Evaluating Salt Accumulation and Release Processes in Riparian Zones of a Semi Arid River System

S. Miyamoto and Fares Howari

Agricultural Research Center; 1380 A & M Circle, El Paso, TX 79968
915-845-911; Fax: 915-8591708
fhowari@tamu.edu;

Research Need, Description and Benefits

Need: Salts are the most frequent contaminant which limits full utilization of water resources in Texas (TNRCC, 1998, 2000). The river systems with salt problems include Red, Wichita, upper Brazos, Colorado, Pecos, and Rio Grande. In the case of the Rio Grande, salinity measured at Amistad International Reservoir has been increasing since its construction in 1968 (Attachment 1) and is now approaching 1000 ppm, the state standard for drinking water supply. Salinity in excess of 1000 ppm also adversely affects horticultural crop production (Miyamoto, 1996). For sustaining irrigated agriculture and ongoing economic developments along the border area, it is important to find the cause(s) of the salinity increase and identify river management options which may help change the current trend.

It will take some time to identify all the causes which have contributed to the increase in salinity. However, indications are that the first major surge of salinity observed prior to 1988 (Attachment 2) is related to salt flushing from the middle Rio Grande above Presidio (Miyamoto, 1996). The streamflow of the middle Rio Grande during the period of salinity increase was much greater than that of the previous period, and salts in an order of several million tons were estimated to have been flushed into Amistad Reservoir (Miyamoto, 1996). More recent salinity increases at Amistad are caused by the reduced inflow from the Rio Conchos, Mexico. More recently, we have found that salinity of the Pecos river which flows into the Rio Grande at Langtry had several salt peaks (Attachment 3), all of which were found to be associated with salt flushing from the Upper Pecos above Garvin. These historical observations indicate that we need to understand the process of salt accumulation and release processes, and to improve river management practices.

Existing literature, mostly originating from semi-arid areas of Australia, shows that salt flushing occurs during bank overflow which picks up the salts accumulated during low flow periods (e.g., Loh and Stockes, 1981), and that bank overflow usually has high levels of Na. The water quality data available for the Rio Grande or the Pecos are not suited for this type of analyses, because they are collected only a few times a month, using grab samples. Nonetheless, salinity during high flow is frequently just as high as during low flow (Miyamoto et al., 2000). The salinity survey of river banks, which we just started, does show high levels of salt accumulation, especially at the bank surface (Attachment 4). Salinity of the soil solution in the next 30 cm soil layer is also as high as salinity of seawater, even though this area was flooded during bank overflow two years ago.

There are, of course, bank areas with vegetation all along the middle Rio Grande. This raises a fundamental question as to what controls the pattern of salt accumulation and release in semi-arid river and what are the options to prevent salinization of riparian zones. Our reconnaissance seems to indicate that the bank with void of vegetation often appears when there is no outlet for surface drainage. This observation leads to our hypothesis that when the slope of the bank is not sufficient to cause salt removal with rain runoff, the salts brought up to the surface with upward capillary flow will acumulate. Because of the preferential precipitation of Ca, mainly as $CaSO_4 \cdot 2H_20$ in these river systems, the soil surface becomes sodic enough to deter water infiltration, and to prevent salt leaching back into the stream during bank overflow. Under this scenario, the highest salt accumulation should be at the soil surface and at the wetting front resulting from the lateral subsurface movement of streamflow. This hypothesis should be evaluated further as it affects not only modeling options, but also river management alternatives to sustain some forms of riparian vegetation for bank stability and biodiversity.

Project Objectives: The goal of this project is to improve the understanding of salt storage and release processes in sufficient details to apply for a larger grant. There are also other purposes to this project; one is to provide the field data needed to incorporate salinity components into the SWAT (conducted by Muttiah at Temple), another is to provide the information useful for assessing the impact of removing saltcedars and planting grass on river banks on salt storage and release. Several agencies including the Cooperative Extension are currently involved in saltcedar eradication programs, which could, in a short term, send more salts to the Rio Grande. The project objectives are: 1) Obtain salinity distribution data along with pertinent soil properties in selected riparian zones of the middle Rio Grande and later in the Pecos subbasin, 2) Compose and validate a model useful for estimating the extent and the types of salt accumulation in soils with or without vegetative covers in the presence of high water table, 3) Explore a spectral method of delineating river banks with high salt storage. In addition, we will begin a discussion on installing continuous salinity and flow monitoring equipment at strategic locations along the middle Rio Grande and the Pecos with IBWC for quantifying salt flushing phenomena.

