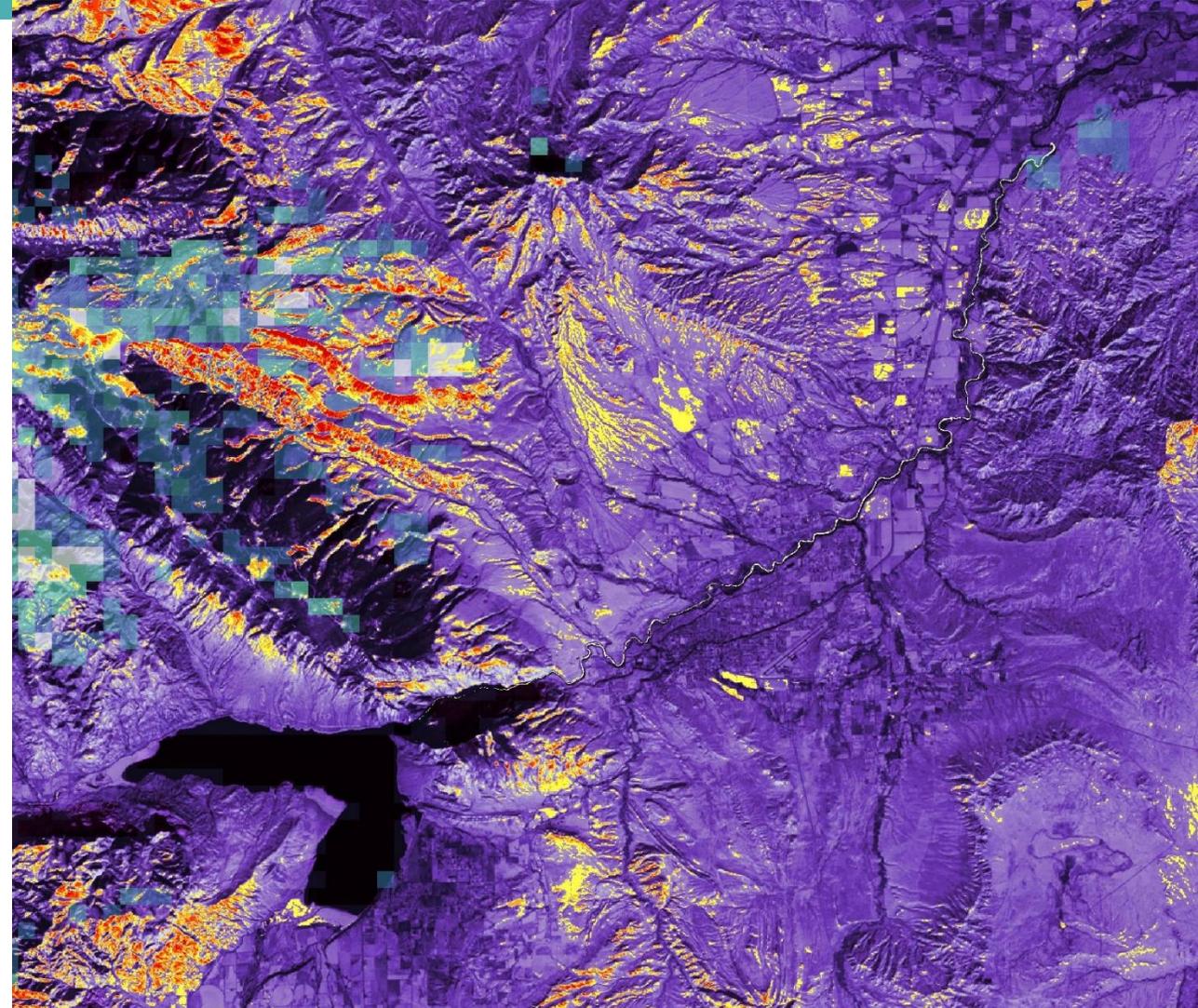




Assessing Sediment Inputs into the Shoshone River in Wyoming to Determine Areas for Protection and Restoration Practices

Caroline Williams, Robyn Holmes, Cassie Ferrante, Nelson
Lemnyuy, Will Campbell, Christian Bitzas, Jillian Greene,
Isabella St John, Austin Madson



BACKGROUND

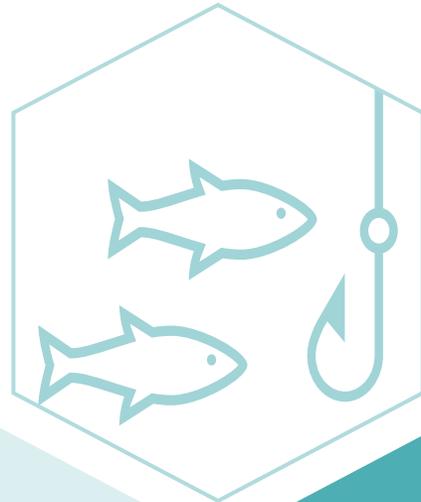


Image Credit: Carmen McIntyre

- In 2016 at the **Willwood Dam** in Wyoming, there was a large release of **accumulated sediments** downstream
- Routine releases of accumulated sediments at the dam greatly reduce the water quality of the **Shoshone River**
- This leads to ongoing **deterioration of riparian and aquatic habitats**, that of which the local community and fishing industry rely on



COMMUNITY CONCERNS



Ecological

Impaired fish spawning habitat

Fishing, tourism, and irrigated agriculture

Economic



Quality of Life

Community member recreation



PARTNER ORGANIZATIONS

Wyoming Department of Environmental Quality (WYDEQ)



The WYDEQ, Working Group 2 concentrates on long-term sediment management at the dam to minimize the harmful impact of aquatic life downstream.

Shoshone River Partners



Formally known as Working Group 3, the Shoshone River Partners focus on identifying sediment sources upstream of the Willwood Dam, as well as implement restoration practices.

USGS WY-MT Water Science Center



The USGS provides technical advising, expertise, and support for the WYDEQ working groups.

