

## Hydrologic Aspects of Paso Del Norte Region

by  
 Thomas Maddock  
 Professor and Head  
 Department of Hydrology and Water Resources  
 University of Arizona

## MODELING THE MESILLA, or IF AT FIRST DON'T SUCCEED, TRY, TRY AGAIN

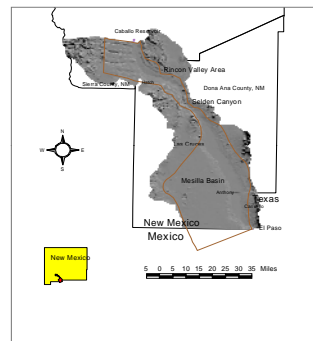
by  
 Thomas Maddock

### Since 1984 There Have Been Seven Major Groundwater Flow Models Built For The Mesilla Basin

This talk will attempt to explain:

- why these models were develop
- how these models changed and integrated in new techniques
- how were they used in management of ground and surfaces water.

### Studies Areas



### Major Groundwater Flow Models Built For The Mesilla Basin

- |   |      |
|---|------|
| • Peterson, Khaleel and Hawley (Palumbo)  | 1984 |
| • Wright Engineers and Maddock            | 1986 |
| • S.S. Papadopoulos                       | 1987 |
| • Frenzel (Gates and Frenzel and Kaehler) | 1992 |
| • Hamilton and Maddock                    | 1993 |
| • Weedon and Maddock                      | 1999 |
| • OSE                                     | 2007 |

### History

- In 1980, the city of El Paso applies for 266 well permits in the Mesilla.
- In 1981, State Engineer Steve Reynolds denies El Paso's permits.
- El Paso sues, and in 1983 Judge Bratton rules for El Paso saying New Mexico violate interstate commerce clause.
- In 1984, New Mexico passes the new 40 Year Rule law.
- These actions spawn three groundwater flow models.

### Peterson, Khaleel and Hawley Model

- Developed own finite difference code - not MODFLOW
- Steam – specified stage
- ET – traditional ET
- Geology – Two layer (alluvium and Santa Fe) and quazi-three dimensional
- Drains – traditional drains
- Agriculture – Recharge and regionalized supplemental pumping

### Stream: Specified Stage

Simulates flow between a stream and a node  $i,j,k$  as,

$$QRIV = CRIV(HRIV - h_{ijk}), \quad h_{ijk} > RBOT$$

$$QRIV = CRIV(HRIV - RBOT), \quad h_{ijk} \leq RBOT$$

There is no flow to or from the stream to the aquifer if

$$h_{ijk} = HRIV$$

Flow is from the aquifer to the stream (a gaining stream) if

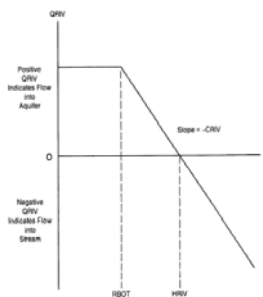
$$h_{ijk} > HRIV$$

Flow is from the stream to aquifer (a losing stream) if

$$h_{ijk} < HRIV$$

The flow is constant from the stream to the aquifer if

$$h_{ijk} < RBOT$$



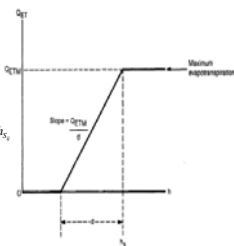
### Traditional ET

$Q_{ETij}$  is the evapotranspiration [L<sup>3</sup>/t] through the cell area

$Q_{ETMij}$  is the maximum value of  $Q_{ETij}$  and is in terms of volumetric discharge.

Thus,

$$Q_{ETi} = \begin{cases} Q_{ETM_i} & h_{ijk} > h_{s_0} \\ Q_{ETM_i} \frac{h_{ijk} - (h_{s_0} - d_d)}{d_d} & (h_{s_0} - d_d) \leq h_{ijk} \leq h_{s_0} \\ 0 & h_{ijk} < h_{s_0} - d_d \end{cases}$$



### Traditional Drain

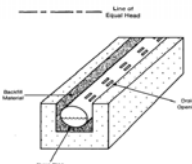
- The discharge  $Q_D$  is given by the equation,

$$Q_{Dijk} = \begin{cases} C_{Dijk}(d_{ijk} - h_{ijk}) \\ 0 \end{cases}$$

- The  $C_{Dijk}$  is a function of,

- Hydraulic conductivity near the drain,
- Distribution of fill material and its hydraulic properties,
- Amount of clogging material and its hydraulic properties, and drain slot openings.

- The coefficient  $C_{Dijk}$  is a conductance.



