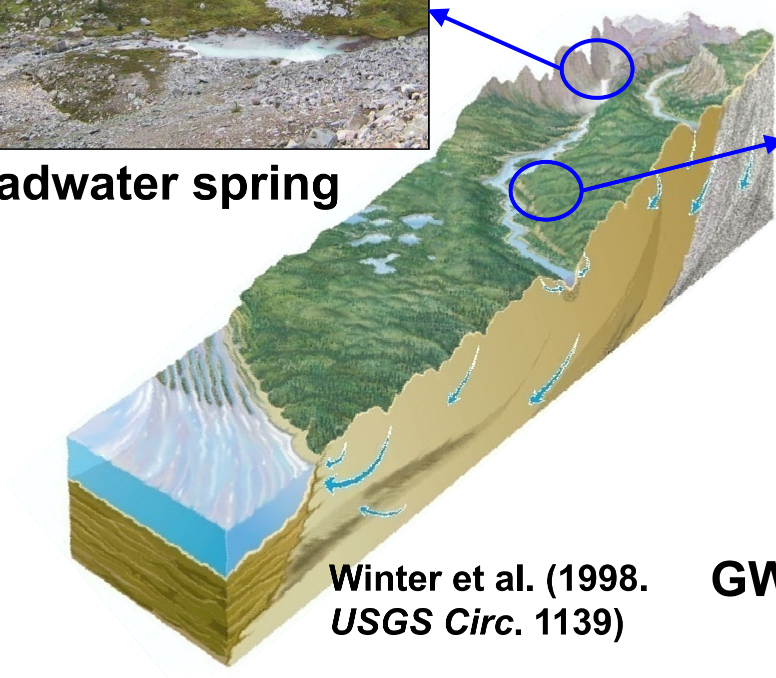
Lecture 3: Groundwater-Surface Water Interaction

Headwater spring

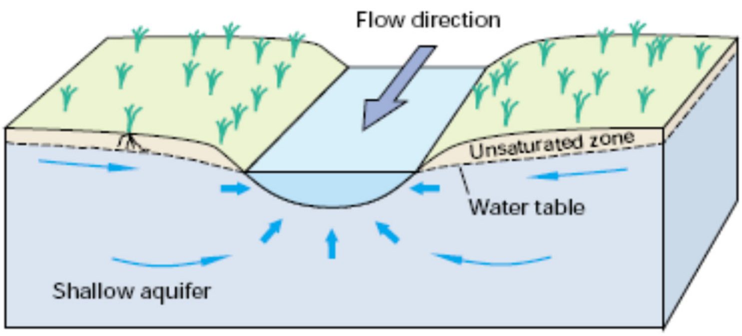


Springs on riverbank

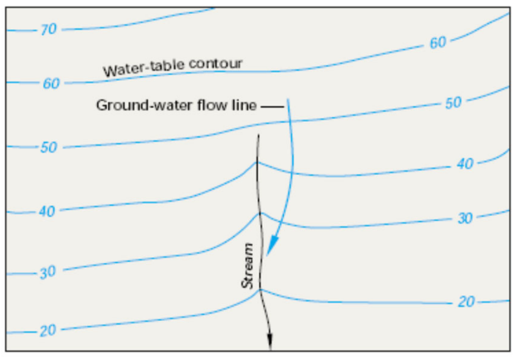
GW-dependent ecosystem

Winter et al. (1998. *USGS Circ*. 1139)

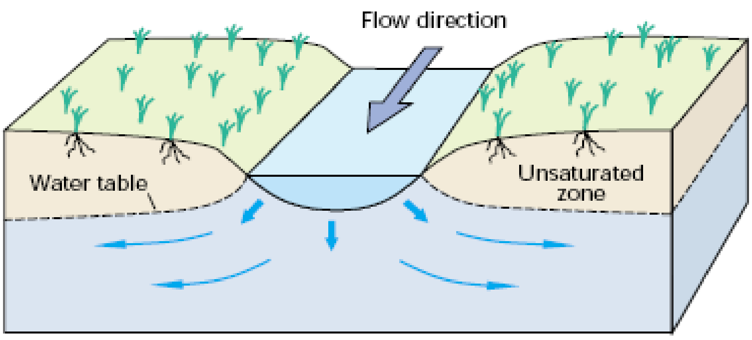
Gaining Stream and Losing Stream



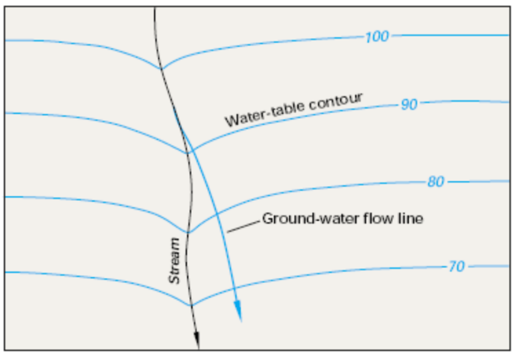
Gaining streams receive GW.



'Valley' of the water table.



