1. Do the computer models we have replicate field behavior ?

Using PONDS 3.2 for Trench Design

The PONDS 3.2 software is a finite difference numerical model which is based on the USGS MODFLOW software. PONDS is commonly utilized for a wide range of retention pond design problems, and can also be utilized to analyze exfiltration trenches.

Following is a comparison of actual field tests performed on test trenches in Broward County, and the predicted response of these test chambers as calculated by the PONDS software.

Field Tests of Trench Exfiltration Rates

SFWMD Technical Publication 87-5, Field Testing of Exfiltration Systems (DRE-236) presents field testing on seven exfiltration trenches in Broward County, Florida.

Of these seven tests, two tests were selected because they provide good measurements of the exfiltration rate over time, as well as ground water measurements in the vicinity of the trench:

Width of trench = 6 ft
Height of trench = 6 ft
Length of trench = 10 ft
Base of trench = 8 ft below ground surface

Field Test Conditions

- Water was supplied using a regulated and metered source
- The trench was first filled as quickly as possible until test water level was achieved
- Once filled, the flow rate was reduced (and periodically adjusted) in order to maintain a constant head for the duration of the test
- Flow measurements into the trench were recorded for the duration of the test
- Periodic ground water measurements were taken in a series of monitor wells installed in near proximity to the trench

MODEL Conditions

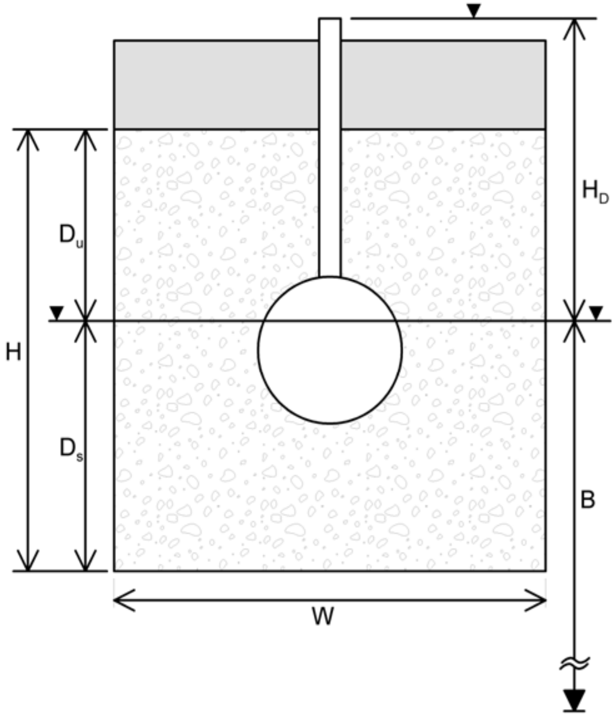
The exfiltration tests were modeled using the PONDS 3.2 Refined Method software. In order to simulate the exfiltration trenches, and test conditions, the following model assumptions were used:

- During the initial filling phase of the test, the inflow to the trench was set equal to the measured inflow into the trench
- Once filled, a constant inflow rate was applied to the trench sufficient to keep the water level in the trench from falling below the constant head test level.
- In order to maintain a constant head in the exfiltration trench, a discharge structure was defined, with the discharge elevation set to maintain a constant head at field test level.

Field Test #6

Test 6

Horizontal Conductivity, K_h = 20.7 ft/day
Insitu Soil Porosity , n_s= 23%
Gravel Porosity, n_g = 40%
Porosity of soil backfill, n_f = 15%
Height of Trench, H = 6 ft
Width of Trench, W = 6 ft
Unsaturated Depth of Trench, D_u = 2.6 ft
Saturated Depth of Trench, D_s = 3.4 ft
Height of Water Level in Test, H_D = 5.2 ft
Aquifer Depth, B = 12 ft



