West Fork Water Budget Analysis

2024



Water Budget Purpose

Enhance understanding of water supply

Support recreation-based economy, including fly fishing, reliant on healthy waters

Identify and implement actions to conserve and restore the ecological health of the river systems

80 square-mile watershed

Data collected from:

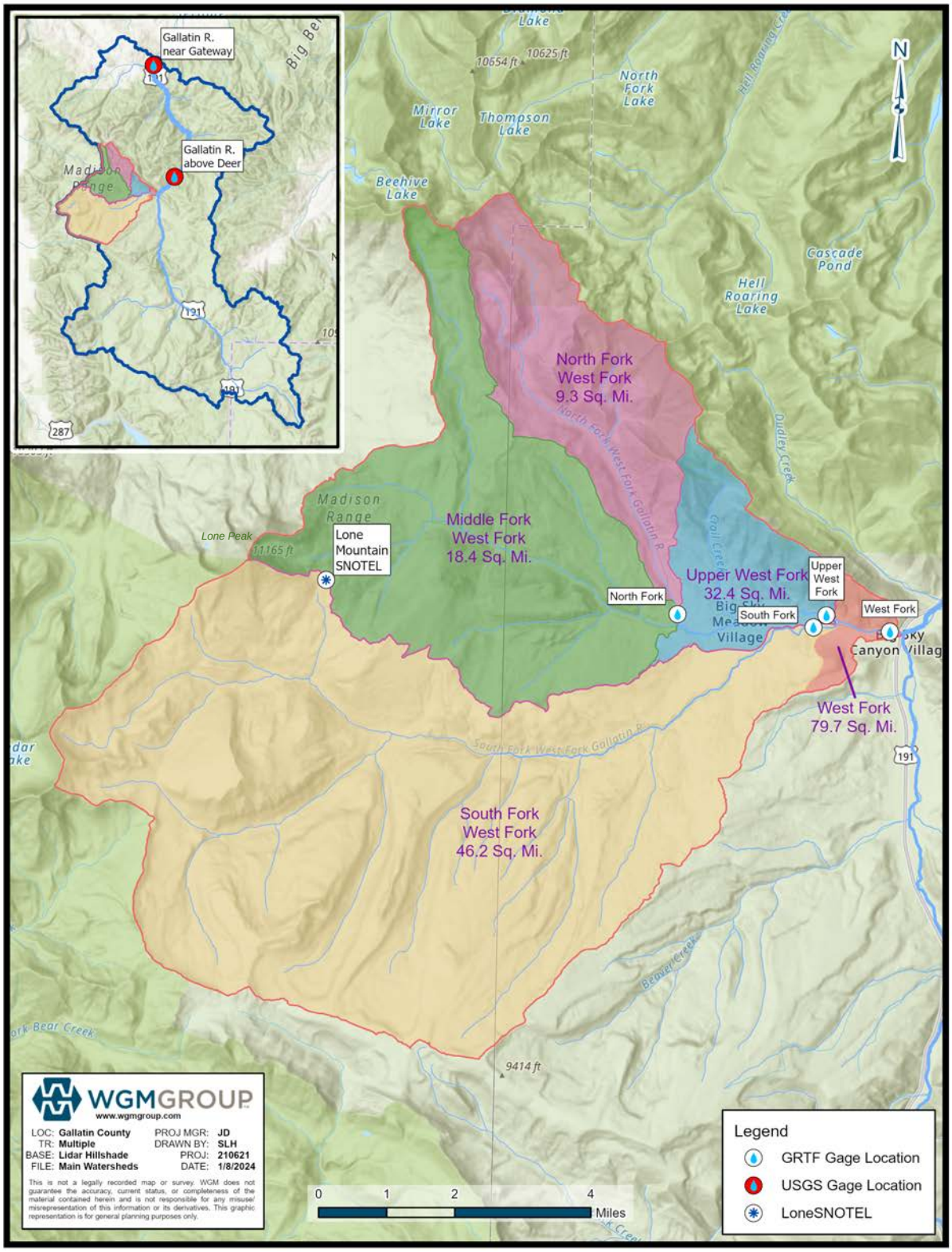
Gallatin River Task Force Streamflow Gages:

- South Fork West Fork Gallatin River
- North Fork West Fork Gallatin River
- "Upper" West Fork Gallatin River
- West Fork Gallatin River

USGS Streamflow Gages:

- Gallatin River Above Deer Creek, near Big Sky
- Gallatin River Near Gallatin Gateway

Lone Mountain SNOTEL



West Fork Gallatin River Watershed and Streamflow Gages

The West Fork Gallatin River Watershed is comprised of three main tributaries: South Fork West Fork Gallatin River, Middle Fork West Fork Gallatin River, and North Fork West Fork Gallatin River.

Hydrologic Cycle



WATER INPUTS:

Precipitation

- Snow
- Rain

WATER OUTPUTS:

Atmospheric Loss

- Evapotranspiration
- Sublimation

Streamflow

Infiltration

- Shallow Groundwater
- Deep Groundwater

The West Fork water budget is an “open” water balance; therefore the inputs may not equal the ouputs based on the available data.

The West Fork Gallatin River (West Fork) watershed is an 80 square mile headwater tributary of the Gallatin River located in the Madison Range of southwest Montana. The West Fork water budget analysis was conducted to characterize the movement of water through the West Fork watershed. This water budget, for the years 2017-2022 provides the Gallatin River Task Force and the Big Sky community an opportunity to identify and implement water management actions that conserve and restore the ecological health of the river systems.

The West Fork water budget accounts for the inputs and outputs that comprise the West Fork watershed’s hydrologic cycle, with inputs from precipitation in the form of snow and rain, and outputs of atmospheric loss, streamflow, and groundwater infiltration.

