#### **Groundwater Resources in Mesa County**



# Upper Colorado River Basin Water Forum Grand Junction, Colorado October 30, 2023

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Steffan Teutsch, CMU Student, HRS Student Intern
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Groundwater – out of sight, but should not be out of mind....

Recharge

Water

Well

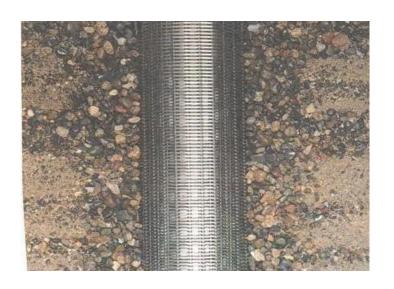
bottle pit

River

Stream depletion means either direct depletion from the stream or reduction of return flow to the stream.

## Groundwater Administration in Colorado

 1965 – Colorado Ground Water Management Act



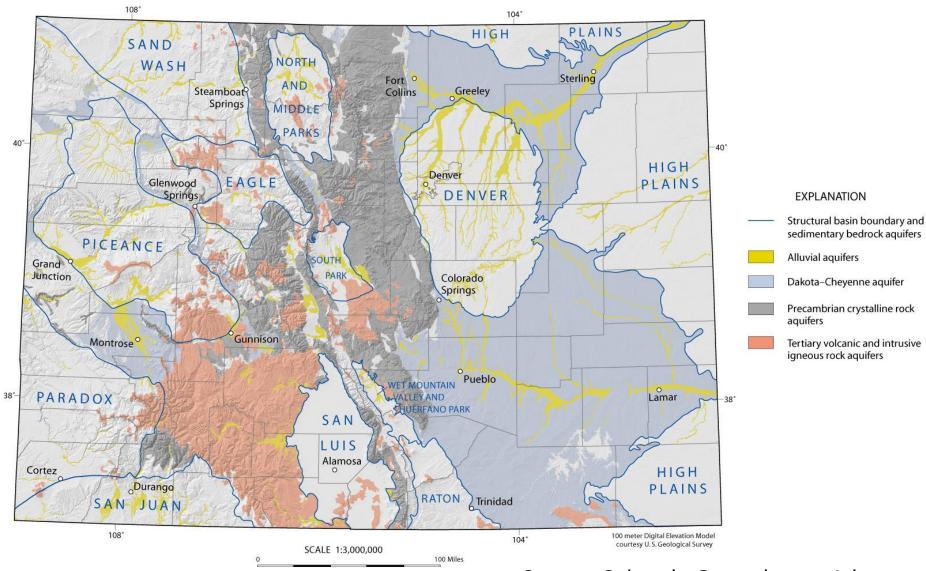


#### **Topics**

- Quick Overview of Area Aquifers
- Groundwater Surface Water Interactions
- GW Highlight Topic
  - GW Recharge (in this talk)
  - Other interesting GW topics ... (not in this talk)
    - Water quality (Se, U, TDS, etc.)
    - Produced Water Reuse
    - GW pumping and influence on In Stream Flow Rights
    - CO2 sequestration
    - Geothermal



#### Colorado Aquifers



Source: Colorado Groundwater Atlas

#### **OPEN-FILE REPORT OF-17-01**

#### Geology and Groundwater Resources of Mesa County, Colorado

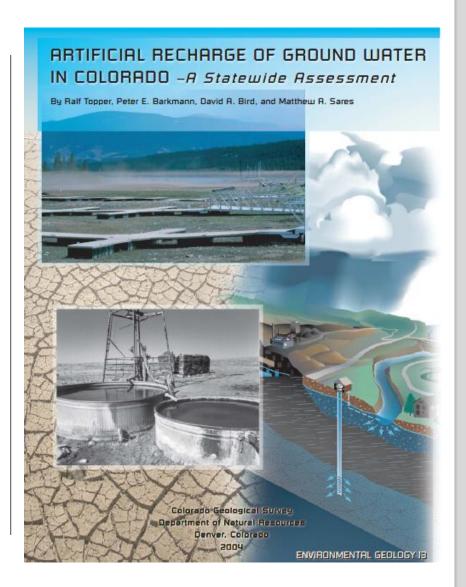
By Lesley A. Sebol, Katheryne H. McGee, Erinn P. Johnson, and Peter E. Barkmann

Colorado Geological Survey Colorado School of Mines Golden, Colorado

2017

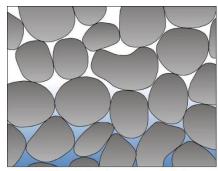




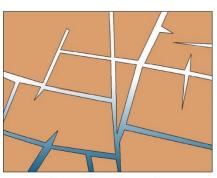


#### **Aquifer Types**

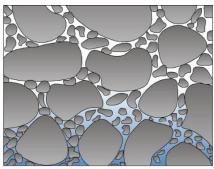
- Unconsolidated
   Sediments
- Sedimentary Bedrock
- Fractured Crystalline
   Rock & Volcanic Rock



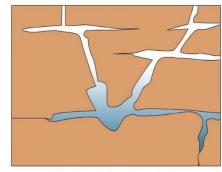
Well-sorted sedimentary material (Alluvium of the South Platte River)



Fractured crystalline rocks (Pikes Peak Granite)

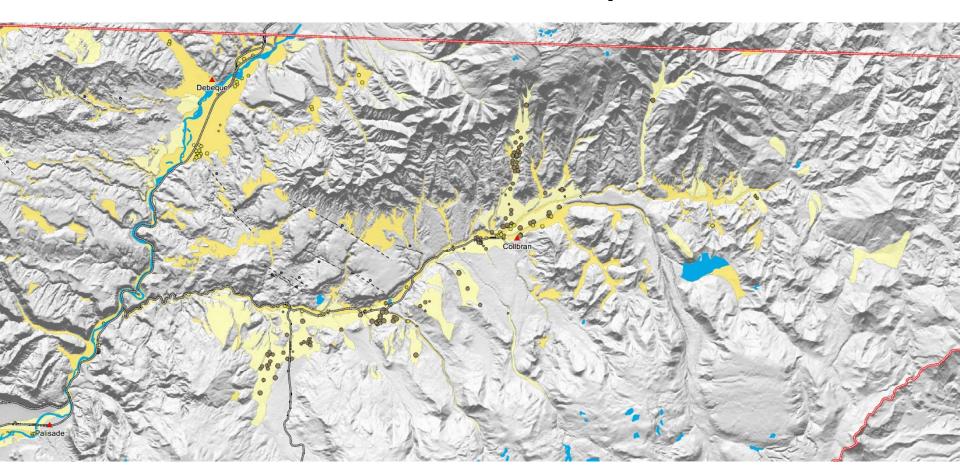


Poorly sorted sedimentary material (Dawson, Denver, Arapahoe aguifers)



Soluble rock-forming material (Leadville Limestone)

#### Unconsolidated Aquifer (cGS)

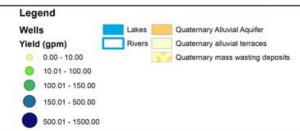


Near Debeque, Colbran, Palisade

## Unconsolidated Aquifer

Groundwater Resources in the Grand Valley

HRS WATER CONSULTANTS, INC.



