CWEMF
IWFM v4.0 Workshop

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Emin Can Dogrul
California Department of Water Resources

Session 3:

Tile Drains, Subsidence, Pumping and Recharge

Tile Drainage

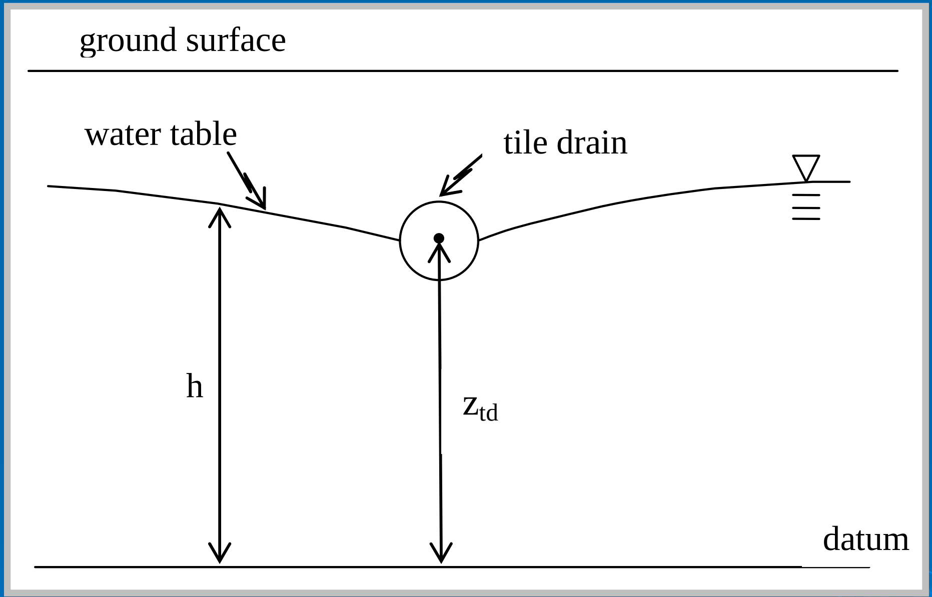
- Used to control the elevation of the groundwater table where drainage is a problem and to promote vertical flow in farmlands for leaching
- Does not interfere with farming operations
- No loss of farming area due to drainage system

Tile Drains

- Simulated as general head boundary conditions:

$$Q_{td} = C_{td}\left(z_{td} - h\right) \leq 0$$

Q_{td} = tile drain flow, $[L^3/T]$
C_{td} = conductance, $[L^2/T]$
z_{td} = tile drain elevation, [L]
h = groundwater head, [L]



- Tile drain flows can be directed into specified stream nodes or outside the model area

Subsurface Irrigation

- Used in arid areas to irrigate deep rooted crops to minimize evaporation
- Simulated as general head boundary conditions:

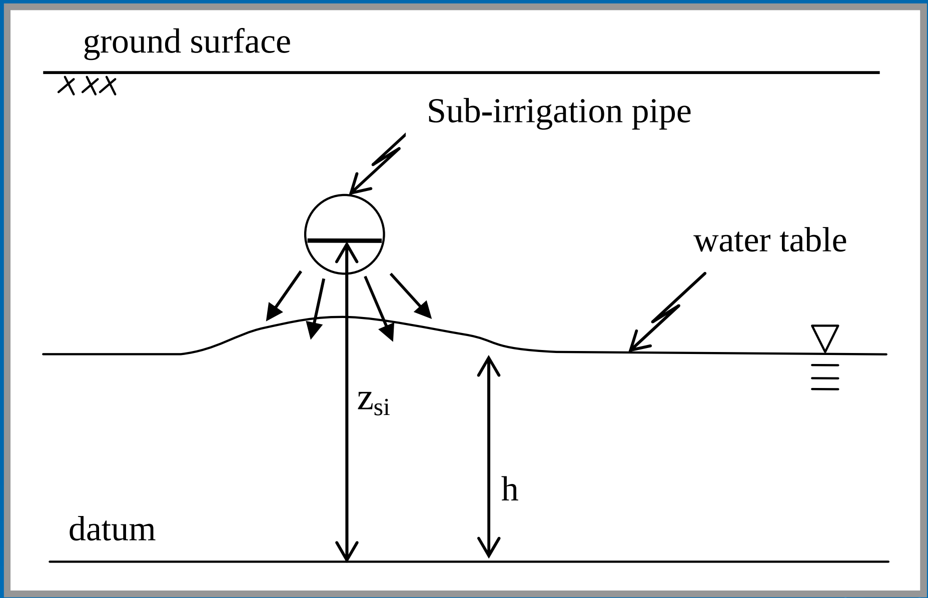
$$Q_{si} = C_{si}\left(z_{si} - h\right) \geq 0$$

Q_{si} = subsurface irrigation, [L^3/T]

C_{si} = conductance, [L^2/T]

z_{si} = head in the subsurface irrigation pipe elevation, [L]

h = groundwater head, [L]

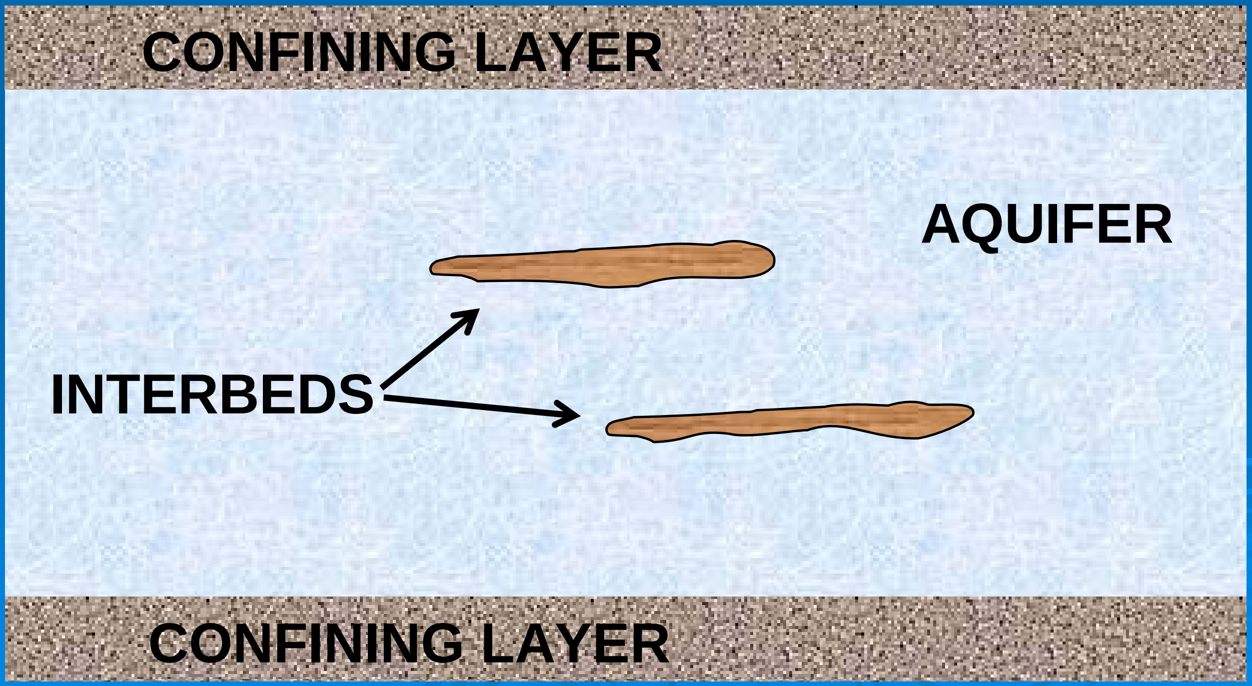


Land Subsidence

- Large amounts of water extraction from the groundwater may cause compaction of the aquifer material
- Elastic compaction or expansion of the aquifer material; soil structure is ***not*** changed permanently
- Inelastic compaction of the aquifer material; soil structure is changed permanently

Land Subsidence

- Land subsidence due to compaction of interbed lenses
- Ground surface elevation and aquifer thickness are not modified during simulation



Land Subsidence

- Modeling elastic change in the interbed thickness

$$\Delta b_{se} = -\Delta h S_{se} b_o \quad \text{if} \quad h \geq h_c$$

- Modeling inelastic change in the interbed thickness

$$\Delta b_{si} = -\Delta h S_{si} b_o \quad \text{if } h < h_c$$

$\Delta b_{se}, \Delta b_{si}$ = elastic and inelastic compaction, (L);
S_{se}, S_{si} = elastic and inelastic specific storage, (1/L);
Δh = change in groundwater head, (L);
h_c = pre-compaction head, (L);
b_o = initial interbed thickness, (L).