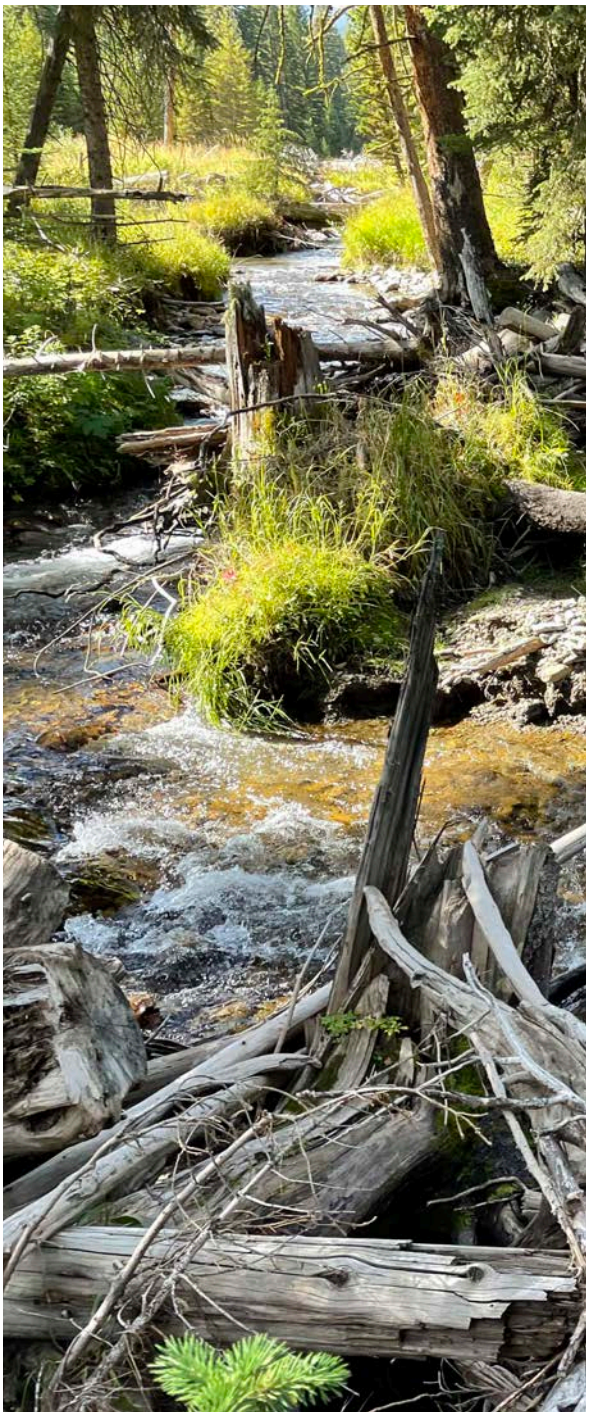
Input: Precipitation
Water from the atmosphere enters the watershed as precipitation; typically snow in the winter and rain in the summer.

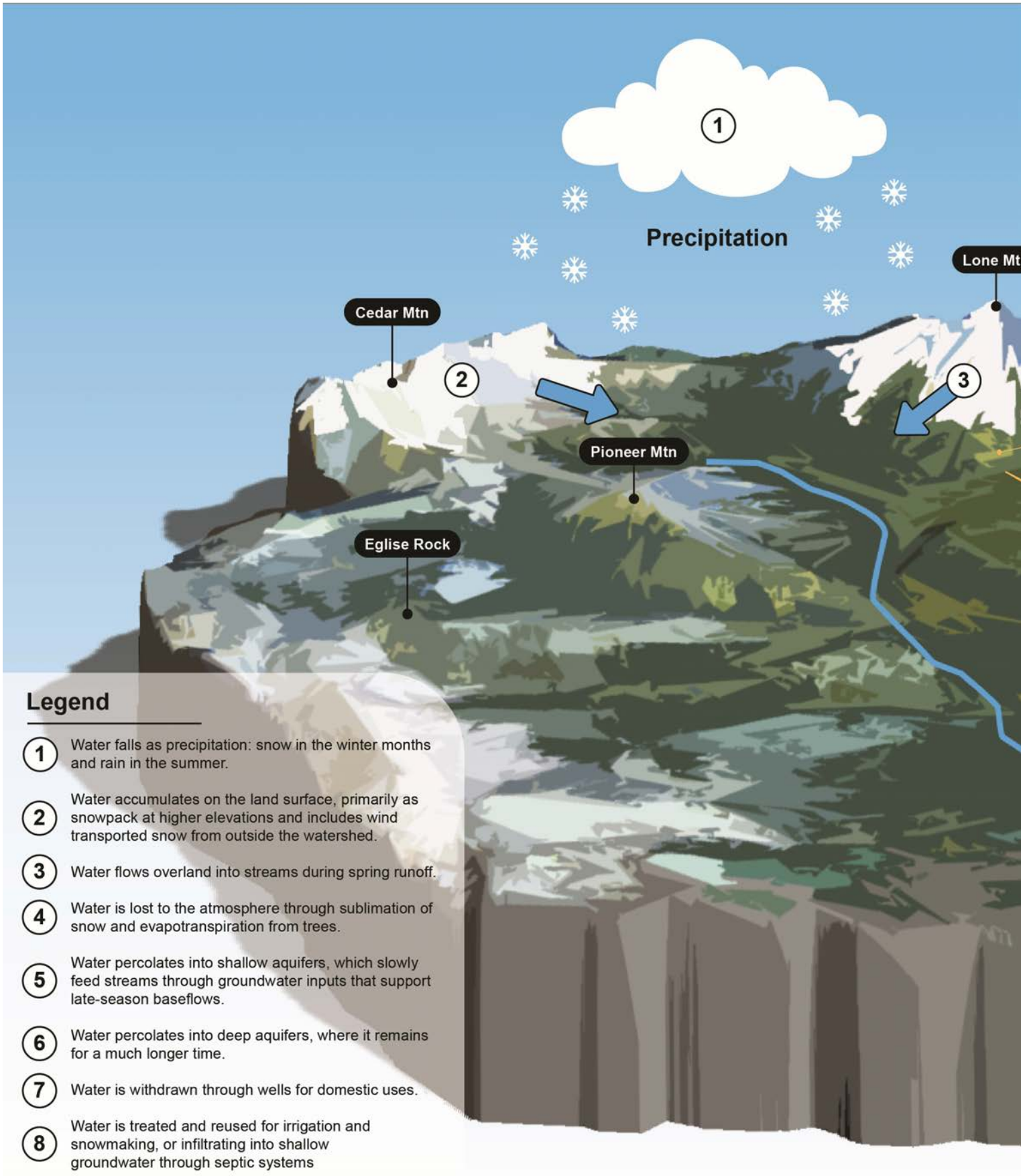
Output: Atmospheric Loss
Water is cycled back into the atmosphere via evapotranspiration and sublimation. Evapotranspiration occurs when water moves from the land to the air, including evaporation from the ground surface and transpiration of water from plants. Sublimation occurs when snow evaporates without first melting.

Output: Streamflow
As snow melts, direct overland flow of water contributes to high streamflows during spring runoff, while late-season baseflows are supported by shallow groundwater infiltration.