PROJECT OBJECTIVES

Term 1: Fall 2022

- Create **categorical sediment contribution maps** indicating priority tributaries
- Conduct **precipitation analysis** to better understand runoff events
- Analyze which **land cover types** are correlated with high turbidity

Term 2: Spring 2023

- Conduct Soil and Water Assessment Tool (**SWAT**) **analysis**
- Improve **plume detection** via turbidity remote sensing
- Conduct a **snow cover time series analysis**



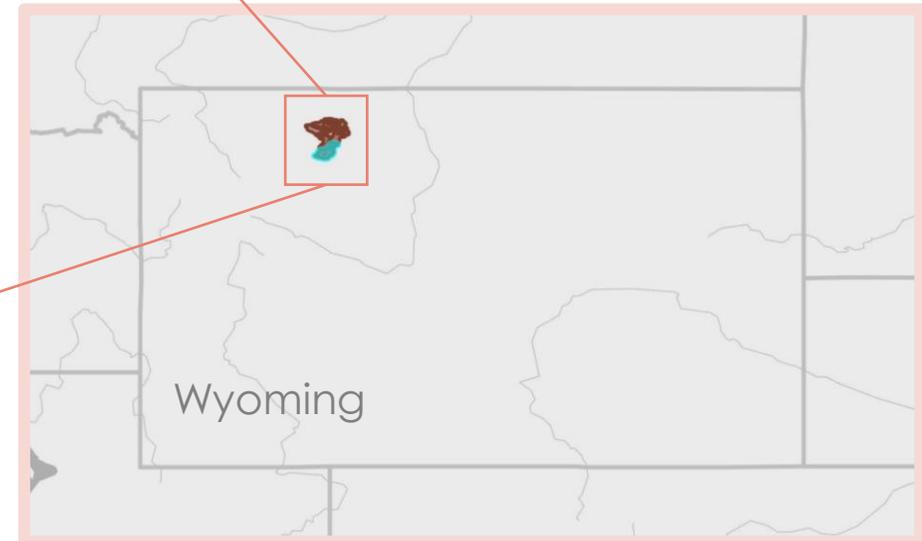
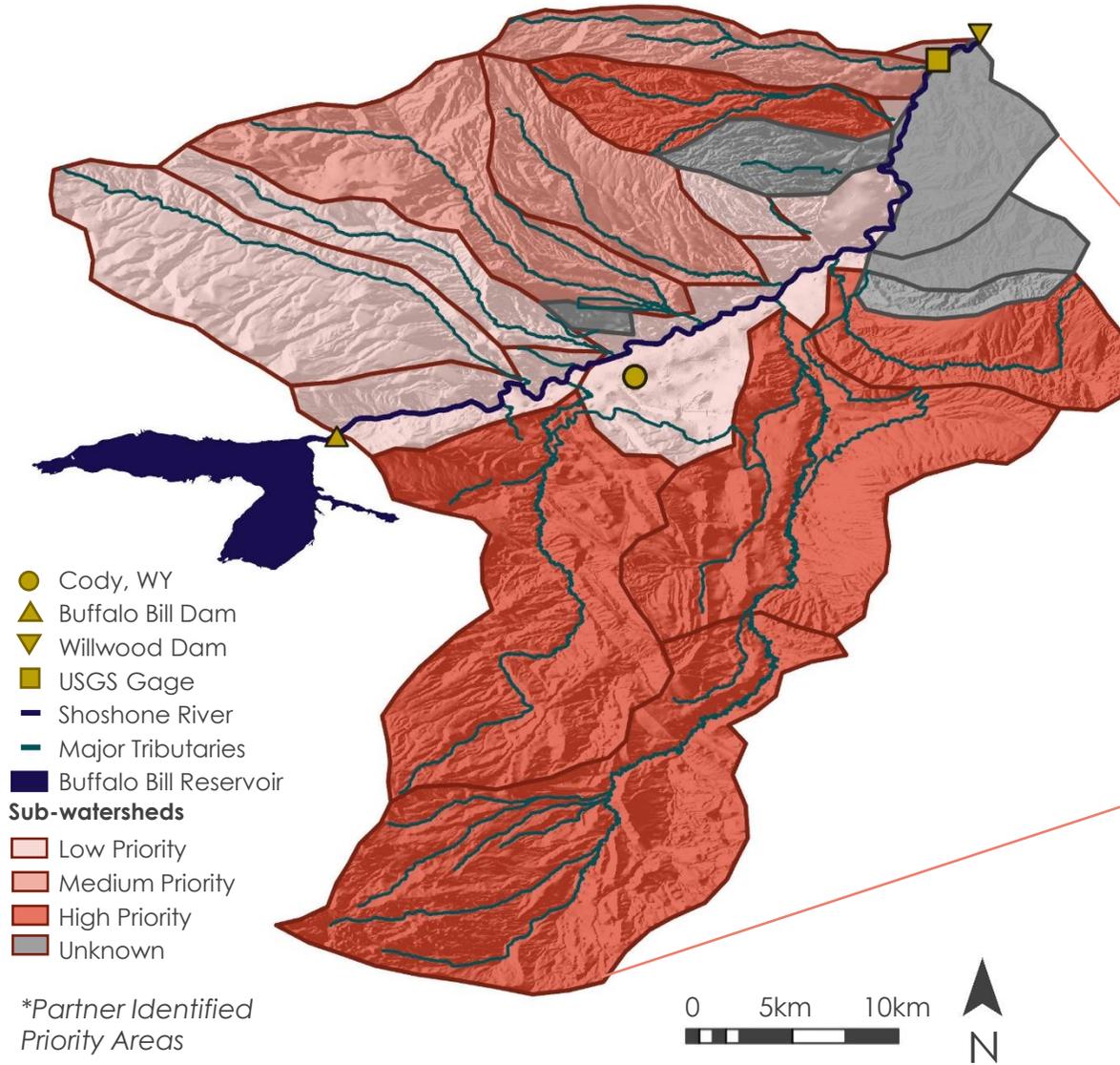
STUDY AREA & PERIOD

Study Area

- Shoshone River, Wyoming
 - Buffalo Bill Dam to Willwood Dam
 - Tributaries & irrigation canals feed into the river

Study Period

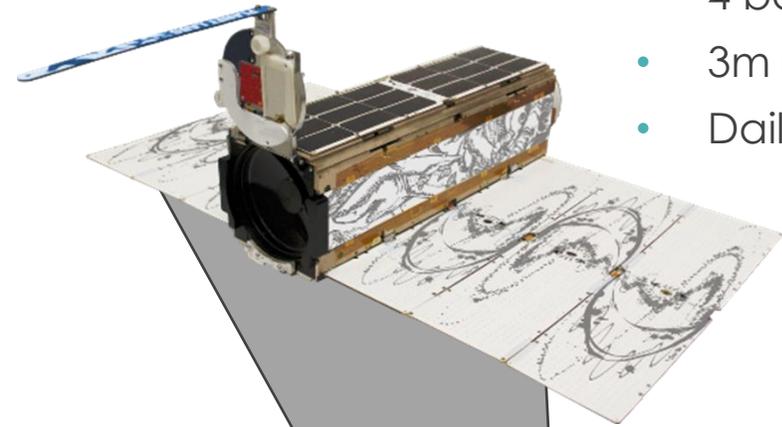
- Jan. 2019 – Oct. 2021
 - USGS operated water monitoring station