- Interbeds cannot be compacted beyond a minimum thickness

Land Subsidence

- The following term is added to groundwater flow equation to incorporate the storage changes due to subsidence:

$$q_s = S_s' \frac{\partial h}{\partial t}$$

q_s = rate of flow into storage due to compaction of interbeds, (L/T);

$$S_s' = \begin{cases} S_{se} b_o & \text{if } h > h_c \\ S_{si} b_o & \text{if } h \leq h_c \end{cases}$$

= skeletal storativity of interbeds, (dimensionless).

Pumping / Recharge

- Pumping / recharge by well:
  - Exact location of wells and pumping/recharge rates are known
- Pumping / recharge by element:
  - Exact locations of wells are not known or modeling every single well is impractical
  - A general knowledge of region where a cluster of wells are located is available and regional pumping/recharge rates can be estimated

Pumping / Recharge

- Distribution of well pumping to vertical layers:

  Kozeny Equation (Driscoll, 1986)

$$f_m = T\ell_s\left[1+7\sqrt{\frac{r}{2b\ell_s}}\cos\left(\frac{\pi\ell_s}{2}\right)\right]$$

f_m = fraction of pumping from aquifer layer m, (dimensionless);
T = aquifer transmissivity, (L^2/T);
ℓ_s = well screen length as a fraction of the aquifer thickness, (dimensionless);
r = well radius, (L);
b = aquifer thickness, (L).

- Distribution of element pumping to vertical layers:
  - Distribution coefficients are supplied by the user

Pumping to Meet Water Demand

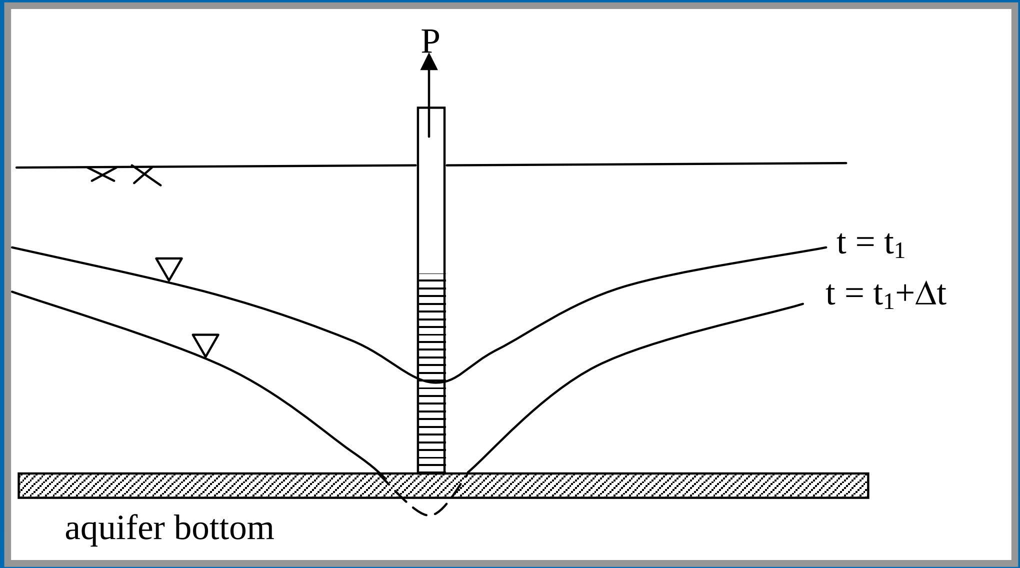
- Well and element pumping can be
  - Used at the same element that the pumping occurs
  - Delivered to a subregion
  - Delivered to a single grid cell
  - Delivered to a group of grid cells
  - Sent outside the model area

Distribution of Regional Pumping Among Wells and Elements

- Regional pumping can be distributed among wells and elements based on
  - Fractions supplied by the user
  - Total area of the delivery destination multiplied by user-defined factor
  - Total agricultural and urban area in the delivery destination multiplied by user defined factor
  - Agricultural area in the delivery destination multiplied by user defined factor
  - Urban area in the delivery destination multiplied by user defined factor

Pumping at Drying Wells / Elements

- To compute actual supply to urban and agricultural lands, it is necessary to calculate the actual amount of pumping at a well / element that goes dry



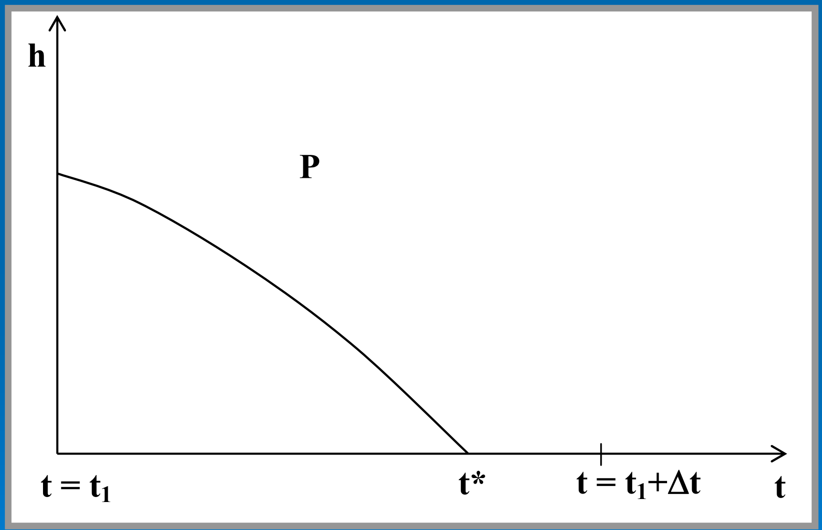
- An iterative procedure is used to compute actual pumping at a drying well / element

- Pumping rate at a drying well / element is modified iteratively to find the rate that will dry the well / element at the end of the time step

Pumping at Drying Wells / Elements

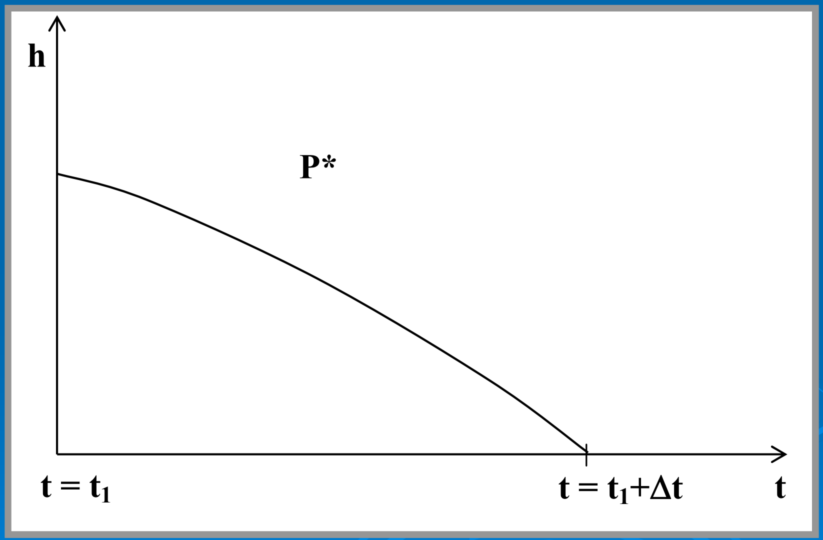
- Inverse problem

  Amount pumped = P x (t^*-t_1)

