

Cross-shore transport pathways between coastal aquifers and coastal seas: Archetype of a nearshore variable-density contaminant plume



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Why an Archetype?

Characteristics of coastal aquifers

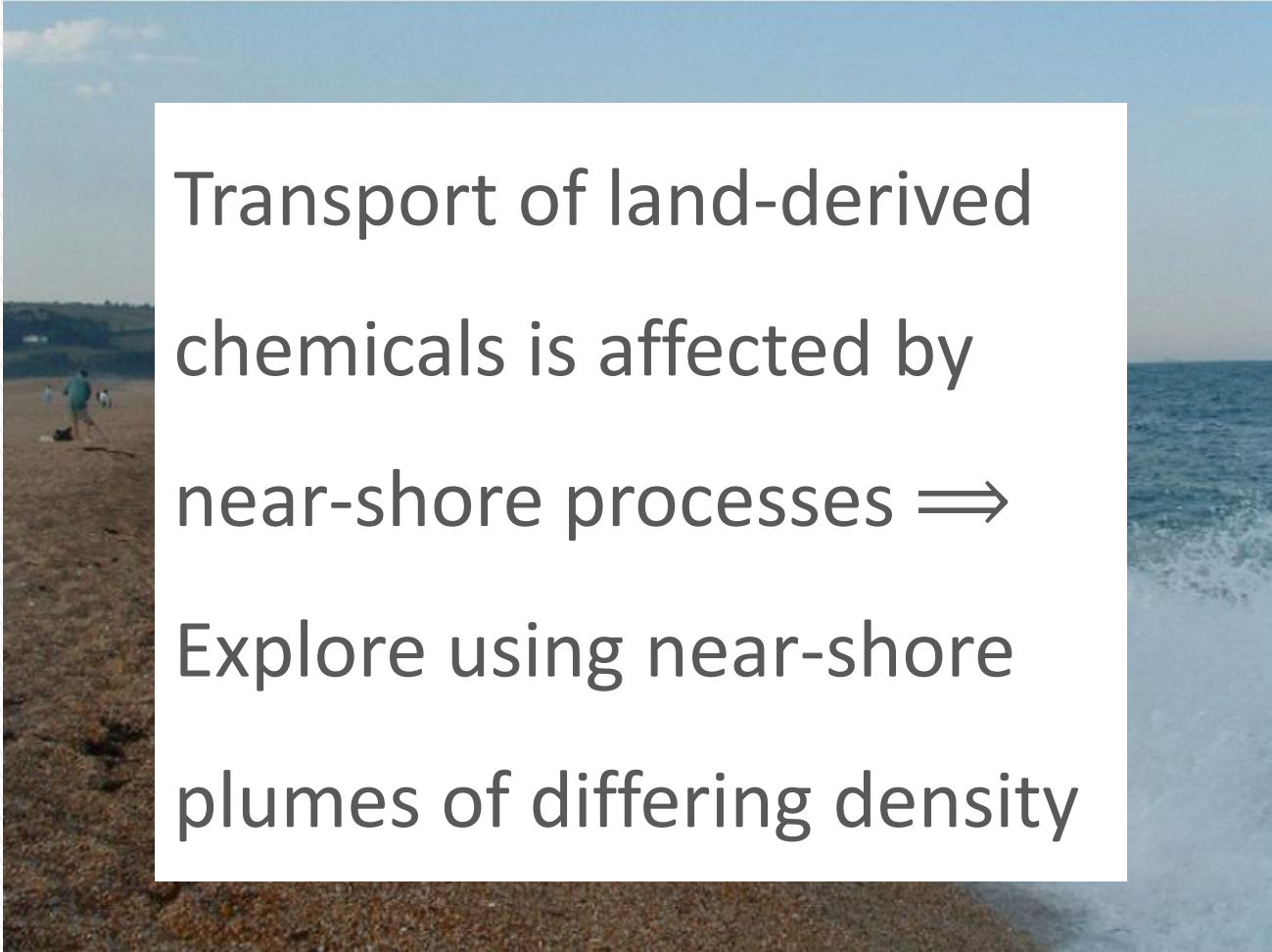
- Saline intrusion
- Tides
- Waves
- Groundwater fluctuations
- Beach morphology
- Cross-shore in/exfiltration



Why an Archetype?

