Modeling Water Flow and Contaminant Transport in Soils and Groundwater Using the HYDRUS Software Packages

***Jirka Šimůnek*[1]**

***Rien van Genuchten*[2], *Miroslav Šejna*[2], *and Diederik Jacques*[4]**

**[1]Department of Environmental Sciences,
University of California, Riverside, CA**

**[2]Department of Mechanical Engineering,
Federal University of Rio de Janeiro, Brazil**

[3]PC-Progress, Ltd., Prague, Czech Republic

[4]Belgian Nuclear Research Centre (SCK•CEN), Mol, Belgium

Jirka Šimůnek

A Professor of Hydrology with the Department of Environmental Sciences of the University of California Riverside. Received M.Sc. in Civil Engineering from the Czech Technical University, Prague, Czech Republic, and Ph.D. in Water Management from the Czech Academy of Sciences, Prague, Czech Republic.

Expertise in Numerical Modeling of subsurface water flow and solute transport processes, equilibrium and nonequilibrium chemical transport, multicomponent major ion chemistry, field-scale spatial variability, and inverse procedures for estimating soil hydraulic and solute transport parameters.

Dr. Šimůnek has authored and coauthored over 200 peer-reviewed journal publications, over 20 book chapters, and 2 books. His numerical HYDRUS models are used by virtually all scientists, students, and practitioners modeling water flow, chemical movement, and heat transport through variably saturated soils. Dr. Šimůnek is a recipient of the Soil Science Society of America's (SSSA) Don and Betty Kirkham Soil Physics Award, the past chair of the Soil Physics (S1) and Fellow of SSSA, and Fellow of American Geophysical Union.

An Associate Editor of Journal of Hydrology and Hydromechanics, and a past AE of Water Resources Research, Vadose Zone Journal, and Journal of Hydrological Sciences.

Rien van Genuchten

A soil physicist originally with the US Salinity Laboratory, USDA, ARS, Riverside, CA. Received B.Sc. and M.Sc. in irrigation and drainage from Wageningen University in The Netherlands, and Ph.D. in soil physics from New Mexico State University.

Rien van Genuchten

Dr. van Genuchten is a recipient of the Soil Science Society of America's Don and Betty Kirkham Soil Physics Award, of the EGU Dalton Medal, and Fellow of the Soil Science Society of America, American Society of Agronomy, American Geophysical Union and American Association for the Advancement of Sciences. Founding Editor of the Vadose Zone Journal. Currently with the University of Rio de Janeiro, Brazil.

Research on variably-saturated water flow and contaminant transport, analytical and numerical modeling, nonequilibrium transport, preferential flow, characterization and measurement of the unsaturated soil hydraulic functions, salinity management, and root-water uptake. The most often referenced researcher in the field of Soil Physics. Dr. van Genuchten is probably best known for the theoretical equations he developed for the nonlinear constitutive relationships between capillary pressure, water content and the hydraulic conductivity of unsaturated media.

Miroslav Šejna

A Director and Development Lead of PC Progress, Software company located in Prague, Czech Republic. Received B.Sc. and M.Sc. from the Charles University of Prague, Faculty of Mathematics and Physics, Prague, Czech Republic, and PhD. from the Czech Academy of Sciences, Prague, Czech Republic.

Expertise in Numerical Modeling of Transonic Flow with homogeneous and heterogeneous condensation and chemicals in steam through Turbine Cascade (Euler and Navier-Stokes equations).

Recently specializes in the development of GUI (Graphical User Interfaces) for FEM/CFD software packages for Windows. He has more than twenty years of experience in developing programs for numerical modeling in Fluid Mechanics and Structural Engineering. His software helps thousands of scientists and engineers from around the world.

Selected Software Projects:

- RFEM, RSTAB - Structural Engineering Software packages, 1995-2009, Ing.-Software Dlubal, GmbH, Germany
- HYDRUS-1D, HYDRUS 2D/3D - Software package for simulating water, heat, and solute transport in variably saturated porous media.
- MESHGEN Plus - FE-mesh generator and open modeling environment for Finite-Element and Finite-Volume applications.
- COCHEM Flow - Software package simulating 2D water steam flow with homogeneous and heterogeneous Condensation.

Mirek Sejna

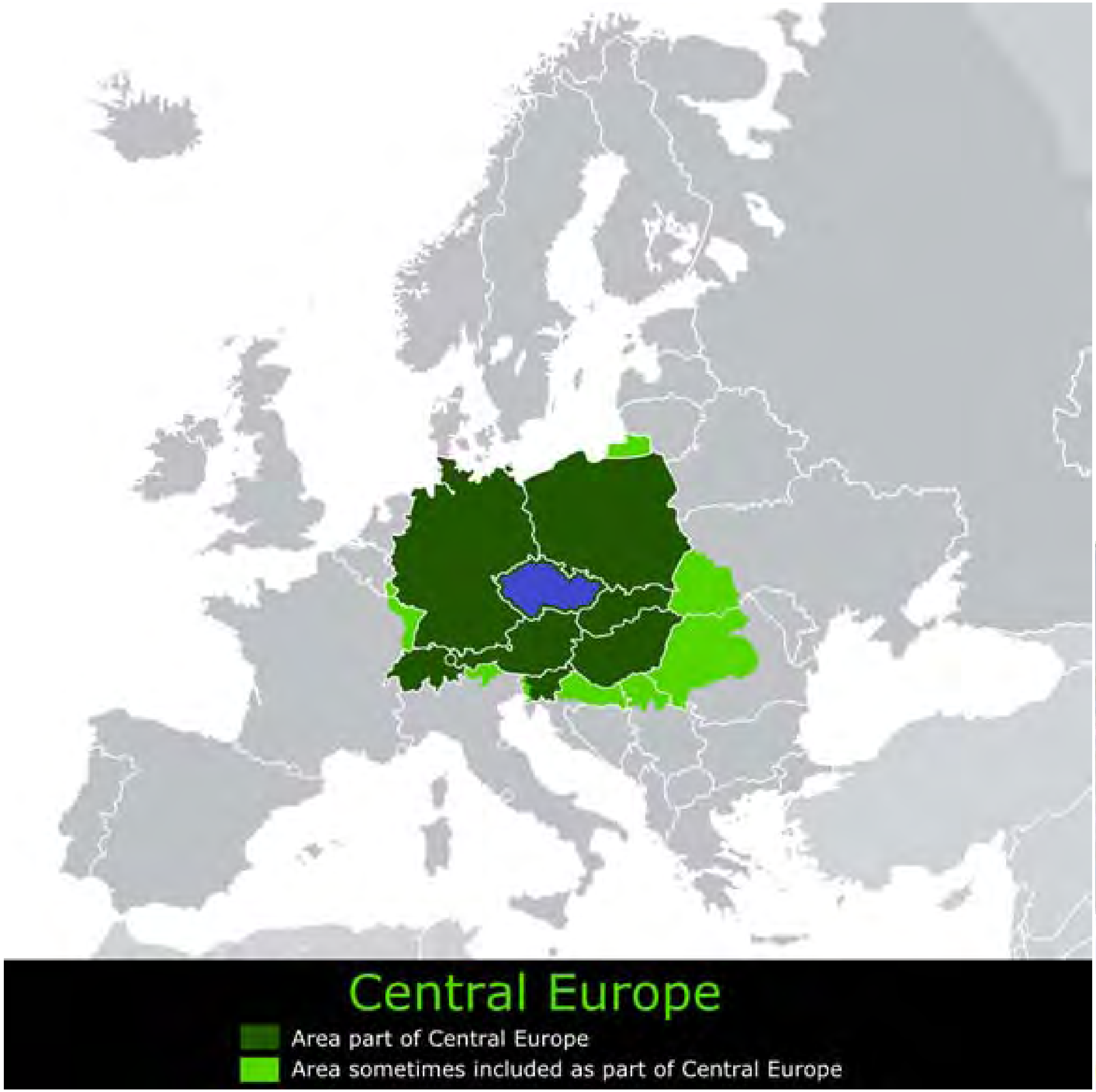
Diederik Jacques

Diederik Jacques is a head if the Performance Assessment Unit, Institute of Environment, Health and Safety of the Belgian Nuclear Research Centre (SCK•CEN) in Mol, Belgium.

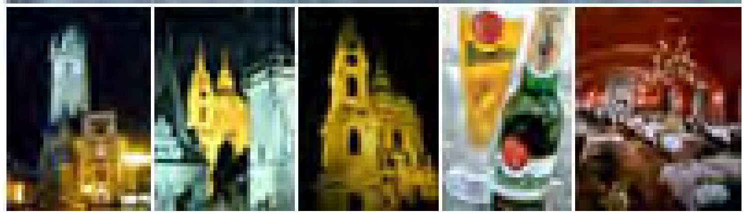
He received B.Sc. and M.Sc. in Bio-Engineering Land and Forest Management, M.Sc. in Statistic, and Ph.D. in Soil Physics; all at the Catholique University of Leuven, Belgium.

His expertise is in modeling water flow and solute transport in unsaturated porous media including characterizing spatial variability and estimating parameters. He has some experience with experiments at the field scale. He is working on different aspects of coupling unsaturated water flow, solute transport and geochemical reaction including the development and testing of the coupled code HP1, application to (long-term) solute transport in soils and interaction between different systems (clay–concrete, or soil–concrete). He is involved in safety and performance analysis of surface and deep geological waste disposal sites, including supporting calculations using reactive transport models.

Czech Republic (Czechoslovakia)



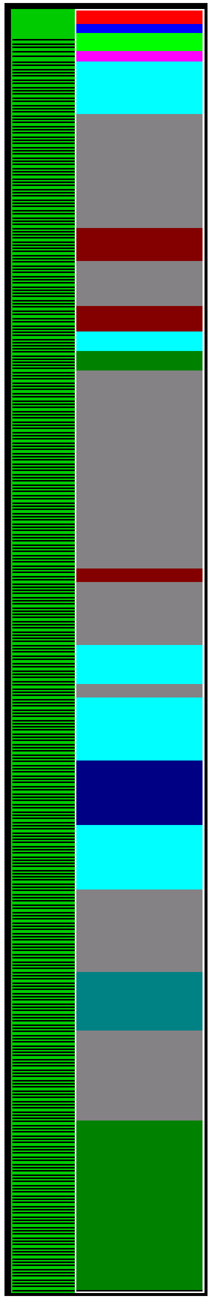
Known for:
1. **Beer (Pilsner Urquel)**
2. **Ice Hockey (Jágr, Hašek)**
3. **Vaclav Havel (former president)**
4. **Beauty of its capital (Prague)**
5. **Dumplings (meal)**
6. **HYDRUS**



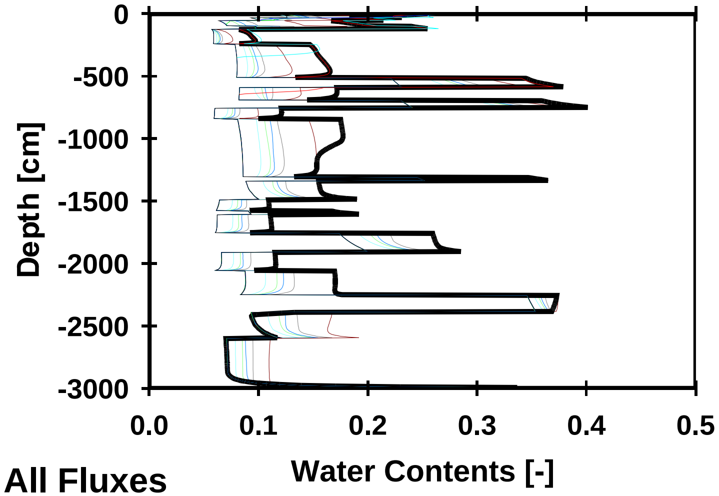
Holland (Netherlands) + Belgium

Known for:
1. **Beer (Grolsch, Heineken)**
2. **Soccer (Robben, Sneijder)**
3. **Beatrix (Queen)**
4. **Beauty of its towns (A'dam, Utrecht)**
5. **Herrings and Cheese**
6. **HYDRUS**

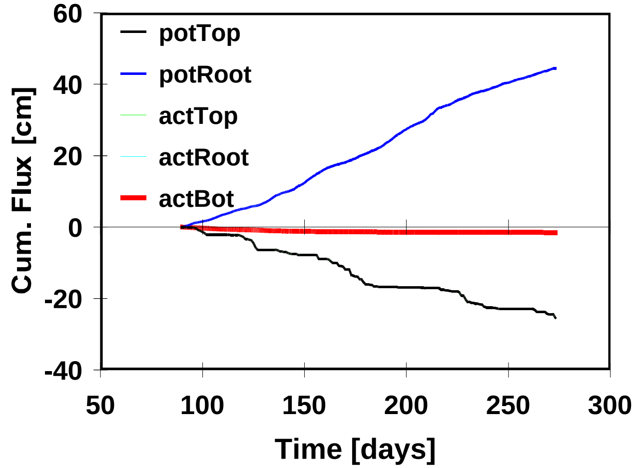
HYDRUS-1D



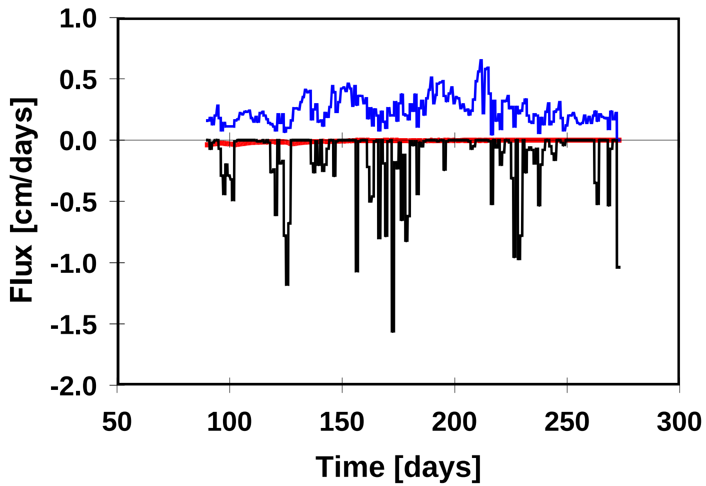
Profile Information



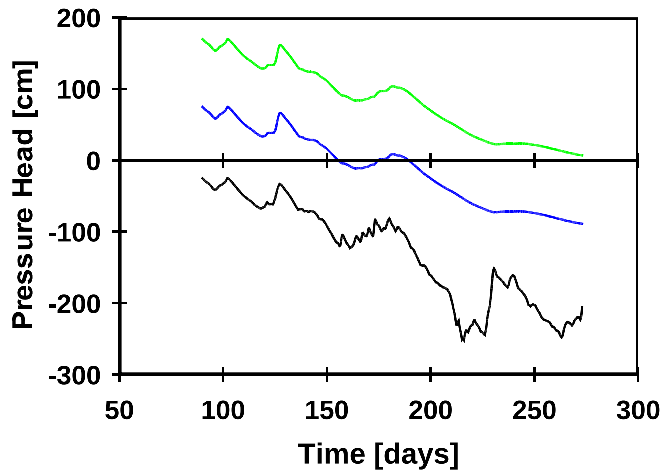
Cumulative Fluxes



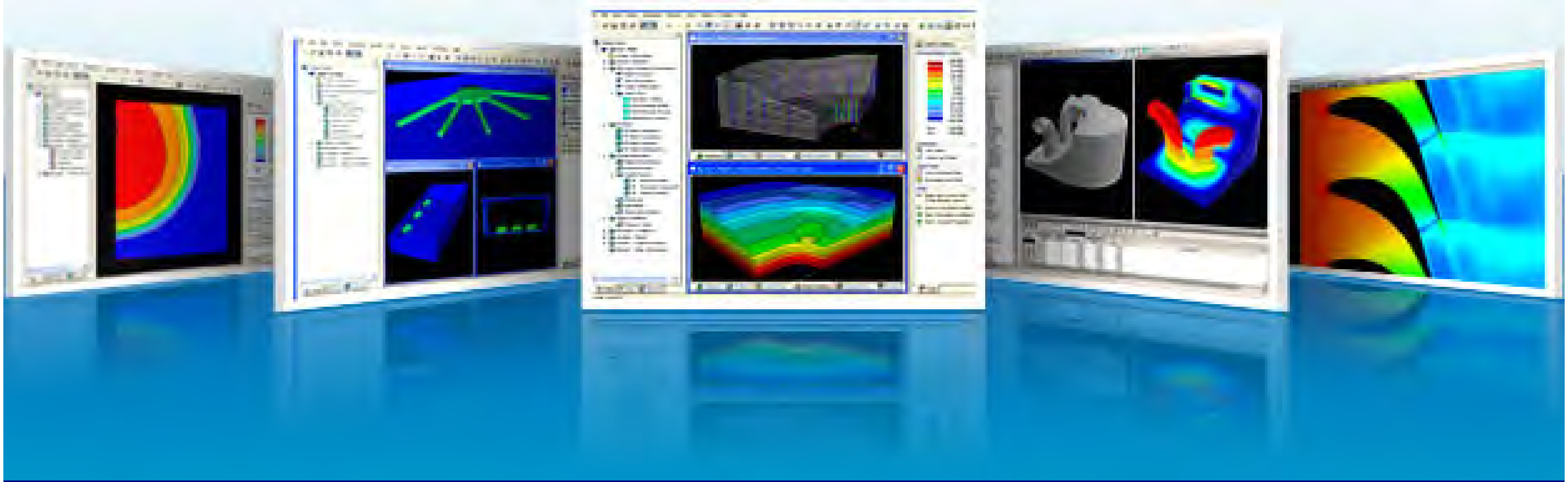
All Fluxes



Observation Nodes

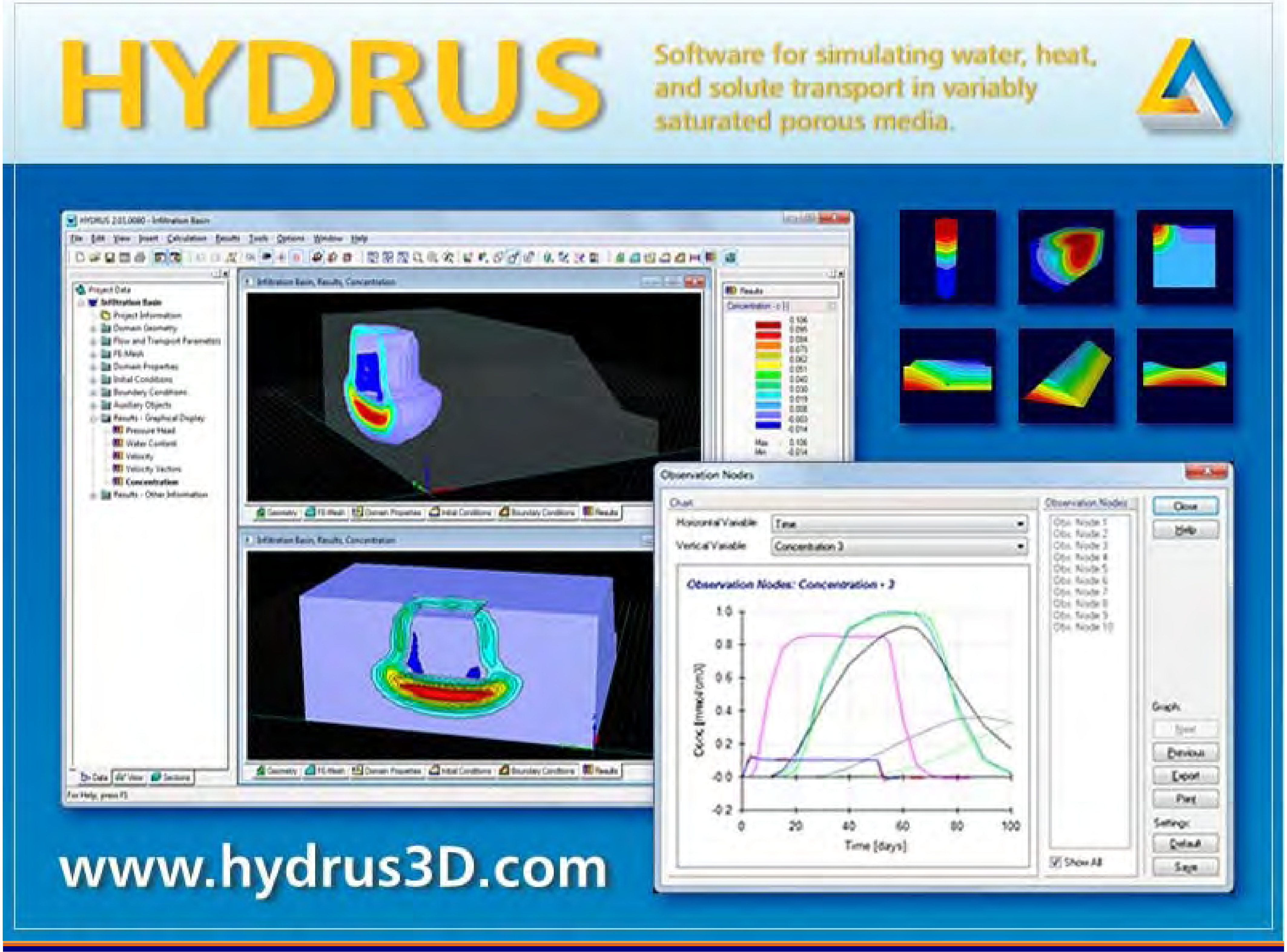


Software for Simulating Water Flow and Solute Transport in One-Dimensional Variably-Saturated Soils Using Numerical Solutions



HYDRUS (2D/3D)

Software for Simulating Water Flow and Solute Transport in Two/Three-Dimensional Variably-Saturated Soils Using Numerical Solutions



HYDRUS
Software for simulating water, heat, and solute transport in variably saturated porous media.
Observation Nodes
Observation Nodes: Concentration - 3
Time [days]
www.hydrus3D.com

HYDRUS - History of Development

Israel: Neuman [1972] - UNSAT
U. of Arizona: Davis and Neuman [1983]

Princeton University:
van Genuchten [1978]

Agricultural University of Wageningen:
Feddes et al. [1978]
SWMII - Vogel [1987]

Massachusetts Institute of Technology:
Celia et al. [1990]

US Salinity Laboratory:
SWMS-2D - Šimůnek et al. [1992]

US Salinity Laboratory: CHAIN-2D
Šimůnek and van Genuchten [1994]

International Ground Water Modeling Center:
HYDRUS-2D (1.0) - Šimůnek et al. [1996]

International Ground Water Modeling Center:
HYDRUS-2D (2.0) - Šimůnek et al. [1999]

US Salinity Laboratory:
SWMS-3D - Šimůnek et al. [1995]

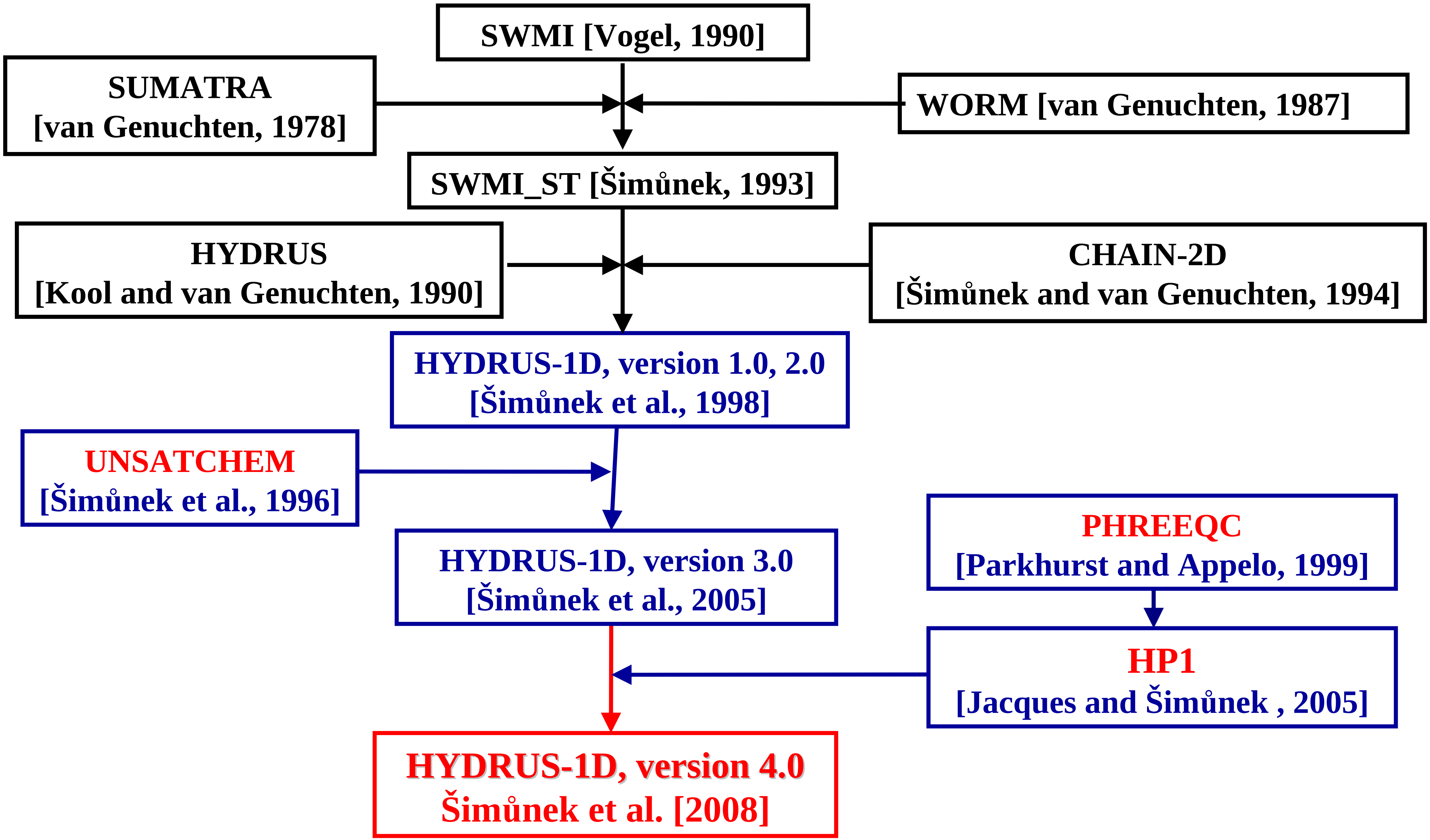
HYDRUS (2D/3D) – v1
Šimůnek et al. [2006]
Šejna and Šimůnek [2006]

Univ. California Riverside:
Wetland – Langergraber and Šimůnek [2006]

UNSATCHEM
[Šimůnek et al., 1996]

HYDRUS (2D/3D) – v2
Šimůnek and Šejna [2011]