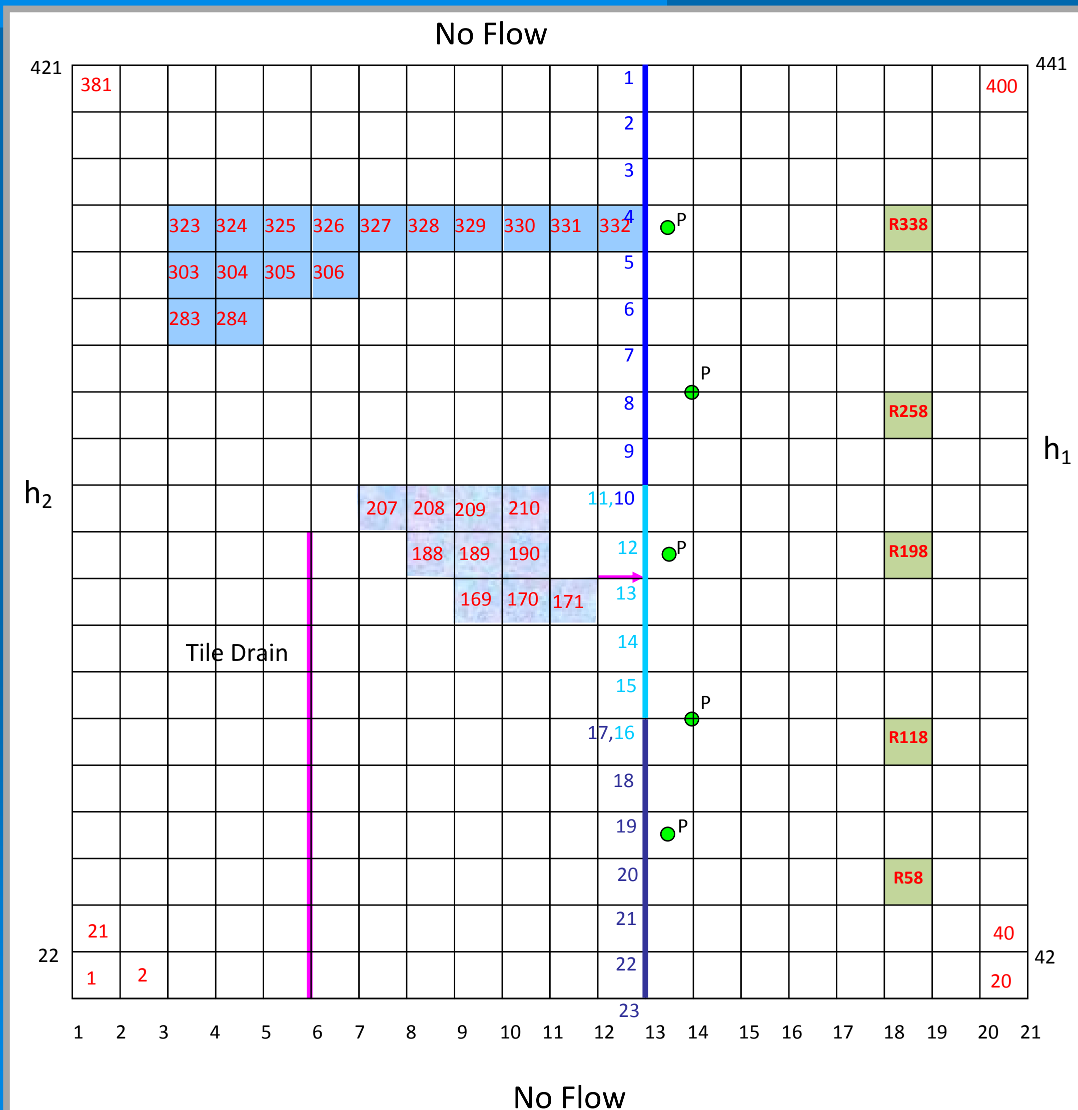


- Approximate solution

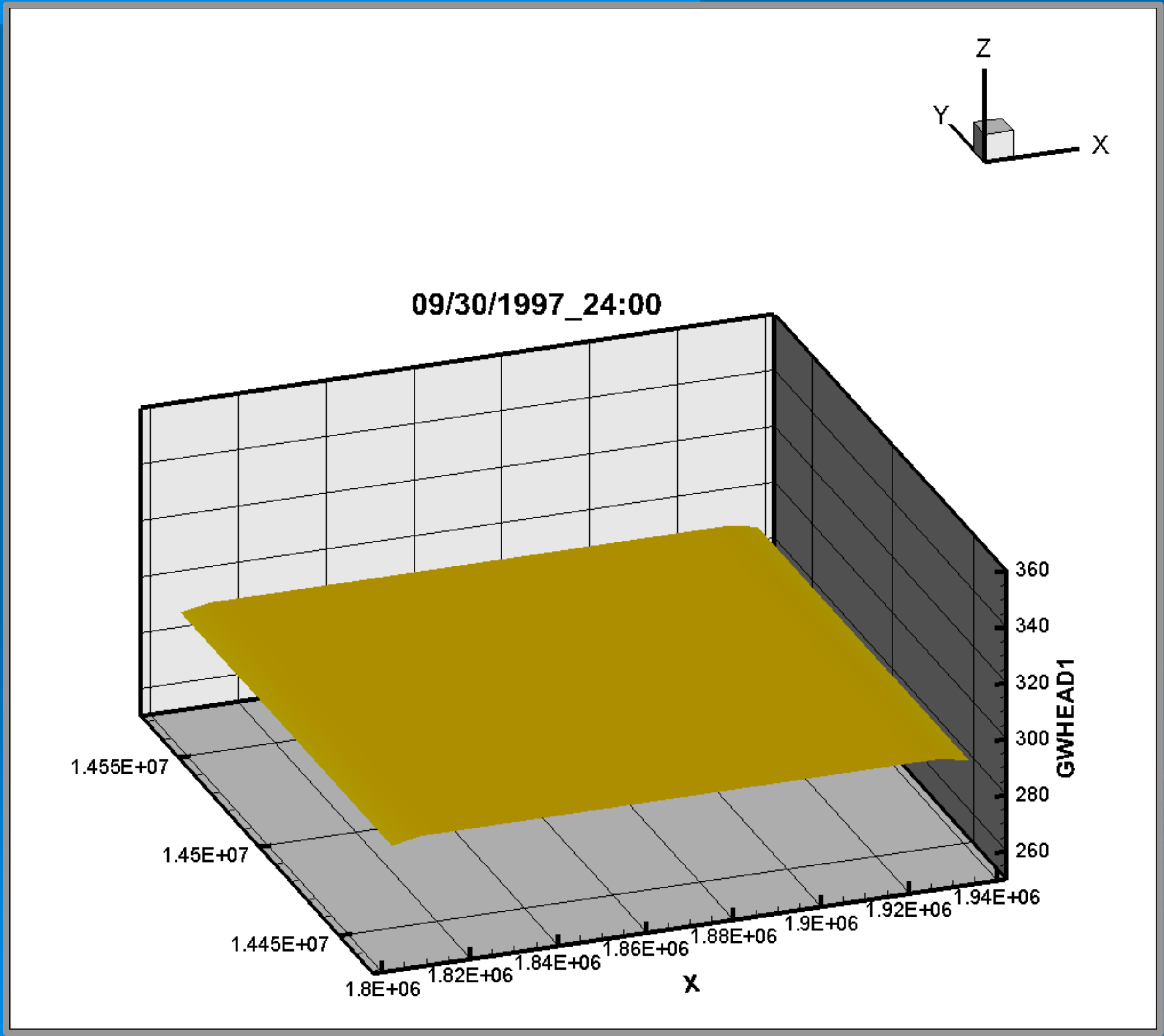
  Amount pumped = P* x Δt



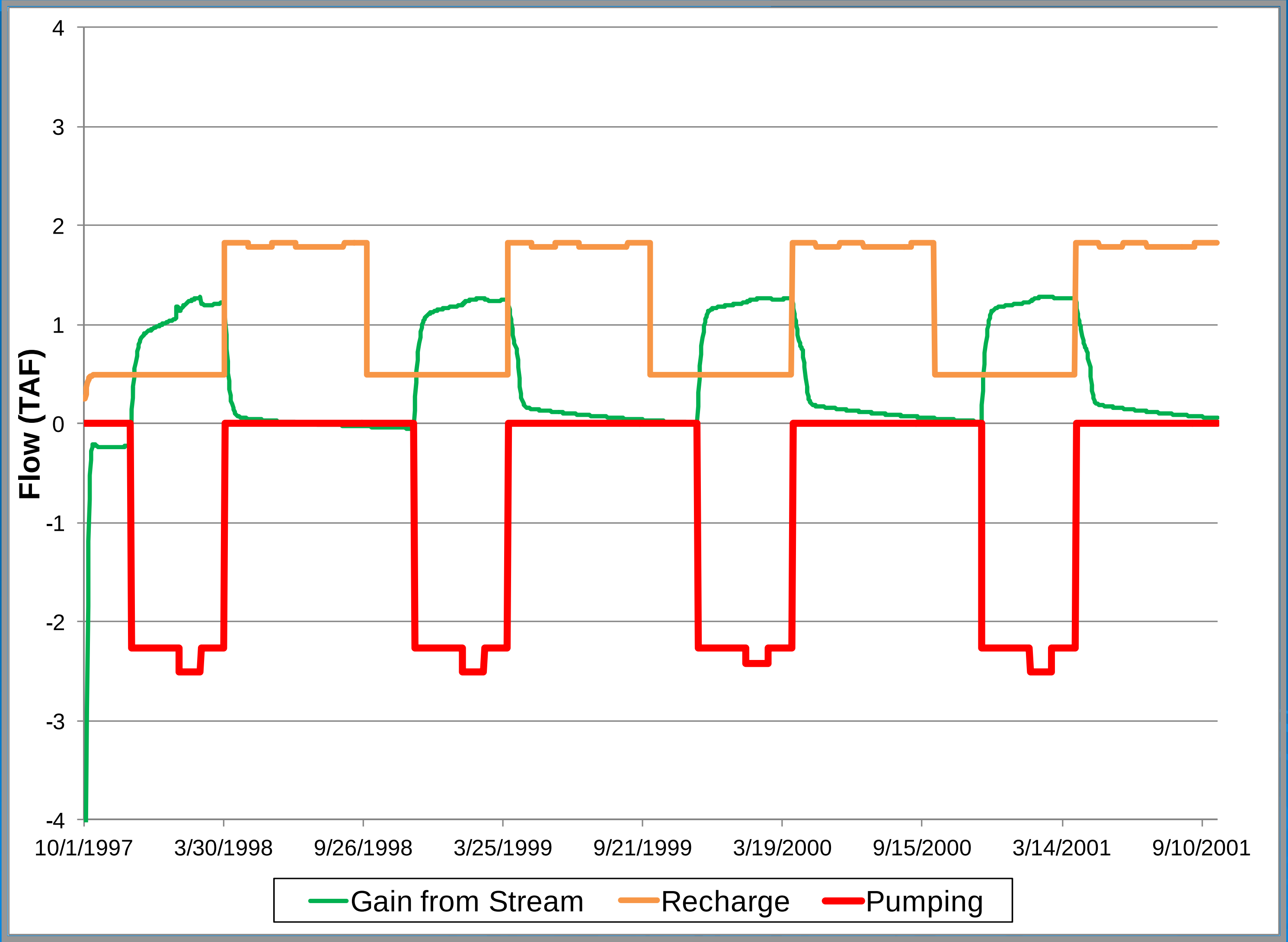
Example 3:
Tile Drains, Subsidence, Pumping and Recharge