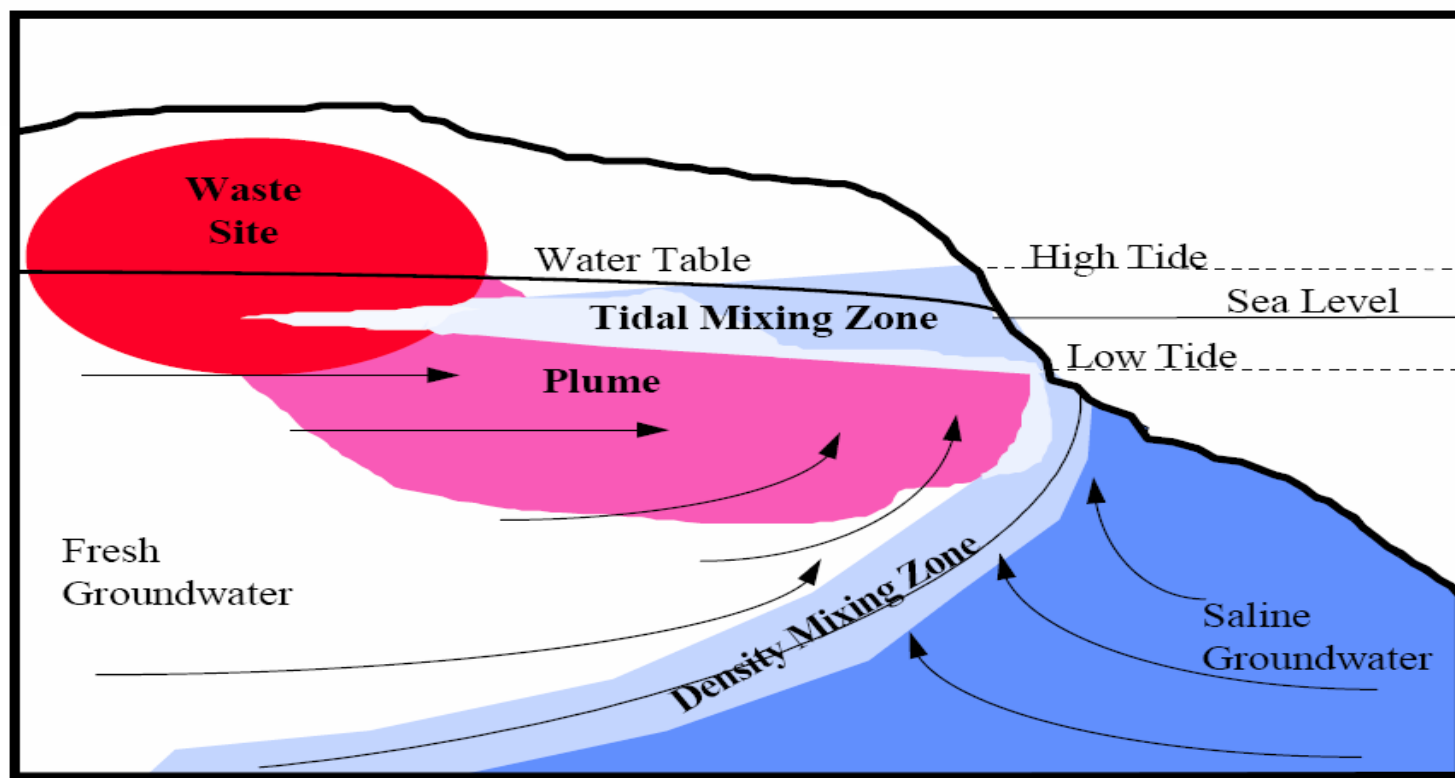
Characteristics of coastal aquifers

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- Beach morphology
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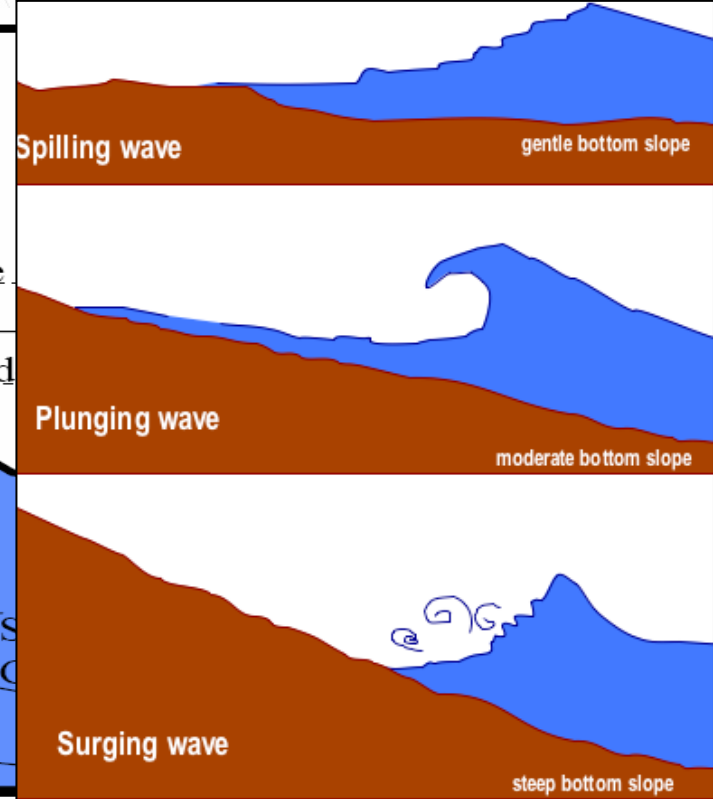
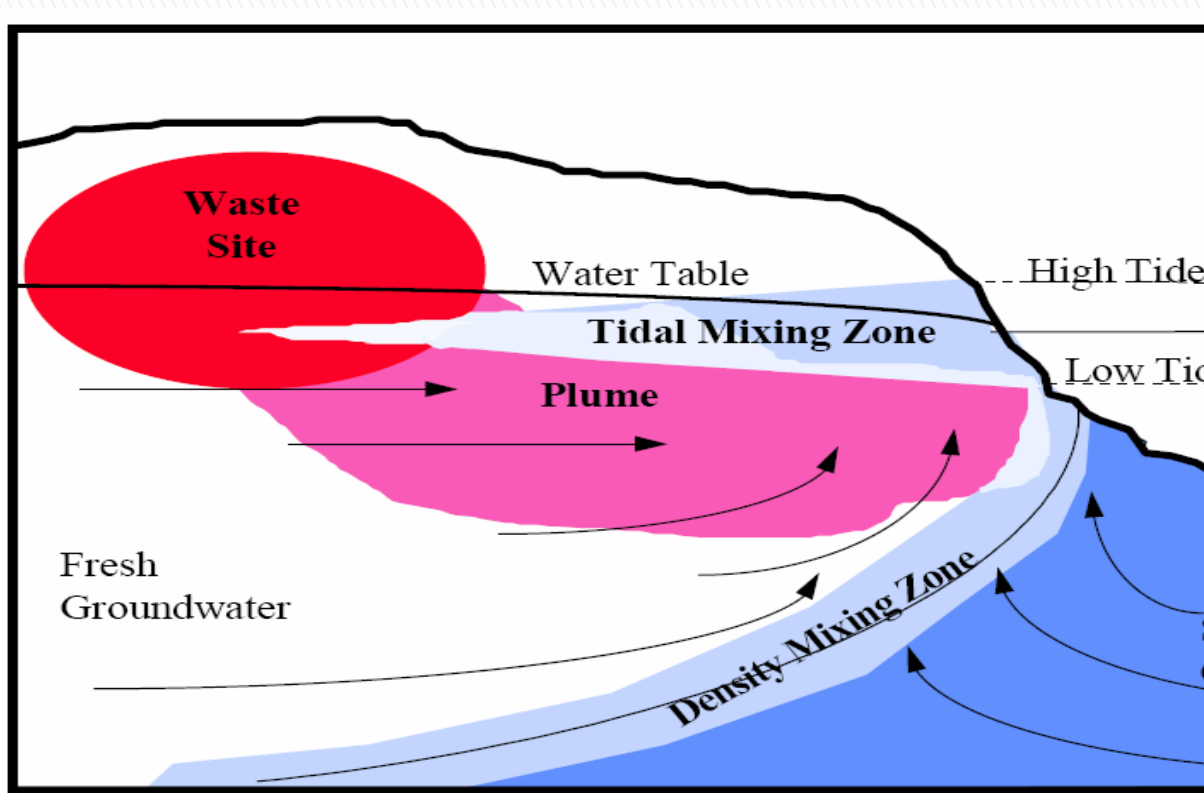
A photograph of a beach with a person walking in the distance, overlaid with a white text box. The text box contains the following text:

Transport of land-derived chemicals is affected by near-shore processes \Rightarrow Explore using near-shore plumes of differing density