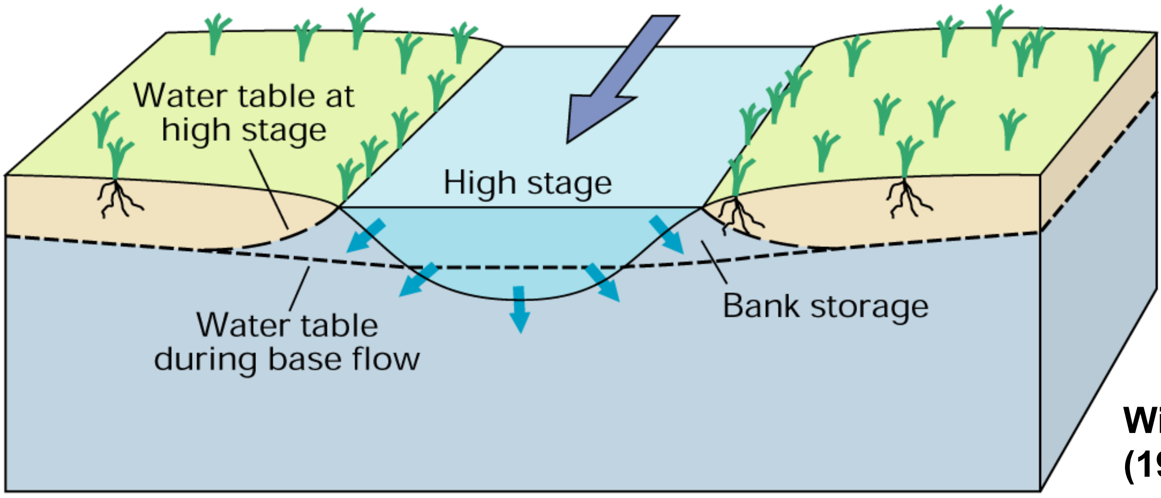
Losing streams recharge GW.



'Ridge' of the water table.

Winter et al. (1998. *http://pubs.usgs.gov/circ/circ1139/*)

GW-SW Exchange by Bank Storage

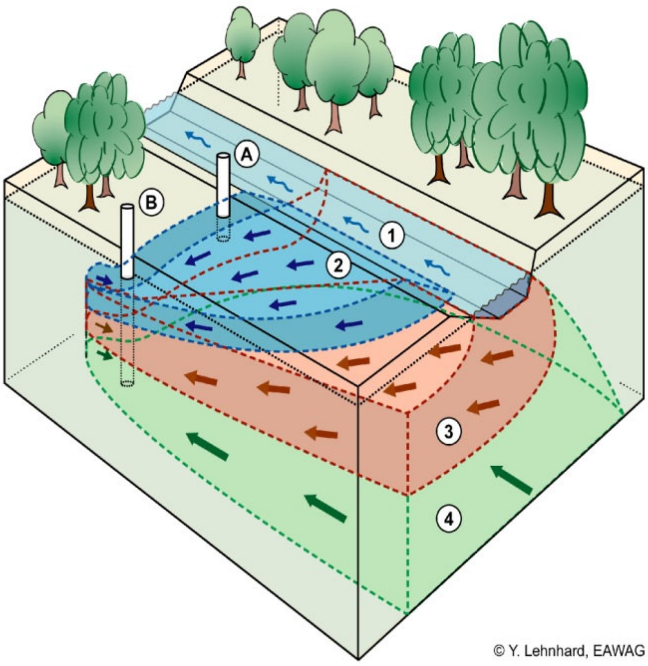


Winter et al. (1998)

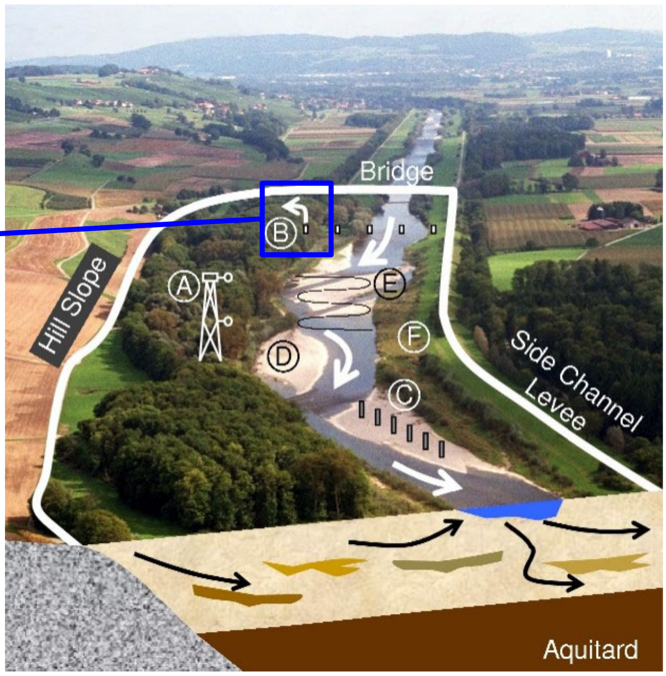
Implications on flood water retention?

Bank Filtration Induced by Pumping

Municipal water supplies use bank-filtrated groundwater.



