United States Department of Agriculture

Lajas Valley Surface Runoff & Tailwater Recovery Initiative (LVSRTR)

Puerto Rico Department of Agriculture Rice Initiative – Farm Tailwater Recovery

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Figure 1. East Lajas Valley view from air at Río Loco Conjunction with Lajas Main Drainage.

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Case Study Overview

Setting

Lajas Valley Agricultural Reserve is located in southwestern Puerto Rico, within the municipalities of Lajas, Cabo Rojo, Guánica, and Sabana Grande. It is surrounded by the Cordillera Central and the Santa Marta hills to the north, the Sierra Bermeja (a small range in Lajas and Cabo Rojo), the Boquerón Bay in Cabo Rojo, and Guánica Bay. Its large expanse and fertile soil has made it a good place for agriculture. However, it is one of the driest places in Puerto Rico, making irrigation necessary.

Lajas Valley drains 160 square miles of Lajas, San German, Sabana Grande and Guánica counties. The Lajas Valley Agricultural Reserve extends from Palomas Ward of the municipality of Yauco on the eastern side, to Boquerón Ward of Cabo Rojo on the west. Lajas Valley Agricultural Reserve encompasses an irrigation system whose main channel is 21 miles long and its lateral channels are over 40 miles long. This irrigation system contains an 18.2 miles long drainage canal, one section of which flows into the sea in the municipality of Guánica on the east, and the other flows toward Boquerón on the west. It also includes 48.5 miles of lateral and inter-farm channels and underground drainage systems.

The Lajas Valley covers a total area of around 105,000 cuerdas (108,108 acres) of land, including public and private land, urban, agricultural reserves, wildlife reserves, and nature areas, out of which close to 19,000 cuerdas (19,560 acres) of the agricultural land can be irrigated.

Problem Description

The Lajas Valley has an irrigation and drainage system that was built to optimize agricultural production. The drainage system provides an effective way to remove salts from the soil profile, preventing the upward movement of salts to soil surface. In addition, water soluble chemicals such as fertilizers, manure and its degradation products, organic compounds and pesticides moving from the soil volume to the drainage system have a significant impact on water quality *(Muñoz & Alameda, 2008).*

Rice is a major staple throughout the Caribbean, including Puerto Rico and the U.S. Virgin Islands. To keep pace with increased food demand, rice farmers will need higher yields, increased hectares of rice production, and more efficient use of water resources. Unfortunately, traditional rice production uses large amounts of water. Irrigation practices are needed to grow rice with less water and on well-drained soils not currently used for traditional flooded rice culture *(Gene Stevens, Earl Vories, Jim Heiser and Matthew Rhine, 2012).*

The PR Department of Agriculture is implementing a new initiative targeting food security in the commonwealth. Northeastern Lajas Valley and the PR Land Authority are implementing an initiative to plant 1,000 acres in rice and over 1,000 acres in sugar cane for molasses by 2018. Those two crops are mostly irrigated by flooding.

The objective of this project is to explore and create efficient methods for farmers to manage water usage during rice production, and to develop a healthier method to manage irrigation tailwater. This project proposes to apply irrigation technology, incorporate sustainable production and water conservation practices, and improve soil stewardship to reach this objective.

Water is a key requirement for rice production, and traditional production employs flood irrigation, a practice that uses a substantial volume of water *(Paul Tracy, Barry D. Sims, Steven G. Hefner and John P. Cairns, 1993)*. Flood irrigation involves a significant degree of water management and requires intensive equipment, labor and energy inputs, and is costly and time-consuming. Flood, or surface, irrigation often implies that water distribution is uncontrolled and inefficient.

Water availability, flooding and storm water runoff water are key concerns in rice and sugar cane production. In the future, water demands from other cropping systems in the Valley will create uncertainty as to whether the volume of irrigation water now used to produce rice can be sustained.

Figure 2. Cristales lateral drain receives all tailwater discharges from irrigation of the rice

While surface irrigation for rice production can be practiced effectively using the right water management systems, flood irrigation poses a number of questions regarding productivity, sustainability and environmental concerns.

Rice producers in Lajas Valley apply water to the top end of their fields so that it flows or advances over the field length, crossing through earthen v-shaped channels to the next field. After water is used on several fields, excess tailwater is discharged straight to the drainage channel without any treatment. This untreated water is discharged to the drainage channel that flows into Río Loco and then to Guánica Bay, where it can impact nearshore coral reefs. Irrigation tailwater discharges may cause adverse effects from salinity not only to farmland, but also to downstream habitats and people. Many rivers, particularly in arid zones, tend to become progressively more saline as the water flows from the headwaters to the mouths. Highly saline aquifers interconnected with these river discharge salts to the river system, adversely affecting downstream water users, particularly irrigated agriculture and, in some special cases, wildlife *(FAO, 1997).*

The primary localized problem with flood irrigation in the Lajas Valley is that not all of the water used reaches the plants. Almost 40% can be lost through evaporation and runoff. Collecting runoff and tailwater can help to address this issue, as the use of tailwater recovery systems, which recycles the excess water, rather than leaving it standing to evaporate or discharge to downstream water courses.

Other problems associated with flood irrigation for rice production in Lajas Valley include:

a) Sediment Suspension – sediment particles are suspended in irrigation water and discharged through tailwater.
b) Waterlogging – Can cause the plant to shut down, delaying further growth until sufficient water drains from the root zone.
c) Deep drainage – Over-irrigation may cause water to move below the root zone resulting in rising water tables. In Lajas Valley regions with naturally occurring saline soil layers or saline aquifers, rising water tables may bring salt back up into the root zone, increasing irrigation water salinity.
d) Salinization – Depending on water quality, irrigation water may add significant volumes of salt to the soil profile or to local water sources.

Major Stakeholders

City of Lajas
City of San German
City of Sabana Grande
City of Guánica
Lajas Valley Agricultural Reserve Residents
Lajas Valley Agricultural Producers
Southwest Soil and Water Conservation District
Natural Resources Conservation Service (NRCS)
Puerto Rico Department of Agriculture (DA)
Puerto Rico Land Authority (PRLA)
Puerto Rico Electric Energy Authority (AEE)
Puerto Rico Authority of Sewers and Water (PRASA)
Puerto Rico Department of Natural Resources and Environment (DRNA)
U.S. Fish and Wildlife Service

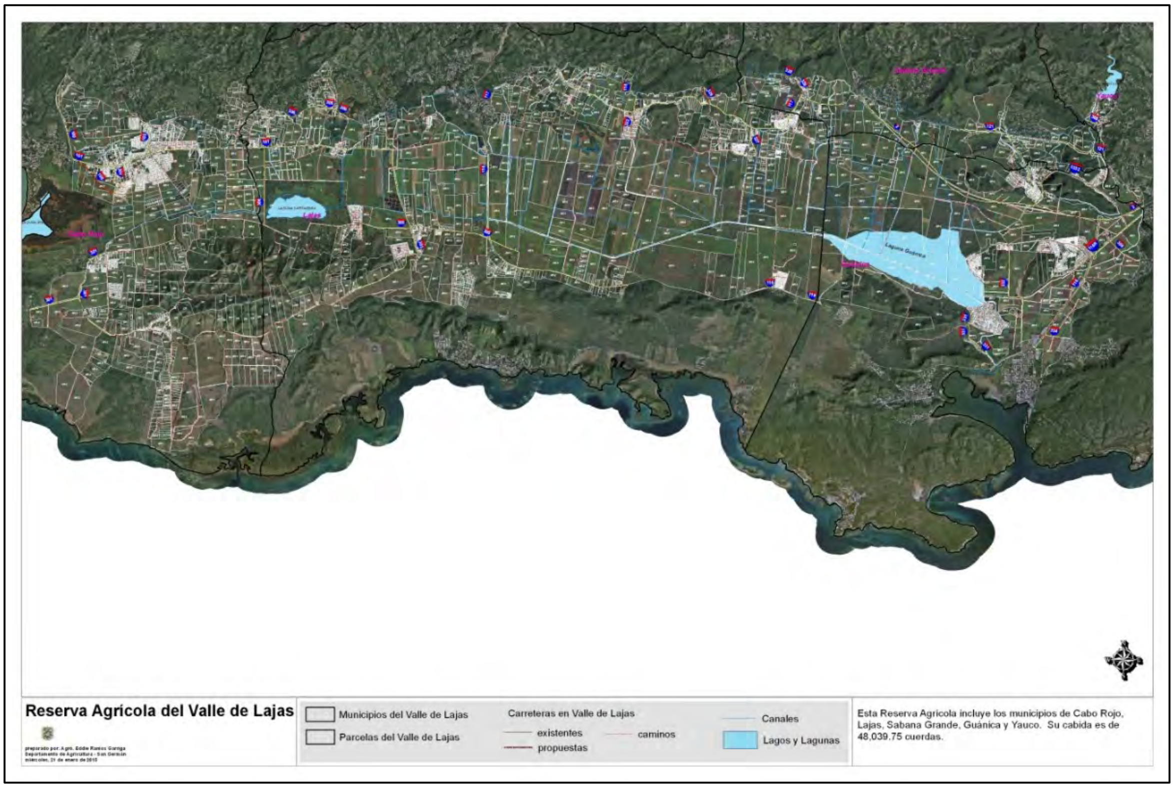

Figure 3. Lajas Valley Agricultural Reserve Land Classification Map.