EARTH OBSERVATIONS

PlanetScope

- 4 band (RGBn) imagery
- 3m resolution
- Daily



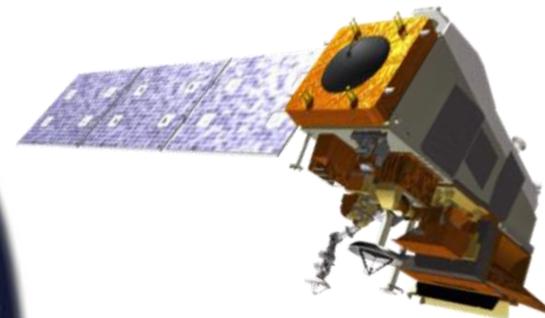
GPM IMERG

- Precipitation
- 10km resolution
- Daily



Suomi NPP VIIRS

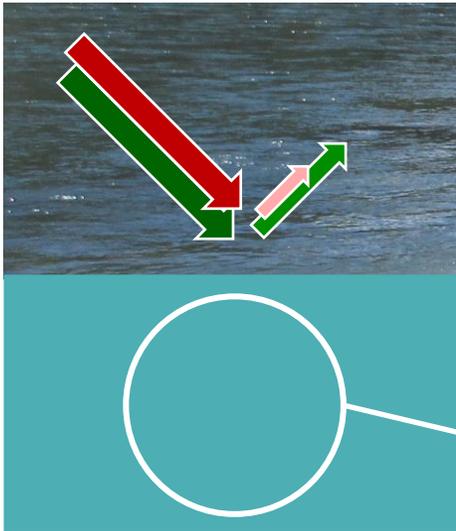
- Visible Infrared Imaging Radiometer Suite (VIIRS)
- 375m resolution
- Daily