Output: Groundwater Infiltration
Shallow groundwater infiltration occurs when water percolates through the soil, moves through shallow aquifers, and resurfaces as streamflow weeks to months later. Infiltrated water in shallow aquifers can also continue down into deep groundwater aquifers, where it is considered lost from the watershed.

There are both natural and human controlled factors that affect the West Fork watershed’s hydrologic cycle. Human uses of water include domestic use, irrigation, and snowmaking. Water extracted from the shallow groundwater system for domestic use is returned to the ground through septic systems, while water treatment facilities’ reuse of water for irrigation and snowmaking cycles the water through the hydrologic system in various pathways.

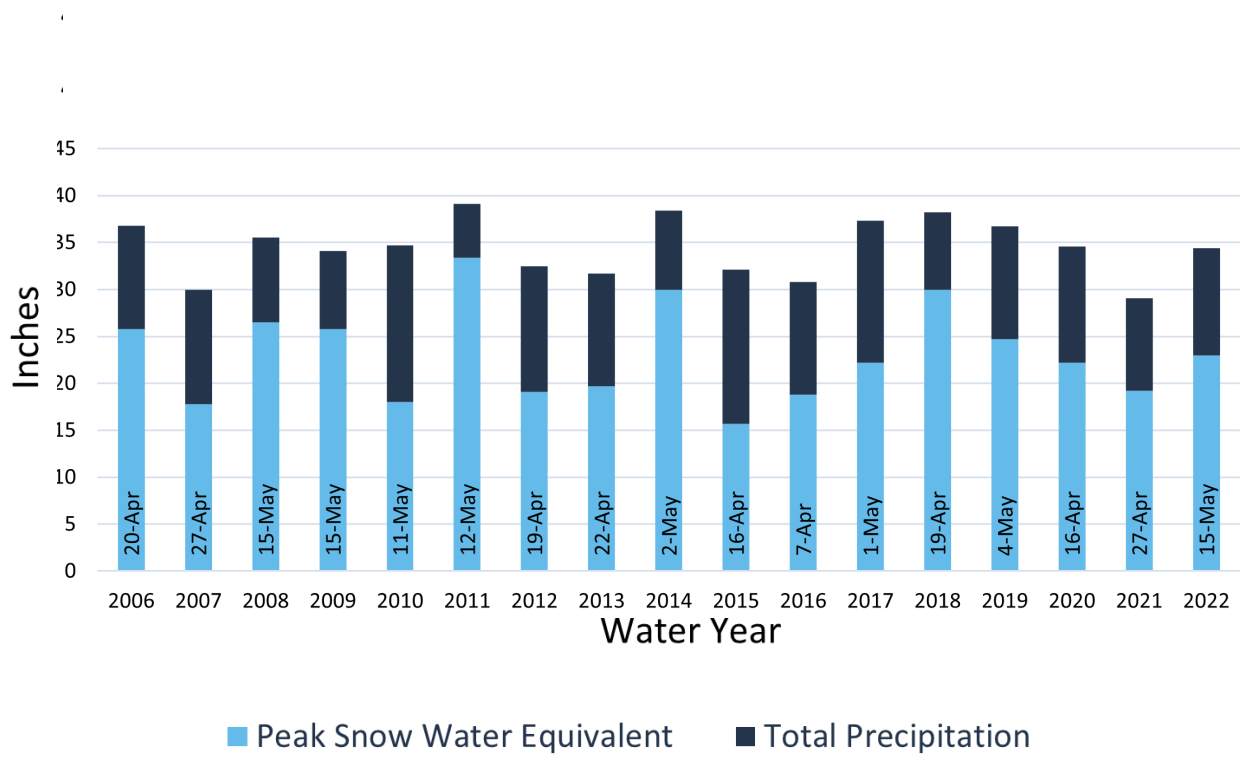




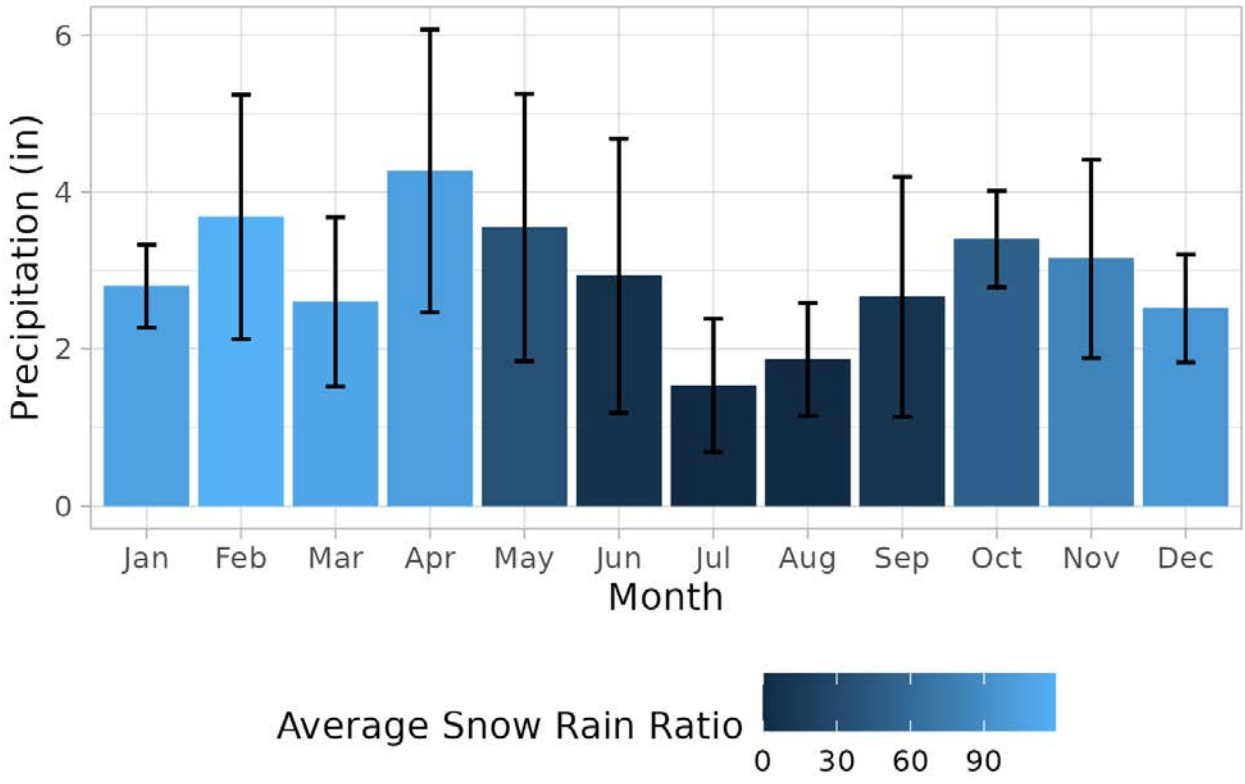
Legend

1. Water falls as precipitation: snow in the winter months and rain in the summer.
2. Water accumulates on the land surface, primarily as snowpack at higher elevations and includes wind transported snow from outside the watershed.
3. Water flows overland into streams during spring runoff.
4. Water is lost to the atmosphere through sublimation of snow and evapotranspiration from trees.
5. Water percolates into shallow aquifers, which slowly feed streams through groundwater inputs that support late-season baseflows.
6. Water percolates into deep aquifers, where it remains for a much longer time.
7. Water is withdrawn through wells for domestic uses.
8. Water is treated and reused for irrigation and snowmaking, or infiltrating into shallow groundwater through septic systems

