

The Development of a Coordinated Database for Water Resources and Flow Model in the Paso Del Norte Watershed (Phase III)

Part III GIS Coverage for the Valle de Juárez Irrigation District 009 (ID-009) (Distrito de Riego 009) Chihuahua, México

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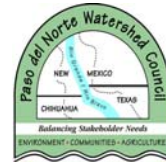
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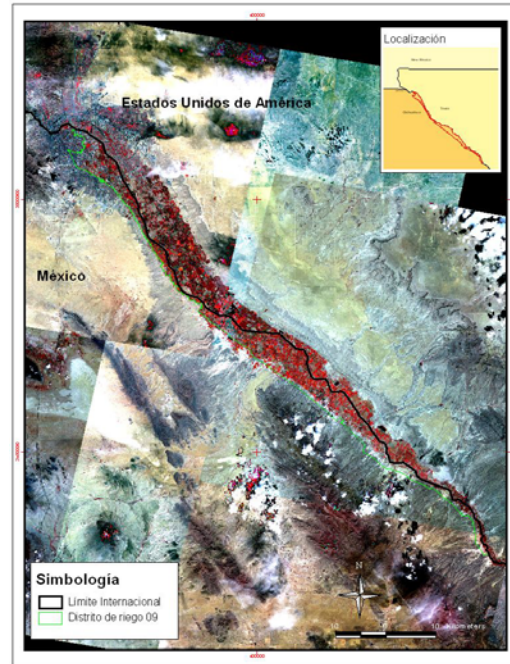
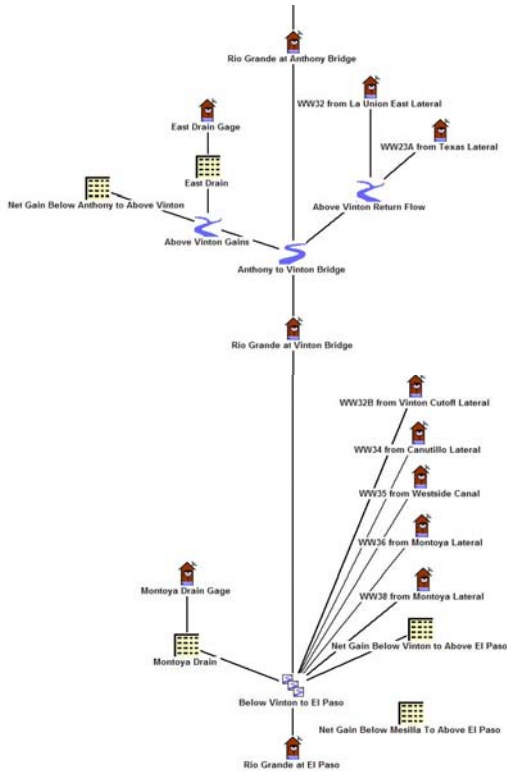
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US Army Corps
of Engineers®



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the U.S. Department of Interior, Geological Survey through the New Mexico
Water Resources Research Institute

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**GIS Coverage for the Valle de Juárez Irrigation
District 009 (ID-009) (Distrito de Riego 009)
Chihuahua, México**

Phase III Final Project Report of Work Completed
under the Cooperative Agreement between
the U.S. Army Corps of Engineers
and
Texas AgriLife Research

(TAES/03-PL-02)
Modification No. 3

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Abstract

This report fulfills the deliverables required by the cooperative agreement between the U.S. Army Corps of Engineers and Texas Agricultural Experiment Station (TAES/03-PL-02: Modification No. 3) on behalf of the Paso del Norte Watershed Council. Tasks accomplished in this phase include (a) assessment of data availability for expansion of the URGWOM model, identification of data gaps, generation of data needed from historic data using empirical methods, compilation and verification of the water quality data for reaches between the Elephant Butte Reservoir, New Mexico and Fort Quitman, Texas; (b) development of the RiverWare physical model for the Rio Grande flow for the selected reaches between Elephant Butte Reservoir and El Paso, beginning with a conceptual model for interaction of surface water and groundwater in the Rincon and Mesilla valleys, and within the limits of available data; and (c) implementation of data transfer interface between the coordinated database and hydrologic models.

This Project was conducted by researchers at Texas A&M University (TAMU) and New Mexico State University (NMSU) under the direction of Zhuping Sheng of TAMU and J. Phillip King of New Mexico State University. It was developed to enhance the coordinated database, which was originally developed by the Paso del Norte Watershed Council with support of El Paso Water Utilities to fulfill needs for better management of regional water resources and to expand the Upper Rio Grande Water Operations Model (URGWOM) to cover the river reaches between Elephant Butte Dam, New Mexico and Fort Quitman, Texas. In Phases I and II of this Project (TAES/03-PL-02), hydrological data needed for flow model development were compiled and data gaps were identified and a conceptual model developed. The objectives of this phase were to develop a physical model of the Rio Grande flow between Elephant Butte Dam and American Dam by using data collected in the first development phase of the PdNWC/Corps Coordinated Water Resources Database and to enhance the data portal capabilities of the PdNWC Coordinated Database Project.

This report is Part III of a three part completion report for Phase III and provides information on water sources, uses, and GIS of the canals and ditches of the Valle de Juárez Irrigation District 009 (ID 009) in the Juárez Lower Valley, Chihuahua, México. The author explains that the water needs of this region have changed in recent years from being primarily for agricultural purposes to domestic and industrial uses currently. Also, the United States wanted to assess and identify new data sources on a GIS format for the Mexican side. Therefore, this project produced several maps with the location of channels and ditches along the Valle de Juárez Irrigation District. This information also will support water planning of the Valle de Juárez Irrigation District 009. The maps were produced from existing digital data regarding water resources and by adding thematic layers such as soil salinity and soil texture from analog maps. ASTER satellite imagery and official panchromatic aerial photography were used to produce the maps.

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**GIS Coverage for the Valle de Juárez Irrigation District 009 (ID-009)
(Distrito de Riego 009)
Chihuahua, México**

Introduction

Mexico's irrigation districts have played an important role in the agricultural economies of these regions and for the general economic health of the entire country. In recent years, Mexico has improved upon its ability to apply technology and generate inventories and statistics on the type of crops, volume of crop estimates, and economic revenue of agricultural products. Of the more than 19 million hectares (ha) cultivated with different crops in the entire country, approximately 14% represent irrigation districts with some kind of hydraulic infrastructure to irrigate and harvest cultivated crops (CNA, 2003).

Texas A&M University (TAMU) Texas AgriLife Research in El Paso, Texas has had research agreements to conduct investigations in Mexico with the Universidad Autónoma de Ciudad Juárez on behalf of the Centro de Información Geográfica for the performance of work and services in connection with development of the Paso del Norte Watershed Council Coordinated Database and GIS. This report is Part III of a three part report for Phase III. Phases I and II of this project were completed earlier.

Experts on GIS technology along with graduate and undergraduate students from the Universidad of Ciudad Juárez Geographic Information Center created, rasterized, and geographically projected thematic layers of digital information on specific items and generated a set of maps that display digital information.

