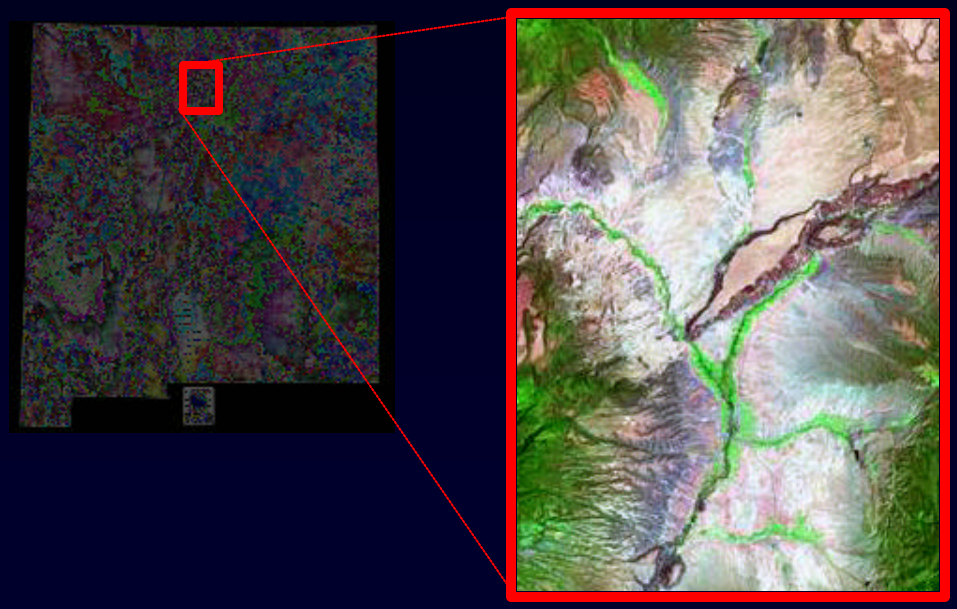
Effects of ditch and field seepage on floodplain water budgets and river flow

A. Fernald, S. Guldan, V. Tidwell, P. King, C. Ochoa, Y. Cevik, A. Helmus, C. Brown, M. Ortiz

USDA CSREES NRI Meeting, Savannah, 2007

ACEQUIAS

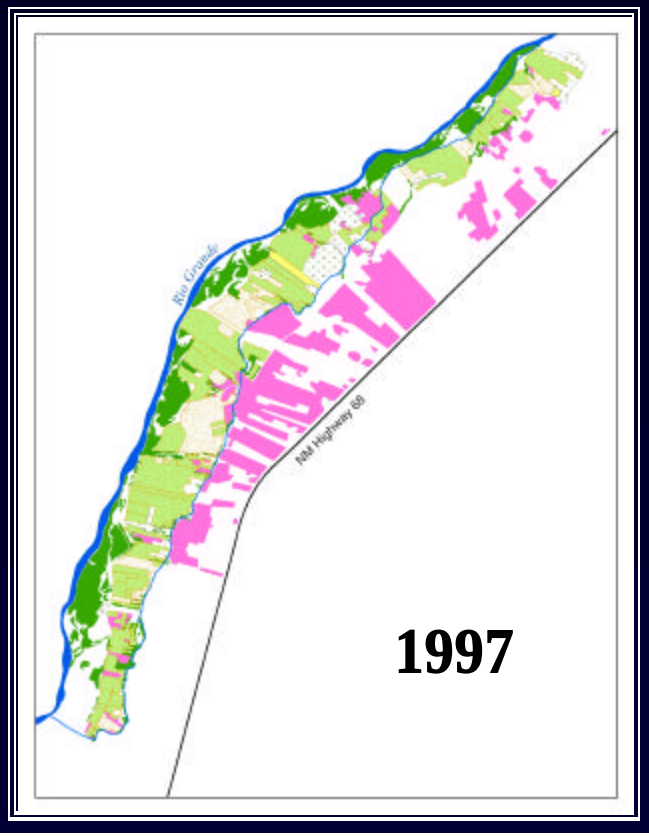
- In northern New Mexico river valleys, traditional acequias are the main irrigation systems



- Water management agencies would like to reduce seepage and precisely control flow

CHANGING LAND USE

- Cash crops to pasture
- Agricultural to residential



1962

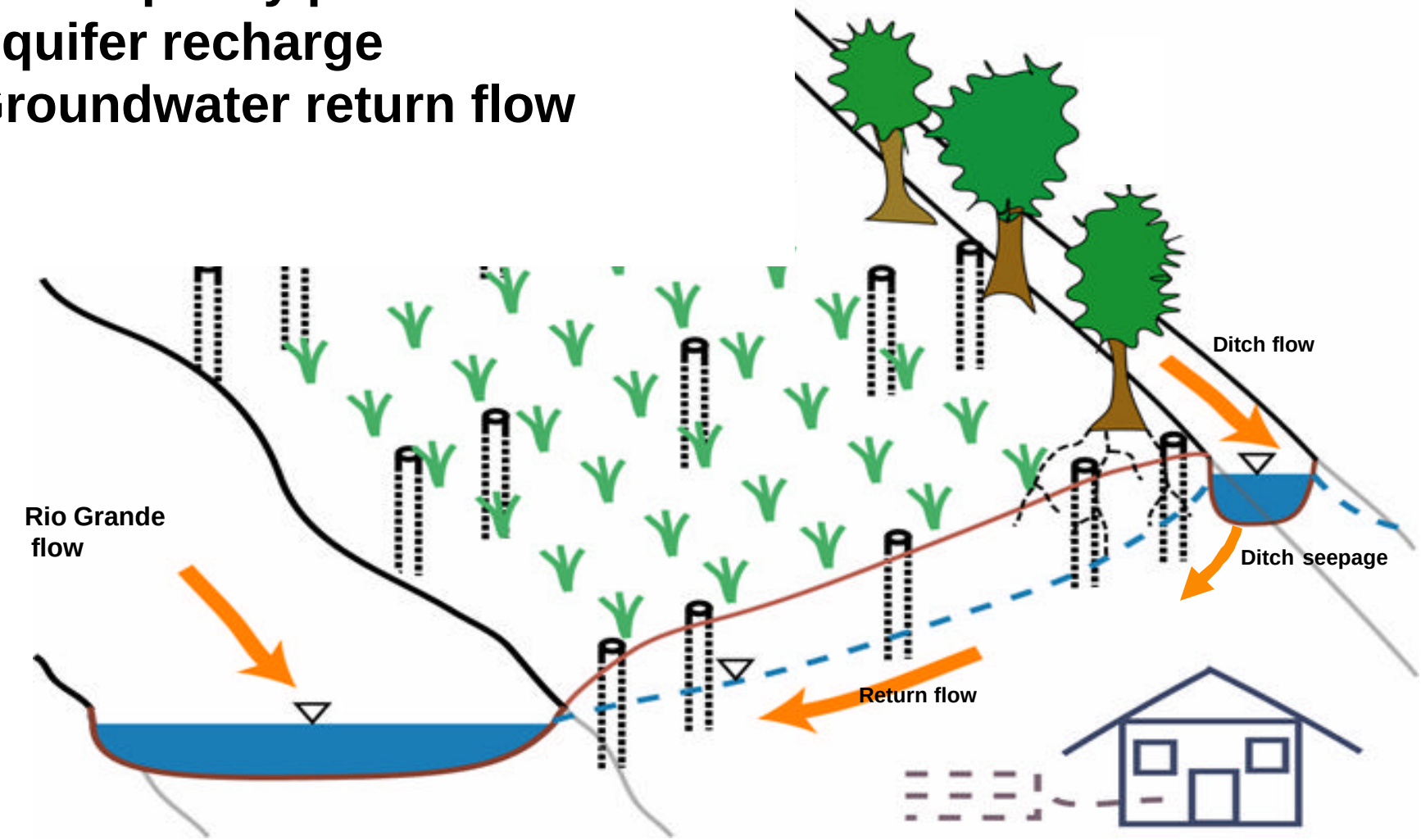
2003

PRESERVING ACEQUIAS

- Existence of acequia systems threatened
- Loosely knit acequia groups seek to protect their way of life

WISDOM OF THE ANCIENTS
BENEFITS OF ACEQUIA SEEPAGE

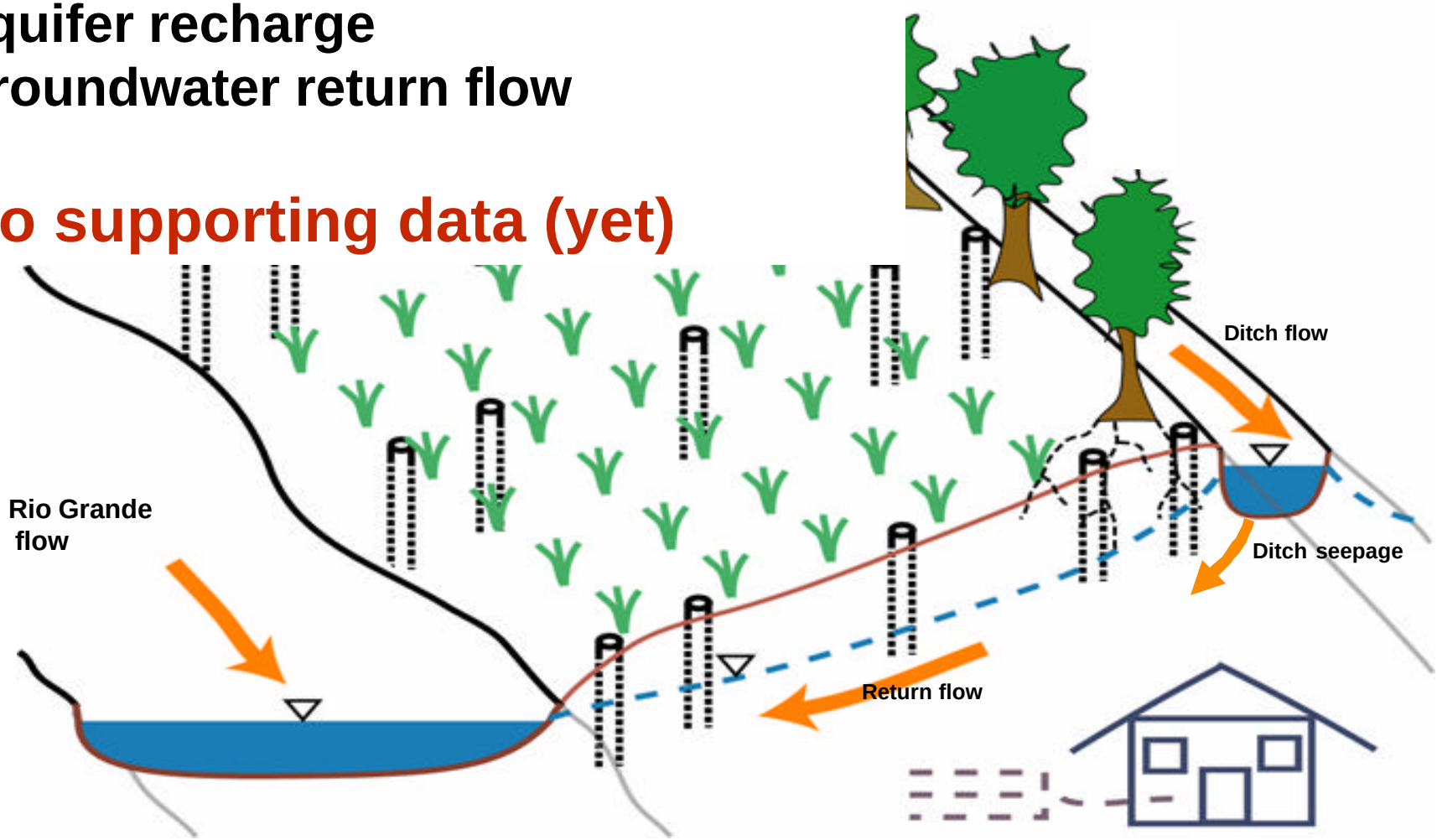
- Riparian vegetation
- Water quality protection
- Aquifer recharge
- Groundwater return flow



WISDOM OF THE ANCIENTS
BENEFITS OF ACEQUIA SEEPAGE

- Riparian vegetation
- Water quality protection
- Aquifer recharge
- Groundwater return flow

…no supporting data (yet)



