Tools for Estimating Recharge in Colorado's Aquifers

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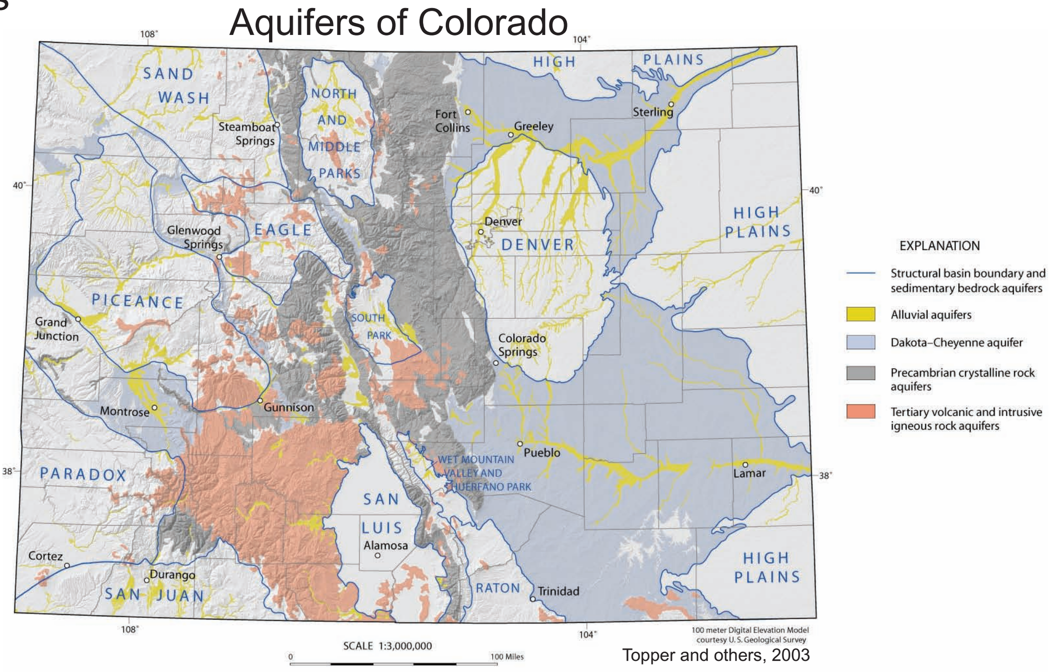
Recharge is water that reaches and replenishes an aquifer, and is often water that moves downward from land surface to the water table.

Successful long-term management of Colorado's ground-water resources requires understanding the fundamental components of aquifer water budgets. These components include recharge, storage, water levels, and discharge. Recharge in Colorado's aquifers is not well understood.

Obtaining reliable measurements of recharge is challenging because controls of recharge vary in space and time.