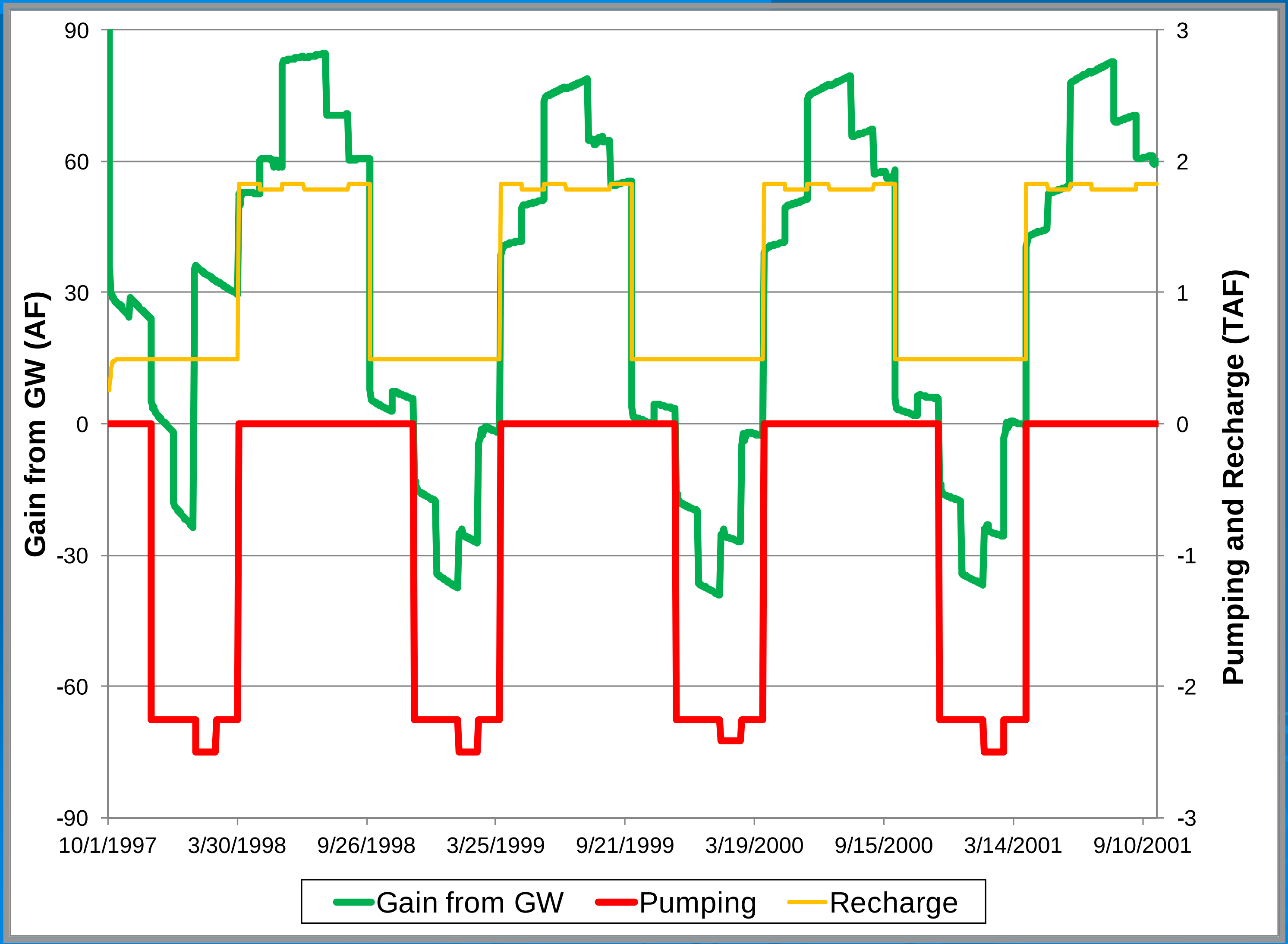
Example 3: Results



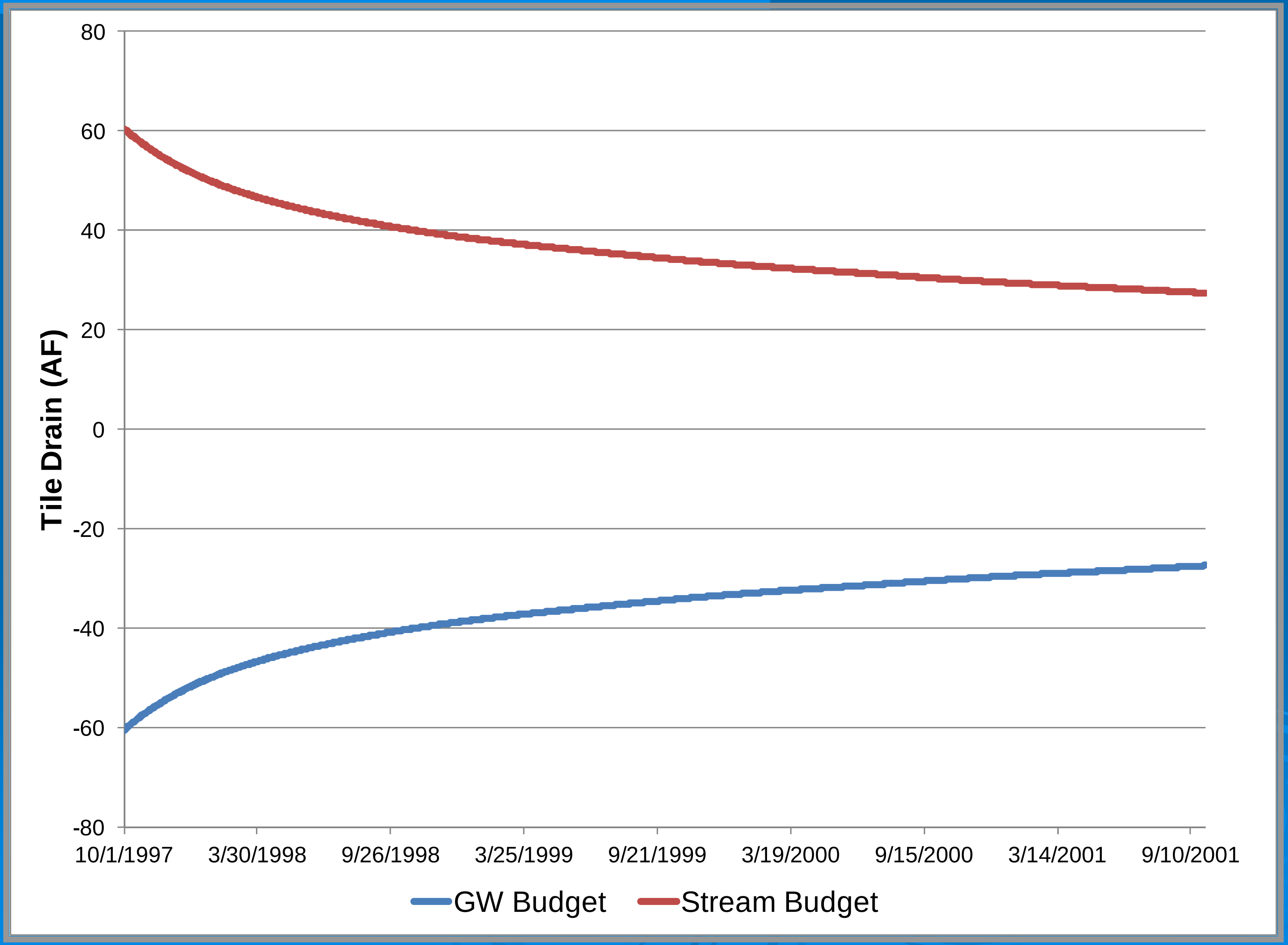
Example 3:
Stream-Groundwater Interaction