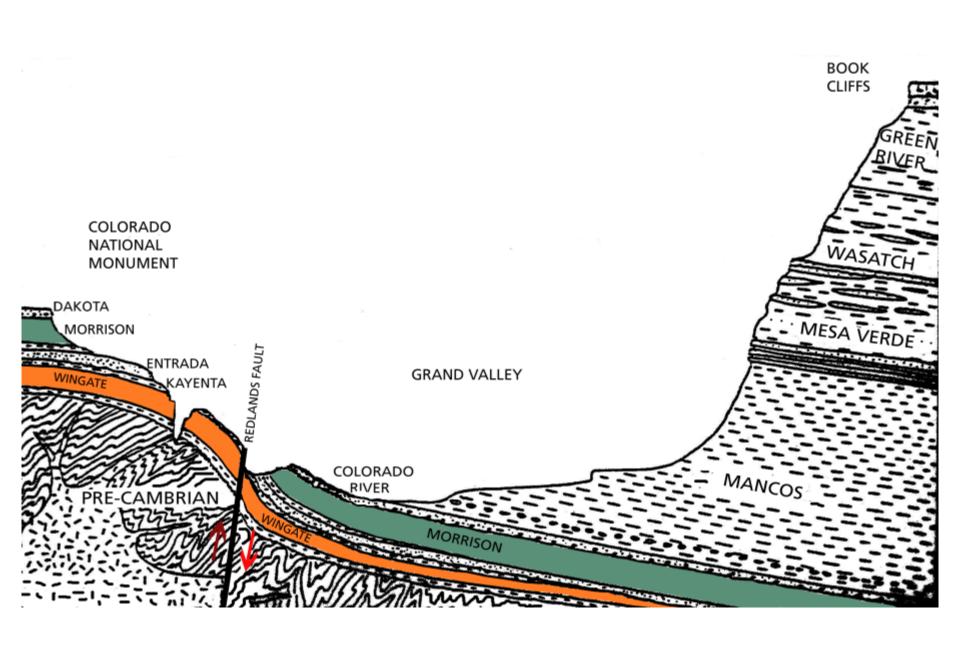


Palisade, Grand Junction, Fruita

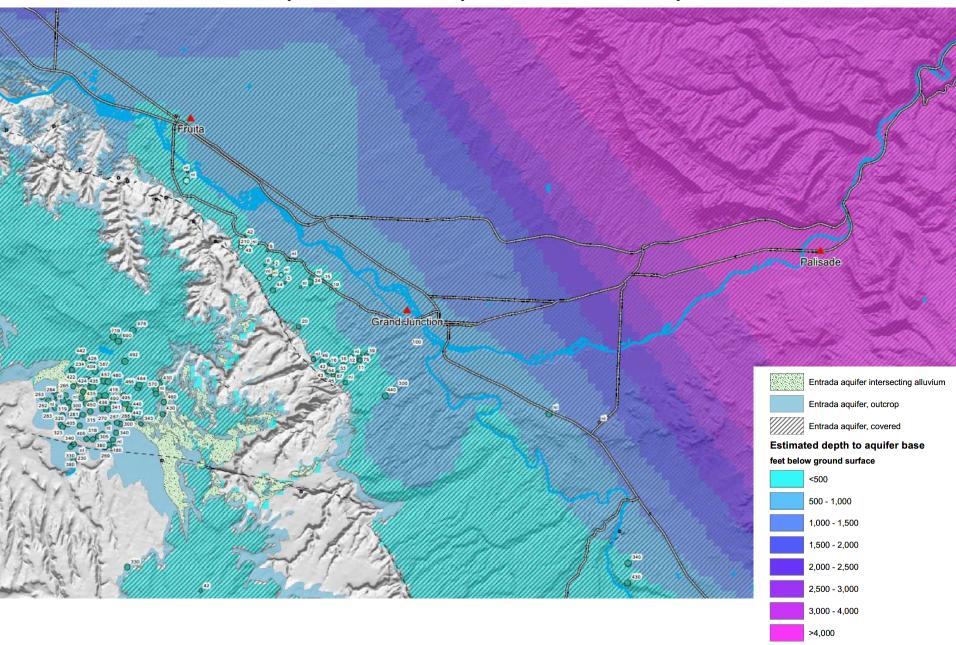
#### Sedimentary Bedrock Aquifers

MESA COUNTY STRATIGRAPHIC COLUMN									
AGE		EOLOGIC UNIT AX. THICKNESS)	LITHOLOGY		MAP IDENTITY	EXTENT	RESOURCE	HYDRO- UNIT	
	Marrison Fit. Salt Wash Mar. (800ft or 2444)			interbedded bentientic shale or muditione, Landmone, conglore, interbedded canditorie and meditione muditione and gyp liferous shale, this canditione and limestone	àm	Limited to the SW corner of the county.	Uranium/ Vanadium; — Glifiger	Brushy Basin: confining unit Morrison Aquitor Tislevili Microsofining unit	
URASSIC	San Rafael Group	Wanakah Fin. (40ft or 12m) Fintrada Sc. (200ft or 61m) Cannel Fin.		insehedded mudisone, sitrst, thin senditione; rare limestone & vol. ash "board bod" - insehedded ISASTONE AFE (File Wudfloris — Sick Rock Mbr eolian canditione undistance and mudisone	ie	Present just below Fruits and Grand Junction.  Limited to the SW half of the county.  Spacely located along SW edge of	Oil & gas	Wanahah Pre- confining unit Enfrank Aquiter predominately a	
JUR	Group	(90ft or 27m) Navajo Se. (260ft or 79m)		eolian canditione	ân	Precent in carryons in the SW corner of the county.		contring unit	
	Glen Carryon Gro	Kayenta Fin. (380ft or 91m)		interbedded shale, mudstone, sittane, saedstone	A	Speed across the SW of the county with the exception of the SE corner.		Glon Caeyon Group Aquifer	
		Wingste St. (420ft or 12km)		eolian randstone, minor mudstone	JW.	Located in the SW extent of the county.	minor Copper		
SSIC	Chinle Fm. (758ft or 229m)			interbedded muditone, sibtione, diale, sanditione, minor limettone, basal gypsum	TRc	Predominately within canyons in the SW half of the county.		Chiele : Masshapi Fras	
TRIASSIC	Moenkopi Fer. (1,000ft or 305m)		332323	Upper - thale, canditione; Mid - conglomerate, arkose, thale; Lower - muditione and sanditione, local basal gypoum	Titos	Limited to the SW corner of the county.		sentining unit	
PERMIAN		Curlei Fe. O picett or 3x7 Proj (Marcon equivalent		conglomerate, arkove, arkestic cased stone; this back of cased y mud mote	Fc	Limited to just 5 of Lost Horse Basin near the 5W conner of the county, lealand outcomes W of Lost Horse Basin and in the 5W conner of the county.	minor Copper	Cutter For Aquifer	
PENNSYLWNIAN	aGroup	Honaker Trail Formation (-985ft or -300m)		contorted beds of conglomerate, arkose, micaceous randstone, muditone, limestone; increasing rait at base	iPh.	Limit to the Sinbad Valley in the SW corner of the county.		Confining sall	
PENNSY	Hermosa	Paradox Formation (-3,000-4,500ft or -900-1372m)		alternating beds of evaporites, fine clastic and carbonates;		Only upper partion exposed within the Sinbad Valley.	Salt, Putach	beds	
CAMBRANA -MISS.	G	t Frs., Leadville Limettone, ray & Elbert Fins., Chaffee oup, Handing, Manitou, & bettere Fins., Ignacie & Sawatch Fins.	at lineardown to 2.	Emertone, chale, dolomite, quartitie	M-C	No exposure in country only in cross section within basel portions of Piceance and Parados basins.	possible geothermal in Leadville Ls.	Lower Palescate continuate aquifer (saline)	
PRECAMBRIAN		Precambrian Igneous and Metamorphic Racks		oracks generowed from this time-perior igneous pluttons, greekses and migrassites of varying age and composition	X2 / 2	Ignees: - SW of Grand Junction and in spots along the W boundary of the country.  Metamosphic - Small outcrops seen W of Grand Junction; Sound centrally on the W boundary of the country.  White the country of the country is seen to the half of the country is exposed by river channels.	minor Molybdenum	Precambrian systelline leetinsh depater	

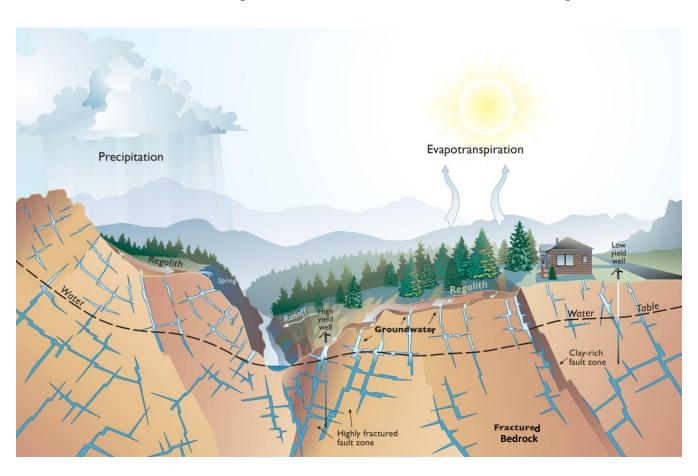
MESA COUNTY STRATIGRAPHIC COLUMN									
A	GE	(M	EOLOGIC UNIT AX. THICKNESS)	THICKNESS) LITHOLOGY		MAP IDENTITY	EXTENT	RESOURCE	HYDRO- UNIT
