MODELING STORMWATER MANAGEMENT SYSTEMS THE BASICS WITH EMPHASIS ON GROUND WATER / SURFACE WATER INTERACTION

prepared for:
FES 1999 STORMWATER MANAGEMENT DESIGNER'S COURSE
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The Radisson Plaza Hotel, Orlando

presented by
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FES STORMWATER DESIGNER'S COURSE - AGENDA

GROUND WATER/SURFACE WATER INTERACTION MODELING

- **List of "Essential Tools" needed by design engineer**
- **Review capabilities & typical applications of demonstration software**
- **Review the typical conceptual models & their input data requirements**
- **Minimum requirements for soils reports. Geotechnical investigation to estimate aquifer parameters.**
- **Construction considerations for stormwater ponds**
- **Example problems using commercially available software**

ESSENTIAL TOOLS

PUBLICATIONS

- **USGS 7.5 minute series quadrangle map**
- **NRCS Soil Survey Book**
- **Aerial photos (if available). REDI, County, FDOT, WMD**
- **Potentiometric surface map of Floridan aquifer for area**
- **SJRWMD Special Publication SJ93-SP10. This is a free publication on stormwater pond design which can be obtained by calling the SJRWMD library at 904-329-4132.**
- **Florida's Geological History & Geological Resources, Florida Geological Survey Special Publication #35**
- **Seasonal high water table paper by Devo (included) & SWFWMD 1998 Training Workshop Course Notes**

ESSENTIAL TOOLS (continued)

SITE-SPECIFIC DATA

- ★ Plan of property with topographic contours and location of pond; predevelopment ground surface elevations
- ★ Characteristics of the predevelopment & postdevelopment contributing drainage area
- ★ Stage-area data of pond, including proposed pond bottom elevation relative to existing grade
- ★ Geotechnical report with borings and recommended aquifer parameters (will discuss minimum requirements for geotech reports)
- ★ Conseqeunce of failure of pond - how sensitive?
- ★ Proximity of proposed pond(s) to adjacent ponds

ESSENTIAL TOOLS (continued)

SOFTWARE

- ★ TR 55 Version 2 - used for computing time of concentration and weighted curve numbers. Available free from NRCS office in Gainesville (904-338-9555, ask for Gene Daugherty or Jesse Wilson)
- ★ PONDS Version 2.26 or Version 3 (or equivalent software)
- ★ May need USGS MODFLOW for more complicated situations. Will explain why later. However, this should only be used by experienced modelers.
- ★ May need adICPR or CHAN or equivalent to interface with PONDS if dealing with system of interconnected ponds.

TYPICAL COMPUTATIONAL MODULES IN SOFTWARE

WATER QUALITY RECOVERY ANALYSES

- Dry retention & wet retention ponds (unlined or partially lined)
- Exfiltration trenches
- Wet detention ponds (with & without ground water baseflow component)
- Dry detention ponds (with & without percolation)
- Underdrain ponds (with & without ground water baseflow component)
- Filtration systems including side-bank, pond-bottom, and VVRS filters
- Swales

TYPICAL COMPUTATIONAL MODULES IN SOFTWARE

TYPICAL HYDROGRAPHS

- **SCS Unit hydrographs (can include recovery time following storm)**
- **Water quality recovery volume hydrographs (automatic setup of time steps for SJRWMD & SWFWMD criteria)**
- **Baseflow Hydrographs**
- **Continuous simulation hydrographs (new type)**
- **Perc Pond Hydrographs**
- **Manually input of hydrograph**

TYPICAL COMPUTATIONAL MODULES IN SOFTWARE

ROUTING HYDROGRAPHS

- True routing with or without credits for infiltration during the storm event. True routing means that the model can predict the peak stage, discharge rates, etc.
- Critical duration analysis is now possible with more recent software where up to 100 hydrographs can be routed and critical hydrograph identified based on parameter.
- For interconnected ponds, the ground water model can interface directly with conventional surface water models such as adICPR, CHAN, etc.

TYPICAL COMPUTATIONAL MODULES IN SOFTWARE

WATER TABLE DEWATERING & DRAWDOWN

- Compute dewatering rates and water table drawdown impact distances for the following applications:
  - ☐ Borrow pits,
  - ☐ Ditches,
  - ☐ Interceptor trenches,
  - ☐ Wet detention ponds,
  - ☐ Road underdrains,
  - ☐ Utility line dewatering,
  - ☐ Etc.
- Assess setback distances from wetlands

TYPICAL COMPUTATIONAL MODULES IN SOFTWARE

OTHER APPLICATIONS - EXTERNAL

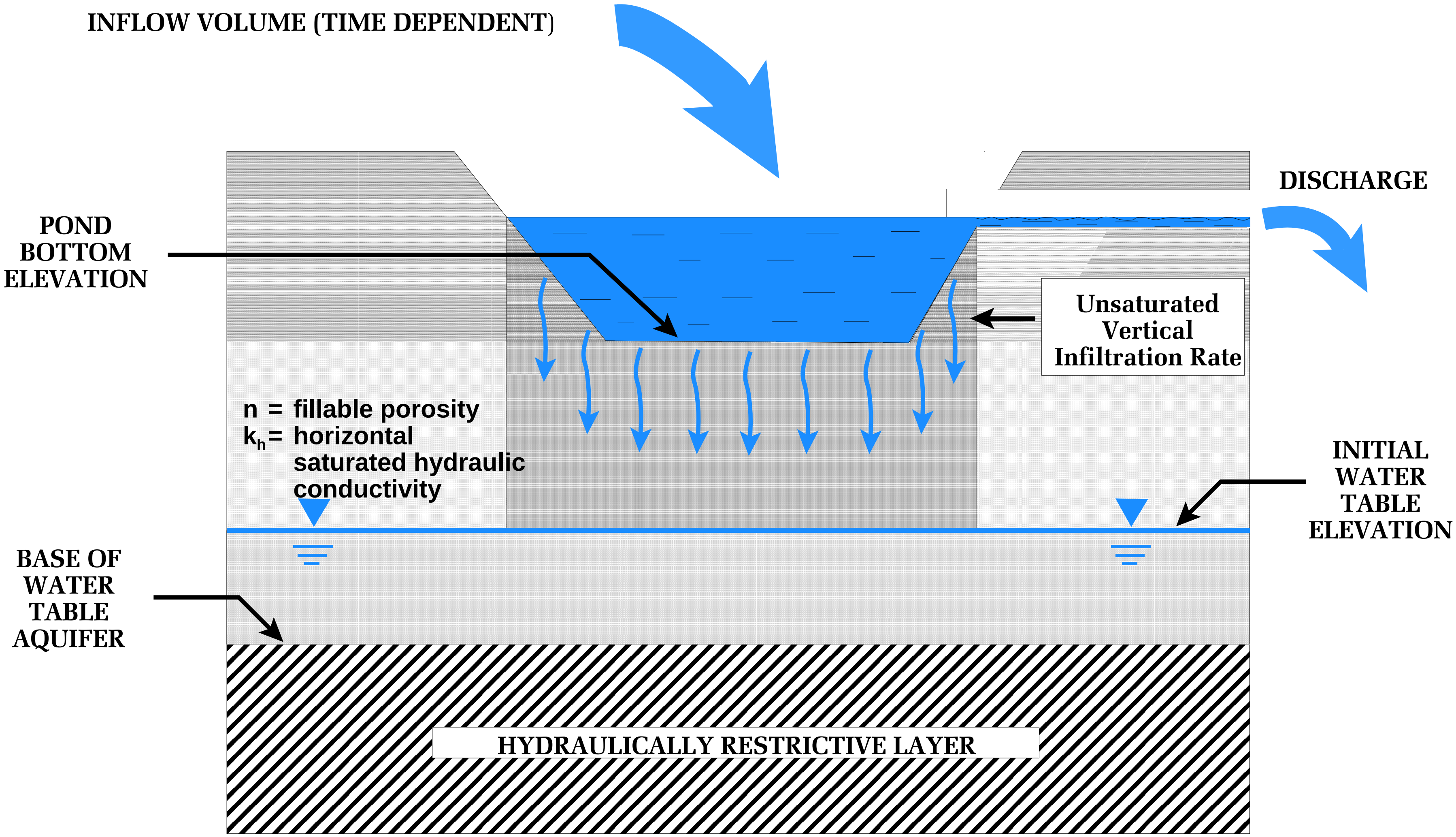
- Retention pond fill berm slope stability analysis
- Channel lining analysis (HEC 15)

WHAT IS A CONCEPTUAL MODEL?

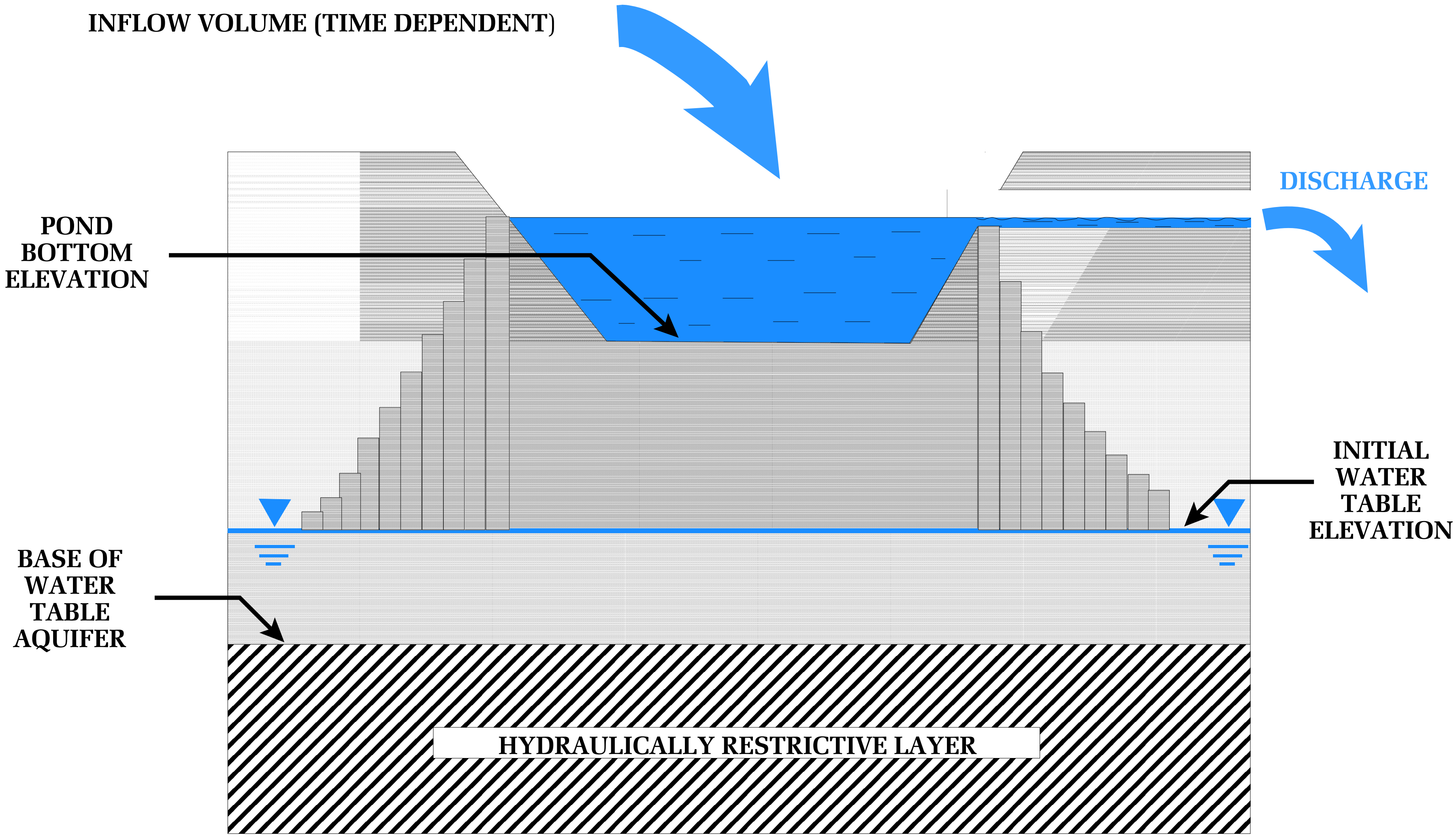
A conceptual model is a pictorial representation of the ground water flow system. In the practice of developing a conceptual model, it is desirable to strive for parsimony, by which it is implied that the conceptual model has been simplified as much as possible yet retains enough complexity so that it adequately reproduces system behavior.

