SPRINGS
OF
TEXAS

GUNNAR BRUNE

VOLUME I
PART 1

BRANCH-SMITH, INC.
Fort Worth, Texas 76101

ISBN: 0-9604766-0-1

Library of Congress Catalog
Card Number: 80-71016

Published and distributed in 1981 by

Gunnar Brune
2014 Royal Club Court
Arlington, TX 76017

Printed in the United States of America
Branch-Smith, Inc. Fort Worth, Texas

As a race they have withered from the land. Their arrows are broken, and their springs are dried up; their cabins are in the dust. Their council fires have long since gone out on the shore and their war-cry is fast dying out to the untrodden west. Slowly and sadly they climb the mountains and read their doom in the setting sun. They are shrinking before the mighty tide which is pressing them away; they must soon hear the roar of the last wave that will settle over them forever. Ages hence the inquisitive white man, as he stands by some growing city, will ponder on the structure of their disturbed remains and wonder to what manner of person they belonged. They will live only in the songs and chronicles of their exterminators. Let these be faithful to their rude virtues as men, and pay tribute to their unhappy fate as a people.

Sam Houston,
Speech in the United States Senate, 1846

$35.00

This detailed study covers three-fourths of the state of Texas. The remaining one-fourth will be the subject of Volume II.

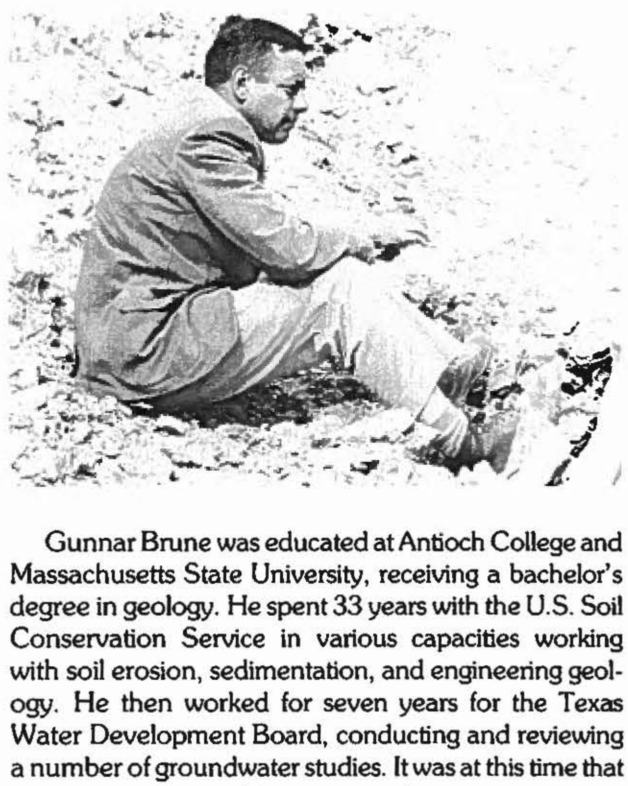
The book is primarily a reference work, providing a thorough discussion of the springs of each county and what has happened to them. But it also contains a wealth of general information on Texas springs' geology, hydrology, archeology, history, and ecology.

The geologic and hydrologic conditions under which springs form, causes of variations in flow, ebb-and-flow springs, thermal springs, caves, and deposits such as travertine formed by springs, all are discussed. The causes of the failure of most of Texas' springs are dealt with, including the clearing and plowing of land, drilling of flowing wells, some of which threw water 26 meters above the surface, and pumping of groundwater, primarily for irrigation. The pollution of most of the remaining springs has been caused by such substances as oil-field brines, sewage, herbicides, and insecticides.

The importance of the springs to Early Americans, as long as 60,000 years ago, is documented by the bedrock mortars, middens, and rock paintings and carvings which they left in the vicinity. Historically the springs provided refreshing stops for early explorers, stage coaches, and river boats, power for mills, and health-restoring minerals at spas. Many towns grew up around springs, and more recently they have been important recreational centers.

Texas' springs supported an abundant ecosystem of plant and animal life. As the springs dried up, most of these plants and animals disappeared. Some, such as the Comanche Springs pupfish, could live only at one or two springs. The springs' vegetation has often been replaced by such plants as mesquite, which can reach down 53 meters or more for groundwater, or salt cedar, which can tolerate contaminated water.

All of the troubles which beset Texas' groundwater and springs can be traced to an exploding world population. The loss of Texas' springs is only one facet in a decreasing quality of life in modern times. Others include the smothering of cities with fumes, the fouling of beaches with oil, and the leakage of atomic wastes. The writer believes that the human race is committing suicide, that man cannot control his own destiny, and that within 500 years he will be extinct, carrying with him most other life forms on earth.



Gunnar Brune was educated at Antioch College and Massachusetts State University, receiving a bachelor's degree in geology. He spent 33 years with the U.S. Soil Conservation Service in various capacities working with soil erosion, sedimentation, and engineering geology. He then worked for seven years for the Texas Water Development Board, conducting and reviewing a number of groundwater studies. It was at this time that he became aware of the sad fate which was overtaking most of Texas' springs. He has spent the last 10 years in research, field studies, and writing for this book. He has written about 50 other articles and books on the subjects mentioned above, as well as on private flying, having owned an airplane for 20 years. One of his more recent publications was *Major and Historical Springs of Texas*, published by the Texas Water Development Board as Report 189.

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To Velma

ACKNOWLEDGMENTS

The more important sources of information are listed under "Selected References." Space limitation prevents the listing of thousands of others from which valuable information was gathered. The writer has relied heavily on groundwater reports, records of spring discharges, low-flow studies of streams, and chemical analyses of spring waters which have been published by the U.S. Geological Survey, the International Boundary and Water Commission, and the Texas Department of Water Resources. A few drawings showing the geologic setting of Texas springs were taken from the Texas Water Development Board's Report 189, Major and historical springs of Texas. Topographic maps published by the U.S. Geological Survey, usually 7½-minute maps at a scale of 1:24,000, often pinpointed the location of springs. Groundwater consultants, including William F. Guyton and Associates and Rollin W. Harden and Associates, provided valuable data.

The Texas Historical Commission furnished important historical and archeological information on many springs. The Eugene C. Barker Library of Texas History of the University of Texas and the Texas State Library made available their incomparable collections of histories, old documents, and maps. The Texas General Land Office county land-survey maps of various ages proved very useful. The Texas Archeological Laboratory at the University of Texas provided much information on archeological sites associated with springs. The writer's son Charles gathered much useful information on springs in the Lower Canyons of the Rio Grande while on a float trip. His daughter-in-law Janet Brune provided valuable assistance in typing the manuscript.

Throughout the state, public and university libraries provided additional information such as unpublished documents and newspaper stories. Offices of the U.S. Soil Conservation Service were very helpful in providing data on land owners, managers, and lessees. City water departments gave much help in regard to use of spring waters.

Many long-time residents furnished priceless information on spring and stream-flow conditions in their early lives. Owners, managers, and lessees of land on which springs flow are owed a great debt of thanks for granting permission to enter their land. Countless other individuals helped to make this book possible. Although they cannot all be listed here, the writer wishes to thank them all.

PURPOSE AND SCOPE

The study of springs is a borderline discipline, because springs are the transition from ground water to surface water. Hence they have been studied to some extent by ground-water specialists and to some extent by surface-water specialists. They have also been of concern in archeological reports, accounts of early explorers, histories, and ecological studies. One purpose of this publication is to pull together all information on the springs of Texas, from whatever sources.

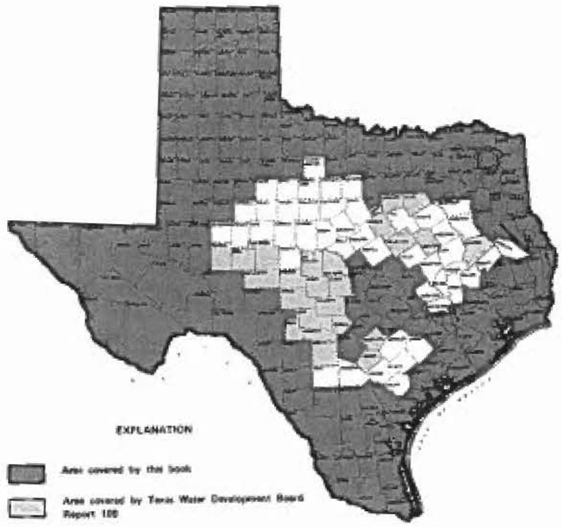
Unfortunately, the story of Texas' springs is largely a story of the past. Many are already gone. It is urgent that data on past and present springs be recorded. In the not very distant future most of Texas' springs will exist only in a legend of a glorious past when mankind was one with, and reveled in, nature. This is an effort to show what is happening to our springs and why, and to depict what is left of the fast-fading natural, beautiful environment in which man and his fellow animals and plants evolved, before it is destroyed by pollution and *overpopulation.*

The writer is primarily a geologist, with experience in the related fields of soil and water conservation, sedimentation, and ground-water hydrology. Other fields such as archeology, history, biology, and ecology must be involved in any study of springs. The writer has made every effort to accurately report information gathered from these fields.

This book is not intended to be light reading. Rather, it is a reference work. There is a certain amount of unavoidable repetition in the summaries for each county.

The study began in 1971 and has consumed the full time of the writer since. Unfortunately, illness of his wife, Lena, interrupted the work. It was decided to gather the information obtained so far and to publish it as Volume I. The accompanying map shows the portion of the state (183 counties) covered by this study. Some additional counties were covered in a preliminary way in the writer's 1975 work, Texas Water Development Board Report 189, *Major and historical springs of Texas.* In the unshaded area on the map much information was gathered, but since detailed research and field studies were not made, no data are presented in this volume. If circumstances permit, the writer hopes to prepare a second volume on the 71 counties not included in Volume I.

In the 1975 report only fresh-water and slightly saline springs (containing less than 3,000 milligrams of dissolved solids per liter) were included. No such restriction is made in this book, and some true brine springs are discussed.



Area covered

METHOD OF STUDY

GENERAL

For each county a thorough study was made of available spring-flow records, water-quality analyses, contamination reports, historical documents and maps, archeological reports, and biological studies related to springs, before leaving Austin. In the field, additional information was gathered from newspaper clippings and long-time residents. At the spring sites, the geologic structure and lithology were studied, field chemical tests performed on the water, photographs taken, an estimate of the flow made if not regularly measured, and information on the springs obtained from the owner, manager, or lessee.

Preliminary data on probable spring locations were plotted on county highway maps of various scales published by the Texas Department of Highways and Public Transportation. Springs studied in the field were located on U.S. Army Map Service topographic maps having a scale of 1:250,000. Geologic information was taken from sheets of the Geologic Atlas of Texas (also 1:250,000), prepared by the Bureau of Economic Geology, University of Texas, where these maps were available. The location and size of springs and seeps were later transferred to the large folded map at the back of this book.

To produce a photographic masterpiece, it is necessary to take pictures of the subject at all hours of the day, under different lighting conditions, in various types of weather, in all seasons, and from different angles. There was not time for this sort of detail, since the writer was presented with the problem of doing justice to each of Texas' 254 counties. But it is hoped that the photos will serve their purpose and accurately show the springs as they exist today.

Unless a spring is on public land, it is of course always necessary to obtain the owner's permission before visiting it. This has become more of a problem in recent years, especially near large cities, where the privilege of entering private land has been abused. Hunters have left dead birds and animals, shot for pleasure only, lying on the ground, gates have been left open, and trash discarded near the springs. Hence it is not surprising that permission to gain access is increasingly difficult to

obtain, and more and more gates are kept locked. Also, few farmers or ranchers live in the country nowadays, and often the owner must be contacted 100 kilometers or more distant.

In the writers's case, every effort was made to contact the owner, manager, or lessee of a farm or ranch to obtain permission to visit the springs. Happily, it was possible to reach nearly every spring and to see at first hand their present condition. In many cases the landowner or his representative kindly guided the writer to the springs.

The object was to do as accurate and complete a job as possible in the time available. But no doubt some springs which are important to local residents have been omitted. Also, since the book was written over a ten-year period, there have probably been changes in land ownership, management, or leases since the writer's visits to many springs.

Spring discharges and water-quality data are usually given for a specific date, as these characteristics change with time. If no date is given, it may be assumed to be during the period of the writer's primary visit, which is given in the discussion of each county.

Where practicable, discharge measurements have been summarized by water years, and an average of available measurements is shown for each year. (A water year extends from October 1 to September 30 and is designated by the calendar year in which it ends.) For the larger springs a longer period of record is usually available. Discharge observations have generally been rounded to two significant figures.

In describing the location of a spring from the nearest town or other landmark, the airline distance is always used. The road or river distance is usually much greater. In unpopulated areas, the location has been given in latitude and longitude. This method has been kept to a minimum, however, because few readers will have readily available detailed maps showing latitude and longitude.

Since the metric system is here to stay and will be increasingly used in the future, most figures given in this work are expressed in metric terms. No doubt there will be some readers who are opposed to change, who prefer the old system of feet, pounds, and miles. For them the accompanying table of conversion factors is provided. In addition to metric units, some Spanish units of measurement (in italics) are also included.

	If you know	**Multiply by**	**To Find**
Length	centimeters	0.394	inches
	meters	3.28	feet
	meters	1.09	yards
	varas	0.911	yards
	kilometers	0.621	miles
	leagues	2.60	miles
Area	hectares	2.47	acres
	square kilometers	0.386	square miles
Volume	liters	1.06	quarts
	liters	0.264	gallons
	liters	0.0284	bushels
	liters	0.0353	cubic feet
	cubic meters	0.000,811	acre-feet
	cubic kilometers	811,000	acre-feet
Mass	kilograms	2.21	pounds
	arrobas	25	pounds
	metric tons	1.10	short tons
Rate	liters per second	0.0353	cubic feet per second
	liters per second	15.8	gallons per minute
	liters per second	0.0228	million gallons per day
	liters per second	25.6	acre-feet per year
	meters per kilometer	5.29	feet per mile
Temperature	degrees Celsius	1.8 (then add 32)	degrees Fahrenheit

Artificial or man-made springs are not generally in· cluded in this work. These include springs created b construction of a dam, canal, or drainage ditch. How· ever, springs which existed naturally and whose flov has been enhanced by man's work are included. A example is San Felipe Springs at Del Rio, whose dis charge has been increased by construction of Amista Reservoir.

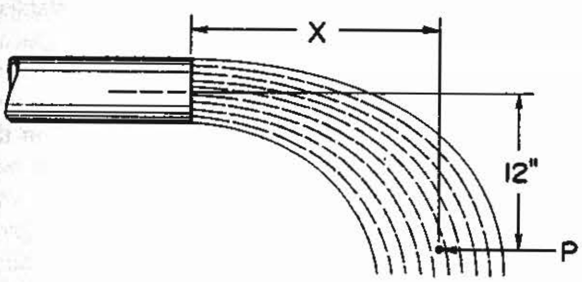
MEASUREMENT OF SPRING DISCHARGE

Spring flow is usually a composite of the flow of man small springs and seeps. Downstream, as more an more springs and seeps contribute their discharge, th flow increases to a maximum, usually within a fe hundred meters. Farther downstream, as the water absorbed by sand or other pervious material, the di charge decreases until often it sinks entirely into t stream bed. In measuring spring discharges, an eff should always be made, and was in this study, to ga the flow at the location of maximum discharge.

The most accurate method of measuring spring discharge, and that which is used by the U.S. Geological Survey and other agencies on most of the larger springs, is to construct a concrete dam and weir over which the water must pass. The flow is calibrated so that for any stage of flow over the weir, the discharge can be easily determined.

Another method is to use a current meter. This is a device attached to a propeller which is lowered into the water at various points in the stream cross-section. It gives a visual or aural reading of the water velocity. This together with the measured stream cross-section is used to compute the discharge.

Where the spring flow passes through a nearly horizontal pipe, flowing full and with free fall from the end of the pipe, the discharge can be estimated as follows. The horizontal distance X from the end of the pipe to the point below which a 30-centimeter (12-inch) drop occurs is measured as shown in the accompanying diagram. The distance X can then be used in the following table to determine the discharge in liters per second.



COURTESY JOHNSON DIVISION, UOP, INC.

Distance X in Centimeters	Pipe Diameter in Centimeters 5.1	7.6	10.2	12.7	15.2	20.3
15	1.3	2.9	5.0	7.9	11	20
18	1.5	3.4	5.9	9.2	13	23
20	1.8	3.8	6.7	11	15	26
23	2.0	4.3	7.5	12	17	29
25	2.2	4.9	8.4	13	19	33
28	2.4	5.3	9.2	14	21	36
30	2.6	5.8	10	16	23	29
38	3.3	7.2	13	20	29	49
51	4.4	9.7	17	26	38	66

The discharge pipe should be at least 1.5 meters long, and the open end should be at least this distance from the nearest elbow, bend, or valve.

The float method may be used if the channel below the springs has a nearly uniform cross-section and grade for a distance of at least 50 meters. The average cross-sectional area and length of reach are measured, and a stop-watch is used to time the passage of the float through the reach. The measured surface float velocity is multiplied by a coefficient ranging from 0.66 to 0.78, depending upon the depth of the channel, to correct for a slower velocity at the channel bed than on the surface. The corrected velocity in meters per second multiplied by the average cross-section in square meters yields the estimated discharge in cubic meters per second. This can then be converted to liters per second.

When the springs issue beneath the water surface in a stream or lake, another method must be used to measure their discharge. The presence of such springs may be indicated by steam rising from the water in winter, or by fish which congregate around the springs. In this case it is necessary to measure the discharge from the lake or stream reach and subtract it from the flow entering the lake or reach, to obtain the flow of the underwater springs.

In the case of subsurface springs in a lake or pond, a computation of the water lost by evaporation can throw light on the rate of spring flow. For example, if in the absence of rainfall a lake just maintains its level at the spillway, with no overflow, it is obvious that there is just enough spring flow in the lake to compensate for evaporation. Net evaporation (in this case spring flow) can be computed by finding the centimeters of evaporation per hectare for the month in question from evaporation maps. This is multiplied by the lake surface area to obtain hectare-centimeters per month. This can then be converted to liters per second.

In some cases a city, industry, or individual pumps water from a spring. In this eventuality an estimate of the pumpage must be obtained and this figure added to the observed discharge downstream from the takeout point, to obtain the total spring discharge. Hancock Springs, used by the city of Lampasas, are an example of this situation.

EVIDENCE OF FORMER SPRINGS

Because many of Texas' springs have ceased flowing in modern times, it is important to determine where the former springs were and, if possible, when they stopped flowing. Texas' historic period may be said to have started about 500 years ago, when Amerigo Vespucci is said to have explored the coast in 1497, probably sending men ashore to fill water casks from fresh-water seeps among the sand dunes. But in this five-century period, detailed studies of ground water and water-table decline have been made only in the last 50 years or so. In many cases we know the present annual rate of decline of the water table. We do not usually know what the original water level was. This must be inferred from information from various sources.

For a spring to have existed in the past, there must be an aquifer capable of carrying water to it, such as a sand or vugular limestone. It must have a sufficiently large recharge area. The beds must be level or sloping toward the spring. There must be enough difference in the elevation of the recharge area and the elevation of the spring to cause it to flow. *And the water table must have been high enough to form an appreciable hydraulic gradient toward the spring.* The last is the factor which has been detrimentally altered all too often by man's activities. If these conditions are all judged to have been met, it may reasonably be assumed that a spring or seep formerly existed at a given location.

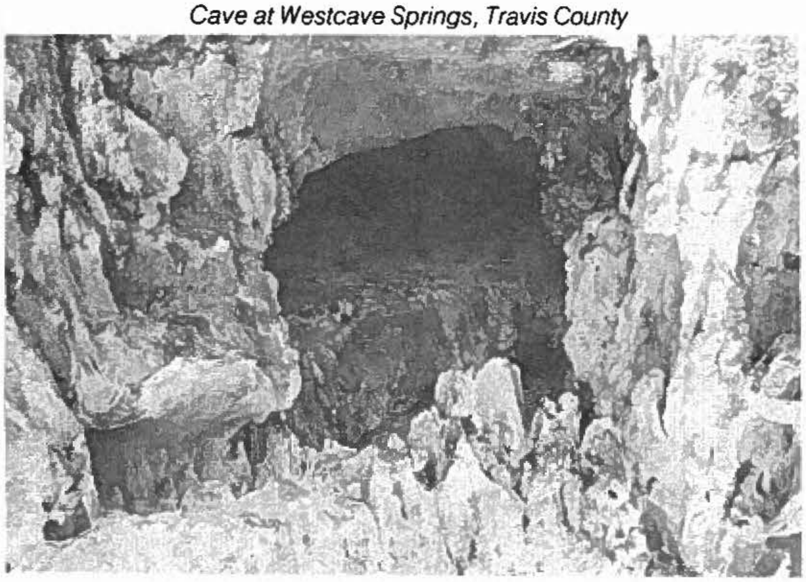
Caves are usually formed by flowing ground water which dissolves away the limestone, gypsum, or other material. Cave openings therefore often mark the site of former springs. But the time since water flowed from such openings may be very long, even hundreds of thousands of years.

Spring water which contains much calcium bicarbonate is apt to precipitate part of its load of this chemical as travertine when it emerges from the ground. This is especially true if the water is warm or falls over a cliff and is thus subject to aeration and evaporation. Travertine deposits may take the shape of draperies around a waterfall, or a series of dams forming pools below a spring outlet.

Such deposits are usually strong evidence that a spring once existed at the location, often in relatively recent times. Sometimes travertine deposits are found at an elevation many meters higher than the elevation of an existing spring. This indicates that the water table, and the spring, was formerly at a higher elevation.

Springs, especially in alluvial deposits, often appeared originally as hundreds of seeps in a boggy area. With a decline in the ground-water table, such springs and the surrounding bogs dried up. But the dark gray soils which formed under such wet conditions remain. They are often a sure indication of former springs and seeps.

Cave at Westcave Springs, Travis County



Travertine dams at Knight Springs, Williamson County.

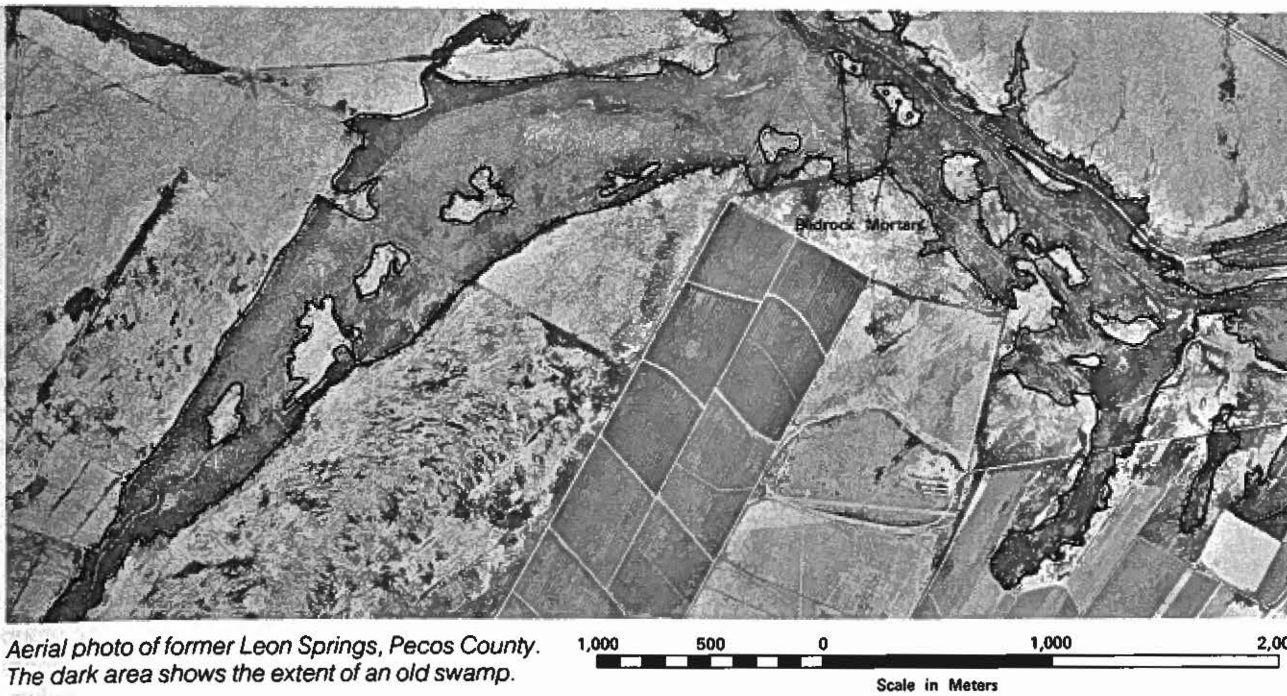
Indians and their prehistoric predecessors often used mortar holes in the bedrock to grind acorns, mesquite beans, corn, and other food. As water was required in the grinding process, it may be assumed that water, usually in the form of a spring or spring-fed creek, was near at hand. Similarly hearths or burned-rock middens indicate a living site with water nearby, even though none may be present now.

Often charcoal or bone found in such ancient sites can be dated by radiocarbon methods, thus establishing a date, within certain limits of accuracy, at which a spring probably existed. But as Brennan (1973) points out, most radiocarbon dates need to be corrected. Cosmic ray activity, which creates Carbon-14 in the atmosphere, has been found to be lower in the past than for the last 2,200 years, when compared with dendrochronology (tree-ring studies). Therefore most Carbon-14 dates must be increased. For example, a test age of 6,000 years is equivalent to a real age of 6,700 years.

A sign of a relatively recent decline in the water table and often of former springs or seeps, is water-loving trees which are dying. These include cottonwoods in the west, cypresses in the east, and willows everywhere. Often these trees are replaced by others such as hackberries, more tolerant of drying conditions.

Records of many former springs, as well as of those which still flow, were written down by some of the early Spanish and French explorers of Texas. Often springs were depicted and named on very old maps. These records, along with more recent histories, provide valuable data on past spring conditions.

Some springs described in old documents or accounts are known only to one or two long-time residents. Finding such springs is a great satisfaction because in a few years there will be no one left who remembers them. Early residents can also furnish much



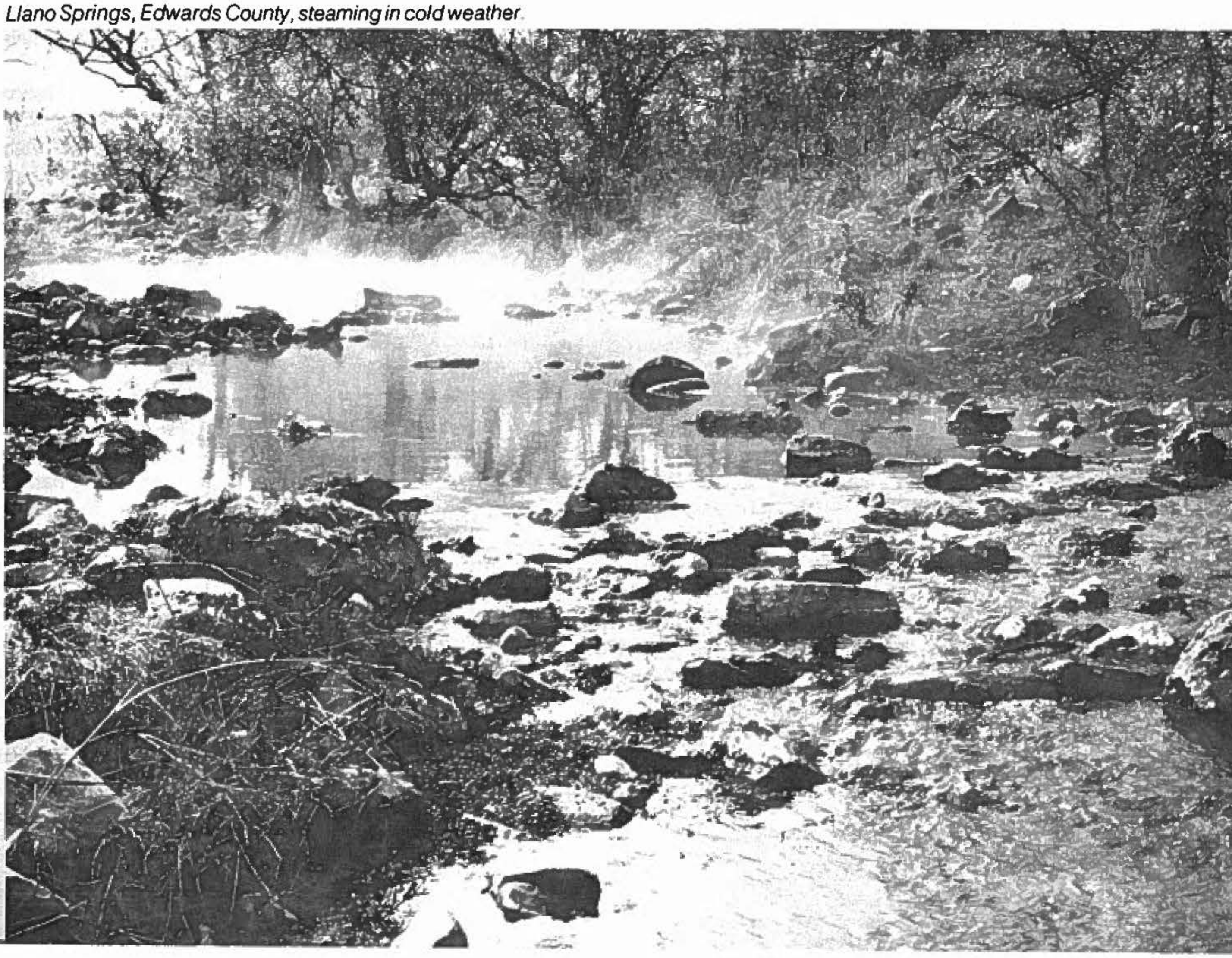
Aerial photo of former Leon Springs, Pecos County. The dark area shows the extent of an old swamp.

information about springs and former springs which is not written down in any history.

One point which should be remembered is that spring waters remain about the same temperature the year around. Hence any appreciable flow of spring water in a lake or stream will prevent it from freezing over. Thus if an old-timer tells of pools in a creek where he used to skate in the winter, one might be reasonably certain that no significant spring flow was involved.

Often when a spring failed to produce sufficient water during a drought period, it was cleaned out and deepened. Eventually it was made into a well, and a windmill added to pump the water. Thus windmills in some cases are indicators of the location of former

Llano Springs, Edwards County, steaming in cold weather.



springs or seeps.

Schools, churches, and communities were often named for important nearby springs in early days. But they can move. "Rocky Springs church" may no longer be located at Rocky Springs. It is necessary to find out from old residents in such cases where the school, church, or community used to be, and where the associated springs were.

Cemeteries are more reliable as indicators of springs or former springs, since they are rarely moved. Hence Rocky Springs should be close to "Rocky Springs cemetery."

NUMBERING AND NAMING SPRINGS

The springs, seeps, and former springs studied were numbered consecutively in each county. The numbers have no particular distribution within the county. But the discussion of springs and seeps in each county is done in a standard fashion. They are discussed in a clockwise order around the county, starting in the west. In a few cases this order was modified because of stream drainage patterns.

Numbers are necessary to avoid ambiguity because the same common name, such as "Cottonwood Springs," may be used for many springs throughout the state. In many cases several springs within a county have the same name. Spring and seep locations and size categories are shown by number on the map, "Location of Springs and Seeps," in the pocket at the back of this book.

Sometimes there is a conflict as to the location of an important spring. Two different landowners may claim that the spring is on their property. Or historians in adjoining counties may both claim a certain spring for their county. In such cases all of the evidence must be sifted and every effort made to determine who is right.

Spring names are kept as simple as possible in this work. For example, suppose that some springs and a creek are named for a man named Taylor who once lived in the vicinity. The correct names would be *Taylor Springs* and *Taylor Creek*, not *Taylor Creek Springs* or *Taylor Springs Creek*.

Spelling of spring names has often been murdered in old reports and maps. Sometimes every conceivable spelling can be found in various sources. The reason, of course, is that many early settlers could not read or write, and names were passed from one to another chiefly by word of mouth. In cases in which it is difficult to determine which spelling is correct, all are given.

In the belief that the English language is already over-complicated, all diacritical marks, such as the cedilla (¸), Tilde (~), dieresis (¨), and acute accent (´), have been omitted. Also, foreign words have not been used unless absolutely necessary. For example, the Latin word *circa* means *around*, so we say *around*.

Most springs break out in many places, even in rock. Hence the plural form "Springs" is usually preferable to "Spring." But if there is definitely only one opening, or if the name has been established by long usage, as at the city of Big Spring, the singular form may be used.

Where a group of springs is fed from many openings or seeps, it is usually hard to separate them or to determine how many there are. The number varies with the discharge, as the water table rises or falls. If the water table is falling, the highest springs in the group stop flowing first. The same is true of a series of springs along a stream. With a falling water table, the headwater springs fail first.

Some springs are named for characteristics of their water, such as *Sulphur* or *Cold Springs*. Some are named for the creek which they feed, or vice versa. Some are named for the town where they are located, or vice versa, such as *Leon Springs*. Some are identified with old Spanish missions or settlements, such as *Ahumada Springs*. Some, such as *Willow Springs*, are named for trees or other plants which grow at the springs. Others, such as *Bear Springs*, for animals which frequented the springs.

Some springs are named for Indians, such as *Hueco Springs*. Some, such as *Cienaga* or *Boggy Springs*, take their names from landforms. Others are identified with early settlers who lived there *(Spencer Springs)* or public figures who visited there *(Sam Houston Springs)*. Other names, such as *Woman Hollering Springs*, have an unknown origin.

Names sometimes give a key to past spring conditions. For example, *Rock Springs* may now be located in a sandy area, with no rock near. But one kilometer upstream there is an outcrop of rock. This may indicate that the springs once flowed at the upstream, rocky location, but have migrated downstream with a declining water table.

It should be pointed out that Spanish spring names are much more explicit than English names. For example, springs called *Little Lion Springs* in English could be any of the following in Spanish:

Ojo del Leoncito (Spring of the Lion Cub)
Ojo del Leoncita (Spring of the Lioness Cub)
Ojito del Leon (Little Spring of the Lion)
Ojito de la Leona (Little Spring of the Lioness)

It is regrettable that many histories, especially local or county histories, completely ignore minority groups. Such accounts make statements such as "Prior to this time, only a few Mexicans lived in the area,'' and then launch into a discussion of the first Anglo settlers. We must not forget that much of the important early history of Texas was made by Spanish, Mexican, and to some extent by French explorers and colonizers. The Anglos arrived on the scene at a relatively late date. And for that matter, we should not neglect the Indians and Paleo-Indians, even though for the most part they left no written records.

CHARACTERISTICS OF SPRINGS

WHAT IS A SPRING?

A ground-water reservoir is like a surface reservoir in many ways. Springs are the spillways through which the overflow or surplus ground water passes. If the water table is lowered, more of the recharge water goes into the underground reservoir and less is available for overflow or springs. Since most springs take their water from the top of the reservoir, any change in the water level has an immediate and very striking effect upon them.

Of course there are important differences between a ground-water and a surface-water reservoir. These, which will be discussed later, deal primarily with the rate at which ground water can be transmitted through various types of rock or unconsolidated material.

A spring issues through a natural opening in the rock or soil, or may result from the coalescence of a large number of seeps. Springs are often cleaned out and deepened in order to increase their flow. If the deepening process continues until there is no longer a flow at the ground surface, the opening becomes a well.

The Water Works Springs in Lockhart (Caldwell County) are an example. Lockhart originally obtained its water from several springs in the vicinity. As the need for water increased, the springs were deepened until now some are in wide pits eight meters deep. They are still called springs by the residents, but actually they have been converted into wells.

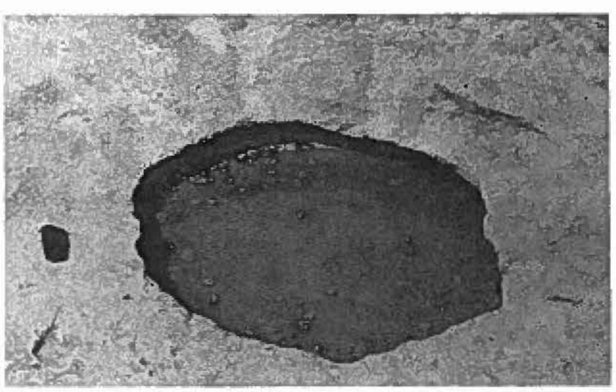
Some springs have a remarkably constant flow. Usually such springs are fed by a large recharge area, often through an aquifer of low transmissivity. The ground water may travel through the aquifer for years before reaching such springs. Other springs fluctuate severely, perhaps flowing only after rains. These springs usually have a small recharge area and a highly transmissive aquifer. The ground water may travel from the recharge area to the springs in days or even hours in such cases.

Usually spring-fed streams and pools can be readily distinguished from those fed by surface runoff. Surface water is usually turbid, containing clay and silt particles eroded from plowed fields, roads, construction sites, and other sources, as well as organic matter and debris. Spring waters, on the other hand, are usually very clear, having been filtered through sand beds and passed through numerous small settling basins in the underground rocks. But some aquifers such as cavernous limestone and gypsum have little filtering action and can transmit turbid water to springs, including leaves, trash, and corn cobs.

The plant and animal life around streams and pools is perhaps a better indicator of whether the water is derived from springs or surface runoff. If pools or streams are fed by surface runoff, they will periodically dry up. If they are fed by springs, the supply of water will be more constant. Plants such as marsh purslane, water pennywort, and cattail require a constant supply of water. Fish, frogs, crawfish, and the animals such as raccoons which feed on them also need a steady water supply.

Texas springs vary a great deal in age. The escarpment along the Balcones fault zone, where the largest springs are located, began to be uplifted in Miocene time, about 15 million years ago. It is likely that springs have been present in the fault zone ever since that time. But the individual locations of springs have of course changed. As the ground water passes through the limestone cavities, it constantly dissolves away the rock, causing the water passages to shift from side to side and downward. Dry former spring openings can often be seen in the limestone cliffs above the present springs.

In unconsolidated material such as sand or gravel, springs may be quite young, and may be destroyed before they are 100 years old. A river may cut away a spring outlet in terrace gravel. A moving sand dune may bury it. Along the coast hurricanes can completely change the landscape. New springs may appear in large, man-made gullies. Provided that the water table remains at about the same elevation, springs in sand or gravel will continue in the same general area even if individual springs are destroyed.



Tinaja, Terrell County.

A *tinaja* is a water hole in impervious rock. As there is no English equivalent, the Spanish word, which also means *large earthen jar*, is used. Tinajas are filled by rainfall and surface runoff, not by springs. Although a few are mentioned in this book, most are not. *Tinajita* or *tinajaca* is the diminutive form.

A *charco* is a water hole in unconsolidated material. It may be fed by seepage water, or it may have to rely solely upon surface runoff water. *Charquito* is the diminutive.

SIZE OF SPRINGS

According to Vineyard and Feder (1974), the largest springs in the world probably occur at the termini of glaciers in Greenland during the summer months. Some of the other largest springs in the world are listed in the following table.

The largest known spring in the world was described by Rosenau and others (1977).

Name	**Location**	**Average Discharge (liters per second)**	**Type of Aquifer**
Spring Creek Submarine Springs	Florida	57,000	Limestone
Ras el 'Ain	Syria	39,000	Limestone
Stella Springs	Italy	37,000	Limestone
Rio Maule Springs	Chile	28,000	Basalt
Malade Springs	Idaho	28,000	Basalt
Fontaine de Vaucluse	France	23,000	Limestone
Silver Springs	Florida	23,000	Limestone
Giant Springs	Montana	17,000	Sandstone
Big Spring	Missouri	12,000	Limestone
Metolius Springs	Oregon	11,000	Volcanic rocks
Spring Creek	California	9,300	Andesite

The largest springs in Texas are listed in the following table. It is worthy of note that all of Texas' largest springs burst from Edwards and associated limestones.

Name	**Location (County)**	**Average Discharge (liters per second)**
Comal	Comal	9,000
San Marcos	Hays	4,300
Goodenough	Val Verde	3,900*
San Felipe	Val Verde	2,600
Barton	Travis	1,400
San Antonio	Bexar	1,400*
Hueco	Comal	1,100
Comanche	Pecos	990*
San Solomon	Reeves	950
Big Paint	Edwards	670
Las Moras	Kinney	620*
Salado	Bell	460
Seven Hundred	Edwards	460
Government	Schleicher	420
Wilkinson	Menard	410
Adams	Sutton	390
Phantom Lake	Jeff Davis	330*

*These figures are for the period of record. It should be noted that Comanche Springs ceased flowing in 1961, Goodenough Springs were covered by Lake Amistad in 1968, and San Antonio, Las Moras, and Phantom Lake Springs have shown a significant decline in discharge in recent years.

The springs of Texas may be classified by size as follows:

Magnitude	Average Discharge (Liters per Second)
Very large	Over 2,800
Large	280 to 2,800
Moderately large	28 to 280
Medium	2.8 to 28
Small	0.28 to 2.8
Very small	0.028 to 0.28
Seeps	Less than 0.028

This is an adaptation of the classification used by Meinzer (1927). Some springs which have been infrequently measured are difficult to classify by size. Spring discharges vary with the amount of rainfall and recharge. If the few measurements were made during periods of abundant rainfall, the flow would be higher and the spring might be classified as larger than it really is. The reverse holds true if the discharge observations were made during dry periods. Hence considerable judgment enters into the classification of springs by size.

Originally (at the dawn of history in the area), Texas had four very large springs: Comal, San Marcos, Goodenough, and San Felipe Springs. Goodenough Springs have been under 46 meters of water in International Amistad Reservoir since it was completed in 1968. They still flow, but probably at a greatly reduced rate. San Felipe Springs fell below a discharge of 2,800 liters per second soon after 1900 because of a declining water table. In recent years, however, they appear to be resuming their status as very large springs as a result of the recharge to their aquifer by upstream Amistad Reservoir.

Although the total flow of Texas' springs and seeps has declined considerably over the years, it is still estimated to be in excess of 117,000 liters per second, or 3.6 cubic kilometers per year.

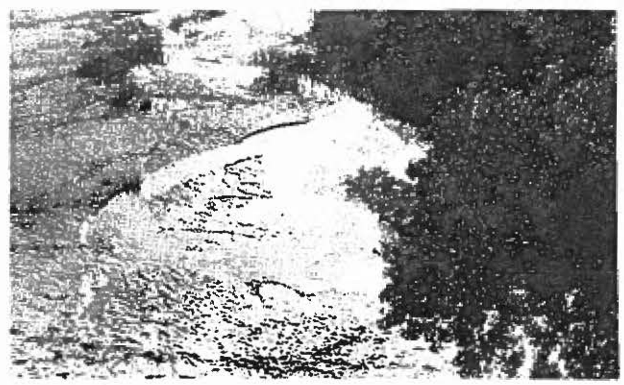
SOME FEATURES OF SPRINGS

Springs may be classified as artesian or gravity springs. Artesian springs issue under pressure, generally through some fissure or other opening in the confining bed which overlies the aquifer. Most of the large springs in the Balcones fault zone are of this type. Often a spring boil or fountain at the orifice is an indication that pressure exists in the springs reservoir system. On the other hand, gravity springs drain from their aquifers with no additional pressure.

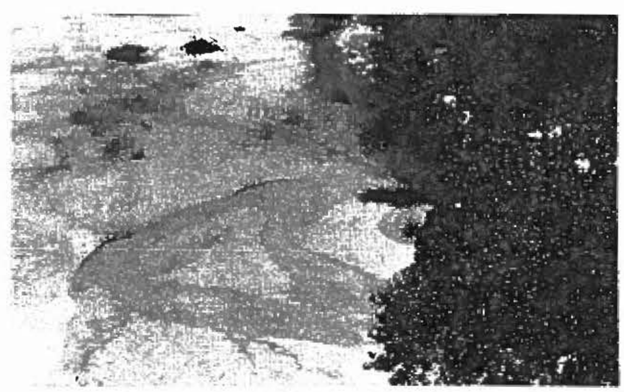
Many springs and spring-fed creeks are subject to diurnal variations in flow. During the heat of summer days, evaporation and transpiration of water by trees and other growing plants causes the spring flow to subside or cease altogether. One large pine tree transpires 0.02 liter of water per second. During the night the spring discharge increases again. Captain Randolph Marcy in his explorations of west Texas around 1850 noted that many streams sank completely into their sand beds during the afternoon, flowing on the surface only during the night and morning.

Many springs also show a seasonal variation in flow. Spring flow may be three times as high in winter as in summer. This is due to several factors. Evapotranspiration uses much ground water in summer. Pumping of ground water for irrigation often causes springs to dry up during the summer months. And snowmelt in the higher mountains such as the Guadalupe and Davis Mountains can cause increased spring discharges in spring.

Some springs are notable for their variation in flow with barometric pressure. Just as water levels in wells vary with barometric pressure, spring flow can also be markedly affected. When the atmospheric pressure is falling and stormy weather is approaching, such springs increase their flow. Owners of these springs are able to predict rain with remarkable accuracy by observing their springs' discharge.



McClellan Creek at Highway 273, Gray County, at 9:00 a.m. on July 14, 1978. Discharge 2.9 lps.



Same site at 2:00 p.m. on July 14, 1978. Discharge 0 lps.

Ebb-and-flow or periodic springs have periods when they flow vigorously, and periods when they ebb, cease to flow or flow at a greatly reduced rate. The periods of flow may occur at nearly regular intervals or at irregular intervals. The interval may range from a few minutes to several days. Nearly all of the springs of this type issue from limestone.

It has been suggested by Vineyard and Feder (1974) that the miracle-working waters described in the Bible (John 5:2-9) were an ebbing-and-flowing spring. In 1724 the periodic action of springs of this type was ascribed by J. T. Desaguliers to natural siphons in the rocks. Studies made to date seem to confirm the siphon theory. Observations suggest that periodicity is a function of spring discharge. Critical discharge ranges appear to exist for each spring, above or below which the spring will flow normally.

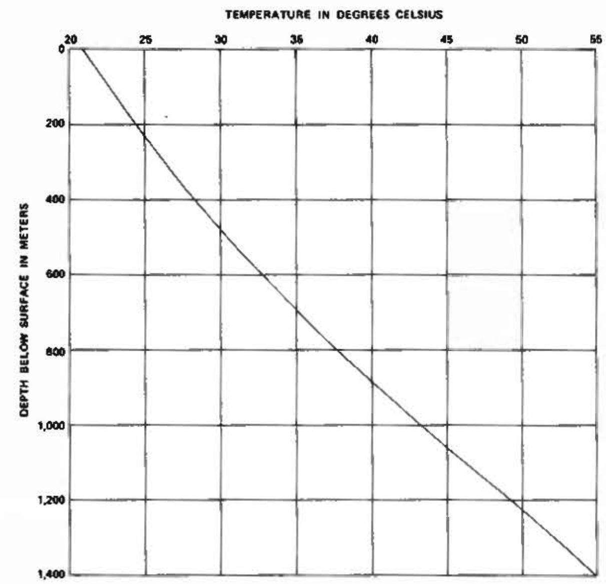
Ebb-and-flow springs are relatively rare and unusual. Only 27 are known in the United States, of which 8 are located in Missouri. The writer has found only one in Texas — at Seiders Springs in Austin (Travis County).

Some springs are classed as thermal springs. Thermal springs may be hot or warm. Hot springs have a temperature higher than 37° Celsius. Warm springs' temperatures range from one or two degrees higher than the local mean annual temperature of the atmosphere to 37° C. Non-thermal springs have temperatures one or two degrees higher than the mean annual local temperature. In Texas the mean annual temperature ranges from 12° C in the north to 23° C in the south. At the back of the book is a map, "Hot and Warm Springs," showing the location of thermal springs in the study area.

Spring waters maintain a constant temperature the year around. In summer non-thermal springs seem cold in comparison with the air temperature. In winter they seem warm. The many springs called *Cold Springs*, *Cool Springs*, or *Agua Fria* were undoubtedly named during the heat of summer. On a cold day in 1913 Gordon called Forestburg Springs in Montague County warm springs. But the writer found them to be normal non-thermal springs with a temperature of 19° C (The mean annual air temperature here is 18° C).

The constant temperature of springs often assists in locating them where they are beneath the waters of a lake or pool. In summer the spring water is much cooler than the surrounding lake water, and fish tend to gather at the springs. In winter the spring water is warmer than the lake water, and often causes some spots to remain open while the rest of the lake freezes over.

Ground-water temperature increases with depth below the land surface at a relatively constant rate. In



Increase in ground-water temperature with depth below the surface, Travis County.

Travis County, as shown in the accompanying graph, the thermal gradient is about 23° C per kilometer of depth, based upon 310 well records. The gradient varies in other areas according to the geologic structure and lithology. The temperatures of thermal springs reflect the depths below the surface to which the water has circulated. At Capote Warm Springs in Presidio County (temperature 37° C), Henry (1976) has estimated that the thermal gradient is at least 40° C per kilometer, and that the spring waters circulate to at least 400 meters depth.

PHYSICAL SETTING OF SPRINGS

PRINCIPLES OF OCCURRENCE

The source of all fresh water in Texas is precipitation on the surface of the land. This ranges from 20 centimeters in the west to 142 centimeters in the east. Only a small part of the precipitation reaches the ground-water reservoir. Part runs off overland (direct runoff), part is consumed by vegetation (transpiration), and part is evaporated. The remaining water percolates downward and after replenishing deficiencies of soil moisture, joins the body of ground water in the zone of saturation below the water table.