Test 6, Time vs. Exfiltration Rate

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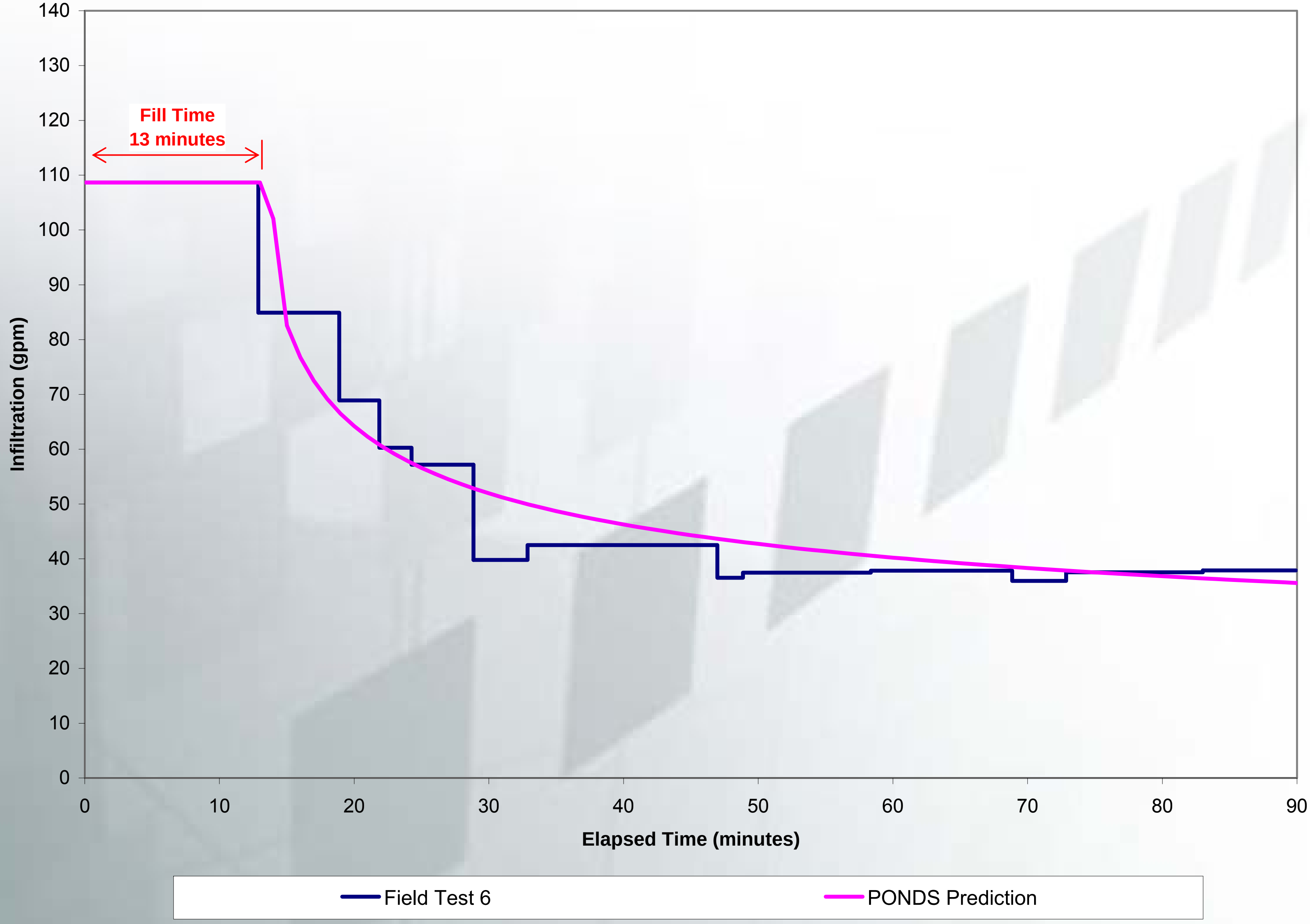
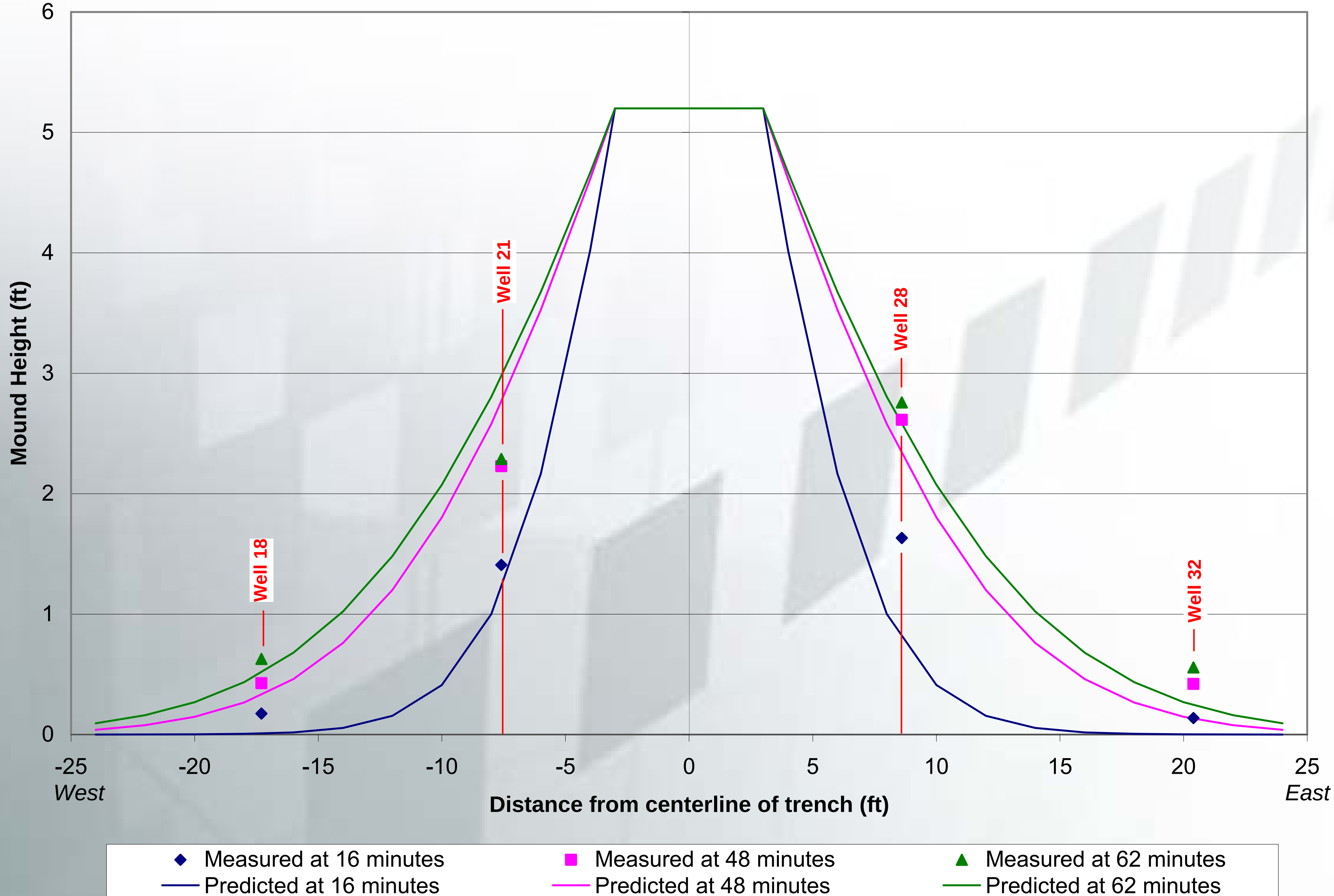


