INTERNATIONAL GROUNDWATER MANAGEMENT: THE CASE OF THE MEXICO-UNITED STATES FRONTIER

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Editor's Preface

by

Thomas G. Bahr, Director
Water Resources Research Institute

The subject of water resources in the southwestern United States never fails to spark discussion among the public. There is no question that water is the life blood of our economy and changes in water management and water-use patterns are certain to affect some group of water users.

An important function of water research is to examine different water management schemes with the goal of predicting the consequences of these actions. Water research in scientific disciplines such as chemistry, physics, biology, etc. can often result in identifying consequences that are fairly well defined. In other words, these fields of inquiry can develop relatively high levels of confidence associated with predictions. Furthermore, the conclusions that result from this kind of research can be subjected to rigorous scientific scrutiny by peers and either by substantiated or rejected on the basis of well-established scientific methodology.

Research in the so-called "soft sciences" such as sociology, political science, and law is somewhat different. Even though the strictest scientific methods may be followed, the results of this research are not often well defined. Here, the large number of interacting variables may quickly confound the confidence of predictions, and conclusions often become interpretations or opinions that cannot be easily evaluated when subjected to scientific scrutiny by peers. In other words, conclusions and recommendations often become the personal opinions of the investigator based on the author's interpretation of the available information. This type of research, however, usually leads to a further clarification of relevant issues and serves to prompt further inquiry into the subject. Results are often highly controversial since others with the same basis of information may draw entirely different conclusions.

This report entitled "International Groundwater Management: The Case of the Mexico-U.S. Frontier" is an example of the latter kind of research. It addresses the legal and institutional aspects of water management. The conclusions of this report are indeed highly controversial.

This report recommends designating "international groundwater areas" along the U.S.-Mexico boundary. That recommendation has prompted concern and disagreement on the part of many. Some argue, for example, that such an arrangement would deprive citizens of Texas of their legal right to groundwater under their land and furthermore that this arrangement would be illegal according to the Texas State Constitution.

Many of these arguments may have good justification, but space does not permit a detailed discussion of them at this time. In this regard, the reader is encouraged to consult various water officials to get contrasting viewpoints on this issue. It is also possible that someone might prepare a contrasting position paper on this same topic. Should this come about, the WRRI will attempt to furnish those who have received this report with the paper.

It is the policy of the WRRI to promote thoughtful discussion of water issues, and this report represents one viewpoint on this important issue. Publication as a WRRI report does not necessarily reflect approval by the WRRI or its reviewers of the conclusions and recommendations reached in this paper.

ACKNOWLEDGEMENTS

Clifford Atkinson served as research associate for this project. His contribution was invaluable. He had prime responsibility for examining the geology and hydrology of the region in question from the El Paso-Ciudad Juarez area to the Arizona State Line, and for doing it in a way which at the same time attempts to be comprehensive, yet non-technical so as to be understandable by the general reader. He also made the survey of groundwater laws in the three states along the U.S.-Mexican border which is an Appendix to this report.

We greatly appreciate the assistance given to us by a number of individuals including Mr. Clyde Wilson, Mr. Joseph Gates, and Mr. John McLean, all of the U.S. Geological Survey; Mr. Tom Cliett of the City of El Paso; Mr. Steve Reynolds, State Engineer of New Mexico; Professor Ludwik Teclaff of Fordham University Law School; Professor Robert Emmet Clark of the University of Arizona College of Law; and Mr. Robert Hayton of Stannage & Hayton, New York City. These persons, in various ways, provided helpful insights, although the judgments and conclusions and errors are strictly ours, and are presented in this rather pioneering effort in the hope that they will stimulate further thought and, perhaps, contribute to a more mature development of legal thinking and legal institutions in the future in view of the little that is written on the subject at the present. It is our hope that groundwater management at the international level will mature to a point that will cause us to look back at this paper as a rather primitive first step or so.

We also are very grateful for the support given to us by the New Mexico Water Resources Research Institute, the University of New Mexico School of Law, and Dean Frederick M. Hart in providing the wherewithal and facilities to do the research. Specifically, we acknowledge that the work upon which this publication was based was supported in part by funds provided through the New Mexico Water Resources Research Institute, by the U.S. Department of the Interior, Office of Water Research and Technology, as authorized under the Water Resources Research Act of 1964, Public Law 88-379, under Project Number 3109-210.

ABSTRACT

The objective of this project is to suggest possible institutional alternatives for the management of transboundary groundwater resources bisected by the U.S.-Mexico border. The report concludes that the heaviest groundwater users in the U.S. are those states which are contiguous to Mexico and yet, paradoxically, the law and institutions of those border states are woefully inadequate to control the exploitation of these groundwater resources. In addition, international competence over aquifers divided by the frontier is largely undefined; it is fair to say that the legal and institutional situation is chaotic. Coincident with this legal near vacuum, significant population increases are projected on both sides of the border which make it reasonable to anticipate that there will be increasing investment in groundwater facilities and accelerating demand placed on groundwater resources which are bisected by the international boundary between the two countries. The coming together of these two factors can be described as a collision course; with increased demand for a limited resource, combined with a striking absence of institutions for either resolving disputes or managing the resource, the potential for dispute between the two countries has to be something more than imaginary.

This legal near vacuum is not unique to the U.S.-Mexico frontier, in that there has been a failure to focus on the regulation and management of groundwater in most legal systems.

In this kind of situation, each quota users water right is insecure because other pumpers may take possession of the mobile resource at any time.

Accordingly, the individual surface owner is encouraged to exploit the groundwater resource as quickly as possible, so that the fluid and mobile water resource will not be captured by others. Thus, specifically along the U.S.-Mexican border, it cannot be said that water users have the security of their expectations, nor can it be said that whatever rights they hold to water and its use will be stable and dependable over time. Quite the contrary. We have: 1) projections for growing population on both sides of the border; 2) a situation in which north of the border (with the exception of New Mexico) no state has legal institutions which are adequate to control pumping; 3) no international control except at Yuma under the interim arrangement of paragraph 5 of Minute 242 which can prevent either nation from "stealing its neighbor's water." Therefore, we have a situation which encourages each nation to outdo its neighbor by developing its groundwater resources as rapidly as possible, perhaps even to the point of depletion of the groundwater resource.

In order to avoid these uncertainties, it is suggested that the International Boundary & Water Commission be given explicit jurisdiction over groundwaters intersected by the international boundary with responsibility to identify and declare "designated international groundwater areas" and authority to apportion the waters of these designated groundwater areas between the two nations and to determine the allowable withdrawals for these areas as determined by the physical criteria of the aquifer. This would establish an objective amount of water to which each nation was entitled. Once the division of the groundwater was made, the internal administrative machinery of each nation would be responsible for allocating that nation's share of the aquifer, according to its water law and administrative procedures. This

would have the advantage of providing security for investment in water resources on each side of the border. It would prevent the possibility of pumping wars, as each side would know with certainty how much water it was entitled to, and there would be no need to try to get there the firstest with the mostest. The resource would not be threatened through uncontrolled exploitation, and the potential for conflict between the two countries would be reduced.

Key words: Calculated mining plan, Correlative rights, Designated international groundwater area, Groundwater management, Prior appropriation, Prorationing, Safe yield, Stock resources, Transboundary resources

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INTRODUCTION

Only by first examining and understanding the realities of groundwater occurrence along the west Texas-New Mexico boundary with Mexico does it then become possible to evaluate accurately the efficacy of groundwater administration in the region. To administer a natural resource in a manner contrary to the nature of the resource is to defeat the purpose of administration: the optimal use of the resource, as measured by economic and social benefit, is not realized. The area of interest for this report is the transboundary region of the United States and Mexico extending from the El Paso, Texas/Ciudad Juarez, Chihuahua area westward to the Animas Valley, New Mexico-northeastern Sonora area, near the Arizona-New Mexico-Mexico juncture. Refer to Figure 1. This section of the paper, which deals with groundwater occurrence by examining the geology and hydrology of the region in question, subdivides the transboundary region into the Hueco Bolson-El Paso/Ciudad Juarez area, the Lower Mesilla Valley area in Dona Ana County, New Mexico, and the border regions of Luna County, New Mexico, and Hidalgo County, New Mexico.

THE HUECO BOLSON: EL PASO/CIUDAD JUAREZ

The Hueco Bolson contains two of three groundwater sources utilized by the cities of El Paso and Juarez: the Hueco Bolson deposits and the Rio Grande River alluvium. The third source, the Lower Mesilla Valley bolson deposits, lies within Dona Ana County, New Mexico, and

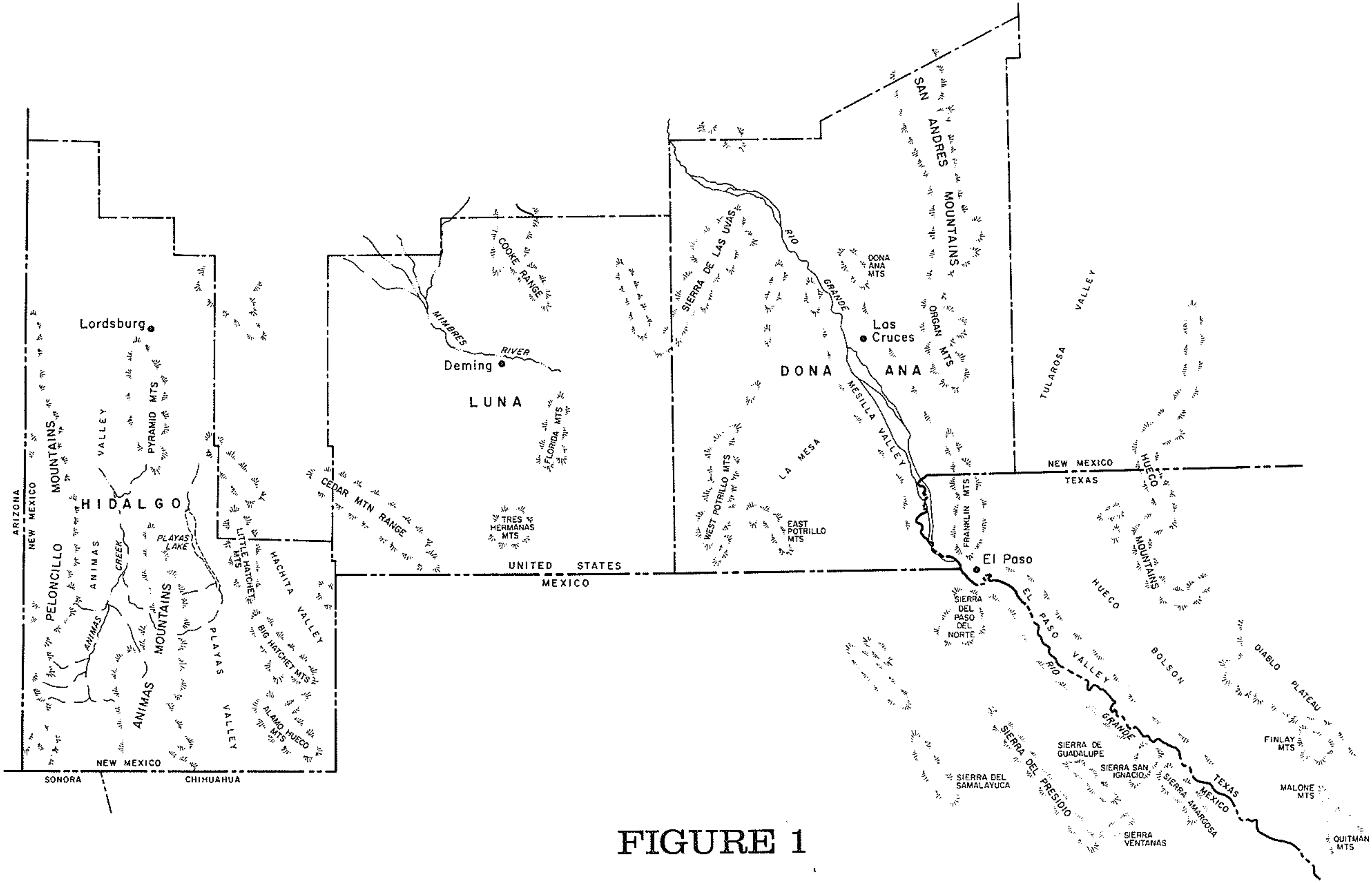


FIGURE 1

THE NEW MEXICO — MEXICO BORDER REGION

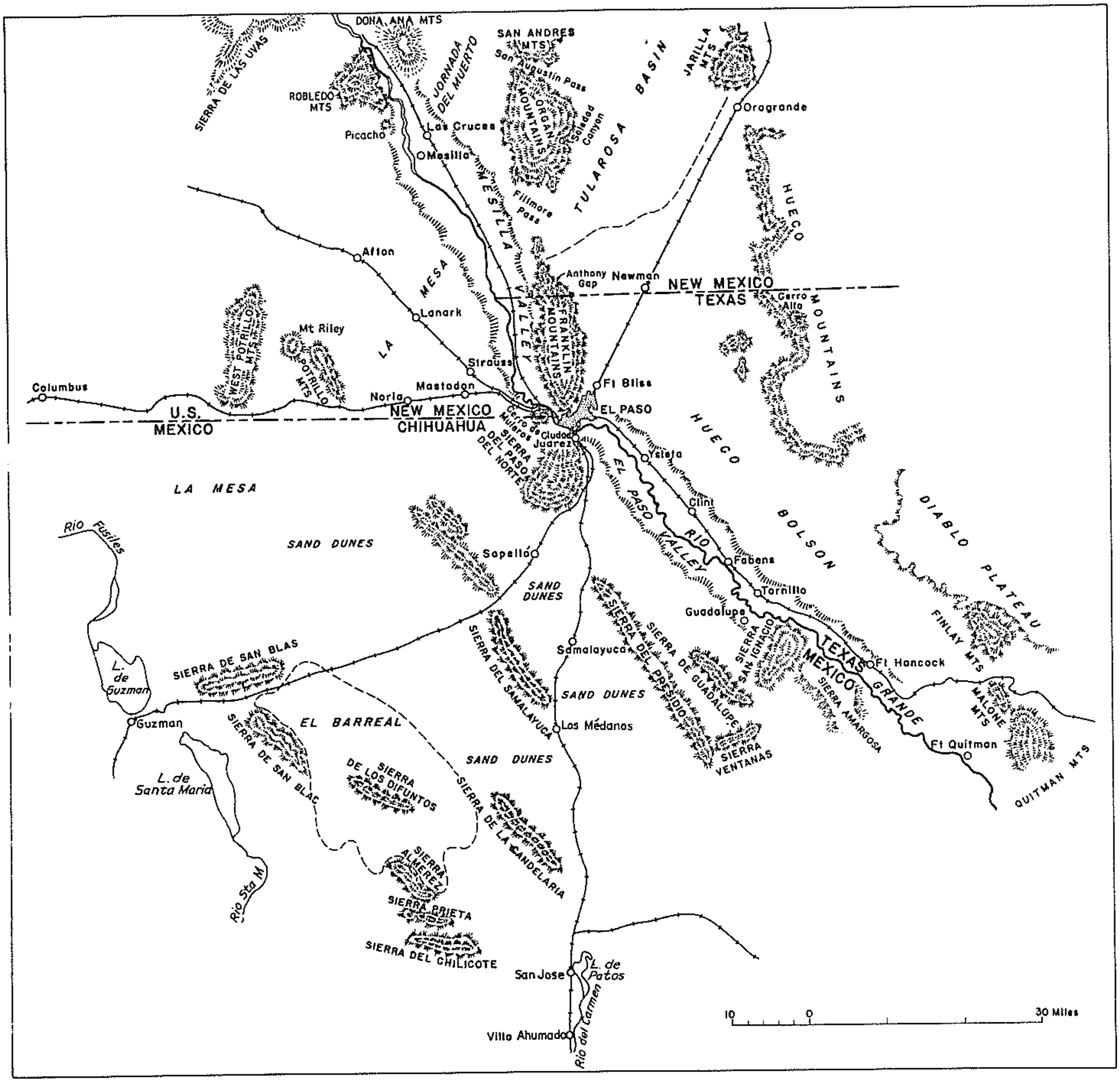
El Paso County, Texas. See below at Page 10 for an explanation of the Dona Ana County investigation.

Geology and Geography

The Hueco Bolson is of particular interest in this paper because it presently provides the El Paso/Juarez area with 65% of the area's total water supply, the remaining 35% coming from the Lower Mesilla Valley and from the surface and subsurface of the Rio Grande River.[1] Bolson[2] is the term applied by Hill[3] to the intermontane basins of the Trans-Pecos region of Texas and New Mexico, ordinarily used to describe a "closed basin with centripetal drainage."[4]

The Bolson's basin-like character is derived from the northwest-southeast trending trough-shaped lowland area lying between the San Andres-Organ-Franklin-Sierra del Paso del Norte and the Hueco-Finlay-Malone-Quitman chains of mountains. See Figure 2.[5] Its trough-like shape is the result of a structural offset, specifically of a graben feature, rather than of an erosional process.[6]

The geologic character of the mountains rimming the low-lying bolson varies considerably between ranges. Igneous, granite, and ryholitic granitic rocks[7] characterize the Organ and Franklin mountains, with small amounts of limestone, shale, and sandstone interspersed among the more common granite.[8] Sierra de Cristo Rey (referred to as Cerro de los Muleros in Figure 2), lying four miles west of the south end of the Franklins, has a core of igneous intrusives overlain by shales and limestones.[9] In combination with the southernmost tail of the Franklins, Cerro de los Muleros physically separates the water bearing bolson deposits of the Lower Mesilla Valley Mesilla



GENERAL MAP OF THE EL PASO AREA

FIGURE 2

Bolson and the Hueco Bolson.[10]

Following the Bolson rim to the southeast, swinging to the northeast, jogging to the east, and then coming back to the northwest, the Sierra del Paso del Norte, Sierra del Presidio, Sierra del Guadalupe, Sierra San Ignacio, Malone, Finlay, and Hueco mountain ranges all are composed principally of limestones of varying geologic ages.[11]

Turning to the geology of the bolson and alluvial deposits, it is apparent that some time after the structural offset created the trough-like bolson, detrital material[12] from the surrounding mountains began filling the trough. The result of this deposition is a largely featureless, superficially homogenous plane, extending roughly twenty miles transversely from the Franklin Mountains to the Hueco Mountains, and approximately eighty miles longitudinally.[13] Along the Franklin-Hueco cross-section the depth of detrital material to bedrock varies from a minimum of less than 100 feet near the Franklins, to a maximum of over 9.000 feet at a point four miles eastward toward the Huecos, to almost 500 feet approximately seventeen miles east of the Franklins.[14] See Figure 3.[15] The bedrock underlying the bolson deposits from the Franklins to the point of maximum thickness is granite; east of that point the bedrock is limestone.[16] The depth of the deposits at a point 8 miles southeast of El Paso-Juarez is estimated to be between 1,000 and 3,000 feet.[17]

Bolson fill is comprised entirely of unconsolidated sediments,[18] consisting of interbedded layers of clay, sand, and gravel. A predominate feature of the Bolson fill is the lack of continuity of similar layers between points within the Bolson,[19] which makes correlation of fresh water bearing strata difficult.[20]

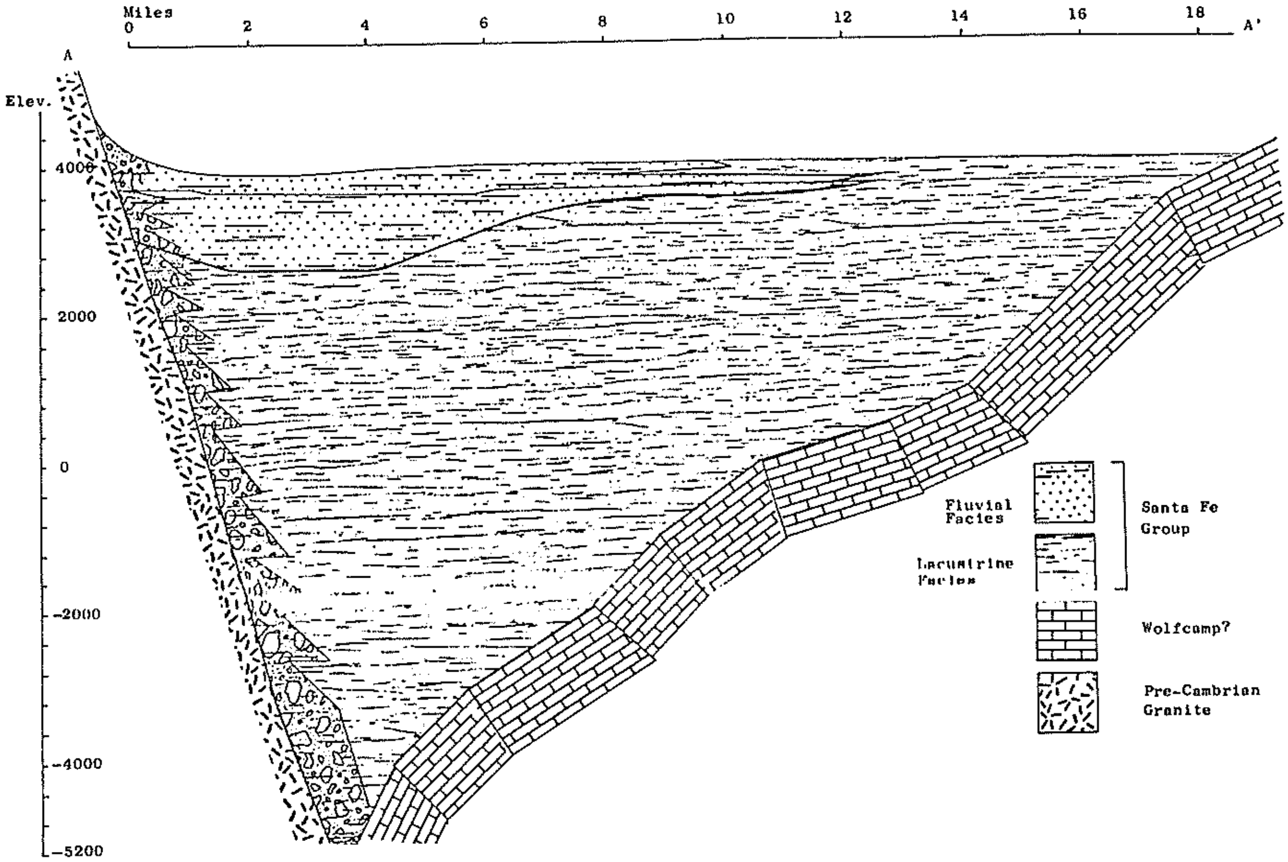


FIGURE 3

Geology of the Hueco bolson.

At one point in time the Rio Grande "established its course through the bedrock barriers [east of the Bolson] and began the downcutting of the Hueco ... bolson surfaces to form the Rio Grande Valley."[21] Deposition of water borne sediments from upstream in the downcut Bolson area resulted in the formation of extensive alluvial deposits, comprised of sand, gravel, and clay, which parallel the path of the Rio Grande. These deposits form a fertile agricultural area and a satisfactory aquifer for residential and industrial water uses. Near El Paso the alluvial deposits are about six to eight miles in width and over 200 feet in depth.[22]

An examination of the geography of Hueco Bolson shows that the surface rises to the east and to the north, so that the cities of El Paso and Juarez and the Rio Grande Valley area are at a lower elevation than the portion of the Hueco Bolson lying 20 miles to the north. Because of its height relative to the cities, the portion of the Bolson lying north of El Paso is known as the Mesa area; the portion lying within the metropolitan areas and beneath the Rio Grande Valley alluvium is known as the City Artesian area.

Hydrology

An aquifer, as distinguished fron an aquiclude or aquifuge, is both permeable and porous, so that it can both contain water and transmit it under hydraulic gradient. Homogeneously coarse grained unconsolidated sediments usually are ideal aquifers because of the great volume of interstitial pore spaces between individual particles which are interconnected to allow the free transmission of water.[23] Where a good aquifer is limited vertically by an underlying relatively impermeable rock, such as granite, shale, or nonporous limestone, it becomes an even better water source because the lower limit of the aquifer allows it to become saturated, providing that there is a nearby source of water.

The bolson and alluvial deposits of El Paso-Juarez fit the above description, in that they are comprised of unconsolidated sediments and are bounded vertically. The bolson deposits are bounded by impermeable bedrock; the alluvial deposits are bounded in some areas by relatively impermeable clays.

A. Pre-Development Reserves

Before the advent of extensive pumping in the El Paso/Juarez area, natural recharge in the Hueco Bolson aquifer equalled natural discharge.[24] Recharge was (and is) available to the Hueco Bolson by infiltration of runoff from the surrounding mountains, primarily from the eastern slopes of the Organ and Franklin ranges.[25] Although, as a result of the lowered water table induced by pumping, the Rio Grande is now the primary source of bolson recharge. The recharge rate of the Bolson was originally estimated to be 13 mgd (million gallons per day)[26] but the rate was recalculated recently to be in the vicinity of 5 mgd.[27] The recharge-discharge phenomenon can be explained as follows:

> Water ... falls on an area or crosses it in surface streams or canal flows from the area as surface runoff. ... Part of the water may percolate downward under the pull of gravity to the water table.... The water that reaches the water table is called groundwater recharge. ...
>
> The amount of water that may be pumped from a groundwater reservoir is limited by the amount of water that is in storage and the amount of recharge to the reservoir.
>
> If groundwater is taken largely from storage the supply will be depleted, and water levels in the reservoir will

> decline until it will be no longer economically feasible to lift the water to the surface, or until the formation in the vicinity of the wells has been pumped dry.[28]

While the Bolson aquifers contain large amounts of water, most of it was saline[29] even before man began to pump out fresh water.[30] The saline character of the water is due to the high amount of dissolved solids resulting from runoff of waters from the surrounding carbonaceous mountains, accompanied by thousands of years of evapotranspiration under closed-basin conditions.