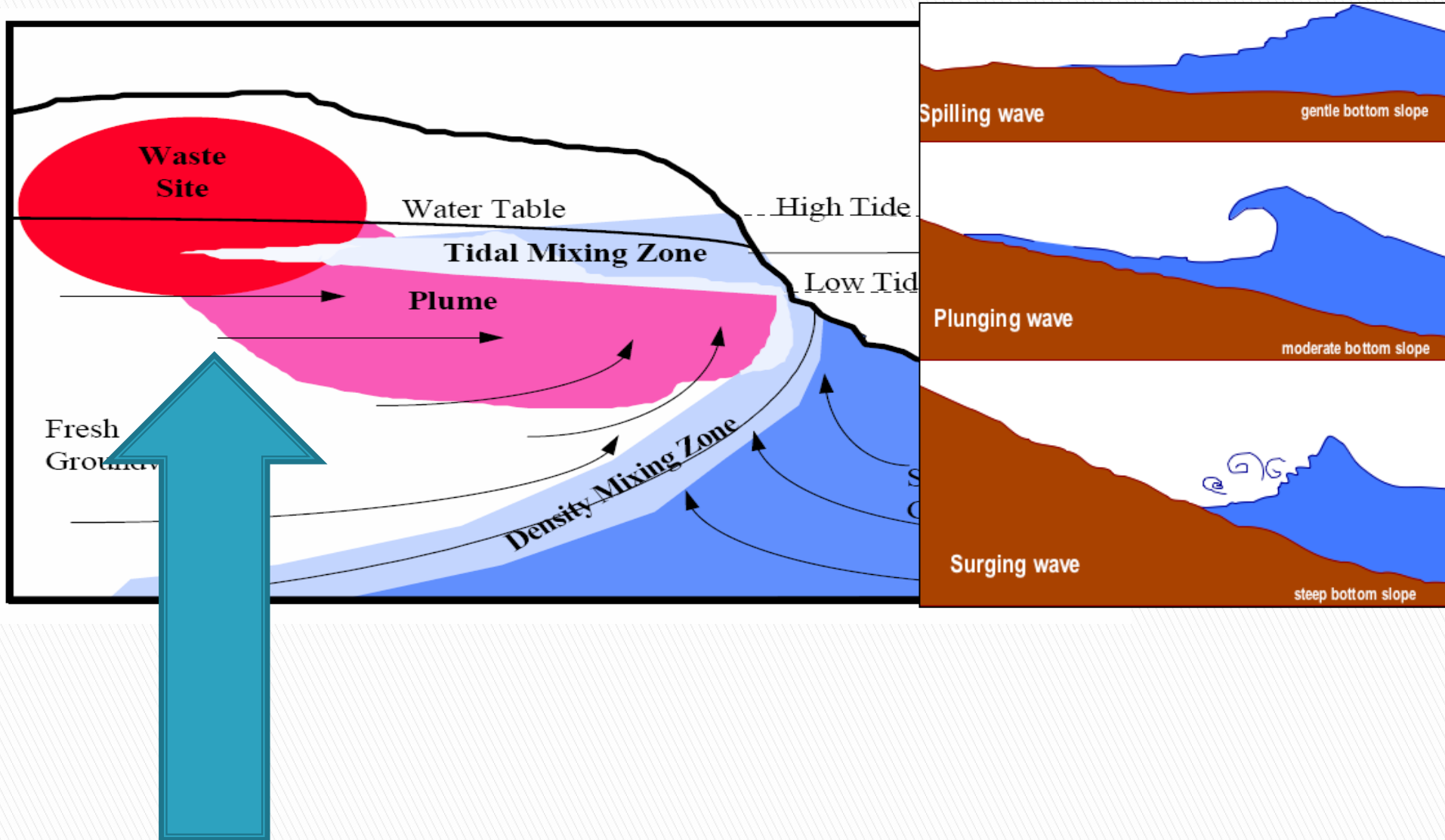
Interacting Processes



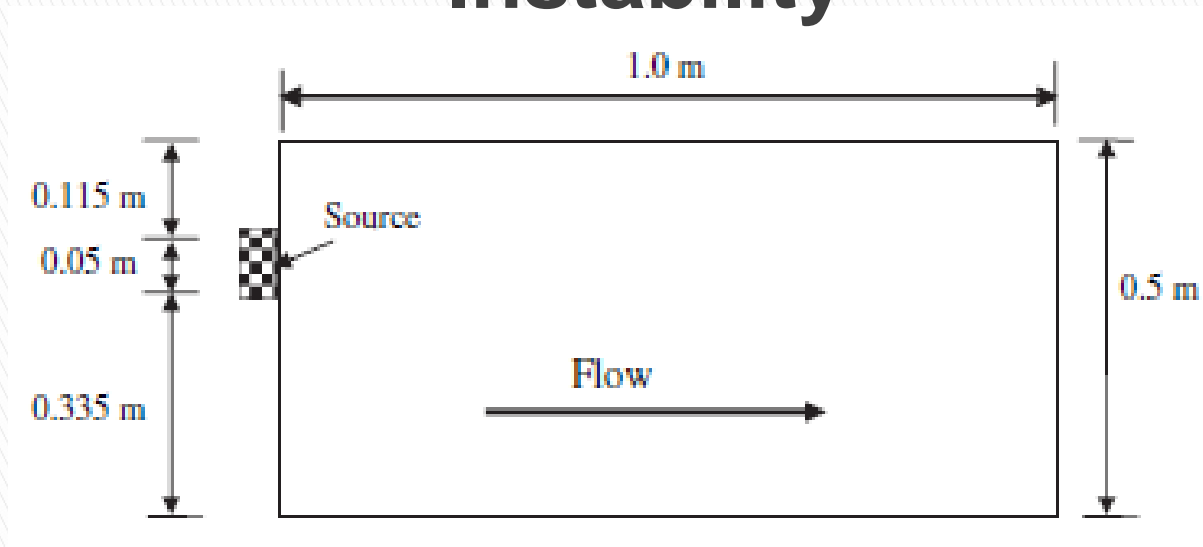
Interacting Processes



Topic 1: Plume Shape

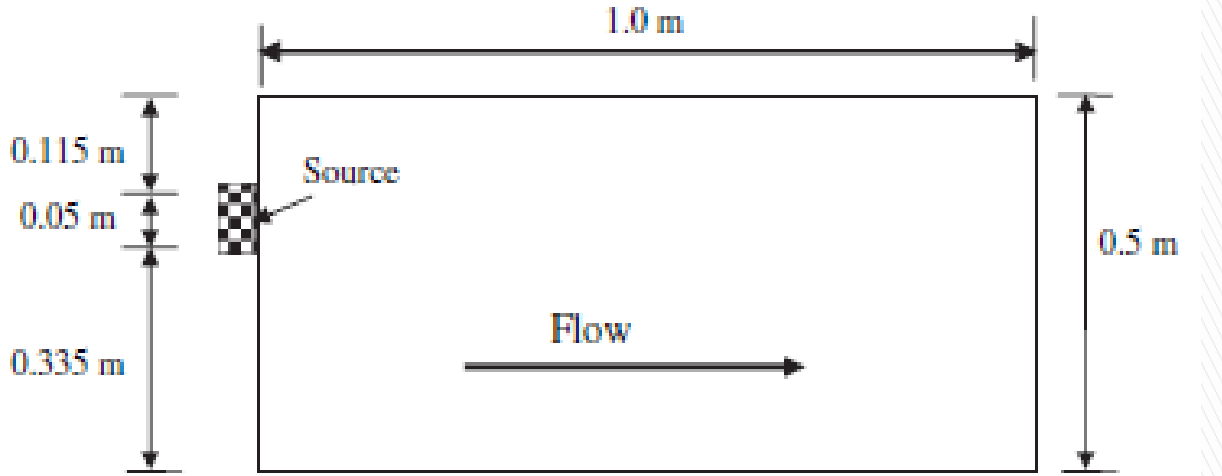


Instability

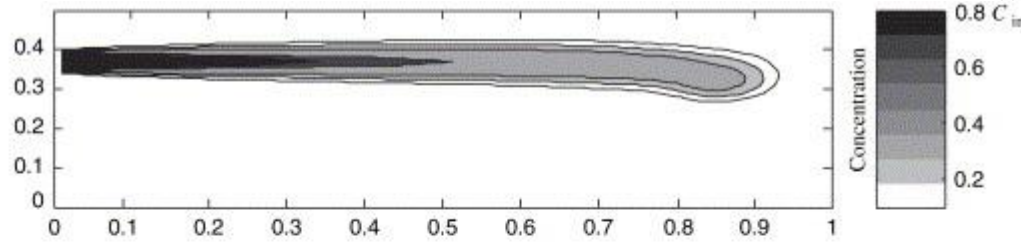


- Zero flux top and bottom boundaries
- Fixed flux at left and right boundaries
- Density-dependent flow due to Source

