Moving to a water-restricted future
Now would be a good time

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Have you noticed?
2-3% growth compounds over the years
Well and spring levels are declining
Periodic little snow in the mountains
Periodic summer drought
El Niño / La Niña precipitation cycles
Climate Change – getting hotter
WHAT IS AN ACRE-FOOT?

1 Acre-foot (AF) = 325,851 gallons

One acre-foot of water covers approximately
1 acre of land
1 foot deep

Ken’s Lake, when full, holds approximately
3,000 acre-feet
Spanish Valley Watershed, the USGS Study Area
The Glen Canyon Group and Valley Fill Aquifers
Well levels are a portent of what’s likely to come: Dry in 1970’s, wet in ‘80s, slowly declining since
• The City presently assumes it can serve water to new residential and commercial developments
  • “Will serve” commitments are neither explicitly stated nor considered by Planning.
  • This may be because the city has ample “paper” water rights for growth.
  
  This must change....

  Years of drought and famine come and years of flood and famine come, and the climate is not changed with dance, libation or prayer.
  John Wesley Powell
The end game for this discussion:

Suggested city policy changes for calendar year 2021:
• Begin “metering” new requests for residential or commercial water
• Requests are in units of Equivalent Residential Connections
  • One ERC is one typical residential housing unit
    • 400 gal/day = 0.45 acre-feet/year
• Participate in upcoming Groundwater Management Plan process

• **These policy changes need not and should not wait** for the GWMP process to complete.
  • GWMP completion is likely a few years away.
  • New development continues apace.
  • Wise water policy means not making commitments we can’t fulfill.
  • The city can adopt any water policy we wish as long as we don’t violate state law.
The end game for this discussion, continued...

What do we mean by “metering”? To be debated. Some ideas:
• Explicitly accepting or denying requests for new water in Planning apps.
• Keeping better records of such requests
• Establishing an annual new ERC quota
• Establishing a maximum ERC limit for any single application
• Offering ERC “bonuses” for conservation or secondary water use
• Metering rules amended periodically as required
• Applicants who contribute their own existing GCGA withdrawals not subject.
• Applicants who contribute their own non-GCGA water not subject.
The basic Water Budget issue:

- We’re talking “culinary” (drinking) water here, not irrigation
- We’re talking ground, not surface, water, i.e. aquifers
- Water rights are not the issue
- Aquifer capacity is the issue

First, how much water each year are we currently using?

- Well known numbers
  - Moab City – 2300 acre-feet
  - Grand County – 1100 acre-feet
  - San Juan County Spanish Valley SSD – 500 acre-feet

Then, how much water do we have to use? Read on…

- Poorly estimated numbers, often apples and oranges confusion
  - USGS study 2018-19
  - Ken Kolm (city sponsored consultant) 2018-19 study/reports
  - USGS/Journal of Hydrology 2019 study
In more detail, how much water each year are we currently using?
History of the city’s water supply:

- Since 1890, Skakel Springs (near Moab Springs Ranch, N of town)
- In 1950’s, purchase of George White (the GW of Red Cliffs fame) ranch (now the Golf Course area)
  - Culinary water reported to DWR of 2159 acre-feet in 2019:
    - Four springs, presently in use
    - Two wells, #6 and #10, presently in use
  - Well #7 used for golf course irrigation; culinary quality water
  - 2009-2012 average of 120 acre-feet/yr reported to DWR
- City’s springs and wells totaled 2279 acre-feet/yr in 2019
Grand County wells also tap GCGA:
- In GCGA rather than Valley Fill Aquifer since good quality
  - George White #4 and #5
  - Chapman
  - Spanish Valley
- Withdrawals reported to DWR in 2019 were 1039 acre-feet
San Juan County SV SSD Well #1 also taps GCGA
- Approved, tested for 500 acre-feet
- In service soon to serve SITLA “South Moab” development
  - A potentially large (15K people) community
- Junior water rights from 2011
- Conditional approval for another 4500 acre-feet
  - Diversion from 20+ GCGA wells desired by District
  - Colo River withdrawal (up Kane Crk) is a backup
• **What is our present GCGA withdrawal?**
  - City – in 2019, 2279 acre-feet
  - Grand County – in 2019, 1039 acre-feet
  - SJSVSSD – planned from one approved well – 500 acre-feet