	CONTERNARY	Antificial Fill (Soft or tiles)  Holocene Allevium, and Macc Wacting Deposits (100th or 18m)  Pleimocene Allevium, Glacial, and Max Wacting Deposits			uit, sand, & rock flagment sand and grown, dit, clay, come boulders; cienga, lacustrine, razoffed or unstratified exilian, sheetwark, flood plain and fan deposits, peridiments, ralue, culturium, socidal, landside and shump block deposits; same as above; glacial SII, rock glocient, grane terrance, pediments, fan and fangliomerate deposits, fan and fangliomerate deposits, fan and fangliomerate deposits salue, collavarium, rockfult, landside	Obt Obt Obt	Artificial Fill - Inodated occurrences in or near urban newas.  Abevium - along risers, tributaries, and guilley.  Mass Warting Deposits - widespread, but more president in the it half of the country.  Albenial Berrases - predominately in the bit half of the country. due to nieve downacting in the Grand Valley.  Glickel Yill - no Grand Mero and Si.	sand and gravel	Albumial Aquider includes boat perchad systems
L		3	(900th or 344m) Quaternary-Tertiary Gravels, undiv.		and slump block deposits sand, gravel, cobbles & boulders	ack deposits of Palisade and			Imited general drained
	NEOGENE	au con	Rasalt Flows (ROOTs or 244m)		basalt, olivine basalt, and basaltic anderite dilete-granediorite, quartz	Tvol	Valcanics - forms cap rock of Grand Meta and furthement bless Introdiver - far if tip of the country is courtern edge of panhandle, may be present beneath basis flows		Tertiary volcanios: variable with porous granular layers. Shackers
	ž	100	(Digocese/Moone)  "Goodenough" Fm.		monzonite, porphyritic claystone, sanditone, conglomerate, thin limestone beds	Tge	omali strings of outcrop SE of Palicade, near Grand Mesa		Variable with porous goroular layers/Uhackures
TERTIMRY			Ulinza Fre. (1,000ft or 205m)		marktone, sittitune, sandstone	Tu	nestricted to the E half of the county, predominately near Collbran		Unita Fee confining unit
	PALEOGENE	Loon	Green River Frs. (3,880ft or 1182m)		interbedded canditione, sibitione, claystone, oil shale, marknore, thin beds of limetone; includes Mahagony bed (a very high yield oil shale), many thin tuff beds	Tg	widespread throughout the NE part of the county	oil shale	Green River Fee: variable notify functions porestly & pervendedly determined with confirming shale, sillularies or olaystories.
		Paleoone	Waxasch Fin: (2,207th or 700m)		claystone, shale, focal sandstone, conglomerate	Tw	NS corner of the county		Wassish Personnishered part of Mesaverde Aspaller
		averde Group	Hunter Canyon/ Williams Fork Frs. (1,400fs or 407m)		interbedded canditione, muditione, carbonaceous obystone, shale and Cameo Coal	Khc	centrally located between Fruits, Palisade, and Debeque	coal, coalbed methane, natural gas	Measureds Aquifer variable with fracture perceit £ preventially
l		Wes awerd	Mt. Garfield/flet Fin. (1298: or 100m)		interbedded randstone, sitstone, shale and Pallicade or Cameo- Fairfield Coal	Kig	linear outcropping NW to SE, passing through Palicade		interdential with confirming chains sill-shares, slaystores or result-tores.
	8	2	Mecaverde Grp. (900ft or 152m)		upper and lower sandstone separate Anchor Coal, over shale	Knot	just 5 of Debeque		THE REAL PROPERTY.
	CNETACEOUS	MinosShile	Parite Carpon Mile  Niside on a Hile- Emolog Hill and Fact Hope  Mantenana Valley & Joanna Lapur Freeze  Joanna Lapur Freeze  Short Hall Hill  Canil Spring, Sandanan,  Hall pr Cond. & Crame on Miles	==1	near sale annears ship in sample phale, interferomerated read-term statement which lime terms, lam former survey, lam former su	Km	NW corner of the county to SE of Grand function and Palicade, comprises most of the Grand Valley	oil and gas	Manson Shales sorthing unit
		H	Dakota Group (1997 or 65m) Burno Canyon Fin. (2107 or 64m)	E a sua a	interbedded randstane, conglors, muditone, shale, minor coal muditone over interbedded randstone, conglomerate, shale	Rd Kbc	just SW of Grand Junction; scattered in SW portion of county SW half of the county	uranium/ variadium; oil & gas	Dahota Aquiter iredusing Burns Carryon Fre.
$\Box$		_	istatuieesi	Postupica (2000)	Services, congrammer, club				7.16.