Thur River, Switzerland



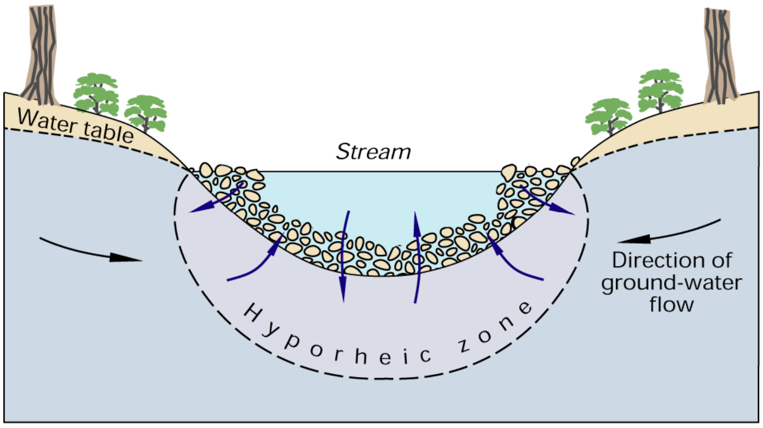
Schirmer et al. (2014, *Hydrol. Earth Sys. Sci.*, 18: 2449)

Hyporheic Zone
Hypo = under and *Rheo* = flow

'The region of saturated sediments beneath and beside the active channel and that contain some proportion of surface water that was part of the flow in the surface channel and went back underground and can mix with groundwater.'

California Department of Water Resources

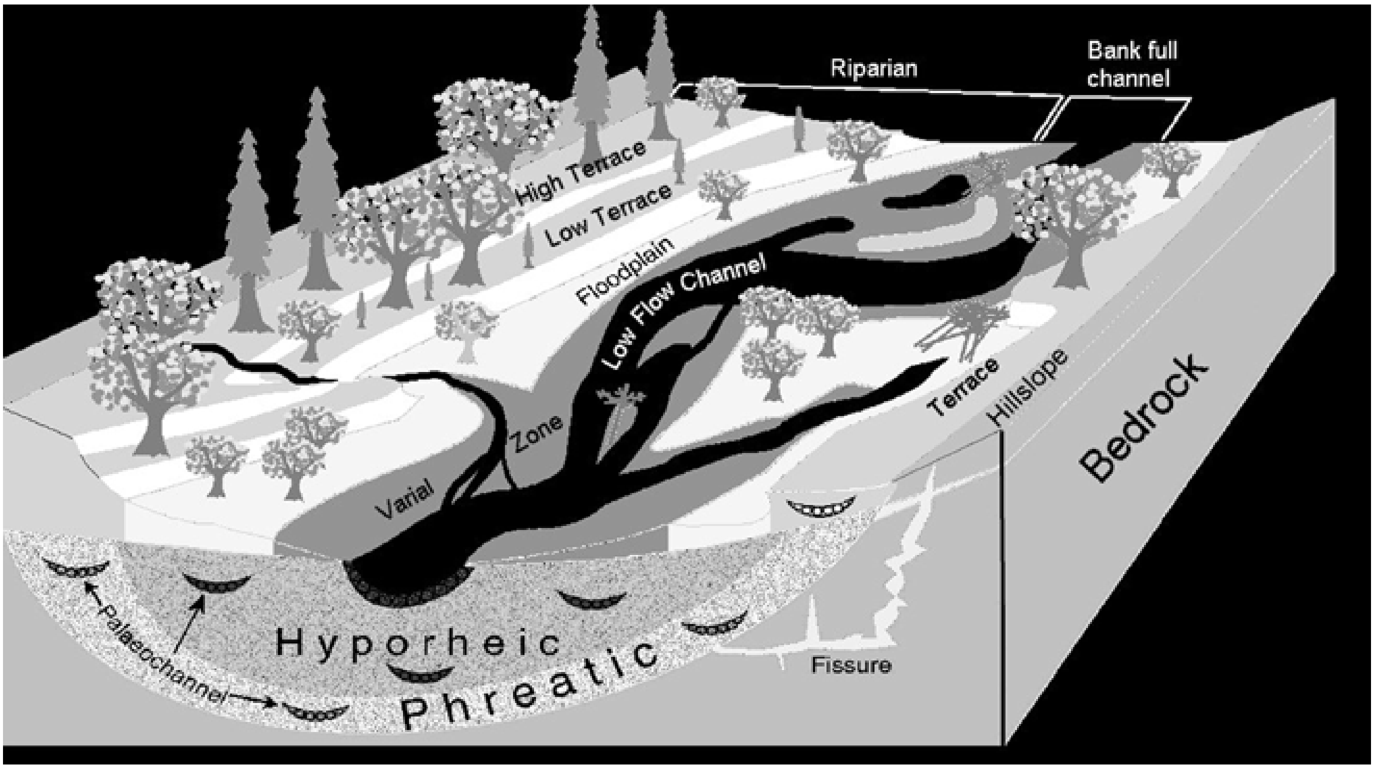
Examples of hyporheos



Hancock et al. (2005. *Hydrogeol. J., 13:98*)

Winter et al. (1998)

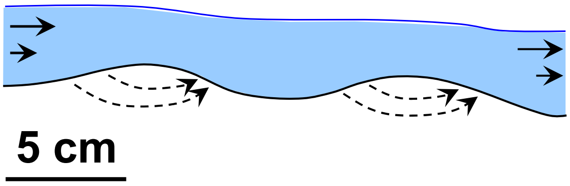
Hyporheos (e.g., benthic invertebrates) can travel 2-3 km away from the flow channel.