• **Total GCGA “existing” withdrawals = 3818 acre-feet**
  - Growing with new developments in pipeline
  - Varies from year to year since culinary water used for irrigation
  - Does not count Lower SV Springs or Private Wells
  - Agrees well with Gardner/USGS value of 3600 acre-feet
Now, in more detail, how much water do we have to use? How is it estimated? Three techniques:

- By modeling groundwater recharge by precipitation (snow/rain)
  - Difficult to do accurately
- By observing discharge in surface (streams, springs) and ground waters
  - Better accuracy estimates
  - Then assume that recharge equals discharge;
    - An assumption not easily verifiable
- By some combination of the above two

- Three contemporary studies, two by USGS (or related authors), one by a consultant (Ken Kolm) hired by city
What did the USGS 2018-19 study say?

• Recharge method: 10 – 30K acre-feet/yr
• Discharge method: 13-15K acre-feet/yr
  • Largest discharge is Mill Creek (base flow) surface water
• Both methods subject to variable climate data
• These count groundwater in the whole watershed (upper, east side of La Sals; and lower, the valley floor), both:
  • Good (culinary) water, from GCGA aquifer
  • Poorer (salty, irrigation) water, from Valley Fill aquifer
What useful things came out of Kolm’s 2018-19 Phase 1-4 study?

• Phase 1 laid the ground work for the remaining reports
• Phase 3 proposed expanded Source Protection Zones for the city’s springs
• Phase 4 proposed an expanded monitoring plan for the area’s ground water table, useful as part of upcoming Groundwater Management Plan sponsored by DWR
• Phases 2 and 4 presented water budgets for the GCGA and Valley fill aquifers respectively
What did the Kolm Phase 2 Water Budget study say?
• 18K acre-feet/yr passing through “Water Budget Area”
• Currently depleting (mining) the GCGA
• Difficult to make policy decisions on the basis of this study alone

• WBA chosen to represent GCGA flow
• WBA chosen to have mostly “no flow” boundaries
  • Surface and few points

The Water Budget Area for Phase 2, the GCGA

Figure 10a. Map showing the location of the Preliminary Water Budget (PWB) area and Hydro Zones of the GCMC hydrologic system with boundary conditions and spring locations.
• Author admits considerable uncertainty, reluctance to make conclusions, more study required
  • Groundwater in/out estimates subject to considerable uncertainty
  • Vegetation losses subject to considerable uncertainty
  • Geochemical tracers not integrated into model
  • Infiltration in high La Sals not integrated into model
  • Surface water balance not integrated into model
What does the USGS/JofH article say?

• 3400 acre-feet/yr recharge of “deep” GCGA
  • This is the part of the aquifer from which city wells draw
  • Uncertainty? – could be from 1500 to 5300 acre-feet
    • Nominal case – we’re at Safe Yield limit now
    • Best case – we have 50% to grow on
So, do we have culinary water to grow on for some time?

Not really. Less than you think. There’s a new hooker, which is:

• The city’s (and county’s) existing culinary water rights and withdrawals are to the “Glen Canyon Group” aquifer.

• The latest USGS/Journal of Hydrology study says the GCGA is already being withdrawn at its long term recharge rate, what the state defines as “Safe Yield.”

• Utah Division of Water Rights is the authority who determines the legal Safe Yield value.

• That value has not yet been determined, a subject of the Groundwater Management Plan process.

• When established, it implies no new (net) withdrawals from the GCGA aquifer, regardless of paper water rights.

• This is a finding that precipitates a paradigm shift for local governments, who must plan far into the future.
What exactly does the state say about “Safe Yield”? 

