January 1991

ANALYSIS BY REPUBLIC OF MEXICO

The following analysis was prepared by the National Water Commission of the Republic of Mexico for submittal to the International Boundary and Water Commission, United States and Mexico (IBWC). The analysis is still under discussion in the international consultation between the United States and Mexico through IBWC. [Editorial Note: The figures included in this attachment are of the best quality available in the United States.]

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Since the 1960s, measuring has been made of ground water depths in wells dispersed along the Mexicali Valley and the San Luis Mesa. The ground water level contours corresponding to different dates clearly demonstrate the ground water recharge received by the Mexicali Valley from its northern boundary. (See Figure No. 1). The ground water flow, based the hydraulic gradient data and transmissivity at a section near the interantional boundary, and more or less parallel to the boundary, and a width similar to the width of the AAC, would result at 80 to 100 million M^3 (65,000 to 81,000 acre feet) per year. This amount coincides, in order of magnitude, with the estimate of AAC water seepage that migrates towards Mexico (the range is based on the uncertainty and variation of transmissivity and hydraulic gradient.) These contours and those corresponding to the Imperial Valley reasonably coincide with the ground water elevations along the border area and when considered in all the ground water recharges these confirm that

the ground water recharge that enters the Mexicali Valley at its northern boundary is from the ACC. (See Figure 2)

Long term ground water level fluctuations, of various meters, have been registered in Mexico, as a product of variations in a magnitude and distribution as that of recharge and pumping. This showed drawdowns during the 1957-79 period, a regional recovery in the 1980-87 period, and resumed drawdowns in the 1988-90 period. (See Figure 3) In general, the maximum fluctuations were of some 7 meters (23 feet) and were present in the central portions of the Mexicali Valley, while the fluctuations at the northern boundary were only 1 to 3 meters (3 to 10 feet). In accordance with information published in U.S. Geological Survey Reports and data provided by the U.S. Bureau of Reclamation, AAC seepage increased the ground water levels up to 15 meters (49 feet) in the southern part of the Imperial Valley under the AAC and in an extensive zone of influence for various depths in Mexican territory, perhaps extending to some 15 kilometers (9 miles) south of the international boundary. (See Figure NO. 4) On the Mexican side this ground water mound experienced growth because systematic observations started in the 1960s when the dome had already stabilized.

Presently the ground water table is very high in the Mexican part of the aquifer thanks to an extraordinary recharge brought about by Colorado River excess flows in the last decade. Due to this, the present ground water elevations levels are from 2 to 10 meters (7 to 33 feet) below the Mexicali Valley land surface and from 5 to 15 meters (16 to 49 feet) at the Andrade Mesa. (See Figure No. 5). Along the foot of the Andrade Mesa the ground water crops out into the La Mesa drain which was constructed in 1960 in order to reclaimed swampy lands. In 1990 flow measurements and electric conductivity measurements were made at various points along this drain and its tributaries, along with laboratory determinations for water salinity. This was performed to understand the flow variations and salinity of the waters. (See Figures 6, 7, and 8)

Figure 7 shows that the La Mesa Drain receives some 2000 lps (70 cfs), distributed as, 400 lps (14 cfs) from various lateral drains and 1600 lps (56 cfs) directly from ground waters. About 60 per cent of this last flow enters in the first 15 kilometers (9 miles) of the drain beginning in the upper part. Figure No. 8 shows that the salinity of the water carried by this drain gradually increases with the downstream flow from 900 ppm in the upper reach to just over 2000 ppm

at its lower part at kilometer 38 (Mile No. 24). The salt content continues to increase downstream of Kilometer 38 (Mile No. 24) at irregular rates due to inflows and diversions to reach an average salinity content of 3500 ppm. The water discharged by very shallow tributary drains, has a salinity value of from 1200 ppm to 4400 ppm, waters which are the product of irrigation return flows that flow on the surface with penetrating the aquifer.

Placing a dissolved salts balance for the La Mesa Drain waters, one can deduce that the flow is made up of some 1000 lps (35 cfs) for Mexicali Valley irrigation return flows with an average salinity of 3500 ppm. The greater water gain with low salinity in the upstream reach of the drain is attributed to the fact that the highest permeability of the aquifer and the condition that best favors seepage from the AAC is found in this area. According to studies by the USBR the reach of the AAC from Pilot Knob and Drop 2 the ground water level is not connected to the canal, a condition that causes a maximum hydraulic gradient which induces losses in this canal. To the contrary, the Drop 2 to Drop 4 reach is hydraulically connected, thus the loss is less then in the first

reach. At the same time, such hydraulic conditions are related, in part, with the hydraulic characteristics of the aquifer. The large transmission capacity of the deposits in the area of the upstream reach permit a rapid dispersion of the seeped water, which with a low hydraulic gradient, the ground water mound did not reach the canal bottom.

The water collected by the La Mesa Drain is diverted for irrigation through intakes. The largest intake structure is at kilometer 40 (Mile 24) diverts 800 lps (28 cfs). There are a large number of pumps with less capacity installed throughout the drain which together divert another 200 lps (7 cfs). The total diverted flow is at some 1000 lps (35 cfs) which is utilized to irrigate 1,200 hectares (2,960 acres) to benefit 60 farmers who are not served by the district.

From the above considerations, and accepting the information provided by the USBR, the seepage from the AAC is distributed as shown in Figure No. 9. Of the total losses in the reach under consideration of some 117 million M^3 (94,800 acre feet) per year, some 5 million M^3 (4,000 acre feet) are utilized by natural vegetation along the canal banks, and 108

million M^3 (87,600 acre feet) are incorporated into the aquifer. Ten per cent of this volume flows towards the Imperial Valley and 90 per cent (97 million M^3 [78,600 acre feet]) migrates towards the Mexicali Valley. This unequal distribution between both sides is due to the less intense surface water irrigation and an insignificant of ground water pumping in the Imperial Valley. Consequently, the ground water is shallow which limits it flow gradient that the ACC induces towards the north. Finally, of the 97 million M^3 (78,600 acre feet) that flow into Mexican territory, some 30 million M^3 (24,300 acre feet) flow into the La Mesa drain and another 67 million M^3 (54,300 acre feet) are transmitted through the aquifer to the south.

EFFECTS OF LINING

Based on information available, the probable effects in Mexico of the AAC lining were analyzed. For this purpose, as a start, a Mexicali Valley ground water model was utilized. The model was calibrated to analyze different joint management and use options. The model is one with finite difference technique based on the Prickett and Lonnquist Acquifer Simulation model which covers an area of approximately 1700 Km^2 (660 Mi^2)

(marked by a crossed lines forming rectangular pixels) within which the eastern part of the Mexicali Valley, the northwest part of the San Luis Mesa, the Andrade Mesa and the southern boundary of the Imperial Valley are located. Its northern border coincides with the line approximately formed by the AAC and for the purpose of the model serves as the recharge boundary represented by seepage from this canal. (See Figure No. 10).

The model was calibrated paying special attention to the northern half of the area considering and adjusting the parameters to reproduce the growth of the mound created by the AAC. The magnitude of losses from this canal was fixed in accordance to data that was presented in this respect at the September 11, 1990 meeting of the IBWC. Once adjusted, the model was analyzed for behavior of the ground water levels that could result after the AAC is lined and the seepage from the AAC were reduced by 80 per cent, utilizing the present situation as a reference.(See Figure No. 11)

The results of analysis, demonstrated in Figures Nos. 12 to 14, show the decline in the ground water mound. The drawdowns would occur in Mexican territory in amounts that would decrease

to the south arriving at values of 5, 10 and 14 meters (16, 33, and 46 feet) in the immediate international boundary area for 3, 5 and 10 years, respectively, after lining. For the same periods, the influence would extend to distances of 4, 8, and 11 kilometers (2, 5, and 7 miles), south of the boundary, respectively. Within this zone of influence, the drawdown caused by the canal lining would be contingent on the drawdown caused by the exploitation of the Mexicali Valley. The results of a simulation of the Mexicali Valley aquifer indicate that the first cause would be of a serious magnitude than the second after a period of 10 to 15 years beginning at the time that the reductions in seepage began. The magnitude would decrease over time until depleting at the end of this period.