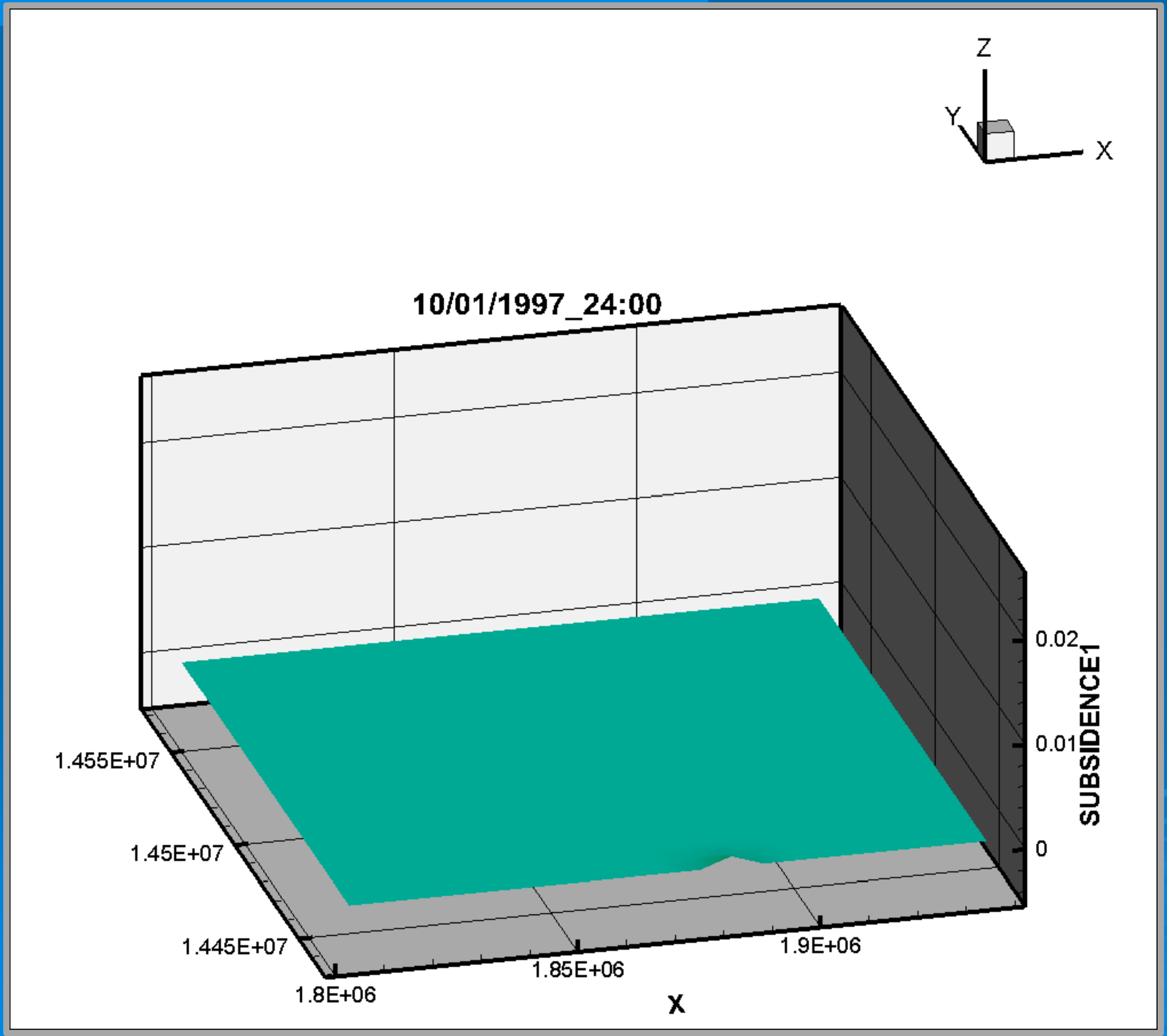
Example 3:
Lake-Groundwater Interaction



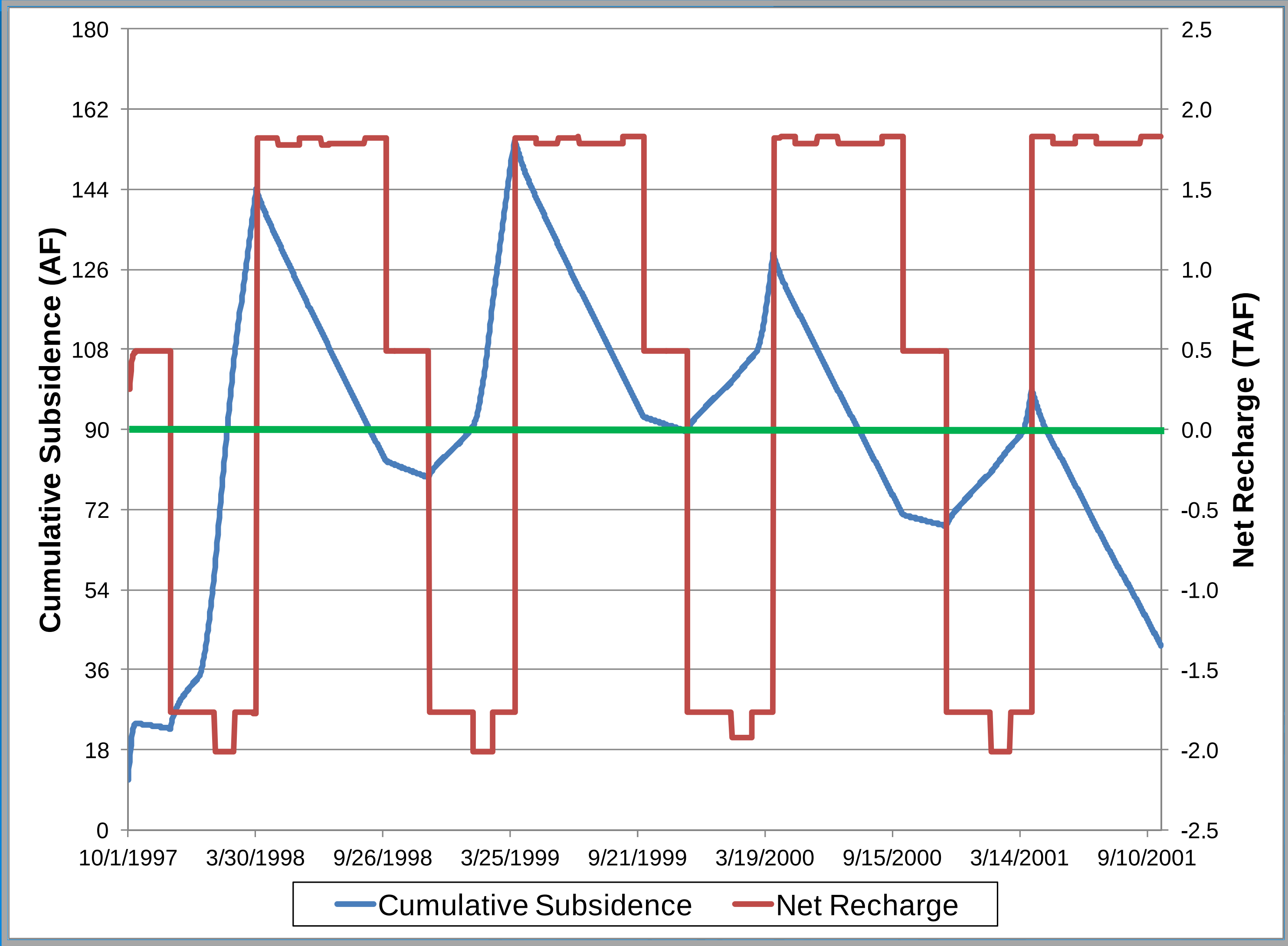
Example 3:
Tile Drains