Lajas Valley Agricultural Reserve Community Profile

The area of the Lajas Valley Agricultural Reserve (LVAR) is located in the southwestern part of Puerto Rico. The LVAR is approximately 30 kilometers long and 6 km wide *(Lajas Valley Agricultural Reserve Farm Inventory*). According to local statistics and assessments, irrigated agricultural land in the Lajas valley (18,679 acres) includes about 1,684 acres (9% of the area) under horticultural crop production. Extensive pasture production for hay or grazing occupies about 7,739 acres (41.6% of the area); shrubland occupies about 8,481 acres (about 46% of the area), and urban land occupies 4% of the area. *(Sotomayor-Ramírez, D. and L. Pérez-Alegría. 2011)*. Data from the PR Planning Board Land Use Plan lists 14,326 parcels totaling 48,035 acres classified as AR-1 and AR-2 (land use for agricultural purposes only) in Lajas Valley.

Agricultural uses are dominated by farms dedicated to pastures for grazing and hay, the other group of farms are in cropland producing fruits, rice and vegetables. The predominant farm size is less than 10 acres, in individual or family farms, operated in full by the owners. The Lajas Valley Agricultural Reserve is composed of 334 farms with 33,631 acres of land total. 7,163 acres are under cash crops and 17,362 acres are under pasture and hay land management *(2012 Census of Agriculture)*.

Farm land by tenure of principal operators breaks down as 51% full owners, 25 % part owners and 24% tenants. Six dairy farms were identified in the area, but there are no significant hog or poultry enterprises.

The farms in the area are mostly under private ownership with full owners and management. The Puerto Rico Land Authority administers 165 farms (28%) and Puerto Rico Land Administration less than 1%. The area of Cartagena Lagoon Natural Reserve is protected by the PR Department of Natural Resources and Environment (DRNE).

The reserve is an attractive agricultural and ecological source income for area residents who live off agriculture either because they are land owners or workers. The properties rented by private seed companies are a source of employment for the population of the area.

Agriculture is one of the largest economic contributors in the area, but problems such as drainage, irrigation, salinity, water availability and fires are identified by land users of the area.

The area is also a popular tourist destination. Throughout the year it receives local and off-island visitors who enjoy the Bioluminescent Bay in La Parguera, Guánica Bay, the Cartagena Lagoon, Guánica Dry Forest, and agricultural products, such as the Cabezona Pineapple, that are unique to the zone.

Lajas Valley Census Data

The following data was gathered from the U.S. Census Bureau, 2010 Census, Lajas Municipio.

General Information

Latitude:	18.0464
Longitude:	67.0562
Population:	25,753
Density:	
Housing Units:	11806
Land Area:	
Water Area:	

Educational Achievement (*over 25 years old*)

9^{th}-12^{th} none diploma	17.5 %
High school graduate	22.2 %
Some college, no degree	10.8%
Associate degree	3.7%
Bachelor's degree	10.2%
Graduate or professional degree	2.9 %

Household Income

$10,000-$14,999	16.5 %
$15,000-$24,999	22.0 %
$25,000-$34,999	9.7 %
$35,000-$49,999	8.6 %
$50,000-$74,999	4.4 %
$75,000-$99,999	1.5 %
$100,000-$149,999	0.6 %
$150,000-$199,999	0.1%
>$200,000	0 %
Median Household Income	$15,754

Marital Status (*over 15 years of age*)

Never Married	25.5%
Married	54.9 %
Separated	3.0 %
Widowed	6.5 %
Divorced	10.1%
Same home 5+ years	76.5 %

Occupation (age over 16 years)

Mgmt/Professional	21.7 %
Service	16.5 %
Sales/Office	22.4 %
Farm/Agriculture	3.7 %
Construction	14.9 %
Production/Transportation	20.8 %
Private wage and salary workers	67.2 %
Government workers	23.5 %
Self-employed workers in own not incorporated business	9.1 %

Unemployment/Poverty

Unemployment	3.3 %
Below Poverty Level	9.6 %

Demographics

Hispanic/Latino	99.2 %
White	86.7 %
Black/African American	2.9 %
American Indian/Alaska Native	0.2 %
Asian	0.1%
Hawaiian/Pacific Islander	0%
Some other Race	7.2%
Multiracial	1.8 %
Veterans	5.9 %

Rural and Urban Interests

The Lajas Valley Agricultural Reserve is characterized primarily by farms and ranches producing pasture for grazing and hay, rice for seed and for consumption, vegetables and garden produce, fruit, grain, aquaculture, sugar cane and pineapples. The area also contains fallow or untilled land.

Land in the area is both under private and public (PR government) ownership and management, with the exception of US Fish & Wildlife Service land on the west side of the valley.

The Lajas Valley Agricultural Reserve is highly influenced by the uncertainty in the agricultural industry. Production factors, such as weather and markets, are out of the landowner's control. Local and federal government agencies have provided assistance, mitigating these concerns where possible. As surrounding urban activities expand and use more water, residents may be impacted by potential major environmental or economic changes in water availability.

AN ACT TO:

declare the public policy of the Government of Puerto Rico with regard to the agricultural development of the lands located within the area known as the Valle de Lajas (the Lajas Valley); to direct the promulgation and adoption of a special zoning resolution to stimulate agricultural production and development; to prohibit land use approval consultations, the granting of construction or use permits in contravention of said public policy and the segregation of farms in parcels smaller than fifty (50) cuerdas by the Planning Board, the Regulations and Permits Administration, and those municipalities with lands where the Reserve is to be established; to establish a special tax; to order the revocation of every permit granted by regulatory agencies and the discontinuation of all non-agricultural activities; to require the identification of the title holders of all properties and the demarcation of the properties with agricultural potential owned by government agencies and public corporations; to develop and execute a plan for the integral development of the Valle de Lajas (the Lajas Valley); and for other related purposes *((S.B. 1656) (Conference) (No. 277) (Approved August 20, 1999))*.

Economic and Environmental Interests

There is high and increasing interest in the environmental impacts produced by ranch and farm lands in the Lajas Valley Agriculture Reserve. The LVAR offers limited opportunities for urban development, but conversion of dry to irrigated cropland may increase, along with opportunities to delineate non-use areas for conservation as natural preserves for wildlife management.

Lajas is a clean and quiet town, and the people of Lajas are mostly simple, humble farmers and fishermen who raise goats and chickens and cater to tourists as a means to support their families. Lajas Valley's population has declined around 8% from 26,673 in the 2000 Census to 25,753 in the 2010 Census, with a further decline to 24,465 in 2014 *(US Census Bureau web data).* Land in agriculture has grown significantly (~54%), from 21,854 acres in 2007 to 33,631 acres in 2012 *(2012 Census of Agriculture)*, as new enterprises, both public and commercial, have been established. The Lajas municipality's economy is generated mostly by the manufacturing, retail and hospitality industries. However, agriculture also plays a large role in this area, increasing its market value from $8.34M in 2007 to $9.73M in 2012 *(2012 Census of Agriculture)* for produce including vegetables, melons, pineapples, rice and sugar cane. Lajas is Puerto Rico's leading producer of hay for feed, sheep and beef cattle.

Fishing is also a significant economic activity in Lajas Valley, especially in La Parguera and Guánica Bay, which are very productive fishing zones in the Southwest. The waters off the coast of Lajas are extremely clear, spectacular, free of currents and very warm. But most of the area's coral reefs and many nearby islands and cays are threatened by land-based sources of sediment from Guánica and Guayanilla coastal areas.

There is widespread support for local agricultural production and marketing connections. Local groups also recommend using the land for wildlife habitat management and other restoration activities. Locally-active environmental organizations would be natural stakeholders.

Government Interests

Public Law 26 of April 12, 1941, as amended, is known as the "Law of Puerto Rico's Land" and created the Puerto Rico Land Authority (PRLA) and entrusted it to develop and implement the Commonwealth's agrarian policy, preserve agricultural heritage lands make them available by lease to farmers for a reasonable fee, and serve as an instrument of farm production, among other responsibilities and functions.

