Non-Saline Horizontal Water Well Aquifer Test Analysis and Licensing

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Waterline Resources Inc.

Presentation Outline

- Regulations and licensing overview
- Applying regulations - horizontal wells
- Aquifer analysis - horizontal wells
- Estimating long-term well yields (Q_{20})
- Summary
- Questions?

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Groundwater Licensing in Alberta

Non-Saline

- Water Act (FITFIR)
- Guide to Groundwater Authorization
- Oilfield Injection Guideline (OIG)

Saline

- ~~Water Act~~ (exempt)
- No AER Licensing Requirements
- Water Management Perspective

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Under the GW Authorization (AB Gov't., 2011)... (historical approach)

- Complete applicable aquifer test:
  - Data Interpretation to estimate T&S
    - Analytical solution
      - Cooper-Jacob, Theis, Neuman, etc.
    - Numerical models
  - Q_{20} Estimation:
    - Farvolden method or Modified Moell method
      - Both based on Theis solution
  - Above developed on "vertical" well assumptions

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Under the Oil Field Injection Guideline…

- Adhere to OIG restrictions:
  - Limit drawdown to <35% in 1st year (at r = 150 m)
  - Limit drawdown to <50% over project life (at r = 150 m)

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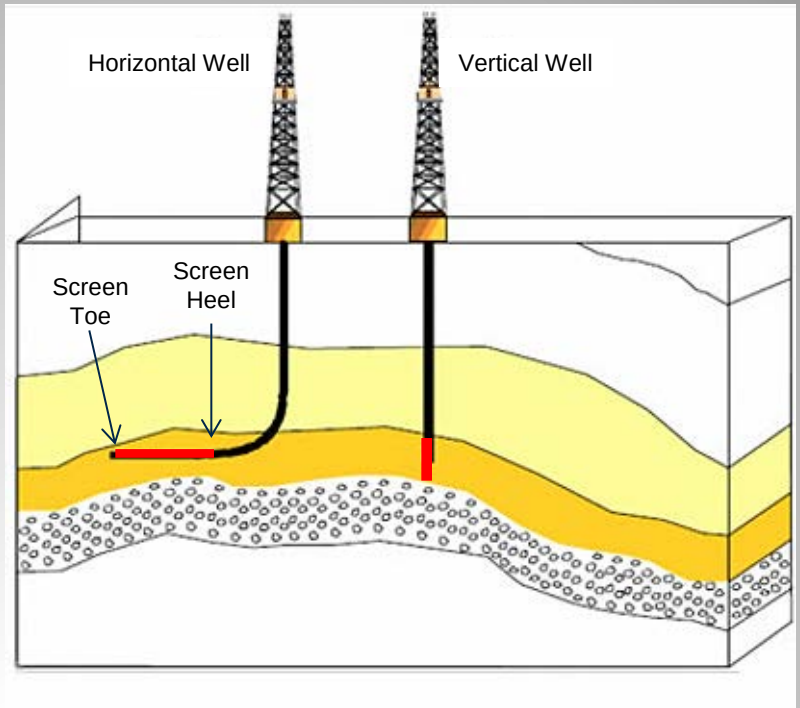
Methods for Estimating T&S in Horizontal Wells

- Analytical Approaches:
  - Daviau et al. solution (utilized in Aqtesolv)
  - E.g., Other software
- Numerical Solution:
  - MODFLOW, FEFLOW



Source: Horizontal well Energy Information Administration, Office of Oil and Gas accessed at: http://www.popularmechanics.com/science/energy/coal-oil-gas/4318390

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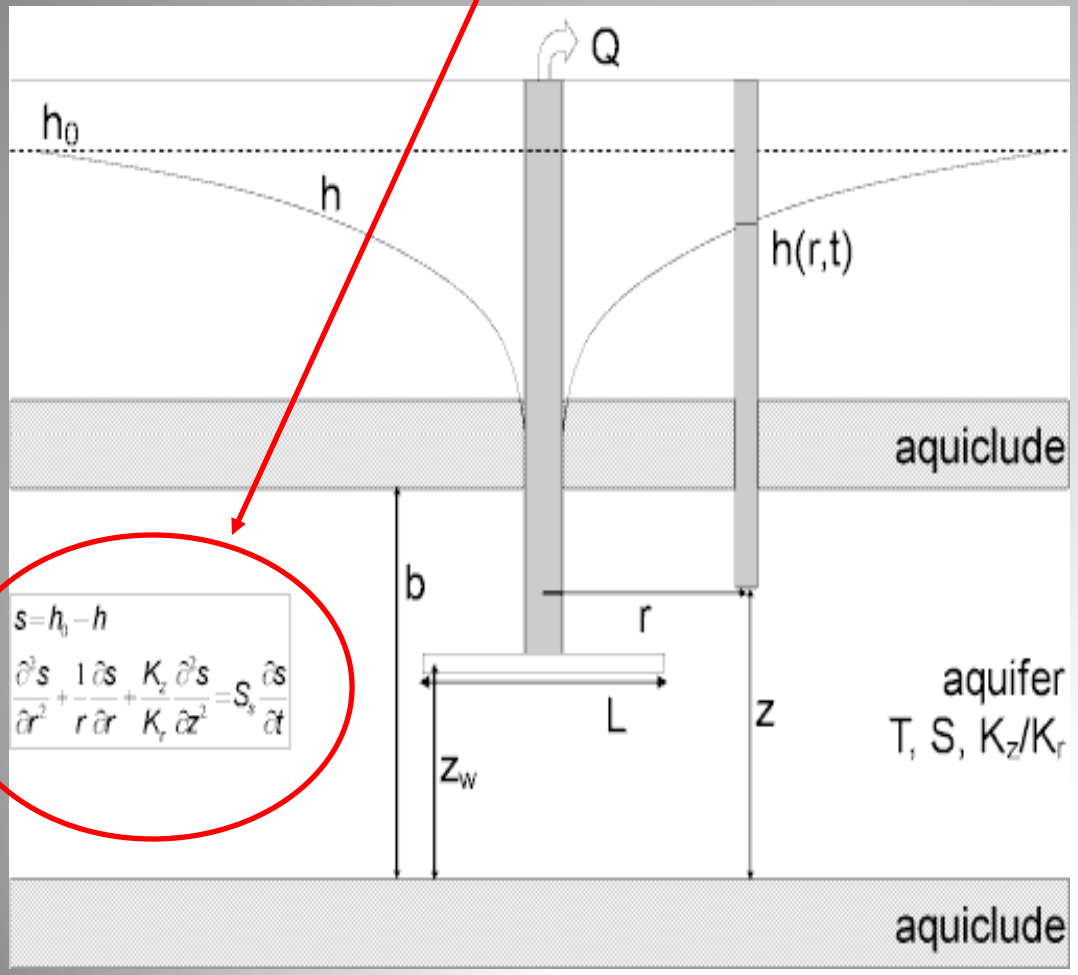
Estimating T&S in Horizontal Wells
Daviau et al. **Solution** (Aqtesolv)