These results are compatible with the fact that it took the mound 15 to 20 years to form since the AAC went into operation in 1940 to the end of the 1950s when the ground water table stabilized. Also this is consistent with the fact that pumping over 15 years of ground water in an amount similar to that at present just barely caused drawdowns of less than 3 meters (10 feet) at the northern part of the Mexicali Valley. (See Figure No. 15)

Thus, the referenced drawdown would cause the following collateral effects:

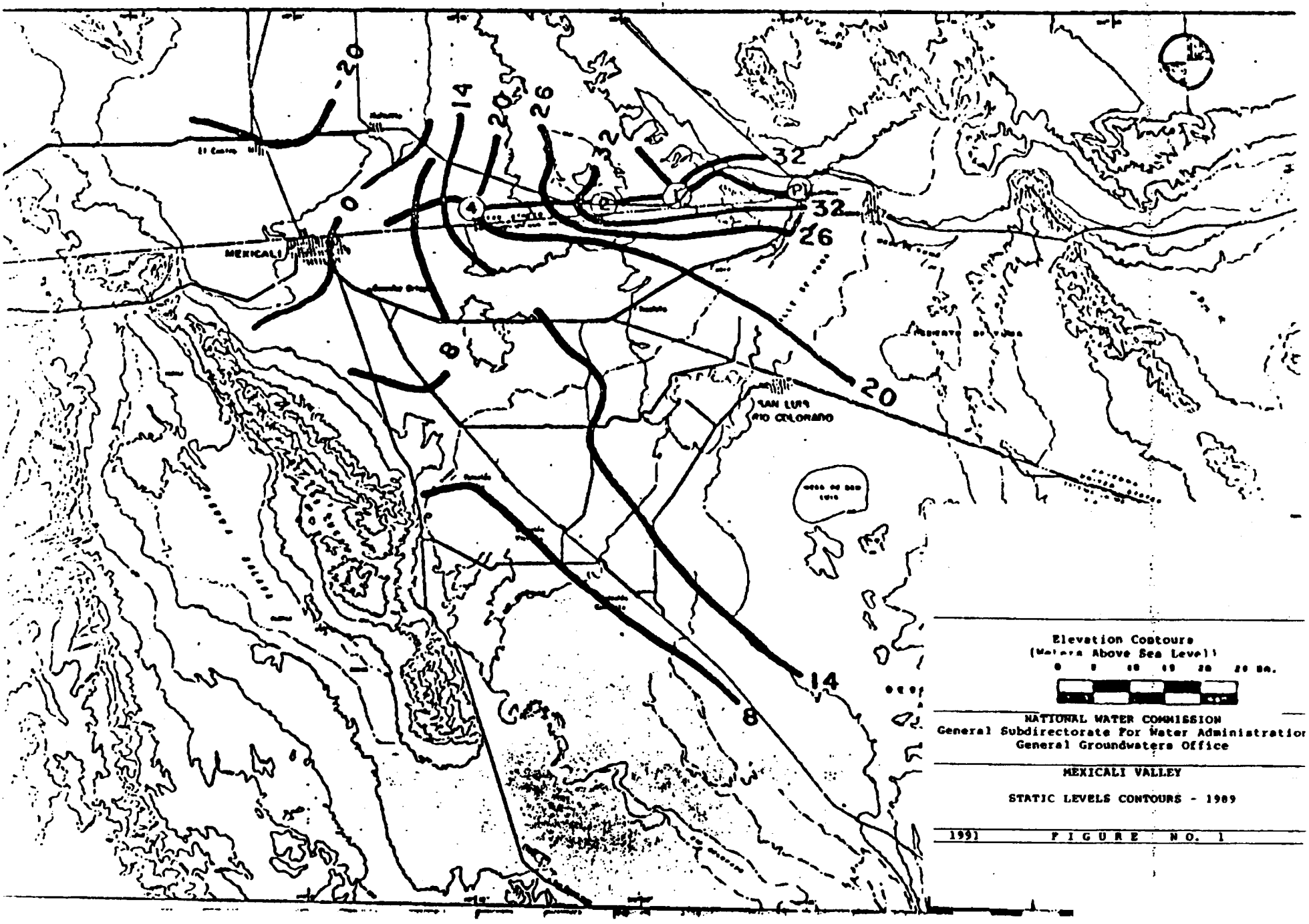
The ground water recharge of the Mexicali Valley will be reduced by 70 million M^3 (56,700 acre feet) an amount equivalent to that which would no longer enter from the northern boundary.

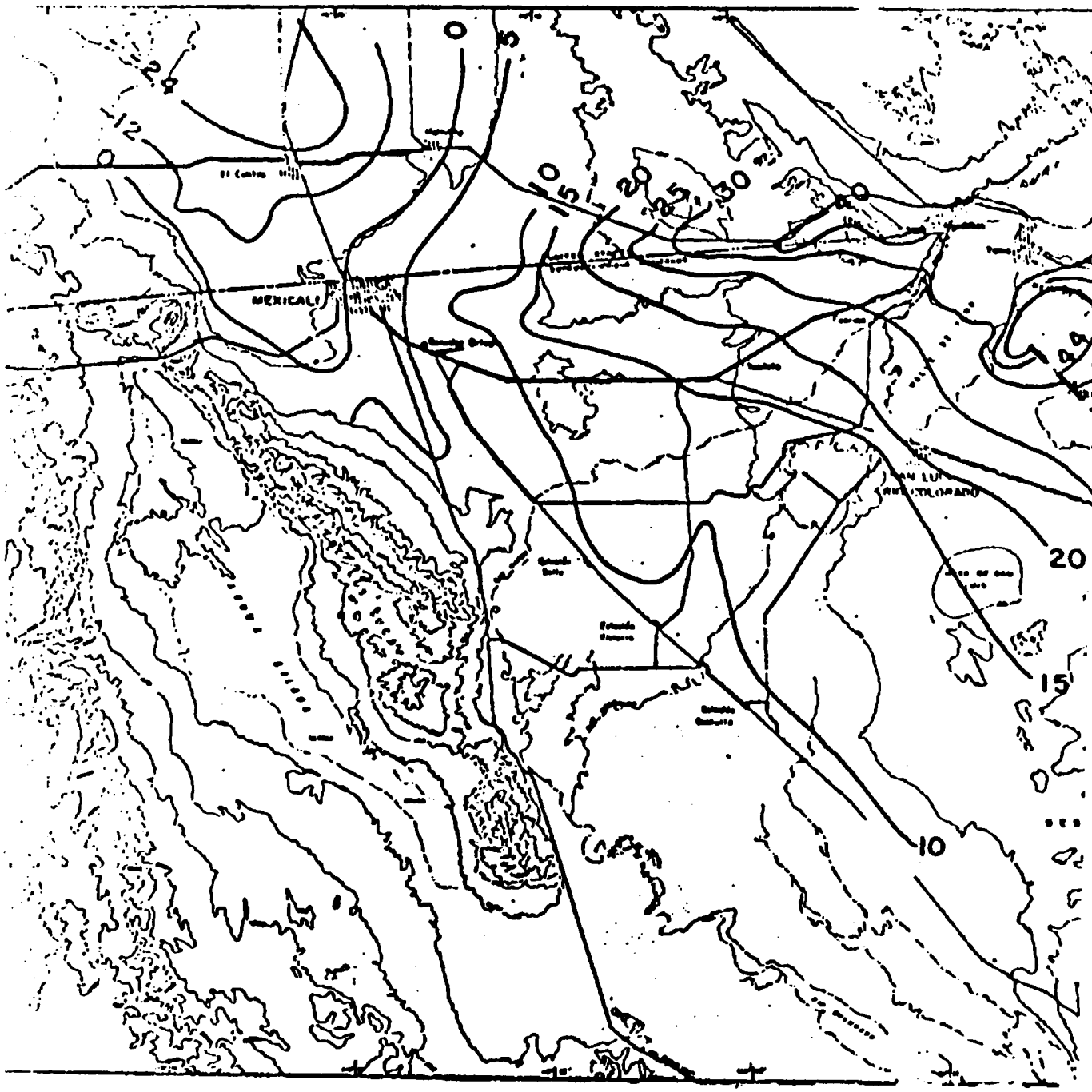
Upon suspending the recharge of fresh water in the northern part of the Mexicali Valley the growing tendency for ground water salinity, caused by irrigation returns seepage, would be accelerated.

The fresh water that the La Mesa Drain receives from the AAC would terminate. As a result, 1200 hectares (2,960 acres) of irrigation would no longer benefit directly and the remaining flows, from irrigation returns, would no longer be useable in agriculture due to their high salinity.

The pumping levels of wells installed in the area influenced by the AAC will have additional drawdowns.

