A preliminary organic matter budget for the Jordan River, Salt Lake County, Utah

Aquatic Biogeochemistry Laboratory, Utah State University

Final Progress Report, 10-October-2014

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Glossary of Terms and Acronyms:

Ash-free dry mass (AFDM) – a measure of the organic content of a given sample.

Bedload - referring to the transport of material along the "bed" or bottom of a river. Bedload is generally thought of in terms of inorganic material such as sand and gravel but may be composed of organic material in certain rivers.

Benthic – referring to the bottom of a water body. Benthic samples are taken from the bottom of a lake or river.

Coarse particulate organic matter (CPOM) – the fraction of the particulate organic material in a stream that is too large to fit through a 1 mm sieve.

Dissolved organic matter (DOM) – the fraction of the organic carbon pool suspended in the water column that moves through a 0.7 µm filter.

Dissolved oxygen (DO) - O_2 dissolved in the stream water.

Fine particulate organic matter (FPOM) – the fraction of the pool of organic matter that does not fit through a 0.7 µm filter but is not captured by a 1 mm sieve (sometimes referred to as VSS). For the purposes of this study the FPOM measurements had the units of mg-C L^{-1} and were not a measure of total organic matter.

Litterfall – the total mass of plant material that falls to the ground per unit area

Organic matter – organic material, generally of plant origin

Sonde – an automated water quality instrument that can be deployed in a river capable of taking regular DO, temperature and other measurements

Surplus Canal – the man-made channel that diverts a large portion of the Jordan River at 2100S and conveys it to the Great Salt Lake.

Total suspended solids (TSS) – the total pool of material (inorganic and organic) that doesn't fit through at 0.7 µm filter but passes through a 1 mm sieve.

Volatile suspended solids (VSS) – the organic portion of TSS, see FPOM (above)

Total maximum daily load (TMDL) – the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.

Background

Water quality in the Jordan River is impaired by low concentrations of dissolved oxygen (DO), particularly in lower segments of the river. Dissolved oxygen is consumed during aerobic decomposition of organic matter (OM) and by oxidation of inorganic chemical species such as ammonia and methane gas. In the absence of these inorganic species, there could be a direct link between measures of OM and DO.

Aside from its relevance to water quality, OM is a key state variable in aquatic ecosystems, representing the base energy available for much of the food web. Thus understanding the sources and fate of OM in rivers such as the Jordan (little is known about the sources and fate of OM in urban rivers) is of fundamental importance. Water quality modeling using QUAL2Kw indicated that OM from outside the impaired segments was likely responsible for DO depletion within those segments. Specific sources of this OM are not known and need to be investigated.

Work Plan (from proposal)

The Jordan River will be divided into 6 study units and instrumented for measurement of organic matter (OM) fluxes and standing stocks at each location. The 6 study units will be established after agreement by the Jordan River TAC, but will include locations upstream and downstream of 2100 S. Preliminary suggestions included: Jordan River Narrows, 7800 S, 5400 S, 2100 S above and below the Surplus Canal diversion, 1800 N, and Cudahy Lane. The following are the tasks to be completed:

1. Continuous monitoring of stream flow and DOM and SPOM fluxes
2. Discrete deployments of sondes to measure biological fluxes
3. Continuous monitoring of dissolved oxygen using optical sensors
4. Discrete measurement of CPOM fluxes to each sample location

5. Discrete measurement of benthic organic matter standing stocks

Participants

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Collaborators

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Status Update

The end of September 2013 marked the end of the water year and the data collection phase of the project. Since August 2012 we had been monitoring discharge and collecting samples at seven sites along the Jordan River monthly to biweekly. The seven sites selected by the TAC include: 7800S, 5400S, 3300S, 2300S, 1700S, 500N, and Cudahy Lane. Including our last sampling date on September 27, 2013, we ended up sampling the seven sites a total of twenty times over the course of the water year.

Biweekly to monthly sampling included the collection of water chemistry, fine particulate organic matter (FPOM), Chlorophyll *a* (Chl *a*), and coarse particulate organic matter (CPOM) samples. In addition to regular sampling of organic matter in transport at all sites, we canoed the study section of the Jordan River quarterly, collecting benthic biomass samples and taking measurements to estimate organic matter standing stocks within each of our reaches. We have generated a large dataset that is now being used to create an organic matter budget for each of our river segments. All samples were collected and processed at the Aquatic Biogeochemistry Laboratory as quickly as possible.

We developed stage-discharge relationships for five of the seven sites, as discharge was measured during most sampling trips and stage data were downloaded periodically (recorded automatically every 15 minutes). Discharge data for 1700S and 500N sites were obtained from USGS and Salt Lake County's online gauges (respectively). Additionally, USGS discharge data from 1700S and surplus canal gauges were used to supplement our dataset for the 2300S site for the time period after the gauge was vandalized and subsequently removed from the site.

Baskets for litterfall collection were deployed from September to early December and litterfall samples (analyzed as AFDM) were used as a proxy for the maximum amount of plant litter directly falling into the river during the fall. Periodically through the year, water quality sondes were deployed at five of the seven sites, and then at all seven sites in February and March. Most recently sondes were deployed at five of the seven sites during the end of July while air temperatures were extremely high. During each deployment, dissolved oxygen and temperature data were collected every ten minutes and will be used to estimate stream metabolism. Additionally, we continuously measured DO and temperature at two sites (3300S and Cudahy Ln) using Mini DO_2T loggers (PME Inc., Vista, CA).

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Photo 1. A litterfall basket deployed along the Jordan River during the fall of 2012.

Photo 2. Julie Kelso during winter benthic standing stock sampling of the Jordan River.

Outreach

A website for the project was developed through Google Sites and made available to the public. The website contains the basic project information such as the sampling sites, protocols, and calendar showing the schedule of project activities. https://sites.google.com/site/jordanriveromstudy/

Products

Protocols - As mentioned above, we developed protocols for all aspects of our work, which are available on the project website. Sampling protocols include:

-Total and volatile suspended solids (TSS and VSS) and dissolved organic matter (DOM)

-Coarse particulate organic matter (CPOM) flux in bedload and water column (including the water surface)

-Water chemistry and chlorophyll *a*

-Benthic organic matter standing stock

A final report is in preparation and will be submitted to the UDWQ later this year.

Contributions

This projects aims to address data gaps identified during phase 2 of the Jordan River TMDL. The organic matter budget in development will help to complete water quality modeling of the river and will help to identify sources of organic matter as part of the TMDL process. The identification of "problem reaches" contributing excessive amounts of organic matter will be crucial to the effort to improve water quality in the Jordan River.

Results

Since the completion of the 2011 TMDL, organic matter has been recognized as a pollutant of concern, contributing to the dissolved oxygen impairment in the lower Jordan River. Modeled after previous studies in relatively pristine watersheds, we constructed an OM budget for a 35 km reach of the Jordan River to understand OM sources and sinks as they relate to the DO impairment. Following in line with the traditional dogma in stream ecology, we discovered the largest OM pool to be in dissolved form; however, DOM did not appear to be entirely generated from CPOM origin. Even though significant inputs of CPOM are clearly visible in the river at different times of year, the total transport of CPOM is relatively insignificant to the total OM budget. We found the 7800 South – 5400 South and 3300 South – 2300 South reaches to contribute disproportionally to the overall OM load, thus increasing OM inputs and exacerbating water quality problems in the lower river.