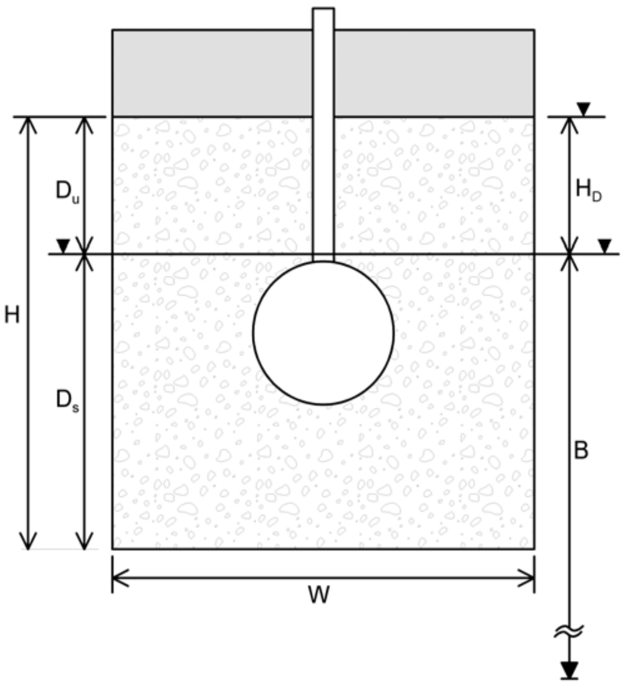
Test 6, Groundwater Mound



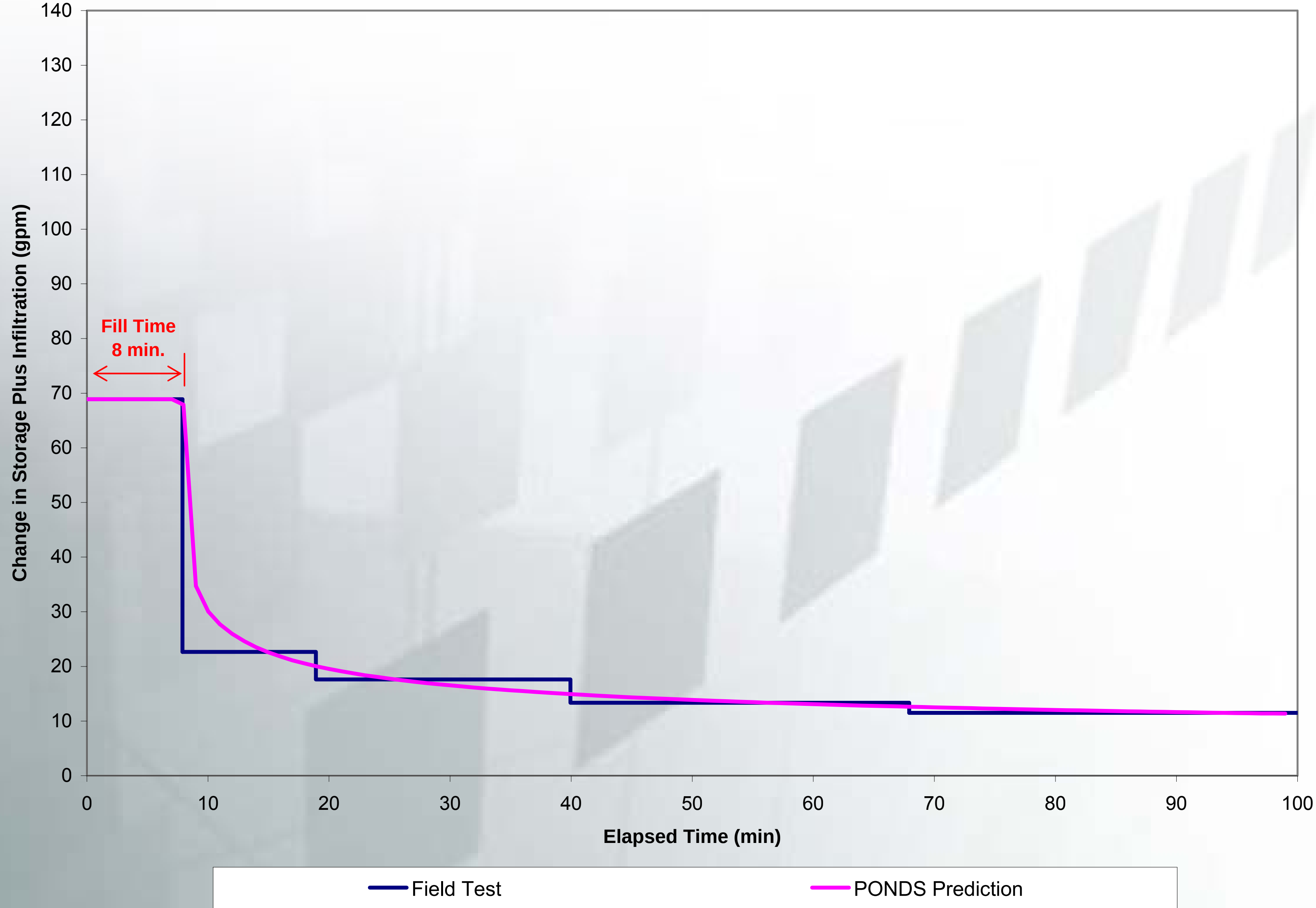
Field Test #7

Test 7

Horizontal Conductivity, K_h = 20.7 ft/day
Soil Porosity , n_s= 23%
Gravel Porosity, n_g = 40%
Height of Trench, H = 6 ft
Width of Trench, W = 6 ft
Unsaturated Depth of Trench, D_u = 1.9 ft
Saturated Depth of Trench, D_s = 4.1 ft
Height of Water Level in Test, H_D = 1.9 ft
Aquifer Depth, B = 12 ft



Test 7, Time vs. Exfiltration Rate