Where:

- b is aquifer thickness [L]
- K_r is radial hydraulic conductivity [L/T]
- K_z is vertical hydraulic conductivity [L/T]
- L is length of the well [L]
- Q is pumping rate [L^3/T]
- r_w is well radius [L]
- s is drawdown [L]
- S is storativity [dimensionless]
- t is time [T]
- T is transmissivity [L^2/T]
- x, y and z are coordinate distances [L]

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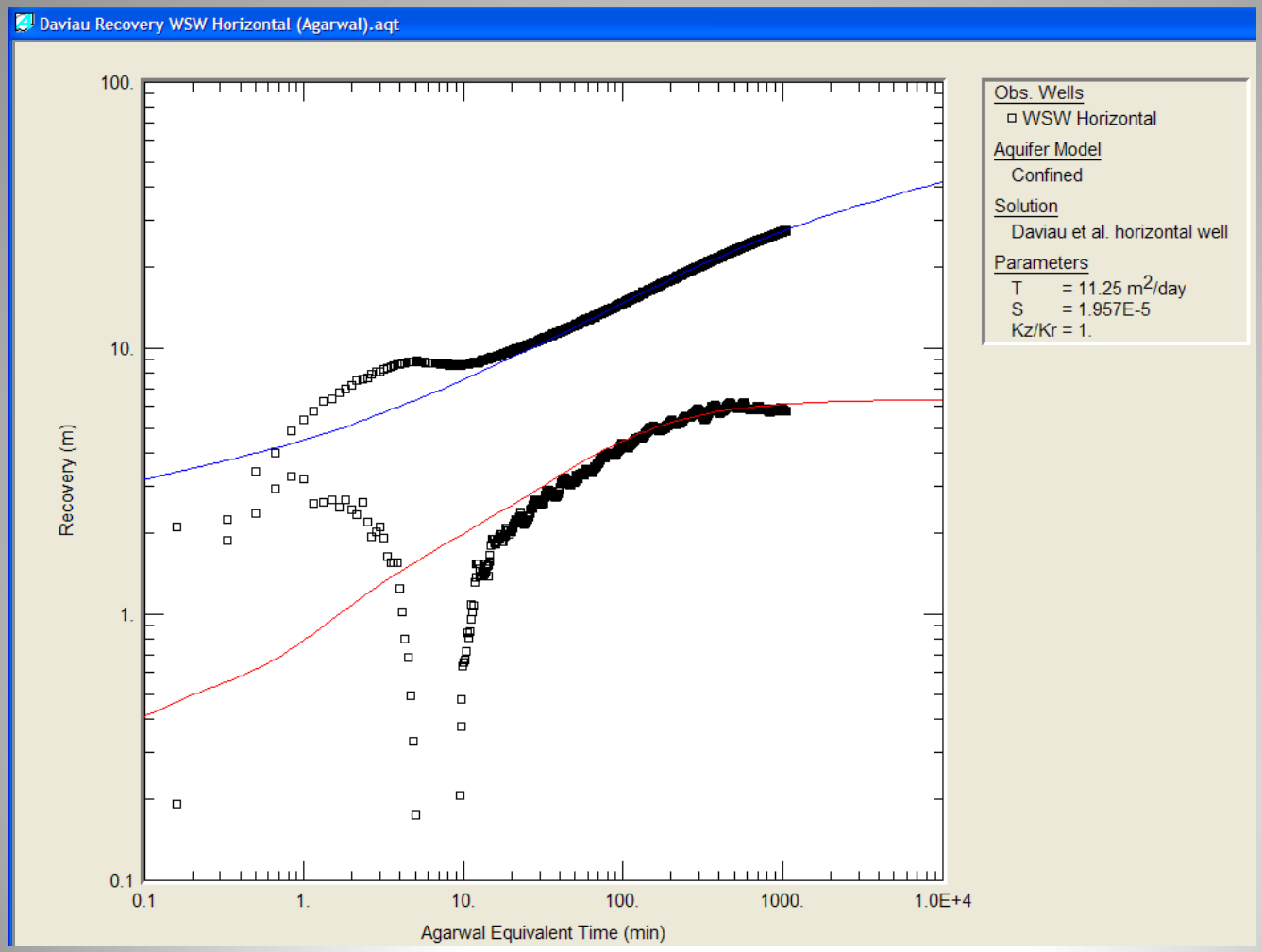
Estimating T&S in Horizontal Wells
Daviau et al. Solution (Aqtesolv)