The total fresh water supply in storage in the Bolson in 1903, before the aquifers were developed, was probably between 15 and 17 million acre-feet.[31] (Mr. Joseph Gates states, however, that approximately 22 million acre feet is a more accurate estimate.) The largest body of fresh water in the Mesa area occurs just east of the Franklins, and is underlain and bordered by saline water. See Figure 4.[32] This body, which is estimated to be greater than 1,000 feet thick, see Figure 5,[33] has maintained its integrity due in part to the low hydraulic gradient in the area. In the Artesian area, the Bolson fresh water supplies are adjoined and underlain by Bolson saline waters and overlain by slightly saline Rio Grande Valley alluvium waters.[35]

Higher surface elevations in the Mesa area and a generally southeastwardly sloping water table resulted, before development, in a uniformly south-southeasterly flow of groundwater from the Mesa area to the Rio Grande Valley area.[36] Once in the Valley, the fresh water from the Bolson aquifer seeped upward into the saline Rio Grande Valley alluvium and thus contributed to the flow of the Rio Grande. This upward seepage

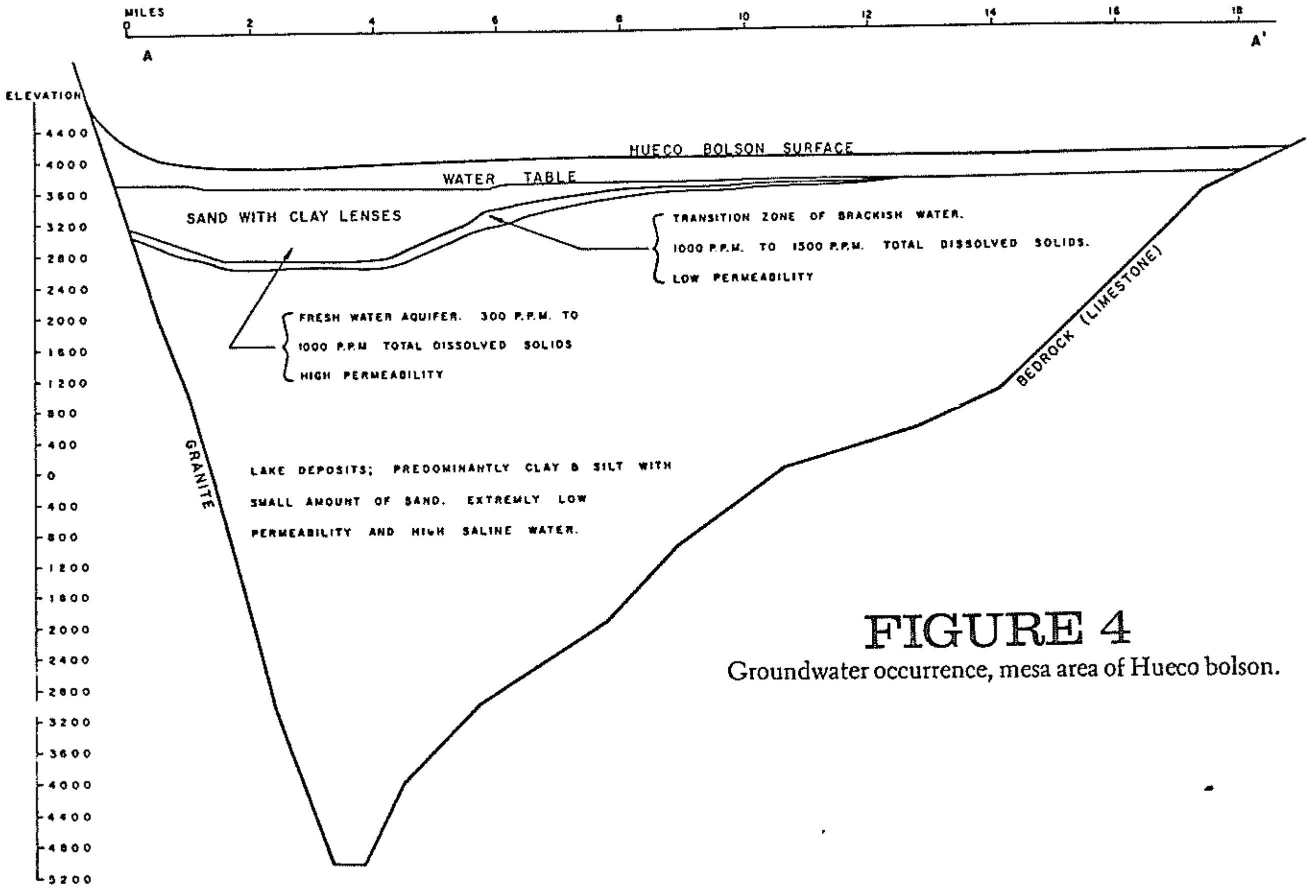
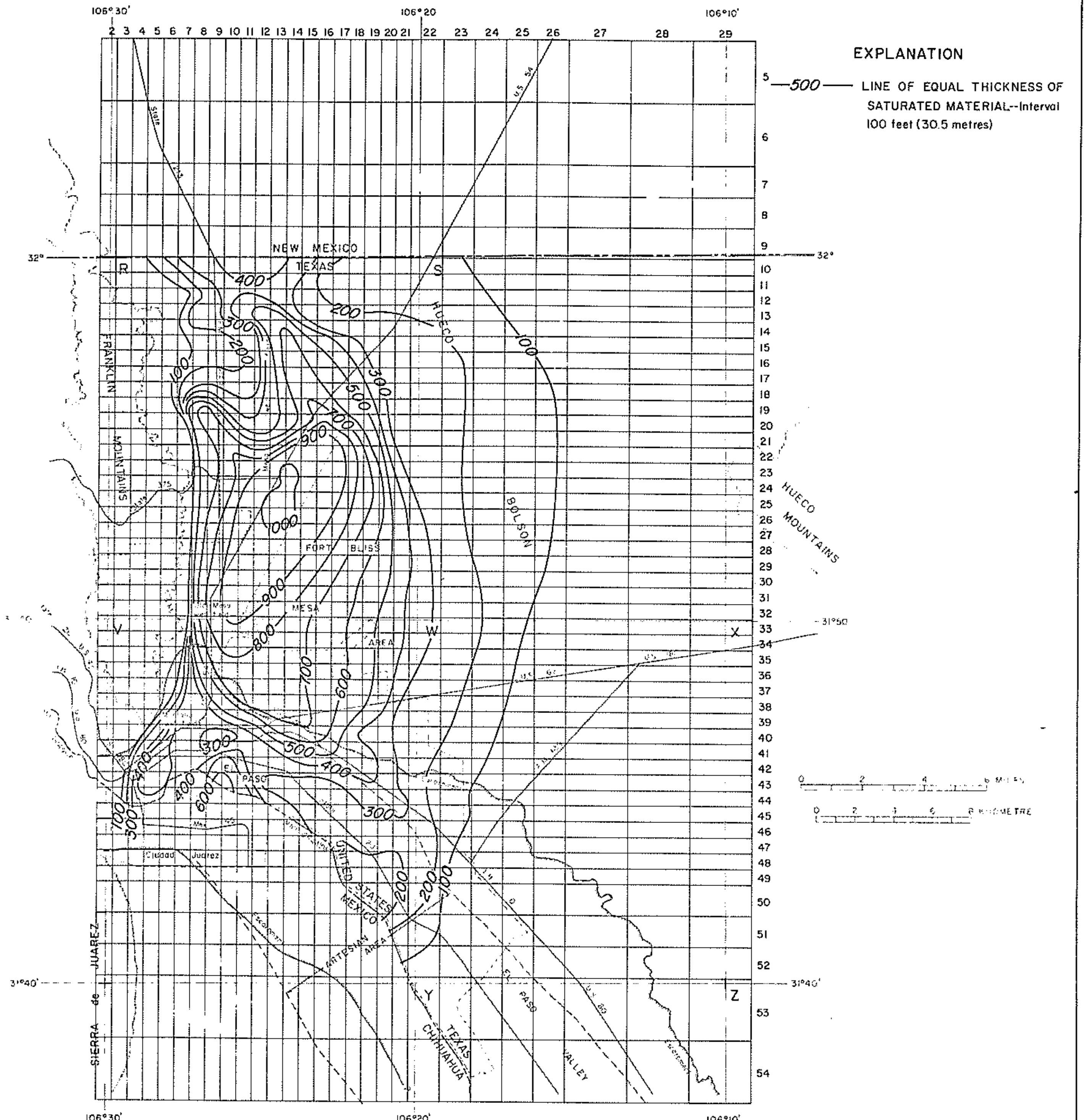


FIGURE 4

Groundwater occurrence, mesa area of Hueco bolson.



Base from U.S. Geological Survey topographic quadrangles and general highway map of Texas

Hydrology modified from E. R. Leggat and M. E. Davis (1966)

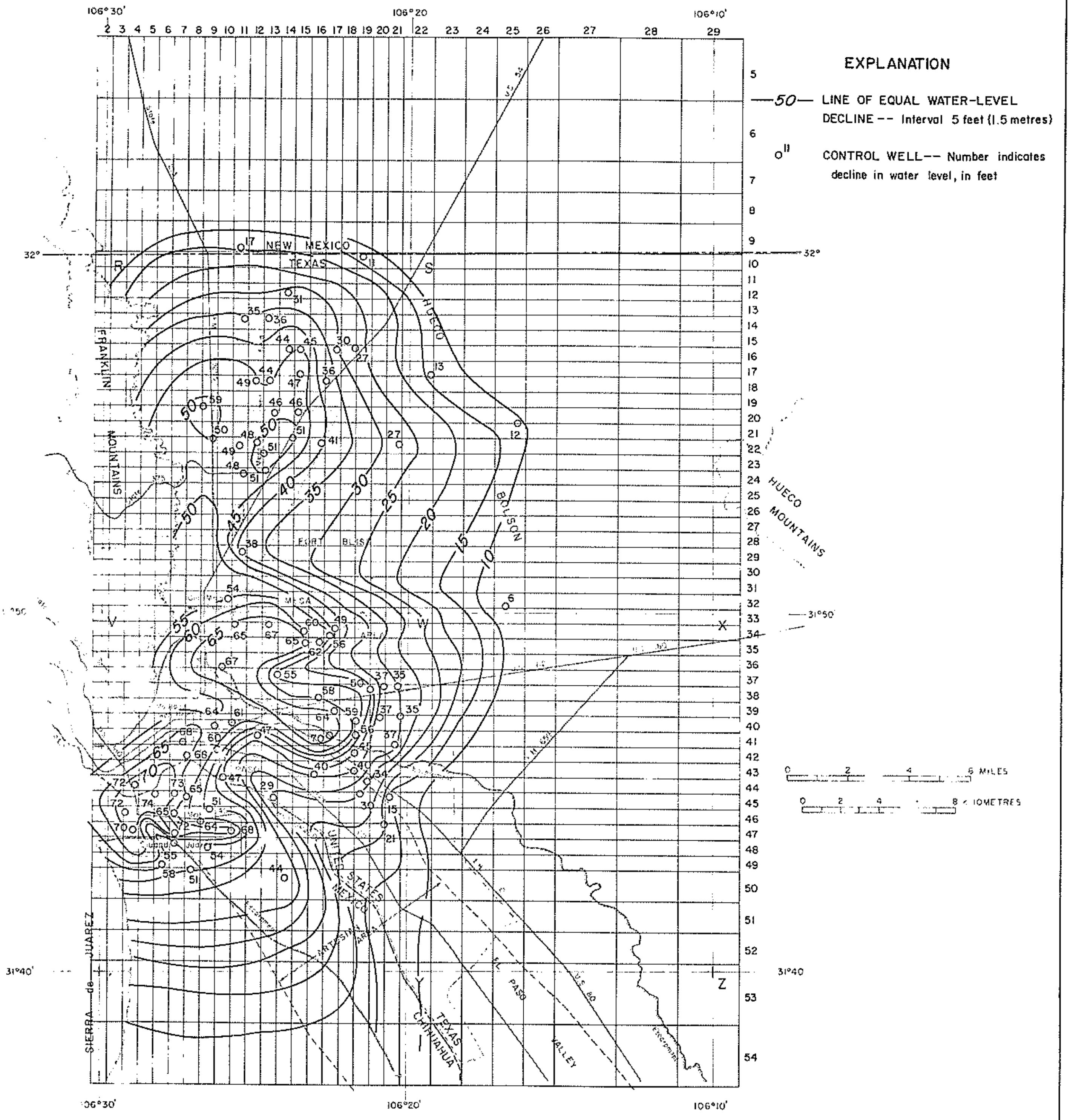
FIGURE 5

Approximate thickness of deposits saturated with fresh water, 1973 occurred because the Rio Grande is the natural discharge area for the Bolson groundwater system.[37] Water moving southward from the higher Mesa area moves upward to the land surface, locally passing through clay lenses.[38] The loss in head as the water moves vertically to the valley means that pressure is greater with depth, and water is under semi-artesian or pseudo-artesian conditions. In either case, prior to development the fresh water Bolson supplies moved upwards and there was no downward leakage of saline alluvial waters into the fresh Bolson waters.

B. The Development of the Area

Deep pumping from the Hueco Bolson began in 1904 and has increased steadily since that time. Pumpage rates from the Bolson alone have increased from 1.2 mgd in 1906[39] to approximately 80 mgd in 1969[40]. Extensive pumping has resulted in broad cones of depletion concentric to the points of withdrawal.[41] Reference to Figure 6,[42] which presents measured drawdown for the Hueco Bolson-El Paso/Juarez area, indicates that in the 70 year period from 1903-1973 there was a maximum drawdown of the water table of 67 feet in the Old Mesa well field. In the downtown areas of El Paso and Ciudad Juarez the maximum drawdown was 74 feet.

Depletion of the water table has manifested itself in ways other than mere drawdown. The direction of flow along the Bolson, from the northwest to the southeast, has reversed near points of withdrawal so that groundwater is now flowing toward the low pressure withdrawal area.[44] Also, there have been some instances of salt water encroachment into fresh water supplies. This is most marked between the fresh water Bolson supplies and the saline alluvial supplies along the Rio Grande. There, the



Base from U.S. Geological Survey topographic quadrangles and general highway map of Texas

FIGURE 6

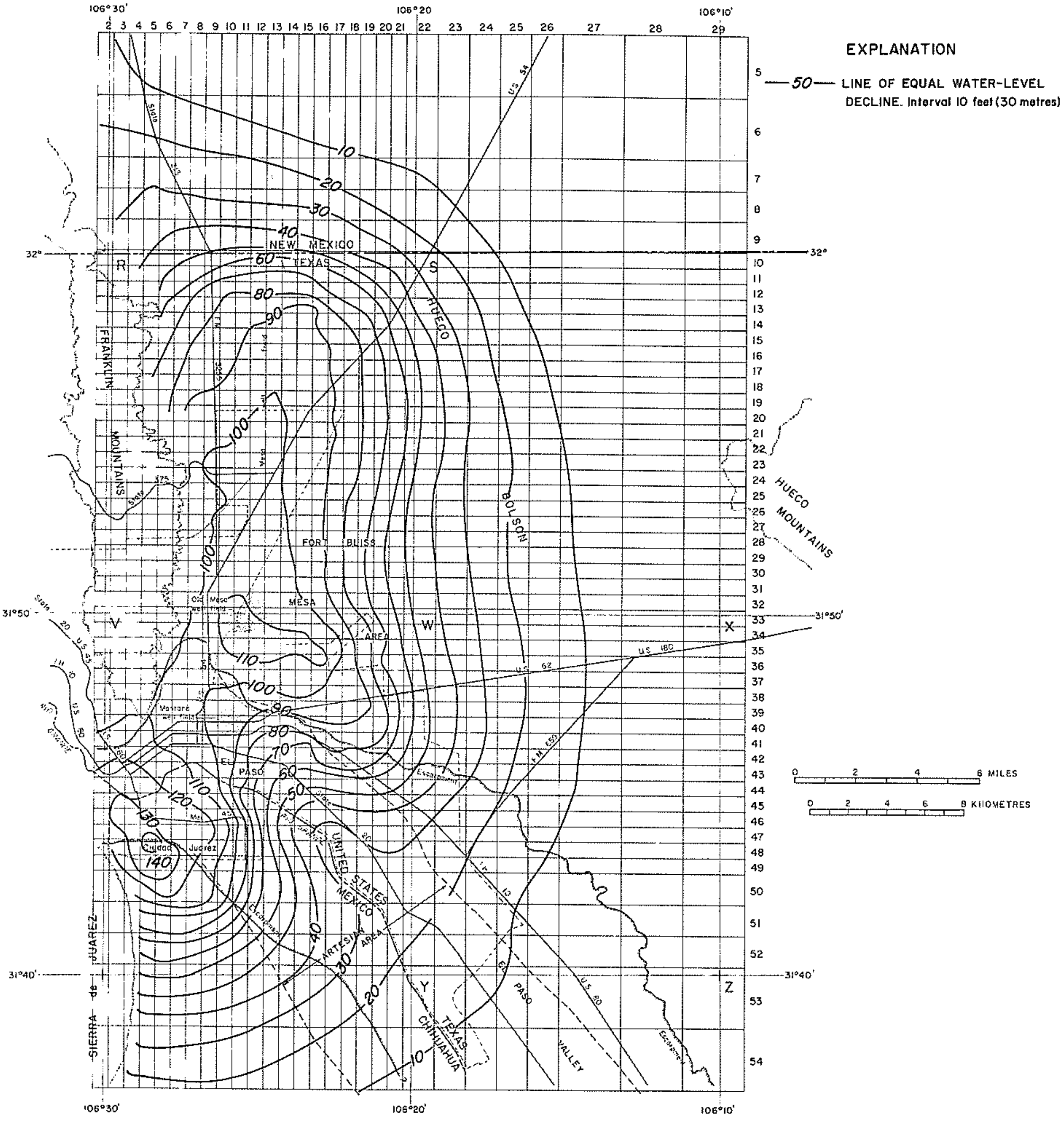
Approximate decline in water levels, 1903-73 predominately saline waters now are moving downward into fresh water supplies because the piezometric surface in the artesian deposits has fallen below that in the alluvium. The most detrimental effect of contamination is the resulting loss of fresh water supplies due to increased dissolved solids contents in the water.[46]

A digital model of the projected drawdown for the Hueco Bolson-El Paso/Juarez area compiled primarily from U.S. data indicates that by 1991 drawdown will be more extensive and more severe.[47] See Figure 7.[48] Drawdown in the central Mesa area of the Bolson is expected to be in excess of 100 feet and drawdown in the Juarez metropolitan area is projected at 140 feet. (According to Mr. Joseph Gates, U.S. Geological Survey, pumpage in Juarez has been greater than was estimated, so that in fact drawdown probably will exceed 140 feet.)

SUMMARY

The Hueco Bolson is a broad structural depression, trending northwest-southeast, the extent of which is roughly delineated by mountain ranges. The depth of the Bolson varies, the deepest portion of 9,000 feet occurs four miles east of the Franklin Mountains and approximately 10 miles north of downtown El Paso. Depth to bedrock decreases to the south; it is between 5,000 and 9,000 feet in the downtown area. Detritus from the surrounding mountains has filled the bolson trough to form the cities' major water source. The planar surface of the Bolson descends slightly to the south and to the west.

Erosional action by the Rio Grande has created a depression in the Bolson surface which varies to 6 miles in width and to 250 feet in



Base from U.S. Geological Survey topographic quadrangles and general highway map of Texas

FIGURE 7

Predicted decline in water levels for 1903-91 as computed by the digital model depth near downtown El Paso. Coincident deposition of water borne sediments in the depression has formed an area of alluvial fill which overlies the City Artesian area of the Bolson. This alluvial fill, known as the Rio Grande Valley alluvium, is a second source of groundwater to El Paso/Juarez, although it is not used at present except for irrigation.

Development and depletion of the Hueco Bolson, in both the Mesa and City Artesian areas, both in the United States and Mexico, has far outpaced the meager natural recharge of the area. In the seventy year period from 1903-1973, more than 2 million acre-feet of the estimated 1903 total supply was pumped, much at rates a fraction of current rates (estimated at 100,000 acre-feet per year).

Drawdown of the water table near areas of withdrawal already has reversed the groundwater flow in many areas, has caused at least some salt water contamination, and has partially depleted the flow of the Rio Grande by pulling the water table below the level of the river bed. It is reasonable to expect future depletion to have even greater impacts.

There is evidence that in places fresh water bolson deposits are in excess of 1,000 feet thick, but there is no question that the fresh water supplies are being depleted. Projected supplies are somewhat tenuous due to the certainty of ever increasing pumpage rates and to the ever increasing possibility of salt water encroachment which would act to reduce fresh water reserves.

The El Paso/Juarez area unquestionably has a long-term water shortage problem. One possible way to delay the inevitable crunch which will result from continued growth and water usage would be to mix slightly saline supplies with fresh water to yield greater quantities of marginally fresh water supplies.[50] Another "solution" might be for El Paso to tap the water of the Mesilla Bolson, examined below, more extensively than it has in the past. (At present, Texas already is withdrawing some 15,000 acre-feet per year from the Texas part of the Mesilla Bolson.)

SOUTHERN DONA ANA COUNTY, NEW MEXICO

As appears in Figure 8,[51] the Rio Grande separates Dona Ana County into northeastern and southwestern triangles. The Jornado del Muerto structural basin monopolizes the northeastern triangle, with the San Andres-Organ chain as the base of this triangle and the Caballo-San Diego-Dona-Robledo-Tortuga chain as the hypotenuse. The Mesilla Bolson, which largely comprises the southwestern triangle, is adjacent to and south of the Rio Grande and the Mesilla Valley and is bounded by the Sierra de las Uvas-Aden Hills-northern West Potrillo-East Potrillo chain of mountains.

The water of the two basins and of the Mesilla Valley is vital to southeastern New Mexico, southwestern Texas, and northeastern Chihuahua, Mexico; to New Mexico because it is the source of water for irrigation and municipal and industrial use; to Texas because 1) depletion of groundwater supplies resulting from increased irrigation in New Mexico could draw down the Rio Grande flow, diminishing the already minimal recharge of the Bolson deposits in the El Paso area, and 2) it offers a partial solution to El Paso's water shortage as an imported supply; to Mexico, because increased usage of the water by either New Mexico or Texas or exportation from New Mexico to Texas may decrease the amount of water arriving in Mexico from the southward moving underground and surface flow.

Because of the recognized importance of the Mesilla Bolson and the

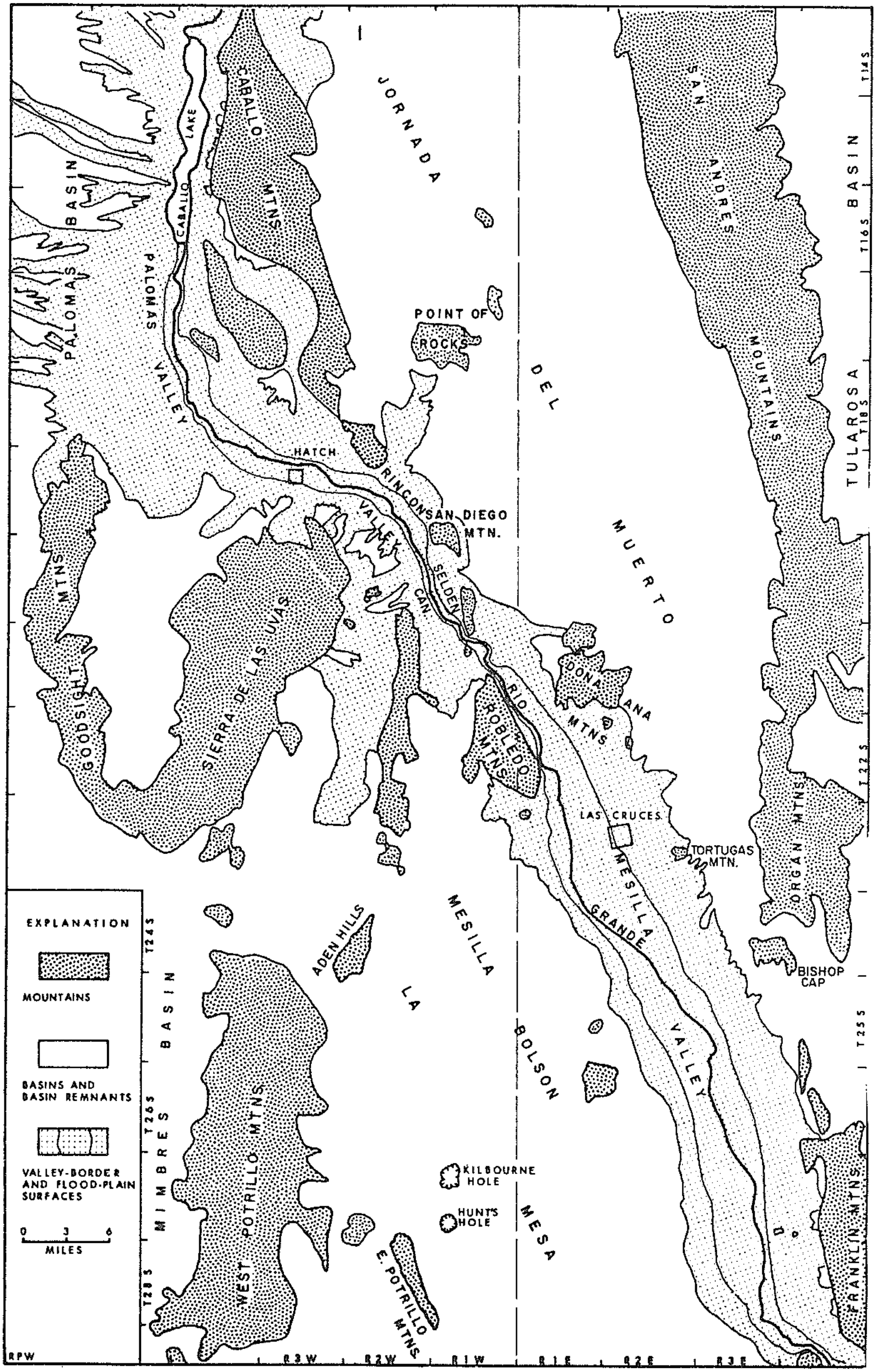


FIGURE 8

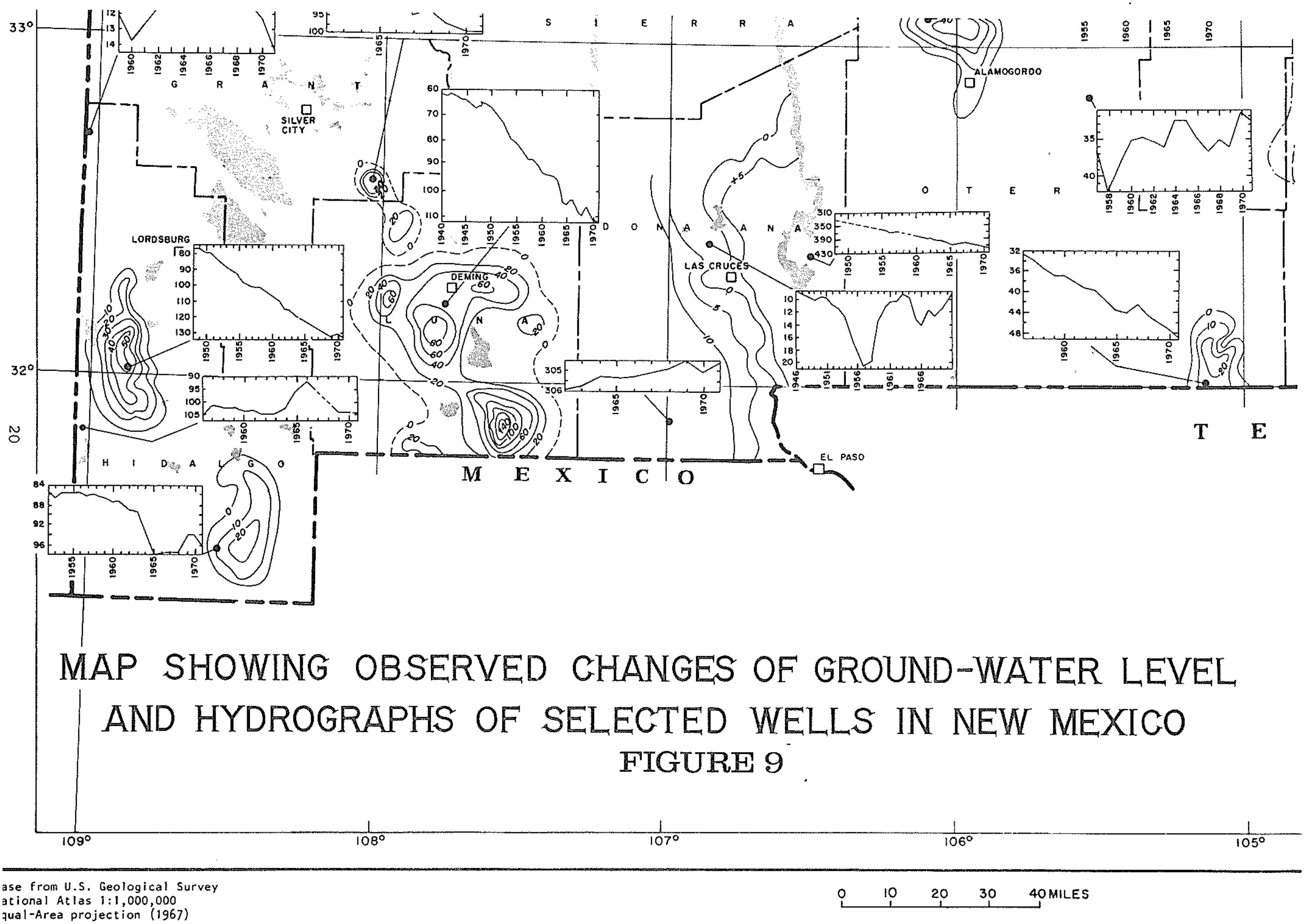
Physiographic Map of the Report Area

Lower Mesilla Valley, numerous studies have been made of the hydrologic conditions in and around southern Dona Ana County.[52] Most of the studies contain information which would be germane to this presentation, were it not for the fact that they are soon to be superceded by a report by Mr. Clyde A. Wilson of the U.S. Geological Survey.[53] Wilson's report, which is to be released as an open file report in 1978, will include an updated analysis of that portion of the Mesilla Bolson and the Lower Mesilla Valley which borders on Texas and Mexico. In light of Wilson's pending report, no study or analysis will be made here, except to note that Figure 9,[54] which displays drawdown for southernmost New Mexico, shows no marked drawdown in Dona Ana County, neither in the Bolson area nor westward near the Potrillo Mountains.

