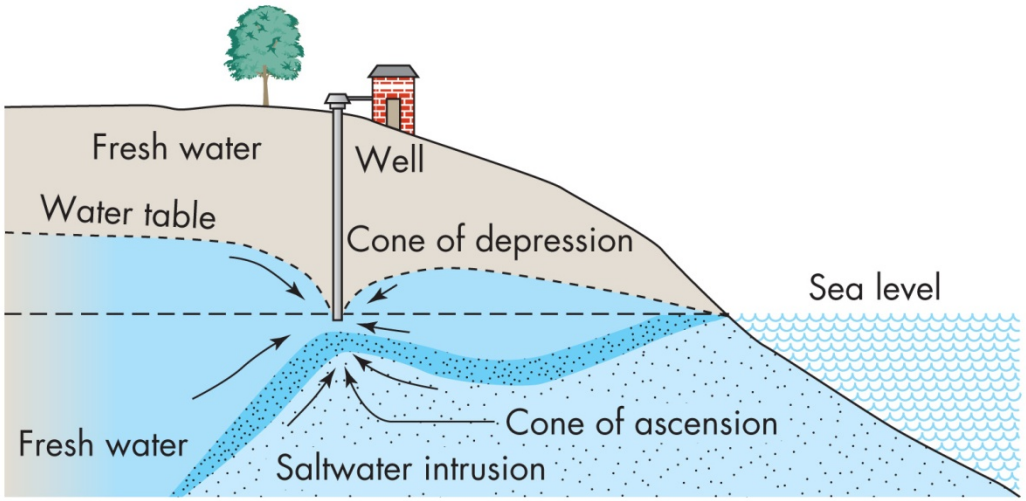
Lecture 22: Groundwater: Pumping Wells and Seawater

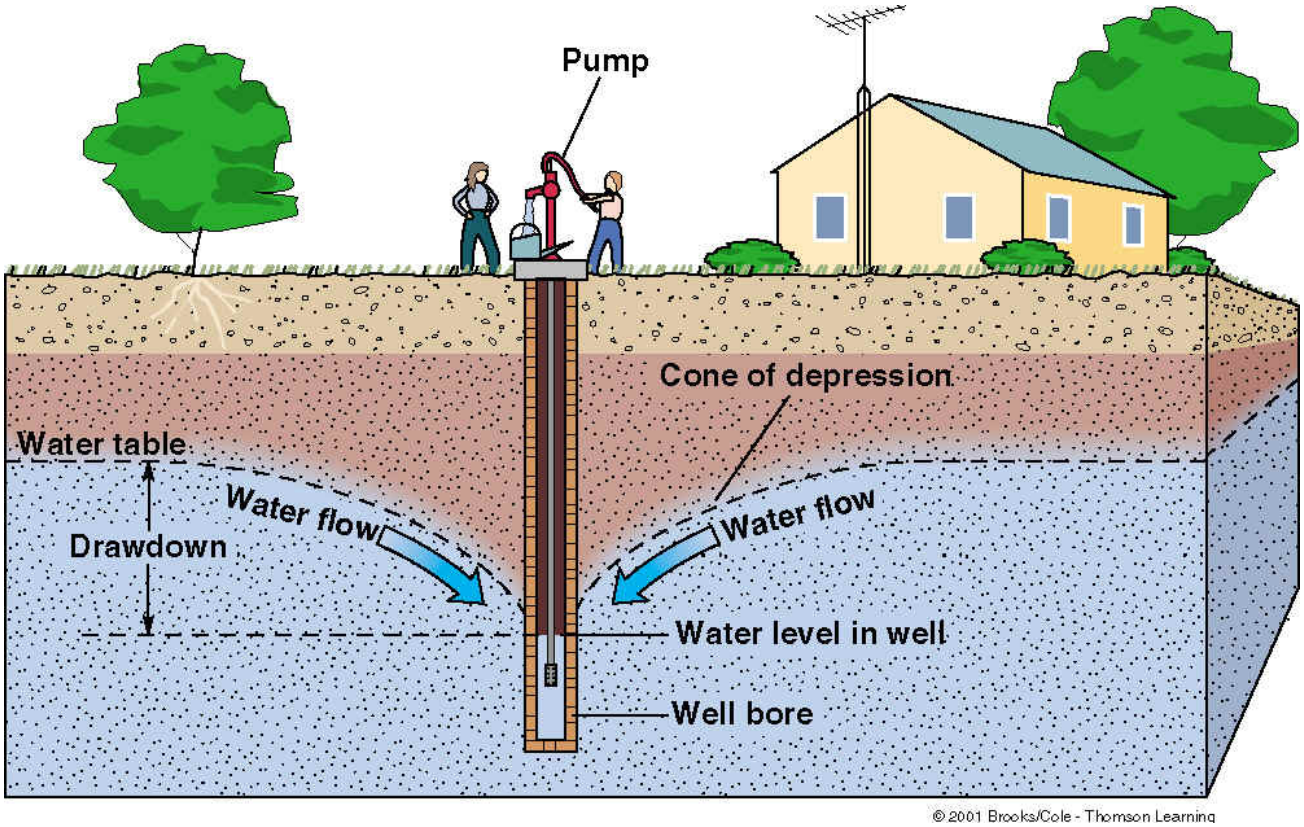
Key Questions

1. How does a groundwater well work?
2. What is a cone of depression and what controls it's size and shape?
3. What problems can occur due to over pumping of groundwater?
4. How does groundwater influence streamflow?
5. What is the Gyben-Herzberg Relation (z = 40h)
6. Why are islands susceptible to sea-water intrusion?

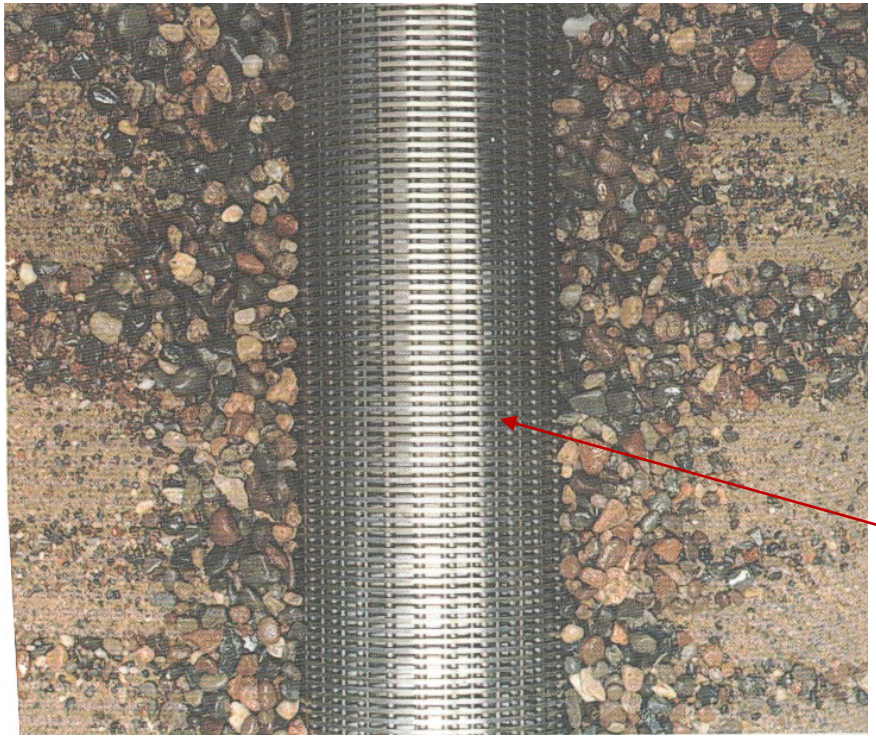


(b)

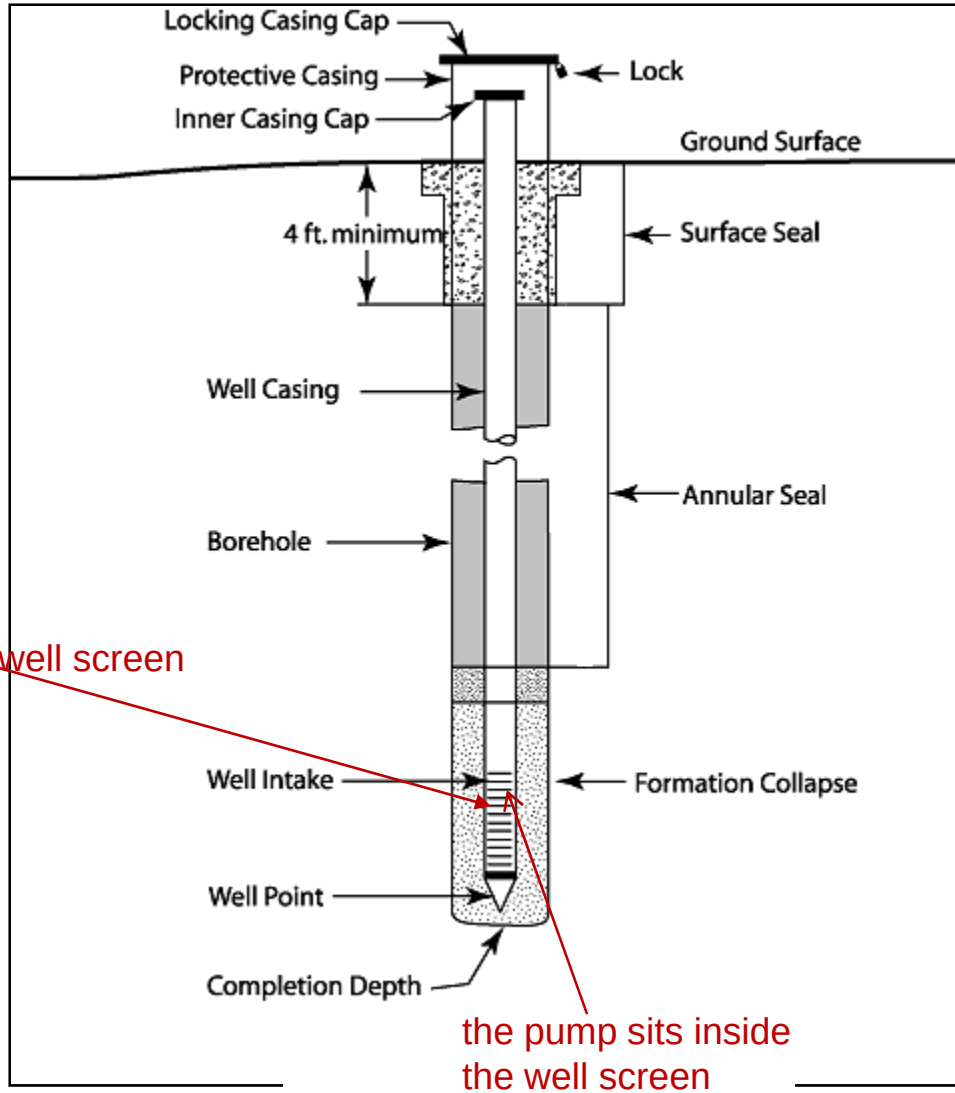
Pumping wells create a cone-of-depression in the water table



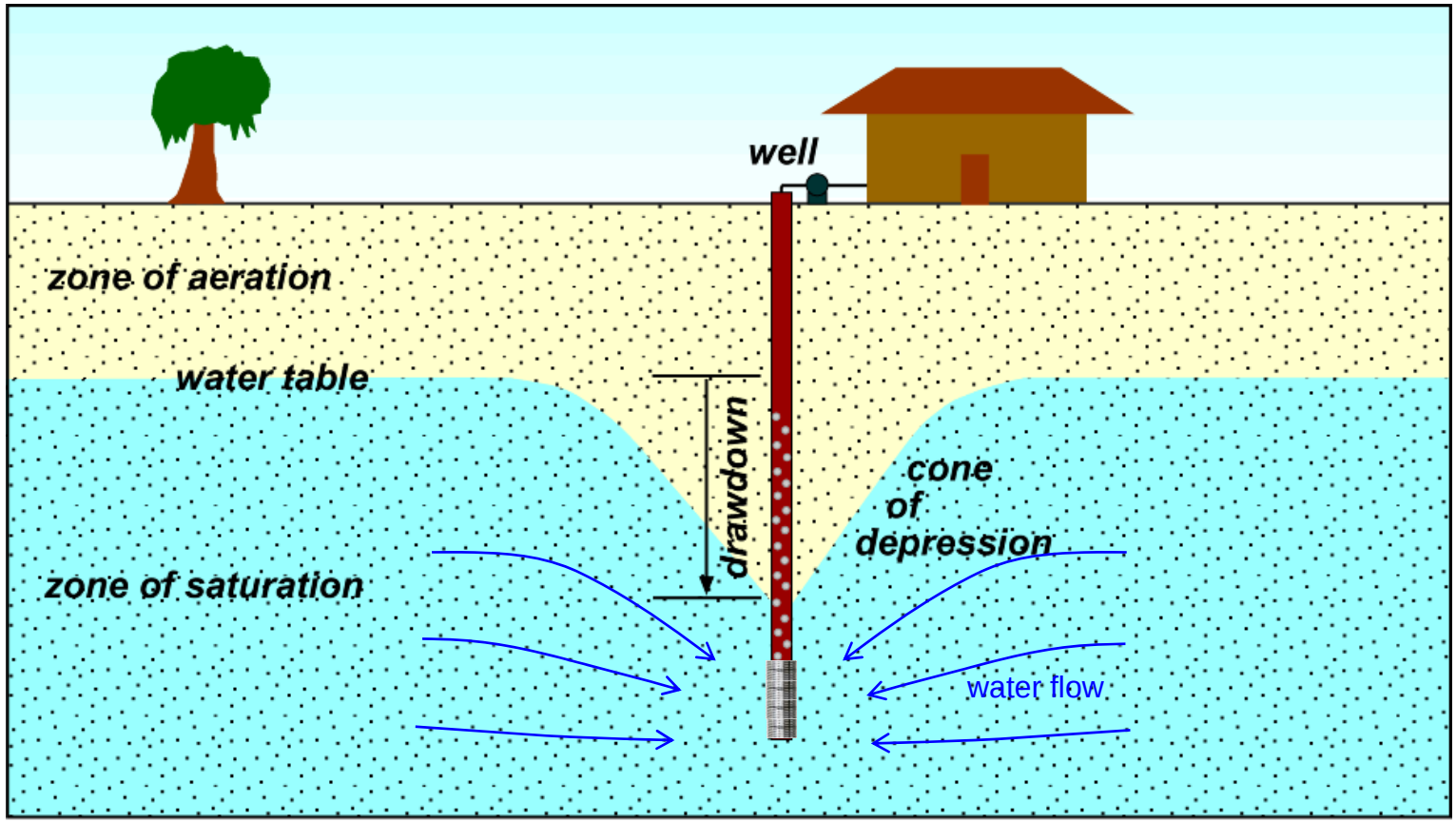
http://www.uwsp.edu/geo/faculty/ozsvath/images/cone_of_depression.htm

