Logan River Observatory Annual Report

2022–2023

Bethany T. Neilson

Patrick Strong

Jeffery S. Horsburgh

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In partnership with:

Preface

This report provides a summary of data collected within the Logan River Observatory as required by funds provided by the Utah State Legislature, which are managed and overseen by the Utah Division of Water Resources. The primary objectives of the report are to highlight the data types and availability within the Logan River Observatory and to summarize recent and ongoing research and outreach affiliated with the observatory.

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2022-2023 SUMMARY OF LOGAN RIVER OBSERVATORY ACTIVITIES AND ACCOMPLISHMENTS

(More details are provided in subsequent sections)

Collecting detailed watershed data (discharge, water quality, climate):

We have maintained 16 discharge stations, 8 full water quality stations, 8 partial water quality stations, 3 full climate stations, and 2 partial climate stations. We are in the process of expanding the gaging station network up the Blacksmith Fork River, a tributary of the Logan River. Raw data are automatically updated online every few hours at 8 flow gaging locations and 8 full water quality stations. All other flow gaging stations with a subset of water quality measurements are downloaded and updated online periodically. Raw field data have been quality controlled and are publicly available via http://lrodata.usu.edu/. Quality controlled data are updated quarterly.

Advancing training and expertise:

Logan River Observatory (LRO) data are consistently used in ~13 upper division/graduate classes (~ 300 students) and were used in a Senior Design project and 2 theses for students completing Master of Science (MS) degrees and one Honors Bachelor of Science (BS) thesis in 2022. The LRO data are currently being used in 7 ongoing PhD dissertations and 6 MS theses. We currently employ, mentor, and continue to train 5 undergraduate student LRO technicians. For more information, see https://uwrl.usu.edu/lro/resources and https://uwrl.usu.edu/lro/people/students.

Addressing existing water issues in the state:

Locally, the LRO currently supports the Logan River Task Force mission by providing data and hosting their website (https://uwrl.usu.edu/lro/logan-river-task-force). LRO-affiliated faculty and students have provided support via modeling efforts and additional data collection to assist the Logan River Task Force's restoration efforts and other ongoing Cache Water District water management projects in the Logan River and the Blacksmith Fork River tributary. In particular, we have provided flow and temperature data and modeling to assist in the Environmental Impact Statement for a redesign of an irrigation diversion that alters flow throughout the Logan City portion of the river. LRO infrastructure and personnel also support Logan City via stormwater monitoring and data dissemination via the LRO website.

At the state level, many of the LRO affiliated faculty are part of USU's Institute of Land Water Air (ILWA). IWLA's stated mission is to bring together USU land, water, and air researchers and connect them with Utah problem solvers. As part of this, LRO faculty participated in the Great Salt Lake Strike Team and helped develop the Great Salt Lake Policy Assessment that is meant to guide Utah's legislators on potential solutions to address concerns regarding very low Great Salt Lake levels.

Supporting new research to advance understanding of Utah's watersheds:

LRO-affiliated faculty continue to pursue research projects that further the mission of the LRO and depend on LRO data. Two proposals are currently pending, and currently funded projects are as follows:

(1) Cooperative Institute for Research to Operations in Hydrology (CIROH): Modernized Standards and Tools for Sharing and Integrating Real time Hydrologic Observations Data, National Oceanic and Atmospheric Administration (NOAA) $729,673, 2022–2025.

(2) Separating the climate and weather of river channels: Characterizing dynamics of coarse-grained river channel response to perturbations across scales (National Science Foundation) $609,086, 2022–2025.

(3) Quantifying Watershed Dynamics in Snow-Dominated Mountainous Karst Watersheds Using Hybrid Physically Based and Deep Learning Models (National Science Foundation) $777,921, 2021–2024.

(4) Hydrochemical Tracer Sampling in Logan River to Inform Future Water Availability. (USU Extension Water Initiative Grants Program) *$39,795,* 2022–2023.

(5) Monitoring and Research for Water Quality and Stormwater Management in Logan City, UT (Logan City) *$208,121,* 2018–2023.

(6) Assessing the sources, transport, and fate of microplastic in the Logan River Watershed (USGS 104(b)) $90,993, 2021–2022.

(7) Microplastic transport to the Great Salt Lake through the Logan and Bear River system (State of Utah Forestry, Fire, and State Lands) $48,495, 2021–2022.

(8) Determining the mobility, fate, and ecological consequences of dust-derived constituents in mountain watersheds (National Science Foundation) $742,072, 2020–2025.

(9) Quantifying microplastic and nanoplastic deposition in the Bear River Mountains (USDA) $20,000, 2021–2024.

LRO researchers have submitted or are revising four additional proposals and had 8 journal articles published in 2022 or will be published in 2023. Five presentations were given at professional conferences, and a senior design group presented their findings to the Cache Water District. All of these articles and presentations highlight the LRO or report research results from the Logan River watershed based on data from the LRO.

Focusing on future challenges associated with limited water supplies:

Given the focus of Governor Cox and the Utah Legislature on addressing low lake and reservoir levels throughout the State of Utah and the Colorado River Basin, many water-related issues are being addressed in the 2023 legislative session and will result in significant need for better water management strategies. Collaborations with the Logan River Task Force, Cache Water District, USU's ILWA, and Great Salt Lake Strike Team will focus on quantifying water availability and establishing appropriate conservation approaches while delivering water to intended downstream users. New efforts this year will include collaboration with the Utah Division of Water Resources and Water Rights to understand measurement, monitoring, and potential modeling needed to ensure conserved water makes it to the intended downstream beneficial use at large spatial scales. Additionally, we will work with various universities and agencies to establish methods for communicating conservation needs regardless of the dynamic yet cyclical climate conditions that result in large interannual flow variability.

BACKGROUND

Water is the lifeblood of Utah. Utah's residents depend on a safe and adequate water supply, not only for drinking, but for other municipal, agricultural, industrial, and recreational uses. Much of Utah's water supply comes from reservoirs or streams that are fed by snowmelt. Utah's climate can be highly variable, with large changes in water availability from year to year. Furthermore, as Utah's climate shifts, historical data may not be predictive of future water supply, raising new questions. For example: *As weather patterns change to more rain and less snow, what will be the effect on springtime river flows that fill our reservoirs and summer flows crucial for meeting agricultural and urban demands? How will Utah's rapidly growing population impact our already limited water supply? How will climate and population changes affect Utah's drought resiliency?*

Over the last few years, water levels have dropped to historic lows in the Great Salt Lake, and concerns regarding the collapse of the lake ecosystem, the potential impacts of low lake levels on industry, and health concerns regarding lakebed dust have resulted in large investments in water conservation and the need for shepherding any saved water to the lake. Currently, the primary related question is: *What conservation practices should be implemented and how do we ensure any water saved is delivered to the Great Salt Lake?* Reliable data are essential for answering questions like these, and monitoring Utah watersheds is necessary for making informed water management decisions. The Logan River Observatory (LRO) is a watershed monitoring network that can help answer these questions by providing data and the research needed to fill these important knowledge gaps.

Origins

In 2012, the three major Utah universities (Utah State University, University of Utah, and Brigham Young University) proposed a new collaborative project for scientists and practitioners to collect, integrate, and share physical, biological, and social water data to advance understanding and generate knowledge needed to solve urban- and arid-region water sustainability problems. The project included infrastructure (human, observational, and cyber) to lay a foundation for addressing water, population growth, and climate change issues that confront the State of Utah. The resulting EPSCoR (Established Program to Stimulate Competitive Research) program funding award from the National Science Foundation launched iUTAH (innovative Urban Transitions and Aridregion HydroSustainability): a 5-year, multi-institution, interdisciplinary project focused on water sustainability in Utah. A lasting legacy of the iUTAH project was its environmental observations via the GAMUT (Gradients Along Mountain to Urban Transitions) network. In the Logan River watershed, eight aquatic monitoring stations and four climate stations were established to measure, record, and publicly distribute a wide range of climate (e.g., precipitation, snow depth, air temperature, relative humidity), hydrology (e.g., water depth, flow rates), and water quality (e.g., water temperature, dissolved oxygen, pH, turbidity, nitrate) information. The sensor network was deployed to log and transmit the data, which are made publicly available via web-based tools and an online data repository. The monitoring sites and information streams established by iUTAH laid a solid foundation for data collection to support better water management in Cache Valley and provided an opportunity to study the long-term impacts of rapidly growing rural counties on water use and quality across the state of Utah.

Logan River Observatory Overview

In 2018, iUTAH's GAMUT network for the Logan River was reorganized into the Logan River Observatory. The overarching goal of the LRO is to provide long-term, comprehensive hydrologic data to inform local and statewide water management decisions based on Utah-specific hydrologic research. In support of this goal, the LRO is an outdoor laboratory and classroom for training the next generation of engineers and scientists who will be Utah's future water managers. Detailed watershed data (discharge, water quality, climate) combined with this increase in expertise provide opportunities to (1) address existing water issues in the state, (2) support new research to advance understanding of Utah's watersheds, and (3) focus on future challenges associated with limited water supplies.

The LRO team has established partnerships with local stakeholders to support and improve existing monitoring infrastructure, including the Utah Division of Water Resources, Utah State University, Logan City, and Cache Water District. The LRO Team also coordinates with the Logan River Task Force and supports their efforts via data collection and modeling efforts.

LRO DATA TYPES AND AVAILABILITY

The LRO data provides critical information to guide northern Utah's water resources planning and management decisions and offers foundational information to support water-related research, which is a primary focus for scientists and engineers at the Utah Water Research Laboratory, other USU departments, and collaborators.

In the original GAMUT network, aquatic monitoring stations were placed within the Logan River watershed (see Appendix A for a detailed description) (1) in a high-elevation first-order stream (Logan River Near Franklin Basin), (2) in a mid-elevation second- or third-order stream (Logan River Near Tony Grove), (3) at a low elevation valley site (Logan River at Main Street (Highway 89/91) Bridge), and (4) near the terminus of the stream below the Logan City urban area of interest (Logan River at Mendon Road (600 South)) in order to span a range of elevations and mountain-to-urban environments. The climate and terrestrial monitoring stations were located at (1) a high-elevation mountain headwater area (Climate Station at Franklin Basin), (2) a mid-elevation area (Climate Station at Tony Grove), and (3) a low elevation area in a valley/urban location (Climate Station at Logan River Golf Course). As detailed by Jones et al. (2017), standard designs for both aquatic and climate stations were established.