Government stakeholders have proposed various projects for the Eastern Lajas Valley Reserve. As public policy, the Puerto Rico Department of Agriculture (PRDA) encourages the establishment and reconstruction of water infrastructure, a scarce and vital resource for agricultural development. This measure is strongly recommended for farmers to avoid a water crisis caused by changes in rainfall patterns, and to increase water use efficiency. Water conservation strategies to promote include: creating storage, rehabilitating irrigation and drainage, and recharging aquifers with infiltration practices to capture excess water.

1. **LAW 277 (20 AUGUST 1999) -** To declare the public policy of the Government of Puerto Rico in relation to the agricultural development of lands within the Lajas Valley. It orders the promulgation and adoption of a special zoning resolution to stimulate agricultural production and development; prohibit the approval of location queries, the granting of permits for construction or use in contravention of said public policy, and segregation of properties in plots of less than fifty (50) cuerdas (51.48 acres) by the Puerto Rico Planning Board, the Regulations and Permits Administration, and relocate those municipalities where reserve land to settle here; establish a special contribution; order the revocation of any permit granted by regulatory agencies and the cessation of any agricultural activity; require identification of ownership of all farms and the demarcation of farms with agricultural potential owned by government agencies and public corporations; develop and implement a plan for the development of the Lajas Valley; and for other related purposes.
2. **PUBLIC POLICY STATEMENT ON CLIMATE CHANGE** (March 6, 2014) **-** Article VI, Section 19 of the Constitution of the Commonwealth of Puerto Rico, provides in pertinent part that it will be public policy of the Commonwealth to effectively conserve natural resources and implement the best development for the benefit of the general public.
3. **Establishment of Sugar Cane for Molasses –** A joint effort between the Department of Economic Development, the Industrial Development Company, Rums of Puerto Rico and the Puerto Rico Department of Agriculture comprising the initial development of 20,000 acres of sugar cane in the south and southwest of Puerto Rico to produce raw material for Puerto Rico's rum industry.
4. **Establishment of Rice production crop for Public Schools** – Established approx. 500 acres of long grain rice production, integral type, to meet part of the institutional market on the island. Rice is the main agricultural product consumed daily in Puerto Rico, but is not produced in commercial quantities locally. A very important aspect of food security is local production of at least a portion of the food needed for local consumption.
5. **Establishment of a Mitigation Bank -** This project was proposed to restore the 1,230.18 acres of agricultural land on the historic Guánica Lagoon site into healthy open water and wetland systems. Additionally, the project proposed to protect and conserve this area, which is recognized as a secondary important site to wildlife, based on its restoration potential for waterfowl and freshwater marsh birds. This Proposal was dismissed by Army Corps of Engineers.

Environment Assessment

*****Refer to CPA-52 ENVIRONMENTAL EVALUATION WORKSHEET Appendix*****

Environmental Resources

Criteria were established to determine the soil and terrain suitability for irrigation on the basis of information provided by the Web Soil Survey soil maps of the area of interest.

The climate of the Lajas Valley is mainly affected by its geographical location in Puerto Rico and the prevailing winds in the south of the island. There are no weather stations to measure wind velocity and direction in Lajas Valley. The nearest station is in Ponce, which may be representative of the prevailing winds in Lajas Valley.

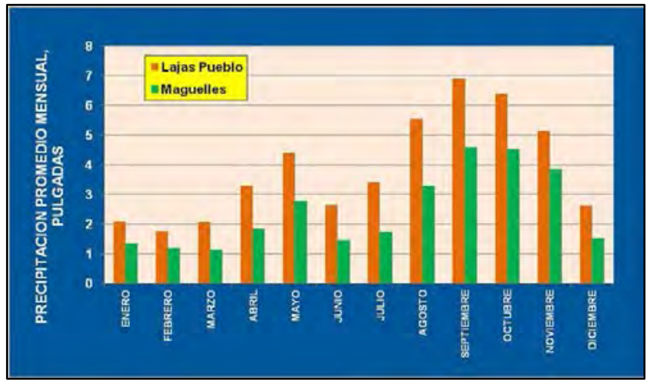

Figure 4. Monthly Precipitation in the Lajas Valley.

Historic average monthly precipitation in Lajas Valley follows a similar curve as the rest of Puerto Rico, but at with lower rainfall amounts. Lajas' average monthly rainfall (1948-2011) varies from a minimum of 1.8" in February to a maximum of 6.9" in September. On the island of Maguelles, 1959-2011 data reflect average minimum highs of 1.1" in March and 4.6" in September. In Lajas, the historic monthly minimum was 0.1" in 1975 and the maximum was 23.11" in 2008; in Maguelles the historic monthly minimum was 0.1" in January 1975 and 21.53" in October 1985 (*Ferdinand Quiñones, 2014*).

The predominant vegetative cover types in the southwest are mangroves, salt flats, littoral woodland (beach thickets), mesquite and semi-evergreen woodland, coastal shrub or thorn woodland, deciduous woodland, agricultural lands including pastures, and residential areas and roadside trees (*McKenzie and Noble, 1990*).

Wildlife Resources

Many factors are suspected to have contributed to wildlife population declines in the Lajas Valley Agricultural Reserve. Those include habitat fragmentation of breeding grounds, habitat deforestation, pesticides, and the cumulative effects of habitat changes. For example the Puerto Rican Crested Toad (*peltophryne lemur*) inhabits low elevation arid or semiarid, rocky areas with abundance of limestone fissures and cavities in well drained soils, its principal threats are habitat loss and predation (USFWS, 1992).

Prior to the construction of the Lajas Valley irrigation canal system in the 1950s, high bird counts were observed in the area (17,000 waterfowl and 100,000 shorebirds). Since the construction of the Lajas Valley Irrigation System, agricultural practices (irrigation canal drainage and fertilizer runoff) have caused about 90% percent of the Cartagena lagoon to fill with cattails, precluding the lagoons' use by almost all other species, animal or plant. *(USFWS 2004).* The valley has endured much stress: nearly all of the land has been converted to agriculture. Agricultural practices and grazing result in non-point source pollution, and to a lesser degree, point-source pollution. Hydrological disruption of the lagoon system has been significant, another result of land conversion. Exotic species have largely replaced the native vegetation in the valley *(USFWS, 1996).*

About 50 different bird species breed in New England and then migrate south along the east coast to Florida and then by island to South America; however, only about 25 species of birds migrate beyond Cuba to Puerto Rico along this route to their winter quarters, while only six species are known to travel to South America by way of the Lesser Antilles. Many thousands of American Coots and American Widgeons, Northern Pintails, Blue-winged Teals, and other waterfowl and shorebirds, regularly spend the winter season in the coastal marshes, inland lakes, and ponds of Cuba, Hispaniola and Puerto Rico *(Lincoln, F., 1999)*.

Geology and Soils

The southwestern part of Puerto Rico is characterized by long ridges such as the Sierra Bermeja, separated by parallel valleys like Lajas Valley. The ridges contain rocks of marine Cretaceous sediments such as ashy shales, massive limestone and agglomerates. The valleys, in contrast, are partly covered with alluvial deposits of recent origin underlain by consolidated carbonate and clastic strata (sedimentary rock of Cretaceous and Tertiary age extended to the east). They are very deep with high, nearly uniform clay content (*Lugo-Lopez et al, 1959*).

The top soil averages 30 cm depth, but in some places approaches 60 cm deep. The small soil pores conduct water well in the top soil but show very slow hydraulic conductivity in the subsoil. The soils are low in organic matter and nitrogen and generally high in soluble salts and exchangeable sodium, notably below 60 cm. The taxonomy of Puerto Rican soils, including those of the Lajas Valley, was outlined according to the new soils classification system (7^{th} approximation) (*Lugo-López and Rivera 1976, 1977*).

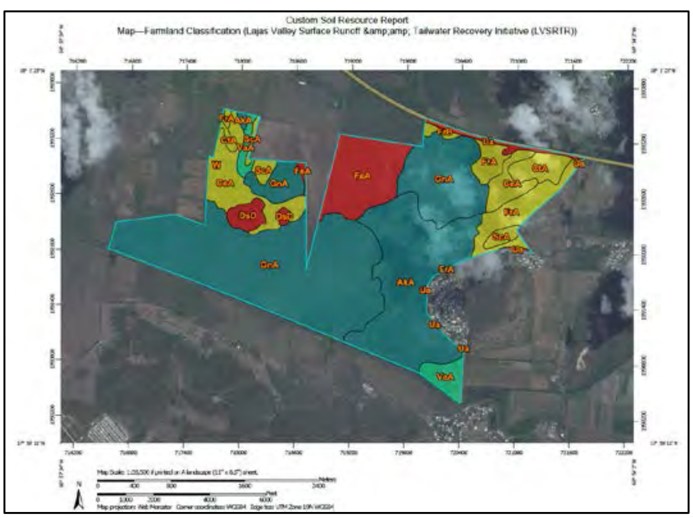

Figure 6. Farmland Classification (Lajas Valley Surface Runoff & Tailwater Recovery Initiative (LVSRTR)).