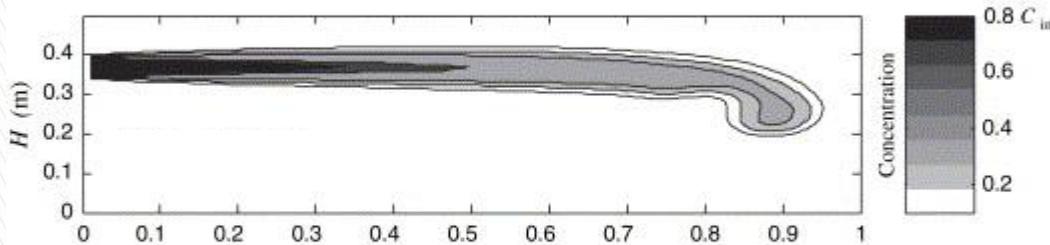
Instability



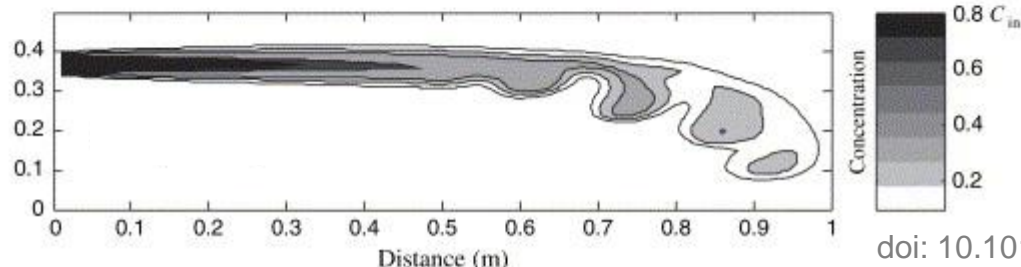
ρ/ρ_0
1.0007



1.0015



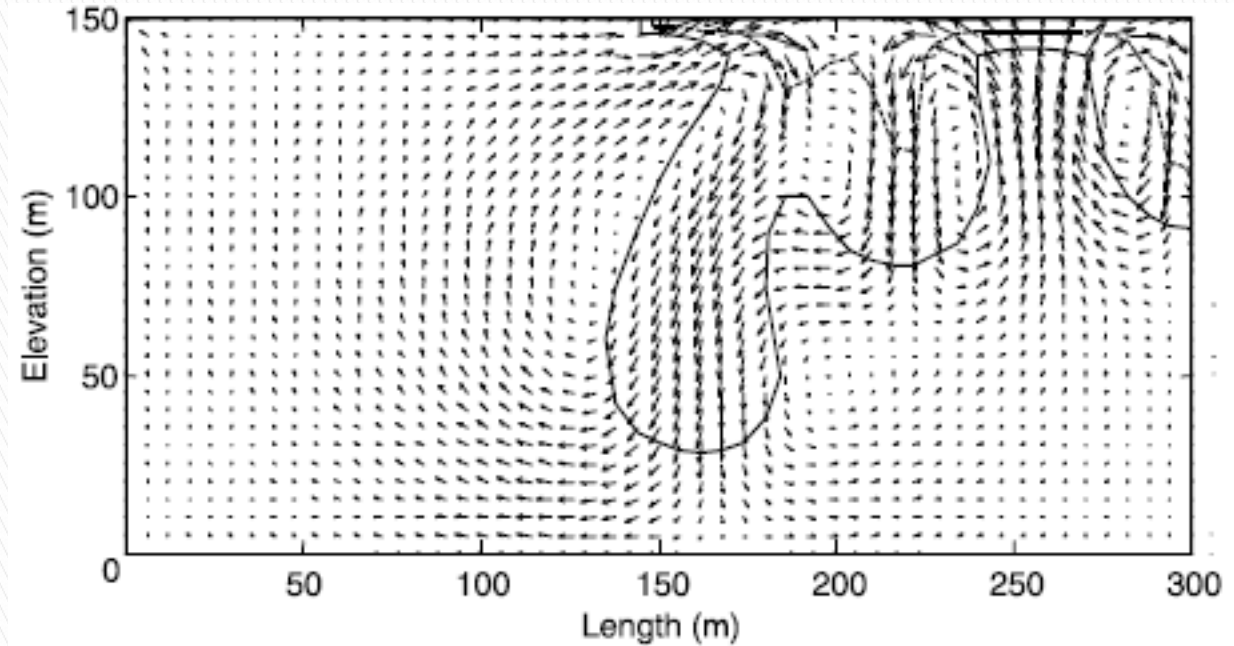
1.0029



Coupling with Flow

Elder problem: Flow due to density alone

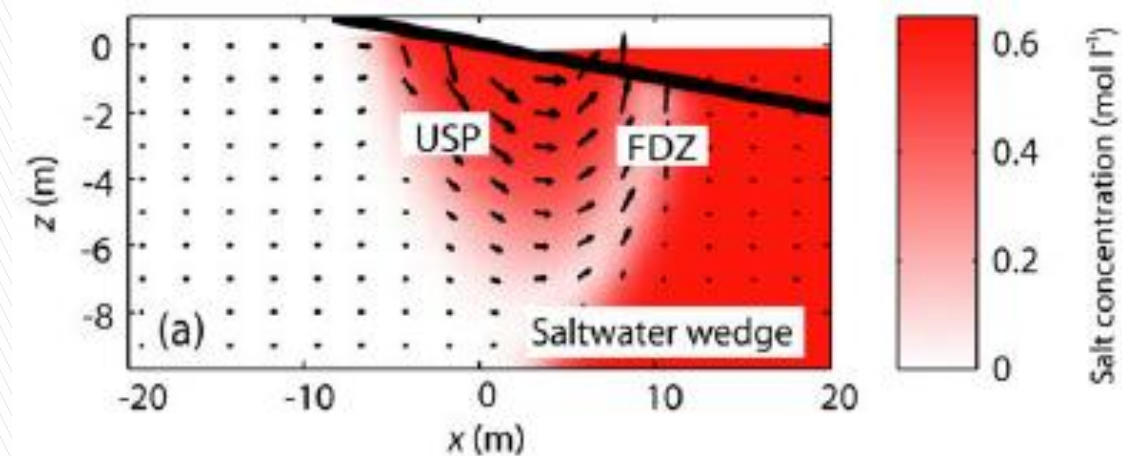
$$\rho/\rho_0 = 1.2$$



doi: 10.1016/S0309-1708(02)00085-4

Tidal fluctuations and groundwater discharge