Test 7, Groundwater Mound

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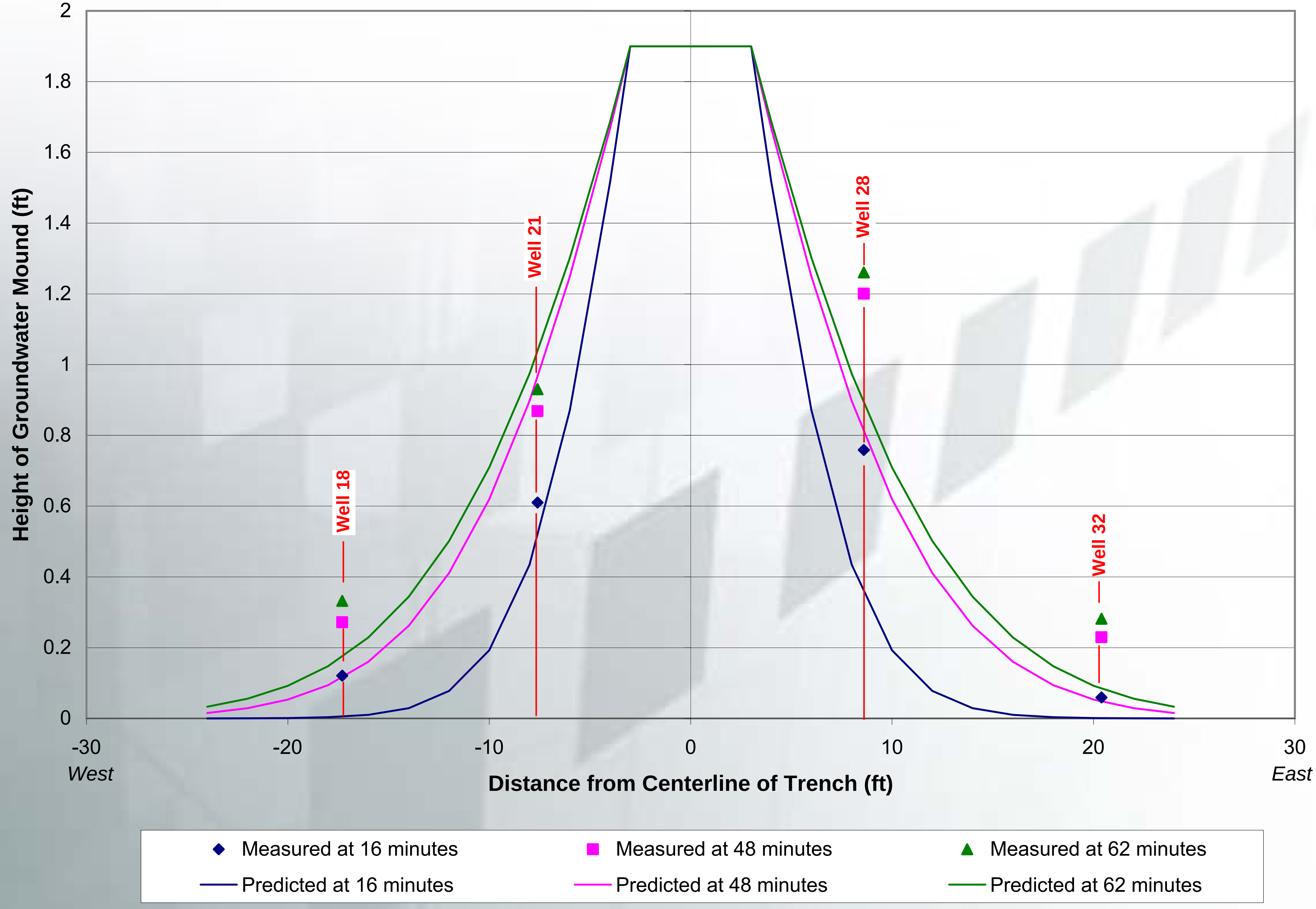


2. Difference between PONDS Software and SFWMD Equation for Exfiltration Trenches.

SFWMD Exfiltration Trench Equation

The South Florida Water Management District (SFWMD) **Technical Publication 87-5, Field Testing of Exfiltration Systems, (DRE-236)** presents a design equation for calculating the required length of exfiltration trench based on Glover's line source theory.

