SALTWATER INTRUSION THROUGH SUBMERGED CAVES DUE TO THE VENTURI EFFECT

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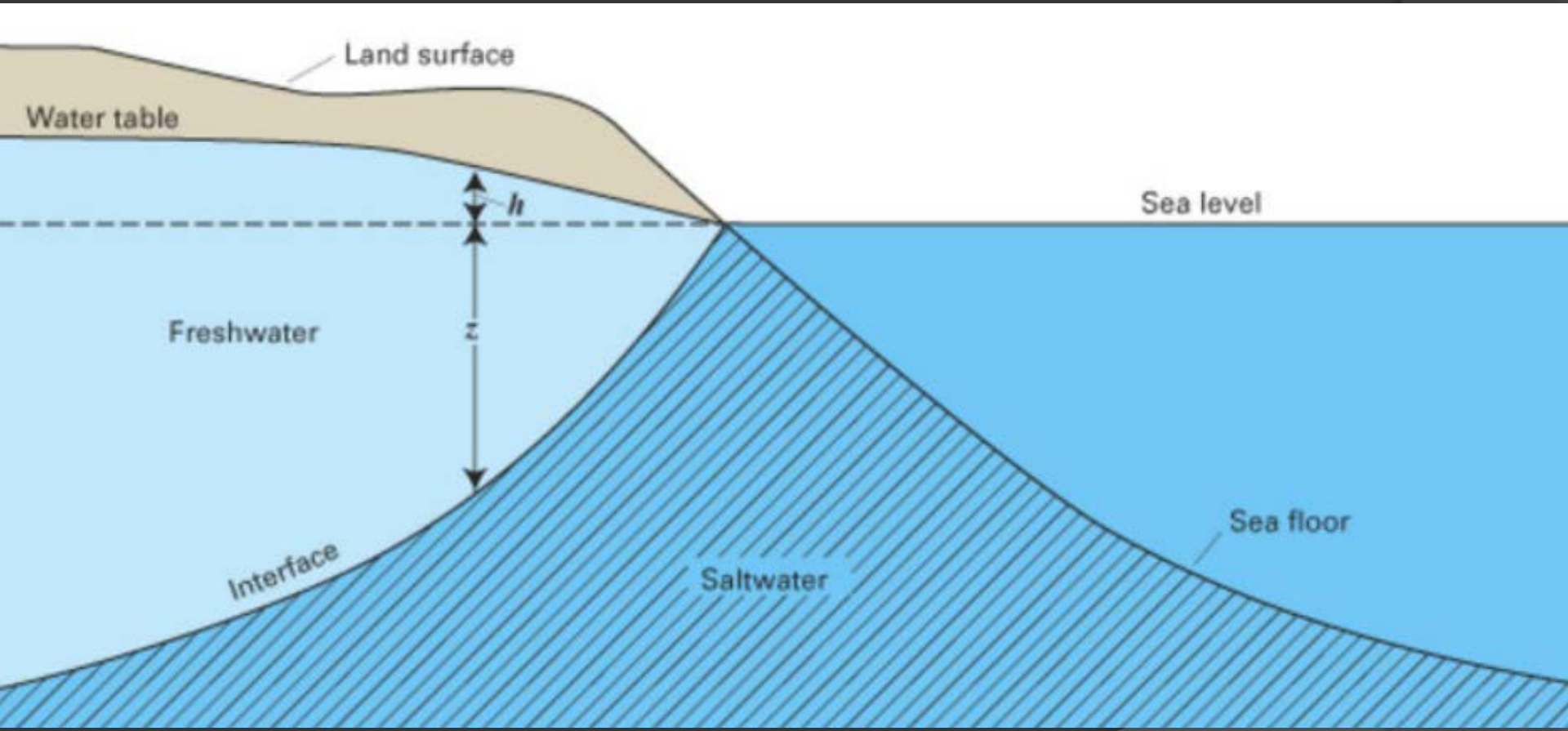
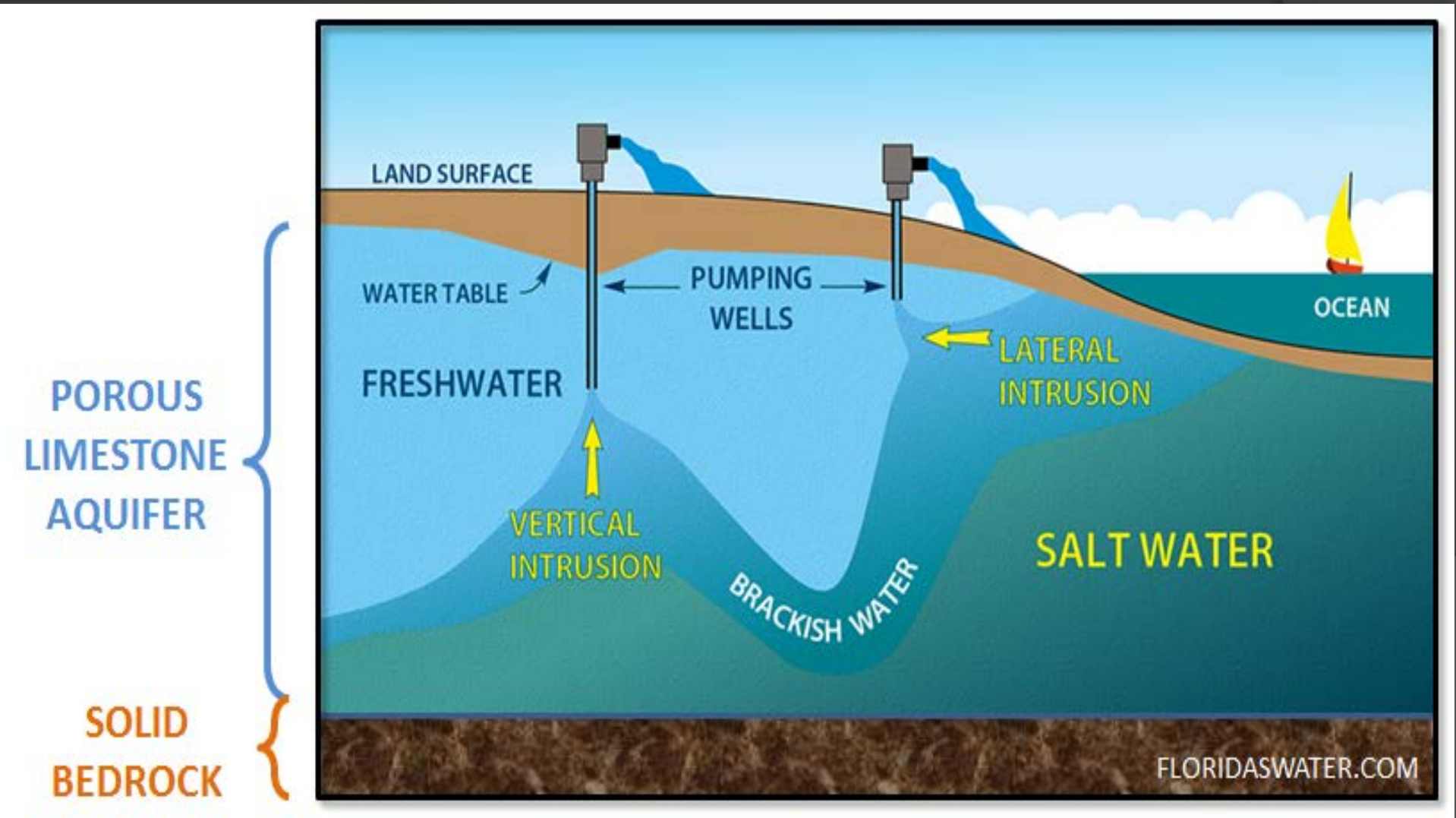
Saltwater Intrusion

