**Yampa Water Resources**

*Monitoring Water Quality and Evaluating Potential Drivers of Algae Blooms in the Upper Yampa River Watershed*

**Project Team**

***Project Team:***

Samrin Sauda (Project Lead)

Erin Weitzel

Ethan Gates

Morgan Guttman

***Advisors & Mentors:***

Dr. Anthony Vorster (Colorado State University, Natural Resource Ecology Laboratory)

Christopher Tsz Hin Choi (Colorado State University, Natural Resource Ecology Laboratory)

Dr. Paul Evangelista (Colorado State University, Natural Resource Ecology Laboratory)

Dr. Catherine Jarnevich (United States Geological Survey, Fort Collins Science Center)

Peder Engelstad (Colorado State University, Natural Resource Ecology Laboratory)

Nicholas Young (Colorado State University, Natural Resource Ecology Laboratory)

***Team Contact:*** Samrin Sauda, sauda.geo60@gmail.com

***Partner Contact:*** Andy Rossi, arossi@upperyampawater.com

**Project Overview**

***Project Synopsis:***

Algal blooms have become increasingly common in waterbodies nationwide, including in the Upper Yampa River Watershed (UYRW) in Northern Colorado. Partnering with the Upper Yampa Water Conservancy District (UYWCD), the DEVELOP team utilized remote sensing data to analyze historical water quality data and drivers of algal blooms in the UYRW. This project monitored lake color and temperature from 1984 to 2021 using Earth observations (EO) and compared the time series with in-situ data to evaluate the accuracy of EOs. This assisted partners in filling historical data gaps and exhibited various trends in water quality parameters to inform future decision making.

***Abstract:***

The Upper Yampa River Watershed (UYRW), located in northwestern Colorado, plays a key role in providing water to the Colorado River. However, the UYRW has been impacted by increasingly frequent and widespread harmful algal blooms (HABs) that emit cyanotoxins and deteriorate the water quality. Due to these cyanotoxins, recreational closures have been enacted and drinking water has been impaired, leading to adverse health, economic, and ecological effects. Partnering with the Upper Yampa Water Conservancy District (UYWCD) and the Colorado State University (CSU) Agricultural Water Quality Program, the DEVELOP team utilized Earth observations from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) to analyze trends in water quality from 1984 to 2021 for nine waterbodies of interest: Lake Catamount, Lake Dumont, Elkhead Reservoir, Fish Creek Reservoir, Sheriff Reservoir, Stagecoach Reservoir, Steamboat Lake, Stillwater Reservoir, and Yamcolo Reservoir. The team generated time series plots and maps exhibiting parameters such as greenness, temperature, Apparent Visible Wavelength (AVW), and Broad Wavelength Algae Index (BWAI). Finally, evaluation plots were created to analyze the correlation between spectral indices and in-situ measurements. Surface temperature has risen on Lake Catamount, Stagecoach Reservoir, and Steamboat Lake. All other water quality parameters varied in trend and significance across all nine waterbodies. The limited amount of in-situ validation data made it difficult to determine the viability of satellite remote sensing as a tool for monitoring water quality in the UYRW.

***Key Terms:***

algae, water quality, harmful algal bloom, remote sensing, lake color, temperature, time series, Upper Yampa River Watershed

***National Application Area Addressed:*** Water Resources

***Study Location:*** Upper Yampa River Watershed, CO

***Study Period:*** June through October of 1984 to 2021

***Community Concerns:***

* Algal blooms have been an ongoing issue in the UYRW, but in recent years, they have become severe enough to cause recreational closures and impair water quality.
* Cyanobacteria, the species of algae found in the lakes and reservoirs, can produce toxins that are harmful to aquatic ecosystems. This can also negatively affect the terrestrial wildlife that is dependent on these water bodies.
* Toxins produced by cyanobacteria can also be harmful to human health and introduce additional complications with regards to treating water for municipal use.
* Recreational closures in the UYRW could have negative economic impacts due to the importance of recreation in the local economy.

