SALT AND SEDIMENT BALANCES IN AN IRRIGATED WATERSHED IN SOUTHERN IDAHO.

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ABSTRACT

The quality of irrigation return flow in a 205,000 acre southern Idaho watershed has changed since 1970. Converting from furrow irrigation to sprinkler irrigation and installation of wetlands and sediment ponds have greatly reduced sediment loss. There is now more sediment in the irrigation water diverted into the watershed than returns to the Snake River (>100 lb a^{-1}) compared to a net loss of 410 lb a^{-1} of sediment in 1971. There is also more soluble salt flowing into the watershed than returning to the river. While continually adding salts to the soil is not desirable, the overall average sodium adsorption ratio (SAR) in the irrigation water was only 0.73 and the average soluble salt concentration was 280 mg L^{-1} or 435 μS cm^{-1}, which are low enough to not impact crop production.

INTRODUCTION

The Upper Snake Rock (USR) watershed is located along the Snake River in southern Idaho. The Twin Falls Canal Company (TFCC) has diverted water from the Snake River since 1905 to irrigate the 205,000 acre watershed. Irrigation water flows by gravity into canals, laterals and coulees as it is distributed to producer's fields. A portion of the water returns to the Snake River as irrigation return flow because irrigation diversions exceed irrigation demand. Irrigation return flow also contains flow from subsurface drains and runoff from furrow irrigated fields that cannot be re-diverted to other fields. Many return flow streams only flow during the irrigation season (April–October), whereas others flow all year due to subsurface drain tiles and tunnels located sporadically throughout the watershed. Drain tunnels are 4 ft wide by 6 ft high and were dug horizontally into the basalt bedrock to remove excess groundwater that percolated up to the soil surface after 5 to 10 yr of irrigation. Rock Creek is the only stream that flows into the watershed. It is ephemeral upstream from the watershed, typically only flowing in spring and early summer from snowmelt in the mountains because rain seldom causes runoff in this area.

The watershed was 95% furrow irrigated until the 1990's when farmers began converting to sprinkler irrigation. Currently, 40-45% of the crop land is sprinkler irrigated. This watershed was selected to be part of the multiagency Conservation Effects Assessment Project (CEAP) to quantify the water quality impacts of conservation practices, primarily converting from furrow to sprinkler irrigation. Monitoring for CEAP began in 2005. Similar monitoring occurred from 1968-1971. Two early studies showed that the USR watershed had a net loss of sediment, nitrate (NO_3-N), and total salts, and a net gain of soluble phosphorus (Brown et al., 1974; Carter et al., 1971). The net losses of 30 lb a^{-1} NO_3-N (Carter et al., 1971) and 410 lb a^{-1} of sediment (Carter et al., 1974) were a concern. A recent study identified that significantly more total phosphorus (P) flowed into the watershed than returned to the Snake River with irrigation return flow, while there was no significant difference between inflow and return flow loads for sediment and dissolved P (Bjorneberg et al., 2014). The objective of this paper is to compare changes in sediment and salt loads in irrigation return flow between two time periods: 1968 to 1970 and 2005 to 2008.

MATERIALS AND METHODS

Twenty-three monitoring sites were established in 2005 to measure the quantity and quality of surface water returning to the Snake River. Two additional return flow sites were added in 2006. Water flowing into the watershed was measured at two sites: the main canal and Rock Creek, which has much less flow than the main canal. Flow rates at all 27 sites were measured with weirs or calculated from stage-discharge relationships. Flow rates were automatically recorded on data loggers at 17 sites. Flow stage at 10 minor sites was manually measured once a week. Automatic water samplers were used at eight sites with the highest flow rates to collect time-composite water samples (0.2 L subsample every 5 h in 2 L bottles). The three or four 2-L composite samples from each site were combined into a weekly composite sample. A 5-h interval was used so samples were not collected at the same time each day. One, 2-L grab sample was collected weekly from the other 19 sites. Water flowed during the winter (December, January and February) at only 12 of the 27 sites. Weekly grab samples (2-L) were collected at these sites when freezing temperatures prohibited the use of automatic samplers.

Samples were collected at the 25 monitoring sites until 2008 when project funding ended. Sampling at seven main return flow sites started again in 2011. Five of these sites flow all year due to subsurface drain flow. Grab samples were collected weekly at all sites during the irrigation season and biweekly during the winter.

All water samples were refrigerated until processed within 24 h of collection. During sample processing, samples were stirred for 1 to 2 min on a stir plate. While stirring, electrical conductivity (EC) was measured and a 20 ml aliquot was filtered (0.45 μm) and stabilized with 0.2 mL of saturated boric acid. The filtered water sample was analyzed by inductively coupled plasma-optical emission spectroscopy (ICP-OES) for P, K, Ca, Mg, Na, Al, Fe, Mn, Zn, and S concentrations, and by flow injection analysis for NO_3-N, NH_4-N, and Cl concentrations. Total dissolved salts (TDS) in mg L^{-1} were calculated by multiplying EC (μS cm^{-1}) by 0.64. All data are available from the STEWARDS database (http://www.nrrig.mwa.ars.usda.gov/stewards/stewards.html). Sample concentrations were multiplied by flow volume to calculate loads for each sampling interval. These loads were summed for the calendar year. Annual loads were divided by annual flow volume to calculate flow-weighted concentrations.