The conceptual models described in this workshop can be applied to the majority of design situations in Florida.

DRY RETENTION - STAGE I FLOW
UNSATURATED VERTICAL INFILTRATION ONLY

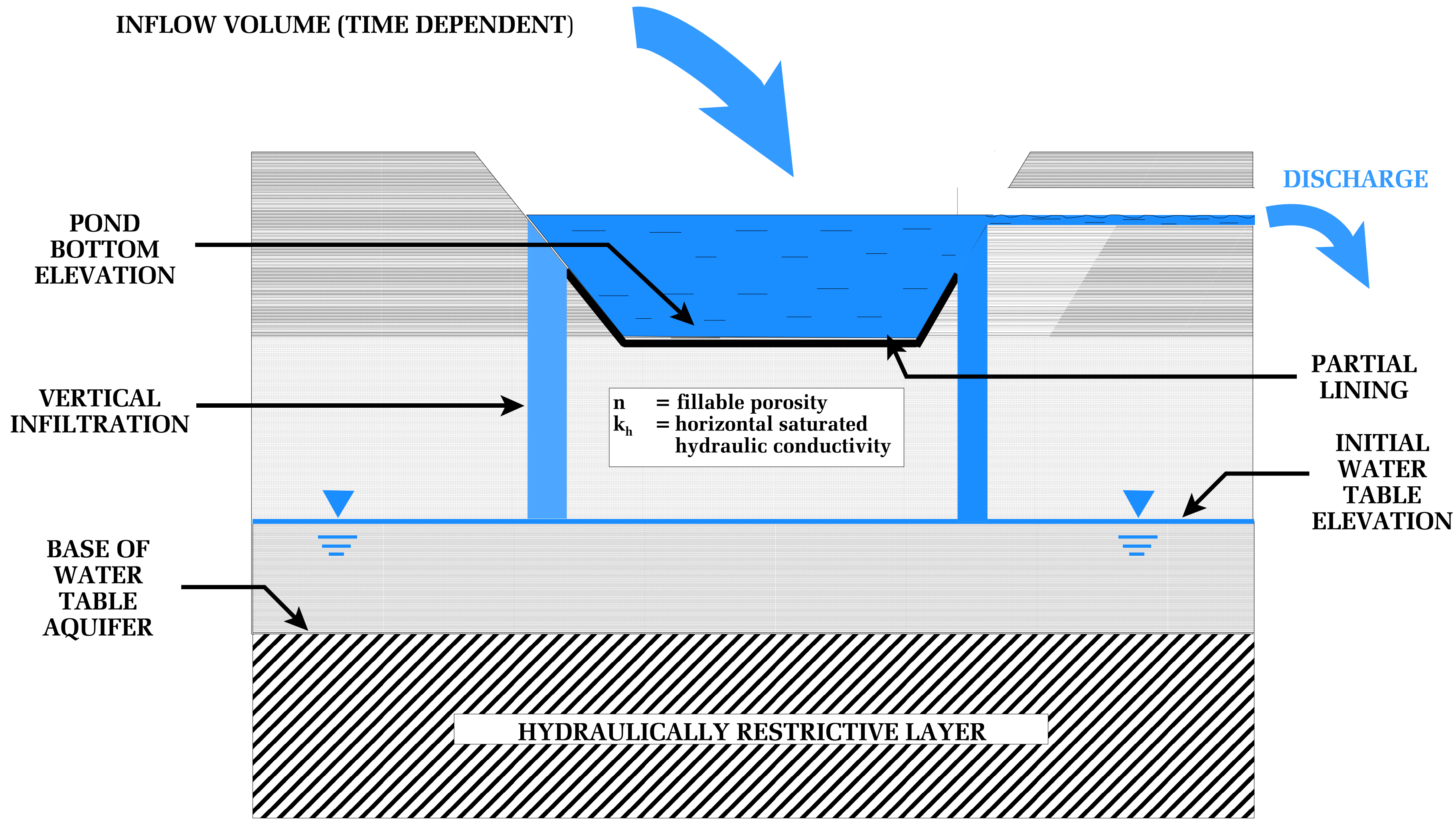


DRY RETENTION - STAGE II RECOVERY
SATURATED LATERAL FLOW

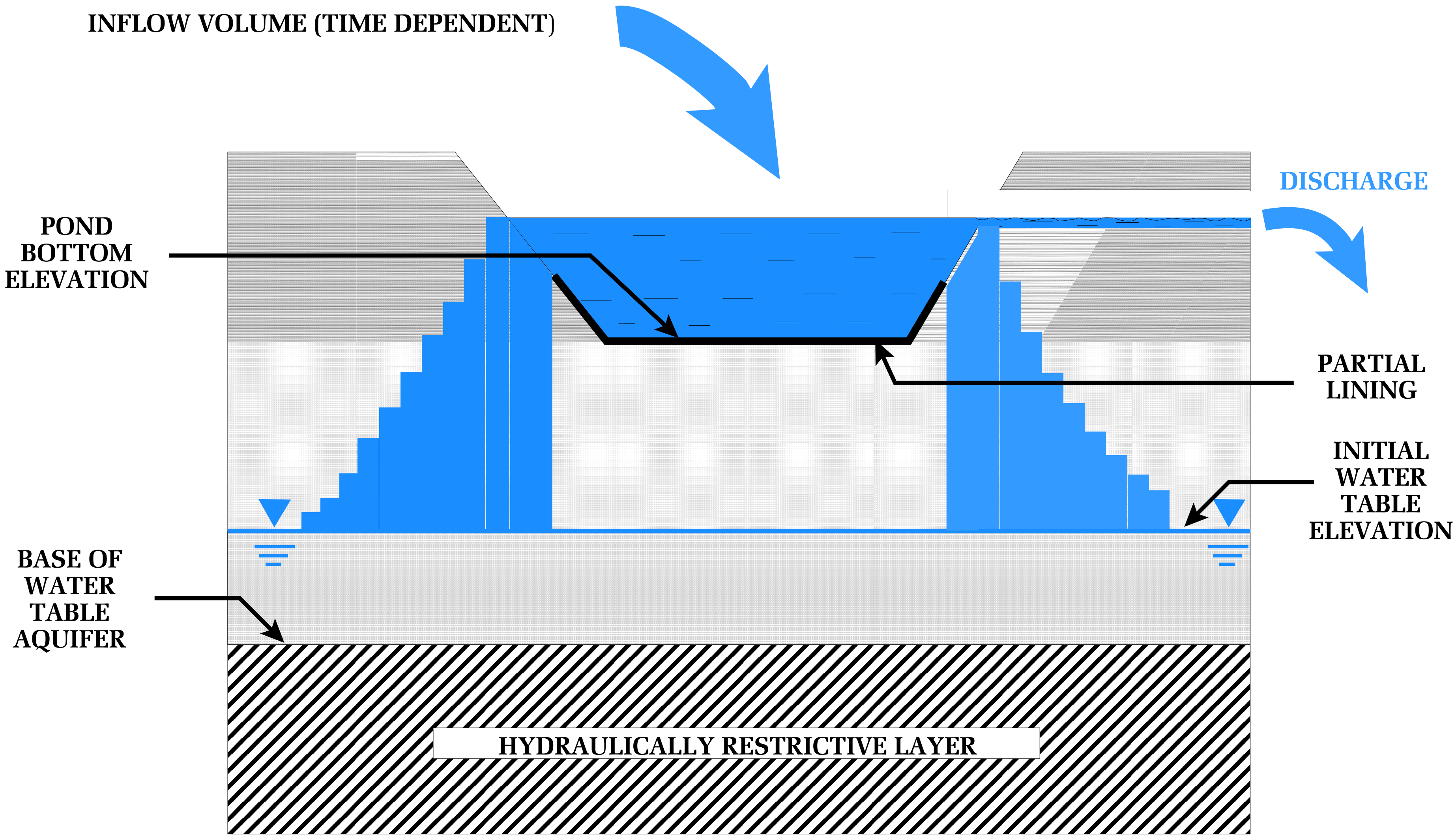


note: initial flat water table assumption is not unrealistic when the natural gradient is considered together with the duration of loading and the corresponding radius of influence.

