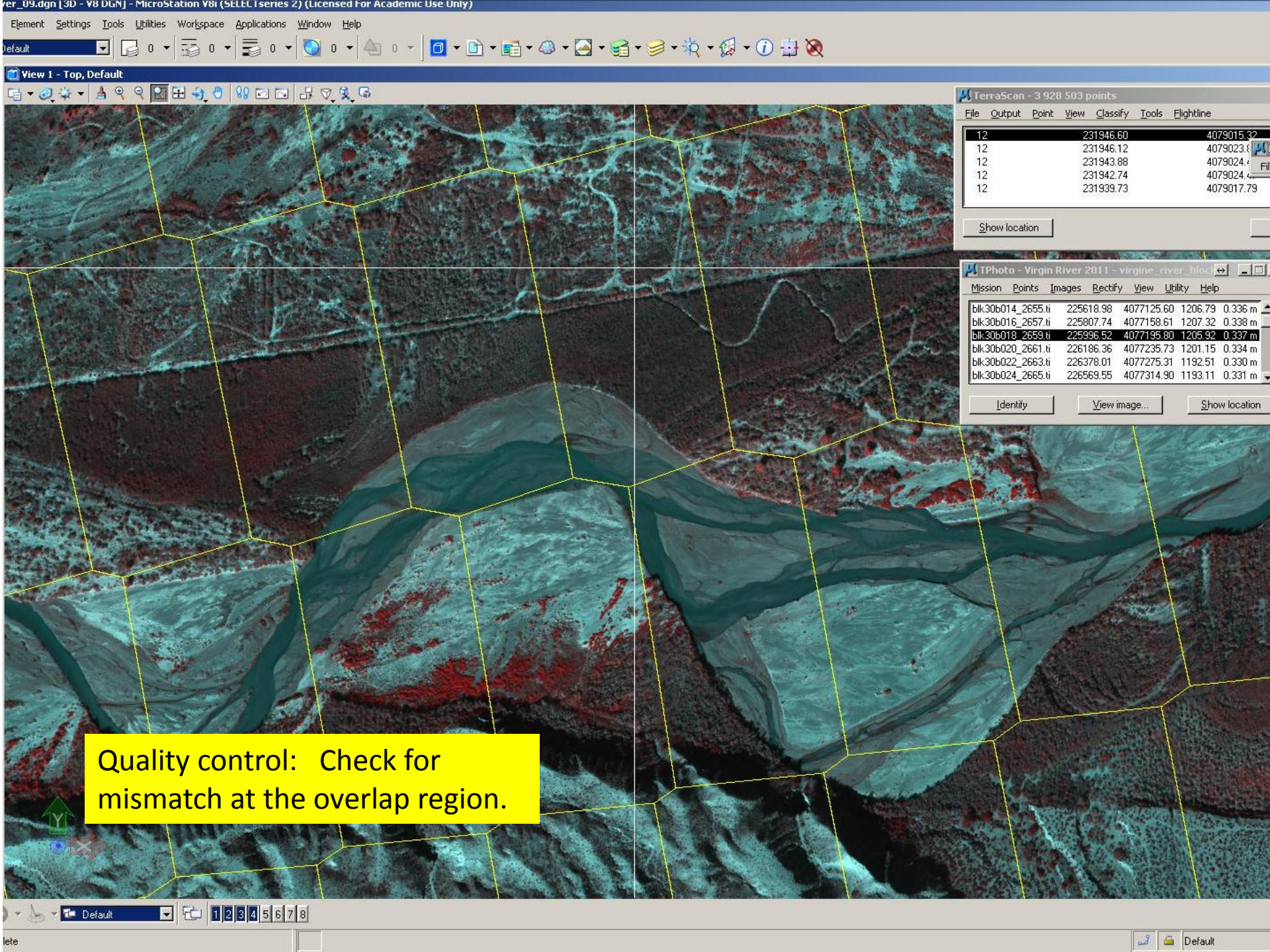
Import Pictometry survey...
Exit
Element Selection > Identify element to add to set
Opened 3928503 points inside fence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blk30b018_2659.ti 225996.52 4077195.80 1205.92 0.337 m
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blk30b022_2663.ti 226378.01 4077275.31 1192.51 0.330 m
blk30b024_2665.ti 226569.55 4077314.90 1193.11 0.331 m
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Workspace Applications Window Help
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Create ortho-rectified tiles.
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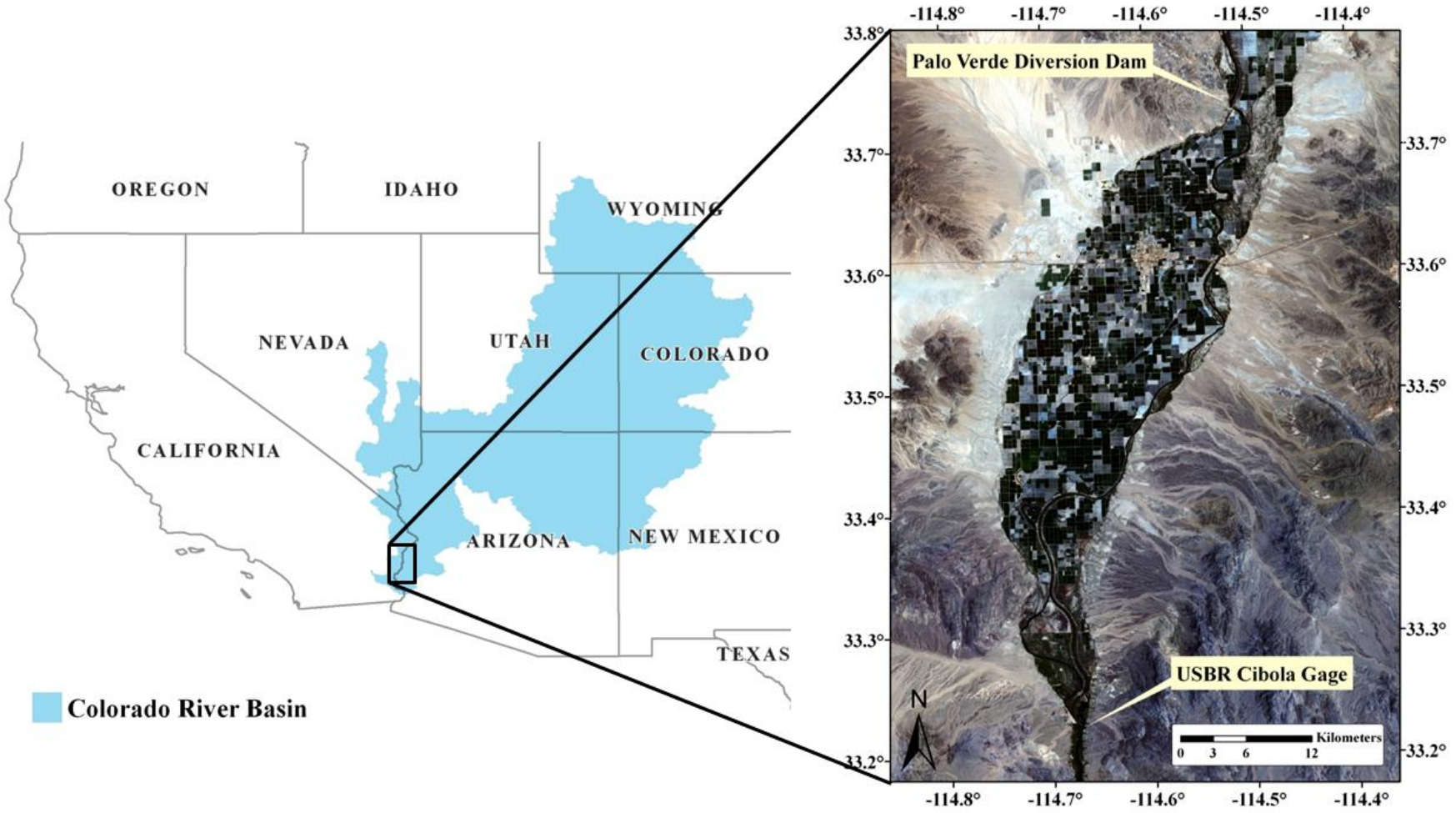
Default