SEEPAGE FROM DITCH

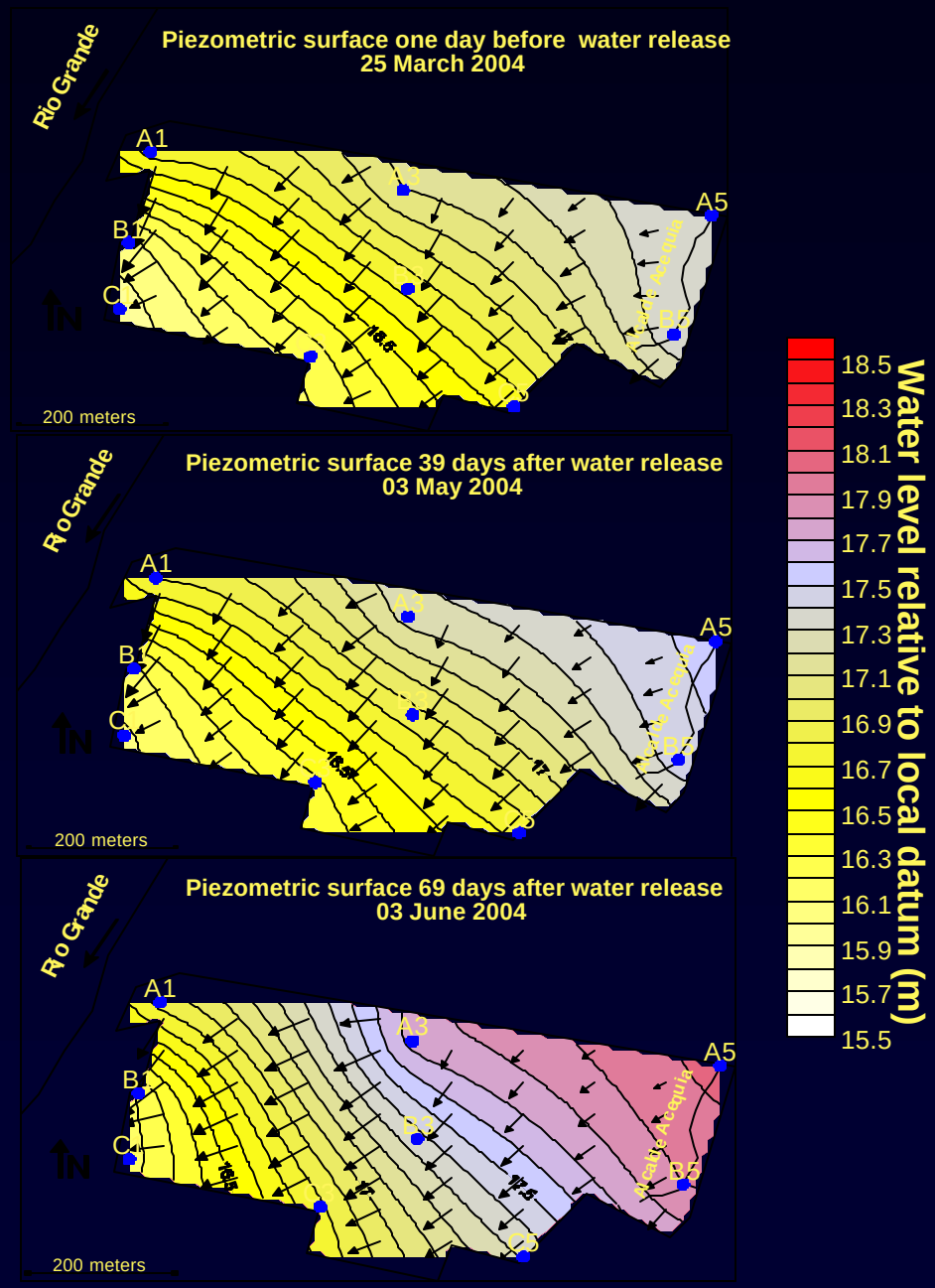
- Impoundment tests
- Inflow-Outflow tests
- 12% -16 % seepage over irrigated length of Alcalde Ditch

SHALLOW GROUNDWATER RESPONSE

- Without seepage, groundwater drops

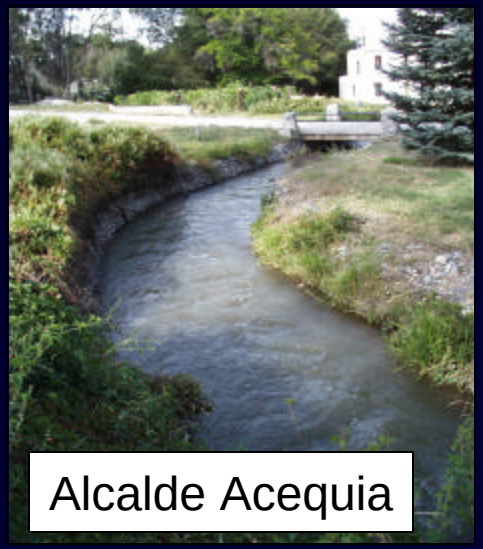
- With ditch seepage, water table starts rising; water quality data confirm ditch water origin of added shallow groundwater

- With ditch seepage and field seepage, water table rises and flowpaths orient more towards river

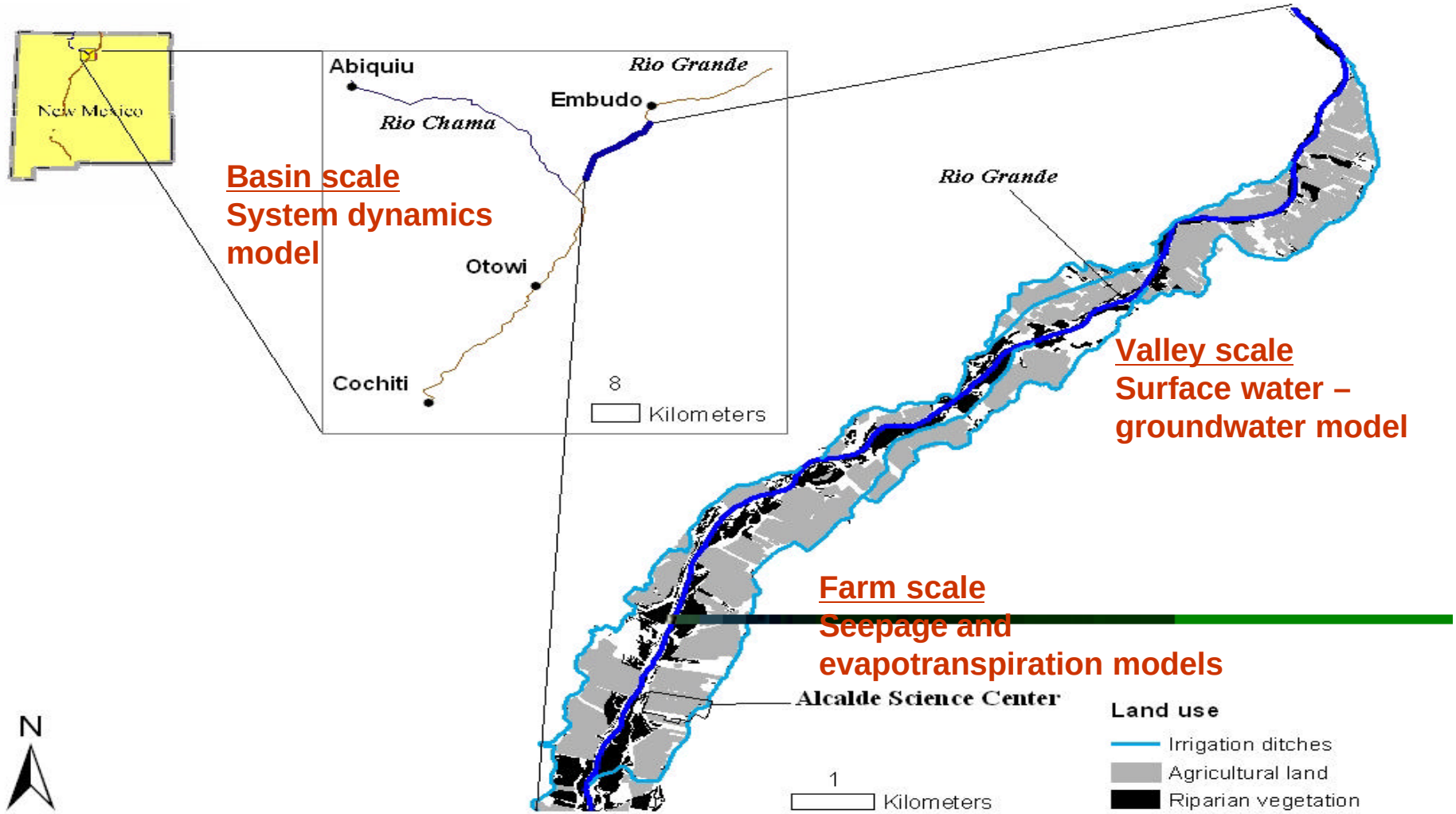


STUDY QUESTION

- How does seepage from irrigation ditches and flood-irrigated fields affect shallow groundwater return flow and river flow in irrigated corridors in semi-arid regions?



STUDY DESIGN



Funded by USDA CSREES NRI

MODELING

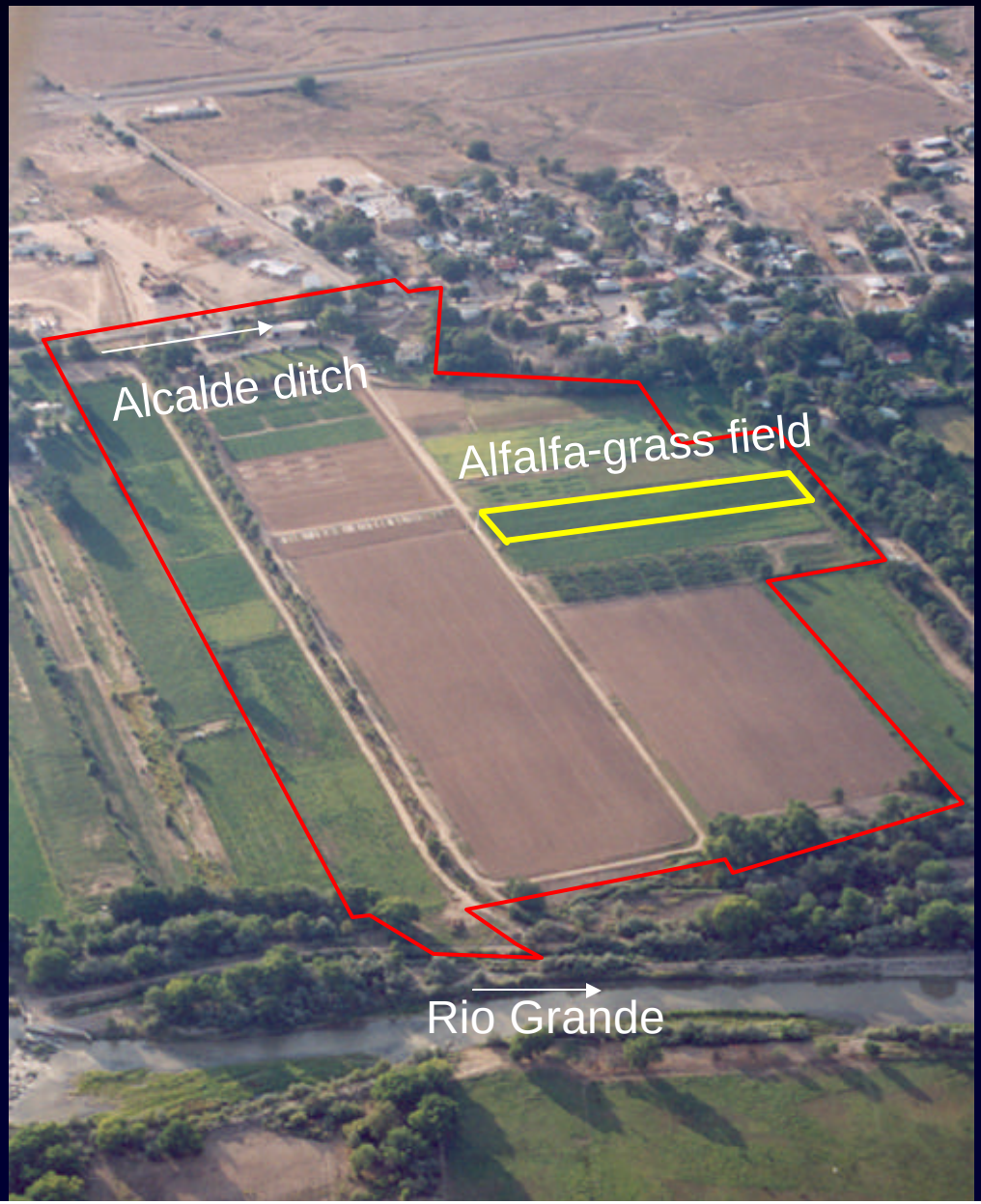
- 1-D (RZWQM) crop percolation

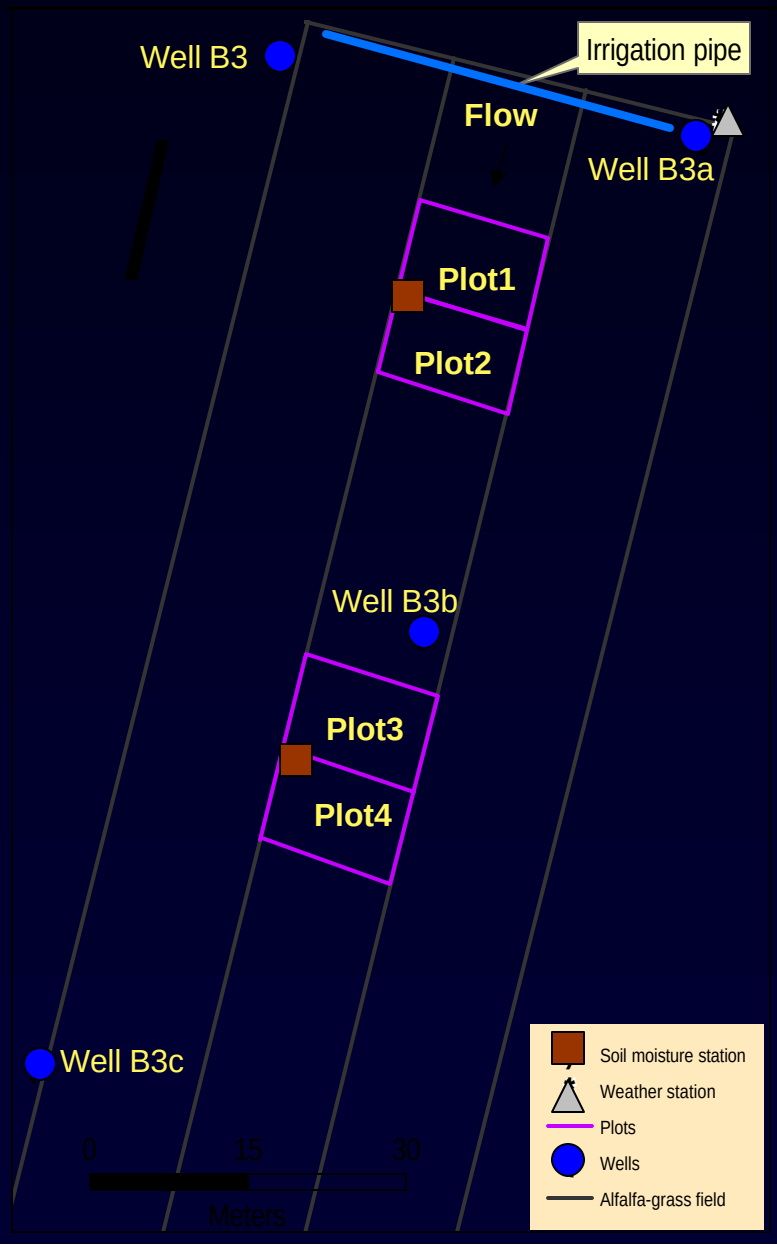
- 2-D (Hydrus-2D) crop and ditch seepage to shallow groundwater

