The Role of Groundwater in Streams, Floodplains, and Riparian Zones

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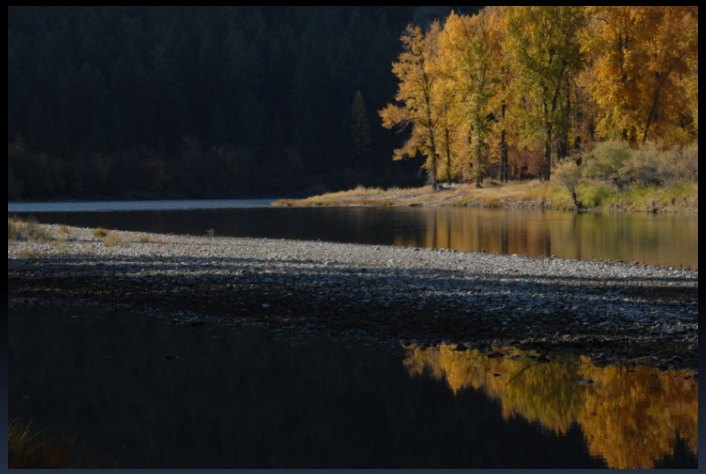
October 21, 2015

Tongue River



Bitterroot River

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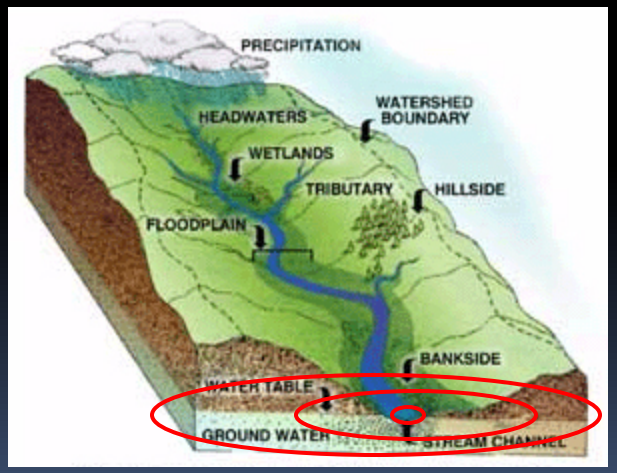
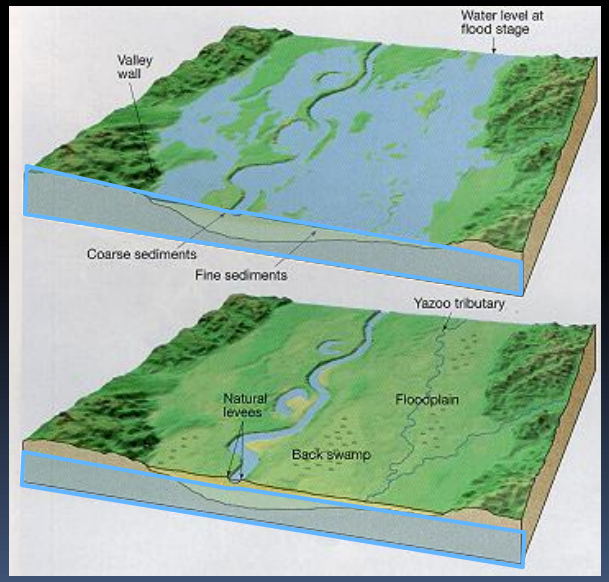
Outline
Building the Conceptual Framework

1. Conceptualizing how groundwater and surface water interact at multiple scales.

2. Conceptualizing the storage and retention of shallow groundwater.





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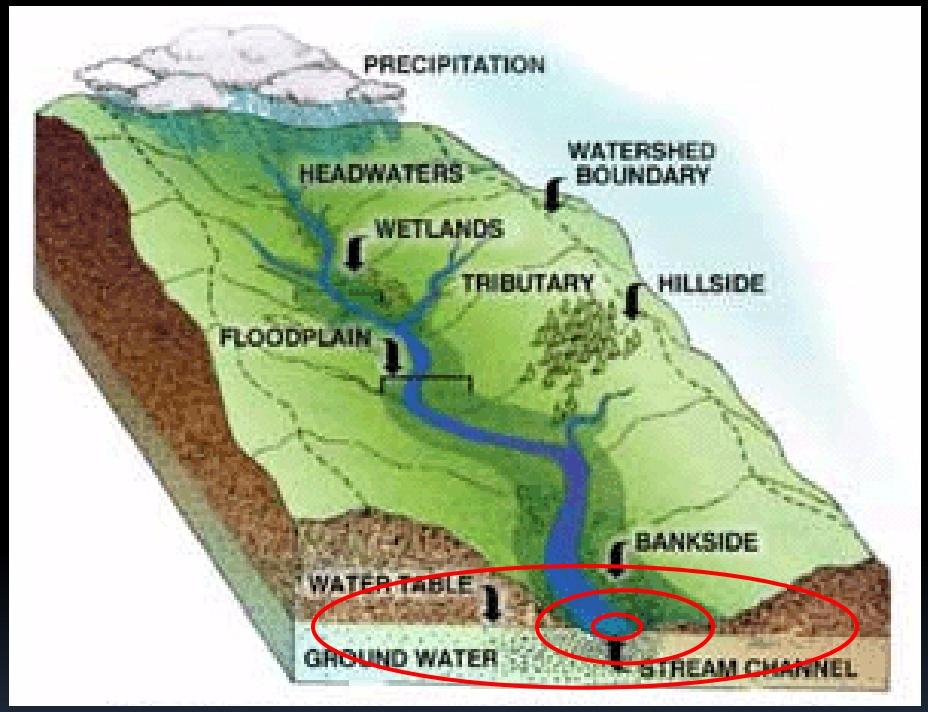
1. Conceptualizing Groundwater Systems at Multiple Scales



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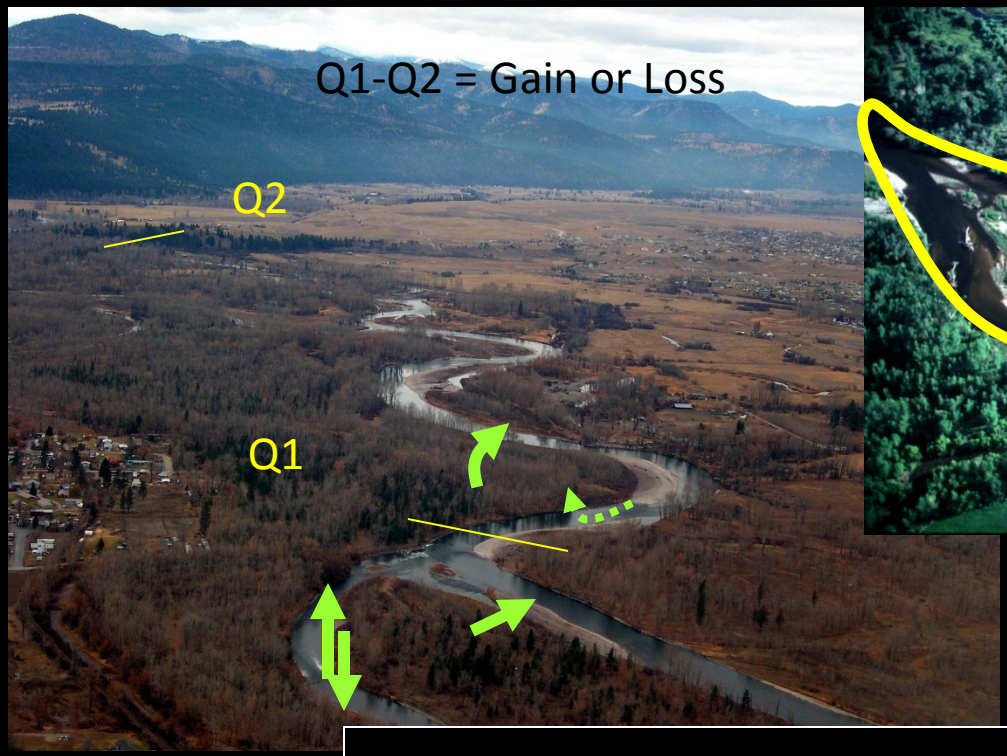
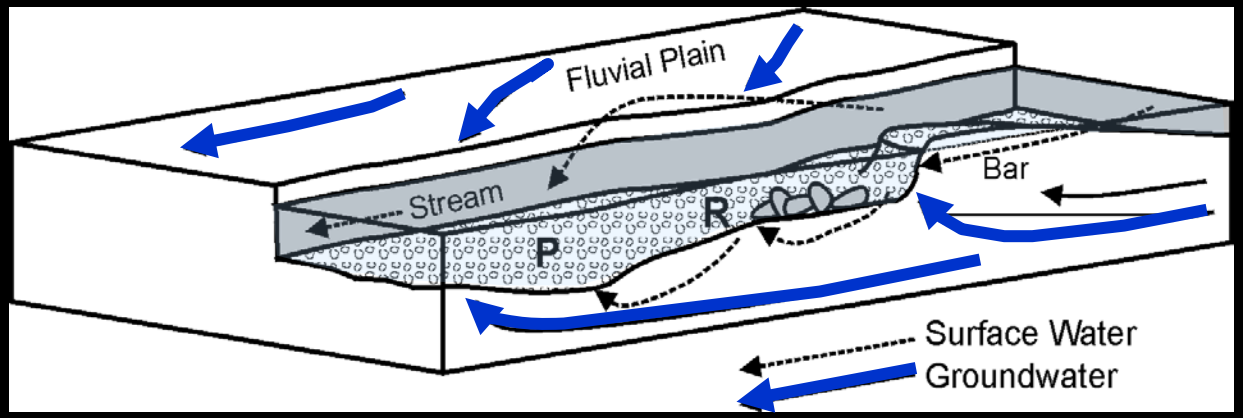
Exchange in the Channel Bed and Near-channel Scale





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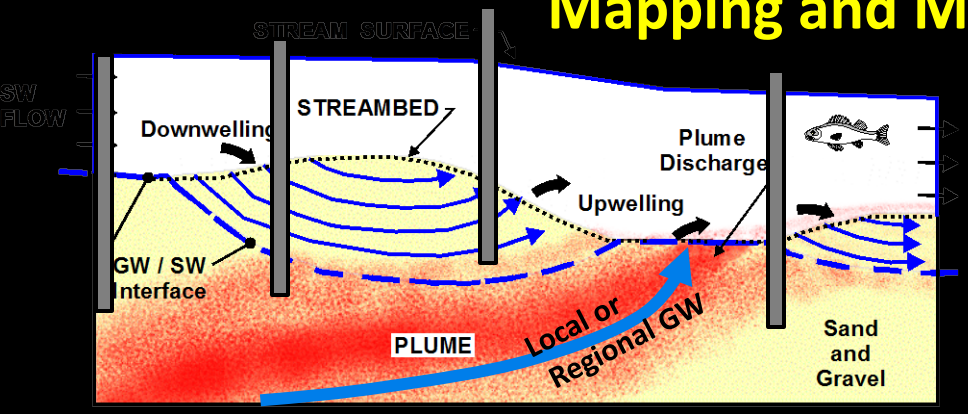
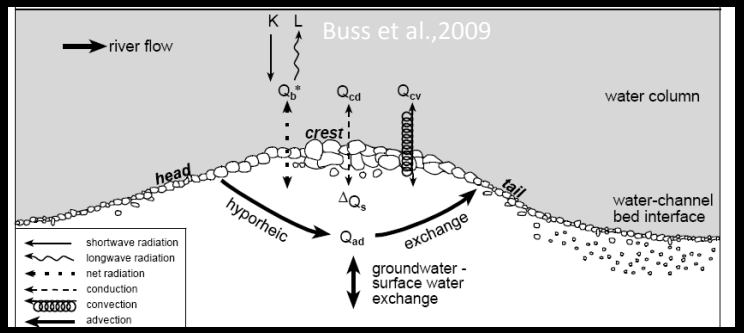
Mapping and Modeling Interfaces

