Date	February 29, 2016
To	Steven J. Burian
From	Matthew Chaney, Manjot Kaur, Brittany Van Grouw
Subject	Progress Report

Purpose: The purpose of this progress report it to give an update on the project, as well as provide an outline of the project. The progress report consists of the following:

- Introduction
- Background
- Data Collection
- Methods/ Alternatives
    - Dissolved Oxygen: WEAP Analysis
    - Dissolved Oxygen: WEAP & Streeter Phelps
    - Temperature: WEAP
- Planning Ahead
- Conclusion

The project's objective is to provide the stakeholder, the Division of Environmental Quality (DEQ), with a WEAP model that assesses the dissolved oxygen levels of the Jordan River and to provide recommendations in order to reduce the impairment of the river. A Github repository can be found on the following link: https://github.com/beeveegee/JordanRiver/wiki

Introduction

The Utah Department of Environmental Quality hired Cirrus Ecological Solutions to conduct a Total Maximum Daily Load (TMDL) water quality study to analyze the levels of Dissolved Oxygen (DO), Total Dissolved Solids (TD), Escherichia coliform (E. coli), and water temperature (Temperature) in the Jordan River in Utah [1] The levels of these constituents violate water quality regulations that have been set by the state of Utah. The purpose of this project is to create a model for DO in the Jordan River using WEAP, and then evaluate different alternatives for improving the DO levels in the river.

Background

The Jordan River flows north from Utah Lake to the wetlands of the Great Salt Lake. The river has approximately 51 miles stretch across three counties: Salt Lake, Utah and Davis [1][2]. Currently the river is heavily contaminated with toxic metal and considered impaired according to EPA standards. Although the Jordan River Corridor is home to thousands of resident many are unaware of the impairments of the river. Approximately every 5 years a survey is conducted to get a public perception of the river, public awareness has declined in the recent years [3]. The surveys were conducted in 2007, 2010 and 2015. In the 2010 survey majority of residents claimed to have known that the Jordan River has poor quality, however in the 2015 survey the public awareness declined significantly many residents did not know about the quality of the Jordan River, Figure 1 illustrates the awareness of impairment within the residents.

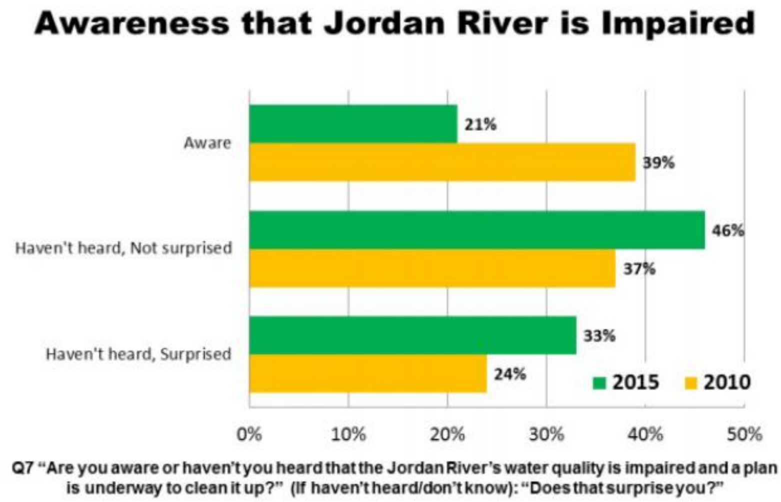

Figure 1: Awareness of Jordan River Impairment [2]

Across the 51-mile stretch the Jordan River corridor is home to thousands of residents. Currently there are plans to clean up the Jordan River and restore it back to its "natural" state. The city's vision statement can be seen below.

"The Jordan River Corridor will become recognized as a valued regional amenity that brings people together and links them with the natural world, providing unique and memorable experiences for residents and visitors alike. With the Jordan River as its heart, this 50-mile-long greenway will connect the freshwater Utah Lake with the marshlands and saline waters of the vast and scenic Great Salt Lake. Meandering through the center of the highly urbanized Salt Lake Valley, the Jordan River corridor will be a continuous system of natural areas, recreation and nature trails, and parks, providing a wealth of opportunities for people to experience and learn about the natural world and enjoy the outdoors….Rundown industrial areas will be reborn into welcoming river centers where residents can enjoy a meal overlooking the river, take a rejuvenating walk during the lunch hour or rent recreational equipment. These "centers" will become places for community gathering and neighborhood renewal"[2]

The basic idea is the city want to restore the Jordan River back to its natural state, however this project has a significant cost association.