As shown in Figure No. 16, the number of wells affected after 3, 5, and 10 years, beginning with the AAC lining would be 27, 95, and 190, for those years respectively. In general the affected wells provide discharges greater thatn 50 lps (2 cfs) with drawdowns of less than 10 meters (33 feet) due to the high transmissivity of the aquifer. Thus in many of these wells the additional drawdown will be equal or greater than that caused by operation.


-20
14
20
26
32
32
32
26
0
8
20
14
8
MEXICALI
SAN LUIS
RIO COLORADO
Elevation Contours
(Meters Above Sea Level)
NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office
MEXICALI VALLEY
STATIC LEVELS CONTOURS - 1989
1991
FIGURE NO. 1



Elevation Contours
(Meters Above Sea Level)

NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office

MEXICALI VALLEY

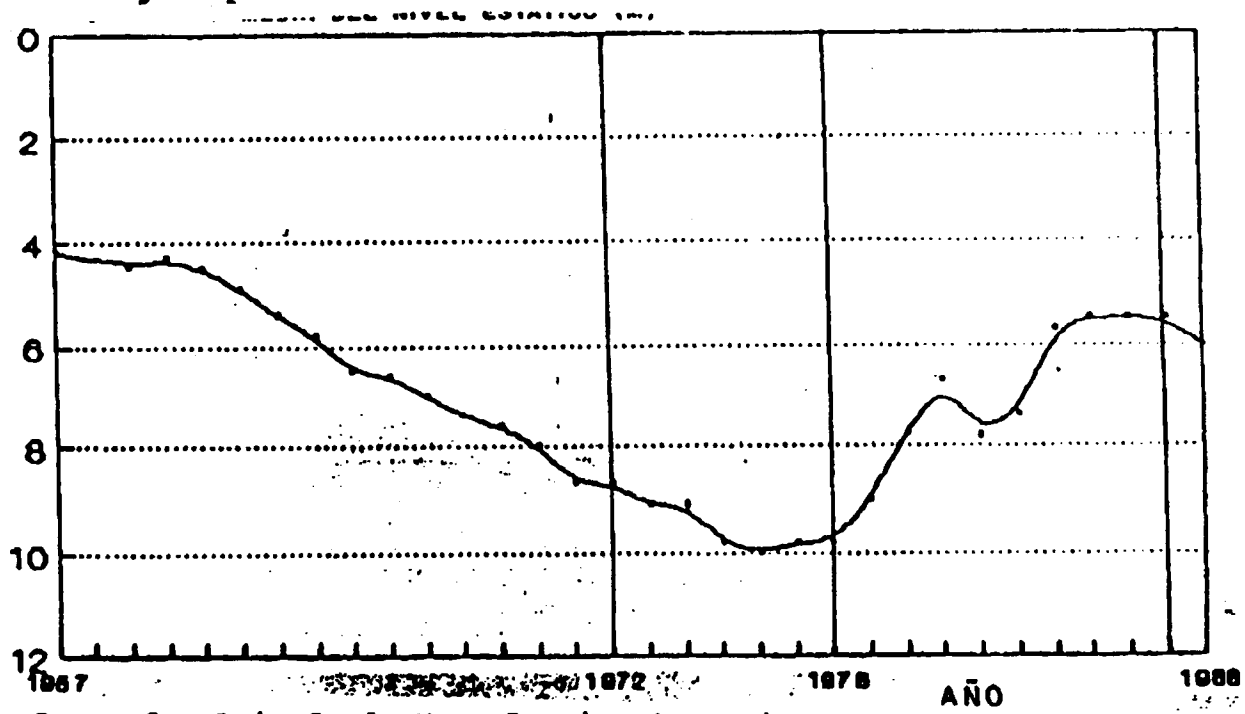