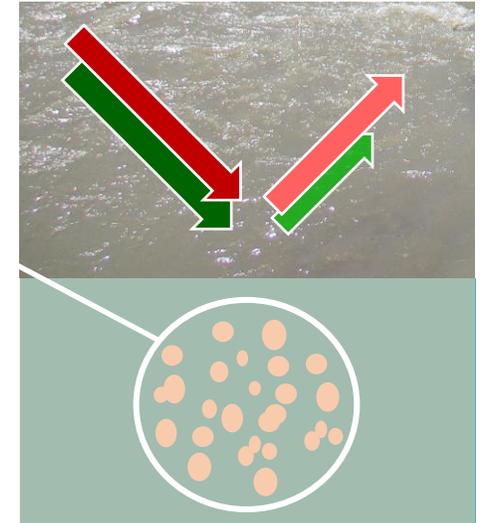
REMOTE SENSING TURBIDITY

Sulphur Creek Sediment Plume

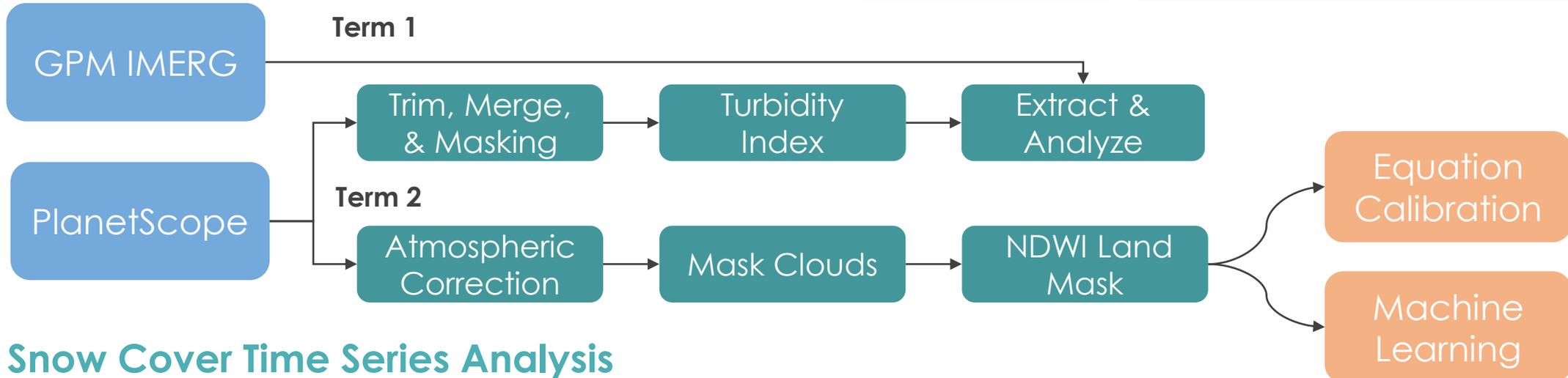
Low Turbidity



High Turbidity



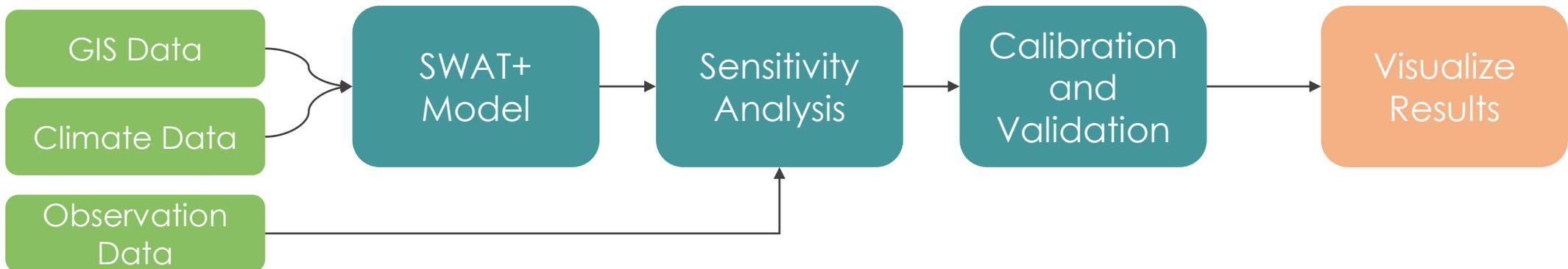
① Turbidity Remote Sensing