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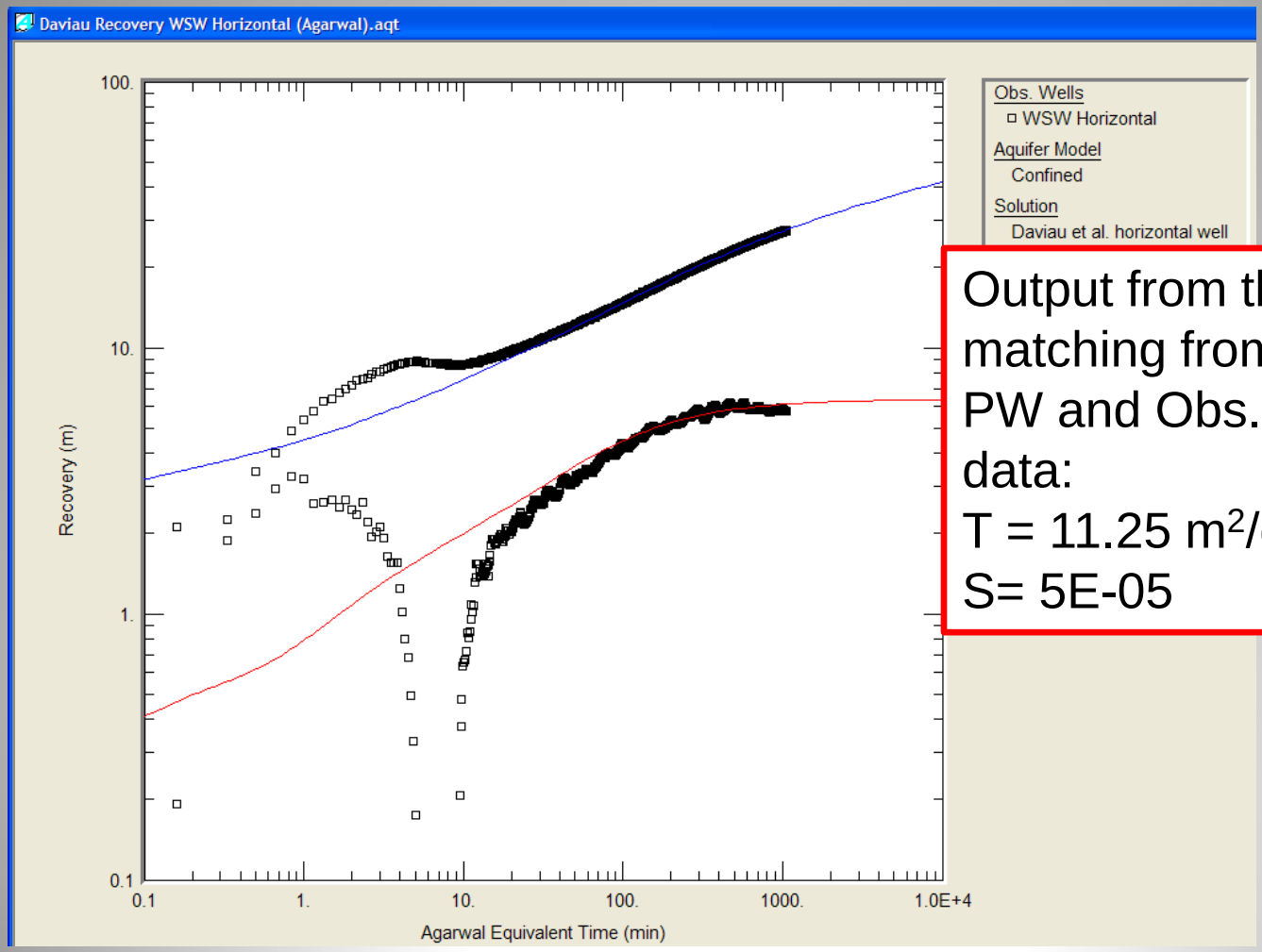
Estimating T&S in Horizontal Wells
Daviau et al. **Solution** (Aqtesolv)



Output from the curve matching from both PW and Obs. well data:

T = 11.25 m^2/day;

S= 5E-05

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Estimating Q_{20} for Horizontal Wells