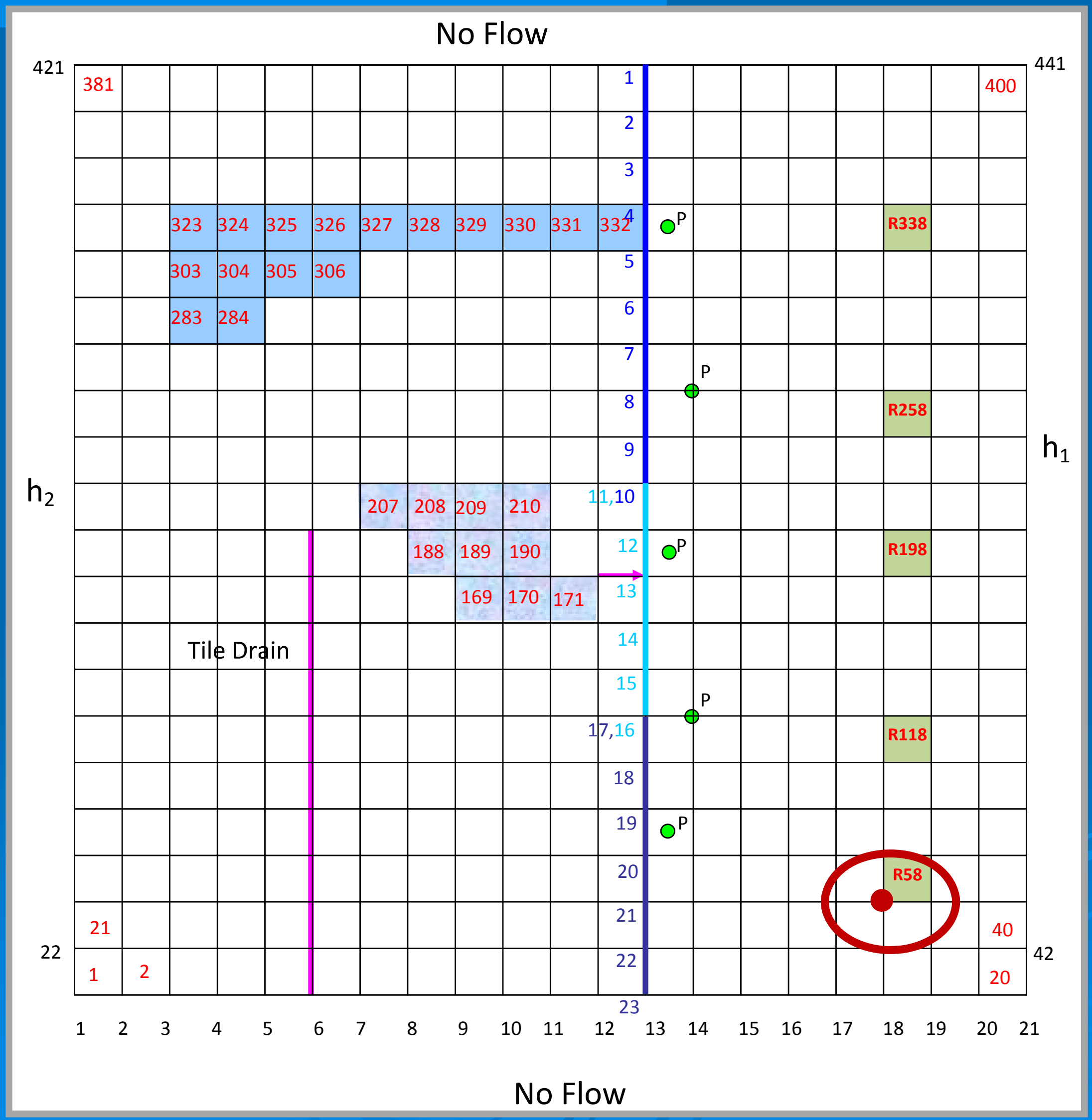
Example 3: Subsidence



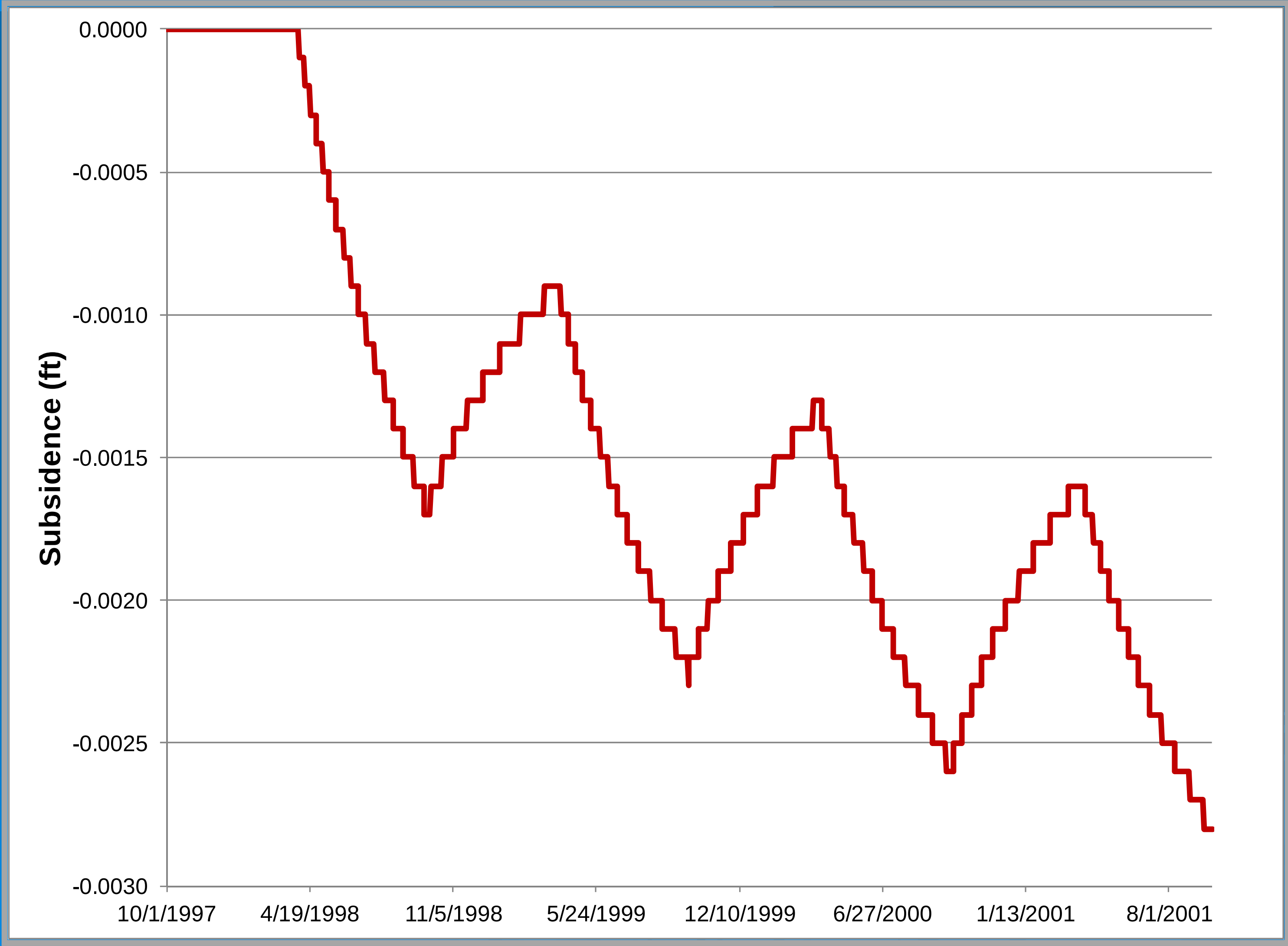
Example 3:
Cumulative Subsidence versus Net Recharge