With regard to the area of southern Dona Ana County west of the Mesilla Bolson, almost no hydrologic or geologic analyses, Figure 9 not withstanding, have been documented. For that reason, no presentation will be made here, beyond a recital of a portion of a report made by King:

> [Refer to Figure 8,] At the south end of Mason Draw [just south of Sierra de las Uvas], a groundwater mound is caused by recharge from the drainage basin of the draw. A component of movement from the south end of Mason Draw is directed toward the southeast through the gap between the Alden Hills and West Potrillo Mountains. The remainder of the groundwater moves southwestward into the Mimbres Basin.
>
> West of the East Potrillo Mountains, ... groundwater movement is into Chihuahua. 55

The Mexican border of Dona Ana County deserves more hydrologic attention than it has received in the past, because it is a relatively rich groundwater area, with large amounts of groundwater in storage, the potential of which has yet to be fully tapped. While most of the land surface on either side of the border is not presently agriculturally oriented,



MAP SHOWING OBSERVED CHANGES OF GROUND-WATER LEVEL AND HYDROGRAPHS OF SELECTED WELLS IN NEW MEXICO

FIGURE 9

ase from U.S. Geological Survey
ational Atlas 1:1,000,000
qual-Area projection (1967)

modern irrigation techniques would allow rapid development.

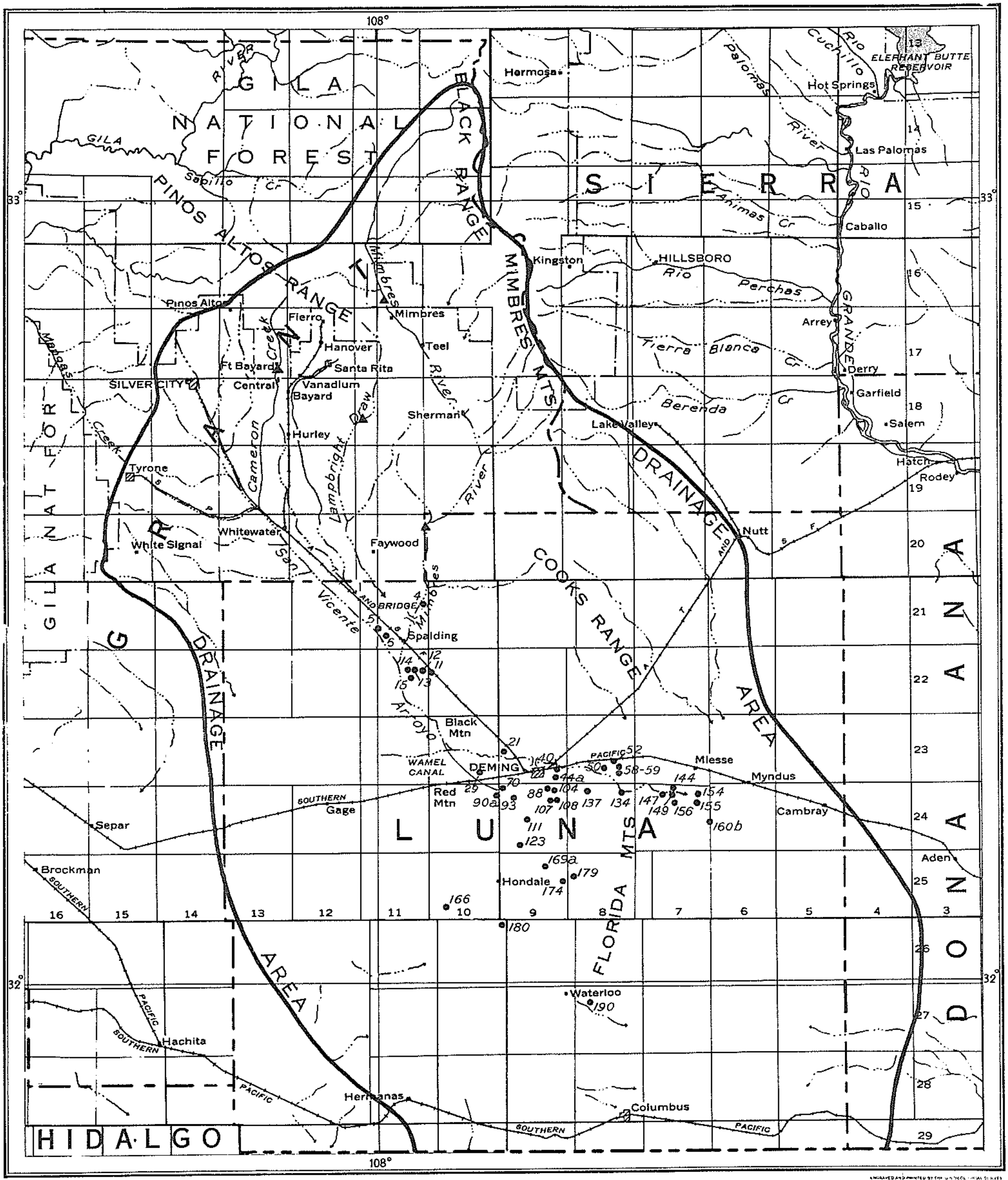
SOUTHERN LUNA COUNTY, NEW MEXICO

Luna County, the second of the three New Mexico counties which border on Mexico, lies west of Dona Ana County. Refer to Figure 1. Agriculture and stock raising are the county's principal industries. Relatively insignificant annual rainfall, approximately 10 inches per year, coupled with greater than 95% evaporation rates,[56] however, put essentially all water use pressure on the perrenial surface flows of the Mimbres River and its tributaries and on groundwater supplies in storage.[57] Luna County lies almost entirely within that portion of the Mimbres Valley drainage area which is north of the international border, so that generalizations true for the Mimbres Valley hold equally true for Luna County. See Figure 10.[58]

Geology and Geography

The surface of Luna County is in large part a broad, flat lowland plain, interrupted in places by ranges of mountains and isolated projections of deeply buried rock masses.[59] Physically dividing the county into hydrologic regimes, the north-south trending Cook Range-Little Florida-Florida-Tres Hermanas chain of mountains is the most evident departure from the otherwise flat surface. See Figure 11.[60]

Gravel, sand, silt, and clay, occurring in interconnected, irregular lenses in places, comprise the valley fill which has created the intermontane lowland plain.[61] These deposits, like those in the El Paso area, are characterized as "bolson" deposits, even though here they do not occur within a basin with centripetal drainage. The sedimentary material



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

MAP OF MIMBRES VALLEY, NEW MEXICO,
AND TRIBUTARY DRAINAGE AREA

▲ Gaging station

Scale $\frac{1}{500,000}$

10 0 10 20 Miles

1930

107 ● Observation well. Number referred to in text

FIGURE 10

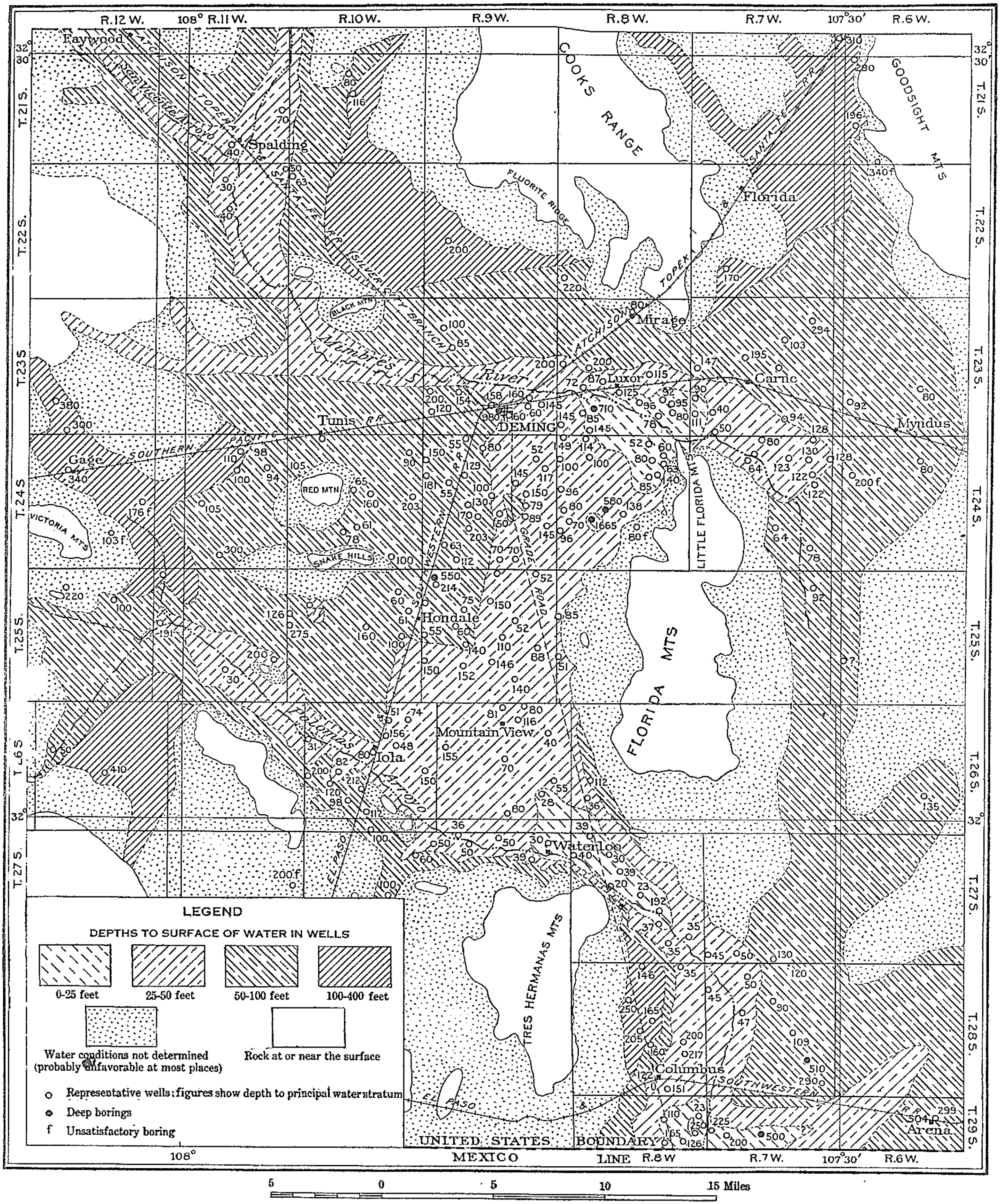

R.12 W.
108° R.11 W.
R.10 W.
R.9 W.
R.8 W.
R.7 W.
107°30′
R.6 W.
T.21 S.
T.22 S.
T.23 S.
T.24 S.
T.25 S.
T.26 S.
T.27 S.
T.28 S.
T.29 S.
32° 30′
32°
Faywood
San Vicente Arroyo
Spalding
Cooks Range
Goodsight Mts
Fluorite Ridge
Florida
Black Mtn
Silver City Branch
Mimbres River
Mirage
Luxor
Carne
Myndus
Tunis
Deming
Gage
Southern Pacific R.R.
Atchison Topeka & Santa Fe R.R.
Victoria Mts
Red Mtn
Snake Hills
Little Florida Mts
Florida Mts
Hondale
Grade Road
Southwestern
Palomas Arroyo
Iola
Mountain View
Waterloo
El Paso
Tres Hermanas Mts
Columbus
Arena
United States Boundary Line
Mexico
108°
R.8 W
R.7 W.
107°30′
R.6 W.
LEGEND
DEPTHS TO SURFACE OF WATER IN WELLS
0-25 feet
25-50 feet
50-100 feet
100-400 feet
Water conditions not determined (probably unfavorable at most places)
Rock at or near the surface
○ Representative wells: figures show depth to principal water stratum
● Deep borings
f Unsatisfactory boring
5
0
5
10
15 Miles

FIGURE 11

in the Mimbres Valley is derived from erosion of the surrounding highlands, which was followed by deposition. The plain surface at the upper end of the valley, north of Spalding, is strewn with gravel that has been "more or less cemented" over a period, to form a hard, relatively impermeable layer.[62] To the south and to beyond the narrow pass between the Little Floridas and Cooks Range, the sub-surface underlying the Mimbres River is composed of less impervious clay and silt beds.

The fill of the Mimbres River channels is characterized by alluvial sediments eroded from the Pinos Altos Mountains, the Black Range, and the Mimbres Mountains, which lie to the north of Luna County, at the Mimbres' source. At the upper end of the river valley, north of Spalding, the river channels are filled with beds of porous, permeable gravel and boulders. Below Spalding the river fill is much finer grained, although it is still permeable, consisting of sand and small pebbles.[64]

No information relating to the depth of the bolson deposits to bedrock or to the geology of the mountain range was found in the reports researched.

Hydrology

A. Pre-Development Conditions

Groundwater in the Mimbres Valley comes chiefly from the upper, northern end of the valley, where the Mimbres River and its tributaries enter the valley.[65] The Mimbres River is considered to be the chief source of groundwater recharge for the Luna County aquifer, lesser quantities being contributed by the Mimbres' tributaries.[66] Runoff from the hard, cemented valley floor north of Spalding feeds the Mimbres and its tributaries, as does storm water runoff from the northwestern slopes of Cooks Range. Upon entering the plain below Spalding, the river shrinks rapidly and in times of low precipitation it disappears entirely.[67]

Some small amounts of the precipitation north of Spalding percolate downward, rather than running off toward the river to recharge the water table directly. South of Spalding almost no direct recharge takes place from precipitation on the valley floor, due to the calcified near-surface layers, so that intake areas are limited to the bed and channels of the river. Precipitation on the eastern and southeastern slopes of Cooks Range, on the low hills to the west of the valley, and on the Florida Mountains, contributes minor amounts to recharge.

An early report estimated the total annual recharge of the Mimbres Valley over a twenty year period to be between 10,000 and 11,000 acre-feet per year.[68] Prior to development, natural discharge is believed to have equalled natural recharge, so than an equilibrium state existed.[69]

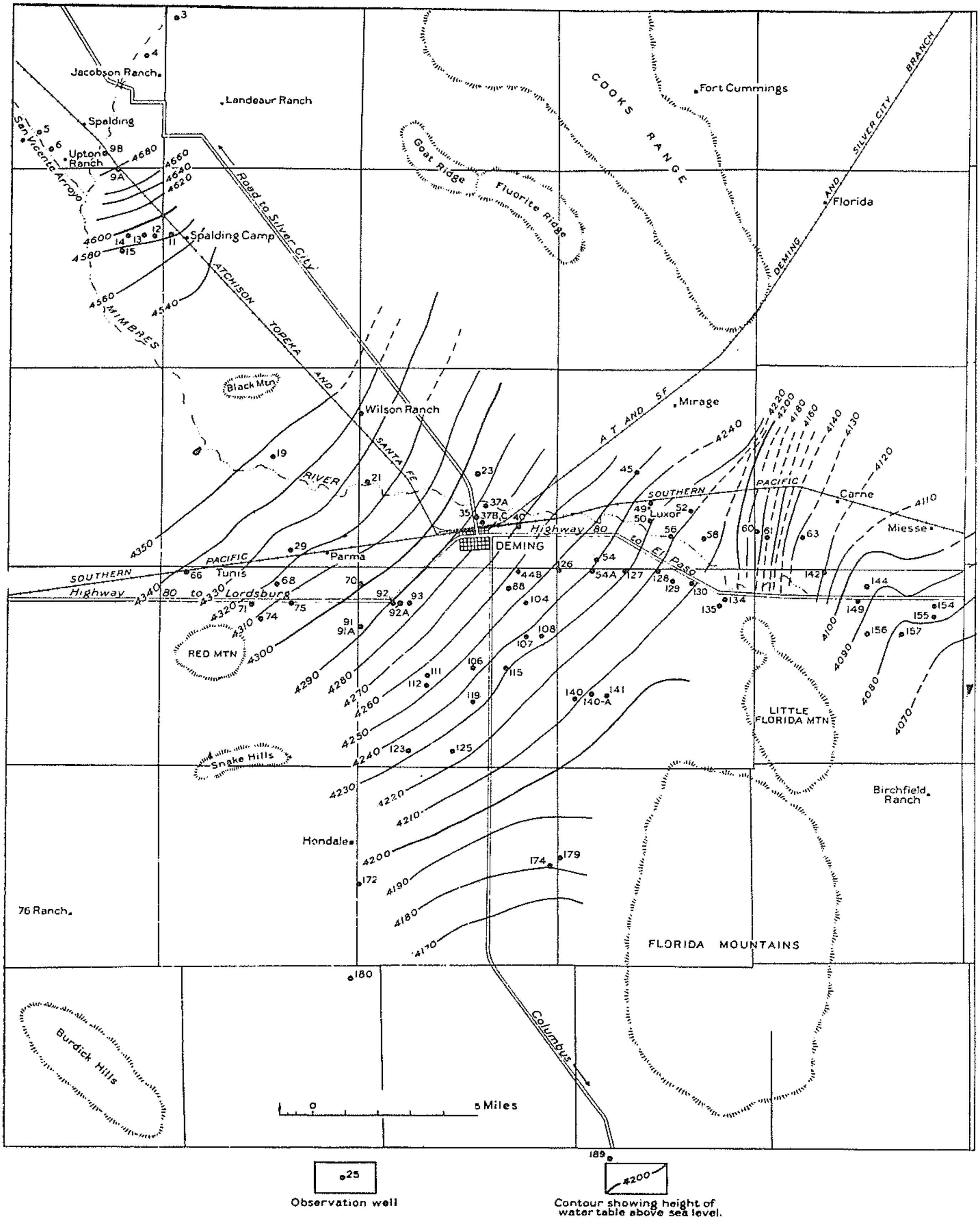
Throughout the Mimbres Valley the water table slopes from the northwest to the southeast, the slope varying from 25 to 35 feet per mile near Spalding, to from 10 to 15 feet per mile south of Black Mountain.[70]

Underground water is contained within many of the bolson deposits, but the beds vary greatly in their capacity to hold and transmit water, both from place to place within the same bed and from bed to bed.[71] An early report estimated most of the water bearing beds to be less than 50 feet thick[72] and to be within 20 to 150 feet of the valley surface. Figure 12[74] depicts a contour map of the form of the water table for 1931 in the vicinity of Deming.[75] Note the steep gradient between the Little Floridas and the Cook Range, evidencing a subsurface ridge which has been hypothesized to form a groundwater dam.[76] (Recent data reveal, however, that the "dam" may not really exist.) The same report estimated the total volume of groundwater within the Deming "area" to be 2,560,000 acre-feet.[77] No volume figures were given for the Mimbres Valley as a whole, except that the quantity is "very large"[78] and that it is " ... probably several times the volume annually discharged by the Rio Grande at the Elephant Butte Reservoir."[79]

Water quality has been characterized as "excellent," but it has been noted that " ... if large volumes are allowed to evaporate on the land [as would happen in irrigation] ["mineral matter"] will accumulate as 'alkali' in or on the soil and finally render it unfit for plant growth."[80] A later study showed that all of the water analyzed from wells in and around Deming was acceptable for domestic and irrigation uses in terms of total dissolved solids, and that the deeper waters were "softer" than the moderately deep waters.[81]

B. Development of Luna County Water Supplies

> Irrigation by pumping from wells began in the Mimbres Valley during the period 1908 to 1911. About 1912 there was a rapid expansion in pumping development ... and ... by 1914 nearly 200 pumping plants were installed or under erection. These pumping plants were spaced over a large area, extending from Deming southward 33 miles to the Mexican border, eastward about 15 miles to Miesse, and westward about 7 miles to the locality of Red Mountain. 82



MAP OF MIMBRES VALLEY, NEW MEXICO, SHOWING OBSERVATION WELLS AND FORM OF THE WATER TABLE IN THE WINTER OF 1931-32

FIGURE 12

In 1910 the population of Luna County was 3,913 people.[83] Later, due primarily to the inexperience of the well operators which caused operating costs to exceed returns, there was a decline in pumping activity. By 1930, however, with the population of the county at 6,247,[84] the number of pumping plants had risen to 116, with about 6,000 acres under irrigation with pumped water.[85] At this time, total pumpage was estimated to be 10,500 acre-feet per year.[86] Irrigated acreage had increased to 12,000 acres for the Mimbres Valley and population had risen to about 7,400 people by 1941.[87]

Figure 13[88] depicts the decline in groundwater levels for the period 1913 to 1940, showing the greatest declines around Deming and northeast of the Little Florida Mountains. Heavy pumpage combined with restricted storage capacity, which results from the natural subsurface dam, is believed to be the cause of heavy drawdowns in the Little Florida area.[89]

A 1942 report stated with regard to future groundwater withdrawals in the Mimbres Valley:

> [M]ost of the water that has been pumped has been derived by depletion of the storage in the underground reservoir. The water levels will continue a downward trend, probably as long as water is pumped and almost certainly for many years.
>
> * * * * * *
>
> [N]o additional development of pumping plants should be undertaken in the heavily pumped areas, but a small amount of new development could be undertaken in lightly pumped areas. 90

If population is any indicator of water use and development, the report's advice was not followed, because by 1969 Luna County's population was 11,000 people.[91] Figure 9 bears out the assumption that

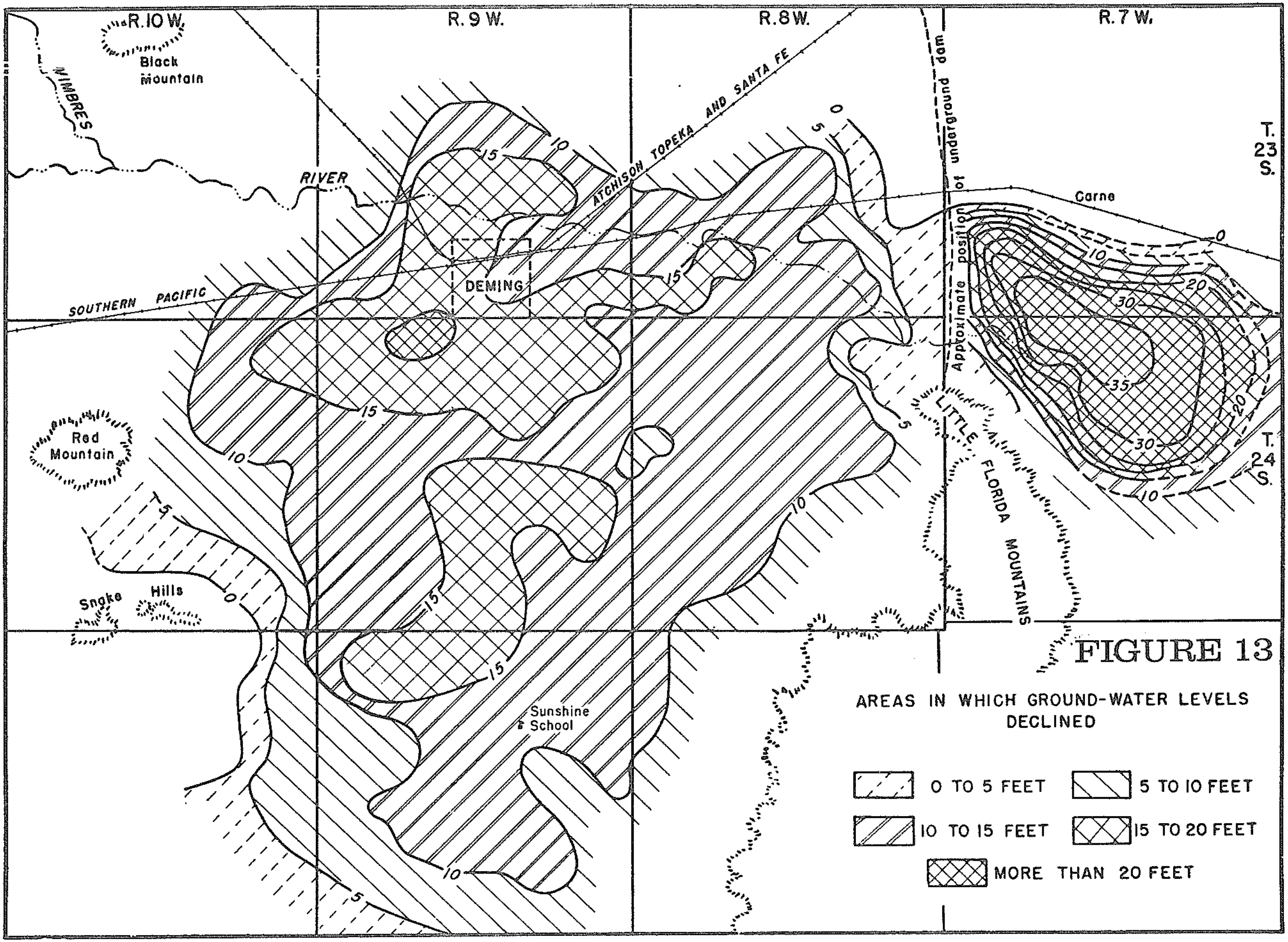


FIGURE 13

Decline of ground-water levels in a part of Mimbres Valley from 1913 to 1940.

water use has increased, showing a drawdown pattern which roughly parallels that of the 1940 map, but depicting greater drawdown quantitatively. Note in addition to the Deming pattern, the marked drawdown pattern lying to the south-southeast of Deming, in the vicinity of Columbus.

