Guánica Lagoon Area Salinity Study
Final Report

Introduction

The Guánica Lagoon area lies at the eastern, downstream end of the Lajas Valley in southwestern Puerto Rice. Surface runoff is ponded at this location during the seasonal wet period, and is detained before it enters the Rio Loco River near it's outlet to the Caribbean Sea. The health of the coral reefs offshore have been impacted by nutrients and sediment delivered by the Rio Loco into Guánica Bay. The Lajas Valley is one of the major tributaries to the Rio Loco, and its land use is agricultural with large scale production of papayas, mangoes, and other crops. Guánica Lagoon formerly existed as a large depressional wetland, which ponded water to a depth of several feet before overflows exited over a natural levee of the Rio Loco. The wetland was drained by the construction of a large main drain, and several associated laterals. Surface runoff from the Lajas Valley, which formerly ponded in the lagoon for several weeks, now travels through the basin directly into the river. The restoration of the original depth and duration of ponding in Guánica Lagoon has been proposed as part of a broad strategy for reducing impacts to the reef. This restoration would allow bio-geochemical processes to improve the quality of the water delivered to the river, and thus reduce the nutrient and sediment loads to the reef. The lagoon can then act as a sink for sediment and phosphorous, and allow denitrification processes to occur.

The Lajas Valley has known areas where salt concentrations reduce productivity. There is a concern that an increase in the depth and duration of flooding in the lagoon will increase salt concentrations on upstream adjacent cropland. To investigate this potential, a mapping effort was conducted on select areas of Guánica lagoon in June 2011, using a Dual EM meter. This device directly reads the electrical conductivity of the soil at the surface, and at 4 meters. The results are expressed in desisiemens. The readings can be used to indicate the relative concentrations of salt, as well as whether the concentrations increase or decrease with depth. After the mapping effort, soil samples were collected for laboratory analysis from locations within the mapped areas. The interpretations presented in this report are the result of an analysis of the Dual EM data along with the soil laboratory data, and available NRCS Soil Survey information for the soil map units in the lagoon area.

Data Sources

Soil Survey Data

The soils in the lagoon area are predominately of one map unit, Guánica Clay. This soil is a Calciaquert. The Water Features Report from Web Soil Survey states that Guánica clay experiences frequent and long-term ponding during the months of August, September, and October, but no dynamic flooding. These water features interpretations are indicative of a depressional wetland soil where surface runoff ponds in a closed topographic depression, and is not subject to dynamic flooding from a stream hydrograph. The depth to water table is shown as >200 cm. This indicates that water is supplied as surface water, a condition known as episaturation. The Physical Soil Properties shows the saturated hydraulic conductivity, Ksat, to be in the range of 0.01 to 0.1 micrometers/sec, which is an extremely low rate of movement. This Ksat value is constant throughout the entire profile, described to a depth of 79 inches. The Water Features, Physical Soil

Properties, and Depth to Water Table reports are included in the Appendix.

Taken together, the information from the Web Soil Survey reports are consistent with a wetland in the Depressional wetland class as defined by the Hydrogeomorphic (HGM) wetland classification system. The Guánica clay soils can be further defined as existing in a Recharge Depression subclass. The direction of movement of water into and out of a wetland is defined in the HGM system as hydrodynamics. In a Recharge Depressional HGM class wetland, surface water moves horizontally into the wetland as surface runoff, and leaves as vertical downward movement to a disconnected deeper water table, and as vertical upward movement as evapotranspiration. The hydrodynamics of the Recharge Depressional wetland are illustrated in Figure 1, below.