Aquifers of Colorado



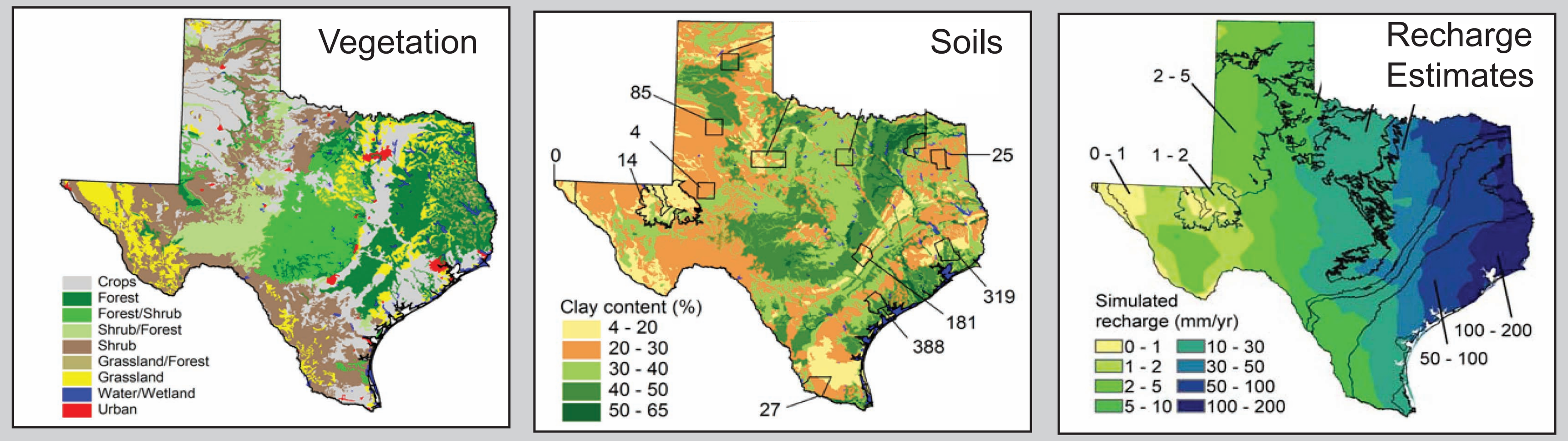
Topper and others, 2003

This poster presents tools for estimating recharge at a variety of spatial and temporal scales, which could be used to improve understanding of water budgets in Colorado's aquifers. The techniques presented here have been used successfully in several adjacent states.

1.0 Regional-Scale Approaches (statewide)

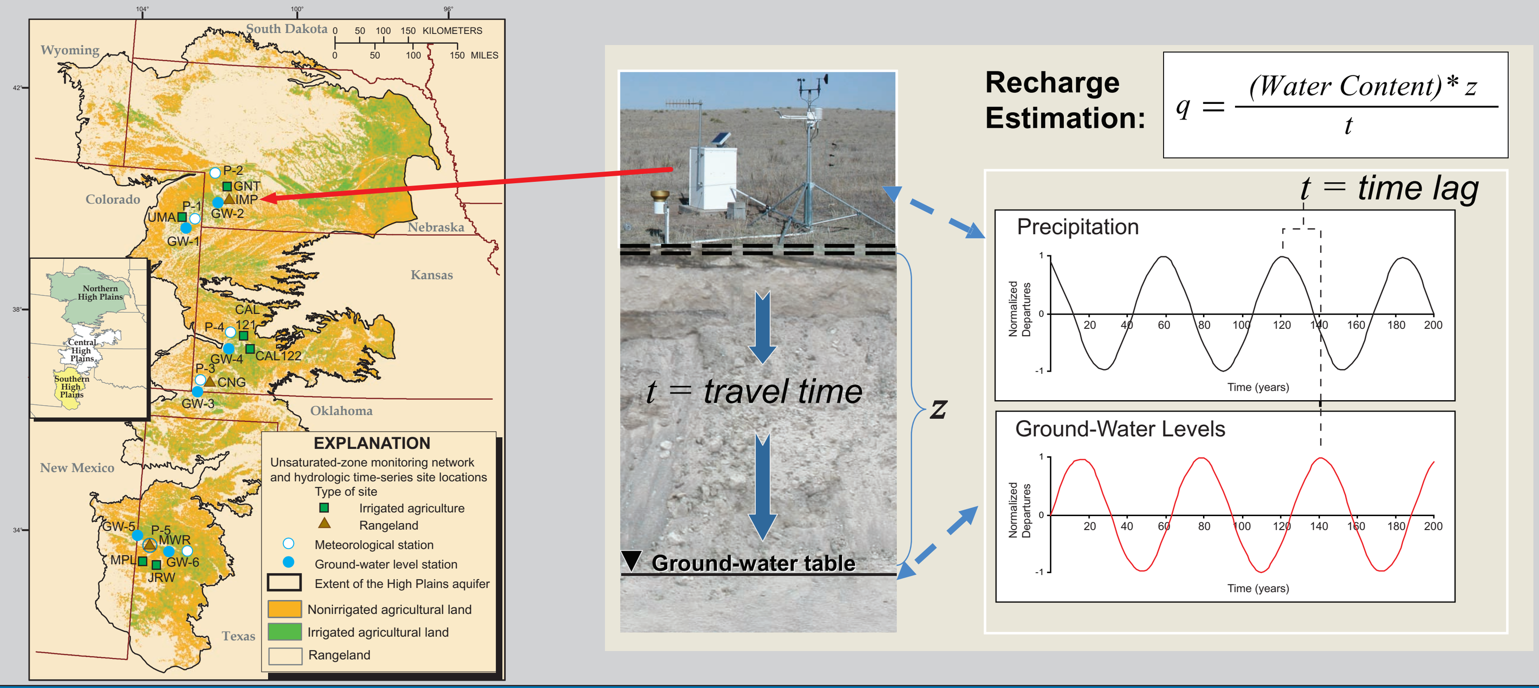
1.1 Coupled Geographic Information System (GIS) and Hydrologic Models

BASIS for METHOD: GIS databases for precipitation, soils, vegetation, and other factors are used as input to numerical models of unsaturated-zone water movement. Model simulations are used to characterize recharge in different environmental settings (Keese and others, 2005).