The primary stakeholder for this project is the Utah Department of Environmental Quality, specifically the Division of Water Quality (DWQ). "DEQ's mission is to safeguard public health and our quality of life by protecting and enhancing the environment. We implement State and federal environmental laws and work with individuals, community groups, and businesses to protect the quality of our air, land and water".

The DWQ has specified the beneficial water uses for the Jordan River as follows in Table 1.

Table 1: Classification of Beneficial Use [4]

Classification	Description
Class 1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water
Class 2B	Protected for secondary contact recreation such as boating, wading, or similar uses
Class 3A	Protected for cold-water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Class 3B	Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain
Class 3C	Protected for nongame fish and other aquatic life, included the necessary aquatic organisms in their food chain.
Class 3D	Protected for waterfowl, shore birds and other water-oriented wildlife not included in classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain
Class 4	Protected for agricultural uses including irrigation of crops and stock watering

The Jordan River was divided into eight water quality segments referred to as DWQ segments. Figure 3 in the Appendix shows the layout of the segments as well as the constituents that violate water quality regulations. From the Jordan River TMDL, Figure 4 includes more detail of how these constituents affect the DWQ segments along the river. Dissolved oxygen affect Class 3B and 3C activities for DWQ segments 1 through 3.

The stakeholder's objectives as listed in the Jordan River TMDL were the following:

- "The purpose of this TMDL study is to define water quality endpoints that will restore the aquatic life beneficial use to segments impaired by OM and resultant low DO based upon the best information available."

- “Future studies are needed to help refine our understanding of OM sources, loading and habitat limitations to the Jordan River.”

The Results of the Jordan River TMDL presented the following:

The total maximum daily load report (TMDL) for the Jordan River was approved by the EPA in June 2013. According the report major concerns for the Jordan River are associated with the organic matter and the dissolved oxygen levels of river. Violations for temperature and total dissolved solids also exist, however this is solely due to natural causes. The model they used for their study showed a strong relationship between Total Organic Matter (OM) and DO. The only section of the Jordan River listed as impaired for DO is downstream of the surplus canal, which is north of 2100 south in Salt Lake City. DO deficits occur year round, but are generally greatest in late summer and early fall. The sources of OM pollution they examined included point sources (wastewater treatment plants, storm water outfalls) and nonpoint sources (Utah Lake, other tributaries, diffuse runoff, etc.). They also projected future OM loads, which were based mainly on population growth.

Finally, the report established the maximum permissible concentration of OM that could be tolerated and still maintain DO levels that fully support designated beneficial uses. According to their model, to reach the target DO levels the various sources of OM would need to reduce their loads between 27 and 54 percent. In order to accomplish this, significant investment will be required, as well as additional data to more accurately assess OM loading. Over the course of this project, our team will develop tools that can be used alongside the work that has already been done, as well as develop alternatives to improve the DO levels in the Jordan River.

Data Collection

The Jordan River has been studied and monitored by the DEQ extensively, Nathan Lunstad from the division of DEQ was contacted in order get access to the data. Mr. Lunstad suggested using the Ambient Water Quality Monitoring System (AWQMS). The system is a public system specifically designed for water quality data. In order to access the system a request has to be sent in. We are still waiting for access to this system. Stream flows for the WEAP model will be collected from United States Geological Survey (USGS) stream gauges and stream flow and rainfall historical data provided by Salt Lake County [5]. If necessary, weather data will be collected from NOAA and/or the iUTAH Gradients Along Mountain to Urban Transitions (GAMUT) monitoring sites.