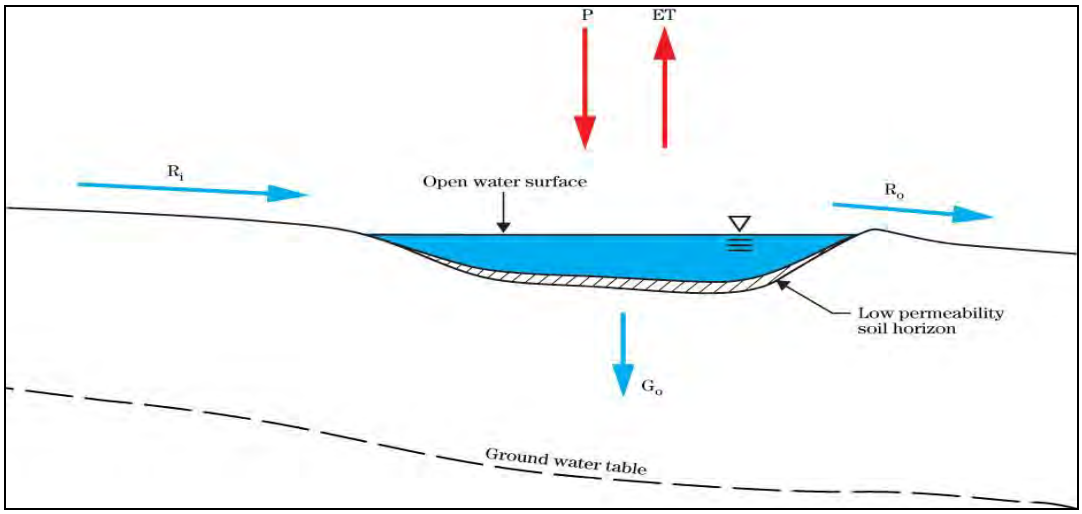

Figure 1. Hydrodynamics of Recharge Depressional Wetlands

In the above illustration, the Ri vector represents surface runoff from the Lajas Valley; the Ro vector represents water delivered to the Rio Loco as the lagoons storage is filled to capacity. The Go vector represents the extremely low rate of water percolation downward to the water table. The water table in the case of Guánica Clay is in excess of 200 cm below the lagoon floor.

In these Recharge Depressional systems, water does not move into or out of the system as groundwater. In the case of Guánica clay, the low Ksat values preclude horizontal groundwater movement. Surface water "perches" on the surface on these low conductivity soils, and most of the water lost is though overflow water and evapotranspiration. The soil profile is in an unsaturated condition at depth. There are no indicators in the Guánica clay description that provide evidence of a high groundwater table. Without a steady high water table, there is no potential for subsurface movement of groundwater from an expanded lagoon.

Dual EM Mapping

The areas mapped were chosen to be representative of the soil conditions across the extent of the lagoon. The device collected data from the soil surface and at a depth of 4 meters. The data was processed using ArcMap 9.3, and is expressed as two separate layers. The associated files have been transferred to NRCS Puerto Rico and other entities involved in the Guánica lagoon restoration effort. Figures 2 and 3 show a view of the GIS map produced from the Dual EM readings. Figure 2 shows the electrical conductivity in the first 2 meters from the soil surface, and Figure 3 shows the conductivity in the soil below 2 meters. The area includes the lower Lajas Valley, with the

Guánica Lagoon outlined in blue.

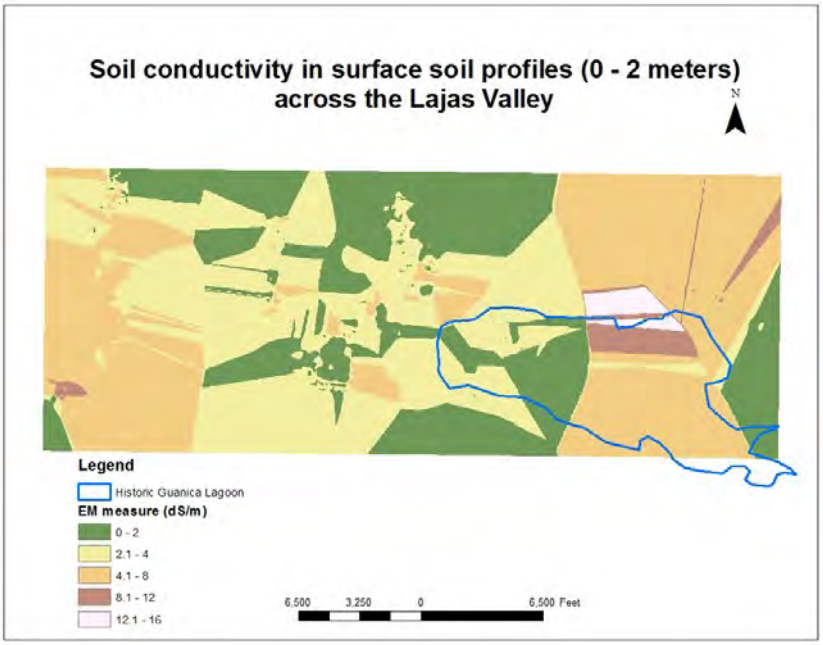

Figure 2. GIS Map of Electrical Conductivity in Guánica Lagoon Near the Surface.