Our sampling of the Jordan River during the 2013-2014 water year generated an informative picture of organic matter (OM) transport. Important changes in OM transport between reaches were largely influenced by changes in discharge and key inputs to certain reaches. Discharge followed a fairly typical seasonal trend with the highest flows during the spring runoff; however, storm events in July and to September resulted in peaks in the hydrograph (Figure 1, Table 1). Even though discharge was a major driver of the magnitude of transport, the greatest transport of DOC and FPOM occurred during fall and summer months, respectively (Figure 2, Table 1). The concentration of DOC was greatest in fall months while FPOM was most concentrated during the late spring and summer. The transport of CPOM was greatest in May and September, corresponding with growth and shedding of riparian vegetation. However, CPOM typically was less than 5% of the total OM in transport in any given month. Due to the dominance of DOC in the OM budget, total OM transport was also greatest during the fall months of October and November.

As shown in Figure 3, discharge increased incrementally with distance downstream from 7800S to 2300S, and the 2300S site conveyed the highest discharge of our seven sample locations consistently throughout the year. Due in part to the elevated discharge at the site, the transport of organic matter through the 2300S site was estimated to be the highest among all sample sites (Figure 3, 4a, Table 1). However, as discharge and material transport predictably increased with distance downstream, the continuum of the Jordan River was disrupted at 2100S where the Surplus Canal diverts a large portion of the river’s flow.

Therefore the magnitude of OM transport through the lower Jordan River (downstream of 2100S) is much lower than it is through the upper river at 2300S. This suggests that we might consider the upper and lower sections of the river somewhat differently, as net transport through the different reaches is not very comparable.

Given that discharge increased with distance downstream (up until 2300S) in the Jordan River and that OM transport through 2300 South was the greatest, much of the increase in material transport could be largely driven by the increase in flow. To better understand changes in OM, we expressed the data as “yield” by dividing transport rates by the area of the contributing watershed at each site (Figure 4b). This analysis stresses the importance of the 7800S - 5400S and 3300S - 2300S reaches in contributing OM to the Jordan River, as the large increase in OM transport in the 7800S-5400S and 3300S-2300S reaches cannot be attributed to increasing contributing watershed area. Clearly there are important inputs of OM into these reaches that are either more concentrated than the Jordan River itself or that cause an increase in OM production in the river. Our analysis indicates that the increases in OM are largely in the form of DOC and FPOM as CPOM inputs were relatively small (Figure 4).

While the OM-rich Jordan River transports algae, macrophytes, leaves, flowers and branches as part of CPOM, our analysis shows that the magnitude of CPOM transport is much less significant than that of DOC and FPOM (Figure 4). We sampled CPOM extensively throughout the water year, both along the streambed and at the water surface, and found the transport to be extremely variable. In an attempt to capture this variability we adjusted the time of collection regularly to ensure the collection of sufficient material for AFDM analysis. We were physically unable to collect and analyze large material such as branches that would not have been feasible to sample and analyze, and we therefore acknowledge that our estimates are conservative. While the variable nature of CPOM flow through the river makes generating reliable CPOM transport estimates a challenge, completely accurate CPOM estimates may not be essential in the total OM budget as CPOM estimates are 1-2 orders of magnitude lower than FPOM and DOC estimates. Even though a portion of the CPOM pool may be readily decomposed and/or broken down into DOM or FPOM fractions, the relative dominance of other OM sources make them much more important in the OM budget as it relates to DO impairment in the lower river.

Litterfall estimates at the 7 sample locations were quite variable in time, space and composition. Samples mainly included leaves (cottonwood, tamarisk, willow, reed canary grass, etc.), branches, macrophytes and filamentous algae, but not all sample types were found at all sample locations. Litterfall baskets were placed on the stream banks and not within the channel and estimates were made with the assumption that 1/3 of total litterfall enters directly into the channel (Fisher 1977). During the spring there was a massive contribution of Russian elm seeds to the river, many of which ended up in our CPOM samples. Litterfall estimates ranged from just 0.13 g-C m^{-2} d^{-1} (AFDM) at 2300S to 0.86 g-C m^{-2} d^{-1} at 5400S. Estimates for total litterfall in each of the reaches for the entire fall of 2012 were on average 1,418 kg-C and ranged from 184 kg-C at 2300S to 3,251 kg-C at 5400S Litterfall may have contributed up to 48% of the CPOM transport at some sites; however, CPOM did not make up more than 1% of total OM transport through the river.

There was a fairly clear change in the composition of CPOM from the upper to the lower limit of the river segment of interest. At the two uppermost sample locations (7800S and 5400S) there was a dominance of filamentous algae in CPOM samples; particularly during the early spring (Photo 3). Long green-brown filaments were captured from the water column, which formed large conglomerates within the sample nets. This contrasted dramatically with the overwhelming dominance of allochthonous plant material in CPOM samples from the lower river, which mainly included flowers, seeds, sticks and leaves (Photo 3). Annual CPOM transport averaged 12,600 kg yr^{-1}, but the highest estimate was at 2300 South (27,514 kg yr^{-1}) and the lowest at 1700 South (6,023 kg yr^{-1}). CPOM was only ~1% of total annual OM transport through the river. Estimates at 1700S were likely reduced due the removal of coarse materials by the 2100 South diversion structure.

FPOM transport was an order of magnitude greater than CPOM transport and was greatest in spring and summer months (Figure 4). Partially due to a reduction in flows out of Utah Lake, winter flows were generally less turbid and FPOM estimates were therefore reduced during winter months. The analysis of total FPOM transport revealed increased transport with each downstream site until 2300S, after which there was a dramatic decrease due to the Surplus Canal diversion. Estimated transport at 7800S was 39,845 kg-C yr^{-1}, 208,425 kg-C yr^{-1} at 2300S, and was 86,460 kg-C yr^{-1} at Cudahy Ln. Yield values followed a similar trend, although the only increases in FPOM transport were in the 7800 South - 5400 South and 3300 South -2300 South reaches, thus identifying these reaches as the "gaining reaches." Yield at 7800 South was 64.1 kg-C km^{-2} yr^{-1}, 174.9 kg-C km^{-2} yr^{-1} at 2300 South and was 51.1 kg-C km^{-2} yr^{-1} at Cudahy Ln. FPOM was on average about 8% of total OM transport. Transport estimates for each site are included in the data supplement.

DOC transport was an order of magnitude greater than FPOM transport and was greatest in fall months (Figure 4). The highest concentrations of DOC at all sites were sampled from October to April (~20 mg L^{-1}), after which concentrations were lower and fairly stable through the rest of the year (~5 mg L^{-1}; Figure 6). Concentrations appeared to increase significantly at the 2300S site and were overall greater in the lower river than in the upper river (above 2300S). The transport of DOC dominated the Jordan River OM budget as it was the most abundant form of OM moving through the river. This transport increased with distance downstream from 7800S to 2300S, but decreased in the lower river due to the water diversion from the Surplus Canal (at 2100S). The greatest increase in DOC transport was within the 3300 South -2300 South reach and there appeared to be a smaller input into the 7800 South -5400 South reach. Estimated DOC transport at 7800 South was 737 tonnes yr^{-1}, 3,427 tonnes yr^{-1} at 2300 South and 1,461 tonnes yr^{-1} at Cudahy Ln. In gross transport numbers, DOC made up about 91% of the total OM budget. The DOC yield at the different sites followed a similar trend to gross transport with 1,188 kg-C km^{-2} yr^{-1} at 7800 South, 2,877 km^{-2} yr^{-1} at 2300 South and 867 km^{-2} yr^{-1} at Cudahy Ln. Yield analysis further identified the 7800 South – 5400 South and 3300 South – 2300 South reaches as the gaining reaches (Figure 4b).