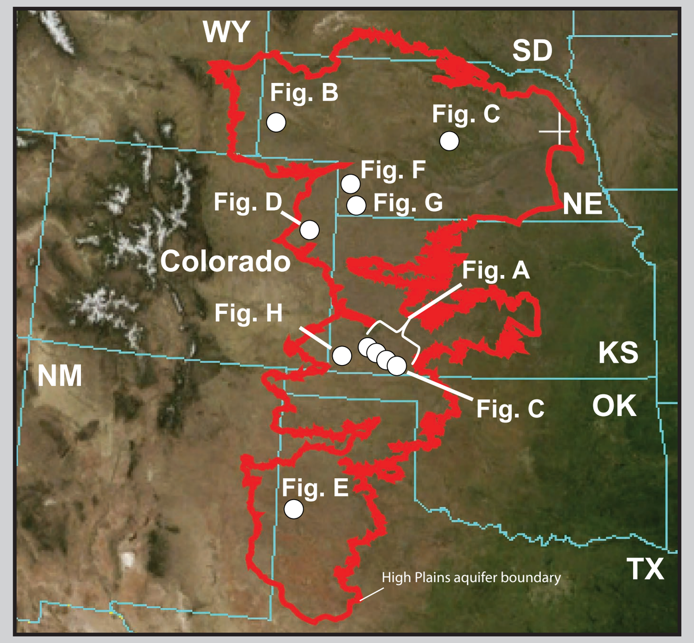


1.2 Hydrologic Time Series Method

BASIS for METHOD: The time lag (t) between correlated precipitation and ground-water level time series is equivalent to travel time (t) for water movement through the unsaturated zone. These time series can be used to estimate travel time and recharge (Gurdak and others, in press).



2.0 Intermediate-Scale Approaches (Km-scale)



Location map for intermediate- and local-scale approaches.

2.1 Ground-Water Age Tracers

(Tritium/Helium-3 [$^3H/^3He$], Carbon-14 [^{14}C], Chlorofluorocarbons [CFCs], SulfurHexaFlouride [SF_6])

BASIS for METHOD: The distribution of ground-water ages in an aquifer depends on recharge rate, aquifer porosity, aquifer thickness, and sample depth, among other factors.

Fig. A

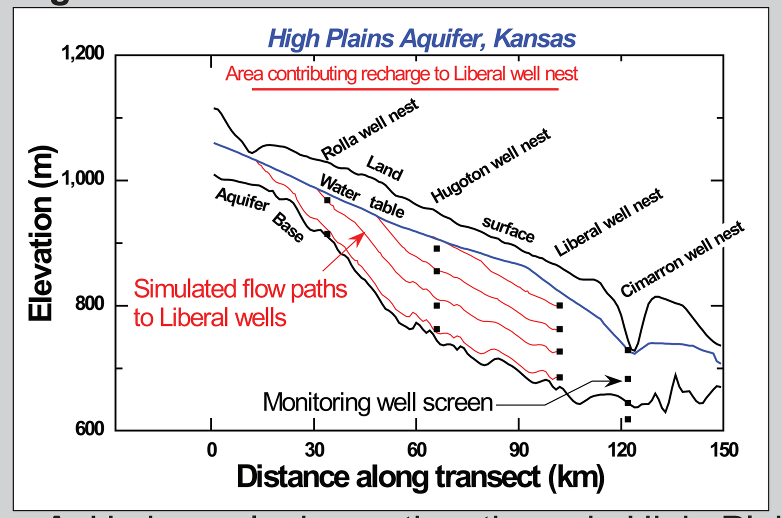
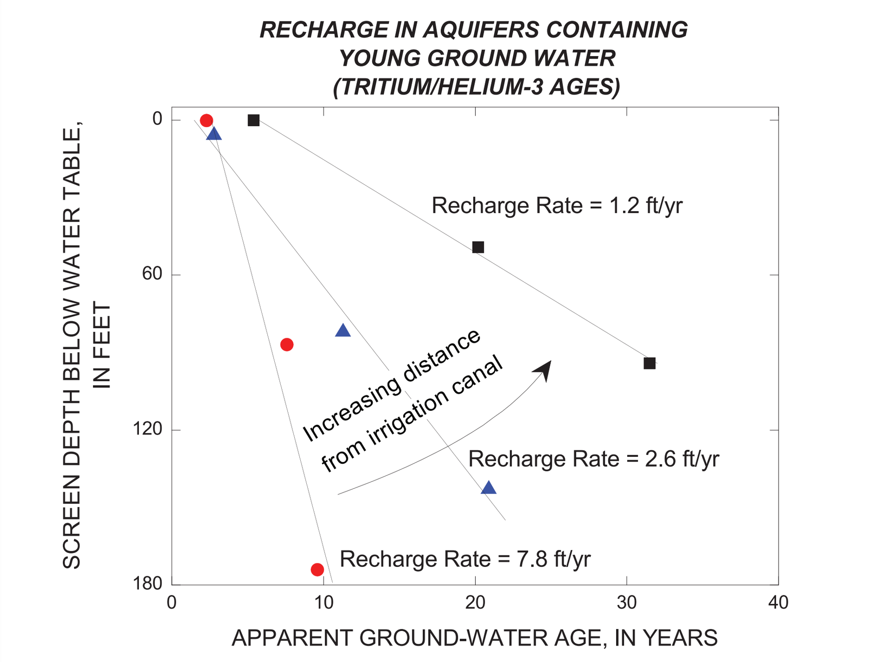