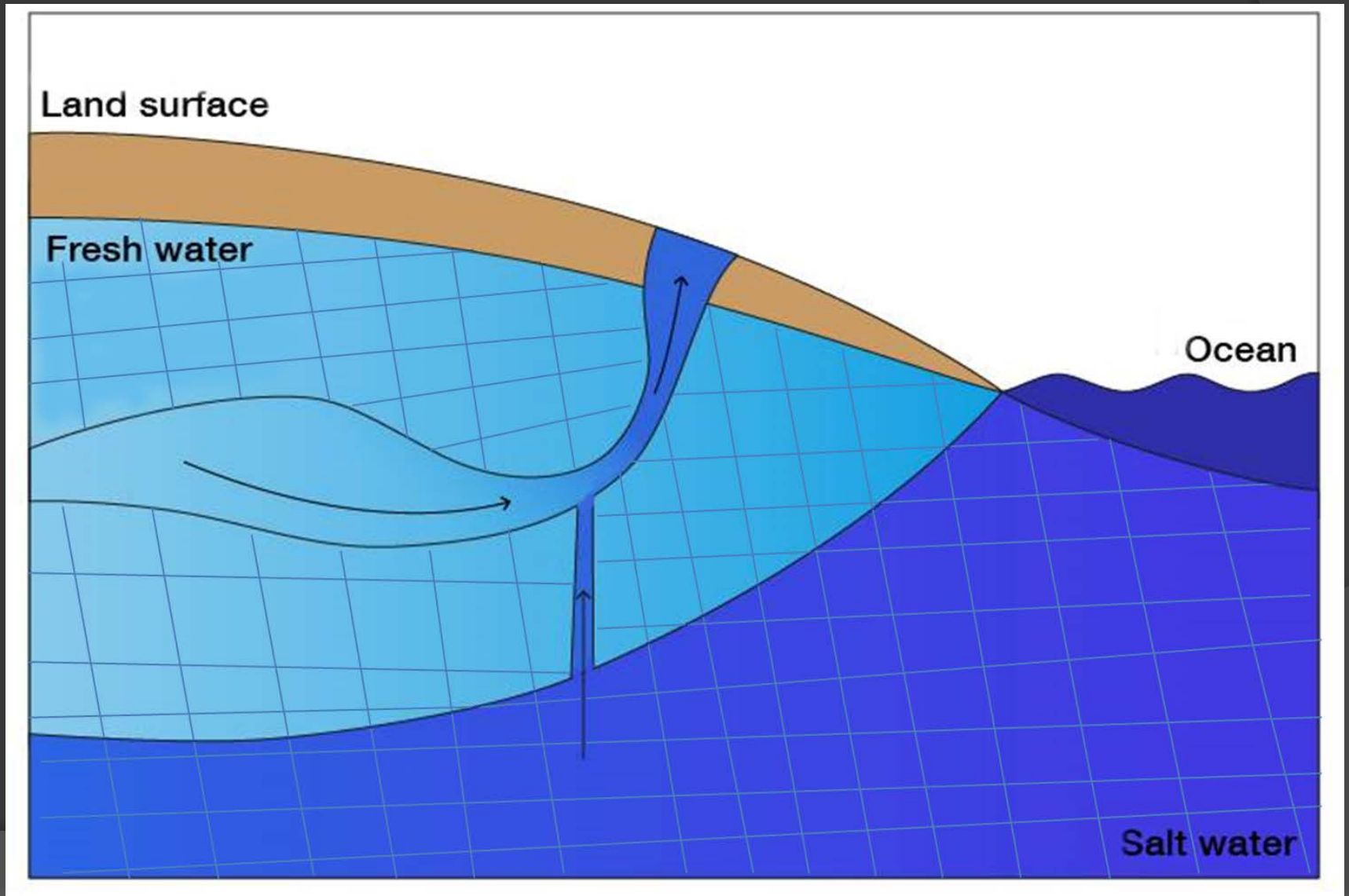


source: www.blogs.ei.columbia.edu

Saltwater Intrusion

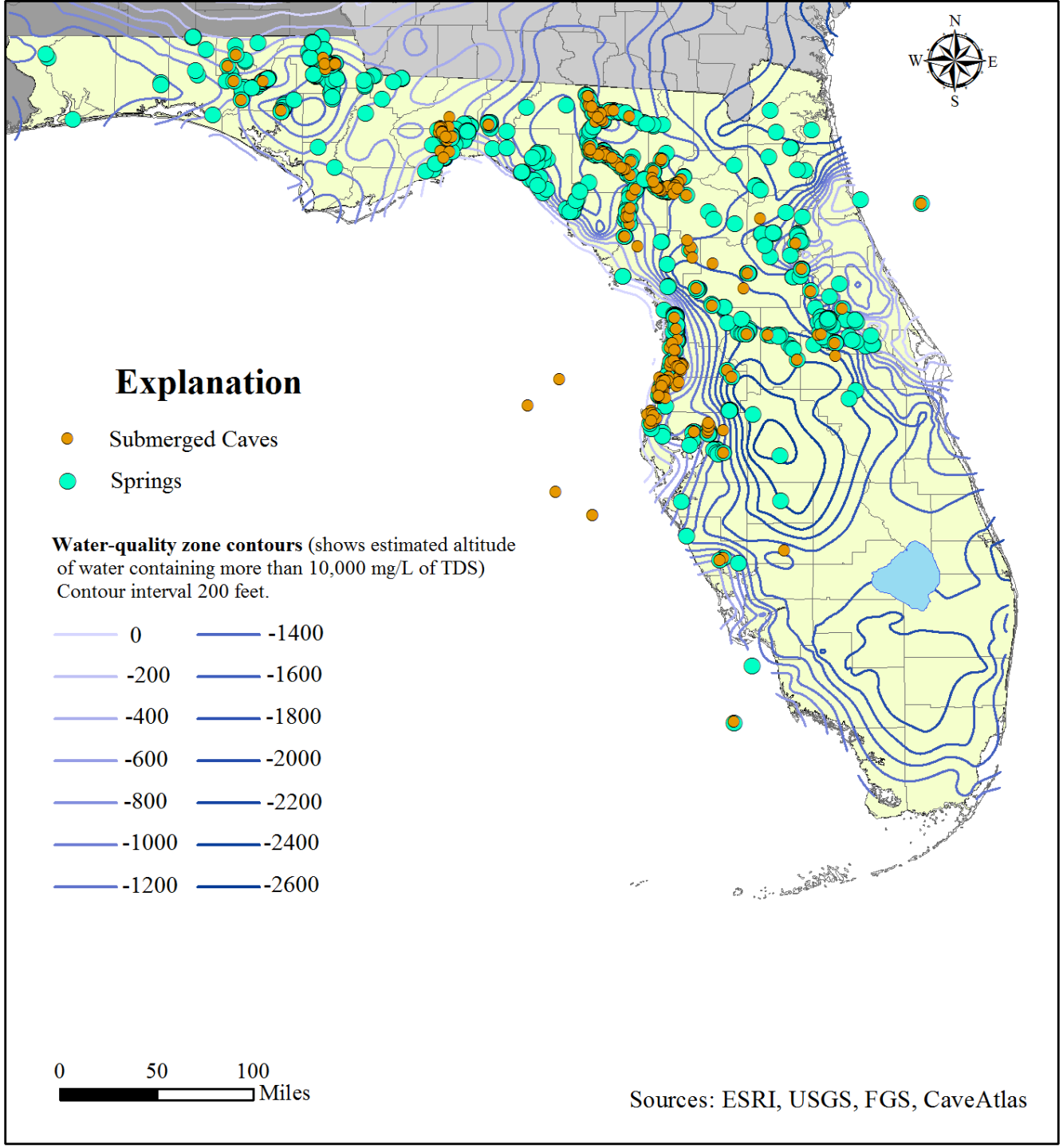


Saltwater Intrusion Through Submerged Caves due to the Venturi Effect



Caves

- More than 1,500 known dry and submerged caves (Kincaid 1999; Florea 2008)
- Only about 50 of submerged caves are mapped and located
- 4,000 have not yet been discovered (Kincaid 2004)