#### Example CGS Map - Entrada Aquifer



#### **Fractured Crystalline Bedrock Aquifers**



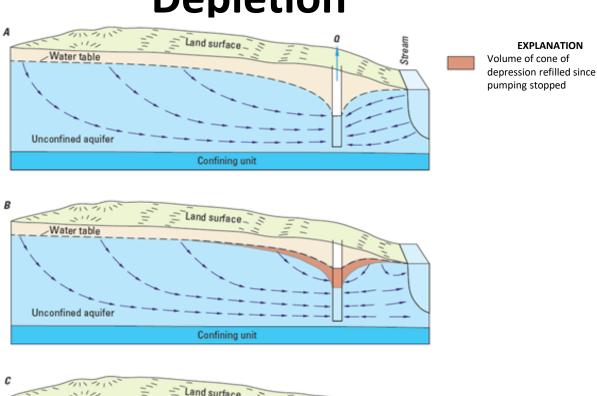
#### Non-injury

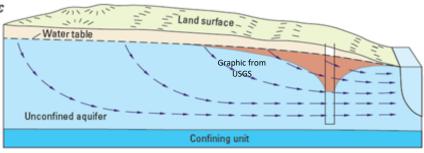
Quantify and replace impacts to surface water rights holders in location, time, and amount of depletions



Well flow meter

# Unconsolidated Aquifer Cross Section Demonstrating Stream Depletion





#### Stream Depletion and Accretion

- Stream depletion is most commonly caused by well pumping.
- Stream accretion is most commonly the result of recharge projects, ditch leakage, lawn or farm irrigation return flow.
- For both stream depletion and accretion there must be a hydraulic connection between the aquifer and the stream in order for stream depletion or accretion to occur.
- Direction and velocity of groundwater flow do not affect results.

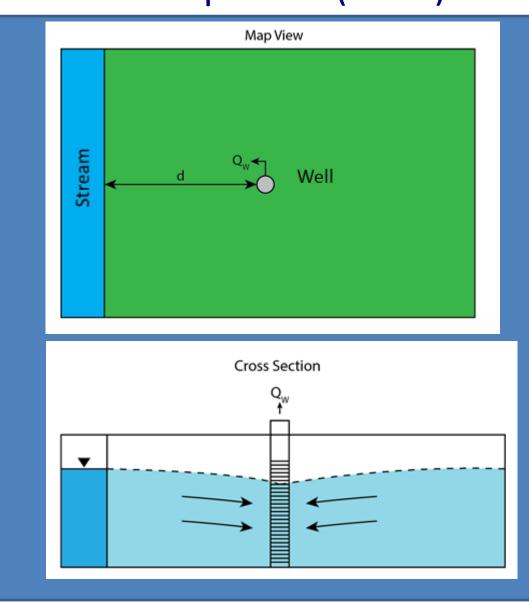
 More accurate estimate -> More conjunctive use w/o injury!

#### Data Needed to use Glover Equation (1954)

#### **Glover Equation**

$$\frac{\mathbf{q}}{\mathbf{Q}} = \operatorname{erfc}\left(\frac{\mathbf{a}}{\sqrt{\frac{4t\mathbf{T}}{\mathbf{S}}}}\right)$$

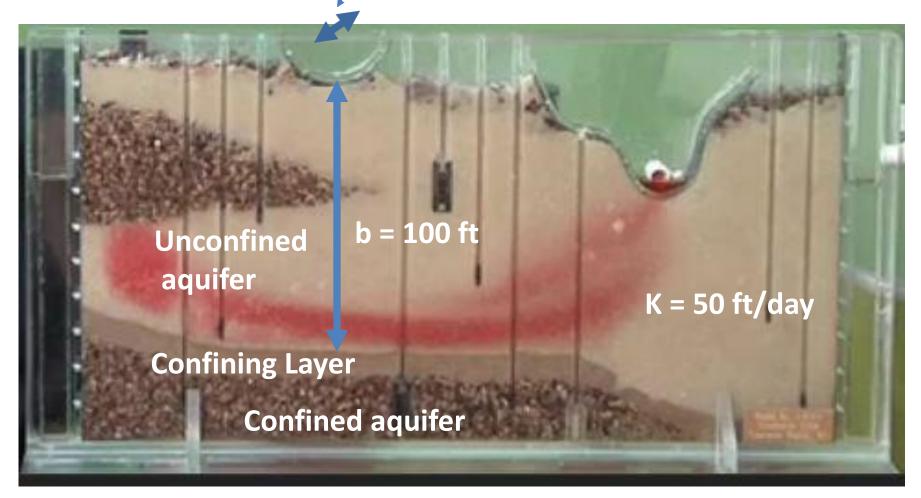
Transmissivity (ft^2/day)
Specific Yield or Storativity (Sy or S)
Distance from well to river