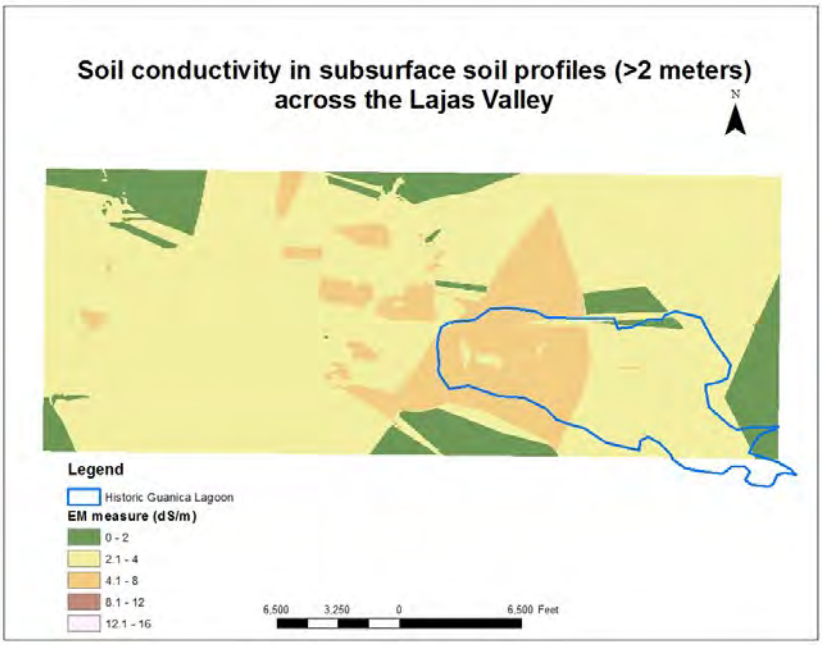

Figure 3. GIS Map of Electrical Conductivity in Guánica Lagoon Below 2 Meters

The results of the mapping effort show a consistent increase in electrical conductivity with depth. This is consistent with the soil hydrodynamics of a Recharge Depressional wetland. Surface water enters the lagoon with a certain concentration of dissolved minerals, including salt. Water with dissolved minerals can only move vertically downward. At depth, the matric potential of vegetation acts to remove pure water, leaving salts behind. This results in an increasing concentration of salt. The actual relationship between depth and salt concentration is a function of

the rooting zone properties of the lagoons vegetation.

Soil Sampling

Soil logging and sampling was conducted by Soil Scientists on the NRCS Puerto Rico staff. Two or more samples were collected per bore hole, and the holes were logged. The samples were transmitted to Ward Laboratories, Kearney, Nebraska, and the results were completed with Ward's soil report of January, 2012. This laboratory analysis conducted a comprehensive testing effort, which included saturated paste ECe, mmoh/cm, and Na concentration, ppm. In the majority of samples, there is a consistent increase in ECe and Na concentration with depth. The Ward Laboratories soil report has been transmitted previously.

Use of Dual EM and Soil Sampling

Originally, the soil sampling effort was intended to provide calibration data for the Dual EM map results. With the use of soil laboratory analysis, the conductivity readings can be converted to salt concentrations. For this calibration effort, the soil samples must be taken from precise locations dictated by a statistical analysis program using Dual EM data. The samples must then be collected at the same surface and 4 meter depths which were sampled by the Dual EM device. Conditions on the ground and workload constraints precluded the close coordination needed to ensure that these samples were taken in accordance with the needs of the calibration effort. However, the results of the soil sampling effort still provided valuable data for determining the source and movement of salts. Likewise, the Dual EM readings also provide valuable information on the concentrations of salts which effect electrical conductivity. However, soil sampling and Dual EM mapping must be analyzed as separate data sources.