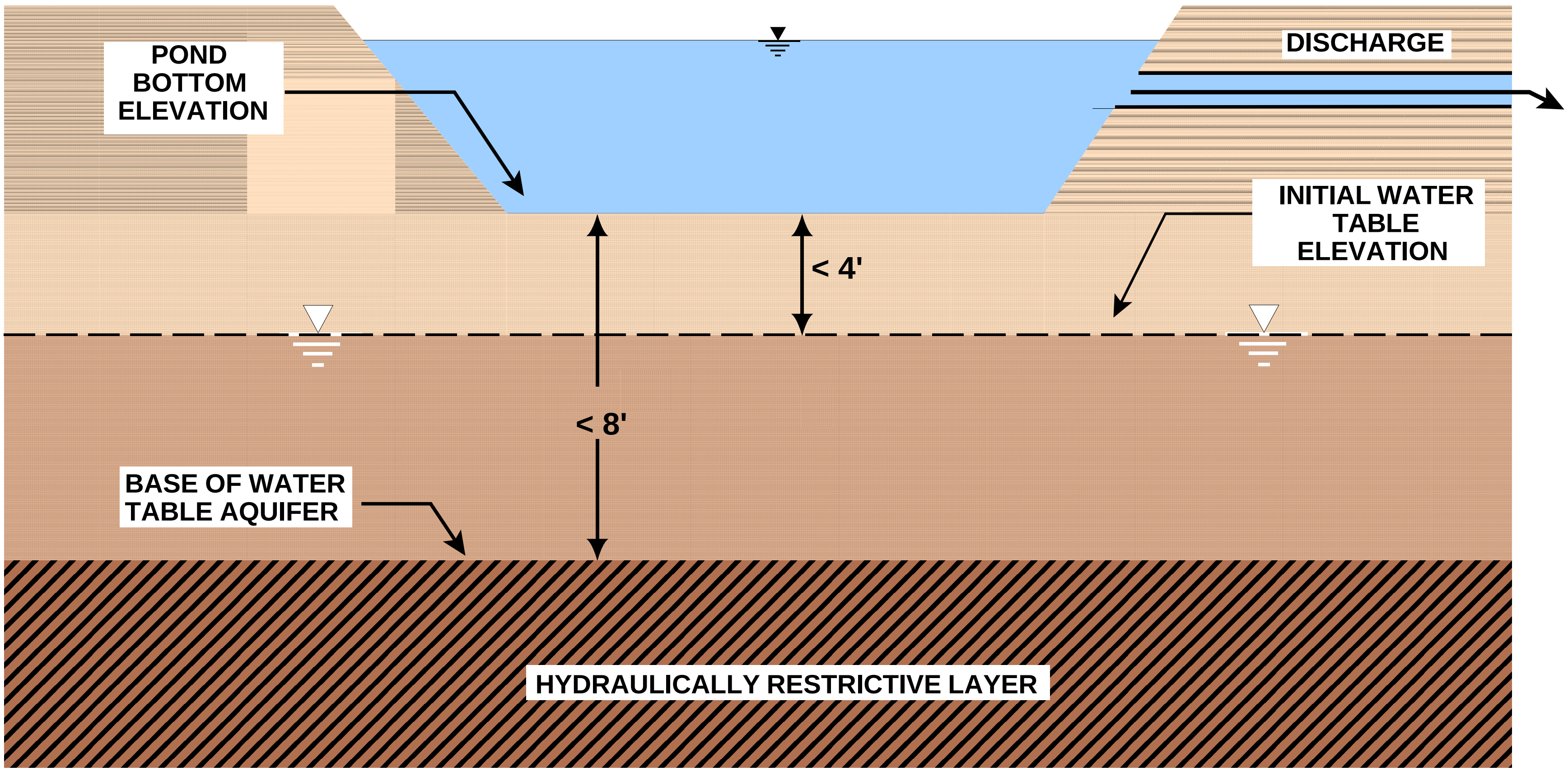
PARTIALLY LINED RETENTION POND (STAGE I FLOW)
UNSATURATED VERTICAL INFILTRATION ONLY



PARTIALLY LINED RETENTION POND (STAGE II FLOW)
SATURATED LATERAL FLOW



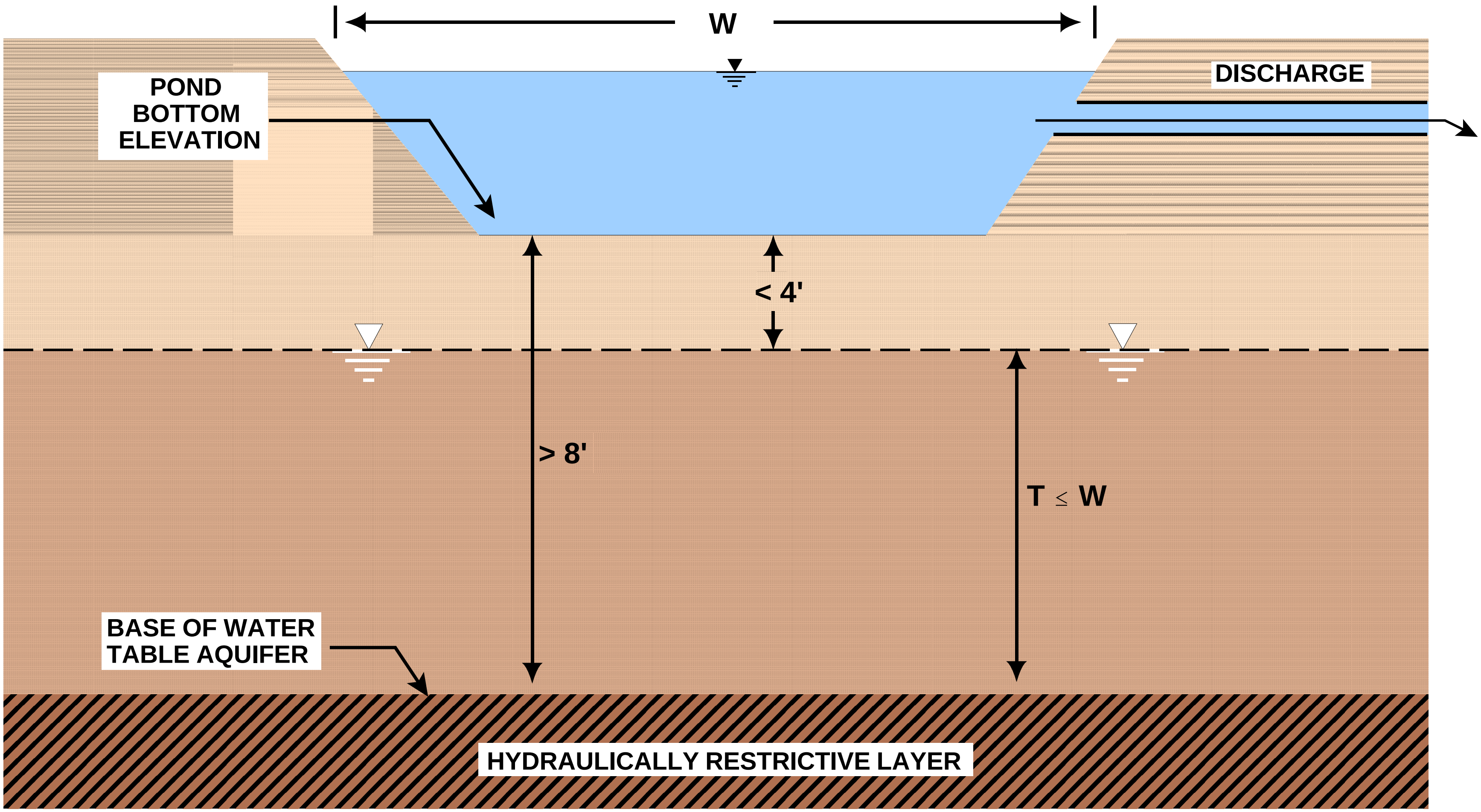
Model #1 - Dry or Wet Retention With Thin Aquifer & Shallow Water Table



Notes:

① Do not use unsaturated infiltration if SHWT within 1.5 ft of pond bottom
② For stormwater modeling, assume soil is confining layer is k <0.1 ft/day
(typical permeability values for soils in Florida from SJRWMD publication)
③ If no confining layer, base of aquifer should not extend below depth of boring
④ Review computation of weighted horizontal hydraulic conductivity
⑤ Wet bottom or dry bottom

Model #2 - Dry Retention With Thick Aquifer & Shallow Water Table

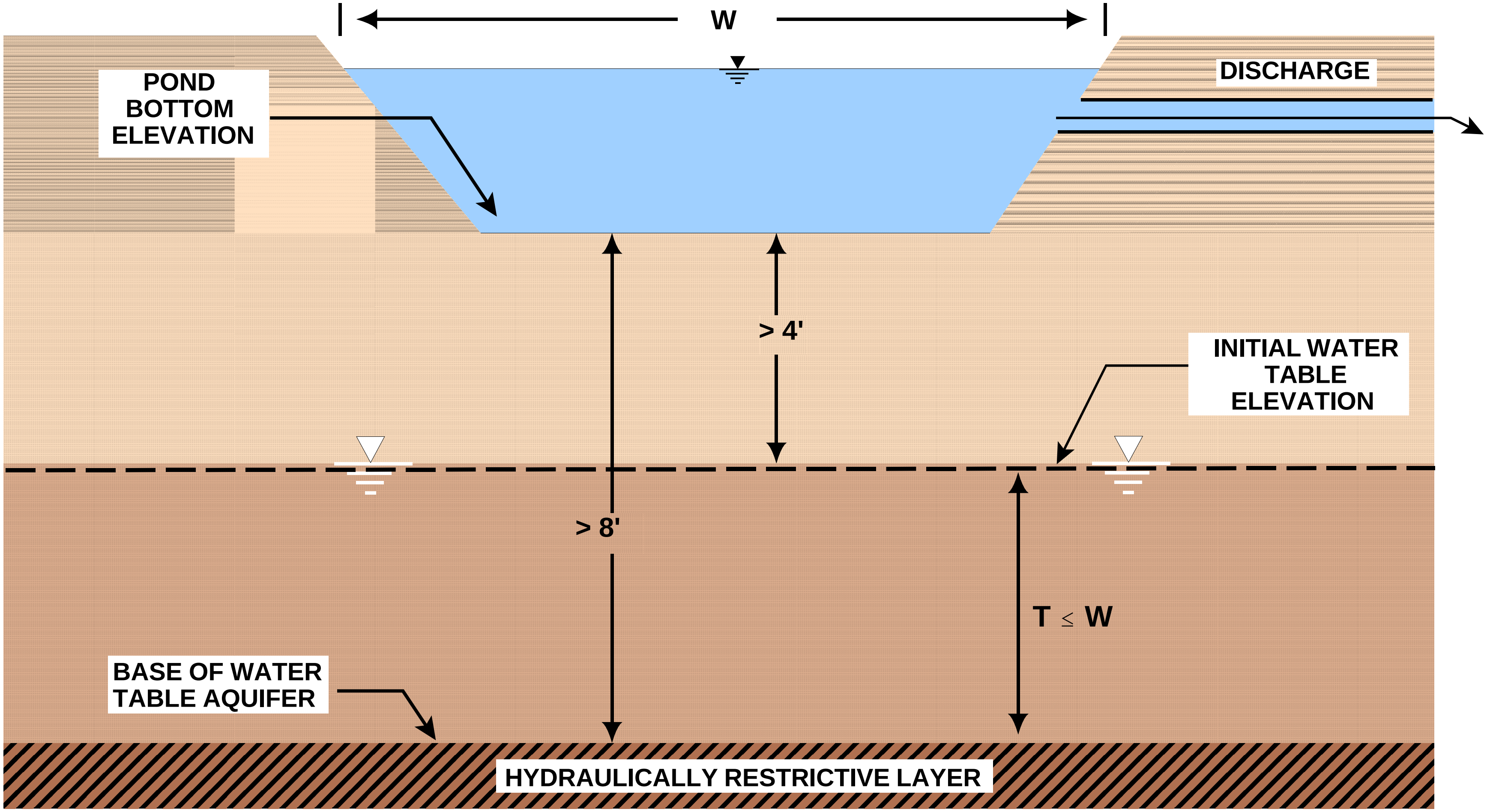


Notes:

① Saturated thickness restricted to width of pond or trench. Important to remember this when modeling exfiltration trenches, narrow ponds or swales, or areas where there are deep saturated sand deposits such as the Lake Wales Ridge in Lake County and west Orange County, the Deland Ridge in Volusia County, and some of the deep sand and shell along some parts of the Atlantic Coastal Ridge in Volusia and Brevard County.