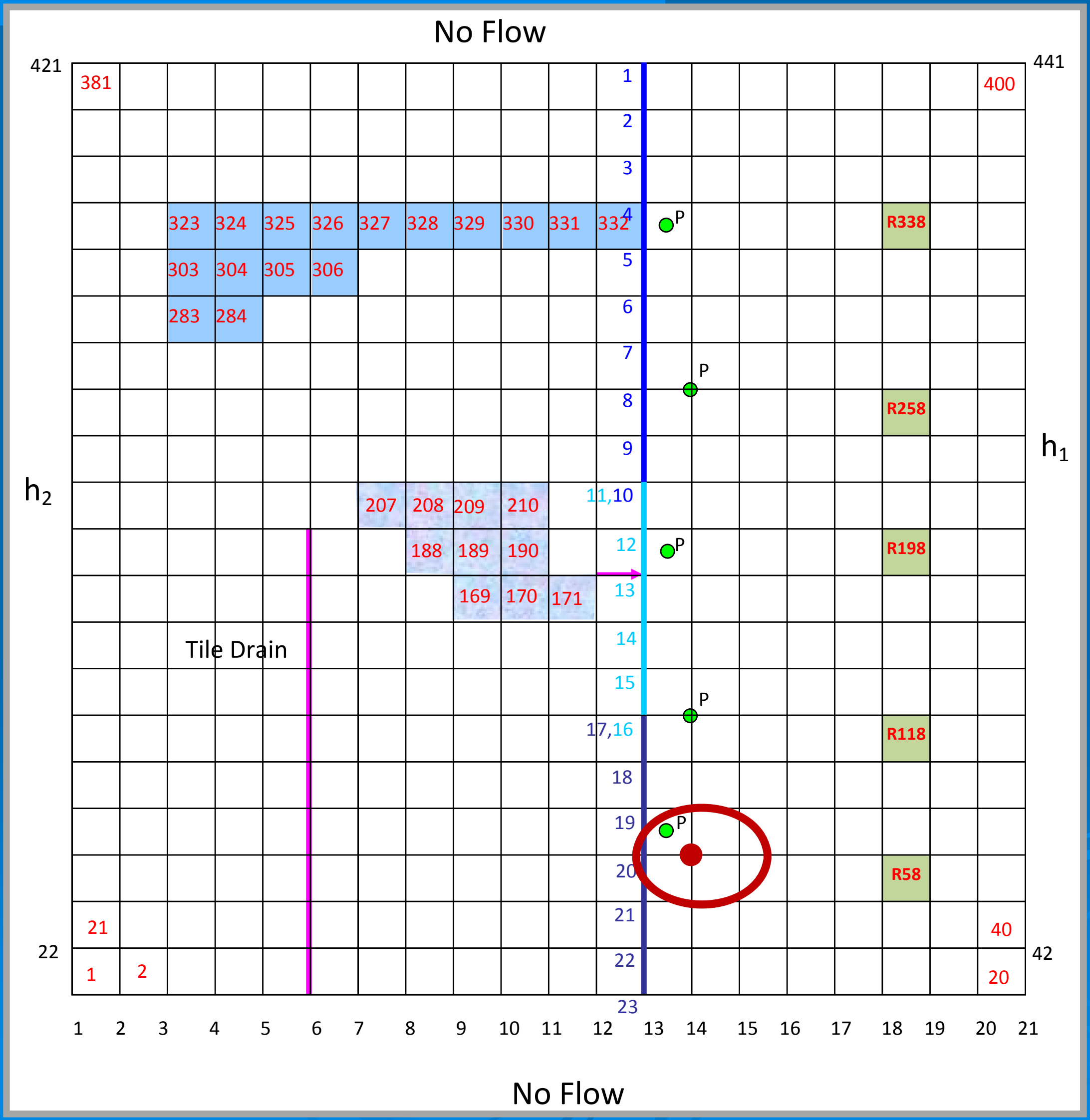
Example 3:
Subsidence at Node 60



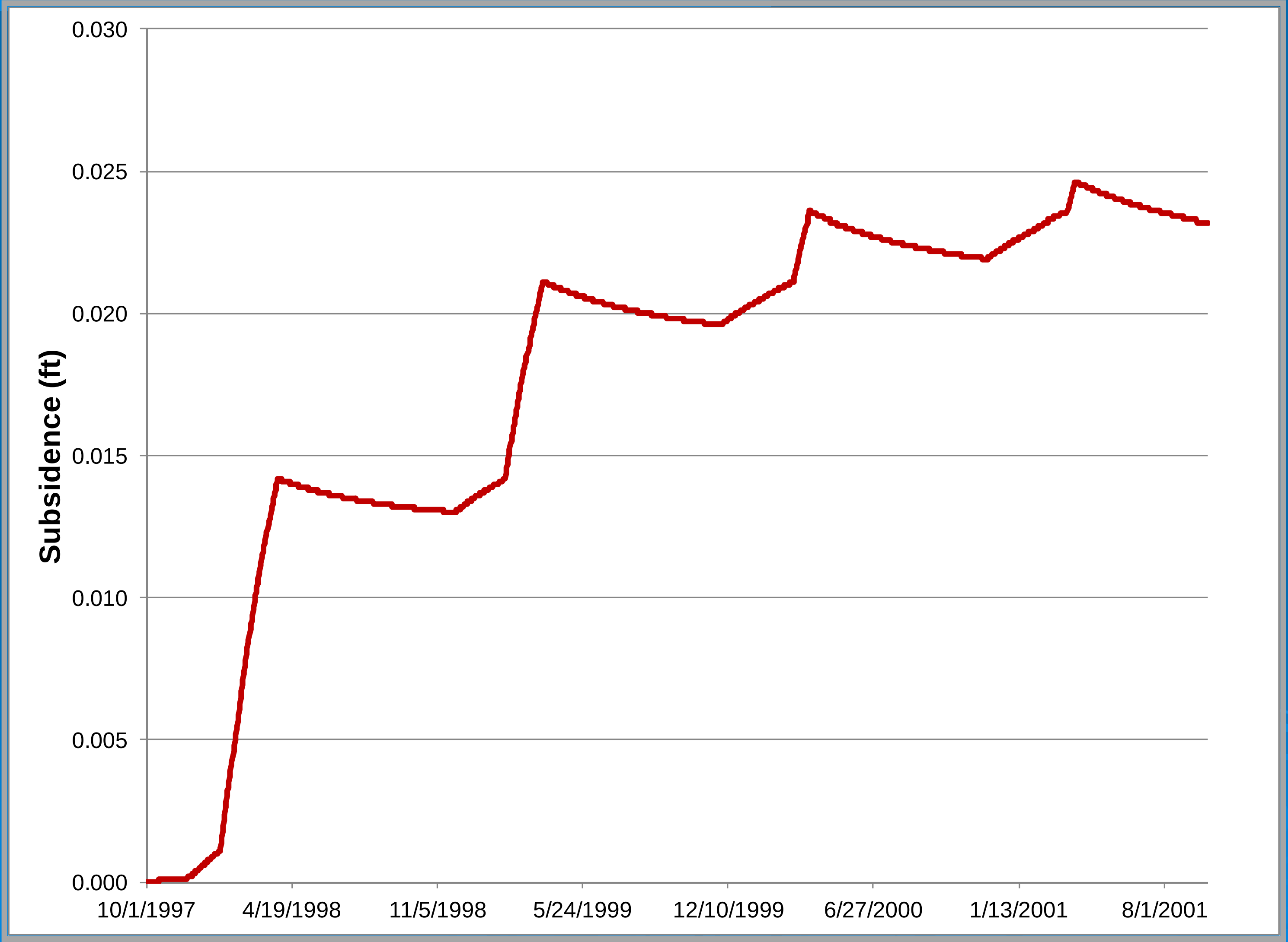
Example 3:
Subsidence at Node 60