SFWMD Alternate Design Equation

$$L = \frac{1.01\ V - 0.084\ D_u\ W\ (K\ H\ N_a)^{1/2}}{0.084\ D_u\ (K\ H\ N_a)^{1/2} + 1.39 \times 10^4\ W\ D_u}$$

where

L = length of trench (ft)
V = design trench capacity (acre-inches)
D_u = unsaturated depth of trench (ft)
K = hydraulic conductivity (ft/sec)
H = height of trench (ft)
N_a = effective porosity of aquifer
W = width (ft)

Reference: SFWMD Technical Publication 87-5, Field Testing of Exfiltration Systems, (DRE-236)

Equation Assumptions

The SFWMD equation has implicit assumptions which may not be applicable to all design situations, such as:

- credit for change in storage plus infiltration over a one hour time period
- a fixed porosity within the trench of 0.5
- a fixed base of aquifer corresponding to twice the trench height
- the trench is always full during recovery, i.e., constant head
- recovery follows Glover's Line Source theory
- trench partially submerged

A Pond versus a Trench

Conceptually, an exfiltration trench is the same as a retention pond, with one important distinction:

The pond is "open", and has a porosity of 1.0 (100%).

An exfiltration trench is usually filled (or partially filled) with gravel, and has a porosity less than 1.0. The porosity of the trench can vary depending on the type of gravel used, etc., and the porosity is not necessarily uniform in the vertical direction as a result of open space in the trench created by pipes or stormwater chambers, etc.

Using PONDS Software for Exfiltration Trench Analysis

The PONDS software assumes that the pond is open with a porosity of 1.0 (100%) and does not directly allow for the possibility of a gravel filled trench.

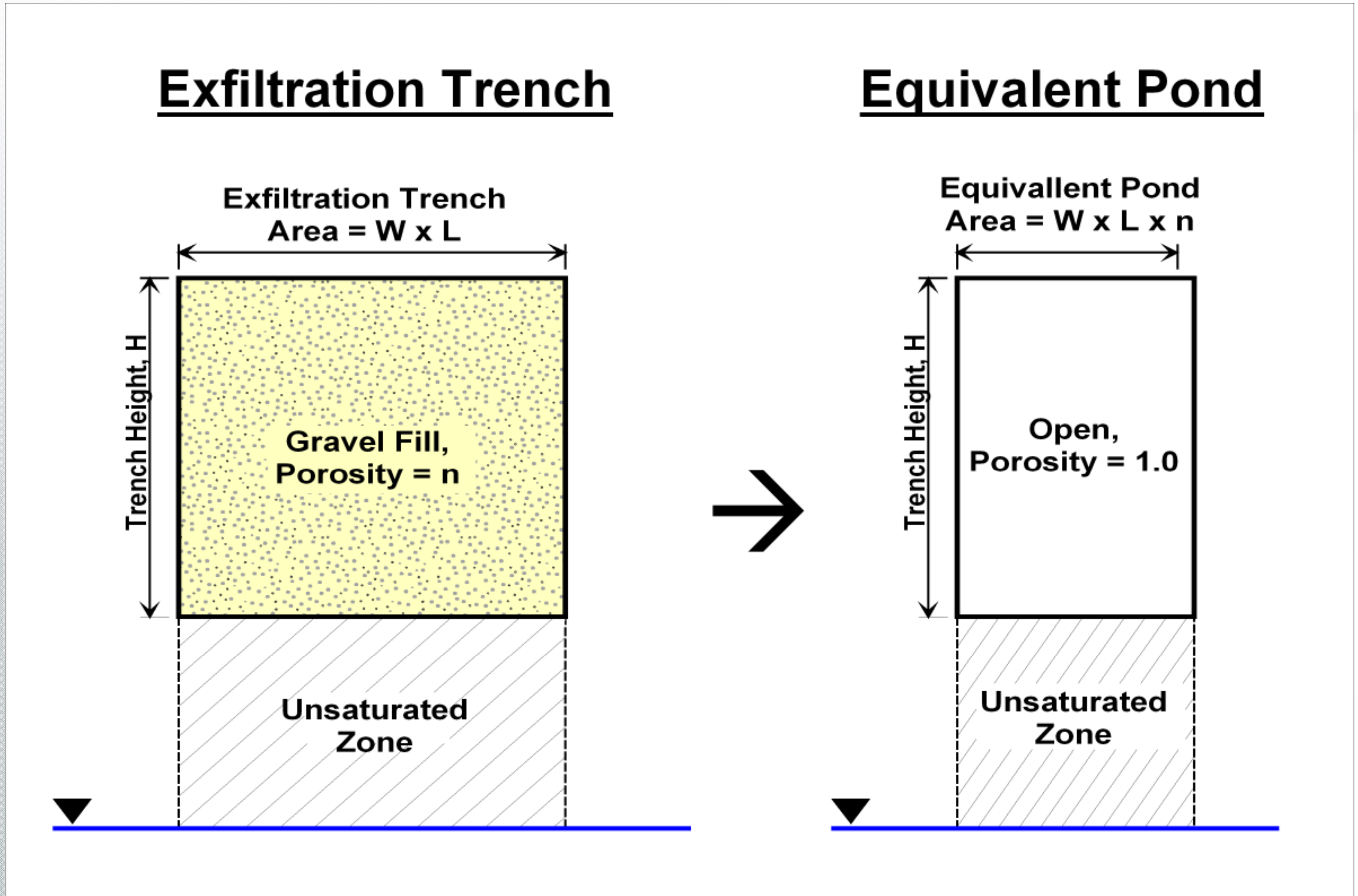
By modifying the stage vs area data in pond, the porosity of the exfiltration trench can be simulated.