… Back to GW Authorization Guideline and OIG…

- Farvolden and Modified Moell-based Q_{20} estimates assume vertical wells – so they can't be directly applied to horizontals; however, we can borrow the Q_{20} concepts
  - Assume only have 70% of actual drawdown at the pumping centre (30% safety factor)
- Still adhere to OIG restrictions:
  - Limit drawdown to <35% in 1st year (at r = 150 m)
  - Limit drawdown to <50% over project life (at r = 150 m)

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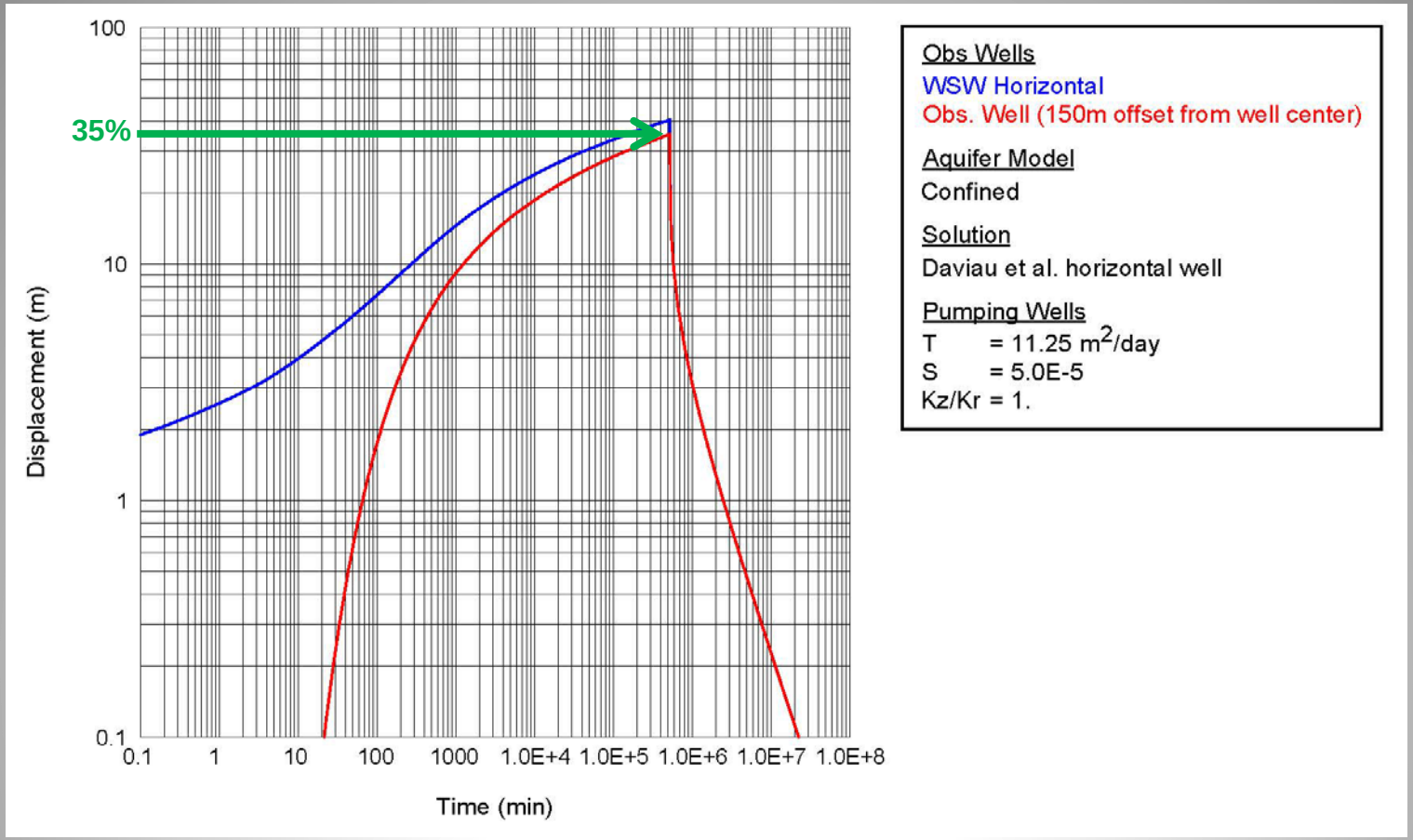
Pumping Rate - AQTESOLV Forward Solution



After iteration, 1 year of pumping at 600 m^3/d yields 35% drawdown at radius of 150 m