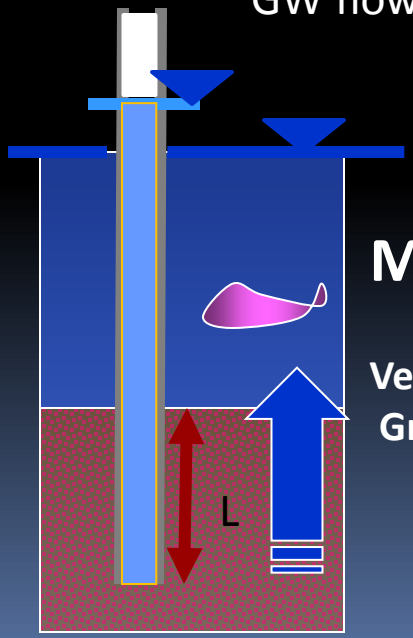


B. Conant Jr. (2000), in EPA Workshop Proceedings

Measuring the Distribution and Fluxes of Contaminants



GW flowing into stream

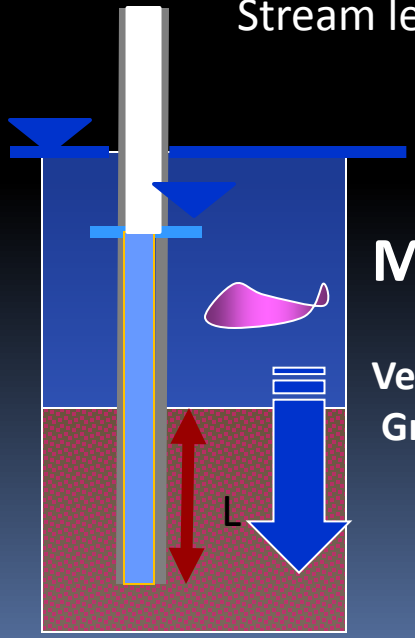


Mini Piezometer

Vertical Hydraulic Gradients (VHG)

$$+\frac{\Delta h}{L}$$

Stream leaking into GW



Mini Piezometer

Vertical Hydraulic Gradients (VHG)

$$-\frac{\Delta h}{L}$$

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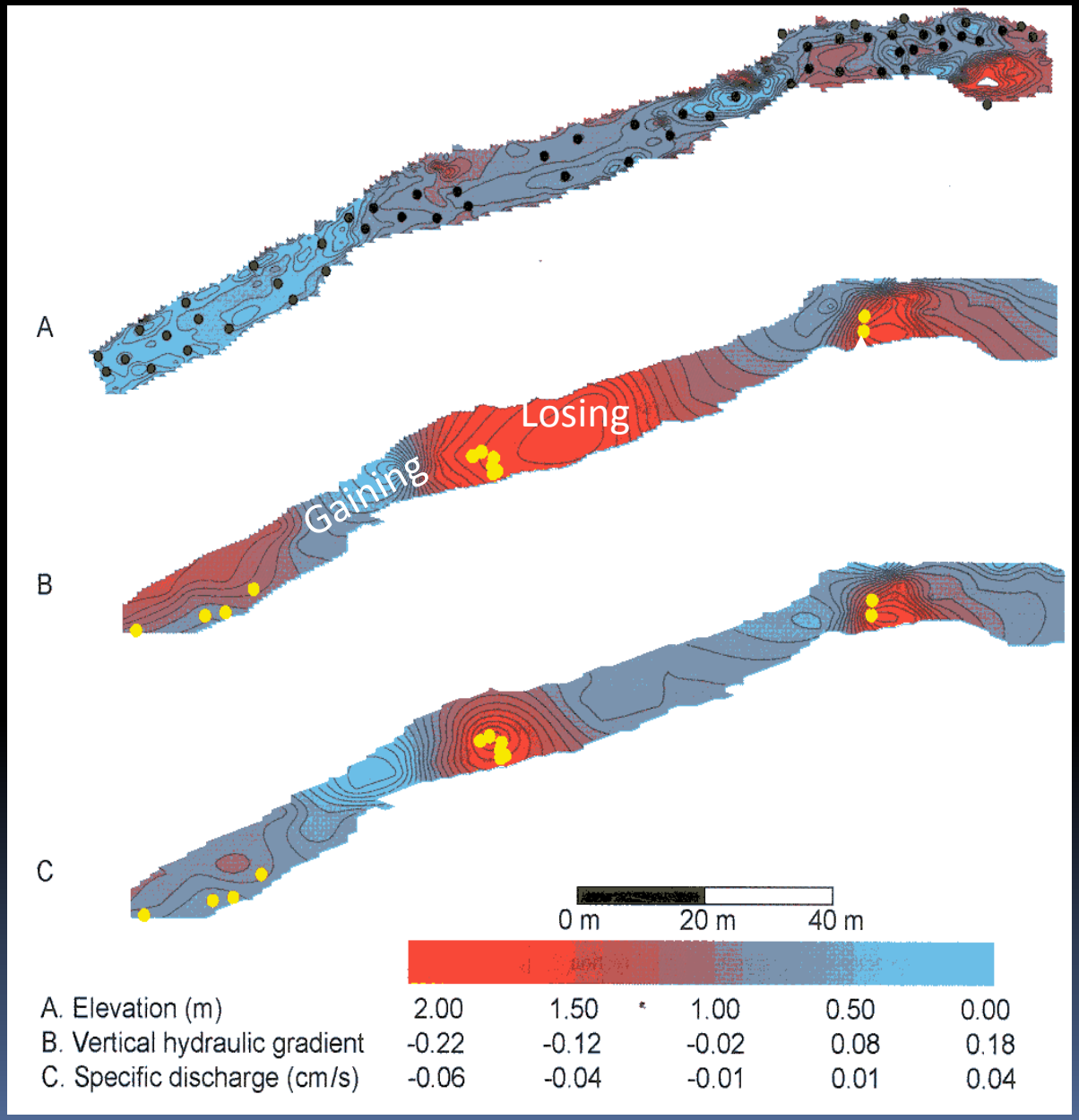
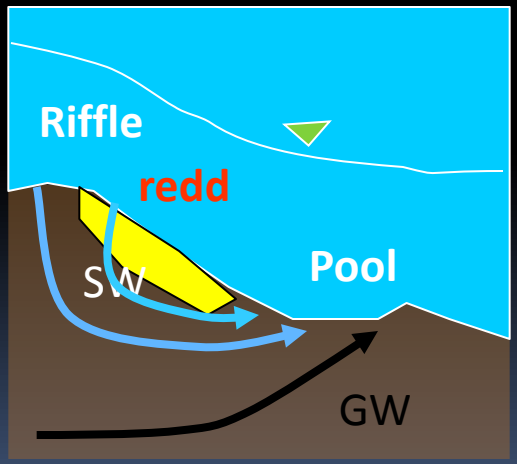
BULL TROUT SPAWNING, Lion Creek, MT.



Baxter and Hauer, 2000, Can. J. Fish. Aquat. Sci. 57



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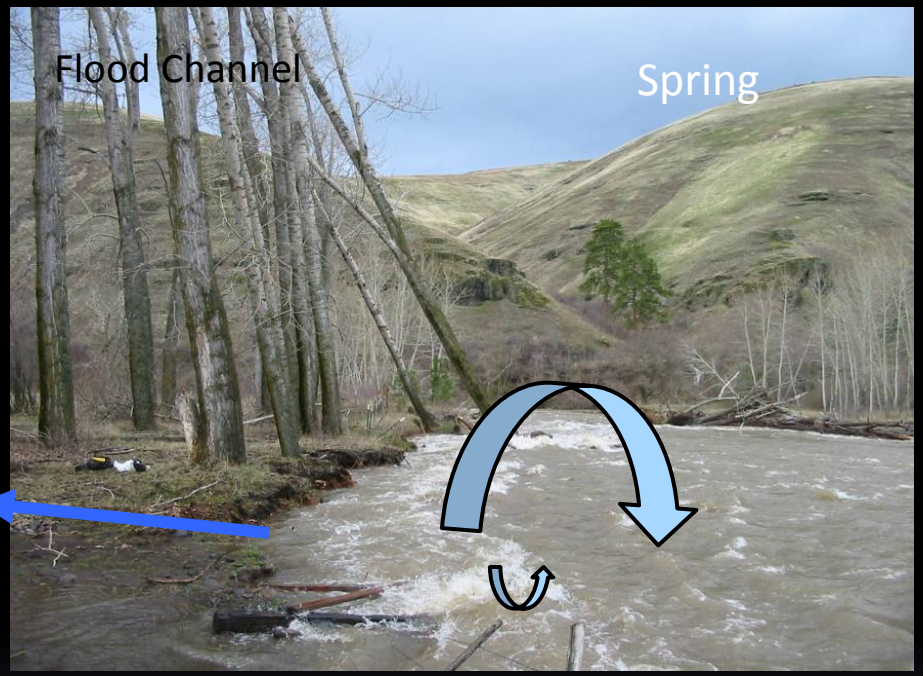
Interface Exchange is not Static, it Varies Temporally and Spatially

Interaction with the Floodplain-Riparian Zone



New flood-flow channel

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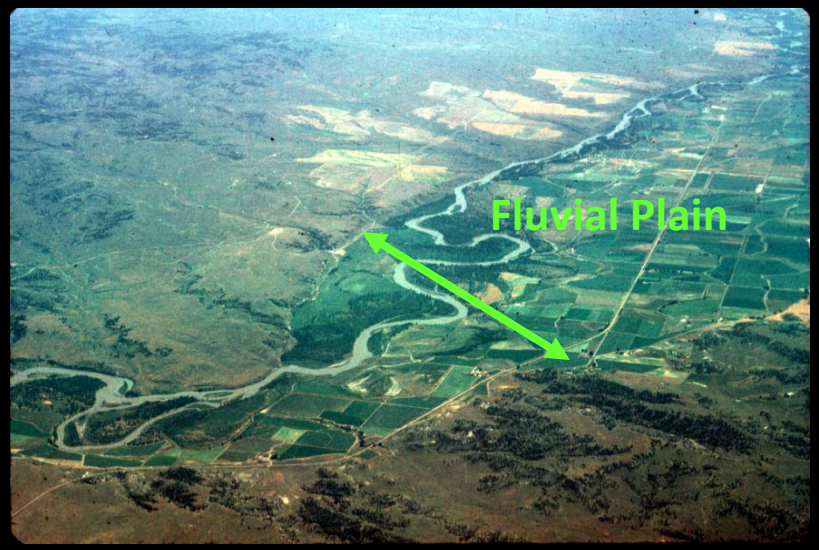
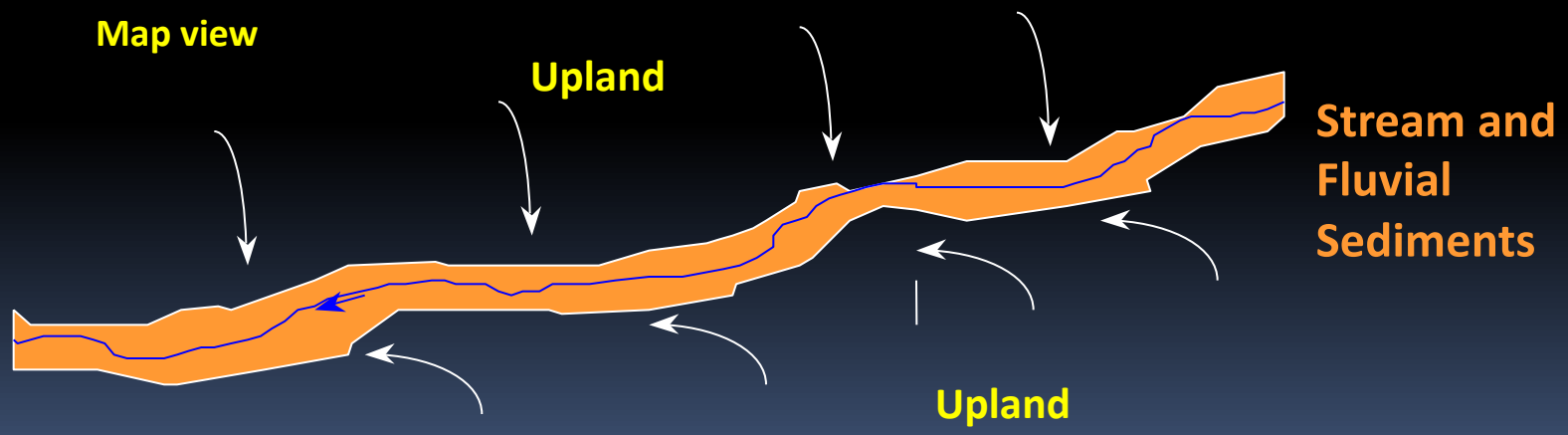
Groundwater Exchange at the Channel-Floodplain Scale

Tongue River

http://meic.org/wp-content/uploads/2013/01/20110702-AKP_7143.jpg

Conceptualizing GW-Stream Exchange
Fluvial Plain/floodplain System Scale





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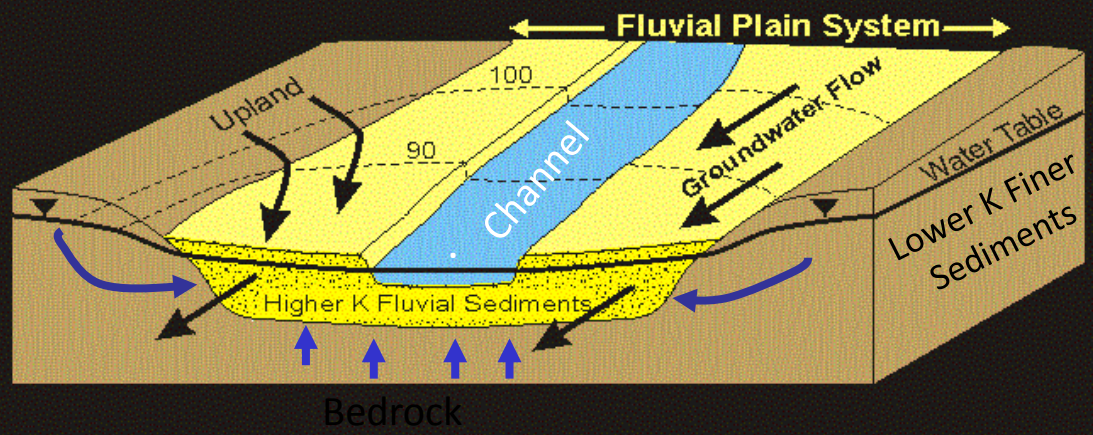
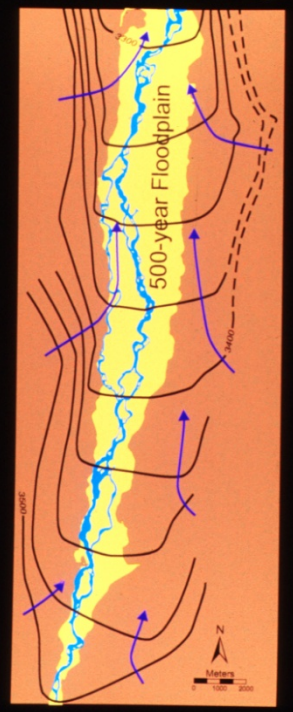
FLUVIAL PLAIN SCALE
100's m^2 to a few km^2



Woessner, W.W., 1998. Changing views of stream-groundwater interaction, American Institute of Hydrology, St. Paul, MN, p. 1-6.