② Do not use unsaturated infiltration if SHWT within 1.5 ft of pond bottom

Model #3 - Dry Retention With Thick Aquifer & Deep Water Table



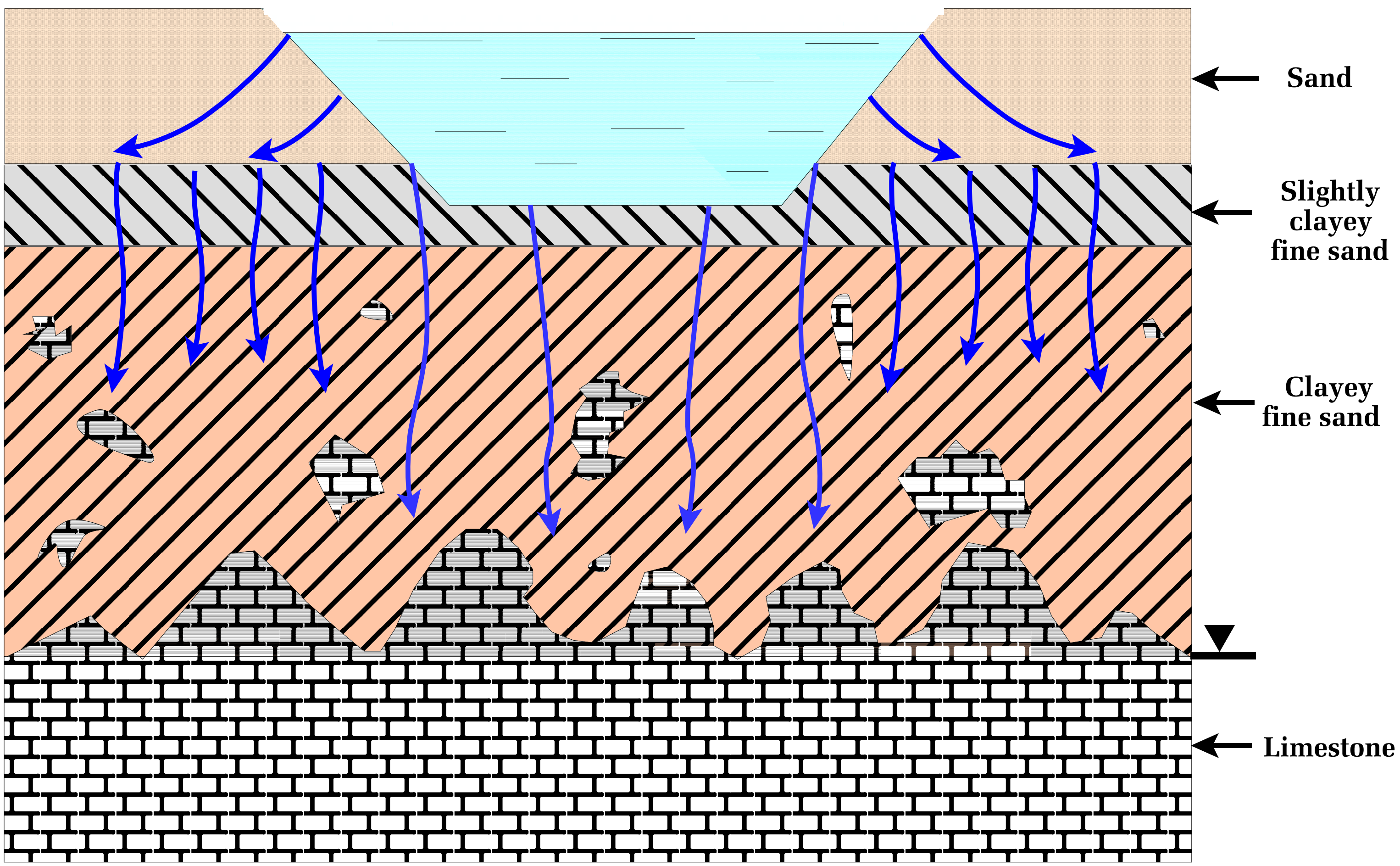
Notes:

① Saturated thickness restricted to width of pond or trench.

② Do not use unsaturated infiltration if SHWT within 1.5 ft of pond bottom

③ Peak stage usually occurs during unsaturated perched flow. Competing software such as MODRET do not have this capability.

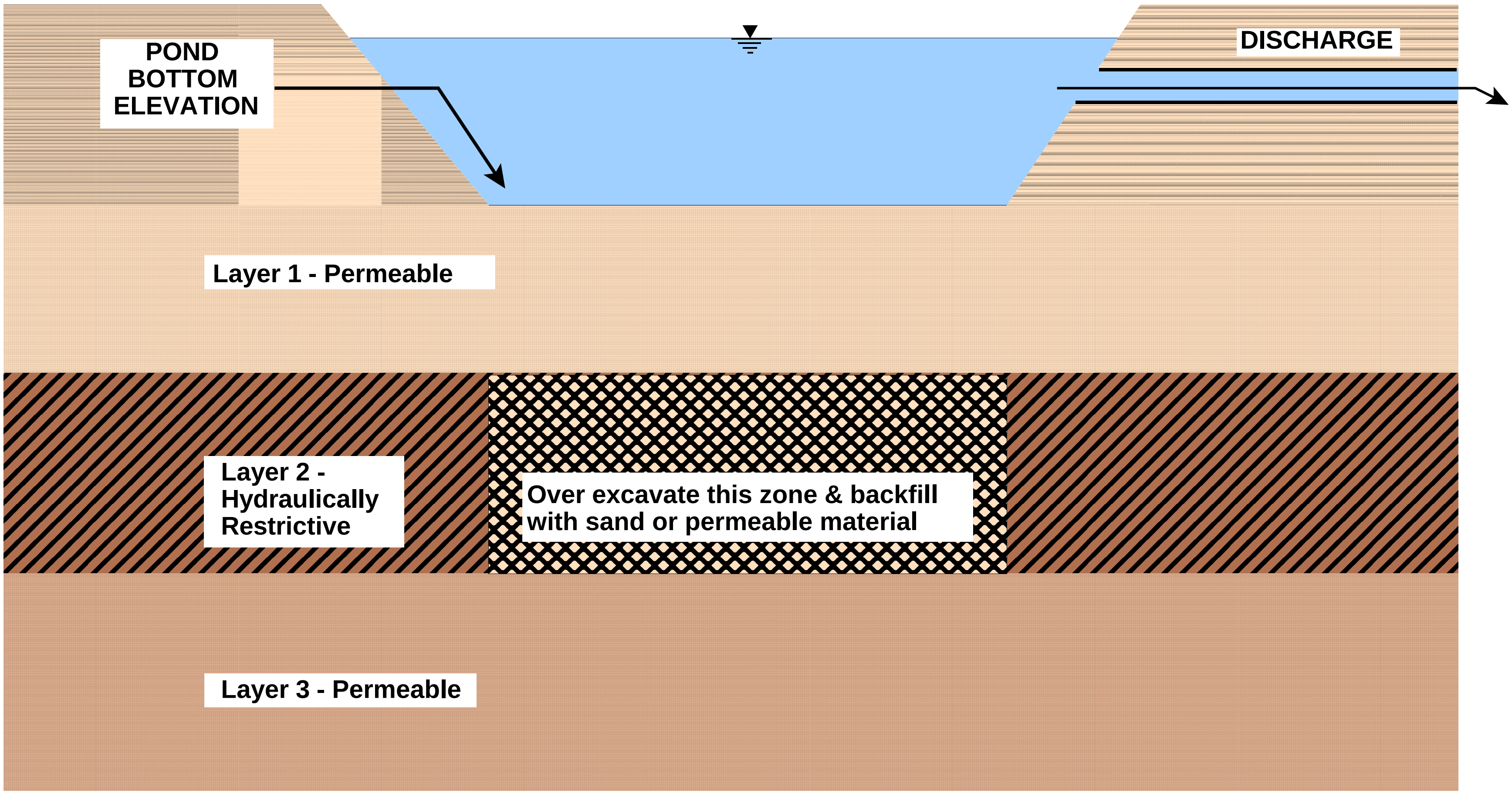
Model #4 - Dry Retention In Leaky Aquifer With Deep Water Table



Notes:

1. Typical of the Marion County area
2. Peak stage usually occurs during unsaturated perched flow
3. Pond bottom excavated into first clayey sand layer. important not to remold & compact clayey sand layer
4. Loading rate is rapid, water does not have much time to spread out in the upper sand for design storm event modeling