Here it may enter an aquifer composed of rock or unconsolidated material. Aquifers vary greatly in their capacity to transmit water, depending upon the size, shape, and arrangement of the openings which they contain. Water moves through these aquifers, usually down the dip or slope of the beds. If the aquifer crops out at a lower elevation than that of the recharge area, water issues from it in the form of springs or seeps.

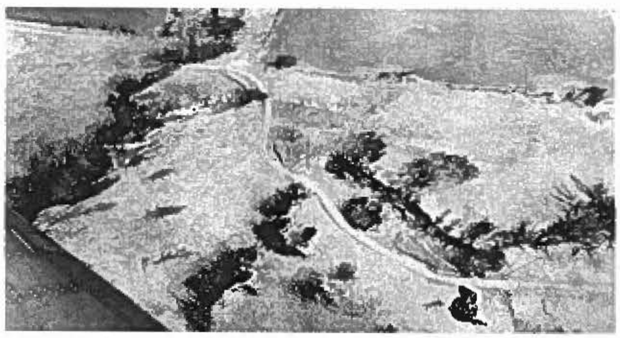
Springs are common at the base of bluffs along major rivers, because of the relatively low elevation. They are also apt to be found below falls or pouroffs in stream channels for the same reason. An example is Pedernales Spring at the foot of the falls in Pedernales Falls State Park in Blanco County.

Recharge can enter an aquifer either directly as rainfall on its surface, or from lakes and streams which overlie the aquifer. A stream which provides recharge to an aquifer is called a *losing stream.* The recharge area may be only a few hectares or hundreds of square kilometers in size.

Recharge to sand and gravel aquifers is usually through countless openings between the particles. Many sands have relatively low transmissivities. Since the ground water moves so slowly through them, springs in sands may continue to flow for many months, or even years, without any rainfall in the recharge area.

Limestone aquifers are usually recharged through sinkholes, often in stream channels. These sinkholes, sometimes 100 meters in diameter, may connect with a network of passages through the limestone. Passage of water through such rock is relatively rapid. The water constantly dissolves the walls of the passages, enlarging

Small sinkhole in Edwards limestone.



Aerial view of gypsum terrain, showing streams entering sinkholes to go underground.

them and usually more than compensating for the plugging action of modern sediment and debris washed into the sinkholes. Gypsum, being much more soluble than limestone, is even more apt to develop and enlarge subterranean passages.

GEOLOGY OF SPRINGS

Before discussing the influence of geologic formations on springs, it will be well to clarify the grade scales used to describe unconsolidated material of various particle sizes. Many different systems are in use, with the result that a sand, for instance, means one thing to one person but something entirely different to another. The system used in this book is the American Geophysical Union classification, as follows:

Material	Size in Millimeters
Very large boulders	Over 2,048
Large boulders	1,024 to 2,048
Medium boulders	512 to 1,024
Small boulders	256 to 512
Large cobbles	128 to 256
Small cobbles	64 to 128
Very coarse gravel	32 to 64
Coarse gravel	16 to 32
Medium gravel	8 to 16
Fine gravel	4 to 8
Very fine gravel	2 to 4
Very coarse sand	1 to 2
Coarse sand	0.5 to 1
Medium sand	0.25 to 0.5
Fine sand	0.125 to 0.25
Very fine sand	0.063 to 0.125
Coarse silt	0.031 to 0.063
Medium silt	0.016 to 0.031
Fine silt	0.0078 to 0.016
Very fine silt	0.0039 to 0.0078
Coarse clay	0.0020 to 0.0039
Medium clay	0.0010 to 0.0020
Fine clay	0.0005 to 0.0010
Very fine clay	Less than 0.0005

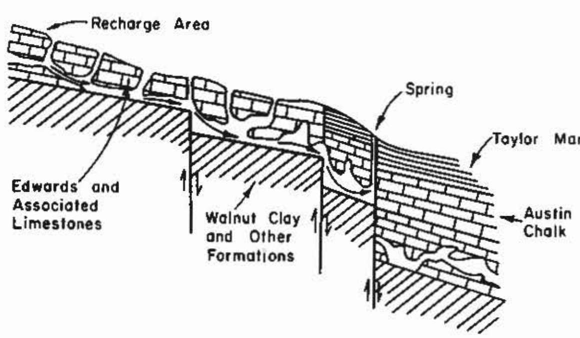
The coarser materials usually form very good spring aquifers, provided that they are *clean;* that is, that they contain little fine material such as silt or clay. Also if sand, for example, has been cemented by silica, making it a sandstone, its permeability and water-transmitting capacity may be reduced.

A fine material such as clay may have the same porosity, or percentage of void space, as a coarser material such as a clean sand. But the smaller pores in the clay cause a great increase in resistance to flow, and a much lower permeability.

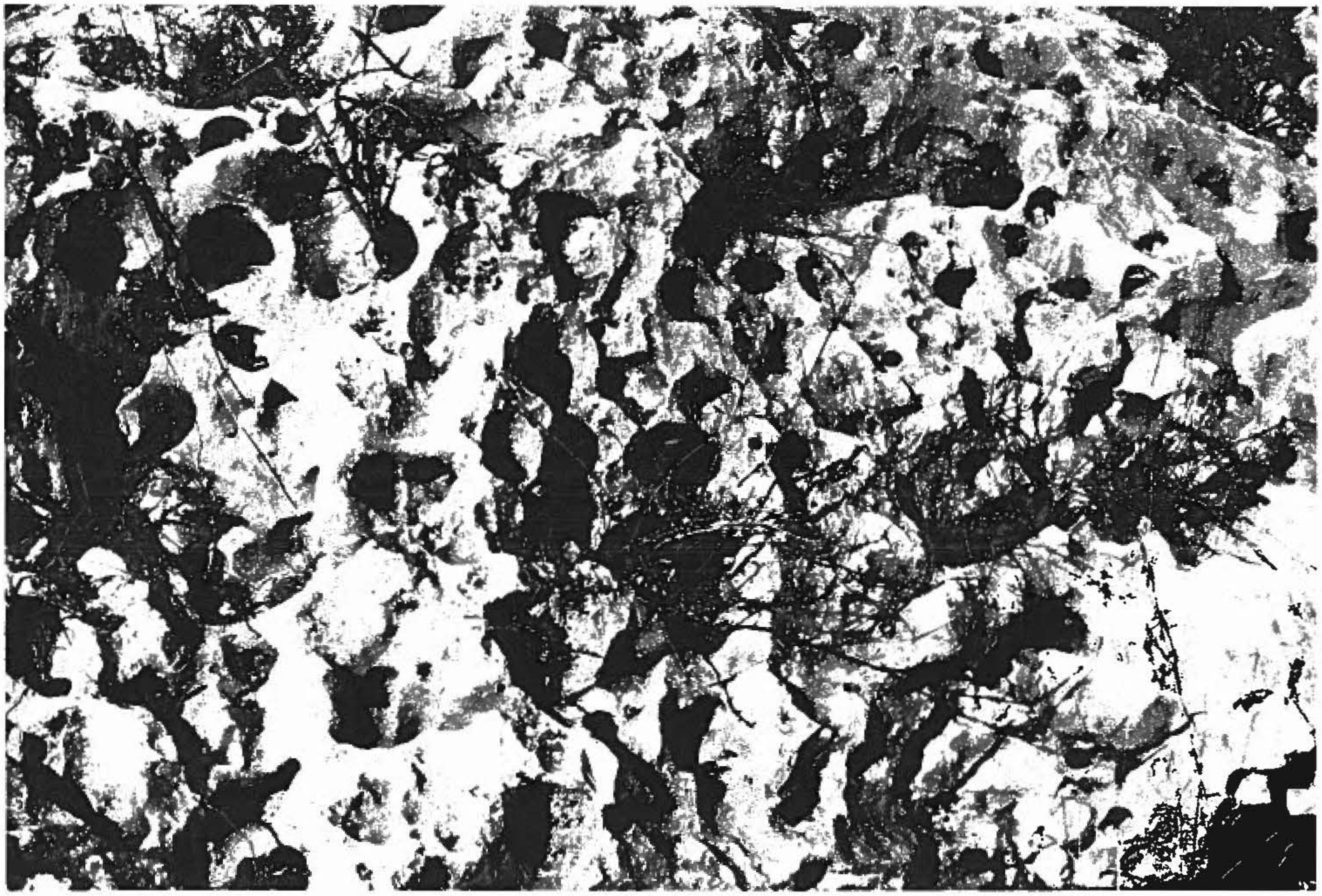
At the back of the book is a "Generalized Map of Spring Aquifers" which crop out in the study area. Many very small areas, such as sand and gravel terraces along streams, could not be shown on this map.

The Edwards and associated limestones (a part of the lower Cretaceous or Comanchean series) constitute by far the most prolific spring aquifer in Texas. Certain parts of these vugular limestones are filled with large, interconnected caverns which can form tremendous underground reservoirs. The flow of many springs from these underground reservoirs tends to fluctuate considerably, depending upon the amount of rainfall, recharge, and water in storage. But the Edwards and associated limestones aquifer shows a remarkable ability to recharge itself quickly whenever recharge water is available.

The accompanying diagram illustrates the geologic structure in the Balcones fault zone, where most of



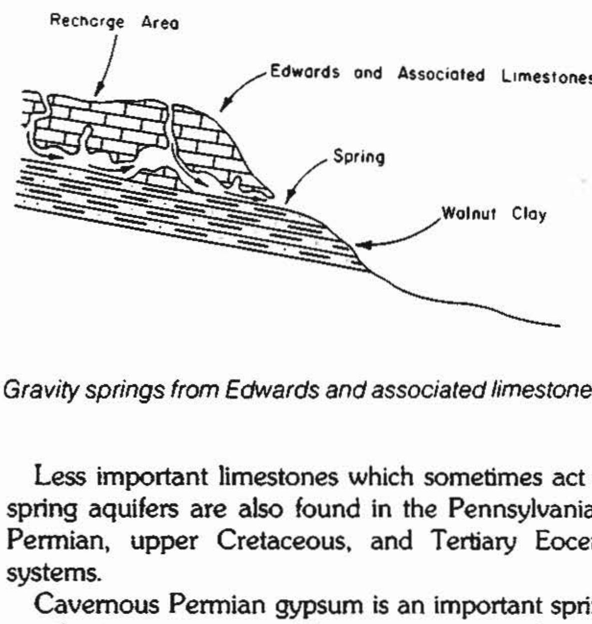
Artesian springs from Edwards and associated limestones, Balcones fault zone.



Vugular Edwards limestone, Uvalde County.

Texas' large springs burst forth. Here displacement of the rocks by faulting has brought the Austin chalk and Taylor marl into contact with the southeast edge of the Edwards limestone underground reservoir, forming an impervious dam. The water, under artesian pressure, is forced to escape upward along the fault planes.

In much of Texas the Edwards and associated limestones provide water which feeds gravity springs. In a typical case the water percolates downward until it reaches the impervious clays of the Walnut formation. Then it moves laterally, emerging as springs on the hillsides or in stream beds.

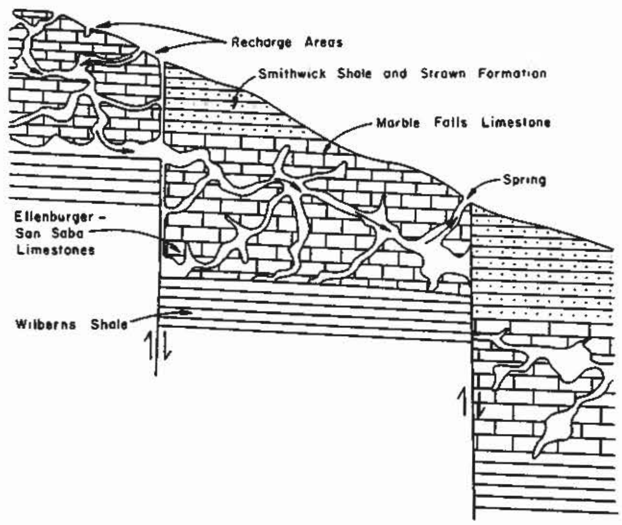


Gravity springs from Edwards and associated limestones.

Another example of a cavernous limestone aquifer is the lower Paleozoic Marble Falls and Ellenburger-San Saba limestones. Partly because of faulting, these limestones are often hydrologically interconnected and function as a common aquifer. Through faulting also the Smithwick shale and Strawn formation are so situated as to form a dam against the limestone reservoir. The ground water escapes through faults as artesian springs.

Less important limestones which sometimes act as spring aquifers are also found in the Pennsylvanian, Permian, upper Cretaceous, and Tertiary Eocene systems.

Cavernous Permian gypsum is an important spring aquifer in some areas. The accompanying diagram shows a typical spring in the Blaine gypsum of the Childress area. The recharge water enters the gypsum



Springs in Marble Falls and Ellenburger limestones.

underground caverns through sinkholes and rock fractures. It then migrates downdip to areas where it is confined above by the less permeable rocks of the Whitehorse group. When it reaches an unconfined spot as shown, it emerges as artesian springs. Gypsum may also take the form of secondary veins of selenite in sandstone aquifers.

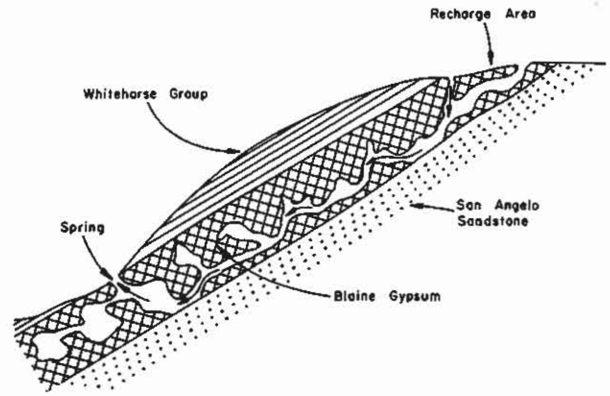
Gravel aquifers often furnish water to strong springs. Most commonly they are found in Quaternary terraces along rivers. Tertiary formations such as the Ogallala also contain significant gravel deposits. Gravel pits are usually indicators of possible springs, provided the water table is high enough. The clean gravel mined in commercial pits is also an excellent aquifer.

Where gravel and cobble deposits cover a river channel, as along the Nueces River, the flow sometimes disappears into the coarse material, becoming *underflow*. When it reappears, perhaps at a rock outcrop, it forms *underflow springs*.

Sand spring aquifers are widespread in Texas. The most important is that underlying the High Plains or *Llano Estacado* in the Panhandle. Bolton (1949), describing Coronado's adventures in 1541, wrote:

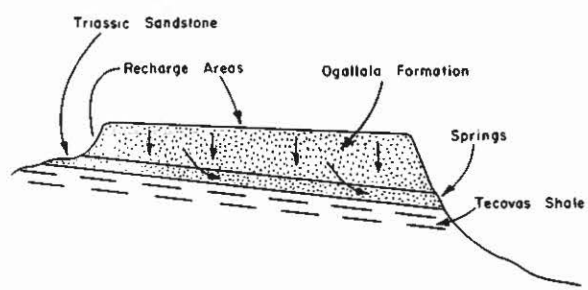
> Toward the east they could see the imposing line of rampart-like cliffs which gave the vast level expanse ahead of them the name of Llano Estacado (Stockaded or Palisaded Plain), later mis-translated by Anglo-Americans into "Staked Plains," which completely missed the point of the Spanish designation. The usual explanation, about driving down stakes to avoid getting lost, is an engaging folk tale.

The Ogallala sand, gravel, and caliche of the High



Springs in Blaine gypsum.

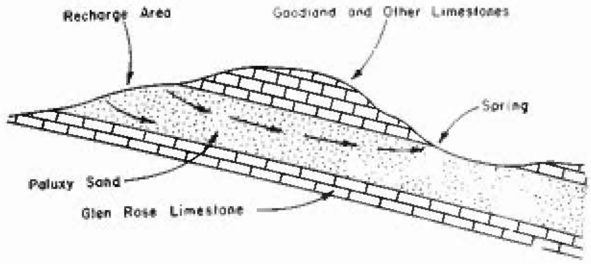
Alluvial gravel, Presidio County.



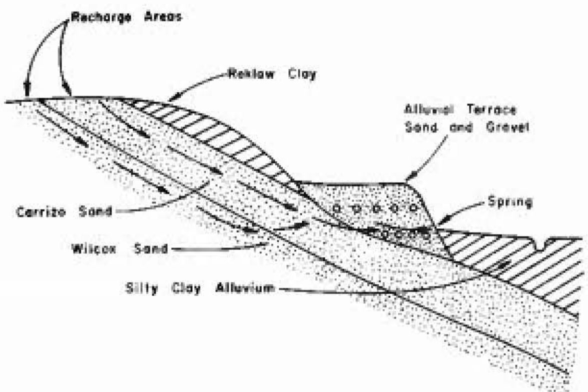
Springs in Ogallala formation and Triassic sandstone.

Plains are often hydrologically connected with th Triassic Dockum sandstone or Edwards limestone be neath, as shown in the accompanying diagram.

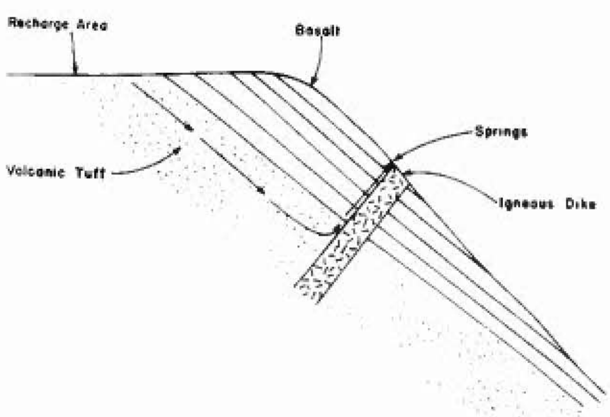
Other sand aquifers are found in Quaternary rive terraces, throughout the Tertiary, and at scattered hor zons in the Cretaceous system. Examples of the situa tions in lower Cretaceous Paluxy and Eocene Carrizo Wilcox sands are shown in the accompanying di



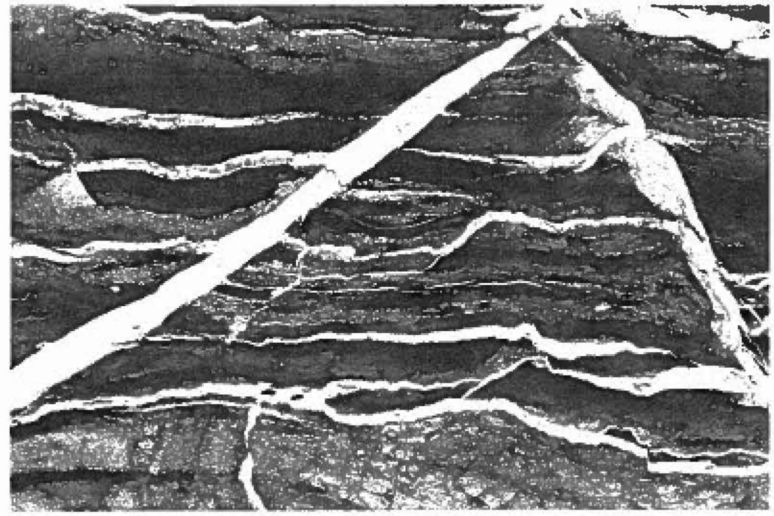
Springs in Lower Cretaceous Paluxy sand.



Springs in Carrizo-Wilcox sands and terrace sand and gravel.



Springs in igneous rocks.



Selenite veinsin Quartermaster formation, Briscoe County.

grams. Springs from sand may usually be described as a large collection of seeps. In some instances, however, if the sand is partially cemented, the water may emerge through one or more distinct openings.

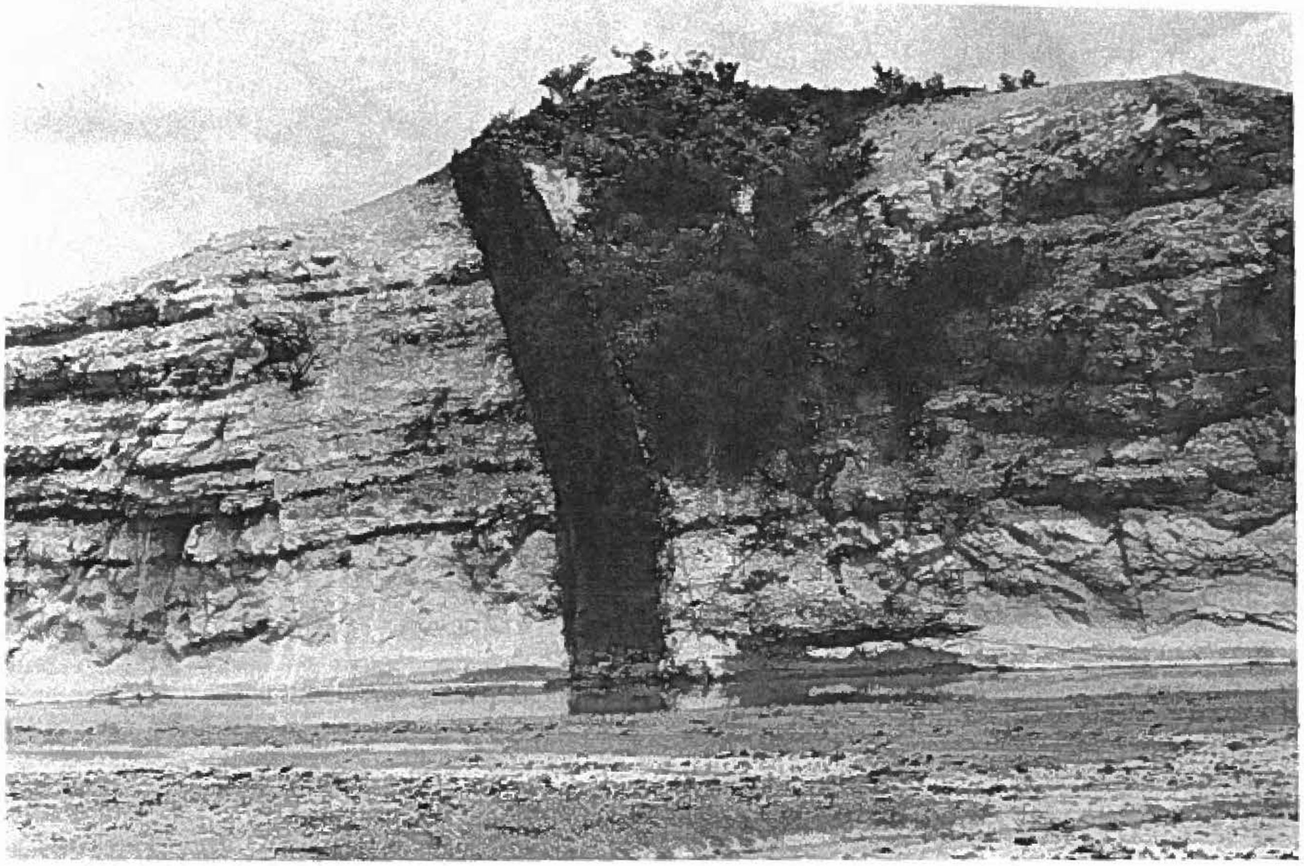
Less common aquifers include sandstone, siltstone, conglomerate, volcanic tuff and breccia, and metamorphic schist. Igneous intrusive rocks such as granite are generally poor aquifers, although when highly weathered and jointed they can transmit small quantities of water.

The structure of geologic formations is important in controlling spring locations. Passages along faults often convey water to the surface. A fold can provide a trough which guides water to springs.

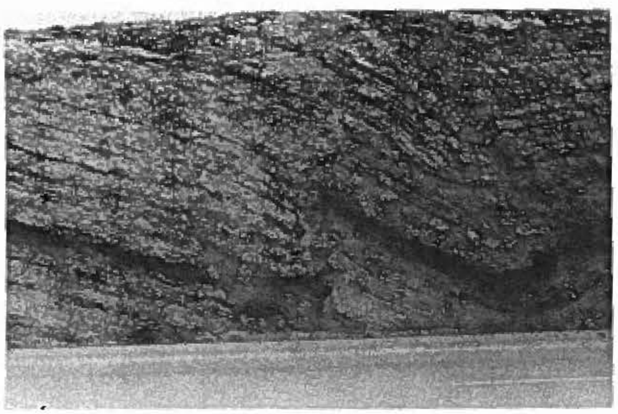
An outcrop of a steeply-dipping resistant bed may force water moving beneath the surface in alluvial gravel or sand to come to the surface as springs. Such resistant beds are often found along faults.

Igneous intrusives such as dikes may form underground barriers, forcing the ground water to emerge as springs.

Outcrop of hard Caballos novaculite forcing subterranean flow to the surface at Cottonwood Springs (30), Marathon Area, Brewster County.



Igneous intrusive dike, Presidio County.



Fault and folds in lower Cretaceous limestone, Kimble County.

QUALITY OF SPRING WATERS

GENERAL

Spring waters are generally very clear because of their low content of suspended matter. A glassful of the water is colorless. But in deep spring pools the water takes on a definite blue color, giving rise to names such as *Blue Springs* or *Blue Hole*.

A general classification of water quality based upon total-dissolved-solids content, developed by Winslow and Kister (1956), is as follows:

Description	Dissolved-solids Content in Milligrams per Liter
Fresh	Less than 1.000
Slightly saline	1,000 to 3.000
Moderately saline	3.000 to 10.000
Very saline	10,000 to 35.000
Brine	More than 35.000

CONSTITUENTS OF SPRING WATERS

The source and significance of the more important dissolved mineral constituents and properties of spring waters are shown in the accompanying table, adapted from Doll and others (1963).

CONSTITUENT OR PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30mg/1. High concentrations, as much as 100 mg/1, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners. In this book 5 to 15 mg/1 is considered medium, 15 to 40 mg/1 high, and over 40 mg/1 very high.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment.	On exposure to air, iron in ground water oxidizes to a reddish-brown precipitate. More than about 0.3 mg/1 stains laundry and utensils reddish brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing and other processes. U.S. Public Health Service drinking-water standards state that iron should not exceed 0.3 mg/1. Larger quantities cause unpleasant taste and favor growth of iron bacteria. In this book 0.3 to 1.0 mg/1 is considered moderately high, 1.0 to 3.0 mg/1 high, and over 3.0 mg/1 very high.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium are desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Found in ancient brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chlorides, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers, and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. U.S. Public Health Service drinking-water standards recommend that the sulfate content should not exceed 250 mg/1.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. U.S. Public Health Service drinking water standards recommend that the chloride content should not exceed 250 mg/1.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual. In Texas the optimum concentration of fluoride in drinking water is 0.6 to 1.0 mg/1.
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. U.S. Public Health Service drinking-water standards suggest a limit of 45 mg/1. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils.	U.S. Public Health Service drinking-water standards recommend that waters containing more than 500 mg/1 dissolved solids not be used if other less mineralized supplies are available. Waters containing more than 1,000 mg/1 dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness as much as 60 mg/1 are considered soft; 61 to 120 mg/1, moderately hard; 121 to 180 mg/1, hard; more than 180 mg/1, very hard.
Hydrogen ion concentration (pH)	Acids, acid generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals. In this book a pH of less than 5.5 is considered very acid, 5.5 to 6.5 acid, 6.5 to 7.5 neutral, 7.5 to 8.5 alkaline, and over 8.5 very alkaline.
Boron (B)	Dissolved in small quantities from rocks and soils.	An essential plant micronutrient up to 0.5 mg/1. Concentrations between 0.5 and 4.0 mg/1 can cause crop damage, depending upon the sensitivity of the particular crop.

Natural oil seeps on water at Union Springs, Nacogdoches County.

Other materials are sometimes found in spring waters. Natural oil seeps may discolor the water and make it unpalatable. Tar from such seeps is reported to have been used by Spanish explorers in the 16th century to caulk their ships.

The shells of some fossil species of mollusks and brachiopods contain relatively large quantities of strontium. Mattison (1978) found as much as 4.1 milligrams of strontium per liter in some of the warm and hot springs in Big Bend National Park. Presumably the rising thermal waters leach strontium from these fossil shells.

Spring waters derived from limestones are usually of a calcium bicarbonate type, very hard, alkaline, and high in silica content. They may be high in sulfate and chloride.

Spring waters from gypsum are of a calcium sulfate type, very hard and alkaline. They may acquire sodium chloride from associated salt beds. Early explorers found that "gyp" water quickly produced diarrhea, but that it was useful in relieving malaria, chills, and fever. They also discovered that beans could not be cooked in gypseous water, because the more they were boiled, the harder they became. But many preferred gypseous water for making coffee.

Sand and gravel spring waters vary considerably in chemical content. In east Texas they are usually soft or moderately hard, of neutral hydrogen ion concentration (pH), and high in silica and iron. In west Texas they are apt to be very hard, alkaline, and high in silica and fluoride. They also may be high in sulfate or chloride.

In southeast Texas rising salt plugs have sometimes raised the overlying sediments into a dome shape. If the salt reaches close to the surface, it may give rise to saline springs, swamps, and "salt licks."

Most spring waters, however, are less mineralized than well waters. Because of the constant natural circulation of the water, there is less chance that a heavy load of chemical constituents will be picked up. Wells, on the other hand, may penetrate very old waters which have been in place for thousands of years and have had plenty of time to become mineralized.

In this connection it may be noted that the larger springs are less apt to be mineralized. Most of the mineral springs which were famous in the past for their health-giving qualities were weak, slow-flowing springs. The very slow flow provided time for the water to pick up its load of minerals in solution. Because their flow was so small, mineral springs have often been the first to fail when the water table declined because of man's activities.

The dissolved-solids content of spring waters varies with the discharge. At Phantom Lake Springs in Jeff Davis County, for example, the total-dissolved-solids concentration has been found to vary from 2,250 milligrams per liter at low discharges to 114 mg/1 at high discharges. During high discharges the water passes through the limestone aquifer so rapidly that there is insufficient time for solution of much mineral material. Such great variations are more common in west Texas than in east Texas, because in the west rainfall is lower and more sporadic.

CONTAMINATION

The most common source of contamination of spring waters in Texas is oil-field brine. Brine is usually produced along with oil and must be disposed of. In the past much brine was pumped into open, unlined pits, where it could seep into the ground and enter spring-water aquifers. Although this practice was ended by law in 1969, the brine disposed into pits in the past will continue to contaminate the ground water for many years.

Brine may also move upward from deep strata through inadequately cased or plugged oil or gas wells. In other words, in some cases the surface casing does not extend deep enough to protect all potable water. In other cases, abandoned oil or gas wells are not properly plugged. Another source of contamination of ground water by brine is rusted and leaking oil-well casings.

Contamination can also be caused by septic tanks and leaking sewage systems. In this case the contaminants are chiefly nitrates, fecal coliform organisms, and streptococci.

Other potential pollutants include insecticides and herbicides which enter the ground-water reservoir along with recharge water, and various harmful chemicals produced by industrial plants.

Sand aquifers can be contaminated by dissolved pollutants such as brine. But coliform organisms, other bacteria, and insecticides are effectively strained out in a relatively short distance. Some sand aquifers have a low transmissivity, and in extreme cases water may require hundreds of years to travel from a recharge area to a spring. Hence a pollution problem may not be recognized until many years after it has originated. And when the source of contamination is stopped, many more years may pass before all of the contaminant is flushed from the aquifer.

Cavernous limestone or gypsum aquifers are much more vulnerable to pollution. They receive recharge from surface water through open crevices and sinkholes without any filtering action. All types of pollutants can readily enter a limestone or gypsum underground reservoir. Therefore, it is especially important to protect the recharge areas of these aquifers and springs from pollution hazards. Since water moves relatively fast through underground passages in limestone or gypsum, it usually reaches a spring in a matter of days. Hence pollution problems can be quickly recognized and stopped.

Another form of pollution is eutrophication of spring-fed pools and ponds, in which an overabundance of mineral and organic nutrients reduces the dissolved oxygen content. This produces an environment that favors plant over animal life, and algae become dominant.

CHEMICAL ANALYSES OF SPRING WATER

Analyses of spring waters are shown in the table, "Selected Chemical Analyses of Spring Waters," at the back of this book. No attempt has been made to list all of the available analyses. Only a few are shown for each county to furnish a general idea of the chemical composition of the springs waters. Where there has been a change in chemical content due to contamination or other causes, more than one analysis may be shown.

Before 1930, most of the analyses were made by the University of Texas. In the 1930s, many were made by the Works Progress Administration. In the 1940s and 1950s most analyses were done by the U.S. Geological Survey. Since 1960 the majority of those shown have been made by the Texas Department of Health. Many field tests of sulfate and chloride content made by the writer have also been included in the table.

The older analyses are of limited accuracy and should be used with care. Also, some of the earlier analyses are low in total dissolved solids because silica and nitrate were omitted, and because there was some precipitation of calcium carbonate before the analyses were made. Nevertheless, if a spring has dried up and no longer exists, an old chemical analysis may provide the only available record of its water quality. Also, if a spring is suspected of having been contaminated, an older chemical analysis may provide the only clue to the original quality of its water.

In addition to the standard chemical analyses listed in the table, certain other constituents have been measured for some spring waters. These include fecal coliform organisms and streptococci; biochemical oxygen demand and dissolved oxygen; detergents; elements such as aluminum, copper, zinc, lithium, strontium, nickel, lead, iodine, mercury, and arsenic; the insecticides aldrin, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, and lindane; and the herbicides 2,4-D plus and 2,4,5-T plus. Tests for these constituents have been made primarily on the large and very large springs of the Edwards and associated limestones in the Balcones fault zone. None of the tests to date have shown dangerous concentrations of any of these components.

PREHISTORIC SETTING OF SPRINGS

MAN'S ARRIVAL IN TEXAS

Man first appeared on earth, in East Africa, about 3.5 million years ago. But it was several million years later before he arrived in the New World. In all that time Texas' springs were used only by plants and animals. Many of the trails to water which the animals made were later adopted by mankind. Some animals such as coyotes were intelligent enough to dig wells when springs and seeps dried up. Some localities are still known as "Coyote Wells."

When early man first arrived in America is still subject to much debate. In northern Delaware a shell pendant was found with a picture of a woolly mammoth etched into it. Its age has been estimated at 60,000 to 100,000 years. Most archeologists believe that these ancient people reached America 30,000 to 40,000 years ago by walking from Asia to Alaska over an 80-kilometer land bridge. During the ice age the sea level was considerably lower because much of the earth's water was locked up in huge inland ice sheets. Thus at times Asia and Alaska were connected by land. Early Americans could also have walked across Bering Strait on the ice at times when it was frozen over, or drifted across on ice islands.

But the advent of man into America was not a one-time event. It continued from the first entry to the present time. Columbus' so-called discovery in 1492 was only one small part of this great migration. Cretan and Phoenician boats are believed to have reached America 3,000 to 3,800 years ago. Marquesan islanders of the Pacific probably visited Peru. Chinese and Japanese fishermen may have drifted along the west coast.

Mankind arrived in Texas at least 30,000 years ago. At an archeological site near Lewisville in Denton County, radiocarbon analysis has dated charcoal from a hearth as at least 38,000 years old. Associated with the charcoal were crude sculptures, spears, and spear throwers. These people always camped near springs or spring-fed streams or lakes. They preferred clear, pure water just as we do today.

The climate of Texas was cooler and wetter 7,000 to 15,000 years ago. Springs were a little more numerous then than at the dawn of history in Texas. Not far west of the New Mexico state line and opposite to the Parmer-Bailey county line is the Blackwater Draw archeological site. Here ancient springs, up to 11,500 years old (but now dry) have been found in association with hunting and butchering tools and the remains of many extinct animals. From 7,000 to 4,500 years ago the climate gradually became drier, according to Creel (1978). Since 4,500 years ago there has been little change.

PREHISTORIC USES OF WATER

Early Americans had strong superstitions about springs. In Horgan's words (1954):

> Gods and heroes were born out of springs, and ever afterward came and went between the above and below worlds through their pools. Every pueblo had sacred springs somewhere near-by. There was every reason to sanctify them — physical, as life depended upon water; spiritual, as they had natural mystery which suggested supernatural qualities; for how could it be that when water fell as rain, or as snow, and ran away, or dried up, there should be other water which came and came, secretly and sweetly, out of the ground and never failed?

At springs where bedrock was close at hand, these ancient people ground sotol, acorns and other nuts, mesquite beans, and grain. Gradually the mortars or grinding holes became deeper, until they were so deep they could no longer be used. Then a new mortar hole was started. These mortars have been left for thousands of years as monuments to the people who lived here.

Other more-or-less immovable evidences of their long residence at the springs include hearths or burned-rock middens, where their cooking was done; grooves in the rock which were used to straighten arrows or spears; crown-polished boulders over which skins were worked to remove hair and fat; pictographs or paintings on the walls of rockshelters; and petroglyphs or carvings in the rock. The distribution of some of these evidences is shown on the map, "Archeological

Bedrock mortars at Boquillas Warm Springs (5), Brewster County.

Features Found Near Springs." at the back of the book.

It can be assumed that every fresh or slightly saline spring was used at one time or another by early Americans thousands of years ago. The sites shown on the map represent only the more important ones which were encountered in this study.

The Pueblo Indians of west Texas used spring waters for irrigation of crops long before the arrival of the Europeans, according to Hutson (1898) and Taylor (1902). This is not difficult to believe. Modern children often play in streams of water and build dams to divert the flow. So also these people probably learned by experimenting that they could dam up spring-fed streams and direct the water to their crops. This would be especially true where streams debouched onto a large river floodplain.

Like the coyotes before them, the Indians knew how to dig wells if their springs failed during droughts, or if natural seepage did not provide sufficient water. An example is Indian Wells in Gaines County, where Indians were found to have dug 20 shallow wells.

In pre-Columbian times, water tables in Texas were much higher than at present. Springs were found high on the hills, almost at the watershed divides. Indians liked to camp at as high an elevation as possible, so as to be able to survey the surrounding countryside for game or enemies. Hence they usually camped near the highest springs, which in most cases no longer exist. Under natural conditions these springs were often surrounded by bogs. In nearly all instances modern man has drained such bogs or else pumped the water table down with wells so that the bogs and springs dried up.

When Europeans entered Texas and began to take the Indians' homeland from them, most battles centered around springs. It was the white men's taking of the Indian's favorite campground at the springs that ired the red men most.

FLORA AND FAUNA OF TEXAS SPRINGS

ANCIENT FLORA AND FAUNA

Springs and spring-fed streams and ponds provide a constant supply of water. They do not dry up often as do streams and ponds fed by surface runoff only. The water is of a constant temperature, winter and summer, in most cases from 13° C in north Texas to 25° C in the south. And it is normally clear and free of the sediment which soils surface waters. These conditions are very favorable to the development of countless types of plant and animal life which could not exist elsewhere.

According to Creel (1978) studies of fossil pollen indicate that 10,000 years ago, when the climate was cooler and moister, most of Texas was a pinon parkland. Animals which frequented the springs at that time included the short-faced bear, giant lion, four-horned pronghorn, giant tapir, giant bison, dire wolf, camel, mammoth, mastodon, and the armadillo-like glyptodont. All of these animals were extinct by 6,000 years ago, some say because of hunting by early man.

By 7,000 years ago, the climate had become drier, and the predominant vegetation became a savannah of grasses with oak and hickory trees. By 4,500 years ago, there was further drying, and mesquite, agave, and acacia shrubs appeared. From 4,500 to 500 years ago, the fauna of mammals of modern species and the flora remained about the same.

PROTOHISTORIC FLORA AND FAUNA

When history dawned on Texas some 500 years ago, the abundance and size of plants and animals which depended upon spring waters was astounding by today's standards. Some hollow sycamore trees could hold 30 men. Some were lived in until a cabin could be built. Grapevines one meter in circumference were not uncommon. Huge grizzly bears roamed the woods, and man-eating alligators were a constant danger in the streams and rivers. Eighteen-kilogram turkeys, 50-kilogram catfish, and crawfish measuring 20 centimeters were the rule. The sky was dark during migrations of passenger pigeons.

At that time most springs were surrounded by bogs and ponds which beavers helped to maintain. In shallow, running water, plants such as water cress, pennywort, and cypress trees thrived. On the damp rocks surrounding springs and waterfalls, numerous ferns (especially maidenhair), mosses, and liverworts made their home.

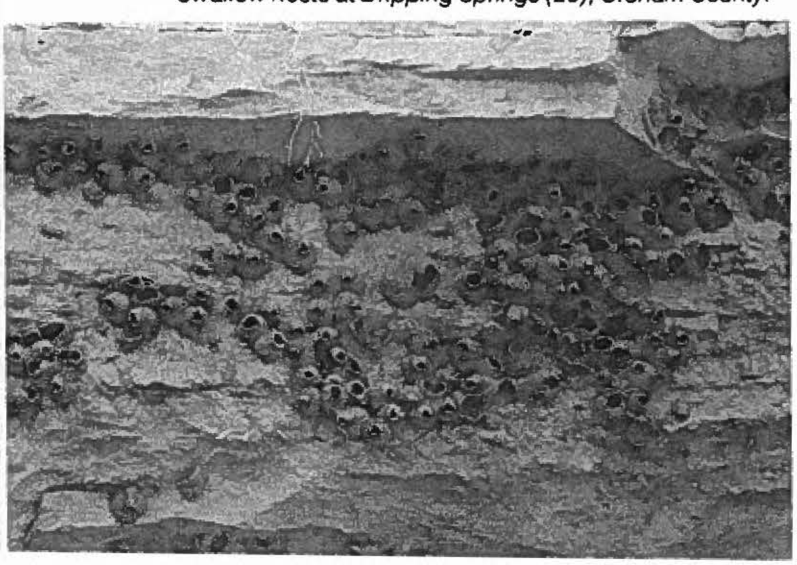
On the shores of pools were, and still are in some cases, cattails, bulrushes, spike rushes, sedges, burreeds, water plantains, arrowheads, and grapevines; and willow, cottonwood, sycamore, sweetgum, and plum trees. In deeper water, rooted in the bottom but with floating leaves, were water lilies, pondweeds, and water shields. Floating in the pools were water ferns, water hyacinths, water lettuce, duckweed, duckmeat, and water meal. Completely submerged plants in spring pools included milfoil, hornwort, naids, waterworts, and fanworts.

Bogs and seepy areas in east Texas contain much peat moss and are bordered by shrubs and trees such as yaupon, baygall bush, leatherwood, viburnum, holly, rhododendron, bay laurel, wax-myrtle, dogwood, and poison sumac, Here brightly flowered herbs also thrive, including violets, grass-of-Parnassus, pitcher plants, grass-pinks, orchids, meadow beauties, and bluehearts.

The springs were, and still are in some cases, inhabited by a large community of small animals such as flatworms, amphipods, isopods, snails, crawfish, insects, salamanders, frogs, turtles, and fish. Animals such as bears, raccoons, snakes, and birds feasted on these aquatic animals.

Many of the small animals such as amphipods, crawfish, and fish, have developed troglobitic or subterranean species. These are adapted to living in the dark in subterranean water passages, especially near limestone springs. They usually exhibit a white or translucent color, reflecting the absence of pigment, and the reduction or loss of eyes. Some are highly endemic, being known only from a single spring or cave stream.

Swallow nests at Dripping Springs (20), Oldham County.



Large herbivorous animals such as deer, elk, and bison came to the springs to drink and to eat the lush spring-fed vegetation. Carnivores such as cougars and wolves waited for their prey at the springs.

VANISHING SPECIES

Many rare plant species have vanished because they were so avidly collected by fanciers. Many animals have been shot into extermination. The extinct passenger pigeon was clubbed to death in its roost.

But far more damaging has been the loss of plant and animal habitat which existed around the springs. Swamps were drained. Irrigation pumps drew down the water table and dried up springs. Forests were cleared and virgin grassland was put to the plow. The process of *desertification* of Texas became more and more evident.

Eckholm (1978) estimated that of 10 million plant and animal species, one is lost every day. A disappearing plant can take with it as many as 30 species of insects, animals, and even other plants. If this process continues, according to Eckholm,

> The fabric of life will not just suffer a minor rip; sections of it will be torn to shreds ... Such a multitude of species losses would constitute a basic and irreversible alteration in the nature of the biosphere even before we understand its workings — an evolutionary Rubicon whose crossing *Homo sapiens* would do well to avoid.

Some rare and endangered plant and animal species are found at only one spring. The Comanche Springs pupfish and Leon Springs pupfish, for example, lived only at Comanche and Leon Springs in Pecos County. Both of these springs are now dry. These two species are being kept precariously extant at San Solomon Springs, Reeves County, along with the endangered Pecos gambusia, a small crustacean, and two kinds of aquatic snails which are believed to live nowhere else.

Species of plants and animals which survive near springs no longer are allowed to grow to a ripe old age. The enormous trees of our once-virgin forests will never be seen again. Deer are shot before they are half grown.

As plant and animal species have been wiped out in Texas, other less desirable species have moved in to replace them. When the ground-water table fell in south Texas because of man's activities, and when the land was also over-grazed, the more desirable grasses died out. But mesquite trees, which can send roots down at least 53 meters (Phillips, 1963), thrived with a lowering water table and took over. At the same time, armadillos succeeded less drought-resistant animals.

Similarly, salt cedar has replaced much more desirable vegetation along west Texas streams. It is tolerant of alkaline and saline water. With declining spring flow into streams like the Pecos River and increasing return flows of salt-laden irrigation water, salt cedars filled the gap where other vegetation could not survive.

It is unfortunate that the destruction of our earth's resources, including its living species, has taken place so slowly in the past that most men and women could not detect the change in their lifetime. Now the rate of destruction is accelerating, and man, by his very nature, is incapable of stopping it.

HISTORICAL SIGNIFICANCE OF SPRINGS

EARLY USES

When European explorers entered Texas, Indians often guided them over well-worn trails from one group of springs to another. Some of these trails later became important routes and some are now followed by superhighways. The more important ones are shown on four maps at the back of the book. They are entitled "Fifteenth and Sixteenth (Seventeenth, Eighteenth, and Nineteenth) Century Trails and the Major Springs Which Served them." No attempt has been made to show Indian trails, as they connected practically every spring in Texas. Some of the more important springs on these old routes are shown on the maps. Many springs were then called "fountains" because the artesian pressure behind them caused them to spurt high into the air.

The routes followed by some of the earliest explorers, such as de Vaca, Coronado, and Moscoso, are still not accurately known. In these cases, the writer has tried to use the routes most favored by the weight of evidence. Many local historians, in a natural desire to add flavor to their home county's past, have tried to route these early explorers through their area. Such arguments must be taken with a grain of salt.

When a network of forts was strung across Texas, they were in nearly all cases located near springs in order to have a reliable supply of pure water. Stagecoaches, freighters, and covered wagons carrying pioneers to California relied heavily upon the springs. Most of the springs in west Texas were very small in comparison with those in central and east Texas, because of the very low rainfall and recharge. Nevertheless, they often meant the difference between life and death to these early travelers.

Springs were the reason most early settlements were located where they were. Many hundreds of communities in Texas were named for their springs. Many of them are now gone although the community of that name still exists. In other cases the community is a ghost town, but the springs for which it was named still pour out. In still other instances both the springs and the community have disappeared. Some towns like Richland Springs in San Saba County still rely on springs as their primary water source.

As river boats provided the easiest mode of travel before the railroads arrived, many early settlements were made on the bluffs adjacent to the rivers. As the base of these bluffs were also favored with many springs, most river ports were well provided with pure water.

Like the Indians before them, the early settlers preferred water from springs or spring-fed creeks to river water, even though in those days river water was relatively clean and not fouled with the enormous amounts of sewage and industrial wastes which are dumped into it today. As Stephen F. Austin wrote concerning a dispute over some land along the Brazos River,

> *I shall therefore not take an inch at that place if I have to drink river water.*

Early residents often used spring waters for irrigation of crops. Generally, only the larger springs, discharging at least six liters per second, could be used for this purpose. Some springs which formerly supplied water for irrigation could not now. Their greatly decreased flow would be lost before it could reach the fields to be irrigated.

Many of the larger springs were used for water power by the early settlers. Hundreds of grist and flour mills, sawmills, and cotton gins were powered by spring waters. Later hydro-electric generating plants operated using the water. (See Plate 14, d). Very few of the olds mills still stand. Sometimes mossy mill ponds and crumbling foundations may be seen.

In the 1880s, many medical or health spas sprang up around the more mineralized springs. Long before, Indians had used these mineral waters for health purposes. The waters of these springs were believed to be beneficial in curing various ailments. Many people stayed at nearby hotels built for the purpose or camped out in summer while drinking and bathing in the waters. The more important mineral springs are shown on the map at the back of the book entitled "Mineral Springs Used for Health Purposes."

Some resorts boasted as many as seven different kinds of water. Most of the waters were high in iron, manganese, magnesium, sulfate, or chloride. They were described as being *chalybeate* (containing salts of iron), or containing *copperas* (ferrous sulfate), *alum* (aluminum potassium sulfate), or *Epsom salts* (ferrous sulfate). Most of these spas are now gone, but a few, such as Indian Hot Springs in Hudspeth County, still operate.

Many springs in Texas have acquired a high recreational value. This is especially true of the larger springs along the Balcones fault zone, such as Salado (Bell County), Barton (Travis County), San Marcos (Hays County), Comal (Comal County), Las Moras (Kinney County), and San Felipe Springs (Val Verde County).

The phenomenon of large volumes of clear, cold water issuing as springs amid rustic and picturesque surroundings make places of wonder and rare natural beauty, which offer a lure and an inspiration, especially to the less fortunate residents of large cities. Each year hundreds of thousands of vacationers, as well as local residents, visit these springs.

Some recreational springs have ceased flowing much of the time, such as Gamel Spring (Mason County), Big Springs (Howard County), and San Antonio Springs (Bexar County). The flow is now maintained by pumping water to the springs. But the artificial spring water seems to lack the cool clarity of natural spring water, and is another example of the decreasing quality of modern life.