T = K \* b b = aquifer thickness

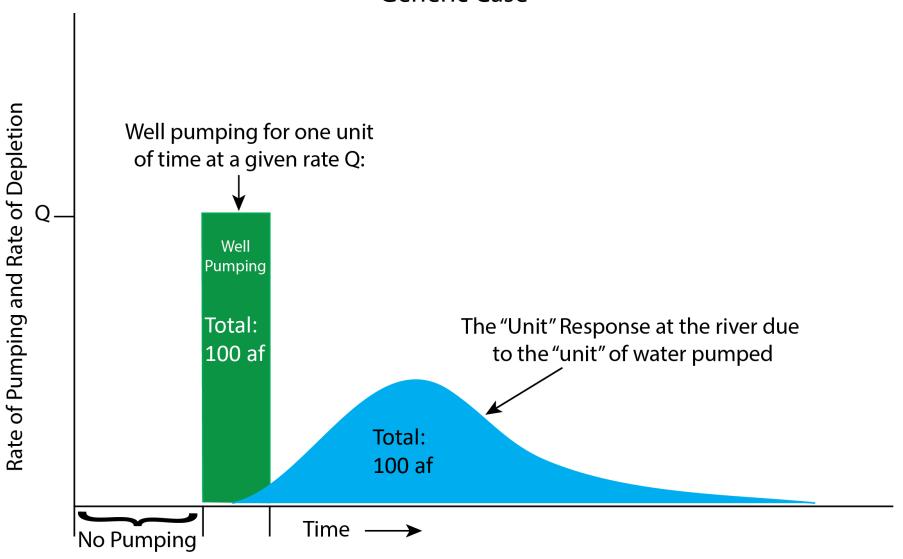
Unit Width of aquifer

T = 50 ft/day \* 100 feet $T = 5,000 \text{ FT}^2/\text{Day}$ 

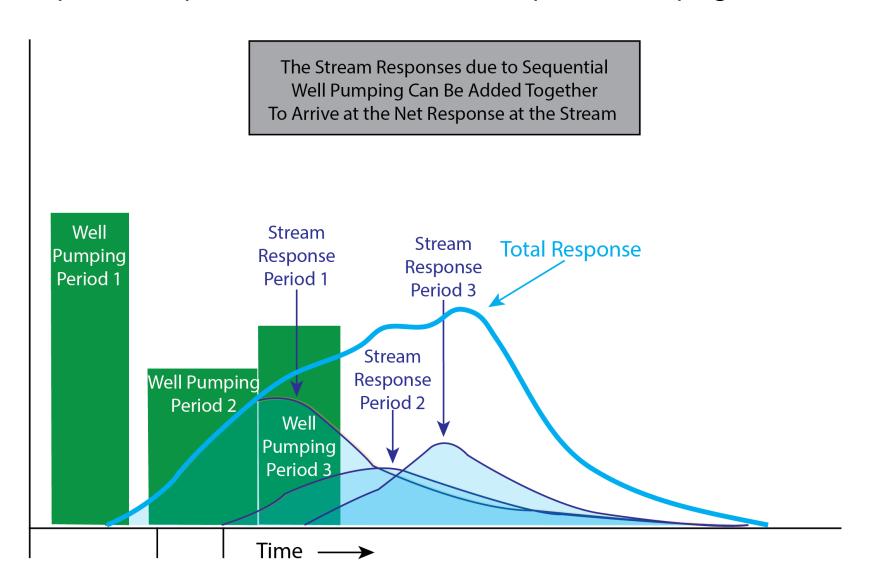


5,000 FT^2/DY\*7.48 = 37,000 gpd/ft

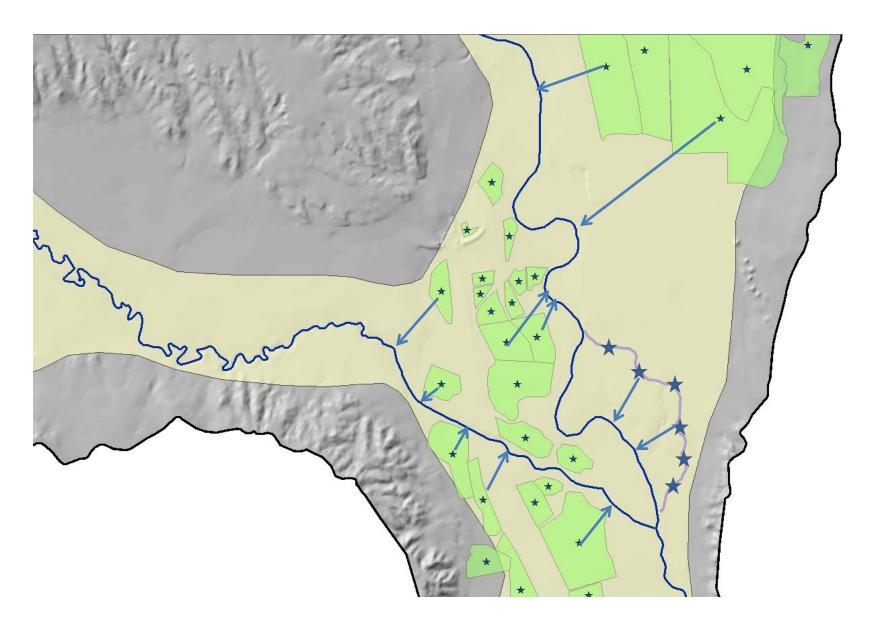
#### Depletion Response at a Stream Due to a "Unit" of Well Pumping: Generic Case