N
W
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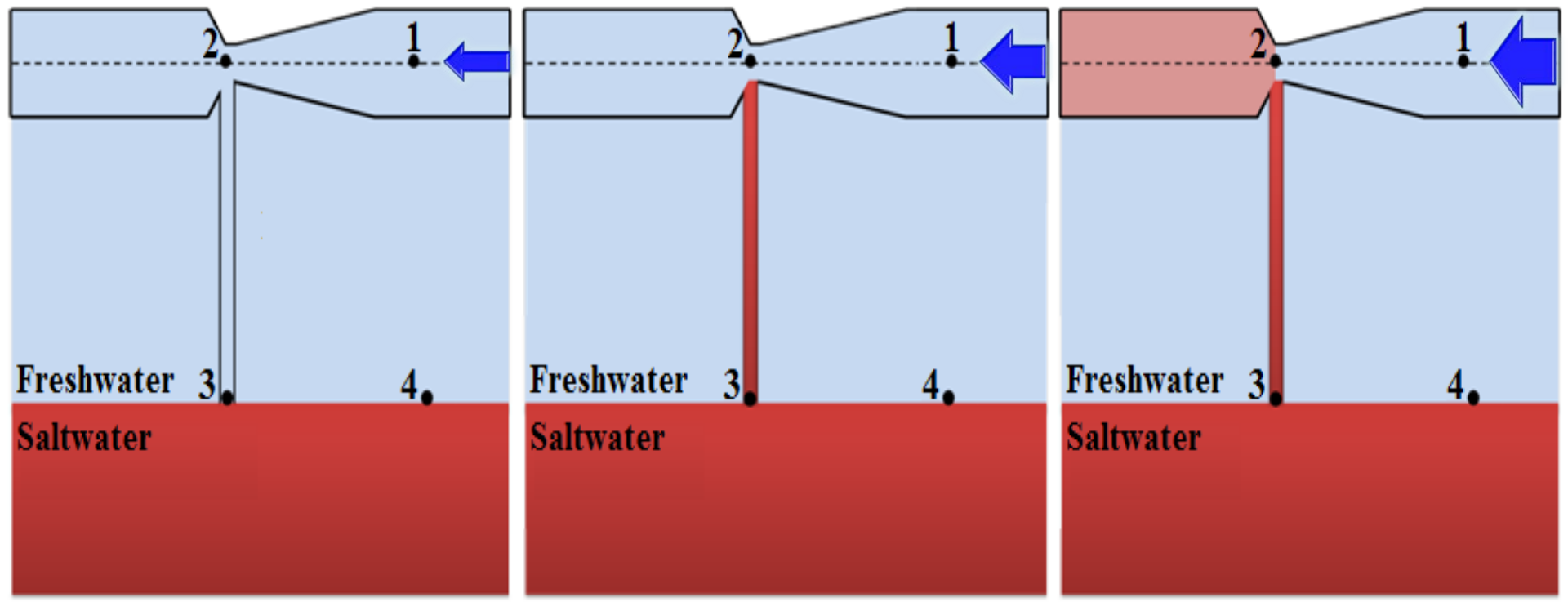
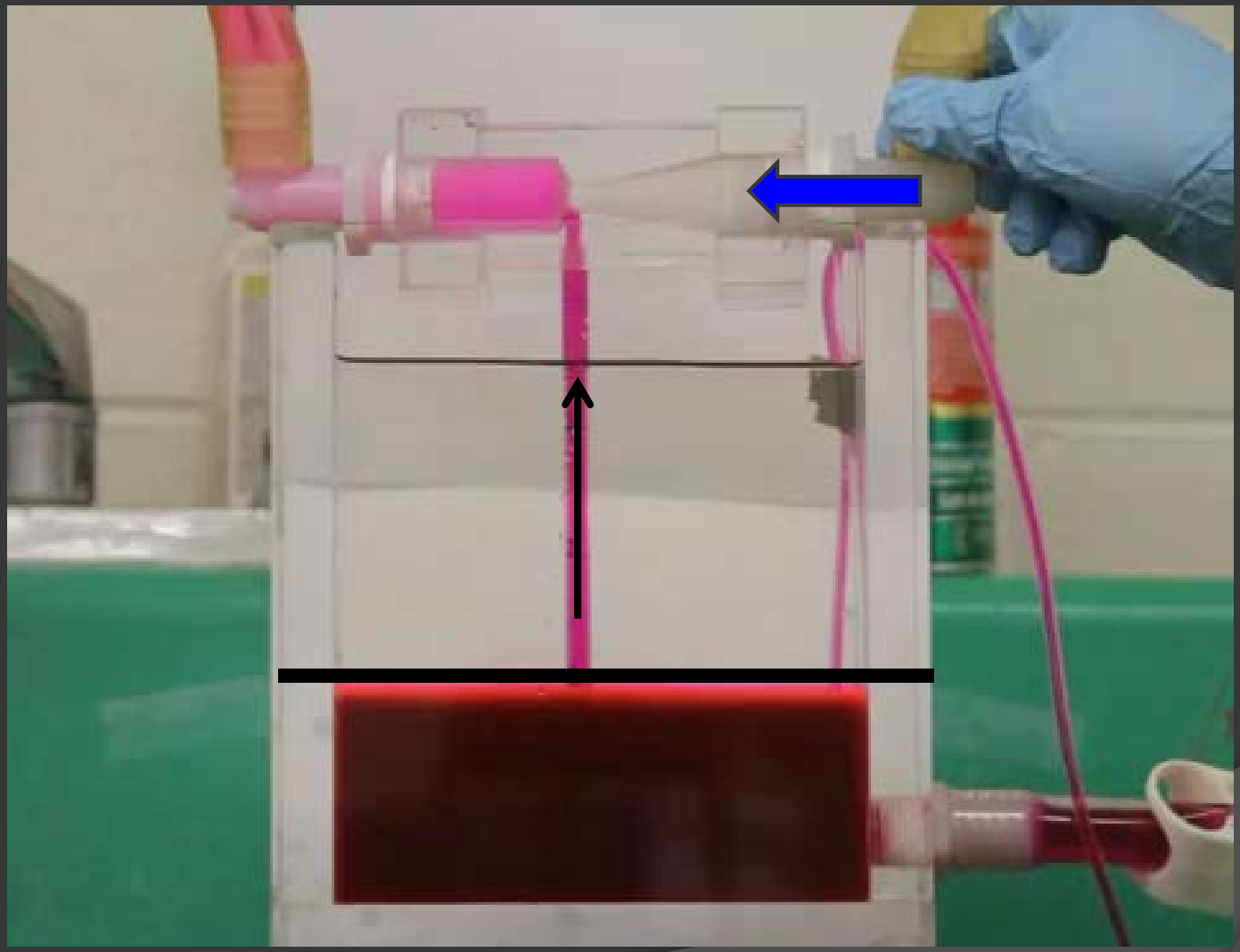
Explanation
Submerged Caves
Springs
Water-quality zone contours (shows estimated altitude of water containing more than 10,000 mg/L of TDS)
Contour interval 200 feet.
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000
-2200
-2400
-2600
0
50
100
Miles
Sources: ESRI, USGS, FGS, CaveAtlas