As the LRO has become more established, additional sites have been added, and adaptations to site specifications have been made to expand the original GAMUT network into what is now the LRO monitoring network. For example, many new aquatic stations that measure flow, temperature, and specific conductance have been added. These new stations capture the influence of tributaries on the Logan River and fill gaps in the initial infrastructure.

The LRO website includes an interactive map of the station locations (https://uwrl.usu.edu/lro/locations) (Figure 1) with classifications of sites maintained by the LRO and complementary sites maintained by the United States Geological Survey (USGS) and the Utah Division of Water Rights. Data for each site can be accessed by clicking on the location markers in the web map. A simplified schematic of primary LRO sites along the Logan River and major inflows and outflows (Figure 2) provides a brief overview of key data collection locations.

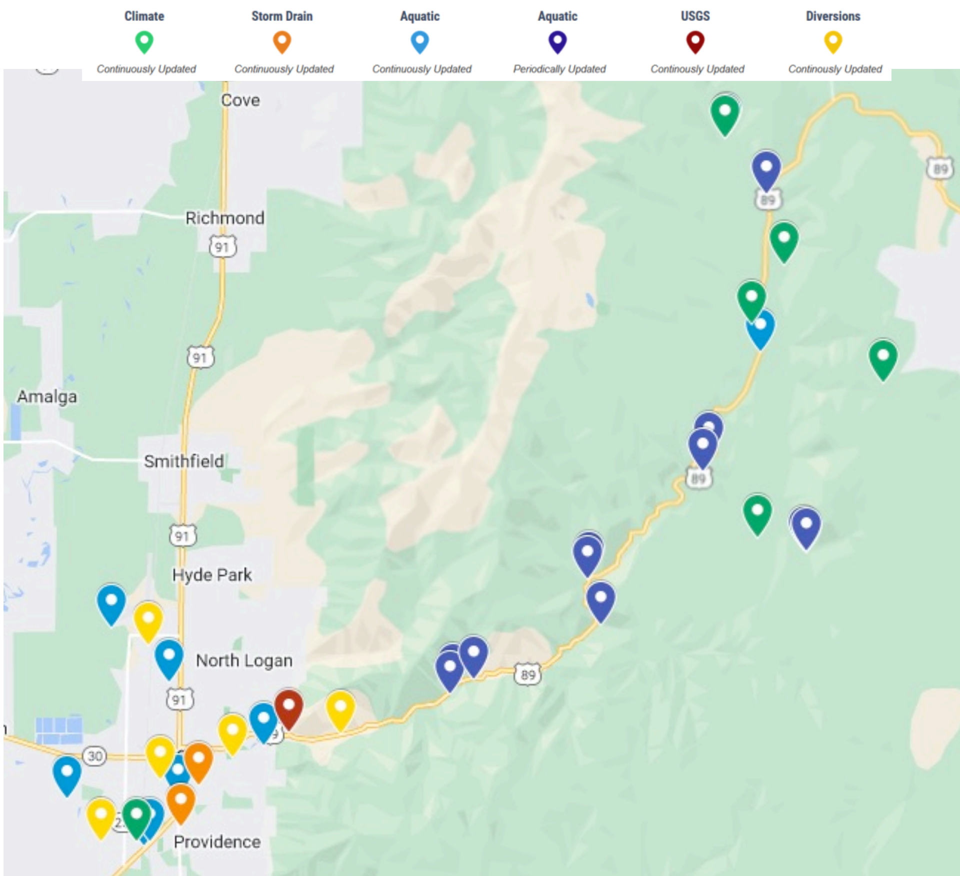


Figure 1. LRO and other relevant monitoring locations that provide complementary data (find this navigable map at https://uwrl.usu.edu/lro/locations).

The more comprehensive list of all LRO monitoring sites, frequency of data updates, status, and the data types or parameters available (Table 1) illustrates the extent of data gathered within the LRO. Given the variety of site types, the data types and frequency of updates can be important factors when using these data for different applications. A similar table is provided for the weather stations in Appendix B (Table B1).

All of the data collected within the LRO are openly and publicly shared within the HydroShare repository. Datasets for monitoring sites at which continuous data are collected are automatically updated regularly and LRO technicians conduct routine quality control for continuous datasets. Many additional periodic monitoring sites are also shared via separate HydroShare resources. These data are downloaded periodically and undergo routine quality control. See all of the sites and links to their respective datasets at http://uwrl.usu.edu/lro/locations.

In Fall 2020, we obtained 0.5 m resolution LiDAR data for the canyon portion of the Logan River watershed. It includes a bare earth digital terrain model (DTM) and a first return digital surface model (DSM) that captures the height of the vegetation. We additionally collected detailed snow-on LiDAR data for a portion of the upper watershed in Franklin Basin in spring of 2021. Given the size of the LiDAR data, they are available on request.

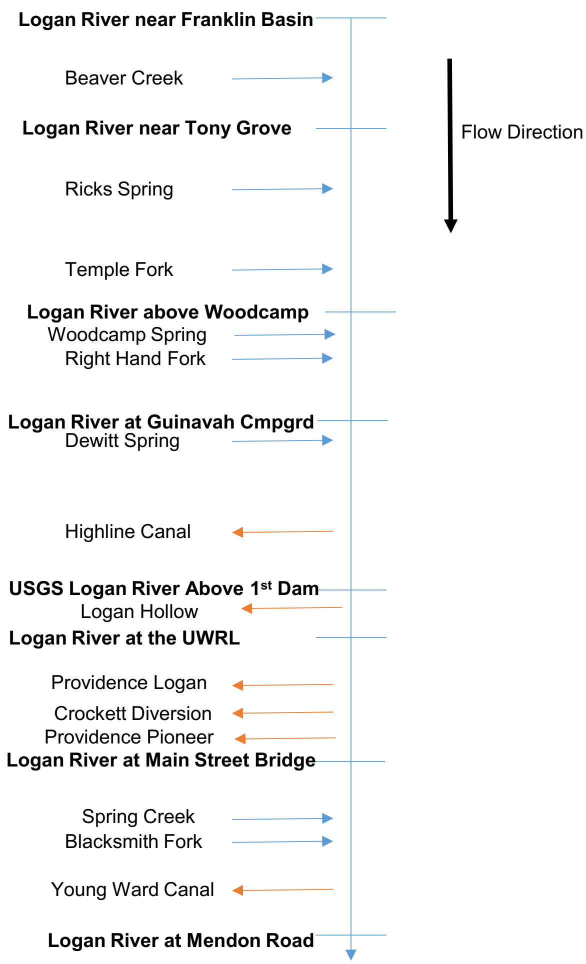


Figure 2. Schematic of primary LRO mainstem and tributary site locations. The vertical line represents the Logan River, with flow from top to bottom. Arrows pointing toward the river (blue) indicate measured inflows, and arrows pointing away from the river (orange) indicate measured withdrawals. Lines that cross the river indicate the locations of aquatic monitoring sites. Flow rates of all diversions are monitored by the Utah Division of Water Rights (some manually) and are included here to provide an overview of primary inflows and diversions.

Table 1. Aquatic sites and variables measured at each site within the Logan River Observatory*.

Site Name	Site Code	Updates	Water Temperature (C)	Specific Conductance (µS/cm)	pH	Dissolved Oxygen (optical, local % saturation, and mg/L)	Turbidity (NTU)	Gage Height (cm)	Water Surface Elevation (m, with respect to benchmark)	Discharge** (cms)	Blue Green Algae (RFU)	Chloro- phyll	CDOM (QSU)	Nitrate (mg/L)	Water Depth (m)	Velocity (m/s)
Logan River Sites																
Logan River near Franklin Basin	LR_FB_BA	Continuously	●	●	●	●	●	●	●	●						
Logan River near Tony Grove	LR_TG_BA	Continuously	●	●	●	●	●	●	●	●						
Logan River Above Wood Camp	LR_WC_A	Periodically	●	●				●	●	●						
Logan River at Wood Camp Bridge	LR_WCB_A	Periodically	●	●				●	●	●						
Logan River at Guinavah Campground Bridge	LR_GCB_A	Periodically	●	●				●	●	●						
Logan River at the Utah Water Research Laboratory west bridge	LR_WaterLab_AA	Continuously	●	●	●	●	●	●	●	●	○	○	○	○		
Logan River at Main Street (Highway 89/91) Bridge	LR_MainStreet_BA	Continuously	●	●	●	●	●	●	●	●						
Logan River at Mendon Road (600 S.)	LR_Mendon_AA	Continuously	●	●	●	●	●	●	●	●	○	○	○	○		
Tributary Sites																
Beaver Creek	BC_CONF_A	Periodically	●	●				●	●	●						
Temple Fork Outlet	TF_CONF_A	Periodically	●	●				●	●	●						
Ricks Spring	RS_CONF_A	Periodically	●	●				●	●	●						
Right Hand Fork	RHF_CONF_A	Periodically	●	●				●	●	●						
Spring Creek above confluence with Logan River	SC_CONF_A	Continuously	●	●				●	●	●						
Blacksmith Fork above confluence with Logan River	BSF_CONF_BA	Continuously	●	●				●	●	●						
Blacksmith Fork above Nibley-Blacksmith Fork Diversion	Online March 2023	Continuously	●	●				●	●	●						
Canal Sites																
Northwest Field Canal at 1600 North	NWF_1600N_CNL	Continuously (Irrigation season only)	●	●	●	●	●	●		●						
South Logan Benson Canal at Benson Irrigation Company Flume	SLB_600W_CNL	Continuously (Irrigation season only)	●	●	●	●	●	●	●							
Storm Drain Sites																
River Heights Storm Drain	LR_RH_SD	Continuously	○							○					○	○

*● indicates that data are presently being collected for this parameter; ○ indicates that data were historically collected for this parameter; Continuously = real-time updates of data online and available via time-series analyst; Periodically = periodic downloads of sensors with data posted on time-series analyst and/or HydroShare (http://www.hydroshare.org/).

** For the continuously updated stations that have discharge, the underlying data and details of the rating curves can be found by clicking "Explore Rating Curve" button below the "Most Recent Instantaneous Measurements" on each site's details accessed from http://lrodata.usu.edu/. The data for these sites, as well as the periodically updated sites, can also be found directly by going to http://www.hydroshare.org and searching for "Logan River rating curves." The exception is the Northwest Field Canal site.