STATIC LEVELS CONTOURS - 1985

1991 FIGURE NO. 2

M E X I C A L I V A L L E Y

MEAN EVOLUTION OF STATIC LEVELS

Average Depth of Static Level in Meters

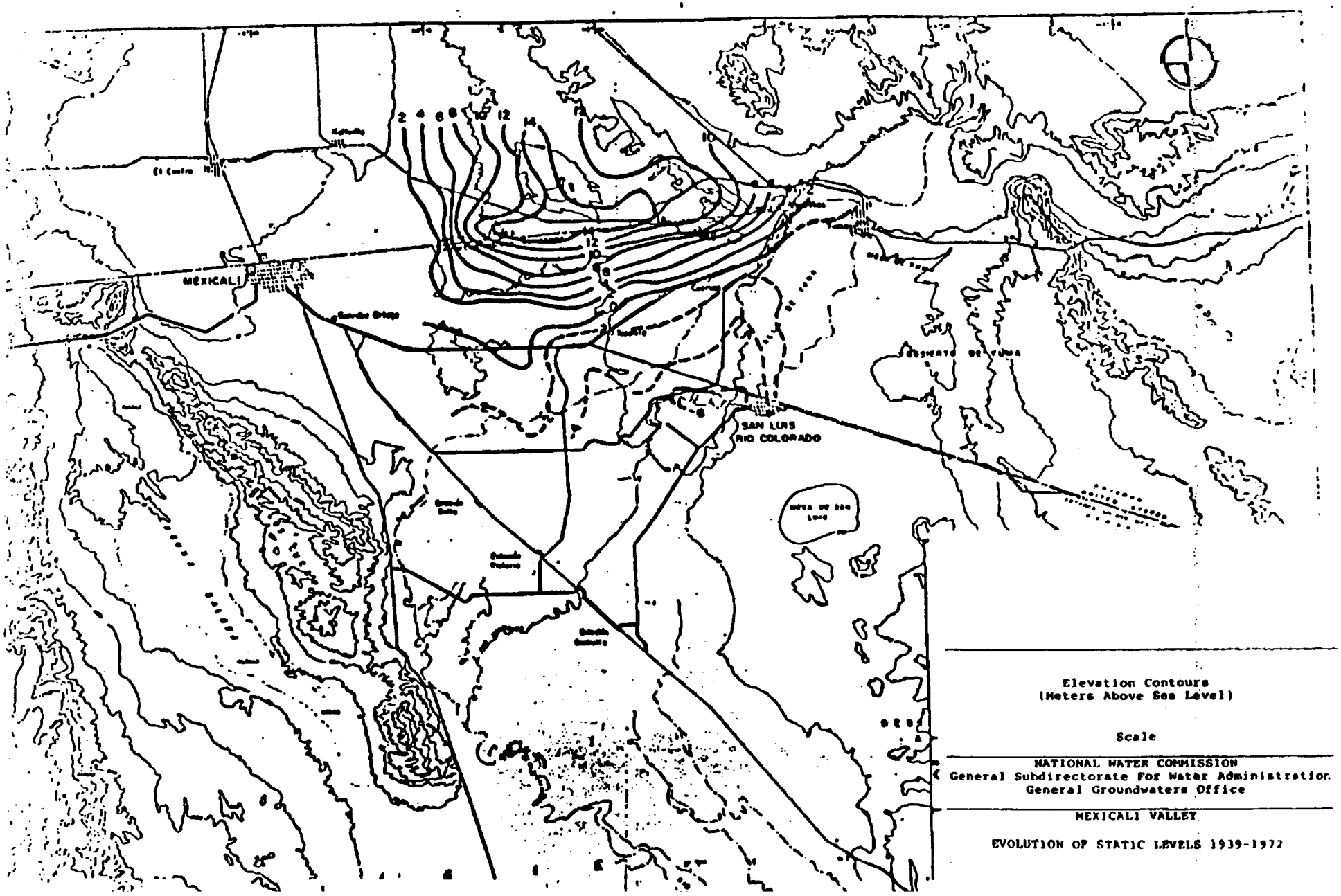


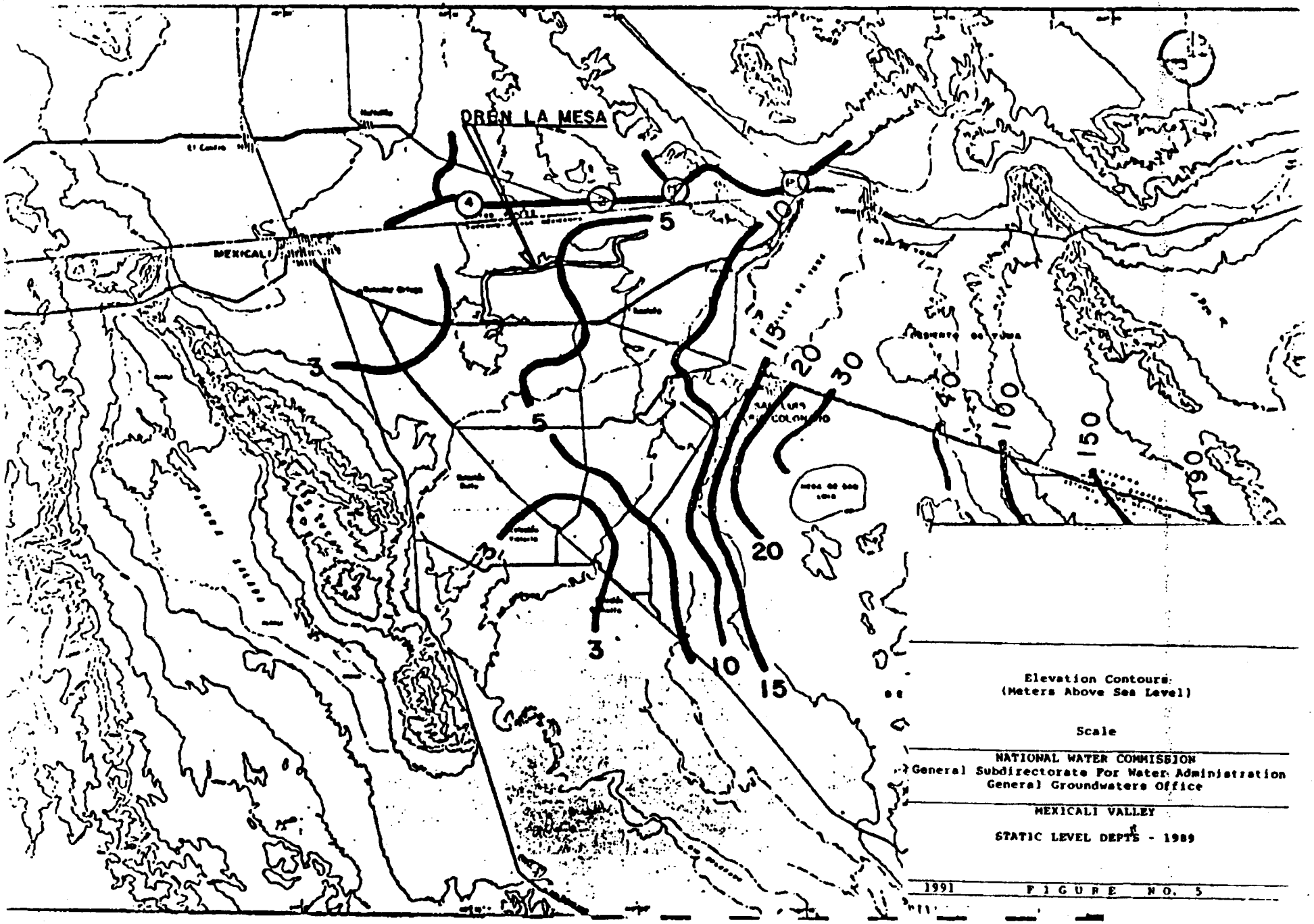
1972--Began San Luis Sandy Mesa Pumping Operations

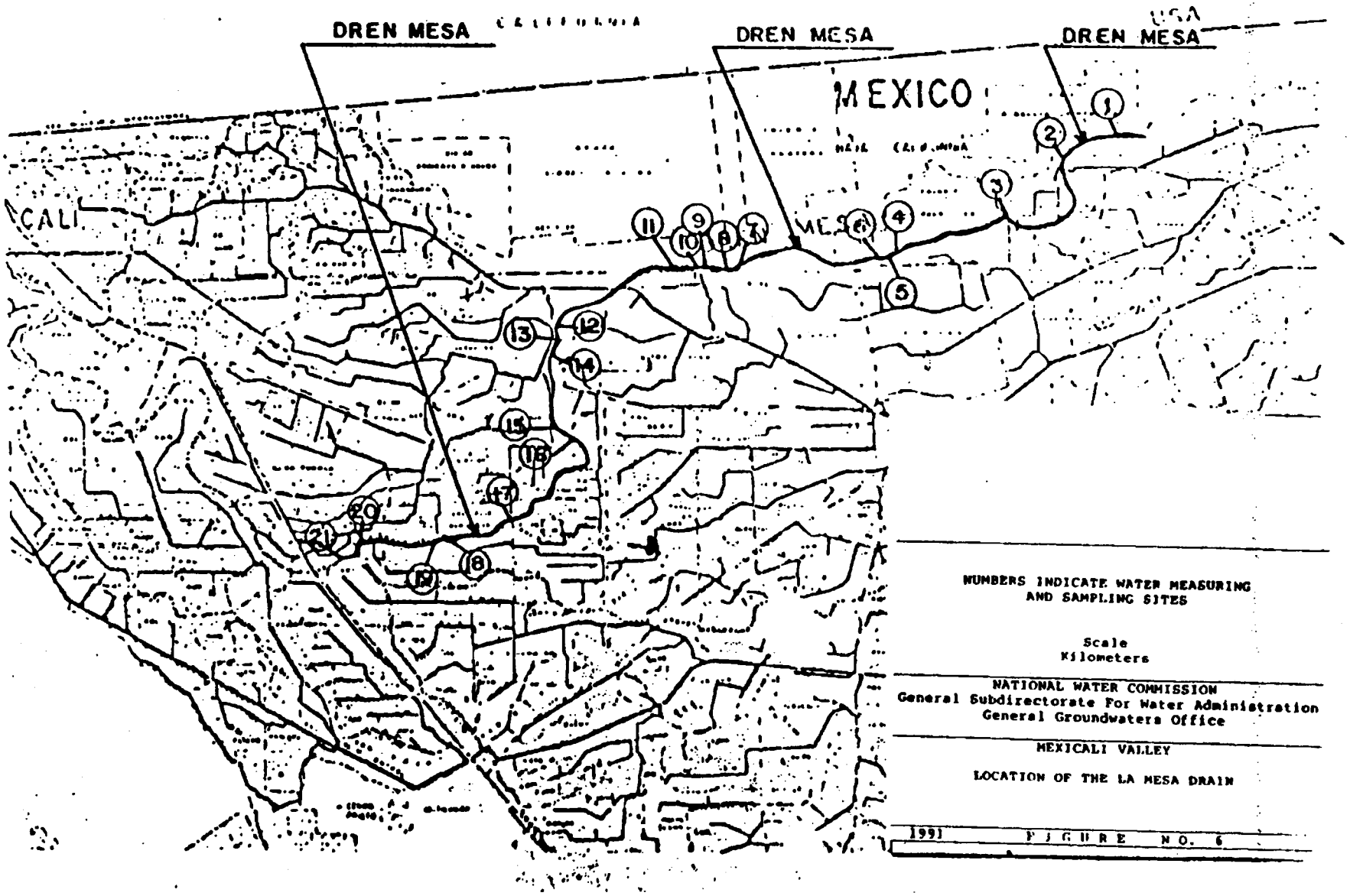
1978--Colorado River excess flows start

1987--Colorado River excess flows end

F I G U R E N O. 3


MEXICALI
SAN LUIS
RIO COLORADO
2
4
6
8
10
12
14
Elevation Contours
(Meters Above Sea Level)
Scale
NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office
MEXICALI VALLEY
EVOLUTION OF STATIC LEVELS 1939-1972


DREN LA MESA
MEXICALI
3
5
10
15
20
30
40
100
150
190
Elevation Contours
(Meters Above Sea Level)
Scale
NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office
MEXICALI VALLEY
STATIC LEVEL DEPTS - 1989
1991
FIGURE NO. 5