Bitterroot Valley and Groundwater Flow System



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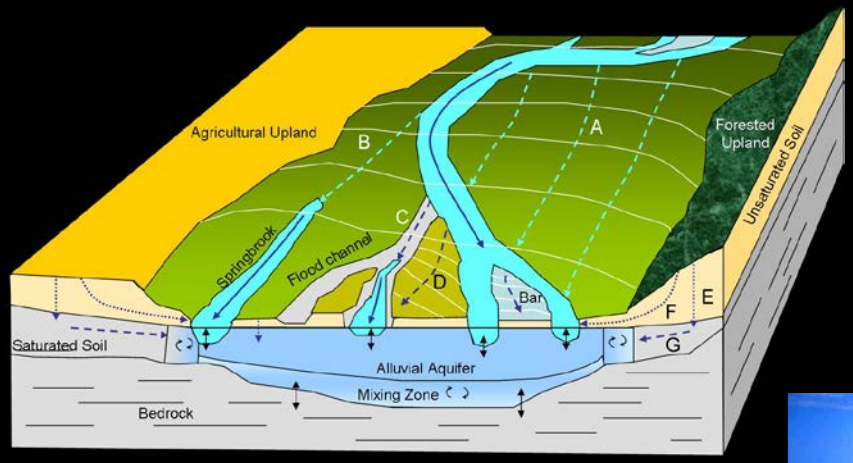
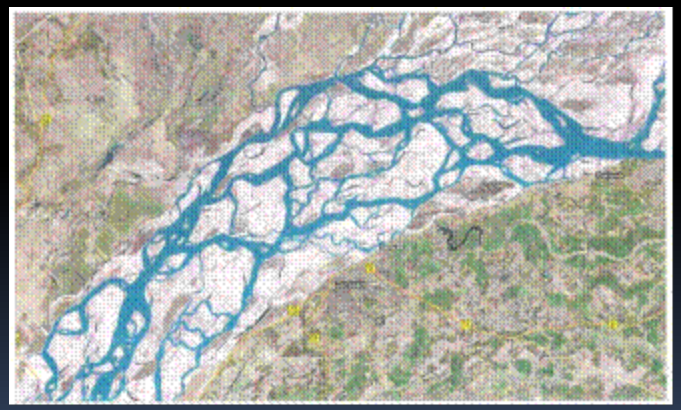
More Complex Fluvial Plan and Channel system





Missouri River

http://www.airphotona.com/stockimg/images/16504.jpg

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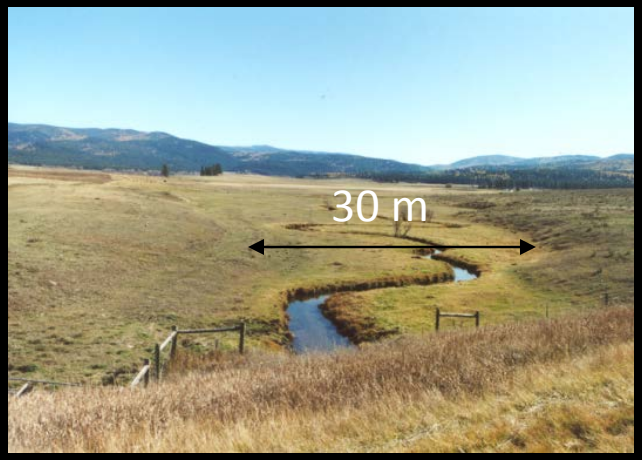
Examples of Fluvial Plains

Elk Creek



NASA image
Missouri R.

Yellowstone

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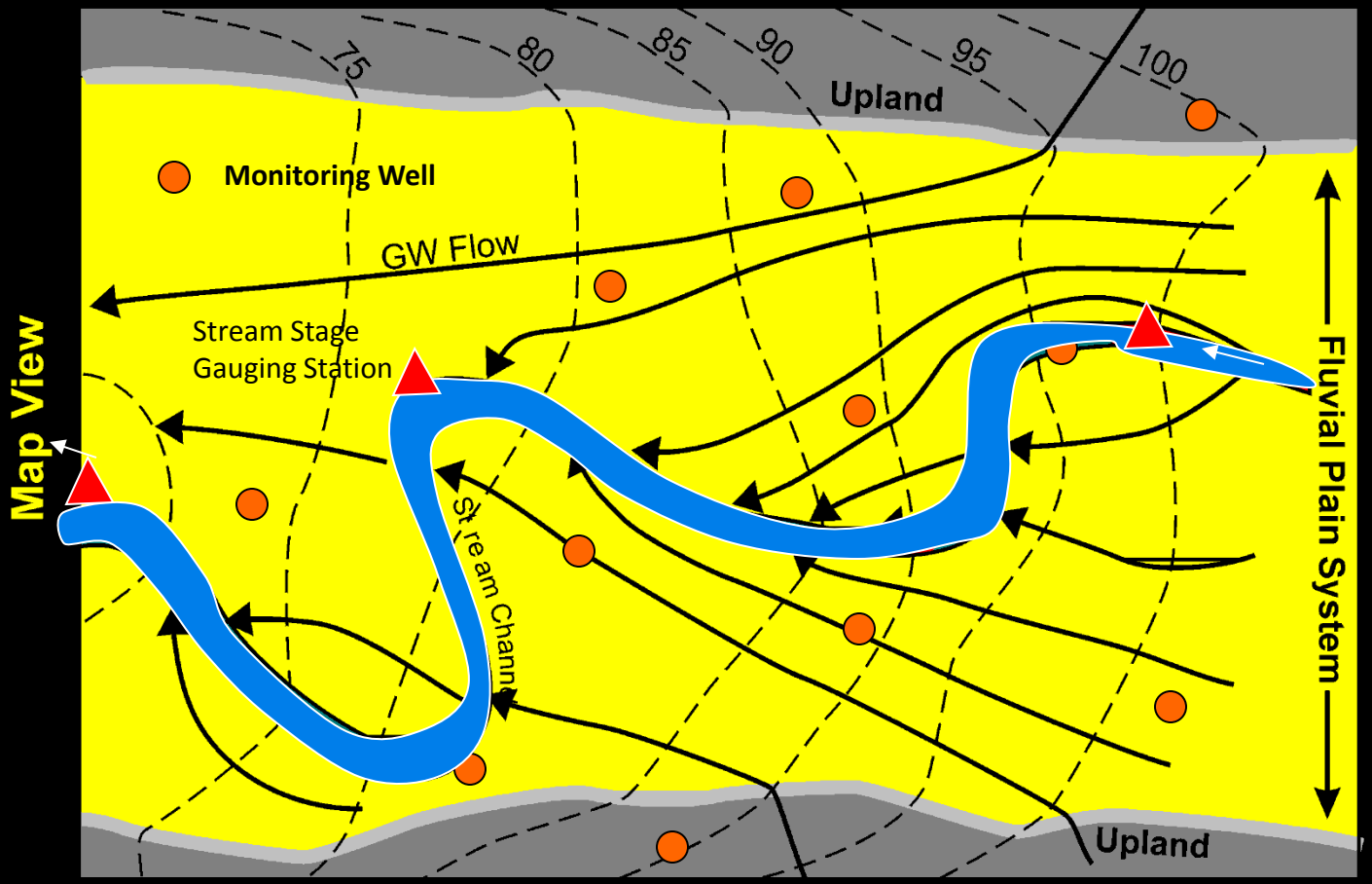
Characterizing GW Conditions in the Stream Reach



Think Various Length Scales

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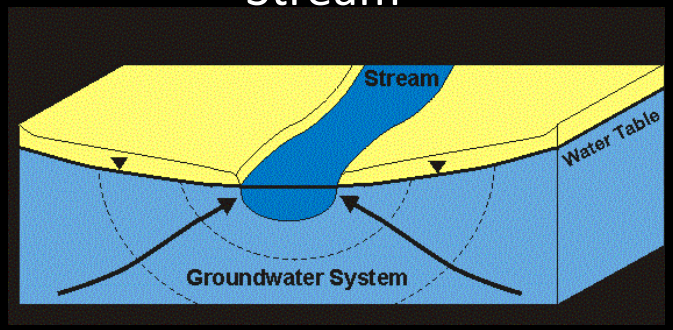
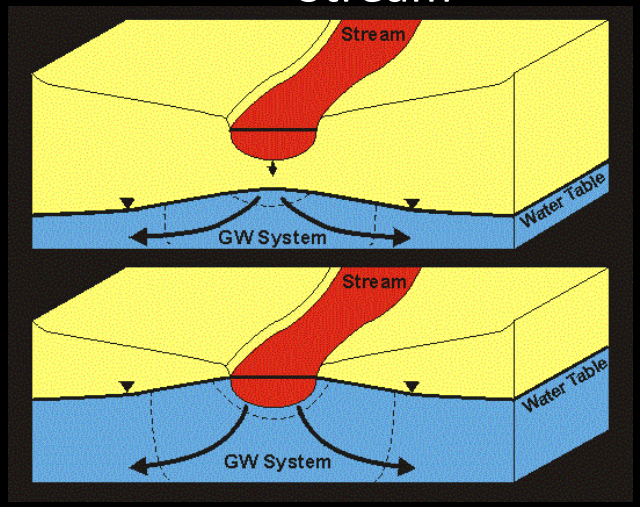
Fluvial Plan and Channel Interactions