Resource Concerns

Soil


Figure 7. Stream banks eroded due to runoff.

1) Concentrated Flow Erosion:
   a) Untreated classic gullies may enlarge progressively by head cutting and/or lateral widening. Ephemeral gullies occur in the same low area and are obscured by tillage. This includes concentrated low erosion caused by runoff from rainfall or irrigation water.
2) Compaction:
   a) Soil compaction symptoms are a result of increased bulk densities that affect the ideal proportion of air and water in the soil. The quality of the soil is destroyed because it restricts rooting depth and decreases pore size. The effects are more water-filled pores less able to absorb water, increasing runoff and erosion, and lower soil temperatures.
3) Sheet, Rill and Wind Erosion:
   a) Detachment and transport of soil particles caused by raindrop impact/splash, rainfall runoff, irrigation runoff or wind that degrades soil quality.
4) Shoreline, Bank and Channel Erosion:
   a) Sediment from banks, shorelines or conveyance channels threatens to degrade water quality and limit use for intended purposes.
5) Soil salinity:
   a) Potential problem in irrigated soils due to high evaporation rates and low annual rainfall, leaving salts to accumulate.
   b) Salts can originate from irrigation water, fertilizers, composts and manure.
   c) Salts can be leached from saline soils by slowly applying excess water.

Table 1 —Irrigation Value Limitations in terms of acres planned to be planted, General (Lajas Valley Surface Runoff & Tailwater Recovery Initiative (LVSRTR)).

Irrigation, General— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Very limited	1,061.7	59.5%
Somewhat limited	225.9	12.7%
Not limited	108.6	6.1%
Null or Not Rated	387.6	21.7%
Totals for Area of Interest	**1,783.9**	**100.0%**

The Area of Interest (AOI) soil rating class indicates the extent to which the soils are limited by all of the soil features that affect the interpretation. “Not limited” indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. “Somewhat limited” indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. “Very limited” indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Water

On average, plants consume from 0.1" to 0.3" in of rainfall or irrigation per day.

Figure 8. Algal bloom as a result of excess nutrients.

- ✓ Sandy soils: Hold between 0.5-1" of water per ft. soil
- ✓ Loams: Hold between 0.8-2" per ft. soil
- ✓ Clay: Hold between 1.3-2.4" per ft. soil

1) Water Quality:
   a) Nutrients (organic and inorganic) are transported from cropland to Lajas Valley drainage waters through surface runoff and tailwater discharge in quantities that degrade water quality, limit use for fisheries and impair coral reefs.
   b) Chemicals are carried by soil amendments that are applied to the land and are subsequently transported by discharge waters in quantities that degrade water quality. This includes the off-site transport of tailwater and runoff from rice production.
2) Water Availability:
   a) Irrigation water is not stored, delivered, scheduled and/or applied efficiently. Surface water withdrawals threaten sustained availability of water. Available irrigation water supplies are reduced due to competition with other cropping systems in the area.
3) Sediment loading:
   a) Off-site transport of sediment from sheet, rill and gully erosion into surface waters that degrades surface water quality and limits use for irrigation and wildlife.
4) Runoff:
   a) Surface water or poor subsurface drainage restricts land use and management goals.
   b) Irrigation and rainfall runoff transports salts to receiving waters in quantities that degrade water quality and limit use for intended purposes.
5) Salinization:
   a) Depending on water quality, irrigation water may add significant volumes of salt to local water sources.
   b) Salts can be leached from saline soils by slowly applying excess water.
      i) Three inches removes about 50% of the soluble salts.
      ii) Five inches removes about 90%.

Table 2 —Water Ponding Frequency Class by Soil Map Unit (Lajas Valley Surface Runoff & Tailwater Recovery Initiative (LVSRTR)).

Ponding Frequency Class— Summary by Map Unit — San German Area, Southwestern Puerto Rico (PR787)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
AkA	Aguirre clay, occasionally ponded	Occasional	362.1	20.3%
CeA	Cartagena clay, 0 to 2 percent slopes	None	140.2	7.9%
CtA	Cortada silty clay loam, 0 to 2 percent slopes, occasionally flooded	None	46.7	2.6%
DsD	Descalabrado clay, 12 to 20 percent slopes	None	32.0	1.8%
FeA	Fe clay, 0 to 2 percent slopes	None	155.9	8.7%
FrA	Fraternidad clay, 0 to 2 percent slopes	None	108.6	6.1%
FrB	Fraternidad clay, 2 to 5 percent slopes	None	8.2	0.5%
GnA	Guanica clay, 0 to 1 percent slopes	Frequent	824.7	46.2%
ScA	San Anton clay loam, 0 to 2 percent slopes, occasionally flooded	None	31.0	1.7%
Ua	Urban land	None	24.1	1.4%
VaA	Vayas silty clay, 0 to 2 percent slopes, occasionally flooded	None	49.2	2.8%
W	Water	None	1.4	0.1%
Totals for Area of Interest			**1,783.9**	**100.0%**

Plants

Figure 9. Tailwater outlet discharging straight to lateral drainage Cristales.

1) Plant Productivity and Health:
   a. Plant productivity, vigor and/or quality negatively impacts other resources or does not meet yield potential due to improper fertility, management or plants not adapted to site.
2) Structure and Composition:
   a. Plant communities have insufficient composition and structure to achieve ecological functions and management objectives.
   b. Inadequate structure and composition also includes degradation of wetland habitat, targeted ecosystems, or unique plant communities.

Table 3 —Yields of Irrigated Crops (Component): 18-month sugarcane (Tons) (Lajas Valley Surface Runoff & Tailwater Recovery Initiative (LVSRTR)).

Yields of Irrigated Crops (Component): 18-month sugarcane (Tons)— Summary by Map Unit — San German Area, Southwestern Puerto Rico (PR787)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
AkA	Aguirre clay, occasionally ponded	60.00	362.1	20.3%
CeA	Cartagena clay, 0 to 2 percent slopes	60.00	140.2	7.9%
CtA	Cortada silty clay loam, 0 to 2 percent slopes, occasionally flooded	69.90	46.7	2.6%
DsD	Descalabrado clay, 12 to 20 percent slopes		32.0	1.8%
FeA	Fe clay, 0 to 2 percent slopes	3.10	155.9	8.7%
FrA	Fraternidad clay, 0 to 2 percent slopes	64.75	108.6	6.1%
FrB	Fraternidad clay, 2 to 5 percent slopes	64.75	8.2	0.5%
GnA	Guanica clay, 0 to 1 percent slopes	60.25	824.7	46.2%
ScA	San Anton clay loam, 0 to 2 percent slopes, occasionally flooded	69.80	31.0	1.7%
Ua	Urban land		24.1	1.4%
VaA	Vayas silty clay, 0 to 2 percent slopes, occasionally flooded	61.00	49.2	2.8%
W	Water		1.4	0.1%
Totals for Area of Interest			**1,783.9**	**100.0%**

Table 4 —Yields of Irrigated Crops (Component): Rice (Bu) (Lajas Valley Surface Runoff & Tailwater Recovery Initiative (LVSRTR)).