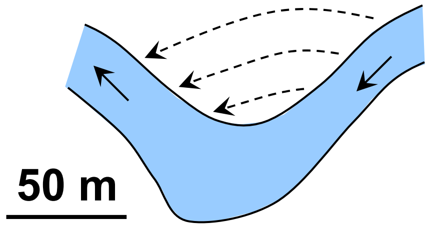
Stanford (1998. *Freshwater Biology*, 40:402)

Hyporheic Exchange Mechanisms

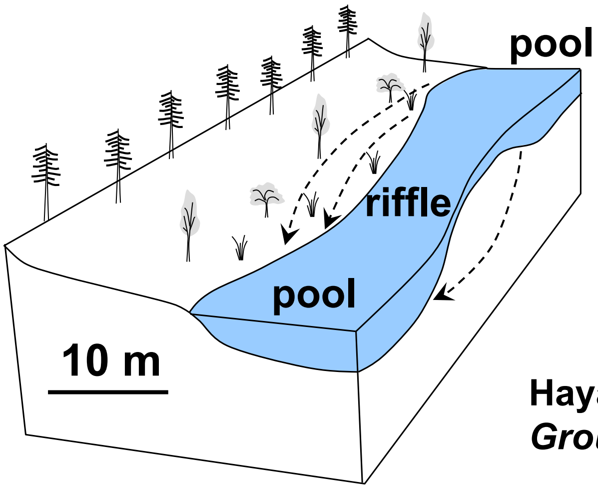
Bedform-induced flow



Meandering channel

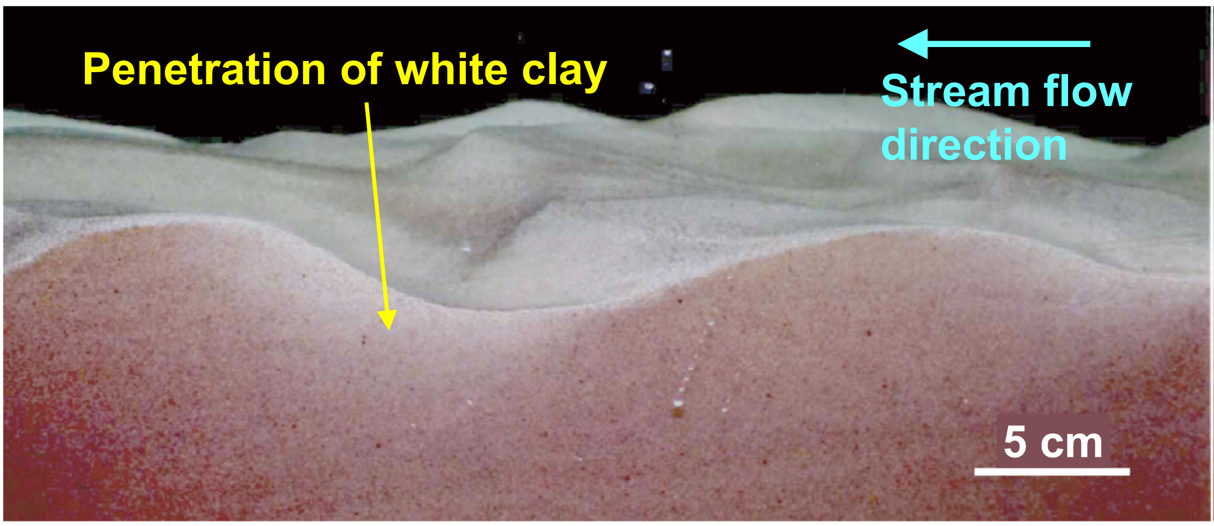


Pool-riffle sequence



Hayashi and Rosenberry (2002. *Ground Water*, 40: 309)