Methods

The goal of using the WEAP model is to use the temperature and BOD data to model the DO levels in the river, and then use the different scenarios to determine ways to improve the DO levels in the river. The group has developed multiple alternatives for the next steps of the project based on the outcome of data availability. Each option requires a basic schematic of the Jordan River Watershed Network in WEAP. A simple schematic has been created and is shown in Figure 6 in the Appendix. This schematic was created using a shape file converted from a KMZ file provided by AECOM's Water Resources Department in Salt Lake City. The shape file was imported into WEAP as a background to allow for easier creation of the schematic. The group plans to analyze DO levels in the Jordan River either using WEAP or WEAP in conjunction with the Streeter Phelps Equation. If the necessary data is not available to complete either of these analyses, high temperature levels will be analyzed in WEAP.

DO: WEAP Analysis

Water quality modeling must be enabled to model water quality constituents such as DO, Biochemical Oxygen Demand, and Temperature. WEAP uses a built-in DO model to simulate changes to DO along the river. The DO model uses BOD as an input, therefore BOD data is necessary. The process to model BOD in WEAP requires temperature data (degrees Celsius) to be entered for each reach or modeled using WEAP [6]. If the AWQMS provides enough data to satisfy these requirements, this will be the primary method to model dissolved oxygen along the Jordan River.

DO: WEAP & Streeter Phelps

It is possible that WEAP is not capable of modeling DO. If this does occur, the group will utilize WEAP to calculate basic flow data for the Jordan River, input it into the Streeter Phelps equation, and conduct a regression analysis to determine the results of different scenarios to reduce the DO concentration in the Jordan River. The Streeter Phelps oxygen-sag curve equation is listed below in Figure 2 where D is the saturation deficit, KD is the deoxygenation rate, KR is the reaeration rate, L0 is the initial oxygen demand of organic matter in the water (BOD), D0 is the initial oxygen deficit, and t is the elapsed time [7].

$$D = \frac{k_D L_0}{k_R - k_D}\left(e^{-k_D t} - e^{-k_R t}\right) + D_0 e^{-k_R t}$$

- This is the Streeter-Phelps oxygen-sag curve formula
- Note that for a constant stream cross-section, t=x/u (with u=stream velocity); therefore:

$$D = \frac{k_D L_0}{k_R - k_D}\left(e^{-k_D x/u} - e^{-k_R x/u}\right) + D_0 e^{-k_R x/u}$$

Figure 2: Streeter Phelps Equations [7]

Temperature: WEAP Analysis

If the necessary data to model DO is not acquired from the AWQMS, we will transition our project to focus on the high temperature values that are observed in DWQ segments 5 through 8. The temperature will be modeled by using a combination of water temperature data entered for a reach as well as utilizing climate stations to model temperature in WEAP. This will be done by collecting data such as air temperature, humidity, wind, and latitude from nearby weather stations. This data will be entered under the "Climate" tab for each reach. Different scenarios will be simulated in the WEAP model to determine ways to lower the temperature levels in the Jordan River.

Planning Ahead

Over the course of the next few weeks, the group will decide which course of action to take regarding the process to evaluate dissolved oxygen or to analyze temperature in the Jordan River. The WEAP schematic will be developed further to be able to calculate the flows through the Jordan River based on provided data from the AWQMS and USGS stream gauges. Additional nodes will be added to the WEAP schematic based on information used in the Jordan River TMDL. This information includes locations of water/wastewater treatment facilities and point sources.

A demonstration of the model will be conducted March 24, 2016 to show how the objectives and performance metrics for our stakeholder are implemented in the model. In addition, development of the GitHub page will continue. The final webpage will include electronic copies of model input data, modeling files, and results such that the reader can replicate the work completed by the group.

Conclusion

The group's primary focus is to analyze dissolved oxygen levels in the Jordan River using WEAP or the Streeter-Phelps equation. Management alternatives to meet the Department of Water Quality's objectives will be evaluated and chosen based on our analysis. If there is insufficient data, or we are unable to access the data from the Ambient Water Quality Monitoring System, the group will simulate high temperatures in the Jordan River and determine through various scenarios the best alternative to lower the temperature in the river.

