Adaptive Hydrology

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Where Land and Water Meet

Missoula Aquifer Sustainability

Phase 1: Historical Analysis

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Executive Summary

1. The Missoula Aquifer is one of only 64 designated sole source aquifers in the United States. As such, it supplies over 75,000 residents, plus businesses, with potable groundwater. Its hydrogeology (e.g. high transmissivity rates) and geography (e.g. downstream location within the Clark Fork and Bitterroot watersheds) have created a resource that has been relatively resilient and predictable over the past 23-years.

2. Due to the unconfined nature of the aquifer and the high transmissivity rates of the geological substrate, the upstream inflows (recharge) and downstream outflows (discharge), are largely controlled by the magnitude and timing of the Clark Fork River. In fact, the Clark Fork River provides over 80% of the annual aquifer recharge. Thus, it is fair to say that any long-term changes in the streamflow will likely have far reaching impacts to the sustainability of the aquifer.

3. Over the past 23-years, population has increased from approximately 57,000 to 78,000 people, roughly translating to an increase in water use of almost 40%. According to the Montana Ground Water Information Center (GWIC) there are currently over 3,500 wells listed in the Missoula area. Of those wells, 247 are labeled as public water, which includes the City of Missoula's water supply. Population is expected to continue to increase over the next few decades, and assuming water use per resident remains consistent, more withdrawals will be necessary to keep up with this growing demand.

4. Climate change is expected to create additional stressors. Increases in temperature and shifts in snowpack runoff may reduce water availability during critical periods of high demand. In addition, when drought does occur, the magnitude and duration is expected to be worse than historical conditions.

5. In spite of the historical changes in population and temperature, the aquifer has been remarkably resilient over the past 23-years. All 16 of the wells used in this analysis have shown increasing average trends over the study period. Additionally, minimum and maximum annual depths have been increasing over this same time period.

6. These increasing trends are almost entirely driven by the increasing annual and seasonal flows of the Clark Fork River. Trends in spring runoff have increased the most during the study period (113 cfs/season) and have likely led to increases in recharge during the summer, when demand is highest. This has created an opportunitistic situation where the timing of maximum supply and demand are perfectly aligned. Unfortunately, there is large uncertainty as to whether this trend and timing in streamflow/recharge will continue into the future.

7. When removing the impact of the increasing trend in the Clark Fork River, the groundwater signal is driven by pumping rates (i.e. overall water demand). Increasing demand leads towards statistically significant decreasing (i.e. unsustainable) trends in groundwater. In addition, over the most recent 10-years, when the Clark Fork River flows have not increased, there are statistically significant decreasing trends in groundwater, which appear to be correlated with increasing withdrawals to match

demand.

8. Aquifer withdrawals are highly correlated with temperature. As temperature increases, pumping rates have historically increased exponentially. In fact, temperature alone explains almost 95% of the variation in pumping rates. This suggests that groundwater levels have been and will continue to be sensitive to climate change due to increases in demand to go along with potential decreases in recharge.

9. Further analysis using physics or machine/deep learning is recommended in order to better understand tipping points created from shifts in discharge timing and magnitude, as well as increases in population. This analysis might also allow for improved management decisions based on real-time and near-time estimates of groundwater sustainability.

10. Given that the aquifer does appear to be sensitive to climate change and withdrawals, it is imperative to be thinking now, while the aquifer is still resilient and plentiful, about ways to maintain a clean and copious groundwater resource for the City of Missoula and beyond.

Introduction

The Missoula Aquifer is one of only 64 designated sole source aquifers in the United States.[1] As such, it supplies over 75,000 residents, plus businesses, with potable groundwater. Historically, the aquifer has shown incredible resilience to drought and increases in population within the Missoula valley area. There have been no long-term signs of depletion in any of the 27 monitoring wells within the aquifer. This is likely due to the very high transmissivity rates, location within the Clark Fork and Bitterroot watersheds, reasonable historical growth rates of the surrounding population, and only mild changes in historical climate (Whitlock et al. 2017).

Due to the unconfined nature of the aquifer and the high transmissivity rates of the substrate, the upstream inflows, and downstream outflows, of the aquifer are largely driven by the Clark Fork River (Tallman 2005; Miller 1991). In fact, according to previous studies, the Clark Fork River provides over 80% of the annual aquifer recharge (Table 1). Thus, it is fair to say that any long-term changes in streamflow will likely have far reaching impacts to the recharge and overall sustainability of the aquifer.

Table 1. Missoula aquifer source of average annual inflow according to Miller (1991).