NUMBERS INDICATE WATER MEASURING AND SAMPLING SITES

Scale
Kilometers

NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office

MEXICALI VALLEY

LOCATION OF THE LA MESA DRAIN

1991 FIGURE NO. 6

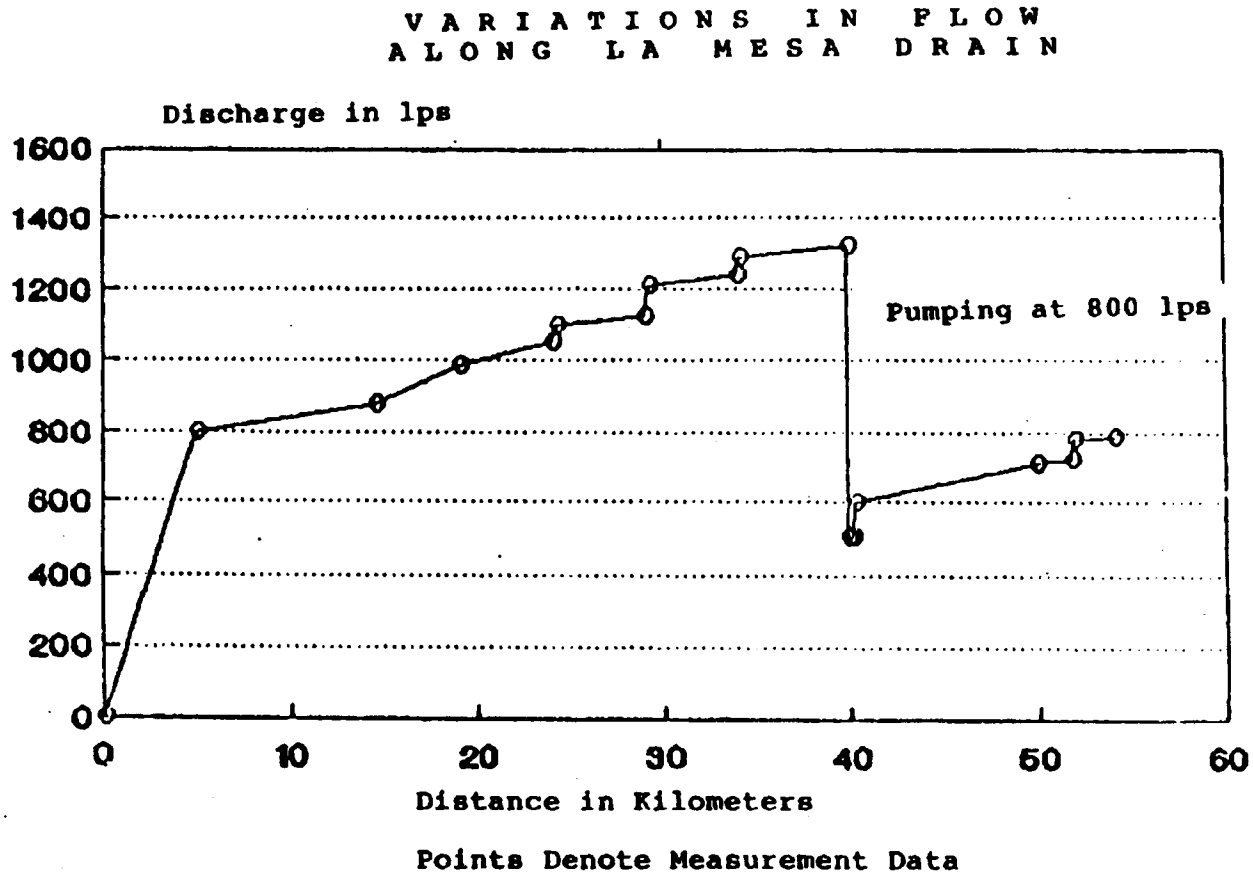

VARIATIONS IN FLOW
ALONG LA MESA DRAIN
Discharge in lps
1600
1400
1200
1000
800
600
400
200
0
Pumping at 800 lps
0
10
20
30
40
50
60
Distance in Kilometers
Points Denote Measurement Data