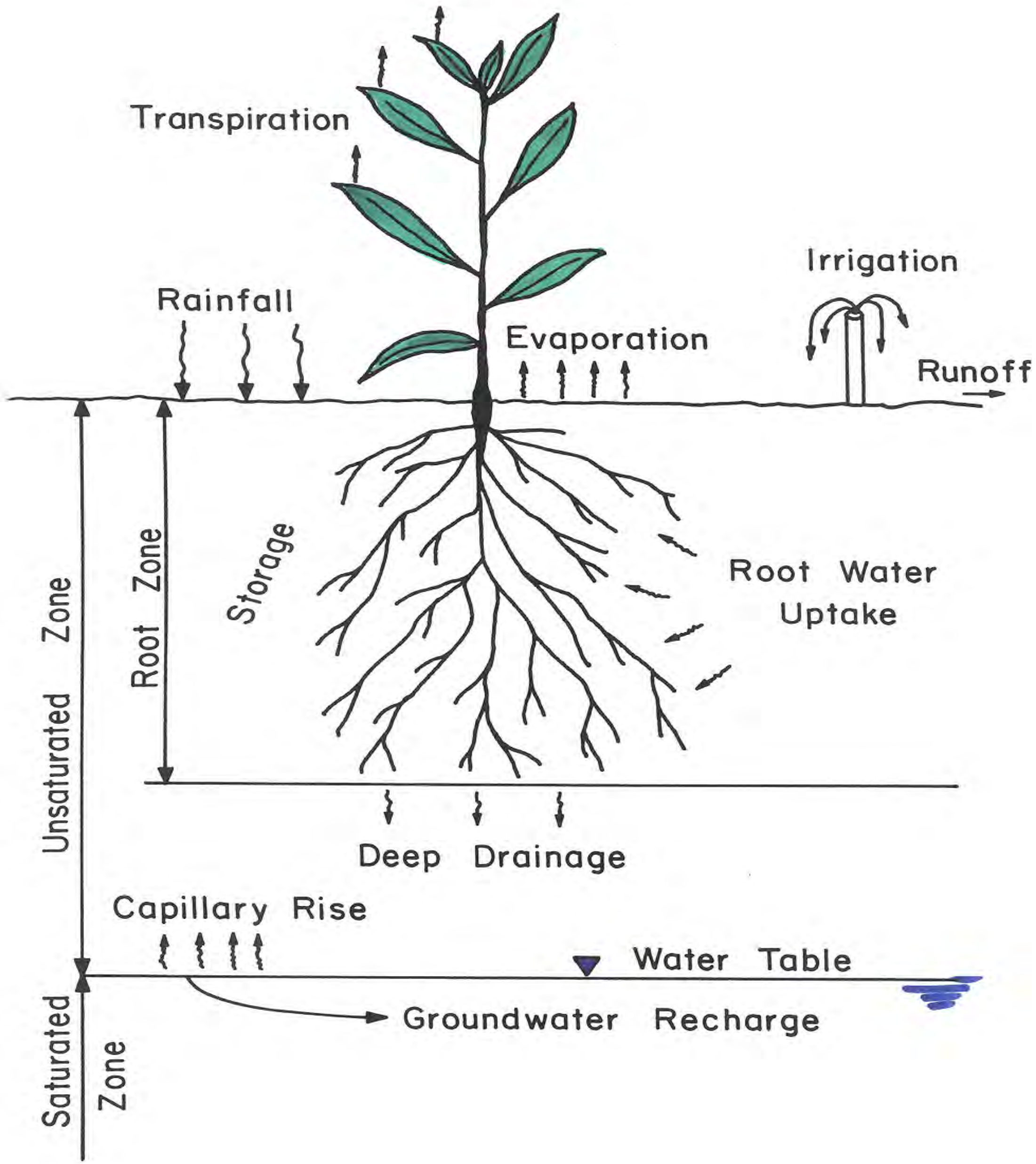
HYDRUS-1D - History of Development



Agricultural Applications

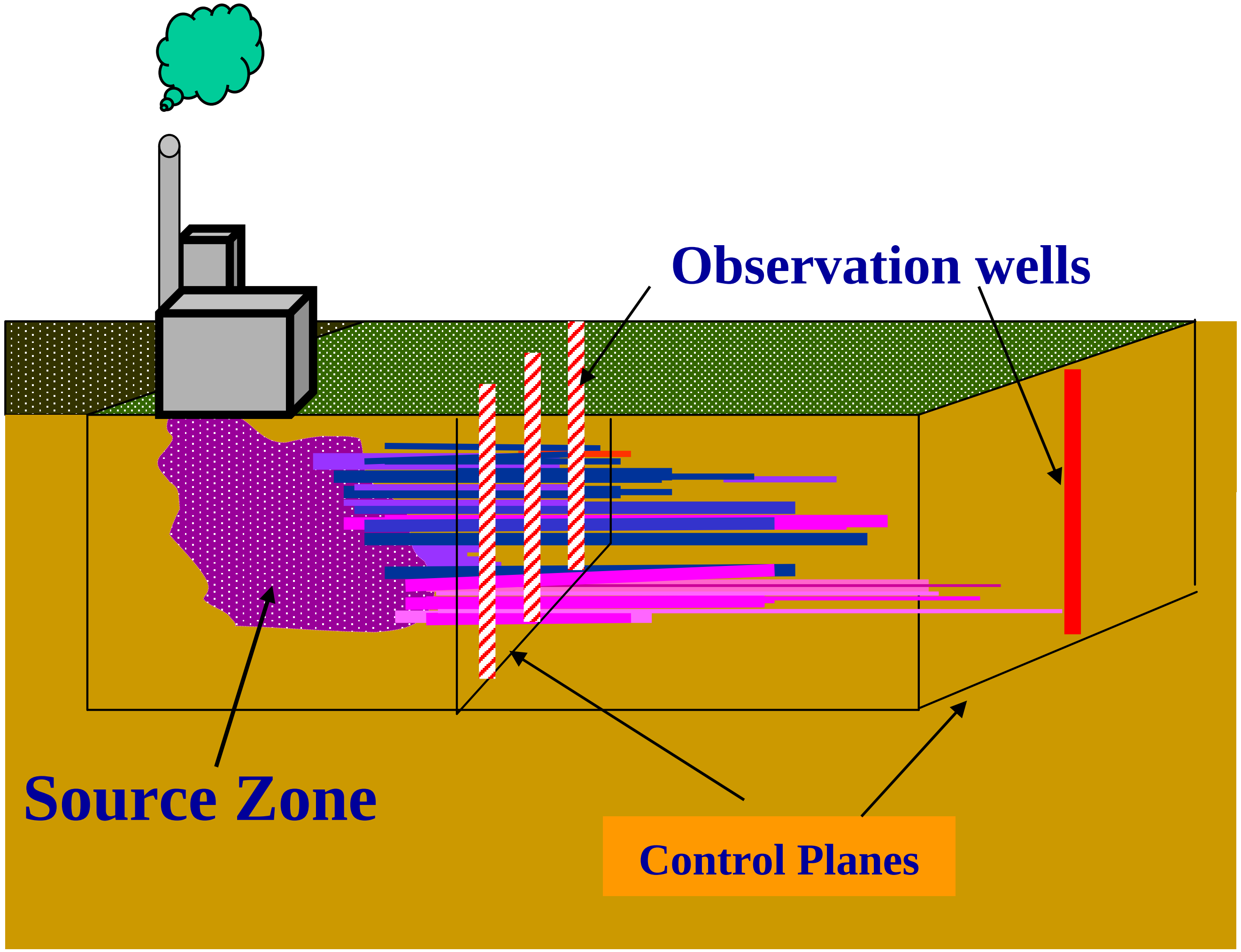
- Precipitation
- Irrigation
- Runoff
- Evaporation
- Transpiration
- Root Water Uptake
- Capillary Rise
- Deep Drainage

- Fertigation
- Pesticides
- Fumigants
- Colloids
- Pathogens
- Nanoparticles



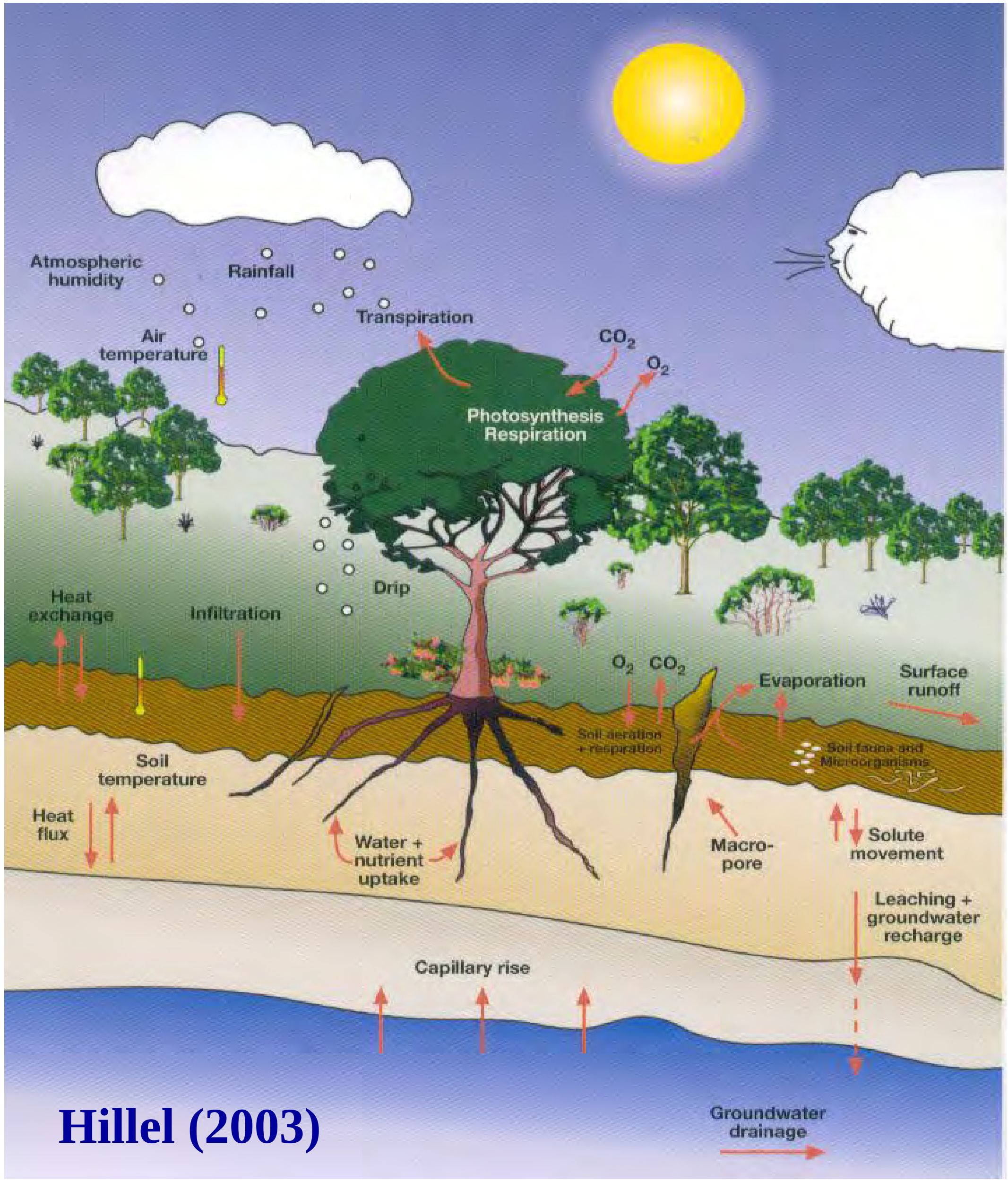
Industrial Applications

- Industrial Pollution
- Municipal Pollution
- Landfill Covers
- Waste Repositories
- Radioactive Waste Disposal Sites
- Remediation
- Brine Releases
- Contaminant Plumes
- Seepage of Wastewater from Land Treatment Systems



Environmental Applications

- Ecological Apps
- Carbon Storage and Fluxes
- Heat Exchange and Fluxes
- Nutrient Transport
- Soil Respiration
- Microbiological Processes
- Effects of Climate Change
- Riparian Systems
- Stream-Aquifer Interactions



Hillel (2003)

Governing Equations

Variably-Saturated Water Flow (Richards Equation)

$$\frac{\partial \theta(h)}{\partial t} = \frac{\partial}{\partial z}\left[K(h)\left(\frac{\partial h}{\partial z} - 1\right)\right] - S(h)$$

Solute Transport (Convection-Dispersion Equation)

$$\frac{\partial(\rho s)}{\partial t} + \frac{\partial(\theta c)}{\partial t} = \frac{\partial}{\partial z}\left(\theta D \frac{\partial c}{\partial z} - qc\right) - \phi$$

Heat Movement

$$\frac{\partial C_p(\theta) T}{\partial t} = \frac{\partial}{\partial z}\left[\lambda(\theta)\frac{\partial T}{\partial z}\right] - C_w \frac{\partial qT}{\partial z} - C_w S T$$

HYDRUS – Main Processes

Water Flow:

- **Richards equation for variably-saturated water flow**
- **Various models of soil hydraulic properties**
- **Hysteresis**
- **Sink term, accounting for water uptake by plant roots** (uncompensated and compensated; reduced due to osmotic and pressure stress)
- **Preferential flow**
- **Isothermal and thermal liquid and vapor flow**

Solute Transport:

- **Convective-dispersive transport in the liquid phase**
- **Diffusion in the gaseous phase**
- **Linear and nonlinear reactions between the solid and liquid phases**
- **Linear equilibrium reactions between the liquid and gaseous phases**
- **Zero-order production, First-order degradation**
- **Physical and chemical nonequilibrium solute transport**
- **Sink term, accounting for nutrient uptake by plant roots (**active and passive**)**

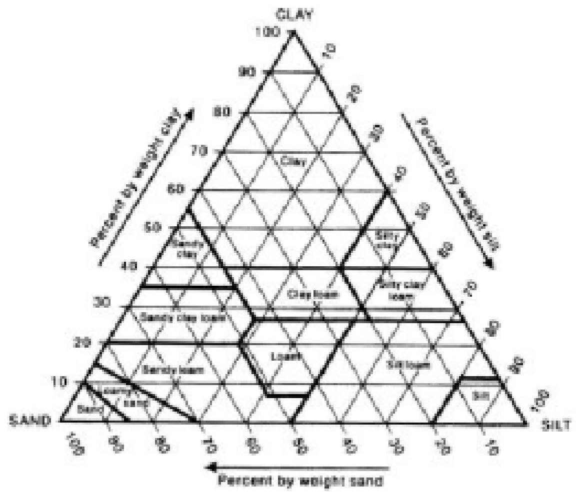
Heat Transport:

- **Conduction and convection with flowing water (transport of latent heat)**

PTFs by Carsel and Parrish (1988)

Average values of selected soil water retention parameters for 12 major soil textural groups

Texture	θ_r	θ_s	α 1/cm	n	K_s cm/d
Sand	0.045	0.43	0.145	2.68	712.8
Loamy Sand	0.057	0.41	0.124	2.28	350.2
Sandy Loam	0.065	0.41	0.075	1.89	106.1
Loam	0.078	0.43	0.036	1.56	24.96
Silt	0.034	0.46	0.016	1.37	6.00
Silt Loam	0.067	0.45	0.020	1.41	10.80
Sandy Clay Loam	0.100	0.39	0.059	1.48	31.44
Clay Loam	0.095	0.41	0.019	1.31	6.24
Silty Clay Loam	0.089	0.43	0.010	1.23	1.68
Sandy Clay	0.100	0.38	0.027	1.23	2.88
Silty Clay	0.070	0.36	0.005	1.09	0.48
Clay	0.068	0.38	0.008	1.09	4.80



USDA Soil Textural Triangle

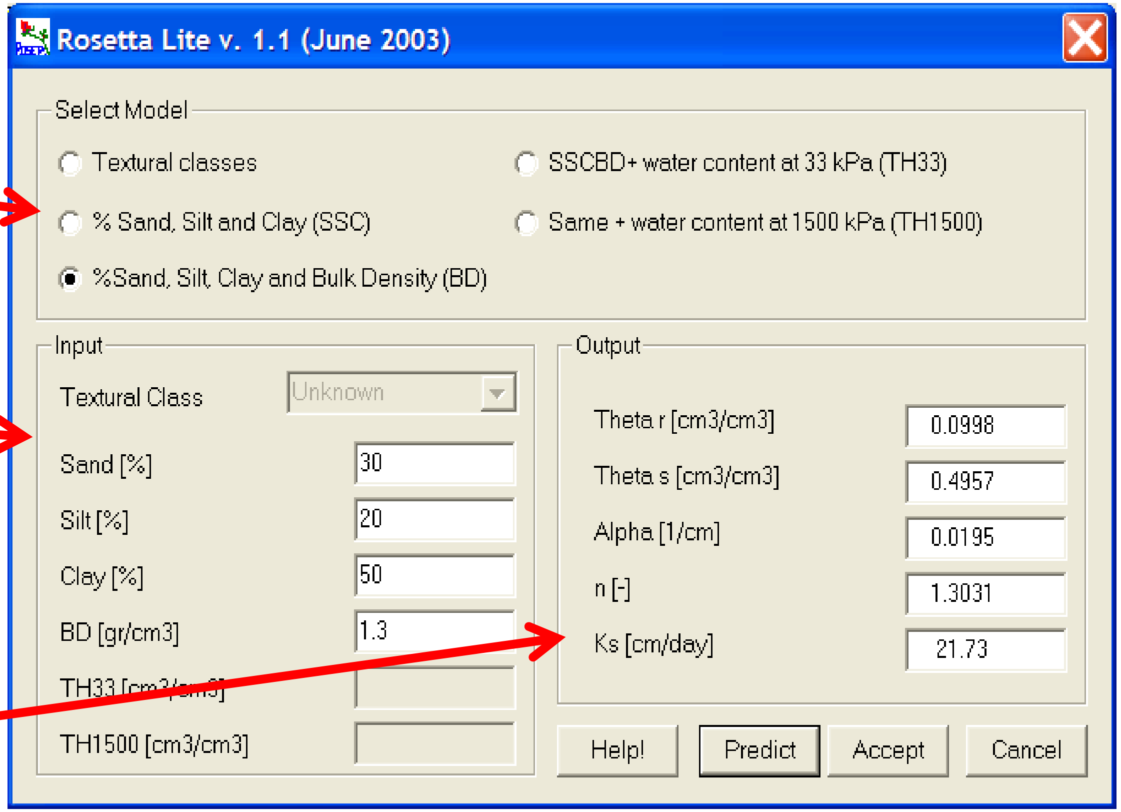
ROSETTA

Software for predicting the Soil Hydraulic Parameters (van Genuchten, 1980) from Soil Textural Properties (Schaap et al., 2001).

Hierarchical Models

Input Data

Predicted Parameters

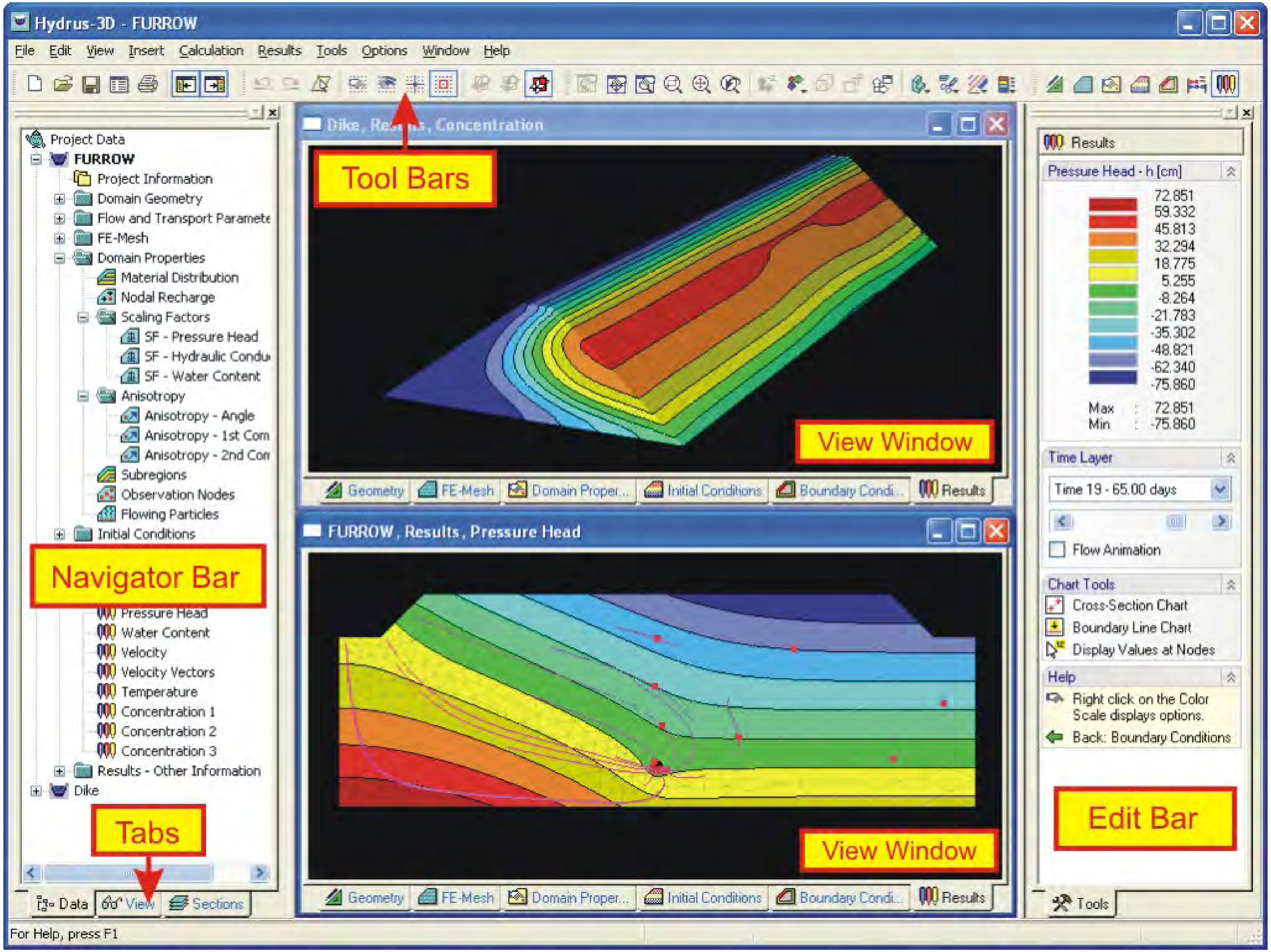


Schaap, M. G., Leij, F. J., and van Genuchten, M. Th., Rosetta: a computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions, *Journal of Hydrology*, 251, 163-176, 2001.

HYDRUS – Solute Transport

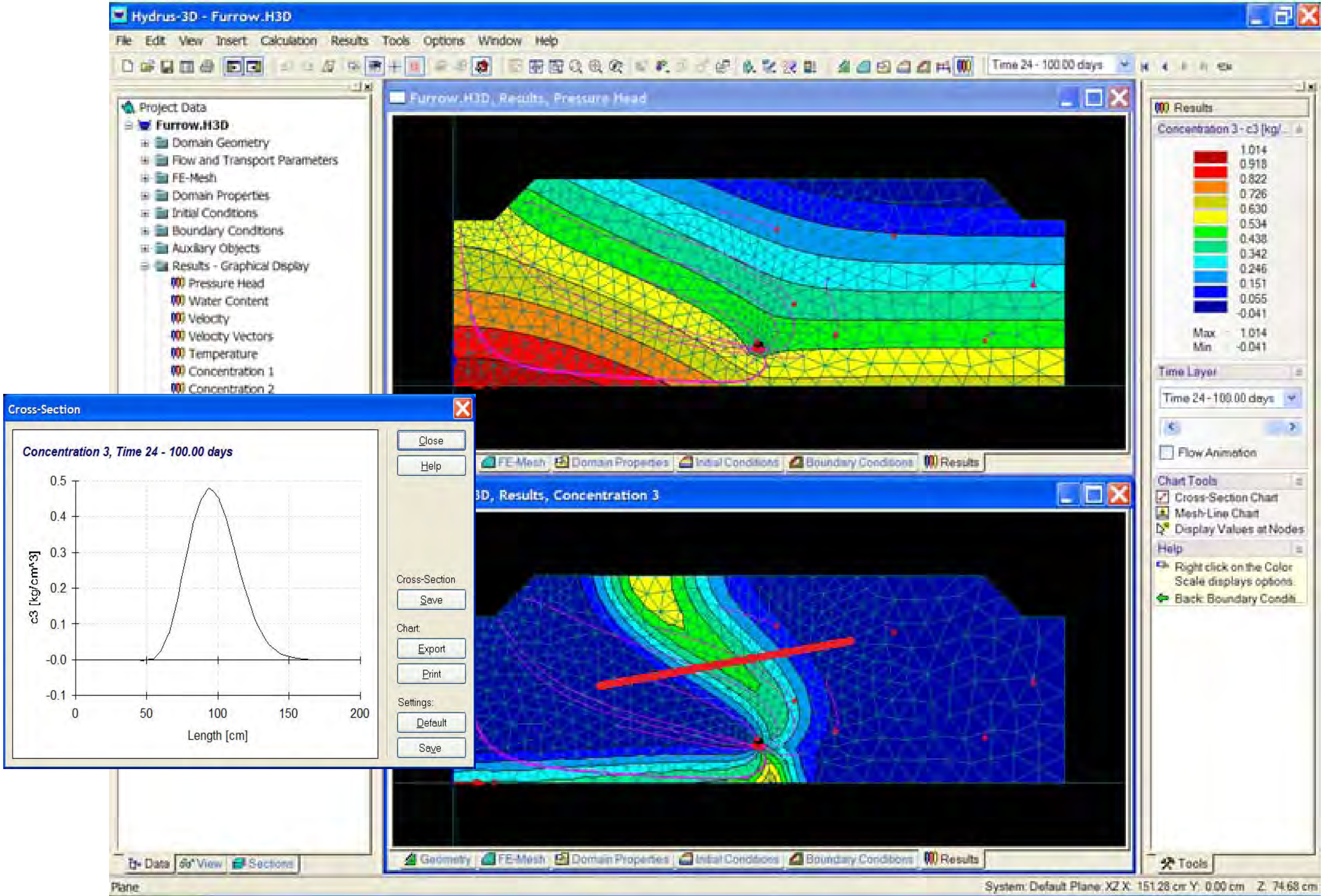
- **Transport of Single Ions or Particles (colloids, viruses, bacteria)**
- **Transport of Multiple Ions (sequential first-order decay)**
  - **Radionuclides:** ^{238}Pu -> ^{234}U -> ^{230}Th -> ^{226}Ra
  - **Nitrogen:** $(NH_2)_2CO$ -> NH_4^+ -> NO_2^- -> NO_3^-
  - **Pesticides:** aldicarb (oxime) -> sulfone (sulfone oxime) -> sulfoxide (sulfoxide oxime)
  - **Chlorinated Hydrocarbons:** PCE -> TCE -> c-DCE -> VC -> ethylene
  - **Pharmaceuticals, Hormones:** Estrogen (17bEstradiol -> Estrone -> Estriol), Testosterone
  - **Explosives:** TNT (-> 4HADNT -> 4ADNT -> TAT), RDX, HMX
- **Transport of Major Ions (the UNSATCHEM module)**
- **General BioGeoChemical Reactions (the HP1 module)**
- **Processes in Wetlands (the CW2D and CWM1 modules)**
- **Colloid-Facilitated Solute Transport (the C-Hitch module)**