The purpose of the Phase III effort was to generate metadata using a Federal Geographic Data Committee (FGDC) format for new datasets identified on the Mexican side of the Juárez Lower Valley. Datasets were identified from Valle de Juárez Irrigation District 009 (ID-009) official documents. These datasets focused on a regional geographic information system (GIS) that included attributes such as aerial photography and satellite imagery, elevation data, surface hydrology, soil types, cadastral information on type of rights under the Mexican Constitution, transportation information on main highways and dirt roads and most importantly, a GIS on the channels and ditches along the ID-009.

These and other digital products may help to identify information on water resources within the study area to improve water management strategies and to generate an open source pool of data containing digital information on the ID-009.

Map Area

The study area focused on the regional extent of the ID- 009 from the area below the transboundary metropolis of Cd. Juárez, Chihuahua and El Paso, Texas to the Cajoncitos region where the river turns into a canyon. The ID- 009 geographic extent is north of the State of Chihuahua between coordinates of longitude 105° 30' and 106° 30'; and coordinates of latitude 30° 56' and 31° 45' (Upper left corner X:350000; Y:3550000 and lower right corner X: 450000; Y: 3450000 under UTM Coordinate System-Figure 1).

The Valle de Juárez-Irrigation District 009 is located within the regional extent of three important municipalities neighboring the northern part of Chihuahua along the transboundary region of the state of Texas. These include the Municipality of Juarez, the Municipality of Guadalupe, and the Municipality of Praxedis G. Guerrero. The ID-009 is divided into three major units (Unidades de Riego), Unidad I, Unidad II and Unidad III. Water for agriculture in these units is derived from an annual allocation from the international treaty (74 Mm³) and from deep agricultural pumping wells in the Hueco Bolson aquifer formation (Figure 1). This region is crossed by a series of arroyos of different magnitudes and hydrological orders, which originally drained into the main watercourse of the Rio Bravo. As ID-009 grew and developed, new hydraulic infrastructure and fields were open for cultivation. Main waterways were erased without leaving the basic infrastructure needed to drain these arroyos, which caused flooding and damage to the recently constructed hydraulic infrastructure (CNA, 2004).

Historically, the region's water demand has been primarily for agricultural purposes. Nevertheless, in recent years the demand for the resource has been diversified into domestic and industrial needs. Ibañez (2003), states that the agricultural activities of the ID- 009 have transformed into "marginal activities" based on their economic potential allowing for the possibility of water transfers from agricultural uses to urban uses. A 2002 study of the Ciudad Juárez workforce indicates that 53% of citizens work in the industrial sector, 43% in services and governmental agencies, and only 0.6% work in the agricultural sector (IMIP, 2003).



Figure 1. Geographic Location of Valle de Juárez-Irrigation District 009

Methods

The project's major tasks were to identify and locate existing digital data regarding water resources, mainly those related to the distribution and allocation of water rights and canals represented by the hydraulic infrastructure where water is located in the DR009, combining these into seamless digital GIS products. Additionally, some thematic layers, such as the soil salinity and soil texture themes produced on analog maps were rasterized from published work (SRH, 1973) and reprocessed by assigning geographical coordinates from existing digital maps using known ground-control points. In addition, other databases that were useful for the project were identified and integrated into the project database. Some examples of these thematic coverages include: land ownership at the DR009 differentiating between the major types of possessions (which include polygons for ejidos, private property, agricultural colonies, and urban areas); the soil salinity and soil textural classification; the land use coverage distinguishing agricultural areas from orchard areas; and the hydraulic infrastructure at the DR009, identifying acequias as drains or canals. These thematic layers were "dropped" on top of ASTER satellite imagery as well as on official panchromatic aerial photography published by INEGI (INEGI, 1997). Project team members worked closely with CNA staff at the local offices responsible for the administration of the ID-009.

A number of technical presentations were given at meetings, forums, and conferences as well as to CNA officials at ID-009 local offices. These presentations informed interested groups, organizations, and agencies of the project and its generated GIS products. Technical presentations to ID-009 officials and to other peer groups provided useful feedback to the project team. Field trips to the lower valley and verification of ditches helped in the understanding of the perspective and importance of the project. The condition of the physical hydraulic infrastructure justified the need for this type of digital product.

Experts from the Geographic Information Center at UACJ concentrated on the applications of the geospatial technology utilizing an array of GIS software to process and generate geospatial information. The combined digital data products of the project were designed to be applied with ESRI software products such as: ArcINFO, ArcView, ArcGIS, ArcMAP, ArcPAD, ArcEXPLORER, ArcIMS and other compatible software.

Metadata was acquired or developed for all spatial components following the Federal Geographic Data Committee (FGDC) standards. The data dictionaries described in detail the contents of a database with emphasis on providing explanations of categories. Most of the spatial components are contained in the digital files provided on CDROM.

Products

The products for this phase are defined at three levels of information. The first is related to a set of maps generated for the project where the display of geographical features is enhanced using a GIS format. The maps accumulated integrated geospatial data representing different layers of information that allow the visualization of thematic features at the research area. The second level of data includes the files containing remote sensing (RS) imagery based on two platforms: the satellite imagery from ASTER missions (2000) incorporating additional areas surrounding the study site, and the aerial photography (AP) generated from the 1994 and 1997, which are the latest flight missions established by INEGI to generate AP. These were the two main products from the integration of the remote sensing datasets. Finally, the third level of information was the Metadata generated for each of the thematic layers of GIS coverages as well as for the RS information. The Metadata files were important for the project's product Quality Assurance (QA).

Map 1 integrates four sets of data layers into a single map that is used for the basemap framework. The map applies the geopolitical division for Mexico and the United States as well as for state levels defined by the geopolitical limits of Chihuahua, New Mexico, and Texas. Lines defining the urban distribution of the two major cities located at the research area were added to the layer coverage on Map 1, which represented the geospatial distribution of main streets and highways located within the cities of Ciudad Juárez, Chihuahua and El Paso, TX. Within the state of Chihuahua, the municipalities of Juárez, Villa Ahumada, and most importantly for this project, the delineation of the municipalities of Guadalupe, D.B. and Praxedis G. Guerrero, where most of the Irrigation District 009-Valle de Juárez (ID-009) is located. Additionally, a shape file for the delineation of Units I, II and III for the ID-009 is included displaying a total area of approximately 24,688 ha out of which a total of 20,788 ha are under irrigation (CNA, 2005). Table 1 shows the distribution of Units I and II into "modules of production" and displays the number of water users within ID-009. Unit III has no modules. Regionalization for the ID-009 is important for administering the irrigation district since CNA bases their management processes on this geospatial distribution. An important aspect of water management based on this distribution is the fact that the entire Unit I is entitled to water from the 1906 Treaty and that land use is changing in this area due to the city of Juarez absorbing agricultural areas into new developments and urban growth. In comparison with Unit II, water is used on a mixture of whatever is left from the allotment of the 1906 Treaty, sewage water from the water treatment plants, and agricultural wells located in Unit II. Unit III is only irrigated with agricultural wells and some illegal pumping from the Rio Bravo/Rio Grande by farmers in the area.