Some springs are used as a source of water for raising game fish and bait. The uniform temperature and high quality of the waters make them ideal for this purpose. Many springs feed private and public lakes where fish are stocked. And of course nearly all spring waters are utilized by livestock.

SPRING DEVELOPMENT

Most people in our modern society have never heard of a *hydraulic ram*. This device is the most pollution-free and least expensive way of getting water to run uphill. In the days before gasoline- or electric-powered pumps, the hydraulic ram was an extremely useful piece of equipment.

It operates as follows. Water, usually from a spring, rushes down a drive pipe and escapes out of a waste valve until enough pressure is built up to close the outlet. When this occurs, water is forced through a check valve into an air chamber. The moving water compresses the air so that it pushes back like a piston. This action closes the check valve and forces water up the delivery pipe to a storage tank, pond, or irrigation ditch. The following table shows the fraction of a liter of water lifted by a hydraulic ram per liter received.

Fall	Height Delivered in Meters							
(Meters)	**3.7**	**5.5**	**7.3**	**9.2**	**11**	**15**	**18**	**22**
0.6	0.10							
1.2	0.18	0.15	0.10					
1.8	0.33	0.20	0.17	0.13	0.10			
2.4	0.42	0.28	0.20	0.17	0.15	0.10		
3.1	0.54	0.36	0.27	0.22	0.18	0.14	0.10	
3.7	0.67	0.44	0.33	0.26	0.22	0.16	0.13	0.10

A minimum source flow of 0.095 liter per second and a minimum head or fall of 0.6 meter are required. Note that the quantity of water delivered to a higher elevation is usually only a small fraction of the supply water. The drive pipe must have a slope of 30 degrees or less, and should range in length from 9 to 76 meters. The pulsations occur from 25 to 100 times per minute, so the resulting discharge is nearly continuous.

Very few hydraulic rams are still in operation at Texas springs. Two that come to mind are at Moritas Springs (10) in Presidio County, and Tecovas Springs (10) in Potter County. It is regrettable that many springs no longer have sufficient discharge to operate this simple, energy-saving mechanism.

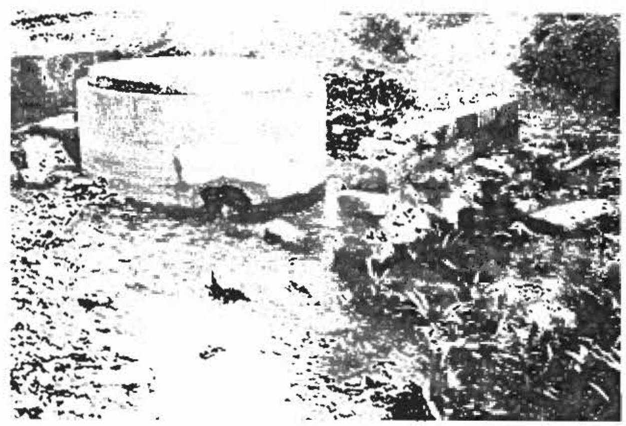
In an effort to obtain more water from springs, early settlers usually deepened them. Often a wall was placed around the springs to deepen the water and facilitate dipping it out in buckets or other containers. But this was often done incorrectly. The stone or brick wall or section of large concrete pipe was placed so that a head of water would form on top of the springs. In the case of springs with very little head behind them, this treatment often caused them to stop flowing. The walled basin should be placed *downstream* from the springs, where it will not back water over the spring outlets.

The same is true of lakes and ponds. Mankind seems to have an uncontrollable urge to build a dam and form a lake wherever he finds running water. Too often these lakes or ponds back water over the springs which feed them. The head of water over the springs counteracts the head which causes them to flow, and the spring flow ceases or even reverses.

Springs are often found in ravines, canyons, and valley trenches. These places are also convenient dumping grounds, and as a result are frequently filled with old car bodies, refrigerators, tires, and other trash. More care should be taken to preserve Texas' beautiful springs. Sometimes associated with the springs are rockshelters containing priceless ancient pictographs. Vandals with cans of spray paint write their names over these paintings, and "sportsmen" use them for target practice. Some landowners have even been known to blast shut such rockshelters in order to stop intruders from coming to view them.

It is encouraging that some counties are moving aggressively toward preservation of scenic springs by public acquisition. Historical studies are placing more emphasis on the importance of springs in our past, and historical markers are being placed at many.

Hydraulic ram at Moritas Springs, Presidio County.



Improper spring development, Williamson County.

THE DECLINE OF TEXAS SPRINGS

CAUSES OF WATER-TABLE DECLINE

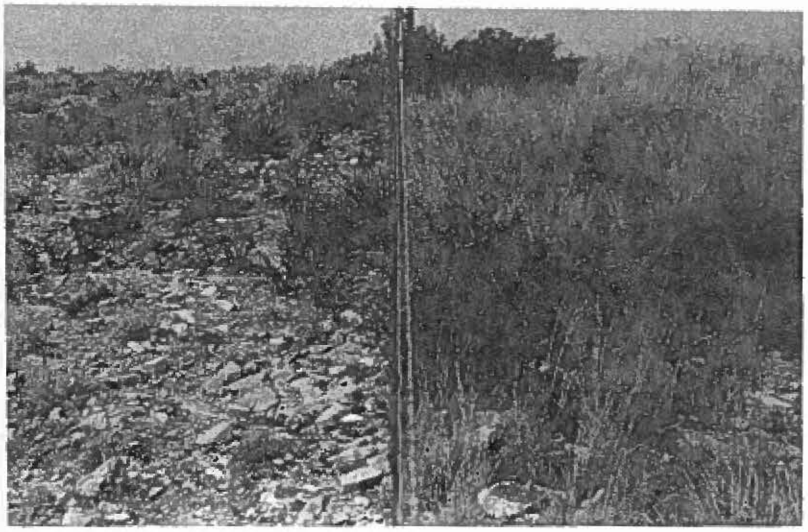
U.S. Geological Survey studies show that the Platte River in Nebraska is dying. Its annual flow now averages only 16 percent of what it was before Nebraska Territory became a state in 1867. This is a devastating statistic. But what most people do not realize is that the same thing is happening all over Texas.

When and why did the ground-water tables of Texas decline so drastically? The Indians cannot be said to have affected water levels significantly. True, some of them dug shallow wells and dipped out water in gourds or pottery jars. And some plowed and cultivated gardens. But these activities were all on a very small scale.

The damage to the ground-water reservoirs was begun by the early Spanish missionaries, but even then it was hardly noticeable for several centuries. Wells were dug for the missions. Trees were cut to provide lumber for barracks and homes. Deforested land was placed in pasture or cultivation. Cattle and other animals began to overgraze the grassland. Enormous herds of buffalo had previously devoured the grasses. But they kept moving, and left the damaged grass almost a year to recover before they returned.

Now a new system of grazing was introduced, under which cattle and other stock were turned into a pasture and kept there permanently. The overgrazed grasses had no chance to recover, and the more desirable species died out. Soon the organic turf was essentially destroyed and the soils became so compacted that they could take in only a small fraction of the recharge which they formerly conveyed to the underground reservoir. The grasses were replaced by brush such as mesquite, whose roots can reach to prodigious depths. The brush aggravated the ground-water decline by transpiring large amounts of water.

Clearing of forests was especially demaging to ground-water levels. The deep, open structure of the forest soils was altered as the organic matter was consumed and the soils became more impervious. Plowing of hillsides soon caused severe erosion and loss of the permeable mulch layer and top soil. Huge gullies began to scar the landscape. Floods and sediment damage



Overgrazing, Val Verde County. The range at the left has been severely overgrazed by sheep.

began to increase in severity.

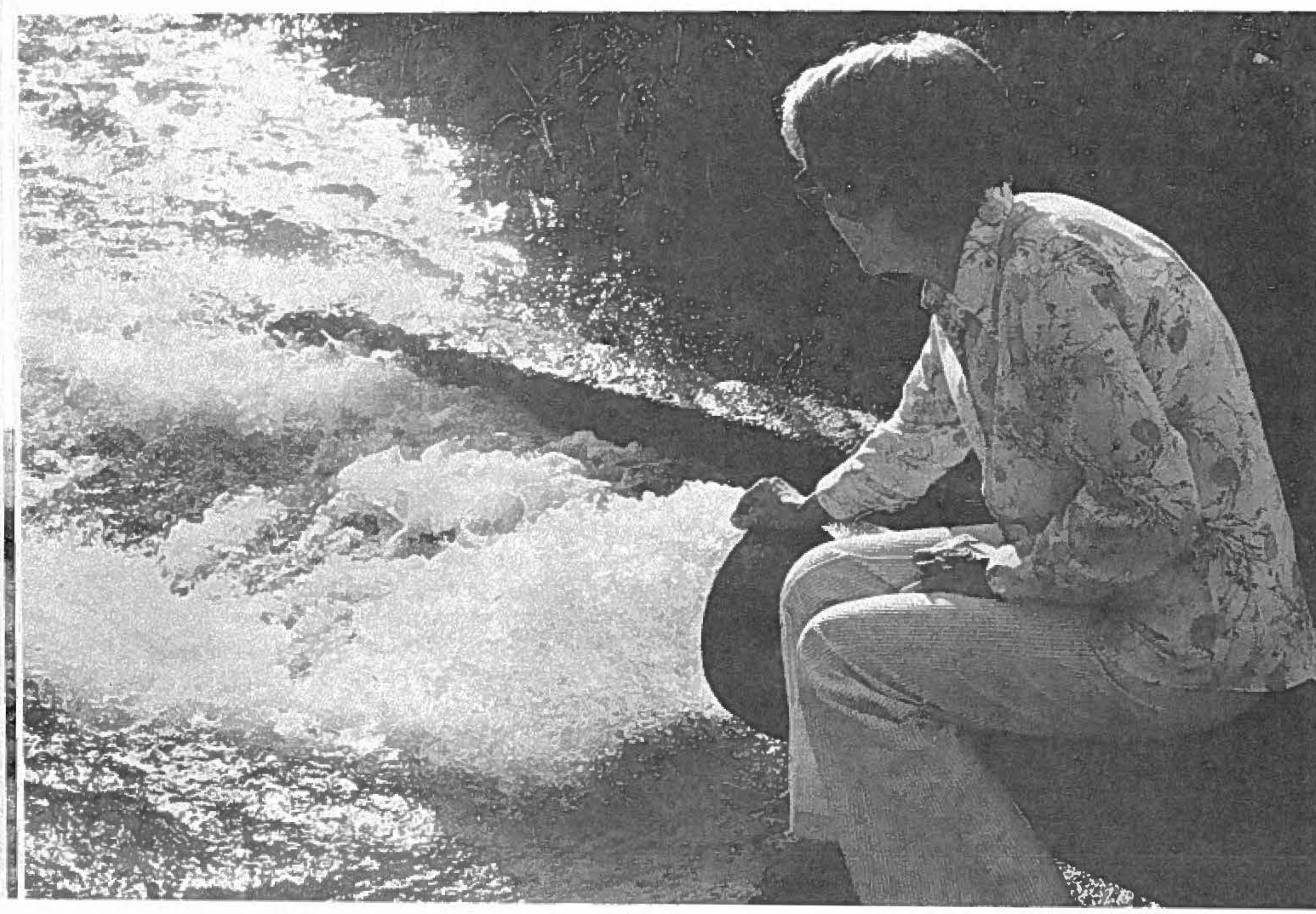
The real damage to the ground-water reservoirs began in the nineteenth century with the influx of Anglo-American settlers. The cattle barons, so often idealized in the literature, caused catastrophic damage when they turned their vast herds onto the native prairie grasses.

In the middle 1800s deep wells began to be drilled. It was found that flowing wells could be brought in nearly everywhere. The "Lunatic Asylum" well in Austin, drilled to lower Cretaceous Trinity sand, threw water 12 meters high. Water from a well south of San Antonio reaching the Edwards limestone rose 26 meters above the surface of the ground. Nothing could have had a more disastrous effect upon spring flows than the release of these tremendous artesian pressures through flowing wells. Most of these wells were allowed to flow continuously, wasting great quantities of water, until their potentiometric heads were exhausted and they stopped flowing. A few still flow to this day.

Although the effects of flowing wells upon water levels were severe, there was more to come. When the wells ceased flowing, pumping began. Ground-water levels were systematically drawn down, as much as 200 meters in some areas. At first pumping for municipal and industrial use was primarily responsible. Beginning around 1930, enormous quantities of ground water began to be withdrawn for crop irrigation. Irrigation now takes about 75 percent of the ground water used in Texas.

Other factors have also affected spring flow. Paving of urban areas has reduced the amount of recharge to some spring aquifers, and increased the severity of runoff, flooding and sediment problems. But in some

Flowing well at Fort Sam Houston, San Antonio.



urban areas springs flow with something like their original force. This results from watering of lawns and gardens with water brought in from another location. The water percolates through the soil and recharges the spring aquifers.

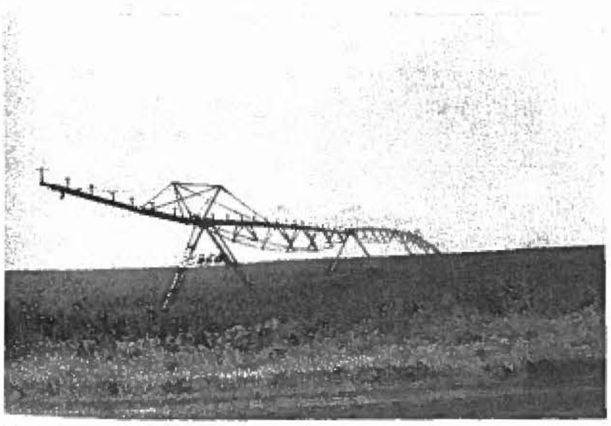
Some springs whose discharge has been measured or estimated only a few times show an apparent increase in flow over the years. Often the increase is accounted for by the fact that the early records were obtained in drought years, and the later ones during periods of high rainfall.

Indians often stopped up springs, just as they burned the prairie behind them, when they were forced to leave their homeland. But mud and rock could not hold back a strong head of water for long. Most such springs would break out again nearby. This can therefore not be considered a serious cause of spring failure.

Earthquakes sometimes roil spring waters or cause springs to stop flowing temporarily. If springs are located on active faults as at Pine Springs (1), Culberson County, earthquakes can cause blockage of the water passages and permanent failure of the flow. It should be remembered that residents of Pompeii, Italy, in the first century had ample warning of the coming explosion of Vesuvio several days in advance when their springs suddenly ceased flowing. They chose to ignore the signal, and the results are well known.

Nearby blasting by seismograph crews searching for oil sometimes impairs or stops spring flow. Evidently it is strong enough at times to close off water passages which feed springs.

Hurricanes along the Gulf coast can change the landscape considerably, destroying some springs and giving birth to others. Hurricane Carla in 1961 caused flooding up to 7 meters above sea level. Other hurricanes have reached even higher, and an area at least 40 kilometers inland from the Gulf is severely affected.



Sprinkler irrigation, Potter County.

Some landowners believe that springs dry up because of disuse. This is not true, but during periods of disuse they may become covered with sediment.

Other spring owners believe that a drier climate now than formerly is the cause of spring failures. Although severe droughts such as that of the 1950s may occur periodically, there is no evidence that Texas' climate has changed in historic time.

EFFECTS OF THE WATER-TABLE DECLINE

Because of declining ground-water levels, some streams which were formerly "gaining" streams, receiving additional water from seepage and springs, are now "losing," and many streams have dried up. Thousands of small springs have ceased flowing, and the larger springs have generally suffered a decrease in flow.

Often in early days a spring failed to produce the amount of water needed, especially during dry periods. The spring was usually cleaned out and deepened. If it still failed to supply sufficient water, it was deepened further and became a well. A windmill pump was usually placed in the well, and drawdown of the water table was begun. Of course from this time on the spring (well) could not be expected to flow.

Many of the larger springs issue or did issue from deep pits, thought by many early explorers and settlers to be bottomless. Leon Springs in Pecos County were an example. In unconsolidated sediments the pit was shaped like an inverted cone. A strong flow of water entering at the apex of the cone carried the normal sediment load up and out of the pool. Such pits at limestone or gypsum springs were usually irregularly shaped caverns.

When the water table and spring flow declined, there was insufficient discharge to carry all of the sediment out of the hole. In addition, clearing and plowing of fields increased the sediment load of streams to around 100 times their natural load. Hence it is no surprise that many of these deep, blue holes have been filled with sand and the spring flow has ceased.

The same principle applies to spring-fed creeks in sandy areas. Many such creeks were once fed by hundreds of springs in their channels. Their constant flow kept the sand moving downstream. When the spring flow declined and soil erosion increased disastrously, the channels were choked with sand and the springs buried.

As the water table declines, springs tend to move downhill. Often old spring boxes or pipes, abandoned windmills, or dying trees can be seen at the former, high

Sand-filled channel, Colorado County.

locations. In a valley the highest springs may move many kilometers downstream in a decade or so.

Springs do not dry up suddenly. They first become intermittent for a period of years. During this time they may flow during the winter when evapotranspiration is at a minimum and when there is no irrigation pumping, but dry up during the summer. Finally they fail completely, remaining dry even in winter. For this reason it is difficult to specify a particular year when certain springs failed. Rather, a period of years must be given.

Many formerly spring-fed natural lakes in Texas have dried up along with their springs. Now dust blows from their dry beds, fouling the air for many kilometers around and severely restricting visibility. Many roads still detour around these dry lake beds. Newer roads go straight across, as there is no longer any water to avoid, except during rare floods.

Earth stock tanks which were formerly fed by springs often suffer the same fate. Many at higher elevations are drying up more frequently as their springs fail.

Bridges across once-spring-fed creeks are no longer needed. Now a small culvert pipe is sufficient, or just a graded crossing through the sand.

Some sand aquifers have a low transmissivity. Many years may be required to transmit water from a recharge area to the springs. In such cases there is a delayed action. The springs may continue to flow for a period of years after the water table in the recharge area has been heavily drawn down, but eventually they are doomed.

EXAMPLES

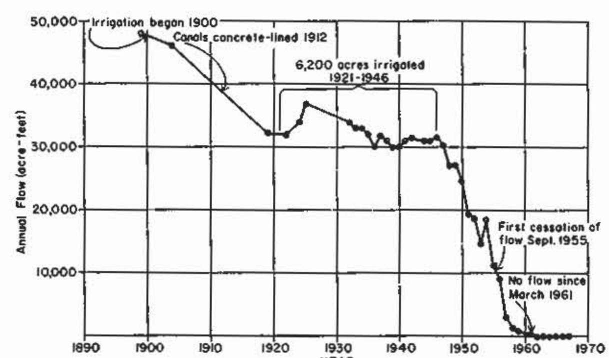
Three examples will illustrate what is happening to Texas' ground-water levels and springs. The first is Comanche Springs at Fort Stockton in Pecos County. They burst from Edwards and associated limestones, flowing as much as 1,870 liters per second, and served the Comanche Indians and their predecessors for uncounted millenia. From 1875 on, they provided the water for an irrigation district which served 2,500 hectares of cropland.

Heavy irrigation pumping of the aquifer, especially in the Belding area southwest of the springs, lowered the water table. The spring discharge began to fall off in May, 1947, and by March, 1961, the flow had permanently ceased.

A second example is the White River above White River Reservoir in Crosby County. Upstream in Crosby and Floyd Counties the White River passes through Blanco Canyon, and farther up, in Hale, Lamb, Castro, and Parmer Counties, it is known as Running Water Draw. True to its name, Running Water Draw formerly ran the year around, fed by hundreds of springs from Ogallala sand, gravel, and caliche. When Henry Smith arrived in Blanco Canyon in 1878, he wrote that one could not travel a half mile without seeing a good spring. At Silver Falls, east of Crosbyton, a huge volume of crystal-clear spring water roared over the sandstone ledges. An ancient people lived at this once-beautiful spot, grinding acorns, mesquite beans, and other food in bedrock mortars which may still be seen.

But pumping of ground water, and especially irrigation pumping, soon began to take its toll. (About 73 percent of all ground water pumped in Texas comes from the Ogallala aquifer.) In the upper reaches of Running Water Draw, in Parmer, Castro, Lamb, Hale, and Floyd Counties, the writer was able to identify 13 former springs, a very small portion of those which once existed. These 13 all dried up between 1920 and 1948.

Farther downstream, in Crosby County, because of their lower elevation, the springs lasted longer. Here seven springs' discharge was measured in 1938 and found to total 78 liters per second. In 1975 only three were still flowing, producing a total of 2.3 lps.



The demise of Comanche Springs, Pecos County.

The base flow provided by springs in Running Water Draw and White River is fast drying up. U.S. Geological Survey records from the stream-gaging station on the White River below Silver Falls confirm that the discharge is declining. Silver Falls now trickle only during the winter when there is no irrigation pumping, and soon there will be no falls, except for muddy surface runoff during storms.

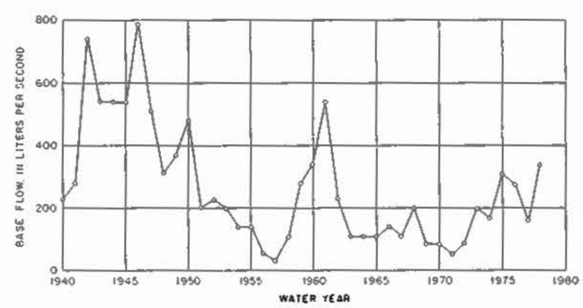
White River Reservoir was built in 1963 to provide water for the towns of Post, Spur, Ralls, and Crosbyton. One cannot help wondering how long the reservoir can supply the needs of these cities when the springs' base flow is gone and the reservoir must depend on surface runoff alone.

A third example is Spring Creek, which forms the boundary between Harris and Montgomery Counties. Long-time residents remember numerous cold, clear springs which made the creek ideal for fishing and swimming in the early 1900s. In those days the town of Spring and the International Great Northern Railroad obtained their water from Spring Creek. The many springs along the creek poured chiefly from Quaternary Bentley sand, also known as the lower Chicot aquifer.

Many of the springs weakened and failed in the early 1900s when the area was covered with shallow windmill wells. Later, when deep rice irrigation wells were installed, most of the windmill wells dried up. Spring Creek is on the northwestern edge of the area of heavy municipal and industrial pumping centered in Pasadena. Here water-level declines of as much as 100 meters were measured in the lower Chicot aquifer up to 1970. This pumping has probably affected Spring Creek to some extent, but pumping of ground water for rice irrigation is the chief cause of the declining water table.

The accompanying graph shows the decline in base flow (flow from seepage and springs) of Spring Creek at spring. It is obvious that the base flow in recent years has declined from that in the 1940s.

In the heavily pumped area to the southeast, the great drawdown in the water table has reversed the hydraulic gradient of the ground water. Instead of fresh water moving out to sea, salt water is now moving inland and contaminating the ground water. Also, heavy ground-water withdrawals have caused land subsidence of almost three meters. This causes cracking of buildings, pipelines, and streets, and increased flooding by high tides.



Base flow of Spring Creek at Spring, Harris County

TEXAS WATER LAW AS RELATED TO SPRINGS

Texas ground-water law affirms that the surface landowner owns the underground water unless it can be shown that the source is a subterranean stream or stream underflow (Yarbrough, 1968). This may be difficult to prove.

An example of stream underflow might be that along the East Nueces River near Montell. Here the river intermittently sinks into gravel beds and reappears as springs. This spring flow would probably be classed as originating from stream underflow and therefore subject to appropriation.

Natural spring waters if taken at their source are considered to be ground water and no permit is required for their use. Once they issue forth and flow in a watercourse, however, they become public surface waters. As such a permit from the Texas Department of Water Resources is required for their use.

A spring is normally a spillway for an underground reservoir. This reservoir may be overlain by land belonging to a number of owners. If the landowners other than the spring owner choose to pump ground water heavily, lowering the water table and causing the spring to cease flowing, the spring owner has no recourse in the courts to prevent them.

An example is Comanche Springs at Fort Stockton (Pecos County). The springs were the basis for an irrigation district. Heavy pumping of the aquifer lowered the water table so that the spring discharge began to fall off in May 1947. The irrigation district sought an injunction in 1954 to restrain pumping which interfered with the normal flow of Comanche Springs. The injunction was denied by the courts, and the springs ceased to flow in March 1961.

For many of Texas' springs, the outlook for long-continued flow is not optimistic. Since heavy ground-water pumping of spring-feeding underground reservoirs is the primary cause of the decline of springs, it is obvious that if in their vicinity such pumping continues or is increased, most of the springs will disappear.

Ground-water districts have certain powers such as the power to control well spacing. This can help to a limited extent in slowing the decline of the water table and the extinction of springs. Ground water and underground reservoirs need to be thought of as public resources rather than as private property.

THE POPULATION EXPLOSION

MAN'S NEED FOR NATURE

Water was the vehicle in which primeval life developed, from which all life on earth evolved. If mankind destroys its natural water sources, upon which it has depended for millions of years, it is indeed doomed.

Our modern world is nothing like the world in which man evolved eons ago and to which he was perfectly adapted. We are suddenly moving away from the pure, simple world of nature into a complex, polluted environment which is becoming more and more impossible to live in. S. F. Olson (1973) said it best:

> The world we face now is a strange one, the great silences replaced with clamor, the hearts of our cities garish with blinking neon and foul with the stench of pollution. We look at the slums, at the never-ending traffic, the shrinking space and growing ugliness, and are appalled. Is this, we ask, what our forebears struggled for? Is this the great American dream?
>
> We enjoy comforts never known before, but they are not enough; somehow, someway, we must make contact with naturalness, the source of all life. The frontiers are still too close to forget and the memory of wilderness goes far back into the eons when man lived close to the earth and was in tune with the ancient rhythms. We still listen to the song of the wilderness and long for a land we have lost. Civilization has not changed emotional needs which were ours long before it arose. This is the reason for the hunger, this the true meaning of wilderness and the search of moderns for places where they can know it again. The battle to save the last remnants is not only a struggle for freedom and beauty, but for the spirit of man in a world that seems to have lost its balance and perspective.

Man is wonderfully attuned to nature — to the tinkling sound of running water, springs, waterfalls, and to all of the trees, flowers, fish, and animals that depend upon the water. It is therefore astounding to hear some ground-water "experts" advocate that to save water, ground-water levels should be drawn down purposely so far that no plants (or animals) could use it. This would certainly conserve water, but man's natural environment would be lost. Man could not stand such barren surroundings for long, with no plants or animals except those artifically raised. The natural result would be riots, anarchy, and war.

DESTRUCTION OF THE EARTH

Destruction of our priceless heritage of ground water and springs is not the only evidence of the failure of modem society to deal with man's destiny. Others, all interrelated, include

- Smothering of our cities with fumes from automobiles, factories, and furnaces, and acid rains which stunt forests and render lakes lifeless.
- Putrefaction of rivers and streams with sewage, industrial effluents, and pesticides.
- Fouling of the oceans and beaches with globs of oil, plastic refuse, and poisonous effluents.
- Climatic changes bringing about disastrous alterations in world temperatures.
- Leakage of atomic wastes and testing of atomic devices.
- Extinction of thousands of species of plants and animals.
- Washing away of precious topsoils, formed over periods of thousands of years.
- Unrestricted noise, traffic jams, and parking problems.

The list could go on and on. When the oceans become sufficiently fouled, tiny plankton will die out. These are the organisms which originally produced oxygen, sending it out of the oceans into the atmosphere so that animals and man could evolve outside of the water. Without this source of oxygen, man will strangle in an atmosphere increasingly loaded with carbon dioxide.

Much has been written about the natural recovery of damaged ecosystems. In the case of ground water and springs, if the process of destruction could be halted, recovery would take a very long time. First, the organic mulch layers and topsoils which were washed away would have to be reformed over a period of thousands of years, so that the soils would again be able to transmit recharge water to the underlying formations. Then, actual refilling of the aquifers would take time, because many have quite low transmissivities. But many aquifers could not be refilled, because former flowing wells would resume flowing, and prevent springs from discharging again.

These problems can all be traced to human nature. It began with the Spaniards who, in their ruthless search for gold, enslaved the Indians who had preserved and nurtured this land for thousands of years. Some of the early explorers and settlers wanted adventure, some wanted to escape from oppression in Europe, but most simply wanted material wealth, and saw the New World as a means of acquiring it.

The Anglo-American cattle barons regarded nature as something to be conquered and put to use. They did not for the most part realize the catastrophic damage which they were inflicting upon the land and underground water reservoirs. Modern irrigation-well pumpers on the High Plains, however, do know that they are mining and using up the ground water, some of which should be left for their children and grandchildren.

But no one cares. Human nature being what it is, the present will always take precedence over the future. Jobs now are seen as more important than saving something of our natural environment for the future. After all, as some say, a maniac may push the atomic war button and there will be no future.

We have seen that natural recharge of the ground-water reservoirs is far too slow to compensate for the enormous withdrawals of ground water which are taking place. Can water be recharged into the ground by artifical means? Artificial recharge has been experimented with and tried by numerous public agencies, farmers, and ranchers in Texas.

In Uvalde County numerous small dams were built to back water over caverns in and near stream channels. The cavern entrances were covered with gratings to keep out trash and allow the water to enter. Some wells were also drilled to recharge water directly into the cavernous limestone. Similar wells were experimented with at Kerrville. The additional amount of recharge accomplished by these means was very small. The introduction of pollutants into the aquifer along with the recharge water is also a problem.

Other methods of artificial recharge have been tried at various locations in Texas, including El Paso, Midland, Martin and Kleberg Counties, and the High Plains. These include recharge through holes, shafts, wells, basins, pits, trenches, canals, and water spreading.

By far the most intensive studies have been made on the High Plains. Here most of the effort has been concentrated on making use of surface water that collects in the numerous playa lakes. This water is allowed to flow by gravity into recharge wells, which deliver it to the underlying Ogallala sand. The primary problem, which appears to be insurmountable at feasible cost, is that the aquifer being recharged soon becomes clogged with the enormous quantities of clay which are carried to it by the recharge water.

Other possible sources of fresh water to replace the ground water which has been wasted include desalting of sea water and weather modification to produce more rain. Both of these options are still highly experimental, and it is doubtful that either could ever satisfactorily replace our great natural ground-water reservoirs and springs.

Artificial recharge through wells, Edwards limestone, Uvalde County.

THE POPULATION BOMB

All of the problems of environmental damage and destruction of the earth can be traced to one cause — the population explosion. There are simply too many people competing for the earth's resources. According to Ehrlich (1968), one million years ago there were 2.5 million people on earth. Three hundred years ago there were 500 million. Now the earth's population is nearly 4,000 million. In other words, the earth's human population is now more than 1,000 times the normal value under which man evolved millions of years ago.

In Texas it has been estimated that the Indian population 500 years ago was about 30,000. Now the population of Texas numbers 14,000,000.

Parts of Texas do not seem overpopulated. In some of the Big Bend area, for example, one can drive all day on ranch roads without seeing another car. But indirectly the area is feeling the pressure from other parts of Texas, other states, and other countries which are overpopulated. The demand for beef to feed all these people causes overstocking of cattle in areas such as the Big Bend. The best grasses, of course, have long been killed off. When a dry period comes, as it does frequently in west Texas, there is nothing left for the cattle to eat, and it is necessary to burn the spines off prickly pear plants and chop the bulbs out of sotol plants to feed them.

Similarly, the south High Plains are not overpopulated. But pressure from areas that are for food and fiber forces every hectare to be placed in cultivation, with irrigation pumps draining the precious ground water night and day. As a result, most of the water in the Ogallala aquifer will be gone in 20 years. As S. Dillon Ripley so ably stated,

> What can we do about it? Very little, I think. The effects of this complex web of changes now set in motion are still so little documented and the pressure for maintenance of human life

is (of necessity) so great, that there is no getting off the train. It is an express now, going faster and faster, relentlessly gaining momentum in the night, its destination totally unknown. Will the planet succumb, and in the process all human life and culture deteriorate to an unrecognizable level?

To put it simply, the human race is committing suicide. Man simply cannot control his own destiny. The interests of the individual, "making a buck now," always take precedence over the welfare of the race and saving something for the future.

The *Zero Population Growth* movement, while a step in the right direction, is far too little and too late. Ehrlich suggests that cutting the world population to ½ billion, or one-eighth of the present figure, would be acceptable. We all like automobiles, air conditioning, and the other conveniences of civilization. And we could have had them, without destroying our environment, if only there had been fewer of us — a lot fewer.

The writer believes that reducing the world population, including that of Texas, by 3½ billion people as suggested by Ehrlich, would not be sufficient. In any case, it could not be done soon enough, as the forces of destruction are already in motion and gaining speed constantly. In less than 500 years, in a scorched earth plagued with famine, pestilence, anarchy, revolution, and global war, man, along with most life on earth, will become extinct.

There is little solace in the thought that after man is gone, perhaps in a few thousand years, ground-water reservoirs will again be full and springs and waterfalls will once more sparkle in the sunlight. The atmosphere, rivers and oceans will gradually rid themselves of pollutants. And perhaps a few primitive forms of plants and animals will make a new start at evolution.

On David Bamberger's ranch, among many springs in the Edwards limestone hills of Blanco County, is a marble monument. It reads:

IN MEMORY
OF MAN
2,000,000 B.C. - A.D. 20 ?
HE WHO ONCE
DOMINATED THE EARTH
DESTROYED IT
WITH HIS WASTES,
HIS POISONS, AND
HIS OWN NUMBERS.

Will man be missed when he departs this world? The writer thinks not. Man has greatly overexaggerated his own importance. His extinction will cause no more of a ripple in the great scheme of things than the extinction of the tiniest microbe.

Monument to man.

DISCUSSION OF INDIVIDUAL COUNTIES

ANDREWS COUNTY

There were 100 years ago numerous springs and seeps in Andrews County. Most of them occurred along the major draws and around the large lakes, where there was sufficient relief to provide a head which would cause spring flow. The chief formations from which they issued were the Ogallala and more recent sands and caliche, and occasionally Cretaceous limestone.

There is abundant evidence that Paleo-Indians many thousands of years ago and more recent Indians camped at the county's fresh-water springs and streams. Early explorers such as Castillo in 1650 also visited them. And when settlement began in earnest in the late nineteenth century, the areas around the springs were of course occupied first.

During the 1886-87 drought many windmill wells were drilled, and ground-water levels began to decline. Later irrigation speeded the decline. But industrial processes have done the greatest damage. Oil-well drilling and repressuring and the use of fresh water to dissolve salt and form underground gas storage cavities have caused further declines in the water table. As a result nearly all springs in the county have now failed.

The spring waters were mostly of a calcium or sodium bicarbonate type, fresh or slightly saline, very hard, and alkaline. The fluoride content was high in most cases, causing mottling of teeth but otherwise no harm. In recent years much of the ground water has been contaminated by oil-field brines and leakage through improperly installed well casings.

High lush grasses formerly covered much of the county. Mesquite was rare. Wildlife of all types frequented the springs and spring-fed streams. With the disappearance of the springs and the destruction of the natural habitat of these animals, most of them have not been able to survive. Mesquite has replaced much of the grass as the water table has fallen, because its roots can reach to great depths.

The writer's field studies were made primarily during the period March 17-22, 1977, after several months of no precipitation.

At Ralph McWhorter's ranch in the northwestern

Andrews County, at latitude 32° 26' and longitude 102°59', were **Scratch Springs (5)**. Indian artifacts here point to extended use of this reliable water supply in the past. According to McWhorter, bison, deer, and antelope hunter Henry Moore settled here in 1872. Many freighters stopped at the springs for water. A cemetery dating from 1888 is one kilometer east of the site. When McWhorter came here in 1923 the springs were dry and a 10-meter well had been dug. The lake to the southeast was full then, but is now dry. Two windmills pumping water into a tank at the springs site have contributed to the fall in the water table.

Seeps also flowed from Ogallala sand around Whalen Lake (6), southwest of Shafter Lake, in the past. Indians are known to have lived here. But when M. M. "Slim" Mathis arrived in 1906, the seeps had disappeared, probably because of overgrazing of the land. In March 1977 most of the lake bed was covered with water. A scum of oil on top of the water, from the many oil wells in and near the lake, has apparently prevented evaporation of the water. Water birds wisely avoid this lake. Much mesquite surrounds it.

Around Shafter Lake northwest of Andrews a number of small springs and seeps formerly issued from Ogallala sand on top of Antlers limestone. On the west side of the lake the writer found several bedrock mortars in the limestone, proof that Indians camped here over a long period of time and that a reliable source of fresh water was located here (3). Many worked fragments of flint, chalcedony, and opal cover the site. Dark gray soils indicate that a swamp was once present below the springs.

In 1875 Col. William Shafter visited the lake, and stated,

> Water permanent, and though quite strongly alkali, can be used from holes dug in the bank. Grass excellent and luxuriant, roots in abundance.

In the 1890's Sam Mooney built a cabin near a spring (4) on the northwest side of the lake. In 1908 the short-lived town of Shafter Lake was established near springs on the west shore. Other springs were located on the northeast side. Now they are all dry. The lake bed, moist but usually containing no standing water, is now surrounded by mesquite, cedar, and hackberry trees.

At the Old Florey community two kilometers east of Florey post office and 16 north of Andrews, a similar situation exists. Here also, along Monument draw, small springs and seeps (2) flowed in the past.

At the Five Wells ranch headquarters in northeastern Andrews County at latitude 32°14' and longitude 102°21', there were formerly seepy areas (1). According to Crimmins (1933), in 1875 Lt. Col. W. R. Shafter found five wells in the ravine here, each 1.8 to 2.4 meters deep, 1.2 to 3.1 meters in diameter, and containing 0.9 to 1.2 meters of water. He also found "excellent grass." These shallow wells were probably dug by the Comanches, whose land this was. When Dennis Harmon, ranch foreman, arrived here in 1922, water was encountered in post holes at a depth of 0.8 meter. Now it is about five meters deep. Irrigation pumping a few kilometers to the northwest has doubtless contributed to the water-table decline.

At Baird Lake in southeastern Andrews County are **Baird Springs (8)**, the only remaining springs in the county. They were called **Beard Springs** by Livermore and Butterfield on their 1881 *Military map of the Rio Grande frontier*. On March 21, 1977, there was a flow of 0.06 liter per second from Ogallala sand, which trickled about 300 meters before disappearing into the dry lake. The entire area had been burned, and the shrubs were all charcoal black. On April 19, 1979, the discharge was 0.10 lps. the springs are in the southern of two tributaries which come together on the west side of the lake before reaching it. Between these two tributaries is a point where caches of flint artifacts, hearths, bone, tools, burials, and the remains of stone house walls have been found by Teddy Stickney, a Midland archeologist. These remains point to long occupation of the site by an ancient people. The northern tributary and others around the lake probably harbored springs also in the past. In 1650 the Spanish explorers Diego del Castillo and Hernan Martin from Santa Fe probably stopped here.

Field tests demonstrate that the Baird Springs water is moderately saline, as shown in the table of Selected Chemical Analyses. Brine shrimp, water striders, mos-

Baird Springs.

quito larvae, and killdeers live in a setting of willows, salt cedar, and saltwort. The water must have been originally less saline to support an Indian population. Numerous oil wells pump in the vicinity.

Five kilometers east-southeast of Baird Springs there were once other springs (9) which fed Anglin Lake. These are believed to have been the **Doolings Springs** shown on an 1881 Texas and Pacific Railway map. The site is now on Guy Mabee's ranch, leased by J. H. Crouch. The very small springs once trickled from Ogallala sand and caliche on top of Antlers sandstone. The springs and lake have long been dry. An earth tank adjacent to a sandstone bluff now catches occasional surface runoffs. Purple sagebrush and yellow day primrose flowers cover the site in spring.

In the southwest part of the county, in an area from two to seven kilometers northeast of the intersection of Highways 115 and 128, there were formerly pools of water (7) among the sand dunes, similar to those which still exist in Winkler County. Bob Blackman and Leslie Imboden of the Three Bar Underground Storage Co. kindly showed some of these spots to the writer. Many Indian projectile points, metates, manos, and potsherds demonstrate that there was a reliable source of water here. Since about 1955 these pools have been dry, but the water table is shallow. Wells or holes dug to water by coyotes are frequently found, and both mule and white-tailed deer frequent the area. Willows and salt cedar occur in the former ponds, with shinnery oak and yucca on the surrounding dunes.

ARANSAS COUNTY

The earliest people of whom we have any evidence in Aransas County were the Archaic Aransas Focus people, who lived here perhaps as much as 6,000 years ago. Undoubtedly there were previous residents using the springs of the area, but evidence of them, and of many springs, has largely been destroyed by hurricanes and other erosional processes. For example, consulting engineers W. H. Espey and E. M. Spencer found that between 1846 and 1878 Aransas Pass moved about 3 kilometers to the southwest.

By historic times the Karankawan Kopanos were living in the area. Interestingly, Newcomb (1961) stated

> Early Anglo-American settlers were perplexed by the fact that the Karankawas always seemed to have an adequate water supply while they could find but little.

Apparently the Karankawas had an instinct for knowing where fresh-water seeps could be found and how to deepen them with simple tools to form shallow wells.

The springs of Aransas County were never large, and many could only be called seeps. They may have provided life-sustaining water for early explorers such as the Spaniard De Pineda who mapped the coast in 1519 and Frenchmen on St. Joseph Island in 1712.

The springs and seeps issue chiefly from Beaumont sand and silt, also called the Gulf Coast aquifer in the subsurface. Heavy pumping of ground water has caused serious declines in the water table, and the failure of many springs. It also threatens to cause salt-water intrusion into the fresh-water aquifer, as most of the county is surrounded by salt water.

Most of the writer's field studies were made on March 21-26, 1976.

The spring water is usually of the sodium bicarbonate type, and is fresh, very hard, and of neutral acidity. The chloride content may be high.

About 17 kilometers north of Lamar, along the county line at longitude 96°59', are some unnamed springs (1). Flowing 0.30 liter per second from Beaumont shell and silt deposits, they are the largest still existing in the county. Some are in Refugio county. Although they are the source of "Salt" Creek, their water is fresh. Located in a pasture, they are difficult to reach.

In the community of Lamar were **Lamar Springs (2)**. In 1528 two members of the ill-fated Narvaez expedition, Enriquez and Esquivel, shipwrecked south of Freeport, are believed to have made their way overland to this vicinity before succumbing to the elements or the Karankawas, according to Castaneda (1936). The springs were a principal reason why Lamar was located here in 1837. Mrs. Charles Gibson, a local historian in Rockport, remembers when her father visited these springs while hunting. Now they are reduced to very weak seeps in Beaumont silt and very fine sand on top of a clay bed. About two kilometers northeast is the Big Tree, the largest live oak in Texas, believed to be 1,000 years old.

Six kilometers north of Fulton were **Live Oak Springs (3)**. Those remaining are seeps from sand, muck, and peat as high as 3 meters above sea level, on the west side of Highway 35 at the south end of the causeway. The old Spanish Fort Aranzazu, built here about 1750 to control privateers and pirates, undoubtedly used the spring water. In 1842 the springs were well known for their fresh water. In the words of

Water plantains at Live Oak Seeps.

William Bollaert, who visited the area in that year (Hollan and Butler, 1956),

> Came to anchor at Live Oak Point. This spot is the residence of Mr. James Power, an old empresario settler. He received us most hospitably. Had "Beefs" (oxen) killed for us, supplied us with milk and fish. He was here with his family and had secreted in various parts of his house and behind doors an armament of loaded rifles and muskets, in case of a sudden attack. Here we took in water, and parties went on shore to wash clothes, fish, "oystering," "gunning" etc.

In 1939 the Texas Board of Water Engineers recorded Live Oak Springs to be flowing on both sides of Highway 35 at this location.

About two kilometers north of Fulton a seep (4) still flows from the sandy barrier beach deposits, according to Kemper Williams of Victoria, an authority on history of this area.

Other springs and seeps are believed to have existed at several locations in the past, although they are dry now or have been destroyed by changes in the landform. One was probably on the landward side of dunes near the south end of St. Joseph Island, which are up to 6 meters high. Here an old Spanish fort, Lafitte's buccaneer fort, and the Confederate Camp Semmes were located. Still others were probably located west of Aransas County airport. Drainage ditches in this area were flowing 3.0 liters per second on March 26, 1976.

ARCHER COUNTY

The springs and seeps of Archer County issue chiefly from Permian sandstones of the Leonardian and Wolfcampian series. These formations dip to the north-northwest at 8 to 12 meters per kilometer. Often the springs appear at the base of a sandstone, where it rests on shale or clay. Most are in the southern part of the county.

The Wichitas and many other tribes before them camped at the springs, leaving mortar holes and basins in the bedrock where they ground acorns, mesquite beans, and other fruits.

The springs originally supported a lush vegetation including water cress, brookweed, marsh purslane, rushes, plum thickets, and willow and cottonwood trees. Many animals such as fish, frogs, raccoons, deer, wolves, and bears depended upon the spring water. With declining water tables most of the springs have weakened or failed. As a result many of the plants and animals once found here have disappeared. In addition, man-made gully erosion has often filled stream channels with silt and buried some springs.

The spring water is generally of a calcium bicarbonate type, fresh, very hard, and alkaline. The content of iron, fluoride, and nitrate may be high. Contamination has been caused by oil-field operations in the past, chiefly from disposal of brine in unlined pits and from inadequately cased wells. Although these practices are no longer permitted, the damage has persisted, usually in the form of high sodium chloride concentrations in some water.

Most of the writer's field studies were made during the period May 3-8, 1979.

Duren Springs (13) were two kilometers west-northwest of Archer City on Martha Killian's ranch. They were named for shepherd W. W. Duren, who came here in 1879. The springs trickled from Leonardian sandstone. An earth stock tank now covers the site. A few elm and willow trees and a field of yellow thelesperma blossoms adorn the place.

Twelve kilometers west of Archer City on the Middle Fork of the Little Wichita River was the French Trading Ground (11). Here in the mid 1700s the French traded guns, ammunition, and other items to the Indians, which they were denied by the Spaniards. Four kilometers southwest, also close to the stream, are the ruins of an 1879 stone house. On May 6, 1979, there was a discharge of 3.4 liters per second in the Middle Fork at Highway 210. Formerly there was constant seepage feeding the creek from Leonardian sandstone on clay. Now the flow is composed chiefly of occasional surface runoffs, and the Middle Fork dries up in summer. Kickapoo Creek to the west, where Kickapoo Indians lived in historic times, must also have had a constant flow at that time.

Morgan Springs (12) are 10 kilometers northwest of Archer City on Claude Cowan's ranch. Now there is only a seepy area and some pools, with rushes, on a sandstone outcrop. Several similar seeps occur to the west, according to Pat Cowan. At various times from 1861 to 1899 a copper mine was operated one-half kilometer east. The mine workers no doubt used the spring water.

Circle Springs (15) are on the old Circle ranch, now James Vieth's, five kilometers north of Windthorst.

Shallow mortar holes may be seen in sandstone boulders here. The ruins of an old rock spring house still stand in the grove of pecans and elms. On May 7, 1979, 0.06 lps of iron bearing water seeped from the sandstone. Water from an earth stock tank just upstream probably assists the recharge of the springs aquifer.

Rock House or **Stone House Springs (5)** are 11 kilometers northwest of Antelope and 2.5 west of their historical marker on Highway 281. They are in a sandstone ravine on Mrs. W. J. McMurtry's property. They were shown on H. O. Hedgcoxe's 1854 *Map of the Peters colony, Texas.* The springs were described by Hoffman in his 1957 study of the California Trail as follows:

> The spring resembled somewhat that of an underground rock house without a roof. On the rocks that lay buried in the ground, were many old names, initials, cattle brands, and dates, which were once carved deep into the soft sandstone, but being exposed to the weather for many years, are almost erased. The most distinct name and date was Greer, May 26, 1880. This name was probably carved by some cowboy who camped here. . . .
>
> During an interview with Mr. McMurtry, he pointed out the old road bed that had been made by earlier travelers. He told that when he was a young boy this spring was kept cleaned out by his father and they used it for their water needs. He went on to say that this spring when cleaned out was four feet deep and would run an inch and a half stream of water. He stated further that his father, when settling here in 1888, had used this road. He also related that as a young boy he could remember people camping at this site.

Part of the old stone wall which once enclosed the springs may still be seen. On May 5, 1979, there was only seepage in a carpet of green rushes in the bottom of the ravine. Hackberry trees and plum thickets grow here. The smaller **Tax Springs** are just to the west.

Two kilometers west of Rock House Springs are **Rock Springs (2)** on Kenny Maxey's ranch. Nearby there is an unusual tray-like mortar table, about 1 by 0.5 meter, cut into a boulder, and probably used by a prehistoric people to grind food. Hedgcoxe's 1854 map and Captain R. B. Marcy's 1854 *Map of the country upon the Brazos and Big Witchita Rivers* both depict Rock springs. Hoffman (1957) wrote:

> This spring is not carved as deeply into the rocks as Rock House Spring. Here also at the head of the spring were names, initials, and dates carved into the rocks. The most legible name and date here was J. F. Key and 1884. Here, as at Rock House spring, most of the carvings have been erased by the elements.

The water emerges from Wolfcampian sandstone in a draw, forming only seepage on May 5, 1979. The

Mortar table at Rock Springs.

water is fresh but high in iron content. Turtles and many birds live among the rushes, dewberries, plum thickets, and trees which fringe the pools.

In recent years the springs have been called **Flag Springs** by some. **Burnett Springs**, about ½ kilometer downstream from Rock Springs, are actually a part of Rock Springs. The water which sinks into the sand downstream from Rock Springs reappears as seeps at Burnett Springs. Rock (Flag) Springs and Burnett Springs have been marked with hand-carved sandstone monuments by historian Jack Loftin. There were also very small springs, now dry, at Confederate Camp Cureton 1.5 kilometers south of Burnett Springs.