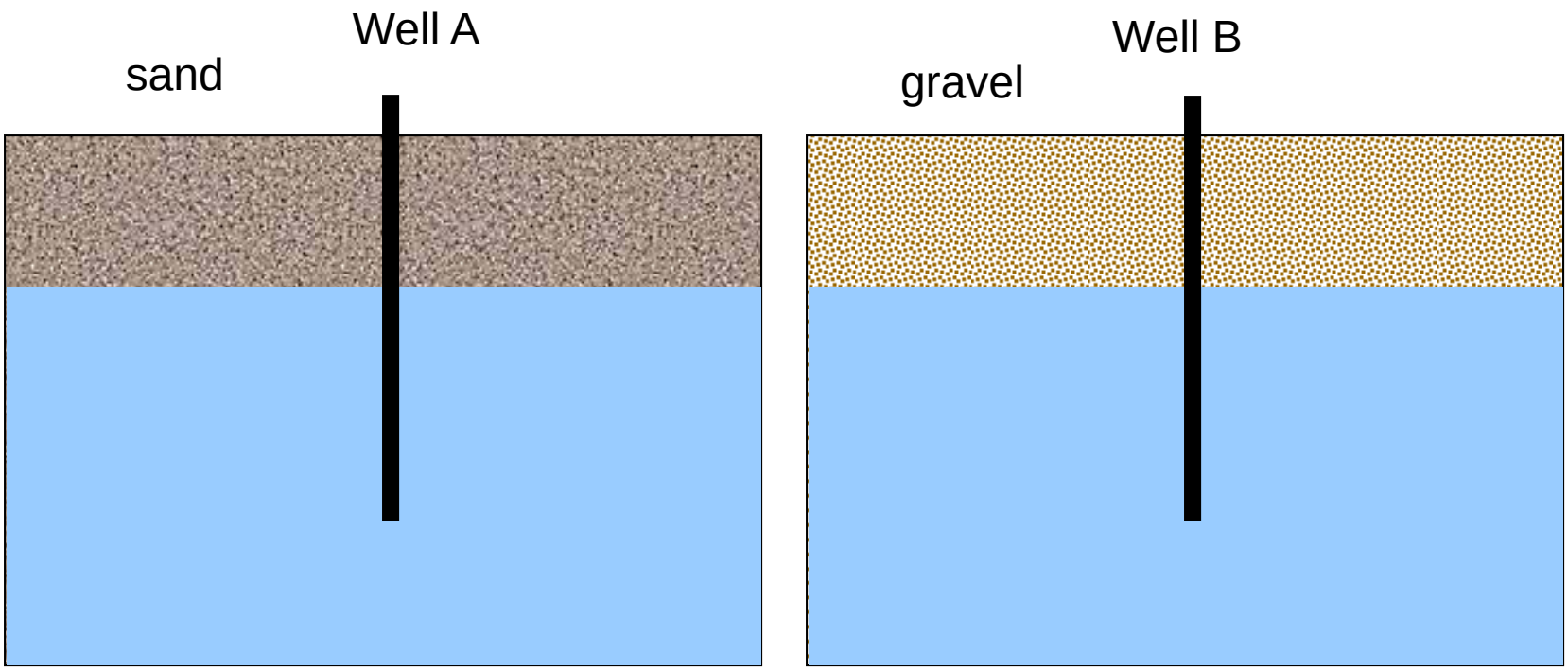


well screen

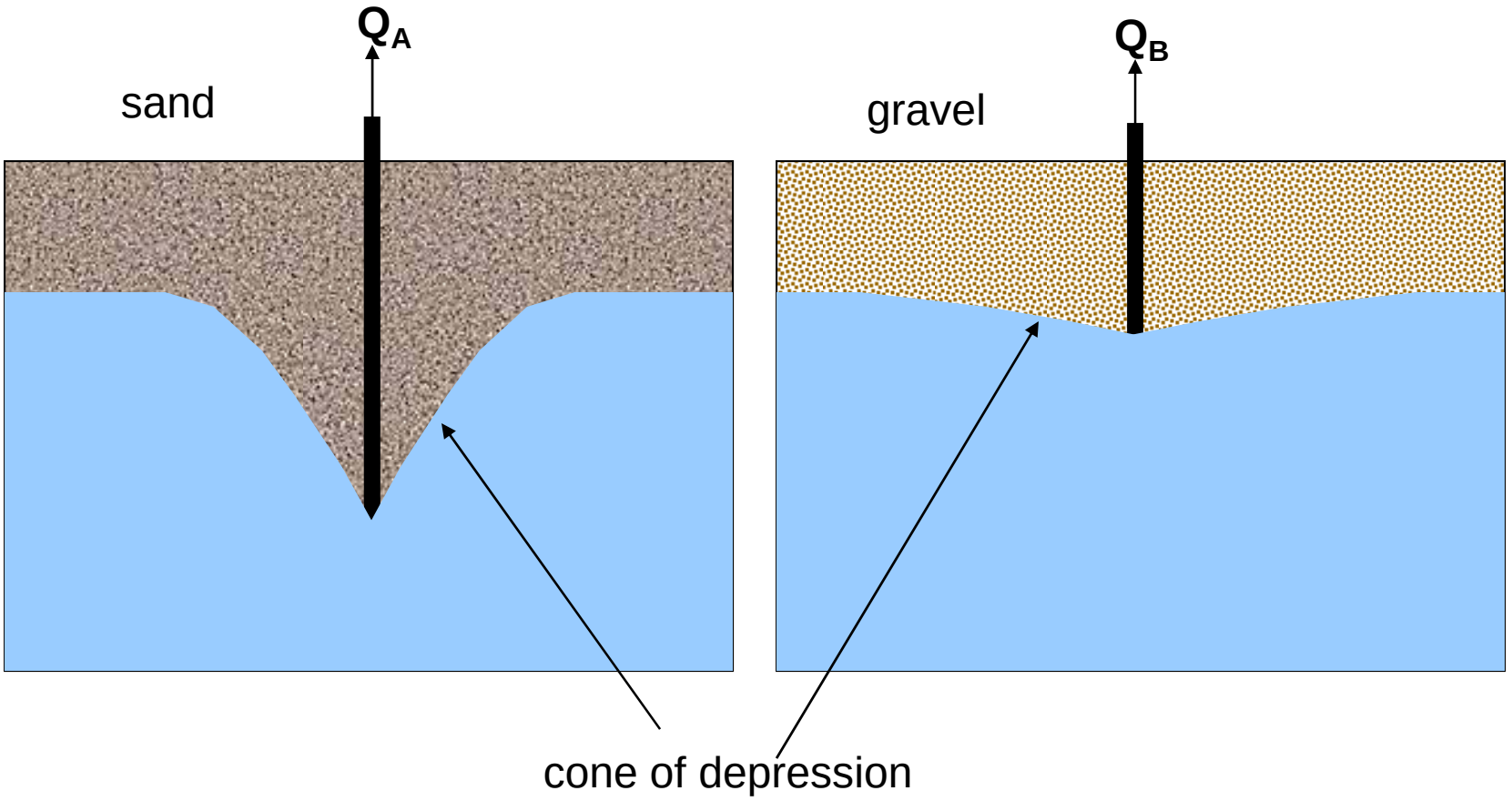


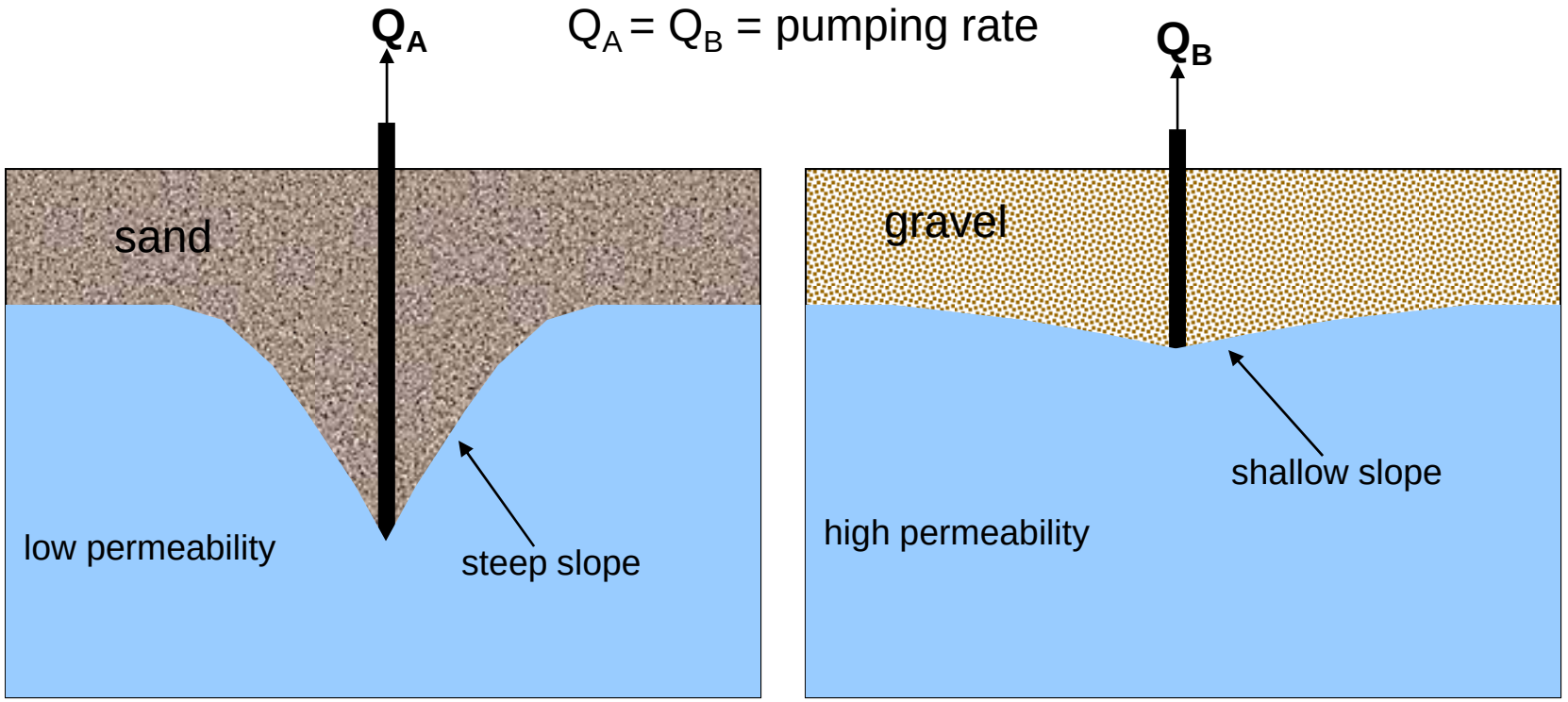
the pump sits inside
the well screen


well
zone of aeration
water table
drawdown
cone
of
depression
zone of saturation
water flow

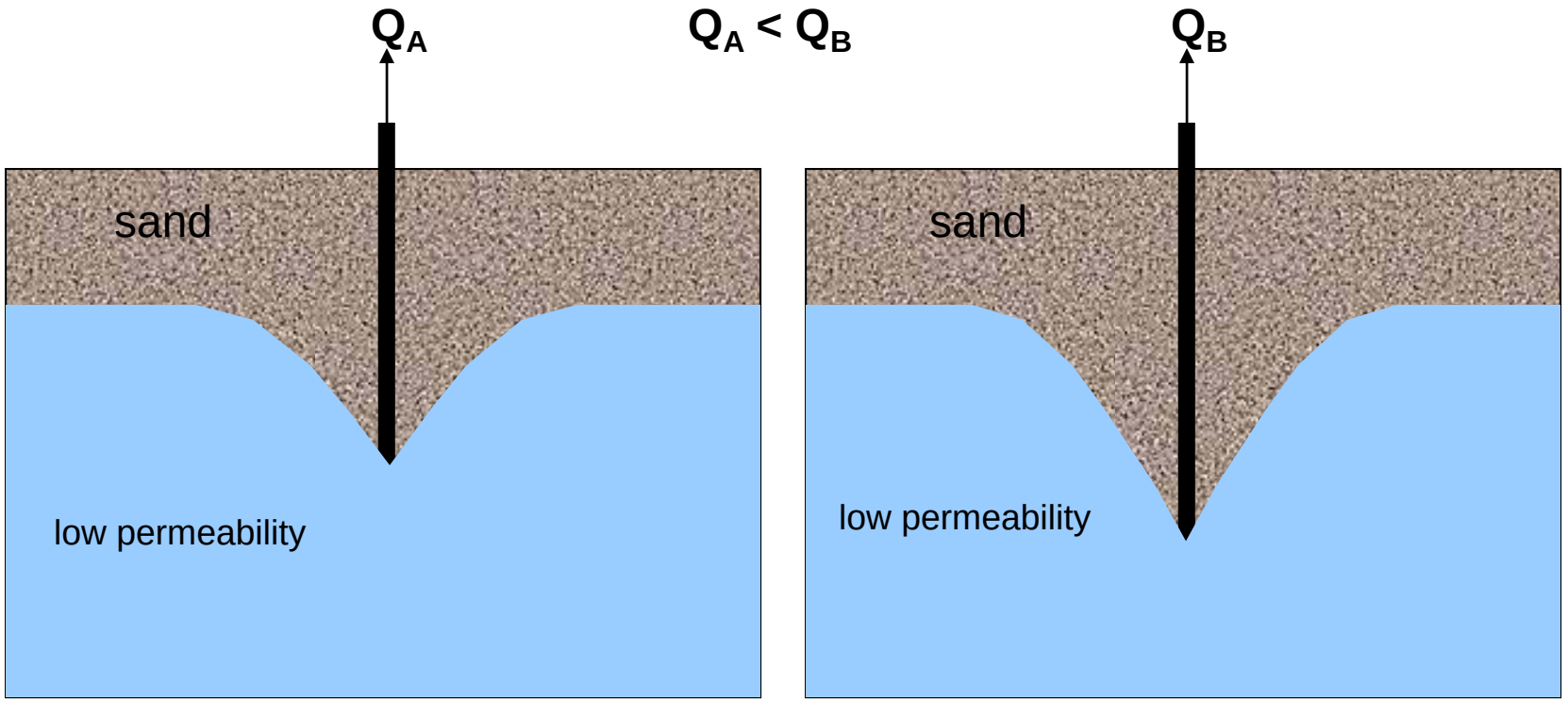

Well A
sand
Well B
gravel

$Q_A = Q_B$ = pumping rate



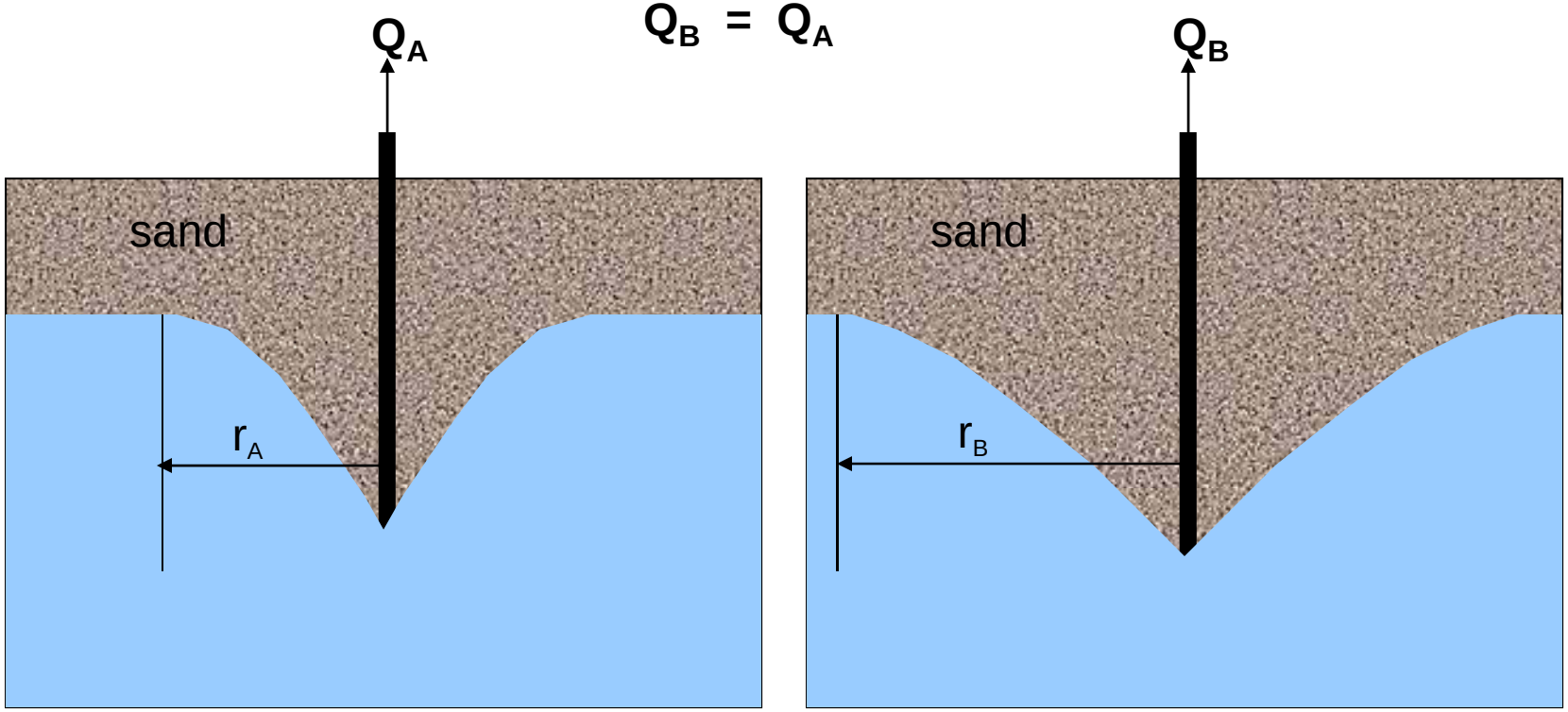


The slope of the cone of depression is determined by the permeability



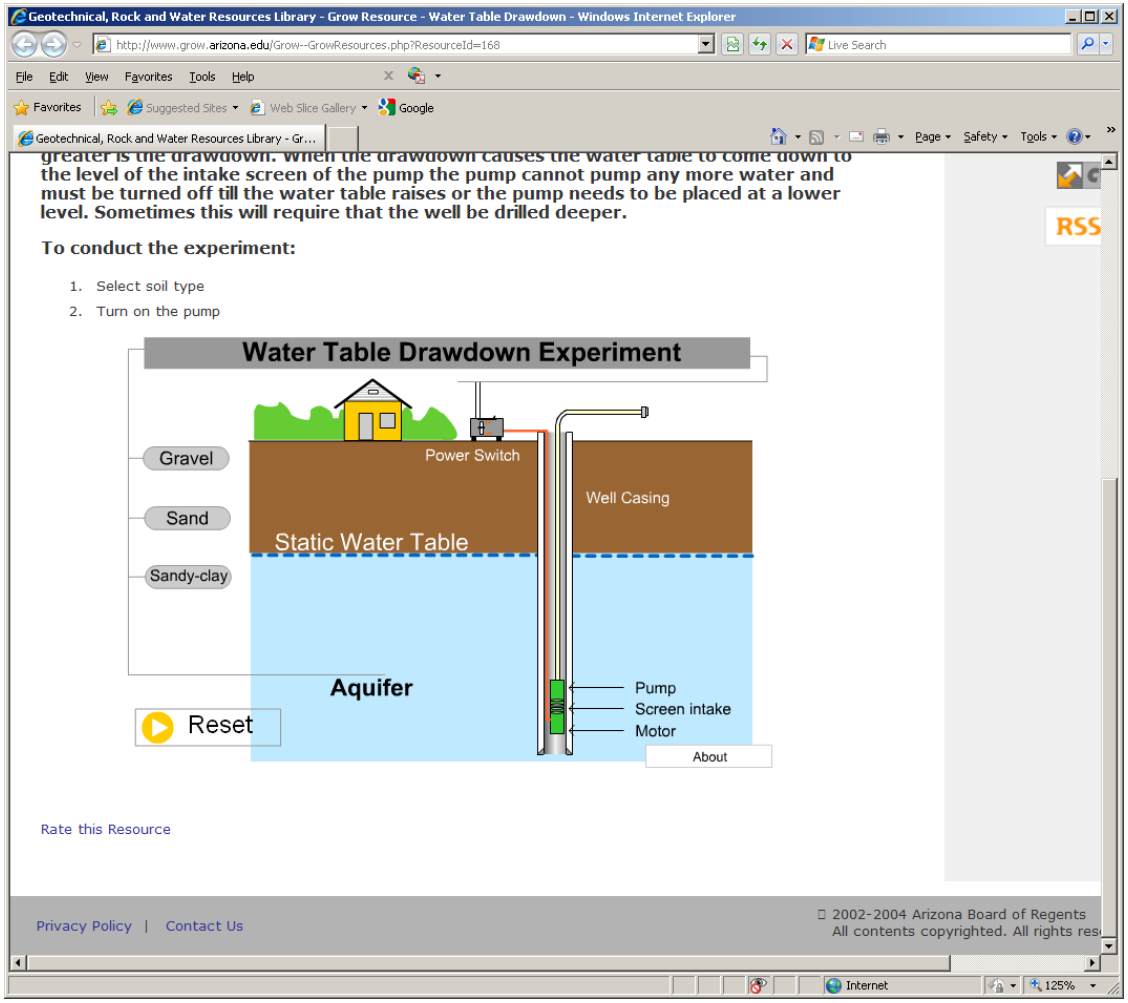
The depth of the cone of depression is determined by the pumping rate

$Q_B = Q_A$



The <u>radius</u> of the cone of depression is determined by the <u>pumping duration</u>