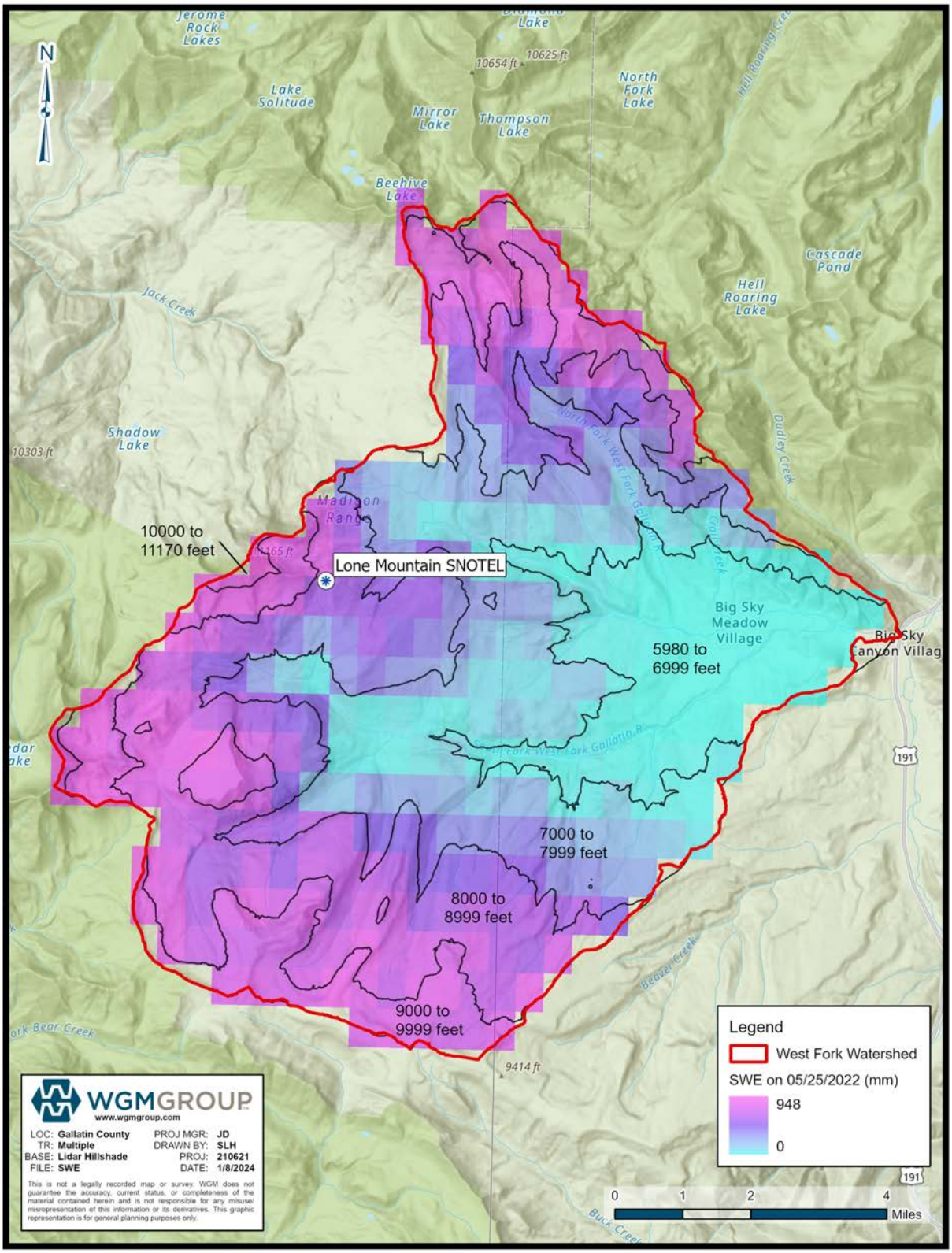

Sublimation
Evapotranspiration
4
Mountain Village
7
Meadow Village
8
5
6
Shallow Aquifer
Deep Aquifer



Lone Mountain SNOTEL peak snow water equivalent and annual precipitation from 2006 - 2022



Monthly average precipitation from 2017 - 2022 with snow/rain ration (lighter blue indicates snow)