To further examine the change in OM transport from the upper to lower river we attempted to correct for the loss of flow into the Surplus Canal. The transport of OM through the 2300 South site was dramatically higher than all other sites, and we hoped to further isolate the influence of flow on OM transport. To do this we added the diverted flow of the Surplus Canal to the discharge measured at each of the sites in the lower river before calculating OM transport. This analysis clarified the dominant influence of flow in determining total OM transport. When we add the flow in the Surplus Canal back to the lower river in a hypothetical scenario, we see that transport rates through the furthest downstream sites would be very close in magnitude to those estimated at 2300 South (Figure 5). This result may not be shocking as the measured concentration of OM samples in the lower river sites were quite similar to those at 2300S (Figure 6) and the hypothetical discharge increased with distance downstream. The gross transport through each site would have been quite similar to that of 2300 South, except for at Cudahy Ln, where there is a clear increase in OM transport (Figure 5a). However, in examining the OM yield, it is clear that the gross increase in OM transport would be fairly small compared to those in the 7800S-5400S and 3300S-2300S reaches, as the yield (transport per watershed area) would decrease at each downstream site in the lower river (as contributing watershed area increases; Figure 5b). This exercise helps to clarify OM transport dynamics in the lower river and to isolate the influence of discharge. It seems unlikely that there are major OM inputs (other than inputs of similar concentration to the river) in the lower river and becomes clear that water quality conditions downstream of 2300 South stay fairly consistent between sites.

Significant water quality changes appear to take place between the upper and lower river (2300S serving as the point of distinction), as DO concentrations decrease, turbidity increases and autotrophic production decreases. Figure 7 demonstrates this reduction in in-stream production where Chlorophyll *a* (Chl a) concentrations were much greater in the upper river than the lower river but on average Chl *a* was only a small proportion (~2%) of total FPOM. Concentrations of Chl *a* were greatest at 5400S (~20 μg L^{-1}) and decreased steadily until 500N and Cudahy Ln (~5 μg L^{-1}). Conglomerates of filamentous algae could commonly be seen in the water column at 5400S during sampling trips. The ratio of FPOM to Chl *a* in the water column increased with distance downstream and dramatically from 3300S to 500N, demonstrating a reduction in Chl *a* in the water column in the lower river. (Chl *a* found in algal cells was a portion of total FPOM and therefore the flux of Chl *a* was incorporated into the transport of FPOM.) This ratio appeared to change very little at the lowermost three sites, which indicates the river takes on a consistent character below the Surplus diversion.

Benthic biomass sampling added further evidence of the change in character in the lower section of the river. This is clearly depicted in Figure 8 as the proportion of each substrate type contributing to the total fine benthic organic carbon (FBOM) estimated in each reach changes dramatically from 7800S to 500N. While the OM pool sampled in the 7800S, 5400S and 3300S reaches was mostly contained on gravel substrates, there were important contributions from rock, wood and fine sediments, with fines contributing a greater portion with greater distance downstream. This contrasts dramatically with the 2300S, 1700S, and 500N reaches, where the vast majority of OM was contained within fine, soft sediments. Substrate surveys throughout the river indicated that downstream of the Surplus diversion the benthic cover is almost entirely fine, soft sediment. These fine sediments are rich in OM and due to the increasing dominance of fine sediments in the lower sites; the estimated standing stock of OM increases with distance downstream in the lower portion of the river (Figure 9).

Our estimates indicate that the annual transport of OM through the Jordan River is much greater than the standing stock of FBOM for most reaches. In fact, the annual transport of FPOM is more than an order of magnitude greater than the estimated FBOM standing stock for all reaches (Table 1). The ratio of FPOM transport to FBOM biomass is the lowest for the 1700S-500N and 500N-Cudahy Ln reaches, due to extensive fine benthic sediments and the high concentration of OM in the sediments. Our data also show that the reaches from 1700S-500N and 500N-Cudahy Ln may be net sinks for OM, with reductions in FPOM yield (Figure 4b). These observations are consistent with past research or conventional wisdom that the river downstream of the Surplus diversion is largely depositional.

Metabolism estimates generated from dissolved oxygen and temperature measurements indicated a gradient from net autotrophy to net heterotrophy with distance downstream. Diel variations in DO concentreations were very high at the uppermost sites and quite low in the lower river, particularly Cudahy Ln (Figure 10). Estimates of reaeration (K) varied both seasonally and between sites but overall a reduction in channel slope with distance downstream resulted in lower reaeration values at sites in the lower river. Average reaeration estimates varied from ~0.4 – 14 d^{-1} where the highest estimates were made at the furthest upstream sites and lower reaeration estimates were associated with the lower river. As expected, the sites with the highest reaeration estimates also were the most autotrophic (7800 South and 5400 South). Metabolism estimates ranged from -5 to 21 g-O_2 m^{-2} d^{-1} with the highest values estimated in the upper river and negative values associated with the lower river. The highest reaeration and metabolism estimates were made at 5400S, which was a highly productive and stream reach with a high gradient.

Organic matter loads throughout the Jordan River are elevated due to anthropogenic influences within the watershed. Our analysis indicates that the increases in OM transport are concentrated in two reaches within the upper river, 7800 South – 5400 South and 3300 South – 2300 South and that DOC was the largest pool of OM transported through the system. Given the estimated spiraling lengths for this carbon (38-68 km), these inputs are likely delivered to the lower river where they contribute to the dissolved oxygen deficit. High estimated uptake velocities indicate there is high demand for water column nutrients and carbon from heterotrophic organisms in the river. This increased transport of OM from the upper river could explain the consumption of DO in the lower river as heterotrophs consume DO in the OM removal process.

Conclusions

Our initial results lend the following conclusions:

1. CPOM transport is variable in space and time, but is much lower in magnitude than FPOM and DOC.
2. The reaches between 7800S-5400S and 3300S-2300S could be described as “problem reaches” because both reaches have an increased OM yield. The majority of OM increase is not CPOM, but rather unmeasured inputs of FPOM and DOC. These reaches warrant further study to quantify the character and definitive source of both OM pools, and their potential contribution to oxygen consumption.

3. Downstream of the Surplus Canal diversion OM yield is reduced, both due to a reduction in the concentration of DOC and FPOM and a dramatic reduction in discharge.
4. Settling of FBOM contributes to FBOM standing stock in river sediments below the surplus canal. Presumably this would contribute to sediment oxygen demand and depleted DO concentrations.
5. OM transport and metabolism indicate an accumulation of OM and an increase in heterotrophy in the lower river.

Photo 3. At left a benthic CPOM sample from 7800S mostly made up of filamentous algae. At right a CPOM sample from Cudahy Lane of almost entirely Russian elm seed pods.

Photo 4. The Jordan River looking upstream from the footbridge at 2300 South. Note the lack of complexity in the channel and riparian vegetation along the banks.

Future Plans

- Use stable isotope and DOC fluorescence information (from samples sent for C and N analysis) to investigate aquatic vs. terrestrial sources of OM.
- Submit a manuscript detailing the findings of the study to a major scientific journal