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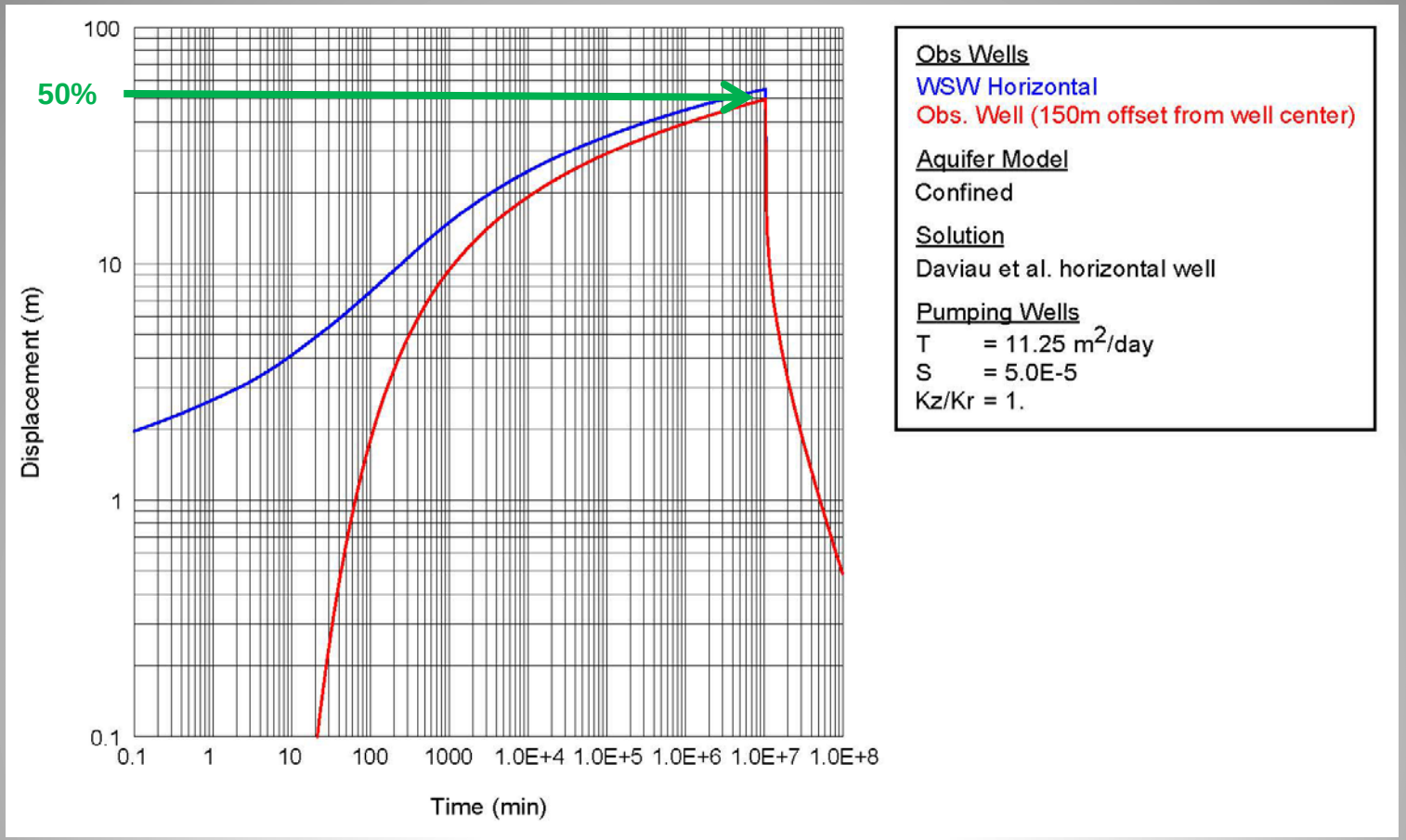
Pumping Rate - AQTESOLV Forward Solution



After iteration, 20 years of pumping at 620 m^3/d yields 50% drawdown at radius of 150 m

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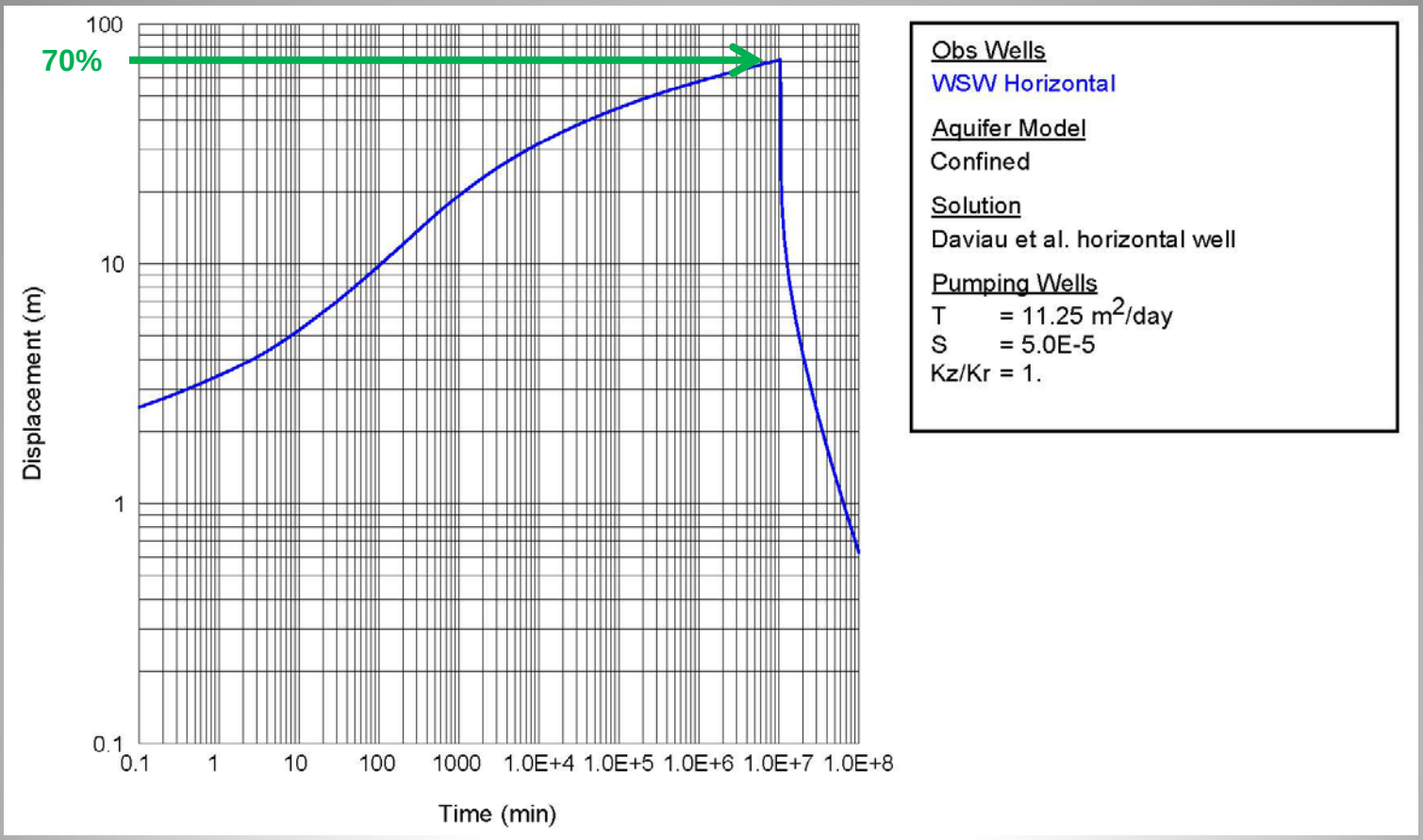
Pumping Rate - AQTESOLV Forward Solution