$r_A < r_B$


Geotechnical, Rock and Water Resources Library - Grow Resource - Water Table Drawdown - Windows Internet Explorer
http://www.grow.arizona.edu/Grow--GrowResources.php?ResourceId=168
Live Search
File Edit View Favorites Tools Help
Favorites
Suggested Sites
Web Slice Gallery
Google
Geotechnical, Rock and Water Resources Library - Gr...
Page Safety Tools
greater is the drawdown. When the drawdown causes the water table to come down to the level of the intake screen of the pump the pump cannot pump any more water and must be turned off till the water table raises or the pump needs to be placed at a lower level. Sometimes this will require that the well be drilled deeper.
To conduct the experiment:
1. Select soil type
2. Turn on the pump
Water Table Drawdown Experiment
Gravel
Sand
Sandy-clay
Power Switch
Well Casing
Static Water Table
Aquifer
Pump
Screen intake
Motor
Reset
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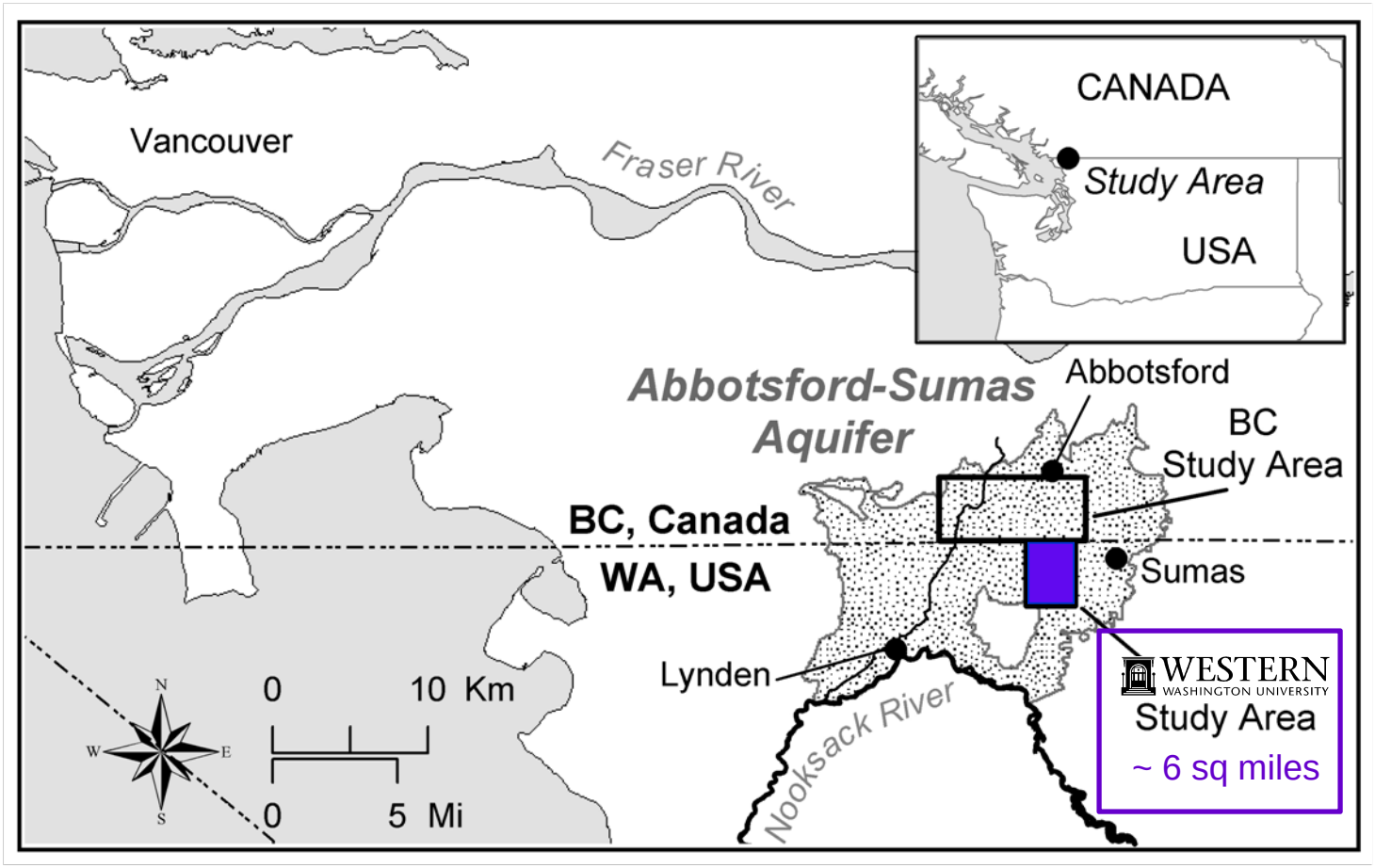
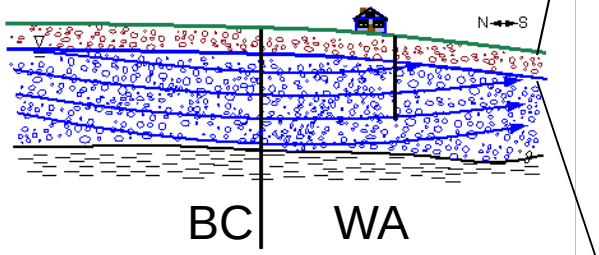
Internet
125%

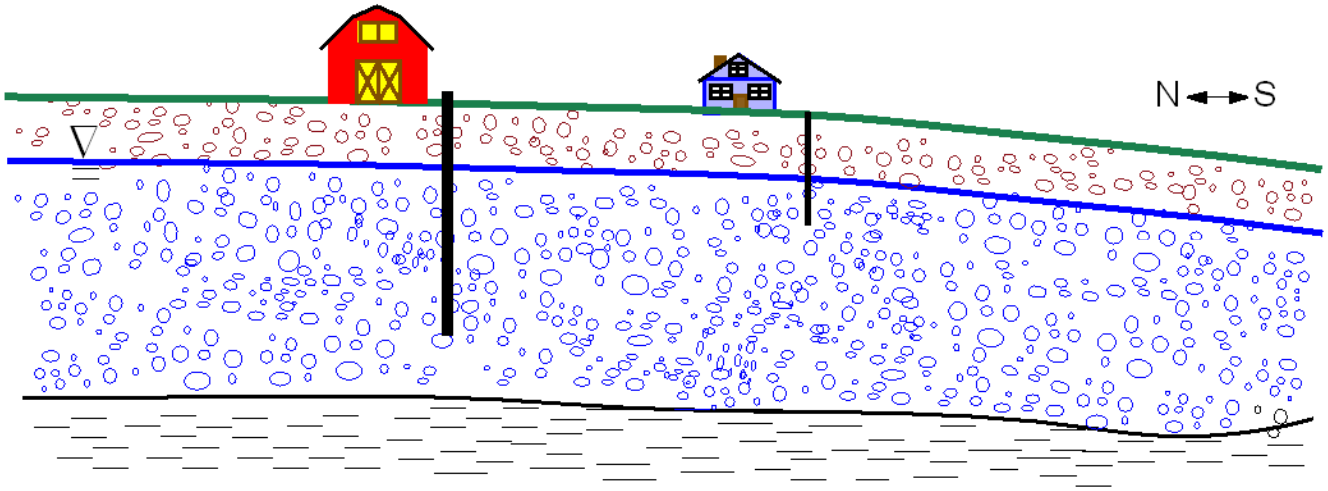
Study Area


Vancouver
Fraser River
CANADA
Study Area
USA
Abbotsford-Sumas
Aquifer
Abbotsford
BC
Study Area
BC, Canada
WA, USA
Sumas
Lynden
Nooksack River
N
W
E
S
0
10 Km
0
5 Mi
WESTERN
WASHINGTON UNIVERSITY
Study Area
~ 6 sq miles

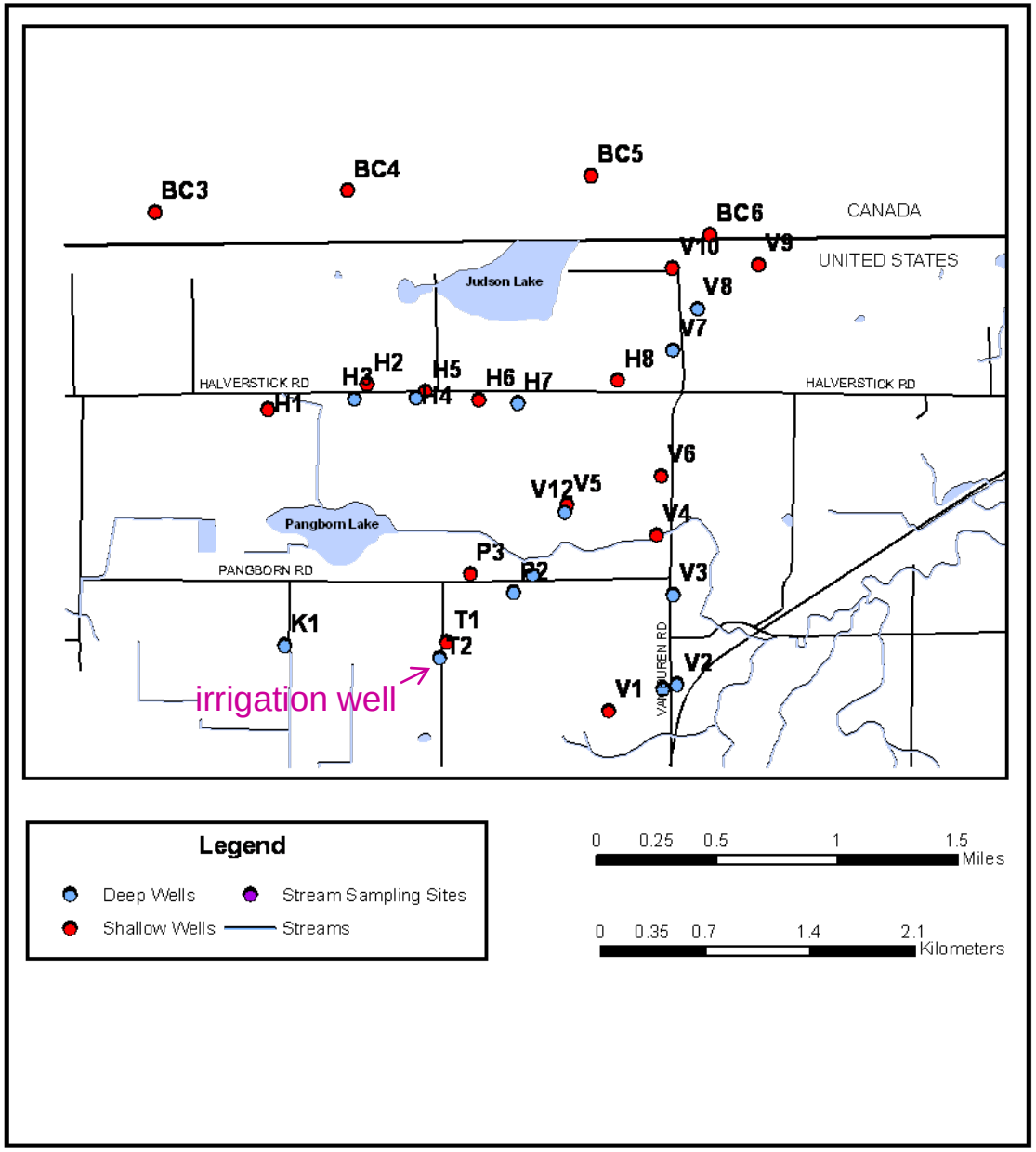


Water table is just below the ground surface

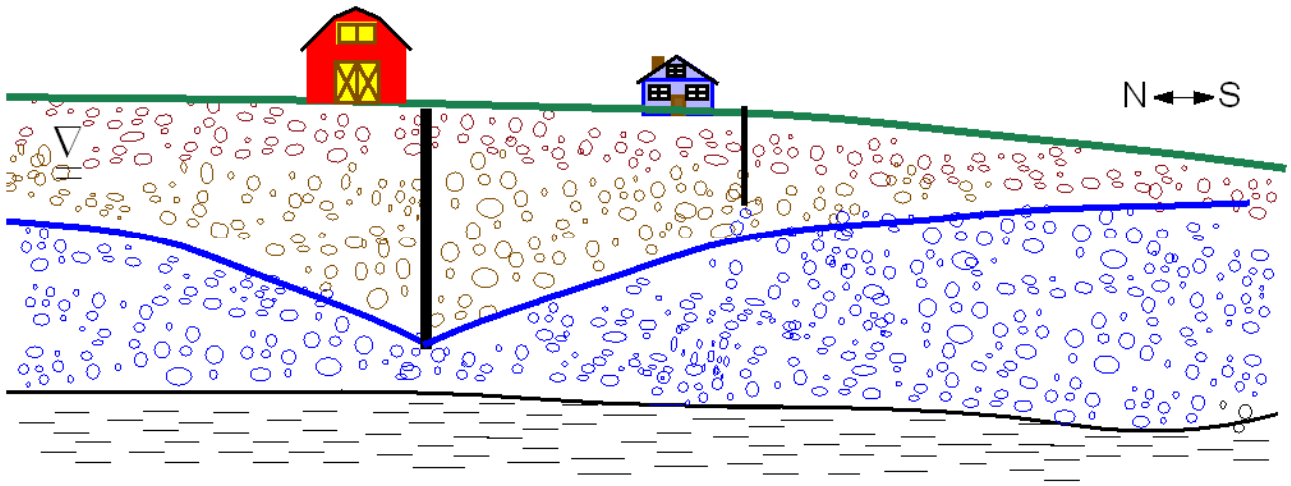
Pumping wells can influence neighboring wells



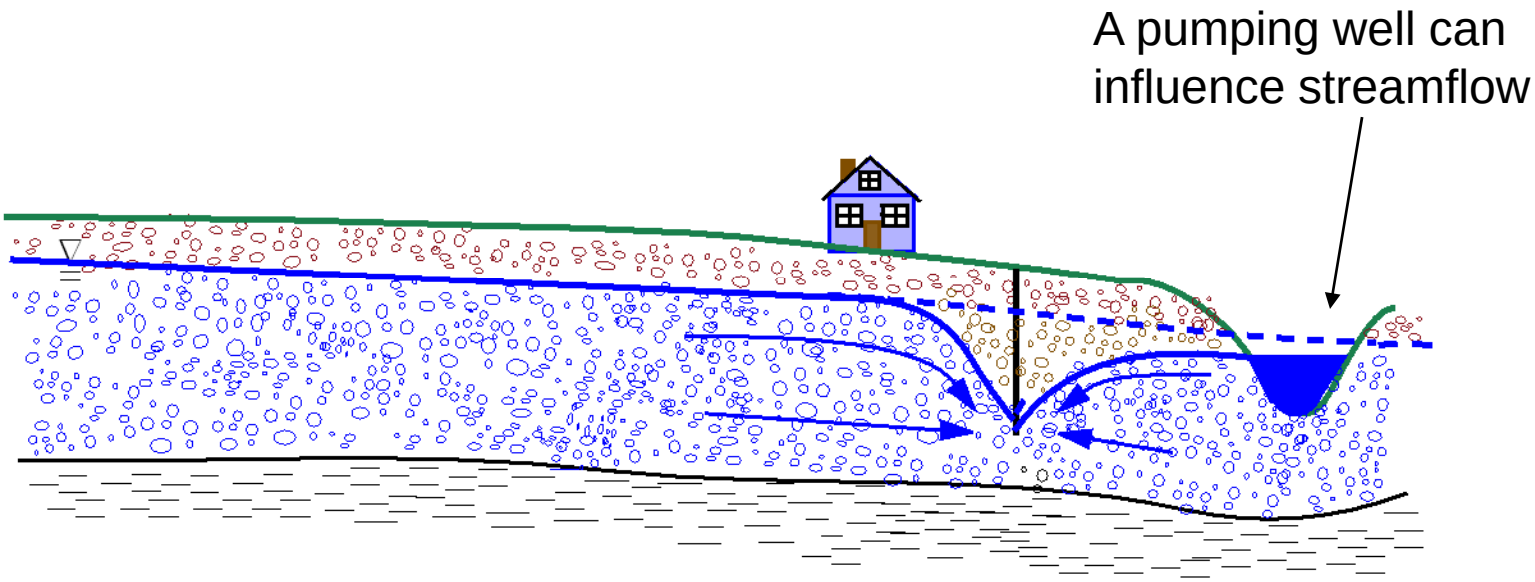
Irrigation Well



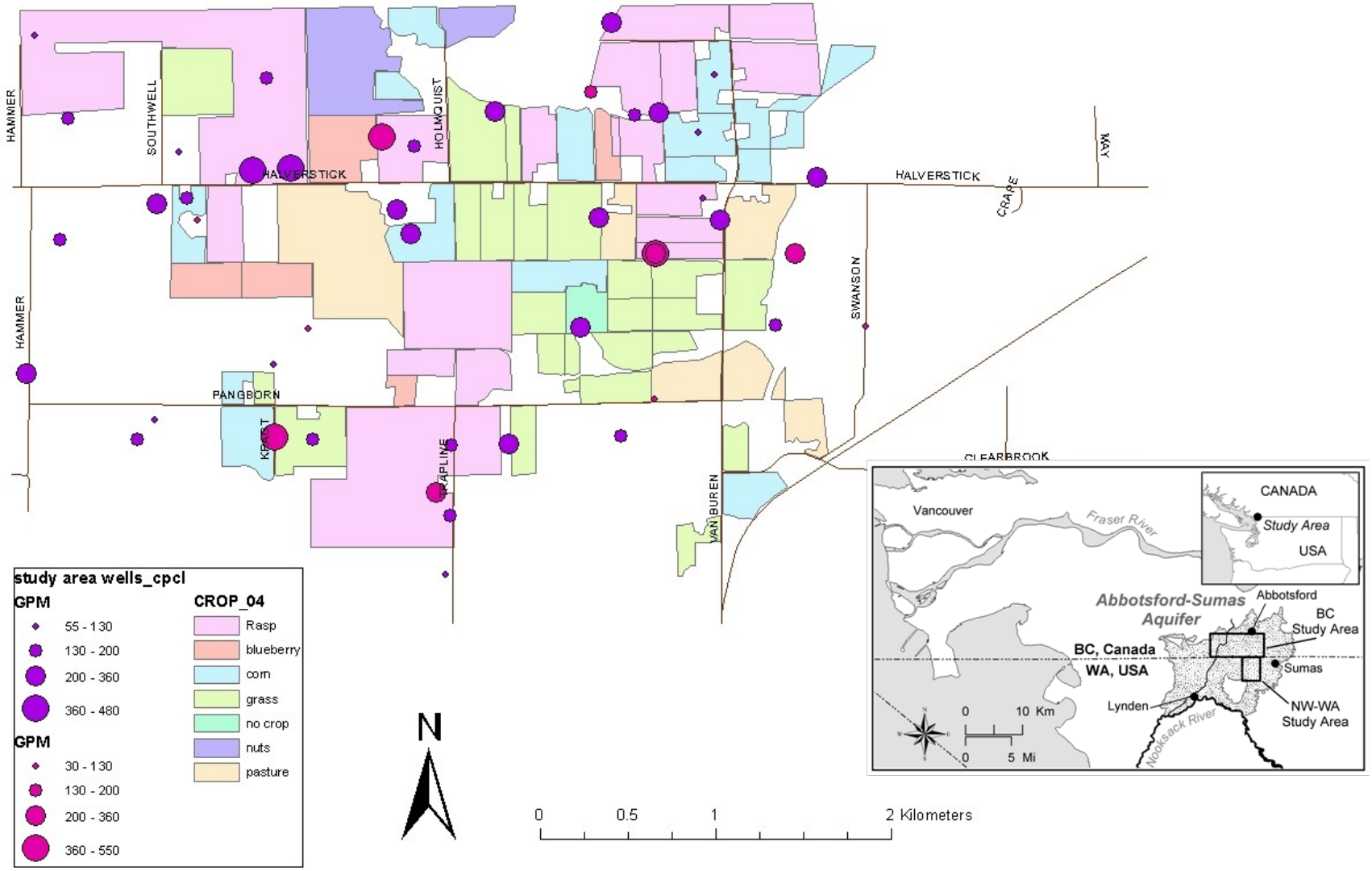
Over pumping of irrigation well lowers the water table below the domestic well (water rights)



