Hydrologic Modeling of Vernal Pools to Support Restoration Design

Review of Existing Studies and Model Selection

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Overview

- Background
- Previous and Current Studies
- Model Comparison and Selection
California vernal pools
- Host to a variety of endemic flora and fauna
- More than 60% destroyed (Barbour et al., 2003)
Background
General

- Vernal pool morphology
  - Undulating micro relief
  - Inundate in the rainy season
  - Desiccate in the summer

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Hobson & Dahlgren (1998)

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Background

General

- Vernal pool conservation / restoration
  - Compensatory mitigation
  - Mitigation monitoring
    - Community composition and species richness
    - Bi-weekly water level readings
    - No pre-construction monitoring
  - But what do we know about the hydrologic regime of vernal pools? Ecological drivers?
Background
Campbell’s Butte County Site

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Previous Studies
Hanes & Stromberg (1998)

- How important are upland hydrologic contributions?
- Do constructed pools impact the hydrologic regime of natural pools?
- Conceptual upland water balance model
Previous Studies
Pyke (2002; 2004; 2005)

- What are the hydrologic variations in rain-fed vernal pools?
  - Seasonal
  - Inter-annual
  - Climate change

- Vernal pool hydrologic regime model, PHYDO

\[ V_t = V_{t-1} + D + R + \Delta S - E_{ow} - O \]
Previous Studies
Williamson et al. (2005); Rains et al. (2006)

- Refine our understanding of VP hydrology
  - Three different study sites
  - How important are upland hydrologic contributions?

- Findings
  - The hydrologic regime varies significantly
  - Perched water tables are responsible for sustaining the water level regime
Current Studies
McCarten (in progress)

- Refine our understanding of VP hydrology
  - Reoccupy Williamson et al. (2005) study sites
  - Collect a lot of field data
  - Apply HYDRUS 2D/3D
- Develop relationships between ecology and hydrology
Current Studies
Campbell (in progress)

- Refine our understanding of VP hydrology
- Inform VP habitat conservation / restoration
  - What are the potential hydrologic impacts of constructed pools on natural pools?
  - Are post-construction monitoring protocols adequate?
- Which numerical model should I use?
  - HYDRUS 3D
  - FEFLOW F3
Model Comparison

- HYDRUS 3D vs FEFLOW F3
  - Both are finite element models for simulating 2D and 3D flow (plus transport and heat) in variably saturated media by numerically solving Richards equation
Model Comparison

Finite Element Mesh

- HYDRUS
- Mesh generator
- Structured, layered
- Unstructured, layered
- Horizontal or sloping lower boundary
- Adaptive mesh and BASD

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Model Comparison
Conductivity and Retention

- **HYDRUS**
  - van Genuchten-Mualem
  - Modified van Genuchten
  - Brooks-Corey
  - Kosugi (log-normal)
  - Dual-porosity (immobile micropores)
  - Dual-permeability (micro and macropores mobile)

- **FEFLOW**
  - van Genuchten-Mualem
  - Modified van Genuchten
  - Brooks-Corey
  - Haverkamp (parametric)
  - Splines
  - Exponential
  - Linear

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Model Comparison

Hysteresis

- **HYDRUS**
  - None
  - van Genuchten-Mualem only
    - In retention curve
    - In retention curve and conductivity
    - In retention curve (no pumping)
    - Select either drying or wetting curve

- **FEFLOW**
  - None
  - In retention curve
Model Comparison
Soil Properties for Water Flow

- HYDRUS
  - Manually specify
  - Soil catalog
  - Rosetta Lite v1.1

- FEFLOW
  - Manually specify

![Rosetta Lite v. 1.1 (June 2003)](image)

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Model Comparison
Initial Conditions

- **HYDRUS**
  - Pressure head
  - Moisture content

- **FEFLOW**
  - Hydraulic head
  - Pressure head
  - Moisture content
  - Saturation
Model Comparison
Boundary Conditions

- HYDRUS
  - General
    - Transient
    - Cross constrained
  - Specific
    - Flux
    - Pressure head
    - Seepage face
    - Free drainage
  - Atmospheric
    - Precipitation
    - Evaporation
    - Transpiration

- FEFLOW
  - General
    - Transient
    - Cross constrained
  - Specific
    - Flux
    - Hydraulic head
    - Pressure head
    - Seepage face
    - Saturation
    - Moisture content
    - Free drainage
  - Atmospheric
    - Precipitation
    - Evapotranspiration

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Model Comparison
Root Water Uptake

- HYDRUS
  - Feddes
  - S-shaped

- FEFLOW
  - Not available

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Model Comparison
Overland Flow and Ponding

- **HYDRUS**
  - Overland flow
    - 2D only, plans for 3D
    - All water in excess of infiltration capacity is lost to surface runoff
  - Ponding
    - Trick it!!

- **FEFLOW**
  - Overland flow
    - All water in excess of infiltration capacity is lost to surface runoff
  - Ponding
    - Trick it!!
Model Comparison
GIS / CAD/ASCII Integration

- HYDRUS
  - Text file for geometry

- FEFLOW
  - ESRI shapefiles
  - AutoCAD DXF files
  - ASCII files
  - TIFF / JPEG
Model Comparison

Visuals / Post Processing / Particle Tracking

- HYDRUS
  Visuals
  - 1D, good
  - 2D, limited
  - 3D, poor
- FEFLOW
  Visuals
  - 2D, on
  - graphics
- FFEFlowExplorer
  Particle tracking
  - Yes

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Model Comparison

Graphical User Interface

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Model Selection Summary

- **HYDRUS**
  - Same core features
  - Better representation of physical process
    - Evapotranspiration
    - Macropores
    - Root water uptake
  - Overland flow and ponding an issue
  - User-friendly GUI

- **FEFLOW**
  - Same core features
    - FEM
    - Richards equation
    - Retention / conductivity
  - Advanced pre- and post-processing utilities
  - Overland flow and ponding an issue
  - Old school GUI

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References


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