- 3-D (MODFLOW) seepage, groundwater flow, and return flow along Alcalde Ditch and larger valley

- System Dynamics (POWERSIM) incorporation of seepage and return flow into interactive Rio Grande Basin model

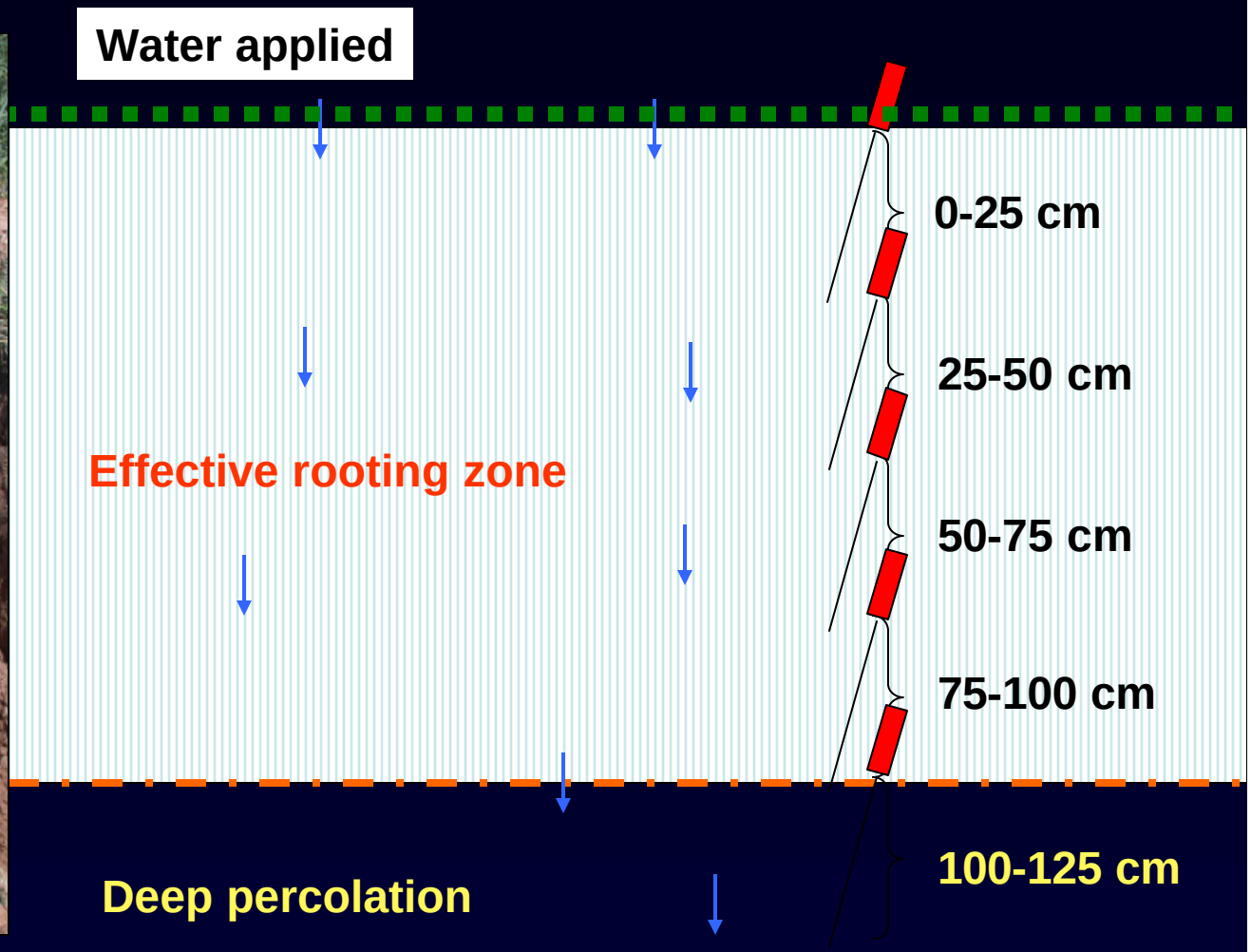
FLOOD IRRIGATION SEEPAGE STUDY





MEASURED DEEP PERCOLATION

TDR soil moisture probe installation for water balance method



ROOT ZONE WATER QUALITY MODEL

Input

- Crop type
- Rainfall, temp, RH, solar radiation, and wind speed
- Soil horizons and properties
- Water applied
- Surface residue

RZWQM

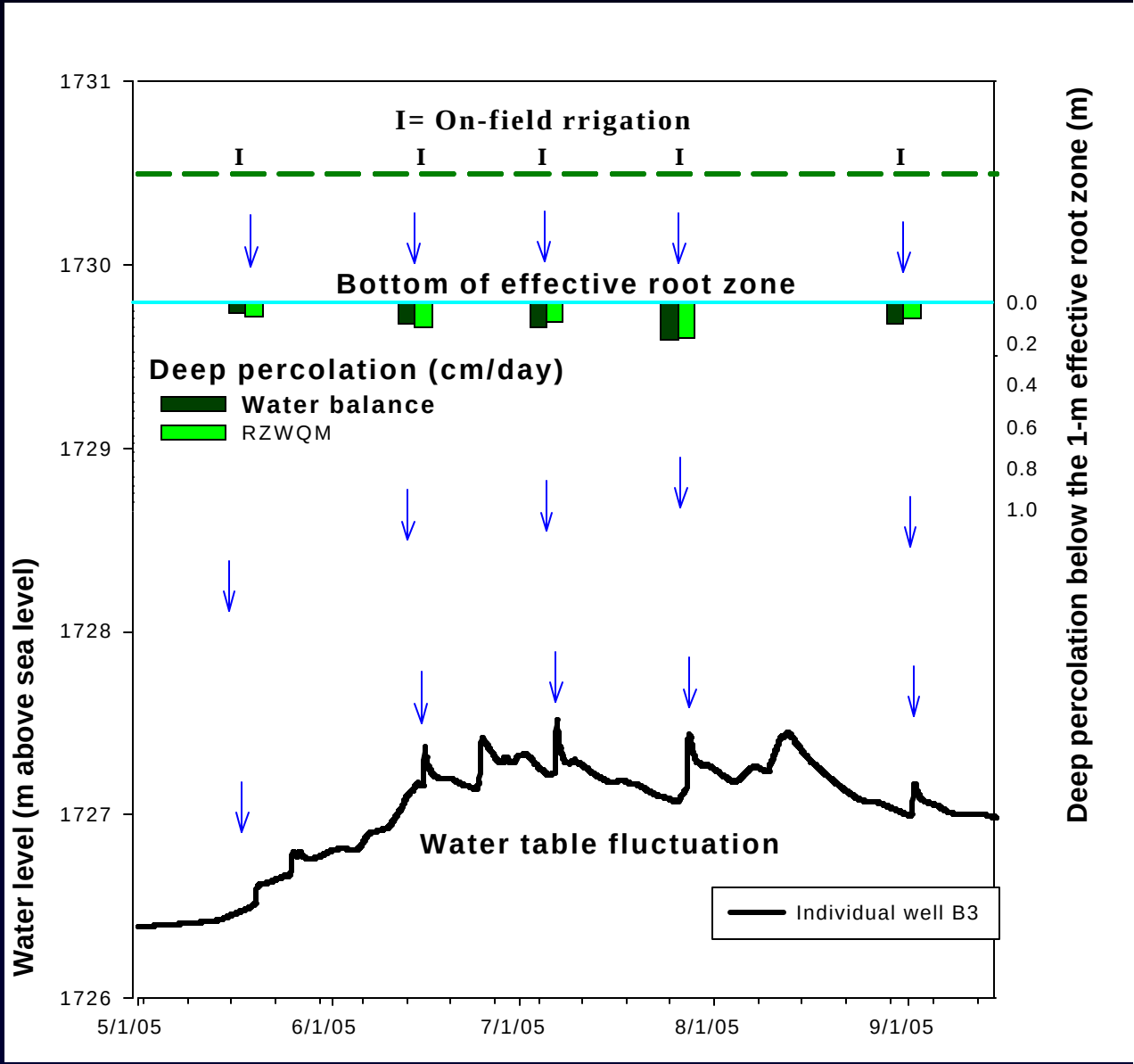
Output

- Deep percolation (cm/day)

PERCOLATION BELOW CROPS

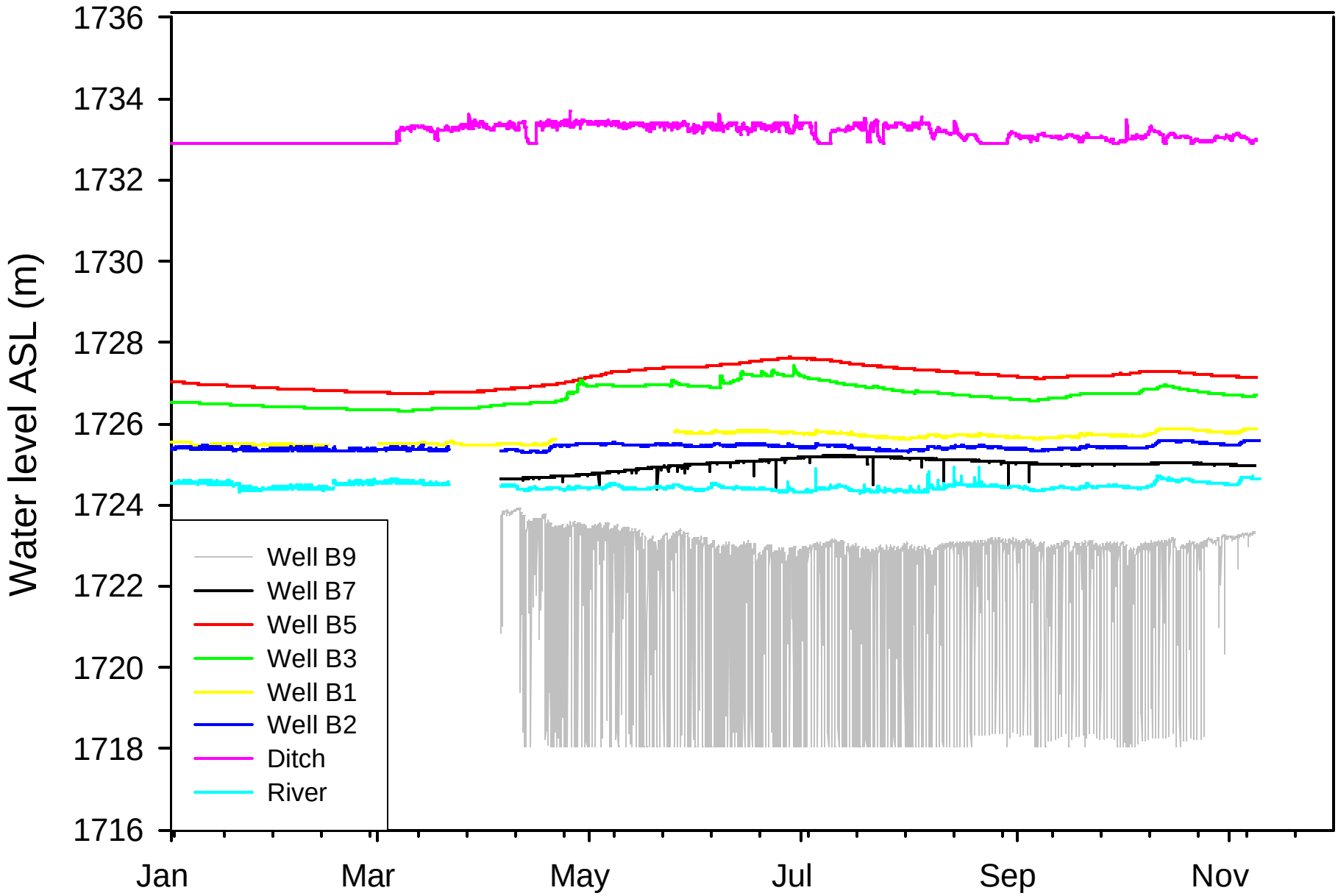
- 15-62% percolation (both measured and modeled) depending on antecedent soil moisture and irrigation amount