② Snow Cover Time Series Analysis

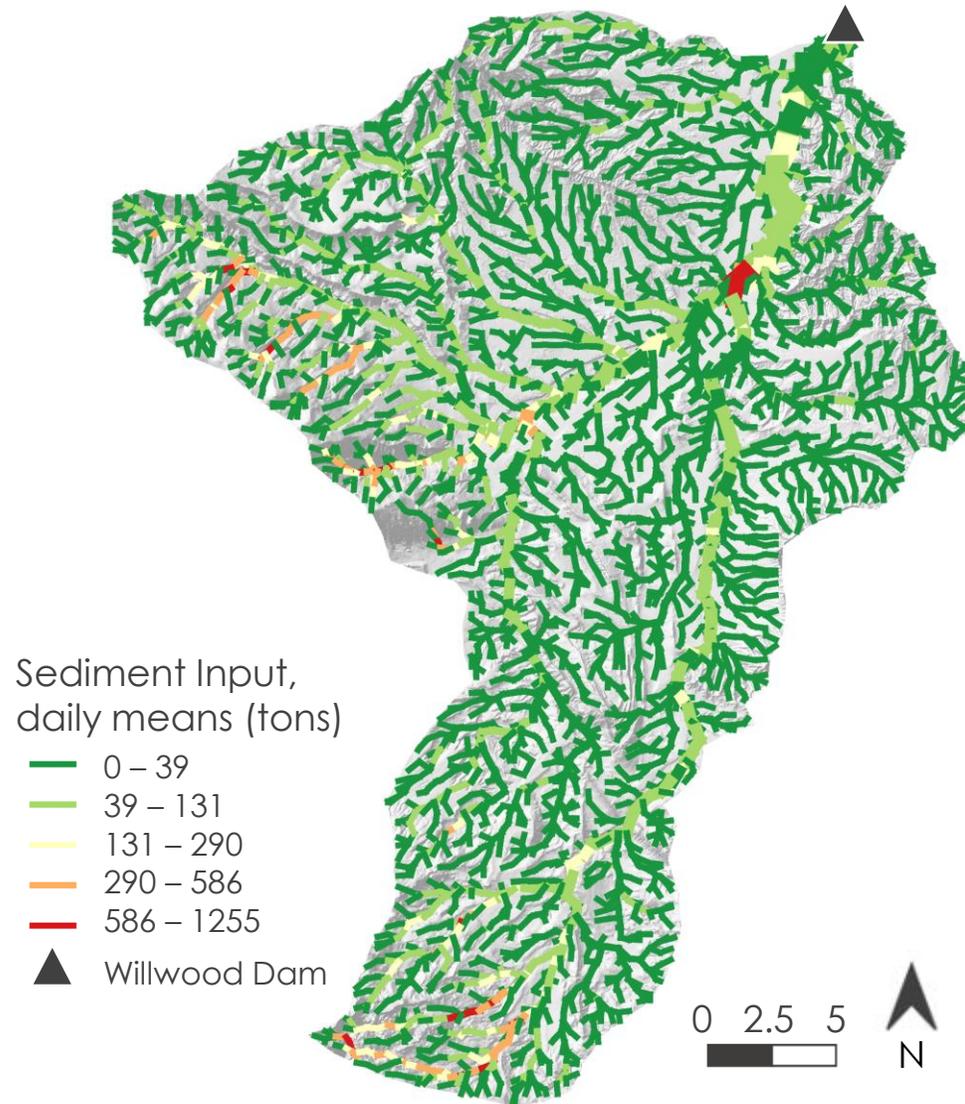


③ Hydrologic Modeling

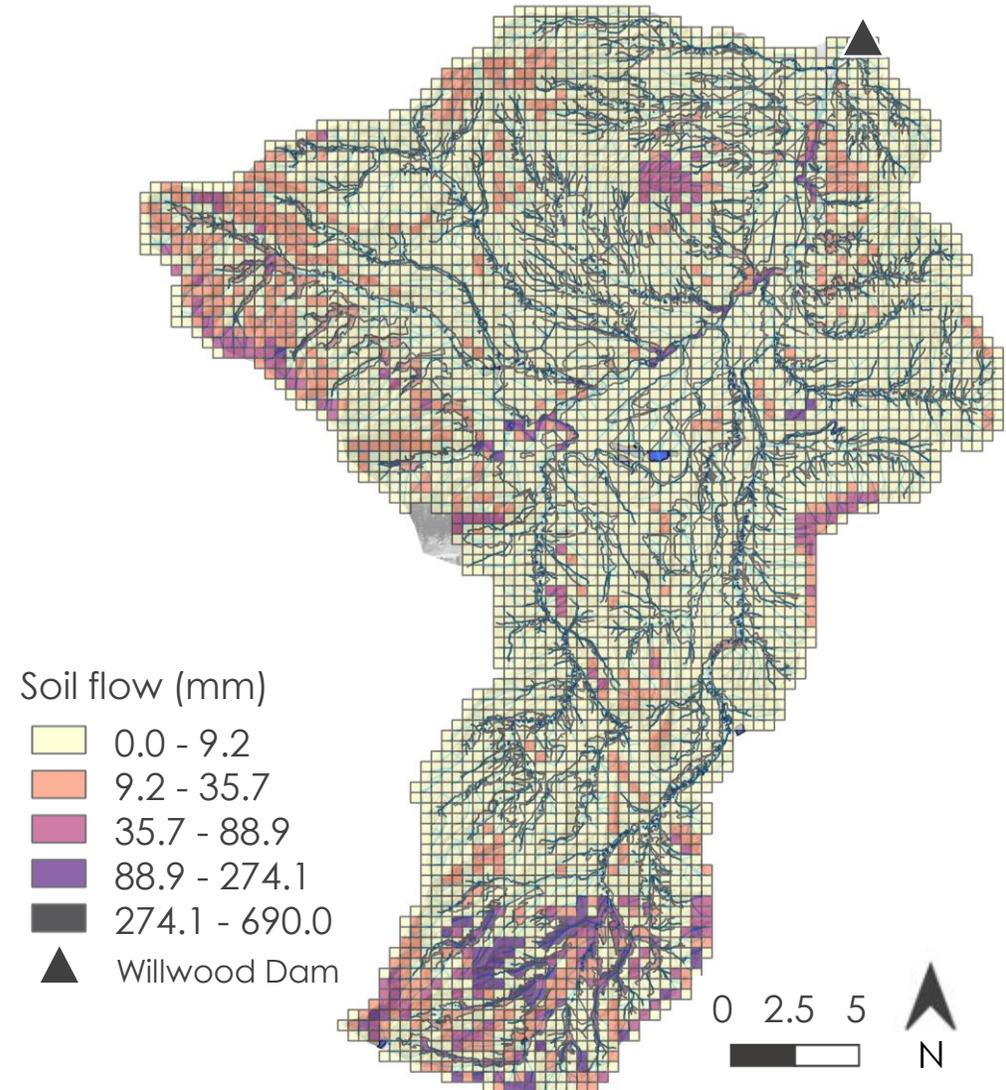


RESULTS – SOIL & WATER ASSESSMENT TOOL

Sediment Input

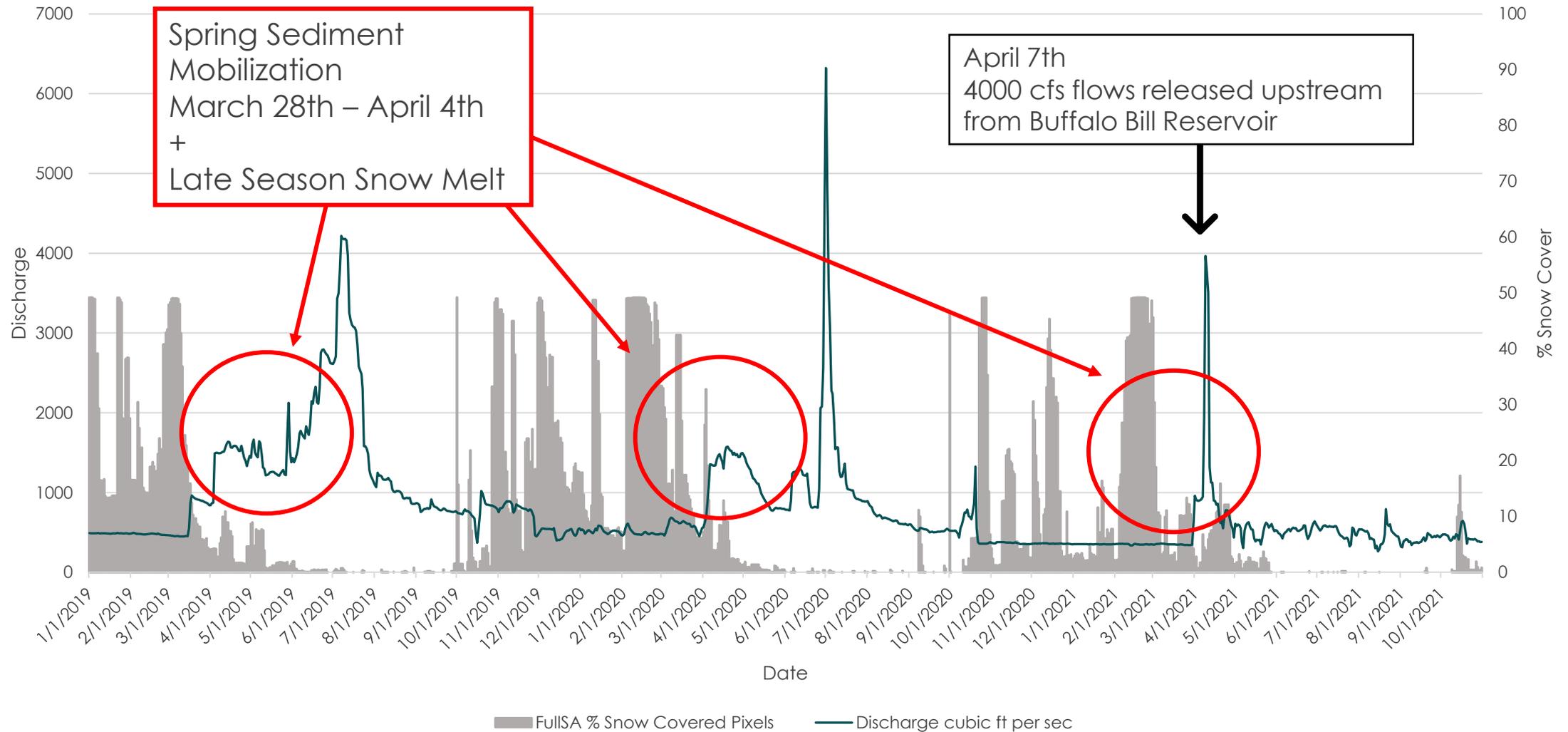