Appendix 1: Supporting Figures

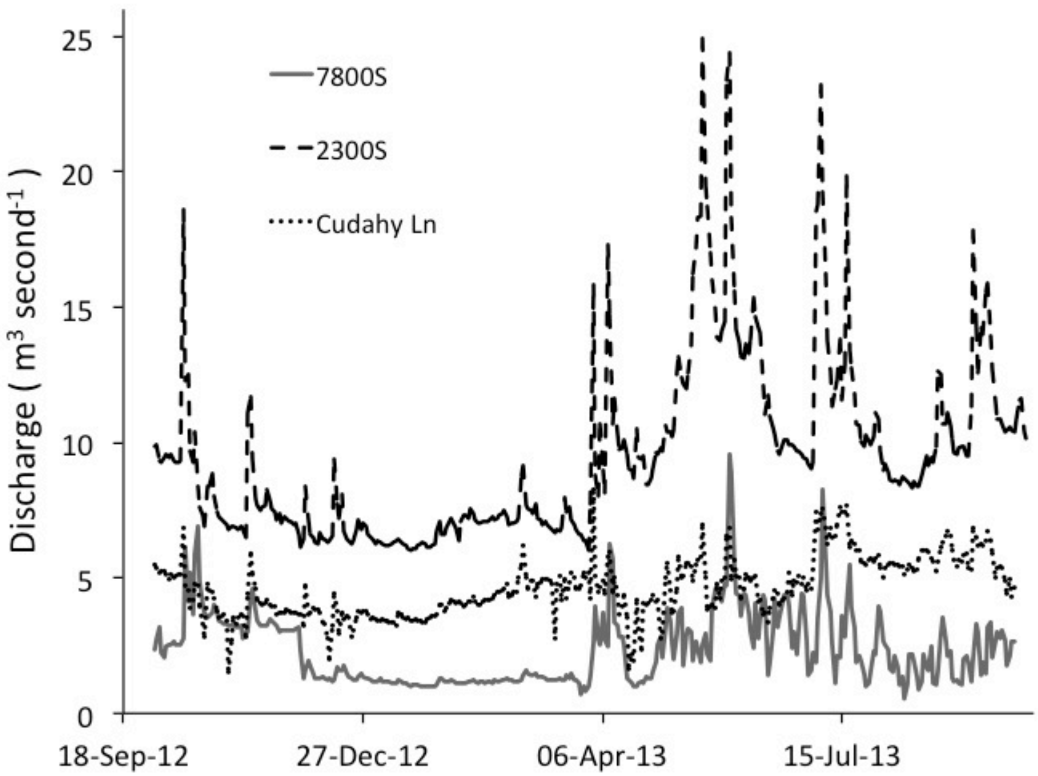

Figure 1. Average daily discharge values ($m^3 s^{-1}$) for three of our sampling sites (7800S, 2300S, Cudahy Ln) along the Jordan River. The highest discharge values were measured at 2300 South during May 2013 and the lowest values for all sites were measured at 7800S during February 2013. The surplus canal (at 2100S) diverts a large portion of the Jordan River at 2100S, thus causing the dramatic decrease in discharge downstream of the 2300S site.

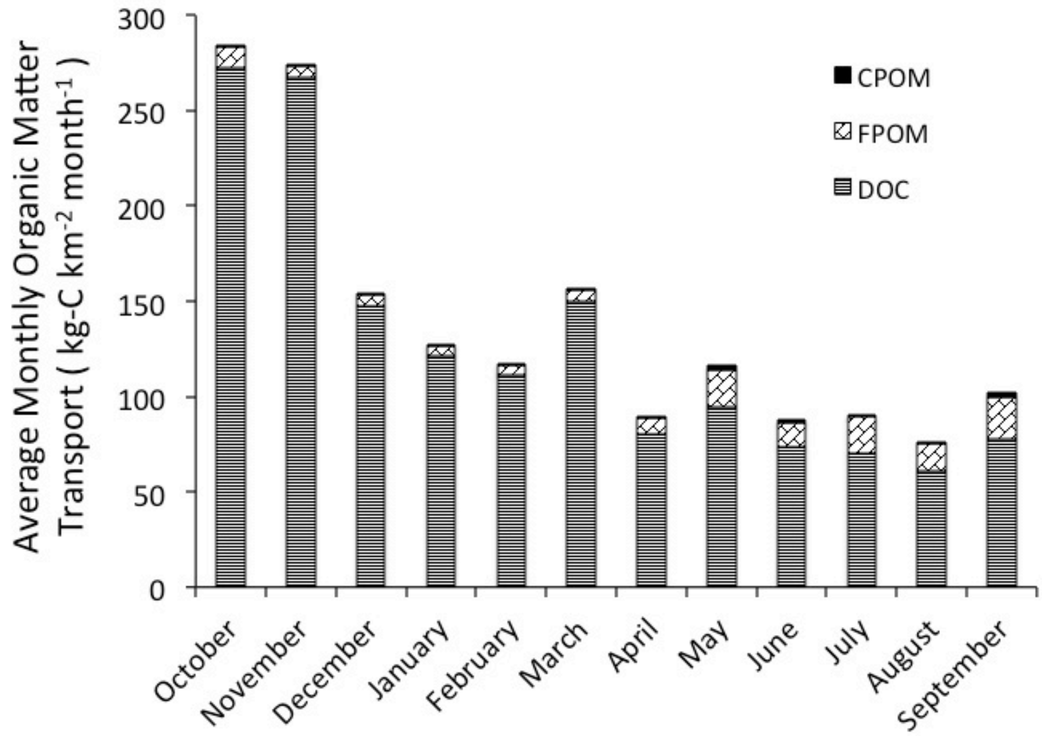

Figure 2. Average monthly organic matter (OM) transport (kg-C km^{-2} $month^{-1}$) through the Jordan River during the 2012-2013 water year. The OM pool is broken up into coarse particulate organic matter (CPOM), fine particulate organic matter (FPOM) and dissolved organic carbon (DOC).

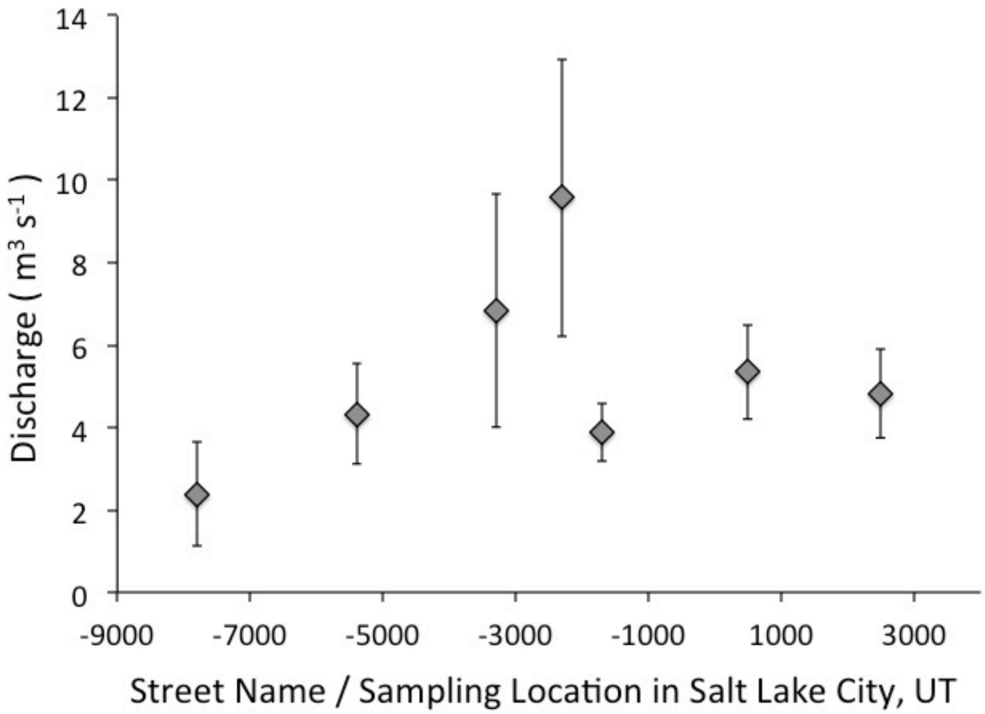

Figure 3. Average discharge (m^3 s^{-1} ± standard error) values for each of the seven sample sites along the Jordan River during the 2013-2014 water year. Sample sites move along the x-axis (left to right) from upstream to downstream. Discharge values were predicted by a stage-discharge relationship we developed throughout the 2013-2014 water year.