Fig. A Hydrogeologic section through High Plains aquifer in southwestern Kansas showing simulated flow paths and area contributing recharge to monitoring wells. Contributing recharge area increases with increasing well depth.

Fig. B

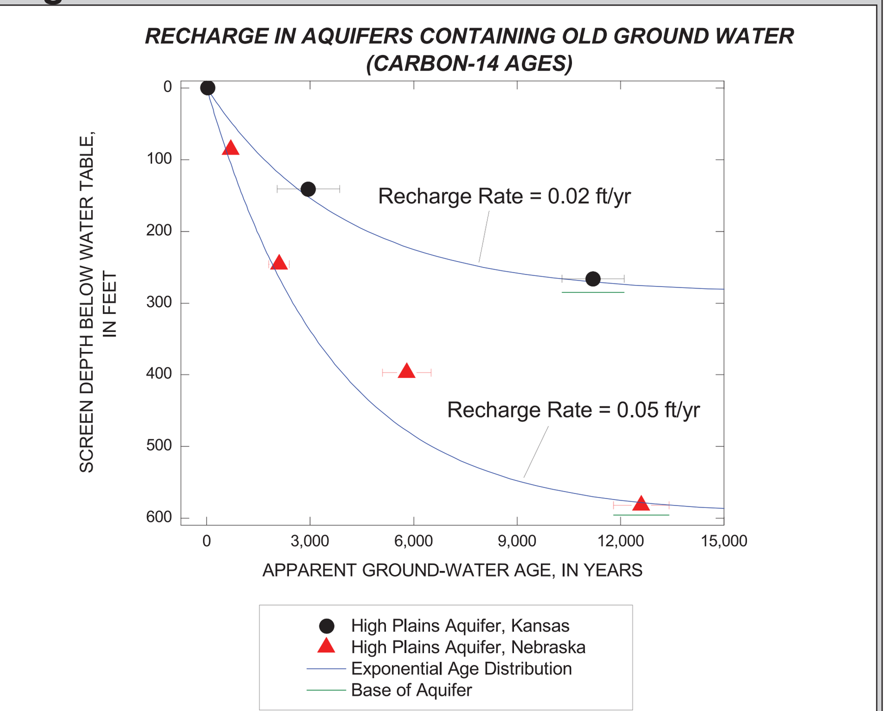


Recharge Rate = (porosity)*(change in depth below water table)*(1/change in ground-water age)

Fig. B Recharge estimates based on a simple model that assumes a linear increase in ground-water age with depth, Dutch Flats Area, Nebraska Panhandle (data from Böhlke and others, 2007).Recharge decreased with distance from irrigation canals.

Water-level measurements and ground-water sampling in the High Plains aquifer.