Yields of Irrigated Crops (Component): Rice (Bu)— Summary by Map Unit — San German Area, Southwestern Puerto Rico (PR787)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
AkA	Aguirre clay, occasionally ponded	127.50	362.1	20.3%
CeA	Cartagena clay, 0 to 2 percent slopes	87.50	140.2	7.9%
CtA	Cortada silty clay loam, 0 to 2 percent slopes, occasionally flooded	0.80	46.7	2.6%
DsD	Descalabrado clay, 12 to 20 percent slopes		32.0	1.8%
FeA	Fe clay, 0 to 2 percent slopes	2.40	155.9	8.7%
FrA	Fraternidad clay, 0 to 2 percent slopes	4.00	108.6	6.1%
FrB	Fraternidad clay, 2 to 5 percent slopes	4.00	8.2	0.5%
GnA	Guanica clay, 0 to 1 percent slopes	81.00	824.7	46.2%
ScA	San Anton clay loam, 0 to 2 percent slopes, occasionally flooded	1.60	31.0	1.7%
Ua	Urban land		24.1	1.4%
VaA	Vayas silty clay, 0 to 2 percent slopes, occasionally flooded	72.00	49.2	2.8%
W	Water		1.4	0.1%
Totals for Area of Interest			**1,783.9**	**100.0%**

Potential Opportunities, Alternatives, and Plausible Solutions

1. Implement a Tailwater recovery system that includes no less than:
    a. Irrigation Water Collection facilities (i.e. water reservoirs)
    b. Irrigation Transfer Facilities
        i. Canals / Pipelines
        ii. Lining/protect existing Canals
    c. Discharge Water Collection Facilities (i.e Tailwater recovery pond)
    d. Re-used water Transfer
        i. Conveyance to Reservoir
            1. Pipelines
            2. Pumping systems
        ii. Conveyance to Treatment Facilities through Canals / Pipelines to Treatment Wetlands and/or Sediment Control Basins
2. Implement water conservation practices on agricultural lands to reduce runoff to stream flows.
3. Implement irrigation water management systems to reduce the quantity of irrigation water withdrawals to the pluvial drainage channel.
4. Eliminate flood irrigation in favor of sprinkler systems on field crops, or conversion to a lower water volume flooding system.
5. Reduce sediment input to the streams to improve coral reef and fish habitat.
6. Install stream bank stabilization and in-stream runoff control structures.
7. Build rock drop structures into stream stabilization measures to create pools that serve as velocity dissipaters and create habitat.
8. Reduce erosion from uplands that contribute large amounts of sediment to streams.
9. Implement crop residue management and promote conservation tillage (direct seeding, minimum-tillage, no-tillage) on both irrigated and non-irrigated cropland.
10. Reduce slope length with terraces, land leveling, strip cropping or contour farming.
11. Enforce federal, state and local environmental laws and ordinances.
12. Employ diversion screening and water quality monitoring.
13. Install riparian fencing along the lower reaches of canals and drainage channels.
14. Modify grazing systems to improve ecological condition and plant cover.
15. Implement nutrient and pest management to improve water quality.
16. Actively manage conservation easement lands.
17. Preserve viable fish & wildlife populations through improved habitat protection and habitat enhancement.
18. Remove hydric, saline and saline-sodic soils from production to reduce dissolved salts in runoff and tailwater.
19. Use hydric, saline and saline-sodic patches as wildlife habitat plots or natural areas preserved through conservation programs.
20. Control drainage and soil salinity through flushing to leach salts from the soil.
21. Reduce water-logging through drainage, tile drainage or water table control by another form of subsurface drainage.

Recommended Conservation Practices for Lajas Valley Surface Runoff & Tailwater Recovery Initiative

A tailwater recovery system is a designed system that can collect, store and transport irrigation tailwater and storm water runoff for re-use in the farm irrigation system or to dispose after treatment. This practice conserves irrigation water supplies by intercepting and re-using tailwater, improving water quality downstream. They are useful for water conservation and keeping sediment and pesticide residues out of public waterways. This system is adaptable to single fields or whole farms. Some of the recommended conservation practices include but are not limited to:

Collection facilities:

Irrigation Water Management (449): The process of determining and controlling the volume, frequency, and application rate of irrigation water to improve irrigation water use efficiency and manage salts in the crop root zone.

Irrigation System, Surface and Subsurface (443): A system in which all necessary earthwork, multi-outlet pipelines, and water-control structures have been installed for efficiently distribution of water by surface means, such as furrows, borders, and contour levees, or by subsurface means through water table control.

Irrigation Land Leveling (464): Reshaping the surface of land to be irrigated to planned lines and grades to improve water use efficiency.

Irrigation Field Ditch (388): A permanent irrigation ditch constructed in or with earth materials, to convey water from the supply source to a field or fields in an irrigation system to improve the distribution uniformity and irrigation efficiency of water applied on irrigated land.

Irrigation Ditch Lining (428): A lining of impervious material or chemical treatment, installed in an irrigation ditch, canal or lateral drain to improve conveyance of irrigation water, prevent water logging of land, maintain water quality, prevent erosion, reduce water loss and reduce energy use.

Water and Sediment Control Basin (638): An earth embankment or a combination ridge and channel constructed across the slope of minor watercourses to form a sediment trap and water detention basin with a stable outlet to reduce and manage onsite and downstream runoff.

Storage Facilities:

Irrigation Reservoir (436): An irrigation water storage structure made by constructing a dam, embankment, pit or tank to provide a reliable irrigation water supply or regulate available irrigation flows and provide storage for tailwater recovery and reuse.

Conveyance Facilities:

Pumping Plant (533): A facility that delivers water at a designed pressure and flow rate from the collection facility to the storage facility or directly to the irrigation system.

Heavy Use Area Protection (561): Used to stabilize a ground surface that is frequently and intensively used by people, animals or vehicles.

Irrigation Pipeline (430): A pipeline and appurtenances installed to convey water from a source of supply to an irrigation system or storage reservoir.

Structure for Water Control (587): A structure in a water management system that conveys water, controls the direction or rate of flow, maintains a desired water surface elevation or measures water.

Treatment:

Land Clearing (460): Removing trees, stumps and other vegetation from wooded areas to achieve a conservation objective. Site preparation.

Clearing and Snagging (326): Removal of vegetation along the bank (clearing) and/or selective removal of snags, drifts, or other obstructions (snagging) from natural or improved channels and streams to prevent excessive bank erosion by eddies or redirection of flow.

Critical Area Planting (342): Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical or biological conditions that prevent the establishment of vegetation with normal practices.

Filter Strips (393): A strip or area of herbaceous vegetation that removes contaminants from overland flow to reduce suspended solids and associated contaminants in runoff.

Constructed Wetland (656): An artificial ecosystem with hydrophytic vegetation to treat contaminated runoff water from agricultural processing or improve the quality of storm water runoff or other water flows lacking specific water quality discharge criteria.

Wetland Enhancement (659): The augmentation of wetland functions beyond the original natural conditions on a former, degraded or naturally-functioning wetland site to increase the capacity of specific wetland functions.

Early Successional Habitat Development / Management (647): Manage plant succession to develop and maintain early successional habitat to benefit desired wildlife and/or natural communities.

Salinity and Sodic Soil Management (610): Management of land, water and plants to reduce accumulations of salts and/or sodium on the soil surface and in the crop rooting zone.

Nutrient Management (590): Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments.

Integrated Pest Management (595): A site-specific combination of pest prevention, pest avoidance, pest monitoring, and pest suppression strategies.

Figure 10. Unprotected irrigation channels conveying water to rice fields.