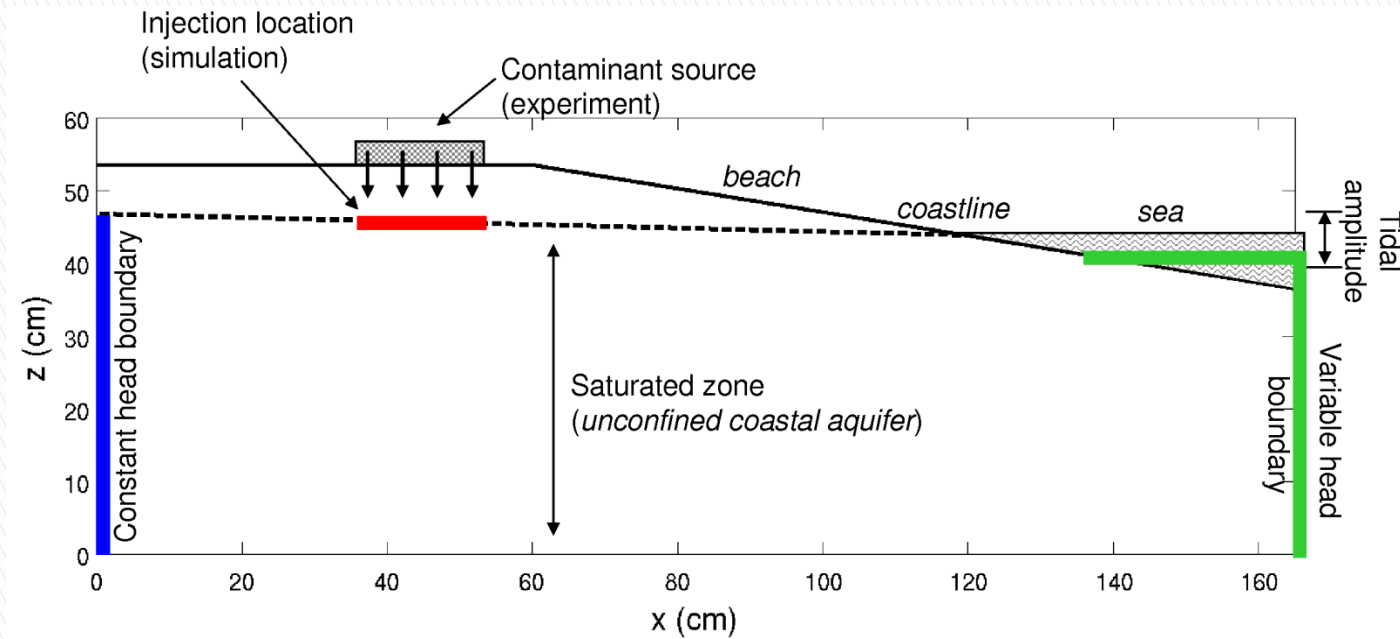
$$\rho/\rho_0 = 1.035$$



doi: 10.1016/j.advwatres.2008.09.008

USP: Upper saline plume FDZ: Freshwater discharge zone

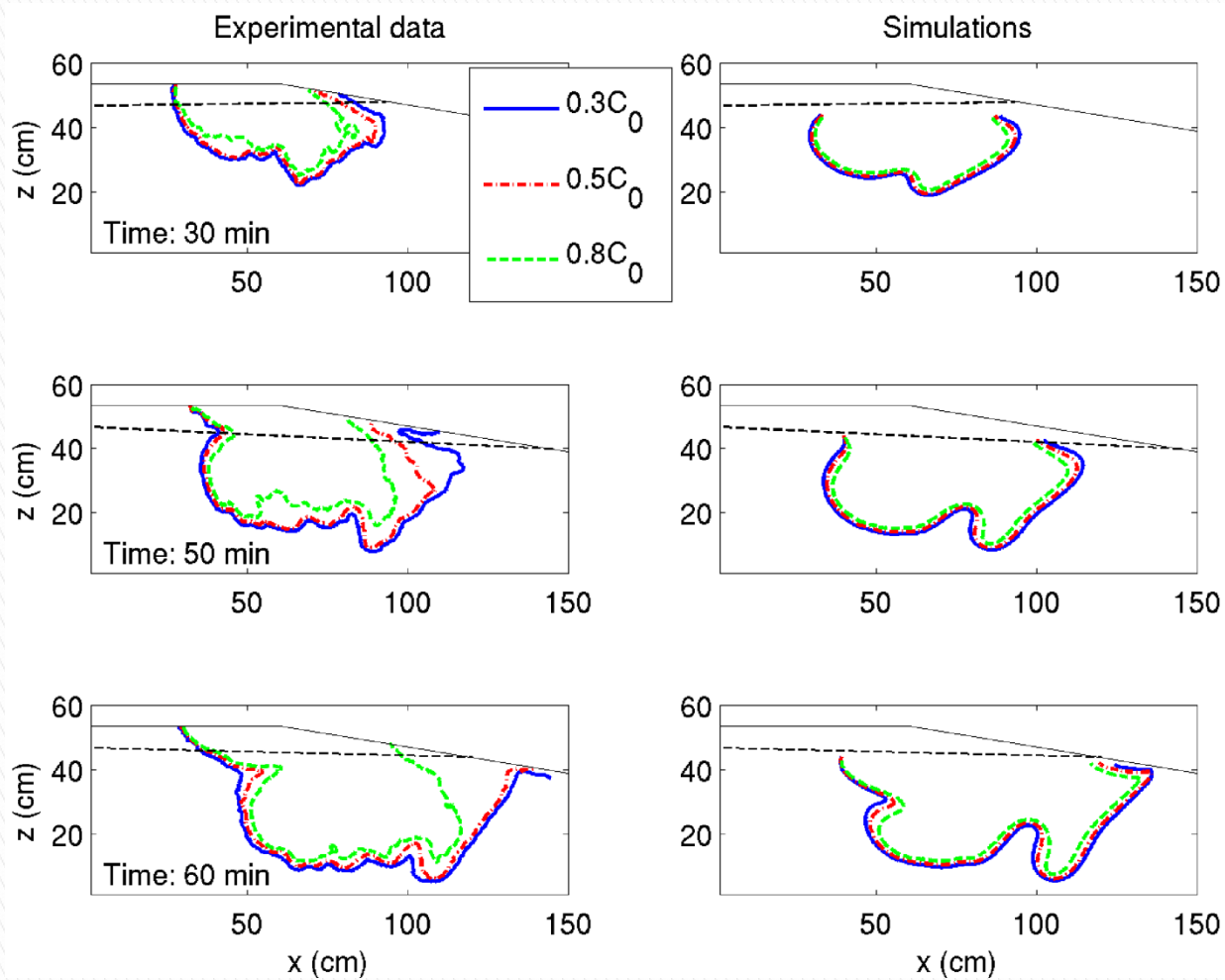
Dense Plume Experiment



- Glass bead porous medium
- Sloping beach with saltwater intrusion
- Fixed head and periodic boundary conditions