SUMMARY

The fact that no recent qualitative reports have been made on pumping or the effects of pumping makes it difficult to determine what the present hydrologic situation is in Luna County. We know, however, that annual recharge is approximately 10,000 to 11,000 acre-feet per year, and that in 1930 total pumpage was 10,500 acre-feet per year, which means that as early as 1930 no annual additions to storage were being made. This allows the inference that any increase in development beyond 1930 levels, absent increased recharge, must have depleted water in storage. In fact, this depletion is apparent in the 1940 contour map which shows declines near Deming and near the subsurface dam. Since population increased by 67% between 1940 and 1969, and by an undetermined but probably even greater amount between 1940 and 1977, and since it is reasonable to assume that irrigated acreage also has increased in the period 1940-1977 (although no figures were found to support this), it therefore follows that water levels have declined from the 1930 near-equilibrium state.

The effect of withdrawals on the southeasterly flow of groundwater into Mexico and on the overall quality of groundwater is unknown, due to the absence of data and analyses. However, it can be inferred from general principles of hydrology that in some areas there will be (or that there has been) a reversal of flow, toward the withdrawal points. This means, in effect, that Mexico conceivably will be deprived not only of groundwater that ordinarily would flow in due course to Mexico, but that water already in Mexico may re-migrate back into the U.S. Of course, the reverse of this situation, where Mexican withdrawals deplete U.S. supplies, is just as likely a possibility in the ill-defined hydrologic situation set forth above.

Whether this is happening on either or both sides of the border, or whether it is even capable of happening under the existing hydrologic conditions, is unknown. However, it is submitted that unless the complete hydrologic picture on both sides of the border is made available to the people attempting to plan future development, there will be no way of hypothesizing the effect that each nation's development will have on the other nation's water users.

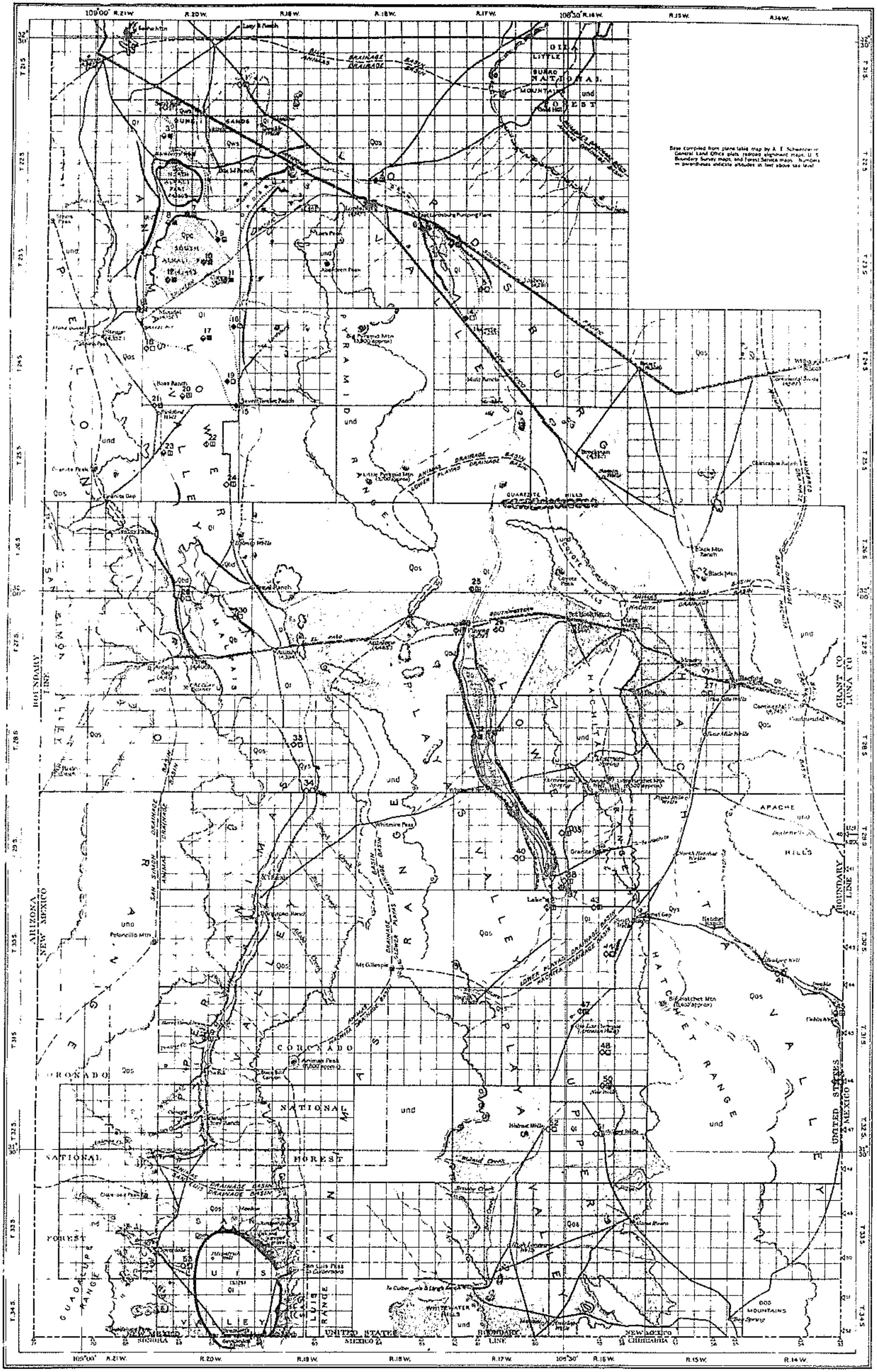
SOUTHERN HIDALGO COUNTY, NEW MEXICO

Hidalgo County, a part of Grant County until 1919, is the farthest west of the New Mexico counties which border Mexico. See Figure 1 and Figure 14.[92] Its main population center is Lordsburg. Hidalgo County's climate is like that of Luna County: hot, temperatures commonly exceeding 100° F. in the summer months,[93] and semi-arid averaging approximately 11 inches of rain per year.[94]

Agriculture and stock raising are the economic mainstays of the county, the Phelps Dodge Corporation copper smelter being the county's only heavy industry. In 1969 there were 5,000 residents in the county, representing only a 60% increase over the 1910 estimate of 3,000.

A concise geographic description of Hidalgo County was given in an early report by Schwennesen:

> [The county] includes four closed drainage basins--the Animas, Playas, Hachita, and San Luis--in so far as they lie within the United States.
>
> * * *
>
> The major features of the area are three nearly parallel, northward-trending mountain chains and intervening plains or valleys. The bounding ranges are not continuous.... Where the mountain ranges are absent, the valleys merge into one another, the drainage divides being very low and inconspicuous, so that these valleys form in reality one great plain.
>
> * * *
>
> The western mountain chain consists of the Guadalupe and Peloncillo ranges; the central chain consists of the San Luis, Animas, and Pyramid ranges; and the eastern chain comprises the Dog Mountains, the Hatchet and Hachita ranges, and the Coyote and Quartzite hills. Still farther east are several detached groups of hills or mountains, the largest of which are the Apache or Doyle Hills and the Little Burro Mountains.
>
> * * *
>
> To the region which is bounded on the west by the Hatchet and Hachita ranges and on the east by the Apache Hills and the group of hills north of the El Paso and Southwestern Railroad and which extends from Black Mountain to the Mexican boundary, the name Hachita Valley is sometimes applied.
>
> * * *
>
> Playas Valley ... is bounded on the west by the San Luis and Animas ranges and on the east by the Hatchet and Hachita ranges and [it] extends from the Quartzite Hills and the south end of the Pyramid Range to the Mexican border.
>
> * * *



Base compiled from plane-table map by A. T. Schwennesen, General Land Office plats, railroad alignment maps, U. S. Boundary Survey maps, and Forest Service maps. Numbers in parentheses indicate altitudes in feet above sea level.

FIGURE 14

Geology by A. T. Schwennesen

Scale $\frac{1}{250,000}$

5 0 5 10 15 Miles

1918

> The region between Peloncillo Range and the Animas and Pyramid ranges, extending from a low divide 9 miles north of the Mexican border to the Gila River divide, is known as the Animas Valley. The plain between the Animas Valley and the Mexican border is known as San Luis Valley. The part of Animas Valley south of the El Paso & Southwestern Railroad is called Upper Animas Valley, to distinguish it from Lower Animas Valley, which lies north of the railroad.
>
> * * *
>
> Upper Animas, Lower Animas, and Lordsburg valleys ... lie in the Animas drainage basin; San Luis Valley is in the San Luis drainage basin; Lower Playas Valley is in the Playas drainage basin, and Upper Playas and Hachita valleys are in the Hachita drainage basin.[95]

Due to the distinct character of each of the three valleys in Hidalgo County, each will be examined separately. The studies are generally confined to the areas of each valley which conceivably interrelate hydrologically with Mexico.

Hachita Valley

The easternmost of Hidalgo County's basins is the Hachita Valley, which lies "... between the Little Hatchet-Big Hatchet-Alamo Hueco mountain chain on the west and the Cedar Mountains, Apache Hills, and Sierra Rica on the east."[96] See Figures 1, 14, and 15.[97] (Note that Figure 14, from a 1917 survey, refers to the Little Hatchets as the Hachitas and to the Big Hatchets as the Hatchets, and that it combines the Sierra Rica and Apache Hills into a contiguous group of hills and combines the Alamo Hueco Mountains and the Big Hatchets into the same range.) The north and central sections of the valley are in the United States, but the south section extends into Mexico.[98]

With regard to the geography of the valley, it "... is characterized by a well-marked central draw that extends from a point a short distance south of Black Mountain southwest to the vicinity of Hatchet Gap, and then southeast to the Mexican border."[99] The valley floor generally slopes to the southeast, at approximately 11 feet per mile.[100] In general, the valley walls are steeper on the west side of the valley than on the east.[101]

A. Geology

No geologic information was found for the northern part of the valley, so this report is limited to the central section and part of the southern section. Faulting is believed to have formed the Big Hatchets, which are composed primarily of Precambrian granites and undifferentiated rocks, overlain in most places by marine sedimentary rocks.[102] Relatively recent alluvial cover obscures the eastern fault line of the Big Hatchets.

The Sierra Ricas also are mostly impermeable limestone and other marine sedimentary rocks, and the western flanks of the Sierra Ricas dip to the southwest at 2° to 4°, toward the Big Hatchets, to form the bed rock of the Hachita Valley. See Figure 16.[103]

Following the rapid uplift of the Big Hatchets, coarse detritus and alluvium from the newly formed mountains was carried down by floodwaters and deposited in what is now the valley. As a result of high velocity flow and flood waters having carried all materials, coarse and fine alike, the same distance into the valley, the alluvium near the mountains tends to be poorly sorted.[104] As a result of this poor sorting, the deposits are very porous but have low permeability. Farther out from the base of the mountains, however, grain size is smaller

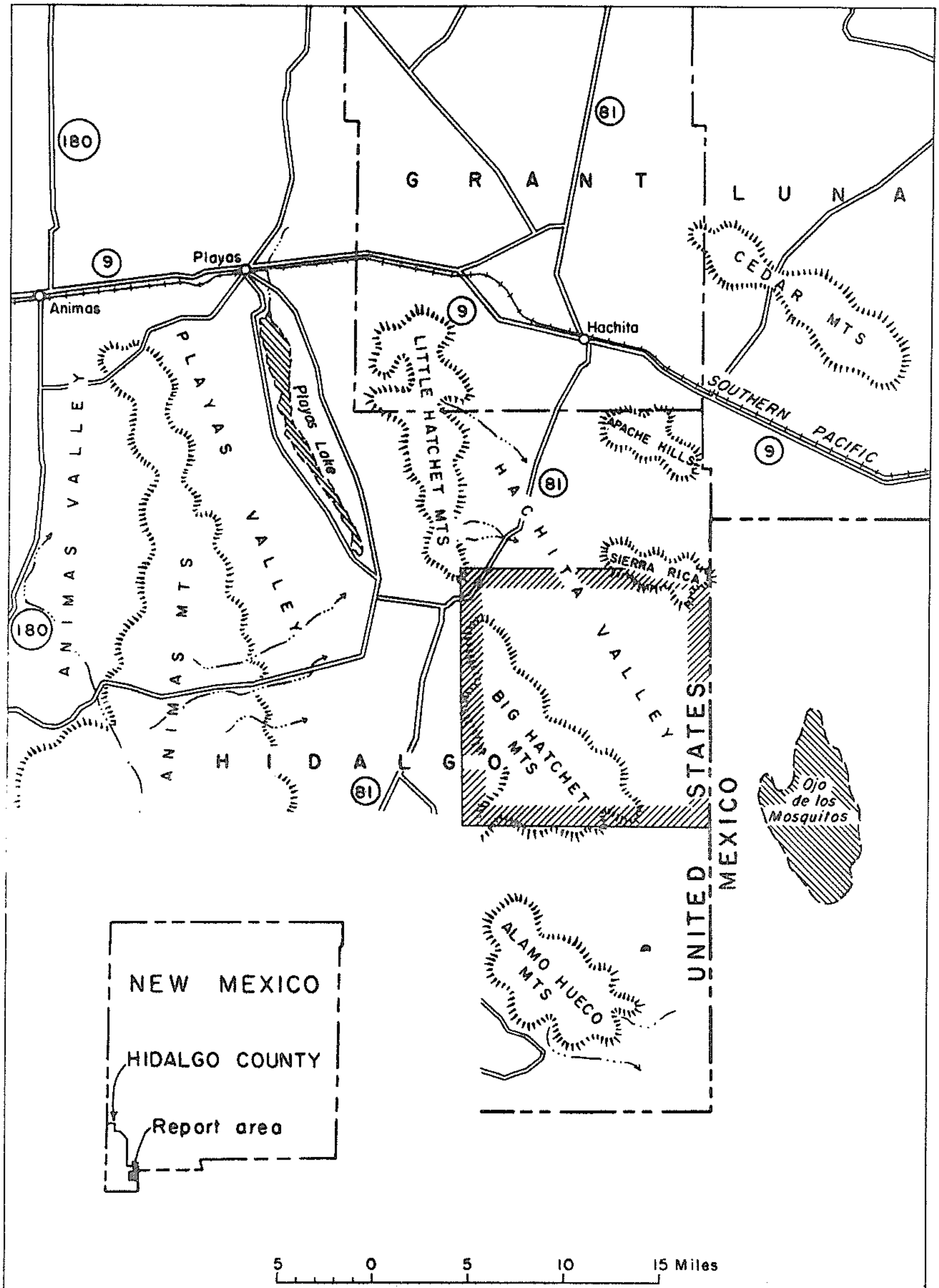
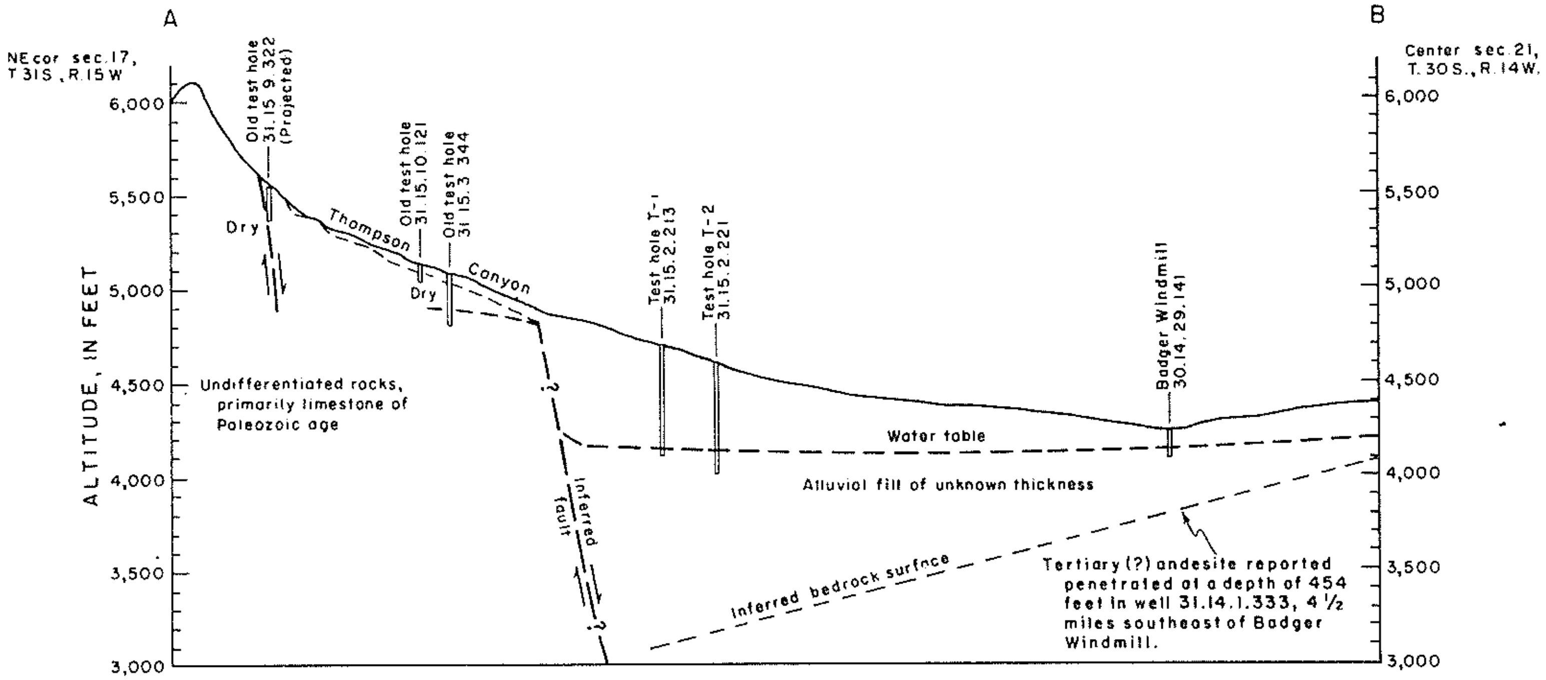

180
9
Playas
Animas
GRANT
LUNA
81
CEDAR MTS
Hachita
LITTLE HATCHET MTS
PLAYAS VALLEY
Playas Lake
ANIMAS VALLEY
ANIMAS MTS
PLAYAS MTS
HACHITA VALLEY
APACHE HILLS
SOUTHERN PACIFIC
SIERRA RICA
BIG HATCHET MTS
HIDALGO
UNITED STATES
MEXICO
Ojo de los Mosquitos
ALAMO HUECO MTS
NEW MEXICO
HIDALGO COUNTY
Report area
5
0
5
10
15 Miles

FIGURE 15



Profile and section along line A – B (pl. 1) showing probable relation of water table, bedrock, and alluvial fill.

FIGURE 16

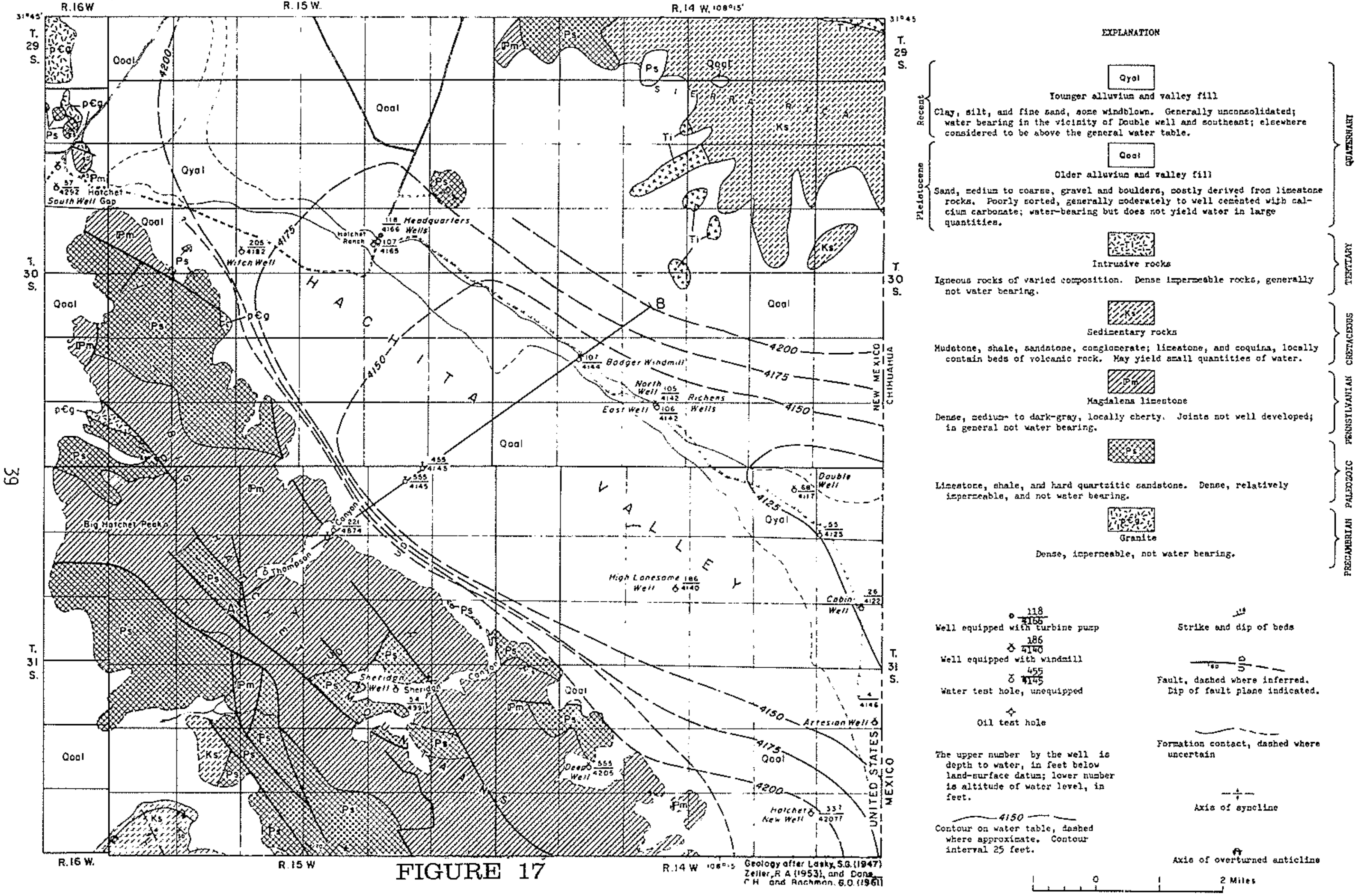
and more uniform, due to the lower velocity of the depositing flood waters, which could only transport particles below a certain size. These deposits tend to be both porous and permeable.[105] At the furthest points from the mountain the flood waters, which by now were moving very slowly and could carry only small particles, deposited silt and fine grained sand. As a result of the uniform, extremely small size of the particles, these deposits are relatively impermeable. Subsequent build up of the fine grained deposits over time, acting in conjunction with cementation resulting from percolation of $CaCO_3$ laden waters from the limestone mountains, has created an impervious layer over most of the larger grained deposits in the valley.[106]

Depth from the present day valley surface to bedrock increases westward from the valley axis, varying from 450 feet along the axis to 1,700 feet about 3 1/2 miles west of the axis. Refer to Figure 16. Alluvium depths are greatest in a band which runs parallel to the Big Hatchets, about 3 1/2 miles west of the valley axis.

Cementation from deposition of $CaCO_3$ from waters which have percolated through the limestone mountains is extensive in Hachita Valley and zones of caliche of two to five feet in thickness are almost uniformly present at or near the surface of the alluvial fans which descend from canyons along the mountain flanks.[107] In places, the veneer of caliche has been cut through by stream channels, so that the underlying, more permeable zones are exposed.

B. Groundwater Supplies

Water table contours indicate, see Figure 17,[108] that groundwater moves southward from northern Hachita Valley into the central and



Geology after Lasky, S.G. (1947) Zeller, R A (1953), and Dane, C H and Bachman, G.O. (1961)

FIGURE 17

Map of Hachita Valley northeast of the Big Hatchet Mountains, Hidalgo County, N. Mex., showing generalized geology, wells and test holes, and contours on the water table, December 1955.

southern parts. The southeasterly slope is somewhat shallower than that of the land surface, so that depth to water is greater in the north than in the south. A subsurface groundwater divide is believed to exist north of Hachita, corresponding roughly with the continental divide and separating the Animas and Hachita drainage basins.[109] See Figure 14.

Groundwater recharge to central and southern Hachita Valley occurs primarily from precipitation, but volume of recharge is small due to the low annual precipitation and high evaporation rates. In addition to these conditions, the impermeability of near-surface cemented, caliche layers, which allows only a very small part of the precipitation to penetrate to the water tables, decreases recharge even more. In places where the caliche layers are cut by stream channels, however, more efficient recharge is possible.

Despite the southeasterly slope of the water table, most of the water in Hachita Valley is not under artesian head, and discharge occurs to the south, in Mexico, under water table conditions.

Water quality in the valley varies, but in most places is acceptable for domestic and stock use.[110] In general, water quality decreases to the southeast as the water percolates through greater and greater volumes of carbonaceous rock and alluvium with time.

Total volume figures for usable water were not presented in the authorities consulted, but one report suggests that "... small to moderate supplies of potable groundwater are available from valley fill under most of Hachita Valley."[111] The report goes on to note:

> The possibilities for the development of adequate supplies of groundwater in the areas immediately

> underlain by bedrock are poor. The rocks of marine origin that make up the Big Hatchet Mountains are not aquifers. No springs or seeps discharge from these rocks, and of three test holes in the Magdalena limestone in Thompson Canyon, two were dry....
>
> * * *
>
> Most of the groundwater developed in the valley is derived from the alluvial deposits of the valley fill. However, the ability of the alluvial deposits to yield water varies appreciably from place to place....112

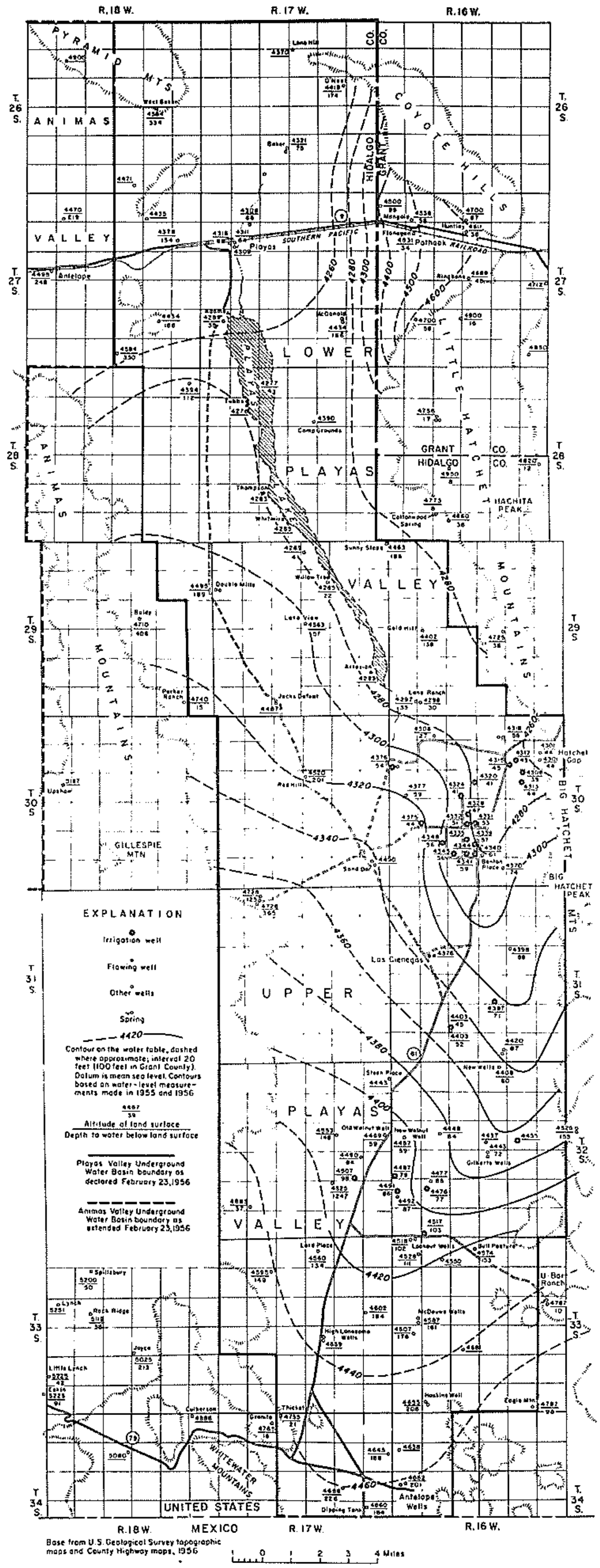
Playas Valley

Playas Valley is a north trending intermontane alluvial trough which is bounded on the west by the Animas Mountains and on the east by the Coyote Hills-Little Hatchet-Big Hatchet-Alamo Hueco chain.[113] See Figures 1, 14, and 18.[114] An alluvial barrier, extending from Mt. Gillespie in the Animas Mountains eastward to north of Hatchet Gap, divides the Valley into lower (northern) and upper (southern) parts.