Other Sources of Information

Conversations with various parties involved in the Guánica lagoon effort have provided some information on the potential sources of salt in the Lajas Valley watershed. There are known areas along the valley margins where groundwater emerges at the surface. These areas seem to contain high concentrations of salts. These areas, as described, are consistent with wetlands of the Stratigraphic Slope HGM wetland class. In these wetlands, the dominant water source is groundwater. The hydrodynamics of this wetland class are illustrated in Figures 3 and 4. The Gi vectors represent groundwater flow into the wetland, and the Ro vectors represent surface runoff out, as spring or seep flow.

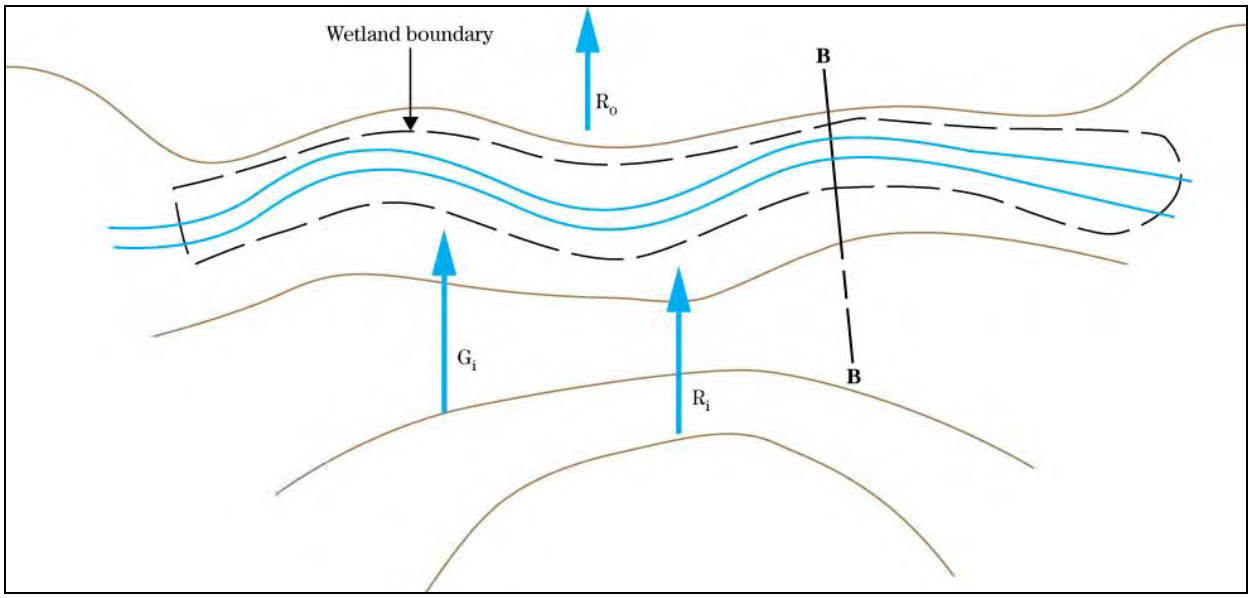

Figure 4. Stratigraphic Slope HGM Wetland Class Plan View

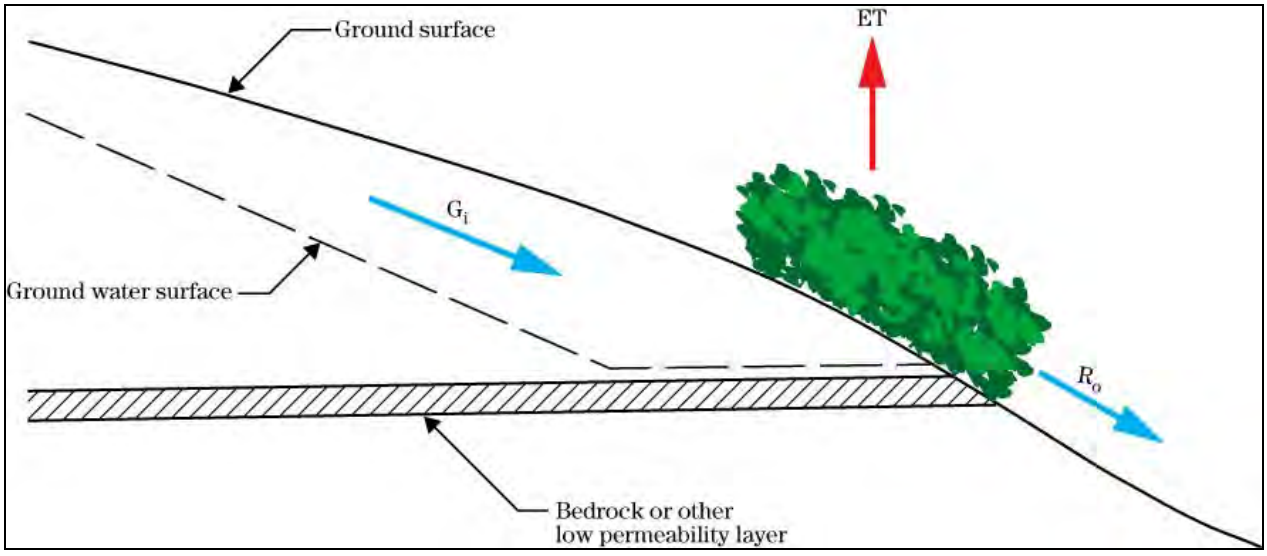

Figure 5. Stratigraphic Slope HGM Wetland Class Section B-B

Groundwater moving though soil and rock layers containing minerals emerges with concentrations of these minerals dissolved. Marine shales are geologic formations which commonly contain high concentrations of salts. If groundwater discharge areas at the margins of the Lajas Valley are coincident with shale outcrops, this might be a significant source of salt. Once the groundwater emerges to the surface in the Lajas Valley, it encounters Guánica clay or similar soils with no ability to allow water to re-enter the water table. From the point of discharge, the water is surface water which flows into the lagoon.

Interpretations

The soils data for Guánica Clay in Web Soil Survey, the electrical conductivity mapping with the Dual EM, and the soils laboratory analysis mutually support the following conclusions:

1. The Guánica lagoon existed as a Recharge Depressional wetland prior to drainage. This wetland received surface runoff from the Lajas Valley, and ponded water above a deeper groundwater table, from which it was hydraulically disconnected.