Model #5 - Over excavate confining layer to access underlying secondary layer



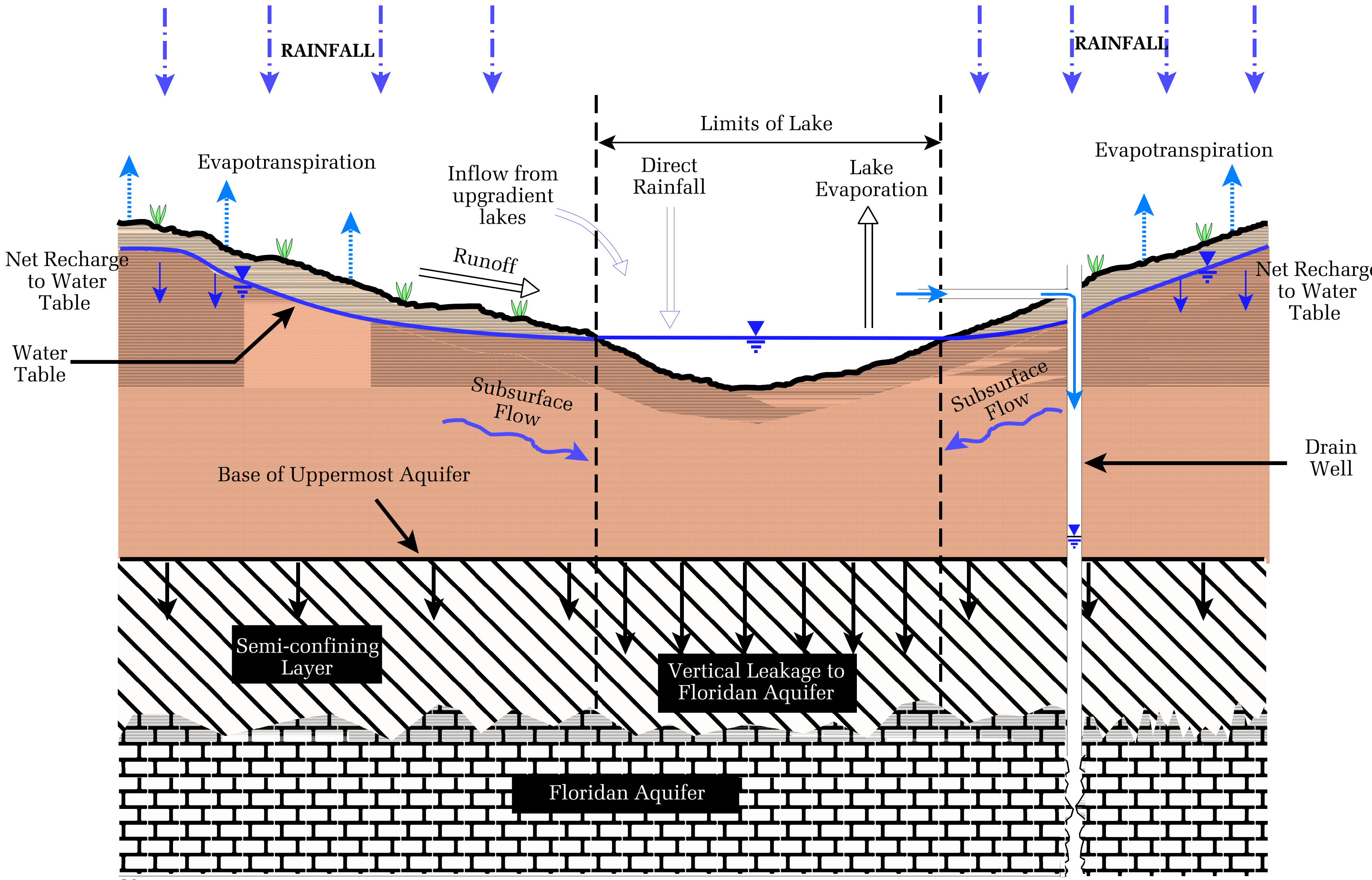
Notes:

① **Typical in Brevard and Indian River County where the hardpan layer can be removed to access the lower zone of sand and shell**

② **Must be inspected by geotechnical engineer**

③ **Weighted horizontal hydraulic conductivity**

Model #6 - Closed Basin With Low or High Vertical Leakage to Floridan Aquifer

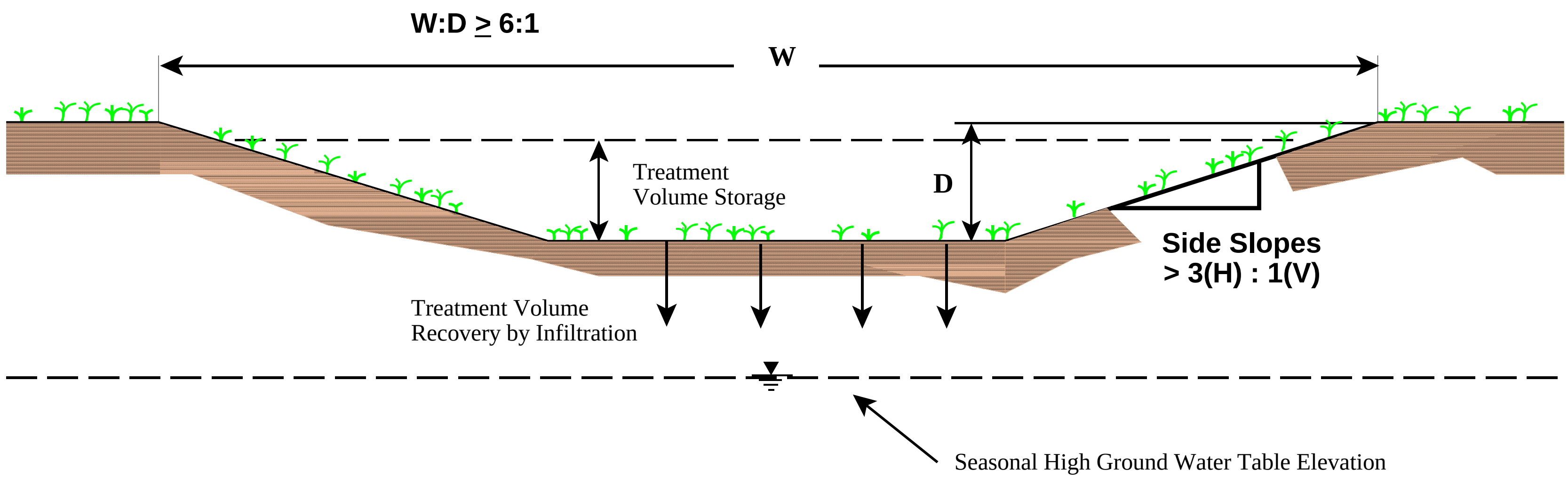


Notes:

① **Difference between pot surface and water (or water table elevation) is more than 5 to 10 ft**

② **These are more susceptible to flooding and may require continuous simulation analysis**

Model # 7 - Swales



Notes:

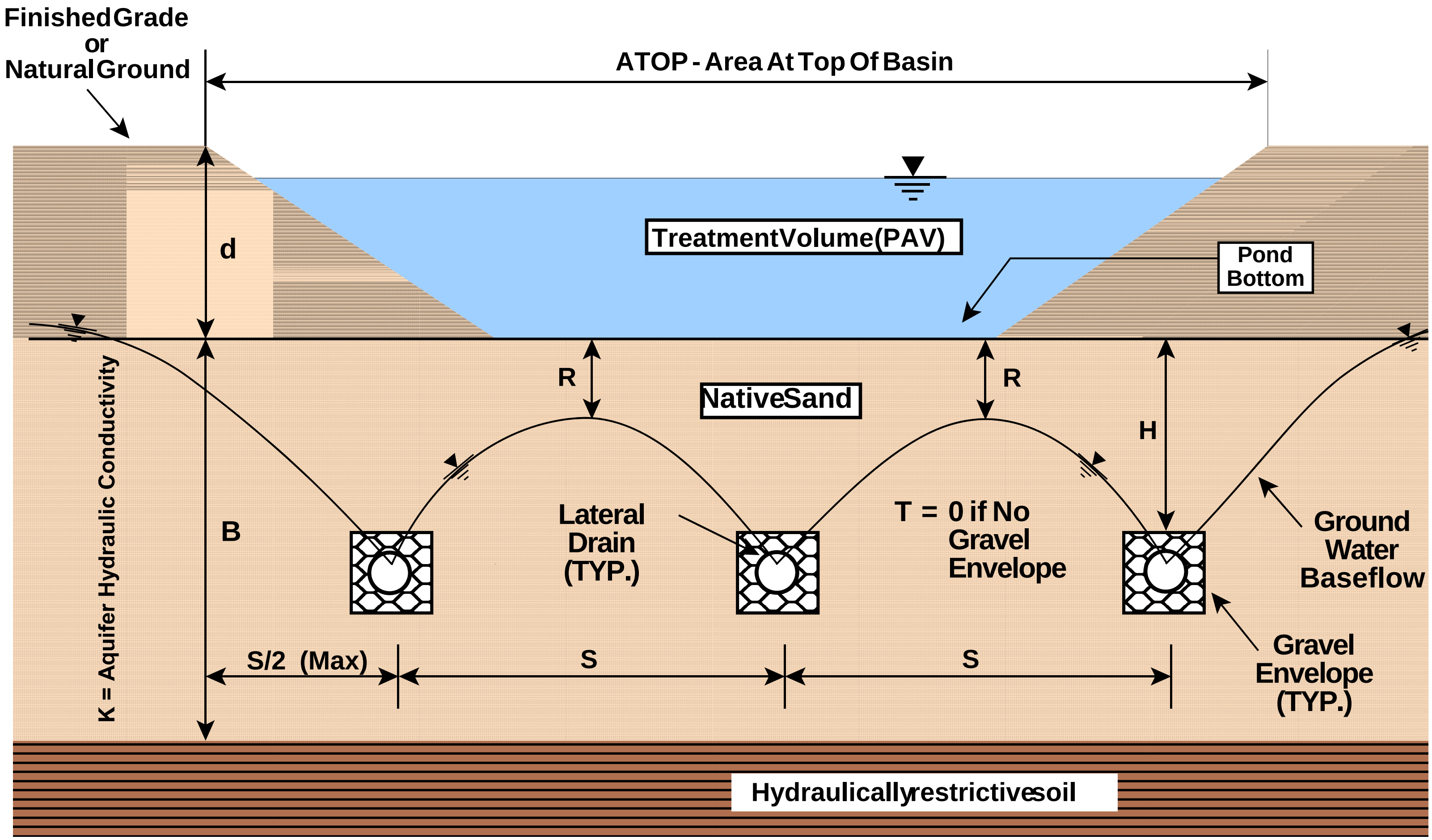
① **Unlike a pond, there is open channel flow while the water is infiltrating**

② **Recommend that this be applied only for unsaturated infiltration. Suitable for sites with HSG "A" soils with sand and deep water table.**