Schematic of the regimes

$P_2>P_3$	$P_2=P_3$	$P_2<P_3$

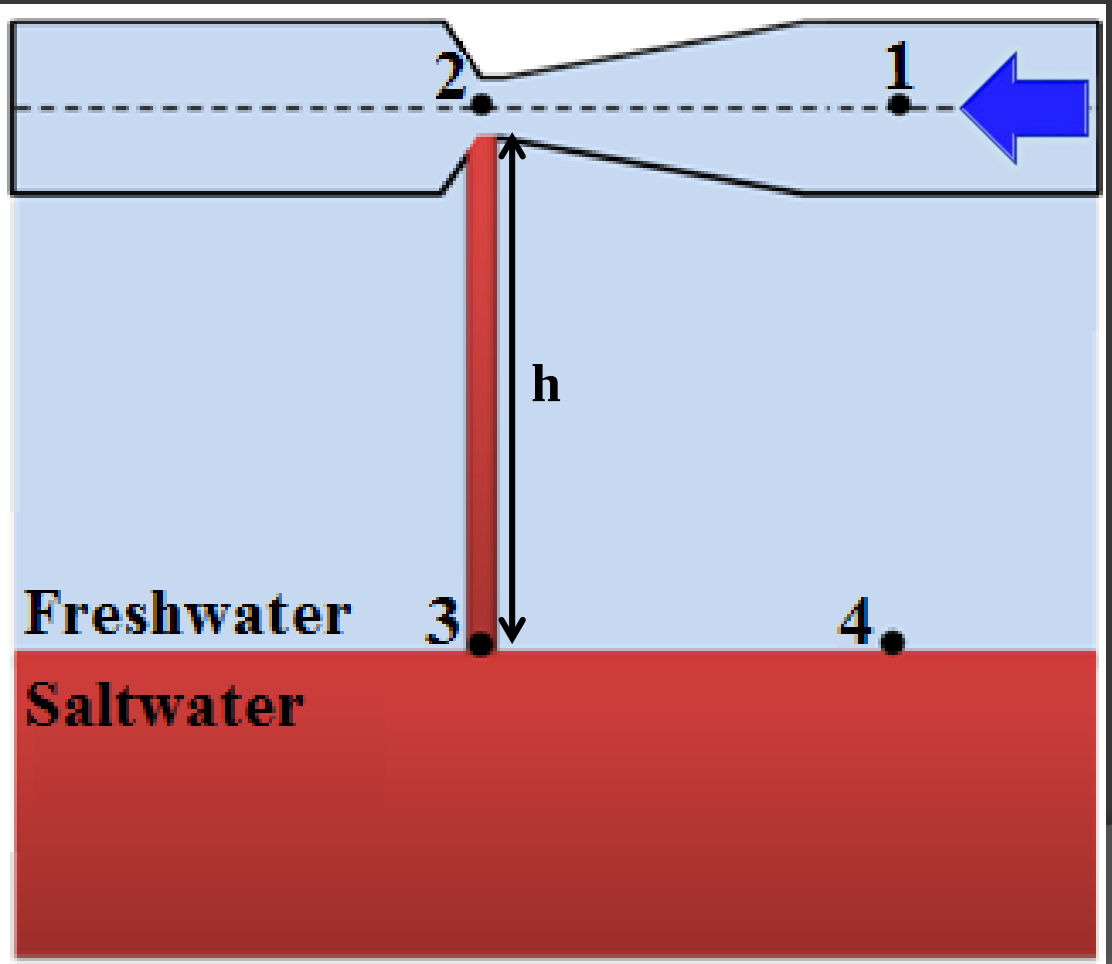


Laboratory Demo



Venturi Model (critical depth)

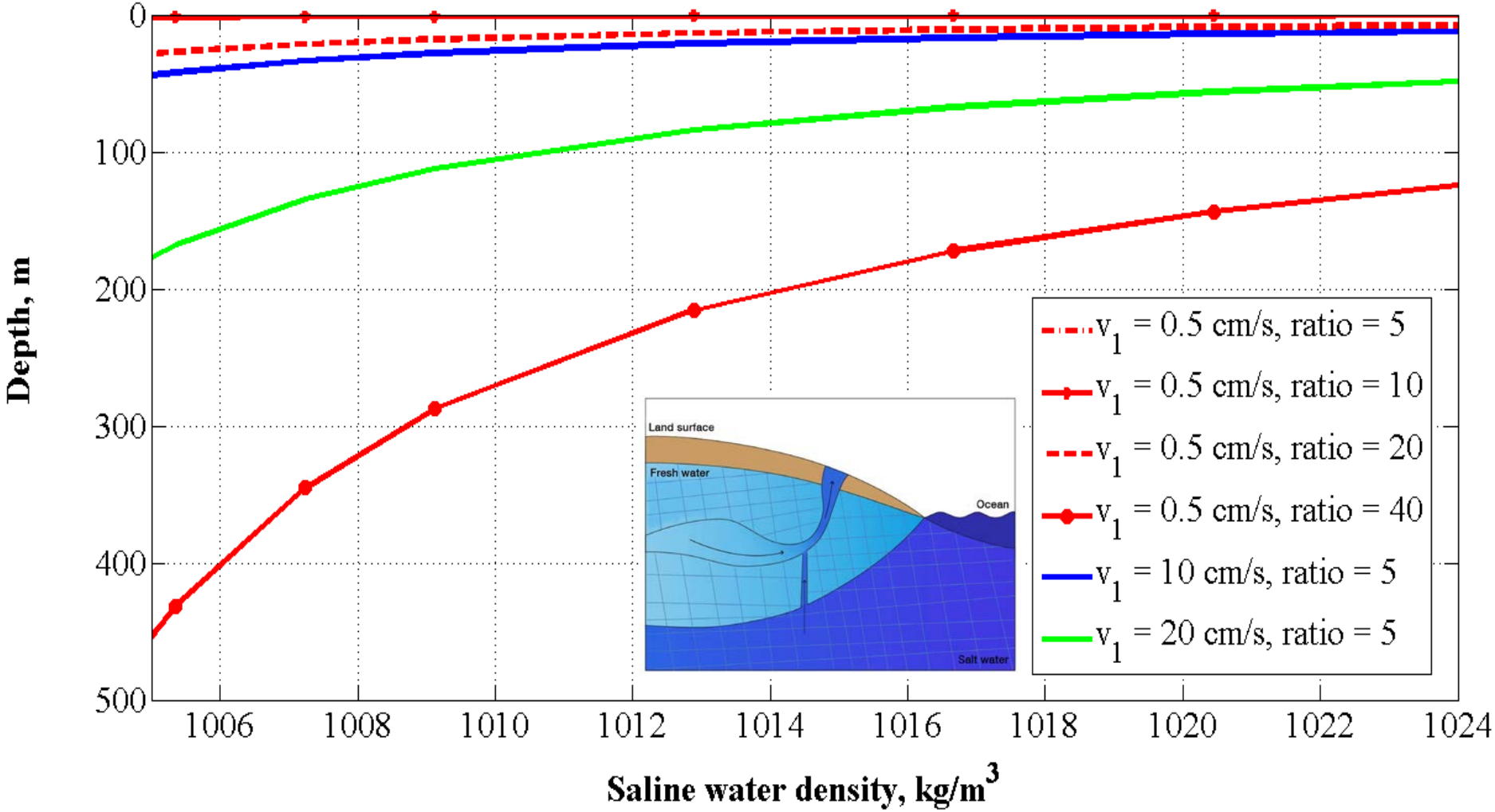
$$h_{max} = \frac{V_1^2}{2g\frac{(\rho_s - \rho_f)}{\rho_w}} \cdot \left(\frac{r_1^4}{r_2^4} - 1\right)$$