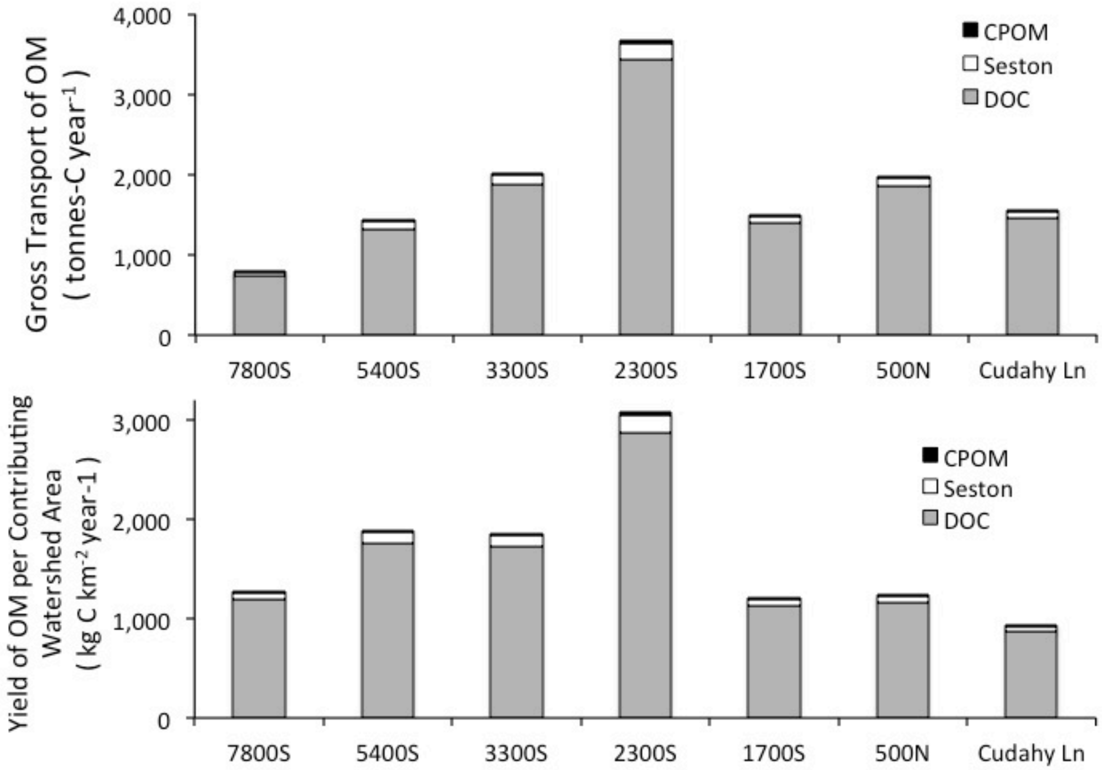

Figure 4. Annual organic matter (OM) transport values for each of the seven sampling sites along the Jordan River. The OM pool is broken up into coarse particulate organic matter (CPOM), fine particulate organic matter (FPOM) and dissolved organic carbon (DOC). Figure 3a shows the gross transport of OM (tonnes-C yr^{-1}) through each site. Figure 3b is the same data divided by contributing watershed area at each site (kg-C km^{-2} yr^{-1}).

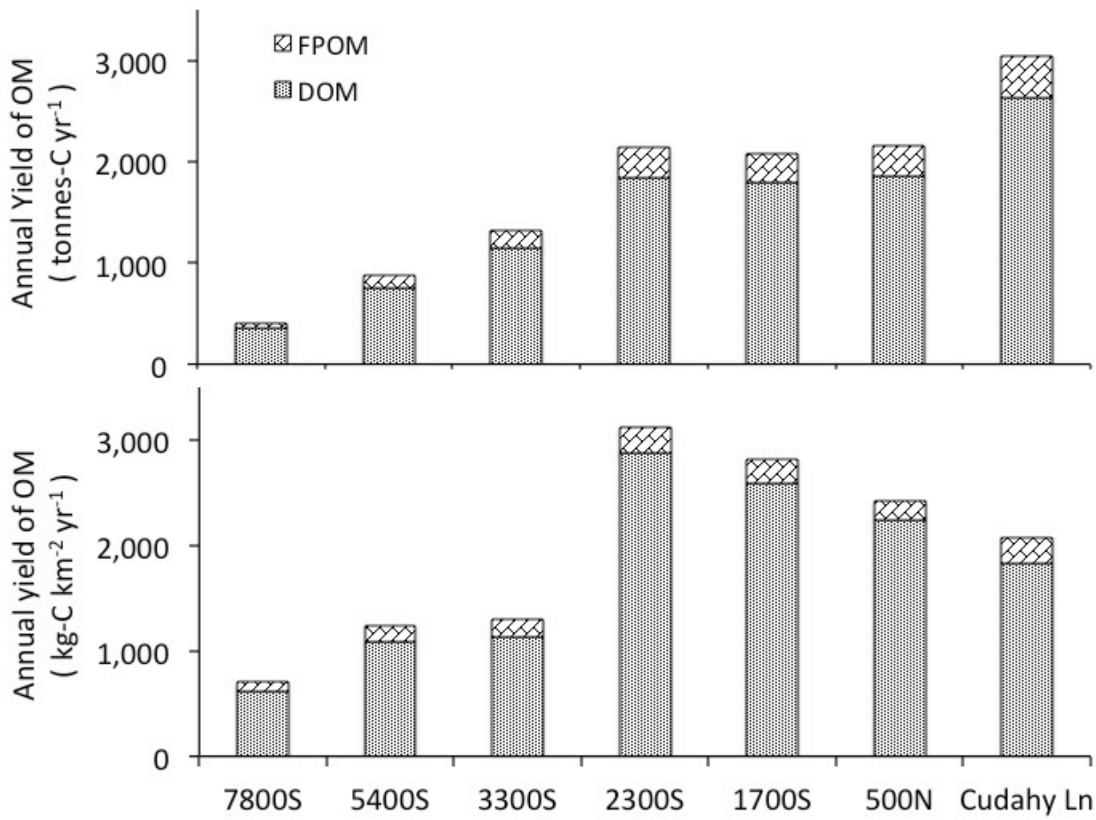

Figure 5. The hypothetical transport rates of OM through each of the sample sites along the Jordan River. Transport rates for 7800S, 5400S, 3300S and 2300S are estimates based on actual measured discharge while the estimates for 1700S, 500N and Cudahy Ln are hypothetical based on theoretical discharge if the Surplus Canal were not diverting a portion of the river at 2100S.