Appendix A: References

1. *Jordan River Total Maximum Daily Load Water Quality Study - Phase 1*. Logan, Utah: Cirrus Ecological Solutions, LC, 5 June 2013. PDF.
2. Salt Lake City County. "Blueprint Jordan River." *Blueprint Jordan River*. Salt Lake City County, Dec. 2008. Web. 01 Mar. 2016. <http://www.slco.org/blueprint/>.
3. Salt Lake County. *Watershed Public Opinion Survey*. Rep. Salt Lake: Salt Lake County, 2015. Web< http://slco.org/watershed/pdf/2015PublicSurvey_Ful.pdf..
4. Salt Lake City County. "Watershed Planning and Restoration Program." *Water Quality*. Salt Lake City County, n.d. Web. 01 Mar. 2016. <http://slco.org/watershed/wtrQual/wqBenificial.html>.
5. Salt Lake City County. "Flood Control Engineering." *Real-time Streamflow Totals-Flood Control*. Salt Lake City County, n.d. Web. 01 Mar. 2016. <http://slco.org/flood-control/real-time-streamflow-totals/>.
6. Sieber, Jack, and David Purkey. *Water Evaluation And Planning System User Guide*. Somerville, MA: Stockholm Environment Institute, U.S. Center, Aug. 2015. PDF.
7. Benoit, Anthony G. "ENV 2101 - The Streeter-Phelps Equation." *ENV 2101 Principles of Environmental Engineering*. Environmental Engineering Technology at Three Rivers Community College, 04 June 2010. Web. 25 Feb. 2016. <http://environmentalet.hypermart.net/env2101/sagcurve.htm>.