Laboratory Experiment on Bedform Effects

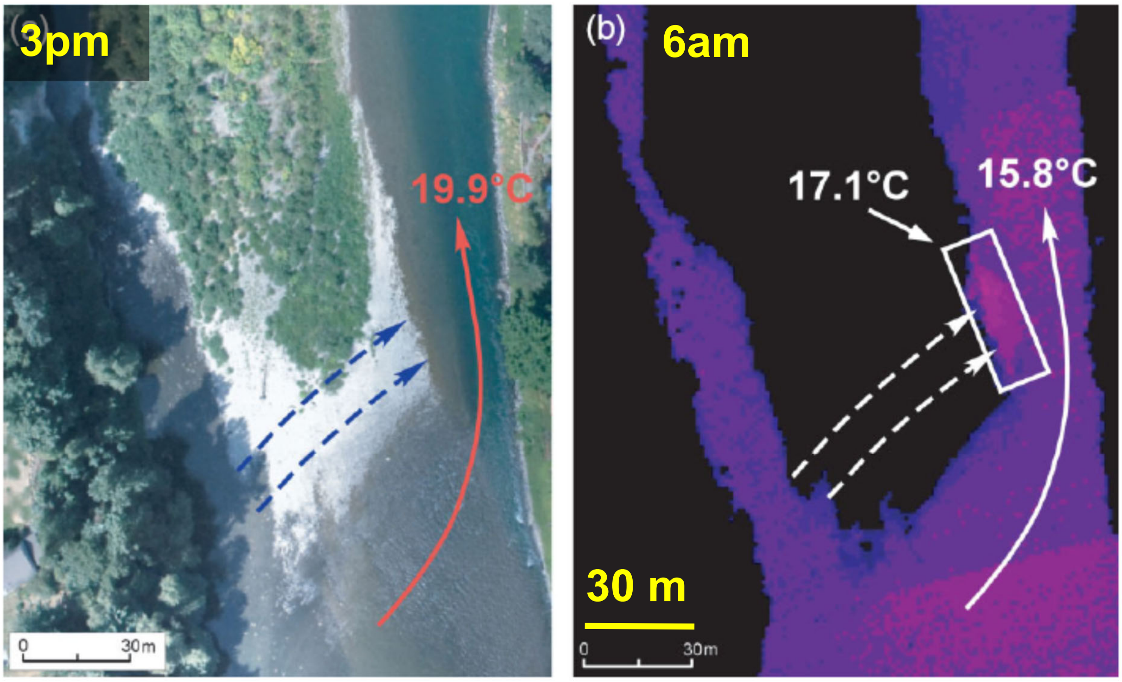


Packman and Mackay (2003. *Water Resources Res.*, 39:1097)

Evidence of Hyporheic Flow by Temperature

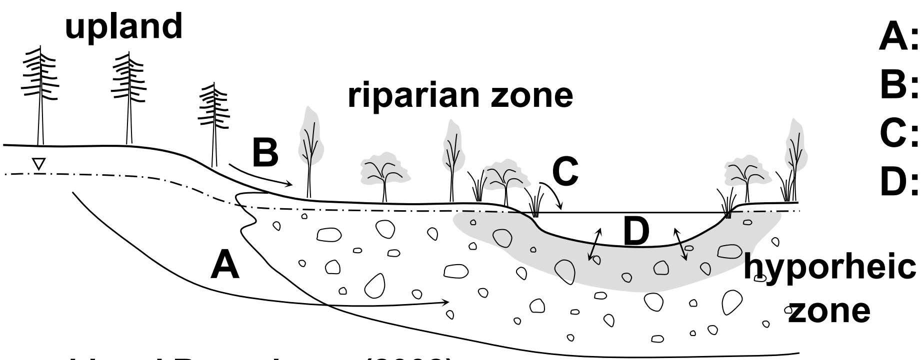
Airborne Infra-Red Thermometry

Clackamas River, Oregon



Burkholder et al. (2008. *Hydrological Processes*, 22: 941)

Pathways of water and nutrients



A: Groundwater
B: Overland flow
C: Litter fall
D: Hyporheic

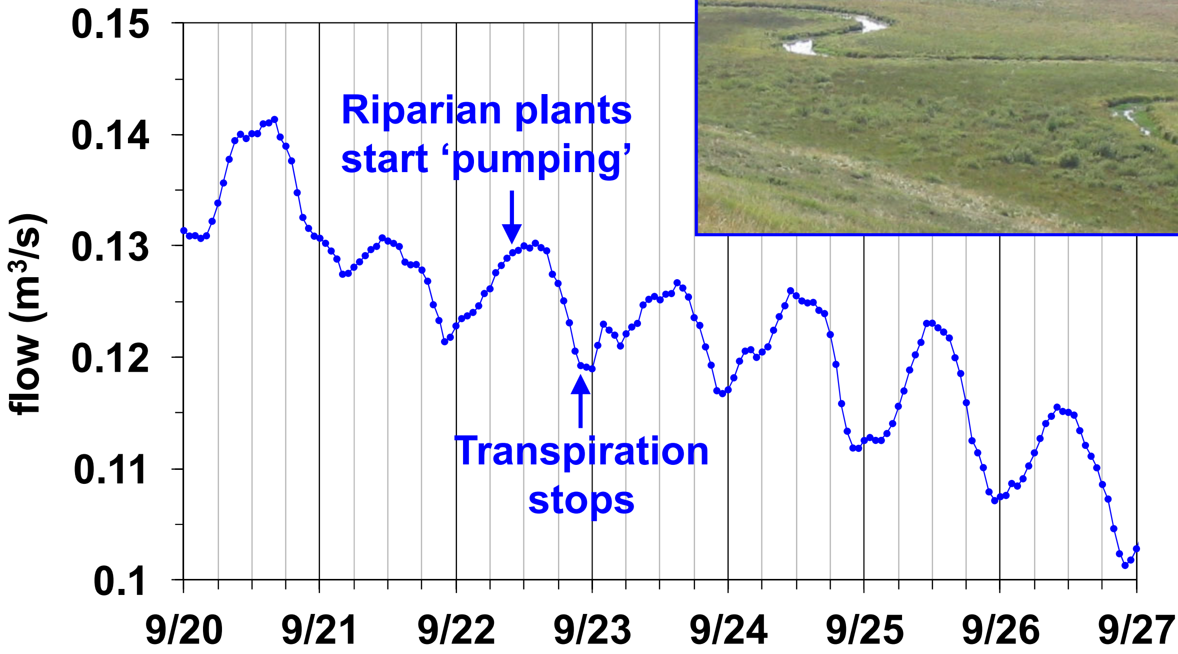
Hayashi and Rosenberry (2002)

Important ecological functions of GW-stream interaction:

(1) It maintains the baseflow during dry periods.
(2) It regulates the temperature of water and stream beds.
(3) It brings nutrients (carbon, nitrogen, etc.) into the stream.
(4) It supports stream-side (riparian) vegetation.