The lower valley is a closed geographic basin with roughly centripetal drainage, while the upper valley is open and slopes to the north-northeast.[115] Alluvial fans flank the western and eastern extremes of the valley near the bordering mountains, the western fans tending to be larger and more gently sloping than the eastern ones.[116]

A. Geology and Structure

Playas Valley "... is underlain by a tilted, downdropped block bordered by relatively uplifted fault-block mountains.[117] The structural and depositional history of Playas Valley is very much like that of the Hueco Bolson and the Hachita Valley. It is characterized by uplift of the surrounding mountains relative to the valley floor, followed by erosion of the calcareous highland rock and by deposition of



Base from U.S. Geological Survey topographic maps and County Highway maps, 1956

FIGURE 18

Map of Playas Valley, Hidalgo County, N. Mex., showing boundaries of declared underground water basin, locations of wells, contours of the water table, and depth to water, 1955-56.

the detritus in the valley to form shallow alluvial fans at the beginning of the depositional era, succeeded by a gradual increase in the size of the fans toward the central valley, until the fans finally coalesced "to form continuous alluvial aprons sloping away from the mountains."[118] The resulting valley fill is a typical bolson deposit, comprised of "... thick but generally discontinuous beds of clay and silt and lenses of clay and silt intermixed with gravel and sand."[119]

Also as occurred in the Hachita Valley, extensive leaching of carbonate rocks in the highlands and redeposition of the $CaCO_3$ in the lowlands have created impermeable carbonate impregnated caliche beds which lie on or near the surface.

B. Groundwater Supplies

The similarity between Hachita Valley and Playas Valley continues with regard to groundwater, in that precipitation in and around the bordering mountains provides essentially all of the groundwater recharge.[120] The same factors which combine in the Hachita Valley to preclude percolation of precipitation to the water table, high volume runoff, high evaporation rates, and impermeable near surface caliche beds, are at work in the Playas Valley, so that less than 1% of the precipitation actually recharges the groundwater supplies.[121] Even so, one authority has estimated the recharge of the valley to be 1,250 acre-feet per year.[122]

Groundwater is believed to occur throughout the Upper Playas Valley, contained within the valley alluvium. The water table of the south upper valley slopes to the north at approximately 7 feet per mile, but due to an even more pronounced slope of the valley surface, depth to groundwater from the surface decreases from south to north.[123] There is a trough in the groundwater table, along which groundwater flows northward, which roughly parallels the topographic low of the valley axis. See Figure 17. While the trough is roughly north-south in the southern upper valley, it begins to channel to the northeast near Las Cienaga in the general direction of Hatchet Gap. Along the sides of the Big Hatchet mountains, groundwater "... moves down the alluvial slopes, flanking the upper valley and then northward toward Hatchet Gap."[124]

Once groundwater from the upper valley arrives at Hatchet Gap, an undetermined amount of it moves across a subsurface barrier of bedrock which separates the Playas and Hachita valleys, the rest of it moving into the lower valley.

Although extensive qualitative chemical analyses were not reported for Playas Valley water, one report states that "[m]ost of the groundwater in Playas Valley is suitable for irrigation,"[125] with a low alkali hazard and a medium salinity hazard.

Despite the fact that "[f]rom the early part of the century until 1948 no significant farming operation developed, and the land was used principally for grazing,"[126] today pumping is the greatest discharge mechanism in the valley. While no precise figure is available, one report estimated that approximately 2,100 acre-feet per year were pumped on the U.S. side of the valley between 1948 and 1956.[127] Whatever the pumpage is quantitatively, the effects of U.S. pumping are displayed in Figure 9, which depicts a widely spread drawdown pattern of relatively small magnitude. No estimates of annual pumping are available for the Mexican side, but since the Mexican town south of Antelope Wells "... has the greatest concentration of population in the Valley at the present time," it is reasonable to assume that Mexican use is extensive.

Pumpage, however, at least for the U.S. side, was not considered to have yet exceeded the natural discharge in 1960,[128] even though the "... water [was] being pumped from storage, [so that] a lowering of water levels [could] be expected each year...."[129] In fact, levels have lowered at intermittent rates from the time the valley was developed in 1949 at an average of 2 feet per year.[130] To support the proposition that drawdown has occurred, one report noted: "The flow of some springs and seeps, as reported in 1913, has diminished or ceased. Several springs along the west side of Playas Lake ... and one at Las Cienagas in upper Playas Valley no longer flow.[131]

Animas Valley and San Luis Valley

Like Playas Valley, Animas Valley is separated into two distinct areas: the lower (northern) valley and the upper (southern) valley. While the lower valley is the more extensively irrigated of the two parts, only the upper valley will be examined, because the lower valley does not interrelate hydrologically with Mexico.

The upper Animas Valley "... is a long, comparatively narrow valley trending nearly north and south between continuous parallel ranges of mountains--the Peloncillo Range on the west and the Animas range on the east."[132] In all, the valley encompasses roughly 500 square miles. There are no population centers in the upper Animas Valley and only small areas are suitable for irrigation and the availability of water.[134] Refer to Figure 1 for the location and form of upper and lower Animas Valley.

Immediately south of the upper Animas Valley lies the San Luis Valley, which is partially in the U.S., and partially in Mexico. A low alluvial divide approximately 11 miles north of the Mexican border marks the boundary between the Animas and San Luis Valleys. The southern Peloncillos and the Guadalupe Range border the San Luis Valley on the West, the southern Animas and the San Luis on the east.

San Luis Valley and the upper Animas were included within a groundwater basin by the New Mexico State Engineer on February 23, 1956.

A. Geology and Geography

A detailed report on the geology of the bordering mountain ranges is not available, except to the extent that it was reported in 1913.[135] That report described mountains which are effectively identical in genesis, composition, and structural history to the ANimas and Big Hatchets, described above.[136]

The valley surface of the upper Animas Valley is similar to the upper Playas Valley in that it slopes to the north, at approximately 23 feet per mile. Differing from both the Playas and Hachita valleys, however, the Animas is not a gently sloping, rolling plain which is drained by sheet flooding, but is a relatively steeply walled narrow valley characterized by well defined drainage channels. Unlike the Playas and Hachita valleys, "... both the central and lateral drainage lines follow definite channels cut into the valley fill."[137]

Animas Creek is the principal drainage channel and it rests within a long, narrow trough of river deposited sands and gravels, which in turn overlies the poorly sorted, calichified clay, sand, and gravel "wash."[138]

Apart from the creek deposits, well sorted porous, permeable deposits of sand or gravel occur intermittently throughout the valley, always on top of the impervious "wash," although the thickness and composition of the beds varies with location.

Most of the closed basin that is the San Luis Valley is filled at depth with detritus from the bordering ranges and with fine grained lake deposits and clays from an ancestral lake.[139] At shallow depths along Cloverdale Creek and in places within the valley itself, deposits of porous sand and gravel are found. This shallow veneer ordinarily is separated from the deeper, less porous deposits by an impervious blue clay stratum.[140]

One notable exception to this depositional array occurs near the southern end of the former lake bed, where "... much coarse detritus has been washed down from the San Luis Range and deposited in large alluvial fans that extend over the old lake flows for a mile or more."[141]

B. Water Supply

Precipitation is the recharge source for the upper Animas Valley, as it is for all of the southern basins examined in Hidalgo County. In Animas Valley, however, the precipiation usually does not penetrate the impervious "wash" but remains perched above the water table, contained within the permeable, porous material laid down by Animas Creek and within the other near-surface aquifers overlying the calcareous deposits.[142]

Due to the irregular distribution of the water bearing beds in the valley and to the low storage capabilities of the beds, however, no truly dependable water supplies exist in the upper valley.[143] Water depth from the surface generally decreases to the north, until it is within 15 feet of the surface in places near Animas.[144]

Water which is available in the upper valley is considered to be the best in chemical composition of any water in Hidalgo County, due to the elevated position of the water-bearing beds and to the method of deposition of the trough alluvium, which did not favor the occurrence of alkali.

Most of the valley fill in the San Luis Valley is non-waterbearing, although there are small supplies present in the shallow, near-surface gravels, from gravels along Cloverdale Creek, and from occasional springs in the southern alluvial fans. The southern springs are artesian waters which have been trapped under impermeable clay beds and which subsequently have come to the surface when the artesian pressure became great enough.

As of 1913, the upper Animas-San Luis region had not been developed to any extent, although "[m]any small orchards and garden patches were being irrigated by windmills in connection with small earth storage reservoirs."[146] At to overall availability of groundwater in the upper Animas, Schwennessen noted that the parts of the valley outside of Animas Creek could not practicaly be irrigated, due to the absence of good quality water in sufficient quantities, stating:

> The amount of good waterbearing material is comparatively small, and consequently the

> storage capacity of the formation also is small and fluctuations in the water table are frequent, the rise and fall being governed chiefly by seasonal rainfall. As the demands made on the groundwater supply are as yet small, the effects due to pumping are hardly appreciable, but the continued development of this supply for irrigation is liable to cause a considerable lowering of the water table. 147

The same report stated with regard to the San Luis Valley that, in light of the local extent of water bearing beds and small storage capacities, "[i]t is not surprising that wells and springs have been known to go nearly dry in years of little rainfall *** [and that] a number of dry years in succession are almost certain to cause a serious shortage of water."[148]

Summary

With regard to the Hachita Valley, a 1917 report stated that [i]rrigation by groundwater is not feasible except in the shallow water area at the lower [southern] end of the valley."[149] This was true at one time, largely due to the available pumping technology. However, even though technology has changed and pumping methods have improved, the scanty data available suggests that there is still a dearth of groundwater in the Hachita Valley. The conclusions of the 1962 report that "small to moderate" quantities of usable water exist bear this out. The effect of withdrawals is not clear from the authorities consulted, but it can be inferred that any substantial development would have significant, detrimental effects due to the small volume of water in storage.

While groundwater development has not been as extensive in Playas

Valley as in some areas, the small development which has occurred it believed to have had an adverse effect on the water supply. A 1960 report stated that pumpage withdrawal had not yet exceeded natural discharge, even though it was twice as great as recharge. In light of water use increases in Playas Valley since 1960, however, it can be assumed that pumping withdrawals are putting an even greater strain on water in storage.

Conclusion

An overview of the valley aquifers studied in this section of the paper demonstrates a marked geologic and hydrologic similarity among them. All of the valleys are characterized geologically by a valley floor which has been downthrust relative to bordering areas and subsequently "filled" with detrital and clastic materials eroded from the highlands. In each of the valleys the bolson aquifers created by the valley fill were at one time saturated or nearly saturated and the natural discharge from the aquifers approximately equalled natural recharge. In all of the valleys except in the Playas Valley and the upper Animas Valley, natural discharge occurs by the flow of groundwater to the south, from the United States into Mexico. (This generalization may not hold true for the valleys lying within Dona Ana County.)

Throughout the area studied, the critical variables which determine the present and future availability of water for the U.S. and Mexico from the shared bolson aquifers are volume of water withdrawn and the rate of depletion. This is so for two reasons. First, theoretically, for a homogenous aquifer any artificial withdrawal of groundwater can reduce the head downstream in the aquifer to the point that downgradient users are no longer able to pump. Second, where artificial withdrawal is great enough, either in absolute volume or in volume per unit time, the upstream head may be reduced relative to the head downstream so that "upstream" becomes down gradient and quantities of groundwater already downstream of the withdrawal point will reverse flow and migrate toward the lower pressure withdrawal point. In either case, the downstream user may be deprived of groundwater.

Whether this phenomenon is occurring along the border area studied, or whether it is even capable of happening under the hydrologic conditions present, is unknown. However, theoretically it could be happening. Unless the complete hydrologic picture, for both sides of the border, is made available to those attempting to plan future resource development, no one will be able to hypothesize the effect that either nation's development will have on the other's water users. One example of the beneficial effect of an exchange of knowledge is the map of projected drawdown for the year 1991, as displayed in Figure 7, from which El Paso's water planners are able to locate future pumping sites.

The necessity of more extensive international cooperation already is apparent in El Paso/Juarez, where even more substantial drawdowns are projected and where some authorities believe there already has been a reversal in the flow direction of underground water, from north to south. In other areas, such as the Mimbres Valley and Hachita Valley, where flow is from north to south but where groundwater drawdown has not yet been extensive, the importance of cooperation is somewhat less pressing and apparent. However, it seems logical that now, at a time when the border area is still largely undeveloped, would be the time to assess conditions on both sides of the border and develop some authority for apportionment of groundwater, rather than to wait until a crisis is at hand. The same rationale applies with regard to the Playas Valley, where flow is presently from south to north, but here the United States would be the protected party.

Along the border area water is scarce and demand is great, or potentially great. In order to exploit existing water supplies most economically and for the greatest common good, some entity must be developed with powers and procedures comensurate to the task at hand. In addition, some method for apportionment of existing groundwater supplies between the two countries must be developed, and then applied by the entity.

A mutual understanding of the water-related problems facing each country, a mutual desire for the solution of the problems, and a willingness to cooperate are required before either the entity or the method can become a reality. When the entity and the method are realized, solution of the problems will become possible.

Footnotes

1. Interview with Tom Cliett, El Paso Water Utilities, El Paso, Texas (Feb. 25, 1977).

2. "Bolson" is Spanish for purse.

3. R. HILL, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, PHYSICAL GEOGRAPHY OF THE TEXAS REGION 8 (1900).

4. A. SAYRE & P. LIVINGSTON, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, GROUNDWATER RESOURCES OF THE EL PASO AREA, TEXAS 11 (Water Supply Paper 919, 1945). [hereinafter referred to as SAYRE & LIVINGSTON].

5. This map is taken directly from SAYRE & LIVINGSTON, *id*.

6. The Grand Canyon of Arizona is an instance where erosional processes created a substantial depression.

7. "Granite" is used here to denote all plutonic intrusives which are low in ferromagnesian minerals.

8. SAYRE & LIVINGSTON, *supra* note 4 at 18, 21.

9. *Id*. at 19.

10. E. LEGGATT, TEXAS WATER COMMISSION, DEVELOPMENT OF GROUNDWATER IN THE EL PASO DISTRICT, TEXAS 1955-60 5 (Progress Report No. 8, 1962) [hereinafter referred to as LEGGATT, EL PASO GROUNDWATER, 1955-60].

11. SAYRE & LIVINGSTON, *supra* note 4 at 19-20.

12. The material was eroded from the surrounding mountains and transported to the bolson by gravity, wind, and water.

13. SAYRE & LIVINGSTON, supra note 4 at 11-12. The longitudinal figure does not include that portion of the bolson which extends northward into New Mexico known as the Tularosa Basin, even though the Tularosa Basin and the Hueco Bolson are results of the same structural offset. The Tularosa Basin is truly a "bolson" as envisioned by Hill, in that it is a closed basin with centripetal drainage containing salt and gypsum deposits. The Hueco Bolson does not have truly centripetal drainage, having a markedly southward flow of runoff waters, and it does not contain any salt or gypsum deposits. See id. at 11.

14. W. MEYER, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, DIGITAL MODEL FOR SIMULATED EFFECTS OF GROUNDWATER PUMPING IN THE HUECO BOLSON, EL PASO AREA, TEXAS, NEW MEXICO, AND MEXICO 5 (Water Resources Investigation 58-75, 1976) [hereinafter referred to as MEYER, DIGITAL MODELING].

15. From a presentation by Tom Cliett, El Paso Water Utilities, to the New Mexico Geological Society.

16. MEYER, DIGITAL MODELING, supra note 14 at 5.

17. J. GATES & W. STANLEY, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, HYDROLOGIC INTERPRETATION OF GEOPHYSICAL DATA FROM THE SOUTHEASTERN HUECO BOLSON, EL PASO AND HUDSPETH COUNTIES, TEXAS 8 (Open-File Report 76-650, 1976) [hereinafter referred to as GATES & STANLEY, GEOPHYSICAL DATA].

18. As opposed to cemented or consolidated sediments such as limestone or sandstone.

19. SAYRE & LIVINGSTON, supra note 4 at 27-28.

20. E. LEGGATT & M. DAVIS, TEXAS WATER DEVELOPMENT BOARD, ANALOG MODEL STUDY OF THE HUECO BOLSON NEAR EL PASO, TEXAS 3 (Report 28, 1966). [hereinafter referred to as LEGGATT & DAVIS, ANALOG STUDY].

21. LEGGATT, EL PASO GROUNDWATER 1955-60, _supra_ note 10 at 5.

22. SAYRE & LIVINGSTON, _supra_ note 4 at 18.

23. Clays are a notable exception to this rule.

24. LEGGATT, EL PASO GROUNDWATER 1955-60, _supra_ note 10 at 1.

25. SAYRE & LIVINGSTON, _supra_ note 4 at 69.

26. _Id_. at 72.

27. MEYER, DIGITAL MODELING, _supra_ note 14 at 29.

28. SAYRE & LIVINGSTON, _supra_ note 4 at 68-69.

28. Saline here does not necessarily relate to NaCl in solution, but to any of the chemical salts such as Na++ or Ca++. Reference to saline waters and fresh waters here refers specifically to ppm (parts per million) dissolved solids. For purposes of this paper, greater than 1000 ppm is considered to be saline, and less than 1000 ppm is considered to be fresh.

29. _See_ LEGGATT & DAVIS, ANALOG STUDY, _supra_ note 20 at 5.

30. This figure is arrived at by adding the figures cited by MEYER, DIGITAL MODELING, _supra_ note 14 at 29. Meyer cited between 8.6 and 10.84 million acre-feet in reserve in Texas, 4 million acre-feet in reserve in Mexico, and 7.07 million acre-feet already pumped from the Bolson.

32. From a presentation by Tom Cliett, El Paso Water Utilities, to the New Mexico Geological Society.

33. MEYER, DIGITAL MODELING, _supra_ note 14 at 5.

34. LEGGATT & DAVIS, ANALOG STUDY, _supra_ note 20 at Fig. 7.

35. _Id_.

36. D. KNOWLES & R. KENNEDY, TEXAS BOARD OF WATER ENGINEERS, GROUNDWATER RESOURCES OF THE HUECO BOLSON, NORTHEAST OF EL PASO, TEXAS 17 (Bulletin 5615, 1956) [hereinafter referred to as KNOWLES & KENNEDY, HUECO BOLSON].

37. GATES & STANLEY, GEOPHYSICAL DATA, _supra_ note 17 at 16.

38. KNOWLES & KENNEDY, HUECO BOLSON, _supra_ note 36 at 19.

39. _Id_. at 6.

40. W. MEYER & U. GORDON, TEXAS WATER DEVELOPMENT BOARD, DEVELOPMENT OF GROUNDWATER IN THE EL PASO DISTRICT, TEXAS 1962-70 5 (Report 153, 1972) [hereinafter referred to as MEYER & GORDON, EL PASO GROUNDWATER 1962-70]. The figure was arrived at by adding the pumpage from the Mesa area and the City Artesian area.

41. KNOWLES & KENNEDY, HUECO BOLSON, _supra_ note 36 at 17.

42. MEYER, DIGITAL MODELING, _supra_ note 14 at Fig. 6.

43. MEYER, DIGITAL MODELING, _supra_ note 14 at 23.

44. LEGGATT & DAVIS, ANALOG STUDY, _supra_ note 20 at 5.

45. GATES & STANLEY, GEOPHYSICAL DATA, supra note 17 at 19. T. Cliett of El Paso Water Utilities noted that contamination has not yet been widespread, but that it would only be a matter of time. Until now the most prevalent cause of contamination was incorrect well drilling and development techniques which would break down the pietometric interface between layers, allowing transmission of saline supplies into fresh supplies.

46. See LEGGATT & DAVIS, ANALOG STUDY, supra note 20 at 6, where the authors discuss the fact that fresh water reserves will depend upon the degree of salt water contamination.

47. MEYER, DIGITAL MODELING, supra note 14 at 25. Compare this figure with Figure 4 for a better perspective on the projected drawdown.

48. Id., at Figure 13.

49. Id. at 27.

50. There are an estimated 34 million acre-feet of slightly saline water available in the Bolson. MEYER & GORDON, EL PASO GROUNDWATER 1963-70, supra note 40 at 27.

51. From W. KING, et al, GEOLOGY AND GROUNDWATER RESOURCES OF CENTRAL AND WESTERN DONA ANA COUNTY, NEW MEXICO, Fig. 3 (New Mexico Bureau of Mines & Mineral Resources Hydrologic Report 1, 1971).

52. C. CONOVER, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, GROUNDWATER CONDITIONS IN THE RINCON AND MESILLA VALLEYS AND ADJACENT AREAS IN NEW MEXICO (Water Supply Paper 1230, 1954); E. LEGGATT, M. LOWRY & J. HOOD, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, GROUNDWATER RESOURCES OF THE LOWER MESILLA VALLEY, TEXAS AND NEW MEXICO (Water Supply Paper 1669-AA,

1964); J. BASLER & L. ALARY, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, QUALITY OF THE SHALLOW WATER IN THE RINCON AND MESILLA VALLEYS, NEW MEXICO AND TEXAS (Open-File Report, 1968); W. KING, et al, HYDROGEOLOGY OF THE RIO GRANDE VALLEY AND ADJACENT INTERMONTANE AREAS OF SOUTHERN NEW MEXICO (New Mexico Water Res. Research Institute Rep. 6, 1969); W. KING, et al, GEOLOGY AND GROUNDWATER RESOURCES OF CENTRAL AND WESTERN DONA ANA COUNTY, NEW MEXICO (New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 1, 1971).

53. Conversation with Clyde A. Wilson, U.S. Geological Survey, Las Cruces, New Mexico (September 29, 1977).

54. From NEW MEXICO STATE WATER PLAN.

55. W. KING, et al, GEOLOGY AND GROUNDWATER RESOURCES OF CENTRAL AND WESTERN DONA ANA COUNTY, NEW MEXICO 59 (New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 1, 1971).

56. N. DARTON, U.S. GEOLOGICAL SURVEY, DEP'T OF INTERIOR, UNDERGROUND WATER OF LUNA COUNTY, NEW MEXICO 27 (Water Supply Paper 345B, 1914) [hereinafter referred to as DARTON, LUNA COUNTY].

57. STATE ENGINEER OF NEW MEXICO, 14th BIENNIAL REPORT 245 (1942).

58. W. WHITE, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, PRELIMINARY REPORT ON THE GROUNDWATER SUPPLY OF MIMBRES VALLEY, NEW MEXICO, Plate I (Water Supply Paper 637B, 1930) [hereinafter referred to as WHITE, PRELIMINARY MIMBREA VALLEY REPORT].

59. Id. at 69.

60. DARTON, LUNA COUNTY, supra note 56, Plate III.

61. STATE ENGINEER OF NEW MEXICO, 14th BIENNIAL REPORT 259 (1942).

62. WHITE, PRELIMINARY MIMBRES VALLEY REPORT, _supra_ note 58 at 77.

63. _Id_.

64. _Id_.

65. _Id_. at 73.

66. _Id_.

67. _Id_.

68. _Id_. at 80.

69. STATE ENGINEER OF NEW MEXICO, 12th BIENNIAL REPORT 151 (1938).

70. WHITE, PRELIMINARY MIMBRES VALLEY REPORT, _supra_ note 58, at 81.

71. DARTON, LUNA COUNTY, _supra_ note 56, at 27.

72. _Id_.

73. _Id_. at 25.

74. STATE ENGINEER OF NEW MEXICO, 10th BIENNIAL REPORT 184 (1932).

75. _Id_.

76. STATE ENGINEER OF NEW MEXICO, 14th BIENNIAL REPORT 237 (1942).

77. DARTON, LUNA COUNTY, _supra_ note 56 at 29.

78. _Id_. at 25.

79. WHITE, PRELIMINARY MIMBRES VALLEY REPORT, _supra_ note 58, at 72.

80. DARTON, LUNA COUNTY, _supra_ note 58 at 30.

81. STATE ENGINEER OF NEW MEXICO, 10th BIENNIAL REPORT 188 (1932).

82. WHITE, PRELIMINARY MIMBRES VALLEY REPORT, _supra_ note 58, at 70.

83. BUREAU OF BUSINESS RESEARCH, UNIVERSITY OF NEW MEXICO, BUSINESS INFORMATION SERIES NO. 40, NEW MEXICO'S POPULATION SINCE 1910 (1962).

84. _Id_.

85. WHITE, PRELIMINARY MIMBRES VALLEY REPORT, _supra_ note 58 at 71.

86. _Id_. at 86.

87. STATE ENGINEER OF NEW MEXICO, 14th BIENNIAL REPORT 247 (1942).

88. _Id_. at Fig. 5.

89. _Id_. at 262-63.

90. _Id_. at 281-82.

91. BUREAU OF BUSINESS RESEARCH, UNIVERSITY OF NEW MEXICO, BUSINESS INFORMATION SERIES NO. 48, ESTIMATES OF THE 1969 POPULATION OF NEW MEXICO COUNTIES (1970).

92. T. SCHWENNESEN, U.S. GEOLOGICAL SURVEY, DEP'T. OF INTERIOR, GROUND WATER IN THE ANIMAS, PLAYAS, HACHITA, AND SAN LUIS BASINS NEW MEXICO, Plate I (Water Supply Paper 422, 1918). [hereinafter referred to as SCHWENNESEN].

93. *Id*. at 36.

94. NEW MEXICO STATE ENGINEER, TECHNICAL REPORT 26, GROUNDWATER IN CENTRAL HACHITA VALLEY NORTHEAST OF THE BIG HATCHET MOUNTAINS, HIDALGO COUNTY, NEW MEXICO 5 (1962) [hereinafter referred to as TECHNICAL REPORT 26].

95. SCHWENNESEN, *supra* note 92, at 11.

96. TECHNICAL REPORT 26, *supra* note 92 at 3.

97. *Id*. at front cover page.

98. *Id*. at 3.

99. SCHWENNESEN, *supra* note 92 at 119.

100. TECHNICAL REPORT 26, *supra* note 94 at 5.

101. *Id*.