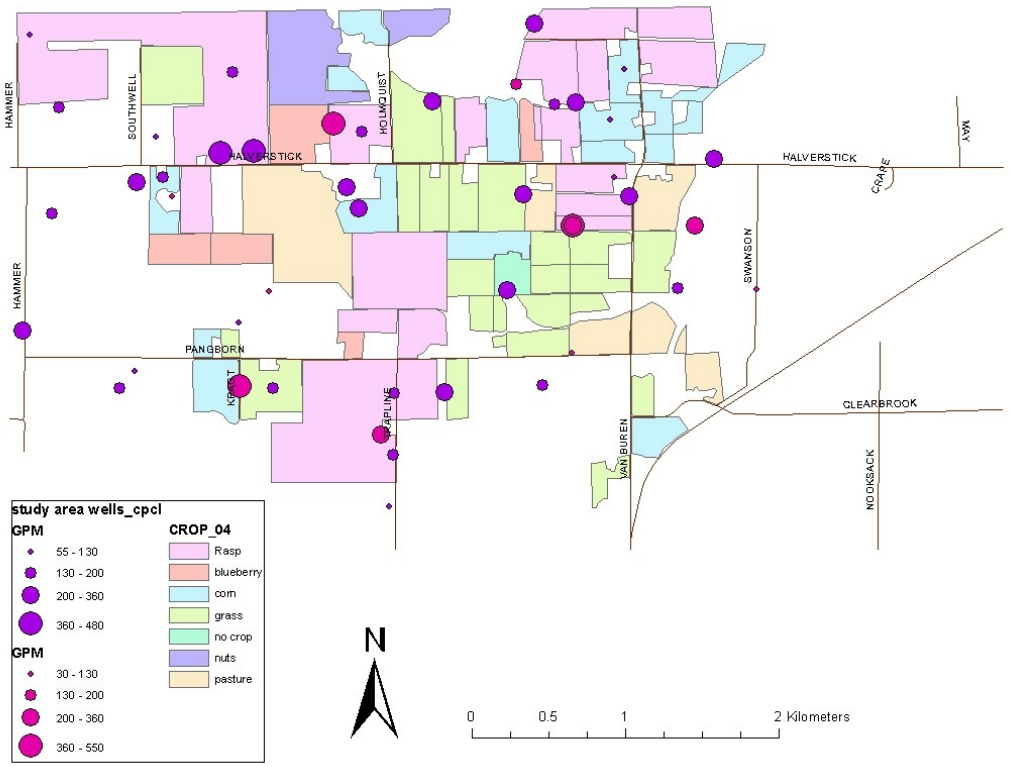
Groundwater surface water interactions



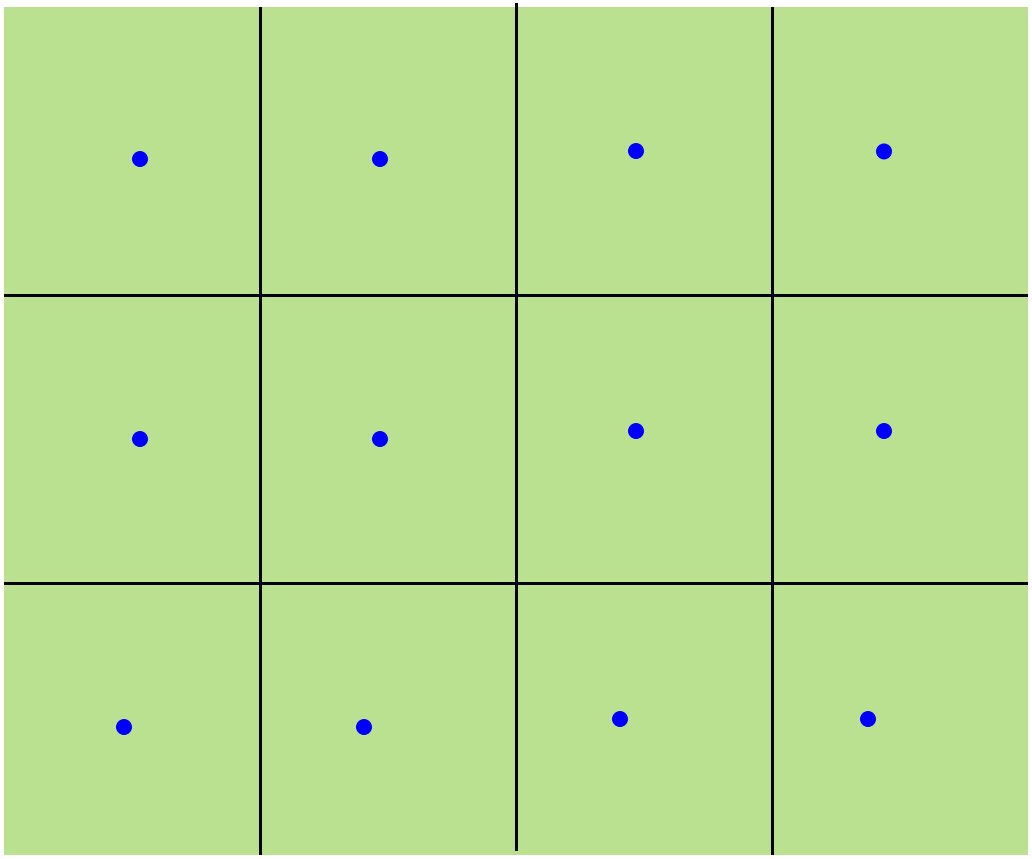
Irrigation Wells in the study area



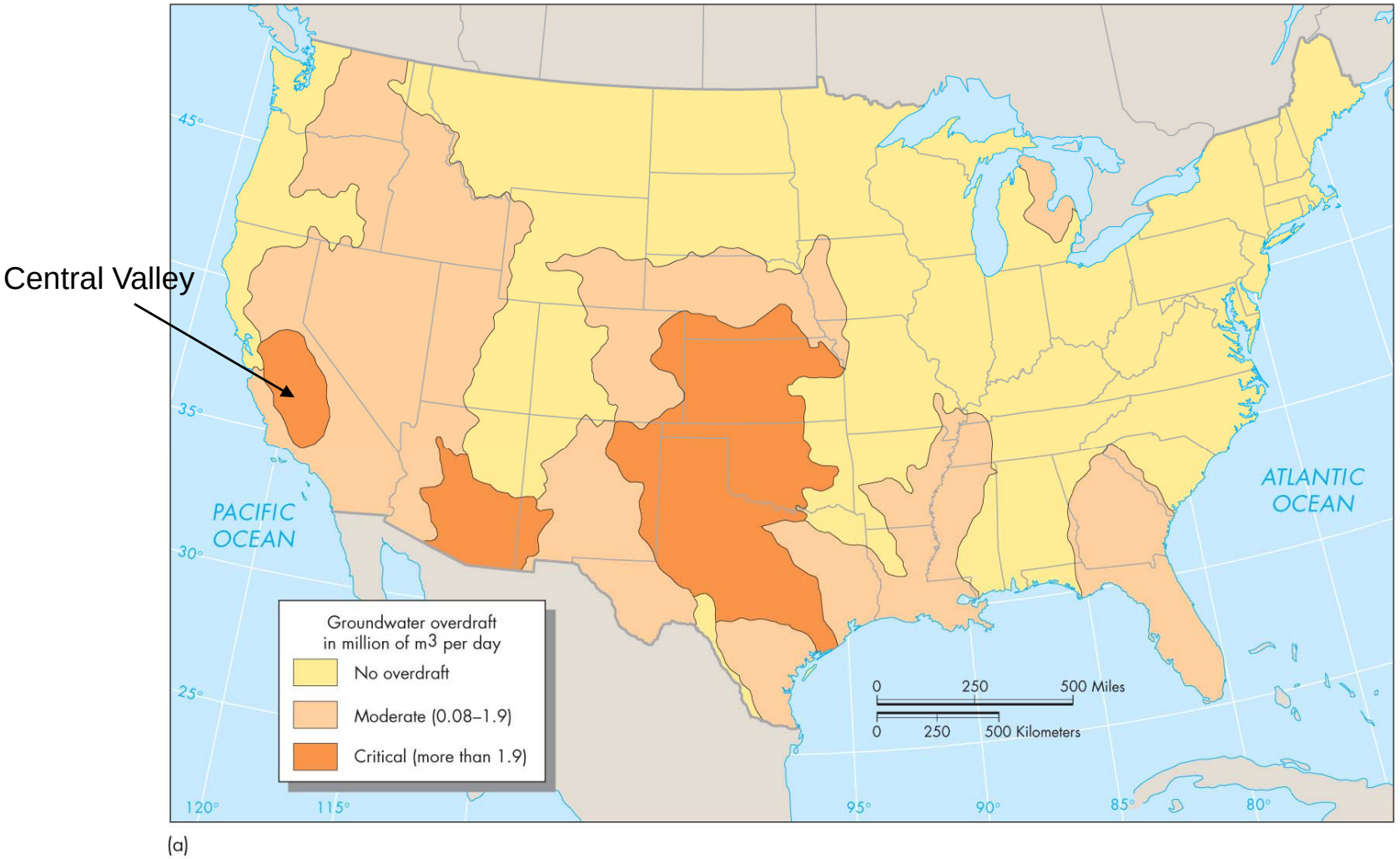
Sate law highly restricts the water rights of farmers



However, State law allows Exempt wells (low use wells). So, farmers could sell there land for subdivisions and many homes can drill a well without needing a water right. This is a problem.

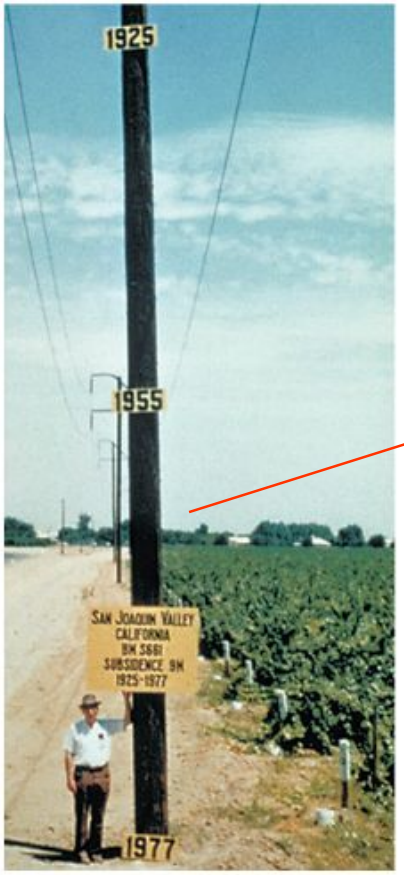


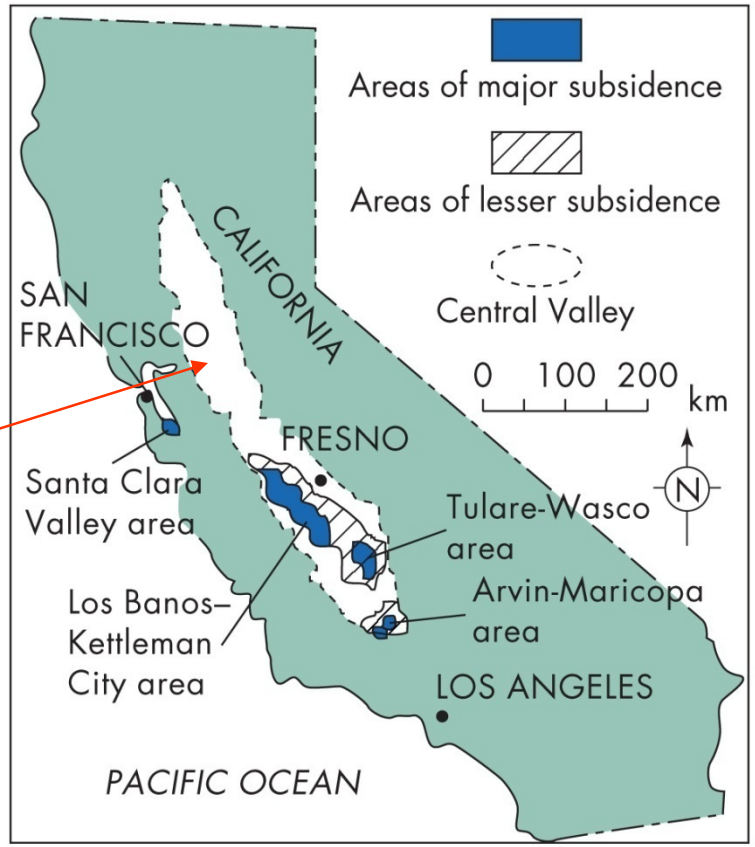
Groundwater “overdraft” mainly due to agricultural irrigation



(a)

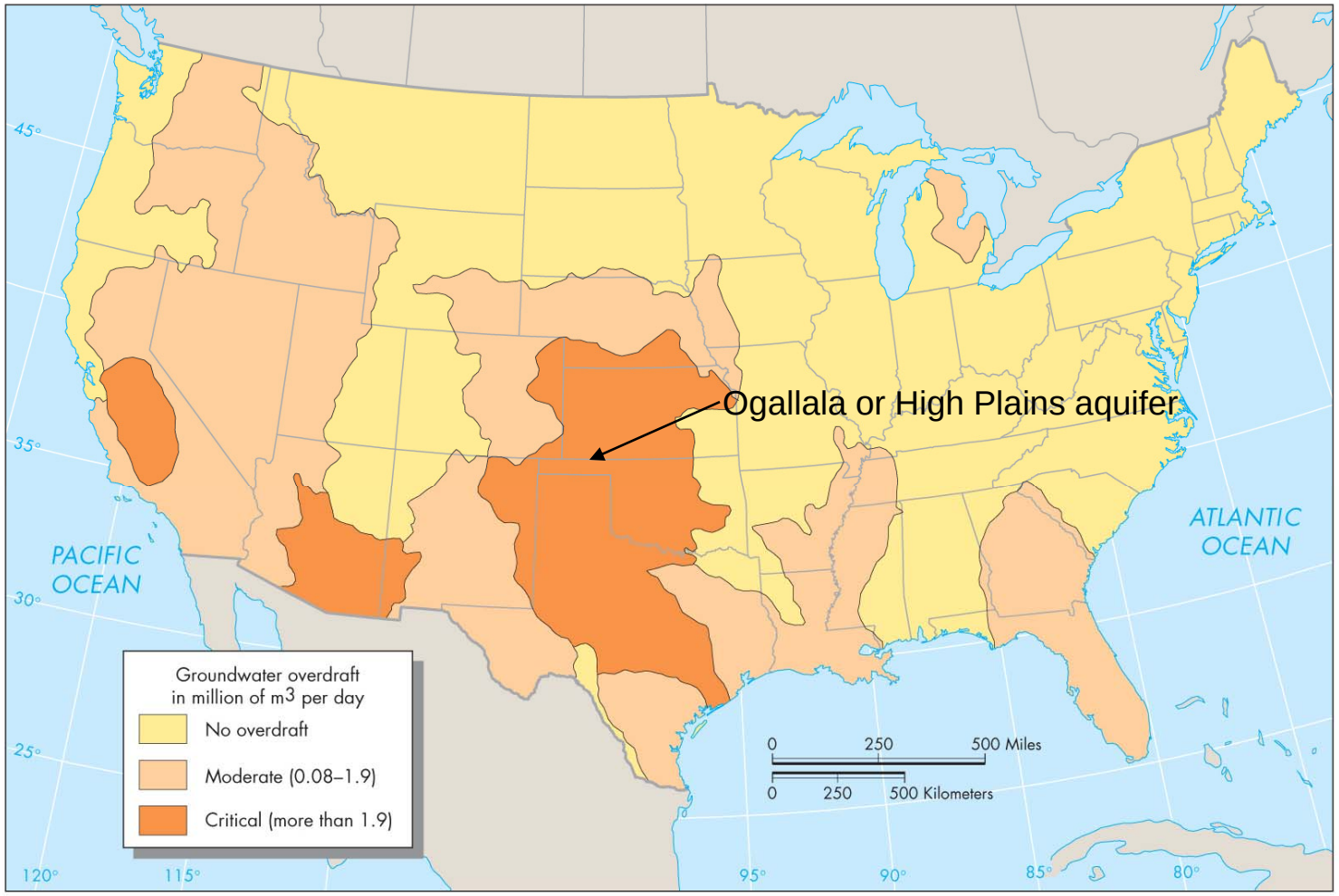
Over pumping can cause land subsidence





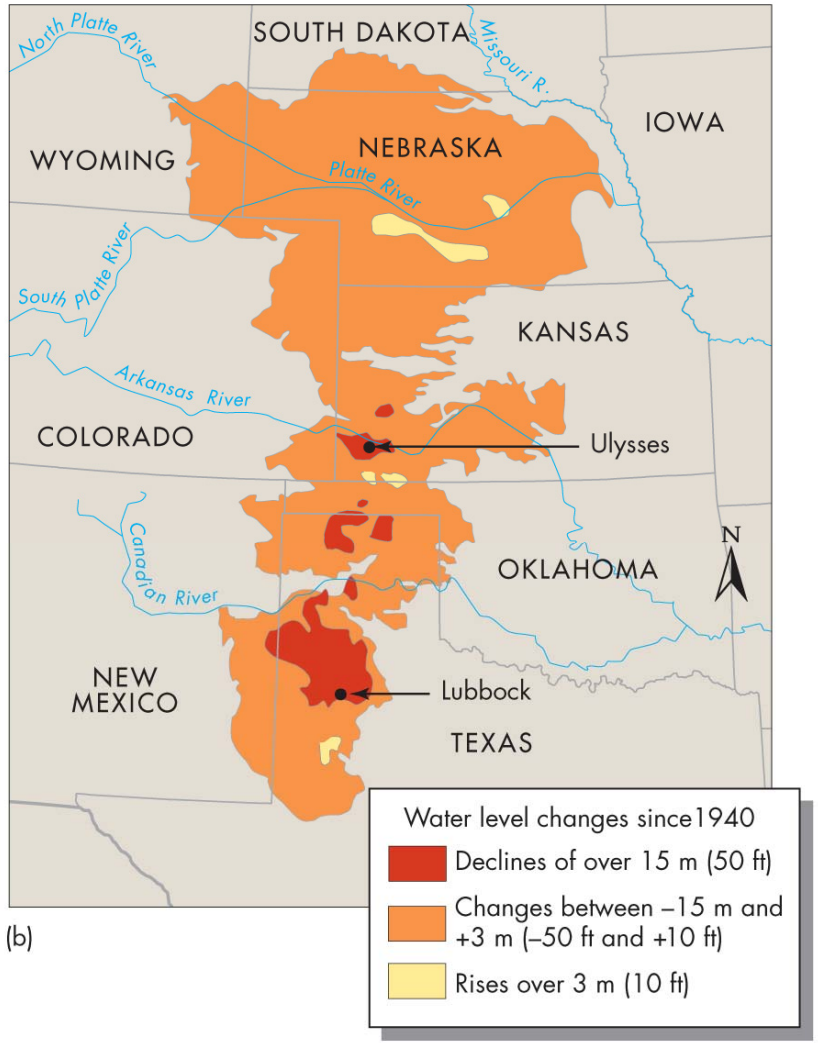
(a)

Groundwater “overdraft” mainly due to agricultural irrigation



(a)

