

SELENIUM LOADS INTO AND OUT OF STEWART LAKE DURING THE ANNUAL FLOOD OF 2001

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Abstract

Extensive studies of Stewart Lake conducted from 1986 to 1990 detected elevated selenium concentrations in water and bottom sediment that resulted in poor nesting success by waterfowl and elevated selenium accumulation by fish. In an effort to lower the concentration of selenium in the bottom sediment, Stewart Lake has been flooded with water from the Green River and subsequently drained on an annual basis since 1997. To compute the net mass of selenium removed from Stewart Lake during the annual flood of 2001, the U.S. Geological Survey did a fine-scale temporal measurement of the selenium load into and out of Stewart Lake. Additional selenium loads from uncontrolled seepage along the north end of Stewart Lake also were quantified. The total volume of water that entered Stewart Lake was 2.53 x 10⁶ cubic meters from seepage along the north end of Stewart Lake. The total mass of selenium that entered Stewart Lake during the flood was 3.5 kilograms (2.7 kilograms from the Green River and 0.8 kilograms from seepage along the north end of Stewart Lake). The total volume of water that exited Stewart Lake at the outlet was 2.53 x 10⁶ cubic meters, and the mass of selenium that exited Stewart Lake at the outlet was 10.3 kilograms. The net mass of selenium that exited Stewart Lake during the flood was 6.8 kilograms. Assuming the excess selenium originated from the bottom sediment, the annual flood removed 0.4 percent of the estimated 1,665 kilograms of selenium that exists in the top 15 centimeters of bottom sediment at Stewart Lake. The relatively small net mass of selenium removed from Stewart Lake during the flood and drain cycle of 2001 illustrates that this is not a successful bottom-sediment remediation strategy. Based on these results, alternative remediation strategies are being considered including sediment removal and additional seepage diversion from Stewart Lake.

Materials and Methods

The U.S. Geological Survey, in cooperation with the Bureau of Reclamation, installed an acoustic Doppler water velocity meter, multiprobe, pressure transducer, and an autosampler at the constructed inlet and outlet of Stewart Lake in the Spring of 2001. The velocity meters, pressure transducers, and multiprobes logged values every 10 minutes. The autosamplers collected samples every 3 to 13 hours.



Stewart Lake inlet. The photo is looking east toward the Green River.

Stewart Lake outlet. The photo is looking south toward the Green River.



Continuous monitoring facility at Stewart Lake inlet. Stewart Lake outlet was similarly equipped.

The velocity and pressure transducer data were combined to compute discharge. The concentration of total and/or dissolved selenium was measured in selected samples collected by the autosamplers and combined with the discharge data to compute selenium loads.

Additional selenium loads from uncontrolled seepage along the north end of Stewart Lake also were quantified. Measurements of discharge were made



Surface drain at Stewart Lake.

Seep at Stewart Lake.

at several seeps along the north end of Stewart Lake and at several sites in surface drains that capture seepage from the north end of Stewart Lake. These sites were sampled while the lake was completely drained in August 2000 and August 2001. Water samples from these locations were collected concurrent with the discharge measurements and analyzed for dissolved selenium. The discharge and selenium data were combined to estimate the selenium load that entered Stewart Lake via seepage during the flood and drain cycle. Discharge and selenium loads from the seeps were assumed to be steady state during the flood and drain cycle.

Quality Assurance

- The concentration of dissolved selenium in all process blank water samples collected from the autosamplers was less than the analytical detection limit (<0.3 µg/L).
- Manual discharge measurements were within 10 percent of data logger values.
- Equal width increment samples showed that water at the inlet and outlet have been completely.