- Flood irrigation percolates past root zone and reaches shallow groundwater

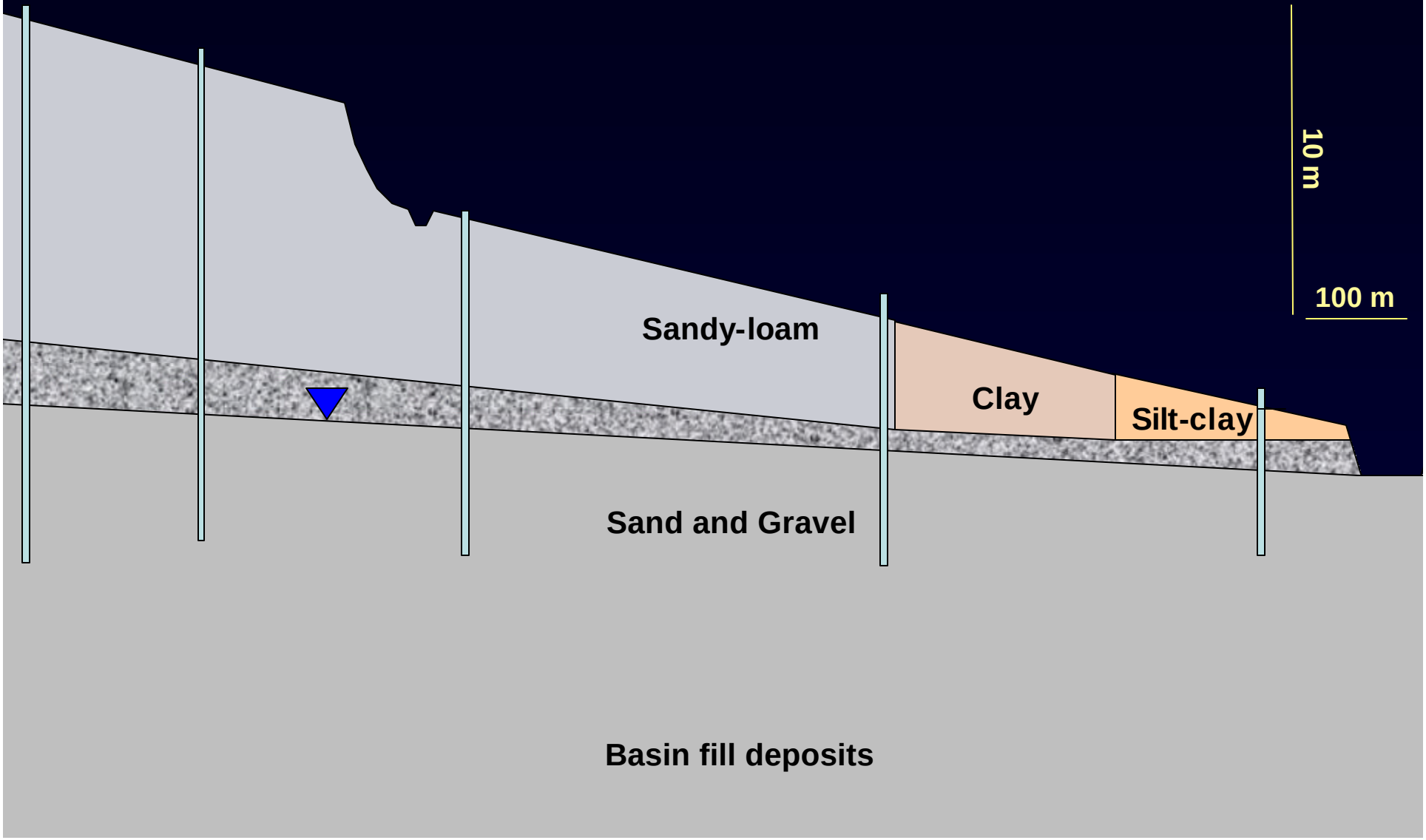


ALCALDE CORRIDOR WELL TRANSECTS

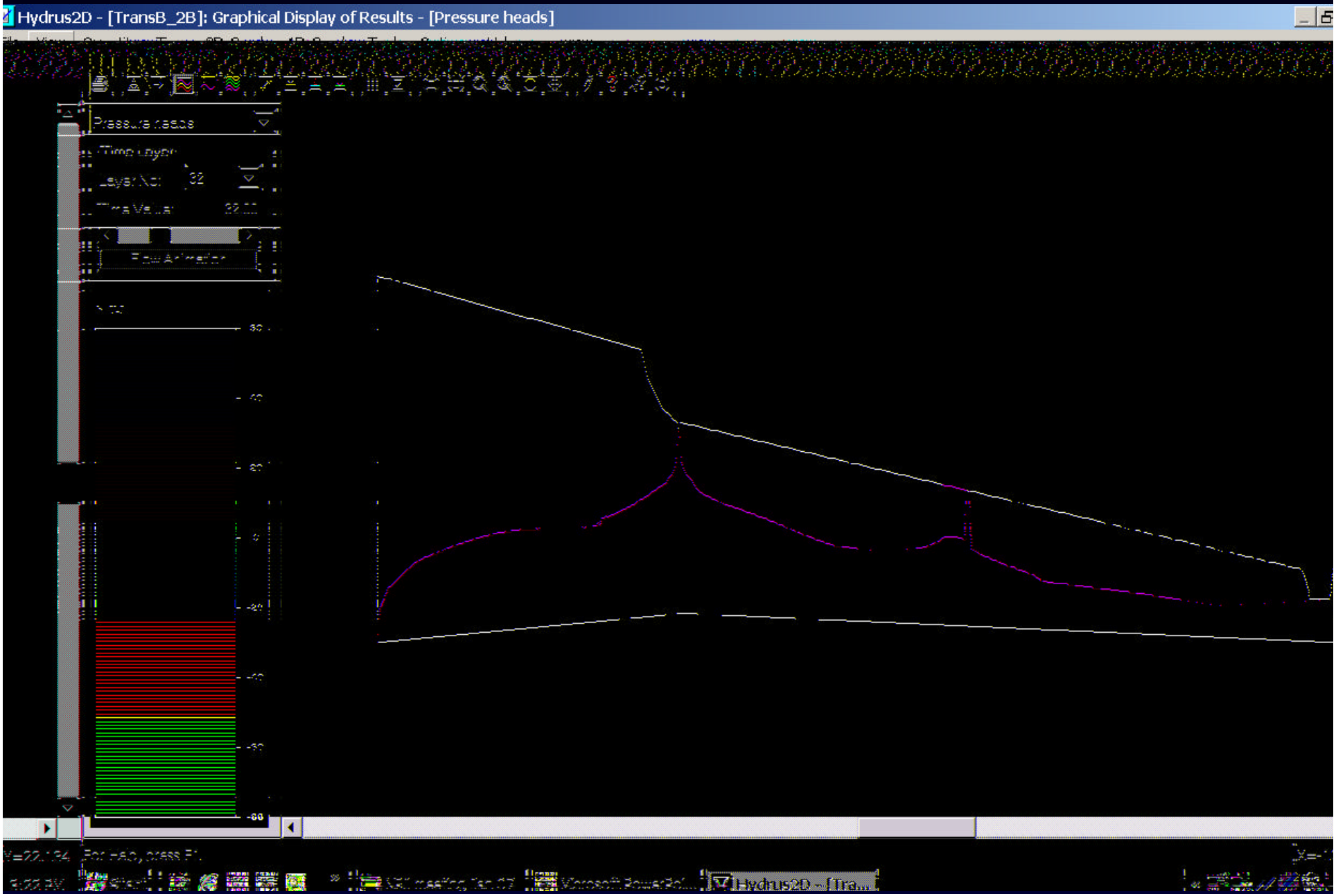
Water levels in transect B during 2006



- **Schematic of transect B for 2-D model**



HYDRUS 2-D SIMULATION



VALLEY WELL LOGS

Of 964 documented wells, 250 were identified with location and stratigraphy information in well logs

151 well logs were used to create the geological model

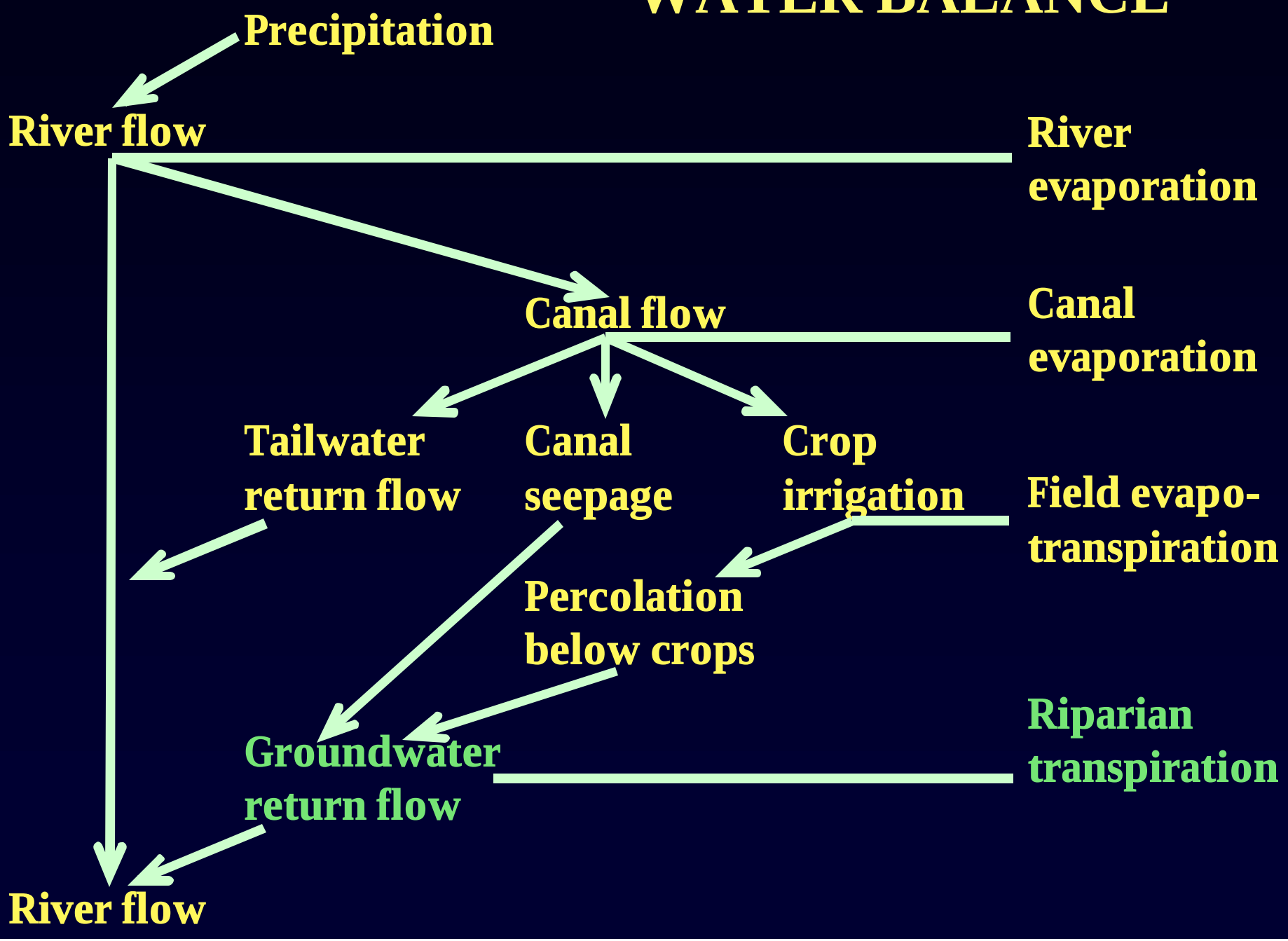
- Well logs were individually interpreted to determine 9 strata:

1)River-terrace deposits of gravel and sand (TAG)
2) Valley Alluvium (VA)
3) Rio Grande channel and floodplain deposits (RG)
4) Valley alluvium and River-terrace deposits (VA-TAG)
5) Lower Santa Fe Group (LSF)
6) Undivided Middle Santa Fe Group (MSF)
7) Landslide deposits (ldsl)
8) Valley alluvium and Landslide deposits (VA-ldsl)
9) Valley alluvium and Rio Grande channel and floodplain deposits (VA-RG)