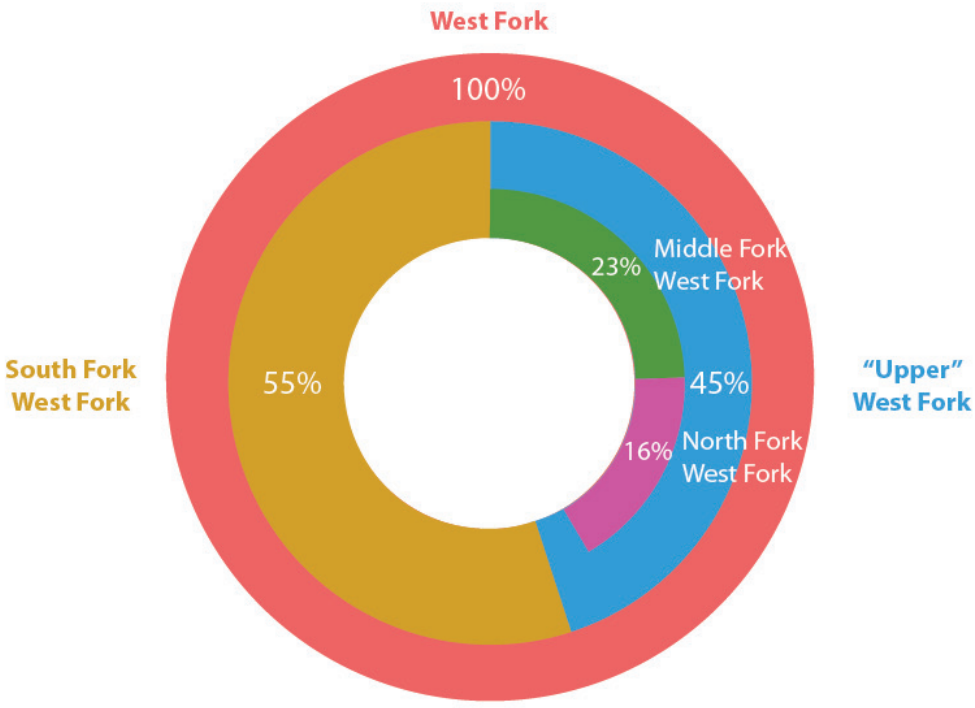


Accumulated snow water equivalent by elevation

Snow accumulation in the West Fork watershed is driven by elevation and aspect, with a maximum accumulation of 37.3 inches (948 mm) at 11,000 feet. Elevations above 8,000 feet contribute 73% of the snow water equivalent accumulated annually, despite representing only 53% of the watershed's area.

Inputs Summary

- Most of the precipitation in the West Fork watershed falls as snow, with an average of 34.5 inches of precipitation each year at the Lone Mountain SNOTEL site.
- Peak snow water equivalent in the West Fork occurred between April 7th and May 15th and averaged 23.1 inches, or about 67% of total precipitation.
- The greatest snowpack and total precipitation for 2006-2022 occurred in 2011, with 33.4 inches of peak snow water equivalent and 36.6 inches of total precipitation.
- The lowest snowpack occurred in 2015, with 15.7 inches of snow water equivalent, and the least total precipitation occurred in 2021, at 29.1 inches of total precipitation.
- For the 2017-2022 timeframe, mean annual precipitation over the entire West Fork watershed amounts to 137,574 acre-feet (44,829 MGY), or 32.4 inches.
- The South Fork West Fork typically receives 55% of the overall precipitation, while the "Upper" West Fork receives 45%.



Percent precipitation in subwatersheds of the West Fork

Outputs Summary

Output as percentage of annual precipitation

Evapotranspiration
69%

Streamflow
49%

Shallow Infiltration
17%

Sublimation
11%

Deep Infiltration
5%

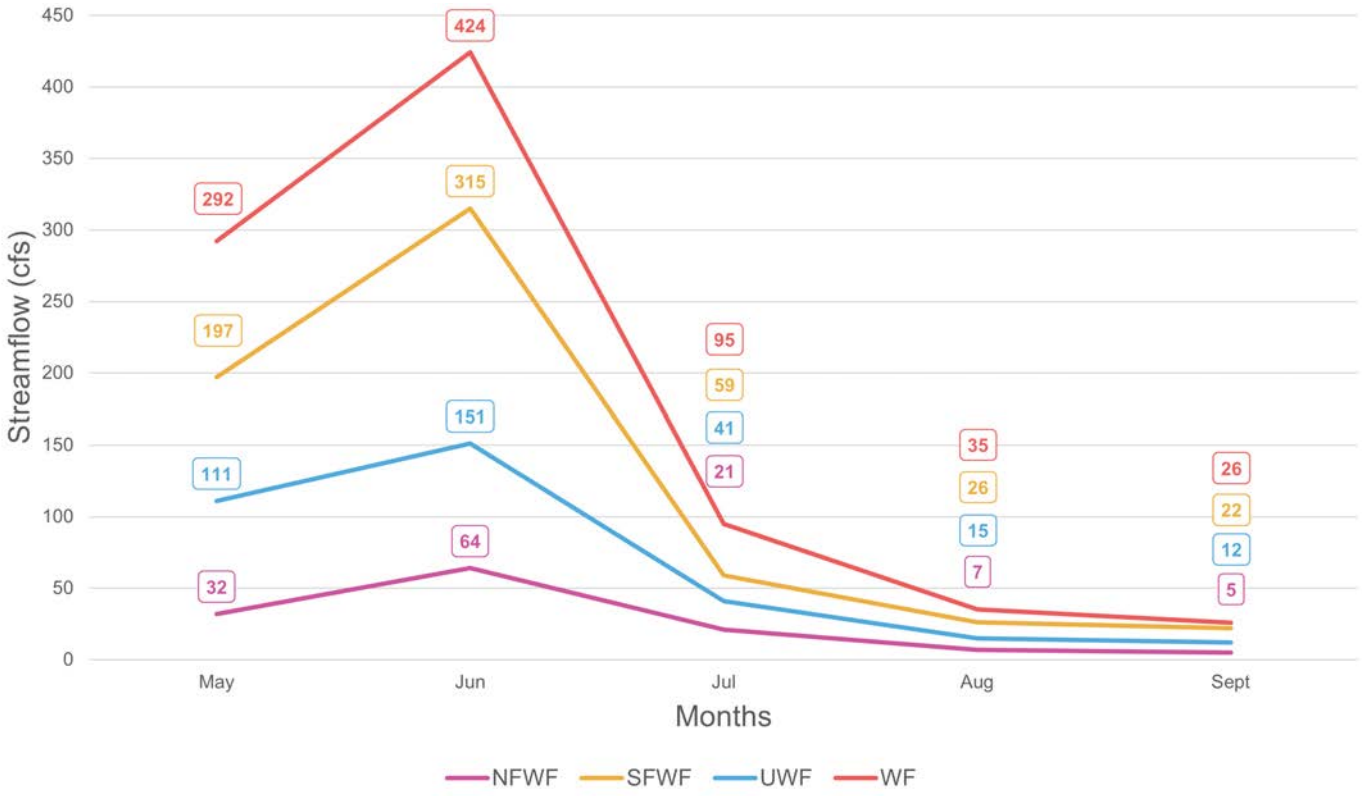
Human Use and Reuse
<1%

Evapotranspiration and streamflow account for the highest percentage output of average annual precipitation. Water loss due to evapotranspiration is highest during June, July, and August – the hottest months with the most growing vegetation, while streamflow is highest and most variable during snowmelt-driven runoff in May and June.

Total annual water demand in the West Fork watershed was estimated at 890 acre-feet (290 MGY) in 2020 and the projected demand by 2040 could amount to 2,946 acre-feet (960 MGY) (AE2S, 2022) assuming 6% annual growth. Current water use accounts for 0.6% of the 137,574 acre-feet of precipitation.