Water Balance of an Irrigated Area: Palo Verde Irrigation District, CA

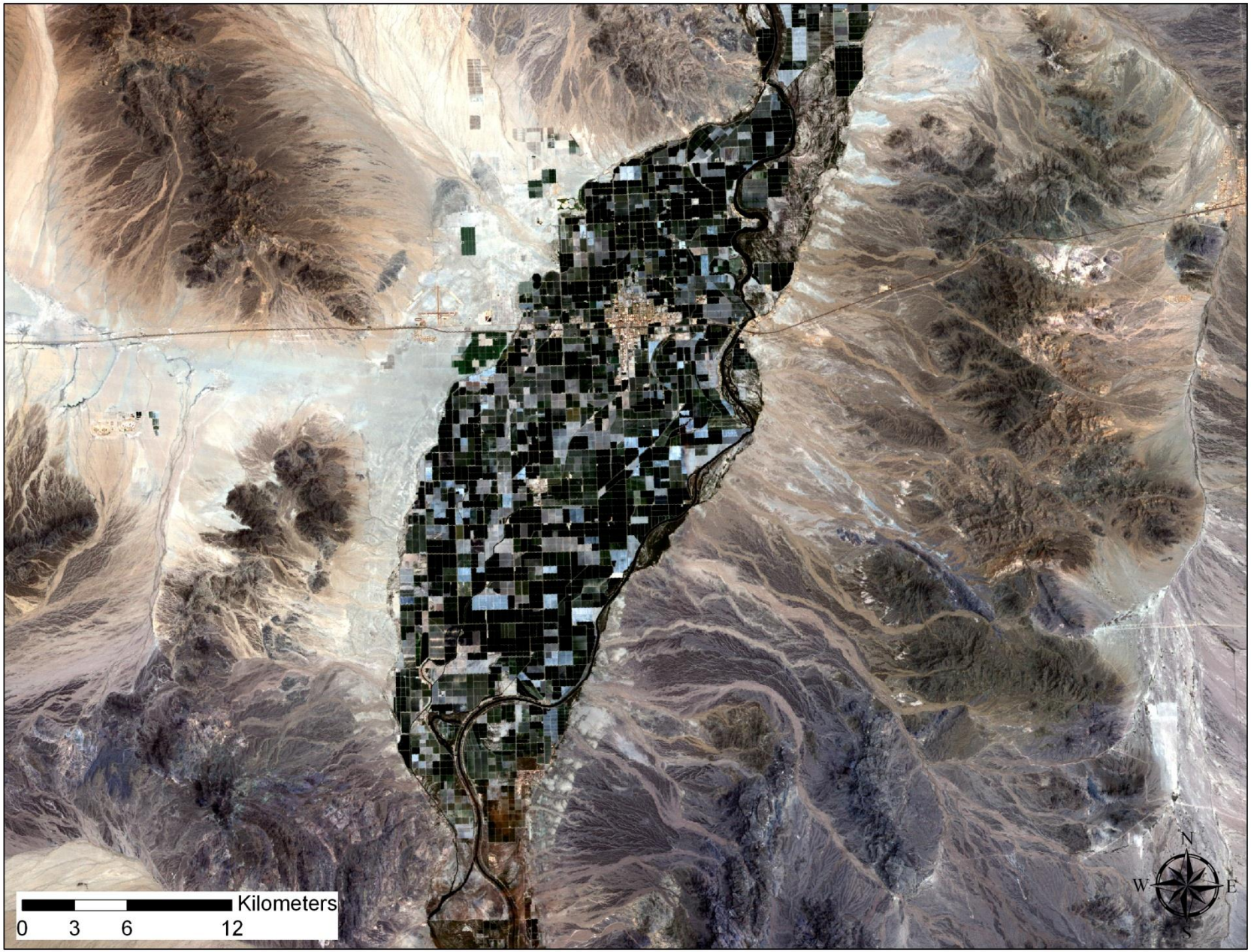


Contribution from Saleh Taghvaeian

Palo Verde Irrigation District (PVID)

- Location: imperial and Riverside counties, CA.
- Area: more than 500 km^2.
- Elevation: 67 m at South to 88 m at North.
- 400 km of irrigation canals and 230 km of drains.
- Predominant crops: alfalfa, cotton, grains, melons.
- Alluvial soil with predominant sandy loam texture.

Study Area: Palo Verde Irrigation District



Water balance of irrigation schemes

$$I + P = ET + DP + RO + \Delta S$$

I: Applied irrigation water;

P: Precipitation;

ET: Evapotranspiration;

DP: Deep percolation;

RO: Surface runoff; and,

ΔS: Change in soil water storage.