GEOPHYSICAL MODEL

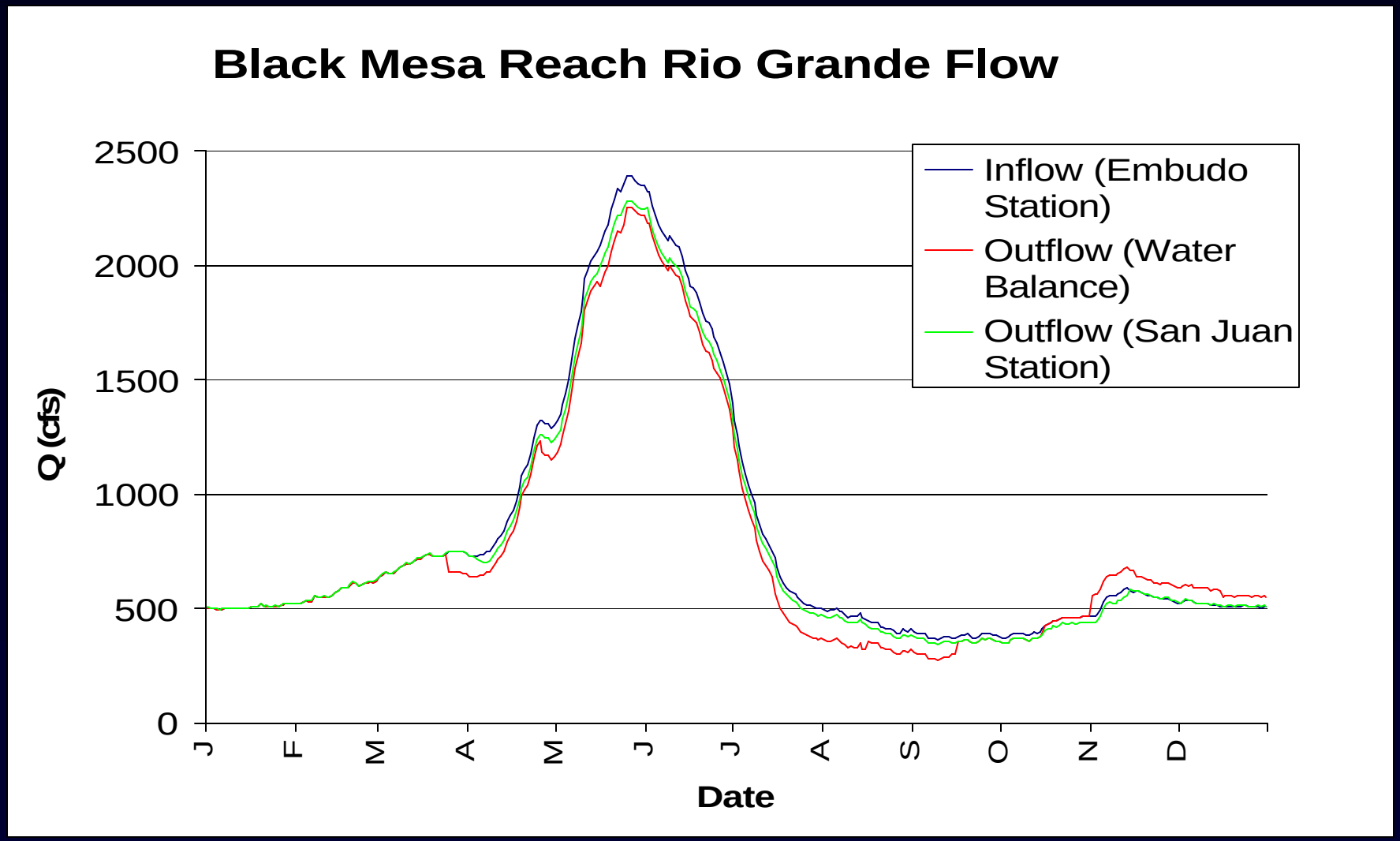
- Geophysical model for 3-D groundwater model was based on continuous layers generated from well log point data

WATER BALANCE



VALLEY INFLOW AND OUTFLOW

Acequia system redistributes river flow from spring snowmelt through shallow groundwater return flow to fall river flow



PRELIMINARY CONCLUSIONS

- Acequia systems act as aquifer storage and recovery
- Net reduction in losses to atmosphere from storage for 1-3 months underground
- Return flow provides wet water downstream when most needed after peak runoff season
- Modeling will integrate surface water and groundwater interactions to predict hydrologic effects of changing land use, water use, and climate

THANK YOU!

Researchers	*Funding*
Guldan, S.	USDA Rio Grande Basin Initiative
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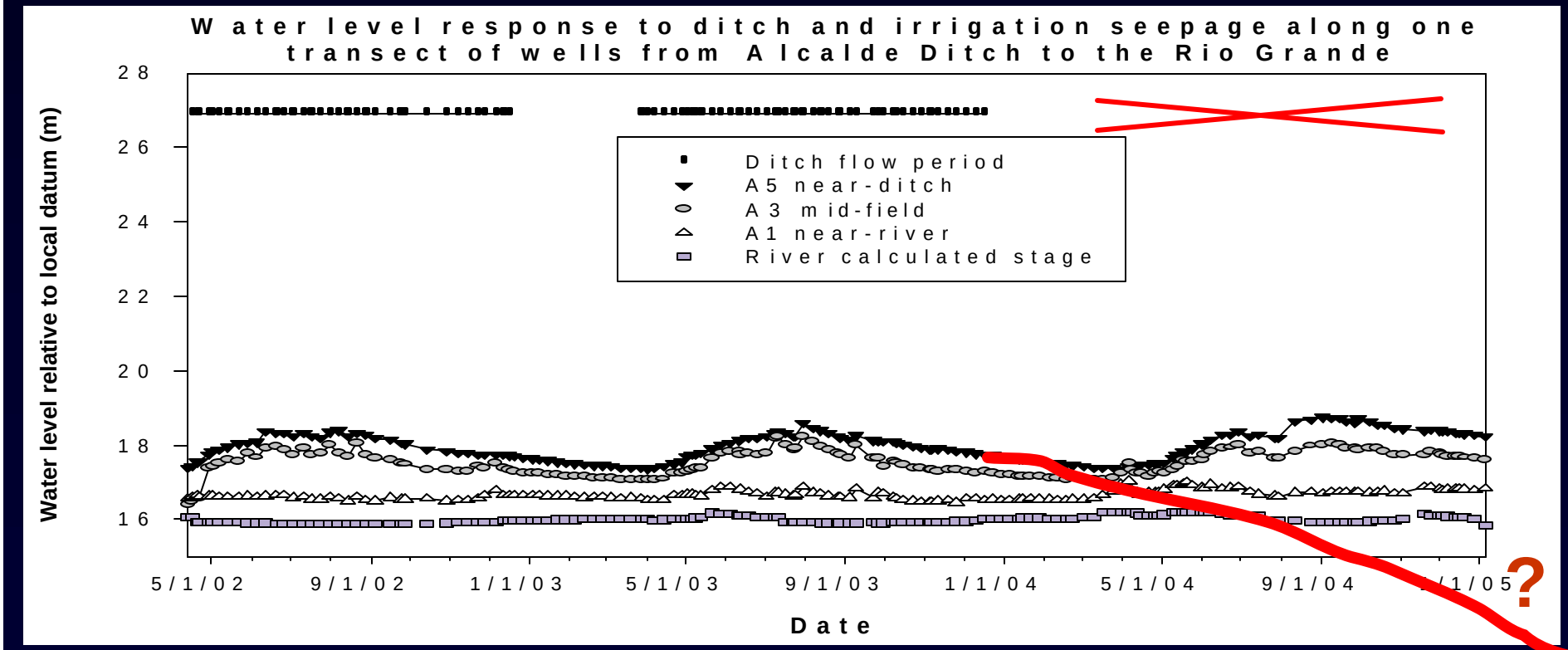
Archuleta, D.	State of New Mexico
Shukla, M.	USDA CSREES NRI
Ulery, A.	
Abbott, L.	
Samani, Z.	
Sevinc, Y.	
Bleiweiss, M.	
VanLeeuwen, D.	

Floodplain hydrology and ecosystem functions supported by acequia systems

GROUNDWATER RECHARGE

- Lost yearly recharge without seepage inputs along Rio Grande



RETURN FLOW TO THE RIVER

- Flow to downstream users later in season when most needed
- Reduced evaporation in northern NM groundwater compared to southern NM surface water

FLOODPLAIN HYDROLOGIC COMPLEXITY

- Hydrologic complexity important for terrestrial and aquatic ecosystems (Landers et al., 2002)

- Before channelization, Rio Grande floodplain more complex with side channels and islands

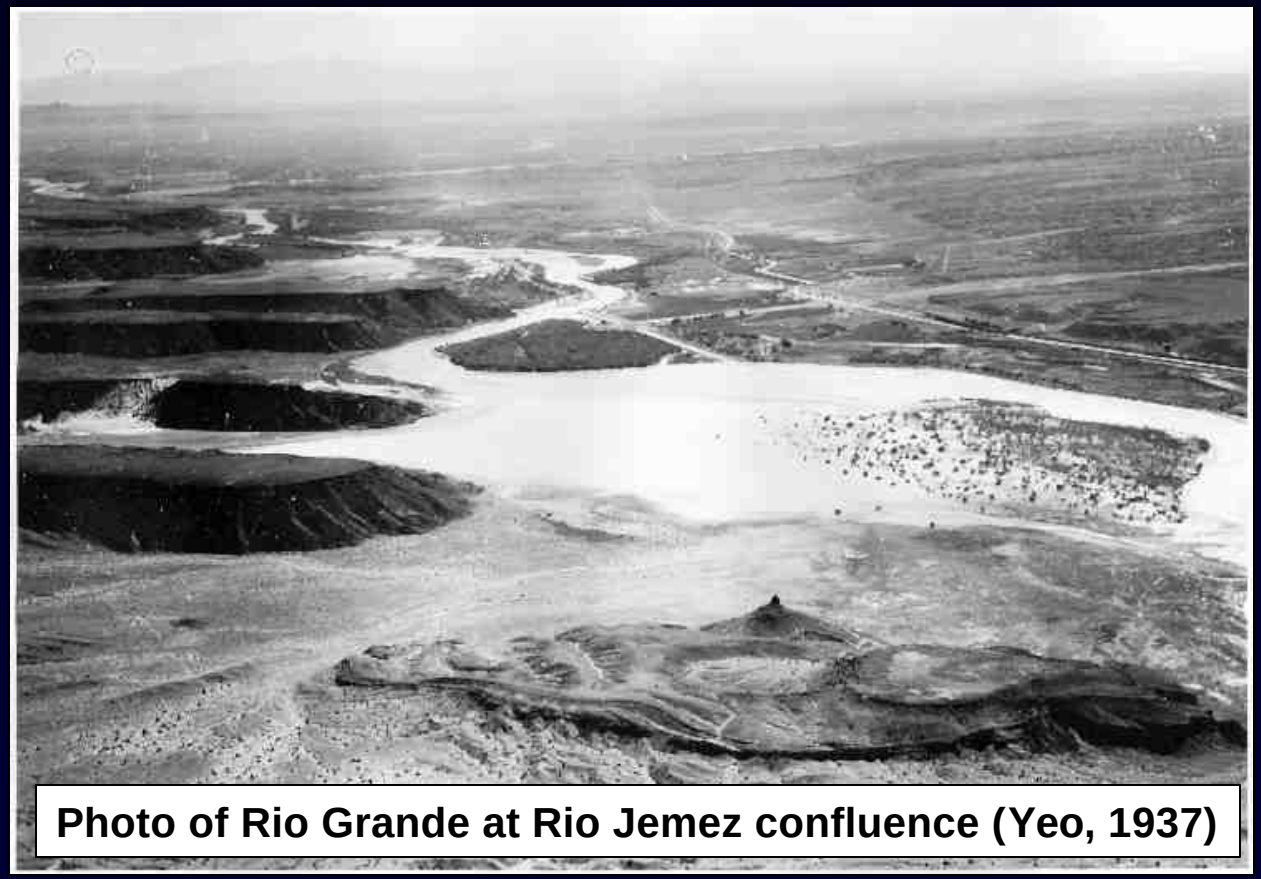


Photo of Rio Grande at Rio Jemez confluence (Yeo, 1937)

Landers D.H., A.G. Fernald, and C. Andrus. 2002. Off-channel Habitats.