HYDRUS (2D/3D)



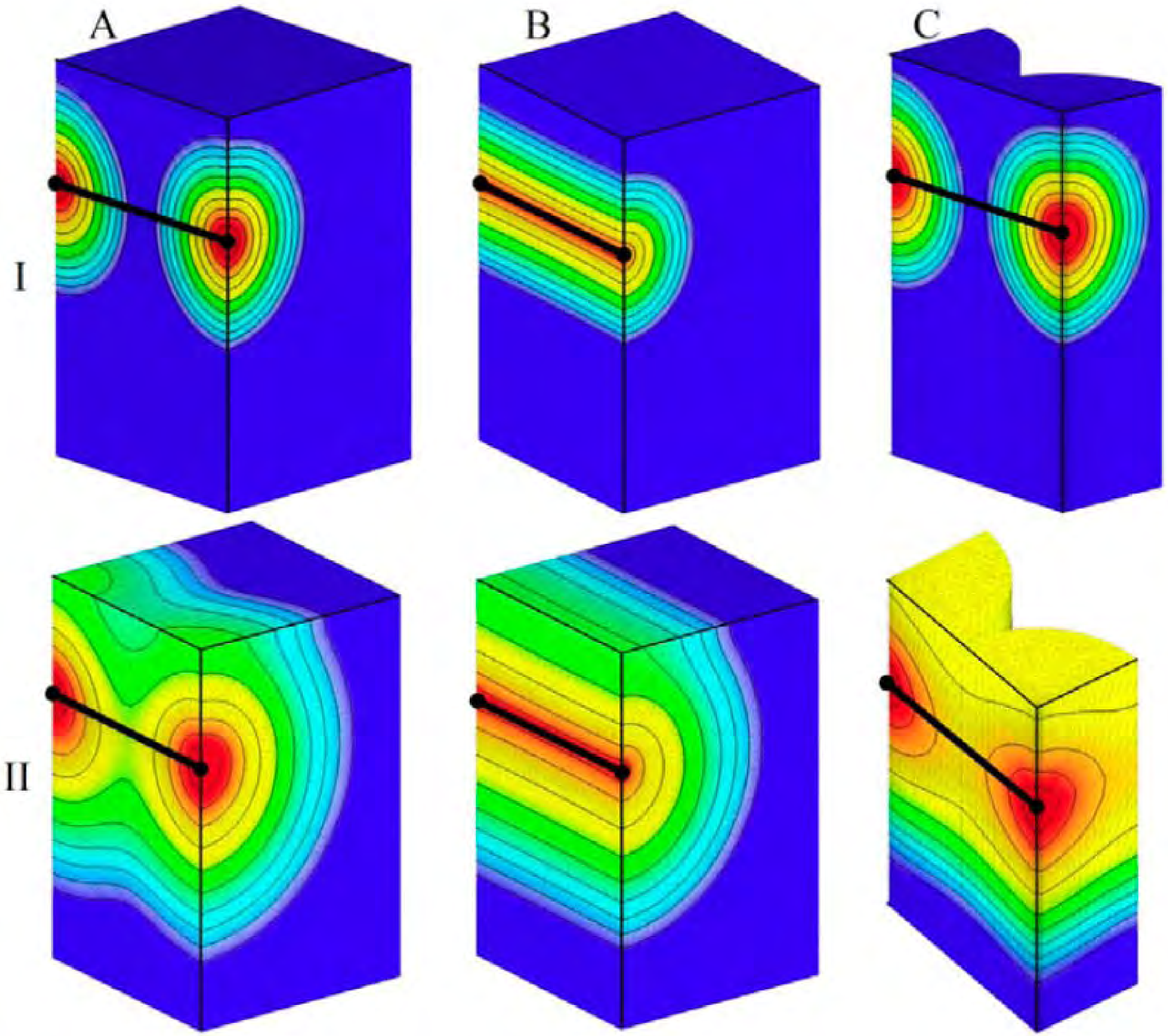
Hydrus-3D - FURROW
File Edit View Insert Calculation Results Tools Options Window Help
Tool Bars
Navigator Bar
Tabs
View Window
View Window
Edit Bar
Project Data
FURROW
Project Information
Domain Geometry
Flow and Transport Paramete
FE-Mesh
Domain Properties
Material Distribution
Nodal Recharge
Scaling Factors
SF - Pressure Head
SF - Hydraulic Condu
SF - Water Content
Anisotropy
Anisotropy - Angle
Anisotropy - 1st Com
Anisotropy - 2nd Com
Subregions
Observation Nodes
Flowing Particles
Initial Conditions
Pressure Head
Water Content
Velocity
Velocity Vectors
Temperature
Concentration 1
Concentration 2
Concentration 3
Results - Other Information
Dike
Data
View
Sections
Dike, Results, Concentration
FURROW, Results, Pressure Head
Geometry
FE-Mesh
Domain Proper...
Initial Conditions
Boundary Condi...
Results
Pressure Head - h [cm]
72.851
59.332
45.813
32.294
18.775
5.255
-8.264
-21.783
-35.302
-48.821
-62.340
-75.860
Max : 72.851
Min : -75.860
Time Layer
Time 19 - 65.00 days
Flow Animation
Chart Tools
Cross-Section Chart
Boundary Line Chart
Display Values at Nodes
Help
Right click on the Color Scale displays options.
Back: Boundary Conditions
Tools
For Help, press F1

HYDRUS (2D/3D)



Hydrus-3D - Furrow.H3D
File Edit View Insert Calculation Results Tools Options Window Help
Time 24 - 100.00 days
Project Data
Furrow.H3D
Domain Geometry
Flow and Transport Parameters
FE-Mesh
Domain Properties
Initial Conditions
Boundary Conditions
Auxiliary Objects
Results - Graphical Display
Pressure Head
Water Content
Velocity
Velocity Vectors
Temperature
Concentration 1
Concentration 2
Furrow.H3D, Results, Pressure Head
3D, Results, Concentration 3
Results
Concentration 3 - c3 [kg/...
1.014
0.918
0.822
0.726
0.630
0.534
0.438
0.342
0.246
0.151
0.055
-0.041
Max 1.014
Min -0.041
Time Layer
Time 24 - 100.00 days
Flow Animation
Chart Tools
Cross-Section Chart
Mesh-Line Chart
Display Values at Nodes
Help
Right click on the Color Scale displays options
Back Boundary Conditi...
Cross-Section
Concentration 3, Time 24 - 100.00 days
c3 [kg/cm^3]
Length [cm]
Close
Help
Cross-Section
Save
Chart:
Export
Print
Settings:
Default
Save
FE-Mesh
Domain Properties
Initial Conditions
Boundary Conditions
Results
Geometry
Data
View
Sections
Tools
Plane
System: Default Plane: XZ X: 151.28 cm Y: 0.00 cm Z: 74.68 cm

HYDRUS (2D/3D)



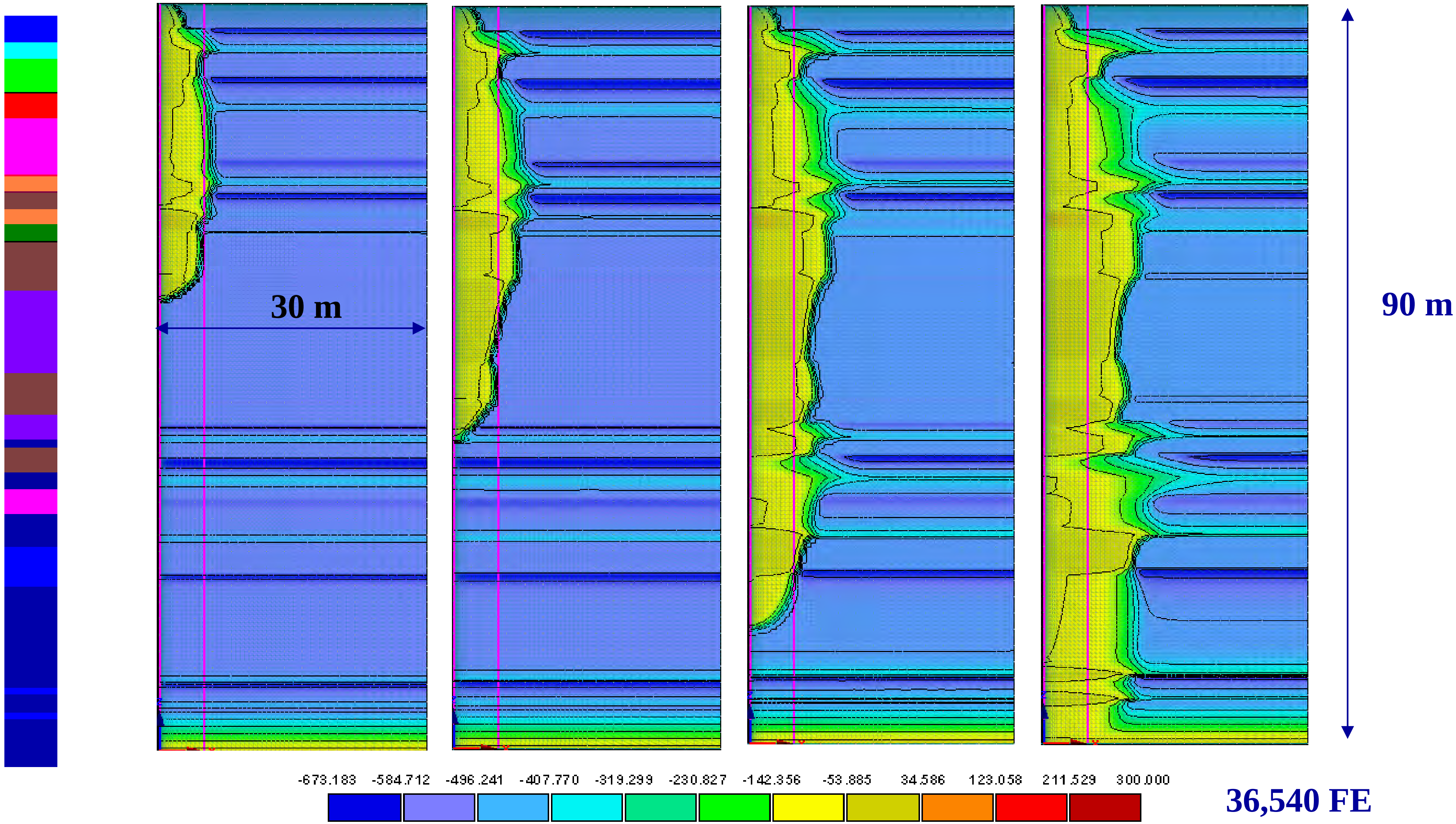
Subsurface Drip Irrigation System

Soil water content simulated as:

A. a **Three-Dimensional** system with **two point sources**
B. a **Two-Dimensional** system with **a line source**
C. An **Axisymmetrical** two-dimensional system with **a point source**

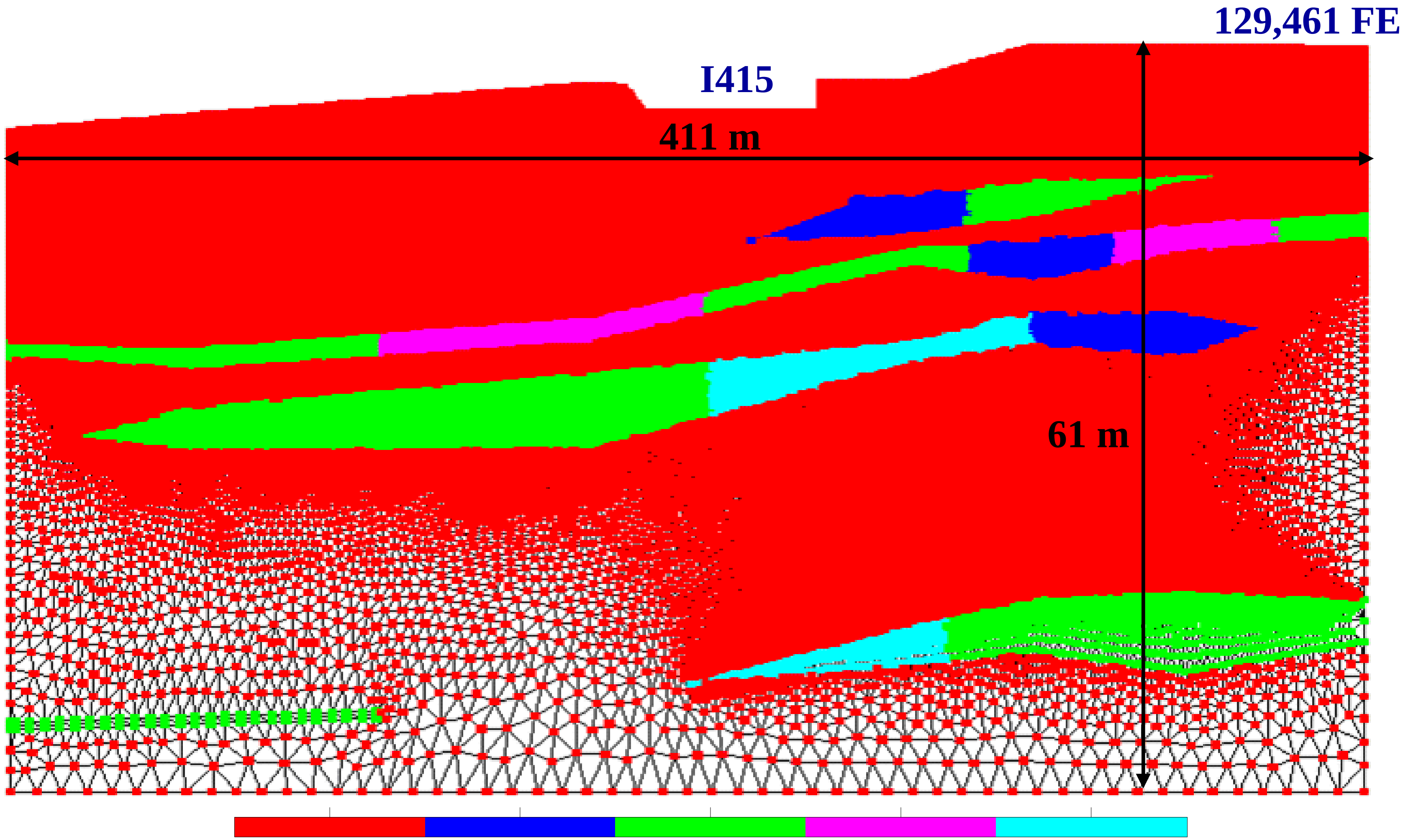
Kandelous, M. M., J. Šimůnek, M. Th. van Genuchten, and K. Malek, Soil water content distributions between two emitters of a subsurface drip irrigation system, *Soil Science Society of America Journal*, *75*(2), 488-497, 2011.

HYDRUS (2D/3D)



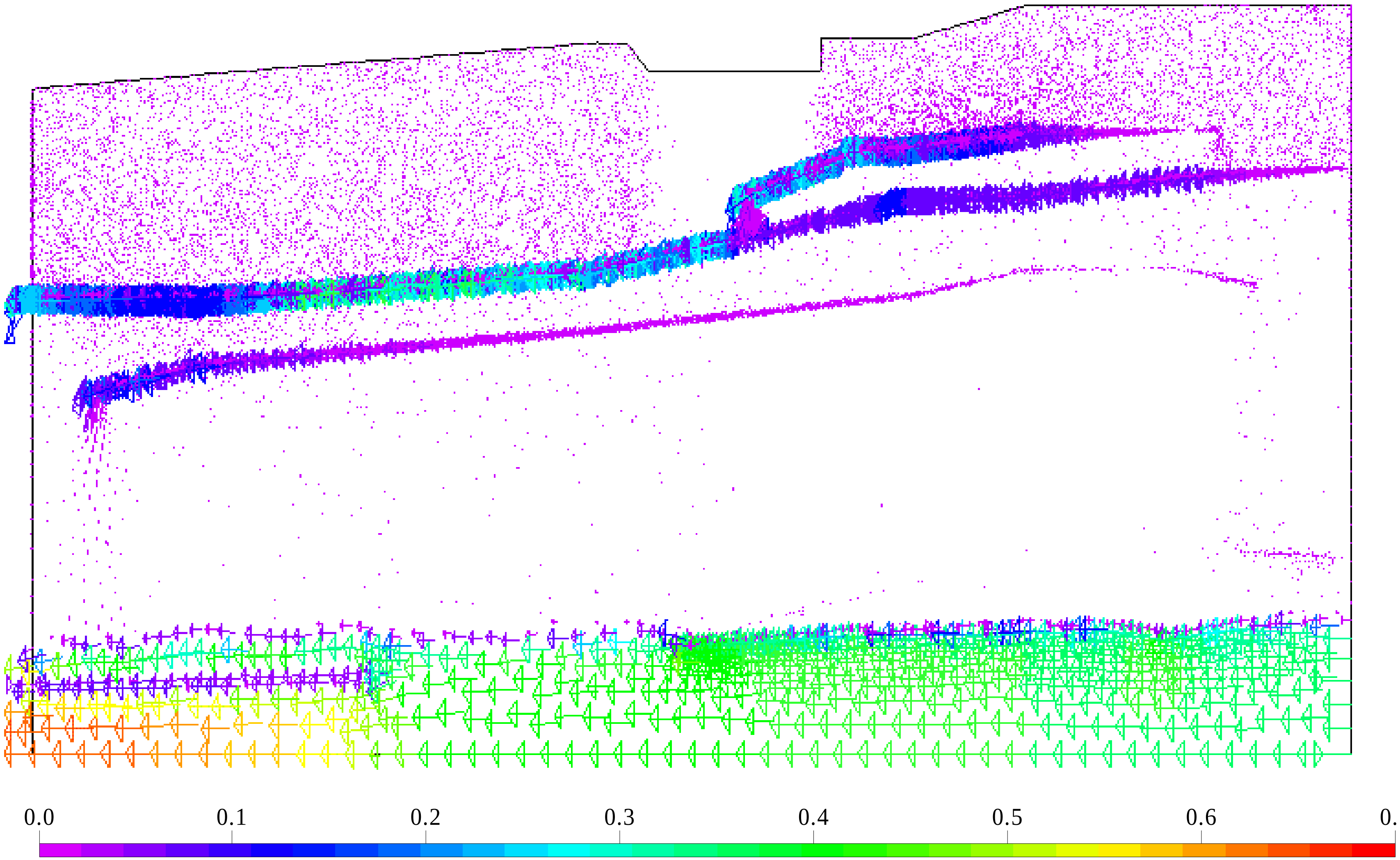
Pressure head profiles after 10, 25, 50, and 100 years.
Leak (2 mm diameter) at the bottom of the Palmdale Reservoir.

HYDRUS (2D/3D)



Finite element mesh and material distribution.
Two-dimensional transect 411 m wide and 61 m deep with a freeway in the middle.

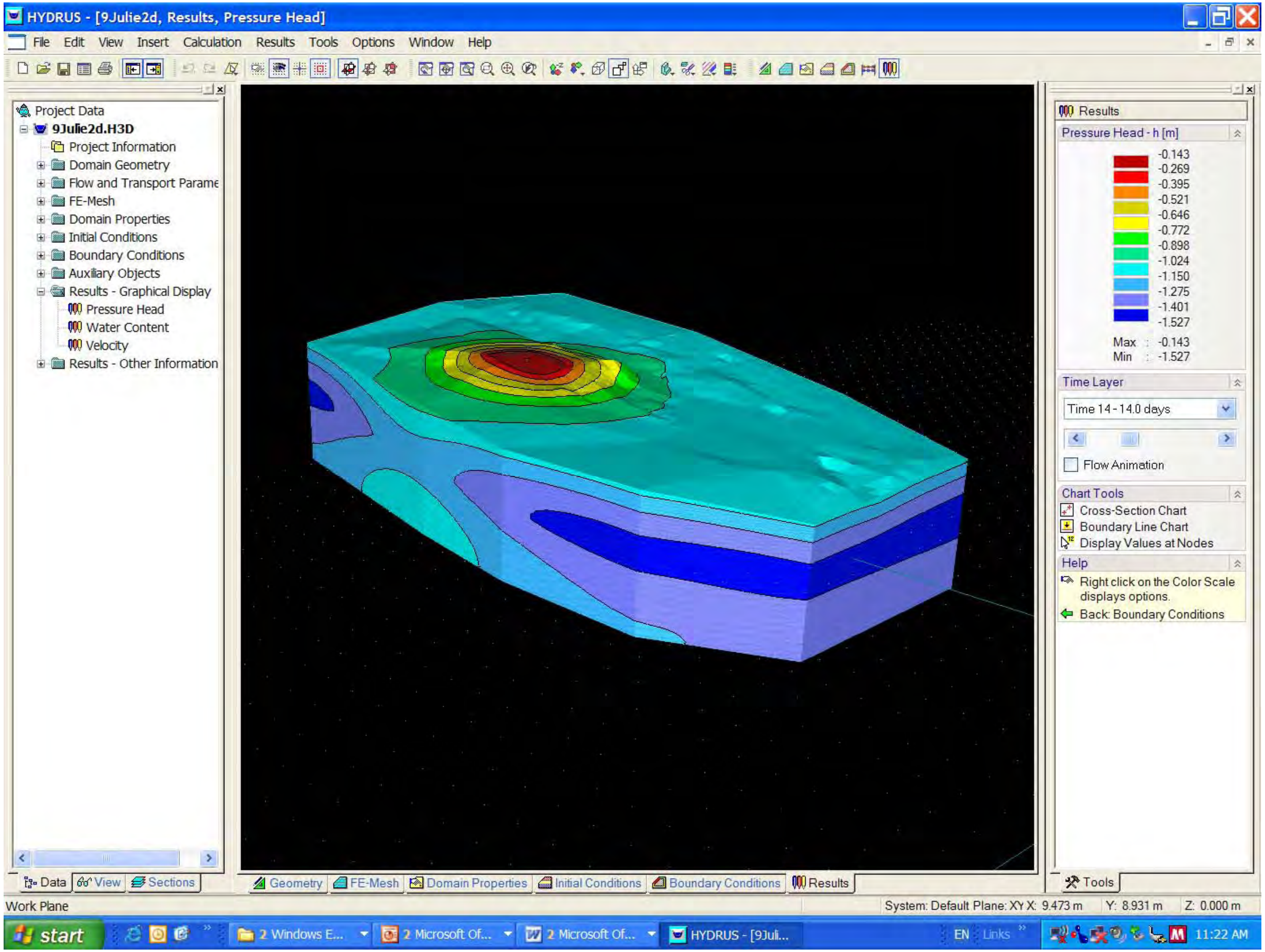
HYDRUS (2D/3D)



Velocity vectors

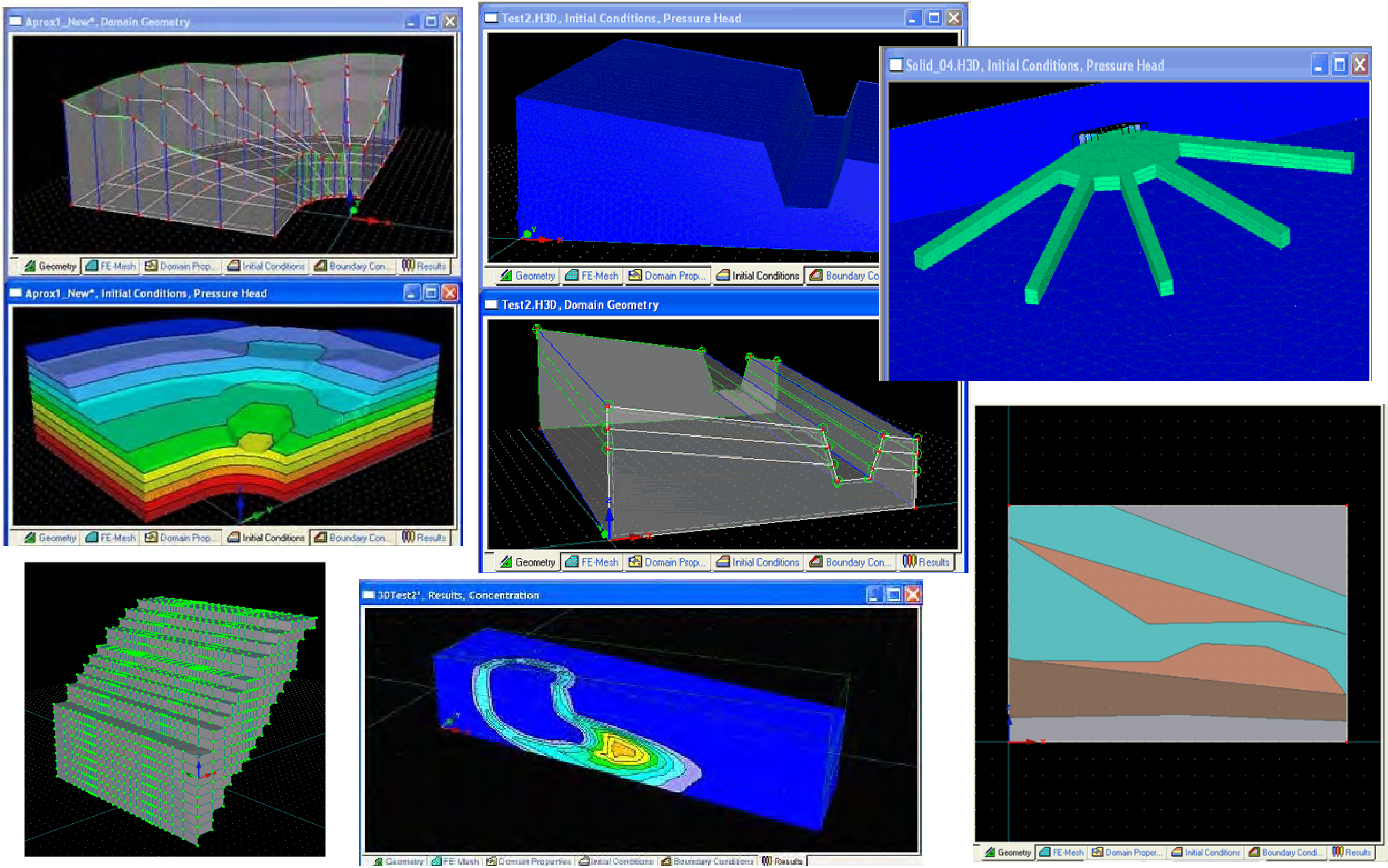
Two-dimensional transect 411 m wide and 61 m deep with a freeway in the middle

HYDRUS (2D/3D)



Three-Dimensional Transport Domain

HYDRUS (2D/3D) Projects



HYDRUS - Transport Domains

A. 2D – Simple

B. 2D – General

C. 3D – Simple

D. 3D – Layered

E. 3D – General

HYDRUS Levels:

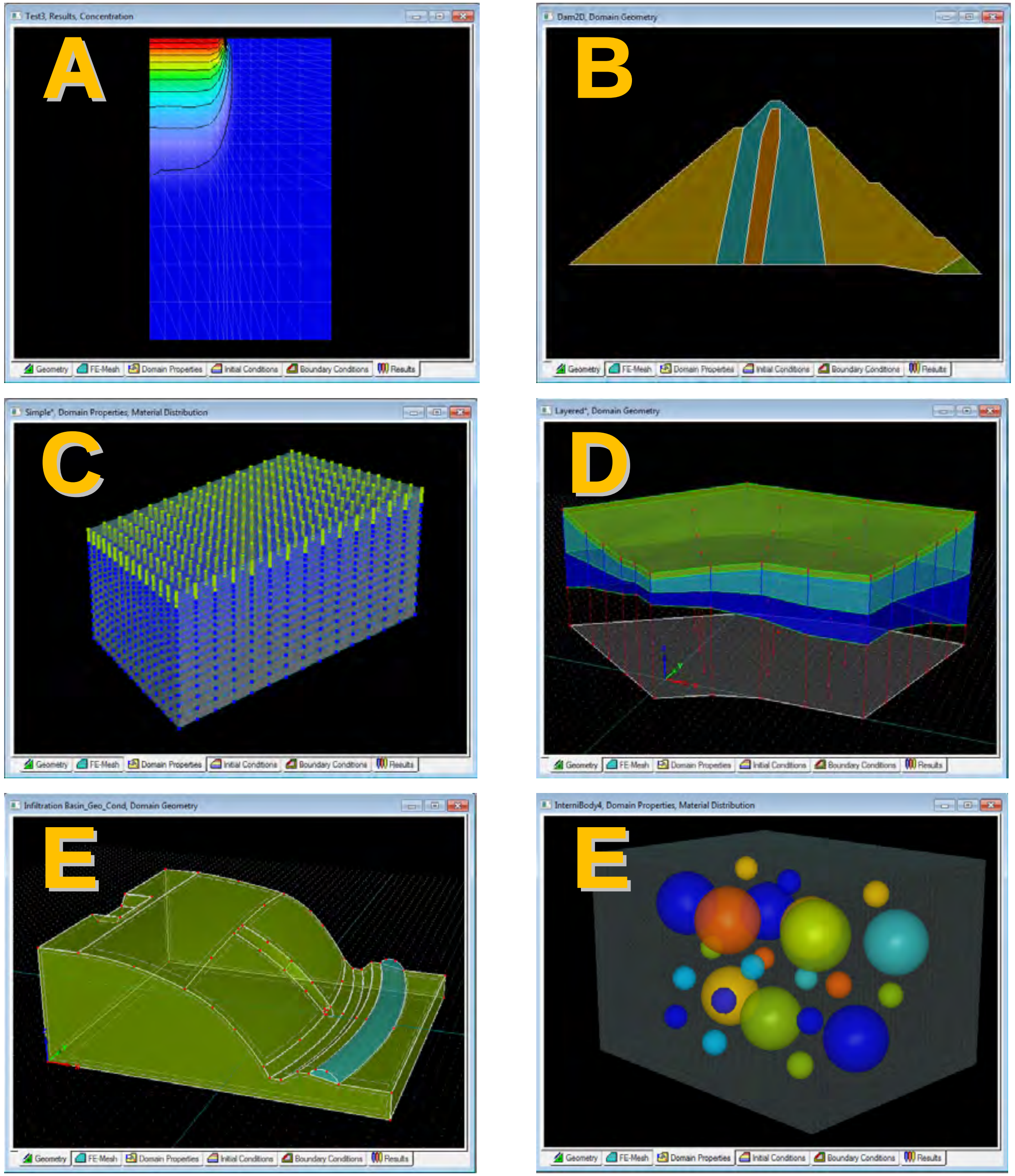
2D – Lite (A)

2D – Standard (A+B)

3D – Lite (A+C)

3D – Standard (A+B+C+D)

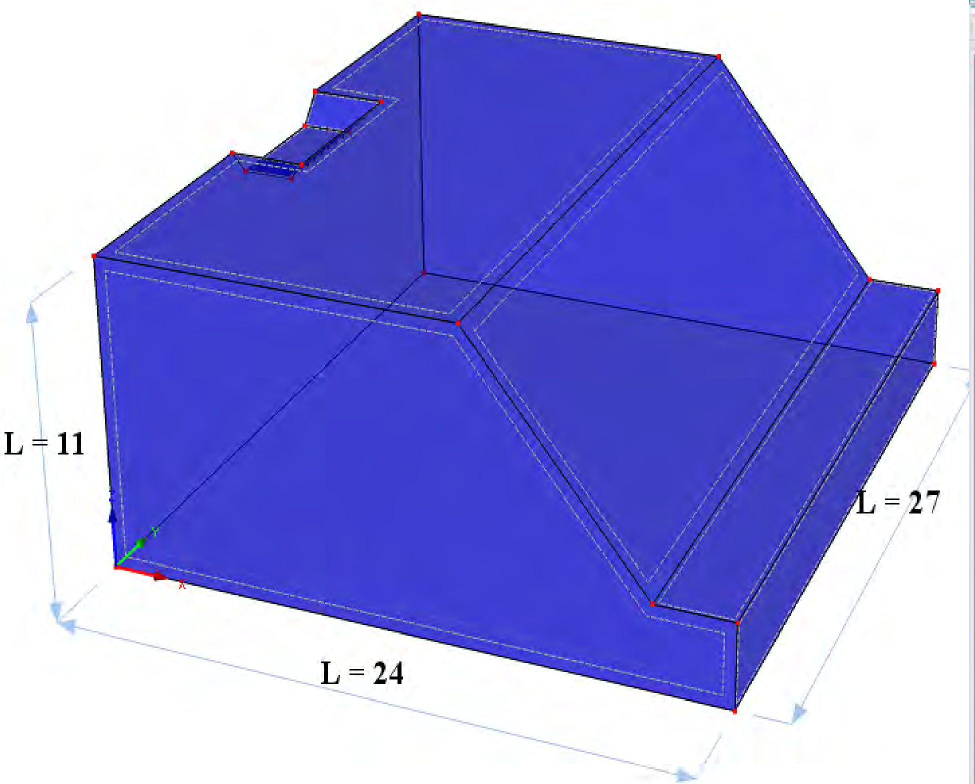
3D – Professional (All)



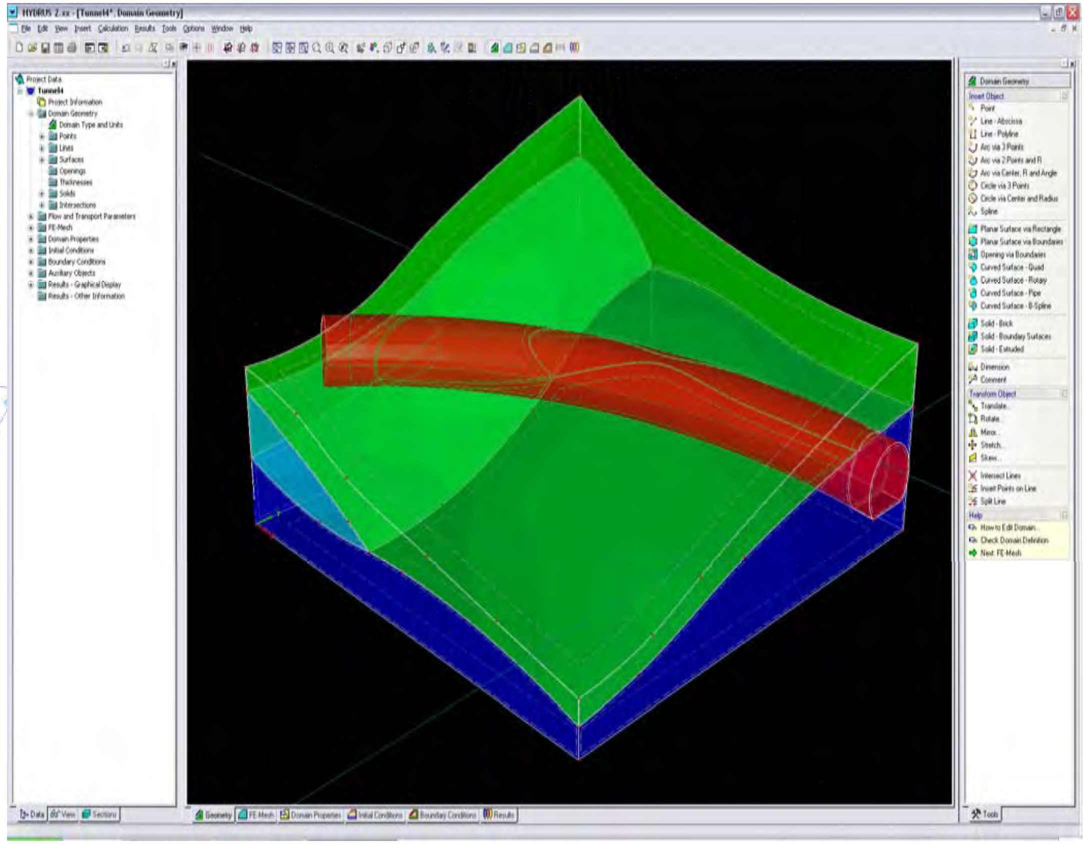
HYDRUS (2D/3D) - Geometries

3D-General Geometries:

Geometry defined using Planar Surfaces:



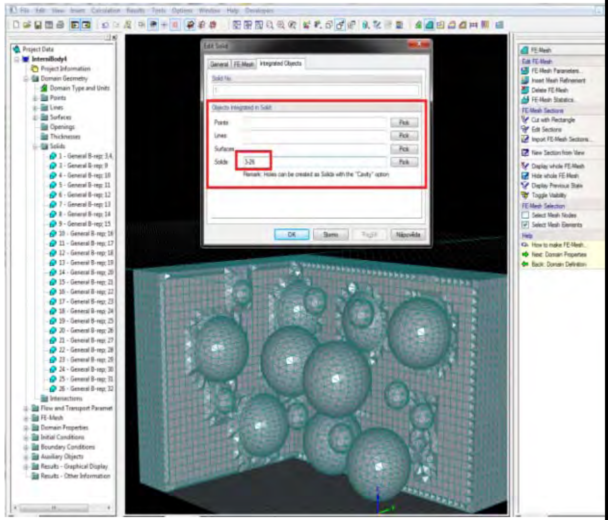
Geometry defined using Curved Surfaces:

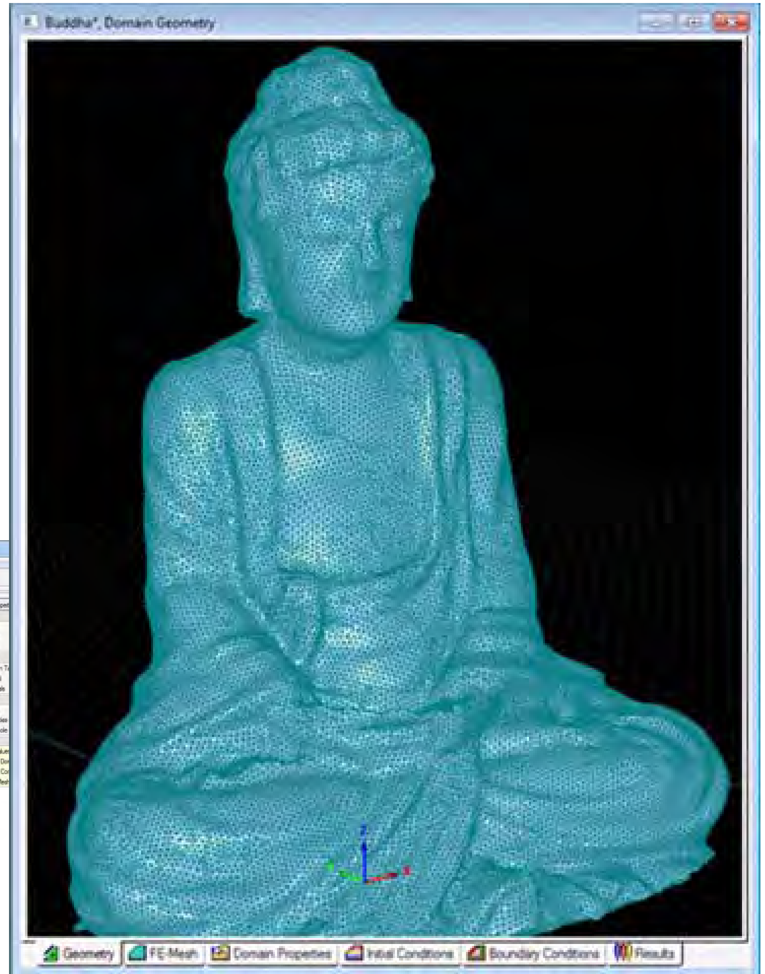


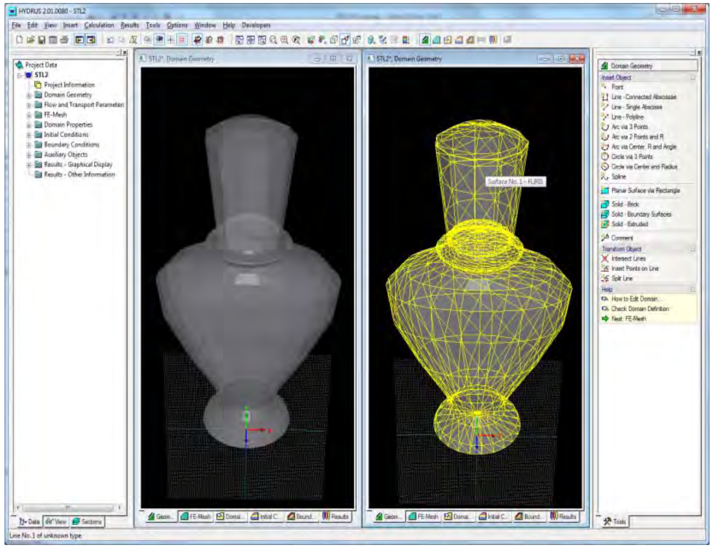
The tunnel (the red object) is defined using a surface that intersects all other three surfaces

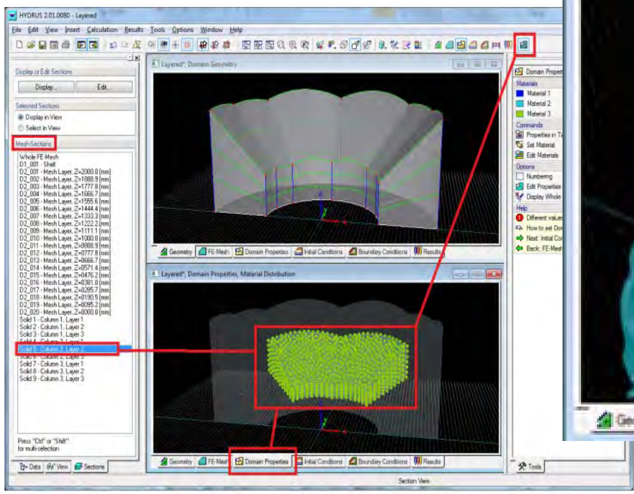
General 3D Geometries

Import of complex Geometries (e.g., DXF, TIN, STL)



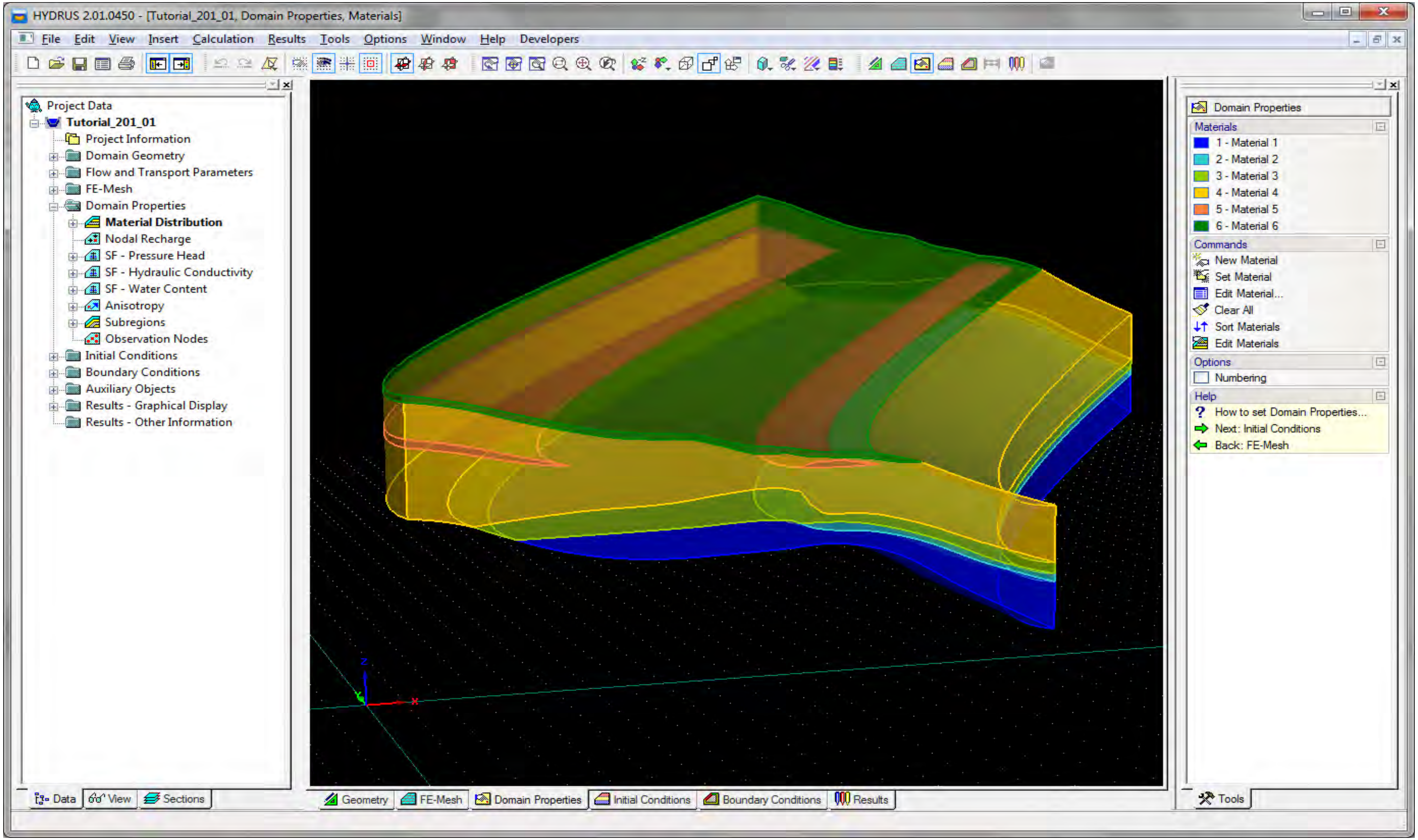






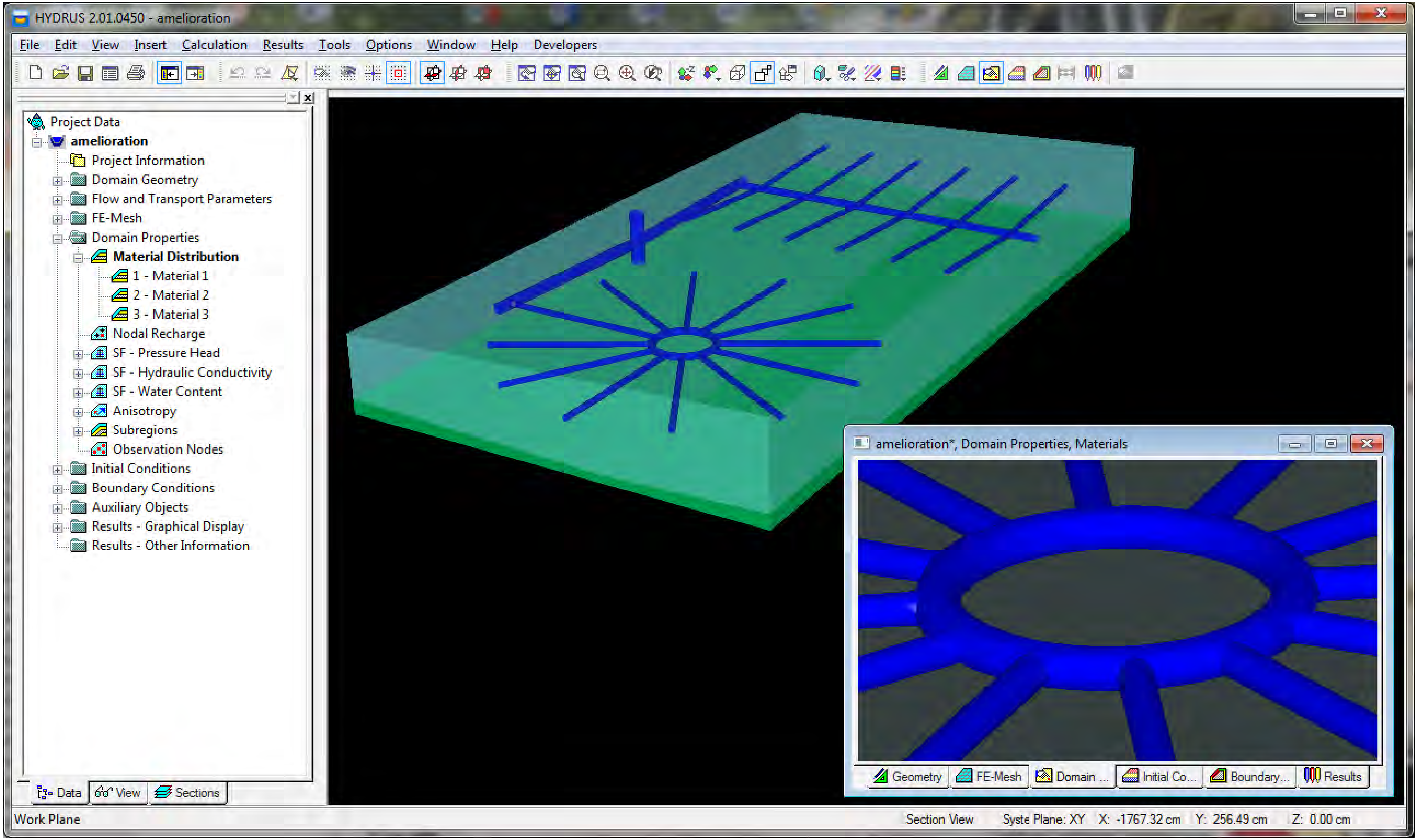
HYDRUS: 3D-Professional

Discontinuous 3D Layers



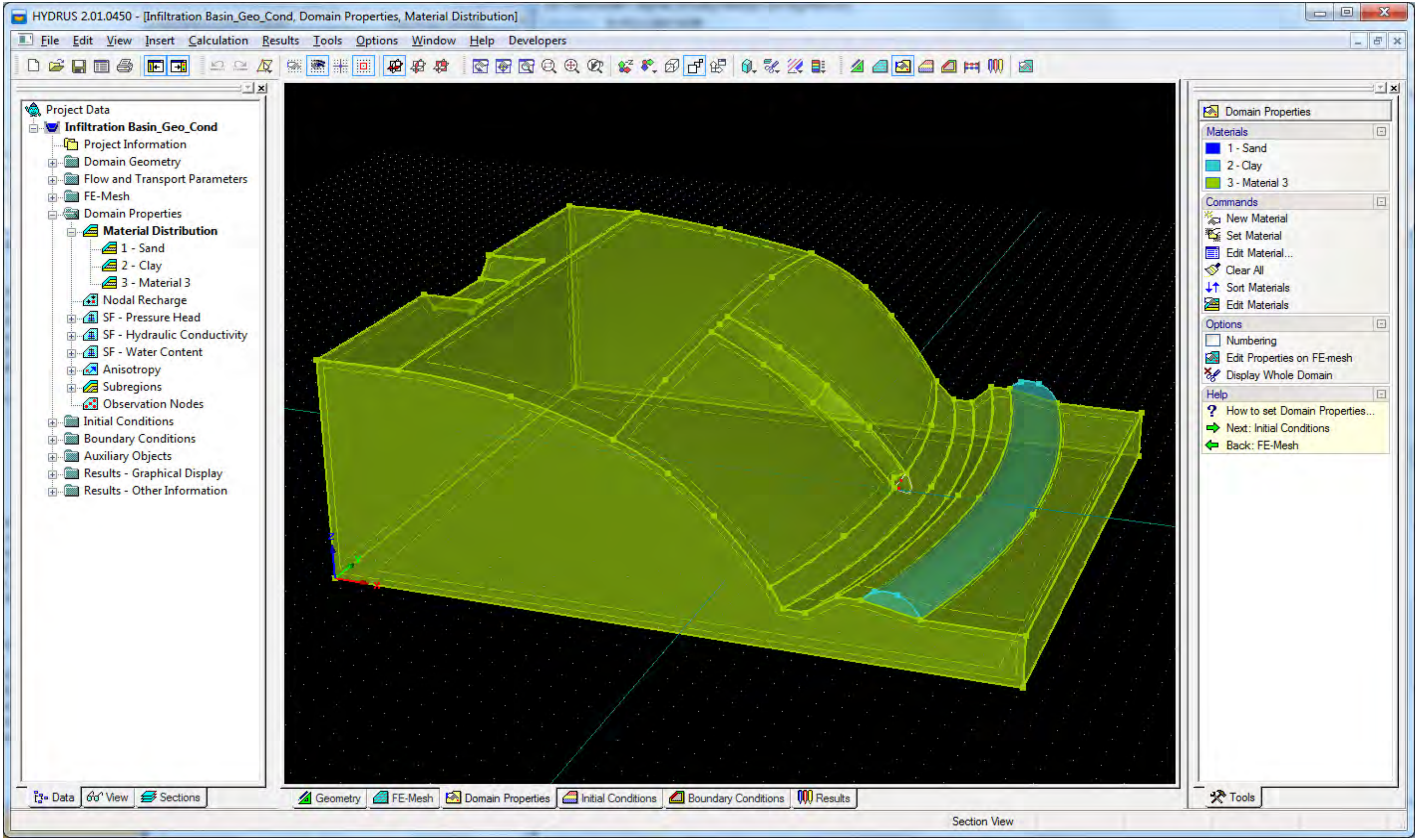
HYDRUS: 3D-Professional

Complex Drainage Systems



HYDRUS: 3D-Professional

Infiltration Basin



ParSWMS – Parallelized Version of HYDRUS

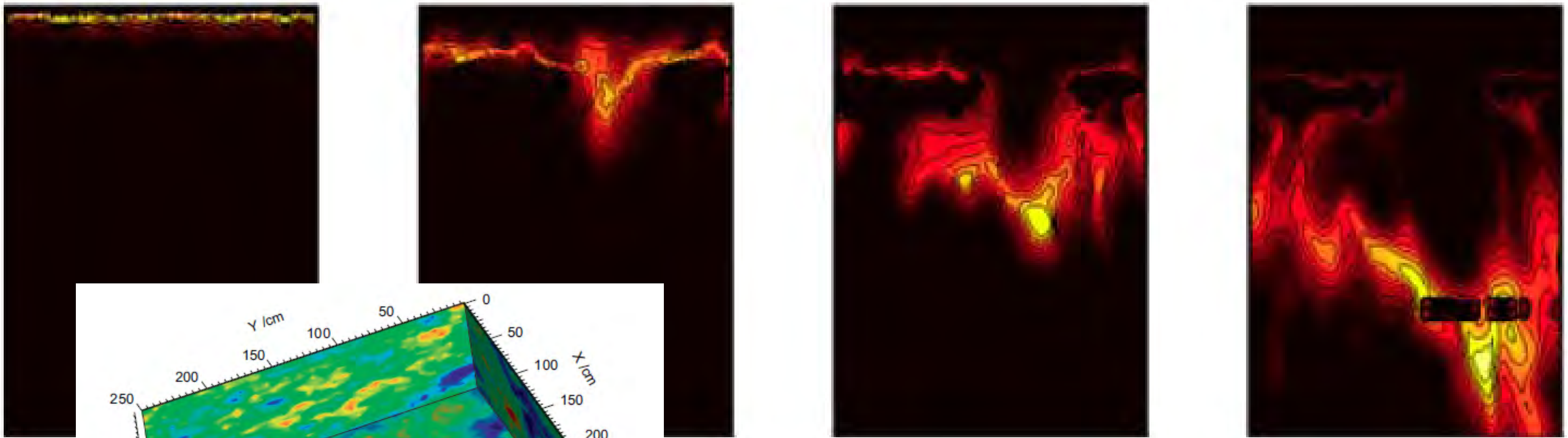
- **ParSWMS (**Hardelauf et al., 2007) **- Parallelized version of SWMS_3D** (Šimůnek et al., 1995)**.**
- **Developed by** *Forschungszentrum Jülich, Germany*.
- **SWMS_3D** – earlier and simpler version of Hydrus-3D
- **MPI (Message-Passing Interface)** - a library specification for message-passing between the different processors. MPI is free software for LINUX or UNIX operating systems.
- **Test**