Appendix B: Figures

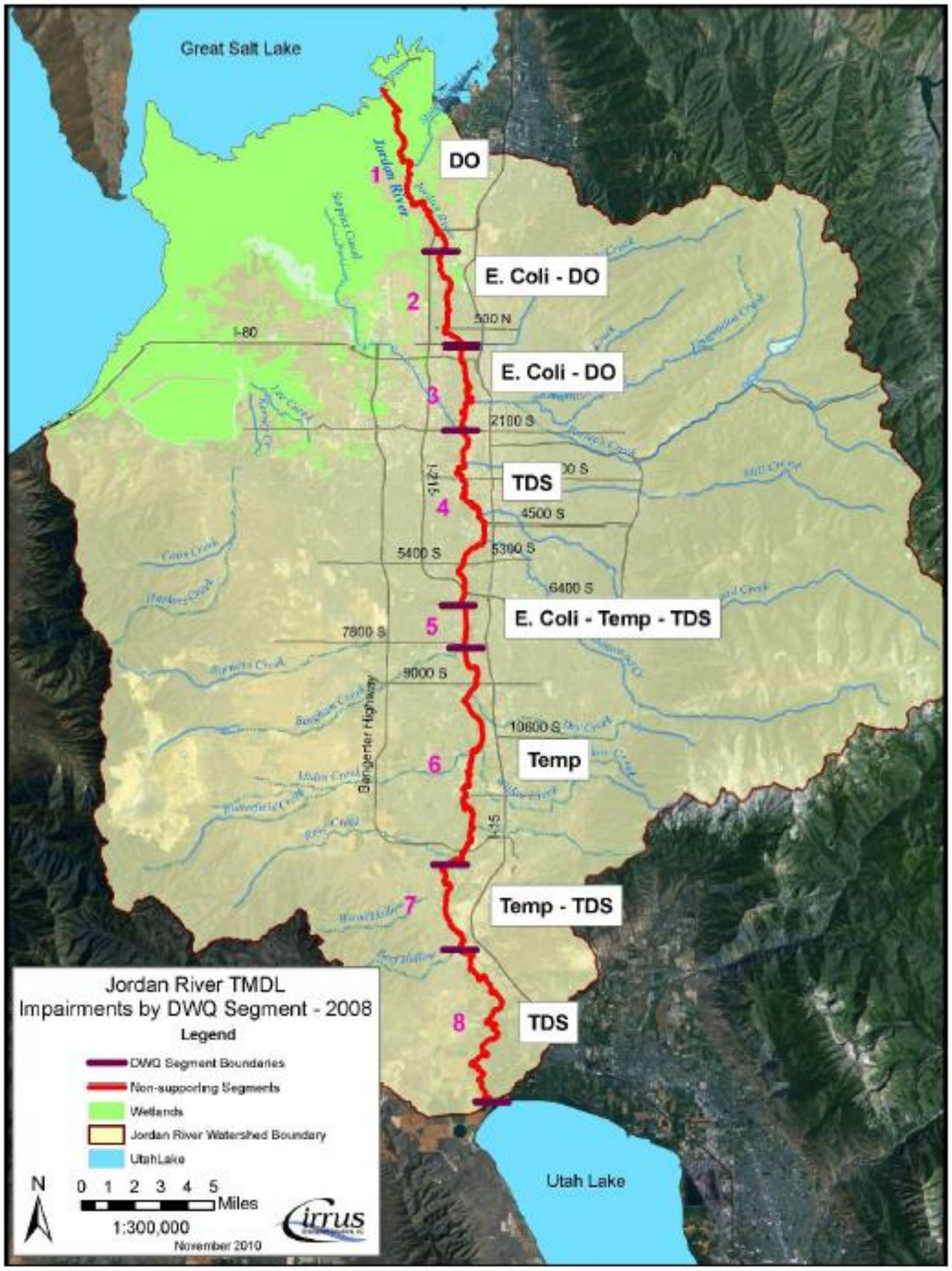

Figure 3: Location of DWQ segments and corresponding pollutant of concern [1]

DWQ Segment	Beneficial Use and Support Status [1]							(Beneficial Use) Pollutant of Concern	Standard or Pollution Indicator Level [2] for Pollutant of Concern
	River Mileage	1C	2B	3A	3B	3C	4		
1	0–6.9				NS	NS		(3B) Benthic Macro Impairment[2] (3B) Organic Enrichment/Low DO (3C) Organic Enrichment/Low DO	(3B) O/E ratio[3] >0.74 or >0.54 per sample size (3B) Min: Aug–Apr = 4 mg/L, May–Jul = 4.5 mg/L (3C) 30-day avg DO = 5 mg/L
2	6.9–11.4		NS		NS			(2B) *E. coli* (3B) Benthic Macro Impairment (3B) Organic Enrichment/Low DO	(2B) Max=940 col/100 mL, Geo. Mean=206 col/100 mL (3B) O/E ratio >0.74 or >0.54 per sample size (3B) Aug–Apr = 4 mg/L, May–Jul = 4.5 mg/L
3	11.4–15.9		NS		NS			(2B) *E. coli* (3B) Organic Enrichment/Low DO (3B) Total Phosphorus	(2B) Max=940 col/100 mL, Geo. Mean=206 col/100 mL (3B) Aug–Apr = 4 mg/L, May–Jul = 4.5 mg/L (3B) 0.05 mg/L (pollutant indicator level)
4	15.9–24.7			[4]			NS	(4) Salinity/TDS/Chlorides	(4) 1,200 mg/L
5	24.7–26.4		NS	NS			NS	(2B) *E. coli* (3A) Temperature (4) Salinity/TDS/Chlorides	(2B) Max=940 col/100 mL, Geo. Mean=206 col/100 mL (3A) Max = 20°C (4) 1,200 mg/L
6	26.4–37.6			NS				(3A) Benthic Macro Impairment (3A) Temperature	(3A) O/E ratio >0.74 or >0.54 per sample size (3A) Max = 20°C
7	37.6–41.8			NS			NS	(3A) Benthic Macro Impairment (3A) Temperature (4) Salinity/TDS/Chlorides	(3A) O/E ratio >0.74 or >0.54 per sample size (3A) Max = 20°C (4) 1,200 mg/L
8	41.8–51.4	[1]		NS			NS	(3A) Benthic Macro Impairment (3A) Temperature (4) Salinity/TDS/Chlorides	(3A) O/E ratio >0.74 or >0.54 per sample size (3A) Max = 20°C (4) 1,200 mg/L

Table 1.1. DWQ segments of the Jordan River included on the Utah 2008 303(d) List (Utah DWQ 2008a).