***Project Objectives:***

* Analyze trends in water quality over time and fill historical data gaps
* Assess the viability of remote sensing to monitor water quality in the UYRW

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Upper Yampa Water Conservancy District** | Andy Rossi, General Manager | End User |
| **Colorado State University** | Robert Woodmansee, Professor Emeritus | Collaborator |
| **Colorado State University Agricultural Water Quality Program** | Christina Welch, Outreach and Research Coordinator | Collaborator |

***Decision-Making Practices & Policies:***

The UYWCD has historically monitored water within the UYRW and managed the water resources within the watershed. The UYWCD has worked to maintain water rights, protect water quality, and promote practices and projects that encourage better water quality and sustainable usage. However, algal blooms have threatened the water quality of the UYRW and have devastated the region's ability to provide recreational opportunities and clean water to its users. In recent years, nutrient and chlorophyll-a concentration regulations have become stricter and more closely monitored by the EPA. Several waterbodies in the UYRW are set for mandated water quality reviews and reformations in 2025. The partners plan to analyze trends in water quality over time utilizing newly obtained historical data to identify how to mitigate algal blooms and prevent poor water quality in the future.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Green band reflectance (GBR), surface temperature thermal band (ST), apparent visible wavelength (AVW), broad wavelength algae index (BWAI) | This dataset provided the temporal and spatial resolution needed to track water color and temperature. |
| **Landsat 7 ETM+** | GBR, ST, AVW, BWAI | This dataset provided the temporal and spatial resolution needed to track water color and temperature. |
| **Landsat 8 OLI** | GBR, ST, AVW, BWAI | This dataset provided the temporal and spatial resolution needed to track water color and temperature. |

***Ancillary Datasets:***

* Upper Yampa Water Conservancy District Water Quality Data – Available annual field-measured data utilized to ground truth remote sensing outputs (temperature string and toxin reports)
* United States Geological Survey (USGS) Stream Gauge Data – Gauge data reviewed to evaluate streamflow into outlined waterbodies of interest
* National Water Quality Monitoring Council – Water quality data from EPA, USGS, and local agencies

***Software & Scripting:***

* Esri ArcGIS Pro 2.9.32739 – Raster analysis and creation of maps for time series
* Google Earth Engine API – Processing of satellite imagery and application of lake color and chlorophyll-a detection algorithms
* RStudio 2022.02.3 – Data manipulation, data visualization, and statistical analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit and Use** | **Software Release Category** |
| **Time Series Plots of Lake Color (AVW and GBR)** | Landsat 5 TM  Landsat 7 ETM+ | Partners will be able to track trends in water color from 1984 – 2021 to put current water quality in context and examine potential drivers. | N/A |
| **Time Series Plots of Temperature** | Landsat 5 TM  Landsat 7 ETM+ | Partners will be able to track trends in water temperature from 1984 –2021 to determine current water quality trends in context of increasing global temperatures. | N/A |
| **Time Series Maps** | Landsat 5 TM  Landsat 8 OLI | Partners will be able to track trends in water color from 1984 – 2021 to put current water quality in context and examine potential drivers. | N/A |
| **Time Series Validation** | Landsat 5 TM  Landsat 7 ETM+ | The time series validation will communicate to partners the reliability of remote sensing for evaluating algal blooms and water quality parameters. | N/A |

***Product Benefit to End User:***

This project will provide partners with time series plots of lake color and temperature from 1984 to 2021. This is crucial for monitoring changes in water quality over time and examining the potential drivers of these changes in the UYRW. Our end product will assess the viability of remote sensing as a tool for algal bloom detection in the future. A scientific poster will also help the end-users better understand the trends of HAB dynamics along with the temperature. These findings will act as a preliminary step to identify the scope of the problems for both the stakeholders and the general public. This will allow them to continue to improve decision-making policies, management, and mitigation strategies for impaired water quality.

**References:**

Day, N. K. (2021). *Assessment of Streamflow and Water Quality in the Upper Yampa River Basin, Colorado*, 1992–2018 (No. 2021-5016). US Geological Survey. From https://pubs.er.usgs.gov/publication/sir20215016.

Colorado State University. (2018). *Agricultural Water Quality Program*. Colorado State University College of Agricultural Sciences. https://agsci.colostate.edu/waterquality/