Fig. C



Recharge Rate = (porosity)*(aquifer thickness)*(1/ground-water age)* ln[aquifer thickness/(aquifer thickness-screen depth)]

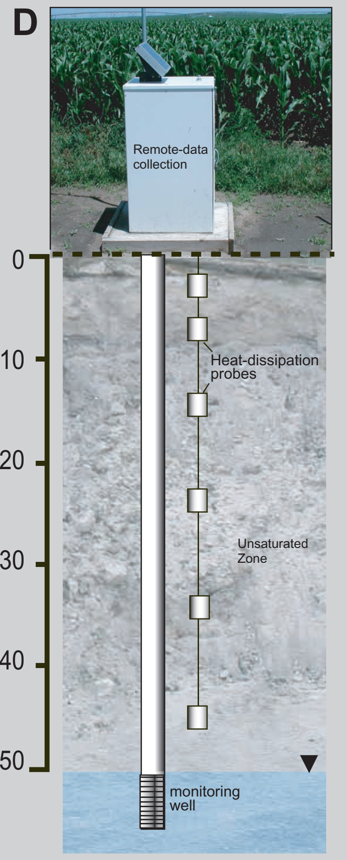
Fig. C Recharge estimates based on a simple model that assumes an exponential increase in ground-water age with depth, High Plains aquifer in Kansas and Nebraska. Recharge was larger in the relatively cool Nebraska study area than in the relatively warm Kansas study area. Mean annual precipitation was similar in both areas. Data from McMahon and others, 2006a, 2006b.

3.0 Local-Scale Approaches (Field-scale)

BASIS for METHOD: Methods 3.1 and 3.2 estimate recharge based on changes in unsaturated-zone water content with space and/or time. Methods 3.3 and 3.4 estimate recharge based on (1) the movement of applied (e.g., Bromide) or environmental (e.g., Tritium) chemical tracers in the unsaturated zones or (2) the accumulated mass of chemicals (e.g., Chloride) in the unsaturated zone relative to chemical deposition at the land surface.

3.1 In Situ Measurements of Water Potential: Darcy Method

Fig. D



(3.1 A)

(3.1 B)

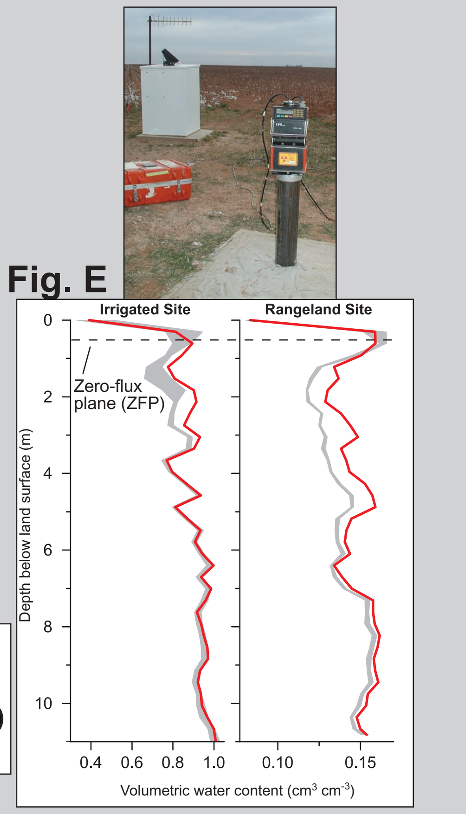
(3.1 A) Heat dissipation probe to measure water potential;
(3.1 B) Cores to measure unsaturated hydraulic properties.

Method 3.1 Recharge Estimate

Recharge = (unsaturated-zone hydraulic conductivity) * [(Δ in matric pressure head/Δ in depth) + 1]