After iteration, 20 years of pumping at 800m^3/d yields 70% drawdown at pumping well

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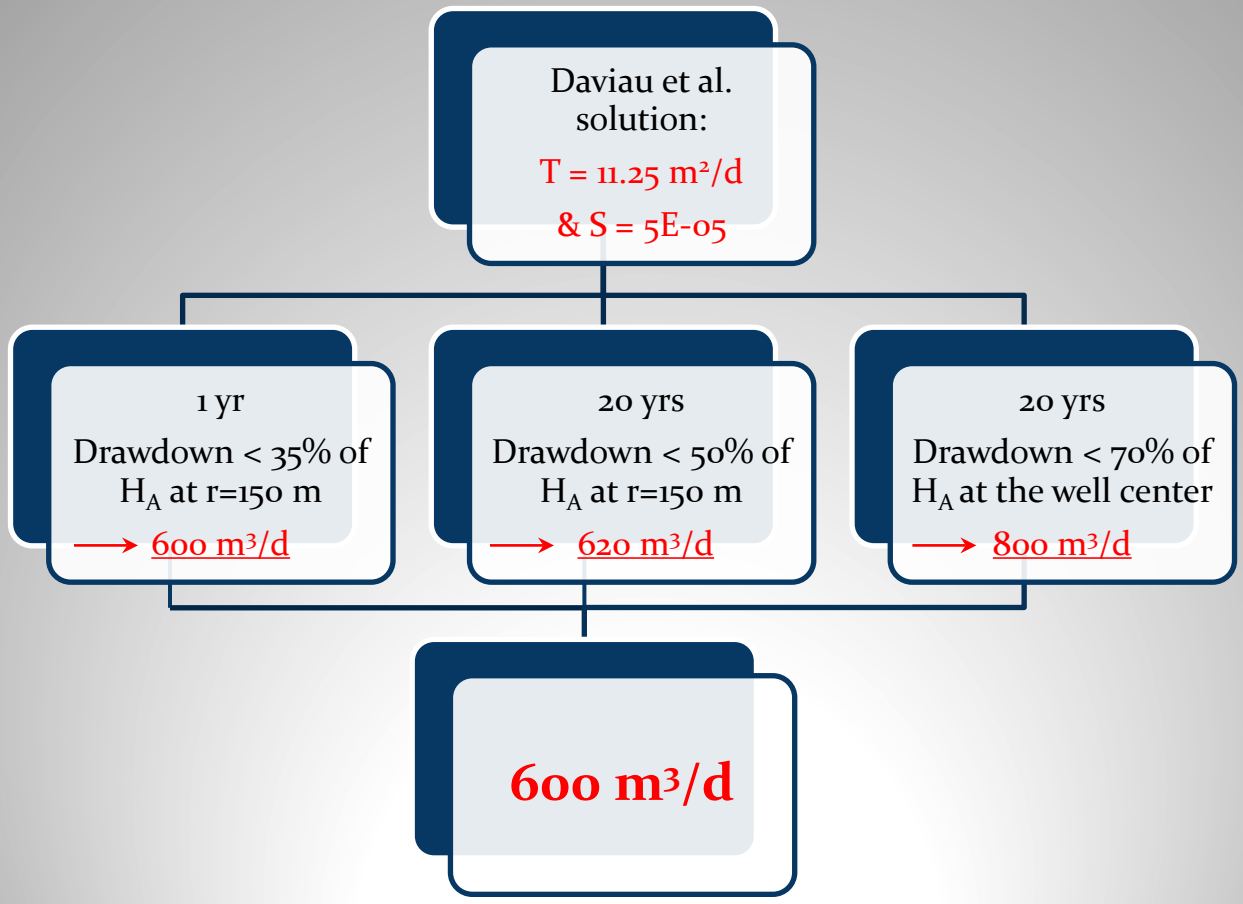
Finalized Q_{20}...

So, In Summary:



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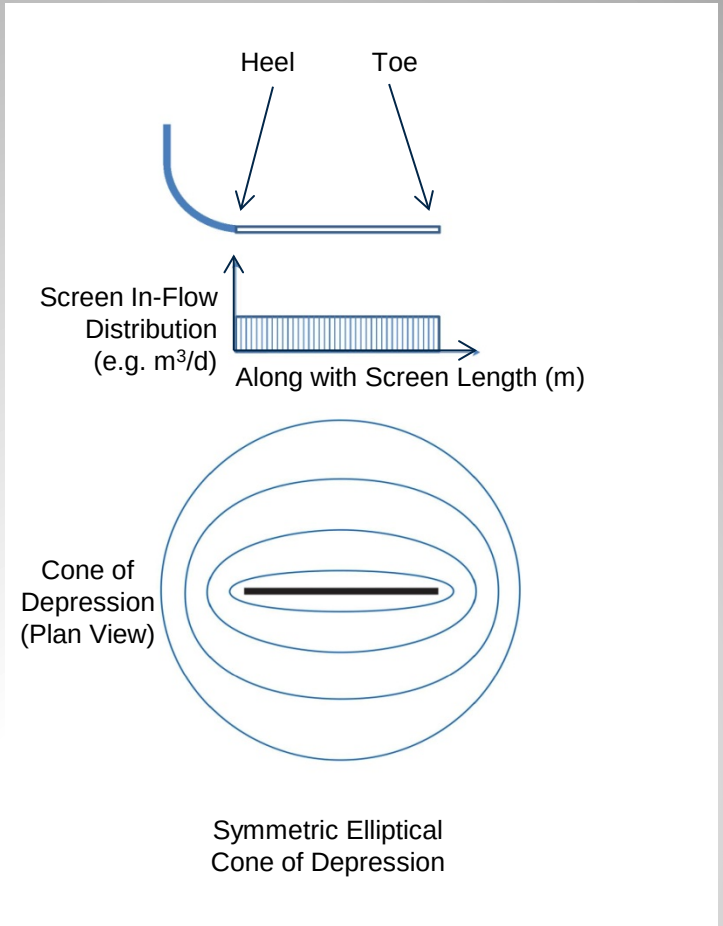
Assumptions to Consider …

- Flow Distribution along the horizontal screen section:
  - Homogeneity of the Formation
  - Development Procedure