102. *Id*. at 7.

103. *Id*. at Fig. 2.

104. *Id*. at 12-13.

105. *Id*. at 13.

106. *Id*.

107. *Id*.

108. *Id*. at Plate I.

109. _Id_. at 14.

110. _Id_. at 15-16.

111. _Id_. at 18.

112. _Id_.

113. NEW MEXICO STATE ENGINEER, TECHNICAL REPORT 15, RECONNAISSANCE OF GROUND WATER IN PLAYAS VALLEY, HIDALGO COUNTY, NEW MEXICO 1 (1960).

114. _Id_., Plate I.

115. _Id_. at 4-6.

116. _Id_. at 5.

117. _Id_. at 10.

118. _Id_.

119. _Id_. at 11.

120. _Id_. at 14.

121. _Id_.

122. _Id_. at 15.

123. _Id_. at 12-13.

124. _Id_.

125. _Id_. at 18.

126. _Id_. at 8.

127. _Id_. at 15.

128. _Id_. at 21.

129. _Id_. at 17.

130. _Id_. at 2.

131. _Id_. at 15.

132. SCHWENNESEN, _supra_ note 92 at 75.

133. NEW MEXICO STATE ENGINEER, TECHNICAL REPORT NO. 11, GROUNDWATER IN ANIMAS VALLEY, HIDALGO COUNTY, NEW MEXICO 3 (1957) [hereinafter referred to as TECHNICAL REPORT 11].

134. _Id_.

135. SCHWENNESEN, _supra_ note 92.

136. _Id_. at 28-29.

137. _Id_. at 75.

138. _Id_. at 78.

139. _Id_. at 104.

140. _Id_.

141. _Id_. at 105.

142. *Id*. at 78.

143. *Id*. at 79-80.

144. TECHNICAL REPORT NO. 11, *supra* note 133, at 1.

145. SCHWENNESEN, *supra* note 92, at 82.

146. *Id*. at 81.

147. *Id*. at 80.

148. Id. at 105.

149. SCHWENNESEN, *supra* note 92 at 125.

"The general picture is one of more recent resort to groundwater ... without an adequate understanding of the physics of the resource and without regard, generally speaking, for the future."[1]

The Legal Context

The heaviest groundwater users in the United States are those states which are contiguous to Mexico,[2] and yet, paradoxically, the law and institutions of those border states are woefully inadequate to control the exploitation of these groundwater resources.[3] In addition, international competence over aquifers divided by the frontier is largely undefined;[4] it is fair to say that the legal and institutional situation is chaotic.

Professor Robert Emmet Clark says that none of the border states has "adequate legislation or regulations for the protection and management of diminishing supplies within the state and in the border areas. New Mexico has the only public control system, but regulations under it do not contemplate joint controls in the area of the border. Arizona and Texas have virtually no controls except voluntary ones, and the California law is beholden to similar rules of capture which do little to discourage excessive pumping and waste."[5]

In contrast to the legal situation on the U.S. side of the frontier, Mexico does have legal authority to control groundwater withdrawals. The National Government, through the Secretariat of Water Resources, can regulate extraction and the Secretary, on his own initiative, can establish prohibited groundwater zones if existing developments or the aquifer are in danger of being adversely affected,[6] or if it is otherwise in the public interest.

Coincident with the legal near vacuum, significant population increases are projected on both sides of the border, which make it reasonable to anticipate that there will be increasing investment in groundwater facilities and accelerating demand placed on groundwater resources which are bisected by the international boundary between the two countries.[7] The coming together of these two factors could be described as a collision course; with increased demand for a limited resource, combined with a striking absence of institutions for either resolving disputes or managing the resource, the potential for dispute between the two countries has to be something more than imaginary.[8]

This situation of a legal near vacuum is not unique to the U.S.-Mexico frontier, since only recently have we directed much attention to groundwater resources. Hayton observes that "traditionally there has been a failure to focus on the regulation and management of groundwater in most legal systems."[9] Clark adds that, "Legislative attention to the physical relationship between surface and groundwater sources is scarcely older than the concern for pollution."[10] It has been, in fact, a question of being out of sight and out of mind. The primary attention of domestic water law has been surface water, and there is an almost complete lack of practice at the international level. There are some treaties, such as the agreement between Poland and the USSR, signed at Warsaw on 17 July, 1964,[11] which refer to groundwaters. That treaty came in to force on 16 February, 1965, by an exchange of the instruments of ratification at Moscow, and in a general way includes groundwaters "intersected by the state frontier" as part of frontier waters,[12] but does not specifically deal with groundwater management. Also, there is Minute 242 between the U.S. and Mexico, limiting pumping on both sides of the frontier in the Yuma area,[13] and the exemplary job of the International Boundary and Water Commission of dealing with groundwater problems on a pragmatic, ad hoc basis must be recognized; but, by and large, groundwaters have not been a matter of concern at the international level. As in the case of groundwaters generally, "it is more a case of non-management than one of mismanagement."[14]

Teclaff points out that frequently groundwater has not been included in the established surface water law regime: "[I]t was thought quite adequate to treat groundwater either as part of the land, or as a commodity, susceptible of ownership through the act of capturing it by sinking a well."[15] For example, under Spanish law, which has influenced the groundwater law in Latin America and the Philippines, "ground waters had traditionally belonged to the owner of the super adjacent land,"[16] and, likewise, English Common Law has given absolute ownership to groundwaters to the super adjacent property owner. For example, Wells Hutchins states that the English Common Law doctrine,

> in its original form ... accords exclusive property rights in the water to the land owner; <u>it gives him the right to pump out the water at any time and in any quantity</u>, for any legitimate enterprise, either on or off the overlying land, ... but if the effect of heavy pumping by a land owner, while engaged in any legitimate enterprise, ... is to exhaust the groundwater supply of his neighbor by drawing all the groundwater from the substratum of the latter's tract into his own heavily pumped well, it cannot become the ground of an action. 17

Texas follows the English Common Law theory, and Roger Tyler succinctly has summarized the Texas law of undergroundwater as "you can steal your neighbor's water, but you can't pollute his well."[18]

Robert Hayton suggests that "the problem, then, for water lawyers and administrators, is to fashion a legal regime and a management machinery ..." which will be integrated "in order to achieve the optimum sustained yield of a nation's, or a region's, total water resources.[19]

Our task is to suggest for consideration possible legal regimes and management machinery to manage the groundwater resources intersected by the U.S.-Mexico frontier.

The Economic Context

In the kind of situation just described under the common law theory, each owner's right to the water itself, or the right to use the water, is insecure because other pumpers may take possession of the mobile resource at any time.[20] Accordingly, the individual surface owner is encouraged to exploit the groundwater resource as quickly as possible, so that the fluid and mobile water resource will not be captured by others. As Ciriacy-Wantrup points out:

> the definite property rights belong only to those who are in possession--that is who gets there fastest with the mostest. Every user tries to protect himself against others by acquiring ownership through capture in the fastest way possible. Deferred use is always subject to great uncertainty; others may capture the resource in the meantime. 21

Terrance S. Veeman adds that,

> in the absence of effective social institutions to guide resource use, private groundwater use can be predicted eventually to generate excessive investment and extraction costs; induce a pumping rate which is greater than socially optimal, and which may lead to irreversible depletion; dissipate economic rent or producer surplus, and in general create economic waste and resource inefficiency. 22

This situation thus leads to great insecurity for all existing users of water from an aquifer. Ciriacy-Wantrup[23] suggests that the concepts of "security" and "flexibility" are essential criteria for an adequate water rights system. Underlying the concept of physical security is the thought that holders of groundwater rights must have a reasonable degree of certainty--

that physical supply of water will not be unreasonably uncertain. Ordinarily, the physical supply of groundwater is more secure than surface water, since the aquifer frequently stores water in seasons and in years of heavy rain and above average recharge that can be used in seasons or years of lower recharge and lower rain fall.

In addition, however, there is the question of what is called "tenure security" which does not refer to reliability of supply, but refers to the reliability of the supply as affected by the actions of human beings. That is, how secure is the land owner from the unreasonable use or export of groundwater by his neighbor. The common law rule of absolute ownership obviously increases this tenure insecurity, because it countenances the unrestrained right of one's neighbor to pump all the water he may need, without restraint or liability to other overlying owners for any adverse effects caused by his pumping. Ciriacy-Wantrup points out that this has the economic effect of stimulating investment in groundwater development because of the uncertainty of one's property right over this "fugitive resource."[24] There is a likely incentive to each land owner to protect himself against his neighbor's otherwise lawful acts by capturing as much of the resource as quickly as possible. In other words, getting there fastest with the mostest. Therefore, there is an economic incentive for overinvestment and for depletion, rather than conservation of the resource.

Kelso, Martin and Mack elaborated on this conceptual approach stating that:

> Two aspects of water rights most significant for an understanding of man's behavior relative to water, and to one another over water are: (1) that whatever rights they hold to water and its use will be stable and dependable over a time, and (2) the flexibility

> permitted to them to effect changes in use and location of use of the water covered by their rights, and to acquire and transfer water rights from and to others ... security and flexibility are the twin essences of socially efficient property relations. 25

Thus, the twin concepts are, first, that the owners of water rights have security in the use of that right, and the second requirement, that of flexibility, relates mainly to the ease with which the water right may be transferred between uses and users. As Veeman points out, "the indefiniteness of property rights associated with a fugitive resource such as groundwater leads to its rapid development and, perhaps, depletion."[26]

Specifically in regard to the situation along the U.S.-Mexican border, it cannot be said that water users have the security of their expectations, nor can it be said that whatever rights they hold to water and its use will be stable and dependable over time. Quite the contrary; we have: 1) projections for growing population along both sides of the border; 2) a situation in which north of the border (with the exception of New Mexico) no state has legal institutions which are adequate to control pumping; 3)and no international control except at Yuma under the interim arrangement of paragraph five of Minute 242, which can prevent either nation from "stealing its neighbor's water."[27] Therefore, we have a situation which encourages each nation to outdo its neighbor by developing its groundwater resources as rapidly as possible, perhaps even to the point of depletion of the groundwater resource.

We have a legal situation which encourages overdevelopment; overdevelopment results in over investment in developing the resource and, therefore, it can be said that both economic waste and waste of the resource are likely due to the insecurity arising from inadequate institutional controls. Moreover, the increase in use by one pumper can lead to increasing the marginal cost of the second pumper. Veeman points out that, in cases where overdraft occurs,

> the private pumper who, through extraction of water, causes drawdown in nearby wells, bears only his private costs of additional withdrawal. Part of the cost of additional pumping is imposed on neighboring users whose conditions of pumping are adversely affected. In these circumstances, the private marginal costs of pumping by the individual user are less than the social marginal cost--a classic case of technological external diseconomy.[28]

In addition to the depletion of the aquifer, the extraction of groundwater can effect the quality of the water by lowering the water table or hydrostatic pressure "so as to allow adjoining, contaminated waters to flow into the reservoir."[29] Hayton projects possible economic ramifacations of deteriorating groundwater conditions as follows:

> Crop yields will decrease; there will be efforts to shift to other crops or activities in the zone, and abandonment of formerly productive economic activity. There will be increased costs to industry to treat water prior to use, or it will be necessary to bring in acceptable water from elsewhere. As the water table is lowered, there is increased consumption of energy for the additional lifting by pumps, and wells will need to be deepened or new wells sunk, to tap the same aquifer. Outmigration of the affected population and changes in gainful activities will result in dislocations affecting economic planning. ... Finally, it is likely that there will be important impacts on the development and conservation of other resources resulting from deteriorated groundwater conditions, where dependence on that source for water is significant. 30

In summarizing the history of groundwater development, Hayton says, "the general picture is one of more recent resort to groundwater ... without an adequate understanding of the physics of the resource and without regard, generally speaking, for the future."[31]

Alternative Institutional Opportunities

In suggesting possible institutional arrangements for the management of transboundary resources between the United States and Mexico, we should consider the twin criteria suggested by the economist of security and flexibility, plus the goal of the lawyer of avoiding conflict between the two countries, and the fundamental goal of the public interest "to provide for an orderly development of groundwater supplies, in the interest of the best utilization of this natural resource."[32]

We should devise a system which will reduce the likelihood of water users on one side of the international boundary adversely affecting water users on the other side of the boundary, thereby causing conflict between the two countries.

Possible Management Options

Option 1, The Status Quo Ante

Leave the situation largely as it is, following the essentially laissez faire English common law doctrine allowing each country on each side of the boundary to use and exploit the groundwater resources on its respective side as it sees fit, without regard to its neighbor. This would lead to: 1) neither of the water users having security in that resource; 2) uneconomic development of the resource by encouraging overly rapid development; 3) increased marginal cost to all exploiters of the resource; and 4) encouragement of the depletion of the resource. It, therefore, would not provide the security to the users of the resource that a good system should. Further, at some point it inevitably would lead to conflict between the two countries which, if not settled amicably by agreement, might be taken to the International Court of Justice or an arbitral tribunal. This scenario is not an attractive one, since friction between the two countries and potential for conflict would be raised to undesirable levels, and the economic waste caused by over rapid development would already have occurred, as well as undoubtedly substantial damage to the groundwater resources due to excessive withdrawals. In addition, it is always hard to assess the perils and uncertainties of resort to litigation.

Option 2, Correlative Rights

Another possible approach would be to establish the doctrine of correlative rights over transboundary aquifers, but this has serious drawbacks. The correlative rights doctrine may be viewed as a limitation on the common law rule,[33] in that, as used in California, the landowner has the right to make use of the waters underlying his lands, subject to the co-extensive and co-equal rights existing in adjoining landowners. Thus, a surface owner's right to use the underlying waters is not unlimited as in the common law rule, but limited by co-extensive and co-equal rights of the adjoining landowners.[34]

The formula for prorationing an aquifer has been expressed as follows: "in a time of shortage each landowner is said to have a share of the underlying water in proportion to the amount of land he owns as compared with the total area supplied by the common water source."[35] This prorationing of the overall pool contemplates that the total pie can be cut into smaller and smaller pieces, so that one individual piece of the pie at the time of development and investment can be reduced to the point of inefficiency. This means that the traditional doctrine contains a large element of insecurity in that there is no limit on the number of pumpers that can begin pumping at any time, since the right to exploit the water is not lost by failure to appropriate, abandonment, or disuse. The New Mexico Supreme Court, in Yeo v. Tweedy, said:

> According to the "correlative rights" doctrine, each overlying owner would have the same right--the right to use whenever he saw fit. The right does not arise from any appropriation to beneficial use, which develops the resources of the state. It is not lost or impaired by nonuse. Regardless of the improvements and investments of the pioneers, later comers or later developers may claim their rights. The exercise of those rights which have been in abeyance will frequently destroy or impair existing improvements, and may so reduce the rights of all that none are of practical value, and that the whole district is reduced to a condition of nonproductiveness. The preventive for such unfortunate and uneconomic results is found in the recognition of the superior rights of prior appropriators. Invested capital and improvements are thus protected. New appropriations may thus be made only from a supply not already in beneficial use. Nonuse involved forfeiture. A great natural public resource is thus both utilized and conserved. 36

McDougal and Haber refer to the correlative rights doctrine as one of "equalitarian rigidity" which "provides little assurance to developers unfamiliar with the hydrologic data necessary to estimate long range water supply, and takes no account of relative diversity of uses in the community."[37] Moreover, they argue that the correlative rights theory does not "succeed in removing the basic drawbacks of judicial administration of groundwater distribution. The hydrologic data required ... are difficult to obtain and the courts do not have adequate staffs to do the necessary fact gathering job"[38] to provide ongoing supervision. It might be postulated that an international agency such as the International Boundary and Water Commission could supervise a correlative rights approach, and make the necessary calculations and technical and engineering studies in order to assure that correlative rights are diminished equally as new appropriators begin to exploit the water under their land. However, it is still a situation in which the security of existing water uses would be protected inadequately, and the flexibility of transfer would be inadequate unless the traditional doctrine were significantly modified.[39]

Option 3, Management, Variation A (Equitable Apportionment)

There is a spectrum of possible variations on the option of establishing institutional mechanisms for managing the resource. One would be to grant the International Boundary and Water Commission:

1. jurisdiction over groundwaters intersected by the international boundary;
2. comprehensive authority to do the engineering studies necessary to determine such information as the area, depth to water, aquifer thickness, volume, quality, quantity, anticipated yields, transmissibility and recharge rate of an aquifer. (It should be noted that the IBWC is already gathering this kind of data. With this information, the Commission could determine allowable levels of withdrawal, in order to maintain a sustained yield from the aquifer or a calculated mining plan);
3. responsibility to identify and declare "designated international groundwater areas" which have "reasonably ascertainable boundaries;"
4. authority to apportion the waters of the aquifer and close the area to withdrawals, beyond the allowable as determined by the physical criteria of the aquifer.

This approach would follow roughly the current practice of the State of New Mexico, in which the State Engineer has jurisdiction over declared basins that have "reasonably ascertainable boundaries,"[40] and the State Engineer does have power to close these declared basins to further withdrawals.[41] The IBWC, rather than waiting for development to reach the point at which a safe yield of the aquifer were threatened, could apportion in advance the groundwaters intersected by the boundary on its own initiative. There are various alternative methods that conceivably could be suggested as guidelines in calculating the division, such as: a) the amount of water that each nation would receive could be based upon the amount of recoverable water underlying each nation, or b) the amount of water could be based upon the relative surface areas of each nation overlying the water--each nation would receive the proportionate share of the groundwater that its surface area reflected in proportion to the total surface area overlying the aquifer--but such approaches would require much more study.[42] There is in fact some international practice in apportioning shared petroleum resources.

Once the division of the groundwater was made, regardless of the method followed in arriving at the division determination, the internal administrative water machinery of each nation would be responsible for allocating that nation's share of the aquifer, according to its water laws and administrative procedures. This would have the advantage of providing security for investment in water resources on each side of the border. It would prevent the possibility of pumping wars, since each side would know with certainty how much water it was entitled to, and there would be no need to try to get there firstest with the mostest. Further, the resource would not be threatened through uncontrolled exploitation, and the potential for conflict between the two countries would be reduced.

In addition, ideally there should be flexibility for transfers of water rights from one use to another, and from one user to another, including transfers of water rights across the boundary. This, perhaps, could be accomplished by term sale arrangements, somewhat akin to a lease, so that if there were a surplus which was going unused in the allocation of one country, and the other country had an excess of demand over its allocation, it would be possible to buy the water from the other country's allocation and use the water on the other side of the border. However, realistically, one would have to suggest that not only would such a transfer be politically impossible, but also probably legally impossible under existing law that would have to be preempted by a treaty. For example, New Mexico law prohibits such transfers.[44]

Option 3, Management, Variation B (Case by Case Negotiation)

Granting the IBWC power to identify and declare "designated international groundwater areas" and authority to apportion the waters of such designated aquifers will be controversial and undoubtedly strongly opposed. The difficulty in obtaining such a treaty cannot be overestimated. Therefore, a less far reaching option than variation A would be a case by case or aquifer by aquifer approach. Individual agreements would be negotiated for each groundwater area as problems arose, using a variety of engineering and legal measures including the negotiated apportionment of the waters of the aquifer. The approach would vary from basin to basin and agreements, therefore, would have to be negotiated on a basin to basin basis.

This we could call the pragmatic, case by case, option--pragmatic both politically and technically. This, in fact, is a description of the present state of affairs. We have dealt with the pumping in the Yuma area by limiting pumping within 5 miles of the border to 160,000 acre feet per annum, under Minute 242. That is a localized legal measure, and we are installing a protective pumping program in the area. This is an example of an individualized technical solution. In addition, the IBWC is carrying on a data exchange program and ongoing aerial surveillance program to identify groundwater developments and potential trouble spots. The IBWC is keenly aware of possible stress points such as in the El Paso-Ciudad Juarez, Nogales, and Colorado River Delta areas.

The problem with such an ad hoc, basin to basin and treaty to treaty approach is that it is so difficult to get on the national agenda that problems tend not to get on the agenda until a crisis is reached. If it were politically possible, it would be desirable to give the IBWC ongoing authority to designate groundwater areas and, therefore, control over withdrawals before the crisis point is reached.

Option 3, Management, Variation C (Comprehensive Management)

Give the International Boundary and Water Commission the complete spectrum of administrative powers from investigation and planning to rule making and enforcement. This would put them not only into the investigative, engineering, and planning functions, but also into the regulatory and enforcement end of the administrative process. This, perhaps, would be the ideal approach, but the least likely to be accepted. It would empower the IBWC to control withdrawals, and thereby preserve the resource, providing security to water users at the time, and it would allow the IBWC to plan for and carry out ongoing policies which would be responsive to changing conditions. Undoubtedly this would be objected to as the creation of a super agency, and would expose the IBWC to the criticism and controversy caused by an international agency being placed in the enforcement business inside the domestic boundaries of a sovereign nation.

Option 4. International Litigation

Whichever of the above options, or combinations of options, might be chosen, undoubtedly it would be better for the two countries to reach agreement on a binational basis rather than allowing the problem to become so intense as to require litigation before the International Court of Justice or a tribunal of arbitration,[45] with all of the perils, uncertainties, and delay that litigation entails.[46]

The problem, succinctly stated, is that there is a limited supply of groundwater along the international frontier, and we are facing the prospect of greater demand because of increased population. It would be highly desirable that we could be rational enough to anticipate the situation before it reached the proportions of a crisis. We should, by agreement, establish the means for managing the resource and avoiding damaging dispute between the two countries. Paragraph 5 of Minute 242 contemplates such an agreement.[47]

The courts, too, undoubtedly would prefer that the parties settle the matter between themselves rather than resorting to litigation. A recent example of this judicial attitude is the North Sea cases, in which the International Court of Justice sent the cases back to the parties for negotiation and agreement on their maritime boundaries in the North Sea.[48] Our own United States Supreme Court made the point clearly in a water quality case when it said, "We cannot withhold the suggestion ... that the great problem of sewage disposal ... is one more likely to be wisely solved by cooperative study and by conference and mutual concession on the part of representatives of the states so vitally interested in it than by proceedings in any court, however constituted."[49] The Court, in Colorado v. Kansas, further elaborated on the point by saying:

> The reason for judicial caution in adjudicating the relative rights of states in such cases is that ... they involve the interests of quasi-sovereigns, of interstate differences of a like nature, that such mutual accommodation and agreement should, if possible, be the medium of settlement, instead of the invocation of our adjudicatory power. 50

Ward Fischer concludes that, in regard to interstate groundwater problems in the United States, there are "two apparently viable alternatives ...: the interstate compact, and litigation between the states."[51] However, he is pessimistic in his assessment of the likelihood of the states reaching agreement before the crisis point is reached and resort has to be made to the courts:

> Our conclusion must be that the interstate compact is by far the most effective, most sound, most flexible, and overall most satisfactory approach that can be recommended. Regretably, our conclusions also must be that, between these two alternatives, it is the less likely; that litigation between the states resulting in equitable apportionment of available groundwaters can be expected, unless there is nonprecedent awakening to responsibility and to reality among the water users and water administrators of the affected states. 52

The record of dealing with joint water problems between the United States and Mexico is a good one, and leaves some room for hope, and even perhaps optimism, that Mexico and the United States might be able to handle the problem in advance by agreement, rather than by resort to international litigation. "In any event, we must expect that our international conflicts will not be limited to surface waters, but rather that, sooner or later, we must grapple with the depletion and pollution of international underground waters."[53]

In the event a groundwater question between Mexico and the United States were referred to litigation, the court undoubtedly would conclude that a nation does not have absolute territorial sovereignty, that it cannot act in disregard of its neighbor.[54]

The position of the U.S. Supreme Court in the interstate water litigation between Wyoming and Colorado would be eminently appropriate; the Court concluded:

> The contention of Colorado that she, as a State, rightfully may divert and use, as she may choose, the waters flowing within her boundaries in this interstate stream, regardless of any prejudice that this may work to others having rights in the stream below her boundary, cannot be maintained. The river throughout its course in both states is but a single stream, wherein each state has an interest which should be respected by the other. 55

The International Court, if given the case by agreement of the parties, would no doubt look with favor upon the language of the U.S. Supreme Court[56] in a suit by Kansas against Colorado for equitable apportionment of the Arkansas River. The Court said:

> Whenever ... the action of one state reaches, through the agency of natural laws, into the territory of another state, the question of the extent and the limitations of the rights of the two states becomes a matter of justiciable dispute between them, and this court is called upon to settle that dispute in such a way as will recognize the equal rights of both and at the same time establish justice between them. 57

The much quoted International Trail Smelter Case, although it deals with air pollution, also would be relevant in its language that states "that under the principles of international law ... no state has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another ... when the case is of serious consequence and the injury is established by clear and convincing evidence."[58] Thus, an international tribunal undoubtedly would reject the international law equivalent of the common law doctrine--absolute territorial sovereignty. It would, instead, look to the Helsinki Rules for guidance in settling a case on the basis of equitable utilization.[59] The Helsinki Rules provide that:

> (2) Relevant factors which are to be considered include but are not limited to:
>
> > (a) the geography of the basin, including in particular the extent of the drainage area in the territory of each basin State;
> >
> > (b) the hydrology of the basin, including in particular the contribution of water by each basin State;
> >
> > (c) the climate affecting the basin;
> >
> > (d) the past utilization of the waters of the basin, including in particular existing utilization;

> (e) the economic and social needs of each basin State;
>
> (f) the population dependent on the waters of the basin in each basin State;
>
> (g) the comparative costs of alternative means of satisfying the economic and social needs of each basin State;
>
> (h) the availability of other resources;
>
> (i) the avoidance of unnecessary waste in the utilization of waters of the basin;
>
> (j) the practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses; and
>
> (k) the degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State.

> (3) The weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable share, all relevant factors are to be considered together with a conclusion reached on the basis of the whole. 60

Similarly, the U.S. Supreme Court has said that equitable apportionment:

> calls for the exercise of an informed judgment on a consideration of many factors. Priority of appropriation is the guiding principle. But physical and climactic conditions, the consumptive use of water in several sections of the river, the character and rate of return flows, the extent of established uses, the availability of storage water, the practical effect of wasteful usage on downstream areas, the damage to upstream areas as compared to the benefits to downstream areas if a limitation is imposed on the former--there all are relevant factors. They are merely an illustrative, not an exhaustive, catalogue. They indicate the nature of the problem of apportionment and the delicate adjustment of interest which must be made.[61]

The problem with litigation is that the question is referred to the court as a last resort when the crisis already has been reached. The courts deal in a case by case, after-the-fact, manner, and are not in a position to anticipate the problem, and to engage in the long term planning and management of the resource that is desirable in order to use it optimally.

Further doubts about leaving groundwater questions to the courts were raised some years ago by McDougal and Haber as follows:

> The hydrologic data required for adequate information about supply, evaporation, and movement of groundwater are difficult to obtain, and the courts do not have adequate staffs to do the necessary fact gathering job. Consequently, the parties must supply the experts, at great expense. ... Moreover, the courts have a long record of ignoring scientific development in this field and certainly are not expert agencies from an engineering perspective. ... 62

However, the most important shortcoming of the courts is the after-the-fact ad hoc nature of their jurisdiction. Tribunals are not equipped to provide the ongoing investigative and administrative machinery required to manage the resource.