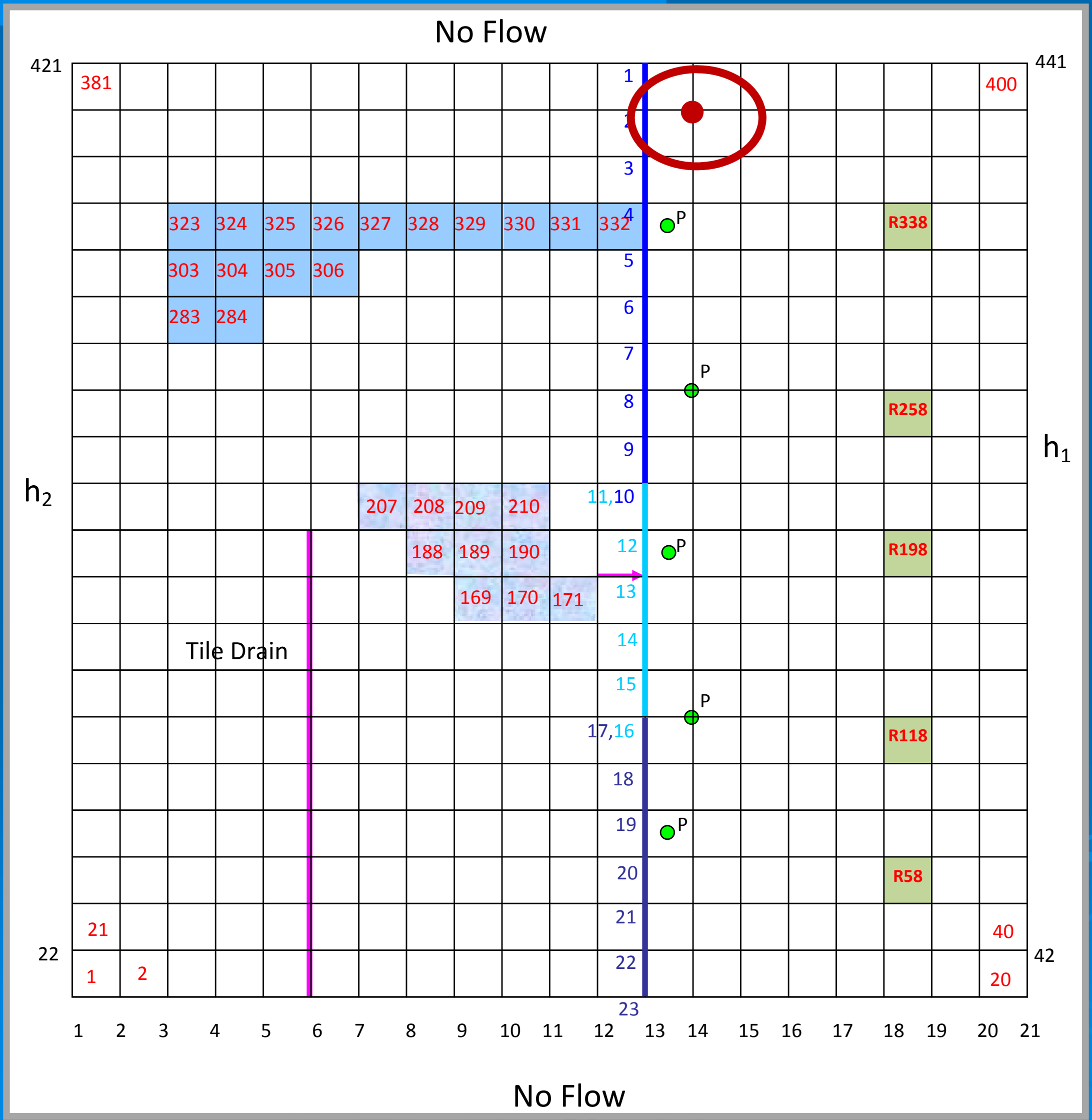
Example 3:
Subsidence at Node 77



Example 3:
Subsidence at Node 77



Example 3:
Subsidence at Node 413



Example 3:
Subsidence at Node 413