FIGURE NO. 7

VARIATIONS IN SALINITY
ALONG LA MESA DRAIN

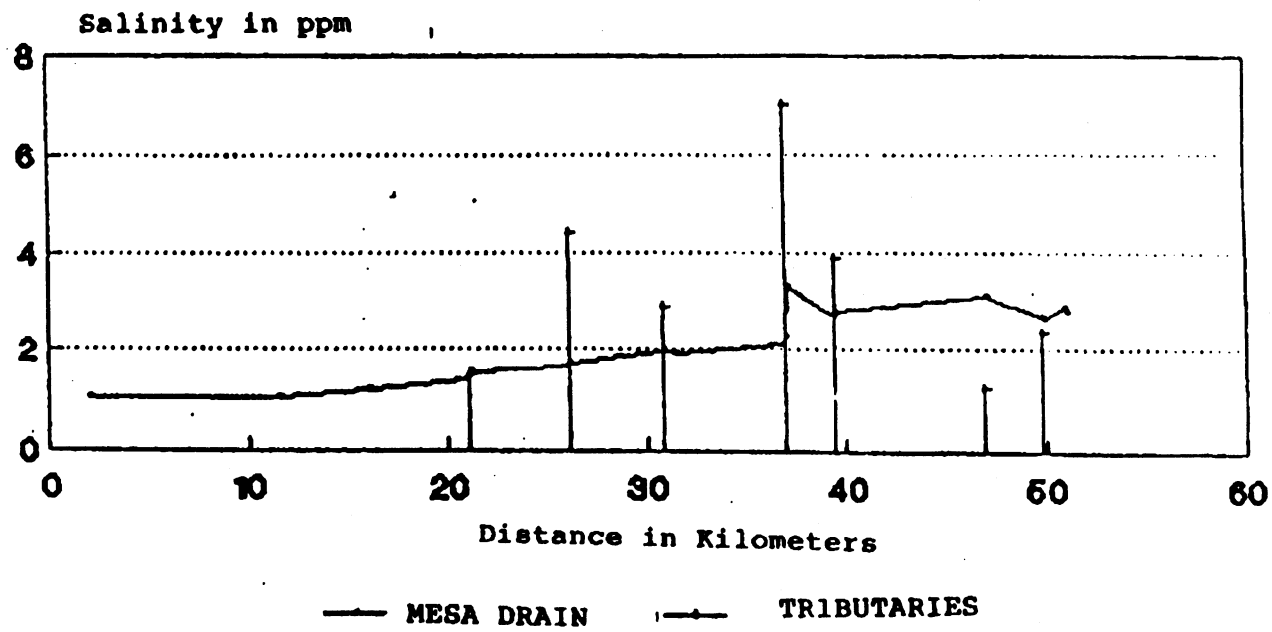


FIGURE NO. 8

WATER SEEPAGE VOLUME DISTRIBUTION

ALL AMERICAN CANAL

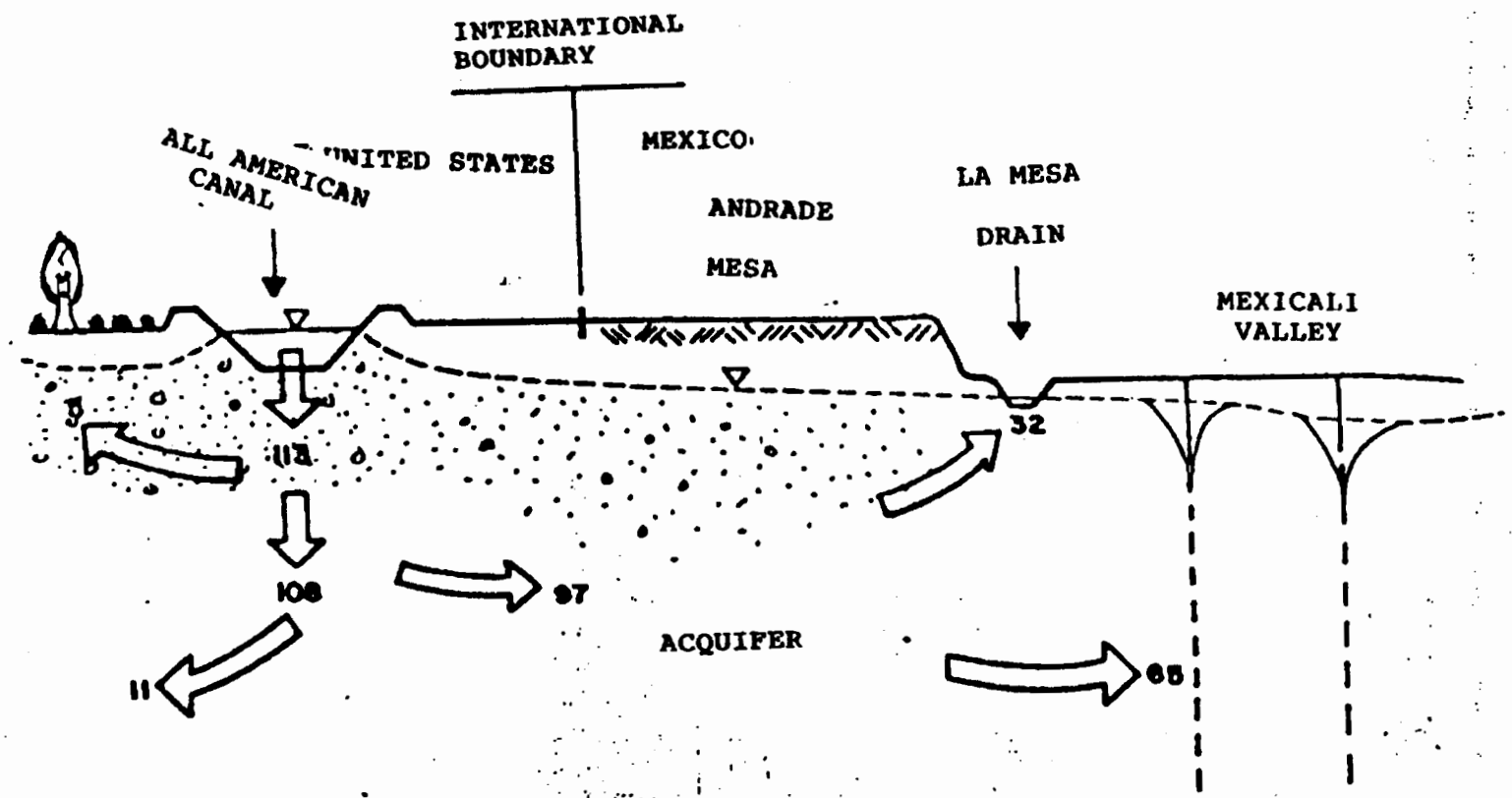


FIGURE NO. 9

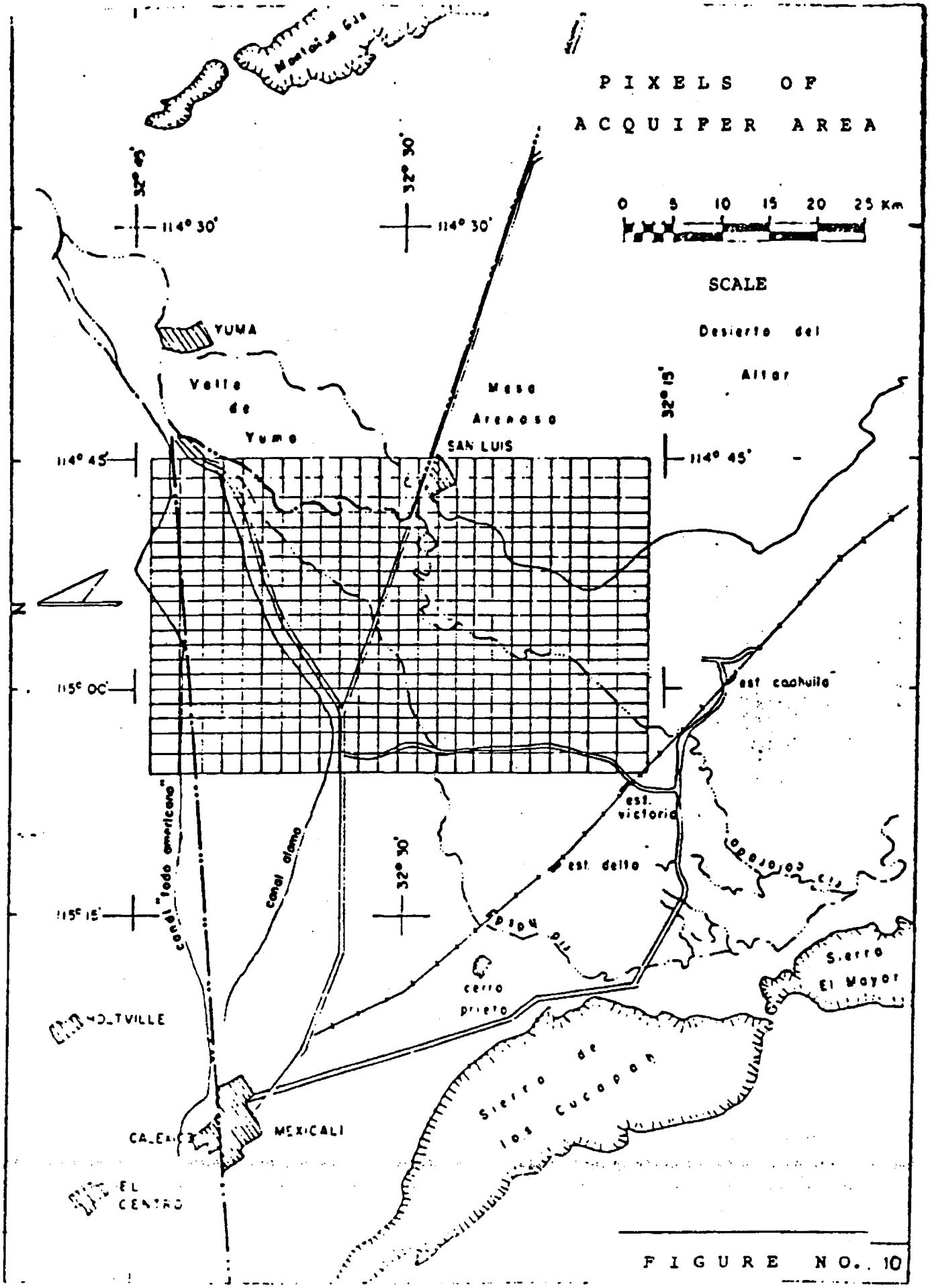

PIXELS OF
ACQUIFER AREA
0 5 10 15 20 25 Km
SCALE
Desierto del
Altar
YUMA
Valle
de
Yuma
Mesa
Arenosa
SAN LUIS
114° 30'
114° 45'
115° 00'
115° 15'
32° 45'
32° 30'
32° 15'
N
est. coahuila
est. victoria
est. delta
canal "todo americano"
canal alamo
cerro
prieto
Sierra
El Mayor
Sierra de
los Cucapah
MEXICALI
EL
CENTRO