As the U.S. Supreme Court itself said in Colorado v. Kansas, water cases "present complicated and delicate questions, and due to the possibility of future change of conditions, necessitate expert administration rather than judicial imposition of a hard and fast rule."[63]

Conclusions

Perhaps the option most likely to be accepted of the various alternatives that might be considered would be a compromise position between the utopian international commission with the complete panoply of powers from investigation and planning to regulation and enforcement and the existing status quo of awaiting the crisis.

A relatively objective and therefore, perhaps, acceptable approach would be one that provided the means for an equitable apportionment of transboundary groundwaters, leaving the actual planning, distribution, regulations, and enforcement of each country's share to that country.

Ward Fischer, in discussing interstate compacts, says that one of the basic decisions:

> required in the development of any particular compact is that between allocation v. management. Should the compact provide that each state is allocated a specific quantity of water? Or, on the other hand, should the states agree that the water resource is one that should be subject to year-to-year or decade-to-decade management, without specific quantities of water allocated to the participating states? Allocation in the absolute quantities or in percentages is the simplest solution. Management is no doubt the best, allowing, for example, planned recharging of the underground water resource for the ultimate greater benefit of all the states. 64

The allocation option is likely to be the simplest for international groundwaters as well. Specifically, this has been the model followed in the case of surface waters shared by the U.S. and Mexico. We have divided the waters of the Rio Grande and Colorado by quantity, leaving the actual administration of each country's amount to each respective country.[65]

Therefore, the skeletal outlines of a procedure might be as follows:

1) The IBWC be empowered to declare any groundwater resource that is divided by the international boundary to be a "designated international groundwater area" when in its judgment: a) demand is likely to exceed recharge so as to endanger sustained yield or water quality due to salt water intrusion; b) groundwater withdrawals are likely to affect or be interrelated with surface waters previously allocated by Treaty[66] or c) the prudent management of the groundwater resource including the decision to mine groundwater makes such designation desirable.[67]

2) Upon declaring a "designated international groundwater area" (DIGWA) and after carrying on the necessary engineering studies, the IBWC shall equitably apportion the "designated groundwater area" between the two countries using established engineering criteria. The IBWC will first obtain information concerning aquifer thickness, saturated thickness, depths, area, quantity and quality of the area, as well as transmissibility, permeability, recharge rates, and other pertinent hydrologic data, before apportioning the waters of the designated area.

Using this data, it will then apportion the water, bearing in mind:

1) the geography of the area, including each nation's proportion of total surface area overlying the "designated international groundwater area;"

2) the hydrology of the area including: a) each nation's proportion of the total volume of the water in the DIGWA which lies within that nation's territory; b) the contribution of recharge by each nation; and c) other relevant, hydrologic considerations;

3) pre-existing utilization by each state;

4) in the event of prolonged drought which in the judgment of the Commission significantly affects recharge, the Commission shall be authorized to reduce the total allowable withdrawal from the "designated international groundwater area" for so long as the Commission deems necessary and each nation's withdrawal shall be accordingly reduced proportionally.[68]

Each of these items can be determined with a reasonable degree of certainty and would provide an objective basis for apportionment. They incorporate some of the central concepts of the Helsinki rules and avoid the complexities of some of the more subjective criteria of the Helsinki rules such as:

> (e) the economic and social needs of each basin state; ...
>
> (i) the avoidance of unnecessary waste in the utilization of waters of the basin; ...
>
> (k) the degree to which the needs of a basin state may be satisfied, without causing substantial injury to a co-basin state. 69

However, in making the decision of whether to mine or not to mine, it would be necessary, certainly, to consider the economic and social needs of the countries.[70]

Some General Considerations

A) The Interrelationship of Surface and Groundwaters

In the management of international groundwaters, it is essential to recognize the interrelationships between surface and groundwaters which frequently are interconnected.

Contrary to hydrologic reality, the law frequently has made distinctions which separate surface waters from underground waters and "percolating waters" from definite underground channels. These distinctions fail to recognize the interrelationships between surface and underground waters and have been characterized as attempts to restate the "physical universe."[71]

Scientists have criticized themselves and the law on this subject:

> Man has coped with the complexity of water by trying to compartmentalize it. The partition committed by hydrologists--is as nothing compared with that which has been promulgated by the legal profession, which has on occasion

> borrowed from the criminal code to term some waters "fugitive" and others "a common enemy." The legal classification of water includes "percolating waters," "defined underground streams," "underflow of surface streams," "water-courses," and "diffuse surface waters;" all these waters actually are interrelated and interdependent, yet in many jurisdictions unrelated water rights rest upon this classification. 72

In view of the agreed upon allocations of surface waters for the Rio Grande and Colorado and the example of the Santa Cruz River upon which both Nogales, Sonora and Nogales, Arizona depend,[73] it is absolutely essential that the interrelationship between surface and groundwaters be recognized.[74] As Thomas and Luna point out,

> We have been discussing ground water more or less as if it were separate and distinct from the rest of the hydrologic cycle. Such segregation has been common among hydrologists as well as the general public, and is reflected in legislation, in the division of responsibility among government agencies, in development and regulation. Yet it is clear that this isolation can be maintained only when and where water is being mined from underground storage. Any water pumped from wells under equilibrium conditions is necessarily diverted into the aquifer from somewhere else, perhaps from other aquifers, perhaps from streams or lakes, perhaps from wetlands--ideally, but not necessarily, from places where it was of no use to anyone. There are enough examples of streamflow depletion by ground water development, and of ground water pollution from wastes released into surface waters, to attest to the close though variable relation between surface water and ground water. 75

Thus, the IBWC will undoubtedly have to treat differently two major classifications of groundwaters: those that are tributary to surface water flows and those which are not tributary, or more precisely, those which are interrelated to surface water flows (which would include, for example, the Santa Cruz, which is tributary to the groundwater supply) and those which are not connected hydrologically with any identifiable surface stream or lake.[76]

In fact, the Rio Grande itself already has provided extensive hydrologic and institutional experience concerning the interrelationships between surface flows and the associated alluvial groundwater system. Hydrologic studies have shown "an intimate hydraulic relationship between the Rio Grande and adjacent groundwater reservoirs. There are extensive sedimentary rocks adjacent to the river ... which form the principal aquifer adjacent to the river. This aquifer is recharged directly by precipitation, by lateral flow of water from adjacent formations, by seepage from Rio Grande tributaries, and in some areas from seepage from the Rio Grande mainstream."[77]

Pumping from groundwater flows thus can have direct affects on surface water flows which can be calculated, once the characteristics of the aquifer are known. Using the formula devised by C.V. Theis,[78] the State Engineer of New Mexico has devised a system of administration which allows new appropriations of groundwater in the Rio Grande basin in New Mexico only "under the condition that the appropriator acquire and retire from usage surface water rights in amounts sufficient at each point in time to compensate for the increasing effects of his pumping on the stream."[79] This conjunctive administration of surface and groundwaters protects prior users of both, and has been upheld by the courts.[80]

B) The Concept of Safe Yield

As Robert Emmet Clark succinctly points out, "all water being pumped from below the earth's surface is either being replaced at measurable or discernible rates, or it is not." Where withdrawal exceeds recharge, the water is being mined and

> thus all ground water pumped is either "mined," i.e., extracted for certain purposes over a relatively short period of time, or it is withdrawn as "milked" from nature's aquifers with some view to continued use for a long or indefinite period ... 81

The term "safe yield," although often criticized, has been used in this paper and elsewhere to indicate generally the "milking" of underground water at rates which would allow for continued use in the future.

A good definition of safe yield or sustained yield is provided in Groundwater Resource Valuation:

> The practical sustained yield is the amount of water which can be withdrawn annually without producing undesirable effects. The practical sustained yield may be limited to an amount less than recharge but cannot exceed the long-term mean annual recharge. ...[82]

The term safe yield is often criticized and frequently avoided in the hydrologic literature because of its uncertainty. Corker points out that:

> it has come to be recognized that the quantity of water which can be extracted annually from a reservoir--surface or underground--depends on both hydrologic and non-hydrologic factors, and that neither hydrologic nor non-hydrologic factors can be determined or predicted precisely. 83

Non-hydrologic factors include economic and legal considerations (such as prior water rights).[84]

C) Flow vs. Stock Resources

A useful concept is the distinction between flow and stock resources. Flow resources are self-replenishing, and would include those groundwaters which are being recharged on a continuing basis as part of the hydrologic cycle of precipitation and evaporation. It is these groundwaters which one would try to use on a "sustained yield" basis.

However, there are aquifers with small recharge, but with large amounts of water in underground storage which "for all practical purposes ... has been sidetracked from the hydrologic cycle and is no longer in transit. In human time, at least, it is not a self-replenishing, but an exhaustible resource, similar to petroleum and other minerals.

These non-replenishing groundwaters are, for all practical purposes, exhaustible "stock resources;" they are not being replenished, and thus continued extraction will lead in time to their complete exhaustion.[85] When exhaustion occurs, or when further mining becomes impractical, the economic activities and other uses dependent upon that supply must turn to other sources or be abandoned. As Bagley points out:

> With a stock resource the decisions to be made are whether and when to use it. A property rights doctrine should recognize that rights to such resources do not involve a perpetual supply. It should permit a decision to hold the stock for use at a later time if it is so desired.
>
> In a flow resource the problem is to make the best use of the supply which is continuously available though not necessarily, and in the case of water ordinarily not, at a constant rate. ... 86

Thus, the concept of sustained yield is useful for aquifers recharging on a continuing basis, and the concept of mining is appropriate for "stock resource" underground waters which are not receiving significant recharge.

D. Management of Groundwater Mining

It is worth making special note of the merit of considerations involved in rationally deciding to mine groundwaters in appropriate circumstances.

Wells Hutchins has postulated that a principal purpose of groundwater laws should be "to provide for an orderly development of groundwater supplies, in the interest of the best utilization of this natural resource[87] and that these laws ordinarily, therefore, do not sanction diversions that would affect adversely the "complete development of the safe yield found to exist in the area,"[88] in order to preserve the water supply in perpetuity. This is an admirable statement when related to "flow" groundwaters, but what of "stock" groundwaters?

As Steve Reynolds points out, it must not be overlooked that in some situations as a matter of policy "the mining of water can be justified in the same way as the mining of non-renewable mineral resources such as uranium, oil, or coal. It is not practical to operate a groundwater basin on a continuous yield basis when the amount of water in storage is very large compared to the annual recharge."[89]

Thus, the decision with respect to "stock" groundwaters is "whether and when to use"[90] them, in that they are not a replenishing, perpetual supply. In order not to oversimplify, it must be pointed out that flow resource groundwaters can be mined too--that is, when withdrawals exceed recharge--and this frequent practice is what actually gave rise to the conservation concept of sustained yield.

There may be situations where it is advisable to "mine" water in basins where there is significant but inadequate recharge to meet water needs. However, such decisions should be made consciously and with knowledge of the economic and social consequences, and an appreciation of the fact that the options of future generations will be limited.

Corker argues that sustained yield should not be a sacred principle, that the decision to mine can be a rational alternative, but that "'Safe yield'--if a proper term can be discovered, or if the old term can be acceptably defined--should be the basis of operation of every groundwater resource"[91] until the decision to mine is made consciously and with full knowledge of its implications.

Such decisions have to be made after thorough investigation and consideration, and the development has to be in an orderly, rational manner; this is particularly so where the groundwater resource is divided by an international boundary, in view of the fact that depletion of the resource and the consequent damage to the other country cannot easily be corrected by natural recharge and at least "stock" groundwaters, once removed, are for all practical purposes gone forever.[92]

Such considerations as the spacing of wells, the rate of drawdown, and the apportionment of each country need to be carried out according to a reasoned development plan.[93]

The New Mexico Supreme Court has recognized the validity of mining groundwaters for reasoned policy goals and, at the same time, recognized the need for careful management of such mining.

> The administration of a non-rechargeable basin, if the waters therein are to be applied to a beneficial use, requires giving to the stock or supply of water a time dimension, or, to state it otherwise, requires the fixing of a rate of withdrawal which will result in a determination of the economic life of the basin at a selected time.
>
> The very nature of the finite stock of water in a non-rechargeable basin compels a modification of the traditional concept of appropriable supply under the appropriation doctrine. Each appropriation from a limited supply of non-replaceable water of necessity reduces the supply in quantity and shortens the time of use to something less than perpetuity. Each approiator, subsequent to the initial appropriation, reduces in amount, and in time of use, the supply of water available to all prior appropriators, with the consequent declines of the water table, higher pumping costs, and lower yields. 94

In areas declared to be "designated international groundwater areas" by the IBWC, the commission should apportion the waters and rate of withdrawal, since the "Time dimension"[95] is an essential aspect of the apportioned water right.[96] Particularly in closed or non-tributary areas, the capability to plan depletion over a calculated period is essential. Often the hydrologic and economic considerations are quite complicated. As an example of the type of factors that must be considered, the State Engineer of New Mexico suggests that if it were determined to set a fixed "life" for a basin and then apportion the water by fixing the annual rates for each nation, deferral of development would be discouraged and there would be a race to achieve the allowed rate of withdrawal at the earliest time to maximize the quantity that could be taken within the "life" of the basin. On the other hand, if there is no limitation on the annual rate, that nation which takes its allocated quantum at a slower rate will have greater pumping lifts and possibly a worse quality of water; this could be mitigated by imposing a reasonable limitation on the annual rate of withdrawal as well as specifying the quantum allocated to each nation. In most situations, it probably also would be useful to require some areal distribution of withdrawals, to insure that one country does not damage the other (and perhaps itself) by concentrating its withdrawals along the international boundary.[97]

Fortunately, the Commission has that capability. The IBWS has the staff, resources, and experience to call on various disciplines for input. As Hayton puts it: "as war is too important to be left to the generals, water law is too important to be left to the lawyers (or engineers or economists) alone. Initial inputs and along the way review ... should be elicited from the relevant disciplines, to ensure the economic, engineering, and administrative soundness ..." of the decision.[98] Also, input from those most affected by the decision would appear to be appropriate through some sort of hearing process.

E) <u>Criticism of Equitable Apportionment</u>

This approach of dividing the waters does not place a comprehensive planning power in an international agency and, therefore, can be criticized for not striving for "optimum utilization."[99] This is a valid criticism. Rather than "optimum utilization," this option seeks "equitable apportionment," a quantitative division of available supply. Such a division of the waters is simpler and, perhaps, politically possible. Even this will be a difficult achievement.[100] Equitable apportionment in the Mexico-U.S. case would have the advantage of:

1) Certainty (through quantification each nation would know its entitlement and could plan, grow, and develop accordingly.) As one commentator has said, "maximum development of water resources depends in large measure upon the principle of certainty;"[101]

2) Political accountability (within each nation there would be control over the decision-making of how that nation's share should be allocated and used.) Thus, this decision-making process would be subject to the ordinary political process of each country.[102]

3) The strength and reputation of the IBWC would be protected from the abrasions that would be incurred by periodic adjustments, not to mention day to day water administration within the boundaries of the sovereign nations;

4) The potential for dispute between the two countries would be reduced greatly;

5) And, of course, of elemental importance, equitable apportionment just

might be politically possible; proposing anything more would border on utopian unreality.

F) The Need for Flexibility

Perhaps the major shortcoming of an equitable apportionment immutably enshrined by a decision of the IBWC, for example, is that of inflexibility. As new information becomes known, determinations such as the boundaries and recharge sources of a particular aquifer, or rate of recharge or sustained yield may need to be adjusted. Walton points out that: "It is seldom that any single value of practical sustained yield can be correct for an extended time, in part due to changing economic conditions."[103]

In order to be responsive to changing conditions and new knowledge, it would be desirable to provide the Commission with authority for periodic review and adjustment. Reopening for further consideration decisions previously made has the potential for being disruptive--often it is better to let sleeping dogs lie--but the complexity of the hydrologic and economic factors indicates the need for some periodic review and the power to make adjustments, even at the expense of certainty and political tranquility. It would appear that basic apportionment decisions should not be tampered with except in extraordinary circumstances, but determinations concerning sustained yield and decisions of whether to mine or not, and at what rate, could well be adjusted with changing conditions and information.

G) Necessary Preliminary Action

In order to obtain the hydrologic and geographic data necessary for the declaration of "designated international groundwater areas," specific actions need to be taken. Robert Emmet Clark suggests specifically that:

1. The International Boundary and Water Commission carry out "a joint research program which would include an inventory of groundwater supplies, detail the areas of availability and present uses. The program should include the study of non-tributary sources and other surface and groundwaters that are interdependent. ...

3. This program, coordinated on both sides of the border, should include the drilling of strategic test wells, well metering, and record keeping which will encompass water quality matters. Selected areas of heavy demand and diminishing supplies should be studied first, particularly in the heavily populated areas...."[104]

In fact, the IBWC is carrying on an inventory of groundwater supplies, and is exchanging data between the U.S. and Mexican sections of the Commission.

Included in the inventory of groundwater supplies and present uses should be the identification and registration of all existing wells. Ideally, there should be compulsory metering and testing of all wells exceeding a specified capacity.[105] With this inventory of existing uses and demand, combined with the hydrologic inventory of groundwater supply and quality, the safe yield could be projected or a "calculated program of mining water supply developed."[106] The IBWC then could declare a "designated international groundwater area," apportion the resource between the nations, and so control withdrawals according to the apportionment and the projected yields or calculated depletion program.

In areas where there is inadequate data, the IBWC would await the development of data from other sources and the completion of its own studies.

This would allow the IBWC to phase its activities with the development along the border, utilization of the resource, and availability of information.

As the physical resources of each area become understood, the IBWC could declare additional "designated international groundwater areas," in order to ensure the prudent utilization of the groundwater resources divided by the international boundary.

H) Enforcement

The actual allocation, administration, and enforcement of water rights within each nation's portion of water in a "designated international groundwater area" would be within the national jurisdiction of that nation and its appropriate political subdivisions.

In addition, there should be a generally overriding, supervisory power lodged in the IBWC to ensure that each nation lives within the total water budget allocated to it by the basic apportionment.

To take the words of Professor Clark,

> There must be administrative authority which is broad enough to carry out the policies of the two countries implemented through the international agency, and this authority must be strong enough to enforce policies designed for particular groundwater areas along and near the border. 107

Basic to the monitoring process of the Commission is the continuing acquisition of information obtained from the metering of wells. "There must be a system of measurement of withdrawals from wells. Records must be kept of withdrawals over time, and the Commission must be able to assure that withdrawals do not exceed allocated amounts in the designated international groundwater areas which are based on calculated mining programs or determined safe yield in terms of water quality and water quantity--specifically the prevention of salt water intrusion."[108]

The Commission's existing treaty authority and established diplomatic channels could be looked to to settle disputes that might arise with respect to the interpretation or application of the treaty.[109]

FOOTNOTES

1. Robert D. Hayton, The Ground Water Legal Regime as Instrument of Policy, Objectives and Management Requirements, 2 Annales Juris Aquarum 2d Int'l. Conf. on Water Law & Admin., 242, Caracas, Venezuela, 8-14 Feb. 1976.

2. Clark, Institutional Alternatives for Managing Groundwater Resources, 18 Nat. Res. J. 153 (1978).

3. Burman and Cornish, Needed: a Groundwater Treaty Between the United States and Mexico, 15 Nat. Res. J. 382 (1975).

4. It has to be noted, however, that the International Boundary and Water Commission has done a remarkable job in resolving groundwater problems to date with a minimum of treaty mandate or international practice as precedent. See also discussion infra at note 11.

5. Clark, supra note 2.

6. L. Teclaff, Abstraction and Use of Water: a Comparison of Legal Regimes. 62 UN E.72 II A 10 (1965); See Art. 27, Mexico Constitution (1917); Constitucion Politica de los Estados Unidos Mexicanos (Mexico, Camara de Senadores 1962) (English translation of text, p. 165); Mexico, Art. 9 & Art. 10, Law of 29 December 1956, Implementing Paragraph 5 of Art. 27 of the Constitution, Concerning Groundwaters.

7. See Day, International Aquifer Management: The Case of the El Paso Juarez Valley, 18 Nat. Res. J. 163 (1978); Bradley and DeCook, Ground Water Occurrence and Utilization in the Arizona-Sonora Border Regions, 18 Nat. Res. J. 29 (1978); and Alba, Condiciones y Politicas Economicas

en la Frontera Norte de Mexico, 17 Nat. Res. J. 571 (1977).

8. Three examples will serve to illustrate the possibilities for conflict over U.S.-Mexican groundwater resources.

Example One. Near San Luis, Sonora, a well field was put into operation in 1972. The field contains 63 wells with pumps and concrete lined laterals. The water is collected in a canal, westerly to San Luis, for irrigation. This pumping by Mexico from the underground reservoir tends to deplete groundwater underlying both the United States and Mexico. The groundwater basin is straddled by the international boundary. Further, the water being pumped on the Mexican side came originally from the Colorado River, in that the water used to irrigate the mesa lands in the Yuma area was diverted from the Colorado. After being placed on the fields in Arizona, it gradually percolated down, forming a mound of groundwater. Since Mexico was pumping water from this underground base, they really were taking Colorado River water which was not charged against the Mexican allocation under the Treaty of 1944, "since underground flow across the border is not considered as "deliveries in satisfaction of the Treaty." Bradley and DeCook, _supra_ note 7. In order to avoid a "pumping war" between the two countries, the governments of the United States and Mexico have agreed to limit to 160,000 acre feet annually pumping of groundwaters within five miles of the Arizona-Sonora boundary near San Luis.

Example Two. In the Nogales region, both the city of Nogales, Sonora, and the city of Nogales, Arizona, are supplied by groundwater for their municipal and industrial uses. On the Mexican side, there are well fields along the Santa Cruz River to supply the city of Nogales, Sonora. On the Arizona side, five wells supply the city of Nogales, Arizona. The Santa Cruz River, which rises in Arizona, flows into Sonora and then loops back into Arizona so that the city of Nogales, Sonora, is in fact upstream to the city of Nogales, Arizona. The wells of the city of Nogales, Arizona, show an immediate response to river flows in the Santa Cruz, so that the depth of water in the city's wells fluctuates from thirty feet to eighty feet. Thus, with both cities really looking to the same limited water supplies for their survival, one readily can see there is potential for conflict between the two countries as population continues to grow on both sides of the international boundary. *See* Bradley and DeCook, *supra* note 7, at 36.

Example Three. The metropolitan area of Ciudad Juarez, Chihuahua, and El Paso, Texas, has nearly one million inhabitants. Both cities depend largely on shared groundwater reservoirs for their municipal water supplies. Studies indicate that both sides now are pumping water at a rate faster than the groundwater reservoir is being recharged. *See* Day, *supra* note 7.

9. Hayton, *supra* note 1, at 275.

10. Clark, *Western Ground Water Law*, 5 WATERS & WATER RIGHTS 411 (R. Clark, ed., 1972). Also see Harnsberger, *Nebraska Ground Water Problems*, 42 Neb. L. Rev. 721 (1963); Moses, *The Law of Ground Water: Does Modern Buried Treasure Create a New Breed of Pirates*, 11 Rocky Mt. Min. L. Inst. 277

(1966); Fischer, Management of Interstate Groundwater, 7 Nat. Res. Lawyer 521, 523 (1974); Teclaff, supra note 6, at 57.

11. U.N. Treaty Series, No. 8054, p. 188 (1966).

12. Id. at Footnote to Article 2.

13. Paragraphs 5 & 6, 69 Dept. of State Bull. 396 (1973); Reprinted in 15 Nat. Res. J. 2 (1975).

14. Hayton, supra note 1, at 242.

15. Teclaff, supra note 6, at 57.

16. Hayton, supra note 1, at 278; see also Food & Agriculture Organization of the United Nations, Las Leyes de Aquas en Sud America, Rome, 1956, by Cano and Vargas-Galindez, Agriculture Development Paper No. 56; and Teclaff, supra note 6.

17. Hutchins, Reasonable Beneficial Use in the Development of Ground Water Law in the West, Comm. on the Econ. of Water Res. Dev. of the Western Agric.-Econ. Research Council, and Western Reg. Research Comm., Ground Water Econ. and the Law, Report No. 5 at 24 (1956). (Emphasis added).

18. Tyler, Underground Water Regulations in Texas, 532 Tex. Bar J., June 1976.

19. Hayton, supra note 1, at 242.

20. See Ciriacy-Wantrup, RESOURCE CONSERVATION, ECONOMICS AND POLICIES, 141-45 (3d ed. 1968).

21. Ciriacy-Wantrup, *supra* note 20, at 142.

22. T. Veeman, Water Policy and Water Institutions in Northern India: The Case of Ground Water Rights. Paper to be published 18 Nat. Res. J. (1978).

23. Ciriacy-Wantrup, *Concepts Used as Economic Criteria for a System of Water Rights*, (Smith & Castle, eds.), ECONOMICS AND PUBLIC POLICY IN WATER RESOURCE DEVELOPMENT 251-71 (1964).

24. Ciriacy-Wantrup, *supra* note 23 at 258-60.

25. Kelso, Martin & Mack, *Owner Supplies and Economic Growth in an Arid Environment: An Arizona Case Study*, 52 and 54 (1973).

26. Veeman, *supra* note 22, at 20.

27. Tyler, *supra* note 18, at 532.

28. Veeman, *supra* note 22, at 24.

29. Fischer, *supra* note 10, at 521-22.

30. Hayton, *supra* note 1, at 286.

31. Hayton, *supra* note 1, at 275.

32. Hutchins, *Selected Problems in the Law of Water Rights in the West*, U.S. Dept. Agric. Misc. Publ. No. 418 (1942).

33. Clark, *supra* note 10, at 413.

34. W. Hutchins, 2 Water Rights Laws in the Nineteen Western States 670 (1974).

35. McDougal and Haber, PROPERTY, WEALTH, LAND (1948).

36. 34 N.M. 611, 620, 286 P. 970 (1929).

37. McDougal and Haber, _supra_ note 35.

38. _Id_. The development of the law and management of oil and gas provides some historic parallels. William Onorato traces this development and points out that the early law of unregulated production or unrestricted capture gave way to the doctrine of correlative rights and duties between owners in a common source. And that the doctrine of correlative rights in turn has been replaced by rules "requiring cooperative development of a shared petroleum resource pool. ... The laws of a majority of oil-producing nations specifically provide that when an oil-bearing structure is located in two or more tracts belonging to two or more different owners and thus the source of dispute between them is to apportionment, the interested parties are obliged to adopt a unitised plan of development under which competition is now altogether eliminated and cooperation is required on coordinating such points as number and spacing of wells tapping the common source. Onorato, Apportionment of an International Common Petroleum Deposit, 17 Int'l. and Comparative L. Quarterly 85, 92 (1968).

39. Corker points out that there is nothing sacrosanct about a particular doctrine which should make it immutable. For example, there is nothing

inherent in the doctrine of correlative rights which would make it impossible to limit the total number of water users, or provide for forfeiture or abandonment, but unfortunately it seems that "a doctrinal label brings an automatically prepackaged assortment of rules ..." C. Corker, Groundwater Management & Administration, Nat'l. Water Comm'n., Legal Study No. 6, 112 (1971).

40. N.M. Stat. Ann. §75-11-1 (Supp. 1963). Also, this proposal is not unlike the 1973 Oklahoma statute (Okla. Stat. Ann. tit. 82, §1020.5) (Cum. Supp. 1976) which, in Clark's words "proposes to assign each landowner a specific quantity of water based on a percentage of the hydrologically determined yield of the basin. His allocation is to be measured, acre for acre, by the relationship his ownership bears to the total acreage overlying the basin. Under this system, each landowner receives a quota, as it were, which he can retain or dispose of and which will exhaust his interest." Clark, <u>The Role of State Legislation in Ground Water Management</u>, 10 Creighton L. Rev. 469, 482 (1977).