Two kilometers northwest of Rock Springs are some stronger springs (3) on the Bridwell ranch, managed by J. E. Hemphill. On May 5, 1979, a discharge of 0.05 lps trickled from Wolfcampian sandstone into a large earth tank.

Elk Springs (1) are 13 kilometers southeast of Archer City on W. S. Ikard's ranch. In the sandstone boulders may be seen shaft-straightening grooves made by a people who lived here long ago. More recently, names and dates have been carved in the soft rock. On May 5, 1979, there was only a seep of fresh water from Wolfcampian sandstone in a ravine. Turtles swim among marsh purslane and rushes in the pool below the seeps. The adjacent slopes are colored in spring with purple winecup, pink wild onion, and yellow bitterweed flowers.

Herron Springs (14) are nine kilometers southeast of Archer City on A. J. Meurer's ranch. They were much used by early settlers in the area. Now they are a seep from an outcrop of massive Wolfcampian sandstone in a ravine. They issue in a concrete box and run about 75 meters before disappearing. White foxglove, pink wild onions, and rushes adorn the site. Raccoons have been trapped here. Meurer stocked the pool with goldfish, which did well until they were washed away in a flood. According to Meurer, the springs water 25 head of cattle and have never failed.

Persimmon Springs (6) are nine kilometers south-southeast of Archer City on Carlton McKinney's ranch. Here also may be seen a large rectangular mortar tray or basin cut into a boulder by a prehistoric people. Most early maps called these springs **Cimarron Springs**. These include G. L. Gillespie's 1875 *Map of portions of Texas, New Mexico, and Indian territory*, Granger's 1878 *Map of Texas*, and Rand McNally's 1883 *Map of Texas and Indian territory*. They were also known as **Cameron Springs** in the past. By 1886 settlers had built a dugout here.

On May 5, 1979, Persimmon Springs produced 0.05 lps, which dripped from Wolfcampian sandstone into a basin at the head of a small ravine, just south of the ranch house. A small concrete dam retains the water. Frogs jump among the brookweed, swamp grass, and dewberries. Trees shade the pools, which contain much algal growth.

In 1854 Captain R. B. Marcy, while exploring for locations for the Texas Indian reservations (according to Williams and Lee, 1947),

> camped at a fine large spring near the head of one of the branches of the West Fork of the Trinity River.

This was six kilometers northeast of Olney on the present Hayden Farmer's ranch. Although much used formerly, the springs (7) are now only seeps from sandstone in a shallow well 1.5 meters in diameter. A few elm and hackberry trees stand at the site. Many oil wells pump nearby.

On Mesquite Creek 16 kilometers southwest of Archer City were once very small springs (8). An archeological site has been found here where an ancient people lived and relied upon the spring waters. Petroglyphs have been carved in the rock on a mountain to the northeast. The creek is now dry except for occasional surface runoffs. The mesquites are still there, along with some elm and other trees.

In 1854 Marcy also stopped at **Furr Springs (9)**, stating:

> Our noon halt today was upon the summit of a hill, where we found a spring of cool, wholesome water, surrounded with a luxuriant crop of grass, which afforded our cattle the very best pasturage.

Furr Springs are on Grover Furr's ranch seven kilometers east-northeast of Megargel. They are now the strongest in the county, producing 0.35 lps of slightly saline water on May 6, 1979. The water pours from a massive Wolfcampian sandstone at an elevation of 390 meters. There are rumors of buried gold here. The water is used by the ranch house as well as by stock. A diversion has been built around the top of the ravine to protect the springs from floods and sediment. Killdeers fly among the swamp grasses, salt cedars, and plum thickets. Just downstream, oil-well brines have killed the vegetation and caused severe erosion.

Comanche Springs (10) are two kilometers northeast of Megargel on John Pechacek's farm. Here in 1859 the Comanches camped while making their weary exodus from Texas to Oklahoma. On May 6, 1979, 0.07 lps. trickled in Kickapoo Creek from seepage after recent rains. Elm, salt cedar, and mesquite trees shade the site. A windmill nearby steals water from the springs.

ARMSTRONG COUNTY

Most of Armstrong county's springs issue from Ogallala sand and gravel, which dip gently toward the east and toward the major streams. Some flow from Triassic Dockum or Santa Rosa sandstone which underlies the Ogallala. Usually the springs emerge from the base of the Ogallala or from Dockum sandstone where these formations rest upon the less permeable Permian shale, siltstone, sandstone, and dolomite.

The springs have been used by man since Paleo-Indian times. Coronado in 1541 found 11 Indian villages in Palo Duro Canyon. *Palo Duro* is Spanish for *Hard Wood* or cedar, which was much used by the Indians. Bolton (1949) described Coronado's entrance into the area:

> "Thus," says Castaneda, "the army arrived at the last barranca," a deep one [Palo Duro Canyon], "which extended a league from bank to bank. A little river flowed at the bottom, and there was a small valley covered with trees, and with plenty of grapes, mulberries, and rose bushes. This" — the mulberry — "is a fruit found in France and used to make verjuice. In this barranca we found it ripe." It is interesting to note that one of the mouths of the Palo Duro is today called Mulberry Canyon. "There were nuts, and also turkeys of the variety found in New Spain, and great quantities of plums like those of Castile."

Palo Duro Canyon was still a favorite winter campground of the Comanches in 1874, when General Mackenzie captured their horses (not ponies) near the mouth of Cita Canyon. *Cita* is the Spanish word for *Engagement*. As late as 1928 there were fresh-water springs in every tributary, nearly all of which flowed the year around. Waterfalls were numerous and much visited for outings.

These springs were the haunt of bears, buffalo, deer, wolves, panthers, elk, turkeys, ducks, and many other animals. Most of them have now disappeared, as have many plants which were associated with the springs. The usual plants still found in the spring environment include cottonwoods, willows, some salt cedars, grapevines, plum thickets, cattails, and rushes.

The water table in the Ogallala formation has fallen greatly in recent years. Pumping of ground water for irrigation has been the primary cause since 1950, but other activities of man caused a drop in the water table long before this. As a result, many springs have weakened and dried up. In addition, many ranchers are finding it necessary to deepen their windmill wells or to haul water to their stock.

There is also evidence of severe erosion in the past, in the form of partially healed gullies. Sand from these gullies has choked many stream channels and buried some springs.

The spring water is generally of a calcium bicarbonate type, fresh, very hard, and alkaline. The content of silica and fluoride may be high.

Most of the writer's field studies were made during the period August 4-9, 1978. It should be kept in mind that the spring flows observed were lower than average because of irrigation pumping and transpiration by plants at this season of the year.

In 1887 the Mulberry or Twin Bar ranch headquarters were established 11 kilometers southeast of Claude. The many fresh-water **Mulberry Springs (3)** emerged here then. The gardens were subirrigated by shallow ground water. Later frequent outings were held here. The present owner, Leroy Campbell, remembers when two boys from Claude drowned while swimming in a 10-meter-deep hole near the springs in 1926. The hole was filled with sand in the 1950s. In 1947 Mulberry Creek still ran in winter through the ranch, but quit soon after. However, 12 kilometers downstream at the road crossing there was still a discharge of 0.35 liter per second on August 6, 1978. According to Campbell, irrigation pumping is drying up the springs in this area.

Salt Fork Springs (1) are on the Salt Fork Red River on Don Thornberry's ranch nine kilometers northeast of Goodnight. On August 6, 1978, they produced a discharge of 0.65 lps among many minnows. This contrasts with a flow of 8.8 lps on March 25, 1940, which issued two kilometers farther upstream, at the Thornberry ranch house. Cottonwood trees extend another two kilometers upstream, indicating that the springs originally emerged here. The Salt Fork channel is largely filled with sand from severe gully erosion in the past.

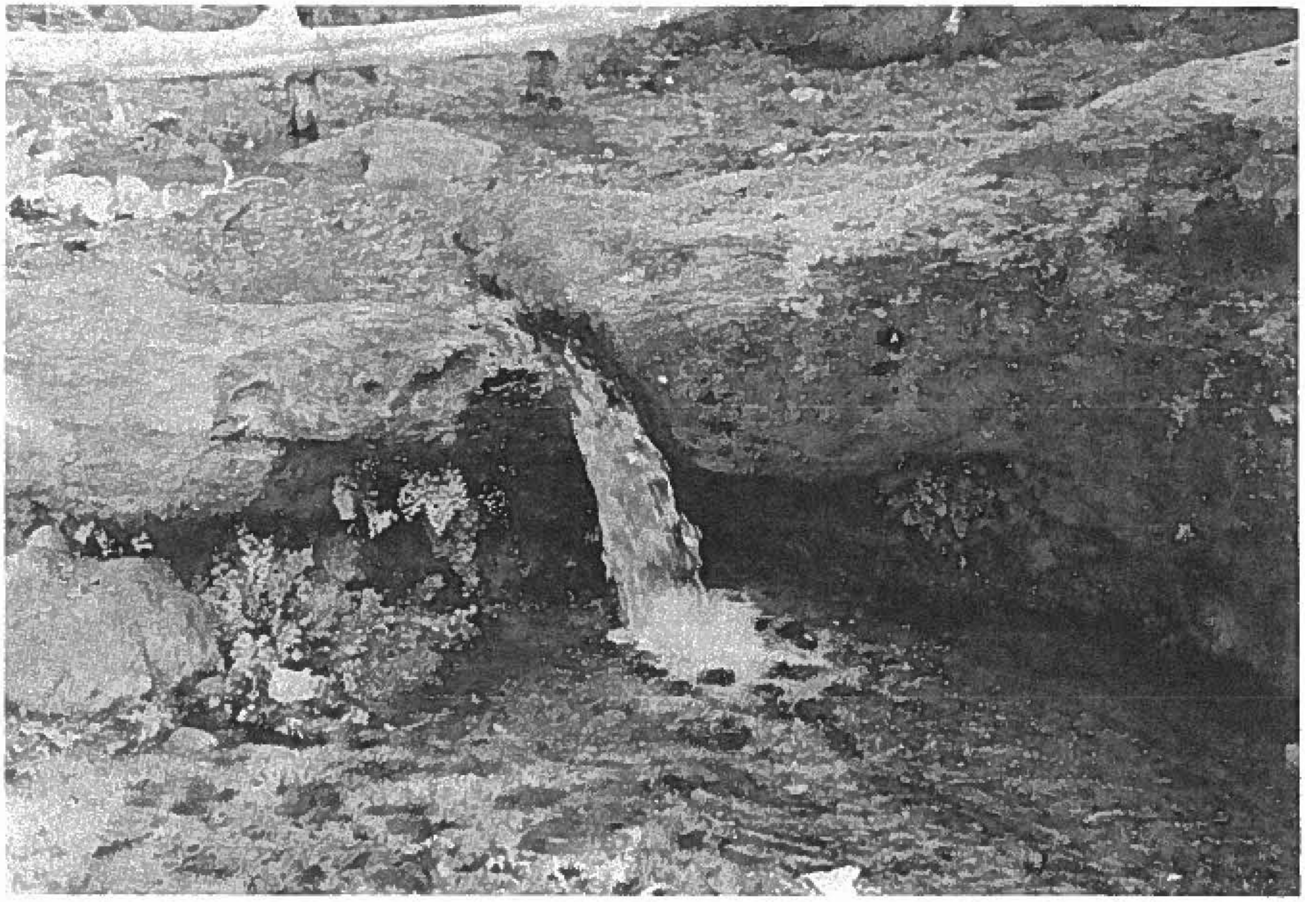
Eight kilometers southeast of Goodnight are **Spring Creek Springs (5)**, which feed Spring Creek. The Spring Creek ranch is owned by Rick Klein and operated by Jim Jones. In the period 1905-1910 Charles Goodnight kept some buffalo here. The main spring waters flow over a ledge of Triassic sandstone at an elevation of about 825 meters, falling one meter into the corrals. On August 6, 1978, the spring poured out 2.4 lps amid much maidenhair fern, water cress, gourds, and other water-loving plants. A former pool below the springs has been filled in about three meters in the last 10 years, according to Jones. Several smaller springs trickle nearby, one of which irrigates a garden. Spring Creek still runs to Mulberry Creek except in the summer. Irrigation pumping, about four kilometers north, has not yet greatly affected these springs. Wild turkeys thrive here.

Blue Hole Springs (2) are nine kilometers southwest of Goodnight on the Mattie Hedgecoke ranch, administered by Beth Louviere. The water falls over a ledge of Triassic sandstone about five meters high into a pool containing tadpoles. (See Plate 5, e). The cliffs are draped with maidenhair ferns and shaded by large cedar trees. An old jeep trail, long unused, winds through the shinnery-covered hills to the springs. On August 5, 1978, 0.06 lps trickled over the falls, increased to 0.35 lps a short distance downstream by other springs. Similar springs occur on Indian Creek, three kilometers south, and in other nearby canyons.

Twenty-four kilometers south of Goodnight are the JA ranch headquarters and Paloduro community. Springs which once poured out at the headquarters were the scene of annual 4th of July barbecues for many years. These springs are now dry, but **Cottonwood Springs (4)**, nine kilometers north of the headquarters in Dutch Canyon, still flow 0.30 lps. According to Snooks Sparks, Cottonwood Springs once filled a 2-inch pipe. They were the source of Cottonwood Creek and were piped three kilometers to several tanks. The ranch is owned by Montie Ritchie and managed by John Farrar.

Baker Springs (6) were 15 kilometers west-northwest of Paloduro on Ed Reed's ranch. In 1940 they produced 0.31 lps. Now they are only a seep in a deep canyon covered with live oak and cedar. **Cox Spring**, 1½ kilometers northwest, once fed a pool four meters deep, but is now only a seep also.

Pleasant Springs (7) feed Pleasant Creek seven kilometers east of Wayside. They are on the Mattie Hedgecoke estate, managed by Lee Palmer. On April 1, 1940, they produced a discharge in Pleasant Creek



Spring Creek Springs.

at Highway 207 of 9.5 lps, running to Prairie Dog Town Fork of the Red River. On August 7, 1978, the flow was estimated to be 1.2 lps, which ran two kilometers, or about halfway to Highway 207, before disappearing. They are the only fresh-water springs on the ranch.

About 8 kilometers northeast, in the river bank, were the **County Road Springs**. They were on the road before it was moved about 1.5 kilometers east. They were possibly used by the Jumanos, who had a village nearby between 1630 and 1670. They also may have been used by S. P. Hamblen, who built a dugout near here in 1901. The water, which emerged from Cloud Chief gypsum, was declared unfit for domestic use in 1940. At that time there was a discharge of 0.19 lps. Now the springs are dry.

Five kilometers north-northwest of Wayside is the Hidden Falls ranch and youth camp, managed by Mike Bellah. Here, in a rugged canyon, are **Hidden Springs (15)**. The combined flow of the several springs and seeps was 1.9 lps on August 11, 1978. Some of the spring waters fall over Triassic sandstone cliffs into attractive pools which are used for swimming by the boys and girls at the camp. Many cedars and live oaks grow here, in addition to the usual water-loving plants. Above the springs is a bed of Ogallala caliche containing much opal. Early Americans who lived here left many worked flakes of opal. In 1541 Coronado's expedition probably replenished its water supply here. Similar springs trickle in other nearby canyons.

In a remote area on the Harrell ranch six kilometers north of Wayside are **Home Springs (14)**. They are at the site of Charles Goodnight's 1876 Old Home ranch. The old house is now at the Ranch Headquarters Museum at Texas Tech University. The springs once ran through a meat and milk cooling house. They now flow only in winter. A historical marker is at the site.

Pony Springs (12) were 11 kilometers north of Wayside on Newton and Ed Harrell's ranch on Pony Springs Creek. They still ran in 1960, when they were shown on a U.S. Geological Survey topographic map, but are now dry. They were located close to an old ranch house for which they provided water. A new house is now (1978) being built here. Three windmill wells just upstream undoubtedly contributed to the failure of the springs. Many mule deer still dart among the few remaining cottonwoods.

Harrell Springs (13) were at the Harrell ranch headquarters on Rush Creek 25 kilometers south of Washburn. That they were a favorite Indian haunt is evidenced by the pictographs, mortar holes, and shaft-straightening grooves in the Dockum sandstone cliffs and boulders. (See Plate 9, a). The sandstone also bears many more recent names and dates, one in 1890. The springs supplied water to the ranch headquarters in early days. A swimming hole was located here, and this was a favorite picnic spot. In 1940 a discharge of 0.63 lps was recorded, but the springs are now dry. Turkeys and antelope still make their home in the vicinity.

Dripping Springs (9) are 19 kilometers south of Claude on Dr. James Goforth's ranch.For many years they were very popular for school picnics and other outings, but are now closed to the public. Maidenhair ferns drape the cliffs, shaded by cottonwoods. In 1940 there was a discharge of 0.95 lps from Dockum sandstone. Now there are only some seeps.

Twenty kilometers south-southwest of Claude are the similar **Luttrell Springs (8)** on Wildon Hundley's lease. They appear in a deep ravine surrounded by cedars, live oaks, and some cottonwoods. On March 12, 1940, they trickled 0.44 lps, but are now only seeps.

The similar **Ransom Springs (10)** were eighteen kilometers southwest of Claude on Roy and Don Ransom's ranch. In 1940 they supplied water to 200 head of cattle. Now they are seeps among sandstone boulders and cottonwoods.

Dry Creek Springs (11) are five kilometers farther west on Tom Christian's ranch. In 1940 they ran 0.63 lps. Now they are seeps among a few cottonwoods in a very deep canyon. They are dry in summer, but still course about ½ kilometer in winter, according to Christian.

AUSTIN COUNTY

The springs of Austin County issue chiefly from Tertiary Miocene (Fleming) and Quaternary (Willis) sands. These formations dip to the south-southeast at 2 to 10 meters per kilometer. Some springs also occur in Quaternary terrace sand and gravel along the major rivers. Most are found in the hillier north portion of the county. The county lies in the Fayette Prairie physiographic area, which contains some wooded areas, especially along streams.

Carbonized wood and acorns associated with human artifacts indicate that at least 5,600 years ago early Americans were living at the springs in the county. In the early eighteenth century Spanish explorers found Indians, probably Tonkawas, living at springs. At that time the rivers and streams contained many deep holes where fish and alligators thrived. Many plants and animals enjoyed a special ecosystem around the springs.

Modern man's activities have caused severe damage to the ground-water reservoir. Water levels declined as much as 1.8 meters from 1956 to 1966. Wastage of water from flowing wells, some of which still flow, contributed to the decline. Pumping of water for rice irrigation has been the major cause, however. The rate of decline in recent years has accelerated. As a result many springs have weakened or failed. The base flow (spring flow) of all streams in the county was estimated to be about 450 liters per second in 1965.

Erosion from formerly plowed slopes has left partially healed gullies in pastures and woods. Sediment from this erosion choked many channels and buried some springs. Ground water has also been contaminated by oil-field operations. This has been caused chiefly by past disposal of brine into open pits and by inadequate casing of oil wells.

The spring waters are generally of a sodium bicarbonate type. fresh, soft, and acid. The content of silica or iron may be high. (See Plate 13, d). Most of the writer's field studies were made during the period April 13-18, 1978. As the preceding several months had been dry, the observed spring discharges are probably lower than normal for this season.

Nine kilometers northwest of Sealy are **Deadman Springs (7)**, the source of Deadman Creek. R. A. Engelking of Sealy once lived here and remembers some excellent fishing in the creek. There are still many bogs and pools fringed with water primrose along the stream. The many springs produced a flow of 0.71 lps in 1978 from Willis sand at the road crossing one kilometer upstream from Highway 36.

About six kilometers east of Cat Spring are **Swearingen Springs (8)**. Here Elemeleck van Swearingen settled in 1831. Some of the springs are on Earl Meyers' ranch east of the old Swearingen cemetery. Others are on Marvin Swearingen's ranch. The combined spring flow in Swearingen Creek at the Millheim cemetery two kilometers north-northeast was 0.95 lps on April 17, 1978. The springs trickle from Willis sand. Deep red Texas stars adorn the surrounding fields, where cattle egrets are common.

Cat Spring (4) is in the Cat Spring community, 500 meters northwest of the Agricultural Society Hall. Chiefly on Mrs. Hilda Michaelis' property now, they were settled by the Von Roeders in 1832. The woods were full of wildcats then, and the first night the Von Roeders camped at the spring a wildcat came to drink. This was the origin of the name **Katzenquelle** or **Wildcat Spring**, later shortened to Cat Spring. There are still some wildcats in the vicinity. The spring was much used by early residents as a water source and for washing clothes. According to W. C. Hillboldt, who guided the writer to the spring, there is rumored to be a cache of gold beneath the nearby large stepping stone of the Hassler-Kinkler store. The store is gone, the stepping stone being the last evidence of it. On April 15, 1978, the spring discharged 0.72 lps from Willis sand in a grove of pinoak trees.

Post Oak Springs (3) are four kilometers northwest of New Ulm on Clarence Schweke's farm. The early settlement of Post Oak Point was here, and the springs feed Post Oak Point Creek. The Loescher brewery and Schweke gin used the water in the 1840s. The springs produced 1.2 lps from Fleming sand on April 16, 1978. According to Schweke they have never failed. Minnows play in beaver-dammed pools fringed with ferns. The adjacent fields are covered with bluebonnets in spring. Indian artifacts have been found here. Sandy Creek, once called Spring Creek, three kilometers east-south-east, now flows only 0.06 lps at Highway 109.

Eleven kilometers west-southwest of Wesley, on Leonard Bruce's property, are **Shelby Springs (2)**. On the highest hill in the area is a monument to David Shelby, who built a cabin here in 1822. Several iron-bearing springs trickling 0.5 to 1.0 lps each issue all around the hill at an elevation of about 130 meters. The water flows from Fleming sand on a clay bed among pennywort and ferns. The black soils indicate that boggy conditions formerly existed farther up the hill. Several Spanish artifacts have been found here, according to Leonard Bruce, Jr. This is not surprising, as an old Spanish trail passed the springs. Bluebonnets and scarlet paintbrushes adorn the adjacent fields in spring. Deer, wolf-coyotes, nutrias, raccoons, turtles, and fish are numerous.

One of the Shelby Springs.

Mayeye Springs (10) are three kilometers southwest of Bellville on Charles Kollman's and Albert Aschenbeck's property. According to Jack Bader of Bellville, many Indian artifacts have been found in this vicinity. This was the probable site of the Mayeye village which Martin de Alarcon stumbled upon in 1718. The springs still produced 2.3 lps in 1978 from Willis sand among water pennywort, marsh purslane, spider lilies, and red buckeye shrubs. They and other nearby springs issue at an elevation of about 60 meters.

Glenn Springs (11) are 100 meters east of the hospital in Bellville. They were a popular haunt of Indians. In 1832 Alex Glenn, great grandfather of Jack Bader, settled here. Until the 1920s, according to Bader, the springs produced a constant running stream to the south. At that time they were still used as a water supply by two families and for a minnow pond. Now the iron-bearing water seeps from Willis sand and produces a wet area for about 50 meters before again sinking into the ground.

Five kilometers southeast of Bellville and one west of Coushatta cemetery are **Coushatta Springs (9)**. Several small springs, now only seeps, issued from Willis sand on a clay layer on a high hill on C. R. Worst's farm. A Coushatta camp ground was located here. Six kilometers east-southeast, on Josephine Krueger's farm, a large cache of projectile points was found. According to worst, many boys used one of the springs for fishing and recreation until about 1930. The seeps now drain into ponds amid water primrose and marsh purslane. Red Texas stars bloom in the surrounding fields where gophers burrow.

Eight kilometers east-southeast of Kenney is a second Spring Creek (12). This spring-fed creek, also called Ives Creek, discharged 18 lps from Willis sand on April 17, 1978 at the Highway 1456 crossing. Water pennywort, marsh purslane, water primroses, and yellow water lilies fringe the pools where large fish dart.

Cumings Springs (6) are nine kilometers north of Sealy on the C. W. Brandes ranch. Many Indian artifacts and burials have been found here. In 1824 Mrs. Cumings and her three sons settled here and built one of the first water-powered saw and grist mills in Texas. Some very small springs still trickle from Lissie sand. Beavers frequent the site.

On upper Bollinger Creek, formerly called *Arroyo Dulce* or Sweet[water] Creek, are **Arroyo Dulce Springs (13)**. The numerous springs rise on Melvyn Levine's ranch, leased by Jim Sartwelle. A discharge of 3.2 lps issues from swales of Willis sand on clay. Many bogs are found here, now partially drained, and deep holes, over a horse's head, exist in the stream channels lined with pennywort. Wildlife is abundant, including nutrias, ducks, skunks, fish, and snapping turtles.

Downstream on Arroyo Dulce and three kilometers northwest of San Felipe was Stephen F. Austin's 1824 cabin. A monument in a wood of pin oaks and other trees, large grape vines, and wild roses marks the cabin site on Frank Koy's property. According to former owner Ollie Kurtz, springs (5) near the cabin site began drying up in the 1930s and failed permanently during the drought of the 1950s. One of the best springs used by Austin was probably 100 meters east of the cabin, where Willis sand rests on a sandstone bed in a draw. Arroyo Dulce still runs past the site, but the water is now a dirty gray, contaminated by various industries upstream.

Along the Brazos River bluffs northeast of San Felipe were formerly several springs (1). According to Doris Starkey, numerous projectile points and potsherds have been found here. Evidently this was a favorite campground of Indians in past ages. The springs poured from Lissie sand. As early as 1736 travelers on the Atascosito road which crossed the river here stopped to quench their thirst. Later the McFarland ferry was located here. And river-boat passengers partook of the waters when the boats tied up to nearby cottonwood trees.

BAILEY COUNTY

Although the springs of Bailey County have nearly all ceased flowing, there were formerly many which issued from Ogallala and more recent sand and caliche, and from Cretaceous limestone. They were located primarily along Blackwater (*Agua Negra*) Draw and its tributaries and adjacent to the larger lakes, where there was sufficient topographic relief for springs to develop. The *black water* was probably produced by the numerous swamps and peat bogs which existed in the upper reaches of Blackwater Draw.

Springs were present and used by the Llano Paleo-Indians at least 11,500 years ago. At the Blackwater Draw site southwest of Clovis, New Mexico, hunting and butchering tools were found at the site of ancient springs in association with the remains of extinct forms of mammoth, bison, camel, horse, antelope, wolf, coyote, peccary, deer, and badger. Similar springs no doubt existed in Bailey County in these ancient times, when the climate was slightly wetter than at present. Also found at the Blackwater Draw site were the oldest artificial wells known in the New World, some 6,000 years old. They were probably dug by the Paleo-Indians during a drought period when the springs failed to flow.

Holden and others (1972) state that an old Indian trail followed Blackwater Draw from the large springs at Portales, New Mexico, to Big Spring and southeastward. This is not surprising, as in "pre-civilization" times, there was abundant water containing many catfish along the draw. Bolton (1949) stated that in 1541, in Coronado's time, there was running water in Blackwater Draw as far west as the New Mexico line and for some distance beyond. The advent of the cattle barons in the 1880s did great damage to the county's springs, principally by overgrazing and destroying the soils' capability to absorb recharge water. By the 1930s the springs along Blackwater Draw were largely gone. More recently irrigation and municipal wells have taken a heavy toll of the ground-water reservoir, causing the water table to fall as much as one meter per year. Abandoned windmills and dying trees which can no longer reach water are frequently seen.

In the 1920s and 1930s wild buffalo, deer, and antelope still roamed the country. With the disappearance of the springs and their natural habitat, these animals are gone now. Many waterfowl, including geese, teal, ducks, shovelers, scaups, and sandhill cranes, still winter at the larger lakes, especially in the Muleshoe National Wildlife Refuge. But with the failure of the springs which formerly fed them, the lakes are drying up and becoming dust bowls. One wonders where the birds will winter when the lakes are gone, to be filled only rarely by surface runoff. Fish and other aquatic life cannot survive under these conditions.

The spring waters were largely of a sodium bicarbonate type, usually fresh, very hard, and alkaline. In some cases the water was highly mineralized, as at **Alkali Springs (13)**. Often the content of fluoride or silica was objectionably high. The writer's field studies were conducted primarily during the period April 8-13, 1977.

Two and one-half kilometers south of Baileyboro is a lake which is variously called Alkali, Baileyboro, or Heifer Lake. Springs on the east side (13) flowed 0.03 liter per second in 1936 from Ogallala sand on top of Cretaceous shale. In 1977 there was only a small pool of standing water surrounded by a crust of gypsum and other salts, and salt-cedar trees. The bones of many cows indicate that the water was too salty for livestock (see Table of Selected Chemical Analyses). According to E. B. Wilson, who operates the Needmore store, a less saline spring on the west side of the lake supplied a stock tank until after the wet year of 1941. This spring and tank are both gone now.

Eleven kilometers southeast of Coyote Lake and one northeast of the Baileyboro community is K. J. Barnett's farm headquarters. Here until 1923 **Barnett Spring (7)** flowed from caliche and sand in the side of a bluff. It supplied water for domestic and stock use. The site is now beneath the floor of a small house. Very likely there were also at one time springs on the west side of a former lake, also on the Barnett farm, three kilometers northwest. The lake is dry and cultivated now.

From both ends of Coyote Lake, 20 kilometers southwest of Muleshoe, plentiful springs (5) once issued from Ogallala sand and caliche. Numerous projectile points, associated bison bones, and hearths found here demonstrate that this was a favorite campsite of prehistoric people. Dark gray soils signify that springs and marshes formerly existed as high as 10 meters above the lake bed. According to Haley (1969), Albert Pike camped here in 1832. G. L. Gillespie on his 1875 *Map of portions of Texas, New Mexico, and Indian territory* and W. F. Cummins on his 1891 *Geological map of the staked plains and adjacent area* showed fresh-water springs here. John Armstrong of Farwell states that in 1947 the springs were flowing and the lake was about one meter deep. They ceased flowing in the 1950s. Now at the spring sites there are only small pools of stagnant, very saline water. The lake is dry and a source of much dust on windy days.

In the sand hills of western Bailey County, at latitude 34°11' and longitude 102°59' on the VVN ranch, there was formerly a group of small springs (6), according to Dee Owen of Farwell. Chalmer Davis, who operates the ranch, kindly guided the writer to this site. The springs, which dried up in the 1930s, flowed from surrounding sand dunes onto a hard caliche bed. Dark gray soils indicate that swamps once existed in the vicinity. Many artifacts such as projectile points, pottery, and metates point to long use of the springs by prehistoric people. Killdeers, prairie dogs, and coyotes are still numerous, but they must now rely on windmill tanks for water, as the springs are gone.

Seventeen kilometers west of Muleshoe on Blackwater Draw were some springs (3) which flowed until the 1930s. John Armstrong of Farwell hunted ducks here in the 1920s. George Cole of Muleshoe has found many Indian artifacts and bison bones at the site, which is under cultivation now. Eunice Crume of Farwell also remembers these springs. Now the water level is about 15 meters below the surface.

Farther east in Blackwater Draw, 10 kilometers west of Muleshoe, was **Blackwater Lake and Springs (2)**. According to Dee Owen of Farwell and Pat Bobo of Muleshoe, these copious springs dried up around 1940. The lake formed by the springs developed dark organic soils, which may still be seen in the dry cultivated fields.

Three kilometers south-southeast of Muleshoe was Willow Lake (11), a small lake fed by seepage from the surrounding sand dunes. Several people kept rowboats at the lake, bordered by willows and wild plum trees. The lake disappeared after the very wet year of 1941. Now rattlesnakes prowl among a few hackberry trees. Many similar small lakes formerly existed in the sandhills belt which traverses the county from west to east.

Three kilometers northeast of Muleshoe there were two springs (4) until about 1925, according to J. E. Embry. The location, now cultivated, is marked by the dark gray soils of an old lake bed or swamp. Capt. Tristan de Luna y Arellano with most of Coronado's army may have stopped here on the return trip west from Tule Canyon in 1541, according to Bolton (1949). These were probably the **Jumbo Springs**, described by Meigs and others in 1922. A General Land Office map of Lamb County in 1884 called them **Turnbo Springs**, probably through a spelling error. In early settlement days it was possible to travel from Muleshoe to Earth by boat through a chain of spring-fed lakes.

In the northeast corner of the county, on the Parmer County line and one kilometer west of the Lamb County line, were **Butler Springs (1)**. They were shown on early maps by the U.S. Engineer Office in 1875, Spaight in 1882, and others. Flowing originally from sand and caliche, they were dry in 1977.

Muleshoe National Wildlife Refuge is ten kilometers south of Needmore. Here a number of springs formerly supplied several large lakes. Many Indian artifacts signify that this was a favored campsite. Only one group, **White Springs (8)**, still flows one kilometer south of White Lakes at an elevation of 1,140 meters. Numerous seeps from sand on top of Tahoka clay produced a flow of 0.06 lps in 1977 which runs 500 meters before disappearing. The White Lakes were dry and covered with a crust of white salts on April 11, 1977. A fresh-water spring at the wildlife refuge headquarters (14) (whose water contained only 619 milligrams of dissolved solids per liter) produced 0.03 lps in 1936 and flowed as recently as 1975, according to

Loyd Brazell. This recent flow may have been due to temporary storage of water behind an upstream dam. Dead cottonwoods indicate that the spring, which issued from Cretaceous limestone, has been dry most of the time for many years. Other springs formerly flowed at Highway 214 east of Goose Lakes (9) and just south of Pauls Lakes (10). As at White Lakes, they issued from sand on Tahoka clay, but are now only damp areas. Only Upper Pauls Lake held water at the time of the writer's visit.

Fourteen kilometers southwest of Needmore, at the northeast end of Monument Lake, springs formerly flowed from Ogallala sand (12). Nearby was a cave in Kiamichi limestone which has been blasted shut. It probably served as a shelter for early Americans, as numerous projectile points and potsherds have been found here. An old wagon road and cattle trail to Fort Sumner passed the springs. According to Mrs. Joe Wheeler, the owner's wife, the springs still run in wet weather. This apparently is not often, as the lake has now become dry enough to drive across with impunity.

BASTROP COUNTY

Bastrop County appears to have been much favored by early Americans, at least 9,000 years ago, as indicated by the many Plainview spear points and other artifacts found near several springs. By protohistoric times the very fleet and nimble, although slightly small, hunting and gathering Tonkawa Indians were using the springs. In 1691 the Spanish expedition headed by Domingo Teran de los Rios, looking for a more direct route from the interior of Mexico to the mission at Nacogdoches, passed through the county. He is believed to have reached the Colorado River about at the Travis County line, followed the river down to Smithville, and crossed it there. In the words of Father Massanet, who accompanied him,

> From this point there could be seen a level space covered with oak trees, and about a league away there was a lagoon running from north to south. The Indians called this in their language Nenocodadda. The lagoon contains many fish and alligators . . . We crossed the San Marcos [Colorado] River in safety, thanks to God, and stopped on the other side of the river in a level spot where there was good pasture for the cattle and horses. Near the river were many springs of cold water, but that of the river itself was very hot and muddy.

The lagoon he described is now known as Shipp's Lake, an old ox-bow lake in a former channel of the river southeast of Smithville. It is now almost filled with flood sediments.

White Springs.

Many of the springs found and used by the Spaniards along the Colorado River still exist, as they are in low situations where the potentiometric surface of the ground water is still above the ground surface. In some parts of the county, however, most of the springs have failed, because ground-water levels have been lowered as much as 30 meters by well pumping. For example, the springs two kilometers north of String Prairie in southern Bastrop County are now dry. They once were a chief source of water for the community.

The county's springs issue chiefly from Quaternary terrace sand and gravel along the Colorado River and from Tertiary Eocene sands such as the Wilcox, Carrizo, Reklaw, and Cook Mountain. The Tertiary formations dip toward the southeast at about 25 meters per kilometer. Displacements by faulting control the location of some springs.

Spring water in the county is generally fresh, of the calcium and sodium bicarbonate type, and hard. Fluoride content is usually less than desirable, and the iron content may be very high. Most of the field studies were made during the period September 24-29, 1975.

Fitzwilliam Springs (3) include several springs four kilometers southwest of Bastrop on Jack Griesenbeck's ranch. They issue from terrace gravel on top of a bed of Wilcox sandstone five meters above the Colorado River bed on its left bank. Some of them, which cascade over a bed of the sandstone, are called **Indian Waterfall** in tribute to the Indians who used them for thousands of years. They were also used by travelers on the nearby Camino Real. Bonnell in 1840 described some animal bones which were found here, including *horns of ten or twelve feet in length, and of eight inches in diameter*. These were probably the tusks of an extinct mammoth such as was hunted by the Paleo-Indians of the area. On March 2, 1953, during a drought, the flow was 0.31 lps, on November 26, 1964, it was 1.6 lps, and on September 27, 1975, a wet year, 6.1 lps. Large water snakes live around the pools of these springs.

Bastrop Springs (2), at the foot of Pine Street in

Bastrop also flow from terrace gravels at 0.31 liter per second. The Old Camino Real or King's Highway, which was hacked out of the wilderness soon after Teran's exploration, crossed the river at these springs. Many very early travelers must have made a refreshing stop here. When Stephen F. Austin's colony settled at Bastrop (then called Mina) in about 1827, the springs were its chief source of water.

Burleson Springs (1), four kilometers northwest of Bastrop, flow from river terrace sands and gravels on the southwest side of the river on Lloyd Ketha's ranch. They were much used by early boat travelers on the Colorado river. When a stagecoach line was established between Bastrop and Austin, this was the first stop after leaving Bastrop. Bonnell described them as *fine springs of crystal water bursting from the hills.* A water-powered corn mill operated here in the 1840s.

Elgin Springs (21) were located two kilometers northwest of Butler and 100 meters upstream from the Elgin pumping plant. In 1922, when they were Elgin's only water source, they produced 2.8 lps. They issued from Wilcox sand beneath a clay layer. The springs cannot be found now, having been buried beneath sand from man-made erosion. But other springs upstream still produced a flow of 32 lps in Sandy Creek adjacent to the former Elgin springs on March 11, 1978. According to L. B. Carter, the springs in the vicinity no longer flow as they once did. Several high-capacity municipal wells pump nearby. Many frogs make their home in the creek.

Sand Springs (8), five kilometers southeast of McDade, were a Southern Pacific Railroad water stop when steam power was in fashion. Issuing from the Carrizo sand, they now emit only 0.06 lps because of pumping from a large adjacent irrigation well. Young swains from McDade and Paige often took their sweethearts by railroad handcar for a picnic at these springs. They were called **Middleton Springs** by Rand McNally in 1877, and are still referred to as "**Mid**" **Springs** by many residents.

Goodwater Springs (22) are five kilometers north of Paige on Mrs. Catherine Rhodes' property. They were an important source of water to early settlers and were depicted on an 1899 Geological Survey topographic map. Rising from a fault in Cook Mountain sand amid many cedar trees, they supply a small lake. On March 13, 1978, the springs flowed 0.26 lps, including water evaporated from the lake and that passing the dam.

When Paige was first settled there were some very useful springs about one kilometer west of the town. G. W. Colton portrayed **Paige Springs (9)** on his 1872 map of Texas. On February 13, 1977, they were producing 1.0 lps from the Cook Mountain sands after recent rains, but they no longer flow in dry weather.

Trigg Springs (4), five kilometers southeast of Bastrop, consist of several springs flowing from terrace gravel on top of the Wilcox sandstones. They are on the north side of the Colorado River (flowing 4.8 lps in 1964). They were used in about 1830 by early settlers at Bastrop. The principal diet of the settlers consisted of wild mustangs which were plentiful on the lush meadows of the Colorado River bottom.

Blue Springs (5), the source of Blue Branch, are three kilometers southeast of Bastrop. In the Pine Forest development surrounding the springs, thousands of Indian artifacts have been found, including Paleo-Indian Plainview flint points, scrapers, punches, drills, corner-tang knives, tomahawks, and grinding stones. It is likely that these ancient people found this a very desirable place in which to live. The strip of pine trees about 4 kilometers wide which runs almost north to south through Bastrop County here owes its existence to the underlying outcrop of Carrizo sand, which forms sandy, well-drained, acid soils. In early settlement days a pottery plant located here also used the spring water.

Although Blue Springs flowed constantly in the past from high gravel deposits on top of Carrizo sand, they have now been reduced to seeps. Probably the water was formerly rejected as recharge into the Carrizo sand, as it was full to overflowing. Now that the water table in the Carrizo has been drawn down by pumping, the water from these high gravels goes to recharge the Carrizo rather than appearing as spring flow.

About seven kilometers northwest of Smithville, where Alum Creek enters the Colorado River, **Alum Springs (6)** flowed from the river terrace at about 1.2 lps in 1975. Just east is a high, tree-studded bluff with many large Queen City conglomerate boulders. The large numbers of Indian artifacts found on this bluff disclose that an ancient people occupied the site. In 1828 an unofficial fort was built here, and the Tonkawas had a camp nearby. The settlement became known as Providence.

When Smithville was first settled in 1828, **Thorn Springs (7)** were undoubtedly very important. They were at the eastern edge of Smithville on the south bank of the Colorado river on Vernon Richards' property, near Cole Street and Turney Lane. The first store and post office in Smithville, as well as the old Thorn house, still stands at the springs. They flow from terrace gravel about 10 meters above the river bed amid much water pennywort and poison ivy. A housing project will

Thorn Springs.

soon surround the springs. Discharge records in lps include:

Jan. 23, 1953 (drought)	0.06	Sep. 28, 1975	1.2
1966	0.31	Mar. 12, 1978	0.52

Seven kilometers southeast of Red Rock, near Sandy Creek on B. G. Henry's property, are **Murchison Springs (20)**. According to Mackey Helford, who guided the writer to the springs, they were formerly much used by area residents. Trickling 0.05 lps in 1978 from Carrizo sand just east of a radio tower, they supply a small pond. The remains of the wooden spring box may still be seen. Marsh purslane is abundant, and yaupon and other trees loaded with ball moss and lichens surround the springs. Gophers inhabit the area. A diversion ditch was built in the past in an effort to keep sand out of the springs. Many wells pump ground water in the vicinity. **Hoy Spring**, on Alvin Bourgeois' property 1.5 kilometers upstream, is similar. **Watson Spring**, still farther upstream, is reported no longer to flow.

BAYLOR COUNTY

The springs of Baylor County flow in nearly all cases from Quaternary Seymour gravel and sand. This formation is found chiefly along the Brazos River. Usually the springs emerge at the base of the Seymour, on top of relatively impervious Permian shales. A few very small and usually saline springs trickled in the past from Permian sandstones and limestones of the Clear Fork and Wichita groups, which dip gently to the west-northwest.

At one time there were perennially flowing streams in most of the county. Catfish weighing 34 kilograms (75 pounds) could be caught by hand or with nets. In 1881, 1886-87, 1892-95, and 1911-12, there were droughts which caused many springs to dry up temporarily. But the factor which has caused permanent damage, especially in the Seymour formation, is pumping of water for irrigation, municipal, and other uses. This has caused the water table to fall and many springs to falter and fail.

In addition, severe soil erosion has filled many stream channels with sediment in modern times, and buried some springs.

The spring water is generally of a calcium bicarbonate type, fresh, very hard, and alkaline. Contamination has occurred in some cases. Contaminants include nitrates from barnyards, feedlots, and septic tanks, brine from oil-field operations, and industrial wastes. The fluoride content of the water may be high.

Most of the writer's field studies were made during the period July 18-23, 1979. As 10 centimeters or more of rain fell in the county during the preceding two weeks, the observed spring discharges are probably higher than normal for this season.

At the north end of Murrel Street in Seymour are some springs (2) on Seymour Creek on W. W. Elliott's property. Chief Quanah Parker and his Comanches camped many times at these springs. In the 1880s a spring-fed pool here, shaded by large elm and hackberry trees and surrounded by wild flowers and plums, was used for baptisms. In July, 1969, the discharge was 0.63 liter per second. On July 20, 1979, the flow was 0.065, running about 75 meters through a barnyard.

One kilometer west of Seymour are some similar springs (3) on James Wallace's property. In July, 1969, the flow was 0.31 lps. On July 20, 1979, it was 0.045 lps, running about 50 meters before disappearing. Nearby irrigation wells and a well at the Wallace house used for watering gardens and lawns usually dry up the springs when pumping. Cattails and rushes grow in the water, shaded by a grove of hackberry and other trees.

Buffalo Springs (1) are four kilometers west of Seymour on Gary Lee's farm. Nomadic Indians who camped here left hearths, crude grinding tools, and stone axes. The springs were frequented by thousands of buffalo and became a hunting camp in the 1870s. The water pours from Seymour sand and gravel at an elevation of 385 meters. Discharge records, in lps, are:

Aug. 7, 1925	2.8	Jul. 20, 1979	0.75
Jun. 22, 1969	1.6		

The 1979 observation included 0.45 lps at the main springs and 0.30 lps at other springs about 0.75 kilometer east. Both were flowing to the Brazos River. The springs are reported never to have failed. Cattails, rushes, crested ferns, arrowhead plants, and water cress fill the pools and streams. Minnows, water snakes, and dragonflies are numerous. Groves of cottonwood, salt cedar, and willow trees, and some buttonbush, surround the springs. The recharge area of some 10 square kilometers lies to the northwest. Other smaller springs trickle nearby.

Five kilometers farther west, on the north side of the Brazos River, are more springs (4) on Delmer Styles' farm. Only July 20, 1979, they were only seeps into an earth tank. Frogs and minnows swim among the water milfoil and rushes, shaded by willow trees. The water has been used to irrigate crops.

Red Springs (5) were four kilometers east of the present Red Springs community on Carl Holder's ranch, according to neighbor Barbara Malone. They were named for the red shale on top of which the water flowed from Seymour sand and gravel. A school was located here in 1898. Several old maps depicted Red Springs, including R. A. Thompson's 1908 *Railroad and County Map of Texas*. In September, 1969, a discharge of 0.32 lps was observed two kilometers down the draw or south. On July 21, 1979, there were only seeps into a chain of pools and an earth tank. Frogs and water striders darted among the rushes.

Cottonwood Holes are near the Knox County line and just north of the Brazos River on Mrs. A. K. Boyd's ranch, leased by C. R. Morris. They are fed by springs (6) from Seymour sand and gravel. In 1879 John Propps settled here. At that time the springs fed a large blue hole of water, now largely filled with sediment. This was a well-known landmark for travelers and a watering place for cattle on drives. Many buffalo bones and Indian artifacts have been found here. An old wagon road passed the springs. Very few cottonwoods remain, but willows shade the pools, filled with cattails and much algal growth. Minnows and snapping turtles swim in the water. On July 21, 1979, the flow was 0.75 lps.

Soap Springs (7) are six kilometers west-northwest of the Red Springs community on William Arledge's ranch, managed by Russell Crawford. The source of Soap Creek, they pour from Seymour gravel on Permian shale in a rugged red-rock canyon covered with cedar trees. The channel, completely filled with sand, is covered with cattails. In October, 1969, the discharge was 1.9 lps. On July 21, 1979, it was 1.0 lps.

Nine kilometers northeast of the Red Springs community are **Dead Man Springs (8)** on Wallace Malone's ranch. Indian residents here left many stone artifacts. In 1854 Captain R. B. Marcy, exploring for a location for an Indian reservation, stopped here. In his words,

> We camped on a very elevated bluff, 400 yards from a small spring in a deep ravine.

In October, 1969, the springs produced 0.63 lps. On July 21, 1979, the discharge was 0.35 lps, which ran 0.8 kilometer before disappearing. According to Malone, in winter the stream runs 1.6 kilometers, or past Highway 1919. The recharge area includes about six square kilometers of Seymour sand to the southwest. Irrigation pumping nearby saps the groundwater supply. Minnows and raccoons make their home among the rushes, cattails, salt cedars, and willow trees. Two other similar springs emerge about two kilometers west.

Ten kilometers north-northeast of Westover are some seeps (18) on Godwin Creek on the Boone ranch, operated by Patrick Boone and Mike Ligon. An Indian camp once used the water here, leaving many projectile points, metates, and other artifacts. This was a favorate water hole for buffalo in dry weather. Marcy also stopped here, taking a noon rest at the "spring of cool wholesome water." The seeps, issuing from Permian limestone and sandstone, form pools of living water most of the time. Five-kilogram (12-pound) catfish can still be caught here. The creek is shaded by elm and a few hackberry trees.

Shawver Springs (16) are 13 kilometers northwest of Westover and just west of the Rendham community on Deep Creek. W. J. Laney's house is immediately east. Here in 1880 Robert Shawver built a dugout. The springs watered hundreds of cattle during the 1886-87 drought. On July 22, 1979, seeps from alluvial gravel still fed pools of live water containing algae and many tiny frogs. Raccoon and skunk tracks can be seen among the willows.

Round Timber Springs (17) were eight kilometers southwest of Westover on J. B. Guthrie's ranch on Ayles Branch. Fishing and trapping were formerly excellent in and near the deep, spring-fed holes. Now the holes have largely been filled. But on July 23, 1979, there were still some seep-fed pools. Turtles and raccoon tracks may be seen among the smartweed and post oak and elm trees.

In southern Baylor County are some springs (12) on Mike and Clayton Brasher's ranch at latitude 33°27' and longitude 99°10'. they pour from Seymour gravel on conglomerate in a rocky ravine. Many flint points and tools have been found around the rockshelters adjacent to the springs. In November, 1968, the discharge was 0.95 lps. On July 22, 1979, it was 0.075 lps. A shallow well nearby no doubt robs the springs of their water. Recharge apparently takes place in an area of about two square kilometers lying to the southeast. Garter snakes, minnows, and dragonflies make their home among the moss-covered rocks, cattails, and vines. Willow and elm trees shade the water.

On Highway 114 four kilometers southeast of Seymour were some springs (13). In December, 1968, they flowed 0.63 lps. On July 22, 1979, there was only seepage into a few pools. A shallow well deprives the springs of their water. Cattails and cottonwood and willow trees grow here.