3.2 Neutron Moisture Measurements

Fig. E

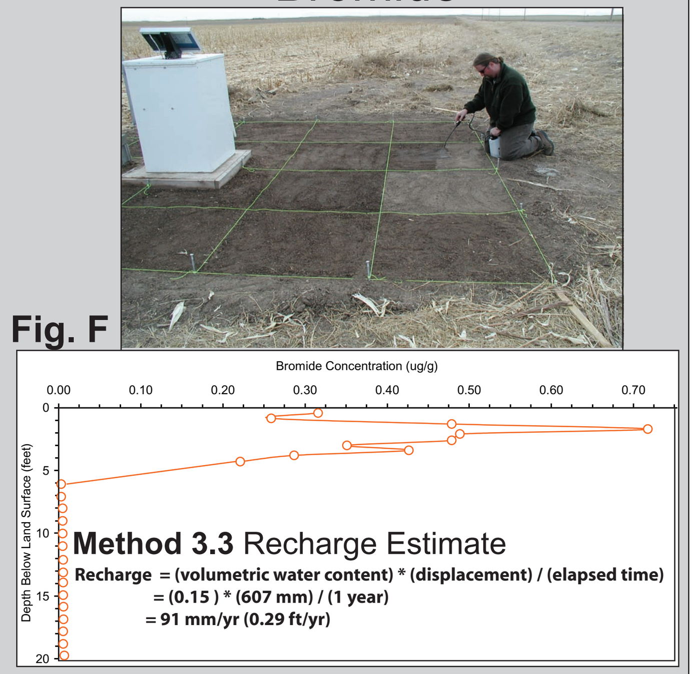


Method 3.2 Recharge Estimate

Recharge = (Δ in water content below ZFP)/(elapsed time) = 75 mm/yr (0.25 ft/yr)

3.3 Applied Tracers: Bromide

Fig. F



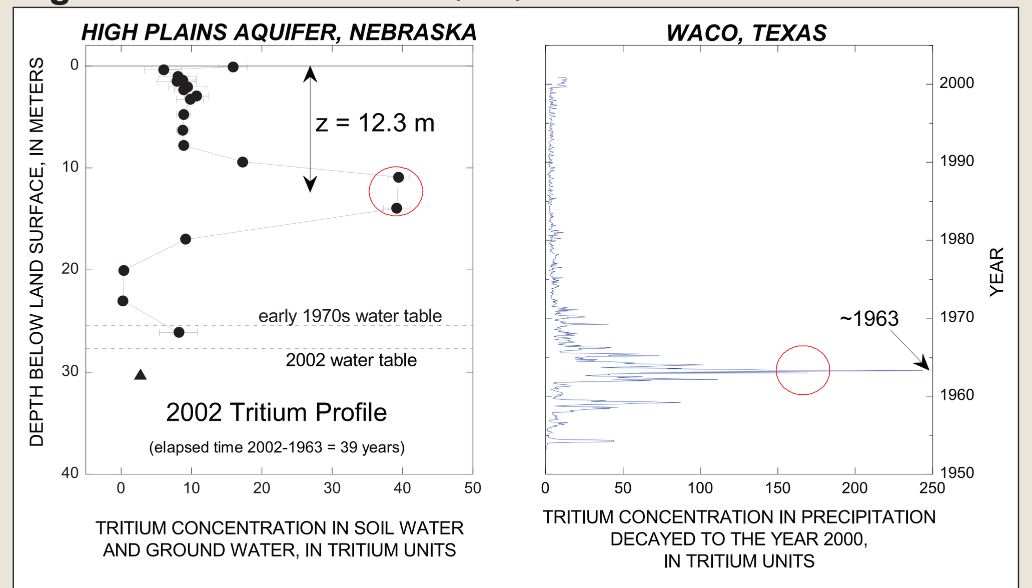
Method 3.3 Recharge Estimate

Recharge = (volumetric water content) * (displacement) / (elapsed time) = (0.15) * (607 mm) / (1 year) = 91 mm/yr (0.29 ft/yr)

3.4 Environmental Tracers:

Tritium (^3H)

Fig. G

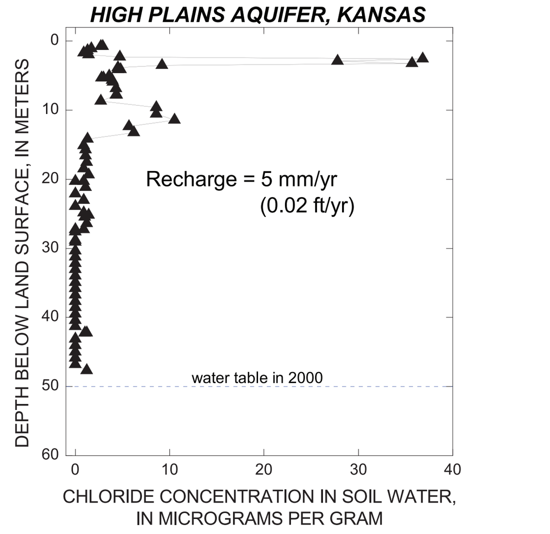


Recharge = (water content)*(z)*(1/elapsed time)

= 70 mm/yr (0.2 ft/yr)

Chloride Mass Balance (CMB)

Fig. H



Recharge $=(P)*(C_p)*(1/C_{UZ})$

P is precipitation rate

C_p is chloride concentration in precipitation

C_{UZ} is chloride concentration in soil water