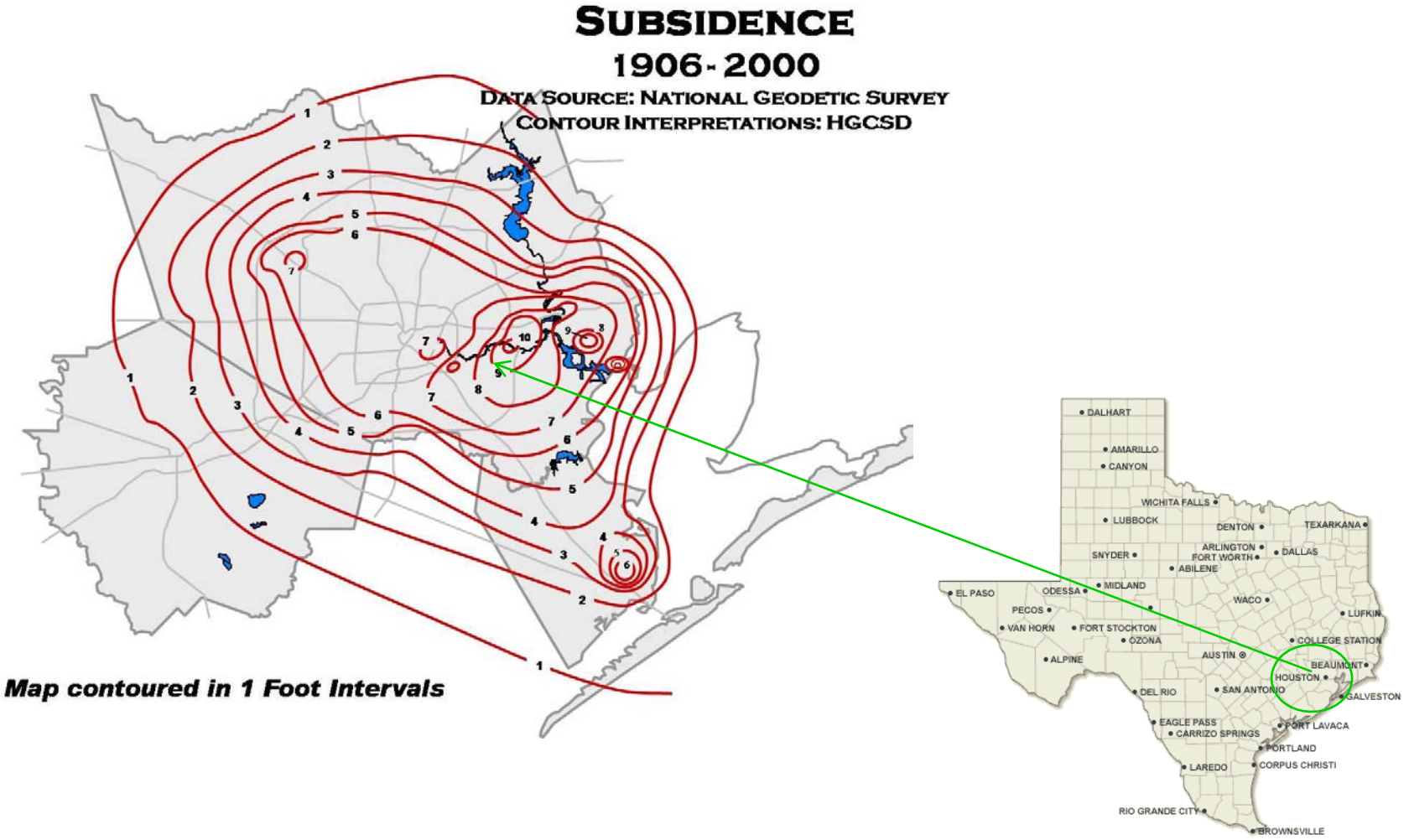
Ogallala or High Plains aquifer



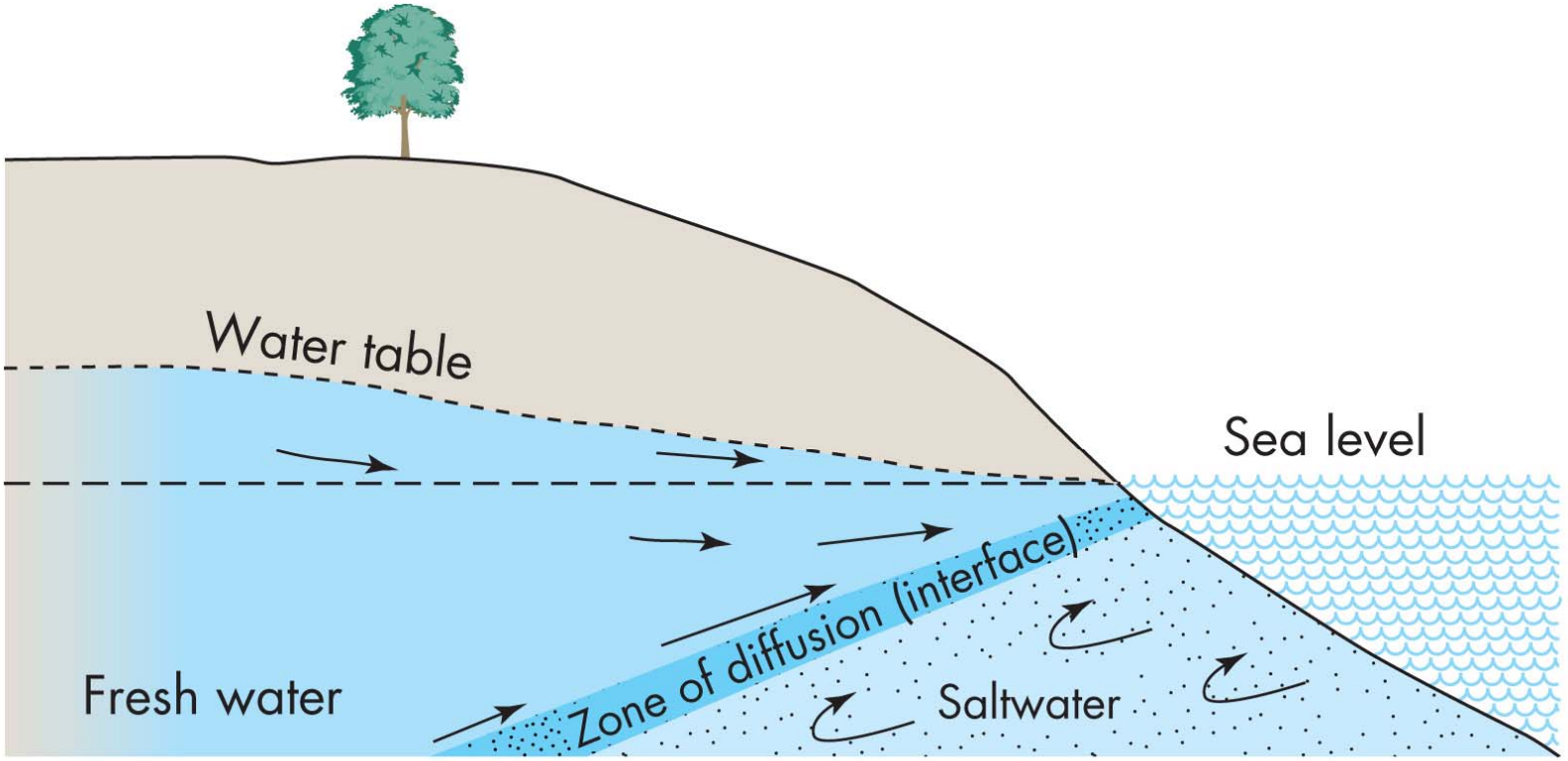
(b)

withdrawal exceeds recharge

Houston region in the state of Texas

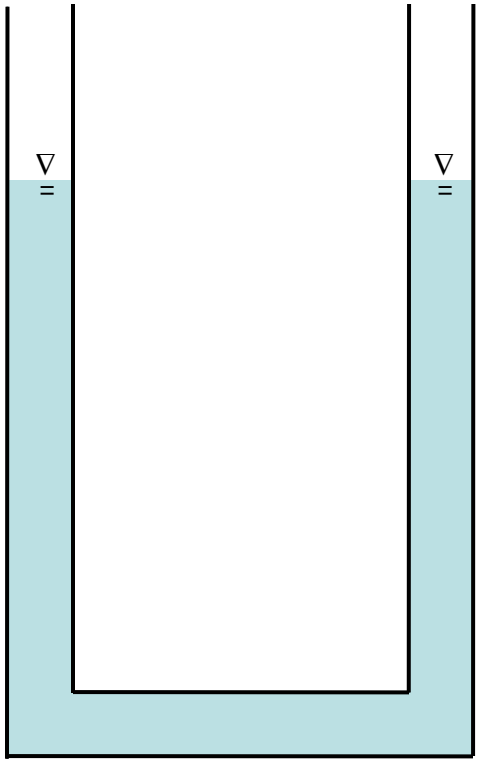


Gyben-Herzberg Relation (sea water intrusion)

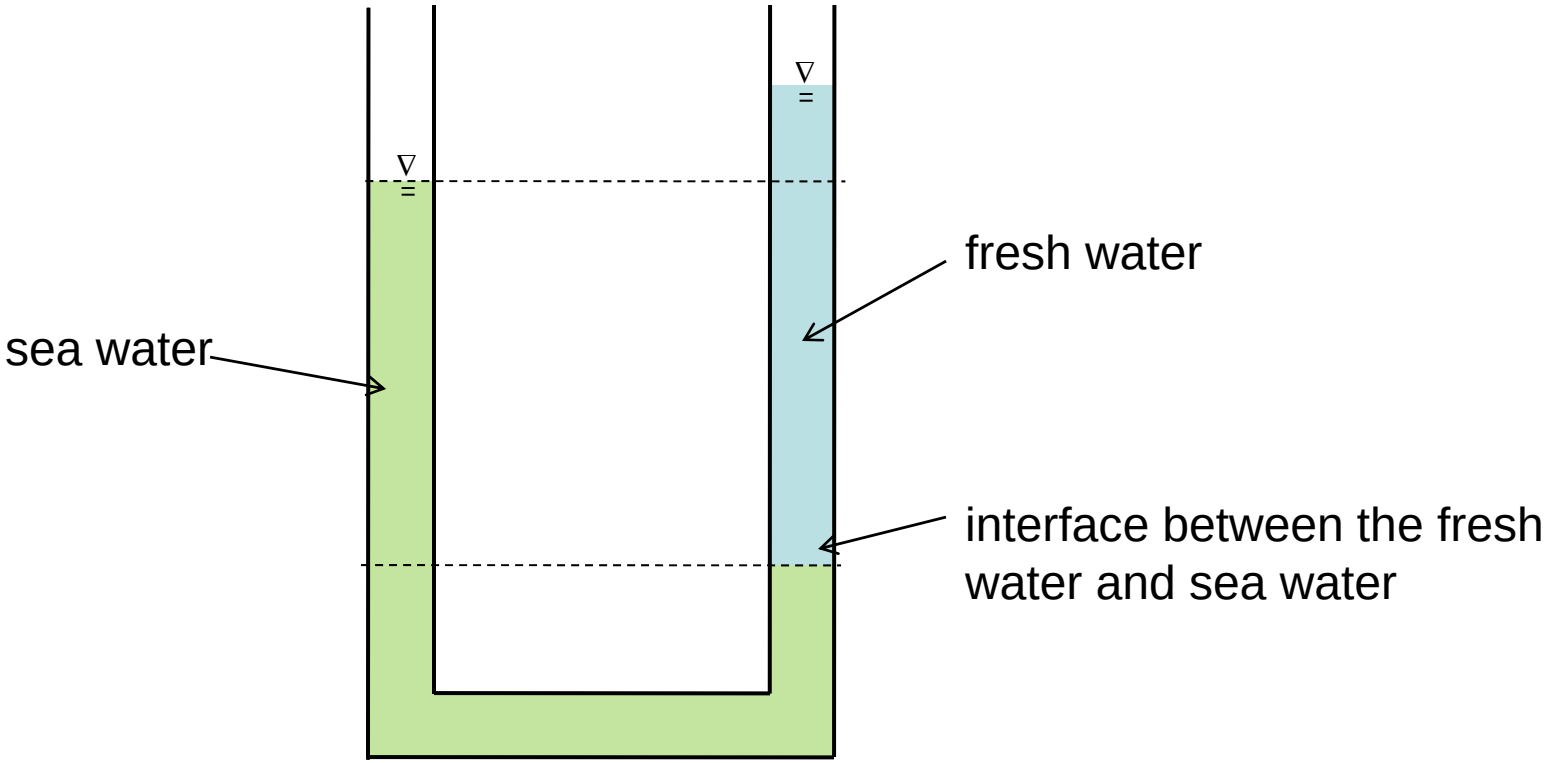


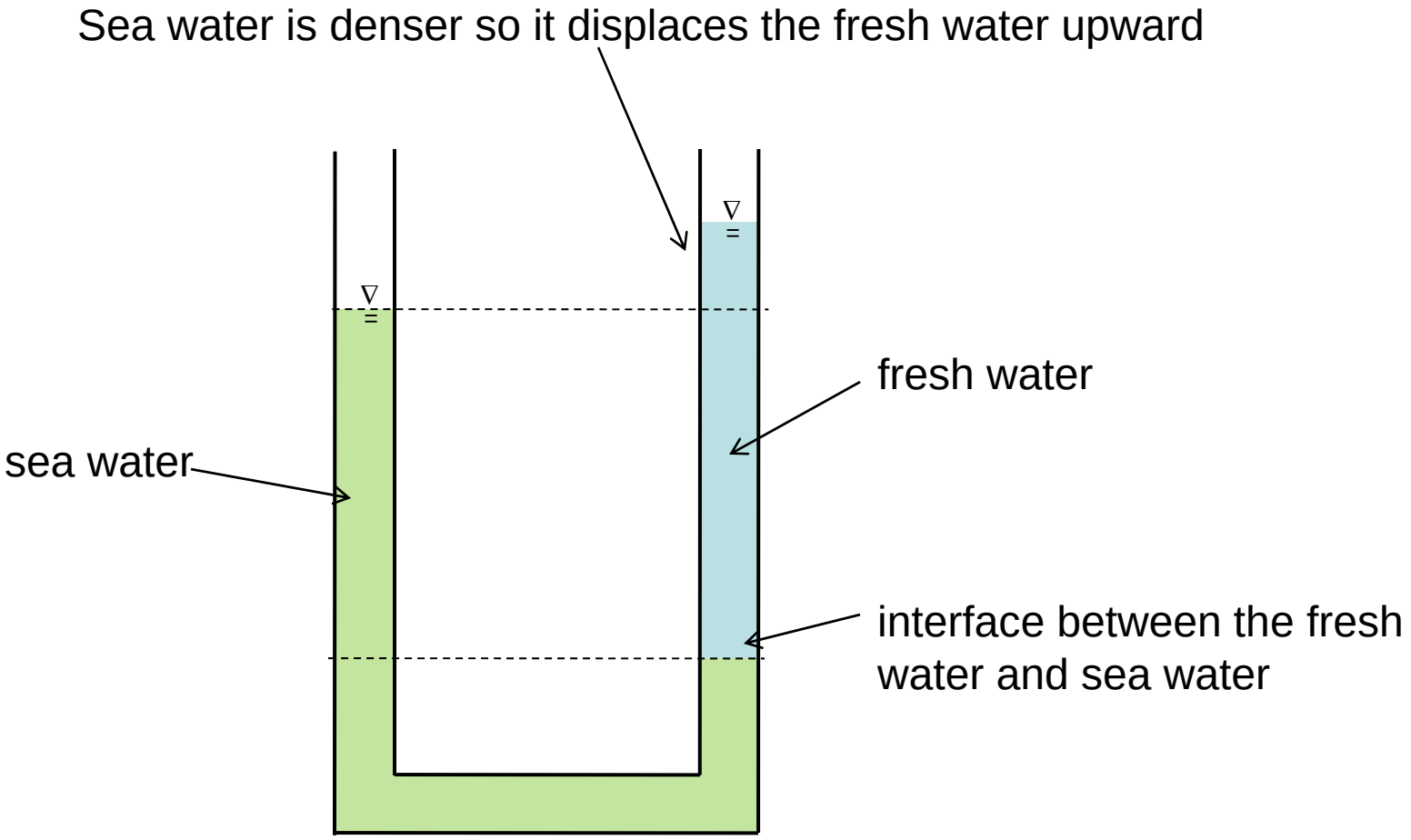
(a)

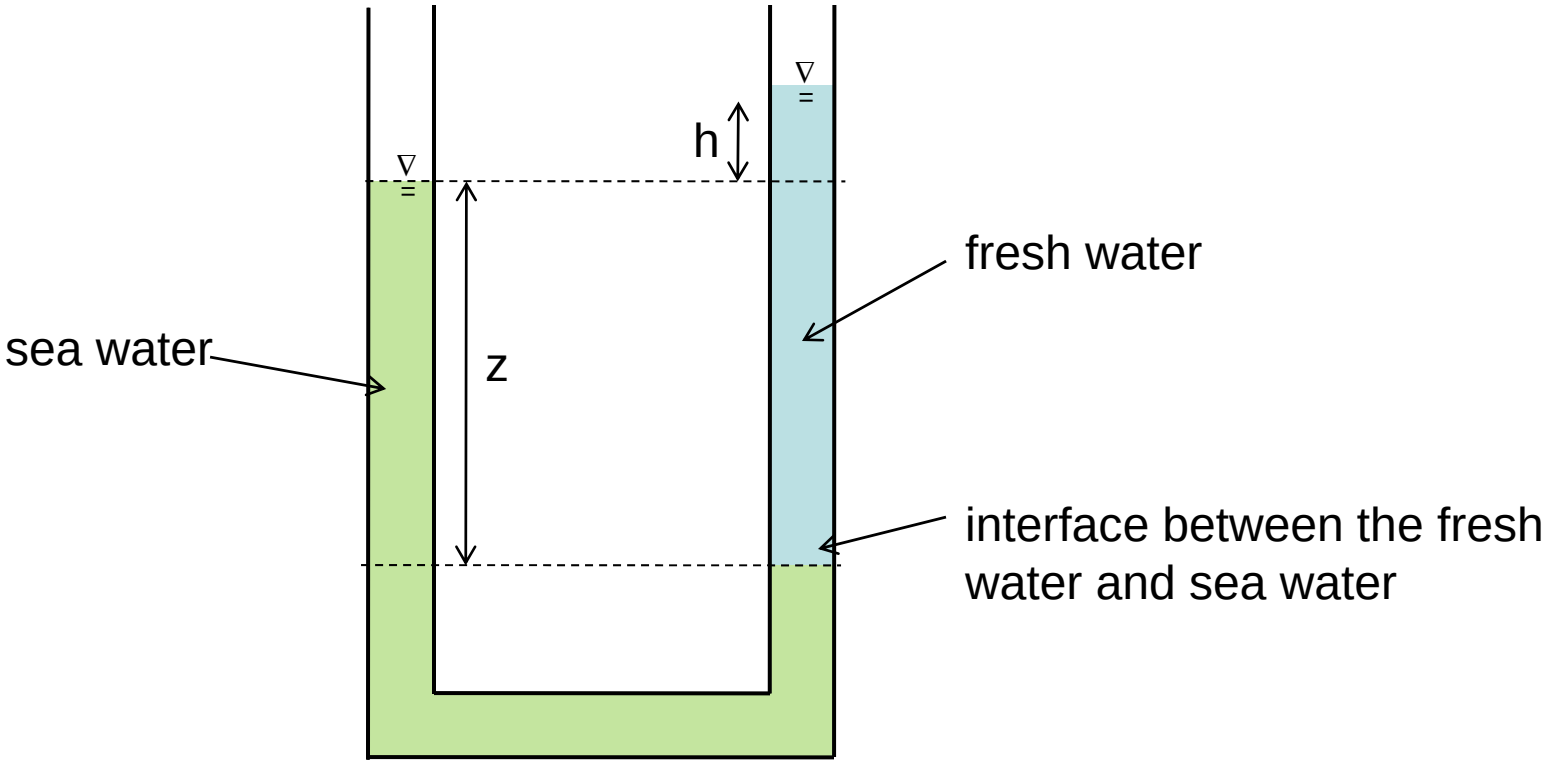
In a ‘U’ - tube, water seeks its own level



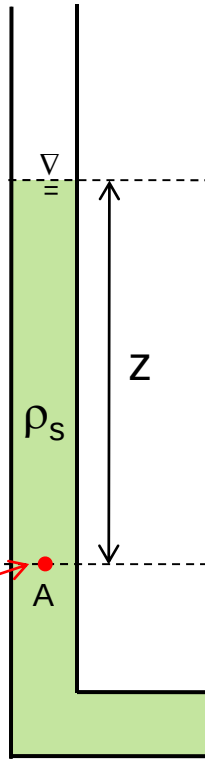
Hydraulic equilibrium between two fluids with contrasting densities