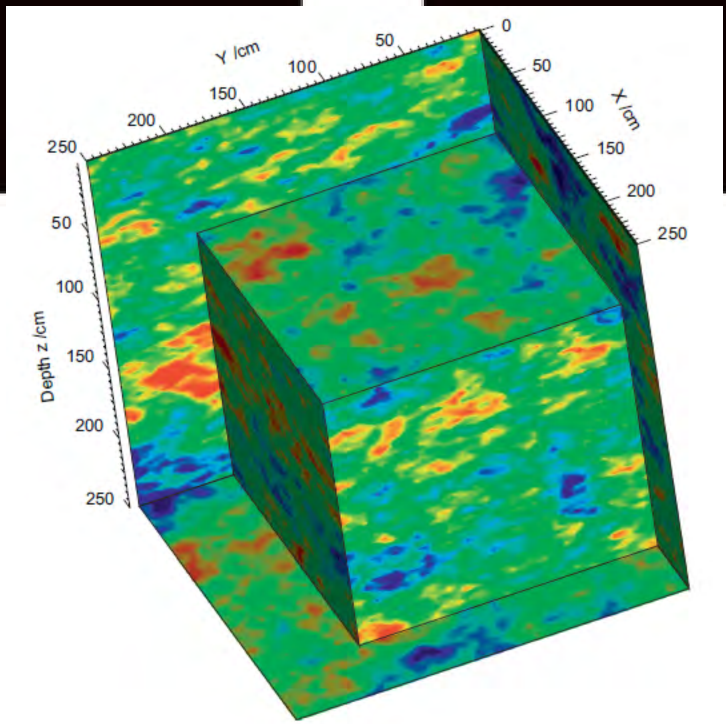
  \- Water flow and solute transport problem - 492264 finite element nodes

  \- Supercomputer with 41 SMP nodes with 32 processors each (total 1312 processors - Power4+ 1.7 GHz)

ParSWMS – Parallelized Version of HYDRUS

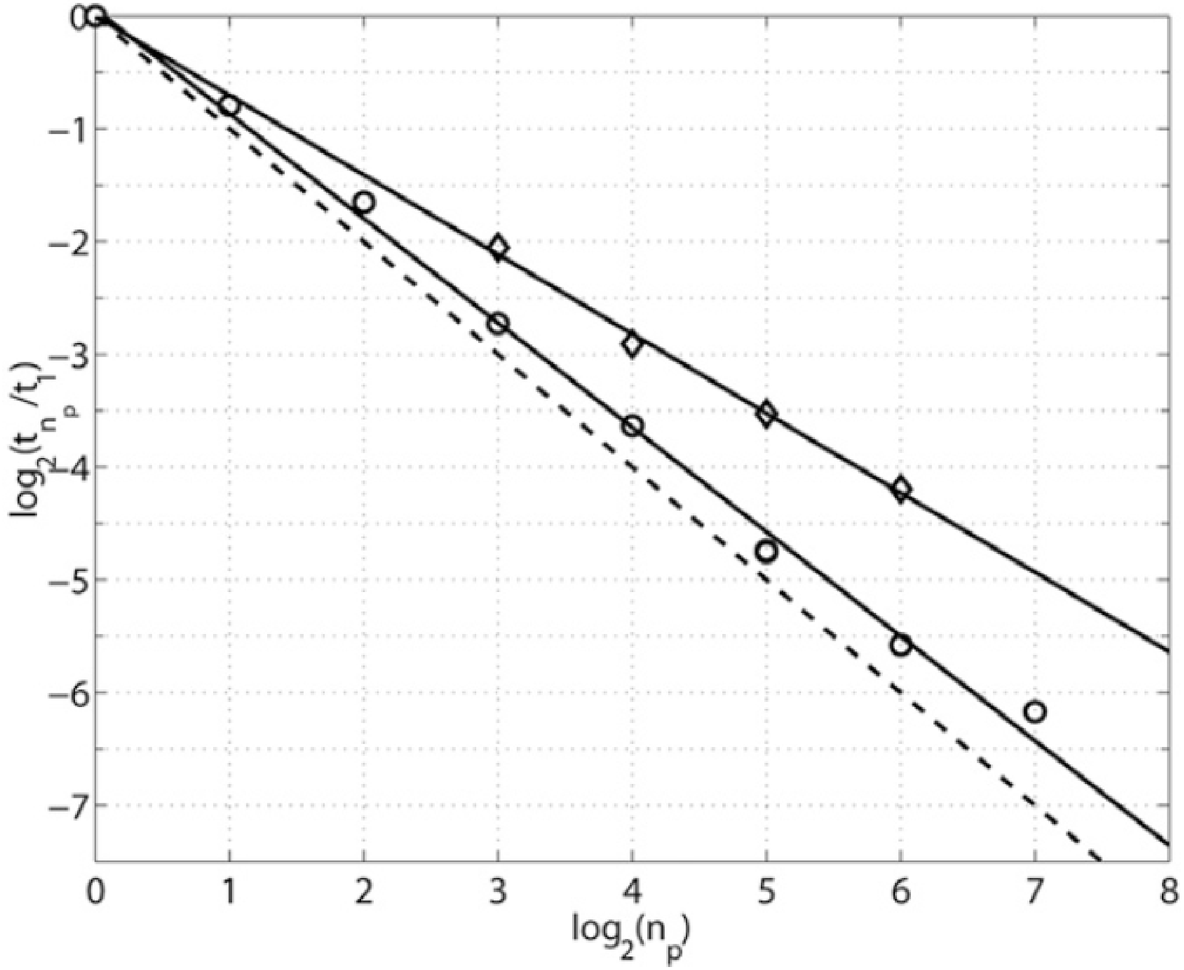
2D Water flow and solute transport (Hardelauf et al., 2007)
492,264 finite element nodes





3D Water flow problem
275,706 finite element nodes
(Herbst et al., 2008)

ParSWMS – Parallelized Version of HYDRUS



Time gain as compared to the one processor run (in log2) as a function of the number of processors n_p (in log2) for solute transport scenario with 492,264 nodes (open circles) and water flow with atmospheric upper boundary conditions (diamonds).

HYDRUS Codes and its Modules

- **HYDRUS + PHREEQC = HP1**
  (hydrological + biogeochemical processes)
- **HYDRUS + UNSATCHEM**
  (hydrological + CO_2 + geochemical processes)
- **HYDRUS + Wetland (W2D/CWM1)**
  (processes in constructed wetlands)
- **HYDRUS + C-Hitch**
  (colloid-facilitated solute transport)
- **HYDRUS + MODFLOW**
  (hydrological processes at the large scale)

HP1 (HYDRUS+PHREEQC)

Simulating water flow, transport and bio-geochemical reactions in environmental soil quality problems

HP1

A Coupled Numerical Code for Variably Saturated Water Flow, Solute Transport and BioGeoChemistry in Soil Systems

HP1

Flow and transport model
HYDRUS-1D 4.0

Biogeochemical model
PHREEQC-2.4

HP1 (HYDRUS+PHREEQC)

HYDRUS-1D:

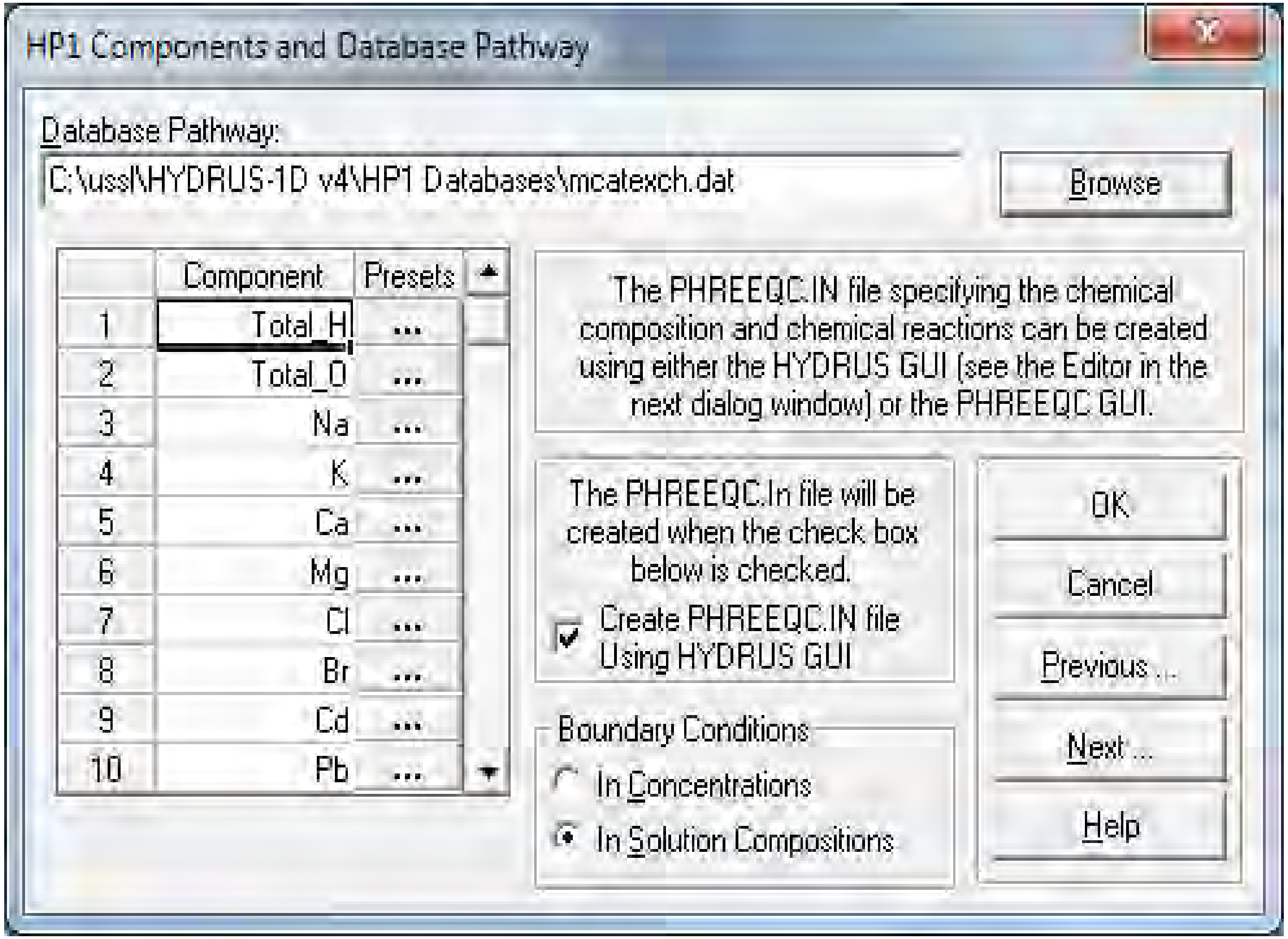
- Variably Saturated Water Flow
- Solute Transport
- Heat transport
- Root water uptake

PHREEQC [Parkhurst and Appelo, 1999]:

Available chemical reactions:

- Aqueous complexation
- Redox reactions
- Ion exchange (Gains-Thomas)
- Surface complexation – diffuse double-layer model and non-electrostatic surface complexation model
- Precipitation/dissolution
- Chemical kinetics
- Biological reactions

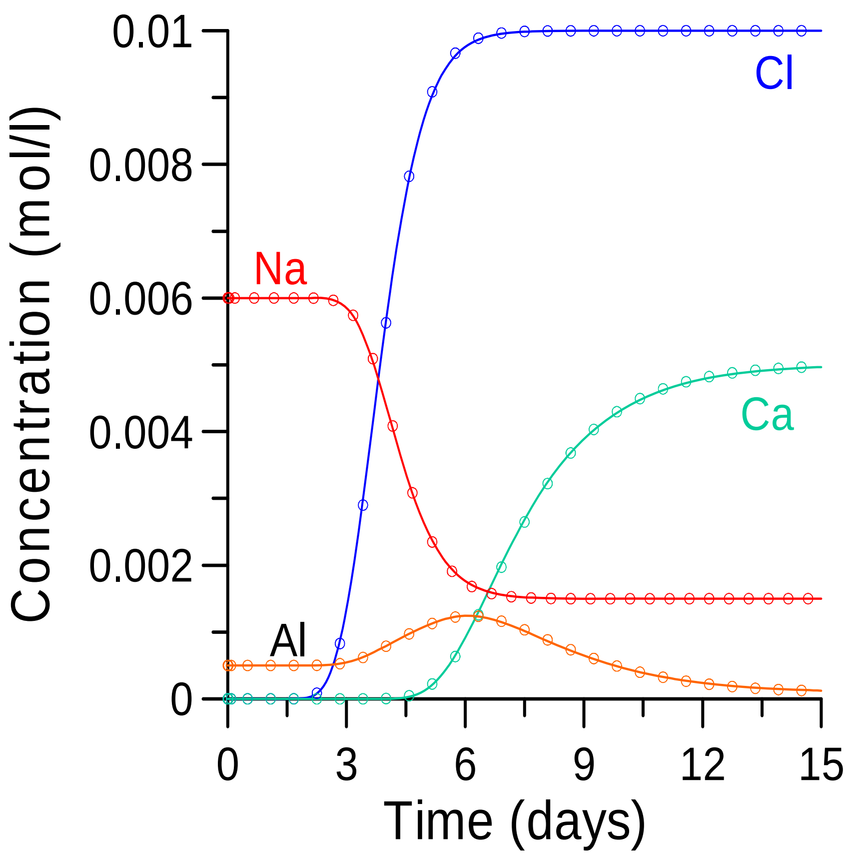
HYDRUS-1D GUI for HP1

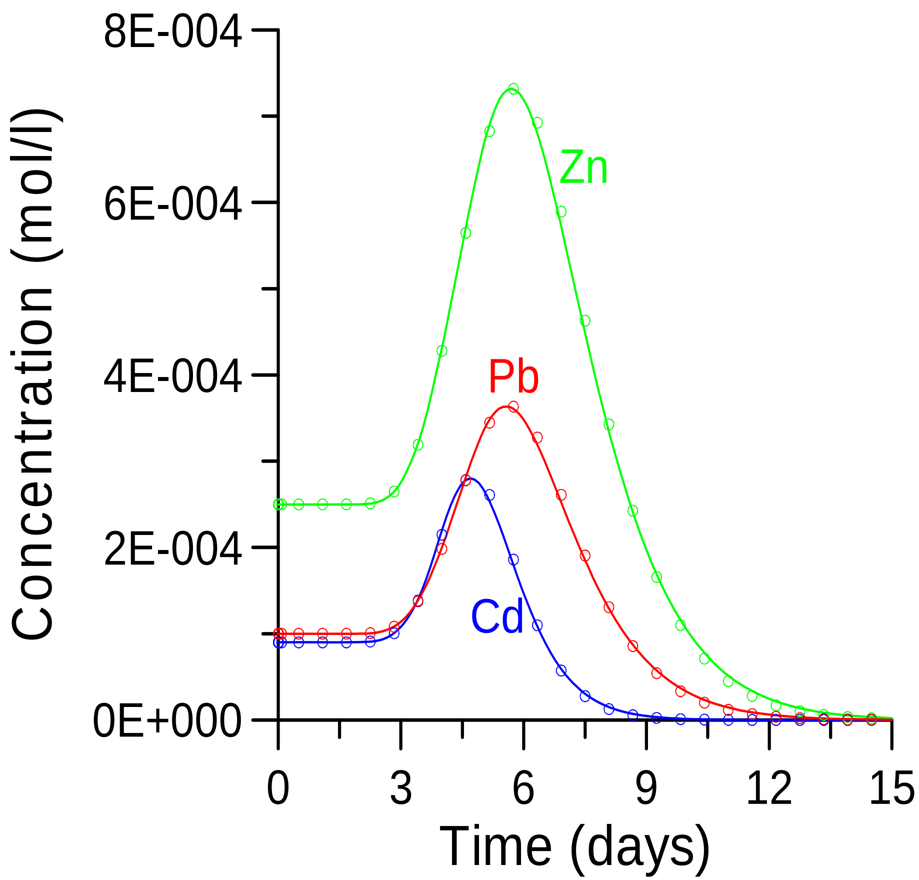


Jacques, D., and J. Šimůnek, Notes on the HP1 software – a coupled code for variably-saturated water flow, heat transport, solute transport and biogeochemistry in porous media, HP1 Version 2.2, *SCK•CEN-BLG-1068,* Waste and Disposal, SCK•CEN, Mol, Belgium, 114 pp., 2010.

HP1 - Transport and Cation Exchange

Involving major ions (Ca, Na, Al, Cl) and Heavy Metals (Zn, Pb, Cd)





8-cm column is initially contaminated with heavy metals (in equilibrium with the cation exchanger). The column is then flushed with a solution without heavy metals.

HP1 Examples

- Transport of Heavy Metals (Zn^{2+}, Pb^{2+}, and Cd^{2+}) subject to multiple cation exchange
- Transport and mineral dissolution of amorphous SiO_2 and gibbsite
- Heavy metal transport in a medium with a pH-dependent cation exchange
- Infiltration of a Hyperalkaline Solution in a clay sample (kinetic precipitation-dissolution of kaolinite, illite, quartz, calcite, dolomite, gypsum, hydrotalcite, and sepiolite)
- Kinetic biodegradation of NTA (biomass, cobalt)
- Long-term Uranium transport following mineral phosphorus fertilization (pH-dependent surface complexation and cation exchange)
- Transport of Explosives, such as TNT and RDX
- Property Changes (porosity/conductivity) due to precipitation/ dissolution

HYDRUS + UNSATCHEM

- **HYDRUS and HYDRUS (2D/3D)**
  - variably saturated water flow
  - heat transport
  - root water uptake
  - solute transport
- **UNSATCHEM (Šimůnek et al., 1996)**
  - Carbon Dioxide Transport
  - Major Ion Chemistry
    - cation exchange
    - precipitation-dissolution (instantaneous and kinetic)
    - complexation

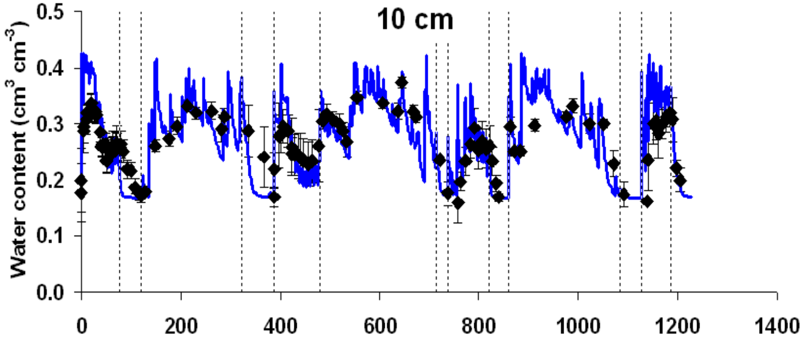
UNSATCHEM Module

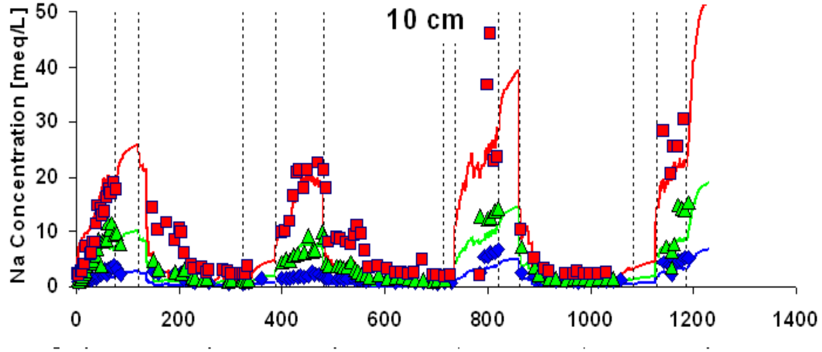
1	**Aqueous components**	7	Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-}
2	**Complexed species**	10	$CaCO_3^{o}$, $CaHCO_3^{+}$, $CaSO_4^{o}$, $MgCO_3^{o}$, $MgHCO_3^{+}$, $MgSO_4^{o}$, $NaCO_3^{-}$, $NaHCO_3^{o}$, $NaSO_4^{-}$, KSO_4^{-}
3	**Precipitated species**	6	$CaCO_3$, $CaSO_4 \cdot 2H_2O$, $MgCO_3 \cdot 3H_2O$, $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$, $Mg_2Si_3O_{7.5}(OH) \cdot 3H_2O$, $CaMg(CO_3)_2$
4	**Sorbed species (exchangeable)**	4	Ca, Mg, Na, K
5	**CO_2-H_2O species**	7	P_{CO2}, $H_2CO_3^{*}$, CO_3^{2-}, HCO_3^{-}, H^{+}, OH^{-}, H_2O
6	**Silica species**	3	H_4SiO_4, $H_3SiO_4^{-}$, $H_2SiO_4^{2-}$

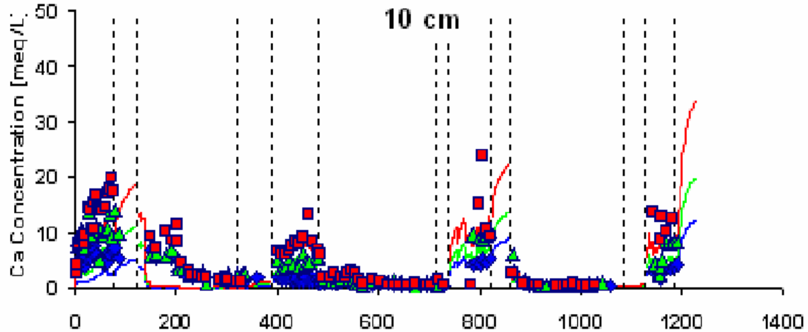
Kinetic reactions: calcite precipitation/dissolution, dolomite dissolution

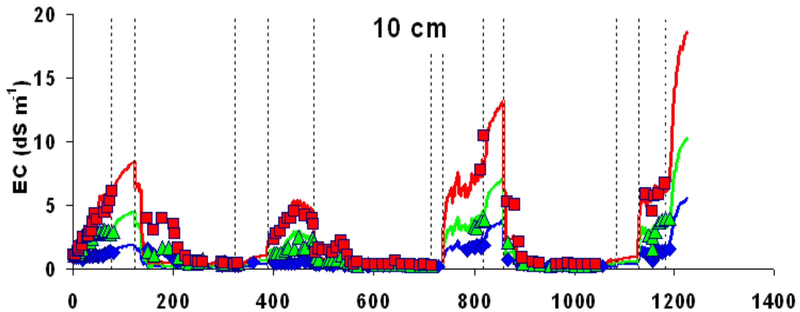
Activity coefficients: extended Debye-Hückel equations, Pitzer expressions

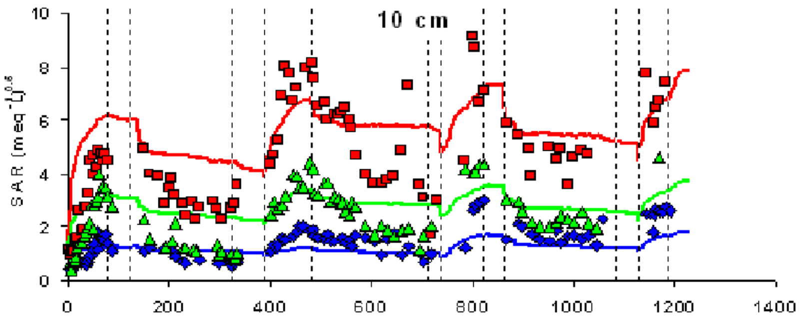
UNSATCHEM - Lysimeter Study









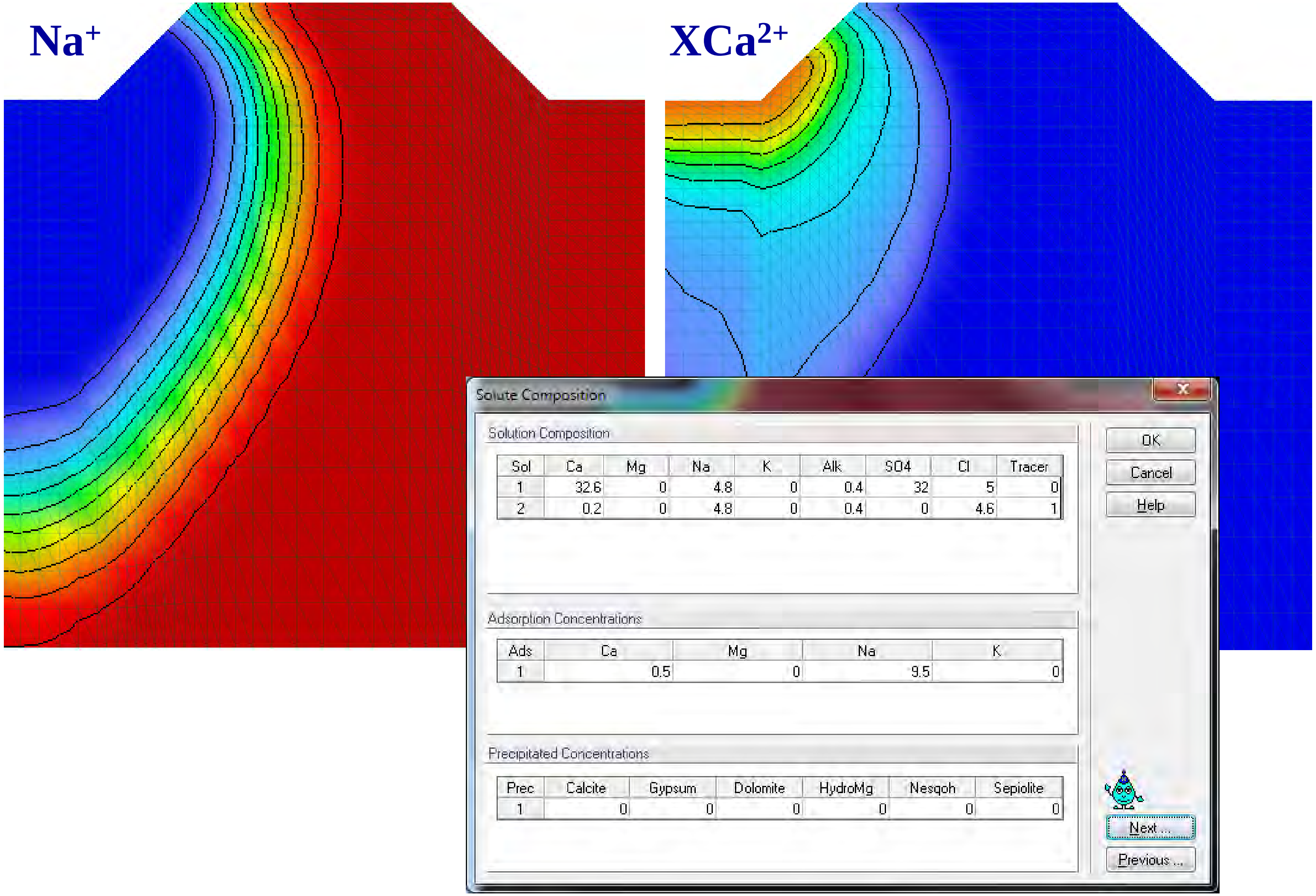


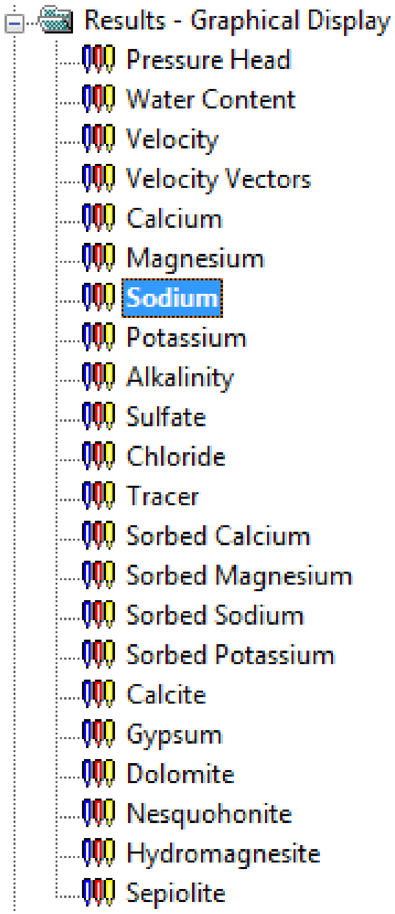
Gonçalves, M. C., J. Šimůnek, T. B. Ramos, J. C. Martins, M. J. Neves, and F. P. Pires, Multicomponent solute transport in soil lysimeters irrigated with waters of different quality, *Water Resources Research*, *42*, 17 pp., 2006.