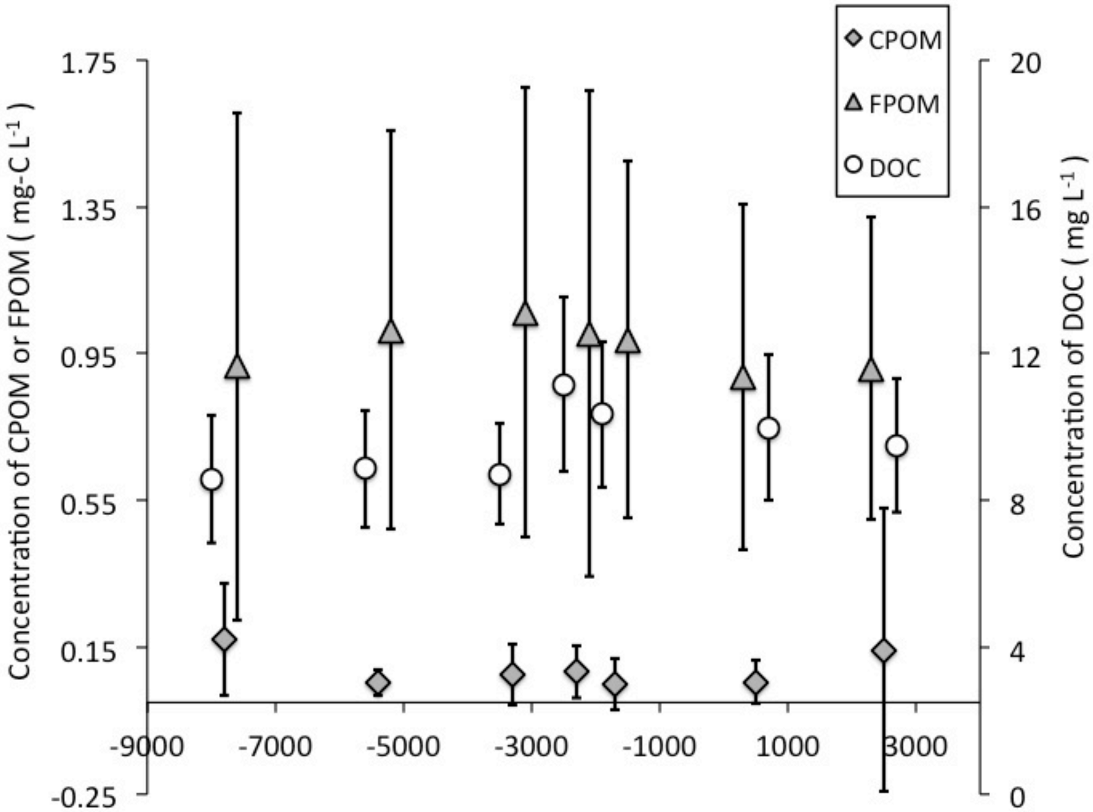

Figure 6. Average concentrations (mg-C L^{-1}) of organic matter in dissolved (DOC), suspended (FPOM) and coarse particulate (CPOM) form at each of seven sample locations along the Jordan River.

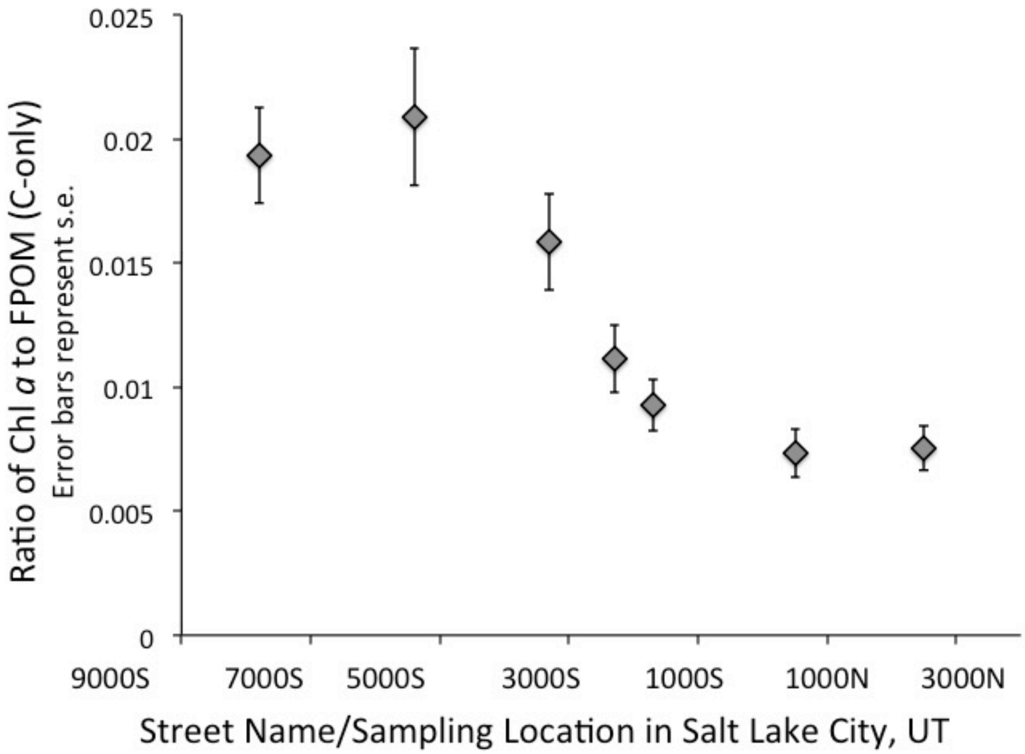

Figure 7. The average ratio of Chlorophyll *a* (± standard error) to fine particulate organic matter (FPOM) at each of the sampling locations. Chlorophyll *a* is found in algal cells, which should be a component of the FPOM pool in the Jordan River. Chlorophyl *a* concentrations in the water column were on average around 10 □g L^{-1} while FPOM concentrations averaged 800 □g-C L^{-1}.

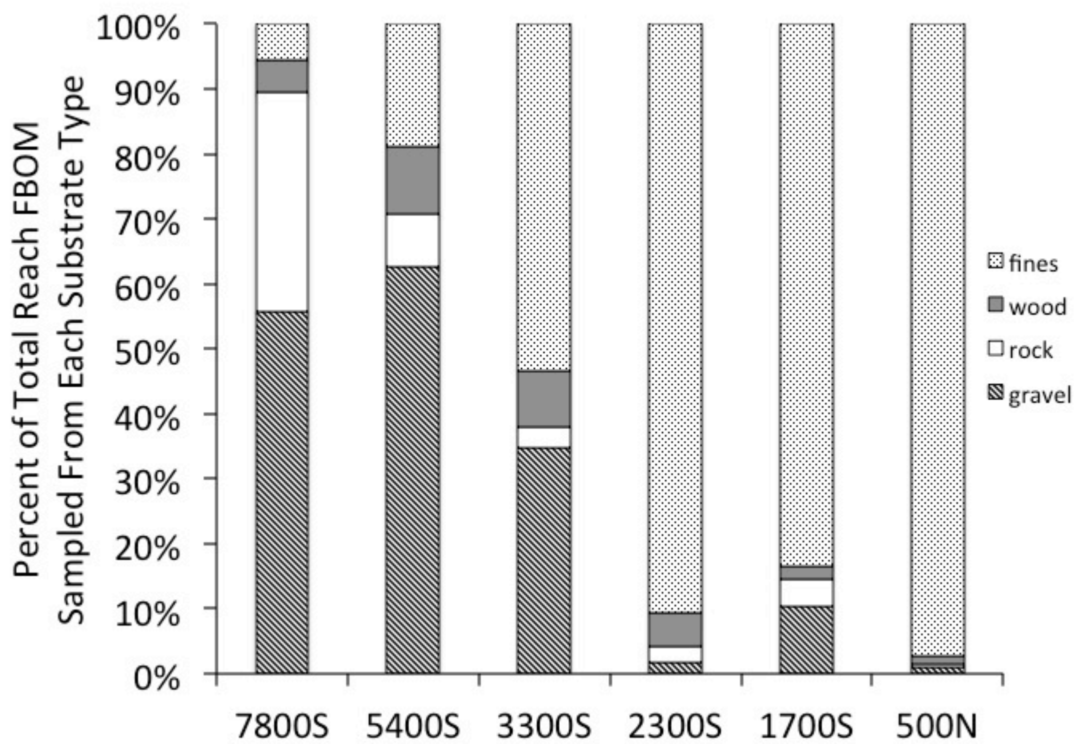

Figure 8. Percent composition of fine benthic organic carbon (FBOC) estimated in each substrate type by reach during biomass sampling. FBOM was removed from wood (fallen branches), rocks, gravel and fine sediments (fines), dried and combusted as a measure of AFDM.