2. Minerals, including salt, which are dissolved with surface runoff water move slowly downward through very low permeability soils. Vegetation removes water from this unsaturated profile, leaving behind salts.
3. The presence of salts in the soil profile is associated only with areas where surface ponding exists.
4. Since there is no shallow water table capable of moving salt laden water into or out of the lagoon, there is no potential for groundwater effects to increase salinity levels in land areas outside of ponded areas.
5. The areas subject to increases in salinity from an increase in depth will be limited largely to the areas actually subject to increased inundation only.

If the lagoon were supplied with groundwater, the groundwater surface profile would be driven upward at the margins of the lagoon because of the planned increase in lagoon depth and duration of ponding. If this groundwater carried concentrations of salts, salinity effects would be felt in areas subject to this groundwater rise. However, evidence provided by soils, electrical conductivity, and soil laboratory analysis mutually support the conclusion that this is not a system supplied by groundwater.

Other Comments

Local landowners are experiencing negative impacts from salts delivered to cropland areas in the Lajas Valley. While the increase in depth and duration of ponding in the lagoon will have minimal impact on the adjacent cropland, the Lajas Valley area can minimize the effects of salinity by maintaining the existing drainage network. This maintenance will have no negative impact on the downstream lagoon. A project that incorporates lagoon restoration, along with drainage improvements, would meet the objectives of coral reef protection while maintaining and improving the conditions on the remaining Lajas Valley cropland.

Appendix

1. Soil Survey Water Features Report
2. Soil Survey Physical Soil Properties Report
3. Soil Survey Depth to Water Table Report