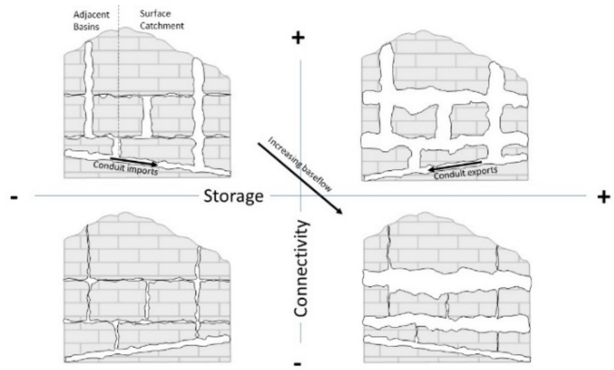
LOGAN RIVER OBSERVATORY RESEARCH

LRO Research Findings/Outcomes

The following paragraphs summarize recent relevant research efforts within the LRO. We have provided a brief description for each along with a listing of significant outcomes from each effort.

Characterizing karst mountain watersheds through streamflow response to snowmelt

Time series analysis of LRO station continuous discharge, specific conductance measurements, and gridded snowmelt predictions from Tyson et al. (2023) were used to characterize seasonal hydrology and evaluate dominant watershed controls for Logan River subcatchments and springs. Unlike many snowmelt-dominated western watersheds, the hydrologic variability between sites was not well described by typical watershed properties, including elevation or surficial geology.



***Outcome*:** A new conceptual framework of karst mountain watershed hydrology to characterize subsurface controls on streamflow dynamics and climate sensitivity based on readily measured hydrologic and climate variables was developed. This conceptual framework improves understanding of complex hydrogeology in the Logan River to guide water managers in estimating future water supply changes.

Thurber, Daniel Meade (2022). "Characterizing Karst Mountain Watersheds Through Streamflow Response to Snowmelt," Master's Thesis, Utah State University, https://doi.org/10.26076/3fb9-d6ee

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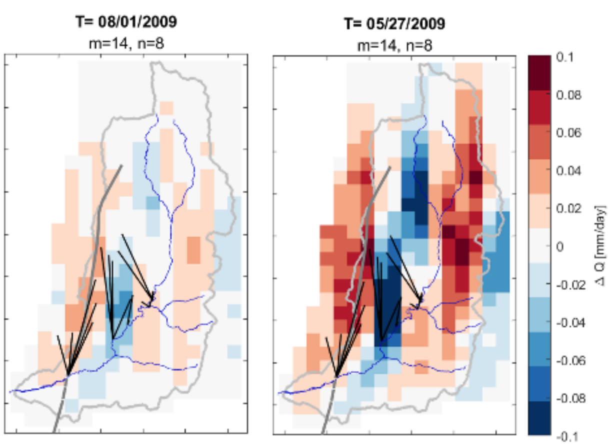
Precipitation changes in snowmelt dominated watersheds with karst geology

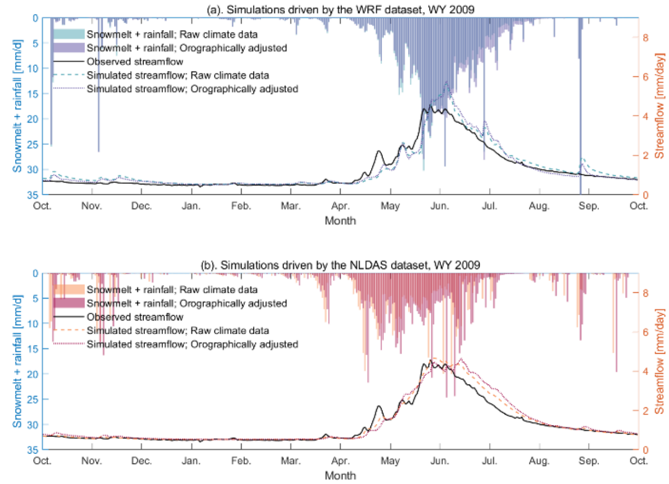


Neilson et al. (2018) (see Appendix C) found that significant amounts of river water were repeatedly exchanged between the river and the local aquifer and that the majority of groundwater entering the river moves quickly through the watershed via karst aquifer conduits. These findings suggest that river flow each summer is highly dependent on very recent aquifer recharge from snow accumulation during the prior winter. Future research will focus on quantifying how changes to snowpack will influence summer streamflow.

Xu, T., Q. Longyang**, C. Tyson**, R. Zeng, B.T. Neilson (2022). Hybrid Physically Based and Deep Learning Modeling of a Snow Dominated, Mountainous, Karst Watershed, *Water Resources Research*, 58 (e2021WR030993), https://doi.org/10.1029/2021WR030993

Effects of meteorological forcing uncertainty on high-resolution snow modeling and streamflow prediction in the Logan River watershed

Accurately simulating streamflow in snow dominated mountainous karst watersheds, including the Logan River watershed, relies on high-quality meteorological forcing at resolutions adequately fine to capture spatial variability controlled by complex terrain. To investigate the impacts of meteorological uncertainty on streamflow simulation, we drove the hybrid process-based and deep learning models developed in Xu et al. (2022) using two meteorological datasets, both at their original resolutions, and downscaled to 100 m based on topographic adjustments.

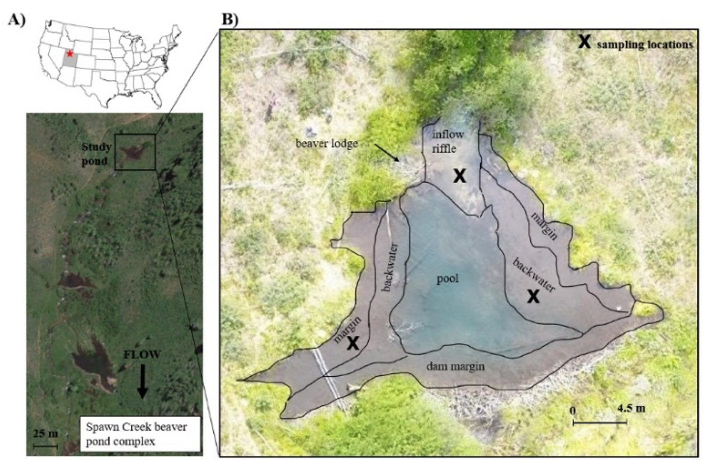


***Outcome*: A detailed understanding of meteorological uncertainty on streamflow simulation specifically for snow dominated mountainous karst watersheds. Results suggest the value of dynamically downscaled meteorological datasets, as well as orographically adjusting coarse-resolution datasets, when the former is unavailable. In addition, ensemble analyses using multiple meteorological datasets can potentially improve streamflow simulation accuracy.

Tyson**, C., Q. Longyang**, B.T. Neilson, R. Zeng, T. Xu (In press). Effects of Meteorological Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed, to *appear in Journal of Hydrology*

Beaver pond geomorphology influences on pond nitrogen retention and denitrification

Beaver ponds dot the headwaters and tributaries of the Logan River watershed. Beaver ponds are composed of distinct geomorphic units (e.g., backwater, margin, riffle). Murray et al. (2023) explored whether nitrogen (N) transformations, such as sedimentation or denitrification, will covary with a pond's geomorphic unit classification. To test this hypothesis, the physical structure of one pond was catalogued using geomorphic unit criteria. We conducted experiments within three geomorphic units to quantify various N cycle steps from sedimentation to denitrification and also measured sediment characteristics related to N cycling such as organic matter concentration and C and N isotope composition.



***Outcome*: Backwater areas were found to facilitate the storage of sediment N and, importantly, denitrification. The inflow riffle facilitated N transport rather than transformation, while nitrification rates were highest in the margin. It was concluded that the geomorphic composition of a beaver pond can inform whether beaver activity can provision water quality remediation.

Murray[**], D., B.T. Neilson, J. Brahney (In press). Beaver pond geomorphology influences pond nitrogen retention and denitrification, *To appear in Journal of Geophysical Research - Biogeosciences*

Toward automating post processing of aquatic sensor data

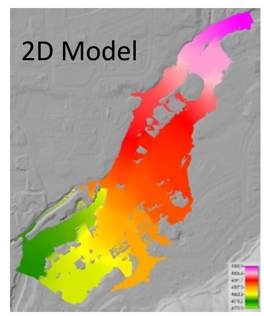
The data collection sites in the LRO generate large volumes of time-series data from in situ hydrology, water quality, and climate sensors. These data contain anomalies—e.g., issues with the data resulting from sensor malfunctions, adverse environmental conditions like ice buildup around sensors, etc. Anomalies must be detected and removed prior to the data being used for important analyses. The removal process is called "quality control" and usually involves a technician visually examining data and applying corrections where needed. However, given the volume of data produced in the LRO, the quality control process is labor intensive and difficult to maintain. In this work, PhD student Amber Jones led an investigation of how data streams from environmental sensors can be automatically processed to detect and correct anomalies.

> ***Outcome***: A software program called PyHydroQC aimed at automating the quality control process and reducing the time required to produce high quality data records.

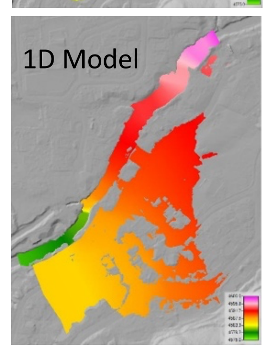
Jones[**], A. S., T.L. Jones, J.S. Horsburgh (2022). Toward automating post processing of aquatic sensor data, *Environmental Modelling & Software*, 151(105364), https://doi.org/10.1016/j.envsoft.2022.105364

Comparing 1D, 2D, and 3D hydraulic models In Logan River flooding applications

Kesler (2023) found a 1D HEC-RAS model to be not ideal for understanding flooding around the Crockett Canal diversion structure along the Logan River. Lateral flow extent for a 2500 cfs flood was not captured well in the 1D model. The 2D model, consistent with the 3D model, showed water leaving the Logan River channel far enough upstream of the diversion structure that there was no indication of the diversion structure causing the flooding. Hydraulic grade lines and water surface elevations do not show significant water accumulating behind the diversion structure.