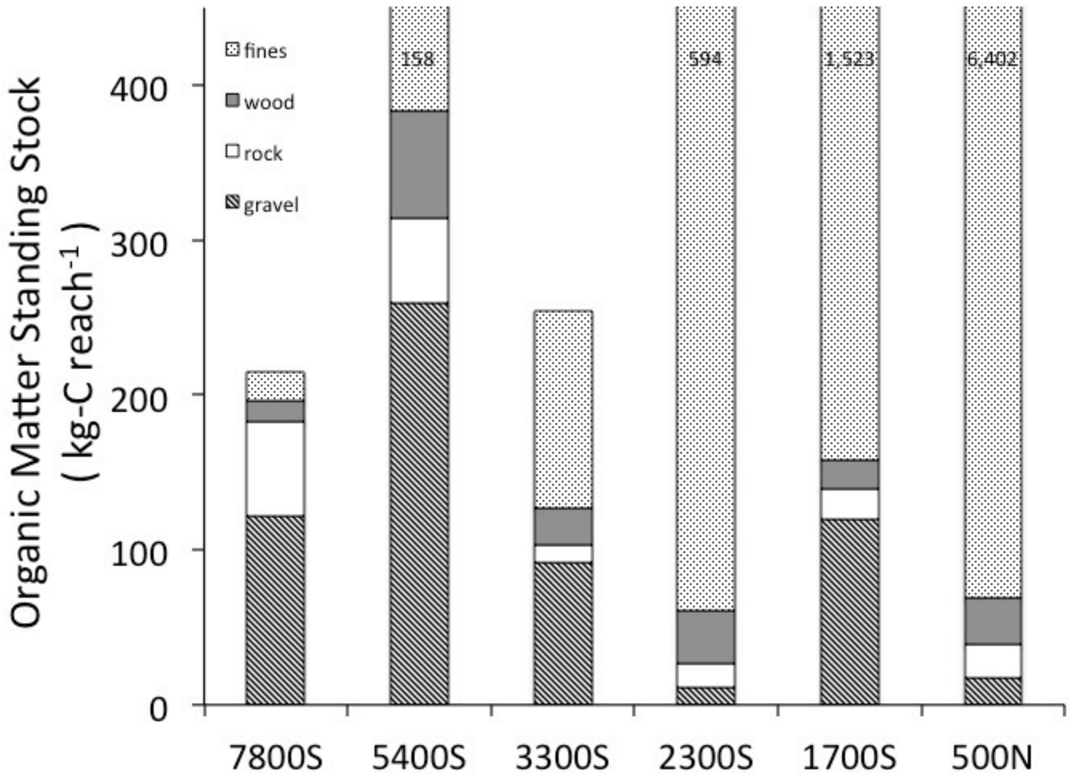

Figure 9. Standing stock estimates of fine benthic organic matter (FBOM; kg-C reach^{-1}) from biomass sampling in each of the six reaches. FBOM was removed from wood (fallen branches), rocks, gravel and fine sediments, dried and combusted to measure AFDM. FBOM estimates from the “fines” compartment extend beyond the scale of this figure, therefore the standing stock estimate is written towards the top of the bar for the reaches where estimates extend off the chart.

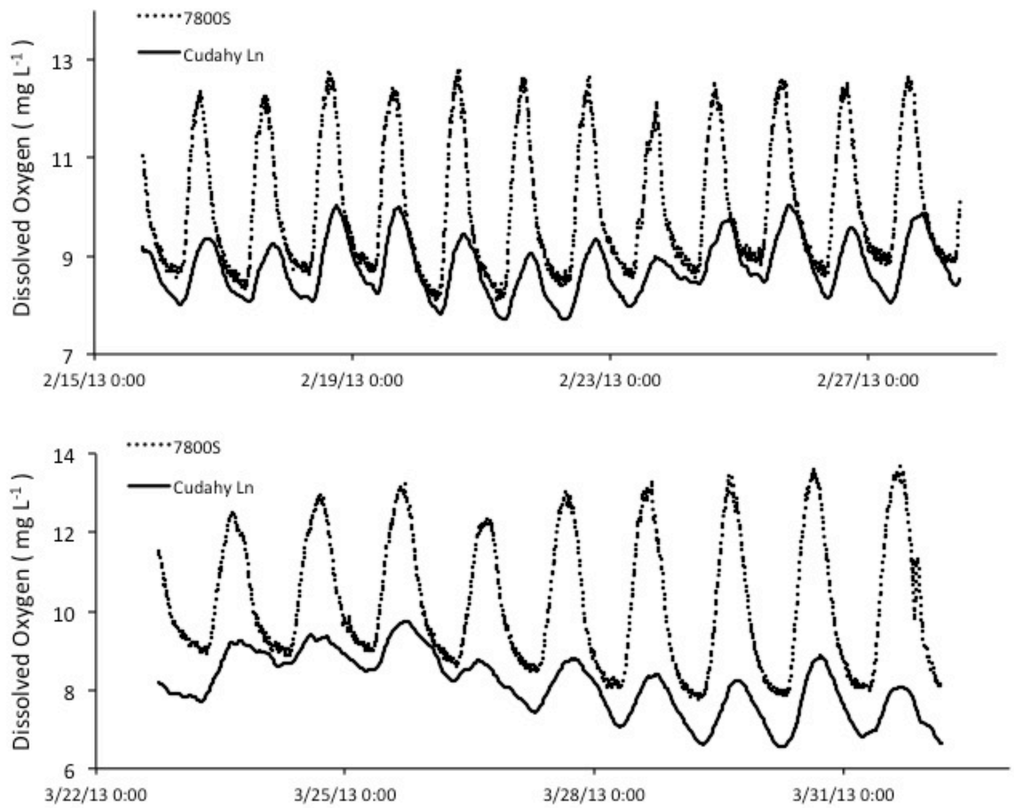

Figure 10. Diel dissolved oxygen curves for 7800 South and Cudahy Ln sites on the Jordan River. Dissolved oxygen and temperature measurements were recorded every 10 minutes by automated water quality sondes. Data displayed here is from two different sonde deployments in February and March 2012.

	Watershed Area	Discharge	CPOM Transport	FPOM Transport	DOC Transport	FBOM Standing Stock	Litterfall
Site/reach	km^2	$m^3\ yr^{-1}$	kg-C yr^{-1}	kg-C yr^{-1}	kg-C yr^{-1}	kg-C $reach^{-1}$	kg-C $reach^{-1}$
7800S	622	7.46E+07	12,279	39,845	737,916	227	1,176
5400S	751	1.20E+08	6,785	84,614	1,324,515	429	3,251
3300S	1,088	2.19E+08	12,766	128,596	1,868,431	245	1,495
2300S	1,191	3.02E+08	27,514	208,425	3,427,084	655	184
1700S	1,243	1.22E+08	6,023	80,085	1,405,851	1,073	1,425
500N	1,606	1.69E+08	8,592	98,940	1,864,311	4,297	1,181
Cudahy	1,684	1.46E+08	14,373	86,460	1,461,050		

Table 1. A table of site attributes and transport measurements for the seven sampling locations/six study reaches. Cudahy Lane served as the terminus of the study reach, as we did not take samples or measurements downstream of the site. Estimates in the last two columns (FBOM standing stock and Litterfall) represent estimates for the reach in between each of the 7 sampling sites. Watershed area (km^2) does not include the watershed feeding Utah Lake. Average FBOM standing stock and litterfall measurements (kg m^{-2}) for each reach were multiplied by the area of the reach to generate total mass estimates.

Supplemental data:

Monthly average discharge values and concentrations of major water chemistry nutrients and OM pools within the Jordan River. There is a separate table for each site.