Streamflow



May - September mean monthly streamflows at Gallatin River Task Force gage stations between 2017 - 2022: North Fork West Fork (NFWF), South Fork West Fork (SFWF), Upper West Fork (UWF), and West Fork (WF)

The tributaries of the West Fork have a snowmelt-driven hydrograph typical of streams in the Mountain West with a period of hyperabundance in the spring and early summer followed by a period of scarcity in late summer and fall.

Spatial variation in precipitation and streamflow within the West Fork's subwatersheds:

The North Fork West Fork

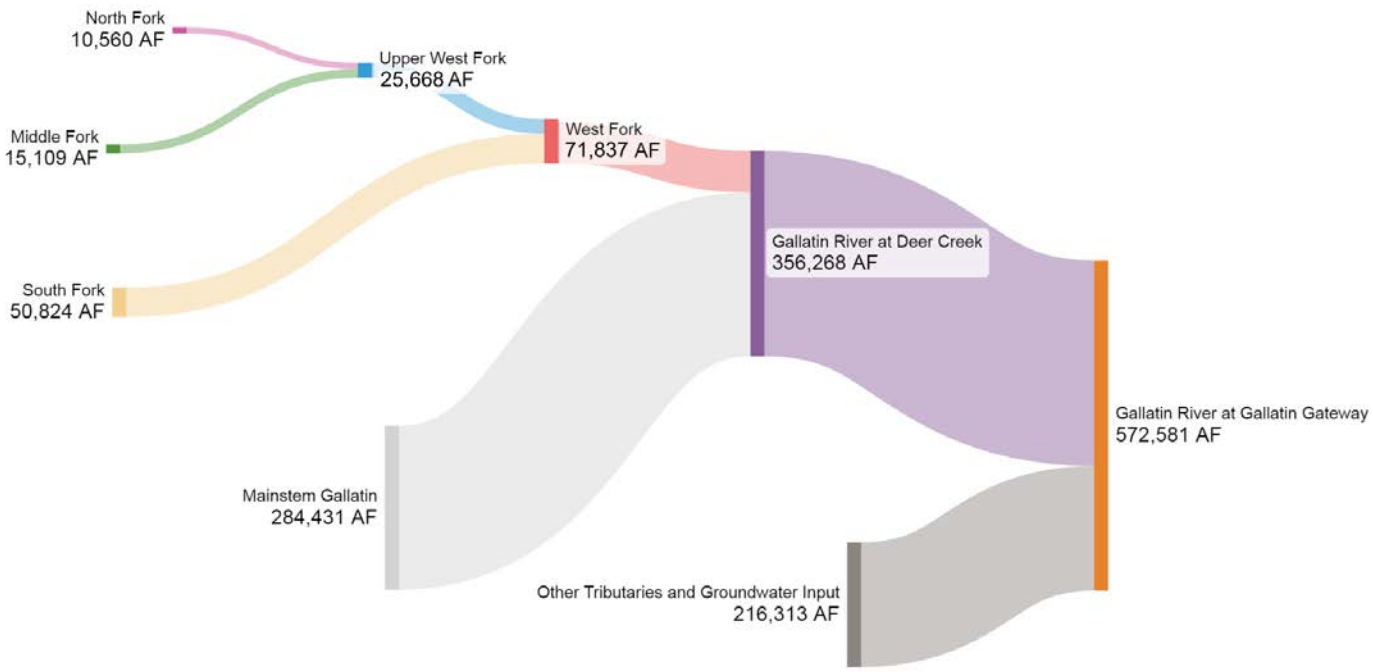
receives the highest percentage of overall precipitation relative to its size, while the South Fork West Fork receives the lowest percentage of overall precipitation relative to its size.

The South Fork West Fork

watershed provides the greatest proportion of streamflow due to its large geographic area, accounting for 58% of the overall watershed area, and contributing approximately twice as much streamflow as the "Upper" West Fork to the overall streamflow in the West Fork watershed.

The Middle Fork West Fork

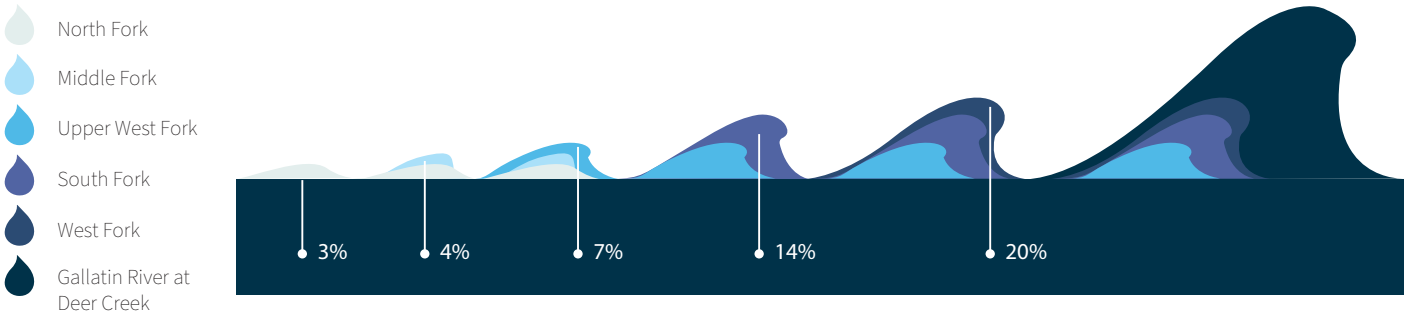
contributes approximately 1.5 times the streamflow as the North Fork West Fork to the "Upper" West Fork watershed.