Rice Initiative Farm Tailwater Recovery Pilot Project Concept

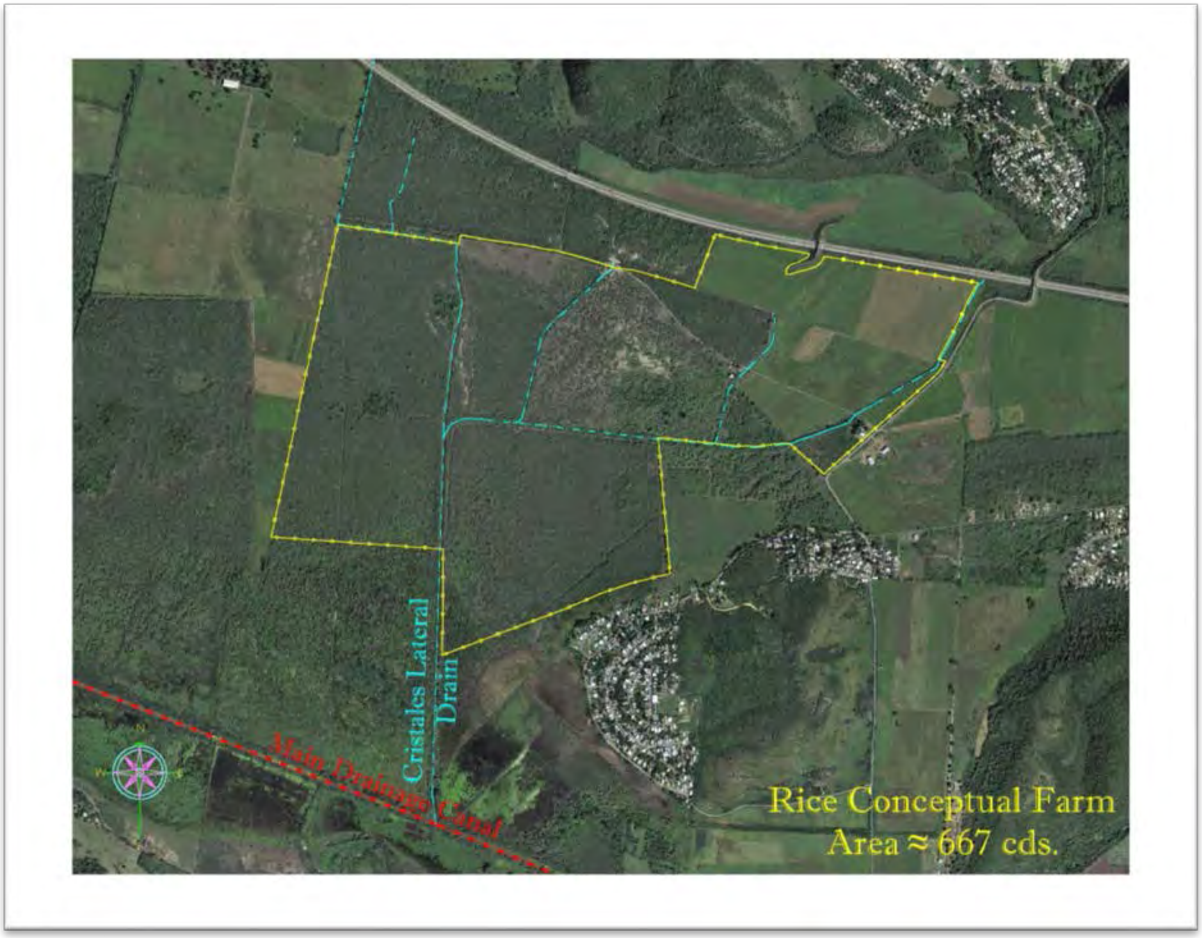

Figure 11. PR Agriculture Department Rice Initiative Farm Area.

The PR Department of Agriculture Rice Initiative comprises approximately 667 acres of prime farmland located in the eastern Lajas Valley Agriculture Reserve, between Sabana Grande and Guánica counties. The land is government-owned, administrated by the PR Land Authority. Inside the farm, four (4) lateral drains connect with the Cristales drainage on the west, which drains excess irrigation water and pluvial runoff south to the Main Drainage Canal. The Main Drainage Canal connects on the east with Río Loco and drains to Guánica Bay. This area was selected to develop a Conceptual Tailwater Recovery Project.

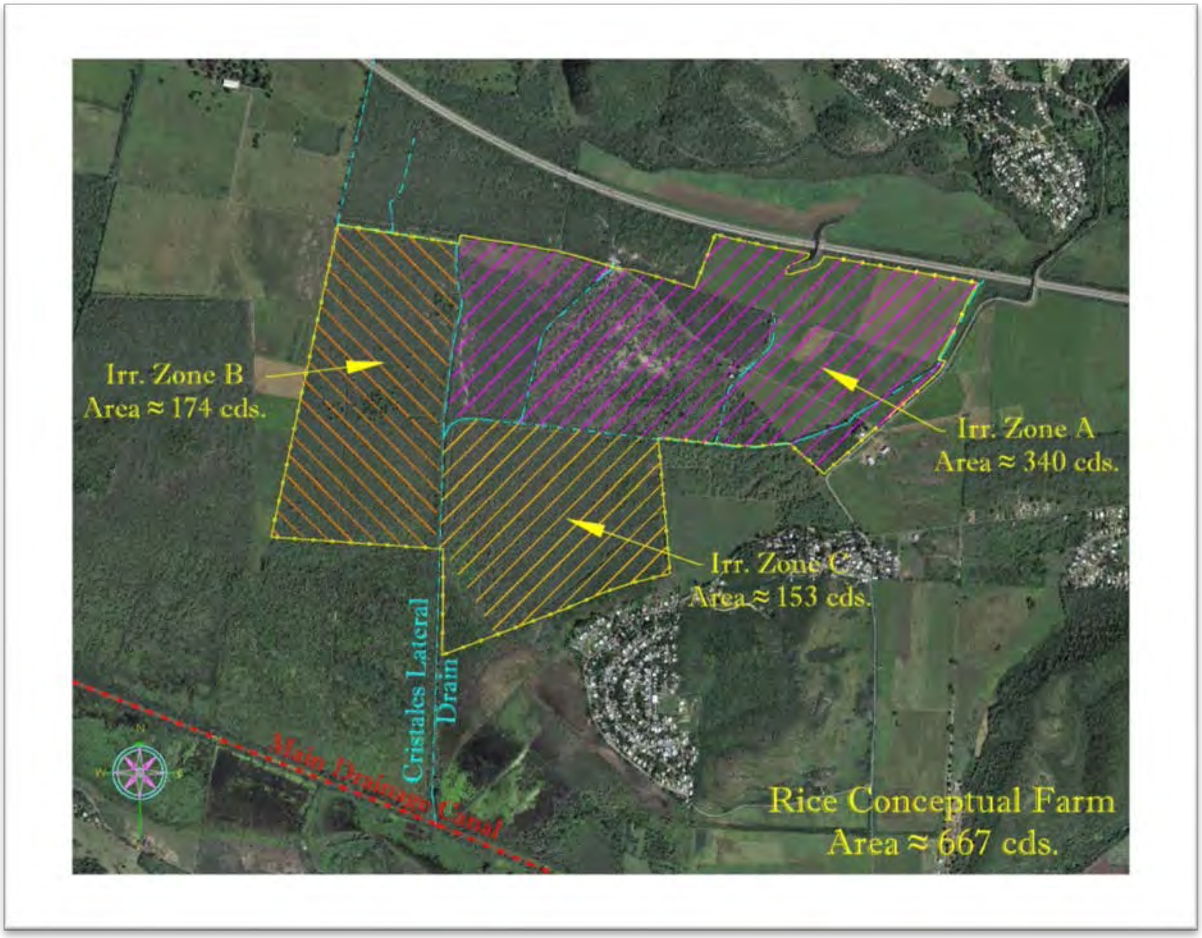

Figure 12. Irrigations zones.

To design the tailwater recovery system for the Rice Conceptual Farm, the farm hydrology was analyzed and the acreage was divided into three irrigations zones (Zones A, B, C) using water movements and land contouring. The existing basin irrigation system is the "flow through system", also called the conventional system. Water supplied to the topmost basin sequentially floods each successive basin as it makes it way to the lowermost basin (elevation). The water is regulated by weirs. Excess water is allowed to spill over the last weir into a drain. By continually supplying water to the top field and allowing a small amount to spill out the bottom field, with the weirs adjusted properly, the water level is automatically maintained, hence the name "flow through system."

The advantages of this system include low installation cost, ability to flush salts from the field, easy installation and removal, and adaptation to irregular slopes. The disadvantages include substantial management, difficulty in preventing excess water in lower basins, and slow response to adjustments. This system is not well-adapted to holding water if required by regulation.

Figure 13. Irrigation Water Reservoir 7-day storage.

Recent increases in agricultural activity suggest that Lajas Valley farmers will be soon operating under limited water availability conditions. On-farm reservoirs, as part of a tailwater recovery system, can improve profitability and reduce dependence on external water sources. The purpose is to regulate available irrigation flows, improve water use efficiency on irrigated land and provide storage for tailwater recovery and reuse. A 7-day storage reservoir is filled once at the beginning of the crop growing season from surface water and/or field runoff. Outlet works provide for controlled gravity release of irrigation water. Then tailwater is returned throughout the season as fresh water is added as needed. The reservoir will also provide sufficient water to increase flow rates and speed up the initial flood process. The objective in the initial flood is to get the entire field wet as quickly as possible. Speedy flooding is desirable to prevent weeds and other pests, such as seedling disease, shrimp and midge from getting ahead of the rice.