Project Activities: For Objective 1, we plan to continue soil salinity and water table measurements in different areas of the middle Rio Grande below El Paso with a guidance from IBWC. The bank area to be tested will include the areas with no vegetation, with grass covers and a thick stand of saltcedars. Sampling at the Pecos River under this program would be limited to one or two exploratory sites due to budget constraints. Water infiltration tests using a double ring infiltrometer will be added, along with laboratory analysis of pertinent soil properties. The data obtained will be shared with the group at Temple, IBWC, and the group working on saltcedar control at Pecos. For Objective 2, we will begin model development using the upward flow component of the EPIC model (Willams and Dike, 1984), which includes the estimate of soil water depletion caused by evaporation or evapotranspiration. We will simply add salt mixing, salt precipitation, and cation exchange reactions. Consultation with Dr. Williams at Temple is expected on the matters related to the EPIC model. The validation of the model will be made first against small lysimeter data. The small weighing lysimeter system will be installed in a greenhouse at El Paso. The lysimeter column will be constructed using PVC pipes placed on a weighing platform, and will be filled with two alluvial soils from the middle Rio Grande and one from the Pecos. Two of the soils will have saltgrass and saltcedars planted. The lysimeter columns will be subirrigated with saline solutions having ionic compositions similar to the Rio Grande, but at higher salinities. The evaporation or the evapotranspiration will be measured gravimetrically using a strain gauge. Soil core samples will be extracted from the lysimeter columns, and will be analyzed for salinity, exchangeable Na, gypsum and soil moisture distributions 1 year after the initiation of this experiment. The verification efforts will also be extended to some of the field data obtained under Objective 1.

For Objective 3, we plan to carry out a pot experiment in a greenhouse. The soils, the same as those used for the lysimeter experiment, will be placed in a series of pots (made of glass) and be subirrigated with saline solutions to form salt crusts in various quantities. An additional series of pots will be prepared, and the salt crusts formed will be sprayed with distilled water in a manner to simulate salt washout with rainfall. The quantities of the saline solutions evaporated will be determined gravimetrically, and the temperature of the crusts with infrared thermometry. Upon drying, the salt crusts will be scanned with a high resolution multispectroradiometer following the procedure of Howari et al (2001). The result will be analyzed to determine the relationship between salinity and gypsum contents of the salt crust inferred from spectra analyses. We will also examine if there is a significant correlation between water evaporation rates and the temperature difference between the atmosphere and the crusts. Research activities related to Objective 3 will be carried out in cooperation with the Pan American Center for Environmental Studies at UT El Paso.

Potential Outcome/Benefits: This project should help improve understanding of salt storage and release processes, which are difficult to simulate. Once these processes are understood, and the continuous salinity monitoring system is installed, we would be ready to work on a model, which simulates long-term trends of salinity. Research activities planned may also contribute to practical aspects of riparian management. Salinity distribution data obtained under Objectives 1 and 2, for example, will benefit several agencies in developing operational strategies for riparian management, which include the impact of saltcedar control on salinity status of the riparian zone. This project may also highlight the significance of maintaining surface drainage for maintaining salt balance in riparian zone. The benefit of research activities outlined under Objective 3 would be long term in nature. Our previous study shows that the salt crust is heterogeneous with its surface consisting of crystal of high solubility such as NaCl and $MgCl_2 \cdot 2H_20$. The removal of highly soluble crystals with rain or bank overflow exposes salts of lower solubility such as gypsum. A high-resolution spectrometer can easily detect the presence of gypsum (Attachment 5). In other words, the spectra from gypsum could be used to identify salt crusts subject to surface drainage. Gypsum spectra are also detectable by high resolution airborne spectroscopy such as AVIRIS. In theory, it would be possible in the future to delineate riparian zones on the basis of surface drainage or surface salinity through analyses of airborne spectroscopy. In essence, this project addresses the following concerns and the issues; water resources- quality, modeling of watershed hydrology and water quality, and riparian management.

Collaboration

International Boundary and Water Commission (IBWC) and Texas Natural Resources Conservation Commission (TNRCC) will guide soil and water sampling for this project. National Park Service, Big Bend will provide continuous streamflow salinity near Big Bend. Their primary interest is to find the cause of fish kills reported after bank overflow. The Cooperative Extension, District 6 is currently involved in eradication of saltcedars. This project will provide the information useful for evaluating the impact of such activities on salt storage and release. Pan- American Center for Environmental Studies will facilitate the use of a spectroradiometer and infrared thermometry for this project. The Texas Agricultural Experiment Station at Temple has been our partner, and this project provides the data needed for incorporating salinity into the SWAT model.

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