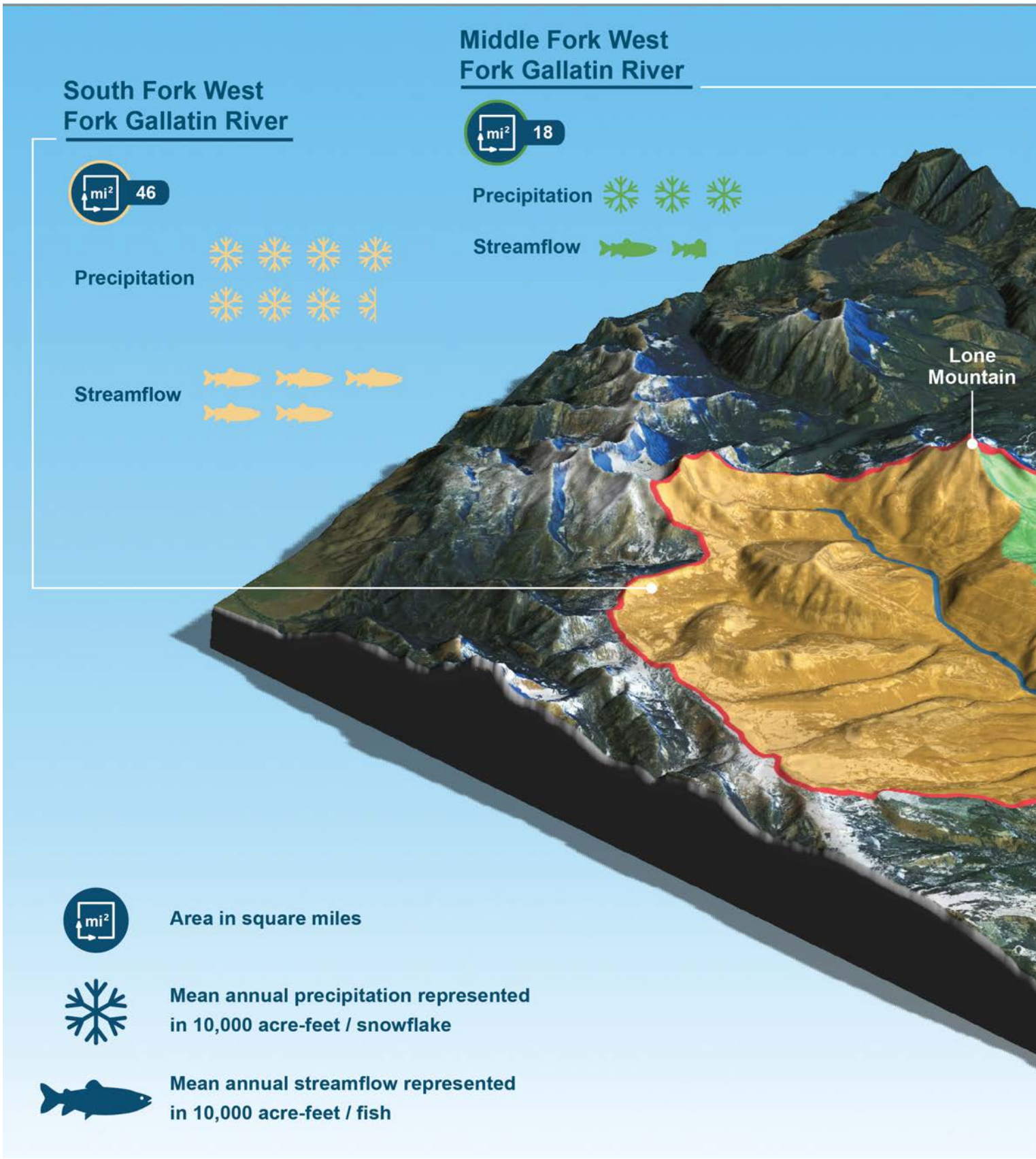


Mean annual contributions of tributaries to the Gallatin River (acre-feet per year)

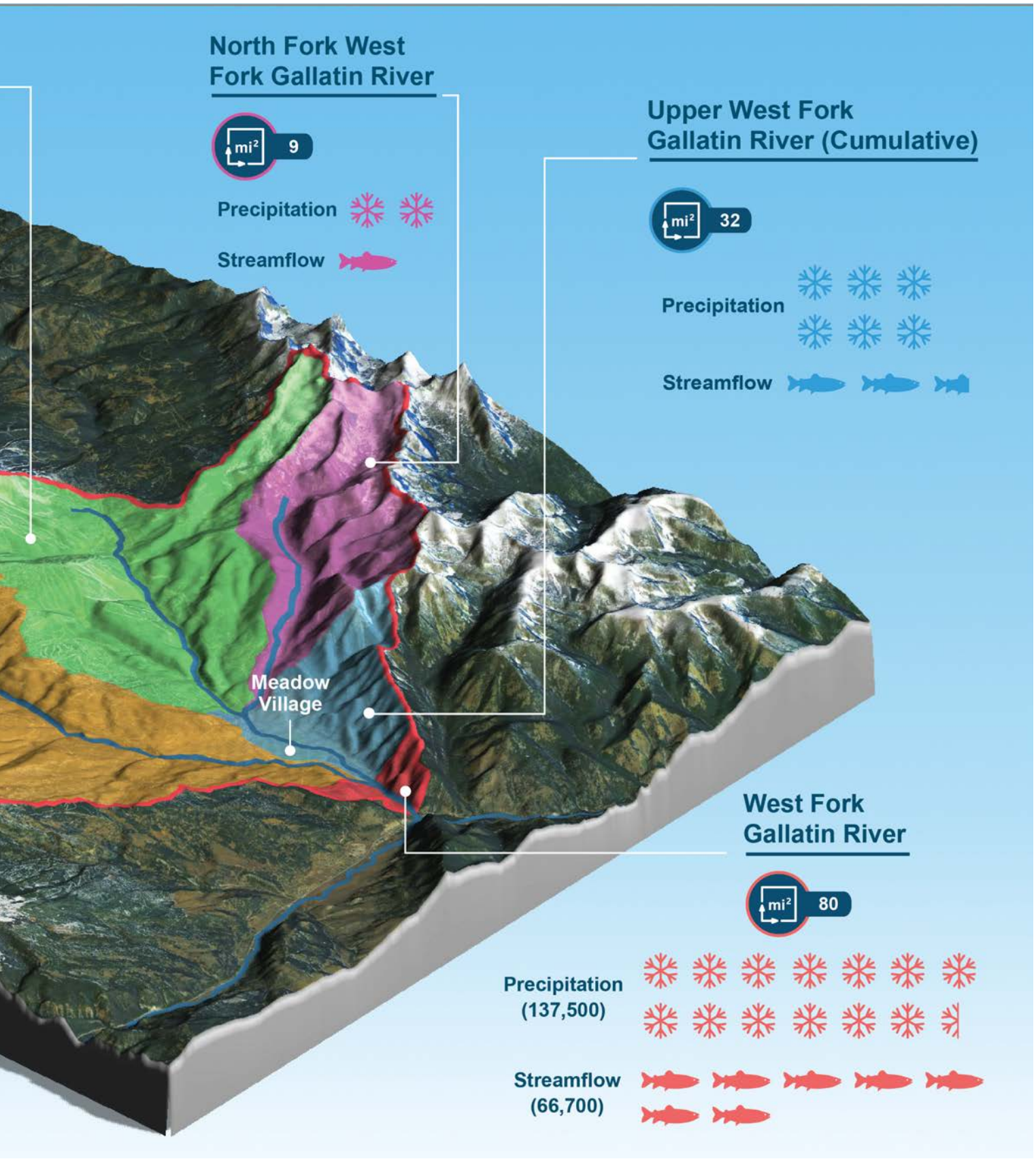
Mean annual streamflow during the period of analysis was highest for the West Fork in 2018, at 82,698 acre-feet (26,947 MGY), and lowest in 2021, at 61,187 acre-feet (19,938 MGY), equating to an approximately 10-15% variation from the mean annual streamflow. The tributaries of the West Fork contribute 20% of the mean annual streamflow in the Gallatin River, as measured at the USGS Gallatin River above Deer Creek gage station, and about 12.5% of the total streamflow at the USGS Gallatin River near Gallatin Gateway gage station.