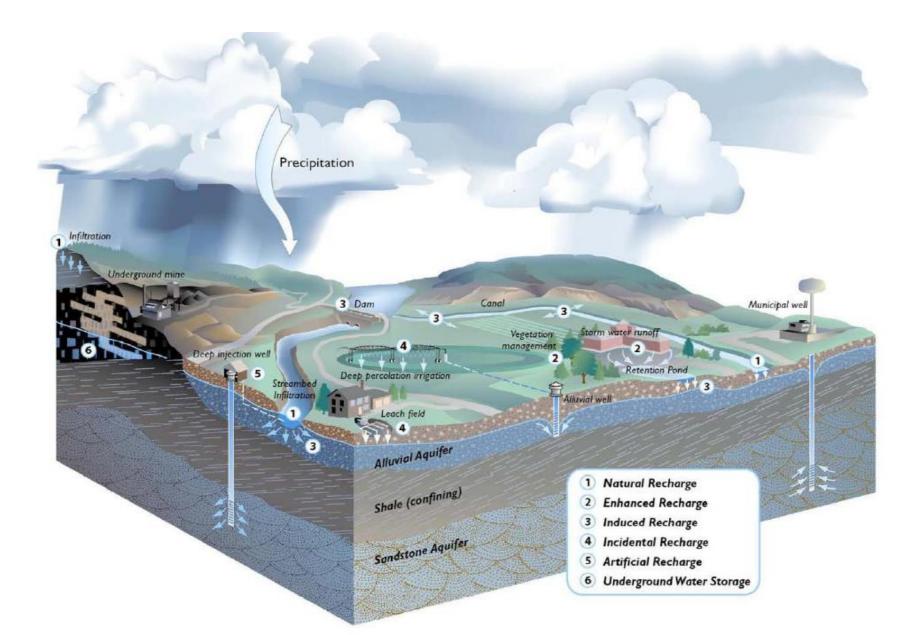
#### Depletion Response at a Stream Due to a Sequential Pumping at One Well



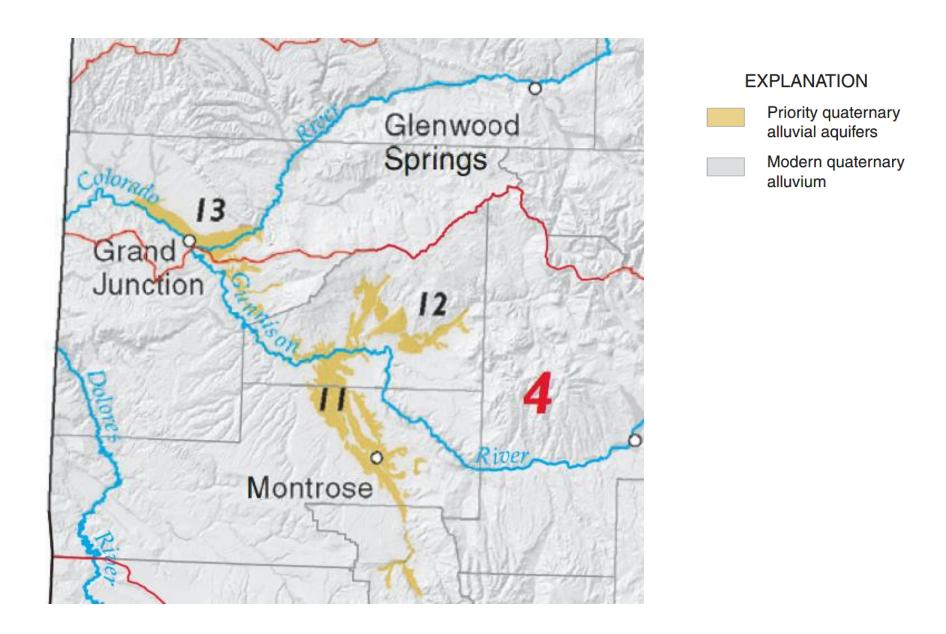
#### Example of Farm Return Flow with Glover Eq.



#### Managed Aquifer Recharge (image: CGS)



#### Colorado Geological Survey Recharge Study – Grand Valley Results



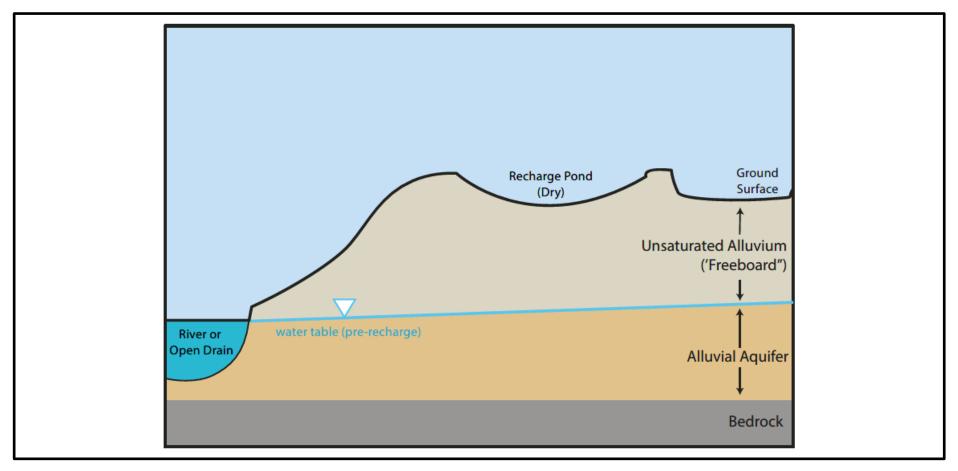
#### TABLE VIII-1. SUMMARY RANKING OF UNCONSOLIDATED ALLUVIAL AQUIFERS

				Storage (ac-ft)		
Basin or Area	Aquifer	Ranking Value	Quality Value	Per Acre	Total (thousands)	Available (thousands)
Lower South Platte River	South Platte River Alluvium	132	20	6.0	4,650	2,320
Lower South Platte River	Bijou Creek Alluvium	128	17	5.3	2,790	810
Lower Arkansas River	Arkansas River Alluvium	118	18	2.3	4,010	500
San Luis Valley	Quaternary Alluvium	113	18	2.3	15,550	3,890
Uncompangre River	Uncompangre River Alluvium	96	17	3.0	1,530	305
Lower South Platte River	Kiowa Creek Alluvium	92	16	5.3	920	405
North Park	North Platte River Alluvium	91	17	4.5	1,530	380
Gunnison River	Gunnison River Alluvium	88	18	2.3	1,175	220
Lower Arkansas River	Big Sandy Creek Alluvium	87	17	4.5	1,130	425
White River	White River Alluvium	81	18	1.5	805	110
Wet Mountain Valley	Quaternary Alluvium	77	16	1.5	1,240	125
Upper Arkansas River	Buena Vista/Salida Alluvium	77	15	2.3	660	125
Yampa River	Yampa River Alluvium	73	17	1.5	685	115
Lower South Platte River	Box Elder Alluvium	71	17	1.5	310	80
South Park	Upper South Platte River	59	16	1.2	270	90
Colorado River	Grand Valley Alluvium	48	16	1.5	395	80