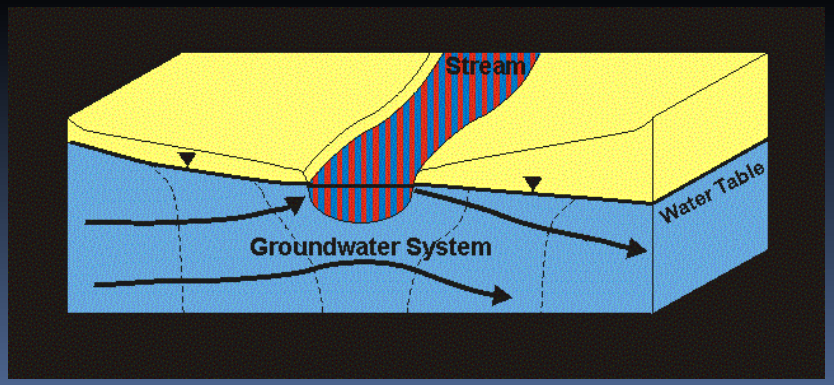
Gaining or Effluent Stream



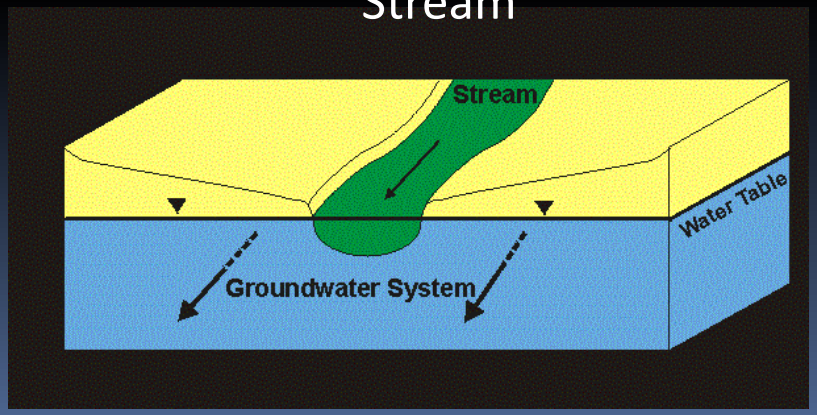
Losing or Influent Stream



Flow Through Stream



Parallel Flow Stream



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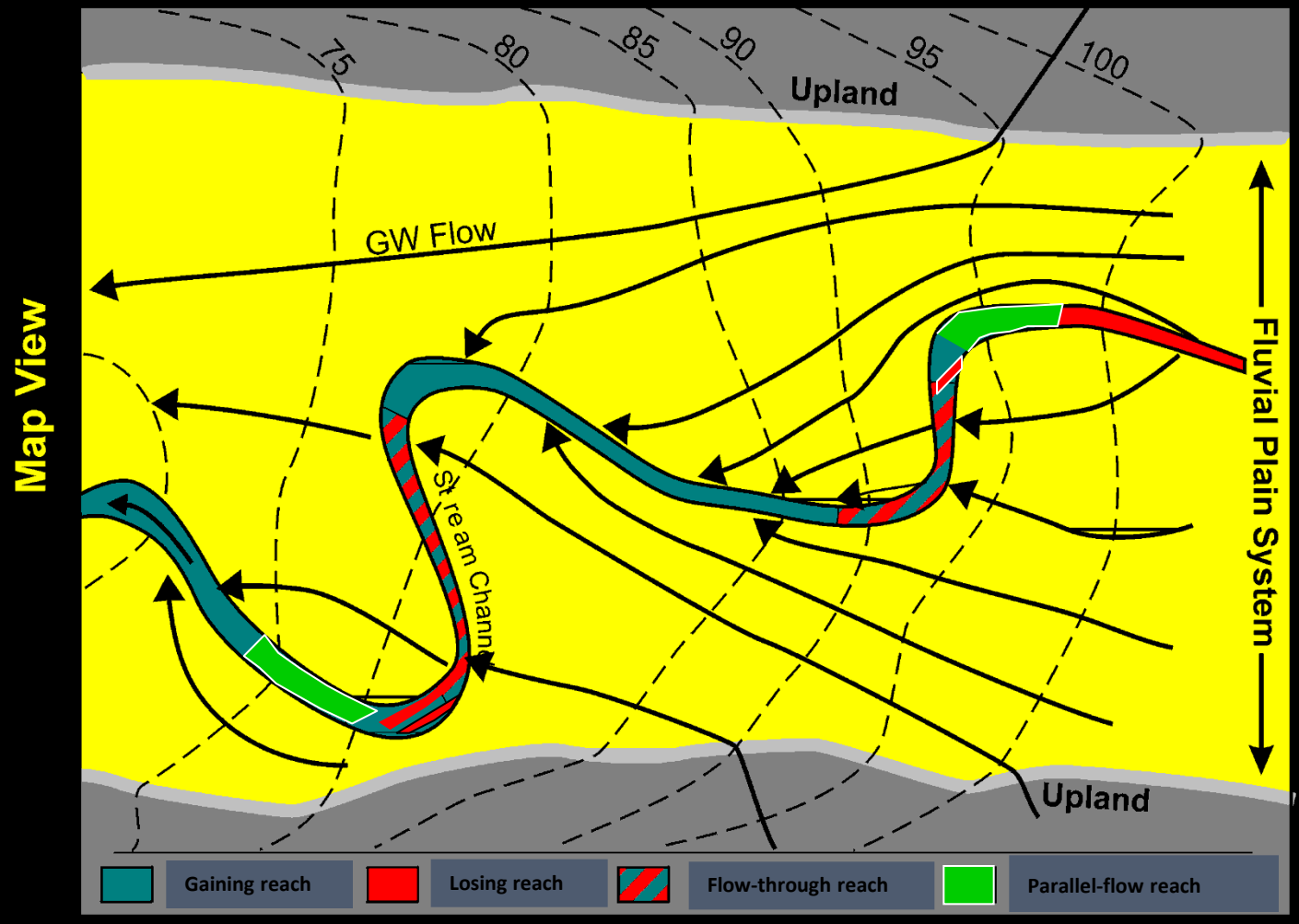
STREAM-GROUNDWATER INTERACTION WITHIN THE FLUVIAL PLAIN



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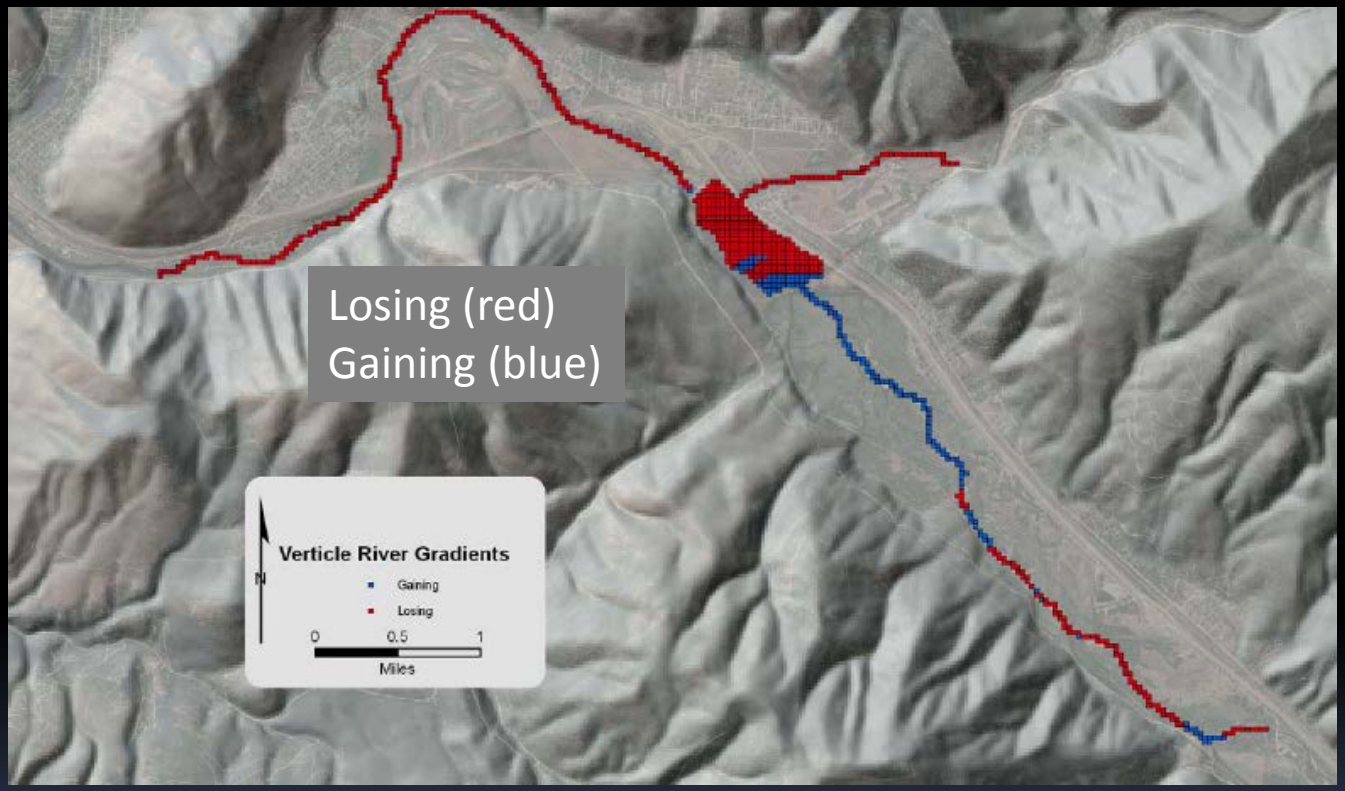
Milltown Dam Clark Fork River



Milltown Reservoir
CIRCLA Site, Montana

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Transient Changes in GW-Stream Exchange

Miller, 1990

Changes in River Stage

http://nwrm.eu/sites/default/files/catalogue-nwrm/n03ill2.png

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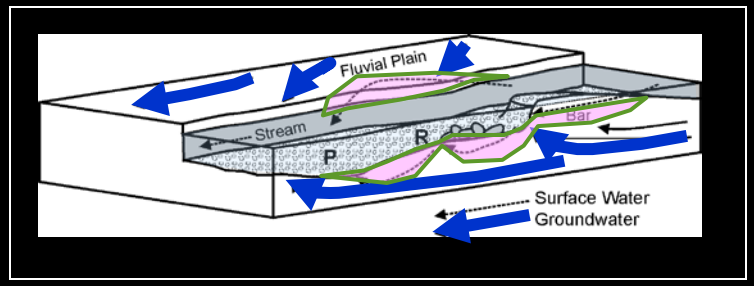
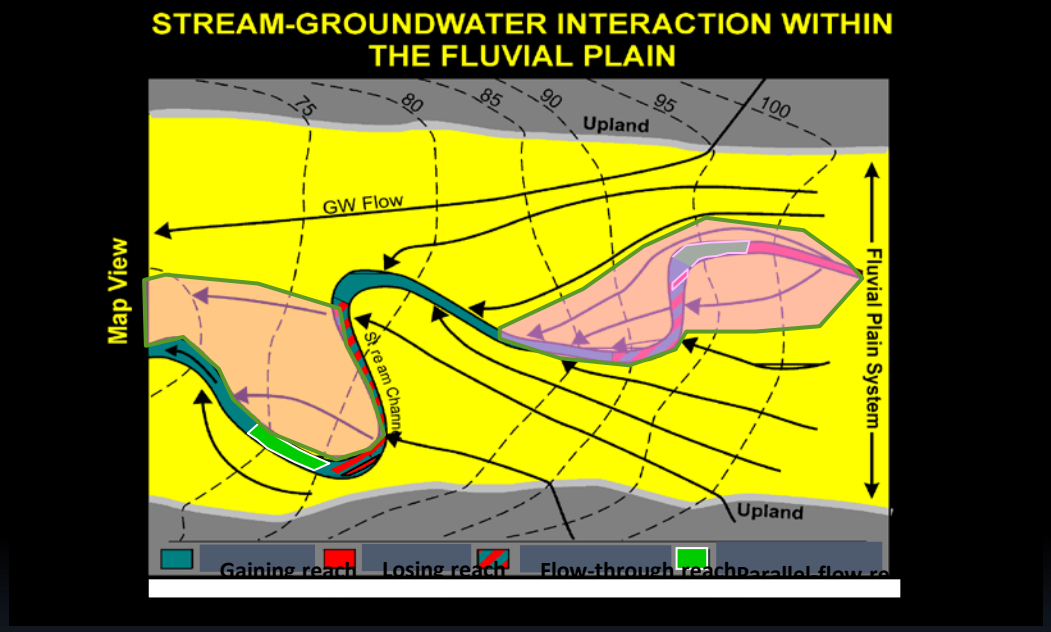
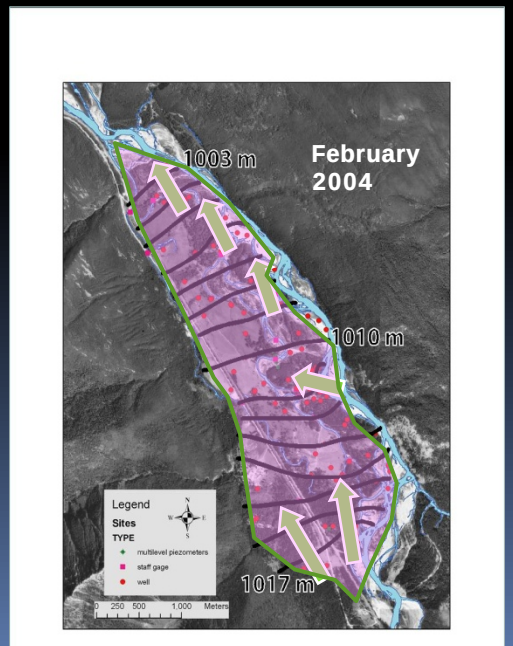
Terms: Hyporheic Water

-Stream water that enters the subsurface and

- discharges back to the stream







MF Flathead R.
1.5 km by 8 km

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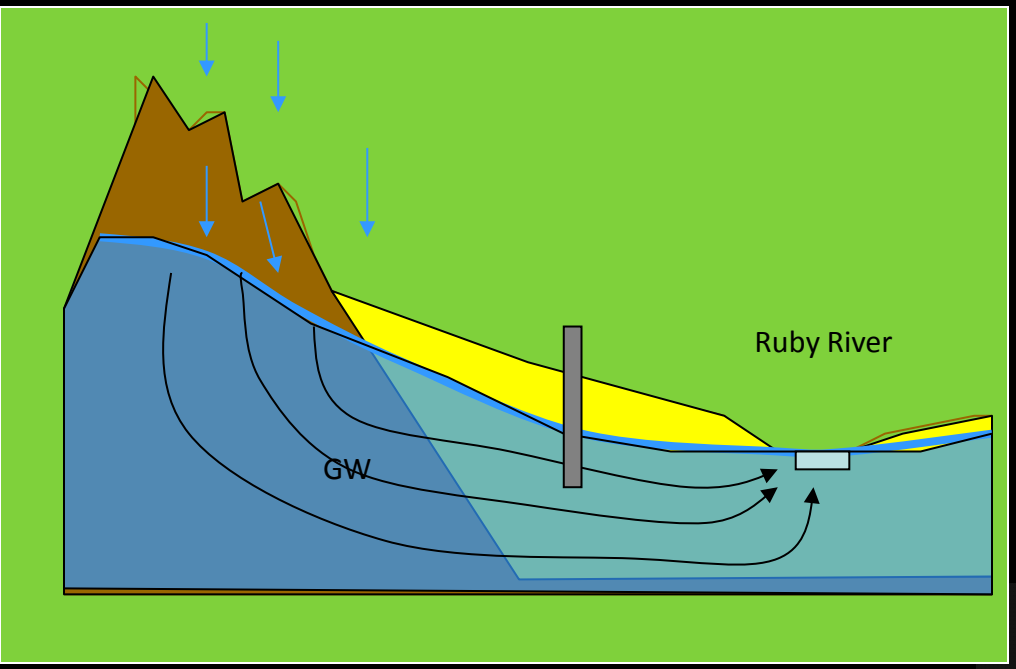
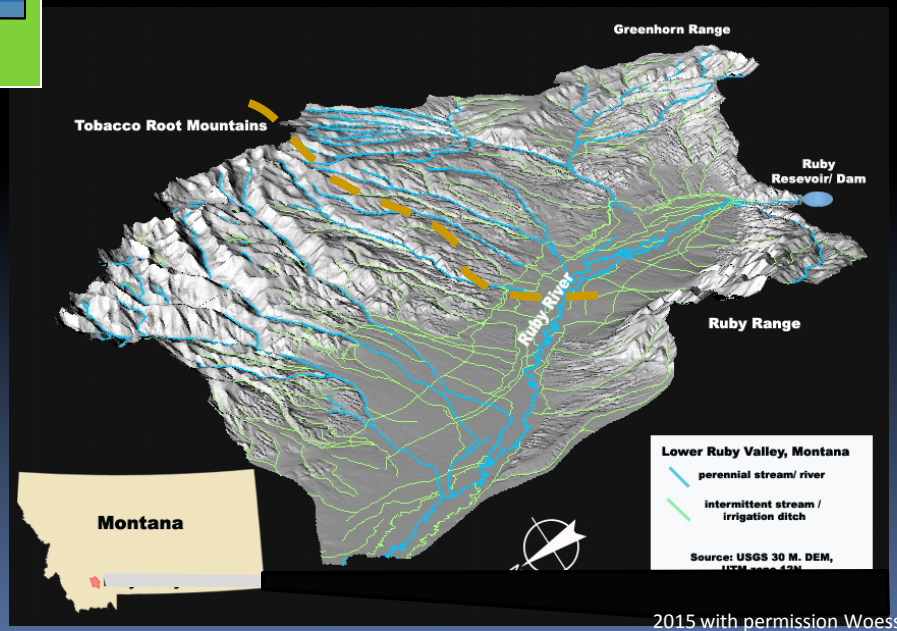
Regional Groundwater Flow Systems are also Linked to SW