DRN6

### Wright-Water Engineers and Maddock

- MODFLOW
- Steam – specified stage – River Package
- ET – traditional ET – ET Package
- Geology – Two layer (alluvium and Santa Fe) and quazi-three dimensional
- Drains – traditional drains – Drain Package
- Agriculture – Recharge and regionalized supplemental pumping

### S.S. Papadopoulos

- Not MODFLOW – Based on Hueco Code
- Stream – Specified stage
- ET – Not explicitly modeled
- Geology – four layers (0-0.5, 0.5-100, 100-400, 400-1500)
- Drains – traditional drains
- Agriculture – Recharge and regionalized supplemental pumping

## History (Cont.)

- In 1990, a USGS model is developed under the SWAB RASA studies (5 layers) and a final version of the USGS model (4 layers) is published in 1992.
- In March of 1991, El Paso and New Mexico negotiate a settlement agreement and form the Joint Settlement Commission.
- Out of the settlement agreement, the Hamilton-Maddock Model is spawned.
- In 1995, the NM OSE adopts a modified Hamilton-Maddock model for well permitting.

## USGS –The Frenzel Model

- MODFLOW
- Stream – specified stage – River Package
- ET – traditional ET – ET Package
- Geology – Four layer
- Drains – traditional drains – Drain Package
- Agriculture – Net Recharge

## Net Recharge (Net Irrigation Flux)

Net irrigation flux implicitly includes all groundwater withdrawals and percolation from irrigated lands.

It is the summation of estimates for annual net diversions, effective rainfall on irrigated lands, effective rainfall on nonirrigated lands, and evapotranspiration from irrigated lands in Mesilla Valley.

## Hamilton-Maddock Model

- MODFLOW
- Stream – Calculated stage (modified STR)
- ET – Traditional ET – ET package
- Geology – Four layer
- Drains – Calculated stage (STR)
- Agriculture – Net Recharge but with diversions explicit

## Stream: Calculated Stage

### Computing Stream Stage in Reaches

- STR Package has an option to calculate the stream stage in every reach.
- The stream stage is computed assuming incompressible steady state flow in the stream at constant depth and using Manning's formula,

$$Q = \frac{C}{n} (AR^2 S^{1/2})$$

where,

$Q$  is the stream discharge [ $L^3/t$ ],

$n$  is Manning's roughness coefficient,

$A$  is the cross-sectional area of the stream [ $L^2$ ],

$R$  is the hydraulic radius [ $L$ ],

$S$  is the slope of the stream channel, and

$C$  is a constant [ $L^{1/3}/t$ ], which is 1.486 for units of cubic feet per second and 1.0 for cubic meters per second.

## Stream: Calculated Stage (Cont)

- The cross-sectional area and the hydraulic radius for a rectangular channel are,

$$A = wd$$

and,

$$R = \frac{\text{cross sectional area}}{\text{wetted perimeter}} = \frac{wd}{w + 2d}$$

where

$d$  is the depth of water in the stream [ $L$ ], and

$w$  is the width of the channel [ $L$ ],

gives,

$$d = \left[ \frac{Qn}{CwS^{1/2}} \right]^{2/3}$$

which computes the stream depth.

### History (Cont.)

- In 1993, Boyle Engineering and Engineering Science corporation begin to develop a combined surface water allocation, groundwater flow and quality model that includes the Mesilla and Rincon Basins.
- In 1995, the Weedon-Maddock model is spawned to provide the groundwater modeling base for the Boyle Engineering model.
- In 2002, a modified Weedon-Maddock model is used to negotiate a contract between EPCWID and the city of El Paso.

### Weedon-Maddock Model

- GIS based MODFLOW model – uses GMS
- Two Season model
- Stream – Calculated stage (modified STR)
- ET – Traditional ET – ET package
- Geology – Four layer and includes the Rincon Basin
- Drains – Calculated stage (STR)
- Agriculture – Net Recharge

### History (Cont.)

- 1997 – U.S. Government files Quiet Title suit.
- EPCWID files cross claim alleging inequitable allocation of Project Water by Reclamation because of groundwater pumping in New Mexico.
- Negotiations among districts, Reclamation, other interested parties commence in 1998, collapse in 2000.
- 2001 – Quiet Title suit stayed.
- 2001 – EBID files suit in federal district court in Albuquerque based on Reclamation's failure to develop and implement an operating agreement.
- In 2002, the NM OSE begins to develop a groundwater flow model for the Adjudication of the Rincon-Mesilla basins and for potential litigation with Texas.