Springs (14) also trickle on Dr. C. M. Randall's ranch five kilometers south of Seymour. Projectile points found here indicate that this was a popular place in past millenia. In December, 1968, the discharge was 0.63 lps. On July 22, 1979, 0.055 lps trickled from Seymour gravel on Permian sandstone, feeding an earth tank. Blackbirds and dragonflies dart over the cattails and algae-laden water.

Ten kilometers south of Seymour in an old gravel pit were some springs (15) on the Frank Allen estate, leased by Don Butler. In March, 1969, 1.6 lps flowed from Seymour gravel and conglomerate. On July 22, 1979, there was no flow here or in the ravine below down to the Brazos River. A few willow and salt cedar trees mark the site.

Seymour conglomerate outcrop at Brasher Springs.

Cache Springs (11) are 13 kilometers southwest of Seymour on Mrs. Dannie Portwood Fancher's ranch. They are the source of Cache Creek, just west of the Highway 2395 bridge. The springs, which emerge at an elevation of 415 meters, were walled up in the 1880s. The Cache Creek community grew up around them. During long droughts the springs furnished thousands of barrels of water to residents in the surrounding area. The spring-fed creek was very popular for swimming and fishing.

Cache Springs still supply fresh water to the Fancher ranch houses and corral. On July 22, 1979, the discharge was 1.9 lps, which ran about two kilometers. In winter the water runs five kilometers to the Brazos River. The channel has largely been filled with sand. Water cress and many algae grow in the water. Many turtles and a few coots live among the rushes, cattails, and willows.

Shady Springs (10) are five kilometers south-southeast of the Red Springs community, south of the Brazos River on Grady and Lee Warren's ranch. Marcy is believed to have stopped here also in 1854. The springs were noted by Gordon in 1913. On July 21, 1979, there were still some seep-fed holes on Young Creek. Deer, quail, and horned toads frequent the spot, where cattails, willows, salt cedar, and plum bushes grow.

BEE COUNTY

Most of Bee County's springs discharge or did discharge from Miocene Oakville and Fleming sandstones, Pliocene Goliad sand, and Quaternary Lissie sand and caliche. These formations dip to the southeast of 4 to 13 meters per kilometer. Water can move through them at about 5 to 15 meters per year. The Reynosa Escarpment, formed by Goliad sandstone, trends northeast-southwest in the northwest corner of the county. Perched water tables are common in the northwest.

The county's springs have been used by man for at least 17,000 years. At the Buckner ranch archeological site near Beeville, Clovis and other ancient projectile points, knives, and tools have been found in association with the bones of mammoths, three-toed horses, dire wolves, camels, and other now-extinct animals. In protohistoric time a number of Coahuiltecan bands called Orejons lived at the springs.

Originally most of the creeks in the county were "beautiful running streams with deep pools full of fish and alligators." Lakes were numerous and brimful.

Sedimentation caused by man-made erosion has filled most of the deep holes and lakes with sand and silt.

In addition, water tables have declined seriously as a result of overgrazing, waste of water through flowing wells, and pumping of wells. As a result most of the springs have greatly weakened or ceased flowing entirely.

In 1863-64, 1871-72, and 1891-98, severe droughts occurred and most springs and creeks stopped flowing temporarily. During the drought of the 1890s many live oak trees died. At these times the settlers who depended upon springs and creeks for water dug shallow holes to water in the creek beds.

For millions of years a complex ecosystem of plants and animals was centered on the springs. When they dried up, most of these life forms disappeared.

The spring and seep waters were mostly of a sodium bicarbonate or chloride type, fresh, very hard, and alkaline. The content of silica and fluoride may be high. Contamination of the ground water has occurred in the past as a result of disposal of oil-field wastes into unlined pits and improperly cased oil wells.

Most of the writer's field studies were made during the period March 26-31, 1979. As six to nine centimeters of rain fell during the preceding week, the observed spring and creek discharges are probably higher than normal for this season.

In 1834 Anne Burke and James Heffernan built a cabin on Poesta creek near Heffernan Street in present Beeville. At that time Poesta creek was a bold running stream with many springs (12), according to historian Mary Welder. The Heffernans must have made good use of the spring waters. Unfortunately they were killed two years later by Indians who took a dim view of being forced out of this choice living area. According to Brenden O'Neill, in the 1870s Poesta Creek constantly discharged so much water that it could only be crossed at St. Marys Street in Beeville, and here it was up to the wagon axles.

On March 30, 1979, 0.35 liter per second still seeped from Goliad sand at this point. Marsh purslane, docks, marsileas, and water hyacinths grow in the pools, edged by willow trees. Minnows, crawfish, snails, and frogs thrive here.

Talpacate Creek northeast of Beeville once contained seep-fed pools of live water which was used by the early settlers. Now there are only a few puddles which hold surface runoff briefly.

In the community of Mineral, a seep (1) of mineral water and oil was found in 1845. In 1877 the mineral water was tapped by a shallow well, a hotel was built, and a health boom began, lasting until 1889. As shown in the table of Selected Chemical Analyses, the mineral content of the water was rather high, containing 3,640 milligrams of dissolved solids per liter.

Field tests made by the writer on water from the nearby M. K. Edgar well show that the mineral content is still approximately the same. The water originates from Goliad sand and sandstone. The water table on March 28, 1979, was 6.5 meters below the surface. San Domingo Creek, into whose channel the seeps once fed, is now dry and choked with sand. Live oaks, grapevines, and mesquites cover the site.

Nine kilometers northeast of Pawnee, in the Monteola community, are some small springs (7). They come out of Oakville sandstone on L. O. Davis' ranch, leased by Phillip May. On March 30, 1979, 0.75 lps of iron-bearing, slightly saline water was flowing. Many minnows and frogs swim among the cattails. Live oak and huisache trees shade the pools in a pasture.

Many similar springs run in this vicinity. Five kilometers south-southeast, northeast of the Caesar community, is a small stream fed by springs. On March 30 it produced 6.2 lps. According to May, it never fails to flow.

About four kilometers south-southwest of Pettus, near the junction of *Medio* (Middle) and Dry Medio Creeks, John Pettus settled around 1855. He found many alligators in the spring-fed creeks (8). Long before that time Indians had made this their home. Seeps still issue from Fleming sand here on Colton Brinkoeter's ranch. On March 30, 1979, Medio Creek discharged 0.55 lps at this point. Dry Medio Creek had only standing pools of live water. Much sand has filled the channels. Live oak, anaqua, willow, and hackberry trees, and grapevines, fringe the channels.

Downstream on Medio Creek, at its junction with San Domingo Creek, the settlement of Normanna was established in 1850. Ottar Beck, who came here from Norway in 1894, remembers that Medio Creek ran constantly until the 1920s, fed by springs (9). As a boy he swam in the holes along the creek, 4 to 5 meters deep. Now the creek dries up in summer, except for a few holes. Much sand has been deposited in the channels here also. On March 30, 1979, Medio Creek here discharged 1.7 lps. San domingo Creek was dry. The creek banks are heavily wooded.

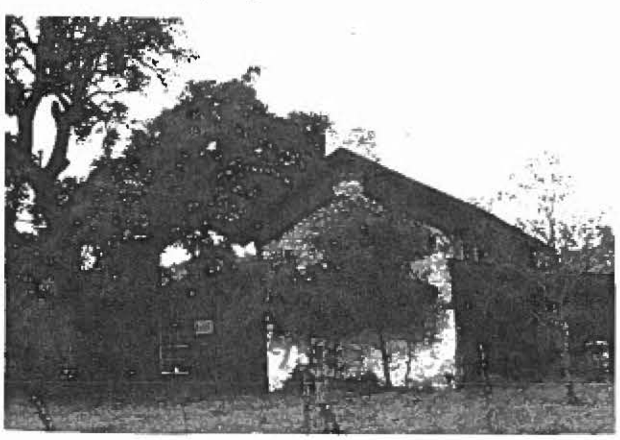
Farther downstream on Medio Creek, at the Highway 59 crossing, was the 1857 settlement of Candlish. Eight hundred meters downstream from the bridge were some strong springs (11). Issuing from Goliad sand, they were on Dr. Scott McNeill's property. during the 1950s drought they dried up and later the channel was largely filled with sand. Some seeps still exist.

In 1834 the Blanconia settlement was started 15 kilometers northwest of Refugio. Near the old cemetery springs (6) flowed from Lissie sand in Neddy Creek. Much sand from gully erosion now chokes the channel. On March 29, 1979, the creek discharge was 14 lps, partly surface runoff from recent rains. Live oaks, grapevines, and dewberry thickets thrive here.

In the 1830s the community of *Papalote* (Windmill) was founded about one kilometer south of present Papalote, near the junction of *Rata* (Rat), Bullhead, and Papalote Creeks. **Papalote Springs (2)** trickling from Lissie caliche, were much used by the early settlers. In 1836 part of Santa Anna's army camped at the Rata Creek springs on their way to San Jacinto. Alberta Kreis remembers a spring on Rata Creek which flowed until the 1950s drought. Some live water holes still exist, in which minnows and water bugs swim.

Corrigan Hole (3) is a water hole in Aransas Creek seven kilometers east-northeast of Skidmore. In 1746 the Spaniard Joaquin Orobio y Bazterra may have refreshed himself here on his way south. Near here John and Ellen Corrigan built a cabin in 1826, using the spring-fed creek water. By 1895 there was a "forest of windmills" here, which no doubt helped to lower the water table. This was a popular swimming and recreation spot. Several drownings took place in the deep hole. It is no longer so deep, however, as modern erosion has washed much sand and silt into it. springs trickle on nearby Spring Creek as well as along Aransas Creek.

Aransas Springs (4) are on Bernard Seger's ranch on Aransas Creek, seven kilometers northwest of Skidmore. On March 29, 1979, they poured 1.3 lps of fresh water from Lissie Sand at an elevation of 45 meters. Here Henderson and Tom Alsop settled in 1857, and in 1861 built a rock house which still stands. Until the 1890s springs broke out on the hillsides here six meters or more above the creek bed. Now they are confined to the creek channel. During and after the 1950s drought the springs weakened considerably, but since 1974, as a result of heavy rains, they have revived to a limited extent. Aransas Creek runs from here to Copano Bay. Minnows and frogs dart among the duckweed, marsilea, and dock. White prickly poppies cover an adjacent field in spring.



Alsop house at Aransas Springs.

Eight kilometers south of Beeville was **Pecan Water Hole (5)** on Dry Creek. Small springs from Lissie sand fed the water hole until around 1900. **Rock Water Hole**, 1.6 kilometers downstream, was similar. Some small pools of muddy water in which whirligig beetles swim still exist. But now they are fed chiefly by surface runoff.

BELL COUNTY

Bell County is rich in springs. This is reflected in the fact that a large number of archeological sites have been found in the county. For example, the Aycock shelter 14 kilometers north of Belton on Kell Branch has been occupied intermittently by early Americans for over 10,000 years. During the great drought of 1855, according to an early account,

> nearly all of the smaller streams and springs dried up completely and most of the larger streams stood in isolated pools.

Early settlers in the area found grass 1.5 meters high, wild honey, grapes, plums, haw berries, pecans, and walnuts. Bears, antelopes, deer, turkeys, and small game were numerous.

Several species of crustaceans have been found to be living in caves and associated springs in the county. As these species can live nowhere else, they will be lost if the springs are allowed to fail.

The county's springs issue chiefly from the Edwards and associated limestones, upper Cretaceous Austin chalk, and Quaternary river terrace sand and gravel. In the western part of the county many knobs of Edwards limestone project above a plain of Walnut clay.

The spring waters are chiefly of the calcium bicarbonate type, very hard, fresh, and alkaline. Some springs in western Bell County were reported in 1874 to contain natural petroleum. Most of the writer's field studies were made on July 19-25, 1975.

Willow Springs (33) were six kilometers southwest of Killeen on Troy Hood's property. They flowed into South Nolan Creek north of the McMillan Mountains. Now there are only pools of seep water at an outcrop of Walnut limestone. The Willow Springs school which once used the water still stands 500 meters south. The willows are gone, but a few cedars and elms stand at the former springs.

Ransomer Springs (12) are eight kilometers north-northwest of Nolanville on the Fort Hood military reservation. Just above the springs are burned-rock middens near which many stone projectile points and tools have been found. Evidently this was a popular camp site in past ages. Petroglyphs, some of historic age, have been carved in the rock. Several springs flow from Edwards limestone into a small natural pond where frogs and minnows swim. Wild buckwheat and tall common reeds grow nearby. A wood of live oaks, pin-oaks, cedars, pecans, willows, and grapevines shades the site. On September 22, 1979, after much rain, the discharge was 1.3 lps, flowing 400 meters before disappearing.

McDaniel Springs (34) are 12 kilometers west-northwest of Belton at Arrowhead Boy Scout Camp. They are in a draw on the south side of North Nolan Creek just east of Nolan Lake. They flow from honeycombed Edwards limestone in a rocky area, fringed with water cress. The main spring appears in a 3- by 5-meter walled-in pool amid live oak and cedar trees. The springs supply several downstream ponds. On October 2, 1937, they produced 5.7 lps, but on January 8, 1978, the flow was only 1.6 lps.

Mountain Springs (30) are in the Owl Creek Mountains about 20 kilometers north-northwest of Belton. They and the similar **Taylor Springs** two kilometers south discharge from Edwards limestone. On the Fort Hood military reservation, they are now relatively inaccessible except by boat on Belton Lake. The site of Mountain Springs church which stood nearby is now beneath the lake.

Originally there were two springs (14) just southwest of Moffat. One has been inundated by Lake Belton, but the other still produced 3.2 lps on May 17, 1975. These springs were the reason why the town of Moffat was located where it is.

Miller Spring (10) is six kilometers north of Belton and two kilometers east of Belton Dam. Massive overhanging cliffs, rockshelters, and large pecan trees are numerous in the area. It is not difficult to imagine that this was a favorite haunt of prehistoric man. In settlement days the spring supplied water for a wide area. It has been a favorite picnic spot and lovers' lane for many years. Miller Spring Park to the west is used as an off-road bike recreation area. The spring produced around 1.3 lps on May 17, 1975.

Fryars Springs (3) are at the head of Fryars Creek, at the intersection of 17th Street and Avenue R in Temple. They are of interest because the ill-fated Santa Fe expedition camped here in 1841. Carroll (1951) described them as

> numerous springs, about one and one-half miles below Bird's battleground.

As they are now closer to two miles south of the battlefield, or downstream, the water table has apparently declined. The first springs spout 1.3 lps from joints in the concrete-lined channel at the intersection mentioned, the flow increasing to 3.0 lps 200 meters downstream. They flow from Austin chalk.

Leon Springs (6), five kilometers north of Belton, issue from the Edwards and associated limestones. In the early 1800s they were known as medicinal springs, and later were a stop on the Chisholm Cattle Trail. They were flowing about 3.4 liters per second in 1968.

Nolan Spring (17) is in Confederate Park in Belton. The settlement here in 1850 was the beginning of the city of Belton. The spring produced 2.5 lps from alluvium on top of Edwards and associated limestones on July 20, 1975, flowing into Nolan Creek. On December 26, 1978, it was dry. A grove of large live oaks and pecans surrounds it.

Taylor Spring (16), three kilometers southeast of Belton, has dried up because of well pumping in the area. This was where William Taylor settled in 1834. His descendants still live at the site.

Six kilometers south-southwest of Belton and just east of old highway 81 on Mrs. J. F. Mabry's property are **Bluff Springs (37)**. They appear in an amphitheatre of Edwards honeycombed limestone about seven meters high, draped with maidenhair ferns. On January 9, 1978, after much dry weather, there were only seeps.

Childers or Spicewood Springs (8), eight kilometers north of Salado at latitude 31°00' and longitude 97°30' are in the Tahuaya Boy Scout camp. They include **Tahuaya** (the largest), **Black**, and other springs. (See Plate 3, b). Thousands of projectile points and other prehistoric relics were found in 1933 during the excavation for the swimming pool, according to Ronald Johnson of the Heart 'O Texas Council, Boy Scouts of America. Spanish silver mines and a powder magazine are reported to have been identified. In 1847 Robert Childers built a corn mill which used the spring waters for power. The mill could grind 8 bushels (282 liters) of corn in 24 hours. Wild turkeys caused considerable trouble by eating the corn meal. The mill was later known as Shanklin's mill and operated until 1905. Later the water was used for irrigation of crops. A historical marker is present at the site. The combined flow of the springs was 96 lps on May 18, 1975.

Little River Spring (9), three kilometers west of Little River, furnished water for Fort Little River, which has a historical marker. The fort was built in 1836 and used for only one year as a military garrison. It is also called Fort Griffin and Fort Smith, making it easily confused with Fort Griffin in Shackelford County and Fort Smith in Arkansas. It was used for many years by the settlers as a place of defense against the Indians. In 1841 the Santa Fe expedition members, encamped here, shot many bison for sport and for the tongues and other choice parts. Many of the animals were wounded by the pistol shots and probably died later.

The spring issued at 0.63 lps on May 18, 1975, from terrace gravel on top of Austin chalk and has formed a deposit of travertine. In 1965 it was reported to be dry. It is at the south edge of a gravel pit just west of the fort, of which nothing remains.

One kilometer east of Little River, on the south side of Highway 436, are **Buchanan Springs (13)** on Tom Russell's farm. North of the highway, on R. N. Allison's property, are a second group called **Willow Springs**. Southeast of here Captain Goldsby Childers in 1835 maintained good relations with the Indians, entertaining them for dinner at his home. The Childers family returned the visits and were treated to a good dinner by the Indians on one occasion, consisting of corn bread, venison, honey, and coffee. Buchanan Park was later located at the springs. Used for irrigation, they issue from Quaternary gravel amid beds of water cress and supply several duck ponds. On July 20, 1975, Buchanan and Willow Springs produced 3.5 lps. On January 9, 1978, after much dry weather, the flow was 1.8 lps.

Elliott Springs (38) are one kilometer south of Little River on Charles Screws' property. They were formerly the water supply for the town of Little River. On January 9, 1978, after much dry weather, they poured out 1.3 lps from gravel amid beds of water cress.

Sulphur Springs (18), five kilometers east-northeast of Salado, flowed 0.32 lps on July 20, 1975. They issue from the Edwards and associated limestones like Salado Springs at Salado. However, toward the east the water in this aquifer becomes saline and contains large amounts of sulfate. This is because the water here does not circulate as freely as that to the west, and therefore has more time to become saturated with minerals. The springs' waters were valued for their medicinal qualities in early days. Around 1859 many families camped there, and a health resort grew up around them. Salado Creek, Springs, and the town were probably named for the saline Sulphur Springs. *Salado* is Spanish for *salty* or *saline*.

Salado Creek and Springs (2) are not in the least saline. Salado Springs water contains only 500 milligrams of dissolved solids per liter (see table of Selected Chemical Analyses of Spring Waters near the back of this book).

Salado Springs were recognized long ago by the Tawakoni Indians as a beautiful place at which to live. They left many flint implements, beads, pottery sherds, and metal ornaments.

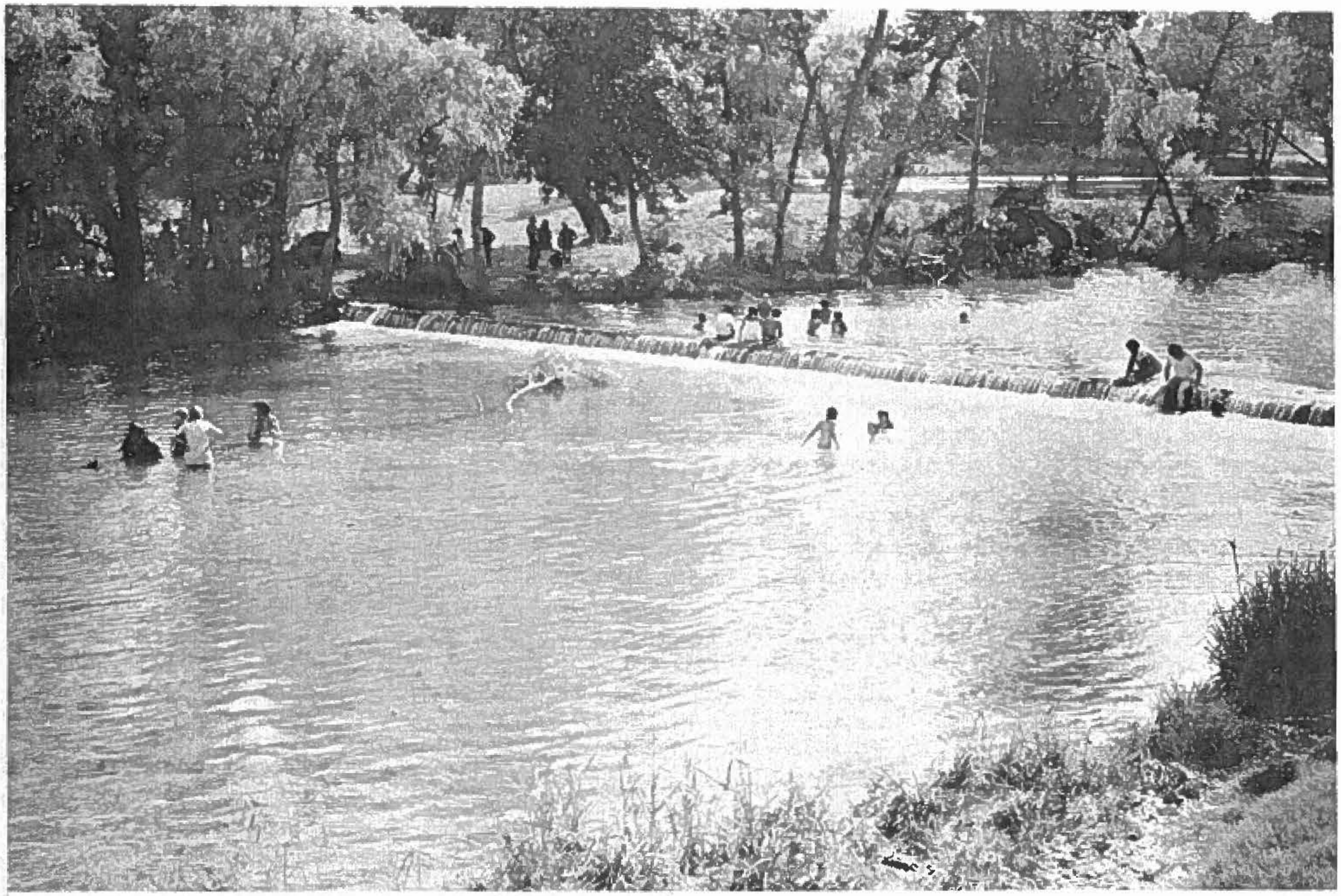
Undoubtedly Paleo-Indian people occupied the site much earlier. In 1732 the Spaniard Bustillo y Ceballos probably stopped at Salado Springs while traveling to the west. The springs were settled in 1851 by Archibald Willingham and became a well-known stage stand. They were described as

> a succession of fine boiling springs which from year's end to year's end send up great volumes of pure, clean water and which in their course to the Leon River cross many rapids and form many pools of rare beauty and utility. The certain supply of water and the swiftness of the stream makes the Salado one of the best streams in the state for water power, and it is only a matter of time until it will be utilized.

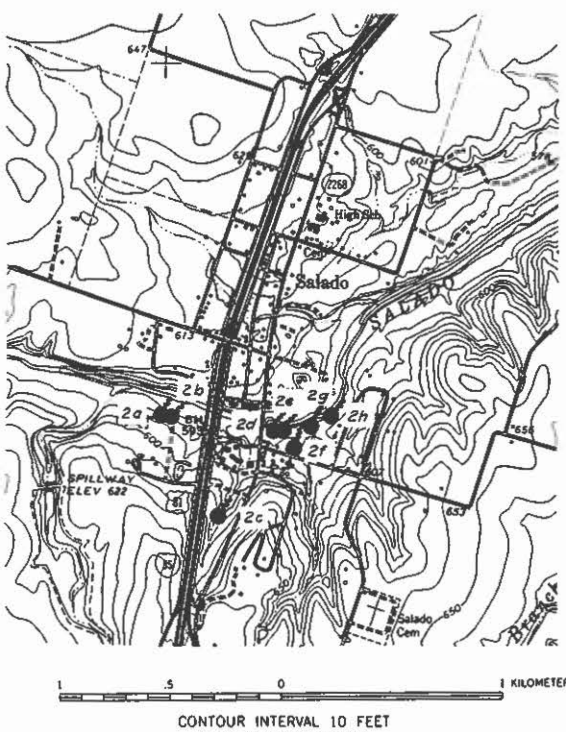
This prediction was soon realized. From 1851 to 1868 there were 11 flour, grist, saw, cotton-gin, and wool-carding mills using the spring water for power. From 1863 to 1878 the Davis mill dam flooded some of the lower springs. A court order forced the lowering of the dam.

Several historical markers are present in the town. Salado has now become a great tourist attraction, with many antique and art stores, the Stage Coach Inn, and a swimming hole.

The location of the springs, all of which rise under artesian pressure through faults in the Edwards and associated limestones, is shown on the accompanying local area map. Most emerge between 160 and 175 meters above sea level. The two moderately large



Swimming hole at Salado Springs.



Location of the various Salado Springs.

Robertson Springs (2a and 2b) are on Mrs. Sterling Robertson's property west of Interstate 35. Next, going downstream, is the **Dining Room Spring (2c)**, a smaller spring which rises near the inn dining room. A cave with buried Spanish gold is rumored to be close to this spring. Next come the two **Big Boiling Springs (2d and 2e)** which reportedly once rose in a fountain almost two meters high. During the days of the Chisholm Cattle Trail drives (1867-1895) a stone wall was erected around these springs to keep the cattle out. Big Boiling Springs were then the water supply of the town. (See Plate 13, f). Farther downstream are the moderately large **Critchfield or Elm Spring (2f)** on Chester Critchfield's property, the smaller **Benedict Spring (2g)** on Dr. O. L. Benedict's place, and the moderately large **Anderson Spring (2h)**. Other smaller springs occur throughout the area.

The recharge area for the springs is believed to be primarily in Williamson County, where several large faults cross Salado Creek about eight kilometers west of Interstate 35, the water entering the Edwards limestones there and moving to the northeast. Discharge measurements, in liters per second by water years, follow:

1902	370	1961	1,000
1903	370	1962	710
1934	220	1963	400
1948	300	1964	310
1950	180	1965	820
1951	160	1966	930
1952	220	1967	400
1954	190	1968	710
1955	160	1969	790
1956	130	1970	650
1957	230	1971	310
1958	680	1972	340
1959	370	1973	820
1960	680		

Measured discharges for individual springs follow:

Robertson Springs	Aug. 26, 1948	28
	Aug. 25, 1950	20
	Aug. 15, 1951	11
Big Boiling Springs	Aug. 26, 1948	14
	Aug. 25, 1950	8
	Aug. 15, 1951	8
Elm or Critchfield Spring	Aug. 26, 1948	48
	Aug. 25, 1950	23
	Aug. 15, 1951	48
Benedict Spring	Aug. 26, 1948	6
	Aug. 25, 1950	3
	Aug. 15, 1951	3
Anderson Spring	Aug. 26, 1948	31
	Aug. 25, 1950	37
	Aug. 15, 1951	45

A second **Elm Springs (30)** were located six kilometers south-southeast of Salado. The Elm Springs school was 400 meters south of these springs from 1894 to 1937. Ernest Townsend, who attended the school in 1914, remembers the small springs on Middle Darrs Creek. The springs, which issued from Austin chalk, are gone now, as are the elm trees for which they were named. A few willows survive, and a historical marker calls attention to the former site of the school. Several wells pumping nearby have lowered the water table.

On the Solana Game Preserve and Breeding Farm, 10 kilometers northwest of Jarrell (latitude 30°53' and longitude 97°40'), are the **Headquarters (22)** and **Warwick (23) Springs**. They discharged 6.3 and 13 lps respectively on June 8, 1975. Indian burned-rock middens are common around these springs on Rumsey Creek. The larger springs on the Solana Ranch are discussed under Williamson County.

On Mustang Creek nine kilometers west-southwest of Salado are **Willingham Springs (35)**, on the C. B. Hodge ranch. Here Wilson Willingham settled in 1851. The Willingham Springs church is one kilometer southeast. About three kilometers downstream are **Three Chimneys Springs (36)**. In addition to these two groups of springs, many other small springs discharge from the Edwards limestone in this scenic, rocky area amid fern-covered bluffs and boulders.

A third **Elm Springs (21)** is five kilometers west-northwest of Salado. This group of three springs on Bill Maedgen's farm produced around 28 lps from the Edwards and associated limestones on May 18, 1975. Wilbur Foster, president of the Salado chamber of commerce, kindly guided the writer to these springs.

On Buttermilk Creek 16 kilometers west-southwest of Salado are **Abbott Springs (32)**. Rising from Edwards limestone on the Lindsey Ranch, they produced a flow of 2.5 lps at the downstream road crossing on January 8, 1978. Many live oak and cedar trees dot the site.

BEXAR COUNTY

Prehistoric people lived in Bexar county many thousands of years ago, especially near the larger springs. According to some accounts a Spanish settlement was made near here in 1632. When Domingo Teran de los Rios and Damian Massanet arrived in 1691, they found several "docile and affectionate" hunting and gathering Coahuiltecan bands called Payayans using the springs. They apparently practiced little agriculture, but were experts at trapping deer, javelina, and water fowl.

Bexar County is one of Texas' richest counties in history. This abundant heritage is tied inextricably to the large springs which were found here. Teran and those who followed him saw the advantages of such a well-watered area, and it was not long (1718) until the first of the Spanish missions, San Antonio de Valero or the Alamo, was established. The other four missions were operating by 1731. Construction of a complex system of irrigation ditches and dams was begun with the San Pedro ditch in 1738, taking water just downstream from San Pedro Springs. The well-preserved Espada dam and aqueduct may still be seen near Mission San Juan in southeastern San Antonio. Numerous mills derived their water power from the larger springs, probably beginning with a sugar and wheat-flour mill at Mission San Jose in 1794. As recently as 1904 four hydroelectric power plants were using the spring waters.

Most of the writer's field studies were made on November 6-12, 1975.

Spring waters in Bexar County are generally fresh, alkaline, and very hard, containing chiefly calcium bicarbonate. Their fluoride content is healthful and the iron content is not high enough to cause staining. In the southeastern part of the county the water is apt to be slightly saline. The spring water is generally highly valued for human consumption. Although it has not become polluted yet, this could easily happen because of the great expansion of San Antonio's suburbs into the aquifer's recharge area.

Glenn Longley of Southwest Texas State University and others have found two species of blind and unpigmented catfish in the ground water of the Edwards limestone aquifer beneath Bexar County. Some appear in springs, where they are quickly eaten by predaceous fish. As they can live only in this aquifer, it is important that this reservoir be protected.

San Antonio Springs (2) are located chiefly on the property of Incarnate Word College north of East Hildebrand Avenue. The accompanying map shows the location of the main existing and former springs. The largest, called **Head of the River** or **Blue Hole (1)** rises about 80 meters west-northwest of the swimming pool at an elevation of 204 meters. It issues from a deep hole in which the water has a blue tint and contains many minnows. An octagonal concrete wall surrounds it. Two other large groups of springs (m and n) break out just west of the Blue Hole.

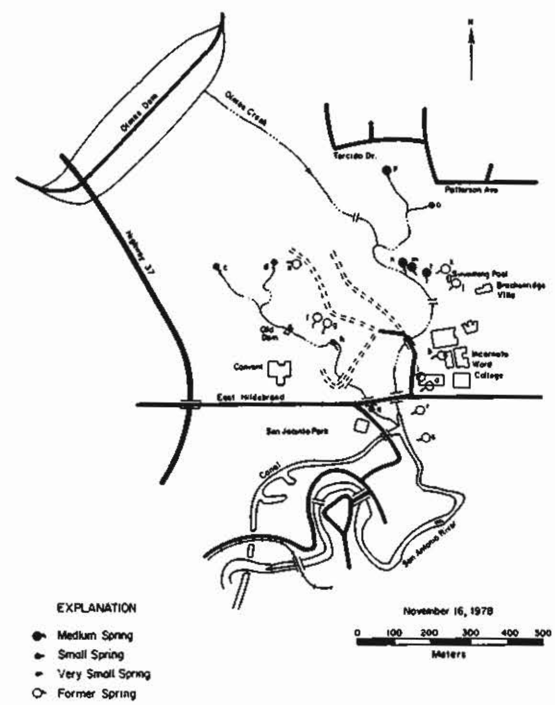
Originally there were over 100. In wet weather the springs are still numerous. In 1973 springs popped up all over the area, some (a, b, and i) endangering buildings on the college campus. Those under and near buildings are now drained by pipes, according to college maintenance chief Marvin Reininger. Most of the springs emerge at an elevation of about 205 meters. The swimming pool, several meters higher, was once fed by springs (k and j). Since 1926 the springs have been at least partially protected by the upstream Olmos dam from flooding and sedimentation. Many other small springs issue beneath the surface of Olmos Creek and San Antonio River. Most of the area is now overgrown with weeds and brush, and much trash has been dumped here.

San Antonio Springs and the surrounding area have been designated the *Source of the River Archeological District* and entered on the National Register of Historic Places. Archeological studies have been made chiefly by Anne Fox of the University of Texas at San Antonio and by Paul and Susanna Katz of Incarnate Word College. Paleo-Indian projectile points over 11,000 years old have been found here. Mounds composed of lithic debris, burned rock, and snails represent ancient living areas. A prehistoric flint quarry was located nearby. As recently as 1924, Ponca Indians stopped here enroute from Oklahoma to northen Mexico to gather peyote, a cactus containing a drug used in religious rites.

Espinosa's diary of 1716 (Tous, 1930b) was probably the first to describe San Antonio Springs:

> . . . we arrived at the River San Antonio. This river is very desirable [for settlement] and favorable for its pleasantness, location, abundance of water, and multitude of fish. It is surrounded by very tall nopals [prickly pears], poplars, elms, grapevines, black mulberry trees, laurels, strawberry vines and genuine fan-palms. There is a great deal of flax and wild hemp, an abundance of maiden-hair fern and many medicinal herbs. Merely in that part of the density of its grove which we penetrated, seven streams of water meet. Those, together with others concealed by the brushwood, form at a little distance its copious waters, which are clear, crystal and sweet. In these are found catfish, sea fish, *piltonte*, *catan* and alligators. Undoubtedly there are also various other kinds of fish that are most savory.

When the missions were established, the Spaniards lost no time in setting up an irrigation system. The first ditch dug at San Antonio Springs was the Alamo Madre in 1745, taking its water from the east side of the



Location of the various San Antonio Springs.

headwaters below the springs.

Until 1761 the missions used the spring waters and that from the river downstream for all purposes. In that year the first well was dug at San Antonio de Valero (at its present location) as a precaution in case a siege by hostile Indians should cut off the inhabitants from the river. In 1857 Frederick Olmsted wrote:

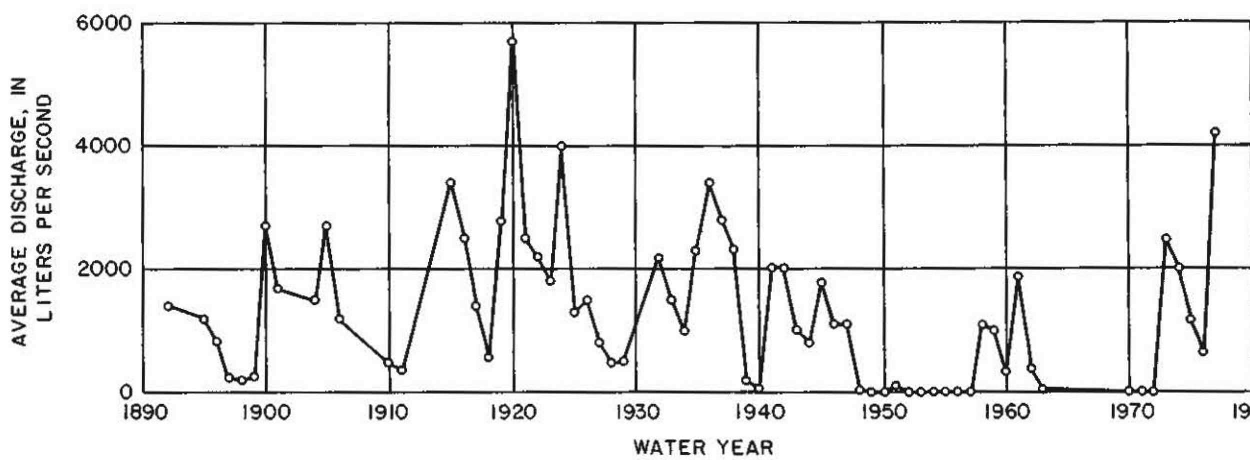
> There are, besides the missions, several pleasant points for excursions in the neighborhood, particularly those to the San Antonio and San Pedro Springs . . . The San Antonio Spring may be classed as of the first water among the gems of the natural world. The whole river gushes up in one sparkling burst from the earth. It has all the beautiful accompaniments of a smaller spring, moss, pebbles, seclusion, sparkling sunbeams, and dense overhanging luxuriant foliage. The effect is overpowering. It is beyond your possible conceptions of a spring. You cannot believe your eyes, and almost shrink from sudden metamorphosis by invaded nymphdom.

By the time of the Civil War both the shallow wells and the spring waters had become contaminated by outhouses and garbage accumulations, and typhoid fever and malaria became prevalent. In the 1880s the first artesian wells were drilled into the Edwards limestone aquifer, which now supplies all of San Antonio.

San Antonio Springs flow under artesian pressure from the Edwards and associated limestones, rising through the Austin chalk by way of faults in the rock. Recharge to the springs occurs to the west, where the Frio, Sabinal and Medina Rivers and Hondo and Leon Creeks cross numerous faults in the Balcones fault zone. Here most of the water in these streams goes underground, entering large crevices and caverns. It moves through the aquifer to the east, thus recharging the springs. The amount of recharge and the discharge of the springs is largely related to the rainfall occurring on these stream drainage areas. Naturally there are few springs in the recharge area, as the surface water is here moving downward into the aquifer.

Discharge records are shown on the accompanying graph. The discharge for 1892 was estimated by R. T. Hill. As early as 1898, Hill and Vaughn recognized that the spring flow had been reduced by flowing wells. They stated

> When the wells are allowed to flow the springs diminish in volume, and the San Antonio River is greatly lowered.



Discharge of San Antonio Springs.

The flow of San Antonio Springs passing over the low-water crossing in Brackenridge Park.

As may be seen in the graph, the flow of San Antonio Springs has become lower and more erratic in recent years because of heavy pumping of the aquifer. The Edwards aquifer has a remarkable ability to recover and refill itself when the rainfall is adequate. But how long it can continue to do so in the face of ever-increasing pumpage is questionable. Flowing wells now assist the natural spring flow in maintaining the recreational value of Brackenridge Park.

Eccleston (1850) observed that in 1832 the flow from the springs inundated the whole of San Antonio for six days, even though there was no rain. But of course there must have been heavy rains in the recharge area to the west even if there were none in San Antonio. Meinzer (1927) noted that the springs ceased flowing entirely during parts of 1897, 1898, and 1899.

San Pedro Springs (4) are mostly located in San Pedro Park in San Antonio, emerging at an elevation of 202 meters. They were very popular with early Americans in prehistoric times. In the vicinity have been found the bones of mastodons, giant tigers, dire wolves, Colombian elephants, and extinct horses. Stone projectile points and tools indicate that these Ice Age animals were hunted by the Paleo-Indians of the area. For thousands of years the tribes of the High Plains and those of the lowlands met here to trade in peace. The Payayas of early historic time called the springs and their village there *Yanaguana*.

According to Father Isidro Espinosa's diary of 1709 (Tous, 1930a)

> We crossed a large plain in the same direction, and after going through a mesquite flat and some holm-oak groves we came to an irrigation ditch, bordered by many trees and with water enough to supply a town. It was full of taps or sluices of water, the earth being terraced. We named it San Pedro Spring (agua de San Pedro).

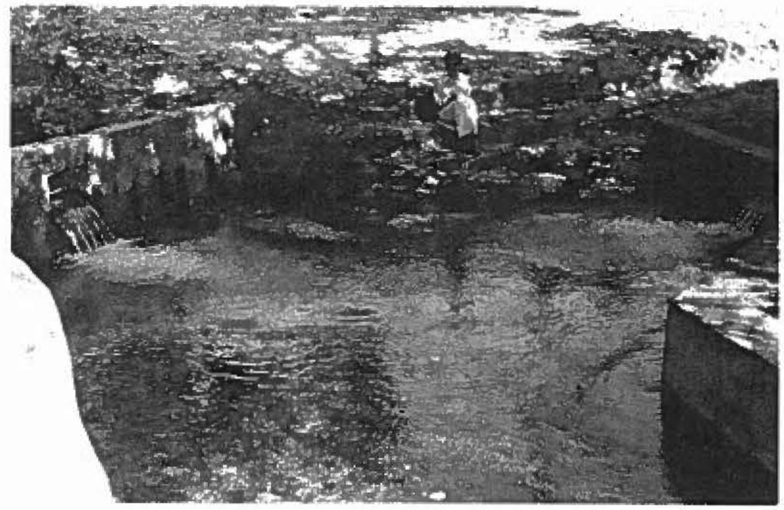
San Pedro Park is one of the oldest in the United States. It is believed to have been used for recreation even during the mission era. About 140 meters east of the main spring is a very old small stone building, now used as a tool shed. With its rifle ports it is thought to have served as a refuge for visitors to the springs in case of attack by hostile Indians in the 1700s.

About two kilometers downstream from San Pedro Springs was the first site of the Mission San Antonio de Valero in 1718. The water was used to irrigate corn, pumpkins, beans, and chili peppers. Numerous old roads, including the *Caminos Reales*, or King's Highways, radiated from this point. The most important of these early roads was that from San Antonio to present Natchitoches, Louisiana. It is often called *the* Camino Real, or the old San Antonio Road. The springs were the site of an Army camp during the Mexican War of 1846-48 and the Civil War.

In 1852 San Pedro Springs and 12 acres surrounding them were sold for $820. The area had always been marshy. The swamp was converted by dams into a series of small lakes with islands, bridges, and pleasure boats. In the 1880s and 1890s mule cars carried sightseers from downtown to the springs. In 1891 a flowing well was drilled near the park. When it struck water, the springflow immediately increased by one-half carrying with it shells, fossils, and yellow clay which muddied the lake below. Evidently the well opened an additional outlet from the Edwards limestone to the springs.

Many caves have been found in this vicinity, including one in San Pedro Park. These caves were formed by the solution of the rock in underground water, when it flowed at higher levels than at present. Francisco Rodriguez, a Canary Island immigrant in 1731, is reported to have buried several chests of gold and silver coins near San Pedro Springs. He died before he could tell any relative where they were buried. They have never been found. The cave in the park was probably a burial site for prehistoric residents, as several skeletons accompanied by artifacts were found in it. It has long been closed because of its dangers.

As is the case with San Antonio Springs, San Pedro Springs receive their recharge from streams up to 100 kilometers to the west. This recharged water flows through the cavernous Edwards and associated limestones toward the springs. There it rises through a fault in the rocks. At the surface the Austin chalk is present on the southeast side of the fault and the Pecan Gap chalk on the northwest.

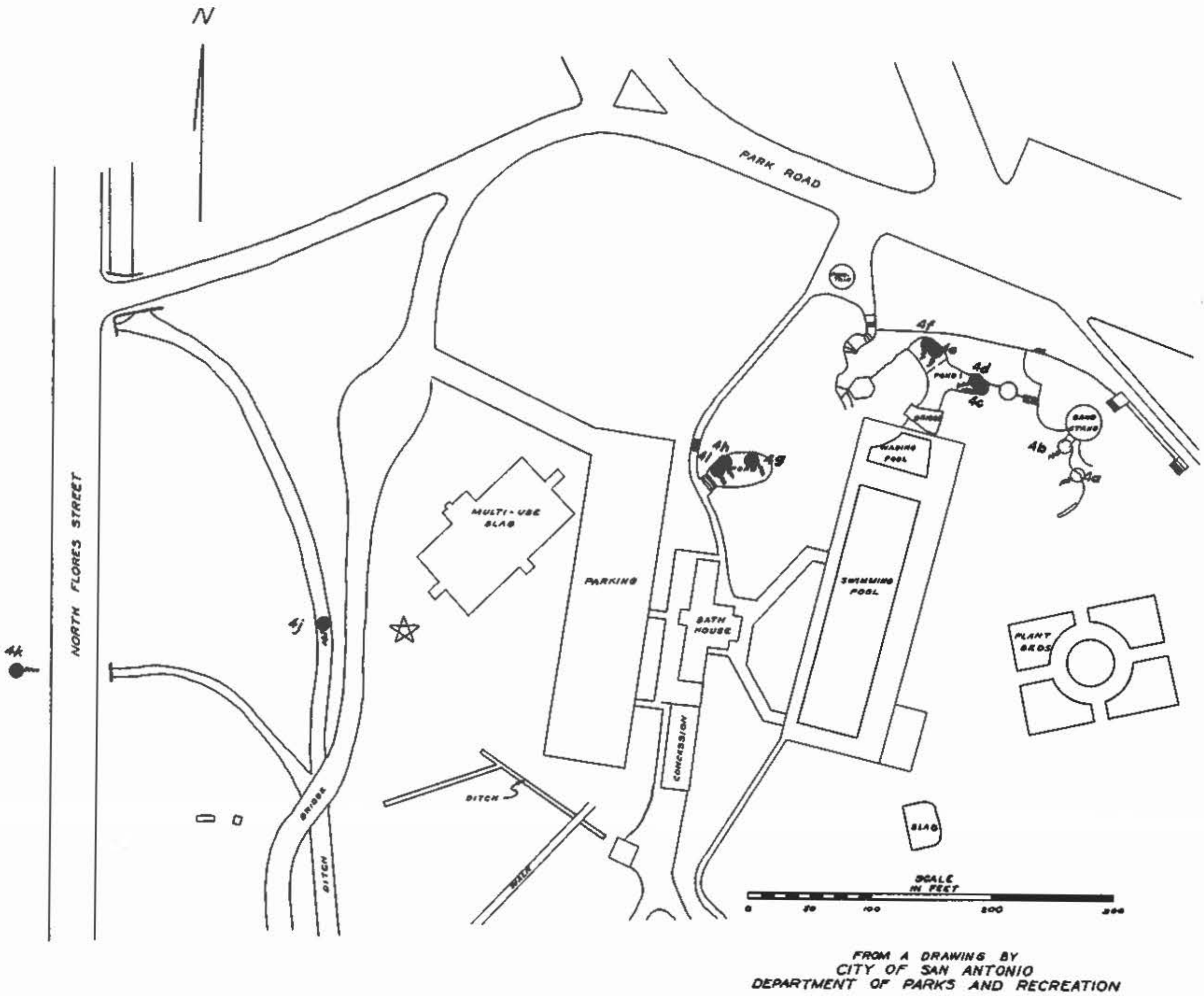


Some of San Pedro Springs (4c to 4f).

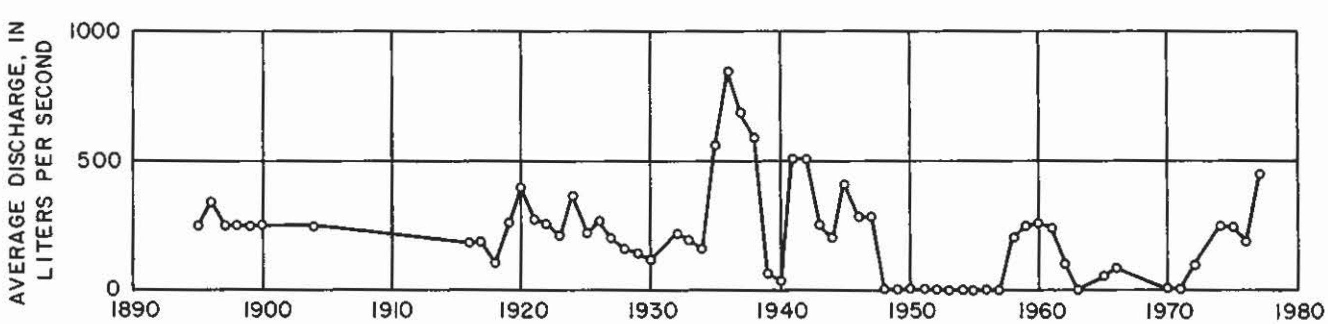
A swimming pool is now fed by the springs, but in dry years when the springs fail, city water must be piped to the pool. Crawfish were originally abundant in the springs and creek. In fact a street, *Calle del Camaron*, was named for them in the 1830s (Pool, 1975). Since the springs have been dry during several recent years, the crawfish and other aquatic life are having an increasingly difficult time. They still survive however. Near the pools, shaded by large live oaks and cypress trees, grow maidenhair ferns and vines.

The accompanying map shows the location of the various San Pedro springs as of November 10, 1975. Two, 4a and 4b, have been sealed by the City Parks and Recreation Department in order to divert more water to the others. Spring 4d is the main spring. Spring 4k is outside the park to the west. As of this date at least nine springs were flowing. Probably others were present but invisible beneath the water surface in the ponds and channels.

Discharge records are shown on the accompanying graph. In recent years the flow of San Pedro Springs has been declining and erratic, because of the heavy demands made on the aquifer by well pumping.



Location of the various San Pedro Springs.



Discharge of San Pedro Springs.