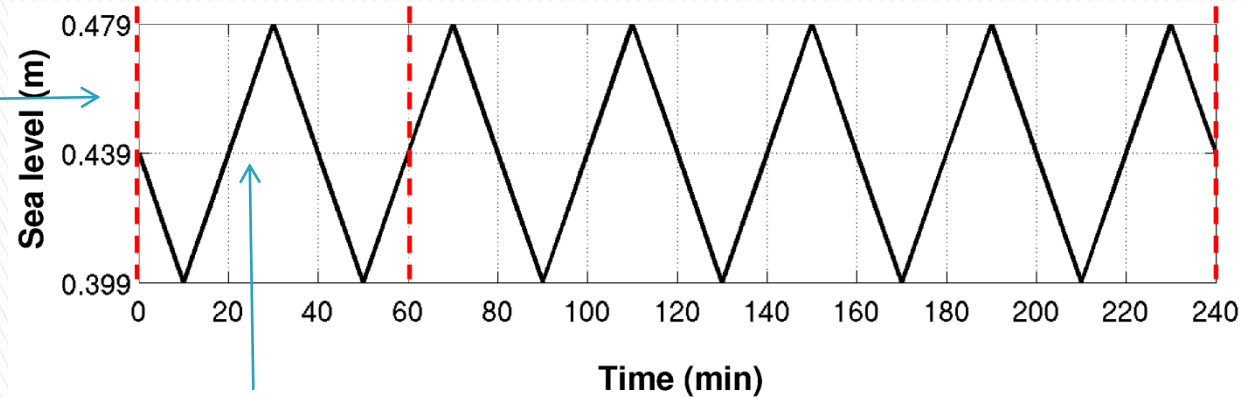
Model Validation

$$\rho/\rho_0 = 1.016$$



Changing Flow Directions

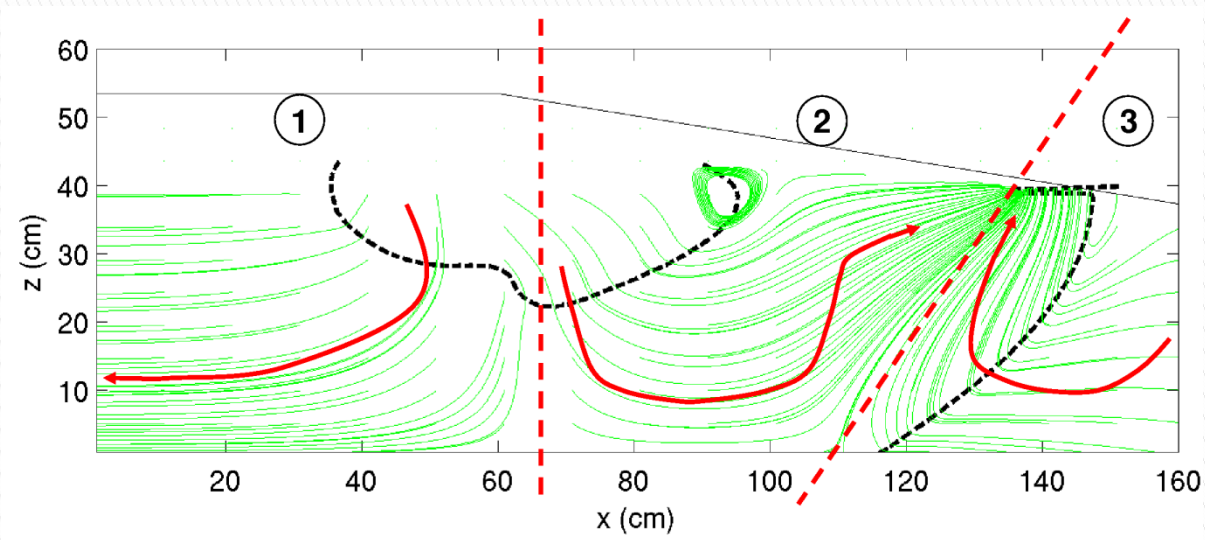
Inland boundary 0.463 m



$t = 25$ mins

Sea boundary 0.459 m

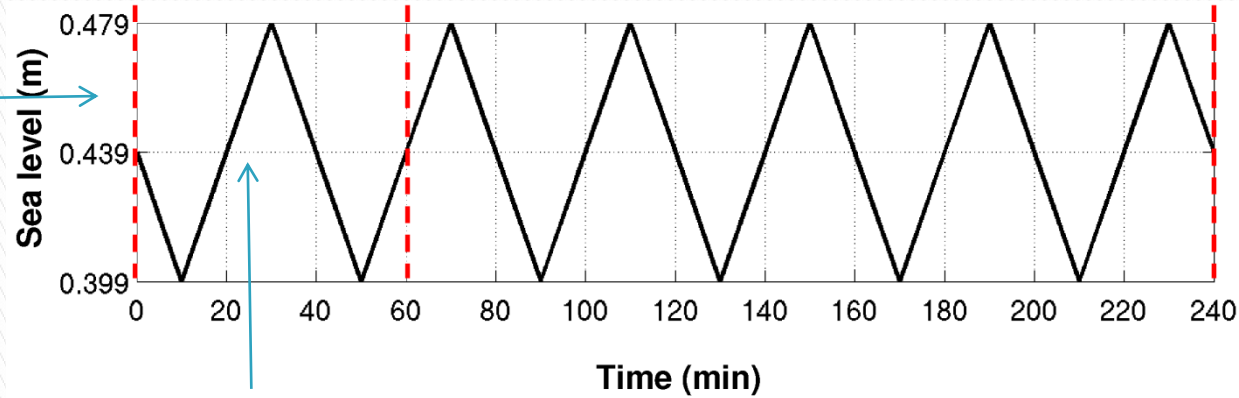
$\rho/\rho_0 = 1.016$



$\rho/\rho_0 = 1.035$

Changing Flow Directions

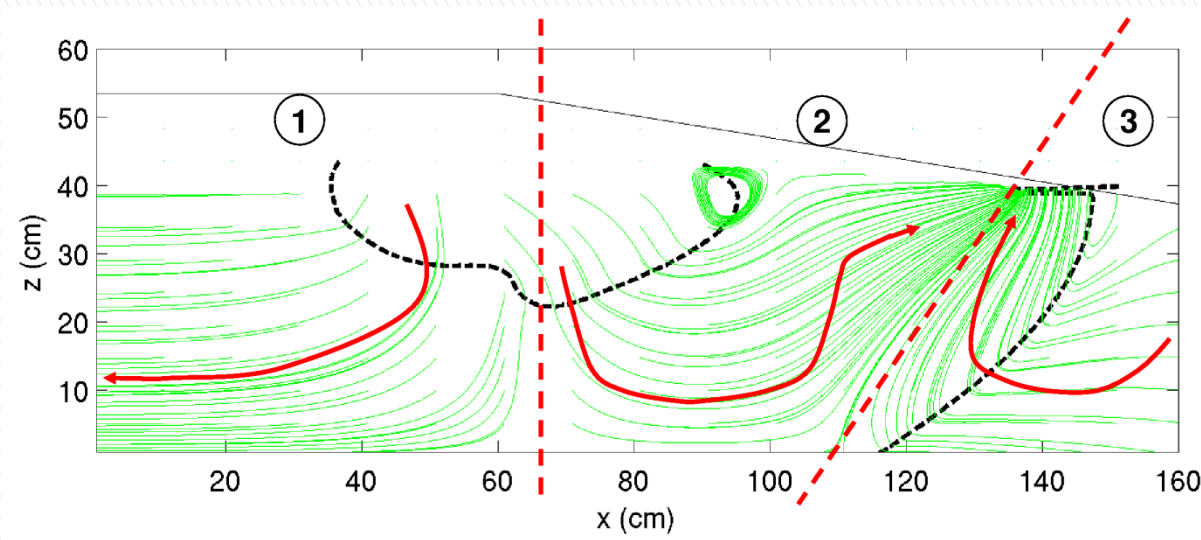
Inland boundary 0.463 m



**Density + flow =
plume shape**

$t = 25$ mins

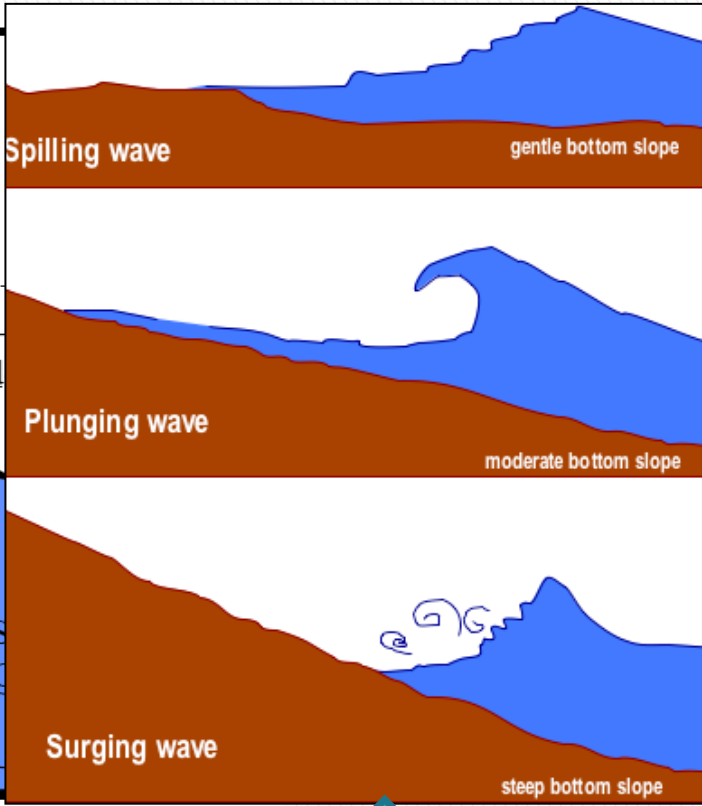
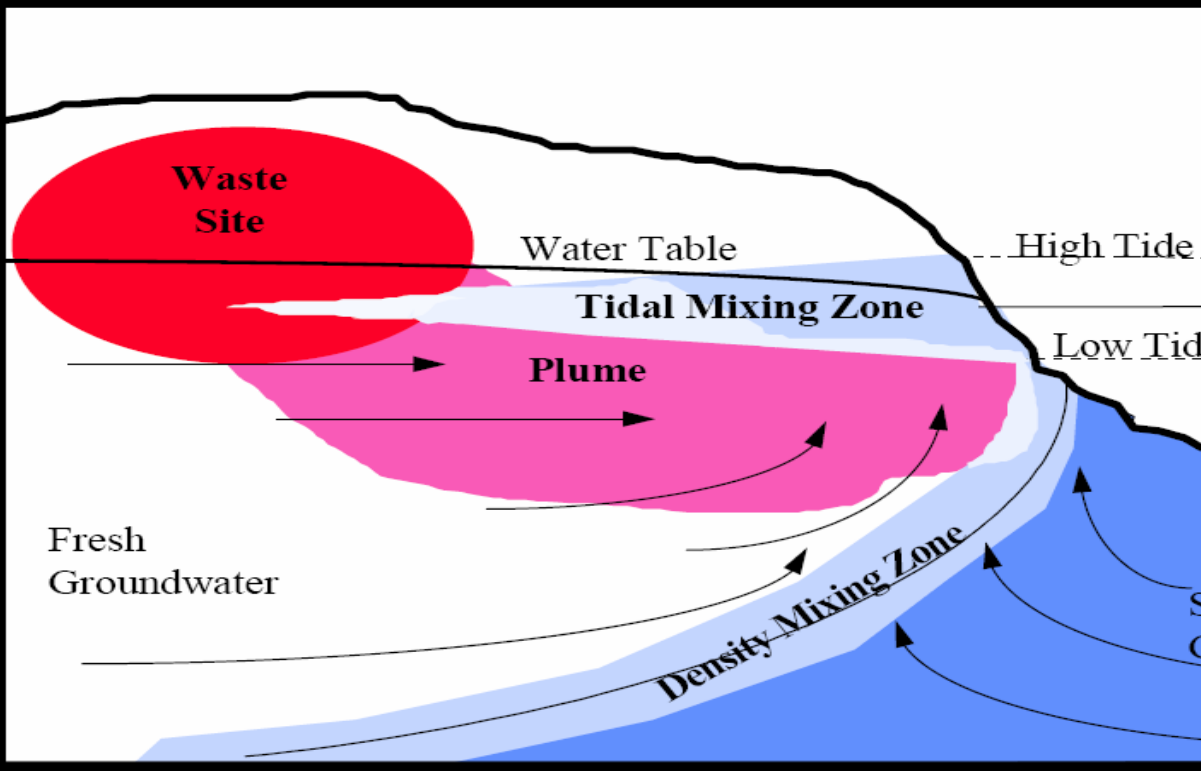
Sea boundary 0.459 m