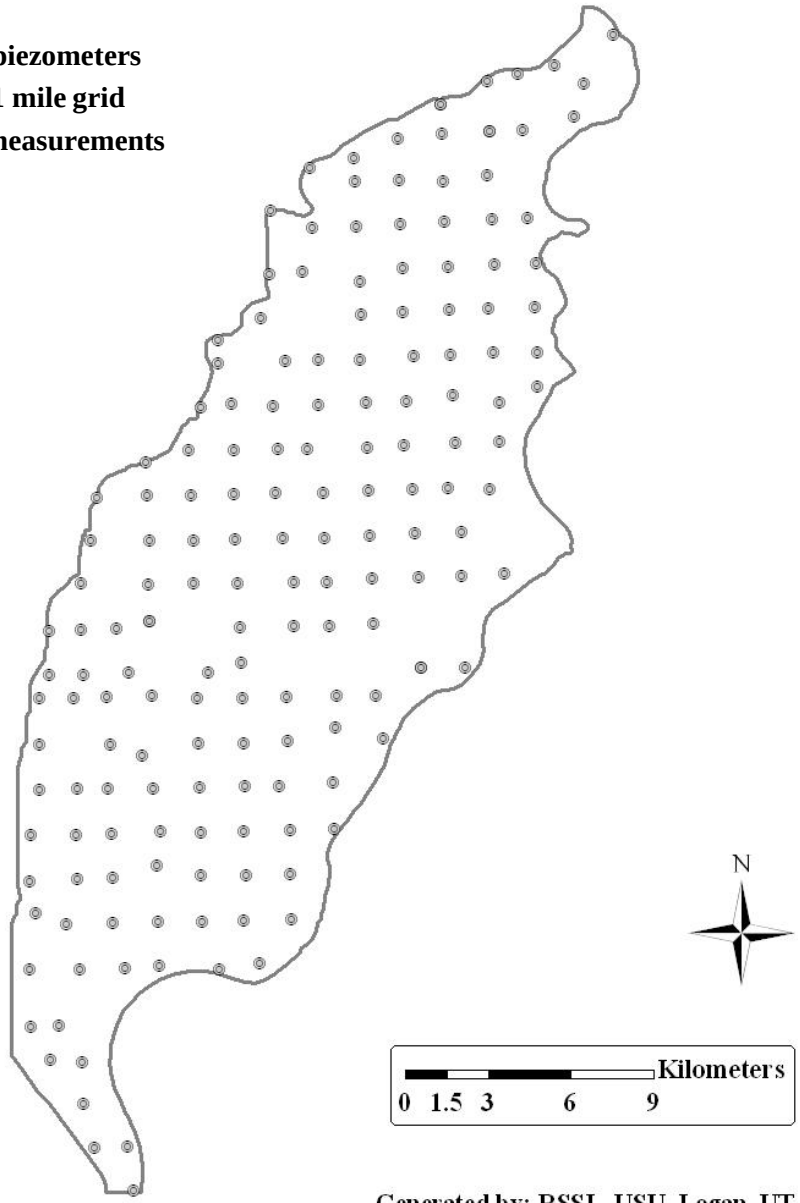
PVID

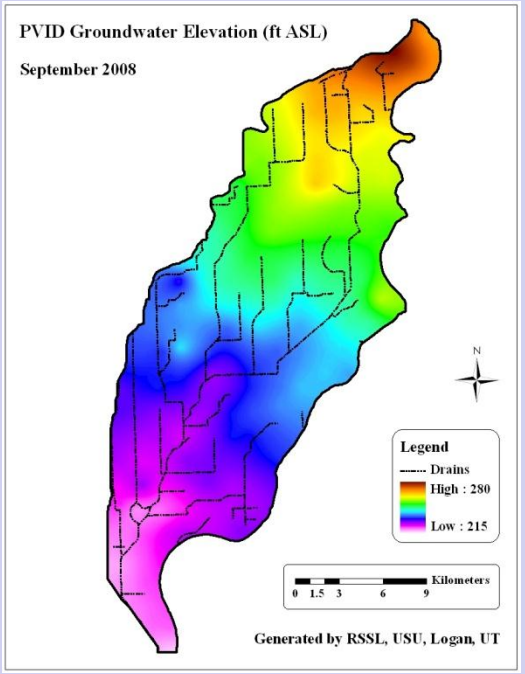
Groundwater

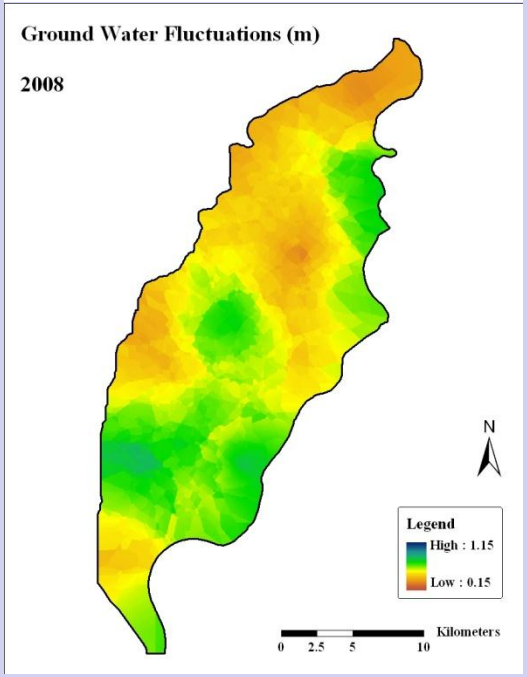
Dynamics

PVID piezometers

Over 260 piezometers
1 mile by 1 mile grid
Monthly measurements

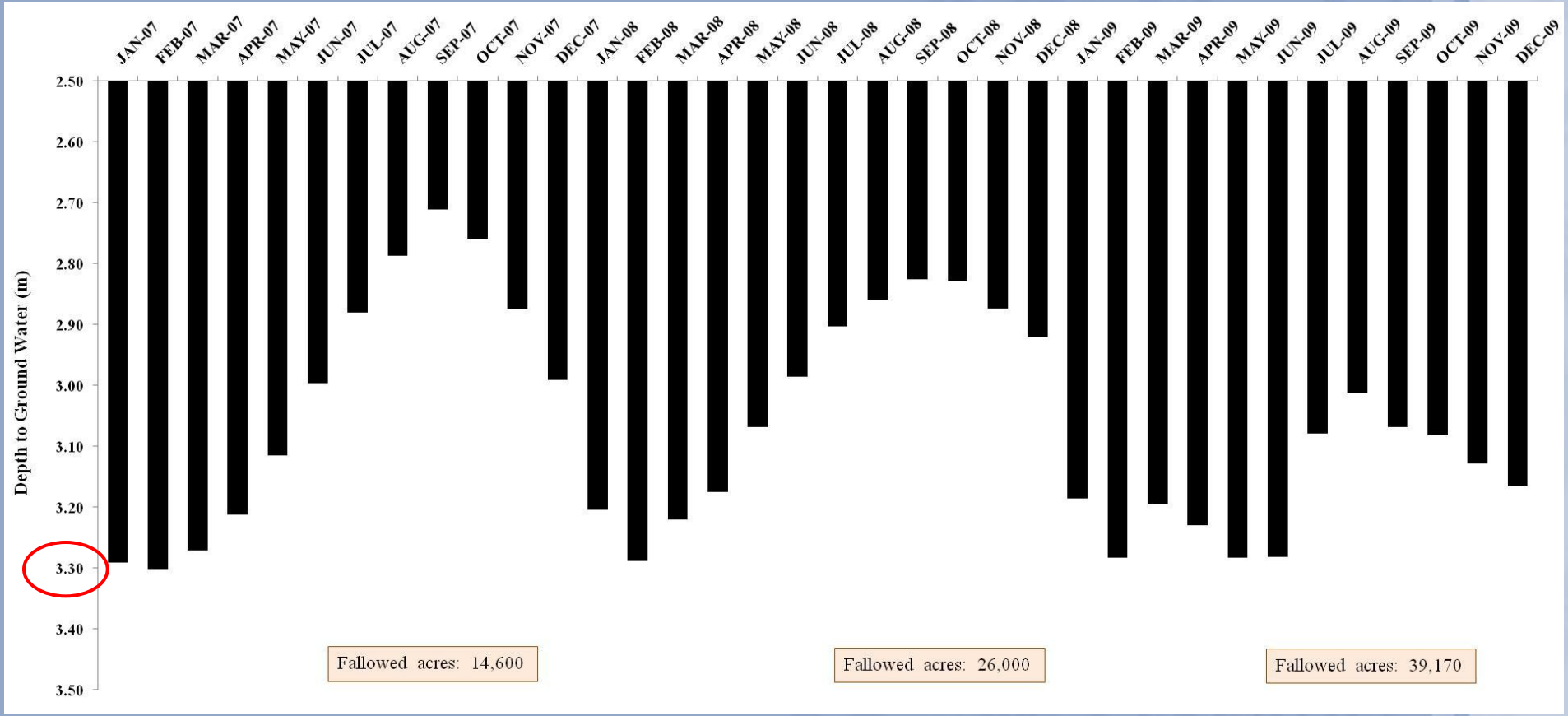






Average Depth to Groundwater (m)