> ***Outcome***: More advanced 3D computational fluid dynamics modeling provides insights regarding flow patterns above the Crockett Diversion structure; however, 2D HEC-RAS modeling provided similar insights regarding the extent of flooding and can provide more reliable results than 1D modeling approaches.



Kesler, Taylor (2023). "Comparing 1D, 2D, and 3D Hydraulic Models in Urban Flooding Applications," *All Graduate Theses and Dissertations*, 8691, https://doi.org/10.26076/38b6-8acb

Logan River Observatory support of local canal companies

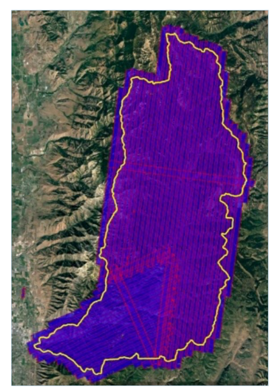
Drought conditions throughout the western US have prompted significant interest in ensuring that the water distribution throughout rivers and canal systems is well understood. The LRO worked with multiple canal companies in summer 2021 and 2022 to:

1. Determine flow measurement accuracy at various Utah Division of Water Rights gaging locations,
2. Estimate flows in ungaged diversions, and
3. Estimate flow gains and losses in various portions of the river and canal system.

***Outcome*:** Michael Lasswell, PhD student, and B. Neilson are working to help understand the environmental impact of proposed diversions and canal system changes along the Logan River below the Utah Water Research Laboratory. Similarly, Lasswell and Neilson are working with the Cache Water District to initiate a more holistic project on the Blacksmith Fork and adjacent drainages to determine the optimal approaches for water management based in part on detailed seepage studies completed on a series of canals and the Blacksmith Fork River in summer 2022.

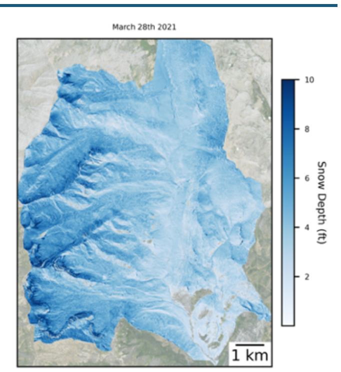
Logan River LiDAR

Light Detection and Ranging (LiDAR) topography data (0.5-m resolution) was collected over the entire canyon portion of the Logan River watershed in Fall 2020. This data collection was a collaborative effort between Logan City, the LRO, and USGS 104(b). The LiDAR data augments data already available for the valley section of the Logan River and has provided coverage of the full watershed to facilitate ongoing and future hydrologic studies.



Outcome: These data are foundational to various on-going or planned research activities. For example, two different PhD students associated with the NSF grant mentioned above are working to establish new methods for mapping sinkholes (or groundwater recharge locations) based on this detailed dataset. Additionally, these data have been used to attract recent NSF funding (see Phillips 2022 NSF Grant), used in various conference presentations, and were instrumental in Benitez (2023) MS thesis.

Snow LiDAR



Snow-on LiDAR data were collected during March 2021 in the Franklin Basin portion of the watershed. The resulting data have been combined with LRO snow-off LiDAR and Citizen Scientist snow data through machine learning to model snowpack at high spatial and temporal resolutions at low cost. Particularly focusing on basin-scale estimation of snowpack in heterogeneous terrain and regions otherwise underrepresented by high-resolution snow products, this work supports our understanding of snow distribution and water availability in critical watersheds.

Outcome: These data are being used to determine future options for using crowdsourced data to understand water availability via more accurate representation of snow distribution.

A hydraulic routing and river temperature model of the valley portion of the Logan River

Buahin et al. (2019) (see Appendix C), developed and calibrated a temperature model for a large section of the lower Logan River. The model provided estimates of lateral inflow volumes and temperatures which were used to indicate whether lateral inflows originated from colder groundwater or warmer urban/agricultural runoff. This modeling framework will be used to assist in assessing the environmental impacts associated with proposed changes to the Crockett Diversion and diversions from the Logan River (see above).

Outcome: This analysis resulted in improved understanding of the dynamic inflows and outflows to the river system. The model will be used in various projects to assess the impacts of different instream flow management options on instream temperatures and impact on fisheries.

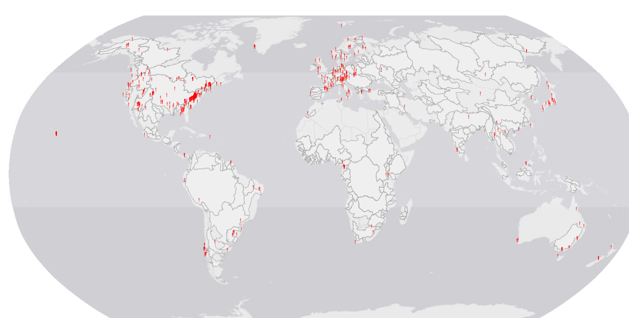
Lateral inflow sources in the valley portion of the Logan River

Building on Buahin et al. (2019), Tennant et al. (2021) used detailed measurements and flow and mass balances to further investigate where gaining and losing conditions occur, when they occur, the source of the flow (urban versus agricultural areas), and whether it joined the river via surface or subsurface flow.

Outcome: Similar to above, these findings will help guide decision making by assessing the impact of different water distribution scenarios on lateral inflows to Logan River that will change as canals are lined/pressurized or stormwater practices are altered.

Logan River Observatory as part of a network of worldwide research and observatory catchments

The Logan River Observatory was included in a Special Issue of the Hydrological Processes journal titled "Research and Observatory Catchments: the Legacy and the Future" (Hydrological Processes: Vol 35, No 5 (wiley.com)). To further promote the contributions of the LRO to the broader research community, a presentation was given at the Research and Observatory Catchments: The Legacy and the Future Seminar Series:



https://www.youtube.com/watch?v=q1mmI2QzAjM&list=PLPG5Ed5L1SY7T_1cb15fD-oQV6nvZsQTw&index=7. The map shows the worldwide network of observatories involved.

***Outcome*:** Neilson et al. (2021) highlighted the LRO as one of the only karst observatory watersheds that has detailed subwatershed flow measurements. This article highlights the importance of flow data in understanding watershed hydrologic responses and the role in future water planning. The State of Utah's investment in long term hydrologic monitoring was discussed and was highlighted as a unique attribute of the LRO. Tennant et al. (2021) also provided additional analyses and further illustrated the utility in the detailed flow measurements that the LRO network provides.

Currently Funded LRO Related Research Projects

The LRO monitoring and data infrastructure provide a scaffolding onto which new, synergistic, and collaborative research projects can be built. The following are ongoing or newly funded research projects that use LRO data and/or research infrastructure. For information on prior projects, go to Projects | Logan River Observatory | USU.

1. Cooperative Institute for Research to Operations in Hydrology (CIROH): Modernized Standards and Tools for Sharing and Integrating Real time Hydrologic Observations Data, J.S. Horsburgh, National Oceanic and Atmospheric Administration (NOAA), 2022–2025, *$729,673.*
2. Collaborative Research: Separating the climate and weather of river channels: Characterizing dynamics of coarse-grained river channel response to perturbations across scales, C.B. Phillips, National Science Foundation, 2022–2025, *$609,086.*
3. Collaborative Research: Quantifying Watershed Dynamics in Snow-Dominated Mountainous Karst Watersheds Using Hybrid Physically Based and Deep Learning Models, B.T. Neilson and D.L. Newell, National Science Foundation, 2021–2024, *$777,921.*
4. Hydrochemical Tracer Sampling in Logan River to Inform Future Water Availability, B.T. Neilson, D.L. Newell, E. Rivers, P. Brooks, USU Extension Water Initiative Grants Program, 2022–2023, *$39,795.*
5. Monitoring and Research for Water Quality and Stormwater Management in Logan City, UT, B.T. Neilson and J.S. Horsburgh, Logan City, 2018–2023, *$208,121.*
6. Determining the mobility, fate, and ecological consequences of dust-derived constituents in mountain watersheds, J. Brahney, National Science Foundation, 2020–2025, *$742,072.*
7. Quantifying microplastic and nanoplastic deposition in the Bear River Mountains, J. Brahney, United States Department of Agriculture, 2021–2024, *$20,000.*
8. Microplastic transport to the Great Salt Lake through the Logan and Bear River system, J. Brahney, P. Budy, B.T. Neilson, State of Utah Division of Forestry, Fire, and State Lands, 2021–2022, *$48,495.*
9. Assessing the Sources, Transport, and Fate of Microplastic in the Logan River Watershed, K. Moor, J. Brahney, B.T. Neilson, United States Geological Survey 104(b)/UWRL, 2021–2022, *$90,107.*

LRO Related Proposals 2022–2023

1. CIROH: Advancing Snow Observation Systems to Improve Operational Streamflow Prediction Capabilities, C.A. Oroza, R. Johnson, D. Taylor, C. Skalka, J. Horsburgh, National Oceanic and Atmospheric Administration (NOAA), 2023–2026, *$1,605,057*, Status: Pending.
2. Advancing Camera-Based Monitoring for Operational Hydrologic Applications, S. Young, J.S. Horsburgh, E. Goharian, United States Geological Survey, 2023–2026, *$729,573*, Status: Pending.

Research Products 2022–2023

See Appendix D for a complete list of prior research products.

*=Post-Doctoral Researcher, ** = Graduate Student, *** = Undergraduate Student

Journal Publications:

1. Pennock, C.A., G.P. Thiede, and P. Budy (In press). Density-dependent processes and population dynamics of native sculpin in a mountain river, *to appear in Ecology of Freshwater Fish,* https://doi.org/10.1111/eff.12710.
2. Leach, J. A., C. Kelleher, B.L. Kurylyk, R.D. Moore, B.T. Neilson (In press). A primer on stream temperature processes, *to appear in WIRES Water*.
3. Tyson, C. **, Q. Longyang**, B.T. Neilson, R. Zeng, T. Xu (In press). Effects of Meteorological Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed, *to appear in Journal of Hydrology*.
4. Murray, D., B.T. Neilson, J. Brahney (In press). Beaver pond geomorphology influences pond nitrogen retention and denitrification, *to appear in Journal of Geophysical Research - Biogeosciences*.
5. Jones**, A.S., T.L. Jones, J.S. Horsburgh (2022). Toward automating post processing of aquatic sensor data, *Environmental Modelling & Software*, 151(105364), https://doi.org/10.1016/j.envsoft.2022.105364.
6. Xu, T., Q. Longyang**, C. Tyson**, R. Zeng, B.T. Neilson (2022). Hybrid Physically Based and Deep Learning Modeling of a Snow Dominated, Mountainous, Karst Watershed, *Water Resources Research*, 58(e2021WR030993), https://doi.org/10.1029/2021WR030993.
7. Lukens**, E., B.T. Neilson, K.H. Williams, J. Brahney (2022). Evaluation of hydrograph separation techniques with uncertain end-member composition, *Hydrological Processes*, 36(9), e14693, https://doi.org/10.1002/hyp.14693.
8. Phillips, C.B., C. Mastellar, L. Slater, K. Dunne, S Francalanci, S. Lanzoni, D. Merritts, E. Lajeunesse, D.J. Jerolmack (2022). How the threshold for sediment entrainment constrains the size and shape of alluvial rivers, *Nature Reviews Earth and Environment*, https://doi.org/10.1038/s43017-022-00282-z.