Lateral Soil Flow into Channels



RESULTS – SNOW COVER TIME SERIES

Discharge Above Willwood Dam vs Snow Cover



RESULTS – SEDIMENT REMOTE SENSING

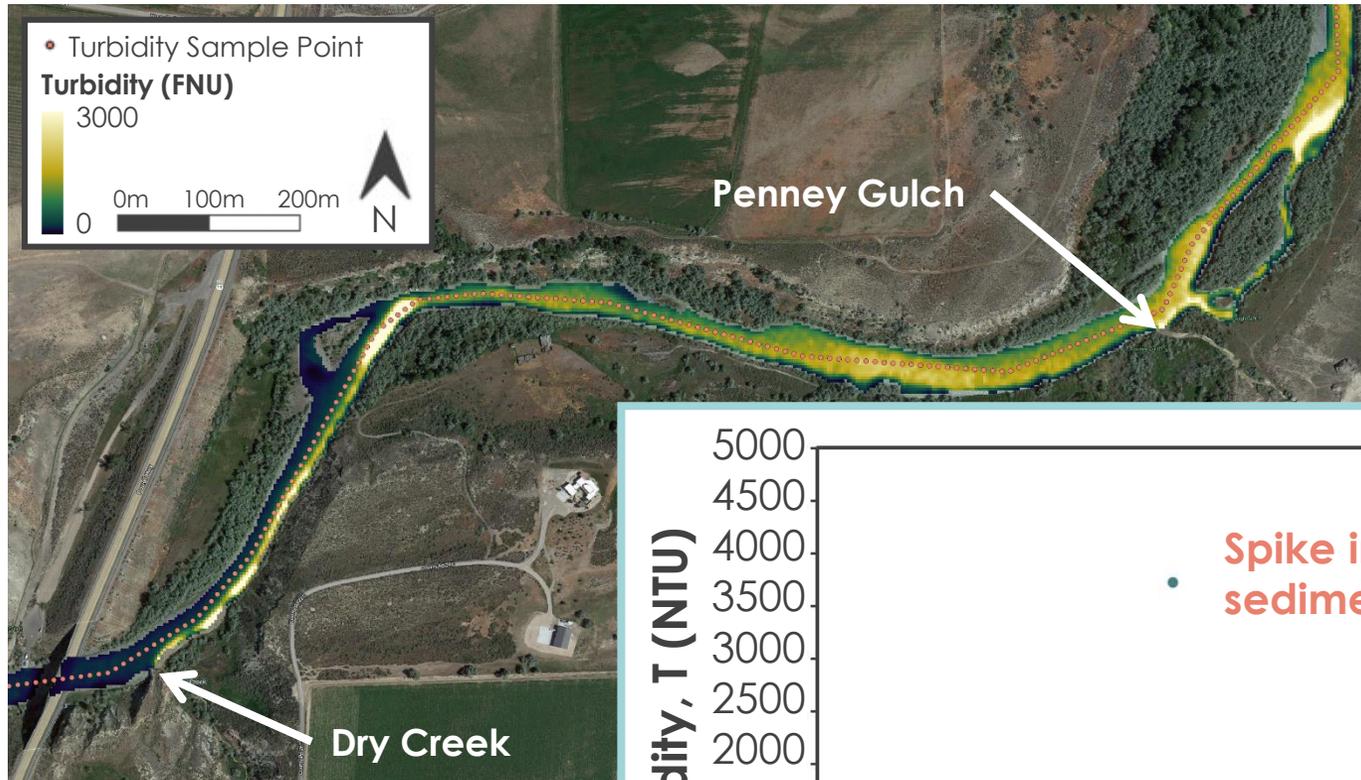
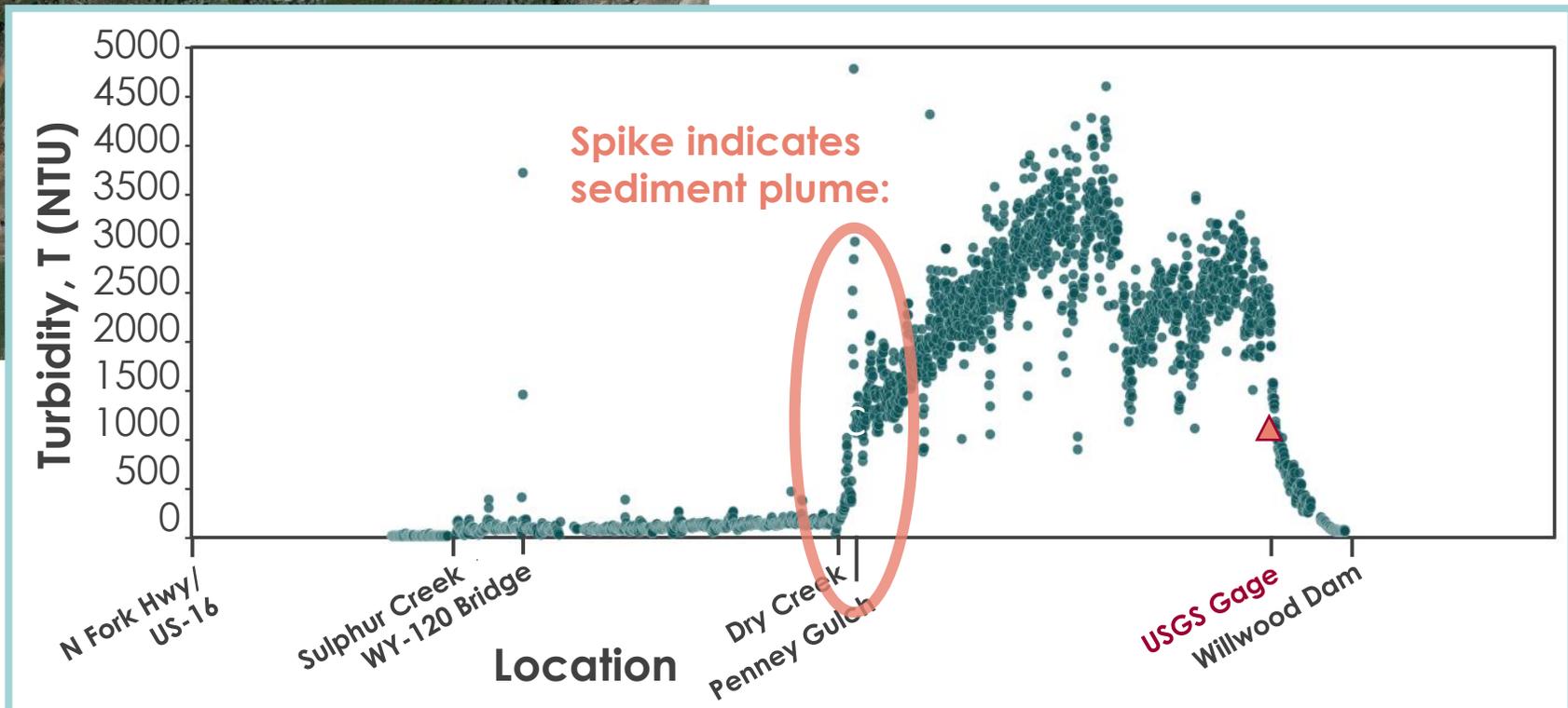