③ **Most engineers do not analyze this properly**

④ **3yr/1 hr storm; analyze to see is 80% of volume can be percolated.**

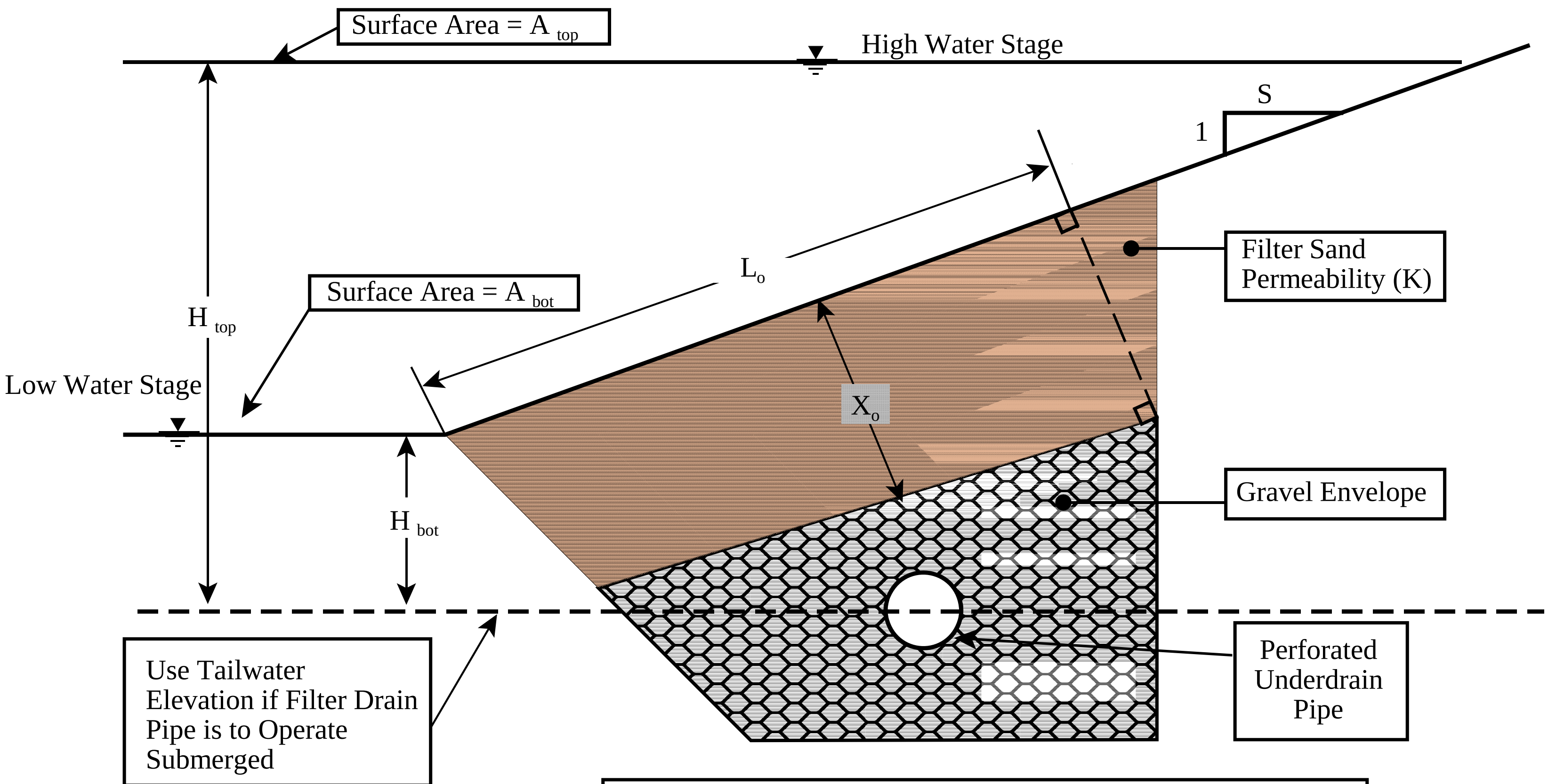
Model #8 - Dry Retention Using Underdrain System



Notes:

1. This system is popular since the retention volume requirements are the same as dry retention ponds
2. Main limitation is finding gravity outfall for the underdrain pipes
3. Baseflow must be included
4. Sometimes hydraulically restrictive soil can be overexcavated from base of pond and replaced with free draining fine sand from onsite source

Model # 9 - Side-bankfiltrationsystem



Notes:

① P = Treatment Volume / Volume between A_{top} and A_{bot} X 100%

Note: For efficient and economical design , Use P $\leq$ 95 %

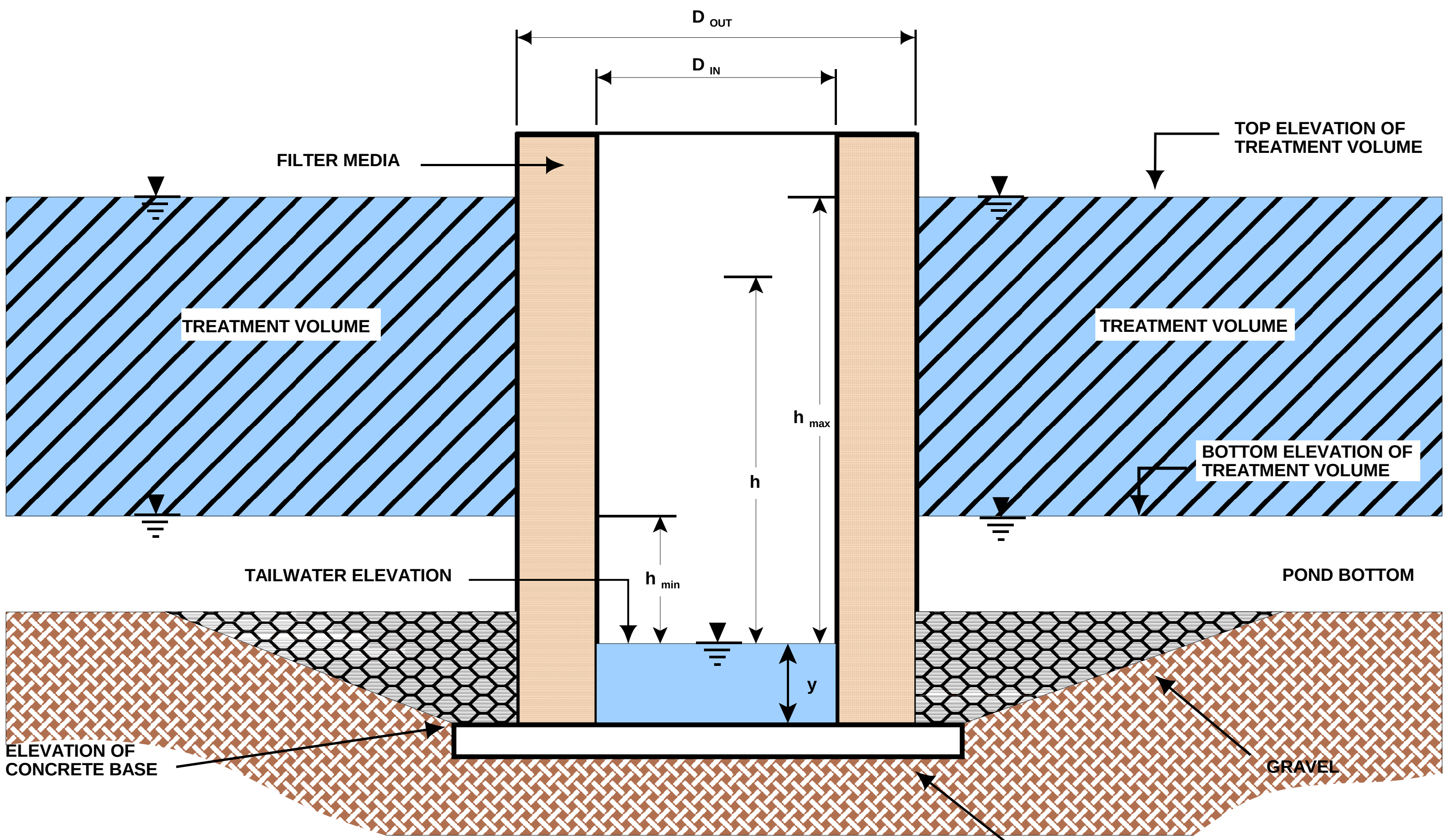
Notes:

① **Nowanindividualpermit**

② **Subjecttocloggingespeciallynexttowetlandtypesolis**

③ **Includegroundwaterbaseflow**

Model # 10 - Vertical Volume Recovery Structures

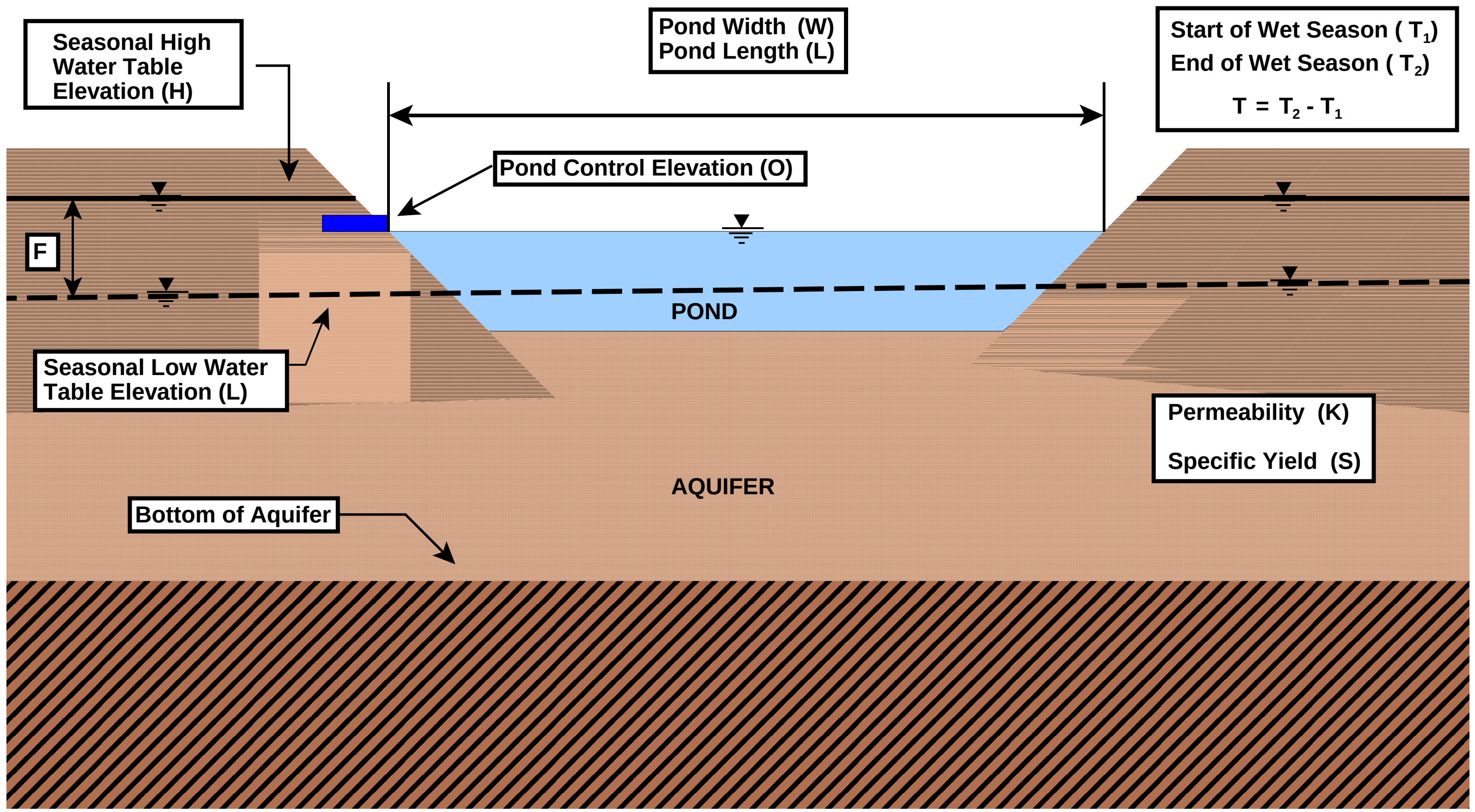


DRAWING NOT TO SCALE

Notes:

① **Now an individual permit**
② **Subject to clogging especially next to wetland type soils**
③ **Include groundwater baseflow**

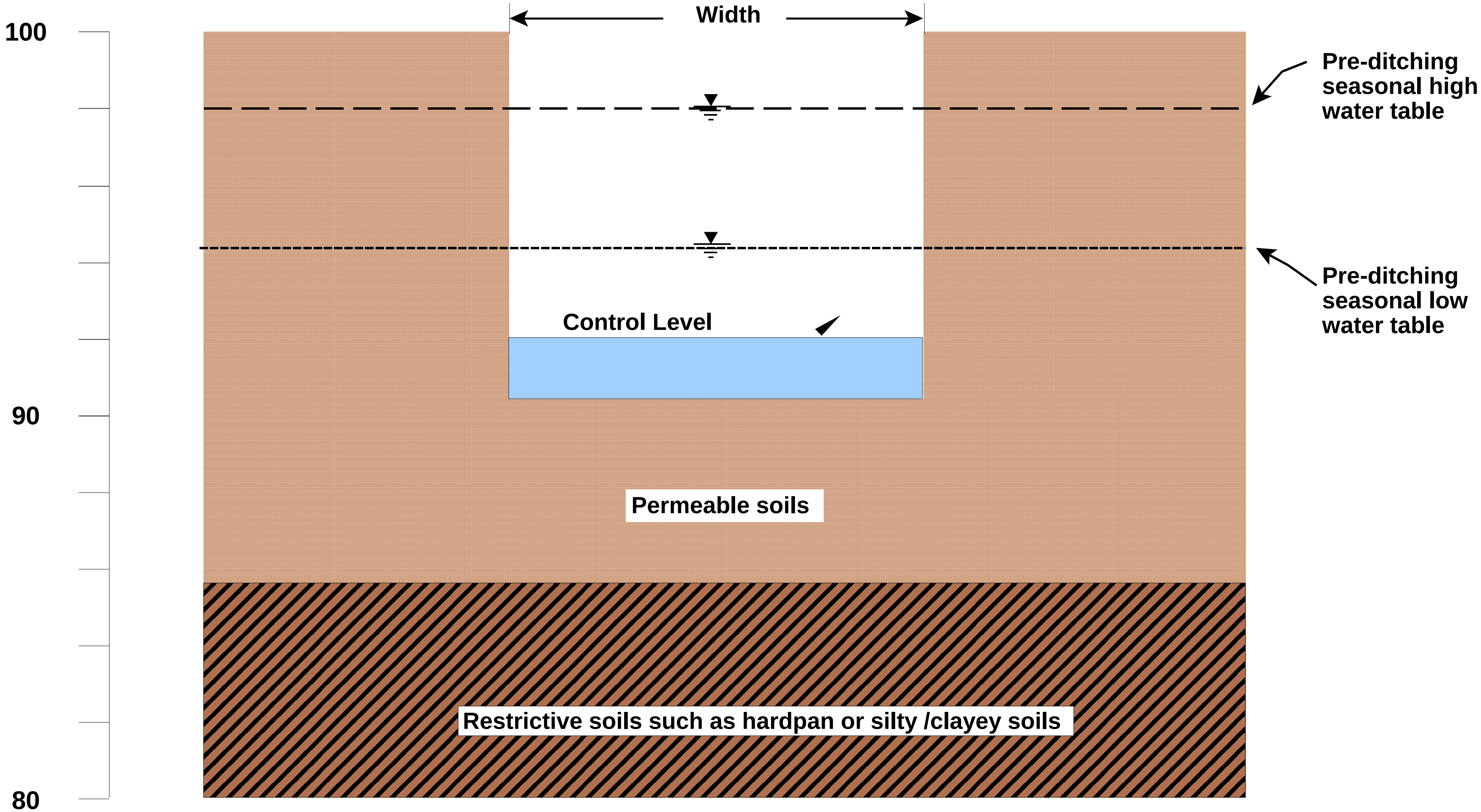
Model #11 - Ground Water Baseflow or Wet Detention



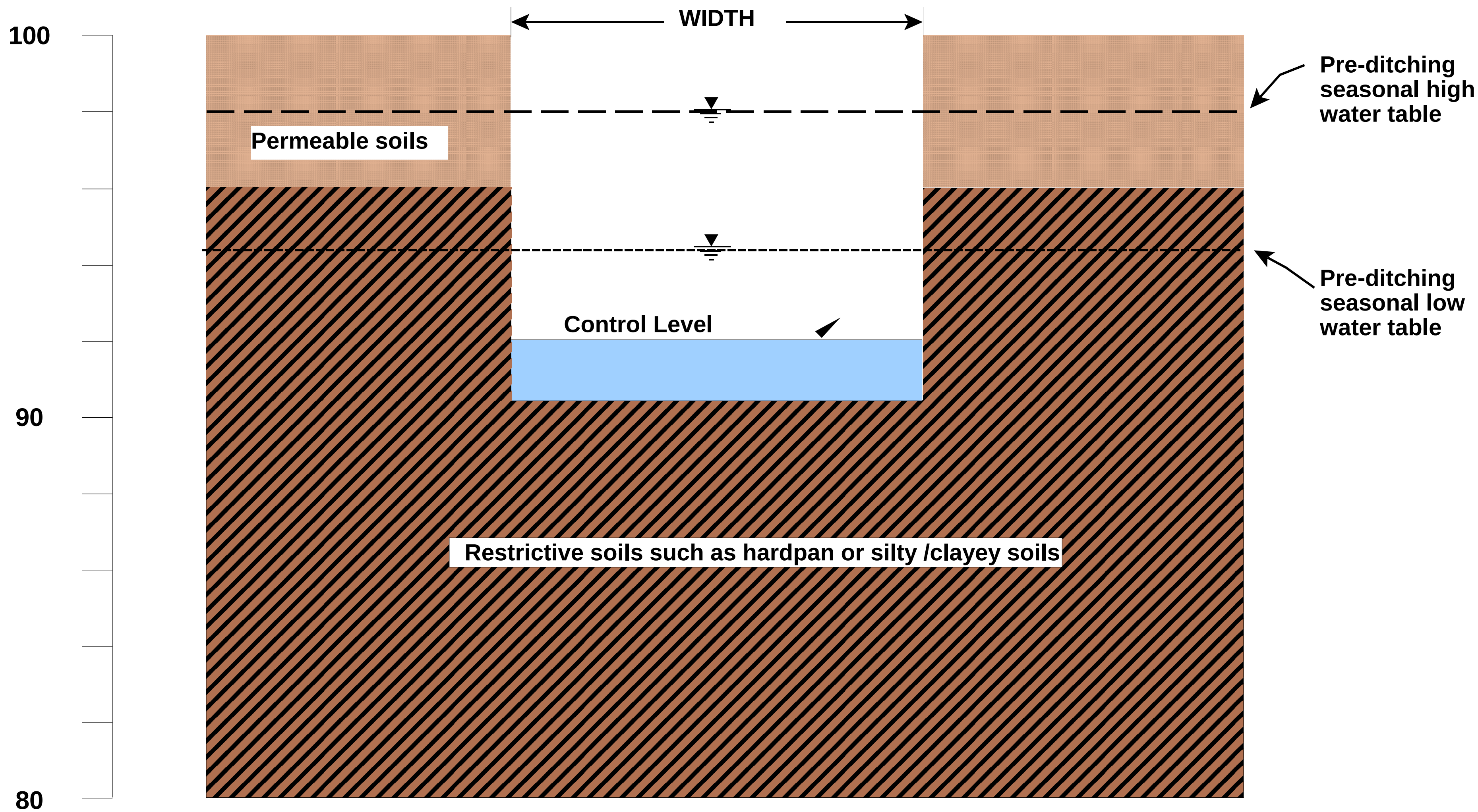
Notes:

① 40C-42 allows us to set the control level at the average wet season water table elevation
② Important to include baseflow in residence time calculations
③ Weighted horizontal hydraulic conductivity

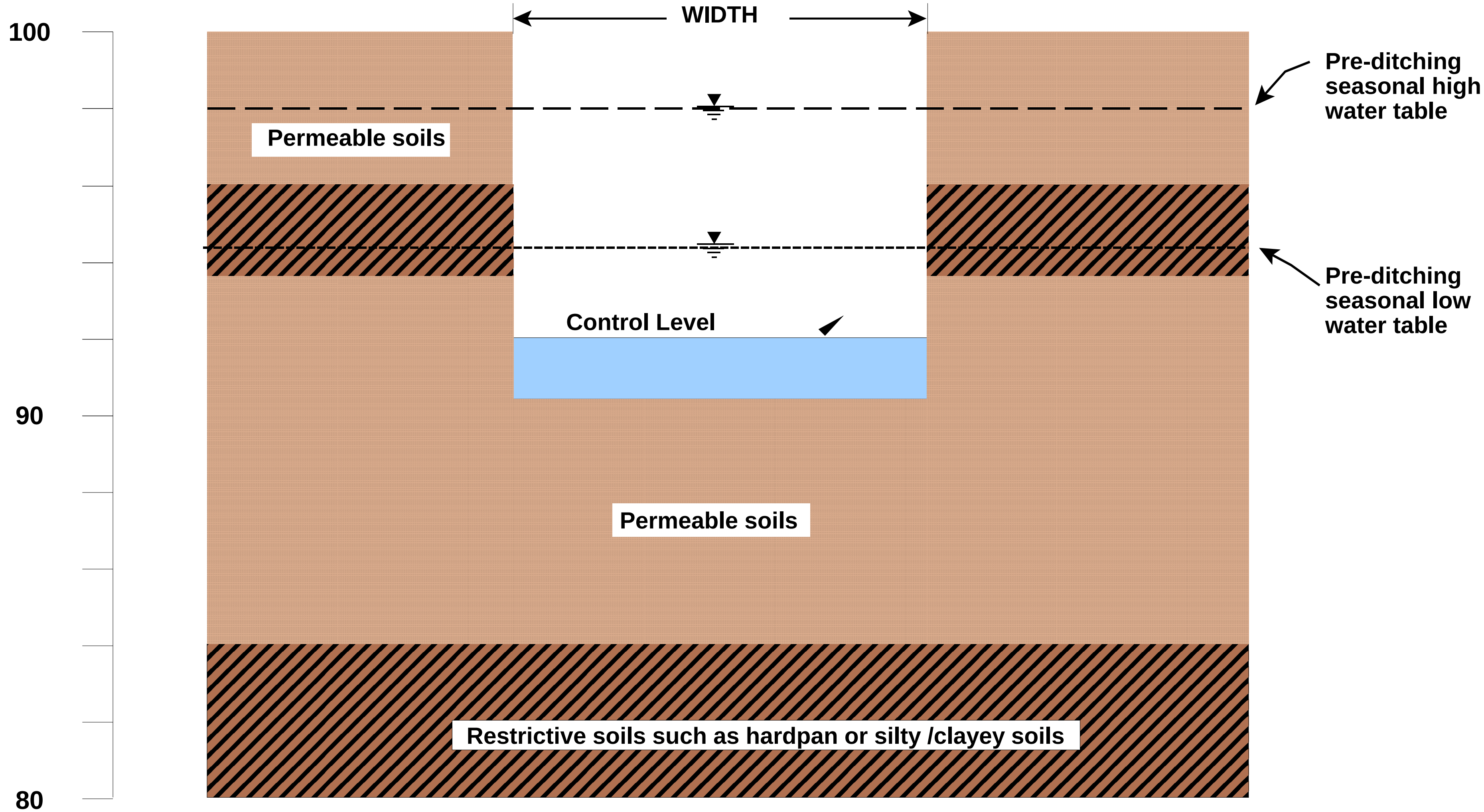
Model # 12a - Ditch Dewatering Scenario #1