FIGURE NO. 10

STATIC LEVELS BEHAVIOR

ALL AMERICAN CANAL LINING

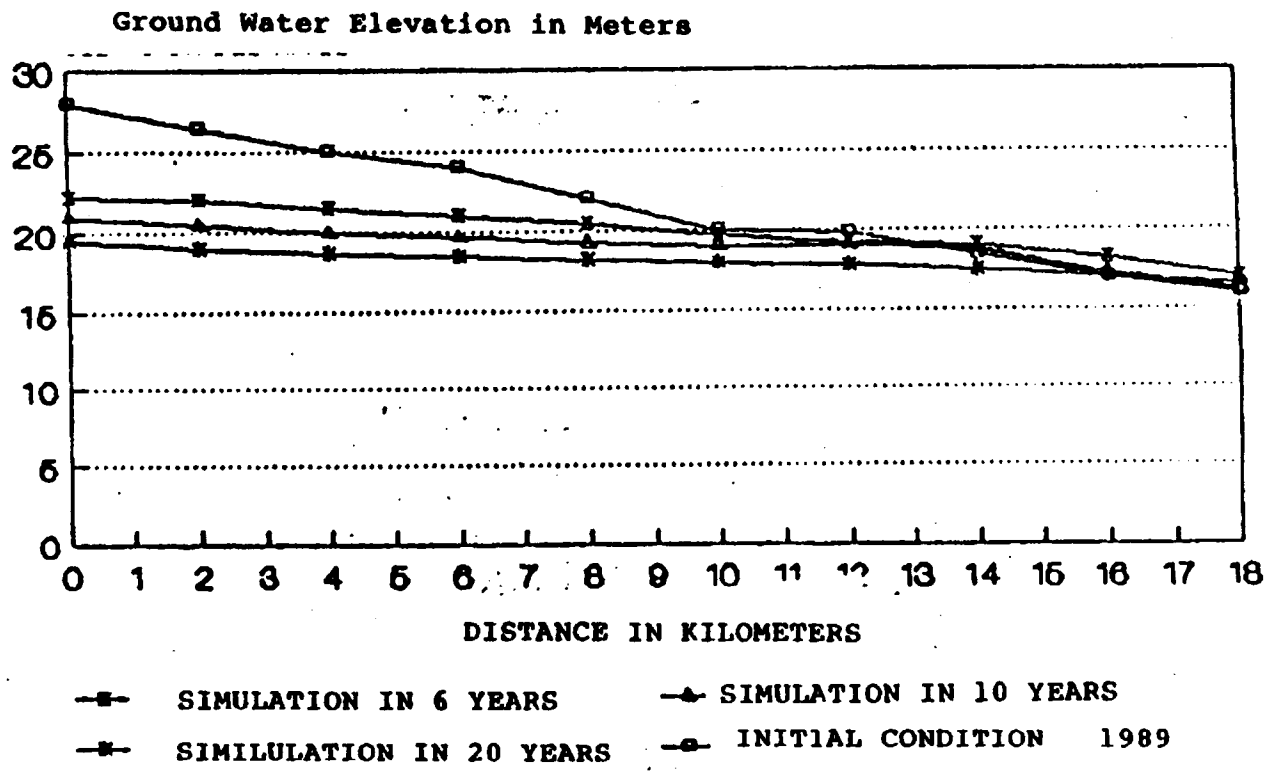
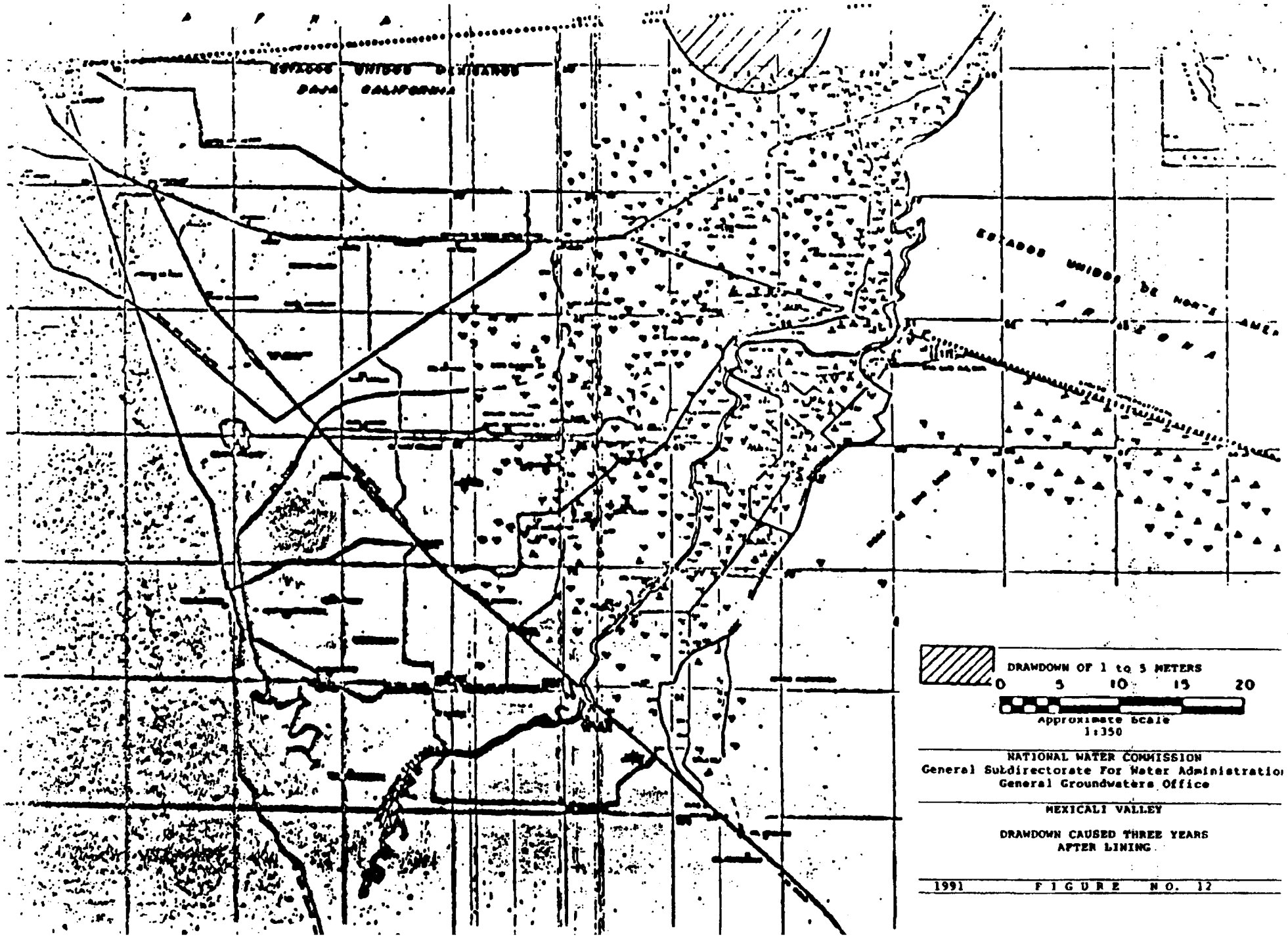