Sea water is denser so it displaces the fresh water upward
∇ =
∇ =
fresh water
sea water
interface between the fresh water and sea water


h
z
fresh water
sea water
interface between the fresh water and sea water

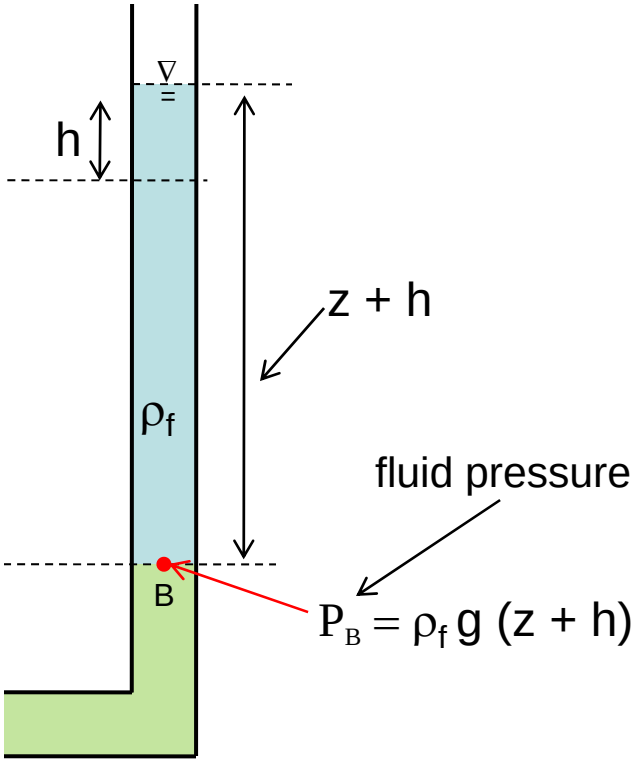
ρ_s= sea water density



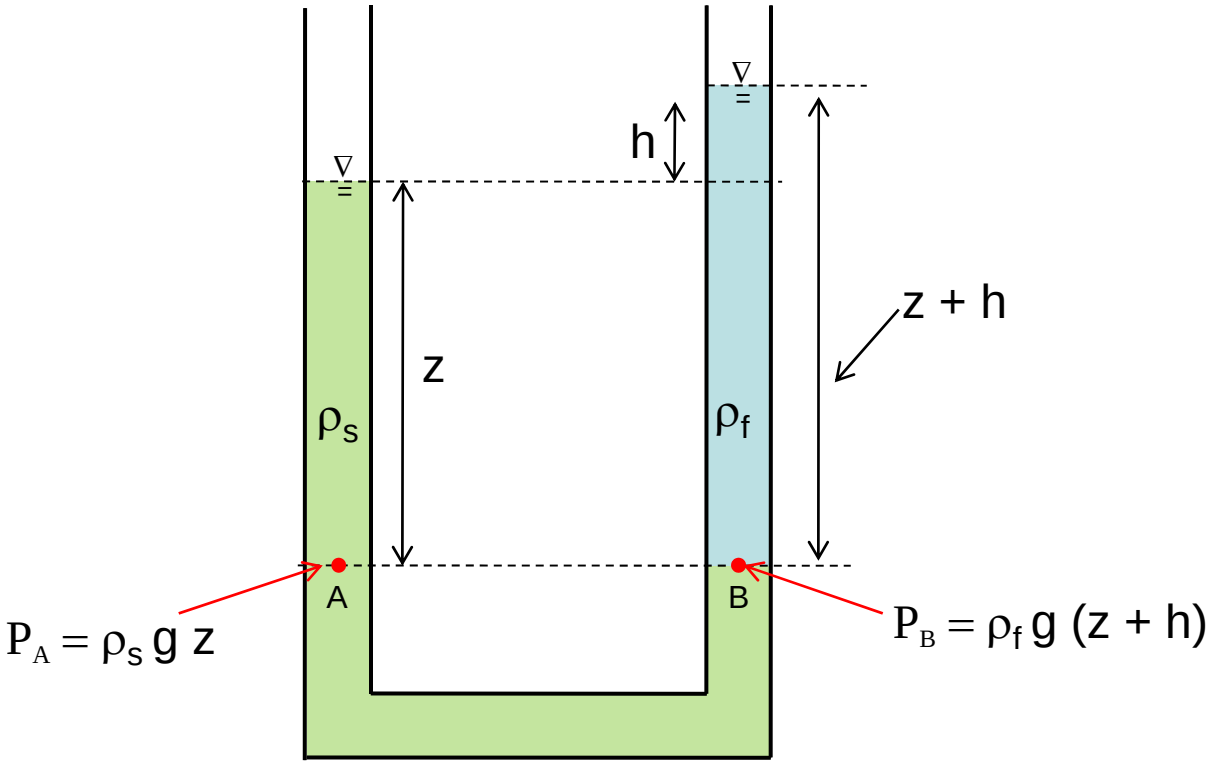
fluid pressure

$P_A = \rho_s g z$

ρ_f = fresh water density



hydraulic equilibrium



$$P_A = P_B$$

hydraulic equilibrium

if

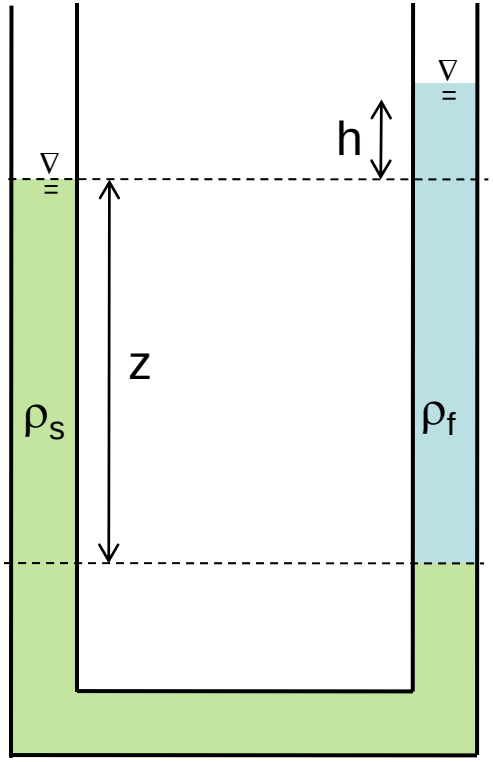
$$P_A = P_B$$

then

$$\rho_s g z = \rho_f g (z + h)$$

solving for “z” yields

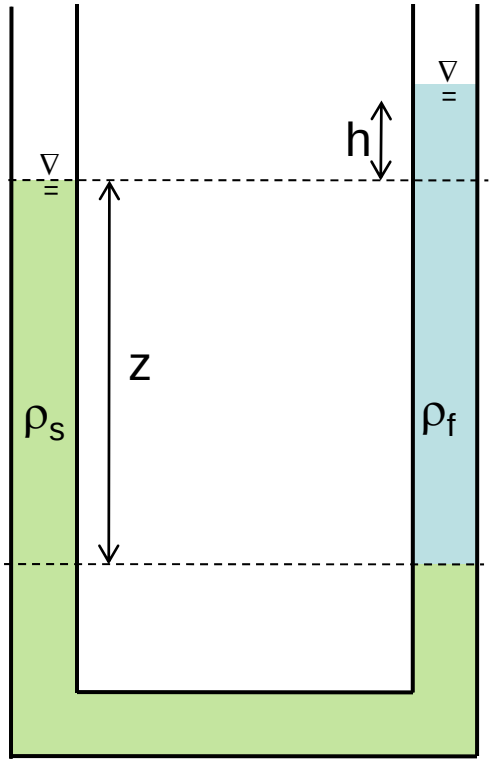
$$z = \left(\frac{\rho_f}{\rho_s - \rho_f} \right) h$$