[1] Shaded cells indicate beneficial uses assigned to each DWQ segment. NS indicates non-support of the assigned beneficial use.
[2] Benthic macroinvertebrate impairment is based on pollution indicator values.
[3] O/E ratio – the measured ratio of observed macroinvertebrate species to expected macroinvertebrate species (Utah DWQ 2008b).
[4] Beneficial use class 3A applies to DWQ Segment 4 above the confluence with Little Cottonwood Creek.

Figure 4: DWQ segments of Jordan River with corresponding impaired beneficial uses [1].

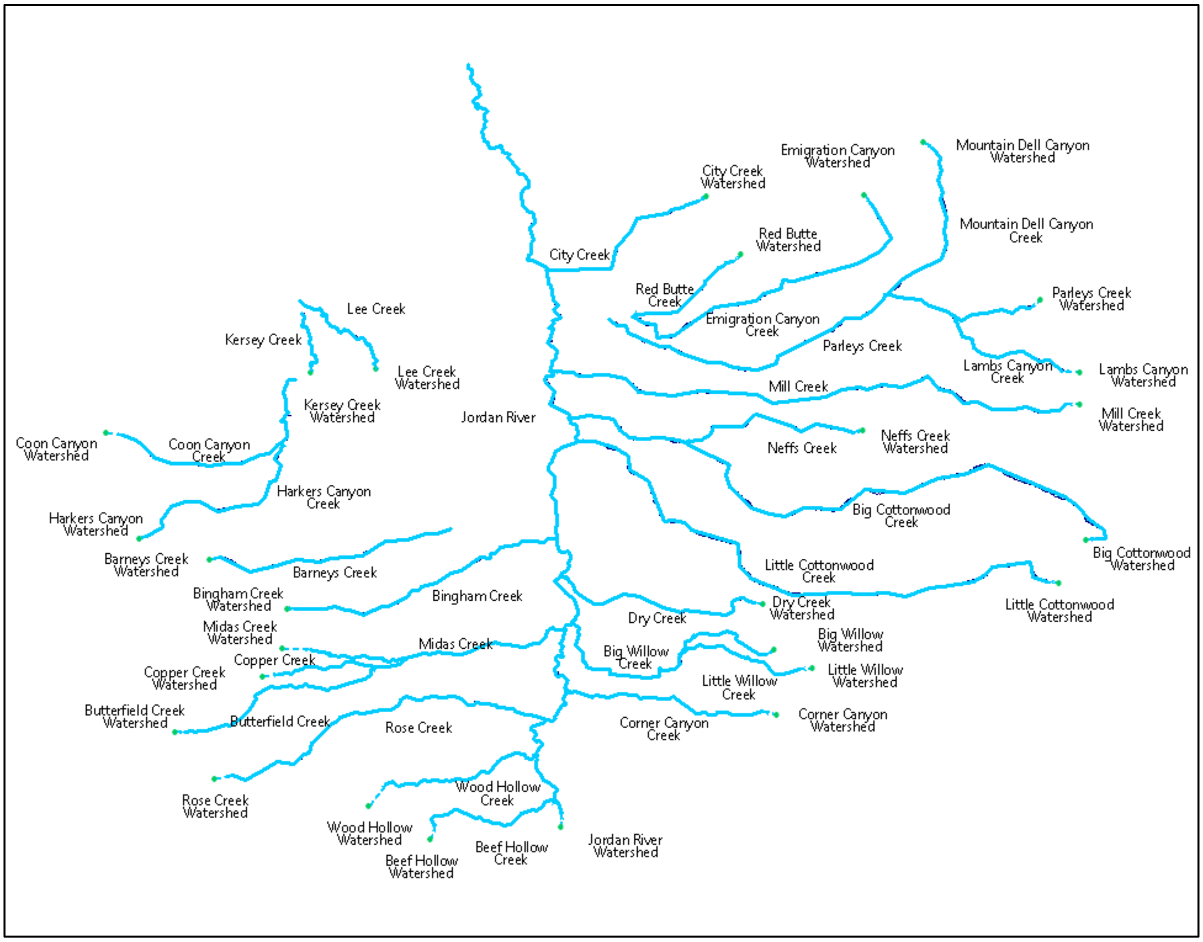

Figure 5: Basic schematic for WEAP model with Rivers and Catchments.