Olmos (Elm) Springs (3) extend along Olmos Creek in north San Antonio from Highway 410 to Olmos Creek's junction with the San Antonio River at San Antonio Springs. On November 10, 1978, after an 8-centimeter rain, the following discharges, nearly all of spring water, in liters per second, were observed in Olmos Creek:

Jackson-Keller Road	Seeps and pools of live water
Montview Street	2.0
San Pedro Avenue	5.8
Tuxedo Avenue	9.8
Jones-Maltzberger Road (Olmos Park)	13
Devine Road	10
Olmos Dam	3.1

Olmos springs issue from Pecan Gap chalk, especially where faults cross the creek in the reach of maximum flow. Many fish formerly lived in the spring-fed creek. Now, because the springs and creek have become intermittent, the fish are largely gone. Ducks still find refuge in the pools near Olmos dam. In 1843 William Bollaert found excellent hunting here. In 1849 General William Worth died at one of the springs just north of the east end of Olmos dam. Called Worth Spring, it is now dry.

Leon Springs (5) are located about one kilometer southwest of the town of that name. They issue from a fault which separates the Edwards and Glen Rose limestones on the north side of a row of hills. They formerly flowed to the northeast, past the old stage stop in Leon Springs, on the San Antonio-to-Boerne road. The old stone buildings here, which date from about 1850, are now used as a restaurant and gift shop. But the springs no longer flow sufficiently to reach the former stage stand. Part of the flow of 0.32 lps is evaporated in a pond below the springs, and the remainder sinks into the sand a short distance beyond.

Panther Springs (14) were eight kilometers east of Leon Springs on the Leon Springs Military Reservation. They issued from a fault in Glen Rose limestone. They are reported to have been dry since about 1963. The area is wooded, largely by live oaks and cedars.

Walker Springs (6) are about six kilometers northwest of San Antonio International Airport, on the former Walker Ranch east of Highway 2696, at latitude 29°34' and longitude 98°31'. They flowed from the bed of Panther Creek through an apparent fault between the Buda limestone and Austin chalk. The Spanish explorer Miranda stopped here in 1755, calling the place *El Paredon*, possibly for the steep *wall* or bluff of limestone. In 1838 the springs were used by the ranch occupants and residents of the nearby Coker community. Mr. Walker believes that the missions may have had a cattle ranch here during the 1700s. There are some very old stone walls near the springs. The springs are now reduced to pools of water standing among large blocks of limestone in the channel.

Fifteen kilometers up Cibolo Creek from Selma are **Hill Springs (13)** on Hugo Borgfeld's ranch. They were named for two Hill brothers who were killed by Indians here. Individual springs in this group have been called **Cherry, Indian, Walnut,** and **Devine Springs**. Burned rock middens and flint fragments disclose that this was a preferred living site in prehistoric times. In early settlement days a pipe was run from the main spring so that residents could drive a wagon beneath it and fill their barrels.

The water flows from Glen Rose limestone at the base of a high bluff, feeding two small reservoirs on Cibolo Creek. The recharge appears to come from the north, probably from a faulted zone on Cibolo Creek where it makes a southward bend two kilometers north. Water losses from Cibolo Creek were observed here by George (1952). Some travertine has been deposited at the springs. At higher flows the springs extend for about 75 meters along the bluff. About three kilometers southeast are Bracken Bat Cave and Natural Bridge Caverns. These caves were dissolved out by flowing ground water similar to that in Hill Springs. The underground flow later moved to lower levels, leaving the caves dry.

On February 5, 1930, a flow of 2.8 lps was measured. On November 10, 1978, after an 8-centimeter rain, the discharge of fresh water from several openings in the limestone was 4.7 lps. Maidenhair ferns and water cress adorn the pools. Cypress, live oak, and cedar trees and algerita shrubs shade the site. Small deer and turkeys may be seen.

Salado Springs (7) are just northwest of the crossing of Austin Highway over Salado Creek in San Antonio. Although Salado Creek, in keeping with its name, may contain salty water farther downstream, the spring water is fresh.

In 1716 the springs were described by Espinosa (Tous, 1930 b) as follows:

> We traversed another league through a rich and flowery region, and half a league to the northeast, we stopped at the Arroyo Salado. In the bed of this stream we found wild vine stocks which appeared to be recently hand planted. Beyond the rivulet which is sometimes dry, to our right, a distance of two gun shots, is a spring of water, which could, according to the experienced, irrigate those lands, though it is not very large.

The springs later became a stop on the Camino Real to Nacogdoches. In 1842 Captain Nicholas Dawson and his company of 54 men were wiped out by Mexican forces here. The historical marker is 50 meters southwest of the springs. The springs flow from terrace gravels and are backed up by a small dam. Numerous other springs of less historical significance can be found along Salado Creek. The discharge, in lps by water years, is as follows:

1919	85	1948	0
1933	42	1951-52	0
1934	23	1970	34
1935	62	1975	1.5

Selma Springs (9), two kilometers southeast of Selma on *Cibolo* or Buffalo Creek, flow from the Pecan Gap chalk. In 1691 Fray Damian Massanet (in Ximenes, 1963) described them as follows:

> . . . one reaches a slope of mesquite woods, then a creek of flowing water. The water from said creek is warm and salty. On the creek itself and in the same water there is a stone which has an opening through which beautiful cold water gushes out . . . I called this site San Felix, it being his day and being a joyous day of abundance of bison, wild chickens, fish, and cold water. In the language of the Indians it is called Papulacsap.

In this vicinity in 1737 the Presidio San Antonio de Bexar established a pasturage for horses, because so many were being stolen by the Apaches from ranches closer to the settlement. The stratagem did not work, as the Apaches raided this pasture just as frequently as the others. The Camino Real to Nacogdoches also passed these springs. There was no flow on March 5, 1963, 4.2 lps on March 4, 1968, and 1.5 on November 10, 1975.

Woman Hollering Springs (8) are the source of the creek of the same name. How they got their name is unknown. On some maps the creek is called Women Hollow Creek. The springs flow from terrace sands and gravels on the golf course on the southeast side of Randolph Air Force Base. Their discharge was 17 lps on March 8, 1968, and 7.1 on November 10, 1975.

Mineral or **Indian Springs (12)** were located in southeast San Antonio on Calaveras Creek. They were in back of Fred Huddleston's garage at 8139 South Foster Road, on Fritz Knust's property. They formerly issued from Midway silt and sand in a grove of live oaks. Indians who camped here valued the water for its medicinal properties. Early settlers also made much use of the springs and held camp meetings here. The springs were shown on Colton's 1855 *Map of Texas*. They have not flowed for many years.

Morty Springs (10) are a group flowing from terrace gravels along Leon Creek above and below Interstate 410 southwest of San Antonio. In 1720 the Marquis de San Miguel de Aguayo crossed Leon Creek near here, remarking that it flowed most of the year and contained several *esteros* (pools) all year round. In 1828 General Manuel de Mier y Teran and party camped here. One of his men killed a hawk and suspended it from a tree with a cord, with a message attached to its wing for a later party expected to pass the springs. On November 10, 1975, 4.0 lps were originating here.

San Lucas Springs (11) are some 28 kilometers west of San Antonio and three kilometers north of Highway 90, on the Broken X ranch, at latitude 29°24' and longitude 98°48'. Issuing under artesian pressure from the Edwards and associated limestones, they rise through a fault in the Pecan Gap chalk and through gravel beds. In 1850 John Adams and six brothers settled here. According to ranch foreman Ray Mata, the springs were dry in 1976 for the first time since the drought of the 1950s. There is more pumping in the vicinity now, so that a drought of lesser intensity than that of the 1950s can cause the springs to fail.

In 1808 the Spanish explorer Francisco Amangual stopped here, writing "San Lucas Creek, which carries very good running water" (Loomis and Nasatir, 1967). In 1849 Lieutenants Whiting and W. F. Smith and their escort, exploring for a road between San Antonio and El Paso, camped at the springs. In 1861 Confederate Col. Earl Van Dorn with 1,300 men captured a force of 270 federal troops at the springs.

BLANCO COUNTY

Blanco county, the town, and the river were named for the *white* limestone which is very common in the area. One of the limestones which is found here however, the Marble Falls limestone, is not white at all, but dark gray. The county is very beautiful, with many natural waterfalls. At the foot of such waterfalls are very likely spots for springs, and they are there.

The springs support a peculiar ecology of plants and animals which must have water. Cypress trees, maidenhair ferns, and water cress are common inhabitants, and also the Blanco crabapple tree, which grows only near springs and streams in Blanco, Kendall, and Kerr Counties.

The county's spring waters are mostly of the calcium bicarbonate type, fresh, very hard, and alkaline. Most of the writer's field studies were made on August 8-14, 1975.

Comanche Spring (16) is located in northwest

Blanco County at latitude 30°28' and longitude 98°34', on Mary Davis' ranch. The fresh water bursts from a major fault between Cambrian Pedernales dolomite and Big Branch gneiss, originating in the cavernous dolomite. In 1857 Frederick Olmsted described it:

> At Comanche Spring, we found a German Stock-farmer, with a considerable establishment. The spring gushes from the rocks of a hillside, furnishing a great abundance of clear water. It was covered with a roof, and flowed into large limestone tanks, for what purpose we did not learn.

He also mentioned that wild game was disappearing before the rapid settlement of the area. A gentleman who resided at Comanche Spring a few years previously undertook to make a collection of the skins of Texas wild animals. A German carpenter employed by him delivered to him 11,000 pounds (5,000 kilograms) of wild meat in nine months.

The water now emerges in a pool in a concrete spring house, whence it is pumped to a hillside tank. On April 6, 1979, after much rain, the discharge was 5.1 liters per second. Small bass, crawfish, and water striders reside in the pools where Comanche Creek begins. Water cress, water milfoil, and small rushes are numerous. Wild turkeys dodge among the algerita shrubs and grapevines.

Blowout Cave, 1.5 kilometers southwest, was dissolved out by running ground water and was at one time the site of similar springs. Millions of bats live here. According to neighboring rancher Arthur Pressler, the name "Blowout" originated when lightning exploded an accumulation of ammonia and other gases generated from bat guano.

Sultemeier Springs (6) flow from the Glen Rose limestone seven kilometers northwest of the Sandy store at latitude 30°25' and Longitude 98°30'. They were used by early settlers on Hickory Creek from 1855 on. Their flow has remained at 0.95 lps in 1941, 1968, and 1975.

Lewis Springs are two kilometers west of Sandy. Harrison Lewis settled near them in 1854. They are unusual in that they flow from the Lower Paleozoic Hickory sand, a rather rare spring aquifer. On August 2, 1941, they trickled 0.44 lps.

Buffalo Springs (2) are seven kilometers northwest of Johnson City on the Orwin Ahrens ranch. The water passes through and below Buffalo Cave, which has been mapped for a distance of about 380 meters in the Lower Paleozoic Cap Mountain limestone. The springs flow from a bluff on Hickory Creek about 300 meters southwest of the cave. They issue from the same joint system in which the cave was formed, which follows the northeast-southwest strike of the rocks. The accompanying map shows a plan view of the cave, from William Russell's 1978 study. The springs produced 31 lps on July 22, 1941, but only 3.5 lps on November 1, 1978, after much dry weather. On the abundant rock outcrops in the vicinity are carpets of tiny yellow flowers in spring. Marsh purslane and water cress adorn the pools. Many small deer dart among the live oaks.

Sharp Springs (5) are two kilometers west of Round Mountain on the D. D. Sharp place near an old stone house. Only intermittent very small springs now, they were an indispensable source of water when Joseph Bird settled near here in 1854.

Hobbs or **Pecan Spring (4)** is at Wayne Roberson's housing development two kilometers northwest of Johnson City. The water issues from Ellenburger dolomite at the foot of a pecan tree and flows 50 meters into the Pedernales River. On May 27, 1969, the dis-

charge was 28 lps. On November 2, 1978, it was 2.1 lps. Water cress, milfoil, and ferns grow in and around the stream. Where the water enters the Pedernales River there is a deep hole which attracts many fish.

Salter Springs (18) are seven kilometers north-northeast of Johnson City on Myron Weir's ranch. Issuing from Cambrian Wilberns dolomite, they feed Salter Springs Creek. On November 1, 1978, the discharge was 1.9 lps. Cattails fringe the pools, shaded by live oaks, pecan trees, and grapevines.

Crofts or **McCarty Spring (3)** is a moderately large, reliable spring six kilometers northeast of Johnson City on Martin Earley's ranch. It issues under artesian pressure from a fault in the Ellenburger limestones. It was once used as a stagecoach stop. It poured out 100 lps on May 28, 1968, and August 10, 1975, and 13 lps on May 28, 1978. The water supplies the ranch house and is used for grass irrigation. Live oaks and pecan trees with much ball moss shade the springs, where varicolored cannas bloom. (See Plate 14,c). Medium-sized fish dart in the pools, fringed with maidenhair and other ferns, pennywort, and water cress. Dark gray soils to the west of the house indicate that there was once a bog here.

Cypress Mill Springs (8) were used as a water supply by a Mormon settlement in 1849. Flowing 31 lps from the Ellenburger limestones on August 9, 1975, they are located on Cypress Creek northwest of Cypress Mill. Especially during drought periods they also helped to power the Mormons' mill just downstream, as these springs are the most reliable on Cypress Creek. The springs are largely under water during normal flows in Cypress Creek, and can only be located by the relatively cold water which emanates from them in summer (or relatively warm in winter) and by the growth of aquatic plants over them. They are in an exceedingly scenic spot, surrounded by huge boulders and cypress trees, and should be preserved from damage in the future.

Pedernales Spring (9) emerges at 245 meters above sea level at the foot of the falls in Pedernales Falls State Park, 18 kilometers east of Johnson City. It issues under artesian pressure from the Marble Falls limestone, and is the largest spring in the county, at 140 lps on August 12, 1975. (See Plate 1, a.) This is a very handsome spot which, since it is now in a state park, will likely be preserved in something like its primitive beauty.

One point should be kept in mind, however. Many springs, especially those which issue from cavernous limestone, are no longer safe to drink from. The water which flows from this spring originates as surface water flowing from various streams into the Pedernales River in Blanco and Gillespie Counties. As it flows downstream it picks up much sewage effluent and other wastes from towns and residences along the river. Some of this effluent is treated and some is not. Dye tests have shown that the water which feeds the springs enters the Marble Falls limestone in the Pedernales River bed about four kilometers upstream, near the R. W. Robinson ranch house. As the water flows through the channels and caverns in the limestone there is no straining or purification as there would be in sand beds. The water which spouts from the spring is clear and looks pure, but it is not.

Also in the park, on a biking trail five kilometers south-southeast of Pedernales Spring, is **Jones Spring (17)**. Flowing from Lower Cretaceous Travis Peak sand, it is small but reliable, still flowing on May 28, 1978, after a year of very dry weather.

Three Springs (19) are ten kilometers east-northeast of Johnson City on the R. W. Robinson ranch, leased by Roy Weinheimer. The copious springs pour from Ellenburger limestone which dips gently toward the east-southeast or toward the Pedernales River. Many small deer dart among the live oaks, cedars, cypress trees, and algerita shrubs.

In a cove eight kilometers east-southeast of Johnson City are **Honeycut Springs (20)** on the C. O. Browning ranch, managed by Bill Watson. Mortar holes in the limestone reveal that this was a prehistoric living site. On November 1, 1978, 1.0 lps trickled from Cow Creek limestone and ran about 500 meters before disappearing. Many deer and snakes prowl among the live oaks and cedars.

The two **Mill Seat Springs (10)** are located on Miller Creek just north of the old Highway 290, 10 kilometers southeast of Johnson City. This is a really enchanting spot, on Mrs. J. W. Farrelly's property, with a fall on Miller Creek over resistant beds in the Lower Glen Rose limestone. The remains of Louis Captain's 1861 grist mill and his restored stone house are at the site. The springs flowed 3.8 lps on August 10, 1975, through beds of maiden-hair ferns below the falls. (See Plate 8,c).

Boardhouse Springs (11) are 12 kilometers east of Blanco, on Boardhouse Creek ¾ kilometer south of Highway 2325, at latitude 30°06' and longitude 98°18'. They were used from 1853 on by early settlers. Their discharge was 3.1 lps in 1969 and 3.8 in 1975.

Twin Sisters Springs (12) are several small springs on the south bank of the Little Blanco River ½ kilometer west of Twin Sisters. They are believed to have been used by the first settlers at Twin Sisters about

1855, and were shown on some early maps as a "fountain." They flowed 0.76 lps on August 7, 1975.

In the vicinity of Blanco several springs rise from the Lower Glen Rose limestones. All were used by prehistoric men long before Columbus arrived in the New World. They include **Koch Springs (1)** two kilometers southwest, **Cold Springs (13)** three kilometers east-southeast, and **Epps Springs (14)** four kilometers west.

Koch springs feed Koch Branch, which flows through Blanco State Park. In 1956 these were probably the "abundant springs", yielding a "buey de agua" (several hundred lps), described by Bernardo de Miranda y Flores on his inspection trip from San Antonio to Los Almagres silver mine in Llano County. They were used by settlers as early as 1853. Discharge measurements in liters per second follow:

June 22, 1938	1.9	Mar. 7, 1962	27
Aug. 20, 1941	0.94	July 13, 1975	3.1
Sep. 8, 1952	17		

The 1952 and 1962 measurements were probably made at the mouth of Koch Branch.

Cold Springs were settled in 1853 by Billie Trainer. In 1855 the town of Pittsburg, now replaced by Blanco, grew up around them. They flowed 0.94 lps in 1938 and 4.7 in 1975. In 1865 they were the scene of a festive dinner given for the returning soldiers.

Epps Springs still boast a very old stone house. It is said to have been the first house in Blanco County with running water. Water was pumped to the attic of the house by a hydraulic ram. These springs still supply Gilbert Zercher's house (although by electric pump now), a pond with large catfish, bass, and perch, and irrigation water for crops. They discharged 7.9 lps on August 4, 1941, and 9.4 on August 9, 1975. Several other good springs flow nearby.

Eleven kilometers southwest of Johnson City, in hilly country on the well-kept David Bamberger ranch, are **Uecker Springs (15)**. Trickling from Edwards limestone, they supply water to the ranch headquarters buildings and corrals, according to foreman Buddy Francis. On November 2, 1978, 0.05 lps ran over a travertine deposit into a small pond containing frogs and bordered with weeping love grass. Stone points and tools found here indicate that the springs were used long ago. The hills are wooded with cherry, walnut, Spanish oak, and other trees which display beautiful red and yellow hues in fall. Many exotic animals are kept here, including buffalo, aoudad sheep, nutria, and sika, axis, and fallow deer.

Many other small springs sparkle in this area. Among them are **Walnut Springs** one kilometer north, and **Duncan Springs** seven kilometers southeast.

BORDEN COUNTY

The extreme western edge of Borden county lies on the *Llano Estacado* (Palisaded Plains). Around the eastern edge of these plains, springs flow from Tertiary Ogallala sand, gravel, and caliche, and from the lower Cretaceous Edwards limestones and Antlers sand. Most of the county lies in the lower Red Bed or Gypsum Plains. Here some springs issue from Quaternary sand, gravel, and caliche, and from Triassic Dockum sandstone. Often the springs appear at the top of the underlying Triassic shale and clay.

In the center of Borden County is a well-known landmark, Muchakooago Peak (also spelled Muchaque, Mushaway, or Mucha Kowa). This and the surrounding country were favorite haunts of prehistoric people and later the Lipan or Cantsi Apaches. After around 1750 the Comanches preempted the area and began living at the springs and trading with Comancheros.

At that time most of the creeks ran continuously, according to Edna Miller, a noted Fluvanna historian. They were fed chiefly by springs in the caprock at the edge of the High or Palisaded Plains.

Irrigation and other well pumping took a severe toll of the ground water. In 1974 the annual decline in the water table was as much as 0.3 meter. It is expected to fall at a slower rate in the future as ground-water reservoirs are depleted. As a result, many springs have weakened and failed.

Severe gully erosion, especially in Triassic shales, has filled many stream channels and buried springs. Some springs have also been inundated by Lake J. B. Thomas.

At some places in the Red Bed Plains where streams formerly ran, there are still pools of live water, marked by cottonwoods, willows, and salt cedars. On May 31, 1979, there was a small, seep-fed flow of 5.0 liters per second in the Colorado River 13 kilometers upstream from Lake J. B. Thomas. Naturally as the springs have dried up, many plants and animals dependent upon the water have disappeared.

The spring waters are normally of a calcium bicarbonate type, fresh or slightly saline, very hard, and alkaline. The fluoride, iron, and silica contents may be high. Contamination by oil-field operations has occurred in the past, adding much sodium chloride to the water of some springs.

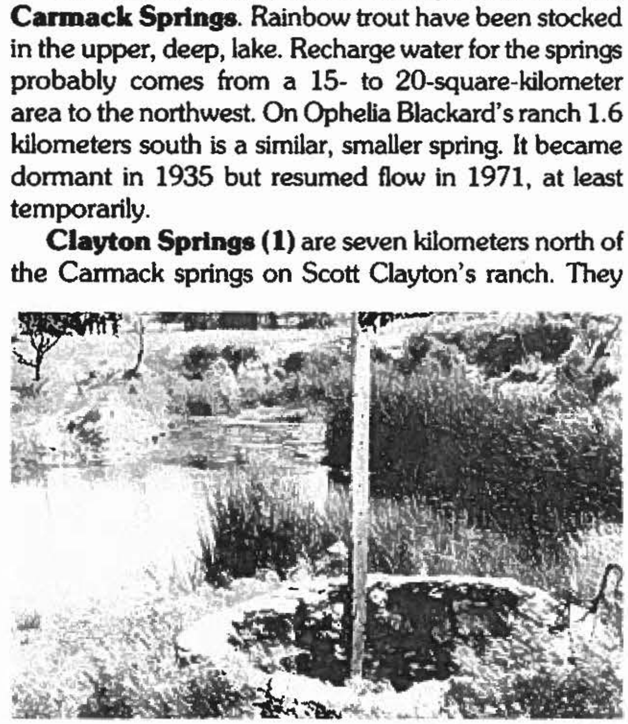
Most of the writer's field studies were made during the period May 27 - June 2, 1979.

Muchakooago Springs (6) were three kilometers west of Muchakooago Peak on Little Grape Creek on Vivian and Pauline Clark's ranch. Here in 1872 Gen. Ranald Mackenzie found a deserted Indian village of at least 150 lodges. In 1875 Lt. Col. W. R. Shafter described several running streams and springs in this vicinity, providing an "excellent and inexhaustible" supply of water. Burned-rock middens, stone tools, metates, and other artifacts testify that these springs were long used by prehistoric people. Now a few holes are fed by seeps most of the year. Raccoons, bobcats, skunks, and antelope frequent the site.

In northwest Borden County, at latitude 32°46' and longitude 101°50', are some springs (2) on C. O. Carmack's ranch, operated by Jack and Marilyn McPhaul. Projectile points found here indicate that this was a popular spot in the distant past. In 1874 when Col. R. S. Mackenzie's forces evicted the Indians from this favorite area, they probably stopped at these springs to fill their water barrels. Later there was a stage stop and dugout here where mules were changed on the Gail-Tahoka run. The slightly saline water issues from Ogallala sand and caliche and Comanche Peak limestone. It forms the head of Mesquite Creek in the caprock at an elevation of 885 meters. Two groups of springs, one walled up, feed two lakes. On May 29, 1979, 2.2 lps were passing the upper, 2-hectare lake.

Salt cedars, cattails, and hackberry trees surround **Carmack Springs**. Rainbow trout have been stocked in the upper, deep, lake. Recharge water for the springs probably comes from a 15- to 20-square-kilometer area to the northwest. On Ophelia Blackard's ranch 1.6 kilometers south is a similar, smaller spring. It became dormant in 1935 but resumed flow in 1971, at least temporarily.

Clayton Springs (1) are seven kilometers north of the Carmack springs on Scott Clayton's ranch. They also flow from Ogallala sand and Comanche Peak limestone, at the head of Salt Creek at the caprock. On August 24, 1948, 0.095 lps of moderately saline water poured over the limestone cliff. On May 29, 1979, there were only seeps dripping into the rockshelter below. Salt cedar, live oak, hackberry, and elm trees thrive in the deep ravine.



Carmack Springs.

In the late nineteenth century, according to Edna Miller, Bull Creek ran continuously. Buffalo hunters camped on upper Bull Creek in 1876. According to Ralph Miller, a nearby rancher, there was formerly a spring (10) and waterfall over Triassic sandstone on Bull Creek 10 kilometers north of Gail. This was on Franklin Miller's ranch.

Similarly, when Edna Miller's father-in-law arrived on Little Bull Creek to the east in 1900, it ran constantly, being fed by springs. Burt Dennis' ranch headquarters is located on Bull Creek (11). Near here Capt. Nicholas Nolan and his company camped in 1877 just before their ill-fated excursion onto the High Plains on which they became lost and some died from lack of water. According to Dennis, in the 1940s the water table was still shallow enough along Bull Creek that holes of live water could be scraped out.

There was also a former spring (9) in a draw on Dick Jones' ranch, 16 kilometers northeast of Gail. It flowed from Ogallala sand and gravel on Triassic shale, but has been dry for many years.

West-northwest of Fluvanna at latitude 32°56' and longitude 101°19' were **Gavett Springs (8)** on Ralph Miller's ranch. Several springs issued from lower Cretaceous limestone and sand at the base of a 5-meter pouroff in a ravine edged with limestone. They were the source of Gavett Creek. Burned-rock middens indicate that this was a living site in ancient times. In the nineteenth century there was a large Indian village here, where buffalo hunter Wright Mooar met Comanche chief Quanah Parker. A cemetery stands nearby. According to Miller, the springs flowed until about 1918, and pools of live water persisted until the 1930s. The gobbles of wild turkeys can be heard here.

Similar springs (7) formerly flowed to the east on Martin Parks' ranch, 12 kilometers west-northwest of Fluvanna. These and Gavett Springs kept Gavett Creek running to its junction with Bull Creek. They were much used during cattle drives. Several cottonwood stumps may still be seen. According to Parks, the springs dried up about 1935, but there is still a little seepage in wet years. Two windmills and an old grave are nearby.

Willow Springs (5) were on willow Creek in the southeast corner of the county, seven kilometers north of Vincent. According to Edna Buchanan, a long-time resident, Willow Creek was always full of running water around 1919. There are still some seep-fed pools from Quaternary gravel, but most of the channel has been filled with modern sediment. Willow and hackberry trees thrive here.

Rattlesnake Springs (4) were two kilometers northwest of Vealmoor on Rattlesnake Creek, on Aubrey and Modesta Good Stokes' ranch. Several burned-rock middens are located here. The springs were in the Rattlesnake pasture of the old Slaughter ranch, according to Mrs. Stokes. The large Rattlesnake earth tank was built to collect the spring waters for use during cattle drives. The remains of the dam may still be seen. Rattlesnake Springs were shown on R. G. Smither's and M. J. Eggleston's 1880 map of a *Reconnaissance of the Colorado River through Mitchell, Howard, Martin, and adjoining counties.* They were also depicted on W. R. Livermore's 1883 *Military map of the Rio Grande frontier.*

On May 30, 1979, pools of slightly saline live water still seeped from Ogallala sand on Triassic clay at Rattlesnake Springs. The largest of the springs still flow southwest of Vealmoor in Howard County. Tiny shrimp, whirligig beetles, and dragon and damsel flies make this their home. Rattlesnakes still abound. Much salt cedar and red-topped canaigre fringe the pools.

North of Rattlesnake Creek are Wolf and Glen Creeks, also on the Stokes ranch.They ran until about 1939, according to Modesta Stokes. Now there are only pools of live water which are used by cattle but which dry up in summer.

Gold Springs (3) are 17 kilometers northwest of Vealmoor on Frank Beaver's lease, operated by Vance Davis. The slightly saline water gives rise to Gold Creek. An Indian burial and several projectile points have been found nearby. On May 30, 1979, the total discharge was 1.6 lps, including many springs within a radius of two kilometers. The creek was flowing for three kilometers. The water issues from Ogallala sand and gravel on Triassic shale. The main spring, shaded by large mesquite trees, was pouring 0.28 lps into two ponds. Small fish and dragon flies dart among the rushes and cattails. Killdeers cry shrilly on the shores. The recharge area for Gold Springs extends to the northwest, including some 50 square kilometers.

BOWIE COUNTY

Archeological studies by the Texas Historical Survey Committee have shown that Bowie County has been very extensively occupied by man from Paleo-Indian through Historic times. Plainview and Meserve projectile points dating from as much as 9,000 years ago have been found in the area, especially near the springs.

Luis de Moscoso, leading the survivors of the Spanish De Soto expedition, was probably the first European to camp at the county's springs. In 1687 the Frenchman Henri Joutel and the remnant of La Salle's expedition found four tribes of the Caddo Confederacy in villages near springs on the Red and Sulphur rivers. In succeeding years the French and Spanish contended for the area. In 1719 the Frenchman Bernard de La Harpe established Fort St. Louis de Kadohadacho near the present Roseboro Lake. Undoubtedly these early explorers and their livestock drank from the abundant springs which then flowed in Bowie County.

By 1788 the Caddo villages on the Red River were deserted, because of raids by the Osages from the north and also epidemics of diseases brought by the white explorers. In 1803, with the Louisiana Purchase, Anglo-Americans began to move into the area and settle near the springs.

The county's spring waters flow chiefly from river terrace sands and gravels, and to some extent also from Eocene sands. In spite of the high rainfall (122 centimeters annually) and recharge to the ground-water aquifers in this area, water tables have declined seriously in places. At the time of the writer's study of the county (January 12-17, 1976) there had been very little rain for 7 months. Hence the spring flows measured were somewhat less than would normally be expected for this season. Several former springs were found which have not flowed for 50 years or more, indicating a decline in water tables.

The spring water is generally of very good quality, being fresh, soft, and of neutral pH. It is usually of the sodium bicarbonate type. In some cases the content of iron, sulfate, or silica may be high. Such waters have often been popular for medicinal purposes.

DeKalb springs (10) were described by Gordon in 1911 and Chandler in 1937, who called them a "fine spring in a ravine one-half mile southwest of DeKalb station." Flowing from the Navarro sand, they are reported to have flowed strongly in the past. They were once used as a baptizing pool. The pool has since been filled in, but the springs, on the school grounds, still flowed 0.32 lps on January 13, 1976.

Pine springs (9) are on the Red River County line at latitude 33°37', 17 kilometers northwest of DeKalb and ½ kilometer southwest of the Pine Springs cemetery. Here in 1814 the first Anglo-Saxon settlement in Texas was begun by the Burkhams. The settlement also extended into Red River County to the west. Later the springs became a state-coach stop on the route from

Rocky Ford to Clarksville. They flowed 0.33 lps on January 13, 1976.

Gay Springs (8) are on the Homer Gay placed 12 kilometers north-northwest of DeKalb in the spring Hill community. Flowing from terrace sands, they were much used by early settlers around 1845. In the 1870s a stage-coach stop and inn were located here, on the road between the rocky Ford of the Red River, near the mouth of Mill Creek, and Clarksville. During the last 25 years beavers have been making a comeback in the area, and their dams may be seen near the springs. On January 13, 1976, the discharge was 0.52 lps.

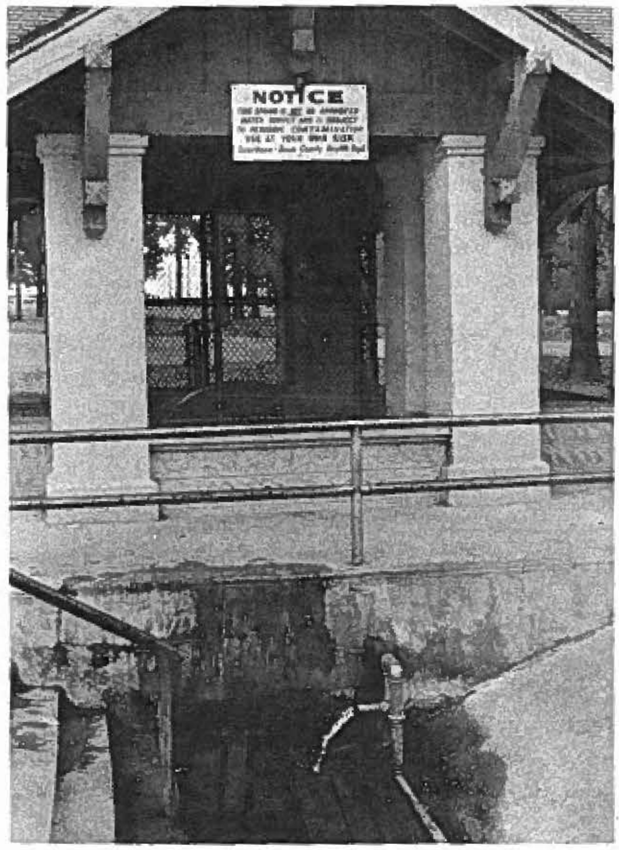
Fourteen kilometers north of DeKalb, on the S. C. Minnick ranch, are **Indian Springs (7)**. Flowing 6.1 lps on January 13, 1976, from terrace sands and gravels, these are the strongest springs in Bowie County. Here between 1819 and 1830 several displaced bands of Indians from the east, including Cherokees, Delawares, Shawnees, and Kickapoos, made their home. Abundant growths of watercress can be found here.

Nanatsoho Springs (6) the source of Spring Branch, are nine kilometers north of New Boston. Joutel found the Nanatsoho tribe of Caddoes living at these springs in 1687. They issue from terrace gravels, flowing 1.3 liters per second on January 13, 1976. Two kilometers northwest, at Spanish Bluff on Highway 8, is a historical marker regarding Richard Ellis, who settled here in 1825.

In 1719 the French explorer Bernard de La Harpe established Fort St. Louis de Kadohadacho for trade with the Nasoni tribe of Caddoes. This was just east of Roseboro Lake, nine kilometers northwest of Wamba. At that time **La Harpe Springs (3)** just east of the fort, furnished good water from river terrace sands. The post, including a flour mill nearby, were occupied by the French until 1779. In 1824 Collin McKinney, one of the first Anglo-American settlers, built a cabin in this vicinity. The springs have now been reduced to seeps.

Myrtle Springs (4), three kilometers northwest of Hooks, were named for the crepe myrtle which formerly grew wild here. They include a group of springs flowing from Paleocene sands just east of the Myrtle Springs church. They furnished water to many early settlers from the 1840s on, and were shown on maps of the 1870s. The largest individual spring was flowing 0.74 lps on January 12, 1976, and the combined flow was 3.0 lps.

Cedar Springs, (5), seven kilometers northwest of Hooks, trickled from terrace gravels. Joutel found the Upper Nasoni tribe of Caddoes living here in 1687. According to nearby residents the springs have been



Ghio Springs.

dry for about 60 years.

Ghio Springs (2) are in Spring Lake Park in northern Texarkana. They were named for the former owner of the park. The Spaniard Luis de Moscoso camped several days in 1542 "at a bold spring", which may have been Ghio Springs. Several springs flowing from terrace gravel were feeding the lake in the park at the rate of 1.0 lps on January 12, 1976. A spring house has been built around the largest. In the 1910s a 57-kilogram turtle lived in the lake.

Red Springs (1) were located close to the presen Red Springs cemetery, at latitude 33°26' and longitude 94°12' four kilometers south of Leary. This area is now in the Lone Star Army Ammunition Plant reservation As early as 1813 travelers on Trammel's Trace, which extended to Fort Tenoxtitlan in Burleson County drank from these springs. The iron-bearing spring flowing from the base of the Wilcox sand supplied wate for the early Red Springs settlers in the 1840s. While th writer was there the woods in the vicinity were bein intentionally burned by the Army. Repeated burnin not only pollutes the atmosphere; it destroys the leave mulch, and organic matter which formerly aided s much in holding rainfall until it could be absorbed into the subsurface formations. This is probably one reason why these springs have gone dry.

Three kilometers west of Maud are **Crystal Springs (14)**, issuing from Wilcox sands. Around 1832 the early settlers at nearby Corley made much beneficial use of them. On January 13, 1976, they furnished water to the Crystal Springs recreational lake at the rate of 0.76 lps.

Boston Chalybeate Springs (13) are ½ kilometer north of Old Boston. From 1813 on they were a stop on Trammel's Trace or the Southwest Trail. Still flowing from Wilcox sands at 0.92 lps in 1976, they were well known as mineral springs in 1892 (Peale, 1894).

Moss Springs (12), five kilometers south-southwest of Old Boston and just south of the Moss Springs church, were also much used in early days. They flowed from Wilcox sands at the rate of 0.63 lps in 1976. Many other springs are present in this area.

Dalby Springs (11) are probably the best known springs in Bowie County. That they were used by prehistoric people for many thousands of years is attested to by the many stone projectile points, axes, and scrapers, as well as pottery, which have been found here. In 1687 Joutel found the Upper Natchitoches tribe of Caddoes living here. From 1813 on Trammel's Trace passed the springs. In 1892 Peale found their discharge to be 1.7 lps, as compared with 0.06 lps in 1976. One, called **Farrier Spring**, was evidently used by the local blacksmith. In 1911 the springs were well known for their medicinal value.

There were originally four springs of different chemical quality flowing from the base of the Wilcox formation. They are located next to the Dalby Springs store 17 kilometers south-southwest of DeKalb. Although the springs still flow weakly, several pitcher-pump wells are now used to obtain the water. The most popular one furnishes iron-bearing water with a strong orange color. A historical marker is located at the church about 200 meters south.

BRAZORIA COUNTY

Springs are not common or large in Brazoria county, owing to its relatively flat situation. However, some may be found at the base of bluffs along the rivers, on the flanks of geologic domes such as Damon mound or on the landward side of the beach ridges.

They were originally the haunts of the Capoque tribe of Karankawa Indians and their predecessors. These tall, handsome people who were expert fishermen and hunters combatted the mosquito problem of the marshlands by covering their bodies with alligator grease and shark oil. In 1497 the first European, Amerigo Vespucci, is believed to have cruised along the coast and mapped it. It is not difficult to imagine his men refilling their water casks from springs, perhaps on the landward side of beach ridges. In 1528 Cabeza de Vaca and his companions were shipwrecked on the coast and were enslaved by the Capoques for a time. Some students believe that De Vaca's *Malhado* or Bad Luck Island was San Luis Island in Brazoria County (now a peninsula) and not Galveston Island as has been commonly assumed.

In this area it was often necessary to assist the flow of springs or seeps by deepening them manually. Mrs. M. S. Helms' account (1884) of her experiences while traveling in 1836 from the mouth of the Brazos River to her home on the lower San Bernard River are revealing:

> I expected to cross the San Bernard above the beach, knowing there would be no ferry-boat at the beach, and depending on the trail of tracks leading up to the settlements. I expected to dine at such crossing and reach home for supper, but to my astonishment about mid-day we arrived at the mouth of San Bernard, where we had so much trouble to cross on our retreat. We failed to find the trail that led up the country, and so had to make the best of our situation. Having spent a night there on our retreat — the first thing I had the wells opened in the sand to get fresh water.
>
> We procured drinking water from the holes we had dug in the sand, and, finding an empty bottle on the beach, we filled it with water to drink on the way, expecting to dine at home, twelve miles off.

The county's springs issue chiefly from Quaternary sands and silts. Measurements by the Texas Water Development Board show that water levels have declined as much as 50 meters in historic time in the shallow aquifers, due to waste of water from flowing wells and later, heavy pumpage. These factors have caused not only the failure of many springs, but land-surface subsidence and salt-water intrusion into the area as well.

Most of the writer's field studies were made on February 23-28, 1976.

At Velasco (now Surfside) at the mouth of the Brazos River, the schooner Lively, with men and supplies for Austin's colony, stopped for ten days in 1821. Probably the settlers were able to obtain fresh water by digging shallow holes in the sand. Later a Mexican fort and customs office was located here.

At Hoskins mound, 20 kilometers east of Angleton, very small springs or seeps probably existed. Removal of great quantities of sulfur, oil, gas, and water have caused this dome to subside at least 5 meters, destroying any former springs. A flowing well from a different aquifer still exists here, however.

The spring waters are usually of a sodium bicarbonate type, and are fresh to slightly saline, very hard, and alkaline. Their content of silica, iron, or chloride may be high.

In old Brazoria, just upstream from the Highway 521 bridge over the Brazos River, are **Brazoria Springs (1)**. They issue from river terrace sand, collecting in a small tributary to the river. The springs were a deciding factor in the location of the town at this spot in 1828. The 1976 spring flow of 0.05 liter per second was much less than the discharge in former years, partly because a nearby well was allowed to flow uncontrolled for many years.

Bell Springs (2) are at Bell's landing or Marion (now East Columbia). They flow from terrace sand just below a large live oak tree, in an area of much foxtail grass. Although at the time of the writer's visit (a very dry period) the springs only seeped, they are reported to flow most of the time. These springs probably were a factor in determining the location of Bell's landing, in 1824 the most important shipping point in Austin's colony.

San Bernard Springs (4)discharge on both sides of the San Bernard River about 2.8 kilometers downstream from the Highway 1301 bridge. They flow from a thick layer of Beaumont sand with some sandstone beds. In 1528 De Vaca and his companions may have refreshed themselves here on their long journey to Mexico. The springs are typical of the decline in spring flow in this area. In 1936 the Texas Board of Water Engineers measured their flow at 3.8 liters per second. On February 28, 1976, the combined flow was only 0.13 lps.

San Bernard Springs.

Damon Springs (3) formerly flowed at several points on the flanks of Damon Mound, a salt dome, near Damon. They flowed from Beaumont sand on top of a limestone cap rock whose top ranges from the surface to 20 meters below the surface. These springs are all dry now. About 0.55 lps of oil-field waste water flowed from the northwest flank of the mound in 1976.

BREWSTER COUNTY

As the largest county in Texas is for the most part quite dry, its springs are not large or especially numerous. Those that exist have been used for at least 15,000 years by man. The earliest residents of the county were big game hunters and gatherers of roots, plants, and nuts. They often used bed-rock mortars to grind mesquite beans, nuts, and roots. In many cases, where they have not been destroyed, the mortars may still be seen near the springs. By the close of the seventeenth century the Mescalero Apaches, Kiowas, and Comanches had taken over the area.

In the 1780s the Spanish missions of San Carlos and San Vicente were established across the Rio Grande at Lajitas and Boquillas respectively. It was not until late in the 19th century that Anglo-Americans began to settle near springs in the area.

Most of the writer's field studies were made during the period May 10-19, 1976. For the purposes of this discussion the county will be divided into three areas: Big Bend National Park, the Marathon Area, and Western and Northern Brewster County.

Big Bend National Park

In Big Bend National Park springs are better known than in the remainder of the county. This is due mainly to the fact that they have been studied in detail by Park scientists, especially W. E. Phillips and Virginia Howarth. Within the Park the springs are also more accessible to the public, most of them being located on hiking trails.

Most of the springs in the Park issue from Cretaceous limestones and sandstones and from igneous rocks. In the *Sierra del Caballo Muerto* (Dead Horse Mountains) to the northeast, the nature and structure of the rocks is such that there are few springs.

There is much evidence that springs were formerly larger and more numerous in the Park. *Alamo* (Cottonwood) Creek no longer supplies water for groves of cottonwood trees. Tobosa Flat before 1919 was covered with tobosa grass and abounded with antelope. The grass was mowed and overgrazed so much that very little now remains, having been replaced by broomweed, creosote bush, and other desert plants. Attempts are being made by Park personnel to reestablish the grass, and these will probably be successful in time, although centuries will be required to restore the land to anywhere near its undamaged state. In the Chisos Mountains there were formerly dense pine forests. Most of these were cut for use as fuel in the Terlingua mercury mines early in this century. Here again, since the forests are now protected, they will gradually recover, but only after many years.

Overgrazing and cutting of forests have removed the protective mulch of organic matter which formerly covered the soils and allowed rain waiter to slowly enter the subsurface instead of running off. Since this recharge has been reduced, the spring flow also has declined. Other factors such as well pumping have also drawn down the ground-water table.

When the springs fail, all of the plant and animal life dependent upon them disappears also. More or less endangered animal species of this area include the Mexican wolf, ocelot, bighorn sheep, Carmen whitetail deer, Mexican duck, southern bald eagle, American peregrine falcon, and the Big Bend gambusia or mosquito fish. Thanks to the Park scientists, these species stand a much better chance of surviving here than in surrounding areas.

The spring water is of a calcium bicarbonate type, and is usually fresh, very hard, and alkaline. Even the hot springs water is classified as fresh and may be taken internally, although it is high in sulfate and iron. Several springs sampled in the Park showed a manganese content of up to 1.5 milligrams per liter, copper up to 0.12 mg/l, zinc up to 1.05 mg/l, and orthophosphate phosphorus up to 2.1 mg/l (Lind and Bane, 1975). The highest concentrations in most cases were found at Boot springs, and were associated with ice formation. Mattison and others (1978) found a strontium content of 4.1 milligrams per liter in the hot water of Social Disease Spring.

Let us start at the north entrance to the park, on Highway 385, and discuss the springs moving in a clockwise direction around the Park. **Hannold, Hector,** or **Brackett Springs (2)** flow from gravel and cobble deposits on the west side of Highway 385 six kilometers northeast of Panther Junction. They were flowing 0.65 liter per second on May 11, 1976. They were described by Edward Hartz in 1859 when he led a camel train through the area. A small graveyard across the highway marks the remains of a very old Indian woman and Mrs. L. C. Hannold.

Grapevine Springs (9) are nine kilometers north of Panther Junction on a primitive road, at latitude 29°25' and longitude 103°11'. They discharge 0.65 lps from gravel on top of the Hannold Hill sandstone, which dips steeply northeast away from the Grapevine Hills intrusion. This may have been the place where Lt. Reuben Mays and his 14 men were killed when they attacked a band of Indians in 1861. The springs were shown on an 1887 General Land Office *Map of Foley, Buchel, and Brewster counties*. They reportedly dried up temporarily during the drought of the 1950s. They flow downstream about 300 meters before disappearing into the gravel and sand. An old dam indicates that the springs formerly emerged 100 meters farther upstream.

Neville Spring (66), also shown on the 1887 map mentioned above, is a very small spring three kilometers south-southwest of Grapevine Springs. **Quail Spring (67)**, is four kilometers south-southeast of Grapevine Springs.

Fourteen kilometers northeast of Panther Junction on a primitive road are **McKinney Springs (3)**. They flow from the *Aguja* (Needle) sandstone, dipping steeply to the north away from the McKinney Hills igneous intrusion. On April 5, 1976 they flowed 1.3 lps from eight or more springs, and on May 11 the flow had increased to 1.7 lps, extending 0.6 kilometer downstream. Here there are many trees such as screwbean and tobacco trees, as well as salt cedar and mesquite which have invaded the area due to misuse of the land. Beautiful rock formations, killdeers, and garter snakes are present. From 1913 to 1919 there was a factory here which extracted wax from the *candelilla* or *little candle* wax plant. For a few years there was a post office at the springs. When the post office was moved to Glenn Springs it was still called McKinney Springs, which caused some confusion.

Muskhog Springs (68), 6 kilometers north of McKinney Springs, are frequented by gray foxes, rock squirrels, deer, javelinas, coyotes, and bobcats.

Seven kilometers south of Panther Junction are **Rock Springs (74)**. Near here, on the southwest slope of Nugent Mountain, are some crown-polished boulders, used by prehistoric people in dressing animal skins.

Willow Springs (70), fourteen kilometers east of Panther Junction, were shown on the General Land Office 1887 *Map of Foley, Buchel, and Brewster counties* and on Spaight's 1882 *Official map of the state of Texas*. Apparently they were important to early travelers in the area.

Estufa (Stove) Spring (69) was six kilometers east-southeast of Panther Junction. Although the spring is now dry, the remains of an old cottonwood tree mark the spot where wildlife once gathered for water.

Ernst Spring (71) is 10 kilometers northwest of Rio Grande Village. The water issues from a fault in Boquillas limestone. A tinaja here holds water all year long. Deer, javelinas, and mountain lions sometimes drown here. Seeking water, they find it impossible to climb out of the tinaja when the water level is low.

At the campground in Rio Grande Village are the warm (32-36°C) **Rio, Pumphouse,** or **Campground Springs (4)**. They flow from 6.2 to 26 lps from a fault in the Santa Elena limestone. The springs flow into a small reservoir which is used as a water supply by Rio Grande Village. There is a thick growth of 5-meter-high cane, vines, and cottonwoods. The springs can only be seen by crawling on one's belly through a tunnel in the cane. An ancient people lived here and left many bedrock mortars nearby where they ground nuts, grain, and beans.

Rio Springs were the home of a rare mosquito fish which is found only in this area. It can no longer live in the springs, but is being maintained in a rearing pond. Beavers also make the springs their home. Salts on the surrounding area are the result of higher spring flows in the past. In 1916 the Deemer store here was raided by bandits. Just across the river is the Mexican farming village of *Ojo Caliente* (Hot spring). Here warm spring waters are used to irrigate crops.

At the entrance of *Boquillas* (Little Mouths) Canyon are **Boquillas Warm** or **Fish Pool Springs (5)**. The discharge was 5.2 lps on May 11, 1976, and 2.5 lps on July 30, 1976. The springs issue from a fault in the Santa Elena limestone. The water is warm (35° Celsius) and supports a thick cane growth. A large group of bedrock mortars in the limestone indicates that this was the site of an ancient village, probably for thousands of years. The blotched water snake, rare in this area, and Big Bend gecko live at these springs.

About 200 meters north of the crossing to Boquillas are **Boquillas Crossing** or **Beaver Marsh Springs (72)**. These are mostly small springs and seeps which had a combined flow of 2.5 lps on April 10, 1974. They flow from gravel deposits but probably originate in faulted Santa Elena limestone. Several beaver dams form pools choked with stonewort, macroalgae, cattails, and reeds. One spring issues into a small concrete tank and was probably used formerly for drinking water. The water is used to irrigate gardens. A rare aquatic insect, *Plea striola*, makes its home here, as do many waterfowl (Lind and Bane, 1975). Tree tobacco, an unusual plant used by Indians in a poultice to relieve pain, can be found here.