Figure 2 illustrates the geospatial distribution of land ownership within ID-009. Four major types of properties are located in the research area: Human Settlements (Asentamiento Humano), Agricultural Colonies (Colonia), Ejidos, and Private Proprieties (Pequena Propiedad). Each municipality has areas inside ID-009 within their geopolitical divisions; hence, in total for the three major municipalities located in ID-009 (Juarez, Guadalupe and Praxedis G. Guerrero), an area of ~5,814.5 ha (~18%) is classified as Human Settlements.

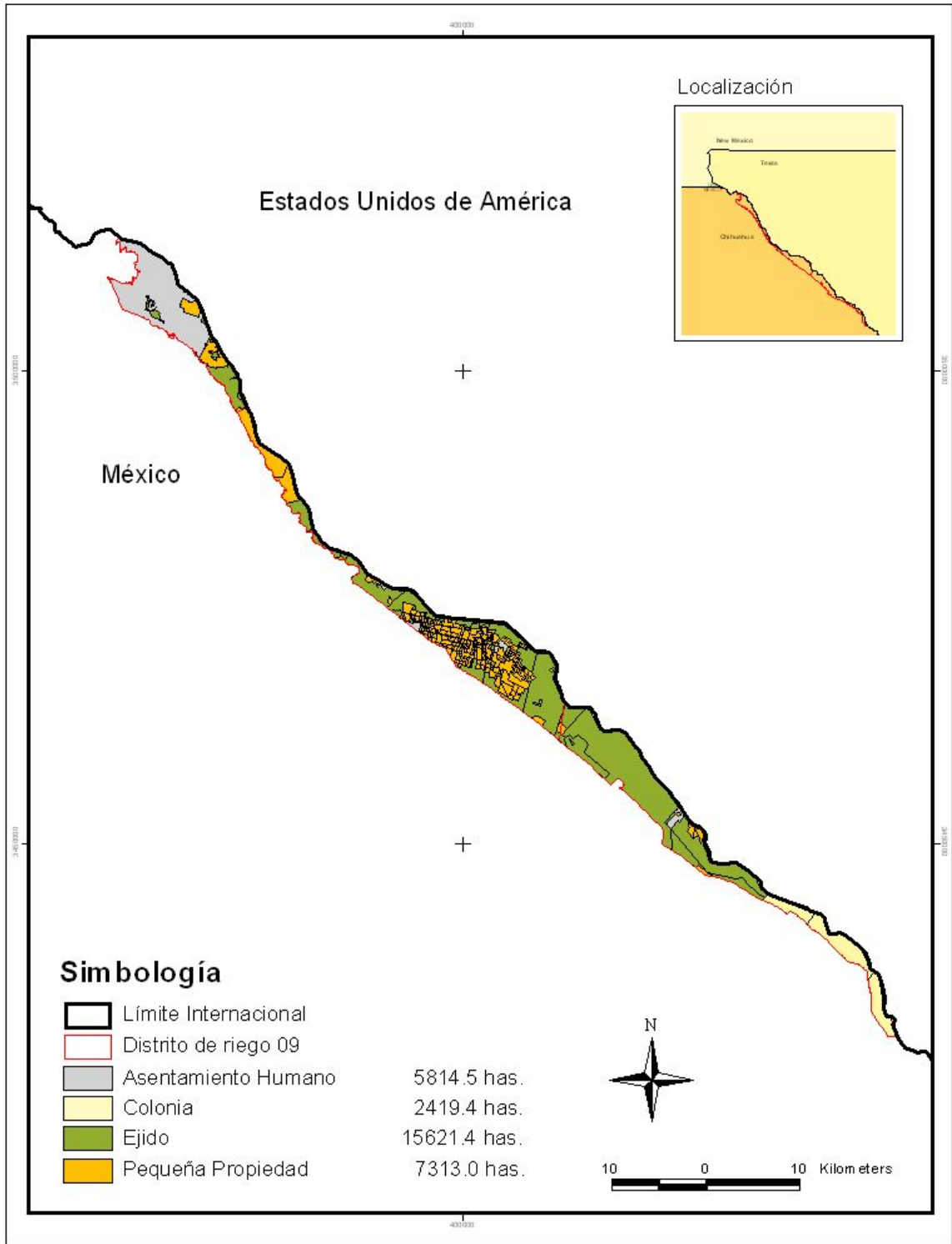


Figure 2. Geospatial Distribution of Land Ownership within the ID-009

Table 1. Distribution of Unit Modules and Users at ID-009

Irrigation Modules			
Name	Total ha	Irrigated ha	Owners
Modulo 1 (1ra Unidad)	1,814.57	1,701.33	224
Modulo 2 (2da Unidad)	3,385.36	3,158.29	570
Modulo 3 (2da Unidad)	9,344.01	9,776.30	858
Modulo 6 (1ra Unidad)	258.01	240.62	46
Modulo 7 (1ra Unidad)	850.79	781.93	192
Modulo 4 (3ra. Unidad)	9,027.71	6,130.18	917
Totals	24,688.45	20,788.65	2,807

Source: CNA, 2005

Agriculture Colonies are a special kind of land possession allowed by the Mexican constitution. These land areas are assigned to Mexican citizens for agricultural production, where their legal status is similar to those rights under Private Properties, but with the advantage that groups and alliances can be formed for agricultural production. These groups have the benefit of accessing cheaper credit lines offered by private or governmental banking institutions. The Agricultural Colonies are approximately 2,419 ha (8.5%) of the total extent of ID-009. An important observation of this type of land possession is the fact that most of these areas are located at the periphery of ID-009, near the Cajoncitos region. No detailed explanation is given as to the reason for this geospatial distribution of land ownership within the Valle de Juárez.

Private Properties constitute the second largest land area within ID-009 with approximately 7,313 ha (~23%) of the total extent of the irrigation district. Most Private Properties are located within Unidad II and constitute one of the most industrialized areas with significant agricultural infrastructure. Large extensions of land under Private Properties are also located at the Unidad I; nevertheless, many of these regions are under urban stress where land use has been changing over time.

Finally, the largest areas identified in ID-009 are the Ejidos, mostly located between Unidades II and III and integrate more than 15,621 ha (~50.6%) of the total extension of the area. In the early 1920s and after the Mexican Revolution, Ejidos were formed to

organize farmers. This type of land possession gave most of the beneficiaries the alternative to organize into groups that were entitled to a certain number of hectares that could be put into agricultural production. However, groups were not allowed to sell or rent these properties without authorization from the “Asamblea General,” the organizational committee that makes decisions for the general benefit of the members of the Ejidos. Currently, this type of land ownership has not been very productive since most farmers prefer to own their land and determine the fate of their own possessions, especially regarding their own belongings. For example, if a farmer has a tractor and decides to sell it, the farmer feels it should be his own decision to sell and not the decision of the rest of the membership. Nevertheless, some Ejidos within the Mexican territory have been successful in putting their land to productive agricultural use, and this system of land ownership is active currently within the Mexican Constitution.