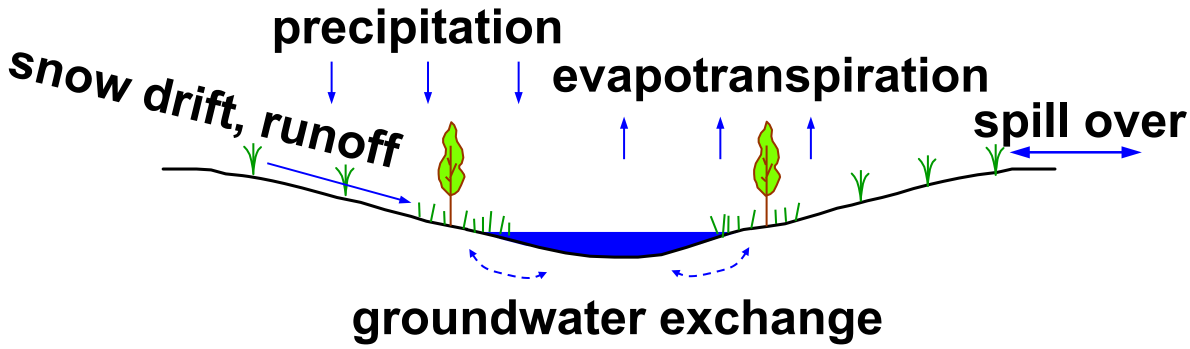
GW-SW Interaction in the Riparian Zone

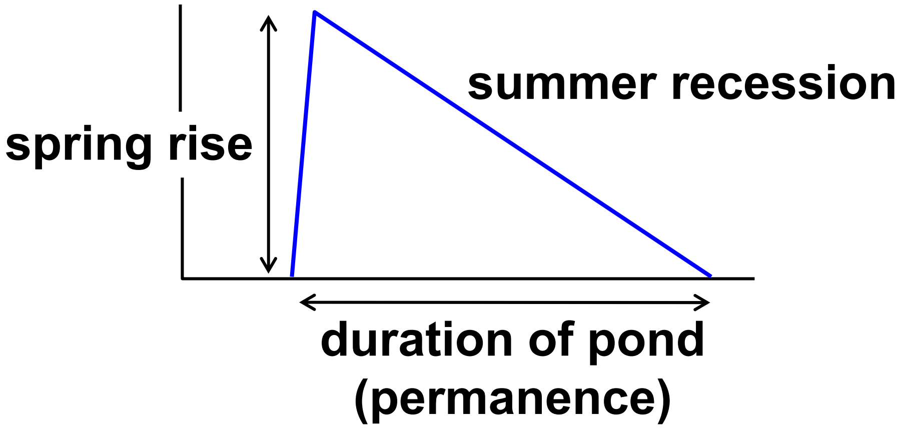
West Nose Creek, near Calgary



Prairie Wetlands in Western Canada/USA

Water Balance of Prairie Wetlands



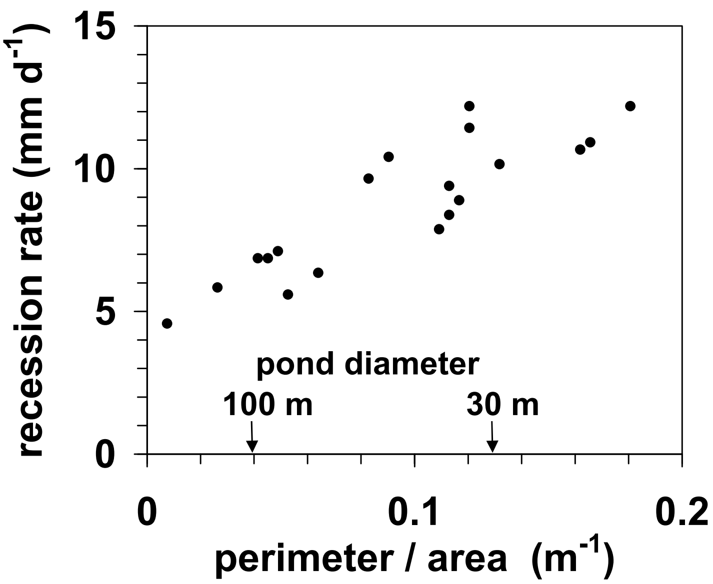


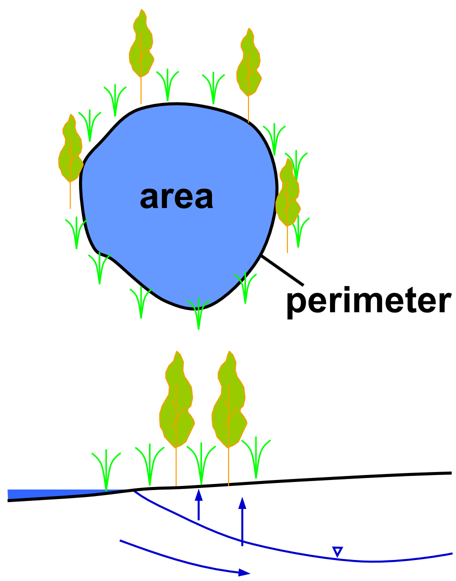
Hayashi et al. (2016. *Wetlands*, 36, S237-S254)

Effects of riparian vegetation

Water update by dense riparian vegetation induces seepage into stream/pond beds. For smaller ponds with larger ratio of perimeter to area, riparian plants have a major effect on water balance.