$$A_{eq} = A_{open} \times n$$

where

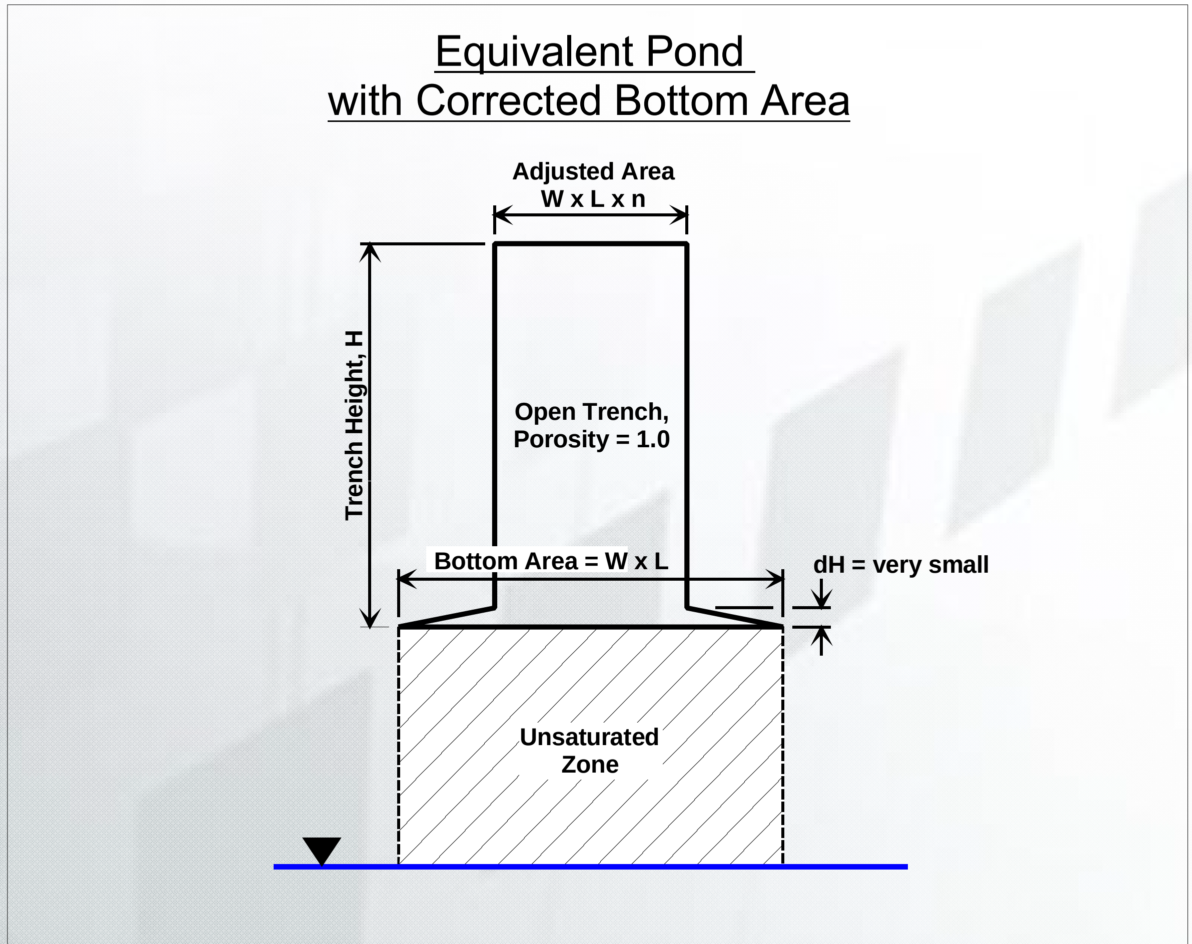
A_{eq} is the equivalent area to use in the PONDS software
A_{open} is the area of the trench excavation, L x W
n is effective porosity of the trench (at a given depth)