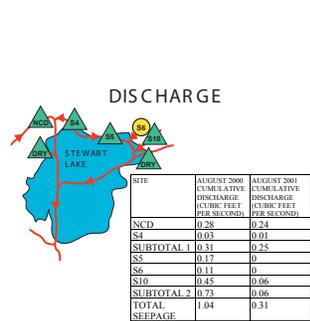
One of the objectives of the Remediation Phase is to lower the concentration of selenium in the bottom sediment. Beginning in the Spring of 1997, Stewart Lake has been flooded with water from the Green River and quickly drained on an annual basis. The objective of the annual flood cycle is to solubilize selenium in the sediment in water from the Green River and export it out of Stewart Lake. Previous estimates of the mass of selenium into and out of Stewart Lake during the annual floods were based on only a few measurements of discharge and selenium concentrations at the lake's inlet and outlet. This poster presents the results of an effort to accurately quantify the mass of selenium removed from the bottom sediment at Stewart Lake during the flood and drain cycle of 2001.

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Results and Discussion

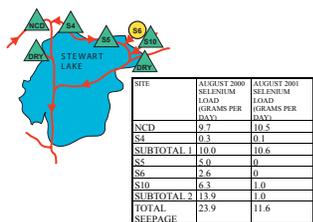
SELENIUM INPUTS STEWART LAKE SEEPS



The total discharge from the seeps was 1.04 cfs in August 2000 and 0.31 cfs in August 2001 (assuming the drainage channels capture most of the seepage). The data from 2001 are not as reliable as the data from 2000 because of large amounts of vegetation in the drainage channels, which made it difficult to get accurate discharge measurements.

Assuming the seeps discharged at a constant rate (1 cfs) during the flood and drain cycle, about 69 ac-ft (8.51 x 10⁶ m³) of water entered Stewart Lake from the seeps.

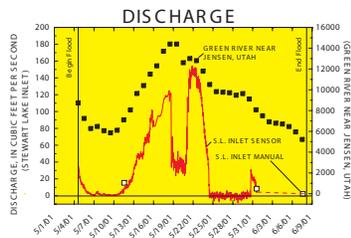
SELENIUM LOAD



The selenium load carried by the seeps was about 24 grams per day (g/d) in August 2000 and about 12 g/d in August 2001. The August 2000 data show that seepage from both the northeast and northwest sides of Stewart Lake are a significant source of selenium.

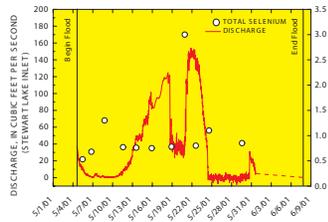
The total mass of selenium delivered to Stewart Lake by the seeps during the flood and drain cycle was about 0.8 kg, assuming a daily load of 24 g/d.

SELENIUM OUTPUT STEWART LAKE INLET DISCHARGE



The volume of water that entered Stewart Lake during the annual flood of 2001 depended on many variables including the elevation of the Green River at the inlet and outlet, the elevation of Stewart Lake, and the elevation of the adjustable weir gates at the inlet and outlet. For example, at the beginning of the flood discharge into the lake increased with increased flow in the Green River; however, by May 18, the elevation of Stewart Lake approached the elevation of the Green River and discharge into Stewart Lake declined. The total volume of water from the Green River that entered Stewart Lake was about 1,982 ac-ft (2.44 x 10⁶ m³).

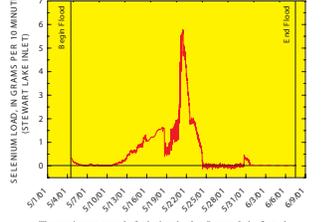
SELENIUM CONCENTRATIONS



The concentration of selenium in water from the Green River at Stewart Lake inlet ranged from 0.5 to 3.0 µg/L.

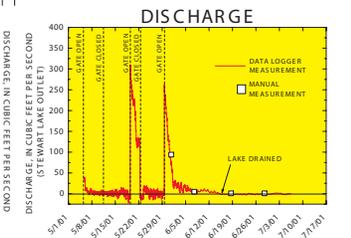
A continuous record of selenium concentrations in Green River water that entered Stewart Lake was constructed by linear interpolation between the measured values.