FIGURE NO. 11

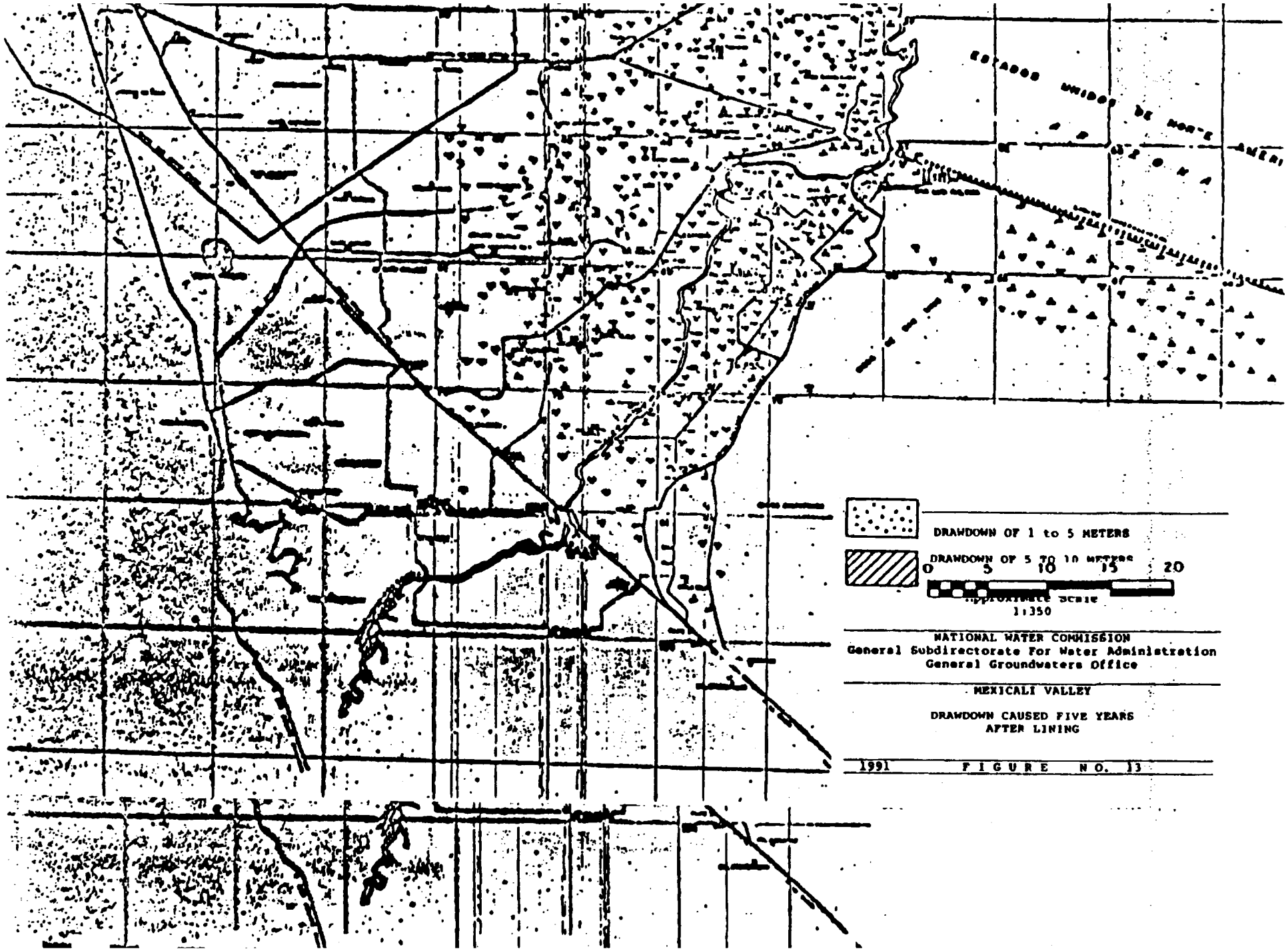


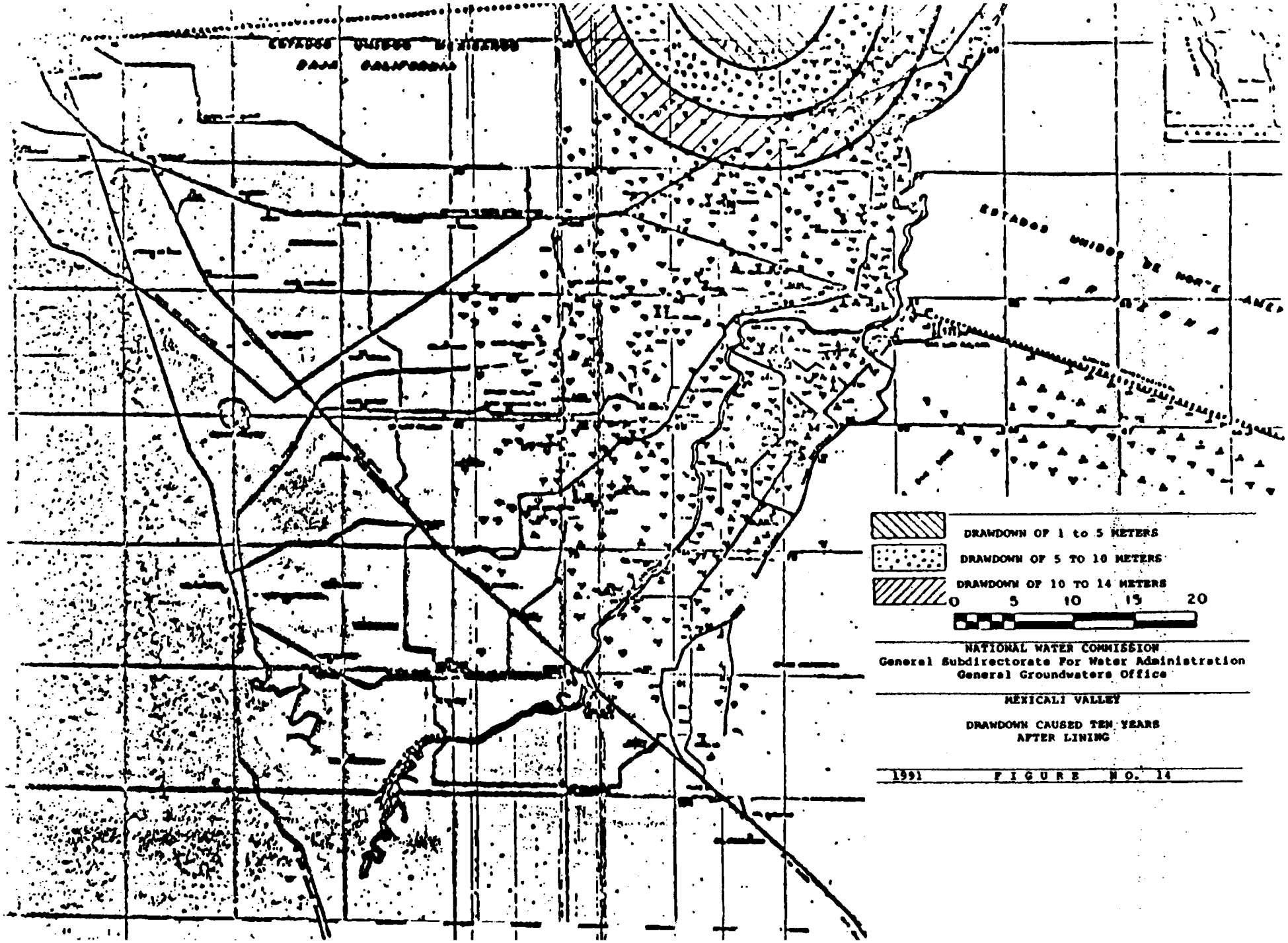
NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office

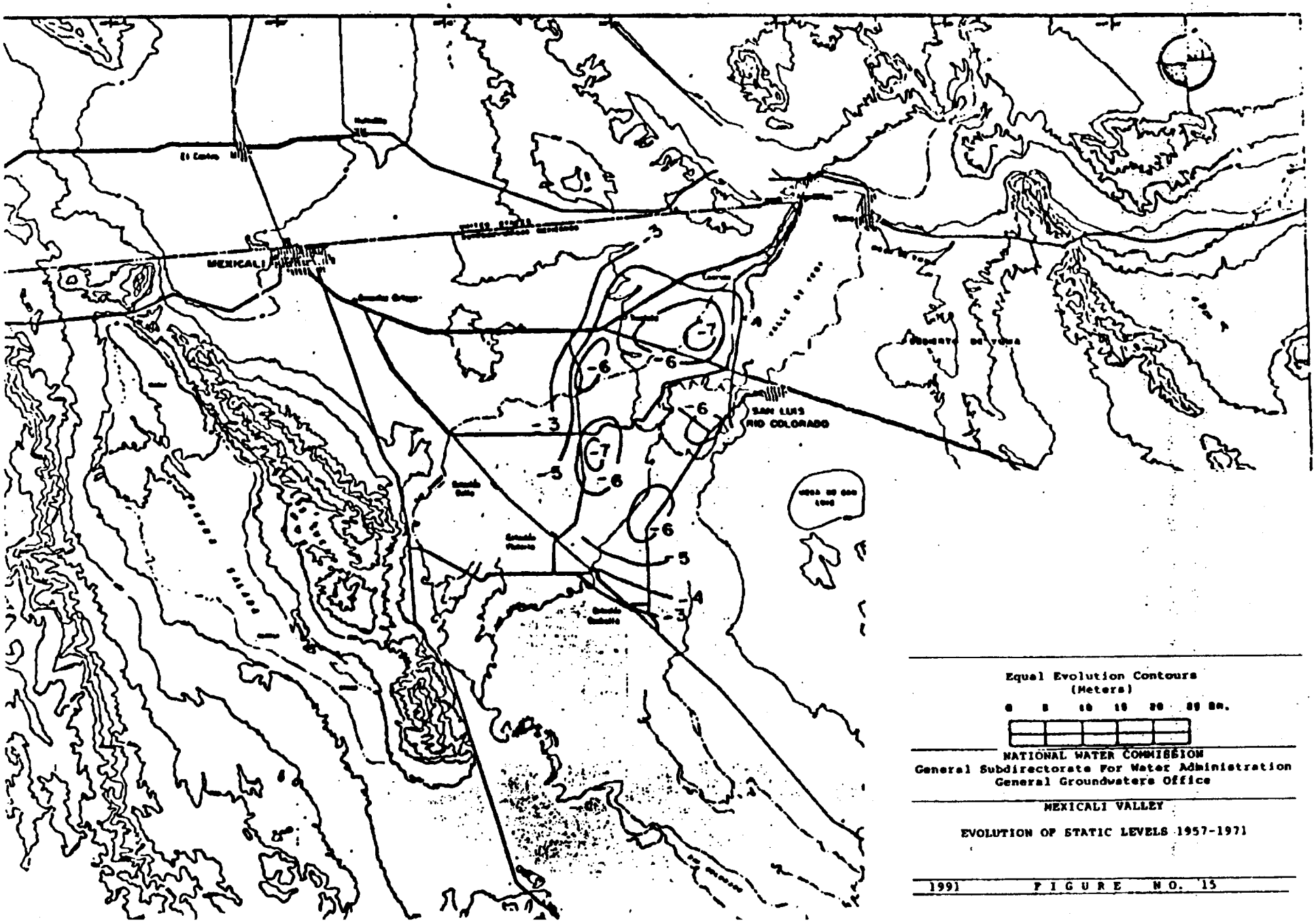
MEXICALI VALLEY

DRAWDOWN CAUSED THREE YEARS
AFTER LINING

1991 FIGURE NO. 12


DRAWDOWN OF 1 to 5 METERS
DRAWDOWN OF 5 TO 10 METERS
0 5 10 15 20
1:350
NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office
MEXICALI VALLEY
DRAWDOWN CAUSED FIVE YEARS
AFTER LINING
1991 FIGURE NO. 13


DRAWDOWN OF 1 to 5 METERS
DRAWDOWN OF 5 TO 10 METERS
DRAWDOWN OF 10 TO 14 METERS
0 5 10 15 20
NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office
MEXICALI VALLEY
DRAWDOWN CAUSED TEN YEARS
AFTER LINING
1991 FIGURE NO. 14



Equal Evolution Contours
(Meters)

0 5 10 15 20 25 Km.

NATIONAL WATER COMMISSION
General Subdirectorate For Water Administration
General Groundwaters Office

MEXICALI VALLEY

EVOLUTION OF STATIC LEVELS 1957-1971

1991 FIGURE NO. 15