Simulating a Trench



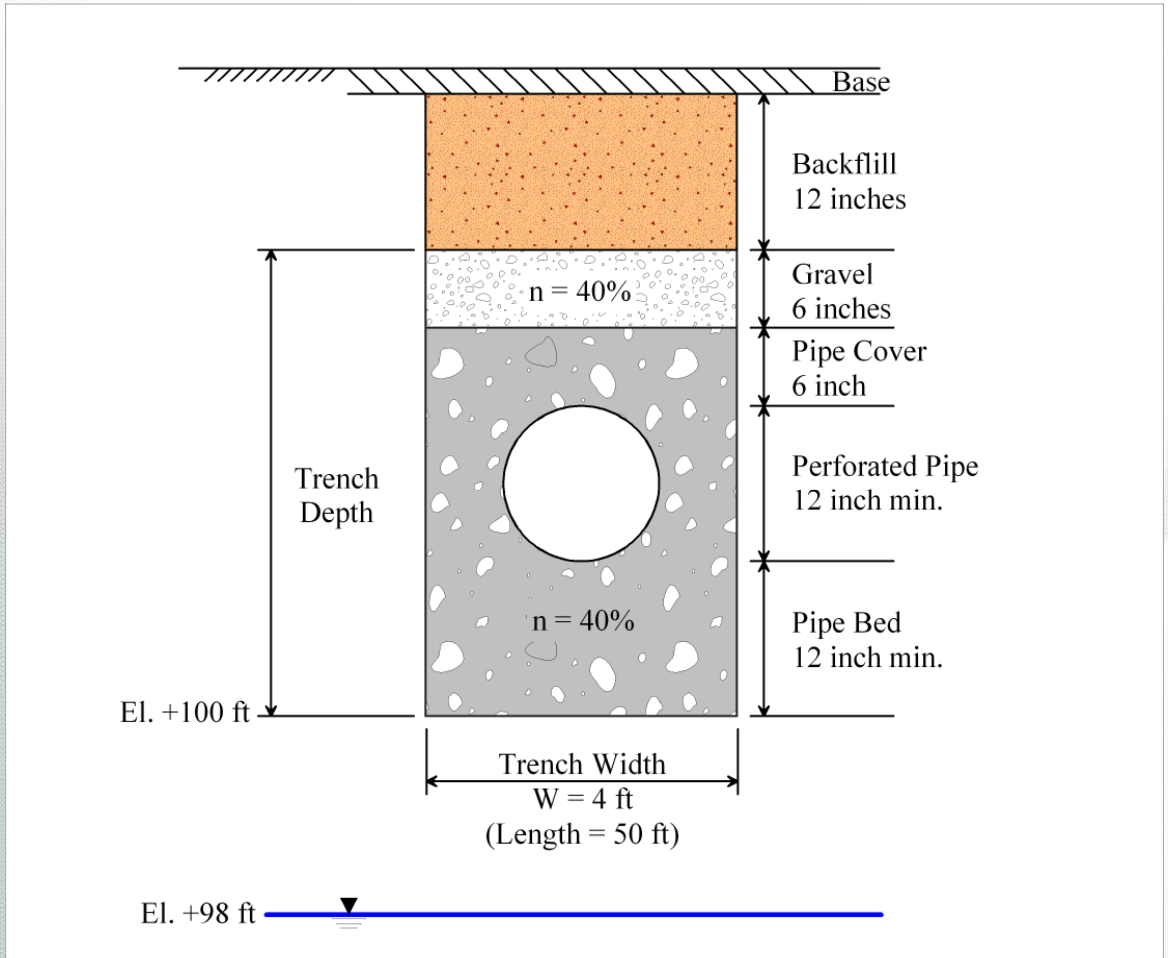
Note the decrease in the soil volume in the unsaturated zone.

Preserving The Bottom Area



3. Example Problem in PONDS Software – Exfiltration Trench

Example Exfiltration Trench



Trench Data

- Length = 50 ft
- Width = 4 ft
- See sketch

Data

Aquifer Data

- Base of aquifer elevation = +93 ft
- Water table elevation = +98 ft
- Horizontal saturated hydraulic conductivity = 5 ft/day
- Fillable Porosity = 20%
- Unsaturated vertical infiltration rate = 1.5 ft/day
- Maximum Area for Unsaturated Infiltration = 4 ft x 50 ft = 200 ft^2

Geometry Data

Equivalent Length = 50 ft (same as trench excavation)
Equivalent Width = 4 ft (same as trench excavation)

Stage vs Area

Zone	Elevation or Range	Area
Base	+100 ft	A = W x L 4 ft x 50 ft = 200 ft^2
Below pipe	+100.01 ft to +100.99 ft	A = W x L x n (4 ft x 50 ft) x 0.4 = 80 ft^2
With pipe	+101 ft to +102 ft	A = W x L x n' (see next slide) (4 ft x 50 ft) x 0.71 = 142.8 ft^2
Above pipe	+102.01 ft to +103 ft	A = W x L x n (4 ft x 50 ft) x 0.4 = 80 ft^2

Average Porosity in Pipe Zone

$$n' = \frac{\text{Actual Storage Volume}}{\text{Open Excavation Volume}} = \frac{[L \times \pi r^2 (1-n)] + [L \times W \times H \times n]}{L \times W \times H \times n}$$

$$n' = \frac{\pi r^2 (1-n)}{W \times H} + n$$

In this example:

- L = 50 ft
- W = 4 ft
- H = 1 ft (height interval of pipe zone)

So

$$n' = \frac{\pi (0.5 \text{ ft})^2 \times (1 - 0.4)}{4 \text{ ft} \times 1 \text{ft}} + 0.4 = \underline{\mathbf{0.71}}$$

Design Event

Calculate the recovery time for a 250 ft^3 treatment volume.