Model #12b - Ditch Dewatering Scenario # 2

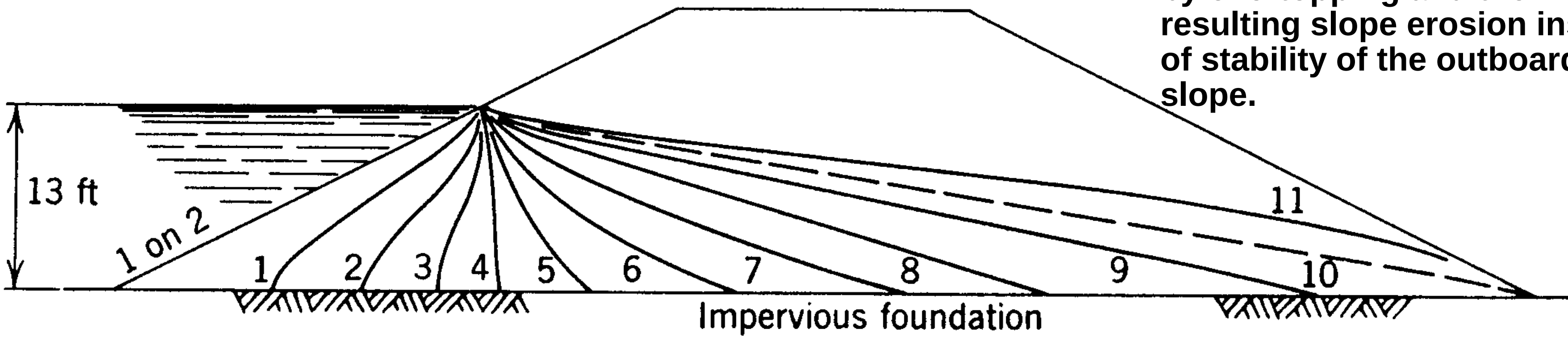


Model # 12c - Ditch Dewatering Scenario # 3



SEEPAGE THROUGH FILL BERM

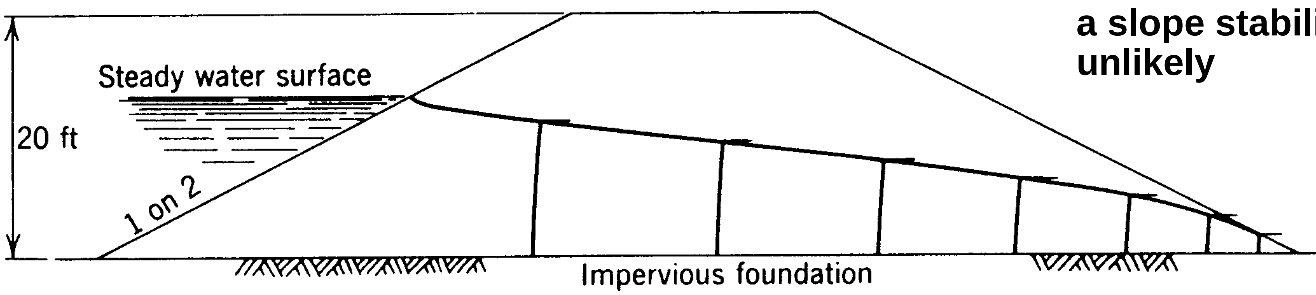
Note: most berms actually fail by overtopping and the resulting slope erosion instead of stability of the outboard slope.



Transient flow situation

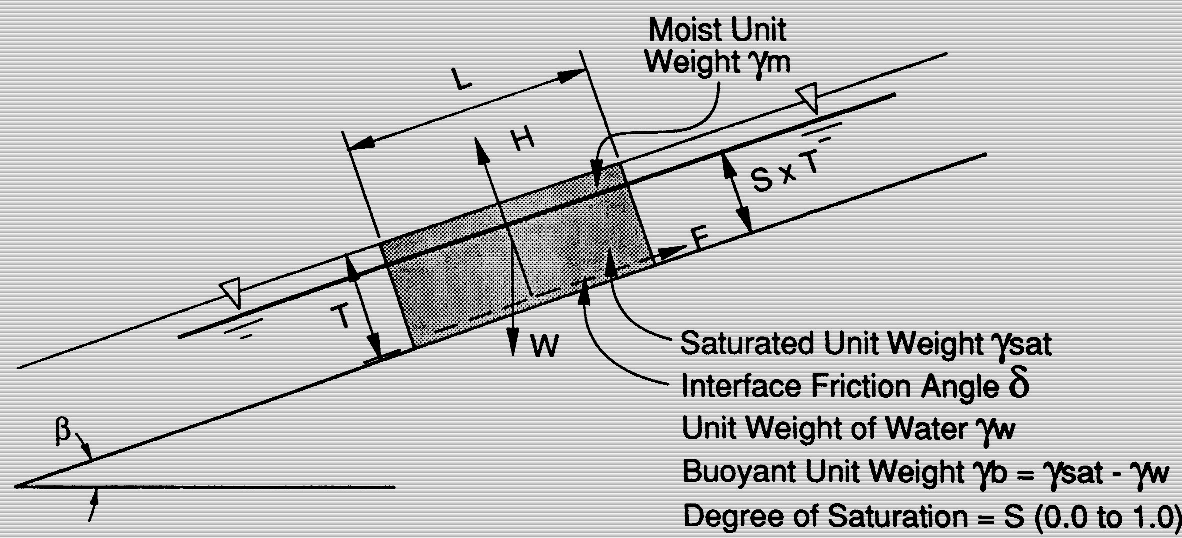
important when more than 3 ft of fill above natural grade

Note: if the pond recovers before the transient flow net exits the outboard slope, then a slope stability failure is unlikely



Steady state flow situation

Illustration of Theory for Slope Stability Analysis of Infinite Slopes (with & without seepage forces)



Σ Forces parallel to slope

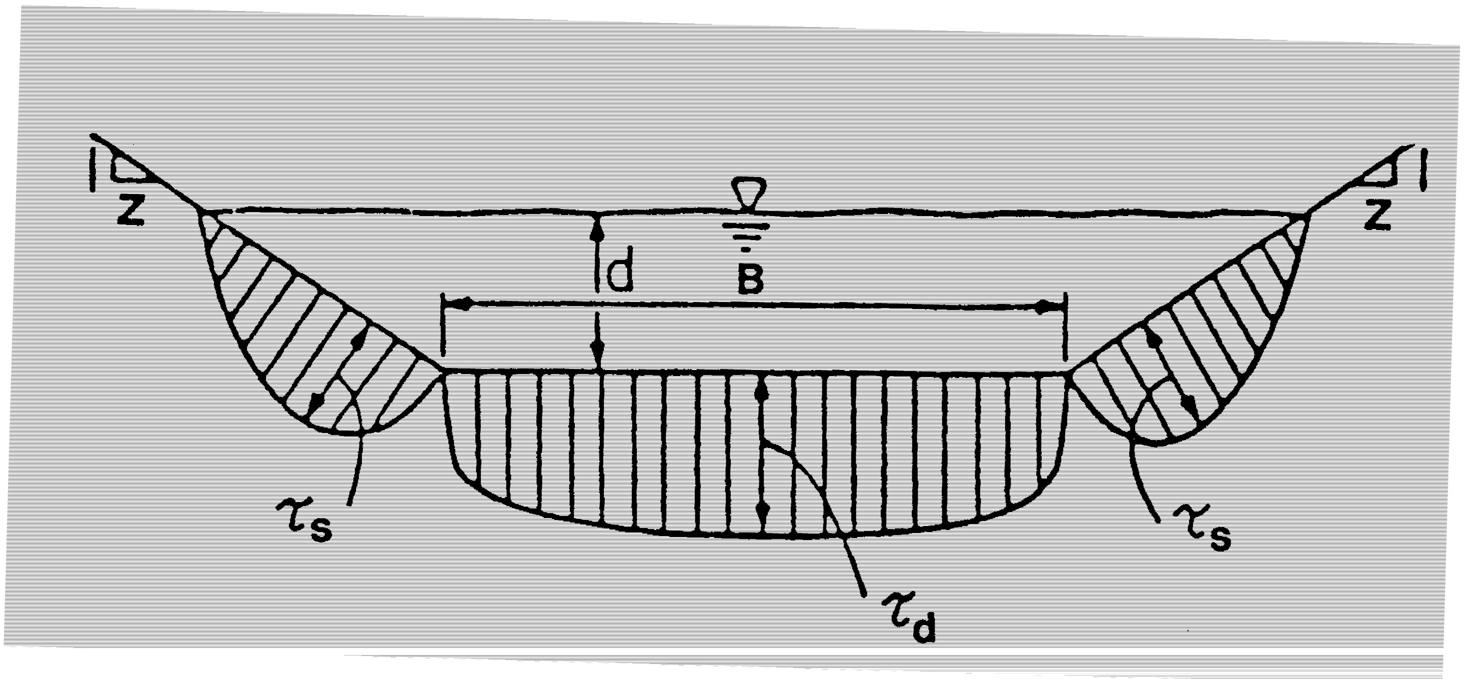
Resisting Force: $F = \{ \gamma m\ T\ (1\text{-}S)\ L\ + L\ \gamma b\ T\ S \}\ \tan \delta\ \cos \beta$

Seepage Force: $= \gamma w\ T\ S\ L\ \sin \beta$

Weight: $= \{ \gamma m\ T\ (1\text{-}S)\ L\ + L\ \gamma b\ T\ S \}\ \sin \beta$

$$\text{Factor of Safety} = \frac{\text{Resisiting Force}}{\text{Seepage Force + Weight}} = \frac{\tan \delta}{\tan \beta} \left\{ \frac{\gamma m\ (1\text{-}S) + \gamma b\ S}{\gamma w\ S + \gamma m (1\text{-}S)\ + \gamma b\ S} \right\}$$

CHANNEL LINING ANALYSIS FOR SWALES & DITCHES



Maximum shear stress criteria as per HEC-15