Other Significant Publications:

1. Anderegg, W., Buttars, C., Ferry, J., Gochnour, N., Shelley, K., Steed, B., Tarboton, D., Ahmadi, L., Albers, E., Bingham, B., Brooks, P., Endter-Wada, J., Hasenyager, C., Lin, J., McEntire, A., Neilson, B. T., Null, S., Perry, K., Stireman, B., Strong, C., Vernon, L., Welch, K., & Yost, M (2023). Great Salt Lake Policy Assessment.

Student Theses/Dissertations:

1. Kesler, Taylor (2023). "Comparing 1D, 2D, and 3D Hydraulic Models in Urban Flooding Applications," *All Graduate Theses and Dissertations*, 8691, https://doi.org/10.26076/38b6-8acb.
2. Thurber, Daniel Meade (2022). "Characterizing Karst Mountain Watersheds Through Streamflow Response to Snowmelt," *All Graduate Theses and Dissertations*, 8673, https://doi.org/10.2076/3fb9-d6ee.
3. Shaver, Ryan (2022). "Long Short-Term Memory for Karst Watershed Modeling: Case Study of Logan River Canyon, UT, USA," Honors Thesis, Barrett, the Honors College, Arizona State University.
4. Benitez, Gabriel (2023). "Exploring variations in high-resolution downstream hydraulic geometry of the Logan River," Masters Thesis, Utah State University.

Conference Presentations:

1. Gustavos[++], M., B.T. Neilson, P. Strong, J. Brahney (2022). Assessing microplastic sources and characteristics from mountain streams to urban rivers, 2022 Joint Aquatic Sciences Meeting (JASM), May 14-20, 2022, Grand Rapids, MI.
2. Thurber, D. and B. Lane (2022). Streamflow response to snowmelt in a karst mountain system, AGU Hydrology Days, Colorado State University, April 27, 2022, Fort Collins, CO.
3. Phillips, C.B., J. Blaylock, J. Woodhouse, G. Benitez, R. Kostynick, and C. Masteller (2022). An exploration of variability in bankfull river width, 2022 Fall Meeting, AGU.
4. Kostynick, R., C. Masteller, G. Benitez, and C. B. Phillips (2022). Quantifying Downstream Variability in Bankfull Width from Digital Elevation Models, 2022 Fall Meeting, AGU.
5. Masteller, C., R. Kostynick, G. Benitez, and C.B. Phillips (2022). Wiggles in width: Insights into alluvial channel dynamics from variability in high-resolution downstream hydraulic geometry. GSA Connects, GSA.

Faculty Involvement

The LRO is a collaborative facility that provides opportunities for collaboration across departments, institutions, and agencies. Faculty involved over the last year include:

1. **Bethany Neilson**, *Utah State University, CEE* (LRO leadership and involvement on a number of projects)
2. **Jeff Horsburgh**, *Utah State University, CEE* (LRO leadership and involvement on a number of projects)
3. **Dennis Newell**, *Utah State University, Geosciences* (Co-PI of karst hydrology NSF collaborative proposal)
4. **Tianfang Xu,** *Arizona State University* (PI of karst hydrology NSF collaborative proposal)
5. **Jim McNamara**, *Boise State University* (Co-PI of karst hydrology NSF collaborative proposal)
6. **Ruijie Zeng,** *Arizona State University* (has a PhD student working on image analysis)
7. **Carlos Oroza**, *University of Utah* (PI on Snow-on LiDAR project in Franklin Basin)
8. **Zac Sharp**, *Utah State University, CEE* (had a MS student focused on modeling detailed impacts of flooding in the urban section of the Logan River)
9. **Belize Lane**, *Utah State University, CEE* (PI on a prior NSF proposal that includes the Logan River; had an MS student focused on analyzing historical time series data from the LRO to understand karst hydrologic connectivity; is part of the work being done by the LRO in the Blacksmith Fork)

10. **Kyle Moor**, *Utah State University, CEE* (PI on prior USGS 104(b) project focused on fate of microplastics in the Logan River, collaborating with Janice Brahney and Beth Neilson)
11. **Janice Brahney**, *Utah State University, WATS* (PI on projects focused on atmospheric deposition of nutrients, metals, and microplastics and how they are transported through the Logan River and throughout the Great Salt Lake Basin, as well as projects examining terrestrial microplastic sources to the Logan River. She is working with Kyle Moore, Beth Neilson, and Phaedra Budy and has had 3 former MS students that have worked within the Logan River and depended on the LRO data).
12. **Sarah Null**, *Utah State University, WATS* (working throughout the Bear River Basin on NSF Career Grant)
13. **Colin Phillips**, *Utah State University, CEE* (has a MS student working on *hydraulic geometry scaling throughout the Logan River based on LiDAR and flow data, PI on NSF proposal based in part on the Logan River).*

LOGAN RIVER OBSERVATORY OUTREACH AND EDUCATION

In addition to its value as a platform and data source for research, the LRO also supports education by:

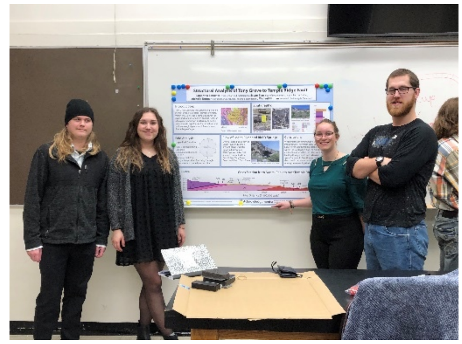
1. Continuing to work to increase public awareness of the connection between the landscape, humans, and water.
2. Providing information to the general public via different media outlets. Examples include:
    - Water Shepherding: USU Experts Discuss How to Ensure Conserved Water Gets to the Great Salt Lake https://www.usu.edu/today/story/water-shepherding-usu-experts-discuss-how-to-ensure-conserved-water-gets-to-the-great-salt-lake
    - Measure to Manage – With Better Water Data https://utahstatemagazine.usu.edu/scitech/measure-to-manage-water-solutions-begin-with-better-data
    - The Great Salt Lake Strike Team: collaborative solutions for a shrinking Great Salt Lake https://uwrl.usu.edu/files/pdf/newsletters/waterblog-nov-2022.pdf
    - Breaking it Down: how microplastics degrade in high mountain streams. https://uwrl.usu.edu/files/pdf/newsletters/waterblog-nov-2022.pdf
3. Supporting stakeholders in water related decision making:
    - Members of the LRO (S. Null and B. Neilson) participated in the Great Salt Lake Strike Team to help provide guidance to the Utah legislature regarding options to address the declining levels in the Great Salt Lake. These members have also worked with legislators and other government representatives to establish better monitoring methods to address conservation and water shepherding needs across the state.
    - We continue to collect detailed temperature data throughout Logan City to support various ongoing Logan River Task Force efforts and help meet monitoring needs.
    - We will continue to expand and refine existing hydraulic routing and temperature models developed for the valley section of the Logan River to guide future water quantity and quality related decisions.

- The LRO has provided detailed temperature and flow analyses to the Logan River Task Force, Cache Water District, and others involved in the Logan River Watershed Project to guide scenario development regarding instream flowrates needed to maintain instream temperatures as part of the Environmental Impact Statement for the Crockett Diversion replacement. This work is ongoing.
- The LRO will work closely with the Cache Water District to establish methods for adapting to ongoing requirements for water conservation.

4. Serving as an outdoor laboratory and classroom for training the next generation of engineers and scientists to address water issues in the state:
    - LRO serves as a data source for real-world classroom exercises for many different USU classes (approximate number of students each year shown in parentheses).
        - **CEE 3610** – Environmental Management (80)
        - **CEE 3430** – Hydrology (70)
        - **CEE 3500** – Fluid Mechanics (65)
        - **CEE Senior Design** (10) – Each year there is at least one group of senior design students focused on different aspects of the Logan River.
        - **CEE 5003/6003** – Remote Sensing of Land Surfaces (8)
        - **CEE 5190/6190** – GIS for Civil Engineers (40)
        - **CEE 5470/6470** – Sedimentation Engineering (15)
        - **CEE 6110** – Hydroinformatics (15)
        - **CEE 6660** - Environmental and Hydrologic Data Analysis and Experimentation (15)
        - **CEE 6400** – Physical Hydrology (20)
        - **CEE 5500/6500** – Open Channel Hydraulics (30)
        - **CEE 6740** – Surface Water Quality Modeling (8)
        - **CEE 6930** – Hydrologic Field Methods (7)
        - **GEO 6190** – Aqueous Geochemistry (10)
        - **GEO 3700** – Structural Geology (12)

5. A recently redesigned version of CEE 6660 - Environmental and Hydrologic Data Analysis and Experimentation, a required class for all water and environmental graduate students in CEE, uses LRO data extensively. LRO data are used in 4 assignments, 3 projects, nearly every lecture, and in ~20 out of 24 in class practice assignments.
6. Dr. Jim Evans (Geosciences) had his GEO 3700 Structural Geology class use data from the LRO to integrate structural,

geologic, and hydrologic data at Ricks Springs as part of group projects. They held a public poster session and plan to present a version of these posters at the 2023 USU Spring Runoff conference.