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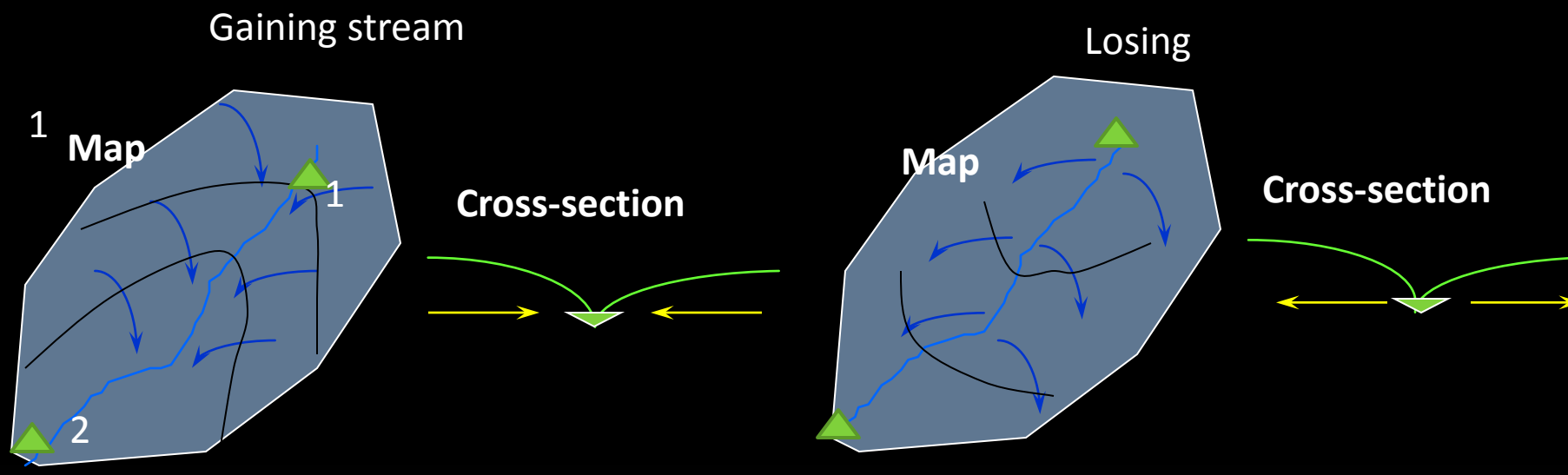
CONCEPTUALIZING BASIN SCALE STREAM-GROUNDWATER EXCHANGE

10'S TO 100'S OF km^2



Seepage Runs or Synoptic Surveys

Q2-Q1 = Gain or loss of stream flow

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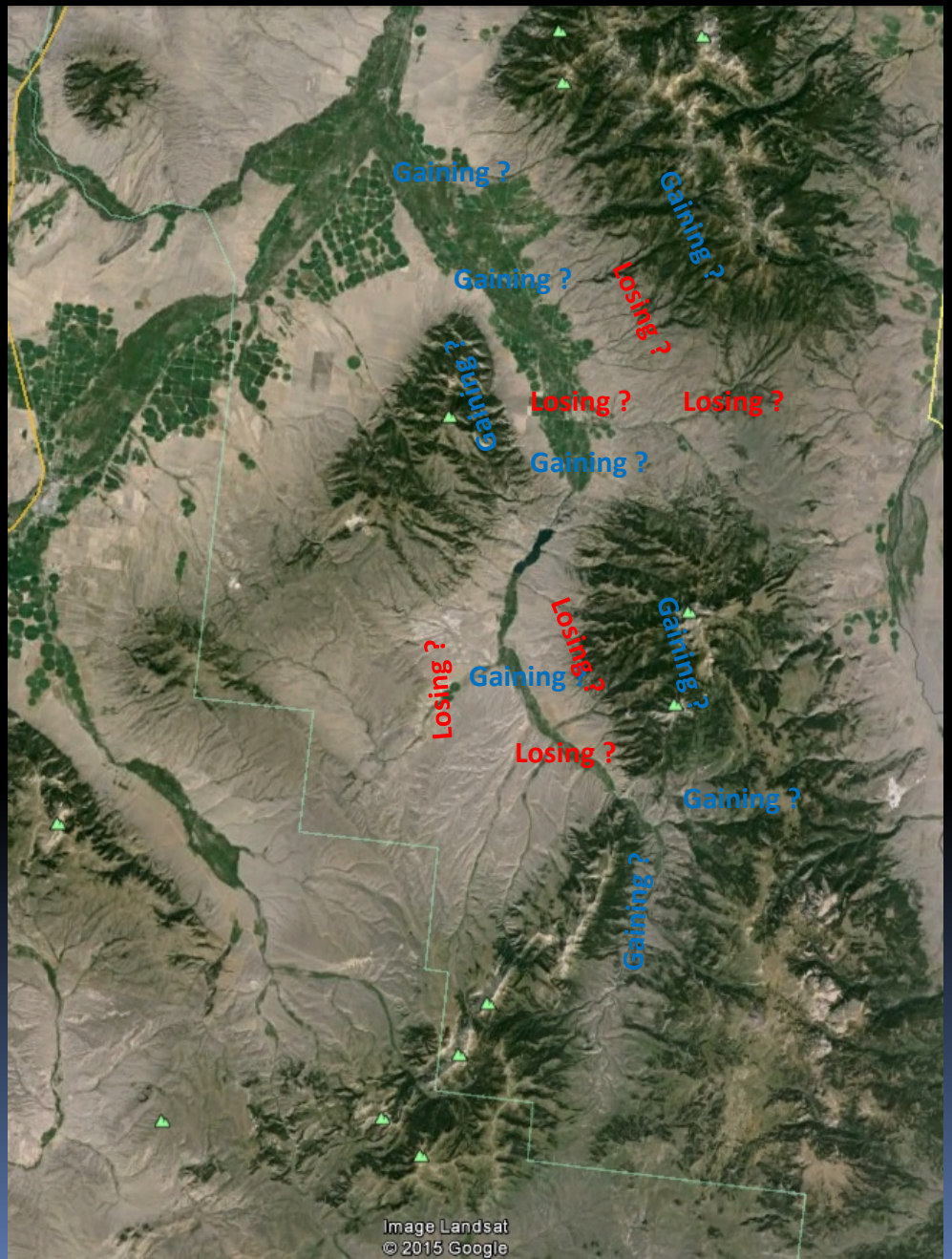
Regional Scale Basin Streams Ruby River



Complexities at the Watershed Scale

Over all is the river gaining or losing flow?…. Zero flow to something

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Base Flow Separation Techniques

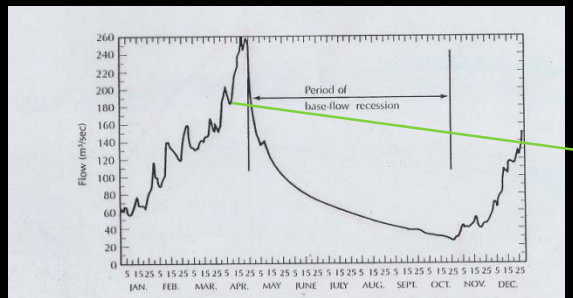


FIGURE 3.6 Typical annual hydrograph for a river with a long dry summer season: Lualaba River, Central Africa. Source: C. O. Wisler & E. F. Brater, eds., *Hydrology*, 2nd ed. (New York: John Wiley, 1959). Used with permission.

Qo

Log Q

Basin

0.1 X Q (700)
= 70 cfs

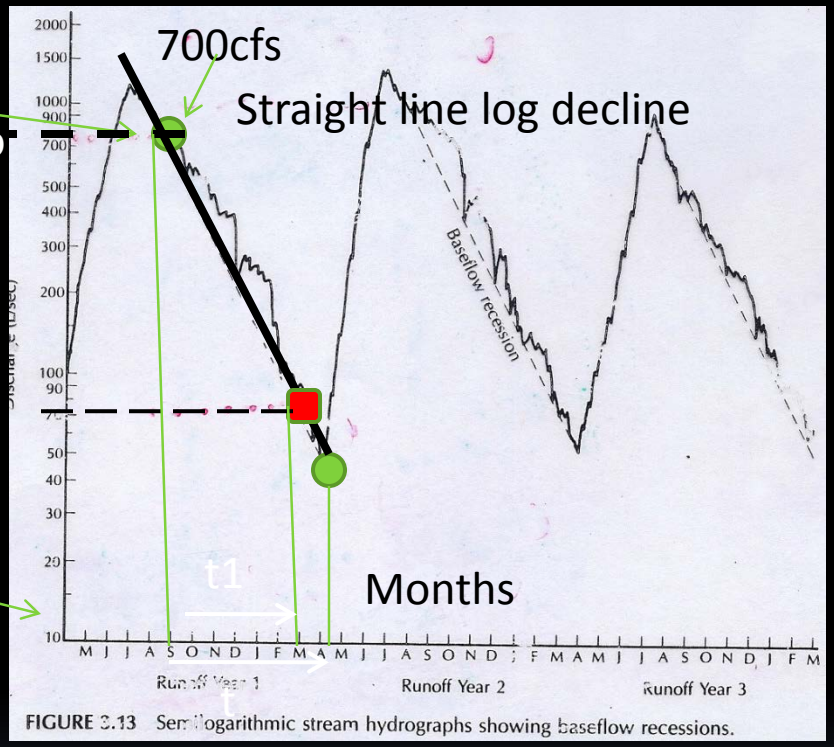
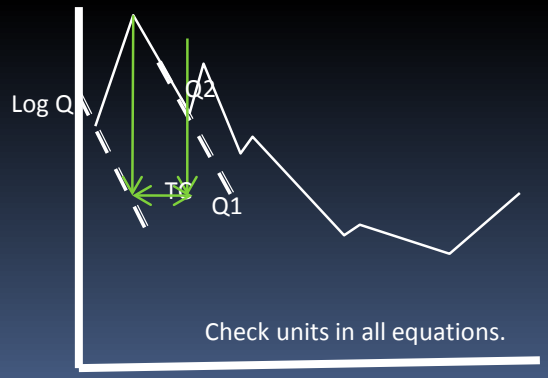
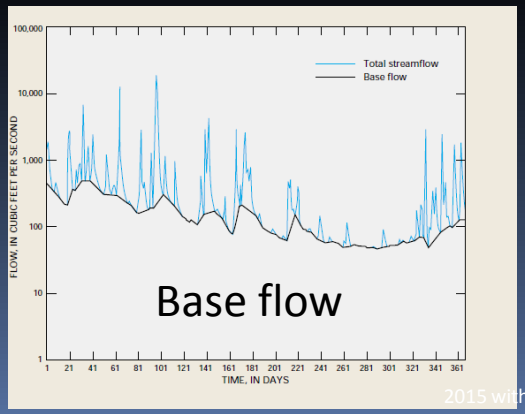


FIGURE 3.13 Semilogarithmic stream hydrographs showing baseflow recessions.