ρ_s= sea water density

ρ_f = fresh water density

Ghyben – Herzberg relation



$$z = \left(\frac{\rho_f}{\rho_s - \rho_f} \right) h$$

if

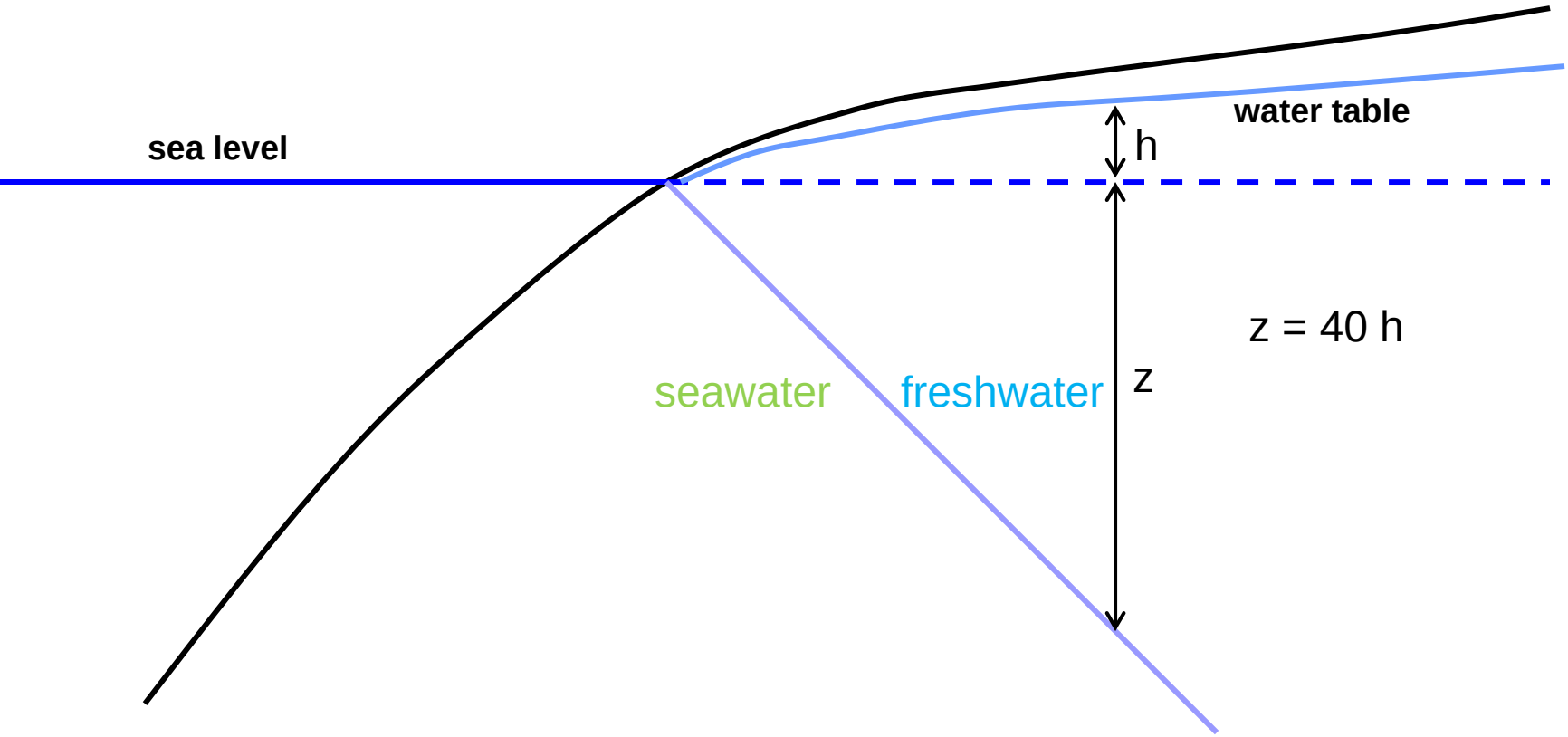
ρ_s= 1.025 g/cm^3

ρ_f = 1.000 g/cm^3

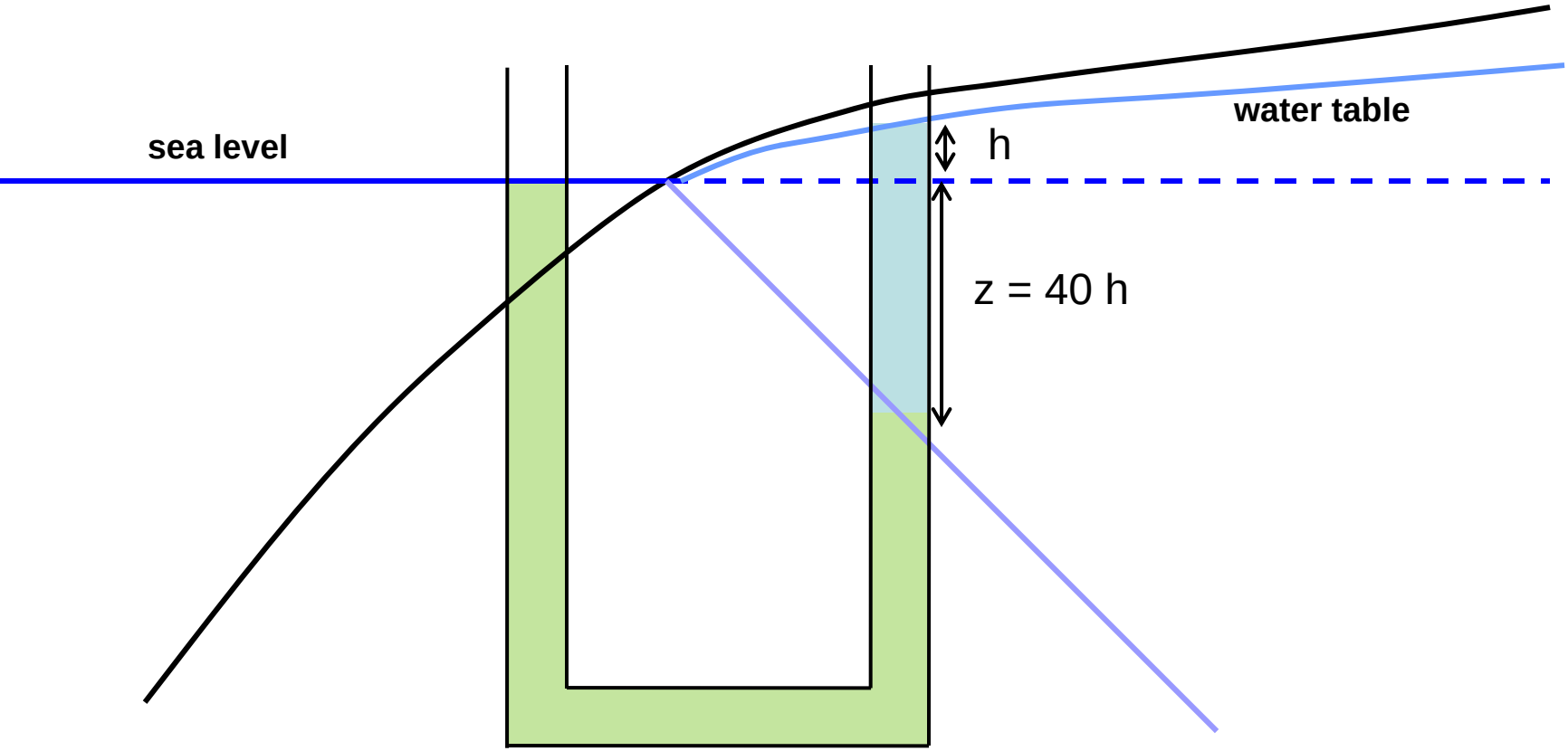
then

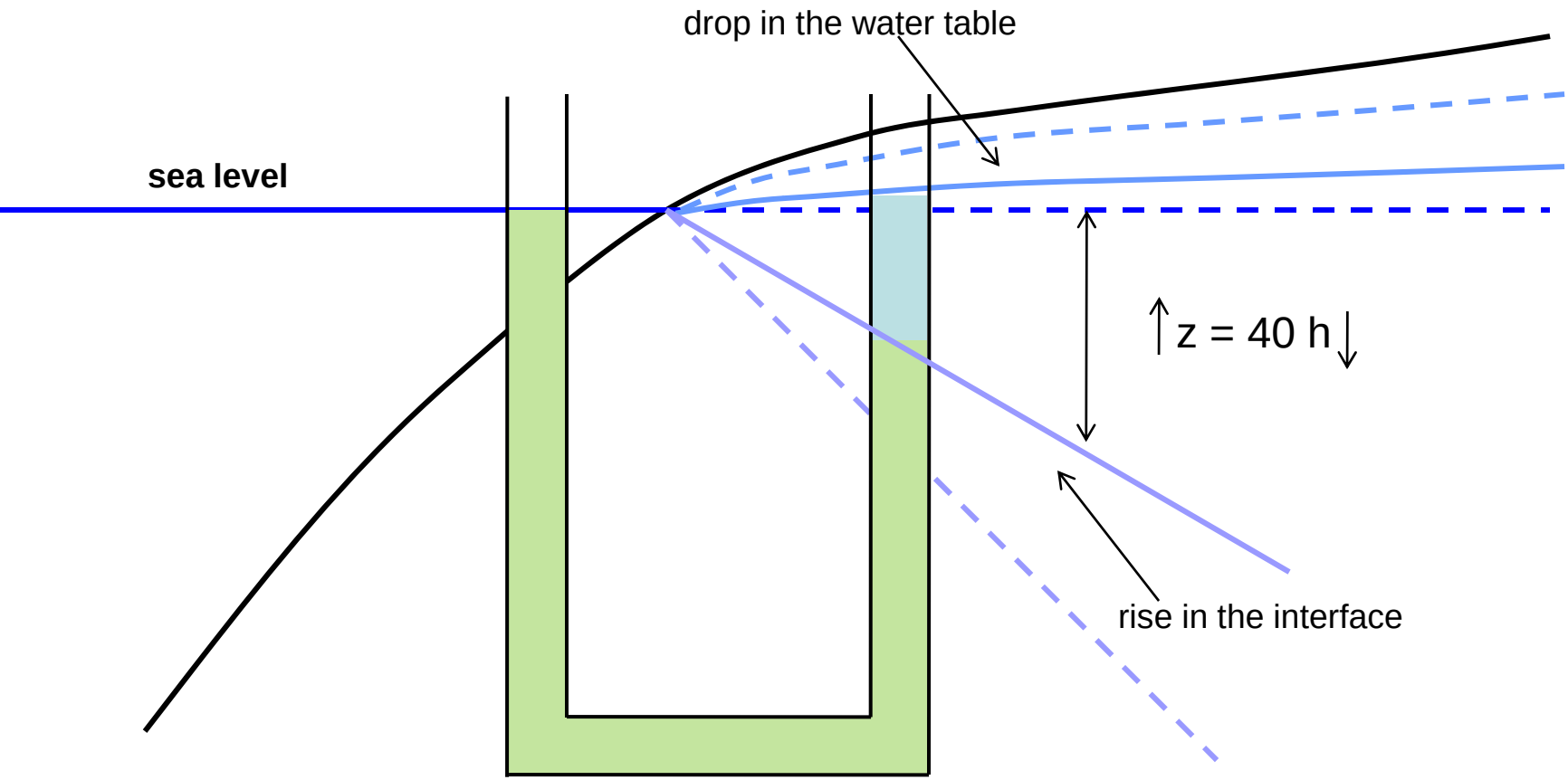
$z = 40h$

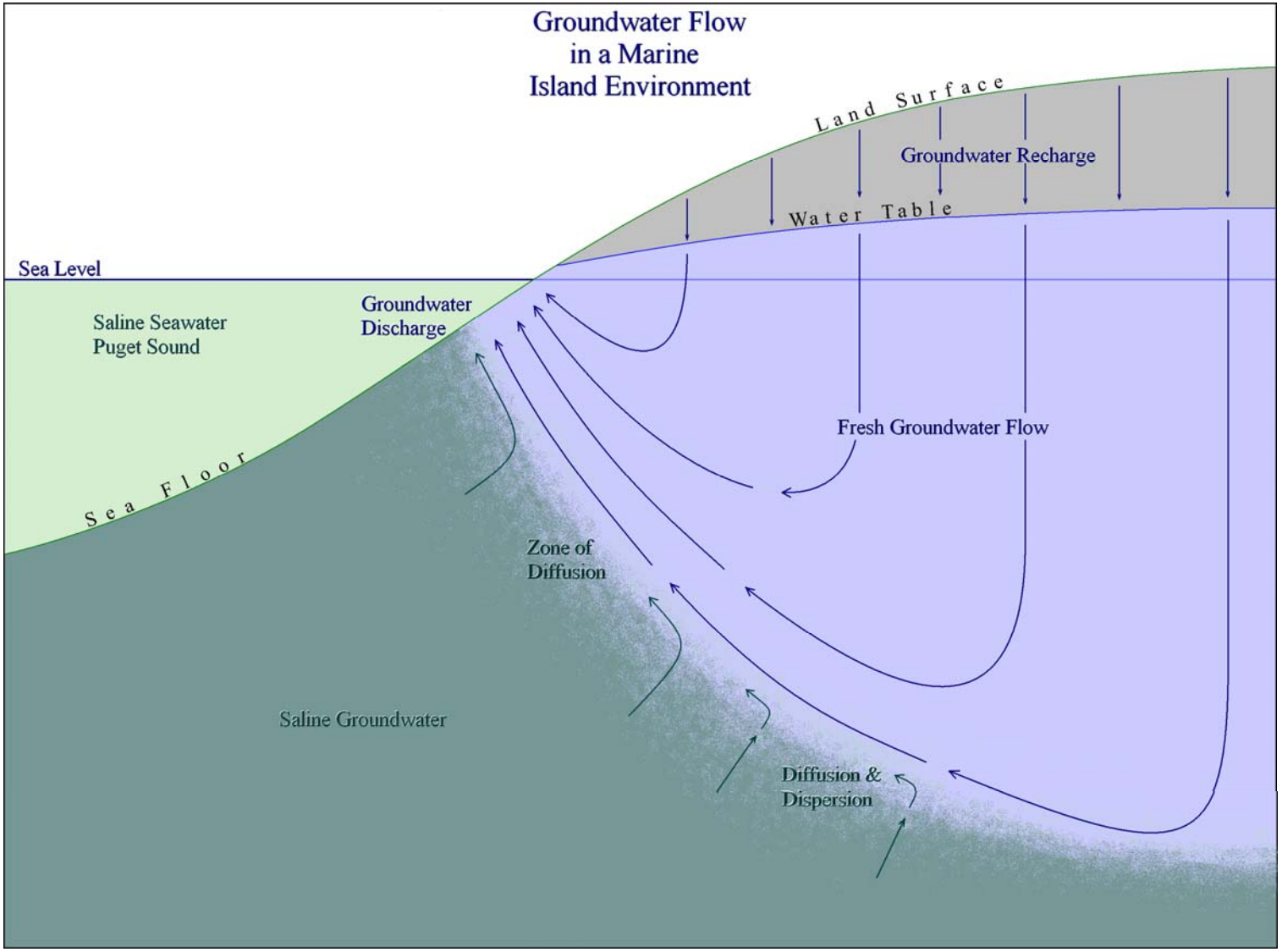
Ghyben – Herzberg relation



The depth to the freshwater/seawater interface (z) is about 40 times the height of the freshwater above sea level (h).


sea level
water table
h
z = 40 h


drop in the water table
sea level
z = 40 h
rise in the interface


Groundwater Flow
in a Marine
Island Environment
Land Surface
Groundwater Recharge
Water Table
Sea Level
Saline Seawater
Puget Sound
Groundwater
Discharge
Fresh Groundwater Flow
Sea Floor
Zone of
Diffusion
Saline Groundwater
Diffusion &
Dispersion

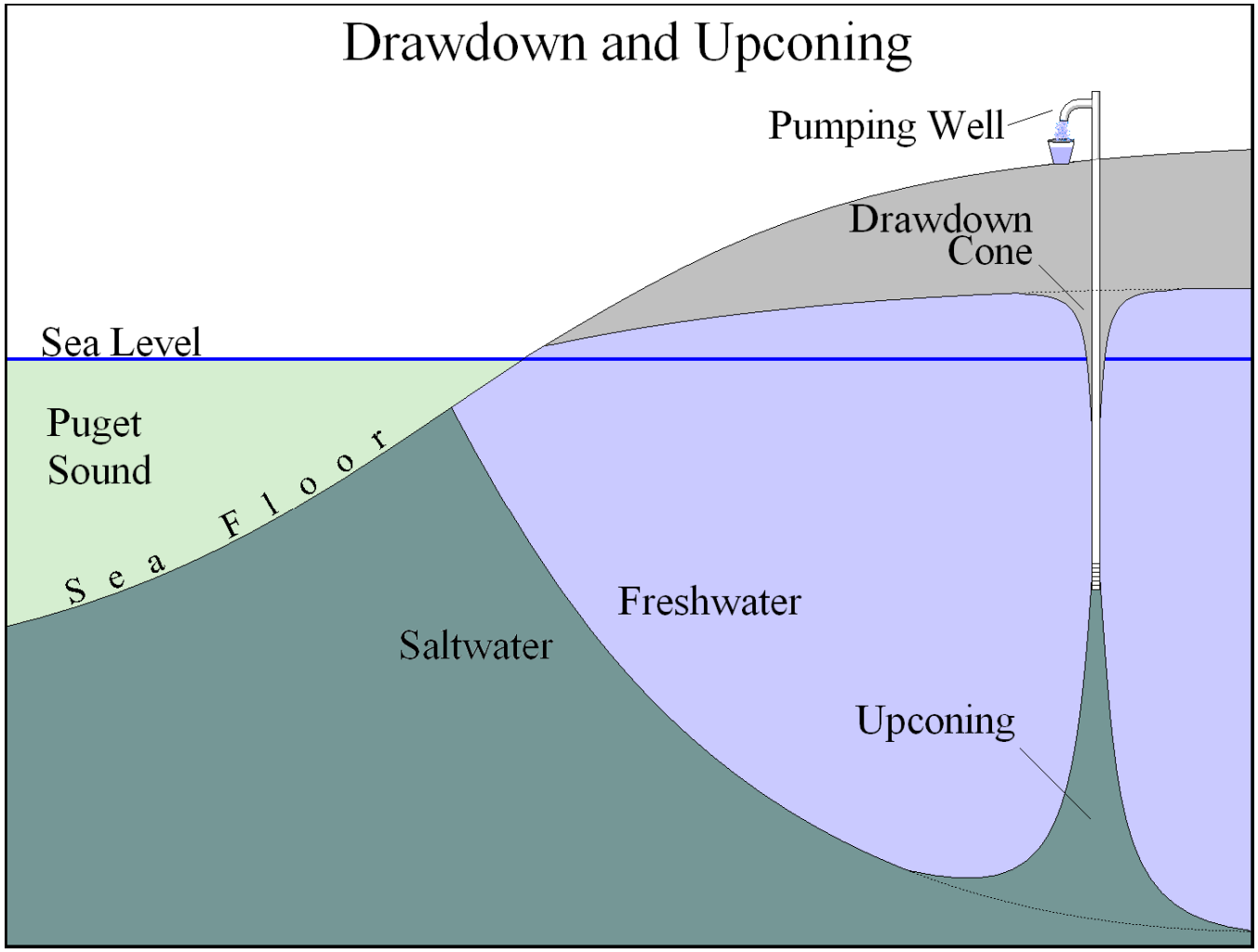
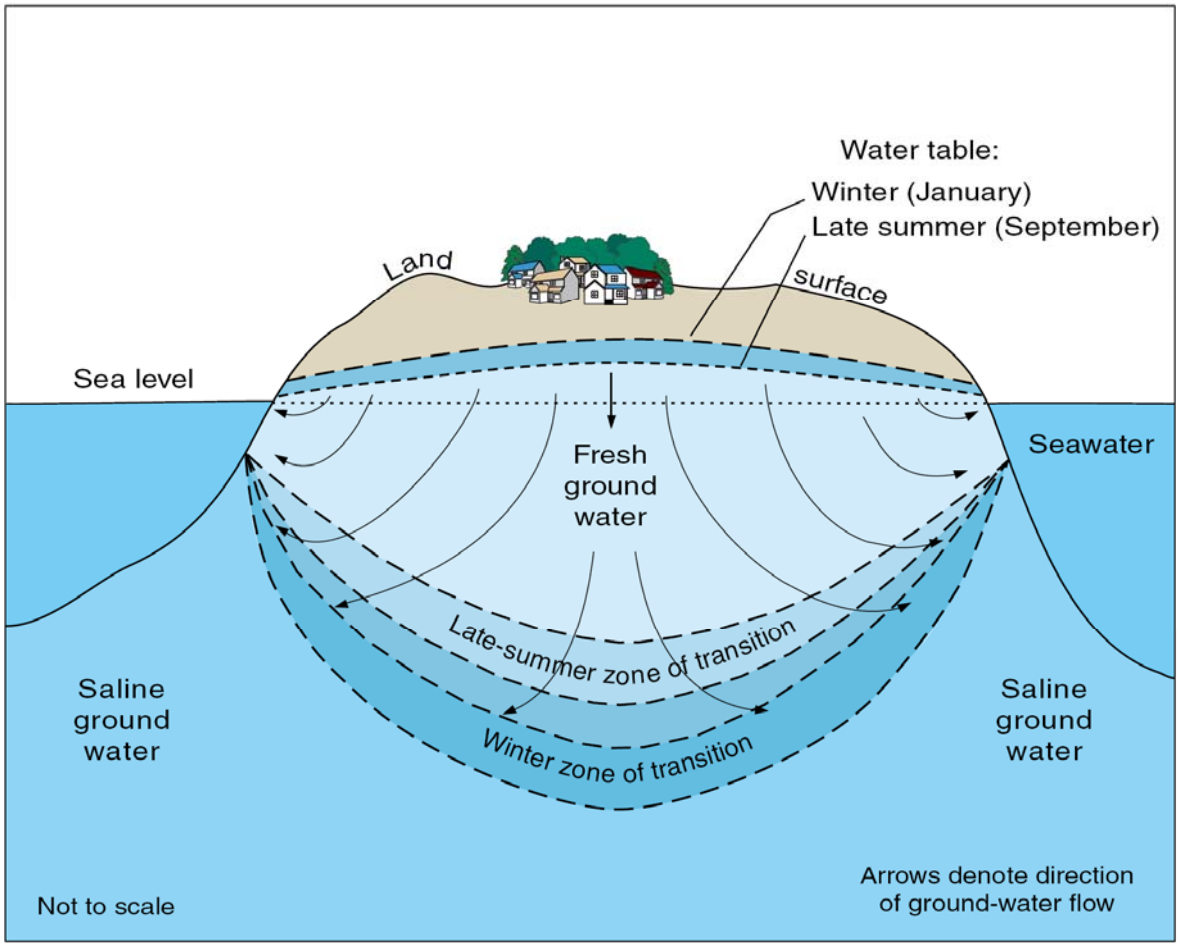

Drawdown and Upconing
Pumping Well
Drawdown Cone
Sea Level
Puget Sound
Sea Floor
Freshwater
Saltwater
Upconing

Figure 3.

Gyben-Herzberg Relation (sea water intrusion)



Lopez Island

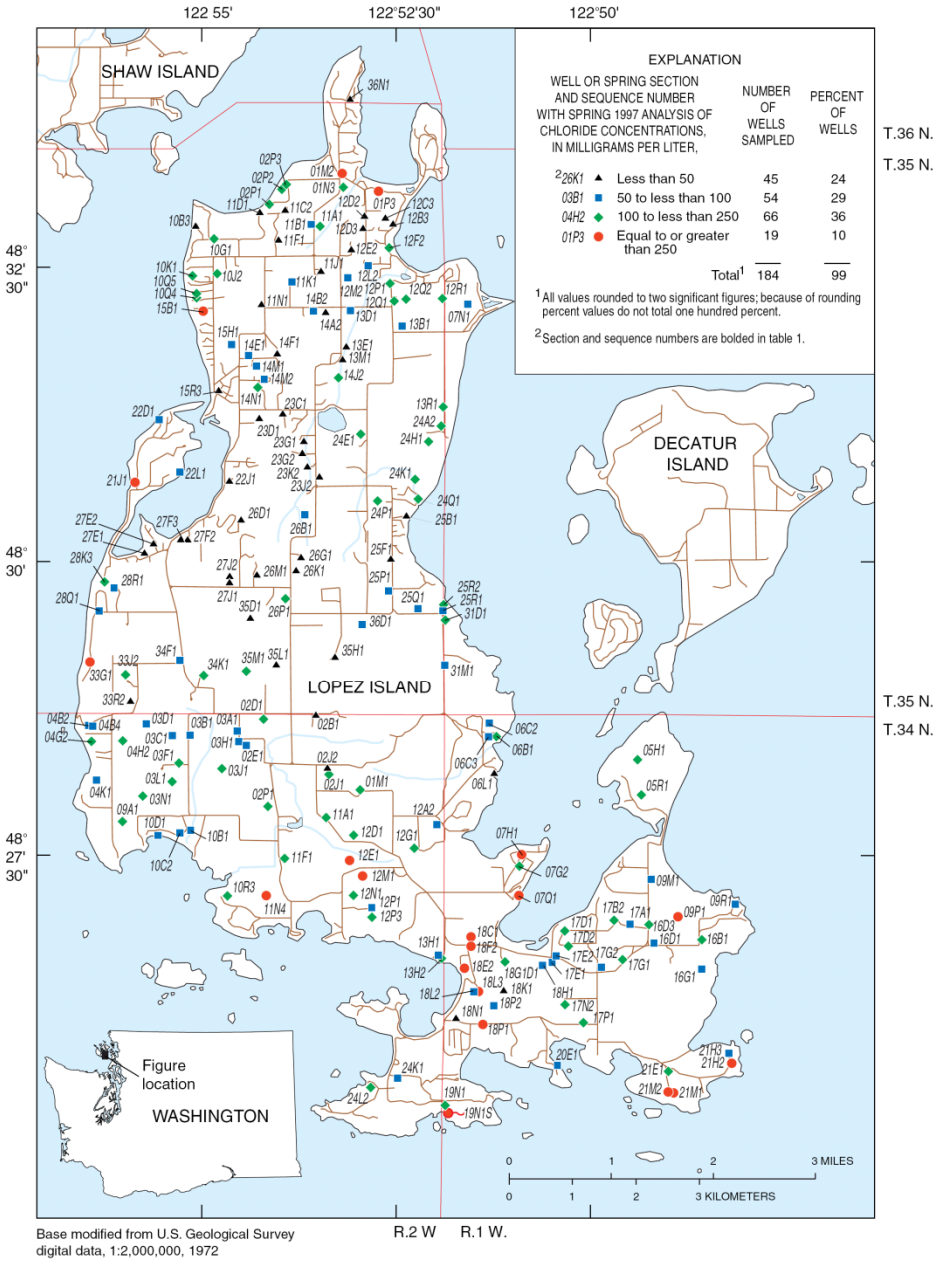
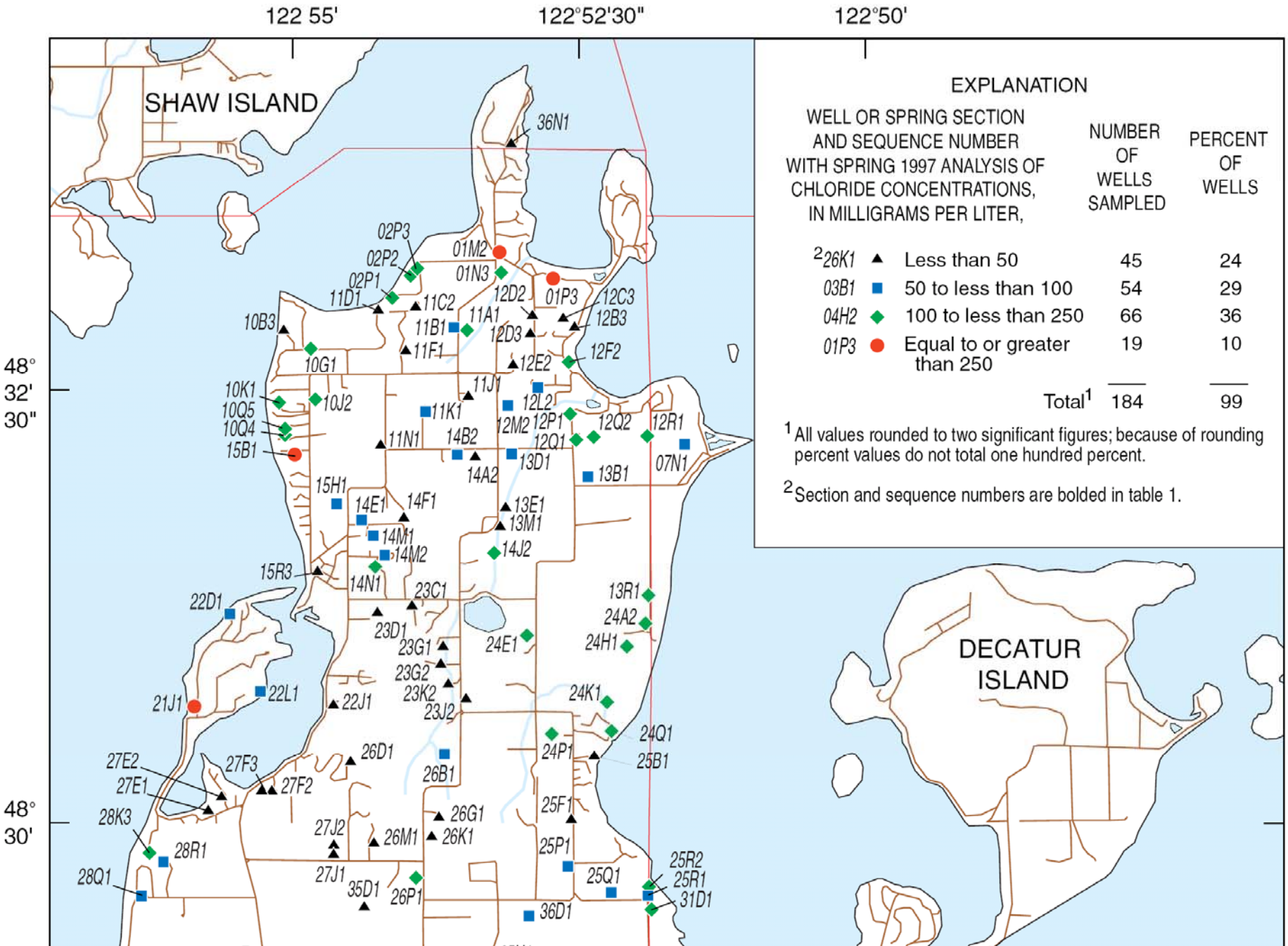


Figure 3. *Areal distribution of chloride concentrations from wells or spring on Lopez Island measured in the spring of 1997.*