Image Credit: Google, Planet Labs

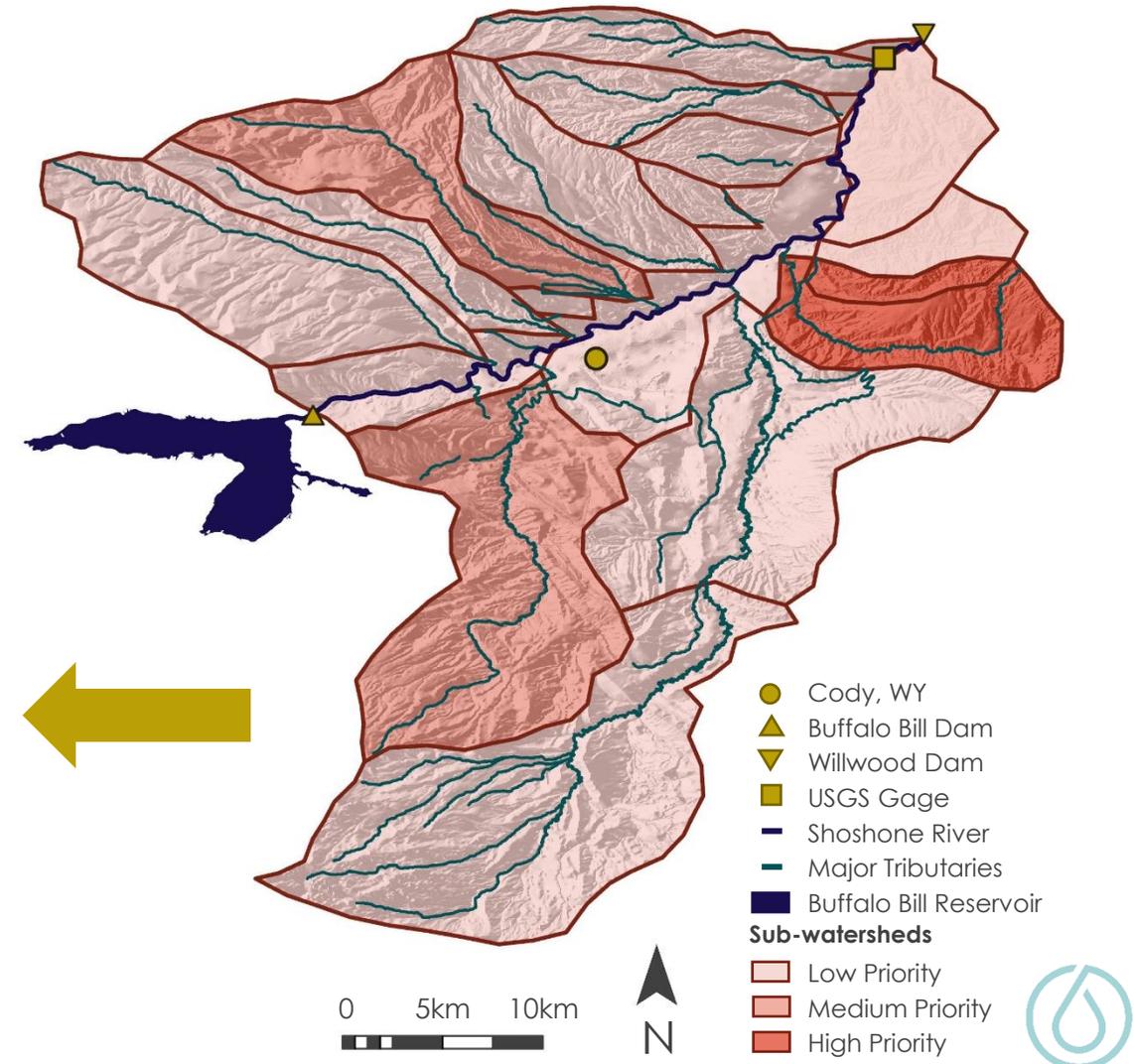
Sampling turbidity values along the river centerline allowed the team to locate sediment plumes.



RESULTS – SEDIMENT REMOTE SENSING

- **Penney Gulch** and **Dry Creek** had the highest turbidity plumes with **turbidity over 200 FNU** on multiple days
- **Sulphur Creek** also had relatively frequent and significant plumes but less concentrated

#	Stream Name	# RS Events	Prior Concern Level
1	Sulphur Creek	Medium	High
2	Cottonwood Creek	Low	Medium
3	Sage Creek	Low	High
4	Idaho Creek	Low	Medium
5	Dry Creek/ Homesteader Creek	High	High
6	Penney Gulch	High	Unknown

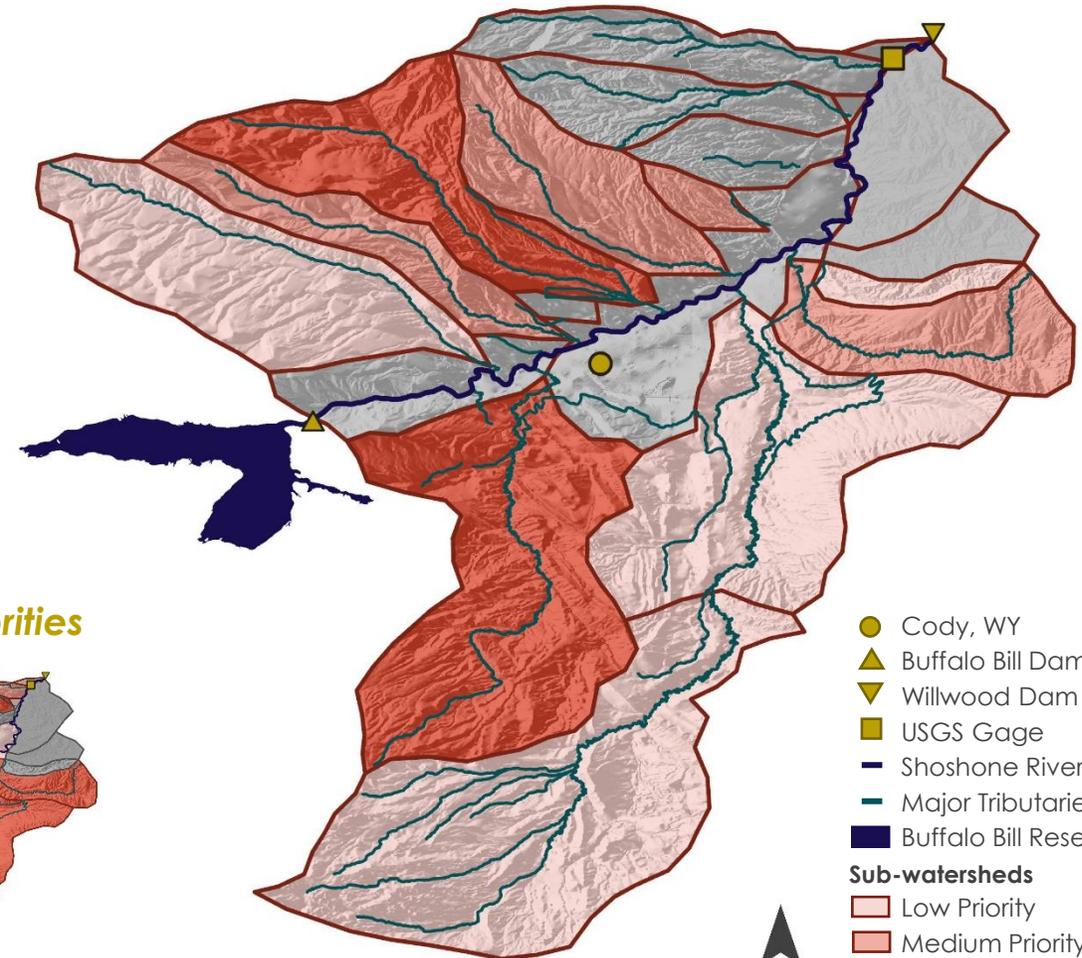
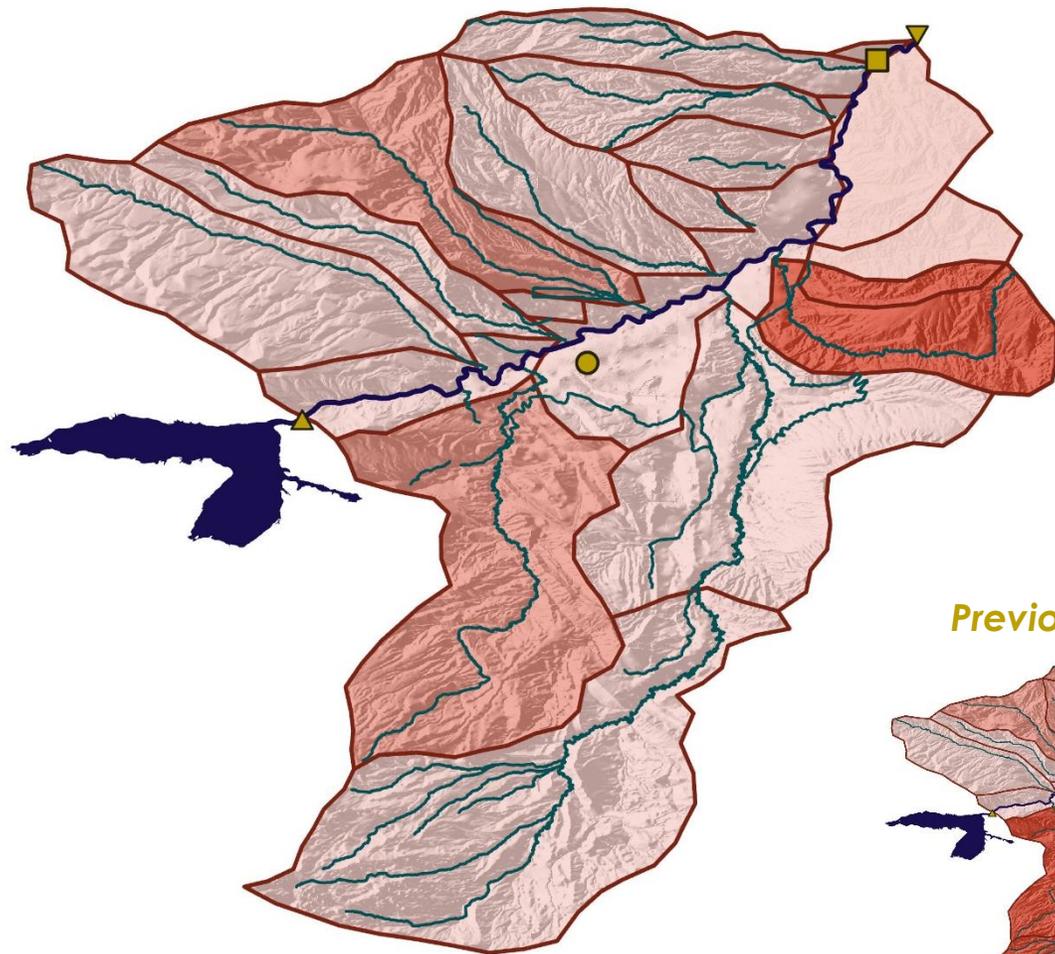


