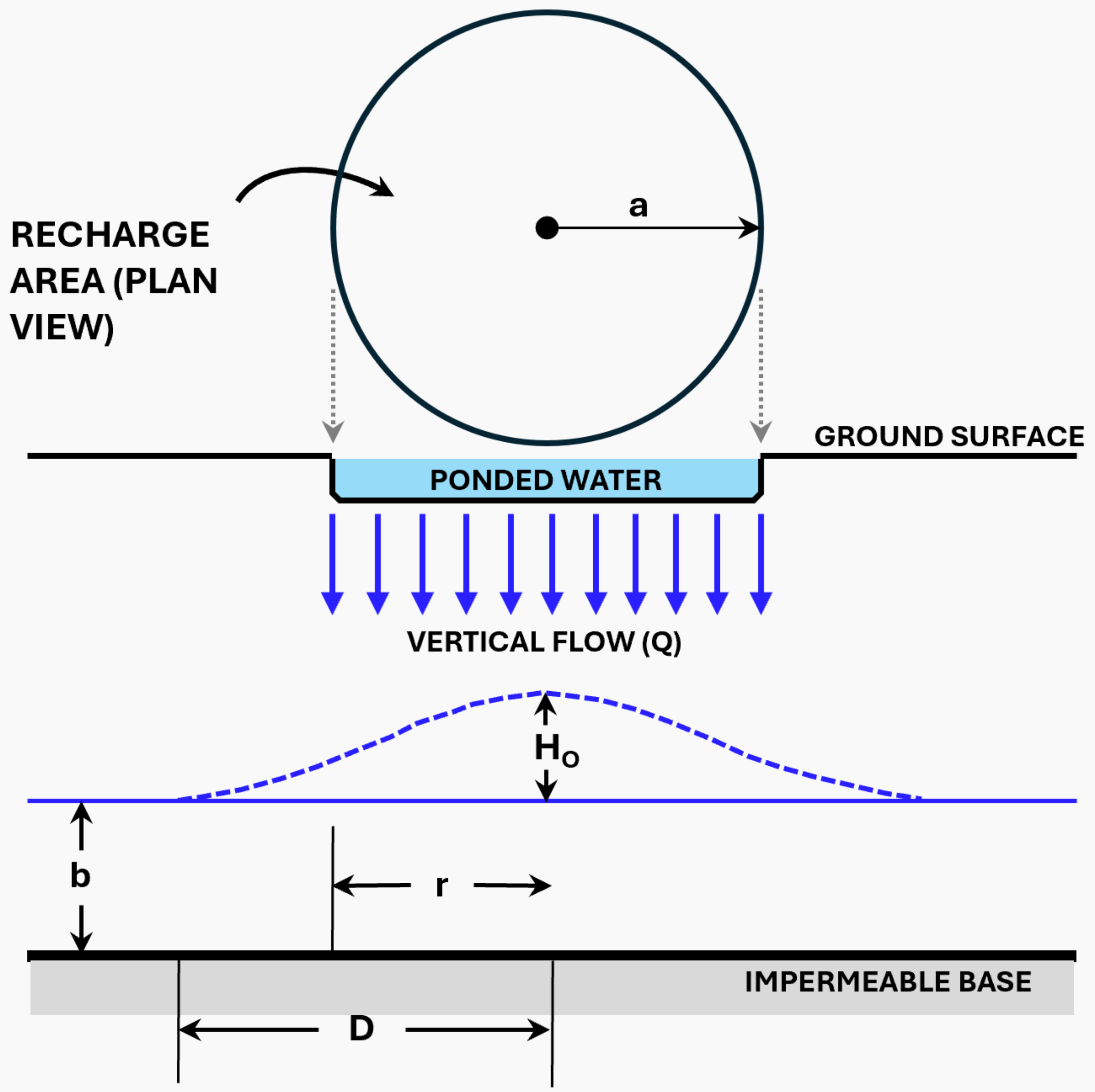
Estimating Transient Groundwater Mounding



Parmley Equation:

$$H_0 = \sqrt{b^2 + \frac{Q \log_{10}\left(\frac{D}{a}\right)}{1.3K}} - b$$

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When to use this

Use the Parmley equation to estimate groundwater mounding beneath an infiltration basin, pond, or impoundment.

It can help test basin recharge rates, check whether a mound may reach a design limit, and estimate when recharge water may affect a nearby receptor.

Applications include:

- Storm retention ponds
- Tailings ponds
- Landfill leachate areas
- Artificial recharge basins.

Limitations & Assumptions

This calculation assumes the aquifer is:

- Homogeneous, isotropic and unconfined
- Underlain by a horizontal impermeable base
- Recharged uniformly from the surface pond/basin.

This calculation is best suited to:

- Circular or square or nearly square basins

Not intended for:

- Long, narrow basins
- Layered or strongly anisotropic aquifers
- Nearby boundaries, drains, streams, wells, or pumping systems
- Short-duration ponding

Equations & Variables

Symbol	Meaning	Units
H_0	Maximum mound above the initial aquifer thickness	L
a	Equivalent circular basin radius	L
b	Aquifer's initial saturated thickness	L
Q	Total recharge flow rate	L^3/T
D	Radius of influence	L
K	Hydraulic conductivity of aquifer	L/T
t	Time since infiltration began	T

Parmley Equation:

$$H_0 = \sqrt{b^2 + \frac{Q\log_{10}\left(\frac{D}{a}\right)}{1.3K}} - b$$

The Parmley equation estimates steady-state groundwater mounding beneath a circular recharge basin using a small set of inputs: recharge flow, basin radius, hydraulic conductivity, initial saturated thickness, and radius of influence.

Its main advantage is simplicity. Unlike Hantush-style methods, Parmley does not require error functions, numerical integration, or special functions, making it easier to set up in a spreadsheet or script.

Transient Extension

Parmley is steady state, but Warner et al. showed that the radius of influence can be treated as time-dependent.

In the implementation presented here, we use that transient radius of influence to estimate how the groundwater mound grows over time.

Warner et al. volume balancing equation for determining Radius of influence (D):

Recharge volume $$(V) = Qt = \frac{SQ}{8K}\left[\frac{8D^3 - D^2a - Da^2 + a^3}{D-a} - \exp\left(\frac{D-a}{D}\right)\left(3D^3 + 2D^2a\right) + a^2\left(\ln\left(\frac{a}{D}\right) - \frac{D}{D-a}\right)\right]$$

Symbol	Meaning	Units
$\mathbf{V}$	Total recharge volume	L^3
$\mathbf{a}$	Equivalent circular basin radius	L
$\mathbf{b}$	Aquifer's initial saturated thickness	L
$\mathbf{Q}$	Total recharge flow rate	L^3/T
$\mathbf{D}$	Radius of influence	L
$\mathbf{K}$	Hydraulic conductivity of aquifer	L/T
$\mathbf{t}$	Time since infiltration began	T
$\mathbf{S}$	Specific yield of aquifer	-

Step-by-step calculation sequence

1. Define the equivalent circular basin radius (a)

    - The Parmley method is applicable to rectangular basins with length to width ratio of about 1 to 1.5. To convert the rectangular basin area (A) to an equivalent circular basin radius (a):

$$a = \sqrt{\frac{A}{\pi}}$$

2. Define total recharge flow (Q). If you only know infiltration rate (I) then use:

$$Q = \mathrm{I}\pi a^2$$

3. Convert recharge flow (Q) to total recharge volume (V) by multiplying by the time (t) you want.

$$V = Qt$$

4. Solve for the transient radius of influence (D) using Warner et al.'s volume balance equation.

    - This equation must be solved iteratively by changing D until the right side (representing volume beneath the mound) is equal to the recharge volume (V) on the left side. Excel's Goal Seek Function can do this quickly for you.

5. Calculate the Mound Height (H_0) using the Parmley equation and your estimate of D from Step 5 (or use alternate estimate method for D).

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Case Study: Field Recharge Test

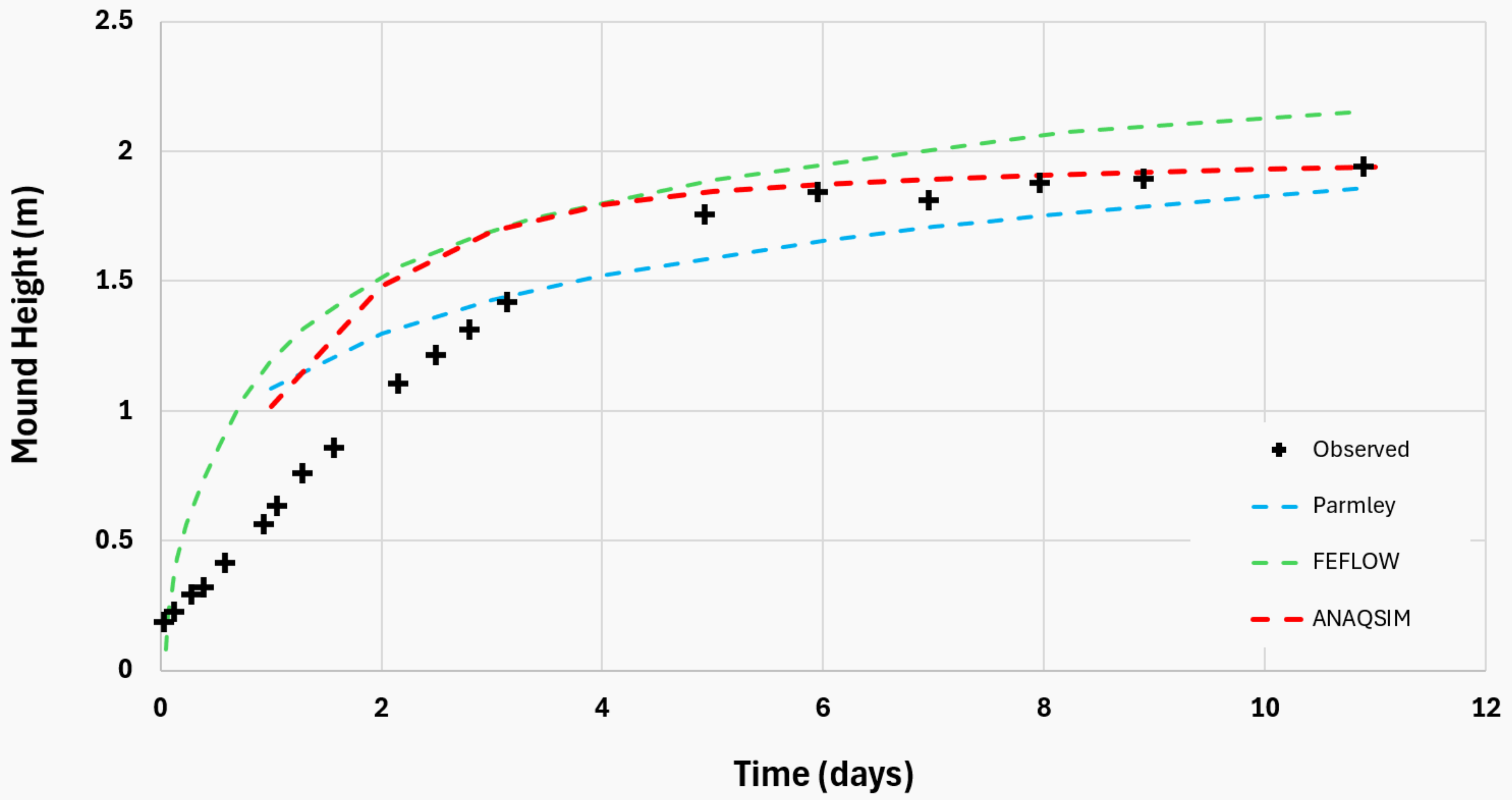
Bianchi & Haskell's 1968 field study monitored groundwater mounding beneath Pond 2, a square recharge basin measuring **90 m × 90 m**. The test was completed in an unconfined aquifer with:

- Hydraulic conductivity of **7.92 m/day**,
- Fillable porosity of **0.052**,
- Initial saturated thickness of **24.38 m**,
- An applied infiltration rate of **0.10668 m/day** over **10.92 days**.

The field program set out to observe how a recharge mound forms beneath an infiltration basin, and how that mound changes after recharge stops. For this cheat sheet, the same basic inputs were used to retrospectively test the transient Parmley method by comparing calculated mound growth against the observed field response.

The transient Parmley results are also compared with two numerical groundwater models to see how the simple analytical estimate performs beside more detailed simulation methods.

Results



The transient Parmley estimate did not closely match the first few days of observed mound growth. The FEFLOW and Anaqsim simulations showed the same early-time mismatch, suggesting the issue was not specific to the analytical equation.

A likely explanation is that the vadose zone was still ‘wetting up’, so the effective recharge rate reaching the water table was changing. After several days, the transient Parmley estimate followed the observed mound reasonably well, suggesting the method is best suited to semi-permanent or permanent pond/basin systems, and less useful for short-duration or intermittent ponding events.

Further Reading

- Bianchi, W. C., & Haskell, E. E., Jr. (1968). Field observations compared with Dupuit-Forcheheimer theory for mound heights under a recharge basin. *Water Resources Research, 4*(5), 1049–1057.
- Chipongo, K., & Khiadani, M. (2015). Comparison of simulation methods for recharge mounds under rectangular basins. *Water Resources Management, 29*, 2855–2874.
- Parmley, R.O. (2001). Hydraulics Field Manual, 3-27–3-28. 2nd Edition, McGraw-Hill, New York, NY.
- Warner, J. W., Molden, D., Chehata, M., & Sunada, D. K. (1989). *Mathematical analysis of artificial recharge from basins*. *Water Resources Bulletin, 25*(2), 401–411.