Table 1

Source	Inflow (af/yr)	Percent of Total
Clark Fork River	192000	82.76
Creek Drainages and Tertiary Hillsides	19000	8.19
Lateral Underflow (Bitterroot and Hellgate)	21000	9.05
Total	232000	100.0

[1] https://www.epa.gov/dwssa

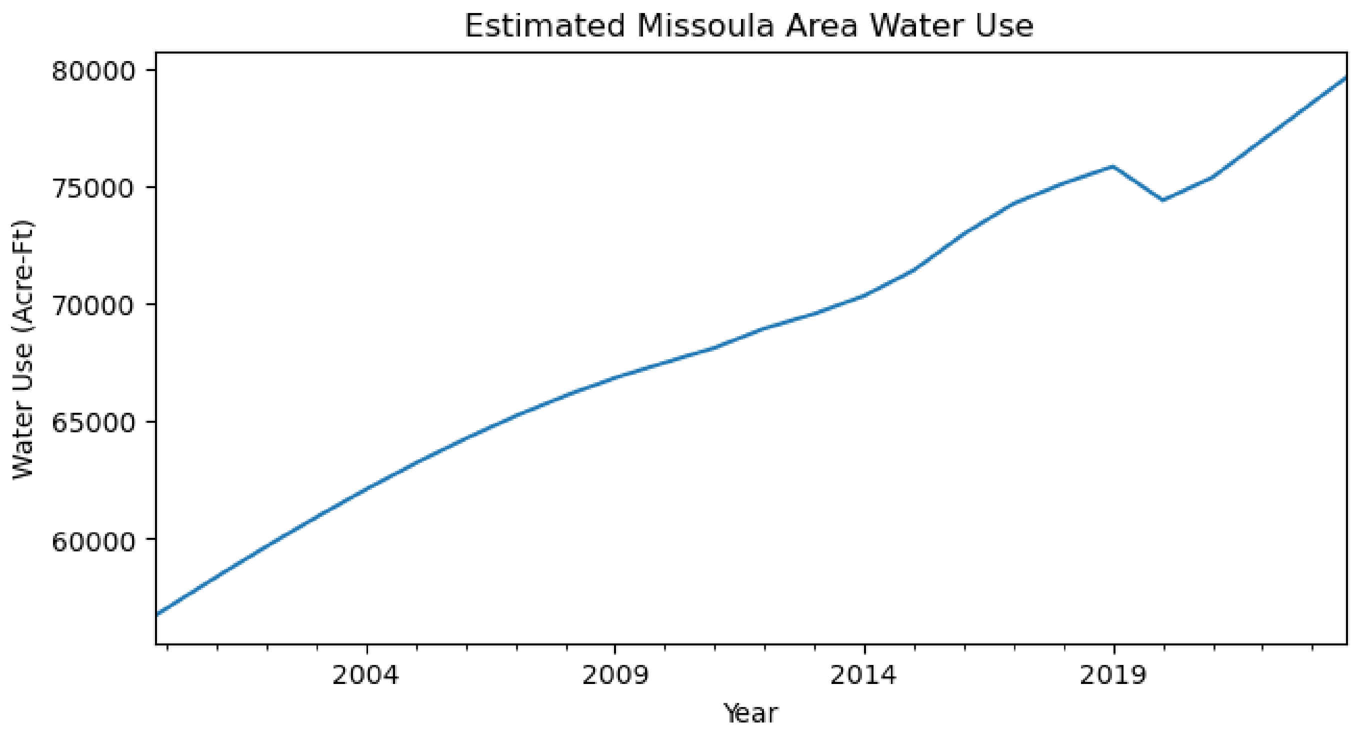

Figure 1. Estimated water use based on the U.S. Census population data within the Missoula area and an average consumption of 160 gallons/day/person.

Climate change is expected to impact the Clark Fork River in numerous ways over the coming decades (Whitlock et al. 2017). Average annual discharge is projected to increase, although there is large uncertainty around this projection. With higher confidence, there is expected to be a shift in the timing of peak runoff leading towards lower base flows in the summer months. In addition, when future drought occurs, the severity is expected to increase, resulting in extended periods of drier than normal conditions (Montana DNRC 2023). These projected changes will undoubtedly affect the groundwater of the Missoula Aquifer and impact local extractions for drinking water, irrigation, and industrial purposes.

From 2000 to 2024 the Missoula area population has increased from 57,000 to 78,000.[2] Using the standard assumption of 160 gallons/day/person, we estimate that water use has increased from 10,200 af to 14,100 af over this same time period (Figure **??**). Consequently, according to the Montana Ground Water Information Center[3] there are currently over 3,500 wells listed in the Missoula area. Of those wells, 247 are labeled as "public water," which includes the City of Missoula's water supply (Figure **??**). Population in the Missoula area is expected to continue to increase over the next several decades[4] likely leading to more wells and higher extraction rates to sustain this growth. In spite of the historical resilience of the aquifer to these changes, many questions still remain unanswered.

What if climate change and population growth converge to maximize stress on the aquifer? While these kinds of scenarios are not determined, they are all well within the realm of realistic possibilities, perhaps even probable. Given the overall resilience that we have

[2]https://www.census.gov/programs-surveys/popest.html
[3]https://mbmggwic.mtech.edu
[4]Correspondence with Marc Hendrickson on 2/13/2024


The Ranch Club
Golf Course
The Barn on Mullan
Mullan Rd

seen in the past, it is possible that the aquifer can withstand these stressors and continue to deliver clean and plentiful potable water to the Missoula community in perpetuity. However, to date, no one has studied these different scenarios to make sure that our future water resources are protected. In this analysis, we first evaluate the long-term historial trends in Clark Fork River discharge, City of Missoula pumping rates, and Missoula Aquifer water table depth. In subsequent analyses (not inlcuded in this preliminary report) we plan to specifically study the impacts of plausible future scenarios on the Aquifer to identify critical tipping points and mitigation strategies.

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