Figure 3 displays the areas under cultivation in ID-009. GIS coverage mapped from the land use thematic layer shows areas identified as agricultural fields totaling 22,269.7 ha, where some kind of crop can be established. However, an interesting fact on this geospatial distribution is that a total of 108.3 ha are identified as orchard areas with some kind of tree establishment while the remaining cultivated areas are mapped as agricultural fields that can be established as furrow cultivars or other crop type throughout the year. Official statistics for the period 2001-2002 show that production of agricultural goods were established for a total extent of 11,689 ha out of which, for this period, a total of 256 ha were pecan trees, the rest being other types of crops such as cotton, sorghum, vegetables, and alfalfa (CNA, 2003).

Table 2 shows the crop establishment in ID-009. Five cycles are identified with one per year from 1999 through 2004. Two agricultural subcycles are provided, one for Autumn and one for Spring as well as areas for perennial crops such as orchards. For the 1999-2000 period, a total cultivated area of 12,418 ha was established in ID-009; during the period 2000-2001, a total of 11,679 ha; for the period 2001-2002, 11,679 ha; for 2002-2003, an area of 10,523 ha was established; and finally, for the period 2003-2004, a total area of 10,915 ha was cultivated. The “2nd Crops” classification refers to areas cultivated twice during both agricultural subcycles, Autumn and Spring (CNA, 2005).

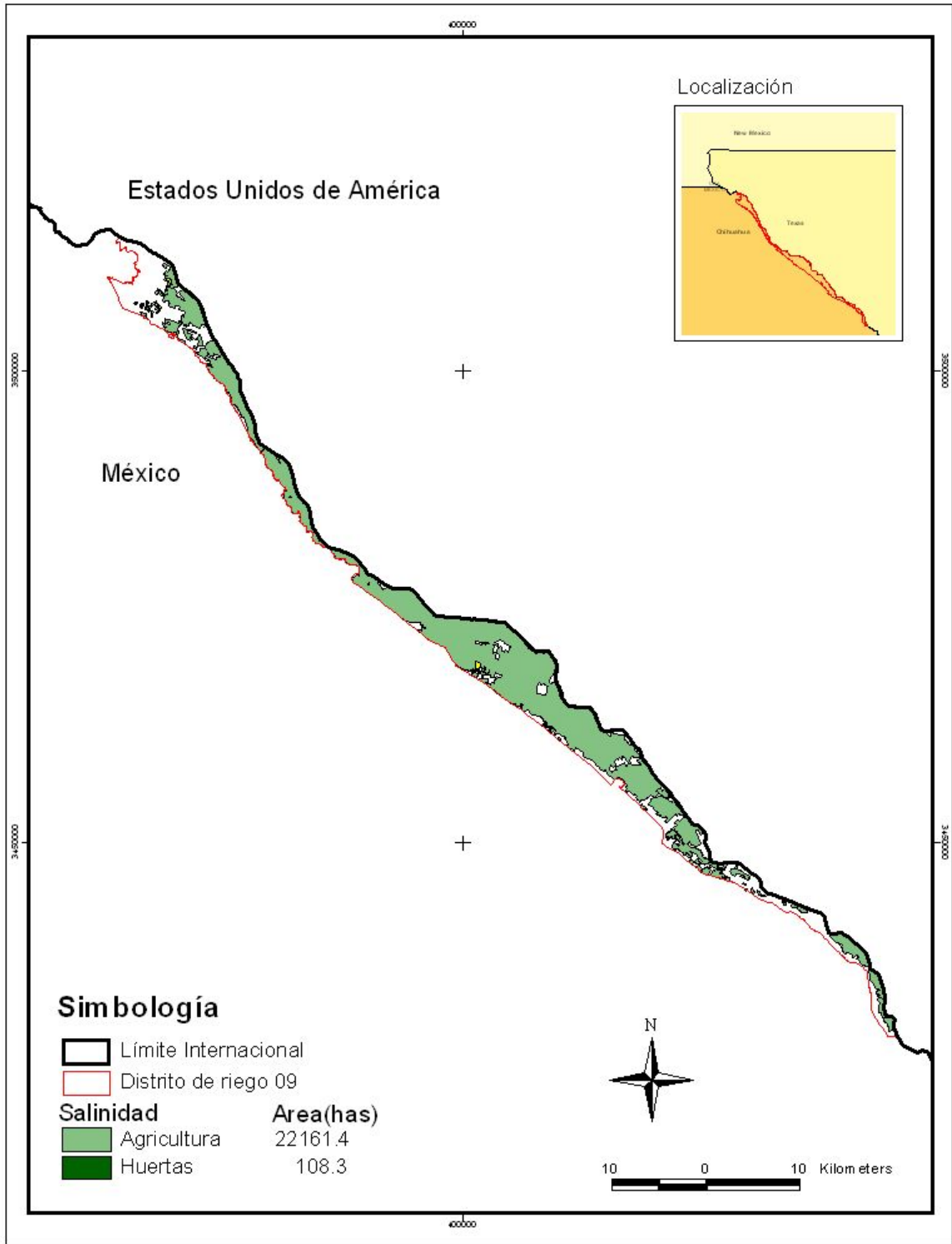


Figure 3. Agricultural and Orchard Areas within Irrigation District 009

Table 2 - Cycle Crop Establishment and Areas

Ag-Cycles	Ag-SubCycles	Established Aears (ha)
1999-2000	Autumn	2,975.0
	Spring	4,439.0
	Perennials	2,798.0
	2nd Crops	2,206.0
	TOTAL	12,418.0
2000-2001	Autumn	2,943.0
	Spring	4,461.0
	Perennials	2,976.0
	2nd Crops	1,959.0
	TOTAL	11,679.0
2001-2002	Autumn	2,358.0
	Spring	4,459.0
	Perennials	3,274.0
	2nd Crops	1,588.0
	TOTAL	11,679.0
2002-2003	Autumn	1,769.0
	Spring	4,440.0
	Perennials	3,295.0
	2nd Crops	1,019.0
	TOTAL	10,523.0
2003-2004	Autumn	1,719.0
	Spring	4,665.0
	Perennials	3,383.0
	2nd Crops	1,148.0
	TOTAL	10,915.0

Source: CNA, 2005.

Figure 4 displays ID-009 soil types based on their texture, which are mostly formed by fluvial and aeolian processes that integrate strata with high heterogeneity at different depths. Soils in this region are mainly clay and sand lenses, products of the meandering river system. The ID-009 soils located in the Rio Bravo floodplain are classified as six major types:

- 1) The Caseta Series has more than 4,612 ha (~ 20% of total area) at the study site. This type of soil is characterized by its location at the deepest sites of the fluvial system with depths reaching as far as 2 m and are limited by their drainage capacity and labor intensive characteristics;

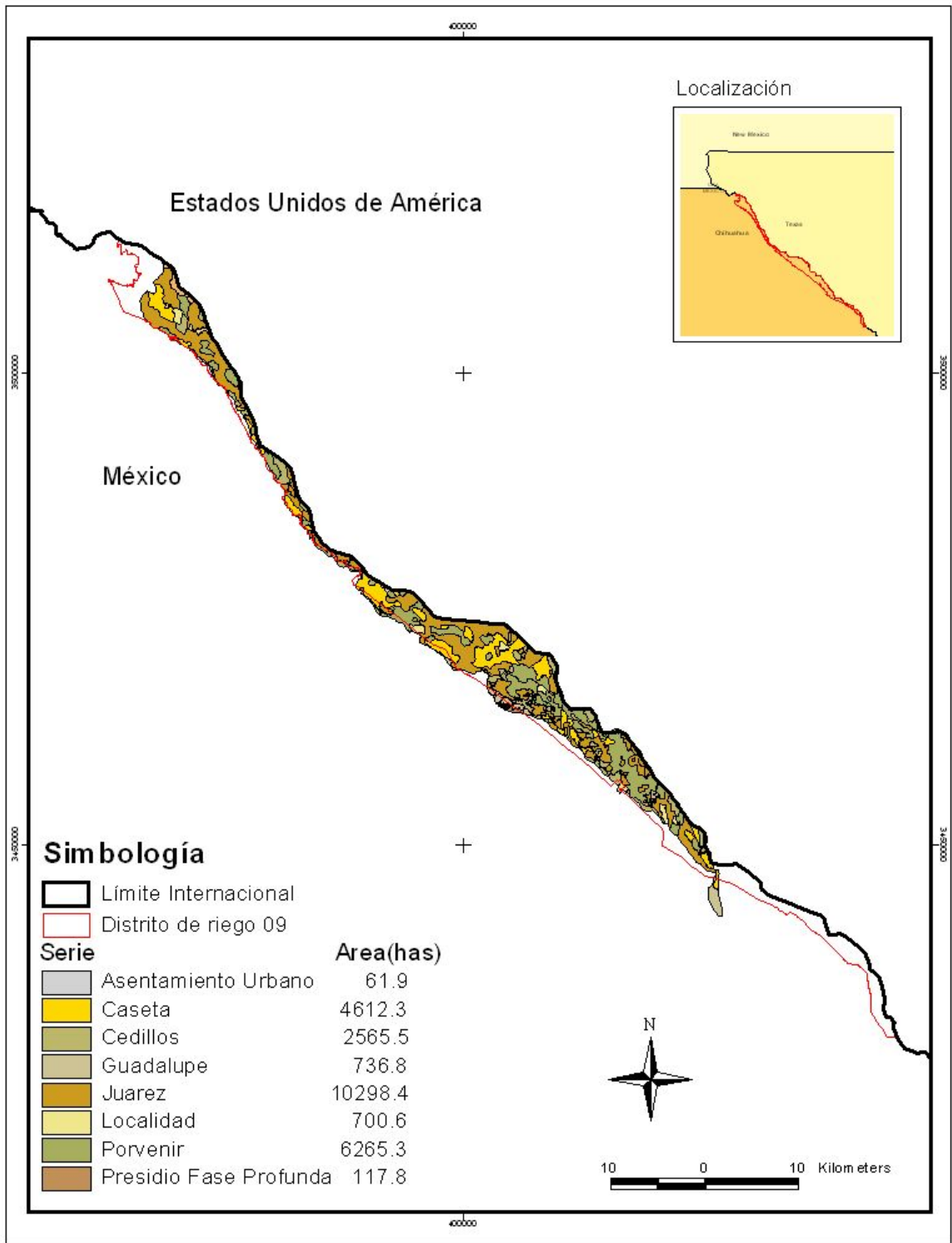


Figure 4. Soil Types and Classification within Irrigation District 009

2) The Cedillos Series are young deep sandy/sandy-loam soils, with good to moderate drainage capacity, and high nutrient content. These soils occupy approximately 2,565 ha (11% of total area);

3) The Guadalupe Series covers up to 737 ha (~3% of total area). These soils are located at the confluence of alluvial fans reaching the river floodplain and are deep soils with a medium texture laying on top of gravel.

4) The Juarez Series are deep soils located at the fluvial terraces of the Rio Bravo characterized by their fine to medium textures with average depths of 90 cm, followed by gravel and sand lenses with good drainage efficiencies. These soils occupy approximately 10,298 ha are the most extensive areas within ID-009, representing more than 40% of total study area;

5) The Porvenir Series occupy more than 6,265 ha (~24% of total area) and are located also at the fluvial terraces of Rio Bravo characterized by deep soils with medium to coarse (heavy) textures with medium to slow infiltration capacity; and

6) The Presidio (Deep Phase) Series are soils located at the flanking small hills surrounding the Rio Bravo floodplain that could or could not have a calcareous conglomerate at depths of ~ 2 m. Coarse texture with abundant gravels and rocks are common with good infiltration capacity. These soils are the smallest area at the ID-009 with roughly 119 ha (~1 % of total area).

Based on the soils hydrodynamic characteristics, three major groups of soils were classified (SRH, 1973). Group A, integrates the Cedillos, Guadalupe, and the Presidio (Deep Phase) Series, where heavy to medium textures are predominant with generally granular structures. Their water holding capacities was classified as low to medium, with an average infiltration velocity ranging from 2 to 12.5 cm/hr and hydraulic conductivity of 2 cm/hr (SRH, 1973). Group B incorporates the Juarez and Porvenir Series, where medium to heavy textures are located at the top layers of soil up to 2 m with medium textures located after this depth. Their water holding capacities vary from 2-3 cm of water for every 30 cm of soil; infiltration capacity varies from 0.5 to 6 cm/hr classified as slow to moderated and its hydraulic conductivity has been estimated to range from 1-2 cm/hr, which is considered slow. Group C includes only the Caseta Series characterized by fine textures up to 1 m depth and in some places 2 m. It has a high water holding capacity of 4 cm per 30 cm of soil due to its clay content.

Figure 5 displays the geospatial distribution of soils affected by salinity-sodicity. The Department of Agrologia (1973) reported the main causes of soil salinity-sodicity were the lower quality of treaty water used for irrigation purposes and wells pumping water from the saline shallow aquifer system.

Irrigation wells at ID 009 have documented high levels of heavy metals (local) and nitrates contaminated most likely from the nearby urban and industrial sites of Ciudad Juárez (INEGI, 1999). Palomo (2003) reported that from 1974 to 1997, an average of 48 Mm³ per

year of sewage/residual wastewaters where used for irrigation purposes at ID-009. Areas heavily affected by soil salinity-sodicity are close to 424 ha; very affected are 1,341 ha; 5,270 ha were documented as soils with intermediate affects; slightly affected soils were estimated as 8,494 ha and finally, soils without soil salinity-sodicity where estimated as 8,858 ha.

Figure 6 displays the physical location and extension of the canals and drains located in ID-009. The infrastructure identified as irrigation canals extend approximately 525 km of lined canals that conduct water to irrigation grounds, 282 km are drains that conduct runoff from agricultural fields and finally, 118 km are acequias that conduct water as main water ways to conduct water into canals. Currently, the irrigation infrastructure is in critical condition. In a special study developed by CNA (2004), it was reported that of the total canals, water drains, and acequias, 27% operated without problems to conduct water, 25% required rehabilitation in the mid- and long-term and 48% of this entire irrigation infrastructure was in critical condition and required immediate rehabilitation.

Table 3 displays the longitudes in km of canals and drains that have concrete lining versus dirt acequias and canals within the different modules and units of ID 009. Module 1 has approximately 26% of its irrigation infrastructure lined in concrete to reduce losses from infiltration and to reduce weed infestation. Module 2 has 83.5% of the canals and drains lined with concrete, and the rest of the modules as well as the last unit (Unit III) of ID-009 are lined with concrete. Nevertheless, according to the report on irrigation conditions at the study site, most of this infrastructure requires rehabilitation. But due to the lack of funding and available economic resources, no maintenance has been applied to this irrigation infrastructure (CNA, 2004).

Table 3 - Distribution of Lined versus Dirt Acequias and Canals

Distribution network (KMS) by Module				
MODULE	TOTAL	LINED	DIRT	%
1	63.1	16.5	46.6	26.1
2	54.5	45.5	9.0	83.5
3	131.3	131.3	-	100
6	6.0	6.0	-	100
7	13.0	13.0	-	100
3ra UNIDA	119.0	119.0	-	100
TOTALS	387.0	331.3	55.6	85.6

CNA, 2004

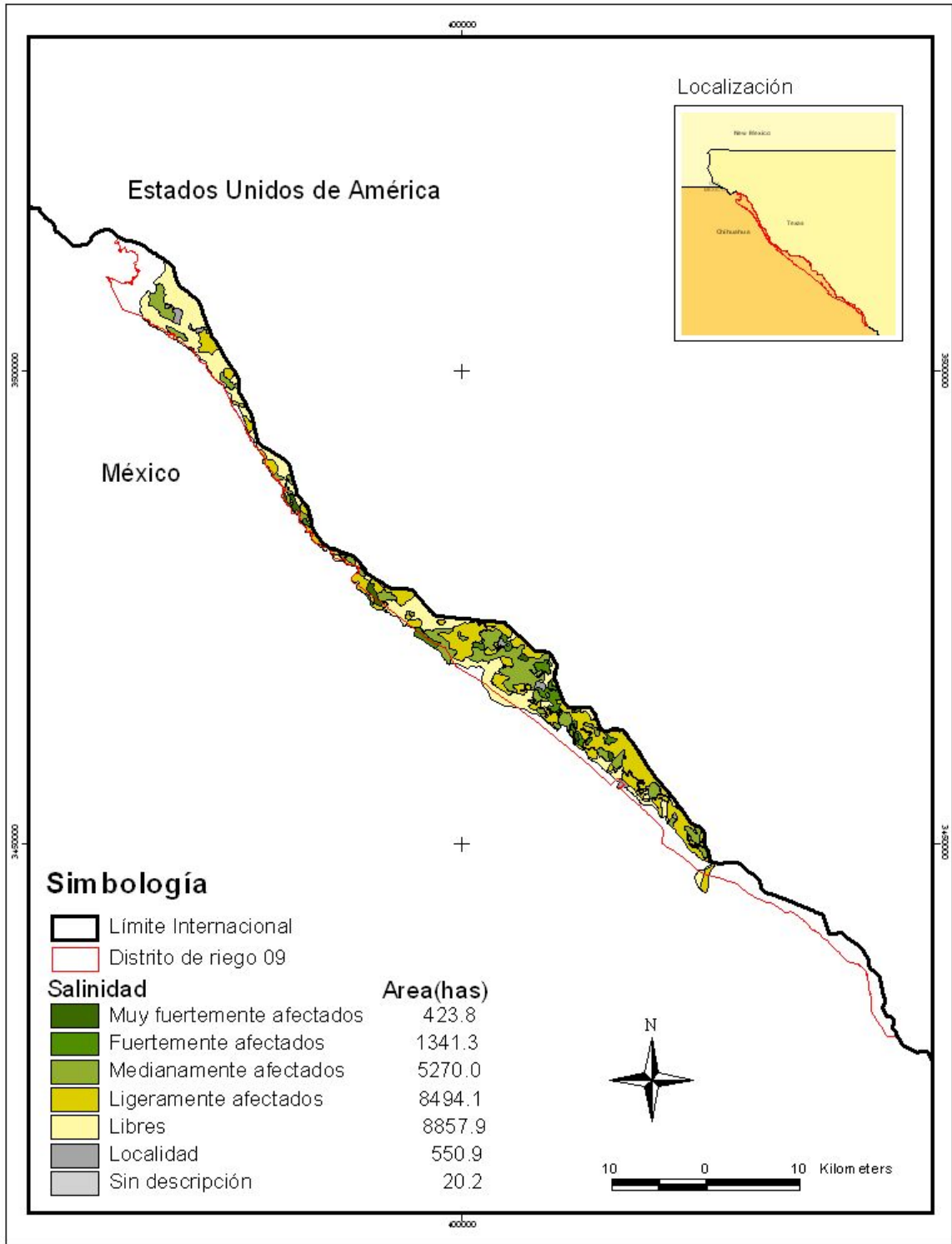


Figure 5. Levels of Soil Salinity-Sodicity Identified at Irrigation District 009

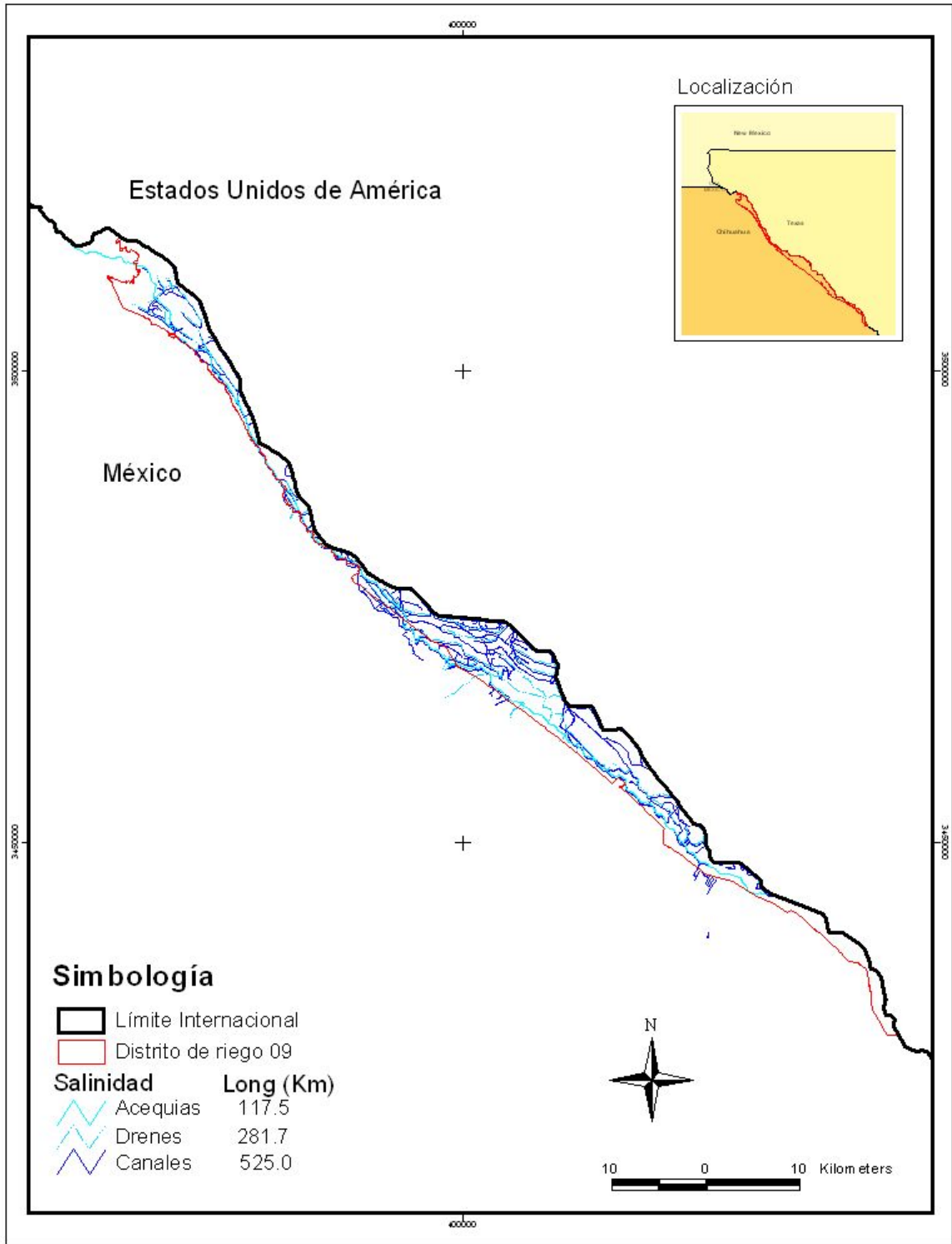


Figure 6. Irrigation and Drainage Infrastructure at the Juárez Lower Valley

Figures 7 and 8 integrate remote sensing (RS) data files from ASTER satellite imagery and aerial photographs produced by flight mission of INEGI (1997). Both of these map products were integrated from a mosaic of images that were geospatially corrected and spectrally enhanced to be applied on the visualization process adding thematic layers of information. ASTER satellite imagery is displayed on Far Infra-Red (FIR) band width with a spatial resolution of 15 m per pixel to visualize vegetation stress. Panchromatic (B & W) aerial photographs were incorporated on the project to enhance scale of visualization since these products had better spatial resolution, with the B & W limitation. Both of these products integrate an extended area from the surrounding zone of interest that incorporated regional view of adjacent watersheds as well as ecohydrological regions.

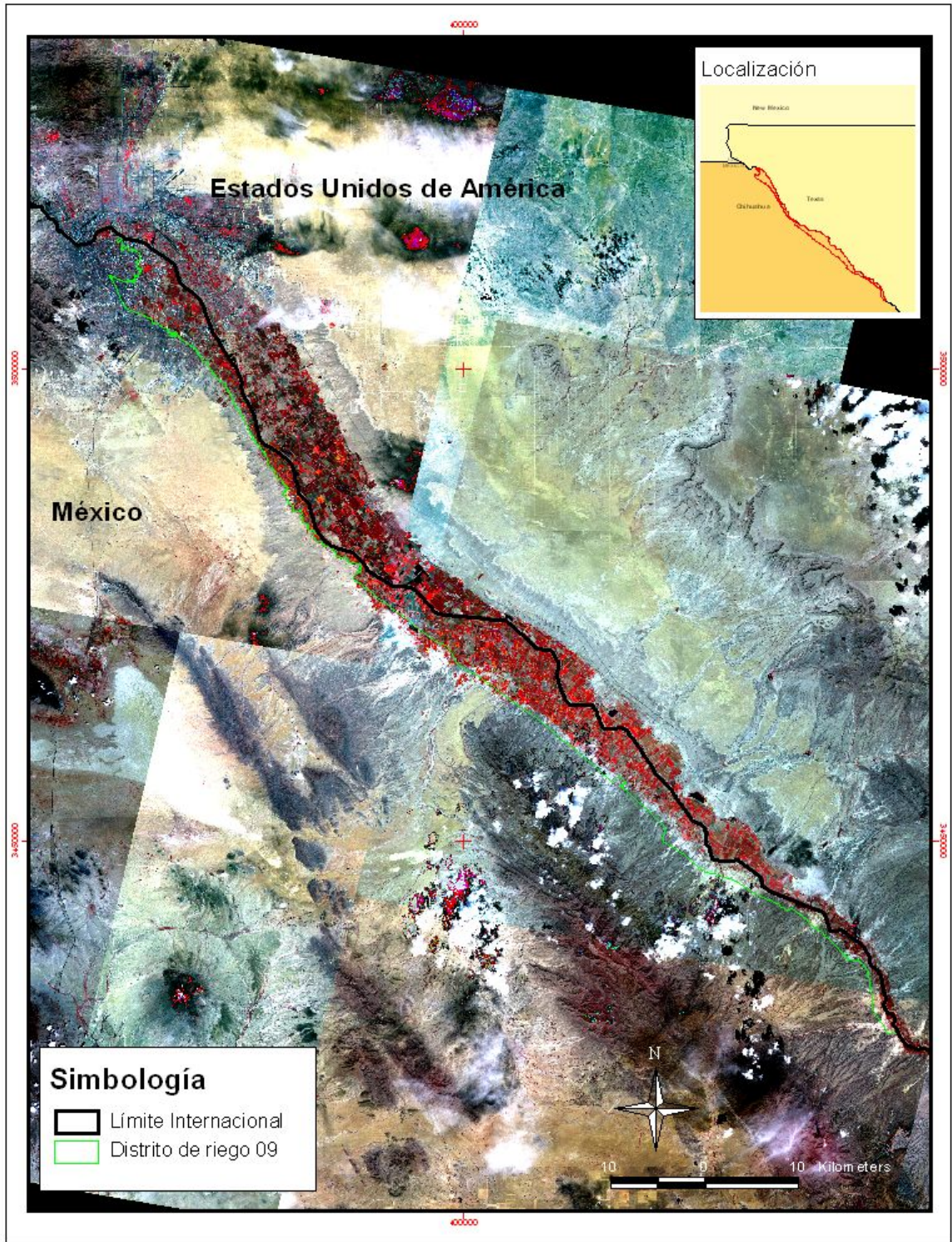


Figure 7. Aster Satellite Imagery of the Irrigation District 009 and Surrounding Areas

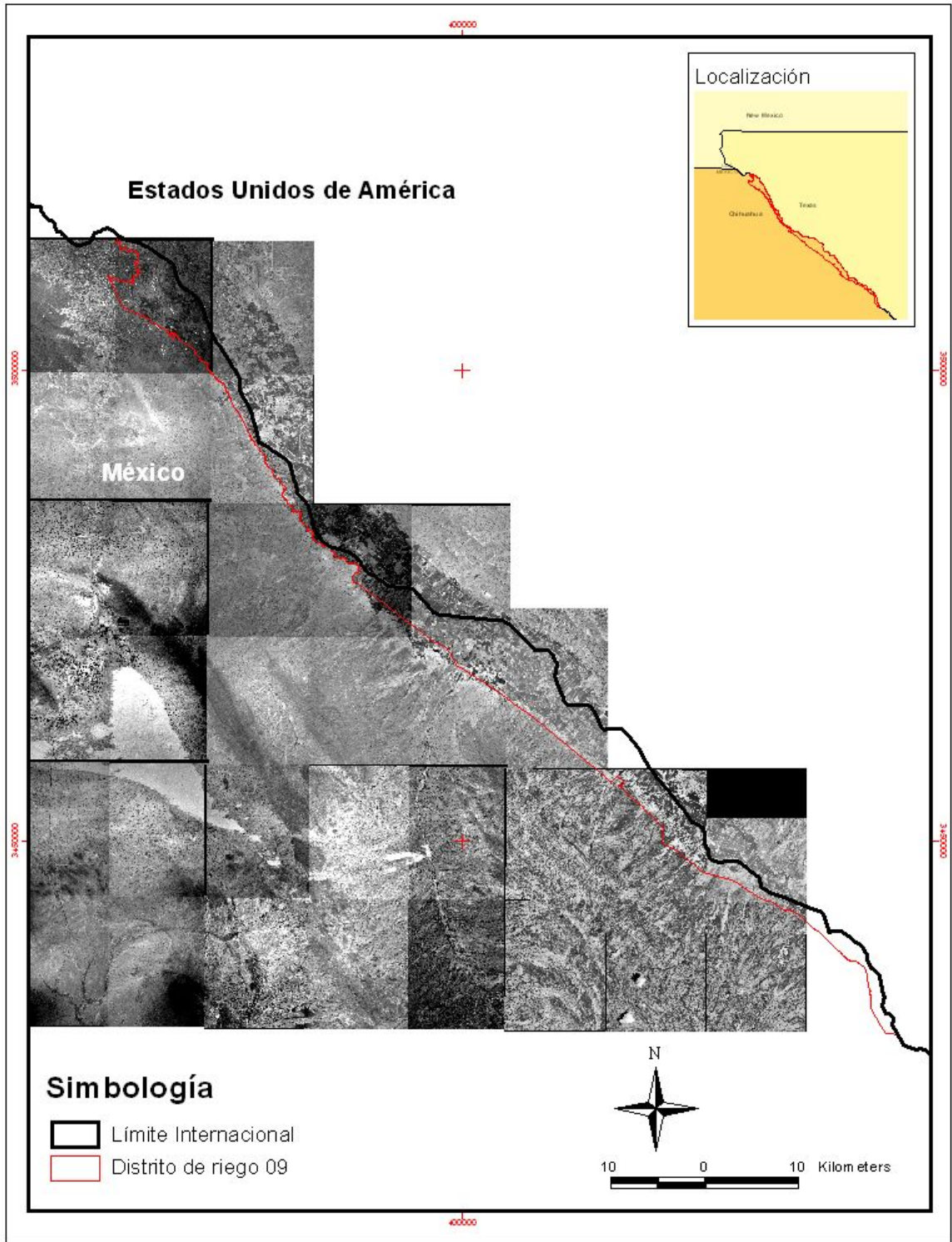


Figure 8. Aerial Orthophotography of Irrigation District 009 and Surrounding Areas

Conclusions

This report provides a review of the available geodatabase in ID-009. It integrated soils, land ownership, topography, hydrology, canals and irrigation ditches, land use, and satellite imagery and aerial photography, using GIS. The completed work on available resources in the ID-009 provides a general description of the actual condition of irrigation infrastructure and geospatial distribution of the area's natural resources. This information may help in identifying potential improvements for water resources management in ID-009. The administrative units (modules) managed by local official CNA office staff have been modified and changed due to land use changes as agricultural areas and urban infrastructure have changed as the city has grown over time. Growth has impacted the use of water resources in the area since a considerable area of administrative Unit 1 (region closest to the expansion of the City of Juárez) has changed from agricultural fields to urban settlements and commercial areas. The change has impacted surface water users since these waters have been provided to users by international water treaties.

The expansion of agricultural land since the 1906 Treaty has resulted in considerable growth in the volume of surface waters entitled to by these international agreements. Deficits have been covered by intensive groundwater pumping along with the use of domestic and industrial wastewaters, which impact regional subsurface flows. While water demands for irrigation in ID-009 have been supplied by three major sources (surface waters from the treaty, groundwater pumping, and wastewater from domestic and industrial flows from the City of Juárez), the quality of these waters is questionable. Salt and contaminant concentrations from untreated surface water applied as irrigation waters on different administrative units have impacted the agricultural soils. Although the impact has not been thoroughly documented, there is a major concern voiced by the area's agricultural community. Farmers complain about the low productivity of the soils and of health problems suffered by citizens of these rural communities.

Furthermore, damage and lack of maintenance of the irrigation infrastructure in ID-009 was documented during field trips taken by team members, students, and CNA technical personnel. On the other hand, specialized teams from Mexican agencies currently are evaluating the functional conditions in ID-009. These teams are trying to improve the efficiency of water management in the area and that may include the potential restructuring of ID-009 within a total reconstruction of the area.

Regarding the agricultural economics of the area, there is a need for long-term planning to administer water resources efficiently while encouraging efficient water technologies (i.e., drip irrigation and genetically enhanced crop production) to accomplish what has been identified by Mexican officials as Rural Sustainable Development. This refers to a national plan to improve the quality of life in rural areas and to which ID-009 will benefit. However, current worldwide economic conditions might have negative impacts on these programs due to the lack of funding and lack of organization by local communities. The economic interests of different political entities and powerful local groups might change or affect the way these programs are established. Changes in land use can be a profitable

business when those land changes are made from agricultural to urban uses. The changes also will affect the production of food and fiber. In the recent past, ID-009 was considered one of the region's most economically profitable areas producing high quality fibers for worldwide consumption.

Recommendations

Additional data elements and items were identified for further study, and the update of different data layers from GIS themes should be considered for future studies and research. Also, specific data elements that were lacking were identified such as soil types and soil salinity-sodicity themes. Refinements should be undertaken to improve or correct current datasets.

The need to add data to thematic layers of irrigation infrastructure and to update of actual conditions of the hydraulic network requires a more profound and concentrated effort. A mapping project with high resolution aerial photography, such as with the Digital Mapping Camera (DMC), should be undertaken. These maps could produce high quality information that could be used throughout an autocorrelation process. A detailed Digital Elevation Model (DEM) would be able to evaluate flood risks and the physical condition of the irrigation infrastructure.

The technical team involved with this effort has gained valuable experience that should be shared with similar efforts along the border. Support should be provided for the dissemination of the map products and to assist the technical team in presenting the project's results to interested bi-national groups.

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