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Scale Affects on Groundwater-Surface Water Exchange At Interfaces

Watershed Scale 100s km
GW discharge to or recharge from

Regional Scale 10s km
Groundwater flow system becomes complex

Local Scale 100s m
Heterogeneities begin to dominate flow conditions

Site Scale 1 to 10s m
Heterogeneities dominate GW exchange sites and rates

Inter face exchange complexity

Role of transients in defining exchanges

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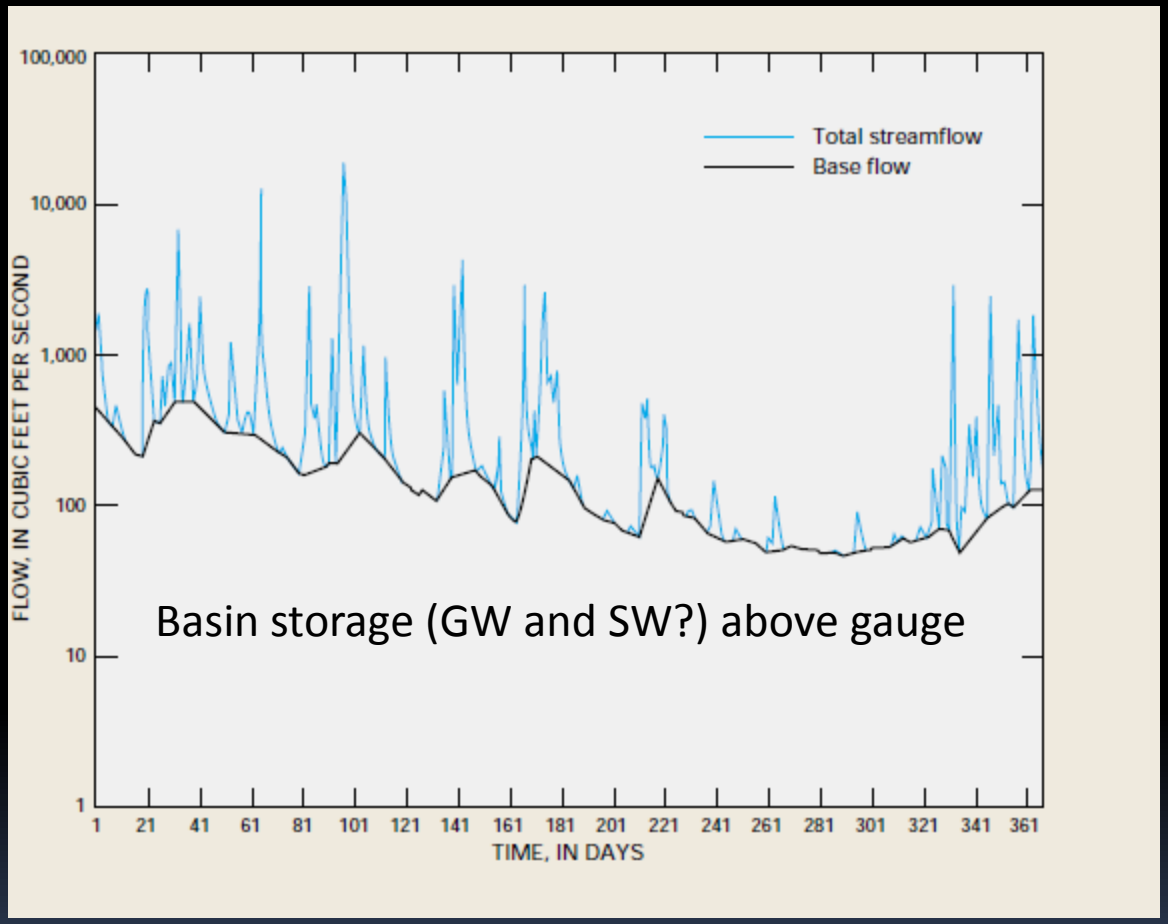
2. Conceptualizing Groundwater Storage and Retention



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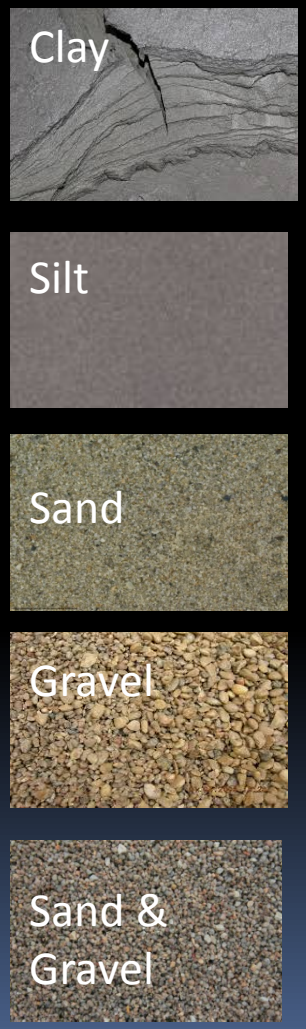
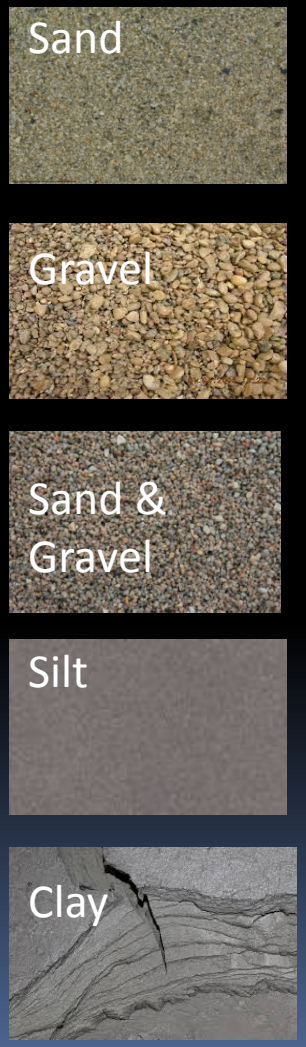
Storage and Retention: Geology of the Area is Important

Volume of pore space
Porosity, n

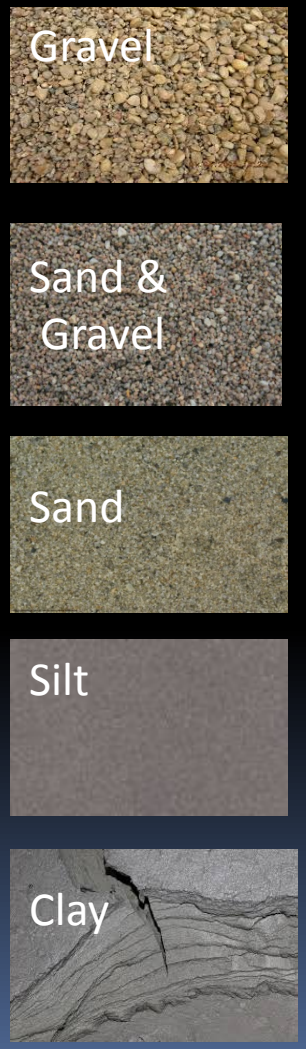


Increasing

Ability to store
and release
Specific Yield, Sy



Ability to transmit
Hydraulic Conductivity, K



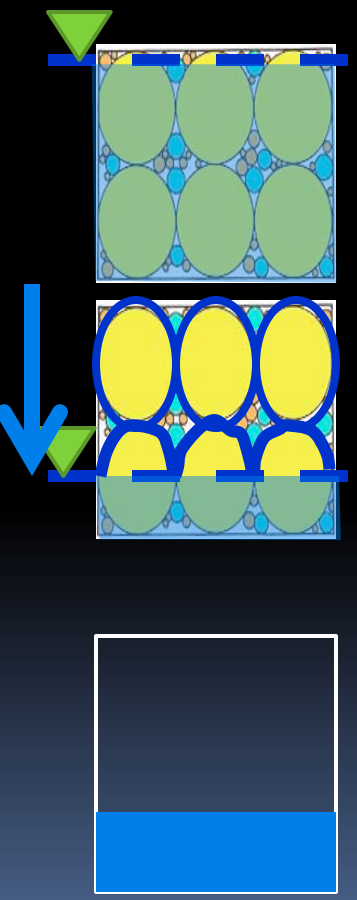
Anderson et al. 2015

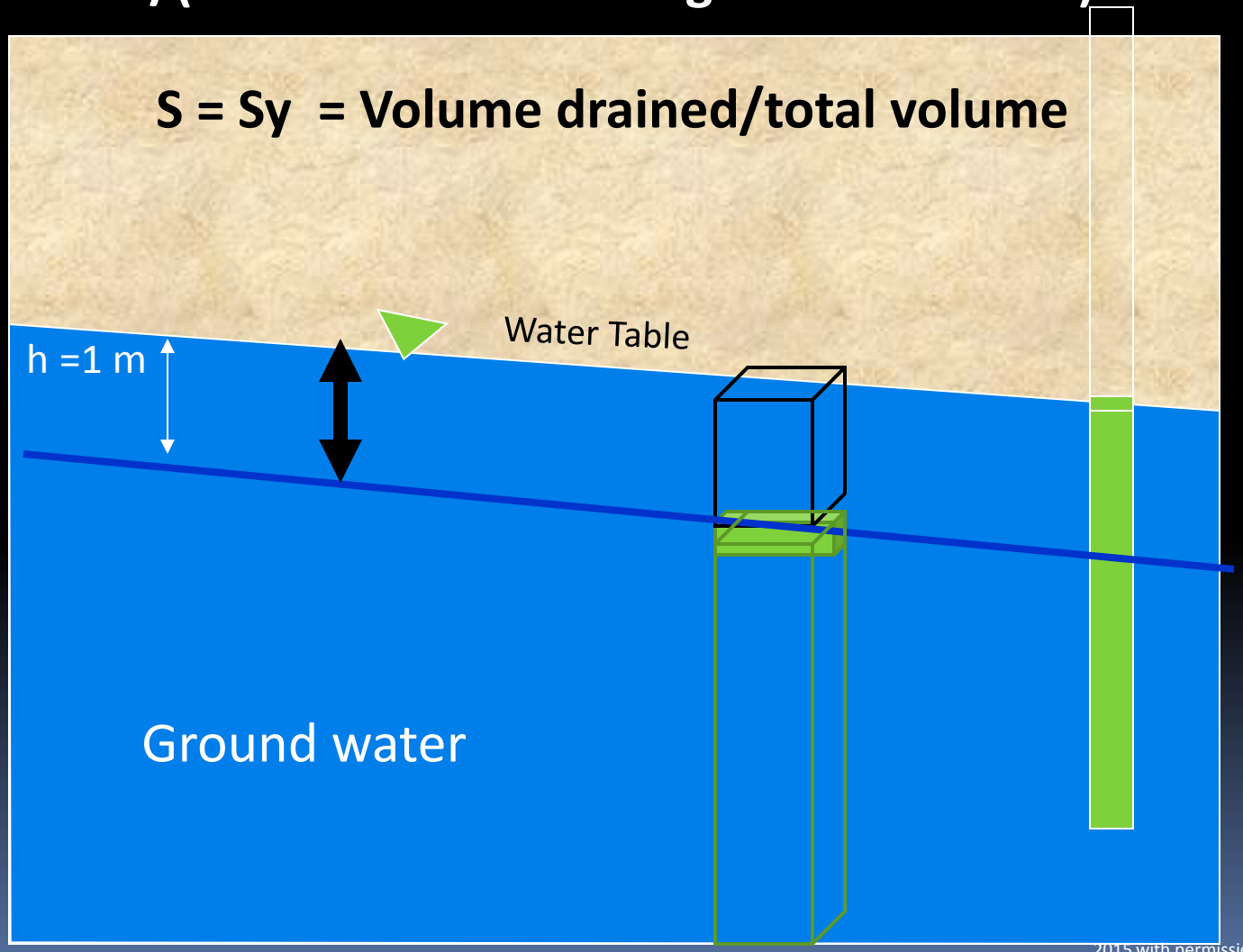
2015 with permission Woessner

Storage Coefficient or Storativity of Unconfined Aquifer

Definition: the volume of water removed or stored per one unit change in the position of the water table over an area of one square unit

S = vol /(unit area* unit change in water level)





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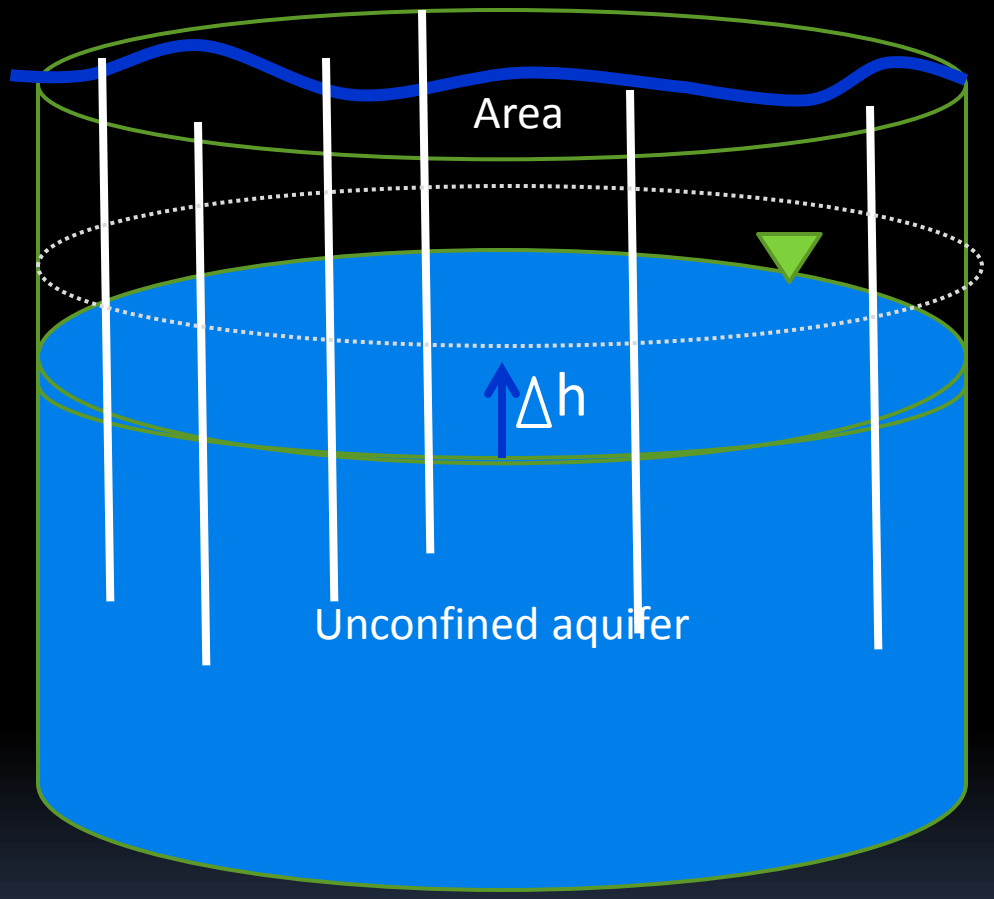
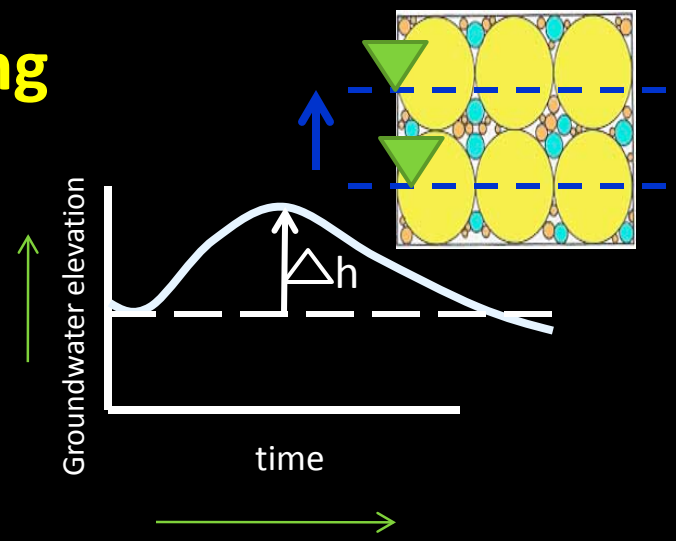
Calculating a Change in Storage using Water Level Data