#### TABLE VIII-2. SUMMARY RANKING OF CONSOLIDATED BEDROCK AQUIFERS

				Storage	e (ac-ft) *
Basin or Area	Aquifer	Ranking Value	Quality Value	Per Acre	Available (thousands)
High Plains Aquifer	High Plains – East	169	19	15.0	95,290
High Plains Aquifer	High Plains - Southeast	162	20	15.0	28,530
High Plains Aquifer	High Plains – North	143	19	4.0	4,570
Denver Basin	Dawson	109	19	6.0	5,010
SE Colorado	Dakota-Cheyenne Group	105	19	0.3	1,280
Sand Wash Basin	Wasatch-Fort Union	94	15	0.3	320
Denver Basin	Laramie-Fox Hills	92	20	0.3	1,285
Denver Basin	Arapahoe	92	19	0.2	590
Middle Park	Troublesome Formation	91	16	7.5	1,025
Raton Basin	Cuchara-Poison Canyon	77	18	1.0	465
Sand Wash Basin	Mesa Verde	70	16	2.0	1,885
Greater Denver Basin	Laramie-Fox Hills	67	15	4.5	5,045
Piceance Basin	Mesa Verde	66	14	2.0	2,865
Eagle Basin & Vicinity	Weber-Maroon-Minturn	62	14	1.0	730
Piceance Basin	Uinta Formation	60	14	7.5	5,015
Denver Basin	Denver	55	19	0.1	155
SW Colorado	Morrison-Summerville-Entrada	55	14	0.8	735
Raton Basin	Raton-Vermejo-Trinidad	54	18	5.0	4,035
South Park	Antero-Wagontongue	51	13	3.8	370
SW Colorado	Wingate	50	12	3.8	1,810

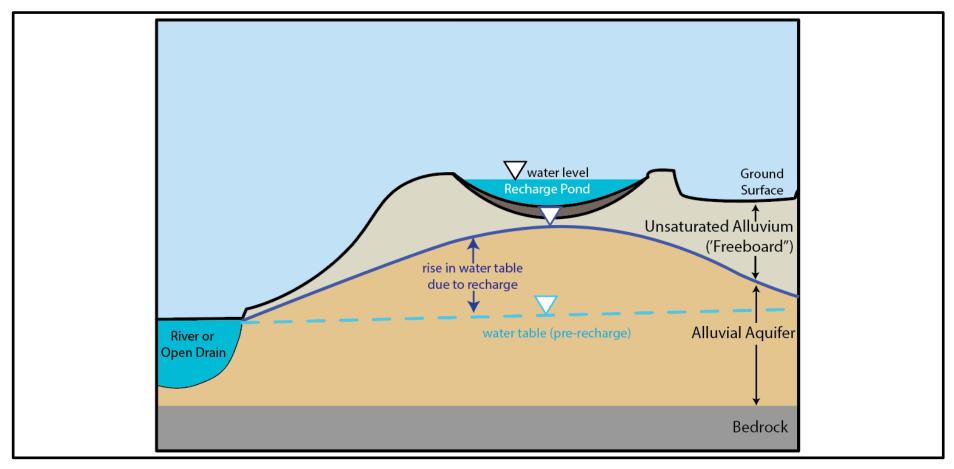
#### Example Alluvial Recharge Operation on Alluvial Terrace







#### Example Alluvial Recharge Operation on Alluvial Terrace







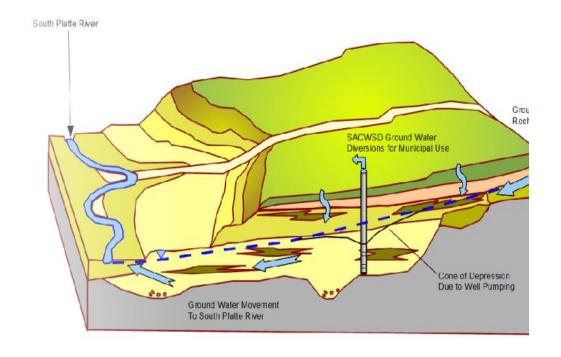
#### Questions

Aquifer recharge and water banking possible in Mesa Co.?

#### Any benefits to conjunctive use?

E.g., Capture early season runoff and re-time to when needed?

Any potentially NT sedimentary bedrock aquifers?