Example Results

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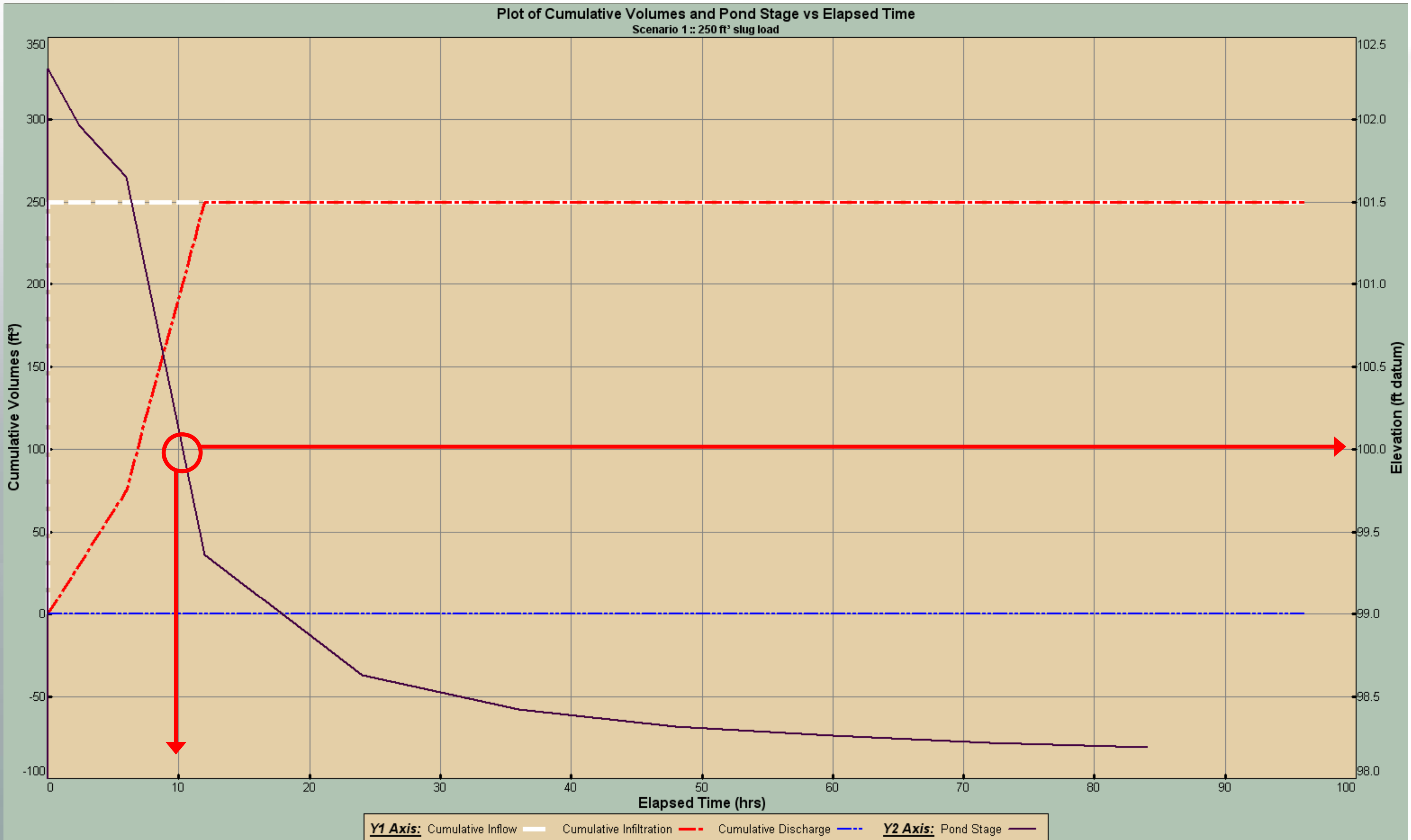

4. Construction Considerations for Exfiltration Trenches.

SETTLEMENT OF LOOSE SAND SUBGRADE UNDER EXFILTRATION TRENCHES

Loose sands may settle (consolidate) due to the hydraulic stresses resulting from the rapid concentration of stormwater runoff in exfiltration trenches. Very loose soil conditions can occur in nature or can be created by the placement of sand backfill without compaction. Settlement of this type usually occurs after the trench receives its first significant quantity of rainfall runoff. While this type of settlement may not be a cause for concern where the exfiltration trench is located within a landscape area, it can lead to distress when the trench underlies a structure such as a pavement.

HOW TO AVOID SETTLEMENT OF LOOSE SAND SUBGRADE UNDER EXFILTRATION TRENCHES

To avoid settlement, it is recommended that, prior to final grading of the cover, the trench be flooded continuously for a minimum period of 8 to 10 hours. Water for flooding may be obtained from a nearby fire-hydrant, well, lake, or potable water connection. This flooding should simulate worst case rainfall runoff conditions and mitigate future generalized or localized subsidence. Settlement of the chambers and the gravel backfill in the trench should be monitored during the flooding and for about a week thereafter, before final grading is performed.

SINKHOLES

- Exfiltration trenches not a good idea in parts of the state where there is a thin overburden and high potential for sinkhole development, unless thoroughly checked out by a geotechnical engineer. Concentration of stormwater can lead to sinkhole development which cannot be seen at the surface.
- FDOT tried this on I-75 (in Marion County) and numerous sinkhole developed leading to a maintenance nightmare. Many of you remember when the southbound of I-75 was shut down. FDOT abandoned the trenches & went with swales.