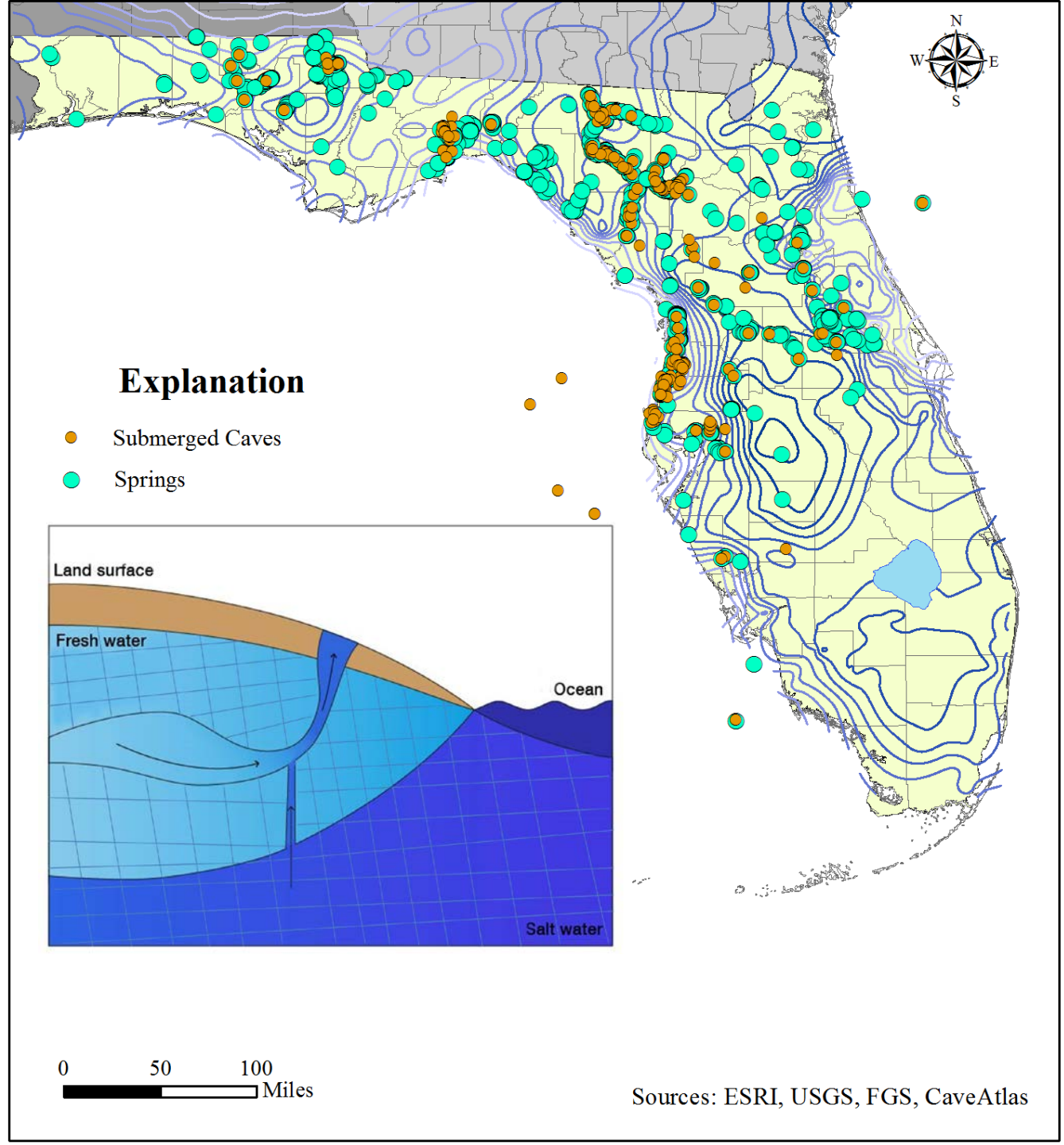
- Restrictions:
  - $2r_2$ ~ 1 – 2 m
  - V_2 ~ 1 – 5 m/s.
- Main cave tunnels
  - $2r_1$ ~ 10 –40 m
  - V_1 ~ 0.5 cm/s – 20 cm/s

(Kincaid 1999).