SELENIUM LOAD



The continuous record of selenium load to Stewart Lake from the Green River is shown above. The total mass of selenium delivered to Stewart Lake from the river was 2.7 kg.

SELENIUM OUTPUT STEWART LAKE OUTLET DISCHARGE

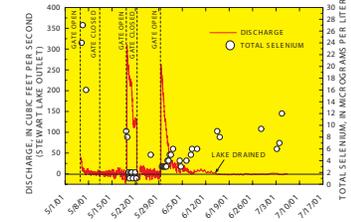


The volume of water that exited Stewart Lake during the annual flood of 2001 was dependent of the same variables as the volume of water entering the lake. The outlet gate was opened and closed several times during the flood, which is obvious in the discharge record shown above.

The discharge record computed from velocity and stage data that were logged when the outlet gate was closed are near zero and fluctuate between positive and negative values. This data was not used to compute the total volume of water that flowed through the outlet or the selenium loads out of Stewart Lake.

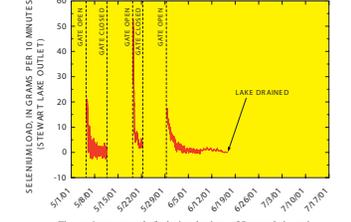
The total volume of water that flowed out of the outlet was 2,055 ac-ft (2.53 x 10⁶ m³).

SELENIUM CONCENTRATIONS



Relative to the inlet, there was large variation in the concentration of selenium in water samples collected from the outlet. The concentration of total selenium ranged from 1 to 27 µg/L. This is probably related to the relative amounts of water from seepage, which has high concentrations of selenium, and the Green River, which has low concentrations of selenium, in water samples collected at the outlet.

SELENIUM LOAD

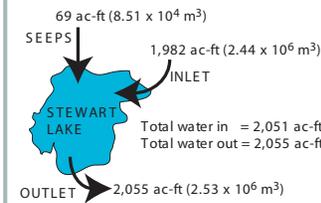


The continuous record of selenium load out of Stewart Lake outlet is shown above. The total mass of selenium that exited Stewart Lake outlet was 10.3 kg.

Conclusions

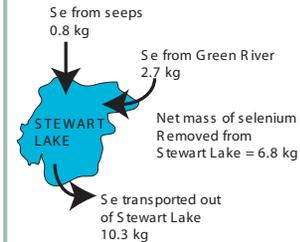
Water Balance

When combined with the seepage measurements, the discharge values logged at the inlet and outlet provided an accurate water balance. The data show that the volume of water that entered Stewart Lake was nearly identical to the volume of water that exited Stewart Lake.



Selenium Loads

During the flood and drain cycle of 2001, an estimated 0.8 kilograms of selenium entered Stewart Lake from uncontrolled seepage and 2.7 kilograms of selenium entered the lake from the Green River. The mass of selenium that exited Stewart Lake during the cycle was 10.3 kilograms. The net mass of selenium removed from Stewart Lake was 6.8 kilograms.



Remediation Performance

The estimated mass of selenium in the top 15 centimeters of bottom sediment at Stewart Lake is 1,665 kg. The mass of selenium removed from the bottom sediment during the flood and drain cycle of 2001 was 0.4 percent of this total.

Efforts are now underway to construct a seepage collection system on the north end of Stewart Lake and alternative bottom sediment remediation strategies are being considered.

References

- Stephens, D.W., Waddell, B., and Miller, J.B., 1988. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the middle Green River basin, Utah, 1986-87. U.S. Geological Survey Water-Resources Investigations Report 88-4011, 70 p.
- Stephens, D.W., Waddell, B., Peltz, L.A., and Miller, J.B., 1992. Detailed study of selenium and selected elements in water, bottom sediment, and biota associated with irrigation drainage in the middle Green River basin, Utah, 1988-90. U.S. Geological Survey Water-Resources Investigations Report 92-4084, 164 p.