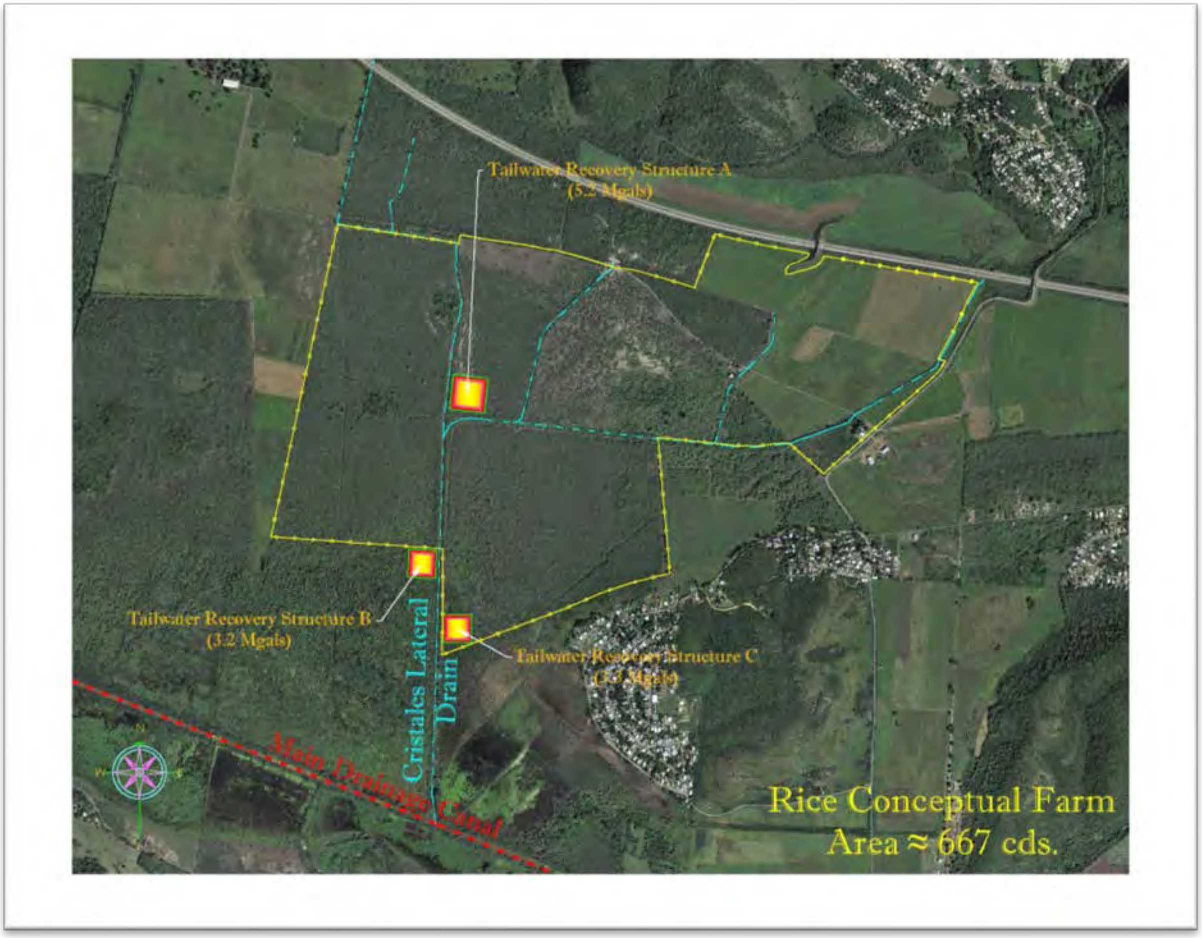

Figure 14. Water and Sediment Control Basins.

A water and sediment control basin located at the lowermost point of each irrigation zone will capture irrigation tailwater and field runoff, allowing excess water to be recycled throughout the production system. It will also capture and detain sediment-laden runoff and other debris for a sufficient length of time to allow it to settle out in the basin, reducing the amount of runoff, sediment, nutrients and pesticides that leave the farm. The primary water quality concern for the rice industry is residue from pesticides applied to the fields, particularly the herbicides thiobencarb and molinate. Long term water holding following application is the primary management method to be used to allow for degradation of pesticides within the field.

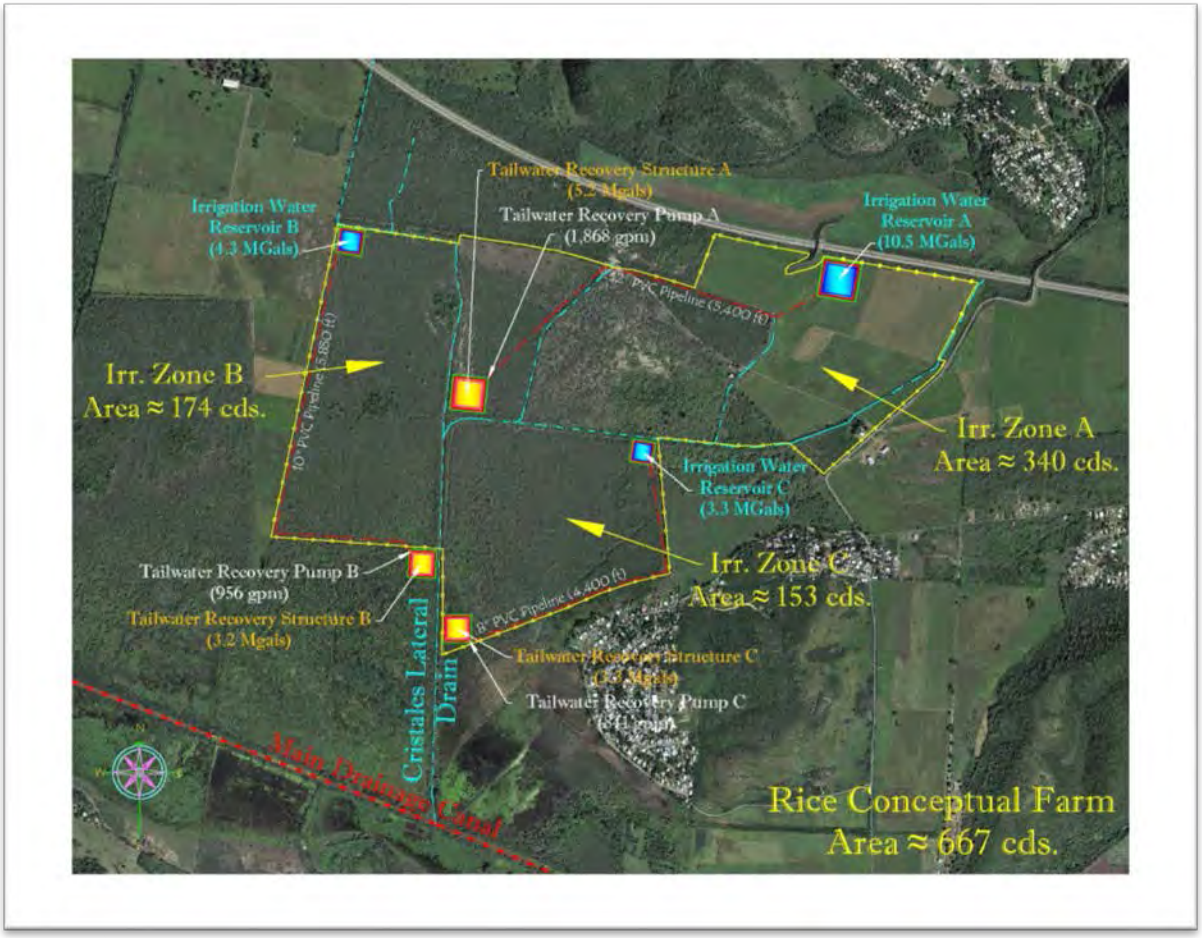

Figure 15. Pumps and Pipelines will deliver and convey water from the Tailwater Basins to the Irrigation Reservoirs.

The recommended pipeline shall meet all service requirements. Both the pump and pipeline capacity are designed to be sufficient to convey the design delivery flow rate. Quick flooding requires roughly 28 gpm/ac. Once a flood is established, the amount needed for maintenance is much less, a continuous flow of 5 gpm/ac over the course of a season. The flow rate in this case was calculated assuming one (1) foot of tailwater along the entire 120-day growing season (0.1 in/day); or 5.5 gpm/ac. Tailwater recovery is an approach to handle salinity. Salinity is managed through dilution with water having a lower salinity, although it may not be easy to accomplish. Addition of fresh water, even if it is somewhat saline but below the salt level in the field, accompanied by draining from the lower end, will dilute problem areas. With continuous flow, salt will not accumulate. With water-holding restrictions, however, draining salty water may be difficult without a fallow field or a district drain. This is when reuse or recirculation becomes necessary.

Budget Analysis for Rice Initiative Farm Tailwater Pilot Project

These systems have many advantages, such as reliability in terms of capturing tailwater in a basin and pumping it back to an upper reservoir for reuse in the same or another field. They are adaptable to single fields, whole farms and whole irrigation districts. This system will help stretch the limited supply of water and allow growers to comply with less restrictive holding requirements. But costs of installation and maintenance could be big disadvantages. To put land out of production to implement these practices, the cost of implementation, and a higher level of management could fall into higher operation costs.