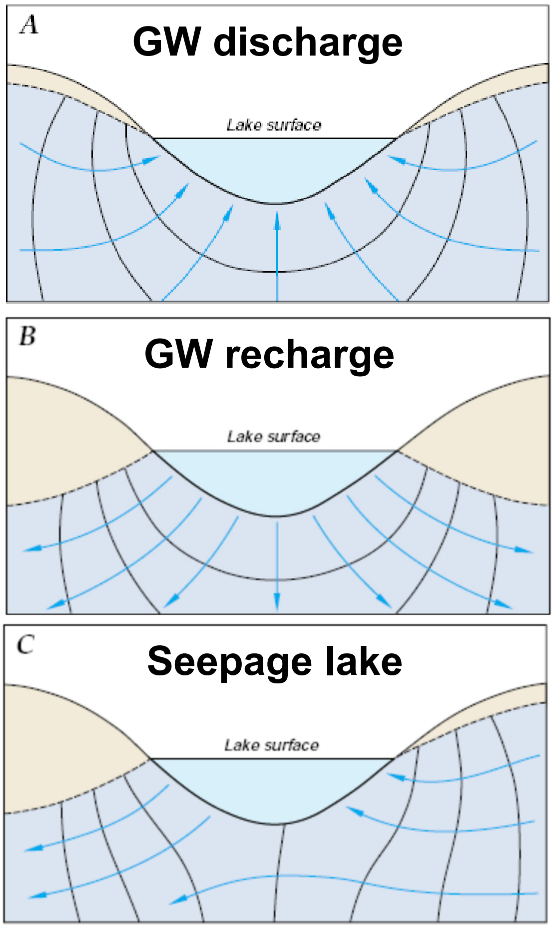
Example: Water level recession in prairie wetlands near Saskatoon.





van der Kamp and Hayashi (2009. *Hydrogeol. J.* 17: 207)

Interaction of Groundwater with Lakes



Lakes can:

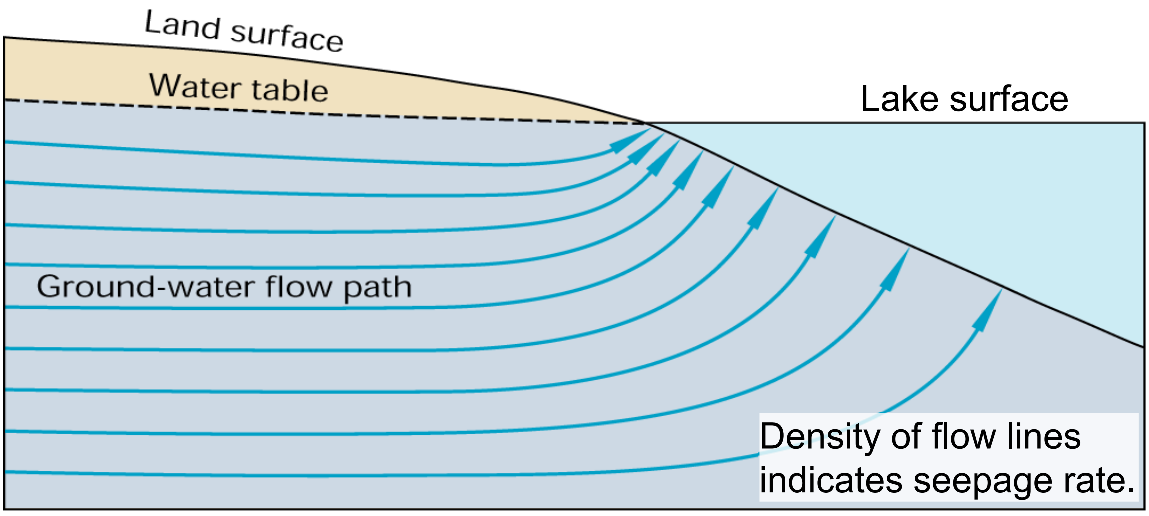
A. receive groundwater inflow,
B. lose water to groundwater, or
C. both (often termed a 'seepage lake').