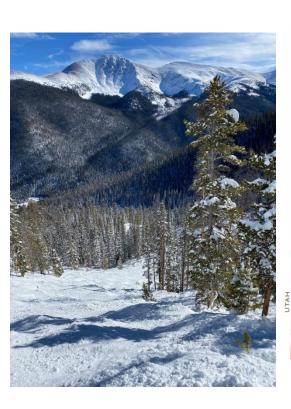


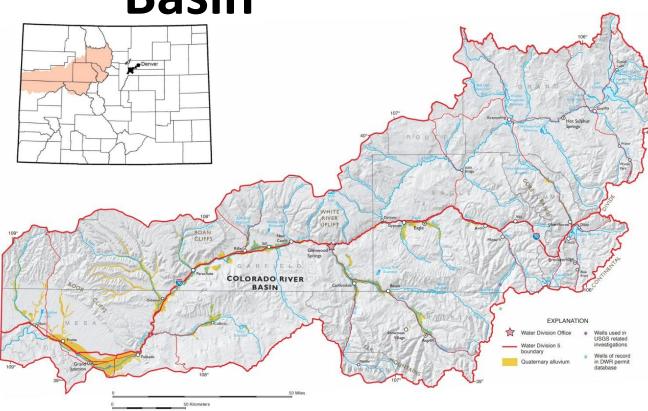
Not to Scale



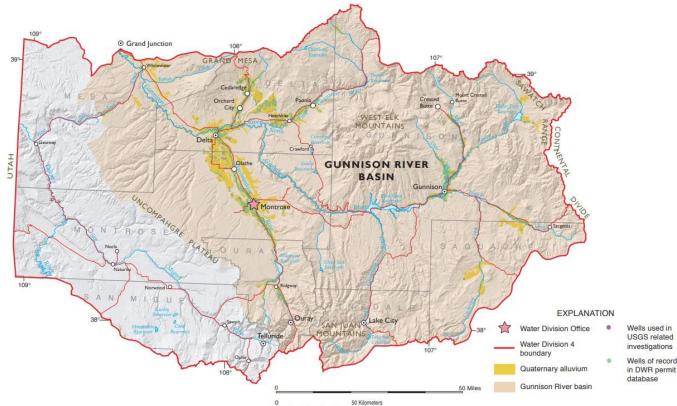
#### **Additional Slides**

### Colorado River Basin

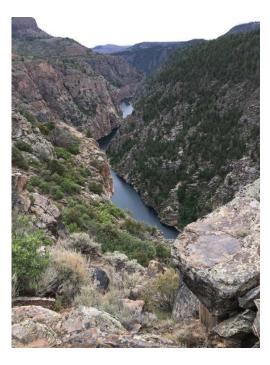


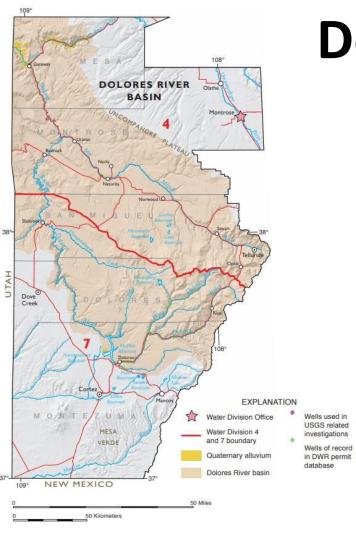


**Gunnison River Basin** 

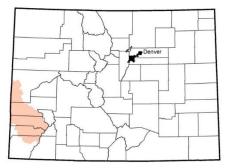








#### **Dolores River Basin**





# Groundwater Administration in Colorado

- Water Right Determination and Administration Act of 1969
  - Integration of GW into SW prior appropriation system
  - "Revolutionary" concept: allowing out-of priority diversions per an approved augmentation plan
  - Creation of Water Courts

"Recogizing that previous and existing laws have given inadequate attention to the development and use of underground waters of the state, that the use of underground water as an independent source or in conjunction with surface waters is necessary to the present and future welfare of the people of this state, and that the future welfare of the state depends upon a sound and flexible integrated use of all water of the state." – 1969 Act (CRS 37-92-102(2).

"Glover Equation" has become the de-facto method in Colorado Groundwater cases.....

# Groundwater 101 – Understanding the inputs to the Glover Equation

#### **Key references:**

Basic Ground-Water Hydrology

By RALPH C. HEATH

Prepared in cooperation with the North Carolina Department of Natural Resources and Community Development



### Streamflow Depletion by Wells—Understanding and Managing the Effects of Groundwater Pumping on Streamflow

By Paul M. Barlow and Stanley A. Leake

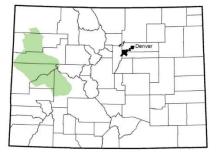


Wyoming Pond on the Wood River, Pawcatuck River Basin, Rhode Island.

**USGS Circular 1376** 

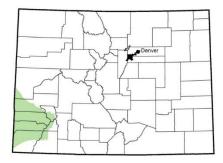
# **EXPLANATION** USGS Wells DWR Wells

#### **Piceance Basin**

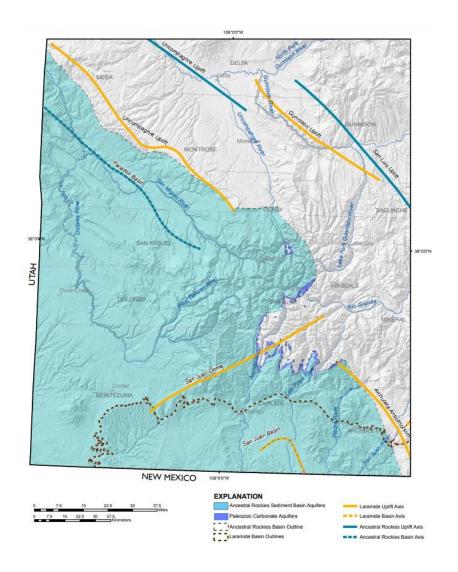




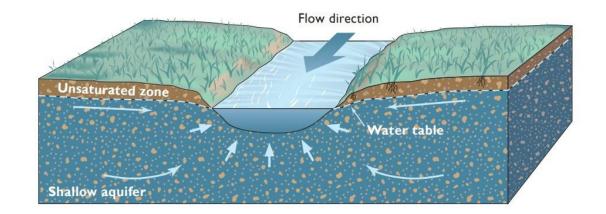
#### **Paradox Basin**



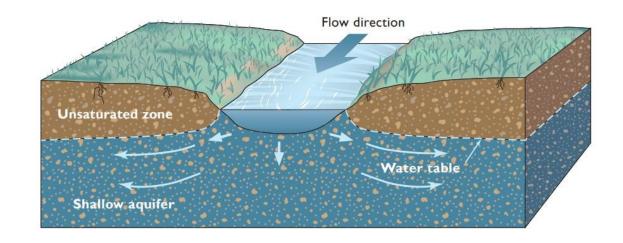




### Gaining Stream:



## Losing Stream:



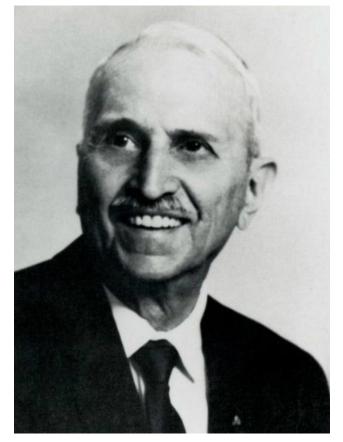
#### Robert Glover

United States Reclamation Service (later USBR) – 1920 through 1954

Boeing aircraft

United States Geological Survey

Developed and taught groundwater course at CSU.



**Robert Ellsworth Glover** (1896 – 1984)

River Depletion Resulting from Pumping a well Near a River (1954)

Textbook: Transient Ground Water Hydraulics (1974)

#### Colorado National Monument