FY	Farmer	Practice (Code)	Description	QTY.	Unit	Unit Price	Total Cost
2014	Irrigation Zone A	Irrigation Water Conveyance (430)	PVC 8" SDR-26	23,936	lb	$ 2.81	$ 67,260.16
2014	Irrigation Zone B	Irrigation Water Conveyance (430)	PVC 10" SDR-26	43,374	lb	$ 2.81	$ 121,880.94
2014	Irrigation Zone C	Irrigation Water Conveyance (430)	PVC 12" SDR-26	64,098	lb	$ 2.11	$ 135,246.78
2014	Irrigation Zone A	Irrigation Water Reservoir (436)	Earthmoving	1,200	cu.yd.	$ 7.04	$ 8,448.00
2014	Irrigation Zone B	Irrigation Water Reservoir (436)	Earthmoving	836	cu.yd.	$ 7.04	$ 5,885.44
2014	Irrigation Zone C	Irrigation Water Reservoir (436)	Earthmoving	673	cu.yd.	$ 7.04	$ 4,737.92
2014	Irrigation Zone A	Access Control (472)	Signage or Markings	2	ea	$ 38.05	$ 76.10
2014	Irrigation Zone B	Access Control (472)	Signage or Markings	2	ea	$ 38.05	$ 76.10
2014	Irrigation Zone C	Access Control (472)	Signage or Markings	2	ea	$ 38.05	$ 76.10
2014	Irrigation Zone A	Roof And Cover (367)	Timber or Steel Roof	144	Sq.ft	$ 9.25	$ 1,332.00
2014	Irrigation Zone B	Roof And Cover (367)	Timber or Steel Roof	144	Sq.ft	$ 9.25	$ 1,332.00
2014	Irrigation Zone C	Roof And Cover (367)	Timber or Steel Roof	144	Sq.ft	$ 9.25	$ 1,332.00
2014	Irrigation Zone A	Structure for Water Control (587)	Small Inlet	1	ea	$ 1,868.30	$ 1,868.30
2014	Irrigation Zone B	Structure for Water Control (587)	Small Inlet	1	ea	$ 1,868.30	$ 1,868.30
2014	Irrigation Zone C	Structure for Water Control (587)	Small Inlet	1	ea	$ 1,868.30	$ 1,868.30
2014	Irrigation Zone A	Structure for Water Control (587)	Slide Gate	1	ea	$ 4,150.19	$ 4,150.19
2014	Irrigation Zone B	Structure for Water Control (587)	Slide Gate	1	ea	$ 4,150.19	$ 4,150.19
2014	Irrigation Zone C	Structure for Water Control (587)	Slide Gate	1	ea	$ 4,150.19	$ 4,150.19
2014	Irrigation Zone A	Structure for Water Control (587)	Culvert Spillway >30 inches HDPE	1,200	D x ft	$ 2.98	$ 3,576.00
2014	Irrigation Zone B	Structure for Water Control (587)	Culvert Spillway >30 inches HDPE	1,200	D x ft	$ 2.98	$ 3,576.00
2014	Irrigation Zone C	Structure for Water Control (587)	Culvert Spillway >30 inches HDPE	1,200	D x ft	$ 2.98	$ 3,576.00
2014	Irrigation Zone A	Fence (382)	Barbed Wire	3,460	ft	$ 2.74	$ 9,480.40
2014	Irrigation Zone B	Fence (382)	Barbed Wire	2,430	ft	$ 2.74	$ 6,658.20
2014	Irrigation Zone C	Fence (382)	Barbed Wire	2,360	ft	$ 2.74	$ 6,466.40
2014	Irrigation Zone A	Land Clearing (460)	Revoming Vegetation for site preparation	11	acre	$ 1,016.78	$ 11,184.58
2014	Irrigation Zone B	Land Clearing (460)	Revoming Vegetation for site preparation	6	acre	$ 1,016.78	$ 6,100.68
2014	Irrigation Zone C	Land Clearing (460)	Revoming Vegetation for site preparation	6	acre	$ 1,016.78	$ 6,100.68
2014	Irrigation Zone A	Pumping Plant for Water Control (533)	Irr. Pump Unit w/ Pump House	61	HP	$ 725.02	$ 44,226.22
2015	Irrigation Zone B	Pumping Plant for Water Control (533)	Irr. Pump Unit w/ Pump House	23	HP	$ 725.02	$ 16,675.46
2014	Irrigation Zone C	Pumping Plant for Water Control (533)	Irr. Pump Unit w/ Pump House	26	HP	$ 725.02	$ 18,850.52
2014	Irrigation Zone A	Water & Sediment Control Basin (638)	Earthmoving	26,117	cu.yd.	$ 5.19	$ 135,547.23
2014	Irrigation Zone B	Water & Sediment Control Basin (638)	Earthmoving	16,067	cu.yd.	$ 5.19	$ 83,387.73
2014	Irrigation Zone C	Water & Sediment Control Basin (638)	Earthmoving	16,451	cu.yd.	$ 5.19	$ 85,380.69
	Grand Total						$ 806,525.80

Figure 16. Budget analysis for tailwater recovery system working alone to resolve excess water use in rice production.

The factors that have influenced the choice between a reservoir and tailwater recovery system include construction costs, water availability, crop mix, environmental concerns, farm size and length of production period. Reservoir construction does not represent a negligible expense. The cost of moving the soil alone has been estimated to be high, and valuable cropland is sacrificed for reservoir construction. Considering the high cost for excavation, the decision was made to balance cut volume from the tailwater basins with the fill volume of the irrigation reservoir. Electric power is not available in close proximity to the fields, therefore internal combustion motor-powered pumps are recommended. Water consumption was estimated using NRCS IWRpm software. Baseline irrigation efficiency with no water conservation improvements is assumed to be 50%. When reservoirs are used in conjunction with other BMPs such as laser leveling and underground pipe water conveyance, size may decrease further while water needs are reduced. Underground pipe is expected to increase irrigation efficiency by 10% (such that rice irrigation efficiency increases from 50 to 60%), whereas laser leveling can increase irrigation efficiency by another 10%.

System implementation cost is estimated to be around $1,210/acre for the tailwater system ONLY, without application of complimentary BMPs. Adding complimentary resource management system BMPs could easily double project costs. State or federal agency financial assistance programs may expand the desirability of resource management systems along with tailwater recovery systems in the Lajas Valley.

Conclusion

Resource Management System (RMS) implementation is recommended along with tailwater recovery system components to resolve environmental resource concerns in the Lajas Valley Agriculture Reserve. The decision should be made taking into consideration the many crop production aspects that are influenced by Lajas Valley's hydrologic environment. Conditions such as precipitation patterns in this semiarid region will influence irrigation needs for grain and pasture production, and require planning for moisture conservation. Drought and water source availability may result in water shortages that affect environment and cropping activities, damaging crops and yields.

Other aspects include soil fertility, salinity, nutrient and energy inputs and losses. For high levels of crop production, nutrients are added through fertilizers, often in excess. Herbicides are also used for unwanted weeds and insecticides used for pest control. Soil salinity occurs frequently in Lajas Valley due to accumulation of soluble salts in the soil profile. Soils such Fe clay, Guánica clay and Cartagena clay are medium to high in soluble salts that rise to the soil surface thru capillarity during water evaporation and then accumulate there. These soils are often irrigated in areas where evaporation exceeds the rate of leaching in order to flush the salts out of the root zone. Recommendations include removing high salinity patches from production to reduce soluble salts in irrigation water that can reduce crop yields, converting those areas to naturalized areas planted with saline tolerant plant material for wildlife, and planning for nutrient and pest management reduce use of inputs.

Today's agro-systems lose significant soil resources essential for crop farming feasibility. Detachment and movement of soil minerals and organic matter by wind and water is often seen in these systems. RMS implementation can mitigate and may resolve issues that increase soil erosion and sediment loading in receiving waters.

In the past, wetland drainage was designed and planned in Lajas Valley to provide more available land for sugar cane production. Wetland loss through drainage destroyed much of the area's wildlife habitat, temporary water storage from runoff and storms, storage for carbon, and nutrient cycling. Planning for wetland delineation and designation of habitat and natural areas on sites where farming is not feasible will mitigate habitat fragmentation and wetland losses.

Water is a critical concern for Lajas Valley. It is the limiting factor in the use of Lajas Valley land for crop production. Irrigation supplies are available for some zones and have enabled production in semiarid areas in this region. However, in some portions of the valley unsustainable water use is a concern. Currently the rate of water use greatly exceeds the rate of aquifer recharge. Other water supplies for crop use, such as the Lajas Valley Irrigation Channel connected to Lago Loco Dam, are likewise threatened. Water quality and quantity needs to be addressed first by implementing a better water management system, including water monitoring, water budgets and irrigation schedules. Then managers can choose what practices to use for collection, transfer and treatment of irrigation discharge water and tailwater.

It is essential to create plans, policies and approaches to protect and safeguard existing land use for crop and animal production. Appropriate approaches include conservation tillage, crop rotation and planned crop placement on the landscape. Irrigation management strategies must be established to increase efficiency and to reduce salinization. Lands should be viewed as producers of multiple benefits, economic as well as ecological. Although increased land use will put pressure on remaining natural environments, thoughtful Resource Management System planning is essential to balance conservation with utilization.

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