January 2007 to December 2009



Evapotranspiration

Remote Sensing of Energy Balance

$\mathbf{R_n = H + G + LE}$

R_n: Net Radiation

H: Sensible Heat Flux

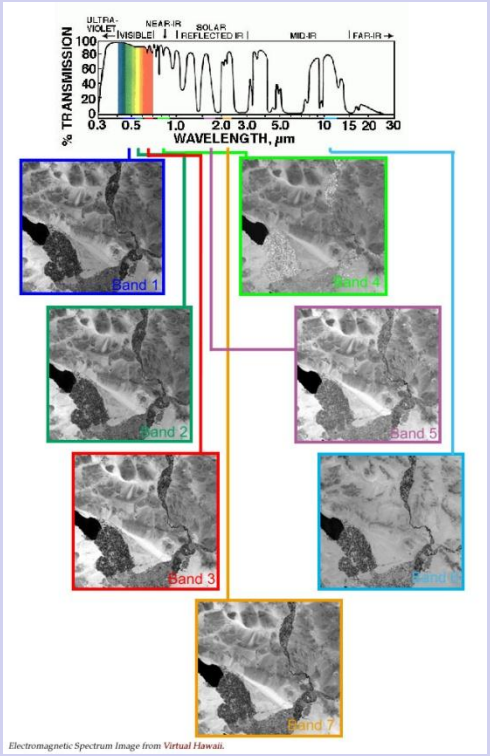
G: Soil Heat Flux

LE: Latent Heat Flux

Surface Energy Balance Algorithm for Land (SEBAL)

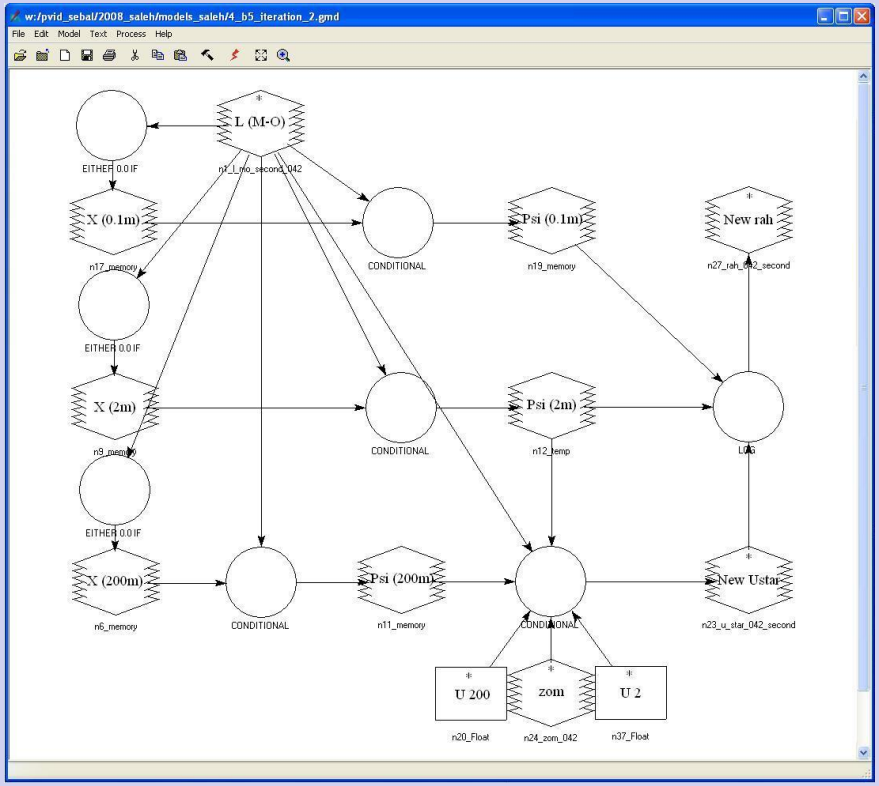
Developed by Dr. Wim Bastiaanssen, Wageningen, The Netherlands