41. For further discussion, see Clark, <u>New Mexico Water Law Since 1955</u>, 2 Nat. Res. J. 484, 496 (1962).

42. The formula for division might be a variation of the correlative rights prorationing formula: each country would have a share of the underlying water in proportion to the amount of its land supplied by the groundwater source within the designated groundwater area as compared to the total area supplied by the groundwater source. This approach is designed for agricultural uses, and does not comfortably suit an urban

situation or mixed agricultural-urban context.

A corrolary formula might be: each country would have a share of the underlying water in proportion to the amount of water presently being beneficially used by it as compared with the water being beneficially used by the other country. This would appear to have serious objections in freezing the future use patterns in conformance to existing patterns. Also, the division could be based upon the guidelines of the Helsinki Rules regarding surface waters. See discussion at note 57 infra.

If the parties were unable to reach agreement on the division of the water, it might be useful to borrow a lead from the last best offer concept of labor relations. Under this concept, each nation could choose one member of an arbitration panel, and then those two would select a third arbitrator with the power to choose the proposal he considered most equitable, each nation submitting a proposal of what it considered to be an equitable division of the aquifer. The presiding arbitrator would determine which offer he considered most fair; he would not be able to amend the offer, or to compromise between the two offers, thereby assuring each nation would be motivated to present as reasonable an offer as possible, thus bringing the proposals of the two nations relatively close to each other because an unreasonable or extreme offer would stand no chance of being accepted.

43. Onorato reports on two binational agreements:

> "... the agreement between the Federal Republic of Germany and the Kingdom of the Netherlands on apportioning common petroleum deposits in the Ems River estuary, and the agreement between Austria and Czechoslovakia co-ordinating

> exploitation of a common field of natural gas in the Zwernsdorf-Vysoka frontier region between the two countries.
>
> ... The former agreement between Germany and Holland provides for joint development of any common petroleum fields found to exist in the frontier area of the Ems River estuary. The agreement clearly provides that concessionaires of each contracting State shall be entitled to equal shares of the produce of extraction. Under provisions of the agreement possession gained by actual extraction by either party is irrelevant to determining the apportionment of the reserve. Regardless of disproportionate production by either German or Dutch interest-holders, the total volume of crude oil extracted is pooled and divided equally between them as are the costs of such extraction.
>
> ... In effect the agreement creates a form of international unitised production aimed at the primary goal of insuring maximum production gained by efficient and co-ordinated programming of exploitation schemes.
>
> The agreement between Austria and Czechoslovakia over division of common gas fields lying in the Zwernsdorf-Vysoka frontier area ... provides for the establishment of a joint commission composed equally of representatives of each of the contracting States. The commission receives the reports of a panel of petroleum geologists and experts and from them calculates the reserves in the deposit, fixes the production rate and allocates production quotas to each State. The commission also approves of and regulates all exploitation procedures employed by either side. In fixing the production rate so far the commission has favored Austria in a ratio of 14:1 on the basis, it appears, of such technical considerations as reserves in place under each State's territory and the relative cost/profit ratios that would otherwise obtain if the deposit was being worked individually instead of cooperatively under an international joint commission.

Onorato, _supra_ note 38, at 98-99.

44. "No person shall withdraw water from any underground source in New Mexico for use in any other state ..." N.M. Stat. Ann. §75-11-20 (Repl. 1966). Also, for example, _see_ _Its Our Water: Can Wyoming Constitutionally Prohibit the Exportation of State Waters_, 10 Land & Water Law Review 119 (1975). In some jurisdictions, such as Switzerland and Turkey, neighbors

are obligated to share surplus waters. See Teclaff, supra note 6, at 185.

45. The Inter-American Arbitration Treaty was developed at the Havana Conference in 1929, and ratified by the Senate of the United States in 1935. It provides that:

> The High Contracting Parties bind themselves to submit to arbitration all differences of an international character which have arisen or may arise between them by virtue of a claim of right made by one against the other under treaty or otherwise, which it has not been possible to adjust by diplomacy and which are juridical in their nature by reason of being susceptible of decision by application of the principles of law.
>
> There shall be considered as included among questions of a juridical character:
>
> a) The interpretation of a treaty;
> b) Any question of international law;
> c) The existence of any fact which, if established, would constitute a breach of an international obligation;
> c) The nature and extent of the reparation to be made for the breach of an international obligation.

Inter-American Arbitration Treaty With Other American Republics, Jan. 5, 1929, 49 State. 3153, 3158, T.S. No. 886, at 6, 8 (effective April 16, 1935). For a discussion of the Agreement, see Meyers, The Colorado River: The Treaty with Mexico, 19 Stanford L. Rev. 367, 400-02 (1967).

46. For a comprehensive discussion of dispute settlements ranging from "referral to government" to arbitration and the International Court of Justice, see Management of International Water Resources: Institutional and Legal Aspects, 144 UN St/ESA/5 (1975).

47. Reproduced in Sept. of State Bull. 395, Sept. 24, 1973.

48. I.C.J. Reports 3 (1969), digested in 63 Am. J. Int'l. L. 591 (1969).

49. N.Y. v. N.J., 256 U.S. 296, 313 (1921).

50. 320 U.S. 383, 392 (1943). (Emphasis added).

51. Fischer, supra note 10, at 546.

52. Fischer, supra note 10, at 546. The discussion in the United States has been going on for some time. In 1961, the Senate Committee's final report commented that "It is possible that where underground aquifers cross State boundaries, consideration will have to be given to interstate compacts to control groundwater withdrawals, to prevent one State from exhausting water supplies used by another state." S. Rep. No. 29, 87th Cong., 1st Sess. 8 (1961). Also see Muys, Interstate Water Compacts (1971).

In fact, the more modern Interstate compacts are now expressly dealing with groundwaters to some degree. For example, the 1969 Niobara River Compact between Tyoming and Nebraska recognizes that groundwater withdrawals may affect the depletion of the Niobara (Act of Aug. 4, 1969, Pub. L. No. 91-52, 83 Stat. 86). The Blue River Compact of 1971 between Kansas and Nebraska includes groundwater infiltration as part of the natural flow of the stream (Act of June 2, 1972, Pl. No. 92308, 86 Stat. 193). The Delaware River Basin Compact (Delaware, Pennsylvania, New Jersey, New York, and the U.S., 1965) recognizes the interrelationship of ground and surface waters and declares that "Water resources shall include water and related national resources in, on, under, or above the ground, including related uses of land, which are subject to beneficial use, ownership or control." Art. L. 2(1), 75 Stat. 688. Also see Hayton, Institutional Alternatives for U.S.-Mexico Groundwater Management, 18 Nat. Res. J. 201 (1978).

53. Fischer, supra note 10, at 545.

54. See Utton, 2 WATER AND WATER RIGHTS 422, (R. Clark, ed., 1967).

55. Wyoming v. Colorado, 259 U.S. 419, 466 (1922); 286 U.S. 494 (1952).

56. In the Trail Smelter international arbitration, the Tribunal by agreement of the parties relied heavily on U.S. interstate decisions and said:

> There are, however, as regards both air pollution and water pollution, certain decisions of the Supreme Court of the United States which may legitimately be taken as a guide in this field of international law, for it is reasonable to follow by analogy, in international cases, precedents established by that court in dealing with controversies between states of the Union or with other controversies concerning the quasi-sovereign rights of such states, where no contrary rule prevails in international law and no reason for rejecting such precedents can be adduced from the limitations of sovereignty inherent in the Constitution of the United States.

Report of Int'l. Arbitral Awards 1964 (1949).

57. Kansas v. Colorado, 206 U.S. 46, 97-8 (1907).

58. Reports of Int'l. Arbitral Awards, supra note 54.

59. Utton, supra note 52, at 422.

60. Art. V., Int'l. Law Ass'n., Report of Fifty-Second Conference, held at Helsinki on 20 August 1966, annex II.

61. Nebraska v. Wyoming, 325 U.S. 589, 618 (1945).

62. McDougal and Haber, supra note 35.

63. 320 U.S. 383, 392 (1943).

64. Fischer, supra note 10, at 521, 532.

65. Sepulveda, LA FRONTERA DEL NORTE (1976); Utton, 2 WATER & WATER RIGHTS (R. Clark, ed., 1967); Hundley, DIVIDING THE WATERS (1966); Meyers, The Colorado Basin, THE LAW OF INTERNATIONAL DRAINAGE BASINS 486-607 (Garretson, Hayton & Olmstead, eds., 1967).

66. This language consciously tried to avoid the complexities developed in western U.S. water law of classifications such as "tributary" and "non-tributary" waters, "percolating waters," "subterranean streams flowing through definite channels," "underflow of streams," while recognizing "the interrelationship between many surface and groundwater sources." Clark, supra note 10, at 415.

67. This is a general provision designed to give the Commission flexibility in anticipating potential problem areas and exercising its judgment as hydrologic data is developed through its own initiative or the activity of others.

68. See 1974 Water Utilization Act, United Republic of Tanzania, as reported by Hayton, supra note 1, at 281-82. Also, Article 10 of the 1944 Colorado River Treaty provides that "In the event of extraordinary drought ... the water allocated to Mexico ... will be reduced in the same proportion as the consumptive uses in the United States are reduced." Art. 10, Treaty

with Mexico Relating to the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Feb. 3, 1944, 59 State. 1219 (1946) T. 994 (effective Nov. 8, 1945). *Also see* Sepulveda, *Instituciones Para la Solucion de Problemas de Aguas de Superficie Entre Mexico y los Estados Unidos*, 18 Nat. Res. J. 131 (1978).

69. Article V., note 58 *supra*.

70. *See* discussion *infra* at note 84.

71. Corker, *Groundwater Law, Management & Administration*, National Water Law Commission Legal Study No. 6, at 146-47 (1971).

72. Thomas & Luna, *Ground Water in North America*, 143 Science 1001, 1003 (March 6, 1964). (Emphasis added).

73. Bradley & DeCook, *supra* note 7.

74. *See* Clark, *Groundwater Management: Law & Local Response*, 6 Ariz. L. Rev. 178, 189 (1965); Hayton, supra note 52; Nat'l. Water Comm'n., Water Policies for the Future 472-83.(1973).

75. Thomas & Luna, *supra* note 70, at 1004. (Emphasis added).

76. Flint, *Ground Water Law & Administration: A New Mexico View Point*, Rocky Mt. Min. L. Inst. 551.

77. Flint, *id*. at 552.

78. Theis, *The Effect of a Well on the Flow of a Nearby Stream, 22*

Transactions, American Geophysical Union 734-38 (1941).

79. Flint, supra note 74, at 553.

80. City of Albuquerque v. Reynolds, 71 N.M. 428, 379 P.2d 73 (1962).

81. Clark, supra note 72, at 189-90.

82. Walton, GROUNDWATER RESOURCE VALUATION 608-09 (1970).

83. Corker, supra note 69, at 169. Clark concludes that the safe yield concept "is properly discredited ... and should be discarded by lawyers" Clark, The Role of State Legislation in Groundwater Management, 10 Creighton L. Rev. 469, 483 (1977).

84. Walton, supra note 80, at 608-09.

85. Bagley, Water Rights Law and Public Policies Relating to Ground Water Mining in South Western States, 4 J.L. & Econ. 144, 147 (1966).

86. Id. at 153.

87. Hutchins, supra note 32.

88. Id.

89. The complete text follows:

> It is desirable, of course, that the groundwater resources be available to future generations in perpetuity; however, the mining of water can be justified as readily as the mining of any of our other mineral resources such as uranium, oil, or coal. It is not practical to operate a groundwater

> basin on a continuous-yield basis when the amount of water in storage is very large compared with the average annual recharge. An average annual recharge is 29,000 acre-feet per year and the permitted withdrawals will average about 440,000 acre-feet per year. The great value of the approximately 27 million acre-feet in storage in the basin when pumping began can be realized only by mining. Furthermore, to justify the marketing, storage, and transportation facilities essential to a competent agricultural economy in the area, it is necessary for the withdrawals to exceed the recharge.
>
> While it is possible to justify the mining of groundwater resources, the practice will make it necessary to face serious water supply problems in the future. In some instances it will be possible to meet these problems only by complete readjustment of the economy of the area. While long range predictions of the value of water in various uses are dangerous, it appears likely that it will not be, in general, economically feasible to import water over appreciable distances for agricultural purposes when the local groundwater resources have been mined out. However, when reduced well yields or excessive lifts make pumping for agricultural purposes uneconomic, the residual water may well supply the municipal and industrial needs of a vigorous non-agricultural economy for many years.
>
> In Lea County pumping for irrigation will probably be uneconomic when about two thirds of the aquifer is dewatered. At that time there will probably remain substantial valuable reserves of oil and gas in the area. To produce and process those reserves it will be necessary to use numerous low-production wells to pump the residual fresh water, and it may also be necessary to desalinize the abundant brackish waters and brines that occur in the area.

Statement of S.E. Reynolds, State Engineer, Santa Fe, N.M., Sept. 30, 1959.

90. Bagley, supra note 83, at 153.

91. Corker, supra note 69, at 174.

92. Fischer, _supra_ note 10, at 521, 524.

93. As Robert Emmet Clark suggests, "a plan should be developed to control future uses, irrespective of whether the aquifer is stabilized or must of necessity be mined." Clark, _Arizona Ground Water Law: the Need for Legislation_, 16 Ariz. L. Rev. 818 (1974).

94. _Mathers v. Texaco_, 77 N.M. 239, 244, 421 P.2d 771, 775 (1966).

95. Flint, _supra_ note 74, at 568; _see also_ Bagley, _supra_ note 83, at 144, 155.

96. _Fundingsland v. Colorado Ground Water Commission_, 171 Colo. 487, 468 P.2d 835 (1970). The court approved a rate of depletion based on a 25 year period.

97. Letter from S.E. Reynolds dated 29 August 1977. Clark, _supra_ note 2; Bagley, _supra_ note 83, at 153.

98. Hayton, _supra_ note 1, at 288.

99. Utton, International Water Quality Law, 13 Nat. Res. J. 282, 299 (1973).

100. _See_, generally, LaMarquand, _Politics of International River Basin Cooperation and Management_, 16 Nat. Res. J. 883 (1976).

101. Flint, _supra_ note 72, at 570.

102. Ingram, _The Political Economy of Regional Water Institutions_, 55 J.

of Agricultural Economics 10 (1973); Fox, Institutions for Water Management in a Changing World, 16 Nat. Res. J. 743 (1966).

103. Walton, supra note 80, at 608-09.

104. Clark, supra note 2.

105. Clark, supra note 90, at 816-17.

106. Id.

107. Clark, supra note 2.

108. Id.

109. The Commission is authorized "to settle all differences that may arise between the two governments with respect to the interpretation or application of the treaty, subject to the approval of the two governments." Art. 24(d).

APPENDIX

COMPARISON OF GROUNDWATER LAWS OF CALIFORNIA, ARIZONA, NEW MEXICO, AND TEXAS

COMPARISON OF GROUNDWATER LAWS OF CALIFORNIA, ARIZONA, NEW MEXICO, AND TEXAS

I. Overview

A. Classification of Groundwaters

Courts and legislatures of the western states generally have divided groundwater into two subclasses, percolating waters and subterranean streams. How those categories are defined will depend upon the jurisdiction in question, but commonly they are distinguished by determining whether the water is "flowing" in a discernible direction within ascertainable boundaries.[1] Usually there is a presumption that groundwaters are percolating and the claimant must show that the waters are "flowing," etc., in order to rebut the presumption. (Exactly what the claimant will have to show will depend upon the jurisdiction.)

B. Theories of Ownership

There are two theories of property ownership applicable to groundwater: ownership of the corpus of the water and ownership of the use of the water. The doctrines relating strictly to ownership of the corpus are (1) the English doctrine, and (2) the reasonable use doctrine. There is a third doctrine, the doctrine of correlative rights, which is a hybrid of the corpus theory and the use theory.

The English rule was propounded in Acton v. Blumdell[2] in 1843. Under this rule, the owner of the surface owns the corpus of all water withdrawn from below the surface and he may withdraw as much water as he desires, but imposes the restriction that the water must be "... put to a reasonable use or beneficial purpose in relation to the land."[5] The correlative rights doctrine attempts to shift the "reasonableness" of the use from reasonable in relation to the land to reasonable with respect to other uses, whereby "... in a time of shortage each landowner is said to have a share of the underlying water in proportion to the amount of land he owns as compared with the total area supplied by the common water source."[6] It is this requirement of proration of the use of the water, suggesting a common ownership, which makes the correlative rights doctrine a hybrid of the English doctrine.

Strict ownership of the use of the water is manifested in the riparian and appropriative systems. The riparian system is based on ownership of land adjacent to and contiguous to a water supply. Water rights so derived are considered to be real property rights to the flow of the water which are held in common by all riparians.[7] While the quantity of water to which a riparian is entitled is ideally unlimited, in some jurisdictions the riparian may be subject to reasonable use restrictions.[8]

Appropriative rights are personal property rights to divert certain quantities of water for some beneficial use, which became vested by the capture and beneficial use of the water. In the appropriative system, all rights have a priority, determined by the date when the water was first captured and put to a beneficial use. A distinguishing aspect of the appropriative system is that the water right can be cut off in time of short supply, the water rights with more recent priorities being cut off first.[9]

II. California[10]

California distinguishes percolating waters from subterranean streams and subdivides subterranean streams into (1) the underflow of surface streams and (2) definite underground streams.[11] All water rights in California are subject to reasonable beneficial use, although what is reasonable and beneficial is a question of fact.[12]

A. Acquisition of the Right

1. Percolating Waters[13]

Percolating waters include all underground waters other than underflows and underground streams. In California they have been defined as "... vagrant, wandering waters moved by gravity in any direction along the lines of least resistance, sometimes coming from underground basins."[14] Until taken into possession, percolating waters are owned by all surface owners in common.[15] Use of percolating waters is governed by the doctrine of correlative rights, giving each overlying landowner a right held in common with other landowners overlying the same supply to reasonable beneficial use of the water.[16] Surplus percolating waters from any given supply is appropriable, subject to all aspects of the prior appropriation doctrine including the cutting off of rights in times of short supply.[17] Additionally, the burden of proof is on the appropriator to show that an appropriable surplus existed.[18] Finally, once the excess water has been appropriated, the surface owners always will have precedence over the appropriator, even where the ownership of the surface is subsequent in time to the appropriation.

2. Underflow

The underflow of a surface stream is the water in the soil, sand, and gravel composing the bed of a stream in its natural state and essential to its existence.[19] Accordingly, the rights to the underflow are coincident with the rights to the surface flow of the overlying stream. Therefore, all riparian or appropriative rights held to the surface flow apply equally to the underflow.[20] (Note that California commonly employs both the riparian and appropriative systems for surface rights in the same surface supply.)

3. Underground streams

An underground stream is a stream flowing in a definite channel in a subterranean watercourse.[21] As noted above, in order to overcome the presumption that an underground supply is percolating water, the claimant must show a direction of flow, confinement within banks, and a flow within a defined channel.[22]

Underground streams are subject to riparian rights and appropriation, as are surface waters. Owing to the practical impossibility of measuring the full flow, rights to an underground stream are fixed at a definite quantity of water.[23]

B. Loss of Right

Correlative rights in percolating waters are not lost by disuse and, therefore, are not subject to abandonment, forfeiture, or adverse use.[24] Riparian rights in underflow or underground streams are subject to adverse use, but are not subject to abandonment or forfeiture.[25] Appropriative rights in underflow, underground streams or the excess of percolating waters are subject to loss by adverse use, abandonment, forfeiture, or period of nonuse.[26]

C. Administration [27]

California is divided into irrigation districts, county water districts, reclamation districts, and water replenishment districts. The Department of Water Resources is charged with all administrative control and supervision of public waters except those delegated to the State Water Rights Board and the Water Commission. The Water Rights Board is primarily concerned with the issuance of licenses or permits to appropriate water. The Commission's main function is to advise the Director of Water Resources.

III. Arizona[28]

A. Acquisition of Rights

The leading Arizona case on underground water supplies, Briston v. Cheatham,[29] states that Arizona has two classes of underground water: underground channels or subterranean streams, and "natural percolating water." There is a rebutting presumption that all underground waters are percolating.[30]

Subterranean streams are defined as water flowing in "definite underground channels" and " ... are subject to appropriation and beneficial use. ..."[31] The Arizona Water Rights Registration Act of 1974[32] requires "... that every person claiming an appropriative right file a detailed written notice ..." in order to confirm their appropriative right. Water in underground channels is considered a public resource.

The State Supreme Court decided in Briston,[33] however, that "natural percolating waters" are not subject to prior appropriation as a public resource. Rather, the court held that percolating groundwater is governed by a rule of private property, vesting ownership of the water in the owner of the surface.[34] Withdrawal is permitted subject only to the reasonable use doctrine, except in critical groundwater areas. The State Land Department is authorized to designate critical groundwater areas.[35]

Until late 1976, the term "reasonable use" had no meaning beyond the facts of a given circumstance. However, the court in Farmer's Insurance Company v. Bettwy[36] defined what is unreasonable as a matter of law, deciding that withdrawal for purposes of exportation off the overlying land is an unreasonable use.

B. Loss of Rights[37]

Waters flowing in definite channels are subject to abandonment and forfeiture.

C. Administration[38]

Arizona is divided into water districts, with one water superintendent appointed by the State Land Department for each district. The State Land Department has the authority to designate critical underground water areas. The Arizona resources board has the duty of preparing and devising means and plans for the development and conservation of all water resources in the state.

IV. New Mexico

A. Acquisition of Rights

There is no distinction made in New Mexico between percolating water and underground streams.[39] Under New Mexico law, all underground waters are public, belonging to the state, and are subject to prior appropriation. No permit is required to appropriate underground waters except in "declared basins," which are basins having "reasonably ascertainable boundaries."[40] Even in a declared basin, however, a landowner may drill a well for domestic use without a permit.

B. Administration

The State Engineer is charged with the general supervision of the measurement, appropriation, and distribution of state waters. As to underground waters, he has the authority to declare basins. Also, the Engineer has the authority to divide the state into water districts and to appoint a water master for each district.

V. Texas

A. Acquisition of Right

Texas, like California and Arizona, distinguishes underground streams from percolating waters. Underground streams are defined as waters that "... flow in fixed or definite channels, the existence and location of which are known or ascertainable from surface indications or other means without subsurface excavations for that purpose."[42] While it is clear that the rights and liabilities of landowners with respect to underground streams are governed by different principles than those applied to percolating waters, it is not clear exactly what principles do govern.[43] In the case of an underflow (See California) the court probably would make a riparian analogy in order to determine the water rights.

Percolating waters have been defined as those that "... ooze, seep, filter, or percolate through the ground under the surface without any definite channel, or in a course that is uncertain or unknown and not discoverable from the surface without excavation for that purpose.[44] Percolating waters are regarded, in accord with the stract English doctrine, as the property of the surface owner.

The owner may "... use all of the percolating waters he [can] capture from wells on his land for whatever beneficial purposes he [needs] it, on or off the land, and [can] likewise sell it to use either off or on the land, and outside of the basin where produced. ..."[45]

The only practical limitation on the withdrawal of percolating waters is that the landowner may not waste it nor may he maliciciously take water for the sole purpose of injuring his neighbor.[46] Corpus Christi arguably narrowed the common law definition of waste to encompass only "illegal" uses of water.

Prior appropriation and riparian rights can attach to percolating water only after its emergence from the ground.[47]

B. Administration

The Texas Water Commission is charged with overall administration of the waters of Texas. The chief engineer is responsible for investigating the availability of underground waters and coordinating the underground water districts of the state.

FOOTNOTES

1. Clinchfield Coal Corporation v. Compton, 148 Va. 437, 139 S.E. 308 (1927).

2. 12 Mees. & W. 324 (1843).

3. *See*, City of Corpus Christi v. City of Pleasanton, 154 Tex. 289, 276 S.W.2d 798, 800 (1955) [hereinafter referred to as Corpus Christi].

4. *See*, Basset v. Salsbury Mfg. Co., 43 N.H. 569, 82 Am. Dec. 179 (1862); *and* see Clark, *Groundwater Management: Law and Local Response*, 6 Ariz. L. Rev. 178, 184 (1965).

5. Clark, *supra* note 4, at 184.

6. McDougal & Haber, Property, Wealth, Land (1948).

7. I.H. Rogers & A. Nichols, Water for California §158 (1967).

8. *Id.*, at §157.

9. *Id.*, at §181.

10. The following information is taken directly from I.H. Rogers & A. Nichols, Water for California (1967).

11. I.H. Rogers & A. Nichols, *supra* note 7 at §246.

12. *Id.*, at §175.

13. Katz v. Walkinshaw, 141 Cal. 116, 70 P. 663 (1902), marks the origin of the California law with respect to percolating waters.

14. I.H. Rogers & A. Nichols, <u>supra</u> note 7, at §249.

15. <u>Id</u>.

16. <u>Id</u>.

17. <u>Id</u>., at §250.

18. <u>Id</u>.

19. <u>Id</u>., at §247.

20. <u>Id</u>.

21. <u>Id</u>., at §248.

22. <u>Id</u>.

23. <u>Id</u>.

24. <u>Id</u>., at §§253-54.

25. <u>Id</u>., at §270, et seq.

26. <u>Id</u>.

27. T. Glidden, Water Administration in the Seventeen Western States 6-8 (1965).

28. Clark, <u>Arizona Groundwater Law: The Need for Legislation</u>, 16 Ariz. L. Rev. 799 (1974), is the source for much of the foregoing information.

29. 75 Ariz. 227, 255 P.2d 173 (1953), <u>rev'd on rehearing</u> 73 Ariz. 228, 240 P.2d 185 (1952).

30. Maricopa County Municipal Water Conservation District v. Southeast Cotton Co., 39 Ariz. 65, 4 P.2d 369, 376 (1931).

31. Ariz. Rev. Stat. Ann. §45-101(A) (1956).

32. Ariz. Rev. Stat. Ann. §45-180 to 193 (Supp. 1974-75).

33. *Supra* note 29.

34. *Id.*, at 174.

35. "Critical groundwater areas" is defined at Ariz. Rev. Stat. Ann. §45-301 (1956) *as amended* (Supp. 1974-75).

36. 113 Ariz. 520, 558 P.2d 14 (1976).

37. Ariz. Rev. Stat. Ann. §45-141, note 34, 35.

38. T. Glidden, *supra* note 27, at 2-4.

39. *See* Flint, *Groundwater Law and Administration: a New Mexico Viewpoint*, 14 Rocky Mtn. Mineral L. Inst. 545 (1968); *see* R. Clark, New Mexico Water Resources Law 17-21 (1964).

40. N.M. Stat. Ann. §75-11-21 (1953 Comp.).

41. T. Glidden, supra note 27, at 33-34.

42. 60 Tex. Juv. 2d *Wateus* §218 (1964).

43. *Id.*, at 219; *see* Houston & T.C.R. Co. v. East, 98 Tex. 146, 81 S.W. 279 (1904).

44. 60 Tex. Juv. 2d Waters §218 (1964); Houston & T.C.R. Co. v. East, *id*.

45. Corpus Christi, *supra* note 3, at 802.

46. 60 Tex. Jur. 2d, *supra* note 43, at §222.

47. *Id*., at §255.

48. T. Glidden, *supra* note 27, at 51-53.