### The OSE Model

S.S. Papadopulos, OSE, Shoemaker, King, and Maddock

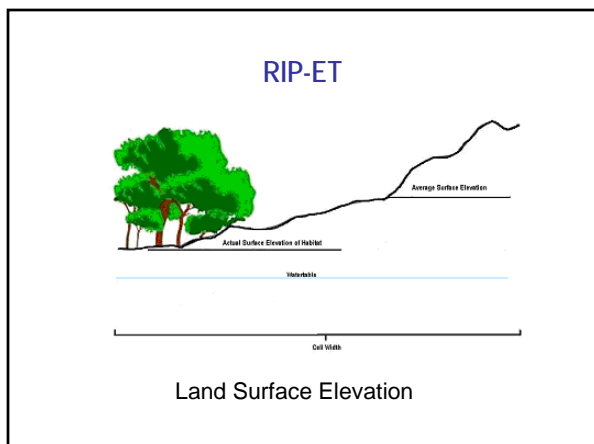
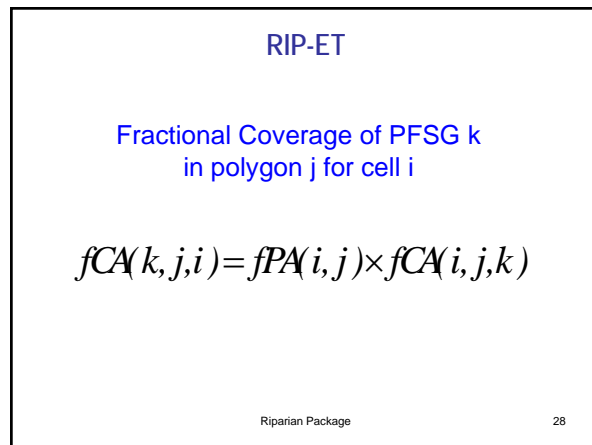
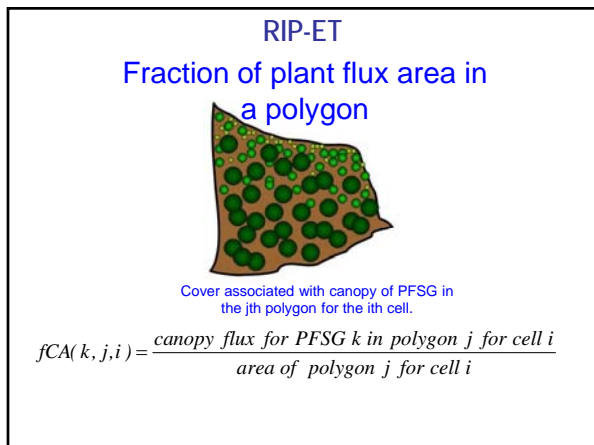
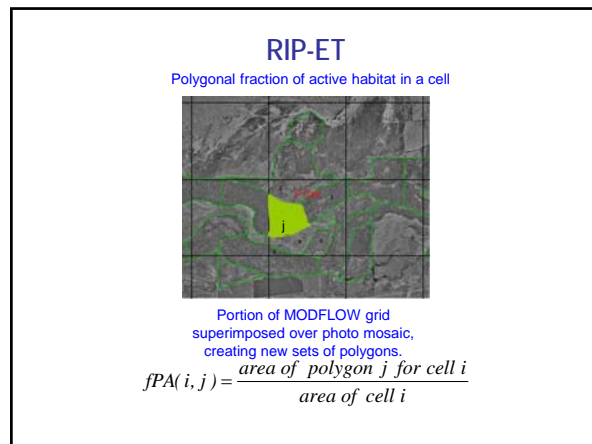
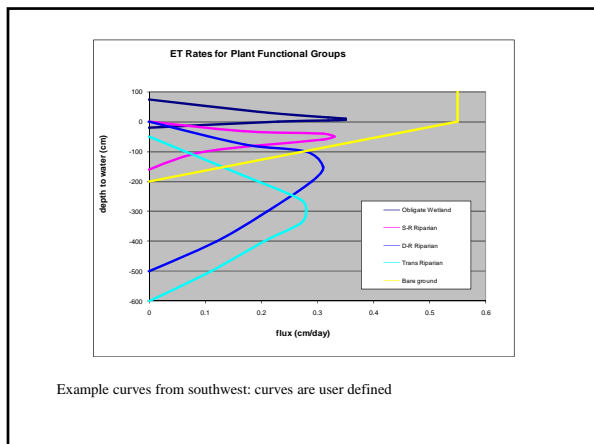
- Two Season model
- Stream – Calculated stage (SFR-1)
- ET – RIP-ET
- Geology – Five layer and includes the Rincon Basin
- Drains – Calculated stage (SFR-1)
- Agriculture –Recharge and Supplemental wells

### SFR

- Has 5 options for simulating stream depth.
  - Specified stage
  - Rectangular stream bed
  - 8 point trapezoid
  - Power function of Q
  - Table or rating curve
- Has 4 options for computing diversions.
  - All available flow diverted
  - Divert if all diversion quantity present in stream
  - Divert a fraction of specified flow
  - Divert all flow in excess of a specified rate
- Has the option to include precipitation, overland flow and evaporation along a stream

### RIP- ET

- Replaces traditional ET curve with one that reflects the physiology of riparian and wetland systems.
- Uses plant function groups and subgroups (PFSG) to elucidate interactive processes of plant ET with groundwater conditions.
- Plant coverage is organized by polygons.
- A polygon consists of a single or mixture of PFSG's.
- A polygon has an approximate uniform land surface area.
- There may be multiple polygons in a cell.



- Future Model(s)**
- Expand into Mexico
  - Ephemeral stream recharge (slope front)
  - Farm module
  - Improved DEMs (3 meter or less)
  - LGR

## Conclusion

The development of these models echoed the conflicts within and between New Mexico and Texas, and ultimately aided in providing a hydrologic basis for the operating agreement between the New Mexico and Texas irrigation districts.

Unfortunately, this operating agreement, orchestrated and negotiated by local farmers at no cost to either state, may deprive lawyers and consultants of millions of dollars, a heartbreaking consequence.