UNSATCHEM-2D Module

Major Ion Chemistry Module

Na^{+} XCa^{2+}





Šimůnek, J., and D. L. Suarez, Two-dimensional transport model for variably saturated porous media with major ion chemistry, *Water Resources Research*, *30*(4), 1115-1133, 1994.

Wetland Module

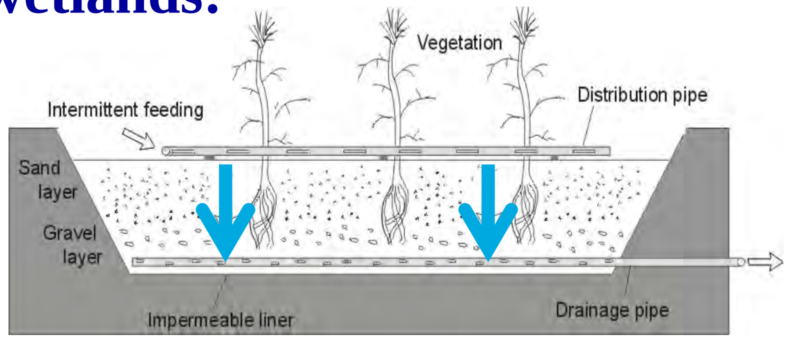
Constructed Wetlands (CWs) or wetland treatment systems

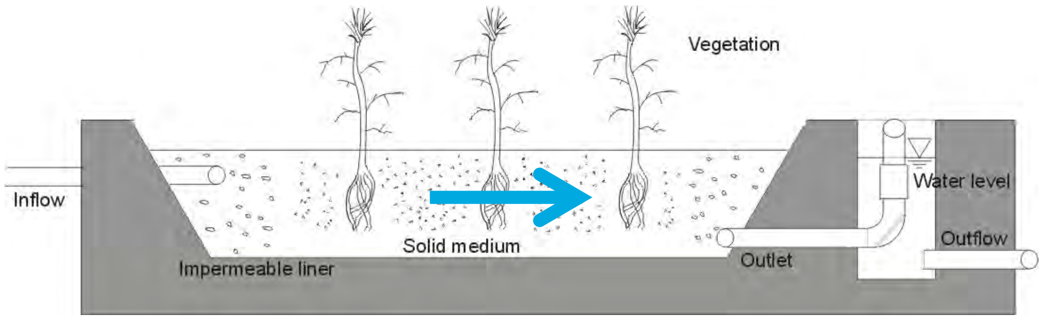
- designed to improve water quality
- use the same processes that occur in natural wetlands but have the flexibility of being constructed
- effective in treating organic matter, nitrogen, phosphorus, and additionally for decreasing the concentrations of heavy metals, organic chemicals, and pathogens

CW2D : aerobic and anoxic processes for organic matter, nitrogen and phosphorus

CWM1: aerobic, anoxic and anaerobic processes for organic matter, nitrogen and sulphur

Subsurface Vertical (CW2D) and Horizontal (CWM1) flow constructed wetlands:



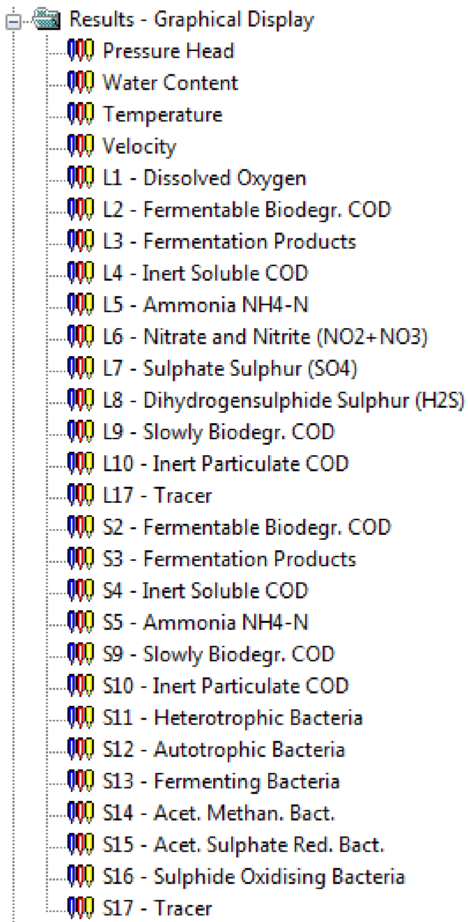


Wetland Modules: Components

CW2D : aerobic and anoxic processes for organic matter, nitrogen and phosphorus
CWM1: aerobic, anoxic and anaerobic processes for organic matter, nitrogen and sulphur

Components:

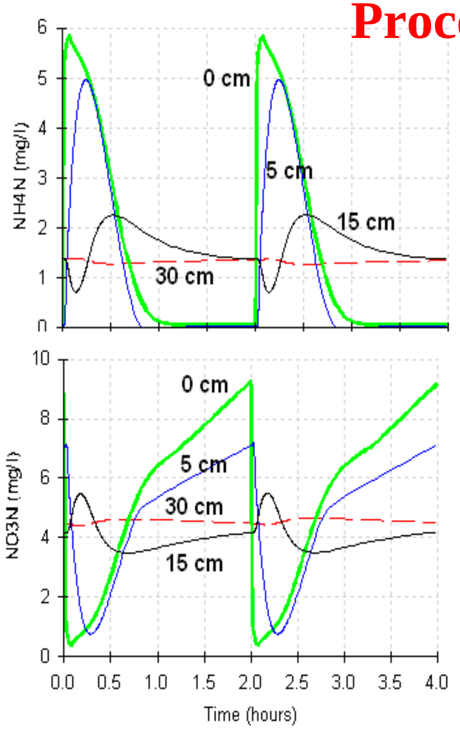
CW2D (Langergraber and Šimůnek, 2005)	CWM1 (Langergraber et al., 2009b)
Organic matter, nitrogen, phosphorus	**Organic matter, nitrogen, sulphur**
CW2D components	**Soluble components**
1. **SO**: *Dissolved oxygen, O2.*	1. **SO**: *Dissolved oxygen, O2.*
2. **CR**: *Readily biodegradable soluble COD.*	2. **SF**: *Fermentable, readily biodegradable soluble COD.*
3. **CS**: *Slowly biodegradable soluble COD.*	3. **SA**: *Fermentation products as acetate.*
4. **CI**: *Inert soluble COD.*	4. **SI**: *Inert soluble COD.*
5. **XH**: *Heterotrophic bacteria*	5. **SNH**: *Ammonium and ammonia nitrogen.*
6. **XANs**: *Autotrophic ammonia oxidizing bacteria (Nitrosomonas spp.)*	6. **SNO**: *Nitrate and nitrite nitrogen.*
7. **XANb**: *Autotrophic nitrite oxidizing bacteria (Nitrobacter spp.)*	7. **SSO4**: *Sulphate sulphur.*
8. **NH4N**: *Ammonium and ammonia nitrogen.*	8. **SH2S**: *Dihydrogensulphide sulphur.*
9. **NO2N**: *Nitrite nitrogen.*	**Particulate components**
10. **NO3N**: *Nitrate nitrogen.*	9. **XS**: *Slowly biodegradable particulate COD.*
11. **N2**: *Elemental nitrogen.*	10. **XI**: *Inert particulate COD.*
12. **PO4P**: *Phosphate phosphorus*	11. **XH**: *Heterotrophic bacteria.*
	12. **XA**: *Autotrophic nitrifying bacteria.*
	13. **XFB**: *Fermenting bacteria.*
Organic nitrogen and organic phosphorus are modeled as part of the COD.	14. **XAMB**: *Acetotrophic methanogenic bacteria.*
Nitrification is modeled as a two-step process.	15. **XASRB**: *Acetotrophic sulphate reducing bacteria.*
Bacteria are assumed to be immobile.	16. **XSOB**: *Sulphide oxidizing bacteria.*
It is generally assumed that all components except bacteria are soluble.	Organic nitrogen and organic phosphorus are modeled as part of the COD.



Langergraber, G., and J. Šimůnek, The Multi-component Reactive Transport Module CW2D for Constructed Wetlands for the HYDRUS Software Package, Manual – Version 1.0, *HYDRUS Software Series 2*, Department of Environmental Sciences, University of California Riverside, Riverside, CA, 72 pp., 2006.

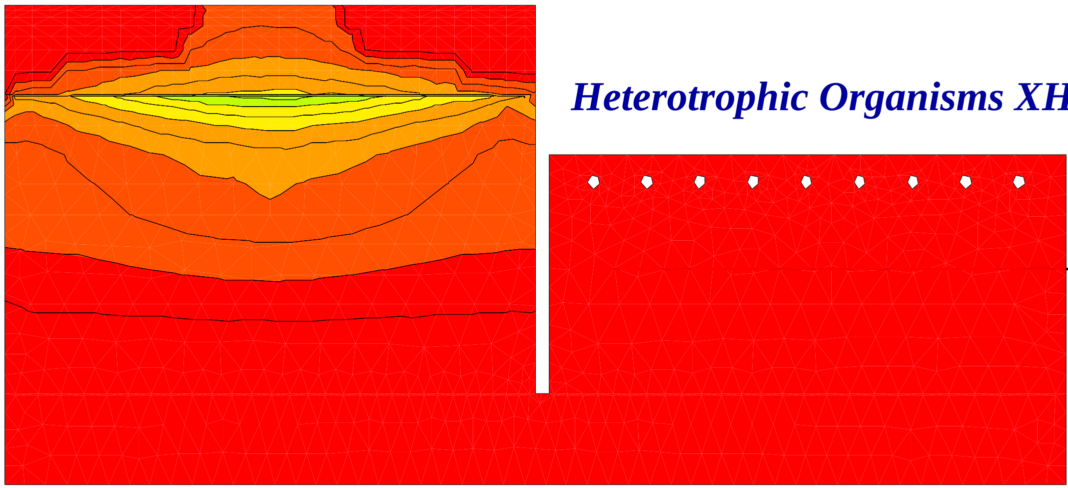
Langergraber, G., D. Rousseau, J. Garcia, and J. Mean, CWM1 - A general model to describe biokinetic processes in subsurface flow constructed wetlands, *Water Science Technology*, 59(9), 1687-1697, 2009.

Wetland Modules: Processes

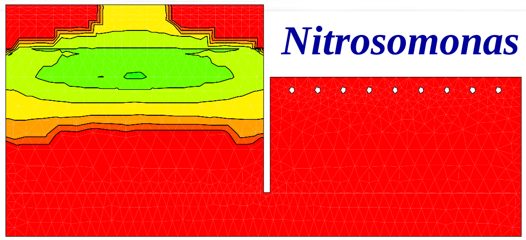


Processes:

CW2D (Langergraber and Šimůnek, 2005)	**CWM1** (Langergraber et al., 2009b)
Heterotrophic bacteria: 1. *Hydrolysis:* conversion of CS into CR. 2. *Aerobic growth of XH on CR* (mineralization of organic matter). 3. *Anoxic growth of XH on CR* (denitrification on NO2N). 4. *Anoxic growth of XH on CR* (denitrification on NO3N). 5. *Lysis of XH*. *Autotrophic bacteria:* 6. *Aerobic growth of XANs on SNH* (ammonium oxidation). 7. *Lysis of XANs*. 8. *Aerobic growth of XANb on SNH* (nitrite oxidation). 9. *Lysis of XANb*.	*Heterotrophic bacteria:* 1. *Hydrolysis*: conversion of XS into SF. 2. *Aerobic growth of XH on SF* (mineralization of organic matter). 3. *Aerobic growth of XH on SA* (mineralization of organic matter). 4. *Anoxic growth of XH on SF* (denitrification). 5. *Anoxic growth of XH on SA* (denitrification). 6. *Lysis of XH*. *Autotrophic bacteria:* 7. Aerobic growth of XA on SNH (nitrification). 8. Lysis of XA. *Fermenting bacteria:* 9. Growth of XFB (fermentation). 10. Lysis of XFB. *Acetotrophic methanogenic bacteria:* 11. Growth of XAMB: Anaerobic growth of acetotrophic, methanogenic bacteria XAMB on acetate SA. 12. Lysis of XAMB. *Acetotrophic sulphate reducing bacteria:* 13. Growth of XASRB: Anaerobic growth of acetotrophic, sulphate reducing bacteria. 14. Lysis of XASRB. *Sulphide oxidizing bacteria:* 15. Aerobic growth of XSOB on SH2S: The opposite process to process 13, the oxidation of SH2S to SSO4. 16. Anoxic growth of XSOB on SH2S: Similar to process 15 but under anoxic conditions. 17. Lysis of XSOB.



Heterotrophic Organisms XH

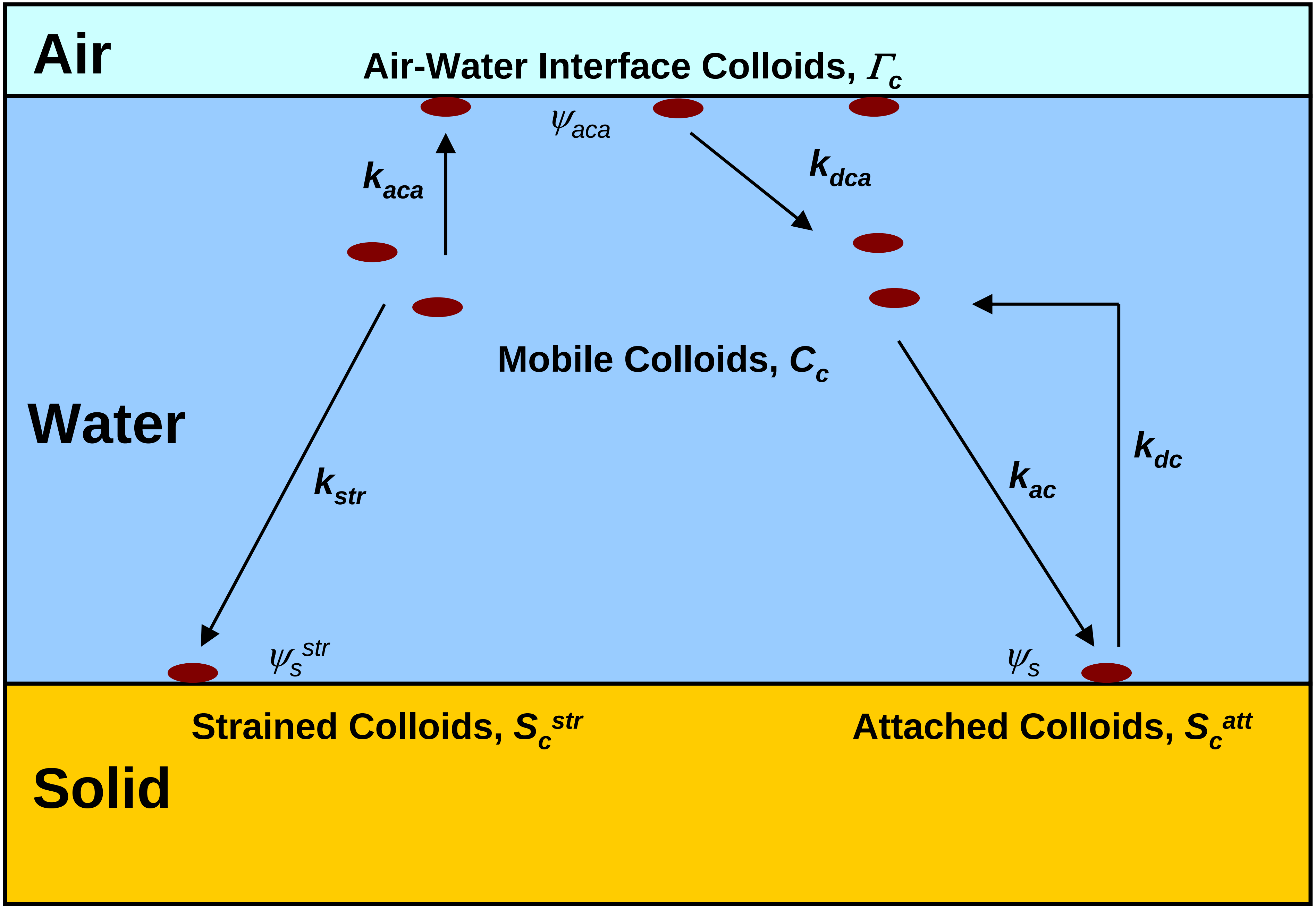


Nitrosomonas XANs

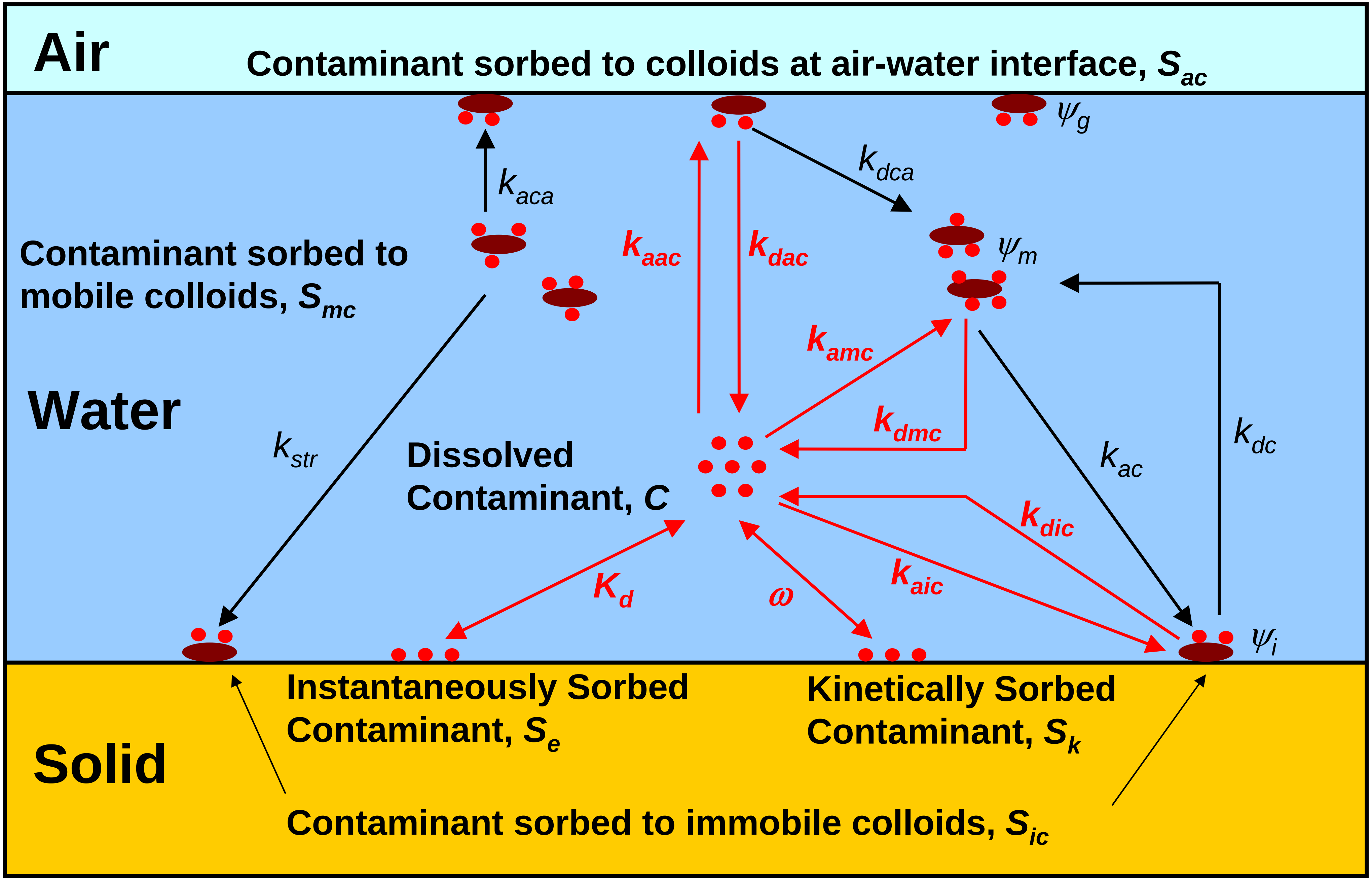
HYDRUS + C-Hitch

- **HYDRUS and HYDRUS (2D/3D)**
  - variably saturated water flow
  - heat transport
  - root water uptake
  - solute transport
- **C-Hitch** (Šimůnek et al., 2006)
  - Particle Transport
    - colloids, bacteria, viruses, nanoparticles
    - attachment/detachment, straining, blocking
  - Colloid-Facilitated Solute Transport
    - transport of solutes attached to particles

Colloid, Virus, and Bacteria Transport

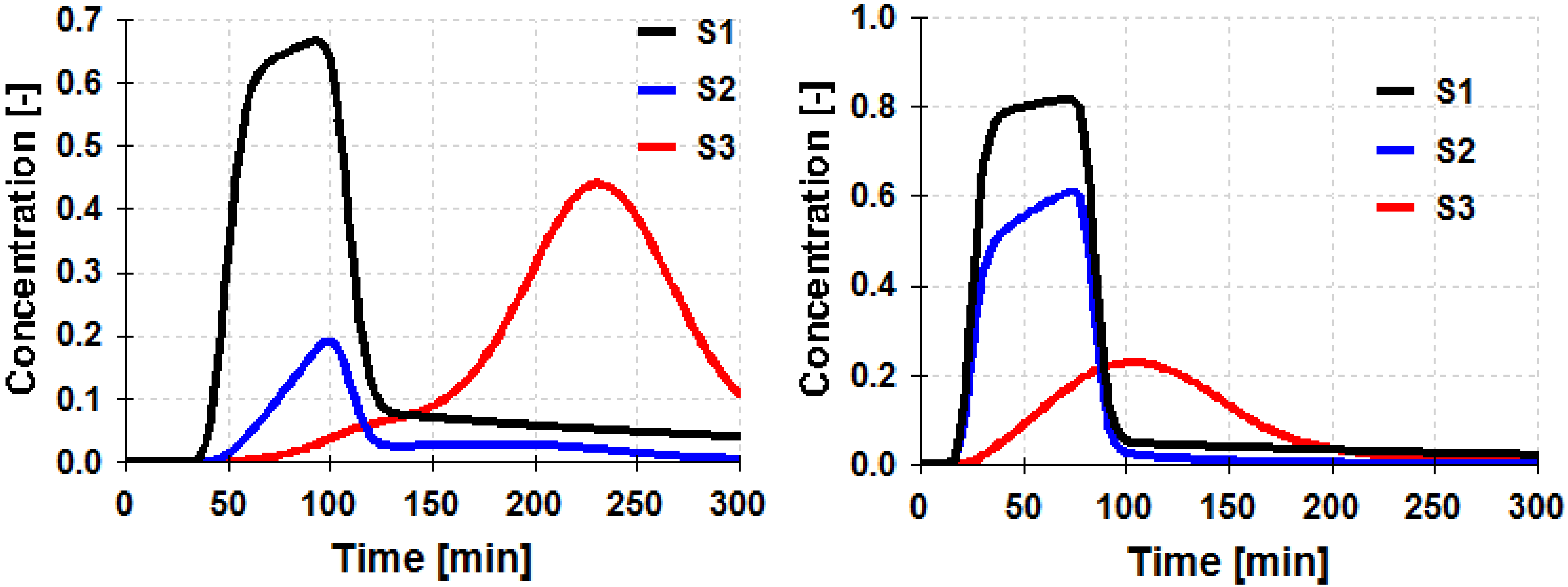


Colloid-Facilitated Solute Transport



Colloid-Facilitated Solute Transport

C-Hitch Module



Breakthrough curves for colloids (black line), solute sorbed to colloids (blue line), and solute (red line) when:

Left: solute and colloids are applied independently or

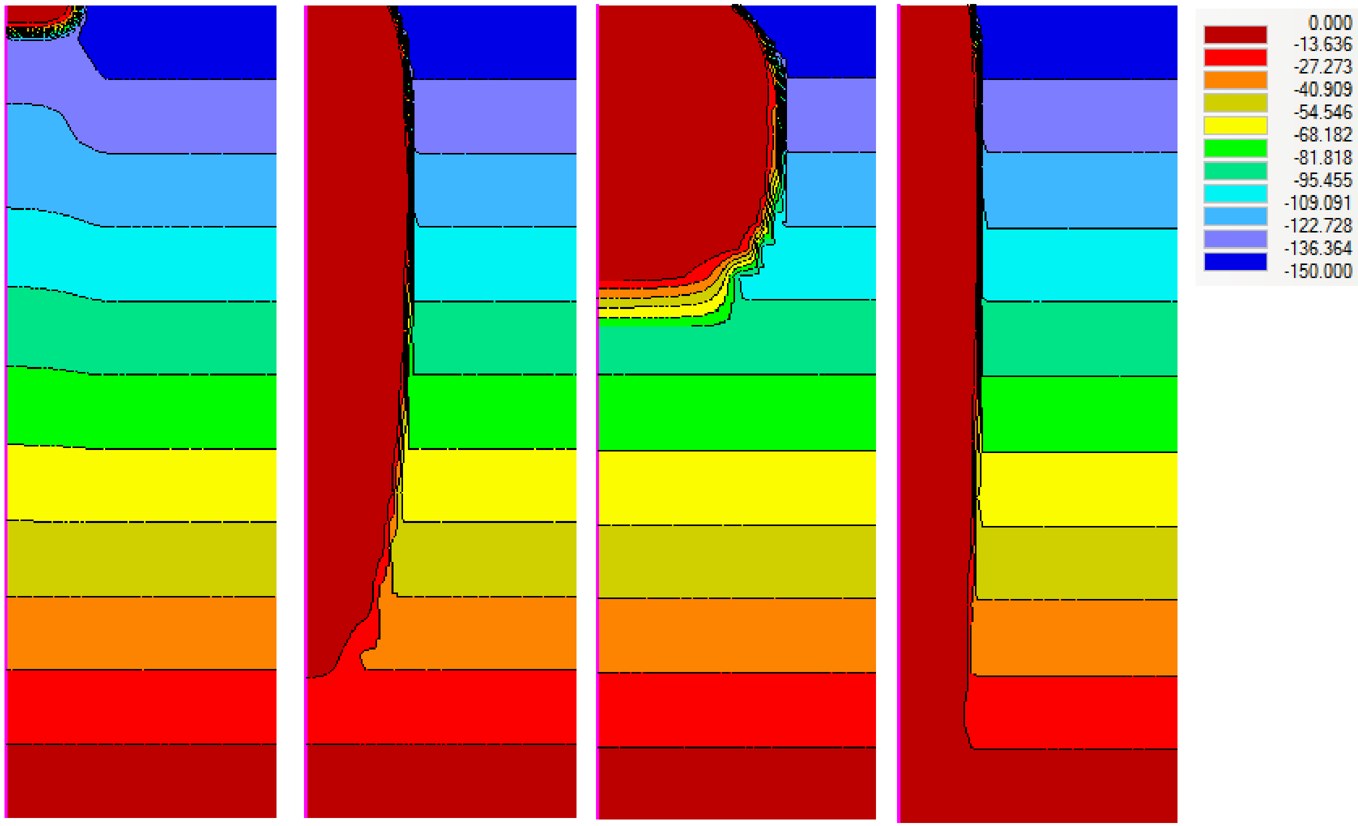
Right: solute is attached initially to colloids

The retardation factor for colloids is equal to 1 and for solute to 4

Unit input concentrations.