7800S	Watershed Area	Discharge (avg. monthly)	TN	NO_3^-	NH_4^+	TP	Ortho-phosphate	DOC	FPOM	CPOM
Month	km^2	$L\ s^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\text{-}C\ L^{-1}$	$mg\text{-}C\ L^{-1}$
October	622	3,204	2.48	1.98	0.0068	0.27	0.17	20.07	0.42	0.10
November		3,124	2.53	0.45	0.011	0.12	0.0095	12.45	0.23	0.062
December		1,641	2.88	0.48	0.033	0.046	0.0071	14.62	0.24	0.040
January		NO DATA								
February		1,119	3.12	1.37	0.034	0.052	0.044	9.34	0.15	0.044
March		978	2.72	2.25	0.49	0.062	0.10	28.49	0.32	0.12
April		2,165	2.10	1.85	0.30	0.072	0.021	3.45	0.32	0.096
May		4,701	2.02	1.37	0.76	0.15	0.070	4.57	0.68	0.24
June		3,628	2.09	1.70	0.017	0.14	0.023	3.63	0.57	0.14
July		3,628	2.64	1.71	0.0078	0.17	0.053	3.54	0.68	0.096
August		2,195	2.68	1.75	0.017	0.24	0.20	4.61	0.82	0.025
September		3,360	2.20	1.24	0.022	0.16	0.042	4.95	1.25	0.088

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5400S	Watershed Area	Discharge (avg. monthly)	TN	NO_3^-	NH_4^+	TP	Ortho-phosphate	DOC	FPOM	CPOM
Month	km²	L s-1	mg L⁻¹	mg L⁻¹	mg L⁻¹	mg L⁻¹	mg L⁻¹	mg L⁻¹	mg-C L⁻¹	mg-C L⁻¹
October	751	4,830	3.60	3.04	0.020	0.71	0.62	19.33	0.49	0.027
November		4,499	3.91	0.62	0.016	0.73	0.13	17.46	0.30	0.016
December		3,203	3.92	0.70	0.034	0.70	0.14	14.07	0.30	0.017
January		NO DATA								
February		2,997	3.49	3.12	0.038	1.03	0.96	11.29	0.28	0.016
March		2,683	3.42	2.55	0.45	0.96	0.89	23.46	0.46	0.021
April		4,121	3.03	2.46	0.73	0.79	0.65	5.21	0.49	0.031
May		6,361	2.45	2.02	0.32	0.52	0.41	5.00	0.80	0.18
June		5,562	2.63	2.13	0.038	0.48	0.39	4.01	0.71	0.10
July		4,844	3.33	2.40	0.036	0.64	0.39	3.95	0.80	0.078
August		3,696	3.25	2.36	0.020	0.62	0.50	4.94	0.93	0.039
September		5,753	2.76	2.20	0.036	0.65	0.46	4.95	1.05	0.13

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3300S	Watershed Area	Discharge (avg. monthly)	TN	NO_3^-	NH_4^+	TP	Ortho-phosphate	DOC	FPOM	CPOM
Month	km^2	L s-1	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg-C L^{-1}	mg-C L^{-1}
October	1,088	5,681	2.87	1.96	0.0031	0.41	0.30	19.14	0.52	0.075
November		5,246	3.34	0.54	0.034	0.40	0.068	15.74	0.27	0.042
December		4,396	3.33	0.58	0.065	0.62	0.095	16.43	0.24	0.024
January		NO DATA								
February		3,668	3.05	2.70	0.11	0.78	0.68	10.56	0.43	0.023
March		3,614	3.29	1.59	0.46	0.68	0.52	19.75	0.49	0.038
April		5,117	2.25	2.11	0.33	0.52	0.48	4.09	0.46	0.030
May		11,663	1.72	1.19	0.35	0.22	0.13	4.74	0.65	0.21
June		10,859	2.27	1.61	0.037	0.35	0.22	3.83	0.49	0.13
July		8,159	2.65	1.67	0.048	0.43	0.27	4.04	0.84	0.028
August		5,746	2.76	1.84	0.051	0.47	0.39	5.97	0.99	0.029
September		7,664	2.67	1.33	0.051	0.44	0.25	5.01	1.06	0.042

2300S	Watershed Area	Discharge (avg. monthly)	TN	NO_3^-	NH_4^+	TP	Ortho-phosphate	DOC	FPOM	CPOM
Month	km^2	L s-1	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg-C L^{-1}	mg-C L^{-1}
October	1,191	9,291	6.15	5.12	0.13	0.99	0.86	20.97	0.64	0.053
November		7,642	8.17	1.21	0.087	1.39	0.22	39.66	0.36	0.049
December		6,771	8.19	1.46	0.15	1.58	0.27	16.18	0.58	0.057
January		NO DATA								
February		6,440	9.81	5.08	0.41	1.40	1.28	21.15	0.48	0.007
March		7,404	8.95	5.71	1.74	1.38	1.27	11.68	0.51	0.030
April		9,076	6.18	5.61	0.51	1.17	1.04	5.24	0.44	NA
May		15,858	3.29	2.69	0.51	0.57	0.46	5.53	0.67	0.12
June		12,130	4.76	4.34	0.14	0.87	0.78	4.78	0.43	0.084
July		14,220	5.56	4.32	0.087	0.95	0.76	4.59	1.05	0.052
August		9,503	6.12	5.35	0.70	0.96	0.98	6.42	0.89	0.037
September		12,188	6.14	3.66	0.61	0.83	0.64	5.51	1.11	0.44

1700S	Watershed Area	Discharge (avg. monthly)	TN	NO_3^-	NH_4^+	TP	Ortho-phosphate	DOC	FPOM	CPOM
Month	km^2	L s-1	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg-C L^{-1}	mg-C L^{-1}
October	1,243	4,029	6.26	5.15	0.22	1.07	0.96	18.79	0.62	0.026
November		3,527	7.34	1.32	0.12	1.24	0.22	38.39	0.31	0.021
December		3,352	7.76	1.45	0.15	1.35	0.25	19.69	0.56	0.062
January		NO DATA								
February		2,971	7.39	4.51	1.06	1.03	0.92	10.96	0.44	0.018
March		2,731	7.49	5.69	1.59	1.12	1.13	20.44	0.44	0.016
April		2,176	6.24	4.82	0.75	1.00	0.91	6.33	0.50	0.026
May		4,595	3.93	3.20	0.32	0.65	0.57	5.12	0.68	0.14
June		4,259	3.78	3.82	0.12	0.78	0.69	4.30	0.51	0.050
July		4,709	5.42	3.77	0.10	0.95	0.68	4.79	0.93	0.028
August		4,061	6.15	3.87	0.76	0.94	0.87	5.92	0.92	0.010
September		4,729	4.55	3.46	0.68	0.80	0.52	5.41	1.02	0.064

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500N	Watershed Area	Discharge (monthly avg.)	TN	NO_3^-	NH_4^+	TP	Ortho-phosphate	DOC	FPOM	CPOM
Month	km^2	L s-1	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg-C L^{-1}	mg-C L^{-1}
October	1,606	5,251	5.03	4.27	0.26	0.87	0.78	21.28	0.57	0.074
November		4,434	5.49	0.98	0.16	1.00	0.15	37.76	0.32	0.078
December		4,434	6.80	1.21	0.19	1.12	0.21	17.80	0.47	0.11
January		NO DATA								
February		3,794	5.37	5.34	1.06	0.97	0.94	11.25	0.40	0.013
March		4,127	7.43	4.79	1.60	1.09	1.03	10.05	0.46	0.018
April		4,048	3.64	2.94	0.66	0.53	0.47	4.64	0.37	0.034
May		6,393	2.66	1.93	0.54	0.42	0.34	5.76	0.67	0.087
June		7,256	3.70	3.03	0.13	0.71	0.55	4.08	0.36	0.021
July		7,777	4.30	3.13	0.14	0.79	0.60	4.53	1.00	0.019
August		5,347	4.59	3.25	0.63	0.75	0.70	5.69	0.78	0.069
September		5,734	4.52	2.57	0.35	0.71	0.51	5.37	0.89	0.053