7. Supporting the research for many graduate and undergraduate students that will generate a better understanding of potential challenges related to our water supplies.
    - Current LRO Undergraduate Student employees and mentees:
        - **Abby Johnson**, BS, CEE
        - **Abby Englund**, BS, CEE
        - **Chelsey Cowburn**, BS, CEE
        - **Anna Fabiszak,** BS, Chemistry
        - **Missy White,** BS, CEE
        - **CEE Senior Design Group** – Neilson Faculty Mentor – Crockett Diversion Replacement Project
    - Appendix D (Table D1) provides a description of the graduate students and projects focused on the Logan River watershed.

APPENDICES

Appendix A:
Logan River Watershed Overview

The Logan River watershed is located in the Bear River mountain range east of Logan, Utah. With headwaters near the Utah-Idaho border, the upper, or canyon, portion of the basin is steep and flows southwest through mostly natural land cover (forest and rangeland) with little development other than paved and dirt roads, a ski resort, and a small number of summer homes. Currently, the majority of precipitation falls as snow, resulting in a snowmelt-dominated hydrograph. Peak flows occur in the late spring, with an average annual flow at the mouth of the canyon of approximately 230 cfs (6.5 cms). The geology of the upper portion of the watershed is primarily limestone and dolomite (Dover, 1995). The topography is characterized by sinkholes and fractures formed by dissolution of the rocks (also known as karst features), which creates underground drainage systems. According to Spangler (2001; 2011), some Logan Canyon geologic layers (e.g., the Garden City Formation and Laketown Dolomite) have more karst development than other layers, but all units have the ability to transmit water via fractures, faults, and bedding planes created and enhanced by dissolution. The exception is the Swan Peak Formation, primarily composed of quartzite, which minimizes vertical groundwater movement between some of the karst layers and intersects the river in multiple places (Spangler, 2011). Groundwater movement is also influenced by the Logan Peak Syncline and the merger of the Naomi Peak Syncline and Cottonwood Canyon Anticline near Wood Camp Spring (Bahr, 2016).

Three major karst springs in Logan Canyon (Ricks, Wood Camp, and Dewitt Springs) provide significant flow to the river throughout most of the year. Numerous smaller springs (both karst and non-karst) feed the Logan River or its tributaries and may or may not flow year-round. Many tracer studies have been conducted in an effort to establish subsurface connectivity between the karst aquifer and these major springs (Spangler, 2001, 2011), as well as other short-residence-time intrabasin and interbasin subsurface connectivity. Dewitt Springs is a primary drinking water source for Logan City, and a large portion of its flow is diverted before entering the Logan River. Three additional perennial tributaries also join the Logan River (Beaver Creek, Temple Fork Creek, and Right Hand Fork Creek). Other tributaries are either limited in their contribution or are intermittent, with no flow reaching Logan River during parts of the year.

In lower Logan Canyon, a series of three small dams (First, Second, and Third Dam) divert flow for hydropower generation. An irrigation diversion between First and Second Dams supplies water to the Highline Canal. Once the river enters the valley portion of the watershed, it flows through residential areas, then more urbanized portions of Logan City, then residential areas again, and finally through agricultural areas west of Logan City. During the summer growing season, most, and sometimes all, of the river's flow is diverted into three additional canals for residential and agricultural irrigation (Sumac, Crockett, and Young Ward Canals). Two major tributaries, Spring Creek and the Blacksmith Fork River, as well as many other smaller inflows, also contribute to the river in the residential, urban, and agricultural areas. These inflows are primarily sourced from stormwater, groundwater drainage, and irrigation return flows. Various restoration efforts led by the Logan River Task Force (https://uwrl.usu.edu/lro/logan-river-task-force) have been implemented in the valley portion of the river to address human impacts throughout the watershed and along the river corridor.

Appendix B:
Climate Site and Parameters Measured

Table B-1. Climate site and parameters measured at each site within the Logan River Observatory.

Site Name	Site Code	Updates	Vapor Pressure (kPa)	Barometric Pressure (kPa)	Cumulative Precipitation (cm)	Snow Depth (cm)	Wind Speed (m/s)	Wind Direction	Air Temperature (C)	Relative Humidity (%)	Incoming Shortwave Radiation (W/m²)	Outgoing Shortwave Radiation (W/m²)	Incoming Longwave Radiation (W/m²)	Outgoing Longwave Radiation (W/m²)	Net Radiation (W/m²)	Incoming PAR (µmol/m² s)	Outgoing PAR (µmol/m² s)	Soil Temperature @ 5,10,20,50,100 cm (C)	Soil Permittivity @ 5,10,20,50,100 cm	Soil Volumetric Water Content @ 5,10,20,50,100 cm (%)
Climate Station at Logan River Golf Course	LR_GC_C	Continuously Updated	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Climate Station at Franklin Basin	LR_FB_C	Continuously Updated	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Wilkins Repeater	LR_Wilkins_R	Continuously Updated					•	•	•	•										
Climate Station at TW Daniels Experimental Forest	Decommissioned	Continuously Updated	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Climate Station at Tony Grove	LR_TG_C	Continuously Updated	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Climate Station at Temple Fork		Periodically Updated		•	•		•	•	•	•										

Appendix C:
Prior Logan River Observatory Research Products

Annual Reports:

1. Neilson, B.T., Strong, P., and Horsburgh, J.S. (2020). State of the Logan River Watershed. Utah Water Research Laboratory, Utah State University, Logan, Utah, USA. https://uwrl.usu.edu/files/pdf/2019-20-state-of-the-logan-river-watershed-6-30-20-final.pdf
2. Neilson, B.T., Strong, P., and Horsburgh, J.S. (2021). State of the Logan River Watershed. Utah Water Research Laboratory, Utah State University, Logan, Utah, USA. https://uwrl.usu.edu/files/pdf/2020-21-lro-annual-report.pdf
3. Neilson, B.T., Strong, P., and Horsburgh, J.S. (2022). Logan River Observatory Annual Report. Utah Water Research Laboratory, Utah State University, Logan, Utah, USA. PDF

Journal Publications:

1. Alger, S.M., B. Lane, B.T. Neilson (2021). Combined influences of irrigation diversions and associated subsurface return flows on river temperature in a semi-arid region, *Hydrologic Processes,* 35(8), e14283, https://doi.org/10.1002/hyp.14283.
2. Neilson, B.T., H. Tennant, P.A. Strong, J.S. Horsburgh (2021). Detailed streamflow data for understanding hydrologic responses in the Logan River Observatory, *Hydrologic Processes*, 35(8), e14268, https://doi.org/10.1002/hyp.14268.
3. Tennant**, H., B.T. Neilson, M.P. Miller, T. Xu (2021). Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory, *Hydrological Processes*, 35, (e14097), https://doi.org/10.1002/hyp.14097.
4. Murray, D.**, B.T. Neilson, J. Brahney (2021). Source or Sink? Quantifying beaver pond influence on non-point source pollutant transport in the Intermountain West, Journal of Environmental Management, 285, 112127, https://doi.org/10.1016/j.jenvman.2021.112127.
5. Buahin* C.A., J.S. Horsburgh, B.T. Neilson (2019). Parallel multi-objective calibration of a component-based river temperature model, *Environmental Modelling & Software,* 116, 57–71, https://doi.org/10.1016/j.envsoft.2019.02.012.
6. Buahin**, C.A., J.S. Horsburgh (2018). Advancing the Open Modeling Interface (OpenMI) for integrated water resources modeling, *Environmental Modelling & Software*, 108, 133–153, https://doi.org/10.1016/j.envsoft.2018.07.015.
7. Jones, A.S., J.S. Horsburgh, D.P. Eiriksson (2018). Assessing subjectivity in environmental sensor data post processing via a controlled experiment, *Ecological Informatics*, 46, 86–96, https://doi.org/10.1016/j.ecoinf.2018.05.001.
8. Neilson, B.T., H. Tennant***, T.L. Stout**, Miller, M., Gabor*, R.S., Y. Jameel**, M. Millington**, A. Gelderloos**, G.J. Bowen, P.D. Brooks (2018). Stream-centric methods for determining groundwater contributions in karst mountain watersheds, *Water Resources Research*, 54, https://doi.org/10.1029/2018WR022664.
9. Jones, A., Z.T. Aanderud, J.S. Horsburgh, D. Eiriksson, D. Dastrup, C. Cox, S.B. Jones, D.R. Bowling, J. Carlisle, G.T. Carling, M.A. Baker (2017). Designing and Implementing a Network for Sensing Water Quality and Hydrology Across Mountain to Urban Transitions, *Journal of the American Water Resources Association,* 1–26, https://doi.org/10.1111/1752-1688.12557.

10. Melcher**, A.A., J.S. Horsburgh (2017). An urban observatory for quantifying phosphorus and suspended solids loads in combined natural and stormwater conveyances, *Environmental Monitoring and Assessment*, 189:285, https://doi.org/10.1007/s10661-017-5974-7.
11. Mihalevich**, B.A., J.S. Horsburgh, A.A. Melcher** (2017). High frequency measurements reveal spatial and temporal patterns of dissolved organic matter in an urban water conveyance, *Environmental Monitoring and Assessment,* 189:593, https://doi.org/10.1007/s10661-017-6310-y.
12. Jones, A.S., J.S. Horsburgh, S.L. Reeder, M. Ramirez***, J. Caraballo*** (2015). A data management and publication workflow for a large-scale, heterogeneous sensor network, *Environmental Monitoring and Assessment*, 187:348, https://doi.org/10.1007/s10661-015-4594-3.