The DualPerm Module

Water flow and Solute Transport in Dual-Permeability Variably-Saturated Porous Media



Pressure head profiles for the matrix (left), isotropic fracture, and fracture with K_x^A/K_z^A=10, and fracture with K_x^A/K_z^A=0.1 (right).

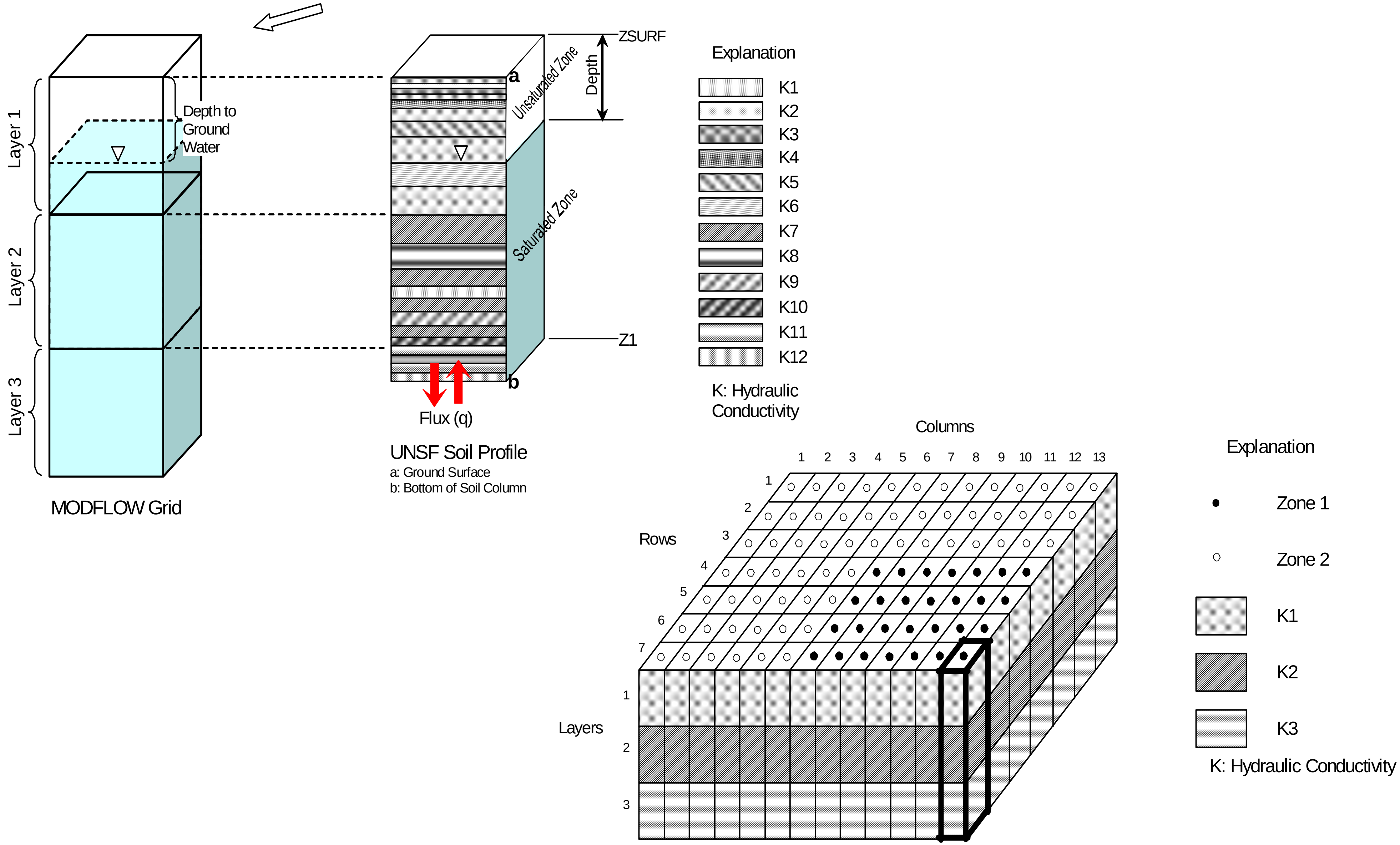
The HYDRUS Package for Modflow-2000

Hyeyoung Sophia Seo, Navin Twarakavi,
Jirka Šimůnek, and Eileen P. Poeter

Seo, H. S., J. Šimůnek, and E. P. Poeter, Documentation of the HYDRUS Package for MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model, *GWMI 2007-01*, International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado, 96 pp., 2007.

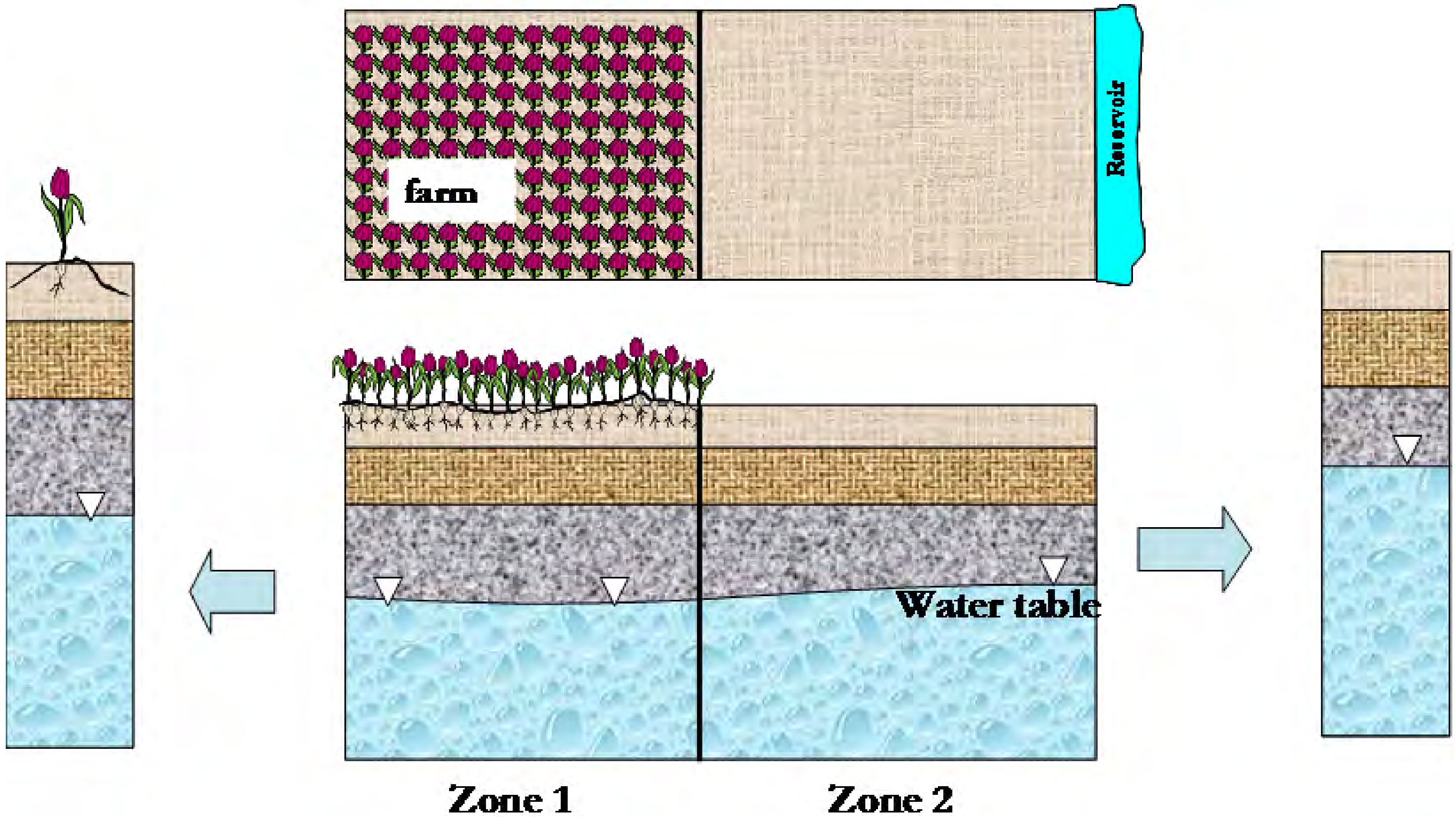
Twarakavi, N. K. C., J. Šimůnek, and H. S. Seo, Evaluating interactions between groundwater and vadose zone using HYDRUS-based flow package for MODFLOW, *Vadose Zone Journal*, doi:10.2136/VZJ2007.0082, Special Issue "Vadose Zone Modeling", *7*(2), 757-768, 2008.

HYDRUS Package for MODFLOW



HYDRUS Package: Zoning

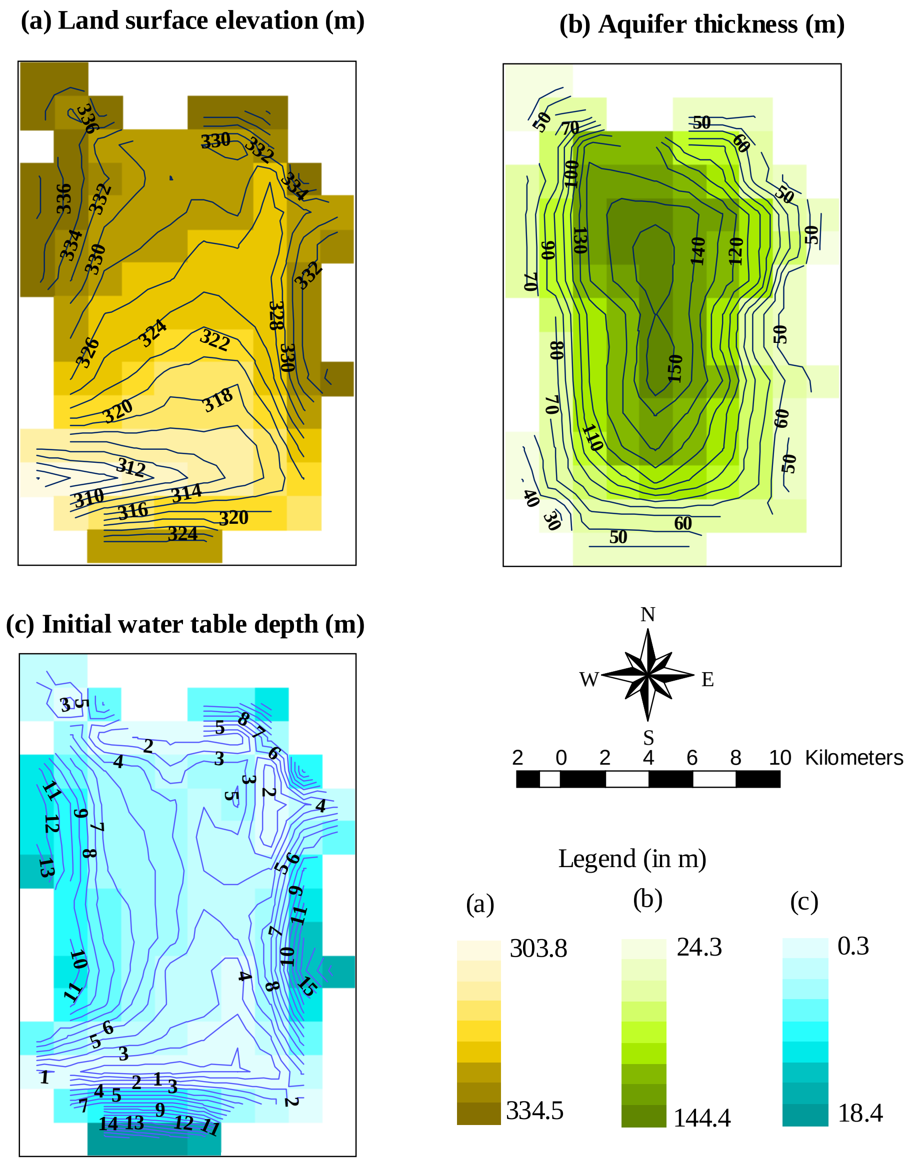
MODFLOW model domain is divided into zones based on similarities in soil hydraulic characteristics, hydrogeology and meteorology.
A HYDRUS vertical profile is assigned to each of the zones, in which the 1D Richards equation is solved.



HYDRUS - MODFLOW - Case Study

Hypothetical regional-scale ground water flow problem:

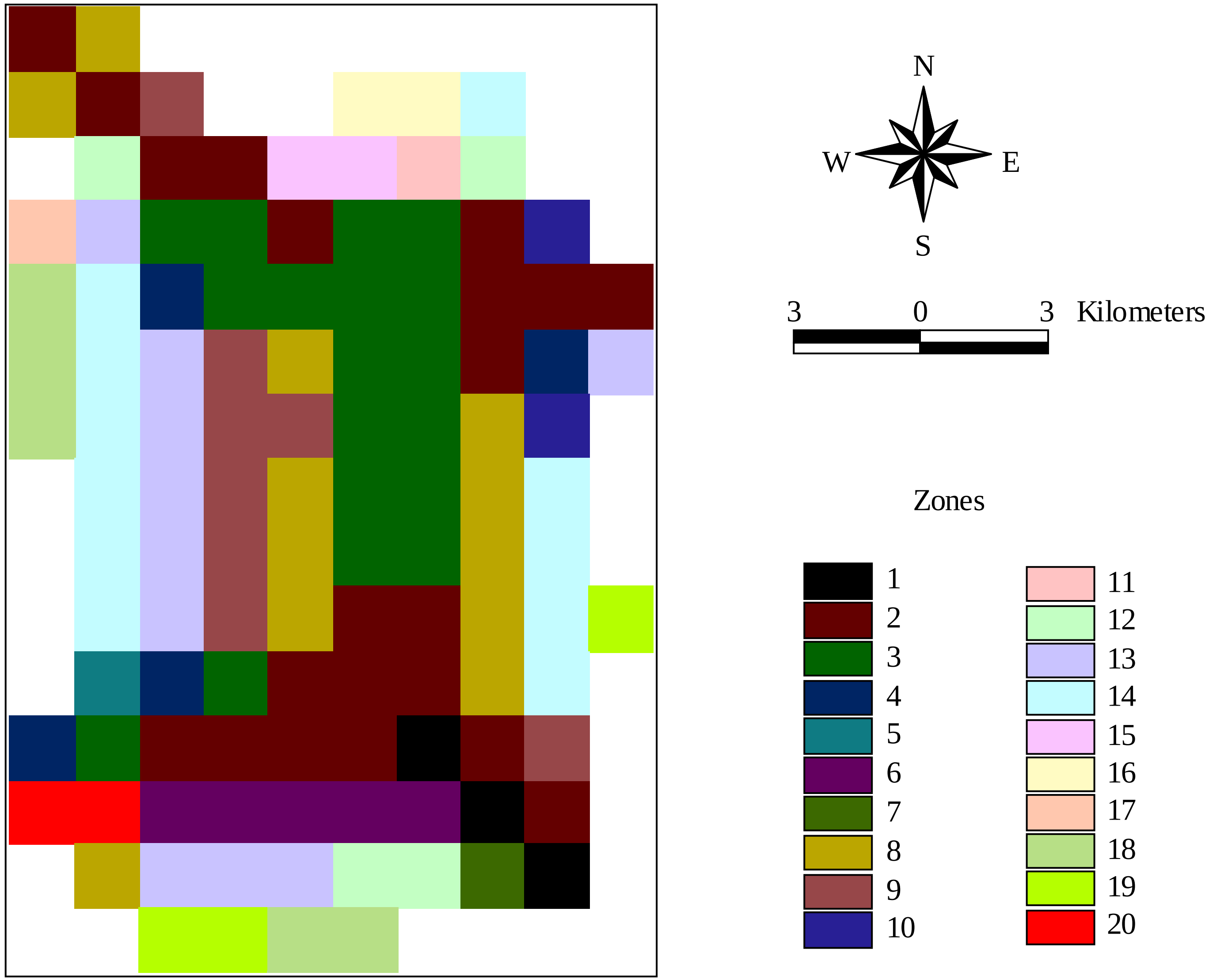
a) Land surface elevation
b) depth to bedrock
c) water table depth at the beginning of the simulation



HYDRUS - MODFLOW - Case Study

Hypothetical regional-scale ground water flow problem:

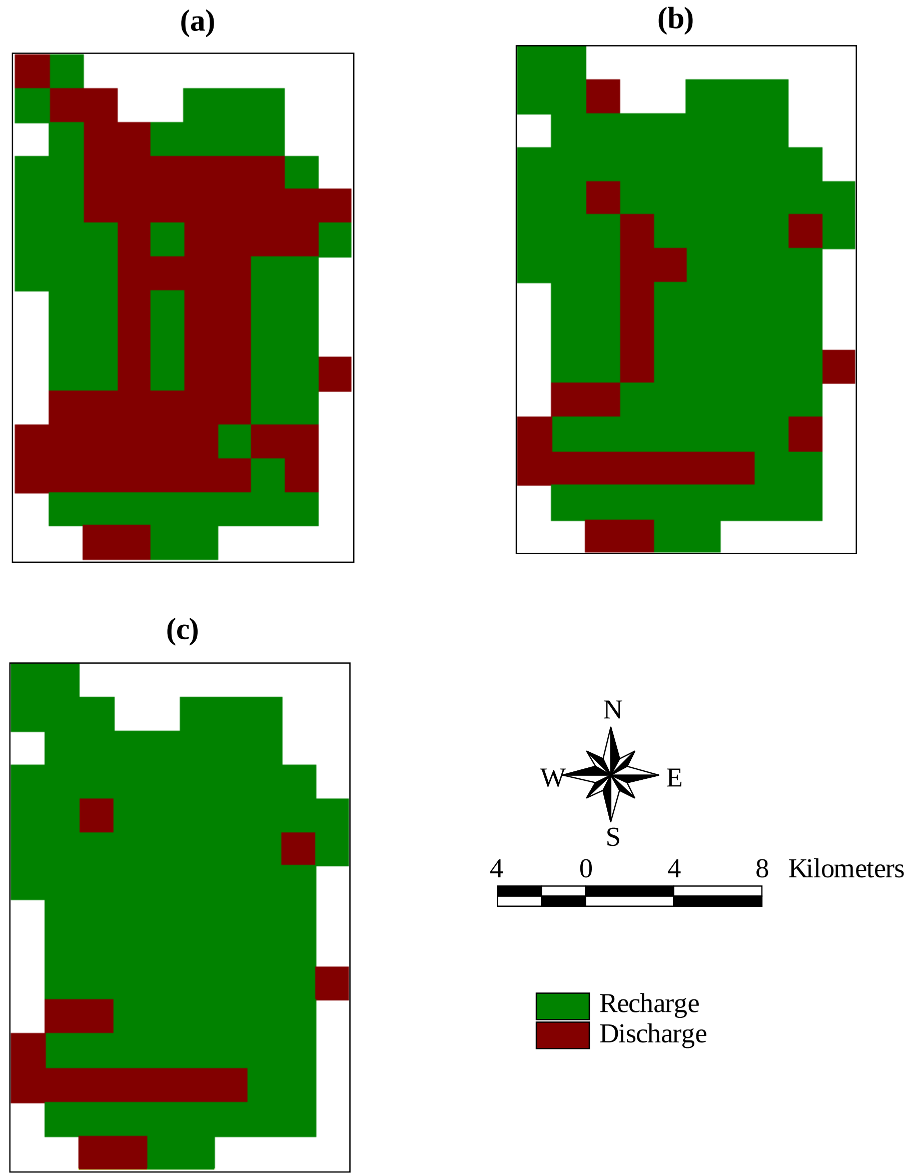
MODFLOW zones used to define HYDRUS soil profiles



HYDRUS - MODFLOW - Case Study

Hypothetical regional-scale ground water flow problem:

Ground water table fluxes (recharge vs discharge) as predicted by the HYDRUS package at the end of stress periods (a) 3, (b) 6 and (c) 12.



HYDRUS - Existing Applications

Agricultural:

- **Irrigation management** (Bristow et al., 2002; Dabach et al., 2011)
- **Drip irrigation design** (Bristow et al., 2002; Kandelous et al., 2010, 2011)
- **Sprinkler irrigation design** (Hansen et al., 2007, 2008)
- **Tile drainage design and performance** (Mohanty et al., 1998, do Vos et al., 2000)
- **Studies of root and crop growth** (Vrugt et al., 2001, 2002; Šimůnek and Hopmans, 2010)
- **Salinization and reclamation processes** (Šimůnek and Suarez, 1998; Goncalves et al., 2006; Ramos et al., 2011)
- **Nitrogen dynamics and leaching** (Ventrella et al., 2001; Jacques et al., 2002)
- **Transport of pesticides and degradation products** (Wang et al., 1998; Pot et al., 2005; Köhne et al., 2010)
- **Non-point source pollution**
- **Seasonal simulation of water flow and plant response**
- . . .

HYDRUS - Existing Applications

Non-Agricultural:

- **Leaching from radioactive waste sites at the Nevada test Site** (DRI, DOE)
- **Flow around nuclear subsidence craters at the Nevada test site** (Pohll et al., 1996; Wilson et al., 2000)
- **Capillary barrier at Texas low-level radioactive waste disposal site** (Scanlon, 1998)
- **Evaluation of approximate analytical analysis of capillary barriers** (Morris and Stormont, 1997; Kampf and Montenegro, 1997; Heiberger, 1998)
- **Landfill covers with and without vegetation** (Abbaspour et al, 1997; Albright, 1997; Gee et al., 1999, Scanlon et al., 2002)
- **Risk analysis of contaminant plumes from landfills**
- **Seepage of wastewater from land treatment systems**
- **Tunnel design - flow around buried objects** (Knight, 1999)
- **Highway design - road construction - seepage** (de Haan, 2002; Hanssen et al., 2005)
- **Stochastic analyses of solute transport in heterogeneous media** (Tseng and Jury, 1993; Roth, 1995; Roth and Hammel, 1996; Kasteel et al. 1999; Hammel et al., 1999; Roth et al., 1999; Vanderborght et al., 1998, 1999)
- **Lake basin recharge analysis** (Lee, 2000)

HYDRUS - Existing Applications

Non-Agricultural:

- **Stream-aquifer interactions**
- **Environmental impact of the drawdown of shallow water tables**
- **Analysis of cone permeameter and tension infiltrometer experiments** (Gribb et al., 1996; Kodešová et al., 1998, 1999; Šimůnek et al., 1997, 1998, 1999)
- **Virus and bacteria transport** (Shijven and Šimůnek, 2002; Bradford et al., 2002a,b; Yates et al., 2000; Gargiulo et al., 2007, 2008)
- **Hill-slope analyses** (Hopps et al., 2010)
- **Transport of TCE and its degradation products** (Scharlaekens et al., 2000; Casey and Šimůnek, 2002)
- **Multicomponent geochemical transport** (Jacques and Šimůnek, 2002, 2008, 2011)
- **Analyses of riparian systems** (Whitaker, 2000)
- **Fluid flow and chemical migration within the capillary fringe** (Silliman et al., 2002)
- **Flow in historical monuments** (Ishizaki et al., 2001)
- **Flow and transport around land mines** (Das et al., 2001; Šimůnek et al., 2001)
- **Analyses of Chloride profiles in deep vadose zones to evaluate historical fluxes** (Scanlon et al., 2003)

HYDRUS Web Site

Over 3 thousand downloads in 2008, and over 5 thousand downloads in both 2009 and 2010; over 10 thousand registered members.