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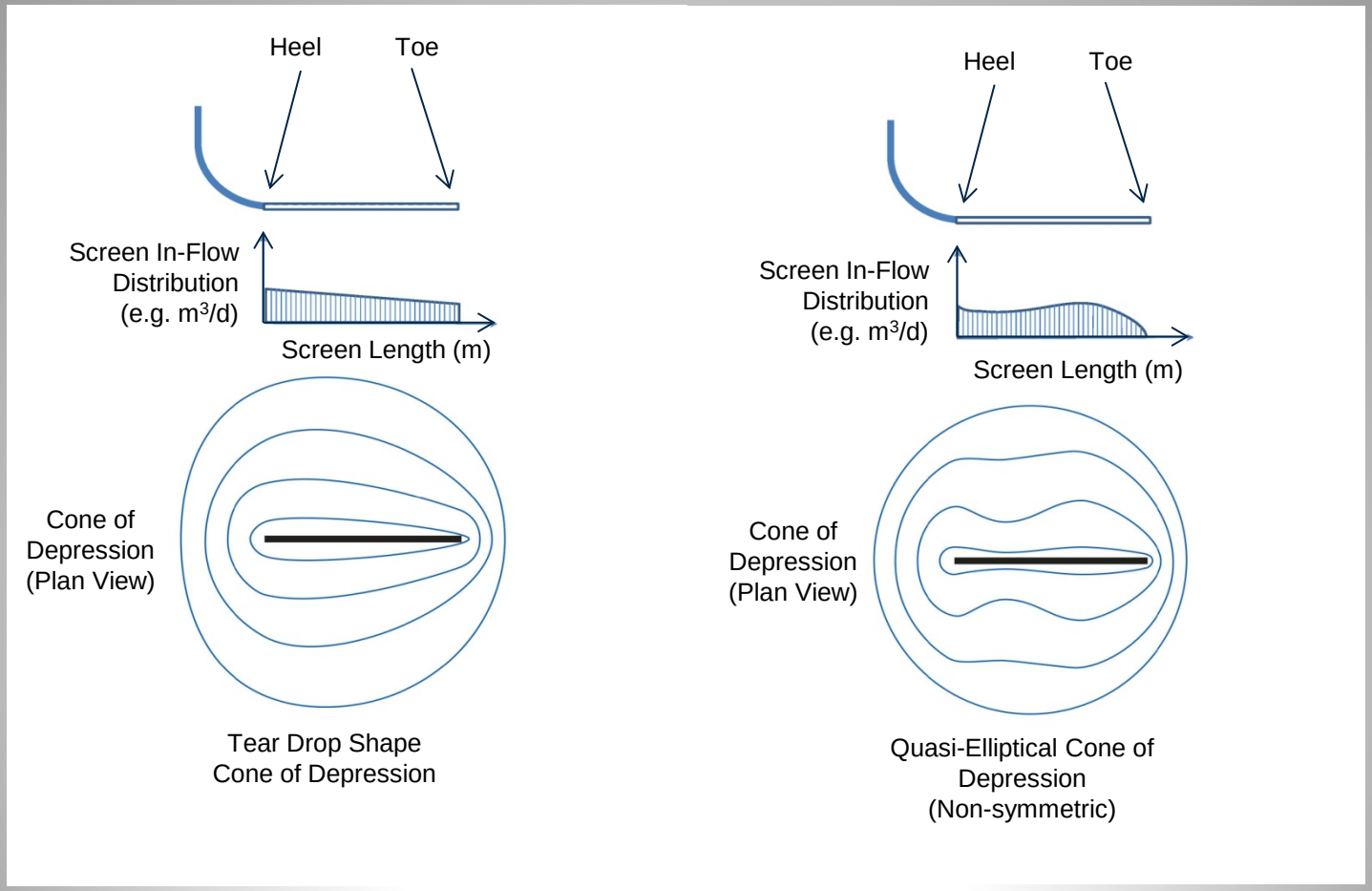
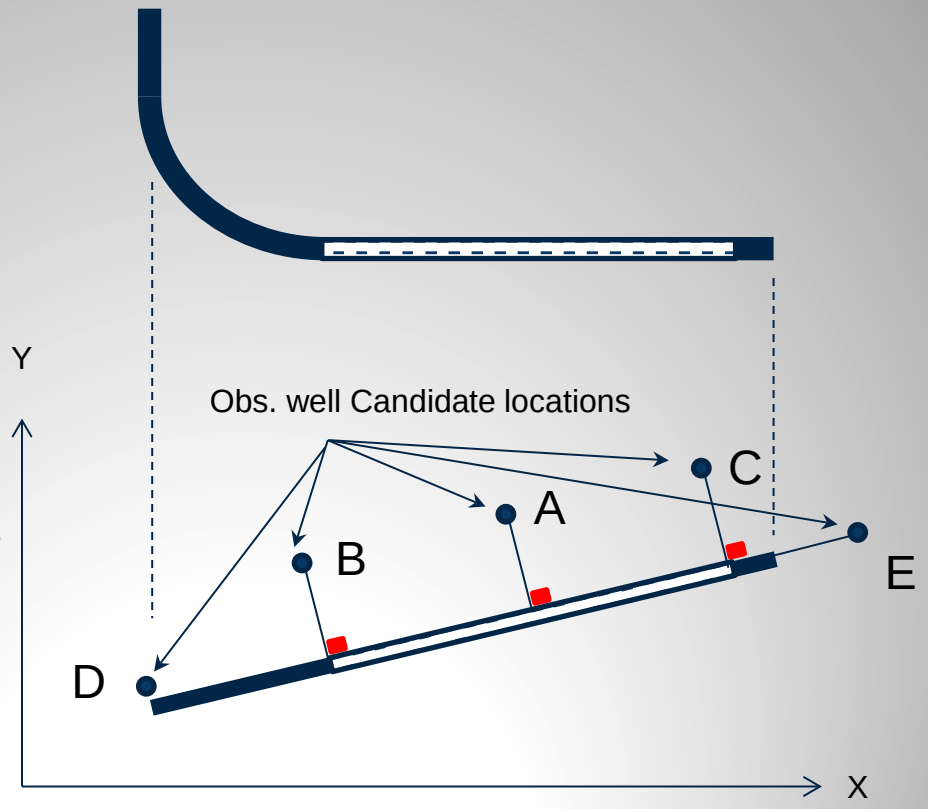
Assumptions to Consider …



Conceptual Monitoring Well Locations

- Orient perpendicular
  - 150 m off-set
- Options include:
  - Mid screen (A)
  - Heel (B)
  - Toe (C)
- Reality
  - Locations controlled by access to drill MWs

  E.g. MW 'D' or MW 'E'



Theoretical Monitoring Wells Coordinates

- For rotation by an angle θ **clockwise** about the origin (Note that this definition of clockwise is dependent on the x axis pointing right and the y axis pointing up.

$$x' = x\cos\theta + y\sin\theta$$

$$y' = -x\sin\theta + y\cos\theta$$

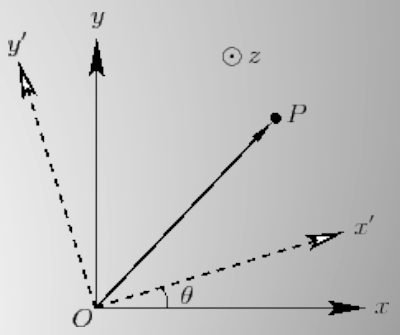
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

- Similarly, for a rotation counter clockwise about the origin, the functional form is:

$$x' = x\cos\theta - y\sin\theta$$

$$y' = x\sin\theta + y\cos\theta$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$



In Summary

- Q_{20} Concept: Limit drawdown to 70% of the H_A (project life-time)
- Oil Injection Guideline:
  - Limit drawdown to 35% of the H_A at 150m offset by the first year of pumping
  - Limit drawdown to 50% of the H_A at 150m offset (project life-time)
- Maintain open communication on methods used for Long-Term Yield Estimation

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Questions?

Thank You!!