Chloride Concentrations are an indication of seawater intrusion

Greater than 100 mg/L means intruded

Greater than 250 mg/L means above drinking-water standard



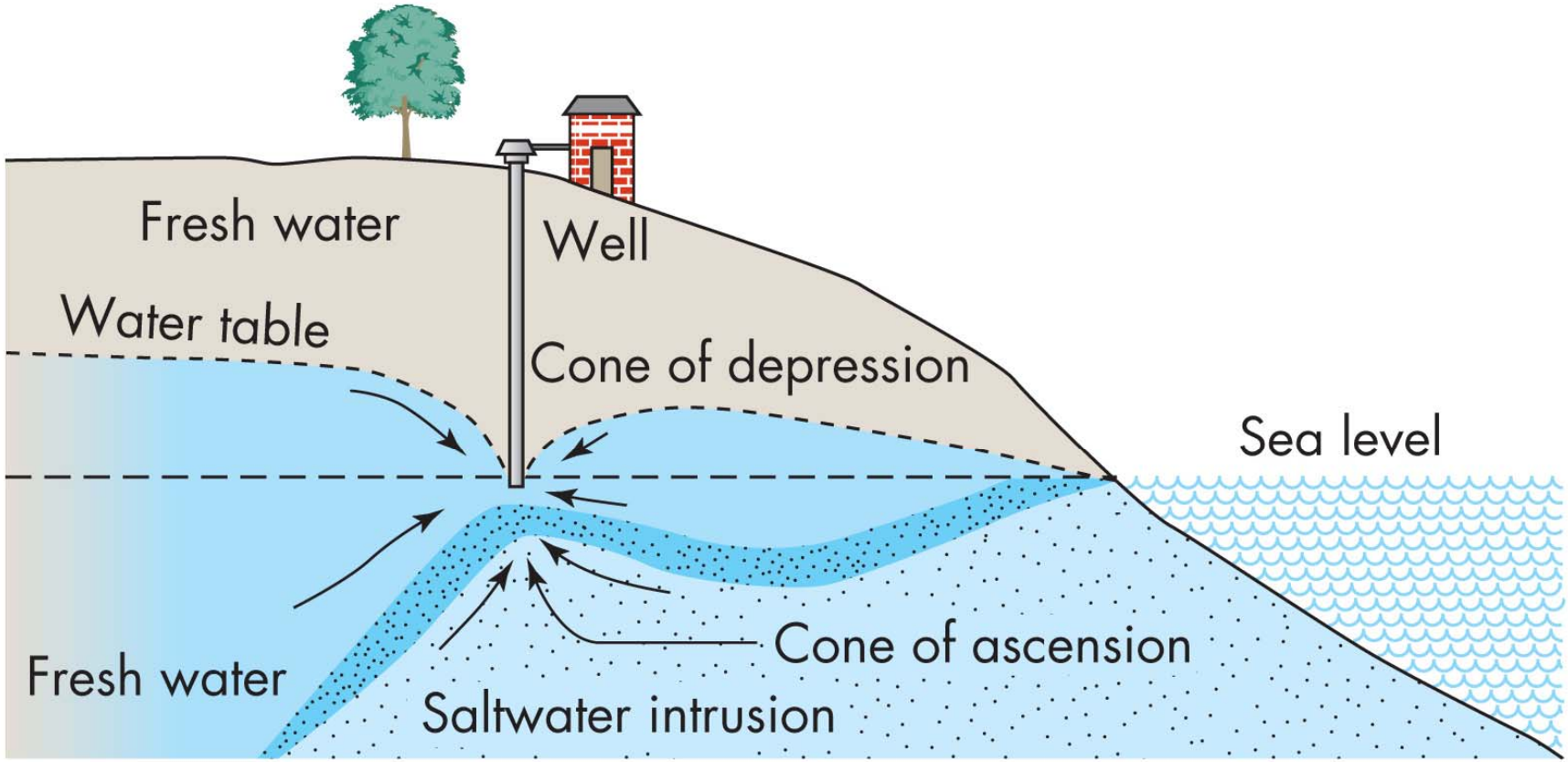
EXPLANATION

WELL OR SPRING SECTION AND SEQUENCE NUMBER WITH SPRING 1997 ANALYSIS OF CHLORIDE CONCENTRATIONS, IN MILLIGRAMS PER LITER,		NUMBER OF WELLS SAMPLED	PERCENT OF WELLS
[2]26K1	▲ Less than 50	45	24
03B1	■ 50 to less than 100	54	29
04H2	◆ 100 to less than 250	66	36
01P3	● Equal to or greater than 250	19	10
	Total[1]	184	99

[1] All values rounded to two significant figures; because of rounding percent values do not total one hundred percent.

[2] Section and sequence numbers are bolded in table 1.

Over pumping of coastal wells can cause sea water intrusion



(b)

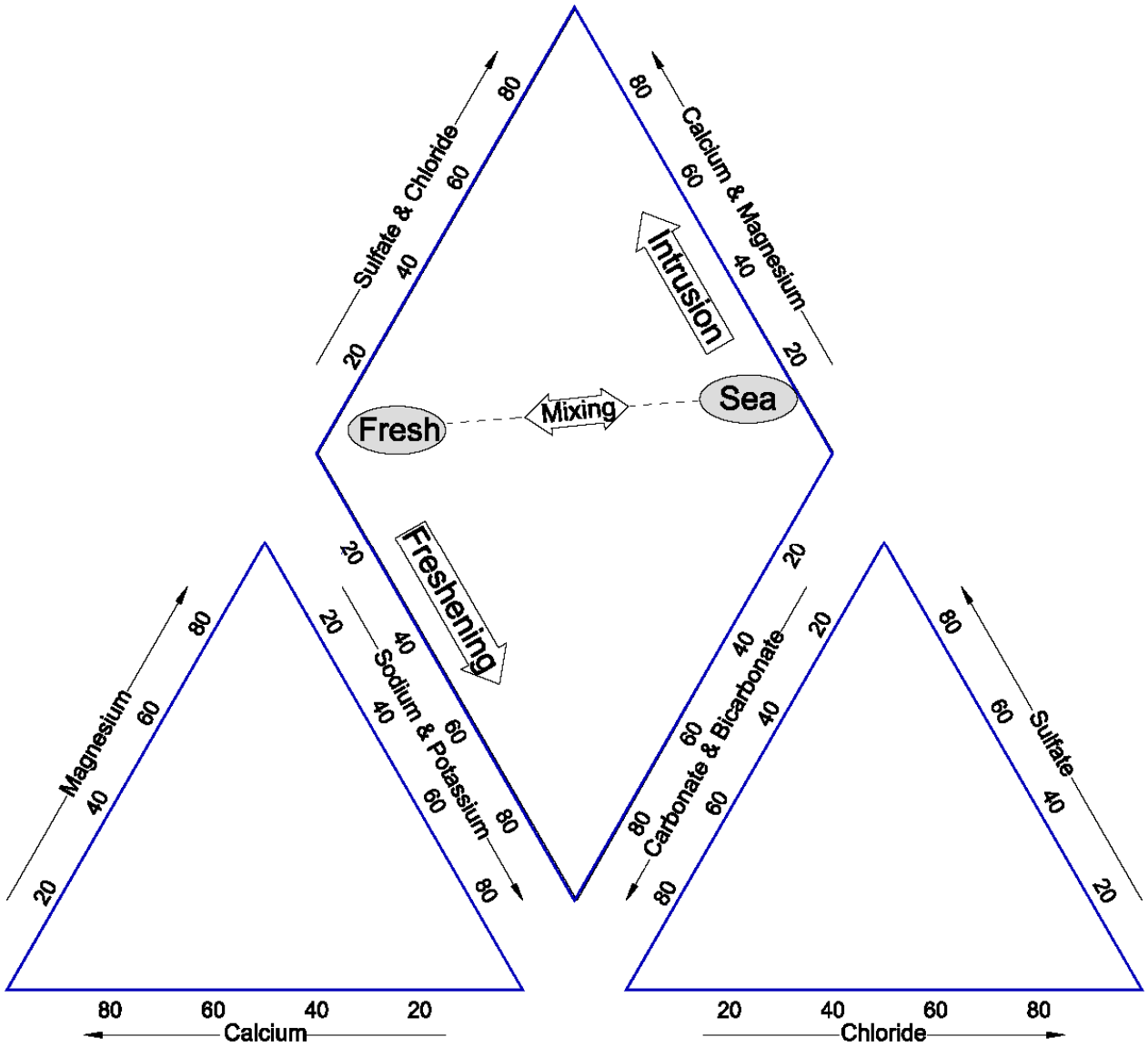

Sulfate & Chloride
Calcium & Magnesium
Intrusion
Fresh
Mixing
Sea
Freshening
Magnesium
Sodium & Potassium
Carbonate & Bicarbonate
Sulfate
Calcium
Chloride
80
60
40
20

Figure 8.

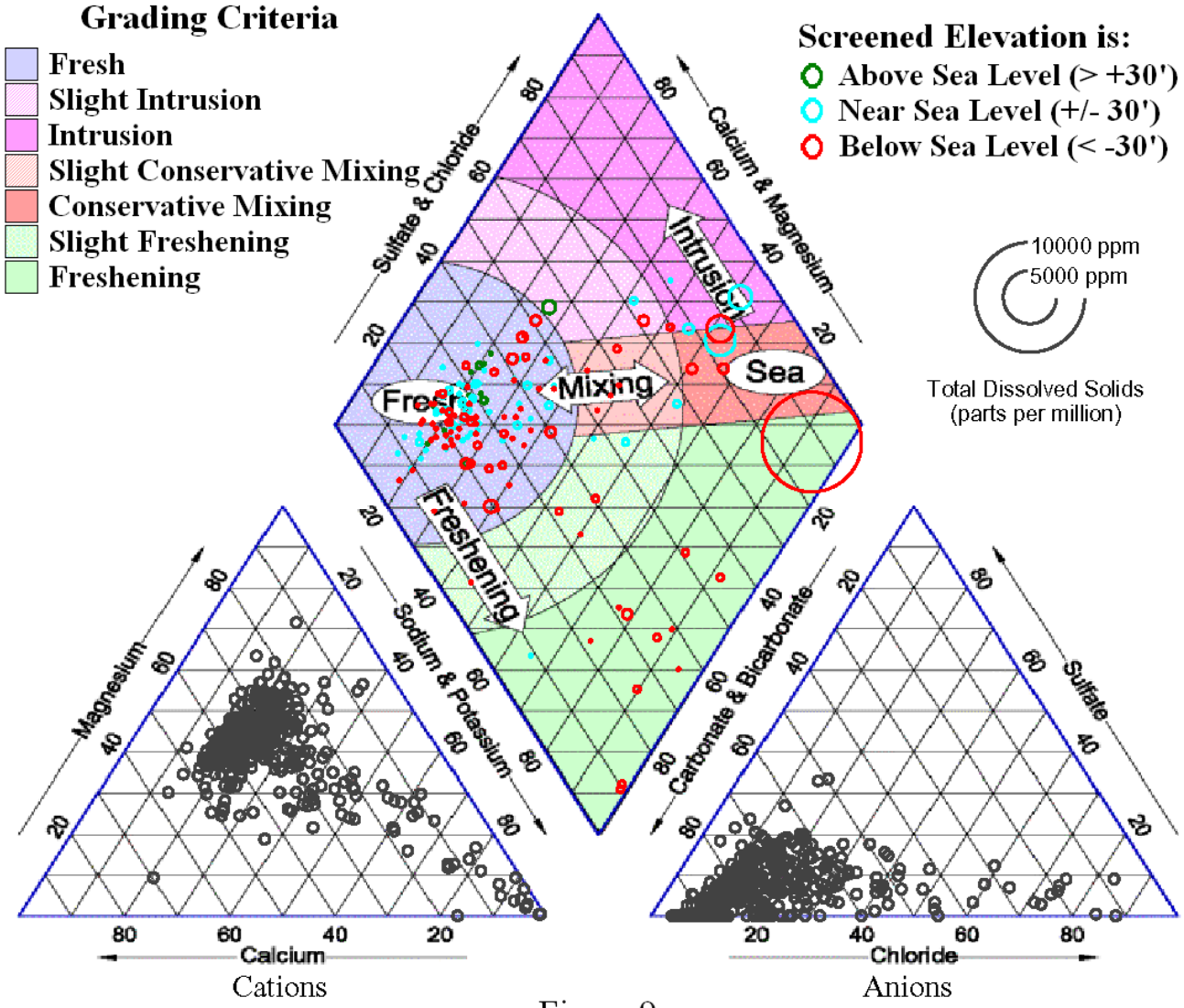
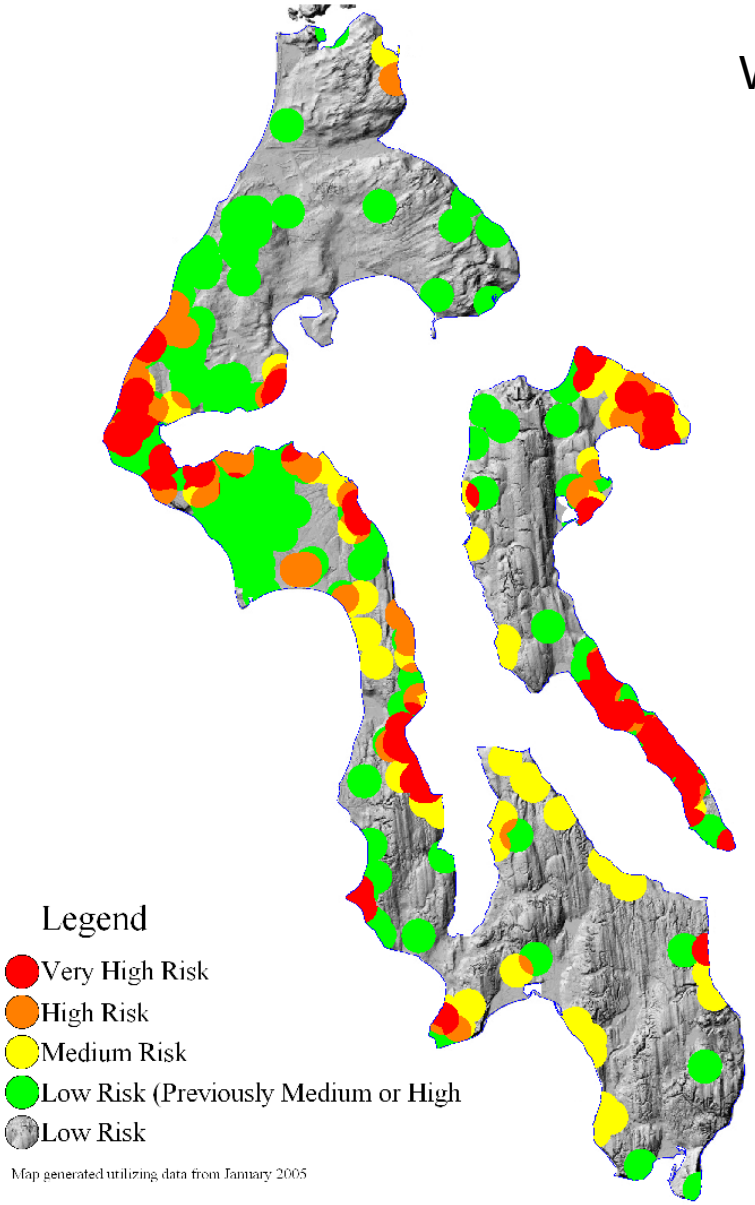

Grading Criteria
Fresh
Slight Intrusion
Intrusion
Slight Conservative Mixing
Conservative Mixing
Slight Freshening
Freshening
Screened Elevation is:
Above Sea Level (> +30')
Near Sea Level (+/- 30')
Below Sea Level (< -30')
10000 ppm
5000 ppm
Total Dissolved Solids
(parts per million)
Sulfate & Chloride
Calcium & Magnesium
Intrusion
Sea
Mixing
Fresh
Freshening
Magnesium
Sodium & Potassium
Calcium
Cations
Carbonate & Bicarbonate
Sulfate
Chloride
Anions

Figure 9.

Whidbey Island



Lummi Island

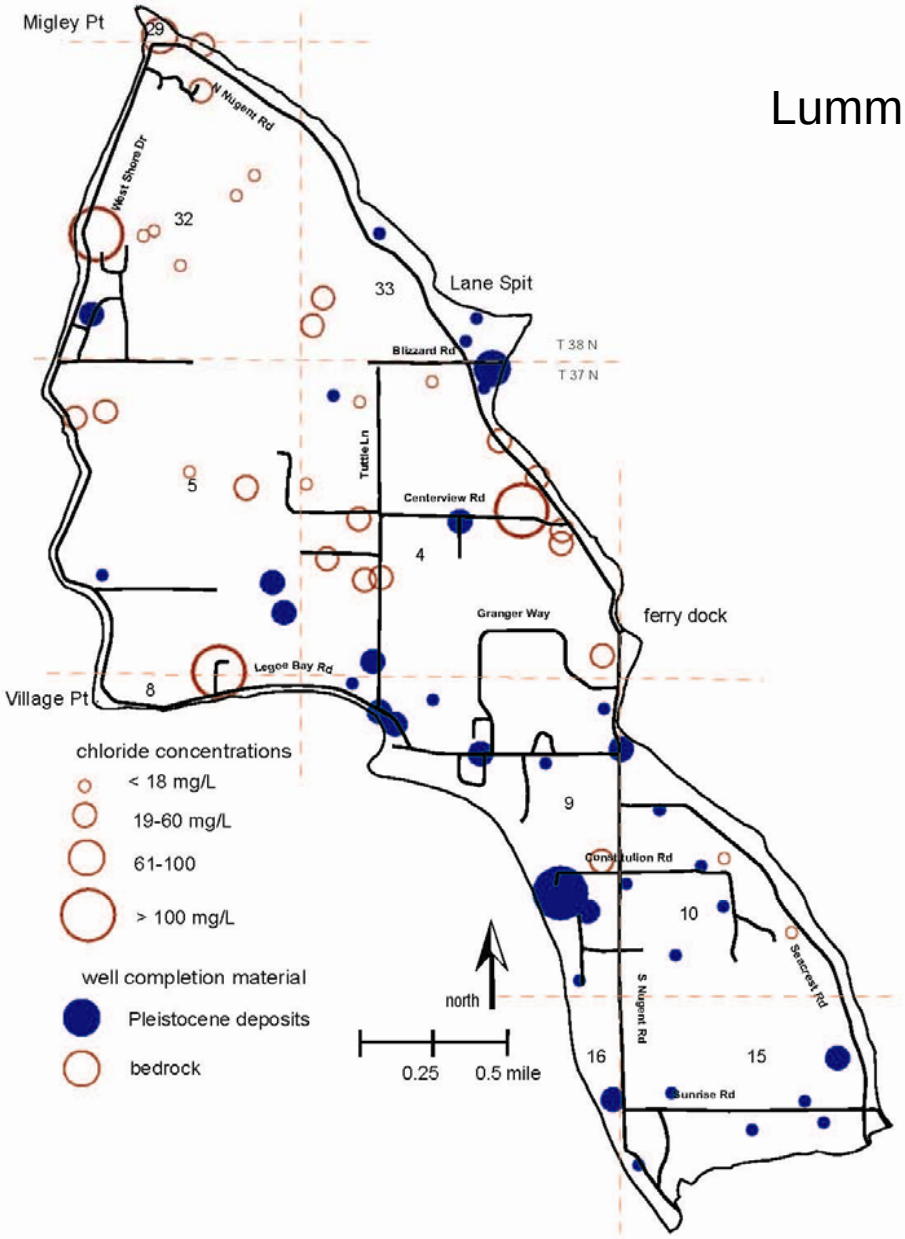


Figure 38a. Chloride concentrations, north Lummi Island, Washington, fall 2002