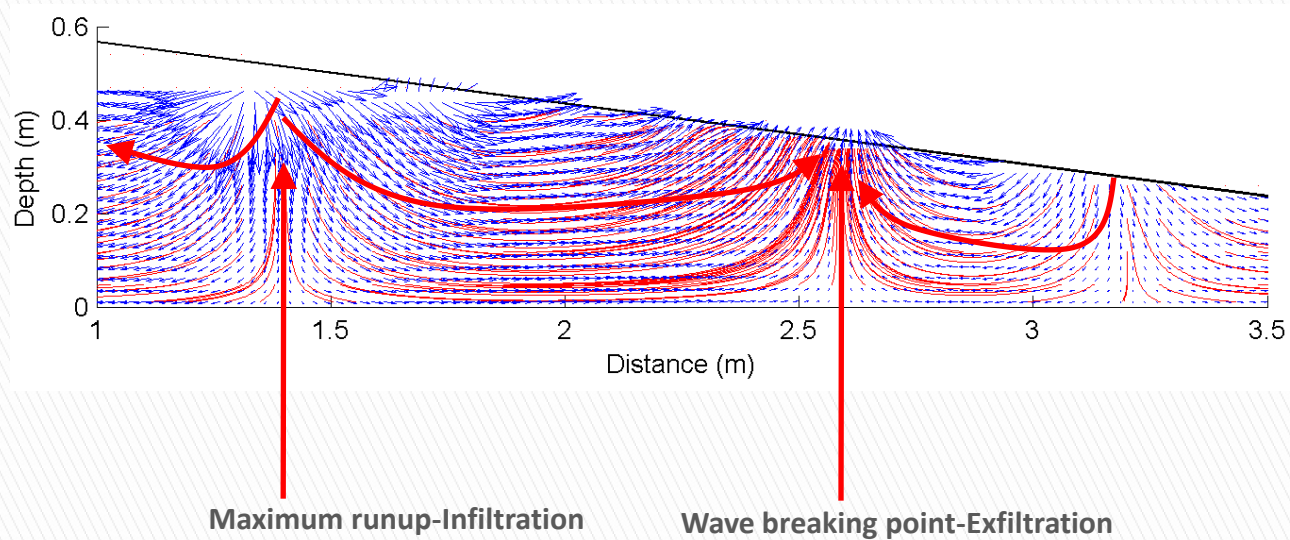
$\rho/\rho_0 = 1.016$

$\rho/\rho_0 = 1.035$

Topic 2: Seaward Boundary – Waves



Wave-Induced Flow

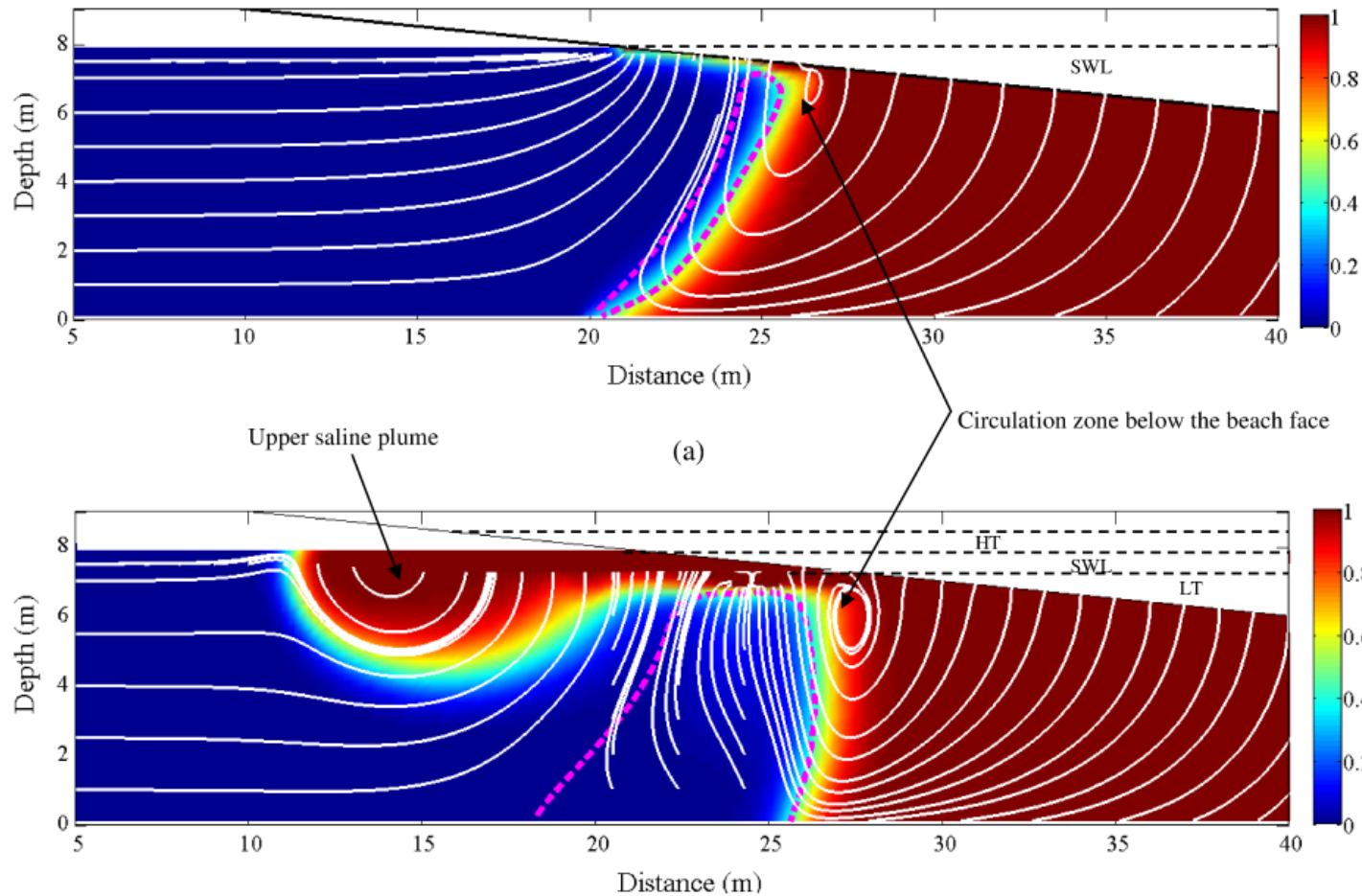


- Phase-averaged wave results – no tide
- Beach morphology affected by wave/swash