The West Fork Watershed contributes 20% of the mean annual streamflow at the USGS Gallatin River at Deer Creek gage:

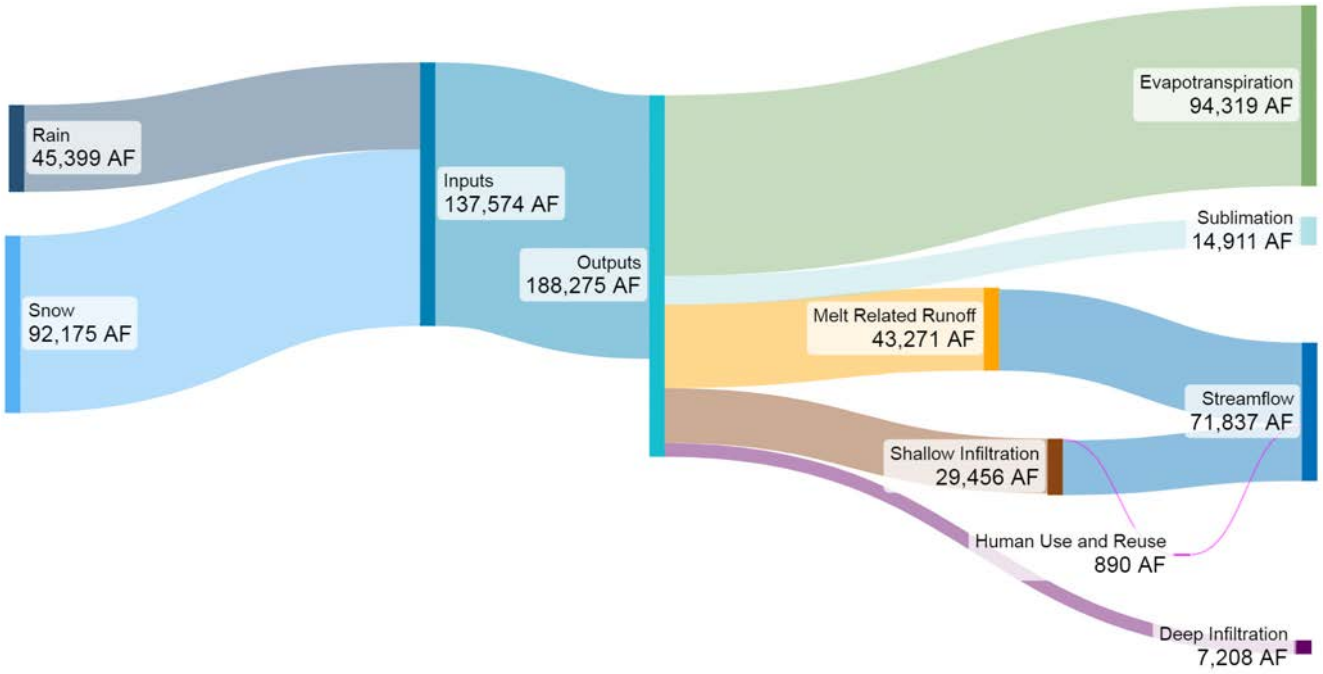




Mean annual precipitation and streamflow 2017 - 2022


North Fork West Fork Gallatin River
mi² 9
Precipitation
Streamflow
Upper West Fork Gallatin River (Cumulative)
mi² 32
Precipitation
Streamflow
Meadow Village
West Fork Gallatin River
mi² 80
Precipitation (137,500)
Streamflow (66,700)

Annual Water Budget



West Fork water budget diagram (acre-feet per year)

Rain and snow are the primary inputs to the West Fork Water budget, totaling approximately 137,574 acre-feet (44,829 MGY). At 69% of annual precipitation, evapotranspiration is the largest output, at 94,319 acre-feet (30,734 MGY). Melt-related runoff and groundwater from shallow infiltration contribute to an annual streamflow of 71,837 acre-feet (23,408 MGY), totaling 52% of annual precipitation. Evaporative loss due to sublimation accounts for an additional 14,911 acre-feet (4,859 MGY), which is 11% of annual precipitation, while groundwater lost to deep infiltration amounts to 7,208 acre-feet (2,349 MGY), accounting for 5% of annual precipitation. Based on available data, outputs from the West Fork watershed exceed inputs by 50,701 acre-feet (16,521 MGY), or in other words, outputs account for 137% of inputs.

West Fork Water Budget Summary



Precipitation | **Evapo-transpiration** | **Streamflow** | **Shallow Infiltration** | **Sublimation** | **Deep Infiltration** | **Human Use and Reuse**

Recommendations

Improve the monitoring network

The annual water budget derived in this analysis is an "open" water balance with outputs exceeding inputs due to a lack of sufficient data. Improving monitoring equipment and expanding the monitoring network will help refine the water budget over time.

- Expand precipitation monitoring
- Expand streamflow monitoring
- Expand groundwater monitoring

Slow the Flow throughout the drainage network

Spatial variation in topography and elevation strongly influences precipitation accumulation and water cycling through the watershed. Developing and enacting water capture and infiltration strategies at key locations in the landscape will help slow the flow of water through the system.

- High-elevation snow retention features that hold natural and artificial snow and provide infiltration opportunities
- Stream restoration treatments that mimic natural processes of large wood debris accumulation and beaver dam complexes
- Peak flow and stormwater capture features, along with treatment wetlands, to maximize aquifer recharge and improve water quality

Optimize water use and reuse

Placing human water use in the context of the overall water budget provides water managers with insights into the timing of water abundance and scarcity. Enacting use and reuse strategies that recycle the water through the watershed will increase water availability during critical times of the year.

- Water conservation measures
- Expand the use of treated wastewater effluent for snowmaking
- Enact aquifer recharge with treated wastewater effluent





For more information visit:
Gallatinrivertaskforce.org

Prepared by:

