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GROUND WATER RECONNAISSANCE OF THE CUATROCIENEGAS AREA

Prepared for

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GROUND WATER RECONNAISSANCE
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CUATROCIENEGAS AREA

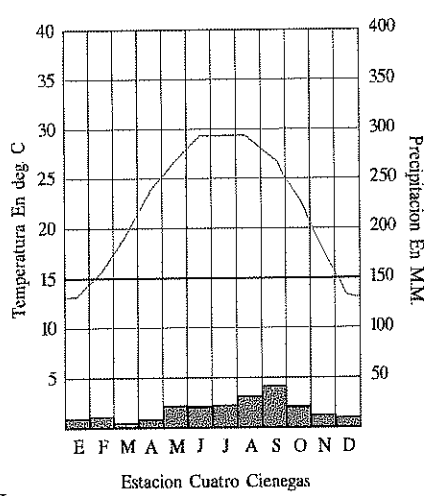
A. INTRODUCTION

This report describes the results of a reconnaissance water resources investigation in the vicinity of Cuatrocienegas, Mexico (see Figure 1 for location). The area is located in northeastern Mexico in the State of Coahuila and approximately 220 kilometers northwest of Monterrey. The land surfaces ranges from a flat plain to rugged mountain ranges. One stream, the Mesquites River, drains the area through a gap to the east along the highway to the City of Monclova.

Just south and west of the Town of Cuatrocienegas are a number of small spring-fed pools (pozas). A number of these ponds are located within a reserve set aside by the Mexican government to protect the habitat. (Area de Proteccion de Flora y Fauna Cuatrocienegas). The source of water for these pools was the purpose of this reconnaissance investigation. To accomplish this, various geologic reports and maps were reviewed together with satellite images and a geographic atlas of the State of Coahuila. Additionally, a field reconnaissance was conducted to field check numerous sites and to interview local residents and water users.

B. CLIMATE

The climate of the area is typical of a continental desert area. As can be noted on the figure below, average precipitation at the Cuatrocienegas station is approximately 220 mm (8.7 inches). About 75 mm (3 inches) falls during August and September while slightly less than 50 mm (2 inches) is reported during the six-month period from November through April.



Source: Estadística, Geografía y Informática

Average daily temperature varies from about 14° C (57° F) to 29° C (84° F), with June, July and August having the highest average daily readings. Locals say that 40° - 45° C (104° - 113°F) occurs "many times" during the hot season.

Of importance to the hydrologic cycle is the rate of evapotranspiration. This rate is estimated to be approximately 6 feet or more per year.

C. GENERAL GEOLOGY

The physical characteristics and topographical position of the rocks are the major controls of water availability in the area. These rocks are of three major types: 1) Limestones, which compose most of the mountains surrounding the plain; 2) shales found interbedded with the limestones; and 3) an alluvium consisting of sand, gravel, silt and clay which compose most of the flat-lying areas (see Figure 2, Geologic Map). The limestones and shales were deposited during the early Cretaceous geologic age by large seas which covered parts of North America. The alluvial material is the result of deposition by streams and wind during the Quaternary geologic period. Additionally, the alluvium consists of hard caliche layers and hard calciferous material found near the surface.

Elevations of the limestones and shales reach above 9900 feet mean sea level while the alluvium generally lies below 3000 feet.

Geologic structure in the area is a series of sharp anticlines and synclines. The majority of the structures trend northwest-southeast. However, the Sierra de Madera is transverse to this orientation and forms the northern boundary of the Cuatrocienegas Valley. Preliminary reconnaissance indicates an east-west trending fault located below the southern flank of the sierra where the Sierra de Madera was possibly torn from the NW-SE trending Sierra de San Marcos (see Figure 2). This fault is probably the key to the upward passage of ground water into the Cuatrocienegas Valley and especially to the ponds.

D. HYDROGEOLOGY

In the Cuatrocienegas basin, two aquifers are known to produce water to wells; the limestones and the alluvial deposits. The limestones are mainly massive, brown to gray in color and in some localities contain abundant sponge fossils and reef deposits. In other localities they are nodular and contain what appears to be some igneous-derived sand. At numerous locales, solution appears to be active along joints. Gypsum beds and shale were also noted in numerous localities as well as thin basal conglomerates.

Little is known by this writer regarding the composition of the valley fill alluvial deposits. Interviews with locals indicate that along the margins of the valley the alluvium may be as thick as 100 feet. The materials comprising the saturated aquifer portion in the area of Cuatrocienegas are reported to be limestone gravels. Toward the center of the valley, no wells were reported by locals interviewed.

The ground water in the basin begins with precipitation which falls on the mountains and the valley floor. Precipitation seeps into the limestones of the mountains and moves down dip of the limestones either through fractures, solution channels, basal conglomerates, or primary porosity within the reef material (see Figure 3). When this water passes below the valley floor, it is under high artesian pressures. The east-west trending fault could provide an upward escape for this water. As the water moves upward, it takes the surrounding limestone into solution and enlarges the passages. This water then discharges into the ponds and recharges the surrounding alluvium.

The alluvial water appears to be a second ground water system in the area and also provides water to the pozas. This is evidenced by water temperature changes. In some of the pozas, both warm and cool water can be felt entering the floor of the same poza. Additionally, the quality of water from the warm water springs reportedly is significantly different than that from the cool water springs. This writer has not confirmed the quality issue. At the time of the field visit, the data sheets regarding water quality could not be found. However, one of the local volunteers reported he had reviewed them and that there was considerable difference in quality between the warm and cool water, especially in total dissolved solids.

It is hypothesized that the deeper artesian system has water which is of somewhat better water quality than the shallower system and of higher temperature. The shallower system probably receives recharge from a number of sources which are: 1) precipitation on the valley floor; 2) infiltration of mountain runoff into the gravels near the edges of the valley; and 3) discharge of the deeper system into the alluvium through springs at the base of the alluvial material. Travel through the alluvium allows the water to cool. Additionally, the water level in the alluvium is shallow and therefore the rate of evaporation is high and concentrates the constituents. Also, it appears that alluvial ground water movement is slow. These two factors generally result in poor water quality with high total dissolved solids.

In addition to the water which sustains the pozas, water is used for irrigation within the valley. Only selected water can be used for crops, due quality constraints. No water samples were taken during this reconnaissance. However, local irrigators are aware of the quality of various waters and do not use water which is "salobre." The result of this selective irrigation process is that water is allowed to flow out of the valley in the Rio Mesquites toward the east. However, it is also understood that a large amount of the water which flows out of the valley are senior water rights which are used for irrigation in the Sacramento and Monclova areas after mixing with higher quality water.

Total area of the Cuatrocienegas basin is approximately 3100 km^2 (1200 mi^2), as can be seen on Figure 1,of which 1800 Km^2 are the mountainous areas with limestone at or near the surface and 1300 km^2 covered by valley floor material. The amount of recharge into the aquifers is not known. However, using the precipitation records from the Cuatrocienegas station and adjusting for elevation in the mountains, a conservative average of 300 mm (12 inches) of precipitation per year falls on the basin. If 5% of the precipitation results in ground water recharge, approximately 38,400 acre-feet/year (af/yr) would be recharged to the aquifers. The

5% value is an estimate based upon this writer's experience and is about 0.6 inch of recharge, which may be high for this area considering the mostly unvegetated slopes of the sierras and the climatic conditions. On the higher elevation areas of the sierras, pine forests exist. These pine forests can be seen from various locations within the Cuatrocienegas Valley and on Figure 4, which is a satellite image of the area. This image includes the infrared band which results in irrigated areas and high precipitation areas to exhibit a red color. It is very possible that only the precipitation that falls on these pine forests results in recharge. These forests are located at high elevations with cooler temperatures and well-developed soils. The precipitation after reaching the ground is provided cover by the pines and can therefore soak into bedrock. On the other hand, precipitation which falls on the valley floor is subjected to high temperatures and very high evaportranspiration rates, the net result being no recharge to the ground water. If this is the case and only recharge occurs in the pine forests, it is possible the recharge from precipitation could be as low as 10,000 af/yr.

Example Recharge Calculations:

A. Example I

1. Precipitation average over the basin - 12 inches/yr (300 mm)
2. Basin size - 1200 square miles (3100 Km^2)
3. Estimated recharge - 5% or 0.6 inches/yr (15 mm/yr)

$$1 \text{ ft/yr} \times 5\% \times (1200 \text{ mi}^2 \times 640 \text{ ac/mi}^2) = 38{,}400 \text{ af/yr}$$

B. Example II

1. Precipitation average over the pine forests - 14 inches/yr (340 mm)
2. Basin size - 125 mi^2)
3. Estimated recharge - 10% or 1.4 inches/yr (36 mm/yr)

$$1.17 \text{ ft/yr} \times 10\% \times (125 \text{ mi}^2 \times 640 \text{ ac/mi}^2) = 9360 \text{ af/yr}$$

From sparse information obtained to date, it appears that the average flow in the Rio Mesquites where it discharges from the valley is between 15-30 cubic feet/second (0.4-0.9 m^3/sec.). If the flow is in this range and the above discussed recharge is in the 10,000 af/yr range (14cfs average), it appears that some inter-basin flow occurs. This inter-basin flow could come from a number of areas. However, the most likely locations would be: 1) the Ocampo Valley located just north of Cuatrocienegas; 2) the Hundido Valley to the southwest; and 3) the large valley directly to the west of the Town of Cuatrocienegas (see Figures 1 and 2).

During this reconnaissance, a field trip was taken into the Ocampo Valley to evaluate possible inter-basin flow. Interviews with local well owners indicate that the ground water levels are about 90-100 feet below ground surface. Most wells are approximately 200-250 in depth and receive water from limestone gravels. The water levels in the southern part of the valley reportedly have declined about 30 feet over the past 10 years. The interviews also show the lack of data in the valley, whereby one irrigator stated that there are more than 300 wells in the valley while a government water department official stated there are approximately 20 wells in the valley. The large discrepancy may be due to the existence of a large number of domestic and/or stock wells. The conclusions reached after the interviews and reconnaissance is that there does not seem to be a ground water connection between the Ocampo valley and the Cuatrocienegas Valley. The geology suggests that no connection exists and the ground water levels are located at considerably higher elevations than in the Cuatrocienegas Valley. However, locals agree that the surface flow from the Ocampo Valley has decreased significantly. More data is required to more fully evaluate the interconnection issue.

The possible ground water flow between the other basins mentioned above was not investigated due to time constraints. However, the existence of salt flats and native vegetation which evapotranspire large amounts of water from the shallow water table, indicate that there are large ground water losses within the Cuatrocienegas basin. This indicates: 1) that either higher rates of precipitation occur and/or a higher percentage of precipitation recharges the ground water; or 2) inter-basin ground water flow occurs.

E. GROUND WATER CONSIDERATIONS

The water quality, quantity and ground water levels appear to be key issues in maintaining the environment for the flora and fauna associated with the ponds and protected area. The actual water levels in the pozas do not appear to be a serious issue at this time. It was reported that the water level decline in some ponds has been 30 cm (1 foot) in some ponds. This has caused undercutting of the banks and silting of the pond bottoms.

The levels in the pozas are controlled by the pond outflow. That is; the levels cannot rise any significant amount because with each small rise, more water flows out of the pozas. However, the amount of water which flows into the pozas controls the temperature and water quality. If less water enters a poza due to less recharge or ground water pumping, there will be less flow through the poza and the time required to completely change over the water in the poza will be longer. Additionally, the velocities on the pond location would be lower. These factors could have an impact on both the flora and fauna associated with the ponds. If large declines in water levels occur, the existing habitat could be seriously injured.

Numerous factors could impact the ground water, most importantly changes in land usage. This may be highly important in some areas such as harvesting of trees in the watershed, ground water pumping, or new irrigation with large return flows upgradient of the ponds. With present knowledge of the water system, only general protection practices can be recommended. However, declines in not only local ground water but regional declines could impact the habitat. In order to determine the water-related factors which impact the subject area, a better understanding of the overall water scenarios is needed. Most importantly the following need to be investigated:

1. Source(s) of water
2. Recharge
3. Seasonal and annual patterns
4. Water table configuration and direction of ground water movement
6. Background of irrigation practices and location of irrigated fields
7. Precipitation and temperature
8. Evapotranspiration of native plants

With a better understanding of the above items, a water budget (balance) can be set up to determine the components of the balance (such as ground water inflow, evapotranspiration, irrigation use, and outflow from the valley) and what happens to each component. This provides better knowledge of the system and which components are sensitive to outside influence.

F. RECOMMENDATIONS

In order to evaluate the factors listed in the Ground Water Considerations section, a hydrogeological investigation of the area should be realized. This investigation should include the following:

1. Regional geological study of the sierras, alluvial fans and valley bottom - The final product of this study would be a geologic map and report which would provide a better understanding of the pathways for ground water movement and sources of water and communication between valleys.

2. Set up a monitoring well system - Water levels and data from various existing wells should be obtained. Approximately 30-40 shallow monitoring wells should be drilled into the alluvial aquifer. These wells can be used to map the water table and to take water samples for water quality analyses. Water levels should be taken on a seasonal basis. Data from these wells would provide the direction of ground water flow, an aerial distribution of ground water quality, and the composition of the alluvial aquifer.

3. A system should be established to measure surface water flow at various points. It is understood that some flow data exists and is kept with some of the ejidos. Additionally, the Comision Nacional de Aguas (CNA) and Profauna reportedly have some data, not only regarding surface flows but also ground water data. In the protection area, measuring devices could consist of simple staff gages near the outlets of various pozas. Additionally, measuring stations should be set up along the Rio Mesquites, one of which should be located in the gap to the east of the town of Cuatrocienegas to measure discharge out of the valley. Measuring stations should also be established on selected irrigation canals.

4. Water quality sampling should be established on a regular basis. Samples should be taken on a seasonal basis for a period of two to four years and then the program re-evaluated to determine sampling intervals. Parameters to be analyzed can be determined after the first samples are analyzed. A regular sampling schedule could be set up for basic analyses by volunteers of the Ph, temperature, and conductivity without laboratory assistance; needing only litmus paper, a thermometer and a conductivity meter. The points of sampling should include a number of pozas, the above mentioned monitoring wells, and the Rio Mesquites. At a minimum of four carefully-selected pozas, samples should be taken under water at points where the warm and cool water springs discharge into the bottom of the pozas.

5. An inventory of area irrigation, stock and production wells should be undertaken. Data regarding the depth, material drilled, water levels and production rates should be collected.

6. The water level data, water balance and geologic investigation should be evaluated to determine if inter-basin flow is occurring and from which basin(s) this takes place.

7. Climatological stations should be established to monitor temperature and precipitation. One of these stations could be set up on the protected area and monitored by volunteers. Establishment of a station in the surrounding sierras would be difficult, not only due to cost but accessibility for regular data collection would be difficult. Therefore, research should be undertaken to find an existing station in one of the adjacent sierras and an interpolation of data be realized.

8. Components of the water balance (budget) for the area should be identified and the balance calculated. This would assist in identifying components which are sensitive to minor changes which could have an impact on the pozas.

Respectfully submitted,

HRS WATER CONSULTANTS, INC.

Robert D. Tafelski
President and Senior Hydrogeologist

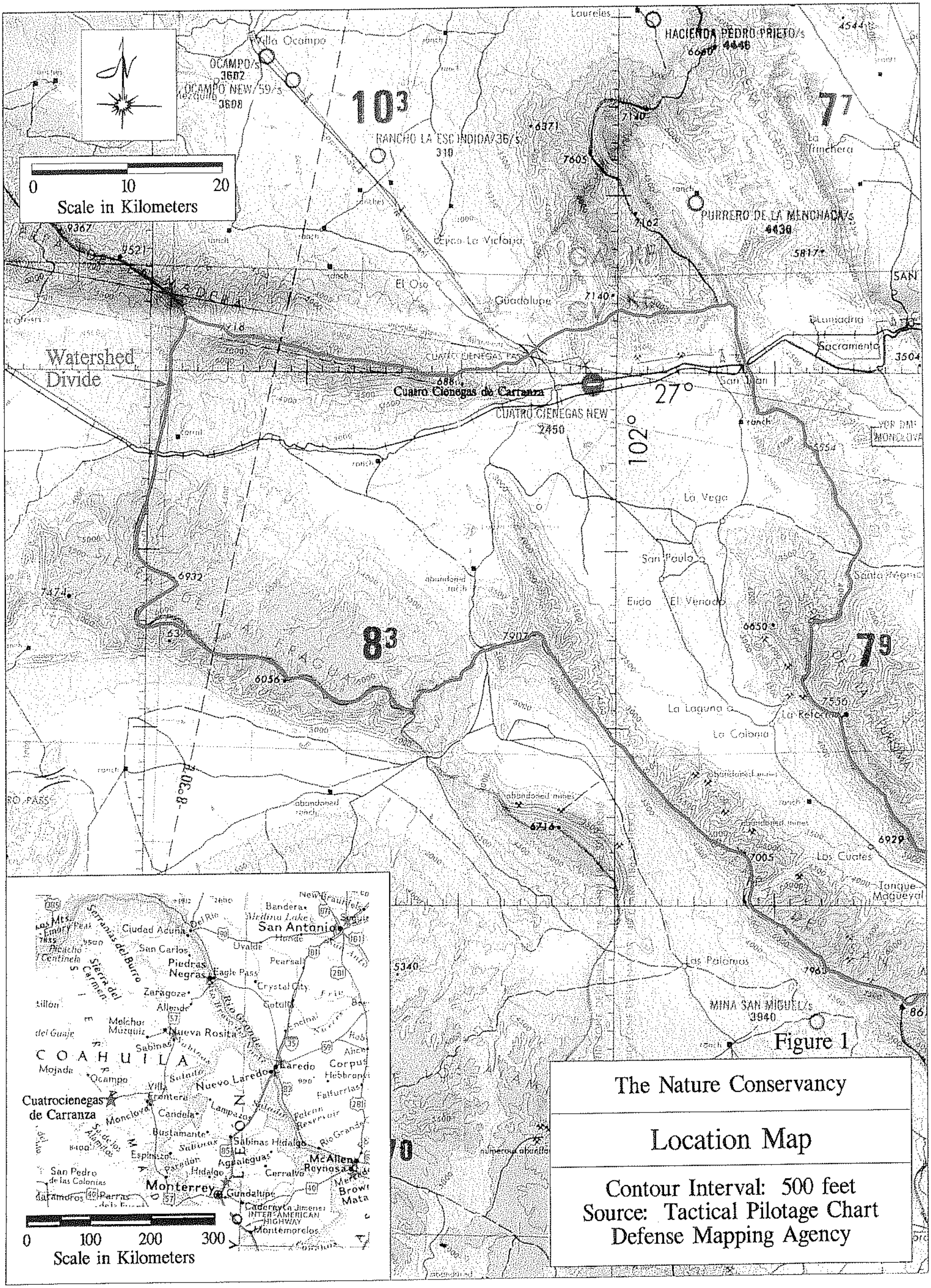
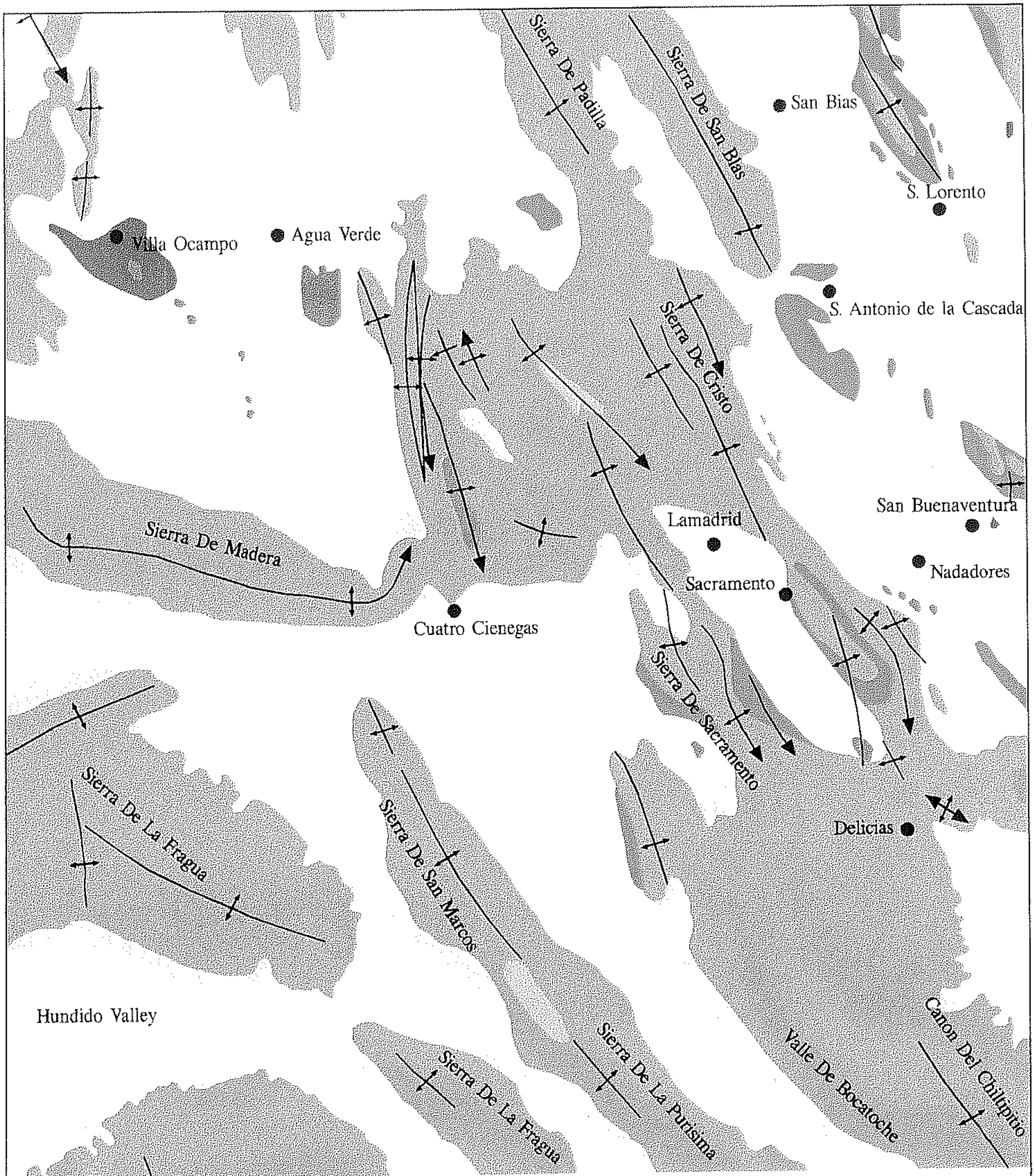


Figure 1

SOURCE: TACTICAL PILOTAGE CHART TPC H-236 EDITION II



Legend

Q	Alluvial Deposits	Ige	Igneous Extrusives
Ki	Upper Cretaceous Predominately Limestone	Jc	Jurasico La Casita
Ks	Upper Cretaceous Limestones and Shales	Igi	Igneous Intrusives
Tc	Terciario Continental	Js	Jurasico Superior

Figure 2

Geologic Map of the CuatroCienegas Area

Source: Carta Geologica del Estadad Cohuila

Scale 1 : 500,000

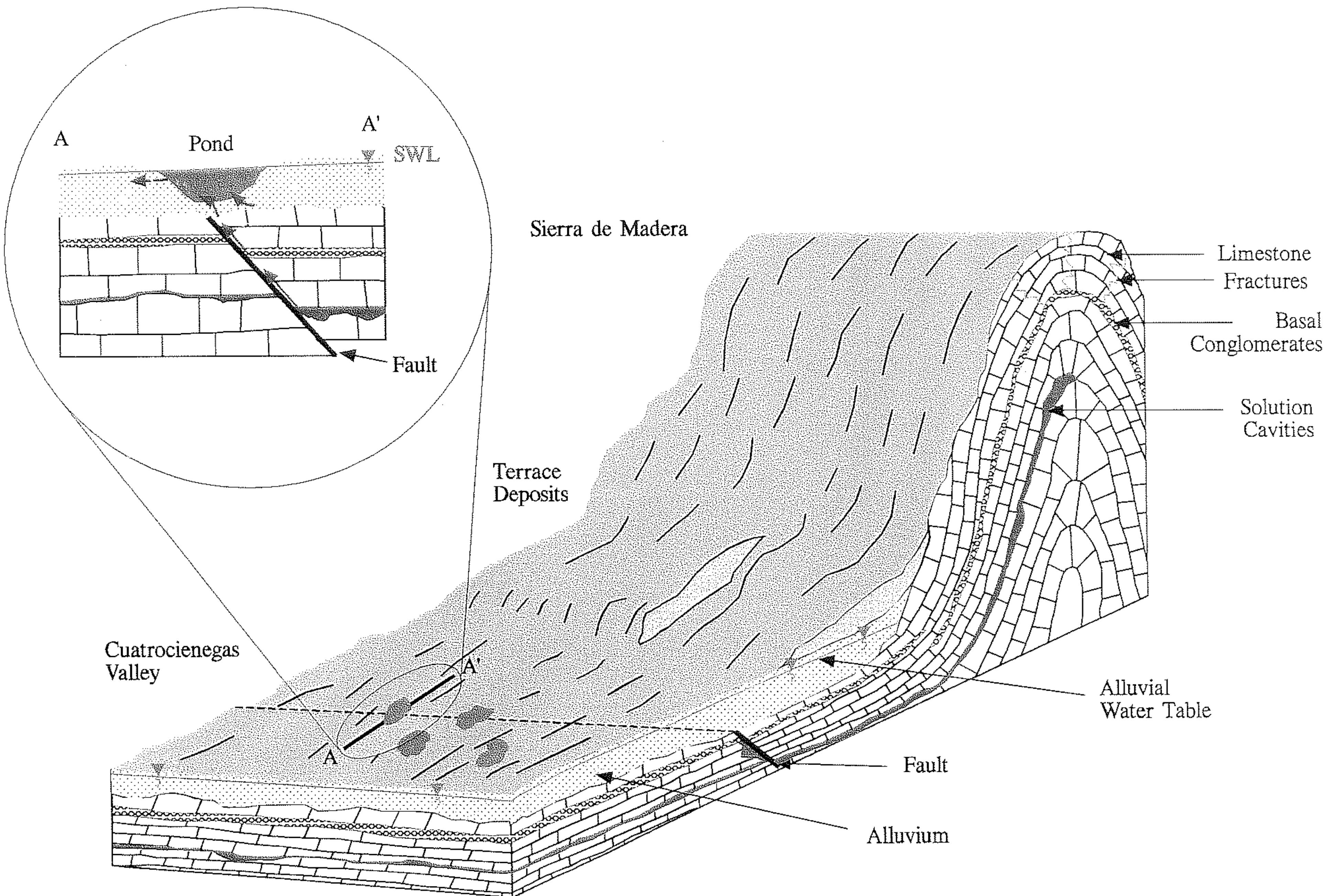
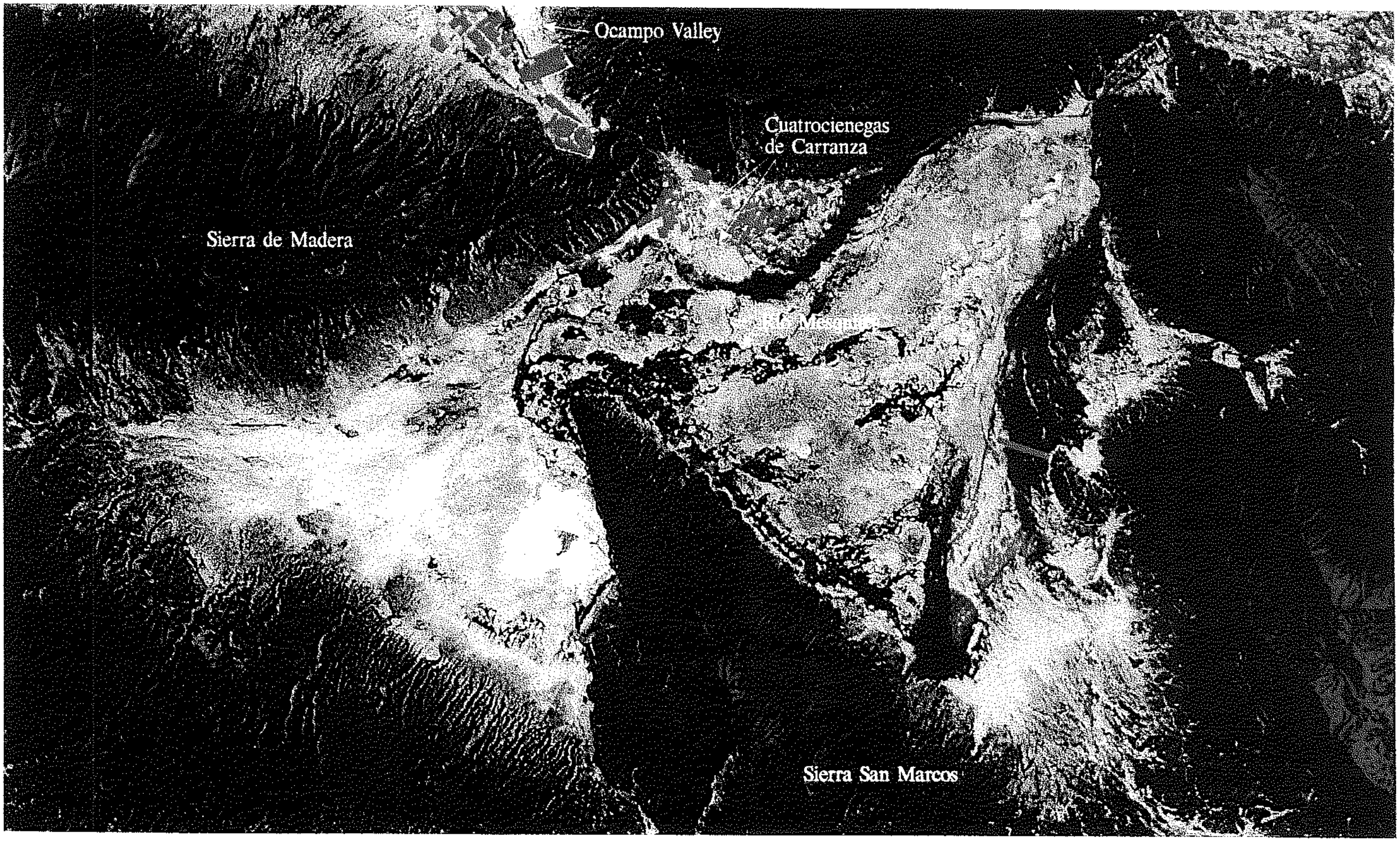


Figure 3

Illustrative Hydrogeologic Section



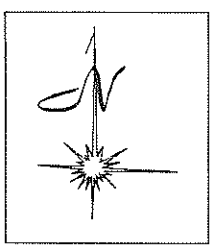


FOTO INFRA ROJO DEL SATELITE

AREA DE CUATROCIENEGAS

INFARED SATELLITE IMAGE

OF THE CUATROCIENEGAS AREA

Figure 4