Vol of water /time = Δh*S*A/time

Where A is the area over which the change in WL occurred, and S = Sy for an unconfined aquifer

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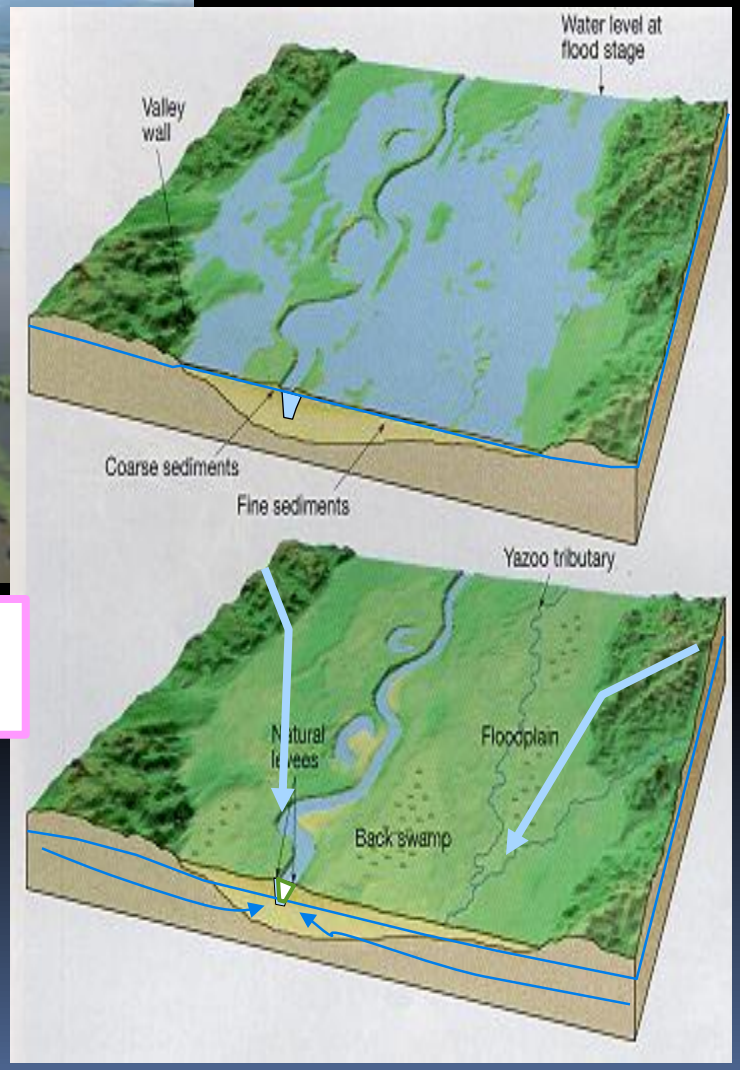
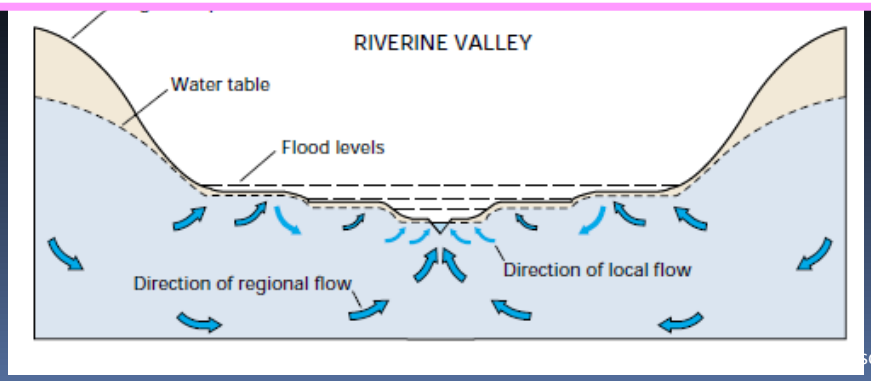
Flood flows Periodically Add Water to the Shallow GW

http://nwrm.eu/sites/default/files/catalogue-nwrm/n03ill2.png

Bank storage



If the WT is naturally high –not much additional room to store water in the floodplain



souristate.edu/emantei/creative/WeathStrem/floodlev.jpg

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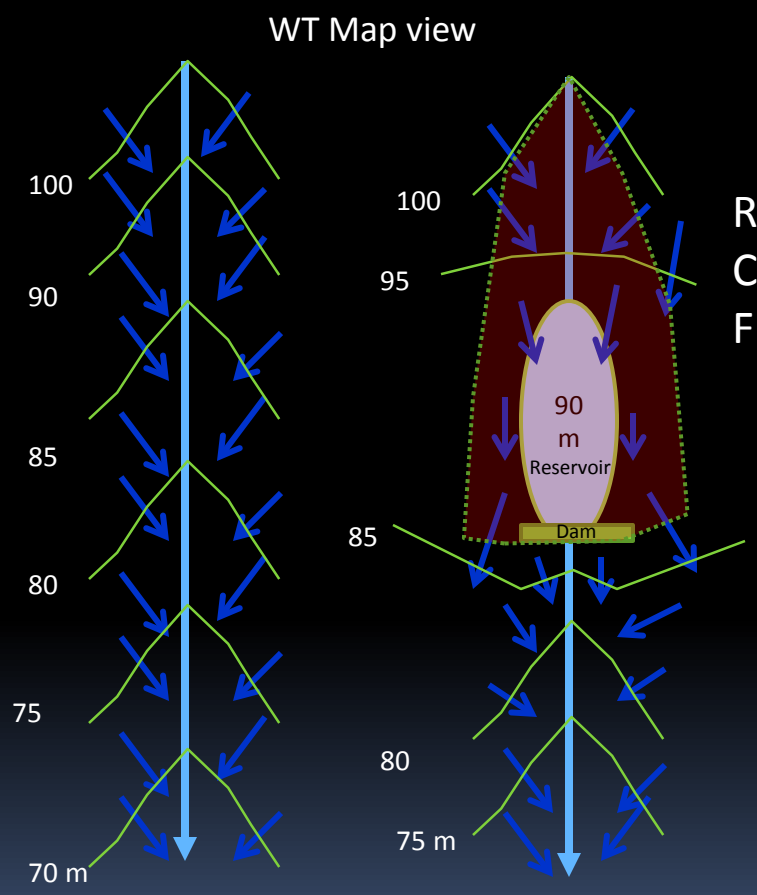
Dams and GW Systems

http://midcolumbiarfeg.com/wp-content
/uploads/2013/03/NF-Teanaway-Rec-Dam_web.jpg



Rise in WT
Change in
Flow

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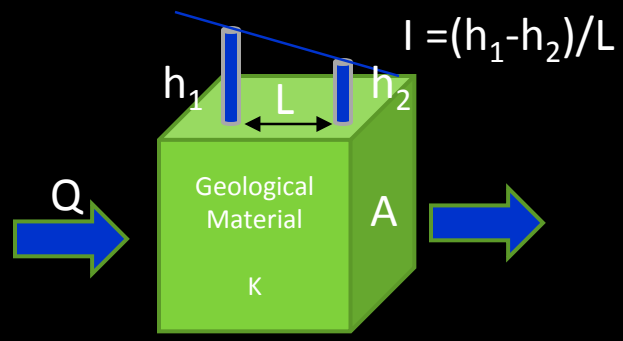
Retention: Delay in Release of Stored GW

How do you increase retention: Change the rate of flow of GW ?

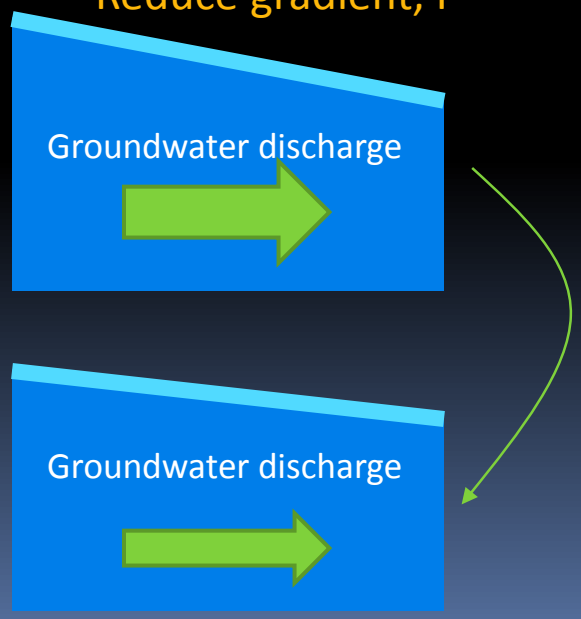
Darcy's Law

Q= K I A

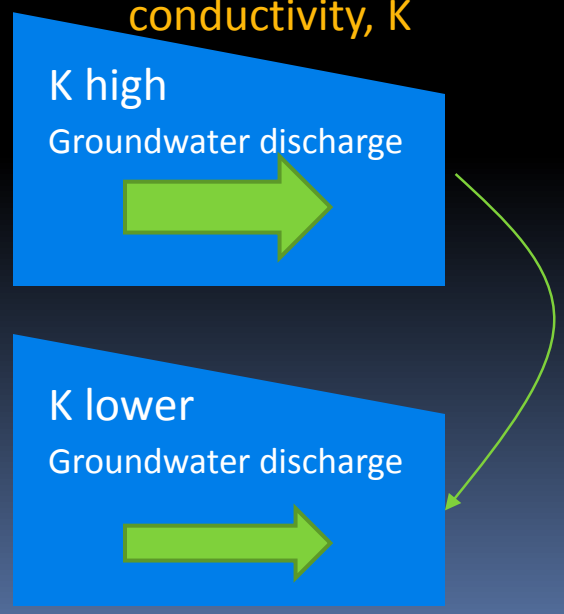


Q is GW discharge
K = Hydraulic conductivity (permeability)
I is the Hydraulic gradient (slope of the WT
A is the cross section area though which flow occurs
v is groundwater velocity
n is the porosity of the sediments

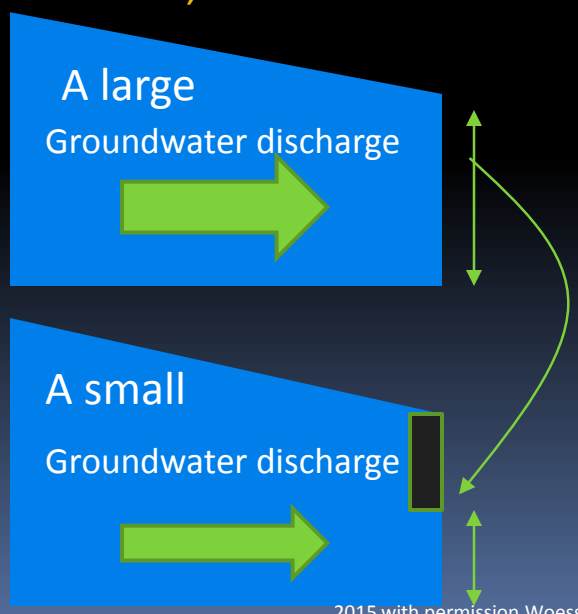
Reduce gradient, I



Reduce hydraulic conductivity, K



Reduce cross sectional Area, A



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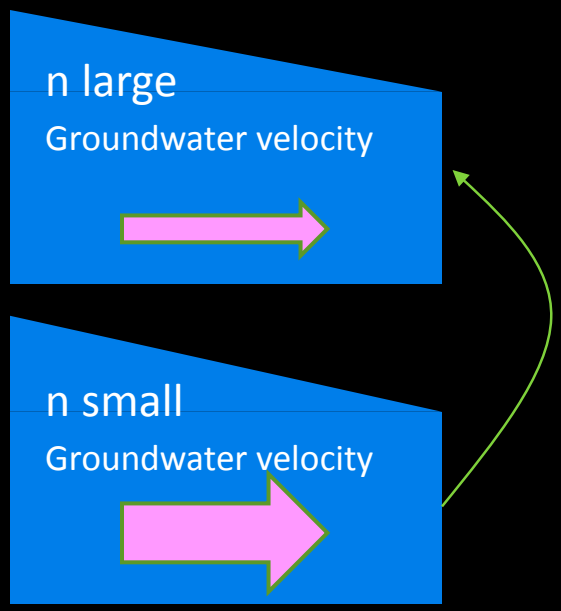
Reduce Groundwater Velocity