RESULTS – SEDIMENT REMOTE SENSING

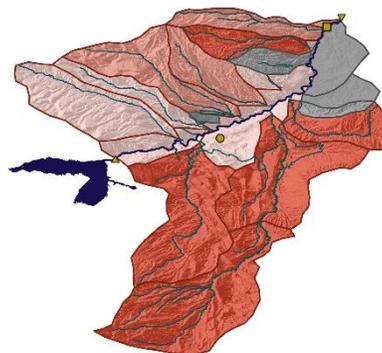
Comparing Methods

Manual Event Interpretation

Automated Event Interpretation



Previous Priorities



- Cody, WY
- ▲ Buffalo Bill Dam
- ▼ Willwood Dam
- USGS Gage
- Shoshone River
- Major Tributaries
- Buffalo Bill Reservoir

Sub-watersheds

- Low Priority
- Medium Priority
- High Priority
- Unknown

0 5km 10km



RESULTS – SEDIMENT REMOTE SENSING

Comparing Methods

	Pros	Cons
Machine Learning	<ul style="list-style-type: none">• Automatically & easily determines patterns to represent data (may be better with more complex band interactions)• Outputs relative importance of bands• Seems to predict winter month inconsistencies well	<ul style="list-style-type: none">• Long image processing time (~10min / image)• Very complex to prove “how” the model calculated the output
Equation Calibration	<ul style="list-style-type: none">• Faster to run image processing• You know exactly what the equation/relationship used was	<ul style="list-style-type: none">• Need user input to choose equation• May struggle with complex relationships or take data preprocessing (i.e., the team needed to give it $\ln(T)$)



Limitations

- **SWAT Model**

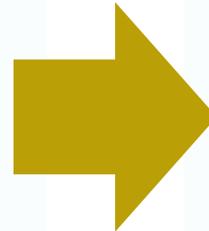
- 266 unknown soil types coerced to most common type
- Limited observed data
- Does not account for controlled irrigation

- **Snow Cover TS**

- Snow/cloud reflectance interference
- Spatial vs temporal resolution tradeoff

- **Sediment RS**

- Winter experiences high variability
- Clouds limit imagery dates, may bias results
- Difficult to distinguish small plumes downstream of other plumes
- Shallow areas, rapids, sand bars, unclipped land, & aquatic vegetation



Future Work

- **SWAT Model**

- Continue to refine SWAT+ model with observed data

- **Snow Cover TS**

- Methods for snow cover analysis are scalable and can be applied to specific sub-watersheds

- **Sediment RS**

- Sediment transport estimations based on plume size, concentration, and streamflow could be explored

CONCLUSIONS

- Coupling **remote sensing** and **hydrological modeling** can enhance watershed management to identify high priority areas and sources of sediment
- Using remote sensing techniques with high resolution imagery produces reliable turbidity measurements
- The time series data provides a visual representation of trends and relationships between hydrologic variables, including the influence of snow cover and snow melt
- The SWAT+ model provides high resolution analysis with limited gauge data
- **Penney Gulch, Sulphur Creek** and **Dry Creek** had the largest plumes



Image: Carmen McIntyre



ACKNOWLEDGEMENTS

Special thank you to the DEVELOP Project Teams, Advisor, and Partner Organizations:

DEVELOP Participants:

- Term 1: Robyn Holmes (Project Lead), Will Campbell, Cassie Ferrante, Nelson Lemnyuy
- Term 2: Robyn Holmes (Project Lead), Christian Bitzas, Jillian Greene, Isabella St John

Science Advisor:

- Austin Madson (University of Wyoming, Assistant Professor)

Partners:

- David Waterstreet (Wyoming Department of Environmental Quality)
- Carmen McIntyre (Shoshone River Partners)
- Jason Alexander (USGS WY-MT Water Science Center)

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