SEBAL

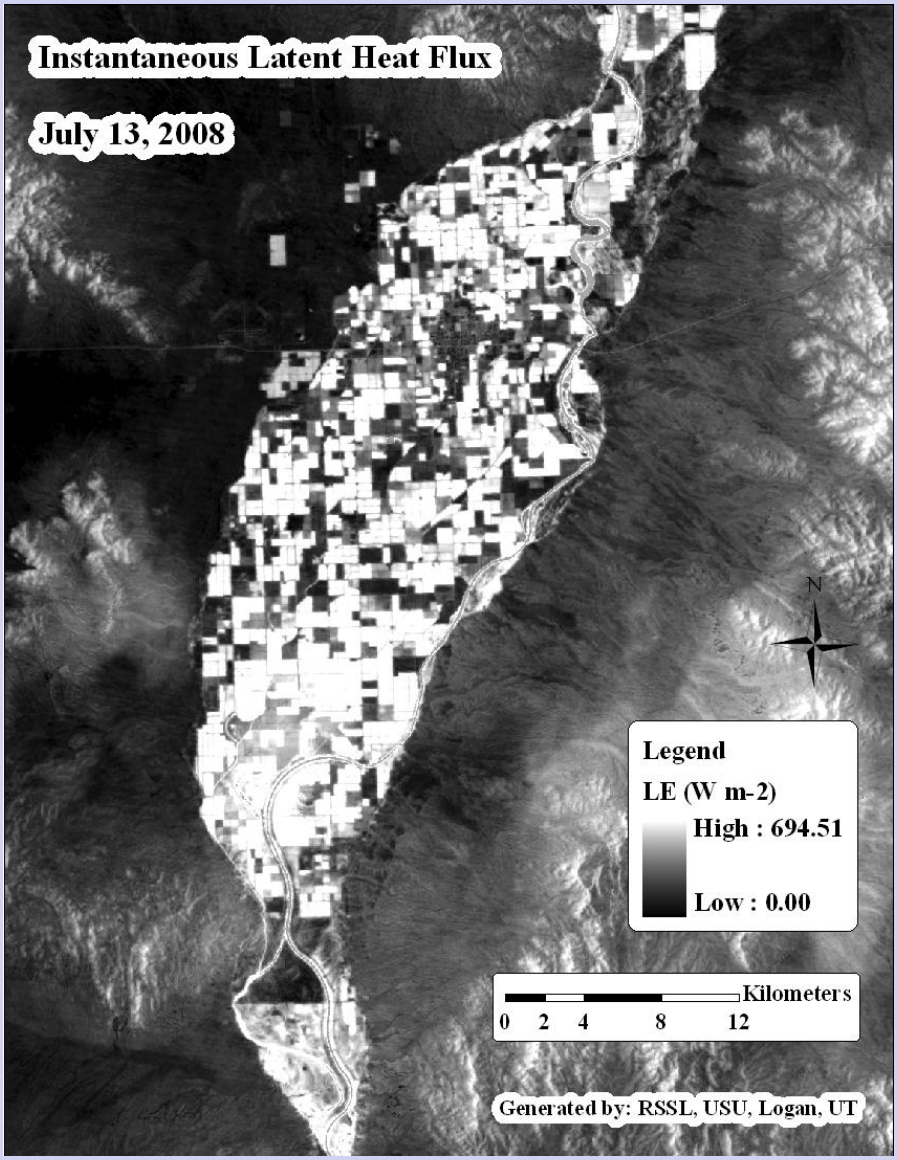


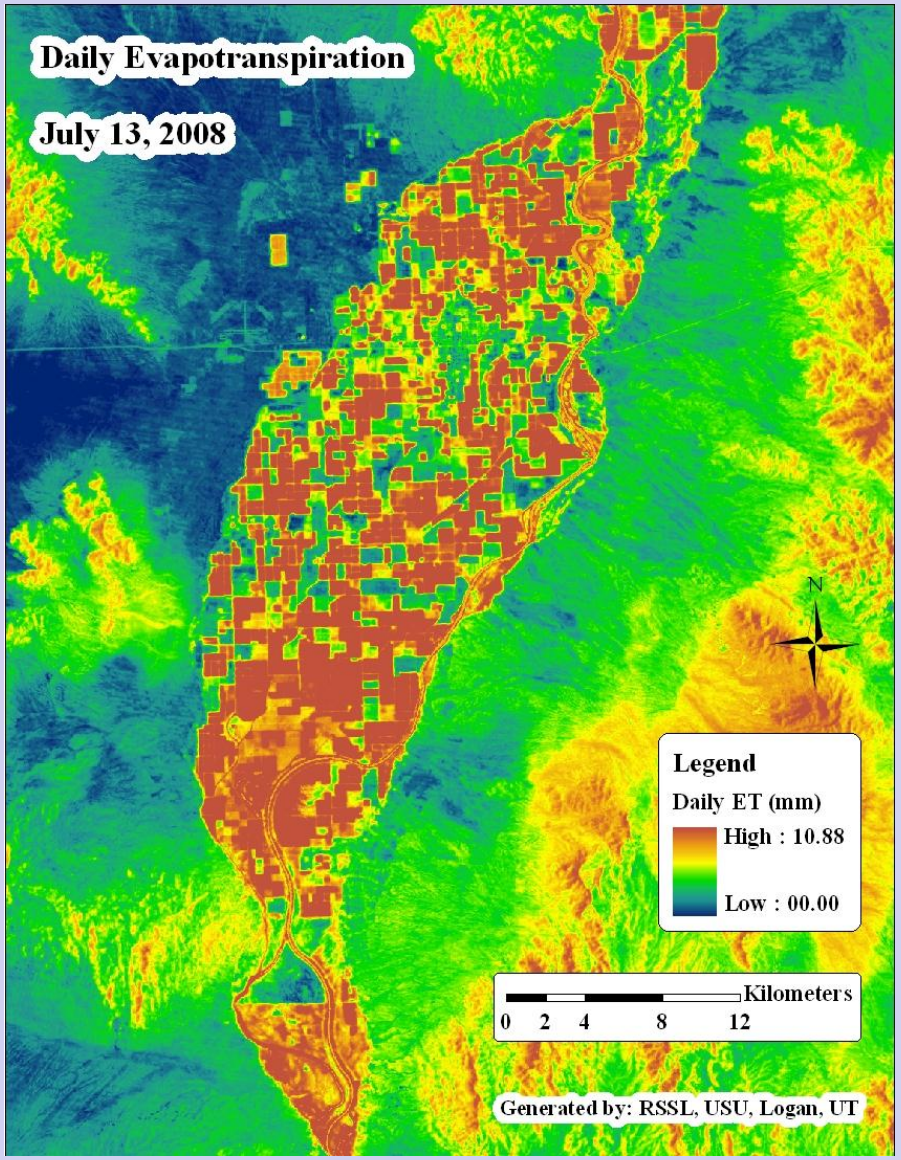
Landsat TM5 imagery

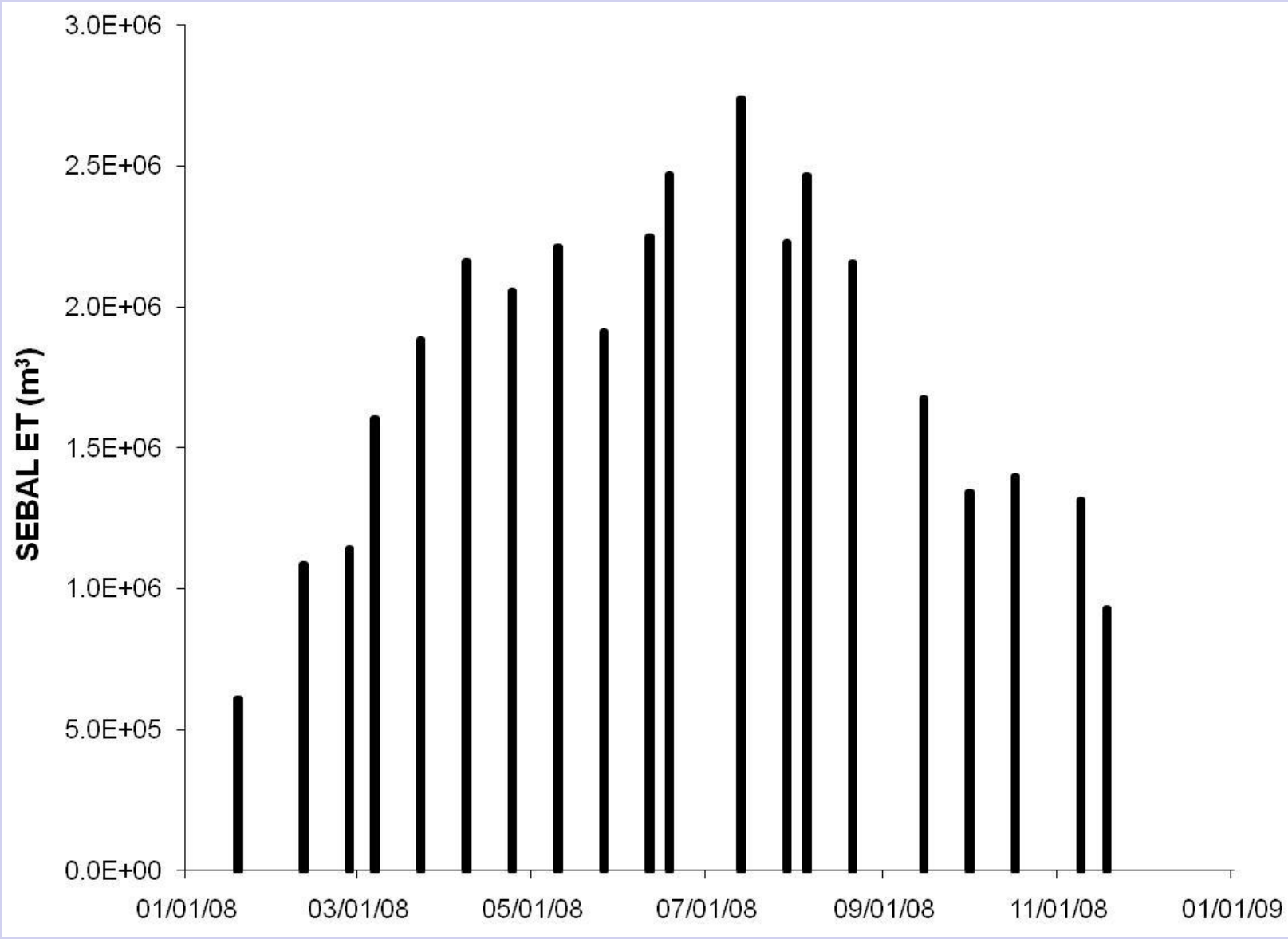
CIMIS Weather data



EToF

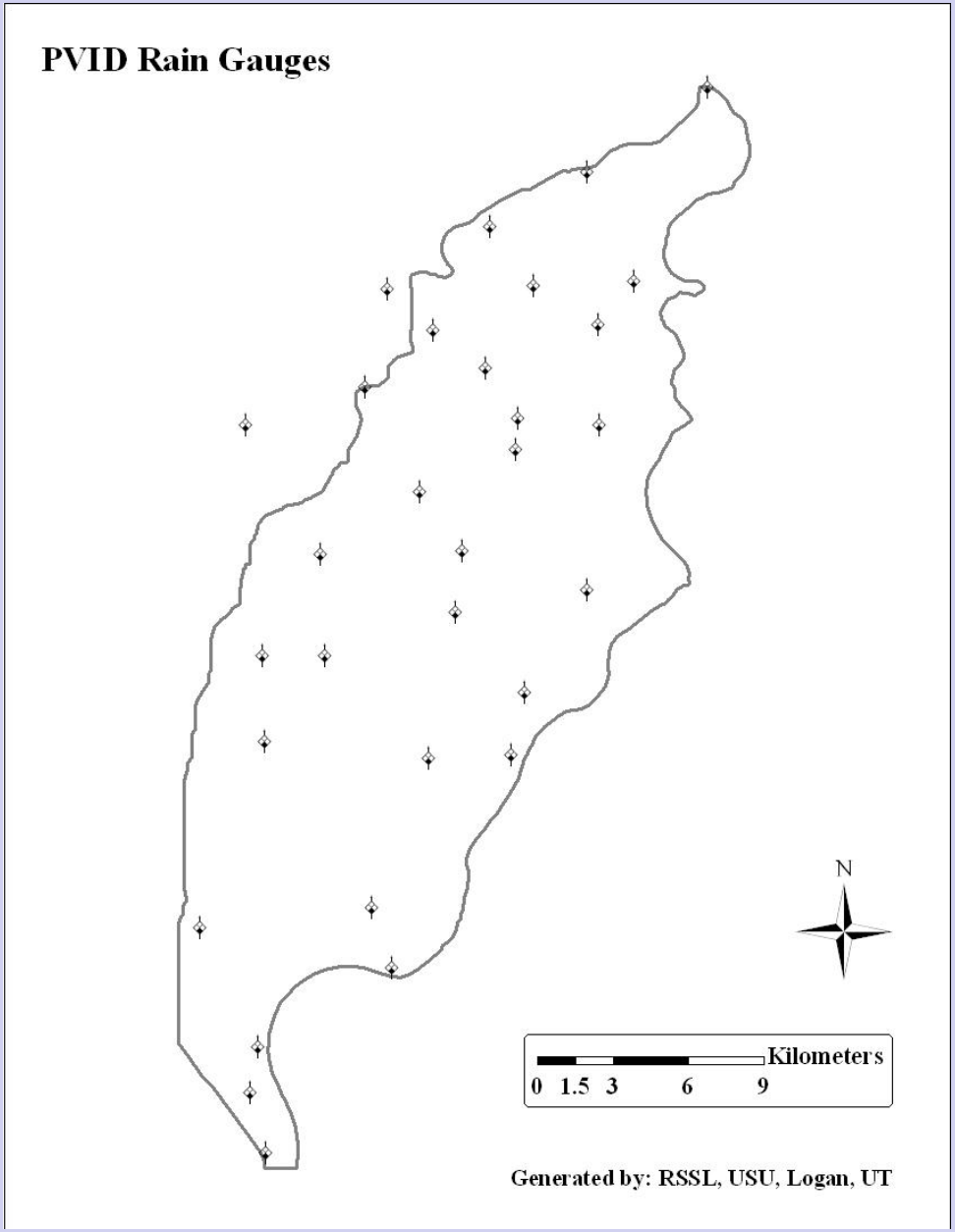

Instantaneous Latent Heat Flux
July 13, 2008
N
Legend
LE (W m-2)
High : 694.51
Low : 0.00
Kilometers
0 2 4 8 12
Generated by: RSSL, USU, Logan, UT

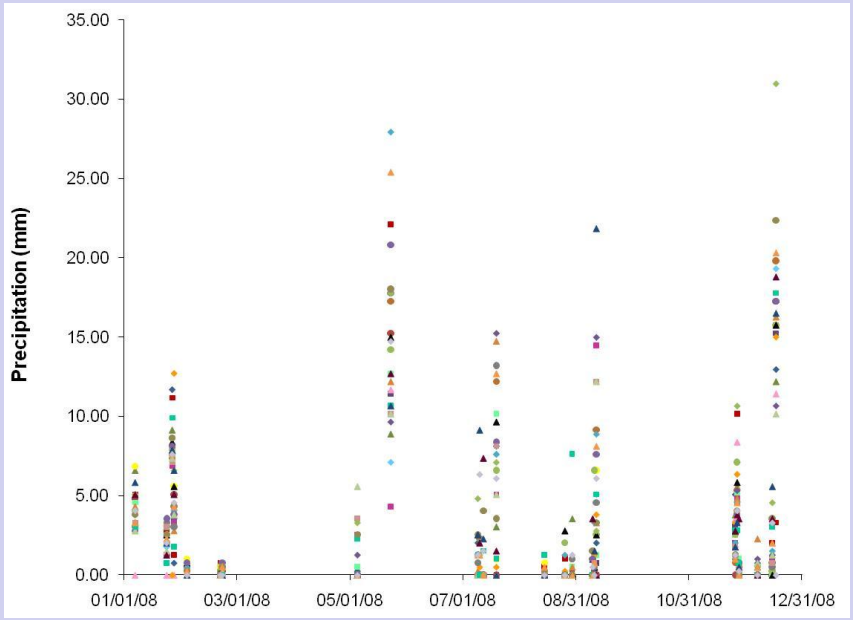

Daily Evapotranspiration
July 13, 2008
N
Legend
Daily ET (mm)
High : 10.88
Low : 00.00
Kilometers
0 2 4 8 12
Generated by: RSSL, USU, Logan, UT