RESULTS AND DISCUSSION

The average annual flow into the USR watershed from 2006 to 2008 was 860,000 acre-ft or 51 inches (Table 1). Rock Creek only contributed 2% of the inflow. Additionally, annual precipitation was 12, 7, and 7 inches in 2006, 2007, and 2008, respectively, at the Twin Falls, ID AgriMet station (USBR, 2015). Precipitation was not included in the watershed inflow shown in Table 1 because precipitation did not add any salts or sediment to the watershed.

Irrigation return flow was 44% of the watershed inflow (Table 1). Including precipitation would reduce the return flow percentage to 37%. This return flow transported 370 lb a^{-1} of sediment, 12 lb a^{-1} of NO_3-N and <1 lb a^{-1} of total and dissolved P annually to the Snake River (Table 1). More sediment and P flowed into the watershed with the irrigation water than returned to the Snake River. The current trend of depositing >100 lb a^{-1} of sediment in the watershed is a major change from 1971 when there was a net loss of 410 lb a^{-1} of sediment (Carter et al., 1974).

This reduction was caused by better irrigation management, conversion from furrow to sprinkler irrigation, and installation of wetlands and sediment ponds.

The net deposition of total and dissolved P was <0.5 lb a^{-1}, which was insignificant from an agronomic perspective. However, diverting irrigation water into the watershed removed 16 tons of dissolved P and 36 tons of total P annually from the Snake River. The net deposition of dissolved P was similar to the 0.6 lb a^{-1} measured in 1968-1970 (Carter et al., 1974).

There continues to be a net loss of NO_3-N from the watershed. The annual average loss was 12 lb a^{-1} for 2006-2008, which was less than the 30 lb a^{-1} measured in 1968-1970 (Carter et al., 1971). While the current amount is not large from an agronomic perspective, irrigation return flow transports almost 1200 tons of NO_3-N to the Snake River each year, which is about $1,000,000 of nitrogen at current fertilizer prices (urea at $400 per ton) or enough to apply 100 lb a^{-1} on 24,000 acres.

On average, irrigation adds 800 lb a^{-1} of soluble salts to the watershed (Table 1). While continually adding salts to the soil is not desirable, salts have not impacted crop production due to the relatively low amount of sodium in the irrigation water. The overall average SAR for samples collected from the main irrigation canal was only 0.73 and the average soluble salt concentration was 280 mg L^{-1} or 435 µS cm^{-1}. The low SAR and EC indicate that salt accumulation from irrigation water is not a concern. It is important to note that this salt balance only includes additions from irrigation water and removal with irrigation return flow. It does not include additions by fertilizers and manure or removal with harvested crops.

Flow weighted annual concentrations of soluble salts are trending down in four main irrigation return flow streams (Table 2). These streams contain surface water and subsurface drain flow. Decreasing concentrations could be caused by a lower proportion of subsurface drain flow, which has higher soluble salt concentration than surface water. If the amount of subsurface drain flow is decreasing, the amount of NO_3-N lost in return flow may also continue to decrease.

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Table 1. Flow, sediment, nutrient and soluble salts loads in irrigation water diverted into the watershed and in irrigation return flow. Data were summed for the calendar year.

	Flow		TSS	DP	TP	Nitrate-N	Soluble Salts
Inflow	(acre-ft)	(inches)	----------	----------	(lb/a)	----------	----------
2006	843,706	50	478	0.42	0.89	0.11	2820
2007	830,115	49	394	0.50	1.17	0.30	3192
2008	920,126	54	590	0.42	0.91	0.32	3351
Average	864,649	51	487	0.44	0.99	0.25	3121
Outflow							
2006	443,370	26	526	0.34	0.79	13.10	2589
2007	347,365	21	274	0.25	0.64	12.44	2209
2008	342,170	20	306	0.27	0.47	10.27	2116
Average	377,635	22	369	0.29	0.64	11.94	2305
Net							
2006	400,336	24	-48	0.07	0.10	-12.99	231
2007	482,751	29	121	0.25	0.53	-12.14	983
2008	577,956	34	283	0.15	0.44	-9.94	1235
Average	487,014	29	119	0.16	0.36	-11.69	816

Table 2. Flow weighted annual soluble salt concentrations in four main return flow streams.

			Soluble Salts		
Year	Cedar Draw	Deep Creek	Mud Creek	Rock Creek	Main Canal
	----------	----------	$mg\ L^{-1}$	----------	----------
1969	532	483	622	534	311
1970	543	486	608	525	329
2006	446	465	559	414	257
2007	505	475	564	468	290
2008	469	457	558	478	275
2012	357	340	449	449	216
2013	384	366	442	442	235
r	-0.79*	-0.62	-0.78*	-0.88*	-0.84*

* r is the correlation coefficient between concentration and year. Correlations are significant at P=0.05 when $|r|>0.75$.

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