Note that:

- **These lakes may have surface water inflow or outflow.**
- **These are 'snapshots'.**
- **Mode of interaction can change (seasonal, inter-annual, inter-decadal).**

Winter et al. (1998. http://pubs.usgs.gov/circ/circ1139/)

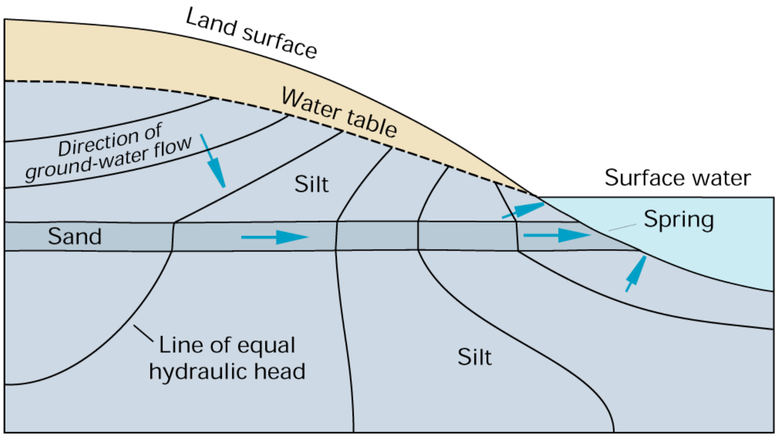
Groundwater Seepage into Lakes



McBride & Pfannkuch (1975. *U.S. Geol. Surv. J. Res.*, 3, 505-512)

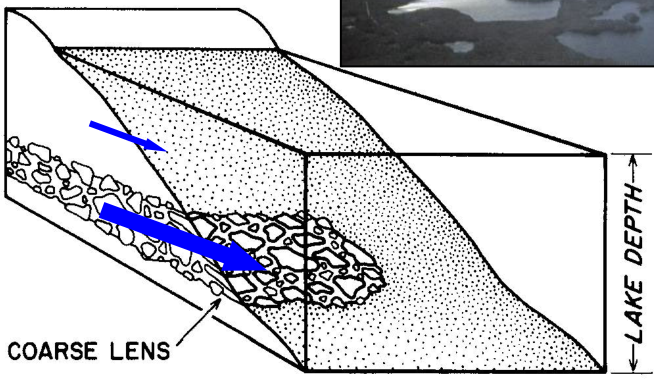
- **Seepage rates are usually greatest near shore and decrease nonlinearly with distance from the shoreline.**
- **This general pattern can have major anomalies caused by geological heterogeneity. → Geology *vs* Topography**

Effects of Geological Heterogeneity



Conceptual model.
→ TopoDrive exercise

Trout Lake (15km^2), Wisconsin. A kettle lake in glacial outwash aquifer. → similar lakes in AB?

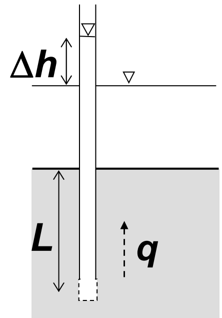


Krabbenhoft & Anderson (1986. *Ground Water*, 24, 49-55.)

Topo Drive Exercise

(Lake-GW interaction)

Measurements of seepage flux

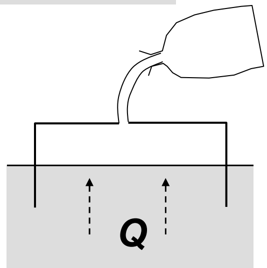


Mini-piezometer

A shallow piezometer is installed in a lakebed to measure the hydraulic head. From Darcy's law;

$q = K\,\Delta h / L$ **Eq. (3.1)**

where K is hydraulic conductivity.



Seepage meter

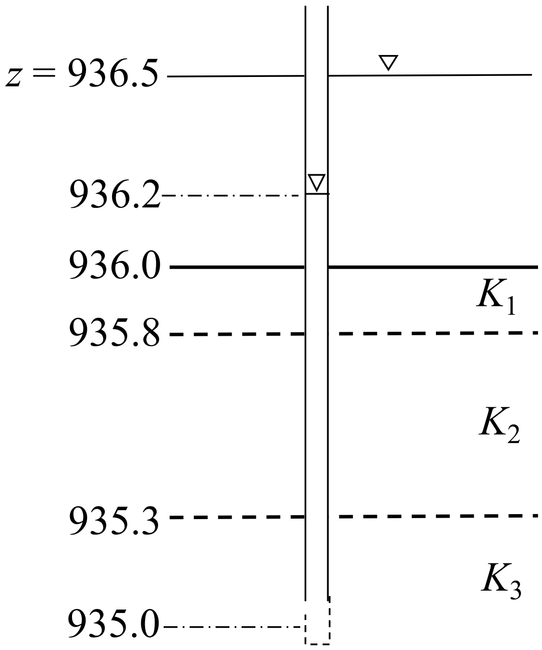
Seepage from the bottom sediment is collected in a plastic bag to estimate q (m s^{-1}).

$q = Q / A$

where Q (m^3 s^{-1}) is the flow rate and A (m^2) is the area covered by the seepage meter.


Photo: Don Rosenberry

Example Problem No. 3



$$q = -K_b \frac{\Delta h}{\Delta z}$$

$$K_b = \left(\frac{\Delta z_1}{K_1 \Delta z} + \frac{\Delta z_2}{K_2 \Delta z} + \frac{\Delta z_3}{K_3 \Delta z} \right)^{-1} \quad \text{Eq. (1.2)}$$

$K_1 = 1 \times 10^{-6}$ m s^{-1}

$K_2 = 2 \times 10^{-4}$ m s^{-1}

$K_3 = 3 \times 10^{-5}$ m s^{-1}

$\Delta z_1 =$

$\Delta z_2 =$

$\Delta z_3 =$

$$\frac{\Delta h}{\Delta z} =$$