• “Safe Yield” - the amount of groundwater that can be withdrawn from a groundwater basin over a period of time without exceeding the long-term recharge of the basin or unreasonably affecting the basin’s physical and chemical integrity

• Utah Code 73-5-15 4(a)(i) : “...the withdrawal of water from a groundwater basin shall be limited to the basin’s safe yield.”

• Utah Code 73-5-15 4(a)(ii) : “Before limiting withdrawals in a groundwater basin to safe yield, the state engineer shall:
  • determine the groundwater basin’s safe yield; and
  • adopt a groundwater management plan for the groundwater basin
If the GCGA were closed to new withdrawals, what other water sources could be tapped for culinary city use?

- **Nothing is easy.** Tapping any other source is fraught with legal, water right, water quality, cost, infrastructure and environmental consequences

- The biggest GCGA discharge is Mill Creek, its surface rights owned by Moab Irrigation Co., a non-profit with senior water rights
  - Could trade agricultural uses for municipal uses

- The only other aquifer is the “Valley Fill Aquifer” with poorer, but treatable, quality water whose rights are held by other users.
  - Tapping its underflow to the Colorado River could impact wetlands

- The county owns unused modest rights to the Colorado River.
  - Expensive to pump and store
  - Could be subject to Colorado River Compact restrictions
More study is needed!

• The city is drilling new well #12 in the golf course area this coming spring
  • An opportunity to cheaply observe aquifer characteristics and do drawdown tests against other wells in the area
• More monitoring elsewhere in the valley is critical
• City contributions to funding will be necessary
To say it again...

- We have a painful, but manageable paradigm shift in front of us
- Until now, the water’s always been there, essentially free
- No more:
  - Water will get more expensive.
  - We’ll have to conserve.
  - We’ll have to buy, trade, share or bank for new water.
  - This may limit new residential and commercial growth.
The remaining slides get into the details, the weeds of water budget and Safe Yield issues.

Policy makers can skip this part if you wish...
What do we mean by “mining” an aquifer?
Aquifer area A acres, say 20K acres

Think of an aquifer as a bucket of wet sand

Bucket full of alluvial sand; Specific Yield y = 10-30%; ie relatively little space for water

Recharge R, af/yr; Also is Safe Yield, say 3000 af/yr

Pre-devel spring flow S (@ W=0, no well withdrawals) (@ pre-devel height h = H0) is just the recharge R; Thus s = kh, where k = R/H0

Spring flow s @ height h, af/yr; s is proportional to height h;

Pre-devel height H0, say 100 ft

Height h, ft

Well withdrawals W, af/yr

Change in storage volume is A(dh/dt) af/yr; Change = (recharge – withdrawals) – spring rate (yA)(dh/dt) = (R-W) – kh;
At a recharge of $R = 3000$ af/yr,
from pre-development state (i.e. full aquifer),
suppose we suddenly begin withdrawing 1000 af/yr

It takes hundreds of years to come to new equilibrium,
because the aquifer volume is much bigger
than the volume withdrawn each year.

Initial pre-devel spring flow
equal to recharge = 3000 af/yr

Not mining the aquifer since withdrawals < recharge = safe yield

Spring flow eventually declines
to 2/3 of pre-devel value, 2000 af/yr
**Mining** the aquifer since withdrawals > recharge = safe yield

At a recharge of R = 3000 af/yr, from pre-development state (i.e. full aquifer), suppose we suddenly begin withdrawing 4000 af/yr. It still takes > hundred years to come to new equilibrium, because the aquifer volume is still much bigger than the volume withdrawn each year.

Initial pre-devel spring flow equal to recharge = 3000 af/yr

Spring flow eventually declines to zero

It still takes > hundred years to come to new equilibrium, because the aquifer volume is still much bigger than the volume withdrawn each year.
What is the title and who authored the latest USGS report?