But

- Wave setup can be used when simulating over a tidal cycle

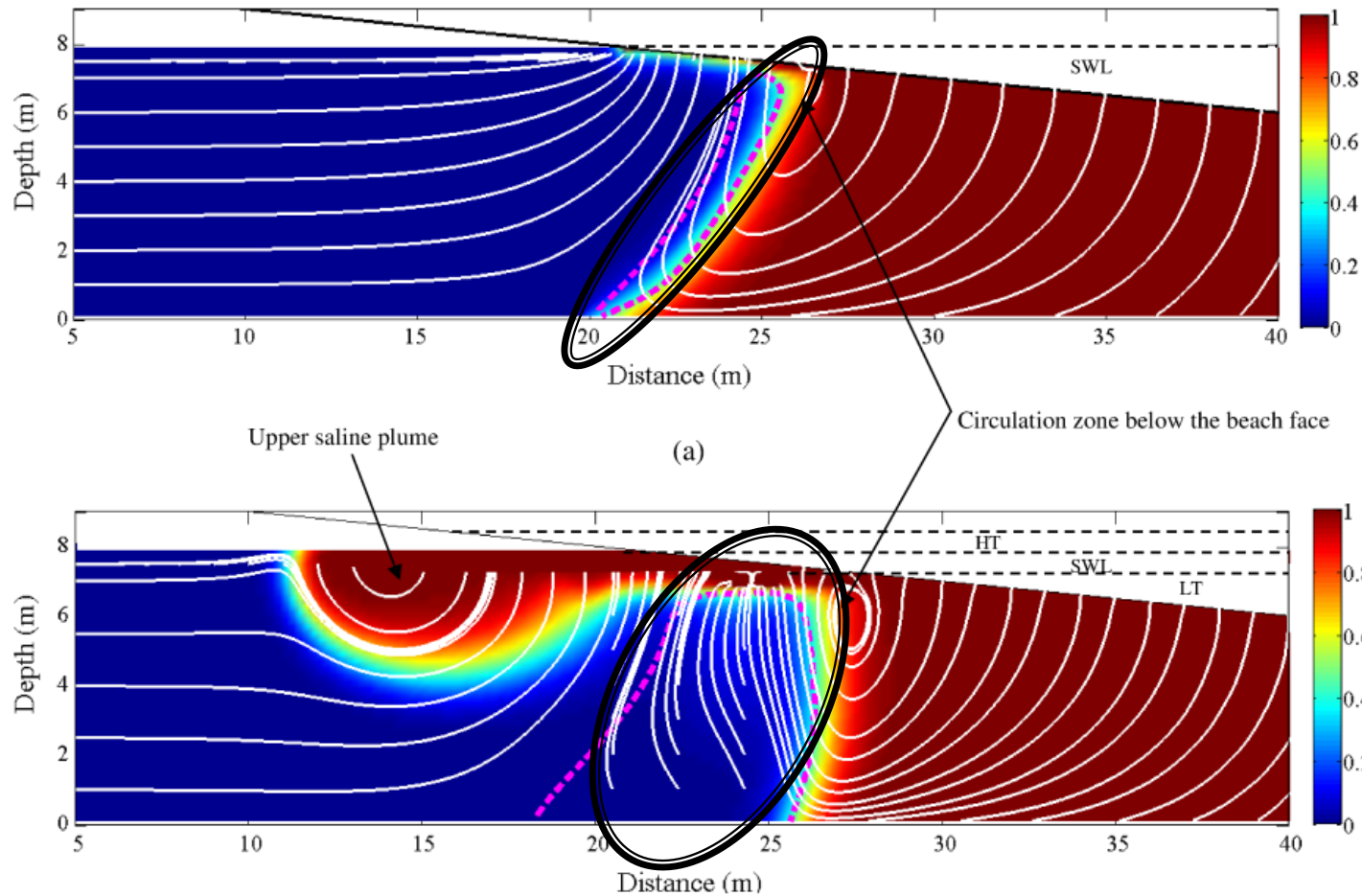
Plume Movement to Coastal Sea



Static sea
boundary

Tidal sea
boundary

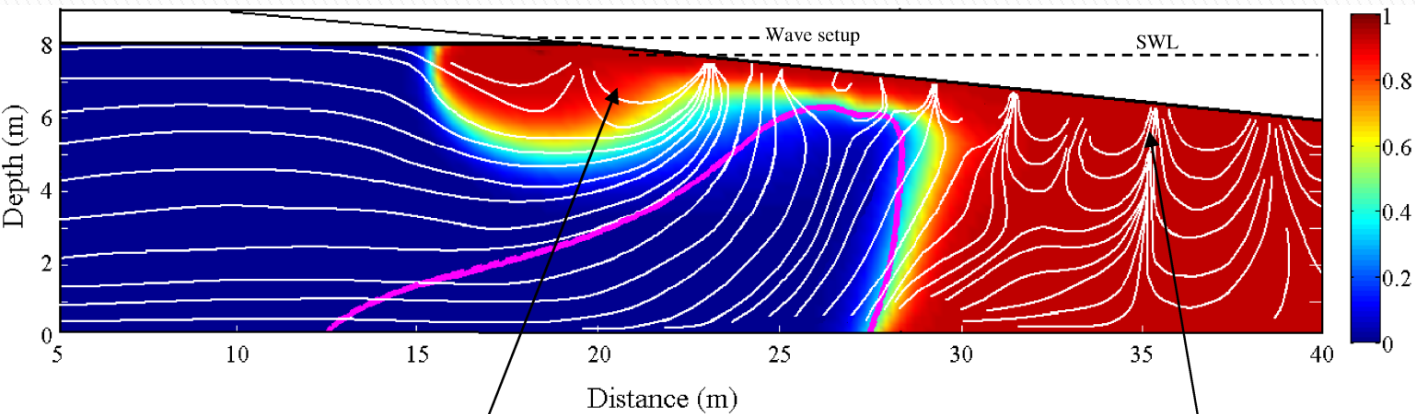
Plume Movement to Coastal Sea



Static sea boundary

Tidal sea boundary

Plume Movement to Coastal Sea

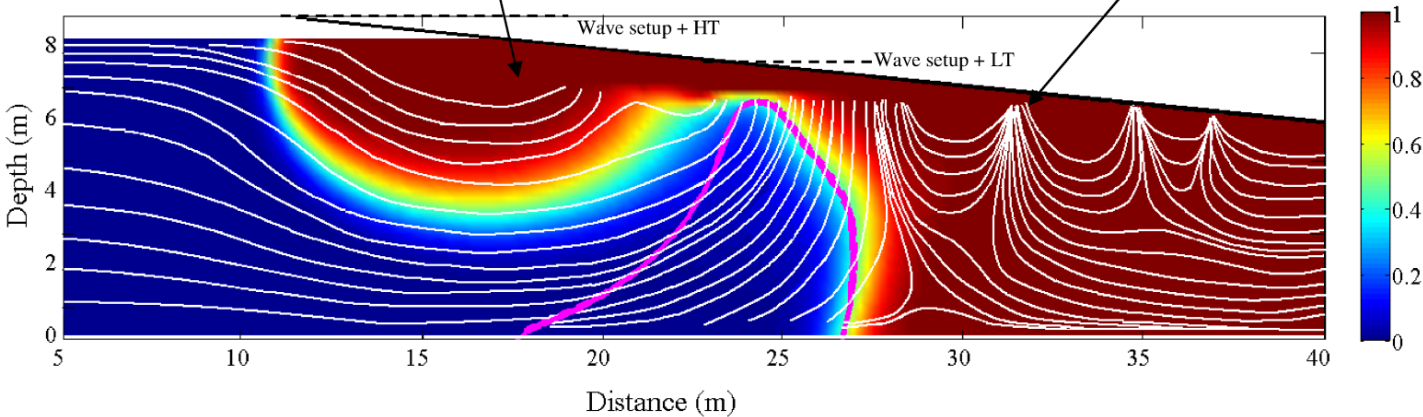


Waves only

Circulation zone near the surface

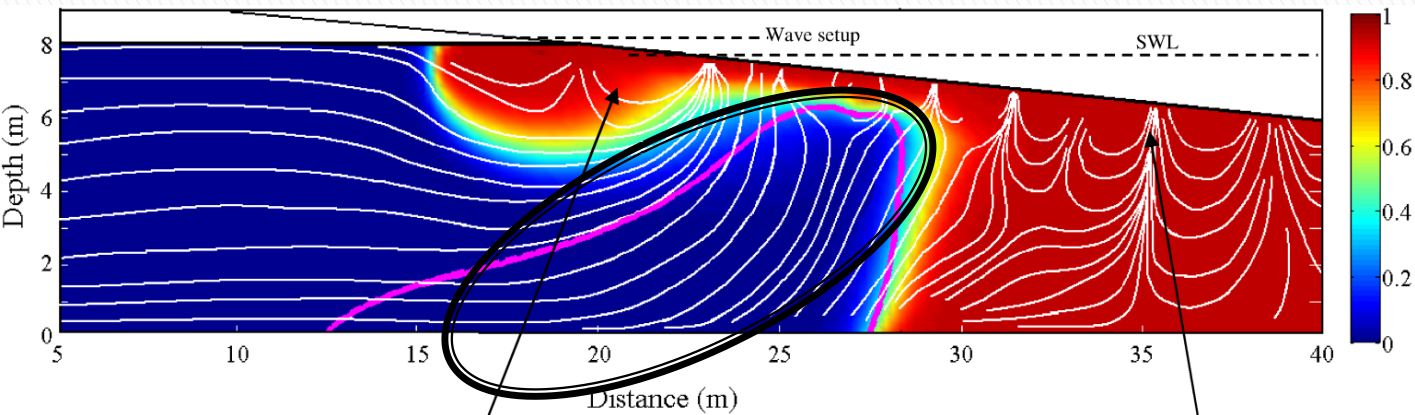
(c)

Convergence zone



Wave setup +
tide

Plume Movement to Coastal Sea

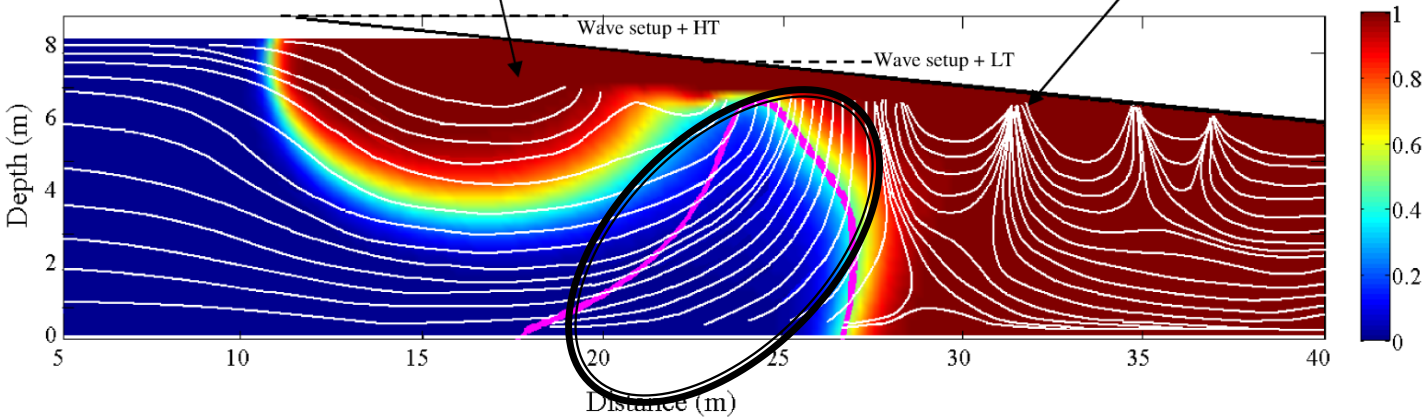


Waves only

Circulation zone near the surface

(c)

Convergence zone



Wave setup +
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A Complex and Dynamic Zone

Recent advances (modeling and experiment) include:

- Interaction of upper saline plume and freshwater discharge
- Combined modeling of wave + swash zone, tides, beach morphology changes and coastal aquifer
- Complex flow patterns exist even if phase-averaged
- Contaminant plume in the coastal aquifer “stresses” the flow paths
⇒ highlights the variety of possible behaviors

The future: Extend detailed studies to 3D