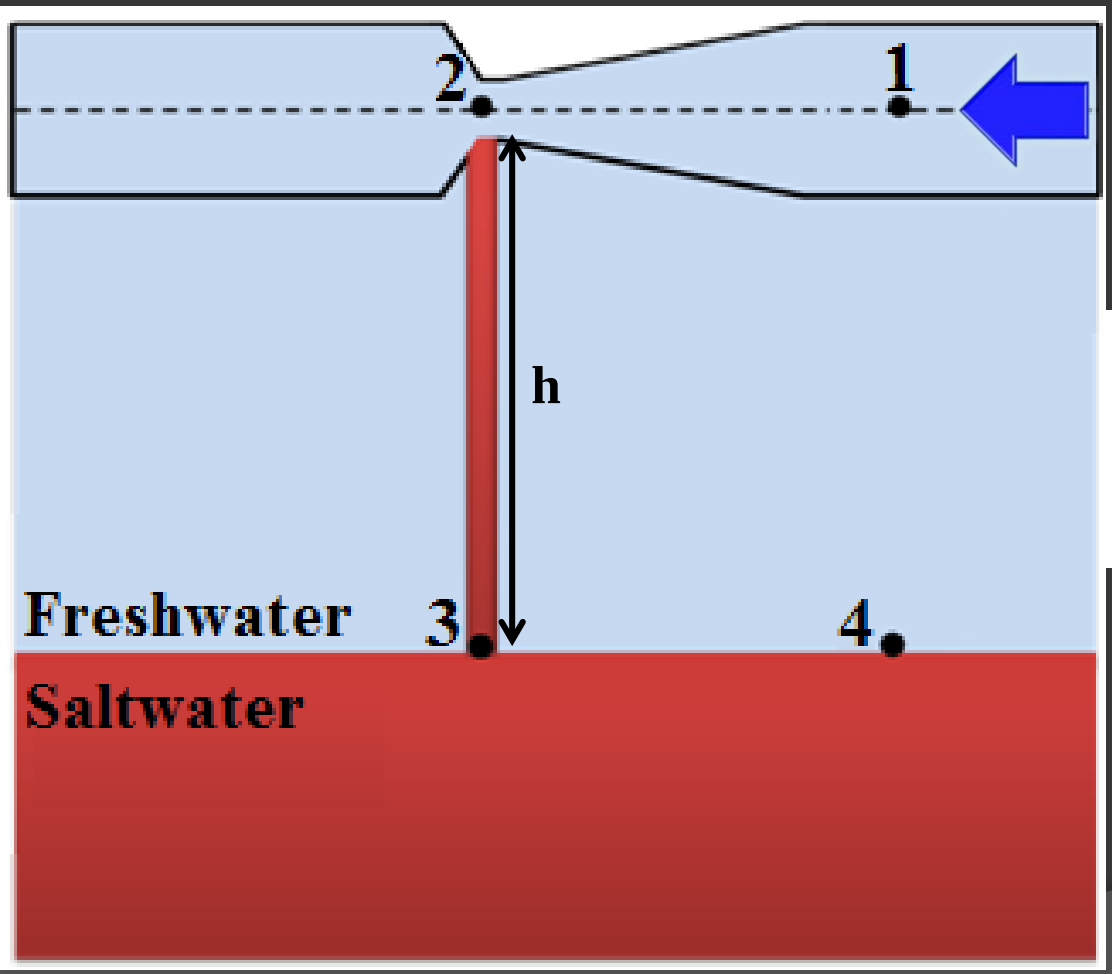
Critical depths (h_{max})



Upward velocity



Upward velocity



$$V_3 = \sqrt{\frac{\rho_f}{\rho_s} V_1^2 \left(\frac{r_1^2}{r_2^2} - 1 \right) - 2gh \frac{\rho_s - \rho_f}{\rho_s}}.$$

Name	Average discharge, m^3/s	Mean TDS, 2001-2006 (greater than 500 EPA standard)	Saltwater interface, m	Predicted Mean Saltwater discharge, m^3/s	Average total discharge/ Predicted Saltwater discharge (less than 19 based on the EPA standard)
Wakulla Springs	11	175	-183	0.19	58
Wacissa Springs	11	153	-305	0.14	81
Homosassa Springs	5	727	-152	0.20	27
Manatee Spring	5	272	-213	0.18	28
Weeki Wachee	5	174	-122	0.21	23
Gainer Springs	5	79	-396	0.07	64
Troy Spring	4	203	-396	0.07	61
Hornsby Spring	4	275	-427	0.02	182
Falmouth Spring	4	209	-305	0.14	30
Chassahowitzka	4	825	-152	0.20	19
Fanning Springs	3	268	-274	0.15	21
Silver Glen Springs	3	1020	-244	0.16	18
Alexander Springs	3	538	-396	0.07	41

Freshwater discharge/Saltwater discharge

$$\frac{Q_f}{Q_s} = \frac{\rho_s - \rho_m}{\rho_m - \rho_f}$$

ρ_m is the density of the mixed water (based on EPA standard cannot have more than 500 mg/L of TDS

ρ_s is the density of the brackish water (10,000 mg/L of TDS)

ρ_s is the density of the freshwater water (0 mg/L of TDS)

Conclusions

- Proposed a new mechanism for saltwater intrusion
- Estimated critical depths from which the saltwater intrusion can occur
- Estimated how much saltwater can intrude through several Florida springs. The research showed that Chassahowitzka Springs and Silver Glen Springs should show significant saline intrusion based on my calculations.
- The model results agree with the measurements from these springs, both of them have an elevated value of TDS.