Three kilometers west of Rio Grande Village are the larger **Boquillas Hot Springs (6)**, which emerge at an elevation of 570 meters on the bank of the Rio Grande. The springs are probably fed by surface-recharged waters which circulate to moderate depths (700 meters approximately), become heated, return to the surface along faults, and emerge from the Boquillas limestone. The temperature is around 41° Celsius. A column of denser cold water can support a taller column of hot water. Thus a hot spring can be higher than its recharge area. In this case the Rio Grande probably contributes recharge to the springs, which appear several meters above the river.

Bedrock mortars used by an ancient people may be seen near Boquillas Hot Springs, as well as rock paintings and smoke-blackened cliffs. These people also dug out a pit for bathing at the springs. When the Spaniard Pedro de Rabago y Teran visited the springs in 1747 he found the Apaches living in villages and growing squash plants. He called the place **Santa Barbara**. Later the springs were on the Comanche Indian trail to Mexico.

For a time early in this century they were a popular bathing resort. The therapeutic value of the water was loudly acclaimed. In addition to the constituents shown in the table of Selected Chemical Analyses 0.2 milligram of lithium per liter is present. The water still flows into a walled-up pool. (See Plate 7,c). The abandoned store and tourist court are nearby. The flow, in liters per second by water years, is as follows:

1936	23	1966	9.5
1953	45	1971	9.1
1964	17	1976	13
1965	17		

Another small hot spring (41° Celsius) issues about 400 meters downstream from Boquillas Hot Springs in a cane brake. It was called **Social Disease Spring** by Mattison and others (1978), who made 62 discharge measurements of the spring in the summer of 1976. The average discharge was 1.6 lps, at a temperature of 41° Celsius. They also noted numerous animals which inhabit the spring, including the Rio Grande leopard frog and red-spotted toad.

Seventeen kilometers southwest of Rio Grande village is the very small **Solis Spring (81)**. Near here, on a plateau south of Talley Mountain, are the adobe ruins of Martin Solis' 1882 ranch house. In this vicinity may often be seen white-winged doves, canyon wrens, cardinals, and black-throated sparrows.

Chilicotal Springs (73) are 11 kilometers southeast of Panther Junction. Sometimes called **Jip Springs** on old maps, they once supported a Comanche campground.

Glenn Springs (7) are 16 kilometers southeast of the Basin, on a very bad road, at latitude 29°11' and longitude 103°09'. They were named **Jordan Springs** on A. W. Spaight's 1882 *Official map of the state of Texas*, G. F. Cram's 1890 *Railroad and county map of Texas*, and other early maps. In 1976 they poured 1.7 lps from Aguja sandstone which dips downstream, away from an igneous rock intrusion. As Casey described them in 1972,

> Glenn Springs, with its bountiful supply of good water, long served as a campsite for the native Indians of the area as is indicated by bedrock mortars, the many grinding stones, and the caches of flint and arrowheads found in the immediate vicinity of the spring. For many years the spring was used by the Comanches as a stopover on their forays into Mexico along the so-called Comanche Trail. Also, it is entirely possible that the camel expedition into the Big Bend in 1859, under the command of Edward L. Hartz, visited Glenn Springs as they followed the Comanche Trail toward the Rio Grande. Thereafter the spring continued to be used by the Indians of the area until the coming of the Anglo-Americans toward the end of the nineteenth century.

Kirkland and Newcomb (1967) found some Indian pictographs on a large block of sandstone east of Glenn Springs. Nearby also are some crown-polished boulders. In the early 1900s the springs served an outpost of Camp Marfa. From 1914 to 1929 a candelilla wax factory was located here. In 1916 the settlement was raided by bandits. Many desert willows, with their pink-purple flowers, grow at the site. The peyote cactus, which was used by prehistoric people for its narcotic effect, formerly grew near the springs. They reportedly dried up temporarily during the drought of the early 1950s.

Several small springs were shown in this vicinity on the 1887 county map mentioned previously. These include **Mozart Spring (79)**, also called **Little Jewel**, five kilometers west of Glenn Springs; **Sorpresa (Surprise) Spring (80)** seven southwest; and **Mabry Spring (82)**, also known as **Loop Spring**, 19 southwest.

Dominguez Spring (109) is 15 kilometers south of the Basin. An old dam, now broken, and a rock house are located here. The more dependable **Silver (108)** and **Carney (87) Springs** are two and three kilometers respectively upstream (north). Carney Spring is frequented by mountain lions, deer, javelinas, and coyotes.

Upper (51) and **Lower (76) Juniper Springs** in Juniper Canyon southeast of the Basin, support thick growths of ferns, oak, and juniper. An old concrete watering trough is reminiscent of the pre-Park cattle days. The springs are not dependable in dry seasons.

Shelf Spring (88), 13 kilometers southeast of the Basin, flows over a 10-meter pouroff decorated with ferns.

Four kilometers south of the Basin were **Boot Springs (13)**, on a hiking trail at latitude 29°14' and longitude 103°18'. An ancient marshy area or meadow existed to the west. Here a prehistoric people left a midden where they baked sotol and maguey bulbs. In 1787 Spanish General Jose del Ugalde attacked a band of Mescalero Apaches who lived at the springs, called as a result **Agua Dolores**, or **Sorrowful Watering Place**. An old Spanish mine is rumored to exist near here. This was an important water source for mule deer, whitetails, mountain lions, and other wildlife. A well at a nearby cabin has reduced the flow to a seep, emerging from the Lost Mine lava. The springs were among the highest in Texas, at 2,075 meters above sea level.

Kibbe Spring (52), is the only important spring in the Chisos Basin. Nearby are some crown-polished boulders. During the drought of the 1950s the spring's normal flow ceased, due to well pumping and previous overgrazing of the recharge area. It now flows only intermittently. The rare Colima warbler has been observed only here and at Boot Springs in the United States.

Four kilometers west of the Basin settlement, and just below the pouroff at the "Window", are **Oak Springs** or **Ojos de Chisos (Chisos Springs) (11)**, at an elevation of 1,290 meters. Here was the headquarters of J. T. Gano's G4 ranch in 1885. The springs flow from igneous rocks, with a discharge ranging from 0.38 to 19 lps since records began in 1954. These figures include the flow from **Cattail Springs** 2 kilometers southeast, which is piped to Oak Springs. The combined flow is used as a water supply for the tourist facilities in the Basin above. At the time of the writer's visit (May 13, 1976), all except 0.15 lps was being used. Spring flow follows precipitation in the Basin by several weeks.

Gano Springs (12) are 9 kilometers northwest of the Basin, at latitude 29°19' and longitude 103°22'. They issue from a gravel deposit on top of a clay. They pour out 1.3 lps, which runs for about 100 meters past the highway to the north. Many flint flakes indicate use of the springs by prehistoric people. Dead cottonwoods suggest that the springs are no longer reliable as they once were.

Burro Spring (55) is 13 kilometers west-southwest of the Basin. It has sometimes been called **Bigelow Spring**. Indian pictographs may be seen on Burro Mesa to the north. Tracks of deer, javelinas, coyotes, and gray foxes can usually be found in the wet soil.

Mule Ear Spring (85) is two kilometers north of Mule Ear Peaks. A rock corral and small adobe house are remnants of the days when huge herds of cattle caused irreparable damage. An old pipe line formerly carried the water downstream to a stock tank.

Apache Springs (89) in Apache Canyon 11 kilometers west of the Basin, are the site of ancient hearths and many projectile points, but appear to be drying up. **Cottonwood Springs (54)**, eight kilometers west of the Basin, appear to be failing also and are being invaded by saltcedar.

Ord Springs (53), six kilometers southwest of the Basin, were depicted on Carrington's 1881 map. They were no doubt named for General Edward Ord. Some maps call them Ward Springs, but **Ward Springs (117)** are 27 kilometers northwest, outside Big Bend Park. The water surfaces where an impervious volcanic dike forms an underground dam. The springs fail only during extended droughts.

Government Springs (62), two kilometers north of Basin Junction, are a resort of javelinas, which perform a valuable service in controlling prickly pear cactus. In 1884 the cavalry had a camp here. A remuda of horses was stolen by bandits but later recovered.

Dripping Spring (64), eight kilometers northwest of Basin Junction, is now dry. **Croton Springs (63)**, eight kilometers west of the junction, seep into two small tanks filled with saltcedar and cattails.

There are many other springs in the Park, too numerous for detailed description. They include **Cedar (56), Reed (57), Rock (58), Christmas (59), Ash (60), Rough (61), Onion (65), Panther (75), Dodson (77), Fresno (Ash) (78), San Jacinto (83), Smoky (84), Trap (86), Carrasco (104), Wasp (105), Tusk (106), Mano (Hand Stone) (107), La Noria (The Water Wheel) (110), Dugout (111), and Red Ass Springs (134)**.

The Marathon Area

The Marathon Area as used in this book is that part of Brewster County north of Big Bend National Park, east of longitude 103°30', and south of latitude 30°30'. It is an extremely interesting area geologically, containing many very old, lower Paleozoic, limestones, shales, and cherts, as well as younger rocks. One very prominent rock is the very hard *Caballos* (Horses) novaculite, which usually forms ridges. The whole area has been greatly contorted with folds, faults, and overthrusts. The latter involve the movement of large masses of older rock over younger beds. The area makes an excellent theater for the study of geologic problems in the field, and draws geologists from the entire country.

The springs rise chiefly from fractured and vugular (containing many small cavities) limestone and alluvial sand and gravel. A stream's discharge commonly flows underground through alluvial sand and gravel until the stream crosses a hard layer of rock, at which point the flow comes to the surface as a spring. The smaller streams were originally wet, grassy swales with no channels. With the destruction of the protective grass cover by overgrazing and cutting of trees, valley trenches began to cut headward, lowering the water table. Downstream channels were clogged with sediment. The loss of the deep grasses and their organic mulch greatly reduced the capacity of the soils to recharge water into the ground-water reservoir.

With a declining water table many springs are failing. For example, **Double Wells** or **Double Mills (103)**, 55 kilometers south of Marathon on Highway 385, were formerly springs. For thousands of years they served prehistoric people and later the early explorers. Their disappearance was in part due to the deepening of Maravillas Creek, in turn caused by modern man's overgrazing and other activities. Several wells here have not helped to restore the springs. Dugout Creek at Lenox Siding, 15 kilometers west of Marathon, flowed until 1886, according to Travis Roberts, a noted rancher and historian.

The quality of the spring water is generally high. It is usually of a calcium bicarbonate type, fresh, very hard, and alkaline.

Buttrill Springs (1) are about 17 kilometers southwest of Persimmon Gap on the north flank of the *Rosillos* (Pink) Mountains. At latitude 29°33' and longitude 103°17', they are on the Houston Harte ranch, managed by Odie Roberts. They issue from Upper Cretaceous limestones adjacent to the igneous intrusive rocks in the mountains. Flowing 2.7 liters of fresh water per second in 1976, they reached a low of 0.65 lps during the 1950s drought. Many projectile points and metates or grinding stones found here indicate that this was a favorite haunt of prehistoric people. The springs were later a stop for war parties on the Comanche trail. Some believe that this is where Lt. Reuben Mays and his 14 men were killed when they attacked the Indians in 1861. Others claim that it was at Grapevine Springs (9). There is a large pecan, other trees, and some adobe ruins below the spring.

A number of smaller springs occur nearby. Thirteen kilometers northeast are the very small **Bone Springs (47)**, named for the bones of many animals that bogged down and died in the seepy area. According to their owner, Odie Roberts, they flowed in 1975 for the first time in many years. Army maps of the 1880s showed them as *reliable springs*. On an 1887 General Land Office *Map of Foley, Buchel, and Brewster Counties* they were called **Guaronza Springs**. R. A. Thompson's 1908 *Railroad and county map of Texas* spelled the name **Guavanga**. Possibly both of these names were variations of *guarango*, Spanish for huisache or acacia, which is found in this area.

Eight kilometers southeast of Buttrill springs are the very small **San Juan springs (46)** on the east flank of the Rosillos Mountains. They are named **Guaracha (Dance) Springs** on several old maps, including A. W. Spaight's 1882 map and the 1887 map mentioned above.

Other very small springs in this area include **Wildhorse (34), Cub (35), Little and Big Corazones (Hearts) (37), Indian (38), Box (39), Rock House (40), Smallpox (41), Willow (42), Alamo (Cottonwood) (43), Goat (44), Cottonwood (45 and 48), Cedar (49)**, and **Mud Springs (118)**. **YE Spring (100)** is believed to be the **Sulphur Spring** shown by Lt. William Echols of camel caravan fame on his 1859 *Topographical reconnaissance map of the Comanche trail.*

Thirty-two kilometers south of Marathon and three east of Highway 385 are **Tinaja** or **Waterhole Springs (112)**, at latitude 29°57' and longitude 103°13'. They flow from Maravillas limestone and are dammed up in pools by the hard Caballos novaculite. They are very small, flowing only 0.19 lps, but supply water for stock and help to feed Spring Creek.

Eighteen kilometers south of Marathon are **Ridge Springs (23)**, at latitude 30°03' and longitude 103°16'. Ike Roberts, who manages this ranch, kindly allowed the writer to visit these and other springs. Ridge Springs are located just west of the old Marathon-Boquillas highway. The new highway, Route 385, has now been relocated about two kilometers west. The geology here is quite complicated and fascinating. A huge mass of rock called the Garden Springs Overthrust has been pushed to the northwest on top of other rocks, accompanied by much faulting. The fresh-water springs flow from these faults in the Maravillas limestone. Several have been developed and walled in along the deep gravel *gouge* zone of one of the faults. The springs derive their name from the fact that they occur in a pass through a ridge of novaculite. In 1937 they poured out 15 to 20 lps. Although they yielded 6.0 lps in 1976, they failed during the drought of the 1950s. The smaller **Mud Springs (95)** are four kilometers northwest.

Garden Springs (24), three kilometers south of Ridge Springs and also on the old Marathon-Boquillas highway, are similar. Their flow of 0.13 lps in 1957 and 1.7 in 1976 collects in a tank and marshy areas. Flowing about 100 meters downstream before disappearing, the water supports large cottonwood and willow trees and many killdeer. The similar **Simpson Springs (93)**, five kilometers west, flowed 0.19 lps in 1957.

Monument Springs (22) are 20 kilometers southwest of Marathon on the Travis Roberts ranch, at latitude 30°05' and longitude 103°23'. They were called **Collins Springs** on Carrington's 1881 map. They issue from the Maravillas limestone which dips downstream or southeast, the water being forced to the surface to flow over the Caballos novaculite. It tastes fresh but has a slight hydrogen sulfide odor, and some white precipitate is present. The springs support a grove of trees and much wildlife. The discharge was 1.3 lps in 1957 and 1976. Many chert flakes indicate that this was a haunt of an ancient people. A monument of stone was built here in pioneering days to guide wagon trains to the spot, according to Mr. Roberts, who is an authority on local history.

A second **Rock House Springs (92)** is three kilometers southwest, yielding 1.6 lps in 1957. Eight kilometers west of Monument Springs, in a gap in the Del Norte Mountains, are **Cherry Springs (91)**. They produced around 2.5 lps from Edwards limestone in 1976, with many Indian pictographs nearby. They were shown on several early maps, including the Bureau of Topographical Engineers' 1857 *Map of Texas and part of New Mexico* and Lt. William Echols' 1859 *Topographical reconnaissance map of the Comanche trail.*

Pena Colorada (Rainbow Cliff) Springs (20) are in a park seven kilometers south-southwest of Marathon. The name is often incorrectly spelled Pena *Colorado*. The springs flow from gravel deposits, and the water comes to the surface where Pena Colorada Creek crosses the very hard Caballos novaculite. Their long occupation is attested by numerous flint flakes in the area. They later became a rest stop on the Comanche trail. In 1859 Lt. William Echols camped here with his experimental train of camels. From 1879 to 1893 Fort or Camp Pena Colorada was located here. Many antelope and some bighorn sheep were found in the vicinity then, grazing on the excellent grass. In 1879 Burr Duval described the place:

> Tuesday, March 23, Moved at 7 A.M. sharp. At 15 miles struck Rainbow Cliff where I found Capt. Robe of the 25th Infantry in camp, or rather rock huts which had been constructed for quarters. Here there is plenty of water, but no wood. Capt. Robe kindly gave me a few sticks for cooking. This is the most

desolate looking place, not a tree or shrub in sight and barren hills all around. The water is in large pools at the foot of a limestone ridge with a capstone of yellow limestone, hence the name "Rainbow" or more properly "Pena Colorado."

A historical marker is near Pena Colorada Springs, many of which are now under water in a lake. The spring water also feeds a swimming pool. About 50 black vultures were perched on fence posts near the springs when the writer visited them. Black and yellow Scott's orioles and red coachwhip snakes may also be seen here. In 1957 the discharge ranged from 9.5 to 28 lps. On May 17, 1976 it was 21 lps. Six kilometers south are the smaller **Sunshine Springs (94)**, which flowed 0.32 lps in 1957.

On Miles Pierce's ranch southeast of Alpine, six kilometers south-southeast of Bird or Altuda Mountain, are some small springs (130). On June 23, 1979 there was only seepage into pools. According to Pierce, during most of the year there is a running flow. The water issues from Permian Word limestone, dipping gently upstream. Nearby are burned-rock middens and crown-polished boulders. Mountain lions, bobcats, and coyotes still prowl the area, killing sheep. Pinon pines, Graves oaks, shinnery oaks, and algerita abound. Water boatmen swim among the algae. Butterflies and bees hover around the pools. Other nearby springs have dried up, according to Pierce.

Eleven kilometers north of Marathon, on the southwest side of Iron Mountain on W. B. Blakemore's ranch were once the **Iron Mountain Springs (96)**. They trickled from intrusive rocks amid a jumble of boulders. Intensive overstocking with sheep and goats destroyed the recharge capacity of the soils, and the springs dried up. But there remains incontrovertible evidence that there was water here, in the form of grinding holes in the rock and crown-polished boulders on which Indians rubbed hides to remove the oil and hair.

Head Springs (97) were 30 kilometers east-northeast of Marathon and 10 north-northeast of Lemons Gap, on the Walter Groth ranch. A. R. Roessler dé-picted them in 1874 on his *Latest Map of the State of Texas*. Several springs flowed from the Tesnus sandstone at an elevation of 1,190 meters. Many burned-rock middens, bedrock mortars, stone artifacts, and pictographs in nearby rockshelters attest to their long use by early Americans. The area has been badly overgrazed, but grasses are coming back now under good management, especially in the swales below the former springs. Deer are still plentiful, probably using sheep watering troughs instead of the springs, which have long been dry.

Fifteen kilometers southeast of Marathon are **Pena Blanca** or **White Cliff Springs (21)**, at latitude 30°08' and longitude 103°07'. The name is very apt, as the springs sparkle below some high white cliffs of-novaculite, which are inhabited by many swallows. On Army maps they were shown as **Soso Springs**. The water rises from the fractured Maravillas chert and limestone where they contact the Caballos novaculite. All of these beds dip steeply downstream. Two dams have been built here to store the spring water. There is a grove of trees, and many ducks and deer frequent the spot. The discharge was 1.3 lps in 1957 and 1976 and 0.92 in 1977.

Reed Springs (32) are at Gage Holland's ranch headquarters, at latitude 30°05' and longitude 103°07', southeast of Marathon. Lt. William Echols called them **Read Springs** on his 1859 *Topographical reconnaissance map of the Comanche trail*. Issuing from Tesnus sandstone dipping steeply to the northeast on top of impervious Caballos novaculite, they were named for a Mrs. Reed and not for the reeds which grow here, according to Mr. Holland. They produced 0.32 lps in 1957 and 0.19 in 1977. They rise in a bog of tules, bordered by cottonwoods, willows, and buttonbush. Five mortar holes in the adjacent novaculite disclose that this was the campsite of an ancient people. It must have taken a very long time, perhaps 1,000 years, to grind one of these deep holes in this very hard rock, essentially as hard as flint. The small **Fern Seep** is three kilometers north.

Five kilometers southeast of the Holland ranch headquarters, on the eastern flank of Horse Mountain, was **Horse Spring (31)**. This very small spring ceased flowing after a nearby seismograph blast in about 1967.

Another **Cottonwood Springs (30)** are seven kilometers southeast of the headquarters on Pena Blanca Creek, rising from gravel where the Hell's Half Acre thrust fault brings the Caballos novaculite to the surface. About 1.6 lps discharged on July 26, 1977. The cottonwood is gone, but willows are numerous, and antelope frequent the site.

Nine kilometers southeast of the headquarters on San Francisco Creek are **Jose Springs (99)**. They also appear from gravel, where the thrust fault brings Maravillas chert to the surface. They were depicted on two 1881 maps: W. R. Livermore's and F. E. Butterfield's *Military map of the Rio Grande frontier*, and Lt. F. de I. Carrington's *Map accompanying report of a scout*. They were flowing 1.3 lps on July 26, 1977, the lowest discharge Mr. Holland had seen here. A mammoth tusk 10,000 or more years old was found in a bog near the springs.

Hood Spring (101) is 18 kilometers south of the ranch headquarters and one kilometer east of Hood Mountain. The water is brought to the surface by near-vertical beds of quartzite in the Tesnus formation. Many projectile points and other artifacts found here point to its use by early Americans. The Army made much use of it in the nineteenth century. Although it formerly watered a large area of range land, it is now only a seep among cattails and other water plants. The Hood Spring topographic and geologic mapping quadrangle was named for this spring.

Five kilometers west was the small **Krebaum Spring**. A well there has dried up the spring.

Four kilometers east-northeast of Hood Spring was **Kincaid Spring (102)**. This was probably what Lt. William Echols called **Dowlins Spring** on his 1859 map. Many stone implements and projectile points have been found here. This spring is gone and replaced by an old wooden windmill. Among dying cottonwoods deer and javelina hide. Gage Holland recognizes that water tables are falling and springs failing in this area. He has built a large number of earth dams and diversions in an attempt to increase ground-water recharge.

Willow Springs (98) are 24 kilometers east-southeast of Marathon and just east of the ghost town of Haymond. They are formed where the flow in gravel along Willow Creek rises to pass over a ridge of Dimple limestone. On July 26, 1977, the discharge was 0.95 lps, running 100 meters downstream before disappearing again. A former swamp surrounded the springs. Lt. E. L. Hartz and his camel train stopped here in 1859. Now the springs are shaded by many willows and buttonbushes. About 0.6 kilometer southwest San Francisco Creek crosses the same limestone ridge, producing smaller springs.

On Mrs. Jack Shely's property, 38 kilometers southeast of Marathon and three west-southwest of Maxon siding, are **Maxon Springs (25)**. They issue from a fault in the Dimple limestone in the bluff on the south side of Maxon Creek, flowing 0.19 lps on September 17, 1976. Pictographs on the bluffs and numerous projectile points of flint and chalcedony indicate long use of the springs by prehistoric people. On Walker's 1805 map they were called **Ojo de Basillo (Cell Spring)**. In more recent years (1871) they were "discovered" by Lt. M. M. Maxon. In 1879 Burr Duval wrote:

> Thursday, March 25. Reached Maxon's Springs (so called) in 4 hours, a hole in a creek but the water is clear tho' full of moss and green vegetable matter. Road very rough, leads through a canon where the breeze could not reach us and it was very, very hot. My animals suffered severely.

Maxon Springs were used for a time by steam locomotives on the Southern Pacific railroad. Numerous deer, a few gray wolves, and sparrow hawks frequent the spot. The very small **Bois d'Arc (Bow Wood) Springs** are 2 kilometers west.

Coe Springs (132) were on San Francisco Creek in eastern Brewster County at latitude 29°53' and longitude 102°23'. The site is on Harry Williams' 121-square-kilometer ranch, operated by Harvey and Alice Glenn. The springs were depicted on an 1898 map by the U. S. Engineer Office. Indian pictographs in caves in the limestone bluff indicate that this was a popular spot in ancient times. The springs maintained a water hole in early times, according to former owner Benny Rusk. Many cowboys' initials dating from the 1880s are carved in the rock. There is still some wet-weather seepage at the site, which is covered with walnut trees, blackbrush, creosote bush, and prickly pears. Deer, javelinas, rabbits, doves, and reddish house finches still inhabit the area, probably obtaining water now from stock tanks or dew on the grass in early morning.

Five kilometers southwest of Coe Springs were **Deerfoot Springs (131)** in Bullis Gap. The late Kyle Slover, who lived in Sanderson, remembered when there was still water here. The springs have long since ceased flowing. The site is covered with chinaberry and cedar trees and algerita and blackbrush.

A large number of springs pour out along the Rio Grande in the Lower Canyons. This is the reach from Boquillas to Amistad Reservoir. For the period 1964-1975 the low flow of the river increased from 8,100 lps at the upper end to 16,600 lps at the lower end of the reach (Hamilton and others, 1979). In other words, the low flow of the Rio Grande is doubled as a result of spring flow in the Lower Canyons. At least half of this spring flow is on the Mexican side of the river.

In 1899 geologist R. T. Hill wrote

> At this point *[Boquillas]* and for about fifty miles down its course, the river is reinforced by a remarkable series of hot springs bursting out of vertical fissures. The first noted of these was in the middle of the stream, and its presence was made apparent by the beautiful, limpid water welling up in the midst of the muddy current.

Practically the only way to see the springs in this *despoblado*, or uninhabited area, is by boat. Several outfitters in Terlingua, Lajitas, and Alpine conduct float trips.

Hundreds of caves along the Lower Canyon represent former spring outlets which have been left high and dry. For many thousands of years these caves and rockshelters were used by Paleo-Indians. Near the springs they left mortar holes in the bedrock where they ground mesquite beans, acorns, and other plants.

The Lower Canyons springs are all warm or hot. Such creatures as the leopard frog, Big Bend slider, and soft-shelled turtle make their home here. Birds fleeing the impact of human settlement have found refuge here, including herons, eagles, and the highly endangered peregrine falcon. Giant cane, sedges, rushes, and ferns surround the springs.

Fifteen airline kilometers downstream from La Linda, the usual put-in point for float trips, are several very small springs (135). On June 24, 1979, they produced about 0.85 lps of fresh water from Glen Rose limestone. Two kilometers farther is a similar group of springs (136). The water is warm (35° C).

Forty airline kilometers downstream from La Linda are the warm (34° C) **Asa Jones Springs (137)**. Their water was once pumped up to the top of the bluff above for use in the manufacture of wax from candelilla plants. On June 26, 1979, they discharged 7.5 lps from Edwards limestone. Springs pour out on the Mexican side here also. Five kilometers east of Asa Jones Springs are the **Bathtub Hot Springs** on the Mexican side, a favorite resting and bathing spot for rafters.

Ten airline kilometers upstream from the Terrell County line are **Lower Madison Springs (138)** and falls. On June 28, 1979, the several springs produced about 0.75 lps of warm (35°C) water from Edwards limestone.

Western and Northern Brewster County

Springs are not numerous in western and northern Brewster County, but some of medium size still exist. They flow chiefly from Cretaceous limestone and sandstone, and from various igneous rocks. Some streams are fed by a large number of very small springs and seeps, too small to describe here.

The springs of this area have a very ancient history. Some of them, such as Kokernot and Leoncita, lay on the most easily traversible trail in the county, used by prehistoric people for thousands of years.

Many springs have failed. According to James Gillett, foreman of the G-4 ranch, in 1885 Terlingua Creek was a

> bold running stream, studded with cottonwood and was alive with beaver. At the mouth of Rough Run there was a fine grove of trees, under the shade of which I have seen at least one thousand head of cattle. Today (1933) there is probably not one tree standing on the Terlingua that was there in 1885.

Although in recent years some of the grasses have begun a valiant effort to come back, the damage done to the topsoil, overlying mulch, and ground-water reservoir by overgrazing would take many centuries to repair. Terlingua Creek still usually flows in places where the creek crosses rock outcrops, but most of the flow has receded underground into gravel beds. Terlingua is a modification of the Spanish *Tres lenguas*, meaning three languages or tongues, in reference to the Apaches, Comanches, and Shawnees who lived on the creek.

There is very little irrigation in Brewster County, but small domestic and stock wells in this area have taken their toll of ground water. Of equal importance probably is overgrazing, which has destroyed the organic layer on the soil so necessary for adequate recharge of the underground water. The 19 centimeters of rain which fell in September, 1978, revived many springs temporarily.

The quality of the remaining spring water is high. It is generally of a calcium bicarbonate type, fresh, very hard, and alkaline. The silica content may be high.

There are many very small springs in the Study Butte vicinity. **Maverick Spring (14)**, is one kilometer east on the west slope of Maverick Mountain. Flowing 0.06 lps from Tertiary intrusive rocks, it supplies the Gulf service station in Study Butte. **Joe Black Spring (115)** depicted on some old maps, is three kilometers north-northeast of Study Butte. **Indian Head Spring (33)** is four kilometers northeast. The rare and acutely endangered rock spikemoss is found in Texas only near the springs east of Study Butte. Also found here is the remarkable resurrection plant, which quickly unfurls its fronds after a rain.

Three kilometers east-northeast of Lajitas on Walter Mischer's property are **Comanche Springs (128)**, feeding Comanche Creek. They were much used by travelers to and from the San Carlos rock-bottom crossing of the Rio Grande at Lajitas, both Indians and later explorers. Kirkland and Newcomb (1967) described Indian pictographs on a high chalk cliff above the springs. During the sporadic quicksilver mining at Terlingua after 1896, water was hauled from the springs to the mines in barrels. It was rationed to the Mexican-American workers, although no limit was placed on the Anglos.

Now Comanche Springs are only some pools of standing water where the Upper Cretaceous Boquillas limestone crosses the channel. Sand-bar willows and the ruins of an old rock house mark the site. The rare Trans-Pecos rat snake is found in this vicinity. Bright orange Mexican poppies and pink-flowered featherplume shrubs are common. Hummingbirds zoom from one flower to the next. Horseback trips to several Mexican springs leave from Lajitas trading post.

Ward Springs (117) are eight kilometers north-northwest of Terlingua. Other springs in this area include **Cigar (113)**, **Willow (116)** at Willow Mountain, **Lost (114)**, and **Yellow Jacket Spring (119)**. **Adobe Walls Spring (127)**, north of Study Butte 17 kilometers, no longer flows, probably because of the windmill well there.

Agua Fria (Cold Water) Springs (15) are 27 kilometers northwest of Study Butte, on land leased by Pat McKinney, at latitude 29°32' and longitude 103°40'. They emerge at an elevation of 1,080 meters. They have given their name to Agua Fria Mountain, just to the east. They were called **Agua Melada (Honey Water)** by F. de I. Carrington on his 1881 *Map accompanying report of scout.* Perhaps *Agua Helada* (Freezing Water) was intended. They were well described by Kirkland and Newcomb in 1967:

> The mountain terminates in an overhanging granite [actually rhyolite] cliff some three hundred feet or more high, at the base of which is a large protected area covered with a deep accumulation of burned rocks and ashes. Only a few yards below this shelter is a huge spring of clear cold water, making it ideal for an Indian camp.

A legend tells of an Indian woman whose baby was born near Agua Fria Springs when the moon was full. A child born under a full moon, it was believed, would turn into some kind of an animal. To save her baby from this fate, the mother dropped it to its death from Agua Fria Cliff above the springs. Some still hear the ghostly cry of the falling baby on nights when the wind whines among the cliffs.

On the cliff wall above Agua Fria Springs are many paintings. There are also numerous flakes of flint, obsidian, jasper, and chalcedony (all of which are fine-grained siliceous rocks). Much archeological digging has been done at the site. Raht (1963) described the remains of a probably prehistoric system of irrigation ditches near here. Omar Kay, the Soil Conservation Service district conservationist in Alpine, reports that the flow was reduced to 1.3 lps in a drought in the late 1940s when a well was dug adjacent to the springs. In 1976 they discharged 3.2 lps of fresh water. This supplies stock troughs and a ranch house, with the excess flowing for about one kilometer downstream. The water flows from the Aguja sandstone along a fault adjacent to the igneous intrusion. It is a very pleasing spot, with a grove of willows and large boulders surrounding the water-cress-laden springs below the cliff.

Twelve kilometers northwest of Agua Fria were the small **Alamo de Cesario Springs (120)** which fed the creek of that name. A. W. Spaight's 1882 *Official map of the state of Texas* called them **Alamos del Saccarea**, and F. de I. Carrington's 1881 map labeled them **Alamo de Sacaria**. The springs trickled from Eocene Duff tuff beds in a painted desert of every color of the rainbow. Nearby are the remains of an old windmill which probably helped to dry up the springs. No *alamos* (cottonwoods) have survived — only salt cedars and mesquites.

Whirlwind Springs (16) are 50 kilometers south of Alpine on the Lykes Brothers 0-2 ranch, leased by Red Nunley, at latitude 29°55' and longitude 103°37'. They were called **Chopwind Springs** on Livermore's and Butterfield's 1881 *Military map of the Rio Grande frontier.* They trickle from a massive conglomerate in the Eocene Pruett formation. A cavern has been dug out beneath the conglomerate, in which the springs form a pool. Some old adobe ruins in a mesquite grove are nearby. The discharge was 0.20 lps on May 15, 1976, supplying a steel tank containing frogs and coursing 300 meters before disappearing. On May 19, 1978, the yield was 0.13 lps with no overflow from the tank.

Other similar small springs occur nearby. **Cottonwood Springs (122)** (one of many Cottonwood or Alamo Springs in Brewster County) are four kilometers west of Whirlwind Springs. They were depicted on Joseph Johnson's 1850 map of west Texas. Livermore's and Butterfield's 1881 map portrayed them as **Hughes Springs.** They originate from the Oligocene Cottonwood Springs basalt. On May 19, 1978, 0.85 lps was flowing to a tank containing many frogs 1.5 kilometers downstream, whence it was pumped to other parts of the ranch.

Duff or **Diff Springs (123)**, nine kilometers west-northwest of Whirlwind Springs, rise from alluvial sand and gravel where Duff Creek reaches an outcrop of basalt. An 1887 General Land Office map of Foley County showed them as **San Aparicio Springs**. R. A. Thompson's 1908 *Railroad and county map of Texas* called them **Ojo de San Aparieto**. **Davenport Springs (121)** are 12 kilometers west of Whirlwind Springs. None of these springs flow as abundantly as formerly, because a large number of wells have been drilled in the area since the 1940s.

Calamity Creek 10 to 25 kilometers south of Alpine is fed by a large number of small springs flowing chiefly from the Cottonwood Spring basalt. Most emerge on the Zeb Decie ranch (126) south of Alpine, the Meriwether ranch managed by Don Coleman (125), William Sohl's Red House ranch (124), and the Luther

Anderson ranch (129). The springs harbor abundant yellow cress, ferns, and small fish.

Calamity Creek's waters were formerly sufficiently abundant to support irrigation of crops on several ranches. Now the flow, although smaller, is sufficient to cause the creek to run usually to a point five kilometers downstream from the Highway 118 crossing. At this crossing, which is upstream from the junction with Ash Creek, the discharge was about 6.0 lps on May 16, 1976, and July 25, 1977, and 3.3 lps on May 19, 1978. On July 25, 1977, Ash Creek was yielding about 5.5 lps at its junction with Calamity Creek. Highly prized plume and moss agates may be found in this area.

Very near the Presidio County line and four kilometers south-southwest of Paisano Peak are **Paisano (Roadrunner) Springs (133)**. They are on Keith Morrow's ranch. Keith Graham, caretaker of the nearby Baptist encampment, guided the writer to them. Bedrock mortar holes and crown-polished boulders are nearby. The water issues from Tertiary volcanic rock in a craggy ravine at an elevation of 1,555 meters. On June 23, 1979, there was seepage into a pool containing frogs.

The springs were portrayed on the Bureau of Topographical Engineers' 1857 *Map of Texas and part of New Mexico*. Paisano Springs were undoubtedly important to travelers on the Indian trail, later the Chihuahua road, through Paisano Pass. The six-meter-deep hole is still popular for swimming. Pink echeverias, cloakferns, milkweeds, and lichens decorate the rocks. Live oaks, cedars, and algerita shade the site. Deer, javelinas, mountain lions, bobcats, gray foxes, and some red foxes frequent the springs. Several other springs still trickle in the vicinity.

Eight kilometers southwest of Alpine, in Ranger Canyon on the Joseph Lane ranch, are **Ranger Springs (17)**. They trickled 0.50 lps of water from sand and tuff in the Duff formation in 1976. This is a beautiful secluded spot with a large grove of trees and rhyolite boulders, among which deer may frequently be seen. Some of the boulders are crown-polished. The springs supply water to the 13-section (34-square-kilometer) ranch. Gray wolves still roam this area.

Kokernot Springs (18) were at Kokernot Lodge and Park in northeast Alpine on Highway 223. These historic springs are well described by Raht (1963):

> While the Kokernot Spring was known to the whites as **Burgess' Spring**, in the lingua franca of the Indian war trail, it has become known as **Charco de Alsate**. Usually the Chihuahua Trail ran through Fort Davis, but after John Burgess had opened up the route through Paisano Pass, this new route became quite popular among the more intrepid of the trail drivers. It was the same route used by the Jumano Indians, by de Vaca, by de Espejo, and Mendoza, in their travels through the Big Bend, as well as being the great Indian thoroughfare of the middle nineteenth century. Perennial rains had formed a chain of water holes, or charcos, at the spring, which led the Indians and Medicans to refer to that watering place as the Charco. The name Charco de Alsate was given to it because the most powerful chief on the war trails at that period was the Apache chief, Alsate — a leader who ranked with Bajo el Sol, Guera Carranza, Victorio and Geronimo, the ablest Indian generals of their time.

Juan Domínguez de Mendoza's account of his visit here in 1684 is as follows:

> . . . This district consists in parts of rock and knolls, and in parts of plain without rocks. It is at the foot of a hill which is toward the east. On the south rises a little arroyo which flows toward the north. There is water sufficient for any herd of horses. The pastures are good, but there is little wood and that which there is at a distance is oak. It was named San Lorenso because of the fire which threatened to burn us by night, but the damage which might have occurred was prevented by the circle which was made round about. The cross was not erected because there was no timber of which to make it.

More than a century later, in 1787, the Spanish general Jose de Ugalde attacked a village of Mescalero Apaches living at **Aguaje de San Felipe,** believed to be Kokernot Springs.

In 1861 the springs were used by the cavalry. They were for a time called **Burgess Water Hole**, for John Burgess who around 1868 stopped here on cattle drives to Mexico. According to Raht the grass was knee to belly high on the horses in 1878. H. L. Kokernot later gave the springs site to the city of Alpine. The recorded discharges were 14 lps on October 31, 1929 and 25 lps in 1947. The springs ceased flowing around 1950, because of the more than 400 pumping wells in the city of Alpine, which have greatly lowered the water table. Large cottonwood and elm trees still stand at the site. Artificial fountains and pools have been installed, using city water, but the natural beauty of the place has been sacrificed to "progress." Historical markers are nearby.

Leoncita (Lioness Cub) Springs (19) are on Ben Tanksley's ranch northeast of Alpine. In 1976 they poured 4.5 lps of fresh water from Cretaceous rocks adjacent to an igneous uplift, giving rise to Paisano Creek. Some old maps portray these springs as **Barrancas (Ravines) Springs**. Others show them as **Barnabas Springs**, probably a variation of Barrancas. Gen. Henry Sibley's command in 1861 called them **McColmes Springs** (Faulkner, 1951). Freighter August Santleben, stopping here in 1869, called them **Leon Seto** springs, and mentioned that Joe Head settled here two years later. Many stone projectile points and metates attest to the springs' long usage by prehistoric people.

Mendoza was probably taken to them by his Indian guides in 1684, describing them as follows (Bolton, 1908):

> . . . we remained in this place, which was named **San Pedro de Alcantara**. It is distant from the place of Los Reyes about six leagues. This detention was at the general request of the Indians of the Jumana nation and the others who came with them, who were constrained by the necessity which they suffered because of not having any food to eat; for this reason they arranged to surround the deer and other kinds of animals, in order to relieve the necessity which we all shared. This place has a beautiful plain which extends eastward, and toward the north are some hills without any trees. From the slope of a hill issues a beautiful spring, round about which there is fine black land. The place has little wood.

In 1859 Lt. W. H. Echols stopped at Leoncita Springs. He described the place as "a beautiful spring in the Arroyo de las Vaccus [Vacas]." From 1857 to 1883 there was a stage stand here on the San Antonio-to-El Paso route through Musquiz Canyon. More recently a grass fire starting here was halted only by a wagon road near Fort Stockton, after cutting a wide swath 64 kilometers long.

The water is now collected in a small reservoir filled with cattails. The overflow passes through a private picnic area with tables. The site is authenticated by a historical monument.

BRISCOE COUNTY

Most of the springs in Briscoe County issue from Tertiary Ogallala sand and Quaternary sands and gravels such as the Tule, in the western part of the county. The Ogallala formation dips gently toward the east, allowing water to move through it at a rate of around 100 meters per year. Beneath the Ogallala is the Triassic Dockum (Santa Rosa) sandstone and conglomerate. As it is hydrologically connected with the Ogallala, ground water often sinks through the Ogallala into the Dockum formation, from which it issues as springs. The eastern portion of the county is underlain by Permian Quartermaster, Cloud Chief, and Whitehorse formations. Sandstone and gypsum in these formations give rise to small springs.

Around 15,000 years ago, when Clovis men frequented the springs, and until about 100 years ago, nearly all of the creeks ran continuously. Springs flowed up to the caprock and above it in some places. The lakes were full, providing excellent havens for ducks, geese, and other waterfowl. Many remains of the mammoths which were hunted by the Clovis people have been found in the county. Hearths, projectile points, paintings on the rock cliffs, and knives and scrapers of Clovis to historic age indicate that the county's springs were always popular living areas. There is much evidence that Coronado in 1541 followed the surging waters of Tule Creek, into Palo Duro Canyon, stopping

Shelter and picnic tables at Leoncita Springs.

at Hulsey Springs (5-7). Near here he was introduced to a, Texas hailstorm "with hailstones as big as bowls," which injured many horses and broke all of the army's pottery and gourds.

The spring-fed streams supported a unique ecosystem. Panthers, bears, wolves, antelope, deer, badgers, wildcats, buffalo, and prairie chickens were abundant. Wild plums and grapes were plentiful. Most of these animals and plants have now disappeared along with the springs. But former spring-fed streams may usually be recognized by the cottonwood, willow, salt cedar, and hackberry trees, and rushes, which replace the cedars and mesquites prevailing elsewhere in the canyons.

Man's activities, such as irrigation pumping, have caused a severe decline in the water table. Near Quitaque the decline was as much as 9.0 meters between 1960 and 1969. This is the major cause of the failure of most springs. Most streams are now dry. Some, like Tule and Las Lenguas Creeks, still trickle weakly.

In addition, catastrophic gully erosion has occurred, especially in the Tule sand. Much land was plowed which should never have been, and the rest was overgrazed. As a result creeks were choked with sand and silt and many springs were buried.

The water from the Ogallala and Triassic formations is generally of a calcium bicarbonate type, fresh, very hard, and alkaline. The content of silica and fluoride is usually high. The water from Permian formations is usually a calcium sulfate type, reflecting the presence of gypsum, slightly saline, very hard, and alkaline. Some Permian spring waters are very saline, containing large amount of sodium chloride.

Most of the writer's field studies were made during the period September 1-6, 1978.

Hulsey Springs are just below the caprock in Palo duro Canyon at an elevation of about 945 meters, 15 kilometers northeast of Vigo Park. They are on W. K. Hulsey's ranch, managed by Archie House. They are rather inaccessible and can be reached only by walking and climbing. Many Indian artifacts have been found here. The springs support willow and cottonwood trees, cattails, rushes, grapevines, and sunflowers. Frogs chirp in the water and wildlife is abundant in the vicinity. Raccoons and skunks frequently raid House's chicken yard. The springs run one to two kilometers on Deer (5) (the northernmost), Turkey (6), and Cedar (7) Creeks. Those on Turkey Creek feed a lake which supports 2.5 kilogram bass and 7 kilo catfish. Discharge records in liters per second follow:

	Sep. 9, 1946	June 23, 1971	Sep. 4, 1978
Deer Springs	19	1.7	1.3
Turkey Springs	25	3.1	2.5
Cedar Springs	16	1.4	1.0

Joe Ed Burnett, who lives 2.4 kilometers southwest of Deer Springs, states that when he was a boy in the 1930s he could hear the roar of the falls below Deer Springs at the house. The water drops about four meters here. Now, of course, the trickle of water which passes over the falls cannot be heard more than a few hundred meters away.

Florenz Springs (14) are in a remote area in northeastern Briscoe County at latitude 34°42' and longitude 101°09'. They are on Billy Cogdell's Tule ranch, managed by Russel Baldwin. They are situated one kilometer southwest of the ranch house on sand-filled Mitchell Creek. G. L. Gillespie depicted them on his 1875 *Map of portions of Texas, New Mexico, and Indian Territory*. On September 6, 1978, 0.20 lps trickled from an outlier of Ogallala sand on top of Dockum sandstone, which dips upstream (northeast). The water ran 400 meters before sinking into the sand. In winter it runs 200 meters farther to feed an earthen tank downstream. Many frogs, tadpoles, and water striders dart in the pools which are fringed with raccoon and skunk tracks. A grove of willows and cottonwoods shades the creek, where cardinal flowers and rushes grow.

Martin Springs (4) were eight kilometers southwest of Brice on Aubrey Martin's farm. They formerly fed a lake, which was drained in 1950. On January 22, 1969, they discharged 0.95 lps, but are now dry. The water was too salty for livestock to drink, containing 10,500 milligrams of dissolved solids per liter.

Burson Springs (1) are 15 kilometers northwest of Turkey. They feed the 2.5 hectare Burson Lake, formerly maintained as a hunting and fishing resort. Some seeps from Quartermaster sandstone and shale still exist beneath the surface of the lake, which is fringed with cattails.

Bell Springs (3) are 10 kilometers northwest of Turkey near the Hall County line on Cody Bell's ranch. Flowing into Lost Mule Creek at an elevation of 639 meters, they produce about 1.6 lps in summer and considerably more in winter. The water contains much sodium chloride (see table of Selected Chemical Analyses) which is derived from Permian shales. These and other nearby springs have been estimated to contribute about 250 tons (227 metric tons) of salt per day to the Little Red River.

Gyp Springs (12) are nine kilometers north-

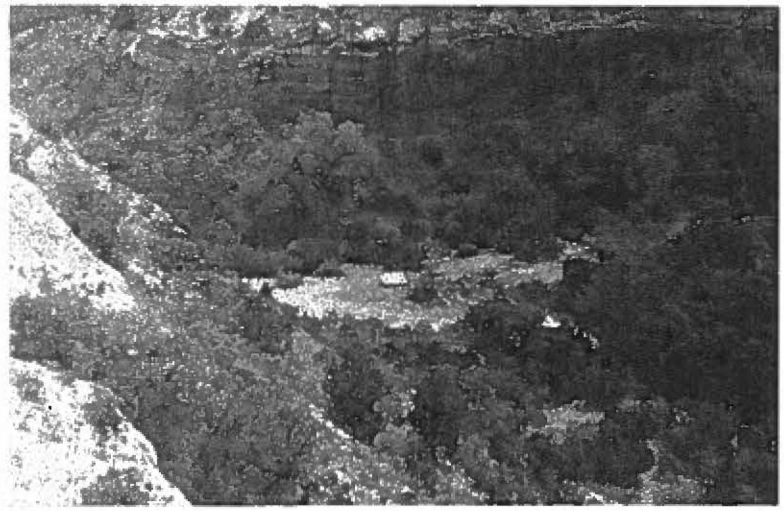
northwest of Quitaque in Caprock Canyons State Park. In 1978 they were difficult to reach over a 4-wheel-drive road which wound through Permian shale badlands. The springs pour from a massive bed of Quartermaster gypsum where it dips to the west beneath the alluvium of the South Prong Little Red River. Eagles Point is one kilometer southeast. Above the springs are bluffs of red sandstone laced with veins of white selenite. Minnows swim in the pools, with cedars, salt cedar, and a few algerita shrubs on the adjacent slopes. On April 21, 1969, the discharge was 6.7 lps. On September 5, 1978, it was 0.12 lps which ran about one kilometer before disappearing. The slightly saline water contains much calcium sulfate.

Three kilometers southeast, near the park headquarters, is Lake Theo. A strong spring formerly flowed where the lake now stands, but it is believed to be only a seep now. On the bluff above this spring Folsom people some 10,000 years ago butchered very large bison of a now-extinct species.

Four kilometers upstream from Gyp Springs on the South Prong Little Red River are **Haynes Springs (2)** at the Haynes Boy Scout Camp. They issue from Triassic sandstone but originate in the Ogallala sand above. On March 21, 1969, they produced 2.5 lps of fresh water. On September 2, 1978, the flow was 0.35. According to Scoutmaster Jimmy Stuart of Littlefield, the springs now dry up during the summer and were just beginning to run again on September 2 with the slackening of irrigation pumping. This fluctuation of flow usually precedes by five or ten years the complete failure of springs. The minnows are gone, since the flow is now intermittent. Water striders still survive, and cottonwoods and grapevines fringe the stream.

Cottonwood and **Red Rock Springs (15)** are seven kilometers west-northwest of Quitaque on Little Cottonwood Creek. They are on Walter Graham's, J. T. Rogers', and Gerald Smith's ranches. They feed Graham and Cottonwood recreational lakes. They were probably used by mammoths which roamed the area some 15,000 years ago. A mammoth tusk was found nearby. Indians later carved designs on the sandstone cliffs and left burned-rock middens and projectile points. More recent names and dates have also been chiseled in the rock.