Retention and Timing

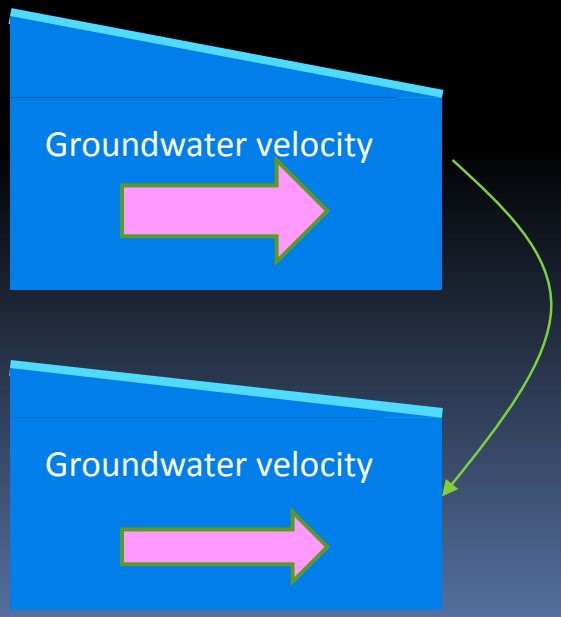
Velocity of GW flow

$$V = (KI)/n = Q/(A)n$$

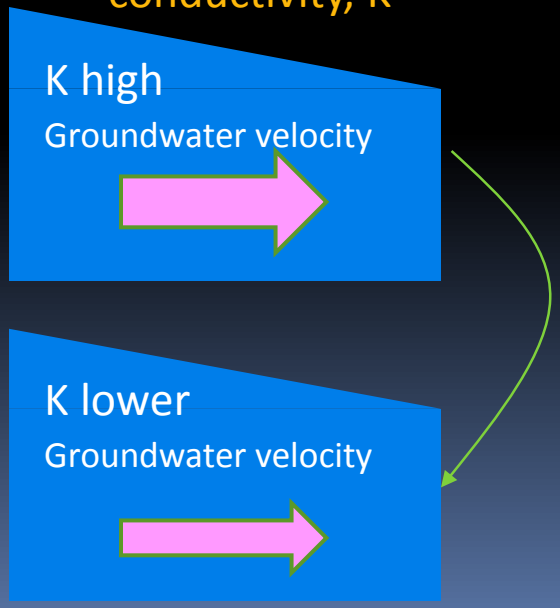
Increase porosity, n??



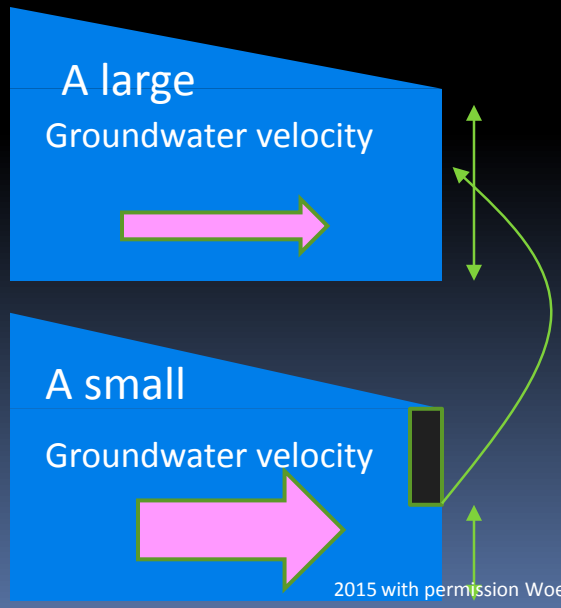
Reduce gradient, I



Reduce hydraulic conductivity, K



Increase cross sectional Area, A



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Retention

$$v = d/t$$

$$t = d/v$$

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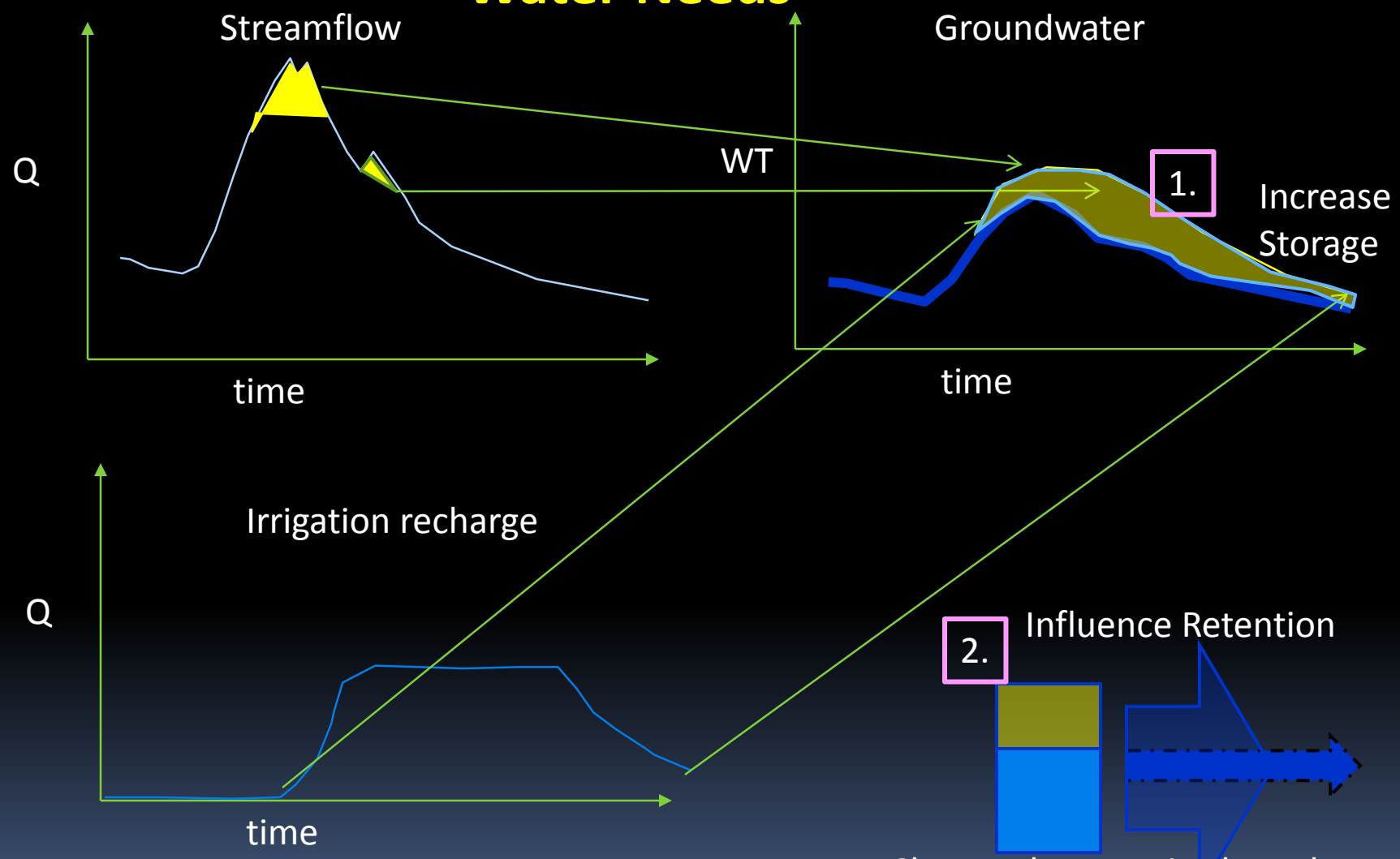
Storage and Retention to Meet Future Water Needs



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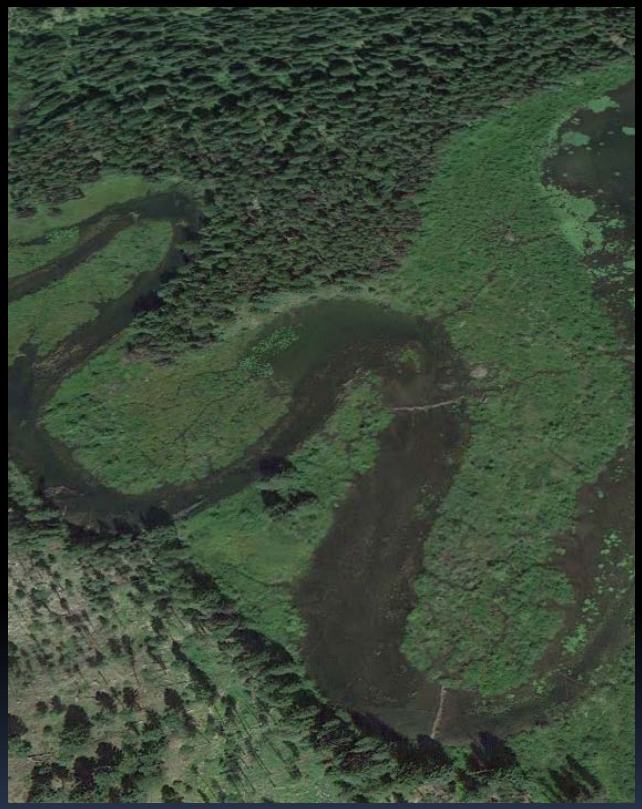
Water Balance and Legal Constraints:

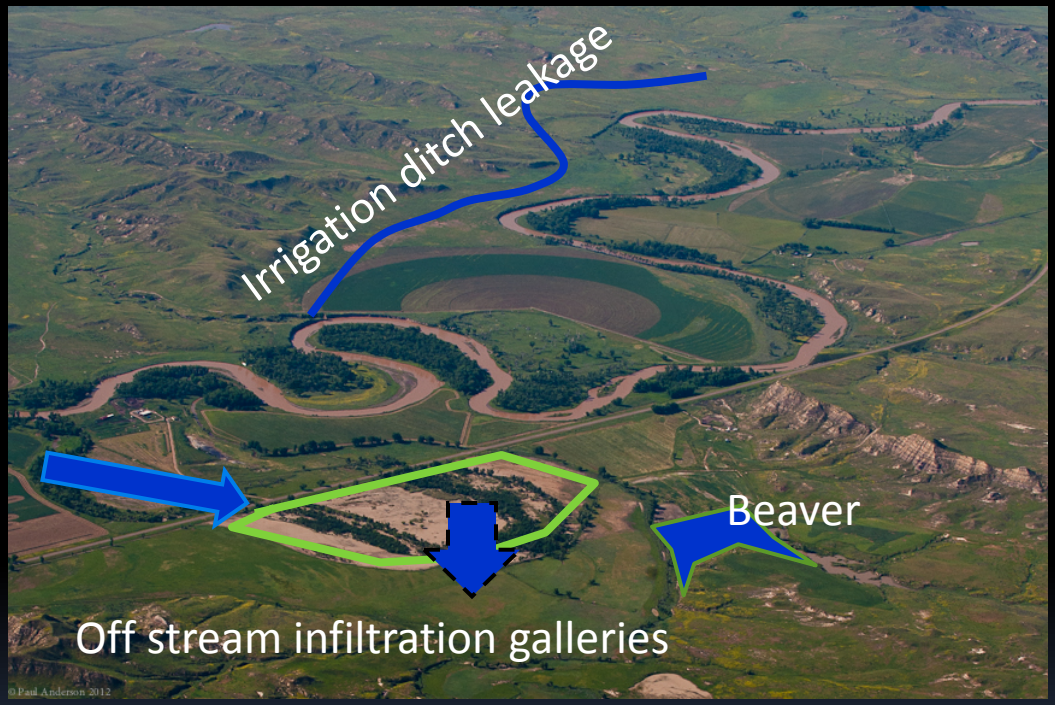
Only so much water available to manage…as you know

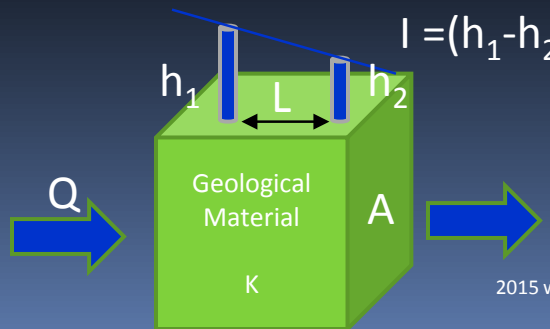
In = Out +/- storage change _

Beaver Dams



Clearwater River





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END

Otter Creek

http://meic.org/wp-content/uploads/2012/02/Otter-Creek1.jpg 2015 with permission Woessner