Conference Presentations:

1. Jones**, A.S., T.L. Jones, J.S. Horsburgh (2021). PyHydroQC: A Python Package for Automating and Streamlining Aquatic Sensor Data Post Processing, American Geophysical Union Fall Meeting 2021, December 13–17, 2021, New Orleans, LA.
2. Benitez**, G., C. Masteller, and C.B. Phillips (2021). Defining the Reach Scale of a Mountain River from High-resolution Hydraulic Geometry, American Geophysical Union Fall Meeting 2021, December 13–17, 2021, New Orleans, LA.
3. Jones**, A.S., T.L. Jones, J.S. Horsburgh (2021). Techniques for increased automation of aquatic sensor data post processing in Python, 12th National Monitoring Conference, National Water Quality Monitoring Council, April 19–23, 2021, Virtual.
4. Liljestrand**, D., C. Oroza, B.T. Neilson, P. Strong, E. Cotter (2021). Leveraging LIDAR, Machine Learning, and Citizen-Science for Low-Cost, High-Resolution Snow-Depth Estimation, American Geophysical Union Fall Meeting 2021, December 13–17, 2021, New Orleans, LA.
5. Xu, T., Q. Longyang**, B.T. Neilson, R. Zeng (2021). Inferring spatiotemporal precipitation-discharge patterns of a snow dominated mountainous karst watershed using a hybrid physically based and deep learning modeling approach, American Geophysical Union Fall Meeting 2021, December 13–17, New Orleans, LA.
6. Neilson, B.T., J.S. Horsburgh, P.A. Strong, H. Tennant, A.S. Jones (2021). Logan River Observatory: karst mountainous pristine to valley human impacted, Spring 2021, Research and Observatory Catchments: The Legacy and the Future Seminar Series, (https://www.youtube.com/watch?v=q1mmI2QzAjM&list=PLPG5Ed5L1SY7T_1cb15fD-oQV6nvZsQTw&index=7).
7. Alger, S.M.**, B. Lane, B.T. Neilson (2020). Lateral return flows control summer stream temperature patterns in irrigation-depleted streams, American Fisheries Society Utah Chapter Meeting. St. George, UT, February 27, 2020.
8. Tennant, H.**, B.T. Neilson, M.P, Miller, T. Xu, P.D. Brooks (2019). Using Naturally Occurring Tracers to Quantify Components of Urban and Agricultural Streamflow, 2019 Fall Meeting, American Geophysical Union, December 9–13, 2019, Abstract H23D-02, San Francisco, CA.
9. Alger**, M., B. Lane, B.T. Neilson (2019). Controls on Summer Stream Temperature Patterns in Irrigation-Depleted Streams, 2019 Fall Meeting, American Geophysical Union, December 9–13, 2019, Abstract H23K-2049, San Francisco, CA.
10. Xu, T., Q. Longyang, C. Tyson**, R. Zeng, B.T. Neilson, D.G. Tarboton (2019). Hybrid physically based and deep learning modeling of a snow dominated mountainous karst watershed, 2019 Fall Meeting, American Geophysical Union, December 9–13, 2019, Abstract H32D-02, San Francisco, CA.
11. Longyang, Q., C. Tyson**, T. Xu, R. Zeng, B.T. Neilson (2019). Effects of Climate Forcing Uncertainty on Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed, 2019 Fall Meeting, American Geophysical Union, December 9–13, 2019, Abstract H33I-2033, San Francisco, CA.

12. Murray[**], D., B.T. Neilson, J. Brahney, N. Bouwes (2019). Can Beavers Mitigate Non-Point Source Pollution?, American Fisheries Society and The Wildlife Society Joint Conference 2019, September 27–October 4, 2019, Reno, NV.
13. Alger[**], M., B. Lane, B.T. Neilson (2019). Characterizing streamflow and temperature patterns on the Blacksmith Fork River to prevent summer dewatering, 2019 UCOWR/NIWR Annual Water Resources Conference, June 11–13, 2019, Snowbird, Utah.
14. Murray[**], D., B.T. Neilson, J. Brahney (2019). Can beavers mitigate non-point source pollution?, 2019 Society for Freshwater Science (SFS) Annual Meeting, May 19–23, 2019, Salt Lake City, Utah.
15. Capito[**], L., B.T. Neilson, J. Brahney (2019). Environmental controls on didymo bloom formation, 2019 Society for Freshwater Science (SFS) Annual Meeting, May 19–23, 2019, Salt Lake City, Utah.
16. Strong, P., H. Tennant[**], J.S. Horsburgh, B.T. Neilson (2019). The Logan River Observatory: A lab in our own backyard, 2019 USU Spring Runoff Conference, March 26, 2019, Logan, UT.
17. Alger[**], M., B. Lane, B.T. Neilson (2019). Characterizing streamflow and temperature patterns on the Blacksmith Fork River to prevent summer dewatering, 2019 USU Spring Runoff Conference, March 26, 2019, Logan, UT.
18. Capito[**], L., B.T. Neilson, J. Brahney (2019). Environmental controls on didymo bloom formation, 2019 USU Spring Runoff Conference, March 26, 2019, Logan, UT.
19. Neilson, B.T., H. Tennant[***], T.L. Stout[**], Miller, M., Gabor[*], R.S., Y. Jameel[**], M. Millington[**], A. Gelderloos[**], G.J. Bowen, P.D. Brooks (2018). Stream-centric methods for determining groundwater contributions in karst mountain watersheds, 2018 Fall Meeting, American Geophysical Union, December 10–14, 2018, Abstract H33E-04, Washington, D.C.
20. Horsburgh, J.S., M.A. Baker, B.T. Neilson, P. Strong, A.S. Jones (2018). Logan River Observatory: Extending iUTAH's GAMUT network for long-term monitoring to inform local policy and water management, 2018 USU Spring Runoff Conference, March 27, 2018, Logan, UT.
21. Tennant[***], H., B.T. Neilson, M.L. Barnes[**], T.L. Stout[**], M. Miller, R. Gabor[*], M. Millington[**], Y. Jameel[**], A. Gelderloos[**], G. Bowen, P. Brooks (2018). Combined Approaches for Estimating Groundwater Exchanges in Karst Watersheds, April 2018, 2018, USU Student Research Symposium, Logan, UT.
22. Jones, A.S. and J.S. Horsburgh (2018). The iUTAH Experience: Cyberinfrastructure and Data Management for a Large, Interdisciplinary Water Project, Universities Council for Water Resources (UCOWR) Annual Meeting, June 26–28, 2018, Pittsburgh, PA.
23. Jones, A.S., J.S. Horsburgh, Z.A. Aanderud, M.A. Baker, D. Eiriksson (2018). A Monitoring Network for Sensing Water Quality and Hydrology Across Mountain to Urban Transitions, Universities Council for Water Resources (UCOWR) Annual Meeting, June 26–28, 2018, Pittsburgh, PA.
24. Buahin[*], C.A., J.S. Horsburgh., B.T. Neilson (2018). Enabling High-Performance Heterogeneous Computing for Component-Based Integrated Water Modeling Frameworks, 9th International Congress on Environmental Modelling and Software, Modelling for Sustainable Food-Energy-Water Systems, Fort Collins, CO.
25. Horsburgh, J.S., A.A. Melcher[**], B. A. Mihalevich[**] (2017). Stormwater Monitoring and Pollutant Load Estimation in Combined Agricultural and Urban Water Systems (*Invited*), Presented at: Rural Water Technology Conference, United States Bureau of Reclamation, March 8–9, 2017, Provo, UT.
26. Mihalevich[**], B., J.S. Horsburgh (2017). Resolving Spatial and Temporal Variability in Dissolved Organic Matter Characteristics within Combined Agricultural and Stormwater Conveyances, Utah State University Spring Runoff Conference, March 28–29, 2017, Logan, UT.
27. Horsburgh, J.S. (2017). Cyberinfrastructure for Water Data: Perspectives from iUTAH's Data-Intensive Water Research, (*Invited*), 45th Annual Utah Section Water Resources Conference, Data for Water Management, May 16, 2017, American Water Resources Association, Salt Lake City, UT.

28. Aanderud, Z.T., A.S. Jones, J.S. Horsburgh, D. Eiriksson, D. Dastrup, C. Cox, S.B. Jones, D. Bowling, J. Carlisle, G. Carling, M.A. Baker (2017). Transcending system boundaries through integrative ecohydrologic research, 11th Annual Salt Lake County Watershed Symposium, November 11–12, 2017, Salt Lake City, UT.
29. Eiriksson, D., A.S. Jones, J.S. Horsburgh, C. Cox, D. Dastrup (2017). Data Quality Control: Challenges, Methods, and Solutions from an Eco-Hydrologic Instrumentation Network, 2017 AGU Fall Meeting, December 11–15, 2017, New Orleans, LA.
30. Jones, A.S., J.S. Horsburgh, D. Eiriksson, D. (2017). Assessing Subjectivity in Sensor Data Post Processing via a Controlled Experiment, 2017 AGU Fall Meeting, December 11–15, 2017, New Orleans, LA.
31. Tennant[***], H., B.T. Neilson, M.L. Barnes[**], T.L. Stout[**], M. Miller, R. Gabor[*], M. Millington[**], Y. Jameel[**], A. Gelderloos[**], G. Bowen, P. Brooks (2017). Combined Approaches for Estimating Groundwater Exchanges in Karst Watersheds, May 2017, American Water Resources Spring Specialty Conference 2017, Alta, UT.
32. Jones, A.S., J.S. Horsburgh, S. Reeder, J. Caraballo[***], D. Smith[***], M. Matos[***], M. (2016). Streaming Sensor Data: Tools for Acquisition, Management, and Visualization., 10th National Water Quality Monitoring Conference, May 2–6, 2016, Tampa, FL.
33. Jones, A.S., J.S. Horsburgh (2016). Water Quality Surrogates: Development of Surrogate Relationships, Review of Recent Advances, and Applications, National Nonpoint Source Monitoring Workshop, August 23–25, 2016, Salt Lake City, UT.
34. Melcher[**], A.A., J.S. Horsburgh, B.A. Mihalevich[**] (2016). Continuous Surrogate Monitoring for Pollutant Load Estimation in Urban Water Systems, National Nonpoint Monitoring Workshop, August 23–25, 2016, Salt Lake City, UT.
35. Melcher[**], A.A., J.S. Horsburgh, B.A. Mihalevich[**], P. Suiter[***] (2016). Continuous Surrogate Monitoring for Pollutant Load Estimation in Urban Water Systems, Utah State University Spring Runoff Conference, April 5–6, 2016, Logan, UT.
36. Mihalevich[**], B.A., J.S. Horsburgh, A.A. Melcher[**] (2016). Spatial and Temporal Variability of Dissolved Organic Matter in a Stormwater Conveyance, Utah State University Spring Runoff Conference, April 5–6, 2016, Logan, UT.
37. Suiter[***], P.J., A.S. Jones, J.S. Horsburgh, B.A. Mihalevich[**], A.A. Melcher[**] (2016). Development of a Mobile Water Quality Monitoring Platform, Utah State University Spring Runoff Conference, April 5–6, 2016, Logan, UT.
38. Neilson, B.T. (2016). Understanding Groundwater Influences in Streams and Rivers, Distinguished Lecture Series, Department of Geology, Utah State University, October, 2016, Logan, UT. (INVITED).
39. Tennant[***], H. and B.T. Neilson (2016). Groundwater Influences on Logan River Watershed, USU Fall Undergraduate Research Symposium, December 2016, Logan, UT.
40. Barnes, M.L. [**], T. Stout[**], H. Tennant[***], B.T. Neilson (2015). Groundwater – Surface Water Interactions in Three Utah Watersheds, April, 2015, Utah State University Spring Runoff Conference, Logan, UT.
41. Tennant[***], H, M.L. Barnes[**], T. Stout[**], B.T. Neilson (2015). Methods and Techniques for Measuring Discharge in Three Utah Watersheds, iUTAH Summer Symposium, July 2015, Midway, UT.
42. Horsburgh, J.S., A.S. Jones, S. Reeder (2014). Automating data management and sharing within a large-scale, heterogeneous sensor network (*Invited*), 7th International Congress on Environmental Modelling and Software, June 15–19, 2014, San Diego, CA.
43. Horsburgh, J.S., A.S. Jones, S. Reeder, J. Patton[***], J. Caraballo[***], M. Ramirez[***], N. Mouzon[***] (2013). Using CUAHSI HIS to support large scale collaborative research in Utah (*Invited*), CUAHSI HIS Cyberseminar, May 1, 2013.