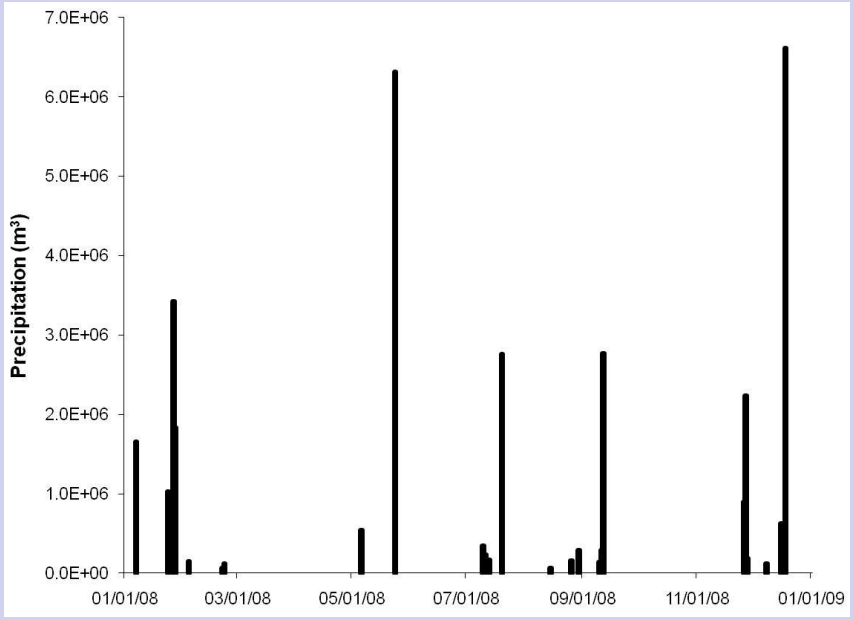


Total volume of water consumption by PVID crops for 20 dates of Landsat overpass

Precipitation

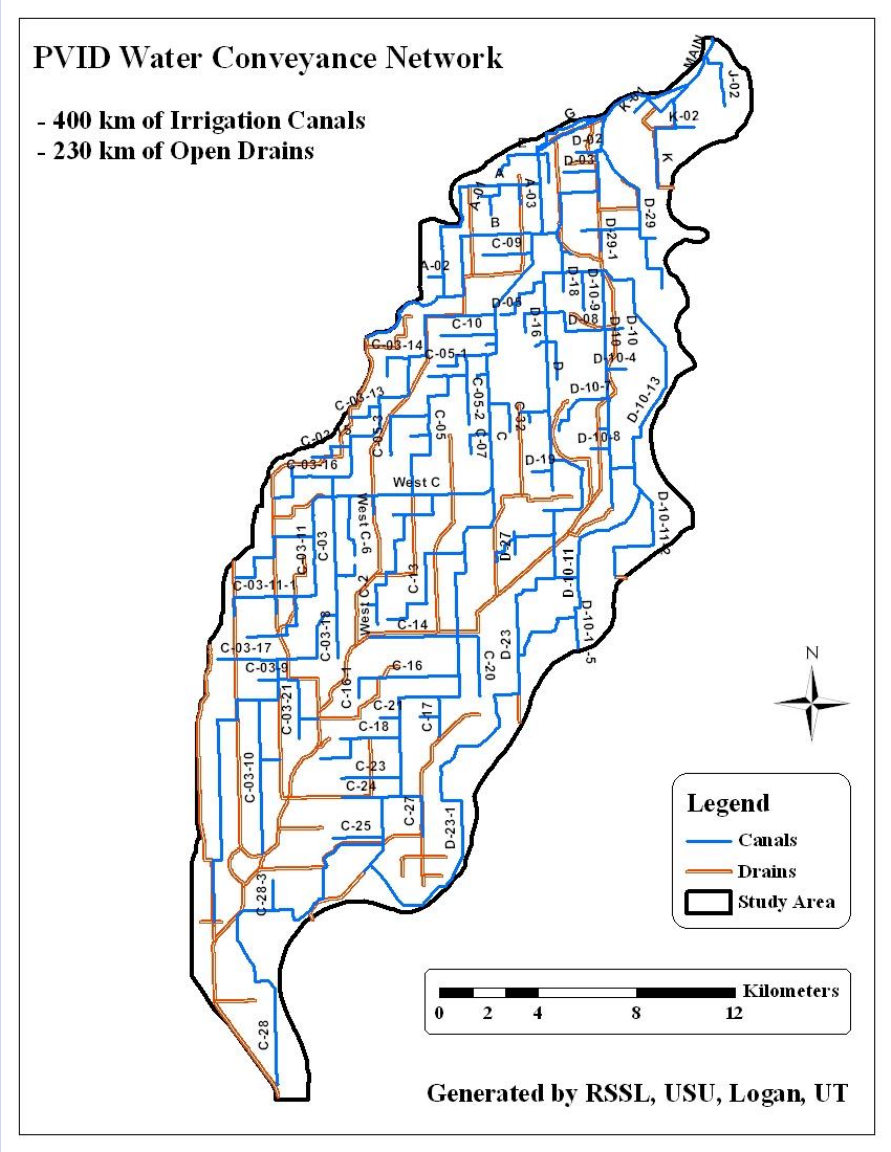

PVID Rain Gauges
N
Kilometers
0 1.5 3 6 9
Generated by: RSSL, USU, Logan, UT

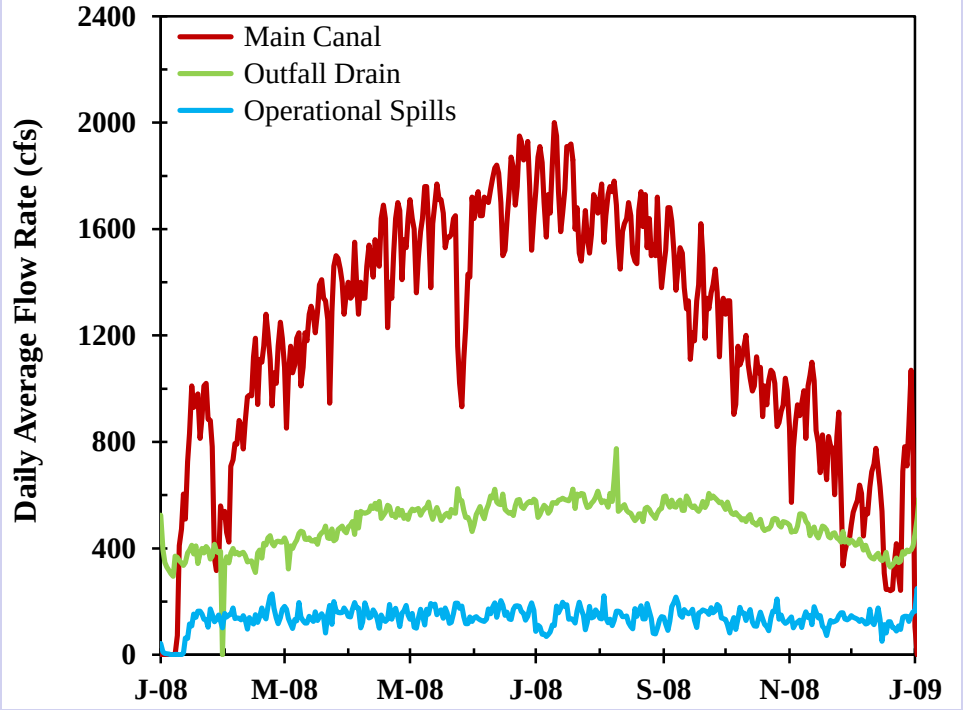

Precipitation (mm)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
01/01/08
03/01/08
05/01/08
07/01/08
08/31/08
10/31/08
12/31/08


Precipitation (m³)
7.0E+06
6.0E+06
5.0E+06
4.0E+06
3.0E+06
2.0E+06
1.0E+06
0.0E+00
01/01/08
03/01/08
05/01/08
07/01/08
09/01/08
11/01/08
01/01/09