Functionally similar floodplain complexity in river side channel and acequia channel

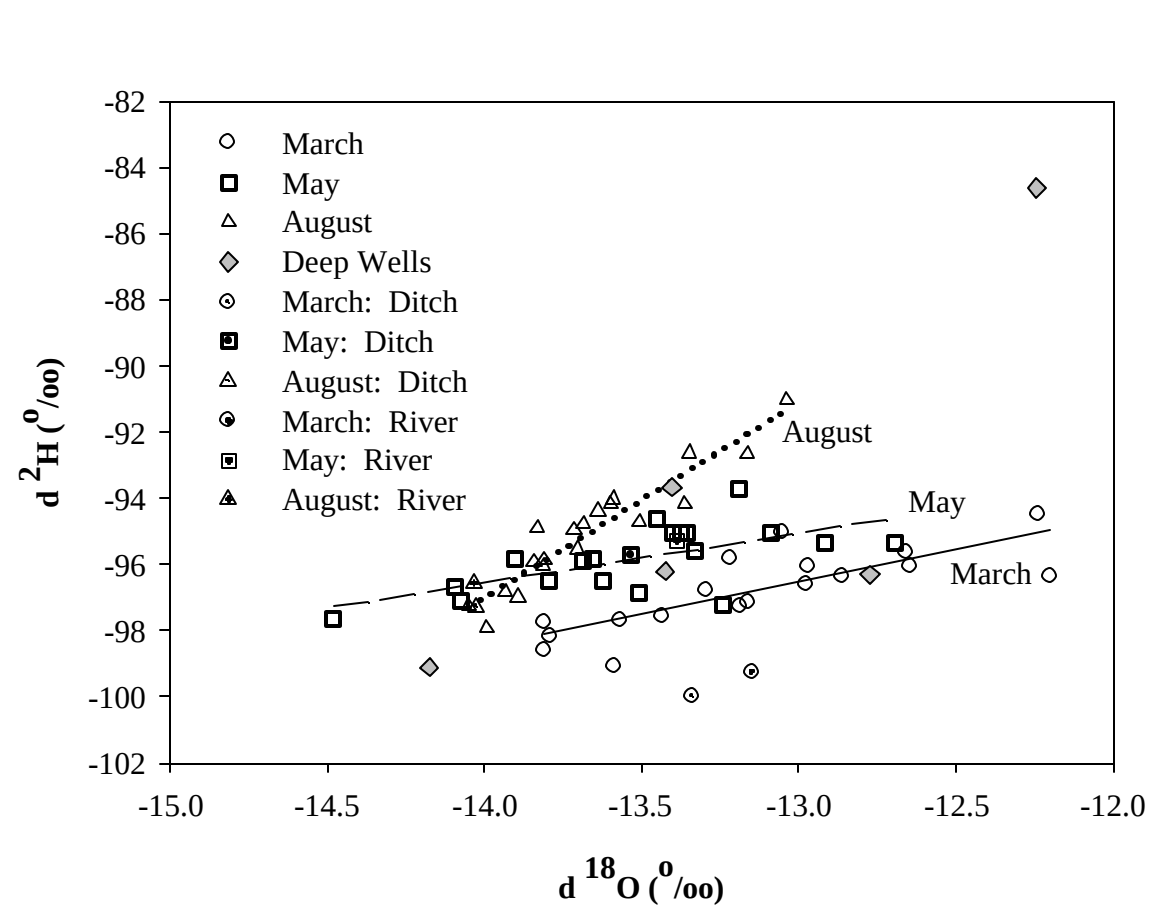
The future…
Integrated floodplain hydrology research for sustainable agriculture and healthy ecosystems in river valleys of water scarce regions

LAND USE ANALYSIS

- Imagery 1962, 1997, 2003
- Ground truthing (1997 recollection) and 2005-2006

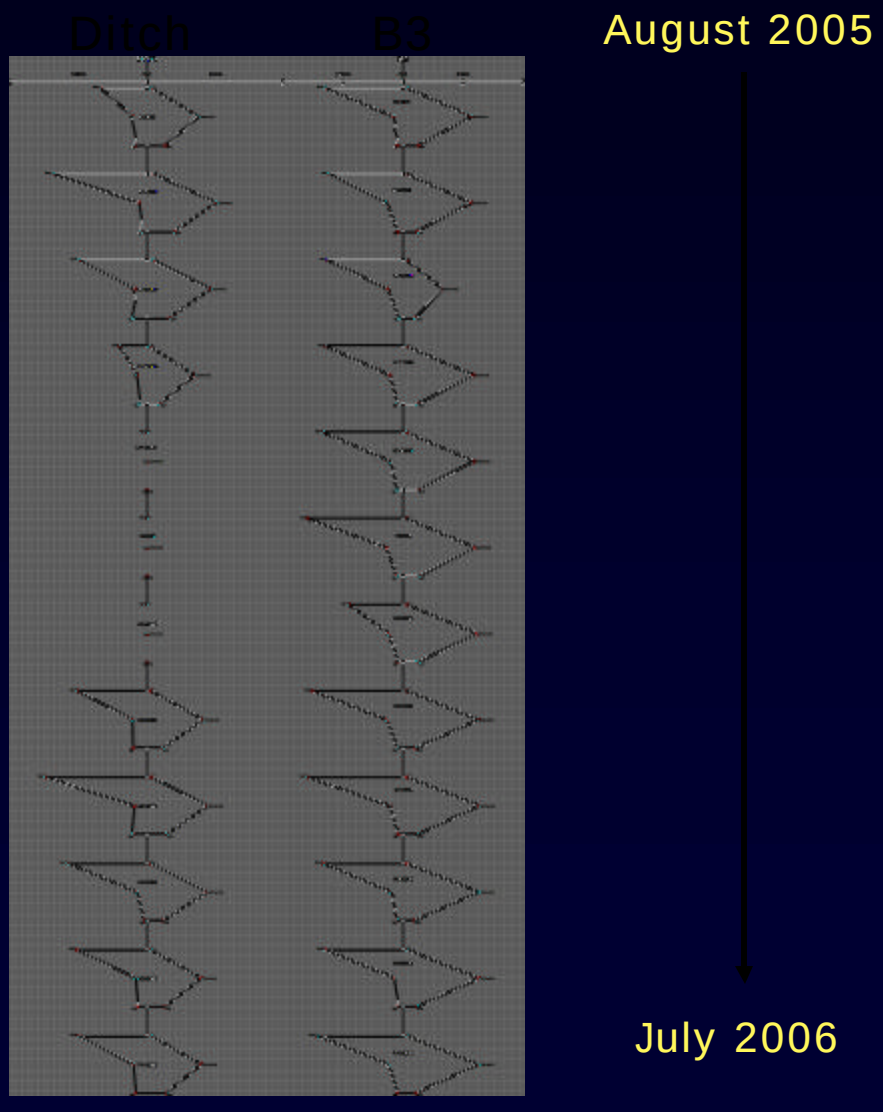
GROUNDWATER SOURCES

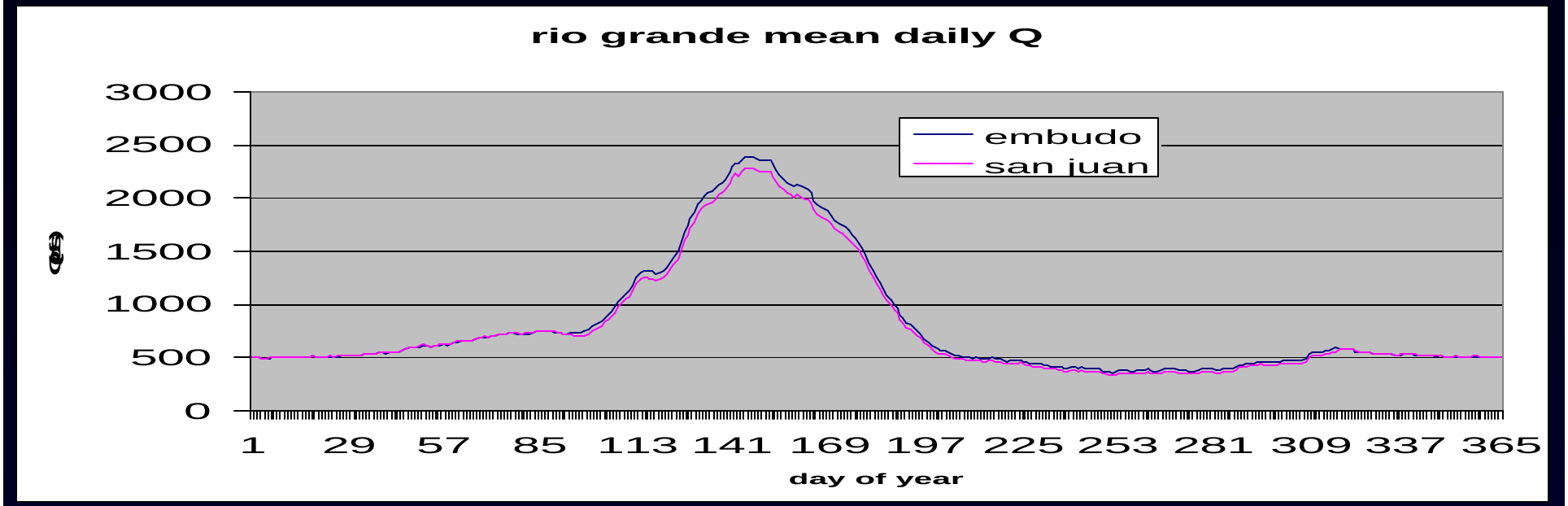
- Stable isotope results show no strong pattern of deep groundwater upwelling

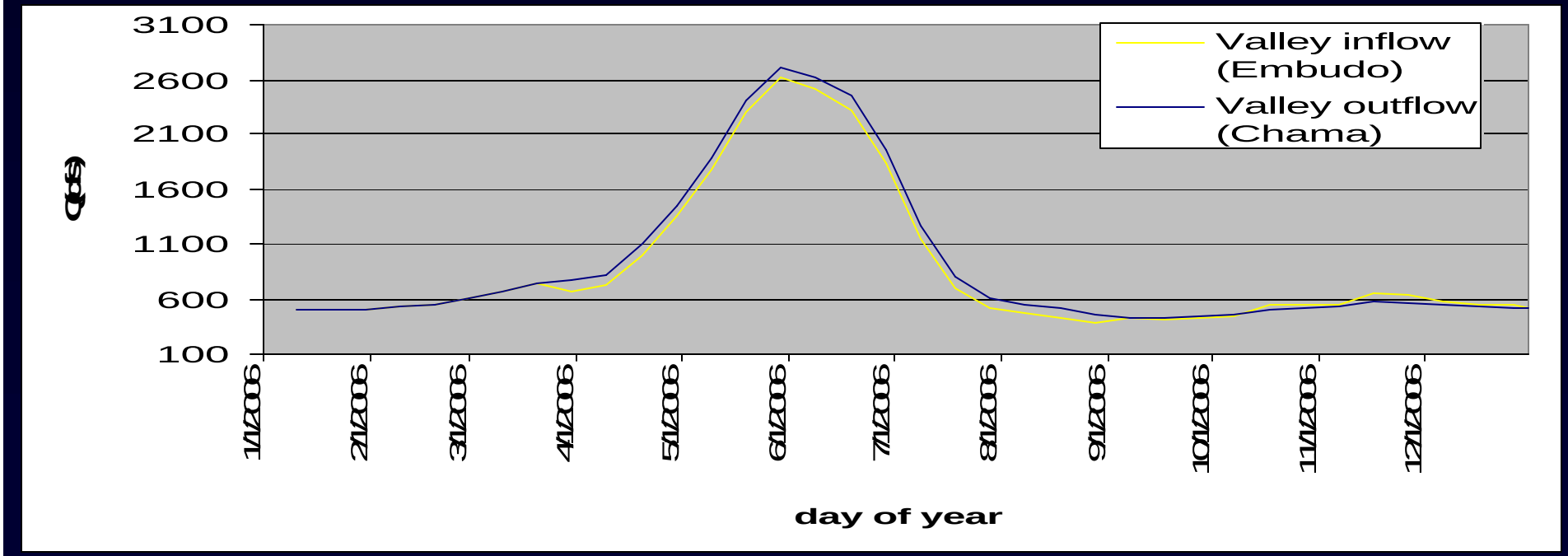


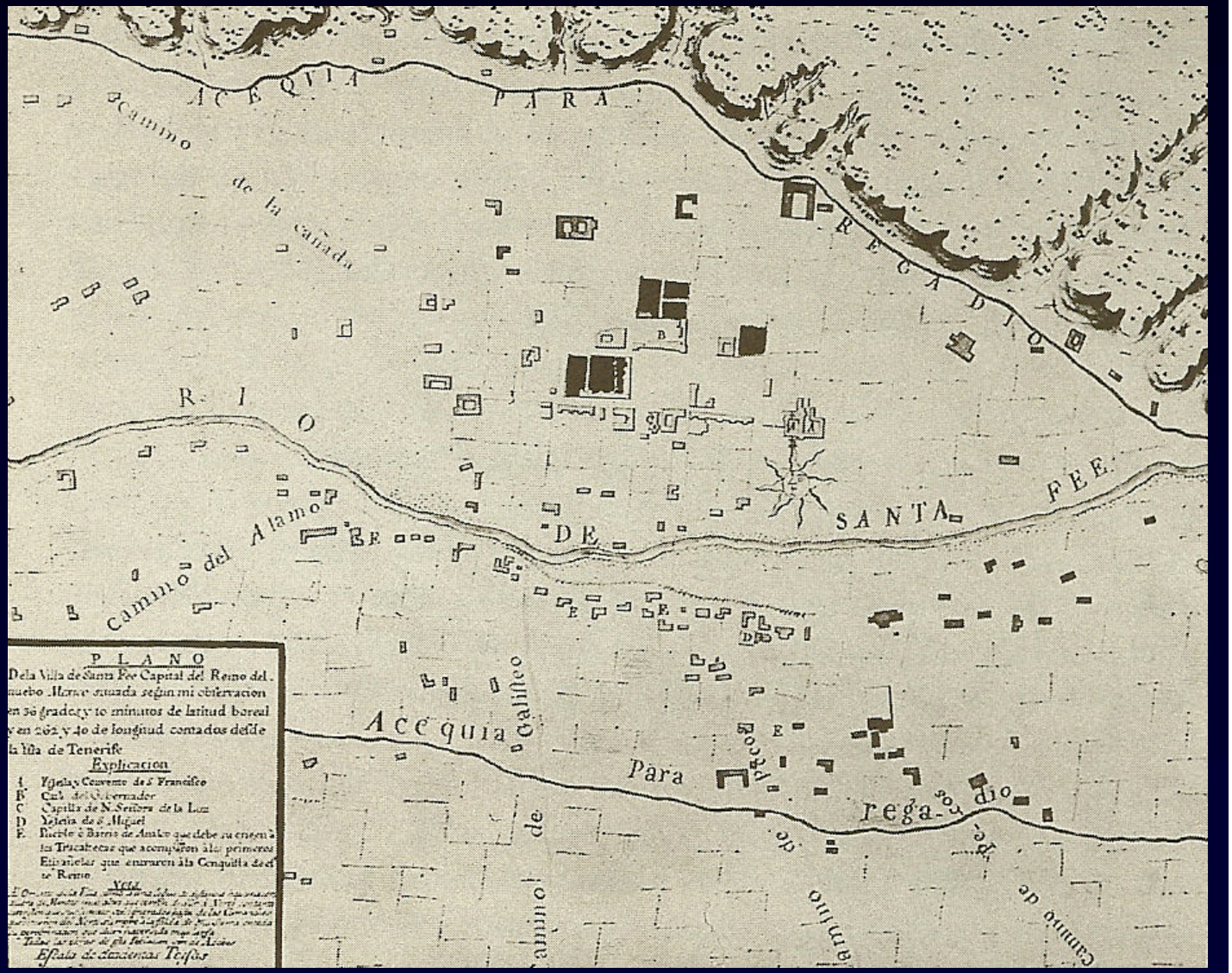
Discussion:

- Ion Concentrations
  - Flood Irrigation and Shallow Groundwater Interactions
    - Ditch inputs occur
      - Similar to ditch during irrigation season
      - Differed after irrigation season




rio grande mean daily Q
3000
2500
2000
1500
1000
500
0
Q (cfs)
1
29
57
85
113
141
169
197
225
253
281
309
337
365
day of year
embudo
san juan


3100
2600
2100
1600
1100
600
100
Q (cfs)
1/1/2006
2/1/2006
3/1/2006
4/1/2006
5/1/2006
6/1/2006
7/1/2006
8/1/2006
9/1/2006
10/1/2006
11/1/2006
12/1/2006
day of year
Valley inflow (Embudo)
Valley outflow (Chama)


ACEQUIA PARA REGADIO
Camino de la cañada
RIO DE SANTA FEE
Camino del Alamo
Acequia Para regadio
Camino de Galisteo
Camino de Pecos
PLANO
Dela Villa de Santa Fee Capital del Reino del nuebo Mexico situada segun mi observacion en 36 grados y 10 minutos de latitud boreal y en 262 y 40 de longitud contados desde la Isla de Tenerife
Explicacion
A Yglesia y Convento de S. Francisco
B Casa del Gobernador
C Capilla de N. Señora de la Luz
D Yglesia de S. Miguel
E Pueblo ò Barrio de Analco que debe su origen à los Tracaltecas que acompañaron à los primeros Españoles que entraron à la Conquista de este Reino
Nota
Escala de dozientas Toisas

REDUCED ACEQUIA FLOWS

- Water transfers to municipalities
- Less agricultural activity
  - Urbanization
  - Rising land values
  - Water transfers

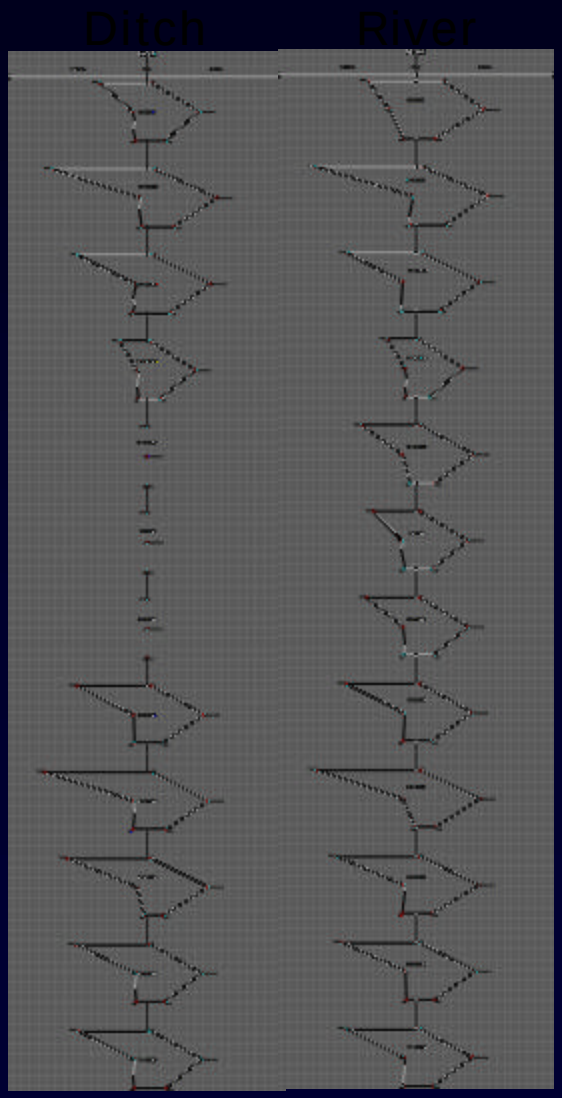
MEASURED VERSUS MODELED DEEP PERCOLATION

Date	Water balance method (cm)	RZWQM (cm)
5/19/05	**5.3**	**6.6**
6/15/05	**10.4**	**11.7**
7/6/05	**12.4**	**9.8**
7/27/05	**18.0**	**17.3**
9/1/05	**10.1**	**7.4**

- **Good match between measured and modeled percolation**
- **Less deep percolation with drier antecedent soil moisture**
- **More deep percolation with greater water application**

DITCH AND RIVER WATER QUALITY

- Stiff diagrams show ditch water little changed from river source water



August 2005

July 2006

WELL TRANSECTS AT ALCALDE CENTER

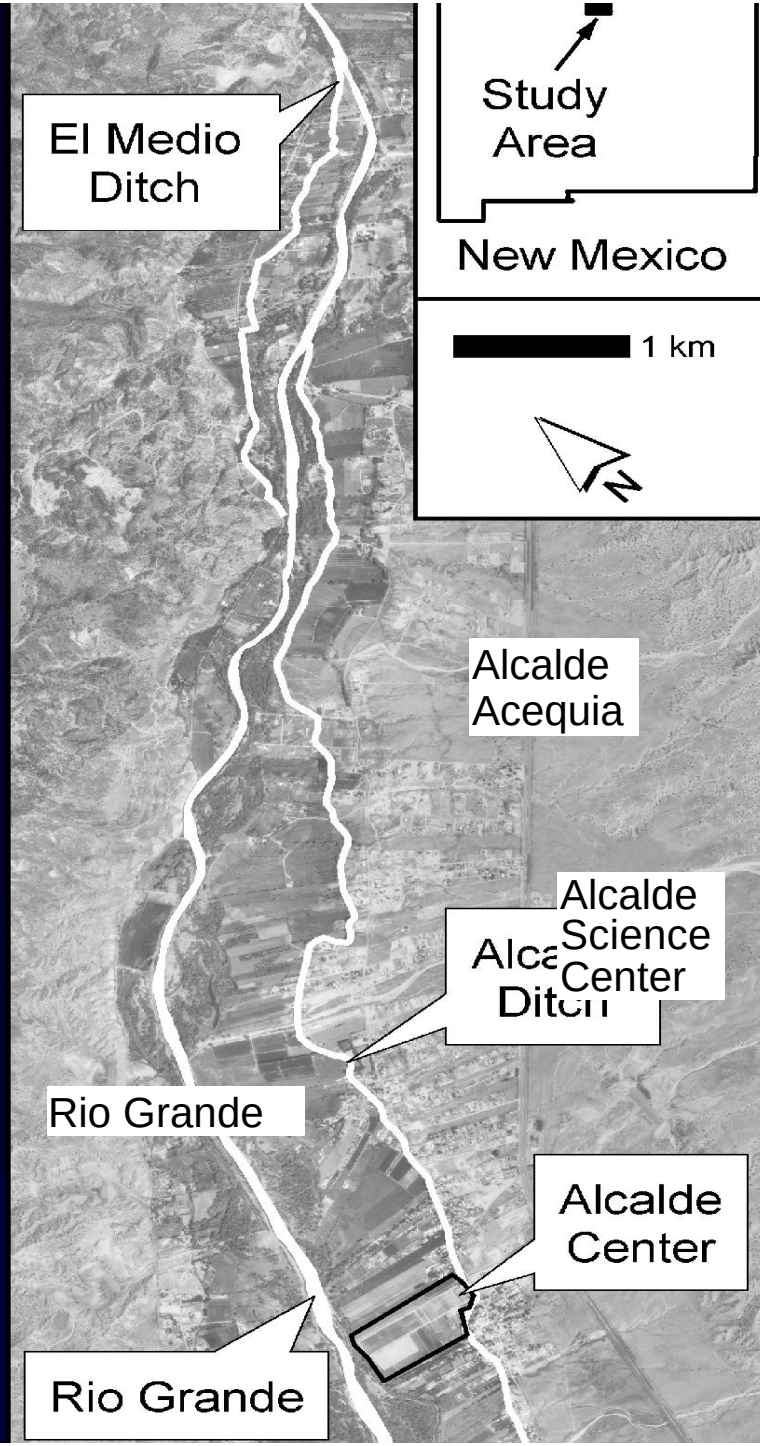
- Three transects of 2” wells
- Water levels since March 2002
- Water quality since July 2003

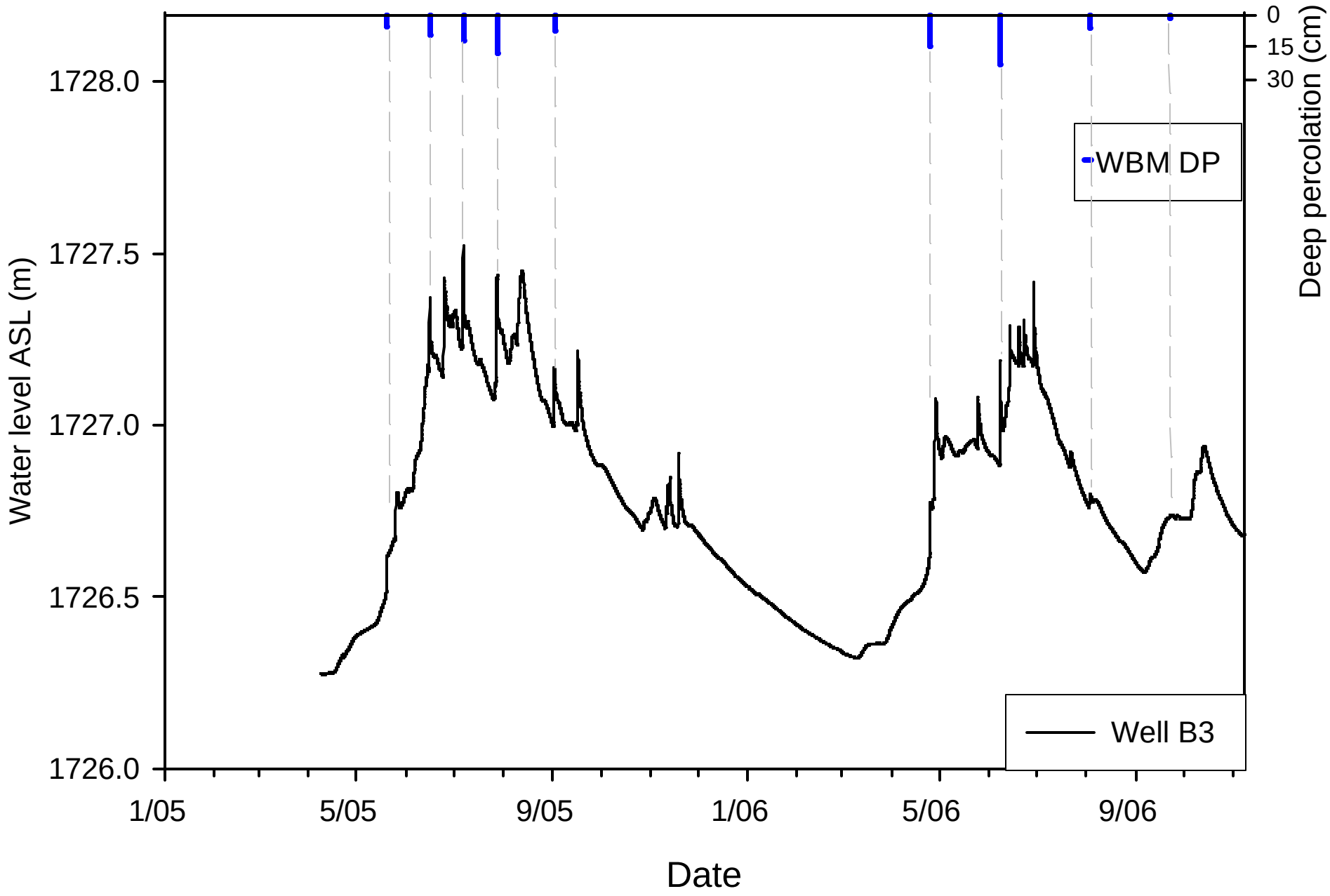
STUDY PROBLEM

- Widespread interest in reducing seepage losses may overlook potential benefits of seepage from acequias and flood irrigated fields