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News
Programs
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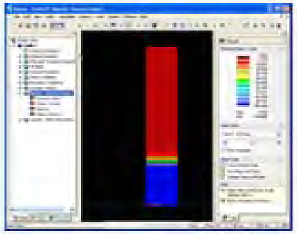
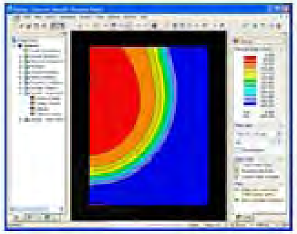
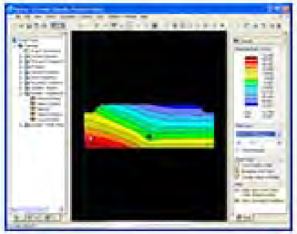
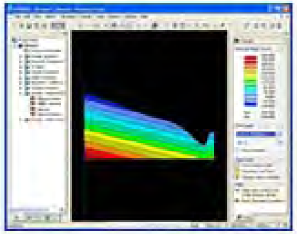
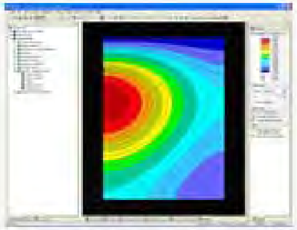
Two-Dimensional Examples



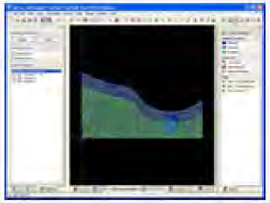






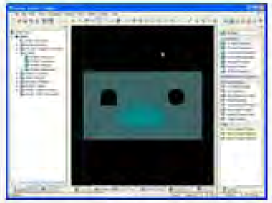


Domain Design and FE-Mesh generation



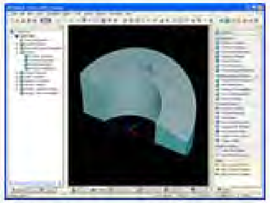
2.01 - 2D Domain composed of three irregular regions
Video (1.2 MB) - Play - Download

This demo demonstrates how to use multiple surfaces to define a single transport domain, and how these **multiple surfaces** can be used to assign various domain properties (e.g., materials).



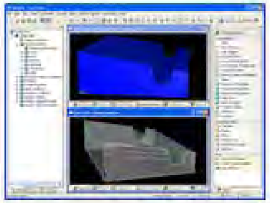
2.02 - 2D Domain with holes and integrated subregion
Video (1.2 MB) - Play - Download

This demo demonstrates how to design a complex two-dimensional transport domain that includes two holes and an **internal surface**. The transport domain is then discretized using a **refined FE-Mesh** inside of the internal surface.



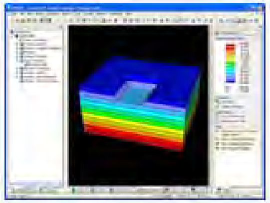
2.03 - 3D Domain, Solid 1 - three video tutorials
Open tutorial

This series of three demos shows how users can create a transport domain shown on the picture. The demonstration is divided into three parts. First, the main transport domain is defined, then a vertical hole is created in the domain, after which the heights are adjusted.



2.04 - 3D Domain, Solid 2 - three video tutorials
Open tutorial

This series of three demos shows users how to create a **transport domain** shown on the picture and to discretize it into finite elements. We first create the transport domain, then add lines at the surface that will help us to discretize the transport domain into finite elements in the next step, after which we implement the finite element discretization.

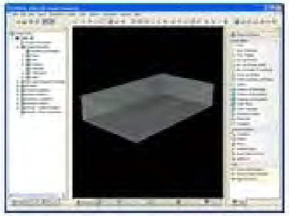


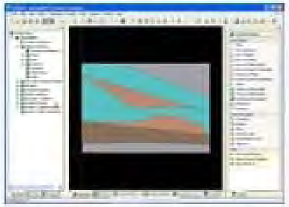
2.05 - 3D Domain, Solid 3 - three video tutorials
Open tutorial

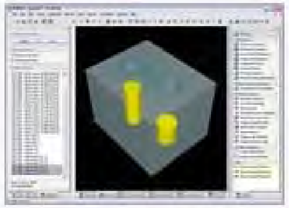
This series of three demos shows users how to create a **transport domain** in the picture, to discretize the domain into finite elements, to create sections, and to specify initial and boundary conditions.

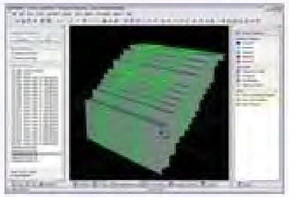
2.06 - 3D Domain, Solid 4 - splitting a Solid into Sub-Layers and Columns
Video (5.3 MB) - Play - Download

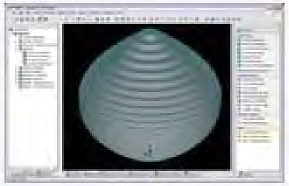
This demo shows how to design a **complex** three-dimensional **transport domain** (which includes horizontal pipes). The transport domain is divided into four **sub-layers** (one with variable thickness). Additional **FE-Mesh sections** are generated as intersections of sub-layers and vertical columns. The use

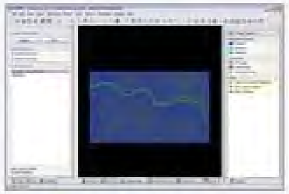












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	Topic	Author	Replies	Read	Last Post	
	boundary conditions	rkv_19	3	374	07/12/2008 00:43:51 by: Jirka	
	nonequilibrium	Srilert	1	229	07/04/2008 14:15:33 by: Jirka	
	Effect of crop data on model convergence	swyman	2	285	06/28/2008 23:58:44 by: Jirka	
	Convergence on high precipitation events	swyman	5	395	06/28/2008 20:36:08 by: swyman	
	transport in porous media	Belkis	3	278	06/26/2008 11:27:38 by: Jirka	
	infiltration with variable bc	kushner	3	865	06/18/2008 14:23:37 by: Jirka	
	where is the output info for all my time points?	jm322	1	231	06/18/2008 14:18:12 by: Jirka	
	time variable boundary condition input data	jm322	6	452	06/18/2008 00:52:13 by: jm322	
	LAI/ground cover	Luca	1	285	06/12/2008 16:31:51 by: Jirka	
	dual-permeability	chrisn	1	235	06/12/2008 16:31:02 by: Jirka	
	HYDRUS-MODFLOW	Srilert	1	825	06/09/2008 17:58:47 by: Jirka	
	Summary - evapotranspiration	ChrisD	9	636	05/29/2008 09:18:15 by: Irina Prinz-Tran	
	Hargreaves PET calculations & specified Ra	John	3	336	05/26/2008 21:54:08 by: Jirka	
	Surface ponding and evaporation	ChrisD	1	305	05/19/2008 20:44:26 by: Jirka	
	Saturated vs. Unsaturated	Isabella	1	449	05/14/2008 22:54:11 by: Jirka	

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HYDRUS Web Site: References

HYDRUS References

See also HYDRUS-1D selected references

Outside reviews of the HYDRUS software packages

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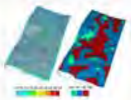
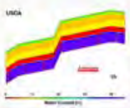
- McCray, J., HYDRUS – Software Review, Southwest Hydrology, 6(1), 41, 2007.
- Tyler, S. 2004. "Review of HYDRUS-2D." Southwest Hydrology, 3(6):37.
- Scanlon, B. 2004. "Review of HYDRUS-1D." Southwest Hydrology, 3(4):37.
- MDH Engineered Solutions. 2003. Evaluation of Computer Models for Predicting the Fate and Transport of Salt in Soil and Groundwater, Phase I Report. Pub. No: T/403
ISBN No. 0-7785-2493-0 (Printed Edition), ISBN No. 0-7785-2494-9 (On-line Edition).
- Diodato, D. M. 2000. "Software Spotlight (Review of HYDRUS-2D)". Ground Water, 38(1), 10-11.

Customer Projects

Dear HYDRUS users, we would like to encourage you to publish here your projects.



Virtual Experiments to Explore Non-Linear Soil Moisture-Hydrology Interactions at the Hillslope Scale
L. Hopp and J.J. McDonnell Department of Forest Engineering, Oregon State University, Corvallis, USA
Abstract Hopp_AGU07_abstract.pdf (19 kB), Read more about the project Hopp_AGU07.pdf (4.4 MB)



Dynamics of Water Flow in Putting Greens via Computer Simulation
McCoy, Ed. and Kevin McCoy, , USGA Turfgrass and Environmental Research Online 5(17):1-15, 2006.
Read more about the project TurfGrass-2006.pdf (636 kB)

Have we missed your work? Please, let us know. HYDRUS team.

HYDRUS Workshops Proceedings

- Proceedings of the First HYDRUS Workshop, October 19, 2005, S. Torkzaban and S. M. Hassanizadeh (eds.), Department of Earth Sciences, Utrecht University, The Netherlands, ISBN 90-39341125, **PDF document, size 4MB**.
- Proceedings of the Second HYDRUS Workshop, March 28, 2008, J. Šimůnek and R. Kodešová (eds.) (eds.), Dept. of Soil Science and Geology, Czech University of Life Sciences, Prague, Czech Republic, ISBN 978-80-213-1783-3, **PDF document, size 3.3MB**.
- Proceedings of the Third HYDRUS Workshop, June 28, 2008, Saito, H., M. Sakai, N. Toride, and J. Šimůnek (eds.), Dept. of Ecoregion Science, Tokyo University of Agriculture & Technology, Fuchu Tokyo, Japan, ISBN 978-4-9901192-5-6, **PDF document, size 7.2MB**.

HYDRUS 2D/3D Selected References

Including Hydrus-2D & Meshgen References (former version of HYDRUS 2D-Standard)
(Notice that HYDRUS-2D is an update of both SWMS-2D and CHAIN-2D)

2009

1. Lü, H., Y. Zhu, T. H. Skaggs, and Z. Yu, Comparison of measured and simulated water storage in dryland terraces of the Loess Plateau, China, Agricultural Water Management, 96(2), 299-306, 2009.
2. McCoy, E. L., and K.R. McCoy, Simulation of putting-green soil water dynamics: Implications for turfgrass water use, Agricultural Wate Management, 2008.

2008

1. Akay, O., G. A. Fox, and J. Šimůnek, Numerical simulation of water flow during macropore/subsurface drain interaction using HYDRUS, Vadose Zone Journal, 7(3), 909-918, 2008.
2. Beal, C. D., D. W. Rassam, E. A. Gardner, G. Kirchhof, and N. W. Menzies, Influence of hydraulic loading and effluent flux on surface surcharging in soil absorption systems, Journal of Hydrologic Engineering, 13(8), 681-692, 2008.
3. Crevoisier, D., Z. Popova, J. C. Mailhol, and P. Ruelle, Assessment and simulation of water and nitrogen transfer under furrow irrigation, Agricultural Water Management, 95(4), 354-366, 2008.
4. De Silva, M.S., M. H. Nachabe, J. Šimůnek, and R. Carnahan, Simulating root water uptake from a heterogeneous vegetative cover, J. Irrig. Drain. Engin.-ASCE, 134(2), 167-174, DOI: 10.1061/(ASCE)0733-9437(2008)134:2(167), 2008.
5. Dudley, L. M., A. Ben-Gal, N. Lazarovitch, Drainage Water Reuse: Biological, Physical, and Technological Considerations for System Management, J. Environ. Qual., 37, S-25–S-35, 2008.
6. Hanson, B. R., J. Šimůnek, and J. W. Hopmans, Leaching with subsurface drip irrigation under saline, shallow ground water conditions, Vadose Zone Journal, doi:10.2136/VZJ2007.0053, Special Issue "Vadose Zone Modeling", 7(2), 810-818, 2008.
7. Hassan, G., R. B. Reneau, Jr., C. Hagedorn, and A. R. Jantrania, Modeling effluent distribution and nitrate transport through an on-sit wastewater system, J. Environ. Quality, 37, 1937-1948, 2008.
8. Heinse, R., S. B. Jones, S. L. Steinberg, M. Tuller, and D. Or, Measurements and modeling of variable gravity effects on water distribution and flow in unsaturated porous media, Vadose Zone J., 6(2), 713–724, 2008.
9. Iversen, B. V., and P. van der Keur, and H. Vosgerau, Hydrogeological Relationships of Sandy Deposits: Modeling of Two-Dimensional Unsaturated Water and Pesticide Transport, J. Environ. Qual., 37, 1909–1917, 2008.
10. Patel, N. and T. B. S. Rajput, Dynamics and modeling of soil water under subsurface drip irrigated onion, Agricultural Water Management, 95(12), 1335-1349, 2008.
11. Roberts, T. L., S. A. White, A. W. Warrick, and T. L. Thompson, Tape depth and germination method influence patterns of salt accumulation with subsurface drip irrigation, Agricultural Water Management, 95(6), 669-677, 2008.
12. Saintenoy, A., S. Schneider, and P. Tucholka, Evaluating Ground Penetrating Radar Use for Water Infi ltration Monitoring, doi:10.2136/vzj2007.0132, Vadose Zone J., 7, 208–214, 2008.
13. Sansoulet, J., Y.-M. Cabidoche, P. Cattan, S. Ruy, and J. Šimůnek, Spatially distributed water fluxes in an Andisol under banana plants: experiments and 3D modelling, Vadose Zone Journal, doi:10.2136/VZJ2007.0073, Special Issue "Vadose Zone Modeling", 7 (2), 819-829, 2008.
14. Segal, E., S. A. Bradford, P. Shouse, N. Lazarovitch, and D. Corwin, Integration of hard and soft data to characterize field-scale hydraulic properties for flow and transport studies, Vadose Zone J., 7, 878-889, 2008.
15. Segal, E., T. Kushnir, Y. Mualem, and U. Shani, Water uptake and hydraulics of the root hair rhizosphere, Vadose Zone J., 7, 1027-1034, 2008.

2007

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Group	Description	Availability
Direct	Basic Direct Problem Examples	Installed with the software
Inverse	Basic Inverse Problem Examples	Installed with the software
HP1	Examples demonstrating the HP1 program (coupled Hydrus-1D and PHREEQC)	Installed with the software
UNSATCH	Examples demonstrating Unsatchem Module (major ion chemistry and carbon dioxide transport modules)	Installed with the software
Fracture	Examples with Dual-Permeability Model and other nonequilibrium models, with emphasis on water flow	Download now (3.9 MB)
VZJ	Examples from Šimůnek and van Genuchten (2008) with emphasis on nonequilbrium solute transport. *For more details see the article published in the VZJ Special Issue on Vadose Zone Modeling* (2MB)	Download now (5.4 MB)
Meteo	Examples demonstrating new options for atmospheric boundary conditions	Download now (0.8 MB)
Atmosph	Examples demonstrating atmospheric boundary conditions with surface ponding or surface runoff	Download now (0.4 MB)
Dual_Atm	An example demonstrating the use of the dual-permeability model with the atmospheric boundary condition with surface ponding or surface runoff. Download brief description now	Download now (0.3 MB)
CXTFIT	An example demonstrating a comparison of calculations carried out using either CXTFIT or HYDRUS programs. Download brief description now	Download now (0.04 MB)
Roots Uptake	Examples demonstrating the use of the new root water and solute uptake term (which	Download now

Public Library of HYDRUS (2D/3D) Projects

HYDRUS Projects - Drip

- **Project Group:** Drip
- **Description:** Examples involving subsurface drip irrigation; described in Hanson et al. (2006, 2008), Skaggs et al (2004), and Siyal et al. (2009).
- **Availability:** Download HYDRUS projects now (11.1 MB)

Project	Description
Sub2f1a	Subsurface drip irrigation for the B fertigation strategy (**fertigation near beginning of irrigation**). Solutes considered: **urea-ammonium-nitrate, potassium, phosphorus** (Hanson et al., 2006).
Sub2f1c	Subsurface drip irrigation for the E fertigation strategy (**fertigation near the end of irrigation**). Solutes considered: **urea-ammonium-nitrate, potassium, phosphorus** (Hanson et al., 2006).
Sub2f3	Subsurface drip irrigation for the M50 fertigation strategy (**fertigation during the middle 50% of the irrigation event**). Solutes considered: **urea-ammonium-nitrate, potassium, phosphorus** (Hanson et al., 2006).
Sub1112	Subsurface drip irrigation, water table depth of 0.5 m, 0.3 dS/m, irrigation efficiency=0.9, 7 per week (Hanson et al., 2008).
Sub1212	Subsurface drip irrigation, water table depth of 0.5 m, 1.0 dS/m, irrigation efficiency =0.9, 7 per week (Hanson et al., 2008).
Sub2111	Subsurface drip irrigation, water table depth of 1.0 m, 0.3 dS/m, irrigation efficiency =0.9, 2 per week (Hanson et al., 2008).

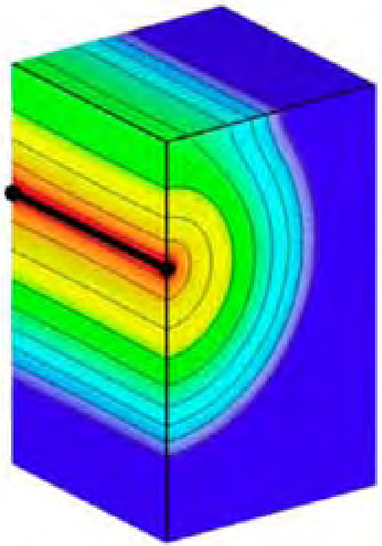
References:

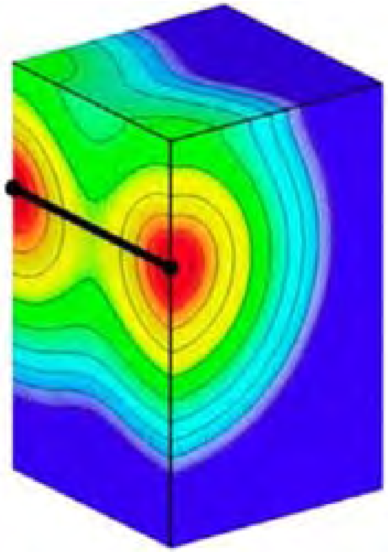
Hanson, B. R., J. Šimůnek, and J. W. Hopmans, Numerical modeling of urea-ammonium-nitrate fertigation under microirrigation, Agric. Water Management, 86, 102-113, 2006.

Hanson, B. R., J. Šimůnek, and J. W. Hopmans, Leaching with subsurface drip irrigation under saline, shallow ground water conditions, Vadose Zone Journal, doi:10.2136/VZJ2007.0053, Special Issue "Vadose Zone Modeling", 7(2), 810-818, 2008.

Skaggs, T. H., T. J. Trout, J. Šimůnek, and P. J. Shouse, Comparison of Hydrus-2D simulations of drip irrigation with experimental observations, J. of Irrigation and Drainage Engineering, 130(4), 304-310, 2004.

Siyal, A. A., M. Th. van Genuchten, and T. H. Skaggs, Performance of pitcher irrigation systems, Soil Science, 174(6), 312-320, 2009.





Short Courses

HYDRUS shortcourse: November 18 - 20, 2009, San Luis Potosí, Mexico

"Modeling Water Flow and Contaminant Transport in Soils and Groundwater Using the Hydrus Computer Software Packages"
"(Modelado del Flujo de Agua y Transporte de Contaminantes en Suelos y Agua Subterránea Usando los Paquetes de Cómputo Hydrus)"

Shortcourse instructor:
Jirka Šimůnek, Dept. of Environmental Sciences, University of California, Riverside (CA)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HYDRUS and HP1 shortcourse: September 28 - October 2, 2009, Gent, Belgium

"Simulating soil water movement and transport using the biogeochemical transport model HP1"

Belgium Nuclear Research Center, SCK.CEN, Mol, Belgium

Shortcourse instructors:
Jirka Šimůnek, Dept. of Environmental Sciences, University of California, Riverside (CA)

HYDRUS shortcourse: July 12-14, 2009, Sede Boqer Campus of the Ben-Gurion University, Israel

"Modeling water flow and contaminant transport in soils and groundwater using the HYDRUS software packages"

Albert Katz International School of Desert Studies at the Sede Boqer Campus of the Ben-Gurion University in Israel

The shortcourse instructors:
Dr. Jirka Šimůnek, Dept. of Environmental Sciences, University of California, Riverside (CA)
Dr. Naftali Lazarovitch, French Associates Institute for Agriculture and Biotechnology of Drylands, The Ben-Gurion University of the Negev, Sede Boqer Campus, Israel

The course begins with a detailed conceptual and mathematical description of water flow and solute transport processes in the vadose zone, followed by an brief overview of the use of finite element techniques for solving the governing flow and transport equations. Special attention is given to the highly nonlinear nature of the governing flow equation. Alternative methods for describing and modeling the hydraulic functions of unsaturated porous media are also described. "Hands-on" computer sessions will provide participants an opportunity to become familiar with the Windows-based HYDRUS-1D and HYDRUS (2D/3D) software packages. Emphasis will be on the preparation of input data for a variety of applications, including flow an flow through a dam, flow and transport to a tile drain, a landfill through the unsaturated zone into grour demonstrated by means of a one-dimensional inverse

HYDRUS shortcourse: March 17-19, 2009, Prague, Czech Republic

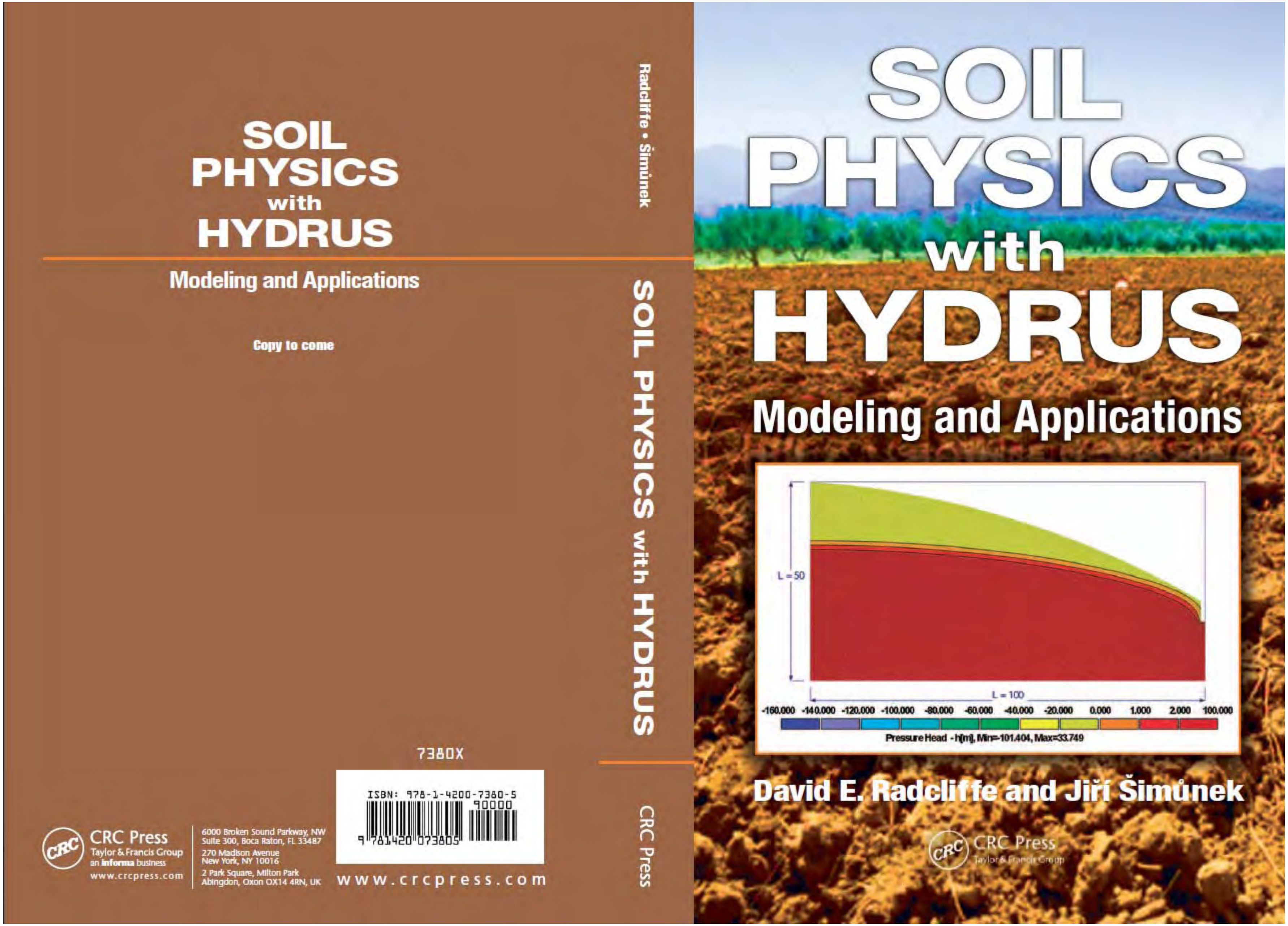
"Advanced modeling of water flow and contaminant transport in porous media using the HYDRUS software packages"

Czech University of Life Sciences, Faculty of Agrobiology, Food and Natural Resources, Prague, Czech Republic PC Progress, Ltd, Prague, Czech Republic

The shortcourse instructors:
Dr. Jirka Šimůnek, Dept. of Environmental Sciences, University of California, Riverside (CA)
Dr. Radka Kodešová, Department of Soil Science and Geology of the University of Life Sciences, Prague, Czech Republic

After a successful experience from our courses held in 2008 in Prague and Japan, we will be offering a standard two-day HYDRUS course followed by a third day, during which we will be covering selected advanced HYDRUS topics.

HYDRUS Textbook Book



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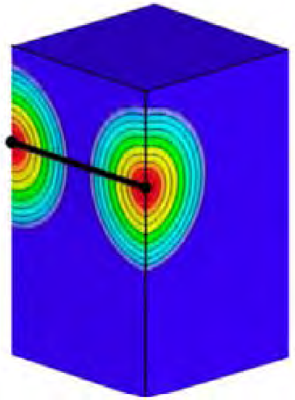

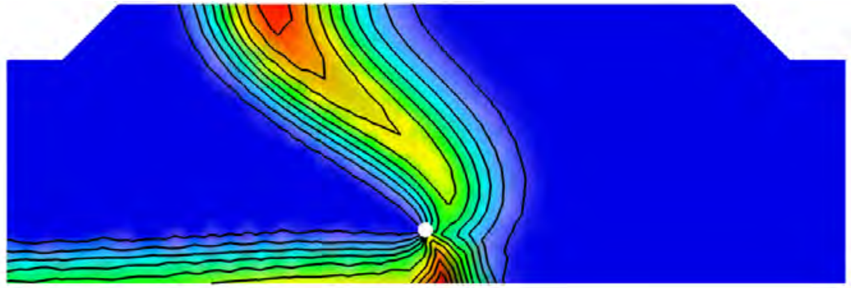

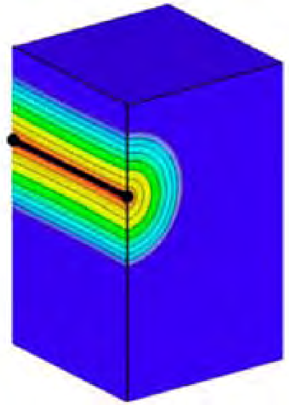

Thank you for your attention