Surface

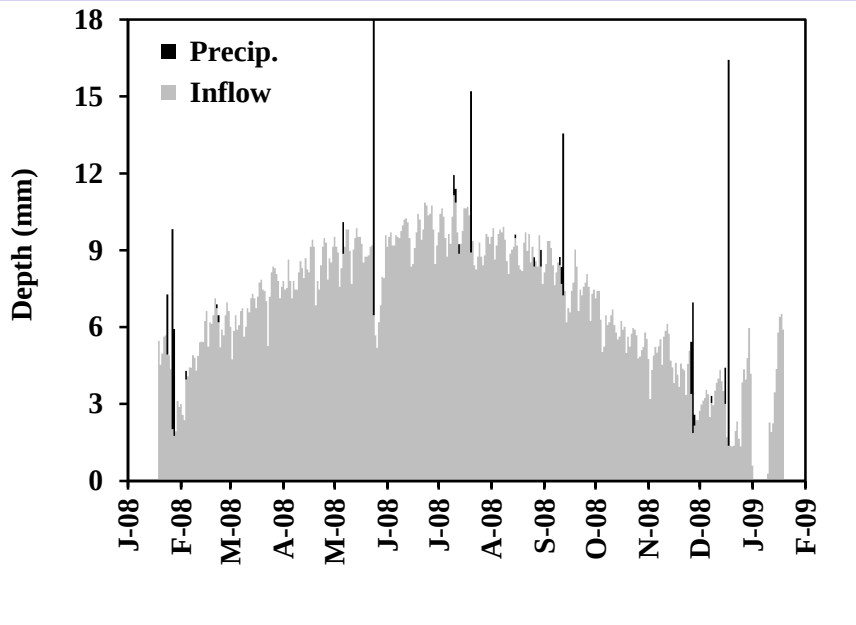
Inflow & Outflow

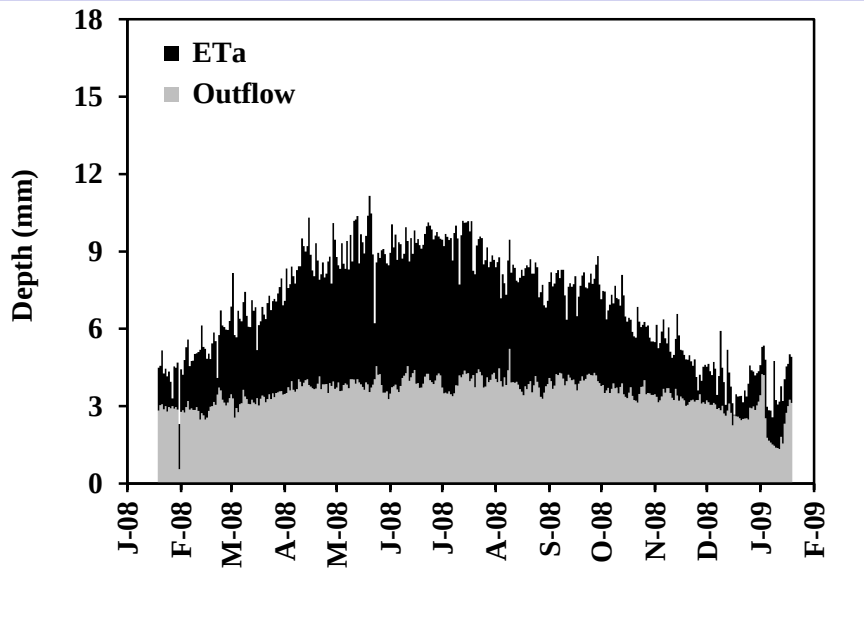

PVID Water Conveyance Network
- 400 km of Irrigation Canals
- 230 km of Open Drains
West C
West C-2
N
Legend
Canals
Drains
Study Area
Kilometers
0 2 4 8 12
Generated by RSSL, USU, Logan, UT


Main Canal
Outfall Drain
Operational Spills
Daily Average Flow Rate (cfs)
2400
2000
1600
1200
800
400
0
J-08
M-08
M-08
J-08
S-08
N-08
J-09

Closing

Water Budget



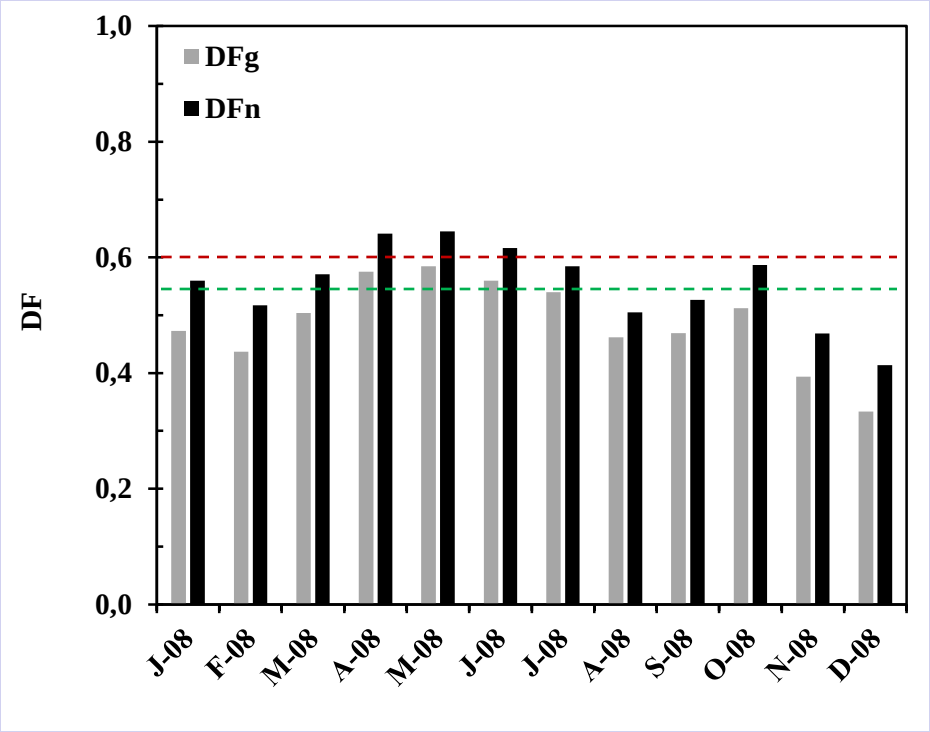


	Depth (mm)	Percentage
Precipitation	**71**	**3**
Surface inflow	**2479**	**97**
Σ Inputs	**2550**	**100**
Canal Spills	**284**	**11**
Drainage	**998**	**39**
Evapotranspiration	**1286**	**50**
Σ Outputs	**2568**	**100**
Σ Inputs – Σ Outputs	**-18**	**-0.7**

Depleted fraction (DF)

- $DF_g = ET_a / (P_g + V_d)$

- $DF_n = ET_a / (P_g + V_a)$



Nilo Coelho:

DF_n = 0.60

PVID:

DF_n = 0.55

Final Observations

- Geo-spatial technologies have facilitated the design and management of large irrigation systems

- Mapping and ET estimates from remote sensing are becoming common approaches for irrigation water management and basin water balance studies

Utah State University

INDRHI

BID

Obrigado!