Appendix D:
Graduate Student Involvement with Logan River Observatory

Table D1. Graduate students that use LRO data for part of their thesis/dissertation or worked on a project focused on some aspect of the Logan River watershed.

Student Name	Degree	Department	University	Advisor	Date of Completion	Thesis/Dissertation Title	Overview of Research	Publications
Current Students								
Braedon Dority	MS	CEE	USU	J.S. Horsburgh			Low-Cost, Low-Power, In Situ Operational Snow Sensing	
Hyrum Tennant	PhD	CEE	USU	B.T. Neilson			Variability of groundwater storage in karst geology and its effects on streamflow.	
Michael Lasswell	PhD	CEE	USU	B.T. Neilson			Advance numerical modeling to understand valley surface/subsurface connectivity to optimize water management in the Intermountain West.	
Devon Hill	MS	CEE	USU	B.T. Neilson			Using natural tracers to understand hydrologic connectivity in the Logan River watershed.	
Gabriel Benitez	MS	CEE	USU	C. Phillips	Defended	Exploring variations in high-resolution downstream hydraulic geometry of the Logan River.	Linking deviations from hydraulic geometry scaling to causal mechanisms and instream processes.	
Nate Ashmead	MS	Hydrological Sciences	Boise State University	J. McNamara			Snowmelt dynamics and streamflow at the watershed scale.	
Macy Gustavus	MS	WATS	USU	J. Brahney			Sources of plastic to the Logan-Bear river system	
Dane Liljestrand	PhD	CEE	University of Utah	C. Oroza			Improving basin-scale snow depth estimation through adaptation of citizen-science collected measurements and LIDAR terrain data.	
Ruoyao Ou	PhD	CEE	Arizona State University	T. Xu			Understanding response of snow-dominated karst watersheds to climate variability using a hybrid physically based and data-driven modeling approach	
Longyang Qianqiu	PhD	CEE	Arizona State University	R. Zeng			Developing physically interpretable deep learning models to simulate hydrologic processes	
Shahin Sujon	PhD	CEE	USU	K. Moor			Microplastic photochemistry and fate in western mountainous rivers.	
Skyler Rousseau	MS	WATS	USU	T. Walsworth			Examining the climatic and landscape controls on the availability and ecological function of intermittent streams	
Amber Jones	PhD	CEE	USU	J. Horsburgh			Machine learning techniques to investigate surrogate relationships, to develop automated methods of quality assurance/quality control of hydrologic and water quality time series data, and to better understand lateral inflow variability throughout the Logan River watershed.	Jones**, A. S., T.L. Jones, J.S. Horsburgh. 2022. "Toward automating post processing of aquatic sensor data." *Environmental Modelling & Software*.151(105364).

Student Name	Degree	Department	University	Advisor	Date of Completion	Thesis/Dissertation Title	Overview of Research	Publications
								https://doi.org/10.1016/j.envsoft.2022.105364.
Completed Students								
Daniel Thurber	MS	CEE	USU	B. Lane	Dec-22	Characterizing Karst Mountain Watersheds Through Streamflow Response to Snowmelt	Exploring potential thesis topics surrounding the relationships between seasonal snowpack storage and the timing/magnitude of Spring and Summer streamflow signatures and the sensitivity of those relationships to climate change.	Thurber, Daniel Meade, "Characterizing Karst Mountain Watersheds Through Streamflow Response to Snowmelt" (2022). Master's Thesis, Utah State University.(https://digitalcommons.usu.edu/etd/8673)
Dane Brophy	MS	CEE	USU	B.T. Neilson	May-21	Testing remote sensing methods for mapping the karst features within Logan Canyon	Dane worked to determine if satellite imagery had high enough resolution information for mapping karst features. He also coarsened very high-resolution UAV imagery to determine the resolution of data needed to map known features.	Brophy, Dane P., "Testing Methods of Surficial Sinkhole Identification Using Remotely Sensed Data" (2021). All Graduate Plan B and other Reports. 1526. https://digitalcommons.usu.edu/gradreports/1526
Hyrum Tennant	MS	CEE	USU	B.T. Neilson	May-21	Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory.	Hyrum used flow, ion, and isotope data to establish detailed spatial estimates of flow losses, flow gains from ungaged lateral inflows, and flow source information throughout the urban and agriculturally influenced portion of the Logan River.	Tennant, H. 2021. "Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory." M.S. Thesis. Utah State University. All Graduate Theses and Dissertations. Tennant**, H., B.T. Neilson, M.P. Miller, T. Xu. 2021. "Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory." Hydrological Processes. https://doi.org/10.1002/hyp.14097.

Student Name	Degree	Department	University	Advisor	Date of Completion	Thesis/Dissertation Title	Overview of Research	Publications
Conor Tyson	MS	CEE	USU	T. Xu/B.T. Neilson	May-21	Effects of Climate Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed	Conor modeled snow accumulation and melt over the entire canyon portion of the Logan River watershed. These model results are being combined with machine learning approaches to link the spatial and temporal snowmelt patterns with streamflow. Conor has successfully completed his thesis and in the process of preparing a journal article for publication.	Tyson, Conor. 2021. "Effects of Climate Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed" M.S. Thesis. Utah State University. All Graduate Theses and Dissertations Tyson, C., Q. Longyang, B.T. Neilson, R. Zeng, T. Xu. (in press). "Effects of Meteorological Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed." To appear in Journal of Hydrology.
Madison Alger	MS	CEE	USU	B. Lane	Jan-21	Controls on summer stream temperature patterns in irrigation-depleted streams	Madison collected a significant amount of flow and temperature data in portion of the Blacksmith River that was dewatered due to upstream diversion structures. She used these data to investigate temperature patterns thoughout this section and how these changed when shallow groundwater from nearby irrigation canals returned to the river.	Alger, Sara Madison, "Summer Stream Temperature Patterns and Controls in an Irrigation Depleted Western Stream" (2021). All Graduate Theses and Dissertations. 8029. https://digitalcommons.usu.edu/etd/8029
Desneiges Murray	MS	WATS	USU	J. Brahney	Jan-21	The fate and cycling of nitrogen, phosphorus, and trace heavy metals in beaver-altered headwater streams	Deni collected a significant amount of inflow, outflow, and within beaver pond physical and chemical data. She used these data how beaver dams influence the fate and transport of nonpoint source pollution.	Murray, Desneiges. 2021. "The fate and cycling of nitrogen, phosphorus, and trace heavy metals in beaver-altered headwater streams." M.S. Thesis. Utah State University. All Graduate Theses and Dissertations. 8035. https://digitalcommons.usu.edu/etd/8035 Murray**, D., B.T. Neilson, J. Brahney. 2021. "Source or Sink? Quantifying beaver pond influence on non-point source pollutant transport in the Intermountain West." Journal of Environmental Management.285, 112127. https://doi.org/10.1016/j.jenvman.2021.112127 Murray, D., B.T. Neilson, J. Brahney. (in press). Beaver pond geomorphology

Student Name	Degree	Department	University	Advisor	Date of Completion	Thesis/Dissertation Title	Overview of Research	Publications
								influences pond nitrogen retention and denitrification. *To appear in Journal of Geophysical Research - Biogeosciences*.
Lindsay Capito	MS	WATS	USU	J. Brahney	Dec-20	Environmental Controls on Didymosphenia geminata Bloom Formation	Lindsay investigated controls on Didymosphenia geminate (or didymo) growth in controlled and natural systems. Didymo is a stalk forming benthic diatom species that can diminish the recreational and aesthetic value of a stream, can cause infrastructure problems such as the fouling of water intakes, and can have significant ecosystem and ecological impacts. Didymo samples are being collected downstream of the UWRL site to monitor time variable responses where blooms have repeatedly occurred. LRO data at the UWRL site will be key in interpreting didymo trends.	Capito, Lindsay, "Environmental Controls on Didymosphenia geminata Bloom Formation" (2020). *All Graduate Theses and Dissertations*. 7941. https://digitalcommons.usu.edu/etd/7941
Greg Goodrum	MS	WATS	USU	S. Null	Aug-20	Improving Aquatic Habitat Representation in Utah Using Large Spatial Scale Environmental Datasets.		Goodrum, Gregory C., "Improving Aquatic Habitat Representation in Utah Using Large Spatial Scale Environmental Datasets" (2020). *All Graduate Theses and Dissertations*. 7902. https://digitalcommons.usu.edu/etd/7902
Beth Ogata	PhD	Biology	USU	M. Baker	Aug-20	Anthropogenic Influences on Bacterial Assemblages in Stream Biofilms	Beth worked to understand anthropogenic influences on bacterial assemblages within stream biofilms, which are an integral component of stream ecosystems, alter stream biogeochemistry. More specifically, her research examined how nutrients and pharmaceuticals, ubiquitous pollutants in streams worldwide, affect bacterial assemblages in stream biofilms.	Ogata, Elizabeth M., "Anthropogenic Influences on Bacterial Assemblages in Stream Biofilms" (2020). *All Graduate Theses and Dissertations*. 7889. https://digitalcommons.usu.edu/etd/7889