1University of Utah Department of Geology and Geophysics, Salt Lake City, UT  
2United States Geological Survey, Nevada Water Science Center, Carson City, NV  
3United States Geological Survey, Utah Water Science Center, Salt Lake City, UT

• This report is currently published as a “pre-proof” Journal of Hydrology article.  
• All authors were authors of the previous 2018-2019 USGS study, *Evaluation of Groundwater Resources in the Spanish Valley Watershed, Grand and San Juan Counties, Utah*  
• This report draws heavily on that previous study.  
• Four of the five authors are still employed by the USGS.  
• 4For these reasons, I have called this study a “USGS” report. However, note that it has been independently published
What does it say that changes the game?

Using a lumped parameter model and 14C groundwater ages, we estimate recharge to the deeper GCGA (DGCGA) to be $4.2 \pm 2.3 \times 10^6 \text{ m}^3/\text{yr} [3400 \pm 1900 \text{ acre-feet/yr}], which is approximately equal to the measured discharge from wells and springs [3600 \text{ acre-feet/year, tabulated in the slides preceding this one}].

Why do I have more confidence in this report than in others?

Gardner used geochemistry and environmental tracers (groundwater dating with tritium/helium and industrial gases, pore-water tritium and chloride measurements from rock cores, etc.) together with what is now a common Lumped Parameter Model technique to focus on water budgets and concepts of physical groundwater flow. This permits better definition of where groundwater comes from and where it did and didn’t go.

Gardner’s agreement between an independently calculated recharge and observed discharge gives confidence in the lumped parameter model.
Where does GCGA water come from and where does it go?

from high in the La Sals
to the NE side of the valley
Gardner thinks the Kayenta middle layer of the GCGA (Navajo, Kayenta, Wingate) often confines water in the Navajo (the “Shallow GCGA”) and the Wingate (the “Deep GCGA”) to those layers.

- Wells and springs are sourced in the DGCGA
- Mill Creek is sourced in the SGCGA

- It takes a long time (2700 years, observed via carbon 14 dating) to get from the mountains to the valley.
The basic **Lumped Parameter Model**:

Water moves horizontally at speed $X/T$ m/year;
Recharge rate $R = V/T$ m$^3$/yr = $X*Y*Z / T$. 

Water enters aquifer at time zero

Aquifer

Water exits aquifer at time $T$ years
(Exponential Piston) Lumped Parameter Model

\[ R = \frac{L\theta(1 + X_{\text{con}}/X)}{\tau}, \]

where

- \( R \) is the recharge rate in m\(^3\)/year over the aquifer portion \( X \);
- \( \tau \) is the mean transit time in years;
- \( L \) is the aquifer thickness in m;
- \( \theta \) is the porosity;
- \( X_{\text{con}} \) is the confined portion of the aquifer;

This results in

\[ R = 4.2E6 \text{ m}^3/\text{yr} \] (3400 acre-feet)/yr

which well matches observed discharges of 3600 acre-feet/yr.
An estimated recharge rate of 3400 acre-feet/yr.  
About what we’re discharging/withdrawing now!  
Is it believable?

• Yes, to the extent of its error bounds.
• There are uncertainties in all LPM parameters
• Their net effect, the total uncertainty in recharge rate \( R \) (or \( Q \) here) can be calculated assuming all errors are statistically independent.

\[
\sigma_Q = \frac{1}{Q} \sqrt{\left( \frac{\sigma_L}{L} \right)^2 + \left( \frac{\sigma_{\theta}}{\theta} \right)^2 + \left( \frac{\sigma_x}{x} \right)^2 + \left( \frac{\sigma_T}{T} \right)^2 + \left( \frac{\sigma_{x_{total}}}{x_{total}} \right)^2},
\]

• This results in a 1-sigma standard deviation (i.e. uncertainty) \( \sigma_Q \) of 2.3E6 m\(^3\)/yr = 1865 acre-feet/yr.
• Thus, this **Safe Yield estimate is 1535 to 5265 acre-feet/year**
• Nominal case, we’re at Safe Yield now, 3400 acre-feet
• Best case, we have (5265 – 3400) / 3600 ~ **50% to grow on.**

• **More study is needed!**
  • The city is drilling new well #12 in the golf course area this coming spring
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Thank you for reading!

Questions?
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