The water issues from Triassic Dockum sandstone, but probably originates from the Ogallala sand above. On July 10, 1979, 1.3 lps was passing the lower (Cottonwood) lake. Rough calculations indicate that as much as 25 lps was being consumed by evaporation. According to Smith, a much larger flow passes the lakes



Canyon at Haynes Springs.

in winter. Bluffs of red sandstone tower over the creek. Willows and some salt cedars fringe the banks. Turtles, frogs, fish, dragon flies, killdeers, and doves make their home among the cattails.

Las Lenguas Falls, fed by springs (13), are 14 kilometers west-southwest of Quitaque on Las Lenguas Creek. The name is Spanish for *The Tongues*, which reportedly refers to the many tongues spoken by the Comancheros (New Mexico traders) and the Comanches, Kiowas, and Apaches whom they met here. It could on the other hand refer to the tongues of the river or to buffalo tongues, which were considered a delicacy in early days. It has been variously misspelled as Los Lingos, Linguish, and Linquist.

The Comanchero trade here with the Indians began in the 1700s and reached a peak in 1864-68. The Indians traded stolen horses, cattle, and sometimes human captives for guns, flour, and other items. The place was reportedly known as the "Valley of Tears" because it was the last stop on the way to oblivion for captive women and children. A Mexican village which grew up here was destroyed by cattle ranchers in 1878.

Las Lenguas Springs pour from Ogallala sand upstream from the falls. On October 19, 1967, 19 lps passed over the falls at an elevation of 845 meters. On September 5, 1978, the flow was 1.9 lps. The water falls about five meters over a massive red sandstone cliff into a pool 50 meters in diameter (See Plate 16,e). In the cliffs are large rockshelters which undoubtedly housed an ancient people. The walls, adorned with maidenhair ferns, bear petroglyphs and innumerable more recent names and dates. A swale of swamp grasses borders the stream. Nearby are some bedrock mortars which were used by prehistoric people in preparing food.

The falls are on Mrs. Nona Lemons' property in a remote area. They can be viewed from W. C. Baird's ranch. Nearly all residents of the area have spent happy days picnicking and swimming here, but the place has now been closed to the public. This is understandable, as many people abused the privilege by camping overnight and leaving much trash. But with the gradual failure of the springs above, the falls are no longer spectacular. Perhaps the public is not missing very much in being denied entrance.

Rock Springs (11) are 12 kilometers west-northwest of Silverton at the head of Rock Creek. They are on Billy McDaniel's property, leased by Mrs. Roy Mayfield. This was formerly a very popular fishing hole, bordered by caliche bluffs and containing much water milfoil. The pool has now largely been filled by sediment from disastrous gully erosion in Tule sand and silt. The silt, up to three meters deep, is very weak, and probably has trapped many a cow. On September 6, 1978, the discharge was 0.36 lps. The springs probably receive some recharge from a large lake just upstream. Raccoon tracks are numerous in the mud surrounding the pool, amid rushes and snow-on-the-mountain flowers. Cottonwoods and willows shade the site.

Three kilometers north-northeast of Rock Springs was **Mayfield Spring (10)** on G. Mayfield's ranch. Here in 1891 G. B. Mayfield built a dugout, the remains of which may still be seen, at a "cool, natural spring." Plums, grapes, and mulberries were abundant. There is now only slight seepage from Tule sand and a pool of water below a caliche ledge. Grapevines and hackberry trees mark the spot. G. Mayfield also remembers a fine spring-fed swimming hole in 1912-15 on Rock Creek to the west. Rock Creek ran for three kilometers the year around at that time.

Just east of Highway 207 and on the south side of Tule Canyon were other springs (8) on G. Mayfield's ranch. Issuing from Tule sand and Dockum sandstone, they discharged 13 lps on September 10, 1946. The cedar-dotted site has been dry since about 1966.

About one kilometer northeast were some other good springs (9) on Jarus Flowers' ranch. They poured out 9.5 lps on September 10, 1946, but are now dry.

BROOKS COUNTY

Brooks County's springs and seeps flow or did flow chiefly from Pliocene and Quaternary sands. These formations generally dip toward the east-southeast at 3 to 10 meters per kilometer. Salt domes complicate the subsurface structure locally and influenced the location of some springs and seeps. In 1840 George Bonnell wrote:

> The Los Olmos is a stream of sixty miles in length, which enters the Lagune de la Madra about twenty miles south of the mouth of the San Gertrudes. Like the San Gertrudes, it runs through a rich musquit prairie, but one that is almost destitute of timber. Upon this stream there was once a considerable Spanish settlement, but the country is now deserted.
>
> A few miles south of the Los Olmos, commences a sandy barren ridge, known by the name of the Wild Horse desert. It extends from the coast nearly one hundred miles inland, and is from ten to sixteen miles in width. It contains but little vegetation, except a coarse sedge grass, and a few live oak bushes. It is so perfectly sterile and dry that it has even been deserted by insects and reptiles, and in passing over it the traveler scarcely meets with a living thing.

The Wild Horse Desert, as Bonnell calls it, is now known as the Sand Plain. It is not as dry as he imagined. There are still several fresh-water lakes in the area, and at that time there were more. Live-oak motts are numerous in the sandier parts of the county.

Flowing wells, many of which still flow, have wasted much ground water. Pumping wells and overgrazing have also contributed to a general lowering of the water table. From 1933 to 1965 the water table in the Goliad sand declined as much as 33 meters. As a result many springs and lakes have dried up. During the severe drought of 1892-94, the flow of most springs was temporarily interrupted.

The springs and seep-fed lakes supported an abundant ecosystem of interdependent plants, trees, fish, amphibians, reptiles, crustaceans, insects, birds, and mammals. As the springs and lakes failed, most of these plants and animals disappeared.

The water is generally of a sodium bicarbonate type, fresh or slightly saline, very hard, and alkaline. The content of silica is usually high. There is evidence of oil-field contamination by sodium chloride through open pits and inadequate well casings.

Most of the writer's field studies were made during the period March 3-8, 1979.

Near the junction of Highway 285 and 339 at the Duval County line are **Palo Blanco (Hackberry) Springs (7)**, the only flowing springs remaining in the county, at an elevation of about 95 meters. They are on the Mills Bennett Palomas ranch, managed by David Garcia. On March 5, 1979, 0.18 liter per second trickled from Quaternary sand down Palo Blanco Creek to feed **Charco Redondo (Round Pool)** a short distance downstream. Six kilometers farther downstream is seep-fed **Charco De Late**. Possibly this was originally called *Charco Delante* or Front Water Hole.

Dark gray soils on the valley slopes indicate that Palo Blanco Springs were once more abundant and numerous. The water appears to have been contaminated but has now partially recovered its original mineral content. (See table of Selected Chemical Analyses). In 1933 water taken from a one-meter-deep test hole near the springs was found to contain 6,000 mg/l (milligrams per liter) of chloride. On March 5, 1979, the writer found only 1,800 mg/l in the springs' water. Minnows play among the marsh purslane and small rushes.

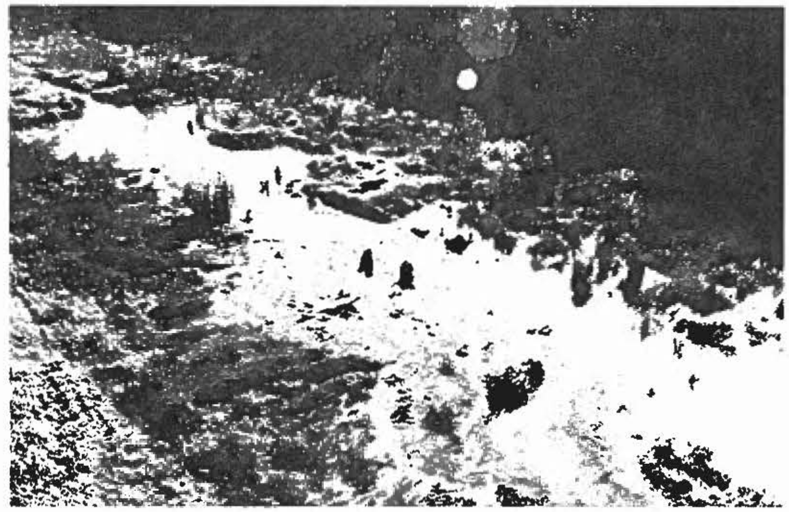
Three kilometers northwest of Falfurrias on Cibolo Creek, a tributary of Palo Blanco Creek, is another **Charco Redondo (1)**. It was depicted on an 1863 General Land Office map of Starr County. According to Antonio Recio of Concepcion, there were running springs here also until about 1964. The charco still is fed by seepage and contains dark water, probably colored by organic matter. It is now about 500 meters long and not round as the name implies. Frogs jump among the water hyacinths and duckweed. Willow and hackberry trees edge the pool. Yellow buttercups and wild indigo and blue-violet phacelias adorn the adjacent slopes.

Farther down Palo Blanco Creek, three kilometers southeast of Falfurrias, was **Charco Salado (Brackish Pool) (9)**. This water hole, on L. J. Hauser's ranch, was originally seep-fed. The creek was dammed to form a lake here in the 1920s, which is now maintained partly by waste from Falfurrias. Ducks, turkeys, javelinas, and skunks are numerous.

Southwest of Falfurrias is *Arroyo Baluarte* (Bulwark Creek) (8), another tributary of Palo Blanco Creek. This creek, largely on the Mills Bennett estate, probably held water constantly at one time, especially near the Alta Verde salt dome 25 kilometers west-southwest of Falfurrias. Areas of dark gray soils indicate the location of former seepy areas along the valley. But it has long been dry.

On another tributary of Palo Blanco Creek, *Una de Gato* or Catclaw Creek, was the formerly seep-fed *Hedionda* (Stinking) Lake (6). It was five kilometers southwest of Falfurrias on the Solomon ranch. Several former lakes in this vicinity were revived briefly after Hurricane Beulah's rains in 1967, but they have since dried up again.

All of these tributaries of Palo Blanco Creek once contributed spring flow to *Laguna Salada* (Brackish Lake) southeast of Falfurrias. In early days the lake was kept full and overflowing constantly, the surplus passing downstream into Kenedy County and Baffin Bay, according to Hector Lopez of Alice. The lake was much less saline then because of the inflow of spring water, and doubtless supported far more wildlife than at present. During Hurricane Beulah the lake did overflow. On March 6, 1979, its surface was about 75 percent covered, but in September, 1978, it was dry.



Palo Blanco Springs.

On the south side of the lake and 0.8 kilometer southeast of a gypsum mine are **Blood Springs (10)** on Garland Lasater's ranch. According to W. P. Wright, Sr., from 1910 to 1930 the springs rose from a cave and deep pool in gypsum. The red iron-bearing water gave them their name. The pool partially filled with sediment in the 1940s, but there is still some seepage. About one kilometer north of Blood Springs is another, deeper pool 100 meters in diameter. Wright used to swim in this seep-fed pool.

Four kilometers northeast of Falfurrias was the 1830 *Los Olmos* (The Elms) settlement on Los Olmos Creek (2). At that time and until about 1919, according to Ramon Navarro of Falfurrias, Los Olmos Creek flowed constantly, being fed by very small springs and seeps. On March 3, 1979, there were pools of water along the creek, fed in part by salty seepage. Dark soils indicating former swampy areas are now buried beneath modern sediment along the creek.

In the extreme northeast corner of the county is Paisano (Roadrunner) Creek. Here on March 6, 1979, were seep-fed pools (11) in Quaternary sand containing minnows, algae, and swamp grasses. Yellow buttercups cover the adjacent slopes in spring.

Laguna Grande (Big Lake) (3) is just north of Rachal on Hector Cantu's ranch. Alonso de Leon, Jr., probably stopped here in 1687 on his trip to Baffin Bay. Many ducks gather on this fresh-water, seep-fed lake. It is no longer "big," but according to Cantu it very rarely dries up. *Laguna Salada* (Brackish Lake) was a similar lake two kilometers southeast of Encino. Cattle were gathered here for the drive to San Antonio, according to Cantu. This lake dried up in the 1930s.

San Francisco Springs (5) were 13 kilometers west-southwest of Rachal on Alfredo Silvas' ranch. They were on the old La Mesa San Francisco grant. The U. S. War Department depicted the springs on its 1854

(?) map, *Routes of military reconnaissances in the military department of Texas.* According to Silvas, until the 1920s the springs, from Quaternary sand, fed a series of ponds downstream, each about 1.5 meters deep. He used to swim in these ponds, where mudpuppies were numerous. Three kilometers west-southwest of the main springs was a spring-fed lake, too deep to cross on a horse.

According to long-time resident Bernardo Solis, before 1900 the San Francisco Springs flow ran southeastward through Tasajal Lake and into Callo Pedrones in Hidalgo County. The enormous rains of Hurricane Beulah in 1967 briefly revived the springs, but they soon dried up again. Now there is only a series of depressions along the draw containing yellow buttercups and white prickly poppies in spring, along with the usual brush. Many windmills pump nearby.

Farther west, 10 kilometers north of Kelseybass pumping station, were the similar **Las Animas (The Spirits) Springs (4)**. They were portrayed on early maps of the area, when they flowed on Las Animas ranch. Now the site is on Hector Lopez's ranch. Like San Francisco springs, they stopped flowing around the turn of the century and are now filled with sand. In recent years wet spots have developed here, possibly because the mesquite trees and other brush, which consume much ground water, have been removed. About four kilometers northeast is a flowing well, fed from Goliad sand 110 meters below the surface.

BURNET COUNTY

Burnet county has a very interesting variety of springs because it possesses a large assortment of geologic formations, ranging from very old (Precambrian) to modern alluvium. In the western part of the county, near the Colorado River and its lakes, are many medium to moderately large springs. They issue from cavernous limestones, chiefly the Ellenburger and Marble Falls. Early Americans have lived at these springs off and on for at least 12,000 years. Clovis-like spear points associated with the remains of mammoths and river clams were found in the area later inundated by Granite Shoals Reservoir (whose name has now been changed by politicians to Lake LBJ). By 1851, there were white settlers near all the springs in the county.

The spring waters of the county are mostly of the calcium bicarbonate type, fresh, very hard, and alkaline. In 1874 it was reported that some springs near Burnet contained asphalt. Most of the writer's field studies were made during the period August 1-6, 1975.

Just west of Burnet and north of Highway 29, a small tributary enters Hamilton Creek from the west. About 50 meters upstream from its junction with Hamilton Creek is **Soldiers Spring (4)**, which served Fort Croghan, about 600 meters southwest. Finding the spring is difficult and involves wading through two-meter-high weeds. The fort was active from 1849 to 1855. The Burnet County Historical Society maintains the fort and has moved several other historic buildings onto the site. The springs issued from Ellenburger limestones at 0.95 lps in 1975.

Big Springs (5) are 6 kilometers west of Burnet on Spring Creek. They include the smaller **Thomas Spring**, which is still at the spring house of the 1864 Frank Thomas homestead. They flow from a fault in Ellenburger limestones. They produced 30 liters per second on August 16, 1961, and 8.2 on August 2, 1975.

Seventeen kilometers northwest of Burnet on George Nalle's Morgan Creek ranch, leased by Clay Lawson, are **Persimmon Springs (13)**. They feed the North Fork of Morgan Creek. An Indian village was once located here. In early settlement days the springs were very popular for outings. Guy Green, who owns the lower portion of the creek, attended a barbecue here in 1908. Large persimmon and pecan trees still stand at the springs. Minnows feed among the water cress, and wild turkeys roam the area. Drinking cups are kept at the main spring, which boils from a cavity in Ellenburger limestone adjacent to a rock bluff.

On June 25, 1978, after several months of very dry weather, the discharge of Persimmon Springs was still 3.5 lps. Other springs such as **Mud Spring**, two kilometers south-southwest, maintain the flow of North

Arden Poole at Persimmon Springs.

Morgan Creek to its mouth, where it enters Lake Buchanan. Here the discharge was 2.7 lps on this date.

Boiling Springs (12), also on the Morgan Creek ranch, are 13 kilometers northwest of Burnet on the South Fork of Morgan Creek. These springs, which gush from a deep fissure in the Ellenburger limestone, are the best on the ranch, according to George Nalle. A small dam once existed here, forming a pool deep enough to swim horses in. A hydraulic ram formerly pumped the water. Minnows and turtles hide in the cattails, while killdeers screech overhead. Live oaks, sycamores, and willows are numerous. These and other springs, some on Otis Baker's ranch downstream, maintained a flow of up to 1.7 lps on June 25, 1978, on most of South Morgan Creek. Only a trickle was reaching Lake Buchanan, however.

Tanyard Springs (17) are near the upper end of Lake Buchanan and thirteen kilometers west-southwest of the Naruna community. They are most easily reached through the Greenwood ranch, a guest ranch and game preserve owned by Ben Carpenter. Faustino Torres, son of the ranch manager, guided the writer to the springs by boat. A leather tannery was once located here.

On August 20, 1978, after much dry weather, Tanyard Springs flowed 0.20 lps from the Tanyard formation of the Ellenburger group, running 50 meters before disappearing. Water cress is abundant, and pecan and sycamore trees shade the springs. The water is used by a hunting camp. About 1.6 kilometers north was the Tanyard crossing, which followed a geologic fault in the rocks across the river. It is now beneath Lake Buchanan, built in 1937. Other springs are numerous in the area. They include **Greenwood Springs** three kilometers north and **Wolf Springs** one kilometer south.

Patterson Springs (10) are in the northwest corner of the county, at latitude 31°00' and longitude 98°24', on the E. G. Thompson ranch. Duard Wilson of Naruna kindly guided the writer to these beautiful springs, which pour from a fault in massive Ellenburger limestone. On May 22, 1977, the main spring discharged 2.5 lps, and several smaller ones totaled 3.0. According to Wilson the main spring never fails, but the smaller ones do during dry spells. They flow amid water cress, pennywort and maidenhair ferns in a grove of pecans, live oaks, cottonwoods, mulberries, and algerita shrubs. Pedro Vial may have stopped here in 1786 en route from Presidio Bexar to the Taovayas village on the Red River. An old wooden watering trough, long since rotted away, is still outlined by a thick layer of travertine deposited from the overflowing water.

Two kilometers southeast of Briggs were **Gum Springs (14)** on Charles Hasty's farm. The first settlers in the area gathered around the springs in the 1860s. In the 1880s a school, church, and cotton gin used the water. The water issued from Edwards and associated limestones into a hollow log with a wooden spout, according to Hasty, who arrived here in 1908. The springs were adjacent to an old road, now abandoned, and were much used by residents of the area. Other springs also trickled nearby in the headwaters of Berry Creek. A large swamp surrounded them, with many deep holes along the creek.

In 1915 an irrigation well was dug at Gum Springs. Soon afterward the springs dried up. The swamp was drained in 1951 to provide more agricultural land for our ever-growing population, at the expense of the wildlife of the area. Black soils still mark the swamp's former location. The spring area was later covered with about 3 meters of sediment from upstream erosion. Some live pools of water still exist along Berry Creek near the former springs. Turtles, nutria, and two-kilogram bass live in the pools. Wild turkeys may be found in the willow groves, and bluebells bloom in the adjacent fields.

Eleven kilometers northwest of Bertram is the 1853 Strickling townsite, indicated by a historical marker at latitude 30°51' and longitude 98°06'. The town was named for Martha Webster Strickling, a survivor of the 1839 Webster massacre near Leander. The weak spring (6) which served the town may still be seen on the north bank of the North Fork San Gabriel River just east of Highway 1174. In 1975 it flowed 0.19 lps from the Glen Rose limestone of the Trinity group.

About 2½ kilometers east of **Strickling Spring** is **Black Spring (7)**, which also flows from the Glen Rose, at 0.25 lps in 1975. It was used by Black's Fort, an unofficial fort 300 meters south, which displays a historical marker. The fort was built by William Black in 1855 and used until 1868, when the Indians in the area were moved to reservations. The stone walls of the fort still stand.

Oatmeal Spring (8) is six kilometers southwest of Bertram and 2 northeast of the Oatmeal school, which has a historical marker. It flows from the Glen Rose limestone in the channel of Oatmeal Creek. Along with other small springs it supplied drinking water to the town of Oatmeal when it was settled in 1849. It is surrounded by a circular wall. When the writer visited it on August 2, 1975, the creek was in flood, inundating the spring, but it was reported still to be flowing around 0.95 lps.

One kilometer northeast of Spicewood are the beautiful **Krause Springs (9)**, the main source of Little Cypress Creek. Formerly known as **Spicewood Springs**, they served as a water supply for the settlement of Spicewood. The thousands of wild turkeys that once fed in this area gave their name to Turkey Bend of Lake Travis to the northeast. The springs issue at a relatively constant discharge (about 19 lps on August 3, 1975) from many openings in the Marble Falls limestone with deposits of travertine.

Krause Springs are listed in the National Register of Historic Places. Many flint projectile points and knives of various ages signify that this was a favorite living site for thousands of years. The flow is difficult to measure exactly, because so many springs cascade into a pool in Little Cypress Creek. Their elevation is about 225 meters. Some also bubble up through the bottom of the pool.

This delightful oasis has been preserved by the owner, Elton Krause, much as it was in days long gone. (See Plate 1, c.) The streams and pools are fringed with maidenhair fern, water cress, pennywort, elephant ears, and cannas. Enormous cypress trees as well as pecans and oaks provide much shade. The spring-fed swimming pool and picnic and camping sites are open to the public for a moderate fee. A metal staircase leads down to one of the waterfalls.

The recharge area is believed to lie a few kilometers to the west, where the water flowing in Little Cypress Creek crosses crevices and faults in the Marble Falls limestone, enters the cavernous aquifer, and moves underground to the springs.

Ebeling Springs (3), the source of Double Horn Creek, are about 11 kilometers south of Marble Falls, at latitude 30°28' and longitude 98°16'. They rise from two openings in a fault between the Ellenburger and Pennsylvanian Marble Falls limestones, flowing 48 lps in 1940 and 27 in 1971. Near these bold springs Jesse Burnham established a sheep ranch in 1855.

Holland and Sand Springs (1) include a number of small springs in the channel of Hamilton Creek five kilometers south of Burnet. They rise from Lower Paleozoic Ellenburger limestones, flowing 1.9 liters per second in 1975. A historical marker is located 300 meters east on the Burnet-Mormon Mill road. In 1847 a Texas Ranger station was located here, taking advantage of the then luxuriant wild hay for the horses. Samuel Holland in 1848 bought the land around the springs, becoming the first permanent settler in Burnet County. In 1849 the Ranger camp gave way to Fort Croghan in Burnet.

Felps Spring (2), moderately large, is 100 meters west of Holland Springs. **Horseshoe** and other small springs are nearby. From 1851 to 1853 a Mormon colony maintained a grist and saw mill and furniture-making shop at the picturesque Mormon Mill Falls 10 kilometers south. Felps Spring provided most of the water which powered the mill. The mill, the remains of which can still be seen, was operated by Noah Smithwick and others after the Mormons moved west. These springs have also been used for irrigation of crops. They also issue from Ellenburger limestones. The flow was 26 lps in 1961 and 32 in 1975.

At Marble Falls were **Sulphur Springs (15)**, on the north side of the Colorado River and just downstream from the Highway 281 bridge and the falls in the river. According to J. G. Michel, who lives nearby, many people came long distances to drink the water, which was believed to have healthful properties, and to fill jugs. There were two springs which flowed well. In 1951 the construction of Marble Falls Reservoir put about seven meters of water over the springs and also covered the upriver falls. The lake is drawn down each year or two for dock repairs and weed control, but not enough to uncover the springs.

Roaring or **Boil springs (16)** are four kilometers east-northeast of Kingsland on the Buckner Boys' Ranch. Located just east of Highway 2342, they issue from Ellenburger limestone at the Roaring Springs fault and flow across the granite to the west. According to Mrs. Emmett Lewis, a long-time resident, camp meetings were held in a brush arbor here as recently as the 1920s. On August 20, 1978, after much dry weather, there was a discharge of 0.73 lps, with no roar or boil. On November 11, 1978, the flow had declined to 0.51 lps. Minnows play among the milfoil in pools fringed with yellow water hyssops.

The similar **Williams Springs (18)** are on the fault two kilometers northeast, also on the Buckner Boys' Ranch. According to Mrs. Lewis, around 1918 the water ran over a kilometer, crossing Highway 2342 and feeding two earth tanks. The flow is much weaker now and does not reach the highway. Two kilometers east are Longhorn Caverns, which were dissolved out of the limestone by ground water similar to that in Williams Springs. Later the underground stream cut downward, leaving the caverns dry.

CALDWELL COUNTY

Most of the larger springs in Caldwell County discharge from sand and gravel of the Quaternary Leona formation. The remainder originate in the Wilcox sand of Eocene age.

The county's spring waters are generally of a calcium or sodium bicarbonate type, and are fresh to slightly saline, usually very hard, and alkaline. The chloride and nitrate content may be high.

Most of the writer's field studies were made during the period September 11-16, 1975.

Although mankind has lived in Caldwell County for thousands of years, the earliest settlement by Europeans was around 1820. By 1830 there were a few cabins and a trading post at Lockhart Springs (1), on the northeast side of present Lockhart. The springs were close to Plum Creek, where vast quantities of wild plums formerly grew. They were also quite close to the Battle of Plum Creek with the Comanche Indians in 1840.

Although the town is no longer called **Lockhart Springs**, the springs (1) still flow at various points from the sand and gravel of the Leona formation. Several fern-draped springs may be found in the City Park, with travertine deposits left by the precipitation of calcium carbonate from solution. In 1946 they flowed 6.3 liters per second and in 1975 they discharged 10 lps. Various other springs contribute to Town Branch. At the intersection of Pear and Little River Streets 3.5 lps issued on February 5, 1977, amid beds of water cress. On the same date springs in a cottonwood grove near North Blanco and Ash Streets, and near North Blanco and Pine Streets, were each yielding 3.0 lps.

The most important of the Lockhart Springs are **Storey Springs**, where Sam Houston spoke in 1857. They are used for minnow tanks at Matt's Bait and Supply Store at 310 North Commerce Street. On February 5, 1977, they were producing 3.2 lps from several openings amid water cress and water-shield beds. Philip von Kohl, chairman of the county historical committee, was very helpful to the writer in locating these springs. (See Plate 10,b).

The **Water Works Springs (2)** are a very interesting group of springs, actually wells now. The water flows from Quaternary Leona terrace gravel. As the need for water increased the springs, on the north side of Lockhart, were deepened between 1905 and 1948 in order to augment their flow. The pits range in size up to 10 by 66 meters, and in depth up to 8 meters. The water emerges at around 160 meters elevation.

In 1943 the water was found to be contaminated by brine from the Larremore oil field five kilometers northwest. The brine had been dumped into surface pits, whence it seeped into the Leona gravel and moved underground to the city's springs. After this practice was stopped, the quality of the spring water gradually improved. As shown in the table of Selected Chemical Analyses of Spring Waters, the chloride content at one of the springs decreased from 1,030 milligrams per liter in 1943 to 85 in 1951. Because of the susceptibility of these springs to contamination, the city of Lockhart has recently drilled several deep wells in the Wilcox formation. The old well-springs are now used only in emergencies. They are capable of yielding about 26 liters per second. However, when they are not pumped, there is little overflow from the pits.

The original white settlers at **Lytton Springs (7)** chose this spot because of its springs, which were just south of the present community. In 1709 the Espinosa-Olivares-Aguirre expedition probably stopped here. At this point the Wilcox sands were dammed up by an underground barrier of Midway clay, due to a fault or displacement of the strata. This forced the water to come to the surface as copious springs. A grove of very large trees still marks the site of the springs. When pumping wells nearby began to reduce the flow, a depression or pond was excavated at the springs. This probably helped for a time, but now only some seeps are left.

Soda Springs (5), on the east bank of Plum creek seven kilometers northeast of Luling, flowed 6.3 liters per second in 1946, but in 1975 were down to 0.13 lps. Many limonite (iron oxide) concretions are present in the sand at these springs. They were formerly widely used for medicinal purposes. Some old maps such as Gillespie's of 1876 depicted them as **Sour Springs**. In 1897 Peale called them **Sour Mineral Springs**. The name "Soda" reflects the high content of sodium carbonate in the water (See the table of Selected Chemical Analyses).

Sulphur Spring (6) was eight kilometers east of Luling, just east of the old Atlanta settlement, now marked only by a cemetery. It also was valued for its mineral water, but is now dry.

Mineral Springs (4) are near the church of that name, 12 kilometers south of Lockhart, on the south bank of West Fork of Plum Creek, about 250 meters west of Highway 671. These springs are also known as **Rogers**, and formerly **Cardwell, Springs**. Mr. Rogers once made mineral salts by evaporation of the spring water and sold them. The water was believed to have curative powers but was *strong, harsh, and unpleasant to taste*. Only some seeps remain today.

Boggy Springs (3), about four kilometers west-southwest of Lockhart, also flow from the sand and gravel of the Leona formation. The springs appear at the edge of the Leona formation where it lies upon

Midway clays. Here a large number of small springs form a boggy area several acres in area. Boggy Creek, which is formed by the springs, was named for this bog. The flow was 19 lps in 1946, 1.3 in 1964, and 10 in 1975.

Harper Springs (8) also flow from river terrace deposits, somewhat younger than the Leona terrace. They are located five kilometers northwest of Martindale, close to the San Marcos River. Their discharge was 9.5 lps in 1946 and 1.6 in 1963.

CALHOUN COUNTY

Springs have never been large in Calhoun County. There were formerly, however, many more of them than at present. The springs which do exist are apt to have a relatively short life, geologically speaking, because of the constant changes wrought by hurricanes and rivers in this area. Studies have shown that Pelican Island was 1.6 kilometers farther southwest in 1856 than in 1956, and that Matagorda peninsula did not exist 5,000 years ago.

The earliest users of the springs in Calhoun County were the tall Karankawas and their predecessors, expert fishermen who traveled the waterways and bays in dugout canoes or pirogues. One of the earliest European explorers was Rene Robert Cavelier, Sieur de la Salle, who landed with 300 colonists on the shore of Matagorda Bay in 1685. La Salle's naval commander intended to sail to Mobile Bay to obtain drinking water for the party, but thought it to be much closer than it actually was, and never reached it. Partly to obtain better water, La Salle built his permanent base farther inland in Victoria county.

Later, in 1722, the Aguayo-Costales expedition found several small springs along the shores of Matagorda and Lavaca Bays, and showed them on a map, a copy of which is reproduced on the back endpaper. Although this map is not particularly accurate, and hurricanes have made changes in the coastline since Aguayo's time, the springs which he depicted can be approximately located. The **Ojos de Agua Dulce (1)** which Aguayo portrayed at the north end of Matagorda Island are doubtless gone now, as Cavallo Pass has moved several kilometers to the southwest since then, and the former location of these springs is now in the pass. They were near Fort Esperanza, and the town of Saluria, which were swept away by the violent storms of 1868 and 1879. Probably they seeped from the landward side of sand dunes.

Aguayo's **Ojo de Agua Dulce** at San Luis, or **San Luis Spring (2)**, may be the wet weather spring one kilometer west of Alamo Beach at latitude 28°35' and longitude 96°35'. On February 2, 1977, 0.75 lps trickled from Beaumont sand on top of a clay layer in a one-hectare swale. The spring water flows into the bay from a grove of acacias, allthorns, and prickly pears. The name San Luis suggests that this may have been the first site of La Salle's Fort St. Louis.

Aguayo's **El Agua Dulce** at San Fernando (3) was probably a small drain which discharges into the bay about two kilometers southeast of Port Lavaca. On February 2, 1977, after several months of rainy weather, 10 lps of fresh water, with less than 100 milligrams of chloride per liter, were flowing from silt and sand here.

Many of the lakes on Matagorda Island contain fresh or only slightly saline water, and are fed by seeps from the adjacent sand dunes. A map by Stephen Austin in 1928 showed fresh water and a grove of trees at Conree Lake (8), 22 kilometers southwest of Port O'Connor. The trees were cut shortly afterward. Unique specimens of the six-lined racerunner live on the island.

The port of Indianola, established around 1840, had a very interesting history. From here gold and silver mined in Chihuahua, Mexico, were shipped. Through this port also came the Army's experimental camels from Turkey, Egypt, Syria, and Spain. But the town had a very severe water problem. Shallow wells were dug by hand but these became contaminated, with the result that 400 immigrants died of cholera in 1845. Most residents collected water from roofs in cisterns. Water, and even ice, was brought in from northern ports and stored.

Springs in the county flow chiefly from Beaumont sand and silt formations. Water tables have fallen considerably, with the result that many springs have stopped flowing. This was caused partly by the many flowing wells drilled in the early part of this century which were allowed to flow continuously, wasting much water. More recently heavy pumpage for rice irrigation has drawn water levels down more severely. Another effect of this pumpage is salt-water intrusion into areas of formerly fresh ground water.

The spring water is generally of a sodium bicarbonate type, and is fresh, very hard, and alkaline. Chloride or silica content may be high.

Most of the writer's field studies were made during the period March 22-27, 1976.

Four kilometers south of Long Mott, on Louie

Walker's place, were **Walker Springs (4)**. Formerly flowing from Beaumont sand and silt, they are now dry. A pumping well at the springs, used for irrigation and domestic water, has lowered the water table to about 2 meters below the surface.

One and one-half kilometers northwest of Long Mott, at the base of a 7-meter-high bluff of sand and silt, there were formerly some small springs (10). When the first Refugio mission was established here in 1793, fresh and pure water was found, and a *Laguna de Agua Dulce* (Sweet-water lake) was situated below the bluff. In 1857 J. C. Reid found "a grocery, a spring of good water, and several extensive pools of rain water" in a grove of blackjack and post oaks here. The site has now been altered by the construction of the Victoria Barge Canal, and pumpage by a large industrial plant to the northeast has so lowered the water table that the springs no longer flow.

Johnson Springs (6) were 12 kilometers west of Port Lavaca on the Joe Brett farm at latitude 28°37' and longitude 96°44'. Consisting now of many seeps flowing from Beaumont sand into Chocolate Bayou, they are rather difficult to reach in a pasture. Here Moses Johnson, a treasurer of the Republic of Texas, lived at various times from 1837 to 1853. From this point downstream on Chocolate Bayou there are many live oaks and other trees.

Some interesting, although very small, springs are **Kabela Springs (5)**, on Ernest Kabela's place eight kilometers northwest of Port Lavaca. They flow from sand in the base of a terrace on top of a clay layer at an elevation of about 80 meters above sea level. Feeding Sixmile Creek at Highway 1090, they discharged 0.03 liter per second on March 24, 1976. According to Mr. Kabela many Indian artifacts have been found here, indicating long prehistoric use. Later the springs were popular with early settlers. They are now enclosed in a box about 1.5 meters square.

At several other localities springs which are dry now probably existed formerly. One was at the base of the bluff at Commerce and Cypress Streets in Port Lavaca, where a flowing well later was located. Another was at Linnville, the town which was wiped out by the Comanches in 1840. Other fresh-water seeps probably also could be found formerly on the landward side of dunes on Matagorda Island.

CAMERON COUNTY

Springs have never been large or numerous in Cameron County. Those that have existed have been transitory because of the relatively rapid geologic changes which are occurring. The sea level has risen 100 meters in the last 18,000 years and the land which remains above sea level is generally so flat as to discourage spring formation. In addition, the Rio Grande has wrought great changes in the landscape through its meanderings. From 1857 to 1974, for example, the mouth of the river moved 1,830 meters to the south. Hency many springs which existed in prehistoric times cannot be found now, and vice versa.

Adjacent to and usually on the landward side of the barrier beach deposits on Padre Island and west of Laguna Madre may often be found seeps and small springs. These usually contain slightly saline but potable water, and often feed lakes of similar water quality. Even the coyotes which eke out a living in this area are intelligent enough to dig shallow holes or wells in seepy areas when the water table declines. The Borrado Indians followed their example, as also no doubt did the Spanish explorers De Pineda, Camargo, and Garay in the early sixteenth century. During the Mexican War in 1846, the army dug a hole at Brazos Santiago, placed a bottomless barrel in it, and obtained brackish water. Early residents who were not so particular about what they drank used the muddy Rio Grande water.

Since settlement and "development" of the valley, great changes have taken place in the flora and fauna. Here were virgin forests of tropical trees such as ebony, cypress, Rio Grande ash, thornless acacia, anagua, and retama, now largely destroyed and replaced by cotton, sugar cane, citrus groves, and truck crops. The very rare and acutely endangered Sierra snakewood survives in Texas only in south Cameron County. Also gone are the cougars, ocelots, jaguars, great red wolves, and bears which formerly lived here.

The ground water has been affected by these profound changes in land use. There was never much fresh ground water in the county. In numerous localities however, there was a thin layer of fresh to slightly saline ground water. Then flowing wells such as the one drilled at Harlingen in 1904 began to remove what fresh water existed at deeper levels. Leaky well casings allowed saline ground water to intrude fresh-water formations. In 1928 irrigation with Rio Grande water began. As a result, the shallow ground water remaining in the county now is more saline than that which existed here in protohistoric times. It is generally of a sodium sulfate or chloride type, slightly or moderately saline, very hard, and alkaline.

Six kilometers north of Rio Hondo, in a draw extending west from the Arroyo Colorado, are some springs called **Ojo de Agua (1)**. Literally translated, this means *Eye of Water*, or *Spring*. The Spanish Ojo de Agua land grant of 1790 was named for these springs. They were shown on the 1848 *Map of the Routes from Brazos to Brownsville*, included in the Rayburns' 1966 study. Davenport and Wells (1918) described them as *a large spring of fine water*. An old settlement existed here, some of the remains of which may still be seen.

Several springs still flow from the sand and muck terrace deposit. A windmill at the upper spring has no doubt reduced its flow, as have deep drainage ditches nearby. On December 6, 1976, the combined flow was 1.2 liters per second. Mesquite and acacia trees line the draw at present. A field test showed the water to be moderately saline, containing 2,400 milligrams of chloride per liter. It was fresher before irrigation with mineralized Rio Grande water began in the springs' recharge area to the west.

A second, smaller, **Ojo de Agua (6)** should also be mentioned. It is ten kilometers west of Port Isabel on the west side of *Laguna Larga* (Big Lake). It was shown on some old maps, and is typical of the small springs and seeps which feed some of the lakes near the coast.

Two old river channels where seeps and springs may be found are the Resaca del *Rancho Viejo* (Old Ranch) (5), about 10 kilometers north of Brownsville, and Resaca de *los Cuates* (the Twins) (3). On the latter, two kilometers northeast of Bayview at *Rancho de los Indios* (Indian ranch) there were probably springs. Since 1928, however, the resaca has been dammed to form a chain of lakes, and the springs are now under water.

Other springs undoubtedly existed along the Arroyo Colorado, an old channel of the Rio Grande. They must have been important to the prehistoric people whose remains have been found here. But drainage ditches, levees, and other construction have so changed the arroyo that the springs are hard to find now. Quinton Barbee, a resident near here since 1909, remembers small springs in the sand five kilometers south-southeast of La Feria, on the south side of the arroyo (2). A drainage ditch now intercepts the flow.

At the former Tiocana (Uncle Cana) Lake, five kilometers northeast of La Feria, small springs (4) flow from the silty terrace. The lake has now largely been drained for cultivation. The spring water flows into a sump where it is pumped out.

CAMP COUNTY

For many thousands of years Paleo-Indians camped by the county's springs while hunting and gathering fruits, nuts, and roots. Later an agricultural mound-building people lived near the waters. At the dawn of historic time the Caddoes lived in villages of thatched houses near the springs. And for a very brief time the Cherokees and other eastern Indians stayed here.

Most of the springs issue from Tertiary Eocene sands, primarily the Wilcox, Carrizo, Reklaw, and Queen City. These sands dip mostly toward the southeast at about five meters per kilometer.

Most streams are spring-fed and run the year around. Especially in areas of heavy municipal or industrial pumping, the water table has fallen and some springs have suffered.

The spring waters are generally of a sodium bicarbonate type, fresh, soft, and of neutral pH. The iron content may be high.

Most of the writer's field studies were made during the period January 21-26, 1978. As an ice storm occurred during this time, the observed discharges are probably higher than normal.

Iron or **Copper Springs (7)** are in Pittsburg, west of Greer Boulevard and just north of Camp County Building and Supply Co. They were a popular playground in the early 1900s. Alice Parker of Pittsburg attended some picnics here. Now they are only seeps of red water from Reklaw sand in some woods.

Camp Branch, 12 kilometers west of Pittsburg, was named for the many Indian camps and burials which have been found there. Numerous Carrizo sand springs (11) feed the branch, including several on Mrs. John Horton's farm.

Eight kilometers northwest of Pittsburg is Picket Spring Branch (13). Many springs from Carrizo sand feed the branch. Which one was **Picket Spring** is apparently no longer known.

Birdsong Springs (14) are five kilometers north of Pittsburg on Colby Pilbro's ranch. Named for an early settler, the springs furnished water for the St. Louis Southwestern Railroad engines. Later they were popular for swimming, picnics, and baptizing, according to Artemesia Spencer, a noted historian of the area. The pond which they feed is still used for fishing. An old brick box from which the springs flowed two meters above the pond is now dry. So is a later section of large tile pipe 1½ meters above the pond. Today there are only seeps from Carrizo sand ½ meter above the pond level.

Spring Hill Springs (12) are five kilometers east of Pittsburg. The old Spring Hill church was originally here, but has moved two kilometers east, according to Ludie Reed, a nearby resident. About 2.0 lps trickled from Queen City sand in the wooded area on January 25, 1978.

Couch or **Lee Springs (3)** are eight kilometers west of Lone Star, two east of Holly Springs, and just east of Couch Mountain. Near here on Greasy Creek, John Couch operated an early corn and wheat mill. Including some other springs such as **Joe's Spring** one kilometer southwest, the total spring discharge from Queen City sand on January 21, 1978, was 7.6 lps. Coyote, wildcat, rabbit, and squirrel tracks could be seen in the snow.

Just northeast of Holly Springs on W. B. Wooten's farm are **Holly** or **Bluff Springs (2)**. In the 1850s a lumber and shingle mill used the water. Caddo pottery, arrow points, axes, and paint found here indicate that this was a favored village site for a long period. According to Wooten, a woman involved in a love triangle was shot at the springs in early days. A dipping vat was dynamited here in the early 1900s, during a time of unrest in the cattle industry.

The springs issue at the base of a bluff of Queen City sand, surrounded by holly trees at an elevation of about 75 meters, and feed Brushy Creek. The flow of 0.10 lps in 1978 provided water for a chicken house (which incidentally had collapsed during an ice storm just before the writer's visit, killing 270 chickens). On Ophelia Banks' farm 1.5 kilometers farther northeast is a similar spring which has been used for a sawmill and syrup mill.

One kilometer southwest of Holly Springs, on Bert Roberts' farm, are **Roberts Springs (4)** on Ellison Branch. They once provided water for a shingle-mill steam engine, according to Roberts. Oxen were used to haul logs to the mill. One spring was enclosed in a 1.5- by 2.1-meter wooden box in 1910, the bottom of which still survives. Just upstream, on James Smith's property, is a similar spring which was once used by a syrup mill and for washing clothes.

Lindsey Springs (1) are four kilometers west-southwest of Holly Springs on Jerry Blankenship's property. Located 300 meters southwest of Antioch church, they were named for an early settler. The Lindsey Springs school, which once used the water, was later moved five kilometers east. The discharge was 1.0 lps in 1978 from Queen City sand amid moss and ferns.

Davis Springs (5) are five kilometers southeast of Pittsburg on George Davis' ranch. According to Artie Spencer, a tannery once operated here. Later a syrup mill used the waters. Two ponds now cover the springs, which come out of the Queen City sand. The computed evaporation from the lakes, plus seepage below the lower dam, indicated a flow of about 0.77 lps on January 24, 1978.

Cary Martin Springs (6), formerly called **Wolf Springs**, are six kilometers south of Pittsburg on Mrs. Jane Martin's property. Several Indian artifacts have been found here. Many early settlers obtained water from the springs. The surrounding area was cleared but has now returned to pine woods. In 1978, 0.35 lps coursed from Queen City sand.

Fourteen kilometers southwest of Pittsburg and northwest of Hopewell church and cemetery are **Yallo Busha Springs (8)**. The name is a Caddo term for *beautiful stream*. The iron-bearing water still flows in a pretty setting, but now there is only second growth trees and brush in contrast to the mighty trees of the primeval forest which stood here then. In 1853 the community of Yallo Busha began to form, but has now disappeared. A flow of 0.82 lps from Reklaw sand passed the county road 0.8 kilometer northwest of Hopewell church in 1978.

Two kilometers farther west, behind Myrtle Springs church, are **Myrtle Springs (9)**, in a myrtle grove. Many residents from the surrounding area formerly came to obtain the iron-rich water. The very small springs from Reklaw sand are enclosed in a section of large tile pipe.

Maple Springs (10) are 1.5 kilometers south of Newsome near the Maple Springs church and cemetery on James Jordan's farm. According to L. C. Irby, a nearby resident, there was once a campground here, on the Jefferson-Sulphur Springs road. The Caddo Trace also passed the springs. Several 2½-dollar gold pieces were found here. On January 22, 1978, the approximately 13 springs produced 0.85 lps from Carrizo sand. Coyote, squirrel, rabbit, and opossum tracks were visible in the snow. A few maple trees still survive.

CARSON COUNTY

Most of the springs in Carson County issue from Tertiary Ogallala sand and gravel which slope gently toward the major rivers and streams. They are most apt to be found where the Ogallala rests upon an outcrop of relatively impervious Permian Quartermaster shale, siltstone, and dolomite. They flow chiefly in the Canadian River "breaks" in the northwest part of the county, and formerly along McClellan Creek in the southeast.

The saturated thickness of the Ogallala aquifer is up to 125 meters now, much more formerly when water tables were higher.

The springs have been used for many thousands of years by early Americans as living sites. Archeologist Floyd Scott of Panhandle has found many sites containing projectile points and tools as old as the Folsom and Plainview types along spring-fed streams and around lakes. Many of the lakes on the plains were once spring-fed and contained a constant supply of fresh water.

In 1601 the Spaniard Juan de Onate wrote of the land in the vicinity of Carson County (Bolton, 1908):

> Each day the land through which we were travelling became better, and the luxury of an abundance of fish from the river greatly alleviated the hardships of the journey. And the fruits gave no less pleasure, particularly the plums, of a hundred thousand different kinds, as mellow and good as those which grow in the choicest orchards of our land. They are so good that although eaten by thousands they never injured anybody. The trees were small, but their fruit was more plentiful than their leaves, and they were so abundant that in more than one hundred and fifty leagues, hardly a day passed without seeing groves of them, and also of grapevines such that although they hid the view in many places they produced sweet and delicious grapes. Because of this the people were very quiet and [not] inclined to injure us in any way.

The wild plums and grapevines still thrive around the springs, as well as cottonwood, willow, and hackberry trees, rushes and cattails. Deer, antelope, turkeys, ducks, geese, raccoons, beavers, snakes, turtles, and other wildlife depend upon the environment of the springs for their lives. But many of the animals and plants of this complex ecosystem are now gone, and the springs are weakening and disappearing. Prairie chickens, for example, were once slaughtered and sent east by the barrel. They are now extinct in this area.

Irrigation pumping is the primary reason for the decline of springs in the county. In 1974 this pumping removed 0.22 cubic kilometer of water from the subsurface reservoir. The ground water is being removed much faster than it can be replaced by natural recharge. In other words, it is being "mined," and eventually it will be gone. As a result the water table is falling rapidly. In the period 1954-63, the water table dropped as much as 8.3 meters. As a result, many springs are drying up.

Most of the springs and streams flow more strongly in winter, when irrigation pumps are idle and vegetation is dormant. In summer they flow more vigorously at night, when evaporation and transpiration by trees and other vegetation is at a minimum.

The scars of formerly severe erosion are still visible in the form of partially healed gullies. Sediment from these gullies has choked many stream channels and buried some springs.

The water is generally of a calcium bicarbonate type, fresh, alkaline, and very hard. The content of fluoride or silica may be high.

Most of the writer's field studies were made during the period July 7-12, 1978.

Formerly there were springs (7) on the West Fork of Antelope Creek 10 kilometers south-southeast of Fritch, on Tom Deal's ranch. Floyd Scott has found Eden lanceolate points here, indicating that the site was favored by early Americans many thousands of years ago. In 1851 Captain Marcy wrote of this place:

> We made a late start this morning and travelled three and a half miles, when, ascertaining that there was no water for a long distance ahead, and Captain Dillard having marched about ten miles to overtake us, I determined to encamp at a ravine where we found wood and water. Although there may be times when there is no water here, yet I think it can always be depended upon, except in the very dryest season. This place cannot be mistaken, as it is due south of, and about two miles from, a very prominent round mound [Antelope Peak] which can be seen for several miles. We have passed over a high rolling prairie for the last three days, destitute of wood, except a narrow fringe of trees upon the borders of the ravines — the soil worthless and utterly unfit for cultivation. We found great quantities of grapes in the ravines near our road, growing on low bushes, very similar to those that are trimmed and cultivated.

The springs are now quite dry, but many cottonwoods still survive.

Seven Holes Springs (6) are nine kilometers southwest of Bunavista on Dick Coon's Sanford ranch, managed by Peeler Haning. Here at least seven holes along the creek are fed by seeps from Ogallala gravel and caliche, but on July 10, 1978, there was no overflow. Sunfish and frogs live among the water milfoil and arrowhead plants while dragon flies and noisy killdeers dart overhead. Somewhat stronger springs occur on the East Fork of Antelope Creek near the ranch house.

Seven Holes Springs.