STUDY AREA

- 9 km-long acequia
- 23 cm/yr average precipitation
- alluvial soils overlying late Pleistocene fluvial gravels




Water level ASL (m)
1728.0
1727.5
1727.0
1726.5
1726.0
1/05
5/05
9/05
1/06
5/06
9/06
Date
Deep percolation (cm)
0
15
30
WBM DP
Well B3

Study site:

- Eight different soil types in the entire corridor

- **Fruitland sandy loam, Werlog clay loam, and Abiquiu-Peralta complex** account for 84% of the total soil in the corridor

- The three soils are present at the NMSU-Alcalde Science Center

Experimental design:

- Six 12 m by 12 m paired-experimental plots

- Three soil types (11, 18, and 21)

- Dependent variables: Soil moisture, soil temperature, water level, water temp

- Treatments: Fixed amounts of irrigation water applied (5cm, 20 cm, 30 cm, 40 cm, and 60 cm)

- Covariate: Depth to water table

Hydrus 2d input data

Hydraulic model:
van Genuchten – Mualem with no hysteresis

Input parameters:

- Soil particle fraction (sand, silt, loam)
- Soil residual water content (at 15 bar)
- Soil water content at saturation (at 0.3 bar)
- Soil bulk density
- Soil initial water content before irrigation
- Upper and lower boundary conditions (e.g. constant pressure and free drainage)

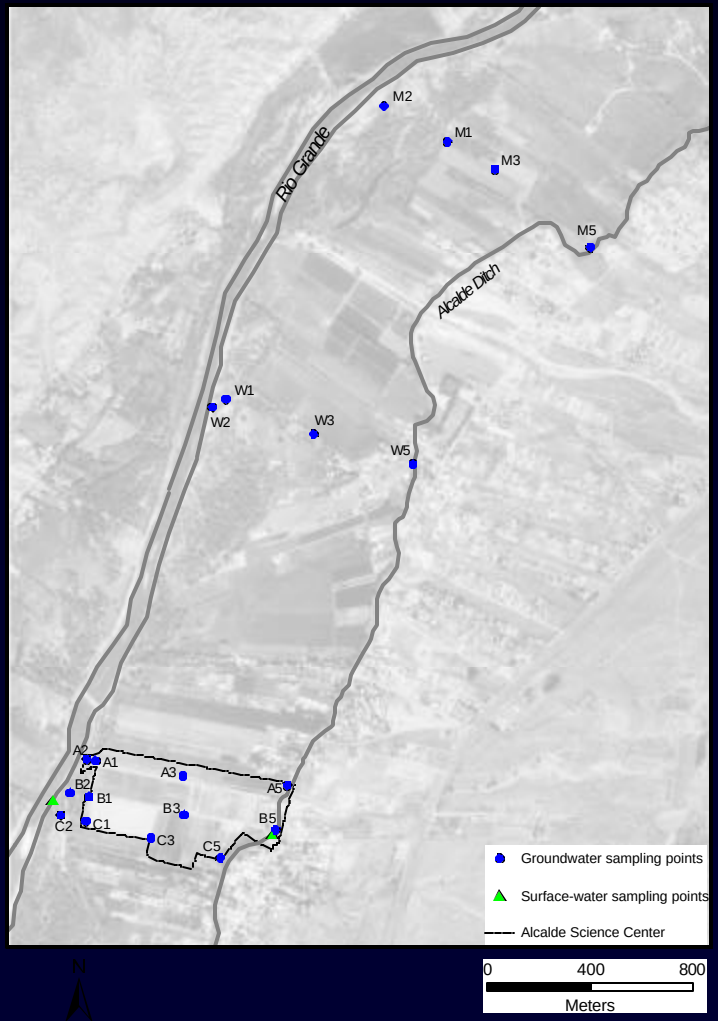
* Soil data will be determined from soil samples collected during the pits excavation

Hydrus 2d expected output data

- Water mass balance
- Deep drainage flux
- Water transport through different nodes
- Water table response

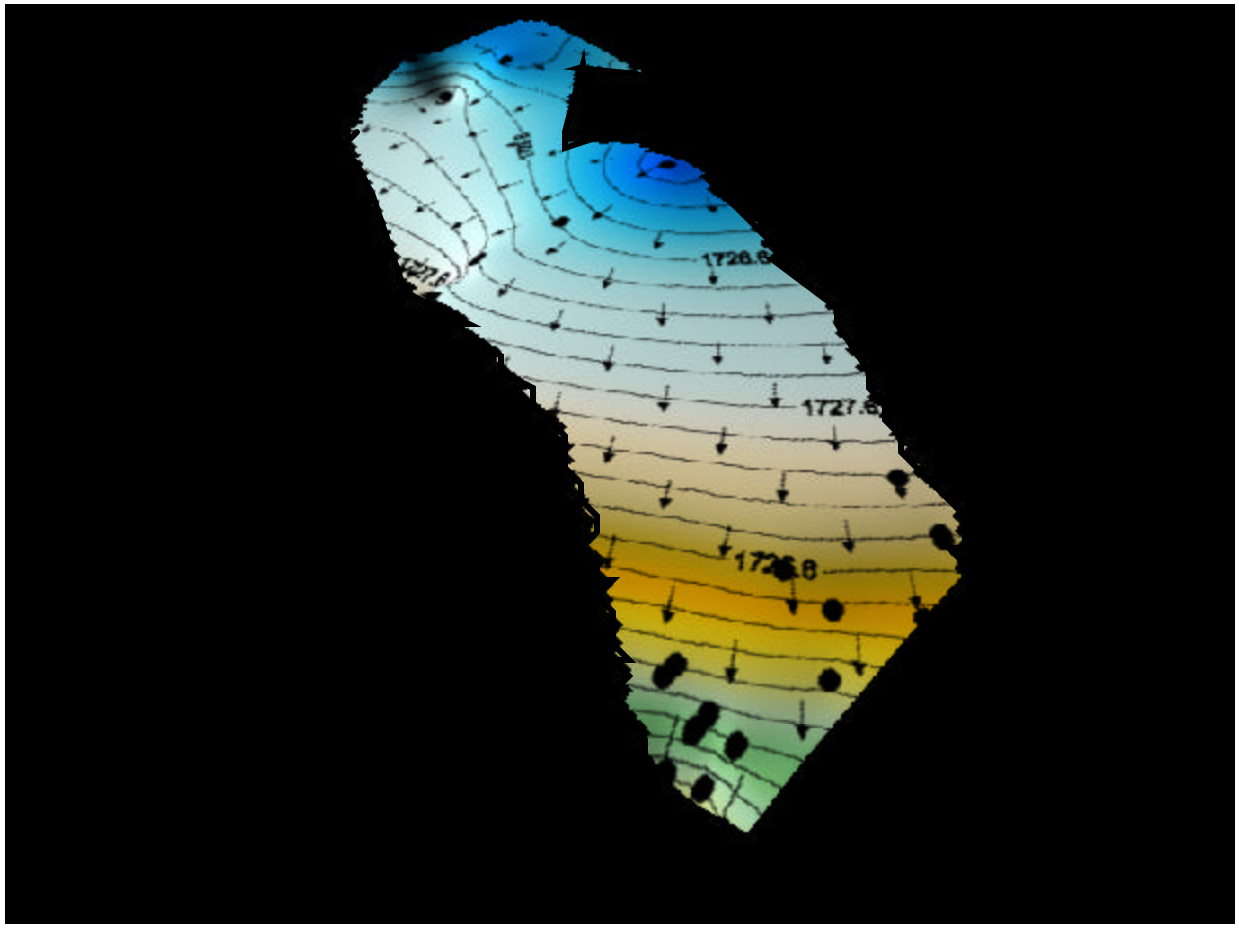
WATER QUALITY STUDY

- Additional well transects
- Monthly samples
- Analyzed for all major ions



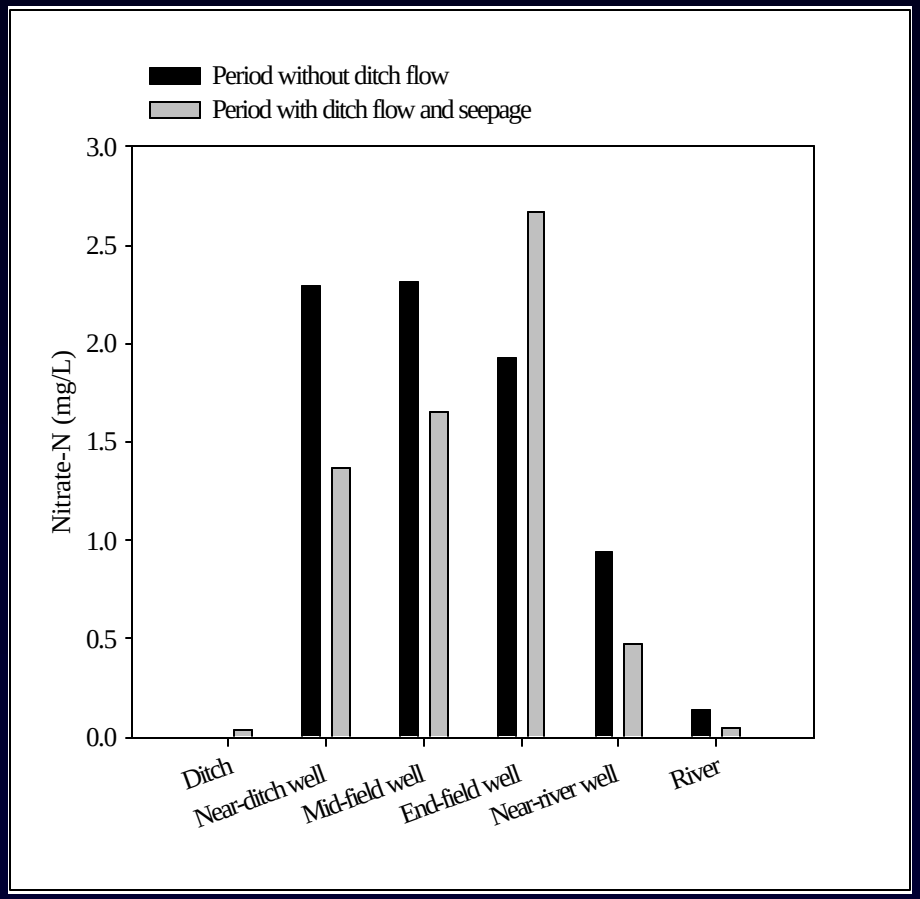
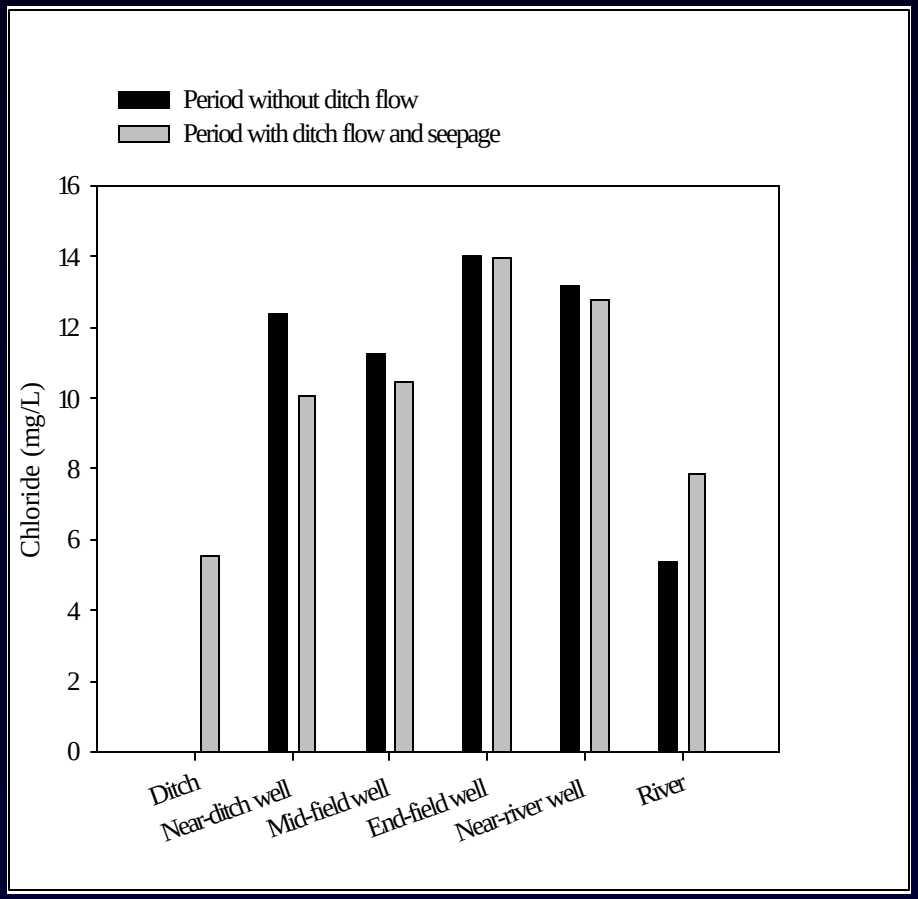
GAINING RIVER

- River stage always below floodplain water table
- Stable isotopes show little deep groundwater upwelling



SEEPAGE DILUTES GROUNDWATER IONS

Nitrate



Chloride